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INTRODUCTION

THE EXPEDITION REPORTED on in the present paper was the first of the Richard Archbold expeditions of the American Museum of Natural History to carry out a program of field work in northeastern parts of the New Guinea mainland. It was based at Lae, in the Huon Gulf. Operations extended through the period March 25 to December 15, 1959, principally on the Eastern Highlands, including the high peaks Mt. Wilhelm, Mt. Otto, and Mt. Michael, also in the Lae-Edie Creek area and the upper Markham River Valley. All working areas were in the Territory of New Guinea, which Australia governs in administrative union with Papua as the Territory of Papua and New Guinea.

The previous expeditions had been concerned with Papua and Netherlands New Guinea. They began in Papua in 1933–1934 with work chiefly on Mt. Albert Edward and its approaches from Hall Sound, and on the Oriomo River in the west (Archbold and Rand, 1935). This was followed by investigations on the Fly River and the Wassi Kussa, in western Papua, in 1936–1937 (Rand and Brass, 1940). The third expedition, biggest of all as regards personnel and collections, was a joint project with the government of the Netherlands Indies in 1938–1939, directed primarily to the Lake Habbema and Mt. Wilhelmina, Balim Valley, and middle Idenburg River areas of Netherlands New Guinea (Archbold, Rand, and Brass, 1942). With the resumption of the New Guinea program in 1953, attention was paid to eastern Papua with work on Cape Vogel Peninsula, Mt. Dayman and its approaches from Collingwood Bay, and Goodenough Island of the D'Entrecasteaux Group (Brass, 1956). The fifth expedition, in 1956–1957, visited Normanby Island and Fergusson Island of the D'Entrecasteaux, the Louisiade Archipelago, Woodlark Island, the Trobriand Islands, and localities on the easternmost part of the Papuan mainland (Brass, 1959).

Participating in the sixth or 1959 expedition were Leonard J. Brass, leader and botanist; Hobart M. Van Deusen, mammalogist; John D. Collins, transport man and field assistant, and six permanently employed natives. Collins, a resident of New Guinea, was the owner of a young coffee plantation in the Mt. Hagen district. Taking part in their third Archbold expedition were Kim, cook and headboy, and Lik-lik, head mammal boy, from Goodenough and Fergusson Islands, respectively. Edewawa, head botany boy and also a Goodenough Islander, was a veteran of the 1956–1957 expedition. To this nucleus of trained and trusty native helpers were added Territory of New Guinea boys familiar with the pidgin English lingua franca of the country.

As regards pidgin English, understanding on the village level in most parts of the Eastern Highlands in 1959 was usually limited to a few individuals who had been away to work for white men, and local interpreters, called "turnem talks" in pidgin, were necessary for satisfactory communication with the people.

The expedition was planned to take advantage of the roads that in recent years have been thrust far and wide on the Eastern Highlands in actions of the Administration first to open up the area and bring it under effective control, then to initiate policies for the economic and social advancement of the native peoples, and to assist the limited number of white settlers who are being given opportunity to take up land, principally for the planting of coffee. Road transport was with a 1-ton Land Rover and $\frac{1}{2}$-ton trailer, bought in Lae and sold there after the completion of the expedition. The rugged, reliable Land Rover served very well on mountain roads which often were practicable only for four-wheel-drive vehicles of this Jeep type. Consideration of weight and bulk, under these conditions, kept the party down to its small size. Besides personnel, and collecting and camp equipment, including tents and flies, stores enough for three weeks could be carried on the Land Rover and trailer without relaying, given some pushing by the passengers on the worst spots on the roads. Extra gasoline was carried to allow use of the Land Rover to extend considerably, from base camps, activities such as trapping, night hunting, and botanical collecting.

Although the Highlands were connected with the port of Lae by a motor road, this

was a dry season road, and basic transport was by air, as had been the case since the discovery and exploration of the Highlands in the early 1930's. Virtually all supplies, including gasoline for the rather numerous motor vehicles in use, were flown in at freight rates made expensive by the small amount of backloading available in an area still in the early stages of development.

The field work of the expendition was in three phases. The first, in the Lae-Edie Creek area, involved three inland localities, all on a good, all-weather, graveled road. Next, driving its motor equipment to the Highlands as soon as that road became well passable after the wet season, the party worked at eight Highlands base camps, 4500 to 11,700 feet above sea level. Finally, when approach of the next wet season made a withdrawal toward Lae advisable, work was carried out at two camps in the Markham Valley en route.

Six of the Highlands camps were on the road system. Access to the other two, on Mt. Wilhelm, was by air to a landing strip on the eastern slopes of the mountain, thence on foot with native carrier transport. The main supply base for work on the Highlands was at Goroka, administrative center of the Eastern Highlands District, chief air and commercial center on all the Highlands, and the only settlement that could be called a town. Kainantu, a subdistrict center, was a later, minor base where supplies could be bought at two local stores. Both centers were at an altitude of about 5500 feet.

As an indication of the "newness" of the Highlands, two camps of the expedition were in areas that had been under government authority for less than five years. Yet, in 1959, but one remote and especially difficult part of the Eastern Highlands administrative district of 6900 square miles retained the designation "uncontrolled."

The prime interests of the expedition were in the collection and field study of mammals and plants. In addition, as secondary interests, Van Deusen collected amphibians and reptiles, and Brass collected insects and spiders. Special collections of ectoparasites of mammals were made by Van Deusen for study by the Institute for Medical Research, United States Army, and blood films of mammals in general and viscera of marsupials for the Queensland Institute of Medical Research in Brisbane.

The zoological materials, with the exception of the blood films and viscera, are deposited in the American Museum of Natural History: the mammals in the Archbold Collection, the remainder in the main collections of the Museum. The botanical collections were presented to the United States National Herbarium, in Washington. By agreement, the Administration of Papua and New Guinea receives, on a first preference basis, duplicate specimens of all collections when such are available, the zoological material for the Port Moresby Museum, the plants for the Forest Herbarium at Lae.

In the Mt. Michael area, John S. Womersley, Chief, Division of Botany, Department of Forests, spent September 2 to 9 with the expedition on a plant-collecting visit. At Kassam, T. C. Maa, collecting insects for the Bernice P. Bishop Museum and ectoparasites for the United States National Institutes of Health, was a guest from October 28 to November 9. Shorter visits, by biologists and others, are recorded in the itinerary.

The project was aided by Research Grant G6122 of the National Science Foundation.

ACKNOWLEDGMENTS

Preliminary arrangements with the Commonwealth Government of Australia and the Administration of Papua and New Guinea were facilitated and expedited by Mr. Walter M. Rudolph, Assistant to the Science Adviser, Department of State.

We are deeply grateful to many persons in New Guinea for assistance and generous hospitality. In Port Moresby, Brigadier D. M. (now Sir Donald) Cleland, Administrator of Papua and New Guinea, sanctioned the expedition. Dr. John T. Gunther, Assistant Administrator, had keen understanding and interest in our work and was directly instrumental in official assistance to the project. For the aid of his Department in innumerable ways, we owe much to Mr. W. R. Suttie, Director of Forests.

Substantial assistance granted by the Administration, especially in transport of supplies, collections, and personnel on aircraft under regular official charter, and in storage space, was facilitated by Mr. John Womers-

ley, in Lae, acting as co-ordinating officer. He gave unfailing help in matters that ranged from the formulation of working plans to liaison with departments of government. His interest, and the resources he could draw upon, were helpful indeed when, upon arrival in New Guinea, we found that through the blundering of shipping agents our gear and collecting supplies, shipped from New York three months earlier, had not arrived and for three weeks we had to work with what could be got together locally.

Our business agents were Buntings, merchants in Lae and Goroka. Mr. Robert F. Bunting, head of the firm, who made special efforts on our behalf, also gave us a very comfortable and convenient house to live in while in Lae. In Goroka, Mr. K. C. James, General Manager, and Mr. Russell Webster, Merchandise Manager, welcomed us as house guests and could always be depended upon in problems of supply.

Of special assistance on the Eastern Highlands was District Commissioner H. P. Seale, who, accompanied by Mr. James, visited one of our camps on Mt. Wilhelm (see p. 173). We were also aided on the Eastern Highlands by Medical Assistant W. McSeveny of Lufa, Assistant District Officer A. M. Bottrill of Kainantu, Patrol Officer Gavin Carter of Okapa, and Mr. P. S. Primrose of Government Stores, Goroka.

One can work efficiently and live comfortably under tentage almost anywhere in New Guinea except at the highest altitudes. It is, however, much better to have a permanent roof over one's head and the amenities that go with this and windowed walls and real floors. For such shelter we were indebted to Mr. Mark Schultz at Oomsis, the Rev. George Horrolt of the Lutheran Mission at Gurakor, Messrs. Robert Franklin at Kaindi, James F. Leahy at Kotuni, Daniel Leahy, Jr., on the Bena Bena River, and most of all to Mr. and Mrs. W. H. Larner, who graciously made us a part of their household for three weeks at Arau.

It was our good fortune to work in an area with more than the usual thin sprinkling of local naturalists and others having an interest in what we were doing. For this interest, and for contributions to our collections, we are especially grateful to Mr. John Gunn and the late Dr. W. E. Smythe of Lae (reptiles), Mr. Lionel Baker of Gabensis Plantation (mammals), Forest Cadets Alan White and Robert Wright at The Bends (mammals), Forest Officer J. J. Havel of Bulolo (mammals and conifer materials), Mr. Richard Leahy of Zenag (mammals), Mr. John H. Barrett of Aiyura (mammals), Miss Ruth Wertz of Gono (lizards and insects), and Mr. K. R. Slater of Port Moresby (mammals and reptiles). A particularly interesting and valuable lot of mammal specimens was contributed by Mr. Horace W. Clissold of Wau (see p. 184). We had gifts of prehistoric stone objects from Messrs. T. W. Bayliss of Bulolo, W. H. Larner of Arau, and Laurence Crowley of Karanka.

The success or failure of an expedition may be influenced by many factors but is often a measure of the personnel in professional capacity, experience, and personal compatibility. Much of the success of the Sixth Archbold Expedition was due to the unselfish co-operation and good work of Hobart Van Deusen. John Collins, besides showing extraordinary ability as a driver on bad roads and mechanic in emergency, was a congenial companion. He helped greatly with the herpetological collection and in trapping and night-hunting for mammals. Collins, assisted by the botany boys, made the higher altitude plant collections on Mt. Otto and the bulk of those on Mt. Michael, and is so accredited on the field labels as co-collector with Brass. Both Collins and Van Deusen collected many plants high on Mt. Wilhelm.

The "boys" of the expedition have already been mentioned. Another New Guinea man deserving special notice is Demkana of Keglsugl, who claimed ownership of most of the eastern slopes of Mt. Wilhelm and the birds of paradise and other valuable properties thereon. Demkana felt responsible for our well-being during the two months we were on the mountain, camped with us all that time, saw that we had ample firewood, furthered our interests in general, and was most amiable and not overly commercial about it all.

Hobart M. Van Deusen has supplied the mammal names for this report. Richard G. Zweifel has identified the amphibians and reptiles. Preliminary sight determinations of plants, made in the field, have been greatly

added to by general lists of identifications received from the Rijksherbarium, Leiden, and R. D. Hoogland, Canberra, but most of the collection still has to be worked out. The mosses have been determined by Edwin B. Bartram, the tree ferns (*Cyathea*) by R. E. Holttum, the Cyperaceae by J. H. Kern, *Ficus* by E. J. H. Corner, and the Ericaceae by H. Sleumer. These contributions are gratefully acknowledged.

The aerial photograph of Mt. Wilhelm is published by the kind permission of the Director of Mapping, Department of National Development, Canberra. The map was prepared by Mrs. Frances Zweifel, with assistance from Dr. Richard G. Zweifel in the difficult compilation and delineation of relief data.

THE AREA

THE FIELD WORK of the expedition took place in the Morobe and Eastern Highlands administrative districts of the Territory of New Guinea. This territory, originally in European occupation a German protectorate, includes former Kaiser-Wilhelmsland or North-East New Guinea on the mainland, the Bismarck Archipelago, the Admiralty Islands, and Bougainville and Buka Islands of the Solomons Group. It came under Australian occupation in 1914, soon after the outbreak of World War I, was held under military government for seven years, and became, under Australian administration, a mandated territory of the League of Nations in 1921. In World War II the Territory was invaded by the Japanese, and much of it was occupied by them from 1942 into 1944. Australian civil administration was fully re-established by 1946, and in that year Australia became the administering authority of the Territory under agreement with the Trusteeship Council of the United Nations Organization. In 1949 the administration was merged with that of the Australian Territory of Papua (formerly British New Guinea) and the Territory of Papua and New Guinea came into being, with headquarters at Port Moresby. In sovereignty, however, the former "German New Guinea" is still a United Nations Trust Territory, while Papua remains an Australian possession (Robson, 1956, 1958).

PHYSIOGRAPHY AND GEOLOGY

For the Territory mainland area of 69,700 square miles, four physiographic provinces have been recognized: the northern littoral, the northern ranges, the central intermontane trough, and the main cordillera. All four provinces extend into west New Guinea; only the northern littoral and the main cordillera reach eastward into Papua. The provinces are ancient structural features, though their modern prominence and definition date only from the late Pliocene. The main cordillera and the northern ranges are geanticlinal provinces, with cores of relatively ancient, complex rocks. The intermontane trough and the northern littoral are geosynclinal provinces which received great thicknesses of Upper Tertiary sediments. Cycles of rapid Tertiary sedimentation and orogenesis have dominated this part of New Guinea, as they have most of the island (Carey, 1938).

The most conspicuous physiographical feature is the main cordillera, the backbone or central range of New Guinea, which runs without break from the Vogelkop in west New Guinea to extreme eastern Papua, and is continued eastward through the drowned chain of the Louisiade Archipelago. It consists of a complex system of ranges, separated in many cases by broad upland valleys. The width of the cordillera is not uniform. A little to the west of the Territory border the distance across the highland belt is only 35 miles from plain to plain. East of there the highlands expand to a maximum width of 150 miles, where they are known as the Central Mountains or, in more recent terminology, the Central Highlands. Within the highlands themselves the topography is relatively mature. Marginal to the highlands, dissection has been proceeding rapidly, and intensely rugged juvenile topography has been the result. An important unit of the Central Mountains, containing many wide, grassy valleys, is known as the Purari Highlands from the great river system which drains them eventually to the south coast of the island. East of these highlands the marginal ranges coalesce to form a single range system about 50 miles in width. The highest point, Mt. Wilhelm in the Bismarck Range, has an altitude of approximately 15,000 feet, and its upper parts show abundant evidence of Pleistocene glaciation (Carey, 1938; Langford-Smith, 1951).

The northern ranges, fringing the north coast, consist of a broken succession of ranges running parallel with the main cordillera. Links in this northern chain in the Territory are the Bewani, Torricelli, Prince Alexander, Adelbert, and, on the Huon Peninsula, the Finisterre and Saruwaged Mountains. Each of these ranges has a complex structure and a core of old crystalline rocks and pre-Tertiary strata. The northern ranges are not so wide or so high as the main range system, but they reach heights of about 13,500 feet on the

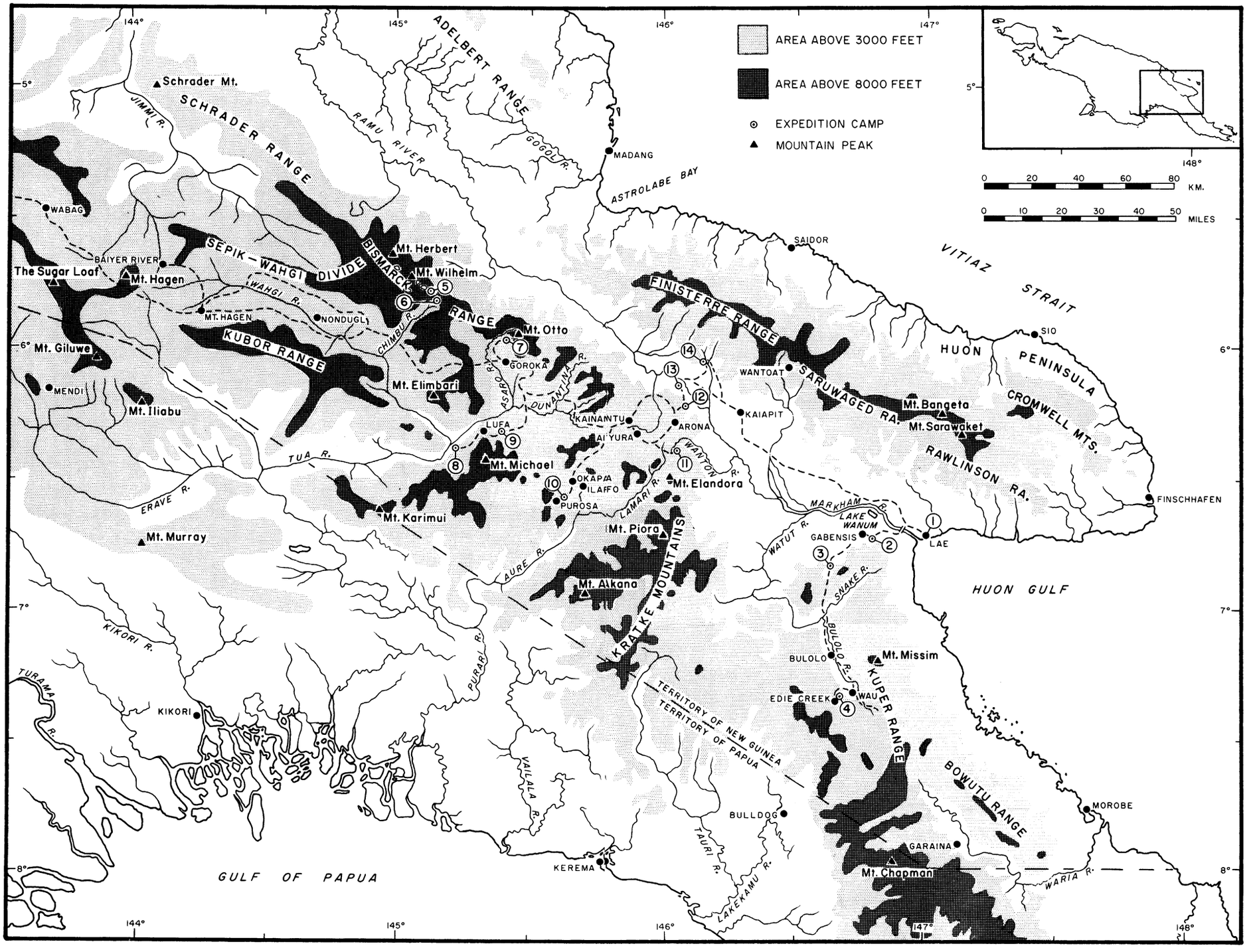

FIG. 1. Map of the eastern mainland of the Territory of New Guineea, and adjoining parts of the Territory of Papua, showing the working areas of the Sixth Archbold Expedition to New Guinea. The 8000-foot contoour may be taken to indicate, approximately, the uppermost limit of cultivation in heavily populated mountain areas. The representation of relief is less accurate west of the 145th meridian than east of that line. Camps of the expedition: 1, Lae; 2, Oomsis; 3, Gurakor; 4, Kaindi; 5, Lake Piumde-Aunde; 6, Pengagl; 7, Kotuni; 8, Gono; 9, Kimi Creek; 10, Purosa; 11, Arau; 12, Kassam; 13, Water Rice; 14, Umi River.

Huon Peninsula (Carey, 1938; Langford-Smith, 1951).

The central intermontane trough is a great, crescentic lowland that separates the main cordillera from the northern ranges. In the Territory, the valleys of the Sepik, Ramu, and Markham rivers occupy and drain this depression. It was a slowly subsiding marine trough during the Upper Tertiary, and, though the sea was driven out by late Pleistocene folding, it is still probably for the most part a sinking area. A considerable part of its floor is close to sea level, and much of it is swampy. The Sepik section of the depression appears to be due to a synclinal fold, but in the east, along the Markham-Ramu trough, faulting seems to be the dominating factor. Profound earth movements and mass displacements appear to have taken place in the Markham Valley during the Tertiary and Quaternary periods (Carey, 1938; Langford-Smith, 1951).

The northern littoral is essentially one of active though not uniform elevation. With few exceptions, the rivers are not navigable. Another feature is raised coral reefs. However, the Morobe Coast of Huon Gulf and southward is a drowned littoral, with a complete absence of raised coral (Carey, 1938; Langford-Smith, 1951).

Formerly the northern ranges were thought to be older than the main cordillera, and probably the only New Guinea land surface in existence from the Middle Cretaceous into the Middle Miocene (David, 1932). Views based on recent field surveys are given in a regional study of the Eastern Central Highlands (the eastern part of the Purari Highlands referred to above) by McMillan and Malone (1960), a study of special interest here in that it concerns the principal working area of the Sixth Archbold Expedition. The oldest rocks in this area consist of a metamorphic complex of schists, gneisses, and other rocks intruded by a vast differentiated or composite mass, the Bismarck Granodiorite, which between them constitute a basement of probably pre-Permian age. This basement is overlain unconformably by a discontinuous and incomplete marine succession of Upper Cretaceous, Eocene, and Oligocene age, and more widespread and greater thicknesses of Lower and Middle Miocene sediments and volcanics. The main post-Paleozoic orogeny started during Miocene time and was most active in the Pliocene [or Plio-Pleistocene]. Elevation is still in progress. There is evidence that in part, at least, the present outcrop area of Paleozoic rocks of the Bismarck Range was land during most of Mesozoic and Tertiary time. Extensive Quaternary lacustrine and alluvial deposits occupy the floors of the long-populated, deforested, and grassy Goroka (Asaro), Arona, and Kainantu valleys at 4400 to 5200 feet above sea level.

On the Western Highlands (the western part of the Purari Highlands), there was strong Pleistocene vulcanism, with foci of eruption in the great volcanic mountains of the Mt. Hagen Range, Mt. Giluwe, and Mt. Ialibu, 13,100, 13,414, and 11,000 feet in altitude, respectively (Rickwood, 1955).

The Pleistocene glaciation of Mt. Wilhelm has been studied by Reiner (1960). He gives the height of the mountain as 14,900 feet, hypothetical present snow line as 15,400 feet. The Pleistocene snow line, as indicated by the altitude of cirque basin floors, was 11,500 to 12,000 feet. Within a summit area of about 100 square miles, glacial tongues extended down a number of valleys for a distance of from 1 to 2 miles from a consolidated snow field on the higher parts of the mountain. Occupying rock basins scooped out by the glaciers are at least 13 lakes from 1 acre to 20 acres in size. Terminal morainic features indicate a descent of the glaciers to an altitude of about 10,900 feet.

Elsewhere in the Territory of New Guinea, Detzner (1919) reported evidence of former glaciation on the Saruwaged Range, but this report apparently awaits confirmation by a geologist.

CLIMATE

Since World War II, much has been learned of the climate and local weather conditions of the Central Highlands from records made at government stations and patrol posts, and especially from the operation of a widely developed network of commercial air traffic with attendant weather forecasting and information services, but apparently little of this knowledge has been published.

As a contribution to the climatology of the entire Territory of Papua and New Guinea,

however, a proposal has recently been advanced by Brookfield (1958) for this "broad threefold climatic division":

1. A truly equatorial belt comparable to "Singapore or the Amazon Mouth," including the coast and mountains north of the Sepik and the islands of Manus, New Ireland, and perhaps Bougainville, where rainfall and temperature are fairly even all year.

2. South of this an "irregular belt characterized particularly by very heavy rain in the low-sun season on all southward and southeastward slopes." Very heavy rainfalls occur along the southern face of the Central Highlands, on the mountains around Lae, and along the southern side of New Britain. This rain derives from the "Coral Sea Trades." Within the belt are some dry, rain-shadow areas, protected by land from the rain-bearing winds. Through this rain-shadow effect the northern face of the Central Highlands is much less wet than the southern, as is likewise the northern side of New Britain. The inner Markham-Ramu Valley is a marked dry area, and the Kainantu-Arona and the Bulolo valleys are relatively dry from the same effect.

3. "Southward again [and outside of our area] is a belt in which rainfall is lower, even on the high mountains." Generally there is a winter drier period, except on slopes exposed to the full force of the trades, a period most marked in southwestern Papua, and particularly along the Port Moresby coast, which lies parallel to the trades. In this southern belt there begins to emerge a seasonal difference in temperature of the order of up to 10° F.

An excellent account of climate and climate control by Hounam (1951) has the disadvantage of being based, apparently, on observations made no later than 1937, and in having no data whatever from the Central Highlands. The seasons and the type of weather experienced are controlled largely by the northwest and southeast monsoons, commonly known simply as "the Nor'west" and "the Southeast." The incidence of the seasons may vary from year to year. The Nor'west, extending from about December to the middle or end of March, is the wet season over most of the area; the Southeast, occurring from sometime in May to late in October, and with stronger and more sustained winds, is the dry season of most parts. Doldrum periods intervene between the seasons.

Hounam's rainfall map, when used in conjunction with a relief map which appears in the same publication, shows well the dependence of local rainfall on topography and orientation to the prevailing air streams. Annual average rainfall for the Territory of New Guinea varies from 69.36 inches at Marienberg (lower Sepik River) to 258.55 inches at Lindenhafen (south coast of New Britain), for stations shown on the map or included in a rainfall table.

The following table of average monthly and annual rainfall (table 1), which is based mainly on records kindly supplied by the Commonwealth Meterological Office at Lae,[1] includes only stations in or adjacent to working localities of the Archbold Expedition.

In exceptionally dry seasons, conditions may become droughty on both lowlands and highlands, with local crop failures or deficiencies and consequent food shortages. The Bena Bena area, in the lower Asaro Valley, is recognized as the driest part of the heavily populated valley system of the Eastern Highlands.

Occasional frosts may occur as low as about 7000 feet, and it would appear that, in general, conditions become too cold for the staple sweet-potato crop of the Highlands peoples to grow well at elevations above about 8000 feet. Periods of exceptionlly severe cold occur at intervals of years, causing the loss of crops and serious shortages of food. Meggitt (1958) described, from the accounts of natives, such an occurrence which affected the Wabag area of the Western Highlands during the winter of 1940 or 1941, when gardens as low as 6500 feet were wiped out by weeks of frost, and, above about 7500 feet, days of sleet not only destroyed gardens but killed domestic pigs and even wild animals.

Snowfalls occur on the highest peaks, but the snow soon melts. Meggitt reported the sighting of snow for occasional brief periods on Mt. Giluwe. On Mt. Wilhelm in June we saw on two different mornings snow down to

[1] Edie Creek and Kaiapit records from Hounam (1951); Gurakor records from James Sullivan, Gurakor Road Camp.

TABLE 1

AVERAGE MONTHLY AND ANNUAL RAINFALL (IN INCHES)
(Stations on the Central Highlands are marked with asterisks; approximate altitudes are in feet.)

	Gurakor (2100)	Edie Creek (7000)	Kaiapit (990)	*Kainantu (5500)	*Okapa (6500)	*Lufa (6300)	*Goroka (5500)	*Keglsugl (7500)
Number of years	6	8	9	5	2	5	5	4
January	12.51	8.19	9.62	8.85	8.32	8.45	9.02	11.35
February	11.95	7.55	9.74	9.43	8.81	9.33	10.99	13.31
March	12.19	12.90	15.11	11.97	11.08	10.47	11.51	13.27
April	11.97	11.54	14.04	8.17	7.07	10.91	9.22	11.09
May	4.78	7.22	5.80	2.87	4.41	4.60	2.37	4.01
June	3.76	4.36	2.47	2.59	1.99	4.78	2.17	3.86
July	5.53	6.60	2.94	2.17	3.54	4.57	2.18	3.90
August	6.32	6.80	2.87	3.70	4.92	3.88	3.05	4.73
September	4.61	8.48	3.73	3.85	5.51	5.61	3.64	5.79
October	4.88	9.16	6.72	6.98	5.24	8.91	5.67	5.30
November	8.78	10.87	8.74	7.57	4.23	9.14	6.83	5.16
December	15.40	13.54	12.80	11.61	10.66	11.29	12.74	9.34
Total	102.68	107.21	94.58	79.76	75.78	91.94	79.39	91.11

somewhat under 13,500 feet on the slopes above our camp, but it melted and disappeared within an hour or two after sunrise. Two days after one of these falls, small deposits of snow were found persisting near the summit of the mountain. Reiner (1960), seemingly on the authority of the missionaries of Toromambuno (Denglagu) on the southeastern slopes of the mountain, stated: "Snow falls only once or twice a year, mainly in August. The whole summit area may then receive a snow cover, which lasts from a few hours to two days."

Local weather notes are included in the descriptions of the 14 camp localities of the expedition.

HISTORY AND EXPLORATION

When Germany in 1884 proclaimed a protectorate over Kaiser-Wilhelmsland, the Bismarcks, and the Admiralties, the first settlement by European traders, missionaries, and planters had already taken place on some of the islands, but the mainland area taken over was completely wild, and no white man lived there. Exploration of the coasts, and the parts of the two big rivers of Kaiser-Wilhelmsland, the Sepik (Kaiserin-Augusta) and Ramu (Ottiliën), that are navigable by small ships, soon followed. There was vigorous development of plantation enterprises locally on the coast where good land and good anchorages occurred together, with coconuts the principal crop.

Contemporaneous with the first political and commercial developments on the mainland were the beginnings of the Christian missions which have played an important part in opening up the country. The first mission to become established, near Finschhafen in 1886, was the Neuendettelsauer Missionsgesellschaft, of Lutheran denomination. The Rheinische Mission, also Protestant, began at Bogadjim in Astrolabe Bay in 1888 (van Hasselt, 1935). The Roman Catholic faith made a start with the establishment of the Society of the Divine Word in the Aitape area in 1895 (Geurtjens, 1935).

Not much was done in exploration of more than the near interior until after the turn of the century. Although in British New Guinea the alpine summit of Mt. Victoria had been reached as early as 1889 by a party led by Sir William MacGregor (MacGregor, 1898), and in Dutch territory the alpine of more remote Mt. Wilhelmina was attained by the Lorentz-van Nouhuys Expedition in 1909 (Le Roux, 1935), not until 1912 did a white man stand

on an alpine peak in German New Guinea. Then the Reverend Christian Keysser, a Lutheran missionary, reached the summit of Mt. Bolan (Bangeta), the highest peak of the Saruwaged Range (Keysser, 1913). This range lies close to the coast, but no high mountain in New Guinea is easy of ascent, and Keysser's was a notable achievement.

The earliest important thrust in overland explorations in the German territory took place in 1896, when the First Ramu Expedition of the New Guinea Company, led by Carl Lauterbach, penetrated from Erima Station in Astrolable Bay to the middle Ramu River and from there reached an altitude of about 3250 feet on the nearby Bismarck Range (Le Roux, 1935). On this, or on the second or third Ramu expeditions which took place in 1898 and 1899–1900, gold was discovered on western tributaries of the river. Concessions were taken up, and a special gold station was established, but after intensive prospecting the station was abandoned in 1902 (Stanley, 1923; Robson, 1956, p. 317).

Important new areas of the near interior were opened up in 1907–1908 by the Dammköhler-Fröhlich Expedition from the Huon Gulf through the Markham-Ramu Valley and down the Kabenau River to Astrolabe Bay. In 1908–1909 the Anglo-German boundary was surveyed as far inland as the 147th meridian by a commission consisting of Foerster and Stollé on the German side and Sabine and Tooth on the British. In 1909 Dammköhler and Oldrup found gold on the Watut tributary of the Markham, where Dammköhler was killed by the natives. In 1913 a party of Lutheran missionaries, led by G. Pilhofer on a long inland trip from the mouth of the Waria River, crossed a 7900-foot plateau between the headwaters of the Waria and Bulolo rivers and followed the Bulolo, Watut, and Markham down to the coast (Le Roux, 1935; Andexer, 1914).

In 1886 the great Sepik River was navigated to a point between the junctions of the May and Yellow rivers, a distance of about 300 miles on the winding course of the stream, by the steamer "Ottilie" on an expedition led by von Schleinitz. The year 1910 saw the beginning of a notable series of geographic and scientific explorations which substantially pushed back the frontiers of the Sepik drainage area. Schultze Jena in that year led an expedition which followed the main Sepik to near its source and made a short side trip into the Star Mountains. The Stollé Expedition, in 1912–1913, explored on many of the main tributary streams of the Sepik (Le Roux, 1935) and probably filled in more map space than any other expedition in New Guinea.

