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Edited by

G. KUNKEL

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CHAPTERS' CONTENTS

PREFACE

When asked by the General Editor to prepare a book-length treatment concerning the nature of the Canary Islands, our aims were rather ambitious. A general monograph was to be written, embracing all the disciplines of natural history applicable to these islands, and over twenty scientists were approached for contributions. However scientists are 'time machines'; our proposed list of contents has changed a good many times. Cooporation of other authors was gained and, finally, a fairly rounded project appeared revealing different and lesser known aspects of Canary Island Nature.

Since Centuries the Canary Islands have attracted the attention of travellers. Earliest reports may be traced back some two thousand years but real scientific investigation began about 1800, the time of Alexander von Humboldt and his visit to the islands; older reports are scarce, sometimes rather confusing because of geographic inaccuracies. But the 19th Century will remain as the century of fundamental explorations, connected with names such as Leopold von Buch, F. C. MacGregor, Sabin Berthelot, Philip Barker Webb, J. Viera y Clavijo, F. von Fritsch, C. Bolle, D. H. Christ, O. Simony, G. Hartung, H. Mayer etc., all familiar and intimately connected with our knowledge of the natural history of the archipelago. Even the much criticised Ernst Haeckel has provided us with lively descriptions of his visit to one of the 'Fortunate Islands'.

The 20th Century brought new interest, new fields to be explored, and new expeditions to the islands. Hundreds of books and papers appeared, especially in Central and Northern Europe, dealing with plant life and birds, vulcanism, history, insects, reptiles, winds, adventures and soforth of the Canaries. The Jet-age, with modern tourism and related facilities has followed, opening the islands to short-term visitors and causing a flood of new investigation, with their respective publications. Almost every aspect of science has been scrutinized and many new data have come to light. I may state that during the last 25 years more has been published about these islands than during the time between Von Humboldt's visit (in 1799) and 1950.

Talking about plants for example (being a botanist myself), a good many of our endemic species were already known to Linnaeus, who gave them their (partly still valid) specific name and provided foundations for future research. The Canary Islands house about 1.750 different species of vascular plants (adventitious species and occasional garden escapes included), of which over 550 taxa are recognized as Canarian endemics, and almost a hundred of these were only discovered during the last 25 years. Another, equally interesting field – entomology – shows similar or even more exciting figures, and entomological investigations might be considered to have a promising future ahead. New roads now give access to little known localities, new researchers have found new methods of investigation, and new schools of thought cause profound changes in established scientific view-points. – The Canary Islands are well explored now; however, they are still not exhausted . . .

Although our book cover only part of the vast natural mosaic of these islands, we hope it may help to fill some of those, before-mentioned gaps. And with this I wish to thank my colleagues and contributors for their efforts which have made this volume possible. My wife Mary Anne has given much help with proof-reading and in the preparation of the register, and many corrections are due to her revisions. I express my thanks to Prof. J. Illies, for his valuable suggestions, and we all may express our gratitude to Dr. W. Junk, Publishers, for showing so much interest in a book concerning the nature of our islands. Finally, I would like to add that English is not the mother tongue for most of us authors; however in order to comply with the Publisher's request we have tried our best and we hope to be forgiven for any linguistic peculiarities.

G. Kunkel

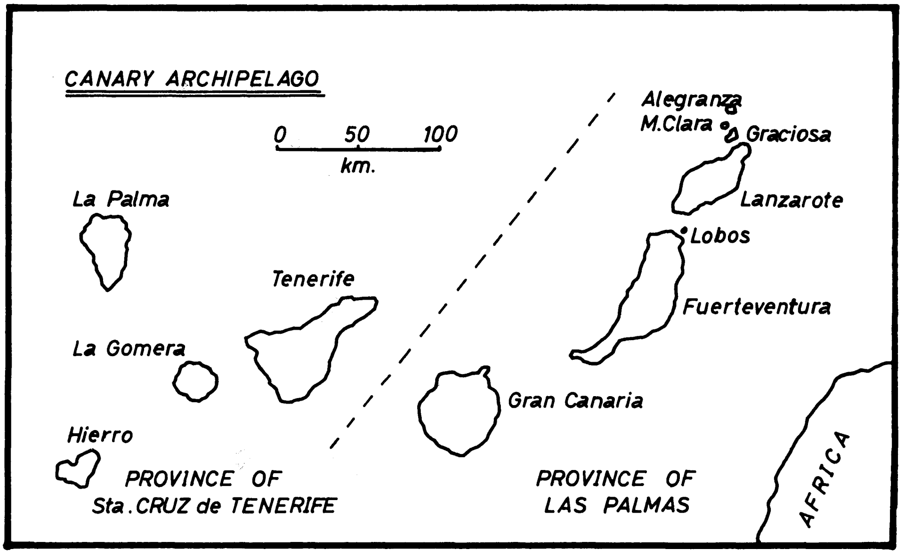
I. INTRODUCTION

by

GÜNTHER KUNKEL

Generalities

The archipelago of the Canary Islands (Span.: Islas Canarias), situated in the Mid-Atlantic west of Southern Morocco, extends over more than 500 km between 27° 37′ and 29° 23′ N, and 13° 20′ and 18° 16′ W. The archipelago consists of seven larger and four smaller islands as well as some inaccessible rocks. According to most cited sources the total area of the islands amounts to some 7.273 square kilometers (2.807 square miles) and the islands are inhabited by approximately 1.3 Million people the majority being of Spanish nationality.



Geographically the archipelago may be considered as an island appendix to the African continent. But politically (since the XV Century) the Canaries belong to Spain and form two provinces: Las Palmas (Gran Canaria, Fuerteventura, Lanzarote and the so-called Islas Menores), and Santa Cruz de Tenerife (Tenerife, La Palma, La Gomera and El Hierro).

Provincial capitals are Las Palmas de Gran Canaria and Santa Cruz de Tenerife, respectively, modern cities each with a large population and

Fig. 1. A mountain road as typical for steeper countrysides passing through planted Canary pines.

all facilities required by both residents and the many visitors. Both main islands (Gran Canaria and Tenerife) have large and busy harbours, and modern airports are situated on all larger islands, except La Gomera. There is a University in Tenerife (La Laguna), and a second, apparently, will be created in Gran Canaria.

The landscapes of the Canary Islands are very varied and it would be impossible to describe a 'typical Canary countryside' as each island is quite different in character and topography. However it is possible to generalize by saying they are all mountainous, and characterized by old or subrecent volcanic activity. Deep ravines, cliffs and precipices are common features on the Canary Islands and roads must perforce follow most tortuous routes.

Maximum altitude is reached on Tenerife, with the Pico del Teide = 3.718 m.; this dormant volcano is not only the highest mountain of the Canary Islands but also the highest elevation of Spain. The other islands, according to T. Bravo (1954) reach

2.413 m – La Palma (Roque de los Muchachos),
1.950 m – Gran Canaria (Pozo de las Nieves),
1.501 m – El Hierro (Malpaso),
1.484 m – La Gomera (Garajonay),
807 m – Fuerteventura (Pico de la Zarza), and
671 m – Lanzarote (Peñas del Chache).

The four smaller islands ('Islas Menores') in no part exceed 290 m in altitude:

289 m – Alegranza (La Caldera),
266 m – La Graciosa (Pedro Barba),
256 m – Montaña Clara (Montaña Clara), and
122 m – Lobos (La Caldera).

Of these smaller islands only La Graciosa is permanently inhabited in the true sense.

The Islands

Each island forming the Canary archipelago is, at is were, a little world of its own. Even at first sight one individual island appears different from its neighbours. More than this, only a matter of a few kilometers may separate one particular landscape from another extremely different one, and this may happen on one same island. The island of Gran Canaria could be considered as a case-study:

Sand dunes of a truly Saharan aspect lie to the south, monotonous windswept plains slope gently to the east, vast banana plantations and other tropical crops occupy well irrigated land in the north and south-west, whereas to the west sheer cliffs fall abruptly to the sea. Higher arid zones in the south support a xerophytic vegetation of spiny or succulent plants, and palms and tamarisk often form green oases in valleys. Agri-

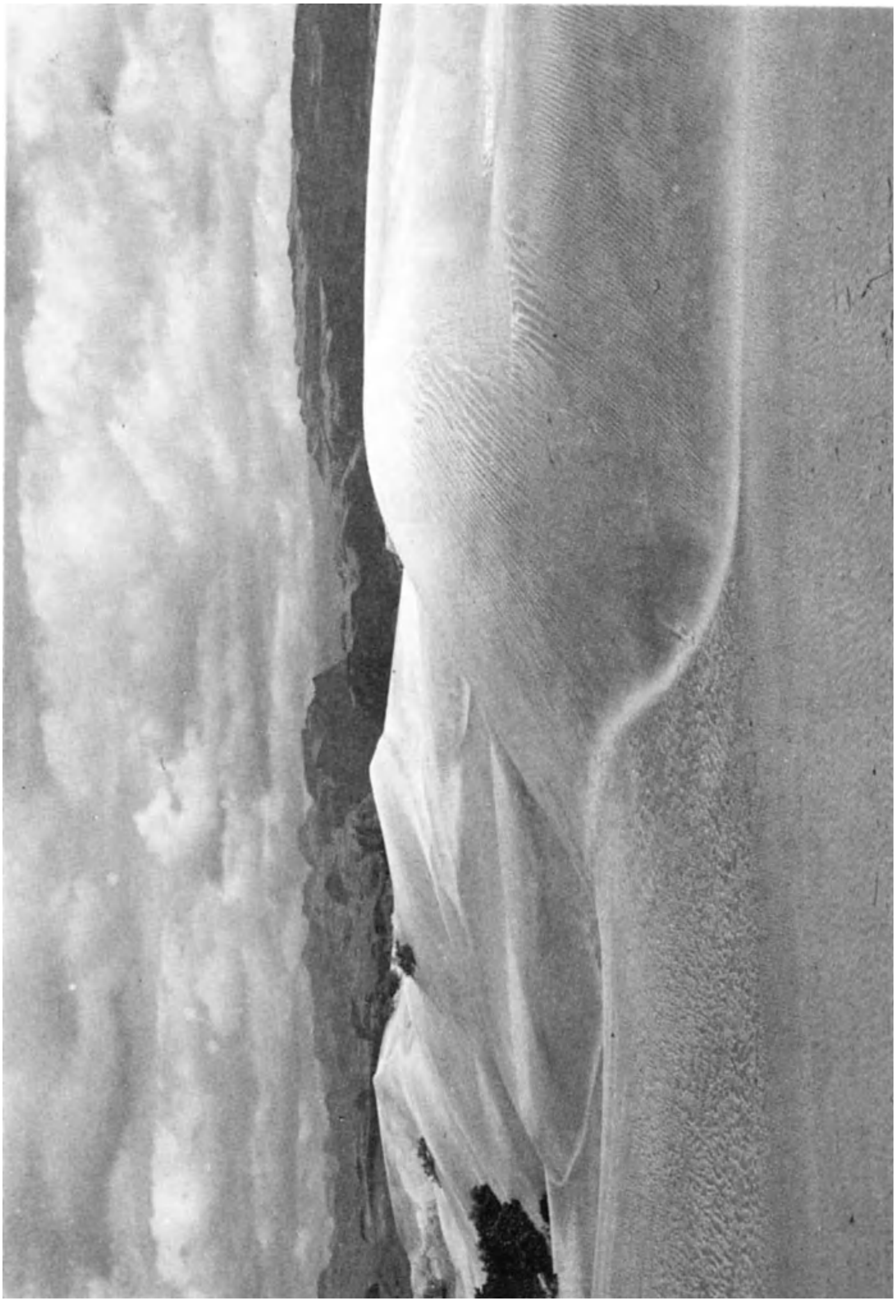


Fig. 2. The sand dunes of Maspalomas, in southern Gran Canaria. At the left: the edge of a Tamarisk growth.

Fig. 3. The hinterland of Gran Canaria: open park-type Pine forest re-establishing itself. The artificial reservoir (centre) forms part of a complex water conservation system.

Fig. 4. Succulents growing on sunbaked slopes: *Euphorbia canariensis* above San Andrés, Tenerife.

culture of European style, with potato fields and fruit orchards are characteristic for large extensions of land in the midlands of the northern sector, the zone of the Cloudforest of which only few relicts remain. Above the 1,000 m line broom and mixed bushland is (or was) typical for the zone above the forest, and an open type of pineforest extends westwards, in places descending to lower altitudes meeting and mingling with palm trees. No true alpine layer is found in Gran Canaria as, for example, in Tenerife.

Gran Canaria is roughly circular in outline, with its highest point in the centre, thus erosion has carved its way out and down towards the coast, causing the deep gorges and barranco systems. Man's activities have also contributed to the shaping of the actual features of Gran Canaria which, in fact, with approximately 340 inhabitants per square kilometer is the most densely populated island of the archipelago.

Neighbouring Tenerife, the largest of all islands, appears greener and, at least in the northern midlands, more 'European'. Here there is less of the feeling of Africa as noticed in the eastern islands and in the south of Gran Canaria. The island is partly wooded, and dominated by the great cone of the Teide volcano and its surrounding Cañadas (the name given to the vast crater of the highland), where strange plant forms composed of stiff brooms and towering Buglosses contrast with deeply eroded rock-

Fig. 5. Dense laurel forest as still found in parts of the central and western islands; moss-covered trees in La Gomera.

Fig. 6. Spiny shrubs, dromedaries, and arid, eroded slopes of southern Fuerteventura.

Fig. 7. Halophytic vegetation of La Graciosa; centre: Montana Clara; behind: part of Alegranza island.

formations and multicoloured ash covered slopes. Tenerife is the biggest exporter of bananas, tomatoes, cut flowers etc.

Further west are La Palma, La Gomera and El Hierro, three islands sometimes to be seen from the higher parts of western Tenerife. Of these, less densely populated than the two central islands, La Palma is the best known, especially for its great pine woodlands, the very impressive Caldera de Taburiente, and because of recent volcanic activity in 1972. The island of La Gomera is famous for its partly well-preserved Tertiary laurel forest which covers the central highlands, whereas the almost forgotten island of Hierro is proud of its forest relicts, especially when Juniper stands are concerned. La Gomera, furthermore, preserves the memory of the numerous visits of the controversial Columbus, on his voyages of discovery to America.

East of Gran Canaria other extremes are noted. Thinly populated Fuerteventura (less than 11 inhabitants per square kilometer) could at the first glance be placed somewhere in arid Northwest Africa from which (coast to nearest coast) it is separated by a relatively shallow sea a mere hundred kilometers wide. Only the impressive Jandia Mountains in the extreme southwest and the much sought-after white sandbeaches are what might be called permanent natural resources, the rest of this large island is much eroded and very short in water. Tiny Lobos island, topographically somewhat similar to Fuerteventura, lies in the strait between this island and Lanzarote; arid, stoney, windswept and yet strangely attractive: it is the object of speculation by the 'developers of the 1970's'.

Further to the northeast, the island of Lanzarote with part of its landscapes modified by historically recent volcanic eruptions (1730–1736, 1824); it has become known as the 'Lunar' island of the archipelago. Lava-flows cover over 200 of its 795 square kilometers, and T. Bravo (1964) has calculated the total volume of lava ash or lapilli (locally 'picón') from these eruptions at approximately 5 cubic kilometers. The central part of the devastated area is known as the Fire Mountains (Montaña de Fuego, or Timanfaya) where at 50 cm depth ground temperatures of some 400° C are recorded. However agriculture has always played an important part in the island's economy, especially by the simple expedient making use of the chemical and capillary properties of the lava ash so abundant in the island.

North again from Lanzarote are situated the small islands of La Graciosa (27 km^2), Montaña Clara (1 km^2), Alegranza (12 km^2), and the rocks known as Roque del Este and Roque del Infierno; they are mountainous, windswept, arid and, except for La Graciosa, without permanent population. However they are relatively abundant in bird and marine life and have a surprisingly rich seasonal vegetation.

Fig. 8. A Canary village, far off and peaceful before road building connects it with civilization.

Facts and Figures

Innumerable books and papers have dealt with the many aspects of the Canary Islands, their nature, natural history, their people and their development, and now again some new approaches are presented in this book. Extensive lists of references and suggestions for further reading are given in the final part of each individual chapter.

The Canary Islands have been inhabited for some thousands of years, they are well known, much visited and yet – still – preserve their secrets such as: What was the origin and language of the inhabitants found by the first North African and European visitors? What of the origin and evolution of the flora and fauna? What of geological thesis and antithesis? What of the future economy and prospects for that future? These are factors which investigators will always have to take into account. – Some questions are dealt with in this present 'Biogeography and Ecology of the Canary Islands'. These, and all others are open to new additions and new opinions, and new studies maybe – one day – will bring light into the darkness still surrounding these islands. We have merely made our contribution.

It is generally accepted that the Canary Islands were known to Phoenician and North African navigators more than 2,000 years ago. That the islands had no aboriginal population but that the first recorded visitors found the islands inhabited by people of unknown origin. That the flora and fauna of the islands is considered to be very peculiar, with evolutionary lines still very much active. That volcanism is responsible for at least the superficial structure of the islands, a dormant status quo, and that the archipelago is extensively explored (I never said: exploited!), The islands reach even politically an interesting position.

Concerning the population and density of population of each island the following data can be given:

Table 1. Population and population density census 1970, after Boletin 16, Centro de Investigaciones Económicas y Sociales, Caja Insular de Ahorros, Las Palmas de Gran Canaria 1973. Fuerteventura includes Lobos, and Lanzarote the islands of La Graciosa, Alegranza and Montaña Clara.

	La Palma	El Hierro	La Gomera	Tenerife	Gran Canaria	Fuerteventura	Lanzarote
Inhabitants	65.291	5.503	19.339	500.381	519.606	18.192	41.912
Density	89,6	19,8	54,7	295,5	339,1	10,5	52,7

As to the size of each individual island as well as the total land area of the archipelago controversial data show up. Mistakes often appear to

Table 2. Data on the size of the islands, based on different sources. The 'official' and 'inofficial' data as given on the last lines were provided by statistical offices in Las Palmas and Santa Cruz de Tenerife. The 'published amount' if given was mentioned by the respective author; the 'summarized amount' has been calculated by the present author.

References	Palma	Hierro	Gomera	Tenerife	Gran Canaria	Fuerte-ventura	Lanza-rote	Smaller islands	Published amount	Summarized amount	Differences
Martínez, 1952	726	277	378	1.946	1.376	1.722	741	45	7.543	7.211	332
Bravo, 1954	730	278	380	2.058	1.532	1.725	796	46	7.167	7.545	378
Dicc. Salvat, 1955	729	278	378	2.058	1.532	1.731	836	? incl.	7.543	(7.543)	—
Matznetter, 1958	728	277	378	2.057	1.532	1.731	795	46	7.273	7.544	271
Lems, 1960	728	277	378	2.060	1.534	1.725	873	? incl.	7.575	(7.575)	—
Schveitzer, 1961	726	312	378	2.053	1.533	2.019	973	? incl.	(7.275)	(7.994)	(719)
Dervenn, 1963	814	312	440	2.352	1.533	2.019	973	? incl.	—	(8.443)	?
Monitor, 1966	663	275	378	1.909	1.532	?	805	? incl.	7.273	—	?
				1.929			806				
Brockhaus, 1966–1974	665	275	378	2.057	1.667	1.722	806	? incl.	7.273	(7.570)	(297)
Klug, 1968	?	277	378	2.057	1.532	1.731	795	? incl.	7.498	—	?
Encycl. Brit., 1969	728	(277)	(378)	2.058	(1.533)	(1.730)	(795)	? incl.	7.500	(7.499)	p.p. in miles
Rob, 1973	728	278	378	2.053	1.532	1.722	795	? incl.	7.273	(7.486)	(213)
Ludewig, 1973	?	?	?	2.352	1.532	1.731	?	?	7.273	—	?
Official data	662	264	353	1.929	1.531	1.663	904	incl.	7.273	7.306	33
Unofficially	730	277	378	2.057	1.532	1.731	836	incl.	7.541	7.541	—

have passed from author to author where no cross checking has correlated single data with total overall data as given by one same author, in one single book.

How large are the Canary Islands? I believe we have to rely on official data, even if here certain doubt is expressed. The differences found between 'official' and 'unofficial but generally accepted data' we may adscribe to a legendary Canary Island known as 'San Borondón'.

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II. THE PREHISPANIC POPULATION OF THE CANARY ISLANDS

by

ILSE SCHWIDETZKY

Introduction

The Canary Islands were not unpopulated when in the course of exploratory ventures more and more Spanish, Portuguese, and Genoan ships docked there for shorter or longer periods of time. The aboriginals vigorously counteracted in many locations of the Spanish Conquista, which had its roots since the end of the 15th Century; but they fought with stone weapons against the iron weapons of the Conquistadores, and their resistance could thus be quickly broken. In relatively short time, the Canarians were hispanisized and christianized and formed together with the Spanish immigrants a single population. Still their particular character remained until their new spiritual guides and other interested Europeans (Torriani 1590, Espinosa 1594, Galindo 1632) collected information about them and were thus able to transmit much to the remainder of the world. Through modern excavations, especially in the 1950's, still much more became known of their material culture, and some things of their social structures. And finally language- and cultural-historical studies, especially in the works of Wölfel (1940, 1950, etc.), concerned themselves with the prehistoric population and studied their cultural background. The expansive skeletal material from the pre-Spanish gravesites was researched and the ancient Canarian population was thus made known from the somatic side as well, whereby quite a few differentiations, in fact even something of the population dynamics, can be ascertained. Many single problems, are, to be sure, still open, but one can nonetheless gather a clearer and more differentiated picture of the pre-Spanish population of the Canary Islands than of many other populations which had been run over by the colonial expansion of the Europeans.

THE ORIGIN OF THE PREHISPANIC POPULATION

Those knowledgeable in ancient Canary sources of material largely agree that the ancient Canary population stems from northwest Africa, but was early isolated. The distance between Cape Juby (Rio de Oro) and the east coast of the Fuerteventura is less than 100 kilometers. The eastern islands – Fuerteventura and Lanzarote – thus lie almost within eye-range of the African continent in clear weather, and the inlet lying between them is completely quiet in summer. Passat winds and ocean currents approach the islands in a north-south direction, but the Harmatan, the feared levant wind which carries the Sahara sands all the way to the islands, can likely drive fishing boats from the west coast of Africa off-course to the islands; in the fall, when cold air fronts form in the central Sahara, the westwinds deviate the passats and in winter drive the surface currents of the sea towards the islands from the northwest (Bravo 1954). With such natural phenomena it is not particularly difficult, even with primitive nautical techniques, to reach the islands from northwest Africa. As opposed to this, to return from the islands is incomparably more difficult.

Proof of northwest African relationships to the ancient Canary population comes from various sides. If one begins with the unfortunately very scanty remains of the ancient Canary language, the relationship to northwest Africa and the proximity to the Berber is clear. Surely the relationship between both languages is not uniform: 'We have words which are semantically in such close agreement, with nearly complete sound uniformity, that we have to conclude the closest relationship; we have others, which ethymologically cannot be viewed as Berberic and texts as well, which do not correspond to mere Berberic accidence and syntax' (Wölfel 1955, p. 20). This relationship can be assumed in several ways. Wölfel finds it most probable that the 'Canary (language), exactly as the Egyptian, compares to the Berberic as a closely-related, as a lybic language.'

Vastly more abundant are the remains of the material culture: stone tools, obsidian knives (Tabonas), mills, clay vessels of various forms and sizes, with and without embellishment; leather work, under which particularly artistically sewn mummy covers protrude; woven mats; wooden objects such as shepherds' canes, tuft ladles, biers, and chieftians' staffs; bone needles, jewelry, in particular the Terracotta pearls, strung on leather strings (Cuscoy 1954, 1958); and clay seals (Pintaderas) from Gran Canaria, which are still in use in Berberic North Africa, namely for the closing of single chambers in the fortified communal stonerooms, which are known in Gran Canaria too (Marcy 1938). There some significant differences between the islands manifest themselves. The ceramic from Teneriffa and Gomera is, on the whole, more simple than that from Gran Canaria, which exhibits a more frequently decorated and, in part, more polished pottery.

In Teneriffa and Gomera the 'megalithic buildings' are also lacking, which according to Wölfel (1941, 1955) fall into the category of 'archaic high-culture' of the Mediterranean area. Cultural places such as Cuatro Puertas on Gran Canaria, fortress structures, like the wall between the two 'monarchies' of Fuertaventura, the grave tumuli, under which project the Tumulus La Guancha near Gáldar, which contains over thirty graves, reflect such common megalithic, religiously pronounced

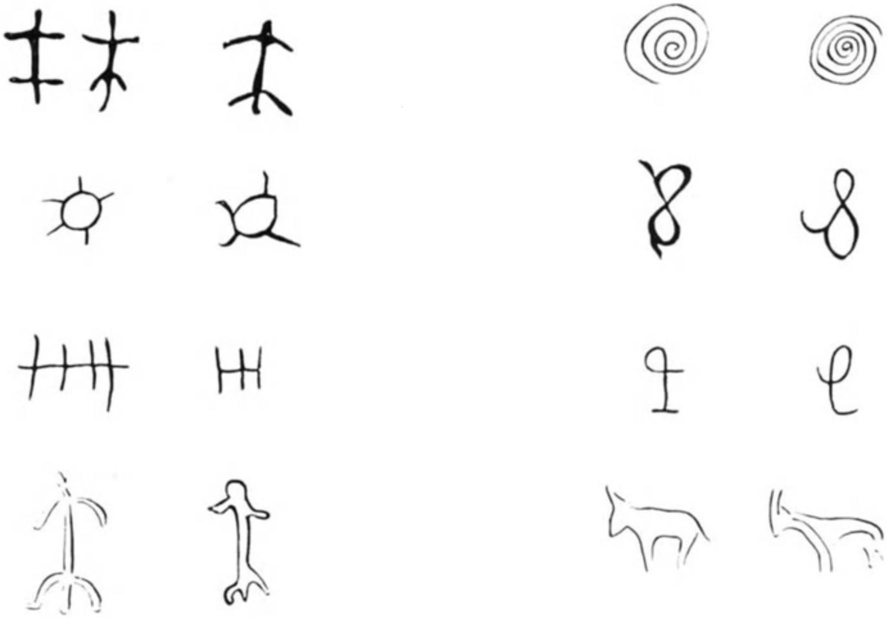

Fig. 1. Relations between Northwest Africa and the Canary Islands I. Figures from rock gravings. In both columns at the left from Northwest Africa, at the right from the Canary Islands; (from Th. Monod 1938 and L. D. Cuscoy 1954, arranged by I. Schwidetzky 1963).

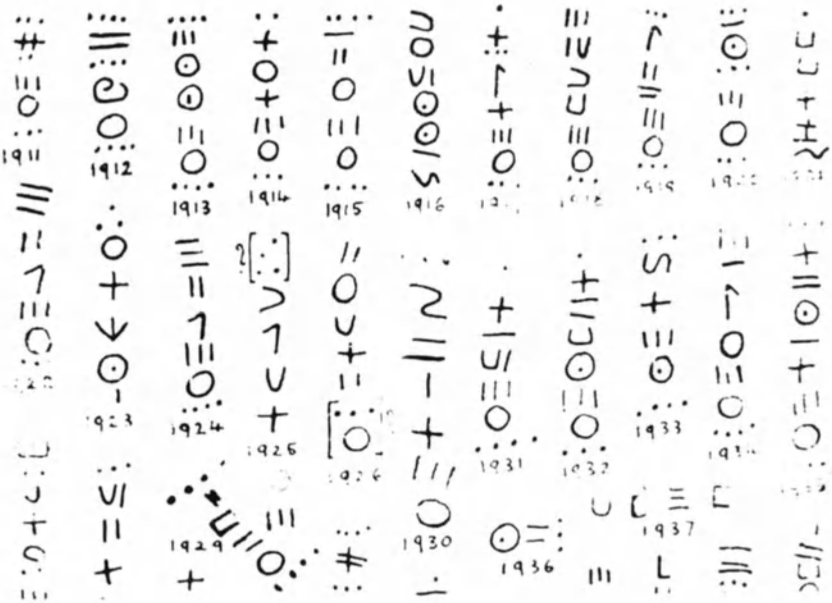

Fig. 2. Relations between Northwest Africa and the Canary Islands II. 'Oldnumidic' inscriptions from La Caleta/Hierro (above) and Tifinagh inscriptions from the Western Sahara (below): (from D. J. Wölfel 1940 and Th. Monod 1938).

Fig. 3. Canarian mummy, from Roque Blanco, Tenerife (from I. Schwidetzky 1963).

construction concepts (Wölfel 1955). The ancient Canary 'inscriptions' and cliff drawings should be mentioned here, too. They rely on geometric patterns (Belmaco/La Palma), but show as well strongly stylized figures (Barranco de Balos/Gran Canaria) or signs resembling writing (La Caleta/Hierro) (Cuscoy 1954; fig. 1). Among the inscriptions of Hierro one finds such which 'permit immediate identification with Libyc writings, the writing of the numidic inscriptions of the punic and Roman period in North Africa and the Tifinagh of today's Tuareg' (fig. 2) and a second type, which 'contains an amount of signs, which are very similar to the signs of the Cretic linear scripture;' thereby one should not conclude a direct Cretic influence, but rather a common source of Cretic and ancient Canary signs (Wölfel 1955, p. 428 ff).

Similarly the ancient Canary custom of mummifying the dead (fig. 3) points to North Africa. It reminds one of course of Egypt; however, there appear to be connecting links in the remaining parts of North Africa (Baumann-Thurnwald-Westermann 1940, pp. 62 and 278). The methods in ancient Egypt and the ancient Canaries are admittedly not identical: in the Canary Island the intestines were apparently only seldom removed, the brain never. Naturally the artistic bandages of ancient Egyptian mummies are also lacking on the Canary islands, because corresponding textiles did not exist. But here, too, no direct connections but rather a common source of this custom is to be considered, as the highly developed Egyptian mummifying techniques must have been preceded by more primitive stages.

The archaeological finds are enhanced by ethnological parallels which are to be assumed from the written sources, including a 'Sachgruppenanalyse' of the remainders of speech (Wölfel 1955). Ancient Canary and Berber acknowledge an almighty being, whose mainfold names are in part the same here and there (Wölfel 1951). From both it can be proved that in times of drought it was attempted to call upon the pity of the gods through the distressful bleating of lambs separated from their mothers; 'The association to the dead was established in exact same manner on the Canary Islands as with the old Libyans, the modern Berbers, the old populace of Malta, and the Greeks: through sleeping on the graves' (Wölfel 1951, p. 434). The superior position of the priestesses on Gran Canaria is reminiscent of old-mediterranean matriarchal characteristics. Even sibling marriages in ruling houses is confirmed from the Canary Islands: The beautiful Ico, who, because of her blond hair, was regarded not to be the natural daughter of her lawful father, King Zonzammas of Lanzarote, but of the galant Spaniard Martin Ruiz, was simultaneously the sister and wife of the later King Guanarame (Viera y Clavijo, I.p. 172, cf. Espinosa I/8, too).

A critical point of the investigation is the dating of the immigration. Because the Canarios at the time of the Conquista did not know any metal, their culture was widely regarded as neolithic and immigration as correspondingly early. Wölfel (1951) estimates the second of the third millennium B.C. as the latest immigration period and relates also the megalithic structures to a neolithic megalithic. More recent prehistoric investigation assumes somewhat later dates and several waves of immigration, at least three. The first wave can probably be dated still in the second millenium B.C., the most recent, with which the large stone graves of Gran Canaria might be associated, belongs already in Christian times, presumably in the 1st centuries A.D. (G. Smolla, personal information; cf. Schwidetzky 1971, p. 236). The cultural differences between the islands can easily be explained by considering that the most recent population immigrations did not reach all islands: Teneriffa and Gomera appear to have been populated only by the oldest immigration group.

With a more recent dating system, however, one problem becomes more distinct: the complete lack of metals. One could surmise that knowledge of metal was lost after the isolation of the islands. In the Canary Islands there are no corresponding natural resources; metal objects which had been brought along would not have had to be replaced afterwards. This hypothesis is insofar not very convincing as metal objects do not so easily dissolve into nothing, and any traces, even if only in discolorations of the soil or human remains, would be expected. One could thus theorize that the Berberic area of North Africa is remarkable conservative in cultural matters: the neolithic remained until the arrival of the Phoenicians; it had stood, at least in areas not easily reached by travel means, in single cultural elements as well. As such large stone graves were apparently constructed up into the Roman Era (Julien 1951, p. 44). To be sure it is difficult to imagine that the Canary colony could have stemmed out of just these late neolithic refuges, i.e. above all out of the North African mountain regions; it is much more probable that they stemmed from the coastal areas. A similarly open question has to do with the fact that no signs of ships are to be found in the archeological remains, nor in the cliff drawings. Should the first immigrants still have arrived as a result of being thrown off-course, then there still had evidently been communications between the islands, which would have been impossible without ships.

PHYSICAL CHARACTERS AND THEIR MEANING FOR THE QUESTION OF ORIGIN

Several things can be said about the northwest African relationships to the ancient Canary population from the aspect of physical anthropology as well. It is well-known to us from numerous skeletal remains from the pre-Spanish gravesites. To be sure, the material is not equally distributed over all the islands. Most material came in Gran Canaria into museums, and from this more than half from one single Barranco, namely a series

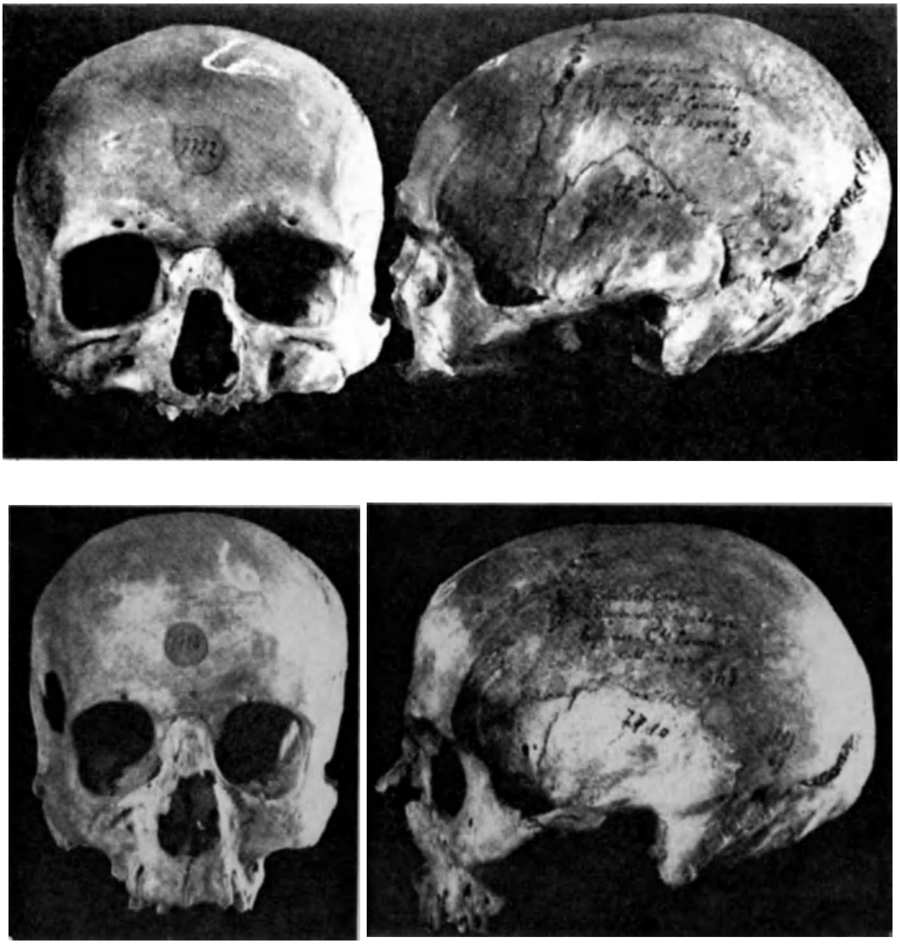

Fig. 4. Variability within the local populations. Male skulls from Guayadeque/Gran Canaria. Above: near the cromagnoid type pole; below: near the mediterranean type pole.

of caves from the long Guadeque Canyon. Teneriffa, too, is well-represented with over five-hundred individuals, as are Gomera and Hierro in relation to their size, with one-hundred individuals each. In opposition to this, only scant anthropological material stems from La Palma and Fuerteventura, and Lanzerote has been up until now completely lacking in finds (Schwidetzky 1963).

Among the earlier anthropologists who concerned themselves with the physical anthropology of the ancient Canary population, Verneau stands out: from 1876 until 1891 he published prolific works resulting from his own excavations and investigations. Already then he saw some differentiations in the population and attempted to describe them through typological categorization. His two main types, which he lables the Guanche-type and the Semitic type, reappeared with varying names in most later anthropological works. The Guanche-type is described as low and wide-faced with low, broad, right-angle eye sockets, prominent supraorbital ridges, rough, broad lower jaw, etc; the similarity with the late paleolithic Cromagnon type of Europe had already been noted by Verneau. The Semitic type, with whose naming the association with a later immigration had already been suggested, is described as having less-robust bone structure, with a narrow, high face. It is later identified with the Mediterranean type. The most recent research of ancient Canary material (Schwidetzky 1963) could confirm this type polarity with modern multivariate statistical methods: with the aid of factor analysis two variation directions were worked out, whose end poles correspond to the Cromagnon and the Mediterranean types; in short, the two pole-types permit description as broad, rough-faced and narrow, gracile-faced (fig. 4). With another multivariate statistical process, the discriminant analysis, an objective basis was further achieved, to arrange the different populations between the Cromagnon and the Mediterranean poles. According to this, Gomera stands by far closest to the Cromagnon pole type, and thus most clearly shows, as Verneau had already seen, the broad, rough-faced type. Teneriffa follows after a certain gap, but is not so strongly differentiated from the remaining islands as is Gomera. At the end of the row, i.e. next to the Mediterranean pole type, is the population of Gran Canaria.

The population of North Africa is seen as well by many authors under the aspect of the variation between Cromagnon and Mediterranean types. The broad and robust-faced type is well-founded from a series of epipaleolithic sites such as Mechta, Taforalt, Afalou-bu-Rhummel, and others. It is, above all, connected to the culture of the Ibero-Maurousien, whereas the more narrow, gracile-faced type which appeared initially only in isolated cases is to be associated with the Capsien culture. The broad, rough-faced quality diminishes in the later, unfortunately not-too-manifold finds. Already in Islamic times the Cromagnon type had 'lost much of its earlier significance; in fact it appears to have been completely submerged under the other anthropological types which from then on prevailed in Algiers and Tunisia. For the present one must assume that the Mechta type has almost completely vanished from Algeria and Tunisia ... we do not rediscover our type in North Africa, but rather in the Canary Islands ...' (Boule-Vallois-Verneau 1934, p. 232).

Certainly the ancient Canary population, in particular that of Gomera and Teneriffa, does not correspond completely to the epipaleolithic robust-boned population of North Africa. They are smaller and less robust-boned. The process of gracilization which has been accomplished in many European populations since the Mesolithic, is clear also through comparing North African and ancient-Canary human remains.

Of special significance: as a result of the development in North Africa one can assume that the earlier immigrants came to the Canary Islands, the more they approximated the broad, rough-faced type. In the population of Gomera and secondly Teneriffa an older population level could therefore be much more strongly represented than would be the case in Gran Canaria. This agrees very well with the archaelogical finds already mentioned.

In particular characters there are, however, some differences between the prehistoric human remains of North Africa and those of the Canary Islands. It is just the North African coastal area which most closely lies to the Canary Islands, and which therefore most clearly comes into question as far as the origin of the ancient Canarians goes which is unfortunately hardly represented in the North African finds. Thus sufficient time and space remain for all those biological processes which may have transformed the population of the North African mesolithic and neolithic into the pre-Spanish population of the Canary Islands: a change of types by selection; various population mixtures, and last but not least genetic drift, i.e. casual events in the small groups, which found their way over the ocean to the islands. If according to the tradition of the Guanche there were only sixty people who first settled on the north coast of Teneriffa (Espinosa I/4), this number need not at all be distant from historical reality. It is therefore quite feasible that certain tribal, or even family or individual characteristics of these first settlers became manifest in the entire island population by natural population growth; and in end effect it is not surprising that anthropological relationships to the North African area of origin are to be recognized only in the main features.

Because the ancient Canarians mummified their dead, other features besides skeletal can be determined which otherwise are known only from living populations: hair and eye color and the ABO blood groups. The material in these areas is to be sure far less prolific. The distribution of hair color (altogether 43 hair samples) demonstrates no significant differences from today's population of the Canary Islands. A certain portion of blondes appears there above all in the children. Early anthropologists preferred to describe the Cromagnon type as blond, the Mediterranean as dark. This has not been verified: from a metrical and morphological standpoint the dark and light-haired are not different in the sense of type polarity. In six mummies eyes, the eye color could be determined. They were in all cases dark (Rohen 1959).

Blondes existed at least in Gran Canaria and Teneriffa in the ancient Canary population; this can be regarded as certain according to written sources. According to a letter from Florentine merchants which Bocaccio received and which S. Ciampi (1827) brought to light, four youngsters from Gran Canaria, whom they had taken along in 1341, had long, light hair. Torriani refers in his description of a Canarian wrestling-match to

Fig. 5. Two young men from Gran Canaria with fair hair; (from Torriani 1592/1940).

six youngsters and men from Gran Canaria with long, blond curls (Wölfel 1940; fig. 5). Galindo (I/16) maintains, however, that primarily dark-colored individuals existed in Gran Canaria. Espinosa (I/4) says of Teneriffa that the Guanche in the south of the island were darker, that in the north a white skin color was predominant, and that the women there were attractive and blond. Antonio de Viana, born in 1578 in La Laguna (Teneriffa), who renders in poetry, all the ethnographic and historical information he collected, describes the great prince Bencomo as 'moreno', with dark eyes. (Song III, p. 64), his young daughter Dacil, on the other hand, as golden-haired (Song III, p. 77), and Guacamara, the daughter of another prince, as blond (rubio), with large, dark eyes. Similar information of the other islands does not exist. Galindo assumes that there were blondes on Gomera, Hierro, and La Palma too. As opposed to this, the populations of the two eastern islands, Lanzarote and Fuerteventura, are described as dark. The blond child of Queen Faina was so conspicuous on Lanzarote that one believed it was not fathered by the King, but rather by a galant Spaniard (Viera y. Clavijo, p. 172).

If thus historical and anthropological information agree that there were light-colored, e.g. above all blond individuals their frequence is overestimated in literary sources. The blond Guanche and Canarians were likely most noticeable to the southers, from whom most reports stem, so that they play an exagerrated role in their reports.

From muscle and skin remains of the mummified dead the ABO blood types could also be determined (Schwarzfischer & Liebrich 1963) and thereby at least one of the serological characters, which play so large a role in modern population biology. The most striking characteristic of the ancient Canarians is the extraordinarily high frequency of blood group O (which was positively determined, not only through lack of A and B). Such high proportions are not known in living European populations. The ancient Canarians are however, closely followed by the Berberic tribes of High Atlas, where the percentage of blood type O reaches as high as 78%, in some cases over 80%. The relation between the ancient Canarians and the Berberics can thus be verified also from the sereological side. It is not surprising that the Atlas-Berbers have a lower percentage of O blood types than the ancient Canarians. The mountains are surely an 'area of retreat'; but they undoubtedly do not isolate so completely as this was the case with the islands. All recent populations of North Africa, in particular the Arabians, are characterized by a much lower percentage of O blood types.

A sereological study on the population of Gran Canaria (Roberts *et al.* 1966) reached however the conclusion that today's population of Gran Canaria shows great similarity to that of northwest Europe and estimates similarly high percentages of Northwest European immigrants. These calculations become untenable; they are predicated on the ABO distribution of today's population, which differs significantly from that of the ancient Canarian population. Nothing is known of a heavy immigration from northwest Europe since the time of the Spanish Conquista, which could have caused these similarities. As opposed to this, the islands had a strong immigration from the Spanish motherland which Wölfel (1930) estimates to have been one-third of the total population. Rösing (1967) determined that the differences in ABO distribution between the ancient Canarian and today's population cannot be explained by this Spanish immigration. Rather, selection-processes must be assumed which could stand in relation to the epidemics, especially smallpox, brought with the Europeans. For there is a well-founded hypothesis (F. Vogel), according to which the ABO distribution, by reason of immunological relationship to antigens of the sickness-producers, drastically changed through selection by the huge epidemics, in particular smallpox and plague.

ECOLOGICAL DIFFERENCES AMONG THE ANCIENT CANARY POPULATIONS

The skeletal remains of the pre-Spanish population are so numerous and stem from so many different localities that it is possible to determine differences within an island's population, at least for the two large islands, Gran Canaria and Teneriffa. There currently exist clear associations to natural areas: in Teneriffa the ancient Canary population from the better-off, fertile, and rainy north differs from the population in the dry and poorer south; as far as Gran Canaria is concerned, mountain populations and coastal populations could be contrasted to one another. On Gran Canaria the differentiation corresponds to that which one with a general population biology background would expect: the mountain population, on the whole, more closely approximates the archaic, Cromagnon type pole than does the coastal population. This is in accord with results of many other population studies which concur that the mountainous retreat areas use to be of an older population level, whereas the coastal area is more strongly subject to more recent immigrations. The regional structure of Teneriffa presents, however, another picture: the better-off north shows stronger Cromagnoid distinctions. This leads one to conclude that the confrontations between earlier and later immigrants did not always correspond the same population-biological pattern. In Gran Canaria the retreat area of the mountains preserved best the older, more strongly Cromagnid group, which also had a larger proportion of the population in the dry southeast than in the coast of the north. In Teneriffa, on the contrary, it was just the more fertile north coast, richer in rain, where the old level was most clearly preserved. It thus seems as if later immigrants found already occupied the more favorable living area in Teneriffa and were, according to number, and according to their means of technology and level of civilization, not able to dispute with the already-existing population. On Gran Canaria, as opposed to this, later settlers evidently had an greater impact and took possession of the better-off north coast.

Also, the mortality factor reflects ecological differences. In Teneriffa in the north with its favorable living conditions the people reached an older age on the average; in the dry, infertile south they died more frequently in younger years.

The pronounced mountainous character of Teneriffa and Gran Canaria, with its deeply embedded Barrancos, rendered the relations between the single settlements difficult and impeded population exchange. It can be proved that they were isolated in the sense of population biology; neighboring local groups show significant differences far more frequently than one would expect by chance. Then, too, every island population had its own particular character which distinguished it from the populace of the other islands; for the sea isolated even more strongly than the mountains and Barrancos, inasmuch – as archaeological finds lead us to believe – the island inhabitants had no or only very slight experience in ship building and ship travel.

SOCIAL-BIOLOGICAL DIFFERENCES

A series of interesting information about the social organization of the ancient Canary population is contained in Spanish sources. On the other hand, skeletal material in relation to burial customs also suggest social differences. One can now attempt to relate historical information to anthropological finds.

The prehistorian has only one means of judging the social rank of a buried person; the outfitting of the grave. The richer it is, the more

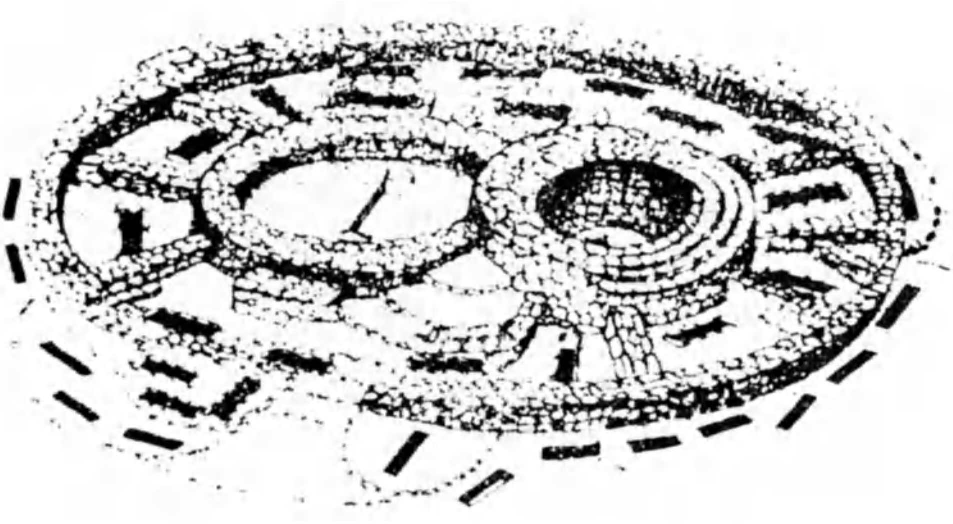

Fig. 6. The grand tumulus La Guancha near Gáldar/Gran Canaria with about 30 graves; (Museo Canario, Las Palmas/Gran Canaria).

elaborate the deceased's last resting place seems to be above the average burial surroundings, the higher one would place him in the hierarchy of wealth or social prestige. There were different burial methods on Gran Canaria. The great majority of the dead were buried in natural caves after being treated with a certain recipe by a particular socially-outlaw professional caste and had been dried in the sun or over a fire. There were some differences in the amount of elaboration: with some individuals the abdomen was opened with a stone knife in order to remove the intestines; with others only an external treatment took place; the dead were either carefully sewn in goatskins, whose numbers varied from 1 to 15, or buried without such protecting leather coverings; as a ground covering one finds wooden caskets with bottom and side walls, plain boards or only loose branches. Besides this, there were on Gran Canaria stone graves, too, with stone heaps (Tumuli) as single graves or as large structures with more than thirty burials.

Historical sources, too, note some things about the social differences of the burials. Viera y Clavijo (I, p. 160) says that caskets were reserved for 'kings and important personalities.' 'The nobility used only one other kind of burial: beneath the earth, i.e. in a ditch between the stones of lava streams. They formed a pyramid over the body with long stones. Then they filled everything around with small stones, until the entire Tumulus was covered ...' Therefore the Tumulus graves would also be categorized as being suited to a socially elevated class, which might above all apply to the large graves (fig. 6).

If there are on the one hand differences in the degree of elaborateness of the burials all other sources, on the other hand, report as well of social classes among the ancient Canarians. Torriani dedicates an entire chapter to the 'Nobility of Gran Canaria'. Therein he describes the nobleman not as a nobleman-by-birth but by achievement, as belonging to a socially open class, in which one can enter through special nobility-probes: 'The nobleman of the Canaries was determined neither by age of the family nor by degree of honor, nor of wealth ... Thus nobility was not hereditary, but rather everyone could become noble by his own virtues, in which he demonstrated signs of public and private excellence from the first year on'. Similarly Espinosa states (1594, I, Ch. 8) of Teneriffa that the king gave each person his share of land 'according to his quality and services rendered'.

For the skeletal material, social placement was made possible through the hypothesis that many of the human remains in which muscle and skin rests existed had been painstakenly mummified with more elaborate methods than had been the case with other individuals, from which only the skeleton had been preserved. One thinks of Heredot (II, 85–87), who described the ancient Egyptian embalming methods. The 'people who understand something of business', immediately ask the surviving members of the family, 'for what price they want to have the corpse done ... if it is a first-class corpse', the brain is removed through the nose and then the stomach cavity opened with a knife made of Ethiopian stone and cleared. Should the family choose second-class, 'because the first was too expensive', the stomach is not opened, but rather sprayed by means of an enema tip with cedar oil; 'In the third type of embalming, with which the less well-endowed were content,' the abdomen was rinsed out only with radish juice.

Indeed there do exist anthropological differences between the 'mummified' and the 'non-mummified', which we also know otherwise from social anthropology: the mummified, who can be regarded as members of the social upper-class, are larger, which is conceivable in body height (calculated from the long bones) as well as in the absolute skull measurements. Furthermore they are more strongly leptosome: this can be chiefly verified by the skull, with its relatively narrow upper face, its high, narrow nose, and its high eye sockets, as well as in the long bones, with their lower indices of robusticity. In the case of the completely preserved mummies, the characters of the mummified are even more evident on the average; the deviation from the average population is thus still greater than in those individuals who show only smaller muscle and skin rests. Also the life span was longer with those who had been mummified. Above average body height, more-marked leptosomy, and longer life span: these are the main biological signs in modern societies, too, of social upper-classes. Also as in the case of modern open or at least half-open societies, this social differentiation may have come about through assortative processes.

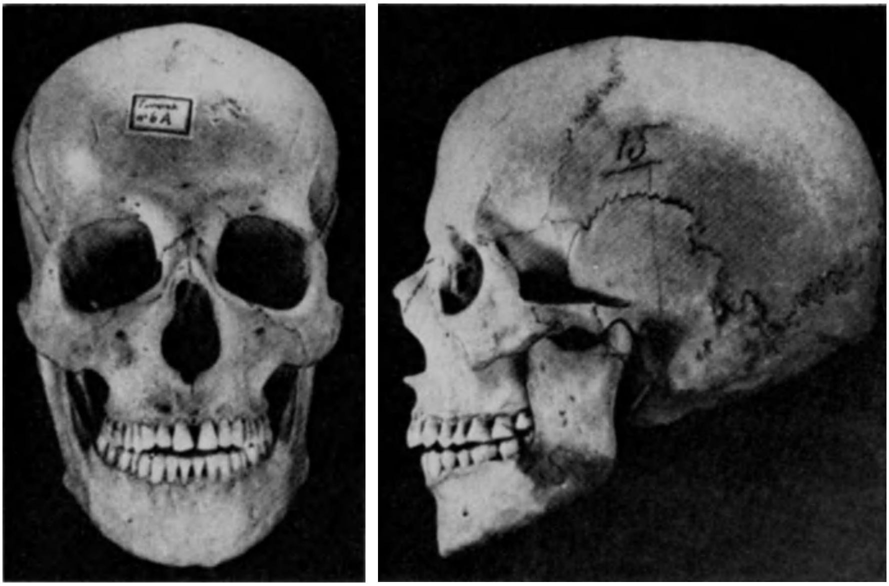

Fig. 7. Male skull from the tumulus la Guancha; (from I. Schwidetzky 1963).

Besides the evidently relatively numerous nobility of Gran Canaria a smaller, narrowly-restricted group of leaders can be evidenced: the Guaires. 'Gran Canaria was reigned over by two kings and a duke, who had been elected; but the actual rulers of the island was a company of knights, whose number was not to be less than 190 and not more than 200, and who could be augmented through the election of sons from within their own classes ... these knights are not associated in the least with the lower classes and belong to the purest nobility.' (Azurara 1448 in Major 1872; Berthelot 1879). There is good reason to relate this high nobility to the buried of the stone graves, in particular of the large stone graves.

The human remains from the Tumulus graves are anthropologically well-characterised and stand out significantly from the remaining population (fig. 7): this is a particularly tall and high-skulled group, whereby the tallness, not however the high-skulled feature, is a sign of the social upper class of the mummified. In other respects, too, the Tumulus dead show some striking features, e.g. a simple sagital suture of the skull. Therein lies a notable similarity between the finds from the extreme north and the extreme south of the island, especially the finds from the Great Tumulus of Gáldar and those of Arguineguin. These finds could most likely be explained by maintaining that they have to do with a socially small breeding circle with strong family relations to one another; and the striking body height as well as the manner of burial points to a socially very distinguished inbreeding group. In respect to settling, the majority of this class seems to have prefered the climatically advantageous north coast, in particular around Gáldar. In the north were the ancient Canarian 'kings' whom the conquistadors in part fighting, in part on diplomatic ground, had to confront. In the court of Gáldar, the 'richest territory of the island', one attempted to call upon the highest nobility and the cream of the bravest men of the island (Viera y Clavijo I, p. 179): here was the old capital and the seat of the entire highest nobility. It is natural to associate the great Tumulus finds with the leading political group, which represented socially so superior an inbreeding group, as is to be suggested on grounds of anthropological markers from the Tumulus finds. One would have thus to assume (at least) two different social differentiations in Gran Canaria, both of which are anthropologically plausible: one numerically small, political ruling class, which supplemented itself always from its own ranks, thus representing a nobility-by-birth; and, on a broader population basis, an echelon according to affluence and prestige, which was open and which supplemented itself in large degree by social upward-mobility.

Fig. 8. Boys from a mountain village of Gran Canaria; (from I. Schwidetzky 1971).

Eugen Fischer (1930) was the first to determine that the old Guanche-type still appears in the population of Teneriffa today. It is, however, evidently common on the other islands in varying degrees, and there are also differences among the local populations. This was corroborated in an anthropological study of the current living population (Schwidetzky 1971, 1975). A total of 6,800 pupils in 129 localities was investigated on all islands, thus a representative random sample of the entire population. Admittedly this concerned itself with non-adult subjects of varying ages; however, the age factor can be eliminated by standardization in the case of age-variable characters, in particular size. The population of Gomera still is today as in pre-Spanish times nearest to the broad, robust-faced Cromagnon type. There is moreover a high rank correlation for distances between the individual islands in pre-Spanish times and today, calculated on the basis of 12 characters. Certainly only those four islands can be considered from which sufficient skeletal material exists. The differences

Fig. 9. Boys from a West coast village of Gran Canaria; (from I. Schwidetzky 1971).

between today's population of the four islands are, however, absolutely slighter than in pre-Spanish times. This can be plausible interpreted by the vigorous population exchange and improved travel methods. The Spanish Conquistidors had already set up their ships for inter-island travel in their times, and today regular ship and air lines bring together almost all the islands.

One can further ask if population structures which had been determined for the prehistoric time can be proved in the present. This is true for the differences between the mountain and the coastal population of Gran Canaria.

The differences in the present have become rather greater than smaller. This is apparently related to the strong Spanish immigration to the coastal areas.

In Teneriffa this immigration has even caused a reversal of the earlier differentiation. Whereas the population in pre-Spanish times varied in the north coast more strongly in the direction of the Cromagnid type, the opposite is the case today. Today the north is more strongly Mediterranean, thanks evidently to the stronger Spanish immigration. For pre-Spanish times a classification according to mountain and coastal population was not possible on Teneriffa. As for Gran Canaria an entirely similar differentiation results in a comparison today: the population of the mountain village varies on the whole more strongly in the direction of the broad-robust type than do the coastal populations. The population biology rule that older population stratas preserved themselves more strongly in the mountains with their isolation and less-favorable economic structure, is thus confirmed.

In the maps of today's population of Gran Canaria still another differentiation is suggested besides the differences between mountain and coastal areas: the places on the west coast are marked as having particularly dark hair color, full lips, and large nasal breadth (fig. 8, 9). The northwest of the island was also, as has already been shown, the main settling area of that population which buried its elite in the large stone graves. The question whether there were relations between the Tumulus population of pre-Spanish times and today's population of the northwest coast, can be answered in the affirmative. In nearly all comparable characters the Tumulus population deviates in the same direction from the pre-Spanish average population as does today's west coast population from the average of Gran Canaria's (fig. 10). It is worth noting that both populations show certain negroid tendencies: with the living population these are pigmentation, lip-thickness and broad nasal structure; with the Tumulus population broad noses and relatively strong prognathy. If one supposes, on the ground of these finds, that the Tumulus population remained on the West coast in greater concentration than in the other regions of Gran Canaria, one can also conclude the appearance of the Tumulus people from today's population. They would have been, there-

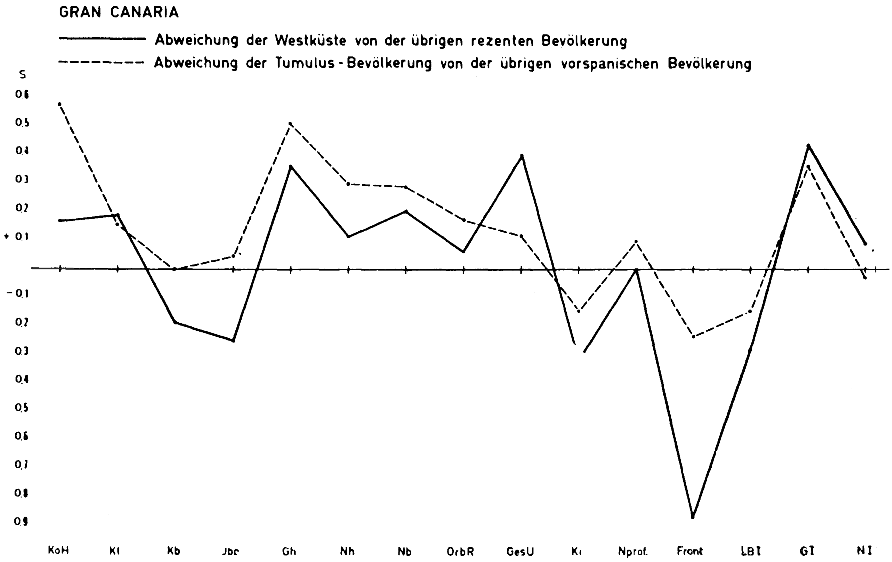

Fig. 10. The West coast population of Gran Canaria and the tumulus population; —— Deviation of the to-day West coast population from the total to-day population of Gran Canaria; ---- Deviation of the tumulus population from the total prehispanic populations; s = percent of standard deviation; below the measurements, indices and morphological characters used for comparison (from I. Schwidetzky 1971).

fore, in comparison to the remaining population of Gran Canaria, relatively dark-haired and dark-eyed and would have had full lips; in general a population type which would well fit North Africa.

One can roughly imagine the population biological processes which exist behind these relationships: immigration of a North African population group, which above all settled on the west coast; within this group development of a nobility-by-birth sitting in Gáldar; no connubium with the earlier population, however a certain population exchange with the non-aristocratic members of the ethnic group; after the Conquista, which operated out of the northeast coast in hard battles, retreat of the ruling class from Gáldar to the southern, inaccessable settlements of the tribe.

Although the west coast population demonstrates certain African traits, it must nevertheless be mentioned that by far the most popular hypothesis relates single negroid characters of the Canary Islands population to the import of Negro slaves in the 18th Century; they were used on the sugar cane plantations which preceded the banana cultures and which were later on sold to America (Matznetter 1958). Perhaps the particular, but clearly negroid characters in Chipude (Gomera), such as narrow-spiraled hair, thick lips, and prognathy, can thus be brought into association: Negroes who wanted to escape the sale perhaps fled from the cultivation area around Valle Gran Rey to this out-of-the-way, inaccessible colony. The hypothesis of the relationship between the west coast population of Gran Canaria and the Tumulus population of pre-Spanish times is supported not only by the dark hair and thick lips of today's population, but also by its similarity to the Tumulus population by the special traits of the west coast population recognizable already in pre-Spanish times.

Summary

The most important results of the Canary investigations can be summarized as follows:

1. History of language, prehistory and ethnology demonstrate numerous relations between the pre-Spanish population of the Canary Islands and North Africa, in particular the Berberic population. It can also be assumed from a geographical standpoint that the islands were settled from northwest Africa. Several immigration waves can be distinguished. The oldest could be dated still in the 2nd millennium B.C., the most recent in the 1st centuries A.D. The different island populations are evidently distributed among the immigration waves in varying degrees: on Gran Canaria the archaeological discoveries show many elements which indicate a later immigrations elements which are not present in Teneriffa.

2. The abundant skeletal material from pre-Spanish burial sites supports this theory. The more archaic features, such as bone robustness and broad, low faces appear more often on Teneriffa and Gomera than on the other islands. By reason of North African finds one can assume that the earlier the immigrants arrived, the stronger they varied in the direction of a broad-faced, robust type.

3. Already the pre-Spanish population of the Canary Islands display a series of differentiations which are related to the natural structure. On Gran Canaria the mountain population distinguishes itself from the coastal population by a stronger pronouncing of archaic features. In accordance with general population biology rules, the older groups in the isolation of the mountains evidently survived better than on the coast, which was more strongly affected by the more recent group of settlers. This holds true for the population, too, which buried its dead in stone graves. Its center was the northwest coast and was tied to the most recent wave of immigration. The mountainous character of several islands and the resulting difficult travel means must have strongly isolated many local populations. This isolation can be verified anthropologically by a relatively strongly-marked difference between neighboring local populations.

4. Socio-biological processes influence the population structure, too.

An extraordinarily favorable situation presents itself for the Canary Islands insofar as historical information from early Spanish sources can be tied to anthropological finds. There are two social differentiations: an open upper-class, which always is supplemented by assortative processes; and, besides this, on Gran Canaria, a small, strictly exclusive ruling group, noble-by-birth, which buried its dead in stone graves.

5. The comparison between the pre-Spanish population and that of today shows the influence of Spanish immigration since Conquista times, which chiefly went to the economically more favorable regions. In Teneriffa it reversed the earlier anthropological relation between the north and the south coasts and in Gran Canaria it strenghtened the differences between mountain and coastal populations. Of particular interest is today's population on the west coast of Gran Canaria. There the most recent wave of pre-hispanic immigration which, among other things, introduced the burial in stones graves, obviously survived.

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III. THE NAMES OF THE CANARY ISLANDS AND THEIR VERIFICATION

by

JAMES KRÜSS

The names for the archipelago

As names for the archipelago we have to discuss the following: the *Elysian Fields*, coming from Homer (about 800 BC), Odyssey, IV, 563–568, adopted by the Greek geographer Strabo (63 BC-AD 26); the 3 *Gorgones* and the 3 *Hesperides*, coming from Hesiod (about 800 BC) in his 'Theogony'; the *Happy Islands*, coming from a wide-spread mythical tradition; the *Atlantides*, coming from Plato's dialogues 'Timaios' and 'Kritias'[1] (428/27–348/347 BC), adopted by the Greek biographer Plutarch (about AD 50–119) and discussed by innumerable authors, the *Eternal Islands*[2], coming, as far as I can see, only from Arabian authors about AD 1000, for example from Abu Ubayd al-Bakri who also tells us that in Greek these islands were called *Quartianis*[3] (maybe from gr. χύαρ, 'cave'); and finally the *Canariae Insulae*, first so named as a group of islands by the African author Arnobius, who died in AD 330. Highly doubted is a relationship between the Canaries and the 'Island of the happies' in the Irish myth, *Mag Mell*, which was reigned over by Thetra, the King of the *Fomores*. (*Famara* is the name of a bay and a mountain on Lanzarote.)

From the *Elysian Fields* Homer tells us that the gods shall bring Menelaos to the *Elysion pedion* at the ends of the world, where the 'brownish' hero Rhadamantes lives and where there is no snow, no hurricane and no rain and where always blows the west wind. *Elysion pedion* is mostly translated as 'dwelling place of the blessed'. Unfortunately my etymological dictionary has only πέδον, hom. πεδόθεν, πέδονδε, 'Grund, Boden' and no explanation for *Elysion.* If this word meant 'blessed' and 'happy' together as in the German word 'glückselig', we can bring together *Elysion pedion* with the *Insulae Fortunatae* (or *Fortunatorum/Beatorum Insulae*) as with *Mag Mell* and the land in the far west, where the blessed live and that was reigned over f.e. by the Egyptian Osiris. Then we have to consider a very old concept, that the dead or the souls of the blessed go as the sun goes to the west, where there is a place for them without the troubles and hardships of life. This 'far west' may have been located in many places, in old Greece for example in *Elis*, the northwest of the Peleponnese. Then *Elis* and *Elysion* may be etymologically related. Although Ptolemy surely knew of the Canaries (he took his O-meridian through the Canary Islands), I doubt, that Homer's *Elysion pedion* meant the Canaries, for between Homer (800 BC) and Ptolemy (200 BC) there are a thousand years. Names and associations spread out with the extension of geographical knowledge. As the name *Atlas* for the mountains in North-West-Africa came from Greece with all its older associations (the Berbers still say *adrar ibudraren*[4] or something similar), so Homer's *Elysion pedion* may have wandered together with geographical knowledge from some place in Greece until finally it came to the Canaries.

The same thing may have happened with the related three *Gorgones* and the three *Hesperides*, best known from Herodots 'Theogony'. Their names, that Hesiod gives, seem altogether purely Greek. The *Gorgones* are called *Stheno* (σϑενός, 'power'), *Euryale* (to Εὖρος, 'southeast-wind'?) and *Medusa* (μέδω, 'I care'). The three *Hesperides* are called *Aigle* (αἴγλη, 'brightness'), *Erytheia* (to ἦρι, 'early'?) and *Hesperia*, *Hesperethusa* or *Arethusa* (ἑσπέρᾱ, 'evening, west', ἕσπερος, 'evening, in the evening'). Also their collective names have a solid Greek base, as the *Hesperides* come from the word for 'evening/west', the *Gorgones* from γοργός, 'awfull, horrible, wild', Γοργώ, 'Schreckgespenst'. Etymologically the six ladies seem of Greek origin, and so their places in the 'far west' may have been formerly somewhere in the Agaen Sea; but as the *Hesperides* are actors in the twelve labours of Hercules, there may be a relationship with Phoenicia, for to-day it is undoubted that a main part of the Hercules myth comes from the phoenician Baal-Melkart from Tyre. The Phoenicians now knew the ocean beyond the 'Columns of Hercules' and we know for certain that they knew the isle of Madeira. So why shouldn't they have known also the Canaries? But first there is no evidence of Phoenician visitors on the Canarian archipelago and second, if the Greek poets used older phoenician stories, did they take over only the plots or also the related geographical knowledge? Did the public of Homer and Hesiod know something about Africa as far as the Strait of Gibraltar? The first Greek colonizers were Ionians from Asia Minor, that came already in the 8. century BC, the century of Homer, to the Black Sea and to Sicily. And in the popular legend from Homer, translated and commentated upon by Wolfgang Schadewaldt[5], Homer is said to have been a Smyrnian named Melesigenes, who after many voyages from Spain and Etruria came back to Ithaca. But I think most of the Greek people of the 8. century BC heard only casually about places as far as Spain or the Canaries, and if a certain gentleman named Melesigenes really came back to Greece from a country as far as Spain his narrations would have been more as stories from a far wonderland than a base for geographical knowledge. It is notable that Homer named the far west of the blessed only the *Elysion pedion*, and that may refer to many places, according to the speakers situation and knowledge. Also the three Hesperides and the three Gorgones, according to Hesiod personalities, that lived in the far west, may have been located in several places until with the progress of writing and communication their dwelling places (on a coast or on isles) were located on or in the Atlantic. If the etymology of the ladies' names is related to their dwelling place, we have for the *Hesperides* (living in a place of the far *west* or of the *sunset*) in *Aigle* exactly the root with the meaning 'brightness', in *Hesperia* once more the root for 'west, evening' and in *Erytheia* maybe the roots ἦρι, 'early', and ϑέᾱ, 'look, sight, view, aspect', which altogether reminds us of a star called *Hesperos* or *Hesperus*, namely Venus, that is the first bright star after sunset in the west and the latest to be seen in the morning in the east. So perhaps the *Hesperides* symbolize the good aspect of the west, namely the arising Venus. But if the names really came from astronomical observations, we once more have to doubt, that their location on earth was so fixed as some authors would have us believe. It is quite another thing with the *Happy Islands* or *Die Inseln der Glückseligen* (with the meanings 'happy' and 'blessed' together). For here is to be seen a clear tradition at least from Quintus Sertorius, the Roman Governor of Spain (123–72 BC), over Vergil (70–19 BC), Horace (65–8 BC), Ovid (43 BC–18 AD), the elder Pliny (23–79 AD) and Plutarch (46–119 AD) – until Torquato Tasso (1493–1569). The poetic tradition from Vergil until Tasso is astonishingly consistant even in its details. I shall give first all four poetical texts in the original here.

The first text are the lines 15–30 from the 4. ecloga from Vergils 'Bucolica'. The poem is dedicated to Asinius Pollio, consul of the year 40 BC, who made peace between Augustus Octavianus and Antonius. So Vergil, hoping that a kind of Golden Age might begin, describes in a prophetic manner the future that the new born son of Pollio expects:

ille deum vitam accipiet divisque videbit
permixtos heroas, et ipse videbitur illis,
pecatumque reget patriis virtutibus orbem.
at tibi prima puer nullo munuscula cultu
errantis hederas passim cum baccare tellus
mixtaque ridenti colocasia fundet acantho.
ipsae lacte domum referent distenta capellae
ubera, nec magnos metuent armenta leones.
ipsa tibi blandens fundent canabula flores.
occiedet et serpens, et fallax herba veneni
occidet; assyrium volgo nascetur amomum.
at simul heroum laudes et facta parentis
iam legere et quae sit poteris cognoscere virtus:
molli paulatim flavescet campus arista,
incultisque rubens pendebit sentibus uva,
et durae quercus sudabunt roscida mella.

The second text are the lines 41–52 from number 16 of Horace's epodes.

Horace, disappointed that Rome's glory is gone, suggests to go to the 'arva divites et insulas' and describes these isles now:

Nos manet Oceanus circumvagus: arva beata
  Petamus, arva divites et insulas,
Reddit ubi cererem tellus inarata quotannis
  Et inputata floret usque vinea,
Germinat et numquam fallentis termes olivae,
  Suamque pulla ficus ornat arborem,
Mella cava manant ex ilice, montibus altis
  Levis crepante lympha desilit pede.
Illic iniussae veniunt ad mulctra capellae
  Refertque tenta grex amicus ubera
Nec vespertinus circumgemit ursus ovile,
  Nec intumescit alta viperis humus.

The third text are the lines 101–112 of the first book of Ovid's 'Metamorphoses'. It is the description of the Golden Age of Saturn, seen not in the future, as in the descriptions of Vergil and Horace, but in the past:

ipsa quoque immunis rastroque intacta nec ullis
saucia vomeribus per se dabat omnia tellus;
contentique cibis nullo cogente creatis
arbuteos fetus montanaque fraga legebant
cornaque et in duris haerentia mora rubetis
et quae deciderant patula lovis arbore glandixes.
ver erat aeternum, placidique tebentibus auris
mulcebant zephyri natos sine semine flores.
mox etiam fruges tellus inarata ferebat
nec renovatus ager gravidis canebat aristis;
flumina iam lactis, iam flumina nectaris ibant,
flavaque de viridi stillabant ilice mella.

The fourth text are the verses 35 and 36 from the XV. song of Torquato Tasso's 'Gerusalemme deliberata'. In the XV. song the two Christian warriors Charles and Ubaldo come with the help of a virgin to the 'l'isole felici', where the hero Rinaldo (Rinaldo d'Este), lives with the beautiful pagan Armida. The first description of these islands (Naturally Tasso had heard of the Canary Islands, which were conquered in his liftime) is the following:

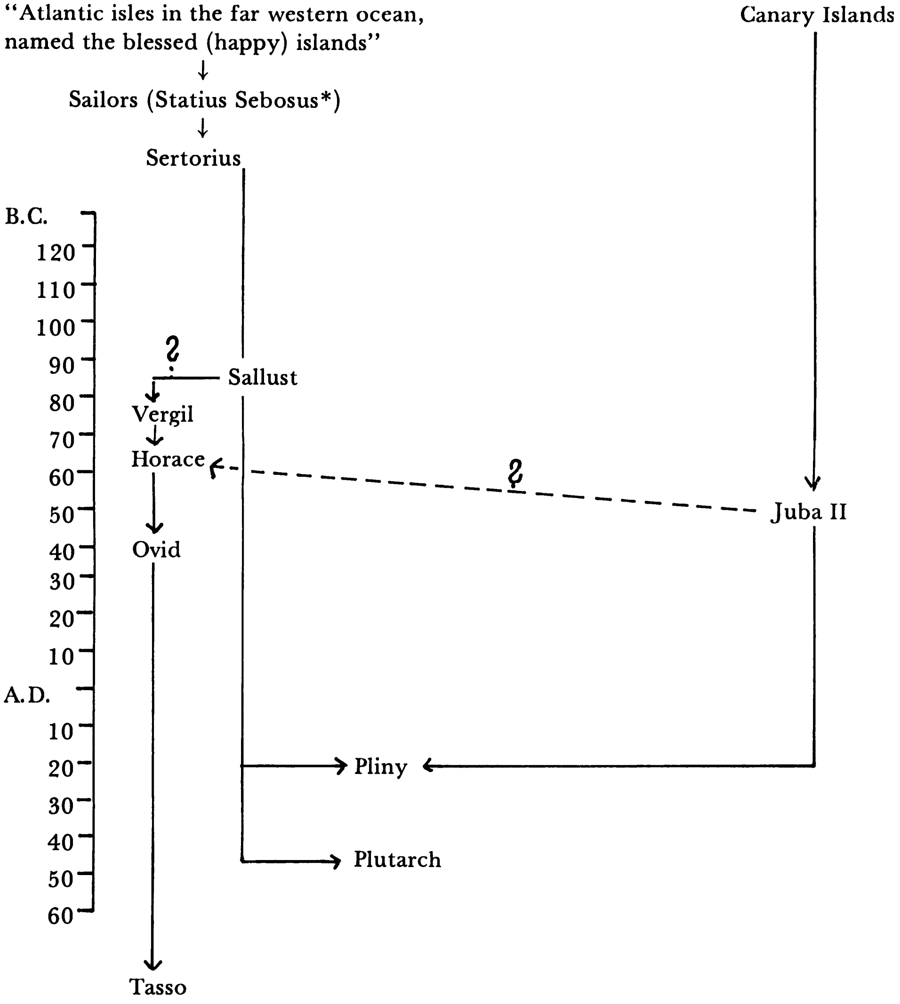
Ecco altre isole insieme, altre pendici
Scoprian al fin men erte et eleuate
Et eran queste l'isole felici.
Cosi le nomino la prisca etate;

A cui tanto stimaua i cieli amici,
Che credea uolontarie, e non arate
Quiui produr le terre, e 'n piu graditi
Frutti, non culte germogliar le uite.

Qui non fallaci mai fiorir gli oliui,
E 'l mel dicea stillar da l'elci caue,
E scender giù da lor montagne i riui,
Con acque dolci, e mormorio suaue:
E zefiri, e rufiade i raggi estiui
Temprarui si, che nullo ardor u e'graue
E qui gli Elisi Campi, e le famose
Stanze delle beate anime pose.

The corresponding details of the verses are: the earth (always *tellus*, Tasso: *terre*) bears uncultivated or unploughed or 'per se' fruits – the fruits are wild grain (Vergil and Ovid *arista*, Horace *ceres*, Tasso only *frutti*), wild wine (Vergil *uva*, Horace *vinea*) or other wild fruits like strawberries (Ovid *fraga*) and olives (Tasso *oliui*) – and all authors speak about wild honey (all *mella*, Tasso *mel*) from oaks (Vergil *quercus*, Horace and Ovid *ilex*, Tasso *elci*).

The earth, that bears fruits without cultivating, is a detail of the description of a Golden Age, no matter if it is seen in the past or as prophecy in the future. We find it as well in the bible where Jesus says, that men can live like the birds without seeding and earning (Matth. 6,26) as in the poetic Edda, where the prophecy says, that 'unseeded' the fields will grow (Völuspa, third part). This detail cannot help us to localize the happy isles. How is it with the other details, wild fruits, honey from oaks and unpastured goats that come alone to the milking place? For this question we first have to study the source material. The chronological order of information and authors and their relations are to be seen in fig. 1. The eldest informant is Sallust, born 86 BC, who tells us in the first book of his 'Histories', that Sertorius, born 123 BC, met in the beginning of his career some sailors, that just had come from 'Atlantic isles in the far western ocean', named 'the isles of the blessed'. As Sallust's book remains only in fragments, we have to read about this episode in books, that cite Sallust, like in Plutarchs 'Life of Sertorius' (I, 8, 2–9) or in Pliny's 'Naturalis historia' (VI, 201–205). Pliny cites also an author, who really seems to have been on the Canary Islands, namely Juba II., king of Numidia and later of Mauretania.[6] From whom came the details of the Happy Islands to the poetical tradition and to whom first? Naturally we have to choose only between Vergil and Horace. Both have in the cited poems older models. For Vergil it was Theocritus, the Greek poet from Syracuse (310–250 BC), for Horace the early Greek poet Archilochos (7. century BC). Two details are now to be found in Theocritus' Idyll XI



about the Cyclop Polyphem, who also acts in the 'Odyssey'. In the translation of Elizabeth Barret Browning the poem goes:[7]

No jot he cared for apples, olives, roses;
  Love made him mad; the whole world was neglected,
The very sheep went backward to their closes
  From out the fair green pastures, self-directed.

Here we have already fruits, not cared for (thus growing wild), and the self-directed goats of Vergil and Horace. But wine, grain and honey from oaks are lacking. From whence came these? And who of both poets was the first? The question is much discussed. Bruno Snell maintains, citing the verses of Theocritus, the priority of Vergil[8]. H. Düntzer, believing, that Horace's poem is older than that of Vergil, maintains the priority of Horace[9]. But these are examinations of literary sources only, whilst we are searching for real news from real islands. What can the poets have heard from Sertorius and Juba? From Sertorius directly they couldn't have heard anything, because when Sertorius was murdered in 72 BC, Vergil was 2 years old, Horace not yet born. But both may have heard through Sallust about the Atlantic isles in the far west. And there is good reason to suppose, that the Greek speaking and reading Horace read the Greek writing Juba II. Undoubtedly Horace must have heard about Juba or maybe have known him personally, for Juba was from 46 until about 29 BC educated in Rome protected by Augustus, and Horace lived from about 42 until 33 in Rome. Also Vergil, who died 19 BC, must have heard about the young African prince, who became during his and Horace's lifetime first king of Numidia, then (25 BC) king of Mauretania. And naturally gossipping Rome spoke about Juba, when he married the daughter of Cleopatra and Marcus Antonius. But Horace lived 27 years longer than Vergil, and as Juba II lived 45 years longer then Vergil, the possibility of Horace having heard or read about the isles, that Juba saw, is greater. Did he hear of them through Juba as Pliny did later? What he says of them (except the uncultivated flowering earth, that may come from another tradition, and the self-directing goats, that may come from Theocritus) is: wild wine, grain, olives and figs, honey from oaks, springs with sweet water, no snakes, no bears.

It would be tempting to compare these words of Horace with the biological facts of the Canaries, especially the fact, that, as far as we know, there have never been snakes on the archipelago. But for the time before Linné it is hard work to identify which word stands for which fact. If we take Horace's *ilex*, it may have been in Greek δρῦς, but this word as well as meaning 'oak' also means 'tree' and again in composita 'wood-'. If we take the word φηγος, which according to my dictionary is the 'edible oak', there are immediately two possibilities for errors, for the word comes from indoeuropean *+bhāgos*, Latin *fagus*, meaning the beech-tree, and a Roman author with little knowledge in botany may have related the greek *fegos* with the Latin *ficus* for 'fig'. But if we are searching for similar Canarian facts on the meanings of Horace's words, we may find the following:

The Canarian wild wine (*Parthenocissus tricuspidata*, first described in 1887)[10] is cultivated and introduced. But the old Canarians made a kind of wine from the fruits of the *Visnea mocanera*, by the old inhabitants called *mocan*, today mostly *mocanéro*. The name for this fruit was *yoya*, according to Dominik Josef Wölfels 'Monumenta Linguae Canariae' related to a berberic word *yaya*, meaning 'berry'.[11]

Grain seems to have been known since very old times, especially barley, for which there are given four different words from four different islands.[12]

For olives there is now known a subspecies *(Olea cerasiformis)*, which according to the latest describer Günther Kunkel may be a native Canarian plant.[13]

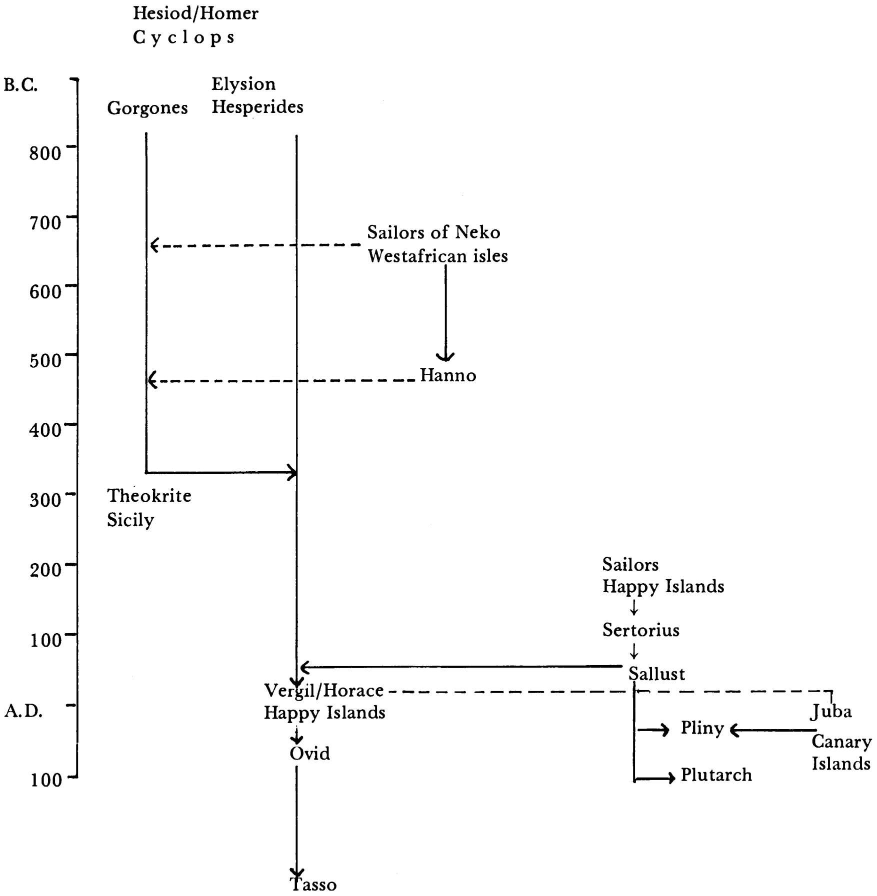
For figs there are some old Canarian words, but mostly with Arabian offspring. So we can doubt, that at the time of Horace there were figs on the islands, but possibly the *yoya* may have been described by visiting sailors as a kind of 'fig'.

Wild honey is very well known on the islands. I myself found it on Gran Canaria in the locality of San Mateo, where it also is sold (I found it in a willow).

The Canarian oaks are according to the botanists introduced, but as we saw, especially with the Greek words for 'oak' there are errors possible. (And if Horace read Juba, he read him in Greek.)

Springs of sweet water were known from all islands except Lanzarote. The absence of snakes is characteristic for the Canarian archipelago, but also for Madeira.

The mention of the absence of bears is a bit strange for the Canaries, but would not be so for the island of Theokrite's idyll, Sicily. And here is the point, where we can think of an Horatian mixture of three traditions: The mythical *Elysion pedion* of Homer and the related *Elysian Fields* by other authors, the *Happy Islands*, that just in the time of Horace through Juba may have been localized on the Canaries, and another not yet mentioned tradition, namely the *Islands of the Cyclops* with the one-eyed *Polyphem*, to be found in the Odyssey in the ninth song and (personalized in Polyphem) in Theokrits XI. idyll. This final tradition may come from Phoenician traditions, namely after navigation of the African coast by Phoenician sailors about 610 BC, sent by the Pharao Nekos and described by Herodot (IV 42). It may have happened in the same way as it did 600 years later in the time of Horace: the older more obscure tradition of Homer's *Islands of Cyclops* became localized somewhere in the Atlantic after the voyage of the Phoenicians. Homer tells us, that on the island grew 'unseeded and ungathered' (like in Matthew 6,26) barley, wheat and wine. The people lived in caves high up in the rocks, organized in clans, and in front of a wonderful bay there was an uninhabited island with wild goats. Homer's view of this kind of life is negative, as is the view of an old Canarian 'idyll' from the islands Palma and La Gomera, in which the giant *Tamuthu*[14] – a horror for all his neighbours – on the top of a mountain had his 'bloody dwelling place' and from where he drove wild goats into the gorges and to their death. The view of Theokrite is mixed: He understands the terrible longing of the giant for the sweet Galathea, but describes him as rough, hairy and barbaric. But with Theocrite the view in the tradition changes: now the unploughed earth, the wild growing fruits and the wild goats, coming since Theocrit self-directed home, are attributes of a paradise-like life, and Polyphem and other giants are lacking. In the greek folk-tradition the words



μαχαρος, 'happy', and μαχρος, 'long' may have been changed by mistake. But the changing from the wild giant's region of Homer, the unknown Canarian author and (in some aspect) Theokrit to the paradisical fields of the tradition since Horace/Vergil is not the changing of a word by mistake, but the changing of social life. The older tradition is that of a half-barbaric people to barbaric ones – with horror (like the giant's neighbours in the Oldcanarian song). The younger tradition is the view of over-cultivated people to the happy simple life – with longing and nostalgia. If the Phoenicians really came to the Canaries, their opinion about the life of the Canarians of that time may have been 'terrible', whilst half a millennium later the opinion of Juba, a king and *arbiter elegantiarum*, was enthusiastic. So – though it may sound astonishing – the Happy Islands of the Roman and following literature come besides other traditions from the Islands of the Cyclopes or Giants and they are only a new interpretation.

The relations between news from Atlantic islands since the Phoenician voyage and literary sources are to be seen in fig. 2. If we bring in order the sources reported here – not searching for missing links between certain authors – we have first the cyclops, according to Homer wild inhabitants of a wild island (and, besides, cannibals), according to Hesiod sons of heaven and earth. Then we have the Hesiodan tradition of the Gorgons and Hesperides, that may have been located on islands, the Gorgons more related to the barbaric cyclops, the Hesperides to Homer's *Elysion pedion*. The tradition of the cyclops goes in the person of Polyphem until Theokrite, who sees the giant already with a psychological point of view. Then this tradition became – without giants – merged with the tradition of Hesperides/Elysion, and it may be that the news from the two phoenician expeditions – Neko's sailors and Hanno with his people – had some influence on this tradition. The next tradition is really news from sailors about 'Happy Islands' – maybe Madeira, maybe the Canaries. But as Madeira seems to have been uninhabited until the time of Henry the Navigator, islands with happy people could only be the Canaries. The news of these islands came by way of Sertorius and Sallust to the two authors, we still can read, namely Pliny and Plutarch, and now in Pliny we have already reliable news from the Canaries through Juba II, king of Mauretania, whilst the poetical tradition of Happy Islands from Vergil to Tasso may have been influenced from many sources, until Tasso really knew, where 'Happy Islands' were located namely in the Canaries, conquered in his lifetime. For the term 'Eternal Islands', coming from Arabian authors, there may be Arabic or other Oriental traditions. I could not find them.

To discuss the literature about Plato's 'Atlantis-island' is impossible in a small paper like this. I personally believe, as do other authors also, that the description of the isle Atlantis is a Platonic myth. But there are two interesting things in this theme, first the relationship between Atlantis and Atlas and so over the Hesperides to the in fig. 2 given greater relationship, second Plato's reference to an old Egyptian narration, that came through Solon to Plato's referent Kritias and that may have existed really, even not in the details given by Plato. The texts of this narration, says Plato's Kritias through the mouth of an Egyptian priest, are hidden in the temples of Sais. Now, if there were really historical notes in the temples of Sais, why does nobody open the big mound of Sa al-Hajar (the former Saïs), in which are the remains of the temples and maybe a note about an island, similar to Atlantis? But what is of most interest in this paper is the distant Canarian relationship to Atlantis through the myth of Atlas and the three Hesperides with their three golden apples. And here we really can relate this theme with old Canarian words and traditions.

According to Hans G. Güterbock, Hittitologist of the Oriental Institute of Chicago, the oldest Sumerian triad is formed by *Nanna*, representing the moon, *Inanna*, representing the morning- and the evening-star, and *Utu*, representing the sun. In the background we find *An* or *Anu*, the 'great bull', father of all gods and 'sky', and *Ninsun*, the 'good cow' or 'Lady Wild Cow'.[15] Another personality, related to the triad, is *Dumuzi*, the semitic *Tammuz*, in some texts the young husband of Inanna, in others the name of *Nanna* as the new light of moon. One of these gods, probably *Nanna*, is described as the herdsman of the stars. Thus the stars are cattle.

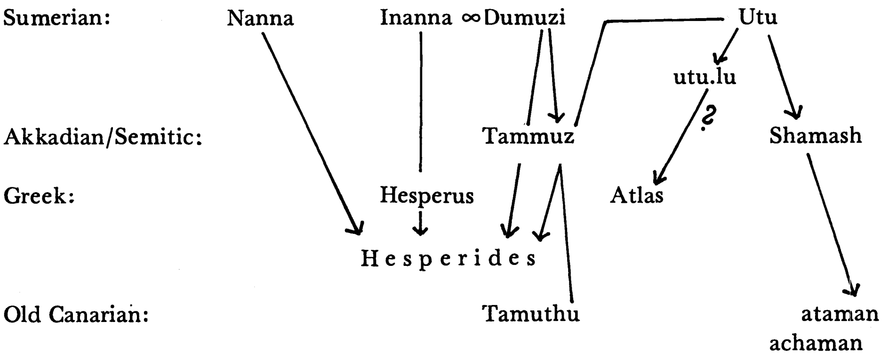
Now we have in Wölfel's 'Monumenta Linguae Canariae' one word for sheep *ana* (with a possible plural form *tahatan*).[16] And we have an old Canarian songtext, that reminds us of a Sumerian myth. In this song a man was thrown into the sea, but his friend *Ananahui* saves him. Now the saved man, whose name is not revealed, from this day on, in all fights protects his friend *Ananahui* with his body. The song ends with the question: Why does *Ananahui* need this helper in fights, he, who conquered the giant *Tamuthu*, who lived high up in the mountains, killing goats by throwing them into the deep gorges? In the Sumerian myth it is *Adapa*, a legendary sage, who is thrown into the sea by the southwind. In his rage he breaks the wings of the south wind. For this crime *Adapa* comes before *Anu*, and here *Tammuz* and *Gizzida* bid for him.

I believe, that the petrified word in these two stories about a sea-thrown man, the name *Dumuzi/Tammuz/Tamuthu*, comes from the same prehomeric mythological substrate and that the Sumeric triad as three animals in the sky in the Greek tradition turned into apples, because the meanings 'small cattle' and 'apple' were represented by the same word: μῆλον, 1. 'Kleinvieh, Schaf', 2. 'Apfel'.[17]

So I believe further, that Homer's *Hesperides* and *Atlas* came from Asia Minor, maybe as *utu-lu* > *Atlas*. (*Utu*, 'father (of gods), sky'; *lu*, 'man').[18] In Greek the name for 'father' is ἄττα. And there is an old Canarian word for 'god/sky' *ataman* or *achaman*,[19] that seems to come from the same tradition, even phonetically. So the old Canarians stood in a tradition of a 'father sky' *(ataman)* and a giant (Tamuthu < *Dumuzi/Tammuz*) like the Sumerians and the Greek, but the first 'Western Islands' must have been west from Asia Minor and that means in the Mediterranean Sea that may have been the first 'Atlantic Sea', until the name wandered further to the West.

Naturally there are possibilities of contacts between the north-african herding period (6000–2000 BC) and Asia Minor, but I doubt, that in this time the Canaries were a known destination for North Africans in (maybe) reed-bundle-boats or that – in case they were known – these islands gave rise to mythical stories in Asia Minor.

Now we have, as may be seen in fig. 3 (still highly hypothetical) relations between a Sumerian triad of astral gods and the *Hesperides* of the Greek tradition, between the Sumerian sungod *Utu* and *Atlas* on one hand, *Shamash* and *ataman/achaman* on the other, and finally a possible



relation from the Sumerian *Dumuz* over semitic *Tammuz* to old Canarian *Tamuthu*. But whilst *Dumuzi/Tammuz* seem to have been saviors, that die and resurrect in the cult like the Babylonian *Baal* and in our days Jesus, the Old Canarian *Tamuthu* was a wild and rough giant like Polyphem, who had his 'bloody dwelling place' on the top of the mountain, who was feared by his neighbours and killed by a hero named Ananahui. And whilst *Utu/Shamash* were sungods, *ataman* or *achaman* was the sky-god.

In any case the tradition from which these old relations may come, is so widespread and between the given points of tradition there are so many local variations, interpretations and misinterpretations also, that it is impossible to give a localization of the source, except that in the relations of fig. 3 the Sumerian tradition seems to be the oldest.

So news from the Phoenicians, from Sertorius' 'sailors' and from Juba II. remain as the possibly first real news from the Canary Islands in Asia Minor and Europe.

The names of the single islands

Whilst for the names for the Archipelago we had to go back into farthest mythical periods, with the names of the single islands we enter into historical times. What we have to discuss are the Latin (and one Greek) names, given by Pliny, and Plutarch, the indigenous names and the islands' names of to-day. The seven most discussed names, given by Pliny and Plutarch for the seven isles that are inhabited to-day (besides La Graciosa, that in ancient times was not inhabited) are: *Pluvialia* (Latin *pluvialis*, 'bringing rain') or *Ombrios* (Greek ὄμβρος, 'rain'), *Junonia Mayor* (according to Torriani[20] coming from a rare Latin word for 'green', but more probably from the Roman goddess *Juno*, the Greek *Hera* and maybe related to the Punic/Berberic *Tanit*), *Junonia Minor*, *Capraria* (Latin *capra*, 'goat'), *Nivaria* (Latin *nivarius*, 'filled with snow') and finally *Canaria* (related Latin words are f.e. *canis*, 'dog', *canere*, 'sing' or *canna*, 'reed(-flute)').

Fig. 4. The isle's name of today according to:

Isles acc. to Pliny/ Ptolemy	Etymology	Curt Müller	A. Hermann	J. Alvarez Delgado	G. Marcy	Torriani	A. de St. Cruz	de Palencia
Pluvialia	lat. *pluvialis*, 'bringing rain'	Lanzarote	Lanzarote	La Gomera	Lanzarote	Lanzarote	Hierro	La Graciosa
Ombrios	ὄμβρος 'rain', greek	dto.	dto.	La Gran Salvaje		Hierro		Hierro
Junonia Mayor	Lat. *Juno*, Roman goddess, Greek *Hera*, punic/berberic *Tanit*	Alegranza	Fuerteventura	La Palma	Tenerife	La Palma		Lanzarote
Junonia Minor		Graciosa	Lobos	La Gomera	La Palma	Gomera		
Capraria	lat. *capra* 'goat'	Fuerteventura	Gran Canaria	Hierro	Fuerteventura	Fuerteventura	Gomera	Fuerteventura
Nivaria	lat. *nivarius*, 'filled with snow'	Tenerife	Tenerife	Tenerife	Tenerife	Tenerife	Tenerife	Tenerife (Planasia) Las Palma(s) (Niguaria)
Canaria	lat. *canis*, 'dog' *canere*, 'sing' *canna*, 'reed (flute)'	Canaria	Gomera	Canaria	Canaria	Canaria	Canaria	Canaria

Fig. 5.

Present name	Etymology	Old Canarian name	Etymology	Latin/Greek name	Etymology
Lanzarote	From Lancilotto Maloicello (1330) But berberic *ancar* = 'rain'	*Tyterogakaet*	Tuareg *tatergaget* = 'she, who is hot/burning'	*Pluvialia*	'bringing rain'
Fuerteventura	Span. *fuerte* = 'strong', *ventura* = 'luck' Latin *forte* = 'strong', *ventus* = 'wind'.	*Dolatelac* *Erbane/Albanye* *Mahorata*	? In Celtic/Ligurian place-names *alb-* = high place From shoes, called maho	*Ombrios* (?) *Capraria*	'rain' 'goat'
Gran Canaria	*canis*, 1. 'dog', 2. name for two constellations, 3. the worst hit with dice or Astragalus (4 ones with 4 dices)	*Tamaran/Tamoran* *Tebicena*	Can. *tamara* = 'date' Can. *tibicena* = '(demonic) dog', Sidi Ifni *tibelbac* = 'small fat dog'	*Canaria*	From Latin words for 'dog' or 'sing' or 'reed' or from an ancient tribe from Marocco, the Canarii
Tenerife	*ti-n-irifi*, '(the island) of thirst 'heat'	*Tenerefiz/Tenerfe* or similar	For the meaning 'snow-mountain' of some authors only Greek νιφα etc.	*Nivaria*	*nivarius* (Lat.) = 'filled with snow'
La Palma	Romanic *palma* = 'palmtree, palmtwig palm of hand', Latin also 'shield'	*Benahoare*	Can. 'my country'?	*Junonia Mayor* *Cornvallis* (?)	From *Juno* Lat. *cornvallis* = 'basin of a valley'
Gomera	Berb. *gumer*, *gummar* = 'cazar'	*Gomera*, *Gumera* or similar	Sidi Ifni *gumer*, *gummar* = 'to hunt'	*Junonia Minor*	like above
Hierro, earlier Ferro	Latin *ferrum* = 'iron', Span. *hierro* = 'iron'	*Esero*	Can *esero* = 'strong'	*Ombrios* *Hero*	'rain' ἱερός, strong, holy

Seven identifications for these names are given in fig. 4. The first two German writers, Curt Müller and A. Hermann[21], are cited and discussed in D. J. Wölfel's Torriani-edition, the second two Authors, Juan Alvarez Delgado[22] and George Marcy[23], are berberologists, the last three authors are early croniclers, Leonardo Torriani, A. de Santa Cruz[24] and Alonso de Palencia[25].

According to these authors, who tried to verify the islands from different aspects it is probable that *Canaria* was always the *Gran Canaria* of to-day, that *Nivaria* was our *Tenerife* of to-day, *Capraria* the present *Fuerteventura* and *Pluvialia* the present *Lanzarote*. But to be more certain about this verification, it would be good to make a synopsis of the present, the Old Canarian and the Latin/Greek names of the islands and the etymology of the words as to be seen in fig. 5.

Here we see, that the Latin and Greek word for 'rain', the roots for the name of Lanzarote, have nothing to do with the Old Canarian name *Tyterogakaet*, in which George Marcy reads 'she, who is hot' or 'she, who is burning',[26] whilst D. J. Wölfel, though very doubtfully suggests that, this word has a relationship to berberic words with the meaning of 'quick running'.[27] But strangely, in the present name of the island, Lanzarote, derived from Lancilotto Maloiccello of Genua, who lived some years on the island before it was conquered, we can find a berberic word for 'rain', namely the word *ançar* from Sidi Ifni[28]. If popular etymology made from *Lancilotto* a *Lanzarote* because of a word for 'rain', phonetically related to *ançar*, then the indigenous name of the island must have had something to do with 'rain'. Then maybe Wölfel's 'quick running' has to do with the rains of Lanzarote, that are really quicker and more violent even to-day than for instance on Gran Canaria. (Sidi Ifni 'to rain' = *kkat.*) *One* good rain on Lanzarote, which splashes onto the large water gathering areas, may fill the cistern for months. So this little synopsis for Lanzarote may concern us a bit more, that it was the ancient *Pluvialia*[29].

In the synopsis for Fuerteventura there may be a relationship between the indigenous name *Mahorata* and the Latin *Capraria*. For the *maho*, the goat-shoe, from which the island's name is a derivation, was made from goat-skin ('de los cueros de las cabras' says Abreu Galindo[30]). So maybe *Capraria* meant 'isle of the people with goat-skin-shoes'. The names *erbane/albanye* seem to come from an Italic-Celtic-Liguric stratum, from which also came *Albion* for 'Britain' and the Galic name for Scotland, *Alba*[30a], whilst *Fuerteventura* seems to come from 'strong wind'[31]. (Spanish *ventura*, 'luck', has to be a secondary meaning). But as *Mahorata* possibly was only the name of the southern part of Fuerteventura and as until to-day the *Mahoreros* are also the inhabitants of Lanzarote as well as those of Fuerteventura, we can suppose that derivations from the word for skin shoe, *maho*, came from inhabitants of other islands, who must have used other kinds of shoes. So as a name for the island, given by the inhabitants, remains *Erbane/Albanye*, coming from a Mediterranian-

Atlantic stratum and meaning 'high place'. And Fuerteventura really is, in the words of the geologist Hans Hausen, 'an island of mountains as well, but these are of middle heights[32]'.

According to Pliny[33] it seems that Lanzarote and Fuerteventura (and maybe also the small islands near them) were the *Purpureae insulae*. But Alonso de Palencia tells us, that the 'barbaric kings' of *Planasia* (without any doubt Tenerife) sometimes met sailors and gave them dye-plants in exchange for 'miserable things of ours'[34]. (And Alonso de Palencia knew, as Juan Alvarez Delgado proved with documents[35], the early notes of the author and bishop Alonso de Cartagena, born about 1384, with all details). So the sporadic trade with dye-plants from the Canaries was not confined to the Eastern islands. Johanna Schmidt even had arguments for the ascertainment that the Canaries were a Phoenician 'purple-colony' and that the name *Canariae Insulae* came from the Phoenician purple-dyer, the Canaanites[36].

As we have to speak now of Gran Canaria, we can discuss here possible relations between the word *Canaria* and plant-names. Many authors bring the word in relation to *caña dulce*, the sugar-cane, but the meaning of the Spanish word *caña* (Latin *canna*) was 'reed', before the sugar-cane came from America. So if there is a relation between *Canaria* and *canna/caña*, we have to think of reed, and maybe of the people with reed-bundle-boats[37], well known from North-West-Africa. Pliny speaks of a tribe in present Rio de Oro, called *Canarii*[38]. Maybe they had reed-bundle-boats and some of them came to the Canaries and had to stay there, because these boats can be used only two months. If in this time the islands had no reeds, the poor people would have been involuntary prisoners.

A plant-name, coming from the old Canarians, is *alicaneja* (*Anchusa* and *Cynoglossum*, Boraginaceae)[39]. As I could show in my paper about Old Canarian plant-names[40] it is not an original Old Canarian name, for it is used also in Spain (and the nomenclature of the botanists knows *Alkanna*, Boraginaceae). But the plant was used in the Canaries for dying or painting the body (like the possibly related Arabic *Alhinna*). So we have here a relationship between the meaning 'dye' or 'paint' and a word with the root – *can* –. (If *ali*- has to do with the Berberic word *ali*[41], we could in the botanist's Latin say *Caneja pendula* (*ali* = to be swinging)). So we would have the relation: Canaria – Caneja – 'painting plant'. (*Canaan*, the old name for Palestine, is mostly, though not proved, translated as 'land of the purple'.)[42]

As according to Dominik Josef Wölfel the name *Canariae insulae* is already early testified (by the African writer Anobius, who died about 330 AD) we can think of a very old African inheritance. And as the Canaanites were great sailors, who came as far as Spain, why shouldn't they have come to North-West-Africa also? D. J. Wölfel, citing A. Herrmann, says in his Torriani-edition, that the main part of the inhabitants of North-West-Africa from Marocco to Tunis were called

Canaan after the son of Ham (Genesis 10) and that Noah according to the Bible was against the occupying of Palestine. In texts outside the Bible we find in Augustin's letters the *Chenani* in the hinterland of Carthago, and the Arabic geographer Ibn Khaldun says, the Berbers are the sons of *Hanaan*[43]. Maybe the Canarii of Pliny in northern Rio de Oro are descendents of בְּנֹצַן *(Kan'n)* and the old Canarians descendents of these descendents, for the paralleles between Old Canarian words and those of Sidi Ifni are really astonishing.

For the indigenous name of Gran Canaria, *Tamaran*/*Tamoran*, we have the word still used today for a ripe sweet date or a date-bunch: *tamara*. Berberic parallels for the meaning 'date' are lacking. We only have Arabic parallels like *tamr*, 'ripe dried date', *tâmir*/*támra*, 'date', *tamar*, 'fruit', and maybe an older meaning in Hebrew *tômer*, 'palmtree, column'. Wölfel says[44], we have to eliminate the word *tamara* from the list of indigenous Old Canarian words, because the word is known in Spain also. But in all my Spanish dictionaries the first meaning of the word is 'palmera de Canarias'. May-be the Arabs brought this word to both places, Spain and the Canaries, for Arabs seem to have been very early on the islands. Sabin Berthelot tells us, that in 999 AD a certain Ben-Farroukh came to Gando on Gran Canaria, where he found Arabic speaking people, living in harmony with the indigenous population[45]. So why shouldn't this word with the meaning 'date' come from the Arabs? But the interesting thing is that the old meaning for the word *tamaran* as island's name, 'brave' or maybe 'isle of the braves', has berberic parallels like *taman*[46], 'valor, precios de las cosas', *tamâra*, 'force, puissance d'action, personne considerable'[47]. Furthermore many Berberic languages are called *Tamashag*, *Tamahaq* or *Tamaçirg* and a berberic word for 'indigenous' is *u tamaçirt*, pl. *ait tamaçirt*[48]. Probably the group of Berberic people, who call themselves or their languages *u tamaçirt* etc. were related with palm-trees, Hebrew *tômer*, and had the palm-tree as symbol for braveness and value[49]. But then the meaning 'date' or 'date-palm-tree' is a younger meaning, that came through Arabs to Spain as well as to the Canaries. (In the Bible, Gen. 38, *Tamar* is the daughter-in-law of Juda, first married to *Ger*, then to *Onan*.)

In any case the old name *Tamaran*/*Tamoran* has definite relations with a group of Berberic people from Africa. (The root *tama-* means in Berberic languages 'coast', 'shore', 'border', 'edge'.)

The name *Tebicena*[50] for Gran Canaria is only given by Leonardo Torriani. *Tebicena* was a kind of demonic dog, and we find – as mostly – a parallel in Sidi Ifni: *tabelbuçt*, 'little fat dog'[51]. But as Torriani believed, that *Canaria* came from *canis* he may have searched for an indigenous word for 'dog' and made from this the island's name.

The name of the island of *Tenerife* (in some European languages called – nobody knows why – *Teneriffa*)[52] is the modern form of one of the indigenous names. The islanders themselves seem to have called their island approximately *chinechi* or – with prefixed *a-* – *achinech*. The name, given by the inhabitants of other islands, is the name, that evolved to *Tenerife*, in the eldest known form *Tenerefiz* with the explanation: 'island of the hell'[53].

For *chinechi/achinech* I believe, as does Georges Marcy also[54], that it has to do with the same thing as the name *tamaran/tamoran* for Gran Canaria, namely with the date, in Sidi Ifni *tiynit*[55]. (It is known and well proved by Wölfel that *t* in Tenerife was often palatalized to *ch*.) But I am not sure, as Marcy is, that the island's Latin name *Junonia* is an *interpretatio Romana* for the Berberic/Punic *Tanit*, goddess of the date-palm-tree, and meant *Tenerife*. As we have seen, also the indigenous name of Canaria seems to be related to 'date', and the oldest meaning of Berberic *Tanit/Tinnit* must have been only a personification of the date-palm-tree in a wide-spread tradition.

For *Tenerefiz*, testified already about 1350 or earlier from a Spanish Franciscan, in later forms *Tinerfe*, *Tenirfe* etc., the oldest explanation is 'snow-mountain'. But there are no Berberic words to testify this translation. Only Indoeuropean words may be related as the Latin *Nivaria*, the name given to Tenerife by Pliny, from *nivarius*, 'filled with snow'. But I think it is more possible that Roman sailors made from a form like *Tenirfe* a *Nivarius*, mingling the meaning 'snow' (that they saw on the Pico de Teide) with the indigenous name than that a hypothetic Indoeuropean influence formed the very Berberic sounding word *Tenerefiz*, *Tinerfer*, *Tenirfe* etc. I think the analysis has to be likened to that from Abercromby *ti-n-irifi/ta-n-urrif*, '(the land) of heat, anger', or like George Marcy *tä-n-ärfä*, 'la de las piedras volcanicas' or like Wölfel, who thinks of words as *aref*, 'chauffer au moyen de pierres chaudes' or *ârefei*, 'éruption, on de bouton de chaleur' and so on. In Sidi Ifni we have *irifi*. 'hot thirst', thus *ta/ti-n-irifi*[56].

As Juan Alvarez Delgado could show, for the sailors of the 15. century and the beginning of the 16. c. *Tenerife* was 'infierno', 'the hell', and here is really a relationship to the given analysis of *Tenrefiz* etc., for in the *interpretatio Christiana* a 'land of heat and anger' is the hell.

The name for the inhabitants of Tenerife, *guanchinet*, *guanches* etc., nowadays often used for all inhabitants of all islands in ancient times, was according to all primary sources only used for the people of Tenerife, and I think Wölfel's analysis is right: *wa-n-cinec/wi-n-cinec*, 'der von Tenerife/die von Tenerife'. (*c* = palatalized *t*; *w* = *w* in English pronounciation, Spanish often written *gu* (*à*), like Padre Ibañez writes the word of Sidi Ifni for 'this (one)', *guann*; and the Spanish Academy writes for 'Whisky' *guisqui*.)

The name *babilon*, given to the people from Tenerife, may come from the fact, that these people spoke (for instance with their 'thick' *t*) in the ears of the other islanders in a stupid manner, and 'a stupid' is in Spanish *bobo* and in a Canarian diminutive *bobilín*.

Rather strange is the fact, that Alonso de Palencia calls Tenerife *Planasia* (Latin *planus* = English *plane*)[58]. I think, he mixed various things, that he had heard from Alonso de Cartagena, namely: *Niguaria* for an 'island' *Las Palmas*, but meaning the older place-name of the *city* of Las Palmas, *Giniguada*, *Niniguada*, *Guiniguada*, meaning 'in the same level as the sea' or 'there in the same level'[59], with the Latin name *Nivaria*, that in Classic Latin only can come from 'snow', but in Palencia's time already could be mixed with a Spanish word, that to-day is *nivel*, 'level'. So he made from the old name of the place of Las Palmas *Gui-niguada* the name *Niguaria* and gave it to the *island La Palma*, and the meaning of 'plane' or 'in the same level' he gave to Tenerife in the word *Planasia*.

The name, given by some sailors to Tenerife, *jiroteror*, seems to me a Spanish compositum or from *jirón*, 'rag', and *tirar*, 'throw' (thus meaning the eruptive Pico de Teide) or from *jira*, a kind of outing, and *terror*, 'terror', thus 'terrific outing', namely to a dangerous volcanic island.

In *La Palma* we meet for the third time the meaning 'palm-tree'. Leonardo Torriani says about the island's name: 'Palma, for the lots of palm-trees so named ...' And later: 'This island was by the old inhabitants *(gli antichi palmesi)* called *Benahorare*, that is fatherland *(patria)* and then *Junonia Mayor (Giunonia maggiore)* either because some Romans, as Pliny tells, here in a temple sacrificed to Juno, or because she was discovered by a *Junius* or because of the green of the woods ...'[60] The here named *Junonia* comes from Pliny. Georges Marcy located it, as we saw, on Tenerife. Another author, Attilio Gaudio[61], locates it on Lanzarote, because Pliny's name is, according to Marcy, a translation of Thanit and must have come from the Carthaganian colony Cerné, to-day Saguia-el-Hamra, to which Lanzarote is the next island. But the identification Cerné = Saguia-el-Hamra is not proved with absolute certainty, and if the Carthagian brothers Hanno and Himilcon came to the Canaries, they surely saw not only Lanzarote. The only sign for a possible visit from Carthage or its colonies, the inscription of Anaga, written probably in one of these degenerated scripts by colonizers of Carthago, was found on Tenerife.

The most interesting thing in relation with *Junonia* is the temple. La Palma had, as far as we know, no temples, but pyramids[61a]. 'Temples' we know from Gran Canaria, one with a stone-statue of a naked man with a 'ball' in his hand, which was brought to Lisbon[62] and still may be there, the other with a naked woman and a he-goat ready for copulation[63]. But in a temple with a man you cannot pray to Juno, and a he-goat is not typical for Juno. Fuerteventura had a labyrinth-temple with a figure 'in human form', as Torriani says, and Fuerteventura also. But in the drawing of Torriani[64] there seem to lack as well a penis also breasts. So maybe it was an androgyne figure, also not qualified for praying to Juno.

The only feminine deities of the Canaries seem to have been Torrianis *armaxes guaiaxiraxi*[65], probably a canarisized name for the Christian *Maria* as mother of god, and from Hierro a kind of 'mother of offspring', called *Moneiba*[66], that remains more – even phonetically – on the Roman *Bona Dea*, that was worshiped – like Moneiba also – only by women. So a temple cannot help us to identify *Junonia*. Also the worshiping of a deity like *Tanit* is until to-day not known, nor the worshiping of palm-trees. The only 'holy' tree from Hierro is not a *palm-tree*, but *Ocotea foetens*, and its name, *Garoe*, is not related to a Berberic word for (date)-palm-tree like *Tiynit*. So, if Pliny does not mingle names from different croniclers, who gave different names to the same islands, we only can hope, that, if the other Latin names are identified, *Junonia Mayor* and *Junonia Minor* can only be the names of the lacking islands *La Palma*, *Gomera* and *Hierro*. And as La Palma is the biggest of the three, it has to be *Junonia Mayor*.

With the indigenous name of La Palma, *Benahoare* (Torrianis *Benahorare* seems according to Wölfel an error) there was some confusion, because George Glas related it to the Berberic tribe of the *Hawara* and its Arabic name-form *Beni Hawara*. Many authors followed him and brought new confusion with Indoeuropean endings. Wölfel seemed to clear the scene. But as we shall see, there are reasons for an offspring of the name from a tribe.

For the meaning of *Benahoare*, from the croniclers given as 'patria, mi patria, mi tierra'[67], Berberic parallels are lacking. Also Padre Ibañez' dictionary of the dialect of Sidi Ifni gives no help. Wölfel attempts to analyse from *quebehiera* from Tenerife ('his/your highness') a possessive-affix *-hiera*, and from many geographical names such as *benchijigua* and others *beni/bena-* as 'land/region of ...', thus together something like 'land of mine/ours', but for the possessive element he himself has doubts, and for *ben-* or *bena-* with the meaning 'land/region of' there seems to be no parallel in semitic, hamitic or indoeuropean languages. Place-names in Morocco are: *Béni Mellal* in Central Morocco, and a bit more western *Ben Guerir*. A tribe of a 'pure hamitic stock', to-day living in Eritrea, are the *Beni 'Amer*, ascendents of the *Beja*, a 'group of nomadic tribes occupying, since 4.000 BC or earlier, the mountain country between the Red Sea and the Nile and Atbara rivers from the latitude of Aswan to the Eritrean plateau'[68]. (But probably all these words have to do with the semitic word like Hebrew *bén*, 'son'.)

It seems, that the relation between *Benahoare* and a tribe's name is more probable than an analysis 'my fatherland' or something similar.

Gomera, as next to La Palma *Junonia Minor*, if La Palma is *Junonia Mayor*, seems to have had always the same name, since Europeans heard of it. The first delivered form, about 1350, is *gommaria*. Wölfel doubts, that it is a Berberic name[69]. But of the parallels that he gives by way of trial is *egmer*, 'chasser', and again we find in Sidi Ifni a phonetically much nearer form to *gomera*, namely *gumer/gummar*, 'to hunt'[70]. Unfortunately the *Gomer* of the bible in Gen. 10, often called as forefather of the people of *Gomera*, is only a cousin of the great hunter, for *Nimrod* is the son of *Chus* and *Chus* is the son of *Ham*, the uncle of *Gomer*. So from the bible comes no help for the meaning 'to hunt'. (Only the prostitute *Gomer*, wife of Hosea, maybe related to the meaning in the form 'hunting men'.) George Marcy[71] relates *Gomera* to the *Gmara*, Berbers of the western *Rif*, but has no explanation for their name, that is, according to him, the arabized form of an elder Berberic word with unknown meaning. So we only can listen to Leonardo Torriani, who says, that the Gomerians were very dexterous in throwing stones with their hands and spears with fire-harded points. The children had very early to learn to dodge from thrown clay-balls and later from spears[72]. This reminds us of a hunting-people, so that again Padre Ibañez from Sidi Ifni was the helper in finding a (in this case forgotten) meaning.

Speaking of the name of the last island, with the indigenous name of *Esero*, then *Fero* or *Fierro*, later *Ferro* and to-day *Hierro*, we have to remember, that in many languages strongness, also of mind, is expressed with a 'material' adjective like 'wooden', 'steely' etc. A strong man in Yugoslavia is of 'bosanski drvo', from 'Bosnian wood'. Adolf Hitler used to satiety the phrase 'eherner Wille', 'determination of ore', (in which the old meaning for *ehern*, 'of ore' is already widely unknown in Germany).

Now to the indigenous name *Esero* seems to have happened this: It meant in the Old Canarian languag(es) as well 'strong' also 'rock' or 'strong rocky place'. And as metal was unknown on the Canaries the word never lost its relation to 'rock'. But for the Illyrers, Celts and Old Germans a related word changed into the meaning 'of iron'. The Canarian meaning of a 'strong stony place' as *Esero* has in the Gallic fortress-name *Isar-nodori* a relation (and thus for the speaker association) to 'iron'. So maybe a Gallo-Roman or a Celt-Iberer, maybe one of the sailors of Sertorius, heard the name *Esero*, perhaps explained in sign language with the fist, related it to names like *Isarnodori* and thus also to 'iron' and told: 'The indigenous people call their island iron or of iron'. With the changing of the word for 'iron' changed the word for the island until to the present name *Hierro*, the modern Spanish word for 'iron'. Wölfel says: 'All nations have understood the word as 'iron'.'[73]

But unfortunately Ptolemy called one island *Hero*, and on Hierro there was another word *hero* with the meaning 'cistern' and a plural *heres*, still used to-day on Tenerife with mute *h*, 'cisterns'. So there came a confusion between the meanings 'rock', misunderstood as 'iron', and the meaning 'cistern'. I think, Alvarez Delgado is right, when he says, that the meaning 'cistern' (or related meanings) is not an accounting for explaining the name of the island[74].

Ptolemy's *Hero* may come from the Greek ἱερός, that means 'strong', but also 'holy'. Then we have to think of one of the most confusing texts of ancient geography, the 'Ora Maritima' of Rufus Festus Avienus[75]. He tells us, that people in 'sewed' boats of skin came from Oestrymnis (located by many authors in many places, also in North-West-Africa) to the holy island in two days, where there lived the *gens hiernorum*, thus 'Hiernons' and where there was nearby an 'insula albionum', that theoretically may be *Albanye* = Fuerteventura. But I think, from the Greek word for 'holy' you can make *gens hiernorum* wherever you want to, and as locations with *Alb-* are widespread in the Atlantic area, also other islands will have an island nearby, whichs name begins with *Alb-*. So we only can state, that, if Ptolemy's *Hero*[76] comes from ἱερος, it has with the indigenous name *Esero* together, besides other meanings, the meaning 'strong'. And we can, for the much discussed question of how the first people came to the Canaries, after having thought about reed-bundle-boats, now also think about 'sewed' boats of skin.

Summary

There is no evidence, that the *Elysian fields*, Homers *Elysion pedion*, nor *the islands of the Cyclops*, nor the *Gorgones* and the *Hesperides* were located from the beginning on to the Canary Islands. But it is possible that these traditions were influenced by the Phoenicians, sent from Pharao Nekos around Africa, and from Hanno and his brother from Carthage, who may have seen the Canaries and mixed, what they had seen, with the old stories. An evidence for the presence of Carthaginians may be the inscription of Anaga, Tenerife. If there is an expert for scripts of Carthaginian colonizers, he might read the text and tell us, who came to Tenerife.

When the old tradition from *Islands of Cyclops* with wild growing plants and fruits was seen by a new highly cultivated generation, the barbaric character of the islands turned into a kind of paradise, the *Happy Islands*, and from now on news from the Canaries always seem to have influenced texts about happy islands, as to be seen in the tradition Vergil-Horace-Ovid-Tasso. The first evidence for the name of the archipelago of to-day is *Canariae Insulae* from the African writer Anobius († ± 330 AD). The name may have to do with the *Canaanites*, who according to Procopius[77] were in the present Tanger and engraved there an inscription into two gigantic columns. Maybe that the tribe of the ancient *Canarii* in South Morocco or northern Rio de Oro is related as well to the Canaanites as also to the Canaries. *Cana-* may be related to reed or to a dye plant, and the Canaanites were dyers. The only relation, that is very doubtful, is to-day's most popular relation with *canis*, 'dog'.

The name *Eternal Islands*, given from Arabian writers to the Canaries, must come from Oriental traditions.

For the names of the single islands it seems to me, though I cannot prove it beyond any doubt, that *Lanzarote* was the *Ombrios/Pluvialia* of Pliny, *Fuerteventura* Pliny's *Capraria*, *Tenerife* the *Nivaria* of Pliny, *Canaria* always *Canaria*, *La Palma* Pliny's *Junonia Mayor* and *Gomera Junonia*

Minor. Hierro may have been Ptolemy's, *Heras nesos*. But this is doubtful.

The indigenous names *Tamaran* for Gran Canaria, and *Chinechi/ Achinech* for Tenerife seem to be related to 'date' or 'date-palm-tree' as *La Palma* also and even in the name *Junonia*, if Juno stands as Roman form for the Berberic/Punic date-palm-goddess *Tanit*. But there is until to-day no evidence for the cult of date-palm-trees or of a deity like *Tanit* on the Canaries. Only one trace may be found, namely the notice by Torriani that from the Old Canarians a woman was highly praised, who invented the sewing of 'la tela tessuta di tenere fogli di Palma', thus woven textile from soft palm-leaves[78]. But this is a very far connection to a *Tanit*-cult.

The name *Mahorata* for Fuerteventura, related to the *Mahoreros*, inhabitants of Fuerteventura and Lanzarote, is related also to *Capraria*, the goat-island, for *maho* were the goat-skin-shoes. This name for one island and the inhabitants of two islands must have come from other islands because of the shoes, that seemed strange for the other islanders. The name *Erbane/Albanye* must be related to Celtic, Liguric, Italic place-names, beginning with *Alb-* and probably meaning 'high place'.

It is not proved, that the name *Tenerife* (from its oldest known form *Tenerefiz* until to the form of to-day) means 'snow-mountain'. More likely it is related to meanings like '(the land) of heat, anger' or similar and probably the *interpretatio Christiana* made from this meaning the translation 'hell'.

For the indigenous name of La Palma, *Benahoare*, is the given meaning 'my homeland'. But one cannot make sure of this meaning in relation to Berberic languages without many doubts. Only a very distant relationship Indoeur. *u-n-*, 'to dwell', Semitic *y-u-n-*, Hebrew *zān*, 'dwelled', *māzōn*, 'dwelling place', may be hidden in Kushitic-Berberic tribe-names. So perhaps the first people of La Palma were from one of these tribes and knew through oral tradition this very old meaning.

That the name *Gomera* comes from a Berberic word for 'to hunt' can be supported by the word *gumer/gummar*, 'to hunt' from Sidi Ifni and from hunter's customs of the Gomerians, described by Leonardo Torriani. But this old meaning may be hidden also in a tribe's name, related to the *Gmara*, Berbers of the western Rif.

The name for the last inhabited island of ancient times, to-day *Hierro*, changed from the meaning 'rock(y)' to 'of iron', but had besides always the figurative meaning 'strong', that we can find also in the Greek word 'strong, holy', maybe related to an island's name *Heras nesos* by Ptolemy. In the Canaries a word *hero* had the meaning 'cistern'.

Names given to things, even to islands, by men, are related to reality only through the brains and tongues of men, who may misunderstand, make mistakes or even lie. This is the difficulty of relating words to things, as I have tried to do between old and new names and seven islands in the Atlantic Sea.

NOTES AND SOURCES

1. In 'Kritias' we find the form Ἀτλαντίδος νήσου βασιλης, 'kings of the island Atlantis'. In: 'Platon, Werke, griechisch und deutsch, herausgegeben von Günter Eigler', vol. 7, Darmstadt, 1972, p. 108d.
2. In 'textos Arabes de viajes por el Atlantico' from Juan Vernet, 'Anuario de Estudios Atlanticos', 17, Madrid-Las Palmas, 1971, p. 401 ff., we find the following passages: 'Refiere Ibn Fātima: Las Islas de la Felicidad (Taza'ir al-Sa'ādāt) se encuentran entre las Islas Eternas (al-jālidāt) y el continente... (p. 412) Ibn Saíd al-Magribī, en su texto que conserva al-Maqqarī en su Nafh al-Tīb (ed. Cairo, 1949) nos dice: Y en el océano están las siete islas eternas, situadas al Oeste de la ciudad de Salé . . . En direccion Norte se encuentran las islas Sa'ādāt . . . la primera de esas islas es Bretaña.' According to this Arabian tradition the Canaries are the *Eternal Islands*, and the *Happy Islands* are f.e. the islands of Madeira or even the British Isles *(Bretaña)*.
3. Juan Vernet, op. cit. p. 416.
4. Fr. Esteban Ibañez, 'Diccionario Español-baamarani', Madrid, 1954, p. 44.
5. Wolfgang Schadewaldt, 'Legende von Homer, dem fahrenden Sänger, ein altgriechisches Volksbuch', München, 1942.
6. 'Iuba de Fortunatis ita inquisivit: sub meridiem quoque positas esse prope occasum, a Purpurariis DCXXV p., sic ut CCL supra occasum navigetur, dein per CCCLXXV ortus petatur. Primam vocari Ombrion . . .' (C. Plinius Secundus, Naturalis Historia, Vol. I, ediderunt L. Ian-C. Mayhoff, Stuttgart, 1967, Liber VI, 32, 203 f.).
7. In 'An Anthology of World Poetry', edited by Mark van Doren, New York, 1928, p. 312.
8. In 'Hermes', Nr. 73, 1938, p. 237 ff.
9. In 'Jahrbuch für Philologie und Pädagogik', Nr. 99, 1869, p. 316 ff.
10. Literature in: Günther Kunkel, 'Plantas Vasculares de Gran Canaria', Las Palmas, 1972, p. 52.
11. Dominik Josef Wölfel, 'Monumenta Linguae Canariae', herausgegeben von Alois Closs, Graz, 1965, IV, § 395.
12. According to Wölfel, op. cit., IV, § 204, we have for barley from Tenerife the word *tamo*, from Gran Canaria the word *amazotan*, IV, § 203, from Hierro, though doubtfully, *tezzeses*, IV, § 205, and from Lanzarote, Fuerteventura and Gran Canaria a form *tamosen*, IV, § 202.
13. Günther Kunkel, op. cit., p. 58.
14. James Krüss, 'Altkanarische Idyllen' in 'Adeva-Mitteilungen', Graz, Heft 40, Dec. 1974, p. 22 ff.
15. His article in the Encyclopaedia Britannica from 1969, II, p. 973.
16. J. D. Wölfel, op. cit., IV, § 174.
17. Johann Baptist Hoffmann, 'Etymologisches Wörterbuch des Griechischen', Darmstadt, 1969, p. 200.
18. *utu*, 'Sonnengott'; *lu*, 'Mann, Mensch, welcher' in: Prof. Dr. B. Meißner/Prof. Dr. K. Oberhuber, 'Die Keilschrift', Sammlung Göschen, Band 708, 708a, 708b, Berlin, 1967, Pp. 154, 149.
19. D. J. Wölfel, op. cit., IV, § 11.
20. Leonardo Torriani, 'Die Kanarischen Inseln und ihre Urbewohner', translated from Italian into German and edited by Dominik Josef Wölfel, Leipzig, 1940.
21. Torriani/Wölfel, op. cit., p. 49, note.
22. Juan Alvarez Delgado, 'Las Islas Afortunadas en Plinio' in 'Revista de Historia', XI, 1945, p. 26–61.
23. Georges Marcy, 'Nota sobre algunos topónimos y nombres antiguos de tribus

Bereberes en las Islas Canarias', traduccion y commentarios por J. Alvarez Delgado in 'Anuario de Estudios Atlanticos', 8, p. 239 ff.

24. Alonso de Santa Cruz, 'Islario General de todas las islas del Mundo', cited in: Francisco Morales Padrón, 'Canarias en las cronistas de Indias'. ('Anuario de Estudios Atlanticos', 10, p. 189.)
25. 'Cuarta Década de Alonso de Palencia', Estudio, texto y traduccion por José López de Toro, Madrid, 1970, part II, p. 40.
26. George Marcy, op. cit., p. 259 f.
27. D. J. Wölfel, op. cit., IV, § 478.
28. Fr. Esteban Ibañez, op. cit., p. 191.
29. Though Pliny's description of *Ombrion* meant undoubtedly the island Hierro of today, there are no other sources for the supposition, that the name *Ombrion* was given to the island of Hierro. It seems more acceptable, that *Ombrion* and *Pluvialia* were the Greek and the Latin name for the same island, probably Lanzarote. Pliny's description goes: '. . . nullis aedificiorum verstigiis; habere in montibus stagnum, arbores similes ferulae, ex quibus aqua exprimatur, e nigris amara, ex candidioribus potui iucunda.' (Nat. Hist., VI, 32, 202–204.)
30. Cited in Wölfel, op. cit., IV, § 262.

30a. Friedrich Kluge, 'Etymologisches Wörterbuch der deutschen Sprache', Berlin, 1967, p. 15.

31. Latin *ventus*, 'wind'.
32. Hans Hausen, 'On the Geology of Fuerteventura', Copenhagen, 1958, p. 13.
33. Nat. Hist. VI, 32, 205. (See note 6).
34. A. de Palencia, op. cit., II, p. 24: 'Nauticis nonnumquam licet ex pacto conversari aliquantisper cum barbaris illis Planasiam possidentibus ut orchiliam scilicet herbam tinctoribus lamificii accomodam es permutatione vilium rerum habeant nostri.'
35. Juan Alvarez Delgado, 'Alonso de Palencia y la historia de Canarias' in 'Anuario de Estudios Atlanticos', 9, p. 51 ff.
36. Johanna Schmidt, 'Jenseits der Säulen des Herkules' in 'Anuario de Estudios Atlanticos', 17, p. 365 f.
37. The Egyptian type of a reed-bundle-boat is to be seen in: Björn Landström, 'Das Schiff', Gütersloh, 1973, p. 10, figure 3.
38. Nat. Hist. V, 1, 13–16: 'qui proximos inhabitent saltus, refertos elephantorum ferarumque et serpentium omni genere, Canarios appelari, quippe victum eius animalis promuscuum iis esse et dividua ferarum viscera.'
39. Literature to find in G. Kunkel, op. cit., p. 62.
40. James Krüss, 'Canarian Common Names of Wild Plants and their Meaning in Botany and Linguistics' in 'Proceedings of the I. International Congress pro Flora Macaronesica', Las Palmas, 1973, p. 49 ff.
41. D. J. Wölfel, op. cit., V, § 291.
42. Encyclopaedia Britannica, 1969, 4, p. 723: 'Canaan, probably meaning "Land of the Purple" . . .'.
43. All these informations are to be found in the note 20, p. 54 of Torriani/Wölfel, op. cit.
44. D. J. Wölfel, op. cit., IV, § 221.
45. Sabin Berthelot, 'Antiquités Canariennes', Paris, 1879, p. 31 f.: 'Ce fut à la tête de cent trente hommes que Ben-Farroukh débarqua sur la côte de Gando, dans un petit port auquel les géographes arabes ont donné son nom. L'île, à cette époque, était couverte de forêts, et les explorateurs furent reçus en arrivant par des Arabes, leurs compatriotes, qui vivaient, paraît-il, en bonne harmonie avec les Canariens et que provenaient d'expéditions antérieures d'Arabes navigateurs, que des circonstances que nous ignorons avaient amenés dans le pays. Ces Arabes conduisirent Ben-Farroukh à Galdar, chez le *guanartème* Guanariga, où lêtranger fut accueilli dans la residence du prince, entouré des ses *guayres* (conseillers).'

The source of this story: 'Sa relation est extraite d'un manuscrit original d'Ibn-el-Koutiàh, conservé, dit-on, à la Bibliothèque de Paris, sous le no 13, traduit par M. Étienne en 1844, et reproduit par don Manuel Osuna Saviñon dans l'abrégé historique que nous avons cité.' (p. 31).

46. Fr. Estaban Ibañez, op. cit., p. 173.
47. D. J. Wölfel, op. cit., IV, § 154.
48. Fr. Esteban Ibañez, op cit., p. 173.
49. As the bisexuality of the palm-tree was already very early known in Babylonia (q. v. B. Meißner, 'Babylonien und Assyrien', I, Heidelberg, 1920, p. 205) and still in the Jewish mystizism of the 13. century the palm-tree figurated as symbol for bisexuality (q.v. 'Das Buch Bahir', translated from Hebrew into German from Gerhard Scholem, Darmstadt, 1970, §§ 138/139) it may be that in ancient cultures with fertility-cults a bisexuell person was reputed as strong and valuable. (And there can be no doubt, that on the Canaries fertility-cults were celebrated.)
50. Discussed in Wölfel, op. cit., IV, § 111.
51. Fr. Esteban Ibañez, op. cit., p. 104.
52. There is often said, that the word *Teneriffa* (instead of *Tenerife*) comes from Alexander von Humboldt. It would be an interesting little study to examine this conjecture.
53. Discussed in Wölfel, op. cit., IV, § 485.
54. George Marcy, op. cit., p. 264 f.
55. Fr. Esteban Ibañez, op. cit., p. 104.
56. All formes, besides the analysis of Marcy, discussed in Wölfel, op. cit., IV, § 111.
57. Wölfel, op. cit., IV, § 486.
58. Alonso de Palencia, op. cit., p. 24: 'Planasia quidem omnium Fortunatarum maxima insula proceritate arborum atque in procera multitudine hominum habetur insignis innumeras profert arbores incredibilis multitudinis alitque ad sexaginta hominum millia.'
    Pliny says (Nat. Hist. 32): '. . . vocari Invallem a convexitate et Planasiam ad specie, Invallis circuitu CCCp.' If I translate right with '. . . called Invallis for its convexity and for its appearance Planasia . . .' it must be a vaulted island that for the observer's eyes seems to be plane.
59. Wölfel, op. cit., IV, § 6.
60. Torriani/Wölfel, op. cit., p. 196/197.
61. Attilio Gaudio, 'Sur l'origine Canariens Prehispaniques' in 'Anuaroiv de Estudios Atlanticos', 4, p. 156.

61a. 'Al parecer, cada cantón poseía uno o mas adoratorios en forma de pirámide . . .'. Mauro S. Hernández Pérez en 'Carta arqueologica de La Palma'. (Anuario de de Estudios Atlanticos, 18, p. 552.)

