The Metallogeny of the Eastern Alps in Context with the Circum-Mediterranean Metallogeny

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Zusammenfassung

Trotz der Erkenntnis einer großen Zahl paläozoischer Erzvorkommen in den Ostalpen ist auf die Anzeichen einer jungen (80—100 my) Metamorphose und Mineralneubildung hinzuweisen. Ein Forschungsprojekt „Erzmobilisierung und alpine Metamorphose" wird bearbeitet. Die Ostalpine Metallogenese wird mit der plattentektonischen Entwicklung des Gebirges in Zusammenhang gebracht und eine Sonderstellung der Ostalpen im alpin-mediterranen Orogen für unwahrscheinlich erklärt. Die Besonderheit der alpinen Metallogenese liegt vielmehr im spezifischen Charakter des tektonischen Baus der Alpen begründet: flache Subduktionen, die nur den obersten Mantel ergriffen haben, und eine ungewöhnliche Aufstapelung von Decken innerhalb der kontinentalen Kruste, durch die das Aufdringen kretazisch-tertiärer Magmen und erzbringender Lösungen erschwert wurde.

In a publication 20 years ago, I subdivided the alpine-Mediterranean Metallogenic Belt into three ore provinces: 1. The East-mediterranean province, comprising the Balkan-Peninsula and Anatolia, 2. the central province, consisting of the Western Carpathians and the Alps, and 3. the West-mediterranean province with the Appenines, the Betic Cordillere and the Atlas Chain. Each of these ore provinces is distinguished by its specific style: the Eastern one by the great number of mineral deposits apparently associated with various magmatic rocks of mesozoic and tertiary age, the central one characterized by an abundance of so-called telethermal deposits with almost no visible magmatic affiliation and the Western one, showing again connection with tertiary magmatites, but also deposits of the platform type. The

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whole Metallogenic Belt was considered to be of predominantly alpidic age (PETRASCHECK, 1964).

Since then new observations have been made, new methods applied, and a new philosophy came in vogue, which particularly has changed our view of the ore genesis in the Alps. However by the new knowledge things became less clear, more contradictions appeared, more open questions arised. In order to articulate the problem, three topics have to be dealt with: the age of the deposits, their origin and their relation to the alpine mediterranean plate tectonics.

The question of the age is the most controversial one. The majority of the deposits is now considered to be palaeozoic. About 80% of the 1500 ore occurences registered in O. M. FRIEDRICH's map (1953) are situated in palaeozoic, respectively metamorphic-palaeozoic rocks; they are classified as volcano-sedimentary, formed in Ordovician till Devonian geosynclinal troughs (cf. SCHULZ, 1974 and later, POHL, 1984 and many others). To this group are attributed the scheelite deposit of Mittersill, the lead-zinc-barite layers in the palaeozoic area near Graz, many sulphide beds in the Grauwackenzone, but also the siderite stock of the Erzberg and the copper ore layers and veins of Mühlbach-Mitterberg in Salzburg. Wherever younger epigenetic features are observable or the mineralization is overlapping into post-palaeozoic strata, the phenomena are explained by mobilization. This delicate problem was discussed for different districts and by different authors in 1981 in Leoben (Ore Mobilization in the Alps and in SE-Europe, Schriftenreihe Erdwiss. Komm. Österr. Ak. Wiss., Vol. 6, Vienna 1983). The results of the discussion were ambiguous.

The "Mobilized" ores are always showing a somewhat different chemical composition than the primary ones—which seems quite natural. But the chemistry of the procedure of dissolution and redeposition of many ore minerals is not understood. Tetrahedrite f. g., occuring in Devonian dolomites in Schwaz, as well as in the adjacent Triassic Muschelkalk, is, according to hydrometallurgical experience, practically insoluble in a reducing environment; a dissolution and decomposition of tetrahedrite to its individual metallic components can only be achieved under high oxygen pressure (WÖBKING, 1983, loc. cit.). Recently in a druse of siderite from the Erzberg, supposed to be a remobilisate from sedimentary siderite, crystals of Xenotym and Circon were found (WALTER and POSTLER, 1984). Ankerite crystals rich in iron were formed at a temperature of almost 400° C (BERAN). Thus the remobilizing fluids were not always harmless chlorine formation waters. Particularly the giant stock of iron carbonate in the palaeozoic limestones of the Erzberg with its famous, large scale replacement structures, locally even ingressing into the overlaying Permo-Triassic sandstones, gives the impression of a throughout penetration by iron bearing solutions. Why, in the case of such an almost complete "remobilizing" environment, local thin layers of iron carbonate should have preserved their structure and even their chemical differentiation from grain to grain (BERAN, 1983)? Would it not be possible that these rare sedimentary occurences are belonging to an entirely different ore forming period—may be an older one, and that the bulk of the ore is the product of a later hydrothermal mineralization? Or in contrary, that the sedimentary ores are younger fillings of palaeo-karstic caves within the siderite stock, like recently assumed by MOSTLER (1984)?