When World War I broke out, survey work was being conducted on the Anglo-German border by Captain Hermann Detzner, who, it would appear, carried out careful mapping as far west as the Kapau branch of the Tauri River. Detzner, upon receiving delayed news of the war, very capably retreated north through country previously unexplored, followed the Watut down to the Markham, and at about the end of 1914 took refuge in the mountains of the Finschhafen hinterland (Detzner, 1928), where, to the embarrassment of the missionaries of the area, who were under Australian military parole, he remained in hiding until the end of the war in 1918.

In a book, however, and a paper and a map published in Berlin, Detzner (1920, 1919) made fantastic claims to travels and discoveries during the war which were largely products of his imagination. That he was eventually forced to retract all fictitious claims, deposit corrected copies of his book and map in the library of the Gesellschaft für Erdkunde, and resign his membership in this geographical society,[1] is not, however, generally known, so that Detzner too often is still thought of as one of the great explorers of New Guinea. The most spectacular of Detzner's imaginary travels was an attempt to reach the haven of war-neutral Netherlands New Guinea by traversing the then totally unexplored area in which the Central Highlands are situated—a journey of fancy which took him to a map position which is in the Chimbu part of the lower Waghi Valley on the maps of today.

In summary, the explorations of the Germans lacked notable vigor or purpose until near the end of their 30-year occupation of

[1] The "Erklärung Detzner" appeared in an unsigned official pronouncement of the society in Zeitschrift der Gesellschaft für Erdkunde zu Berlin (1932, pp. 307–308).

Kaiser-Wilhelmsland. The outer barriers of the central mountains had barely been penetrated by expeditions which for the most part followed the larger rivers, and extensive unknown areas remained between these rivers. Only limited areas on or near the coast were under effective government control, and little or no effort had been made to introduce control elsewhere.

The Australian administration, before doing much on a program that was designed in the first place to open up the country gradually and bring it firmly under government influence and authority, had to build up and season a civil service. Administrative districts and district services were established. But progress was slow until stimulated by big finds of gold in the Morobe District, beginning in 1926 and centered at Edie Creek, Wau, and Bulolo. The absence of roads, and the great engineering problems, time, and cost that would be involved in building roads in very rugged mountain terrain, led to the early adoption of air transport to service the goldfield. The air support of prospectors and government patrols, as they pushed out into new territory, came as a parallel though gradual development, retarded by high costs and the difficulties of operation where every new venture of the kind meant the preparation of a new landing strip.

In the constantly widening search for gold, E. W. Rowlands in 1929 crossed over the Bismarck Range from the Markham-Ramu Valley and at about 5000 feet on well-populated grassy plateau country drained by the Ramu, near where Kainantu now stands, made a promising find which soon drew other prospectors to this hitherto unexplored area. Rowlands had discovered the eastern edge of what was later called the Central Highlands. Some idea of the great extent of these highlands was gained in 1930 when, bypassing the new diggings to the north, Michael J. Leahy and Michael Dwyer climbed over the Bismarcks and found themselves on headwaters of the Dunantina River. For two weeks they moved westward downstream, through grassy highlands always expanding and more densely peopled, to where the river junctioned with the Asaro at the head of a tremendous gorge in which the waters turned south. Already short of food, and doubtful about the safety of their small party of 18, all told, on a retracement of route, Leahy and Dwyer decided to follow the gorge and the river and eventually, in one of the epics of New Guinea exploration, reached in another 23 days the south coast in the Purari Delta.

The Leahy-Dwyer expedition, commemorated in Mt. Michael, opened up the eastern part of the Central Highlands. During further prospecting, supported for a time by the New Guinea Goldfields Company, Leahy and his brother Daniel in 1933 discovered the great Wahgi Valley of the Western Highlands. This, after aerial reconnaissance, was explored by a strong party, in part government escort, led by Assistant District Officer J. L. Taylor and the Leahys and accompanied by Surveyor K. L. Spinks. Supply was by aircraft at prepared landing strips, and purchase of native foods. From a base camp and temporary police post set up at or near the present site of Mt. Hagen Government Station and township, a large extent of country, including adjacent high valleys of Purari and Sepik waters, was examined, and Mt. Hagen was climbed.

For a year or two following, the "Hagen strip" provided a starting point for wide-ranging and never very successful prospecting parties, some of which worked on branches of the Yuat (Dorfer) tributary of the Sepik and usually continued by rafts down to the main river or struck overland on foot to Madang on the north coast. The Leahys in 1934 proceeded west and northwest, climbed Mt. Giluwe, and, at times under sharp attack by the natives, reached a point beyond Wabag (for the Leahy journeys, see Leahy, 1936, and Leahy and Crain, 1937). Also in 1934, the prospectors T. A. and Jack Fox, with 18 carriers and living almost solely on food bought from the natives, struck westward on a round trip which, if it was entirely as claimed, took them about 250 miles to the Star Mountains and Digoel River headwaters in Dutch territory, on a truly remarkable journey which, incidentally, yielded no gold (Fox, 1936; Leahy and Crain, 1937, pp. 258, 270). The last of the great explorations in the Territory, the Hagen-Sepik Patrol of 1938–1939, led by Taylor and provided with radio communications and air support, including the parachuting and dumping of sup-

plies, soundly filled in the preliminary map of about 20,000 square miles of country on both the north and south sides of the Papua-New Guinea border from Mt. Hagen to Telefomin, near the head of the Sepik and close to the Dutch border (Taylor, 1939; Anon., 1939).

Close behind the first explorers of the Central Highlands came missionaries of three rival denominations. The Lutherans would appear to have opened a station at Kainantu in 1930–1931 but to have made no far penetration until a mission "rush" set in for the new territory of the Wahgi. In this the Catholics took the lead. Before the Leahy-Taylor discoveries, they knew of the Wahgi from women of the valley who had been traded as wives to men of the Bundi area, in mission territory on the north slopes of the Bismarck Range. In November, 1933, a reconnaissance party led by Father William Ross crossed over the range by native path from Bundi to the head of the Chimbu Valley and went on to the Mt. Hagen airdrome. A Lutheran party, walking in from the Markham Valley, reached Mt. Hagen the following June to find Catholic missions recently established there and at Denglagu in the Upper Chimbu. The Seventh Day Adventists were third among early missionary arrivals on the Highlands (Anon., 1934; Leahy and Crain, 1937, pp. 216, 234; Nilles, 1953).

Early in 1935, after the killing by natives of two Catholic missionaries in the Upper Chimbu and of a prospector on the Dunantina, most of the Highlands area was closed to non-official Europeans, except on special permit. The established missions, for example, could continue their work within prescribed limits; the much-respected Leahys were allowed to mine gold that they had discovered near Mt. Hagen; but the area remained essentially closed until about 1951. Government authority had been very limited, and only one post (at Kainantu) existed on the Highlands at the time of the closure. Additional posts were soon established at Bena Bena, Kundiawa (Chimbu), and Mt. Hagen, and a system of bridle paths was put in to connect the administrative posts and the missions. During World War II there were groups of military personnel at Bena Bena, Goroka, and Mt. Hagen. Patrolling and extension of authority over the natives continued during this period. The principal bridle paths were converted into Jeep roads which since the war have been further improved as a trunk system of dirt roads for all-vehicle, all-weather traffic.

Before the war, the search for gold had spread over most of the Territory north of the Central Highlands. It was most successful, in small finds, in the northern ranges behind Wewak and Aitape, an area that was fairly well gone over by prospectors. Prospecting for oil had also covered much ground. The Germans had found indications of oil on the Aitape coast and were preparing for large-scale investigations when war broke out in 1914. Under Australian auspices, extensive surveys and prospecting began in 1921 and were continued after World War II, mainly on the Aitape-Wewak coast and the Sepik River, but the discovery of oil in commercial quantity has yet to be achieved (Raggatt, 1951; Robson, 1956, p. 316).

In 1959 it was expected that the last populations of especially inaccessible or hostile people on the Highlands and in other parts of the Territory of New Guinea, estimated at about 60,000, would be brought under government influence by the end of 1963 and under control within perhaps another three years. The censused native population was then about 1,250,000 and on the Eastern and Western Highlands alone well over half a million. For some time the emphasis in native affairs had passed from the penetration and exploration of new areas to improvement of the lot of the natives already under administrative authority. Health, educational, and agricultural extension services were being expanded rapidly. Substantial extension of the secondary road system was being made every year. Under the open rules imposed by the United Nations charter, religious missions had multiplied to more than 20 denominations or sects on the Highlands alone—a situation deplored by Assistant Administrator Gunther, who wrote (1958): "I frankly think we can do without some of the small organizations which often lack scholarship and financial support . . . no missionary should be acknowledged in the Territory who has not an understanding of social anthropology."

In economics, the gold-mining industry

had declined greatly since World War II, and new industries in agriculture and the manufacture of plywood were flourishing. But the annual report of the Administration for fiscal 1959–1960 showed that products of the coconut, the original main plantation crop, accounted for 63 per cent of the income from exports, followed in order of importance by plywood and timber, cocoa beans, coffee beans, gold, peanuts, passion-fruit juice and pulp, marine products, and crocodile skins.

Reference to local products is made in the following sections of this report. Worth special mention, however, is a novel trade that has developed in air-freighting fresh vegetables and cut flowers of fine quality from the Highlands to coastal towns such as Port Moresby and Lae. Most small crops of temperate regions grow very well on the Highlands. The great native populations of the area, dependent very largely on sweet potatoes as a staple diet, were quick to accept potatoes and a wide variety of "white man's vegetables" as crops, perhaps first for purposes of trade with white people, but before long for the improvement of their own living and nutrition. New ornamental plants were as readily adopted.

PREVIOUS COLLECTIONS

THERE IS NEED for the publication of a detailed history of the many biological collecting activities that have taken place in New Guinea. As it is, only the botanists have the advantage of a "Cyclopaedia of Collectors" (and collections) aimed at completeness, containing numerous incidental references to zoological and anthropological collections, and with the whole of Malaysia as its scope (van Steenis-Kruseman, 1950, 1958, used extensively below). The present report is confined to mention of some of the more important or historically interesting biological, and particularly mammal and plant, collections made on the Territory of New Guinea mainland, with special reference to the Morobe District and Central Highlands areas in which we worked in 1959.

Apparently the first European, scientific or otherwise, to live on the Territory mainland was the Russian zoologist and anthropologist Nikolai Nikolaevitch Miklouho-Maclay. With a Swedish sailor named Uhlson and a Polynesian as servants, he landed at Konstantinhafen, in Astrolabe Bay, from the Russian warship "Vitiaz" on September 19, 1871, had the warship's crew build him a hut protected by land mines, and there had his headquarters until December 25, 1872. On a second visit to the same general area, since known as the Maclay Coast, Maclay spent nearly 16 months in 1876–1877, and on a third visit 10 days in 1883. He made anthropological, zoological, and botanical collections (Greenop, 1944). Maclay himself described two of his Maclay Coast marsupial collections in the Proceedings of the Linnean Society of New South Wales (Laurie and Hill, 1954, pp. 11, 28); von Mueller of Melbourne published some of the plants (van Steenis-Kruseman, 1950).

In their check list of the land mammals of Malaysia east of Wallace's Line, Laurie and Hill (1954) recognized as occurring in New Guinea, including the adjacent islands of the three political territories, 74 genera and 185 species containing 333 forms. Of the 53 genera and 85 species, containing 111 forms, listed for the Territory of New Guinea mainland, four genera and 15 species, with a total of 50 forms, were originally described from the area: Huon Peninsula, 15 forms; mountians of the Morobe Goldfields and adjacent areas, eight (and the new hydromyine genus *Pseudohydromys*); subsidiary mountain ranges of the Sepik Basin, three; the Central Highlands and enclosing mountains, 18 (and the new hydromyine genera *Neohydromys*, *Mayermys*, and *Baiyankamys*); the lowlands, six. It is evident that by the time attention was turned to extensive and intensive collecting in the Territory the generally wide-ranging lowland mammal fauna of the mainland was already fairly well known from activities in Dutch territory and Papua. Most of the northern ranges and approximately the western half of the main cordillera in the Territory of New Guinea, comprising a length of about 600 miles of medium-altitude to high mountains, are still virtually unknown for mammals.

Most of the prominent collectors of mammals in the Territory were also collectors of birds, or had even wider interests. Such was F. Shaw Mayer, whose beautifully prepared collections of birds and mammals, made for Tring and the British Museum, respectively, mainly from the upper Waria River and especially the Central Highlands in the period of 1932–1953, ranked first in size for mammals from the Territory before our expedition and contained most of the mammalian novelties that have been described from the Central Highlands to date (Laurie, 1952; Laurie and Hill, 1954). Shaw Mayer since 1953 has been in charge of the Hallstrom Wildlife Station at Nondugl, on the Western Highlands. Unfortunately, no account has been published of any of the 20 collecting trips that he made into various parts of New Guinea, for live birds for the London Zoo as well as skins and skulls for the museums, beginning on the Vogelkop in Dutch territory in 1928. Intensive mammal collecting can be said to have been done only in some of the localities of Shaw Mayer and those of Van Deusen on our 1959 expedition, and Shaw Mayer's collections, though rich in marsupials and rodents, contained few bats.

E. Thomas Gilliard and his associates,

while making a comprehensive survey of the birds of the Central Highlands for the American Museum of Natural History in 1950, 1952, and 1953, collected about 800 mammal specimens (nearly all in pickle or represented by skulls only), also amphibians and reptiles, fishes, Lepidoptera, and some plants (Mayr and Gilliard, 1954). The Gyldenstolpe Expedition in 1951, primarily for birds, collected about 200 mammals at Nondugl and on nearby slopes of the Wahgi-Sepik divide, and in addition insects, plants, and materials for two habitat groups at the State Museum of Natural History in Stockholm (Gyldenstolpe, 1953). E. Le G. Troughton and Norman Camps, on a short expedition for the Australian Museum in 1954, collected in the Wahgi Valley, about Mt. Hagen, and down to 1200 feet on the Jimmi tributary of the Sepik, about 150 mammal specimens, besides birds, amphibians and reptiles, fishes, and insects (Anon., 1954; camp localities and a sketch map in Whitley, 1956). Some useful mammal collecting has been done by collectors of ectoparasites on the Highlands and in other parts of the Territory: in 1957 George P. Holland and E. G. Munroe of the Canadian Department of Agriculture, collecting fleas, but chiefly pyralid moths and other light-trapped insects (Holland, 1958; Munroe, 1958); and in 1959 Tsing-Chao Maa of the Bernice P. Bishop Museum, who worked mainly on the Eastern Highlands (see p. 176). The Australian Museum has received from the Highlands several small collections made by government officers and visiting research workers.

In the Morobe District, mammal collections made on the upper Waria River by F. Shaw Mayer in 1936 are mentioned above. Small but important collections from Mt. Misim and elsewhere in the goldfields area were made in 1932–1933 for the Museum of Comparative Zoölogy of Harvard College by Herbert Stevens, a retired tea planter from Assam, who collected chiefly birds and insects. On the Huon Peninsula, an area barely touched by us at our Umi River Camp on the north side of the Markham Valley, the most noteworthy of a number of early collections of mammals appears to have been made about 1912–1914 for the Berlin Zoological Museum by the Lutheran missionary C. Keysser (see p. 157), in various localities, including the Rawlinson Range and up to high altitudes on the Saruwaged Range.[1] Ernst Mayr, collecting primarily birds for the American Museum and Tring in 1928–1929, also collected (for Berlin) mammals and plants from lowland localities to high on the Saruwageds; he later spent about a month in the Herzog Mountains of the Morobe goldfields area. R. H. Beck, of the American Museum's South Sea Expedition, took a few mammals while collecting birds in the Cromwell Mountains of the Huon Peninsula in 1929.

Early botanical collecting in our special areas was concentrated chiefly about Finschhafen, first administrative headquarters of the Germans, and at adjacent low to middle altitudes of the Huon Peninsula such as the Sattelberg. Prominent in this work, collecting for Berlin in the 1880's, were U. M. Hollrung, Ludwig Karnbach, F. C. Hellwig (up to about 7000 feet), and Otto Warburg. Carl Hunstein, collecting principally birds but also plants, worked in the area during the same period. Lauterbach (1928) mentioned important collections that were made on the Sattelberg in the 1890's by G. Bamler, a Lutheran missionary stationed there, Karnbach, the Hungarian zoologist Biro-Lajos (collections at Budapest), and especially the Swedish botanist E. O. A. Nyman (collections at Uppsala).

Climaxing numerous journeys on the Huon Peninsula, C. Keysser in 1912 climbed the Saruwageds and made there, for Berlin, the first collections of alpine plants for what is now the Territory of New Guinea (Diels, 1929; includes a summary of exploration and botanical collecting on this range). Keysser collected on the Saruwageds again in 1916. C. E. Lane-Poole (1925), Australian forester, ascended this range in 1923, collected plants in the approach and summit areas, and wrote an excellent account of his observations and experiences. Mrs. Mary Strong Clemens, who made very large plant collections in the mountains of the Huon Peninsula in 1935–1941, principally for Berlin and the Arnold Arboretum, worked up to at least 10,000

[1] On the older maps, and still to some extent in common usage, the Saruwageds are considered to be the eastern part of the Finisterre Mountains, and not another range.

feet on the Saruwageds, also high on the Rawlinson Range, and up to about 6000 feet at Wantoat in the Finisterres.

Elsewhere in the Morobe District, some botanical collecting was done at the head of the Huon Gulf, in the lower Markham Valley, and south along the coast by the early Germans. Rather numerous collections have since been made in these parts and in commercial timber areas centered on Bulolo, principally by Department of Forests personnel. From a nucleus of local collections established by Australian Army forestry units during World War II, the Lae Herbarium has been greatly expanded since 1946 by J. S. Womersley and his assistants, whose field work has spread to selected localities throughout most of Papua-New Guinea (Womersley, 1953).

Especially noteworthy among other plant collections from the Morobe District are those of F. R. R. Schlechter, from the Waria River and Huon Peninsula areas. One of the botanical "greats" of New Guinea, and a noted specialist in orchids, Schlechter had as his primary object, on two long expeditions in the 1901–1909 period, a search for plants yielding rubber and guttapercha. He made many trips, on which he reached altitudes up to about 5000 feet in the Finisterres and 8000 feet on the Bismarck Range, besides doing much work in the Ramu Valley, on the Sepik River, and along the north coast. The first to collect plants on the Bismarck Range, however, were Carl Lauterbach and Otto Kersting of the First Ramu Expedition, who climbed to 900 meters (3250 feet) in 1896. In climbing 11,600-foot Mt. Otto in 1924, Lane-Poole was the first to attain a major peak on this range, but the ascent took place in mist and rain and no plants were collected (personal communication). In clear weather, Lane-Poole must have looked down into the great, populated Asaro Valley from the top of Mt. Otto, and thus have discovered the Central Highlands five years before Rowlands crossed the mountains and found himself on the Upper Ramu Plateau.

Botanizing on the Central Highlands may have begun on the Leahy-Taylor explorations in the Wahgi Valley in 1933 when Taylor, on rest days, "collected seeds and specimens of plants for some botanical friend" (Leahy and Crain, 1937, p. 173). The first collections of which I can find a record from alpine altitudes of the Highlands are a few rhododendrons taken by C. R. Stonor at uncertain dates (during World War II according to van Steenis-Kruseman) on Mt. Hagen and Mt. Wilhelm and deposited in the Edinburgh Herbarium. Australian Army forestry collections were made at Aiyura and Goroka by Lindsay S. Smith in 1944. The 1950 collections of Gilliard (presented to the Arnold Arboretum), referred to above, gave the first preliminary general sampling of the alpine flora of Mt. Wilhelm and Mt. Hagen. F. Shaw Mayer, in 1951, made small collections for the British Museum up to 7300 feet on Mt. Giluwe and 11,000 feet on Mt. Hagen. On a mountain-climbing vacation in 1953, Noel M. Semple and L. T. Rayner ascended both Mt. Wilhelm and Mt. Giluwe, making small collections of high-altitude plants for the Melbourne Herbarium and color photographs of wildflowers; Patrol Officer A. M. Keogh, who escorted the party on Mt. Wilhelm, collected 40 botanical specimens for Lae.

The first major botanical collection from any high mountain rising from the Central Highlands was made in July, 1956, by R. D. Hoogland and Royal Pullen, who spent 10 days high on Mt. Wilhelm and collected up to the summit (Hoogland, 1958). In six days, ending early in August of 1956, another large lot of alpine and subalpine plants was collected on this mountain by Womersley and an assistant, Michael Calaro (personal communication). Ross G. Robbins followed with a smaller though substantial collection in August, 1957. In the same month Pullen visited previously unexplored southern high slopes and collected 69 numbers of plants at altitudes up to about 12,500 feet (letter dated March 9, 1960). John H. Barrett, a government entomologist, made small gatherings high on the mountain in 1957 and 1959. All of these men, Gilliard, and the Semple-Rayner-Keogh party climbed high peaks of Mt. Wilhelm, and most of them the main peak.

Hoogland and Pullen were botanists and Robbins was plant ecologist of an Australian CSIRO (Commonwealth Scientific and Industrial Research Organization) land-use survey

group which worked on the Eastern and Western Highlands in 1956–1957 and prepared an extensive preliminary report on the area which, unfortunately, remains unpublished and is not available for quotation. Large collections of plants were made on less elevated parts of the Highlands, where J. C. Saunders and Pullen paid special attention to commercial types of forest surviving on upper slopes of the valleys. On later CSIRO surveys, Hoogland and Richard Schodde, also Robbins, made extensive botanical collections on Mt. Sugarloaf (about 13,000 feet) and in the Wabag area of the Western Highlands in 1960. In 1961 Pullen visited Mt. Giluwe briefly; Schodde made big collections during a stay of about two months on the mountain, during which time his wife, Sandra, collected more than 400 bird skins for the Wildlife Survey Section of CSIRO.

Other noteworthy botanical collections from the Central Highlands include those of Womersley from various areas, and of A. G. Floyd and K. J. White, former assistant botanists at Lae. Collections of the Gyldenstolpe Expedition are mentioned above. A fair-sized collection made in the Wahgi Valley and on the Eastern Highlands by H. S. McKee in 1954 went to the Sydney Herbarium.

ITINERARY AND ROUTES

INCLUDED IN THIS SECTION are descriptions of minor collecting localities; major collecting localities are described in the next section. The numbers of mammals (M), herpetological specimens (H), fresh-water fishes (F), and plants (P) taken are indicated for all localities.

MARCH–APRIL

Van Deusen and I traveled by QANTAS Airways from New York to New Guinea, via Sydney, Australia. Arriving at Port Moresby on March 22, we were met by Womersley (see p. 150), conducted official business there until March 25, then flew on to Lae. A 40-pound detail of our baggage from Port Moresby was a complete, freshly injected specimen of the peculiar pitted-shelled turtle of the Fly River, *Carettochelys insculpta*, generously presented by K. R. Slater. Collins was waiting for us in Lae.

As working quarters and repository for supplies and collections in Lae, the Department of Forests placed at our disposal ample space in a well-ventilated bulkstore building in the Botanic Gardens. Our Land Rover, previously ordered with mud-grip tires, tire chains, and a spotlight, was ready for delivery. As already mentioned, the equipment and supplies that had been shipped from New York in December had not arrived, but by various means an outfit was got together, and we were able to begin a program of limited field work almost immediately.

RECONNAISSANCE OF THE EASTERN AND WESTERN HIGHLANDS

Accompanied by Womersley, Van Deusen and I left Lae on March 31 to reconnoiter by air previously considered working areas on the Highlands. By courtesy of the Administration, we had seats on weekly connecting charter flights on a round trip of two days.

Leaving Lae at 7.30 A.M. in a single-engined Otter, we flew off the regular course at first for an examination of the southern slopes of the Saruwaged Range. The remarkably braided Markham River ran muddy on the south side of its broad, flat-floored valley. Prominent features of the rain-forested lower valley of the Markham were cocoa plantations and extensive sago (*Metroxylon*) swamps. Farther inland, where the vegetation of the valley began to change from rain forest to savanna grassland, large areas were under peanuts. Clouds cut off, and hid above about 5500 feet, the mountains which rose to generally 11,000 and up to 13,500 feet on the Saruwaged side of the valley, and on the less lofty and continuous heights of the Kratke Mountains, which formed the southern wall of the valley. For the most part the lower mountain slopes were grassy and almost treeless but for dark forest strips in gullies, clearly as a result of deforestation by native populations. Deforestation seemed generally to go higher on the topographically more mature southern slopes. Most of the visible lower slopes of the Saruwageds and, farther on, the Finisterre Mountains, were steep, rubbly, and unstable, and some of the grassy foothills, strikingly dissected in sharp ridges and gullies, were accentuated by the strike of the early morning light. Broad washes and remarkable alluvial fans were formed where larger feeder streams of the Markham, notably the Erap, Rumu, Leron, and Maniang, already braided in their detritus-filled lower mountain courses, issued from the Saruwageds and Finisterres and broke up into numerous anastomosing channels in their flow across broad grass plains in the main valley of the middle and upper river. These relatively dry, flat, open plains were over large expanses without streams or apparent watercourses. Big native plantings of bananas were seen on alluvial fans of some of the smaller streams, where no doubt ground water level stayed permanently high.

The chief object of our detour was a view of the surroundings of Wantoat, an air-supplied patrol post at about 4000 feet in a secluded small headwaters valley of the Leron, in the heart of the eastern Finisterres. Approaching it, we flew close to populated steep slopes covered mostly with second-growth forest in which graceful clumps of a big bamboo were prominent. Hamlets with smoky wet thatch were perched high on spur ridges. Some newly built ponds showed up

as we circled the Wantoat Valley, and we were told of a fish-culture project, based on *Tilapia*, that was begin pushed by the Administration to provide needed animal protein supplements in the native diet. Streams in the valley were deeply entrenched or engorged between vertical banks of rubbly, slaty-looking material.

Out over the Markham Valley again, we saw that the coterminous upper Ramu Valley was of a similar flat, grassy character, bottomed between partly grassy and partly forested high mountains and extending out of sight to the northwest beyond an imperceptible water parting with the Markham. The first of the open, grassy, heavily populated valleys of the Highlands was seen as we slipped through Arona Gap in the Kratkes and soon landed at Arona Livestock Experiment Station, over 4000 feet above sea level on a ridgy plateau area that drains to the Ramu. Forest covered the upper parts of the nearby Kratkes and Bismarcks and the tops of the higher plateau ridges. Emergent tall *Araucaria* trees showed conspicuously in the forest patch of an isolated eminence near Arona called Yonki Dome. The Arona station bred grade Shorthorn cattle and saddle horses and experimented in improvement of the natural pastures.

A flight of seven minutes over the Upper Ramu Plateau took us to Aiyura and another four minutes to Kainantu, at 5400 and 5500 feet, respectively. At Aiyura was situated the Highlands Agricultural Experiment Station, concerned mainly with coffee culture, currently also pyrethrum and fish ponds, and with some special strains of early cinchona plantings still preserved. Nearby, at Ukarumpa, were the headquarters of the Summer Institute of Linguistics, an American religious organization with aims to carry the Gospel to the native populations of Papua-New Guinea in their hundreds of languages and dialects.

Kainantu, an administrative subdistrict center of the Eastern Highlands and site of a government hospital for natives, was pleasantly situated in a wide, basin-like valley nearly treeless except for casuarinas growing along the streams and the usual forest topping the mountains roundabout. Here in 1932 the first airstrip and government post were established for opening up the Highlands, then being vigorously prospected for gold. Alluvial gold was still being won here, principally by enterprising natives who could work at a profit ground too poor to attract a European. It was a center for coffee planting and trading, and had a good small hotel. Pioneer stations of the Lutheran and Seventh Day Adventist missions were situated near Kainantu; the Salvation Army had recently moved in for child welfare work among the native peoples.

Very soon after leaving Kainantu on the 20-minute flight to Goroka we crossed a forest-crested, 7000-foot divide between Ramu waters and the great drainage system of the upper Purari River and were over the main central plateau of the country. The valleys were deeper here, their grassy floors generally about 5000 feet above sea level. The mountain ranges, 20 to 30 miles apart, rose to 11,600 feet in Mt. Otto of the Bismarcks to the north and about 12,000 feet in the Mt. Michael Range to the south. Goroka and its busy airport, in the wide Asaro Valley, were on a high old alluvial fan at an elevation variously given on maps as 5140 and 5500 feet. The town of about 500 European population had several good stores, two banks, a hotel, European and native hospitals, aircraft repair facilities, a planing mill, brickworks, coffee and passion fruit (*Passiflora edulis*) processing plants, a corn mill, and a potato-chip factory. Electricity was provided by a small hydroelectric plant. Water, reticulated through the town in open races, kept lawns green and gardens bright with flowers. It was an impressive new post-war development, based almost entirely on air transport in which large dependence was placed on the Douglas DC-3.

On a 20-minute flight westward to Kundiawa we passed over, at about 8000 feet, the forested crest of the Asaro Range, a southern spur of the Bismarcks, and entered the Chimbu country, drained by tributaries of the Wahgi branch of the upper Purari. Chuave Patrol Post, on our course, was in limestone so rugged that no suitable place could be found for an airstrip. The limestone showed in some tremendous white faces, partly forested, and was said to contain bat caves which coffee planters were investigat-

ing for guano. Kundiawa, established in 1935 and with a white population of 25, mostly government employees, was head station for the Chimbu Subdistrict, an area included in the Eastern Highlands District though actually on the Western Highlands. Our proposed working localities on Mt. Wilhelm were in this subdistrict, an area that in some valleys carried the highest human population density in Papua-New Guinea. A population average of 320 per square mile, and up to 600 per square mile for some small areas, was reported (Brown and Brookfield, 1959).

Returning to Goroka in mid-afternoon, we drove by Jeep 11 miles by a good, though in places steep, truck road to a sawmill at 7200 feet on the south slopes of Mt. Otto (P 4), which was later to be a working base of the expedition.

Take-off from Goroka for the Western Highlands next morning by DC-3 was delayed by thick weather, but eventually, on a diverted course, we were able to get a close view of parts of Mt. Wilhelm. Dark, rainy clouds hid most of the great mountain, but Keglsugl airstrip at 8400 feet on the east slopes, and extensive forests above it, were clear, and we could see enough to be assured of ample scope for our purposes in forests below the subalpine on the mountain.

Our first landing on the Western Highlands was at Minj, a subdistrict station and minor coffee-growing center at 5500 feet on the south side of the wide, grassy, middle Wahgi Valley, under the Kubor Range. Here we talked with F. Shaw Mayer (see p. 161), who had driven 12 miles across the valley by Jeep to meet us. On a 13-minute flight on to Mt. Hagen, administrative center of the Western Highlands District, we had rough air, and not much could be seen because of white cumulus clouds and dark thunderheads. The high Kubor and the huge Pleistocene volcanoes of Mt. Hagen (13,100 feet) and Mt. Giluwe (13,414 feet) were completely blotted out. Coffee growing, by Europeans in scattered plantations and by natives in usually small plots, and passion-fruit production by natives alone, were thriving new industries in the Mt. Hagen area. The township, 5500 feet above sea level, had a white population of about 50, but as yet no hotel for the accommodation of travelers. Roman Catholic and Lutheran missions were situated in the neighborhood, as was also a Seventh Day Adventist leper hospital with 450 patients.

We returned to Goroka before rain closed the Mt. Hagen airstrip, found the weather fast worsening on the Eastern Highlands, and made a hurried departure for Lae. Circling in rain over the Asaro Valley to gain altitude to clear Asiloka Pass, in the Bismarcks to the north, we flew almost blind over this, through wild clouds, then dropped probably 7000 feet into the Ramu Valley. In bad weather there, too, it was necessary to keep low for visibility. The Ramu, rising and muddy, seemed even more remarkably braided than the Markham, and it had a wider valley.

