

## **GYSIFEROUS OUTCROPS IN SE SPAIN, REFUGES OF RARE, VULNERABLE AND ENDANGERED BRYOPHYTES AND LICHENS**

Juan GUERRA<sup>1</sup>, Rosa María ROS<sup>1</sup>, María Jesús CANO<sup>1</sup> & Manuel CASARES<sup>2</sup>

<sup>1</sup>Departamento de Biología Vegetal (Botánica), Facultad de Biología, Universidad de Murcia, 30071 Murcia, Spain

<sup>2</sup>Departamento de Biología Vegetal (Botánica), Facultad de Farmacia, Universidad de Granada, 18071 Granada, Spain

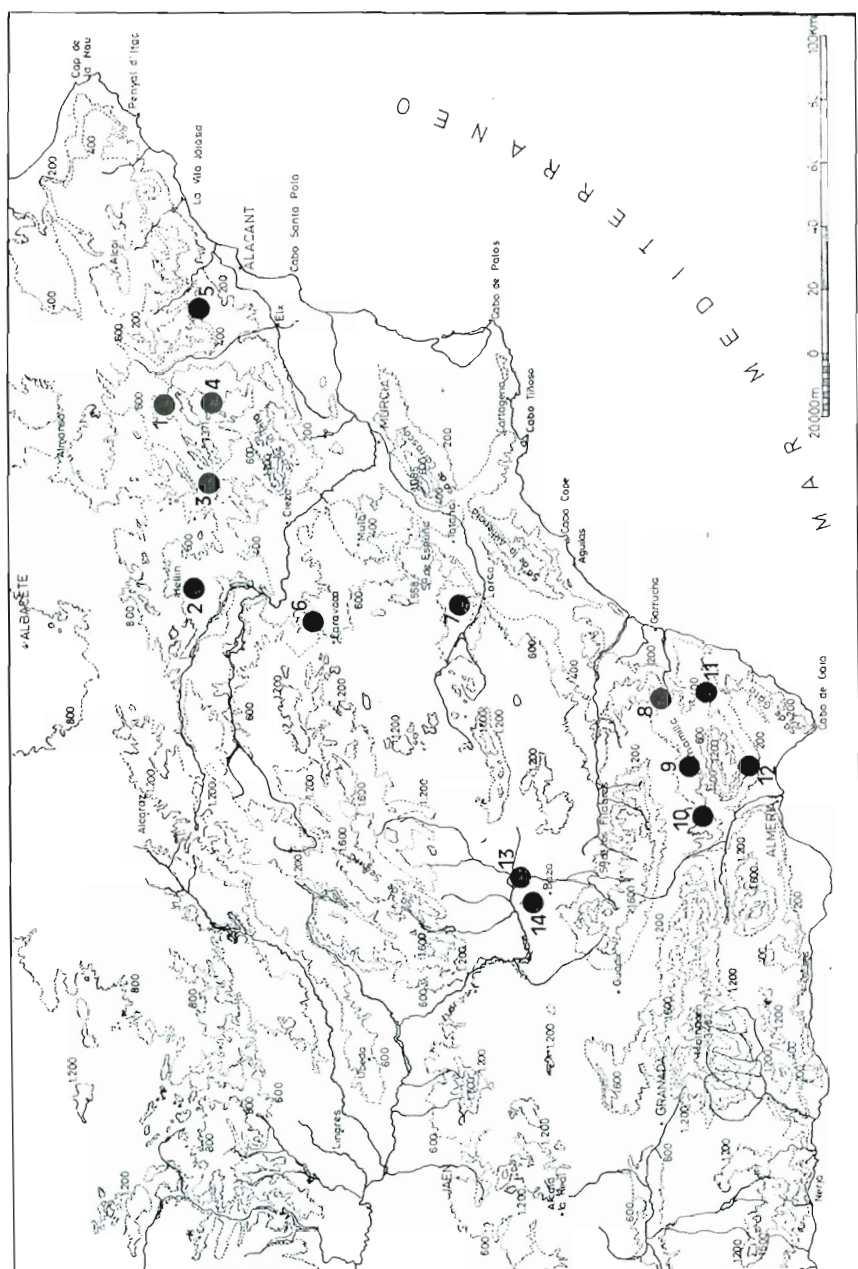
**ABSTRACT** - After studying the bryophyte and lichen flora of the gypsiferous outcrops of SE Spain, it is becoming clear that these sites are important as a refuge for rare, vulnerable and endangered species. Twenty one bryophyte taxa and 17 lichen taxa, about 20% of the total bryophyte and lichen flora, are rare or endemic species, which live exclusively or almost exclusively on gypsiferous substrates. It is proposed that 14 areas should be protected since all of these species grow there. Finally the different impacts that affect these outcrops in the SE of Spain are analysed.