In spite of these sceptical objections many convincing examples of ore remobilization in alpine deposits are described in the proceedings of the above mentioned Symposium.

An interesting research project was started a few years ago by H. WENINGER, 1980, but interrupted by his tragic death: it was the investigation of fluid inclusions in minerals of alpine ore veins. It would be worth studying the chemical composition and the homogenization temperatures of the primary and of the remobilized minerals.

The age of the mobilization is already known in a few cases. The important copper ore vein of Mühlbach-Mitterberg, situated in Silurian schists and crosscutting their stratification and also their transversal schistosity, passes over into the overlaying Permian sandstones with reduced thickness and impoverished mineral content; the higher section of the vein could indeed be a remobilized prolongation. These Permian sandstones contain a few small layers of sedimentary uranium ore, but along the salbands of the mobilized ore vein nodules of uraninite, up to one centimeter in diameter, sometimes with native gold in their cracks, were found (SIEGL, 1972); in the deeper levels of the main vein no trace of uranium at all could be detected. Thus, the uraninite nodules were formed by dissolution and redeposition of the sedimentary ore, when the remobilizing metalliferous solutions pervaded the Permian. An absolute age determination of the uraninite nodules, carried out by Prof. KÖPPEL, pointed to 90 ma, thus indicating the age of the remobilization.

The austroalpine Grobgneis of the Eastern Central Alps is in several places traversed by mylonitic zones containing the so called Weisschiefer, a mixture of chlorite, serizite and quartz; compared with the rather homogenous Grobgneis, the Weisschiefer is showing a certain addition of magnesium. The age of the mylonitization and of the Weisschiefer is alpidic. The supply of magnesium reminds of the underlying Penninic ophiolites, from which magnesium could have been set free by serpentinization (MODSTAHEDI and WIESENEDER, 1974). Anyhow, it must be admitted that typical indicator elements for this provenience, like Co and Nö, are missing (PROCHASKA, 1984).

The siderite deposit of Knappenberg-Hüttenberg (Carinthia), by strong geological arguments declared as epigenetic and alpidic (CLAR, 1981), was also recently considered as synsedimentary-palaeozoic. This deposit contains rare accessory uranium ore, which shows an U/Pb-ratio, possibly pointing to about 70 ma. (Determination by Prof. KÖPPEL according to communication by Prof. PAAR.)

A red haematitic pigment, generated by metamorphism of the palaeozoic magnesites of Entachen (Salzburg), has been proved to be Cretaceous by palaeomagnetic measurements (MAURITSCH, 1980).

These few examples are demonstrating various chemical and thermal reactions in ore deposits of the Eastern Alps during a time span between 70 and 120 ma, that is between Upper Cretaceous and Palaeocene. The same period was attributed to a wide spread metamorphism in the Eastern Central Alps recognized by FRANK and collaborators (1983) on the basis of the K/Ar and Rb/Sr-method. Several regions, g. i. on both sides of the Lavanttal in Carinthia and in SW-Tyrol are showing the amphibolite facies, which means a temperature of about 500° C, whereas the greater parts of the Central Alps, including the southernmost marginal parts of the Kalkalpen, have been affected by the greenschist-facies (around 350° C).

From all these findings we may conclude that a regional thermal and in some way also metallogenic event has occured during this epoch and that the "outdated" idea of an Upper Cretaceous-Tertiary metallogeny in the Alps was not so misleading. This event probably depends on the amount of fluids which have been set free by the metamorphism (FRANK).

A recent research project with the scope of correlating the alpidic metamorphism and the ore mobilization can perhaps reconsile the theories of the paleozoic and of the alpidic ore formation.

