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## **Metallophytes in the Eastern Alps**

### **With Special Emphasis on Higher Plants Growing on Calamine and Copper Localities**

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With 1 Figure

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#### Summary

PUNZ W. 1995. Metallophytes in the Eastern Alps. With special emphasis on higher plants growing on calamine and copper localities – *Phyton* (Horn, Austria) 35 (2): 295–309, 1 figure. – English with German summary.

Information about metallophytes in the Eastern Alps is briefly reported, recent metallophyte terminology including the conception of GAMS 30 years ago is discussed. Beside the small number of eumetallophytic taxa, the majority of metal resistant taxa occur in *Caryophyllaceae*, *Poaceae*, *Brassicaceae*, *Asteraceae*, *Lamiaceae*, *Scrophulariaceae* and *Rubiaceae*. A map of floristically investigated heavy metal localities in the Eastern Alps is given. The metallicolous plant associations of the Eastern Alps belong to five classes but not to the *Violetea calaminariae*.

#### Zusammenfassung

PUNZ W. 1995. Metallophyten („Erzpflanzen“) in den Ostalpen mit besonderer Berücksichtigung der Höheren Pflanzen auf Galmei- und Kupferstandorten. – *Phyton* (Horn, Austria) 35 (2): 295–309, 1 Abbildung. – Englisch mit deutscher Zusammenfassung.

Der heutige Stand des Wissens über die „Erzpflanzen“ in den Ostalpen wird kurz zusammengefaßt; das Schwergewicht liegt dabei auf den Höheren Pflanzen der Galmei- und Kupferstandorte. Die einschlägige Terminologie (inklusive des Kon-

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zepts von GAMS vor 30 Jahren) wird kurz diskutiert. Es gibt wenige „echte“ Erzpflanzen („Eumetallophyten“) in den Ostalpen, wohl aber zahlreiche erzholde Taxa („Pseudometallophyten“), vor allem in den Familien *Caryophyllaceae*, *Poaceae*, *Brassicaceae*, *Asteraceae*, *Lamiaceae*, *Scrophulariaceae* und *Rubiaceae*. Ein Überblick über floristisch untersuchte Schwermetallstandorte im Ostalpenraum ist in Form einer Karte beigelegt. Die metallicolen Assoziationen in den Ostalpen gehören fünf Klassen an, jedoch nicht den *Violetea calaminariae*.

## Introduction

Some 30 years ago, GAMS in his article „Erzpflanzen der Alpen“ (1966) gave some glimpses on the „plantae aerariae vel chalcophilae“, i.e. on „plants that grow regularly resp. exclusively on substrata containing high concentrations of heavy metals . . . being less sensitive to their toxicity, and even accumulating those elements to a considerable extent“. For the Eastern Alps, he mentions the description of *Iberis cepaeifolia* (today's *Thlaspi rotundifolium* subsp. *cepaefolium*) by Franz Xaver von WULFEN („in valle Raiblensi copiose prope fodinas calaminaria“) in the Carnic Alps some 200 years ago. Apart from this flowering plant (GAMS did not include the serpentinophytes) there are a number of chalkophilic mosses and lichens, which are described in detail in this paper.

Can we – now 30 years after GAMS – support his ideas on (Eastern) Alpine „Erzpflanzen“? Can we add some new species, or do we have to deny his concept of metallophytes? To approach an answer we collected both literature and field data on flowering plants, preferably from calamine and copper localities (for synopsis see PUNZ 1988, 1991, 1992, 1995 [Eastern Alps in general]; PUNZ al. 1990b, 1994 [Tyrol]; PUNZ & al. 1990a [Styria]; PUNZ & SCHINNINGER 1995, PUNZ & MAIER 1995 [Carinthia]; ZECHMEISTER & PUNZ 1990 [mosses]). To evaluate our findings, we also took into consideration the current knowledge of serpentine vegetation as well as informations on mosses and lichens. (We are very grateful, therefore, to all colleagues who provided us with information on their special field of investigation, namely to Univ.-Prof.Dr. Roman TÜRK [lichens], Dr. Harald ZECHMEISTER and Prof. Franz GRIMS [mosses], and Dr. Christoph JUSTIN [serpentine vegetation] for their help and assistance.) We think that now is the time to give a provisional resumé of our knowledge of metallicolous plants on calamine and copper soil in the Eastern Alps.

## The Area: the Eastern Alps and the Localities of Metallicolous Plants

Though we have focused mainly on calamine and copper sites, it is impossible to neglect the findings on other substrata („Sonderstandorte“). Therefore we have established a documentation of all localities at which

information on metallocolous plants (Higher Plants) was available. From these, a map showing all sites in the Eastern Alps was compiled in Fig. 1. Compared with latest publication of this map three years ago (PUNZ & SIEGHARDT 1993), the new version comprises more than 40 additional localities.

### Metallophyte Terminology (I)

In order to answer our questions, we should first take a look at metallophyte terminology that has arisen during the last decades. Based upon LAMBINON & AUQUIER 1964, ANTONOVICS & al. 1971 defined metallophytes as "taxa found only on metal contaminated soil" (dividing them into