Reconnaissance of the Morobe Goldfields Area

April 3 to 5 were spent on a road trip to examine the country in a generally south-southwesterly direction from Lae to Bulolo and on to Wau, Mt. Kaindi, and Edie Creek, again with Womersley's guidance. Leaving Lae through a fine avenue of planted rain trees (*Samanea saman*), we drove through luxuriant lowlands rain forest to the Markham River, a distance of approximately 10 miles. Young cocoa plantations, some of them coming into bearing, occupied much of the roadside strip. A shallow, rapid river, the Markham flowed in several channels around low silt islands, and was crossed by a steel Bailey bridge 1700 feet in length. Outer foothills of the Herzog Mountains, partly deforested by native population, formed a high point of land on the south bank and continued as the road first followed up the river on low banks, then swung away to the west on rising ground above riverine sago swamps to Oomsis Prison Camp and the lower valley of Oomsis Creek, where a site was selected for an expedition camp.

About 5 miles farther on, the road turned south and began a steady, and initially very winding, climb, called The Bends, through uninhabited rain forest. Gurakor, a later collecting locality of the expedition at 2100 feet in the steep, narrow valley of the Wampit River, was reached 45 miles from Lae. Mid-mountain oaks appeared in a changed type of forest, and the first small coffee planting occurred here.

From Gurakor the road followed the Wampit in steepening grades in a valley that narrowed almost to a gorge with increasing altitude. The first of the mountain rhododendrons appeared at about 3000 feet, where the showy orange-flowered *R. aurigeranum* grew on a clayey road bank. Leaving the forest at the head of the Wampit, the road mounted a grassy crest at 3600 feet and began to descend into the open Snake River Valley. On broad grassy slopes at Zenag in the upper part of this valley, Michael J. Leahy, principal explorer of the Central Highlands in the early 1930's, had a big farm that produced fresh milk delivered daily to householders in Lae and Bulolo, also vegetables, poultry, pigs, and beef cattle. The main Snake, toward the lower end of its valley, flowed in a wide, shingly flood bed, some remarkable truncated terraces occurred along the river, and slumping and slipping of very steep rubbly grass slopes endangered the road in the wet season. Mumeng Subdistrict Station was situated here.

The Snake River occupies the north arm and the Bulolo River the south arm of an elevated strike valley that drains to the Watut tributary of the Markham. Unlike the Snake Valley, the Bulolo Valley is broad, flat-bottomed, and has generally more gentle slopes. Though most of its lower and middle slopes were deforested by native populations long ago, it seems that when first seen by white men the Bulolo Valley was an uninhabited no-man's-land between the very wild and warlike Kukukuku to the west and other tribes to the east. A prominent and most unsightly feature of the Bulolo today is the ridged gravel beds, formed by gold-dredge tailings, which occupy most of the river flats and, though dating as far back as 1932 in an area with about a 60-inch rainfall, exhibit little but early regenerative stages of the original forest vegetation.

The development of the Morobe Goldfields is mentioned on page 158. After a "rush" to Edie Creek in 1926, the most important development was the introduction of big, deep-digging dredges to work the rich Bulolo flats. In the absence of any road (the present road was built during World War II), the dredges were designed in pieces that weighed up to about three tons and were flown in from Lae in the largest of all air-freighting operations before the war. Eight dredges, powered by three hydroelectric plants, were at work at the time the Japanese invaded New Guinea in 1942, when the dredges were scuttled and the power plants put out of action. After the war, the equipment was returned to use, but, with the inevitable working out of available ground, only one dredge remained in operation in 1959. However, attention had turned to a great wealth of coniferous softwoods (*Araucaria klinkii* and *A. cunninghamii*) on forested slopes of the valley, and in 1953 a very modernly equipped plywood mill began production of a high-grade product, principally for export to Australia and the United States. The lumbering operation is planned on a sustained yield basis, with a 50-year rotation period, the silvicultural part being the responsibility of the Department of Forests of Papua-New Guinea. After lumbering, the forest is clear-filled, burned, and planted to *A. cunninghamii*, which shows remarkably good, even growth. Difficulty has been encountered in establishing *A. klinkii* as a plantation subject.

Bulolo (M 30, P 9), about 2400 feet above sea level and 82 miles by road from Lae, has an excellent hotel. Wau (P 2), another 19 miles, has an elevation of 3600 feet at the top of its steeply sloping airstrip. Between the towns, the road for some miles passes through Bulolo Gorge, where magnificent stands of *Araucaria klinkii* stand out on towering, precipitous slopes. Wau is administrative headquarters for the goldfields. It was the original gateway to the area on which converged the main trails of the native porters who, in several days of hard travel from Salamaua, on the coast, brought all supplies before the establishment of air transport in 1927. Sluicing and reef mining for gold still goes on in the neighborhood, a fair-sized sawmill cuts "Klinki-pine," fresh vegetables are farmed, but coffee growing seems to rank first in industry at the present time.

Eleven miles of narrow road (P 16), cut out of the mountain sides and with tremendous drops below it in places, connects Wau with Edie Creek (P 3), some 7000 feet above sea level. A grand view of the Wau Valley is had from The Lookout at 5800 feet on this road. Edie Creek was the northern termina-

tion of the war-time Bulldog Road, put through by the Australian Army as a back-door supply route for forces in the goldfields area when the Japanese held all the north coast. Bulldog Landing, at the head of launch navigation on the Lakekamu River, Gulf of Papua, was the southern termination. Passing through a high rainfall area and almost unbroken forest, the road crossed the central range at 10,000 feet. It is no longer passable for vehicles, but it gives access by foot to a remote, sparsely inhabited area of Kukukuku country, and some outposts of the Lutheran Mission.

The third collecting base of the expedition decided upon on this survey was at Kaindi, in the Edie Creek area. It may be mentioned here, however, that we went as far as we could on a new road (P 10) which was being made to the top of 7750-foot Mt. Kaindi to service a radio-telephone automatic repeater station for traffic between Lae and Port Moresby.

On April 10 we moved from Lae to Oomsis with what equipment and collecting supplies we could muster. We returned to Lae on April 20 to receive our delayed cargo from New York, and were back at Oomsis, fully equipped, on April 24.

MAY

Picturesque Lake Wanum, about 200 feet above sea level in the lower Markham Valley, was visited from Oomsis Camp on May 2. The lake is of irregular outline, roughly 2 miles by 1 mile, and the water is clear, fresh, and apparently deep. Marshy eastern shores are fringed with reeds and great beds of pink lotus (*Nelumbo nucifera*); the other shores rise in grassy hills capped or patched in places by relic rain forest. The shallows of little sandy bays[1] sparkle with mica flakes. Numerous crocodiles suggest an abundance of fish. The only surface outlet of the lake is a small two-way connection with Oomsis Creek, a muddy gutter through which the lake also receives water when the creek is in flood (F 9, P 18).

Oomsis Camp (M 144, H 64, P 198) was vacated and the party moved to Gurakor on May 4. Work proceeded there until May 11 (M 43, H 16, P 125), when we moved on to Kaindi. At this mountain camp we had the pleasant company of Forest Officer J. J. Havel for three days, for extension of his knowledge of the montane flora; and of Richard Leahy, who for a week helped in hunting for mammals and had instruction in the preparation of mammal specimens. Work at Kaindi was terminated on May 28, when we returned to Lae to make final preparations for the second, high-mountain, phase of our program.

A considerable quantity of collecting supplies and field equipment had already been air-freighted to Goroka and held for us in Government Stores. Food supplies had been ordered from our agents in Goroka, charter flights were arranged, and plane loading and carrier transport were worked out in detail.

JUNE

With about a ton of cargo on the Land Rover and trailer, Collins and I, with two boys, left Lae on June 1 on the 214-mile road journey to Goroka. Van Deusen, with three boys, flew in on June 3. Our road trip was leisurely, designed for an examination of the country en route as well as getting to a destination. Starting from Lae a day behind us, on the real opening of the road at the beginning of the dry season, was a big convoy of government and privately owned vehicles ranging from Volkswagen cars to two heavy trucks carrying bulldozers, which with mutual help would be sure to get through, barring unexpected torrential rains.

The first 108 miles of the road ran through the flatlands of the Markham Valley. For about 21 miles, to where the great Nadzab complex of war-time bomber and fighter airstrips had begun, the vegetation was rain forest in which, especially in the first few miles, were numerous cocoa plantations. Here, with diminishing rainfall, the forest began to break up into an ecotone with a savanna type of vegetation perhaps best described as open, kangaroo-grass (*Themeda australis*) plains with a thin scattering of small, crooked *Antidesma ghaesembilla* and *Albizzia procera* trees. With local variations from savanna woodlands to treeless grassland, associated with changing edaphic conditions, open vegetation continued to the

[1] The new mollusk *Gyraulus limbatus* (Jutting, 1963) was collected on a beach of the lake.

upper end of the Markham Valley and far beyond into the Ramu Valley. Seldom seen were the gallery rain-forest strips which are generally found along streams under such conditions in New Guinea.

Thirty miles from Lae the bridged Erap River was crossed. Here, in open, rather dry, grass country, which might be rated second-class grazing for cattle, were the Lowland Livestock Station and some experimental sisal plantings of the government. The grass plains varied from about 2 to 10 miles in width as the valley narrowed and broadened.

Sixty-two miles from the coast and 800 feet above sea level we came to the dreaded Leron River, crossed by a difficult ford and the principal obstacle on the road. Gravelly and bouldery, and constantly turbid with gray silt from unstable slopes of the Saruwageds and Finisterres, the Leron was a fast stream with several changing channels between sharp-cut banks about 400 yards apart at the crossing. With the sparkplugs and distributor of the Land Rover previously waterproofed, and the fan belt off, Collins drove diagonally downstream with the current in the deepest and widest channel. We had an inch or more of water in the cab, and it washed over the top of the low-loaded trailer, but the motor kept going and we got through safely, if somewhat shaken by the experience. A bridge has since been built where the Leron issues from the mountains and its bed is narrower.

Virtually treeless, wide, grass plains of fine-textured chocolate soil, carrying thousands of low cycads (like *Cycas media*), presented a remarkable sight beyond the Leron (and gave off choking dust on our return journey in November). Only a very scattered native population had been seen along the road until we reached the Maniang River at 74 miles. This river had a soft shaly bottom and, until bridged, was the worst ford on the road. A sizable village stood on the east bank, its conical grass roofs reminiscent of East Africa. The women here wore grass skirts and were bare above the waist. We were getting away from the semi-sophistication and the unsightly Mother Hubbards of the coast.

On approaching the Umi River, we detoured into the forested foothills of the Finisterre Mountains where first the Ofim branch of the Umi, then the main stream, were crossed on swinging bridges of wire cables and steel Marsden matting in deep, narrow valleys. These bridges would carry only light traffic (heavy vehicles crossed by a deep ford downstream). They bounced when walked upon, and the segmented steel decking rose in ripple ridges before the wheel thrust of the Land Rover. A site for the concluding camp of the expedition was chosen on the Umi, about 95 miles from Lae. Returning to the grassy main valley, we passed several big villages well shaded by tall coconut palms, mango, and other trees, and at 108 miles reached Water Rice, 1500 feet above sea level. From here the old war-time vehicle track we had followed most of the way from Lae continued on into the upper Ramu Valley, and our Highlands road, opened for traffic in 1957, swung south toward the mountains. A government rest-house at Water Rice later made a convenient collecting base for the expedition.

At Water Rice we were leaving the lowlands and the cultures of the lowlands peoples. We therefore bought a stock of betel-nut and betel-pepper to help the morale of our lowland native personnel while on the high, cold slopes of Mt. Wilhelm, also a few ripe grating coconuts to flavor their rice and rub on their hair—while the supply lasted. Then 5 miles through savanna forest on gently rising ground brought us to the beginning of a hard, tortuous, 5-mile climb of 3300 feet to Kassam Pass. Rain forest came low in a narrow valley we followed, which soon became a gorge. Oaks were conspicuous from about 2000 feet up to the Pass, and between about 2400 and 4200 feet on the Markham slopes *Araucaria klinkii* attracted special attention as a tall, emergent tree of oddly primeval appearance. The road passed in and out of this forest, with emergences on a grassy spur ridge which gave spectacular views of the coterminous Markham-Ramu valleys and the high Finisterres and Saruwageds, which formed a continuous range on the far side of the valley.

The vicinity of Kassam Pass, sole road entrance to the Central Highlands, is described elsewhere as a part of the working area of our Kassam Camp, situated where the road came out on the open Highlands

about 2 miles beyond the Pass. Of two roads leading to Kainantu, we took the long one of 32 miles via Arona and Aiyura to examine a ridge-top body of *Nothofagus* forest previously observed from the air, and to call at the Agricultural Experiment Station. Much of the grassland soil between Arona and Aiyura was lateritic. The local natives, who maintained the road one day a week, did it with grace and decorated their work, as about their own villages and gardens, with colorful edgings of "dracaenas" (*Cordyline terminalis*) and other ornamental shrubs and herbs. We stayed the night at the Kainantu Hotel, 152 miles by our route from Lae. There was a darts board in the bar, a log fire made the parlor comfortable in the evening chill of the Highlands, and we were glad of three thick blankets on our beds.

From Kainantu on June 2 we climbed gradually through grasslands and in about 10 miles topped the Ramu-Purari Divide at 6200 feet, the highest point on the road between Lae and Goroka. A considerable body of primary *Castanopsis*-oak forest, much disturbed by the rootings of village pigs, occurred here. The only forest of consequence surviving near the road from there to Goroka was a striking patch of *Araucaria cunninghamii* on the Dunantina River near Henganofi Patrol Post. Forty miles from Kainantu we mounted a grassy 5200-foot divide from Dunantina waters and entered the great Asaro Valley—wide, grassy, and not so very hilly as the small valleys we had passed through that morning. Coffee plantations, situated on virtually treeless slopes and river flats and shaded by *Albizzia stipulata* and other planted trees, became a prominent feature on and near the Bena Bena River. Everywhere on the better lands reasonably close to waters for domestic supply were the villages and gardens of a very numerous native population of friendly, unwashed, smelly, and often noisy peoples seemingly devoted to an unadorned and timeless existence of raising crops of the staple sweet potato, tending the ubiquitous, well-fed, roaming, and inquisitive pigs, and procreating their human kind, for, deceptively no doubt, evidence of little else appeared to the passer-by.

Not very encouraging recent efforts had been made near Bena Bena in the reafforestation of eroded, no longer cultivable, grassy slopes by plantings of *Araucaria cunninghamii*. But near Goroka was seen the beginning of good natural regeneration by woody growths on long-deforested lands which in recent years had been protected from fire by strictly enforced official policy.

In two charter flights on June 6 of a QANTAS Otter aircraft piloted by Ross Crabb and co-piloted by Jim Taylor, all personnel and gear and supplies for two months, totaling 4307 pounds, were transported from Goroka to Keglsugl, at 8400 feet on the eastern slopes of Mt. Wilhelm. Flying time from Goroka to Keglsugl was only 25 to 30 minutes, and the whole operation ended by 9.30 A.M. Early flying and quick turnabouts were dictated by the expectation of strong winds on the Keglsugl strip after about 10 A.M. in the Southeast season, which then prevailed.

Kuglsugl strip, opened in 1936 by the Catholic Mission for supply by light aircraft of its Denglagu station, about 900 feet lower on the slopes of the Upper Chimbu Valley, was made difficult for take-offs by a slope of some 200 feet from top to bottom ends, and for landings it was made a "one-shot" strip by its position in a narrow valley which no ordinary aircraft could climb or bank out of after a wrong approach. During the war an American Liberator bomber crashed on the mountain at 13,500 feet after reportedly having attempted a landing at Keglsugl, then trying to climb out. We camped at the strip two days to send out word for carriers and somewhat accommodate oursleves to the altitude. A warm grass hut was built for the boys, and our cargo was stacked in a small storehouse kindly made available by Father N. Beutener of the Mission.

On June 8 we started up the mountain at 8 A.M. with 53 male porters and accompanied by numerous women carrying garden products for sale upon arrival at our destination. At 8600 feet, the upper limit of gardens in the neighborhood, the old path we followed passed through a planted grove of a big-seeded *Pandanus*, called *karuka* here, then entered good primary forest on easy slopes. In about an hour of rather slow travel, a stream called Pengagl was reached at 9100 feet, where a high bank offered a suitable site for our second collecting camp on the mountain.

The route then led on up the bed of the creek, with good travel on bare stones. In less than a mile I left the main party and, with a guide, followed an old trail through the forest off the south bank to examine a place where E. T. Gilliard had collected birds for the American Museum for four days in June, 1950 (Mayr and Gilliard, 1954, p. 320). Gilliard's "Forest Camp" had been in a small clearing at 9800 feet by my aneroid in low, damp forest cluttered with scrambling bamboo. Birds of paradise were hunted in the locality, according to my guide, and a low hut with *Pandanus* thatch stood in the clearing.

At 9850 feet the trail left the bed of Pengagl Creek and began a long, steep climb through forest that changed in composition and became lower and increasingly mossy with altitude. Alpine grassland was reached at the lower end of a deep, U-shaped, glacial valley at about 10,900 feet. Somber subalpine forest clothed the slopes almost down to the valley floor. Both living and dead fronds of a squat tree fern (*Cyathea atrox*), plentiful on the grassland, provided fuel for quick fires around which the carriers, most of them virtually naked, gathered to keep warm while they rested.

In following the poorly drained bottom of the glacial valley, the trail kept to the best ground, but often it was a trail of sticks laid on peaty bog badly cut up and mired by our carrier traffic. The valley rose gradually in steps, on one of which, at 11,400 feet, the entrenched small drainage stream, called Iubuka, formed a conspicuous cascade. Cold, misty rain began at noon, an hour before I, at the end of the transport line, reached what we called the Piunde-Aunde Camp site at 11,700 feet. Collins and Van Deusen had roughly rigged a tent to protect the cargo. Smoke belched from two low huts of grass and bark, but most of our hardy Chimbu and their womenfolk contented themselves with fires in the open.

During a break in the rain the cargo was lined up and the carriers were paid in cash and tobacco, the garden produce was weighed and bought from the women, and most of the people departed for their homes down the mountain. About 20 men who stayed to help build camp retired to more grass huts across the valley. We put our boys into one of the huts at the camp site, and ourselves crawled into the other. Leaks developed with heavy rain toward nightfall, and we spread a fly over the roof. But with choking smoke which filled the hut until we let the fire die down, hard ground, and cold drafts coming through the walls, none of us had much sleep.

The morning broke clear and for an hour or more, when rain set in again, snow glistened on the heights down to about 13,500 feet. Through a truly miserable day of intermittent cold rain our Chimbu helpers, supervised by Collins, brought in timber and grass and built a hut, 11 by 13 feet, which we could stand up in. We had our beds on the ground, well padded beneath with (wet) grass, and wall shelves of sticks for stores and personal belongings, around a central log fire. The old huts were repaired, and two work tents were rigged. All possible comfort was needed for an extended stay at this altitude. And during the past 24 hours four of our five permanently employed boys, including the cook, had gone down with "Echo 6," a virus complaint then epidemic in eastern New Guinea, which none of the party escaped.

From this camp Collins with two Chimbu guides, Wak and Tobram, climbed to the summit of the north or main peak on June 16. Collins and Van Deusen with three Chimbu, Tobram, Demkana, and another, made the ascent on June 18, when Collins also climbed the south or second-highest peak. Collins with Tobram and another Chimbu, Ongorgor, made a third ascent of the main peak on June 27. My highest point on the mountain was 13,450 feet, attained while botanizing on June 26.

Doubts exist about the height of Mt. Wilhelm. Recent maps (for example, Territory of Papua and New Guinea 1:2,534,400, National Mapping Office, Canberra, 1954) give it as 15,400 feet. The mean of four aneroid readings made by Collins on his three ascents of the main peak, called Enduwa-kombugu by the Chimbu, was 14,950 feet. This accords closely with a boiling-point determination of "about 14,900 feet" by Vial and Noakes on June 27, 1939, and aneroid readings of 14,900 feet by Pullen and 15,000 feet by Pullen and Hoogland in July, 1956 (records in a cairn on the summit, see p. 185),

and is probably near the true height of the peak. The number 2 or south peak is about 50 feet lower.

As Collins had built with Chimbu labor on June 22 to 26 comfortable huts at the camp site selected on Pengagl Creek, we abandoned Piunde-Aunde Camp (M 262, H 90, P 403) on June 29 and moved down to the new camp with 44 lightly laden carriers.

JULY

At Pengagl Camp we had as guests from July 13 to 15 District Commissioner H. P. Seale and Mr. K. C. James of Goroka. Accompanied by Collins, they climbed to the Piunde-Aunde lakes and returned to camp on July 14.

In a long walk of 10½ hours, Collins on July 29 made an examination of Bundi Gap, on the Bismarck Range at the head of the Chimbu River, and returned to Pengagl. He reported magnificent beech forests between elevations of 8500 and 9700 feet on gentle slopes in the Gap area. The top of the Gap, at 9500 feet, was reached in an hour and a half of fast travel from Keglsugl airstrip.

Work at Pengagl Camp (M 562, H 673, P 608) was concluded on July 31, and gear and collections were carried down to Keglsugl to be weighed and organized for transport back to Goroka. The small quantity of surplus stores on hand was given to the mission at Denglagu.

AUGUST

With two charter flights of an Otter aircraft piloted by Captain Taylor, and limited to a payload of 1500 pounds for the high-altitude take-offs, transport from Keglsugl (M 8) to Goroka was completed by mid-morning of August 1.

Supplies for two weeks were loaded on the Land Rover, and we left Goroka on August 4 to take up quarters at Kotuni Sawmill, on the south slopes of Mt. Otto. While in Goroka we had met Philip Spalding, Russell F. Peterson, William Hosmer, Lionel J. Evennett, and Philip Spalding, Jr., of the Spalding-Peterson Expedition to Australia and New Guinea of the American Museum, and were able to assist the party with local road transport. They went on to the Western Highlands for a short period of mammal and herpetological collecting at Nondugl and Mt. Hagen.

On August 10, and again in more favorable weather on August 12, Collins and my two botany boys, Edewawa and Soni, made day-long collecting excursions to the summit area of 11,613-foot Mt. Otto, reached in a very steep climb of three to four hours from Kotuni. We finished at Kotuni (M 126, H 962, P 330) and returned to Goroka on August 20.

August 21 and 22 were spent by Collins and me on a ground reconnaissance of the Mt. Michael area in the Land Rover, while Van Deusen collected mammals at Daniel F. Leahy's coffee plantation on the Bena Bena River, not far above its junction with the Asaro.

The road to Mt. Michael crossed the Dunantina River on a teetering, wire-cable, swing bridge and in a long, winding, generally easy climb over grasslands and past scattered villages reached a 6250-foot saddle on a spur ridge of the northeastern slopes of the mountain. In 2 miles from there through garden lands and forest relics we came to Thick's sawmill at Guruka, at 6200 feet on the lower edge of a fine body of *Nothofagus* forest which contained other millable hardwoods and some *Podocarpus* softwoods. Scattered big kauri pines (*Agathis*) towered in the lower beech forest, and in *Castanopsis*-oak forest that survived in gullies at somewhat lower levels. Some beech logs at the mill were up to 5 feet in diameter. Haulage was by Caterpillar tractors and jinker truck, under fairly easy conditions of slope.

A mile past the sawmill the road rose to 6800 feet and entered a splendid *Nothofagus-Castanopsis* forest in which our Kimi Creek Camp was later situated. Lufa Patrol Post, at 6300 feet on a bold grassy bulge on the edge of the Asaro Gorge and almost due north of Mt. Michael summit, lay another 8 miles on, the intervening area of slopes being generally grassy below the road and forested not far above it. Established in 1953 and built mostly of native materials, Lufa had a small detachment of armed native constabulary, a hospital for natives, and a government elementary school. A mile farther along the road was the Havakeveta station of the Faith Mission, in the charge of the Reverend Harold Sellars.

Accompanied by Medical Assistant McSeveny of Lufa, we continued 12 miles around the mountain to the end of the road at Gono, on the western slopes. This was new road, opened the previous November, and an excellent example of what often is done by non-engineer personnel in Papua-New Guinea in driving roads through most difficult mountain country. It had been laid out by a patrol officer, and the work was done by local natives supervised by native police. Much of the distance was on very steep slopes of crumbly soft mudstone, the forest broken rarely by small villages and native gardens, for not even New Guinea people could cultivate such precipitous ground. From a high point of 7480 feet on a spur called Hogave, the road descended to 6400 feet at Gono. The *Nothofagus* forests of the northern slopes had extended for about 4 miles around the mountain from Lufa, there to be replaced by mixed rain forest under apparently much wetter and more misty climatic conditions. A pinnate palm grew commonly in the rain forest up to the Hogave high point, the highest at which arboreal palms were seen on this expedition. From what could be made out of Gono in late afternoon mist and rain, it was decided upon as a working place, and we returned to Lufa to dine with the hospitable McSevenys and sleep in the absent patrol officer's house.

Some botanizing was done along the road next morning (P 8). At Bena Bena (M 12) Van Deusen's traps had yielded only *Rattus ruber* and the very common *R. exulans* of the grasslands, but our first specimen of fruit-eating *Rousettus amplexicaudatus* had been caught in a bat net placed under a wild fig tree. Except for a few casuarinas and rain-forest regrowth trees along the river, the area was virtually treeless grassland, with tall reeds (*Phragmites*) and pit-pit (*Saccharum*) on sandy and gravelly flood terraces. Dry, hot weather was being experienced, and, despite the prohibition on burning, there were grass fires in the valley. From a native on the edge of one of the fires we bought the head of a badly scorched bandicoot (*Echymipera kalubu*) for a shilling. Catfish (Siluridae) were reported to occur in the Bena Bena.

With the Land Rover on August 24 we left Goroka and established ourselves at Gono. This camp of bad weather and poor collecting (M 25, H 121, P 48) was closed on August 29, when we moved back 18 miles along the road and set up our tents and flies at Kimi Creek.

Collins, with my two botany boys and Tobram of the mammal crew, climbed Mt. Michael in good weather on August 31. They left camp at dawn and drove to Havakeveta, where six small boys were picked up as guides. In a rapid ascent, the first alpine grassland, at about 11,200 feet, was reached in three hours. From there the party botanized up to the first small peak of a long summit ridge, where at 11,700 feet a yellow-painted marker for air traffic had been built, and on to the main peak, approximately 12,000 feet, in actual walking time estimated at about one hour. A trail that they followed passed in and out of stunted forest from the first alpine grass to the marker peak, which was timbered to within 30 feet of its crest, thence on tussocky grassland to the true summit. On the grasslands a dog belonging to one of the guides caught a phalangeroid marsupial, *Pseudocheirus cupreus*, usually considered arboreal in high-altitude forests, and the bleached skull of a giant rat, *Mallomys rothschildi*, was picked up. The 14-hour excursion yielded a fine lot of plants (P 121) as the first botanical collection to be made on the upper parts of this isolated high mountain.

SEPTEMBER

John Womersley with a native assistant, Nima, arrived at Kimi Creek Camp on September 2 for a week of botanizing. On September 5 and 6, in more or less rainy weather, a party led by Collins and comprised of Womersley and Nima, Van Deusen, Tobram, Soni, and carriers from Lufa, made an ascent of Mt. Michael. Following Collins' route of August 31, they spent the night of September 5 at what was called "Mt. Michael Ridge Camp," at 10,200 feet, went on to the main peak next morning, and returned to Kimi Creek. On a prominent group of granite[1] rocks that distinguished the actual summit, previous visitors had inscribed these records, as copied by Womersley: "13,000′ Mt. Michael, Nielsen & Robertson 1/5/41";

[1] Specimen identified by Brian H. Mason, the American Museum of Natural History.

"27.6.54 Bridges, McGrath, Thyer, Zachar, 11,800 ft."; "8. 8. 59 W. R. McSeveny." The high-altitude botanical collections of this trip (P 59) contained only a few species that were not collected on August 31 (see p. 174).

Dr. Morris Rapson, Chief, Division of Fisheries at Port Moresby, and his son Philip were our guests at Kimi Creek on September 9 and 10. With John Barrett, entomologist at Aiyura Experiment Station, they had recently made a four-day visit to the Piunde-Aunde lakes on Mt. Wilhelm (see p. 185). Kimi Creek Camp (M 111, H 783, P 214) was closed and we returned to Goroka on September 14.

Mention may be made here of annual flights of a brown beetle, *Lepidiota vogelii* Brensk, according to John Barrett, which take place in the Asaro Valley. The flights are said to occur about the time of the September moon. They begin with the first good rain, and recur after the next few rains. The beetles, about an inch in length, appear in vast numbers from underground on grassland late in the afternoon, mate in low flight, and return underground about dusk. They are caught in quantity by the local natives, who relish them as food. Collins saw a flight in Goroka on August 17 and collected specimens. On September 15, about the time the last flight of the season was expected to occur, a few beetles for gastronomic sampling by Van Deusen and myself were produced by watering a patch of lawn. A distinct cathartic effect can be reported.

The work planned for western parts of the Eastern Highlands was now completed. Collections were flown out to Lae, supplies were reorganized, and on September 17 we drove east to Kainantu. The following day, in search of a camp site in good primary forest, we traveled a fairly good road for 36 miles in a southwesterly direction to Okapa Patrol Post, then a recently completed and in places very steep road another 16 miles to where a camp was set up at an elevation of 6400 feet near Purosa.

Nine miles from Kainantu and about 6000 feet above sea level we had entered beech forest of tall, gray-boled, rather slender trees, with an admixture of *Castanopsis*. Somewhat broken by grassy areas, this forest continued for about 4 miles to near Sonofi village, where the country changed to limestone, with conspicuous jagged outcrops, and an open, small valley contained a numerous native population. Past Sonofi, hilly man-induced grasslands prevailed, and no large body of forest was passed through until, 23 miles from Kainantu, we took a new loop road and were soon in good forest. *Nothofagus* trees were not seen in this, and it had the character of mixed rain forest. In it were villages, but, although no great break occurred for 7 miles, we saw no place suitable for a camp. Little of the original forest remained close to the road about Okapa, though *Nothofagus* reappeared here. And from 2 miles past Okapa to about 2 miles from our Purosa Camp, forest was not entered. Though a part of the Eastern Highlands, the country passed through this day presented a major ecological difference from the Kainantu-Dunantina-Goroka area in that, rather than being a great, long-established grassland from which the original forests had retreated to the mountain tops, it was a forest area broken by grasslands of which some were of no great age and others were in the process of being established.

Situated at about 6500 feet in picturesque mountain surroundings, Okapa Patrol Post was established in 1954. It has become well known as the center for research on *kuru*, an almost invariably fatal neurological disease which causes high mortality in females and is found only in the Fore linguistic group and their immediate neighbors (Zigas and Gajdusek, 1959). In the valley of the Lamari River, within sight from the patrol post and at considerably lower elevation to the southeast, were extensive stands of *Araucaria*, unexploited for lumber but used as a source of seed for reafforestation projects on the Highlands. The area carried only a small native population and was known to be a reservoir of cerebral malaria.

From Purosa Camp on September 28 bat-hunting excursions were made to limestone caves in the vicinity of Okapa. A small cave under the old Kainantu road, 6 miles beyond Okapa, yielded nothing. A Jeep road descending from the patrol post toward the *Araucaria* forests was then followed for 2 miles to Ilafo village, from where Van Deusen and Collins, with local guides, walked another mile to a large cave called Esindona,

at an elevation of about 5500 feet. In this cave (M 96) *Dobsonia moluccensis* was shot, and *Miniopterus australis* and *M. schreibersi* were caught by various means, including my butterfly nets.

OCTOBER

Purosa Camp (M 203, H 120, P 289) was evacuated on October 3, and we returned to Kainantu by the old or west road from Okapa. Much good *Castanopsis* forest and mixed rain forest occurred between Okapa and Moifa, a distance of 13 miles, the forest fragmented by old and new garden clearings but surviving in considerable bulk. Scattered big beeches occurred with the *Castanopsis* at about 7000–7300 feet in the Moifa area. At Sonofi we found based in the government resthouse T. C. Maa of the Bernice P. Bishop Museum, collecting ectoparasites of birds and mammals and making a specialized insect collection. Only swiftlets were found in a big cave near the road in which we searched for bats. Maa, however, was kind enough to share with us (M 8) a nice lot of *Miniopterus australis* and *M. schreibersi*, caught by natives in other caves in the neighborhood.