The origin of the ore metals should be discussed in context with the mediterranean plate-tectonic evolution. In a recent publication POHL (1984) gave a synopsis of the paleozoic ore deposits in the Eastern Alps; he attributed them to different magmatic phases of diabases and keratophyres. Although in POHL's view, periods of crustal extension and compression were alternating, no convincing evidence for a real large palaeozoic ocean floor in the main territory of the Alps was demonstrated. I myself am of the opinion—different from STUMPFL and EL AGEED (1981)—that the ultramafites of Kraubath and Hochgrössen, containing insignificant occurrences of chromite and asbestos, are not remnants of an ocean floor, but local intrusives from the upper mantle into the continental crust—analogous to the palaeozoic serpentinites in the Eastern Rhodopi Mts. in Bulgaria—because they are not associated with the typical ophiolitic "Steinmann Trinity" of gabbros, diabases and particularly cherts. A real oceanic realm between the alpine area and Africa from Upper Ordovician till Lower Carboniferous may have existed only before the fusion to Pangaea (FRISCH et al., 1984). The area of the Alps, from the Cambrium till Permian consisted of a mobile continental crust subdivided by intracontinental troughs ("aulacogens"), similar to the area of Central Europe. The crust was comparatively thin, particularly during the geosynclinal phases. Therefore we have the typical bimodal magmatism and the polymetallic ore association of an intracontinental metallognesis (SAWKINS, 1982). W and Be-bearing minerals are indicators of a continental provenience.

A striking phenomenon is the scarcity of ore deposits around the Hercynian granites in the Alps—quite different from the granitic massifs in Central and Western Europe. The same phenomenon applies to the granites in the Slovakian Carpathians and the South Bulgarian granites in the Rhodopi Mts. OULIANOFF (1943) once has tried to explain this by a kind of destillation process during the alpidic metamorphism. I am not inclined to accept this hypothesis, because the synsedimentary deposits of palaeozoic age have safely survived the alpidic metamorphism. I would prefer the explanation by ILAVSKY (1977), given for the Carpathians, namely that the frequency of the deposits decreases with the thickening of the continental crust which has reached a maximum after the carboniferous compression phase. The only minable fruit of the hercanian orogenesis is an important group of spodumen-pegmatite veins within the crystalline schists of the Koralpe in the Eastern Central Alps.

The ore deposits of the Permian, according to HADITSCH and MOSTLER (1974) and DROVENIK et al. (1980) are partly related to the subsequent extrusive magmatism (Cu, U), partly to exogenic enrichment by erosion and sedimentation in post-orogenic basins (U and evaporites) (ERKAN, 1977).

The break up of the Euro-African land mass began in Triassic time with the formation of tension fractures for which the name rifts—as sometimes used—seems not quite adequate. These zones are characterized by porphyritic, partly also diabasic volcanism, by an inquiescent and shallow seawater sedimentation and by Fe-Mn-Pb-Zn-Hg deposits of syngenetic, as well as of epigenetic nature. To these zones belong the deposits of the Northern Dobrogea, of the Peleponnes, of Montenegro (Brskovo), Bosnia (Vareš, Suplija Stjena) and Slovenja (Idrija). The original tectonic features of these "rifts" were completely disturbed by the later compression phases.

Into this group the numerous lead-zinc deposits on both sides of the Alpine-Dinaric cicatrice can be encompassed (Bleiberg, Raibl, Mežica, Salafossa etc.). They are products of a mineralization along an incipient rift which much later was revitalized and transformed into the Periadriatic Lineament. The Triassic age of the ores is now without any doubt; syndiagenetic and epigenetic features are occuring together (SCHULZ, 1983). The Pb-isotopes point to a provenience from the Palaeozoic basement, from which the metals probably were leached by saline brines (KÖPPEL). A direct connection with the Triassic diabases can be excluded, but a magmatic heat source is likely. A clear distinction between ore veins, formed per ascensum and veins formed by remobilization (if ever there existed such ones) is not yet possible. The similar deposits in the Northern Kalkalpen in Tyrol and Bavaria can be best explained by later nappe movements from the South.

The opening of the Tethyan ocean started in Upper Jurassic time and continued until the Lower Cretaceous with the formation of the South- and North Penninic troughs. How large these troughs have been, is under dispute; to my opinion they were "microoceans", similar to those in Greece. But there is a remarkable difference regarding the metallogeny: whereas the ophiolitic assembledge in Greece, Albania, Yougoslavia and Turkey is extremely rich in chromium-, copper- and nickel ores, the alpine ophiolites are poorly mineralized. Only small copper-pyrite occurences are existing in the Tauern Window.

The reason for this may be found in the fact that the alpine underthrusting planes were shallow, flat, intracrustal (TRÜMPY). They did not plough deeply into the upper mantle; there were no real subduction zones operating as metallotects, as EVANS stated already in 1975.