62. Sabin Berthelot, op. cit., p. 42.
63. Sabin Berthelot, op. cit., p. 212: 'Une citation, extraite des annotations d'André Bernaldez, nous renseigne sur ce culte des idoles: 'Dans la Grande Canarie, dit cet historien, il y avait un édifice destiné à la religion; c'était là qu'on vénérait une idole en bois, de la longueur d'une demi-lance, représentant une femme nue et posée de manière à montrer toutes ses formes. Debant cette femme se trouvait une autre sculpture qui figurait une chèvre disposée à l'accouplement, ayant derrière elle un bouc prêt à la couvrir pour la féconder'. The he-goat, ready for copulation, remains on the famous Sumerian statues of he-goats, erected like a man, with the forlegs in a kind of tree. A photograph of such a statue is f. e. to be seen (with *penis erectus*) in the volume 'Sumer' of the 'Universum der Kunst', Verlag C. H. Beck, München, 1962, p. 161.
64. Torriani's drawing of the statue is to be seen in the Spanish edition of Torrianis book, translated by Alejandro Cioranescu, Santa Cruz de Tenerife, in front of page 72. (1959).
65. Torriani/Wölfel, op. cit., p. 71.
66. Torriani/Wölfel, op. cit., p. 86.

67. Discussed in Wölfel, op. cit., IV, § 151.
68. Encyclopaedia Britannica, 1969, 3, p. 407.
69. Wölfel, op. cit., IV, § 491.
70. Fr. Esteban Ibañez, op. cit., p. 75.
71. George Marcy, op. cit., p. 288.
72. Torriani/Wölfel, op. cit., p. 181.
73. Wölfel, op. cit. IV, § 315.
74. In his commentary to George Marcy, op. cit., p. 275.
75. Rufus Festus Avienus, 'Ora Maritima', Latin and German, with the German translation by Dietrich Stichtenoth, Darmstadt, 1968, p. 18–21. Because Avienus says, that these isles are near Cadiz, the ancient Tartessus, and Abila and Calpe, today on the Strait of Gibraltar, we really can think of the Canaries. But then he speaks about metals, which, as far as we know today, never were found on the Canaries. The verses about the skin-boats (99–107):

    'Superbus animus efficax solertia
    Negociandi cura iugis omnibus
    Nolusque cum bis turbidum late fretum
    Et beluosi gurgitem oceani secant
    Non hi carinas quippe pinu texere
    Facere morem non abiete ut usus est
    Curuant fasello sed rei admiraculum
    Nauigia iunctis semper aptant pellibus
    Corioque uastum saepe percurrunt salum'

    Then he speaks about the holy island, *sacra insula*, to which the people of the Oestrymnic Bay with their skin-boats came in a two-day's journey (108–114):

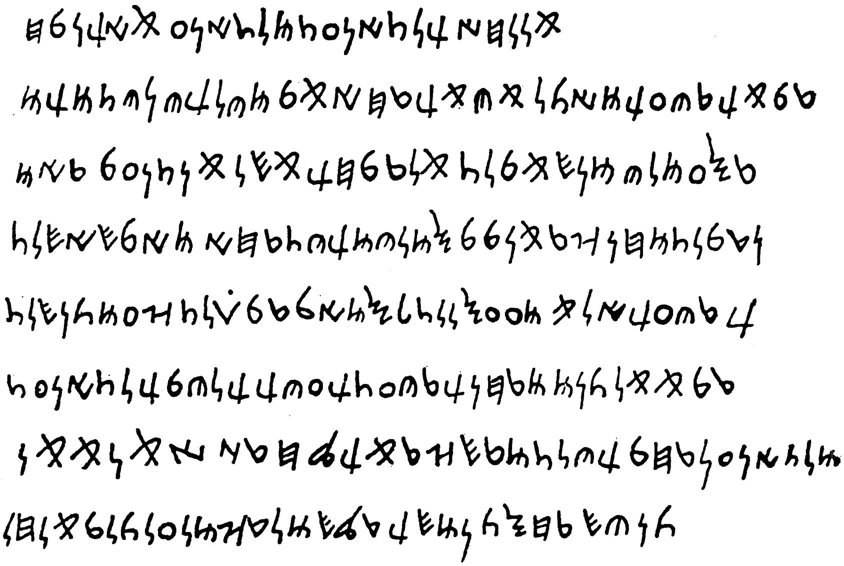
    Ast hinc duobus in sacram sic insulam
    Dixere prisci solibus cursus rati est
    Haec inter undas multam caespitem iacet
    Eamque late gen hiernorum colit
    Propinqua rursus insula albionum patet'

    If *rursus* here means 'behind' and the 'insula albionum' means Fuerteventura, then the holy island, behind which Albionum lays, has from the view of the coast to be Lanzarote and not Hierro.
76. The island's names according to Ptolemy were: Aprósitos, Heras nesos, Plouitána, Kaspería, Kanaría, Pintouaria or Kentouaría. ('Claudii Ptolomaei Geographia', Paris, 1901, I, p. 202.)
77. Procop in his 'War of Justinian against the Vandales', cited by Francisco Sureda, Blanes, 'Abyla Herculana', Calpe, 1925, p. 60. The text of the inscripcion, as given there: 'Nosotros somos los hijos de Josué el Ladrón, los expulsados de su patria legítima.'

    As in Spanish 'Josué' is the successor of Moses (English Joshua), who conquered Canaan, we may think of the Canaanite-Phoenician inscription of Paraiba, Brazil, as given in figure 6. (From Federico Pérez Castro, 'La "inscripción" Fenicio-Cananea de Paraiba' in 'Anuaria de Estudios Atlanticos', 17, p. 310/311.) If the inscription is true, is still discussed. One of the last publications is Lienhard Delekat, 'Phönizier in Amerika. Die Echtheit der 1873 bekanntgewordenen kanaanäischen (altsidonischen) Inschrift aus Paraiba in Brasilien nachgewiesen' in 'Bonner Biblische Beiträge', 32, Bonn, 1969.

    If the document is true, the people from Paraiba, who came from Sidon through the Red Sea, surrounding Africa, to South America, have nothing to do with the people of the above cited inscription. But both begin: 'We are the sons of...'

Fig. 6. The Phoenician-Canaanite inscription from Paraiba, Brasil, according to Ladislau Netto, published by Gordon, 'Orientalia', 37, p. 77:



The transcription and Spanish translation by Federico Pérez Castro:

1) nḥn' bn kn‘n mṣdn mhqrt hmlk sḥr hšlak-
2) n' 'l 'y z rḥqt 'rṣ hrm wnšt bḥr lʿlywnm
3) wʿlywnt bšnt tšʿt wʿšrt lḥrm mlkn' 'br
4) wnhlk mʿṣywn gbr bym sf wnnsʿ ʿm ʿnyt ʿšrt
5) wnhyh bym yḥdw štm šnm sbb l'rṣ lḥm wnbdl
6) myd bʿl wl' nh 't ḥbrn' wnb' hlm šnm ʿsr
7) mtm wšlšt nšm b'y ḥdt 'š 'nky mt ʿšrt 'br-
8) ḥ blt y' ʿlywnm w'lynt yḥnn'

1) «Somos hijos de Canaán, de Sidón, la ciudad del rey. El comercio arrojó- 2) nos a esta lejana ribera, un país de montañas. Pusimos (= sacrificamos) un joven a los excelsos dioses 3) y diosas en el año diecinueve de Ḥiram, nuestro poderoso rey. 4) Partimos de Elyon-Geber por el Mar Rojo y viajamos con diez barcos. 5) Estuvimos juntos en el mar dos años alrededor del país perteneciente a Ḥam (= Africa), pero fuimos separados 6) por la mano de Ba'al (= ¿una tormenta?) y no estuvimos [ya más] con nuestros compañeros. Así hemos venido aquí doce 7) hombres y tres mujeres, a una costa que yo, el almirante, domino. 8) Pero ¡quieran dioses y diosas favorecernos!».

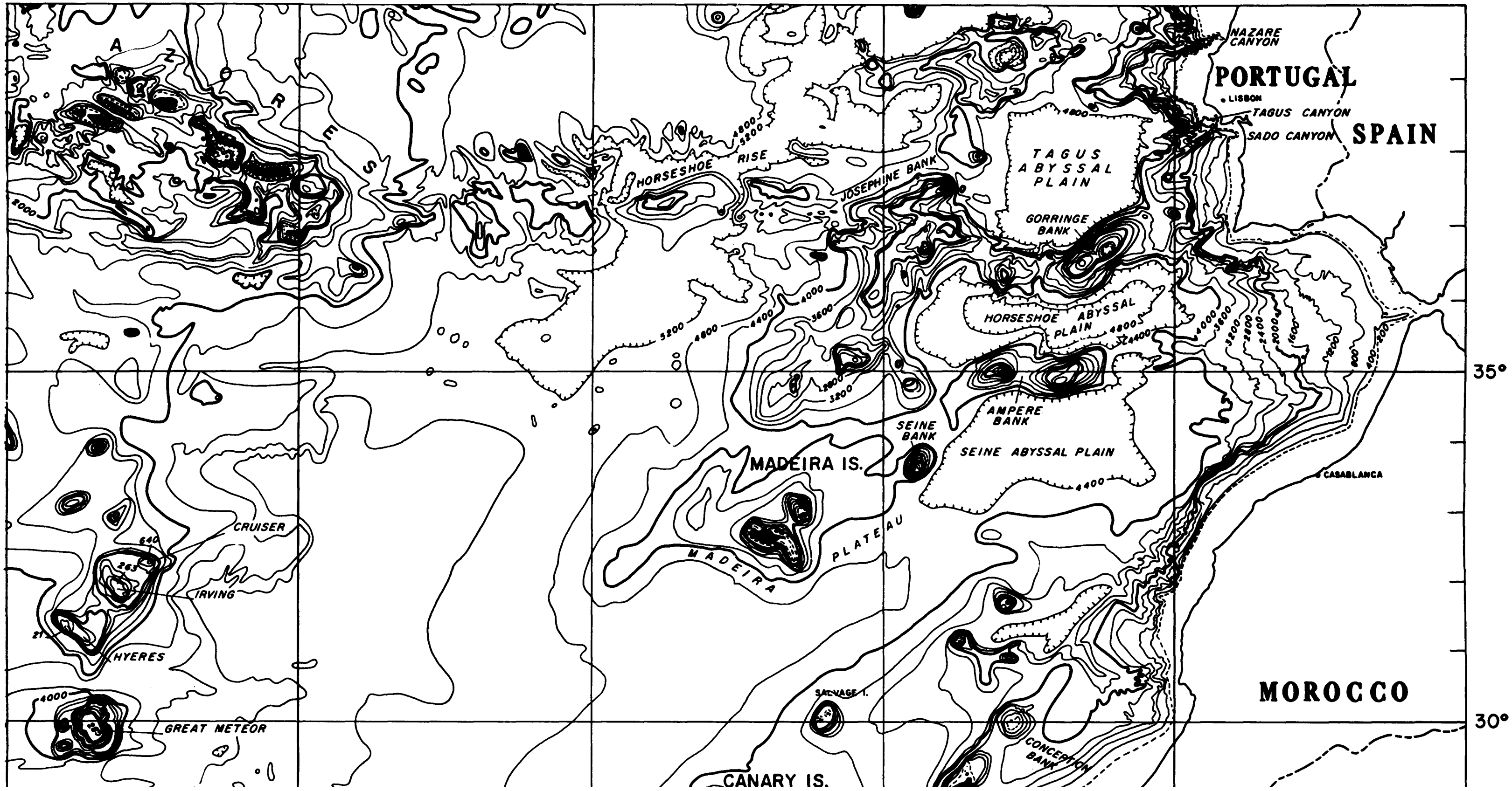
English version of the Spanish translation:

1) 'We are sons of Canaan, from Sidon, the city of the king. The commerce threw
2) us to this far shore, a country of mountains. We sacrificed a young (man) to the high gods
3) and goddesses in the year 19 of Hiram, our mighty King
4) We set out from Elyon-Geber through the Red Sea and travelled with ten vessels.

5) We have been together two years in the sea in the region of the country belonging to Ham (Africa), but we were separated
6) by the hand of Ba'al (a thunderstorm?) and did not stay (more) with our companions. So we came here as twelve
7) men and three woman, to a shore whom I, the admiral, rule over.
8) But may the gods and goddesses take care of us'.

Then one group says 'Canaan', the other 'Joshua', successor of Moses and conquerer of Canaan. If this beginning is a conventionalization, related to Canaan, it would be interesting, if the inscription from Anaga, Tenerife, begins in the same way. But, unfortunately, until today nobody was able to read the inscription.
Arabian historians like ET-Taberi and Es-Souli, cited in Ibn Khaldoùn, 'Histoire des Berbères', Paris, 1968, vol. I, p. 175 f., speak from a Canaanite origin of the Berberic people.

78. Torriani/Wölfel, op. cit., p. 116/117.


35°
30°
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PORTUGAL
LISBON
TAGUS CANYON
SADO CANYON
SPAIN
MOROCCO
CASABLANCA
TAGUS ABYSSAL PLAIN
GORRINGE BANK
HORSESHOE ABYSSAL PLAIN
AMPERE BANK
SEINE ABYSSAL PLAIN
SEINE BANK
JOSEPHINE BANK
HORSESHOE RISE
MADEIRA IS.
MADEIRA PLATEAU
SALVAGE I.
CANARY IS.
CONCEPTION BANK
A Z O R E S
CRUISER
IRVING
HYERES
GREAT METEOR
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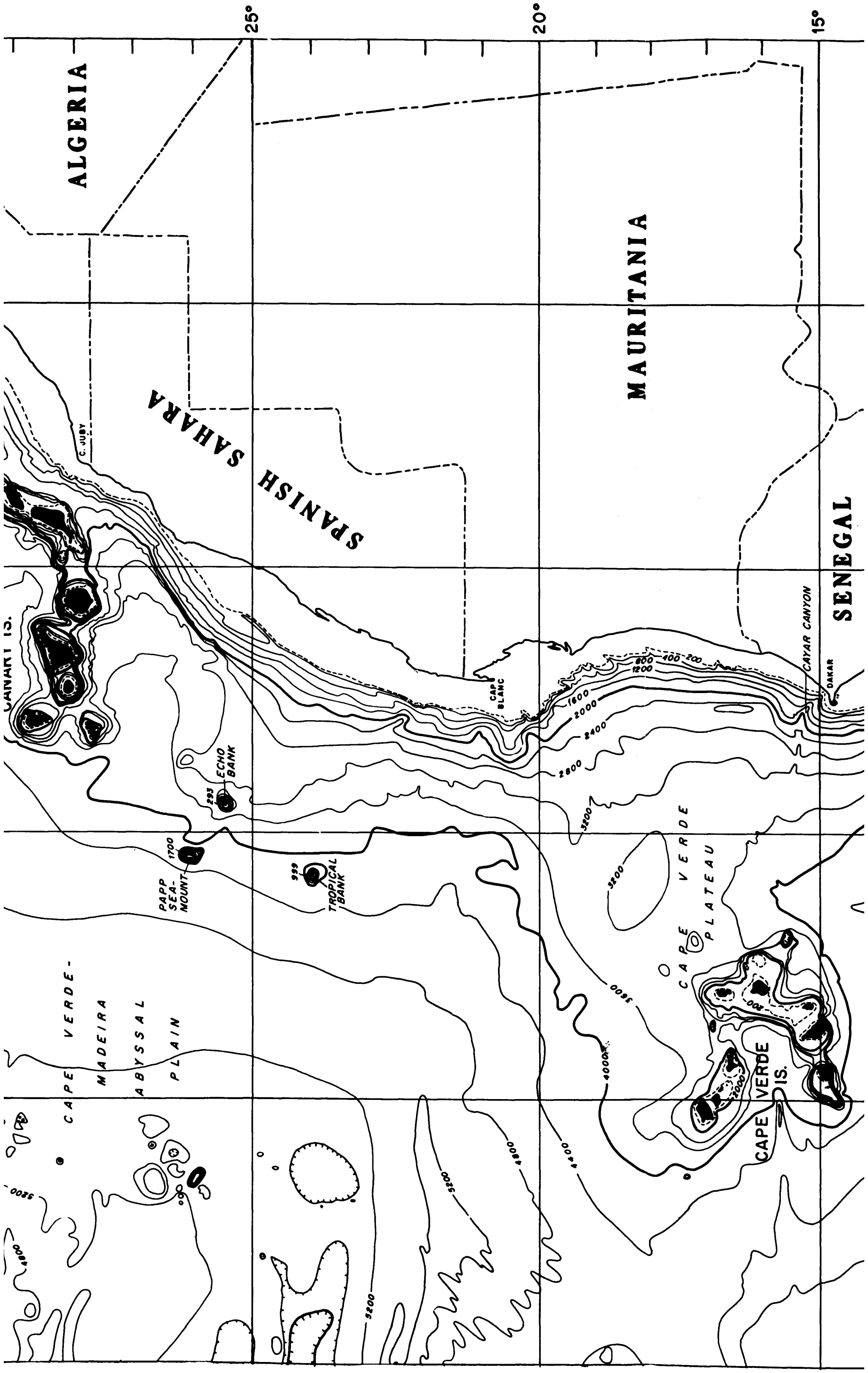
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ALGERIA
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DAKAR
200
400
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4000
4400
4800
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293
ECHO BANK
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PAPP SEA-MOUNT
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TROPICAL BANK
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CAPE VERDE-MADEIRA ABYSSAL PLAIN
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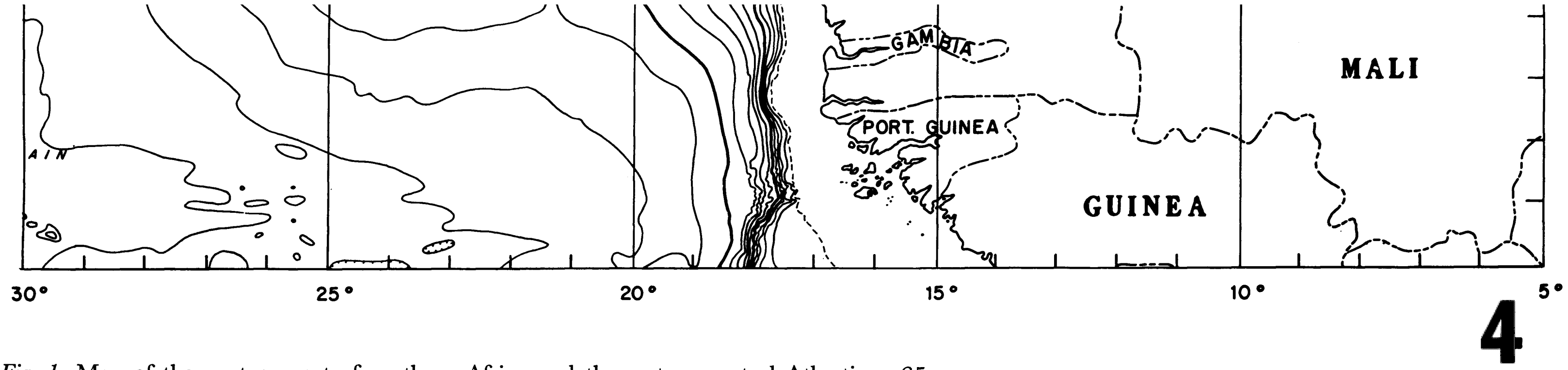

Fig. 1. Map of the western part of northern Africa and the eastern central Atlantic with bathymetric contours (in meters) and major islands (from Dillon & Sougy 1974, Fig. 9, after Uchupi).

IV. THE GEOLOGY OF THE CANARY ISLANDS[1]

by

HANS-ULRICH SCHMINCKE

Introduction

The Canary Islands, built on the continental rise and slope (Figs. 1, 2), are one of the major volcanic island chains in the oceans. There is hardly another group of volcanic islands in the world, neither the Azores nor the Hawaiian islands, with such long histories of eruptions (Fig. 3) – spanning 20 or more Ma[2] on some individual islands – and such an enormous variety of volcanic and plutonic rocks. Moreover, the magnificent outcrops on the leeward sides of the islands, due to low rainfall, scant or absent vegetation, and deep canyons, make the islands especially appealing to the earth scientist. No wonder, therefore, that the geology of

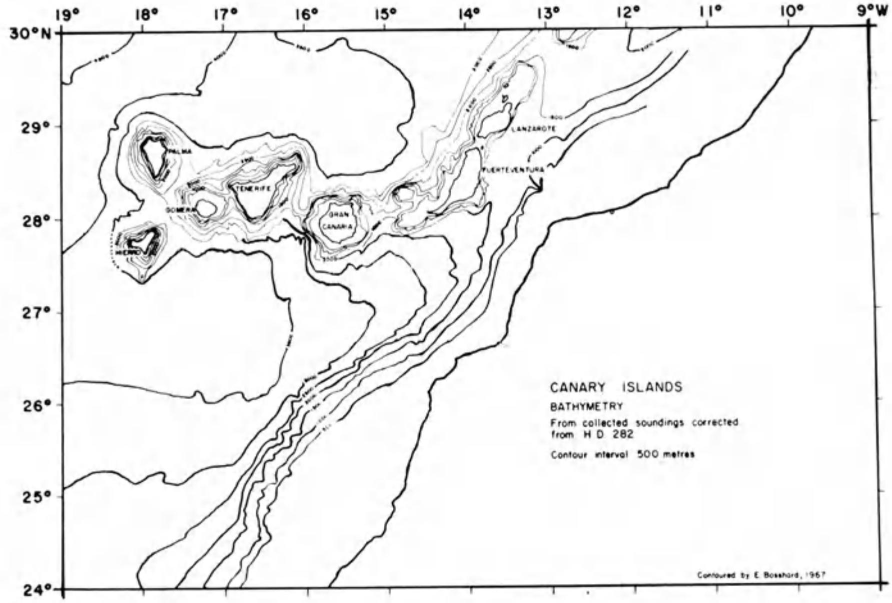

Fig. 2. Bathymetry of the Atlantic ocean basin in the vicinity of the Canary Islands. Contour intervals 500 meters. From Bosshard & MacFarlane (1970).

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[1] Much of this review was written in 1970 but additions were made up to 1974.
[2] Ma = Million years.

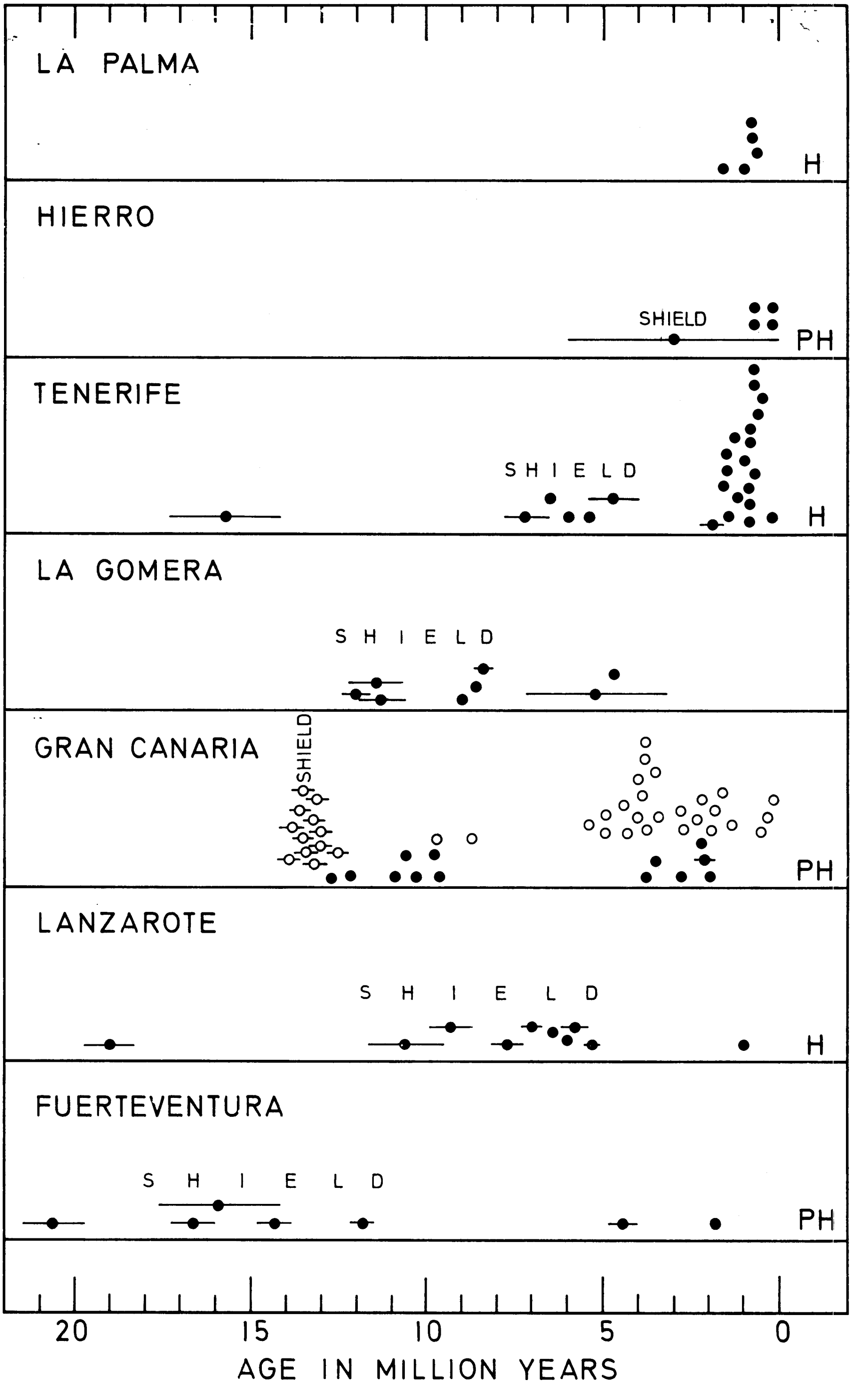

Fig. 3. Potassium-argon ages from rocks of all Canarian islands. Data from Abdel-Monem et al. 1971; 1972 (dots); Lietz & Schmincke 1975 and McDougall unpublished (circles). Some older dates from Fuerteventura and the Gran Canaria shield series ages from Abdel-Monem et al. 1971, are not shown. H = historic eruptions recorded; PH = prehistoric eruptions.

the Canary Islands has been studied by many geologists, beginning with Leopold von Buch (1825) 150 years ago. Yet, most work is of reconnaissance type, or consists of petrographic studies of samples collected by somebody else. Hartung's studies on Lanzarote and Fuerteventura (1857) and those by Fritsch & Reiss (1867) on Tenerife are more comprehensive classic works, and still informative. Hernandez-Pachecos' publications on Lanzarote (1910) and Navarro's on Gomera (1918), are important contributions in the first half of this century. A modern series of monographs started with Bourcart & Jeremine (1937, 1938) on Gran Canaria and Fuerteventura. Madame Jeremine's petrographic and petrochemical studies in the thirties are exceptionally lucid and thorough. Hausen (1956–1973) published extensive monographs on each of the larger islands, summarizing, in English, the state of knowledge up to that time. Save for the description of individual localities, these are superseded in many respects by more modern monographs on Fuerteventura, Lanzarote, Gran Canaria, and Tenerife, each with a colored geologic map (1 :100 000) by Fuster and co-workers (1968a–d). The same group of investigators is currently mapping all of the Canary islands at the scale of 1 :50 000 – maps of Fuerteventura, Lanzarote, and Tenerife have already appeared – and is also publishing papers on many aspects of Canarian geology and petrology. Petrologic and geologic studies on igneous rocks from Gran Canaria are conducted by Schmincke and co-workers (1965 to present) and Borley and co-workers have published several detailed petrologic studies on rocks from Tenerife (e.g. Ridley 1970). Geophysical studies were conducted by MacFarlane and by Bosshard & Dash and paleomagnetic and absolute age studies by Watkins and associates. Sedimentary rocks and unconsolidated sediments on and off the eastern islands are being investigated by Müller and co-workers (Müller 1964; Müller & Tietz 1966; Rothe 1968a, b; Tietz 1969; Müller 1969) and on Gran Canaria by Lietz (1973). A summary of the results of ten years of cooperative work between zoologists, botanists and geologists has recently been published (Evers *et al.* 1970).

This report is divided into two parts. The first part covers two main aspects:

At first, some general ideas on the origin of the Canary Islands are reviewed. This is the most speculative section of the paper. It is followed by a description of the main rock types, principally volcanic, as they appear in the field and as they are characterized by their chemical compositions. Fossil flora and fauna is also briefly treated here.

The second part is a description of the geology of individual islands, proceeding, for each island, stratigraphically, that is from the oldest to the youngest formations. For most islands, information is culled from the literature, especially from the modern series of monographs by Fuster and co-workers. The geology of Gran Canaria, however, is treated in much more detail because this is the island I know best; this chapter also contains a large amount of previously unpublished information.

GENERAL PROBLEMS

Introduction

The proximity of the Canary Islands to the African continent (about 100 km) (Figs. 1, 2) has stimulated the imagination of most geologists who have worked on the islands, and particularly many of those who have vacationed there. Nearly every paper has something to say on the origin of the Canary Islands, based on radiometric ages, inter-island correlations, mineralogical and chemical composition of rocks, and on structural trends. The idea that the Canarian islands may have been the site of mythical *Atlantis* has been an especially controversial issue triggering an impressive volume of papers on the subject. Yet this problem is really one of '*parascience*'. If there ever has been a *real* place for Plato's Atlantis, it was probably the volcanic island of Santorini in the Aegean sea, as described in several recent books (see e.g. the popular account by Luce 1969). Much of the profuse literature on the Canaries and Atlantis is reviewed by Lundblad (1947) to which the reader is referred for more detailed discussions.

These speculations were commonly made in the context of an entirely geological problem: were the Canary Islands once a continuous landmass or did they form as independent islands? Was this hypothetical landmass or any of the islands ever connected to Africa?

Other general problems concern the age of individual islands, of the archipelago as a whole, the location of the island group and the geodynamic causes for their formation and long histories, the interpretation of the basal complexes occurring on many islands, the interpretation of all facets of Canarian geology in the light of plate tectonics and many others. None of these problems is solved as yet and partial answers come from various geological disciplines. In the present account only some of these will be discussed more fully. Emphasis is on the general geologic and petrologic problems.

Age of the Canary Islands

There have been many speculations in the past on the age of the Canary Islands and ages as old as Paleozoic were discussed up to very recently (Macau Vilar 1963).

Nothing is known about the age of the large submarine parts of any of the islands. Considering that the ocean floor around the Canary Islands

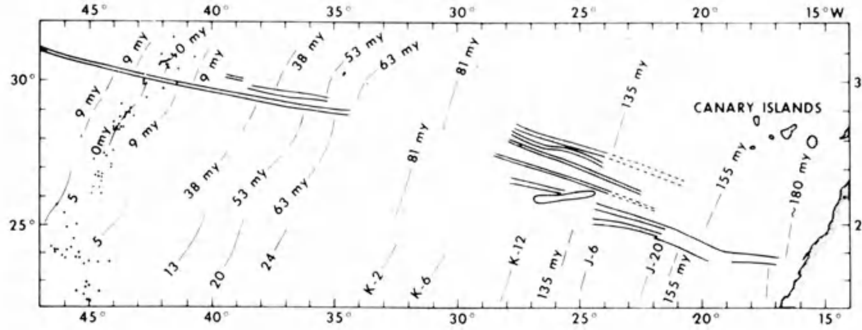

Fig. 4. Position of the Canary Islands with respect to the Atlantis fracture zone system (diagonal lines trending W-NW). Ages of the oceanic crust are tentative. Numbered lines and 'K'- and 'J'-series are identified remanent magnetic anomalies. From Rona & Fleming (1973, Fig. 2).

is about 180 Ma, according to magnetic lineations, the islands apparently are much younger structures (Fig. 4).

While the oldest sedimentary rocks known are Cretaceous in age according to paleontological evidence (Rothe 1968a), no igneous rocks older than about 35 Ma are known so far (Abdel Monem *et al.* 1971, 1972; Rona & Nalwalk 1970).

Luyendyk & Bunce (1973, p. 545) postulate that volcanic activity in the area of the Canaries began at least in the late Cretaceous; they tentatively identified acoustically stratified sections in reflection profiles of the oceanic bottom sediments in the area as volcanic detritus derived from the Canaries.

A more detailed study of the Cretaceous rocks on Fuerteventura – which is badly needed – should provide unequivocal evidence on this point. Available data suggest that volcanic activity did not start prior to the Oligocene. The ultramafic to mafic plutonic rocks on some islands are thought to be pre-Cretaceous in age (e.g. Cendrero 1971) but there is no evidence to substantiate this interpretation.

The studies of Abdel Monem, Watkins and Gast have provided very valuable potassium-argon and paleomagnetic data establishing an age framework for most islands (Fig. 3). However, owing to incomplete geologic knowledge of most islands, stratigraphic control of many of these data is not precise, and a number of important formations remain undated. Recently the number of K/Ar-dates has been tripled for Gran Canaria (Lietz & Schmincke 1975; McDougall, unpublished (fig. 3)).

Most islands are made up dominantly of one or more main basaltic shield volcano (the 'tableland series' of Hausen) (Fig. 3) – in some islands underlain by a 'basement complex' (see below). These are followed by several younger episodes of volcanic activity, generally from more centralized volcanic structures producing less voluminous material but containing a larger amount of differentiated rocks. Hausen (1958 to 1973) postulated that the basaltic lavas of his tableland series were erupted roughly at the same time producing a continuous microcontinent, later disrupted by tectonic fracturing. Schmincke (1967a) showed that Gran Canaria was built up as an individual volcanic structure. This theory questioned Hausen's model of a once continuous 'tableland' but it did not pertain to the problem of synchronous activity of the shield-building lavas in the islands.

The potassium-argon dates by Abdel-Monem *et al.* (1971, 1972) on the shield-building lavas seem to prove that the shields on the different islands did not form at the same time. On the other hand, the large spread of the ages of the shield-building lavas indicated to Abdel-Monem *et al.* that the periods of activity for the shields was overlapping on different islands, as shown by the following data, single ages being shown in parenthesis: Fuerteventura 12 to 17 Ma (20), Lanzarote 5 to 11 Ma (19), Gran Canaria 10 to 16 Ma, Tenerife 5 to 7 Ma (16), Gomera 8 to 12 Ma (Fig. 3). However, recent potassium-argon determinations of some 10 samples of the Miocene shield basalts on Gran Canaria showed that all are in the age bracket of 13.5 to 14 Ma (McDougall, unpublished) (Fig. 3). This is more consistent with geologic evidence suggesting rapid build-up of the shields, at least for Gran Canaria. Neglecting the single old dates for some islands, it appears that the shields on Gran Canaria and Fuerteventura are the oldest (Middle Miocene), those of Gomera and Lanzarote are formed in the Upper Miocene while that of Tenerife is the youngest and partly formed in the lower Pliocene (the boundary Miocene-Pliocene being taken as 5 Ma) (Fig. 3). The relatively small number of determinations and the generally somewhat altered nature of these basalts, however, does not permit a more precise statement. Thus all shields (except that of Hierro which is Pliocene, Abdel-Monem *et al.* 1972) are Miocene in age, but formed in quite different parts of the Miocene. Clearly, these shields need to be restudied in some detail.

The shield-building phase is followed in practically all islands by a large erosional hiatus lasting about 3 to 5 Ma, judging from the still meagre data of Abdel-Monem *et al.* (1971, 1972) (Fig. 3). The duration of this erosional gap is of some importance in establishing boundary conditions for magma generating processes. The duration of this gap may decrease from east to west.

Historic volcanic eruptions occurred on Lanzarote (1730, 1824), Tenerife (1704, 1705, 1706, 1798, 1909), and La Palma (1585, 1646, 1677, 1712, 1949, 1971). Prehistoric eruptions have been dated from Gran Canaria (3075 ± 50 B.P.) (Nogales & Schmincke 1969) and Hierro (2900 ± 130 B.P.) (Hausen 1973) and the youngest eruptions on Fuerteventura are probably not much older judging from their well preserved surface features. Thus, the entire Canarian archipelago can be considered as an active volcanic area. In fact, the Canaries are the most active volcanic island group among Atlantic oceanic islands, apart from Iceland and the Azores.

Faults

The present discussion is concerned with faults on land. For evidence of off shore faults see e.g. Bosshard & MacFarlane (1970) and Beck & Lehner (1974).

For many years, major faults were postulated on and between the islands. Bourcart (in Bourcart & Jeremine 1937) e.g. 'described' major faults on Gran Canaria, some with vertical displacements up to 700 m. Hausen (1956–1962), following up many of the earlier ideas (e.g. Gagel 1910), postulated many large faults oriented along the 'Atlas structural trend' which he thought fractured a microcontinent encompassing the entire archipelago and along which crustal blocks between the islands had foundered. Lotze (1971) speculated about Alpine type folding in the center of Gran Canaria based on earlier ideas held by Hausen (1962). The presence of these faults was generally accepted (even as late as 1970 by Bosshard & MacFarlane).

However, most of these faults are not present as shown by field evidence (Schmincke 1968, 1971a, b). The reasons for postulating the faults are manyfold, for example: volcanic terrains with a long history of alternating periods of eruption and erosion develop complex field relationships to be resolved only by detailed field examination. Deep canyons, cut entirely by erosion, commonly persist throughout the geologic history of an island. Marine erosion in the Canaries has preferentially attacked the NW-sides of the islands, as recognized long ago (e.g. v. Fritsch 1867), leading to skewed profiles with steep coasts in the W-NW. Finally, it was the idea that the Canary Islands were caused or affected by the orogenic movements in the Atlas that prompted workers to postulate faults on and between the islands.

Those faults that do exist can generally be attributed to volcano-tectonic processes such as caldera collapse (e.g. Schmincke & Swanson 1966) or to landsliding (Schmincke 1968) (Fig. 5).

On the other hand, there is certainly some likelihood that the fractures along which the magma rose to build the islands and, along which, in part, the islands themselves were moved vertically (e.g. La Palma, Fuerteventura, La Gomera), formed in response to a regional stress-field whose major structural trend is NNE.

Before I discuss this trend which is also evidenced by marine geophysical data in more detail, evidence for vertical movement on the islands need be considered.

Coastal terraces, eustacy, and isostasy

Coastal terraces have been studied and correlated among several islands

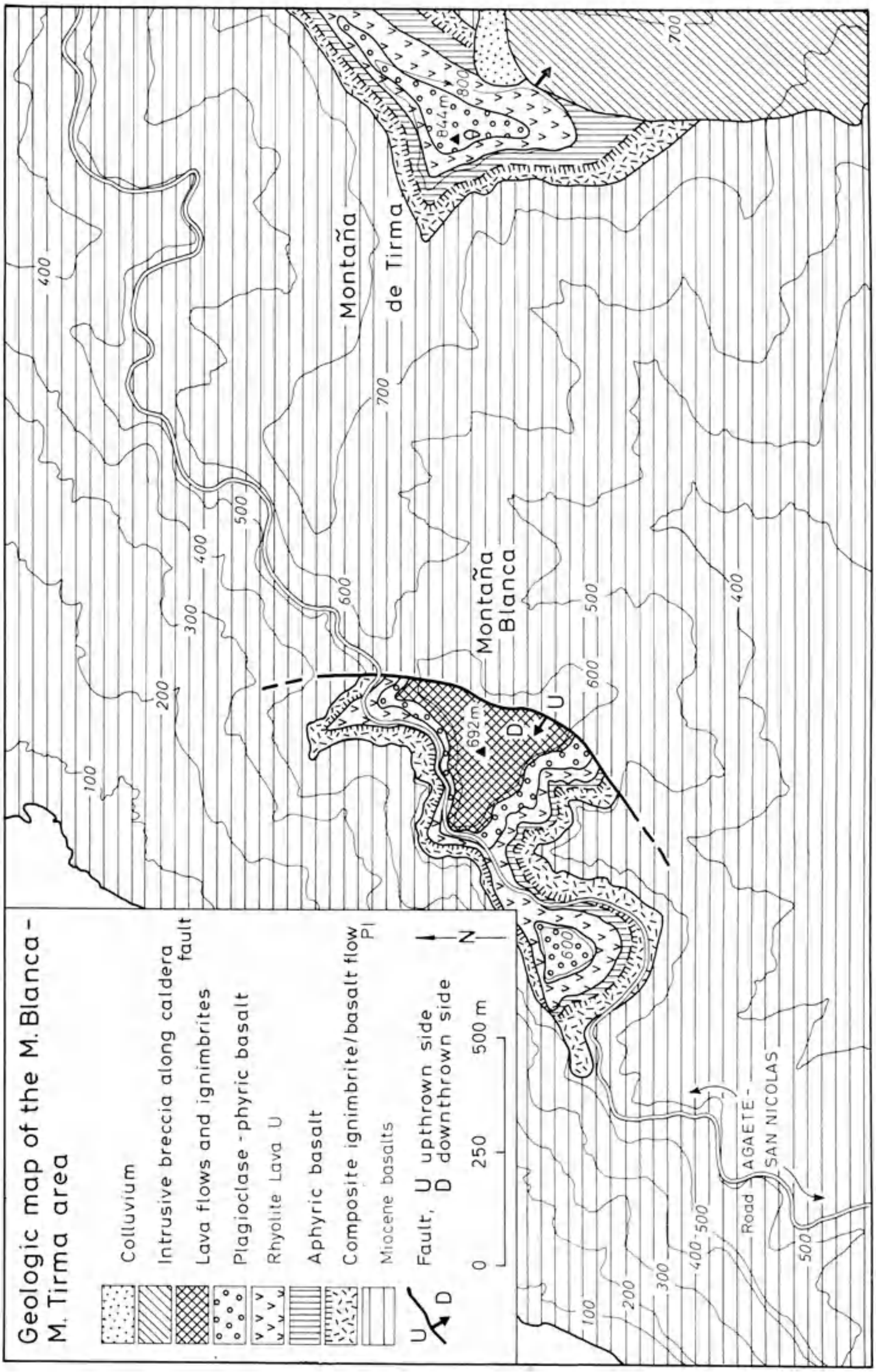

Fig. 5. Geologic map of the Montaña Blanca – Montaña Tirma area (San Nicolas, Gran Canaria) showing one of the few real large faults on the Canary Islands (Modified from Schmincke 1968a, Fig. 12).

for some time (e.g. Driscoll *et al.* 1965; Lecointre *et al.* 1967; Klug 1968; Lietz 1973). The basic assumption was that the islands are stable while the sea level was fluctuating.

However, such studies on volcanic islands generally have to consider isostatic and other vertical movements, and this factor was discussed in more detail by Schmincke (1971a), Lietz & Schmincke (1975) and Lietz (1975) for Gran Canaria.

Oceanic islands show a characteristic pattern of up-and-down movements during their history. After a submarine phase of construction producing mainly pillow basalts and hyaloclastites (Moore & Fiske 1969) which may last on the order of 10 Ma (Menard 1969) the weight of volcanic materials transferred from the mantle to the top of a growing volcanic island may cause it to sink into the underlying crust and mantle in order to reach isostatic equilibrium. When the volcanic activity on an island has ended and erosion constantly transfers material from it to the sea, the island may rise again (Moore 1970). These individual up-and-down movements make it very difficult to correlate coastal terraces.

Lietz & Schmincke (1975) recognized and dated several transgressions and regressions on Gran Canaria, tentatively relating some to isostatic and other vertical movements but most to glacioeustatic causes. As to isostatic factors, they concluded that 'the magnitude of vertical isostatic movements due to volcanic loading and erosional unloading is probably a function of eruptive rates and absolute volumes, thickness of the crust and probably also the depth of magma generation or subcrustal storage. Furthermore, the timing of the vertical movements may be out of phase with the loading and unloading periods because of the high viscosity of mantle material. Because both absolute volumes and eruptive rates are smaller by a factor of about 10 on Gran Canaria compared with Hawaii (see above), isostatically caused vertical movements may have much smaller magnitudes on Gran Canaria. The occurrence of arch and moat around the Canaries makes it likely however, that vertical isostatic movements analogous to those in Hawaii, did indeed occur'.

Eustatic changes in sea level, as recorded by terraces and marine sediments and pillows on land and isostatic movements cannot explain, however, the vertical movements inferred from the occurrence of lithified and folded marine sediments of Cretaceous age on Fuerteventura and a pillow complex several hundred meters above sea level on La Palma.

Structural trends in the Canary Islands

Structural grains in the area of the Canary Islands are generally thought to be dominated by N, NNE, and NE and, to a lesser degree, by NW-trends, as inferred from several lines of evidence: shape of an island such as the NE-elongation of the eastern Canaries; orientation of faults; orientation of dike swarms such as the NNE dike swarms on Fuerte-

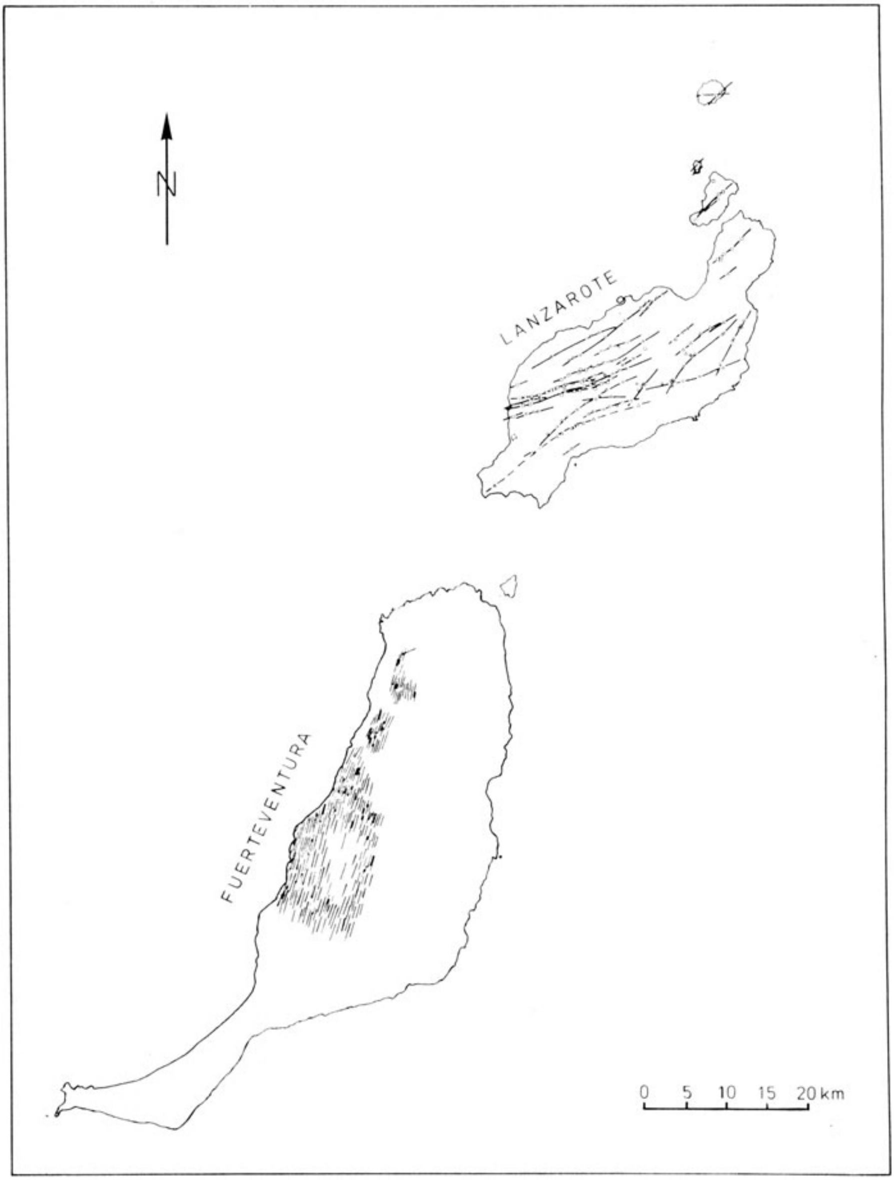

Fig. 6. Strike and main outcrop area of Miocene basaltic (altered) dikes of the basal complex of Fuerteventura (lower part) and alignment of eruptive centers of Quaternary age on Lanzarote (triangles = series II; circles = series III; squares = series IV) (combined after Fuster et al. 1968a, Fig. 24; 1968b, Fig. 64). Note relationship between major tectonic and eruptive trends and shape of islands. Differences in strike between Fuerteventura dikes (NNE) and vent alignment on Lanzarote (NE, ENE) are pronounced. On the other hand, note change in strike from NE (older series) to ENE (historic eruptions) on Lanzarote.

ventura (Fig. 6); alignment of cinder cones such as the NE alignment of Quaternary to Historic cones on Lanzarote (Fig. 6), alignment of islands such as the NE alignment of Lanzarote and Fuerteventura, the NE-alignment of Hierro-Gomera-Tenerife; and the WNW alignment of Gran Canaria–Tenerife–La Palma; and seismic and gravity data (for more detailed recent discussions see Rothe & Schmincke 1968; Bosshard & MacFarlane 1970; Schmincke 1971a, b, 1973; Hernandez-Pacheco & Ibarrola 1973; Lietz & Schmincke 1975). Hernandez-Pacheco & Ibarrola (1973) called the NNE-SSW trend the 'African trend' in contrast to a NW-SE 'Atlantic trend'. The N to NE-trends are generally thought to be a continuation of similar tectonic trends caused by Miocene deformations in the Atlas Mountains of Africa, the W-NW-trends being thought to be parallel to an old fracture zone (see below) (Fig. 4). To what degree this stress field formed in response to eastward movement of the African plate, to northward movement of the African plate relative to Europe, to basinning of the shelf between the eastern Canaries and Africa, or to other causes is as yet unknown.

Tectonic trends on some islands may change in time, however. For example, dikes in the Miocene basalts of Gran Canaria show a general radial trend (Schmincke 1968) with a strong NE component while Pliocene Roque Nublo dikes show a pronounced N to NE alignment (Brey 1973). Both are roughly parallel to the regional Canarian trend. In contrast, the nephelinites and younger lavas on the island were erupted from NW-SE trending fissures (Fig. 1 in Lietz & Schmincke 1975).

A strikingly similar 90° change in direction was noted by Jackson & Wright (1970) between the feeder dikes for the tholeiitic shield building and the posterosional nephelinitic lavas of Oahu. The strike of the latter parallels the hinge area between areas of isostatic subsidence and uplift which migrates with considerable time lag parallel to the centers of volcanic activity in the Hawaiian chain. In other words, while the tectonic trend of the feeder dikes of the shield building lavas may be caused by regional factors that of the younger fissures is caused by dynamic processes in the mantle-volcano system.

However, two other factors need to be considered: Fiske & Jackson (1972) have recently shown that the orientation of many rifts (characterized by dense dike swarms) on the Hawaiian islands is due to gravitational stresses in the apron of an older neighbouring volcano. Moreover, those rifts that are apparently due to regional structure rather than local gravitational stress, are oriented parallel to the general alignment of the island chain the direction of which differs appreciably from that of the Molokai and other prominent fracture zones in the area. Turcotte & Oxburgh (1973) attempt to explain the orientation of fracture zones, alignment of islands and orientation of en échelon rift zones on the islands in the Hawaiian chain in terms of tensional stresses – thermal stresses due to the cooling of the lithosphere and 'membrane stresses' due to changes in the radii of plate-curvature or a combination of both.

No analysis of Canarian trends has yet been published with these local and regional factors in mind.

Oceanic versus continental nature of the Canaries

The Canaries are situated on what is commonly called a 'passive' ocean margin. Such margins generally lack earthquakes and widespread volcanism in contrast to active ocean margins (e.g. those around the Pacific ocean) which are characterized by a deep sea trench, abundant earthquakes, abundant volcanism, and mountain building. Thick continent-derived clastic wedges unfortunately hide the deeper structures of passive margins. Thus the tectonic configuration of crustal blocks probably formed by block faulting during the initial separation of the American and African continents and particularly the exact boundary between thick continental and thin oceanic crust are very poorly known along these margins (Fig. 7).

The long-held views that all of the Canaries are underlain by continental crust – forming a microcontinent which many believed to represent mythical Atlantis – does not receive support from modern studies. Schmincke (1967a) proposed that Gran Canaria and probably also the western Canaries are oceanic volcanic islands. Rothe & Schmincke (1968) reviewed geologic information on the problem of continental versus oceanic origin of the islands. They concluded that the western islands are oceanic while the eastern islands (Fuerteventura and Lanzarote) are 'continental' in character and possibly underlain by continental crust because of quartz-bearing sedimentary rocks on Fuerteventura (Rothe 1968a) and quartzite inclusions in basalts on both eastern islands. In addition, a landbridge was postulated to have existed between the eastern islands and Africa because of the presence of fossil ostrich eggs on Lanzarote (Rothe 1964; Sauer & Rothe 1972). This interpretation of the 'continental' nature of the eastern islands was accepted by Dietz & Sproll (1970) who believed a reconstruction of computer calculated precontinental drift fit showed that the eastern Canaries had been part of the African continent but later separated from it. Seismic and gravimetric studies in the western Canaries (Dash & Bosshard 1968; Bosshard & MacFarlane 1970) revealed the presence of oceanic crust in the west becoming transitional under Gran Canaria and farther east possibly continental (Fig. 8). Seismic, magnetic and gravimetric work by Roeser *et al.* (1971) shows that Lanzarote and Fuerteventura which are separated only by a very shallow strait are underlain by transitional type crust. In the area between these islands and the African continent about 10 000 m of sediment have accumulated. The transitional crust beneath this through may have been once oceanic,

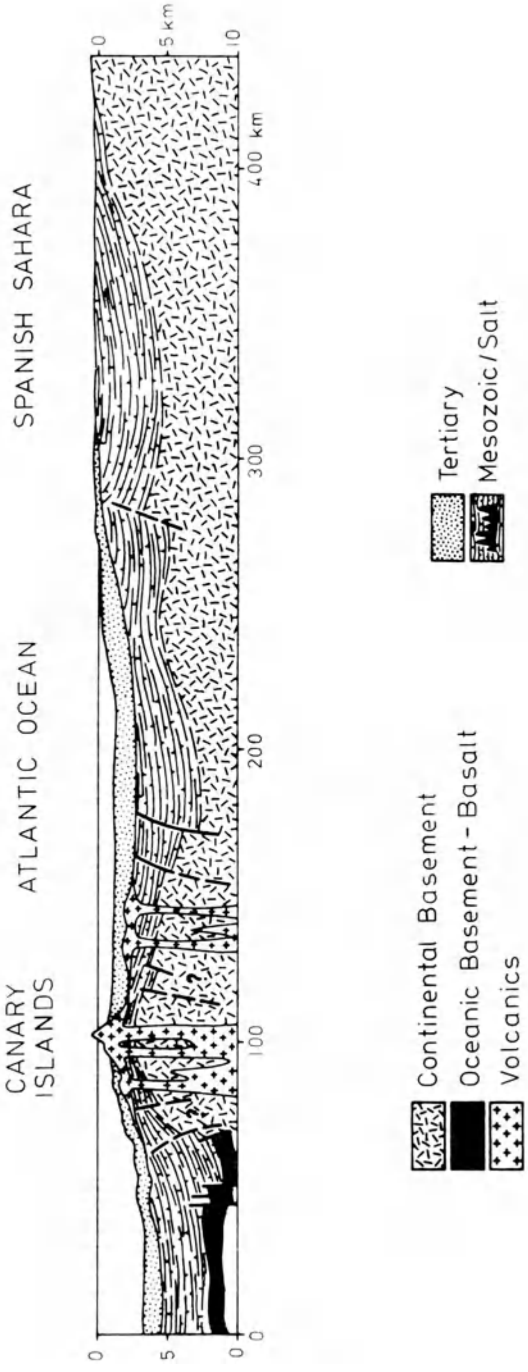

Fig. 7. Schematic cross-section through the eastern Canary Islands and the adjacent African continental margin (from Beck & Lehner 1974, Fig. 12B).

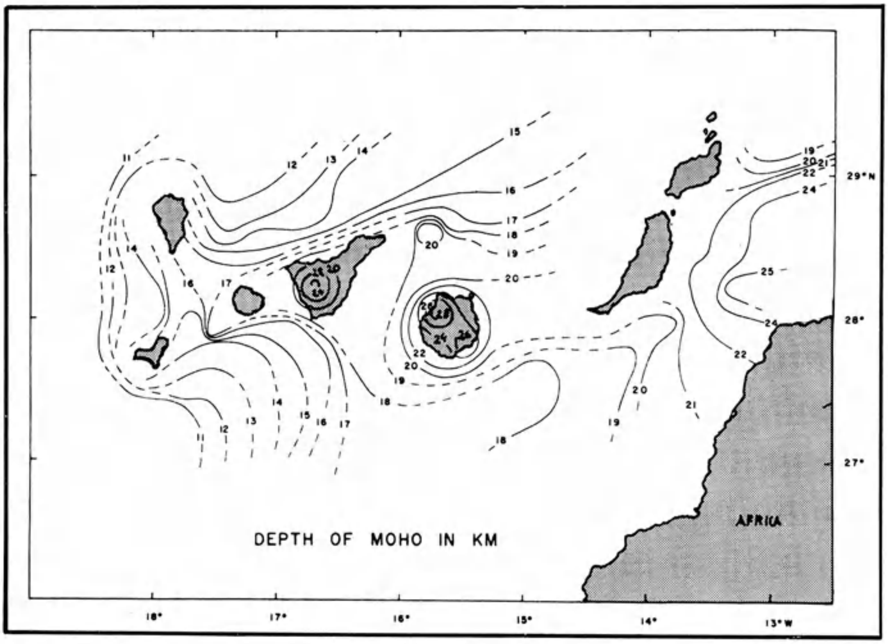

Fig. 8. Depth of Mohoroviçic discontinuity beneath the Canary Islands (from Bosshard & MacFarlane 1970).

changed later into a transitional type by continuous sedimentation and simultaneous subsidence since the opening of the Atlantic (Roeser *et al.* 1971). Sauer & Rothe (1972) stress that the eastern islands are underlain by continental crust and were once attached to Africa while Schmincke (1973) interprets the occurrence of quartz-bearing marine sedimentary rocks on Fuerteventura as evidence of Africa-derived marine sediments later uplifted, but not necessarily as evidence for continental crust. Gravity data for Lanzarote are more in favor of a large mafic igneous intrusion beneath the island than of sialic crust (MacFarlane & Ridley 1969).

When all geologic evidence presently available is critically evaluated, there is no compelling proof for the existence of continental crust beneath the eastern Canaries.

The quartz-bearing marine sediments indicate only that some of their components were derived from the African continent and that folding and vertical uplift had occurred. They could have been deposited entirely on oceanic crust. The same holds true for the quartz sandstone xenoliths in the lavas.

The problem of landbridges can be divided into two parts:

a. Evidence for landbridges is compelling.

In this case, three types of landbridges can be visualized: a continuous strip of continental crust (since subsided) from Africa to the Canaries; detachment of the eastern Canaries from Africa and westward drift; and a volcanic landbridge.

It is difficult to see how any substantial continental landbridge, later subsided, existed during the late Tertiary because one would expect at least some traces of continental Africa-derived sediments interlayered with the lavas. The ostrich eggs occur in calcarenites of a type presently formed on many Canarian and other purely oceanic islands.

Sauer & Rothe (1972) favor the hypothesis of Dietz & Sproll (1970) which postulated detachment of the eastern Canaries from Africa during the Triassic or early Cenozoic. It seems difficult to decide on continental versus volcanic landbridges using as only evidence the former existence of flightless birds on Lanzarote (and land turtles on Tenerife!). Also, there is no evidence at present that the eastern islands rose above sea level earlier than the Miocene (possibly Oligocene), not taking isostatic or other subsidence into account.

Moreover, the seismic, bathymetric, gravimetric and magnetic data by Roeser *et al.* (1971); Young & Hollister (1974); and Dillon (1974) indicate that deposition of sediments in the basin between the eastern Canaries and the adjacent Aaiun basin along the African coast was practically continuous from at least Early Cretaceous to Eocene. After this time, sediments were transported from Africa across the shelf to build the continental slope and rise. Thus, if the eastern Canaries were detached from Africa, this must have occurred during the early stages of the formation of the Atlantic and there is nothing at present to suggest that the Canaries are older than Oligocene.

There is some evidence from bathymetry and positive magnetic anomalies, in part associated with sea knolls (Roeser *et al.* 1971; Dillon 1974; Hinz, pers. comm. 1974) for the existence of volcanic seamounts east of Fuerteventura and a number of such structures also occur to the north and northeast of Lanzarote. If these once rose above sea level and were once so numerous as to form a continuous land connection with the eastern Canaries, at least for a short time, they could have provided a dry path for land animals to migrate from east to west.

b. Evidence for landbridges is not compelling.

While landbridges are certainly the least complicated transport model for animals, they are most demanding on geology. To get around this problem one has to invoke all sorts of transporting agencies, such as tree rafts, to provide for transportation across some 150 km of sea. Although the number of such agencies one can think of are usually determined by one's imagination and experience, to postulate a realistic transporting vehicle for ostriches and land turtles remains a knotty problem. A problem that is part of an old and long-debated controversy which cannot be fully discussed in the present report.

In the face of these difficulties, a plea is made for keeping many working hypotheses alive.

As an example for an additional, albeit outrageous, working hypothesis, one might postulate that the sea floor between the eastern Canaries and Africa – presently as shallow as 1000 m – fell dry during the middle Miocene as a result of two causes: drastic lowering of sea level (for which abundant evidence is accumulating, c.f. Lietz & Schmincke 1975) maybe by 500 m or more combined with a higher elevation of the sea floor.

The number of hypotheses can be reduced by appropriate experimental designs, three of which are:

Firstly, deep sea drilling should be carried out between the eastern Canaries and Africa to reach the base of the sedimentary pile. The age of the oldest sediment would put constraints on the date of the hypothetical detachment of the Canaries from Africa. Sediments, in particular those of Miocene age, should be examined for their depth of deposition, source and major environmental change.

Secondly, the basement highs and sea knolls east of Fuerteventura should be drilled to determine their composition, age, and former depth below (or height above) sea level.

Thirdly, additional detailed geophysical studies in these areas should be done to provide more exact boundary conditions for theories involving the existence of former landbridges, continental or volcanic.

Origin of the Canaries in the framework of plate tectonics

Undoubtedly the Canary Islands hold a key position in the analysis of sea floor spreading and plate tectonics with regard to movement of the African plate (Fig. 9). The sea-floor-spreading hypothesis postulates that new oceanic crust is constantly being produced at the midoceanic ridges by extrusion and intrusion of basaltic magmas. The new crust plus part of the upper mantle (the 'lithosphere') are rapidly being transported away from the ridges as if on conveyor belts (about 1–2 cm/year in this part of the Atlantic according to Philips 1968). Thus the crust is youngest at the ridges and oldest at the continents.

Abundant evidence has recently been accumulated to show that the North Atlantic opened about 230 Ma ago (Luyendyk & Bunce 1973) and the South Atlantic about 130 Ma ago (Larson & Ladd 1973) although there may have been a precursor, the so-called Proto-Atlantic (Rona 1970).

The Canary Islands are situated within the magnetic quiet zone which ends just W of the islands where the crust has an age of about 155 Ma (Rona *et al.* 1970; Fig. 4). The magnetic quiet zone is much narrower than in the western Atlantic, 'implying that sea-floor spreading prior to

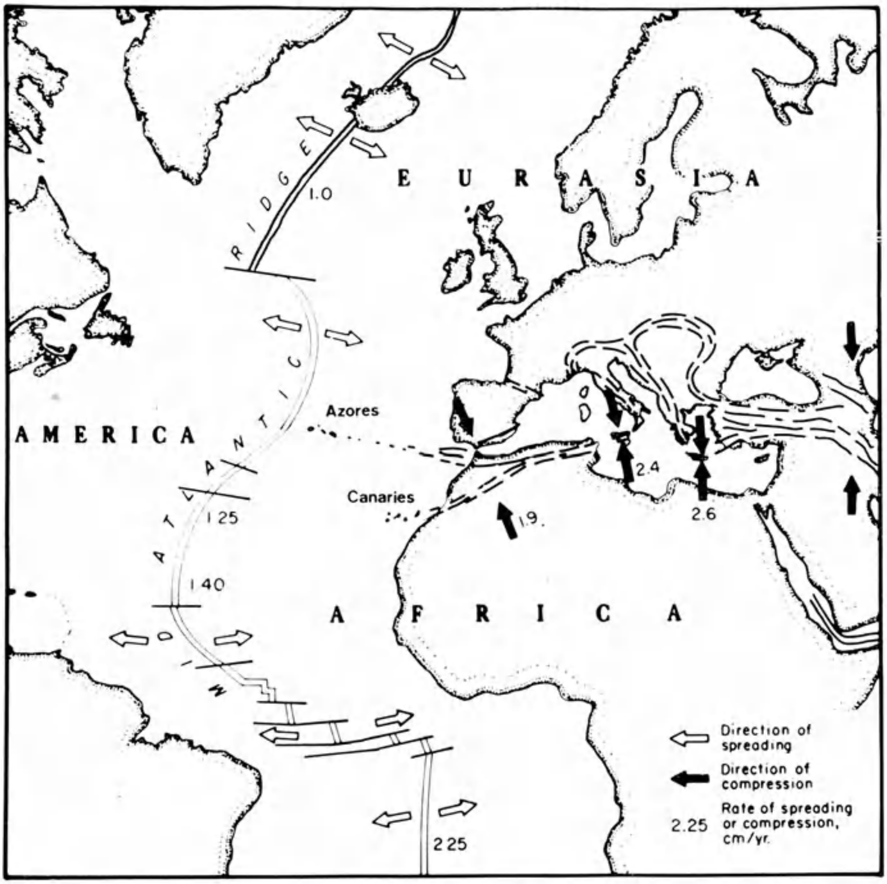

Fig. 9. Tectonic position of the Canary Islands with respect to the eastern and northern boundaries of the African plate. The extension of the North African fold belts into the ocean basin is highly speculative. From Ninkovich & Hayes 1972, Fig. 10, modified after Le Pichon 1968.

the time of the magnetic boundary was asymmetric, favoring growth of the west side of the Atlantic. The asymmetric growth may have resulted from a faster rate of spreading on the west flank of the then-active oceanic ridge or migration of the active ridge eastward. The near equivalence of distances between the opposing magnetic boundaries and the present axis of the mid-Atlantic ridge, as well as the suggested mirror-image correlations between anomaly sequences seaward of the magnetic boundaries, imply that sea-floor spreading became more symmetric after the time of the magnetic boundary in the central North Atlantic.' (Rona *et al.* 1970, p. 7419).

Drake & Woodward (1963), Le Pichon & Fox (1971), and Pitman & Talwani (1972) postulated a Canary Fracture Zone linking the Kelvin

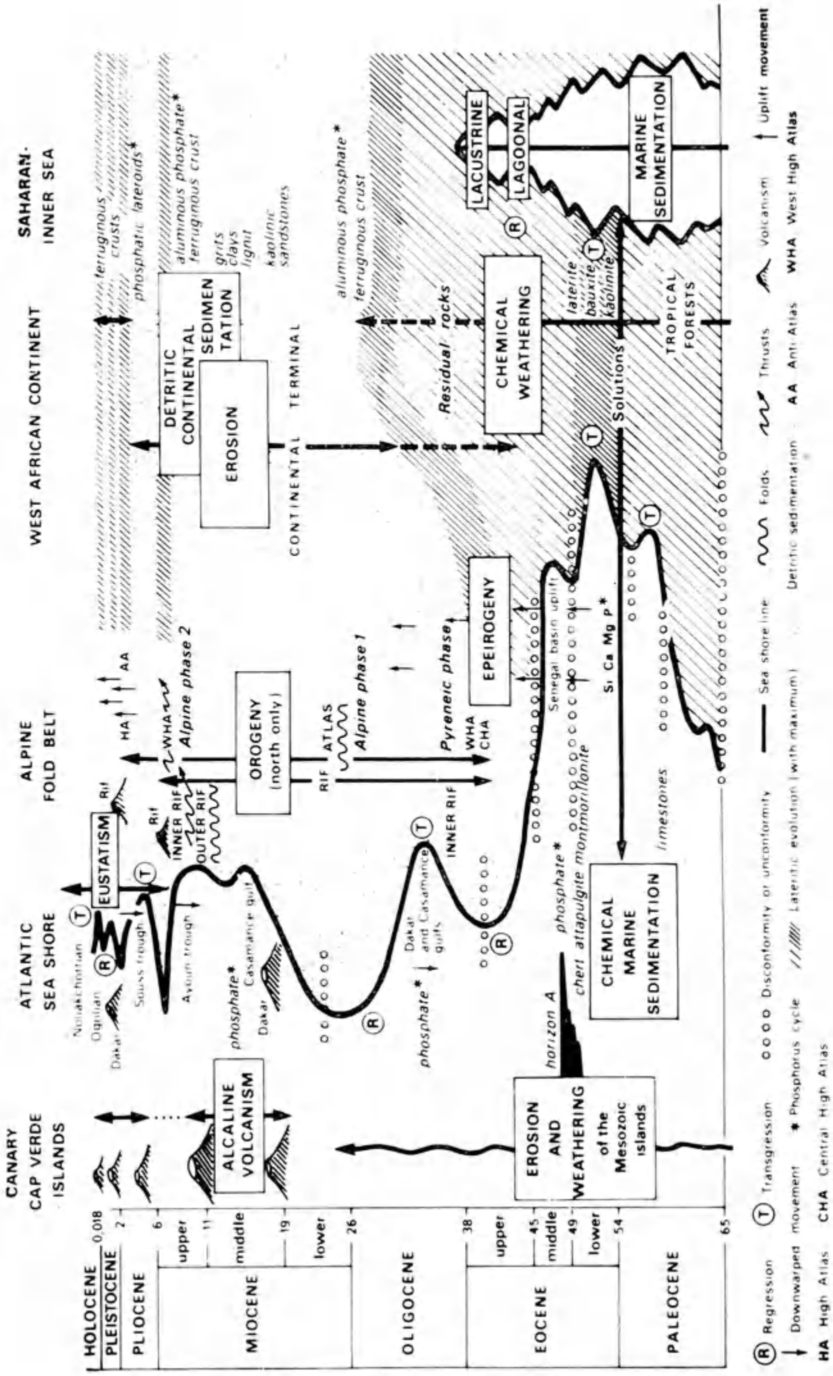

Fig. 10. Synoptic geologic history of the western part of the African continent and the adjacent Atlantic basin during the Tertiary and Quaternary periods. From Dillon & Sougy (1974, Fig. 15).

chain of seamounts to form a New England-Canary Fracture Zone supposedly formed early in the Atlantic opening (Fig. 4). Pitman & Talwani, noting a discrepancy between the Mesozoic origin of this postulated fracture zone and the late Cenozoic age of the Canary Islands, proposed that the Canaries and the south Atlas fault are related to differential movements along the east side of a New England – Canaries Fracture Zone.

The eastern Atlantic margin differs from the western Atlantic by showing abundant volcanic islands and submarine volcanic cones (Fig. 1). Many of these, particularly north and south of the Canaries, are situated along the continental rise. In a very broad sense, the Madeira and Cape Verde islands are also part of this zone running a few 100 km west but parallel to the west African coast. It is highly suggestive to look for a common cause both in time and space for the formation of those volcanoes in the eastern central Atlantic basin but no satisfactory theory is available at present.

Major melting events in the sub-Canarian mantle apparently did not start until about late Tertiary, lasting for about 30 Ma to the present. The onset of Alpine deformation at about the same time (Fig. 10) possibly due to repeated collisions between the African and European plates (Le Pichon 1968; Phillips & Forsyth 1972; Dillon & Sougy 1974) may have initiated the melting.

The eruptive patterns in the Canaries, if they are not random, maybe explained by two main models.

Synchronous eruptive periods

The assumption underlying this model is that some regional geodynamic processes are responsible for the generation of magmas underneath several islands at the same time. Such processes may be sudden changes in the velocity or direction of plate movement or the collision of the African with the Eurasian plate (Fig. 9). On a coarse scale, the Miocene age of the shields on many Canarian islands may reflect one or more major geodynamic event in the middle Miocene with age differences in the shield lavas of different islands being due to differences in magma production rates at different sites and/or different elevation from the sea floor. Such an interpretation may receive some support from the fact that most older Atlantic islands are not older than Miocene. On the other hand, such time spans for islands may reflect the average duration of a melting episode beneath an island.

Migration of volcanic activity

It has long been known through morphologic studies that the degree of erosion increases from W to E in the Canary Islands, Fuerteventura's 'old' rocks being the most strongly denuded.

This apparent westward migration of volcanic activity was suggested by absolute age measurements (Abdel Monem *et al.* 1967) and was explained as possibly due to ocean-floor spreading (Schmincke 1967a) resp. migration of the lithosphere over a relatively fixed melting spot (Schmincke 1973). This migration appears striking when all age data available are plotted for each island (Fig. 3). This migration is reminiscent of that in the Hawaiian islands (McDougall 1964; Jackson *et al.* 1972), as is the relatively even spacing between islands in the E-W direction (ca. 110–140 km). These data strongly suggest that the pattern of volcanic activity in the Canaries must be viewed in the context of ocean floor spreading and plate tectonics.

However, the more detailed modern work in the Hawaiian Islands shows that the progression of volcanic activity is non-linear and that magmas may rise simultaneously above a melting anomaly some 300 km in diameter (Jackson *et al.* 1972; Shaw 1973; Shaw & Jackson 1973; Dalrymple *et al.* 1974). Thus, plate velocity cannot be directly inferred from a propagation of volcanism noted for the Canaries, unless linearity can be proved.

The main purpose of this speculative discussion is to give a brief perspective of the major geodynamic problems that could be profitably analyzed on the basis of a large number of dated rocks taken from stratigraphically precisely controlled sites. While at least the subaerial part of most Canary islands is largely volcanic in origin, the eastern islands are at least partly underlain by marine sedimentary rocks and possibly even by continental crust. A more detailed analysis of the interplay of eastward spreading of the Atlantic plate, northward movement of the African plate and collision with the Eurasian plate and interaction of the Atlantic oceanic and African continental lithosphere and a more precise elucidation and interpretation of the nature of what geophysicists call 'transitional type crust' is needed in order to gain more information on the origin of the Canaries.

One may speculate, that the main Canarian trends are due to two main factors: (a) Opening of tensional, perhaps en echelon, N to NE fractures at the approximate boundary between the oceanic and continental parts of the African plate. (b) These fractures were used as pathways for rising magma along a more E-W oriented trajectory of plate movement over a large primary melting anomaly.

Magmatic evolution in the Canaries will be discussed following the description of the major rock types.

Mafic and ultramafic plutonic rocks

Basal complexes, consisting of peridotites (dunites, pyroxenites, and wehrlites), alkali gabbros, diorites, and syenites occur on Fuerteventura,

Table 1. Comparison of basal complexes of La Palma, La Gomera and Fuerteventura after Hernandez-Pacheco 1971.

La Palma					La Gomera				Fuerteventura			
Age Miocene Quaternary	Post-basal-complex series: Recent and subrecent series Cumbre Vieja series Basaltic series of the Caldera Wall and El Time Old basalts of Cumbre Nueva			Dike complex	Age Mio-cene Quater-nary Lower or middle Miocene	Post basal complex series: Old and subrecent basalt series			Age Miocene Quaternary	Post basal complex series: Basaltic series I, II, III, IV		
						Trachytic-phonolitic series		Alkaline intrusions		Syenite complex		Alkaline intrusions
	Polygenic volcanic agglomerates Recent submarine emissions		Dike Complex		Cretaceous Miocene	Submarine series (basic lavas, sediments)	Dike Complex		Post lower Miocene	Subaerial tuffs and agglomerates Submarine volcanic rocks Siliceous sediments Layered plutonic basic complex	Dike complex	
	Alkali gabbros Old submarine series Salic metamorphosed rocks olivine (Peridotites) (gabbros) gabbros	Dike Complex			Pre-Cretaceous	Plutonic basic complex (Gabbros, peridotites, pyroxenites)			Pre-Miocene			

Gomera, and La Palma (Table 1). They are of alkalic affinity and are associated with pillow lavas, quartz-bearing sedimentary rocks and subaerial breccias. Some or all of these rock units are cut by one or more dike swarm(s) of great density. Parts of the complexes are slightly metamorphosed. These complexes have been recently studied by Gastesi *et al.* 1966; Fuster *et al.* 1968; Lopez Ruiz 1969; Gastesi 1969; Cendrero 1970, 1971; and Hernandez-Pacheco 1971. Much petrologic and some geologic details (exact stratigraphic sequence of the rock units) are still lacking, however, in part owing to complex mutual intrusive relationships, density of dike swarms, and metasomatism.

Fuster and co-workers postulate that these stratiform plutonic bodies formed in the upper mantle or lower crust, and form a common basement that underlies all of the Canary islands and may even extend further. They further postulate erosion (or uplift and erosion), (re)submergence, deposition of sediments and pillow lavas and later uplift. The ages assigned to the stratiform complexes (e.g. pre-Cretaceous: Cendrero 1970, 1971) would indicate that this basement formed not long after opening of the Atlantic, at least much earlier than the exposed extrusive volcanic rocks which are dominantly Miocene or younger.

In the absence of reliable absolute age data on the plutonic rocks, this hypothesis essentially rests on the interpretation of the – poorly exposed – contact between the folded Cretaceous marine sedimentary rocks on Fuerteventura (Rothe 1968a) and the adjacent plutonics of the Betancuria massif. Fuster *et al.* (1968a) regard the plutonics to be older while Rothe thinks they are younger.

This interpretation is more likely. If the intrusives were older, one would expect detritus derived from these to be interbedded with, or part of, the sedimentary rocks. Such is not the case. On the island of La Palma, the plutonic complex was also formerly regarded as the oldest part of the island (Gastesi *et al.* 1966), but Hernandez-Pacheco (1971) regards the older pillow series as possibly being older in age.

At present no rigid analysis of the basal complexes has been made within the framework of ocean-floor spreading (Vine & Hess 1971; Moores & Vine 1971).

To resolve this dilemma is of some importance with regard to two problems: do the basal complexes represent oceanic crust or even mantle and, if so, do stratiform complexes of alkalic affinity exist in the upper mantle? Or do they constitute the eroded, perhaps slightly uplifted, cores of oceanic volcanoes built on top of the oceanic crust?

Although layered gabbros have been found in the oceanic crust of the Atlantic (Melson & Thompson 1970) and although Borley *et al.* (1971) postulate layered plutonic complexes in the upper mantle beneath Tenerife at a depth between 11 and 30 km (based on nodule mineralogy and geophysical data), the last alternative interpretation receives some support from the following data: work on oceanic basalts during the last several years shows that alkali basalts occur preferentially in sea mounts and volcanic islands. Even on Cyprus, only the uppermost pillow lavas of the Troodos massif contain alkalic rocks, all others being tholeiitic (Moores & Vine 1971). From the best studied recent volcano (Kilauea on Hawaii) it is well known that the active magma chambers are situated at depths of about 3 km (Fiske & Kinoshita 1969) and that series of nestled fossil magma chamber bottoms, made up of ultramafic cumulate plutonics, constitute the core of the volcano (Hill 1969; Jackson 1968). Moreover, dense dike swarms probably extend close to the surface, particularly in the rift zones (Fiske & Kinoshita 1969).

On Gran Canaria, intrusive essexites and hauynophyres occurring about 1500 m above sea level and associated with a dike swarm and a partly preserved cover of lava flows and breccias (Brey & Schmincke, in prep.) are an example of such a dissected alkalic volcano. Although these plutonics are only slightly layered, ultramafic nodules of similar mineralogy and with excellent cumulate texture occur abundantly in the covering breccias (Frisch & Schmincke 1969). An interpretation of the mafic to ultramafic complexes of the other islands as high level rocks – as contrasted with a mantle origin – would remove the difficult-to-envisage up and down movements of oceanic crust/mantle plates.

At present, most data indicate that the mafic-ultramafic plutonic complexes are the result of slow cooling of alkaline basaltic magmas intruded into submarine, partly volcanic partly sedimentary crust which was later uplifted. It is not clear, whether this crust is old oceanic crust or whether it represents a younger submarine volcano. It is also unknown whether all intrusions formed after uplift was completed or, in part, earlier.

Recent work by Bennell-Baker *et al.* (1974) indicates that the geologic history of the basal complex on Fuerteventura is much more complex than previously supposed and it will probably take many years before more precise and realistic models of the early geologic history of the Canary Islands can be developed.

Nodules

Nodules of diverse rocks occur on all of the Canary Islands. Their study is of some importance for a number of geologic problems. Nodules give us a glimpse, mostly tantalizing, of the substructure of a volcano not exposed on the surface, or of the upper mantle and may thus help to elucidate the origin of the different magma types.

Nodules of sedimentary rocks, commonly (metamorphosed) limestones, occur abundantly in lavas and pyroclastic rocks on many of the Canaries. While mostly derived from near surface calcarenites interbedded with the lavas, some may have a deeper origin and may, perhaps, be part of an old ocean floor or even be continental.

Gabbros (both tholeiitic and alkalic) are perhaps the most abundant type of nodule on the Canaries. Frisch (1970) has made a detailed petrologic analysis of a gabbro from Lanzarote, concluding that it crystallized from a tholeiitic magma at a depth of less than 9 km.

Syenites and quartz syenites occur in many trachytes and rhyolites on Gran Canaria. They crystallized in a high level reservoir from the magma represented by their host lava (ignimbrite) (Schmincke 1973).

Lherzolites, in particular harzburgites, generally occur together with the younger, commonly more alkaline and silica undersaturated lava types, as on Hierro (Jeremine 1935) and Gran Canaria (Schmincke 1973) and Lanzarote and Fuerteventura (Sagredo 1969) which are erupted during the later stages in the evolution of an island. This is similar to the occurrence of lherzolite nodules in the Hawaiian island (White 1966; Jackson & Wright 1970) and may indicate that these later lavas came from greater depths and carried fragments of upper mantle material, part of it refractory, to the surface.

Munoz & Sagredo (1974) have studied the composition of clinopyroxenes in mafic and ultramafic nodules from several islands as geobarometers. Their data and conclusions are discussed by Frisch (1975).

A detailed study of the mineralogy of harzburgite nodules occurring in hauyne-melilite nephelinite is given by Schmincke *et al.* (in prep.).

LANZAROTE AND FUERTEVENTURA

The most famous Canarian nodule-bearing localities are on Lanzarote where almost 50 individual sites are known, mostly in the late Quaternary to Historic formations (series III and IV of Fuster *et al.* 1968b) (Sagredo 1969). Most ultramafic nodules are peridotites and of these mostly dunites with lesser amounts of lherzolites, harzburgites, and wehrlites; some are phlogopite-bearing. Sagredo (1969) reports many chemical analyses of the rocks and some of their constituent minerals. Absence of correlation of type of nodule – which also occur in the historic tholeiitic lavas – with the chemical and mineralogical composition of the host basalt and solid state deformation of the olivine have led Fuster *et al.* (1969) and Sagredo (1969) to interpret the nodules as xenoliths. While Fuster *et al.* (1969) emphasize cumulate textures in the xenoliths and think the ultramafic nodules are derived from the layered mafic to ultramafic plutonic complexes, i.e. from lower erosion levels than those exposed in Fuerteventura, Gomera and La Palma, Sagredo (1969) infers an upper mantle origin. Gabbro nodules are also abundant on Lanzarote, some containing olivine and two pyroxenes (Frisch 1970). Nodules on

Fuerteventura are of similar composition and are similarly restricted to the Quaternary lavas (Sagredo 1969).

GRAN CANARIA

Nodules in rocks from Gran Canaria occur in at least 4 different rock units: a. Several units of the Miocene series (mildly alkaline basalts and oversaturated silicic rocks) contain plutonic nodules of cognate origin (gabbro and diorite in the basalts and quartz syenites and alkali granites in comenditic and pantelleritic ash flow tuffs) (Schmincke 1973). b. The Pliocene Roque Nublo breccia contains abundant nodules ranging from kaersutitites and clinopyroxenites to essexites and syenites (Bourcart & Jeremine 1937; Frisch & Schmincke 1969). c. Melilite nephelinites overlying the Roque Nublo rocks contain phlogopite-harzburgites and lherzolites (Schmincke *et al.*, in prep.). d. Hausen (1962) reports a large suite of nodules ranging from peridotites to anorthosites in young cinder cones on La Isleta, N of Las Palmas.

TENERIFE

Xenoliths of Tenerife have been studied by Ibarrola & Viramonte (1967), Gastesi (1967) and, in more detail, by Borley *et al.* (1971). Dunites and clinopyroxenites occur in the Miocene basalts, gabbroic xenoliths in the Pedro Gil region, nepheline-syenite xenoliths in the Las Cañadas area and ultramafic to syenitic xenoliths in the Anaga peninsula close to syenite intrusions. In general the ultramafic nodules appear to be of cumulus origin formed at depth between 11 and 30 km according to Borley *et al.* (1971).

LA PALMA

Ultramafic xenoliths (consisting of clinopyroxene, amphibole, mica and olivine) also occur on La Palma, particularly at the southern tip of the island (Volcan de San Antonio, Jeremine 1933; 1971 eruption).

LA GOMERA

Cendrero (1971, p. 34) reports gabbroic, peridotitic, and dunitic nodules in the subrecent basalts from Gomera; significantly they are much more common than in the older basalts of La Gomera.

HIERRO

Jeremine (1935) reports an orthopyroxene-bearing nodule in a nepheline basanite (ankaratrite) flow.

STRUCTURAL ROCK TYPES

1. Basalts sensu lato

The commonest rock types on the Canary Islands are aa-basalt flows (< 5 m in thickness) with top and basal breccias, crude joints and rare pyroclastic interbeds (Fig. 11) commonly erupted from dikes (Fig. 12). When fresh, they appear as gray to black, dense, tough basalt layers alternating with highly porous breccia horizons. In older sequences (e.g. the Miocene basalts on Gran Canaria, Tenerife, Lanzarote, Fuerteventura) many rocks are greenish-gray due to alteration and softer than the unaltered basalts and the contrasts between the dense and brecciated layers is lessened because of secondary minerals deposited in the voids.

Fig. 11. Aa-type lava (thin, poorly jointed flows separated by thick breccia) in Miocene basalts at mouth of Barranco de Tazartico (Gran Canaria). Person (right foreground) for scale.

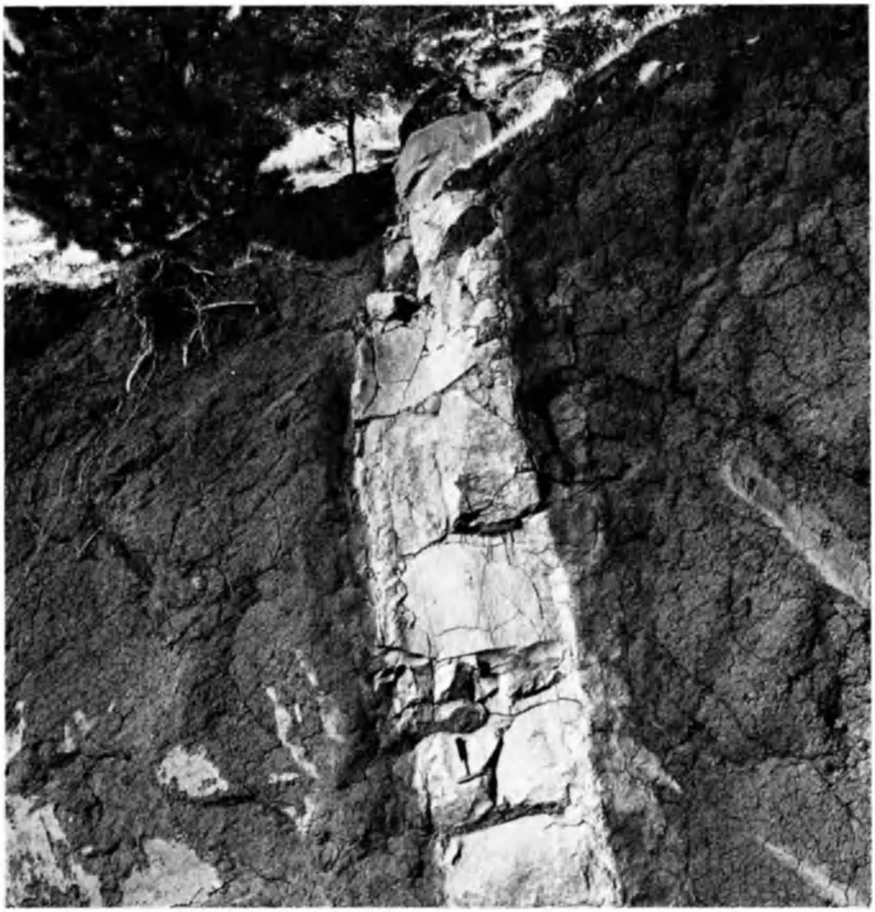

Fig. 12. Dike of nephelinite intruded into altered nephelinitic pyroclastics. 2 km NW of Cruz de Tejeda (Gran Canaria). Hammer for scale.

Pyroclastic interbeds of basaltic ash and lapilli are rare except near eruptive centers. These pyroclastics are commonly reddened at the top where in contact with an overlying basalt flow due to baking – a feature commonly mistaken for 'lateritization'. Lava tubes are common (Fig. 13).

Pahoehoe lavas with ropy surfaces and pseudo-pillow cross sections are rare (Fig. 14). True subaquatic pillow lavas occur on Fuerteventura, Gomera, Gran Canaria (overlying the Las Palmas terrace just west of Las Palmas) and as a thick, altered and tilted sequence on La Palma (Fig. 25a).

2. *Hawaiites and mugearites (trachybasalts)*

Owing to the higher viscosity of these lavas the trachybasalt (a field term encompassing hawaiites and mugearites) flows are thicker (Fig. 40) than

Fig. 13. Radially oriented thin columns of basalt (rosette) filling a lava tube in the upper part of a Pliocene basalt lava flow (thick columns). Barranco de Agaete (Gran Canaria). *Euphorbia Canariensis* for scale.

Fig. 14. Miocene basaltic pahoehoe lavas in road cut along road San Nicolas-Agacte (Gran Canaria).

the basalt flows and are characterized by platy jointing, the joints showing a characteristic sheen due to alignment of feldspar microlites. The rock is light gray and commonly aphyric. Hawaiites generally occur near the top of thick basalt sequences (e.g. Miocene series of Lanzarote, Fuerteventura and Gran Canaria). They make up much of the *cobertera*, (the basalt sequence above the main unconformity, i.e. the upper Caldera sequence) on La Palma, and are also common on other islands such as Hierro.

3. Phonolites and trachyphonolites

The trachybasalts grade through trachyandesites into phonolites, trachytes and trachyphonolites. Trachyandesites are absent on Gran Canaria ('Daly-Bunsen' silica gap) but may be common on other islands such as La Palma (Hausen 1969).

The phonolite and trachyte flows (Fig. 15) are generally thick (up to 50 m or more) show columnar and platy jointing and have top and basal breccias. The phonolites are commonly green – due to the abundance of aegirine in these peralkalic rocks – while the trachytes are colored various shades of gray. The phonolite flows generally are short and stubby, but

Fig. 15. Pico Viejo (Tenerife) with young blocky lava flows descending from Pico de Teide in foreground. Note levees and main channel in flow descending to the left.

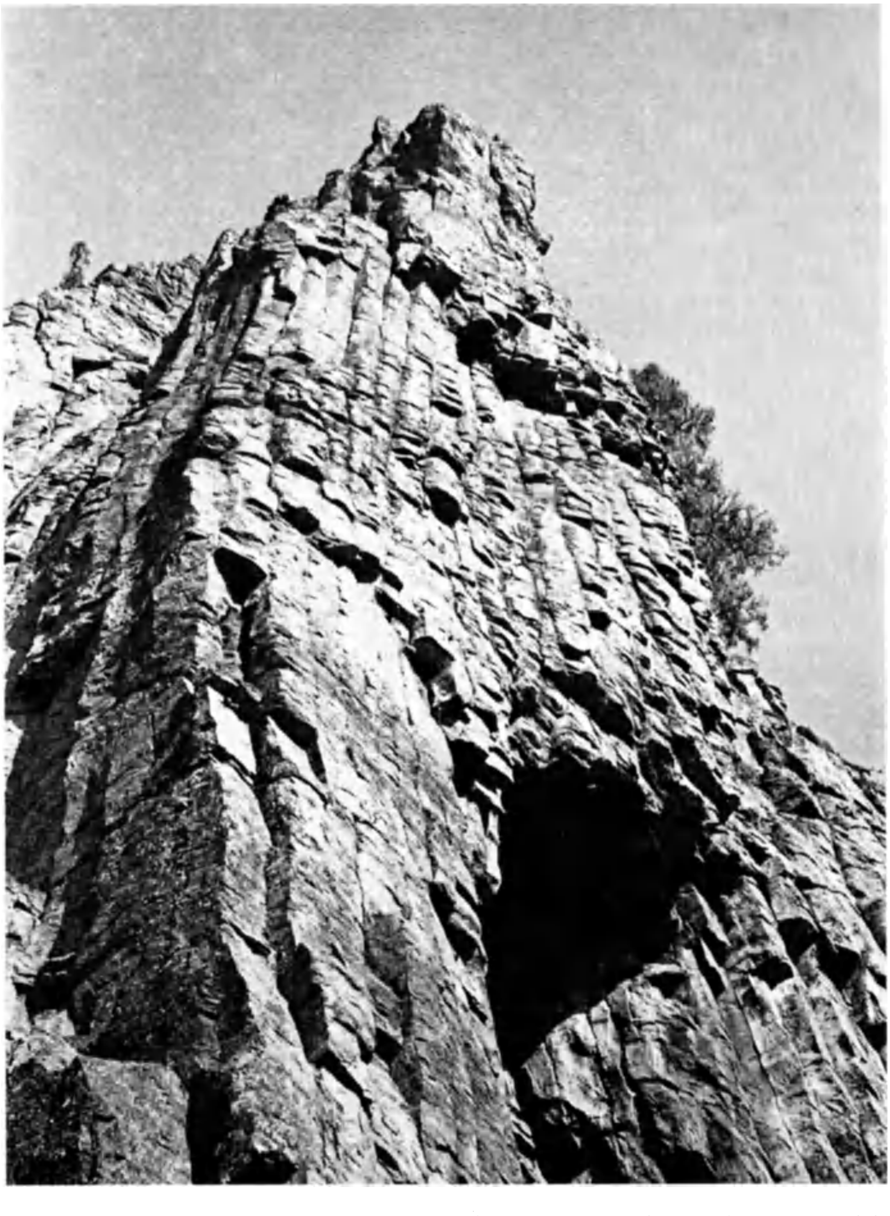

Fig. 16. Columnar hauyne phonolite neck of Pliocene age at Pajonales (Gran Canaria). Width of columns about 0.7 m.

Fig. 17. Unwelded phonolitic pumice flow deposits at Medano (Tenerife). Two flow units are visible in the photograph both showing reverse size grading with dense phonolite clasts at the base and large pumice clasts (head of hammer) at top.

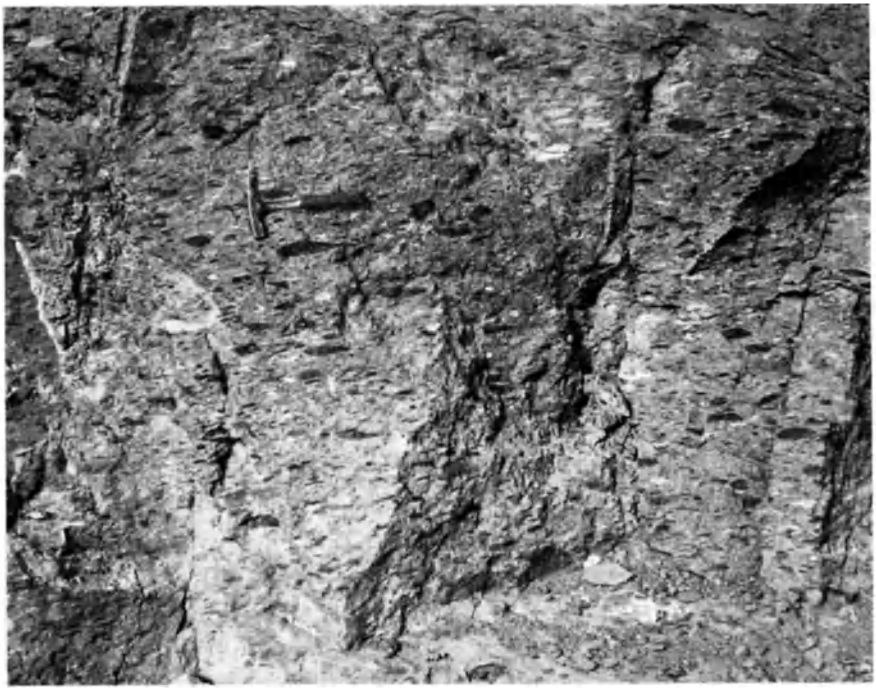

Fig. 18. Comenditic (alkali rhyolite) welded tuff (ignimbrite) A in Barranco de Tauro (Gran Canaria). Lenses are collapsed pumice lapilli. Hammer for scale.

surprisingly the Miocene trachyphonolite lavas on Gran Canaria travelled well over 10 km. More prominent topographically than the flows are the phonolite (and trachyte) plugs, erosional remnants of strikingly columnar rocks (Fig. 16). Such plugs, many of which more than 100 m in diameter, are landmarks on almost every island, particularly Gran Canaria, Gomera, and La Palma.

4. Pyroclastic flow deposits

Welded rocks deposited from hot pyroclastic flows (ignimbrites) are known so far only from Gran Canaria and Tenerife (Figs. 17–20). They are 15–30 m thick on the average and show the vertical zonation typical of ignimbrites. Those of Fe-rich peralkalic composition on Gran Canaria show laminar viscous flowage structures (Schmincke & Swanson 1967a).

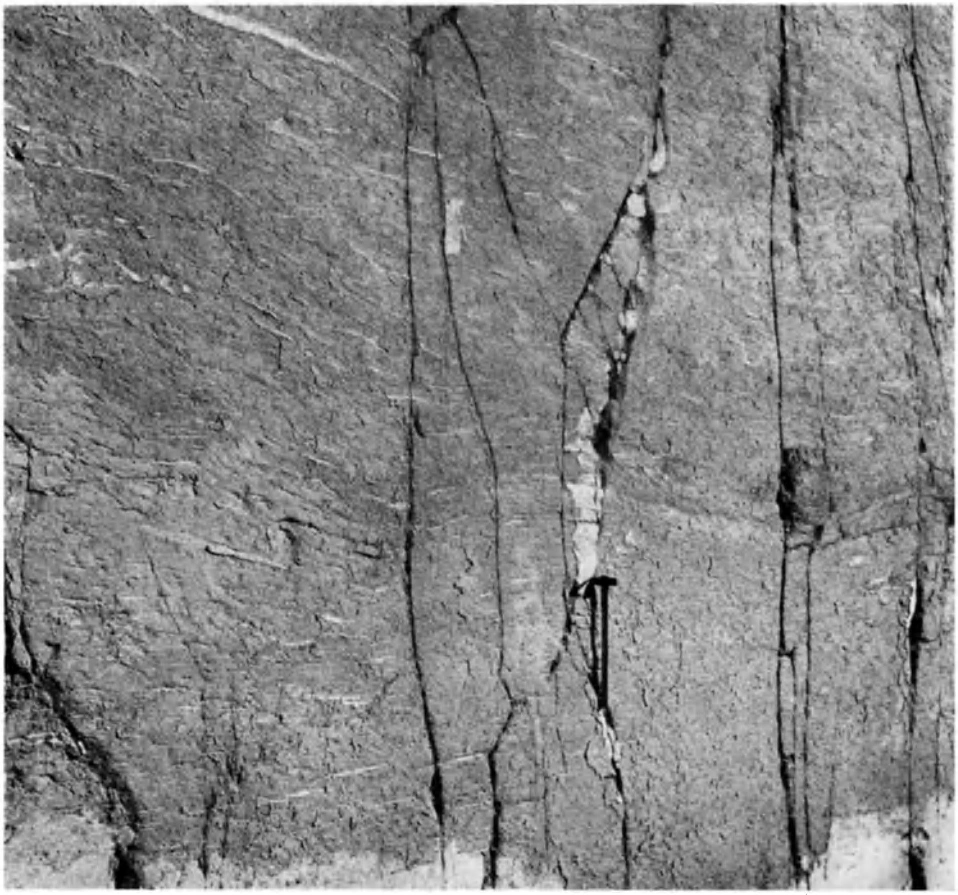

Fig. 19. Strongly welded comenditic ignimbrite E showing white, granophyrically crystallized pumice lapilli in a light gray (lower flow unit) and darker gray (upper flow unit) matrix. Note wavy contact between both flow units. Road cut Puerto Rico (Gran Canaria).

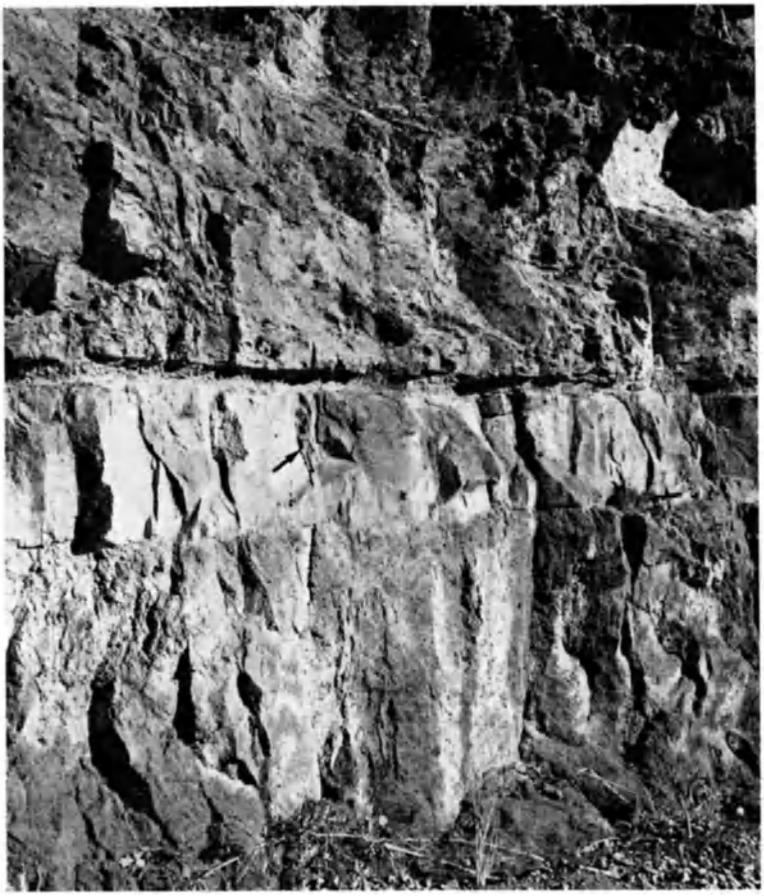

Fig. 20. Top part of pantelleritic ignimbrite B overlain by pantelleritic ignimbrite C. Two flow units, a lower coarse-grained and an upper fine-grained one, can be distinguished in the top part of ignimbrite B. Note many inclusions and 'imbricate' structure in ignimbrite C. Road cut Barranco de Taurito (Gran Canaria).

Unwelded pumice flow deposits ('puzzolane', 'trass') occur on Gran Canaria and cover large stretches on the SE-coast of Tenerife (Fig. 17), an area where laharic (volcanic mudflow) pumice deposits also occur.

Various extrusive and intrusive volcanic breccias emplaced at low and high temperature occur on all islands. Most spectacular are several thick (up to over 50 m) widespread (up to about 20 km long) sheets of the Roque Nublo Breccia (Figs. 21, 22, 52-54) on Gran Canaria (Brey & Schmincke, in prep.). This breccia grades into bedded and laharic rocks farther away from the eruptive centers.

5. *Ash, lapilli, scoria, cinder cones*

Alkalic basaltic magmas, in contrast to tholeiitic ones, generally have

Fig. 21. Massive sheets of Roque Nublo breccia flow deposits at Ayacata (Gran Canaria). Pliocene Ayacata formation. Cliffs are more than 100 m high.

Fig. 22. Detail of Roque Nublo Breccia showing abundant dark rock fragments. Light colored matrix rich in pumice. Road Cruz de Tejeda – Artenara (Gran Canaria).

Fig. 23. Basaltic cinder cones surrounded by lava flows formed during 1730 eruptions. Montaña Fuego (Lanzarote).

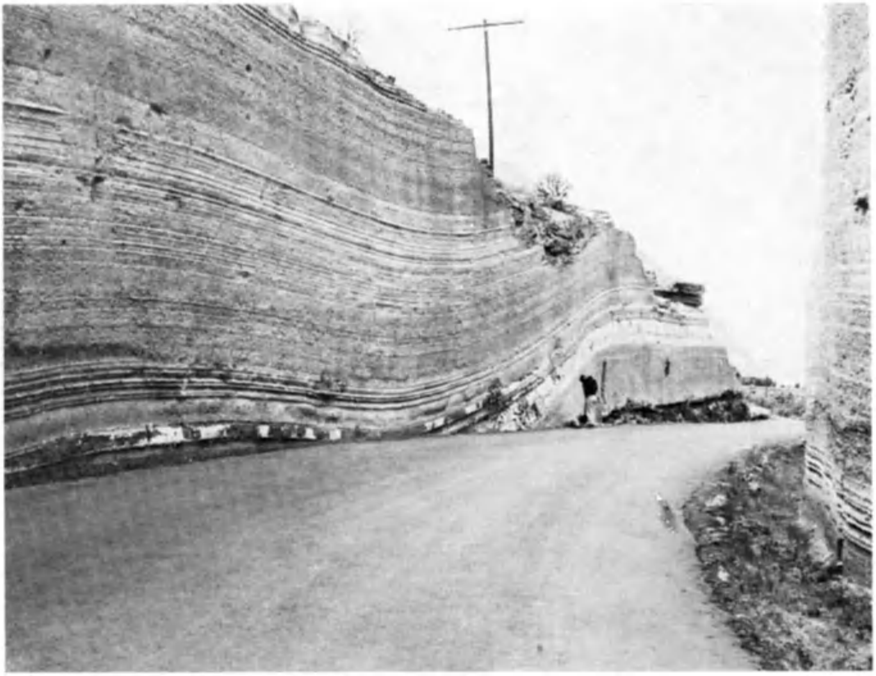

Fig. 24. Well-bedded air-fall tuff showing mantle bedding. More massive band just above road is shown in more detail in Fig. 63. Roadcut between Adeje and Los Cristianos (Tenerife).

much more H_2O and therefore are more explosive. Thus, all of the Canary Islands are characterized by pyroclastic cones of various ages, the most prominent ones being the historic cinder cones on Lanzarote (Fig. 23). These consist generally of ash and lapilli and, closer to the vent, of coarser scoria and locally agglutinates. However, no systematic studies on the grain sizes and other characteristics of these pyroclastic materials have been published. Air-fall tuffs of phonolitic composition are particularly common on Tenerife (Fig. 24).

6. *Hyaloclastites*

Hyaloclastites are basaltic pyroclastic rocks formed when basalt magma comes into contact with external water resulting in granulation due to thermal shock and/or disruption due to steam explosions. They generally form well-bedded deposits of palagonitized sideromelane fragments cemented chiefly by zeolites. The most prominent hyaloclastites occur in tuff rings on the west coast of Lanzarote (El Golfo and others) (Fig. 25) and on the east coast of La Palma (Caldera de Concepción, just south of Santa Cruz). These cones formed when lava flowed into sea-water and by ascent of the magma through groundwater horizons.

Explosions resulting when rising basalt magma heated and evaporated

Fig. 25. Bedded palagonite tuff cone of El Golfo (Lanzarote). The irregular erosional caverns are made of discontinuous, cemented surface crusts. Height of cliff about 20 m.

groundwater combined with caldera collapse also resulted in a number of spectacular craters on some islands, three of which (e.g. Bandama Crater) were described from Gran Canaria (Schmincke *et al.* 1974) (Fig. 26)[1].

The importance of external water for influencing type of eruptions is also evident from the reports of historic eruptions both on Lanzarote and La Palma (Hausen 1959, 1969) some of which have erupted hot water, steam, and mud. Thus, the Hoyo Negro (La Palma) pyroclastic products are the result of phreatomagmatic eruptions (Fig. 71).

Hyaloclastites formed by submarine eruptions of lava are common in the uplifted submarine complexes of Fuerteventura, La Gomera and La Palma (see below).

Fig. 25a. Basaltic pillow lavas of upper part of submarine Angustias pillow complex. Branching lava 'fingers' in upper left; their cross-sections resemble pillows (lower right). Lower course of Barranco de las Angustias (La Palma).

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[1] For figure 26 see foldout between pages 146-147.

7. *Pillow lavas*

Basaltic lava flowing into, or being erupted under, water may proceed in a system of tubes, the ellipsoidal cross sections of which resemble pillows (Fig. 25a). Rarely, large 'drops' of lava may become pinched off from the feeding tube, thus coming to resemble a pillow in three dimensions. To recognize pillow lavas on land can be very important because on most oceanic islands this means that lavas, formed under submarine conditions, were later uplifted or that the sea level dropped, lakes or glaciers such as those on Iceland (famous for its subglacial pillow-hyaloclastite complexes) being absent on the Canary Islands. Pillow complexes may represent three different conditions and environments of formation: Firstly, subaerial lavas flowing into the sea may form pillow complexes with minor hyaloclastites, pronounced foreset bedding and no dikes. Examples are Roque Nublo lavas on the Las Palmas Terrace (see below) and some pillow lavas from Fuerteventura (Fuster et al. 1968a). Secondly, they may represent uplifted parts of a volcano's submarine flanks. Such complexes have more abundant hyaloclastites and dikes and may lack subaerial lava flows and detrital rocks entirely. The Angustias pillow complex of La Palma is the most striking example of this group (Figs. 25a, 70). The pillow lavas of Gomera may also belong to this type. Finally, pillow complexes may represent Mid-Oceanic Ridge associations. In this case, the basalt should probably be of abyssal tholeiitic composition and be associated with deep sea sediments. While such sediments are probably represented by the Cretaceous series on Fuerteventura (Rothe 1968a), it is uncertain whether the overlying pillows belong to this or a much younger unit.

Chemical rock types (major elements)

The large increase in chemical analyses during the last five years plus detailed petrologic studies show that several distinct magmatic lineages are present in the Canaries. Different lineages may occur on adjacent islands, but may also appear on a single island that has a long and complex magmatic history somewhat analogous to changes in geochemical trends with time in the Hawaiian islands (MacDonald 1968). Gran Canaria has such a complex history.

1. *Tholeiitic series*

This is the least common series. It is represented by historic lava flows on Lanzarote and some prehistoric ones on Fuerteventura (data in Fuster *et al.* 1968a, b) and hypersthene-bearing gabbroic xenoliths occurring in alkali basalt on Lanzarote (Frisch 1970). The K_2O-content (0.7–1.0%) is higher than that in Hawaiian tholeiites (0.4–0.6%) (MacDonald 1968). Reiss (1861) described hypersthenites from the Caldera de Taburiente (La Palma) but Cohen (1896) identified the pyroxenes in the same samples as augite, although later authors (e.g. Navarro 1926, p. 91) apparently overlooked Cohen's correction. Hausen (1969, e.g., p. 91) frequently refers to the occurrence of orthopyroxene in alkaline mafic lavas from La Palma, but thin sections of these samples kindly sent to me by Hausen were lacking in orthopyroxene. Gastesi (1969, p. 1023) reports orthopyroxene in gabbros from Fuerteventura but gives no optical or chemical data.

2. *Transitional series*

Many authors (e.g. Coombs 1963; Upton & Wadsworth 1966) have recognized basalts that fall outside the Hawaiian pigeonholes, alkalic basalts that lie near the critical plane of saturation, i.e. are barely hy-normative. Such transitional basalts are represented by some of the Miocene shield lavas on Gran Canaria (Schmincke 1969a, b). While Fuster *et al.* (1968c) and Borley (1974) believe that the oversaturated normative character of these rocks is due to oxidation, some basalts remain hy-normative even after recalculating to FeO = 1.5% (Schmincke 1969a, b). Moreover, the 3 new ne-normative analyses presented by Fuster *et al.* 1968c, Table 3, No. 1–3 (see also Ibarrola 1970) as belonging to the Miocene basaltic series are apparently misplaced because they are from a much younger basaltic series as can be seen from the localities given. Possibly some of the older basaltic series of Fuerteventura, Lanzarote, Gomera, and Tenerife may belong to this transitional series (Schmincke 1973). The evolved members of this series are voluminous only on Gran Canaria, encompassing subalkalic and peralkalic rhyolites, trachytes, and trachyphonolites (Schmincke 1969a, b).

3. *Alkali basalt series*

Most basalts on the Canary Islands are members of the alkali basalt-trachyte series comparable to the Hawaiian alkali series, but are more alkalic and undersaturated (Ibarrola 1969, 1970). Basanites and ankaramites are particularly common with hawaiites and mugearites probably being less abundant than in Hawaii. The hawaiites commonly are plagioclase-phyric. Clinopyroxene, plagioclase and Fe/Ti-oxides are the dominant groundmass minerals in the basaltic rocks. Sporadic amphibole occurs in many basalts. The evolved rocks encompass trachyte and nepheline phonolite. This series, and the basanite series (4) with which there are all gradations, are probably represented on each of the Canary Islands. The plutonic equivalents of this and the next series (essexite-syenite series) occur in larger bodies on Fuerteventura, Gran Canaria, La Gomera, and La Palma.

4. *Basanite-ankaramite-tephrite-ordanchite series*

Very alkalic and highly undersaturated series leading to hauynophyric rocks (generally intrusions) are represented by the Roque Nublo series

(Bourcart & Jeremine 1937; Hausen 1962; Fuster *et al.* 1968c; Frisch & Schmincke 1969; Anguita 1972; Brey 1973) of Pliocene age on Gran Canaria and the Cobertera series on La Palma (Hausen 1969; Middlemost 1972). Hauyne-bearing phonolites are also present on Gomera (Bravo 1964) and Tenerife (Fuster *et al.* 1968d; Ridley 1970; Araña 1971). The tahitites on the northern coast of Gran Canaria may also belong to this group (Hernandez-Pacheco 1969).

5. *Olivine nephelinites*

Olivine nephelinite and melilite nephelinite flows are so far known in greater abundance only from Gran Canaria (Schmincke 1973; Ibarrola & Martorell 1973). Jeremine (1935) reports 'ankaratrite' (nephelinite?) from Hierro.

6. *Carbonatites*

Dikes of carbonatite were found on Fuerteventura by Fuster *et al.* 1968a.

TRACE ELEMENTS

There are relatively few data on trace elements from Canarian volcanic rocks. Ridley (1970) and Brändle (1973) have published a large number of trace element data from the Cañadas and Teide rocks (Tenerife). Some of these are plotted together with preliminary trace element compositions from Gran Canaria (Schmincke, unpubl.; table 2) in Fig. 27. These data are in general similar to those of other alkalic volcanic suites on oceanic islands (e.g. Carmichael *et al.* 1974).

On a finer scale, suites differing in alkalinity and silica saturation are also characterized by typical trace element concentrations: the Miocene only slightly silica-undersaturated to oversaturated suite from Gran Canaria has lower concentrations of the trace elements Zr, Nb, Rb, Sr than the more alkalic suites on Tenerife (Fig. 27) and on Gran Canaria (table 2). Secondly, the peralkaline rhyolites (comendites and pantellerites) from Gran Canaria whose correct identification has been doubted by some (e.g. Fuster *et al.* 1968c) show trace element compositions characteristic of those of such rocks elsewhere: Zr and Nb concentrations are much higher and Sr-concentrations much lower than those of calc-alkalic rhyolites (Fig. 27, compare with table 5–1 in Carmichael *et al.* 1974). In fact, the extremely high Zr concentrations in comendite E (nearly 2700 ppm) are among the highest known for such rocks. Thirdly, there is a more or less continuous variation between the basaltic and derivative rocks of a particular series, strongly suggesting that both are genetically related (c.f. Weaver *et al.* 1972)[3]. Moreover, while the trace

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[3] Feldspar fractionation probably was the dominant mechanism in the evolution of this series (Schmincke, 1969) although not enough data are available to prove or disprove major influence of a vapor (fluid) phase.

Table 2. Chemical analyses and CIPW-norms of representative volcanic rocks from Gran Canaria.

Magmatic phases	Magmatic phase I (Miocene: ca. 14 - 9.6 M.a.)										
Formations	Guigui Formation				Hogarzales Formation			Mogan Formation			
Computer number	2091**	2092**	2093**	2094**	2095**	2097**	2098**	33*	2115*	1022*	
Field number	1262	1263	1264	1265	1268	1270	1271	132	700	697	7
SiO_2	44.26	46.51	44.55	44.72	48.67	47.61	47.54	68.8	68.2	70.1	45
Al_2O_3	8.63	13.92	9.55	11.68	14.21	14.99	13.77	15.1	13.9	12.2	14
Fe_2O_3	4.61	5.64	4.22	5.13	5.64	5.73	6.83	2.4	3.0	3.8	4
FeO	8.02	6.86	7.84	7.25	6.45	7.04	6.53	0.3	0.17	0.4	8
MgO	19.37	6.15	16.79	11.88	4.53	4.63	5.12	0.6	0.3	0.4	5
CaO	8.73	10.69	8.95	9.97	9.47	9.66	9.75	1.5	0.9	0.9	10
Na_2O	2.00	3.02	1.91	2.51	4.13	3.42	3.71	6.2	7.1	5.9	2
K_2O	0.70	1.31	0.70	1.00	1.10	0.90	1.00	3.3	4.1	4.5	1
H_2O^+	0.93	1.19	2.50	2.16	0.95	1.03	0.71	0.4	0.4	0.06	2
TiO_2	2.50	4.03	2.71	3.52	4.13	4.22	4.32	0.6	0.9	0.7	3
P_2O_5	0.25	0.45	0.29	0.38	0.59	0.45	0.42	0.3	0.1	0.06	0
MnO	0.15	0.18	0.14	0.14	0.18	0.16	0.15	0.18	0.23	0.28	0
Co_2	–	–	–	–	–	–	–	–	–	–	–
Cl	–	–	–	–	–	–	–	–	–	–	–
So_3	–	–	–	–	–	–	–	–	–	–	–
–O=	–	–	–	–	–	–	–	–	–	–	–
Total	100.15	99.95	100.15	100.34	100.05	99.84	99.85	99.7	99.83	99.30	99
CIPW - norm $^{(+)}$											
Q	–	–	–	–	–	–	0.7	17.4	13.1	20.0	–
C	–	–	–	–	–	–	–	–	–	–	–
or	4.2	7.9	4.3	6.0	6.6	5.4	0.6	19.6	24.4	26.8	7
ab	11.1	22.0	16.0	16.0	32.7	29.4	29.0	52.8	49.0	38.0	21
an	12.6	20.9	15.8	18.0	17.2	23.3	18.2	3.7	–	–	24
lc	–	–	–	–	–	–	–	–	–	–	–
ne	3.2	2.2	0.3	3.1	1.5	–	1.6	–	–	–	–
ac	–	–	–	–	–	–	–	–	8.7	10.9	–
ns	–	–	–	–	–	–	–	–	0.4	–	–
Di wo	12.3	12.5	11.6	12.5	11.1	9.4	11.7	0.7	1.1	1.2	10
en	8.6	6.8	8.1	8.2	5.5	4.5	5.8	0.6	0.8	1.0	5
fs	2.7	5.3	2.6	3.5	5.3	4.7	5.7	–	0.2	–	4
Hy en	–	–	–	–	–	2.0	–	0.9	–	–	0
fs	–	–	–	–	–	2.0	–	–	–	–	0
ol	37.7	11.4	33.2	22.7	8.6	7.9	–	–	–	–	12
cs	–	–	–	–	–	–	–	–	–	–	–
mt	2.2	2.2	2.2	2.2	2.2	2.2	2.2	–	–	0.1	2
il	4.8	7.8	5.3	6.8	7.9	8.2	8.3	1.0	1.7	1.3	7
hm	–	–	–	–	–	–	–	–	–	–	0
tn	–	–	–	–	–	–	–	0.16	–	–	–
ap	0.6	1.1	0.7	0.9	1.4	1.1	1.0	0.7	0.2	0.1	1
cc	–	–	–	–	–	–	–	–	–	–	–
DI	18.6	32.0	20.6	25.2	40.7	34.8	36.5	89.9	86.4	84.8	29
Na_2O/K_2O	2.86	2.31	2.7	2.5	3.73	3.78	3.70	1.88	1.73	1.31	1
K/Na	0.39	0.42	0.41	0.45	0.30	0.30	0.58	0.60	0.64	0.85	0
K_2O/P_2O_5	2.8	0.89	2.41	2.63	1.86	2.0	2.40	11.0	–	11.25	1
Mg-number	77.63	52.94	75.89	68.60	46.20	45.29	46.87	–	–	–	51
AI	–	–	–	–	–	–	–	0.91	1.16	1.19	–
Trace element abundances (ppm)*** (XRF)											
Rb	10	27	15	26	34	19	10	n.d.	n.d.	n.d.	
Sr	280	492	302	278	649	440	535	n.d.	n.d.	n.d.	

				Magm. phase II (4.4-3.7 M.a.)				Magmatic phase III (2.8 M.a. to late subrecent)			
	Fataga Fm	Tejeda Fm		Roque Nublo Group				Llanos de la Pz Fm	Los Pechos Fm	un-named	La Calderilla Fm
35*	1727**	43*	2119*	2107*	1752**	1691*	1726*	1687*	1770*	2106*	2111*
167	1208	606	1375	1418	1260	1147	1155	1118	1153	P17	1433
68.5	62.8	58.9	59.2	43.8	47.00	50.5	57.6	39.2	38.83	41.5	42.2
19.6	17.3	17.1	17.5	11.9	16.31	16.7	21.1	10.2	9.19	10.2	12.4
7.5	2.6	2.8	2.8	5.5	5.26	3.8	1.6	4.2	2.71	5.5	4.5
0.1	0.7	2.1	2.0	8.1	6.28	3.5	0.75	8.0	9.14	7.4	8.5
0.1	0.4	0.4	1.4	9.4	4.76	3.1	0.1	13.5	16.04	13.6	11.3
0.5	0.8	0.9	2.4	11.1	9.32	6.6	1.2	13.8	14.10	11.4	11.2
5.2	6.3	9.6	7.1	2.9	3.44	5.8	9.6	3.1	2.60	3.6	3.0
4.5	5.8	5.1	4.2	1.2	2.02	4.2	6.1	1.3	0.75	0.7	1.5
1.7	2.3	1.2	0.9	0.8	1.57	1.7	1.7	1.3	1.94	1.0	0.75
1.0	0.79	1.1	1.3	3.9	3.64	2.7	0.0	3.4	3.01	3.7	4.0
0.1	0.07	0.09	0.38	0.91	1.06	0.75	0.05	1.1	1.14	0.91	0.75
0.45	0.17	0.4	0.21	0.2	0.18	0.16	0.16	0.18	0.20	0.18	0.19
—	—	—	1.0	—	—	—	—	—	—	0.5	—
—	—	—	—	—	—	0.13	—	—	—	—	—
—	—	—	—	—	—	0.15	—	—	—	—	—
—	—	—	—	—	—	0.03	—	—	—	—	—
99.3	100.03	99.69	99.89	99.71	100.84	99.8	99.86	99.28	99.65	99.69	99.74
25.6	2.3	—	—	—	—	—	—	—	—	—	—
—	—	—	0.1	—	—	—	—	—	—	—	—
27.3	35.1	30.6	25.1	7.2	12.1	25.3	36.7	—	—	4.2	8.9
24.9	54.6	40.0	59.5	17.6	25.0	25.4	27.7	—	—	2.8	2.4
—	1.8	—	3.1	16.1	23.3	8.3	—	10.3	11.5	9.8	16.1
—	—	—	—	—	—	—	—	6.1	3.6	—	—
—	—	11.3	0.7	6.6	2.4	14.9	26.1	14.5	12.2	15.3	12.5
17.8	—	8.2	—	—	—	—	4.7	—	—	—	—
—	—	3.0	—	—	—	—	0.3	—	—	—	—
0.2	0.7	1.6	—	14.1	6.8	—	1.8	14.5	13.0	17.4	14.6
0.2	0.6	0.5	—	8.3	3.5	—	0.3	9.8	9.0	11.6	9.3
—	—	1.3	—	5.1	3.2	—	1.7	3.7	2.9	4.5	4.3
0.1	0.4	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	1.6	2.5	18.1	12.0	3.2	—	24.3	30.4	22.9	20.2
—	—	—	—	—	—	—	—	4.4	6.6	—	—
—	0.5	—	3.4	2.2	2.2	2.2	—	2.2	2.2	2.2	2.2
1.2	1.5	2.1	2.5	7.5	7.0	5.2	—	6.6	5.9	7.2	7.7
1.6	2.3	—	—	—	—	—	—	—	—	—	—
1.0	—	—	—	—	—	—	—	—	—	—	—
0.2	0.2	0.2	0.9	2.2	2.5	1.8	0.1	2.7	2.8	2.2	1.8
—	—	—	2.3	—	—	—	—	1.2	—	—	—
77.8	91.9	81.5	85.2	26.5	39.5	63.0	90.5	20.6	15.8	22.3	23.9
1.16	1.09	1.88	1.69	2.42	1.70	1.38	1.57	2.38	3.47	5.14	2.0
0.97	1.03	0.60	0.66	0.46	0.66	0.81	0.71	0.47	0.62	0.22	0.56
45.0	82.8	56.7	—	1.32	1.91	5.6	122.0	1.18	0.66	0.77	2.0
—	—	—	—	61.13	39.24	—	—	71.44	75.14	70.62	66.28
1.4	0.96	1.25	0.93	—	—	0.84	1.06	—	—	—	—
n.d.	n.d.	147	n.d.	29	n.d.	n.d.	211	18	11	n.d.	37
n.d.	n.d.	4	n.d.	870	n.d.	n.d.	83	1326	1459	n.d.	995

Zr	187	301	196	245	485	300	246	n.d.	n.d.	n.d.
Nb	18	36	24	29	50	31	23	n.d.	n.d.	n.d.

* Analyst: M. Weibel, B. Arancyi, R. Heusser
** Analyst: under the direction of K. Langer
*** Analyst: G. Smith, J. Ward, R.S. Starmer
DI = Differentiation Index (Q + or + ab + lc + ne)

$$\text{Mg} - \text{number} = \frac{\text{Mg}}{\text{Mg} + \text{Fe}^{2+}} \quad (\text{Fe}_2\text{O}_3/\text{FeO} = 0.25)$$

$$\text{AI} = \text{Agpaicity Index} \quad \frac{\text{mol } (\text{K}_2\text{O} + \text{Na}_2\text{O})}{\text{mol Al}_2\text{O}_3}$$

(+) = CIPW-norms for rocks with DI<45 calculated on base of Fe_2O_3 = 1.5%

Sample localities, petrographic descriptions and modal compositions (Volume percent, 1000 points counted in each section with Eltinor point counter).

Guigui Formation

1262: Picritic alkali olivine basalt. Lava flow, type locality at mouth of Barranco de Guigui, 5m above sea level.
Phenocrysts: Olivine (26.9%), clinopyroxene (19.4).
Groundmass: 53.7% (plagioclase, clinopyroxene, Fe/Ti-oxides, olivine, amphibole?)

1263: Alkali olivine basalt. As in 1262, 15 m above sea level.
Phenocrysts: Clinopyroxene (3.8%), plagioclase (3.3%), olivine (1.4%).
Groundmass: 91.5%. Composition as in 1262, but no amphibole (?).

1264: Picritic alkali olivine basalt. As in 1262. 20 m above sea level.
Phenocrysts: Olivine (26.8%), clinopyroxene (8.5%).
Groundmass: 64.7%, as in 1263.

1265: Picritic alkali olivine basalt. As in 1262. 26 m above sea level.
Phenocrysts: Olivine (19.5%), clinopyroxene (6.0%).
Groundmass: 74.5%. As in 1263.

Hogarzales Formation

1268: Hawaiite: As in 1262, directly above palagonite tuff and fanglomerate along unconformity. 100 m above sea level.
Phenocrysts: Olivine (< 1%), clinopyroxene (< 1%), plagioclase (< 1%).
Groundmass: as in 1263.

1270: Hawaiite: Barranco de Guigui Grande, NW-side, 1.1 km inland, 225 m above sea level.
Phenocrysts: 1 to 2% each of clinopyroxene, olivine, plagioclase, and Fe/Ti-oxides
Groundmass: Same as phenocrysts.

1271: Hawaiite: as in 1270, 250 m above sea level.
Phenocrysts: Plagioclase (tr), clinopyroxene (tr).
Groundmass: Plagioclase, clinopyroxene, olivine (iddingsitized), Fe/Ti-oxides.

Mogan Formation

132: Alkali rhyolitic ignimbrite P1: Lower part of composite flow (P1) at head of Barranco de Mogan, 650 m above sea level, 50 m south of road Mogan-Ayacata.
Phenocrysts: anorthoclase (with oligoclase cores) (47.2%), edenitic hornblende (1.2%), Fe/Ti-oxide (0.8%), zircon (tr).
Rock fragments: Mostly basaltic (2%).
Groundmass: 46.6%.

700: Comenditic lava flow V: 15 m above base of 20 m thick flow. North slope Montaña Cedro, 435 m above sea level. 15 m above base of 20 m thick flow.
Phenocrysts: anorthoclase (ca. 12%), augite and hypersthene (< 1%), Fe/Ti-oxides (< 1%).
Groundmass: anorthoclase, quartz, alkali amphibole, aegirine (tr.).

715: Pantelleritic ignimbrite X: 15 m above base of 25 m thick flow. Locality as in 700, 535 m above sea level.
Phenocrysts: anorthoclase (ca. 35%), richterite (ca. 2%), Fe/Ti-oxides (< 1%), sphene (< 1%) plagioclase (tr), perrierite (tr)
Rock fragments
Groundmass: anorthoclase, quartz, aegirine, alkali amphibole, alunite (?).

n.d.	n.d.	1390	n.d.	287	n.d.	n.d.	1215	268	271	n.d.	285
n.d.	n.d.	359	n.d.	55	n.d.	n.d.	64	79	92	n.d.	57

697: Alkali olivine basalt: 20 cm inside 3 m thick dike.
Locality and elevation as for 700. Feeding dike for basalt T4 (below ignimbrite A).
Phenocrysts: aphyric.
Groundmass: plagioclase, clinopyroxene, Fe/Ti-oxides, olivine.

167: Pantelleritic ignimbrite D: 2 m above base, road cut on west side of Barranco de Taurito (type locality). Ca. 80 m above sea level.
Phenocrysts: < 1% anorthoclase, richterite (tr).
Groundmass: 99.2% (anorthoclase, quartz, aegirine).

Fataga Formation

1208: Trachyphonolite: 3 m above base of lava flow, 200 m S of Casa Forestal de Tirajana, 1300 m above sea level.
Phenocrysts: alkali feldspar (< 1%), clinopyroxene (tr).
Microphenocrysts: altered nepheline (ca. 5%).
Groundmass: alkali feldspar, aegirine, alkali amphibole, analcime.

Tejeda Formation

606: Phonolite dike: Top of Montaña Horno, glassy margin of offshoot of large phonolite intrusion underlying the northern part of Montaña Horno, 1360 m above sea level.
Phenocrysts: < 1% anorthoclase, clinopyroxene (tr).
Groundmass: slightly devitrified glass.

1375: Syenite: 100 m south dam of Presa de Paralillo, Barranco de Tejeda. Ca. 300 m above sea level.
Mineralogy: partly sericitized, antiperthitic alkali feldspars with minor biotite, sulfides, apatite, altered nepheline (?), carbonate, fluorite, leucoxene (after sphene), layer silicates.

Roque Nublo Group

1418: Alkali olivine basalt: Thin flow in olivine phyric pahoehoe basalt series near base of Mesa de Junquillo Formation, Road Sta. Lucia-Temisas, 1 km southeast of Sta. Lucia, ca 720 m above sea level.
Phenocrysts: olivine (10.8%), clinopyroxene (7.6%).
Groundmass: 81.6% (plagioclase, clinopyroxene, Fe/Ti-oxides).

1260: Tephrite: 20 cm above base of 3 m thick lava flow directly underlying 100 m thick Roque Nublo Breccia sheet forming top of Mesa de Junquillo, 630 m above sea level.
Phenocrysts: clinopyroxene (4.4%), Fe/Ti-oxides (3.3%), plagioclase (2.5%), olivine (0.2%).
Groundmass: 89.6% (plagioclase, clinopyroxene, Fe/Ti-oxides).

1147: Tephrite: 50 cm above base of 4 m thick lava flow above Risco Blanco Intrusion (1155), 1560 m above sea level.
Phenocrysts: clinopyroxene (9.3%), plagioclase (3.3%), amphibole (kaersutite?) (2.9%), hauyne (2.5%), Fe/Ti-oxides (1.8%), sphene (0.4%), apatite (0.2%).
Groundmass: 79.6%; mineralogy similar to phenocrysts but also alkali feldspar.

1155: Hauyne phonolite: see Lietz & Schmincke (1975).

Llanos de la Paz Formation

1118: Olivine nephelinite: see Lietz & Schmincke (1975).

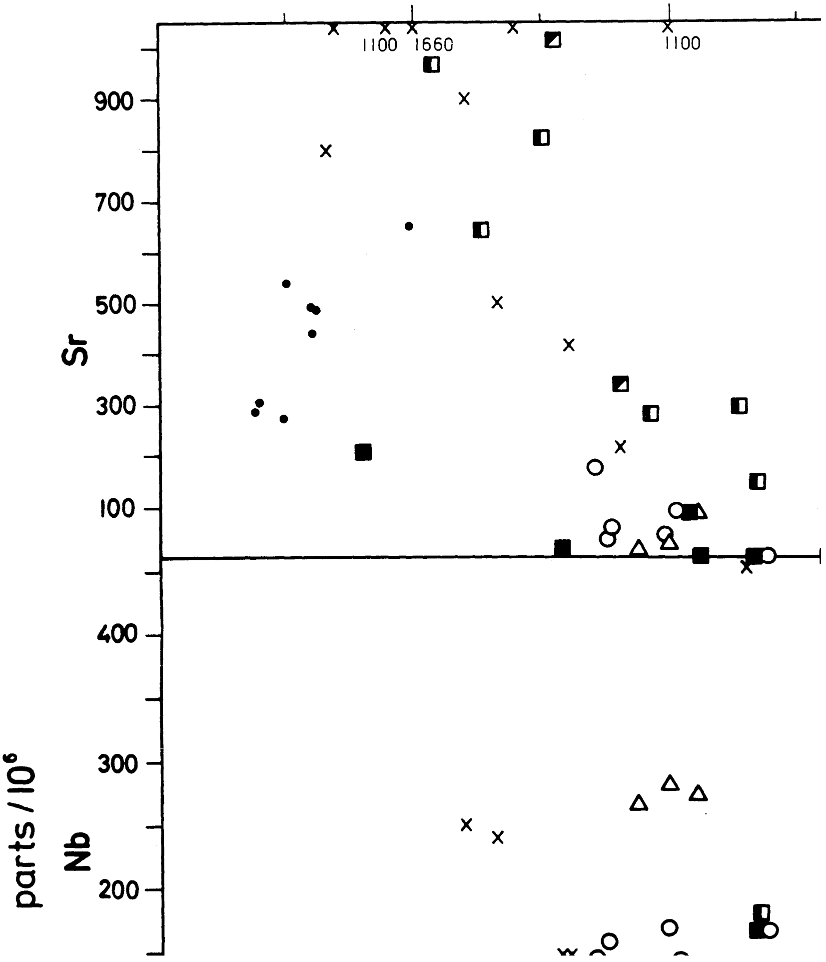
Los Pechos Formation

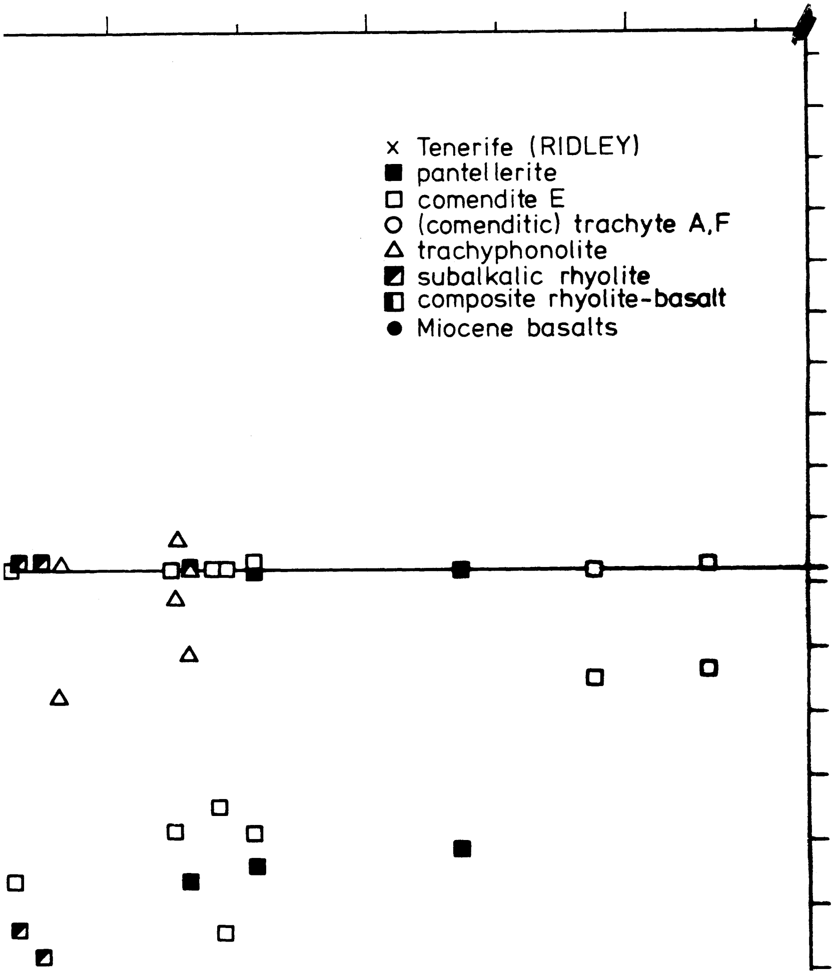
1153: Hauyne-melilite olivine nephelinite: near base of 20 m thick ponded flow remnant making up scarp above Risco Blanco Intrusion, 1857 m above sea level.
Phenocrysts: olivine (ca. 12%), opaques (ca. 2%).
Microphenocrysts: melilite, hauyne.
Groundmass: clinopyroxene, nepheline, opaques, perovskite, olivine.