Hitherto, virtually all of our collecting on the Highlands had been at elevations above 6000 feet. For investigation of the next altitudinal zone below, we therefore, on October 5, set out for the Arau-Karanka area, on the easternmost edge of the Highlands. Information on this area had been hard to obtain, and about all we knew about it was that good primary forest and limestone caves existed there, and two newly established coffee plantations.

We followed the Lae-Goroka road to some miles beyond Aiyura, then a branch road going south to Omaura Mission of the Seventh Day Adventists at about 5000 feet. A considerable amount of fragmented original forest here, on reddish lateritic soil, consisted of a typical mid-mountain stand dominated by oaks and *Castanopsis*, with an occasional *Araucaria* protruding above it. A mile or two to the south, the King Island Scheelite Company was testing for gold, by churn drill, a big body of iron pyrites. On a very hilly new road east from Omaura, we crossed a divide between Ramu and Markham waters, descended several hundred feet to a bridge over the Wanton River and made a short climb to Arau No. 1 village and resthouse, 24 miles from Kainantu and 4600 feet above sea level. Continuing, we soon came to trim young coffee plantings and, beautifully framed in oak forest and mountains, the most attractive homestead and most colorful gardens we had seen anywhere on the Highlands. Though entirely unexpected by them, we were given a warm welcome by Mr. and Mrs. W. H. Larner and gladly accepted the offer of a spare house to base in and quarters for our native personnel.

From Arau on October 17 Collins, with botany boy Soni and Hetanin, the cook's helper, walked between four and five hours to Obura village in the broad, grassy valley of the upper Lamari River. On October 18 they climbed 8300-foot Mt. Elandora, on the nearby Kratke Mountains, and returned to Arau with the first botanical collections (P 43) from that prominent, sharp-topped peak (see p. 203).

Work at Arau (M 159, H 150, P 336) was terminated on October 26, when the party returned to Kainantu, obtained fresh supplies, and proceeded to Kassam, on the Lae-Goroka road, to establish the last base of the expedition on the Highlands.

Also on October 26, with the idea in mind of a short-term camp to terminate the expedition, I made a charter flight with Laurence Crowley, in a Cessna 170, for a closer survey of the Wantoat Valley than had been possible on our aerial reconnaissance of March 31. Take-off was from Karanka, near Arau, and almost on the edge of the Markham Valley. Most of this great grassy valley looked green, but big areas of the eastern foothills had been burned, and the ground left a dead black, only a day or two before. After circling the Wantoat Valley we landed at the patrol post. The valley contained some secondary grassland but mostly a vegetation of second-growth forest with relics of the original forest in gorges and a clothing of primary forest fairly high on steep slopes. For satisfactory working, the valley would require camps low and high on the slopes and more time than was available to us. My flight ended at Kainantu.

We were glad to have entomologist T. C.

Maa as our guest at Kassam from October 28 to November 9.

NOVEMBER

On November 9 collections, spare gear, and supplies were taken to Kainantu for air transport to Lae, Kassam Camp (M 126, H 689, P 212) was closed, and we moved down to Water Rice in the Markham Valley. After our five months on the Highlands the heat of the valley felt oppressive, and we had some sunburn.

Gusap cattle property in the upper Ramu Valley, about 8 miles by road from Water Rice and at an elevation of about 1400 feet, was visited on November 11 (P 7). The property had been taken up in 1956 and comprised 42,000 acres. A growing herd of 1100 well-managed cattle consisted of a basic Shorthorn-Zebu cross into which Santa Gertrudis blood was being introduced. The only bad pest was a screwworm fly, thought to be a native species. It was planned to kill the fat cattle output at Gusap and air-freight the beef to Lae and other towns where a market offered.

On November 13 we left Water Rice (M 22, H 300, F 50, P 33) and set up camp at the Umi River bridge. This last collecting base of the expedition (M 111, H 25, P 206) was closed on November 29, a little earlier than originally planned because of local heavy rains, the river in constant spate, and therefore apprehension about the big Leron River, which had to be forded on our way to Lae.

A call was made at Kaiapit, on the north side of the Markham Valley en route to Lae. The Leron was found to be in low stage, with about 2 feet of water in the deepest channel and, for that river, easy to cross with the Land Rover and trailer. In fact, hot, dry conditions obtained in the Markham Valley from the Maniang River, only 21 miles from the Umi, to the edge of the continuous rain forest of the lower valley, approximately 20 miles from the coast, and even in the rain forest the last water had dried from small swamps on the roadsides.

DECEMBER

December 1 to 3 was spent by Van Deusen and Collins on a road trip from Lae primarily to Bulolo and Wau to take delivery of mammal specimens that friends had collected for us. On December 4 and 5 I visited areas of the Territory hitherto unknown to me on a "Rabaul Courier" round-trip flight of Mandated Airlines from Lae, with stops at Goroka, Madang, and Wewak on the mainland, Momote in the Admiralty Group, Kavieng on New Ireland, and Rabaul on New Britain.

The packing of our ocean freight for the United States having been completed, Van Deusen left Lae by air on December 9, first for a two-day visit with F. Shaw Mayer at Nondugl, thence via Goroka to Port Moresby, and on to Australia. There, on mammal research, he visited museums and other scientific institutions in Brisbane, Innisfail, Sydney, Canberra, Melbourne, Hobart, Adelaide, and Perth, and made a number of field trips, before his return to New York on February 21.

With Womersley and the Reverend N. E. G. Cruttwell, a house guest who for 12 years had made important botanical explorations in his mission area in far eastern Papua, I visited by air from Lae on December 13 the very colorful Wau Annual Show. Borrowing a Jeep, Cruttwell and I drove up to the 5800-foot Lookout on the Kaindi road to collect, on special request from the Flora Malesiana Foundation, and as the last gathering of the expedition, pickled material of *Lobelia angulata*, common there.

I flew from Lae to Port Moresby on December 15 to wind up official business. On December 20 I took an airplane to Cairns and thereupon began a stay in Australia, principally on vacation, from which I arrived back in New York on January 24, 1960.

COLLECTING STATIONS

LAE, MOROBE DISTRICT

MARCH 25 TO APRIL 10; APRIL 20 TO 24; MAY 28 TO JUNE 3; NOVEMBER 29 TO DECEMBER 15

A RATHER COMPACT, tree-planted place with a European population of about 1600 in 1959, Lae (originally Lehe) is situated at the head of Huon Gulf, with the mangrove-fringed mouth of the Markham River close to the west. The small Butibum River reaches the sea on the east edge of the town. Other short and at times turbulent small rivers, rising on the Rawlinson Range (the Busu, Bupu, and Bunga), flow across a narrow coastal plain in the next 6 or 8 miles, which was as far east as our field activities took us. The unbridged Bunga had a wide gravelly bed and was unfordable by a motor vehicle when we saw it. The Markham is a big river, but shallow to near the sea (see pp. 154, 167). At its lower end the broad flat valley of this river pinches in between the high Herzog Mountains on the south side and a limestone ridge, about 200 feet high immediately behind the town and up to 1130 feet some 5 miles inland.

The old town of Lae is built on what appears to be a marine terrace that widens out to give room for the length of the airport runway, one end of which begins on the brink of a 30-foot cliff rising from the waters of the Gulf. The new town, holding most of the government offices and the main shopping section, is well laid out on an elevated river terrace, up to perhaps 100 feet above the sea, on which mangrove mud and mangrove wood have been found in excavations for the foundations of buildings. Magnificent views of nearby mountain masses are had from parts of the town, the lofty dark Saruwageds and the Rawlinson Range piling up to the north and northeast, the almost equally impressive Herzog Mountains to the south.

Lae has an average annual rainfall of about 190 inches, most of it said to occur at night. The seasons are reversed from the regime most prevalent in the Territory in that the Southeast season is the wettest, with monthly highs in May and September, and the Northwest the driest, with a January–February low, though average rainfall is ample in every month. In general, hot, humid conditions prevail. The high mountains are not close enough to benefit the town with cooling downdrafts at night, but the frequent rains have a moderating effect on temperatures.

The natural vegetation in the area, and still for the most part the existing plant cover, is a tall, floristically rich, luxuriant lowland rain forest, merging into foothill types of rain forest, and some swampy rain forest toward the coast and along the Markham. Easterly from the town the primary forest is much broken for several miles by coconut plantings, native villages and gardens, forest regrowths, and apparently long-established strips and patches of secondary grassland with tall, coarse grass cover and scattered small trees and cycads (*Cycas ?media*). In the "Trans-Busu," ending at the Bunga, a timber concession was being spot lumbered with tractors and other modern equipment, the most notable tree being a great dipterocarp (*Anisoptera kostermansiana*), abundant on the foothills and inner parts of the coastal plain. Other important timber trees included species of *Dysoxylum*, *Aglaia*, *Celtis*, *Alstonia*, *Terminalia*, *Sterculia*, *Pterocymbium*, *Sideroxylon* and *Spondias*, *Pterocarpus indicus*, *Intsia bijuga*, *Dracontomelum mangiferum*, and *Octomeles sumatrana*. An unusual dearth in palms attracted attention.

Westerly from the outskirts of the town and for some miles into the Markham Valley the rain forests were broken by cocoa plantations, then coming into bearing, and other recent clearings. Within the town boundary, an area of 144 acres of varied terrain had been reserved for a botanical garden and a good start had been made with plantings, plant houses, and other physical developments. Special features of the gardens included massed outside displays of epiphytic orchids such as *Vanda*, *Arachnis*, and *Dendrobium veratrifolium*, and a surviving belt of tall rain forest noisy at times with the raucous calls of birds of paradise (*Paradisea apoda augustae-victoriae*) in the treetops.

The pressure of other duties precluded all

but slight attention to botanical collecting at Lae, an area already fairly well known for plants. Van Deusen's trapping for mammals was done with inadequate make-do equipment before the arrival of our delayed cargo from New York. Traps would be sprung by rain or the giant toads (*Bufo marinus*) which appeared at night in considerable numbers,[1] and only *Rattus rattus* was caught. In night-hunting with jacklights, and a spotlight on the Land Rover, Van Deusen and Collins, usually accompanied by keen local residents, ranged extensively on a complex of war-time back roads. The best of rather sparse results in flying foxes (*Pteropus neohibernicus*), bandicoots (*Echymipera kalubu*), gray cuscus (*Phalanger orientalis*), striped possum (*Dactylopsila trivirgata*), and *Petaurus breviceps* were had in an area where ordnance dumps had been widely dispersed through the forest, and there might still have been some danger from concealed land mines and other lethal relics. Bat shooting at dusk yielded insectivorous small *Miniopterus australis* and especially *Pipistrellus papuanus*. From mist nets set in the Botanic Gardens came good catches of the fruit- and nectar-eating small bats *Syconycteris crassa*, *Nyctimene albiventer*, and *Macroglossus lagochilus*.

OOMSIS, MOROBE DISTRICT

April 10 to 20; April 24 to May 4

This lowlands and foothills camp, 350 feet (about 100 meters) above sea level and 22 miles west of Lae on the Bulolo Road, was at "Mark Schultz's place," where unoccupied buildings provided comfortable quarters for all personnel, and good primary forest came to within yards of the door in an area without any near native population. The site lay in the small, shut-in, flat-floored valley of upper Oomsis Creek, which ramified on gentle gradients into the abrupt northern slopes of the Herzog Mountains and was closed in on the other side by a fronting ridge of about 1000 feet. Except for small, weedy plantings of cocoa and some more or less grassy young forest second growths on bouldery, obviously at times flash-flooded ground on the creek at camp, the view was of apparently uninterrupted forest in every direction and at every level.

The outermost of the large cocoa plantings of the Lae area in this direction, Gabensis Plantation with some 200 acres under trees, occupied good alluvial land cleared from rain forest 2 miles down the creek and the road. Two or 3 miles up the road, on Gabensis Creek, was the populous and sophisticated Gabensis community of villages. Both Gabensis and Oomsis creeks flowed to the lower Wampit River and within 10 miles from camp, in a northerly direction, the Markham. An attractive, fair-sized, gravelly stream with low, eroding, forest-walled banks, usually of small flow and easily crossed by wading, Oomsis Creek during sustained dry weather was said to become a succession of clear pools separated by stretches of dry bed.

Camp lay close to the inner edge of the reversed seasons area at the head of Huon Gulf, with most of a reputed annual rainfall of about 100 inches occurring in the Southeast period. We had changeable weather there. First came abundant mostly afternoon and night rains from the last of the northwest monsoon, then, after mid-April, generally oppressively hot sunny mornings, deflected southeast breezes coming up-valley from a northerly direction after noon, sometimes with showers, and often much rain at night. The deflected breeze strengthened during our last four days, and no rain fell.

The virgin aspect of the forest was more apparent than real. Some two and a half million board feet of lumber had been taken from the 400-acre Schultz property three or four years before our visit. Subsequent lumbering operations of the Department of Forests had almost cut out the best timber on neighboring lower mountain slopes up to levels of 600 and 700 feet. Numerous access and haulage roads, for the big motor trucks and bulldozers in use, gave us easy entry into the forest and good approaches to the higher slopes. Still, only where the cutting had been especially heavy had the essential nature of the forest ecosystem been substantially changed, so far as could be seen.

The 600- to 700-foot levels marked approxi-

[1] These South American toads probably reached Lae in cargo from North Queensland, where they were introduced to eat troublesome beetles in the sugarcane fields.

mate local upper limits for the occurrence in commercially attractive volume of *Anisoptera kostermansiana*, locally dominant and the prime timber tree here as in the Trans-Busu, although scattered, great, clean-boled, brown-barked trees of the species grew higher on slopes examined by us. On some lower slopes the stand had been so dense that logging had almost completely wrecked the forest. Good natural regeneration of the *Anisoptera* was, however, taking place. Logs of this tree, if left on the ground, soon became infested by the larvae of a big longicorn beetle (collected by us but as yet unidentified), which the natives chopped out of old logs to eat. We were informed that the beetle attacked only damaged parts of standing, living trees. But a day or two after the trees are felled ovipositing takes place in the numerous bruised parts of the soft, fibrous bark. The eggs hatch rapidly, and only expensive barking of the logs, or their early removal to the mill, will prevent extensive wood damage by the larval borings.

A golden brown under surface of the *Anisoptera* leaves gave the foothills forest a distinctive appearance. Associated locally with this tree on the lower foothills was another dipterocarp (*Hopea*), gregarious, tall, slender, and beautifully straight, which had been conserved in part for special spar timbers. Other canopy trees included *Intsia bijuga*, *Vitex cofassus*, *Pometia pinnata*, and species of *Cryptocarya*, *Litsea*, *Aglaia*, *Terminalia*, *Celtis*, and *Planchonia*. Unlike most rain forest, this often lacked a subcanopy layer of smaller though sizable trees, the second layer then being a substage of slender trees and tall saplings, among them commonly *Gnetum gnemon*, the young leaves of which furnish a good "cabbage." Slender arecoid palms of several species were conspicuous, also a small fan palm (*Licuala*) and a stilt-rooted *Pandanus*. A weak representation of climbing plants and epiphytes included, however, as root climbers, much *Pothos helwigii* reaching high on tree trunks, and a remarkable orchid (*Dipodium*) with fleshy distichous leaves and closely appressed stem and branches. High in the trees were the ant-house plants *Myrmecodia* and *Lecanopteris*, and an occasional giant staghorn fern (*Platycerium wilhelminae-reginae*). A thin topsoil over stiff yellow clay supported a meager assortment of woody and herbaceous undergrowth plants, and a thin layer of leaf and twig litter lay on the ground.

The creek flats and basal slopes carried good primary forest of small commercial value, not much disturbed by logging, in which large leaf size became a feature in the subcanopy and lower layers. Various aroids, Zingiberaceae and Marantaceae, and the small fan palm of the foothills, gave big-leaved luxuriance to an abundant undergrowth, above which climbed other aroids and aromatic *Piper* species. In quick-growing second growths of *Macaranga-Pipturus-Melanolepis* type in natural openings in the forest, on roadways, and patches of ground formerly cultivated by natives, tall wild bananas (*Musa*) were prominent.

At 1200 feet on a minor eminence, the highest point reached from this camp, the wet lowlands lushness disappeared in an almost complete change of vegetation to a forest of oaks (*Quercus*) in which a tall *Casuarina* grew intermixed. A matted scrambling fern (*Gleichenia*), difficult to cut through, filled a sizable opening. Visibility was limited by a chilly mist.

Our visit coincided with a rather abundant flowering in the forest, although more trees bore fruits than flowers; much more time than was available could have been spent in profitable botanizing. Certain tall canopy trees held special interest for bats. The fleshy big purple fruits of a sapotaceous tree, for example, seemed particularly attractive to the very large *Pteropus neohibernicus*, which probably migrates in its food quest. Many small insectivorous bats were observed in flight, sometimes late at night, about the tops of flowering *Octomeles sumatrana* and pink-blossomed *Evodia ?elleryana* trees, as if hawking for food. *Miniopterus australis* was shot under these circumstances.

A very satisfactory total of 26 species of mammals collected here included no fewer than 14 species of bats. Of these a white-spotted black *Taphozous*, still undetermined as to species, and *Philetor rouhi* (several collected by our cutting down a hollow tree) represented new generic records for the Territory of New Guinea; *Rhinolophus euryotis* and *R. megaphyllus*, new species records.

Other Microchiroptera were *Emballonura nigrescens*, *Hipposideros calcaratus*, *Pipistrellus papuanus*, *Miniopterus australis*, and *M. schreibersi*. In Megachiroptera other than *Pteropus*, a specimen of large *Dobsonia moluccensis* was shot in the tall sapotaceous tree; small *Nyctimene albiventer*, numerous individuals of *Syconycteris crassa*, and a single specimen of *Paranyctimene raptor* (very rare in collections) were taken in mist nets set at trees of *Ficus pungens*, a common fig of young second-growth forest with innumerable small "fruits" soft and red when ripe, borne on nearly leafless long branchlets pendent from its short, usually multiple stems and lower limbs.

Bandicoots (*Echymipera kalubu*), coming at night to feed beneath the *Ficus pungens* trees, were caught for us in spring snares and deadfalls by Schultz's native caretaker. *Echymipera rufescens*, a single example shot in the forest at night, had not previously been recorded for the Territory. Other marsupials collected were the spotted cuscus (*Phalanger maculatus*), usually shot by day while asleep in tall trees, *P. orientalis*, and the almost ubiquitous flying "squirrel" *Petaurus breviceps*.

Trapping for rodents was not very productive, and even after we had proper equipment and bait some nights yielded nothing. Most commonly caught were *Rattus exulans*, *R. ruber*, and *Melomys rufescens*. Single specimens of *M. platyops* and the large water rat *Hydromys chrysogaster* were taken. The wide-ranging giant rat *Uromys caudimaculatus* was cut from hollow trees, as were numbers of a gregarious *Pogonomys* of still undetermined species.

On nights when mammal hunting was spoiled by rain, attention was turned to the frogs, which became active under such conditions. One result, in the hills, was the unusual flattened, yellow *Genyophryne thompsoni*, scratched out from the leaf litter in which it called on the forest floor. A very small gray frog, probably a newly metamorphosed *Rana*, hopped in great numbers by day on moist gravel beds in the creek. The most common lizard taken was a medium-sized brown skink (*Sphenomorphus megaspilus*), caught in the mammal traps. Three species of geckoes included big, banded *Gymnodactylus novaeguineae*, shot high in trees by jacklight, and house-inhabiting *Gekko vittatus* and *Hemidactylus frenatus*, which quickly snapped up most insects that lit on the screens of our house at night.

A high screening turnover of unsuitable aspirants for jobs and consequent frequent shortage of native helpers at this early shakedown and training camp prevented much sustained activity in catching diurnal insects. Light trapping for a few nights, when finally we had the equipment, yielded little variety and was discontinued. An abundance of many species of dragonflies was found at small stagnant pools formed along logging roads in the forest. In other groups the best results showed in Hemiptera and Coleoptera, weevils being especially well represented among the beetles.

Lake Wanum, visited from this camp, is referred to on page 169.

GURAKOR, MOROBE DISTRICT

MAY 4 TO 11

Situated at an elevation of 2100 feet (640 meters) in the narrow, steep-falling valley of the upper Wampit River, on the rugged western slopes of the Herzog Mountains, this camp lay 45 miles from Lae on the road to Bulolo. Through the hospitality of the Reverend George Horrolt, we had for headquarters a good spare house of the Gurakor Lutheran Mission and another house for our boys. Mt. Shungol, the dominant physical feature of the neighborhood, rose to nearly 9000 feet about 6 miles to the east-southeast, its upper slopes and rock-walled summit usually hidden in a dark blanket of clouds. The Wampit flowed out of sight in a gorge, 200 to 300 feet below the mission. A fine view out of the mountains downstream took in a segment of the sunny lower Markham Valley, and beyond, the high Saruwageds 40 miles to the north.

The mission stood on one of several fairly extensive sloping and irregular benches in the neighborhood, where, on both sides of the Wampit, a localized native population of perhaps 2000 people had their villages and gardens. Records kept at a nearby road maintenance camp indicated an average annual rainfall of 102.68 inches, with a December through April wet season and a May to November

drier season in which June, the driest month, had an average of 3.76 inches (see table 1). Occasional temperatures observed by us ranged between 68° F. and 80° F. We had variable weather, with a tendency for dark mist clouds to blot out the mountains down to about the 3000-foot level after midafternoon, and for rain to fall in the afternoon or night. Mr. Horrolt informed us that beginning a little later in the Southeast season there would be much mist on the slopes down to 200 or 300 feet below the mission.

Only relics of original forest remained on the populated benches, where second growths of various ages prevailed and a certain amount of induced *kunai* (*Imperata*) grassland occurred. But enough forest survived elsewhere to show it as a type intermediate between lower mountain mixed rain forest and fagaceous mid-mountain forest dominated by *Castanopsis acuminatissima* and oaks, with, locally, the dipterocarp *Anisoptera kostermansiana* present as a much taller emergent tree. Some *Anisoptera* trees, felled and left to rot on the ground in fairly recent lumbering near the mission, were up to 5 feet in diameter and as big as any seen at Oomsis. Above this forest, in a pattern of altitudinal distribution well known in New Guinea but never satisfactorily explained, mixed rain forest of essentially lowland relationships, thrusting up the gorges of the Wampit and local feeder streams, spread out and took occupation of steep slopes up to an observed 400 to 500 feet above the *Castanopsis*-oak community of the moderate slopes. Mr. Horrolt's observation with regard to Southeast season mists at Gurakor is of interest in this connection, for, throughout the mountains of New Guinea, the lower limits of the oak-*Castanopsis* forest coincide with the lower edge of the afternoon cloud body which in the Southeast season forms almost daily, at remarkably constant and well-defined levels on the slopes.

The forests, especially in gorges and ravines, carried a rich flora in which many genera commonly found in moist mountain habitats appeared for the first time in our collections, among them *Begonia*, *Medinilla*, *Tecomanthe*, *Cyrtandra*, *Saurauia*, *Equisetum*, and in ferns *Grammitis* and *Asplenium*, and for the very modest altitude a surprising abundance of filmy ferns (Hymenophyllaceae) grew as low epiphytes and on the granite-like rock of the ravines.

Among 12 species of mammals collected, the marsupials comprised the striped possum *Dactylopsila trivirgata*, *Echymipera kalubu*, *Phalanger orientalis*, and *Petaurus breviceps*. In bats were *Dobsonia moluccensis*, *Hipposideros cervinus*, *Emballonura beccarii*, replacing *E. nigrescens* of lower levels, *Miniopterus tristis* as a first record for the Territory of New Guinea, and small *M. australis*. The three rodents *Rattus exulans*, *Melomys platyops*, and *M. rufescens* had already been taken at Oomsis.

KAINDI, MOROBE DISTRICT

MAY 11 TO 28

At the chilly, 6750-foot (2060-meter) altitude of Kaindi, we were glad to have a tightly built house, with open fireplace, and a good "boyhouse," generously given for our use by Mr. Robert Franklin, owner of the Day Dawn Mine. "Franklin's Camp" stood on a steep rise of ground above Meari (or Merri) Creek, main right-hand branch of Edie Creek, near what had been the center of a general area called Kaindi in the early mining days. A mile or so to the south, near the head of Edie Creek, were the old Edie Creek diggings. Immediately to the east and southeast of camp and the rugged high basin in which the main mining areas were situated, the high ridge called Mt. Kaindi rose to about 7750 feet (2360 meters). The Day Dawn, with a 10-head battery, had been closed for some years, and in 1959 only four small "shows" were working in this once very active Edie Creek-Kaindi area, where phenomenally rich gold had been won in the 1920's. Our field work took in Mt. Kaindi (see p. 169), the vicinity of the old Edie Creek diggings, and to some extent the Watut-Edie Creek Divide, a long 7000-foot ridge a mile or more to the west of camp.

From the high basin of the gold mining area, Edie Creek dropped rapidly into a very deep, rocky gorge in its flow north and east to the Bulolo River, a branch of the Watut tributary of the Markham River. The small

local streams occupied narrow, rocky and gravelly, deep ravines and gorges. Two small dams, one up Meari Creek, the other at the head of Edie Creek, provided water for some of the placer mining still being done in the area. A hydroelectric power line came over Mt. Kaindi from Wau.

Former mining operations had greatly disturbed the ecology locally at levels below about 7000 feet and left much bare, hard, clayey red ground slowly being colonized by *Gleichenia* and other ferns, and, among shrubs, *Rhododendron invasorium*, *R. gracilentum*, *Vaccinium mollissimum*, and other Ericaceae. Before the discovery of gold in 1926, the area had been uninhabited by man and completely forested except for rock faces in the gorges.

Surviving scraps of forest at about camp level indicated that the original vegetation down to approximately 6500 feet had been tall beech forest dominated by *Nothofagus grandis*, with leaves rather large for the genus and grayish when old. This forest still covered the lower slopes of Mt. Kaindi, capped most of the Edie Creek-Watut Divide, and occupied undisturbed bits of upper slope in the Edie Creek Gorge. From about 7200 or 7300 feet up to the summit of Mt. Kaindi another *Nothofagus*, somewhat flat-topped, with small leaves reddish in flush, and of more compact growth, replaced the first as major dominant. On ridge tops at about 7000 feet at the head of Edie Creek and on the Edie Creek-Watut Divide, the continuity of the beech forests was broken by sizable stands of an unusual tall forest of a brownish leaved *Castanopsis* and blackish barked *Phyllocladus hypophyllus*, from which *Nothofagus* seemed absent. From about 6500 feet down to 6000 feet on very steep slopes of Edie Creek Gorge a conspicuous gray-foliaged oak, sporadic above in the lower beech zone, occurred as a forest dominant with another *Quercus* and *Castanopsis acuminatissima*, in an expected orderly succession from beech forest to mid-mountain forest with decreasing altitude.

Except for the seeming absence of *Nothofagus*, the *Castanopsis-Phyllocladus* forest appeared in no way essentially different from the beech forest in structure or flora. Both, in evidence of a wet, misty climate, had at least a partial fuzzy moss covering on lower tree trunks and undergrowth, some moss on the ground, and heavy mossing[1] on trees and ground on exposed crests of ridges. Common to both forest types was a rampant scrambling bamboo ascending to 20 or 30 feet but seldom in quantity greatly to hinder progress through undisturbed forest. No palms were noted and very few tree ferns, apart from *Cyathea pachyrrhachis*, a species common in second growths. Most of the larger angiospermous trees of the upper beech forest had small, stiff, convex leaves, obtuse to rounded or emarginate at the tip. In this upper forest a leached gray topsoil had under it a stiff yellow clay, and above it a thin peat layer thinly covered with litter. A crumbly dark gray slate showed in some road cuts.

Phyllocladus occurred scattered through the beech forests as a big canopy tree, as did several *Podocarpus* species and a *Papuacedrus* as other conifers, a holly (*Ilex*), and a *Schizomeria* made conspicuous by a profusion of small white flowers. A very mixed subcanopy layer included, besides canopy trees not fully grown, species of *Acronychia*, *Cryptocarya*, *Platea*, *Quintinia*, *Elaeocarpus*, *Rapanea*, *Casearia*, *Planchonella sussu*, and strikingly brownish leaved *Galbulimima belgraveana*. Slender substage trees of a layer sometimes abundant, sometimes sparse, included *?Myrtus* with very small leaves, *Astronia*, *Polyosma*, *Sericolea*, *Acronychia*, *Drimys*, *Pygeum*, *Streblus glaber*, and the conifer *Dacrydium falciforme*. A predominantly woody undergrowth contained most commonly as shrubs or treelets *Rapanea*, *Symplocos*, *Drimys*, *Bubbia*, *Acronychia*, and *Eurya*. Fleshy herbs, such as *Elatostema*, *Pilea*, and a showy pink *Begonia*, appeared along streams and in other moist, rather open habitats. *Hymenophyllum* and other ferns, mostly small, grew on mossy ground and lower tree trunks, accompanied sporadically by *Medinilla*, *Cyrtandra*, and *Oleandra* as shrubby low epiphytes. High epiphytes, often associated with massively cushioned bryophytes, included *Pittosporum pullifolium*, *Rhododendron leptanthum*, and *Vaccinium*

[1] At these altitudes and higher on the mountains the most abundant bryophytes are usually leafy liverworts.

cyclopense as shrubs, various xeric small ferns, and some beautiful small orchids of the genera *Dendrobium*, *Mediocalcar*, and *Glomera*. Climbing plants other than the bamboo were few, but among them *Vaccinium amoena* figured as a large green-flowered liana, and root-climbing *Freycinetia* species gave spots of color with their big orange or red bracts.

A pioneer community of lower beech forest second growths is mentioned above. Extensive areas carried low growths of secondary forest very different fron those of the mixed rain forest of lower altitudes, and still young in appearance on ground probably disturbed up to 33 years before our visit. Steep ridges and more gentle slopes had fairly distinct communities no more than noted here. Represented were a big-leaved *Homalanthus* and several fleshy *Saurauia* species as major dominants, accompanied by *Ficus* (several), *Eurya* (several), *Sericolea*, *Timonius*, *?Myrtus*, *Rhodomyrtus*, *Trimenia*, *Quintinia*, *Ternstroemia*, *Trema cannabina*, *Pipturus*, *Caldcluvia* with big pinnate leaves red when young, *Elaeocarpus* (several), *Dimorphanthera* (several), and at lower altitudes *Macaranga* and *Breynia* of lowland affinities. The small-leaved *Nothofagus* regenerated prolifically after disturbance of the forest high on Mt. Kaindi.

Two flowering seasons are generally recognizable in New Guinea, one at about the beginning of the local wet season, the other about the beginning of the dry, besides a certain amount of ever-blooming and erratic flowering. We experienced the start of a flowering season at Kaindi, in an area where Edie Creek records (see table 1) indicated annual wet periods of about equal strength in March–April and November–December, and a total rainfall of 107.21 inches.

Our first week at Kaindi was in unseasonable rainy and drizzly, often misty weather with most rain falling after midafternoon and at night. During much of the rest of our stay, not enough rain fell to provide household water from our galvanized iron roof, but occasional late afternoon and evening showers, mists, and night fogs kept the vegetation in constantly moist condition. Occasional shade temperature readings gave an extreme high of 70° F. and an extreme low of 46° F. As an indication of the climate in terms of human comfort, the mining boys at all times wore thick flannel shirts at their work.

In this locality we had splendid assistance in the collection of mammals from Horace Clissold who, during our visit and later, encouraged his mining boys to hunt during weekends, with very good results in the larger mammals. Contributing also to the mammal collections were Kukukuku mountain natives, until fairly recently considered untamable, who worked on the new Mt. Kaindi road, carried bows and arrows on the job, and happily dropped picks and shovels on any opportunity considered more advantageous or offering more excitement than work for the government.

From the area we had in total 27 mammal species: in monotremes, *Zaglossus bruijni;* in marsupials, *Antechinus naso* from rat traps, the bandicoots *Echymipera kalubu* and *Peroryctes longicauda*, arboreal *Phalanger gymnotis*, *P. vestitus*, *Dactylonax palpator*, *Petaurus breviceps*, the ring-tailed possums *Pseudocheirus forbesi*, *P. corinnae*, *P. cupreus*, the tree-climbing kangaroo *Dendrolagus dorianus*, and forest wallabies *Dorcopsulus vanheurni* and *Thylogale bruijni*. While hunting in tall forest in early evening, Collins had the good fortune to observe a *Dactylonax* exploring, for food, a rotting dead tree about 50 feet tall and 2 feet in diameter. The whole tree, trunk and branches, was "completely scarified from the bites of this small possum in its search for grubs," he reported.