**RESUMEN** - Tras un prolongado estudio realizado sobre la flora briológica y líquénica de los afloramientos yesíferos del sudeste de la Península Ibérica, se llega a la conclusión de que éstos resultan ser importantes refugios para especies raras, amenazadas y en peligro de extinción. Veintiuna especies de briófitos y 17 de líquenes, alrededor del 20% de la flora brio-líquénica de estos territorios, son especies raras o endémicas que viven, casi o exclusivamente, en sustratos yesíferos. Se proponen 14 áreas que deberían ser protegidas para conservar estas especies y se analizan, por último, los impactos más frecuentes que afectan estos hábitats.

**KEY WORDS:** Bryophytes, Lichens, southeast Spain, gypsiferous soils, threatened species.

### **INTRODUCTION**

The most important gypsiferous outcrops of Spain coincide more or less with the great Tertiary depressions. These are the outcrops of Duero, Ebro and Tajo, of which the last two are quite similar from a floristic point of view. Another very important outcrop reaches, almost without interruption, from the coast of Almería to the interior region of the depression of Baza (province of Granada). Other, less extensive outcrops can be found in the provinces of Murcia, Albacete and Alicante. During the Miocene a great transgression of the Mediterranean Sea took place, invading many parts of the Mediterranean coast and connecting the Mediterranean broadly with the Atlantic Ocean. The later regression in the same period caused a crisis of salinity in the Mediterranean Sea, since it left behind isolated or poorly communicating basins. In



these hypersaline basins the deposition of gypsum and other evaporite stone occurred, since the water evaporated and the salts precipitated. This is the origin of the numerous gypsiferous outcrops of southeast Spain. The largest ones and those with the major floristic importance are shown in Figure 1.

The dominant vegetation is formed by open scrub and thyme formations that grow on haplic gypsisols and petrogypsic gypsisols (FAO-UNESCO 1988). Numerous species of chamaephytes and nanophanerophytes that form these scrubs are endemic in these zones, for example *Helianthemum squamatum* (L.) Dum. Cours, *Lepidium subulatum* L., *Ononis tridentata* L., *Helianthemum alypoides* Losa & Rivas Goday, *Teucrium balthazaris* Sennen and *Herniaria fruticosa* L. The annual precipitation of these regions, which are situated in the thermomediterranean or mesomediterranean belt (cf. Rivas-Martínez 1988) is the lowest of the Iberian Peninsula, reaching from 200 to 300 mm. This gives a semiarid ombroclimate.

During the last eight years we have studied the bryophyte and lichen flora of southeast Spain. This area includes the gypsiferous outcrops and supports the major biodiversity in arid zones of the Iberian Peninsula in respect of bryophytes and lichens. More than 100 bryophyte and 80 lichen taxa have been identified (cf. Ros & Guerra 1987, Martínez-Sánchez *et al.* 1991, Guerra *et al.* 1990, 1992, 1993a, 1993b, Casares & Gutiérrez-Carretero 1993). In this article we want to show the importance of the gypsiferous outcrops of the Spanish SE as refuges of the rare bryophyte and lichen species that will be listed below. In order to indicate the degree of danger to which the species are exposed in their habitats, we use the categories proposed by the IUCN: rare (R), vulnerable (V) and endangered (E). Furthermore we take in consideration the observations made by Schumacker (1992).