Pleistocene basanites

P 17: Basanite: see Lietz & Schmincke (1975).

1433: Basanite: Base of 2 m thick lava flow, 100 m east of spatter cone of prehistoric vent, 200 m east of rim of Marteles Caldera, 1588 m above sea level.
Phenocrysts: olivine (12.3%), clinopyroxene (1.4%).
Groundmass: 86.3% (clinopyroxene, plagioclase, olivine, opaques).


1100
1660
1100
900
700
500
Sr
300
100
400
300
parts / 10⁶
Nb
200


× Tenerife (RIDLEY)
■ pantellerite
□ comendite E
○ (comenditic) trachyte A,F
△ trachyphonolite
◪ subalkalic rhyolite
◧ composite rhyolite-basalt
● Miocene basalts

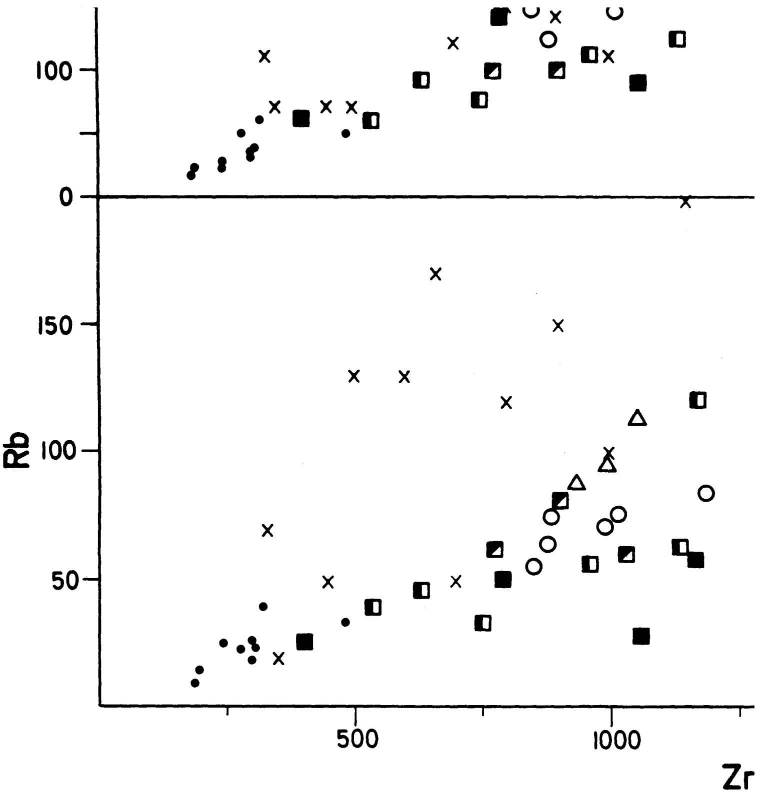
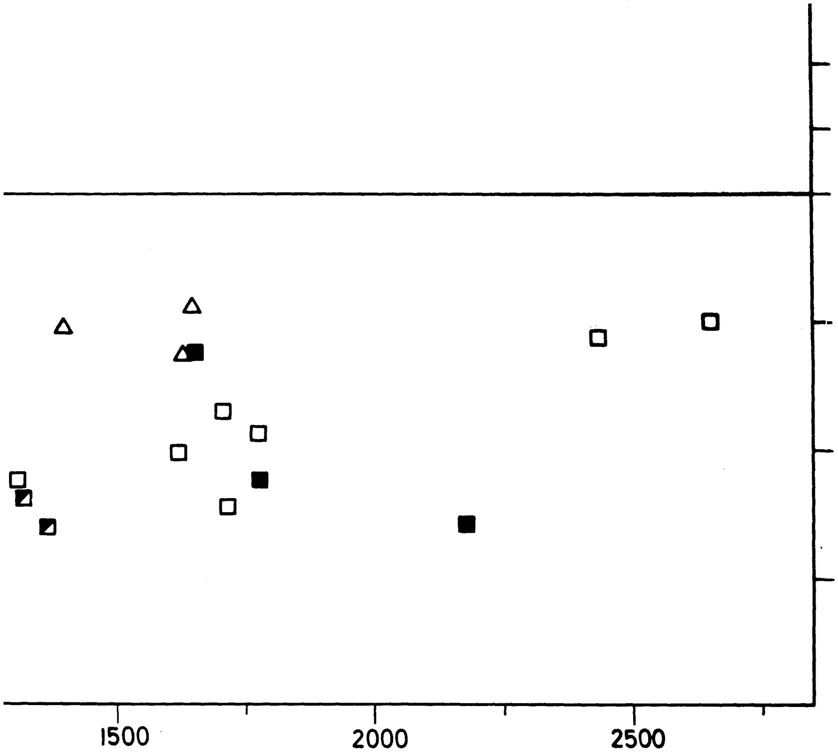


Fig. 27. Selected trace element compositions of rocks of the Mogan Formation oversaturated) and Fataga Formation (silica undersaturated). Some mafic (Miocene) from Gran Canaria and some data from the Cañadas series from T (Ridley 1970) are shown for comparison. Data for Gran Canaria from Sch (unpublished) and from Table 2.



(silica-
rocks
enerife
mincke

element abundances of the several oversaturated compositional groups of derivative rocks on Gran Canaria converge toward their presumed basaltic parent compositions, the Nb (possibly also Rb) abundances of the trachyphonolites are nicely linear but do not extend toward the Miocene basaltic compositions but rather toward more alkalic (hypothetical) basalts. These geochemical data, albeit still sparse, would not favor a genetic relationship between the oversaturated Miocene volcanics and the overlying trachyphonolites although the absence of a time break between both series, absence of associated alkali basalts, and other factors have been interpreted as indicating such a relationship (Schmincke 1969).

Hertogen *et al.* (in prep.; written comm. 1975) have analyzed a large number of rocks from Fuerteventura for rare earth elements and many trace and minor elements. Their data show no significant differences in absolute trace element abundances for the same rock types from different volcanic series, indicating that the magmas were derived from the same type of parental material throughout the evolution of the island. Chemical differences between basanitoids, ankaramites, alkali olivine basalts and olivine basalts are explained by different degrees of partial melting.

Sr- AND Pb-ISOTOPES

There are only 9 published determinations of $^{87}Sr/^{86}Sr$-ratios available from samples from La Palma, Hierro, Gomera, Tenerife, and Lanzarote (Bence 1966; O'Nions & Pankhurst 1974). All values range between 0.7031 and 0.7039 and are similar to Sr-isotope compositions from many other oceanic islands volcanic rocks. Preliminary data from a much more detailed study of rocks from the three magmatic phases of Gran Canaria described suggest a decrease from the mildly alkalic basalts of phase I to the nephelinites from phase III. Late stage nephelinites from other oceanic islands such as Oahu and the Cape Verde Islands also have relatively low $^{87}Sr/^{86}Sr$-ratios. (O'Nions & Schmincke, in prep.).

Lead isotope compositions from many samples of rocks from Tenerife and some from La Palma, Fuerteventura, and Lanzarote are presented by Oversby *et al.* (1971). The isotopic compositions indicate a multistage history for the upper mantle under the Canaries. Moreover, isotopic compositions are different for rocks from the eastern Canaries (Lanzarote and Fuerteventura) compared with those from the western islands Tenerife and La Palma suggesting that the mantle composition might differ between both areas, possibly related to crustal differences discussed above.

MAGMATIC EVOLUTION

All volcanic rocks of the Canary Islands are formed from magmas that occur on other oceanic volcanic islands as well. This includes the abundant rhyolitic rocks of Gran Canaria sometimes regarded as indicating presence of continental crust. Even for the eastern Canary Islands there is no convincing evidence that the magmas were contaminated by continental crust. According to current thinking (see review in Carmichael *et al.* (1974) chemical differences between the various mafic basaltic magmas are best explained by different degrees of partial melting, the most alkalic magmas representing the smallest degrees of partial fusion of mantle peridotite. On the other hand, mantle heterogeneities, non-equilibrium melting and other factors are increasingly recognized as additional variables. At the present level of investigation, chemical differences between islands can only be defined (e.g. differences in major element composition between eastern and central Canaries: Ibarrola 1970; Schmincke 1973; or differences in Pb-isotope compositions: Oversby *et al.* 1971), but no satisfying theory can be offered to explain these differences.

Primary magmas originating in the mantle and not being appreciably modified prior to eruption are difficult to define and the conditions of their formation at the site of melting are poorly understood. Perhaps most basaltic lavas on the Canary Islands are probably not primary in the sense defined above, that is which would be in equilibrium with mantle peridotite (perhaps excepting the olivine and melilite nephelinites). Rather, ascending magmas probably accumulated a few km below an island's surface, were stored there in magma chambers at various residence times and cooled to variable degrees. Crystals, chiefly olivine and titaniferous augite – Cr-spinel being extremely rare in Canarian olivines – growing in the mafic magmas were left behind in varying amounts during subsequent eruption of the now modified magma. At lower temperatures, Fe/Ti-oxides and plagioclase and, in the more alkalic and hydrous magmas, kaersutite, apatite, a more sodic pyroxene and sphene were also fractionated.

This process of low pressure crystal fractionation – recognized first from some Atlantic islands more than 100 years ago by Darwin – has been invoked by many workers to explain chemical variation in rock series such as the various Las Cañadas magmas on Tenerife (Ridley 1970; Araña 1971; Brändle 1973) and the trachytic/rhyolitic series on Gran Canaria (Schmincke 1969a, b) (Fig. 28).

Other processes such as vapor phase transfer of certain elements, in particular alkalis, has also been proposed but is generally difficult to pinpoint because elements amenable to such transport are commonly also lost easily during eruption in the gas phase, during crystallization or during diagenesis of glassy volcanic rocks. Very high concentration of alkalis, however, in some strongly differentiated series such as the Roque Nublo volcanics (Fig. 29), are difficult to explain by crystal fractionation alone and maybe due to preferential migration of alkalis, perhaps in a fluid phase.

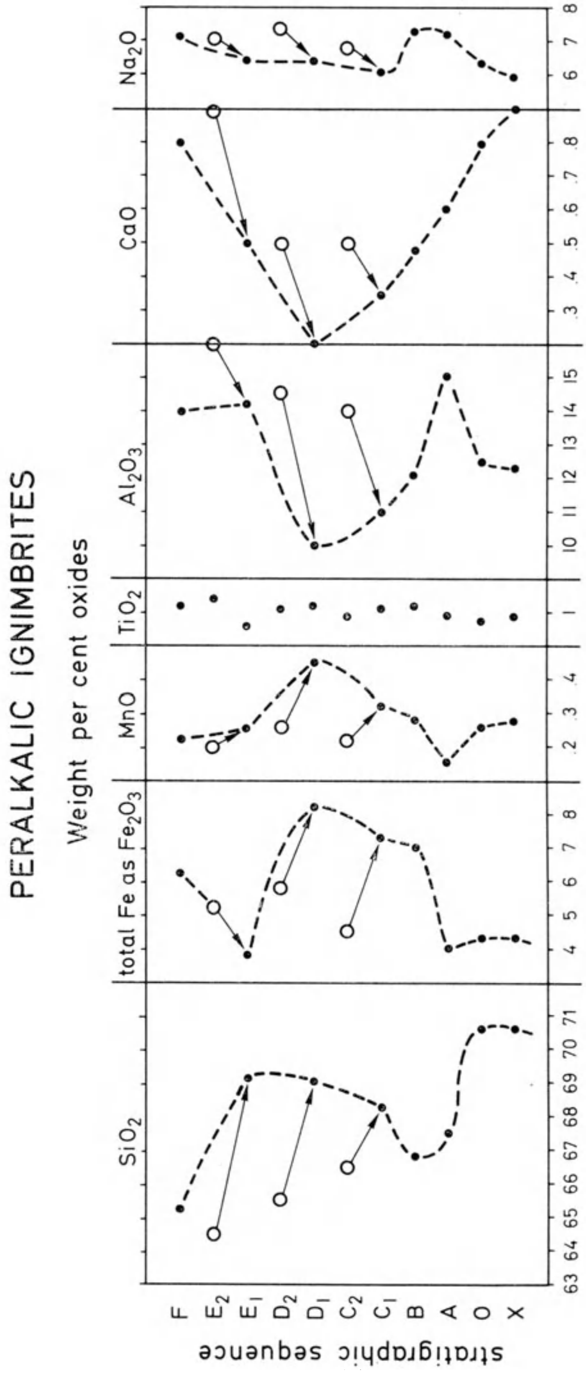


Fig. 28. Chemical composition versus stratigraphy of the peralkalic ignimbrites of the upper Mogan Formation (Miocene) from Gran Canaria (compare Figs. 44 and 45). Each letter represents a cooling unit, for which generally several chemical analyses were averaged. The cooling units C, D, and E show particularly striking change in chemical composition from the basal, main part (subnumber 1; dot) to the top flow units (subnumber 2; circles) which are generally more mafic and less peralkalic. This is thought to represent the upside down stratigraphy of chemically and mineralogically zoned magma chambers in the upper parts of which the most differentiated and most peralkalic magmas developed.

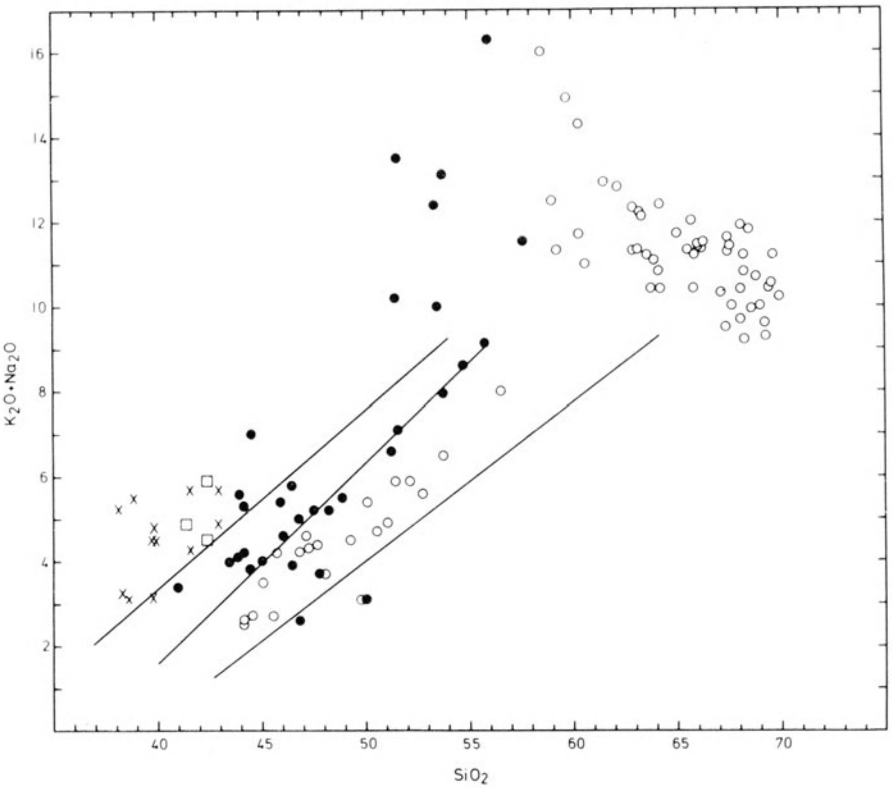


Fig. 29. Alkali/silica variation diagram showing analyses of rocks from the three main magmatic phases on Gran Canaria. Circles denote Miocene rocks (phase I); dots represent rocks from the Pliocene Roque Nublo Group (magmatic phase II); squares and crosses are late Pliocene and Quaternary rocks (phase III). The lines separate tholeiites from alkali basalts (lower line) in Hawaii (MacDonald & Katsura 1964); the middle line separates alkali basalts and basanites on Moheli Island (Indian Ocean, Strong 1972); the upper line separates basanites and nephelinites in eastern Africa (Saggerson & Williams 1968). Most analyses are unpublished; some are from Fuster et al. 1968c.

A particularly interesting type of magmatic evolution is the occurrence of several distinct magmatic phases (Figs. 29–31).

The chemically defined rock suites described above show a systematic succession on several islands, the more alkalic magmas generally being erupted during the later stages in the evolution of an island (Hausen 1962; Ibarrola 1969, 1970; Schmincke 1967a, 1973, 1974; Hernandez-Pacheco & Ibarrola 1973; Schmincke & Flower 1974). Such a succession is most strikingly developed on the island of Gran Canaria (Fig. 29, 30; table 2).

During the almost 15 Ma long history of the island, three major magmatic episodes occurred. The first episode includes a shield-building

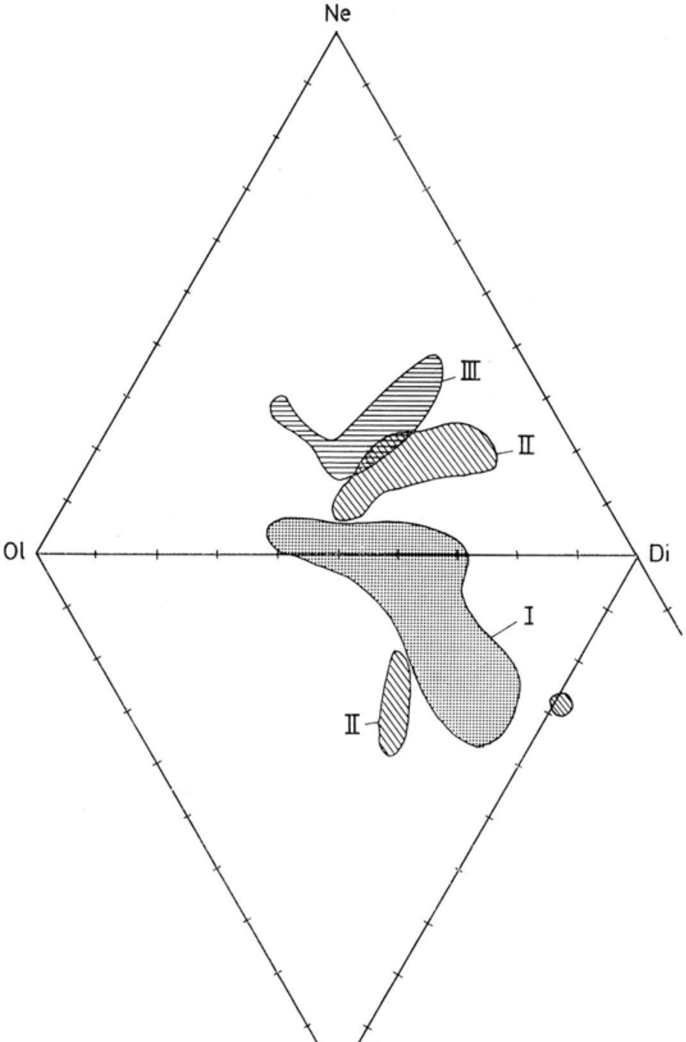


Fig. 30. Normative compositions of basaltic rocks (DI < 35) of magmatic phases I to III from Gran Canaria. Fe_2O_3 recalculated to 1.5 weight per cent prior to calculation of the CIPW norm.

series of slightly alkalic (compared to later series) basalts comprising both ne- and hy-normative compositions. It is overlain by voluminous peralkaline rhyolites, trachytes, and trachyphonolites. This first phase is separated from the second one by an erosional interval of 5 Ma. The second phase is composed of more alkalic and undersaturated basalts, basanites, ankaramites, tephrites and hauyne phonolites. An erosional interval of about 1 Ma separates this from the third magmatic phase, comprising dominantly nephelinites, still later melilite nephelinites, and basanites.

These 3 rock series can be well distinguished from each other in an alkali-silica diagram, from which the following information can be gained (Fig. 29): 1. Each rock series occupies a distinct field in the diagram with little overlap. 2. In each group, the derivative rocks are clearly related to the basaltic ones suggesting genetic relationships. 3. Magmatic series I and II have abundant differentiates while those of phase III have almost none. 4. With decreasing age the rocks become more alkalic and less silicic.

Taking the basaltic rocks only (DI < 35), a clear distinction can also be made in Fig. 30. Basalts of phase II comprise a few hy-normative flows near the base of the formation. There is a suggestion that there may be actually 2 cycles in the island's magmatic evolution: cycle I (phase I: Miocene basalts plus silica-oversaturated rocks; phase II: trachyphonolites (no parental basalts erupted); phase III: nephelinites of El Tablero Formation); cycle II (phase I: 'tholeiites' near the base of Roque Nublo group basalts; phase II: bulk of Roque Nublo volcanics; phase III: identical to phase III in the 1 cycle model). However, many more data are needed to define cycles and phases more precisely.

The type of cycle described above does appear to occur, though less clearly developed, on other Canarian and Atlantic islands as well (Schmincke 1973; Schmincke & Flower 1974). It most strongly resembles the Hawaiian magmatic evolution (table 3; Fig. 31).

Table 3. Magmatic phases on Hawaii and Gran Canaria

Common parameters	Differing parameters
Three magmatic phases separated by erosional intervals	Durations of magmatic phases and erosional intervals
Decreasing volumes and eruptive rates of successively younger phases	Absolute volumes
Increasing alkalinity, silica undersaturation, incompatible elements, light REE during younger phases	Eruptive rates
Decreasing Sr-isotope ratios	Composition of phase I and II, to a lesser degree phase III magmas
Gabbroic xenoliths in phase I and II, 'mantle' xenoliths in phase III volcanics	Volume and composition of derivative magmas

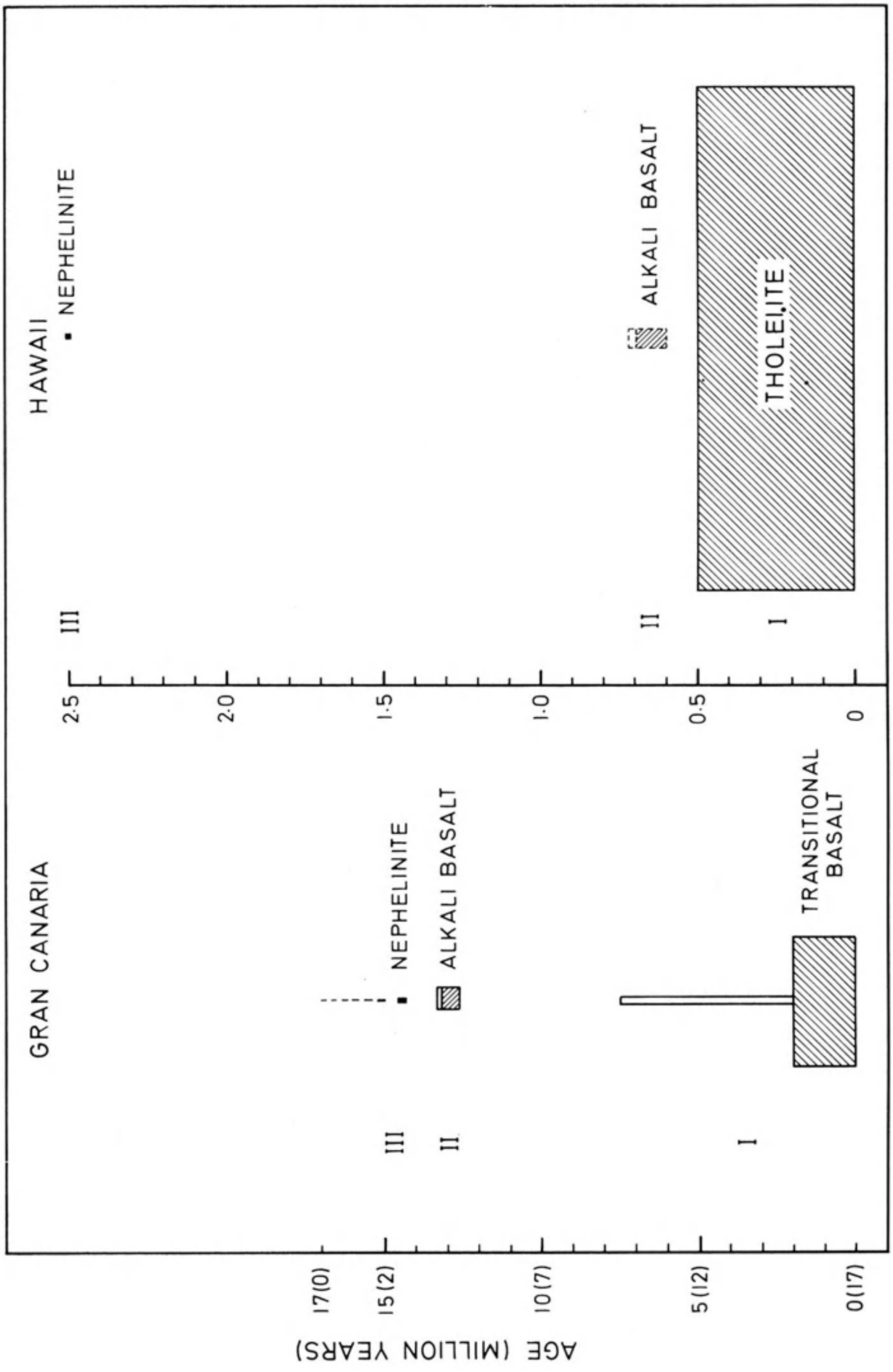


Fig. 31. Comparison of three-phase magmatic evolution between Gran Canaria and Hawaii. The rectangles indicate volumes of igneous rocks. For scale, the shield-building lavas of Hawaii (phase I) are assumed to have a volume of 20 000 km^3. Striped patterns indicate mafic rocks, white rectangles differentiated derivatives. Note difference in scale between both provinces. Data for Hawaii are taken from various sources and are highly simplified.

The properties listed on the left side of Table 3 are those that describe the main boundary conditions of the magma generating processes to some degree while the properties on the right side are second order features depending on rate of ascent, establishment of a magma chamber, eruptive rates etc.

The melting episode in the mantle beneath an island during which the shield building lavas are produced may be called primary melting episode, and those of the second and third stage secondary melting episodes if we accept that the occurrence of the second and third stage is in many cases a consequence of the first one. Thus the initial or primary melting event during which large volumes of mantle were affected started and caused a chain of events consisting of periods of alternating non-productive (erosional) time intervals (repose) and productive phases generating smaller volumes of more alkalic and silica-undersaturated magma at roughly the same place but perhaps from different mantle material and perhaps coming from successively greater depth. The magmas used the same general reactivated conduit system. It is probable that the sites of the instabilities generating at least the secondary melting episodes reside near the base of the lithosphere. The initiation of the first melting event is a matter of conjecture. Perhaps the most common and simplest explanation is that of a propagating fracture with consequent pressure release leading to partial melting and rise of magma or to upwelling of mantle diapirs. The origin of such fractures has been explained recently by Oxburgh & Turcotte (1973) as due to membrane or thermal stresses as the lithospheric plate cooled. Other theories include the shear melting of Shaw (1973) and the rising mantle plumes of Morgan (1972). No matter how melting was initiated it proceeds very rapidly in the beginning maybe by thermal feed back and runaway reactions.

Shaw & Jackson (1973) have recently proposed a model in which mantle residue left after melting is heavier than the surrounding material and acts as a gravitational anchor which tends to fix a melting anomaly with respect to the mantle.

This downwelling of dense mantle residua not only stabilizes the anomaly but also causes inflow of fresh parental material into the area of melting.

This ingeneous model is concerned, however, with what is here called primary melting episode and is constructed to explain the shield building phases of linear volcano chains. *It does not attempt to explain the one or more juvenescent stages. Perhaps the origin of the succession of magmatic phases is in some as yet obscure way related to the interplay of vertical downward movement of a heavy residue left after the primary melting episode and horizontal movement of the lithosphere with respect to the asthenosphere.*

Apart from the Mesozoic marine assemblage on Fuerteventura and the heterogeneous pyroclastics and epiclastic conglomerates and fanglomerates which occur in all islands, there are abundant calcarenites, in part cemented, being particularly common on Fuerteventura, Lanzarote and, to a lesser degree, Gran Canaria. They are made up of fragments of calcareous shells of marine organisms washed ashore by wind and currents (in part forming large dunes); all white beaches on the Canaries are dominantly calcarenites, which may become cemented by evaporating seawater and diagenetic alteration. They have been studied in detail by Müller and co-workers (Müller 1964; Müller & Tietz 1966; Rothe 1968b; Tietz 1969; Müller 1969). 'Beach rocks' are also common (Fig. 32).

Large clastic wedges (fossil alluvial fans) have developed at the mouth of major barrancos and may continue far into the ocean judging from submarine contour lines (e.g. on Gran Canaria, Schmincke 1968). The most detailed study is that on the Las Palmas fan on Gran Canaria which consists of conglomerates, fanglomerates, mud flow deposits and sand and siltstones, interbedded with hyaloclastites, calcarenites and volcanic rocks (pumice flow deposits, Roque Nublo breccia sheets, and basaltic

Fig. 32. 'Beachrock' (beach sand cemented by carbonate minerals formed during evaporation at low tide) at mouth of Barranco de los Frailes (Gran Canaria).

lava flows, in part pillowed) (Lietz 1973, Lietz & Schmincke 1975, Navarro *et al.* 1969).

Several stages of lowered sea level were dated on Gran Canaria (Lietz & Schmincke 1975) and they coincide with regressions from other parts of the world during Late Miocene-Pliocene.

Fossil flora and fauna

The general paucity of fossils on the Canary Islands is not surprising since basaltic volcanoes grow very rapidly with little time for the accumulation of sediments. Moreover, stream erosion is not rapid during build-up of such volcanoes because of the high permeability of basalt flows. During longer erosional intervals most of the epiclastics formed are washed off an island. Those few fossils that are found, however, are generally important, not so much because of their stratigraphic value, but more because of their ecologic significance, e.g. as indicators of landbridges, migratory paths and interinsular transportation vehicles, sea level fluctuations and paleoclimate.

The oldest known fossils are Cretaceous foraminifera on Fuerteventura (Rothe 1968). Next in age are ostrich eggs of Miocene/Pliocene age found in calcarenites interbedded with basalts on Lanzarote (Rothe, 1964, 1966; Sauer & Rothe 1972). Since all evidence indicates that ostriches were never able to fly, these birds must have walked (or run) from Africa to the Canaries via some type of landbridge. Long known are the 'Mid-Miocene' marine fossiliferous calcarenites of the 'Las Palmas Terrace' on Gran Canaria (Rothpletz & Simonelli 1890). These rocks are discussed in more detail below.

During Roque Nublo time (Early Pliocene) Gran Canaria was forested as shown by abundant leaf impressions, trees (now dolomitized) (Fig. 33) and many tree molds, including bamboo, palm, and laurel-type trees (Schmincke 1967b, 1968b). Such trees, torn away by storms or heavy rains, could have provided ideal rafts for inter-island transportation of smaller animals and of plants. Tree molds and skeletons of turtles and giant lizards were described from pumice flow deposits of late Pliocene (?) age from Tenerife (Burchard & Ahl 1928; Hausen 1956).

Marine (?) fossils of Miocene (?) age were described long ago from the base of a fossiliferous fanglomerate at the mouth of Barranco de las Angustias on La Palma (Gagel 1908; Hausen 1969). Because of their importance these deposits and their fossils need to be restudied. A fossil forest, about 3000 years B.P. old, made of *Pinus Canariensis* has been found during excavation of a cinder cone on Gran Canaria (Nogales & Schmincke 1969) (Fig. 34).

Fig. 33. Completely dolomitized tree trunk at base of Roque Nublo Breccia. Head of Barranco de Agaete (Gran Canaria). Age of tree about 4 million years.

Fig. 34. Trunk of *Pinus Canariensis*, 3075 ± 50 years (B.P.) old, formerly covered with basaltic cinder. Caldera de los Arenas (Gran Canaria).

GEOLOGY OF THE INDIVIDUAL ISLANDS

In the remainder of this report, the geology of individual islands is discussed, proceeding from east to west.

The most detailed stratigraphic framework of the different rock series on the islands is given by Fuster and co-workers. Its basic structure is as follows, in order of decreasing age: basaltos I, basaltos II, basaltos III, and basaltos IV. The advantage of this system is that it allows quick identification of the relative age of a rock series.

There are two main drawbacks to this system. Firstly it is too rigid, and many exceptions have already been made by Fuster *et al.* For example, the second most voluminuous basaltic series on Gran Canaria is that following basaltos I. While one would have expected it to be called basaltos II, it was called 'Pre-Roque Nublo Basalts' by Fuster *et al.* (1968c) and basaltos II are a still younger series of lavas. A more serious disadvantage of the system is that it immediately suggests inter-island stratigraphic correlation. But, in fact, basaltos I etc. may be of quite diverse ages on different islands (Fig. 3).

In the present report, stratigraphic terms not implying inter-island correlation have thus been used for most islands. A more formal rock stratigraphic nomenclature (group, formation, member) is used for Gran Canaria, the best studied island. Type sections are illustrated by photographs and some chemical data are given. This formal system should eventually be used on other Canary and Atlantic islands as well.

Fuerteventura

This is the second largest (1731 km^2, 807 m maximum elevation above sea level) island but is very thinly populated. Major geologic studies are those by Hartung (1857), Bourcart & Jeremine (1938), Hausen (1958), and Fuster *et al.* (1968a). Perhaps the most challenging geologic aspects are those of the basal complex in the western part of the island (Fig. 35; table 4).

THE BASAL COMPLEX

The basal complex of Fuerteventura is significantly older than the subaerial volcanics which cover most of the island above sea-level. The largest exposure of this complex makes up the Betancuria Massif, and there are isolated smaller areas to the north and south. Recent work by Gass, Stillman, Fuster, Hernandez-Pacheco and coworkers led to a considerable revision of ideas on the basal complex. Part of this work has been published in abstract (Bennell-Baker *et al.* 1974) and the following section is based on this publication.

Table 4. Stratigraphy of Fuerteventura

Bourcart & Jérémine (1938)	Hausen (1958)	Fúster *et al.* (1968a)	Bennell-Baker *et al.* (1974)
Basaltes historiques	Recent volcanoes	*Basaltic Series IV* Cinder volcanoes	
Basaltes antéhistoriques	Subrecent and Late Quaternary volcanoes.	*Basaltic Series III* Cinder volcanoes *Basaltic Series II* Cinder volcanoes	
Basaltes des plaines	Shield volcanoes	Shield volcanoes	
Basaltes des plateaux	Basaltic tableland formation	*Basaltic Series I* Fissural basalts	
		Syenitic ring complexes	Late Plutons – syenitic and trachytic ring complexes, layered gabbros, ultramafic gabbroic diapirs.
Roches grenues	Ophiolites	Subaerial tuffs and agglomerates	
			Main Phase dike swarm
		Submarine volcanic rocks	Mesozoic and Tertiary marine sediments and submarine volcanics, and early pyroxenite and gabbro plutons, syenites and carbonatites
Trapps	Spilite complex	Detrital sediments	
		Basic stratiform complex	

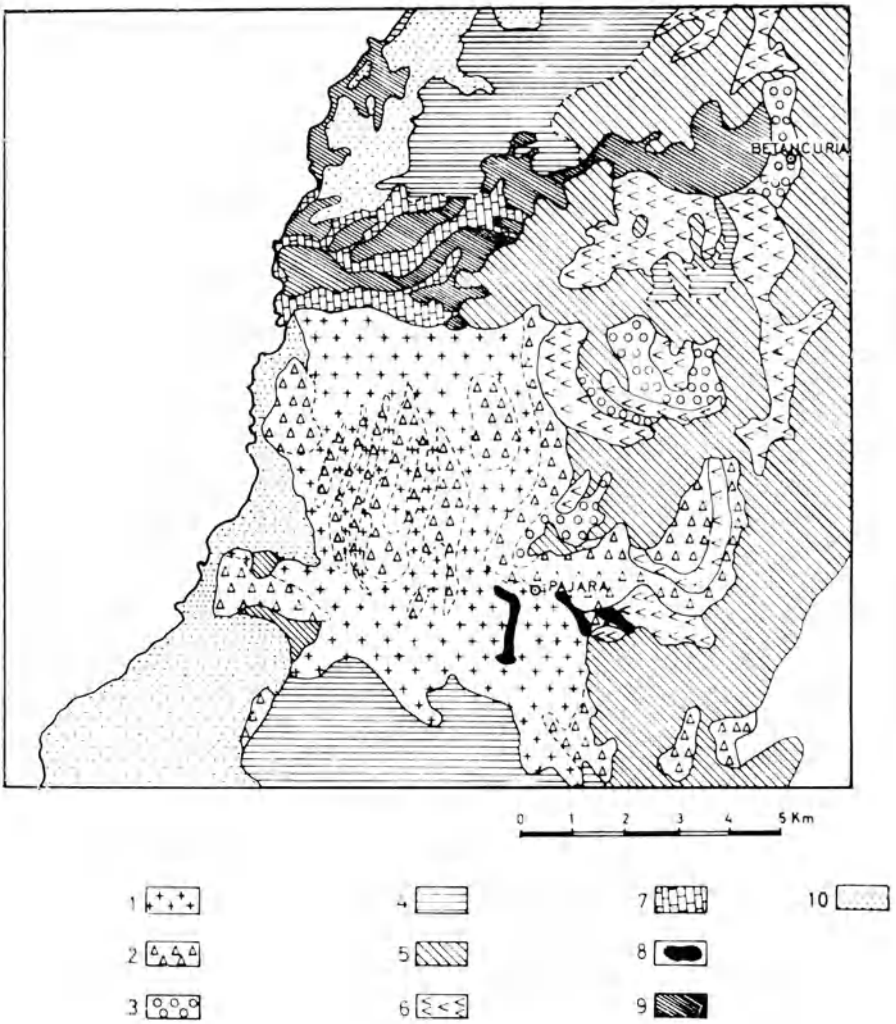


Fig. 35. Geologic map of the Betancuria-Pajara area (modified after Gastesi 1969, Fig. 3). 1: Peridotites; 2: Gabbros; 3: 'Alkalinized' rocks; 4: Submarine volcanics; 5: Subaerial volcanic rocks; 6: Alkaline intrusions; 7: Cretaceous marine sedimentary rocks; 8: Quaternary basalts; 9: Pliocene (?) basalts; 10: Calcarenites.

MESOZOIC AND TERTIARY SEDIMENTARY ROCKS AND SUBMARINE VOLCANIC ROCKS

Mesozoic and Tertiary sedimentary rocks and submarine volcanic rocks (Detrital sediments of Fuster *et al.* 1968a, p. 196; Submarine volcanic series and subaerial volcanic tuffs of Fuster *et al.* op cit. p. 199).

The oldest rocks seen at the present erosion level are submarine volcanics overlain by marine sedimentary rocks discovered by von Fritsch (1867) and re-discovered by Fuster & Aguilar (1965) and Rothe (1968a). In part of the sequence foraminifera of Cretaceous age have been found (Rothe 1968a). These Mesozoic sediments are laminated shales and siltstones, turbiditic sandstones, thin tuffs and limestones; metamorphism and metasomatism has converted the laminated shales to siliceous hornfelses resembling banded cherts and the limestones to unique marbles. The sediments have been involved in deformation which has imposed a regional cleavage usually almost parallel to the bedding and much of the observed sequence is inverted by large-scale folds. According to Rothe (1968a) these rocks are similar to rocks from the adjacent African continent and from the Island of Maio (Cape Verde Islands). Clastic components of quartz, quartzite, rounded zircons etc. indicate derivation of these sediments from the African continent (Rothe & Schmincke 1968). At the top of this sedimentary sequence interbedded hyaloclastites and pillow lavas appear, and the succession passes into a thick series of submarine volcanics. The bulk of these rocks are hyaloclastites and volcanic breccias; reworked volcaniclastic sediments are common. Pillow lavas make up a small percentage of the sequence and some bedded tuffs are recorded. The bedded volcanic rocks are traversed by a number of synchronous sheet intrusions of petrographic types identical to those of the pillow lavas.

Because of subsequent intrusion of a dike swarm it is difficult to trace the continuity of the stratigraphic sequence, but it seems that towards the top of this submarine volcanic pile tuffs become much more common, calcareous tuffs appear with thin limestones which become more frequent until thick fragmental limestones containing abundant shell debris are seen. Fossils of Miocene to Eocene age have been recorded from this horizon (Fuster, pers. comm.). The question as to whether there is a continuous succession from the Cretaceous to Tertiary rocks has not been resolved. Neither the regional cleavage nor the large scale folding and overturning of the Mesozoic sediments and early volcanics can be traced into the Tertiary tuffs and limestones, and it might well be supposed that a significant break occurs within the succession, but that this is concealed by the dike swarm which makes up from 50 to 100% of the observed outcrop.

According to Fuster *et al.* (1968a) the volcanic sequence continues upwards into sub-aerial tuffs and agglomerates.

EARLY PYROXENITE AND GABBRO PLUTONS, SYENITES AND CARBONATITES

Early pyroxenite and gabbro plutons, syenites and carbonatites. (Part of the 'Basic stratiform complex' of Fuster *et al.* 1968a, p. 189).

In the central part of the Betancuria massif a large plutonic mass of ultramafic and mafic rocks is seen. The relationship between these rocks and the Mesozoic sediments is not clear as the contact is obscured by the subsequent dike swarm. Intruding both the plutonics and the sediments are abundant veins and occasional small intrusive bodies of syenite and in several localities on the coast, small carbonatite dikes. The syenites are essentially marginal to the mafic and ultramafic plutonics and do not extend far into the sediments. In the absence of absolute age determinations it is not possible to say whether these plutonics intrude the sediments or are overlain by them, but the balance of evidence so far suggests that the mafic and ultramafic rocks may have been emplaced in the lower part of the sedimentary sequence at the same time as the Mesozoic to Tertiary submarine volcanics were being erupted.

MAIN PHASE DIKE SWARM

The sediments, submarine volcanics, early mafic and ultramafic plutonics, syenites and carbonatites are all traversed by a swarm of mainly basaltic and ankaramitic dikes with a general NNE-SSW trend. The swarm contains dikes of more than one age, but the majority belong to a major phase of permissive emplacement which involved no deformation of the host rocks but merely a distension of the crust. Throughout this phase of emplacement, later dikes inject earlier ones and individual dikes may be dismembered and spread over a considerable width. Both the dikes and their host rock show the imprint of a greenschist facies metamorphism typical of that seen in active spreading zones of the ocean floor (Melson and van Andel 1966). These rocks are the 'spilitic suite' of earlier authors and an age of 35.3 Ma has been obtained from an altered dike (Abdel Monem *et al.* 1971).

This dike complex is injected repeatedly by later dikes of very similar composition but commonly in a lower state of metamorphism; some contain zeolites but many have only primary igneous minerals. The bulk of these later dikes follow the same trend as the earlier ones and it is apparent that the initial trend of sheet intrusions was dictated by regional stresses but subsequent emplacement was controlled by the grain of the crust imposed by the dike swarm. The intensity of dike injection is variable and the proportion of dikes to host rock ranges from 50 to 100%.

LATE PLUTONS – ULTRAMAFIC AND MAFIC DIAPIRS, LAYERED GABBROS AND SYENITIC AND TRACHYTIC RING INTRUSIONS

Late plutons – ultramafic and mafic diapirs, layered gabbros and syenitic and trachytic ring intrusions. (Ring complexes and dikes of syenitic-trachytic composition of Fuster *et al.* 1968a, p. 20, and part of the Basic stratiform complex of Fuster *et al.* op. cit. p. 189).

Within the 'Basic stratiform complex' of Fuster *et al.* (1968a) later plutons of ultramafic rocks and gabbros have been distinguished. These bodies appear to have been diapirically emplaced and to have produced metamorphic aureoles which permit the clear distinction of successive phases of emplacement. The aureoles affect both the main dike swarm and its host rocks of sediment, volcanics and early plutons and partial melting of the country rock occurs in places along the margins of the intrusions. Occasional marginal foliation and internal cataclasis was apparently produced by stresses developed during emplacement as essentially solid masses. The largest mass of these plutons forms the core to the Betancuria massif, though individual intrusions are seen in areas to the north (Fig. 35). These are commonly gabbroidal, often with primary amphibole, and show fine igneous layering on a variety of scales. Some of these intrusions may have been emplaced under the regional stress field that produced the dike swarm; these are often elongated parallel to the dike swarm. Others have been emplaced largely by stoping, as can be seen in marginal and roof zones and may be associated with ring fracturing.

In each phase of plutonic emplacement, ultramafic or gabbroidal rocks are succeeded by syenites or trachytes. The latest of these form large partial ring dikes and sheet intrusions which have been described by Fuster *et al.* (1968a) and Muñoz (1969). Some are oversaturated such as the quartz-bearing varieties at M. Tindaya in N. Fuerteventura, others are undersaturated, carrying modal nepheline. Age determinations (Abdel Monem *et al.* 1971) have yielded ages of 18–21 Ma. Carbonatites are also associated with the late plutons.

'Old basalts'

'Old basalts', (table-land formation of Hausen 1958; Basaltic series I of Fuster *et al.* 1968a, p. 211).

These basalts (Fig. 36) form a series up to 800 m thick (Jandia). They are composed of several subunits of lava flows and breccias (generally near the base of the series) which are difficult to interpret due to pervasive diking and alteration. Local unconformities and interbedded pyroclastic and epiclastic sedimentary rocks indicate that volcanic activity was very intermittent (Fuster *et al.* 1968a, p. 215), in contrast to the old basalts e.g. on Gran Canaria where only one major unconformity and few epiclastic rocks have been found so far (Schmincke 1968a). Divergent trends of dikes indicate several eruptive centers (Fuster *et al.* 1968a, Fig. 74). Age determinations of these basalts from the N-coast (20.6 Ma), east-central part (11.8 Ma) and the upper Jandia section (14–17 Ma) (Abdel-Monem *et al.* 1971) also indicate a long history of eruption.

Fig. 36. Areal distribution of Miocene basalts on Fuerteventura (redrawn after Fuster et al. 1968a, Fig. 67).

PLIOCENE AND QUATERNARY BASALTS

Pliocene and Quaternary basalts (Basaltic series II and III of Fuster *et al.* 1968a, p. 220).

A long erosional interval of possibly 10 million years duration separates the rocks discussed above and several younger eruptive periods (Abdel-Monem *et al.* 1971).

Fuster's Series II basalts comprises the shield volcano basalts of earlier authors (mainly west of M. Tindaya), and the large field in the center of the island (between Ampuyenta and Antigua) and poorly preserved cones (Tetir group). Dates from these in Barranco de M. Molinos are 4.2 and Toston 1.8 Ma (Abdel-Monem *et al.* 1971).

Series III basalts (Fuster *et al.* 1968a, p. 225) (flows and cinders cones) are somewhat better preserved than those of series II. They occur only E and NE of La Oliva. Some flows show tholeiitic affinities.

SUBRECENT BASALTS

Subrecent basalts (Series IV of Fuster *et al.* 1968a, p. 229).

The youngest basalt flows and cinder cones are subrecent, show very well preserved geomorphic forms, and are probably at most a few thousand years old. These rocks cover much of the northern part of the island, a large area in the southern center of the island (Gairia), and the island of Lobos. Cendrero (1966) studied them in detail.

Lanzarote

Lanzarote has an area of 795 km^2 and rises to 671 m above sea level. The sea floor to the east of the island is about 1000 m deep while that to the west drops rapidly to over 3000 m.

Owing to its easy accessibility because of low elevations and many roads and its special charm – probably not the least due to the cones and flows of the spectacular historic eruptions (Fig. 23) – Lanzarote is geologically one of the best known islands. The main monographs are by Hartung (1857), Hernandez-Pacheco (1910), Hausen (1959), and Fuster *et al.* (1968b), the latter containing a colored 1 : 100 000 geologic map. Fuster and coworkers have also published a number of special papers on various aspects of the island's geology and also published geologic maps on the scale 1 : 50 000 (see references in Fuster *et al.* 1968b).

Table 5. Stratigraphy of Lanzarote after Fuster *et al.* (1968b)

Hausen (1959)	Fuster *et al.* (1967)
	Trachytes and trachytic tuffs.
Basaltic tableland series	Basaltic Series I.
	Basaltic Series II.
Quaternary volcanoes	
	Basaltic Series III.
Subrecent volcanoes	
	Basaltic Series IV.
Historic volcanoes	

Miocene basalts

Miocene basalts (shield-building series; table-land formation of Hausen 1959; Basaltic Series I of Fuster *et al.* 1968b, p. 144).

The oldest rocks on the island are a series of mainly basaltic lavas and pyroclastics of more than 600 m total thickness, cropping out mainly in the southern (Los Ajaches) and Northern (Famara) highlands. The oldest part is a strongly diked subunit of basalts and trachytes, exposed mainly along the south coast (Punta Papagayo), from where one age determination of 19 Ma was reported (Abdel-Monem *et al.* 1971). At Janubio and Punta Fariones, Miocene calcarenites separate two units of Miocene basalts, although both sections may not be correlative (Fuster *et al.* 1968b). The calcarenites near Punta Fariones contain ostrich eggs (Rothe 1964). Fuster *et al.* (1968b) believe the sedimentary rocks to be no younger than early Miocene while Rothe (1964, 1966) assigns to them a Miocene/Pliocene age which is corroborated by absolute ages of 12–6 Ma for the northern and 6–7 Ma for the Ajaches basalts.

Quaternary basaltic rocks

Quaternary basaltic rocks (Basaltic Series II of Fuster *et al.* 1968b, p. 152).

After extrusion of the Miocene basalts, Lanzarote was strongly eroded during an interval that probably lasted about 5 Ma. Poorly preserved cones and flows of basaltic lava (1 Ma and less old – Abdel-Monem *et al.* 1971) occur mainly SW and NE of Ajaches and around Teguise, south of Famara. They were subdivided by Fuster *et al.* (1968b) in subseries IIa which formed after the 50 m but prior to the 15–20 m beach, and subseries IIb which formed earlier than the 10 m beach and shows better preserved geomorphic forms. For a more detailed discussion of fossil beaches see Klug (1968).

Subsequently most of the island was covered by basaltic lava flows and almost 100 pyroclastic cones (basaltic series III of Fuster *et al.* 1968b) which formed between the 10 m and 5 m beaches. The cones are better preserved than those of the older unit and are less covered with caliche (calcareous crusts formed during weathering) than the older cones.

Recent volcanism

Recent volcanism (Basaltic series III and IV of Fuster *et al.* 1968b, p. 156).

Recent and historic flows and pyroclastics predominate in the western and northeastern part of the island (Figs. 6, 23, 37). Most historic eruptions in western Lanzarote (Timanfaya–Montañas del Fuego) occurred in 1730–1736 and a few in 1824. Together they form the most voluminous historic eruptions on the Canary Islands. Surface temperatures of 425 °C were measured near M. del Fuego (Fuster *et al.*1968b)*. The lavas of the 1730–1736 eruptions are unusual as some show a

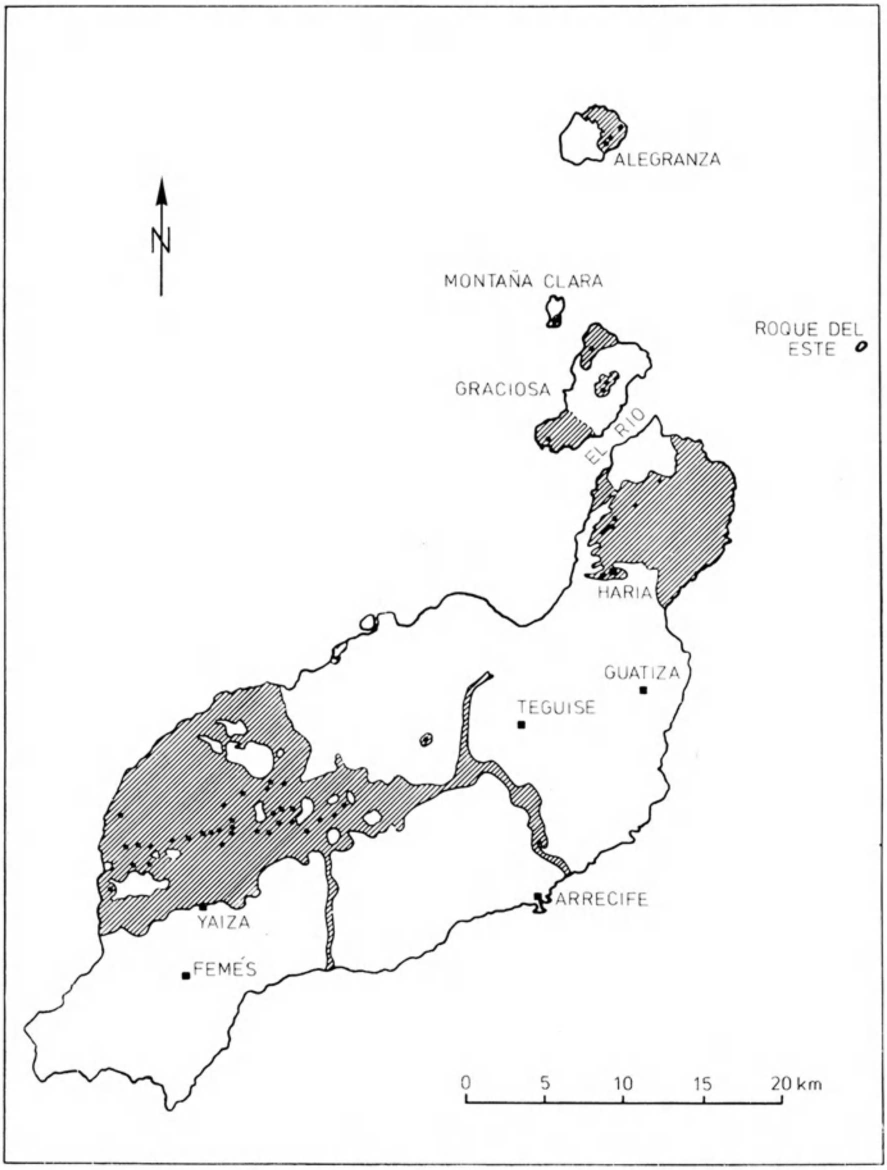


Fig. 37. Areal extent of historic basalt flows on Lanzarote. Black dots indicate eruption centers (redrawn from Fuster et al. 1968b, Fig. 48).

tholeiitic composition which is unique in the Canary Islands. *The thermal anomalies were studied recently by Araña *et al.* (1973).

Xenoliths are common in the rocks of historic eruptions but also occur in the older units. They comprise a variety of plutonic rocks ranging from anorthosites through gabbros and peridotites to dunites. Of particular interest are those of tholeiitic affinity (orthopyroxene-bearing) in alkalic rocks. One such nodule was analyzed in some detail (Frisch 1970). Other xenoliths are contact-metamorphosed calcarenites, probably torn from the sedimentary rocks described above.

More important are quartzitic inclusions (Rothe 1967; Rothe & Schmincke 1968; Fuster *et al.* 1968b) which are evidence of Africa-derived quartz-bearing sedimentary rocks underlying the island.

Gran Canaria

INTRODUCTION

The rugged topography of the center and southern half of the island (1532 km², 1950 m above sea level) has delayed detailed geologic studies until recently, although the very deep canyons extending radially from

Fig. 38. Spatter cone built above eruptive vent during 1730 AD eruption. Montaña del Fuego (Lanzarote).

Table 6. Stratigraphy of Gran Canaria (from Fúster *et al.*, 1968c)

	J. Bourcart & E. Jérémine (1937)	H. Hausen (1962)	Fúster *et al.* 1968c
VI	Arucas Tahitiite Very recent basalts	Quaternary and recent volcanism	Basaltic series IV Basaltic series III
V	Valley basalts Plateau basalts	Late-Tertiary volcanism	Basaltic series II
IV	Vindobonian ordanchites Nublo, Dehesa, etc. breccias Vindobonian basanite	Highly Na-alkaline phonolitic lavas Roque Nublo agglomerates and the interfingering tephritic lava effusions	Ordanchitic series Roque Nublo series Pre-Roque Nublo series
III	Gray rhyolites Merdejo trachyte Cinerites (canto blanco) White phonolites and trachytes	Puzzolane (canto blanco) Phonolite lavas	Phonolitic series Dislocated old trachytes
II	Syenites Rhyolites and trachytes Phonolites	Syenitic plutonic bosses Young trachytes Table-land basaltic formation	Syenitic-trachytic complex Basaltic series I
I	Old basalts		

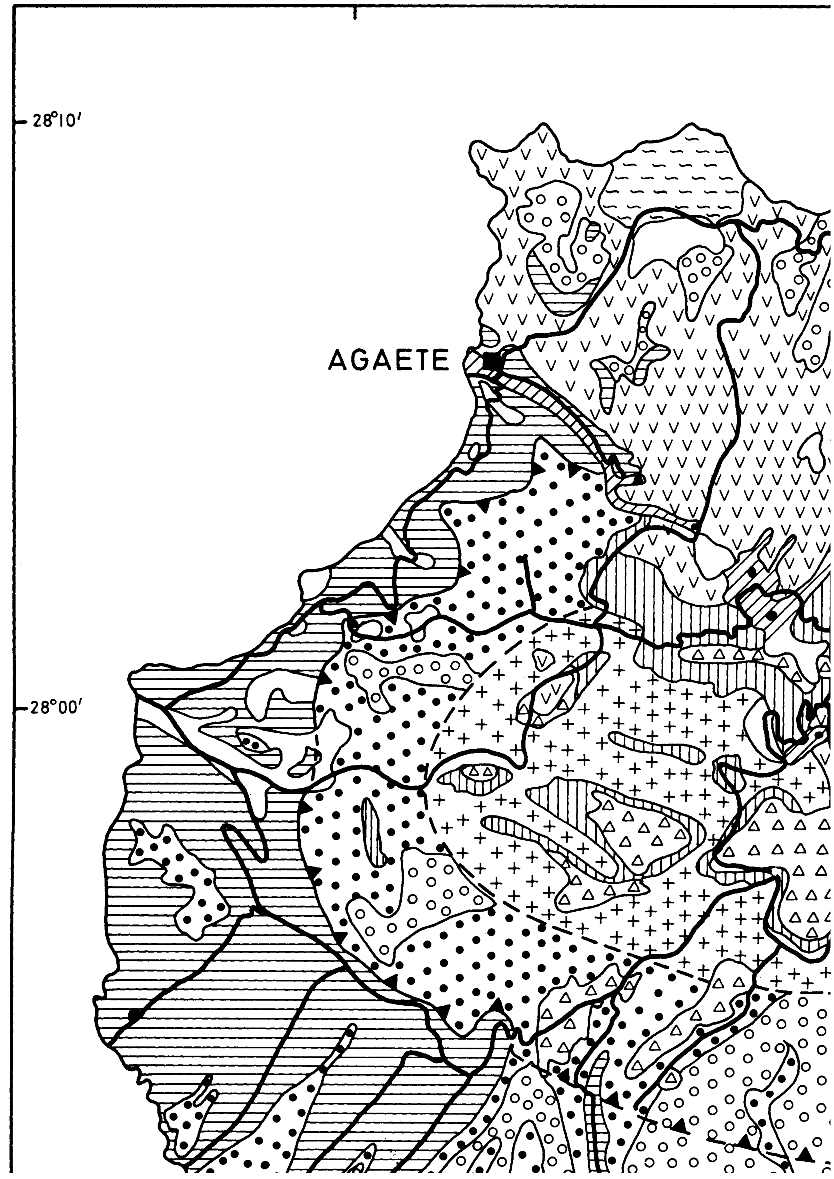
Table 7. Stratigraphy of rock groups and formations on Gran Canaria (Schmincke, unpubl.) The K-Ar dates are from Abdel-Monem *et al.* 1971; Lietz & Schmincke 1975 and McDougall, unpublished.

	K/Ar-age (approximate)	
POST ROQUE NUBLO VOLCANICS GROUP		Magmatic phase III
Undifferentiated Rost Roque Nublo 'basalts.' A general term of the Pleistocene and late Pliocene mafic lava flows and pyroclastics covering the NE part of the island. Includes Basaltos II, III, IV of Fúster *et al.* (1968c) Three formations are distinguished in the highlands:		
La Calderilla Formation. Quaternary to prehistoric basanitic pyroclastic cones and lava flows		
Erosional unconformity		
Los Pechos Formation. Lherzolite-nodule bearing melilite nephelinites. (part of Basaltos II of Fúster *et al.* 1968c)	1.8 M.a.	
Erosional unconformity		
Llanos de la Paz Formation. Olivine nephelinite lava flows. (Part of Basaltos II of Fúster *et al.* 1968c)	2.7 M.a.	
Major erosional unconformity		
ROCK NUBLO GROUP		Magmatic phase II
Tenteniguada Formation. Endogeneous domes and local lava flows of hauynophyre.	3.7 M.a.	
Ayacata Formation. Thick unwelded lapilli breccia sheets of phonolitic tephritic to phonolitic composition, feldspar-rich		
	(approximate)	
Presa de Hornos Formation. Complex near vent assemblage of intrusive and extrusive essexites and hauynophyres resp. basanites, tephrites and phonolitic tephrites.		
Erosional unconformity		
Los Listos Formation. Alternating coarse unwelded basanitic to tephritic pyroclastic breccias and lava flows (always amphibole-bearing).		
Mesa de Junquillo Formation. Olivine alkali basalts, ankaramites, tephrites.	4.4 M.a.	
El Tablero Formation. Isolated olivine nephelinite lava flows in the southern part of Gran Canaria.	4.9 M.a.	

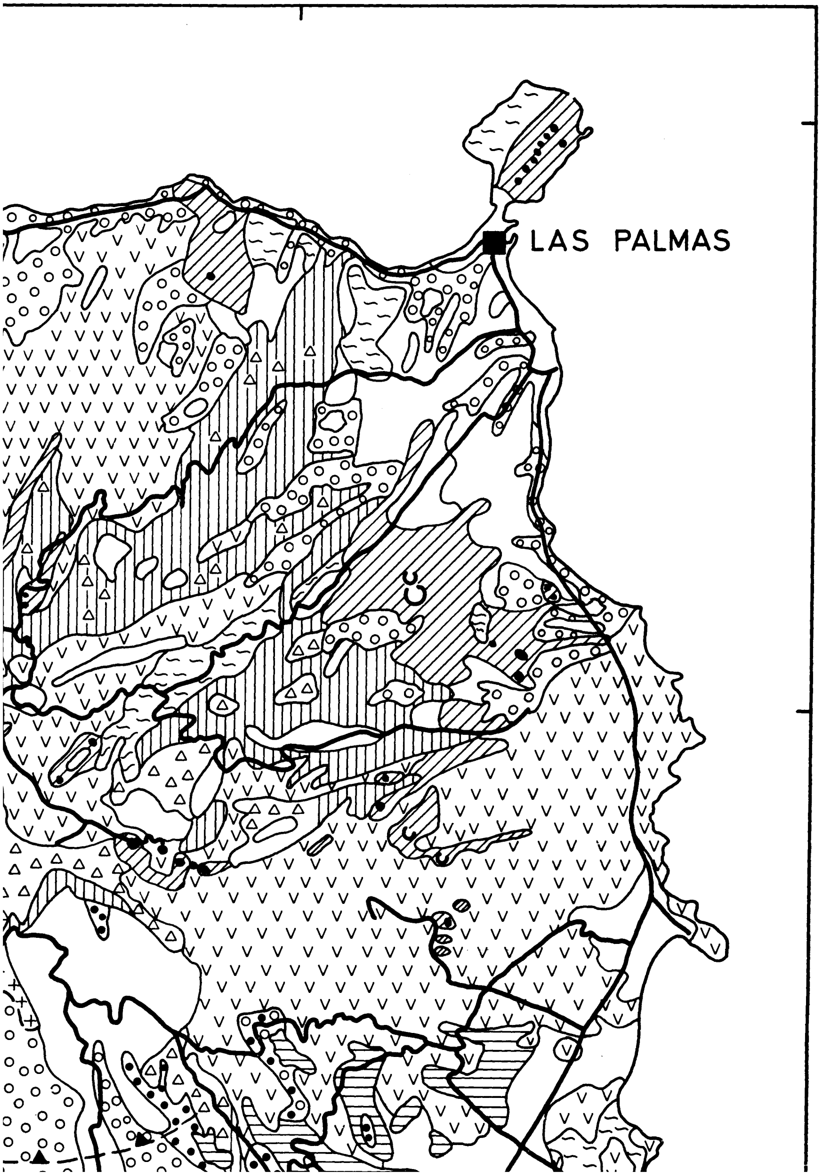
Table 7 continued

	K/Ar-age (approximate)	
Miocene and Pliocene sedimentary formations. Conglomerates, fanglomerates, mud flows, calcarenites and intercalated marine fossiliferous sediments. Three formations can be distinguished:		Erosional interval
Tirajana Formation: Coarse clastics containing dominantly olivine nephelinite and basanite clasts.		
Las Palmas Formation: Coarse clastics containing dominantly Roque Nublo clasts.		
Arguineguin Formation: Conglomerates containing exclusively Miocene clasts (dominantly phonolites).	9.6–2 M.a.	
Major erosional unconformity		Magmatic phase I
MIOCENE SALIC ROCK GROUP (Intracaldera facies)		
Tejeda Formation. Syenites, trachyte dikes and younger phonolite dikes and stocks forming a giant cone sheet swarm cutting Montaña Horno Formation of which only few remnants are left locally.	8.5(?)–10(?) M.a.	
Montaña Horno Formation. Air fall tuffs, breccias, welded and unwelded ignimbrites, agglutinates of rhyolitic to phonolitic composition. Partly oxidized and silicified. At least in part equivalent to extra caldera Mogan and Fataga formations.		
MIOCENE SALIC ROCK GROUP (Extracaldera facies)		
Fataga Formation. Slightly undersaturated trachyphonolitic to phonolitic lavas and ignimbrites.	9.6–10.9 M.a.	
Mogan Formation. Trachytic to rhyolitic, subalkalic to strongly peralkalic lavas and ignimbrites, with one intercalated transitional alkali basalt member.	13–13.5 M.a.	
Local erosional unconformities		
MIOCENE BASALT GROUP		
Hogarzales Formation. Aphyric to slightly clinopyroxene-plagioclase phyric mildly alkalic hawaiites and mugearites.	13.5 M.a.	
Erosional unconformity		
Guigui Formation. Olivine- and clinopyroxene phyric alkali basalts. Strongly diked.	?13.5–14 M.a.	

GRAN C



ANARIA



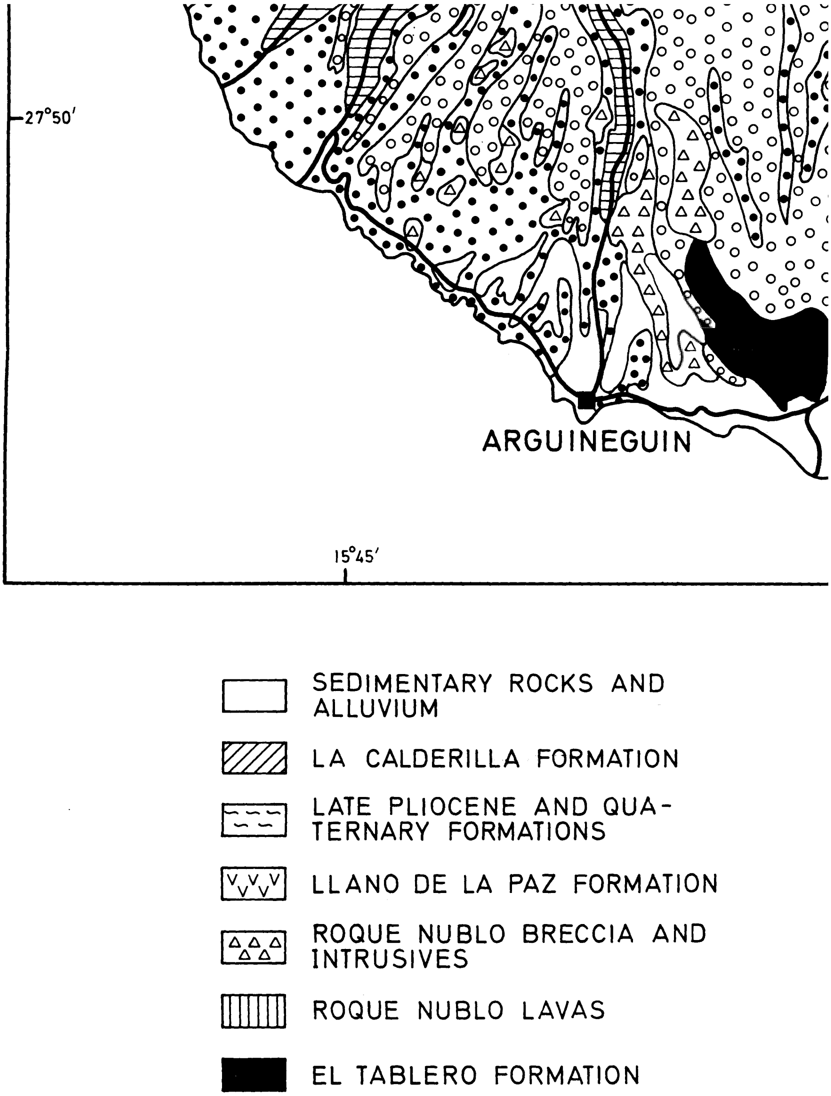
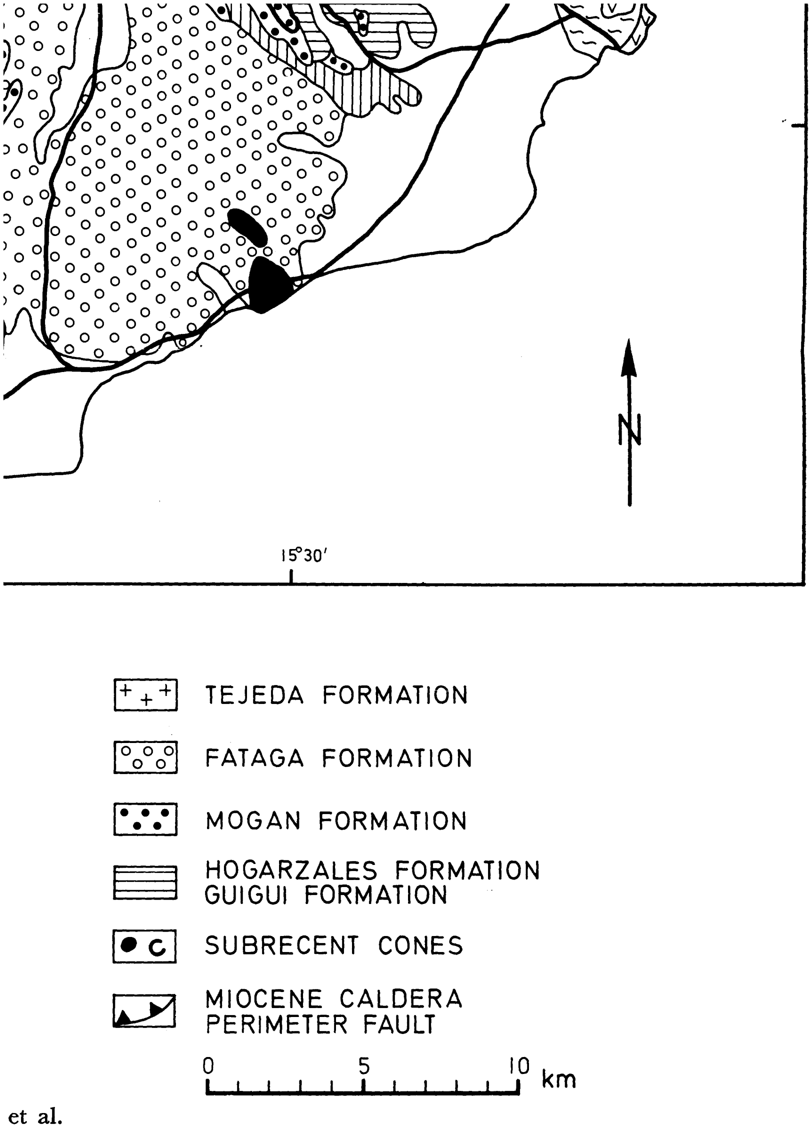


Fig. 39. Geologic map of Gran Canaria, simplified and modified after Fuster 1968c. Stratigraphic nomenclature after Schmincke (this report). Identification Tablero rocks in S. E. Gran Canaria is tentative.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the center (Figs. 41, 52) allow a more complete reconstruction of successives stages of a volcano's development than on any of the other islands. There are three main monographs on the island's geology: Bourcart & Jeremine (1937); Hausen (1962) and Fuster *et al.* (1968c, including a colored geologic map on the scale 1:100 000). Schmincke and co-workers (1965–present) are studying the rocks of this island in greater detail.

The depth of the Moho is about 24 km beneath Gran Canaria and 12 km in its surroundings (Bosshard & MacFarlane 1970) (Fig. 8). Two gravity highs are located in the NW and SE of the island, possibly indicating olivine-pyroxene cumulates which filled fossil magma chambers beneath two major eruptive centers (Bosshard & MacFarlane 1970; Schmincke 1971).

The subaerial volcanic geologic history of the island can be divided into three major episodes (tables 6, 7; Fig. 39): 1. During the Miocene (about 14–9.5 Ma), a complex basaltic shield volcano with several eruptive centers was built. It was subsequently covered with numerous trachytic, rhyolitic, and phonolitic lava flows and ignimbrites, totalling at least 1000 m in thickness. During the early part of this emission, the central part of the island collapsed to form a huge caldera basin of about 15 km diameter in which the earlier rocks were downdropped at least 1000 m. This basin was filled by volcanics similar in composition to those outside the caldera and subsequently intruded by small syenite stocks and huge trachytic to phonolitic cone sheet dike swarms. 2. During an erosional interval of about five million years thick clastic debris fans, interbedded with marine sedimentary rocks, were formed. Accumulation of these clastic rocks overlapped with renewed volcanic activity during which the previously carved deep canyons were partly filled with lavas and thick breccia sheets mostly issuing from the center of the island (4.4–3.7 Ma). 3. Emission of mostly basanitic to nephelinitic lavas and pyroclastics occurred intermittently up to prehistoric times.

The geology of Gran Canaria will be discussed in more detail than that of other islands because it is the most varied and because the diversity of its flora is greater than on any other island.

MIOCENE BASALT GROUP

Miocene basalt group (table-land formation of Hausen (1962), Basaltic series I of Fuster *et al.* 1968c, p. 191).

The oldest rocks are a series of basalt flows of 1000 m total thickness above sea level which crop out mainly in the west and southwest parts of the island (Fig. 39). They constitute a complex shield volcano which was fed from several eruptive centers. A strong angular unconformity separates this series at Barranco de Guigui into two units, the older Guigui Formation and the younger Hogarzales Formation (Schmincke 1968a;

Fig. 40). Elsewhere this unconformity is only slightly angular but it can be traced at least as far east as Barranco de Arguineguin, 20 km east of Barranco de Guigui (Robinson, pers. comm. 1975). Positive gravity anomalies (Bosshard & MacFarlane 1970), concentration of dike swarms, abundance of pyroclastics and primary dips suggest that there may have been three main eruptive centers for the basalts: one near Agaete (or off the coast) in the northwest; one south of San Nicolas in the Guigui Grande area; and a third in the southeastern part of the island near Aguimes.

GUIGUI FORMATION

The oldest shield-forming lavas appear near sea level at Barranco de Guigui (Fig. 40) and rise southward to several hundred meters above sea level. Three main features distinguish these from the younger shield-forming lavas: picrites and ankaramites are common; the lavas are highly altered; and dikes are very abundant (Fig. 40). Fresher and aphyric lavas may locally appear as well, however (Fig. 11). On the base of these properties, the thick basalt series at Agaete and the smaller one

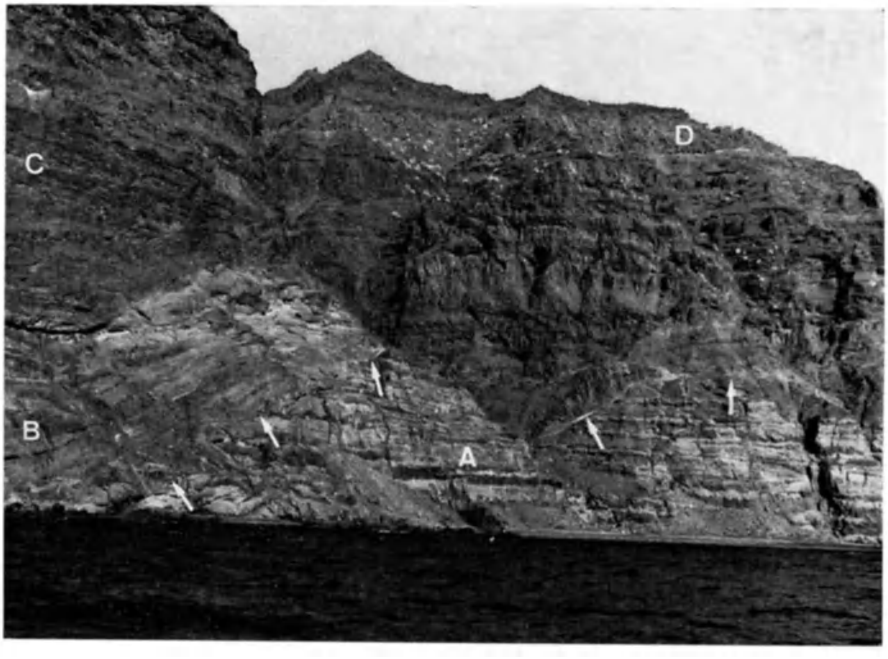


Fig. 40. Barranco de Guigui (southwest coast of Gran Canaria) showing unconformity (above arrows) between lower, strongly diked Guigui Formation (A) and thick fresher hawaiite and mugearite flows of Hogarzales Formation (C), both being separated by palagonite tuffs and fanglomerates (B). Composite rhyolitic ignimbrite-basalt flow (P 1) (basal cooling unit of lower Mogan Formation) on top of cliff (D).

at Aguimes may be correlative with the Guigui Formation. The lavas at Guigui are approximately 13.5 to 14 Ma old (McDougall, unpubl.).

HOGARZALES FORMATION

Overlying these basalts with a strong erosional unconformity (Fig. 40) are several m of palagonite tuffs and fanglomerates in the SW of Gran Canaria (between Montaña Hogarzales and Barranco de Guigui) followed by a trachybasaltic series (Schmincke 1968a, Figs. 11, 13) here called Hogarzales Formation. These fine-grained, thick, brecciated trachybasalt flows (hawaiites and mugearites) decrease in thickness from several 100 m thickness at Barranco de Guigui to about 100 m farther inland (from Montaña Tirma in the west to at least Barranco de Mogan in the east) where the unconformity is generally not obvious. A subunit of strongly plagioclase-phyric pahoehoe basalts generally makes up the lower part of the Formation (Fig. 14). Westward of Barranco de Mogan a sequence of relatively fresh olivine-phyric basalts lies below (and locally above) the plagioclase-phyric basalts (Robinson, pers. comm. 1975).

MIOCENE SALIC ROCK GROUP

Miocene salic rock group (extra caldera facies) (Syenitic-trachytic complex of Fuster *et al.* 1968c, p. 197).

The Miocene basalts are overlain by a very widespread composite flow grading from a sodarhyolitic ignimbrite at the base to a trachybasalt at the top (Fig. 40) (Schmincke 1967a). The cooling unit is 10 m thick on the average and has a minimum areal extent of 250 km^2. This unit (called P1, Figs. 44, 45) is absent north of Barranco de Tirajana (where emplacement of Miocene felsic flows was frequently interrupted by erosion), strongly unconformable in the bottom of Barranco de Tirajana (where the Hogarzales flows may not have been emplaced?) but elsewhere is practically conformable, local slight angular unconformities probably being due to a widespread sheet overlying lava flows of small extent.

Emission of P1 initiated a period of eruption of nearly exclusively trachytic, rhyolitic and phonolitic volcanism, lasting some 3 Million years, with intermediate lava flows being completely absent. This sequence is subdivided into a lower oversaturated (Mogan Formation) and upper slightly undersaturated series (Fataga Formation). Such a subdivision also can be made in the extra- and intracaldera rocks (see below).

MOGAN FORMATION

The Mogan formation (Figs. 41, 43, 44) ranges in age from approximately 13.5 to 13 Ma (McDougall, unpublished) and is made up of two conform-

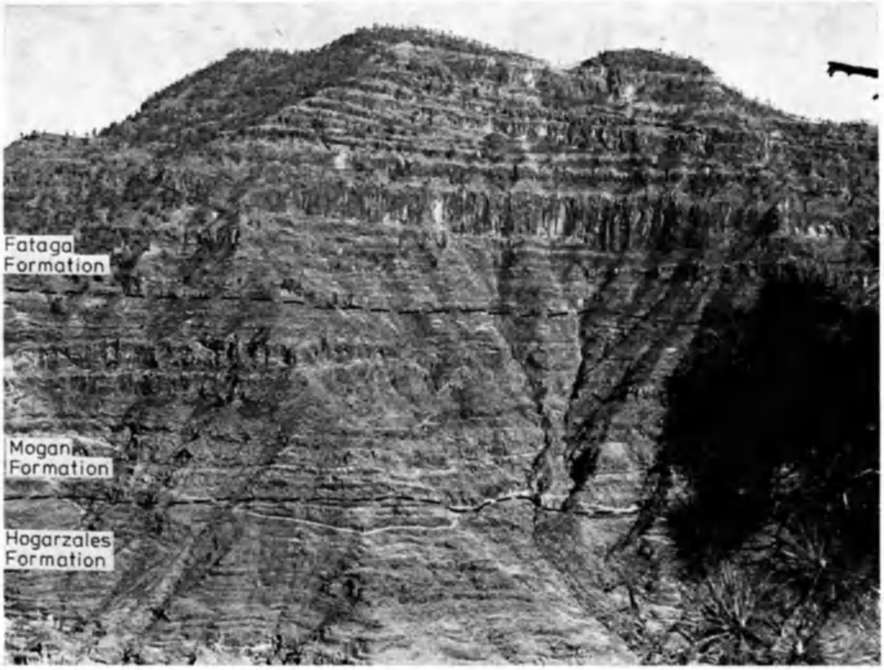


Fig. 41. Thick section of Gran Canaria Miocene rocks. Lower dark broken line separates mugearites and hawaiites of Hogarzales Formation just below the composite flow basalt-rhyolite (PI). Upper dark broken line separates rhyolites of Mogan Formation (mostly ignimbrites) from trachyphonolites of Fataga Formation (thick columnar lava flows and thinner ignimbrites). Height of section approximately 600 m. Upper part of Barranco de Mogan below Montaña de Tauro (Gran Canaria).

able units. These rocks underlie most of south and south-west Gran Canaria but also occur in the north at San Lorenzo (Schmincke 1968a, p. 44) so they originally probably covered most of the island. The lower part, about 150 m thick, is made up of about 7 soda rhyolite (and 1 trachyte) lava flows and ignimbrites, many of which are compositionally zoned (Fig. 44). The uppermost flows are slightly peralkalic. Hypersthene, clinopyroxene and anorthoclase (Or_{15-20}) (oligoclase in one) are the characteristic phenocrysts in the lavas but edenitic amphibole substitutes for pyroxenes in the ignimbrites (Schmincke & Frisch 1972) (Figs. 44, 45). The upper part is composed of about 9 comenditic and pantelleritic ignimbrite cooling units (anorthoclase Or_{20-30}, richterite and Fe/Ti-oxide phenocrysts) with one moderately alkalic basalt horizon interbedded in the lower part. Abundant laminar flowage structures particularly in the highly peralkalic pantelleritic ignimbrites, indicate eruption from the islands interior (Schmincke & Swanson 1967a; Schmincke 1975), now occupied by syenitic, trachytic and phonolitic intrusives (Schmincke 1967a; Figs. 48, 49). Two widespread air fall tuffs occur in the lower part

Fig. 42. Hawaiites and mugearites of Hogarzales Formation (left) separated by caldera perimeter fault (almost vertical irregular contact just to left of white arrows) from intracaldera rhyolites of Montaña Horno Formation. Damsite of Presa de Mulato in foreground. Head of Barranco de Mogan (Gran Canaria).

of this sequence; one is commonly fused and makes an excellent stratigraphic marker (Fig. 46).

FATAGA FORMATION

Fataga Formation (Phonolitic series of Fuster *et al.* 1968c, p. 208).

The Mogan formation is overlain by up to about 500 m of generally trachyphonolitic ignimbrites (with anorthoclase Or_{30-44}, amphibole or phlogopite and Fe/Ti-oxide phenocrysts) and very thick columnar, platy, and partly brecciated lava flows (anorthoclase and Na-rich clinopyroxene). These rocks overlie much of the southeastern and southern (east of Barranco de Veneguera) part of Gran Canaria but also occur in the north and northwest. The main eruptive center of the phonolites appears to be the highly diked area between Cruz Grande, Chira and Ayacata, an area which also contains the most abundant phonolite tuffs. Phonolite flows from the upper part of the Fataga formation range in age from about 10.5 to 9.6 Ma (Abdel-Monem *et al.* 1971).

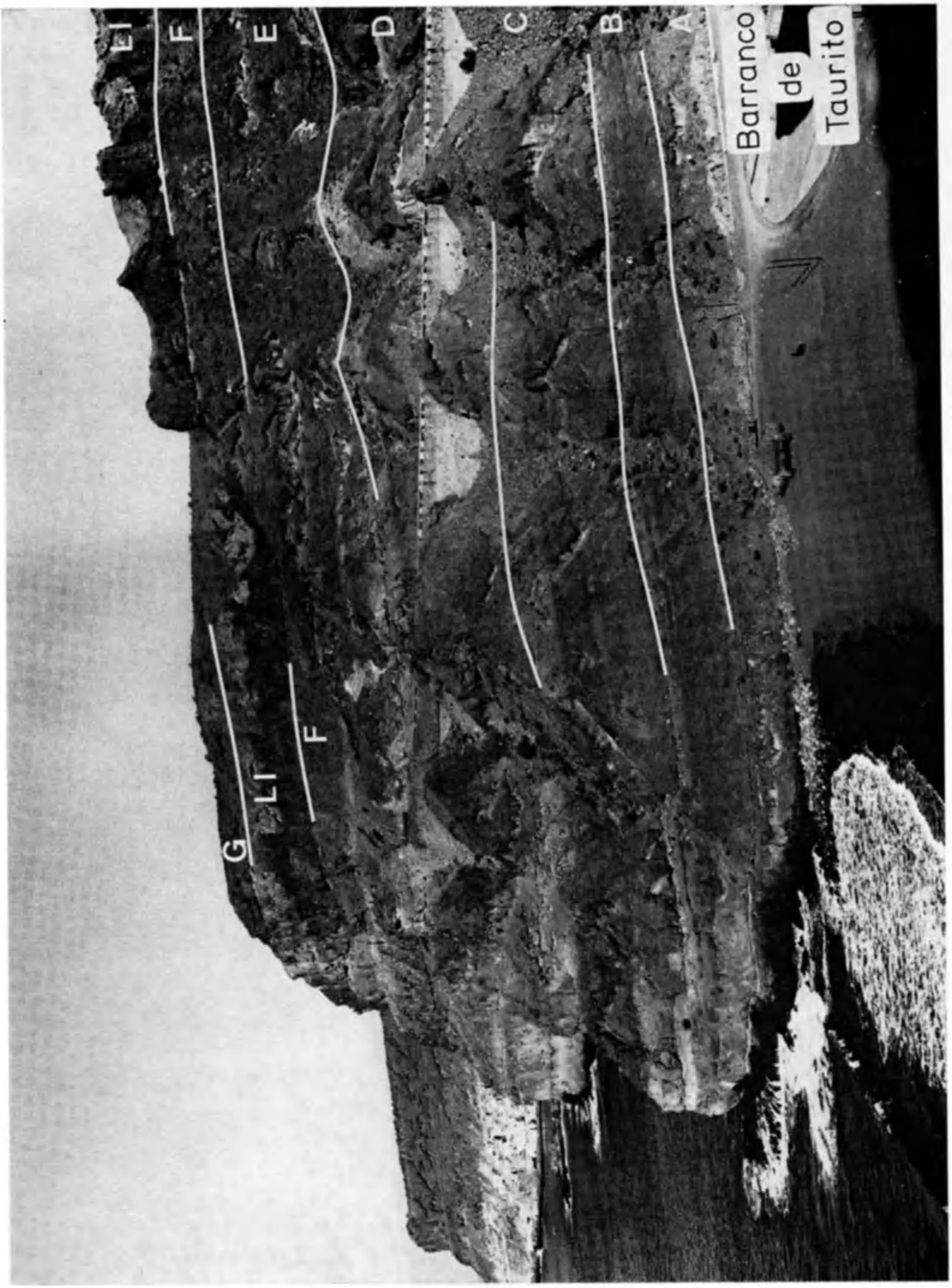


Fig. 43. Barranco de Taurito (Gran Canaria), type locality of the Upper Mogan Formation showing the main peralkalic silicic ignimbrites (A to E), trachytic ignimbrites F and G, and trachyphonolitic lava LI. See following figures for more detailed informaiton.

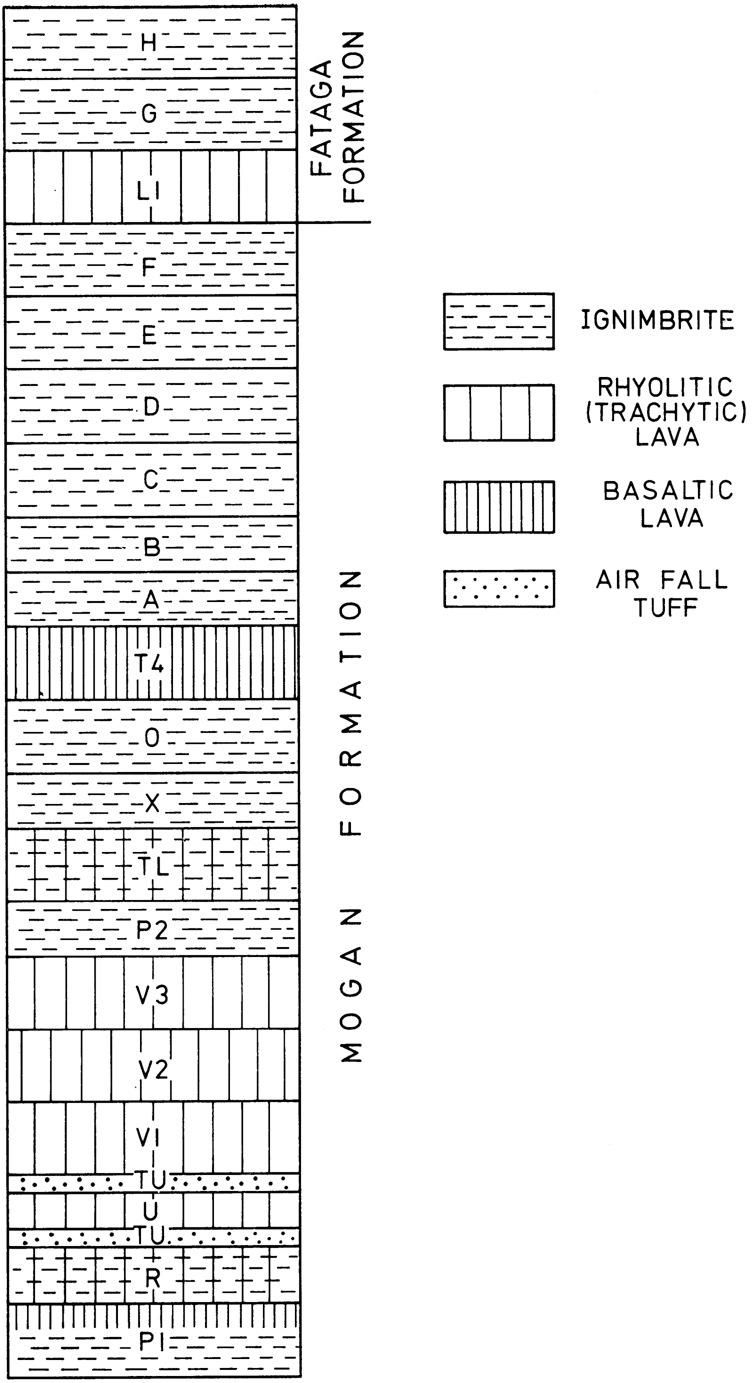
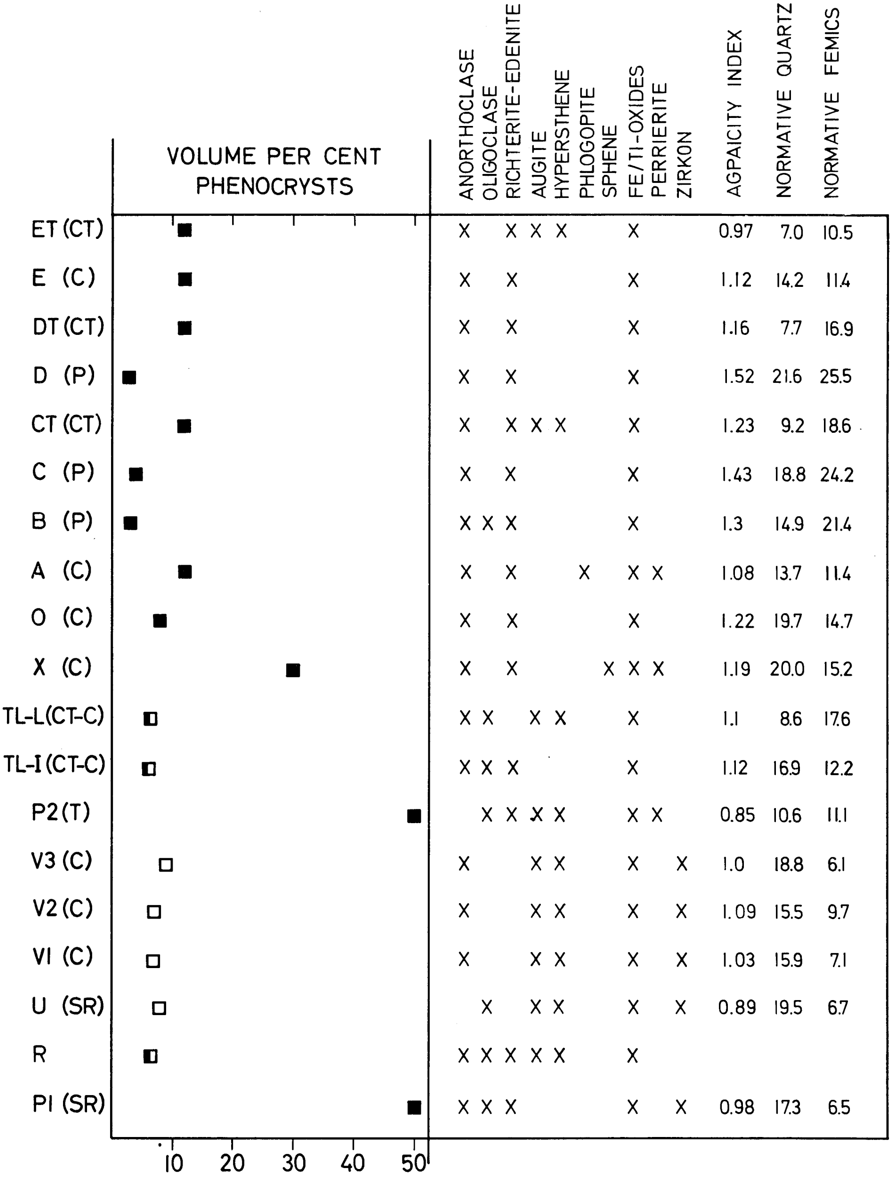


Fig. 44. Stratigraphic section of Mogan Formation and basal flows of Fataga Formation. Most of the individual cooling units are between 10 and 30 m thick. The section is representative for the Mogan Formation of most of southern and western Gran Canaria, from Barranco de Tirajana in the east to San Nicolas in the west. Locally restricted flows – such as the basalt flow above U in Fig. 5 – are omitted. Chemical and mineralogic characteristics of this section are shown in Figs. 28 and 45 and a photograph of the Upper Mogan Formation is given in Fig. 43. Some flows are illustrated in Figs. 18–20.



	ANORTHOCLASE	OLIGOCLASE	RICHTERITE-EDENITE	AUGITE	HYPERSTHENE	PHLOGOPITE	SPHENE	FE/TI-OXIDES	PERRIERITE	ZIRKON	AGPAICITY INDEX	NORMATIVE QUARTZ	NORMATIVE FEMICS
ET (CT)	X		X	X	X			X			0.97	7.0	10.5
E (C)	X		X					X			1.12	14.2	11.4
DT (CT)	X		X					X			1.16	7.7	16.9
D (P)	X		X					X			1.52	21.6	25.5
CT (CT)	X		X	X	X			X			1.23	9.2	18.6
C (P)	X		X					X			1.43	18.8	24.2
B (P)	X	X	X					X			1.3	14.9	21.4
A (C)	X		X			X		X	X		1.08	13.7	11.4
O (C)	X		X					X			1.22	19.7	14.7
X (C)	X		X				X	X	X		1.19	20.0	15.2
TL-L(CT-C)	X	X		X	X			X			1.1	8.6	17.6
TL-I (CT-C)	X	X	X					X			1.12	16.9	12.2
P2 (T)		X	X	X	X			X	X		0.85	10.6	11.1
V3 (C)	X			X	X			X		X	1.0	18.8	6.1
V2 (C)	X			X	X			X		X	1.09	15.5	9.7
VI (C)	X			X	X			X		X	1.03	15.9	7.1
U (SR)		X		X	X			X		X	0.89	19.5	6.7
R	X	X	X	X	X			X					
PI (SR)	X	X	X					X		X	0.98	17.3	6.5

Fig. 45. Phenocryst mineralogy, normative quartz, normative femics, and agapicity index of main silicic cooling units of Mogan Formation. The letters to the left correspond to those in the stratigraphic section (Fig. 44). Those in parenthesis indicate the nomenclature: P = pantellerite; C = comendite; SR = subalkalic rhyolite; CT = comenditic trachyte; T = trachyte. From Schmincke (1975).

Fig. 46. Fused bedded crystal vitric tuff separating alkali-rhyolitic lavas of Lower Mogan Formation from dominantly peralkaline ignimbrites of Upper Mogan Formation. Montaña Cedro (Gran Canaria). Thickness of tuff 50 cm. Plants are *Juncus* and to the left *Echium decaisnei.*

MIOCENE SALIC ROCK GROUP (INTRACALDERA FACIES)

The eruption of silicic material was accompanied by caldera collapse of the center of the island (Figs. 39, 42, 47). Neither basalts nor Na-rhyolites of the Mogan formation are found in the center of the island within the confines of the caldera basin indicating that it foundered after emplacement of these rocks. The major phase of caldera foundering probably occurred after eruption of the basal composite flow P1, the most voluminous cooling unit of the Mogan formation.

Although individual cooling units cannot unequivocally be correlated sofar between the rocks inside and outside the caldera, the rocks inside seem to represent both the upper Mogan and part of the Fataga formations. The absence of noticeable erosional breaks between deposition of lower and upper Mogan series at about the time the caldera must have formed, plus indications of vertical movements along the caldera wall (Schmincke & Swanson 1966), and the subsequent history (see below) indicate some caldera collapse after effusion of the lower Mogan series.

An erosional origin was proposed by Bourcart & Jeremine (1937) and Fuster *et al.* (1968c) for the zone interpreted as a caldera wall by Schmincke & Swanson (1966) but they gave no evidence to support this hypothesis nor any evidence that would negate a caldera.

MONTAÑA HORNO FORMATION

In the south and west of Gran Canaria, the rocks inside the caldera are much more resistant to erosion than those outside, in part due to extensive oxidation and silicification inside but locally also outside the caldera wall. These processes must have taken place prior to emplacement of the upper Fataga formation rocks because there is an unconformity between lower oxidized and upper non-oxidized rocks of this series in upper Fataga valley and elsewhere. Also, the sequence underlying Montaña Horno inside the caldera is oxidized in only the lower two thirds; the upper trachyphonolitic cap has not been oxidized. In general, the oxidation zone marks the continuation of the caldera margin from Soria (Barranco de Arguineguin) to La Sorrueda in Barranco de Tirajana. A large central volcano (or volcanoes) were probably built inside the caldera basin. These filled the caldera, from its unexposed downdropped floor upwards, with bedded tuffs, breccias, pumice flow deposits and lava flows (Figs. 47, 48).

TEJEDA FORMATION

The caldera fill was subsequently intruded by several syenite intrusives and then by innumerable trachyte dikes which formed at least one huge cone sheet swarm and also some late phonolite dikes (Figs. 49, 52). Irregular nepheline phonolite intrusives (very Na-rich and undersaturated) also underlie much of northern Montaña Horno from where they extend eastward. The phonolite intrusives are generally the youngest of the Miocene intrusive rocks. The intrusives of the Tejeda Formation are being studied in detail by Starmer (unpubl.).

MIOCENE-PLIOCENE CLASTIC FORMATIONS

Miocene-Pliocene clastic formations (Miocene sedimentary deposits of Fuster *et al.* 1968c, p. 212).

Like in other volcanic terranes, drainage patterns were extraordinarily stable on Gran Canaria. Not only were the three major present lowlands (Arguineguin, San Nicolas, Las Palmas) established during Miocene time by the morphology of the composite basaltic shield volcanoes, but also major canyons, such as Barranco de Tirajana, had clearly developed at the same time (Schmincke 1968). This is perhaps the reason for the striking paucity of epiclastic rocks in the Mogan and Fataga formations, erosional detritus being channelled by the large canyons which have been active till today (Figs. 50, 51).

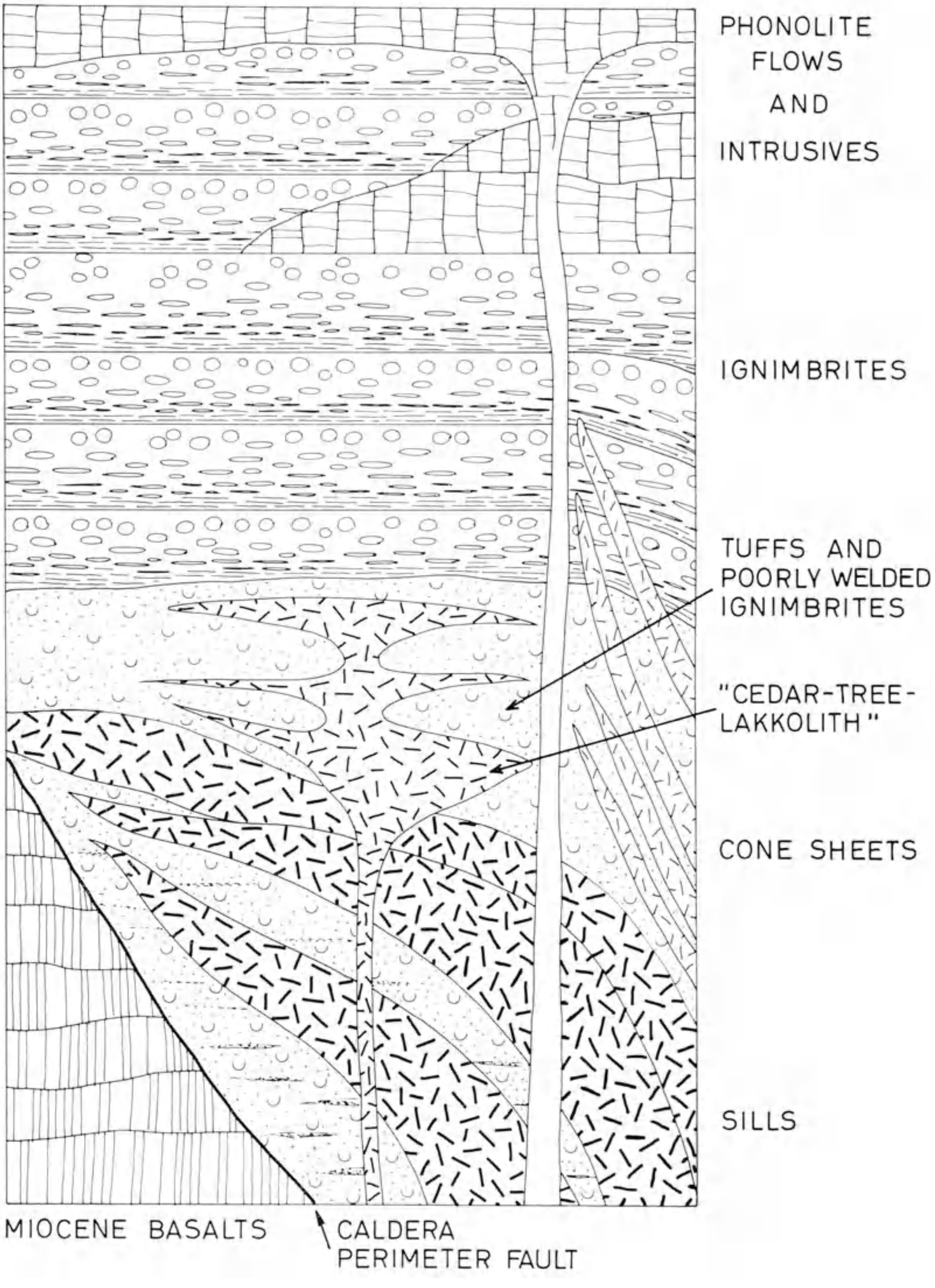


Fig. 47. Schematic stratigraphic section at Miocene Caldera margin, showing Miocene basalts, the Montaña Horno Formation (layered intra-caldera rocks) and part of the Tejeda Formation (intrusive intra-caldera rocks). From Schmincke 1968a, Fig. 11 C.

Fig. 48. Extrusive and bedded volcanic rocks of Montaña Horno Formation (horizontal layering) and intrusives of Tejeda Formation (mostly dikes dipping to the right (east)) of Miocene intracaldera sequence. Junction of Barranco de Siberio and Barranco de Tejeda (Gran Canaria). Height of cliff about 400 m.

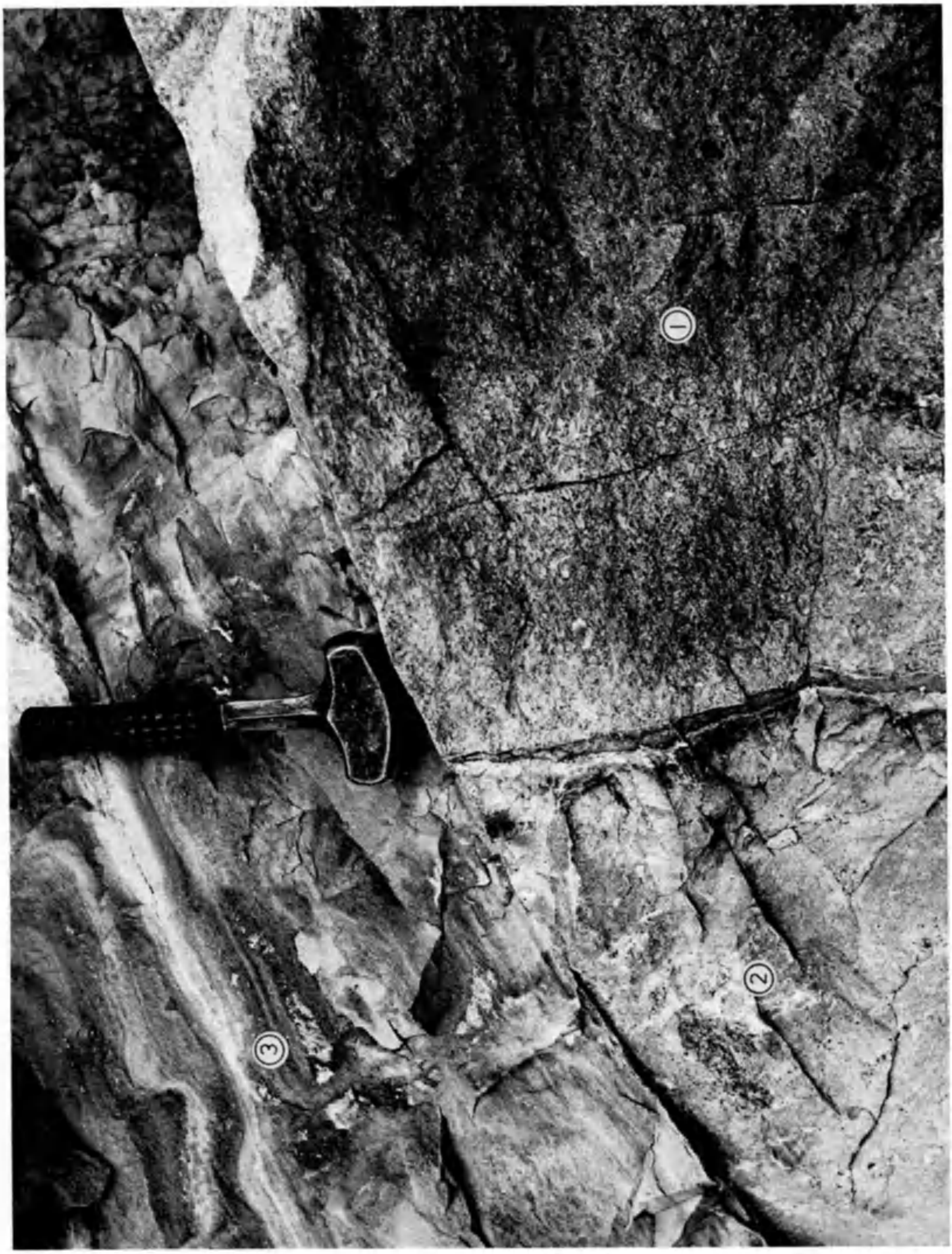


Fig. 49. Contact of three generations of intrusives of Tejeda Formation: syenite (1) is cut by vesicular trachyte dike (2), both being intruded by fine-grained dense trachyphonolite (3). Barranco de Tejeda (Gran Canaria).

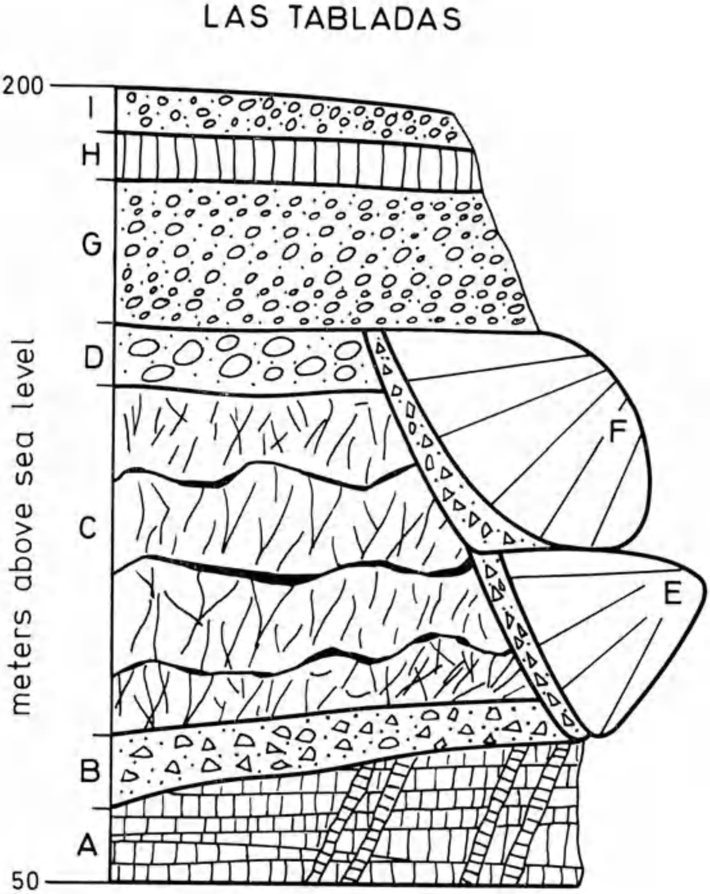
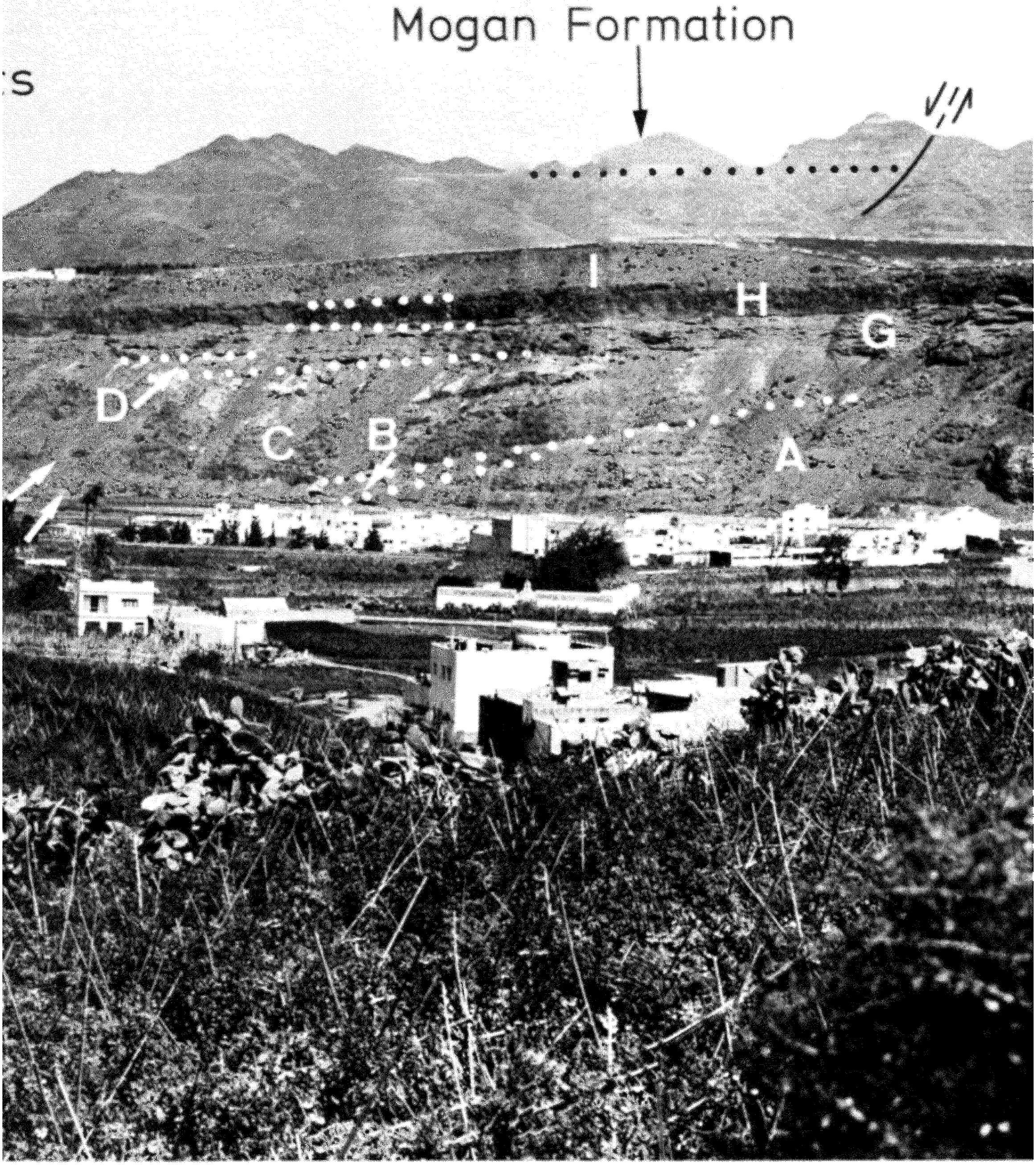


Fig. 50. Stratigraphic section through Las Tabladas Terrace (San Nicolas) showing A: (Miocene basalts, strongly diked, (Guigui Formation?)); B: conglomerate; C: rhyolites (strongly fractured) of Montaña Horno Formation (probably emplaced as land slide material); black material between rhyolites is highly irregular montmorillonized tuff; D: phonolitic conglomerate of Arguineguin Formation; E: Intracanyon basalt flow (Mesa de Junquillo Formation?); F: younger intracanyon basalt flow (Roque Nublo Group?); G: conglomerate containing Roque Nublo type rocks (Las Palmas Formation?); H: early Quaternary (?) basanite lava; I: late Quaternary fanglomerate sheet. This section represents the northern cliff of Barranco de San Nicolas. See also Fig. 51.

Nevertheless, most workers agree that the interval between the end of Miocene phonolitic and beginning of Roque Nublo volcanism – now known to have lasted from about 9.5 to 4.5 Ma (Lietz & Schmincke 1975) – was the period of most intense erosion; most canyons were established at that time and not appreciably deepened since then (Schmincke 1968).

The lowlands were the sites of accumulation of thick debris fans


Miocene basalt


ts
Mogan Formation
I
H
G
D
C
B
A


Caldera
Perimeter
Fault
F
E

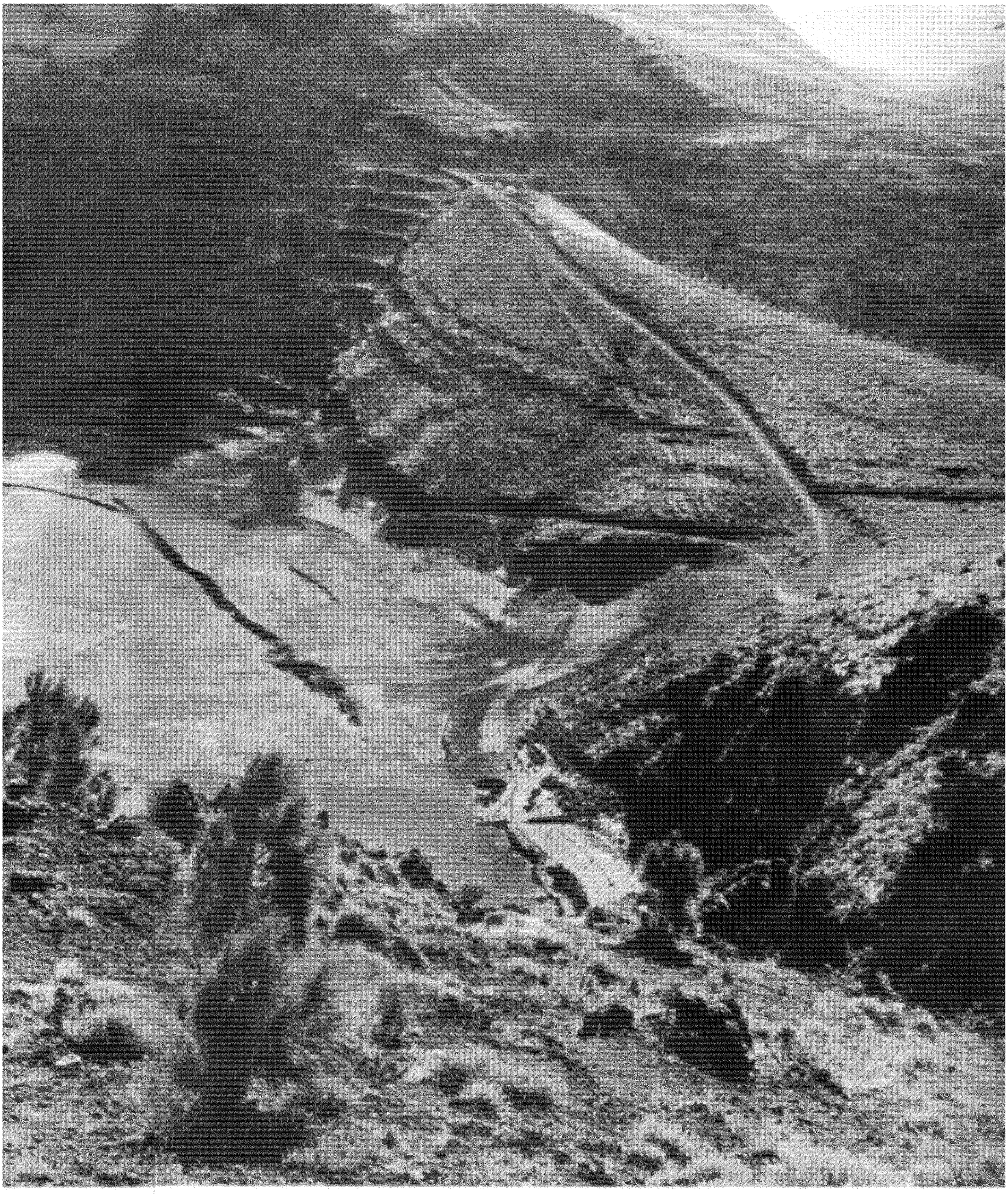


Fig. 52. Major unconformity separating trachyte cone sheet swarm (Tejeda Formation) dipping to the left (east) from horizontal basaltic lava flows and thick breccia sheet at top of Roque Nublo Group (Mesa de Junquillo Formation). Unconformity (with conglomerates) represents time interval of 5–6 Ma. Roque Nublo breccia sheet (Ayacata Formation) on top is 100 m thick. Barranco de Tejeda (Gran Canaria).

consisting of thick conglomerate, fanglomerate, mud flow, sandstone and marine calcarenite, among which are the famous 'Miocene' fossiliferous shallow water marine sediments (Rothpletz & Simonelli 1890). Recent work has shown that at least three marine horizons can be recognized and that three major formations can be distinguished (Lietz 1973; Lietz & Schmincke 1975).

ARGUINEGUIN FORMATION

Arguineguin Formation is the name here given to a widespread gravel first recognized in the Arguineguin area (Hausen 1962) and shown to consist exclusively of Miocene rocks, chiefly phonolites (Schmincke 1968). The same gravel body, generally about 50 m thick, is also present around Las Palmas (Navarro *et al.* 1969; Lietz 1973) and at San Nicolas (Figs. 50, 51). It is interbedded with phonolitic ignimbrites both west of Arguineguin and around Las Palmas. At Bahia Confital west of Las Palmas, the conglomerates overlie marine *Lithothamnia*-bearing sediments at about 60 m above present sea level; their age is assumed to be approximately 8–9 Ma (Lietz & Schmincke 1975).

LAS PALMAS FORMATION

A second marine horizon transgressively overlies the phonolitic gravels and occurs between 40 and 130 m above present sea level, depending on the location of the sediments. These sediments are associated with widespread olivine-clinopyroxene-plagioclase-phyric pillow lavas grading upwards into pahoehoe lavas. The lavas are 4.3 Ma old (Lietz & Schmincke 1975) and thus date the main fossiliferous bed as early Pliocene.

The marine sediments are in turn overlain by another thick wedge of clastic fan material, including many mud flow deposits and dune sediments. Predominant clasts are of basanitic, tephritic and phonolitic Roque Nublo rocks. Some Roque Nublo breccia sheets are interbedded with these sediments. They may be part of the Ayacata Formation (Table 7), according to petrographic criteria (predominance of feldspar-phyric tephrite and particularly phonolite).

TIRAJANA FORMATION

A third marine horizon of probable late Pliocene age cuts back these deposits and is in turn overlain by coarse alluvial sediments, containing as principal clasts olivine nephelinites and basanites, as well as older rocks.

This is the most poorly defined of the three main sedimentary formations and much work is needed for more precise dating and correlation of the younger clastic sedimentary rocks. More detailed descriptions of the Miocene/Pliocene clastic rocks are given in Lietz (1973 and unpubl.).

EL TABLERO FORMATION

Olivine nephelinite lavas and pyroclastics were erupted in southern Gran Canaria around El Tablero around 4.9 Ma ago (Lietz & Schmincke 1975). A similar age was found for olivine nephelinites found as intracanyon flow remnants near the mouth of Barranco de Tazartico (Schmincke 1968; McDougall, unpubl.). The occurrence of these rocks does not fit with the simple scheme of a 3-phase magmatic evolution discussed earlier.

ROQUE NUBLO GROUP

Roque Nublo group (Pre-Roque Nublo series; Roque Nublo series; Ordanchite series (Fuster *et al.* 1968c).

The Roque Nublo group is made up of three main types of rocks: lava flows in the basal part, crudely bedded tuffites and breccia sheets interbedded with lava flows in its lower middle, thick massive breccia sheets in its upper middle part, and strongly hauyne-phyric intrusives and a few hauyne-rich lava flows in its upper part. To this may be added the central intrusive complex in the islands center which is composed of several kinds of intrusive plutonic rocks and breccias.

MESA DE JUNQUILLO FORMATION

Mesa de Junquillo Formation (Pre-Roque Nublo series of Fuster *et al.* 1968c, p. 214).

The Mesa de Junquillo formation consists of a series of lavas up to 200 m thick filling many of the deep barrancos carved previously, particularly in the western and eastern center of the island and in northern Gran Canaria (Fig. 52). Only a few flows (Barranco de Chira) spilled into the southern highlands. The general sequence of rock types is, from the base upwards: olivine tholeiites (?), olivine-phyric basanites, strongly clinopyroxene- and Fe/Ti-oxide-phyric ankaramites which are the most characteristic and widespread Roque Nublo lavas. Tephrites to phonolites become dominant in the upper part of the sequence. They contain clinopyroxene, kaersutitic amphibole, plagioclase, hauyne, Fe/Ti-oxide, and sphene phenocrysts.

LOS LISTOS FORMATION

Los Listos Formation (Roque Nublo series of Fuster *et al.* 1968c, p. 220).

The Los Listos formation, underlying the eastern central highland of Gran Canaria at the head of Barranco de Tirajana is made up of alternating lava flows (mostly ankaramites and tephrites) and bedded to massive pyroclastic rocks. It was studied in detail by Brey (1973) and Brey & Schmincke, in prep.

AYACATA FORMATION

Banked against the Los Listos sequence along a steep north-south trending contact of erosional and/or volcanotectonic origin is the massive Roque Nublo facies which makes up most of the central highland between Ayacata, Roque Nublo and Pozo de las Nieves (Figs. 21, 53, 54). It consists of massive breccias and intrusive rocks (essexites, theralites) which surround the central intrusive complex of coarse-grained essexites. Some of these breccias form sheets that covered large parts of the island and are the most spectacular rocks of Gran Canaria both as to erosional forms, structures, and inferred origin (Figs. 21, 54). The breccia sheets, several tens of meters thick, are made up of varying proportions of pumice, ash, lapilli, crystals, angular dense rock fragments (Fig. 22) and some also contain what appear to have been huge 'blebs' of lava, many m^3 in volume, evidently incorporated in the deposit as liquid material.

The ubiquitous presence of pumice, and the occurrence of some purely pumiceous flow deposits, is evidence of explosive blasts. The striking absence of sorting in some breccia sheets, even at distances more than 10 km from the source indicates that eruption columns were heavily loaded and did not project very high (Brey 1973; Brey & Schmincke, in prep.). Although many of the pumice/breccia flows were probably warm during transport there is no evidence for welding of shards. While Anguita (1973) interprets these breccias as welded tuffs (ignimbrites), Brey (1973) presented abundant evidence that the strong degree of induration of many breccias is due to diagenetic zeolitization, mostly by analcime, chabazite, and philippsite. Locally, viscous lava flows of phonolite composition were able to ride 'piggy-back' in a pumice/breccia flow, autobrecciating during transport (mouth of Barranco de Tauro; road cuts east of Arguineguin). Some of the Roque Nublo breccias are pure phonolitic pumice flow deposits (Brey 1973), others are deposits of volcanic mudflows (lahars).

ROQUE NUBLO NODULES

Plutonic nodules from the Roque Nublo formation, first reported by

Fig. 53. Crudely layered Roque Nublo Breccia at Pajonales (Gran Canaria). Height of cliff about 100 m.

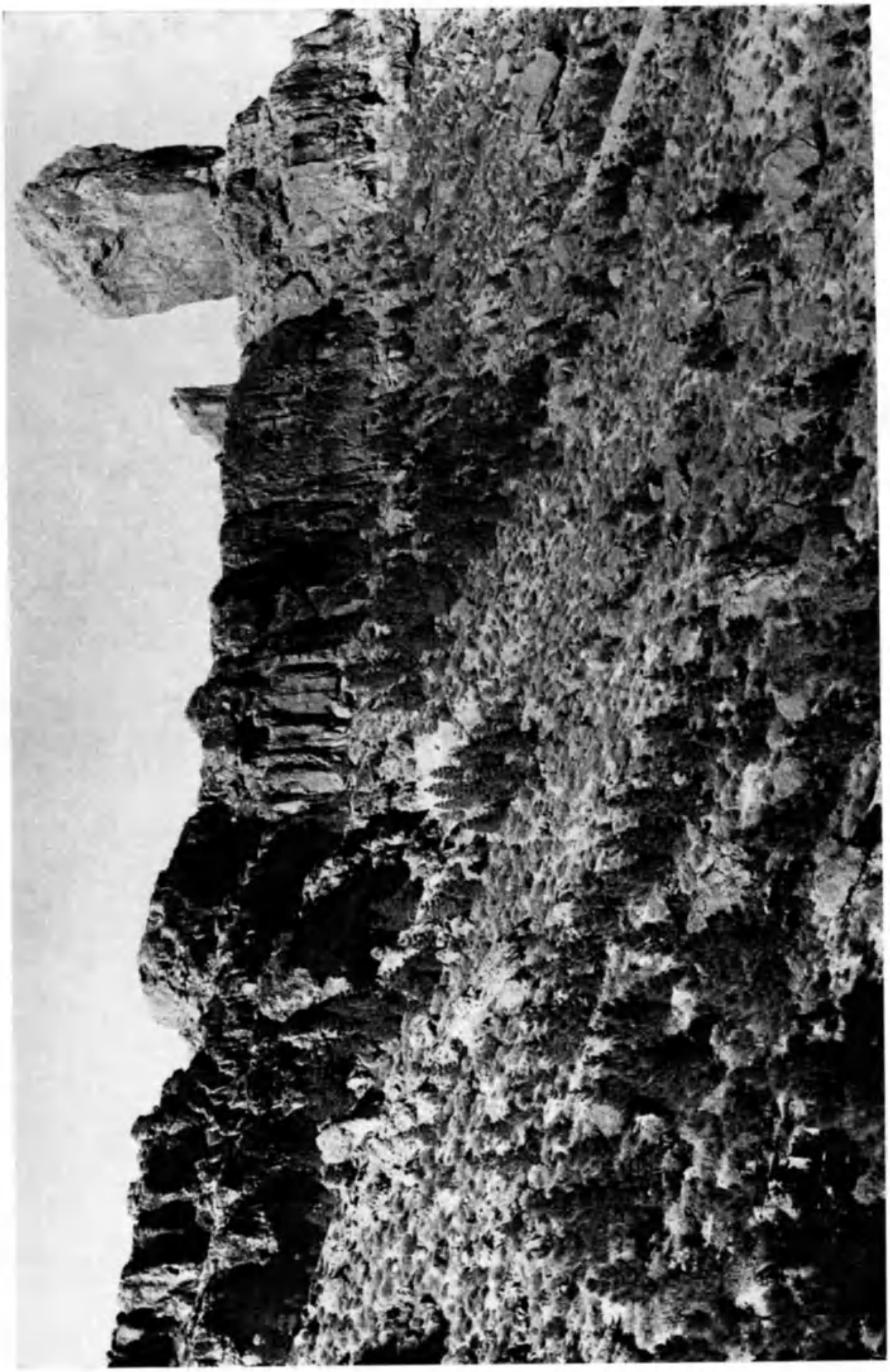


Fig. 54. Thick sheets of the youngest Roque Nublo breccia (Ayacata Formation). Roque Nublo monolith (right) is 80 m high.

Bourcart & Jeremine (1937), were found in great quantities weathered out of Roque Nublo Breccia at Pajonales (Frisch & Schmincke 1969). Mineralogically they range from kaersutitites to pyroxenites. With increasing amounts of sphene, apatite, hauyne, nepheline, alkali feldspar and plagioclase they grade into alkali monzonites.

TENTENIGUADA FORMATION

Tenteniguada Formation (Ordanchitic series, Fuster *et al.* 1968c, p. 224).

Strongly phyric (hauyne, clinopyroxene, sphene, apatite, amphibole, Fe/Ti-oxide, biotite, alkali feldspar), strongly alkalic and peraluminous intrusions (endogenous domes) make up several prominent monoliths in the Eastern highlands of Gran Canaria (e.g. at Tenteniguada) (Figs. 16, 55). Lava flows of similar mineralogical and chemical composition are associated with these intrusions above Risco Blanco in Barranco de Tirajana. Definite intrusive relationships (Schmincke, unpublished) confirms that Risco Blanco (Fig. 55), one of the most prominent of these rock bodies, is intrusive as thought by Hausen (1962) and not an erosional remnant of the older phonolites (cf. Fuster *et al.* 1968c)[4]. Stocks and dikes of these hauynophyres also occur along the northern margin of the Tejeda complex (Schmincke, unpublished) and at least some of the prominent phonolite stocks along the southern margin of the Tejeda complex (e.g. Pajonales and between Cruz Grande and Ayacata) are hauyne-bearing and chemically much more similar to the Roque Nublo than to the Miocene phonolites (Table 2), of which they were formerly thought to be part (Hausen 1962, p. 171; Fuster *et al.* 1968c). A hauyne phonolite intrusion 2 km west of Artenara was recently shown to have the same age as Risco Blanco (McDougall, unpubl.).

POST ROQUE NUBLO BASALT

Post Roque Nublo Basalt – Nephelinite Group (Post-Miocene basaltic series of Fuster *et al.* 1968c, p. 226–236).

Subdivision of these rocks by geomorphic – stratigraphic criteria is difficult, because ‘no systematic lithological differences between series have been found and no better criteria are available for differentiation purposes than the degree of erosion and weathering of the materials’ (Fuster *et al.* 1968c, p. 227). Preliminary work in the highland of Gran Canaria shows, however, that at least in this area three rock series younger than Roque Nublo rocks can be distinguished based on a) state

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[4] This interpretation is also supported by the absolute age of the intrusion (3.7 M.a.; Lietz & Schmincke, 1975).

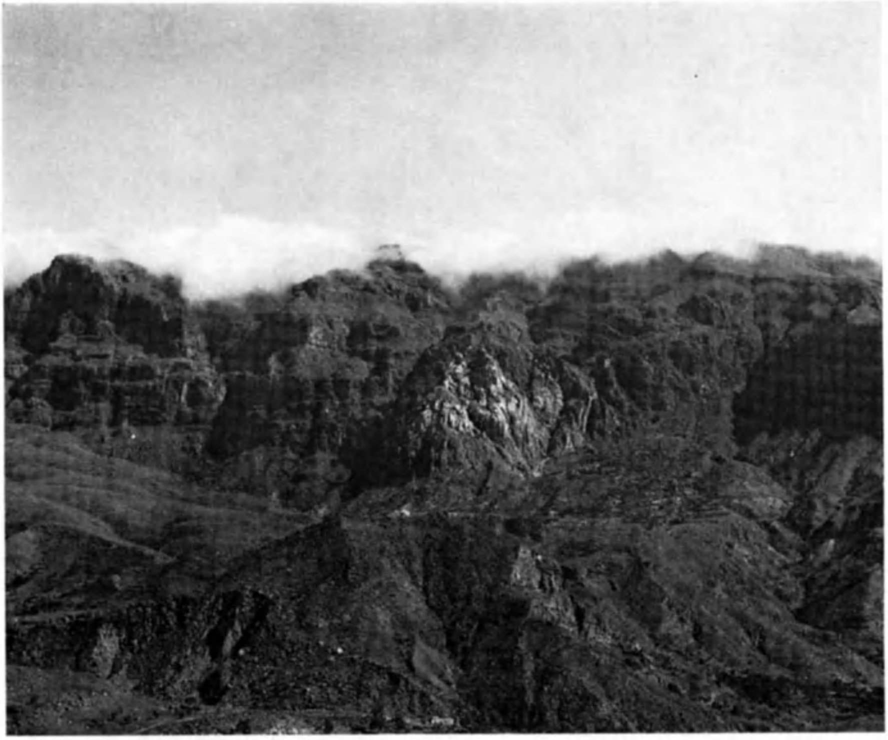


Fig. 55. Conical intrusion of hauyne phonolite of Tenteniguada Formation (Roque Nublo Group) (light colored, center of photograph) intruded into horizontal lavas and breccias of Los Listos Formation. Barranco de Tirajana (Gran Canaria).

of erosion of surface forms and of alteration of rocks, b) erosional unconformities, and c) clear petrographic and chemical criteria as discussed below (Schmincke 1973). However, it is quite uncertain if these three eruptive periods well separated in time and having distinct mineralogy and chemistry have their stratigraphic equivalents on the lower slopes of northern and eastern Gran Canaria which are dotted with numerous pyroclastic cones some of which emitted lava flows or if activity was more or less continuous in these areas.

Recent age determinations (Lietz & Schmincke 1975) have confirmed the subdivisions which were based on field, mineralogic, and chemical criteria. On the other hand, additional formations will eventually be distinguished when more detailed work has been done.

LLANOS DE LA PAZ FORMATION

Llanos de la Paz Formation (in part Basaltic Series II of Fuster *et al.* 1968c, p. 227).

A series, about 200 m thick, of at least 8 columnar nephelinite lava flows and associated pyroclastics covers much of the central highland, from at least El Mirador to Caldera de los Marteles at the head of the eastern barrancos (Fig. 56). These rocks have generally only olivine phenocrysts, rarely clinopyroxene, and, when crystallized, groundmass nepheline instead of plagioclase, the dominant felsic groundmass mineral of all older basaltic rocks. This formation is separated from the Roque Nublo rocks by several m of tuffaceous sandstones and tuffs and an erosional unconformity. The age of the nephelinites is 2.8 Ma (Lietz & Schmincke 1975). At least part of the large volume of lavas and pyroclastics of the Basaltic Series II of Fuster *et al.* covering the central eastern and northwestern part of Gran Canaria belongs to this nephelinite formation.