Only a few bats, all small insectivorous species, were collected or seen: *Pipistrellus papuanus*, larger *P. angulatus*, *Miniopterus australis* from a mine tunnel, and *M. schreibersi*. In rodents, *Rattus exulans* and the mountain *R. niobe* were taken commonly in traps, which also yielded *Melomys* of two species, the jumping mouse *Lorentzimys nouhuysi*, and from beside running water the very rare hydromyine *Baiyankamys shawmayeri*. In giant rats, *Hyomys goliath* and *Mallomys rothschildi* were obtained by Clissold's boys; *Anisomys imitator* was taken by a Kukukuku who climbed a tree and pulled it out of a hollow.

For an open ridge site which looked rather sterile in daylight, and a locality with few bats, Kaindi Camp gave excellent results in light-trapping for insects, especially moths

and beetles on warm, foggy, dark nights. Odonata were scarce at this altitude. We were too high for most reptiles and amphibians. A skink, *Scincella stanleyana*, was taken in sunny places about camp; *S. elegantoides*, from the summit of Mt. Kaindi. The only snake seen, at 7000 feet, got away. Eight of the 15 frogs collected were small green *Cophixalus variegatus*, from high on Mt. Kaindi, a species widely distributed in the mountains of eastern and central New Guinea.

LAKE PIUNDE-AUNDE CAMP, EAST SLOPES OF MT. WILHELM, EASTERN HIGHLANDS DISTRICT

JUNE 8 TO 29

This "Top Camp" (see p. 172) was on a flat-topped, open, grassy rise at the lower end of the first of two closely adjacent, deep, alpine lakes encountered on the climb toward Mt. Wilhelm summit from Keglsugl airstrip. We determined the altitude as about 11,700 feet (3560 meters) by averaged aneroid readings. Confusion exists as to the names of the lakes. Seemingly, both lakes were called Piunde-Aunde by the Chimbu people, proclaimed owners of the area, or perhaps more particularly the hunting rights, some of whom were always with us at this camp. But as in most reports the lower lake is called Aunde, and the other, 300 feet higher in elevation, Piunde, both with variations in spelling, it seems advisable for practical purposes to retain here the supposed distinction in names.

A conspicuous white-water cascade connects the two lakes. A small pond or tarn at about 13,100 feet on the south side of the same valley, described as about 60 by 80 yards by Collins, who alone of our party visited it, has about it stunted timber suitable for firewood, and might with advantage be considered by some future party as a camp site from which to investigate upper levels of the mountain not well workable from either of the Piunde-Aunde lakes.

Pullen (1957) has given a history of the rather many ascents which have been made of the higher peaks of Mt. Wilhelm; Van Deusen of our party has a more detailed account in preparation for publication. Climbs concerned with our particular biological interests are mentioned on page 163. Another, of special interest in being the first by a biologist, and the fact that a record of it left on a scrap of blue paper in a cairn on the main peak is now in such bad condition as not to be attributable to anyone, was made by P. J. Darlington, Jr., entomologist, of the Museum of Comparative Zoölogy at Harvard College who, as an officer of the American Forces in World War II on leave, climbed to the summit from a camp on Lake Aunde on October 21, 1944 (Darlington, MS). It would appear that all the Europeans who climbed or attempted to climb Mt. Wilhelm made their approach from the east and that most of them camped at our Piunde-Aunde site.

It is reported that in 1936 Patrol Officer C. D. Bates went to 14,000 feet on the mountain, and "during his ascent . . . discovered two inland lakes," presumably the Piunde-Aunde lakes (Anon., 1936). The first white man to climb Mt. Wilhelm was Patrol Officer Leigh G. Vial, who ascended the main peak on August 15, 1938, recorded "sago snow," and built a cairn which has been the repository for records of most subsequent climbs to the topmost point. Vial, accompanied by L. C. Noakes, a geologist, made a second ascent on June 27, 1939. Collins of our party was the first to make three ascents (see p. 172), a record equaled in 1960 by Father Ernst Borgmann, botanist-cytologist of the Max Planck Institute für Züchtungsforschung at Cologne, who made three different collecting visits to the mountain in that year (Anon., 1962). The height of Mt. Wilhelm is discussed on page 172. We accept it provisionally as about 14,950 feet (4550 meters) for the north or main peak, about 14,900 feet for the south or second-highest peak.

An examination of the Piunde-Aunde lakes was made in September, 1959, by A. M. Rapson (see p. 175). The greatest depths in soundings from an inflatable rubber raft were 27 fathoms for Piunde, 18 fathoms for Aunde. Among water temperatures recorded for Piunde were 54° F. on the surface near shore and at the center at 10 A.M.; at the bottom at 27 fathoms, 52.9° F. Samples of bottom mud and aquatic life, including copepods, were collected. Rapson considered conditions promising for the introduction of salmonid

fishes (personal communications).[1] The only aquatic vascular plants found by us in the lakes were *Scirpus crassiusculus* and *Callitriche verna*, submerged in marginal shallows.

Keogh (MS) remarked on the brilliant colors of the Mt. Wilhelm lakes, from jet black in overcast weather to bright blue or green in sunny weather. To these could be added a deep violet-blue as seen from the heights on clear, calm days, and a semi-liquid appearance less of water than of violet-blue paint. Much else was colorful: the straw tints of tussock grasslands, contrasting strongly with the blackish green of contiguous subalpine forests; a pale yellowish green peculiar to the short grass of the upper levels, in pleasing contrast with the dark grays of the granodiorite rock, which when worn smooth by weathering, as much of it was, had a leaden appearance. Sometimes the rocks looked purplish. Local white and yellowish mineralization, and lichenization, of the rock and an occasional pale, small erosion scar, stood out conspicuously at the higher elevations. Flowering *Olearia* thickets made patches of white on forest edges of lower slopes, where on closer view was red of *Rhododendron*, *Dimorphanthera*, and *Rubus* flowers, orange of clustered *Pittosporum* fruits, gray of massed *Anaphalis*, and spots of other colors.

Rare perfectly clear sunny days brought a peculiar blackish brightness of landscape that is characteristic of the high mountains of New Guinea. Although on only one day were conditions bad enough to stop all field work, we had much uncomfortable cold overcast to misty and rainy, often windy weather. A good part of the heaviest rain fell at night, with wind strong and gusty but below storm strength, blowing either up or down the valley. Frequently after early morning, local clouds hid the mountain above about 13,000 feet, clearing away before nightfall. A trend toward colder and drier conditions set in during our last few days, when the boys, stimulated perhaps about equally by welcome sunshine and the prospect of soon leaving this, to them, anything but pleasant camp, washed clothing and "cold shirts" (sweaters) in preparation for a partial descent of the mountain. On one of the blackish, clear days I noted that "insolation and evaporation were so high that my typewriter ribbon dried as it unrolled from the reel, and carbon paper curled between the pages."

Freezing temperatures were not recorded on thermometers set a meter above ground under a grass-roofed shed at camp, but we had nine light to very heavy frosts on the grass. Icing of wet ground and small pools took place occasionally. During two nights snow fell on the mountain down to 13,400 to 13,500 feet, but at those levels it melted before midmorning. Temperatures under the grass shed for June 14 to 28, inclusive, were maximum 10° C. to 16.5° C., mean 13.3° C.; minimum 2.5° C. to 5.0° C., mean 3.8° C.

Beautifully situated scenically, but too exposed to the cold winds, camp occupied the only spot in the neighborhood with enough good ground for our huts and tents. Even so, the ground was wet, and on slopes where latrine pits were dug a peaty soil went down a foot to the mineral base. Fires in the huts burned holes fully 6 inches deep in this peat, and the frames of tents and stake supports of our rough work tables sank into it. Native women, thinking nothing of the climb of about 3500 feet from their gardens, with loads, brought potatoes, sweet potatoes, and cabbages above our needs, also peas, broad beans, tomatoes, strawberries, passion fruit, and much sugarcane. Women were on hand to salvage surplus food when camp was vacated, and if they sold it to us again we did not mind.

From camp we overlooked the deep, U-shaped, glacial valley, with poorly drained stepped bottom, which ended in a sharp drop at about 10,900 feet on our approach from Keglsugl (see p. 172). A lateral moraine described by Reiner (1960) was prominent. Lower lay the ridge-ribbed upper end of the densely populated Chimbu Valley, deforested and pale up to cultivation limits at 8000 feet or more. Beyond this were seen on clear mornings two-domed Mt. Otto, other heights of the Bismarck Range, and in the far distance the high, blue Finisterre Mountains. Above camp and Lake Aunde the valley changed character and in mounting toward

[1] Fishes are not known to occur naturally at high altitudes in New Guinea.

the mountain summits became very steep and rugged, exhibited more and more bare rock, and some striking cliff topography. Jagged skylines of bare, dark rock defined the summit ridges. A fronting ridge immediately before the two culminating peaks hid them from the camp.

Hoogland (1958) has described briefly, and illustrated with good photographs, the vegetation of this part of the mountain. Robbins (1958) made extensive use of his observations on Mt. Wilhelm in a classification of the plant communities of the Central Highlands. In the descriptive part of the present paper I retain an earlier classification of my own (1941), proposed for New Guinea as a whole, and leave discussion of the matter to a concluding section. In the Piunde-Aunde locality, my subalpine forest and alpine grassland were represented.

A considerable amount of fragmented, heavily mossed, low, subalpine forest occurred on slopes in the vicinity of camp, diminishing rapidly up to tree limit at 13,100 to 13,200 feet, and increasing downward until it almost completely covered the slopes and all but the cold, mostly ill-drained bottom of the U valley. The uppermost isolated clump of subarborescent growths examined, at 13,250 feet, consisted of *Olearia*, *Drimys*, and *Coprosma* 10 to 15 feet high. Down the mountain, the subalpine forest merged into a different forest type in a broad ecotone, with a rather definite change apparent at about 10,800 feet. Typically, the subalpine forest consisted of a dense canopy layer, 25 to 30 feet high, of generally crooked small trees with small stiff leaves and erect stiff branchlets, of the genera *Podocarpus*, *Rapanea*, *?Myrtus*, *Quintinia*, *Acronychia*, *Pygeum*, *Sericolea*, *Symplocos*, *Drimys*, *?Amaracarpus*, and *Olearia*, and, as multistemmed big "shrubs" with conspicuously larger leaves, *Schefflera* and *Pittosporum pullifolium*. *Podocarpus compactus*, up to about 40 feet tall, often formed a distinct, discontinuous or patchy, emergent tree layer, and sometimes with it were *P. brassii*, and *Pittosporum* and *Schefflera*.[1] Trees that appeared from about 11,000 feet downward in this forest, and probably not to be considered subalpine here, included abundant *Elaeocarpus*, *Decaspermum*, and *Papuacedrus*.

A forest border community so narrow and dense as to be thought a part of the forest proper but for the fact that few of the constituents entered the forest, contained as tall shrubs five *Olearia* ("tree-daisy") species; many Ericaceae, including *Rhododendron atropurpureum*, *R. womersleyi*, *R. beyerinckianum*, *R. culminicolum*, *R. gaultheriifolium*, *Dimorphanthera microphylla*, *D. collinsii*, *Vaccinium keysseri*, and *V. cruentum;* besides *Coprosma*, *Eurya*, *Drimys*, *Amaracarpus*, *Polyosma*, *Symplocos*, and, unexpected here, *?Leucosyke* of the Urticaceae. The stout tree ferns *Cyathea vandeusenii* and *C. percrassa* belonged here, up to 12,000 feet. Several *Rubus* species occurred. Numerous herbs included gregarious *Anaphalis mariae* and *Acaena anserinifolia*, *Hebe albiflora*, *Libertia pulchella*, *Epilobium*, *Galium*, *Geranium*, *Sagina*, *Potentilla*, *Oxalis magellanica*, and the ferns *Blechnum*, *Plagiogyria*, and *Gleichenia bolanica*. Bryophytes built up in depth from the ground and heavily cushioned the branches of emergent trees.

Within the forest, a thin bryophyte layer constituted the only ground cover in very dense shade. Elsewhere an occasional herb entered from the borders to associate with a few true undergrowth plants such as *Pilea*, a big *Pteris*, the tree fern *Cyathea semiamplectens*, and *Polyosma* and *Drimys* as large woody plants. Apart from mosses and hepatics, epiphytes were rather few in species, mainly small ferns (*Ctenopteris*, *Grammitis*, *Belvisia*, *Hymenophyllum*, *Selliguea*, *Humata*, *Asplenium*) and orchids (highly colored dendrobiums). *Henslowia* and a red-flowered *Amyema* occurred as woody hemiparasites on trees.

Every small decrease in elevation below about 11,400 feet brought in additions to the forest flora, while certain higher altitude elements dropped out. Some canopy trees intruding from lower levels are mentioned above; woody genera following forest borders from below included *Homalanthus*, *Saurauia*, *Daphniphyllum*, *Evodiella*, *Piper*, *Jasminum*, *Dodonaea viscosa*, and the prickly unbranched tree *Harmsiopanax*. Especially incongruous in sheltered forest borders at 11,300 feet, and

[1] According to Robbins, high mountain forest if with emergent trees, alpine shrubbery if without.

showing minor frost damage, were robust zingiberaceous herbs of two species.

The dead stubs of trees and isolated living *Podocarpus compactus* out on grasslands, up to as high as 13,000 feet on favorable slopes, indicated that formerly the forests were more extensive in the upper parts of the valley. Evidence of fire, doubtless attributable mainly to native hunters, was present in some places. The alarm and quick action taken by Chimbu in camp, when boys of ours carelessly started a small grassfire, showed the respect felt for government orders that are now in force against burning.

Alpine grassland, as original primary vegetation, occupied the mountain above the forest zone, and below that ground too wet or too cold for forest. At camp level, in the valley bottom down to 10,900 feet, and up to variously 13,000 to 13,500 feet on open slopes, was tussock grassland. A short-grass community, already in evidence at camp level and below, replaced the tussock grasses at the higher elevations. At lower to middle levels the long-grass or tussock grassland ("peaty grassland" of Hoogland) occupied mainly poorly drained or seepage-wet peaty soils, at higher levels well-drained soils, some of which, as noted above, formerly carried forest. With the principal tussock grasses, *Deschampsia klossii* and *Danthonia archboldii*, were a *Poa* and *Hierochloë longifolia*, 2 to 3 feet high, and occasional large sedge clumps of *Carex philippinensis* and *Scirpus subcapitatus*, forming a dense ground cover or more or less open and easy to walk through. In interstices, on generally mossy ground, grew slender tuft grasses such as *Anthoxanthum angustum*, *Agrostis reinwardtii*, *Brachypodium sylvaticum*, *Deyeuxia brassii*, *Dichelachne novoguineensis*, and *Danthonia schneideri*, and the sedges *Carex finitima*, *C. capillacea*, and *C. perileia*. Herbs included tall *Erechtites arguta* and *Anaphalis lorentzii*, *Wahlenbergia confusa*, *Epilobium*, *Lactuca*, *Gnaphalium*, *Tetramolopium*, *Potentilla*, *Gentiana*, *Euphrasia*, *Trigonotis* in mats, *Cerastium*, *Ranunculus*, *Geranium*, *Oreomyrrhis linearis*, *O. andicola*, *Trachymene tripartita*, *Astelia alpina* in big gray cushions, and above 13,000 feet clumps of the curious xeric fern *Papuapteris linearis*. Shrubs of common occurrence included *Coprosma*, *Hypericum macgregori*, *Styphelia suaveolens*, *Drapetes ericoides*, *Gaultheria mundula*, *Vaccinium amblyandrum*, *Haloragis microphylla*, and at the higher elevations *Eurya brassii*, *Olearia*, *Rhododendron commonae*, and *Detzneria tubata* with deep blue flowers and curiously cold leaves. Peculiar cycad-like tree ferns, resistant to frost and fire, were a striking feature of this community: *Cyathea atrox*, scattered or in great numbers locally below 11,300 feet; *C. muelleri* at middle levels; *C. gleichenioides* from about 11,400 feet to 13,100 feet.

On well-drained stony or rocky ground in tussock grassland of the lower valley a community of densely gregarious, erect, small ferns, and associated shrubs, showed indications of development into forest. Constituents were chiefly *Gleichenia vulcanica*, *G. erecta*, *G. pulchra*, and *Symplocos*, *Rhododendron inconspicuum*, and other shrubs of the forest borders.

Hoogland observed that few species are restricted to either of the two types of alpine grassland, though their frequency may be quite different. There is also interchange of herbs between grasslands and forest borders. At lower and middle levels much of the short-grass community is on boggy ground, it fills gaps between tussocks, and on paths it shows in a bright green strip where the yellowish tussock grasses have been killed by trampling. The dwarf grasses *Monostachya oreoboloides* and *Poa crassicaulis*, and the sedge *Oreobolus pumilio*, up to about 2 inches high, form tight cushions or stiff turf. The community thins out with increasing dryness and rockiness with altitude until, near the summit, only scattered small cushions and tufts are found in crevices of bare rock. Common herbs of the short grass include cushion-forming *Centrolepis philippinensis*, *Astelia alpina*, *Ranunculus*, *Cerastium*, and *Oreomyrrhis andicola;* mat-forming *Trigonotis*, *Lycopodium*, and *Triplostegia glandulifera;* dwarf *Eriocaulon* and *Lactuca*, *Potentilla* species, *Ischnea elachoglossa* (above 13,000 feet), and *Keysseria radicans* in rosettes; blue and white *Gentiana*, *Hebe ciliata*, *Euphrasia*, *Trachymene*, *Juncus;* *Pterostylis* and *Liparis* as orchids; and the tufted small grasses and sedges *Danthonia vestita*, *Poa*, *Carpha alpina*, and *Scirpus merrillii*. Common shrubs are

Trochocarpa dekockii and a *Diplycosia* of prostrate habit, and, reaching very high on the mountain in small tufts, *Styphelia suaveolens*, *Tetramolopium*, and *Drapetes ericoides*.

As regards the upper limits of vegetation, Hoogland listed five species of flowering plants found "very close [to] the summit." Robbins, apparently in error, enumerated nine flowering plants and two ferns as remaining "at the highest point." Gressitt (1956) wrote, "A single small woody plant was found growing a few meters below the summit of the [south] peak, considerably higher than the highest bunch grass seen." At about 14,700 feet (4480 meters) Van Deusen and Collins collected, mostly in crevices on almost sterile rocky slopes, 18 species of phanerogams and seven of bryophytes, including the new moss *Andreaea novo-guinensis*. A single tuft of grass shows in the foreground of a photograph made by Collins on the summit of the south peak.

A paucity of mammal species was anticipated at the high altitudes, and only six were collected in the Piunde-Aunde locality. Blackish *Rattus niobe* was trapped easily in grass and forest, and snared in large numbers on tussock grassland by visiting natives; *Pogonomelomys sevia* was trapped fairly frequently on grasslands, occasionally in forest. The giant gray rat *Mallomys rothschildii* (one specimen 31½ inches in total length and weighing four pounds) was trapped only on tussock grassland but probably entered the forest. This also applies to the bandicoot *Peroryctes longicauda*. The gentle little marsupial *Eudromicia caudata* of the forest, caught by hand in old bird's nests, and trapped, and the ringtail *Pseudocheirus cupreus* doubtfully ventured far from forest cover at any time. No bats were seen. From levels below the subalpine, the Chimbu brought mammals for sale almost daily in good weather; all species so obtained were taken later at Pengagl Camp and are enumerated for that locality.

Of amphibians and reptiles, only two species of microhylid frogs were collected or seen: *Sphenophryne brevicrus*, common about camp, and *Asterophrys wilhelmanae*, represented by a single specimen from 11,150 feet (3400 meters).

Insects were scarce and received rather slight attention by hand net, beating sheet, and light-trapping. A small damselfly emerged about June 25, and several were netted near camp. Four species of butterflies were seen, all fast, dodgy fliers; the first specimen of the one species taken was picked up when it fell from a tree of the forest edge, apparently immobilized by cold.

The botanical collections from this camp, and the one below it, were labeled "Mt. Wilhelm, east slopes," with the altitude of the actual collection in each case. Camp names were not used on the labels.

PENGAGL CAMP, EAST SLOPES OF MT. WILHELM, EASTERN HIGHLANDS DISTRICT

JUNE 29 TO JULY 31

At 9100 feet (2770 meters) by aneroid on the high south bank of Pengagl Creek, some 40 minutes' walk on the trail from Keglsugl airstrip up to the Piunde-Aunde lakes, the site of this camp, called Komanimambulo by the local Chimbu people, was marked by an old planted grove of *tangat* (*Cordyline*) trees which could be expected to survive for a long time. It was in primary forest in general little disturbed except by exploitation for timber for house frames and garden fences, and bark for house walls, by the local people, and the rootings made by pigs of the Chimbu on easily accessible ground up to several hundred feet in altitude above our camp.

Altogether too numerous domestic pigs, highly prized and living partly by hand feeding and partly by free foraging, are a major pest to the biologist seeking to work in localities near large human populations on the Highlands. The pigs roam the forest, have shelter sheds or even warm huts built for them in small clearings, and sometimes bridges by which they may safely cross fast-flowing streams.

In the Pengagl area, selected coniferous trees had been pit sawn to supply lumber for the Catholic Mission at nearby Denglagu and the government station at Kundiawa, the latter two days distant for porters carrying the sawn product. If only for its wastefulness, however, the most serious disturbance of the forest was by the bark strippers, who either cut down trees and left them to rot

after taking the bark, or entirely stripped standing trees as high as they could reach with an axe from the ground, and thus killed them. The thin fibrous bark of *eganindi* (*Papuacedrus*), a big coniferous tree, was in special favor. As a consequence one found dead *eganindi*, mostly fine, big, clear-boled specimens that would have been valuable for lumber, all through the forest of the ridges.

A tributary of Goi Creek, one of the main headwaters of the Chimbu River of the Wahgi-Purari system, the Pengagl stream had its source on southeastern alpine heights of Mt. Wilhelm. Iubuka stream, draining the Piunde-Aunde Valley, junctioned with it about one-third of a mile below camp, after union with the Iumbaga (or Umbaga) stream, also fed by Mt. Wilhelm water. Pengagl Creek bore evidence of a tremendously violent recent flood. Apparently this had happened early in 1958 when a landslide, high on the creek, dammed the water and the dam broke. The resulting flood stripped low terraces of vegetation, cut into high banks of glacial till, more or less leveled the bed of the stream, and left on top of high rocks deposits of stones and of loose soil still being eroded away by rains. The stream, in its raw surfaces, therefore differed greatly from the Iubuka and Iumbaga, in which were many small pools in beds filled with big mossy boulders, and the only bare ground was on occasional small beaches and in erosion breakaways on high concave banks.

Camp was so closed in by forest that the only distant views were of alpine heights up the creek and a glimpse of mountains near Bundi Gap, on the Bismarck Range at the head of the Chimbu. Apart from work tents, the establishment consisted of *Pandanus*-thatched huts, much more roomy than the grass huts of Top Camp, the main one having a big open fireplace of poles and bark, and stones cemented with mud. Extensive trail cutting was necessary to supplement native paths and open up the area for trapping.

Temperatures recorded under a bark shed on the edge of camp, for July 3 to 31, inclusive, were maximum 13.5° C. to 21.0° C., mean 17.2° C.; minimum 5.0° C. to 9.5° C., mean 6.8° C. With these cool temperatures, and rain during 25 of the 24-hour periods spent at this camp, "wretched," "foul," and other adjectives appeared often in daily weather notes.[1] Most of the rains were described as light and only three falls were called heavy, but they commonly kept on for hours. Mornings most often were overcast by 8 o'clock, but rain fell before noon on only four days, and the time of onset was generally 2 to 4 P.M. Cloud drift came nearly always from the east, the direction of Bundi Gap, as a deflected, southeast-tradewind movement. Clouds rising from the Ramu Valley frequently filled the Gap after early morning, and thunderstorms which formed there later in the day brought much of the rain at camp. There were 12 more or less rainy nights, but nights tended to be clear, and early mornings bright and crisp, with a keen breeze coming down from the heights. Mists, though rare at camp, commonly blanketed neighboring ridges after midmorning. An almost constant state of saturation of moss cover obtained in the forest. This and poor visibility, in addition to actual rain, considerably hampered field work. Our boys always dressed for warmth in the forest, and we regularly carried pieces of plastic sheeting big enough to shelter three men from rain.

A depth of up to about 20 feet of soil, with varying quantities of boulders intermixed, showed in eroded banks of Pengagl Creek. A dark gray, friable, forest soil seemed not at all peaty and had a fertile appearance. The cultivation zone ended hereabouts at about 8600 feet (2620 meters), a limit perhaps imposed by frosts (see p. 155), and at that altitude it was said that the crops grew slowly and the staple sweet potatoes were small. This, too, was the approximate limit of lower-altitude elements of the forest flora, such as *Ficus*, *Syzygium*, *Uncaria*, *Psychotria*, *Lucinaea*, *Rhamnus*, and *Impatiens*, although others extended higher. It was above the range of palms, of which the one example seen in the area was a climbing *Calamus* planted at 8000 feet.

Little change in the character and composition of the forest, except a sifting of some species into ridge or valley habitats, occurred from about the 8600-foot level up to 9850

[1] Short-term average annual rainfall for Keglsugl (actually Denglagu Mission at about 7500 feet), under deforested and much drier conditions, was 91.11 inches (see table 1).

feet, where the slopes began a sharp "jump-up" of over 1000 feet to the lower end of the Piunde-Aunde U-shaped valley. Called the broadleaf-gymnosperm alliance of the lower montane rain forest formation by Robbins (1958), it was a mixed, very moist forest of principally straight-boled trees 60 to 100 feet tall with fairly even, irregular, or broken canopy, scattered emergent taller trees, and where best developed in valleys and on moderate slopes, having more or less distinguishable subcanopy and substage tree layers. Bryophytes abounded in a fuzzy covering or heavier growths low on the trees and on the predominantly woody undergrowth. Under thin or broken canopy, a condition common on ridge crests, the "mossing" became very heavy on trunks and branches of trees and on the ground, and a slender scrambling bamboo, present everywhere in the forest, ran rampant and formed dense tangles. In occasional small seepage areas of broken canopy through fall of trees or wetness of ground, a big stilt-rooted *Pandanus* was especially common, numerous epiphytic orchids grew close to the ground in heavy moss, *Rhododendron maius*, with big carnation-scented white flowers, was conspicuous on logs, and red-flowered *R. vandeursenii* grew low on trees.

The big emergent trees were conifers: most commonly *Papuacedrus*, *Podocarpus papuanus*, and *P. ?neriifolius*. Important canopy trees included *Dryodaphne novoguineensis*, *Elaeocarpus trichophyllus*, *E. polydactylus*, *Timonius* species; *Akama*, *Weinmannia*, and *Opocunonia* of the Cunoniaceae; *?Myrtus* and *Decaspermum* of the Myrtaceae; *Quintinia*, *Pygeum*, *Adinandra*, *Ternstroemia*, *Ilex*, *?Claoxylon*, *Saurauia*, *Astronia*, and *Podocarpus pilgeri*. Few tree species could be called strictly subcanopy in ultimate growth, but *Turpinia pentandra*, species of *Zanthoxylum*, *Bubbia*, *Evodiella*, and the big *Pandanus* were typical of that layer. In mostly slender polewood trees of the substage, some of them attaining the subcanopy, *Symplocos* species were especially abundant, and other elements included *Sphenostemon papuanum*, *Geniostoma arfakense*, *Evodia*, *Acronychia*, *Bubbia*, *Drimys*, *Eurya*, *Rapanea*, *Daphniphyllum*, *Carpodetus major*, *Pittosporum berberidoides*, *Quintinia*, *Schuurmansia henningsii*, *Polyosma*, *Pygeum*, *Helicia*, *Ilex*, *Casearia platyphylla*, *?Litsea*, and *Saurauia*.

Scandent and subscandent plants, besides the bamboo, attained some prominence in *Dimorphanthera robbinsii*, *D. collinsii*, *D. denticulifera*, *Celastrus novoguineensis*, *Clematis*, *?Jasminum*, *Alyxia*, *Piper*, *Cyrtandra*, *Aeschynanthus*, and three species of *Freycinetia*.

Notable in the forest for their striking growth forms were the big *Pandanus*, called *karuka* by the Chimbu and the only species present, and tree ferns: *Cyathea rigens*, *C. pachyrrhachis*, *C. foersteri*, *C. atrispinosa*, and the very attractive small *C. hooglandii*. The common *C. rigens* produced a second crown after being topped for its "fiddles," which the natives cooked in their stone ovens and ate with pig. *Karuka*, undoubtedly a wild species here, also planted about native homesteads and on garden lands at the upper limits of cultivation, is one of several tall species of the New Guinea mountains with big, easily shelled, very palatable, oily seeds valuable as food to the Highlands peoples. The effects, as of intoxication, from eating the unripe "nuts" of one of these pandans are described by Meggitt (1958). Reay (1959, pp. 188–190) likens the effects to "mushroom madness," which she also observed on the Highlands.

Of special botanical interest here was the downthrust or downdrift of alpine and subalpine elements in open habitats in the forest. One example was an *Equisetum-Carex* community on slumping ground and a stable bog at 9850 feet on Pengagl Creek, containing several alpine herbs, *Styphelia suaveolens*, and bordered with shrubberies of *Rhododendron beyerinckianum*, *Haloragis microphylla*, and *H. ?halconensis*. In open beds of streams, Pengagl most of all, one found, with typical stream-bed plants of the altitudinal zone such as big-leaved *Gunnera macrophylla*, *Cardamine*, *Nertera granadensis* and shrubby *Coriaria novoguineensis*, usually scattered alpine *Ranunculus*, *Potentilla*, *Oxalis magellanica*, *Hebe albiflora*, *Trigonotis*, *Sagina*, *Epilobium hooglandii*, *Anaphalis lorentzii*, *A. mariae*, *Acaena anserinifolia*, *Poa*, *Schoenus curvulus*, *Scirpus merrillii*, and *Carex perileia*. Several of these alpine herbs also appeared in small pig-house clearings at about 8600 feet in the forest, in association with the

widespread weeds of cultivation *Galinsoga parviflora*, *Stellaria media*, *Siegesbeckia orientalis*, *Tagetes glandulifera*, *Physalis peruviana*, and *Sonchus oleraceus*.

In the succession by which forest became re-established in small clearings and on other disturbed ground, pit-pit, or wild sugarcane, *Saccharum floridulum* (*Miscanthus floridulus*), a very tall clump grass which occupied extensive areas in the cultivation zone, formed small pioneer colonies up to about camp level. Prominent as weak or scrambling plants in early growths were *Gleichenia reflexipinnula*, several *Rubus* species, *Muehlenbeckia monticola*, *Gynura procumbens*, *Arrhenechthites novoguineensis*, *Scaevola oppositifolia*, and a big *Coprosma*. Major elements in later shrub and small-tree growths were *Dodonaea viscosa*, *Homalanthus*, *Olearia*, *Pittosporum ramiflorum*, and several *Saurauia* species.

On the jump-up, the broadleaf-gymnosperm alliance of Robbins soon gave way to a lower, more uniform, and in general more heavily mossed forest which clothed the slopes up to the subalpine at approximately 10,800 feet. This was a single tree-layer forest of often crooked small-leaved trees with dense crowns, about 35 to 60 feet high: the montane cloud forest of Robbins, and what I (1941), for want of a better name, called mossy forest. The principal dominants were *?Myrtus* (two species), *Decaspermum*, and *Xanthomyrtus* of the Myrtaceae, *Ilex*, *Quintinia*, *Macaranga ?albescens*, *Podocarpus papuanus* or *compactus*, another podocarp, and at upper levels an abundant *Papuacedrus*.