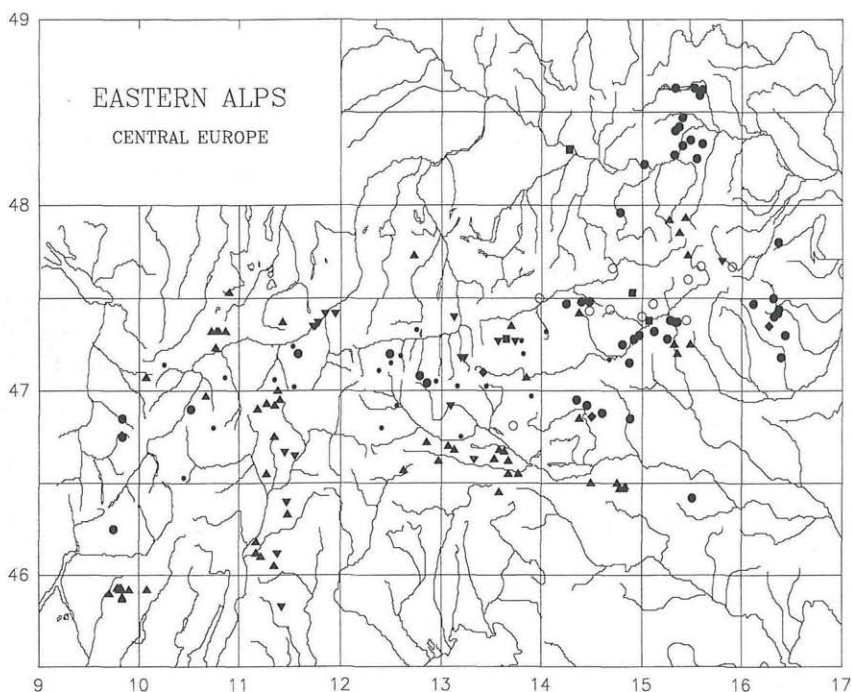


Fig. 1. Localities with high substrate metal concentration in the area of the Eastern Alps at which information on vegetation cover (higher plants) is available. To give an idea of distribution of heavy metal mosses, however, we added some findings of *Mielichhoferia*, the most prominent copper moss species (most data from GRIMS, written information). For sources of higher plant localities see the compilations of PUNZ 1991, 1992 (Eastern Alps in general), PUNZ & al. 1990 (Styria), PUNZ & al. 1994 (Tyrol), PUNZ & MAIER 1995 (Carinthia), and JUSTIN 1993 (serpentine).

Symbols used: calamine = triangle upward; copper = triangle downward; serpentine = filled circle; magnesite = hollow circle; arsen and others (predominantly iron) = square; small dots = *Mielichhoferia mielichhoferi*.

"absolute metallophytes": "found only on metal contaminated soil over all their distribution"; and "local metallophytes": "found only on metal contaminated soil within a given region but occurring also in a phyto-geographically distinct non contaminated area"); in contrast, there are the "pseudometallophytes" ("taxa occurring both on contaminated soils and on normal soils in the same region") with the subdivisions "elective pseudometallophytes" ("abundant and often more vigorous on contaminated soil"), "indifferent pseudometallophytes" ("live on contaminated soil regularly but show neither abundance nor particular vitality"), and "accidental metallophytes" ("usually woods and ruderals appearing sporadically and showing reduced vigour on metal contaminated soil"). Similar to this concept, BROOKS 1987 proposed the Begriffspaar "obligate" and "facultative" (for serpentinophytes), the latter being "taxa which will grow quite well on serpentine soils without having a specific requirement for any of the edaphic or physical properties of the substrate", while "obligate species are presumed to grow on serpentine because of a specific nutritional or other requirement which only such soils can provide". But in contrast to ANTONOVICS & al. 1971, BROOKS reminded that "great care must be taken in definition of the term obligate. ... it would seem that these plants are obligate to serpentine only insofar as such soils provide a refuge from biotic factors present in non-serpentine substrates". We think that this warning should be kept in mind, although in the case of ophiolitic substrata (namely for reason of the complex "serpentine factor", see WENDELBERGER 1974, GAMS 1975, PROCTOR & WOODSELL 1975, MUNTEAN 1977, BROOKS 1987, ROBERTS & PROCTOR 1992, BAKER & al. 1992, JUSTIN 1993), there are some different aspects.

Equipped with this information, we may attempt to answer the first question: are there any true metallophytes *sensu* ANTONOVICS (to avoid misunderstanding we would prefer to use the term "eumetallophytes" instead) in the Eastern Alps?

### Eumetallophytes in the Eastern Alps

Information on substrata other than calamine and copper is given in *petit*.

Higher plants. Considering the metallophytes in the Eastern Alps, we have to concede that there is only a small number of eumetallophytic taxa among higher plants. For calamine soils, there are *Thlaspi rotundifolium* subsp. *cepaefolium*, *Alyssum wulfenianum* und *Viola tricolor* subsp. *subalpina* var. *raiblensis* (see also PUNZ & al. 1993). For all three species (originating from a "classic" calamine site: Raibl = Cave del Predil/Italy), caryological findings are available (LAUSI & CUSMA VELARI 1986, 1992).

For ophiolitic substrata we may consider *Asplenium adulterinum*, *A. cuneifolium*, *A. scolopendrium*, *Myosotis stenophylla*, *Notholaena maranthae*, *Potentilla crantzii* subsp. *serpentinii* and *Veronica scardica* to be serpentinyphytes (JUSTIN 1993).

Mosses. Our recent review about mosses on heavy metal rich substrata (calamine and copper sites; ZECHMEISTER & PUNZ 1990) showed that most species do not grow exclusively on mine spoil but include photo- and thermophilous species preferably growing at open ("pioneer") sites. Still, there are true "copper mosses", among them the "classic" *Mielichhoferia mielichhoferi*, *M. elongata*, *Merceya* (= *Scopelophila*) *ligulata*, *Grimmia atrata*; *Gymnocolea acutiloba*, *Cephaloziella phyllacantha*, *C. massalongoi*. Their occurrence is restricted to copper localities and they are therefore classified as eumetallophytic. For these, we proposed two new subassociations: *Rhacomitrio-Andreaetum rupestris mielichhoferietosum* and *Pogonadetum urnigeri mielichhoferetosum* (ZECHMEISTER & PUNZ 1990).