## RESULTS

### Bryophytes

*Acaulon casasianum* Brugués & Crum - Described from gypsiferous soils of the NE of the Iberian Peninsula (Brugués & Crum 1984), its presence in the gypsiferous areas of SE Spain confirms its clear preference for soils of this type. Not known from outside the Iberian Peninsula or from other types of substratum, it can be considered an Iberian endemic. (V).

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Figure 1. Geographic situation of the gypsiferous outcrops. 1: Villena (Alicante), XH8274, DM. 2: Agramón (Albacete), XH2060, SM. 3: Cerro de la Rosa (Murcia), XH5555, SM. 4: Pinoso (Alicante), XH7350, SM. 5: Campello (Alicante), YH0671, ST. 6: Cañara (Murcia), XH0820, SM. 7: Lorca (Murcia), WH9402, SM. 8: Sorbas-Los Castaños (Almería), WG7903 and WG8409, ST. 9: Venta Los Yesos (Almería), XG6203, SM. 10: Yesoncillo de Enmedio (Almería), WG4300, ST. 11: Cerro de las Cuevas (Almería), WF8498 and WF8697, ST. 12: Cuevas de los Medinas (Almería), WF6283, ST. 13: Galera (Granada), WG3976, DM. 14: Benamaurel (Granada), WG3069, DM. Bioclimatic belt: DM=dry mesomediterranean, SM=semiarid mesomediterranean, ST=semiarid thermomediterranean.

*Acaulon dertosense* Casas, Sérgio, Cros & Brugués - Described from Catalonia (Spain) (cf. Casas *et al.* 1986), this is a relatively frequent species found on almost all of the gypsiferous soils studied in the SE of Spain. Its distribution in the Iberian Peninsula is not well known yet, but it appears at various localities of the Spanish east coast, from Tarragona to Almería. It can be considered an Iberian endemic which shows a clear preference of loamy-gypsiferous soils. (R).

*Aloina bifrons* (De Not.) Delg. - This is a species with a poorly known distribution in Europe, probably due to its rarity (cf. Düll 1984), although there are more precise data concerning its presence in Asia Minor, South Africa and North America. In the Iberian Peninsula it can be found frequently, but only on dry gypsiferous or loamy-gypsiferous soils, especially in SE regions with an arid or semiarid ombroclimate. (R).

*Crossidium aberrans* Holz. & Bartr. - Discovered in Europe by Ros & Guerra (1986) on gypsiferous soils, this species has later been recorded from various points in the Iberian Peninsula, but almost every time on gypsiferous or loamy-gypsiferous soils. In the rest of Europe it is known only in France (cf. Pierrot 1986). (R).

*Crossidium laevipilum* Thér. & Trab. - Known from the N of Africa (Thériot 1931), Israel, Jordan (Frey & Kürschner 1991a) and in Europe from the Iberian Peninsula (Cano *et al.* 1993, Casas *et al.* 1993). In the Spanish SE it grows on gypsiferous soils of the most arid zones. (R).

*Crossidium seriatum* Crum & Steere - Up to now this species is only known from the American Continent (cf. Crum & Steere 1958, Zander 1977, Stark & Whitemore 1992) and from the Iberian Peninsula, where it is frequent on gypsiferous soils in somewhat continental areas of southeast Spain (cf. Cano *et al.* 1992). (R).

*Didymodon aaronis* (Lor.) Guerra - An Irano-Turanian species, known from Israel, Jordan, Iran, Iraq and Egypt (cf. Agnew & Townsend 1970, Agnew & Vondracek 1975, Frey & Kürschner 1983). In Europe it is only known from the provinces of Murcia, Alicante (unpublished) and Almería, in SE Spain. It has always been found on gypsiferous or loamy-gypsiferous substrates that are more or less nitrogen-enriched (cf. Guerra & Ros 1987). (R).

