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SULFIDE MINERALIZATION IN THE RANSKO GABBRO – PERIDOTITE MASSIF, CZECHOSLOVAKIA

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Abstract

The Ransko gabbro–peridotite massif can be correlated to some extent with concentrically zoned mafic bodies, *i.e.*, the Alaska–Ural type of intrusion, or with the polygenic type of Thayer (1971). Its tectonic position is strongly controlled by the crossing of two deep fault systems. This cylindrical massif intruded into crystalline schists at the Proterozoic–Paleozoic boundary, and it may have some genetic relationship with the roots of Proterozoic volcanic complexes. The rocks of the massif are the products of crystallization and differentiation of Al-rich tholeiitic magma. The older olivine-rich rocks (dunite, peridotite, troctolite) differ geologically and geochemically from the pyroxene-rich series in which pyroxene gabbro and pyroxene-hornblende gabbro are the most representative. The ore deposits of the Ransko massif include Ni–Cu and Cu–Zn sulfide mineralization. The Ni–Cu mineralization is apparently restricted to a NE striking zone. The Zn–Cu sulfide ore deposits may represent a special type of complex mineralization in the Ransko pipe-like feeder.

Sommaire

Le massif gabbroïque et péridotitique de Ransko peut, jusqu'à un certain point, se comparer aux intrusions à zones concentriques de l'Alaska et de l'Oural, ou au type polygénique de Thayer (1971). L'intersection de deux systèmes de failles profondes en gouverne la position tectonique. C'est un massif cylindrique, intrusif dans les schistes cristallins au contact entre le Proterozoïque et le Paléozoïque, probablement relié aux racines de complexes volcaniques protérozoïques. Les roches qui le composent résultent de la différenciation d'un magma tholéitique alumineux. Au double point de vue géologique et géochimique, les roches plus anciennes, riches en olivine (dunite, péridotite, troctolite) diffèrent des séries de roches à pyroxènes, consistant surtout en gabbros avec ou sans hornblende. Les gisements métalliques du massif comprennent deux types de minéralisation en sulfures: Ni–Cu et Cu–Zn. La minéralisation Ni–Cu se limite à une zone NE–SO; les gisements de sulfures Zn–Cu représenteraient un genre inusité de minéralisation complexe dans une cheminée d'alimentation du massif.

(Traduit par la Rédaction)

Introduction

The Ransko gabbro–peridotite massif has been a subject of interest because of its economic sulfide mineralization and its complex structure and geochemical history. It covers an area of about 10 km^2 at the northeastern margin of the Moldanubian core of the Bohemian massif. The primary contacts and numerous xenoliths demonstrate the massif's magmatic and intrusive origin. The geology of the massif has been described by Mísař (1960), Weiss (1962) and recently in a compendium edited by Mísař (1974b). The sulfide mineralization was studied in detail by Pokorný (1969), Holub & Pokorný (1970), and in summary in Mísař (1974b). The geochemical data of Bouška *et al.* (1977) strongly support existing concepts on differentiation trends in the massif. Recent investigations on pyroxene, spinels and olivine, as well as the interpretation of the geotectonic significance of the basic and ultrabasic rocks in feeder channels in the Bohemian massif (Mísař 1974a), may help to decipher the complex geological history of the Ransko massif and its environment. Quite recently a stimulating paper on reinterpretation of the Obrázek Zn–Cu ore deposit has been published by Watkinson *et al.* (1978).

General Characteristics of the Ransko Massif

The tectonic position of the Ransko massif is controlled by the crossing of two major deep fault systems (Fig. 1). The first one, trending NW–SE, corresponds to the southern margin of the Elbe tectonic zone, whereas the second one, striking NE–SW or NNE–SSW, follows a steep gravity gradient between the Bohemian and Moravian segments of the Moldanubicum. The Proterozoic volcanic centres are thought to be connected with the latter tectonic zone (Vachtl 1972).

In shape, tectonic position and rock association, the Ransko massif resembles the Alaska–Uralian type in the sense of Taylor & Noble