Fig. 56. Erosional unconformity between complex Roque Nublo near vent assemblage (Ayacata Formation) (light colored rocks in upper lower half of photograph) and dark horizontal olivine nephelinite lava flows of Llanos de la Paz Formation (2.8 M.a. old) underlain by tuffaceous sediments. Presa de los Hornos (Gran Canaria).

Fig. 57. Harzburgite-nodule bearing hauyne-melilite nephelinite (Los Pechos Formation) unconformably overlying tuffs of Llano de la Paz Formation. Height of cliff 20 m. Roque Redondo (Gran Canaria). White circles enclose two persons.

Los pechos formation

Very late, pegmatoid and lherzolite nodule bearing hauyne melilite nephelinite flows and dikes (Fig. 57) unconformably overlying the nephelinites occur at Los Pechos, about 1 km SE of Pozo de las Nieves and at Fortaleza (B. de Tirajana) (Schmincke 1973).

Olivine melilite dikes are reported from northwestern Gran Canaria at Pico del Viento (Ibarrola & Martorell 1973).

Reconnaissance work shows that these extremely commonly nodule-bearing lavas form the uppermost flows in the eastern part of Gran Canaria, between about Barranco de Tirajana and Aguimes, being fed from sources in the highland of Gran Canaria.

These rocks may be between 1 and 2 Million years old judging from the degree of erosion and weathering in comparison with the well dated older and younger rocks.

PREHISTORIC ERUPTIONS

Prehistoric eruptions (Basaltic series IV of Fuster *et al.* 1968c, p. 234–236) ('Calderilla Formation').

Well preserved cinder cones and intracanyon lava flows are evidence of very young volcanic activity on Gran Canaria. A C^{14}-date of 3500 years B.P. was obtained of *Pinus Canariensis* wood that had been covered by cinders in the highlands between Cruz de Tejeda and Artenara (Nogales & Schmincke 1969) (Fig. 34) a reasonable age that might also hold for the other very young eruptive centers. Many lavas of this formation, named after excellent outcrops of La Calderilla (Schmincke *et al.* 1974; in prep.), are characterized by small inclusions of trachyte/syenite; olivine phenocrysts; pyroxene phenocrysts with green cores; and by plagioclase in the groundmass.

The tahitites and associated tephrites north of Arucas (Hernandez-Pacheco (1969)) which are known for their large blue hauyne phenocrysts are 0.3 Ma old (Lietz & Schmincke 1975).

Three spectacular craters in the Calderilla formation (Bandama, Marteles, Calderilla) (Fig. 26) are interpreted as formed by phreatomagmatic explosions (Schmincke *et al.* 1974).

Tenerife

INTRODUCTION

Probably more scientific papers have been written on the geology of Tenerife (Fig. 58) than on any other Canary islands. The three standard monographs are those by Fritsch & Reiss (1867), Hausen (1956), and Fuster *et al.* (1968d) which includes a geologic map at a scale of 1:100000. Jeremine (1933), Smulikowski (1937), and Smulikowski *et al.* (1946) provide petrographic data. The Cañadas and Pico de Teide volcanics were studied in detail recently (Ridley 1970, 1971; Araña 1971; Araña

& Brändle 1970; Brändle 1973). Petrologic data on pyroxenes and plutonic nodules are provided by Borley *et al.* (1971).

MIOCENE BASALTS

Miocene basalts (tableland formation of Hausen 1956; old basaltic series of Fuster *et al.* 1968d, p. 183).

A series of shield-building Miocene to Pliocene basalts and ankaramites crop out in the Anaga (NW) and Teno (W) peninsulas. Lava flows make up much of the unit, though pyroclastics, including formerly buried cinder cones, predominate locally, particularly in the lower part of the series. Some epiclastic bedded sedimentary rocks divide the series locally into a lower and upper subunit. Dikes are abundant, especially in the lower part of the series, generally striking N 60 °E in the Anaga and N 60 °W in the Teno peninsulas. Aphyric trachybasalts of hawaiitic and mugearitic affinities also occur. Chemically these rocks are more mafic and silica-undersaturated than the Miocene basalts on the eastern islands.

Many basalt outcrops in the center of the island (Ladera de Guimar) were correlated by Hausen and Fuster *et al.* with the Anaga and Teno basalts. The correlation was based on the high degree of alteration of all rocks of this unit. However, while rocks from Anaga are around 16 Ma and from Teno around 5–7 Ma old, those from Ladera de Guimar are only around 1–2 Ma old (Abdel-Monem *et al.* 1972), contradicting the earlier correlations.

Some phonolitic intrusives in the Miocene basalts were thought by Hausen (1956) to be differentiates of the basalts while Fuster *et al.* (1968d) consider them to be feeders of the Cañadas rocks.

CAÑADAS VOLCANICS

Cañadas Volcanics (Cañadas series of Fuster *et al.* 1968d, p. 191; Vilaflor Complex of Ridley 1970, 1971).

Unconformably overlying these rocks are the Cañadas Volcanics, separated into a lower and upper Cañadas series (Fuster *et al.* 1968d), although local absence of the unconformity and similarity of rock type makes a distinction difficult. The rocks were emplaced between 2 and 0.6 Ma (Abdel-Monem *et al.* 1972). Table 8 (after Araña 1971, table 1) gives the subdivision of their stratigraphic units.

Table 8. Stratigraphy of Cañadas series (after Araña 1971, table 1)

Stratigraphy units	Rock content	Locality of occurrence
Upper Cañadas Formation	Mafic rocks, predominantly basanites	Well preserved centers in Bandas del Sur. Base of Teide-Pico Viejo complex.
	Third salic episode eutaxites, hauyne phonolites	Roof of eastern wall
	Mafic rocks (trachybasalts, tephrites)	Western sides of Bandas del Sur. Eastern wall. Tigaiga block
Lower Cañadas Formation	Second salic episode, trachytes, nepheline phonolites	Western wall. Montaña Tejina, Tonasoro, Los Andenes, Risco Atravesado etc. Ico and Alto escarpment (Tigaiga)
	Mafic rocks (basalts, trachybasalts, plagioclase basalts)	Barrancos de Ajabo, Erque, Rey, Cuervo, Rio, Magdalena. Base of eastern wall, Boca de Tauce. Acantilado de Tigaiga.
	First salic episode (trachytes, sodalite phonolites)	Base of Macizo de Tigaiga, base of eastern wall, barrancos del Rey, Infierno.

LOWER CAÑADAS SERIES

Lower Cañadas series (Fuster *et al.* 1968d, p. 192)

The Lower Cañadas series includes trachytes, 'mafic' phonolites and trachybasalts, making up the lower part of the large central volcano of Tenerife below Las Cañadas caldera, but some intrusions and a few flows occur in other parts of the island including the intrusive and extrusive phonolites of Anaga and Teno peninsulas. The lower stratigraphic section of Las Cañadas caldera wall (Portillo, Tauce, Tigaiga) belongs to this subunit. The trachytes (in part ignimbrites as at San Juan de Rambla) have phenocrysts of anorthoclase, aegirine-augite and alkali amphibole. The mafic phonolites have anorthoclase, plagioclase, amphibole and sodalitic feldspathoids. The basalts and trachybasalts (the bulk of the series) are similar to the Miocene rocks although chemically they are less mafic and more alkaline.

UPPER CAÑADAS SERIES

Upper Cañadas Series (Fuster *et al.* 1968d, p. 195).

The upper Cañadas Series is about 400 m thick and composed mainly of thick, columnar phonolite lava flows and 'eutaxites', principally visible

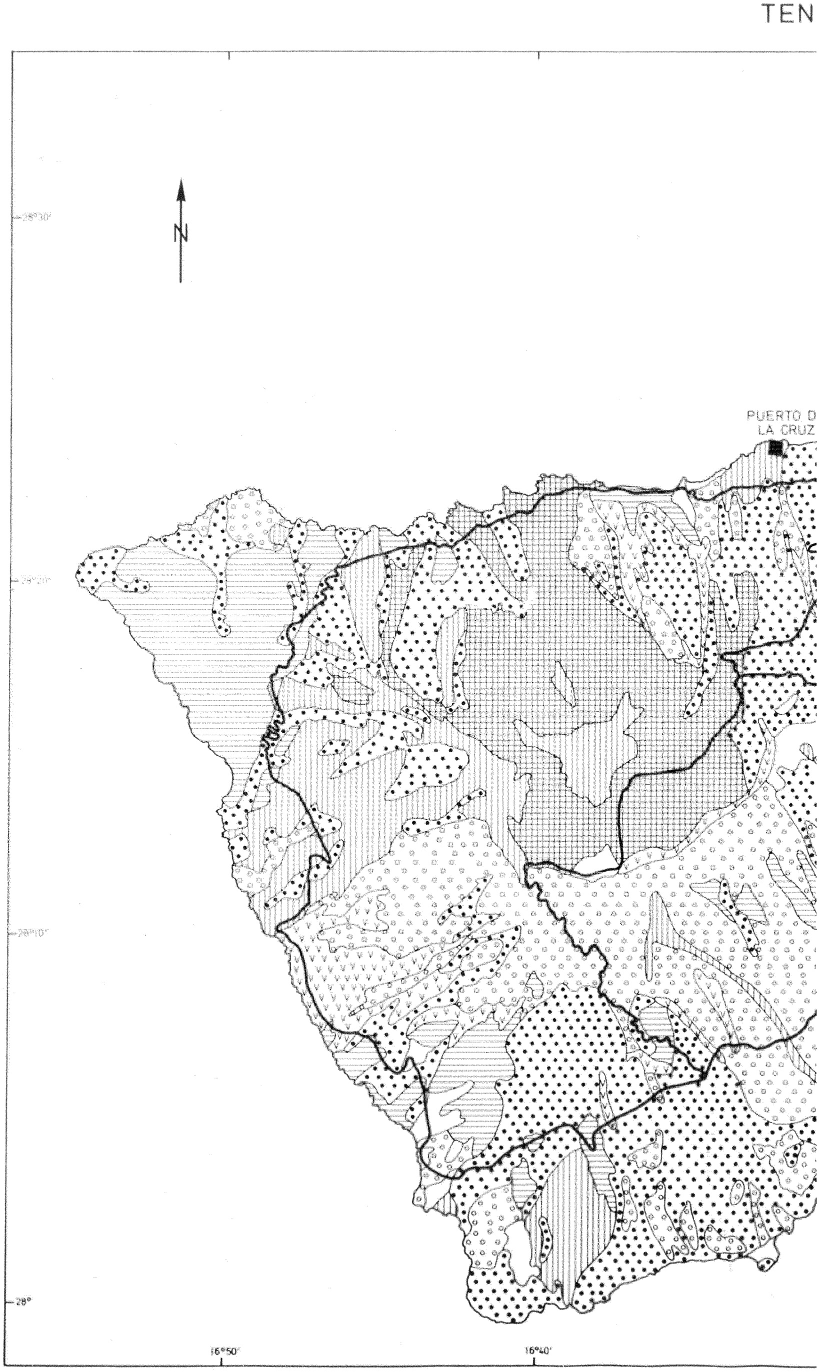
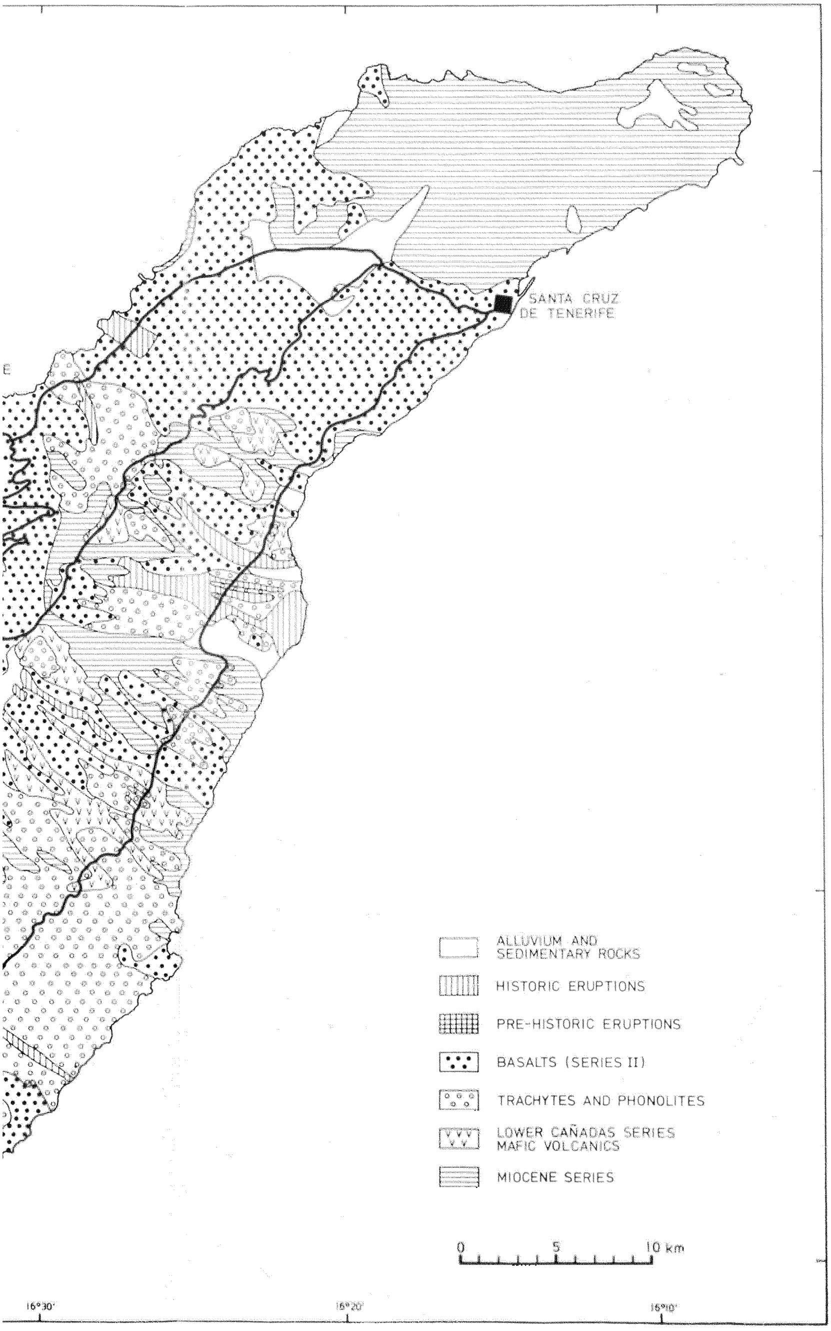


Fig. 58. Geologic map of Tenerife. Highly simplified after Fuster et al. (1968d)

ERIFE


SANTA CRUZ DE TENERIFE
E
ALLUVIUM AND SEDIMENTARY ROCKS
HISTORIC ERUPTIONS
PRE-HISTORIC ERUPTIONS
BASALTS (SERIES II)
TRACHYTES AND PHONOLITES
LOWER CAÑADAS SERIES MAFIC VOLCANICS
MIOCENE SERIES
0
5
10 km
16°30'
16°20'
16°10'

).

in the upper scarps of Las Cañadas caldera wall, with minor intercalated trachybasalts and pumice flow deposits (Fig. 62). The most famous and controversial rocks of this unit are the 'eutaxites'. They were first described by Fritsch & Reiss (1867) who recognized their pyroclastic character as well as the emplacement by flowage. On the basis of the excellent description of these rocks by Fritsch & Reiss, Smith (1960) recognized that the eutaxites resembled rocks now called welded tuffs or ignimbrites, i.e. rocks formed deposits of hot pyroclastic flows. Schmincke & Swanson (1967b) showed that the eutaxites of Fritsch & Reiss comprised both ignimbrites (e.g. at Arico and San Juan de la Rambla) and brecciated lava flows, such as the Cañadas 'eutaxites'. These Cañadas rocks (Ridley 1967, 1971) seem to be ignimbrite-like rocks at the base grading upward into 'homogeneous' columnar, platy, phonolite lava flows. Possibly these are formed by one type of eruptive mechanism (suspension flow or fire fountain) being gradually succeeded by another (continuous outflow of lava).

More common than nepheline phonolites are hauyne phonolites with phenocrysts of anorthoclase, aegirine-augite, a little amphibole and a sodalitic feldspathoid. The phonolites are perhaps the most exhaustively chemically analyzed Canarian rocks showing (partly peralkaline) phonolitic composition with transitions to trachytes.

Between this and the next unit of young basalts is a unit of trachytes and trachybasalts, which are between 0.6 and 0.2 Ma old (Abdel-Monem *et al.* 1972).

YOUNG BASALTS

Young basalts (Basaltic series III of Fuster *et al.* 1968d, p. 203).

These thin, fresh basalt flows, fresh pyroclastics and well preserved cinder cones cover much of the present island outside of the interior of the caldera and the peninsulas. Olivine-clinopyroxene-phyric (in varying proportions) basalts dominate with a few aphyric trachybasalts. Most rocks have more than 10% normative ne and are basanites or ankaramites.

The Cañadas caldera probably formed shortly after the first lavas of the above unit were emitted (Fuster *et al.* 1968d) because the lowermost flows overlie those of the upper Cañadas series in the caldera wall (Fig. 61).

CAÑADAS CALDERA

The Cañadas caldera is one of the most impressive geomorphic-volcanic features on the Canary Islands. From its floor at about 2000 m rise the Pico de Viejo (3103 m) (Fig. 15) and Pico de Teide (3718 m) (Fig. 59) whose pyroclastics and lavas have covered much of the caldera floor. Only the southern half of the caldera which actually consists of two

Fig. 59. Pico de Teide (3718 m), draped by dark phonolite lava flows, rising from flat bottom of Cañadas Caldera (ca. 2000 m) (Tenerife).

Fig. 60. South wall of Caldera de las Cañadas as seen from Pico de Teide (Tenerife).

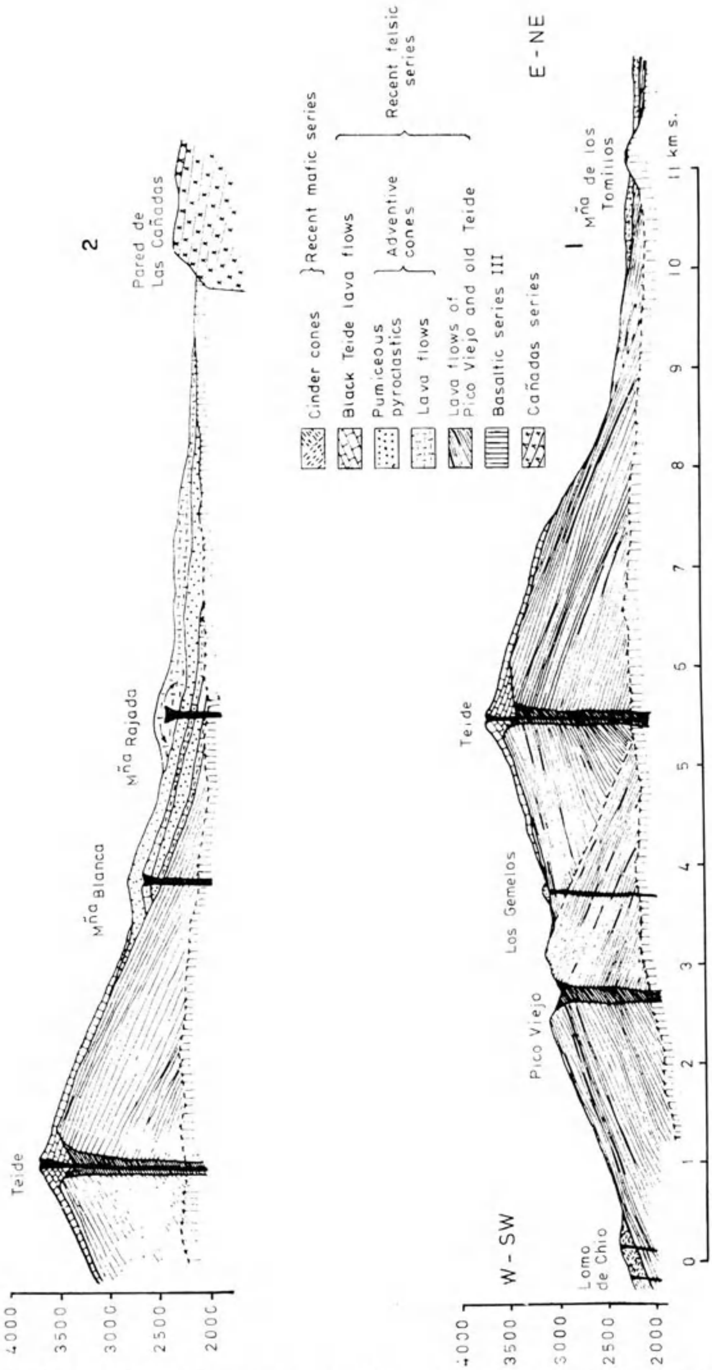


Fig. 61. Geologic sections through Pico de Teide Complex (Tenerife) (Modified from Fuster et al. 1968d, Fig. 75).

basins is preserved (Fig. 60). The origin of this double caldera has been much debated in the past (Hausen 1961; Fuster *et al.* 1968d). 'Caldera' in its strict volcanological sense means collapse of an unsupported volcano roof due to copious eruptions or magma withdrawal at depth. Large-scale Plinian eruptions producing the Granadilla Pumice deposit may have been the reason for this collapse (Hausen 1961; Booth 1973); northward landsliding later modified the caldera wall (MacFarlane & Ridley 1968).

Recent intra-caldera volcanism created the two cones of the main Teide volcano and Pico Viejo, and also smaller eruptive centers on their flanks (e.g. Montaña Blanca, Montaña Rajada etc.) and finally El Pitón which is the cone forming the top of Pico de Teide. The rocks from these eruptions form a continuous series from trachybasalts to phonolites which are generally vitrophyres with phenocrysts of mainly anorthoclase and lesser amounts of aegirine-augite and rare biotite. The trachybasalts have plagioclase, aegirine-augite and amphibole phenocrysts. Chemically these rocks are very rich in alkalis and are highly silica-undersaturated.

Historic eruptions

Historic eruptions (Recent basic series of Fuster *et al.* (1968d, p. 213)).

A number of historic basaltic eruptions occurred on Tenerife (Figs. 64, 65) producing both cinder cones (e.g. in the lower Orotava Valley) and aa lava flows (mainly during the 15th and 18th century, and in 1909). Most basalts are augite- and olivine-phyric; the more common trachybasalts having plagioclase, augite and amphibole phenocrysts. The trachybasalts are unusually rich in alkalis.

Pyroclastic flow and fall products

Pyroclastic flow and fall products (Pumice deposits of Fuster *et al.* 1968d, p. 216).

Pumice-rich deposits cover much of the southern lowlands of Tenerife but occur also at high elevations (e.g. Cañadas caldera). Stratigraphically they seem to belong to several units (Fuster *et al.* 1968d). Apart from bedded air fall tuffs (Fig. 24), some of which carry abundant accretionary lapilli (Fig. 63), there are several kinds of pyroclastic flow deposits. Some are clearly associated with ignimbrites; these are poorly welded or un-welded but are cemented by secondary minerals. The most abundant type in the Bandas del Sur appears to be produced by pumice flows; they are thoroughly zeolitized. Some of these are up to 20 m thick cooling units (unwelded) composed of several flow units which may be less than 1 m thick and may show excellent reverse grading (dense small rock fragments at the base; large pumice clasts at the top) (Fig. 17).

Fig. 62. Phonolitic ash flow tuff (light colored) overlying basaltic lapilli (black) in east wall of Caldera de Las Cañadas (Tenerife).

Spectacular road cuts between Adeje and Los Cristianos show air fall tuffs (Fig. 24) against which bank pumice breccias rich in rock fragments (lahars). Booth (1973) has studied air fall pumice deposits in detail.

La Gomera

The island has an area of 380 km^2 and its elevation is about 4000 m above sea bottom and 1487 m above sea level. The main geologic studies on La Gomera are by Navarro (1918), Gagel (1925), Jeremine (1935), Hausen (1965, 1971) Bravo (1964a, b – including a colored geologic map), and Cendrero (1967, 1970, 1971); the papers by the latter two authors provide most information.

BASAL COMPLEX

The basal complex in the northern part of the island, around Vallehermoso, – first recognized by Gagel (1925) – is the oldest part of the island. It is made up of plutonic rocks ranging from ultramafics to syenites (the latter with an age of about 15 Ma – Abdel-Monem *et al.*

Fig. 63. Detail of Fig. 24 showing air-fall tuff consisting almost exclusively of accretionary lapilli with coarse-grained core and fine-grained rim.

1971), unconformably overlain by basaltic pillow lavas of probable marine origin, and associated quartz-bearing sedimentary rocks (Fig. 66). All these rocks are cut by a very dense dike swarm which constitutes the bulk of the basal complex. This complex has been studied in most detail by Cendrero (1970, 1971) who, like Gagel (1925), noted many similarities to the basal complexes of Fuerteventura and La Palma. Dikes of the swarm strike predominantly close to EW with NE/SW orientations being prominent in the NE (Cendrero 1970, Fig. 6).

Cendrero (1970, p. 558) postulates a complex history: slow crystallization of alkalic basaltic melts in large magma chambers situated in the crust or upper mantle, followed by uplift, erosion, and later sinking – all this assigned to pre-lower Cretaceous time (for which there is no evidence). After depositions of the quartz-bearing sediments, on top of this series, the whole assemblage was uplifted again, eroded, and intruded by a dike swarm. After long erosional activity, several other volcanic units were erupted. Hausen (1971, p. 5), on the other hand, believes the pillow basalts to be host to the plutonic intrusive rocks. Many of the basement rocks are deeply weathered (Gagel 1925; Müller 1930).

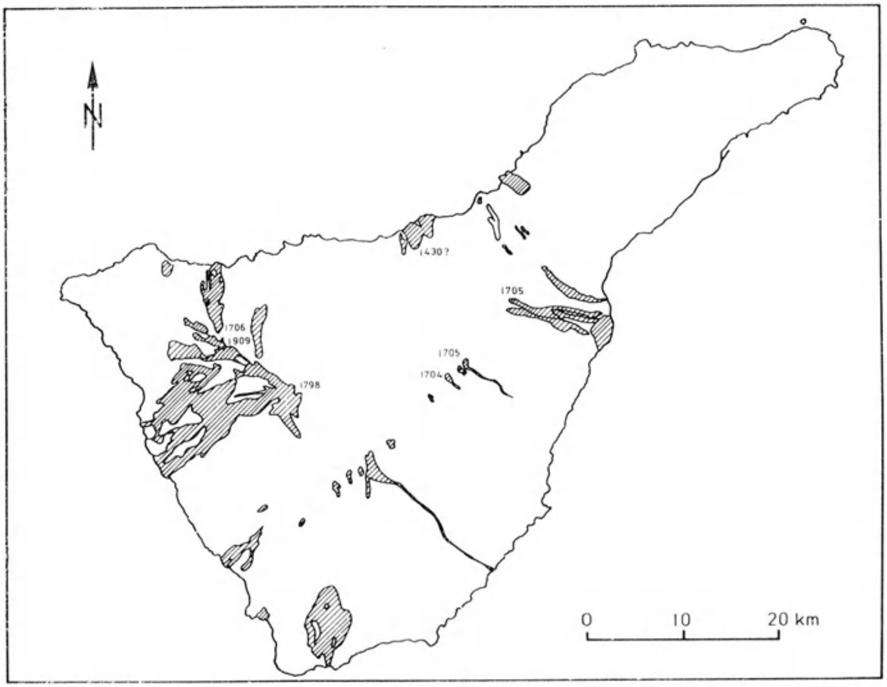


Fig. 64. Areal distribution of Recent lava flows on Tenerife (from Fuster et al. 1968d, Fig. 97).

TRACHYTE-PHONOLITE SERIES

Trachytic and phonolitic intrusions, flows, and breccias (mostly of nepheline phonolite composition) cover an area of about 12 km^2 near Vallehermoso (Cendrero 1970). They are cut by trachytic-phonolitic and basaltic dikes.

OLD BASALTIC SERIES

Old basaltic series (basaltos antiguos of Bravo 1964a)

This series is made up of three subunits (Cendrero 1970): (a) lower, highly altered, generally olivine and clinopyroxene phyric, some plagioclase phyric basaltic flows with 250 m thickness separated by an unconformity from (b) basaltic 'agglomerates' being 150 m thick, also much altered, overlain by (c) 500 m of upper old basalts. Abdel-Monem *et al.* (1971) determined ages as 11–12 Ma and 8.4–8.8 Ma.

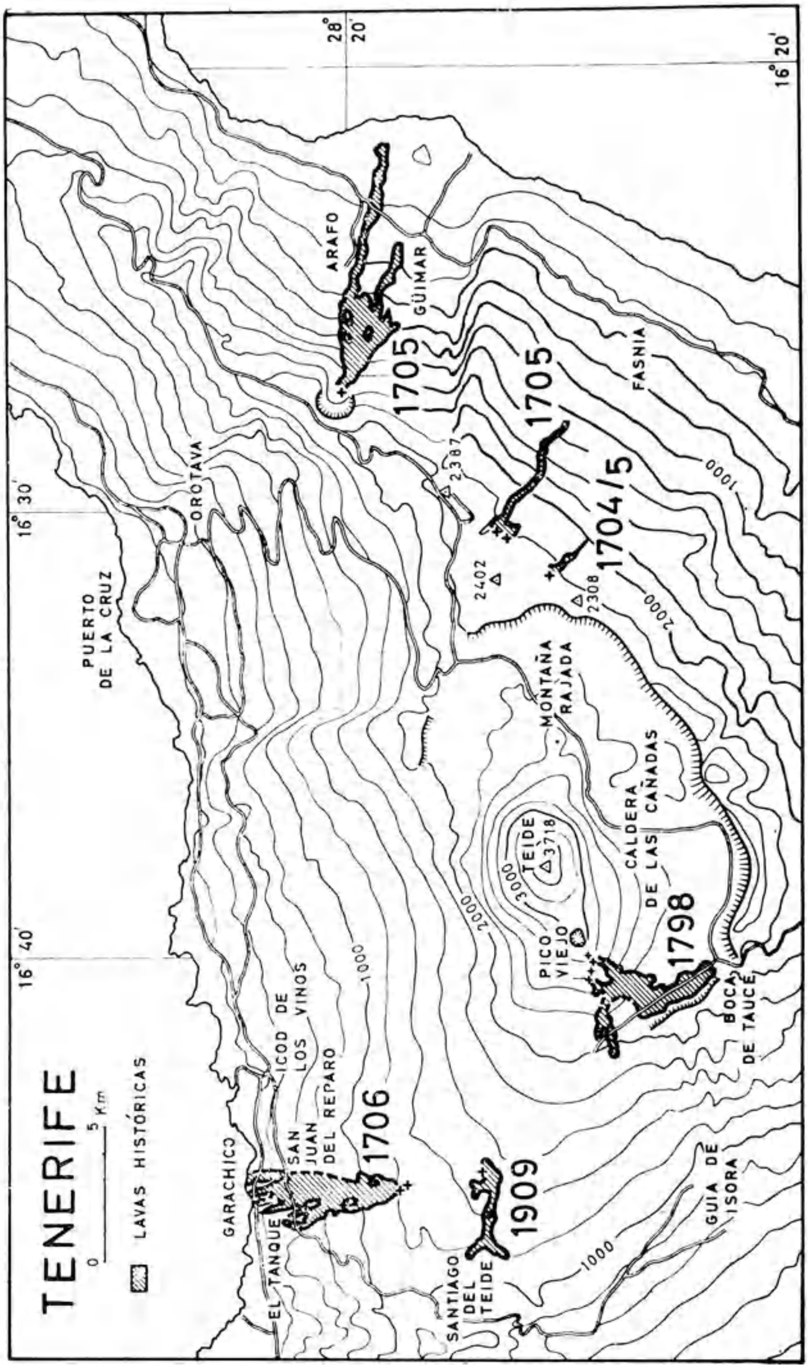


Fig. 65. Detailed map showing locations of historic eruptions on Tenerife (from Machado 1964, Fig. 2).

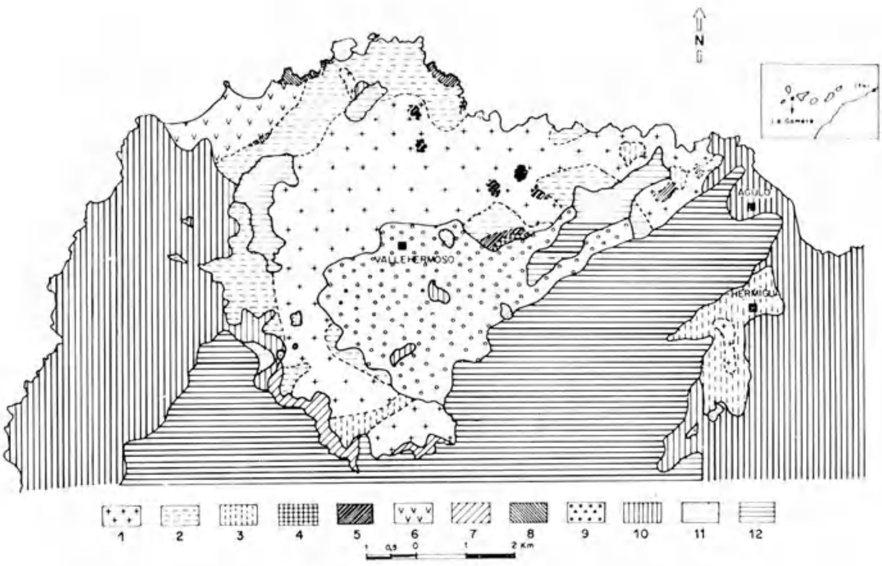


Fig. 66. Geologic map of northern part of La Gomera. Legend: 1. Olivine gabbros; 2. Wehrlites; 3. Gabbros; 4. Syenites; 5. Zones of alkalinization; 6. Submarine volcanics; 7. Marine sedimentary rocks; 8. Volcanics of uncertain stratigraphic position; 9. Trachytic-phonolitic series; 10. Old basalts; 11. Roque series; 12. Subrecent basalts. Covering Quaternary sediments are not shown. From Cendrero (1971, Fig. 1).

ROQUE SERIES

Phonolitic and trachytic subvolcanic intrusives were emplaced after the old basalts but in part during emission of the later flows. These rocks occur predominantly in the SE of the island and were studied in most detail by Bravo (1964). Most are nepheline phonolites but a few are hauyne-bearing (Jeremine 1935).

HORIZONTAL AND SUBRECENT BASALTS

These two basaltic series (Bravo 1964a, b) separated by a pronounced unconformity from the older rocks were called collectively 'subrecent basalts' by Cendrero (1970) although absolute age determinations (Abdel-Monem *et al.* 1971) giving ages of 5.2 and 4.7 Ma showing that at least some of these flows are early Pliocene in age. Petrographic descriptions by Bravo (1964b) show that most flows are aphyric to slightly porphyritic rocks with plagioclase predominating and with trachytic texture. Thus, the 'horizontal' basalts – a series about 1000 m thick – may be mostly hawaiites and mugearites.

The 'subrecent' basalts of Bravo (1964a, b) are, again, more clinopyroxene- and olivine phyric.

La Palma

INTRODUCTION

La Palma has an area of 730 km^2 and rises 3500 m above the sea floor and 2423 m above sea level. The least known of the larger islands is famous chiefly because of its gigantic Taburiente Caldera which is the type caldera (v. Buch 1825; Lyell 1855; Gagel 1908; Reck 1928) (Fig. 69). Ironically, it is generally agreed that it is not, strictly speaking, a volcanic caldera (i.e. neither formed by collapse of the roof nor by explosion) but a giant, vertically walled hollow, carved by erosion, as first proposed by Lyell (1855). Of major interest to geologists are the plutonic rocks at the bottom of the caldera and the pillow lavas (Reiss 1861; Gagel 1908; Gastesi *et al.* 1968; Hernandez-Pacheco 1971) and the historic eruptions, the two latest being in 1949 and 1971 (San Miguel de la Camera & Fuster 1952; San Miguel de la Camera & Bravo 1966; Machado 1963; Chaigneau & Fuster 1972). Hausen (1969) presents a small geologic map, a review of the older literature and a summary of the islands geology, as does Middlemost (1970) in lesser detail. Middlemost (1972) presents new, partial chemical analyses of younger rocks.

BASAL COMPLEX

Basal complex (Basement formation of Hausen 1969; Complejo basal of Hernandez-Pacheco 1971; Caldera Floor formation of Middlemost 1972).

The bottom of the Taburiente Caldera is made up of plutonic rocks ranging from ultramafics through alkali gabbros (the dominant rock type) to syenitic rocks, intruded by innumerable dikes of various rock types, chiefly basalt and overlain by breccias (Table 1; Figs. 67, 68).

The caldera is drained to the SW by the largest canyon of the island, Barranco de las Angustias. A series, about 2500 m thick, of pillow lavas, submarine clastic rocks, and dikes is exposed along the canyon walls. These rocks are being studied at present in some detail (Hernandez-Pacheco 1971; Hernandez-Pacheco & Santin 1974; Schmincke & Staudigel 1975, see appendix). These rocks form by far the thickest submarine volcanic series on the Canary Islands, allowing a study of the uplifted submarine flank deposits of a volcanic island. While some earlier authors interpret this series to be younger than the plutonic complex inside the caldera, this seems unlikely because no detritus of plutonic rocks was found in the clastic units of the submarine series. The dikes within the submarine series make up about 1000 m and consist of 3 generations, the oldest (feeder dikes for the submarine volcanics?) dipping 60–70 °WNW, a younger swarm dipping 50–60 °NE, while the youngest (feeder dikes for the Cobertera lavas?) are steep and dip WNW.

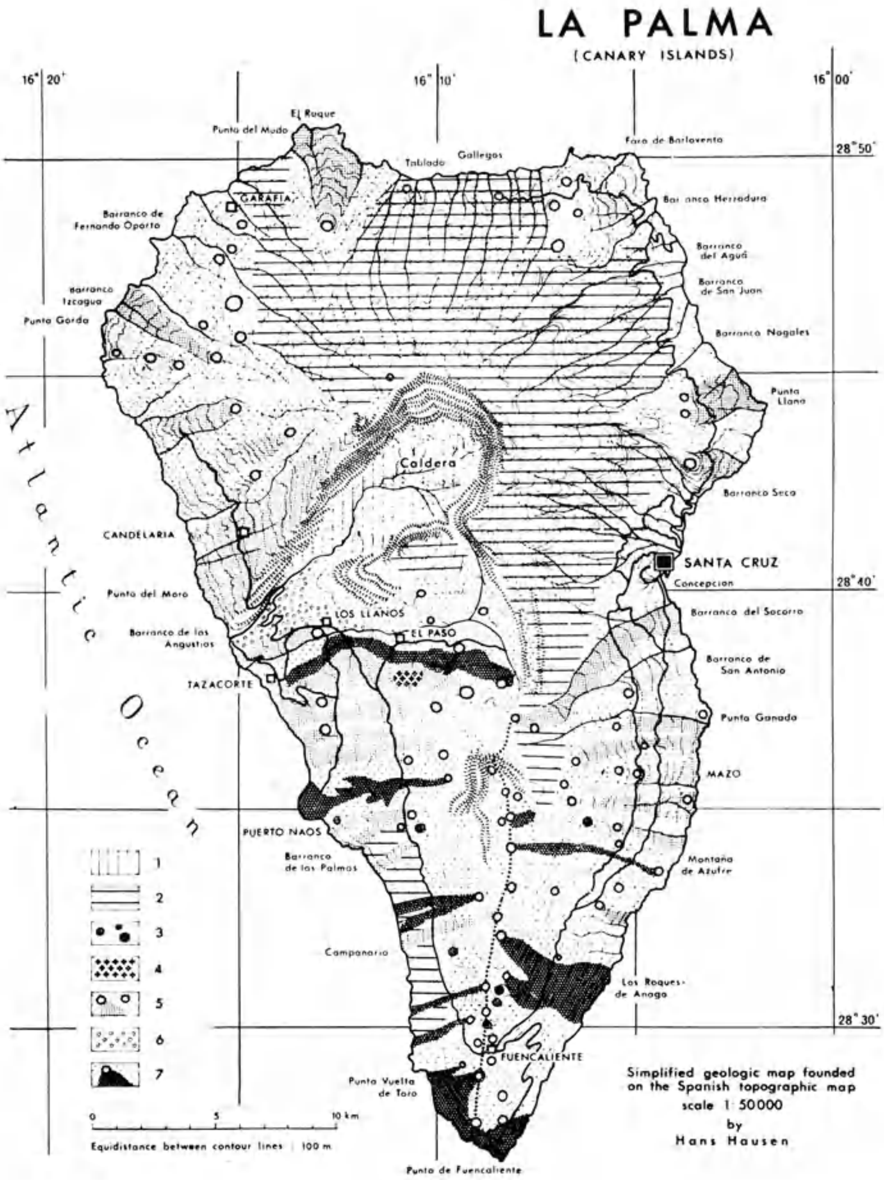


Fig. 67. Geologic map of La Palma. Legend: 1. Basement complex; 2. Cobertera Formation; 3. Phonolites; 4. Alkali trachyte of Monte Enrique (El Paso); 5. Quaternary basaltic cones; 6. Barranco de Angustias clastic sedimentary rocks; 7. Historic lava flows and pyroclastics. From Hausen (1969).

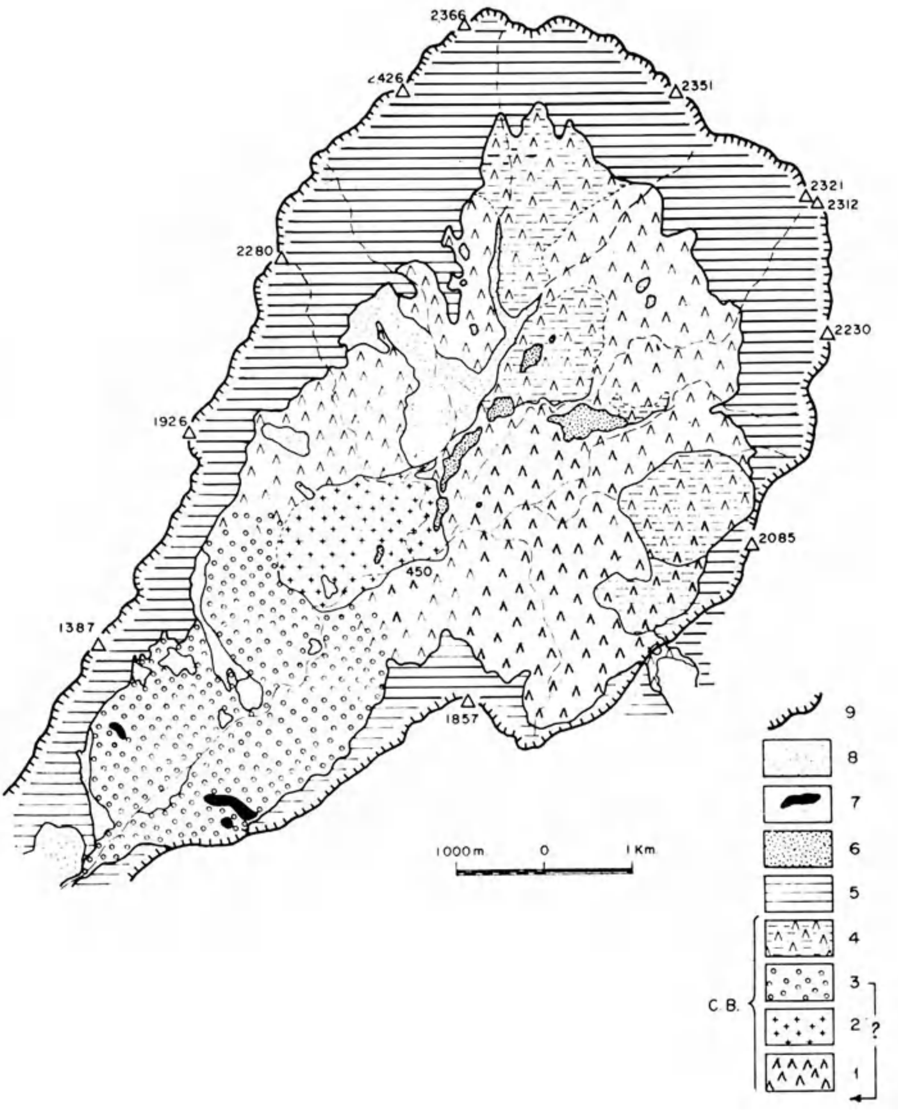


Fig. 68. Geologic map of basal complex in Caldera de Taburiente (La Palma). Legend: 1. Mafic plutonics and basalts; 2. 'Transformed' leucocratic rocks; 3. Partly pillowed submarine lavas; 4. Volcanic-sedimentary agglomerates; 7. Quaternary basaltic eruptive centers; 8. Sedimentary deposits; 9. Caldera wall. From Hernandez-Pacheco (1971, Fig. 1).

The submarine series is layered, dipping WSW up to 50°, possibly indicating later tilting. Pillowed units (Fig. 25a) are generally less than 50 m thick and make up about 60% by volume of the series. They alternate with pillow breccias (Fig. 70) and finer-grained, in part well-

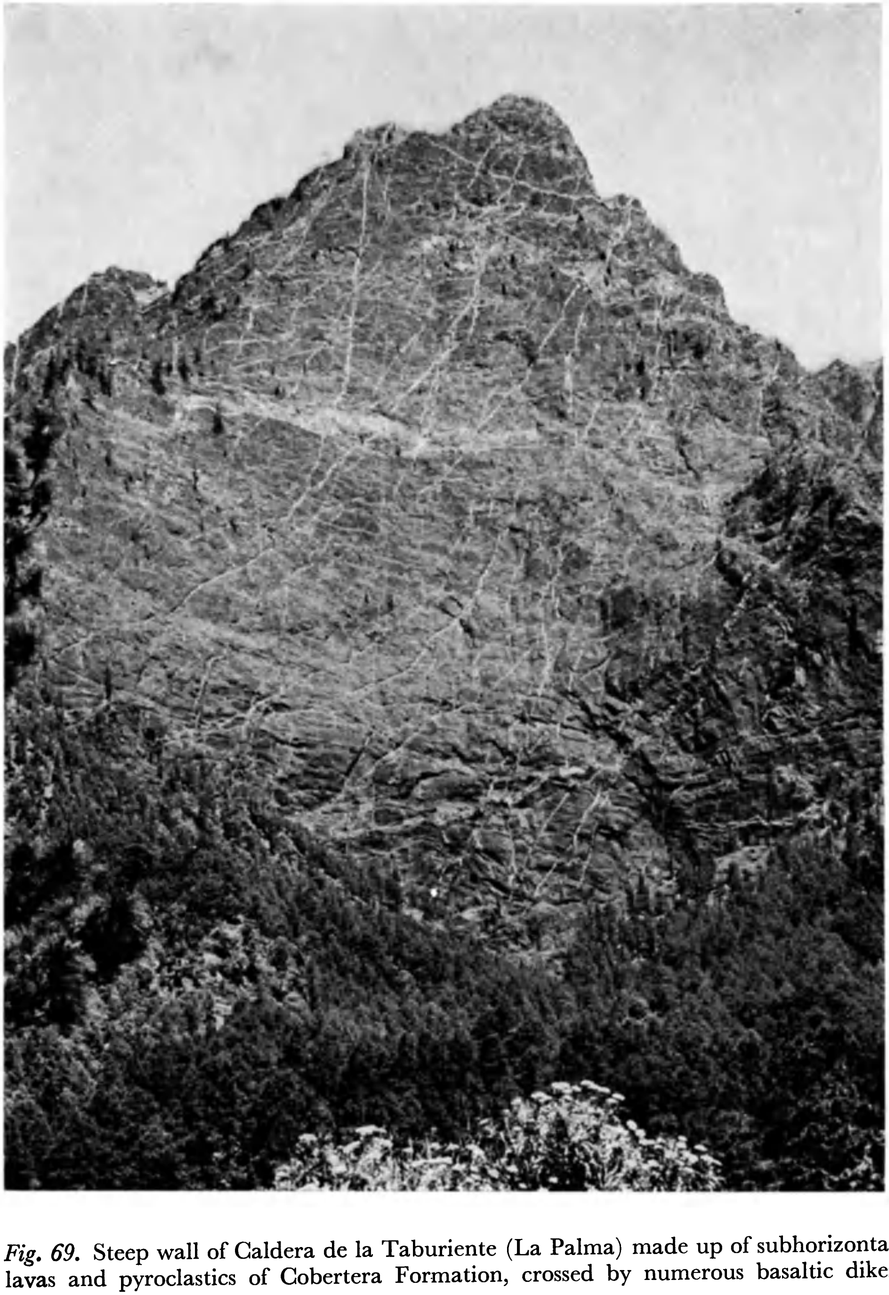


Fig. 69. Steep wall of Caldera de la Taburiente (La Palma) made up of subhorizontal lavas and pyroclastics of Cobertera Formation, crossed by numerous basaltic dikes (light colored).

Fig. 70. Basaltic pillow breccia cut by dikes, central part of Angustias pillow complex. Note paucity of fine-grained matrix and angular shape of pillow fragments. Middle course of Barranco de las Angustias (La Palma).

bedded hyaloclastites. At least 4 petrographically distinct units can be distinguished, which are, from east (the oldest) to west: aphyric trachytes becoming phyric westwards; plagioclase-phyric intermediate volcanics; aphyric mugearites and hawaiites; and, towards the west, in part extremely phyric ankaramites and picrites. Each petrographic group consists of both pillow lavas and clastics and probably also feeder dikes. Most of the series is altered to the greenstone facies, the degree of alteration, as the density of dikes, increasing towards the plutonic caldera complex in the east (Hernandez-Pacheco & Santin 1974). This alteration was the reason for calling the rocks 'diabase' (central European usage) (Reiss 1861).

Except for the youngest clastic rocks, pebbles or other detritus that may indicate near-shore facies are missing. Thus, the entire submarine series was formed before the island of La Palma rose above sea level in this general area, or they represent deep water facies or both. Pillows occur up to an altitude of about 1000 m above sea level, evidence for major uplifting, since eustatic or other sea level changes are unlikely to have been of such magnitude. Hernandez-Pacheco & Santin (1974) report Miocene fossils in this series. Since both uplift and subsequent

Fig. 71. Phreatomagmatic (in part base surge) deposits of 1949 Hoyo Negro eruption (La Palma) (1800 m above sea level) showing several tree trunks *(Pinus canariensis)* buried but not burned by the relatively cool clastic eruptive products. Note good bedding, poor sorting and abundance of angular rock fragments.

erosion occurred prior to eruption of the overlying Pleistocene lavas, structural events that led to the uplift must have taken place between Miocene and early Pleistocene.

LA COBERTERA

(La Cobertera, Hausen 1969; El Time formation, Middlemost, 1970; in part 'series post-complejo basal', Hernandez-Pacheco 1971).

A major erosional unconformity separates the basement complex from an overlying series (about 1000 m thick) consisting of – from the base: thick clastic deposits, picrite and ankaramite lavas, 'agglomerates', and trachybasalts interbedded with abundant pyroclastic rocks. This thick unit makes up the bulk of northern La Palma, the lavas dipping away from the Caldera area. They are also cut by many feeder dikes (Fig. 69) which make up a mere fraction of those in the basement complex. This series also extends under the elongate ridge of southern La Palma although here it is covered mostly by younger basaltic lavas. Dating of flows which probably belong to this series from the mouth of Barranco de Las Angustias yielded ages of 1.0 and 1.6 Ma (Abdel-Monem *et al.* 1972)

PHONOLITE INTRUSIVES

A number of hauyne-bearing phonolitic intrusives and flows (and rare trachytic intrusives and extrusives) are scattered over the southern – and rarely northern – part of the island, some lying along the axis of the southern ridge. They are similar to the hauyne bearing phonolites from Gran Canaria and Tenerife and have been studied by Hausen (1969) and Middlemost (1972). One such intrusion was dated as being 0.6 Ma (Abdel-Monem *et al.* 1972).

BARRANCO DE LAS ANGUSTIAS CLASTICS

The lower course of Barranco de Las Angustias is cut deeply into a thick gravel fan at the base of which Miocene (?) marine fossils occur (Gagel 1908). Most of the conglomerate, however, seems of terrestrial origin, and it contains interbedded un-pillowed basalt flows.[1]

QUATERNARY AND SUBRECENT BASALTS

Much of the southern – and marginally northern – part of the island is covered by basaltic lavas and well-preserved pyroclastic cones. It is partly cut into by barrancos. Most lavas are pyroxene/hornblende-phyric rocks. The morphology and location of most cones were mapped and discussed by Sapper (1906).

HISTORIC ACTIVITY

Subrecent and historic volcanic activity (1585, 1646, 1677, 1712, 1949, 1971) took place principally along the western part of the southern flank, the Cumbre (Fig. 71). Rocks of these eruptions can be recognized by absent or scant vegetation, and well preserved geomorphic forms such as the cinder cones along the coast. Particularly striking are the volcan San Antonio – erupted in 1677 and the cones and flows of the 1971 eruption at the southern tip of the island. The historic eruptions are discussed by San Miguel de la Camara *et al.* (1952, 1966), Machado (1963) and Chaigneau & Fuster (1972).

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[1] The fan consists of at least two major gravel deposits, the younger one of which being cut by the present barranco.

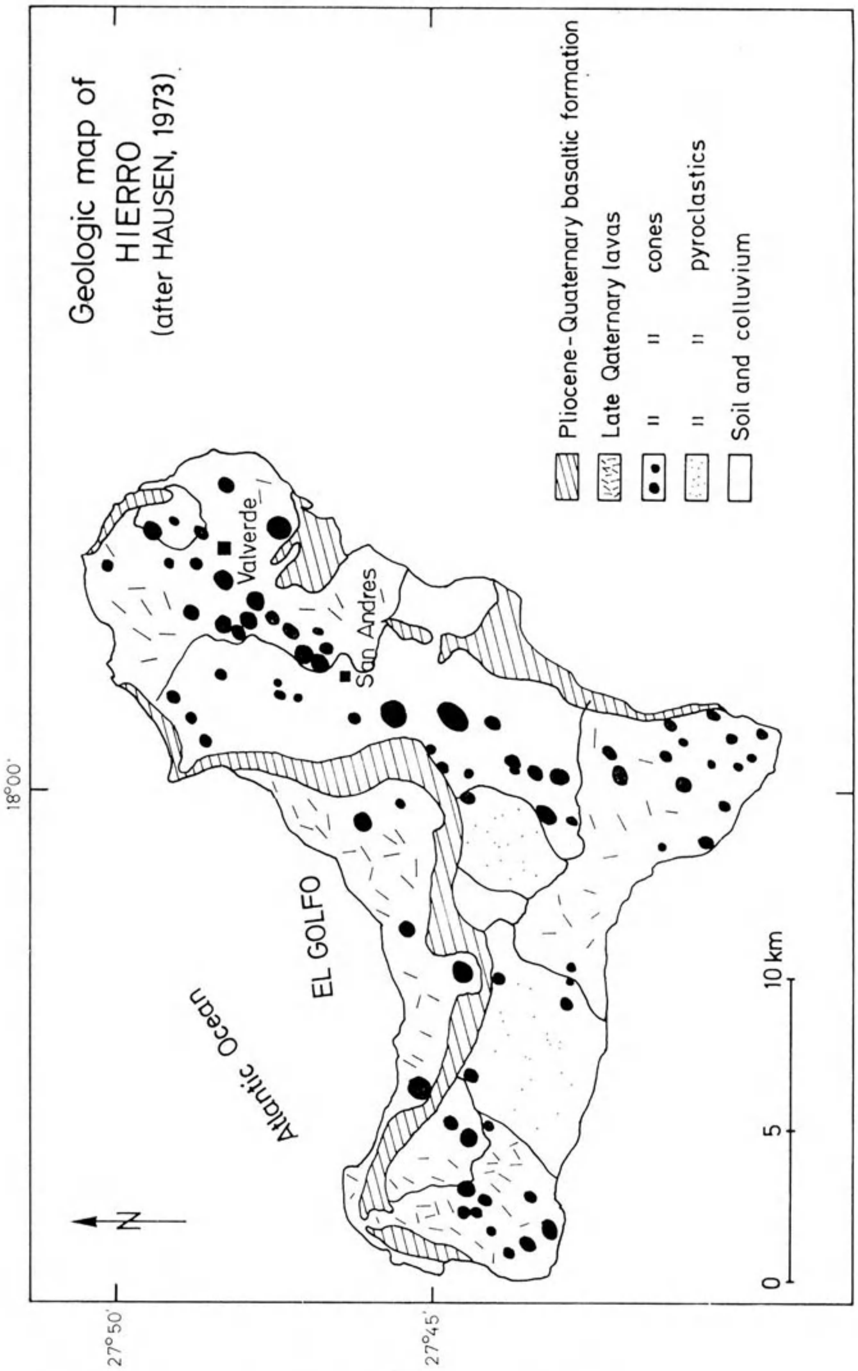

Fig. 72. Simplified geologic map of Hierro. After Hausen (1973).

Hierro

The smallest (278 km^2), westernmost and least-described of the Canary Islands rises more than 3300 m from the sea floor and 1500 m above sea level (Navarro 1908; Jeremine 1935; Hausen 1964; 1973). It consists mainly of two formations (Fig. 72).

The older subhorizontal basaltic formation ('tableland formation' of Hausen 1973) is made up chiefly of olivine-phyric basanites in its lower, basaltic pyroclastics in the middle and olivine/augite-phyric and aphyric alkalic basalts and trachybasalts (hawaiites? and mugearites?) in the upper part, the whole forming a pile over 1000 m thick. Eruption was mainly from dikes. The formation is approximately 3 to 0.2 Ma old (Abdel-Monem *et al.* 1972). Possibly trachyte dikes and lava occur within this formation (Navarro 1908; Hausen 1973).

These rocks are covered by 'basaltic' cinder cones, lava flows and tuffs. One of the youngest eruptions occurred 2900 ± 130 years ago as determined by C^{14} from pine wood overran by lava at Solimán (Hausen 1973, p. 88). Compositionally these Quaternary rocks appear more undersaturated and alkalic than the older ones and some carry amphibole (kaersutite?) in addition to olivine and titanaugite as phenocrysts.

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ADDENDUM

The following papers appeared during 1974/75 after the manuscript was completed. Most of them could not be incorporated into the manuscript.

Hernandez-Pacheco, A. & S. F. Santin 1974. Las Formaciones volcanicas submarinas de la caldera de Taburiente en La Palma (Canarias) y sus transformaciones metasomaticas. Bull. Volcanol. preprint. 1–12.

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The eruption of volcano Teneguia (La Palma) (26.10–18.11 1971) and its products are described in great detail by Professor Fuster and his co-workers in a special volume of Estudios Geológicos (December 1974).

V. CLIMATIC CHARACTERISTICS OF THE CANARY ISLANDS

by

DENNIS FERNANDOPULLÉ

Introduction

The Canarian archipelago, which is situated between 27° 38′ and 29° 25′ N and less than 100 kms off the west coast of the African continent, is characterised by a mild climate due largely to the oceanic influence which alters the proper latitudinal climatic situation.

The north-east trade wind which is the return component of the anti-trades arriving from equatorial regions in fact blows throughout the year. In winter time however, cyclonic influence coming from the Atlantic weather system, often creates unstable conditions which result in generalised bad weather occuring all over the archipelago. Sometimes the tail-ends of depressions occuring in the North Atlantic area affect the islands giving ample precipitation. Hot dry dusty winds coming from the Sahara bring in also spells of dry weather with the characteristic lack of visibility. Hence we can say that the Canary Islands are found on the

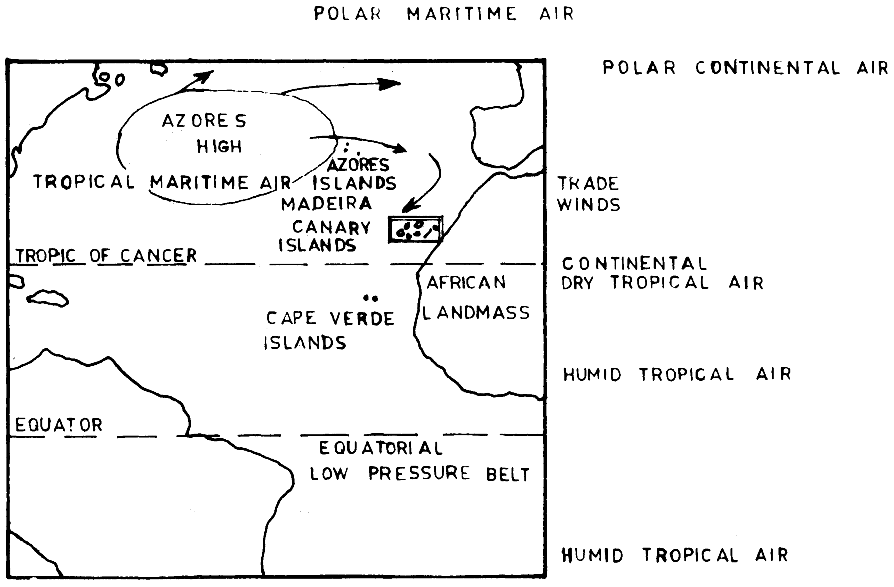

Fig. 1. Situation of the Canary Islands.

cross roads of several weather systems in which the influence of the trades is dominant (See Fig. 1).

This climatological situation results in a scanty and variable annual rainfall even though the trades and associated winds give a seasonal stamp to the winter rainfall regime.

The Canarian Islands are also characterised by temperatures varying between 20 °C and 22 °C. Such cool temperatures much below the normal for their latitudinal position are largely influenced by the cool ocean currents and the cold upwellings occuring off the African coast. The north-east trade winds blowing over the ocean towards the islands are actually cool winds influenced by these cool ocean waters.

Within the general picture, a great variety of climatic situations occur due largely to the distance of the islands off the African coast, altitude control of rainfall, and to exposure differences between southern and northern slopes.

Temperature Conditions

Environmental temperatures over the Canary Islands are conditioned as stated before by cool currents and cold upwelling waters over which the trades blow. However the altitude control of mean temperatures inland is strong.

The daily range in most stations is between 5 °C and 7 °C. Higher extremes are found with altitude and also on the southern slopes. This is explained by the occurence of temperature inversions above 1000 m and frequent windlessness on southern slopes.

MEAN MONTHLY TEMPERATURE

The mean monthly temperature regime of selected stations in the archipelago is given in Fig. 2. In the majority of stations the peak is found in August, and the monthly means vary between 18 °C and 24 °C according to altitude. The lowest monthly mean coincides with January, where the variation is between 5 °C and 18 °C according to the altitudinal position. In winter, during the months of December and January, frost is common over 2000 m. altitude. Snow occurs above this line. Thus over the Teide Volcano, 30–40 cm of snowcap is not uncommon, with a duration of over a month.

ALTITUDE CONTROL OF TEMPERATURE

The altitude control of the mean monthly temperature is shown in Fig. 3. Difference of exposition does not seem to affect mean temperatures, even though it does affect the daily range.

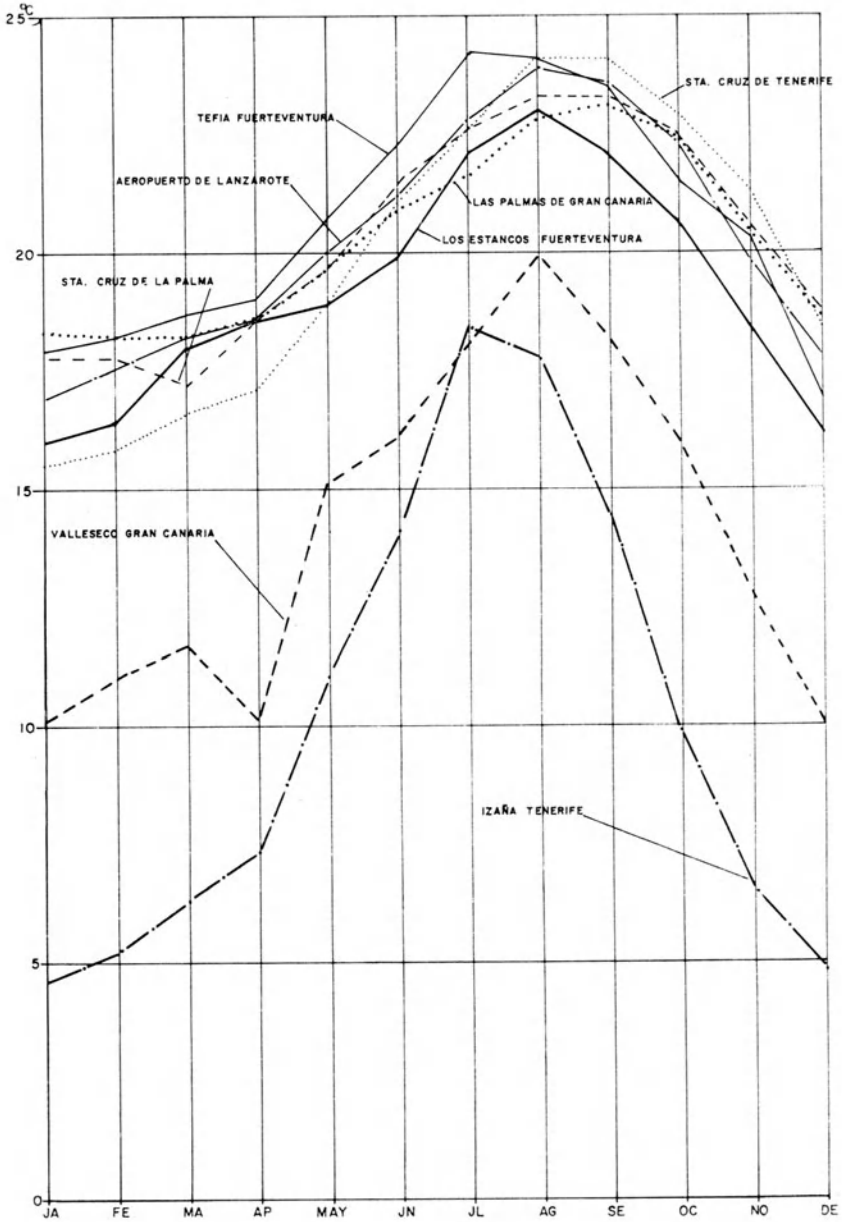

Fig. 2. Mean monthly temperatures 1964/68.

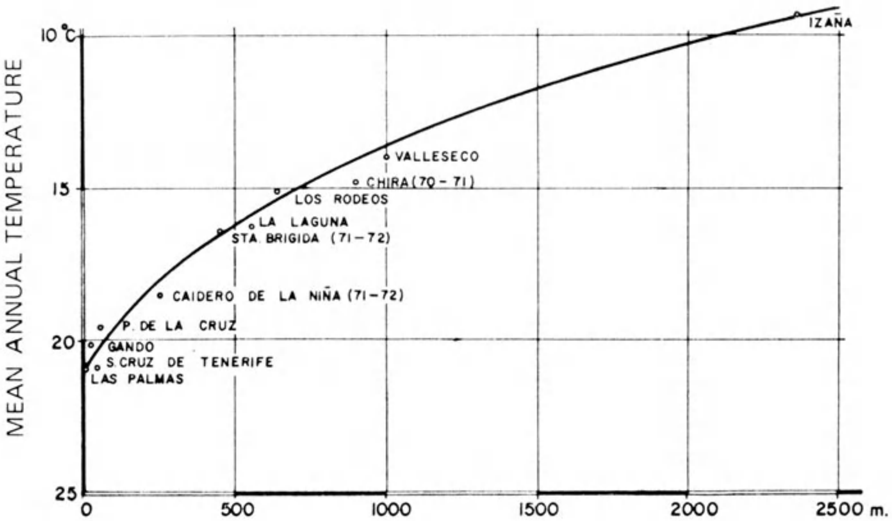

Fig. 3. Altitude-Mean annual temperature relationship.

According to the altitudinal variation of mean monthly temperature we can define the following temperature zones:

7,5° C – – Above altitude 3.200 m (found around Teide Volcano)
7,5° – 10,0 °C – Between 3.200 m and 2.000 m (sub-alpine zone)
10,5° – 12,5 °C – Between 2.000 m and 1.250 m (upper temperate zone)
12,5° – 15,0 °C – Between 1.250 m and 750 m (lower temperate zone)
15,0° – 17,5 °C – Between 750 m and 350 m (sub-temperate zone)
17,5° – 20,0 °C – Between 350 m and 50 m (upper sub-tropical zone)
20,0° – 27,0 °C – Between 50 m and sea-level (lower sub-tropical zone)

Winds, Humidity and Air Masses

WIND DIRECTIONS AND VELOCITIES

The Canarian Archipelago is submitted principally to the trade winds blowing generally from a northern to north-eastern direction. As is shown in Fig. 4, three stations, i.e. Arrecife, Gando and Sta. Cruz de Tenerife, were studied. The geographical situation of these stations greatly affect wind direction as mountain barriers and the shape of the coastline chanalize local wind direction. In this diagram the salient feature is the high frequency (over 50%) of winds arriving from the northern and north-eastern sectors, all components of the north-east trades. These winds also coincide with the highest mean wind speeds

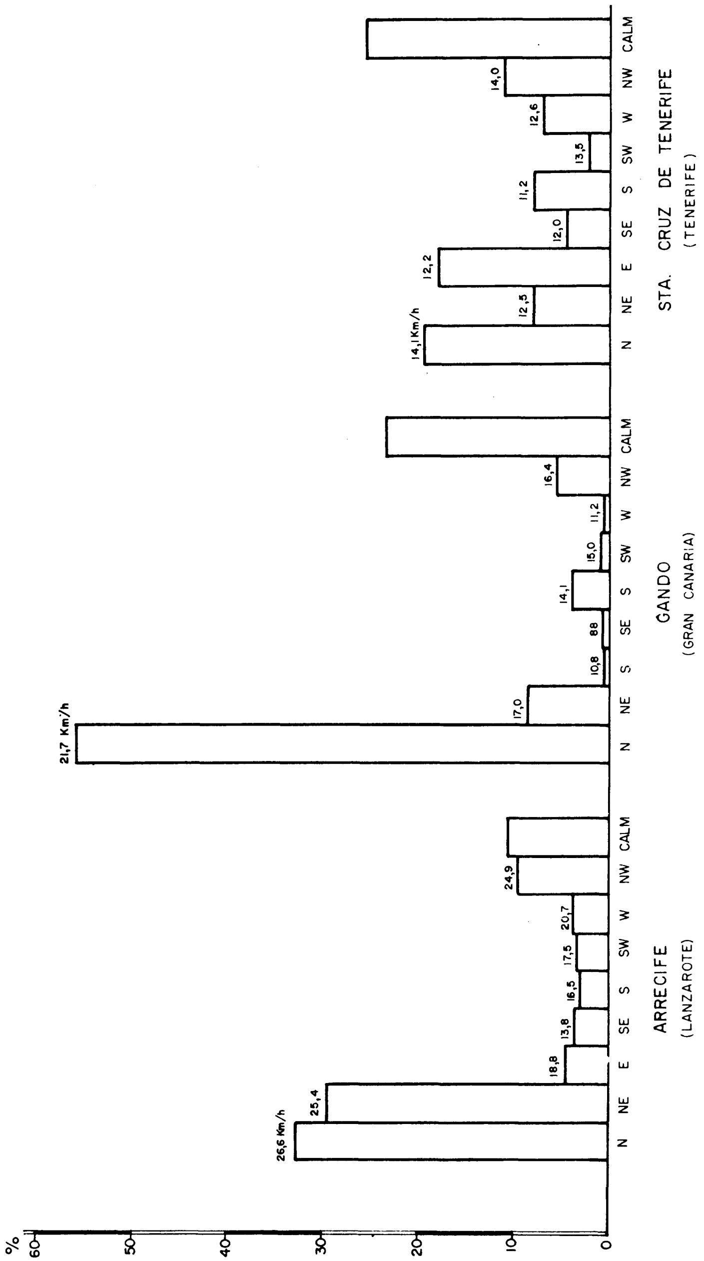

Fig. 4. Average wind direction and velocities (1969/71).

ranging between 27 km/h in the barrierless northern region (Arrecife) to gradually decreasing speeds, 22 km/h in Gando affected by coastal deviation and 14 km/h in Sta. Cruz de Tenerife this latter being on the leeward side of the barrier created by the Anaga Peninsula. There is also a relatively high percentage of calm days (25%) wherever a barrier effect or a coastal shelter is found, as in the case of the two latter stations.

Winds blowing from the N.W., W. and S.W. are related to winter depressions coming over the Atlantic Ocean. On the other hand, anti-trade effects and Sahara winds are related to S., S.E. and sometimes E. Mention must be made of land and sea breezes which occur locally, being the result of the differential heating of land and sea masses.

HUMIDITY CHARACTERISTICS

As is to be expected, there is quite a big variation in the relative humidity of air, both according to season and altitude. In Fig. 5 is shown the relative humidity characteristics and variations of two of the stations studied. The variation of humidity conditions depend mostly on the characteristics of the airmass itself. During the north-east trade wind regime, an important humidity variation is found between the winds blowing nearer the sea surface, and the high winds blowing in the same direction; the same difference being reflected on temperature conditions. The southwestern and northwestern winds connected with cyclones are normally charged with humidity whereas the ones blowing from the Sahara region are dry.

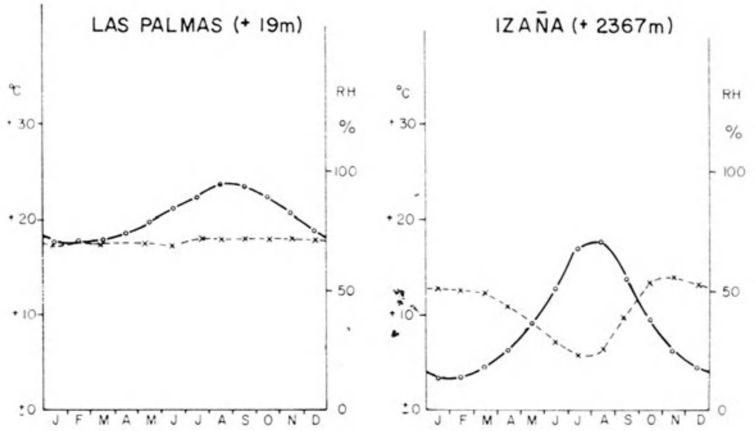

Fig. 5. Average monthly temperature and relative humidity (dotted line) at Izana and Las Palmas. Data from Huetz de Lemps, 1969.

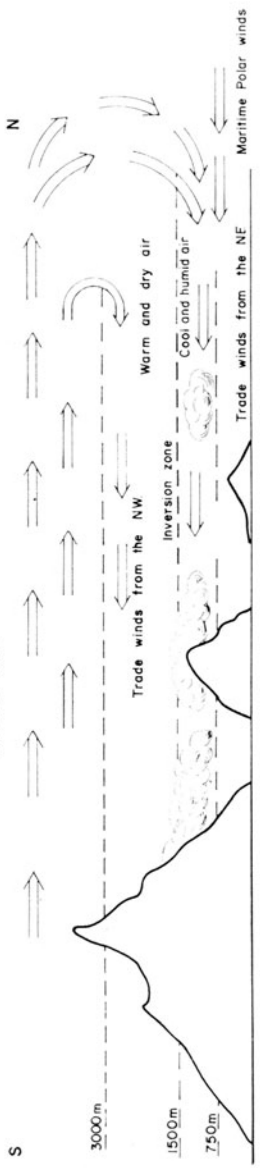

Fig. 6. The system of winds around the Canary Islands and the three types of islands; (after Huetz de Lemps, 1969).

TEMPERATURE INVERSION AND 'CLOUD BANKS'

The principal air masses blowing over the Canary Islands are the ones associated with the Azores anticyclone existing over the North Atlantic region. The outward eastward blowing component acquires a northeasterly direction as it turns towards the south. The lower strata of these trades are generally thin (1000 to 1500 m) and acquires its humidity blowing over the cool ocean waters. The layer is characterised by the formation of extensive strato-cumulus clouds. Between the upper northward blowing hot and dry wind and the lower humidified air there develops a temperature inversion seen often around 1000 m altitude over the higher islands principally in Tenerife and Grand Canary as seen in Fig. 6. However this limit varies according to the season being lower in summer and higher in winter. This is to say that the lower humid layer attains its maximum thickness in winter due to reinforcement by the N-W trade component. During the months of June and July the presence of the 'cloud banks' associated with the lower layer is permanent, on the contrary the frequency of the strato-cumulus layer around the island in November and December is only a little more than 50%. This is due to the disappearance of the trade winds with the arrival of cyclonic air masses from the north Atlantic region.

Local land and sea breezes, however have an effect on the form of the 'cloud banks'. Over the sea the clouds are widespread. Arriving on the windward side, they pile up on the mountain slopes. During mid-day they attain their highest thickness aided by the sea breezes. During the night and towards early morning, the sky clears up as the land breeze blows the strato-cumulus clouds off shore.

On the leeward side the 'cloud banks' are found 10 to 15 km. offshore, the dry winds often being responsible for their disappearance due to the heating effect produced by descent over the dry slopes.

These dry winds blow chiefly from the NW and attain their maximum frequency in early summer but diminish in frequence in the height of summer due to the frequent incursions of dry southern and eastern winds blowing from the Sahara. In summertime, however, there exist also the anti-trades arriving from the southern sector, connected with the upper circulatory system of the North Atlantic system off the African coast.

Cyclonic depressions and precipitations

The normal trade winds are often replaced by cyclonic depressions in winter time. These air masses associated with the North Atlantic weather system bring in frontal influences to the Canarian Archipelago. The air masses affecting the archipelago depend on the position of the Azores high on the Atlantic Ocean. Essentially two positions seem to control the irruption of polar winds towards the southern regions.

In the first case, the Canarian Archipelago is situated in a 'valley' created by the existence of the Azores High in the western part of the North Atlantic while low pressure areas are found over Western Europe. The influx of cold currents arrive over the Archipelago from the north and north-west. The importance of rain depends on the position of the islands in this 'valley', if found on the eastern slope the winds are forced to rise giving precipitation.

In the second case, the archipelago is under the influence of low pressure lying off the Iberian coast and the resulting precipitation is of cyclonic origin. In both cases, the winds are from the N.W. or West.

Sometimes heavy precipitations also occurs when winds arrive from the S.W. bringing in humid tropical maritime air masses. This situation occurs when depressions form South of the Azores islands. In this case the Canarian Archipelago is entirely under its influence. The depressions either move to the north-east, south-east or remain over the region. Generally such depressions have high gradients, with strong winds more than 150 km/h and the isobars are generally aligned south-west to north-east.

The southern slopes get heavy rain as they are reached first by the humid winds. The humid air masses push up in height eliminating the inversion layer and heavy cumulus clouds are formed accompanied by thunder and lighting.

This type of cyclonic weather associated with tropical maritime air masses gives a rain distribution pattern contrary to a depression coming from the north-west, associated with polar maritime air masses.

When maritime air masses are stagnant over the archipelago, the weather is variable with spells of heavy rains followed by clear sunny skies. In most cases, the trajectory of the depressions is from west to east.

Occasionally tropical cyclones may also arrive over the region originating from the Inter-tropical Front existing over the Sudan region in summer. These cyclones occur mostly in late summer or in autumn, and they persue a path east-west at first, then turn N.E. along the African coast. In the Canaries heavy precipitation may occur with an extraordinary development of cumulus and cumulonimbus cloud formations off a temporary 'valley' found over an extensive anticyclone spreading from the Azores to South Europe. Before the development of such disturbances, dry dusty winds blow over the Canaries from the Sahara.

If winter is the principal period of air mass activity producing rain, the summer on the other hand is largely a calm period with the maritime trade winds blowing steadily over the Archipelago originating from the anticyclone over the Azores. However, during the course of the summer months, changes do occur. In the height of summer during July and August, heat waves from the Sahara influence weather conditions over the Canaries up to 20–25% of the time. The influence of the trade is highest in June accounting for about 90% of the time. This influence decreases gradually towards September to 65–70% of the time when winter cyclonic activity begins to appear.

The great contrast in the type of air masses affecting the Canaries explains the rainfall regime as well as its great variability in time. This feature will be analysed in the following section.

Rainfall Regime

Earlier it was pointed out that the main rainbearing air masses and winds arrive from the N, NW, W and SW directions. Those blowing from N and NW directions in fact are the dominant rainbearing winds. In most cases the trade winds get mixed up with the cyclonic winds. It is evident that the polar maritime identifies itself with the trades in winter time. This explains the disappearance of the trades when cyclonic activity is present. These winds bring rainfall either to northern slopes or to the entire island. The western and south western winds affect mostly the southern slopes as said before.

OROGRAPHIC CONTROL OF PRECIPITATION

There is an appreciable difference between southern and northern slopes, as far as precipitation is concerned. The generalised scheme of this contrast is shown in Fig. 7.

Northern slope: a. Up to 500 m of altitude rainfall is produced only by an affluence of cyclonic activity, as the north-east trades generate only thin clouds. b. Between 500 m and 1500 m is a high sloping area with rainfall occuring with the passage of depressions as well as from trades, the latter giving rain due to orographic uplift of the humid winds. Horizontal rainfall, droplet condensation by fog and mist are common forms of precipitation in this zone. In fact it corresponds to the upper humid strata of the trade winds. c. Above 1500 m is the highest zone, normally dry but receiving rainfall with the invasion of polar maritime air.

The southern slopes have only two contrasting zones: a. Up to 750 m there is an arid zone with little precipitation occuring only during downpours originating from southern winds. b. Above 750 m corresponding to a more humid zone receiving rainfall mostly from incursion of depressions arriving from the south and south-west.

The orographic factor seems to control the general distribution of rain in the islands. Thus in Lanzarote, Fuerteventura and the minor islands of Graciosa and Alegranza, the lack of high relief barriers exclude higher mean annual rainfall. These low lying islands remain below the cloud forming zone. The islands of Hierro and Gomera are of medium altitude ($\simeq$ 1000 m) and are in the zone creating 'cloud banks'. In such islands the crests both in the northern and southern slopes are often under cloud cover and fog. The islands of Gran Canaria, Tenerife and La Palma, with relief above 1.500 m form rainfall relief barriers to rainbearing winds and have a clearly defined climatic zonation. The control of mean rainfall by orographic factors can be appreciated in Fig. 8.

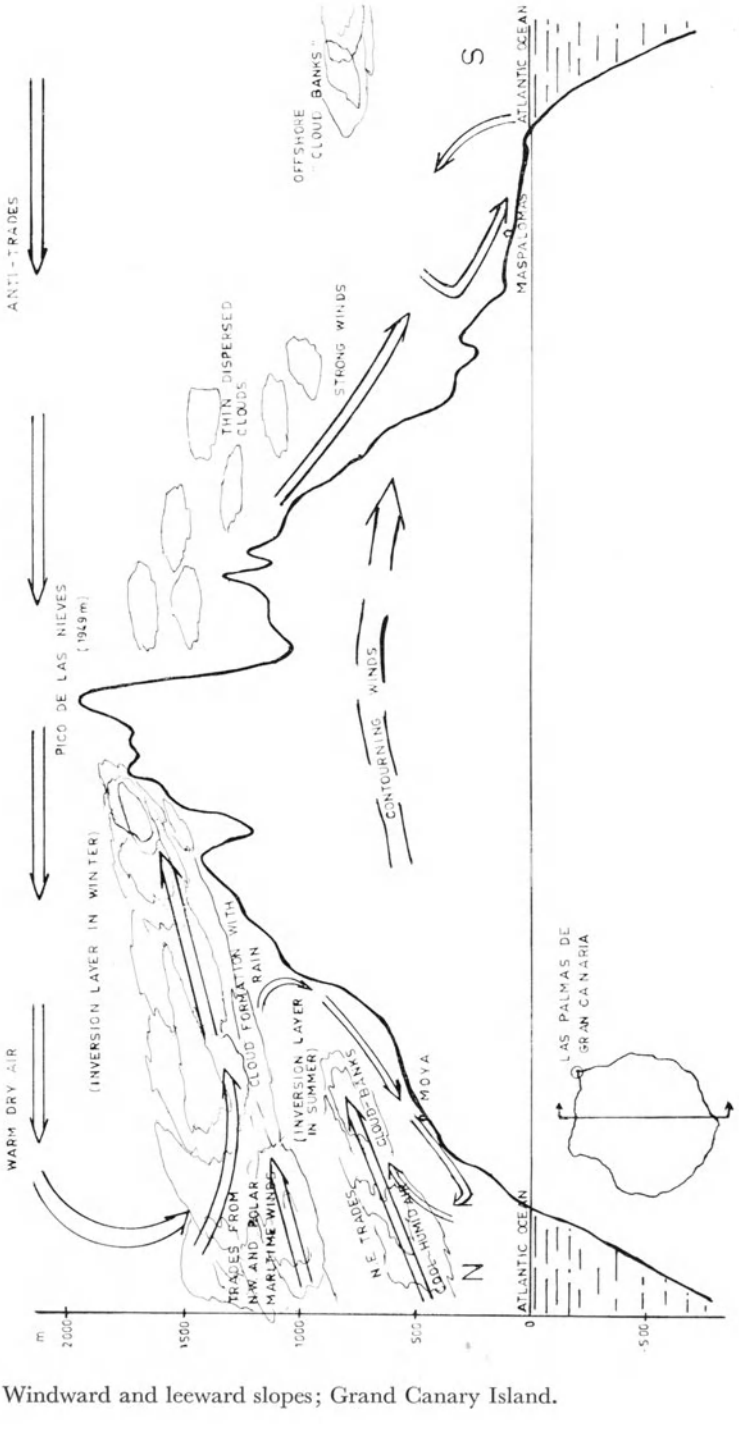

Fig. 7. Windward and leeward slopes; Grand Canary Island.

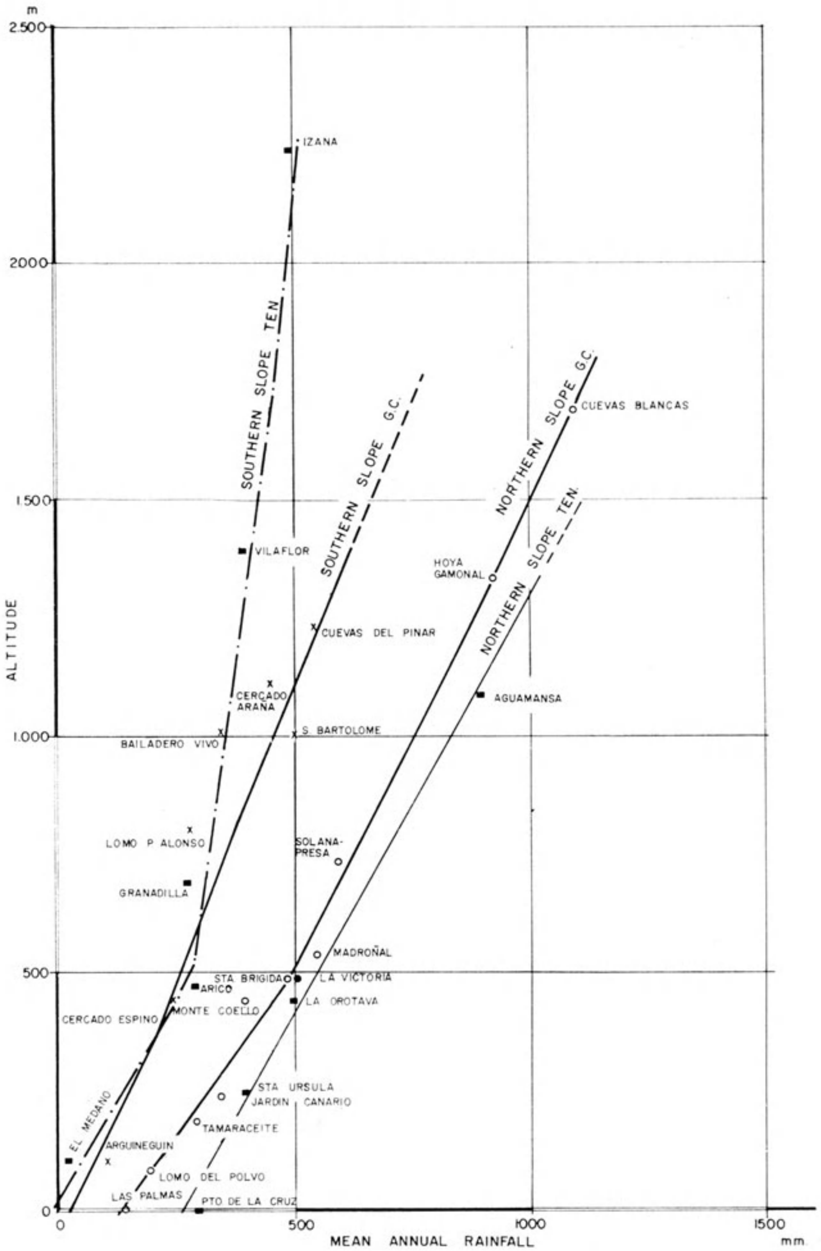

Fig. 8. Orographic control of precipitation; Gran Canaria (mean 1949/50–66/67); Tenerife (mean 1940/41–65/66).

DISTRIBUTION OF RAINFALL

Isohyetal maps compiled for each island for the period 1949–1967 demonstrate the orographic control of rainfall. The northern slopes receive in the major islands between 150 mm to 1.000 mm according to altitude, whereas on the southern slopes the variation is between 50 mm along the coast to about 500 mm on the high slopes.

The mean rainfall of the islands for the period 1949–1967 is calculated as follows:

Lanzarote	135 mm/year
Fuerteventura	147 mm/year
Gran Canaria	325 mm/year
Tenerife	420 mm/year
Hierro	426 mm/year
Gomera	410 mm/year
La Palma	586 mm/year

The islands in the above table are arranged east to west. It is clear that the mean rainfall augments as one goes westward. Thus Lanzarote and Fuerteventura nearer the African coast have a semi-desert climate, whereas the others have a more semi-arid climate. The southern slopes in most cases due to the scarcity of rainfall approach also desertic conditions.

When we study the rhythm of monthly distribution, about 80% of yearly rainfall occurs between October and March and about 60% in December-January. In some stations November is however the highest rainfall month with often a secondary peak in January.

The dry season lasts from May to August even though September could be also dry but July is generally the driest month with no recorded rainfall (See Fig. 9).

STATISTICS OF RAINFALL VARIABILITY

One of the salient features of the Canarian climate is the great variability both spatial and annual, explained by the great range of climatic factors intervening in the region.

In most stations, the totality of the annual precipitation occurs between 10 and 40 days of rainfall. The intensity of rainfall is similar in the northern and southern slopes, but the number of raindays with less intense rainfall is high in the northern slopes. In some of the stations examined with high totals in the upper altitudes, daily intensities varying between 25 to 300 mm/24 h have been registered which indicates that from 25 to 40% of the total yearly rainfall can occur in 24 hours.

As for the variation of the annual rainfall several stations have been examined for the 1949–1967 period and the tendencies are found to be similar. Only very few stations possess records from the early part of this

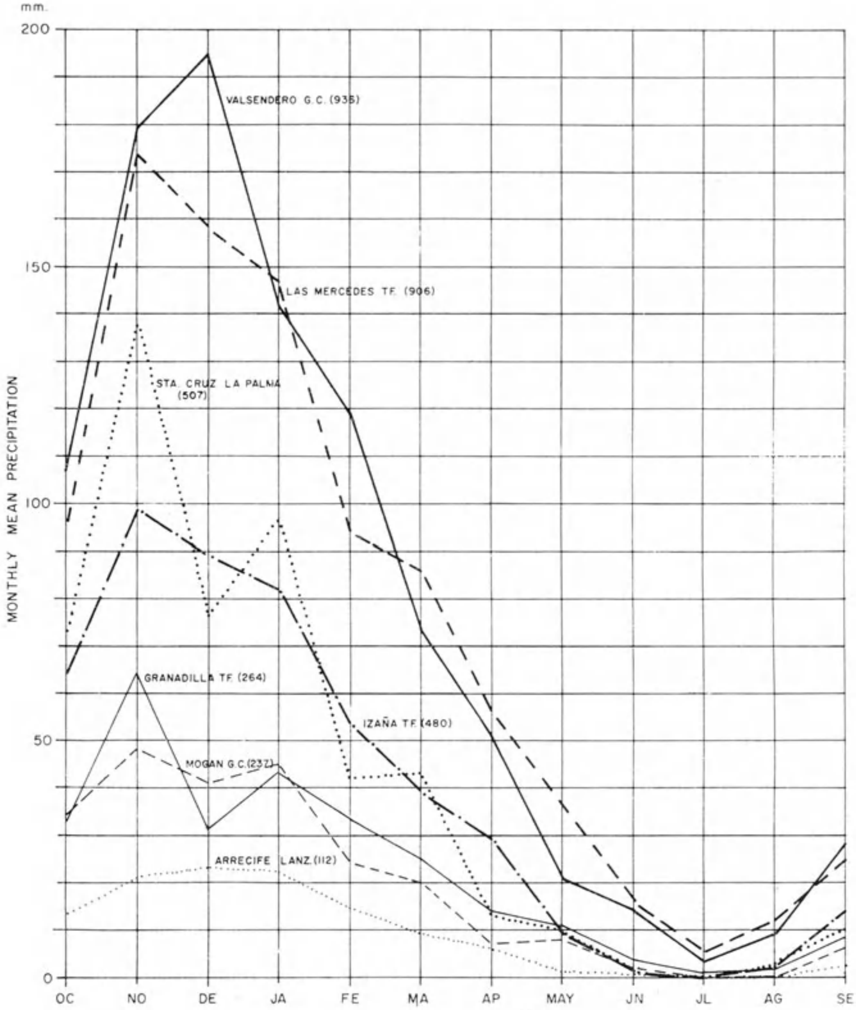

Fig. 9. Mean monthly rainfall (1949/67); Canary Islands.

century of which Hoya del Gamonal in Grand Canary Island is shown in Fig. 10.

A study of the rainfall variation of this station fairly representative of the entire archipelago, shows that from 1925 to 1949 there has been a dry period in the Canary Islands, from 1950 to 1954 there had been a wet period and from 1954 up to now a variable period with a series of dry and wet years. The years 1972 and 1973 were average years.

The long-term annual rainfall record of raingauge stations follow the Gaussian distribution as shown in Fig. 11, at station Tamadaba for the period 1935–1971. If the median rainfall is 560 mm, it increases to 900

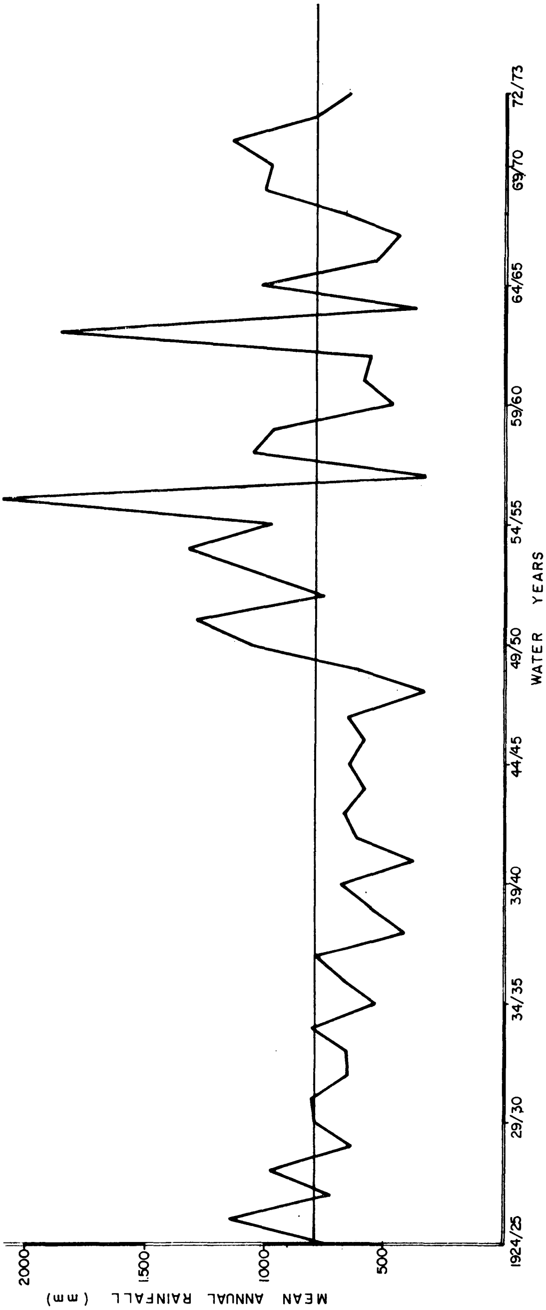

Fig. 10. Mean annual rainfall (1924/25–71/72); Station: Hoya del Gamonal Alt 1370 m.

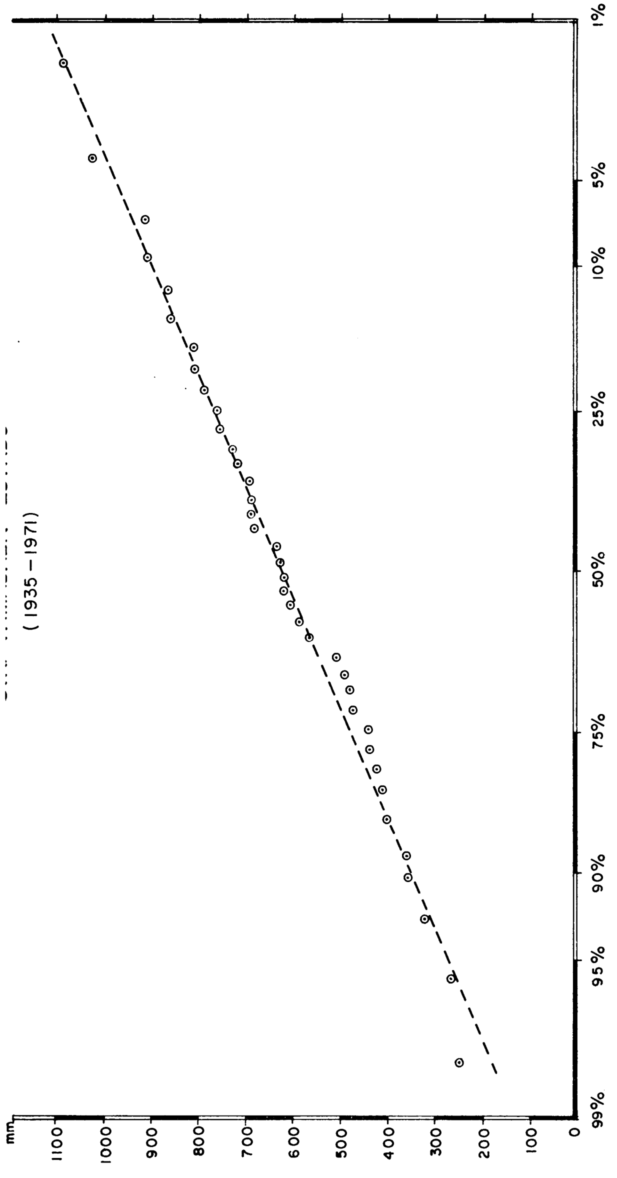

Fig. 11. Frequency distribution at station Tamadaba Estado years 1935/71.

mm for a frequency of 1 in 10 years and to 1.500 mm for 1 in 50 years. Also for 1 in 10 years in the dry phase the rainfall decreases to 350 mm and to 200 mm for 1 in 50 years. The rapid increase and decrease in wet and dry years respectively demonstrate the great variability of the pluriannual tendencies of the Canarian climate.

This factor also indicates that the mean annual rainfall on a short-term record is very deceptive. Thus for the Grand Canary island, the mean for 1949–1971 is about 326 mm, but if we extrapolate for the period from 1924 to the present day, through correlation with long term records of the available stations, the mean rainfall can be estimated to be about 290 mm only.

Other Climatic Features

Besides rainfall, temperature, humidity and winds, some idea of sunshine and evaporation can be obtained from the scanty data available.

SUNSHINE

The monthly distribution of sunlight hours for Las Palmas and Gando in Grand Canary Island, is compared with the theoretical data for latitude 28 ° N in Fig. 12. This seems to indicate that in the northern slopes as represented by Las Palmas, sunshine hours decrease due to cloudiness in summer time related to the lower humidified trade wind layer, and in autumm time with the increasing influence of the Atlantic system, sunshine increases as a result of the disappearance of this cloud layer. In the southern slopes the sunshine hours generally coincide with the theoretical figures.

EVAPOTRANSPIRATION

A comparative study from evaporation (Class A type) for northern and southern slopes of Gran Canaria is shown in Fig. 13. The tendencies are

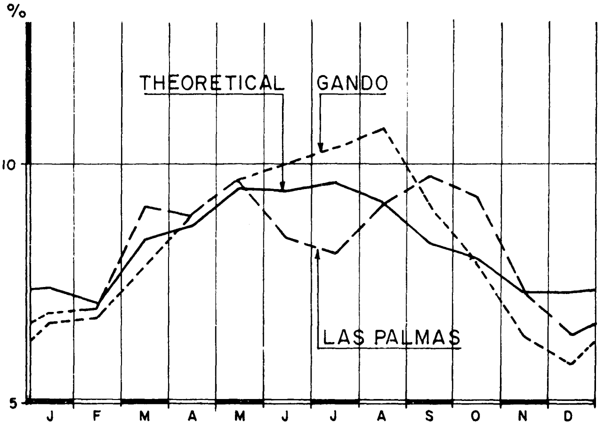

Fig. 12. Monthly distribution of sunlight hours for 2 stations in Gran Canaria and theoretical data for latitude 28 °N.

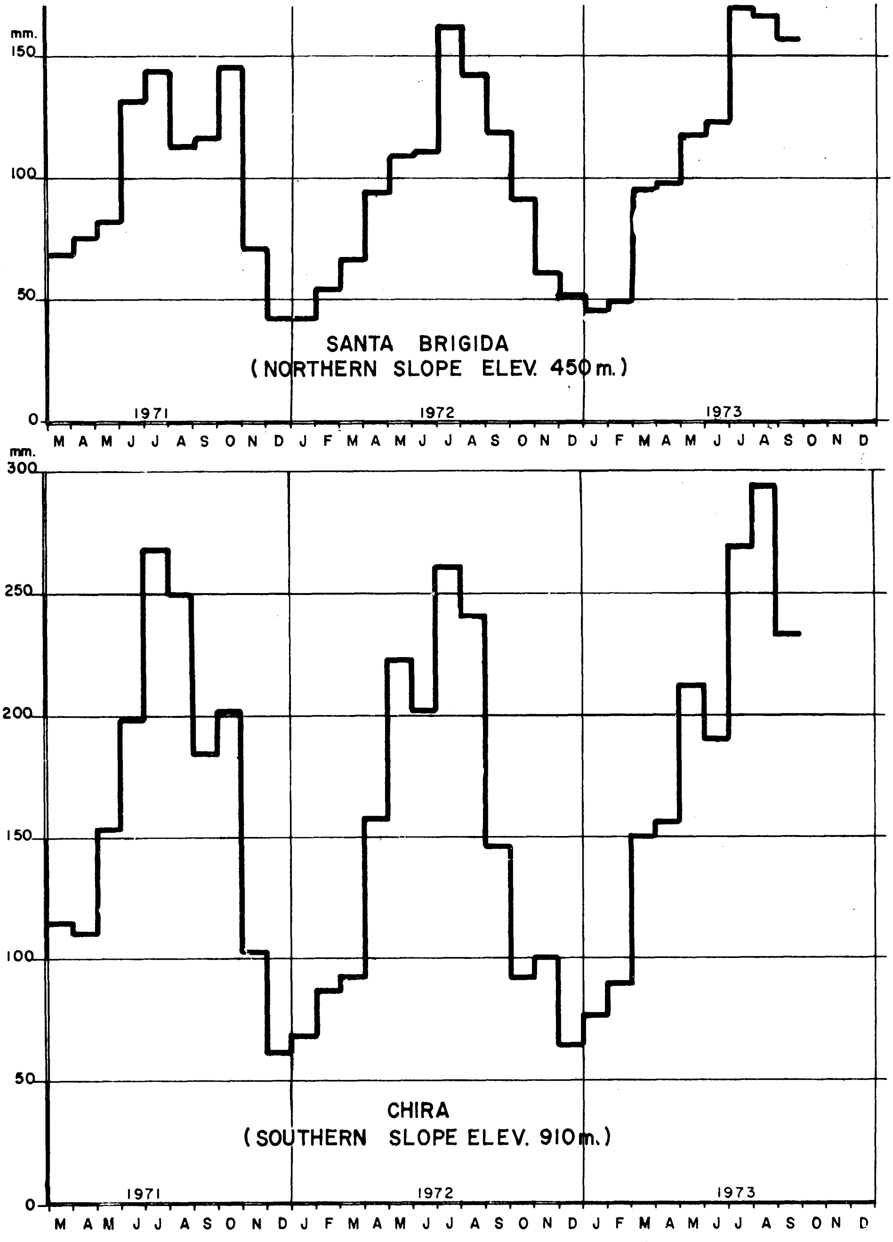

Fig. 13. Class a pan evaporation for 2 stations in Gran Canaria.

similar, with the highest in summer; however evaporation is twice as high in the southern slopes. The potential evapotranspiration on the northern slopes of the island vary between 700 mm on the upper slopes to around 1000 mm on the coastal areas. On the southern slopes it increases from 1.000 mm on the heights to more than 1.500 mm on the southern coastal periphery.

Also studies have been made of the loss by real evapotranspiration under nature conditions and in irrigated plots. In the northern slopes under natural conditions most of the loss is limited to the rainfall period as is expected. This can vary for about 150 to 300 mm/year. But on the coastal areas and in the south for crops under irrigation, water consumption tends to attain the potential evapotranspiration figures. Hence the real evapotranspiration in these zones can vary from 1.000 to 1.500 mm/year.

CONDENSATION PHENOMENA

There exists a belief among the inhabitants of the island that condensation is important and can give even local supplies of water. No systematic investigations have been made of this phenomenon even though some trials were made to study surface interception of dew and fog. In certain zones bathed by the 'cloud banks' and specially in the islands of Gomera and Hierro, fog interception by plants explains in fact the maintenance of extensive forest tracts. However in the other areas, its contribution as precipitation is believed to be small.

Water Cycle

Some details investigations have been recently made of the nature of the hydrologic cycle. The knowledge of this phenomenon is important both for a study of the water resources and for an understanding of the vegetation and ecological systems.

The nature of the water cycle depends not only on the rainfall regime, specially its distribution in time and space, but also on the moisture content of the soils as well as on the nature of the geological formations permitting deep percolation.

RUNOFF AND EVAPOTRANSPIRATION LOSSES

There are no permanent rivers in the Canary Islands excepting for Bco. de Angustias in the Caldera of Taburiente in La Palma island and Bco. El Cedro in Gomera, both abundantly supplied by springs. About 50 years age water flow was a common phenomenon in the upper part of the 'barrancos' or valleys of Grand Canary Island. At the present moment runoff occurs only at rare moments in the different barrancos of the island after heavy showers. It can last normally between 1 to 30 days according to the intensity and nature of the rainfall. The maximum flow occurs between December and February. Due to the heavy slopes and intense nature of rainfall the runoff coefficient for a storm can vary from

0,20 to 0,75. But if we take the entire rainfall of the year, runoff accounts for only 5 to 20% according to island.

The losses by evapotranspiration under natural conditions, as said earlier, is estimated between 150 and 300 mm depending on the area. This would account for the major fraction of losses from rainfall varying from 50 to 70%.

INFILTRATION

Infiltration is a phenomenon which depends on the nature of the soil and the geological materials. Most soils in the Canary Islands have high soil moisture capacities varying from 50 to 250 mm. Soils are better developped in the northern slopes and only incipient profiles are found in the southern regions but decomposed rocks of a certain depth are not rare. Most of the rocks are of basaltic nature excepting in the southern part of Grand Canary where extensive Phonolites and Ignimbrites do occur and also in parts of Fuerteventura, La Palma and Gomera where plutonic rocks are found. Deep percolation normally occurs in all soils developped on Modern as well as Old Basalts, both in pyroclastic and lava beds.

The fraction of the rainfall which is not removed by real evapotranspiration enters the deeper layers as infiltration. Also a part of the runoff returns to the soil due to percolation loss. The total infiltration can vary from about 5% in the drier islands and regions, to about 25% in the wetter northern slopes.

ANNUAL VARIATION

The real evapotranspiration constitutes the principal outflow element in the water cycle and this remains rather constant from year to year. Runoff is negligeable and hence the principal inflow into the ground is composed of infiltration. There is a certain relationship between rainfall and infiltration but this relationship is based on the combination of the water characteristics of the transmitting soil cover over a short space of time. This implies that on an annual basis there is a great difference, also reflected by the rainfall variation. For the same annual rainfall it is hence not uncommon to have different infiltration rates.

Runoff depends not only on the state of moisture of the soils but very much on the intensity of the rainfall. Hence a great variation occurs from year to year. Vegetation occurring in riverbeds will thus be adapted to this great variability of flow.

Evapotranspiration is an element relatively constant, as said earlier, and this means that the natural vegetal zones on the rainy slopes will be guaranteed with a certain regularity since some rainfall is bound to occur in winter months on the higher altitudes.

Altitude m	Climatic Characteristics				Vegetation Characteristics
	Temp. °C	Humidity %	Rainfall mm/year	Evapotranspiration mm/year	
0– 250 N. Slope	20–22 Little annual variation	75–85	⩾200, 10 to 15 raindays	High Potential ⩾1000	Irrigated crops, Bananas, tropical plants and fruits.
0– 250 S. Slope	20–25 Large daily variation	50–60 Windy	⩾100, 5 to 10 raindays	High Potential ⩾1500	Irrigated crops, tomatoes, bananas. Natural vegetation xerophytic.
250– 600 N. Slope	15–20	75–85	300–600, 20 to 30 raindays	800–1000	No irrigation. Dry farming, potatoes, subtropical fruits, vines. Laurel vegetation.
250– 600 S. Slope	15–25	40–50 Windy	200–300, 10 to 20 raindays	1000–2000	Irrigation. Dry farming, potatoes, dry mediterranean fruits and flora – olives, almonds, figs, etc.
600–1000 N. Slope	15–18	60–70 Fogs	500–800	800–1000	No irrigation. Potatoes, winter crops (wheat etc.), mediterranean fruits, vines, olives, pears, etc. Laurel vegetation. Pine trees.
600–1000 S. Slope	15–18	40–50	300–500	1000–1200	Dry farming. Pine trees.
1500–2500 N. Slope	12–15	70–80 Fogs	800–1000	⩾800	No irrigation. Temperate fruit trees. Natural vegetation is *Pinus canariensis*.
1500–2500 S. Slope	12–15	50–60 Fogs	500– 800	⩾800	Idem.
1500–2500 N. Slope	12–18 Inversion zone Clear skies, 5–10 days < °C, high variation	50–60	800–1000 Snowfall	⩾600	Grasslands and Pine trees.
>2500	⩾10 variation	⩾50 Windy	800 Snowfall	400–600	Grasslands

Climatic Zones

We can define the climate of the Canarian Archipelago as subtropical semi-arid to arid but a large variation occurs due to vertical stratification. No systematic study of the nature of the canarian climate has been made. On the whole the following stratification can be proposed.

Altitude	Northern Slopes	Southern Slopes and low lying eastern islands
0– 250 m	Dry subtropical	Arid subtropical to semi-desertic
250– 600 m	Humid subtropical	Semi-arid subtropical (dry Mediterranean type)
600–1.000 m	Humid subtemperate (Mediterranean type)	Semi-arid subtemperate (dry Mediterranean type)
1.000–1.500 m	Humid temperate	Dry temperate
1.500–2.500 m	Dry temperate (continental)	Dry temperate (continental)
>2.500 m	Sub-Alpine	Sub-Alpine

The principal climatic and vegetational characteristics of these zones are given in the accompanying table.

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VI. THE ENDEMIC FLORA OF THE CANARY ISLANDS; DISTRIBUTION, RELATIONSHIPS AND PHYTOGEOGRAPHY

by

DAVID BRAMWELL

Introduction

The flora of the Canary Islands is exceedingly rich in endemic species. Recent estimates (Lems 1960; Bramwell 1972) put the size of the flora at between 1600 and 1700 species. About 470 of these are endemic to the islands, while another 110 or so are found also on other islands of the Macaronesian region (Macaronesian endemics). The nonendemic flora, some 1100 species, consists mainly of a native Mediterranean element and a large proportion of introduced weeds and aliens.

Generic endemism is a notable feature of the Canary Islands flora, 19 genera being found only in the Canarian Archipelago and 12 more shared with other islands of Macaronesia. The Canarian genera are listed in Table 1 and the Macaronesian in Table 2.

Table 1. The Endemic Genera of the Canary Islands.

	No. of Islands	Life Form	No. of Species
Dendriopoterium	1	N.	1
Greenovia	5	Ch.	4
Schizogyne	7	N.	2
Heywoodiella	1	Ch.	1
Vieraea	1	N.	1
Sventenia	1	Ch.	1
Todaroa	5	Ch.	2
Drusa	7	Th.	1
Dicheranthus	3	Ch.	1
Neochamaelea	4	N.	1
Allagopappus	5	N.	2
Gonospermum	4	N-Ch.	4
Parolinia	3	N.	3
Ixanthus	5	N.	1
Spartocytisus	5	N.	2
Plocama	7	N.	1
Kunkeliella	2	N.	2
Tinguarra	5	Ch.	1
Gesnouinia	4	N.	1

Table 2. Macaronesian Endemic Genera found in the Canary Islands.

	No. of Archip.	Life-Form	No. of Species
Picconia	3	M.	2
Bencomia	2	N.	6
Marcetella	2	N.	3
Argyranthemum	2	N.	Ca. 25
Aichryson	3	Ch.-Th.	12
Monanthes	2	Ch.-Th.	Ca. 13
Sinapidendron	3	N.	Ca. 9
Cedronella	3	N.	1
Pleiomeris	2	M.	1
Phyllis	2	Ch.	2
Isoplexis	2	Ch.	4
Visnea	2	M.	1

In addition to generic endemism in the Canary Islands a number of genera exhibit endemism at the section level, for example *Echium* (sects. *Simplicia* and *Gigantea*), *Descurainia* (sect. *Sisymbriodendron*), *Sonchus* (sect. *Atalanthus*). These endemic sections usually consist of local endemic species with woody life-forms, nanophanerophytes and chamaephytes, whereas their non-endemic, continental counterparts tend to be herbaceous and widespread.

Distribution of Endemics

The group of genera and species endemic to Macaronesia tends to be widespread in the Canary Islands, particularly in the forest floras of the western islands. According to Sunding (1970) these species generally belong to the 'Endemiske Floraelelementer'. Bramwell (1971), in a more critical analysis, places them in the 'Mediterranean Element: (B) Tertiary Mediterranean group'.

The Canarian endemics are, however, a more heterogeneous group. Some are widely distributed within the archipelago for example *Drusa glandulosa* and *Schizogyne sericea* which are both recorded from all the islands. *Bencomia*, *Gonospermum*, *Greenovia* and *Todaroa* are found only on the western islands and Gran Canaria, whereas a number of endemic genera such as *Lactucosonchus*, *Dendriopoterium*, *Vieraea*, *Heywoodiella* and *Sventenia* are confined to small areas of individual islands and in some cases apparently to single, very small localities.

The endemic flora of the Canary Islands is generally considered to be a relict one with its greatest affinities amongst the Tertiary floras of the Tethyan-Tertiary region (Meusel 1953; Tahktajan 1969; Bramwell 1972) and the evidence to support this view from several independent fields is very strong indeed. Data obtained from taxonomic, cytological, morphological, palaeobotanical, distributional and phytogeographical studies all indicate that the endemic flora is of considerable age and may represent the ancestral condition of many modern Mediterranean genera and species. Meusel, in a series of papers (1953, 1965) demonstrates the pathways by which modern Mediterranean herbaceous types may have arisen, in response to climatic changes, from woody ancestors still represented today in the endemic floras of the Macaronesian islands.

Bramwell (1972) discusses briefly the evidence from various disciplines and this is considered in more detail in the following paragraphs.

TAXONOMIC ISOLATION

Skottsberg (1925) considers that the taxonomically isolated endemic flora of the Juan Fernández Islands[1] was continental in origin and that it has survived to the present day in insular isolation as the ancestral 'Tertiary Antarctic flora' was wiped out during the Pleistocene. Tahktajan (1969) has advanced a similar theory for the Macaronesian forest floras and Bramwell (1972) suggests that the taxonomically isolated position of many of the Canarian endemic genera is the result of their having been separated from their nearest relatives since the Tertiary period.

From the Macaronesian and Canarian endemic genera listed in Tables 1 and 2, it can be seen that most of these have their greatest concentration in the Canary Islands where the widest range of ecological diversity is to be found.

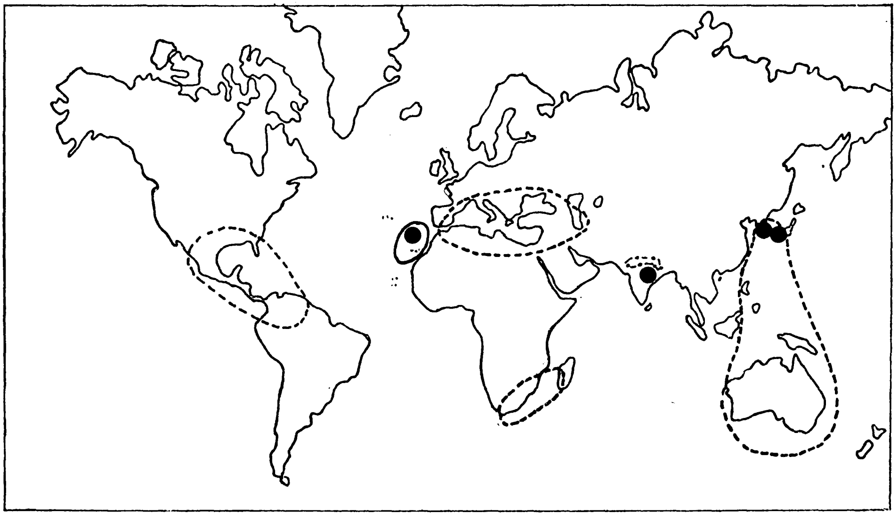

Fig. 1. Distribution of the sections of the genus *Teucrium* occurring outside the Mediterranean region; —— Teucropsis; ---- Teucris; ● Pycnobotrys; -.-.- Leucosceptrum.

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[1] Now officially known as 'Archipiélago Robinson Crusoè'.

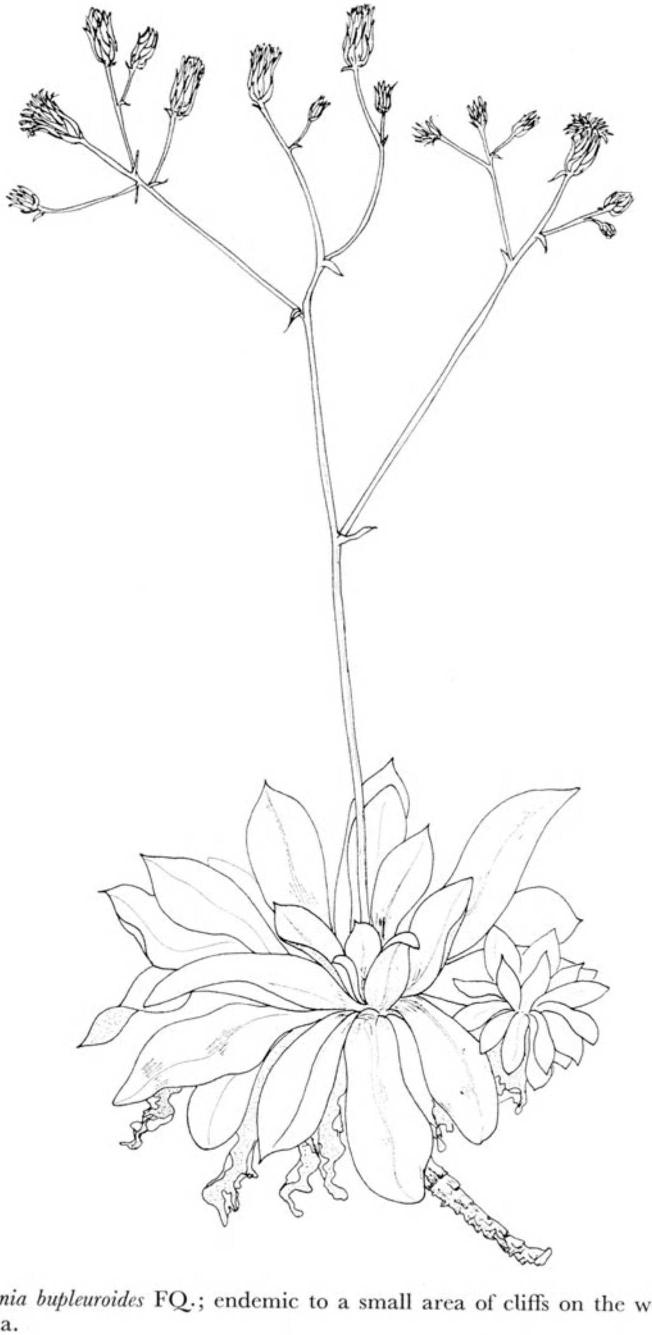

Fig. 2. Sventenia bupleuroides FQ.; endemic to a small area of cliffs on the west side of Gran Canaria.

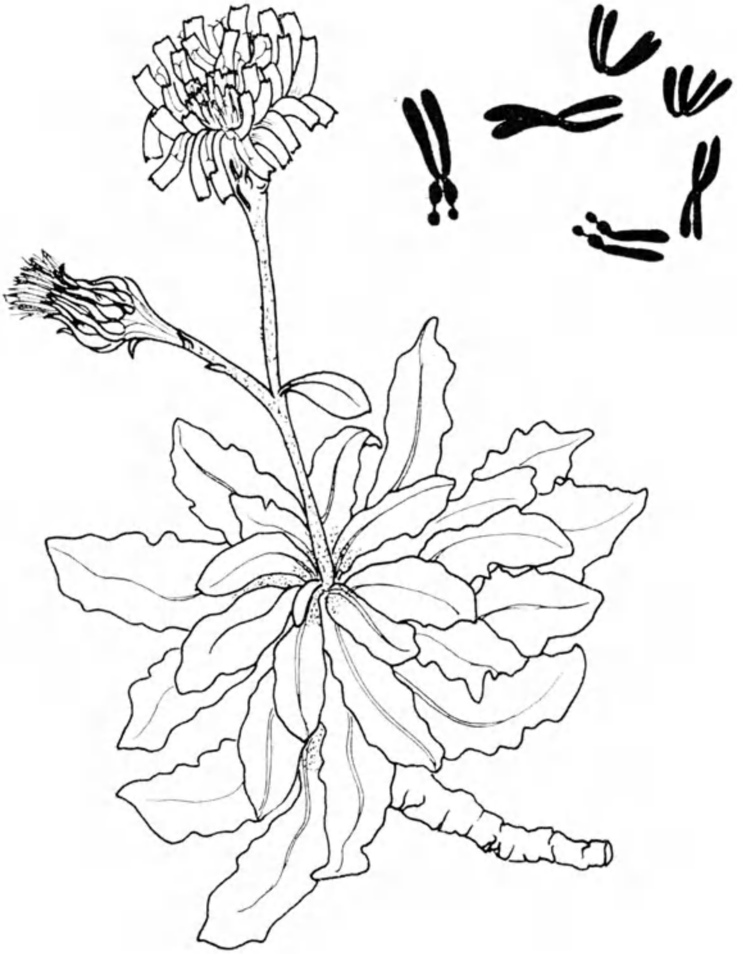

Fig. 3. Heywoodiella oligocephala Svent. & Bramwell, endemic to a single cliff-face on the north-west coast of Tenerife. The karyotype of the species is also shown.

On considering the genera with endemic sections in Macaronesia a review of their taxonomic history shows that many of these sections have, in the past, been treated as separate genera. The section *Leucophäe* of the genus *Sideritis* has often been regarded as a separate genus (Webb & Berthelot, 1836–1850; Pitard & Proust 1908; Lems 1960). The endemic sections *Frutescentes* and *Floridi* of *Convolvulus* have been treated as a single distinct genus *Rhodorrhiza* Webb and *Sonchus* section *Atalanthus* was recently given generic status as *Taeckholmia* (Boulos 1967).

The centre of distribution of the genus *Teucrium* is in the Mediterranean region. There are, however, three sections of the genus not found in this region (Fig. 1). Section *Leucosceptrum* occurs only in the Himalayan region.

Section *Teucropsis* is endemic to Macaronesia and section *Pycnobotrys* has a disjunct distribution with species in Eastern India, Japan and the Macaronesian island of Madeira. Such local endemism and disjunct distribution at sectional level implies that a long period of isolation has occurred in their evolution. The Himalayan and Macaronesian sections seem to be relicts of long standing, a view which is supported by the fact that only a single species of any of the widespread Mediterranean sections has reached Macaronesia despite the common occurrence of suitable ecological situations.

Some of the endemic genera and sections are mono- or oligotypic and are found on cliffs in old, Tertiary basalt mountain blocks. Examples are *Sventenia* (Fig. 2), a genus with a single chasmophytic species found on Tertiary basalt cliffs on the west side of Gran Canaria, and *Heywoodiella* (Fig. 3) which is known only from a single locality on a cliff-face in the Teno mountains of Tenerife.

Other endemic genera and sections are represented in the Canarian flora by a number of species and seem to have undergone adaptive evolution in the islands since their arrival (*Limonium*, *Senecio*, *Argyranthemum*, etc.). Relicts behaving in this manner have been termed active epibiotics (cf. Bramwell 1972). As Stebbins (1947) points out, old, 'static' taxa often still retain the genetic potential for further evolution in response to particular conditions and he cites the example of the Californian Redwood *Sequoiadendron giganteum*, a classic relict and 'static' species, which after several generations in cultivation produces numerous sports and cultivars.

CHROMOSOMAL DATA AND ENDEMISM

The system of classification of endemics based on their ploidy level devised by Favarger & Contandriopoulos (1961) has been provisionally applied to the Canary Islands flora by Bramwell *et al.* (1972). In this system four types of endemics are recognised: palaeoendemics, schizoendemics, patroendemics and apoendemics. As Bramwell *et al.* (1972) have shown, the Canary Islands are rich in the older types of endemics i.e. palaeoendemics, patroendemics and schizoendemics and these represent an ancient element in the flora. The islands have, however, very few apoendemics suggesting that the flora is poor in young or neoendemics.

Palaeoendemics

Favarger & Contandriopoulos (1961) define palaeoendemics as species of monotypic or oligotypic genera or taxonomically isolated sections of genera with no corresponding non-endemic taxa. From a cytological point of view palaeoendemics can be either diploids or polyploids (palaeopolyploids, Favarger 1967). As examples of diploid palaeoendemics in the Canarian flora species of the following genera can be cited: *Gonospermum* (Compositae) 2n = 18, *Allagopappus* (Compositae) 2n = 20, *Schizogyne* (Compositae) 2n = 18, *Vieraea* (Compositae) 2n = 16, *Greenovia* (Crassulaceae) 2n = 18, *Parolinia* (Cruciferae) 2n = 22, *Phyllis* (Rubiaceae) 2n = 22, *Messerschmidtia* s.s. (Boraginaceae) 2n = 16, *Cedronella* (Labiatae) 2n = 20, *Astydamia* (Umbelliferae) 2n = 22, *Dracaena* (Liliaceae) 2n = 40, *Semele* (Liliaceae) 2n = 40.

Palaeopolyploids (Favarger 1967) are ancient polyploids without near relatives or whose nearest relatives are of a higher polyploidy level. Bramwell *et al.* (1972) give the following examples in the Canarian flora: *Isoplexis* (Scrophulariaceae) 2n = 56 (8 x), *Bystropogon* (Labiatae) 2n = 42 (6 x) and several other genera such as *Plocama* (Rubiaceae) 2n = 44 and *Erysimum* sect. *Cheiranthus* (Cruciferae) 2n = 28 also seem to be palaeopolyploids.

Patroendemics

Patroendemics are defined as diploid endemic species whose corresponding non-endemic taxa are polyploid. They are considered by Favarger & Contanriopoulos (1961) to be older than their corresponding taxa. Bramwell *et al.* (1972) cite *Laurus azorica* (Lauraceae) 2n = 36 with the Mediterranean *Laurus nobilis*, 2n = 48 as its corresponding taxon and *Adenocarpus viscosus* (Leguminosae) 2n = 24 which has the corresponding species *A. complicatus*, 2n = 52, in North Africa and the Mediterranean region.

Echium. In the genus *Echium* (Boraginaceae) the common occurrence of the base number x = 8 from widely separated parts of the range of the genus suggests that it is the primary basic number from which have been derived, by centromeric loss, x = 7 and x = 6 known in W. and C. Mediterranean and E. Mediterranean/Caucasian species respectively (Fig. 4). Both diploids and tetraploids are known in the x = 8 and x = 7 series whereas the x = 6 series is tetraploid.

The Macaronesian species are all diploids of the x = 8 series and in view of their frutescent habit can probably best be considered as a primitive group. The West Mediterranean and North African species of the x = 8 series are annual to perennial herbs sometimes with a woody rootstock. In some species both biennial and perennial races occur and in many of the species both diploids and tetraploids are found. *E. asperrimum* (x = 7), a biennial species of the West and Central Mediterranean region, has both diploid and tetraploid races. *E. maculatum (E. russicum)* (x = 6) from the East Mediterranean and the U.S.S.R. is tetraploid with 2n = 24.

In the absence of data from a number of Mediterranean and North African species it is only possible to speculate as to the evolutionary significance of changes in chromosome number in *Echium* but the following

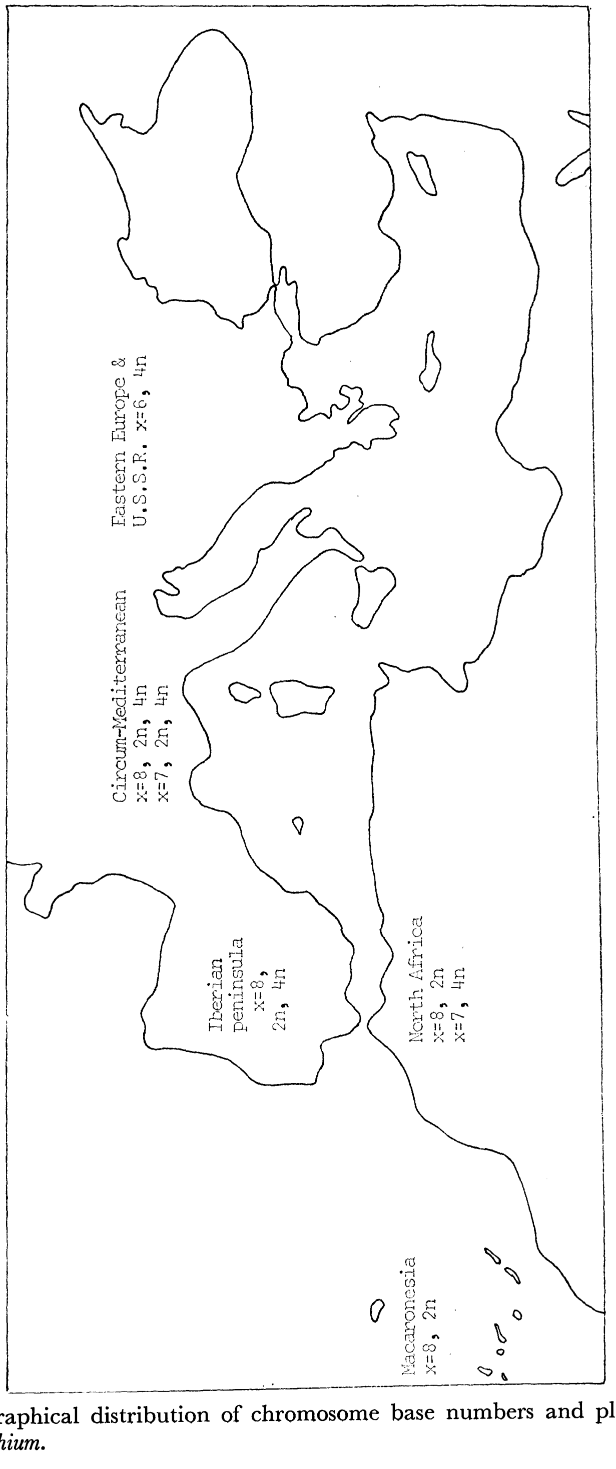

Fig. 4. Geographical distribution of chromosome base numbers and ploidy levels in the genus *Echium.*

trends seem to emerge: 1. reduction in woody habit and decrease in the length of the life-cycle seems to have been accompanied by trends toward increased polyploidy and reduction of the base number; 2. the Macaronesian species which are all diploid seem to represent a cytologically primitive type (Britton 1951) which may be ancestral to the remainder of the group; 3. centres of diversification of the genus are found in the Canary Islands, North Africa and the Iberian Peninsula, in the last two areas diversification has been accompanied by some degree of polyploidy.

Sonchus. The genus *Sonchus*, in which the frutescent Macaronesian species are all diploid ($x = 9$, $2n = 18$), shows a similar trend with tetraploids and hexaploids *(S. arvensis, S. gigas, S. grandiflorus)* amongst the Mediterranean and North African species and also a group of annual-biennial species with a reduced base number (*S. oleraceus*, $x = 8$; *S. tenerrimus*, $x = 7$).

Schizoendemics

Schizoendemics are that group of diploid of polyploid endemic taxa whose corresponding non-endemic taxa are at the same level of polyploidy. This group, in fact, covers a wide range of endemics, both young and old, and presents some problems when applied to insular floras such as that of the Canary Islands. Groups of endemic species, for example the frutescent *Echium* species, are patroendemic when compared to their non-Canarian or Macaronesian relatives but if each local Canarian endemic species is compared with the other species of the Canarian group then it must be considered as a schizoendemic as all the Canarian taxa have the same chromosome number. These taxa are the result of secondary evolution in relict groups (active epibiotics, cf. Bramwell 1972) and are vicarious taxa usually found only on a single island and often restricted to one or a few localities. As Bramwell *et al.* (1972) point out these schizoendemics are usually diploid and are, in most cases, taxonomically isolated as a group from their nearest non-Macaronesian relatives. Some even have a different chromosome base number from the non-endemic corresponding taxa, for example *Limonium* section *Nobiles* which has the base number $x = 7$ ($2n = 14$) which has so far been found only in this section of the genus.

There also exists a group of schizoendemics which appear to be rather younger in origin. These are closely related to Mediterranean or North African taxa from which they are differentiated only at the species level. Examples are *Pancratium canariensis* $2n = 22$ and *Androcymbium psammophilum* $2n = 18$, vicariants of the Mediterranean species *Pancratium maritimum* $2n = 22$ and *Androcymbium gramineum* $2n = 18$ respectively.

Polyploidy Spectrum of the Canarian Flora

The level of polyploidy in the Canarian flora has been calculated as about

Table 3. Polyploidy levels in floras of the Canary Islands, Sahara, Europe and Subantarctic Islands.

	Diploids %	Polyploids %
Canary Islands	76.5	24.5
Algerian Sahara	62.2	37.8
Cyclades	63.0	37.0
Rumania	53.2	46.8
Hungary	51.4	48.6
Central Europe	49.1	50.9
British Isles	46.7	53.3
Sweden	43.1	56.9
Faroes	31.7	68.3
Iceland	34.1	65.9
S.W. Greenland	29.0	71.0
Spitzbergen	23.8	76.2
Peary-Land	14.1	85.9
Falkland Islands	34.0	66.0
Macquarie Island	38.0	62.0

24.5% (26.5% in Borgen 1969; 24.4% in Bramwell *et al.* 1972). This is the lowest level known for any flora investigated to date and if one accepts the view expressed by Reese (1958) 'De jünger die Flora, um so höher der anteil der polyploiden' then the relict hypothesis for the Canarian endemic flora is confirmed. As can be seen from the above table (table 3) the younger, postglacial floras of Central and North Europe have a much higher percentage of polyploids.

Woody life-forms

In a series of papers on insular floras Carlquist (1965, 1970a, b; 1971) argues that the endemic, frutescent species found on many oceanic islands are the result of an increase in woodiness in response to the uniformity of insular climates. He does not consider these plants to be relict but to be secondary derivatives of herbaceous ancestors and he has used several genera of Canarian plants (*Echium*, *Plantago*, *Euphorbia* etc.) as examples to support his view.

The opposing view that the woody insular species are relicts which have survived in their relatively undisturbed insular habitats is presented by Meusel (1953), Lems (1960) and Bramwell (1972).