GAMS 1975 doubts the existence of ophiolithophilous mosses but presumes mosses such as *Nanomitrium tenerum* var. *moravica* and *Encalypta streptocarpa*, *Weisia viridula* and *Cephaloziella starkei* to be some kind of euryophiolithophilous. Investigating scoricolous vegetation in Styria (PUNZ 1989a, b), we found that metal-containing blast furnace slag heaps were covered by the *Tortelletum inclinatae*, a xerophytic moss association on calcareous soils (ZECHMEISTER & PUNZ 1990).

Lichens. In the Eastern Alps there are true "Erzflechten", i.e. lichens that are able to grow on metal-containing substrata. In the area they seem to be restricted mainly to the metamorphic rocks of the Central Alps. There are some "classic" localities such as the "Schwarzwand" near Großarl (Salzburg/Austria) and the "Pfunderer Berg" near Klausen (Southern Tyrol/Italy) (POELT 1955, GAMS 1966, 1972). Apart from them there is a wide distribution of lichens on more or less metal-containing rocks, mostly represented by species of the genera *Acarospora*, *Bellemerea*, *Haematomma*, *Lecanora*, *Lecidea* and *Rhizocarpon*. Phytosociological coverage of the area is poor (see the recent comments of OBERMAYER 1993); the well-known lichen association for heavy metal substrata, the *Acarosporietum sinopicae*, is frequently reported from the Alps, but also the *Lecanoretum epanorae* has already been found.

HAFELLNER 1991 gives some literature on serpentinycolous lichens in the Alps; he presumes that most species that can be found on ophiolitic substrata can be considered as facultative serpentinyphytes sensu BROOKS 1987.

More detailed information can be drawn so far from the bibliobiography by TÜRK & POELT 1993.

## Metallophyte Terminology (II)

So far, we have used a very formal if not rigorous conception of metallophytes. There are, however, recent ideas which promote a broader use of the term metallophyte: ERNST al. 1990 propose a new definition of metallo-

phytes as "plants which can maintain a population in a metal-enriched environment". This is in agreement with BAKER 1981 who thinks that "the presence of a species or a race on metal-contaminated soil implies that it is tolerant of metal toxicity". (See also GELDMACHER 1984: "on heavy metal contaminated soils only such plant populations can grow that are genetically tolerant to the metals".) BAKER adds that such adaptations ask for, either, a constitutional tolerance, or ecotypical differentiation into adapted metal-tolerant races; but: "tolerance has arisen independently in the full spectrum of families; no obvious phylogenetic relationships are apparent" (BAKER 1987). KRUCKEBERG & KRUCKEBERG 1990 have no doubt that "some taxonomic groups indeed have a metallophytic potential" while "entire genera and families appear to avoid metalliferous substrates". The fact is emphasized by BAKER & PROCTOR 1990 for the British Isles: "the majority of widespread British metal tolerant taxa occur in only three families – the *Poaceae*, *Brassicaceae* and *Caryophyllaceae*. Other large families such as the *Cyperaceae*, *Asteraceae*, *Rosaceae* and *Apiaceae* are poorly represented."

Let us now leave aside the theoretical assumptions, turn to the real situation on Eastern Alpine calamine and copper soils and put forth the question: which are the taxa and taxonomic groups that bring forth resistant metallophytes in the area? (In spite of the widespread use of the word "tolerant" we prefer the more comprehensive term "resistance" which includes the components avoidance and tolerance as well: LEVITT 1972, 1980).

### Higher Plants in the Eastern Alps Colonizing Calamine and Copper Soil

The following synopsis is compiled from several works. For details and references see PUNZ 1991, 1992, 1995 and ORASCHE 1993.

For substrata with exceedingly high concentrations of zinc and lead ("Galmei" = "calamine") the top twenty on calcareous soil can be listed as follows: *Silene vulgaris*, *Minuartia gerardii*, *Galium anisophyllum*, *Poa alpina*, *Thymus praecox*, *Anthyllis vulneraria*, *Viola dubyana*, *Scrophularia juratensis*, *Euphrasia salisburgensis*, *Festuca ovina*, *Epipactis atrorubens*, *Thlaspi rotundifolium*, *Dianthus sylvestris*, *Cardaminopsis halleri*, *Biscutella laevigata*, *Lotus corniculatus*, *Campanula cochleariifolia*, *Geranium robertianum*, *Calamintha alpina*, *Silene pusilla*. On metamorphic or plutonic soil, the following plants occur most frequently: *Silene rupestris*, *Silene vulgaris*, *Betula pendula*, *Cardamine resedifolia*, *Linaria alpina*, *Avenella flexuosa*, *Agrostis stolonifera*, *Anthoxanthum odoratum*, *Galium anisophyllum*, *Poa alpina*, *Silene nutans*, *Pinus sylvestris*, *Picea abies*. Most frequent ferns are *Asplenium viride*, *Asplenium ruta-muraria*, *Cystopteris fragilis*, *Gymnocarpium robertianum*, *Asplenium septentrionale*; bryophytes: *Tortella tortuosa*, *Bryum*

*caespiticium*, *Cephaloziella starkei*; lichens: *Cladonia pyxidata*, *Stereocaulon alpinum*, *Lecanora polytrapa*.

On copper soil the vegetation cover is poor, on calcareous substrata it is nearly lacking. The species most frequently occurring were *Silene vulgaris*, *Picea abies*, *Larix decidua*, *Alnus viridis*, *Acer pseudoplatanus*, *Saxifraga stellaris*; ferns: *Asplenium viride*, *Asplenium ruta-muraria*, *Dryopteris villarii*; lichens: *Cladonia*, *Cetraria*, *Lecanora*, *Rhizocarpon* and *Stereocaulon* species.