*Enthostodon hungaricus* (Boros) Loeske - A species recorded from the steppes of eastern Europe (Boros 1924) and from Israel (Herrnstadt *et al.* 1991). It presents a disjunction in the Iberian Peninsula. It is found exclusively on saline soils in gypsiferous depressions or near saline lagoons. It is known from Los Monegros (Casas & Brugués 1978), from Las Bárdenas (Fuertes & García-Gómez 1981), from south of Madrid (Brugués & Cros 1986) and from the SE of the Iberian Peninsula in the Provinces of Alicante (cf. Guerra *et al.* 1989) and Granada (unpublished). (E).

*Grimmia mesopotamica* Schifffn. - Known from Israel, Jordan, Iraq (Frey & Kürschner 1991b) and from the Republic of Turkmenia (former USSR) (Abramova & Abramov 1988). In Europe it has been found at one site at Almería (Spain), where it colonizes rocks and slopes of gypsum under a semiarid climate (cf. Guerra *et al.* 1993a). (V).

*Gymnostomum lanceolatum* Cano, Ros & Guerra - Up to now only known from the Iberian Peninsula, it occurs at various sites at Almería and Alicante (cf. Cano *et al.* 1994a). It grows on gypsiferous slopes protected by chamaephytes. (R).

*Phascum cuynetii* Biz. & Pierrot - Only known from the SE of the Iberian Peninsula (Alicante and Almería) (cf. Bizot *et al.* 1970, Guerra *et al.* 1991), this species can at present be considered an Iberian endemic. It is a terricolous species with a clear preference for loamy and gypsiferous soils. (V).

*Phascum longipes* Guerra, Martínez & Ros - An Iberian endemic described by Guerra *et al.* (1990) from gypsiferous outcrops of the province of Almería. One other locality in the NE of Spain is known (unpublished). (V).

*Phascum piptocarpum* Dur. & Mont. in Mont. - This species is known only from one site in north Africa (Montagne 1856), from another site in the SE of the Iberian Peninsula (cf. Guerra *et al.* 1991), and from recent records in Catalonia (cf. Brugués *et al.* 1993). It grows on gypsiferous and saline soils that are temporarily wet, localized in depressions between gypsiferous hills. (V).

*Phascum vlassovii* Laz. - A very rare species, only known from localities in Armenia, Ukraine, Central Asia (cf. Lazarenko 1938, Savicz-Ljubitzkaja & Smirnova 1970), Turkey (Cetin 1988), British Columbia (McIntosh 1989) and the Iberian Peninsula (Guerra *et al.* 1991, Brugués *et al.* 1993). In SE Spain it appears on gypsiferous or saline soils localized in depressions between gypsiferous hills. (V).

*Pottia pallida* Lindb. - A circum-mediterranean species, also present on the Canary Islands (cf. Guerra & Ros 1988). It is a rare species, which is restricted to saline soils, either in depressions between gypsiferous hills or at the margin of saline lagoons. In both cases it may colonize considerable surfaces of bare soil between higher plants that are temporarily inundated (Guerra *et al.* 1989). Because of its special ecological behaviour the saline sites where it grows should be protected. (E).

*Pterygoneurum compactum* Cano, Guerra & Ros - A very rare species, which is only known from the Iberian Peninsula (one site in Lérida and one other in Alicante) (cf. Cano *et al.* 1994b). In both cases it grows on dry, exposed gypsiferous or saline soils. (R).

*Pterygoneurum crossidioides* Frey, Herrnstadt & Kürschner - A species known from the desert areas near the Dead Sea (cf. Frey *et al.* 1990), it has recently been found by us on gypsiferous soils in the province of Albacete. No other European locality is known. (V).