There are several basic weaknesses in the evidence presented by Carlquist in support of his hypothesis particularly when applied to the Canary Islands. The Canarian climate is far from uniform as can be seen from the data on rainfall and temperature accumulated by Ceballos & Ortuño (1951) (Fig. 5) which shows a distinct cool period of winter rain and a long, hot, dry summer for all the islands. Carlquist also emphasises

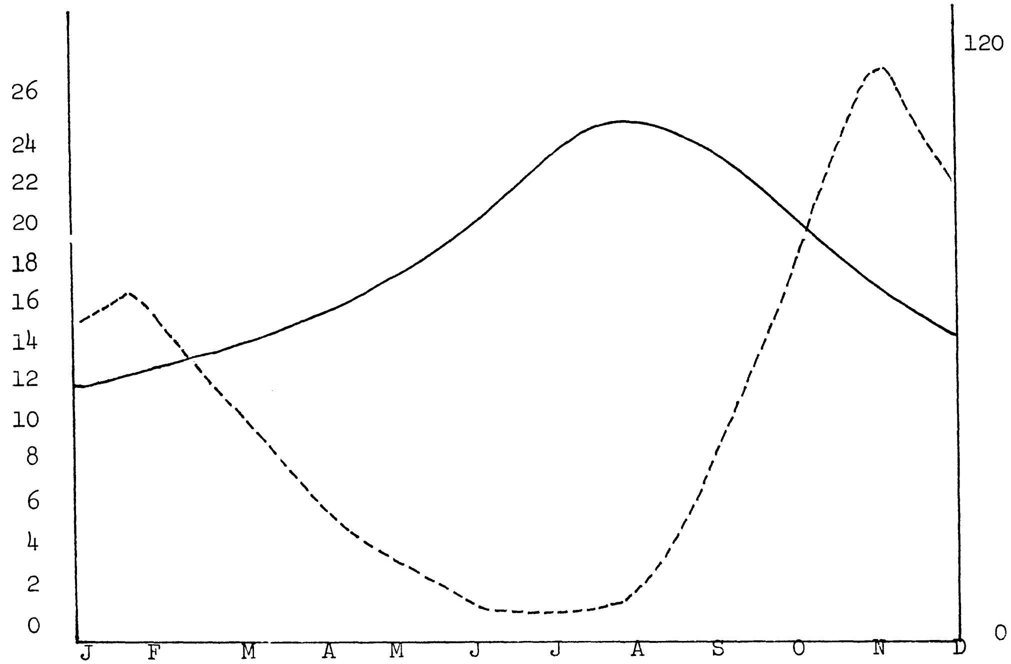

Fig. 5. Annual range of temperature —— (°C) and rainfall ----- (mm) for La Laguna, Tenerife.

the woody anatomy of his examples to the exclusion of all other relevant data. He takes no account of chromosome data or of the taxonomic relationships of the insular endemics. This is evident in a recent paper on the wood anatomy of insular species of the genus *Plantago* (Carlquist 1970a). In this paper Carlquist states that insular species such as *P. arborescens* and *P. webbii*, both Canary Islands endemics, are more woody than their mainland counterparts and that they have evolved from herbaceous mainland ancestors.

If one considers, however, the nearest continental relatives of *Plantago arborescens* and *P. webbii* one finds that they are a group of species belonging to the subgenus *Psyllium* a number of which also have a frutescent habit and closely resemble the Canary Islands species. *P. sempervirens* occurs in Spain, Portugal, S. France and N. Italy and is a dwarf shrub up to 50 cm. *P. asperrima*, a local endemic of C. and S. Spain, is another frutescent, continental member of the group and amongst the N. African species *P. mauritanica* is a small shrub. Other frutescent species of the subgenus include *P. euphratica* of Turkish Armenia and *P. sinaica* which seems to be endemic to the Mount Sinai region of Palestine. This group of species is probably best considered as a relict with a Saharo-Sindian or Irano-Tauranian origin.

The herbaceous members of the subgenus *Psyllium* are generally

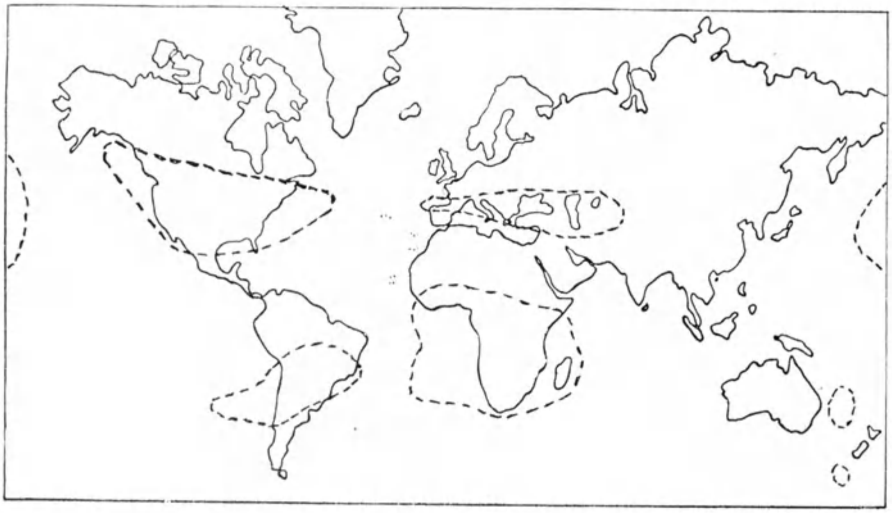

Fig. 6. Worldwide distribution of *Plantago* sect. *Palaeopsyllium.*

derived annual weeds, for example *P. indica*, *P. afra* (common in the Canary Islands), *P. phaeostoma* and *P. squarrosa*. These are all species of xeric conditions and seem to be derived from the more mesic frutescent group.

A second group of *Plantago* species which, though not found in the Canary Islands, is, nevertheless, extremely important in general considerations of insular woodiness is the section *Palaeopsyllium* (Pilger 1937). The distribution of the group is shown in Fig. 6. Carlquist (1965, 1970a) considers several of the insular members of this section such as *P. robusta* (St. Helena) and *P. fernandezia* (Juan Fernandez Islands) to be derivatives of herbaceous forms such as that of *P. lanceolata*. *Plantago* section *Palaeopsyllium* has, however, a relict, disjunct distribution with a number of continental African and American species. Its Pacific Islands distribution with isolated endemic species in Hawaii, Juan Fernandez, Rapa, Australasia and Sub-Antarctic Islands with outlying endemics in St. Helena and Madagascar suggests that it belongs to what Skottsberg (1925) has described as 'an ancient Antarctic and South Pacific flora now broken up and scattered'. It has been suggested by Melville (pers. comm.) that this group of *Plantago* species has retained a very primitive form of leaf-venation pattern and this seems to be in keeping with their being an old Tertiary group of relicts (cf. also Croizat 1952).

Meusel (1953) takes the view that the woody Macaronesian species represent the ancestral forms of many modern Mediterranean herbaceous species and that their frutescent growth-form is the basic one from which the herbaceous forms have been derived by reduction in lignification and adaptation to more extreme conditions. In this paper Meusel shows the

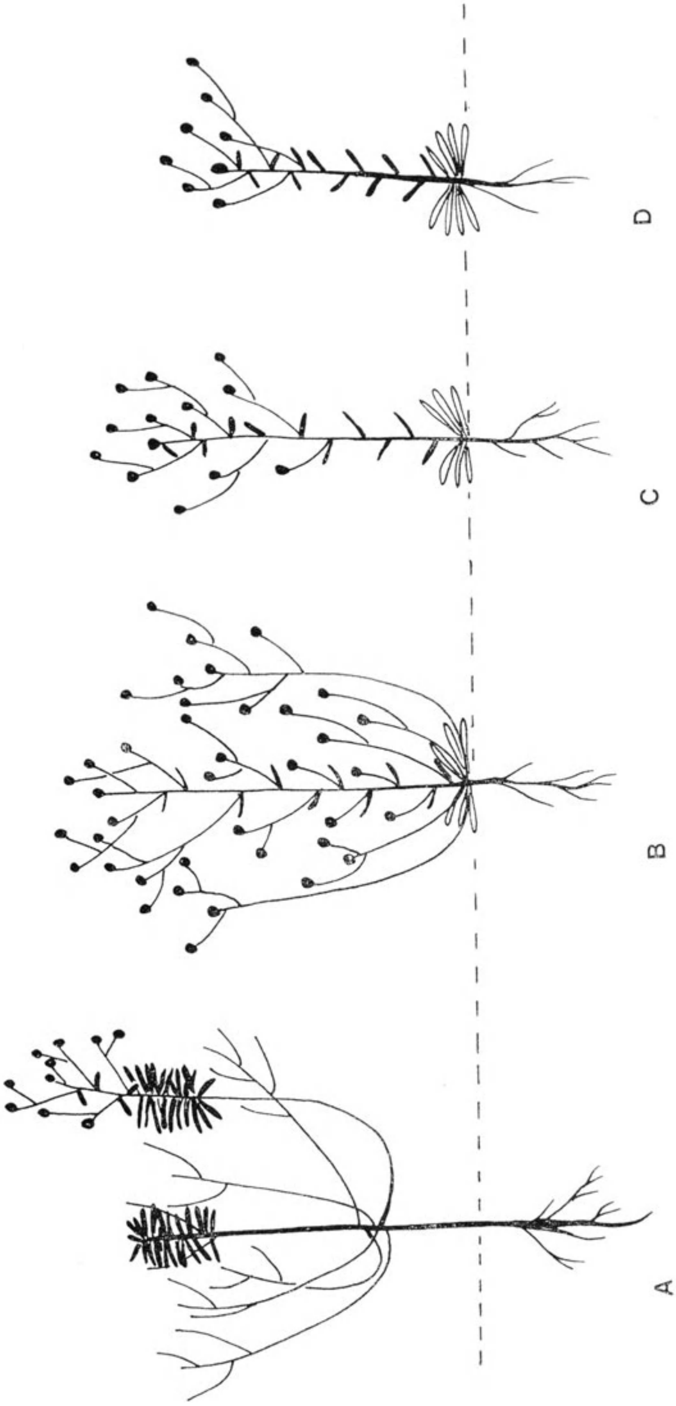

Fig. 7. Growth-forms of *Carlina* in Macaronesia and the Mediterranean region. A. Macaronesian frutescent form; B. Mediterranean herbaceous perennial; C and D. Mediterranean herbaceous biennial/annual.

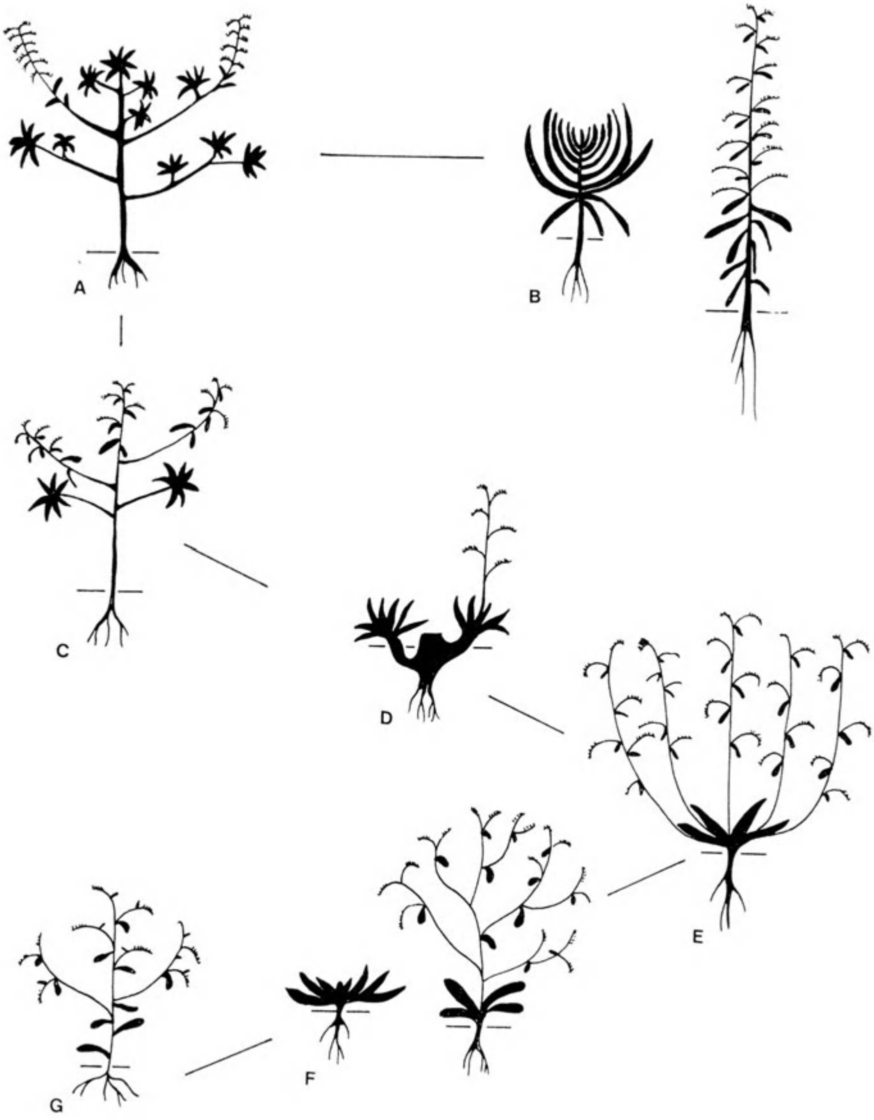

Fig. 8. Growth-forms of *Echium* in Macaronesia and the Mediterranean region. A, B and C. Macaronesian frutescent forms; D. Macaronesian/Mediterranean perennial with woody stock; E. Mediterranean herbaceous perennial; F. Mediterranean herbaceous biennial; G. Mediterranean annual.

probable stages in reduction of woodiness in the Mediterranean flora and cites a number of examples such as *Carlina* and *Echium*. His accounts of these two genera are summarized in Figs. 7 and 8.

Sonchus. A further example is to be found in the genus *Sonchus*. Most of the herbaceous Mediterranean species of this genus seem to be post-Pleistocene weed species though relicts with woody life-form are found in the Anti-Atlas region of Morocco *(S. pinnatifidus)* and in Macaronesia. Many of the Tropical African subgenus *Origosonchus* also have a woody stock and Boulos (1960) presents a very plausible argument for the origin of *Sonchus* in the central African region. He regards the subgenus *Origosonchus* as the most primitive living group species and these are linked to the Macaronesian *Dendrosonchus* group by the West African species *S. angustissimus*. In Boulos' opinion the subgenus *Sonchus*, consisting of annual to perennial herbs, is an advanced one with its most primitive elements in North West Africa and he suggests that subgenus *Sonchus* has arisen directly from *Dendrosonchus*-like ancestors in this area. This is in keeping with Babcock's view (Babcock 1947) that the *Sonchus* species of North West Africa (Atlas region), Madeira and the Canary Islands are amongst the most primitive. Meusel (1953) also considers the herbaceous Mediterranean species of *Sonchus* to have been derived from woody forms similar to those found in the Canary Islands at the present time.

The proliferation of *Sonchus* species in the Canary Islands has been shown by Bramwell (1972) to be the result of adaptive radiation and vicariant evolution.

Aeonium. The genus *Aeonium* (Crassulaceae-Sempervivoideae) was the subject of an extensive study by Lems (1960). In his paper he presents evidence for the adaptive radiation of the genus in the Canary Islands and considers it to be a botanical equivalent to Darwin's finches. Lems regards the frutescent habit as primitive within the group and suggests that the East African/Macaronesian disjunct distribution of the frutescent growth-form supports this view. It is also the most widespread form in Macaronesia occurring in the Canaries on all the islands and in the Cape Verdes. The Moroccan species *A. arboreum*, which is probably native only on the S.W. coast of Morocco and at the western edge of the Anti-Atlas range, is a frutescent species as is *A. leucoblepharum*, and East African species which represents a major disjunction.

In the family *Rosaceae* (Sanguisorbiae) there are three closely related woody Macaronesian genera, *Marcetella*, *Dendriopoterium* and *Bencomia*. Their nearest relatives are frutescent to arborescent genera of East Africa *(Hagenia)* and South America *(Polylepis)* and their distribution seems to represent a very old disjunction (see p. 222 and Fig. 9). The frutescent species of *Argyranthemum* (*Chrysanthemum* s.l.), a genus found only in Macaronesia, appear to have their nearest relatives amongst a group of poorly known woody *Chrysanthemum* species in the Cape region of South Africa. A further apparently ancient woody group of species are those of the section *Nobiles* of the genus *Limonium* (Plumbaginaceae) which are generally woody subshrubs and shrubs with *L. arborescens* and *L. dendriodes* reaching a height of 1–2 metres.

The genus *Euphorbia* is represented in Macaronesia by a group of

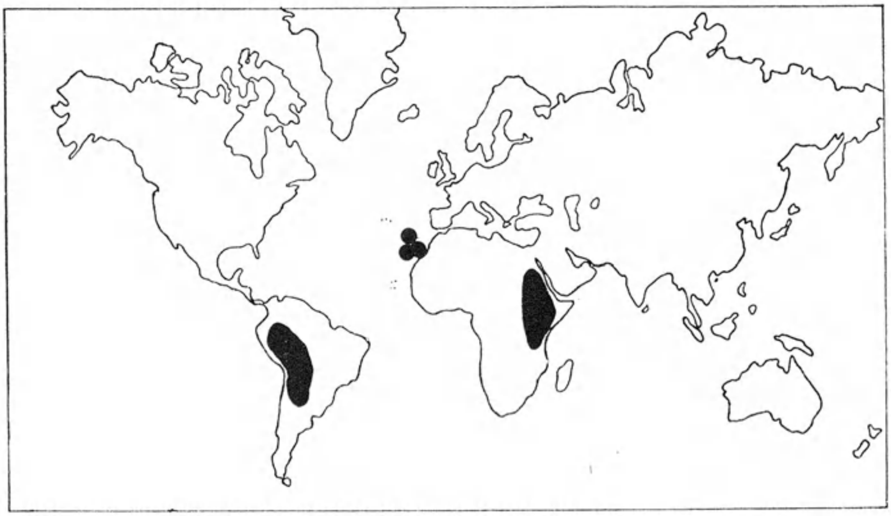

Fig. 9. The distribution of frutescent genera in the *Sangisorba* group of Rosaceae. Macaronesia: *Bencomia*, *Marcetella* and *Dendriopoterium*; S. America: *Polylepis*; E. Africa: *Hagenia*.

10-a

10-b

10-c

10-d

species belonging to the section *Pachycladae*. This section has its greatest concentration of species in the Canary Islands, Madeira and the other Macaronesian Islands but it has outlying representatives in the Mediterranean region *(E. dendroides)*, Morocco *(E. obtusifolia* var. *pseudodendroides)* and *E. balsamifera* has a Saharo-Sindian distribution from the Canary Islands and southern Morocco to South Arabia. This distribution pattern suggests that the *Pachycladae* section of *Euphorbia* is a group of relict species of a Tethyan-Tertiary group once more widespread in the Mediterranean region.

The relict frutescent habit is found in many other Macaronesian representatives of Mediterranean genera such as *Dorycnium*, *Erysimum*, *Descurainia*, *Pterocephalus*, *Convolvulus* and *Crambe*. Some frutescent genera illustrated in Fig. 10 and others which have disjunct distributions will be discussed at a later stage in this paper.

Palaeobotanical Evidence

The Miocene and Pliocene fossil floras of Southern Europe have been investigated by a number of workers including Depape (1922), Saporta (1862–1874) and Schenk (1907). Dansereau (1968), Cifferi (1962), Takhtajan (1969) and Bramwell (1972) have discussed the fossil floras in relation to the modern Macaronesian forest vegetation. Takhtajan (1969) writes: 'The Tertiary laurel-leaved forest of Europe is well known to be best preserved in the Canary Islands where members of the Lauraceae form beautiful groves on the islands of Gomera, Ferro, Tenerife and Palma' (Ciferri 1962).

There the lauraceous species grow at 500–1,200 m on mountain slopes exposed to the south-east Trade Winds, and also in deep moist ravines (Burchard 1929). In such forests grow *Laurus azorica* (the most important forest-forming species in the Canary Islands, which also occurs in Madeira and the Azores), *Persea indica* (the most moisture-loving of the Canary laurels), *Apollonias barbusana* (which is mainly found as an accessory constituent of the groves of Canary laurel) and, finally, *Ocotea foetens*,

10-f

Fig. 10. Macaronesian frutescent genera and species whose nearest continental relatives are herbaceous. A. *Echium decaisnei*, Gran Canaria, Tejeda; B. *Sonchus abbreviatus*, Tenerife, Anaga; C. *Parolinia intermedia*, Tenerife, Teno; D. *Bencomia cf. sphaerocarpa*, La Palma; E. *Aeonium nobile*, La Palma, Tigarafe; F. *Cheiranthus cinereus*, Tenerife, Valle de Santiago.

which flourishes in practically all the laurel forests of the Canary Islands. In the Late Tertiary all these species were widespread in the Mediterranean area, while *Persea indica* and *Apollonias barbusana* were similarly established in the Neogene (possibly Late Miocene) flora of the Goderdzi Pass in south-west Georgia. A whole series of relicts of the Tertiary subtropical flora of southern Europe and North Africa is still preserved in Macaronesia. 'The flora of Macaronesia' wrote Wulff (1944) 'is an ancient remnant of the Tertiary flora, which has been preserved to the present day and affords us a graphic example of what the flora of the Tethyan region was like in the first half of the Tertiary Period.'

Towards the end of the Tertiary period the subtropical forest flora was displaced due to changes in the climatic zones and the probable southern migration of a cooler, drier climate which led to the development of the modern Mediterranean sclerophyllous vegetation which, as Takhtajan points out, comprises xerophilous derivatives of subtropical and temperate elements with a number of tropical forms which have persisted as relics to the present day.

Saporta (1862–1874) and Depape (1922) have examined macrofossils in Miocene and Pliocene deposits in the western Mediterranean region in great detail and the following list of species of the present-day Macaronesian flora have also been detected in the Tertiary deposits:

Woodwardia radicans	– well represented in Tertiary floras of Europe, present day distribution disjunct.
Pinus canariensis	– recorded by Saporta as *P. consimilis* Sap. and by Depape as '*Pinus* sp. foliis ternis'.
Smilax mauritanica	– Rhone Valley, present disjunction in distribution.
Smilax canariensis	– recorded as the fossil species *S. targionii* Gaud. which, is according to Depape, very similar to *S. canariensis*.
Myrica sp.	– the fossil material is said by Depape to be near to *M. cerifera*, an American species which resembles *M. faya* of Macaronesia.
Laurus azorica (*L. canariensis* auct. non Willd.)	– widespread in Tertiary floras from E. Spain to S. Georgia as *L. canariensis pliocenica*.
Persea indica	– reported by Depape as *P. indica pliocenica* and also known from the Eocene.
Ocotea foetens	– this species is reported by Saporta as *Oreodaphne heeri* which Depape considered to be conspecific with *O. foetens*.
Apollonias canariensis	– both Saporta and Schenk list this species from Miocene deposits in the Mediterranean region.
Maytenus canariensis *(Catha cassinoides, Celastrus cassinoides)*	– reported by Saporta as *Celastrus gardonensis* which was considered by Depape to be identical with the living Canarian *Catha cassinoides*.
Ilex canariensis	– fossil material of this species is well known from the Rhone Valley (Saporta, Depape etc.).
Viburnum rugosum	– Saporta recorded *V. pseudotinus* from southern France and the fossil material was later considered by Marty (cf. Depape, 1922) as very similar to the Canarian species *V. rugosum*.
Picconia excelsa	– reported from the Rhone Valley as *Notelea excelsa* by Depape.
Phillyrea latifolia	– this fossil species first reported by Boulay and Saporta was treated as identical with the living species *P. latifolia* of Iberia and the Canary Islands by Depape.
Clethra berendtii *Dracaena brogniartii* *Apollonias aquensis* *Phoenix* sp.	– These species are reported in Tertiary deposits from Hungary – by Andreanszky (1968) and are equated by Sunding (1970) with living Macaronesian species of the same genera.

Other species which seem to belong to the old Tethyan-Tertiary flora and which still survive as relicts in Spain, Portugal and Greece include *Laurocerasus lusitanica*, *Laurus nobilis*, *Myrica faya*, *Culcita macrocarpa*, *Davallia canariensis*, *Hypericum caprifolium* and *Dactylis smithii* subsp. *smithii* and subsp. *hispanica*.

The vicarious species *Arbutus canariensis* and *A. unedo* probably had a common origin in the Tethyan-Tertiary flora as did *Anagyris latifolia* and

Anagyris foetida. Other species in the Macaronesian flora which have their present day affinities with tropical and subtropical floras but which probably form part of the Tethyan-Tertiary element are the forest trees *Sideroxylon marmulano* (Sapotaceae), *Pleiomeris canariensis*, *Ardisia bahamensis* (Myrsinaceae) and *Visnea mocanera* (Theaceae).

The modern Macaronesian flora, judging by the Miocene and Pliocene fossil record, appears to comprise only a small part of the Tethyan-Tertiary forest flora. The fossil plants which can be identified with surviving Macaronesian species amount to some 16 per cent of the total number of Tertiary species reported by Depape (1922). As noted by Bramwell (1972) a number of tropical and subtropical elements such as *Cinnamomum*, *Sapindus* and *Buettneria*, well known from the fossil record, are not found in the extant flora of Macaronesia. A number of temperate elements are also absent, for example *Alnus*, *Quercus*, *Populus*, *Acer* and *Carpinus*, and these may have entered the Tethyan-Tertiary region too late to have invaded Macaronesia. The surviving Macaronesian flora does, however, seem to be only a small fragment of the Tethyan-Tertiary flora formerly found in the Mediterranean basin.

As suggested by Bramwell (1972) the present day distribution of species such as *Persea indica* and *Maytenus canariensis* represent only a small part of their former range so that they can be considered as good examples of palaeoendemics in the classical sense.

Disjunct Distributions

Most modern phytogeographers tend to accept the hypothesis that major discontinuities result from the extinction of members of the now discontinuous group in the area now constituting the disjunction as a result of climatic or other changes so that the explanation of most, if not all, disjunctions is to be found in historical rather than contemporaneous biological causes (Cain 1944).

On the basis of this hypothesis it is possible to assess the age of many major disjunctions using data from palaeobotany and palaeoclimatology in conjunction with studies of plate tectonics and palaeomagnetism.

A number of genera and species occuring in Macaronesia have wide disjunctions in their distributions and examples of these are given by Meusel (1956), Sunding (1970) and Bramwell (1972). Several of these disjunctions seem to be of great age, especially the Macaronesian/South American and Macaronesian/South African ones. At least the former probably dates back to the Cretaceous Period. Most of the other Macaronesian disjunctions seem to be explicable within the framework of climatic and topographical changes in the Tertiary Period, largely those connected with the decline of the Tethys Sea. These disjunctions are examined in more detail in the following paragraphs.

Lems (1960) suggests that the Macaronesian/American disjunction can be explained by long-distance dispersal by water. Skottsberg (1925), however, commenting on the effect of long-distance dispersal on the flora of the Juan Fernandez Islands was dubious about its importance in the original colonisation of the islands:

'There is a Polynesian (roughly defined) element in Juan Fernandez. But why is there not, save for a couple of widespread littorals, a single identical species on both sides of the ocean? In spite of favourable winds and currents, this element evidently is not recruited by new additions, nor has it been for ages. Logs of Chilean trees are sometimes carried to the shores of the islands; I have observed them in Mas-a-Fuera, always much waterworn and without a trace of bark they seem useless as carriers of plants and seeds. And few people will believe that the Hawaiian flora nowadays receives new species other than through human agency. That now and

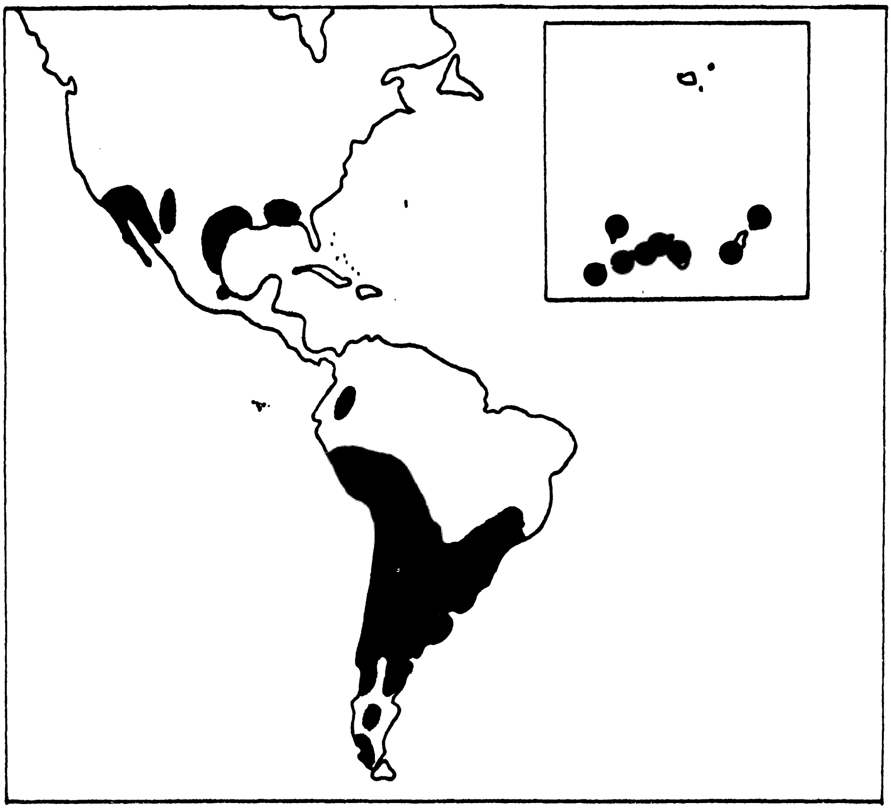

Fig. 11. The distribution of the Hydrocotyloid Macaronesian Umbellifer *Drusa glandulosa* (inset) and its American relatives *Bowlesia* and *Homalocarpus.*

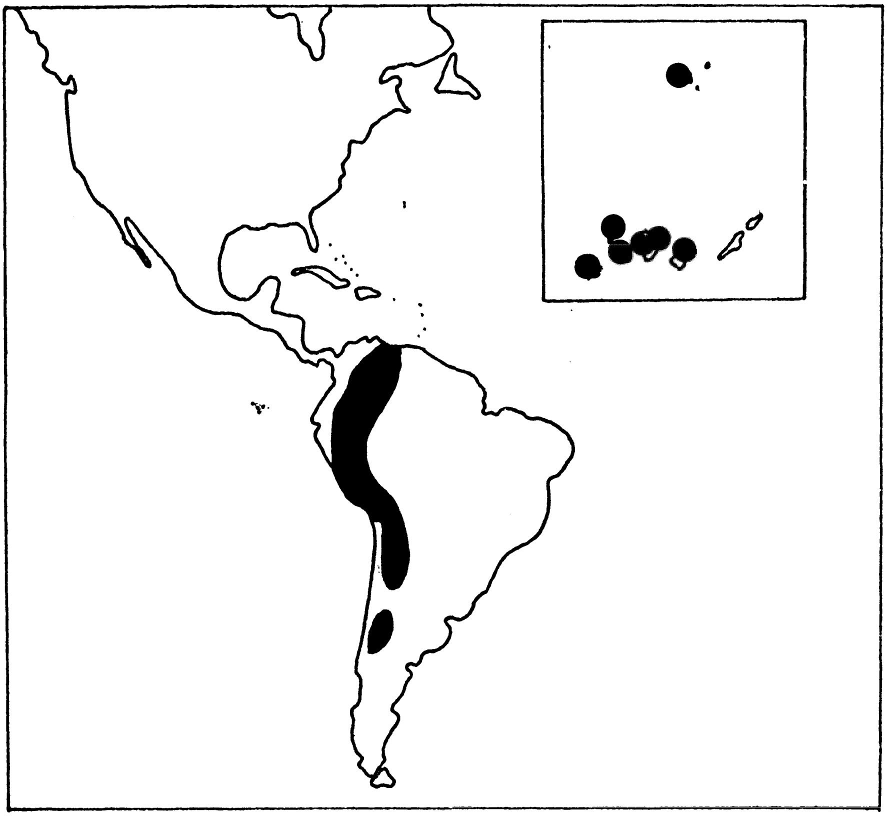

Fig. 12. The distribution of the genus *Bystropogon* (Labiatae) in Macaronesia (inset) and S. America.

then spores of cryptograms reach remote islands has never been disputed, but such happy instances do not lend themselves to far-reaching conclusions. The embarrassing fact remains that oversea migration has practically ceased altogether. This is recognised by Guppy, who turns to the supplementary theory that the natural agencies, that were so wonderfully effective during bygone ages, have lost their efficiency. He gives no reply to the questions 'how' or 'why', it suffices that they have played out their rôle. The currents perhaps changed their course, the winds blew from other directions, the birds have died out, gone elsewhere or acquired new habits. For my part I find it easier to believe that their performances have been largely overestimated ...'

It is in view of the western South American distribution of genera such as *Bystropogon*, probably more likely that these formed part of a pre-drift landmass flora dating from the Cretaceous Period. Genera with this type of discontinuous distribution are *Drusa* (Umbelliferae, Fig. 11), *Bystro-*

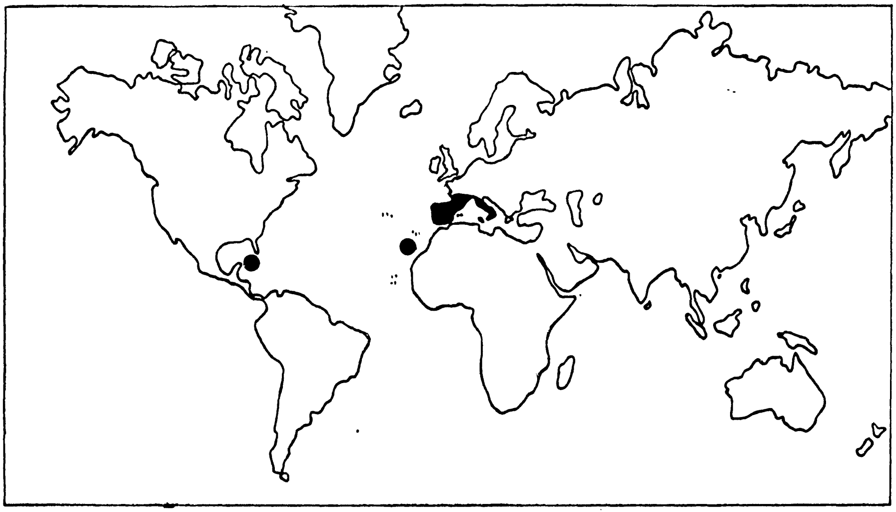

Fig. 13. Worldwide distribution of the family Cneoraceae.

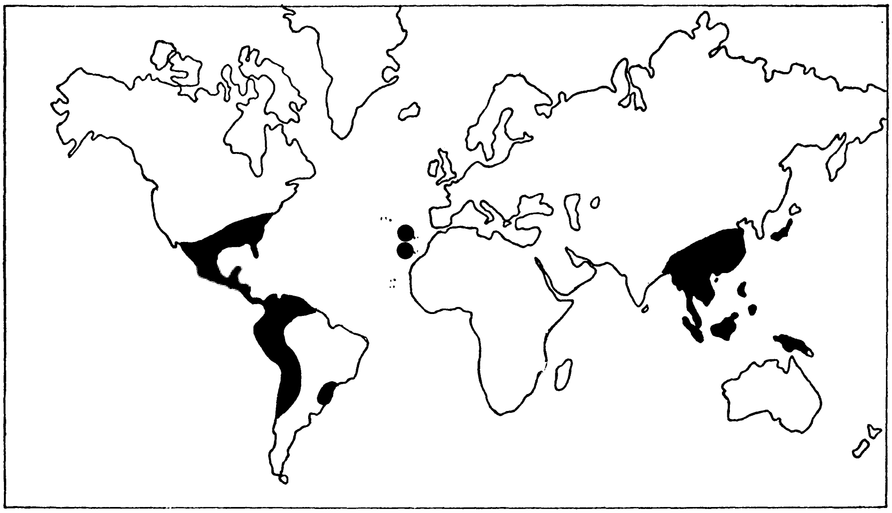

Fig. 14. Worldwide distribution of the family Clethraceae.

pogon (Labiatae, Fig. 12), *Ilex* sect. *cassinoides* (Aquifoliaceae), *Heberdenia* (Myrsinaceae) and *Cneorum* (Cneoraceae, Fig. 13).[2]

A further group of genera has an American/Macaronesian/S.E. Asian distribution pattern. This group includes *Clethra* (Clethraceae, Fig. 14), the genera of the Theaceae including *Visnea* in Macaronesia (Fig. 15),

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[2] The Canarian species *Cneorum pulverulentum* has been referred to a distinct genus *Neochamaelea* (Erdtman, 1952).

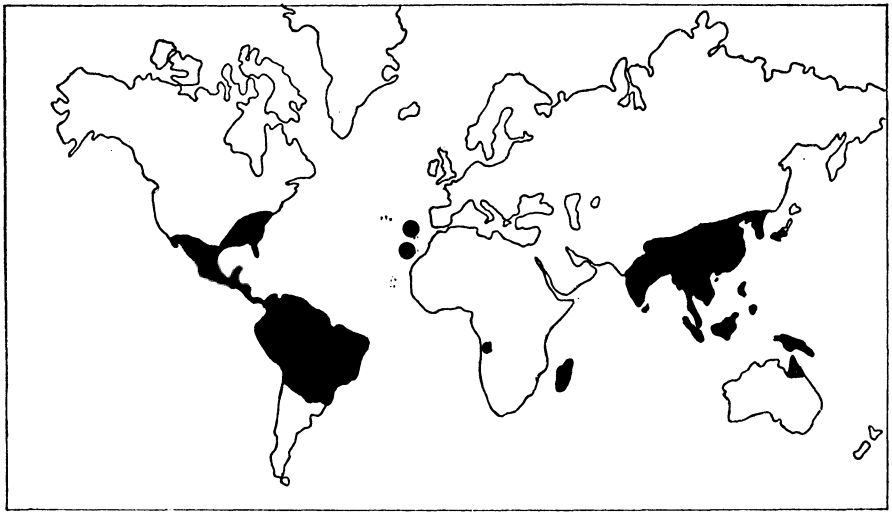

Fig. 15. Worldwide distribution of the family Theaceae with the endemic genus *Visnea* in Macaronesia.

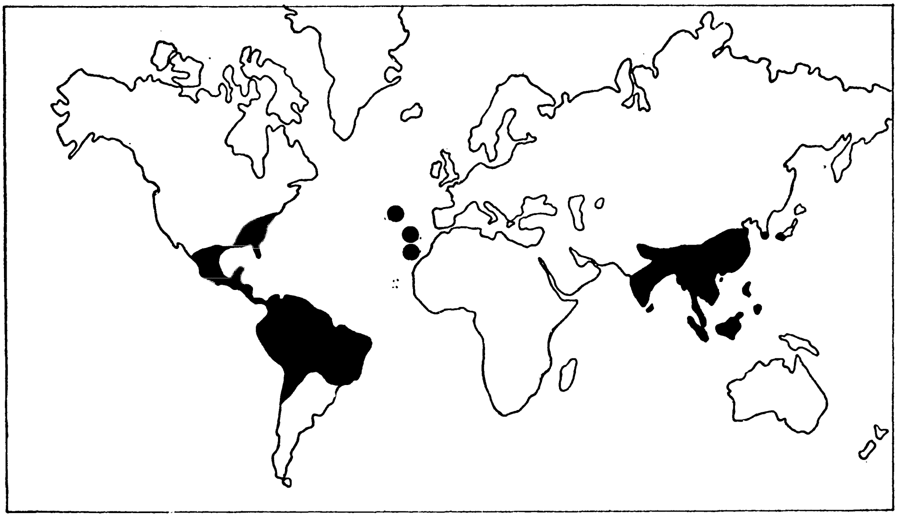

Fig. 16. Worldwide distribution of *Persea* (Lauraceae).

Persea (Lauraceae, Fig. 16), *Myrica* (Myricaceae) and *Laurocerasus* (Rosaceae). All these genera appear to belong to the pre-drift landmass element and all the families concerned (in the case of *Myrica* the genus itself) have been recorded from the Cretaceous Period. *Ilex* section *Aquifoliodes* subsection *Oxydontae* with *I. aquifolium* in Europe and *I. perado* in Macaronesia is a predominantly south-east Asian group which extends

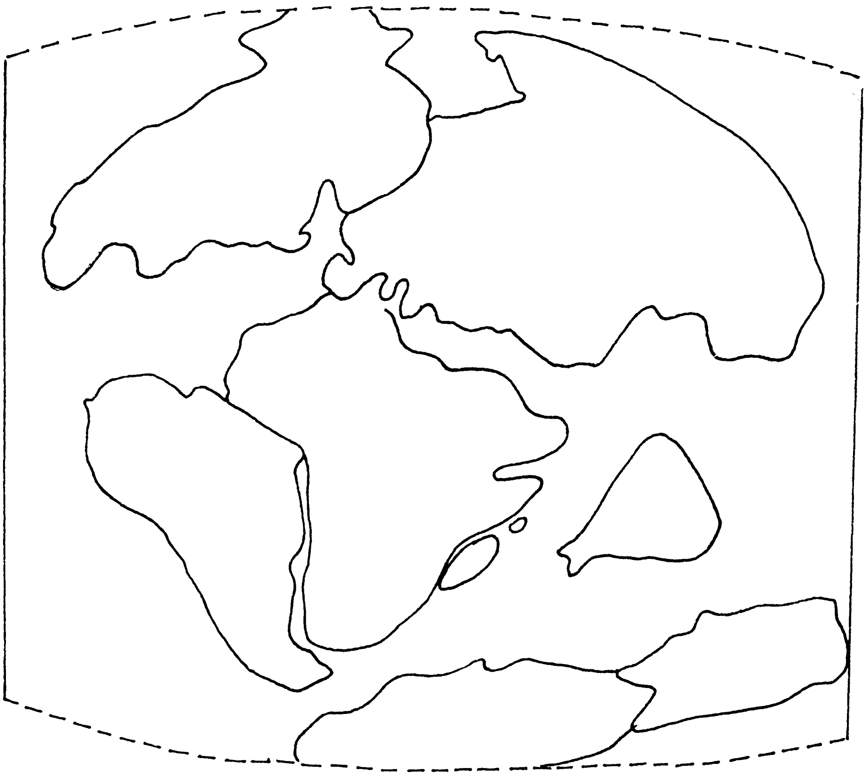

Fig. 17. Approximate position of the drifting continents in the Mid-Cretaceous (130 m years).

from China and Formosa across the Indian subcontinent to Persia and Western Europe with its western extremity in Macaronesia. The section *Cassinoides* of *Ilex* is, however, predominantly American with 13 species distributed between Brazil, Columbia and Peru in the southern part of the continent and Bahamas, Cuba, Mexico and the Eastern United States in the North. Two further species are known from South-West China and Japan and *Ilex canariensis* is found in Macaronesia giving this section a 'Clethra' type of distribution pattern.

A recent estimate of the positions of the drifting continents in the Cretaceous period has been given by Tarling & Tarling (1971) and suggests that the now widely disjunct areas of South and Central America, Indian subcontinent and Macaronesia (Lanzarote and Fuerteventura; Rothe & Schmincke 1968) were all part of a single landmass at a similar latitude and were much closer together than they are at the present day (Figs. 17, 18). Several genera such as *Myrica* and *Clethra* seem to have been carried into the South East Asian region when India migrated from its original 'African' position to its present-day Southern Asian location in the Tertiary Period.

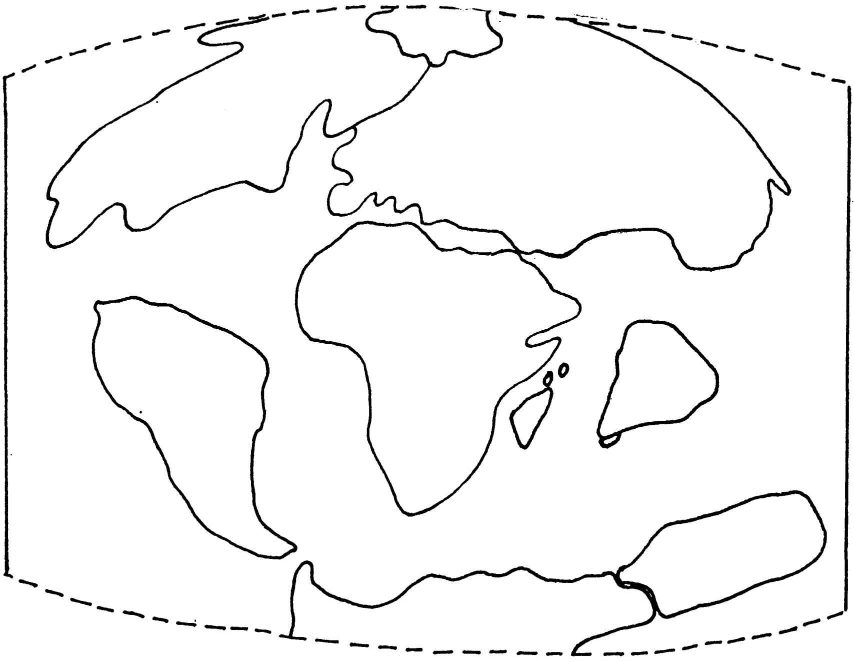

Fig. 18. Approximate position of the drifting continents in the Tertiary (60 m. years).

MACARONESIAN/SOUTH AND EAST AFRICAN DISJUNCTIONS

A second series of Macaronesian plants have their nearest relatives in South and East Africa. These include genera such as *Canarina*, *Aeonium*, *Lyperia*, *Argyranthemum*, *Phyllis*, *Adiantum* and *Echium* (Fig. 19).

Burtt (1971) has pointed out that many mainly South African genera that also occur in the Mediterranean region are found in the high mountain areas of East Africa and Ethiopia. The genus *Erica* is a classical example of this type of distribution.

Many of the Macaronesian genera noted above show at least part of this distribution pattern having disjunct distributions to the East African Highlands or the Cape region. These seem to represent the relicts of a once much more widespread distribution, possibly extending from southern Africa via the East African Highlands and the mountains of central Sahara such as Hoggar and Tibetsi into the western part of North Africa and possibly from there to Macaronesia. The distribution of some of these genera seems then to have extended into the northern part of the Mediterranean region.

The distribution of *Erica arborea* (Hedberg 1961) and of the genera *Adenocarpus* and *Androcymbium* (Burtt 1971) support this hypothesis and the primitive, frutescent species of *Echium* found in Macaronesia seem

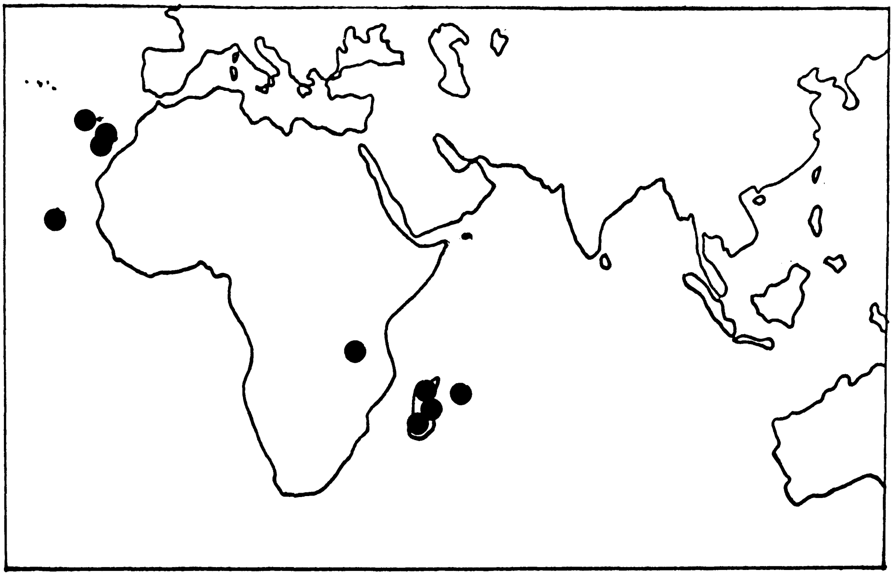

Fig. 19. The disjunct distribution of *Adiantum reniforme.*

very similar in indumentum structure (Bramwell, unpubl.), habit and the frequent occurrence of a more or less regular corolla to the South African genus *Lobostemon.* The frutescent Macaronesian *Argyranthemum* species also seem to have their nearest allies amongst the frutescent *Chrysanthemum* species of the Cape region.

As Hedberg (1961) suggests, these disjunctions date from the Tertiary Period and the West Mediterranean species of genera such as *Echium*, *Erica* and *Chrysanthemum* s.s. are secondary derivatives from ancestors of the Macaronesian/South African forms. It might be suggested that the Tertiary forms of these genera did not initially penetrate the North Mediterranean region direct as the Tethys Sea was probably an effective barrier to their northerly distribution. They probably spread westwards across North Africa and from there reached the Iberian Peninsula and the North Mediterranean regions. This suggestion seems to be borne out by the cytological evidence for genera such as *Sonchus* and *Echium* presented earlier in this paper.

MACARONESIAN/WEST MEDITERRANEAN DISJUNCTIONS

A number of genera and species found in Macaronesia also occur, or have their nearest relatives, in the West Mediterranean region notably in the Iberian Peninsula. Several of these *(Davallia canariensis, Leuzea cyanaroides, Umbilicus heylandianus, Laurocerasus lusitanica)*, were discussed by Font Quer (1957) and others by Bramwell (1972) who suggests that these may be relicts of the Tethyan Tertiary forest floras of the Mediterranean region.

Meusel (1952) derives the modern European species of *Digitalis* from the frutescent Macaronesian genus *Isoplexis* which he considers to be an ancestral form. The Iberian species *Digitalis obscura* which closely resembles the *Isoplexis* species, especially *I. sceptrum* of Madeira, in its frutescent habit, coriaceous leaves and orange flower pigments, seems to be a relict survivor of the Tertiary flora (cf. Rivas Goday 1946).

The Canarian *Hypericum coadunatum* has its nearest relatives in southern Morocco and southern Spain and is, apparently, an ancestral form related to the more advanced *Elodes* group of species in Europe (Robson, pers. comm.). Davis & Hedge (1971) summarizing the Tertiary history of the Mediterranean region state that southern Spain and Morocco were linked by a land connection from the Mid-Miocene to the early Pliocene.

Dactylis is represented in Macaronesia by *D. smithii* which has a diploid subspecies *smithii* confined to the Canary Islands and two polyploid subspecies *hylodes* and *marina* found throughout Macaronesia with the last named subspecies also occurring in the Mediterranean region and south-west Portugal (Parker 1972). The genus *Teline* has its main centre of distribution in the Macaronesian Islands, especially in the western Canaries, and two species are also found in the Mediterranean region. *Lotus* section *Pedrosia* is also similarly distributed with numerous species in Macaronesia and a single species *L. arenarius* with several subspecies also occurring in N. Africa and the Iberian Peninsula.

The species *Scrophularia arguta* which is found in the Canary Islands, Madeira, North Africa and Southern Spain also has this type of distribution.

MACARONESIAN/EAST MEDITERRANEAN DISJUNCTIONS

Floristic connections between Macaronesia and the East Mediterranean are shown by vicarious taxa in genera such as *Sideritis* (sect. *Empedoclea*) (Fig. 20), *Erysimum* (sect. *Cheiranthus*), *Bosea*, *Cheirolophus* and the *Ranunculus creticus/cortusifolius* group. These indicate that there may have been dispersal of northern Mediterranean elements into the south-west region of North Africa and into Macaronesia before the dessication of the Sahara region in the Holocene. Davis & Hedge (1971) suggest that such vicariants were first separated in the Tertiary or at the latest in the Pre-Pleistocene period. At this time the East Mediterranean region appears to have been linked to North Africa via Sicily. Several other Macaronesian genera such as *Ammodaucus*, *Pistacia* and *Convolvulus* (*C. caput-medusae* group) have an Irano-Turanian or Saharo-Sindian connection and according to Davis & Hedge (1971) these may also have a Tertiary origin, especially those species which are local endemics such as *Convolvulus caput-medusae* which is confined to the Canaries and has the vicariants *C. trabutianus* in N.W. Africa and *C. hystrix* in Egypt and the Palestine/Arabian region and a related species *C. leiocalycinus* in S.W. Asia.

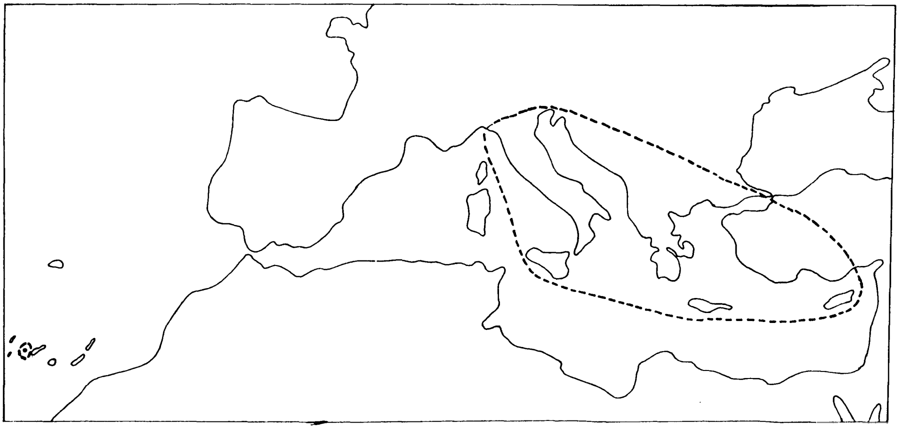

Fig. 20. The E. Mediterranean disjunct distribution of *Sideritis* section *Empedoclea.*

Summary and Conclusions

The considerable age of the endemic flora has been established by means of data drawn from a number of independent fields of study and it appears that many habitats in the Macaronesian islands have survived more or less unchanged over a long period of geological time and have acted as refugia for endemic relict taxa.

The breaking up of the Gondwanaland continent in the Cretaceous probably led to the origin of the Canary Islands in the Palaeo-Atlantic split. The eastern islands of Lanzarote and Fuertaventura were originally part of the North African continental mass (Rothe & Schmincke 1968). Sedimentary rocks of Cretaceous origin are found on Fuertaventura and these are very similar to rocks known from the nearby south west part of Morocco. The western Canary Islands, however, appear to have a wholly volcanic origin.

The disjunct distribution of families such as *Myricaceae*, *Lauraceae*, *Rosaceae* (*Sanguisorba* group) and genera like *Drusa* (Umbelliferae), *Bystropogon* (Labiatae) and *Clethra* (Clethraceae) suggests that they had their origin in the pre-drift landmass of Gondwanaland and that these form the very oldest element in the Macaronesian flora.

The endemic flora also has very strong Mid-Tertiary links, with several elements of major importance from the point of view of their origin. The Laurel forest flora seems to have been present for a very long time and dates back at least to the early Tertiary. This flora appears to be basically part of a subtropical flora which covered the Mediterranean region throughout most of the Tertiary period. Other elements seem to have their origin in southern Africa and may have been part of more xeric subtropical flora which reached Macaronesia and the Mediterranean region via the East African Highlands and the mountains of the central

Saharan region. A further element probably entered Macaronesia rather later in the Tertiary via a land connection between the East Mediterranean and North Africa (cf. Davis & Hedge 1971).

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ADDENDUM

Since this paper went to press there have been a number of developments in research into both the habit of island plants and the phytogeographical aspects of continental drift. Generally the results of this research are in accordance with the views expressed in this paper.

The existence of modern families and genera in the late Cretaceous and early Paleogene is now well documented and attention should be drawn to the extensive review of the subject by Raven P. H. & D. I. Axelrod 'Angiosperm Biogeography and Past Continental Movements', Anns. Miss. Bot. Gard. 61: 539–673 (1974).

An important contribution to wood anatomy and the habit of island plants was published in 1974 by D. J. Mabberley 'Pachycauly Vessel Elements, Islands and the Evolution of Arborescence in "Herbaceous" Families'. New Phytol. 73: 977–984, 1974.

VII. THE LAURISILVA OF HIERRO

by

EMIL SCHMID

The flora of the Canary Islands, Madeira and Azores

The character of the flora of these Islands is defined and determined by old indigenous genera and species like *Aeonium* species, *Apollonias*, *Visnea mocanera*, *Forskohlea angustifolia*, *Paronychia canariensis*, *Persea indica*, *Pleiomeris canariensis*, *Ixanthus viscosus*, *Ceropegia fusca*, *Echium* spec. div., *Sideritis* spec. div., *Gonospermum canariense*, *Sonchus* species,. Its a consequence of the seclusion of the islands are absent competitors, and the genera have produced many species from trees to annual species and subspecies. That is also the reason for the immigration and the propagation of species like *Erigeron karwinskianus*, *Oxalis pes-caprae*, *Calendula arvensis*. The apportioning to the vegetation belts is not always convincing if we have few species as in the high mountains, the zone of the two alpine belts. The subalpine *Pinus* belt is present with the *Pinus canariensis* and its flora. The subtropical Genisteae-Ericoideae belt is represented by the *Myrica-faya-Erica arborea* zone (Fayal-Brezal). The best represented belt is the Laurisilva, the Lauraceae belt. Below are mixed parts of the xeric *Quercus-Ilex* belt with *Juniperus phoenicea* and *Stipa capensis* and species of the *Argania sideroxylon* vegetation of Morocco.

THE LAURISILVA OF HIERRO

The flora of this island is composed of rests of old connections and of young immigrants. Old are the relations with Africa testified by the genera *Hypericum*, *Erica*, *Echium* in relationship with *Lobostemum* in South Africa and with Northern Africa by *Olea*, *Euphorbia*, with the subtropical vegetation belt in connection with Asia and North America with *Persea*, *Apollonias*, *Laurus*, with the rests of the European neogen like *Pinus*, *Ilex*, *Visnea*, with immigrants from the zone of winter rain. From the mediterranean region are present *Viburnum*, *Inula viscosa*, *Notholaena marantae*, *Juniperus phoenicea*, *Stipa capensis*. On Hierro are numerous the indigenous species of the Canary islands like *Aeonium holochrysum*, *Aichryson laxum* (Haw.) Bramw., *Ilex canariensis*, *Hypericum canariense*, *Echium strictum*, *Bystropogon canariensis*, *Sonchus hierrensis*. Numerous are also the plants imported by man, cultivated or adventitious, like *Spergula arvensis*, *Cerastium glomeratum*, *Stachys arvensis*, and *Castanea sativa*. On the northwest side, four levels above the sea can be observed. From sea till 500 m the *Juniperus* belt, from 500–950 m the *Laurocerasus* belt, the belt of Laurisilva,

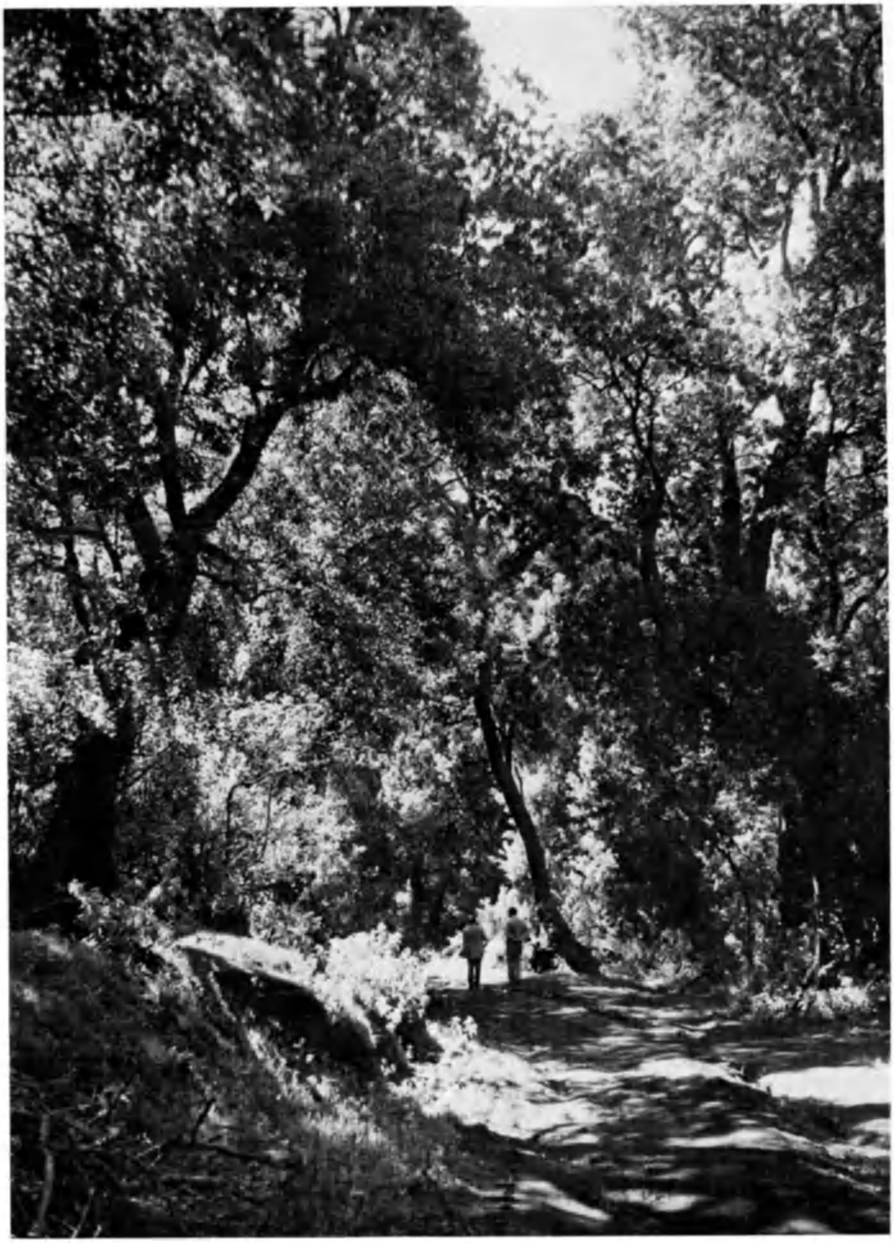

Fig. 1. The 'Fayal' of Hierro, a fascinating and almost homogeneous formation. (Photo Courtesy Foto Baeza).

from 950–1400 m the *Myrica faya* vegetation (Genisteae-Ericoideae belt) and the limit is occupied by *Pinus canariensis* wood. The condensation of water increases with the elevation above the sea; in the upper Fayal-Brezal the dew comes like a drizzling rain.

There can be distinguished the closed formation in which every participant occupies its position, an entirety with its parts, for example the 'Laurisilva' in which the ecological forms, ecotypes, are formed by the essential life conditions. In the open formation is missing, in general, the influence between mutual plants and vegetation climax, for example the grassland. Here we find more species and more ecological forms. We have to distinguish further the solitary plants, the hermits living in isolation, for example the plants of rocky slopes and debris. A closed formation in which every position is occupied by the corresponding ecotypes exists only in single places. At the very most it is a question of the influence of man who is disintegrating the structure of the formation. The humidity of the atmosphere in these northwest exposed slopes is high; we had at noon in April always about 90–92 per cent under the trees, and the dew in summertime is abundant and compensates the missing rain. On the rocks in the shade of the trees we see high and mighty shrubs of *Rumex maderensis*, *Sonchus hierrensis*, *Sideritis dendrochahorra*. The genus *Echium* has developed ecotypes, ecological forms for all levels even for the high mountains. In the alpine zone we have the form of the tropical mountains with *E. wildpretii*, a gigantic biennal half rosette plant with an enormous inflorescence, a form just like the famous *Argyroxiphium* of the Hawaiian Islands or the *Lupinus* in the high mountains of Ecuador. At the altitude of the Laurisilva, woody plants, high till 3 m and simply branched, are present. In the dry lowland, all transition from herbs of short lifetime to annual plants can be seen. This evolution into so many ecotypes is rare and explicable with long times and missing competition on the isolated islands. It can be found also in the genera *Aeonium*, *Cytisus*, *Hypericum*, *Micromeria*, *Sempervivum*, *Sideritis*, *Sonchus*, *Limonium* and others.

The unique Laurisilva of Hierro occurs on the north-western side above Frontera at an altitude of 600–900 m. Its vegetation is influenced by man, and therefore, it is very complicated to rebuild the phytocenose from extant fragmentary remains. Most impressing is the dominant tree *Visnea mocanera*. *Tamus edulis* is an deciduous perennial plant of the *Laurocerasus* belt with a bulbous axis and heart-shaped leaves. With only one more species this genus is distributed in southwestern Europe from Persia to the Canary Islands. *Rubus fruticosus*, a section of the genus *Rubus* with various species in the woods of the *Laurocerasus* belt and the belt of Genisteae and Cytiseae, has seasonless leaves and long creeping and only at the base woody shoots. In the humid fissures of the rocks in the wood we see the splendid *Sonchus hierrensis*, a half-woody plant. One of the 12 endemic *Sonchus* of the Canary Islands is the most imposing representative of this genus. It is here in danger to be extirpated by the grazing goats. The genus *Sonchus* is indigenous in Africa, Europe and Asia. Also African relations can be stated with *Canarina canariensis* of which are noted *Canarina eminii* from Banssoro and *C. abyssinica* from Galla highland in southern Abyssinia, a herb with whool-like foliation and large red flowers living on rocks in the woods. It is difficult to form an opinion on the origin of *Drusa glandulosa*, a herb of the Umbelliferae family with relations to South American species. It is doubtful if it is native or an adventitious plant; it is a creeping herb of the lighter places in the wood. *Drusa* has another station in Morocco. The fruit is very adhesive, and that could be an argument, a counter-evidence to the idea of the indigenous occurrence because on the Islands there do not exist any animals which could spread it. On the other side, the same connections are to be seen in the Cruciferae family in the genus *Crambe* with species in Patagonia and on the Canary islands. *Crambe strigosa*, a herb with a lignified basis can be found in the Laurisilva. *Myosotis macrocalycina* differs from the extratropical *M. silvatica* by its larger and broader leaves. It flowers and fruits without interruption during the whole year like *Stellaria media*. *Geranium canariense*, a high perennial plant nearly cognate with *Geranium atlanticum* from Algeria, with a strong shaft and large leaves is also a characteristic of the humid shady subtropical wood. *Geranium canariense* with thick rhizome and stem is characteristic for the Laurisilva. Subtropical intermediary forms are *G. atlanticum* from Morocco between the woody bushes of the Tropics like *G. neurophyllon* from the Sandwich Islands and the several perennial of *G. macrorhizum* in the *Quercus-Tilia-Acer* belt of southern Europe. Further examples of trends from shrub to annual forms are *Teucrium*, *Sonchus*, *Rumex*, and *Hypericum*. There are two *Rubus* species in the Laurisilva: the endemic *Rubus bollei* Focke, with up to 15 m long axes, leaflets narrower and longer pointed, with prickles ending parallel to the branches, and *Rubus ulmifolius* widespread in southern Europe, northern Africa and western Asia, with shorter axes, broader leaflets, with robust straight prickles ending rectangularly to the branches, underside of leaf with white tomentum. *Brachypodium silvaticum* belongs to the tall grasses of the subtropical and humid extratropical woods from the Azores through North Africa, Europe to Persia and Japan. The tall plant, 1 m, with dense fertile and sterile shoots, with broad leaves forms tufts and is not seasoned. It has nothing to do with *Brachypodium pinnatum*. It prefers always humid habitats while *Brachypodium silvaticum* belongs to the primary subtropical plants which can survive in most places in the shade of humid woods and can advance the warm temperate regions like *Carex pendula*, *Ilex aquifolium*, *Taxus baccata*, *Buxus sempervirens*, *Daphne laureola*, *Hedera helix* and others. *Rumex lunaria* is a 1 m high ligneous shrub, young shoots axillary, with long internodes and with fleshy broad oval leaves, and is frequent on rocky slopes in the wood, like *Rubia* *fruticosa* var. *angustifolia*, a 2 m high shrub with woody root and shaft with white bark, additional shoots with long internodes.

INTRODUCED PLANTS

Introduced by man with grazing animals are for instance *Aira caryophyllea*, *Hyparrhenia hirta*, *Anthoxanthum aristatum*, *Avena barbata*, *Trachynia distachya*, *Bromus madritensis*, *Briza maxima*, *Cynosurus echinatus*, *Lolium perenne*, *L. multiflorum*, *Hordeum murinum*, *Poa annua*, *Vulpia myuros*, *Carex divulsa*, *Cyperus rotundus*, *Parietaria debilis*, *Rumex bucephalophorus*, *Cerastium glomeratum*, *Spergula arvensis*, *Capsella bursa-pastoris*, *Raphanus raphanistrum*, *Aphanes microcarpa*, *Trifolium subterraneum*, *Geranium robertianum*, *Mercurialis annua*, *Oxalis pes-caprae*, *Scandix pecten-veneris*. *Anagallis arvenis*, *Ballota nigra*, *Marrubium vulgare*, *Stachys arvensis*, *Stachys ocymastrum*, *Solanum nigrum*, *Antirrhinum orontium*, *Orobanche ramosa*, *Galium aparine*, *G. parisiense*, *G. rotundifolium*, *Sherardia arvensis*, *Calendula arvensis*, *Inula viscosa*, *Cotula coronopifolia*, *Galactites tomentosa*, *Senecio vulgaris*, *Silybum marianum*, *Bidens pilosus*, *Sonchus oleraceus*, etc.

Nanismic imported plants on rocks in the wood can exist because the humidity of the air is continuous and we find a dense cover of plants like *Lagurus ovatus*, *Vulpia bromoides*, *Anthoxanthum odoratum*, *A. aristatum*, *Lamarckia aurea*, *Aira caryophyllea*, *Trachynia distachya*, *Luzula elegans*, *Polycarpon tetraphyllum*, *Rumex bucephalophorus*, *Anagallis arvensis*, *Silene gallica*, *Cerastium glomeratum*, *Spergula arvensis*, *Fumaria montana*, *Aphanes microcarpa*, *Trifolium subterraneum*, *T. campestre*, *Ononis dentata*, *Geranium rotundifolium*, *Geranium molle*, *Torilis arvensis*, *Veronica arvensis*, *Wahlenbergia lobelioides*, *Cotula coronopifolia*. Nearly all these plants came from the Mediterranean region, specially from the part with winter rain, but here they can exist without soil in smallest forms from 1 to a few centimetres. All bear flowers and fruits, and the fruit of a plant of ten millimetres gives under normal conditions a normal plant.

The investigation of the flora of an island is complicated and requires taxonomic, chorological, phylogenetic, and epiontological determination, analyses of the environment, general and local climate, condition of the soil, determination of the ecotypes and their trends within the genera and not least checking the influence of man.

Plant List by E. Zogg

NW-facing slope above Frontera (Hierro), Laurisilvavegetation, 600–900 m alt.

Selaginella denticulata (L.) Link
Notholaena marantae (L.) R.Br. ssp. *subcordata* (Cav.) Kunkel
Adiantum reniforme L.
Anogramme leptophylla (L.) Link
Pteridium aquilinum (L.) Kuhn

Davallia canariensis (L.) J.E.Sm.
Asplenium hemionitis L.
A. trichomanes L.
A. adiantum-nigrum L.
A. onopteris L.
A. aethiopicum (Burm.f.) Becherer
Ceterach aureum (Cav.) v.Buch
Cystopteris diaphana (Bory) Blasdell
Dryopteris oligodonta (Desv.) Pic.Ser.
Polypodium australe Fée

Juniperus phoenicea L.
Pinus canariensis Sweet ex Sprengel

Myrica faya Ait.
Castanea sativa Mill.
Forskohlea augustifolia Retz
Gesnouinea arborea (L.) L'Hér.
Parietaria debilis Forst.
Urtica morifolia Poir.
Cytinus hypocistis (L.) L. on *Cistus monspeliensis* L.
Rumex bucephalophorus L. ssp. *canariensis* (Steinh.) K.H.Rech.
R. maderensis Lowe
R. lunaria L.
Cerastium glomeratum Thuill.
Silene vulgaris (Moench) Garcke
S. berthelotiana Webb
Spergula arvensis L.
Stellaria media (L.) Vill.
Ranunculus cortusaefolius Willd.
R. muricatus L.
R. parviflorus L. var. *acutilobus* DC
Apollonias barbujana (Cav.) Bornm.
Laurus azorica (Seub.) Franco
Persea indica (L.) Spreng.
Fumaria montana Schmidt
Capsella bursa-pastoris L.
Cheiranthus virescens Webb ex Christ
Crambe strigosa L'Hér.
Lobularia intermedia W.B.
Raphanus raphanistrum L.
Aeonium holochrysum W.B.
Greenovia aurea (Chr.Sm.) W.B.
Aichryson laxum (Haw.) Bramwell
A. parlatorei Bolle
Monanthes muralis (Webb) Christ
Rubus ulmifolius Schott
Bencomia caudata (Ait.) W.B.
Aphanes microcarpa (Goiss. ex Reut.) Rothm.
Pyrus communis L.
P. malus L.
Chamaecytisus proliferus (L.f.) Link
Cytisus stenopetalus (Webb) Christ
Psoralea bituminosa L.

Vicia cirrhosa Chr.Sm.
V. lutea L.
Trifolium subterranum L.
Erodium cicutarium (L.) L'Hér.
Geranium canariense Reuter
G. molle L.
G. robertianum L.
Mercurialis annua L.
Oxalis pes-caprae L.
Ilex canariensis Poir.
Visnea mocanera L.f.
Hypericum canariense L.
H. grandifolium Chois.
Cistus monspeliensis L.
Tuberaria guttata (L.) Fourr.
Viola silvestris Lam.
Hedera canariensis Willd.
Bupleurum salicifolium Soland. ssp. *aciphyllum* (Webb ex Parl.) Sunding et Kunkel
Drusa glandulosa (Poir.) Bornm.
Todaroa montana Brouss. ex Benth. et Hook.fil.
Ferula linkii W.B.
Scandix pecten-veneris L.
Erica arborea L.
Arbutus canariensis Veill.
Anagallis arvensis L. ssp. *coerulea* (Schreber) Schinz et Keller
Jasminum odoratissimum L.
Picconia excelsa (Ait.) DC
Ixanthus viscosus Griseb.
Echium strictum L.f. var. *lineolatum* Jacq.
E. plantagineum L.
Myosotis macrocalycina Coss.
Ballota nigra L.
Bystropogon canariensis (L.) L'Hér.
Cedronella canariensis (L.) W.B.
Marrubium vulgare L.
Micromeria varia Benth.
Sideritis dendro-chahorra Bolle
Stachys arvensis L.
S. ocymastrum (L.) Briq.
Solanum nigrum L.
Misopates orontium (L.) Raf.
Scrophularia smithii Hornem.
Orobanche ramosa L.
Lytanthus salicinus (Lam.) Wettst.
Galium aparine L.
G. rotundifolium L.
G. parisiense L.
Phyllis nobla L.
Rubia fruticosa Ait. var. *angustifolia* Ktze.
Sherardia arvensis L.
Viburnum rigidum Vent.
Canarina canariensis (L.) Vatke
Wahlenbergia nutabunda A.DC.
Andryala pinnatifida Ait.
Artemisia canariensis (Bess.) Less.

Bidens pilosa L.
Calendula arvensis L.
Carduus tenuiflorus Curt.
Carlina salicifolia (L.f.) Cav.
Cotula australis (Less.) Hook.fil.
Galactites tomentosa Moench
Gonospermum elegans Webb
Inula viscosa (L.) Ait.
Kleinia neriifolia Haw.
Senecio murrayi Bornm.
S. vulgaris L.
Silybum marianum (L.) Gaertn.
Sonchus hierrensis (Pitard) Boulos
S. oleraceus L.

Dracunculus canariensis Kunth
Aira caryophyllea L.
Hyparrhenia hirta (L.) Stapf
Anthoxanthum aristatum Boiss.
Avena barbata Potter
Trachynia distachya (Hasselq. ex L.) Link
Brachypodium silvaticum (Huds.) P.B.
Bromus madritensis L.
B. villosus Forsk. var. *gussonei* Parl.
Briza maxima L.
Cynosurus echinatus L.
Lolium perenne L.
L. multiflorum Lam.
L. gracile Parl.
Hordeum murinum L.
Lamarckia aurea (L.) Moench
Poa annua L.
Stipa capensis Thunb.
Vulpia myuros (L.) Gmel.
V. bromoides (L.) S. F. Gray
Carex canariensis Kückenth.
C. divulsa Good.
Luzula elegans Lowe
Allium trifoliatum Cyr.
A. subhirsutum L.
Asphodelus microcarpus Salzm. et Viv.
Semele androgyna (L.) Kunth
Smilax aspera L. var. *altissima* Mor. & DeNot.
Tamus edulis Lowe
Romulea columnae S. et Maur. ssp. *grandiscapa* (Webb) Kunkel
Gennaria diphylla (Link) Parl.
Orchis patens Desf. ssp. *canariensis* (Lindl.) Sunding & Kunkel

VIII. NOTES ON THE INTRODUCED ELEMENTS IN THE CANARY ISLANDS' FLORA

by

GÜNTHER KUNKEL

Introduction

As in any other region, the plant life of the Canary Islands is divided into three larger groups: the native elements, the involuntarily introduced (or escaped) elements or 'weeds', and the cultivated plants. Such a division is relatively easy to document if a given area is an island, or a group of islands, with the most natural borderline around: the sea.

Although until now no complete inventory has been made, we estimate a total of over 3.000 plant species that may be found in Canarian gardens, on agricultural land, and in the wild countryside. Out of this total sum of vascular plants, some 550 species are considered as Canarian endemics in the strict sense (Kunkel 1974:26). Another 450 to 500 taxa are known to be native in the islands, as Macaronesian elements or having an even wider distribution including the western Mediterranean zone and/or North Africa. Some 700 species have been registered as involuntarily introduced weeds or plants escaped from gardens and now well established. Summarizing before mentioned data leaves us with further, aproximately 1.300 species which are truly cultivated plants, rare or common in Canarian parks and gardens, along roadsides, in fields or in greenhouses; only in trees a preliminary inventory shows a figure of over 300 introduced species, against a sum of some 40 native elements.

Considering figures such as these one might expect to find a totally unbalanced flora in the islands. Such is true when surveying the plant life of inhabited zones and areas of agricultural activity. However the picture changes when in the field, in the native woodlands or in mountain countrysides where native elements – at least in parts – still dominate.

The true cultivated element

The history of agriculture in the Canary Islands, according to the scarse sources available (i.e. Matznetter 1958) is thought to have begun some two thousand years ago when the primitive Canarios or Guanches immigrated to the islands and introduced their barley and a few other crops. During this period of many, many centuries naturally some parts of the natural landscape were modified, to a greater or lesser extent. However modification on a large scale only started at the end of the 15th

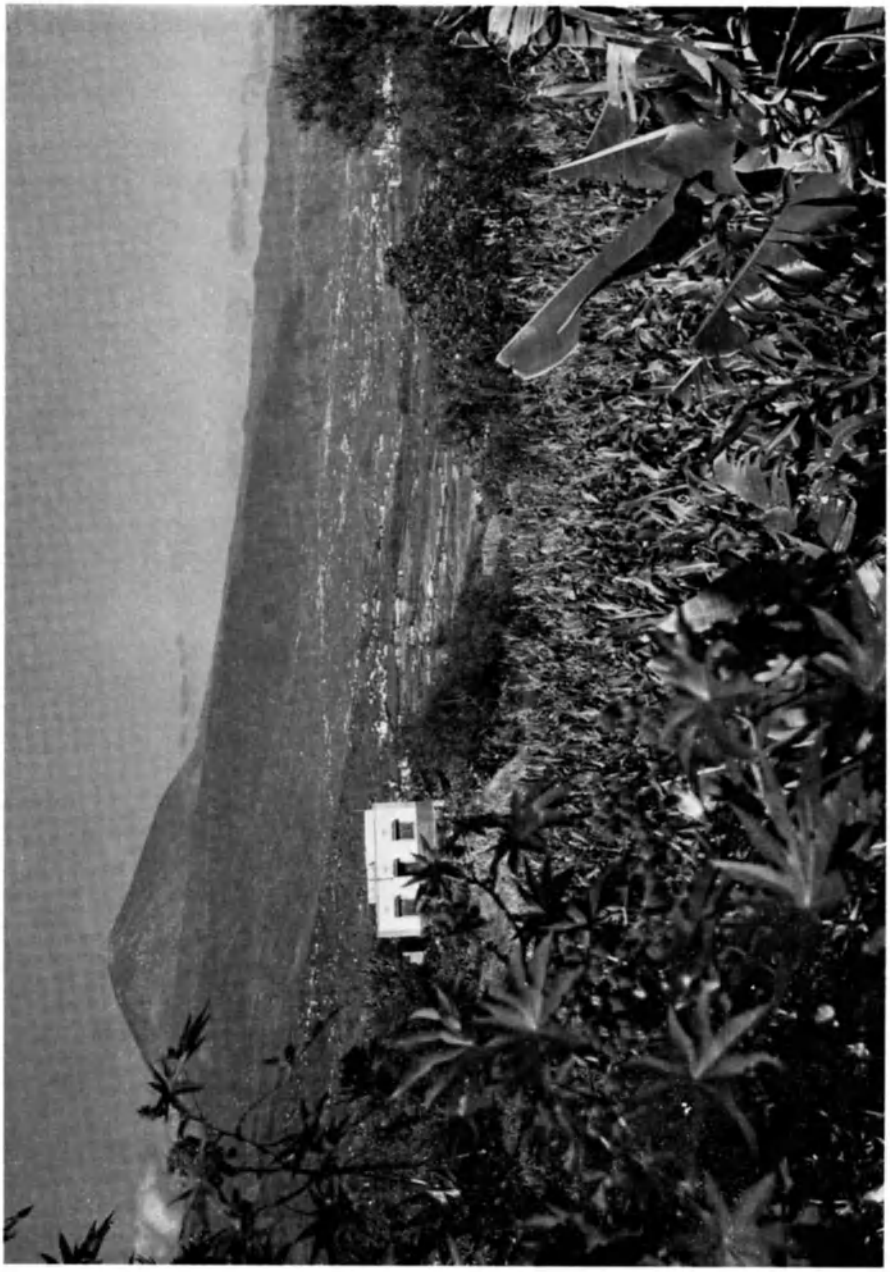

Fig. 1. The laurel forest was destroyed and converted into a cultivated landscape: The Orotava valley, on Tenerife, with banana plantations. Foreground, left: *Ricinus communis*.

Century, when the modern Conquista took place. Much timber and firewood was needed, large extensions of land came under cultivation, and weeds accompanying civilization established themselves. The laurel forest became almost totally destroyed and was partly replaced by fields of sugar cane. Later, cultivation of tomatos, maize, bananas and potatoes took over, and more than half of the total of the islands' surface, at one time or another, has been under cultivation. Tomato and banana plantations still occupy large parts of the islands, at least in the central and western part of the archipelago.

The modern trend is towards more intense (but not more diverse) methods, and greenhouses replace part of the traditionally extensively cultivated land. Cucumbers, peppers, cut-flowers, decorative plants and even early tomatoes are the new products, mainly destined for export to European markets. Certain abandoned areas (mountain slopes) have been reafforested, partly – and unfortunately – with exotic species, mainly of the genus *Pinus*. And as is happening all over the world, agricultural land is continually lost to urbanization. And in such places it is true that visitors may travel for kilometers without seeing much vegetation original to the islands, except for a few and very resistant native elements.

Main crops

In places where 'dry' cultivation is practised and where rainfall is depended upon, the land (usually terraced) is sown with cereal crops such as *Avena*, *Triticum*, *Secale* and, especially, varieties of *Hordeum*. Other gramineous species such as *Zea* need irrigation, and *Sorghum* is occasionally planted bordering banana plantations. The cultivation of *Saccharum*, once very important to the islands, is now restricted to a few fields in the central islands (Gran Canaria and Tenerife). On moister northern slopes of medium-high elevation, vegetables and potatos are grown which may be irrigated during the summer or (in case of several crops) almost all year round if rainfall is insufficient. Some other dryland crops (after a good rainy season only) include *Pisum*, *Cicer*, *Lathyrus* and *Lens*, *Lupinus* and *Vicia* are sown as forrage plants. Other crops such as *Phaseolus*, *Faba*, alfalfa and the numerous clases of Cucurbitaceae need more special care (Kunkel 1970).

After trying several species and varieties of bananas in the islands, practitioners of monocultural plantations decided on *Musa acuminata*, the Cavendish or Chinese banana now commonly known as the Canary banana; according to some authors the species is considered as *M. cavendishii* var. *nana*. This species is successfully cultivated from sealevel to about 300 to 400 m a.s.l.; however shortage of water, rising costs, and heavy competition from Central America have caused a decline in banana production, and a good many growers are tending to change over to greenhouse crops.

The second monocultural crop of importance embraces the complex of *Lycopersicon esculentum*, the common tomato and its varieties. Both crops mentioned are mainly destined for export. The once important *Citrus* plantations have been much reduced due to introduced pests such as ants, red spiders, and a tiny insect locally known as 'Mosca blanca' (White fly). It is understood that lack of water was also part-responsable.

The drier, rocky slopes, especially in the eastern islands, were once important for the cultivation of cacti (especies of *Opuntia*), for the subsequent harvest of the Cochinille, the dye-colour producing cochineal insect (T. Bravo 1954). The Cochineal cultures suffered much owing to the invention of artificial colourants but it experiences, at present, a renaissance as certain artificial colourants have proved to be responsible for a cancerous skin desease.

'Leaves' (cladodes, pads or joints) of *Opuntia* as well as the leaves of *Agave americana* are appreciated as fodder material during the long, dry summer in the islands. Several species of *Agave (A. sisalana, A. fourcroydes)* were cultivated on a large scale in Fuerteventura, promoted by the Spanish Government, but even these crops are abandoned now as the plastic alternative is found to be stronger and easier to manufacture.

Fig. 2. Opuntia, infested by Cochinille.

ORNAMENTALS AND OTHER FLOWERING PLANTS

The inhabitants of the Canary Islands, although rather irreverent as far as the native vegetation is concerned, are true plant lovers. Introduced plants, flowering or not, are treated with great care and, considering the often critical water situation, cultivated only by sacrificing other interests. Roadsides, fences, gardens, balconies and patios give testimony of the love of plants, and only the modern city block is finally able to discourage such efforts. Unfortunately, recent road widening operations have destroyed much of the both interesting and colourful road-side vegetation, and as these actions seem to be directed by 'human computors', re-planting hardly ever takes place.

However to return to the natural plant love of people concerned with their own plots and gardens, here one may find an amazingly varied selection of plants, such as *Hibiscus*, *Bougainvillea*, *Ficus*, *Pelargonium*, *Philodendron*, *Codiaeum*, *Impatiens*, *Acalypha*, *Aloe*, *Acacia*, *Euphorbia* etc., and several species of Bignoniaceae, also palms and ferns are very common. Plants seem to have been introduced from every continent and almost every climate, although the tropical and subtropical elements dominate. Even the so-called 'poor peoples gardens' are spots of special horticultural interest to every visitor.

The new gardens of Tourist Developments appear far less interesting, tending to be rather monotonous, less colourful and less imaginative. Here exotic and native species grow side by side, landscaped and planned into submission, and although new species are continually being tried out, the gardens somewhat lack the caring touch of the country people.

Also in the field of ornamentals modern horticulture again prefers monotony under glass. Roses, carnations, Strelitzias, bromeliads and Chrysanthemums are grown mainly for export, and most of them leave the islands before any flowers are seen.

FRUIT TREES

The Canary Islands, known in mythology as the 'Gardens of Hesperides', are one of the few places in the world where palms and pines meet and grow together, in their natural distribution. The multitude of cultivated fruit trees meeting here is an equally interesting phenomena.

As there is no real fruit tree native in the islands (the fruits of wild-growing *Visnea mocanera* and *Arbutus canariensis* were eaten but the species never cultivated), the history of the fruit bearing trees begun with the arrival of man. *Ficus carica* and *Phoenix dactylifera* were introduced long before the colonization of the Canaries, by the Spanish or on behalf of the Spanish crown. The majority of species, however, arrived later and our list (Kunkel 1970) contains at least 60 different taxa all of which have been introduced since 1500, brought to the islands by the new settlers.

Fig. 3. The 'new forest' in the drier interior (Gran Canaria), formed by Almond trees.

Due to the previously mentioned difficulties with *Citrus* trees only the Common Chestnut *(Castanea sativa)* and the Almond tree *(Amygdalus communis)* remain in more or less extensive plantations. Both of these latter species regenerate naturally and now form a kind of 'new forest' in some parts of the islands.

Although *Persea amaricana* (Avocado tree), *Mangifera indica* (the Mango tree), *Carica papaya* (Paw-paw), Apple trees (*Malus* spp.) etc. have been known in Canary gardens for hundreds of years, their cultivation on a commercial scale dates back only 10 or 12 years, when new varieties were introduced. However almost every country garden seems to have as well as these, a Lemon tree *(Citrus)*, a Japanese Loquat *(Eriobotrya)*, the White Zapote (*Casimiroa*), Pomegranate *(Punica)* and a few others more. *Ceratonia siliqua*, *Morus nigra* and *Ficus carica* are often found growing in fields where they serve both as fruit and shade trees. In higher zones they are replaced by Chestnut and Walnut trees. Of special consideration furthermore is the Olive tree; planted locally the species forms an open woodland in the higher regions of certain zones of some islands having a southernly orientation.

Coffee *(Coffea)* is frequently grown as a shrub bordering banana plantations, where attempts to raise other tropical species such as Bread fruit *(Artocarpus)*, Zapote *(Manilkara)* and Litchi *(Litchi chinensis)* failed or were little successful.

Fig. 4. Eroded surface on slopes previously planted with *Eucalyptus globulus.*

REAFFORESTATION

Until some 50 or 60 years ago the native woodlands of the islands merely served as 'eine rein raubwirtschaftlich ausgebeutete Rohstoffbasis' (Matznetter 1958, p. 84). Reafforestation has been practiced only with conifers, and besides the native Pine *(Pinus canariensis)* several exotic species (*P. radiata*, *P. halepensis* etc.) have been used with varying degrees of success to reestablish wooded areas in the Canary uplands. Unfortunately none of the destroyed laurel forest zones have ever been replanted or, if reafforestation took place, this noble plant community was merely replaced by pine species and *Eucalyptus* (especially *E. globulus*).

The idea to protect the native woodlands in the islands is new, and even more recent are the efforts to reintroduce species of the native laurel woods (Laurisilva canaria; see Sanchez 1973). Referring to proposals of reafforestation, at least in the western Canary Islands, see also Ceballos & Ortuño (1951). Extremely useful data on the ecological importance of the native woodlands are given by F. Kämmer (1974). V. Voggenreiter (1974) showed the degree of destruction of the native woodland elements and presented proposals for their reestablishment and/or conservation.

The situation in other Macaronesian islands might be similar, as recently published by E. Sjögren (1973a, 1973b) and other authors.

Weedy plants in the Canarian landscape

As already indicated, a great number of species found in the Canary Islands are considered as introduced weeds. Some of them are hardly noticeable, others are common; some have become virtually harmless components of the islands' flora, others have established themselves as aggressive elements. At least 15 species may now be considered as serious pests, being of both invading and destructive character, and responsible for modifications to the vegetation generally. Except for occasional action against some common weeds in fields and plantations, nothing has been done yet, to control these aggressive introduced elements.

It seems typical for a properly balanced, ecologically healthy flora as found in the Canary Islands, that no native species (except two examples cited on p. 264) could be considered as an 'aggressive element', dangerous to other species or communities; the two species to be mentioned (*Asparagus pastorianus* and *Launaea arborescens*) are only spreading owing to lack of the accustomed competition with other natural companion plants.

WEEDS AS 'COMPANIONS'

Most introduced, weedy species have found their ecological niche and – to the uninitiated visitor – they are hardly noticeable. These elements may include all forms from herbs, succulents, shrubs and climbers to trees. Many of them were introduced centuries ago, together with seeds of crop plants, or they arrived with or by means of domestic animals. This group of plants is numerous and mainly of Mediterranean origin.

With the exception of species to be mentioned in the next chapter, the most common weeds in the Canary Islands belong to the following families and genera:

GRAMINEAE (or Poaceae): *Avena*, *Bromus*, *Cynodon*, *Hordeum*, *Poa*, and *Setaria*; LEMNACEAE: *Lemna*; AMARANTHACEAE: *Achyranthes* and *Amaranthus*; CARIOPHYLLACEAE: *Cerastium*, *Silene*, *Spergularia* and *Stellaria*; CHENOPODIACEAE: *Atriplex* and *Chenopodium*; COMPOSITAE (or Asteraceae): *Bidens*, *Calendula*, *Carduus*, *Carthamus*, *Centaurea*, *Cichorium*, *Conyza*, *Cynara*, *Erigeron*, *Galactites*, *Lactuca*, *Silybum*, *Sonchus*, and *Xanthium*; CONVOLVULACEAE: *Convolvulus*; CRUCIFERAE (or Brassicaceae): *Brassica*, *Capsella*, *Coronopus*, *Hirschfeldia*, *Raphanus*, *Rapistrum*, *Sinapis*, and *Sisymbrium*; EUPHORBIACEAE: *Euphorbia* and *Mercurialis*; FUMARIACEAE: *Fumaria*; GERANIACEAE: *Erodium*, *Geranium* and *Pelargonium*; LABIATAE (or Lamiaceae): *Lamium*, *Marrubium*, *Mentha*, *Prunella* and *Stachys*; LINACEAE: *Linum*; ONAGRACEAE: *Epilobium* and *Oenothera*; OXALIDACEAE: *Oxalis*; PAPAVERACEAE: *Argemone*, *Eschscholzia*, *Glaucium* and *Papaver*; PAPILIONACEAE (or Fabaceae): *Lathyrus*, *Medicago*, *Melilotus*, *Scorpiurus*, and *Vicia*; PLANTAGINACEAE: *Plantago*; POLYGONACEAE: *Emex*, *Polygonum* and *Rumex*; PORTULACACEAE: *Portulaca*; PRIMULACEAE: *Anagallis*; ROSACEAE: *Sanguisorba*; RUBIACEAE: *Galium* and *Sherardia*; SCROPHULARIACEAE: *Cymbalaria*, *Misopates*, *Verbascum* and *Veronica*; SOLANACEAE: *Datura*, *Nicandra* and *Solanum*; TROPAEOLACEAE: *Tropaeolum*; UMBELLIFERAE (or Apiaceae): *Ammi*, *Apium*, *Conium*, *Foeniculum*, *Petroselinum*, *Scandix* and *Torilis*; URTICACEAE: *Parietaria* and *Urtica*, and VERBENACEAE: *Phyla* and *Verbena*.

Although some of the species mentioned are really common, none of them are considered as serious pests or dangerous to the – still surviving – native plant communities. Referring to a more extensive but already outdated list, see Kunkel 1972. Other data have been published by A. Hansen (1970) and, well documented by maps, by V. Voggenreiter (1974a).

THE AGGRESSIVE ELEMENTS

The list of so-called aggressive elements is short. Nevertheless the names given are important enough to be dealt with in detail. The first survey of such invadors was written six years ago (Kunkel 1969) but published after much delay (1973). – For convenience the species dealt with are cited in alphabetical order.

Agave spp. (Agavaceae); Span.: Pita, or Pitera

A number of species have been introduced from Central America. *Agave sisalana* and *A. fourcroydes* have already been noted in connection with agriculture, especially in the eastern islands. They are also well established in some other islands but have never become 'weeds'. More persistant is *Agave ferox* which, similar to the preceeding species, grows on roadsides and freely reproduces from stoloniferous or basal shoots. Finally, although useful but difficult to control and therefore a more serious problem, *Agave americana* is to be dealt with. This vigorous species, known as the 'Century plant', was originally planted in gardens, on roadsides, and bordering fields and country paths. Due to the ease with which it reproduces it now covers quite large areas and – when growing together with cacti – forms truly impenetrable communities. Thanks to the shortage of forage the leaves of the pitera are frequently cut for animal feed and so a certain use and, therefore, control still seems assured.

Ailanthus altissima (Simaroubaceae); Span.: Arbol del cielo, or Zumaque-falso

This species is also known as *Ailanthus glandulosa* and has been introduced to some parks and gardens of the central Canary Islands. Reproducing by seeds and from root shoots, specimens easily multiply and spread to cover more ground than was intended, and even fire causes only a temporary setback. The species might become a serious danger if once taking root in the wood or bushland zones of the islands.

Albizia lophantha (Mimosaceae); Span.: Mimosa

Another garden escape of bushy habit or growing into small trees. Although cultivated in all major islands of the archipelago, it escaped cultivation in Tenerife, Gomera and La Palma, and has become a true 'weed' on some northern slopes of Gran Canaria (ex laurel dominium). Several hectars are now covered with this ever spreading plant which reproduces by the many and fecund seeds. The species (in the field) is of no agricultural use and has hardly any natural enemy. However, like *Acacia*, it has proved useful in some efforts to control erosion and is quite resistant even on denuded slopes previously occupied or still so, by *Eucalyptus*.

Atriplex spp. (Chenopodiaceae); Span.: Saladillo

There are two bushy species native to the islands: *Atriplex glauca* var. *ifniensis*, and the widely distributed *A. halimus*. *Atriplex patula* was recently introduced to Lanzarote and seems well established now in and around some gardens. *Atriplex suberecta* is recorded from Fuerteventura and Gran Canaria only and shows tendencies of spreading further, whereas *A.*

semibaccata (from Australia) has become an invador even in the most arid countrysides of many islands. This decumbent species is evergreen, growing (and fruiting) almost all year round, and obviously has found no natural enemy in the islands. It might sound an exaggeration to call *Atriplex semibaccata* an aggresive species but it certainly needs control in order to avoid further spreading.

Cyperus rotundus (Cyperaceae); Span.: Jucia, Juncia, or Ajucia

A serious pest in fields and gardens, probably introduced with cultivated plants and, as may be expected, in almost any plant nursery being daily distributed to uninfested ground. Apparently not recorded (yet!) from some western Canary Islands, although it seems only a matter of time before La Palma and Hierro will be reached. A very troublesome species because it grows from seeds, bulbs and runners. In banana plantations it is a pest, and treatment with special herbicides bring only temporary results, by killing all exposed parts of the species whilst new growth (from subterranean parts) begins again soon after, with renewed vigor.

Eupatorium spp. (Compositae or Asteraceae); Span.: Sándara

Although officially not recognized, beside the 'blackberry' this is the most serious weed ever introduced to the Canary Islands. Two species are recorded: *Eupatorium riparium*, on La Palma (recently also recorded from Tenerife), and *E. adenophorum* on Gran Canaria, Tenerife, La Gomera, and La Palma. According to new taxonomic seggregations the species are also treated as *Ageratina riparia* and *A. adenophora*, respectively. *Eupatorium* might, at one time, have been introduced as garden plants; the complex is native to North America.

Eupatorium adenophorum, the most widely distributed species, grows in moist localities: waterchannels, watertanks, walls, moist slopes and cliffs and, especially, in cliffs and ravines of the laurel forest area. And here the species is an ecological disaster. Germinating readily from numerous seeds which are distributed by wind and passing animals, once established plants form very homogenous dense stands usually one meter high and so prevent germination and development of seedlings of all other species. The plant is responsible for the extinction of several native species in one or the other of the islands, and determined steps will have to be taken soon in order to prevent further damage.

Euphorbia prostrata (Euphorbiaceae); Span.: Golondrina, or Lechetrezna-menor

Small, procumbent herb hardly noticeable at first but soon covering larger areas of gardens and irrigated land; in most of the Canary Islands.

Poisonous and, therefore, without natural enemies, the species is distributed mainly by means of seeds or as seedlings with garden plants from professional nurseries. No way has been found, yet, to control this weed except by (generally damaging) herbicides and manual weeding.

Inula viscosa (Compositae or Asteraceae); Span.: Altabaca, or Altavaca

Probably of Mediterranean origin and established since many years in the islands. This plant has become more obvious during the last decades following soil-moving operations by heavy machinery. *Inula* (or *Cupularia*) *viscosa* is now recorded from all seven larger islands and is spreading on slopes and recently disturbed roadsides, gradually encroaching into natural bushland zones. Although not eaten by animals plants are occasionally cut to serve as bedding in cow-sheds.

Mirabilis jalapa (Nyctaginaceae); Span.: Bella de noche, or Jasmín rústico

In the Anglo-American language known as 'Marvel of Peru' or, more frequently, as 'Four o'clock', this species escaped from the Botanical Garden (Tenerife) and is now known in most of the Canary Islands. Especially in Gran Canaria, Tenerife and La Palma roadsides and banana plantations are invaded, and as no attempt is made to control it, the species distributes freely and spreads every year more.

Nicotiana glauca (Solanaceae)

The Wild or Tree tobacco, from South America and at home now in all the Canary Islands, is locally known by many names: bobo, calentón, malgusto, maribobo, mimo, rompemuro, tabaco moro, venenero etc., names which indicate the true character of the species as well as its 'appreciation' by the people. The species was introduced to the Canary Islands (Tenerife) early in the XIX Century and thanks to its very numerous and minute seeds (and with the help of birds) it is now found widely distributed, even in the driest zones of Fuerteventura, Lanzarote, La Graciosa etc., and one may assume that the species will spread much further. The plant is poisonous to man and domestic animals.

We have found the Tree tobacco growing in pots, gardens and fields, in inaccessible cliffs and in walls; even roofs and other plants (i.e. palms) may provide roothold. In the arid eastern islands the plant grows in dry ravines, dunes and in the lava fields; in Fuerteventura it grows along asphalted roads almost as regularly as if it had been planted. *Nicotiana glauca* may reach 4 m in height and attains a diameter (at base) of up to 20 cm.

Fig. 5. In Fuerteventura *Nicotiana glauca* grows along asphalted roads as regularly as if it had been planted.

Opuntia spp. (Cactaceae); Span.: Tunas, or Tuneras

Like *Agave* also of Central American origin, these plants were introduced early to the Canary Islands. Several species are recorded of which *Opuntia dillenii*, *O. vulgaris* (O. monacantha) and *O. ficus-indica* (O. ficus-barbarica) are the most common. They have now spread over most of the major islands and are, owing to their resistant character and their efficient natural defenses, in a very strong position. It is a troublesome genus, even botanically seen, and the naming of species present in these islands is not at all secure.

Distribution by seeds (fruits freely eaten by both birds and man); pads or joints breaking off by their own weight root easily, and it has even been observed that strong winds act as agents for distribution by transporting pads over considerable distances. The 'Prickly pears' are still planted in the islands (for the cochineal louse), and at least *Opuntia ficus-indica* is appreciated as a forage plant and also for its edible fruits for which there is a good market in the islands.

Oxalis pes-caprae (Oxalidaceae); Span.: Trebolina

Originally introduced from South Africa and for a long time known as

Fig. 6. Cacti (*Opuntia* spp.) have taken over and cover large extensions of land.

'Oxalis cernua', the species is now a serious and practically uncontrollable pest in many countries; I believe only strong frost prevents its further distribution northwards or upwards to higher elevations. Known from all major Canary Islands, the 'Bermuda Buttercup' has invaded gardens, fields and entire slopes, especially of the moister, northern sector of the islands. It forms low but very dense communities in which not even grasses or other weeds may persist. Besides the typical form a double-flowered variety is also common. The plants now get further distributed in company with ornamental plants from commercial nurseries, and it also accompanies tree seedlings to reafforestation sites from governmental nurseries. – Also recorded from these islands are *Oxalis corniculata*, *O. latifolia* and a few others, all of minor importance when comparing them with *O. pes-caprae*. It seems all grazing animals avoid eating them.

Psoralea bituminosa (Fabaceae or Leguminosae); Span.: Tedera

The opinion of botanists as to whether this plant is introduced or not is still rather divided. Some dictionaries mention Arabia as the native country of this species, others, such as 'Flora Europaea' simply state 'S. Europe'; but something similar is said about *Psoralea americana* and so one can not be sure in this case.

The 'bitumen' plant (post-Linnean name: Asphaltium bituminosum) now grows in all larger Canary Islands, sometimes forming rather dense, bushy communities, and it is even found in the most inaccessible cliffs of Lanzarote and Fuerteventura where shrubs up to 1 m tall have been observed, having a trunk of 10 cm in diameter. The species is fairly drought-resistant and green plants are accepted by grazing animals; it grows easily from seeds, and sprouts even after rigorous pruning. In dense stands the species interferes with the composition and strength of native plant communities.

Pteridium aquilinum (Pteridophyta; Hypolepidaceae); Span.: Helecho común

Represented in the islands by its ssp. *capense*, this plant is most common in the northerly orientated midlands. Growing on denuded lands, the 'Bracken fern' covers large extensions reaching some 40 or 50 cm in height. However when found growing between bushes in moist ravines some specimens may grow up to 2 meters tall. The species is supposed to be native in the islands (?) and is relatively easily controlled by reafforestation as it does best on open slopes.

Ricinus communis (Euphorbiaceae); Span.: Tártago

According to some books this ought to be a 'herb up to 5 ft. tall' but we may assure those authors that the 'Castor Oil plant', in the Canary Islands, is a woody bush with spreading branches which may attain a height of over 3 meters. The species as found originally has escaped from gardens but is now seen along roadsides with a tendency to invade fields and even some hillsides. A purple-leaved and redfruited form (*sanguineus*, or cv. 'Cambodgensis') is also well distributed. The species, may one day, need controlling action.

Rubus ulmifolius (Rosaceae); Span.: Zarzamora

Few other species have invaded more space than this Mediterranean 'Bramble' or 'Blackberry', a serious pest of many subtropical and temparate countries. The species may have been native in the Canaries for Centuries before really 'exploding', and nobody knows when or how it reached the islands. However a good many hectars of agricultural and bushland are now occupied by this vigorous, prickly species and there seems little hope of controlling it: cutting, fire, and even herbicides seem to stimulate growth; may be only goats (another 'pest' of the islands!) are able to restrict further spreading of the species. As the Bramble germinates easily from seeds, and as branches root even more freely (tips reaching favourable ground), once established the situation soon becomes hopeless; we have seen walls pulled down or otherwise broken by this 'aggressor'.

There are also some native or endemic species of *Rubus* in the islands, restricted to the woodland region where they have their proper place; however hybrids with the above mentioned *Rubus ulmifolius* make the situation a good deal more difficult.

Ulex europaeus (Fabaceae, or Leguminosae); Span.: Tojo

Probably introduced with pine seeds, the species has established itself in Tenerife and becomes dangerous in zones where forestry operations create clearings. The species should be kept under observation in order to avoid further invasion of natural communities.

SOME OTHER SPECIES TO BE MENTIONED

There are some trees, introduced and well enough established to be mentioned, viz *Eucalyptus camaldulensis* (occasionally growing from seeds), *Ulmus* cf. *minor*, and two Poplars (*Populus alba* and *P. nigra*). *Ulmus* and *Populus nigra* have been planted along roadsides and sprout frequently from root shoots, whereas *P. alba* may form dense tangles especially on moister slopes.

Of course species like *Convolvulus arvensis*, *Bidens pilosa*, *Cynodon dactylon*, *Hirschfeldia incana*, *Erigeron karvinskianus* etc. are true weeds and are widely distributed in the islands; however their degree of aggressivity is less pronounced than in the species mentioned in detail. – In watertanks *Azolla* and *Lemna* occur, pests up to a certain point but of certain use as – thanks to their dense coverage – they help to reduce excessive evaporation.

Out of the large number of native species only *Asparagus pastorianus* and *Launaea arborescens* are of any importance under the heading of 'aggressive plants'. These are however only troublesome in localities where the original vegetation has been destroyed in order to bring the land under cultivation, especially in the semi arid sector of the islands. A last genus to be cited is *Cuscuta*: Present in the islands are probably just two species which may be seen here and there covering and eventually killing both wild and cultivated plants; both species are registered as native in the islands.

Summary

Out of a total of over 3.000 plant species known in the Canary Islands, some 1.300 taxa are cultivated plants. Analyzing the remaining number of 1.700 species, approximately, some 700 taxa are known to be introduced to the islands.

The author mentions the main crop plants including commonly planted fruit trees, some ornamentals, and cereals, and gives a brief review concerning the forest situation in the islands. In the main chapter the so-called weedy elements are briefly cited, and the more aggressive plants and serious invadors described in more detail.

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IX. LICHEN FLORA AND LICHEN VEGETATION OF THE CANARY ISLANDS

by

GERHARD FOLLMANN

Introduction

Like on other relatively young volcanic islands, the percentage of lichenophytes in the plant cover of the Canary Islands is obviously high. From the very beginning, therefore, the luxuriant lichen vegetation has attracted botanists visiting the archipelago or studying plant samples from that island group.

The first lichen specimen cited from the Canary Islands is probably '*Lichen roccella* L.', the 'Canary weed'. Bory de Saint Vincent (1803) circumscribed herewith several fruticose dye lichens not distinguished at that time. Feijó (1815) and Brotero (1824), too, have mentioned those roccellaceous species in a general manner. In fact, before the discovery of tar dyes, i.e., up to the end of the 19th century, lichens from the Canary Islands have had considerable economic importance as original material of valuable purple dyes. The antique name 'Purpuraries' for the more eastern and dryer islands of the group and many local names like 'Puerto de Orchilla' remind of those days, and till now the Roccellaceae are one of the best represented and most developed lichen families on the archipelago, especially regarding the plant communities of the rocky shore.

Although some scattered general hints on Canarian lichens can be found in the classical lichenological publications, particularly those of Acharius (1810, 1814), the first comprehensive list has been prepared by Montagne (1841), who reported already 88 lichen taxa based on collections made by Berthelot and Webb. Only a few years later, Taylor (1847) noted some more Canarian lichens. Hartung (1857) added to his geological observations on Fuerteventura and Lanzarote also a list of lichen species. Stirton (1875) and Crombie (1878) arranged the lichen collections of the Challenger Expedition to the islands of the Atlantic Ocean and recorded various taxa new to the Canaries. Other important contributions to our knowledge of the lichen flora of the archipelago have been those of Stizenberger (1890, 1891, 1895) and Steiner (1904). However, only the cumulative list of Pitard & Harmand (1911) with 165 new records and a total of 399 species, varieties, and forms gave a certain impression of the wealth of lichens on the Canary Islands.

In the meantime, Steiner (1911, 1912), Bouly de Lesdain (1923), Vainio (1924), Erichsen (1926), and others determined lichen collections made mostly by non-specialists on the larger islands of the group enabling Tavares (1952) to list 585 lichen taxa for the archipelago. Finally, Klement's (1965b) compilation based mainly on own observations increased the total number of Canarian lichens to 643. Nevertheless, the large lichen collections made also on the smaller islands of the group by various lichenologists, including the author, during the last years show clearly that our informations on the lichen flora of the Canary Islands are still incomplete and much remains to be discovered and refined within the taxonomic sphere, that aside for a few exceptions precise ecological data for most species are still lacking, and that many questions of chorological nature remain unanswered or, indeed, have scarcely been posed. However, in the context of this monograph, omission of a lichenological review would be a major one, for the Canarian lichenophytes represent not only the most remarkable pioneer plants of the archipelago but include also many species of significant chorological and ecological interest as do the characteristical associations formed by these.

Taxonomy and chorology

Including the observations of Follmann & Klement (1969), Imshaug & Harris (1971), Follmann, Redón & Huneck (1973), Østhagen (1974), Follmann (1975), and some unpublished data, the total number of Canarian lichens (species, varieties, and forms) is actually 698, a few of which – especially older uncontrolled records – are still uncertain. The limited space does not permit a listing of the single taxa here, but the corresponding genera (115) and families (38) are arranged in Table 1 according to modern systematical viewpoints (Poelt 1973, Henssen & Jahns 1974). Subsequently, the lichen flora of the Canary Islands is (like that of the phanerogams) by far the richest of all Macaronesian archipelagoes. This can be explained – at least in part – by the larger land mass and greater ecologic variety. Regarding the species' numbers of vascular plants as accepted by Bramwell (1972), Sunding (1973), and Kunkel (1974), the lichen coefficient of the Canary Islands is about 0.4, thus corresponding with other tropical volcanic islands like the Hawaiian Archipelago, where also a similar absolute lichen number has been recorded (Mattick 1953, Magnusson 1955, Klement 1966).

In the floristic composition, however, remarkable peculiarities can be observed: The coniocarpous, corticolous, pandemic Caliciales, e.g., are only poorly represented. The same is due to the hysterocarpous, corticolous, tropical Graphidineae within the Ostropales and the discocarpous, calcicolous, temperate Gyalectales. Moreover, very few representatives of three pyrenocarpous orders appear: The unitunicate, foliicolous, tropical Sphaeriales, the saxicolous, extratropical Verrucariales, as well as the foliicolous, tropical Pyrenulales, both bitunicate,

Table 1. Systematical synopsis of Canarian lichen genera (first cipher: known taxa number; second cipher: number of accepted endemics).

- Ascolichenes
  - Caliciales
    - Caliciaceae
      - *Calicium* 3
      - *Chaenotheca* 1
      - *Coniocybe* 1
      - *Sphinctrina* 1
    - Cypheliaceae
      - *Cyphelium* 1
    - Sphaerophoraceae
      - *Sphaerophorus* 2 (1)
  - Lecanorales
    - Lecanorineae
      - Collemataceae
        - *Collema* 8
        - *Leptogium* 11
      - Parmeliaceae
        - *Cetraria* 1
        - *Hypogymnia* 3
        - *Parmelia* 50 (5)
        - *Parmeliopsis* 1
        - *Platismatia* 2
        - *Pseudevernia* 1
      - Usneaceae
        - *Alectoria* 8
        - *Cornicularia* 4
        - *Evernia* 1
        - *Letharia* 1
        - *Usnea* 36 (8)
      - Lecanoraceae
        - *Aspicilia* 3
        - *Haematomma* 1
        - *Lecania* 1
        - *Lecanora* 47 (13)
        - *Omphalodina* 2
        - *Phlyctis* 1
        - *Squamarina* 6
      - Lecideaceae
        - *Bacidia* 10 (4)
        - *Catillaria* 2
        - *Lecidea* 28 (5)
        - *Lecidella* 3
        - *Psora* 4
        - *Rhizocarpon* 5
        - *Toninia* 4
      - Baeomycetaceae
        - *Baeomyces* 1
        - *Icmadophila* 1
      - Cladoniaceae
        - *Cladonia* 59 (3)
      - Stereocaulaceae
        - *Stereocaulon* 7 (2)
      - Umbilicariaceae
        - *Lasallia* 1
        - *Umbilicaria* 6
      - Ramalinaceae
        - *Desmazieria* 1
        - *Ramalina* 55 (16)
      - Acarosporaceae
        - *Acarospora* 7
        - *Biatorella* 2
        - *Sporastatia* 1
      - Pannariaceae
        - *Erioderma* 1
        - *Pannaria* 4
        - *Parmeliella* 4
        - *Psoroma* 2
      - Coccocarpiaceae
        - *Coccocarpia* 1
      - Heppiaceae
        - *Heppia* 1
        - *Solorinaria* 1
    - Lichinineae
      - Lichinaceae
        - *Collemopsidium* 1
        - *Gonohymenia* 1
        - *Lichina* 1
        - *Pyrenopsis* 1 (1)
        - *Thyrea* 2 (1)
    - Peltigerineae
      - Placynthiaceae
        - *Placynthium* 1
        - *Polychidium* 2
      - Peltigeraceae
        - *Nephroma* 7 (1)
        - *Peltigera* 12 (1)
      - Stictaceae
        - *Lobaria* 10 (2)
        - *Pseudocyphellaria* 7
        - *Sticta* 11 (1)
    - Teloschistineae
      - Candelariaceae
        - *Candelariella* 5
      - Teloschistaceae
        - *Caloplaca* 38 (6)
        - *Fulgensia* 2
        - *Protoblastenia* 1
        - *Teloschistes* 7
        - *Xanthoria* 13 (1)
    - Physciineae
      - Physciaceae
        - *Anaptychia* 4
        - *Buellia* 17 (4)
        - *Dimelaena* 1

      - *Dirinaria* 1
      - *Heterodermia* 5
      - *Physcia* 17 (2)
      - *Physciopsis* 1
      - *Physconia* 2
      - *Pyxine* 1
      - *Rinodina* 11 (4)
      - *Tornabenia* 2
  - Pertusariineae
    - Pertusariaceae
      - *Ochrolechia* 6
      - *Pertusaria* 25 (3)
      - *Placopsis* 1
    - Trapeliaceae
      - *Trapelia* 1
- Gyalectales
  - Gyalectaceae
      - *Coenogonium* 1
      - *Gyalecta* 1
- Ostropales
  - Ostropineae
    - Thelotremataceae
      - *Diploschistes* 8
      - *Ocellularia* 1
      - *Thelotrema* 2 (1)
  - Graphidineae
    - Graphidaceae
      - *Graphis* 1
      - *Phaeographis* 1
- Sphaeriales
    - Porinaceae
      - *Porina* 1
- Verrucariales
  - Verrucariaceae
      - *Dermatocarpon* 4 (1)
      - *Polyblastia* 1
      - *Verrucaria* 1
- Pyrenulales
  - Microglaenaceae
    - *Microglaena* 1
  - Pyrenulaceae
    - *Anthracothecium* 1
    - *Melanotheca* 1
- Arthoniales
  - Arthoniaceae
    - *Arthonia* 3
  - Roccellaceae
    - *Dirina* 2
    - *Roccella* 13 (6)
  - Lecanactidaceae
    - *Catinaria* 1
    - *Lecanactis* 1
    - *Schismatomma* 1
  - Opegraphaceae
    - *Chiodecton* 1
    - *Enterographa* 3 (1)
    - *Opegrapha* 11 (1)
    - *Sclerophyton* 1
- Pleosporales
  - Arthopyreniaceae
    - *Arthopyrenia* 2
    - *Leptorhaphis* 1
    - *Polyblastiopsis* 1 ?
- Deuterolichenes
    - *Cystocoleus* 1
    - *Lepraria* 4
    - *Leprocaulon* 1
    - *Normandina* 1

are extremely rare. Among all these basically different groups, only a single endemic has been found (*Sphaerophorous globosus* (Huds.) Zahlbr. var. *palmanus* (J. Stein.) Zahlbr.).

On the other hand, some suborders of the discocarpous Lecanorales show a vigorous development as to numbers of species and density of individuals: within the Lecanorineae particularly the foliose Parmeliaceae and the fruticose Usneaceae and Ramalinaceae, all three of ubiquitous, worldwide distribution; within the Peltigerineae the foliose, corticolous, temperate to tropical Stictaceae; within the Teloschistineae the multiform, nitrophilous, tropical Teloschistaceae; and within the Physciineae the mainly foliose, ubiquitous, Arctic to temperate Physciaceae. The unitunicate Lecanorales have their counterpart in the bitunicate Arthoniales, where a similar development can be observed between the fruticose, discocarpous, halophilous, tropical Roccellaceae and the crustose, hysterocarpous, corticolous and saxicolous, temperate to tropical

Opegraphaceae. The highest percentage of endemics is also found among the Lecanorales and Arthoniales (Ramalinaceae: 30%, Roccellaceae: 40%).

Presumably, the evolution of the lichens in general coincides more or less with the formation of the Canary Islands during the Late Tertiary (des Abbayes 1951, Dietz & Sproll 1970, Mattick 1953, Rothe 1974). Concerning morphology (external habit) and metabolism (secondary products), the underrepresented group consists mainly of little differentiated taxa of very special ecologic requirements, whilst the predominant group is composed in large part by highly developed forms of considerable competitive potency. Evidently, the latter proved to be the more effective colonizators. The marked heterogeneity in the floristic composition of the Canarian lichen population, therefore, can be attributed rather to ecological than to phylogenetic causes.

Table 2. Chorological elements in the Canarian lichen flora

Mediterranean species	49%
Subcosmopolitic species	15%
Macaronesian species	12%
Pantropical species	11%
Arctoalpine species	6%
Paleotropical species	5%
Neotropical species	2%

Table 2 shows the principal chorologic relationships of the actual lichen flora of the Canary Islands. The most striking character of the geographic spectrum is the low portion of endemic taxa: 12% if the entire Macaronesian region is considered and only 8% if the strictly Canarian elements are taken into account. On the one hand this is in sharp contrast to the vascular plants of the archipelago (≈ 30% if the actuoflora is treated, ≈ 50% if the neophytes are excluded), but on the other hand corresponds with the situation on other oceanic volcanic islands like the Galápagos Archipelago (Weber 1966). There are neither endemic lichens of supraspecific rank on the Canaries nor microendemics have been observed on single islands of the group.

Only a few endemic taxa can be taken for paleoendemics (e.g., *Usnea canariensis* (Ach.) du Rietz), whereas the bulk of them represent most probably neoendemics (e.g., *Roccella teneriffensis* Vain., *Ramalina webbii* Mont., *Sticta canariensis* (Ach.) Bory). The differences in number, level, and affiliation of vascular and lichen endemics may be due to the more effective long-distance dispersal of the latter by soredia, isidia, or other vegetative propagules and cannot be used, therefore, in the discussion about the age of the Canarian endemic flora in general. In any event, the high percentage of Mediterranean species demonstrates clearly the close floristic relationships of the two neighbouring Holarctic regions.

Most of those Mediterranean elements simultaneously exhibit marked Oceanic distributional tendencies (e.g., *Parmeliella atlantica* Degel., *Lobaria laetevirens* (Lightf.) Zahlbr., *Parmelia dilatata* Vain.), and the greatest concentration of these taxa is still found in the zone of the Canarian laurel forest. Pantropical species like *Teloschistes flavicans* (Swans.) Norm., *Dirinaria picta* (Swans.) Tuck., or *Heterodermia leucomela* (L.) Poelt prefer the semidesert succulent scrub of the lower altitudes. Considering the ecological niches occupied (mural crowns, fenceposts, road trees), the Subcosmopolitic species are in large part of synanthropic origin (e.g., *Candelariella aurella* (Hoffm.) Zahlbr., *Lecanora muralis* (Schreb.) Rabenh., *Xanthoria parietina* (L.) T. Fries).

For reasons of varying extension, relief, altitude, and humidity, qualitative and quantitative differences exist between the lichen populations of the single islands of the group, Tenerife housing the highest percentage of all Canarian lichens (89%), El Hierro the smallest (46%). Although the absolute lichen number on the lower and dryer eastern islands (Fuerteventura, Lanzarote) is clearly inferior to that of the western (Tenerife, Gran Canaria, La Palma, La Gomera, El Hierro), the higher percentage of Pantropical, Paleotropical, and particularly Northafrican elements on the former underlines the possibility to distinguish two chorological subprovinces (Oriental Canaries, Occidental Canaries) within the archipelago as proposed by Ceballos & Ortuño (1951), Rivas-Martinez (1973), and others as well as the assumption of a different origin of both groups (Dietz & Sproll 1970, Rothe 1974). If the entire Macaronesian region is taken in account, the closest relationships are found between the Canaries and Madeira which have about 50% joint species, many of them again of oceanic Mediterranean distribution.

Ecology and sociology

In contrast to the highly altered communities of vascular plants, due to human influence, the saxicolous lichen vegetation of the Canary Islands still consists of mainly undisturbed natural associations.

On the steeper and somewhat protected coastal rocks of all islands of the group, one of the most common and most remarkable Canarian lichen associations occurs: the *Roccelletum canariensis* Follm.[1] (Figs. 1, 2). This is especially composed of the large, fruticose, whitish to grey, sometimes also brownish thalli of *Roccella canariensis* Darb., *R. tuberculata* Vain., *R. fuciformis* (L.) de Cand., *R. teneriffensis* Vain., *R. maderensis* (J. Stein.) J. Stein., *R. vicentina* (Vain.) Vain., *R. fucoides* (Neck.) Vain., *R. immutata*

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[1] This epilithic association has been first described by Klement (1965b) as *Roccelletum tinctoriae* Klem. from the Canary Islands, but more detailed vegetation analyses proved *Roccella tinctoria* de Cand. to play only a subordinated role in the association mosaic and cannot be used, therefore, as naming species.

Fig. 1. Roccelletum canariensis Follm. on vertical basaltic cliffs on Gran Canaria (50 m, NW; main species: *Roccella canariensis* Darb.; scale 1 : 4).

Fig. 2. Roccelletum canariensis Follm. on impending basaltic tuff on Lanzarote (300 m, NE; light fruticose species: *Roccella teneriffensis* Vain., dark fruticose; species: *Roccella tuberculata* Vain., light crustose species: *Opegrapha huneckii* Follm. & Klem.; scale 1 : 4).

J. Stein., and *R. boergesenii* Vain. (arrangement according to abundance and constancy), whilst crustose growth forms are only little represented (e.g., *Dirina repanda* E. Fries, *Lecanora atra* (Huds.) Ach., *Pertusaria teneriffensis* Vain.). Physiognomically, the *Roccelletum canariensis* Follm. corresponds completely to other saxicolous associations of the Paleotropic and Neotropic diversity centres of the Roccellaceae on the Southwest African and Southwest Southamerican coasts (Follmann 1964). With slight floristic variations it appears also on the Cape Verde Islands and Madeira. This highly productive maritime association behaves relatively stenoclimatic and colonizes all kinds of volcanic rock within the aerohalin belt. In upwind regions it may exceptionally be found up to 700(–1000) m above the hightide level. Ecologically to be characterized as neutrophytic, halophilous, anemophilous, hygrophilous but xeroresistant, and photo-tolerant, the development of the *Roccelletum canariensis* Follm. is undoubtedly limited by sufficient atmospheric humidity combined with constant salt spray facilitating the water uptake (Follmann 1967).

An increasing number of yellowish ribbon-like Ramalinaceae of similar size and vitality marks the transition from the *Roccelletum canariensis* Follm. to the *Ramalinetum bourgeanae* Follm. (Fig. 3), where the different varieties of the polymorphic *Ramalina bourgeana* Mont., *R. subdecipiens* J. Stein., *R. vulcanica* (Mont.) Nyl., *R. decipiens* Mont., *R. maciformis* (Del.) Bory (restricted to the Oriental Canaries), *R. dendriscoides* Nyl., and *R. mediterranea* Magn. dominate over few inconspicuous crustose species

Fig. 3. Ramalinetum bourgeanae Follm. on vertical basaltic tuff on Gran Canaria (200 m, SE; main species: *Ramalina subdecipiens* J. Stein.; scale 1 : 5).

Table 3. Ecological synopsis of the most characteristic Canarian lichen associations (syntaxonomic denominations adapted to idiotaxonomic nomenclature without change of author names).

- Saxicolous associations
  - Basal dry zone
    - Caloplacion decipientis
      - *Caloplacetum murorum* (du Rietz) Kaiser
    - Parmelion conspersae
      - *Parmelietum pseudotinctorum* Klem.
    - Stereocaulion ramulosi
      - *Stereocauletum vesuviani* Klem.
    - Roccellion tinctoriae
      - *Ramalinetum bourgeanae* Follm.
      - *Roccelletum canariensis* Follm.
  - Subalpine dry zone
    - Omphalodinion rubinae
      - *Dimelaenetum oreinae* Frey
    - Umbilicarion cylindricae
      - *Umbilicarietum cylindricae* Frey
- Terricolous associations
  - Basal dry zone
    - Toninion caeruleonigricantis
      - *Fulgensietum fulgentis* Gams
    - Diploschistion scruposi
      - *Diploschistetum albescentis* Klem.
  - Montane humid zone
    - Cladonion rangiformis
      - *Cladonietum mediterraneae* des Abb.
- Corticolous associations
  - Basal dry zone
    - Lecanorion carpineae
      - *Dirinetum ceratoniae* Klem.
    - Xanthorion parietinae
      - *Physcietum leptaleae* Klem.
    - Buellion canescentis
      - *Ramalinetum duriaei* (Duv.) Barkm.
    - Teloschistion chrysophthalmi
      - *Teloschistetum flavicantis* Follm.
  - Montane humid zone
    - Xanthorion parietinae
      - *Physcietum ascendentis* Ochsn.
    - Buellion canescentis
      - *Ramalinetum subgeniculatae* Klem.
    - Parmelion saxatilis
      - *Pseudevernietum furfuraceae* (Hil.) Ochsn.
    - Lobarion pulmonariae
      - *Pannarietum leucostictae* Klem.
      - *Nephrometum laevigatae* Klem.
      - *Lobarietum meridionalis* Klem.
    - Usneion florido-ceratinae
      - *Usneetum decorae* Klem.
      - *Usneetum rubicundae* Barkm.
      - *Usneetum atlanticae* Klem.

(Lecanoraceae, Pertusariaceae). Apart from the high number of Macaronesian endemics, this pioneer association is clearly related to the *Ramalinetum siliquosae* (du Rietz) Follm. of the silicate rocks of the European Atlantic coasts (Follmann 1973). Compared with the *Roccelletum canariensis* Follm., the *Ramalinetum bourgeanae* Follm. behaves less halophilous but in addition nitrophilous, more photophilous and xeroresistant. Consequently, it occurs on more exposed cliffs, boulders, and ridges as well as on tops of single lapilli and lava blocks from the upper aerohalin to the lower mountain belt (30–900 m) and also gains ground in the interior of the islands. Poorer subassociations are again found on the Cape Verde Islands and Madeira.

On the vast torrents of lava on the Canary Islands, the vegetation cycle is regularly initiated by the relatively monotonous *Stereocauletum vesuviani* Klem. (Fig. 4), absolutely governed by dense cushions of the silvery grey *Stereocaulon vesuvianum* (Laur.) Pers. with its var. *umbonatum* (Wallr.) Lamb. None of the fruticose companion species like *S. vulcani* (Bory) Ach. and *S. ramulosum* (Swans.) Raeusch. or the crustose *Lecanora sulphurata* (Ach.) Nyl., *Acarospora massiliensis* (Harm.) Magn., *Placopsis gelida* (L.) Nyl.,

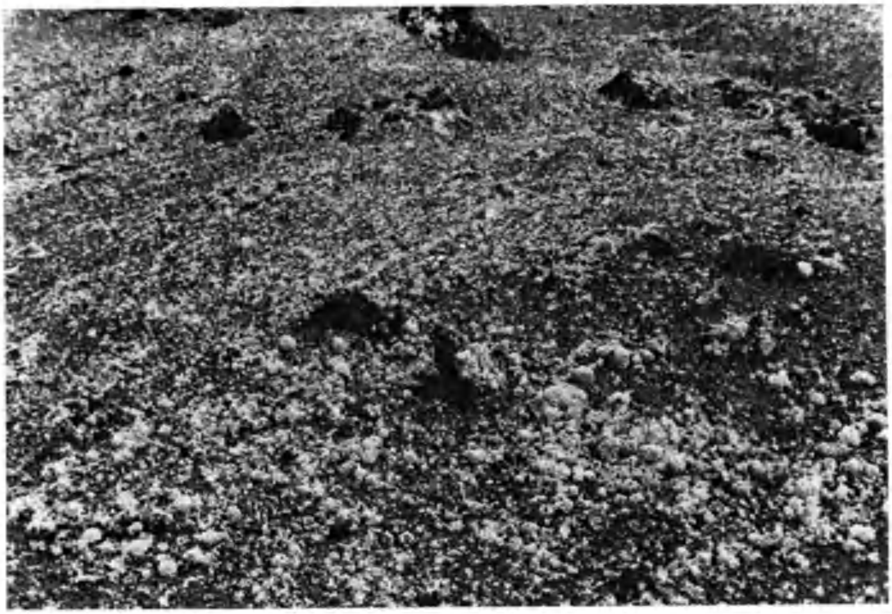

Fig. 4. Stereocauletum vesuviani Klem. on horizontal lapilli-covered ground on La Palma (100 m, SE; main species: *Stereocaulon vesuvianum* [Laur.] Pers.; scale 1 : 20).

Lecanora atra (Huds.) Ach., and *Rhizocarpon geographicum* (L.) de Cand. reach a similar abundance and constancy. Floristically comparable neutrophytic, hygrophilous, xeroresistant, and photophilous subassociations exist on all Macaronesian archipelagoes, and structurally similar communities occur on younger lava flows in the volcanic zones of both hemispheres. Owing to the enormous reproductiveness of the naming species, the colonization begins shortly after lava formation. Initial stages of the association have even been observed on lava ledges not completely cooled down. On the Canaries, the typical *Stereocauletum vesuviani* Klem. is found in the basal semidesert up to approximately 500 m above sea level, whilst a variant with the bright orange, long-barbate *Usnea canariensis* (Ach.) du Rietz (Fig. 5) appears in the cloud zone between 500–1500 m (Follmann, Redón & Huneck 1973). The rough inner crater edges are often completely covered by this colourful community. At the same altitude, more shadowy lava flows become occupied by an impoverished variant characterized by the endemic, dark grey *Stereocaulon sphaerophoroides* Tuck. While the water requirements of the two ecological variants are covered by fog condensation, the typical association depends mainly on dew-fall.

From the coastal to the mountain belt, older, smoother, and plainer surfaces of basaltic rocks are frequented by the *Parmelietum pseudotinctorum* Klem., in which grey, foliose, isidiose, and sorediose lichens clearly prevail (Fig. 6). The most typical of these are *Parmelia pseudotinctorum* des Abb., *P. perrugata* Nyl., *P. soredians* Nyl., *P. tinctina* Mah. & Gill., *P. saxatilis* (L.) Ach., and *P. stenophylla* (Ach.) Heug. (*P. molliuscula* (Ach.) du Rietz). The settlement starts with crustose forms like *Aspicilia intermutans* Nyl., *Caloplaca festiva* (E. Fries) Zwackh, or *Candelariella vitellina* (Ehrh.) Muell.-Arg. Although the naming species tends to the tropics, with its many Mediterranean taxa this xerophytic association is floristically and ecologically related to the subacidophilous, photophilous, and thermophilous *Parmelietum stenophyllae* Gams of rocky sites in southern Central Europe (Wirth 1972).

In the alpine belt (2000–3000 m), i.e., only on La Palma and Tenerife, scattered colonies of a Macaronesian subassociation of the Arctoalpine *Dimelaenetum oreinae* Frey are found. Besides the crustose *Dimelaena oreina* (Ach.) Norm. (*Rinodina oreina* (Ach.) Mass.), *Lecanora polytropa* (Ehrh.) Rabenh., *L. rupicola* (L.) Zahlbr. var. *sorediata* Erichs., and *Rhizocarpon alpicola* (Hepp) Rabenh., this is particularly characterized by the subfoliose *Omphalodina melanophthalma* (Ram.) Follm. & Redón, *O. peltata* (Ram.) Follm. & Redón, and *Physcia albinea* (Ach.) Nyl. Normally, the summits of lava blocks and andesitic rocks used by birds as perches are colonized. In contrast to the typical neutrophytic, mesophilous, and photophilous European association, the Macaronesian community shows a higher degree of nitrophily and xeroresistance. More exposed and unfertilized sites at similar heights bear fragments of a second Arctoalpine

Fig. 5. Stereocauletum vesuviani Klem. on exposed tuff boulder on Gran Canaria (900 m, NE; filiform species: *Usnea canariensis* (Ach.) du Rietz, cushion-like species: *Stereocaulon vesuvianum* (Laur.) Pers., grey crustose species: *Diploschistes aggregatus* Vain.; scale 1 : 5).

association (*Umbilicarietum cylindricae* Frey), recognizable by small thalli of *Umbilicaria cylindrica* (L.) Del., *U. polyphylla* (L.) Baumg., and *Parmelia omphalodes* (L.) Ach. (Klement 1955).

Soil-inhabiting lichen communities, so important in treeless Mediterranean-type ecotopes, are little developed on the Canary Islands. Due to the absence of calcareous substrates, only fragments of the widely distributed, varicoloured *Fulgensietum fulgentis* Gams occur on open gravelly soil in the hilly country. Contrary to *Fulgensia fulgens* (Swans.) Elenk., *Psora decipiens* (Ehrh.) Koerb., and *Toninia caeruleonigricans* (Lightf.) T. Fries, the sole faithful species showing normal sociability and vitality is *Squamarina crassa* (Huds.) Poelt. However, more or less plain loamy patches, even in small depressions of lava ridges and terraces ('loam pans'), become usually occupied by a rapid growing association of whitish crustose lichens of high competitive potency *(Diploschistetum albescentis* Klem.). The initial phase is dominated by *Diploschistes albescens* Lett., *D. steppicus* Reich., *D. bryophilus* (Ehrh.) Zahlbr., and *Collema tenax* (Swans.) Ach. An increasing number of Cladoniaceae leads over to the mats of the *Cladonietum mediterraneae* des Abb. (Fig. 7), which finds optimal developmental conditions in the somewhat protected blanks of the juniper and tree heath scrub between 400–1000 m above sea level, where already some humus has been accumulated. The most showy species of this Canarian subassociation of the acidophytic to neutrophytic,

Fig. 6. Parmelietum pseudotinctorum Klem. on slightly inclinated andesitic rock on Tenerife (200 m, NE; main species: *Parmelia pseudotinctorum* des Abb.; scale 1 : 4).

Fig. 7. Cladonietum mediterraneae des Abb. in horizontal blank of tree heath scrub on Gran Canaria (900 m, NW; light species: *Cladonia mediterranea* Duv. & des Abb., dark species: *Cornicularia aculeata* [Schreb.] Ach.; scale 1 : 5).

hygrophilous, thermophilous, and phototolerant Mediterranean lichen community are the fruticose *Cladonia mediterranea* Duv. & des Abb., *C. rangiformis* Hoffm., *C. aberrans* (des Abb.) Klem., *C. furcata* (Huds.) Schrad., *Cornicularia aculeata* (Schreb.) Ach., and the foliose *Cladonia nylanderiana* Cout., *C. pocillum* (Ach.) Rich., and *C. convoluta* (Lam.) Cout., several of these in different varieties and forms.

In view of the extensive cultivation of the Canary Islands, nowadays the bark-inhabiting lichen communities are in wide parts forced back to the relics of natural scrub and woodland. On the candelabra shrubs and spiny microphylls in the hot and dry lowland up to 500(–700) m above sea level, here and there colonies of the neutrophytic, coniophilous, hygrophilous, xeroresistant, and photophilous *Teloschistetum flavicantis* Follm. appear (Follmann 1962 a,b). In this epiphytic association mainly composed of orange and grey, densely branched, fruticose forms (Fig. 8), pantropical species like *Teloschistes flavicans* (Swans.) Norm., *T. villosus* (Ach.) Norm., *Heterodermia leucomela* (L.) Poelt, and *Tornabenia atlantica*

Fig. 8. *Teloschistetum flavicantis* Follm. on spurge shrub on lava shoulder on Lanzarote (500 m, NE; main species: *Teloschistes flavicans* [Swans.] Norm.; scale 1 : 4).