### Families with Metal-resistant Taxa in the Eastern Alps

Which are the taxonomic groups that include metal resistant species in the area? Or, using the words of BAKER & PROCTOR 1990: which families represent the majority of Eastern Alpine calamine and copper resistant taxa? Well, at the first place in our list there are the *Caryophyllaceae*, a family of plants that have the ability to keep the internal cation concentration low (usually by forming oxalate) and, therefore, to colonize both calcareous and halic substrata with a considerable number of species (for details see ALBERT 1982, KINZEL 1982). The genus *Silene*, with the species *S. vulgaris* (frequently with the subspecies *glareosa*), represents the most successful plant on heavy metal substrata of Eastern Alps altogether: based on a broad ecological amplitude, high genetic variability, rapid seed germination and a strong primary root that reaches great depths rapidly, metal resistant races or populations have developed (cf. FRIEDRICH 1961 ff, VERKLEJ & PRAST 1989, ERNST & al. 1990, SCHAT & al. 1993, PUNZ & KÖRBER-ULRICH 1993). *Silene vulgaris* subsp. *glareosa* is able to incorporate Zn into oxalate crystals thereby contributing to internal detoxification (SIEGHARDT 1985). There are other *Silene*-species as *S. rupestris*, *S. alpina* and *S. pusilla* which can colonize moderately metal-containing substrata; *Silene rupestris* is known to be the character species of the *Silene rupestris* – *Asplenietum septentrionalis*, found on metamorphic rock with high metal concentrations (PUNZ & ENGELHART 1990, MUCINA 1993, PUNZ & al. 1993). *Minuartia gerardii* (including probably all former findings of *M. verna* in the alpine area: see FISCHER 1994) proved to be dominant in the *Minuartia gerardii*-(Thlaspi)-Gesellschaft in the metal containing rock-debris of the Northern Calcareous Alps (MUCINA 1993) It is considered a glacial relic on the "open" metal containing localities, just as *Armeria maritima*; this is known as the paleoendemism hypothesis (STEBBINS 1942, opposed by ANTONOVICS & al. 1971 see ERNST 1969, 1990).

Since the early findings of BRADSHAW 1952, numerous members of the *Poaceae* family have proved to be metal resistant, among them *Agrostis*, *Deschampsia*, *Festuca*, *Anthoxanthum* species (see ANTONOVICS & al. 1971, BRADSHAW & CHADWICK 1980). According to BAKER 1987 "the prevalence of reports of metal tolerance in members of the *Poaceae* family

probably merely reflects the disproportionately large size of the family". Unfortunately, this explanation does by no means take into consideration ecophysiological findings, neither the economical use of water by grasses (which leads to reduced uptake of minerals compared to dicots), nor the ability of grasses to exclude undesired ions to a considerable extent through special endodermal features known for halophytes and, sometimes, through excretory structures (ALBERT 1982). This is supported by the fact that hyperaccumulation has never been reported for Poaceae (BAKER & BROOKS 1989); in contrast, they show excluder type of heavy metal uptake, i.e. the ability to keep the concentration of heavy metals in the shoot constant, in spite of high soil concentrations (BAKER 1981, PUNZ & SIEGHARDT 1993).

*Brassicaceae* are adapted to colonize calcareous and halic soil because of their specific "physiotype" (KINZEL 1982), especially the ability to accumulate cations in soluted form by means of uptake and synthesis of antagonistic ions. It is feasible that the same mechanisms might also function in species on metal-containing soil with the exception of copper-rich substrata: the increased ability of *Brassicaceae* to take up and store copper rapidly leads to toxic internal concentrations (MUTSCH 1981, POPP 1982). In contrast to the *Poaceae*, *Brassicaceae* tend to accumulate heavy metal ions in the shoot, with the exception of lead (PUNZ & SIEGHARDT 1993, PUNZ & al. 1994, PUNZ & SCHINNINGER 1995) representing an "accumulator"-type sensu BAKER 1981. For ophiolitic soil, nickel hyperaccumulation (= accumulation of heavy metals exceeding 1000 resp. 10.000 ppm: BROOKS & al. 1977) of *Brassicaceae* is well-documented (BROOKS 1987, BAKER & BROOKS 1989, BAKER & WALKER 1990, ROBERTS & PROCTOR 1992). A list of plants hyperaccumulating zinc which is given by BAKER & BROOKS comprises 10 *Thlaspi*-species (apart from 5 other *Brassicaceae*). Out of these, findings for *Thlaspi rotundifolium* subsp. *cepaefolium* originate from the Eastern Alps (Raibl: see above). We could also find *Thlaspi caerulescens* (= *alpestre*) in the Central Alps on the spoil of an old silver mine; this species is known from mining areas in Belgium, Germany and Great Britain (REEVES & BROOKS 1983) and supposed to be an absolute metallophyte for England and Wales (BAKER & PROCTOR 1990, BAKER & al. 1994). Both, *Thlaspi rotundifolium* subsp. *rotundifolium* and South Eastern Alpine *Thlaspi minimum* (= *kernerii*), proved to hyperaccumulate zinc, too. For the "Erzblume" *Cardaminopsis halleri*, occurrence on metal-contaminated soil and zinc hyperaccumulation has been known for a long time from other localities (MARKGRAF 1986 ff, ERNST 1968); MELZER 1988 reports it to grow under electricity pylons in Styria (similar AL-HIYALI & al. 1988 for England). *Cardamine resedifolia* - hyperaccumulating zinc in our investigation area - is known to be a nickel hyperaccumulator on serpentinites in Italy (VERGNANO GAMBI & GABBRIELLI 1979, 1981).

No "classic" chalkophytes are known among *Asteraceae* all the more as protoplasmic findings are dubious (*Tussilago*: REPP 1963, cf. PUNZ & KÖRBER 1993). This "successful" family occurs frequently on metal contaminated soils (*Achillea*: SHIMWELL Laurie 1972, ERNST 1976). This might be due to avoidance strategies which have been observed in accidental metallophytes (BAKER 1987). High frequency of *Lamiaceae* is mainly due to *Thymus*-species (ERNST 1974), of *Scrophulariaceae* due to *Euphrasia* (which is capable of increased heavy metal uptake: ERNST 1965, 1972, 1990), *Scrophularia* and *Linaria* (hyperaccumulating nickel on Italian ophiolites: VERGNANO GAMBI & GABBRIELLI 1981). Among *Violaceae* there are *Viola tricolor* subsp. *subalpina* var. *raiblensis* (see above), *Viola dubyana* BURNAT ex GREMLI "spesso in strati ricchi di metalli pesanti" (PIGNATTI 1982), and *Viola lutea* (subsp. *sudetica*) "am Rande einer alten Bergwerkshalde" (MELZER 1979).