Containing 34 species, the mammal collection from Pengagl was the largest and richest for any camp on the expedition. Much in rarities was owed to Collins, who in support of Van Deusen when the latter for much of the time was obliged to stay at the preparations table, did special, wide-ranging trapping for the hydromyine rodents. Visiting natives brought specimens from probably as low as 6500 feet on the slopes below camp, in a trade which from the beginning was made very selective. The collection comprised, in marsupials, *Antechinus melanurus*, *A. wilhelmina*, *Peroryctes longicauda*, *Phalanger vestitus*, *Eudromicia caudata*, *Pseudocheirus forbesi*, *P. cupreus*, *P. corinnae*, *Petaurus breviceps*, and native trophy skulls of *Dorcopsulus vanheurni* and a species of *Dendrolagus*. The larger marsupials were probably kept at rather low population levels by local hunters, ranging the forests with dogs, and climbing or cutting down trees for arboreal species.

Among bats, a few individuals of *Pipistrellus angulatus* were shot at camp at dusk, *Syconycteris crassa* was mostly netted, and natives brought *Miniopterus australis* and big-eared *Nyctophilus microdon* from lower levels. The rodents showed great dissimilarity in abundance, *Rattus niobe*, for example, being extremely common, while six of a total of 19 species were represented by only one specimen in the collection. The species, besides *Rattus niobe*, were *R. ruber* (from the lower levels), *R. exulans*, *Anisomys imitator*, *Pogonomys sylvestris*, *P. mollipilosus*, *Lorentzimys nouhuysi*, *Melomys fellowsi* and three other species of the genus, *Pogonomelomys sevia*, and *Macruromys major* in murines. Trapped and snared in the forest were the very small, very rare, shrew-like hydromyines *Pseudohydromys murinus*, *Neohydromys fuscus*, and *Mayermys ellermani*. Taken in traps in creek-bed habitats were the big water rats *Baiyankamys shawmayeri*, *Parahydromys asper*, and the highly specialized *Crossomys moncktoni*, with great paddle-shaped hind feet, very thick tail with distichous lateral lines of bristly hairs, elevated nostrils, and concealed ears only 1 mm. long.

Frogs, as often elsewhere, provided an interest for hunters unsuccessful in jacklighting for mammals at night. Of eight to 10 species collected, only *Cophixalus darlingtoni*, the new *C. riparius* (Zweifel, 1962), and *Hyla micromembrana*[1] have been identified. One of three species of skinks (*Scincella elegantoides*, *S. stanleyana*, *Sphenomorphus flavipes*) collected in the area was found sunning on rocks in the creek bed up to 9800 feet, the upper altitudinal limit for reptiles observed on the expedition.

Of invertebrates, a most interesting occurrence was of big gray leeches entirely beneath the skin of the legs and belly of frogs of the genera *Hyla* and *Nyctimystes*. A gomphid dragonfly was collected up to 9800 feet in the open bed of Pengagl Creek. Butterflies

[1] Determination by Michael J. Tyler, University of Adelaide, Australia.

showed a marked increase in species and abundance over Piunde-Aunde, and a preponderance of yellow and black in coloration. Very good, varied catches were made by light-trap and by selective methods at the lights of camp in favorable weather. Too often, however, in our exposed creek-bank position, this collecting was spoiled by the cold downdraft from Mt. Wilhelm.

The freedom from invertebrate pests which one enjoys in the high mountains of New Guinea obtained here in large measure. There were no mosquitoes, mites, or leeches troublesome to man. Sandflies, particularly in the open creek bed, were a nuisance at times. The one troublesome biting insect was the "kamikasi-fly," a blackfly of the *clathrium* species group of *Simulium*,[1] which favored one's forehead for attack and raised welts that lasted a few hours. Local representatives of the noisy "six o'clock crickets" (actually cicadas) of the mountains sounded regularly as the day grew light but were never heard in the evening.

Observations on the cultivation zone were made down the slopes past Keglsugl airstrip to an altitude of 7700 feet on Goi Creek. No vestige of the original forest remained below about 8400 feet. The numerous native population lived in scattered homesteads, for the most part old established. Around these, within stake fences, were the neat sweet-potato gardens, small patches of taro on wet ground, and incidental plantings of crops of recent introduction (see p. 186). Sugarcane so tall that to be kept erect it was tied to long poles set in the ground was a specialty feature of some gardens. The paper mulberry (*Broussonetia papyrifera*), called *koragi*, and a *Commersonia* (*umbana*) were grown for their bark fiber; *Casuarina oligodon* (*iaganbani*), for firewood and timber and to rejuvenate fallow land. *Eucalyptus deglupta* (*tamgugl*), said to be propagated by cuttings, was probably a fuel and timber tree. A *Nothofagus* (*yomba*), brought from the forests of Bundi Gap and planted because the people "liked it," grew vigorously to a height of fully 60 feet about homesteads. Big-leaved *Ficus dammaropsis*, the "mountain breadfruit" of some authors, was planted, mostly in fence rows, for its leaves, which when young were eaten as greens and when old served the functions of plates and wrapping paper. Planted also in fence rows, and as living fences, was *tangat*, the leaves of which provide the posterior decency piece in Chimbu dress, and are good tying material.

The highly developed agriculture of the Chimbu was described by Montgomery (1960). Nilles (1943) dealt with the life and culture of the people of this part of the valley.

KOTUNI, SOUTH SLOPES OF MT. OTTO, EASTERN HIGHLANDS DISTRICT

AUGUST 4 TO 20

Kotuni, so far as we were concerned, was the name of a sawmill, owned by Collins Brothers, 7200 feet (2200 meters) above sea level in the narrow, steep-falling valley of Iamahagi Creek, 11 miles by vehicular road in a northerly direction from Goroka. Iamahagi Creek flowed into the Asaro River of the Purari drainage system. A seldom-used trail led from the sawmill to the 11,613-foot (3540-meter) summit of Mt. Otto, on the Bismarck Range. The mountain was twice ascended by Collins and my two botany boys (see p. 173).

Climatic conditions at Kotuni differed greatly from those of the open, sunny, almost entirely deforested, wide, main valley of the Asaro. We were in the cloud zone. In weather anything but uniform, three consecutive bright clear days were experienced. On almost every other day, overcast conditions prevailed after early morning, and from about 1500 feet above camp the mountains were hidden in a pall of dark cloud from mid-morning on. Rain fell on nine days, with remarkable irregularity of onset between noon and 6 P.M. During a northwesterly disturbance which closed to traffic many airstrips on the Highlands, rain continued from 2 P.M. one day until 11 A.M. the next day. Temperature records were not kept at Kotuni.

Below the sawmill, most of the original forest had been destroyed and replaced by gardens, fallow lands and *Pandanus* groves of the Kotun people, and by forest regrowths and tall grass. From the sawmill up to 8000 to 8500 feet or more, despite often great

[1] Tentative identification by Pedro W. Wygodzinsky, the American Museum of Natural History.

steepness of slopes, the forest had been very badly damaged by the exploitation of timber and the establishment of an extensive system of log-haulage roads for use by bulldozers. It was a good example of the cut-out and get-out philosophy of lumbering unfortunately necessary to the requirements of a new, rapidly developing country. The roads, reaching as high as 9000 feet, greatly facilitated our work. But after eight years of operations the concession of 3500 to 4000 acres was nearly exhausted. One of two powerful bulldozers stood idle, while gangs of natives, on contract, cut what was left in reachable timber. By a combination of man-handling and shooting down declivities, they brought logs to the mill at less cost than would have been possible by machinery using diesel fuel flown in to Goroka from the coast. The mill was powered by a Pelton waterwheel.

On approach from Goroka, the first relics of primary forest near the road appeared in clumps and, in a ravine at about 6600 feet in the lower Iamahagi Valley, a conspicuous strip of mid-mountain *Castanopsis* forest on ground too rocky to cultivate. Of characteristic brownish appearance, this virtually pure forest was rich in ground ferns, but poor in epiphytes except for mosses near the ground. It was not possible to determine how far up the valley forest of this type had extended on slopes long occupied and cultivated by the natives.

Enough remained of the next recognizable zone of forest, beginning at the sawmill, to show a complex, rich, montane, mixed rain forest of Robbins' broad leaf-gymnosperm alliance, more middle altitude in appearance and floristics than the forest of Pengagl Creek. Remaining trees of the canopy layer included *Cryptocarya*, *Rapanea*, *Planchonella sussu*, *Galbulimima belgraveana*, *Sphenostemon pauciflora*, *Ficus*, *Quintinia*, *Podocarpus*, much *Papuacedrus* at upper levels, and two species of oaks, one grayish in young leaf and conspicuous in the forest, the other brownish. It was said that formerly the oaks had been cut in large quantity, but it could not be ascertained whether they had formed localized stands of oak forest.

On the upper slopes and fairly broad crest of a spur ridge, beyond the logging area on the trail to the summit, I examined a stand of beech forest extending from 8650 feet to above my stopping place at 8800 feet. The New Guinea beech forest is always impressive. This contained occasional big *Papuacedrus* trees, but a small-leaved *Nothofagus* had virtually sole dominance in a well-spaced stand of big, straight trees with rough, dark gray bark and stubby, thick limbs very heavily laden with cushioned moss and epiphytic ferns and orchids. Among other high epiphytes were almost tree-sized *Vaccinium amplifolium*, bearing a profusion of shining red flowers, and *Rhododendron vandeursenii*. A slender *Freycinetia* climbed in quantity on lower tree trunks. Up to 5 feet in diameter above thick, basal, spur buttresses, the tree trunks carried little moss, but much grew on the ground. Mossy fallen timber and an abundance of scrambling bamboo and undergrowth of slender, mainly small-leaved little trees and tall shrubs made getting about in the forest no easy thing.

The men who made collections higher on the mountain described a narrow ridge crest by which they approached the summit area as covered with a mossy low scrub, 7 to 15 feet high, from an elevation of 10,000 feet up to at least 10,800 feet. From the collections it would appear that this represented a reduced growth of my (1941) mossy forest, dominated by two species each of *Decaspermum* and *Xanthomyrtus* and containing, more or less commonly, *Olearia*, *Rapanea*, *Eurya*, *Sericolea*, *Evodiella*, *Schuurmansia*, *Ilex*, *Vaccinium*, *Rhododendron*, *Helicia*, and *Symplocos*.

Photographs made by Collins, and the plant collections, definitely established the occurrence of subalpine forest at elevations of about 11,100 to 11,400 feet on the mountain and reaching highest in hollows. Collins' photographs, and one made by James F. Leahy in 1955, showed a dense low forest with an emergent layer of *Podocarpus compactus*. Many of these conifers in growth, and dead timber scattered on adjacent tussock grassland, indicated a reduction of the forest in both area and upper altitudinal limits by fire. Numerous compact shrubberies of *Eurya*, *Rapanea*, and *Acronychia* on the grasslands denoted a vigorous regeneration of the subalpine forest after being burned.

Collins estimated an area of about 60

acres of tussocky alpine grassland on and about a notched south peak and somewhat higher north peak of the mountain, and in a small valley between the peaks. *Danthonia archboldii* was the dominant grass. The smaller grasses and some herbs had been heavily grazed by wallabies, but fairly extensive collections showed a flora very similar to that of the drier grasslands at comparable levels on Mt. Wilhelm, though naturally much poorer in species on such a limited area. A common *Coprosma* and big gray cushions of *Astelia alpina* were prominent features. A new variety of the alpine tree fern *Cyathea atrox* was collected here.

The descent of alpine plants to lower altitudinal levels in open habitats has been noted for Pengagl Creek on Mt. Wilhelm. Alpine *Ranunculus*, *Oxalis magellanica*, *Epilobium prostratum*, *Anaphalis lorentzii*, *Hebe albiflora*, and *Schoenus curvulus* came down to at least 7200 feet in the open bed of Iamahagi stream.

The effects of disturbance to forest by lumbering and clearing are more severe at these fairly high altitudes than on the lower mountains and sweltering lowlands. Temperatures are moderate, but, weakened though the sun may seem, it has great drying powers here in clear weather. Damage to the forest is more permanent and the regrowths are much slower to become well established than at lower levels. Prominent constituents of the Kotuni regrowths, at most eight years old, included *Homalanthus*, *Piper*, *Saurauia*, *Debregaesia*, *Pipturus*, *Arrhenechthites novoguineensis*, and *Microglossa pyrifolia* as generally rather fleshy small trees and large shrubs.

At Kotuni the zoological collections benefited from our close contacts with a sawmill work force of about 160 enterprising Mt. Hagen and Chimbu men, and especially from the proximity of Kotun villages. The Kotun, though well below average in the generally not very high standards of personal cleanliness on the Highlands, had spick-and-span villages, and were an eagerly acquisitive people who brought for sale a steady flow of mammal specimens and lizards, and very numerous frogs.

Although in gross aspects similar to that of Pengagl Camp, the mammal population, as represented by 28 collected species, lacked the small hydromyine rodents of Mt. Wilhelm and contained four species new to the collection: the marsupial "cat" *Satanellus albopunctatus*, marsupial "mouse" *Phascalosorex dorsalis*, the giant rat *Uromys anak*, and, caught in the roof of a sawmill boy-house, *Murina*, a genus of bats hitherto unknown on the mainland of New Guinea (Van Deusen, 1961). Other mammals collected here were *Antechinus melanurus*, *A. wilhelmina*, *Peroryctes longicauda*, *Phalanger vestitus*, *Eudromicia caudata*, *Pseudocheirus forbesi*, *P. cupreus*, *P. corinnae*, *Petaurus breviceps*, *Syconycteris crassa*, *Pipistrellus angulatus*, *Miniopterus australis* (taken in a boulder cave up the creek), *Anisomys imitator*, *Pogonomys*, *Mallomys rothschildi*, *Rattus exulans*, *R. ruber*, *R. niobe*, three *Melomys* species, *Pogonomelomys sevia*, *Baiyankamys shawmayeri*, and *Parahydromys asper*.

Our only snakes from the Bismarck Range were three specimens of *Natrix mairi* (*Amphiesma mairi*)[1] caught here. A dozen or more presumed species of frogs included the microhylids *Cophixalus darlingtoni*, *C. parkeri*, and *C. riparius*. With weather usually overcast, when not actually raining, the take of Odonata and butterflies was poor indeed. Some excellent catches were had at the lights, notably in moths, some of them of extraordinary beauty. Beetles and most other night-flying groups were scarce.

A successful introduction of rainbow trout had been made in the Iamahagi stream, but reportedly the fish had lost size and were in poor condition through overstocking.

GONO, WEST SLOPES OF MT. MICHAEL, EASTERN HIGHLANDS DISTRICT

AUGUST 24 TO 29

This disappointing locality, chosen as a working place on mistaken impressions gained on an inspection in thick weather (see p. 174), was vacated when its limited possibilities became fully apparent. We occupied as a camp a government resthouse and police barracks in a spacious fenced compound on the crest of a high ridge, open to the elements, and

[1] Identifications by Sam B. McDowell, Rutgers University.

commanding a great, sweeping panorama of mountains which took in the strikingly scarped limestone peak of 9500-foot Mt. Elimbari to the north-northwest, 7000-foot Mt. Karimui on the Papuan border to the southwest, and other mountains, nameless on our maps, to the south and southeast. At an altitude of 6400 feet (1950 meters) by aneroid, camp was situated at the upper edge of native population, 12 miles by motor road from Lufa Patrol Post and 62 miles from Goroka. Twice we could see briefly, and close by through broken cloud soon after dawn, parts of the grassy summit area of Mt. Michael, called Amoi (ah-moy) by the Gono people. As very interested and hospitable neighbors, about half a mile away, we had the Reverend Ben Wertz and his family of the Faith Mission, of American affiliation, established there in 1955, at about the time this area was brought under government control and declared open to non-natives.

Gono was near the head of a small valley which in a short distance dropped into the great gorge in which the Asaro joined the Wahgi to form the Tua, main headwaters stream of the Purari River. From Gono a government patrol "road" and chain of resthouses extended to the Karimui area, only recently brought under control. Another track, much traveled by natives en route to feasts and other traditional events, passed around the south side of Mt. Michael and into the Gimi and Fore country to the southeast. The Mt. Michael slopes rose abruptly, and, if proximity should prove the determining factor, Gono would offer a somewhat better approach to the summit of the mountain than Lufa, from where our party made the climb.

Our departure from the area was hastened by very misty, rainy Southeast weather which had a limiting effect on field work and in which the trampled clayey ground of the resthouse compound became unpleasantly sloppy and muddy. Advantageous to us, however, were still, warm, foggy, drizzling nights which brought great numbers of moths and other insects to the lights.

Forest relics on rather broad ridge crests about camp level were principally of a *Castanopsis* and two species of oaks of the mid-mountain forest. Above that, slopes of finely bedded gray mudstone, crumbly where exposed and often so steep as to be difficult to negotiate, were covered with a montane type of primary mixed rain forest found also in ravines below the *Castanopsis*-oak zone. Where the lower edge of the primary forest met the upper edge of the garden lands, the natives had their planted groves of tall nut-bearing *Pandanus* tress. *Pandanus ?conoideus*, a relatively small species with fleshy, long, cylindrical fruit heads, used for food and for rubbing on the body in a glistening red coat, was grown in odd places. Where not actually under crops (here as nearly everywhere else on the Highlands principally the staple sweet potato), the garden lands carried mostly a very tall, coarse, *Miscanthus* grass cover, tunneled in every direction by pig trails. On land not so long cultivated, tongues of low secondary forest thrust downward from the primary forest. A very tall palm (*Gulubia*) grew scattered as a forest relic on the upper grass slopes.

Prominent in both flora and fauna were lower-altitude elements unexpected at this height, of probable ascent from the south by way of the Tua Valley. Examples of this in forest plants were *Mussaenda*, *Canthium*, Acanthaceae, *Cissus*, *Mallotus*, several *Ficus* species, and the peculiar tree *Itoa stapfii* (Flacourtiaceae). A tall betel-nut palm with crowded fruits (*Areca macrocalyx*) grew plentifully in relic forest in a gully, and local men were seen carrying bunches of the fruits, presumably for chewing. The palms "jump up nothing," we were told in pidgin, meaning they were not planted, a statement interesting if true. This was the only betel nut seen growing on the Highlands under conditions that did not suggest recent introduction by employed betel-chewing natives from the lowlands or lower mountains, or by Highlands natives returning from employment on the coast with an acquired habit of betel chewing. Introduction by an old trade route, following the Tua and Purari, seemed a likely explanation for the presence of betel nut at Gono.

The meager mammal collection of nine species from Gono contained white-footed *Rattus verecundus*, new for the collection and turning up later at Arau, 1800 feet lower in the mountains. Other species were *Antechinus naso*, *Pseudocheirus forbesi*, the fruit bat

Dobsonia moluccensis, *Pipistrellus angulatus*, *Lorentzimys nouhuysi*, *Rattus niobe*, and one species each of *Pogonomys* and *Melomys*.

Attempts by Collins and Van Deusen to visit a reputed bat cave on slopes of Gono Spur were frustrated by sudden failure of memory on the part of their guides as to the whereabouts of the cave! However, the natives told of a big tailless animal which lived in the cave, raided their gardens, and ate pigs and babies. It was ascertained on these excursions that the natives also believed in the existence of "little folk," whose attitude toward ordinary humans unfortunately was not recorded in my notes.

KIMI CREEK CAMP, NORTHEAST SLOPES OF MT. MICHAEL, EASTERN HIGHLANDS DISTRICT

AUGUST 29 TO SEPTEMBER 14

Kimi Creek was a small, rocky stream crossed by a bridge in tall forest about 8 miles to the east of Lufa Patrol Post on the Goroka-Lufa-Gono road. Camp was at an altitude of 6500 feet (1980 meters), not far above the very steep, grassy, upper slopes of the Asaro Gorge. The nearest villages lay about a mile to the east and at a somewhat lower altitude. Of the various peoples with whom we had close contacts on the expedition, those of this locality alone could be called troublesome. Many of the men who visited the camp behaved badly, some were insolent, and a few truculent and provocative in their attitude. Furthermore, these people were the least washed of all we came across. They fairly stank with filth.

Weather conditions during our stay at Kimi were much less rainy and misty than at Gono. Further, the ecology of the area seemed to indicate a distinctly drier climate than that on the west side of the mountain. At Kimi, a deflected and at times strong southeast trade wind came from the great Asaro-Dunantina valley to the east where, apparently, it lost much of its moisture, while at Gono the trade wind struck without local obstruction from the southeast. Dry, windy spells of as much as three days and nights were experienced at Kimi, also heavy downpours of mostly afternoon rain and one completely wet day. Nights as a rule were clear and crisp; the early mornings, foggy or misty. Clouds usually covered, or hid from view, the upper parts of Mt. Michael after about 8 A.M.

The forest consisted of a fine stand of *Nothofagus ?perryi* and *Castanopsis acuminatissima*, with a sprinkling of oaks and other trees, in which the beech attained very large size. This forest continued without significant change in composition to the top of a spur ridge which rose to over 7000 feet immediately above camp. A sporadic occurrence of three *Podocarpus* species was noted, chiefly on ridge crests. Only in the ravines of the several small streams could the forest flora be called rich, and there occurred a wealth of woody and herbaceous undergrowth plants, bryophytes, and especially epiphytic and terrestrial ferns, but surprisingly few tree ferns. Palms, too, were few in species and individuals, but this was expected at the altitude. Several *Pandanus* species included one of great size (fully 100 feet tall, thick in stem, and widely branched) said by the natives to bear big edible seeds, but seen by us only in very young fruit. Toward Lufa, as about Guruka on the Goroka side of camp (see p. 173), scattered, very large kauri-pines (*Agathis*) rose high above the forest canopy.

Most of our Kimi Creek area lay within a timber concession which operated by mechanical haulage methods to supply a sawmill at Guruka. Heavy spot lumbering, principally of beech, and attendant disturbance by tractor access roads, had already advanced to near the camp site. Probably in a year or two little of the forest of our working area would remain undamaged.

In two ascents of Mt. Michael from this camp, parties of the expedition made a roundabout approach via Lufa (see p. 174). Alpine tussock grassland, plainly visible from below, was found to occupy, at altitudes of about 11,200 to 12,000 feet, a rather narrow strip on a long, knolled, summit ridge. This grassy strip was followed from approximately west to east for about an hour to the main summit, and it extended still farther in an easterly direction along the summit ridge. The dominant tussock-forming grasses were *Deschampsia klossii* and *Danthonia archboldii*. *Cyathea muelleri* occurred sparingly as a grassland tree fern. Our rather extensive

collections indicated a flora of stock genera of the lower alpine of New Guinea, for example, *Monostachya*, *Poa*, *Agrostis*, *Oreobolus*, *Carex*, *Schoenus*, *Potentilla*, *Euphrasia*, *Hebe*, *Gentiana*, *Ranunculus*, *Astelia*, *Epilobium*, *Trigonotis*, *Gnaphalium*, *Tetramolopium*, *Anaphalis*, *Trachymene*, and *Oreomyrrhis* as herbs, *Coprosma*, *Drapetes*, *Hypericum*, *Haloragis*, *Styphelia*, *Trochocarpa*, *Gaultheria*, and *Rhododendron* as shrubs. *Detzneria*, *Ischnea*, and *Papuapteris*, found at higher elevations on Mt. Wilhelm, were absent. Most of the alpine species collected on Mt. Michael also occurred on Mt. Wilhelm. A conspicuous exception was the umbelliferous herb *Trachymene adenodes*, with big leaves for the genus and a peculiar smoky smell, found by us on Mt. Michael but not on Mt. Wilhelm, and formerly known as a Saruwaged Range endemic.

It would appear from the collections, including those of Womersley (see p. 174), and photographs taken in mist, that the subalpine forest of Mt. Michael differs from that of Mt. Wilhelm and Mt. Otto chiefly in not having the conspicuous, dark-hued *Podocarpus compactus* as a tree. *Podocarpus compactus* has a wide range in the New Guinea subalpine. Its absence from Mt. Michael would seem unlikely, present evidence notwithstanding.

In addition to *Pseudocheirus cupreus* and *Mallomys rothschildi*, mentioned on page 174, a *Melomys* and *Rattus niobe* were collected in the summit area of Mt. Michael. Van Dusen, in his diary, records that after setting traps in cold mist and rain at the 10,200-foot camp of his party: "I then persuaded the small boys to join in a hunt for the frogs that were calling constantly from various spots in the humus. We turned up 13 all told." Seven of these represented a new species, *Cophixalus nubicola;* the others were *C. darlingtoni* and an *Asterophrys* (Zweifel, 1962). Especially impressive to Van Deusen on this excursion was the sight of a peregrine falcon, flying in a break in driving clouds and light rain over grassland of the summit ridge at 11,400 feet.

At Kimi Creek Camp the local natives, to give them their due, brought for sale all the garden produce we could use. They contributed little to the collections except a few common rats, and a great many frogs which the small boys found easy to catch. An extreme abundance of *Cophixalus variegatus* came as a surprise; this frog, though of wide distribution in New Guinea, was previously known from only six specimens. Poor results were had in insects, diurnal and nocturnal. Only one still, foggy night gave a good catch at the lights.

A total of 18 species of mammals collected at Kimi Creek included two new for the expedition: the rare bat *Otomops secundus*, shot near dusk by John Collins in high, straight, fast flight out of the forest, and a series of a species of *Pogonomys*. Others were *Peroryctes longicauda*, *Phalanger vestitus*, *Eudromicia caudata*, *Pseudocheirus forbesi*, *P. cupreus*, *P. corinnae*, *Petaurus breviceps*, *Dendrolagus* (pelvic bone only), *Thylogale bruijni* (mandible only), *Syconycteris crassa*, *Pipistrellus angulatus*, *Rattus exulans*, *R. ruber*, *R. niobe*, *Melomys*, and *Hydromys chrysogaster*. Van Deusen noted what he regarded as subspecific differences, still to be elucidated, between some elements of the mammal populations of the Bismarck Range and those of Mt. Michael.

Several of the women who visited camp wore as facial adornment a slender bone from the wing of a flying fox (probably *Dobsonia*), standing at an angle in front from a socket made near the point of the nose.

PUROSA CAMP, OKAPA AREA, EASTERN HIGHLANDS DISTRICT

September 18 to October 3

This, the last of our camps at middle altitudes on the Highlands, stood in good primary forest at 6400 feet (1950 meters) in the drainage area of the Lamari River, an eastern headwaters stream of the great Purari, some 16 miles by road south-southwest of Okapa Patrol Post and less than 30 miles from the Papuan border. It was in the South Fore census division, an area brought under government control only four or five years before our visit. Near the end of the road and on the forest edge at Purosa, 2 to 3 miles past camp, was a newly established government medical aid post staffed by native orderlies, and beyond it the sole station of the World Mission, in the charge of an American evangelist. An extensive grassy valley, carrying a numerous native population, opened out

beyond the mission and sloped away in a southerly direction. Camp was near the head of this valley, deep in an extensive tract of forest covering a divide on the northern or Okapa side of which, a mile or so from camp, was the head of a smaller grassy valley occupied by the people of Kamina (Kamila, Kamira) and other villages.

The highest ridges in the neighborhood rose only 500 feet above camp level. The terrain, though mountainous, was easy to get about in except for the deep ravines of numerous small streams. Some old native paths in the forest were going out of use since the recent construction of the Jeep road by which we entered the area, but they provided good trails for night hunting. A deep chocolate-brown soil, with the stickiness when moist which denotes good loam to the gardener, derived from mudstones like the strata of Gono, about 30 miles to the northwest. Much rain fell during our stay, as a rule after two o'clock in the afternoon or during the night. Evening and early morning mists, coming down to the ground in the forest, were a feature of the local weather, as were frequently overcast days, and nights usually clear and sharp until toward dawn.

A nearly pure, rather mossy *Castanopsis* forest occupied the tops of some of the higher, but not the highest, ridges. This forest had in general a sparse undergrowth, but in semi-open places along paths grew orange and pink balsams (*Impatiens*), perhaps planted, and a showy red-flowered gesneriad (*?Dichrotrichum*), worth a place in any greenhouse, climbed low on mossy tree trunks or sprawled on the mossy ground. Almost certainly planted beside an old path by wayfarers, in a common native practice which perhaps has led to some confusing records in the botanical literature, were well-grown young *Papuacedrus* and *Araucaria cunninghamii* trees, conspicuous conifers seen nowhere else in this area.

Isolated in the prevailing mixed rain forest, on a prominent spur ridge at about 200 feet below camp level toward Purosa, was a patch of typical, dryish-looking oak-*Castanopsis* forest, with a plentiful woody undergrowth. Relics of a similar forest occurred at about the same elevation on the Kamina slopes, and at higher levels on those slopes the forest contained a scattering of an oak made conspicuous by leaves brown floccose below, a species widespread on the Highlands.

Our time was far too short for a satisfactory examination of the rich development of montane mixed rain forest which comprised the great bulk of the primary vegetation cover of the area; not all parts within easy reach from camp could be worked. Tall and well-grown everywhere, this forest varied greatly in composition and appearance from the bottoms of ravines at about 6100 feet to the tops of the highest ridges at about 6900 feet. Some big trees, in the grandeur of their long straight boles and in bark characters, seemed at first sight to be *Nothofagus*, but the genus apparently was absent. A list of canopy trees attaining very large size would include species of *Syzygium*, *Terminalia*, *Endiandra*, *Cryptocarya*, *Caldcluvia*, *Alstonia*, *Sloanea*, and *Planchonella*, red-flowered *Hibiscus archboldianus*, *Podocarpus imbricatus*, and a very dark-leaved species like *P. neriifolius*. Among lesser canopy and subcanopy trees were *Erythroxylum ecarinatum*, *Gillbeea papuana*, *Schizomeria*, *Symplocos*, *Mallotus*, *Dictyoneura*, *Turpinia*, and a species of *Metrosideros* with a profusion of yellow blossoms. Forming mostly slender substage trees were species of *Barringtonia*, *Claoxylon*, *Evodia*, *Evodiella*, *Casearia*, *Urophyllum*, *Guioa*, *Calophyllum*, *Dysoxylum*, and *Octamyrtus*, and one of *Syzygium* with big red flowers, and the tall tree ferns *Cyathea procera* and *C. womersleyi*. The towering *Gulubia* first met with at Gono grew to over 100 feet in height, its crown level with the forest roof, and its very lightweight brownish pith serving the native childen for footballs, when cut to appropriate shape.

The floristic wealth of the rain forest was most clearly evident in its undergrowth, and this, in ravines and especially shallow gullies, acquired a great lushness in dense stands of herbaceous and soft-woody *Elatostema*, virulently stinging *Laportea decumana* and other Urticaceae; *Psychotria*, *Ophiorrhiza* and other Rubiaceae; *Cyrtandra*, *Symbegonia*, *Alocasia*, and large ferns including *Marattia*, *Pteris tripartita*, the delicate little tree fern *Leptopteris alpina*, and *Cyathea eriophora*. Such genera as *Ardisia*, *Graptophyllum*, *Boerlagiodendron*, *Mackinlaya*, *Acronychia*, *Saurauia*, *Amaracarpus*, *Lasianthus*, *Chloranthus*, *So-*

lanum, *Polyosma*, *Meliosma*, and *Beccarianthus* provided other woody undergrowth elements. A distinctive though obscure assemblage consisted of the small saprophytes *Corsia* and *Sciaphila*, on rich mold in deep shade and nearly always found together. Rare, low, orange-yellow clumps of root parasitic *Balanophora* were conspicuous when discovered.

Besides many terrestrial ferns, many were epiphytic in this forest. Orchids, mostly epiphytic and inconspicuous, were not especially abundant. Large woody epiphytes of the canopy included *Rhododendron incommodum* and *R. scabribracteatum* with red flowers, *Hydnophytum* "anthouses," and *Schefflera* species, associated with the parasitic shrubs *Henslowia*, *Amyema*, and *Notothixos*. The remarkable mosses *Spiridens aristifolius* and *S. perichaetialis*, of radial growth, formed large clumps, often on the stems of tree ferns; while a pendent moss, *Neckeropsis lepineana*, hung in soft masses fully 6 feet long on the lower trunks of some big trees. A plentiful complement of climbing plants included as canopy lianas Apocynaceae, Monimiaceae, *Gouania*, *Vaccinium fissiflorum*, *Dimorphanthera splendens*, and *D. brachyanthera*. A big scrambling bamboo was common on ridge crests. Present as root climbers were *Ficus ovatacuta*, *F. odoardi*, and other figs, *Freycinetia*, *Dichrotrichum*, and, otherwise scandent, *Medinilla*, *Poikilospermum*, *Piper*, *Jasminum*, *Clematis*, *Cyrtandra*, *Lucinaea*, and several ferns.