*Pterygoneurum sampaiantum* (Mach.) Mach. - First described from chalky clay in the Algarve (cf. Machado 1925), this taxon has been little studied due to its rarity. Nevertheless it is relatively frequent on gypsiferous or saline soils in the SE of the Iberian Peninsula (Almería, Albacete and Murcia). It is also present in central and NE Spain, showing the same ecological preferences. It has not been recorded outside the Iberian Peninsula. (V).

***Riccia crustata*** Trabut - A circum-mediterranean species, which lives on gypsiferous and saline soils. In the SE of the Iberian Peninsula it colonizes considerable areas in clearings, in scrub and in saline depressions between gypsiferous hills, where it grows with *Pottia pallida*, *Enthostodon hungaricus*, *Pterygoneurum sampaianum* and *Phascum piptocarpum*. All these species are mentioned in this list of rare or endangered species, emphasizing the enormous importance of conserving the gypsiferous and saline areas. (V).

***Tortula brevissima*** Schiffn. - Described by Schiffner (1913) from the Middle East, this species has later been recorded from France, Switzerland, Germany (cf. Boudier 1988, Reimers 1941) and various sites of the Iberian Peninsula. In Europe it can generally be considered a rare taxon, but it is quite frequent on the gypsiferous outcrops in the SE of the Iberian Peninsula. (R).

***Tortula caninervis*** (Mitt.) Broth. subsp. *spuria* (Amman) W. Kramer var. *spuria* - Recorded from some Middle Eastern countries (Afganistan, Iran, Iraq, Turkey) and from Ukraine and Central Europe (Czechoslovakia and Switzerland), this species is known in the Iberian Peninsula only from one site in Catalonia (Brugués *et al.* 1993), Almería (cf. Martínez-Sánchez *et al.* 1991) and Alicante (Moya *et al.* 1994). (R).

## Lichens

***Acarospora clauzadeana*** (Llimona) Casares & Hafellner - Described from Almería (Spain) as *Biatorella clauzadeana* (cf. Llimona 1974), this species has recently been placed in *Acarospora* (cf. Hafellner & Casares-Porcel 1992). It grows exclusively on saccharoide or cristalline gypsum. Although previously considered an Almerian endemic, it has recently been found in North America (Mexico and New Mexico) (cf. Weber & Nash 1992). (V).

***Acarospora placodiiformis*** H. Magn. - An Ibero-Maghrebian species present in thermo- and mesomediterranean gypsiferous soils. At the hottest sites it appears rarely and then with few fructifications.(V).

***Buellia almeriensis*** Llimona - Described from the SE of the Iberian Peninsula (cf. Llimona 1974), it appears on hardened crusts of gypsum. Up to now its only known sites are in the province of Almería (Spain) and Morocco (cf. Casares-Porcel *et al.* 1994). (E).

***Buellia heliophylla*** Llimona - Described by Llimona (1974) from Venta de los Yesos (Almería, Spain), it seems to be a very rare species, since no other populations have yet been found. It grows exclusively on gypsum. (E).

***Buellia zoharyi*** Galun - Although it was described from the Negev Desert in Israel on loess soils (cf. Galun 1970), it seems to be much more frequent in the Iberian Peninsula, where it grows almost always on gypsum. Recently, it has been recorded as new to Africa (cf. Casares-Porcel *et al.* 1994), growing on gypsiferous soils. Its distribution shows a remarkable disjunction between the eastern and western extremes of the Mediterranean region. It is common on gypsiferous soils of SE Spain. (R).

*Collema coccophorum* Tuck. - There are scattered records from Australia, North and South America, Africa and Europe. This species is limited to bare chalky or gypsiferous soils (cf. Degelius 1954, 1974). In the Iberian Peninsula it is frequent on gypsiferous soils, especially in the SE. It has been included in the Red Data Book of macrolichens of the European Community. (R).

*Diploschistes ocellatus* (Vill.) Norm. var. *almeriense* Llimona - A taxon described by Llimona (1974) growing on gypsiferous crusts at some sites in Almería. It may be considered an exclusively Almerian endemic. (E).