Apart from these families, single other taxa are known to be heavy metal resistant (i.e. they are at least able to grow on heavy metal enriched soil in the Eastern Alps). Among them are: *Linum catharticum* (known to occur on metal contaminated soil of Great Britain: ERNST 1968; see also SCHWANITZ & HAHN 1954); *Rumex acetosa* (SCHWANITZ & HAHN 1954); *Thesium* ("can occur on slightly metal enriched serpentines": ERNST 1990); *Anthyllis*, *Lotus* (GAMS 1966). We should not forget plants like *Armeria alpina* which occurs only on a single (but heavily contaminated) site in the Southern Alps (Hochobir) and shows remarkable high protoplasmic zinc tolerance (KÖRBER-ULRICH in PUNZ & KÖRBER-ULRICH 1993; for "classic" German localities see ERNST 1964, RÜTHER 1967).

Ferns frequently grow on ophiolitic substrata (for the Eastern Alps: JUSTIN 1993 and in prep.), but are also well known from mining areas; *Asplenium septentrionale* is supposed to have "local metallophyte status at old lead and copper workings in Northern and central Wales" (PAGE 1988, BAKER & PROCTOR 1990). According to ERNST 1974 ferns presumably have a reduced heavy metal uptake. NISHIZONO & al. 1987 proved cell walls of *Athyrium yokoscense* (including individuals growing on uncontaminated soil) to have very high constitutional ion storage capacity. We can assume that in this case the avoidance-component of resistance plays an important role, but there is a deplorable lack of intensive investigations, especially when it comes to the different stem architecture (archaic stela!) of ferns.

### Concluding Remarks

Thirty years after GAMS, we could hardly find any additional "Erzpflanzen" (in the sense of "eumetallophytes") among Higher Plants in the Eastern Alps (see above). What has changed is our expectation: rather than searching for another Blaue Blume among the absolute metallo-

phytes, we went through the formerly neglected pseudometallophytes. We can prove now that there are large systematic entities with an outstanding capacity to colonize calamine and copper soil, among them genera from *Caryophyllaceae*, *Poaceae*, *Brassicaceae*, *Asteraceae*, *Lamiaceae*, *Scrophulariaceae*, *Rubiaceae* and selected species from other families – a finding that has been already reported by BAKER & PROCTOR 1990 for the British Isles and can be now confirmed for the Eastern Alps. On the other hand, there are also (in the words of KRUCKEBERG & KRUCKEBERG 1990) “entire families (that) appear to avoid metalliferous substrate” or – at least – are poorly represented here, among them large families like the *Rosaceae*, *Ranunculaceae*, *Apiaceae*, *Cyperaceae* (on family largeness in the area see FISCHER 1994, FISCHER & HÖRANDL 1994).

Being aware of the findings of BAKER 1981, 1987 we have to oppose GAMS in restricting metallophytes to accumulating species only (even LARCHER 1994 still uses a biased wording and identifies metallophytes with indicators: “Metallophyten nehmen Schwermetallionen in großer Menge auf und speichern sie in [extremen] Konzentrationen . . .”): to our opinion, plants who are able to exclude heavy metals to a more or less extent belong to the metallophytes, too. Nevertheless we should concede to GAMS 1966 that his “soft” definition of “Erzpflanzen” as “Pflanzen, die besonders regelmäßig bzw. ausschließlich auf Unterlagen wachsen, welche . . . Schwermetallelemente . . . in größeren Mengen enthalten” already provided a very modern conception.

There is hardly any doubt that “resistance has arisen independently in the full spectrum of families; no obvious phylogenetic relationships are apparent” (BAKER 1987). In the context of this statement we would like to point out that the numerous mechanisms and strategies of resistance (compiled in PUNZ & SIEGHARDT 1993 following the arrangement of SCHLEE 1992) are usually neglected. The complex phenomenon of heavy metal resistance is far from being completely understood and cannot be explained exclusively on a cellular, let alone a purely biochemical level (BARCELO & POSCHENRIEDER 1990). Floristic screening together with more morphological, anatomical and ecophysiological work, can help us to avoid a narrow-minded view of the problems of metallophytes.

Let us, at last, cast a glance on phytosociological aspects of metallophytes in the Eastern Alps. The early conception of ERNST 1965, 1974, recently repeated 1990, which coerced all plant communities over heavy metal soils to a single and separate class, the *Violetea calaminariae* can now definitively be dismissed for our region (PUNZ & MUCINA, in prep.; for today’s classification in Germany see POTT 1992; for the Italian part of the Eastern Alps phytosociological studies of heavy metal vegetation is lacking with the exception of the Predil=Raihl area [PIGNATTI, written information]). In contrast, Austrian metallicolous plant associations belong to no

less than five different classes, according to the "Pflanzengesellschaften Österreichs": the Marsupelletum emarginatae (subassociation mielichhoferetosum) to the Montio-Cardaminetea (ZECHMEISTER 1993); the Sileno rupestris – Asplenietum septentrionalis and Notholaeno – Sempervivum hirti to the Asplenietea trichomanis (MUCINA 1993); Thlaspietum cepaeifolii and *Minuartia gerardii* (Thlaspien) – association to Thlaspietea rotundifolii (ENGLISCH & al. Armerio – Potentilletum arenariae to Festuco-Bromeetea (MUCINA & KOLBEK 1993); finally, the Festuco eggleri – Pinetum and Festuco ovinae – Pinetum to Vaccinio-Piceetea (WALLNÖFER 1993). Comparing the data from far more than 100 sites we must conclude: in the Eastern Alps there are no Violetea calaminariae.