(Ach.) Kur. are accompanied by various local endemic Ramalinaceae. Similar to the adjacent Moroccan coast, in the eastern Canarian subprovince (Lanzarote, Fuerteventura) also fragments of the Mediterranean *Dirinetum ceratoniae* Klem. and *Ramalinetum duriaei* (Duv.) Barkm. are found, the first preferably on palm trunks, the second on spurge shrubs (Klement 1965a).

As a matter of fact, the most luxuriant epiphytic lichen vegetation is met with the forest ecosystems of the cloud zone between 600–1800 (–2000) m above sea level (Kämmer 1974). In the shadowy humid interior of the dense laurel forest, substratohygrophilous associations of foliose lichens predominate. The *Lobarietum meridionalis* Klem. with *Lobaria meridionalis* Vain., *Pseudocyphellaria aurata* (Ach.) Vain., *Leptogium azureum* (Swans.) Mont., *L. palmatum* (Huds.) Mont., *Lobaria immixta* Vain., *L. variegata* J. Stein., *Sticta dufourei* Del., *Sticta canariensis* (Ach.) Bory, *Sticta weigelii* (Ach.) Vain., and many other broad-lobed species can be taken for one of the most characteristic of these (Fig. 9). No

Fig. 9. Lobarietum meridionalis Klem. over moss cover in dense evergreen forest on La Palma (700 m, NW; broad-lobed species: *Lobaria meridionalis* Vain., fine-lobed species: *Sticta canariensis* (Ach.) Bory; scale 1 :3).

preference is given by the strictly muscicolous, acidophytic, skiophilous association to specific bryophytes. On the Canary Islands, the *Lobarietum meridionalis* Klem. is actually restricted to the laurel forests of La Gomera, La Palma, and Tenerife; on Gran Canaria only fragments remain. Except the Cape Verde Islands, floristically distinct subassociations occur likewise on the other Macaronesian archipelagoes. Accordingly, the borders of the Canarian laurel forest are occupied by the closely related but more photophilous *Nephrometum laevigatae* Klem. (*N. lusitanicae* Barkm.) and the more pluviophilous *Pannarietum leucostictae* Klem.

The most striking lichen association of the open pine savanna is, on the other hand, the aerohygrophilous, acidophytic, phototolerant *Usneetum atlanticae* Klem., characterized by the long, yellowish green

Fig. 10. Usneetum atlanticae Klem. near upper border of laurel forest on La Palma (1200 m, NW; main species: *Usnea articulata* [L.] Hoffm. subsp. *mediterranea* Mot.; scale 1 : 7).

garlands of *Usnea articulata* (L.) Hoffm. subsp. *mediterranea* Mot., *Usnea atlantica* Vain., *U. hesperina* Mot., and *Alectoria cana* (Ach.) Leight. (Fig. 10). Less foggy sites of the Canarian pine forest are frequented by the *Usneetum rubincundae* Bakm., composed of short-barbate, sometimes orange to red forms like *Usnea rubescens* Stirt. or *U. rubicunda* Stirt. In the upper natural confines of the evergreen forest, slender twigs, especially those of tree heath shrubs, are often covered by the short rigid thalli of *Usnea decora* Mot., *U. maderensis* Mot., *U. subcomosa* (Ach.) Vain., *U. subscabrosa* Nyl., and other – partly juvenile – species (*Usneetum decorae* Klem.). In the *Ramalinetum subgeniculatae* Klem., at last, filiform Usneaceae are completely lacking. All these epiphytic associations have clear floristic connections with the Atlantic Mediterranean region.

Finally, some anthropogenous lichen associations may be mentioned, which on the Canaries – as in other parts of the world – are rapidly gaining ground. On all kinds of artificial calcareous substrates (bricks, flags, mortar, concrete), the subcosmopolitic *Caloplacetum murorum* (du Rietz) Kaiser is found, consisting of few inconspicuous crustose species. The nitrophilous *Physcietum ascendentis* Ochsn. of road-side trees is equally poor represented. In the lower cloud belt it is replaced by the closely related Mediterranean *Physcietum leptaleae* Klem. Older trees in orchards and plantations of the central fog zone often bear dense covers of a Macaronesian subassociation of the widely distributed *Pseudevernietum* *furfuraceae* (Hil.) Ochsn., here especially rich in *Evernia prunastri* (L.) Ach., *Usnea hirta* (L.) Wigg., and various Parmeliaceae.

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X. A REVIEW OF THE FUNGAL FLORA OF THE CANARY ISLANDS

by

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Introduction

The first report on Canarian fungi was published by Montagne (1840) based on specimens collected by P. Barker-Webb, S. Berthelot, and J. M. Despréaux. Among the 53 fungus species recorded, several were described as new. Some of these fungi have subsequently been transferred to other genera or have proved to be imperfect states of other species (e.g. in the *Uredinales*), but some species are still valid.

Subsequent to Montagne's initial paper, there have, to my knowledge, been about 35 papers published which deal solely, or in part, with the Canarian fungal flora. Many of these authors studied fungal material specifically collected by other botanists or phanerogamic collections were examined to ascertain which, if any, fungi were to be found on such material. It is therefore obvious that our knowledge of the Canarian fungi varies very much. Best known are the *Ascomycetes* and *Uredinales*, but even within the *Uredinales*, there is still much work left to be done with respect to the geographical distribution of those rusts now known to be present there and, it is my opinion, additional rust species and host records will be obtained when further collections are made. I have the feeling that the same will be true with respect to other groups of fungi as well.

In the following I have tried to give a short review of the literature concerning Canarian fungi. However, no claim is made with respect to the completeness of the reference list; references to odd finds may well have escaped. I have not treated the different classes of fungi in a uniform fashion herein. In classes where only a few species have been recorded either they are all listed or I have stressed those species whose type localities are in the Canary Islands. In other classes, too many fungi are known to list all species, not even those having their type localities in the islands, but I have noted new genera and attempted to point out total numbers of new species reported by various authors.

For valuable help with providing the literature I want to express my sincere thanks to Dr. Per Sunding and Mrs. Torill Johannessen, Botanical Museum of the University of Oslo, and to Prof. F. Roll-Hansen, Norwegian Forest Research Institute, Ås- NLH, and to Prof. J. Reid, University of Manitoba, Winnipeg, for their valuable suggestions and

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Bibliographical review

MYXOMYCETES

Montagne *(op. cit.)* mentioned one species, viz. *Stemonites fusca* Roth. Later Urries (1957a) reported the presence of three additional species, Marie L. Farr (1959) added two and Wildpret de la Torre *et al.* (1972a) one more species to the class. Three of the species known have been reported from Tenerife, three from La Palma, and one species from Gran Canaria.

CHYTRIDIOMYCETES

Two species have been reported, viz. *Synchytrium papillatum* Farl. by Magnus (1893) from Tenerife, and *Physoderma ornithogali* Maire by Jørstad (1966) from Gran Canaria.

OOMYCETES

Bornmüller (1903) recorded *Albugo candida* (Pers.) Kze. (= *A. cruciferarum* DC. ex S. F. Gray), and Urries *(op. cit.)* reported *Cystopus convolvulacearum* Otth (= *A. ipomoeae-panduratae* (Schw.) Swingle). Later Jørstad (1962, 1966) added records of three additional species of *Albugo*, one of them only identified to genus, *Bremia lactucae* Regel, and six species of *Peronospora*. Oospores were present in the unidentified *Albugo*, in *Bremia*, and in four of the *Peronospora* species.

ZYGOMYCETES

The only published records of fungi belonging to this class were given by Schroeter (1884) and Jørstad (1966), who reported *Mucor stolonifera* Ehrenb. and *Pilobolus* sp., respectively, from Tenerife.

HEMIASCOMYCETES

Only one species of each of the genera *Taphrina* and *Protomyces* have been reported from the Canary Islands. Both Spegazzini (1915) and Jørstad (1962) noted the occurrence of *Taphrina deformans* (Berk.) Tul., which was collected at Gran Canaria and Tenerife. Schroeter *(op. cit.)* and Jørstad *(op. cit.)* also reported *Protomyces macrosporus* Unger from Tenerife.

PLECTOMYCETES

The first mildew recorded from the archipelago was *Erysiphe communis* Schlecht. (= *E. umbelliferarum* de Bary *sensu* Blumer 1933 and *E. heraclei* St.-Am. *sensu* Junell 1967) (Montagne 1840) from Gran Canaria. Bornmüller *(op. cit.)* added two species of *Erysiphe* to the list, and Urries *(op. cit.)* added four additional species of *Erysiphe*, as well as *Leveillula taurica* (Lév.) Arn. and *Podosphaera leucotricha* (Ell. & Ev.) Salm.

The largest contribution to our knowledge of the Canarian *Erysiphaceae* was made by Jørstad (1962). In this publication he placed all of his material of *Erysiphe* in only three aggregate species, viz. *E. cichoracearum* DC. ex Merát, *E. communis* Wallr. ex Fr., and *E. graminis* DC. ex Merát, which, collectively, occurred on 110 host species. In the same publication he noted the occurrence of *Arthrocladiella lycii* (Lasch) Vassilk., and also *Leveillula taurica* on 18 host species, two species of *Microsphaera*, *Podosphaera tridactyla* (Wallr.) de Bary, and four species of *Sphaerotheca*. Later Jørstad (1966) and Gjaerum (1970) added a few new host records and localities for some of the species mentioned by Jørstad (1962).

PYRENOMYCETES, DISCOMYCETES, AND LOCULOASCOMYCETES

Most authors working with Canarian fungi have recorded fungi from one or more of these classes. Montagne *(op. cit.)* listed three species of *Pyrenomycetes* and nine species of *Discomycetes*, among them a few of which were newly described. Berkeley (1875) listed three species of *Discomycetes*. Other authors who have contributed here are Bornmüller *(op. cit.)*, Spegazzini *(op. cit.)*, Sydow & Werdermann (1924), Cath. Cool (1924, 1925), Jørstad *(op. cit.)*, Gjaerum *(op. cit.)*, and Wildpret de la Torre *et al.* (1972a).

The main contributors to our knowledge of these classes of the *Ascomycetes* in the islands, are Petrak and Urries. All of the fungi noted by Petrak were based on his study of specimens collected by A. Ade. In the first of two papers on these fungi, Petrak (1929) described two new genera, *Amphididymella* and *Adea*, with their respective type species, as well as 20 additional new ascomycetous species. Two additional species were described by Ade in this same publication. In a second publication Petrak (1948) described one more ascomycetous species.

Urries treated material collected by himself, and the *Ascomycetes* were published in three separate papers. In the first of these Urries (1956) described 19 new species, while his second paper (Urries 1957) was a discussion of some other of his specimens collected in the islands. In his third paper (Urries 1957a) he listed all his finds. More than half of all the species listed are saprophytes.

Thanks to the work by these two well known, now late mycologists the *Ascomycetes* are among the best known fungi in the Canary Islands.

Wildpret de la Torre *et al.* (1969) noted the occurrence of some of the larger *Ascomycetes* of the genera *Xylaria*, *Peziza*, and *Urnula*, and Kohlmeyer (1967) reported 17 species of *Ascomycetes* and four species of *Fungi Imperfecti* collected on wood, algae, shells, and in the foam along the shore of Tenerife.

HYPHOMYCETES AND COELOMYCETES

Most of the authors mentioned previously have also contributed to our records of fungi in these two classes as well. Montagne (1840) noted the presence of *Sporotrichum flavissimum* Lk. and *Polytrinchium trifolii* Kze., the latter fungus also reported by Schroeter (1884), while Berkeley (1875) recorded *Isaria floccosa* Fr. from insect larvae, and Bornmüller (1903) noted *Macrophoma canariensis* Magn. (in Bornm. Plant exs. canar. nr. 1621 = *M. pinea* (Desm.) Petr. & Syd.) and *Graphiola phoenicis* (Moug.) Poit., *Pycnomma* Syd. and *Thyrodochium* Werd., with their type species, and *Pachybasidiella tilletioides* Werd. were published in Sydow & Werdermann (1924), while Deighton & Gjaerum (1969) contributed a short note on *Cercosporidium punctum* (Lacr.) Deight.

The main publications for these two classes, as for the *Pyreno-*, *Disco-*, and *Loculoasco-mycetes* are those of Petrak (1929, 1948) and Urries (1956, 1957, 1957a), but Jørstad (1962, 1966) has also made a significant contribution. Petrak (1929) reported ten new species of which two were described by Ade, and later he (Petrak 1948) added further four new species to the Canarian flora. Urries (1956) described two new genera, *Moralesia* and *Oramasia*, with their type species and 15 other species of various genera. One more species was described later (Urries 1957), and his large collection of Canarian fungi was discussed in a second paper that year (Urries 1957a). In addition to listing a large number of mainly parasitic fungi, Jørstad (1962) described *Cercospora isoplexidis*, and later he (Jørstad 1966) described four new species.

Altogether a large number of species of the *Hypho-* and *Coelomycetes* are known, but still there is much to do, particularly with respect to the geographical distribution of the various species known in the Archipelago.

TELIOMYCETES

Of the two orders belonging to this class, the *Uredinales* are the best known. Again our knowledge starts with Montagne (1840) who reported the presence of 13 rust species, many of them described as new. Species described as *Aecidium* and *Uredo* have later been included in other, perfect species, while *Puccinia atropae* described from Gran Canaria and *Puccinia pseudosphaeria* from Tenerife are still valid, the latter, however, has been transferred to *Miyagia* as *M. pseudosphaeria* (Mont.) Jørst. Magnus

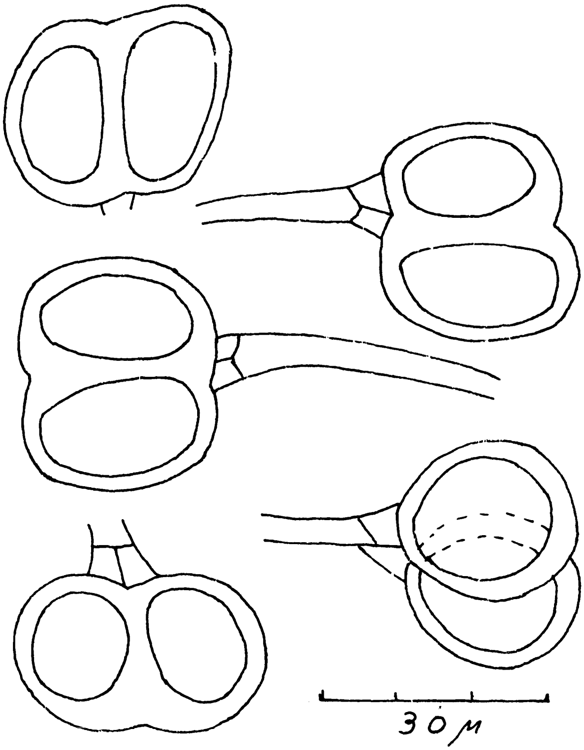

Fig. 1. Teliospores of the endemic rust *Dicheirinia canariensis* Urries.

treated four species collected by Bornmüller who himself (Bornmüller 1903) reported other species which he had collected.

Spegazzini (1915) added a few additional records of species, among them *Uredo marmoxaiae* which he described from Gran Canaria. Sydow in Sydow & Werdermann (1924) described two species from Tenerife, viz. *Puccinia venosa* and *Phragmidium bencomiae*, the latter known only from the type locality.

Other authors who have mentioned rusts species are P. & H. Sydow (1904, 1910, 1924), Walker (1922), Lindinger (1926), Guyot (1957), Guyot & Viennot-Bourgin (1946). Urries (1954) described *Dicheirinia canariensis* from Gran Canaria as the first species of *Dicheirinia* known from outside the Americas, and Cummins (1956) reported *Puccinia hyparrheniicola* Jørst. & Cumm., collected by Jørstad at Tenerife.

The main contribution to our knowledge of the Canarian rust flora was that of Jørstad (1958), wherein he listed 82 species which, with appropriate hosts, resulted in a total of 212 rust/host combinations. One of them, viz. *Puccinia lagunensis*, was described as new from Tenerife. Sixty-five species were recorded on Tenerife while only three on Fuerteventura and

18 on Lanzarote. Though *Uredinales* are probably the best known order of the Canarian fungi, Jørstad stated that this uneven distribution: 'gives an indication of how inadequately investigated the Canaries still are with respect to rusts'.

In subsequent publications Jørstad (1962, 1966) and Gjaerum (1970, 1974) added two species records each, some additional host records, and many new locality records.

The smuts *(Ustilaginales)* seem to be less well known. One of the species reported by Montagne *(op. cit.)* as a rust, *Uredo ranunculacearum* DC., has later proved to be the smut *Urocystis ranunculi* (Lib.) Moesz. Bornmüller (1903) listed the same species (as *Urocystis anemones* Schroet.) and added four additional smuts of the genus *Ustilago*, parasitizing graminicolous hosts. Lindinger (1926) recorded *Urocystis ranunculi* from Tenerife. Viennot-Bourgin (1946) reviewed the smuts on the Atlantic isles without giving exact localities, and Urries (1957a) added records of 7 species, all parasites on *Gramineae*. Jørstad (1962) listed 15 species of which eight were new to the archipelago, and also reported many new Canarian hosts for those smut species previously reported.

HYMENOMYCETES

In 'Dictionary of Fungi' (Ainsworth 1971) this class has been divided into two subclasses, *Phragmo-* and *Holo-basidiomycetidae*. Very few fungi from the first subclass have been reported from the Canary Islands. The only reports being that of Montagne (1840) for *Exidia auricula-judae* Fr. (= *Hirneola auricula-judae* (L.) Berk.) and *Naematella rubiformis* Fr. (the latter genus is considered doubtful) and Cath. Cool (1924, 1925) for *Tremella mesenterica* Retz. *H. auricula-judae* has also been reported by Wildpret de la Torre *et al.* (1972a, as *Auricularia auricula-judae* (L. ex Fr.) Berk.

Various authors have reported the presence of members of the *Holobasidiomycetidae*. Geyler (1874) described the fungus *Exobasidium lauri* which causes galls on *Laurus azorica*. Such galls, attributed to *Clavaria lauri* Bory by Montagne *(op. cit.)*, have later been collected by several botanists, but without finding the fungus. But in the parenchyma, both Tubeuf (1913) and Jørstad (1966) have found a mycelium which might belong to this fungus.

Contributions to the *Aphyllophorales* are few. However, Montagne *(op. cit.)* reported *Stereum hirsutum* Fr. (also reported by Berkeley 1875) as with two species of *Polyporus*. Cath. Cool *(op. cit.)* added two more species of *Stereum*, four species of *Polyporus*, and one *Fomes*. These species are, together with those reported by Wildpret de la Torre *et al.* (1969), included in the list by Ryvarden (1972). In this list he includes a total of 19 species of which 14 belong to the *Polyporaceae* and five to the *Stereaceae*. Wildpret de la Torre *et al.* (1972a) reported two species of which one was

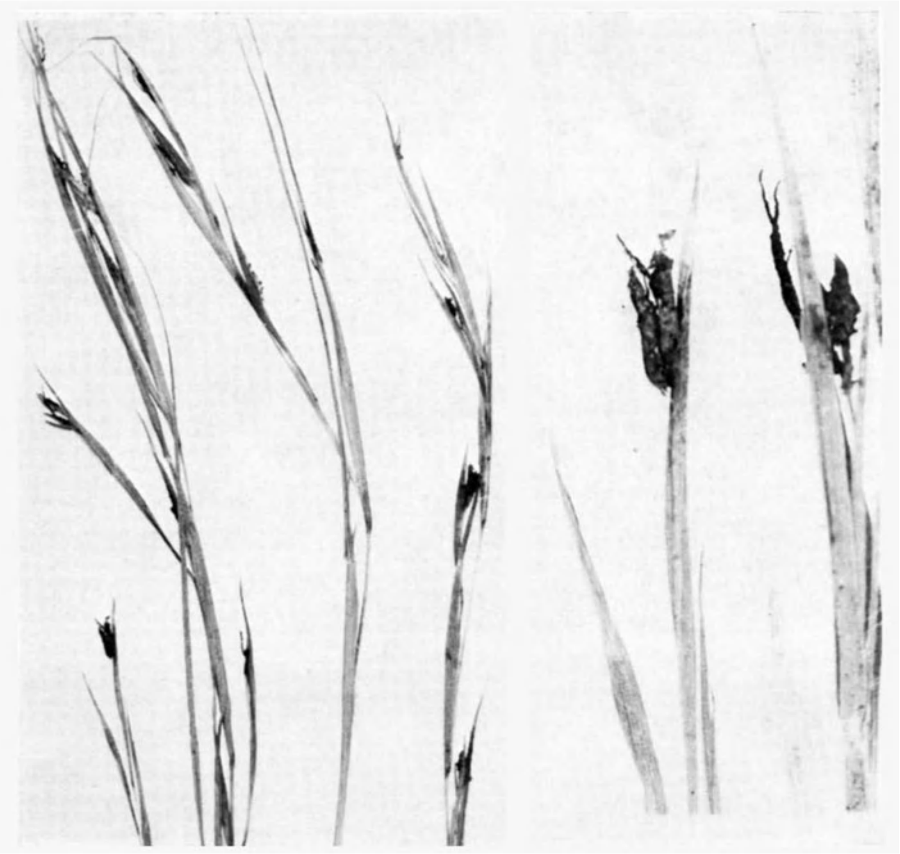

Fig. 2. Ustilago andropogonis Opiz on *Hyparrhenia hirta*, common in the Canaries. Left ×1, right ×4. (Photo J. Drew Smith).

new to La Palma. Recently Beltrán-Tejera (1974) published a catalogue over the *Polyporales* (= *Aphyllophorales*) known in the Archipelago.

More interest has been paid to the *Agaricales*. Montagne *(op. cit.)* listed four species of *Agaricus*, three of *Cortinarius*, one *Lactarius*, and *Schizophyllum commune* Fr. The latter has also been reported by Cooke (1961) and Jørstad (1966). Berkeley (1875) listed five species of *Agaricus*. The main contributors to records of this order are Cath. Cool *(op. cit.)*, Wildpret de la Torre *et al.* (1969), and Wildpret de la Torre *et al.* (1972a).

As most material has been collected at Tenerife and La Palma, further investigations will no doubt yield more interesting knowledge.

GASTEROMYCETES

As for some other classes of fungi, our knowledge of the Canarian *Gasteromycetes* begins with Montagne (1840) who listed four species. Later

Fig. 3. Galls probably caused by *Exobasidium lauri* Geyler on *Laurus azorica.* × 1. (Photo Bjørn Eidissen).

Spegazzini (1915) added one species, and Cath. Cool (1924, 1925) added four species records. Eckblad (1962) listed eight species of which two were identified only to genera. According to him *Montagnea arenaria* (DC.) Zeller has not been reported since Spegazzini (*op. cit.*, as *Montagnites candollei* (Fr.) Sacc.). Wildpret & Santos (1972) reported one species of *Gasteromycetes*, Wildpret de la Torre *et al.* (1972a) three species, and Wildpret de la Torre *et al.* (1972) added seven additional species to the list of *Gasteromycetes*. Pérez de Paz (1972) has discussed the distribution of *Pisolithus tinctorius* (Mich. ex Pers.) Cok. & Couch more in detail. Finally Wildpret de la Torre et Beltrán-Tejera (1974) reported three more species new to the Canaries.

Plant pathology

In the literature and review journals available to me, very few papers occur which are concerned with fungi parasitizing cultivated plants in the Canary Islands. Walker (1922) reported *Puccinia porri* Wint. (= *P. allii* Rud.) on cultivated onion and Heim (1946) reported *Thielaviopsis paradoxa* (de Seynes) Höhn. and *Gloeosporium musarum* Cke. & Massee (= *Colletotrichum musae* (Berk. & Curt.) v. Arx) as the cause of the main-stalk rot on bananas with *T. paradoxa* as the most important. The so-called 'Panama disease' caused by *Fusarium oxysporum* Schlecht. ex Fr. var. *cubense* (E. F. Smith) Wollenw. has been reported by Champion and Monnet (1962, as f. sp. *cubense*) causing injury to dwarf bananas under certain ecological conditions. *Colletotrichum musae* and *Piricularia grisea* (Cke.) Sacc., the latter causing blight on bananas, have been discussed by Plata *et al.* (1974).

Potentially dangerous plant parasites are e.g. the cereal rusts which occur in the Archipelago.

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XI. NATURAL PRODUCTS ISOLATED FROM PLANTS OF THE CANARY ISLANDS

by

ANTONIO G. GONZÁLEZ

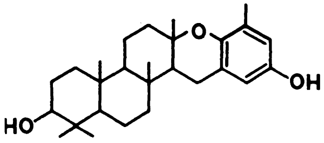
Introduction

This work reports the results obtained from investigations on the natural products of 129 plants. 105 of them are endemic to the Canary Isles; 14 are not endemic but widely distributed over the whole archipelago; 5 (*Senecio petasitis* D.C., *Asparagus plumosus* Baker, *Asparagus tenuissimus* (Hort.) Kudo, *Sansevieria trifasciata* Prain., and *Yucca gloriosa* L.) are intensively cultivated as ornamental plants; the remaining 5 (*Euphorbia echinus* Hook, *Euphorbia hernandez-pachecoi* Cab., *Withania frutescens* Pauq., *Isoplexis sceptrum* (L.) Steud., and *Senecio antieuphorbium* (L.) Sch. Bip.), although they are not found in the archipelago, have been included because they may be of interest in chemotaxonomy due to their relation with endemisms of the Canary Isles. The order and circumscription of the families is that of Melchior in A. Engler's Syllabus der Pflanzenfamilien, ed. 12 (1964).

Of the natural products cited 116 are new in the literature; the structure of 4 already known ones has been revised and several have been synthesized. The physiologic activity of some of them has also been studied.

Marine algae

Taonia atomaria (Dyctiotaceae) was shown to contain the new component taondiol 1 whose structure was determined by spectroscopic and chemical methods and confirmed by X-ray analysis and synthesis. The taondiol dimer 2 was also isolated (Gonzalez *et al.* 1971a, 1972a, 1973a).



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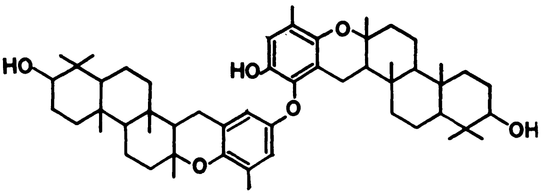
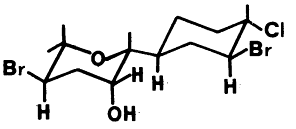


2

Laurencia caespitosa Lamx (Rhodomelaceae) yielded the new halogenated sesquiterpenes caespitol 3 and isocaespitol 4 and a furane compound named furocaespitane 5 (Gonzalez *et al.* 1973b, 1974a).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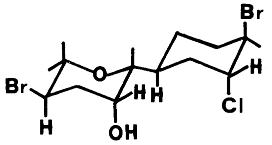
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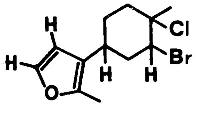
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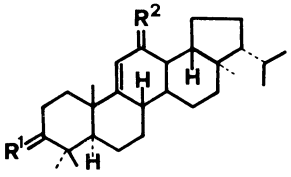
Lichens

Ramalina tingitana Salzm.: From the ethanolic extract (+)usnic acid, brassicasterol and peroxyergosterol have been isolated as well as lupane, lupeol, 3-keto-30-nor lupane, 3β-acetoxy-30-norlupane and other triterpenes now under study (Gonzalez *et al.* 1973c).

Xanthoria resendei Poelt et C.Tav. (*X. subelegans* C.Tav. et Poelt): The ether extract yielded peroxyergosterol, the anthraquinone pigments physcion, fallacinal and fallacinol and the new migrated hopene type triterpenes 12α-acetoxy-3β-hydroxyfern-9(11)-ene 6, 3β,12α-dihydroxyfern-9(11)-ene 7 and 3,12-diketofern-9(11)-ene 8 (Gonzalez *et al.* 1973d, 1974b).



	R^1	R^2
6	—OH, ···H	—H, ···OA
7	—OH, ···H	—H, ···OH
8	=O	=O

Flowering plants

CRUCIFERAE

Cheiranthus scoparius Brouss.: From the aerial part we have isolated strophanthidin, its 16β-acetoxy- and 16-dehydroderivatives, the new monosides arguayoside (16β-acetoxystrophanthidin-3β-D-digitoxoside) and taucidoside (16β-acetoxystrophanthidin-3β-D-boivinoside) together with the known ones helveticoside and corchoroside A (Gonzalez & Luque 1975a).

CRASSULACEAE

For some years now it has been quite common to use chemical constituents of plants as an aid to their classification. Supposing that the alkane distribution pattern present in the leaf wax might be characteristic of a species or a whole group within a certain genus, we have studied a great number of closely related genera of the subfamily Sempervivoideae (Crassulaceae) endemic to the Canary Isles. Owing to the wide climatic

Table 1. Genera of Sempervivoideae (Crassulaceae) examined

Aeonium:
A. simsii (Sw.) Stearn
A. canarienses (L.) W.B.
A. castello-paivae Bolle
A. cruentum W.B.
A. cuneatum W.B.
A. decorum Webb ex Bolle
A. goochiae W.B.
A. haworthii W.B.
A. holochrysum W.B.
A. lindleyi W.B.
A. manriqueorum Bolle
A. nobile Praeg. et Burch.
A. palmense Webb ex Christ
A. percarneum (Murray) Pitard
A. rubrolineatum Svent.
A. saundersii Bolle
A. sedifolium (Webb) Pitard
A. smithii (Sims) W.B.
A. spathulatum (Hornem.) Praeg.
A. subplanum Praeg.
A. tabulaeforme (Haw.) W.B.
A. urbicum (Chr. Sw.) W.B.
A. virgineum Webb ex Christ
A. viscatum Webb ex Bolle

Aichryson:
Ai. dichotomum (D.C.) W.B.
Ai. punctatum (Chr. Sm.) W.B.

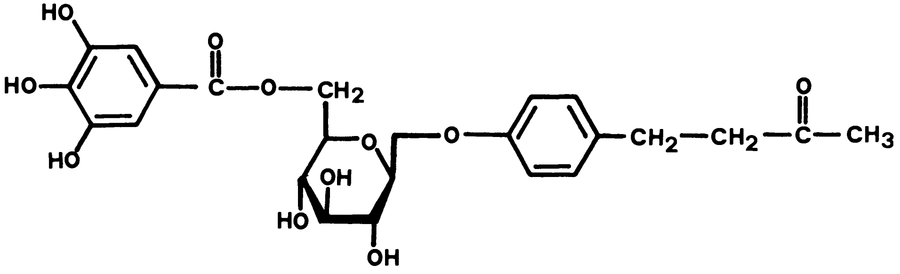
Greenovia:
G. aurea (Chr.Sm.) W.B.
G. diplocycla Webb

Monanthes:
M. amydros Svent.
M. anagensis Praeg.
M. brachycaulon (W.B.) Lowe
M. laxiflora Bolle
M. muralis (Webb.) Christ
M. pallens Christ
M. polyphylla Haw.

variation and diverse terrain found in these islands the variety of forms is an excellent example of 'adaptive radiation'. The species examined (Eglinton *et al.* 1962a; Eglinton & Hamilton 1963a) include plants from all the constituent genera of the Sempervivoideae, except *Sempervivum* (Table 1). From the results obtained we may draw the following conclusions. Of the genus *Aeonium* the species classified within the section Holochrysa show closely similar hydrocarbon patterns. The same is also true for the section Urbica, which is in disagreement with the botanical subdivision proposed by Lems, and for Goochia with the exception of *A. spathulatum* and *A. cruentum*. The section Canariensia may be divided in two main groups: the hydrocarbon patterns of the first one are closely related with those of the Holochrysa and Goochia species while the patterns of the other are much more akin to those of the section Urbica; besides, *A. tabulaeforme* shows certain anomalies. The hydrocarbon patterns of the less extensively studied genera *Greenovia*, *Aichryson* and *Monanthes* are consistent within each group except *M. amydros*. A relationship is suggested between the genera *Greenovia* and *Monanthes* and the sections Urbica and Megalonium of the genus *Aeonium*, instead of that between *Greenovia* and the section Canariensia proposed by Lems.

From the leaves of *Aeonium manriqueorum* Bolle 3-methoxyquercetin and the new flavone 3,7-dimethoxyquercetin have been isolated (Del Castillo *et al.* 1968a).

Aeonium lindley W.B.: An important constituent of the leaf-wax is the new diterpene labdane-8α,15-diol (Baker *et al.* 1962b). From the polar fractions of the plant extract a glycoside of the probable structure 9 is obtained in good yield, which we have named lindleyin (Gonzalez *et al.*, to be published).



9

LEGUMINOSAE (FABACEAE)

Adenocarpus foliosus (Ait.) DC.: The leaves were shown to contain L-adenocarpine and santiaguine (Gonzalez & Mora 1953a).

Adenocarpus viscosus (Willd.) W.B. *var. spartioides* W.B.: From the leaves we have isolated D-adenocarpine (teidine) (Gonzalez *et al.* 1951a), obtained simultaneously by Ribas & Taladrid (1950a) from *A. complicatus* (L.) Gay.

Anagyris latifolia Brouss. ex Willd. afforded D-sparteine, anagyrine and cytisine. A comparison of the yield in these alkaloids from leaves of wild plants and specimens cultivated in the Botanical Garden of La Orotava (Tenerife) showed an extraordinary difference in favour of the former (Rodriguez 1959a).

Cytisus canariensis L.: The main alkaloids were found to be cystisine and N-methylcytisine, traces of anagyrine also being present (Henry 1949a).

Cytisus proliferus L.f.: The aerial part was shown to contain L- and DL-sparteine and the seeds DL-calycotomine (Henry 1949a).

Cytisus stenopetalus Christ is very frequently found also in the Cabo Verde Isles (Portugal) and contains mainly cytisine and N-methylcytisine and traces of anagyrine (Henry 1949a).

Retama monosperma (L.) Boiss. *ssp. rhodorrhizoides* W.B.: From the twigs we have isolated anagyrine, N-methylcytisine, retamine, D-sparteine, sophochrysine, sophoridine, and sophoramine for which structure 10 was proposed (Gonzalez *et al.* 1959b; Diaz *et al.* 1966a) and confirmed by synthesis (Okuda *et al.* 1962c).

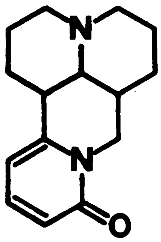
Table 2. Triterpenes isolated from Euphorbia species

Species	Euphol	Euphorbol	Cicloartenol (Handianol)	24-Methylene-cycloartenol	Lanosterol	Lanostenol	Germanicol	Obtusifoliol	Lupeol	β-Sitosterol	α-Amyrin	β-Amyrin	Uvaol	Betulin	Ursolic acid	Oleanolic acid
E. aphylla Brouss.			+		+	+										
E. atropurpurea Brouss.			+		+	+										
E. balsamifera Ait.[1]			+		+		+									
E. bravoana Svent.			+		+	+										
E. canariensis L.	+	+														
E. echinus Hook					+	+										
E. handiensis Burch.[2]	+		+													
E. hernández-pachecoi Cab.			+		+	+										
E. obtusifolia Poir.[3]			+					+								
E. paralias L.									+	+	+	+	+	+	+	+
E. regis-jubae W.B.					+	+										
E. segetalis L.			+	+					+	+						

[1] For the first time lanosterol is obtained from a higher plant.

[2] Handianol (cycloartenol) is isolated for the first time.

[3] Obtusifoliol [4α-methyl-24-methylene-8(9)-cholesten-3β-ol-] is found for the first time in Nature.



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Spartocytisus filipes W.B.: From the seeds D-lupanine was obtained and the new alkaloid spartocytisine (Gonzalez *et al.* 1962d) whose structure is at present being revised.

EUPHORBIACEAE

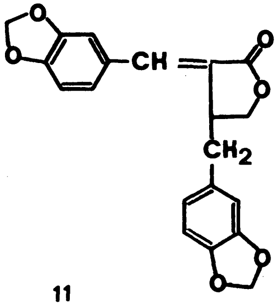
The triterpenes of twelve *Euphorbia* species have been studied (Gonzalez *et al.* 1949b, 1950b, 1951b, 1952a, 1953b, 1954a, 1955a, 1956a, 1957a, 1958a, 1959c, 1967a, 1969a, 1970a, 1972b). Two of them *(E. echinus* and *E. hernández-pachecoi)* were collected in Spanish West Africa and the remaining ones are endemic to the Canary Isles with the exception of *E. paralias* and *E. segetalis.* The results are summarized in Table 2 (Ponsinet & Ourisson 1968b).

Table 3. Coumarins isolated from *Ruta oreojasme* Webb and their distribution

Coumarins	Roots	Stems	Leaves
Gravelliferone methyl ether	+++	++	—
Sabandinin	++	—	—
Herniarin	—	—	++
6,7,8-Trimethoxycoumarin	—	—	++
Psoralen	—	—	+++
Bergapten	++	+++	+++
Xanthotoxin	—	—	+++
Isopimpinellin	—	+++	+++
Benahorin	+++	+++	++
Isoimperatorin	—	—	++
Imperatorin	—	—	++
Xanthyletin	+++	+++	—
Luvangetin	—	++	—

—	not found
++	isolated in minor proportion
+++	isolated in major proportion

Ruta microcarpa Svent.: From the leaves the coumarins bergapten, byakangelicin, luvangetin and xanthyletin have been isolated and the lignans savinin and sventenin 11, the latter being obtained for the first time (Agullo *et al.* 1967b, 1969b).



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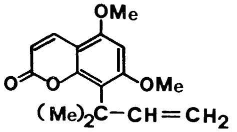
Ruta oreojasme Webb: Table 3 summarizes the coumarins found in the roots, stems and leaves (Estevez *et al.* 1966b, c; Gonzalez *et al.* 1972c).

Ruta pinnata L. fil. contains a great number of coumarins (32), 23 of them already known and 9 new in the literature, namely: pinnarin 12, sabandinin 13, sabandinone 14, sabandinol 15, sabandin 16, furopinnarin 17, benahorin 18, tederin 19 and pinnaterin 20 (Estevez & Gonzalez 1963b, 1965a, 1966c, 1968c, 1969c, 1970b, 1971b; Gonzalez *et al.* 1970c, 1971c, 1972d, e, 1973e). The distribution of the coumarins found in the different parts of the plant is given in Table 4. The lignans savinin and sventenin acetate as well as quercetin were also isolated.



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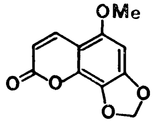

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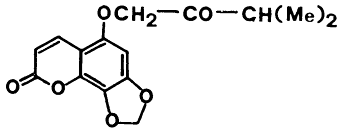

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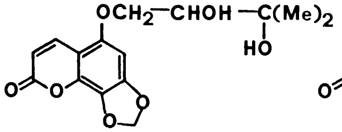

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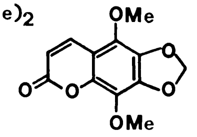

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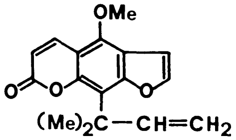

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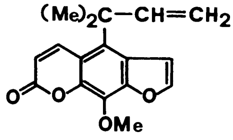

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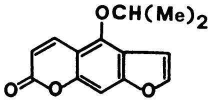

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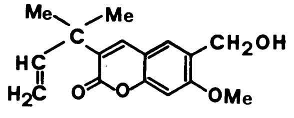

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Table 4. Distribution of the coumarins isolated from *R. pinnata L. fil.*

Coumarin	Fruits	Leaves	Stems	Roots
Aesculetin	—	—	+	—
Benahorin	—	—	++	+++
Bergapten	+++	++	++	++
Byakangelicin	—	+	+	—
Coumarin	+	+	—	+
Furopinnarin	++	++	—	++
Gravelliferon methyl ether	—	—	—	++
Herniarin	+	+	—	—
Isobergapten	+	—	—	—
Isoimperatorin	++	—	+++	—
Isopimpinellin	++	++	—	+++
Limettin	—	—	—	+
Luvangetin	—	—	++	++
Marmesin	—	—	++	—
Oxypeucedanin	+	—	—	—
Oxypeucedanin hydrate	—	—	+++	—
Pangelin	+	—	—	—
Pinnarin	—	—	++	++
Pinnaterin	—	—	—	++
Psoralen	—	+	—	—
Sabandin	—	+++	+++	+++
Sabandinin	++	—	—	++
Sabandinol	—	++	—	—
Sabandinone	++	—	—	—
Scopoletin	—	—	+	—
Seselin	+	+	—	—
Sphondin	++	—	—	—
Tederin	++	—	—	—
Thamnosin	—	—	—	++
Umbelliferone	—	+	+	—
Xanthotoxin	+	+	++	—
Xanthyletin	—	—	++	+

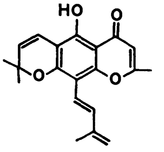
— not found
+ traces
++ isolated in small quantity
+++ isolated in major quantity

The essential oil of the fruit was shown to contain approximately 60% methyl-n-nonylketone, 36% methyl-n-nonylcarbinol, 1% hydrocarbons and 2% coumarins; that of the leaves consisted of 85% methyl-n-C_x-ketones (83% C_9, 9% C_8, 8% C_7, and traces of C_6) and 14% methyl-n-C_x-carbinols (89% C_9, 3% C_8, 7% C_7, and traces of C_6); from the roots an oil of penetrating odour was obtained consisting of 94% caryophyllene, 1% methyl-n-pentylketone, 2% non identified products, small quantities of coumarins (pinnarin, xanthyletin, limettin, coumarin) and traces of methyl-n-nonylketone and the corresponding carbinol (Gonzalez & Estevez 1963c, 1970d).

Ruta sp. (Tene. 29.662): From the aerial part, collected near Santa Cruz de La Palma (Canary Isles), the coumarins bergapten, furopinnarin, sabandinin, isoimperatorin, marmesin, and benahorin have been isolated (Gonzalez *et al.* 1972e).

CNEORACEAE

Neochamaelea pulverulenta (Vent.) Erdtm. (*Cneorum pulverulentum* Vent.): Besides the coumarin cedrolepsin we have isolated from the aerial part the known chromene-chromones 3,3-dimethylallyl-spatheliachromene and alloptaeroxylin and the new ones named neochamelin 21 and pulverochromenol 22 as well as the oxepinchromone ptaeroxylinol acetate 23 (Gonzalez *et al.* 1972f, 1974d).



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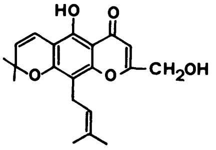

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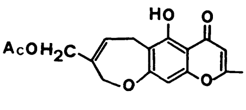

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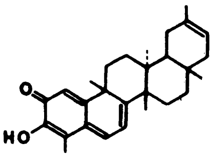
CELASTRACEAE

Maytenus canariensis (Loes.) Kunkel & Sunding is the only representative of this family found in the Canary Isles. From the root bark, in addition to β-amyrin and pristimerin, a new compound named iguesterin has been isolated and its structure determined as 24 on the basis of spectral data (Gonzalez *et al.* 1974e).



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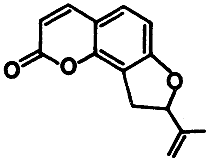
UMBELLIFERAE

Astydamia latifolia (L.f.) Baill.: The essential oil of the fruit contains mainly myristicin (95%) and scoparon (0.5%) (Gonzalez *et al.* 1974f).

Pimpinella rupicola Svent.: From the roots we have isolated coumarin, bergapten, isopimpinellin and the new coumarin masquin 25 (Agullo *et al.* 1967c).



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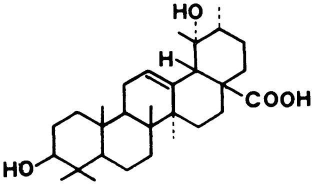
ASCLEPIADACEAE

Periploca laevigata Ait. is widely distributed in the Mediterranean area and the Canary Isles. Unlike other species of this genus, which contain cardioactive glycosides, from the stems of *P. laevigata* we have only obtained β-sitosterol, lupeol and α- and β-amyrin (Bermejo *et al.* 1966d).

LABIATAE

Micromeria benthami W.B.: The aerial parts yielded β-sitosterol, betulin, lupeol, α- and β-amyrin as well as ursolic and oleanolic acids commonly present in Labiatae; we also obtained betulinic acid, pomolic (benthamic) acid 26 isolated simultaneously by Brieskorn & Wunderer (1967d) from apple peels, and the new micromeric acid 27 (Bermejo *et al.* 1967e, 1968d; Breton *et al.* 1968e, 1969d).



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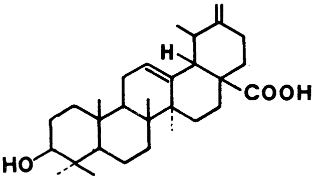

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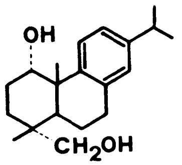
Other *Micromeriae* endemic to the Canary Isles: From the aerial parts of *M. densiflora* Benth., *M. hyssopifolia* W.B., *M. julianoides* W.B., *M. lepida* W.B., *M. pineolens* Svent., *M. terebinthinacea* W.B., and *M. varia* Benth. the following triterpenes have been isolated: betulinic (not found in *M. julianoides*), micromeric, pomolic, ursolic and oleanolic acids (Arteaga *et al.* 1970e).

Nepeta teydea W.B.: From the aerial part we have obtained β-sitosterol, its β-D-glucoside, stearic, ursolic, oleanolic, 2α,3β-dihydroxy- and 2α,3β, 19α-trihydroxyursolic (tomentosolic) acids as well as the new diterpenes teideadiol 28, 13α-isopropyl-8(14)-podocarpen-7α,15-diol 29 and 13α-isopropyl-7(8)-podocarpen-14α,15-diol 30 and the spirostans 2,2,8,8-tetramethylspiro-(5,5)-undecane-4,10-dione 31 and its corresponding diol (Breton *et al.* 1970f; Gonzalez *et al.* 1973f, 1974g).



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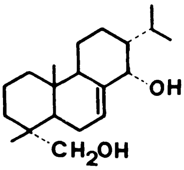

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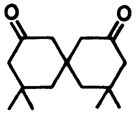

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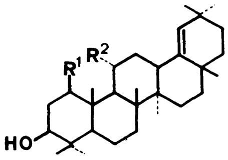
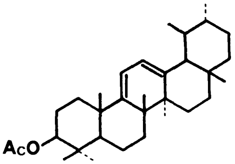
Salvia broussonetii Benth.: Besides β-sitosterol, taraxerol acetate, germanicol, ursolic and oleanolic acids, the aerial part was shown to contain the new diterpenes anagadiol 32, nivadiol 33, and α-amyradienyl acetate 34 (Gonzalez *et al.* 1971d, 1972g).



32 R^1 = OH, R^2 = H

33 R^1 = H R^2 = OH



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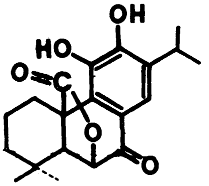

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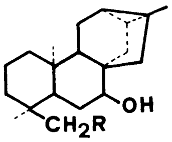
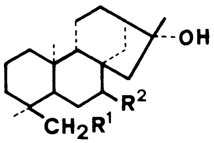
Salvia canariensis L.: From the aerial part we have isolated squalene, chlorandiol, salviol and the new diterpene galdosol 35 the structure of which was established by spectroscopic and chemical methods (Gonzalez *et al.* 1973g).

Sideritis argosphacelus (Webb.) Clos.: The aerial part yielded glutinol, β-sitosterol, its β-D-glucoside, campesterol, stigmasterol, α- and β-amyrin, ursolic and oleanolic acids (Gonzalez *et al.*, unpublished results).

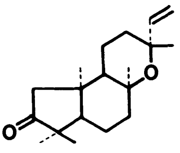
Sideritis canariensis L. is very rich in diterpenes. Besides the already known dihydroabietane, (-)kaurene, epicandicandiol, 7β,18-dihydroxy-(-)kaurene and (-)13-epimanoyl oxide the following ones have been isolated for the first time in Nature: of the trachylobane series, trachylobane, trachinol 36, trachinodiol 37, and its 7β-acetate whose structures were determined by chemical and spectroscopic methods; of the (-)kaurane series, vierol 38 which was synthesized from epicandicandiol, and powerol 39 which was related with (-)kauranol and (-)kauren-7β-ol acetate; of the (-)13-epimanoyl oxide series, tiganone 40 and ribenol 41 (Gonzalez *et al.* 1971e, 1973h). The lignan (+)sesamin and the new coumarin siderin 42 were also obtained as well as glutinol, β-sitosterol,



36 R = H
37 R = OH



38 R^1 = OH; R^2 = H
39 R^1 = H; R^2 = OH



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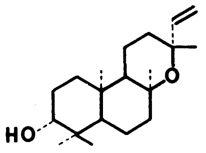

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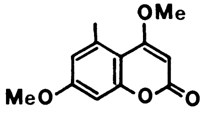

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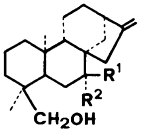
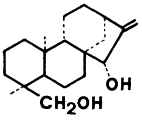
its β-D-glucoside, campesterol, stigmasterol and α- and β-amyrin (Gonzalez *et al.* 1972h, 1974h).

Sideritis candicans Ait. *var. eriocephala* Webb.: From the aerial part the new diterpenes candicandiol 43 as major component and epicandicandiol 44 and candidiol 45 as minor ones have been isolated (Breton *et al.* 1969e; Rodriguez *et al.* 1970g; Piozzi *et al.* 1971f).

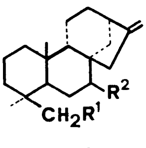


43 R^1= H; R^2= OH
44 R^1= OH; R = H



45

Sideritis candicans Ait., not yet determined variety: On the basis of the chemical results obtained we suppose that this variety differs from *var. eriocephala* Webb. because although collected in Tenerife at the same altitude it was shown to contain epicandicandiol and its 7β-monoacetate as major components and the new diterpenes candol A 46 and B 47 as minor ones while candicandiol was not found. Candidiol and (-) 13-epimanoyl oxide were also isolated as well as glutinol, β-sitosterol, its β-D-glucoside, campesterol, stigmasterol, ursolic and oleanolic acids (Gonzalez *et al.* 1973i).



46 R^1= H; R^2= OH
47 R^1=OH; R^2= H

Sideritis dasygnaphala W.B.: From the aerial part we have isolated candol A, epicandicandiol, glutinol, squalene, β-sitosterol, campesterol, stigmasterol, α- and β-amyrin, ursolic and oleanolic acids and the flavones cirsimaritin and xanthomicrol (Gonzalez *et al.*, unpublished results).

Sideritis dendro-chahorra Bolle: The aerial part was shown to contain trachinodiol 7β-acetate, candidiol, candicandiol, epicandicandiol and its 7β-monoacetate, squalene, β-sitosterol, campesterol, stigmasterol, α- and β-amyrin, ursolic and oleanolic acids (Gonzalez *et al.*, unpublished results).

Sideritis macrostachya Poir.: From the aerial part we have obtained glutinol, β-sitosterol, ursolic and oleanolic acids (Gonzalez *et al.*, unpublished results).

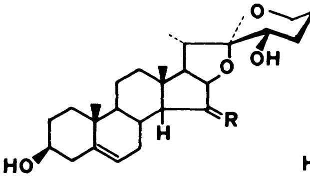
SOLANACEAE

The alkaloids of two *Nicotiana* species frequent in the Canary Isles have been studied, obtaining the following results (Gonzalez & Diaz 1962e):

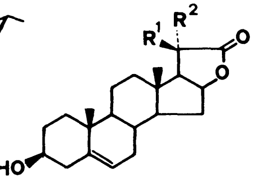
Nicotiana glauca Grah.: From the aerial part, D,L-anabasine was isolated and the presence of L-nornicotine, nicotine, pyridine, and piperidine was detected by chromatographic methods.

Nicotiana paniculata L.: From the mixture of alkaloids we obtained L-nicotine and chromatographically showed the presence of L-nornicotine, pyridine, and β-nicotyrine.

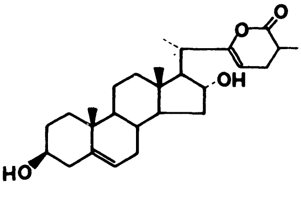
Solanum vespertilio Ait.: Besides β-sitosterol and diosgenin the fruit yielded the new sapogenins anosmagenin 48 and 15-dehydro-14β-anosmagenin 49 whose structures were determined by spectroscopic methods and confirmed by synthesizing their dihydro derivatives from digalogenin. For the first time from a plant source 16-dehydropregnenolone has been isolated as well as the new steroid lactones vespertilin 50, 20S-hydroxyvespertilin 51, and bajamarin 52 (Gonzalez *et al.* 1971g, 1972i, 1973j, 1974i).



48 14α-H; R = β-OH
49 14β-H; R = O

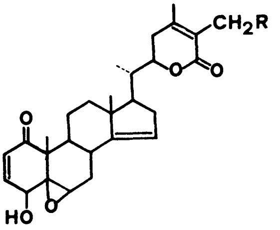


50 R^1 = H, R^2 = Me
51 R^1 = Me, R^2 = OH

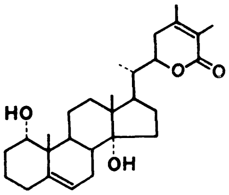


52

Withania aristata (Ait.) Pauq.: Of the five withanolides isolated from the aerial part, two were identified with withaferin A and 2,3-dihydrowithaferin A which had been obtained for the first time from *W. somnifera* Dun. by Lavie *et al.* (1965b). The third one, 4β-hydroxy-1-oxo-5β,6β-epoxy-22R-witha-2,14,24-trienolide 53, was obtained simultaneously from both pants (Kirson *et al.* 1971h). The structures of the remaining two correspond to 4β,27-dihydroxy-1-oxo-5β,6β-epoxy-22R-witha-2,14, 24-trienolide 54 and 1α,14α-dihydroxywitha-5,24-dienolide 55 and were confirmed by chemical transformations (Gonzalez *et al.* 1972j, 1974j).



53 R = H
54 R = OH



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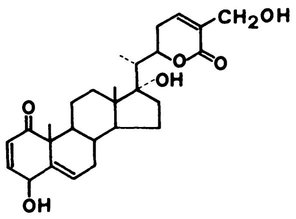

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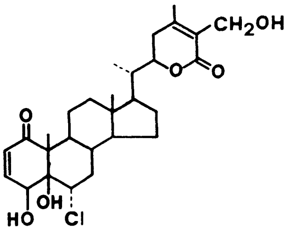
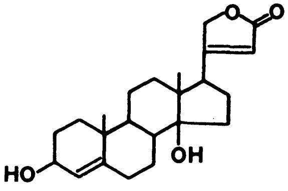


57

Note. From the leaves of *W. frutescens* Pauq., collected near Cádiz (Spain), the three new withanolides 4β,17α,27-trihydroxy-1-oxo-22R-witha-2,5,24-trienolide 56, its 2,3-dihydro derivative and 4β,5β,27-trihydroxy-1-oxo-6α-chloro-22R-witha-2,24-dienolide 57 have been isolated in addition to withaferin A, dihydrowithaferin A and compound 54 (Gonzalez *et al.* 1974k). A comparison of our results with those obtained by Lavie (1970h) reveals a certain uniformity in the steroids found in this genus of Solanaceae.

SCROPHULARIACEAE

Isoplexis canariensis (L.) G.Don (*Digitalis canariensis* L.): The extract of the leaves proved to be 4 to 10 times more cardioactive than that of *Digitalis purpurea* L. From the unsaponifiable part uzarigenin and xysmalogenin were obtained together with the new cardenolide canarigenin 58, its 5(6)-anhydro derivative and other artefacts. Among the sugars isolated after hydrolysis of the glycosides the new 2,6-dideoxy-D-arabinohexose named D-canarose was found. On the other hand, partial hydrolysis of the glycosides gave a mixture of the following monosides: uzarigenin digitoxoside, canarigenin digitoxoside, xysmalogenin canaroside and probably canarigenin canaroside. From the mixture of glycosides the new diglycosides canarigenin glucosidodigitoxoside, canarigenin glucosido-fucoside, canarigenin glucosidocanaroside and uzarigenin glucosido-

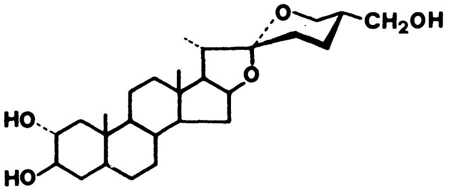


58

canaroside were obtained (Gonzalez *et al.* 1955b, 1960a; Delgado *et al.* 1962f, 1965c; Tschesche *et al.* 1963d; Studer *et al.* 1963e; Spengel *et al.* 1967f). Furthermore, β-sitosterol, tigogenin, gitogenin and the new spirostan sapogenin crestagenin 59 have been isolated (see Observations).

Isoplexis isabelliana (W.B.) Masf.: From the unhydrolyzable extract of the leaves digitoxigenin, uzarigenin, xysmalogenin, β-anhydrouzarigenin (artefact), and gitoxigenin have been isolated. Partial hydrolysis of the glycosides gave several monosides formed by the above genins and the following sugars: D-glucose, D-digitoxose, 6-deoxy-D-glucose, 6-deoxy-D-allose, and D-canarose, the disaccharide canarobiose being obtained for the first time. The mixture of glycosides yielded the diglycosides glucoevatromonoside, cheiroside A and '*digitalinum verum*' together with other derivatives of digitoxigenin, uzarigenin and xysmalogenin directly bound to 6-deoxy-D-glucose, its 2-O-acetyl compound, D-canarose or D-digitoxose and terminating by a glucose unit. The C_{21}-steroid glycosides digifolein, diginin, lanafolein, 14α-digipronin and strospeside and the genins γ-digiprogenin, purpnigenin, 3β,14β-dihydroxypregn-5-en-20-one, 3β,14β-dihydroxypregn-5-en-15,20-dione and its digitoxoside were also found as well as the spirostan sapogenins tigogenin and neotigogenin (Breton & Gonzalez 1960b; Rees *et al.* 1961a; Pavanaram *et al.* 1963f; Freitag *et al.* 1967g).

OBSERVATIONS: Both *Isoplexis canariensis* (L.) G.Don and *I. isabelliana* (W.B.) Masf. are very rich in cardiac glycosides of the same type as those found in European *Digitalis* species and also contain the same spirostan sapogenins. Moreover, from *I. canariensis* we have isolated gitogenin and the new spirostan sapogenin crestagenin 59 (Delgado *et al.* 1969f). It is noteworthy that the latter compound was also obtained from *I. sceptrum* (L.) Steud., endemic to Madeira (Portugal) and a third representative of this small group of plants. It does not contain any cardenolides but a great variety of spirostan sapogenins, namely tigogenin, diosgenin, gitogenin, $\Delta^{25(27)}$-gitogenin and crestagenin as well as sceptrumgenin 60, isoplexigenin A 61, B 62, C 63 and D 64, funchaligenin 65 and its 25R-epimer 66 which have been isolated for the first time. It also yielded quinones of the same type as those found in *Digitalis* species, such as 1,4-dihydroxy-2-methyl- and 1-hydroxy-3-methyl-anthraquinone, in addition to the new plant pigment madeirin 67 (Breton *et al.* 1966e; Freire *et al.* 1968f, 1970i; Gonzalez *et al.* 1972k, 1973k). These findings reveal a great difference between the two *Isoplexis* endemic to the Canary Isles and that from Madeira.



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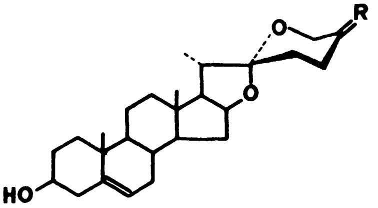
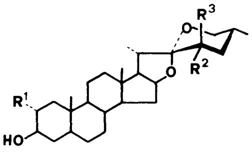
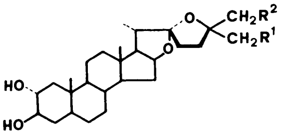


60 R = CH_2

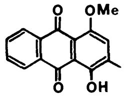
62 R = $\overset{H}{\underset{Me}{<}}$



	R^1	R^2	R^3
61	H	OH	H
63	OH	OH	H
64	OH	H	OH

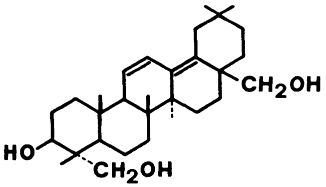


	R^1	R^2
65	OH	H
66	H	OH



67

Scrophularia smithii Hornem.: From the twigs the two new pentacyclic triterpenes smithiandienol A 68 and B 69 have been isolated (Gonzalez & Breton 1963g).



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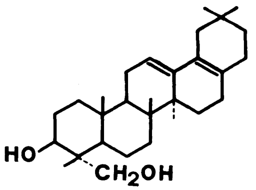


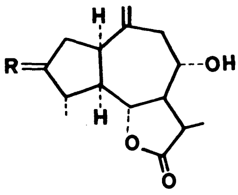
69

Scrophularia calliantha W.B.: From the leaves we have obtained α-spinasterol and smithiandienol A 68 (Breton *et al.* 1964a).

Scrophularia glabrata Ait.: The leaves were shown to be very rich in n- and iso-alkanes (C_{18} to C_{26}) and also contained p-methoxycinnamic acid and α-spinasterol (Breton *et al.* 1964a). No triterpenes have been found.

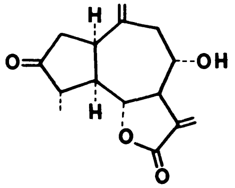
COMPOSITAE

Amberboa lippii D.C. (*Centaurea lippii* L.) is widely distributed in the Mediterranean area and also very frequently found in the Canary Isles. From the aerial part we have isolated the sesquiterpene lactones amberboin 70, lipidiol 71 and their C_{11}-epimers, and grosshemin 72. The latter compound had already been obtained from *Grossheimia macrocephala* (Muss.-Puschk.) D.Sosn. et Takht., being assigned formula 73 (Rybalko & Scheichenko 1965d). The structure of amberboin was determined on the basis of chemical and spectroscopic methods and by relating it with substances of known configuration. On the other hand, the structures of the remaining compounds were established by relating them with amberboin (Breton *et al.* 1968g; Bermejo *et al.* 1969g; Gonzalez *et al.* 1970j, 1973m).



70 R = O

71 R = $\overset{OH}{\underset{H}{<}}$



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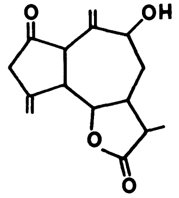
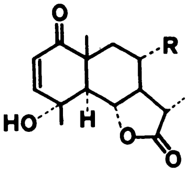


73

Artemisia canariensis (Bess.) Less: From the aerial part isopimpinellin and the two sesquiterpene lactones vulgarin 74 (tauremisin) (Rybalko & Dolejs 1961b; Geissman & Ellestad 1962g; Geissman & Irwin 1970k) and tabarin 75 have been isolated, the latter one being new in the literature (Gonzalez *et al.* 1973n).



74 R = H

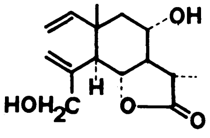
75 R = OH

Centaurea arbutifolia Svent.: From the leaves we have obtained β-sitosterol, taraxasterol, β-amyrin (probably), and a mixture of flavonoids from which 3-methoxykaempferol, chrysoeriol, 3-methoxyquercetin and the new glycoside 7-rutinosyl-3-methoxykaempferol were separated (Breton *et al.* 1969h).

Centaurea arguta Nees: The leaves were shown to contain the new glycoside 7-rutinosyl-3-methoxykaempferol and the flavonoids naringenin, hispidulin and 5,7,4′-trihydroxy-6,3′-dimethoxyflavone (Breton *et al.* 1967h, 1968h).

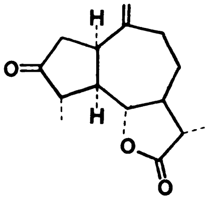
Note: Unlike the other *Centaurea*, *Artemisia*, *Picridium* and *Sonchus* species (endemic to the Canary Isles or collected in the Spanish mainland) which we have studied, in the extracts of *C. arbutifolia* and *C. arguta* no sesquiterpene lactones could be detected.

Centaurea melitensis L., found in West Mediterranean countries, is very abundant in the Canary Isles. From the aerial part we have isolated the new sesquiterpene lactone melitensin 76 whose structure was confirmed by synthesis from cnicin (Gonzalez *et al.* 1971i, 1974m).



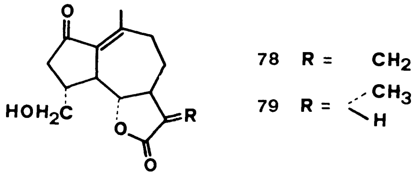
76

Centaurea webbiana Sch. Bip.: From the aerial part dihydroestafiatone 77 has been obtained for the first time in Nature and crustecdysone for the first time from a composite (Gonzalez *et al.* 1972m, 1973o).



77

Picridium cristallinum Sch. Bip.: The extract of the aerial part yielded the very bitter tasting new sesquiterpene lactones picridin 78 and dihydropicridin 79 as well as deacetylmatricarin and ψ-taraxasterol (Gonzalez *et al.* 1974n).

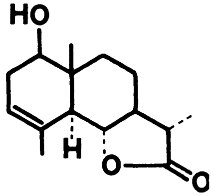


Genus *Sonchus*. Bramwell & Dakshini (1971j) have studied the phenolic compounds of 20 species of *Sonchus* collected in the Canary Isles and by paper chromatography found the presence of scopoletin in all of them, cichoriin in 15, aesculin in 5, and the flavone luteolin and/or its 7-glucoside in 19 species.

We have investigated the following species: *Launaea arborescens* (Batt.) Murb. (*Sonchus spinosus* D.C., *Zollikoferia spinosa* Boiss., *Launaea spinosa* Sch. Bip.): Cichoriin, aesculin, aesculetin, scopoletin, a mixture of taraxasterol and ψ-taraxasterol, and β-sitosterol have been obtained from the stems (Bermejo *et al.* 1966f).

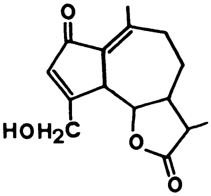
Sonchus gummifer Link: The unsaponifiable extract of the stems was shown to contain β-sitosterol and taraxerol (Gonzalez & De Leon 1963h).

Sonchus hierrensis (Pit.) Boulos *var. benehoavensis* Svent.: From the tubers we have isolated the new sesquiterpene lactone dihydrosantamarin 80 (Bermejo *et al.* 1968i), together with jacquinelin 81 which had first been obtained from *S. jacquini.*



80

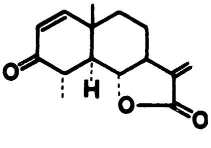
Sonchus jacquini D.C., *S. pinnatus* Ait., and *S. radicatus* Ait.: From the aerial part of these three species a new bitter substance was obtained which we have named jacquinelin and whose structure was established as 81 (Bermejo *et al.* 1966g)



81

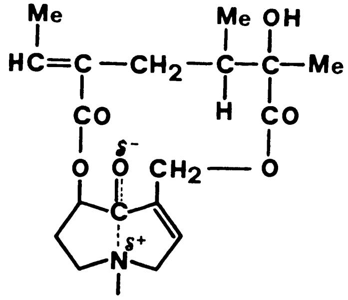
Sonchus leptocephalus Cass. and *S. ortunoi* Svent.: From their stems we have isolated hexacosanol, β-sitosterol, and the triterpenes taraxasterol, ψ-taraxasterol, β-amyrin and germanicol (Bermejo *et al.* 1963i, 1966h).

Sonchus tuberifer Svent.: The roots yielded the new sesquiterpene lactone tuberiferin 82 (Bermejo *et al.* 1967i, 1968j).



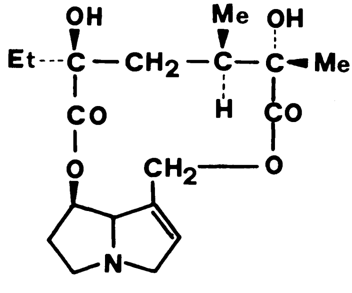
82

Senecio kleinia Sch. Bip. (*Kleinia neriifolia* Haw., *Cacalia kleinia* L.): From the stems we have isolated two alkaloids. One was identified with integerrimine and squalidine, and the other proved to be identical to renardine and senkirkine, its structure being confirmed as 83 (Gonzalez & Calero 1958b; Diaz *et al.* 1967j).



83

Senecio petasitis D.C. is cultivated as ornamental plant and on the Canary Isles is frequently found on the borders of roads. From the aerial part we have obtained a pyrrolizidine alkaloid which behaves like bisline isolated from *S. othonniformis* Fourcade (Coucourakis *et al.* 1970m, 1972n). On the basis of spectral data and hydrolysis products it has been assigned structure 84 (Gonzalez *et al.* 1973p).



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Note: *Senecio antieuphorbium* (L.) Sch. Bip., collected in Sidi-Ifni (Spanish West Africa) yielded the same alkaloids as *S. kleinia* (Diaz & Gonzalez 1969i).

LILIACEAE

Asparagus: Table 5 summarizes the spirostan sapogenins found in several species.

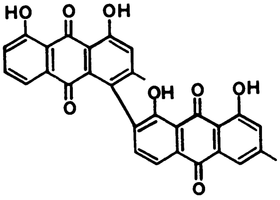
Asphodelus microcarpus Salzm. et Viv. (*A. ramosus* Desf.) is very abundant in the Canary Isles and widely distributed all over the Mediterranean area. From the defatted tubers collected in Egypt Rizk *et al.* (1972o) obtained 1,8-dihydroxyanthraquinone (probably a decomposition product of 1,8-dihydroxydianthraquinone), 5,5′-bichrysophanol, aloe-emodin, chrysophanol, and an unidentified anthraquinone. From the tuberous roots collected in Tenerife (Canary Isles) we have isolated chrysophanol and the two new bianthraquinones asphodelin 85 and microcarpin 86

Table 5. Spirostan sapogenins isolated from *Asparagus* species

Species		*Diosgenin*	*Hecogenin*	*Hispidogenin*	*Pennogenin*	*Sarsasapogenin*	*Tigogenin*	References
A. asparagoides Druce[1]	rhizomes	+		+				Giordano & Gonzalez 1967k
A. falcatus Link	roots				+			Fernandez *et al.* 1967m
A. plumosus Baker[2]	rhizomes	+	+					Fernandez *et al.* 1967n
A. scoparius Lowe[3]	roots, twigs		+				+	Fernandez *et al.* 1967m
A. tenuissimus (Hort.) Kudo[2]	rhizomes							Fernandez *et al.* 1967n
A. umbellatus Link	rhizomes		+	+			+	Fernandez *et al.* 1967o

[1] Not endemic to the Canary Isles.
[2] Cultivated as ornamental plant. In *A. tenuissimus* no steroids were found.
[3] Also found in Madeira and the Cabo Verde Isles (Portugal).

whose structures were established by spectroscopic and chemical methods (Gonzalez *et al.* 1973q).



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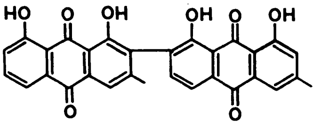
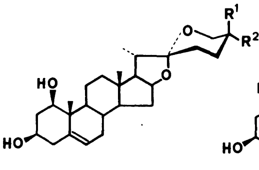
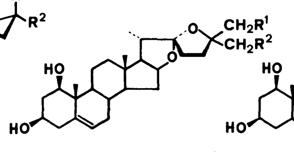


86

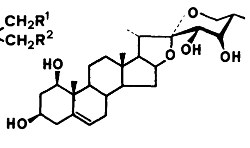
Semele androgyna Kunth.: Besides β-sitosterol, diosgenin, isoplexigenin B 62 and ruscogenin, the twigs yielded the five new sapogenins isoandrogenin A 87 and B 88, androgenin A 89 and B 90, and 25S-dihydrodracogenin 91 (Gonzalez *et al.* 1973r).



87 R^1 = OH; R^2 = Me
88 R^1 = Me; R^2 = OH

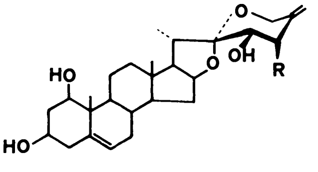


89 R^1 = H; R^2 = OH
90 R^1 = OH; R^2 = H

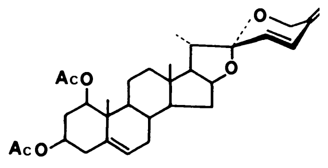


91

Dracaena draco (L.) L.: From the cortex the new spirostan sapogenin dracogenin 92 has been isolated. Its structure and stereochemistry were determined spectroscopically and by transforming it on the one hand into a mixture of ruscogenin and 25S-ruscogenin acetates (via compound 92a) and on the other hand into the 25S-epimer of 25(27)-dihydrosansevierigenin (Gonzalez *et al.* 1971k, 1972p).

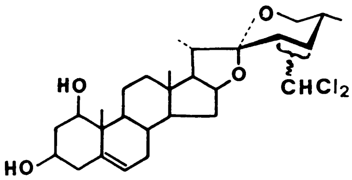


92 R = OH
93 R = H



92a

Sansevieria trifasciata Prain is not endemic to the Canary Isles but is intensively cultivated as ornamental plant. From the leaves β-sitosterol, ruscogenin, neoruscogenin and three new spirostan sapogenins have been obtained, namely 25S-ruscogenin, sansevierigenin 93, and abamagenin for which structure 94 has been proposed, *i.e.* (20S,22S,25R)-23-dichloromethyl- or (20S,22R,25S)-24-dichloromethyl-spirost-5-en-1β,3β-diol. The formation of abamagenin cannot be explained in terms of the biogenetic rules suggested for this class of compounds (Gonzalez *et al.* 1972q).

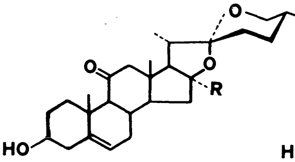


94

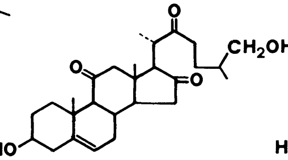
Yucca gloriosa L. is not an endemism of the Canary Isles but frequently cultivated as an ornamental plant. From specimens collected in America Marker *et al.* (1943a) isolated smilagenin and Heitz *et al.* (1954b) gitogenin and tigogenin, whereas from samples collected near Valencia (Spain) Davila & Panizo (1958c) obtained smilagenin, tigogenin, and a new hydroxy-keto-sapogenin named gloriogenin. On the other hand, the leaves of *Y. gloriosa* cultivated in Tenerife (Canary Isles) yielded β-sitosterol, smilagenin, gitogenin, hecogenin, rockogenin, gloriogenin whose structure was established as 12-ketosmilagenin, and the new sapogenin 12β-hydroxysmilagenin (Gonzalez *et al.* 1972r). It seems that the results obtained depend on the provenance of the plant, although it may partly be due to the fact that the authors cited perhaps worked with different quantities of material.

Tamus edulis Lowe: Besides β-sitosterol and diosgenin seven new sapogenins have been isolated from the twigs: 7-ketodiosgenin, tamusgenin 95, its 7-keto and 25S-hydroxy derivatives, lowegenin 96, eduligenin 97, and afurigenin 98. The structures of the first three were established by spectral analyses and confirmed by synthesis; that of lowegenin was determined on the basis of its NMR data and by relating it with compound 97 which behaves like 11-ketokryptogenin. On the other hand, 25S-hydroxytamusgenin has been related with the products 95 and 98 (Freire *et al.* 1968k, 1970n; Gonzalez *et al.* 1971m).

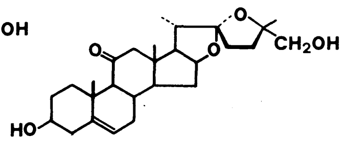
Note: From the twigs of *Tamus communis* L., collected in Pontevedra (Spain), only diosgenin has been obtained (Laorga & Pinar 1960c).



95 R = H
96 R = OH



97



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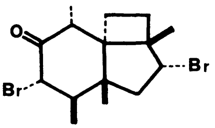
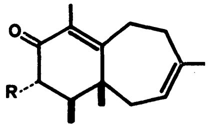
ADDENDUM

Marine algae

Laurencia perforata (Rodomelaceae): From this marine algae we isolated three new sesquiterpenes with new carbon skeletons, they were perforatone 99, perforenone A 100 and perforenone – B 101 (González *et al.* 1975b).



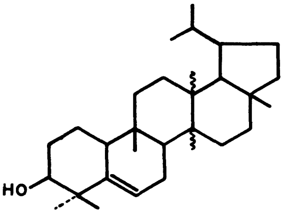
99



100 R = OH
101 R = Cl

CRASSULACEAE

Ceropegia dichotoma Haw: We obtained guimarenol 102, a new migrated lupene type triterpene and lup-18–en–3 β ol 103 (González *et al.* 1973s).



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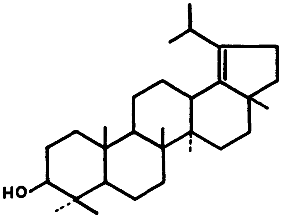
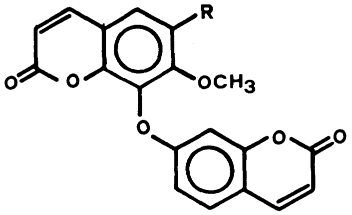


103

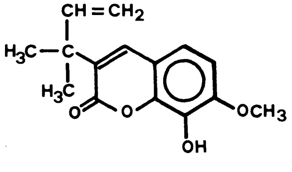
RUTACEAE

Ruta oreojasme Webb.: The fruit yielded two new dicoumarins namely oreojasmine 104 and fatagarine 105 (González *et al.* 1975c).

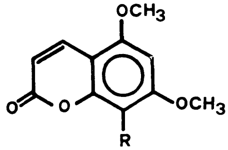


104 R = OCH_3
105 R = H

Ruta sp. (Tene 29.662): From this plant, a not yet classified species, three new coumarins have been isolated: 3-(1,1-dimethylallyl)-7-methoxy-8-hydroxy-coumarin 106, 5,7-dimethoxy-8-hydroxy-coumarin 107 and 5,7,8-trimethoxy-coumarin 108 (González *et al.* 1975d).



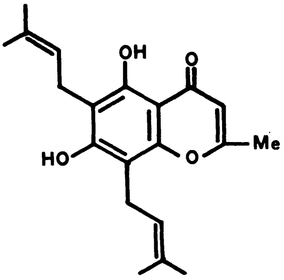
106



107 R = OH
108 R = OCH_3

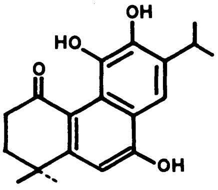
Neochamaelea pulverulenta (Vent.) Erdtm. (*Cneorum pulverulentum* Vent.) From fruits of this plant we isolated, besides the products mentioned above, the new chromones pulverin 109 (González *et al.* 1975e).

From this plant the products following have also been obtained: cneorum-chromones C [5-hydroxy-8-8 hydroxy.methyl-2,2-dimethyl-10 (3-methyl-2-butenyl)-2H, 6H [1,2-b: 5,4-b) dipyran-6-on]; cneorum coumarine B [7-hidroxy-8-(-2-hydroxy-3-methyl-3-butenyl) -6-methoxy coumarin]; sterol B (3 β, 7α, 20-trihidroxy stigmart-5- en]; and four new sexteterpenes g., h., i.,] the cneorines A,B,C, and D, (Mondon *et al.* 1975f).



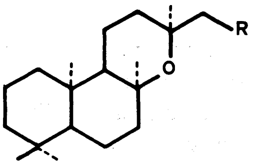
109

Salvia canariensis L.: From the aerial part we have isolated galdosol (González et al. 1973g) besides squalene, clovandiol, salviol and the new diterpene arucatriol 110 (González *et al.* 1975k).

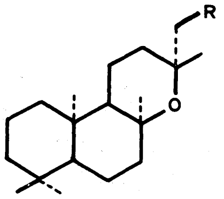


110

Sideritis gomerae Bolle: We isolated from the aerial part four new labdane diterpene oxides; gomeradehyde 111,13-epigomeraldehyde 112, gomeric acid 113 and 13-epigomeric and 114 as well as epeou -13- ene -8 β, 15 diol (ent-labd- 13(14)-ene 8 α, 15- diol) (González *et al.* 1975m).



111 R = CHO
113 R = COOH



112 R = CHO
114 R = COOH

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XII. THE INFLUENCE OF MAN ON THE VEGETATION OF THE ISLAND OF HIERRO (CANARY ISLANDS)

by

FRANCO KÄMMER

Introduction

This paper attempts to make quantitative statements on the influence of man on the vegetation of the island of El Hierro, in particular by contrasting present-day potential natural vegetation with present-day real vegetation. This provides, among other things, a scientific basis for nature conservation. The paper is limited to El Hierro, because there are only few publications relating to this island.

The researches were carried out in 1972 and 1974 and were supported financially by the Deutsche Forschungsgemeinschaft.

El Hierro represents the westernmost (between 18° 09′ W and 18° 10′ W) and southernmost (between 27° 38′ N and 27° 39′ N) extremity of the Canary Islands. It is the smallest of the seven main islands of the archipelago and has an area of about 278 km^2 and a maximum altitude of about 1500 m. All the percentage area data in this paper refer to the map area of the island, not to the complicated surface which is actually available to settlement by pteridophytes and spermatophytes. One percent then corresponds to about 2.78 km^2. The outline and contour lines in Figs. 1 to 16 are taken from a vegetation map by Ceballos & Ortuño (1951).

For the geology of the island see Rothe (1974). From the point of view of geology, geomorphology and soil science the most remarkable feature of El Hierro is that great parts of it are covered with mostly younger volcanic material (lavas, lapilli, ashes, etc.). In contrast to such areas of more or less uniform relief (hills, slopes, plains, etc.), there are some regions which show great variety. These landscapes with rocky slopes, cliffs and barrancos (ravines) are found principally in the north (El Golfo district) and the south-east and consist of mostly older volcanic rocks. The climate has been treated by Matznetter (1958), Walter & Lieth (1960–1967), Huetz de Lemps (1969), Knapp (1973), Kämmer (1974), Walter *et al.* (1975) and other authors.

Present-day Potential Natural Vegetation

The concept of 'present-day potential natural vegetation' was defined by Tüxen (1956). Walsemann (1967) proposed to replace it by 'present-day potentially natural vegetation'. Indeed, Tüxen (1974), Horvat *et al.* (1974) and other authors have recently used the corresponding German term. However, in this paper I use it in accordance with Tüxen (1956) to refer to a formally and substantially unequivocal definition (see Mueller-Dombois & Ellenberg, 1974).

In any case the concept refers to the vegetation in its postulated natural final state of development that would be possible if man's influence ceases while the other present conditions of life remain unchanged.

The vegetation maps by Knoche (1923), Ceballos & Ortuño (1951) and Knapp (1973) probably represent the present-day respectively former potential natural vegetation of El Hierro, though these authors do not explicitly say so.

There are various possible ways of classifying vegetation, as has been shown by Ellenberg (1973), Horvat *et al.* (1974) and Mueller-Dombois & Ellenberg (1974), among others. I use in this paper, for the sake of comparability, the classification which is customary in the botanical

Fig. 1. Present-day potential natural vegetation zones of El Hierro. Contour line interval 200 m (See Table 1). White: Treeless or almost treeless; Dots: *Juniperus phoenicea* forests and scrubs. Vertical lines: Laurel forests and scrubs in the broader sense; Horizontal lines: *Pinus canariensis* forests.

Table 1. Present-day potential natural vegetation zones as percentages of the area of the island of El Hierro.

Treeless or almost treeless	15
Juniperus phoenicea forests and scrubs	8
Laurel forests and scrubs in the broader sense	34
Pinus canariensis forests	43

literature on the Canary Islands. Thus three ecologically very different vegetation zones (a, c, d) and one transitional zone (b) (with *Juniperus phoenicea*) are distinguished. These zones are named after dominant species or particular features of life forms (see Kämmer 1974).

Fig. 1 and Table 1 show results of studies on the present-day potential natural vegetation of El Hierro. The vegetation zones are discussed briefly below, according to their arrangement in the landscape with increasing altitude.

a) The treeless or almost treeless vegetation zone would be dominated by shrubs, of which many are drought-deciduous, as for example the woody *Euphorbia* species.

b) The *Juniperus phoenicea* forests and scrubs would form the lower margin of the predominantly evergreen forest and scrub zones (c, d). They would be characterized above all by *Juniperus phoenicea* itself.

c) The term 'laurel forests and scrubs in the broader sense' can be used for those forests (and scrubs in rocky sites) which would be made up mainly by the species named in Table 4, except for *Juniperus phoenicea* and *Pinus canariensis*.

d) The laurel forests and scrubs in the broader sense would merge into the *Pinus canariensis* forests, dominated by the name-species. In the transitional zone (c-d) *Myrica faya* and *Erica arborea* would occur in the undergrowth of the *Pinus canariensis* forests.

In the present-day potential natural vegetation the 15 species dealt with more completely in Chapter 4 (Table 4) together with a few other would determine the structure of the predominantly evergreen forest and scrub zones (b, c, d) of El Hierro (about 85% of the area of the island). These species are therefore of interest also in this connection. According to their height and form the species can be arranged in two groups.

a) Trees that probably also on El Hierro reach a height of more than 5 m: *Juniperus phoenicea*, *Erica arborea*, *Pinus canariensis*, *Myrica faya*, *Visnea mocanera*, *Ilex canariensis*, *Picconia excelsa*, *Laurus azorica*. Trees that probably also on El Hierro reach a height of more than 5 m: *Arbutus canariensis*, *Apollonias barbujana*, *Ardisia bahamensis*.

b) Shrubs that occasionally on other islands of the archipelago and probably also on El Hierro grow tree-like and (nearly) reach a height of 5 m: *Olea europaea*, *Maytenus canariensis*, *Viburnum rigidum*, *Sideroxylon marmulano*.

Present-day Real Vegetation

The term 'present-day real vegetation' refers to the vegetation which actually exists at the present time (see the literature mentioned in Chapter 2, paragraph 1).

Data on the present-day respectively former real vegetation of El Hierro can be found especially in Knoche (1923), Burchard (1929), Ceballos & Ortuño (1951)*, Lid (1957), Cartografía... (1962, 1963)*, Mapa Militar ... (1964)*, Mapa Topográfico ... (1965)*, Expedition ... (1965), Mapa Forestal ... (1967)*, Comisión ... (197), Barquín (1972), Knapp (1973)*, Tierra ... (197), Kämmer (1974). An asterisk after the date of the year in brackets indicates that the real vegetation is mapped.

Tables 2 and 3 summarize results of studies on the present-day state of the vegetation on El Hierro.

'Less influenced by man' refers to vegetation which resembles at least floristically the types named in Table 1. This vegetation is mostly subject to forestry or to non-intensive agricultural, but is comparatively natural.

'More strongly influenced by man', that is obviously changed by man floristically and usually also structurally, are the following units.

a) Man-made forests of non-native trees, as *Pinus radiata*, *Eucalyptus* species, etc.

b) Areas used for non-intensive agriculture (but comparatively not natural), as pastures dominated by herbs, fallows, etc.

c) Areas with cultivated plants under intensive cultivation, as orchards, vineyards, banana plantations, gardens, arable land, etc.

d) Human settlements.

Table 2. Present-day real vegetation (vegetation zones) as percentages of the area of the island of El Hierro.

A.	Less influenced by man:	
	Treeless or almost treeless	28
	Juniperus phoenicea forests and scrubs	1
	Laurel forests and scrubs in the broader sense	11
	Pinus canariensis forests	10
B.	More strongly influenced by man:	
	Man-made forests	1
	Areas used for non-intensive agriculture (comparatively not natural)	27
	Areas used for intensive agriculture	19
	Human settlements	3

Table 3. Differences between the percentages of the vegetation zones in Tables 1 and 2A.

Treeless or almost treeless	+13
Juniperus phoenicea forests and scrubs	— 7
Laurel forests and scrubs in the broader sense	—23
Pinus canariensis forests	—33

Traditional forms of human settlements and of agriculture and forestry are shown, among other things, in Figs. 17 to 23.

About 1970, thus later than on most other islands of the archipelago, on El Hierro has begun an (at that time still modern) development that perhaps not only from the viewpoint of nature conservation is disadvantageous.

In the first place must be mentioned in this connection that the country is being built over to a rapidly increasing extent with scattered constructions of the most varied types, as the airport, roads, houses, etc. This form of unplanned development is particularly far advanced on Tenerife and Gran Canaria and is creating a great problem for nature conservation on the other islands of the archipelago too.

In the second place in relation to the intensity and permanence of the destruction of nature comes agriculture. A few years ago irrigation became possible on El Hierro (at least temporarily) by the exploitation of underground water supplies. Especially in the El Golfo district great areas have been leveled, filled up with earth from the deforested mountains (Fig. 23) and irrigated. Widespread banana plantations now dominate the landscape, where a few years ago almost natural bush vegetation was prevalent (Fig. 17). Furthermore, in these monocultures biocides are used abundantly. The loss of natural or almost natural landscapes caused by the spreading of agriculture, the exploitation of earth in other areas in connection with agriculture, and the plundering of forests also furthered by agriculture (see below), are critical in various respects.

In the third place comes forestry. In the last few years forest roads passable for lorries have been constructed which have made possible the widespread clearing of the laurel forests and scrubs in the broader sense (Fig. 18). The young timber obtained is used in the banana plantations to prop the fruits. The banana plantations also use manure made from cattle dung mixed with chopped-up twigs, leaves and leaf litter from the forests. By this exploitation and by the transformation of natural or almost natural forests into man-made *Pinus radiata* forests, great areas have been changed in a short time, particularly on Tenerife, La Palma, La Gomera and El Hierro.

The Influence of Man on the Native Taxa and Populations

In Chapters 2 and 3 quantitative statements on the influence of man on the vegetation of El Hierro have been made by contrasting present-day potential natural vegetation with present-day real vegetation. Studies on the influence of man on the native taxa and populations of an area are likewise important for the scientific basis of nature conservation. This has been shown, among others, by Stern & Tigerstedt (1974), Stern &

Roche (1974), Farnworth & Golley (1974) and several authors in the Proceedings... (1974).

Probably almost half of the at present about 600 species of pteridophytes and spermatophytes that grow wild on the island are not native to El Hierro, the Canary Islands or Macaronesia. Of the remaining native species more than half are endemic to El Hierro, the Canary Islands or Macaronesia. The increase of the floristic diversity on El Hierro caused by man, which favours non-native species and disfavours native ones, must largely be seen as negative. This is shown, among other things, by the following data on the distribution of the native taxa and populations.

Figs. 2 to 16 and Table 4 show the present-day distribution of 15 native evergreen tree and shrub species which grow wild on El Hierro. Only 4 of these species are now widespread on the island (*Juniperus phoenicea*, *Erica arborea*, *Pinus canariensis* and *Myrica faya*). The remaining 11 species, apart from a single find of *Laurus azorica*, are known at present exclusively from the north side of the island, where they are scattered or rare. This distribution, which is shown quantitatively in Figs. 2 to 16 and in Table 4, has natural as well as human causes (see below).

Fig. 2–16. Locality maps of the present-day distribution of 15 native evergreen tree and shrub species growing wild on El Hierro. Based on observations by the author. Contour line interval 200 m (See Table 4).

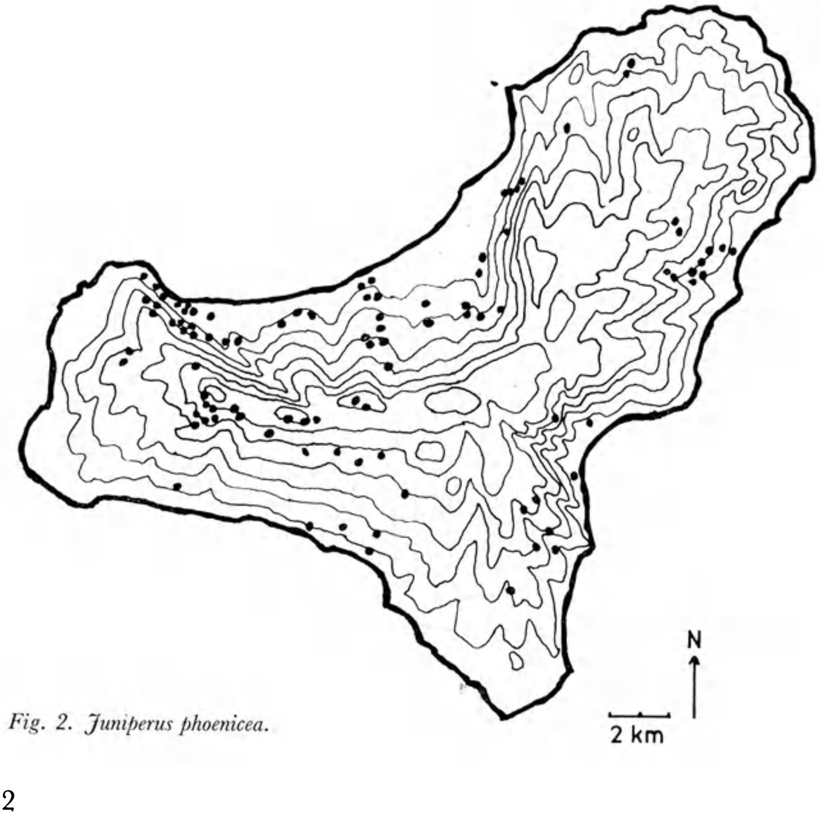

Fig. 2. Juniperus phoenicea.

Fig. 3. Erica arborea.

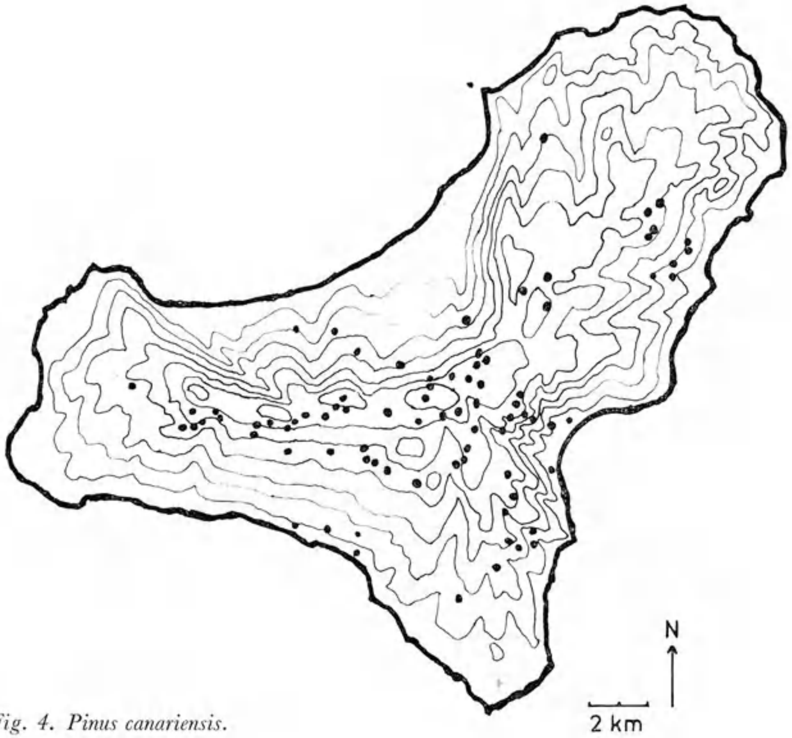

Fig. 4. Pinus canariensis.

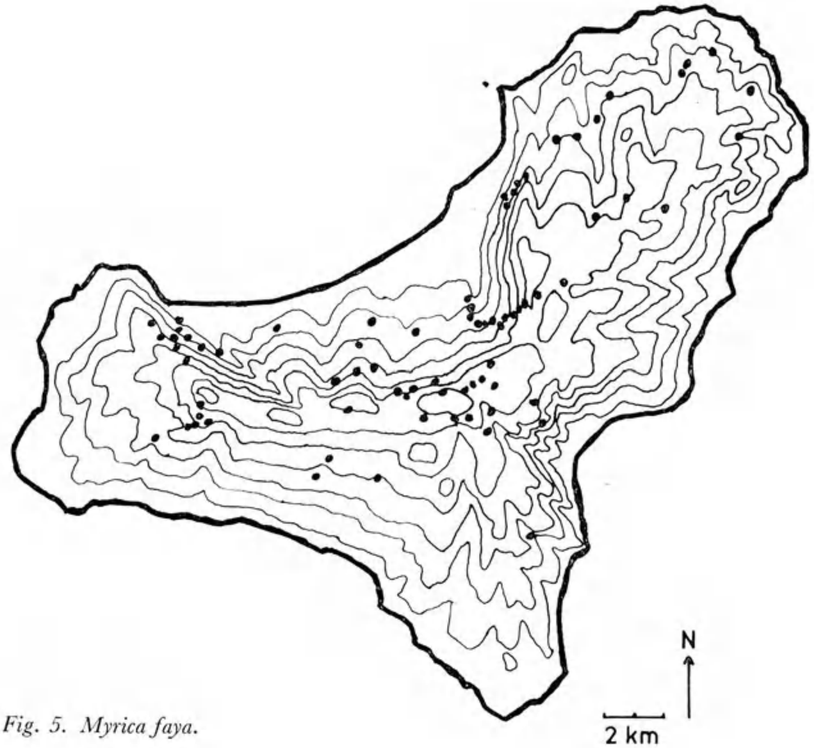

Fig. 5. *Myrica faya*.

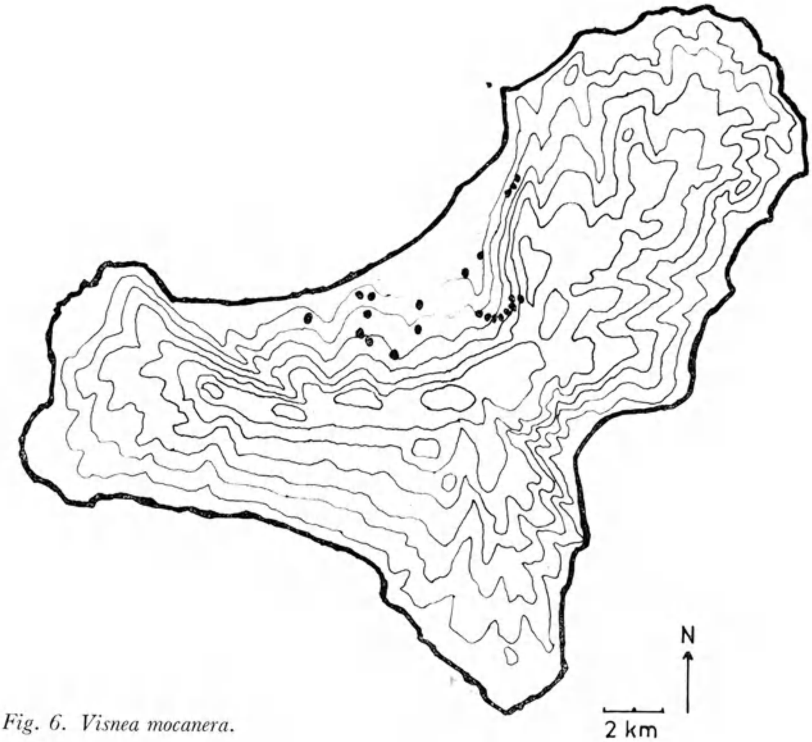

Fig. 6. *Visnea mocanera*.

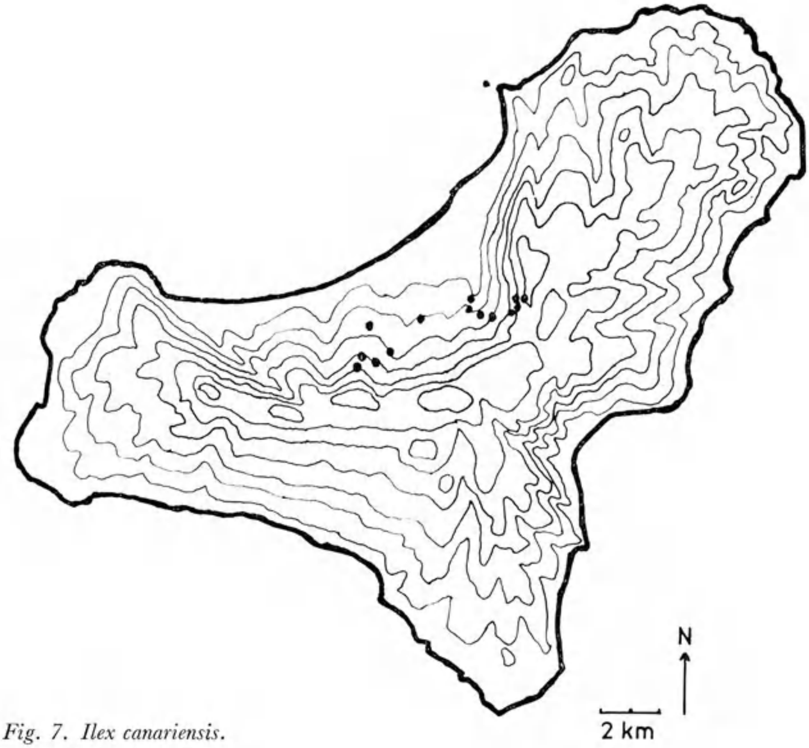

Fig. 7. *Ilex canariensis.*

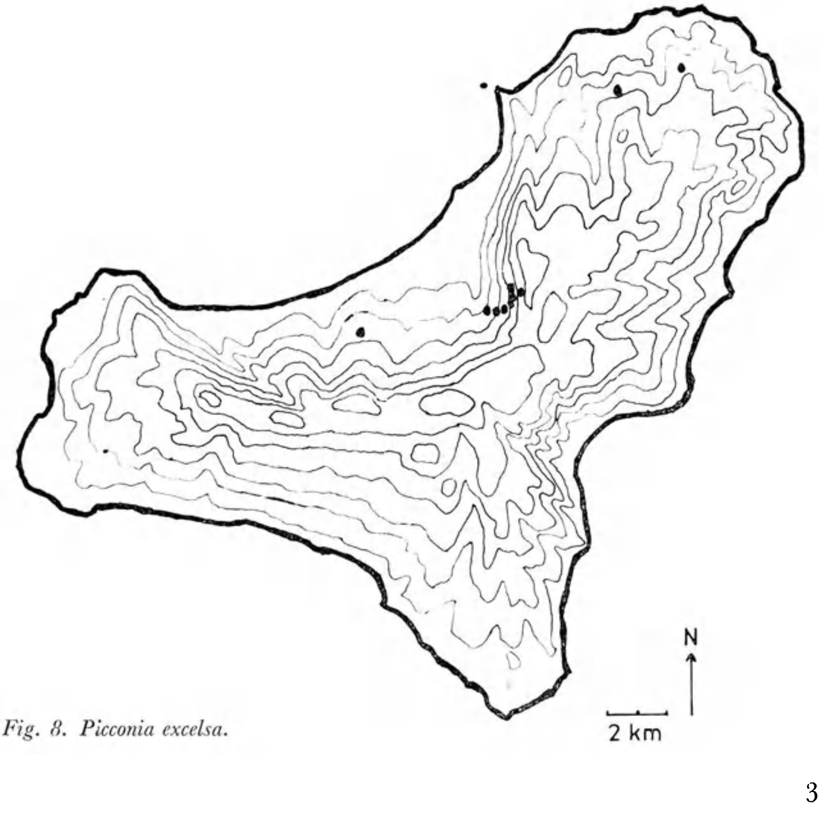

Fig. 8. *Picconia excelsa.*

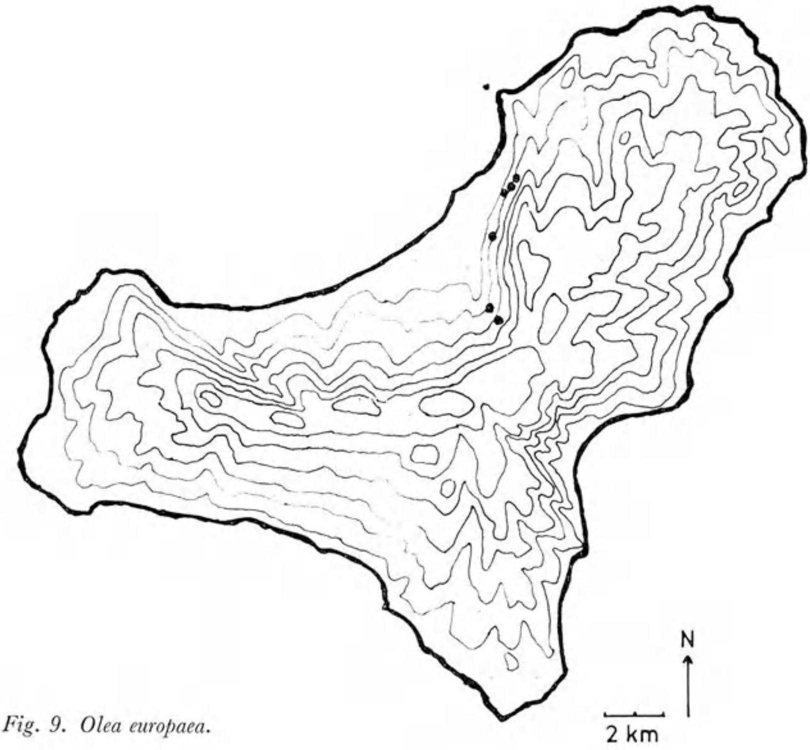

Fig. 9. *Olea europaea.*

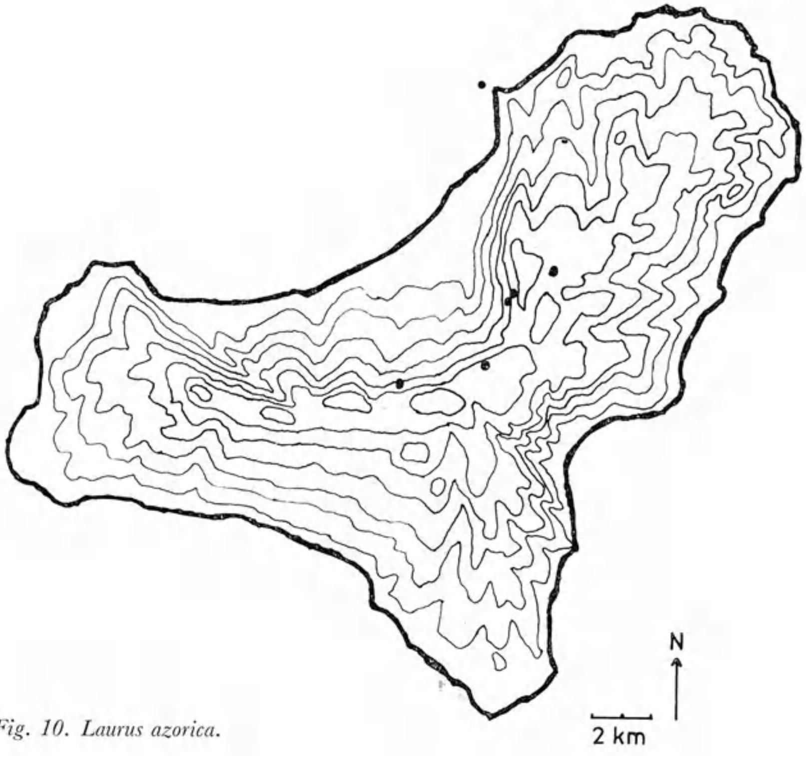

Fig. 10. *Laurus azorica.*

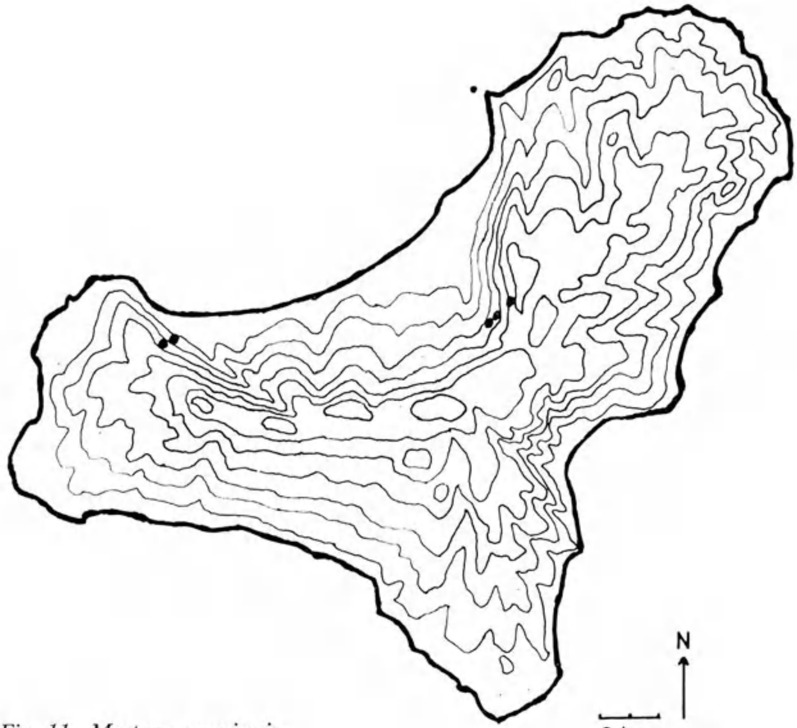

Fig. 11. Maytenus canariensis.

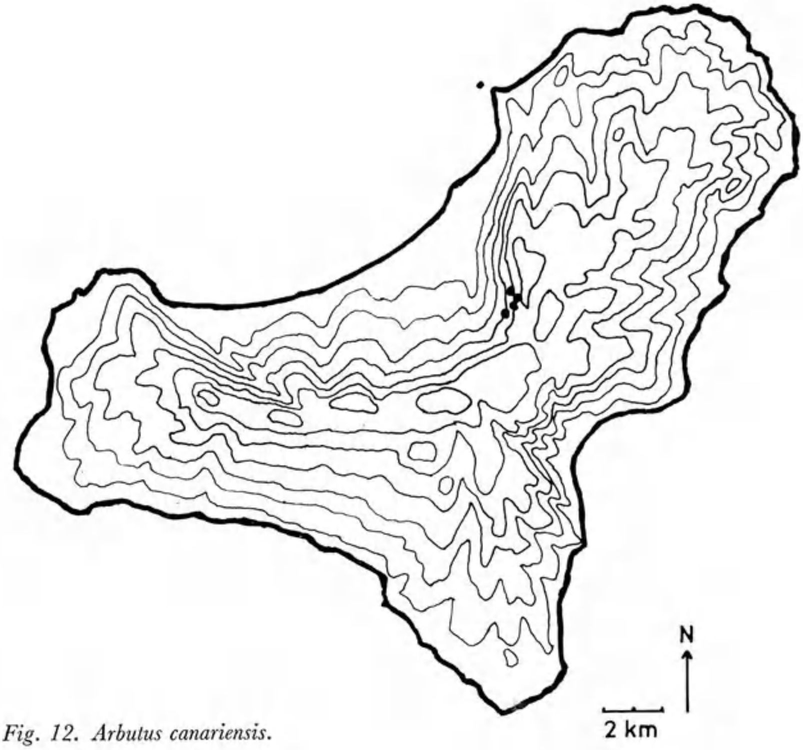

Fig. 12. Arbutus canariensis.

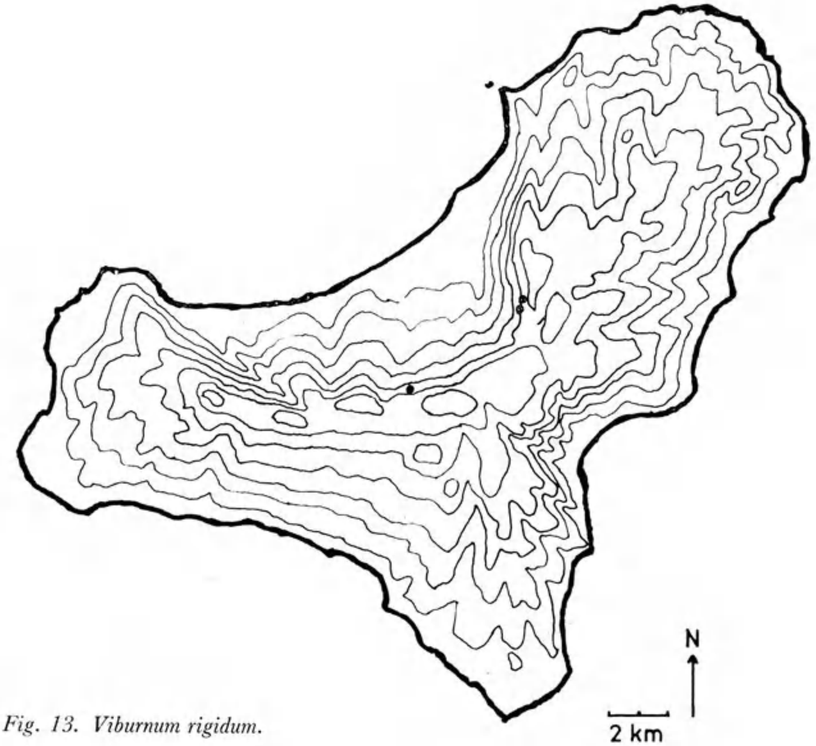

Fig. 13. *Viburnum rigidum.*

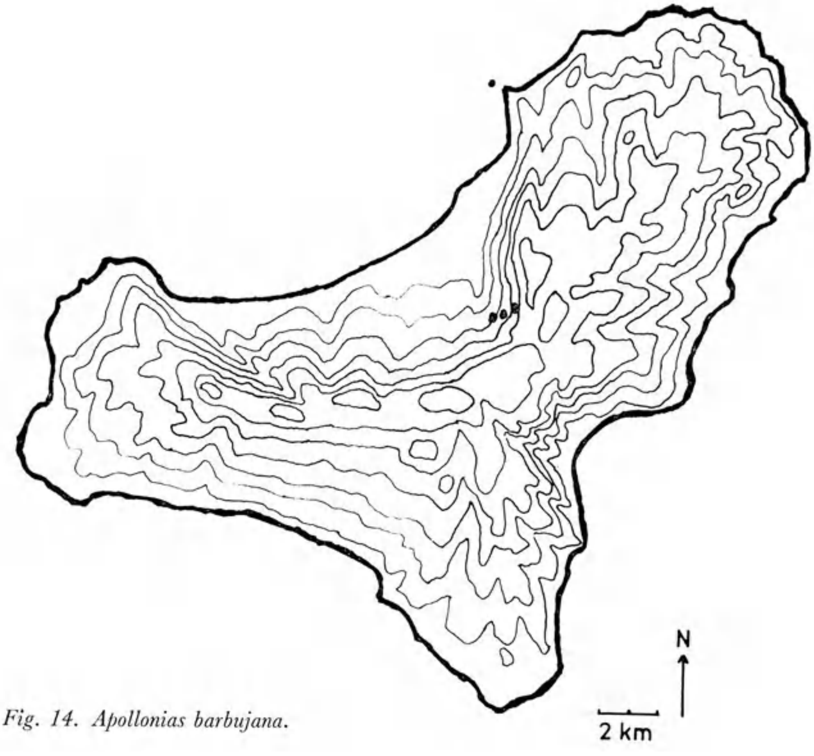

Fig. 14. *Apollonias barbujana.*

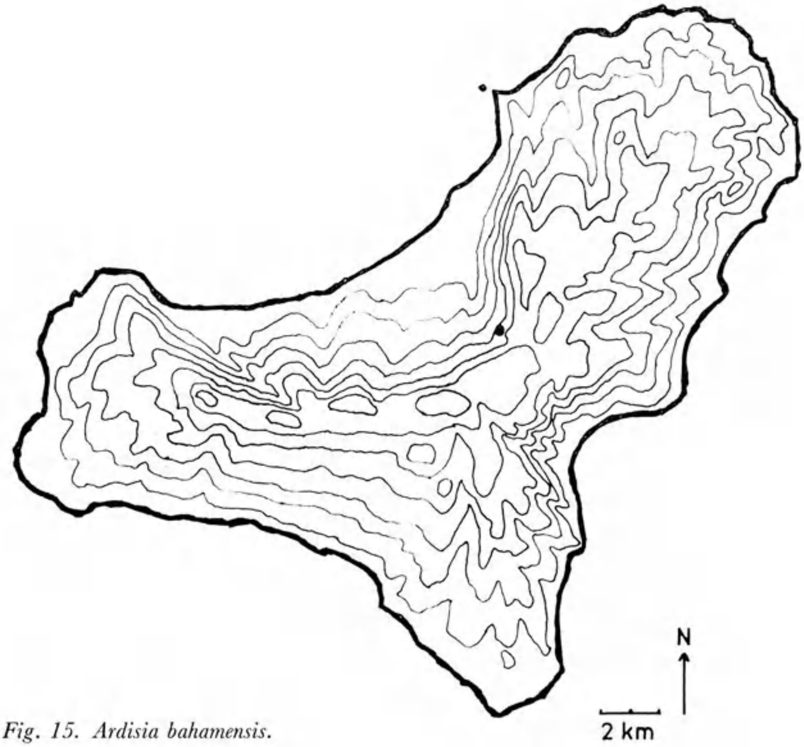

Fig. 15. Ardisia bahamensis.

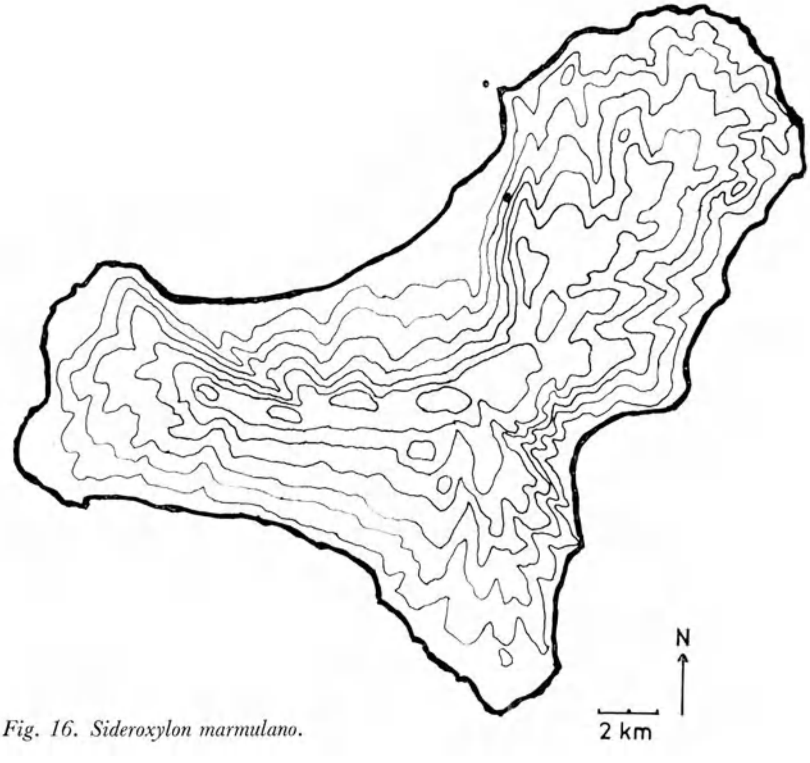

Fig. 16. Sideroxylon marmulano.

Table 4. Number of present-day localities for 15 native evergreen tree and shrub species growing wild on El Hierro. Based on observations by the author. (See Figs. 2 to 16).

Juniperus phoenicea	96
Erica arborea	92
Pinus canariensis	83
Myrica faya	75
Visnea mocanera	22
Ilex canariensis	14
Picconia excelsa	10
Olea europaea	6
Laurus azorica	5
Maytenus canariensis	5
Arbutus canariensis	4
Viburnum rigidum	3
Apollonias barbujana	3
Ardisia bahamensis	1
Sideroxylon marmulano	1

Fig. 17. El Golfo district near Los Mocanes. Present-day real vegetation: Rocky slopes poor in vegetation, areas used for traditional agriculture (fields, fallows, etc.), banana plantations between rests of almost natural bush vegetation. Present-day potential natural vegetation: In the picture at lower right rocky slopes with laurel scrubs in the broader sense, at the lower left *Juniperus phoenicea* forests and scrubs, other areas treeless or almost treeless.

Fig. 18. El Golfo district between Tigaday and the Malpaso (1500 m). Present-day real vegetation: Terrace fields under traditional cultivation, merging into laurel forests and scrubs in the broader sense with clearings caused by forestry. Present-day potential natural vegetation: Laurel forests and scrubs in the broader sense, extending from their lower margin (lower right in the picture) up to their transition into *Pinus canariensis* forests (in the highest mountains).

Starting from Fig. 1 and Tables 1 to 3 and from the other data in Chapters 2 and 3, it is to be expected that the influence of man on the distribution of the native taxa and populations on El Hierro is partly positive and partly negative. In any case the present-day more or less man-made condition of the flora and vegetation on the Canary Islands should not be considered as disadvantageous in every particular (Kämmer 1974, 1975).

A positive effect is the spreading of some native taxa and populations on El Hierro caused by man. It appears also from Table 3, for the treeless or almost treeless vegetation zone, that native shrubs, in particular, have been able to spread because of man-made changes in the vegetation, especially the partial clearing of the forests. Among the species shown in Figs. 2 to 16 and Table 4 this is probably also true of *Juniperus phoenicea*, as a comparison of Figs. 1 and 2 suggests.

A negative effect is the decline caused by man in the distribution of numerous native taxa and populations on El Hierro, and the resultant loss of genetic diversity.

The non-native species already mentioned, making almost half of the total, predominate in the vegetation more strongly influenced by man.

Fig. 19. East of Mocanal. Present-day real vegetation: Overgrazed pasture, with *Myrica faya*, *Picconia excelsa* and planted *Castanea sativa* in the little valley. Present-day potential natural vegetation: Laurel forests in the broader sense.

Fig. 20. West of San Andrés. Present-day real vegetation: Completely deforested arable land under traditional cultivation. Present-day potential natural vegetation: Transition from *Pinus canariensis* forests into laurel forests in the broader sense.

Fig. 21. As Fig. 20. Overgrazed *Micromeria* pasture.

As shown in Table 2, such areas constitute about 50% of the area of the island. In the other areas native species predominate. Examples of rarity, to which man has contributed, of species which are native on El Hierro but not endemic to this island are given in Figs. 6 to 16 and Table 4. The natural centre of the distribution of these 11 species is indeed on the north side of the island, but they are becoming, like many other species, more and more limited to special localities that have been little influenced by man (rocky slopes, cliffs, barrancos, etc.).

The existence of small populations, mainly of taxa endemic to the island, is endangered by man to a much greater degree. Moreover these small populations are often little known or have still to be described. As examples of the large number of almost extinct endemic taxa (Bramwell 1974) and populations (Kämmer 1972), two cases are mentioned here.

Fig. 22. As Fig. 20. Pastures and intensive soil erosion.

Fig. 23. As Fig. 20. Exploitation of earth for banana plantations.

Adenocarpus ombriosus is endemic to El Hierro and taxonomically critical, it is known from only one locality. *Plantago arborescens* occurs on several islands of the archipelago, it is found in two places on El Hierro that are inhabited by morphologically distinct populations, of which one at least has not been described. Each of the three localities where these two rarities occur are only a few hundred or thousand square metres in size and could easily be changed by man to the detriment of the endemic species or populations.

Summary

In this paper a quantitative ecological approach to the influence of man on the ecosystems of the Canary Islands has been applied to the island of El Hierro, with special reference to nature conservation.

The present-day potential natural and the present-day real vegetation are described and classified on floristic and ecological criteria. Potential and real distribution of vegetation types are compared numerically in relation to the impact of modern civilisation, agriculture and forestry on island ecosystems.

Numerical data are given for introduced, native non-endemic and native endemic plant species to demonstrate floristic change. The present distribution of 15 native trees and shrubs is shown as example of the considerable number of nearly extinct plant taxa or populations endemic to the Canary Islands.

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XIII. INTRODUCTION TO A FAUNAL STUDY OF THE CANARY ISLANDS' LAURISILVA, WITH SPECIAL REFERENCE TO THE GROUND-BEETLES

(Coleoptera, Caraboidea)

by

ANTONIO MACHADO

Introduction

The laurisilva has usually been dealt with from a strictly botanical point of view, without taking into account its certainly rich and interesting fauna. The global study of the fauna of this vegetal formation is far from being realizable even today, due to the present state of the knowledge of the different zoological groups present in the Archipelago. We have nevertheless wished to approach this line of work for we consider it of great ecological, biogeographical and evolutionary interest.

We may think, for example, on the old problem of how the Macaronesian Archipelagos were colonized: by land? by sea? ... The answer would be simple if only we knew the origin of these islands, greatly debated even by geologists. But principally there are zoologists who, in order to explain some faunistic coincidence or the other, have devised a series of land bridges between the islands or with the continents, when they have not been dedicating themselves to the sinking or rising of lands that existed, at least in their imaginations, at some time in the past.

The origin of the islands only concerns, strictly speaking, the geologists, in so far as it treats of a geological process, but without doubt detailed knowledge of the terrestrial biota that inhabits the different islands can help greatly in the sense of supporting or confronting the diverse hypothetical aspects that geology can offer. What does not seem correct is the devious handling of geology to explain the biogeographic phenomena, rather it is in the fauna and flora where one should reestablish and try to find the ecological, palaeobiogeographical or evolutionary explanations in order to adapt them to the geological facts.

The laurisilva plays an important role in this context in that, excepting the Salvages, it may be considered as the 'common denominator' of Macaronesia (see fig. 1). The careful study of its fauna will bring about the establishment of some faunistic interrelations that can say a lot about the evolution of the whole group.

In a first approach, for example, it is observed that the greatest percentage of the so called 'macaronesian elements' are inhabitants of the

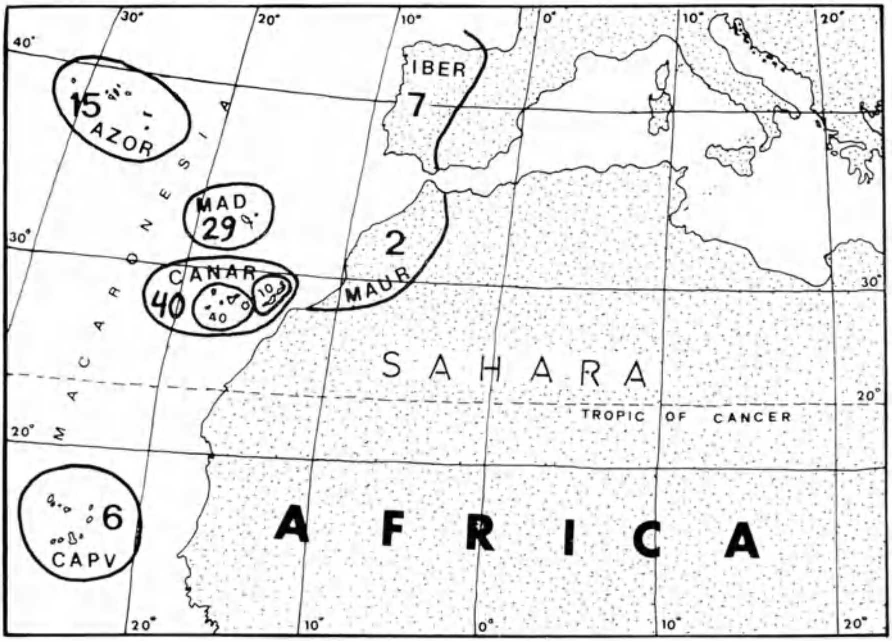

Fig. 1. Map of the numerical distribution area of the *Pruno-Lauretea* Oberdorfer (see the species list on page 352). Only the areas shown are taken into account = Macaronesia sensu lato. The Salvages are not considered as the class *Pruno-Lauretea* does not exist there. (Taken from Voggenreiter, 1974, simplified).

laurisilva. Likewise, the greatest percentage of the palaeoendemic fauna is bound to this formation that is – par excellence – a vegetal relict ('Paleoflora vivente', Ciferri 1962). The laurisilva also represents the stratum where many groups reach their maximum of endemicity, and in fact, some cases exist where all the forms present are endemic, and almost without exception exclusively of the laurisilva.

Another evolutionary aspect of the insects that live in the laurisilva which deserves notice is the frequent coexistence of closely related species, even without apparent ecologic barriers. These cases of sympatry, often multiple, may be explained by repeated invasions of a same original line, with the corresponding intermediate periods of isolation, or perhaps consider that the laurisilva could also have acted, in some cases, as a center of secondary sympatry. In order to understand this idea it must be noted that not only different populations exist among the laurel forests of the various islands, but also within the same island; in Tenerife for example, differences between the fauna of formations located in distinct zones may be found. These laurisilva 'islands' may contain exclusive forms that have been displaced by some means to the dominion of its vicariant.

Fig. 2. Aspect of the laurel forest at Agua Garcia, Tenerife. 'Viñátigo' = *Persea indica* (L.) Spreng. in the foreground, with its trunk covered by lichens. Photo A. Machado.

The role that vulcanism could have played in this phenomenon should not be neglected. Lava flows, very common in these islands, can isolate (in certain zoological groups) small populations (c.f. Thiele 1971) in which genetic drift facilitates differentiation so that, when communication is reestablished in the course of time, they coincide in secondary sympatry with the descendents of their ancestors.

This is, of course, speculative terrain, but there is no doubt that careful study of the fauna (components, distribution, ecologic preferences, etc.) is more than justified because it is basically the only way to try to solve some of the problems – sometimes characteristic of this ecosystem – and to be able to understand evolution that in islands such as these becomes strikingly complicated.

Difficulties encountered

The botanical aspect does not entail great difficulties. An extensive bibliography on the laurisilva is avaible (see in Sunding 1973), and apart from taxonomic and floristic investigations some structural studies of great interest have been made (Dansereau 1968). The problem resides in zoology.

In the introduction we have already commented on the impossibility of realizing a complete faunistic study of the laurisilva. Works on the fauna of the Canary Islands are fairly numerous – especially those referring to the entomological fauna – but this does not imply that an exact knowledge of this fauna has been achieved. On the contrary, we believe that the present state of our knowledge is very unsatisfactory. Whole gaps exist in certain groups, and even most of the studies already made need to be thoroughly revised and complemented by more intensive field work.

Unfortunately there are few recent works. If we add to this, the total dispersion of publications dedicated to the theme, and at the same time, take into account the numerous collections with their corresponding type species, one may then have some idea of the difficulties concerning the fauna of these islands, particulary in relation to any vegetation level of the islands.

Another problem, difficult to remedy, adds to this lack of scientific framework (principally in taxonomy). Here we refer to the present state of conservation of the laurisilva in the Canary Islands (even more disastrous in the Azores, Madeira and Cape Verde). Ceballos & Ortuño (1951) give a rather illustrative map of the existing forest relicts conserved at that time in the Islands of Hierro, Gomera, La Palma and Tenerife, even though the limits of the natural forest dominion do not appear very correct. Voggenreiter (1974) has recently published an extensive work on the vegetation of Tenerife, that treats the syntaxonomic class *Pruno-Lauretea* Oberd. 60 em. 65 with some detail, concerning the Maca-

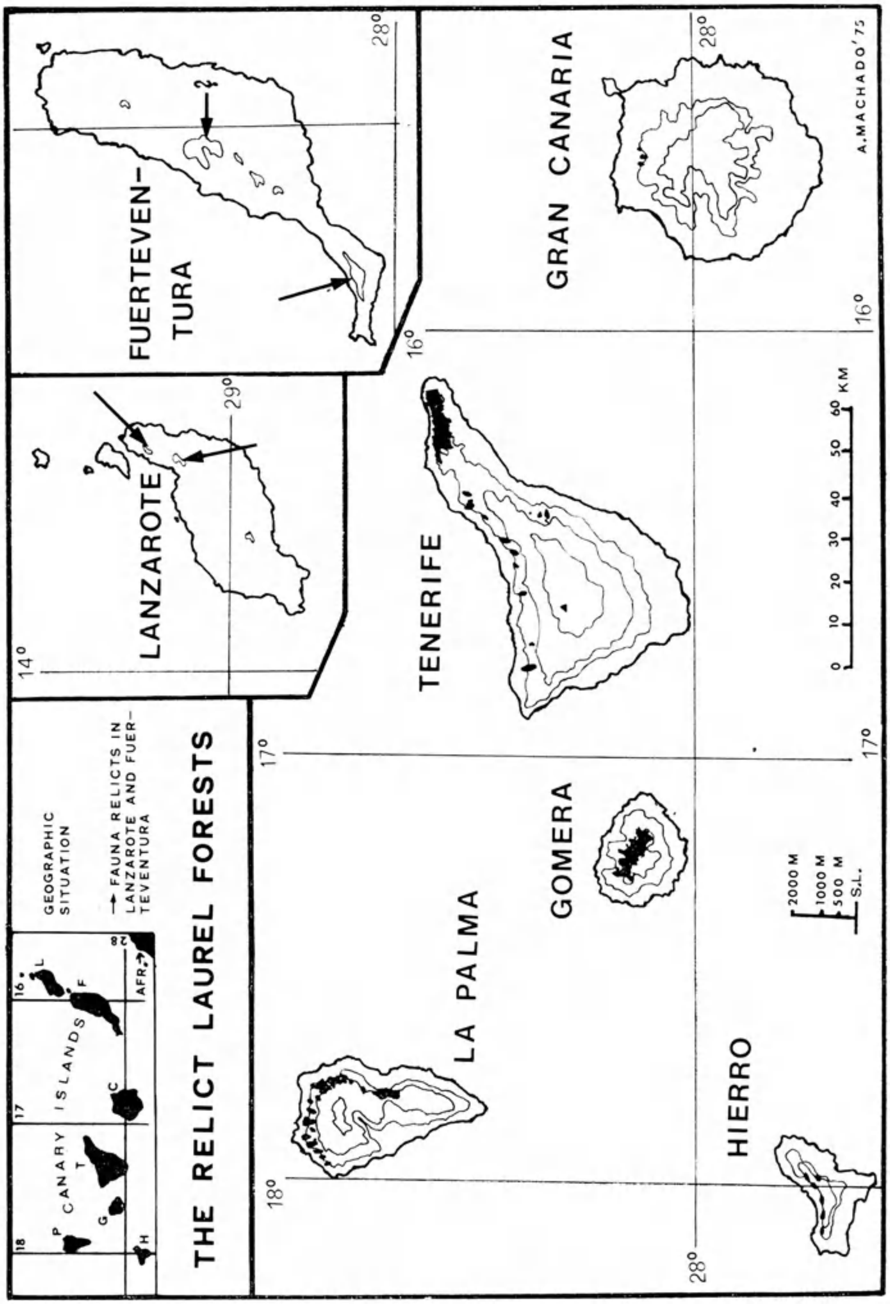

Fig. 3. Approximated distribution of the laurel forest relicts, mainly of secondary character.

ronesian laurisilva. This autor dedicates special attention to the recent destruction of these forests. Reading this chapter (*ibid.*, pp. 107-161), along with the references given by Webb & Berthelot (1840), will give the zoologist an impression of the magnitude of the regression that the laurisilva has suffered at the hands of man and his activities. This leads to the impossibility of perfectly reconstructing the original fauna, and it is very probable that more than one animal species may have disappeared owing to the reduction or destruction of its habitat.

Along with the intrinsic difficulties of this region we have those classical problems confronting faunistic studies that have been fully commented on by Leclercq (1964). Both qualitative (species present in a region and absent in another) and quantitative (species abundant in a region and rare in another) differences are of interest in a faunistic study. If we analyze the bibliography or the existing collections concerning the Canaries, we see that these fundamental aspects, above all quantitative, have scarcely been taken into account. The following comment by Leclercq (*op. cit.*, p. 372) serves to illustrate our case: «A cause du même culte des trophées de chasse, les entomologistes ont pris l'habitude de ne publier que des captures de raretés alors que ce sont des inventaires complets par biotope, par commune, par région, qu'il faudrait pour caractériser valablement le paysage zoologique.»

The Potential Distribution of the Laurisilva and its Faunistic Importance

«Avant la conquete des Canaries, la région lauríifière devait s'étendre jusque dans le voisinage du littoral, partout où l'exposition et les autres causes influentes étaient venues favoriser le développement des arbres. Les premiers navigateurs que visitèrent ces îles en ont parlé comme d'un pays boisé jusqu'á la mer; mais aujourd'hui les forêts sont loin du rivage.» (Webb & Berthelot 1840, p. 111).

It is necessary for the zoologist to know the potential distribution of the laurisilva in the Archipelago. The distribution of an animal species of the laurisilva may be affected in different ways by the regression or degeneration of its habitat. For the phytophags or xilophags, often specifically bound to only one plant or group of plants, the alteration of the environmental conditions may or may not be so decisive and they will be found where their food plant persists. The numerical distribution area map of the *Pruno-Lauretea* in Tenerife (fig. 4) presented by Voggenreiter (1974) gives an excellent idea of the repartition-persistence of the forty vegetal species considered[1].

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[1] *Athyrium umbrosum*, *Erica scoparia* ssp. *platycodon*, *Ixanthus viscosus*, *Rubus bollei*, *Laurocerasus lusitanica* ssp. *hixa*, *Ardisia bahamensis*, *Myosotis macrocalycina*, *Geranium canariense*, *Senecio populifolius*, *Hypericum glandulosum*, *Cedronella canariensis*, *Smilax* (genus), *Ilex perado* ssp. *platyphylla*, *Woodwardia radicans*, *Rhamnus glandulosa*, *Ocotea foetens*, *Arbutus canariensis*,

The principal limiting factors for other animals are those of an abiotic type (usually humidity or lack of) and, according to their ecologic valence, they may or may not resist a notable injury to their habitat. Certain species of insects have been relegated to real 'sanctuaries' out of which they are not found (these are in great danger of extinction!!), while others persist in the substitute biotopes, taking refuge in certain microenvironments that satisfy their ecologic necessities. There are also others that adapt themselves perfectly to new conditions and even those that take advantage of it to increase their distribution area.

Water utilization will cause aquatic or riparian species to disappear in places suitable in other respects. The edaphic species usually persist for a certain time even after the most radical modifications in the atmobius. Clearly, one must know in a broad sense the ecologic necessities of the group under consideration, as dependent on them, we must consider the potential distribution of the laurisilva in some detail for a better judgement of the repartition of said animals.