*Fulgensia desertorum* (Tomin) Poelt f. *macrospora* Llimona - A taxon known only from the SE of the Iberian Peninsula and Morocco (cf. Casares-Porcel *et al.* 1994) where it is frequent on gypsiferous outcrops. (V).

*Fulgensia poeltii* Llimona - Described by Llimona (1974) from the gypsiferous outcrops of Almería, this species is frequent on the principal gypsiferous outcrops of Spain. It can be considered an Ibero-Maghrebian species with an exclusively gypsiculous habitat. (V).

*Lecidea circinarioides* Casares & Hafellner ad. int. - A very frequent species on saccharoide or crystalline gypsum, it resembles species of the genus *Aspicilia*, which has led some authors to confuse it with *A. contorta* (Hoffm.) Krempelsh. subsp. *hofmanniana* Ekman & Froberg. It is an exclusive gypsophyte and can be considered an Ibero-Maghrebian species. (V).

*Lecidea gypsicola* Llimona - Frequent on the mesomediterranean gypsiferous outcrops, it was described by Llimona (1974) from gypsum in the river Ebro valley. Its area shows a disjunction with Central Asia (Tadzikistan) where it has been collected by Hertel (1977). It reaches the gypsum of the depression of Baza but is absent from Almería. (R).

*Lepraria crassissima* (Hue) Lettau var. *isidiata* Llimona - Always present on shaded slopes with gypsum dust in the principal gypsiferous outcrops of the Iberian Peninsula. It is an Ibero-Maghrebian taxon which is especially abundant in the Iberian SE. (V).

*Llimoniella scabridula* (Müll. Arg.) Navarro-Rosinés & Hafellner - A lichenized fungus described from the Swiss Valais, its only known sites are the type locality and the gypsiferous outcrops of the Iberian Peninsula (Hafellner & Navarro-Rosinés 1993, Gutiérrez & Casares 1994). (R).

*Placidiopsis tenella* (Nyl.) Zahlbr. - A very rare species known from some sites in Algeria. The only European record is from the gypsum of Almería (cf. Gutiérrez & Casares 1994). (R).

*Psora saviczii* (Tomin) Follm. & Crespo - Known from Ukraine, where it was first described, Morocco and the gypsum outcrops of the Iberian Peninsula. It represents an interesting floristic disjunction and is abundant in the SE of the Iberian Peninsula. (R).

*Rhizocarpon malenconianum* (Llimona & Werner) Hafellner & Mayrhofer - Always epiphytic on the thallus of *Diploschistes diacapsis* (Ach.) Lumbsch, this is one of the

most characteristic species on gypsum. Its distribution is poorly known. In Spain it is restricted to gypsiferous areas and is frequent in SE. It has been recently recorded in North Africa (cf. Casares-Porcel *et al.* 1994) (R).

*Teloschistes lacunosus* (Rupr.) Sav. - A terricolous or semivagrant species that is disjunct between the Irano-Turanian territories and the Iberian Peninsula. It is especially abundant in the gypsiferous areas of SE Spain. (R).

## THREATS AND APPROACHES TO CONSERVATION

Practically all the sites shown in Figure 1 are subject to the extraction of gypsum. Therefore the sites are affected by the construction of roads, and by contamination of the soil and air by dust produced by the heavy machinery used at the quarries. Today the ploughing of these sites for agriculture forms another threat, which is difficult to understand since these areas support little agricultural production. In many of sites there are illegal deposits of rubbish from nearby villages, that cause considerable nitrification of the soils. From all of the areas shown in Figure 1 only three, in the province of Almería, are included in the Catalogue of Natural Protected Sites of the Environment Protection Agency of the local government of Andalusia. All the other sites are unprotected, in spite of their being known by the scientific community of Spain as important zones for endemics and as refuges for rare and endangered species. If all these gypsiferous areas (Fig. 1) were considered Natural Sites, the threats to bryophyte and lichen species could be eliminated or at least controlled, thus saving the species from possible extinction.

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