### L i t e r a t u r

- AL-HIYALI S. A., MCNEILLY T. & BRADSHAW A. D. 1988. The effects of zinc contamination from electricity pylons. Evolution in a replicated situation. – *New Phytologist* 110: 571–580.
- ALBERT R. 1982. Halophyten. – In: KINZEL H. (Ed.), *Pflanzenökologie und Mineralstoffwechsel*. p. 33–215. – E. Ulmer Verlag Stuttgart.
- ANTONOVICS J., BRADSHAW A. D. & TURNER R. G. 1971. Heavy metal tolerance in plants. – *Adv. ecol. Res.* 7: 1–85.
- BAKER A. J. M. 1981. Accumulators and excluders – strategies in the response of plants to heavy metals. – *J. Plant Nutr.* 3: 643–654.
- 1987. Metal tolerance. – *New Phytologist* 106: 93–111.
- & BROOKS R. R. 1989. Terrestrial higher plants which hyperaccumulate metallic elements – a review of their distribution, ecology and phytochemistry. – *Biorecovery* 1: 81–126.
- & PROCTOR J. 1990. The influence of cadmium, copper, lead and zinc on the distribution and evolution of metallophytes in the British Isles. – *Plant Syst. Evol.* 173: 91–108.
- & REEVES R. D. 1992. The vegetation of ultramafic (serpentine) soils. – *Intercept Andover Hampshire*.
- REEVES R. D. & HAJAR A. S. M. 1994. Heavy metal accumulation and tolerance in British populations of the metallophyte *Thlaspi caerulescens* J. C. PRESL (*Brassicaceae*). – *New Phytologist* 127: 61–68.
- & WALKER P. L. 1990. Ecophysiology of metal uptake by tolerant plants. – In: SHAW J. (Ed.), *Evolutionary aspects of heavy metal tolerance in plants*, p. 156–177. – CRC Press Boca Raton.
- BARCELO J. & POSCHENRIEDER C. 1990. Plant water relations as affected by heavy metal stress: A review. – *J. Plant Nutr.* 13, 1–37.
- BRADSHAW A. D. 1952. Populations of *Agrostis tenuis* resistant to lead and zinc poisoning. – *Nature* 169: 1098.
- & CHADWICK M. J. 1980. *The restoration of land*. – Blackwell Oxford.
- BROOKS R. R. 1987. *Serpentine and its vegetation*. – Croom Helm London Sydney.
- & JOHANNES D. 1993. *Phytoarchaeology*. – Hist. ethno- & econ. Bot. Ser. 3. – Dioscorides Press Portland.

- LEE J., REEVES R. D. & JAFFRE T. 1977. Detection of nickeliferous rocks by analysis of herbarium specimens of indicator plants. – J. Geochem. Explor. 7: 49–57.
- ENGLISCH T., VALACHOVIC M., MUCINA L., GRABHERR G. & ELLMAUER T. 1993. *Thlaspie-tea rotundifolii*. – In: GRABHERR G. & MUCINA L. (Eds.): Die Pflanzengesellschaften Österreichs II, p. 276–342 – G. Fischer Jena.
- ERNST W. 1965. Ökologisch-soziologische Untersuchungen der Schwermetall-Pflanzengesellschaften Mitteleuropas unter Einschluß der Alpen. – Abh. Landesmuseum Naturkde. Münster/Westfalen 27: 1–54.
- 1968. Zur Kenntnis der Soziologie und Ökologie der Schwermetallvegetation Großbritanniens. – Ber. deutsch. bot. Ges. 81: 116–124.
- 1969. Pollenanalytischer Nachweis eines Schwermetallrasens in Wales. – Vegetatio (Tüxen-Festschrift) 18: 393–400.
- 1972. Schwermetallresistenz und Mineralstoffhaushalt. – Forschungsber. Land Nordrhein-Westfalen 2251: 1–38.
- 1974. Schwermetallvegetation der Erde. – G. Fischer Stuttgart.
- 1976. Physiological and biochemical aspects of metal tolerance. – In: MANSFIELD T. A. (Ed.), Effects of air pollutants on plants, p. 115–133. – Cambridge University Press London.
- ERNST W. H. O. [= ERNST W.] 1990. Mine vegetation in Europe. Heavy metal tolerance in plants. – In: SHAW J. (Ed.), Evolutionary aspects of heavy metal tolerance in plants, p. 211–237. – CRC Press Boca Raton.
- SCHAT H. & VERKLEIJ J. A. C. 1990. Evolutionary Biology of metal resistance in *Silene vulgaris*. – Evolutionary Trends Plants 4: 45–51.
- FISCHER M.A. (Ed.) 1994. Exkursionsflora von Österreich. – Ulmer Stuttgart Wien.
- & HÖRANDL E. 1994. Das Forschungsprojekt zur Schaffung einer wissenschaftlichen Flora Österreichs. – Fl.Austr.Novit. 1: 4–33.
- FRIEDRICH H. C. 1961–1979. *Caryophyllaceae*. – In: CONERT H. J. & al. (Eds.), G. HEGI, Ill. Fl. Mitteleuropa, 2<sup>nd</sup> ed., 3 (2): 763–1182. – Parey, Berlin, Hamburg.
- GAMS H. 1975. Vergleichende Betrachtung europäischer Ophiolith-Floren. – Veröff. geobot. Inst. Rübel ETH Zürich 55: 117–140.
- 1972. Zur Pflanzendecke um Klausen. – Der Schlern 46: 395–398.
- 1966. Erzpflanzen der Alpen. – Jb.Ver. Schutze Alpenpfl. -Tiere 31: 65–73.
- GELDMACHER-VON MALLINCKRODT M. 1984. Ökogenetik. – In: MERIAN E. (Ed.), Metalle in der Umwelt, p. 249–252. – Verlag Chemie.
- HAFELLNER J. 1991. Die Flechtenflora eines hochgelegenen Serpentinistockes in den Ostalpen (Österreich, Steiermark). – Mitt. naturwiss. Ver. Steiermark 121: 95–106.
- JUSTIN Ch. 1993. Über bemerkenswerte Vorkommen ausgewählter Pflanzensippen auf Serpentinstandorten Österreichs, Sloweniens sowie der Tschechischen Republik. – Linzer biol. Beitr. 25: 1033–1091.
- KINZEL H. 1982. Die calcicolen und calcifugen, basiphilen und acidophilen Pflanzen. – In: KINZEL H. (Ed.), Pflanzenökologie und Mineralstoffwechsel, p. 216–380. – E. Ulmer Verlag Stuttgart.
- KRUCKEBERG A. R. & KRUCKEBERG A. L. 1990. Endemic metallophytes: their taxonomic, genetic and evolutionary attributes. – In: SHAW J. (Ed.), Evolutionary aspects of heavy metal tolerance in plants, p. 301–312. – CRC Press Boca Raton.