In an inverse sense, the fauna can provide new data to botany. Thus, the presence of 'typical' laurisilva species in places no longer inhabited by this plant community can suggest the existence of the latter in the not too distant past. If some day we could know the distribution of certain insects, it would not be surprising that it would coincide quite well with the limits of the potential distribution of the laurisilva.

According to Dansereau (1968) the animal dispersal diaspores are extremely abundant in the tree layer, and Voggenreiter (1974) notes the imperative necessity of making ornithological investigations, concerning bird distribution and the possibility that interisland migrations exist.

The Laurisilva as an Ecosystem; Subtypes

It is easy for the zoologist to recognize the environmental diversity that the laurisilva offers to large and small animals. Referring to insects, the most diverse and best represented group, we find them under bark, in the dry leaves hanging from the *Aeonium*, in dead wood, under stones or fallen trunk of trees, in the green parts of plants, in water, soil, fallen fruits, etc. The richness of ecological niches in this vegetal formation is really great, but to this primary division one of a second order is superimposed. Marked differences exist between the entomological population of a rocky area and that of the forest interior or the border of a path, almost always

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Convolvulus canariensis, *Picconia excelsa*, *Canarina canariensis*, *Ilex canariensis*, *Myrica faya*, *Hedera canariensis*, *Gesnouinia arborea*, *Apollonias barbujana*, *Semele androgyna*, *Persea indica*, *Viburnum rugosum*, *Cytisus canariensis*, *Phyllis nobla*, *Laurus azorica*, *Galium ellipticum*, *Visnea mocanera*, *Asplenium hemionitis*, *Asplenium adiantum-nigrum*, *Ranunculus cortusaefolius*, *Pteridium aquilinum*, *Hypericum grandifolium*, *Erica arborea*, *Brachypodium silvaticum*.

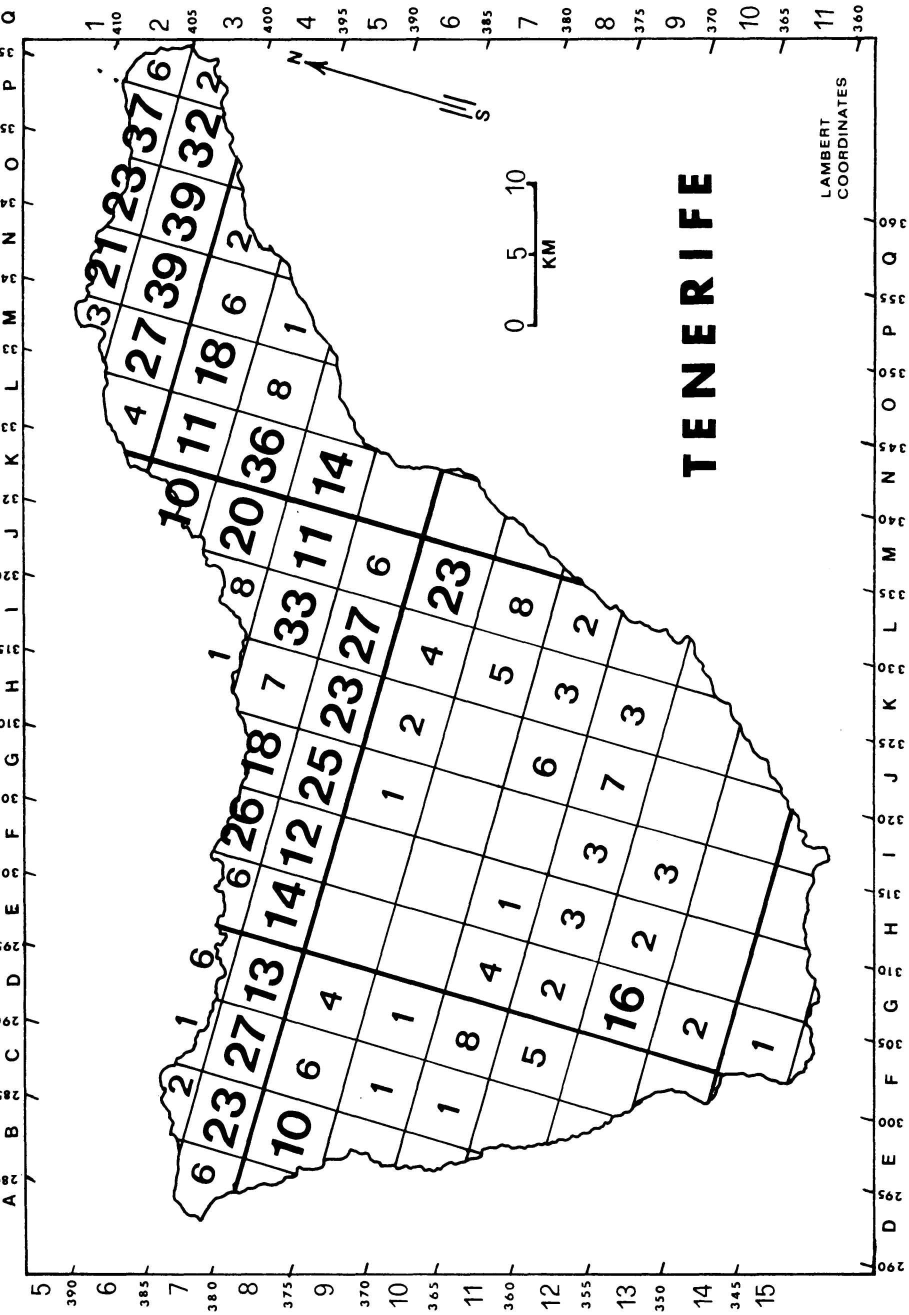

Fig. 4. Map of the numerical distribution area of the syntaxonomic class *Pruno-Lauretea* Oberdorfer in Tenerife, after Voggenreiter, 1974 (simplified).

corresponding to the different vegetal composition or to hygrothermic differences.

We believe that it would be more correct to consider the laurisilva at a higher level, as an ecosystem, that is to say, including the faunistic components in the concept. For greater ease in the study of the fauna it is better to consider the laurisilva, as applied in a botanical sense, as a habitat in which the fauna is established. For this reason we shall frequently refer to the fauna that inhabits the laurisilva, and not the fauna that constitutes it.

But even within botany one must establish the true scope of the term 'laurisilva', and the ecologic variants (that would be subecosystems) encompassed within it.

Kämmer (1974), in a recent study on Tenerife, points out the confusion existing between the concepts 'laurisilva', 'fayal-brezal' and 'monteverde', and proposes a new division for what he calls the 'laurel forests in the broadest sense' into the following subtypes[2]:

- *Erica scoparia* shrub-forests
- Epiphyte-rich laurel forests
- Epiphyte-poorer 'normal' laurel forests
- Shrub-rich laurel cliff-forests
- Formations in the dry marginal zone of laurel forests

At the same time this author emphasizes that the potential inferior forest limits have usually been placed very high above sea level. He also mentions the little consideration that other authors have given to the *Pinus canariensis*-laurel mixed forests ('Pinar con sotobosque de laurisilva'), that are very extensive in certain zones (e.g., in La Palma). In this formation (ecotone type), which he includes as a subtype of the *Pinus canariensis*-forests (= woodlands, after Dansereau 1968), the environmental factors of water and radiation (light + temperature), and probably also soil, differ from those prevailing in the pure pine forest and true laurel forest. On Kämmer's map (fig. 5) it can be observed how the laurisilva of the extreme West of the Island (Teno), for example, is 'isolated' by this mixed formation from the rest of the laurisilva of the N-NW side of the Island. It may have some influence on the 'laurisilva islands' mentioned in the introduction.

A superposition of the numerical distribution area maps for the syntaxonomic clases *Pruno-Lauretea* Oberd. 60 em. 65 and *Cytiso-Pinetea canariensis* Rivas Goday & Esteve Chueca 1965, presented by Voggenreiter *(op. cit.)*, reveal the coincidence between both, though without many details referring to the limits. The natural potential vegetation maps of Ceballos & Ortuño (1965) or Voggenreiter *(op. cit.)* do not

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[2] We abstain from including the characteristics of the subtypes, and recommend the reading of pp. 16–22 in the work of Kämmer, *(op. cit.)*.

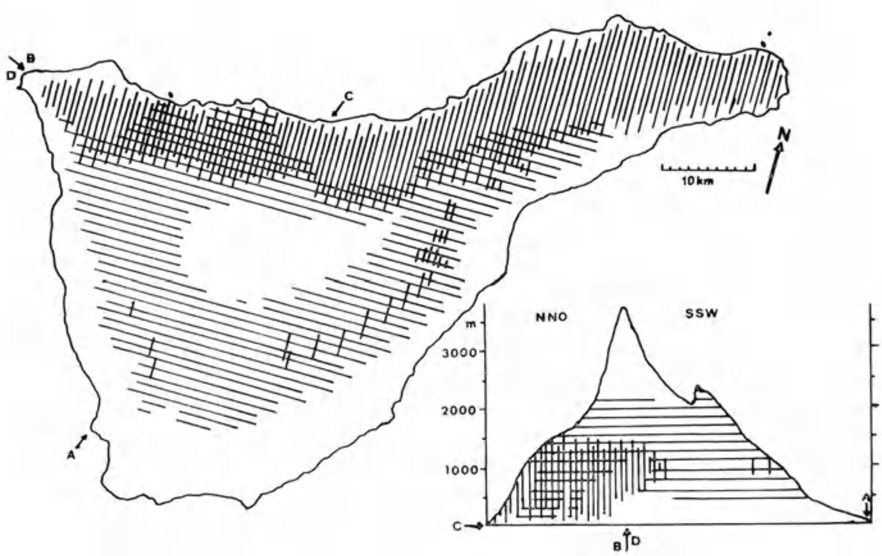

Fig. 5. Potential natural vegetation of Tenerife, after Kämmer, 1974. Vertical lines: Laurel forests in the broadest sense; Horizontal lines: *Pinus canariensis*-forests; White: Few or no trees.

consider this peculiarity and, in our opinion, can lead to erroneous faunistic interpretations.

Both the potential vegetation map of Kämmer (lamentably only of Tenerife), as well as the division into subtypes of the 'laurel forests in the broadest sense' are, in our judgement, of great accuracy in that they coincide with our empirical knowledge of the fauna, the fruit of various years of field work in the Archipelago.

Nevertheless, we believe that the problem of terminology is not resolved. A term is needed which not only designates the laurel forests but also takes in account the laurel components of the mixed forest. We have elected the term 'laurisilva' because it has been used frequently in this sense and because it is rather versatile. One may speak also of the Tenerife, Canary, Macaronesian or Chilean laurisilva, for example (c.f., Rübel 1930). The term 'laurel forest' could be used to refer to the forest manifestations.

The fayal-brezal considered by many authors as a natural formation, does not represent more than a degradation state of the laurisilva due to the effect of lumbering (Melville & Bramwell 1972; Santos Guerra 1973; Sánchez García 1973; Voggenreiter 1974) except when appearing as marginal formations, sotoforest of pine woods, etc. The present extent of these former 'artificial' formations is very much superior to that of the real laurisilva and the Canary peoples do not distinguish between one and the other, designating them as 'monte-verde'. (green wood).

Until the present time no complete analysis of any group of the laurisilva fauna has been made. Some general, more or less detailed commentaries do exist[3] on coleopterans (Wollaston 1865; Palm 1967, etc.). Lindberg (1953), in his monograph on the Canary hemipterans, presents an ecological classification[4] of the species of the cloudbelt zone ('Wolkenzone'); Frey (1936) studied the zonal distribution of the Tenerife dipterans, and gives lists (with number of specimens) of the species collected at certain localities in the cloud-belt zone, later dividing the species into characteristic and secondary or casual species, presenting also their frequency as a percentage.

Gangwere *et al.* (1972) recently made a lengthy study of the Orthopteroid distribution in Tenerife, in which they pay special attention to the orthopteroids unique and exclusive (marked *u*) to the important zones (among these, the 'tropical forest zone or laurisilva') and those so commonly encountered there as to be considered to be typical of them (marked *t*).

An ecological division, as well as a classification according to abundance, are of great interest, but in order to represent the real character of the laurisilva fauna, it is necessary to make – whenever possible – a faunistic analysis that reflects the source, zoogeographic value, etc. of the species. For future studies, we propose the following classification and symbols:

Forms present in the laurisilva. –

Autochthonous	Exclusive	of stenoecious character	W′
		of euryoecious character	W
	Not exclusive		Y
Introduced	from neighboring biotopes		R
	by human means		X
	(adventitious species		X′)

Some dipteran examples will help to understand this classification. The autochthonous forms of the laurisilva may be exclusive or not to this formation; thus the syrphid *Chrysotoxum triarcuatum* Macq. lives in the Inferior Zone as well as in the Middle Zone, and would be a Type Y species. Among the exclusive forms it is interesting to differentiate between those that, due to their reduced ecologic valence (stenoecious), remain intimately bound to the laurisilva and are only found in forest relicts,

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[3] Usually on the Island of Tenerife, being the most representative and best studied.

[4] 1. Ground species ('bodenbewohnende Arten') of the forests. 2. Species from the trees and shrubs from the laurel forests. 3. Species from the *Erica-Myrica* forests. 4. Species from the *Cytisus proliferus*-stands. 5. Pine-inhabiting species. 6. Species from the xerophytic formations of the cloud-belt zone.

as in the case of *Calliphora splendens* Macq. (Type W′), while others, due to their more euryoecious character, have also maintained themselves in the former laurisilva domains (see figs. 29 and 30). In the helomyzids, whose larvae feed on decomposing vegetal material (wood, leaves, etc.), *Suillia oceana* Beck. is one of Type W, present in the true forests as well as in the fayal-brezal or posterior degraded states. These are very interesting 'typical' laurisilva species in that, in certain groups, they may be used to indicate the past existence of laurisilva.

We may also frequently collect many forms in the laurisilva that are not proper to this formation. We are then dealing with forms that were recently introduced through human activities. Road-building, for example, has permitted the settlement of numerous weeds, coming from the Inferior Zone that are frequently accompanied by their animal cohort. The number of these Type X forms will be greater as more 'contamination' enters the laurisilva. We also include here the adventitious species ('Adventivarten', Freude, Harde & Lohse 1965) of our fauna, that is to say, those that have been introduced into the Islands by man or his activities (among these, the synanthropical species), and which because of their great ecologic valence (eurytopes), and/or while not encountering opposition, extend themselves through numerous island biotopes – including the laurisilva – and settling in them. These members of our allochthonous fauna should be distinguished as Type X'. Livestock activities in the laurisilva domain, for example, permit the existence of species bound to domestic animals, as in the case of *Stomoxys calcitrans* L. (Muscidae).

In this section of 'introduced' forms we have included those (Type R) coming from neighboring biotopes that make sporadic but frequent incursions. We cite, for example, the solvid *Solva nigritibialis* Macq., whose larval stage developes on the succulent plants of the Inferior Zone and is relatively frequent in the laurisilva (Baez, pers. comm.).

Although it only gives us an empirical idea of little statistical value (see Leclercq 1964) it is interesting to note whether the species is rare (*r*), occasional (*o*), common (*c*), or abundant (*a*). The finding of a species may be due to totally fortuitous circumstances and it would be convenient to designate it as casual(*s*). If a not exclusive species presents its maximum abundance in the laurisilva it would be a typical species *in*, but not typical *of* the laurisilva. Finally we believe that it is of great interest to designate, by means of an asterisk (*) or two (**), whether endemic or Macaronesian (at least Madeira and the Canaries) forms, respectively, are being treated.

This proposed scheme will not resolve all of the cases that present themselves. Nature is not easily forced to comply with human concepts, especially when aspects that are so variable are being considered. Groups exist which are better fitted than others for doing chorologic or geonemic studies. Likewise, the proposed scheme may be used in some groups, while for the analysis of others we find ourselves obliged to make certain modifications in order to better adapt it to peculiarities of the group in question (feeding regime, phenology, local fidelity, etc.). Thus, this scheme does not pretend to be more than a guide.

Reflexions on the Ground-Beetle Fauna

In the present work we have wanted to comment – although not exhaustively – on a group that would be representative to a certain degree. We have selected the ground-beetles (Col., Caraboidea *sensu* Jeannel 1941–1942) because we have dedicated some years to their taxonomic study. Nevertheless, as we have not finished their revision, and many data have not been published, we have chosen to rely on the antecedent taxonomy, that established by authors who have worked on this group in the Archipelago: Wollaston, Bedel, Alluaud, Lindberg, Mateu, Colas, Jeannel, Bolivar y Pieltain, Israelson, etc.

The bibliographic study, that of the collections of the Museo Insular de Ciencias Naturales (Santa Cruz de Tenerife) and our own (La Laguna), as well as our contacts with some colleagues (J. M. Fernández, Dr. Th. Palm, Dr. Oromí, etc.), have permitted the confection of the following list. In it we have employed the symbols proposed above (page 357). The distribution of the forms in the Archipelago is also indicated by means of capital letters (**H** for Hierro, **G** for Gomera, **P** for La Palma, **T** for Tenerife, **C** for Gran Canaria, **F** for Fuerteventura and **L** for Lanzarote). The heavy-typed letters (e.g. *Demetrias atricapillus* (L.) **T**) mean a new record for said Islands, and that it is presently at the publishers or that it will be duly published in the near future.

FAUNISTIC LIST

Fam. CARABIDAE			
X′	*Campalita maderae* (F.)	(o)	**G** P T C F L
W′	*Carabus faustus* Brull.* s.l.	(r)	T
W	*Carabus interruptus* Dej.*	(c)	T
W?	*Carabus coarctatus* Brull.*		C
Fam. NEBRIIDAE			
W	*Leistus nubivagus* Woll.*		T
W	*Nebria dilatata* Dej.*		T
W?	*Nebria currax* Woll.*	(r)	C
Y	*Notiophilus geminatus* Dej.		H G **P** T C F L
Fam. APOTOMIDAE			
Y?	*Apotomus angusticollis* Müll.	(r)	T C
Fam. BROSCIDAE			
W′	*Broscus crassimargo* Woll.*	(c)	G
W	*Broscus rutilans* Woll.*		T
W?	*Broscus glaber* (Brull.)*		C

Fam. TRECHIDAE

Y	*Perileptus nigritulus* Woll.*		G T C
Y	*Thalassophilus whitei brevicornis* Jeann.*		G P T C
W	*Trechus detersus* Woll.*	(r)	F L
W′	*Trechus laureticola* Jeann.*		G
W′	*Trechus fortunatus* Jeann.*		T
W′	*Trechus uyttenboogaarti* Jeann.*		T
W	*Trechus felix* Jeann.* s.l.	(a)	T
Y	*Trechus flavocinctus flavocinctus* Jeann.*	(a)	T
Y	*Trechus flavocinctus gomerae* Jeann.*	(c)	H G
W?	*Trechus flavolimbatus* Woll.*	(a)	C
Y	*Trechus flavocircumdatus* Jeann.*	(c)	P
Y	*Trechus atlantidis* Paw.*		P
W′	*Anchotrechus punctipennis* Jeann.*		T
W′	*Anchotrechus cabrerai* Jeann.*		T
W′	*Limnastis gaudini gaudini* Jeann.*	(r)	T
W′	*Limnastis gaudini gomerensis* Franz.*	(r)	G
Y	*Eotachys bistriatus* (Dfts.)		G **C**
Y	*Tachyura parvula* (Dej.)		G P T C F L
Y	*Tachyura haemorrhoidalis* (Dej.)		G T C
Y	*Philochtus iricolor* Bed.		**T** C
Y	*Bembidion fortunatum* Woll.*	(t)	H G P T C L
Y	*Bembidion schmidti subcallosum* (Woll.)*	(t)	H G P T C
Y	*Bembidion inconspicuum* Woll.*	(r)	T
Y	*Bembidion c. crotchii* Woll.*	(r)	P
Y	*Ocydromus a. atlanticus* (Woll.)		H G P T C F L
Y	*Princidium laetum* (Brull.)		**H** **G** T **C** F L
Y?	*Asaphidion delatorrei* Uytt.*	(r)	C

Fam. HARPALIDAE

W?	*Nesarpalus fortunatus* (Woll.)*	(c)	C
Y	*Nesarpalus uyttenboogaarti* (Van Emden)*		C
Y	*Nesarpalus micans* (Woll.)*	(t)	G
Y	*Nesarpalus sanctae-crucis* (Woll.)*	(t)	T
Y	*Harpalus schaumii schaumii* Woll.*		H **G** P T
Y	*Harpalus schaumii grancanariensis* Van Emden*		C
X′	*Harpalus tenebrosus* Dej.		P **T** F L
Y	*Stenolophus teutonus* Schr.	(o)	G P T C F
W	*Bradycellus ventricosus* Woll.*		T
Y	*Acupalpus dorsalis* (F.)		G T C L

Fam. PTEROSTICHIDAE

R	*Orthomus barbarus berytensis* R. & S.	(o)	P T C F L
W′	*Paraeutrichopus harpaloides harpaloides* (Woll.)		H
W′	*Paraeutrichopus harpaloides pecoudi* Mat.*	(a)	G
W′	*Eutrichopus fernandezi* Mat.*	(a)	T
W	*Eutrichopus gonzalezi* Mat.*		T
W′	*Gomerina calathiformis* (Woll.)*		G
W?	*Gomerina nitidicollis* (H. Lind.)* [see page 380]	(r)	C
W′	*Pseudoplatyderus amblyops* C. Bol.*	(r)	G
Y	*Platyderus languidus alticola* (Woll.)*		T
W′	*Pseudomyas doramensis* Uytt.*	(r)	C
W	*Calathidius acuminatus* (Woll.)*		T
W′	*Calathidius sphodroides* (Woll.)*	(r)	T
W′	*Calathus rufocastaneus* Woll.*		T

W?	*Calathus rectus* Woll.*	(c)	T			
W	*Calathus freyi* Colas*		T			
W	*Calathus depressus* Brull.*	(a)	T			
W	*Calathus ciliatus* Woll.*	(r)	T			
W	*Calathus auctus* Woll.*		T			
W	*Calathus abacoides* Brull.*	(c)	T			
W′	*Calathus amplius* Esc.*		T			
W′	*Calathus carinatus* Brull.*	(r)	T			
W	*Calathus angustulus* Woll.*	(a)	T			
Y	*Calathus ascendens* Woll.*	(a)	T			
W	*Calathus cognatus* Woll.*	(c)	G			
W′	*Calathus laureticola* Woll.*	(c)	G			
W	*Calathus obliteratus* Woll.*	(c)	G			
W	*Calathus marcellae* Colas*		G			
W	*Calathus gomerensis* Colas*		G			
W′	*Calathus apicerugosus* H. Lind.*	(r)	G			
W′	*Calathus appendiculatus* Woll.*		C			
W	*Calathus canariensis* Har.*	(c)	C			
W?	*Calathus angularis* Brull.*	(a)	C			
Y	*Calathus spretus* Woll.*	(t)	H			
W	*Calathus simplicicollis simplicicollis* Woll.*	(r)	L			
W	*Calathus simplicicollis gonzalezi* Mat.*		F			
Y	*Licinopsis alternans* (Dej.)*		T			
W′	*Licinopsis bucheti* Alluaud*	(r)	G			
W′	*Licinopsis gaudini* Jeann.*	(r)	P			
W′	*Licinopsis picescens* (Woll.)*	(r)	H			
Y	*Amaroschema gaudini* Jeann.*		T			
X	*Laemosthenes complanatus* (Dej.)		P	T	**C**	**F**
Y	*Olistophus glabratus* Brull.*		H	G	T	C
Y	*Olistophus palmensis* Woll.*	(c)	P			
X′	*Anchus ruficornis* Gze.		T			
W′	*Agonum nicholsii* (Woll.)*		G	T?		
W′	*Agonum debile* (Woll.)*	(r)	C			
Y	*Agonum marginatum* (L.)		G	T	C	
X′	*Amara aenea* De Geer	(o)	P	T		
Y	*Zabrus laevigatus* Zimm.*		G	T	C	
Y	*Zabrus crassus* Dej.*		T			

Fam. LICINIDAE

W	*Zargus crotchianus* Woll.*		G

Fam. MASOREIDAE

Y	*Masoreus alticola* Woll.*		T

Fam. LEBIIDAE

X′	*Demetrias atricapillus* L.		T			
W′	*Cymindis velata* (Woll.)*	(a)	G			
W	*Cymindis amicta* (Woll.)*		G	C		
W?	*Cymindis cincta* (Woll.)*		C			
W	*Tarulus zargoides* (Woll.)*	(c)	T			
W	*Dicrodontus separandus* H. Lind.*		T			
W′	*Dicrodontus alluaudi* Mat.*	(r)	C			
W′	*Dicrodontus aptinoides* (Woll.)*		G			
W?	*Dromius angustus brittoni* Mat.*	(r)	F			
W′	*Dromius angustus plagipennis* (Woll.)*		H	G	T	C

W′	*Dromius strigifrons strigifrons* Woll.*	(r)	G
W′	*Dromius strigifrons tinerfensis* Mat.*		T
W′	*Dromius amoenus* Woll.*		T
Y	*Philorhizus l. longicollis* (Woll.)*		T
Y	*Philorhizus atlanticus atlanticus* Mat.*	(c)	C
Y	*Philorhizus atlanticus fortunatus* Mat.*		T P
W′	*Philorhizus parvicollis parvicollis* (Woll.)*	(r)	G
W?	*Philorhizus parvicollis fumatus* Mat.*	(r)	T
W	*Philorhizus elliptipennis elliptipennis* (Woll.)*	(a)	T C
W′	*Philorhizus elliptipennis bravoi* Mat.*		G
Y	*Syntomus foveatus inaequalis* (Woll.)*	(c)	H G P T C
W?	*Syntomus lanzarotensis* (Woll.)*		C F L
Y	*Metadromius pervenustus* (Woll.)*		G P T **C**
?	*Apristus hololeucus* H. Lind.*	(r)	C
W	*Microlestes negrita* Woll.		T **C**
Y	*Microlestes corticalis* Duf.		G T C F L
W′	*Microlestes gomerensis* H. Lind.*		G
Y	*Microlestes maurus* Sturm.		P T
X′	*Microlestes luctuosus* Hold.	(o)	T C

H	G	P	T	C	F	L
13	45	21	74	47	14	13

In this list we have considered the polytypic species subdivided, but only if they present inter-island subspecies (geographic island races). The cases of intra-island subspeciation are excluded, figuring the species s.l. as a unity. We believe that in a comparative faunistic study between islands, as in this case, subspecies has enough value to be considered as a unit, as a 'faunistic element' to which we shall refer as a 'form' throughout the text for more agility. Also, when we present faunistic considerations within the same island, the intra-island subspecies will have this same unit value, If a more profound study is to be made, then it would be fitting to give a distinct category to the polytypic and monotypic species.

STATISTICAL ANALYSIS

We begin by analyzing this list from the point of view of the carabids, comparing the laurisilva fauna with that of the total present in the Islands.

The laurisilva fauna contains 130 forms, being 70% of the total forms (186) present in the Archipelago (see table I). It is curious that this 70% found for the forms (= faunistic elements) repeats itself for the genera and species. Of the 76 genera present in the Archipelago, 53, and of the 171 species (that we know) 120, are found in the laurisilva. This high percentage explains itself in the function of the more or less marked hygrophylic character that this group presents. The humidity is probably the most decisive limiting factor for most of the carabids. Since the laurisilva is the most humid vegetation level in the Islands, it is not surprising that the better part of the carabid fauna is bound to it.

Table 1. Comparative Analysis of the Carabid Fauna of the Canary Archipelago with that of the Laurisilva

	Archipelago Fauna		Laurisilva Fauna		Laur/Arch. × 100
Number of Families	15		10		
Number of Genera	76		53		70%
endemic	10	13%	10	19 %	100%
Macaronesian	2	3%	2	4 %	100%
Number of species	171		120		70%
endemic	97	57%	92	77.5%	96%
Macaronesian	2	2%	2	2.5%	100%
Total Number of Faunistic Elements[1]	186		130		70%
Total Number of Endemic Elements[1]	120	65%	108	83%	90%

[1] The polytypic species are found broken down into their different subspecies, but only if geographic island races are being treated.

The fauna of the Archipelago contains 15 families of carabids (sensu Jeannel 1941–1942), and only 5 of these are not represented in the laurisilva. These are: Siagonidae, Cicindelidae, Scaritidae, Callistidae and Brachynidae. The first has only one species, probably introduced and settled in the Inferior Zone of some Islands (T, C y F).

In the Cicindelidae, only three specimens of *Cicindela nilotica* Dej. are known, having been collected in the sands of Maspalomas (C). Much discussion has been made as to wether this species is autochthonous or not, since its presence in the Canaries would mean a clear disjunction in its distribution area. We do not believe that this is a serious objection since many similar cases are known within the Canary entomological fauna, even within the carabids (*Apotomus angusticollis* Müll., *Crassodactylus punctipennis* Guèrin, etc.)

In the Scaritidae we have a *Scarites* and various *Dyschirius* bound to the littoral and sublittoral sands. The three species of Callistidae form a part of the riparian fauna of the lower zone, and the Brachynidae are represented by only one species, *Pheropsophus hispanicus* (Dej.), perhaps introduced.

Aside from the ecologic reasons (hygrophylia), the fact that most of the carabids are in the laurisilva is also due to evolutionary and palaeobiogeographic reasons.

The Canary Islands are about 30–35 million years old (Bravo, pers. comm.), and the laurisilva (a flora proper to the Tertiary) along with the pine woods, must constitute one of the oldest island environments. Thus it is logical that, apart from being one of the richest faunal layers, its level of endemism would be very high in function of this antiquity. On one hand we have the palaeoendemisms, forms that disappeared on the continent but that have persisted in the Islands bound to environments more or less constant throughout time, in an almost perfect orthogenetic evolution. They are forms frequently marked by the presence of archaic or ultraevolved characteristics. On the other hand we have the neo-endemisms, or forms that reached the Archipelago and have differentiated themselves under the effects of insularity sensu lato, showing a manifest divergent evolution in various cases.

In this process, a great number of species can originate from a few initial forms. Zimmerman (1948, taken from Franz 1970) for example, estimates that the 5000 species of the insect fauna of Hawaii have been formed from some 250 stock forms by extreme splitting.

From this it can be deduced that it is of great interest to observe the level of endemicity of the carabid fauna and its representation in the laurisilva. Above all we consider the endemic genera, although the legitimacy of this and other supraspecific categories has been much argued by various authors as to their subjectivity. In this respect we would like to attract attention to the opinion given by Alston & Turner (1963) in a treatise on systematic biochemistry: «What is often overlooked here is that the subjectiveness is in applying terminology; the objectiveness of the category under consideration, from a biological point of view, is real» (taken from Leclercq 1964).

The Canary carabid fauna consists of 10 endemic genera, all of them in the laurisilva: *Anchotrechus*, *Gomerina*, *Pseudomyas*, *Pseudoplatyderus*, *Eutrichopus*, *Paraeutrichopus*, *Calathidius*, *Licinopsis*, *Amaroschema* and *Dicodontus*. Actually only 7 of these are exclusive to the laurisilva, but it is very probable that in the beginning all of them pertained to it. The genus *Dicrodontus* is the only one that has a species totally absent from the laurisilva, *D. brunneus* (Dej.), endemic to Las Cañadas (T), but this is a species that must have originated recently because Las Cañadas is only about 200,000 years old (Bravo, pers. comm.). In *Gomerina* and *Licinopsis* are Type Y species, that probably originated in the laurisilva, but have extended their distribution to other biotopes. The two Macaronesian genera (*Zargus* and *Nesarpalus* sensu Puel 1836) are also bound to the laurisilva, at least partially in *Nesarpalus*.

Of 97 endemic species, 92 (96%) are found in the laurisilva, but this percentage is reduced somewhat, to 90%, if we consider the total endemic forms. As will be seen below, 76 forms are exclusive endemisms of the laurisilva, which implies about 2/5 of the total fauna.

We should note that the numbers referring to the fauna of the Archipelago, although corrected, do not have to be considered with extreme rigor. Nevertheless the proportions are extremely high and indicate to us

Fig. 6. The Anaga Massif, Tenerife (seen from Pico del Inglés at an altitude of 1,000 m), which has the richest flora of laurisilva. Photo A. Machado.

Table 2. Quantitative analysis according to character, endemicity and distribution of forms in the different families (*sensu* Jeannel, 1941–1942).

Families	W′/W′*	W/W*	Y/Y*	R/R*	X′	?/?*	Total	% of 130/% of each total
CARABIDAE	1/1	2/2			1		4/3	3/75
NEBRIIDAE		3/3	1/0				4/3	4/75
APOTOMIDAE			1/0				1/0	0.8/0
BROSCIDAE	1/1	2/2					3/3	2.3/100
TRECHIDAE	7/7	3/3	17/11				27/21	20.7/77.7
HARPALIDAE		2/2	7/5		1		10/7	7.7/70
PTEROSTICHIDAE	18/18	18/18	10/9	1/0	3		50/45	38.5/90
LICINIDAE		1/1					1/1	0.8/100
MASOREIDAE			1/1				1/1	0.8/100
LEBIIDAE	10/10	9/8	7/5		2	1/1	29/24	22.3/82.7
Total	37/37	40/39	44/31	1/0	7	1/1	130/108	
% of 130/% of each total	28.5/100	30.8/97.5	33.8/70.5	0.8/0	5.4	0.8/100		

that practically all of the endemic carabid fauna is found concentrated in the laurisilva.

In Table I we have cited 2 Macaronesian species. These are *Thalassophilus whitei* Woll. s.l. with the typical form in Madeira, and the ssp. *brevicornis* Jeann. in the Canaries, and *Philorhizus longicollis* (Woll.) s.l. with 2 subspecies in the Canaries (see page 378) and the ssp. *vieirai* Mat. in Madeira.

The number of Macaronesian species (in this case, common to Madeira and the Canaries) is really very small, but this has its explanation.

If the distinct Macaronesian Archipelagos really received a similar colonization in the past, as appears from botanical deductions[5] (source of the biogeographic concept of Macaronesia), in zoology these affinities at the specific level have been lost almost completely under the incidence of time and insularity, and if an interrelation persists, it must be looked for at generic or population level.

We abstain from treating these interesting Macaronesian biogeographic and evolutionary aspects here, considering that they demand a separate study that we hope to do some day.

In Table II a more detailed analysis of the laurisilva carabid fauna, attending to the character and endemicity of the forms and their distribution in the different families is made. 93.1% (= W′ + W + Y) of the forms are autochthonous, which indicates that a very 'pure' fauna is being treated, having few introduced forms (6.2%). The proportion of W′, W and Y varies greatly according to the peculiarities of each Island (if they present another forest formation type, or according to the regression level of the laurisilva), but in the general computation give 28.5%, 30.8% and 33.8% respectively.

It is interesting to note that 100% of the W′ forms are endemic (see the interior circle of the Faunistic Diagram on page 383). Only one case of a non endemic W is found, *Microlestes negrita* Woll. (perhaps introduced??), 97.5% of the remaining W being endemic. As could be expected, the percentage of endemisms in Y is reduced (70.5%).

The most representative family of the laurisilva is the Pterostichidae (38.5% of the total), followed by the Lebiidae (22.3%) and the Trechidae (20.7%). The same order kept with respect to the percentage of endemisms within each Family (90%, 83% and 78%, respectively), if we do not consider the Families with little representation. None the less, the Broscidae should be noted, having 3 species in the Archipelago, all of which are endemic and exclusive (?) to the laurisilva. The Lebiidae (the Genera *Dromius* and *Philorhizus*) are even more promising, giving further field studies.

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[5] After Dansereau (1968), of the 68 vegetal species of the laurel forest, no less than 64.7% are endemic to Macaronesia, at least at the specific level.

THE INTRODUCED SPECIES

We have disregarded certain species from the faunistic list. Knowing their habits and the localities where they were found, makes one think that they are fortuitous introductions, which is not rare in these Islands where seaports are abundant and international commerce is intensive.

Such cases are: *Elaphrus riparius* L. («A dead and damaged specimen, ... in the neighbourhood of a shed with imported material for packing bananas», Uyttenboogaart 1930 p. 211), *Perigona nigriceps* Dej. and *Carterus cordatus* Dej. The introduced forms considered in the list are (except one R, from the Inferior Zone) adventitious species, some of recent introduction as *Demetrias atricapillus* (Machado 1975), and others known since the time of the earlier authors (e.g., Wollaston, in 1865). Three of them, *Amara aenea*, *Anchus ruficornis* and *Laemosthenes complanatus* (synanthropic) are known as European introductions in North America (Lindroth 1960). The carabid fauna of laurisilva lacks any Type X forms (perhaps *Microlestes luctuosus*); these are found more often in the phytofagous groups (in hemipterans, for example).

Only the Type-specimen of *Apristus hololeucus* is known. From the locality (Valle de Tejeda), very little can be deduced about its possible adhesion or faunistic character, but we have included it in the list as ? based on the considerations that will be made in treating the Island of Gran Canaria.

CARABID FAUNA OR FAUNULA?

Is it correct to apply the term 'fauna' in a strict sense to the carabids of the laurisilva? Mac Arthur & Wilson (1967) defines a Fauna as «the animal species of a particular region», but indicates that «a fauna can also be somewhat more precisely defined as a set of species in a region isolated enough so that the set is more or less peculiar to it, as opposed to faunula (= a set of animal species found in a relatively small, poorly isolated region and not peculiar to it)». After this definition, and taking into account the above mentioned numbers, we hope that no doubt will remain as to the legitimacy of the carabid fauna of the laurisilva. On the concept of 'region' in faunistics, see Leclercq (1964, p. 372).

ETHOLOGY

The greater part of the carabid beetles are predators and hunt at night. Nevertheless numerous species or groups exist that present a more varied food regimen (e.g., several Harpalidae), also eating grain, shoots, etc. There are also species (*Cicindela*, *Notiophilus*, *Demetrias*, etc.) that hunt by day, but these cases are very infrequent. Generally, the carabids lead a nocturnal life, remaining hidden during the day in very diverse places.

In order to collect these beetles one must know their habits. In the Islands, these habits are usually the same as that of their parents on the continent, but some variations are observed.

Only two endogeous species are known: *Limnastis gaudini* s.l., wingless and eyeless, present in the soils of the laurisilva of Teno (T) and Gomera (ssp. *gomerensis*), and rather rare. Even more rare is *Pseudoplatyderus amblyops*, of which only the type is known, seemingly lost (Mateu in litt.), and which was collected, according to the author of the genus and the species in breaking up an enormous trunk in an advanced state of decomposition. The degeneration of its eyes is notable, being reduced to a small nucleus of depigmented cornea facets, the pigment having emigrated and is now placed irregularly around the eyes, useless for vision (Bolivar y Pieltain 1940).

The greater part of the laurisilva carabids are epiedaphic and we find them hidden under stones and fallen trunks, or if their size is not very large, among the leaf-litter.

In the zones that are little or not altered (?), where the vegetal layer reaches its maximum, the sotoforest is deep shade (Rübel 1909, measured 43 BE within the forest of Agua García in Tenerife, compared to 1,000 BE in the exterior; taken from Rübel 1930). Among the leaf-litter the darkness is more manifest, and many small carabids (e.g., *Trechus*) show activity also in the daylight hours.

In this layer we find the best represented and most typical genera of the laurisilva: *Trechus* and *Calathus*, and also *Broscus*, *Carabus*, *Zargus*, *Cymindis*, *Nesarpalus*, *Bradycellus*, etc. and most of the Pterostichidae. It is frequent that the same stone is shared as a refuge by representatives of very different genera. Colonies of *Calathus* are also frequently found (often mixed, of two or three species), and those of *Olistophus*, *Cymindis* and *Eutrichopus* are not rare. The relative frequency with which this phenomenon is observed, above all in *Calathus*, makes one think that a truly social phenomenon is being presented, rather than crowding behaviour motivated by humidity in periods of relative dryness.

It is frequent that the borders of the roads form almost vertical banks in the laurisilva (see fig. 7). When the earth is loose or the rock has many crevices, it is easy to dig with a spade and find diverse arthropods (arachnids, tisanurids, myriapods, etc.) with insects predominating, above all the carabid beetles. The *Carabus*, *Nebria*, etc. use this exceptional refuge, and the *Calathus* also appear here forming colonies.

A great number of laurisilva carabids having somewhat less hygrophilic tendencies exist, being found in more exposed spots, such as the leaf-litter or beneath the stones on roadsides, clearings or in the mixed forest that exhibits zones, in relation, somewhat more xerophitic. Among these forms (most of which are Type Y′) we should cite: *Zabrus*, *Nesarpalus*, *Cymindis (cincta* and *amicta)*, *Leistus nubivagus*, *Masoreus alticola*, etc. This last species shows a clear divergence from the habits of its fellows

Fig. 7. Eroded path-way crossing the laurel forest of Llano de los Viejos, Anaga/ Tenerife. Of special interest is the small vertical earth bank at right. Photo A. Macado.

which are proper to unplowed land areas or coastal brackish zones.

The arboricolous forms are par excellence *Dromius* and *Philorhizus*, being found under bark, between epiphytic mosses, in the semidry foliage of fallen branches, etc. They are rather rare among leaf-litter.

In the bark we also find some *Calathus* (e.g., *C. laureticola*) and *Trechus* (*T. felix*, *T. laureticola*, etc.), among others which are less common, but we believe that this is, in the most cases, only a refuge niche.

The loose and hanging bark of *Erica scoparia* constitutes a unique habitat, housing the richest bark-fauna. In addition to its proper fauna, numerous terricolous species climb through it (*Calathus angustulus*, abundant, *C. auctus*, *Calathidius*, *Eutrichopus*, etc.). Sifting at *Erica scoparia* ('tejo' in Spanish) is a gratifying expirience for any entomologists.

The dead leaves which remain attached to the branches of some plants (several *Aeonium* – see fig. 8 – and *Sonchus*) mantain a microclimate that

Fig. 8. Epiphytic *Aeonium cuneatum* Webb & Berthelot on *Laurus azorica* (Seub.) Franco trunck, a refuge of certain carabids. Photo J. M. Fernández.

is made use of by many insects. Carabids use it as a simple refuge or source of moisture. From here we have frequently obtained *Dicrodontus separandus*, *Tarulus zargoides*, *Calathus rectus*, *C. freyi*, etc.

The riparian fauna

(The term 'riparian' is used in the meaning of the French's 'ripicole'.) We have separated the riparian fauna in order to present some characters worthy of comment and analysis in greater detail.

In the past, numerous streams must have existed that maintained their flow throughout the year. Intensive water use and lumbering has reduced these streams to only two, the one known as 'El Rio' that cuts through the El Cedro Forest of La Gomera (fig. 9), and that which runs through the Iguana ravine at Anaga (T), though even this sometimes dries out. It

Fig. 9. 'El Río' at the Cedro forest, Gomera, which is the only remaining stream of laurisilva. Photo: J. M. Fernández.

follows that the general riparian fauna would have dwindled greatly since those earlier times.

The laurisilva still contains a good representation of riparian carabids, not only found in these two streams but also in wet rocky spots and small springs. Most of the riparian carabids are represented by Bembidiitae *(Bembidion, Philochtus, Ocydromus, Princidium, Asaphidion, Tachyura* and *Eotachys)*. They are all Type Y forms, present in aquatic media both in the lower and upper regions, justified not only by their high hydrophile level but also by their great flight capacity. Nevertheless, some are typical in the laurisilva, as *B. fortunatum*. The most abundant form is *B. schmidti subcallosum*, also frequent in the wet rocky spots.

Some cases of anomalous behaviour are also found. *Philochtus iricolor* is a species from the seacoast of Western Europe and the Western Mediterranean; it has been found only in the inland waters of the Canaries (300 and 700 m.a.s.l.) On the other hand, *Ocydromus atlanticus*, which Franz (1970) includes as a xerophilic faunistic element, shows a most curious chorologic phenomenon. In the Eastern Islands (F and L) it is found in its xerophilic environment and with its normal light colouration, but in the Western Canaries (H, G, P, T and C) its colouration is totally dark blue and it is of typical riparian habit, bound to the waters of the Inferior Zone (pond borders, for example) and the streams of the Mountain or Middle Zone. The blue individuals have been differentiated as var. *phobon* Netol. Perhaps it is a true subspecies and not just a simply variety.

Further riparian forms are *Thalassophilus whitei* (in spite of its name, it is not a seashore form), *Perileptus nigritulus*, *Acupalpus dorsalis*, *Stenolophus teutonus* (o), *Agonum marginatum* (o) and *Apotomus angusticollis* (see page 398). Only three (?) exclusively riparian carabids are encountered in the corresponding laurisilva environments. May be that in the past there existed more. Actually we have: *Agonum nichollsii* (fig. 10, B) very common in El Rio (fig. 9) and of which only one doubtful reference exists for Tenerife; *A. debile* (fig. 10, A), from Gran Canaria, a species that we are not familiar with in natura and perhaps now extinct; and *Anchotrechus punctipennis*, of the Anaga Massif (T), for which some old references state its localization under stones in forests zones rich in leaf mold, but we have only collected it in typical riparian media (The other species of this endemic genus, *A. cabrerai*, coexists in Anaga, living in leaf-litter). The *Nebria* are sometimes found near springs or small water-falls, but it is wrong to consider them exclusive of this environments. We shall return to the riparian fauna in dealing with the Island of Tenerife, but would like to take note of a very interesting fact.

Of the 44 Type Y forms present in the laurisilva, 11 are not endemic, and of these 11, 10 belong to the riparian fauna. The riparic environment is probably the least specific habitat of the laurisilva, and with the exception of two cases *(Notiophilus geminatus* and *Microlestes negrita)*, all of the autochthonous non-endemic fauna of the laurisilva is bound to it.

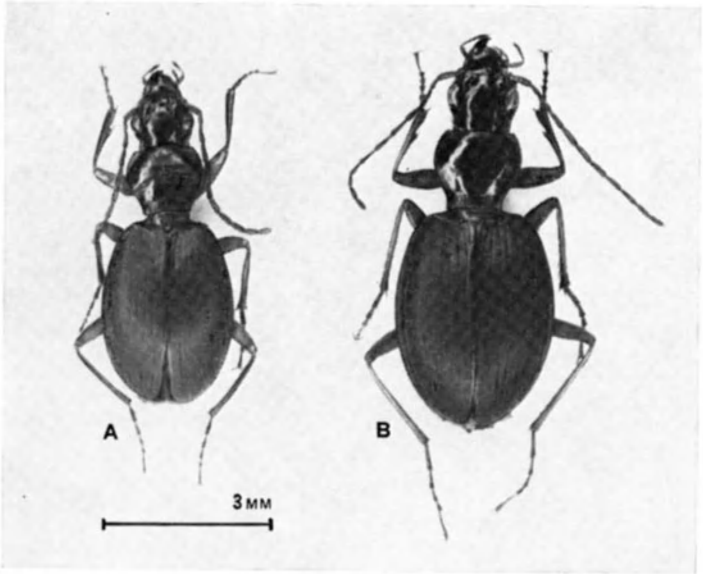


Fig. 10. A. *Agonum debile* (Woll.), B. *Agonum nichollsii* (Woll.), Photo A. Machado.

The three (?) exclusively riparian forms of the laurisilva (Type W′) must depend on some factor other than water; probably on reduced light conditions (photophobic). We have always found them in extremely dark places (streams and springs).

PHENOLOGY

Data on the phenology of the Canary carabids does not exist. As observed in dates of collection and our own impressions, we doubt that there are many cases in which the distinct development stages present a seasonal sinchronization such as occurs in Europe, where the seasons are much more marked and rigorous. The laurisilva is perennial, and given the generally uniform climatic conditions encountered in the Islands, the changes are very mild. The leaf-litter, the foliage and the cloud layer (NE-trade wind) prevent the floor of the laurel forest from drying out. However if partial drying occurs, sufficient humid places remain to permit the continued development of the organisms. Most of the carabids can be found throughout the entire year, which makes one think that population overlapping occurs if the species is not a very long-lived one, not rare for the carabid beetles (for example, *Carabus* lives at least two years, Lindroth 1974). Thus we do not believe that many species exist in which the larvae estivate. The only notable variation observed is a qualitative and quantitative faunal increase in the humid periods, but this does not signify a typical seasonal synchronization, as we have stated above, since the precipitation pattern is rather variable. Last year (1974), for example, the laurisilva exhibited its 'summer' aspect in January (dry paths, ant activity, etc.) and the rains began to fall in late March.

Amaroschema gaudini, for example, appears after the first rains bring forth grass shoots and mosses on the road margins or exposed zones. It is collected beneath little stones in these areas.

ECOLOGY

It is not possible to assess the faunistic differences among the diverse laurisilva subtypes without a deeper understanding of the environmental and biocenotic conditions of a given area. Empirically, it is observed that the fauna is richest in the first three Kämmer subtypes (see page 355). The epiphyte-rich laurel forest (fig. 11), which is a climax formation, presents

Fig. 11. Aspect of the epiphyte-rich laurel forest at the Anaga Massif (Tenerife). Photo J. M. Fernandéz.

the maxima of carabid endemics; we have already mentioned the *Erica scoparia*-shrub forest by dealing with the bark-fauna of *Erica* trees. The 'normal' laurel forest is probably the richest in variety (abundant Type Y forms), while the fauna decreases considerably in the cliff-forest and in the drier marginal zones of the laurel forests. It is an ecological fact that marginal biotopes contain a relatively low diversity of species.

The mixed forest is rather rich in carabids, without noticing the 'edge effect' (Dajoz 1974) while the other component, the pine woods, are very poor in carabid fauna (possessing almost no exclusive forms). Thus the mixed forest has less species diversity as compared to the true laurel forest.

Concerning the carabids, the fauna of the former is typically that of the laurisilva and should simply be considered as another subtype of this formation (laurisilva as undergrowth in the pine woods). This does not mean that its inclusion as a subtype of Kämmer's *Pinus canariensis*-forests is wrong. In other zoological groups the picture may be very different.

The fayal-brezal which results from the cutting of the laurisilva presents a fauna that depends on the forest character. The product of the first cut is usually a forest of *Myrica*, *Erica*, *Ilex* and some noble species. Its successive exploitation leads to a *Myrica-Erica* forest, then to a *Erica-Myrica* bushland, *Erica* bushland, ending in a *Cistus* brake, pasture or bedrock. Soil is lost by erosion, the relative humidity decreases notably, and the accumulation of *Erica arborea* (Spanish 'brezo') bristles all contribute to the progressive faunal decrease as the cutting continues.

The fayal-brezal is rather interesting in some zones where no manifestation of the pure laurisilva remains because that is where the surviving fauna finds refuge. On the other hand if true laurel forest exist in the vicinity, the carabids must have emigrated there, while only few are found in the fayal-brezal, although it may not have been cut for a long time. From the carabid point of view, the fayal-brezal can be considered as a degenerate laurisilva.

The absence of carabids in apparently healthy zones of laurisilva, floristically speaking, is usually due to the activity known as 'rastrillados' (= rakings) which consists in the removal of the leaf-litter for agricultural use. This is catastrophic for the ground-dwelling carabids because even if they withdraw to their refuges, they are now left with almost no food: snails, worms, microarthropods, etc, that are normally abundant in this biotope.

THE HISTORIC-INDICATOR FORMS

In a strict synecological sense, the indicator forms would be some of those that we have designated as W′ (37 in all), although in the carabids, because of their mobility, their quality as an indicator is not as good as that in other biological groups (amphipods, for example). The Type W forms would not fit the ecological concept of indicator, but they are highly useful, for being found outside the forest zones, they do indicate to us the former existence of laurisilva in said zone. In reality, these forms should more correctly be called historic-indicators.

Concerning *Syntomus foveatus inaequalis*, Wollaston (1864, p. 16) commented: «It is eminently a sylvan insect, the few specimens which I have observed in comparatively open spots being probably the remains of a fauna which has more or less died-out since the timber has been destroyed.» This is not a typical (exclusive) laurisilva form as it also inhabits the pine woods, but as a typical sylvan insect it is the only form that lives in the five Western Islands.

Knowledge of the distribution of the W forms is very useful when one wishes to establish the potential limits of the laurisilva. A serious study of this aspect should be attempted and not only from a botanical standpoint as is usually the case. The laurisilva as an ecosystem is the result of a plurality of interacting components. Therefore its study should thus be interdisciplinary, taking into account the botany, zoology, climatology, edaphology, geology, etc. of the system. In addition to these natural sciences, historical sources can provide data of very valuable interest (c.f. Dansereau 1968, p. 232).

CONSIDERATIONS OF SINGLE ISLANDS

Until now we have treated the carabid fauna of the laurisilva as a whole, without considering the personality of each island.

The differences at this level are considerable, not only because of the distinct geographic situation, climatology, topography, etc., but also due to the different states of preservation of the laurisilva in each of them, and because of certain palaeozoogeographic factors that will be duly commented on.

To discuss each of the Islands to the required extent would vastly augment the subject matter in this work. We thus shall limit ourselves to the inclusion of a faunistic diagram in which the distinct faunistic composition of the carabid fauna of each Island may be observed, and cite only those general aspects as well as those singular or interesting due to their newness.

Hierro

This is the smallest (278 km^2) of the Canary Islands, the westernmost, and until recently, the least accessable. A few laurel forest remains (e.g., Jinamar) are seen on the cliff sides of the Valley of El Golfo (fig. 12). The fayal-brezal formations are more abundant, and sometimes persist in the zones of the center and NE. Mixed forests and some magnificent pine woods exist. A small forest of enormous *Myrica* trees (Spanish 'faya'),

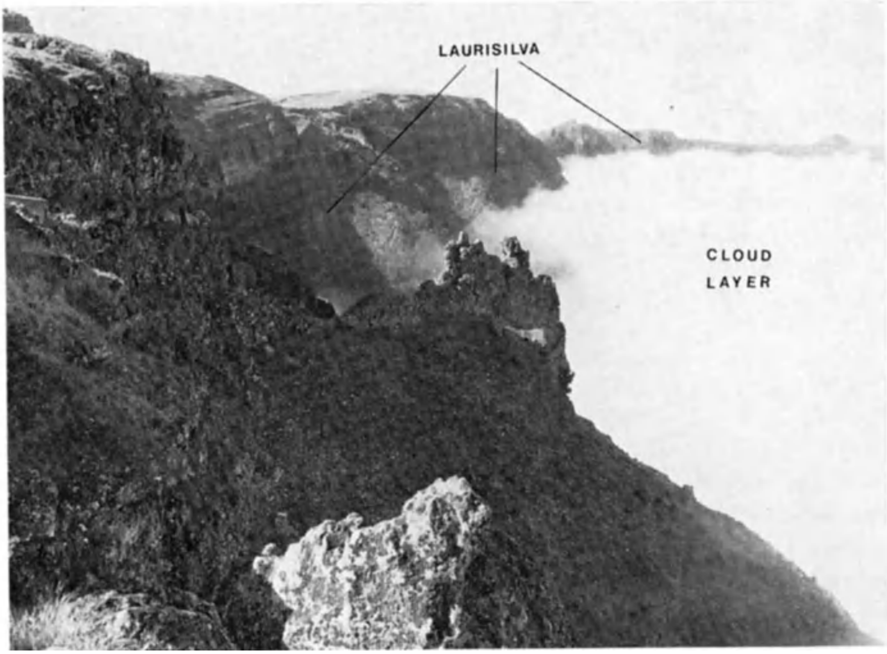


Fig. 12. Characteristic cloud layer at El Golfo (Hierro), touching the cliffs occupied by remains of laurisilva. Photo Baeza.

called El Fayal, is found on the southern slope, with an almost complete absence of brezos. We do not know if it is a natural formation, but it is the only one of its kind.

The total number of laurisilva carabid beetles is very low (13), which may be connected to the Island's small size or to the above mentioned isolation, and it is probable that it is the least studied Island in this respect. To this must be added the difficulty encountered in collecting specimens. A great part of the zones where the laurel forest persists is ground covered by a thick layer of small pebbles and stones (sometimes more than 1 m thick) on which the fallen leaves rest. The carabids take refuge among these stones and escape faster than one can dig for them.

Only 2 Type W′ species are known proper to this Island: *Licinopsis picescens* y *Paraeutrichopus h. harpaloides*, both extremely rare. *Dromius angustus plagipennis* is also W′, but it is also present in Gomera, Tenerife and Gran Canaria. It is curious that *Philorhizus longicollis* s.l. that inhabits the laurisilva of Tenerife *(longicollis s.str.)* is present in Hierro (ssp. *ferranius* Mat.) but only being known from the pine woods. There is only one *Calathus*, *C. spretus*, which represents *C. ascendens* (Type Y) of Tenerife, inhabiting the pine woods and the laurisilva and being typical in the fayal-brezal. Also the only one *Trechus* known, *T. flavocinctus gomerae*, is Type Y.

Fig. 13. Licinopsis picescens (Woll.) endemic from Hierro (specimen loaned by Dr. H. Franz), 2 cm approx. Photo A. Machado.

The greater part of the carabid fauna of the Hierro laurisilva is Type Y, corresponding to forms which are not proper to the Island, (see the faunistic diagram). The greater affinity has it to the laurisilva fauna of Gomera, having *T. flavocinctus gomerae* and an endemic and monospecific genus *(Paraeutrichopus)* in common, along with their corresponding two vicariant subspecies.

N.B. After completing this study, Dr. H. Franz (Vienna) sent to us one specimen of *L. picescens* (fig. 13) and one of *P.h. harpaloides* captured in La Restinga (S-coast), locality where laurisilva does not exist nor seems ever to have existed. Nevertheless we believe that they are laurisilvan species, but if the locality is correct, then they would be not W′. Maybe they are simply a casual find or, perhaps, they have immigrated from a once-forested locality nearby.

Gomera

With its 380 km^2 and maximum altitude of 1,480 m, it is probably the Island that had the greatest proportion of its surface covered by laurisilva. Natural pine woods are lacking, and thus also mixed forest (*Pinus radiata* D.Don have recently been planted in great extentions of the upper parts of the Island). It is also the Island that has not experienced volcanic activity for the longest period of time (about two million years), which has a repercussion in the richness of its fauna. The last cone – trachytic – known as 'La Caldera', is located in the South and is of Quaternary age.

Gomera conserves magnificent laurel forests, that from a forest mass standpoint, are the best in Macaronesia (the qualitatively best laurisilva is to be found in the Anaga Massif – see fig. 6 –, in Tenerife). Some forests have been very slightly altered in comparison with other islands, which has logically influenced the purity of the fauna. With 45 laurisilva carabids, it occupies the third place in spite of its being the second smallest Island of the Archipelago. The richness of this fauna does not therefore appear to be connected to its surface area.

In this context we wish to call to mind a reference by Lindroth (1971, p. 68): «A study of the small Westman Islands showed a good correlation between the distribution of insects and plants but almost none between number of species (beetles) and distance from the main island. The area of an island, involving variety of habitat, as a rule, has apparently greater importance».

In our Islands, another factor (antiquity and vulcanism) establishes itself as highly influential in the richness of the fauna. This aspect will be noted in detail in treating the Island of Tenerife.

The Gomeran laurisilva shows the maximum percentage (51%) of exclusive forms (23) in relation to its proper fauna, surpassing even Tenerife. This is due in part to the great extent of the laurel forest in the Island and the absence of pine woods, thus the sylvan Y forms hardly exist. In turn, the greater part of the exclusive forms (W′ + W) are proper to the Island (which makes a general rule in the Archipelago), while the non-proper forms predominate in the non-exclusive autochthonous forms (Y), in turn present in two or more Islands. We should recall that all of the exclusive forms (except one, see page 367) are endemic. Thus, the laurisilva of each Island contains its particular forms.

Five endemic genera are present in the Gomera laurisilva, and one, monotypic, is exclusive to it, *Pseudoplatyderus*, which has been discussed above. (page 369) The genus *Gomerina* had been considered until recently as monotypic and proper to Gomera. We have been able to confirm that *Platyderus nitidicollis* H. Lind. of Gran Canaria is really a *Gomerina* (the new combination will be published shortly). Six *Calathus* are also notable in this small Island, compared with three in Gran Canaria which quadruples the former's surface area. Also found, among others, 2 *Trechus* (only one is proper), a *Broscus* (see fig. 26), a *Licinopsis*, a *Dicrodontus*, a *Nesarpalus*, 2 *Cymindis* (only one being proper), and as a unique case, an endemic *Microlestes*, *M. gomerensis*.

The riparian (see p. 372) and arboreal fauna is also well represented. If to this number of proper endemic forms, high percentage of palaeoendemisms and good representation in the three strata, we add the fact that Gomera is the only place where the genus *Zargus* (Macaronesian)

Fig. 14. Laurel forest at Raso de la Bruma (Gomera). The ground covered by ferns *(Pteris* and *Dryopteris)*. Photo A. Machado.

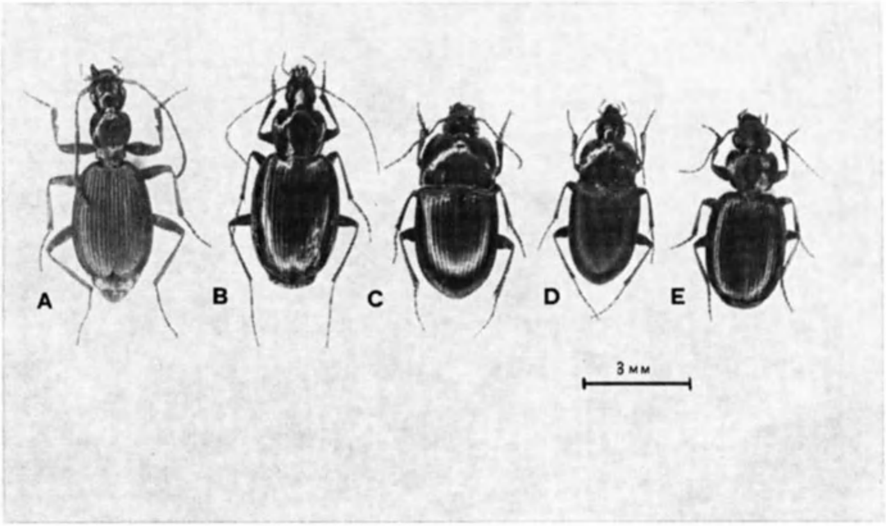


Fig. 15. Some endemisms from the Gomera laurisilva: **A**. *Dicrodontus aptinoides* (Woll.), **B**. *Zargus crotchianus* Woll., **C**. *Paraeutrichopus harpaloides* ssp. *pecoudi* Mat., **D**. *Gomerina calathiformis* (Woll.), **E**. *Cymindis velata* (Woll.). Photo A. Machado.

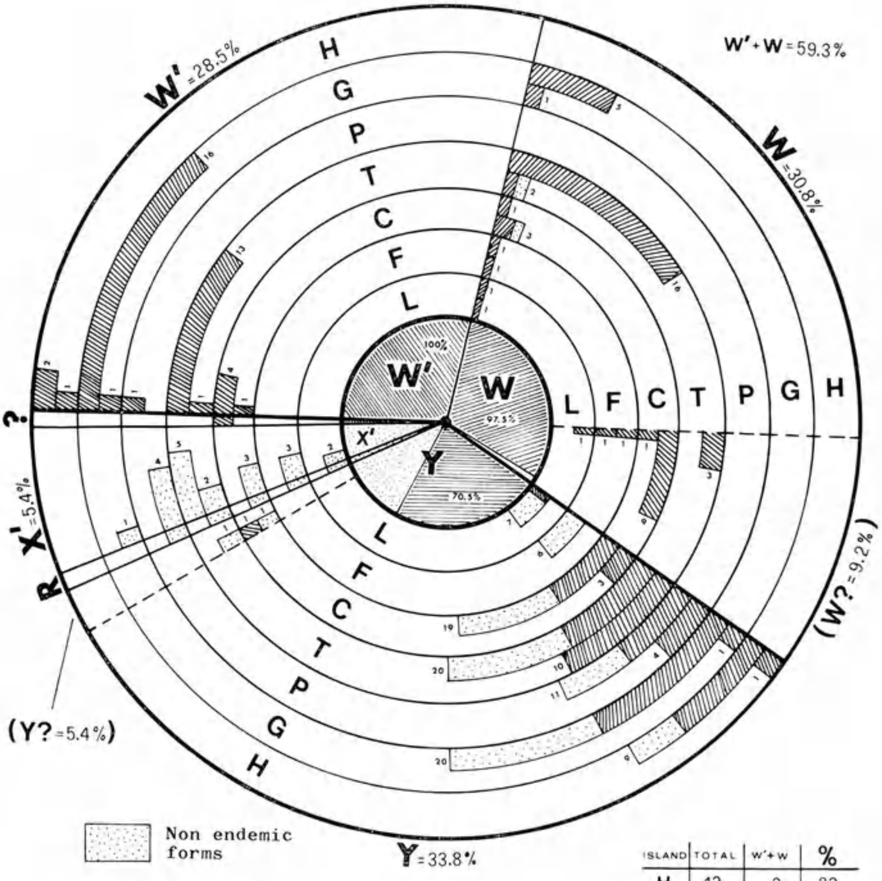
is found, this laurisilva fauna turns out to be one of the richest, most complete and oldest; only Tenerife excedes it in this regard. The absence of *Carabus*, *Nebria* and *Bradycellus* (or *Leistus*) in this Island is curious.

It has multiple affinities. Principally it shares an endemic genus with Hierro (see p. 379): *Dicrodontus* and *Broscus* with Tenerife and Gran Canaria (fig. 31); *Gomerina* and a species of *Cymindis*, alone with Gran Canaria; alone with Tenerife, *Limnastis gaudini*, though not an endemic genus (Jeannel 1929, admits the possibility), as a hypogeous and very specialized form, has a great zoogeographic value. The genus *Licinopsis* is the only one that unites the four westernmost Islands (H, G, P and T), see fig. 16.

Thus, Gomera presents a rich and most interesting laurisilva carabid fauna, very complete and the purest. For this reason it is urgent that it be studied more thoroughly before man's interference upsets yet further the forest structure.

La Palma

Surface area 730 km^2, maximum altitude 2,423 m. The extention of the laurisilva was very considerable (fig. 18 A), and a great part of the laurel forests still exist but as secondary formations. The accessable zones have been continually cut resulting in a wider extention of the fayal-brezal,



▨ Non endemic forms

▨ Endemic forms

FIG.A

'Proper' forms: They appear only in this island in the Archipelago.

'Non proper' forms: They appear also in other islands from the Archipelago.

ISLAND	TOTAL	W'+W	%
H	13	3	23
G	45	23	51
P	21	1	5
T	74	35	47
C	47	18	38
F	14	4	28
L	13	3	23

Faunistic diagram. (Showing the composition of the Ground-Beetle fauna of the Canary Islands laurisilva). The inner circle shows the character and endemicity of the global fauna (the percentages shown outside the diagram). The outer circle is subdivided into seven circular bands, each of which corresponds to an island (represented by their initials); it is also divided (fig. A) into an external and an internal portion. For the key to the symbols see page 357.

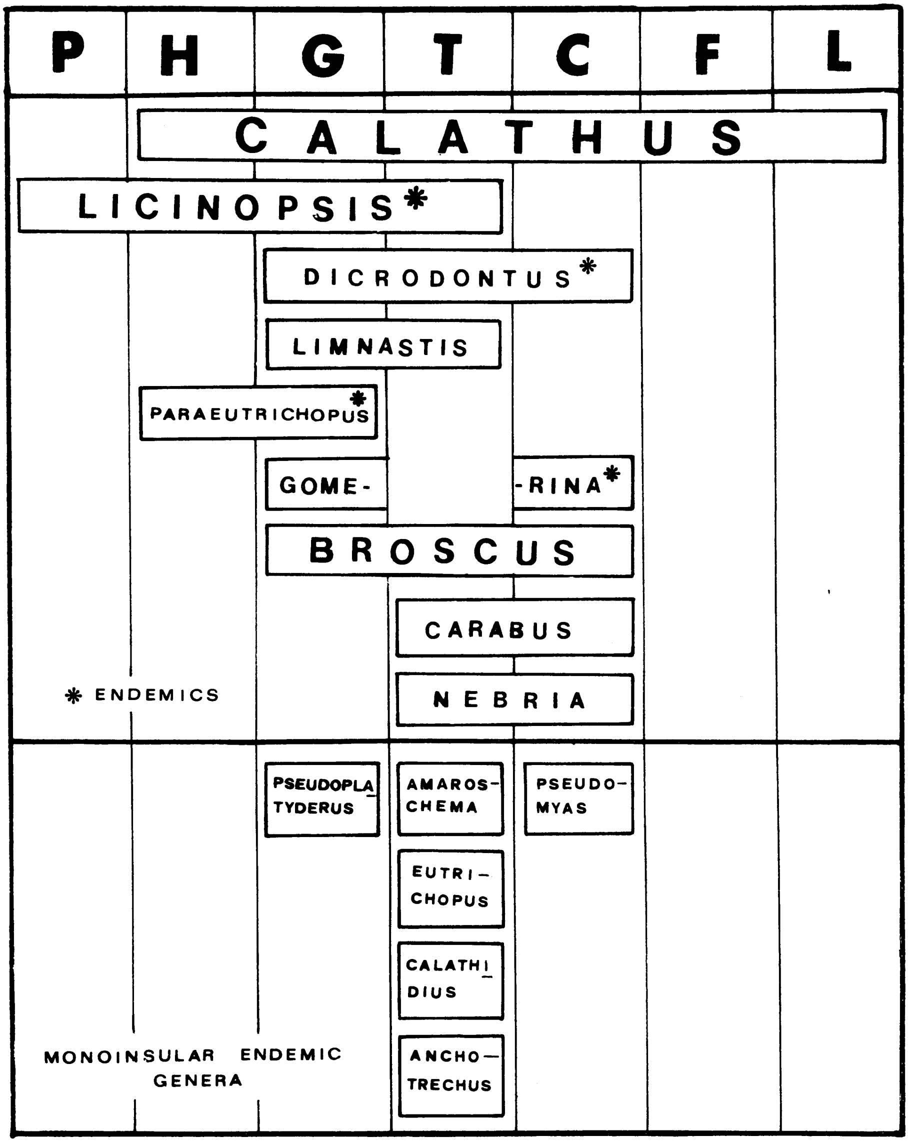


Fig. 16. Inter-island distribution of some genera of faunistic interest.

the greatest of the Archipelago. It is actually the Island most affectated by lumbering.

This Island is a true enigma from a laurisilva carabid standpoint. A quick glance at the faunistic diagram reveals that an exclusive fauna is practically lacking. Only one extremely rare species is known, *Licinopsis gaudini*. This represents but 5% of the autochthonous fauna of the laurisilva, an astonishing datum if we compare it with those of the other Islands. Even the total fauna (21) is relatively small, above all if we consider the enormous extent of the laurisilva. Only in the Y forms do we find some proper endemics. It is the second Island after Tenerife (7 X′ forms) in presenting the most adventitious forms (4).

The faunistic discordance is certainly surprising if we do a brief analysis (fig. 16). The *Calathus*, by far the most typical representatives of the laurisilva (including at least Madeira), are totally absent. Gomera has 6, Grăn Canaria 3, Hierro and the Eastern Islands 1 and Tenerife 11. Also absent are all of the endemic genera excluding *Licinopsis*, and the rest of the typical laurisilva genera, such as *Broscus*, *Nebria*, *Cymindis*, *Nesarpalus*, etc. Only *Trechus* is represented by two species, but they are shared with the pine woods, the formation that attains a splendid development (the mixed forests are very extensive). The only carabid that we can consider typical in laurisilva is *Olistophus palmensis*, also surprising in that the rest of the Western Islands share another species, *O. glabratus*.

The riparian fauna is very poor contrasting with the humidity present on the Island, termed 'la Isla Verde' (= Green Island). The absence of *Agonum* is also strange. The only fauna somewhat represented is the arboreal, *Dromius* and *Philorhizus*, unfortunately very little studied, but they do promise to allow some faunistic interrelations to be established (We are presently studying some of this material). Only *Ph. atlanticus fortunatus* is presently known to be shared with teneriffan laurisilva. *Ph. lindbergi* Mat. has been collected until now only from pine woods.

Apart from this connection with Tenerife, the carabid fauna of the La Palma laurisilva is seen as closed and very poor. We do not know the reasons for this phenomenon. From a botanical and edaphologic point of view if the La Palma laurisilva presents certain peculiarities (c.f. Lohmeyer & Trautmann 1970, Voggenreiter 1974), these are not so marked as to justify such a manifest discordance. We thought of a possible shortcoming in the entomological field-work that, although more frequent than in Hierro for example, could have been very superficial.

This brought us to undertake a personal expedition, because of the present study, to La Palma in order to visit the best conserved zones of laurisilva and set pit falls in them. This little campaign (see fig. 18 B) took place between February 1–9, 1975. We wish to express our gratitude to Dr. Oromí, who helped set the falls, as well as to the botanist specialist of La Palma, Arnoldo Santos, who aided us to withdraw the pit falls and had previously marked the most interesting zones on a map. We employed molasses mixed with beer as bait. The lack of time, and the orography only permitted us to set 150 pit falls (the project called for 500). We did not catch any new forms, only the *Trechus* and *Olistophus* that where already known. *Licinopsis gaudini* was not caught, in itself rather rare, but this could be due to a secondary factor. In El Cubo de la Galga (fig. 17), locality where this endemism is known (Palm, in litt.),

Fig. 17. Interior view of the laurel forest at Cubo de La Galga (La Palma). At the left, see a channel deviating the water of this particular ravine. Photo A. Machado.

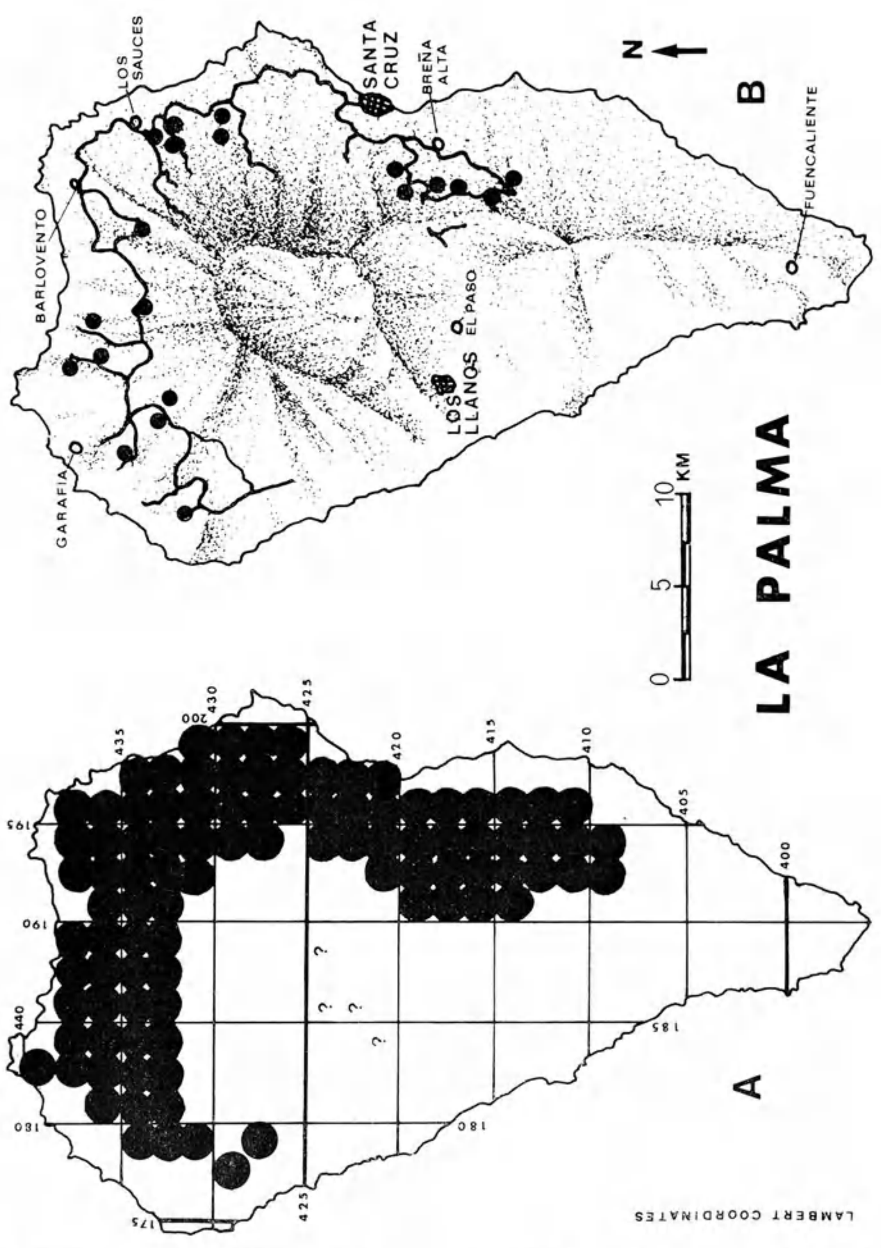


Fig. 18. **A.** The potential natural distribution area of the *Pruno-Lauretea* class in La Palma (based on Voggenreiter, 1974). **B.** Itinerary of the La Palma Expedition February-1975. Black circles: Zones where pit falls were placed.

the plague of rats which has been scourging La Palma was very intense, as could be deduced from the great quantity of tree branches with dried tips. Many pit falls were gnawed, drunk dry, or found with insect remains.

Are the typical representatives of the laurisilva absent from La Palma? Does *Calathus* 'palmensis' exist? The negative value of the expedition undertaken is not absolute, though it remains to be a datum to take into account. If this faunistic poverty is certain, we believe that it could be due to the relative geologic youth of the surface of the Island of La Palma.

Tenerife

This is the largest (2,058 km²) and highest (Teide Peak, 3,715 m) Island. The potential extent of the laurisilva was treated above (fig. 5), and it is important to keep it in mind because the forests have suffered very marked regression. It is difficult to believe today, for example, that the laurisilva reached to below La Laguna (La Cuesta) at the time of the Conquista (XV cent.). Viera y Clavijo (1774) cites that the first contact that the Spanish had with the 'guanches' (the aborigines of the Islands) took place in the midst of a forest between Santa Cruz and La Laguna.

Some of the few present-day manifestations are conserved in an acceptable state (though very endangered), and house the richest laurisilva flora (Anaga Massif). Since the times of Wollaston (second half of the XIX century), some of the magnificent laurel forests have disappeared, such as that of Agua García often cited by this author (today only a few remains are seen, fig. 2) and the typical locality of not a few of the endemic forms of our fauna. Another forest, already absent in those times, was that of Agua Guillén[6], where Alluaud made very interesting collections of the surviving fauna.

The abundant references of the earlier authors permit a partial reconstruction of the distribution of the carabid fauna of the laurisilva.

Apart from the 74 laurisilva carabids, with 35 exclusive forms and a very high percentage of proper forms, the interesting of Tenerife is the presence of distinct zones and types of distribution for the carabid fauna of the laurisilva. In fig. 20 we have marked these areas with letters, even though we have not wished to place the limits, always difficult to draw.

Zone A. – Includes the Anaga Massif (Aguirre and Las Mercedes forests, Vueltas de Taganana, Barranco de Iguana, etc.); its limit would fall approximately at the 'Laguna belt' (c.f. Gangwere *et al.* 1972)

Zone B. – Includes the forest of Agua García, La Esperanza, Las Lagunetas (mixed forest), etc.

Zone C. – Including Agua Mansa, Barranco de San Antonio, Monte de Icod, as far as Erjos.

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[6] «Station 125, Tenerife, 8 Juin 1889. Source et ruisseau de Agua Guillen, emplacement d'une ancienne foret de Lauriers, aujourd'hui détruite, 750 m» (Alluaud, 1891).

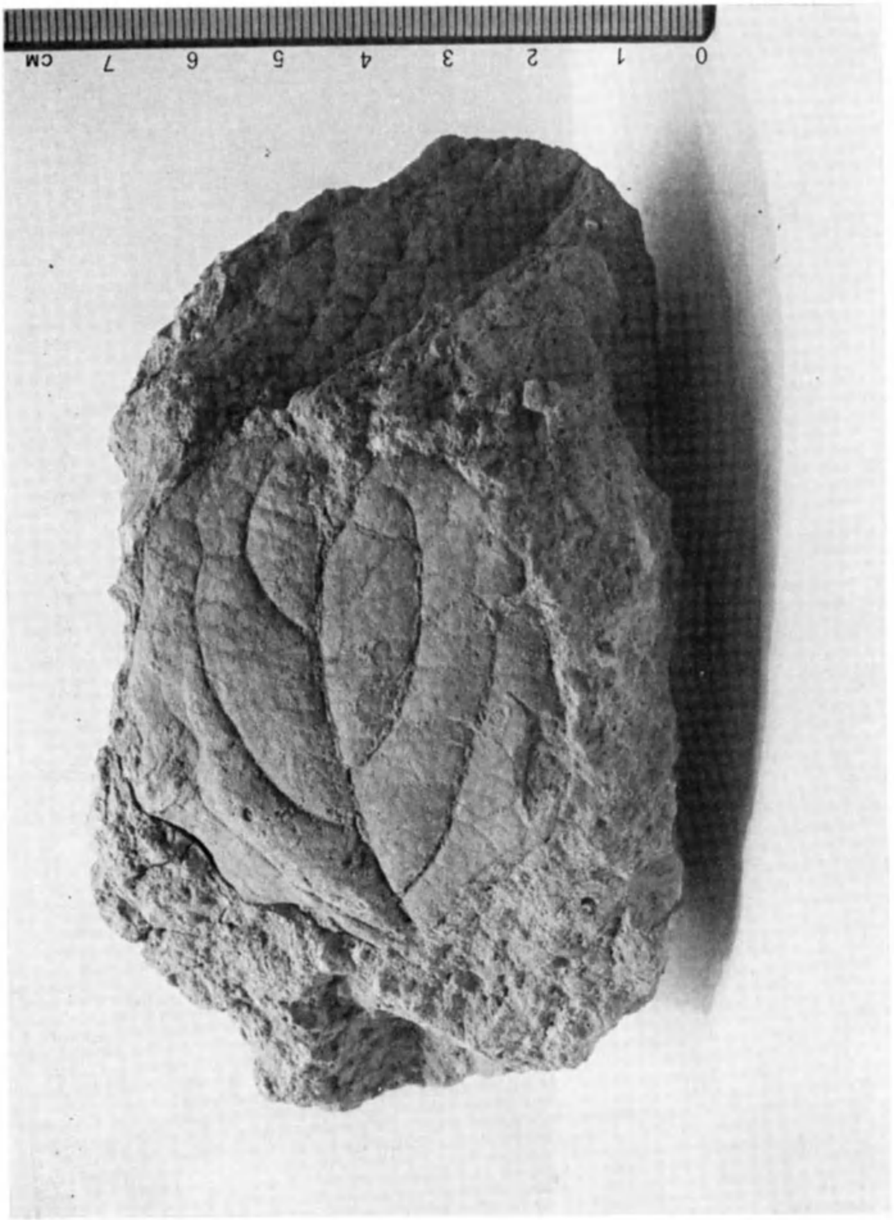

Fig. 19. Print of a leaf of laurisilva (*Viburnum*?) in puzolanic material, found at 30 m depth in the Lomo de Mena (950 m a.s.l.), at Güimar, Tenerife, and for which Dr. T. Bravo estimates an age of 400,000–600,000 years. Photo A. Machado.

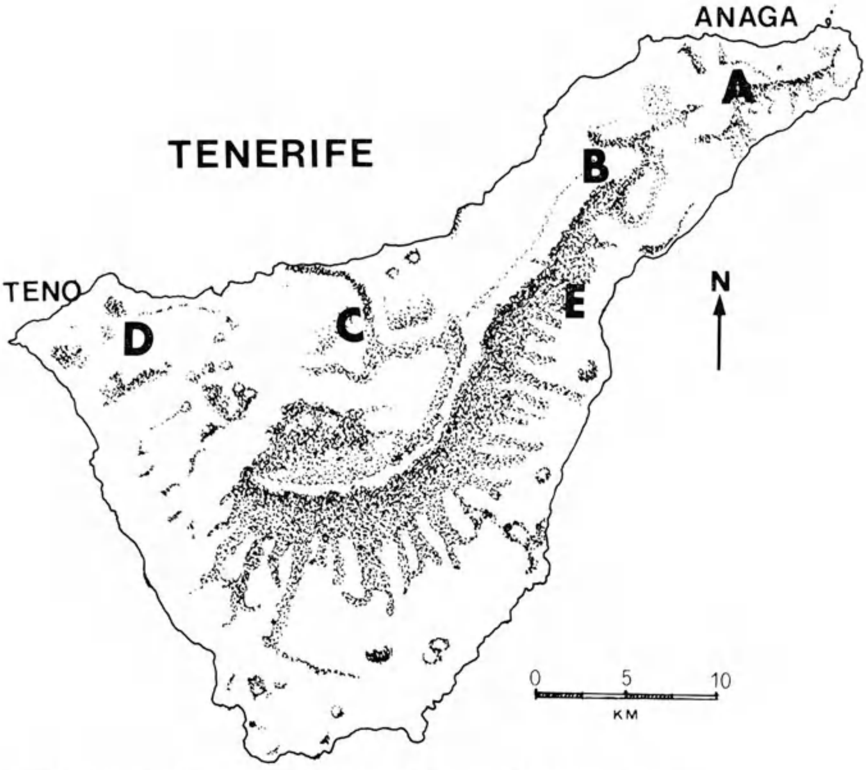

Fig. 20. Distributional areas of the laurisilva carabids in Tenerife.

Zone D. – Includes the Teno Massif, with Los Silos forest (= Monte del Agua). It appears that the limit between C and D lies in the Monte de Erjos, where we have been able to observe some mixtures.

Zone E. – Including the laurisilva of the S-E side (Monte de Agua Guillén†, Barrancos de Güimar, Adeje, etc.). Unfortunately, very few references are available from this zones.

The distribution types are indicated according to the zones that they include, for example, A-B, or D-C-B, and we group them into three categories according to whether they are or are not found in the Anaga Massif and/or in the Monte de Los Silos (Teno Massif). The importance of this two regions lies in that they correspond to the principal zones of outcrops of the 'Old Series' (c.f. Fuster *et al.* 1968). As we shall see, this has a very interesting evolutionary repercussion.

1. Present in Anaga, absent in Monte de los Silos (Teno).

Distribution Type	
A	*Trechus uyttenboogaarti* *Trechus felix felix* *Trechus felix faustus* *Trechus felix tahodiensis*

	Anchotrechus punctipennis
	Anchotrechus cabrerai
	Eutrichopus fernandezi
Distribution Type A-B	*Carabus faustus* 'typus faustus' (today only A)
	Bradycellus ventricosus
	Calathus carinatus (today only A)
Distribution Type A-B-C	*Carabus interruptus* (today extending also to upper regions)
	Nebria dilatata
	Leistus nubivagus
	Calathus rufocastaneus
	Calathus auctus
	Dromius amoenus

2. Present in Anaga and Monte de los Silos (Teno)

Distribution Type A-B-C-D	*Calathidius acuminatus*
	Calathidius sphodroides
	Calathus depressus
	Calathus abacoides
	Calathus angustulus
	Tarulus zargoides
	Dicrodontus separandus
	Philorhizus e. elliptipennis
	Philorhizus l. longicollis
Distribution Type A-B-C-D-E	*Trechus f. flavocinctus* (also in Adeje)
	Calathus ascendens
	Calathus rectus
	Calathus freyi

3. Present in Monte de los Silos (Teno), absent in Anaga.

Distribution Type D	*Carabus faustus* 'typus cabrerae'
	Trechus fortunatus
	Limnastis g. gaudini
	Calathus amplius
Distribution Type D-C-B	*Broscus rutilans*
	Trechus felix antonii
	Eutrichopus gonzalezi
	Calathus ciliatus

In this list it is noted how the Anaga laurisilva and that of Teno have a peculiar yet similar carabid fauna. It is interesting to observe the phenomenon present in various forms, which extend from Teno toward the East, but not reaching Anaga (D-C-B), while others, starting at Anaga, go toward the West without penetrating Teno (A-B-C). The western limit establishes itself, as we have stated, in Erjos.

A faunistic irradiation is observed, starting at both nuclei, Anaga and Teno. Some authors (Simony 1892, Evers 1964) believe that Tenerife formed itself from three separate islands: Anaga, Teno and Adeje (where the Old Series is also exposed, see fig. 21), and that they were united by later eruptions that ended in the formation of the Teide Peak. Bravo and his collaborators (pers. comm.), in subsurface geological investigations,

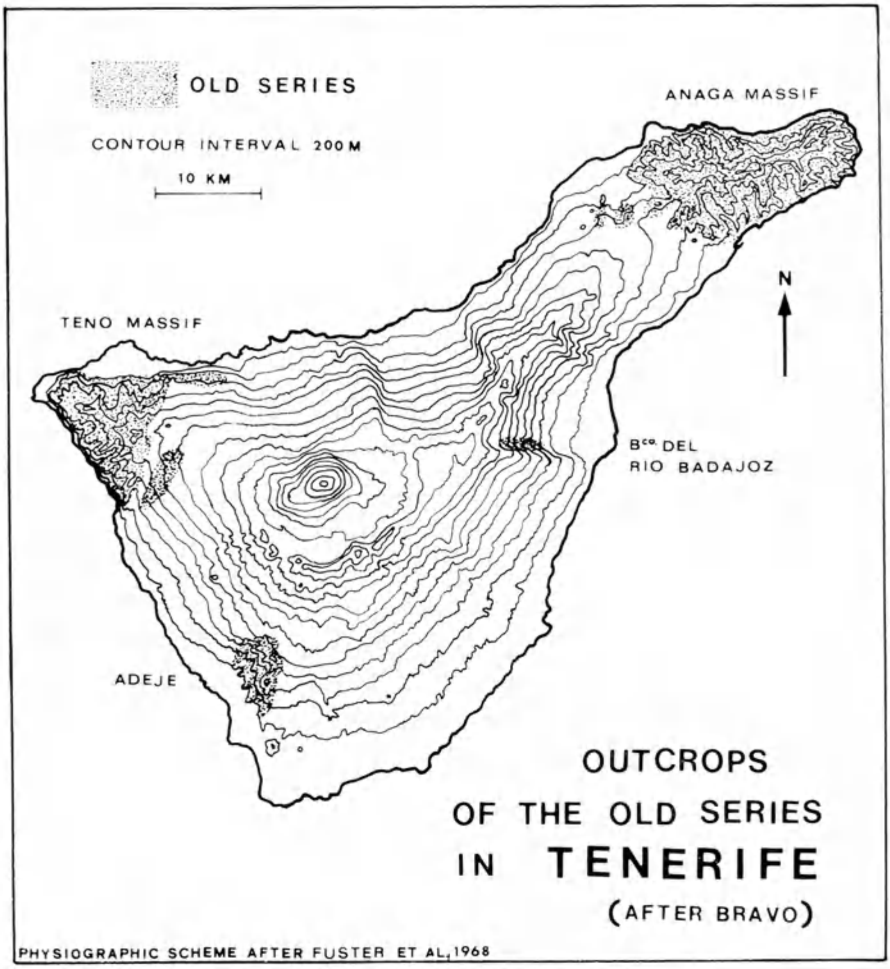

Fig. 21.

have found the Old Series in various zones of the Island, which implies a continuity of this material among the three principal outcropping points; for this reason, the above mentioned hypothesis seem little valid. Besides, other minor zones of outcropping of the Old Series have been localized, after having been exposed through erosion. (fig. 21).

However, if these massifs of Teno and Anaga were not as affected by the later eruptions that sterilized the intermediate regions (see fig. 19), they conserved the existing fauna that afterward, throughout time, colonized the new zones as they transformed themselves and made themselves more adaptable. Thus it is that the laurisilva of Teno and Anaga may be considered as 'faunistic irradiation centers', at least in respect to

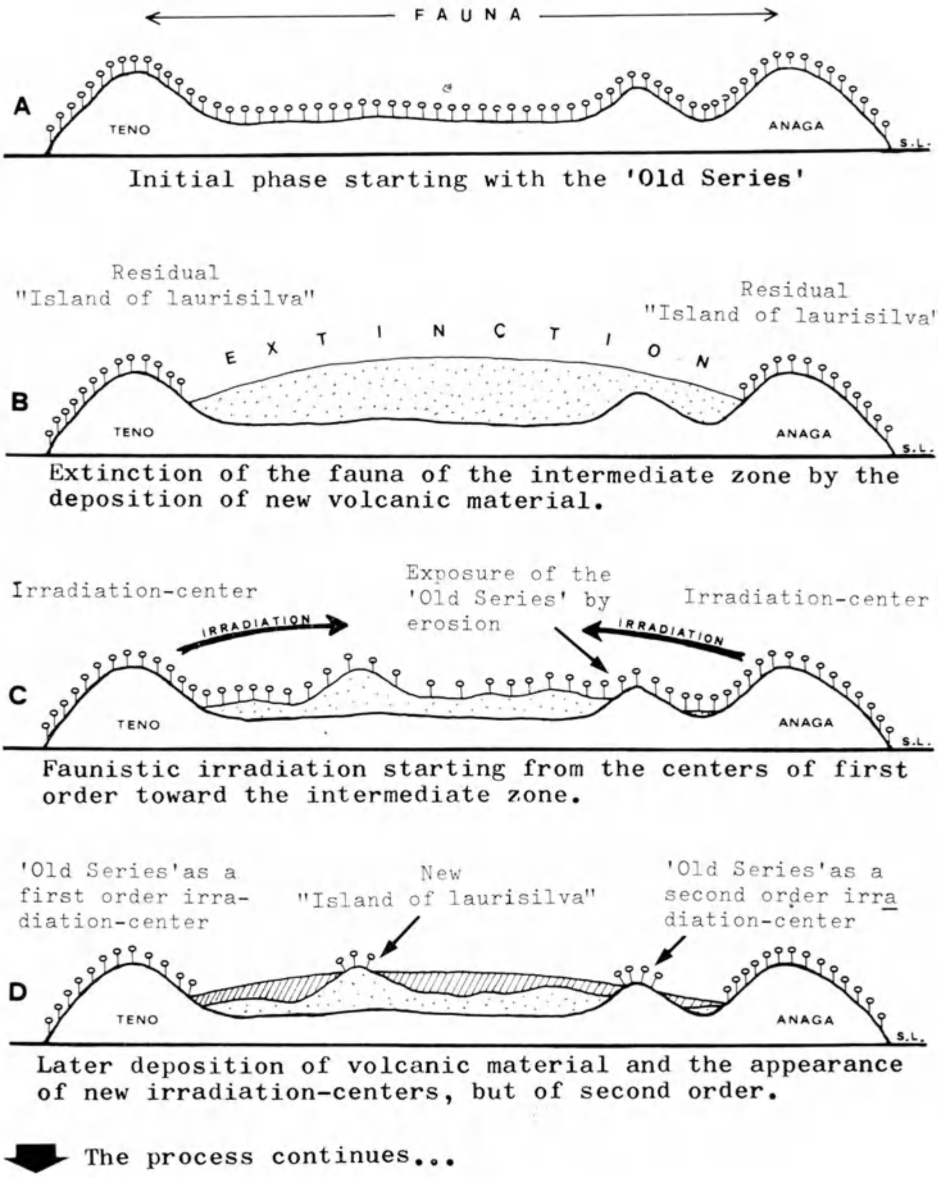

Fig. 22. Edification process of the Island and its importance in the evolution of the fauna.

the carabids. This could be one explanation of the 'laurisilva islands' mentioned in the introduction. See fig. 22.

The hypothesis would also be valid for the other principal outcrop zone of the Old Series (in Adeje) where today only few relicts of laurisilva remain, and to a minor degree, for the secondary type exposures. It should also have a repercussion in the other groups bound to the laurisilva.

In the numerical distribution area map of Voggenreiter (fig. 4) it is observed that the squares having the highest number of members of the syntaxonomic class *Pruno-Lauretea* correspond in a general way to the outcrop zones of the Old Series (*c.f.* Fuster *et al.* 1968, p. 11). Thus it seems that botany supports this hypothesis, even though it is necessary to undertake studies that are more concrete and localized in this sense, and investigate the other zones where material of this old type are found.

During this period of isolation, some forms must have become differentiated (*Eutrichopus*, *Calathidius*, *Carabus*, etc.), which later could or could not have extended their range.

Thus, from an ancestral *Eutrichopus*, *E. fernandezi* in Anaga and *E. gonzalezi* in Teno were formed. The former has remained limited to its locality of origin, while the latter extended toward the East, until reaching La Esperanza (Zone B). Nevertheless, it is more abundant in its place of origin, in the Monte de Los Silos, at Teno. Another clear example of the Anaga-Teno disjunctional distribution is that observed in the genus

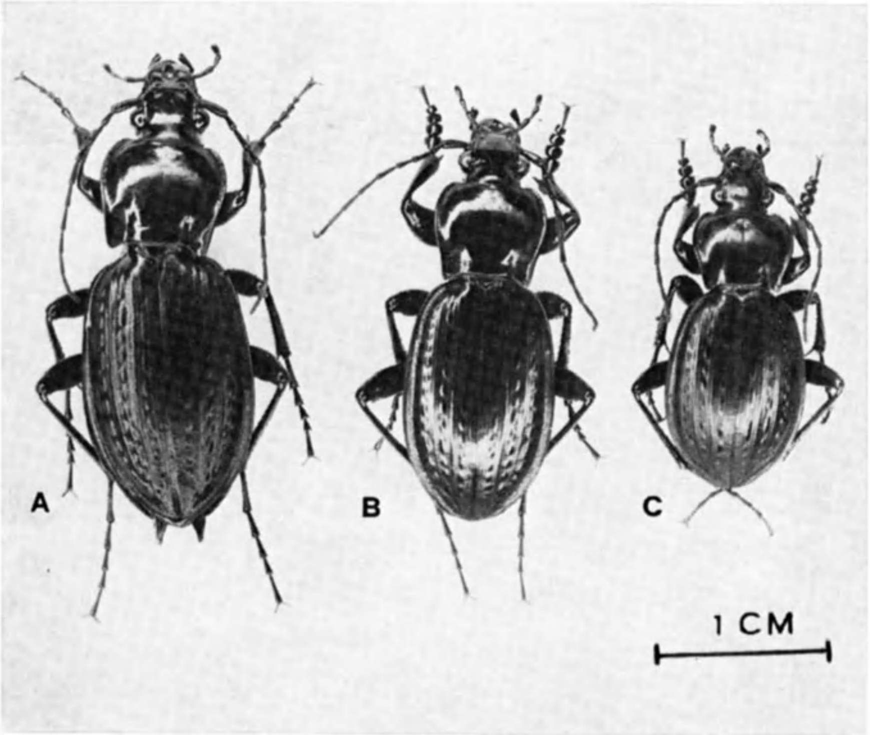

Fig. 23. The genus *Carabus* in Tenerife: **A.** *C. faustus* 'typus faustus', **B.** *C. faustus* 'typus cabrerai', **C.** *C. interruptus* Dej. Photo A. Machado.

Carabus (fig. 23), even though the differentiation level reached is debated among taxonomists. We shall thus speak of a *Carabus faustus* s.l., distinguishing the Teno population as 'typus cabrerai', and that of Anaga as 'typus faustus', without assignating any fixed taxonomic position.

The 'typus cabrerai' is found limited to the Monte de Los Silos, while the 'typus faustus' reached to Agua García (Zone B), where it became extinct. Today it appears only to live in the Anaga Massif, where it is rather rare (it is a coveted entomological 'treasure', which has partly caused its regression). One citation (?) for *Carabus faustus* (Cabrera leg., taken from Lagar 1965) is known from the locality of 'El Río', on the SE side. Dr. A. Cabrera probably referred to the 'Barranco del Río Badajoz' where an outcrop of secondary type of the Old Series is to be found, and that, according to scheme of fig. 22, could be considered as a 'laurisilva island', and even as a second order irradiation-center.

A second (or third) *Carabus*, *C. interruptus* (fig. 23, C), exists in Tenerife, being much more abundant and having certain tendencies to expand its range to upper zones. This is probably a second line which arrived later.

The two *Calathidius* (fig. 24) – an endemic genus of the Tenerife laurisilva – must have evolved in the same way, but we don't know which

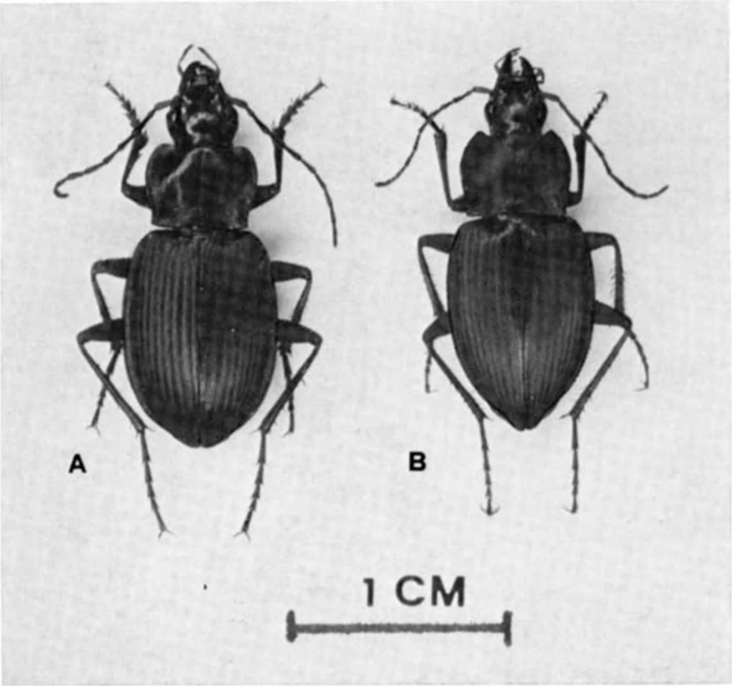

Fig. 24. The Teneriffan endemic genus *Calathidius* Putz.: **A.** *C. sphodroides* (Woll.), **B.** *C. acuminatus* (Woll.). Photo: A. Machado.

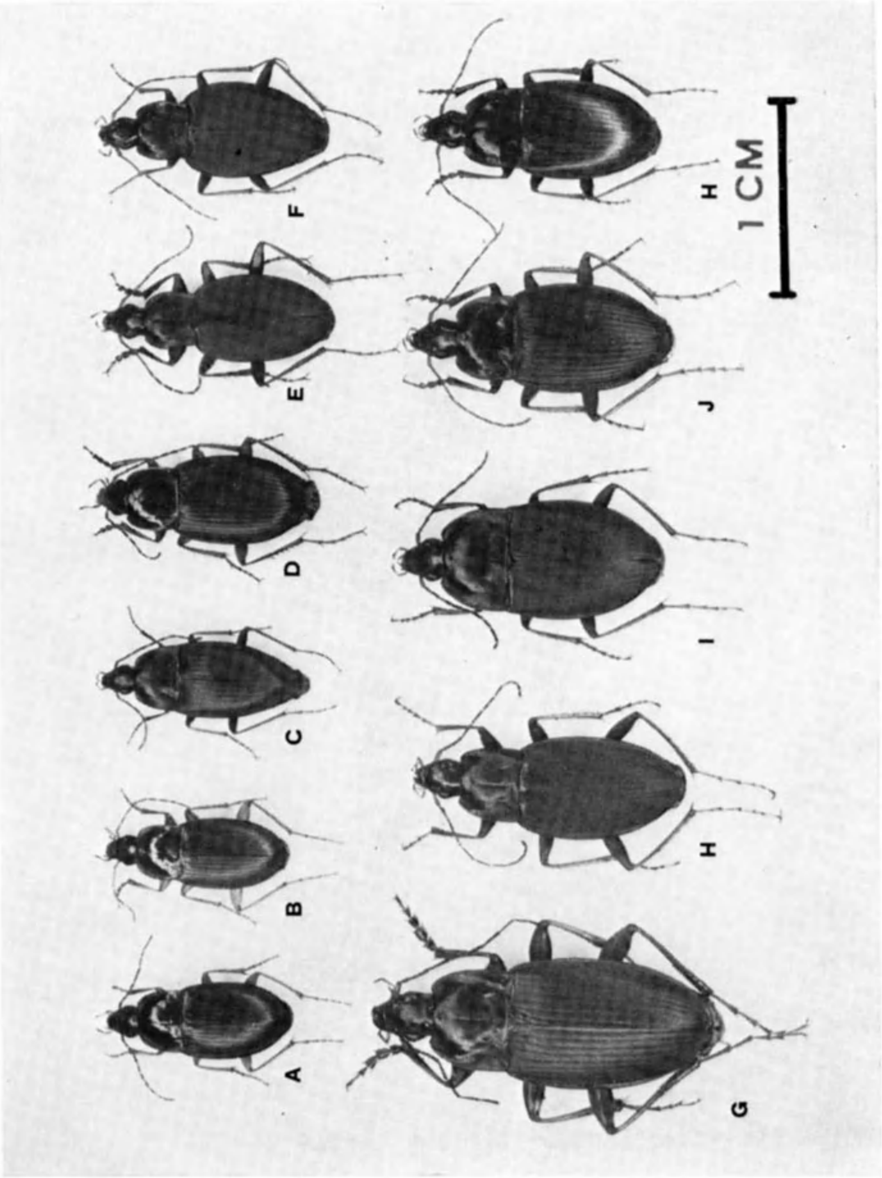

Fig. 25. The genus *Calathus* in Tenerife: **A**. *C. freyi* Colas, **B**. *C. rectus* Woll., **C**. *C. abacoides* Brullé., **D**. *C. ascendens* Woll., **E**. *C. angustulus* Woll., **F**. *C. carinatus* Brullé, **G**. *C. ciliatus* Woll., **H**. *C. auctus* Woll., **I**. *C. amplius* Esc., **J**. *C. rufocastaneus* Woll., **K**. *C. depressus* Brullé. Photo A. Machado.

species originated on which side, now that their expansion has overlapped their distribution areas. *C. acuminatus* is common, while *C. sphodroides* is very rare. This seems to be the known effect of many sympatries of this sort.

The most surprising sympatry presents itself in the genus *Calathus* (fig. 25), which in Anaga alone includes 9 species. Two more exist (11 in all), the *C. amplius* known only from Teno, and *C. ciliatus*, which does not pass the Zone B. According to Mateu (1957), the *Calathus* appear to group themselves in pairs, but to explain the evolution of the eleven forms supposing past Teno-Anaga disjunctions would be very difficult. One might think of isolations in other 'island'-type old sectors, or even in successive invasions as mentioned in the introduction. The most probable would be an interaction of these two processes.

Hypothetically, vulcanism seems to have played a very important role in the evolution of certain groups that show a high fidelity.

In other cases, the isolation factors seem to obey the orography and distinct ecologic conditions. At Anaga we have three subspecies of *Trechus felix*, about which their author comments: «Chaque forêt de Lauriers possède sa race particulière du *T. felix* et il est même très extraordinaire de trouver à quelques kilomètres de distance les unes des autres

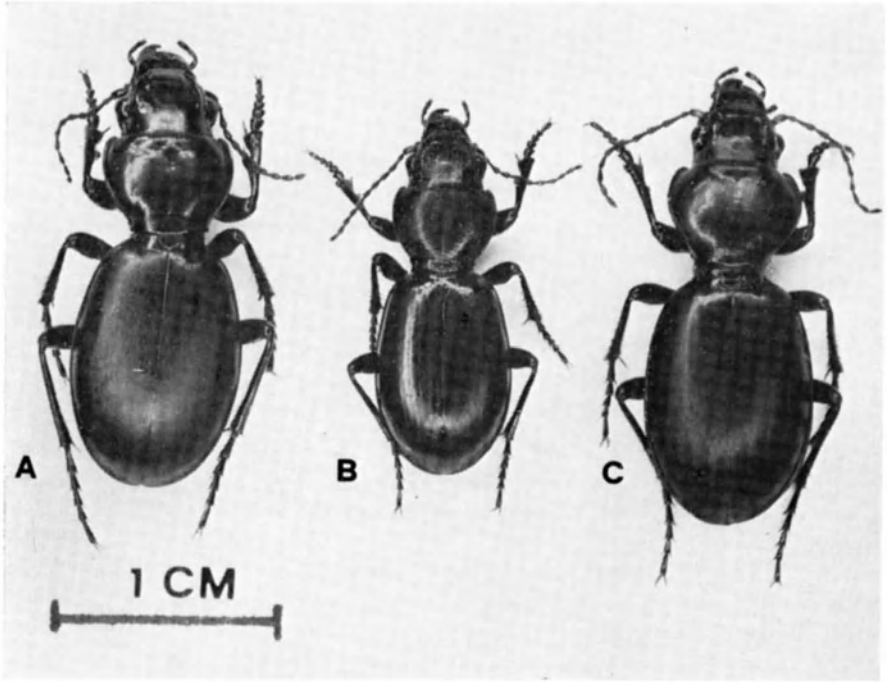

Fig. 26. The three Canarian *Broscus*: **A.** *B. crassimargo* Woll., (Gomera), **B.** *B. rutilans* Woll., (Tenerife), **C.** *B. glaber* (Brull.), (Gran Canaria). Photo A. Machado.

dans l'étroit promontoire que forme la partie orientale de l'île, trois races très individualisées par des différences notables de leurs organes copulateurs.» (Jeannel 1936, p. 18).

One of these three subspecies – *felix* – occupies the centre of Anaga (Cruz de Taganana) at 1,000 m, and the others at lower altitude on the northern side (Cruz del Carmen) – *faustus* –, and on the southern side, *tahodiensis*. This evolution, if it is true, could be linked to the laurisilva subtypes, orography and the different mesoclimatic conditions on one and the other exposure.

The genus *Anchotrechus* constitutes an evolutionary problem; it is a Tenerife palaeoendemism that presents primitive morphologic characters (pubescent elytra) as well as an ultraevolved copulatory organ (Mateu 1961). The two species coexist in the Anaga Sierra. The one with the most reduced area is *A. cabrerai*, living in leaf-litter, while *A. punctipennis* extends to Las Mercedes, and is proper to the riparian media where extreme darkness persists. Successive invasions? Sympatric evolution? Secondary sympatry? ...

Another singular aspect of Tenerife is that it once harbored a lagoon. It is possible that another existed in Gomera, at the locality known as 'Laguna Grande', but the orography of the zone suggests that it can not have been very large, nor persistent. The Tenerife lagoon is from historic times and a map, on which it appears, even exists (Torriani 1590), on which it is seen to be very reduced and lying at one extreme of the city thus called 'La Laguna', the old capital of the Island. Torriani mentioned that it was fed by a stream coming from the North and that it emptied toward the East.

The broad extent of the sediment zone of the Valley of Aguere suggests that the lagoon was much larger in the past, receiving water from the forests of Las Mercedes (not from La Esperanza). Some zones remained muddy in certain periods.

This now nonexistent habitat must have housed a particular laurisilva subtype, as well as a fauna proper to it. The reconstruction of the carabid fauna is now difficult because not even vestiges of the lagoon exist any longer. Nevertheless, some typically hydrophilic forms are predominant in this zone, always linked to humid usually artificial microconditions. Such is the case with *Princidium laetum*, *Agonum marginatum*, *Apotomus angusticollis*, *Acupalpus dorsalis*, *Stenolophus teutonus*, etc. Many of the riparian elements mentioned above (p. 373) must have found an adequate habitat in this lagoon. It should be noted that *Apotomus angusticollis* is likewise found in Bajamar (coast), in a zone where artificial ponds have been abundant for a very long time.

Of the 10 endemic genera, the Tenerife laurisilva contains 4 proper, of which only *Amaroschema* is not exclusive (Type Y). It likewise shares another two (*Dicrodontus* and *Licinopsis*) with other Islands. The affinities with the laurisilvae of Hierro, Gomera and La Palma have already been treated on discussing these Islands. It exclusively shares the genera *Carabus* and *Nebria* with Gran Canaria, as well as *Broscus* and *Dicrodontus* also present in Gomera (see fig. 31). Some forms are also only known from Tenerife and Gran Canaria: *Apotomus angusticollis*, *Philorhizus e. elliptipennis*, *Philochtus iricolor*, *Microlestes negrita*, etc.

Several genera are present only in the Tenerife laurisilva. Such is the case with *Masoreus*, with *M. alticola* (Type Y); *Bradycellus ventricosus*, representing the *Bradycellus* of Madeira, which are also of the laurisilva; *Tarulus*, with *T. zargoides*, that would come to represent the *Cymindis* of Gomera and Gran Canaria, absent in the laurisilva of Tenerife; *Leistus*, with *L. nubivagus*, related to *L. ellipticus* Woll. of the Madeira laurisilva, and *Platyderus*, with *P. languidus alticola*, Type Y.

We see how the Tenerife laurisilva presents a rich, very characteristic and complete carabid fauna, in which are even found representatives (vicariant forms) of the Madeira laurisilva carabids, absent in the rest of the Canary Islands. One great exception exists, the Macaronesian genus *Zargus*, that lives, as we have seen, only in Gomera.

Its richness is due partially to environmental diversity and in great measure to the mentioned palaeozoogeographic phenomena. The fact that it is the best studied Island also probably has an influence.

Gran Canaria

This is the third Island in terms of surface area (1,532 km^2), and in altitude (1,950 m). Within the Canaries, man has reached his 'climax' of the degradation of Nature in this Island. Of the enormous forests which once covered the Island, only a few manifestations of *Pinus canariensis* woods remain. It has been recently reafforested with *Pinus radiata*, and some areas have been planted with *Eucalyptus*, chestnuts, etc., but even so, the forest mass is very small and today, the Island that was once humid and rich in water reserves, now frequently goes thirsty (see Steinert 1975). Kunkel (1975) estimates that the remains of the laurisilva existing today on this Island amounts to less than 1% of its original distribution area.

Today, remains of laurel forest are found in Los Tiles de Moya, El Brezal del Palmital and the Barranco de la Virgen (upper part of the Barranco de Azuaje). Some show an interesting floristic composition (Kunkel & Sventenius 1972, Kunkel 1973c), but their extent is so reduced and the soil conditions are usually so altered that they cannot house a fauna in its natural state (fig. 27). The laurisilva of Gran Canaria is not in a condition to be studied directly for its fauna, and we must base much on extrapolations.

The first difficulty which presents itself is that of not knowing the natural area of the laurisilva. Sunding (1972) presents a map of the actual vegetation and of the potential natural vegetation. The limits that

Fig. 27. Aspect of Los Tiles de Moya, one of the last laurel forest remains in Gran Canaria (considered to become a protected area). In the centre *Ocotea foetens* (Ait.) Benth. et Hook.f. = 'til'. Photo A. Machado.

Fig. 28. Detail of the route map of M. Ch. Alluaud, 1891 (see text for explication).

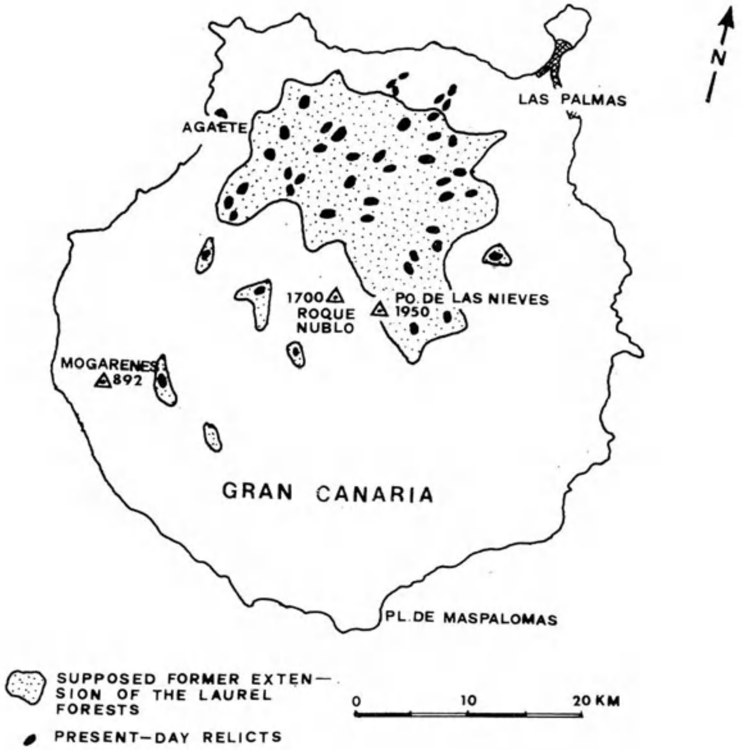

Fig. 29. The original laurel forest zones of Gran Canaria (an attempted reconstruction) and the present day relicts (Kunkel, 1973).

he establishes for the laurisilva (in Sunding = Order *Pruno Lauretalia* + Order *Fayo-Ericetalia arboreae*) do not coincide very much with those of Kunkel (1973b) in his 'Attempted reconstruction' (fig. 29). In our judgement the lower limit of Sunding has been drawn very high, as can be deduced from various earlier authors such as Viera y Clavijo (1866) or Alluaud (1891), who states of his localities 18: «Canaria, 12 Nov. 1889, Los Laureles pres Tafira, Dans l'eau et sur les rives d'un torrent ombragé de lauriers géants, 300m» – and 29 – «Canaria, 8 Janv. 1890, Píc et Cratère de Bandama; (puis comme au n° 18), 450 m.» (fig. 28)

Sunding's upper limit also seems drawn too low. Kunkel, based on small relicts[7], reconstructs the distribution far more generously (see map, fig. 29).

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[7] «On the other hand the small relicts, often only a few square meters in extent, when they are not located on inaccessable rock cliffs, are only found within farmed areas where they may have been left to provide shade for grazing animals» (Kunkel 1973b, p. 126; translation).

The laurisilva carabids are found very scattered throughout all the N and NE of the Island. Some forms (the W′) have remained linked to the small remains of the laurel forest (*Calathus appendiculatus*, for example). Others seem to have become extinct: *Pseudomyas doramensis*, *Asaphidion delatorrei*, *Dicrodontus alluaudi*, or are extremely rare, as *Nebria currax*.

The remainder show clearly disjunct distribution areas, and the major part of which occupy the high and more humid zones of the Island.

We don't know whether these high-lands occupied today by agriculture (e.g., chestnuts) and a formation of high-mountain legumes (perhaps a climax formation of *Chamaecytisus proliferus*, *Teline microphyla*, etc.?), were really once laurisilva or pine woods (*cf.* Nogales & Schmincke 1969).

It is possible that the carabid fauna would have displaced itself toward a higher zone searching for moisture and adapting to the present formation of legumes and the farming zone. We have thus designated these forms as W?. The study of the edaphic fauna (springtails, par example) could perhaps resolve this question. Personally, we are inclined to think that we are dealing with what used to be a mixed forest.

We include an original map (fig. 30) on which the finds of some frequent forms are noted by letters. It may someday help to reconstruct the real potential distribution map, but in the meantime, and for faunistic studies, we employ that of Kunkel (fig. 29), although we push the inferior limit a little lower in some places.

The e? on the map is a reference to a *Broscus glaber* captured in 1858 «beneath stones on the dry calcareous hills above Las Palmas» (Wollaston, 1865). We think that this/these specimens found by Wollaston must have been carried by flowing water and deposited at the lower end of the ravine.

Prospections amed at the discovery of remains of the carabid fauna of the laurisilva, but not to collect in the known localities, promise to result in interesting discoveries. Guided by this intent, during our last trip to Gran Canaria (1974), we discovered several laurisilva species in La Atalaya, at Santa Brigida, among the carabids *Carabus coarctatus* (6 specimens), *Trechus flavolimbatus* and *Calathus angularis*. It was a surprise to collect a *Carabus* at less than 20 m from some 'tabaibas' (*Euphorbia obtusifolia*).

Trechus flavolimbatus, due to its small size and its adaptation to minimal microconditions, could be used as an excellent historic-indicator species.

Compared to Gomera or Tenerife, the Gran Canaria carabid fauna of the laurisilva may be considered as quite complete though poor (impoverished). e.g., it only contains one *Trechus* and three *Calathus*.

Most of the typical genera are present: *Dromius*, *Philorhizus*, *Broscus*, *Dicrodontus*, etc. Notable are *Pseudomyas*, paleoendemism in this Island, the presence of *Carabus* and *Nebria* relates it to the laurisilva fauna of Tenerife, and of *Cymindis* and *Gomerina*, connecting it with that of Gomera. It is interesting to observe the interrelations among these three Islands, forming something like a unit. At the same time taxa exist which relate

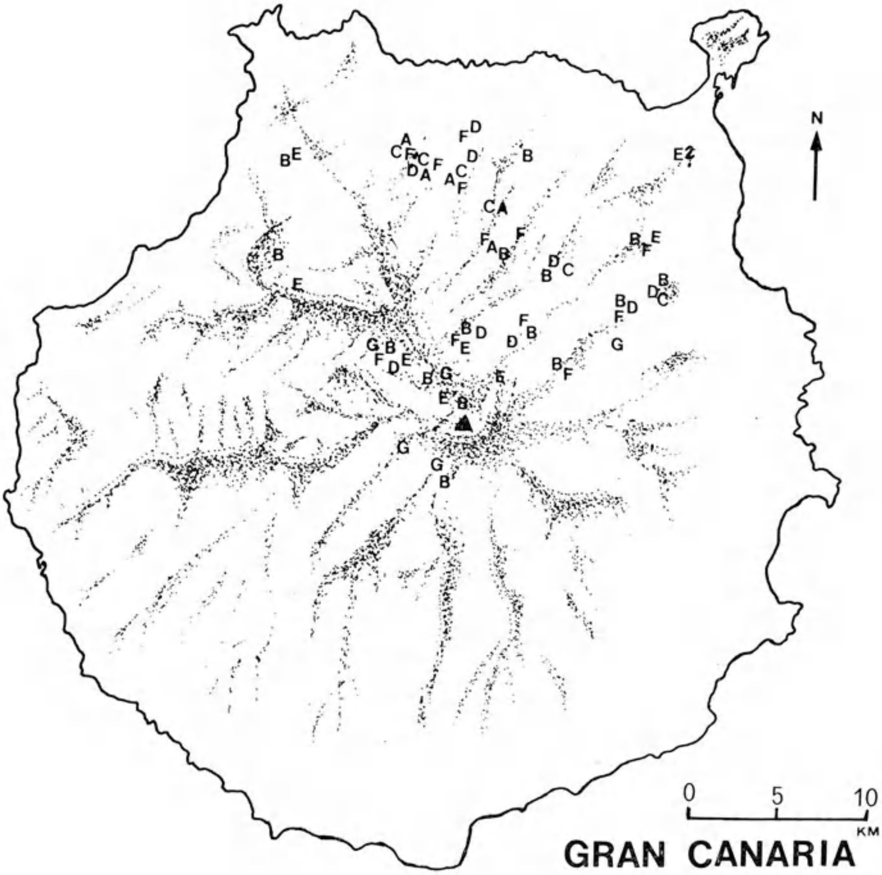

Fig. 30. Distribution of some typical laurisilva carabids of Gran Canaria: **a**. *Calathus appendiculatus* Woll., **b**. *Calathus angularis* Brull., **c**. *Calathus canariensis* Har., **d**. *Carabus coarctatus* Brull., **e**. *Broscus glaber* (Brull.), **f**. *Trechus flavolimbatus* Woll., **g**. *Cymindis amicta* (Woll.).

each the three Islands, and others that relate them in pairs. We have attempted to summarize these affinities in fig. 31. We have not included the coincidences in *Dromius* and *Philorhizus* because, as noted above, they are very little studied.

Fuerteventura and Lanzarote

These two Islands present some very marked common characteristics that we shall treat them as a unit. The German scientists usually refer to them as the 'Purpurarien'. In reality Lanzarote and Fuerteventura were separated recently (after the last glaciation) and share the same geological

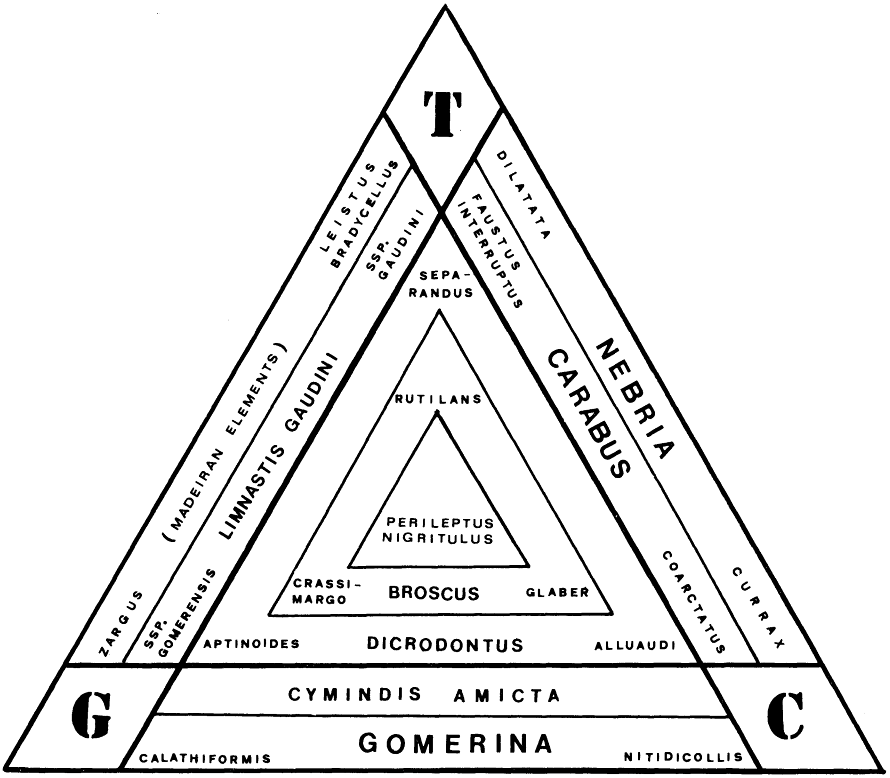

Fig. 31. Faunistic interrelations between the laurisilvae of the three central Islands: Tenerife (**T**), Gomera (**G**) and Gran Canaria (**C**).

base. The La Bocayna Strait separates them by some 11 km, and its depth is not more than 50 m.

Fuerteventura is the longest Island (100 km), and with its 1,725 km^2 (altitude = 870 m), is the second largest in surface area, after Tenerife. Lanzarote, with its 796 km^2, is somewhat smaller than La Palma, and with a maximal altitude of 671 m, it is the lowest of the seven main Canary Islands.

According to Dansereau (1968), laurisilva can only have been present on the Western Canaries. Engler (1910) cites some *Laurus* from Lanzarote, as well as several typical accompanying forms from Fuerteventura. Burchard (1929), referring to La Zarza Peak (807 m), states: «Aside from the local peculiarities, I have noted succeeding species that as a whole even point out the partial forestation which existed in far distant times» (translation), and gives a brief list of these plants. Later botanical studies have brought to light (e.g., Kunkel 1974a) other characteristic laurisilva species (*Myrica faya*, *Apollonias barbujana*, *Erica arborea*, several ferns, etc.), and many present-day botanists differ from Dansereau's opinion when speaking of 'the last laurel forest relicts' (Voggenreiter 1974), or of the 'perhaps always small' forest zones (Kunkel 1974b).

The present aspect of Fuerteventura and Lanzarote is very different from that of the other Islands. The former are semidesertic, rather flat and without forest formations, having only little stands of *Phoenix*, *Tamarix* (or mixed). But this has not always been the appearance of these Islands.

In the Mid or Late Tertiary, the laurisilva extended from the Atlantic zone, along the Mediterranean region to the Middle East or even further. During the epoch in which the African-facing side of the Canaries was covered with laurisilva[8], the Lanzarote-Fuerteventura of that time must have enjoyed a similar climate that permitted the covering of a great part of the Island surface by laurisilva (We are considering the Islands as oceanic). The great climatic changes, and the recent desert-forming process suffered by Africa, eliminated the continental laurisilva leaving only a few remains (see Fig. 1). The Eastern Islands, due to their lower altitude and closeness to Africa (110 km), have participated in this desert-formation, although it must have been quite decidedly out of phase due to the moderating action of the Ocean.

It is difficult to evaluate the intensity of this desert-formation to relate it to other factors, volcanic or others of a more artificial type, that must have contributed enormously to the creation of the present arid landscape of these two Islands. Some data conveniently illustrate the desert-formation to which we refer.

According to Torriani (1590), at that time the following existed in Fuerteventura: 60,000 goats and sheep, 4,000 camels, 4,000 donkeys – which came to constitute a plague –, 1,500 horned cattle, 150 pure bred horses «senza infiniti, che sono quasi cosi boni come quelli di Lanzarote», and 70,000 wild animals (probably domestic animals turned wild). A simple calculation gives us a density of 100 large herbivores per square kilometer!!! (no comments).

Bravo (1964) occupies himself with the desertification of these Islands and notes the presence of *Antophora* (Hymenoptera) nests that are found accumulated by the hundreds in diverse zones (see fig. 32). He has observed (pers. comm.) *Antophora* making this type of nest with mud, near La Orotava (T), which makes him suppose that the Eastern Islands had, until recently, a climate similar to that of the North of Tenerife. The internal shell of a *Limax* (Gastrop. Pulm.) has also been found to be very common, (subfossil). Bravo has collected a living specimen in a spring at Famara (N Lanzarote), and recently we also (1974) in the La Zarza Peak

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[8] «What will probably stand out is the fact that the Canary-laurel forest, far from being an intact relict of Mid- or Late-Tertiary times, is a much impoverished segregate of a richer matrix which has given rise to many other segregates, but remained nowhere in its original undifferentiated state.» (Dansereau, 1968, p. 270).

Fig. 32. Antophora nests (subfossil) in sublitoral Fuerteventura. Photo A. Machado.

(F.). The distribution of the *Limax* shells in many zones also speaks of a fairly humid general past climate.

The carabid fauna of the laurisilva of these Islands has disappeared along with the soil and vegetation, and as with the latter, only some vestiges remain in the highest and most humid parts of the Islands (see fig. 3), where the clouds (c.f. Kämmer 1974) have permitted their survival. The most typical relict species is *Calathus simplicicollis*, that has produced a subspecies in each Island (*simplicicollis* in Lanzarote, *gonzalezi* in Fuerteventura). It is extremely localized. The laurisilva of these Islands also contains at least one *Trechus*, *T. detersus*, common to both.

The last laurisilva refuge in Fuerteventura is found in the Cumbres de Jandía, in an almost vertical wall on the N-western side (principally) of La Zarza Peak. Part of the old soil is preserved among the rocks and in the crevices, wherein the remains of the previous fauna are found. It is also observed that many animals take refuge in the hanging leaves of *Odontospermum sericeum* (fig. 33) that characterize the vegetation of the zone. In Lanzarote the refuge corresponds to a vaster region at the Peñas del Chache.

These *Trechus* and *Calathus* are the only carabids that we can consider with some probability as proper to the extinct laurel forests. Of the other forms we only suspect that due to their present localization (they are also to be found in lower zones) not much can be deduced. Such is the case with *Syntomus lanzarotensis*, but Uyttenboogaart (1930) cites it from Los Tiles de Moya on Gran Canaria. This suggest that it is really a sylvan

Fig. 33. Odontospermum sericeum (L.f.) Sch. Bip., characteristic species of some cliffs of southern Fuerteventura (Jandía). The persisting dry leaves (arrow!) being a refuge for the remaining laurisilva fauna. Photo A. Machado.

form, adapted to the new conditions of the eastern Islands (as W? in the list).

Dromius and *Philorhizus* should also have existed but we saw that the arboreal stratum has completely disappeared. Nevertheless, some references are known. *Dromius angustus brittoni* was described from a specimen coming from Betancuria (included as W?). *Philorhizus notatus incertus* (Woll.) was collected by its author in Lanzarote (2 specimens) «amongst dry earth and rubbish on some rocks at Ye» (not included at present). We found a *Philorhizus* (?) in the crests of Jandía, among leaves of *Odontospermum sericeum*. It is possible that here this group could give new forms on further investigations, allowing some interrelation with the laurisilva of the other islands to be established. Nevertheless it is evident that the faunal regression is too advanced for it to be reconstructed today.

The high number of laurisilva forms noted for Lanzarote (13) and Fuerteventura (14) is due, as can be observed in the faunistic diagram, to the Type Y forms present in the laurisilva of the other Islands, and also found in the Eastern ones. They must therefore have lived in the laurisilva when this existed.

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XIV. NOTAS SOBRE LA DISTRIBUCION Y EVOLUCION DE LA AVIFAUNA CANARIA

por

JUAN JOSÉ BACALLADO

Introducción

Cualquier intento de estudio histórico-evolutivo y de distribución de la avifauna de las Islas Canarias, no puede ni debe desligarse de las hipótesis existentes sobre el origen de las mismas, así como de sus particulares y especiales condiciones fitoclimáticas.

Permítasenos pues, exponer brevemente los últimos conocimientos sobre estos temas, así como nuestra opinión personal sobre lo que pudo ocurrir en tiempos pretéritos.

Las Islas Canarias, junto con los archipiélagos de las Azores, Madera y Cabo Verde, como también los pequeños islotes de las Salvajes, constituyen una unidad fitogeográfica denominada Macaronesia.

Las diversas teorías emitidas por los investigadores sobre el origen del Archipiélago Canario giran en torno a dos hipótesis fundamentales: la que afirma que las islas estuvieron unidas al continente africano y la que niega rotundamente tal conexión.

Dentro de la primera idea, defendida por zoólogos y biogeógrafos, existen ciertas discrepancias; así unos autores consideran a las islas como restos del borde continental, mientras otros aseguran que son producto de un intenso volcanismo marino cuya principal consecuencia fue la unión, más o menos amplia y en diversas épocas, de las nuevas tierras emergidas, y la posible conexión de las islas más orientales con Africa.

Rothe (1964) señala la presencia en Orzola (isla de Lanzarote) de huevos fósiles de avestruz; Evers y colaboradores toman este dato como un punto más de apoyo para reforzar su teoría de supuestos puentes terrestres entre Lanzarote y Fuerteventura con el continente vecino.

Sin embargo, recientes investigaciones realizadas por el buque oceanográfico 'Meteor' han puesto de manifiesto la existencia, en el área comprendida entre el continente africano y las islas de Gran Canaria y Fuerteventura, de una amplia capa de sedimentos de más de 8000 m. de espesor.

Bravo (1970) explica este relleno sedimentario de las grandes fosas canario-africanas, por un hipotético ciclo erosivo continental con la consiguiente separación entre el archipiélago y la costa africana. Asimismo piensa que dicho proceso tuvo que comenzar antes del Terciario, apoyándose en la existencia de capas fosilíferas miocénicas fácilmente observables en nuestras costas.

Parece pues bastante probable, si nos atenemos a los últimos descubrimientos geológicos e investigaciones oceanográficas, que las Islas Canarias son de origen oceánico y nunca estuvieron unidas entre sí ni al continente.

Clima y Vegetación

Prácticamente son nulos los conocimientos y evidencias directas sobre los cambios climatológicos prehistóricos de Canarias; sin embargo, son más que probables sus semejanzas con las fluctuaciones climáticas de Berberia, al menos en sus características principales.

En la actualidad, las islas gozan de un clima muy peculiar y heterogéneo que podemos encuadrar como subtropical y de tipo mediterráneo. Debido a la situación geográfica, se hallan influenciadas en su climatología por dos factores esenciales, los vientos alisios procedentes del NE como respuesta a la situación de la zona de calmas por encima del paralelo 40, y la corriente de Canarias. El primero de estos factores aporta las masas nubosas que al chocar con los sistemas montañosos, favorecen su condensación y posterior precipitación del agua contenida en ellas, en unos límites altitudinales más o menos definidos. El segundo factor por su parte, ejerce un efecto regulador y de tampón en las variaciones térmicas, de manera que los cambios de temperatura son débiles en general. Esto en lo que afecta a las cotas inferiores de todas las islas, o a la totalidad de ellas en el caso de Lanzarote y Fuerteventura, ya que a medida que vamos ascendiendo a cotas superiores, van variando las influencias de los factores señalados. El efecto de la corriente de Canarias, decrece paulatinamente y por su parte los alisios sólo afectan hasta alturas alrededor de los 1500 m. Por encima de estas cotas, la climatología viene condicionada principalmente por los vientos del NW, secos y en las zonas más altas pueden incluso notarse los contralisios, afectando a las islas de Gran Canaria, La Palma y Tenerife. En estas dos últimas se presenta además una zona de carácter subalpino que afecta a las grandes alturas por encima de los 2000 m. En dicha zona, la influencia marítima es nula y las principales características climatológicas se traducen en cambios bruscos de temperatura, con precipitaciones de nieve en el invierno.