The Upper Cretaceous compression periods which lasted until Mid Tertiary were presumably connected with remelting of the deeper parts of the continental crust and with simultaneous metamorphism. Upper Cretaceous granites, so frequent in the SE-Carpathians and Balkan mountain chains, are missing in the Alps. A remarkable link however between the non-magmatic Cretaceous metamorphism and ore mobilization in the Alps and the magmatogenic ore formation in SE-Europe are the small massifs of granite, 110 ma old, in the Gemerske Rudno Horjie of the Slovakian Carpathians. In this district the assembledge of ores—siderite, chalcopyrite, tetrahedrite, magnesite, accessory cinnabar—is almost identical with that of the Grauwackenzone. A siderite vein was even found within one of these Cretaceous granites (oral communication by Mr. BERNARD). Anyhow, the majority of these deposits is now considered to be Palaeozoic. But until now none of the adherents of a Palaeozoic ore formation in the Slovakian Carpathians has discussed the fact in the nearby situated siderite deposit of Rudabanya in Northern Hungary only Triassic Muschelkalk has been mineralized by the same ore association as as known from the Palaeozoic deposits in the Gemerides.

The idea of a combined magmatogenic-metamorphogenic ore formation in the Alps, a long time ago expressed by CLAR, FRIEDRICH and others, was later abandoned when migrating fronts became out of vogue and metamorphism was regarded as isochemical. I would however like to draw the attention to the occasional occurence of fuchsite in white Triassic quarzites and marbles of the Lower Austroalpine sequence, lying above the Penninic ophiolites. This evidence of a migration of chromium may indicate the possibility of other migrating elements (Mg, Fe, Au, Cu?). A study of the regional distribution of these secondary fuchsite occurences with regard to the position of the ophiolites would be of interest. KARAMATA (1983) has shown that Cu, Co and Cr have been incorporated into Tertiary magmas and their associated ores, when having passed through the ophiolites of the Vardar Zone. In the Slovakian Carpathians fuchsithe represents the earliest stage of the mineralization; its chromium is derived from neighbouring Mocks (P. IVAN 1982). So the problem of metamorphism and ore remobilization arises again.

A Tertiary metallogenetic epoch in the Alps is more clearly established than the Cretaceous one. The most manifest examples are the gold veins in the Hohen Tauern, which intersect all the alpidic nappe structures. Probably of Eocene age are the siderite deposits in the Central Alps of Styria and Carynthia, as they are showing a post-tectonic fabric and are locally penetrating into Triassic limestones. Porphyritic dykes have been brought into genetic association with this mineralization (FRIEDRICH). The Tertiary Periadriatic massifs are remarkably sterile, perhaps because they are the products of continental-crustal collision. The long stibnite veins of Schlaining on the most Eastern end of the Central Alps might be related to an ill defined andesite in the neighbourhood. Their hostrocks are cretaceous anyway.

Conclusions

This article certainly gives the impression of the rather personal authors attempt of maintaining his concept about the alpine metallogeny, expressed 10 and 20 years ago, of repeating his arguments and of adapting his theory to the new findings and ideas. This indeed is the case, because the proponents of the unitaristic Palaeozoic and sedimentary metallogeny, inspite of their new and irrefutable observations, almost never have tried to disprove and to explain the opposite arguments. Therefore in this article a few suggestions for research projects have been made with the aim of finding elements to bridge over the two concepts.

My main reason for an alpidic metallogeny in the Eastern Alps is the fact that this mountain chain is a limb of the giant Mediterranean-Himalayan orogenic belt, which has been composed and formed in Mesozoic-Tertiary time with all the phenomena of magmatism usually related to plate tectonic events. Everywhere else this magmatism is associated with metallogenic phases. Promising steps have been made to explain the character of the alpine-mediterranean metallogeny in the frame of the concept of plate tectonics (PETRASCHECK, 1974, EVANS, 1975, JANKOVIĆ, 1977). These publications were generously ignored by FINLOW-BATES and TISCHLER (1981) in their complex synthesis of the alpidic mineralization.

The metallogenic zoning in the whole belt from Gibraltar till Western Asia, the Alps included, is generally the same: predominance of copper in the Northern branch in connection with subduction zones and ophiolites, predominance of lead-zinc in the Southern branch, inherited from the northern margin of the African Plate. Why should the genesis of the ores in the Eastern Alps be a unique and specific Austrian exception?

The pecularity of the alpine metallogeny is conditioned by the specific character of the tectonic structure of the Alps: flat subductions which have affected only the uppermost parts of the mantle and an unusual accumulation of nappes within the continental crust which has prevented the rising of cretaceous-tertiary magmas.

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