- LAMBINON J. & AUQUIER P. 1964. La végétations des terrains calaminaires de la Wallonie Septentrionale et de la Rhenanie Aixoise. – *Natura mosana* 16: 113–131.
- LARCHER W. 1994. Ökologie der Pflanzen. – Ulmer Stuttgart.
- LAUSI D. & CUSMA VELARI T. 1986. Caryological and morphological investigations on a new zinc violet. – *Studia geobot.* 6: 123–129.
- & — 1992. Cariologia di taxa critici su suoli calaminari (Cave del Predil, Alpi Giulie, Italia). – *Studia geobot.* 12: 153–167.
- LEVITT J. 1972. Responses of plants to environmental stress. – Academic Press New York.
- 1980. Responses of plants to environmental stress. 2nd Edition. – Academic Press New York.
- MARKGRAF F. 1986. *Cruciferae*. – In: CONERT H. J. & al. (Eds.), G. HEGI, Ill. Fl. Mitteleuropa, 3<sup>rd</sup> ed., 4 (2/1): 73–514. – Parey, Berlin, Hamburg.
- Melzer H. 1979. Neues zur Flora von Steiermark XXI. – *Mitt. naturwiss. Ver. Steiermark* 109: 151–161.
- 1988. Neues zur Flora von Steiermark XXX. – *Mitt. naturwiss. Ver. Steiermark* 118: 157–171.
- MUCINA L. 1993. *Asplenietea trichomanis*. – In: GRABHERR G. & MUCINA L. (Eds.), Die Pflanzengesellschaften Österreichs II, p. 241–275. – G. Fischer Jena.
- Kolbek J. 1993. *Festuco-Brometea*. – In: MUCINA L., GRABHERR G. & ELLMAUER T. (Eds.), Die Pflanzengesellschaften Österreichs I, p. 420–492. – G. Fischer Jena.
- MUNTEAN H. 1977. Vegetation und Ökologie steirischer Serpentinstandorte. – Diss. Univ. Graz.
- MUTSCH F. 1981. Schwermetallanalysen an Freilandpflanzen im Hinblick auf die natürliche Spurenelementversorgung und die Schwermetallintoxikation. – Diss. Univ. Wien.
- NISHIZONO H., ICHIKAWA H., SUZUKI S. & ISHII F. 1987. The role of the cell wall in the heavy metal tolerance of *Athyrium yokoscense*. – *Plant Soil* 101: 15–20.
- OBERMAYER W. 1993. Die Flechten der Seetaler Alpen (Steiermark, Österreich). – *Mitt. naturwiss. Ver. Steiermark* 123: 91–166.
- ORASCHE I. 1993. Schwermetallstandorte im Ostalpenraum und ihre Vegetation. – Diplomarbeit Univ. Wien.
- PAGE C.N. 1988. Ferns: their habitats in the British and Irish landscape. – New Naturalist Series. Collins London.
- PIGNATTI S. 1982. Flora d'Italia. – Edagricola Bologna.
- POELT J. 1955. Flechten der Schwarzen Wand in der Großarl. – *Verh. zool.-bot. Ges. Wien* 95: 107–113.
- POPP M. 1982. Genotypic differences in the mineral metabolism of plants adapted to extreme habitats. – *Proc. 1st Int. Symp. on genetic specificity of mineral nutrition of plants (Beograd)*: 159–171.
- POTT R. 1992. Die Pflanzengesellschaften Deutschlands. – Ulmer Stuttgart.
- PROCTOR J. & WOODDELL S. R. J. 1975. The ecology of serpentine soils. – *Adv. ecol. Res.* 9: 255–366.
- PUNZ W. 1988. Standorte von Schwermetallvegetation in Österreich. – *Symp. synanthropic flora and vegetation V (Martin/CSSR)*: 209–219.