At Purosa we enjoyed associations with a friendly native population, personally cleanly to the highest degree we saw on the Highlands. At first, they helped us clear ground and set up our tents and flies. In garden produce they brought excellent taro (*Colocasia esculenta*), a bunched yam, sweet potatoes and sugarcane, and, in crops recently introduced, potatoes, "taro kong-kong" (*Xanthosoma*), pumpkins, peanuts, very good tomatoes and shallots, and occasional cabbage and string beans.

Especially pleasing was the keen interest these people took in our doings and the important part they played in bringing in mammals for the collection. A generally recognized advantage in such a situation as regards mammals, and one which held here, is that many of the more rare non-volant species of expeditions are obtained by local hunters, snarers, and trappers, few of them being caught with factory-made traps and made-up bait, though night hunting with jacklights may be very successful in this respect. Often at Purosa Van Deusen worked late into the night in preparation of the day's take in mammals. Trade for most specimens, and for food, was in tobacco, newspaper, salt, and beads. Special mammals were bought for cash, always in one-shilling or two-shilling pieces, smaller silver coins and pennies not being recognized as currency.

The collection of 31 species of mammals from this camp included 12 marsupials: *Antechinus naso*, *Satanellus albopunctatus* (trapped with meat sets), *Peroryctes longicauda*, *P. raffrayanus* (new for the collection), *Phalanger vestitus*, *Eudromicia caudata*, *Dactylopsila trivirgata* (with longer pelage and the black parts blacker than in specimens previously taken), *Petaurus breviceps*, *Pseudocheirus forbesi*, *P. cupreus*, *P. corinnae*, and *Thylogale bruijni* (mandible only). The only bats were *Syconycteris crassa* and *Pipistrellus angulatus*. There were 17 rodents: *Pogonomys* (three species), *Lorentzimys nouhuysi*, *Rattus exulans*, *R. ruber*, *R. niobe*, *Melomys* (three species), *Pogonomelomys sevia*, *Uromys caudimaculatus*, *U. anak*, *Macruromys major*, the bright reddish brown jumping rat *Leptomys elegans* (new for the collection), the first known female specimen of *Mayermys ellermani*, and *Hydromys chrysogaster*. From a limestone cave near Okapa the additional bats *Dobsonia moluccensis*, *Miniopterus australis*, and *M. schreibersi* were taken (see p. 176).

Herpetological collections, though not large, included about 10 species of frogs, four of lizards, and four of snakes. Night-flying insects, especially moths, turned up well and the catches of some single nights were as good as any on the expedition. But so scarce were day fliers, owing in part to overcast conditions, that after a while I gave up carrying a net into the field. A feature of the locality worth special remark, and one that apparently had not been investigated in connection with the endemic *kuru* disease of the general area (see p. 175), was an unusual abundance of sandflies or "no-see-ums" (Ceratopogonidae), which sometimes gave trouble through day

and night and made for the first time during our work on the Highlands the common use of an insect repellent necessary for comfort.

We were frequently aware, too, of rather unexpected lowland or lower-altitude elements in this camp area. In mammals, *Peroryctes raffrayanus*, *Dactylopsila*, *Leptomys*, and *Uromys caudimaculatus* were examples. Here we first found on the Highlands (and collected) a land leech, brown in color, which attacked man. A new sound for us in the Highlands forests was the noisy call of megapods. Blue pigeons (*Ducula*), though seen or heard before at comparable altitudes, or higher, were common here, feeding in tall fruiting trees. They were often shot for the pot, and a pigeon soup in the concoction of which our cook was a master of some repute.

ARAU, EASTERN HIGHLANDS DISTRICT

October 5 to 26

Still on the plateau uplift of the Eastern Highlands, but below the Highlands proper in a short, largely forested marginal valley in the Kratke Mountains drained by the Wanton River, this base was at Arau (formerly Moolamurua) coffee plantation, 4600 feet (1400 meters) above sea level. Down the valley, about a mile to the north, an eastern tributary, the O'awa, joined the Wanton, and in another half mile were Karanka airstrip and coffee plantation at 4450 feet. The main streams cut deeply into country rock in part granite and in part limestone, the descent to the Wanton from Arau homestead being 340 feet by steep slopes of yellow clay. A little beyond Karanka the river entered a narrow gorge in limestone, then turned east and dropped about 3000 feet into the Markham-Ramu rift valley to join the Markham. Adjacent heights of the Kratkes rose to 5000 and 6000 feet.

A site on the Wanton was under consideration for a hydroelectric power plant to supply the Lae-Madang-Eastern Highlands area. Streamflow and flood gauges had been installed in Karanka Gorge, and a flood level of 34 feet was recorded there. A successful postwar planting of tea had been made at Karanka but not brought into production. Most of the recent plantings of coffee there and at Arau, and the native villages, were on fairly level, wide, ridge tops of irregular shape, with fertile brown soil of considerable depth.

A generally equable rainfall approached 100 inches a year, but periods of deficiency occurred. Before our arrival the longest rainless spell at Arau in 1959 had been four days. We experienced first eight days of fairly regular early morning mist, overcast days, and heavy rains from late afternoon into the night. The Wanton rose in two 20-foot floods. Then came 10 days with only one light rain and maximum shade temperatures of 27.0° C. to 28.5° C. (81° F. to 83° F.). Taking advantage of the dry weather, the local natives burned off newly cleared gardens. With extensive burning of grassland down in the Markham Valley, the afternoon air became thick with smoke haze, and, before good rains fell again, there were dust on the road and a cracking of the heavy soil exposed on steep slopes. The lowest temperature recorded was 8.0° C. (46° F.).

Remnants of primary forest surviving on the flattish ridge tops indicated that formerly the forest there may have been a nearly pure stand of oaks and *Castanopsis*, with a local admixture of magnoliaceous, and magnolia-like, *Elmerillia papuana*. Elsewhere, from the tops of ridges to river banks, and up to my 5000-foot limit on the mountain slopes, the very extensive, little-disturbed forests represented a transition between mid-mountain fagaceous forest and a lower montane mixed rain forest, with oaks (at least five species called, generically, *santuna*, it seemed; the acorns 10 to 55 mm. in diameter) and *Castanopsis* (one species) supplying the bulk of the tree stocking. Minor co-dominants included *Engelhardia rigida* (common here), *Dillenia montana* (a valued timber tree with reddish papery bark), *Gordonia*, *Myristica*, *Dysoxylum*, *Aglaia*, *Cryptocarya*, *Sloanea*, *Gillbeea papuana*, *Podocarpus*, and, common on riverbanks and planted in villages, tall *Casuarina papuana*.

It was a forest rich in herbaceous undergrowth, including ferns, but rather poor in woody undergrowth, epiphytes, and climbers. Lowland or lower-altitude influences were most apparent in ravines and on river flats, where the undergrowth consisted largely of rain-forest elements. The forest carried a sig-

nificant amount of moss patched on tree trunks, draped on woody undergrowth, and covering the flanged and often coppiced bases of old oaks and *Castanopsis*, but very little on the ground except on rotting wood. Slow decay of the coriaceous oak and *Castanopsis* leaves resulted in a plentiful leafy ground cover. Frequent flooding limited species representation along the river, and no woody rheophytes were noted. Low banks on one stretch of the Wanton carried a very tall stand of "pit-pit," apparently the wild sugarcane *Saccharum robustum*.

Vigorous regenerative growths of big shrubs and small trees occupied much of the ground which the natives had cleared of forest for gardens and then abandoned in their shifting cultivation. Especially prominent here were several *Macaranga* and *Saurauia* species, *Dodonaea viscosa*, *Mallotus paniculatus*, *Homalanthus*, *Glochidion*, *Breynia*, *Pipturus*, *Ficus pungens* (at which, as at Oomsis on the lowlands, numerous frugivorous small Megachiroptera were netted), and in older growths, up to 60 and 80 feet tall, *Timonius timon* and *Pittosporum ramiflorum*.

Where pressure of land occupancy had led to the establishment of grasslands, a condition prevalent on the broad ridge tops, an *Ischaemum* was the principal grass in a dense, tangled stand about 3 feet high, very difficult for a man to make his way through or over. *Miscanthus floridulus* and in some places *Pennisetum macrostachyum* and *Themeda gigantea* formed thickets or clumps 8 to 12 feet tall. *Kunai* grass (*Imperata cylindrica*), erect to 2 feet or more, took over in places, accompanied by a few other grasses and grassland herbs. A tree fern, *Cyathea angiensis*, attracted attention among the taller grasses.

The not notably energetic, mildly sophisticated Arau natives viewed our activities with some detachment. They brought in a few mammals; the children, an appreciable lot of frogs. It was the custom of these people to make crude blinds of branches and leaves along forest paths from which to shoot with arrows, at very short range, birds and mammals attracted by a bait of chopped-up sweet potatoes. But employed in clearing land were numbers of half-wild, very keen little men of Obura, a village group on the slopes of Mt. Elandora and in the valley of the upper Lamari River, who, under the tolerant eye of Mr. Larner, manager and part owner of the plantation, lost no chance to profit themselves by catching all they could in mammals. They were paid full value for the catch but had the body to eat after we took the skin and skull. Among things obtained in this way were three specimens of the docile little feather-tailed arboreal marsupial *Distoechurus pennatus*, so rare or hard to come by that only two had been taken on all the previous Archbold expeditions.

Other marsupials among the 29 species of mammals collected here were *Antechinus melanurus*, *Peroryctes longicauda*, *Echymipera kalubu*, *Phalanger vestitus*, *Dactylopsila trivirgata*, *Pseudocheirus forbesi*, and *P. corinnae*. A good variety of bats comprised *Rousettus amplexicaudatus*, *Dobsonia moluccensis*, *Syconycteris crassa*, *Paranyctimene raptor*, *Emballonura beccarii*, *Hipposideros cervinus*, *Pipistrellus angulatus*, *Miniopterus australis*, and *M. schreibersi*. Of rodents were *Pogonomys mollipilosus*, *Lorentzimys nouhuysi*, *Rattus exulans*, *R. ruber*, *R. verecundus*, *Melomys rubex*, *M. rufescens* and topotypic *M. levipes shawmayeri*, *Uromys caudimaculatus*, *Macruromys major* (topotypes), and *Hydromys chrysogaster*. Two trophy skulls of *Zaglossus* were obtained. Some *Dobsonia*, *Emballonura*, and *Miniopterus schreibersi* specimens were taken in a cave in Karanka Gorge.

F. Shaw Mayer had collected mammals at Arau and other localities in the general area in 1932. In unsuccessful efforts to obtain wallabies and tree-climbing kangaroos that he had collected, and the monotremes, all customarily hunted with dogs, we offered high pay to the people of both Arau and Obura. Most desirable were the monotremes: *Zaglossus*, of sparse general distribution in the mountains throughout New Guinea, and *Tachyglossus*, long known from Papuan lowlands but from nothern New Guinea known only from a few fragments secured in our part of the Kratke Mountains by Shaw Mayer. The Arau natives spoke familiarly of both: the long-nosed *Zaglossus*, they said, lived only back in the mountains; the short-nosed *Tachyglossus* was "everywhere" in the forests but nocturnal in habits and discoverable only by dogs.

For the dual purpose of hammering-in the word on the larger mammals and doing a botanical sampling of 8300-foot (2530-meter) Mt. Elandora, on the rim of the Markham Valley about 15 miles south of Arau, Collins camped the night of October 17 at Obura and next morning climbed the mountain (see p. 176). Tall forest without *Nothofagus* or recognizable conifers was entered at about 6000 feet (1000 feet above Obura) and continued on moderate slopes to 8100 feet, above which came an almost perpendicular climb through stunted timber, scrambling bamboo and ferns, to the summit. Exposing weathered gray granite,[1] the summit was described by Collins as about 20 by 60 feet in area and covered mainly by a fern (*Gleichenia*) tangle bordered by dense woody growths up to 15 feet high. Prominent in the woody growths were a member of the myrtaceous genus called *?Myrtus* in this report and abundant on Mt. Wilhelm, *Sericolea*, *Eurya*, *Drimys* and *Adinandra*, accompanied by *Quintinia*, *Elaeocarpus sayeri*, *Acronychia*, *Daphniphyllum*, *Pygeum*, *Timonius*, *Streblus urophyllus*, and scrambling *Vaccinium keysseri*. With epiphytic ferns and orchids, but little moss, were *Rhododendron christi* and *R. gracilentum* as small shrubs.

Striking evidence existed that in ancient times, of which the present native population knows nothing, even in legend, people of a different culture lived on the broad ridge tops of Arau and Karanka, the most eminently desirable lands for cropping today. Relics of this former population, or populations, are widespread in the mountains of eastern New Guinea in the form of stone mortars and pestles and a few other kinds of stone artifacts (Bulmer, MS). At Arau we were presented with two of four mortars unearthed at depths of 2 feet or less when holes were being dug for planting coffee. From Karanka, we were given a smaller mortar, of different design, found about 8 feet down when the airstrip was being leveled, and a roughly round object which may have been a grinding stone with two indentations for finger grips. The latter object had been used as a rain stone by the moderns, who, when rain was needed, cast it into the Wanton.

[1] Specimen identified by Brian H. Mason, the American Museum of Natural History.

KASSAM, EASTERN HIGHLANDS DISTRICT

October 26 to November 9

If the gorge by which the Ramu River descends from the Highlands to the broad Markham-Ramu rift valley is regarded as the division between the Bismarck Range and Kratke Mountains, the position of Kassam was on the western slopes of the latter, within 6 miles of their northern end. The mountains thereabouts rose to a maximum of about 5000 feet. Kassam was situated at 4500 feet (1370 meters), near the head of Aindo Creek of the Ramu watershed, where the Lae-Goroka road, having climbed from the Markham Valley to Kassam Pass (4800 feet), then descended for about 2 miles through extensive primary forest which covered the upper parts of the Kratkes, emerged on the open grassy Highlands.

The name Kassam applied to a former patrol post and in our time a road camp for long-term prisoners who, under a corporal's guard of armed native police, maintained the difficult stretch of road over the range and down the Markham scarp. The 26 prisoners were in no visible way unhappy, though rules demanded their being locked up at night. A rather surprising amount of road traffic, averaging perhaps three or four vehicles a day, included the "betel-nut express," run by an enterprising native who, periodically, hurried up and down the road in a pick-up truck, carrying betel nut and betel pepper from the Markham Valley villages for sale in centers of population on the Highlands where traditional betel chewers from the lowlands were employed.

In weather largely overcast, we had some early morning mist or fog, only four falls of rain, these beginning late in the day and extending into the night. The forested range top had more rain. Our stay was near the change of the seasons. At times clouds overhead drove strongly from the southeast, but Kassam was sheltered from these winds, and the crest of the range, lying more or less parallel with the strike of the trades, showed no wind clipping of vegetation or evidence of very constant misty conditions.

Aindo Creek was an attractive stream, rocky toward its source in the forest, gravelly

and sandy and containing numerous clear pools where it flowed past the prison camp, with grassland on the camp side in this vicinity and forest on the other. In the surrounding area of high-hilly but generally not very steep terrain, villages were scattered in the pioneer fringe, or line of active disturbance between forest and grassland. Relic gallery strips of primary oak-*Engelhardia* forest cut through the open grasslands. Elsewhere, in gullies and along the edge of primary forest were fairly extensive developments of second-growth forest of various ages. These second growths had in the main the composition noted for Arau. But here *Engelhardia rigida* was an important pioneer tree in the re-establishment of forest on apparently old grassland. A giant banana, *Musa ingens*, with pseudostems up to 30 feet tall and more than 6 feet in basal circumference, described by Simmonds (1962) as "the largest herb known to science," grew commonly in roadside seral growths in the Pass.

The primary forests, of *Castanopsis* and oaks for the most part, carried more of an admixture of other, here generally larger, trees than at Arau and had in general the appearance of mixed rain forest rather than mid-mountain fagaceous forest. So prominent were the Lauraceae (*Cryptocarya*, *Endiandra*, *Cinnamomum*) in the canopy and other tree layers that it could well be called *Castanopsis*-oak-Lauraceae forest. Other canopy elements included *Calophyllum*, *Garcinia*, *Planchonella*, *Sloanea*, *Elaeocarpus*, *Opocunonia*, *Galbulimima belgraveana*, *Hibiscus archboldianus*, *Artocarpus vrieseanus*, *Elmerillea papuana*, *Engelhardia rigida*, and locally gregarious *Annesijoa novoguineensis*, an interesting euphorbiaceous tree made briefly conspicuous by a profuse display of white flowers. Palms came into some prominence with *Orania*, *Calyptrocalyx*, *Gulubia*, *Ptychandra*, *Calamus*, and at least two other genera represented. A high-climbing "D'Albertis' creeper" (*Mucuna*) produced brilliant masses of cauliflorous red flowers in the middle spaces and near the ground. It was a forest rather poor in undergrowth and substage species, and nowhere very mossy.

The extensive man-induced grasslands occupied varied terrain from creek flats to high ridge crests. Topsoils ranged from heavy black over yellow clay to reddish lateritic. Very tall grasses such as *Miscanthus* were of minor importance here; *Imperata cylindrica* dominated what seemed early stages of establishment. The principal dominant, *Themeda australis*, was accompanied by *Capillipedium parviflorum*, *Sorghum nitidum*, *Arundinella setosa*, and on low ground replaced by tangled *Ischaemum barbatum*. *Buchnera tomentosa*, *Wahlenbergia bicolor*, *Cynoglossum*, *Spilanthes*, *Polygala persicariaefolia*, *P. longifolia*, *Viola betonicifolia*, *Cassia mimosoides*, *Desmodium microphyllum*, and other grassland herbs occurred.

Special efforts to obtain *Tachyglossus* were continued at Kassam. Collins visited villages in search for trophy skulls, and he hunted in the forest at night with natives and their dogs, but the only proceeds were the nose part of a skull and some spines from an animal that had been eaten at a village two days before our arrival. The 30 other mammal species collected here, with good cooperation from local natives, included *Antechinus melanurus*, *Satanellus albopunctatus*, *Peroryctes raffrayanus*, *P. longicauda*, *Phalanger gymnotis*, *Dactylopsila trivirgata*, *Pseudocheirus forbesi*, and *P. corinnae*. Of bats were *Dobsonia moluccensis*, *Syconycteris crassa*, *Nyctimene albiventer* (our first since Oomsis Camp on the lowlands), *Emballonura beccarii*, *Pipistrellus angulatus*, *Philetor rohui* (first record for the Highlands), *Miniopterus australis*, and *M. schreibersi*. The rodents comprised *Pogonomys* (two species), *Hyomys goliath*, *Lorentzimys nouhyusi*, *Rattus* (*exulans*, *ruber*, and a species new for the expedition), *Melomys* (*rubex*, *rufescens*, and two other species), *Macuromys major*, *Leptomys elegans*, and *Hydromys chrysogaster*.

Twelve species of this list not collected by us at Arau brought our total for the Kratke Mountains to 41, as compared with Shaw Mayer's 37, and increased the number of mammals known from the Kratkes to 54 species, a high number for a small area of slight altitudinal range in New Guinea. Included in Shaw Mayer's collections but not in ours were *Thylogale bruijni*, *Dorcopsulus vanheurni*, *Dendrolagus goodfellowi*,[1] *Dactylo-*

[1] We later obtained a specimen brought alive from Gwasiram, on the eastern fall of the Kratke Mountains near Mt. Piora.

nax palpator, *Pseudocheirus cupreus*, *Petaurus breviceps*, *Murexia longicaudata*, *Hipposideros muscinus*, *Anisomys imitator*, *Mallomys rothschildi*, *Uromys anak*, *Parahydromys asper*, and *Crossomys moncktoni*.

Secondary zoological collections from this camp included a big and varied lot of frogs, brought in principally by villagers and road workers. Wind blowing up or down the open Aindo Valley every night spoiled night trapping for insects. Pressure of time did not allow much attention to diurnal insects, apart from Odonata, which were collected on a special priority basis throughout the expedition.

Here difficulties occasioned by shoddy though by no means cheap botanical drying supplies, which first showed up at Purosa, became acute. Standard red driers, which had already become brittle, were now rapidly breaking up into a dust irritant to, and raising hive-like swellings on, my hands and face. Heavy web straps, used in making up plant bundles, had deteriorated under the heat of the Coleman pressure lamps used in the drying process, and now had to be replaced by makeshifts. Night shifts worked in efforts to dry collections, sometimes necessary at all camps, became much more frequent after Arau.

WATER RICE, MOROBE DISTRICT

NOVEMBER 9 TO 13

Situated at about 1500 feet (450 meters) on the floor of the upper Markham Valley where the Lae-Goroka road, on descent from Kassam, turned southeast toward the coast, this short-term camp was at a government resthouse on the bank of fast-flowing, perennial Rering stream. A variation of the pidgin place name was Wararais. Fertile soils of the valley bottom supported a numerous native population, living largely on bananas, and having big villages (for example, Lagasaria and Marawassa) shaded by a great many tall old coconut palms. Very different from the Highlands peoples, those of this area were mostly tall, slender, and had thin features—a pleasant people whose children, bright, lively, and in no way a nuisance, liked to play about our camp.

Including very gentle lower slopes below the foothills on the Water Rice or south side, the Markham Valley narrowed hereabouts to a width of perhaps 4 miles, about half of the width being actual valley floor, almost flat, and covered principally with open grasslands of *Themeda australis* on light soils and *Imperata cylindrica* on heavy, blackish soils. A savanna vegetation characterized by *Nauclea orientalis* as a big-leaved shady tree up to about 50 feet in height occupied parts of the valley floor. On the gentle slopes were savannas and savanna forests in which sparsely foliaged, smaller *Albizzia procera* held first place, and the *Nauclea* occurred commonly among few tree species. Here also were small sago (*Metroxylon*) swamps, and small patches and gallery strips of a poor type of rain forest. A dense stand of tall grasses on the savannas of the slopes had already grown waist- to head-high after being burned about July. Prominent in this habitat were a wild banana (*Ensete calosperma*), with hard black seeds about a centimeter in diameter, and a giant *Amorphophallus*, in flower and releasing a fetid odor. The presence of rain forest and the pattern of its occurrence, coupled with a seeming poverty in savanna species, suggested that the savannas and open grasslands of the area were a condition following deforestation by man, but an old condition maintained by perhaps centuries of firing.

At Gusap cattle property (see p. 177) about 5 air miles to the northwest, where Markham Valley conditions were virtually duplicated in the coterminous Ramu Valley, annual rainfall was about 85 inches, well distributed though the year but with a preponderance in the Northwest monsoon season. The valley climate was said to be moderated by air movements. At Water Rice, breezes up and down the valley had a cooling effect and helped at night to subdue a largely anophelene mosquito pest. Rain from a thunderstorm during our stay ran the larger headwaters streams of the Markham which before that had been merely wide, open, sun-heated dry washes of boulders or gravel holding occasional pools.

Mammal collecting, the chief interest at our Water Rice camp, produced nothing of special note. *Phalanger maculatus* (an entirely white male) and *Pteropus macrotis* (the only specimen collected on the expedition) were typical lowland species taken here, be-

sides *Satanellus albopunctatus*, *Petaurus breviceps*, *Nyctimene albiventer*, *Pipistrellus papuanus*, *Rattus ruber*, *Melomys rufescens*, and *Hydromys chrysogaster*. Through the failure of guides to turn up, we were unable to find, on a visit to Gusap, a reputed bat cave in limestone on the lower southern slopes of the Ramu Valley. Many frogs of probably eight species were brought in by the village children. Eight species of snakes included the death adder, *Acanthophis antarcticus*, said to be common in the general area and to cause losses in cattle at Gusap. Small fishes of two species were caught on bent pins at camp.

UMI RIVER, MARKHAM VALLEY, MOROBE DISTRICT

NOVEMBER 13 TO 29

Down the valley toward Lae from Water Rice, the Umi is the first major tributary to join the Markham from the 13,000-foot Finisterre Mountains. Camp, at an elevation of 1600 feet (490 meters), was in forested foothills where a swing bridge crossed the river a short distance up a very narrow valley from the broad grass plains of the Markham, about 13 miles by road from Water Rice and 95 from Lae. We occupied one of two old grass-thatched huts, roomy and with a dirt floor, of a former road camp; discouraging use of the other hut were 10 greasy old cases of gelignite, an explosive used for blasting rock, stacked and seemingly forgotten. A clear small stream, with its source in the hills nearby, provided an excellent water supply.

The Ofim or east branch of the Umi, flowing in another gorge-like valley, was spanned by a shorter swing bridge about a mile from camp, and it junctioned with the main stream just within the foothills and the forest. Both rivers exhibited series of narrow, level terraces, there being six in some places on the Umi, the highest perhaps 100 feet above the present river bed. A steep and broken country of foothills and low mountains, attaining about 2500 feet above sea level nearby, had often unstable rubbly slopes and in general immature gray soils. The watershed of the Umi and Ofim, or much of it, appeared subject to rapid erosion, as evidenced by the turbidity of the river, with water always gray with silt or, in spate, brownish. These rivers and the likewise perennial Maniang and Leron tributaries, farther down the Markham Valley, were said never to run clear.

The Umi flowed strongly over a bouldery bed edged with bare gravel beaches and at low stage could be crossed here and there by wading. But we were in the heat build-up which preceded the turn of the seasons. Heavy afternoon or night rains from thunderstorms caused freshets and a steady rise in the river which finally restricted our crossings to the bridges. In one spell of exceptionally hot, muggy weather a shade temperature of 92° F. was recorded on the hut veranda—a high reading for New Guinea. A severe earth tremor occurred during the evening of November 20, making our hut sway and creak and swinging a hanging lamp on an arc of about 70 degrees.

Seral forest of *Macaranga* type occupied ground disturbed by native gardeners along the edge of the Markham Valley and on non-flooded terraces of the Umi and Ofim. Flood beds and the lowest terraces carried a mixture of tall cane grass (*Saccharum robustum*) and ligneous growths. On somewhat higher terraces *Albizzia falcata*, a species of *Neonauclea*, and one of *Casuarina* formed more or less open seral stands of tall, rather slender trees. The primary vegetation of terraces and slopes was a mixed rain forest, without oaks or *Castanopsis* or Dipterocarpaceae, rather poor in canopy and lesser tree species, but attaining great height in favorable situations. *Pometia pinnata* and *Dysoxylum* species were prominent canopy trees; others included *Sloanea*, *Sterculia*, *Syzygium*, *Ficus*, *Harpullia*, *Thespesia*, *Octomeles sumatrana*, *Cananga odorata*, *Aleurites moluccana*, and *Pterocarpus indicus*. Notable in the lower layers on terraces were abundant stinging trees (*Laportea*) of four species, none very virulent. Characteristic of a lush, principally herbaceous undergrowth on low terraces above ordinary flood level were *Elatostema* species, Marantaceae, and many large ferns ("*Dryopteris*," *Nephrolepis*, *Diplazium*, *Marattia*, and other genera). Mossiness in the narrow valleys was of a degree that indicated conditions fairly constantly moist. The flowering of many species made the period generally favorable for botanical collecting.

A patch of several acres of primary or at least apparently mature tall forest, isolated on the Markham grass plain but near its edge, gave evidence of both gain and loss of ground by forest in competition with grasses. A drier forest than that of the hill country, this contained in the canopy chiefly *Pterocarpus indicus*, *Dysoxylum*, *Sterculia; Mangifera* and *Artocarpus communis* (breadfruit), not noted on the hills, and on margins seral *Kleinhovia hospita*. A small-tree and palm underbrush combined with the bigger trees to present a dense external wall of foliage. *Curcuma longa* and a species of *Zingiber* grew abundantly as border herbs in the grass. All surrounding grassland had been burned during the dry season. On the southeast side the fire had entered the forest 10 to 12 feet on a face and killed two sizable trees. Damage was less severe on the sheltered northwest side, but it exposed a half-grown *Cycas ?media* plant, a true grassland species which almost certainly must have become established during a regression of the forest, and survived when the forest invaded the grass.

People of the Amari tribe (also at Water Rice) occupied villages in the main Markham Valley at no great distance from camp, growing in mostly open gardens a large variety of food crops besides their staple primitive bananas. Another people, planting mostly sweet potatoes in gardens fenced against pigs, had Tsingitrompon village in the mountains about 2 miles up the Ofim from the swing bridge. All the villagers owned more dogs than most New Guinea people, and, more of note, the dogs were well cared for. From the leisurely Amari we had early assurance of the presence in the bush of numerous desirable mammals, especially in the mountains upstream, where *kapul* (*Phalanger* and *Pseudocheirus*) and *sikau* (wallabies) were "like rubbish." And indeed we were greatly helped by the locals, hunting the larger mammals with their dogs.

Included in 23 species of mammals taken were the marsupials *Peroryctes raffrayanus*, *Echymipera rufescens*, *Phalanger orientalis*, *P. gymnotis*, *Petaurus breviceps*, and *Thylogale bruijni* (the largest 20 pounds in weight).

From shooting by Van Deusen and Collins at dusk, mist nets set for the small Megachiroptera, and roosting places found in a cave and hollows of trees came a pleasing collection of bats, namely, *Dobsonia moluccensis* (some adults and young taken from a hollow nursery tree in the forest); *Macroglossus lagochilus*, *Syconycteris crassa* and *Nyctimene albiventer* from nets; *Emballonura nigrescens*, *Hipposideros cervinus* (from a cave in the forest beyond Tsingitrompon), *H. bicolor* and *H. diadema* (both new for the expedition), *Pipistrellus papuanus*, *Miniopterus australis*, *M. schreibersi*, and a still unidentified species of *Nyctophilus*. An individual *Miniopterus schreibersi* here, and one of *Philetor rohui* at Kassam, were the only insectivorous bats caught in mist nets during the expedition.

Rodents are often exasperatingly hard to trap in the rain forests of the lowlands and lower mountains of New Guinea. From lines of about 150 traps in two weeks in the Umi area the only *Rattus* rat was a specimen of *R. exulans*, caught at the camp garbage pit. Other rodents taken, numbering only 14 specimens, some of them shot by jacklight, were *Melomys platyops*, *M. rufescens*, *Uromys caudimaculatus*, and *Hydromys chrysogaster*.

Tachyglossus was known to the people of the area as confined to the mountains. The Umi being the last camp of the expedition, every effort was made to obtain this elusive or actually rare monotreme, without success. We ceased buying easily caught herpetological specimens from the natives, with the result that collections in this category were small. They included, however, two common reptiles of striking shades of green: the monitor lizard *Varanus indicus* and the python *Chondrophyton viridis*.

A muddy anabranch pond some half mile up the river from camp, secluded in the forest and surrounded by *Polygonum* beds, ranked as the best collecting place for Odonata on the expedition. Many species of dragonflies and damsel flies were netted there, and some, the flight habits of which kept them away from the banks, went uncaught. Moderately good results were had from light-trapping in camp.

THE VEGETATION

ECOLOGICAL STUDIES as a part of land-use surveys, instituted in the Territory of Papua and New Guinea by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in 1953, continue to this time. As an early result of the work, Robbins (1958) presented a classification of the montane vegetation of the Central Highlands, the "natural" communities of which are cited below, with the induced communities omitted:

	FEET
Lower Montane Rain Forest Formation	3000–10,000
Fagaceous forest alliance	
Castanopsis acuminatissima-Quercus spp. association (1)	Below 7500
Nothofagus spp. association (2)	7000–9000
Broadleaf-gymnosperm alliance (3)	
Montane Cloud Forest Formation (4)	9000–11,000
High Mountain Forest Formation (5)	At 12,000 on Mt. Wilhelm
Alpine Shrubbery Formation (6)	11,000–12,000
Alpine Grassland Formation (7)	11,000–14,000
Alpine Bog Formation (8)	11,000–14,000
Herbaceous Swamp Formation	
Phragmites karka association (9)	
Cyperaceae association (10)	

Robbins has presented a unified system in terminology widely current, though the subject of controversy and therefore variously applied. My "major plant communities" are a nomenclatural hodgepodge. Robbins' classification was adapted from one proposed by Beard (1955) for tropical American vegetation types in which the basic unit is the association (a floristic grouping), and associations are further grouped together according to structure and physiognomy (life form) into formations, independent of flora. The Beadle and Costin (1952) concept of an alliance as a group of floristically related associations, of similar structure, appears to have been adopted by Robbins. My classification was based principally on flora, phylogeny, and geographical affinities. We are in near agreement in recognition of the various communities. Our differences are mainly interpretive, and in naming.