Si bien de una manera general, teniendo en cuenta estos factores y la orientación, se pueden señalar las distintas zonas climáticas insulares, no es menos cierto que la accidentada orografía, con sus numerosos barrancos, montañas y otros accidentes, así como la distinta constitución de suelos y rocas, dan lugar a que las condiciones climatológicas sean variables en una misma cota, existiendo infinidad de microclimas que de acuerdo con los caracteres ecológicos señalados posibilitan y condicionan la presencia de biocenosis vegetales de composición distinta a la domi-

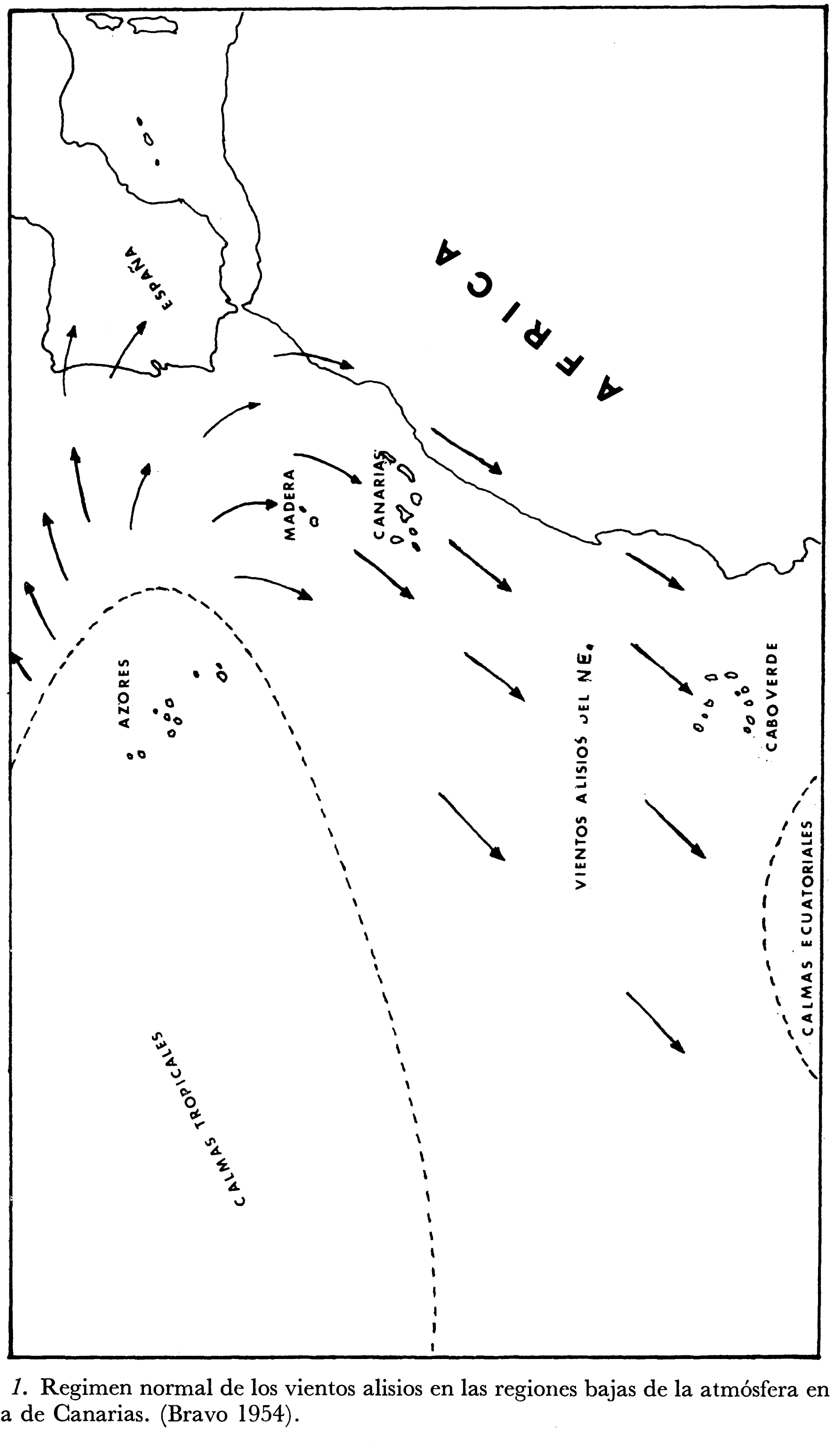

Fig. 1. Regimen normal de los vientos alisios en las regiones bajas de la atmósfera en la zona de Canarias. (Bravo 1954).

nante en la zona, las cuales ejercen un importante papel en el mantenimiento y desarrollo de otros grupos vivientes, contribuyendo de forma clara y notable al desarrollo y evolución de las especies existentes.

Tomando como base la característica climatológica más importante, la influencia de las nubes, se ha realizado un estudio de conjunto de las asociaciones vegetales. Estamos de acuerdo con Kunkel (1973) en que la clasificación que presentamos a continuación parece idealizada ya que no todas las islas sobrepasan la altura media (dentro de las nubes) y porque las condiciones en los sectores 'Norte' y 'Sur', ecológicamente son muy diferentes. Asimismo hay que tener en cuenta, como hice notar anteriormente la gran cantidad de microclimas existentes.

Asi pues, de una manera esquemática nos encontramos con los siguientes pisos de vegetación:

1. Piso Basal o zona Baja (bajo las nubes) con un clima cálido, seco e insolación alta. Se puede distinguir una primera faja litoral directamente influenciada por el cloruro sódico, que determina una vegetación de halófilas, variable según se trate de acantilados o de playas. Es de escasa altitud aunque puede alcanzar en casos extraordinarios los 100 m. Sigue una faja sublitoral ocupada por plantas suculentas y algunas especies arbóreas, sobre todo en el 'Norte'. Nos encontramos con tabaibales, cardonales, tarajales, palmerales, dragos, almácigos, etc. Comprende hasta los 300 m. en el N-NE y los 600 en el S-SW. Por último aparece una faja superior de transición hacia el piso montano.

2. Piso Montano o zona Media (dentro de las nubes) de clima húmedo y fresco. En este piso se distribuyen el grueso de los bosques isleños, hoy altamente degradados por la actividad humana. La laurisilva se extiende de los 500 a los 1000 m. en las orientaciones N y NE, o en condiciones muy especiales en puntos aislados de las zonas meridionales. El fayal-brezal se sitúa como formación propia por encima de la laurisilva y como componente de ésta. El pinar ocupa la zona superior de este piso montano (1000–1500, 1800 m.) donde reina un clima más seco de tipo continental.

Aparece también el escobonal, como formación propia, con tendencia a situarse en la parte superior de transición al piso subalpino.

3. Piso Subalpino o zona Superior (encima de las nubes) donde por inversión climática nos encontramos un clima bastante seco, caracterizado por grandes oscilaciones en la temperatura; comprende las altiplanicies y crestas insulares. Hasta los 2500 m. de altitud domina el matorral de leguminosas de alta montaña (retamar, codesal) y por encima de esta cota, en condiciones desfavorables, sólo se encuentran restos de retamares y la violeta del Teide.

Las islas orientales, Lanzarote y Fuerteventura, sólo presentan la zona baja ya que carecen del piso montano.

Se puede afirmar que las peculiaridades anteriormente esbozadas, es decir, la insularidad, climatología y vegetación han sido las responsables de que el Archipiélago Canario posea una avifauna relativamente rica y variada.

Sorprende sin embargo el bajo número de especies endémicas, que queda reducido a tres: 'Paloma Rabiche', 'Tarabilla Canaria' y 'Pinzón del Teide', estas dos últimas politípicas. Otras cuatro, 'Paloma Turqué', 'Vencejo Unicolor', 'Bisbita Caminero' y 'Canario', son endemismos macaronésicos, donde sólo la primera presenta subespeciación.

Sucesivas inmigraciones, alejadas en el tiempo, han sido las responsables del poblamiento de aves en las islas, exceptuando las especies introducidas por el hombre. Bernis (1972) postuló que las especies continentales que dieron origen a cada uno de los endemismos canarios y macaronésicos pudieron ser las siguientes: Paloma Torcaz (para las palomas Turqué y Rabiche), Tarabilla Común (para la Tarabilla Canaria), Pinzón Vulgar (para el Pinzón del Teide), Bisbita Campestre (para el Bisbita Caminero), Vencejo Palido (para el Vencejo Unicolor) y Verdecillo (para el Canario).

Parece claro que los elementos endémicos, del nivel específico y subespecífico, más netamente diferenciados, corresponden a las formas estrechamente ligadas a la paleoflora canaria. La Paloma Turqué (*Columba trocaz bollii* Godman) y la Paloma Rabiche (*Columba junoniae*

Tabla 1. Terciaro; 65 milliones de años.

Pleistoceno (glaciaciones)	3 m.d.a.—actual
Plioceno	12— 3 m.d.a.
Mioceno	25—12 m.d.a.
Oligoceno	35—25 m.d.a.
Eoceno	55—35 m.d.a.
Paleoceno	65—55 m.d.a.

Tabla 2. Cuadro cronologico de las glaciaciones cuaternarias; (Según S. F. Hulse, 1963 in Fuster, 1969).

Escala temporal en años	Glaciaciones	Epocas	
50.000	WURM	Holoceno (Paleolítico)	
		superior	Pleistoceno
200.000	RISS		
500.000		medio	
700.000	MINDEL		
		inferior	
1.000.000	GUNZ		
2.000.000		Villafranquiense	

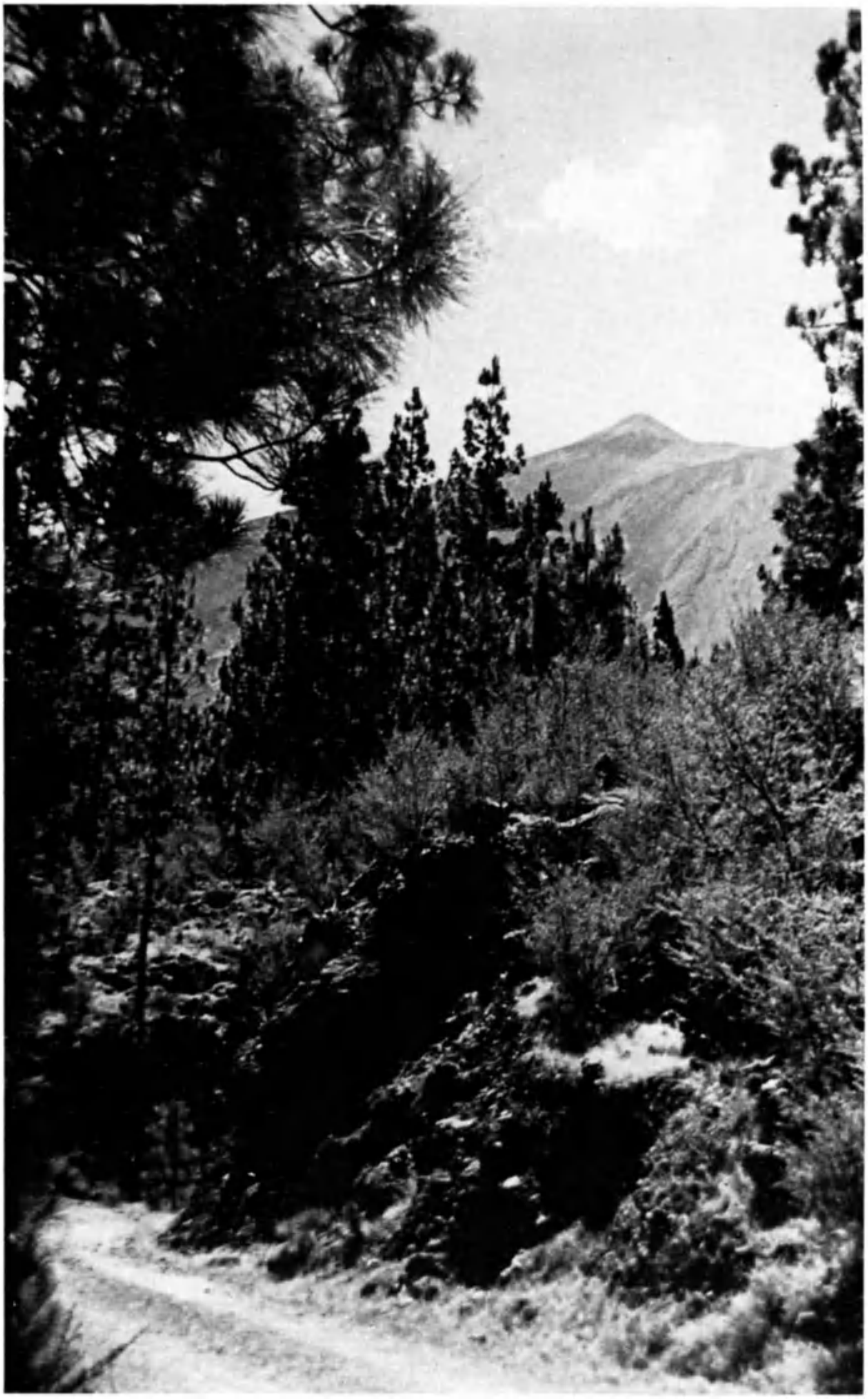

Fig. 2. Cumbre del Realejo Bajo (1.600 m) *Pinus canariensis* con sotobosque de *Chamaecytisus proliferus*, habitat típico del Pinzón del Teide. (Foto: J. Bacallado).

Hartert) han evolucionado en notorio paralelismo con su habitat, el bosque relíctico de laurisilva y podemos considerarlas como auténticos fósiles vivientes. Ambos elementos serian el resultado de sendas inmigraciones de diferente antigüedad que podríamos situar, para la Paloma Rabiche en la base del Plioceno y para la Paloma Torcaz al final de dicho periodo.

Más modernamente, en plenos periodos glaciales, las islas sirvieron de refugio a inmigrantes del Norte, Centro y Suroeste de Europa, actuando de puente el Norte de Africa, cuyas condiciones climáticas fueron muy distintas de las actuales y posiblemente similares a las del Archipiélago.

Cabe destacar, por tratarse de un interesantísimo caso de evolución insular, también ligado a los bosques laurifolios, los pinzones de Canarias. Nos referimos al Pinzón Vulgar (*Fringilla coelebs* L.) con tres razas bien diferenciadas: ssp. *tintillon* Webb, Berthelot et Moquin-Tandon, en las islas de Tenerife, Gomera y Gran Canaria; ssp. *palmae* Tristam, en La Palma y la ssp. *ombriosa* Hartert, en el Hierro. El colorido más vivo e incluso la robustez de estas subespecies endémicas, destacan sobremanera con respecto a la especie madre continental. Un amplio estudio comparativo podría arrojar más luz sobre las características de estos pinzones, cuya evolución nos atrevemos a situar en el primer periodo interglacial.

El habitat de estos pinzones no parece bien definido en la actualidad; si bien presentan marcadas preferencias por la laurisilva, también viven y nidifican en el pinar.

El bosque de *Pinus canariensis* representa, sin duda, otra reliquia de la flora canaria casi tan antigua como la laurisilva. Su gran resistencia al fuego ha condicionado su supervivencia y evolución, que ha tenido lugar junto con el volcanismo. Firmemente arraigado a esta formación vegetal se encuentra el Pinzón del Teide (*Fringilla teydea* Moquín-Tandon) con toda probabilidad el endemismo más bello y diferenciado de toda la avifauna canaria; procedería de una inmigración muy antigüa, durante el Plioceno, del Pinzón Vulgar. La forma típica se encuentra en Tenerife, mientras que la ssp. *polatzeki* Hartert habita en los escasos pinares de Gran Canaria.

En cuanto al habitat del Pinzón del Teide podemos afirmar sus preferencias por las cotas altas de pinar, llegando a adentrarse, en época favorable, en los retamares del piso subalpino, sin que hasta la fecha se haya podido comprobar su nidificación en ellos. En inviernos excesivamente crudos bajan hasta la zona de fayal-brezal.

Mayor ligazón con el biotopo de *Pinus canariensis* presenta el Pico Picapinos (*Dendrocopos major* L.), cuyas dos subespecies endémicas se encuentran en las islas centrales; la ssp. *canariensis* Koenig, en Tenerife y la ssp. *thanneri* Le Roi, en Gran Canaria. Ambas subespecies se encuentran severamente amenazadas de extinción. Resulta curioso que en las dos islas más occidentales, La Palma y El Hierro, con espléndidas manifesta-

Fig. 3. Pollos de *Anthus bertheloti* (Foto: A. Machado).

Fig. 4. Anthus bertheloti. (Foto: A. Machado).

ciones de pinares canarios, esta especie esté ausente. Posiblemente arribaron a las islas durante el Pleistoceno inferior.

Otras muchas especies viven indistintamente en la laurisilva o en el pinar, sirviendo de nexo de unión el fayal-brezal; se trata casi exclusivamente de pequeñas aves insectívoras, que encuentran en estas formaciones vegetales el habitat adecuado para sus exigencias alimenticias.

El Herrerillo (*Parus caeruleus* L.) denota marcadas preferencias por el pinar, aunque su presencia e incluso nidificación no es rara en los bosques perennifolios de laurel. Dicha especie es otro claro exponente del fenómeno evolutivo insular, siendo la única que ha diferenciado cuatro razas vigorosamente definidas: ssp. *teneriffae* Lesson, en las islas de Tenerife, Gran Canaria y Gomera; ssp. *palmensis* Meade-Waldo, en La Palma; ssp. *ombriosus* Meade-Waldo, en el Hierro y la ssp. *degener* Hartert, en Fuerteventura y Lanzarote. El habitat semidesértico de esta última contrasta con el boscoso de las tres primeras.

El Petirrojo (*Erithacus rubecula* L.) es otra especie politípica cuyas dos razas canarias presentan colores más vivos que la forma típica europea de la que proceden; la ssp. *superbus* Koenig, se encuentra en las dos islas centrales, Tenerife y Gran Canaria, mientras que la ssp. *microrhynchus* Reich., está confinada en las pequeñas islas occidentales. La ausencia de sotobosque apropiado, otrora muy abundante en las formaciones boscosas, han condicionado sus preferencias, que hoy se inclinan por el matorral bajo de fayal-brezal.

Phylloscopus collybita V., (Mosquitero) y *Regulus regulus* L., (Reyezuelo) habitan igualmente todo tipo de bosque, llegando el primero hasta los matorrales, setos y jardines de las ciudades. Nos parece más antigua en las islas la presencia del Mosquitero que la del Reyezuelo, como lo demuestra el hecho de que aquél aparece más diferenciado y diversificado que éste.

Mayor valencia ecológica presenta el Mirlo (*Turdus merula* L.) posiblemente restringido, durante y después de las glaciaciones a los abundantes bosques de pinos y laurel que prácticamente cubrían las islas; hoy los seguimos encontrando en todo tipo de formaciones boscosas así como en matorrales, parques y cultivos hortícolas.

Las especies del género *Sylvia* se han habituado a las zonas de matorral, zarzales, fayal-brezal y cultivos. Muy posiblemente procedan de inmigraciones post-glaciales ya que sus razas no presentan rasgos muy llamativos. En este caso particular podríamos incluir al Gorrión Chillón (*Petronia petronia* L.).

No podemos datar con seguridad la edad en la que se desarrolló la zona baja de tipo semidesértico, sin embargo cabe pensar que dicha zona se formó primero en el 'Sur' que en el 'Norte' de las islas. Las erupciones volcánicas preglaciales tuvieron una influencia decisiva y posteriormente el seco clima postglacial, determinó su formación.

Sea como fuere, la aparición de esta zona significó el establecimiento de

Fig. 5. Sylvia conspicillata orbitalis. (Foto: J. Bacallado).

un nuevo habitat, receptor y virgen, que pronto fue colonizado por aves tipicamente erémicas, procedentes del vecino continente africano. En el límite de esta zona con los bosques, que poco a poco se retiraban a cotas más elevadas, se diferenciaron también las dos especies europeas que dieron lugar a la Tarabilla Canaria y al Bisbita Caminero. Este último creemos procede de una inmigración que situamos hacia el segundo periodo post-glacial. Paralelamente al progresivo aumento de la zona baja semidesértica, el *Anthus berthelotii* Bolle se fue extendiendo por casi toda la superficie de las islas, llegando incluso a establecerse en la faja subalpina cuya formación, Bravo (comunicación personal) no excede de los 150 a 200 mil años.

Las especies erémicas de procedencia africana y colonización más reciente son: Camachuelo Trompetero, Alcaraván, Ganga Ortega, Hubara Canaria y Corredor.

Una diferenciación similar pudo haber ocurrido con las especies hoy asociadas a las áreas de cultivo. De todas ellas, el Canario (*Serinus canaria* L.), endemismo macaronésico, es la más llamativa y vieja; el resto: Triguero (*Emberiza calandra* L.), Millero (*Acanthis cannabina* L.), Abubilla (*Upupa epops* L.), Tórtola (*Streptopelia turtur* L.), Codorniz (*Coturnix coturnix* L.), y otras son relativamente modernas.

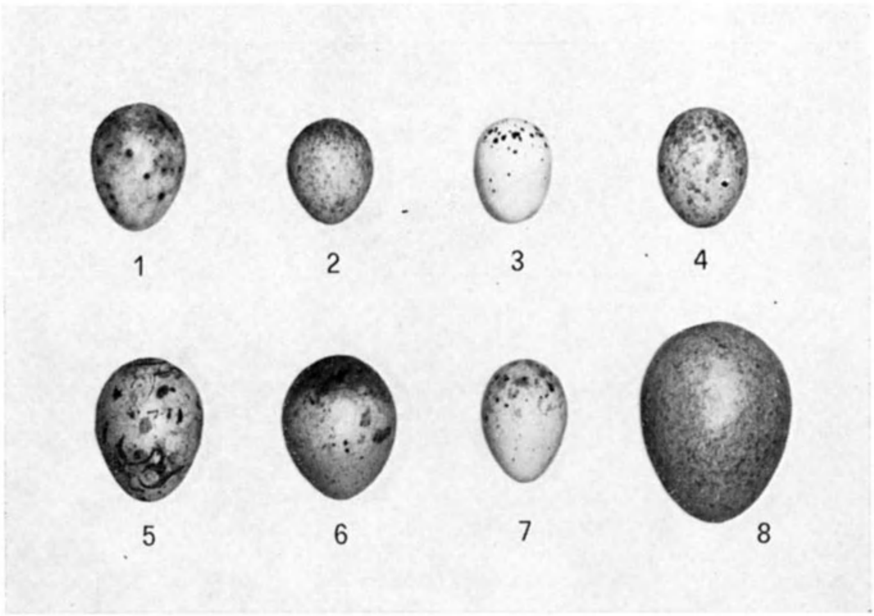

Fig. 6. Huevos de algunas aves canarias. 1. *Sylvia atricapilla atricapilla*; 2. *Sylvia conspicillata orbitalis*; 3. *Phylloscopus collybita canariensis*; 4. *Motacilla cinerea canariensis*; 5 y 6. *Emberiza calandra*; 7. *Acanthis cannabina meadewaldoi*; 8. *Turdus merula cabrerae.* Foto: A. Machado.

Especie típicamente sinantrópica y de muy reciente introducción es el Gorrión Moruno (*Passer hispaniolensis* Temm.), que rápidamente se ha extendido por todas las islas amenazando con desplazar a otras especies.

Consideraciones biogeográficas

En el estado actual de nuestros conocimientos no podemos pronunciarnos a favor o en contra de determinadas teorías sobre el origen de los archipiélagos de Madera y Canarias. No sucede lo mismo con Azores, cuyo origen oceánico está fuera de toda duda.

Según Tuzo Wilson (1963) la edad de las islas en el oceano Atlántico tiende a aumentar con su distancia a la cordillera centro-oceánica. Para Bravo (comunicación personal) la edad aproximada de los archipiélagos de Azores, Madera y Canarias oscila entre los siguientes valores (dados en millones de años): de 3 a 8, de 60 a 70 y de 35 a 40 respectivamente. Esta aparente contradicción puede explicarse teniendo en cuenta la escasez de dataciones sobre las Islas Canarias; es probable que futuras investigaciones nos hablen de una mayor edad con respecto a estas islas, en las que un moderno e intenso volcanismo parece haber enmascarado series más antiguas.

Tabla 3

	Superficie	Distancia mínima al continente	Avifauna N° de especies	Ropalóceros N° de especies
Canarias	7.167 Km²	111 Km	60	26
Madera	1.540 Km²	600 Km	42	14
Azores	2.529 Km²	1.400 Km	21	8

Tabla 4

	Superficie	Distancia a Cabo Juby	Altura máxima	Avifauna N° de especies
Lanzarote	875 Km²	122 Km	671 m	36
Fuerteventura	1.731 Km²	111 Km	807 m	35
Gran Canaria	1.532 Km²	245 Km	1.950 m	45
Tenerife	2.058 Km²	333 Km	3.718 m	53
Gomera	379 Km²	417 Km	1.340 m	39
La Palma	729 Km²	489 Km	2.423 m	39
Hierro	278 Km²	489 Km	1.512 m	31

La relativa antiguedad de los archipiélagos citados así como su mayor o menor proximidad al continente (ver Tabla 3) ejercen una influencia notable en la riqueza o pobreza de su fauna, incluyendo por supuesto, grupos que, como los Lepidópteros y las Aves, poseen una gran capacidad de dispersión.

Sin embargo, si estudiamos los archipiélagos por separado, considerando cada una de las islas que los componen, la influencia de estos factores no parece ser decisiva. En el caso concreto de Canarias y su avifauna (ver Tabla 4) podemos afirmar que la edad, superficie y distancia de cada isla al continente no son los responsables directos de su mayor o menor riqueza en especies.

La altitud (ver Tabla 4) se nos presenta como el factor primordial que condiciona el número de especies. En efecto, es en las islas de máxima altura donde tienen cabida los dos biotopos fundamentales de vegetación relíctica: la laurisilva y el pinar. Ambas formaciones vegetales han sido el refugio de la mayor parte de los inmigrantes antes, durante y después de las glaciaciones, actuando asimismo como centro donde han tenido lugar los más interesantes casos de evolución insular. Esta diversificación se ha visto facilitada por la relativa gran distancia que separa una isla de otra, observándose el claro fenómeno ecológico de que la razas de las islas occidentales presentan una coloración más oscura que las de las formas nidificantes en las islas orientales. Un caso similar se aprecia en las especies endémicas de Heteróceros, contrastando notablemente las tonalidades negruzcas de las formas ligadas a la laurisilva (en las islas occidentales) frente a las amarillo-terrosas de las purpurarias.

El caracter de la avifauna canaria es sin duda eminentemente paleártico con un mayor dominio de elementos procedentes de las zonas boscosas del centro y sur de Europa, frente a los típicamente mediterráneos. Estos últimos quedan circunscritos a las zonas medias y bajas de matorral. Más reducido es el grupo de representantes de la fauna africana, relegados a las áridas islas de Fuerteventura y Lanzarote así como a los biotopos semidesérticos de las islas centrales: Gran Canaria y Tenerife.

La paulatina y progresiva desaparición de las masas boscosas de laurisilva y pinar, debido a una abusiva tala por parte del hombre así como la introducción de especies botánicas foráneas, supone una constante y real amenaza para la supervivencia de determinadas especies. En este sentido podemos afirmar que especies tan interesantes como *Dendrocopos major*, *Fringilla teydea*, como también las dos palomas del laurel se encuentran al borde de la extinción. Se impone una verdadera toma de conciencia sobre este problema y una urgente y decidida actuación para evitar consecuencias irreversibles.

Por otra parte existen aún muchos puntos oscuros sobre la biología, etología y ecología de gran parte de la avifauna canaria; futuras investigaciones y estudios comparativos nos revelarían detalles inéditos de gran trascendencia para la ornitología y sobre todo para un mejor conocimiento de la especiación insular.

Finalmente debemos hacer constar que, al comparar la avifauna de Canarias con el resto de la Macaronesia, nos ha parecido oportuno dejar a un lado las islas de Cabo Verde ya que, en lo que a la fauna de aves y lepidópteros se refiere, sus conexiones con el resto de los archipiélagos no son significativas; es más, la influencia palearctica en estas islas es débil, destacando sobremanera su caracter eminentemente etiópico.

Cuadro faunistico de las aves canarias

	H	P	G	T	C	F	L	M	A	Habitat
Corvus corax tingitanus	+	+	+	+	+	+	+	—	—	barrancos, montes, terrenos abiertos
Pyrrhocorax pyrrhocorax barbarus	—	+	—	—	—	—	—	—	—	preferentemente barrancos de pinar
Motacilla cinerea canariensis	?	+	+	+	+	—	—	—	?	zonas encharcadas y barrancos húmedos
Motacilla cinerea schmitzi	—	—	—	—	—	—	—	+	—	ídem
Anthus berthelotii berthelotii	+	+	+	+	+	+	+	—	—	cultivos, zonas desérticas y semidesérticas
Anthus berthelotii madeirensis	—	—	—	—	—	—	—	+	—	ídem
Calandrella rufescens rufescens	—	—	—	+	—	—	—	—	—	cultivos de la zona baja y media
Calandrella rufescens polatzeki	—	—	—	—	+	+	+	—	—	ídem
Passer hispaniolensis hispaniolensis	+	+	+	+	+	+	+	+	—	cultivos y zonas habitadas por el hombre
Petronia petronia madeirensis	+	+	+	+	+	—	—	+	—	barrancos y cercanias de zonas habitadas
Fringilla teydea teydea	—	—	—	+	—	—	—	—	—	con preferencia pinares situados en cotas elevadas
Fringilla teydea polatzeki	—	—	—	—	+	—	—	—	—	pinares
Fringilla coelebs tintillon	—	—	+	+	+	—	—	—	—	laurisilva y pinar
Fringilla coelebs ombriosa	+	—	—	—	—	—	—	—	—	laurisilva y pinar
Fringilla coelebs palmae	—	+	—	—	—	—	—	—	—	ídem
Fringilla coelebs madeirensis	—	—	—	—	—	—	—	+	—	laurisilva
Carduelis carduelis parva	—	+	+	+	+	+	—	+	+	cultivos y terrenos baldíos
Carduelis chloris chloris	—	—	—	+	—	—	—	—	—	cultivos y fayal-brezal
Carduelis chloris aurantiiventris	—	—	—	—	—	—	—	+	—	ídem
Acanthis cannabina harterti	—	—	—	—	—	+	+	—	—	cultivos y terrenos baldíos
Acanthis cannabina meadewaldoi	+	+	+	+	+	—	—	—	—	ídem
Acanthis cannabina nana	—	—	—	—	—	—	—	+	—	ídem
Rodopechys githagineus amantum	—	—	—	+	+	+	+	—	—	zonas desérticas y semidesérticas
Serinus canaria canaria	+	+	+	+	+	—	—	+	+	cultivos, barrancos y bosques

	H	P	G	T	C	F	L	M	A	Habitat
Emberiza calandra	+	+	+	+	+	+	+	—	—	trigales y terrenos baldíos
Parus caeruleus teneriffae	—	—	+	+	+	—	—	—	—	preferentemente pinares; también en laurisilva
Parus caeruleus palmensis	—	+	—	—	—	—	—	—	—	ídem
Parus caeruleus ombriosus	+	—	—	—	—	—	—	—	—	ídem
Parus caeruleus degener	—	—	—	—	—	+	+	—	—	tarajales
Lanius excubitor koenigi	?	+	?	+	+	+	+	—	—	linderos de bosque, zona de halófilas y retamares del Teide
Turdus merula cabrerae	+	—	+	+	+	—	—	+	—	bosques de pinar y laurisilva; cultivos y parques
Turdus merula agnetae	—	+	—	—	—	—	—	—	—	ídem
Turdus merula azorensis	—	—	—	—	—	—	—	—	+	bosques y parques
Erithacus rebecula superbus	—	—	—	+	+	—	—	—	—	todo tipo de bosques
Erithacus rubecula microrhynchus	+	+	+	—	—	—	—	+	—	ídem
Erithacus rubecula rubecula	—	—	—	—	—	—	—	—	+	ídem
Saxicola dacotiae dacotiae	—	—	—	—	—	+	—	—	—	terrenos semidesérticos con plantas halófilas
Saxicola dacotiae murielae	—	—	—	—	—	—	+*	—	—	*Alegranza. ídem
Regulus regulus teneriffae	+	+	+	+	—	—	—	—	—	matorrales y todo tipo de bosques
Regulus ignicapillus madeirensis	—	—	—	—	—	—	—	+	—	ídem
Regulus regulus regulus	—	—	—	—	—	—	—	—	+	ídem
Sylvia atricapilla atricapilla	+	+	+	+	+	—	—	—	+	cultivos y matorrales
Sylvia atricapilla obscura	—	—	—	—	—	—	—	+	—	cultivos y matorrales
Sylvia conspicillata orbitalis	+	+	+	+	+	+	+	—	+	zarzales y matorrales
Sylvia conspicillata bella	—	—	—	—	—	—	—	+	—	ídem
Sylvia melanocephala leucogastra	+	+	+	+	+	+	+	—	—	fayal-brezal y zarzales
Phylloscopus collybita canariensis	+	+	+	+	+	—	—	—	—	todo tipo de bosques
Phylloscopus collybita exul	—	—	—	—	—	—	+	—	—	tarajales y cultivos
Dendrocopos major canariensis	—	—	—	+	—	—	—	—	—	bosque de Pinus canariensis
Dendrocopos major thanneri	—	—	—	—	+	—	—	—	—	ídem
Upupa epops pulchra	+	+	+	+	+	—	—	—	—	cultivos y zonas áridas con matorral
Upupa epops epops	—	—	—	—	—	—	—	+	—	ídem

	H	P	G	T	C	F	L	M	A	Habitat
Upupa epops fuerteventurae	—	—	—	—	—	+	+	—	—	ídem
Apus pallidus brehmorum	+	+	+	+	+	+	+	+	—	todas las islas. Riscos y aleros
Apus unicolor unicolor	+	+	+	+	+	+	+	+	—	ídem
Asio otus canariensis	+	+	—	+	+	—	—	—	—	bosques, palmerales y barrancos
Asio otus otus	—	—	—	—	—	—	—	—	+	bosques y barrancos
Tyto alba alba	—	+	—	+	+	—	—	—	—	campos abiertos y proximidades de zonas humanizadas
Tyto alba gracilirostris	—	—	—	—	—	+	+	—	—	ídem
Tyto alba schmitzi	—	—	—	—	—	—	—	+	—	ídem
Columba junoniae	—	+	+	—	—	—	—	—	—	barrancos de laurisilva, pinares y fayal-brezal
Columba trocaz trocaz	—	—	—	—	—	—	—	+	—	laurisilva
Columba trocaz bollii	?	+	+	+	—	—	—	—	—	laurisilva
Columba livia canariensis	+	+	+	+	+	+	+	—	—	barrancos y acantilados
Columba livia atlantis	—	—	—	—	—	—	—	+	—	ídem
Columba livia livia	—	—	—	—	—	—	—	—	+	ídem
Streptopelia turtur turtur	+	+	+	+	+	+	+	—	—	pinares; campos de gramíneas
Pterocles orientalis	—	—	—	—	?	+	+	—	—	terrenos áridos y desérticos
Haematopus ostralegus meadewaldoi	—	—	—	—	—	+	+	—	—	playas y roquedos
Charadrius dubius curonicus	—	—	—	+	+	+	—	+	—	zonas litorales
Charadrius alexandrinus alexandrinus	+	+	+	+	+	+	+	+	+	ídem
Burrhinus oedicnemus insularum	—	—	—	—	—	+	+	—	—	zonas desérticas y pedregosas
Burrhinus oedicnemus distinctus	+	+	—	+	+	—	—	—	—	ídem
Cursorius cursor bannermani	—	—	—	+	+	+	+	—	—	zonas desérticas; playas y dunas
Larus argentatus atlantis	+	+	+	+	+	+	+	+	?	marino
Sterna hirundo hirundo	+	+	+	+	+	+	+	+	?	litorales y playas
Puffinus puffinus puffinus	+	+	+	+	—	—	—	+	?	marino
Puffinus assimilis baroli	—	—	—	+	+	—	+*	+	?	*solo en Graciosa, Montaña Clara y Alegranza
Calonectris diomedea borealis	+	+	+	+	—	—	—	+	?	marino
Bulweria bulwerii bulwerii	—	—	+	+	—	—	+*	+	—	*Alegranza y Montaña Clara; acantilados

	H	P	G	T	C	F	L	M	A	Habitat
Hydrobates pelagicus	—	—	—	+	—	—	+	+	—	playas pedregosas y acantilados
Gallinula chloropus chloropus	—	—	—	+	—	—	—	—	—	estanques y zonas encharcadas
Clamydotis undulata fuerteventurae	—	—	—	—	—	+	+	—	—	parajes desérticos y semidesérticos
Alectoris rufa intercedens	—	—	—	—	+	—	—	—	—	introducida; cultivos y pastizales
Alectoris rufa hispanica	—	—	—	—	—	—	—	+	—	cultivos y pastizales
Alectoris barbara koenigi	—	—	+	+	—	+	+	—	—	laderas de bosques y zonas semidesérticas
Coturnix coturnix confisa	+	+	+	+	+	—	—	+	—	trigales y monte bajo
Coturnix coturnix conturbans	—	—	—	—	—	—	—	—	+	ídem
Neophron percnopterus pernocpterus	—	—	+	+	+	+	+	—	—	terrenos montañosos y áridos
Milvus milvus milvus	+	—	+	+	+	—	—	—	—	pinares y campos abiertos
Accipiter nisus granti	—	+	+	+	+	—	—	+	—	ídem
Buteo buteo insularum	+	+	+	+	+	+	+	—	—	montes, laderas y zonas cultivadas
Buteo buteo harterti	—	—	—	—	—	—	—	+	—	montes y campos abiertos
Buteo buteo rothschildi	—	—	—	—	—	—	—	—	+	ídem
Falco peregrinus pelegrinoides	—	—	—	+	+	+	+	—	—	barrancos y acantilados
Falco eleonorae	—	—	—	—	—	+	+	—	—	acantilados
Falco tinnunculus canariensis	+	+	+	+	+	—	—	+	—	barrancos, montañas y campos abiertos
Falco tinnunculus dacotiae	—	—	—	—	—	+	+	—	—	ídem
Pandion haliäetus	—	—	+	+	+	+	+	+	—	acantilados

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XV. THE AMPHIBIA AND REPTILIA OF THE CANARY ISLANDS

by

KONRAD KLEMMER

Introduction

As in all oceanic islands, the herpetofauna of the Canary Islands is poor in species and lacks larger systematic units as the Caudata within the Amphibia or the Serpentes within the Reptilia. Most of the few autochthonous species of frogs and lizards of the Canary Islands are endemics to these islands only living there. Therefore these species of terrestrial vertebrates are of special interest for the study of the evolution processes on islands.

The exploration of the herpetofauna of the Canary Islands started with Bory's book (1803), much later than the first studies of the flora of the Canaries and of the mammals and birds of economic interest to man. Bory already noted the complete lack of snakes on the Canary Islands. Among the Canarian amphibians and reptiles, he distinguished between the tree frog and a 'wood frog', and he mentioned a 'gray lizard', being very common on all of the islands. In comparison with the many studies of the birds of the Canary Islands, reptiles and amphibians found little interest if any, and there is no up-to-date monograph on the herpetofauna of the Canaries comparable with Bannerman's book (1963) on the ornithofauna of these islands. Even in the most recent fieldguide by Salvador (1974), the Canarian amphibians and reptiles are treated but marginally and incompletely. In addition to the following notes on the recent herpetofauna of the Canary Islands it is therefore tried to give an as complete list of references as possible.

Amphibia

On the Canary Islands, the Amphibia are represented by two species only. Of these, the tree frog *(Hyla meridionalis)* is probably the only autochthonous amphibian species. It inhabits all seven large islands of the Canaries from where it is known already by the first visitors of these islands. The marsh frog *(Rana perezi)* is probably introduced by the Spaniards from continental Spain for having this source of food also available on the islands. The introduction must have been done more than 200 years ago. To-day, the marsh frog has occupied all available fresh water bodies on the islands. There are records of the common toad

(Bufo bufo) from the Canary Islands and of the common frog *(Rana temporaria)* but these records could never be verified and they may result from unsuccessful introductions of these latter species.

FAMILY: HYLIDAE

Mediterranean tree frog *Hyla meridionalis*

1874 Hyla arborea var. meridionalis Boettger, Abh. senckenberg. naturforsch. Ges., 9: 186. Frankfurt am Main. – Terra typica restricta (by Mertens & Müller 1928): Valley of Orotava, Tenerife.
1954 Hyla meridionalis – Chaplin & Lester, Proc. zool. Soc. London, 124: 196.

DESCRIPTION

A usually bright green tree frog of 55 mm total length (head and body) with a head broader than long, rounded snout. The tympanum has half the diameter of that of the eye. Toes webbed at their base, like the fingers with terminal adhesive pads. Dorsal coloration green, sometimes greyish or blackish. A dark marking running from the nostril to the eye and, getting broader, to near the insertion of the fore-legs is always discernable. In contrast to *Hyla arborea* no lateral dark bands on the flanks. Belly usually whitish to yellow.

BIOLOGY

In spring, the male tree frogs sing in or near fresh water ponds usually in choruses. Their call can be heard at a distance of few kilometers. Calling activities are highest just before dusk and during the first hours of warm nights. The females produce clumps of 500 to 1000 eggs each. The tadpoles hatch within six to 15 days, depending of the water temperature. They pass metamorphosis within 80 to 120 days after hatching. The adult frogs live on the higher vegetation, on the Canary Islands especially on the banana plants, sometimes far from the nearest fresh water basin. Due to the many fresh water tanks, built near the banana plantations for irrigation of the fields, tree frogs are extremely common. Cott (1934) calculated that there are 1 million of tree frogs on an area of one square mile within the banana plantations of Orotava valley.

DISTRIBUTION

Hyla meridionalis is known from all seven large islands of the Canaries. On the western islands and on Gran Canaria, the tree frog is wide spread and especially abundant in fields and cultivations with fresh water tanks for irrigation. On the eastern islands of Lanzarote and Fuerteventura, the tree frog is restricted to a few wells and water holes having fresh water.

Outside the Canary Islands, *Hyla meridionalis* is known from southern France, the Iberian Peninsula, and Northwest Africa.

FAMILY: RANIDAE

Marsh frog, *Rana perezi*

1885 *Rana esculenta perezi* Seoane, Zoologist, London, (3) 9: 171. London. – Terra typica: La Coruña, Spain.
1925 *Rana ridibunda perezi* – Mertens, Abh. senckenberg. naturforsch. Ges., 39: 54. Frankfurt am Main.
1974 *Rana perezi* – Hotz, Natur und Museum, 104: 269. Frankfurt am Main.

DESCRIPTION

A typical frog of the genus *Rana* with pointed head and head and body length up to 150 mm. Tympanum well developped, about 3/4 of the diameter of the eye. Toes webbed, finger and toes without enlarged pads. Glandular folds along each side of the dorsum well developped. Coloration extremely variable, usually an olive ground colour dorsally with dark markings. Some specimens show bright green, even yellowish coloration, the markings being black, mostly dark grey or brownish. Rather often, they form longitudinal bands, leaving the middle line free of blotches. The under parts are white, creamy, with little dark pigment. Physiological colour changes are not so evident as in the tree frogs, but individual variability in the coloration is confusing.

BIOLOGY

The marsh frog is living in or near fresh-water ponds, usually irrigation tanks, all the year round. In spring and summer, the marsh frog can easily be located by his croaking, uttered even in day-time. The marsh frog calls only while in water, usually floating at the surface. After mating, the frogs regulate their individual distances by producing short croaks, thus making optimal use of the food reservoire. The marsh frog is preying on every live animal of suitable size, mostly insects but also small vertebrates, even young ones of the own species. On the Canary Islands, the marsh frog has no predator, except man, being of any importance for the regulation of the adult frog populations. Infraspecific competition for food and preying on the young ones seem therefore the main factors for the regulation of the island frog populations.

Rather late in spring the female marsh frogs produce about 3000 to 10000 eggs each. The tadpoles hatch within five to six days and pass metamorphosis within three to four months. The frogs get adult in their third or fourth year of life.

DISTRIBUTION

Rana perezi can be found on Gran Canaria, Tenerife, Gomera, Hierro, and La Palma islands of the Canaries. There are a few old records from Lanzarote and Fuerteventura islands, but the occurrence of the marsh

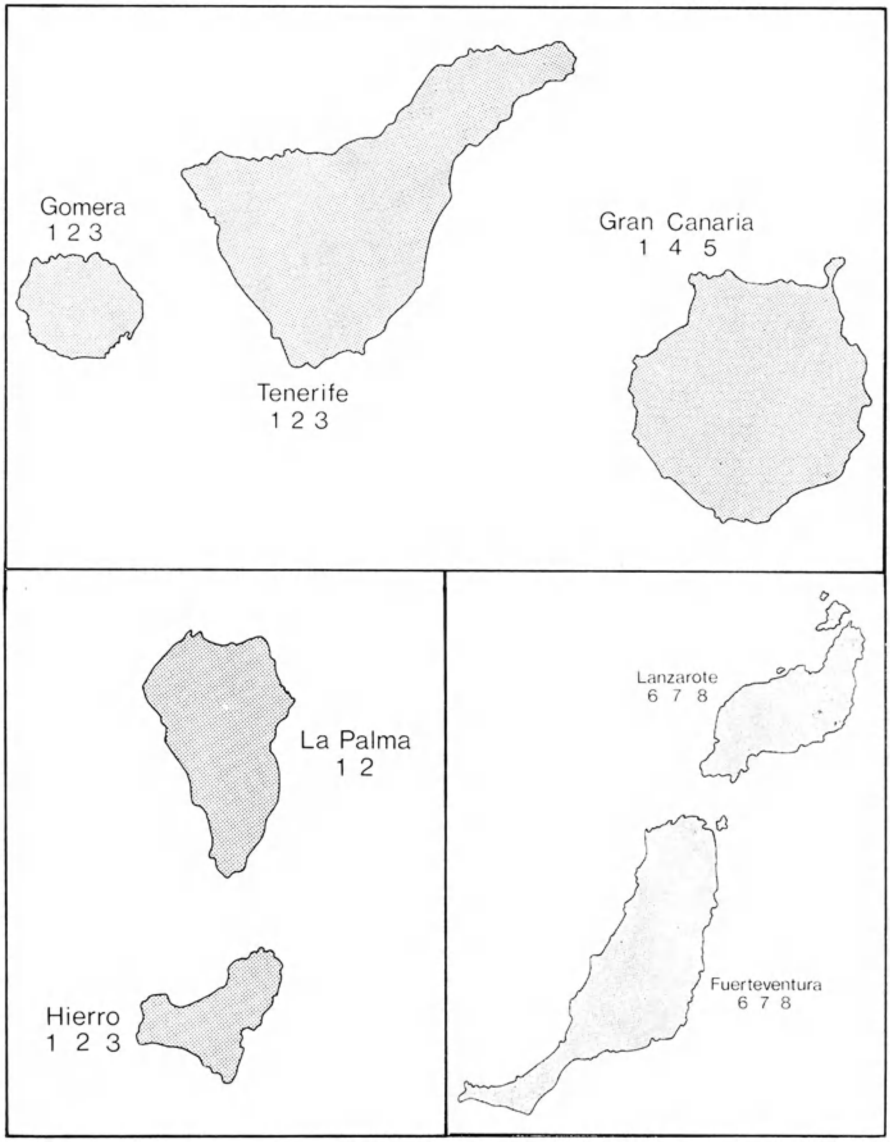

Fig. 1. Map of the Canary Islands, with the distribution of the reptile species indicated: 1: *Tarentola delalandii*, 2: *Lacerta galloti*, 3: *Chalcides viridanus*, 4: *Lacerta stehlinii*, 5: *Chalcides sexlineatus*, 6: *Tarentola mauritanica*, 7: *Lacerta atlantica*, 8: *Chalcides ocellatus*.

frog on these desertic islands could not be verified within the last decades. On the central and western islands of the Canaries, the marsh frog is very abundant wherever fresh water is available. This means that *Rana perezi* is common in cultivated land, mainly in banana plantations, where there are many irrigation tanks. It has been postulated that the marsh frog has been introduced on the Canary Islands by the first Spanish settlers coming from continental Spain. If so, the introduction has been successfully done in the 18th century or earlier.

Outside the Canary Islands, *Rana (ridibunda) perezi* is distributed on the Iberian Peninsula and in northwest Africa.

Reptilia

As a rule, all larger islands of the Canaries have an endemic representative of the reptile families Gekkonidae, Lacertidae, and Scincidae. There is only one notable exception of this rule as La Palma island lacks the scincid population. There are no snakes and no tortoises on the Canary Islands.

As all Canary reptiles have evolved endemic forms, mostly at species level, it is clear that the reptile populations are autochthon and passed a considerable time of evolution on the inhabited island. The Canarian lacertids and scincids are already known as fossils from volcanic tuffs of probable pleistocene origine.

FAMILY: GEKKONIDAE

Macaronesian wall gecko, *Tarentola delalandii*

1836 *Platydactylus delalandii* Dumeril & Bibron, Erpétol. génér., 3: 324. Paris. – Terra typica: Tenerife.
1845 *Tarentola delalandii* – Gray, Cat. Spec. Liz. Coll. brit. Mus.: 165. London.

Tarentola delalandii delalandii

1947 *Tarentola delalandii delalandii* – Loveridge, Bull. Mus. comp. Zool., 98: 331. Cambridge, Mass.

DESCRIPTION

A flat bodied lizard with adhesive pads at both fingers and toes, and with claws. Dorsal skin with enlarged tubercular scales among very small scales. Eyes snake-like, covered by the transparent fused lids. Tail easily autotomized, the missing tip is regenerating with uniform scalation.

Coloration usually pale, whitish, with very small darker spots. Belly white. The wall gecko has a remarkable ability to change its coloration. Specimens basking in the morning sun for getting warmed up can be nearly black in colour. In contrast, during the night the geckos are mostly chalky white. Head and body length is 140 mm or less.

BIOLOGY

The Macaronesian wall gecko is mainly nocturnal but regularly seen in day-time when basking in the sun. It is found in or near human settlements but also in the open country in rock crevices and under stones. Adult geckos occupy territories which are defended against intruders of the same species and sex. The geckos eat insects and spiders and therefore can be seen often near street lamps which attract nocturnal insects, mainly moths. The female lay two eggs glued to the rock in some suitable crevice. The eggs are hard-shelled and give rise to rather large young ones. The place for the deposition of the eggs is usually used by several females and for more than one reproductive season.

DISTRIBUTION

The subspecies *Tarentola delalandii delalandii* occurs on the western Canarian Islands, including Tenerife, and also on the smaller rocks and islets surrounding these islands. Thus, the subspecies is known from Tenerife and the nearby Roque de Fuera, from Gomera, La Palma, and Hierro and the islets Roques del Zalmor. On Tenerife, the gecko climbs up to 2000 m, living in some houses of the Cañadas.

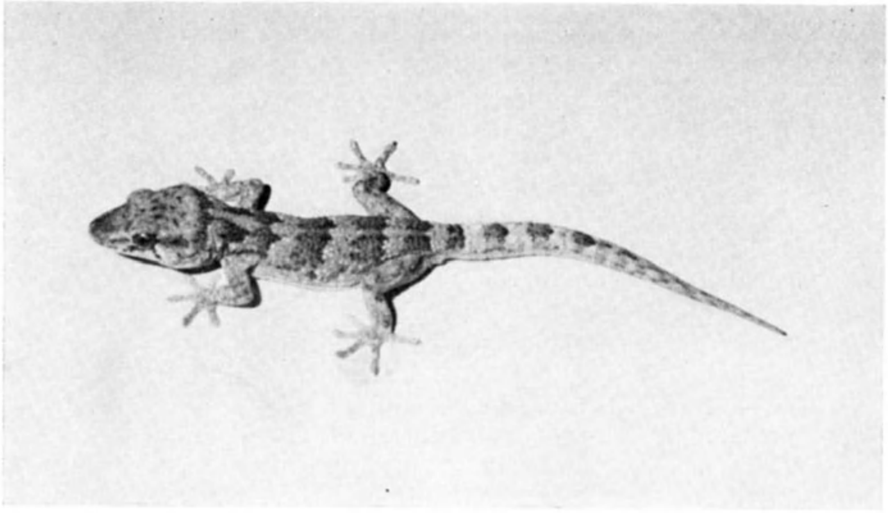

Fig. 2. Tarentola delalandii boettgeri, from Gran Canaria.

Tarentola delalandii boettgeri

1891 *Tarentola delalandii* var. *boettgeri* Steindachner, Ann. nat.-hist. Hofmus. Wien, 6: 301. – Terra typica: Gran Canaria.
1947 *Tarentola delalandii boettgeri* – Loveridge, Bull. Mus. comp. Zool., 98: 330. Cambridge, Mass.

Description

Similar to the nominate subspecies but distinguished by 16 to 18 rows of tubercular scales on the back instead of 12 to 14 as in *Tarentola delalandii delalandii.* The tubercles of the Gran Canaria gecko are less prominent than those of the western geckos.

Biology

Same as in *Tarentola delalandii delalandii.*

Distribution

The island of Gran Canaria, including La Isleta. Outside the Canary Islands, *Tarentola delalandii* is inhabiting (with other subspecies) the Cabo Verde Islands, the Salvages, and Madeira, on the last two island groups most probably introduced.

Mediterranean wall gecko, *Tarentola mauritanica angustimentalis*

1891 *Tarentola mauritanica* var. *angustimentalis* Steindachner, Anz. Akad. Wiss. Wien, math.-naturwiss. Kl., 28: 144. – Terra typica: Fuerteventura.

Description

Very near to the continental *Tarentola mauritanica* and similar to the Macaronesian wall gecko. The tubercular scales are arranged in only 5 to 6 rows, much more pointed than in *Tarentola delalandii* but less rugose than in continental *Tarentola mauritanica.* Head and body length up to 160 mm, the island geckos usually smaller.

Biology

Essentially the same as in *Tarentola delalandii*, probably more anthropochore than this species. *Tarentola mauritanica* could not penetrate into the desertic regions of Lanzarote and Fuerteventura but could reach the smaller islands of Graciosa and Allegranza and establish thriving populations there.

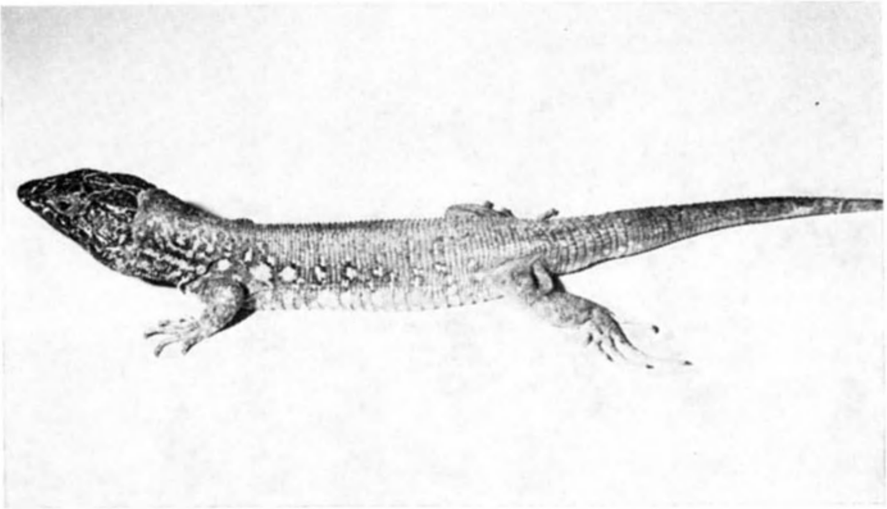

Fig. 3. Lacerta atlantica, ♂, from Lanzarote.

DISTRIBUTION

The eastern Canarian islands of Lanzarote, Fuerteventura, Graciosa, and Allegranza. The subspecies is restricted to these islands.

Outside the Canaries, *Tarentola mauritanica* has a very wide distribution, living in nearly all circum-mediterranean countries and in northwest Africa, south to the central Sahara.

FAMILY: LACERTIDAE

Purpurarian lizard, *Lacerta atlantica*

1882 *Lacerta atlantica* Peters & Doria, Ann. Mus. Genova, 18: 433. – Terra typica: Lanzarote.

DESCRIPTION

The smallest of the Canarian lacertid species, males reaching head and body length of 240 mm. Lizard-like, with a rather high head, well developped limbs, movable eye-lids, sunk but visible tympanum, tail – if not regenerated – longer than head and body.

The coloration of adult males is dark, nearly blackish, the lighter supraocular stripes usually visible. The flanks show large, bright blue spots, the mid-dorsal stripe some lighter, mostly greenish tint. Throat and collar are bluish grey, the belly dark. Female and young Purpurarian lizards are less dark in their general coloration, the longitudinal light stripes are clearly visible.

Biology

This Canarian lizard species is adapted to the most arid conditions of the eastern group of islands, named the Purpurarian. They are living in all parts of these islands having at least a sparse vegetation. Only the fresh lava fields cannot be inhabitated by the Purpurarian lizard. The lizard populations are remarkably less dense than those of *Lacerta galloti* of Tenerife. As in all Canarian lacertids an important part of their food consists of vegetables, mainly fruits and seeds of different grass species. Besides these vegetables, also insects, snails, worms, birds' eggs, and other smaller vertebrates are taken as food. Even carrion and garbage is taken. Those food resources help establishing the largest lizard populations near the rubbish dumps of the islands' villages.

There is very little known on the reproduction of *Lacerta atlantica.* Females produce rather small clutches of three to four eggs twice a year. The young lizards get sexual mature in their second year.

As in all Canarian lacertid species, *Lacerta atlantica* utters a faint, high pitched squeek when taken or when attacked by a predator. This sound plays a role also in the intraspecific communication, probably in saving the young lizards from being eaten by the adults.

Distribution

Lacerta atlantica is inhabiting all the islands of the western group, namely Lanzarote, Fuerteventura, Graciosa, Allegranza, Lobos, Montaña Clara, and even the steep rocks of Roque del Infierno and Roque del Este, on this last island living together with a breeding colony of *Falco eleonorae.*

Canarian lizard, *Lacerta galloti*

Lacerta galloti galloti

1839 *Lacerta galloti* Dumeril & Bibron, Erpét. génér., 5: 238. Paris. – Terra typica: Tenerife.

1914 *Lacerta galloti galloti* – Boettger & Müller, Ann. Mag. nat. Hist., (8) 14: 68. London.

Description

A stout, heavily built lizard of very dark, in adult males even black coloration. Males reaching 350 mm total length and 150 mm head and body length.

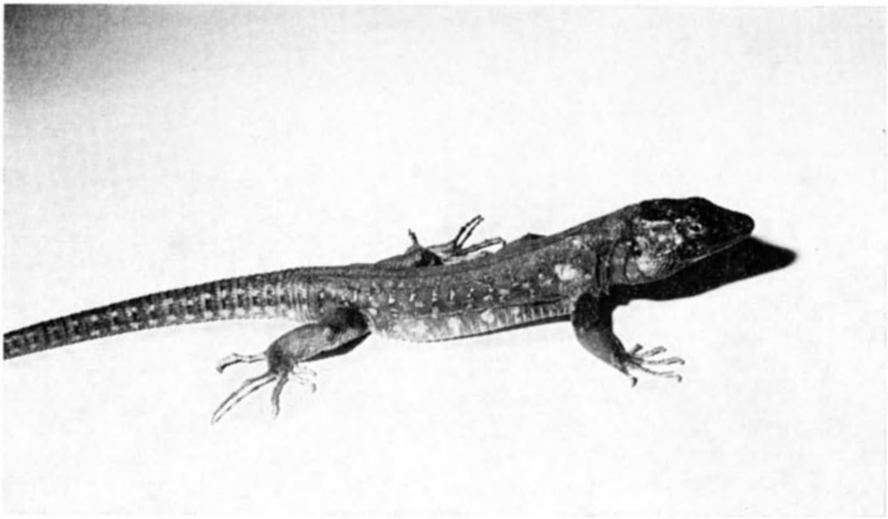

Fig. 4. Lacerta galloti galloti, ♂, from Tenerife.

Fig. 5. Lacerta galloti galloti, ♀, from Tenerife.

Male lizards are dark, usually blackish, with ocellated spots across the body. This ocellation is blue at the flanks and green on the dorsum. The spots may form transversal bars. Throat and venter are also dark with bluish tint. Females and young ones are usually brown in dorsal coloration, some lighter longitudinal stripes visible. Most impressive is the light coloured, silvery to yellow iris of *Lacerta galloti galloti*, giving this lizard a piercing appearance. The age and sexual polymorphism in this lizard species is enormous, giving many visitors the impression that Tenerife is inhabited by more than one lacertid species.

BIOLOGY

Lacerta galloti galloti is very adaptable to different factors, thus making good use of plantations and settlements of man. They eat plant stuff, fruits and seeds of many kinds, even hay and dried leaves. The damage done by this lizard to vinyards and tomatoe plantations is usually much exaggerated. Nevertheless is the lizard killed in the fields and poisoned by baits made of tomatoe or fruit ketchup with strychnine added. In every pharmacy are those dangerous venoms offered for sale to everybody. Besides plant material also animals are taken as food, mainly worms, slugs, and snails, much less insects as grass-hoppers and beetles. Also carrion is eagerly eaten.

Adult Tenerife lizards are very shy and difficult to approach in the field. They flee under thorny bushes or in rock crevices. Like *Lacerta atlantica* they can squeek.

DISTRIBUTION

This subspecies has a range covering the whole island of Tenerife and its costal islots. It is known from the Roques de Anaga and from the Roque del Fuera. On Tenerife, *Lacerta galloti galloti* climbs up to the flanks of Teide mountain, it has been found there in an altitude of 3200 m.

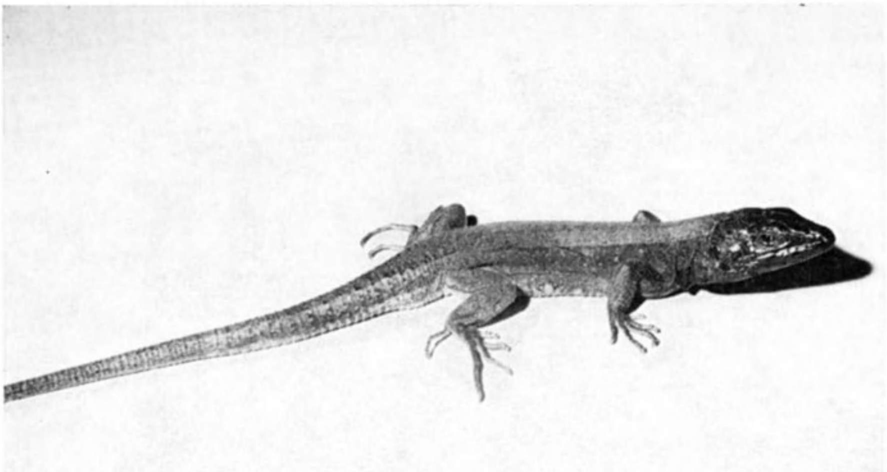

Fig. 6. Lacerta galloti caesaris, ♂, from Hierro.

Lacerta galloti gomerae

1914 *Lacerta galloti gomerae* Boettger & Müller, Ann. Mag. nat. Hist., (8) 14: 72. London. – Terra typica: Gomera.

DESCRIPTION

Similar to *Lacerta galloti galloti* but smaller in size, males black with much less blue or green spots, those never in transverse rows. Maximum head and body length in males 110 mm. Females and young ones greyish or reddish brown, longitudinal bands and stripes mostly apparent. Sexual dimorphism is very strong also in this subspecies.

BIOLOGY

There is very little known on the biology and reproduction of the Gomera lizard. Most probably, the data referred to the Tenerife lizard are applicable also for this subspecies.

DISTRIBUTION

The island of Gomera for which this subspecies is endemic. The whole island is populated by this lizard except the dense laurisilva forests which are too shadowy on the forest floor to provide suitable habitats for *Lacerta galloti gomerae*.

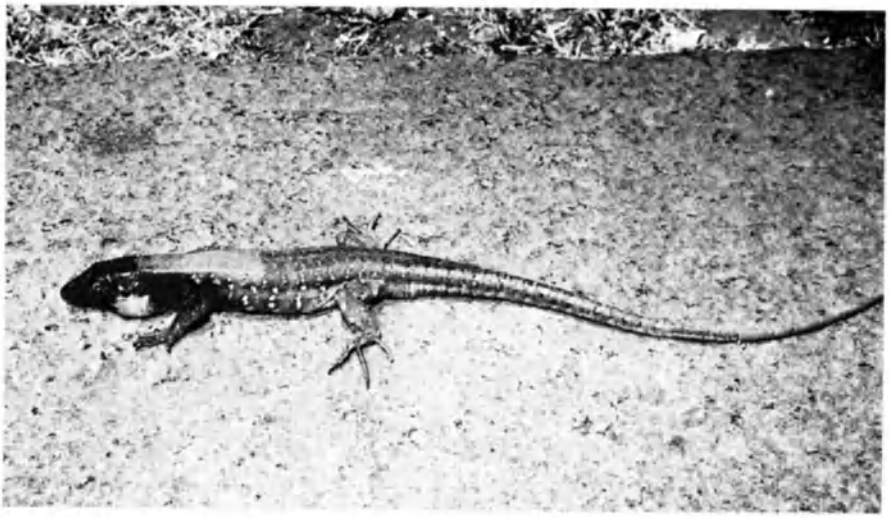

Fig. 7. Lacerta galloti palmae, ♂, from La Palma.

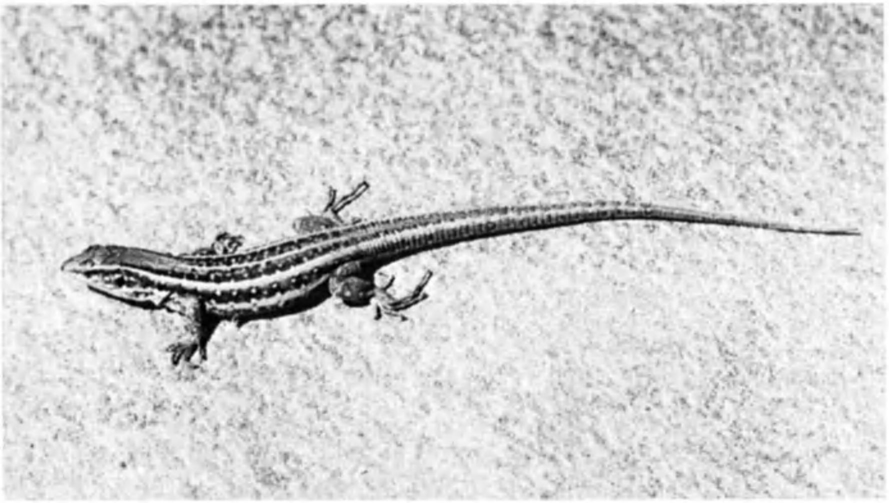

Fig. 8. Lacerta galloti palmae, ♀, from La Palma.

Lacerta galloti palmae

1914 *Lacerta galloti palmae* Boettger & Müller, Ann. Mag. nat. Hist., (8) 14: 71. London. – Terra typica: La Palma.

DESCRIPTION

In size intermediate between *Lacerta galloti galloti* and *Lacerta galloti gomerae*, *Lacerta galloti palmae* is easily recknognized by the bright blue sides of the head in male animals. They always lack the transverse bars of the Tenerife lizard, they are instead dark brown with a bluish hue. The head, except its sides, the neck and the anterior portion of the body are deep black. To the tail, the coloration gets gradually lighter. Female and young animals are of a lighter brown ground coloration, lacking the bright blue sides of the head.

BIOLOGY

Exact data for the biology of the La Palma lizard are not known. The general data given for the other subspecies are probably also true for this lizard. As far as known, six eggs are produced in a single clutch, smaller females producing less eggs. The most dense lizard populations have been observed in this subspecies. In the fields and meadows above El Paso on La Palma, checking this population resulted in an estimate of one lizard per 4 m^2. Even in such dense populations, at least males keep a territory and defend it against other males, a territory much smaller than the food range of an individual.

DISTRIBUTION

The whole island of La Palma except the recent lava fields and the dark laurisilva forests on the north-east slopes of the island.

Lacerta galloti caesaris

1914 *Lacerta caesaris* Lehrs, Proc. zool. Soc. London, 134: 681. – Terra typica: Hierro.
1914 *Lacerta galloti caesaris* – Boettger & Müller, Ann. Mag. nat. Hist., (8) 14: 74. London.

DESCRIPTION

The smallest and most melanistic subspecies of *Lacerta galloti*, males not reaching a head and body length of more than 90 mm. Males usually black with only a few blue dots on the flanks, getting a little bit lighter in coloration in the posterior portion of the body and on the tail. Also throat and belly is completely black. Female and young Hierro lizards more brownish with narrow longitudinal light stripes.

BIOLOGY

Same as in the preceding subspecies. The Hierro lizard is probably more foraging between the rocks of the sea shore than the other subspecies, looking there for *Ligia* and other suitable food. The number of eggs

Fig. 9. Lacerta stehlinii, ♂, from Gran Canaria.

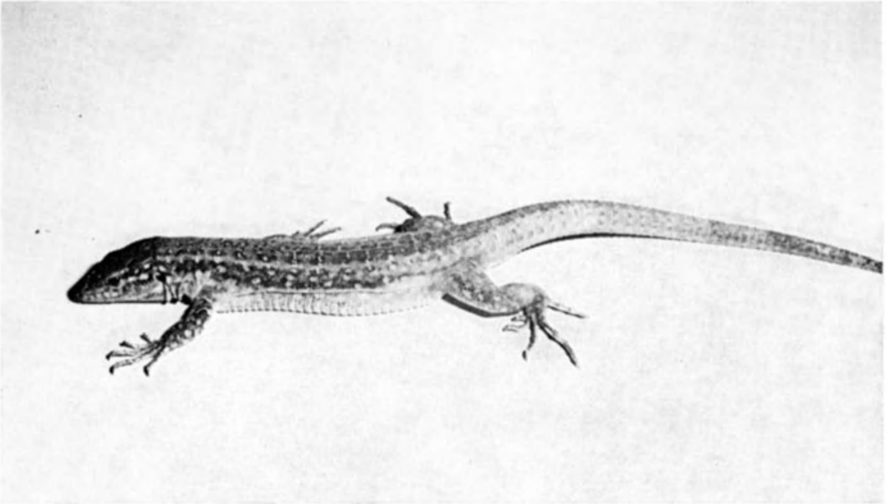

Fig. 10. Lacerta stehlinii, ♀, from Gran Canaria.

produced by this subspecies is not known but most probably smaller than in the larger subspecies of *Lacerta galloti.*

DISTRIBUTION

The island of Hierro and the larger of the Roques del Zalmor.

Gran Canaria giant lizard, *Lacerta stehlinii*

1901 *Lacerta galloti* var. *stehlinii* Schenkel, Verh. naturforsch. Ges. Basel, 13: 187. – Terra typica: Gran Canaria.
1909 *Lacerta stehlinii* – Lehrs, Zool. Jb., Syst., 28: 12. Jena.

DESCRIPTION

Largest of the recent Canarian lizard species, reaching a total length of 800 mm and a head and body length of 250 mm in adult males. In *Lacerta stehlinii*, there is no tendency for melanism in its coloration, adult animals usually being uniform brown with a yellowish tint. Young lizards are blotched, showing a pattern of lighter and darker brown blotches with the white supraocular line, though sometimes interrupted, quite conspicuous. Throat and sides of neck of a more or less bright yellow, belly brownish.

BIOLOGY

Due to its strength and body size, *Lacerta stehlinii* is a predacious animal, hunting for every smaller vertebrate which can be overcome. It also takes fruits and carrion as food. Because of its eating tomatoes, the Gran Canaria lizard is also poisoned like *Lacerta galloti galloti* on Tenerife. *Lacerta stehlinii* is rather common on Gran Canaria but due to its shyness not so easily seen. It lives in and near villages, even in the city parks of Las Palmas, where it is abundant again near the garbage dumps. But *Lacerta stehlinii* can also be found far away from human settlements in the mountains of Gran Canaria, but less frequent there than near villages where the food resources are apparently much better.

The female produce up to 12 eggs in one clutch, they need about two months until the young hatch. The young are adult within their fourth year of life. Like in all reptiles, old specimens of *Lacerta stehlinii* can grow to remarkable size and weight.

DISTRIBUTION

Lacerta stehlinii is endemic for Gran Canaria and distributed on the whole island up to the summit of Pozo de las Nieves at 1950 m. The lizard is not known from the small costal islands around Gran Canaria but there is a large lizard population on the peninsula of La Isleta.

†*Zalmore giant lizard*, *Lacerta simonyi*

1889 *Lacerta simonyi* Steindachner, Anz. Akad. Wiss. Wien, math.-naturwiss. Kl., 26: 260. – Terra typica: Roques del Zalmor, off Hierro.

DESCRIPTION

This extinct lizard is similar to *Lacerta stehlinii* from Gran Canaria, of about the same measurements, but has in contrary to this species a row of broad yellow spots along the sides of head and body. Otherwise, *Lacerta simonyi* is of dark brown, the limbs and the tail becoming a little lighter in coloration.

BIOLOGY

Nothing is known of the biology of this giant lizard known only from the Roques del Zalmor, off the north coast of Hierro. It is difficult to imagine how such a large and heavy lizard could survive on an islet of a few hundred m² surface. There are breeding sea birds and a breeding pair of the osprey *(Pandion haliaetus)* on the Roques but the food resources seem to be extremely limited for such a lizard.

DISTRIBUTION

Known with certainty only from the Roques del Zalmor until the thirties of this century. The latest record is probably a stuffed specimen kept at

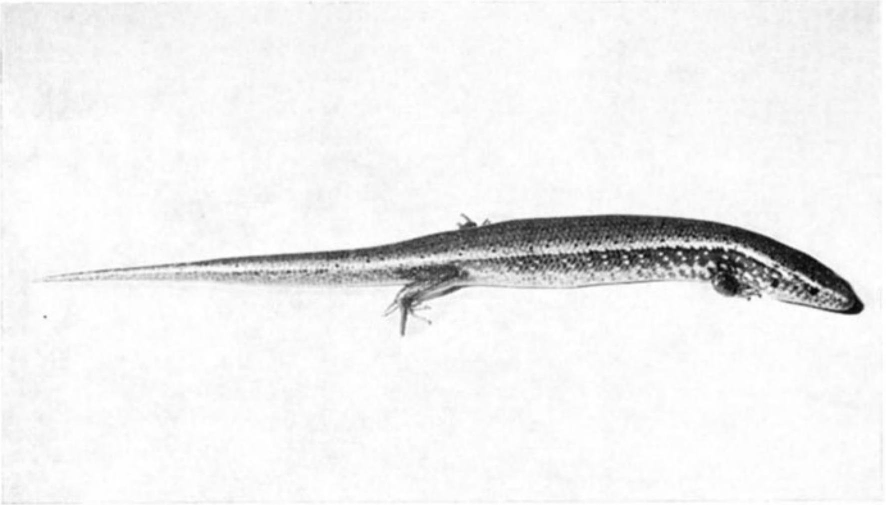

Fig. 11. Chalcides sexlineatus, from Gran Canaria.

the Museo Arqueológico at Santa Cruz de Tenerife, said to be collected during World War II and kept for a few years by a man on Tenerife. Later visits of Hierro and the Roques del Zalmor, also by the author, revealed no trace of *Lacerta simonyi,* neither on Hierro nor on the Roques. The larger of the Roques del Zalmor is instead inhabited by *Lacerta galloti caesaris* and by *Tarentola delalandii delalandii.* The people of Hierro speak very much of a large lizard, called 'lagarto perro', occurring there and on the Roques but nobody could show even a trace of a big lizard. *Lacerta simonyi* is therefore regarded as extinct and included in this report only for comparison.

FAMILY: SCINCIDAE

Purpurarian skink, *Chalcides ocellatus occidentalis*

1891 *Chalcides simonyi* Steindachner (nec *Chalcides viridanus* var. *simonyi* Steindachner 1891), Ann. naturhist. Hofmus., 6: 299. Wien. – Terra typica: Fuerteventura.

1900 *Chalcides ocellatus* var. *occidentalis* Steindachner (nomen novum pro *Chalcides simonyi* Steindachner, 1891), Denkschr. Akad. Wiss., math.-naturwiss. Cl., 69: 331. Wien.

1946 *Chalcides ocellatus occidentalis* – Bertin, Mém. Soc. Biogéogr., 8: 94. Paris.

DESCRIPTION

A fat, round glossy lizard with small, but well developped limbs, the hind leg in length being one fourth of the length of head and body. Tail shorter than head and body. Snout rounded, the mouth being slightly set back on the underside. Scales uniform. imbricate, smooth and glossy. Total length up to 250 mm.

Coloration brownish with many dark brown and whitish small spots. the light spots can be arranged in obscure longitudinal bands. Belly white. No sexual dimorphism, also the young ones have the same coloration as the adults but a reddish to yellowish tail.

BIOLOGY

This terrestrial lizard is mostly borrowing in the soil and not too much seen on the surface. They usually come out only in the early morning to warm up immediately in front of their hole. They are completely carnivorous eating any small invertebrates, mainly snails, caterpillars and worms. Like many other skink species, *Chalcides ocellatus occidentalis* is giving birth to live young ones, usually four.

DISTRIBUTION

Known only from Lanzarote and Fuerteventura, but not from the smaller islands of the eastern, Purpurarian group of the Canary Islands.

Gran Canaria skink, *Chalcides sexlineatus*

1891 *Chalcides viridanus* var. *sexlineata* Steindachner, Ann. naturhist. Hofmus., 6: 298. Wien. – Terra typica: Caldera de Tirajana, Gran Canaria.
1914 *Chalcides sexlineatus* – Boettger & Müller, Ann. Mag. nat. Hist., (8) 14: 76. London.

DESCRIPTION

Smaller and thinner than preceding species with slender, cylindrical body, the head scarcely set off from neck and body. The limbs short and weak, used only in slow locomotion.

The back is brownish with light spots arranged in longitudinal rows. The flanks are blackish brown, separated from the dorsum by a light supraocular line, bordered with black. The lower flanks show a 'pepper and salt' coloration, the lower surface is yellowish, often greenish white with many small grey dots on the belly. The is usually ochraceous yellow.

Total length less than 120 mm.

BIOLOGY

The Gran Canaria skink lives secretive in the gardens, irrigated fields,

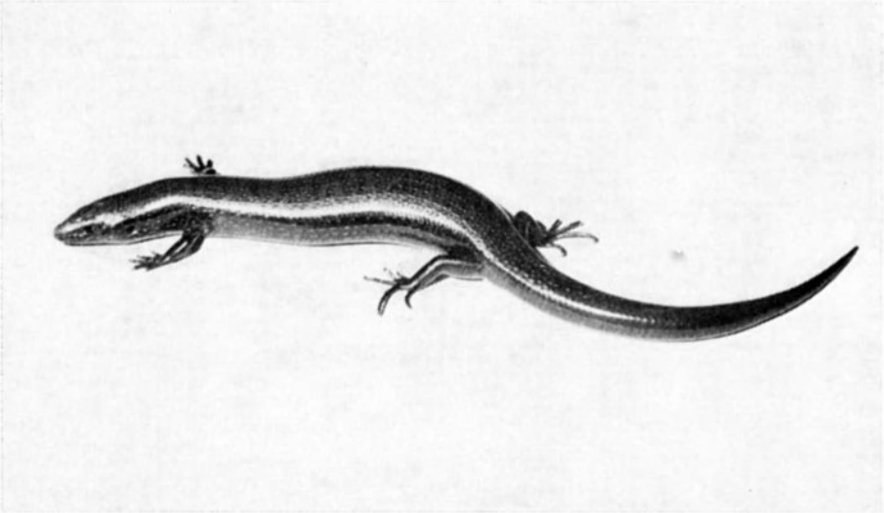

Fig. 12. Chalcides viridanus, from Hierro. All photographs of live specimens by author.

even in houses, but also far from human agriculture in the mountains where it can be found under stones and in rock crevices. Little is known of its biology but it is also eating small insects, molluscs, spiders, and worms. *Chalcides sexlineatus* is also ovoviviparous, giving birth to two young ones, then having already have the length of the mother. The bright coloration of the tail of the young ones is said to be a warning signal against being preyed upon by the adult skinks.

Distribution

The island of Gran Canaria from the sea shore to the top of the mountains; endemic species for this island.

Canarian skink, *Chalcides viridanus*

1851 *Gongylus viridanus* Gravenhorst, Verh. k. leop.-carol. Akad. Naturforsch., 15: 348. Breslau. – Terra typica: Tenerife.
1887 *Chalcides viridanus* – Boulenger, Cat. Lizards brit. Mus. nat. Hist., 3: 402. London.

Description

Similar in shape and size to the preceding species, but with the upper side of head and body of a warm brown, slightly olive, with apparent metal gloss. The sides and flanks are black, with a sharp line between these two ground colours. The lower side is also dark grey or black. In the adults, the tail is usually regenerated and also brownish black, in young ones instead with a bright bluish-green tint. Completely melanistic specimens occur rather often, especially on Gomera.

BIOLOGY

Wide-spread and rather unspecialized in its habitat, *Chalcides viridanus* can be found in nearly every niche on the inhabited islands, except within the dense laurisilva forests. As the other skink species it eats small invertebrates. The female produce usually two young ones.

DISTRIBUTION

Recorded from Tenerife from the sea shore to the Cañadas at 2800 m altitude, from Gomera and Hierro. It is also known from Roque del Fuera, off Tenerife. It is curious to observe that there is no representative of the family Scincidae on the island of La Palma, the only exception of the rule that all larger Canarian islands have a gekkonid, lacertid, and scincid species each.

Remarks on the Biogeography of the Canarian Herpetofauna

The amphibians and the reptiles are but poorly represented on the Canary Islands, an observation characteristic for oceanic islands far from the continents. If we exclude the marsh frog as probably introduced to the Canaries, there are just one representative of four herptile families present on the seven large islands of the Canaries: a hylid, a gekkonid, a lacertid, and a scincid species. *Hyla meridionalis* has a wide range covering the whole western Mediterraneis including north-west Africa and the Canaries, thus being the only Canarian herptile not endemic for this group of islands. In contrary, all Canarian reptile forms are endemic within subspecies or species level, either for the group of islands or for the inhabited island only. This means that the Canarian reptiles must have passed a considerable way of their evolution on these islands from the time of invading the Canaries until nowadays.

The systematic relationships of the Canarian amphibians and reptiles clearly point to the western Mediterraneis where the nearest related congeners are still living. The Canarian geckos belong to the *Tarentola mauritanica* species group, the Canarian lacertids to the subgenus *Timon* with *Lacerta lepida* as the only continental species of this subgenus, the Canarian skinks to the *Chalcides ocellatus* species group with several continental species in the southwestern Palearctis. There are no biogeographic relationships to the New World fauna across the Atlantic Ocean and there are very little reasoning for establishing a special Macaronesian sub-zone including the Canaries, Madeira and the

Salvages Islands, the Cabo Verde Islands and probably a narrow costal zone of northwest Africa, characterized by the range of *Argania spinosa.* Within the reptiles, only the range of the gecko species *Tarentola delalandii* could be considered in this respect, a range covering the central and western Canarian Islands and all Cabo Verde Islands. The species is not known on the continental Africa but replaced there by other *Tarentola* species.

The occurrence of only one species per family on all Canarian Islands – the exception on La Palma where the scincid species is missing has already been discussed – makes it easy to consider that also only one invador species managed it to get to the islands and to occupy successfully the open niches. This hypothesis is supported by the observation that the western Canarian Islands, situated farther from the continent show the endemics of higher level. For example, the skink species *Chalcides sexlineatus* and *Chalcides viridanus* of Gran Canaria and of Tenerife, Gomera, and Hierro respectively are well characterized endemics whereas the skink species of Lanzarote and Fuerteventura, *Chalcides ocellatus*, has a wide range on the continent.

The picture gets more complicated when the lacertid species are studied more in detail. All Canarian species are well characterized endemic forms easily arranged in two species groups, the smaller, more generalized species *Lacerta galloti* and *Lacerta atlantica*, and the larger species *Lacerta stehlinii* and *Lacerta simonyi.* Character analysis and pattern support this grouping. Doing so the geographical distribution of the *Lacerta simonyi stehlinii* species group on the Roques del Zalmor and on Gran Canaria is difficult to understand as the islands in between are occupied by *Lacerta galloti.* For the Canarian lacertids, it is therefore obvious to propose two ancestor species colonizing the Canarian islands at different times, that of the *Lacerta simonyi stehlinii* species group being the older, that of the *Lacerta galloti atlantica* species group being the younger invador of the islands. The findings of fossil or subfossil lizard skulls on Tenerife and Gran Canaria, skulls rather similar, even larger than those of *Lacerta simonyi* and *Lacerta stehlinii* made it sure that representatives of these large lizards were also living at least on Tenerife. The findings of fossil tortoises and of a fossil mouse *(Canariomys bravoi)* explains that the Canarian fauna was probably much richer in species than today. The extinction of so many endemic vertebrate species may be due to the reduction of suitable habitats and food resources by volcanic activity and lately also by the activities of man.

Insular species living on a rather restricted range are very sensitive against any deterioration of their biotope. As insular species have less enemies than continental ones their reproductive rate is usually low and critical population densities are easily ending in the extinction of the species.

Summary

The Amphibia are represented on the Canary Islands by two species only (*Hyla meridionalis* and *Rana perezi*), the terrestrial Reptilia by eight species. Each of the larger islands has a scincid species (*Chalcides viridanus* on the western islands, *Chalcides sexlineatus* on Gran Canaria, *Chalcides ocellatus* on the eastern islands), a lacertid species (*Lacerta galloti* on the western islands, *Lacerta stehlinii* on Gran Canaria, *Lacerta atlantica* on the eastern islands), and one gekkonid species (*Tarentola delalandii* on the western islands including Gran Canaria, *Tarentola mauritanica* on the eastern islands). There is an exception of this rule as there is no scincid species on La Palma island. *Lacerta simonyi* from the Roques del Salmor, off Hierro, is extinct since at least 20 years, its occurrence on Hierro could not be proved.

The Canarian amphibians and reptiles, though half of the number of species are Canarian endemics, show clear zoogeographic relationships to the west Mediterranean fauna of Northwest Africa and the Iberian Peninsula. Except for *Tarentola delalandii*, there are no relationships to the herpetofaunas of the other Atlantic islands.

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XVI. AN ACCOUNT OF THE LIMNETIC FAUNA OF THE CANARY ISLANDS

Water Flea (Cladocera) and Webbed Foot Crab (Copepoda) from Tenerife and their Distribution in North and West Africa.

by

PETER RÖBEN

Abstract

Whilst Insects and Birds of the Canary Islands have been extensively studied, other groups, particularly of the subsoil and freshwater fauna have, as yet, been only very little explored. For an enumeration of the latter, 23 water samples from different regions of Tenerife Island were examined for Crustaceans. 4 Cyclopoid and 9 Cladoceran species were found, 5 of the latter being hitherto unknown on the Canary Islands, and one further species being new for Tenerife. The Canarian Crustacean fauna shows clear relations to that of Africa, particularly to the northwest. Nevertheless, on account of the fact that certain developing stages are easily distributed, no conclusions about former land bridges may be drawn from this. True subsoil water fauna is poorly developed on Tenerife Island due to the extreme perviousness of the soil.

Introduction

Since Richard (1898) published a short report on the collections of C. Alluaud and E. Chevreux, there have been, besides the notice of two Harpacticoidea by Noodt (1955) and the description of two new species of the genus *Parastenocaris* (Harpacticoidea) by Schminke (1971), no limnological investigations of the Crustacean fauna of the Canary Islands. Lundblad (1962) reported upon Water mites from the Canary Islands, for the rest the limnetic fauna is so far completely unexplored. A series of plankton samples, which were collected at various locations on Tenerife Island in 1970/71, produced a noticeable expansion of the species lists of this island. Calanoida do not occur on Tenerife; Harpacticoida were not included in the following investigation.

The amount of precipitation in the northern and northwestern parts of the island is quite considerable – not least from the condensation from the trade-wind clouds, especially in places with a suitable thick vegetation. However, permanent natural accumulation of water is lacking due to the highly permeable upper layers of soil. On the other hand, the countless artificial water tanks, which serve primarily the irrigation of banana plantations, provide good possibilities for sample-taking. With one exception (No. 20), these water tanks are small bodies of water with maximum length around 15 m. The tanks found to be especially rich in life were those with little or no waterflow as a consequence of the disuse of the corresponding plantation.

LOCATIONS OF SAMPLE GATHERINGS (Fig. 1.)

1. (Dec. 26, 1970): Outlet of the galeria 'El Pinalete', about 1 km west of La Guancha. 19 °C; pH 7; 9° dH[1]. No Crustaceans.
2. (Jan. 1, 1971): stagnant, very muddy part of an irrigation canal about 2 km southwest of La Guancha. A* a few m², D* maximum 40 cm; 21 °C; pH 6; 11° dH.

Eucyclops serrulatus, *Paracyclops fimbriatus*

3. (Jan 1, 1971): Spring coming out of a rock, which however, judging from the composition of plankton, originates from surface water. About 2 km west of Icod de los Vinos. 17.5 °C; pH 6.5; 8.5° dH.

Alona tenuicaudis, *Chydorus sphaericus*; *Eucyclops serrulatus*

4. (Jan 1, 1971): moss and algae pad on a rock under this spring.

Alona tenuicaudis

5. (Dec 28, 1970): Water tank about 0.5 km east of Buenavista. A appr. 10 × 15 m, D about 2.5 m.; 16.2 °C; pH 7; 33° dH.

Ceriodaphnia dubia; *Acanthocyclops robustus*

6. (Dec 28, 1970): unused double water tank about 0.5 km south of Buenavista. A appr. 10 × 10 m and 4 × 10 m respectively, D appr. 3 m; 15.5 °C; pH 7; 16° dH.

Daphnia sp. (ephippia); *Acanthocyclops robustus*

7. (Jan 1, 1971): Water tank about 2 km south of Buenavista. A appr. 6 × 6 m., D appr. 3.5 m; 16.5 °C; pH 6; 6° dH.

Ceriodaphnia dubia; *Acanthocyclops robustus*

8. (Jan 1, 1971): Water tank directly adjacent No 7. A appr. 5 × 5 m, D appr. 3.5 m; 16 °C; pH 6; 6° dH.

Daphnia carinata; *Acanthocyclops robustus*

9. (Jan 4, 1971): shallow water pool, very rich in sediment, of about 50 m² surface area in the Llano de Ucanca at 2015 m a.s.l. (depression

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[1] dH° - total hardness; A-surface area; D-depth of water.

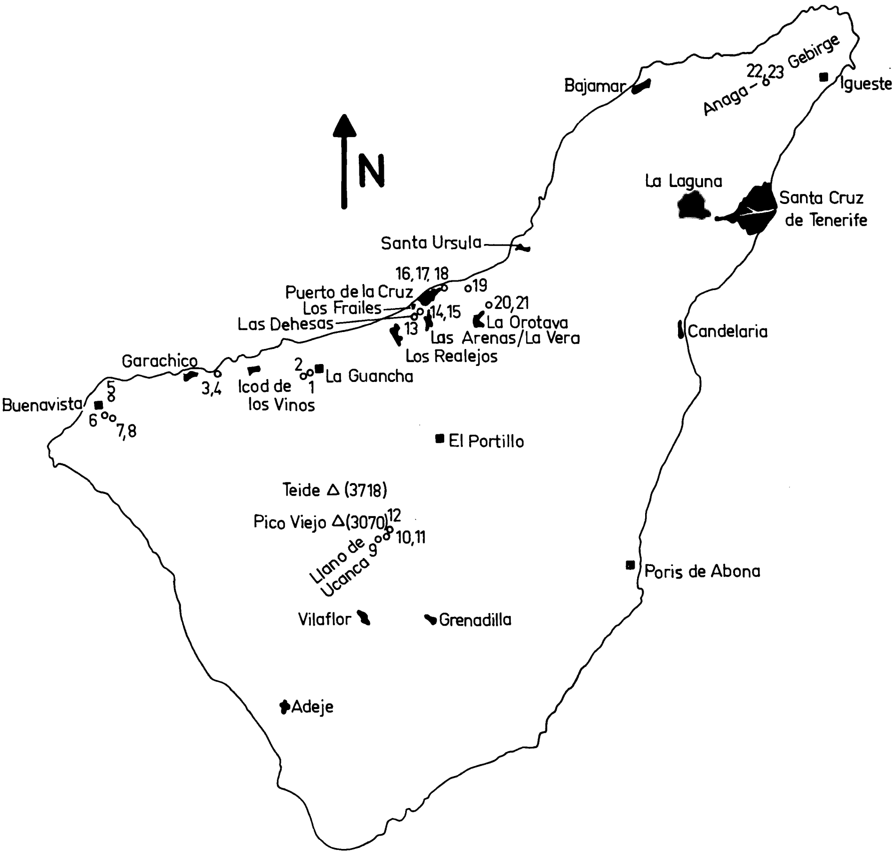

Fig. 1. Positions of sample-taking locations on Tenerife Island.

south of Pico Viejo). The ephemere waters (14.8 °C, pH 5, 1° dH) had accumulated in the otherwise arid depression through the melting of a large amount of snow which had fallen just a few days earlier.

Remains of *Acanthocyclops robustus* of uncertain origin (displacement by water birds?)

10. (Jan 4, 1971): Well on the eastern edge of the Llano de Ucanca at about 2050 m a.s.l.; 10.5 °C; pH 5.5; 1° dH.

The Trichoptera larvae and Chironomid larvae as well as Tardigrads and Ostracods which were found in the samples indicate that the well is fed by a canalized creek or river. No Cladocera or Copepoda.

11. (Jan 4, 1971): Moss and blue algae growths on a rock neighboring the well.

No Crustaceans.

12. (Jan 4, 1971): Pool with weak current along a small stream on the 'blue rocks' (Los Azulejos) between Llano de Ucanca and the Cañadas at 2100 m a.s.l.

No Crustaceans.

13. (Dec 27, 1970): Water tank near Las Dehesas. A appr. 10 × 12 m, D appr. 2m; 18 °C; pH 7; 9 °dH.

Undeterminable juvenile Cyclopoids and nauplia.

14. (Dec 31, 1970): Water tank east of Las Dehesas. A appr. 5 × 10 m, D appr. 2m; 17.5 °C; pH 7; 10 °dH.

Strong *Gambusia* occupation. Consequently very little plankton development.

Macrothrix laticornis; *Alona tenuicaudis*; *Chydorus sphaericus*; *Tropocyclops prasinus*.

15. (Dec 31, 1970): Tributary of 14; 17.5 °C, pH 7, 8 °dH.

Remains of *Eucyclops serrulatus*.

16. (Dec 30, 1970): Unused water tank east of Puerto de la Cruz (below La Paz), appr. 50 m up a steep slope above the seashore. A appr. 2 × 15 m, D appr. 2 m; 17 °C; pH 6.5; 7 °dH.

Ceriodaphnia dubia; *Eucyclops serrulatus*, *Tropocyclops prasinus*, *Paracyclops fimbriatus*

17. (Dec 30, 1970): Algae growth on wet rock and small pool of water about 50 m away from 16.

Paracylops fimbriatus

18. (Dec 30, 1970). Algae trickled over by water on the ceiling in a rock cavity about 50 m above 16.

Paracyclops fimbriatus
19. (Jan 2, 1971): Irrigation ditch on a banana plantation about 3 km east of Puerto de la Cruz. 17 °C; pH 6; 5 °dH.

Simocephalus vetulus; *Eucyclops serrulatus*, (?) *Tropocyclops* ♂, *Acanthocyclops robustus*
20. (Dec 27, 1970 and Jan 3, 1971): Reservoir northeast of La Orotava. A appr. 100 × 100 m, D appr. 10–12 m; 17° C; pH 7; 4.5 °dH.

Daphnia magna, *Ceriodaphnia dubia*, *Alona pulchella*, *Leydigia leydigii*, *Chydorus sphaericus*; *Acanthocyclops robustus*
21. (Jan 3, 1971): Tributary of 20 with strong current. 18.4 °C, pH 7, 3.7 °dH.

Indeterminable Cyclopoid nauplius
22. (Jan 3, 1971): Stream in the Anaga mountains (in the northeast of the island), about 1 km south of El Bailadero. 14.7 °C, pH 5, 7 °dH. Places with weak current were sampled.

Indeterminable juvenile Cyclopoid
23. (Jan 3, 1971): Moss lump near 22.
No Cladocera or Cyclopoida.

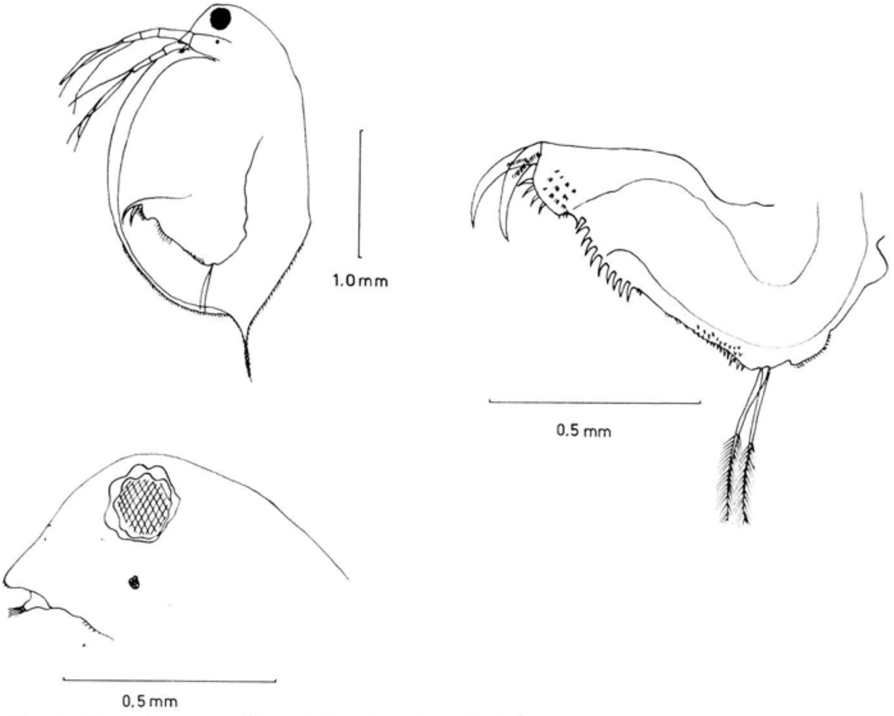

Fig. 2. Daphnia magna, ♀ total, head, and post-abdomen.

ENUMERATION OF SPECIES
(with remarks on their distribution in northern and western Africa)

Daphnia magna Strauss, 1820 (Fig. 2.)

The occurrence of *Daphnia magna* on Tenerife seems to be limited to a swamp, very large in proportion to the island's other water accumulations, located directly northeast of La Orotava. The total length of adults on the average was 3 mm. The distal section of the post-abdomen appears quite compact and bears 4 to 5 teeth.

Besides numerous finds in northern Algeria and Tunesia (Gauthier 1928 b; also Blanchard & Richard 1890 and Gurney 1909), this species, which is widespread in Europe, Asia, America and Africa, has also been found in southern Morocco, the closest land in the vicinity of the Canary Islands at many locations by Brehm (1954 b). Gauthier (1929 b) and Lepiney (1961) found *Daphnia magna* in the more northern areas of Morocco. Evidence for the central Sahara was produced by Brehm (1934).

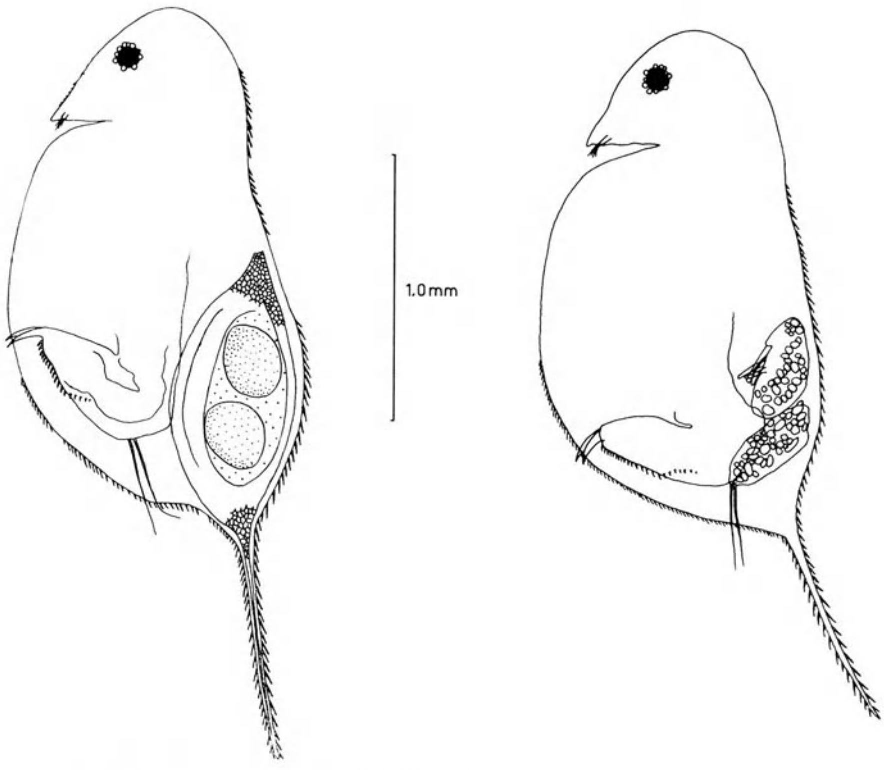

Fig. 3. Daphnia carinata, ephippia-bearing and partheno-♀.

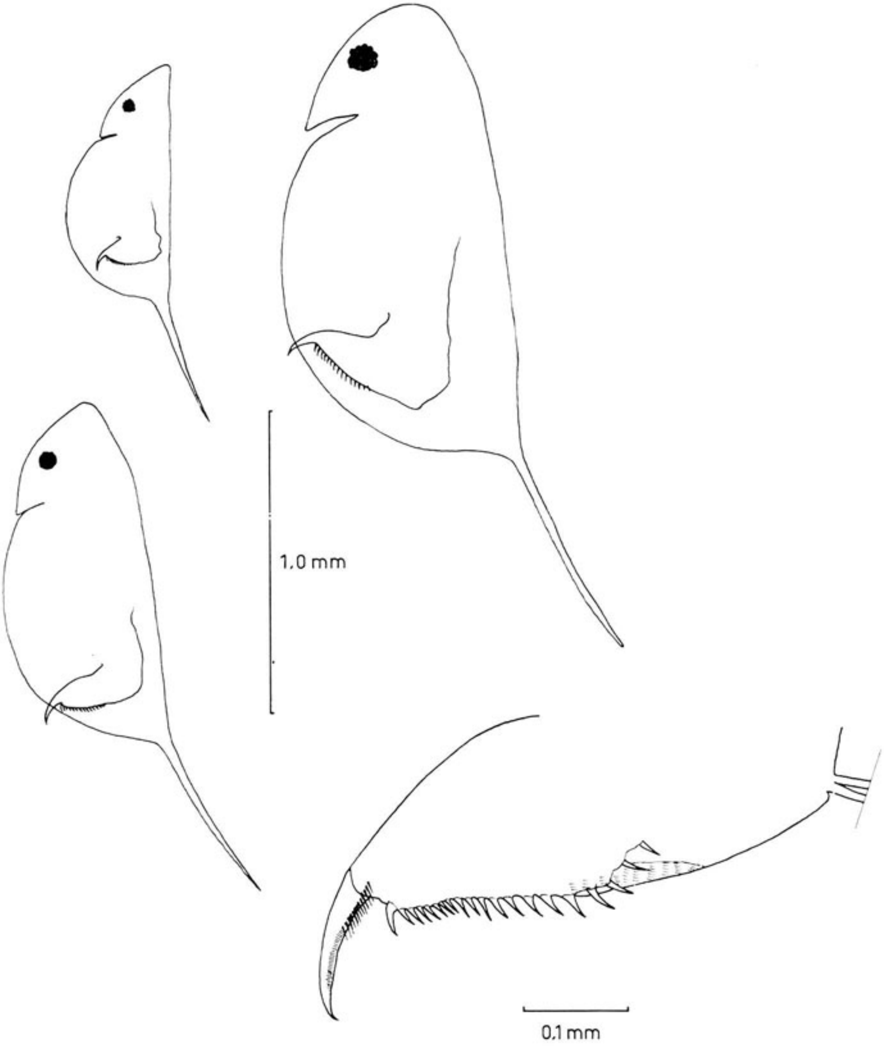

Fig. 4. Daphnia carinata, different age stages and ♀ post-abdomen.

Daphnia carinata King, 1853 (Fig. 3 and 4.)

In contrast to *Daphnia carinata deserti*, which was found by Gauthier (1929 a and 1937) (seen as only a variant), the South moroccan *Daphnia carinata* lacks the 9 side spines found on the post-abdomen of *deserti*. The animals which were collected by the author on the west side of Tenerife proved to have 5 side spines on the post-abdomen. Brehm (1954 a) mentions, without further statements, specimens of *Daphnia carinata* from 'earlier investigations [of] Panouse which resemble the variant *deserti*.

Hence the spines of the post-abdomen of *Daphnia carinata* may be considered variable and of little taxonomic relevance.

The extraordinarily dense population at one of the two localities consisted of Partheno- ♀♀ in a preponderant majority, beside which ephippia-carrying ♀♀ occurred far less numerously.

The species does not appear to have a very wide distribution in Northwest and West Africa; hitherto it was reported only relatively sporadically by Gauthier (1928 b, 1929 a, 1931 and 1937) in northern Algeria and Tunesia, in the central Sahara and in northeastern Mauritania (Agueraktem) as well as by Brehm (1954 a) in southern Morocco (Torkoz-Assa).

Simocephalus vetulus (O. F. Müller, 1776)

Repeatedly found in northern Morocco (Brehm 1950, 1954 a, 1954 b; Gauthier 1929 b; Lépiney 1961); finds in central and southern Morocco as well as in West Africa, have still not been recorded. On the other hand, *Simocephalus vetulus* is widely distributed out in northern Algeria and Tunesia (Gurney 1909; esp. Gauthier 1928 b).

The single specimen from Tenerife was found in an irrigation ditch of a banana plantation east of Puerto de la Cruz.

Ceriodaphnia dubia Richard, 1897

This species was found in Algeria and Tunisia (Gurney 1909; esp. Gauthier 1928 b) as well as in Egypt (Gurney 1911) and is known to occur in northwestern Africa through a find near Boulhaut (east of Casablanca) (Gauthier 1929 b); none found as yet in West Africa.

On Tenerife *Ceriodaphnia dubia* occurs widely and mostly in high density.

Macrothrix laticornis (Jurine, 1820)

Except for finds by Brehm (1934) in Upper Volta (Ouagadougou and Bobo-Dioulasso) and the Ivory Coast (near Man), the species is not known to occur in West Africa; Gauthier (1928 b) made two finds, in northern Tunisia and in the northeastern border area of Algeria.

The only specimen found on Tenerife was caught in a watertank, strongly settled by *Gambusia*, above Puerto de la Cruz.

Alona pulchella King, 1855

Besides the many finds in northern Algeria and Tunisia (Gauthier 1928 b), there are two finds in the central Sahara (Gauthier 1929 a and 1931) as well as a report from northern Morocco (Lépiney 1961). Until now *Alona pulchella* has not been known to occur in West Africa.

The only documentary specimen from Tenerife originated from the largest accumulation of water of the island, east of La Orotava.

Alona tenuicaudis G. O. Sars, 1862

Gurney (1909) reports the species for Algeria and Tunisia without making any more exact statements. Gauthier (1928 b) found *Alona tenuicaudis* at two places in northern Algeria. There are no further reports from North or West Africa. Gauthier (1931) found this species in the central Sahara (Hoggar).

Alona tenuicaudis could be found in many small accumulations of water on the western and northwestern parts of the island. It is noteworthy that the species was also found in moss pads which were frequently moistened by flowing water.

Leydigia leydigii (Schoedler, 1863)

Evidence from northern and western Africa only exists until now for northeast Algeria (Gauthier 1928 b) and for northwestern Morocco (Brehm 1954 a and Lépiney 1961).

On Tenerife the occurrence of the species is apparently limited to the repeatedly cited larger reservoir east of La Orotava.

Chydorus sphaericus (O. F. Müller, 1785)

This extraordinarily ubiquitous species is broadly distributed in northern Tunisia and Algeria (Gurney 1909; esp. Gauthier 1928 b); Brehm (1954 a) made finds in northern Morocco; on the other hand, reports are completely lacking for the southern parts of North Africa and for West Africa.

On Tenerife *Chydorus sphaericus* settle in accumulations of water, large and small, in the west and northwest without showing any conspicuously wide distribution as in many other areas.

Eucyclops serrulatus (Fischer, 1851)

Over all of northern Africa to the southern border of Morocco countless finds for this cosmopolitan species are given (François 1949; Gauthier 1928 b; Gurney 1909; Kiefer 1928, 1938 and 1954; Lindberg 1950 and 1952; Roy 1924); conversely, this species is lacking from the southern areas of Western Africa, with the exceptions of a find in West Senegal (De Guerne & Richard 1892) and one in the southwest of the Ivory Coast (Lindberg 1957).

On Tenerife *Eucyclops serrulatus* is fairly widely distributes, however never in great density.

Tropocyclops prasinus (Fischer, 1860)

Tropocyclops prasinus is known to be widely distributed in North Africa (François 1949; Gauthier 1928 b; Gurney 1909; Lindberg 1951 and 1952; Roy 1924). Finds also exist from the central Sahara (Gauthier 1931) and from the southern Ivory Coast (Kiefer 1934 and Lindberg 1957).

On Tenerife the species could be found only in the area of Puerto de la Cruz.

Paracyclops fimbriatus (Fischer, 1833)

Paracyclops fimbriatus is apparently widely distributed in North Africa, although not very continuously (Gauthier 1928 b; Kiefer 1928, 1934, 1952, 1954; Lindberg 1950). Between southern Morocco (Aouinet-Torkoz; Kiefer 1928) and a find in the southern Ivory Coast (Kiefer 1934), the species is hitherto unknown.

On Tenerife this species was found especially in small waters. It was also found on algae (trickled over by water), on the ceiling of a cave.

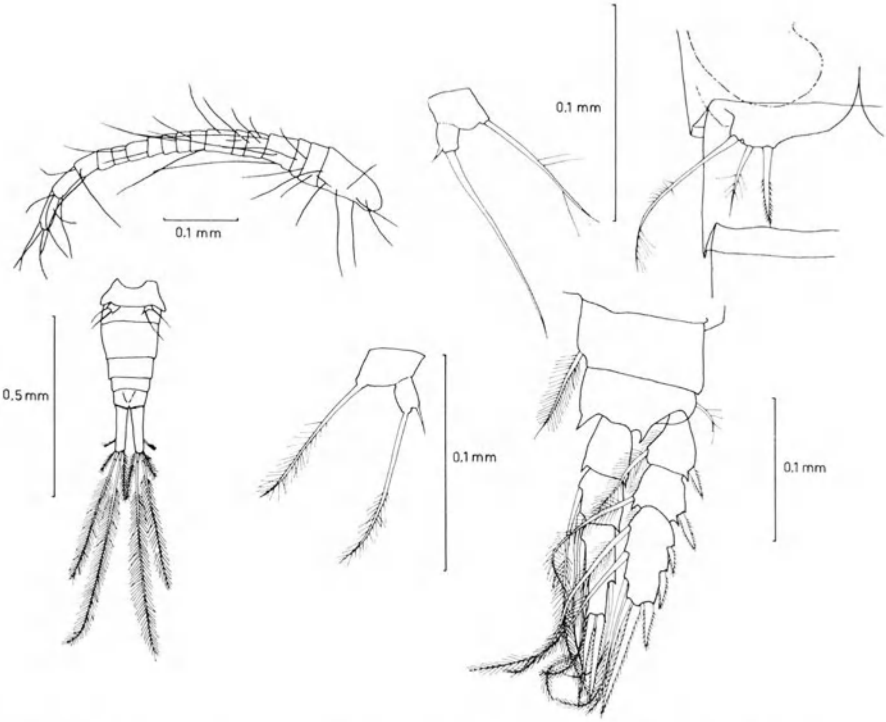

Fig. 5. Acanthocyclops robustus, ♀ first antenna, abdomen and fifth leg (left side); ♂ fifth leg, genital valve and forth leg (right side).

Acanthocyclops robustus (G. O. Sars, 1863[1]) (Fig. 5.)

This species, the most widely distributed of all Cyclopoids on Tenerife, is found, with the exception of the smallest waters, in water accumulations of every form, frequently in heavy population density.

The total length of adult ♀♀ is about 1.5 mm, without terminal setae of furca 1 mm (from the front end to the hind edge of the furcal rami). The somewhat smaller adult ♂♂ attain a total body length of about 1.35 mm, without the terminal setae of furca about 0.9 mm. The first antenna is 17-segmented and extends to the rear end of the cephalothorax. The length of the furca amounts to about 0.125 mm with an average width of about 0.027 mm (length:width = 4.5:1). The third (and longest) terminal seta of furca is 0.55 mm; the length of the four terminal setae had the following proportions: (from outer to inner) 1:5.2:7.8:1.9; the middle two are not setaceous in their proximal section. The fifth leg has two segments; the two terminal setae are about the same length. The side spine on the end segment is about 1/7 of the end setae. The base segment is drawn to a sizeable width; the total length of the fifth leg is about 0.12 mm.

Acanthocyclops robustus is known to occur in northern Algeria (Gauthier 1928 b) and in Morocco (Lindberg 1950); there are no other reports from the rest of northern or western Africa.

List of species found (with location of the find):

Daphnia magna[1] (20)
Daphnia carinata (3, 8) (only Fuerteventura[1])
Simocephalus vetulus (19)
Ceriodaphnia dubia (5, 7, 16, 20)
Macrothrix laticornis (14)
Alona pulchella (20)
Alona tenuicaudis[1] (3, 4, 14)
Leydigia leydigii (20)
Chydorus sphaericus[1] (3, 14, 20)
Eucyclops serrulatus[1] (2, 3, 15, 16, 19)
Tropocyclops prasinus[1] (14, 16)
Paracyclops fimbriatus[1] (2, 16, 17, 18)
Acanthocyclops robustus[1] (5, 6, 7, 8, 9, 19, 20)

On the Zoogeography of the Canary Islands

Although the discussion of an earlier land connection of the Canary Islands with the African mainland is far from being concluded, it may be

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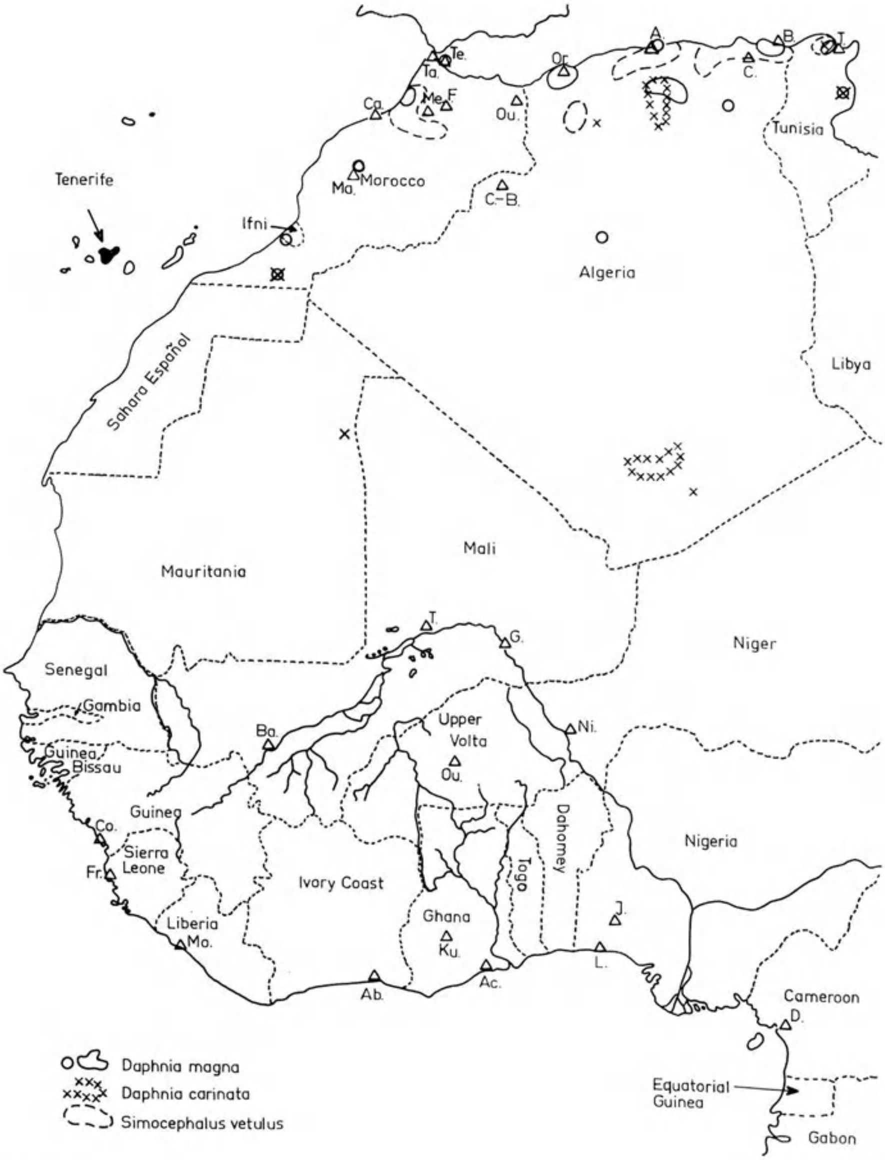
[1] For the identification of this species I give my sincere thanks to Prof. F. Kiefer (Konstanz).

[1] Recorded from the Canary Islands already by Richard (1898).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Algeria
Sahara Español
Libya
Mali
Mauritania
T.
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Niger
Senegal
Gambia
Ba.
Upper Volta
Ou.
Ni.
Guinea Bissau
Guinea
Co.
Sierra Leone
Fr.
Dahomey
Nigeria
Togo
Ivory Coast
Ghana
Ku.
J.
Liberia
Mo.
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Ab.
Ac.
Cameroon
D.
Equatorial Guinea
Gabon
Daphnia magna
Daphnia carinata
Simocephalus vetulus

Fig. 6


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Guinea Bissau
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Dahomey
Nigeria
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Cameroon
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Equatorial Guinea
Gabon
Ceriodaphnia dubia
Macrothrix laticornis
Alona tenuicaudis
Alona pulchella

Fig. 7


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Cameroon
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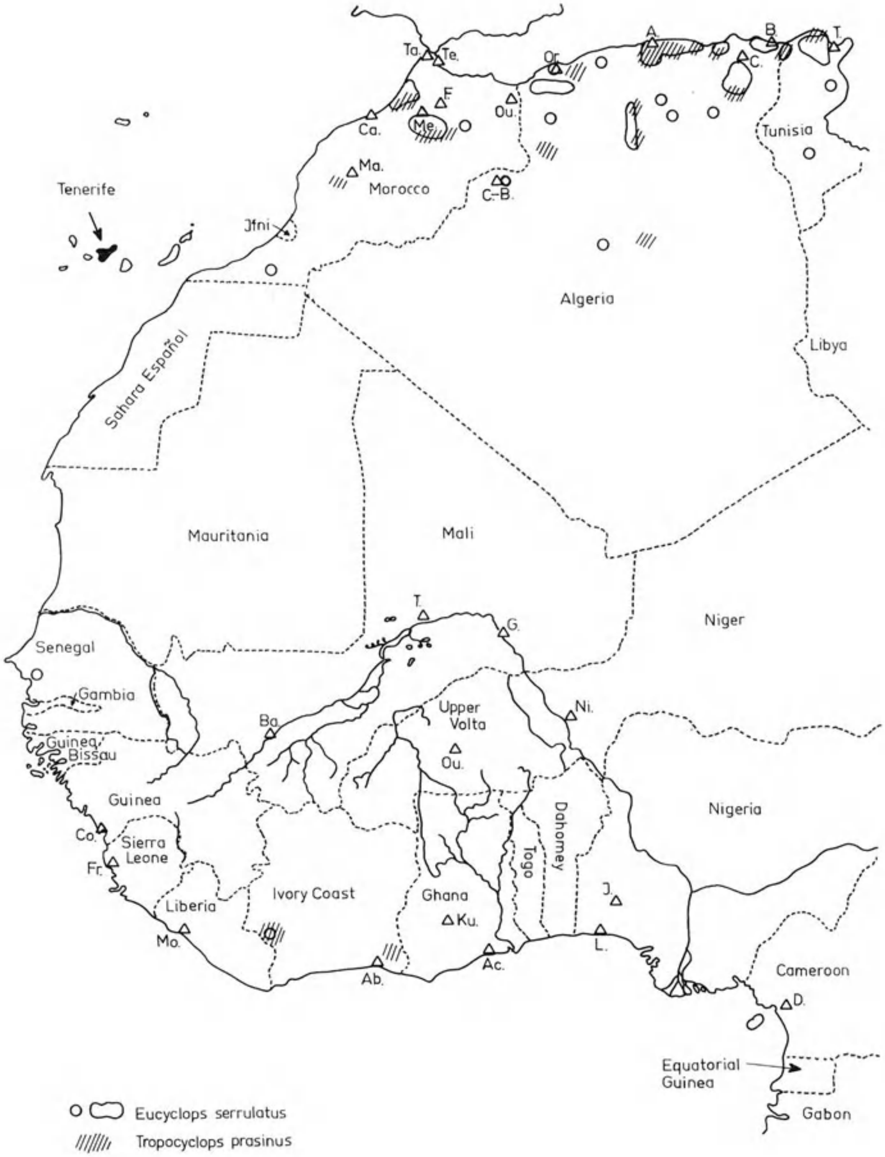
× Leydigia leydigii
○ Chydorus sphaericus

Fig. 8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Cameroon
D.
Equatorial Guinea
Gabon
Eucyclops serrulatus
Tropocyclops prasinus

Fig. 9

Fig. 6–10. Finds recorded up to now in North and West Africa of Cladoceran and Cyclopoid species occurring on Tenerife Island (based on different authors cited in the reference list); △ Capitals or other large towns.

safely assumed from the view of zoogeography that at least the eastern island group (around Fuerteventura and Lanzarote) has in its origin a firm connection to the continent. The finds of fossilized eggs of ratite birds (Rothe 1964; Sauer & Rothe 1972) as well as recent geological surveys (Rothe 1968 a, b; Rothe & Schmincke 1968) point to this conclusion. The land connection assumed by Mertens (1942) based on the discovery of *Lacerta goliath* (now extinct) on the central island group does not seem convincing, and even the giant tortoises found in fossiled form an Tenerife (Gagel 1926; Burchard & Ahl 1927) do not sustain this opinion. From a geological point of view a land connection is not probable (Evers *et al.* 1970). Because of the proximits of the islands from the mainland the possibility of drift certainly cannot be ignored. This is especially true for a former fauna exchange, including the larger and less mobile species, between the islands of the central and western group of the Canaries, which Schmincke (1968) explained on the basis of his research in Gran Canaria.

Unfortunately, the crustaceans particularly relevant to this question, e.g. Bathynellacea, cannot be brought into the discussion because they are evidently absent on Tenerife. A ground water system in the true sense is poorly developed on the island, and other crustaceans living in the mesopsammal, only occur to a limited extent. My results are therefore confined to Entomostraca living in surface habitats which are not powerful as evidence for eventual continental connections due to their good transportability.

Two subterranean Harpacticoidea found by Schminke (1971) in the South of Tenerife near Adeje proved to be new species *(Parastenocaris inferna* and *Parastenocaris ursulae)*, they exhibit clear relations to mediterranean forms. As for the rest, the limnetic Harpacticoidea of the Canary Islands still remains almost completely unexplored; only the two cosmopolitical species *Phyllognathopus viguieri* and *Epactophanes richardi* have been found by Noodt (1955) out of a sample taken from a colony of diatoms in a barrance. Also wide spread is *Nitocra spinipes* recorded by Richard (1898) from a salt-lake on Lanzarote together with *Artemia salina* (Anostraca).

The first (and only) conclusive discoveries on the Crustacean fauna of the Canary Islands originate from Richard (1898), notably from a time at which the corresponding investigations from the nearby areas of Africa had not yet been done. The report was of special interest because it made inferences for the composition of the Moroccan freshwater Crustaceans.

The first data on the Copepoda of northwestern Africa was provided by Kiefer (1926, 1928); a report on Euphyllopoda and Cladocera of Morocco appeared a short time later (Gauthier 1929 b). Since then the Crustaceans of this area have been worked on more extensively, however, much work remains to be done. The southern part of the country, precisely that of most interest in connection with the Canary fauna, has been practically ignored; and finally the area of the Spanish Sahara has not been worked on at-all.

For these reasons the apparent distribution gaps for a number of Crustaceans occuring on the Canary Islands are not significant.

While the following Cladocera species found during the present work on the Canary Islands: *Daphnia magna*, *Daphnia carinata*, *Simocephalus vetulus*, *Ceriodaphnia dubia*, *Alona pulchella*, *Leydigia leydigii*, and *Chydorus sphaericus* are known to occur in Morocco, proof for the occurrence there of *Macrothrix laticornis* and *Alona tenuicaudis* found on the Canaries is lacking as yet; they are, however, known to occur in central and eastern North Africa.

Four Cladocera *(Daphnia obtusa*, *Daphnia curvirostris*, *Alona alluaudi*, and *Alona intermedia)* from the Canary Islands reported by Richard (1898) which I could not substantiate for Tenerife have never been known to occur in North Africa at-all. Three other species *(Ceriodaphnia quadrangula*, *Moina rectirostris*, and *Dunhevedia crassa)* cited by Richard (1898), which I could not confirm for Tenerife either have been found in Morocco.

Finally, 13 Cladocera species, known in Morocco, have not yet been found on the Canary Islands: *Daphnia atkinsoni*, *Daphnia lumholzi*, *Ceriodaphnia reticulata*, *Simocephalus exspinosus*, *Scapholeberis mucronata*, *Moina dubia*, *Bosmina longirostris*, *Macrothrix chevreuxi*, *Macrothrix hirsuticornis*, *Alona guttata*, *Alona costata*, *Alona affinis*, and *Alona karua*. In new, intensive limnoplankton investigations on the other islands of the archipelago, especially on Gran Canaria, one can expect some of these species to be found.

In comparison to the Cladocera, the Moroccan Copepoda known to occur on the Canaries, have evidently fewer and unequal distribution possibilities. In the Copepoda list, composed by Kiefer (1954) from all finds in Morocco up to that date, are 10 Calanoid species *(Lovenula alluaudi*, *Metadiaptomus chevreuxi*, *Diaptomus cyaneus*, *Diaptomus kenitraensis*, *Hemidiaptomus macroccanus*, *Eudiaptomus chappuisi*, *Mixodiaptomus incrassatus*, *Mixodiaptomus laciniatus*, *Arctodiaptomus salinus*, and *Arctodiaptomus wierzejskii)* of which apparently only one occurs on the Canary Islands *(Lovenula alluaudi)* and this exclusively on Lanzarote (Richard 1898).

The named list comprises 13 Cyclopoid species: *Macrocyclops albidus*, *Eucyclops serrulatus*, *Eucyclops hadjebensis*, *Tropocyclops prasinus*, *Paracyclops fimbriatus*, *Paracyclops finitimus*, *Cyclops strenuus*, *Megacyclops viridis*, *Diacyclops bicuspidatus*, *Thermocyclops oithonoides*, *Thermocyclops schurmanae*, *Metacyclops minutus*, and *Metacyclops planus*. To this list should be added *Acanthocyclops robustus* recorded by Lindberg (1950). Only four of these 14 species could be verified for Tenerife. Furthermore, *Cyclops strenuus* and *Thermocyclops oithonoides* were stated by Richard (1898) to occur on the Canary archipelago.

All species of Cladocera which we will take into consideration here could be transported as ephippia, at least primitive ephippia, by air currents or water birds, without difficulty. In principle, these ways of distribution also apply for Copepoda; however, by far not for all species. Stages transportable over land or by air respectively could be resting eggs or certain encysted copepodid stages. Apparently relatively few Copepoda were successful in settling the Canary Islands from the African mainland, whereas the Cladocera clearly had more success.

Areas other than northwestern Africa come much less under consideration as possible exit areas for Canary fresh-water Crustaceans, nevertheless we must consider Europe as well as other parts of Africa because of the possible transportation by migratory birds.

Simocephalus vetulus, *Ceriodaphnia dubia*, *Macrothrix laticornis*, *Alona pulchella*, and *Leydigia leydigii* are new for the Canary Islands. *Daphnia carinata*, which was only known to occur on Fuerteventura, is new for Tenerife.

With the exception of two species of *Parastenocaris* described as new by Schminke (1971) none of the fresh-water Crustaceans found up to now on the Canary Islands is endemic, if we disregard the uncertain species *Alona alluaudi* alleged by Richard (1898); this was presumably *Alona pulchella* (Petkovski, in litt.). The *Acanthocyclops*, entered here under *Acanthocyclops robustus*, deviates to some extent from the comparable central European material, but a new classification, considering the variability of this group (cf. Reed 1971), should not be advocated at this time.

Completely in contrast to these conservative results about limnetic Crustacean fauna are the results from Noodt (1958) concerning marine Harpacticoida from Tenerife, where, from 20 species gathered, 11 were described as new. Earlier investigations (Noodt 1955) had already pointed to endemic forms. According to the results of Hartmann (1959) the same is true for marine Ostracoda; unfortunately, the limnetic species are as yet completely unexplored.

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XVII. CONSERVATION OF FRAGILE ECOSYSTEMS IN THE CANARY ISLANDS

by

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Introduction

Highly specialized ecosystems of islands and archipelagos are among the earth's treasures most valuable to science, to tourism economies, to recreation, education, and inspiration. The establishment of national parks in New Zealand, the Hawaiian Islands, and the Galápagos Archipelago have produced attractive revenue from tourism, but these places are literally part of a universal heritage, and they deserve the utmost care and preservation by governmental bodies.

One of the most recent examples of prudent planning for island ecosystems is that undertaken in Ecuador. An inter-institutional commission of the Ecuadorian government prepared, early in 1973, a report on the future of the Galápagos Islands, most of which are enclosed within Galápagos National Park. The substance of the report was that the natural ecosystems of the islands, because of their uniqueness, could not be duplicated if destroyed, and therefore merited maximum preservation. The report also made clear that status of the area as a national park was important to the Ecuadorian economy. Within six months a master plan for the conservation and use of the park was drafted: on approval this plan will have the force of law. New Zealand has also prepared master plans for its national parks, as has the United States of America and other nations.

There is, in fact, rather a worldwide rush to halt the severe destruction of island ecosystems, particularly in Mexico, Canada, Japan, Venezuela, Panama, the Seychelles, Kenya, France and, of course, Spain. The Costa Rican government recently reversed a decision to lease an island for tourism development and instead took steps to convert the island into a nature reserve. The principal reason for all such efforts is altruistic: to save for future generations some portion of the original natural heritage. But the economic advantages are not overlooked; a U.S.A. economist estimates that in all countries the relatively low investment cost of land acquisition and subsequent administration of national parks can yield as much as 700% profit.

The Canary Islands

All this should be particularly applicable to the future of the Canary Islands. The uniqueness, the extraordinary number of endemic plant species, and the outstanding volcanic features, such as Montaña de Fuego, Isla de Lobos, and the Jameos de Agua, appear to meet informally established criteria for national parks or related reserves. At the same time, the Canary Islands have their share of industrial encroachments, exotic wildlife, planning problems and other man-originated activities that threaten the scenic beauty of the islands. The cactus and the goat, those universal hazards, seem as well established on the Canaries as on other islands. Unfortunately, the elimination of them has proven exceedingly difficult in other archipelagos. Recent studies of the problem seem to suggest, however, that diligent control by firearms can reduce populations of non-native goats, at least to less competitive levels. The eradication of spiny plants has been undertaken in Hawaiian park areas where it was desirable to restore the original vegetation, and this has been quite successful. Ideally, aggressive non-native flora should be removed entirely from specialized island ecosystems, but the job may be so immense and economically impractical that postponement is necessary. However, the reduction of non-native biota should remain a continuing government policy.

A Fragile Ecosystem

Around the world, petroleum pollution constitutes a formidable threat. In the Canary Islands it has struck not only where wastes have floated ashore and killed aquatic life on the north side of Gran Canaria Island, but where derivatives such as fuel oil and gasoline are burned and their residues contaminate the air. We may believe that fresh winds blow away such pollution, but this is not entirely true, and the damage to plant tissues caused by sustained high levels of airborne toxic pollutants is well known. All insular life systems should be considered vulnerable to airborne and waterborne contaminants.

This is all the more reason, perhaps, for a global monitoring system and the establishment of a series of environmental 'bench marks,' that is, a series of scientific monitoring stations where environmental data are periodically recorded. Assessment of these records over a period of time should reveal where certain segments of the natural environment begin to deteriorate.

At present, the principal threat to many world islands is uncontrolled and unplanned urbanization. Apart from population and global environmental considerations there is little objection to the rational spread of human settlements as long as they do not destroy unique natural areas or concentrations of wild places needed for heritage preservation, scientific study or outdoor recreation. Too often, however, settlements are expanded without consideration of natural ecosystems, or the consequences of interrupting stream flow or dumping wastes into bays with unique and fragile aquatic life. The government of Lanzarote Island, on the other hand, possesses a land use plan that merits careful study, for it officially classifies the public domain into land uses that include 'natural areas.'

Actually there appear to be good opportunities to forestall damage to the vulnerable Canary environment not only by studying and monitoring dynamic ecosystems, but by supporting efforts at master planning, zoning and mapping (such as that done on Lanzarote), and research projects that would decrease the islands' dependence on petroleum. Park or recreation area installations, for example, and perhaps even botanical gardens, could undertake experimental solar energy conversion to provide electricity. Likewise, local efforts with regard to self-contained water desalinization processes could be strongly supported.

Tourism, even in fragile natural sites, can be multiplied many times without damage to environments, but only with strict planning and control. This has been done with extraordinary success in the Hawaiian Islands, the key being a sound master plan followed by control of tourist numbers, distribution and behavior.

Recommendations

The sense of conservation on the part of the Spanish Government has long been manifest in the Canary Islands, and one has only to study the history of ICONA (Instituto Nacional para la Conservación de la Naturaleza) and its predecessor organizations to see a continuity of advancement in the field of forest management. The establishment of national parks has been given priority and at this writing there are Teide National Park, on the island of Tenerife, and Caldera de Taburiente National Park on the island of La Palma. These parks are protected by wardens, have facilities for public use in or near them, and are administered by the highest government authority (ICONA). Both units fulfill the criteria for national parks, as does the proposed Montaña de Fuego National Park, on Lanzarote Island, a volcanic landscape with striking natural features.

Other areas are under consideration, and perhaps will have been established by the time these pages are printed. As new generations of Canary Islanders take over there will be more ideas, because an unusual variety of features could well be placed in a national inventory of proposed reserves. Of special fascination are the pelagic ecosystems, especially where unusual faunal or algal associations exist; seashores highly suitable for recreation areas; rocky areas and cliffs where rare and unusual plants survive; unusual geologic features, such as volcanic dike systems and active volcanoes; dunes such as those at Maspalomas, on Grand Canary Island: laurel forests; pine forests; relatively undisturbed islands such as those off the north coasts of Lanzarote and Fuerteventura: the Anaga area of Tenerife; and subtropical forests on Hierro and Gomera Islands.

Once an official, scientific inventory is made of areas that exist or can be restored to high quality, there are numerous ways they could be preserved. These include botanical reserves, especially suitable for rare or endangered species; faunal reserves, where attempts would be made to restore certain species in natural ecosystems; strict nature reserves; park reserves; new national parks; provincial parks; environmental education study areas; forest reserves; recreation areas, and historic-archeologic sites.

It cannot be too strongly emphasized that master plans for proposed areas have been found highly helpful to many governments. In Turkey, Jordan, Venezuela, Guatemala, Costa Rica, Ecuador and the U.S.A., to name a few, these plans have provided a clear indication of governmental policy and action. The result has been public, legislative and international support. The master plan itself usually includes a wide range of topics. Among them are: detailed descriptions of the resource (flora, fauna, geology, cultural history), weather, water, land use, status of research, protection and management proposals, land classification, planned development, if any, restrictions, economic and other benefits, and costs. Such plans usually have maps, and may be prepared before or after establishment of an area.

Remarks on the Flora

In the Canary Islands, ICONA and provincial officials are very much cognizant of the requirements for careful planning to save the unique and irreplaceable natural resources. It is therefore possible to look forward with optimism, even though, as in all countries, a considerable task remains and much opposition may be expected. Canary Island reserves, and those of other archipelagos in the Macaronesica region, can be windows on Atlantic gardens of natural history. Two of the most conspicuous endemic plants in the Canary group, *Canarina canariensis* and *Euphorbia canariensis*, indicate the broad range of conservation opportunities. The latter is a cactus-like plant of multiple arms that dominates tourist views in arid and semiarid localities. But clumps of it also constitute miniature ecosystems that could be of extraordinary value in environmental education classes, scientific field trips, or national park nature trails. This is actually an island resource of great significance, though perhaps too commonplace to be thought special by local inhabitants. The less often seen *Canarina canariensis*, on the other hand, is a shade-loving plant that bears large bell-shaped pink and lavender flowers. These showy and attractive blossoms have evidently been too often plucked, and the plant is now rare. But few other plants so well exemplify the unique 'garden' aspect of these islands, and the conservation of this species has become a rallying point around which public support is engaged.

Perhaps the most spectacular floral display is that of the two species of *Echium*. These send up their giant stalks of red or blue flowers in summer and are thus missed by the great number of tourists who come to the islands in winter. They are protected in Teide National Park, on Tenerife, and require continued vigilance to assure that the flower plants or their attractive post-blossoming stalks are not removed.

The flowers of *Senecio tussilaginis* and *S. webbii* have particularly noteworthy colors from a tourism point of view. Likewise, the large yellow heads of *Aeonium manriqueorum* may seem unspectacular to Canary residents, but their conservation should be of capital interest to the tourist industry. More delicate, but nearly as conspicuous, are the abundant patches of *Asphodelus microcarpus*, a delicate white lily that most visitors pass by. One could also mention the brilliant endemic *Geranium canariense*, the tiny *Arisarum vulgare*, the leafless *Euphorbia aphylla*, the thousands of acres of white, yellow, green, orange and red lichens on lava flows, and numerous succulent plants such as *Aeonium sedifolium*, *Traganum moquinii*, and *Zygophyllum fontanesii*. If tourist group leaders could increase public attention to such floral masterpieces, the conservation of the biota would be more secure. Special botanical tours would indeed be a distinct possibility.

Each Canary Island is one of a kind. The variety of nature on each is virtually endless. All of these resources thus constitute a unit of extraordinary value in the world community, and where conservation of the natural resources is considered, the Canaries should have their rightful place.

GENERAL INDEX[1]

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[1] The names of single islands are listed only when dealt with in some detail. For exact chemical formulae refer to the text.