- 1989a. Zur Ökologie von Pflanzen auf Hochofenschlackenhalden. – Verh. zool.-bot. Ges. Österreich 126: 139–158.
- 1989b. Zur Vegetation von Hochofenschlackenhalden. – Linzer biol. Beitr. 21: 211–228.
- 1991. Zur Flora und Vegetation über schwermetallhaltigem Substrat im Ostalpenraum – Eine Übersicht. – Verh. zool.-bot. Ges. Österreich 128: 1–18.
- 1992. Schwermetallstandorte im Ostalpenraum und ihre Vegetation. – Ber. naturw.-med. Ver. Innsbruck 79: 67–80.
- & ENGENHART M. 1990. Zur Vegetation auf Blei-Zink-Halden im Raum Niedere Tauern. – Sitzungsber. österr. Akad. Wiss., math.-naturwiss. Kl. Abt. I 198: 1–12.
- , — KOVACS G., PUNZ-GUSCHLBAUER U., THONKE A., WIELÄNDER B. & WIESHOFFER I. 1993. Pflanzen auf Schwermetallhalden im Ostalpenraum – Neue Befunde. – Sitzungsber. österr. Akad. Wiss., mat.-naturwiss. Kl. Abt. I 200: 1–16.
- & KÖRBER-ULRICH S. M. 1993. Resistenzökologische Befunde von Pflanzen an Schwermetallstandorten im Ostalpenraum. – Verh. zool.-bot. Ges. Österreich 130: 201–224.
- KOVACS G., THONKE A., WIELÄNDER B. & WIESHOFFER I. 1994. Schwermetallstandorte im Mittleren Alpenraum – Neue Befunde. – Verh. zool.-bot. Ges. Österreich 131: 1–26.
- KOVACS G., MAUTHNER G., SAPELZA W., ULRICH S. M., WIELÄNDER B. & WIESHOFFER I. 1990[b]. Zur Ökologie und Ökophysiologie der Vegetation im Bereich des Bergbaugebietes St. Martin am Schneeberg im Passeier. – Der Schlern 64: 480–515.
- & MAIER 1995. Vorkommen und Anpassungsstrategien von Schwermetallpflanzen im Raum Kärnten. – Carinthia Sonderh. 53: 112–114.
- & ORASCHE I. C. 1995. Pflanzen auf Schwermetallstandorten im Ostalpenraum und deren Häufigkeitsverteilung. – Verh. zool.-bot. Ges. Österreich 132: 61–80.
- & SCHINNINGER R. 1995. Metallophytes in the South-Eastern Alps. – Acta pharmaceutica 45: 187–180.
- , — & ENGENHART M. 1990[a]. Floristische Bearbeitungen von Schwermetallstandorten in der Steiermark – Eine Übersicht. – Mitt. naturwiss. Ver. Steiermark 120: 291–297.
- & SIEGHARDT H. 1993. The response of roots of herbaceous plant species to heavy metals. – Env. exp. Bot 33: 85–98.
- REEVES R. D. & BROOKS R. R. 1983. European species of *Thlaspi* L. (*Cruciferae*) as indicators of nickel and zinc. – J. Geochem. Explor. 18: 275–283.
- REPP G. 1963. Die Kupferresistenz des Protoplasmas höherer Pflanzen auf Kupfererzböden. – Protoplasma 57: 643–657.
- ROBERTS B. A. & PROCTOR J. 1992. The ecology of areas with serpentinized rocks. A world view. – Kluwer Acad. Publishers Dordrecht.
- RÜTHER F. 1967. Vergleichende physiologische Untersuchungen über die Resistenz von Schwermetallpflanzen. – Protoplasma 64: 400–425.
- SCHAT H., KUIPER E., TEN BOOKUM W. M. & VOOLJS R. 1993. A general model for the genetic control of copper tolerance in *Silene vulgaris*: evidence from crosses between plants from different tolerant populations. – Heredity 70: 142–147.
- SCHLEE D. 1992. Ökologische Biochemie. – Springer Berlin.

- SCHWANTZ F. & HAHN H. 1954. Genetisch-entwicklungsphysiologische Untersuchungen an Galmeipflanzen II. Über Galmeibiotypen bei *Linum catharticum* L., *Campanula rotundifolia* L., *Plantago lanceolata* L. und *Rumex acetosa* L. – Z. Bot. 42: 459–471.
- SHIMWELL D. W. & LAURIE A. E. 1972. Lead and zinc contamination of vegetation in the Southern Pennines. – Environ. Pollut. 3: 291–301.
- SIEGHARDT H. 1985. Zur Frage der Besiedlung schwermetallhaltiger Abraumhalden in Bleiberg/Kärnten I. *Silene vulgaris* ssp. *glareosa*. – Carinthia II. 175(=95): 27–45.
- STEBBINS G. L. 1942. The genetic approach to rare and endemic species. – Madrono 6: 241–272.
- TÜRK R. & POELT J. 1993. Bibliographie der Flechten und flechtenbewohnenden Pilze in Österreich. – Biosystematics and Ecology Series 3 (Austrian Academy of Sciences).
- VERGNANO GAMBI O. & GABBRIELLI R. 1979: Ecophysiological and geochemical aspects of nickel, chromium and cobalt accumulation in the vegetation of some Italian ophiolite outcrops. – Ofioliti 4: 199–208.
- , — 1981. La composizione minerale della vegetazione degli affiorimenti ofiolitici dell'Alta Vale de Ayas. – Rev. Valdotaïne d'Hist. nat. 35: 51–61.
- VERKLEJ J. A. C. & PRAST J. E. 1989. Cadmium tolerance and co-tolerance in *Silene vulgaris* (MOENCH.) GARCKE [= *S. cucubalus* (L.) WILB.]. – New Phytologist 111: 637–645.
- WALLNÖFER S. 1993. Vaccino-Piceetea. – In: MUCINA L., GRABHERR G. & WALLNÖFER S. (Eds.), Die Pflanzengesellschaften Österreichs III, p. 283–337. – G. Fischer Jena.
- WENDELBERGER G. 1974. Die Serpentinpflanzen des Burgenlandes in ihrer pflanzengeographischen Stellung. – Wiss. Arb. Burgenland 53: 5–20.
- ZECHMEISTER H. 1993. Montio-Cardaminetea. – In: GRABHERR G. & MUCINA L. (Eds.), Die Pflanzengesellschaften Österreichs II, p. 213–240. – G. Fischer Jena.
- & PUNZ W. 1990. Zum Vorkommen von Moosen auf schwermetallreichen Substraten, insbesondere Bergwerkshalden, im Ostalpenraum. – Verh. zool.-bot. Ges. Österreich 127: 95–105.

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