The time has perhaps arrived for leaving New Guinea ecology to the ecologists. I feel, however, that this opportunity should be taken to comment on the subject as it concerns the montane vegetation. Such remarks will apply chiefly to a comparison, and attempted reconciliation, of Robbins' system with a classification that I proposed in 1941, in an effort to improve on an earlier one offered by Lane-Poole (1925) for what is now the Territory of Papua and New Guinea. My 1941 classification was for New Guinea as a whole, and I have preferred to retain it for local descriptions of vegetation in the present report (original meters converted approximately to feet):

Savanna and savanna forest	0–5600
Monsoon forest	0–1500
Rain forest	0–7900
Mid-mountain forest	1600–7700
Beech forest	2800–10,200
Mossy forest	4900–10,500
Subalpine forest	9850–13,300
Alpine grassland	9500 up to permanent snow line

Robbins (1958, p. 192) observed: "Lowland forests often penetrate via long valleys into the higher altitudes and montane formations may overlap broadly with lowland vegetation and thus a classification based on altitudinal zones becomes unworkable. For example on the Mt. Wilhelm massive all the forest zones are elevated 1000 ft. higher than elsewhere on the Highlands." On southern slopes of the mountains of Papua I noted in 1933–1934 (1941, p. 337) that the lower edge of the cloud bank which formed daily between 2 P.M. and 5 P.M. marked almost exactly, in an ob-

lique line ascending with the mountains, the lower edge of the mid-mountain forest (*Castanopsis-Quercus* association of Robbins). My mossy forest (montane cloud forest of Robbins), higher on the slopes, was observed to be generally under cloud by about 10 A.M. or noon. These observations were made in the Southeast trade-wind season, when the wind, though varying from year to year, blows with greater strength and steadiness than in the Northwest season.

The "mossy forest" was absent from mountains I visited in west New Guinea in 1938–1939 (1941, p. 337), and there on slopes rising from the Meervlakte, and apparently on upper slopes of the Balim Valley in the Snow Mountains, the beech forest descended just to the lower edge of the clouds that formed about midmorning. In other respects the forest zonation of the mountains agreed with that of Papua.

Robbins remarked of the Central Highlands ranges that cloud formation is not a regular daily occurrence, and "only where it is prolonged and more or less regular does a sharp transition occur between the Lower Montane Rainforest and the Montane Cloud Forest." On this, certain correlations between cloud cover and forest zonation seem unquestioned. In inner valleys of the mountains, such as those of the Central Highlands, the trade winds are often retarded or deflected, and their influence on cloud formation and the zonation of vegetation must accordingly be less pronounced than on slopes exposed to the full force of the winds.

Cloud layering as seen by me on the mountains of the Central Highlands had, however, on some slopes a regularity that could be expected to indicate sharp differentiation between lower mountain mixed rain forest and mid-mountain forest, but because of distances involved or most often the virtual disappearance of the forest at these levels, no check could be made on the ground. As Robbins noted, very little of the mid-mountain forest survives on heavily populated parts of the Highlands; so it was in our Kotuni, Gono, and Kimi Creek working areas. More massive occurrences at Purosa could be observed only as we lived and worked in the forest, without outside view. Scraps of typical mid-mountain forest survived at Arau and Kassam, but in close proximity to extensive forests of an ecotonal or transitional type in which the mid-mountain oaks and *Castanopsis* mingled in the canopy with elements of the mixed rain forest from below.

The forest immediately below the first of Robbins' montane formations on the slopes is called by him lowland rain forest. It is a part of the great, diversified body of forest which I in the past have called merely rain forest or mixed rain forest and considered basically lowland in origins, extending from the sea in high-rainfall areas, abutting on the lower edge of the distinctive *Castanopsis-Quercus* forest on mountain ridges and especially exposed ridges, but bypassing this forest in the narrower valleys and ascending in such sheltered situations to a maximum altitude of about 8000 feet. Robbins' broadleaf-gymnosperm alliance, with Cunoniaceae, Elaeocarpaceae, Lauraceae, Podocarpaceae, and *Papuacedrus* as principal dominants, is the upper part of this mixed forest. This was the forest of our Pengagl Creek camp locality and on up the east slopes of Mt. Wilhelm to about 10,000 feet, also the principal forest at Kotuni, likewise on the Bismarck Range. The prevailing mixed forests of Gono and Purosa were more lowland in appearance and floristics. I am now of the opinion that Robbins' broadleaf-gymnosperm forest should be recognized, with an altitudinal position of approximately 7000 to 10,000 feet.

The common identity of Robbins' *Castanopsis-Quercus* association and my mid-mountain forest is noted above, as is also the distribution of the forest in our 1959 working areas. Curiously, Robbins does not mention for the Central Highlands the presence of *Engelhardia rigida* (Juglandaceae) as a co-dominant in this forest. We found the tree common in that role at Arau and Kassam, as it had been in a number of localities visited by previous Archbold expeditions to Papua and west New Guinea. As an example of the occasional descent of mountain forest to low elevations, small pure stands of an oak occur on ridge crests less than 100 feet above sea level on Rossel Island in the Louisiade Archipelago (Brass, 1959, p. 56).

Robbins' *Nothofagus* association and my beech forest are obviously the same community, and *Nothofagus* is the better term for

formal use. However, Robbins' statement that this forest "belongs rightly and only to the Lower Montane Rainforest formation," though applied only to the Central Highlands, seems open to question. The propriety of bringing together the *Nothofagus* association (or associations) and the *Castanopsis-Quercus* association in a fagaceous forest alliance may also be questioned. Though in the one family, *Nothofagus* is a south temperate or subantarctic genus reaching its northernmost extension in the mountains of New Guinea; *Castanopsis* and *Quercus* (also *Engelhardia*) are northern genera finding their southernmost limits here. The two types of fagaceous forest may often be contiguous, and intergrade, as for example at Kimi Creek and in the Kainantu-Okapa area. Just as often, as on slopes of Mt. Otto above Kotuni, and apparently also in Bundi Gap (see p. 173), they may be well separated by Robbins' broadleaf-gymnosperm forest. When occurring separately the forests are very different in appearance as well as composition, and the *Nothofagus* forest is much more temperate in appearance.

I agree with Robbins that the term "mossy forest," which I took from Lane-Poole, should be dropped as already applied to various forests, montane and even lowland, dissimilar except in bryophyte cover. But Robbins' name, "montane cloud forest," seems little better for this community, a generally though not always low forest with one tree layer chiefly of Myrtaceae (*Xanthomyrtus*, *Decaspermum*, *?Myrtus*) and conifers (*Phyllocladus*, *Podocarpus*). The three montane forest types below this on the slopes could also properly be called "cloud forest."

The high mountain forest formation of Robbins and my subalpine forest are the same. The term "subalpine" gives the forest a precise place in zonation; "high mountain" is inexact in meaning and potentially confusing if used merely as a term, unaccompanied by description by which the forest can be placed in altitudinal sequence.

Robbins' alpine shrubbery formation was included by me in the subalpine forest, with which it agrees in composition and differs only in the absence of emergent trees. Robbins saw his high mountain forest only on Mt. Wilhelm. He gave no floristics for the body of this forest, but mentioned *Papuacedrus* and *Podocarpus* as emergent conifers. If small and non-emergent, however, these conifers were considered an integral part of his alpine shrubbery and were so listed, together with examples of the angiospermous tall shrubs and small trees which, in fact formed the bulk of the stocking of both "shrubbery" and forest. Such an interpretation surely is going very far in adherence to the concept of formations that are based on structure and physiognomy alone, and in ignoring floristics. "Shrubbery," because of its rather general popular application to lower growths than these (which Robbins gives as up to 20 feet in height on Mt. Wilhelm), is a confusing term which might well be replaced by the equally correct term "scrub" for a community not more than 8 meters in height. The term "alpine," in its ecological meanings, is always, so far as I know, restricted to communities above timber line, and therefore cannot properly be applied to our arborescent or subarborescent closed scrub of the New Guinea mountains.

The above remarks notwithstanding, a case does exist for the differentiation of subalpine communities, though not, in my view, at the formation level. This was not very clearly seen on Mt. Wilhelm. But on the basis of observations made on the Wharton Range and Mt. Albert Edward area in Papua, and on the Lake Habbema to Mt. Wilhelmina section of the Snow Mountains (Orange-Nassau Range) in west New Guinea, which I visited on the first and third Archbold expeditions, respectively, my subalpine forest is divisible into at least three substantial communities.

First in ascending order in the subalpine of the Mt. Albert Edward area came a closed coniferous forest of *Podocarpus compactus* and *Papuacedrus papuanus*, 40 to 45 feet high, with a stiff small-tree substage principally of *Vaccinium macbainii*, about half of the height of the canopy layer. With increasing altitude the conifer stand thinned out and lost dominance to the trees of the original lower layer, now increased in species but still chiefly *V. macbainii*, and forming a dense canopy above which the conifers (only *Podocarpus* at the higher levels) thrust their upper trunks and crowns to form an open, emergent tree layer.

In the Mt. Wilhelmina area the first sub-

alpine community of Mt. Albert Edward was found locally at the lower edge of the formation and above that under optimum conditions provided by limestone, with the same dominant conifers and *Vaccinium dominans* replacing *V. macbainii*. The second community of Mt. Albert Edward was well represented, with *V. dominans* the principal dominant of the canopy layer and *Podocarpus compactus* (chiefly), *Papuacedrus papuanus*, and, of lesser frequency, *Phyllocladus hypophyllus* as emergent trees. As altitude increased, the spacing of the emergent conifers became sparser. At about 11,500 feet (3500 meters) they disappeared altogether, leaving a dense scrub still largely composed of *Vaccinium dominans* but with *Rapanea* and *Drimys* becoming prominent, which extended, more and more interrupted by grassland, for some miles in distance and about 1600 feet in altitude to the upper limits of closed arborescent vegetation at approximately 13,100 feet (4000 meters). Absolute tree limit was 200 feet higher, in the shelter of a north-facing bluff (Brass, 1941, pp. 318, 323–325).

Opportunity exists in the Lake Habbema-Mt. Wilhelmina subalpine for the recognition of other Beardian formations. With the dropping out of the conifers, their place up to about 12,500 feet (3800 meters) was taken by Araliaceae as smaller, generally quite scattered but prominent emergents, first *Schefflera megalantha* (ascending from the conifer zones), and above about 12,000 feet *S. falcata*. Under presumably unfavorable edaphic conditions on sandstone about Lake Habbema (10,580 feet), and especially on the edges of small valleys not well drained, an apparently primary *Papuacedrus*-grass savanna occurred.

Robbins and I both regard the alpine grassland as a climatic climax. It shows a high degree of uniformity throughout its range and in its best development is a tussock grassland with species of *Deschampsia* and *Danthonia* as major dominants. Under less than optimum conditions, particularly on wet to boggy ground at the lower levels and replacing the tussock grasses at high elevations, is a short-grass community characterized by dwarf, stiff *Monostachya oreoboloides*, *Aulacolepis epileuca*, species of *Poa*, and the sedge genus *Oreobolus*. Several species of tree ferns (*Cyathea*), tolerant of frost and fire, are a striking feature of the tussock grasslands up to, variously on different mountains, 12,000 to 13,000 feet. Alpine grassland occurred on Mt. Wilhelm, Mt. Otto, and Mt. Michael in our working localities of 1959.

I see no good reason for recognizing as a formation the alpine bog which Robbins himself describes as a boggy aspect of the alpine grassland.

The herbaceous swamp formation of Robbins, with *Phragmites karka* and Cyperaceae associations, occurs in the bottoms of the main valleys of the Central Highlands, outside any working area of our expedition of the present report.

While some reference has been made here to concepts followed by Robbins in his classification of the major vegetational units of the Central Highlands, a detailed discussion, in view of the complexities involved, is avoided. A quotation from Beadle and Costin (1952, p. 70), in their discussion of the purely structural concept of the formation, may, however, be given: "[Since this] system is by far the most rapid and requires least botanical knowledge, it is usually preferred by workers engaged in reconnaissance ecological surveys or in surveys which require a knowledge of the vegetation merely as a background for the study of some other feature of the environment."

Robbins has a good knowledge of the plants he deals with. It is my opinion, however, that the establishment of a graded hierarchy of major plant communities, such as he has proposed, is premature and cannot be satisfactorily achieved on our present knowledge. In Robbins' view (1958, p. 192), "There is no doubt that the montane regions of New Guinea will require much more detailed investigation before a final assessment and classification of the plant formations is reached."

RESULTS OF THE EXPEDITION

THE FOLLOWING IS A LIST of the material proceeds, excluding special collections of blood films and viscera mentioned in the Introduction as having been made for the Queensland Institute of Medical Research, and a few odds and ends such as fresh-water crustaceans, land snails, and annelids:

Mammals	2,294 specimens
Birds	24 specimens
Amphibians and reptiles	4,095 specimens
Fresh-water fishes	59 specimens
Insects and spiders (approximately)	44,500 specimens
Ectoparasites	170 vials
Plants	3,635 numbers
Rocks	4 specimens
Ethnological and archeological	13 specimens

With the exception of the plants, and the materials for medical research noted above, all collections of the expedition are deposited in the American Museum of Natural History.

The botanical collections were presented to the United States National Herbarium, Smithsonian Institution. They comprised 3206 numbers of vascular plants represented by 18,138 sheets of specimens, 419 numbers of bryophytes, and 10 numbers of other cellular cryptogams. Duplicate specimens have been distributed by the recipient institution to the herbaria at Lae, Leiden, Kew, Canberra, the Arnold Arboretum, the New York Botanical Garden, Manila, Bogor and Stockholm, in that order of priority.

Seeds or spores of 16 species of ornamental plants, principally palms and tree ferns, were sent by air to the Fairchild Tropical Garden, the United States National Arboretum, and Longwood Gardens.

In photography, approximately 2000 35-mm. Kodachrome and Ektachrome transparencies were made as a record of the expedition.

A mimeographed list of publications based wholly or in substantial part on the collections, research, and field activities of the Archbold Expeditions, now (September 17, 1963) consisting of 292 titles, is available upon request from Archbold Expeditions, the American Museum of Natural History, Central Park West at 79th Street, New York, New York, 10024.

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1

2

1. Lowland rain forest, Oomsis
2. Cycads on Markham Valley grasslands; Kratke Mountains in distance

1


2


1. Kaindi Camp locality, from about 7400 feet on the west slopes of Mt. Kaindi; Ekuti Range in distance
2. Umi River swing bridge, expedition Land Rover, and Umi River Camp
Photographs by H. M. Van Deusen

1

2

1. Ofim River, looking upstream from its junction with the Umi in foothills rain forest at 1600 feet
2. *Nauclea orientalis* savanna near Water Rice, at 1500 feet in the upper Markham Valley

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1. Deforested foothills of the Saruwaged Range; the braided Erap River flowing into the Markham Valley at upper left

2. The Markham-Ramu Valley from about 3700 feet on slopes below Kassam Pass; the "imperceptible water parting" is in the upper center; Finisterre Mountains in distance

1

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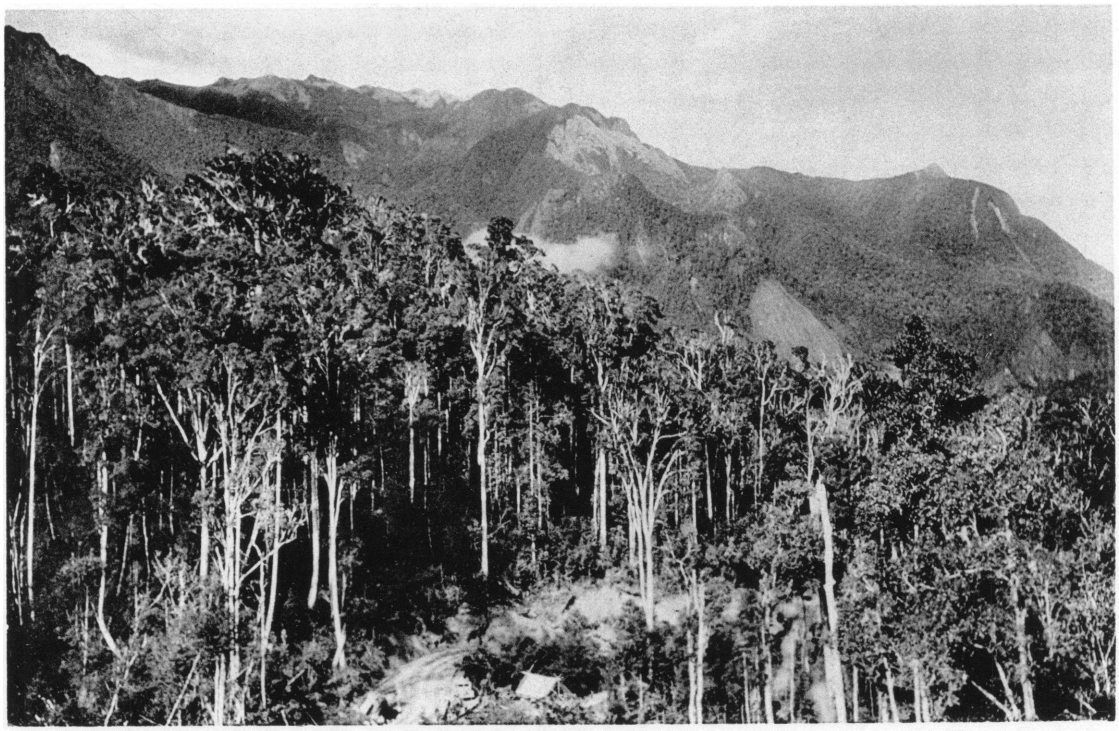
1. Pattern of native sweet-potato gardens, and a mission station, at about 6000 feet in the deforested upper Bena Bena Valley, Eastern Highlands

2. Kassam Camp locality, at 4500 feet on the Eastern Highlands; forest chiefly of *Castanopsis* and oaks; *Ficus dammaropsis* in lower right



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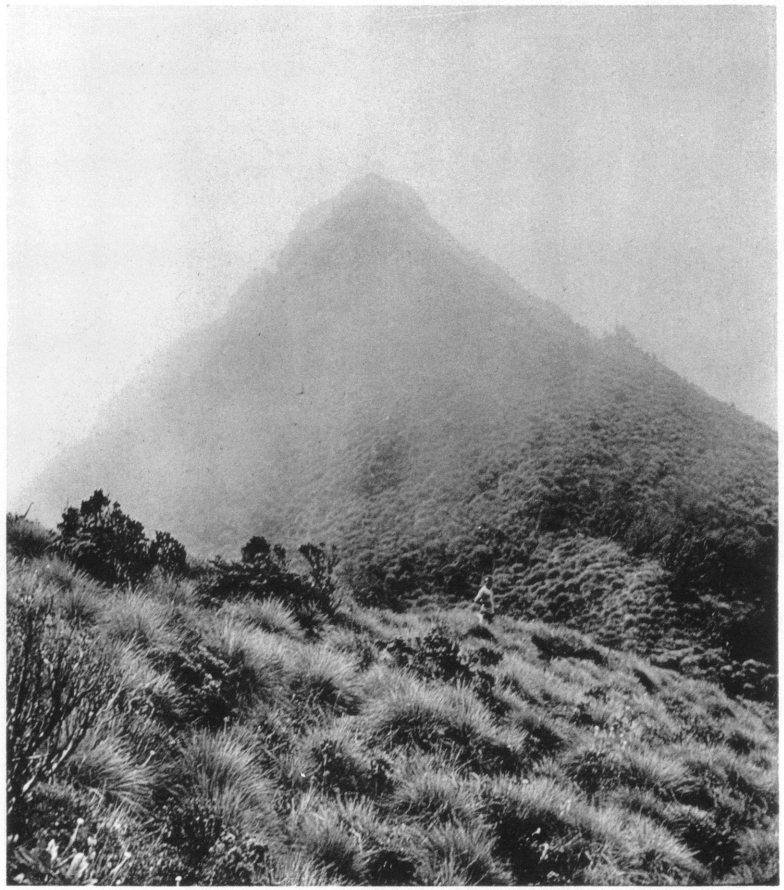
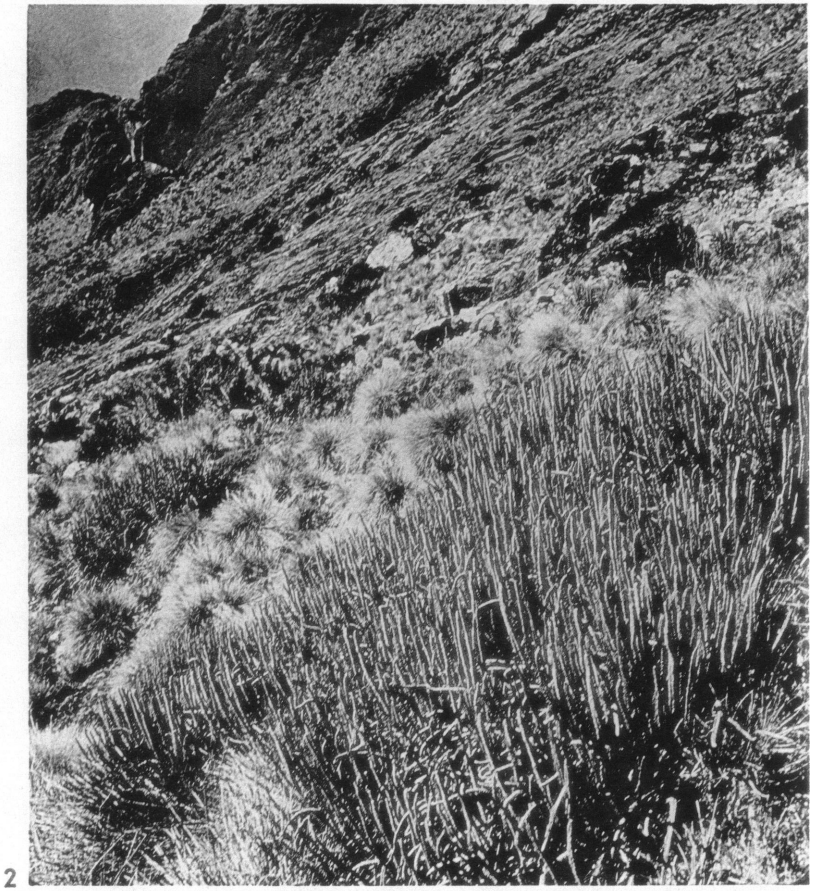
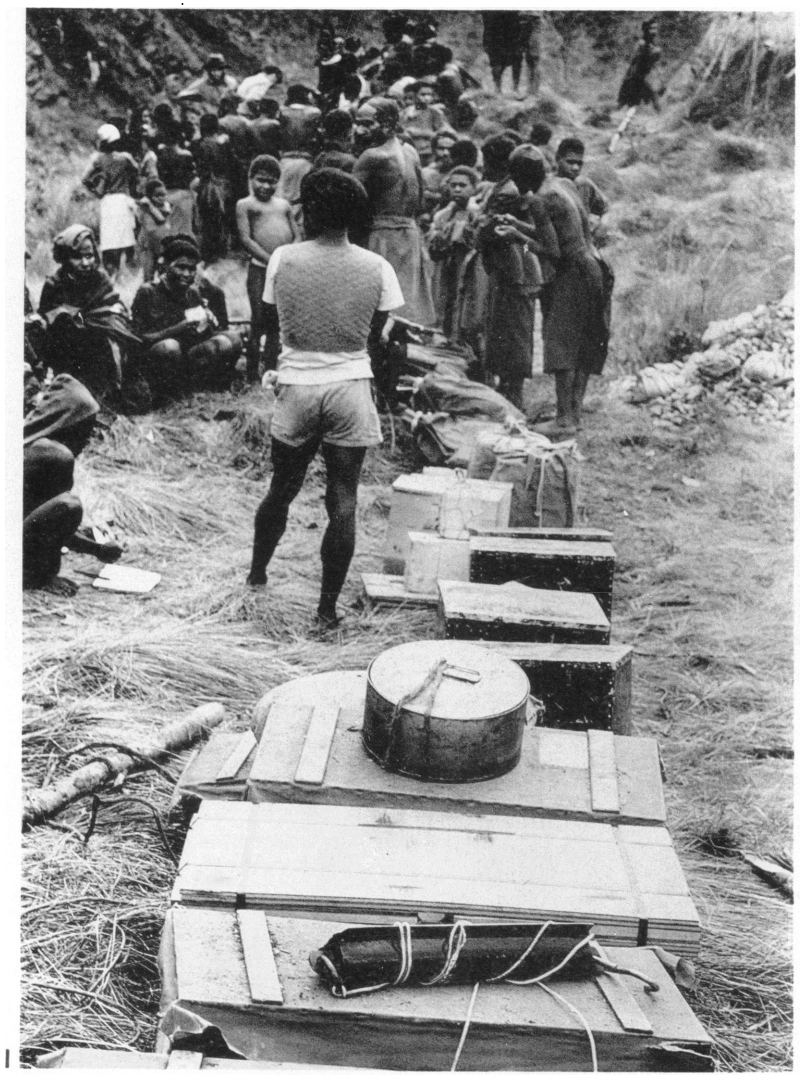
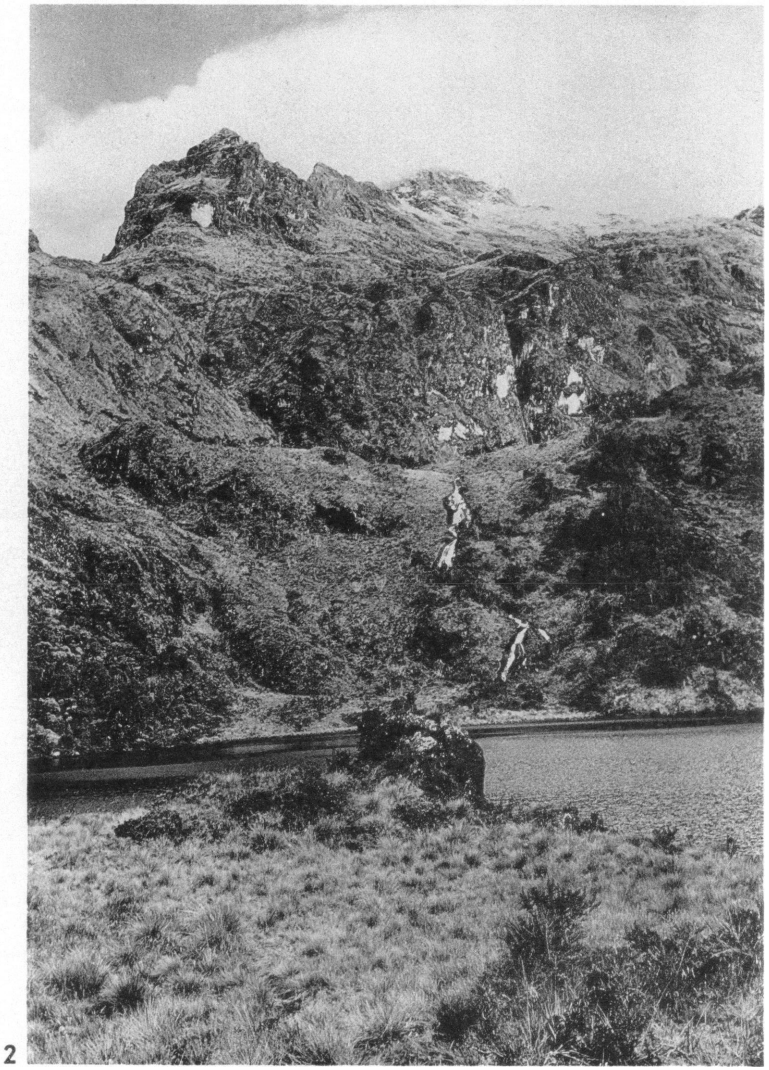
1. *Nothofagus-Castanopsis* forest at Kimi Creek Camp (6500 feet); Mt. Michael in background
2. Pengagl Camp, at 9100 feet on Mt. Wilhelm; young *Pandanus* trees at right; Bundi Gap on Bismarck Range in the distance





1. Highest knoll of Mt. Michael summit ridge (about 12,000 feet), and alpine tussock grassland
2. The alpine fern *Papuapteris linearis* among grass tussocks at 13,600 feet on Mt. Wilhelm
Photographs by H. M. Van Deusen





1. Expedition gear and carriers at Piunde-Aunde Camp site at 11,700 feet on Mt. Wilhelm; food pile on right
2. Heights of Mt. Wilhelm after a snow fall, from Lake Piunde-Aunde Camp, highest peaks not visible

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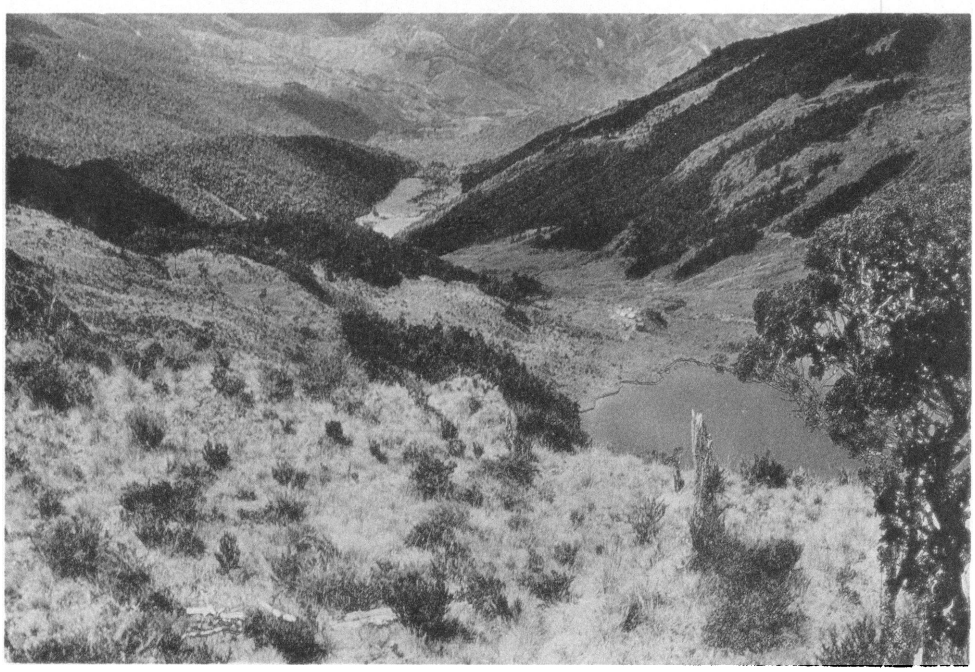

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1. Tree ferns (*Cyathea atrox*) near edge of the subalpine forest at 11,300 feet in the Piunde-Aunde Valley, Mt. Wilhelm

2. View over Lake Aunde and down the glacial valley from about 13,000 feet on the east slopes of Mt. Wilhelm; a relic *Podocarpus compactus* tree and fire-killed remains of others on right; grassland shrubs mainly *Coprosma*

2

1. Alpine tussock grassland and subalpine forest at 11,700 feet in the Piunde-Aunde Valley, Mt. Wilhelm

2. Expedition camp on alpine grassland at Lake Aunde, with fragmented subalpine forest in background, *Cyathea muelleri* on left, *Coprosma* and other shrubs in foreground

1. Collins and Chimbu guides on summit of the main peak, Mt. Wilhelm (about 14,950 feet); view to the east-southeast. Photograph by H. M. Van Deusen

2. Bleak alpine valley of Lake Bendenumbun, a source of the Jimmi tributary of the Sepik River, in a view north-northwest from the summit of the main peak, Mt. Wilhelm; head of the valley, in foreground, over 14,000 feet in elevation. Photograph by J. D. Collins

East slopes of Mt. Wilhelm from an altitude of 25,000 feet; Piunde-Aunde lakes and extensive alpine grasslands in upper left, Keglsugl airstrip and native gardens in lower right. ADASTRAPHOTO, published by permission of the Director of Mapping, Department of National Development, Canberra