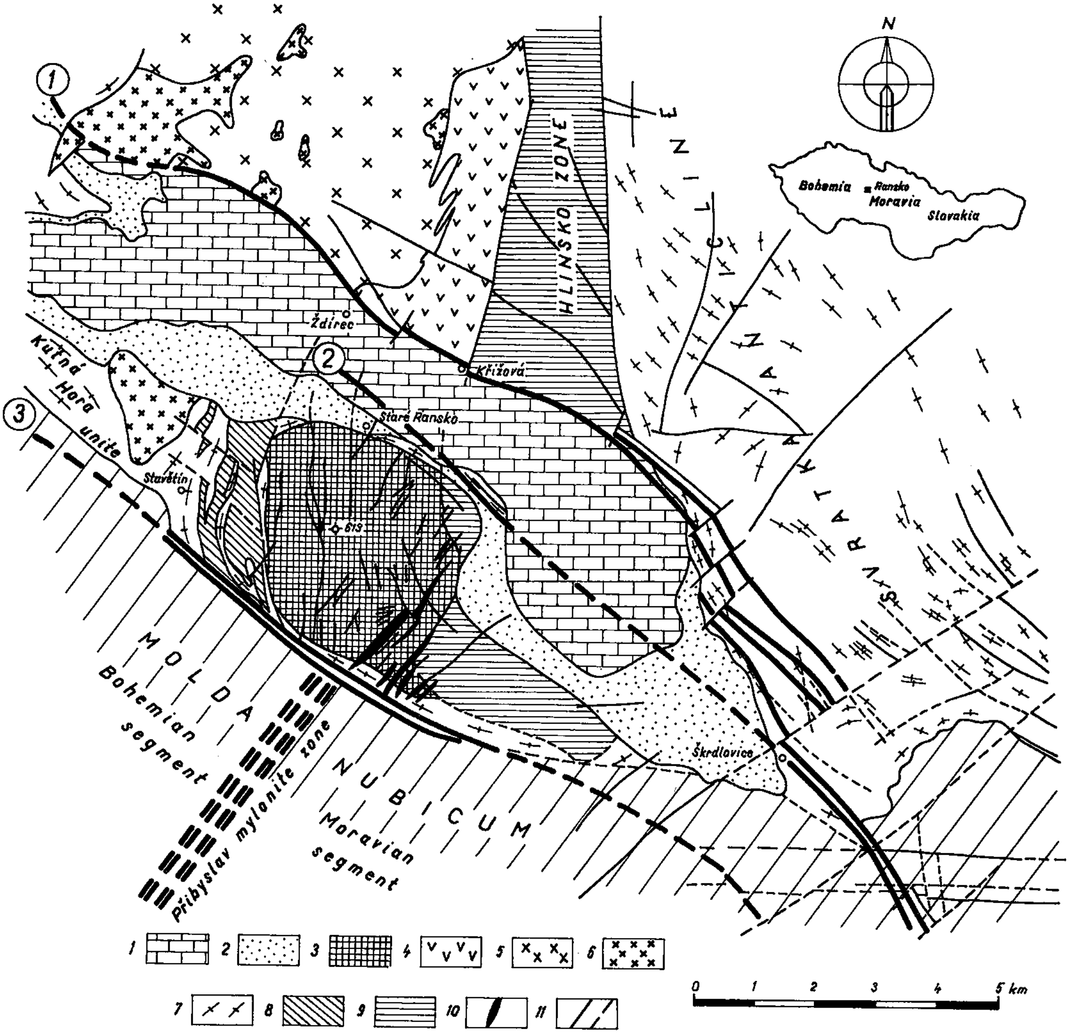

FIG. 1. Structural map of the Ransko area. 1. Turonian sediments. 2. Cenomanian sediments. 3. Ransko gabbro–peridotite massif. 4. Albite quartz porphyry. 5. Albite granite. 6. Hornblende diorite. 7. Mica schists and migmatites of the Kutná Hora unit. 8. Amphibolites and gabbro–amphibolites. 9. Upper Proterozoic metamorphic rocks. 10. Hercynian granite porphyry. 11. Biotite–sillimanite gneisses and migmatites of the Moldanubicum. Encircled numbers: main faults.

(1960), Taylor (1967), Jackson & Thayer (1972) and Moores (1973). According to Thayer's classification (1971), the ultramafic and gabbroic rocks of the Ransko massif, as the host rocks of the Ni–Cu sulfide mineralization, may be classified as polygenic. However, they still display some specific features of the parent magma, falling between the two end-members in the classification of Naldrett & Cabri (1976). Also, the zonal structure of the Ransko massif is not strictly regular and concentric. The ultramafic rock series (dunite–peridotite–troctolite) forms huge blocks in a younger gabbroic mass (Fig. 2). This is contrary to the usual relationship seen in ultrabasic and gabbroic rocks, *e.g.*, in the Duke Island massif of Irvine (1967a).

The Ransko gabbro–peridotite massif is an example of a strongly differentiated intrusion. The tholeiitic magma, relatively rich in alumina, probably differentiated in two stages at different depths. Primary magma from a depth of about 35–45 km, near the Moho discontinuity, was trapped in the lower crust in a transitory chamber

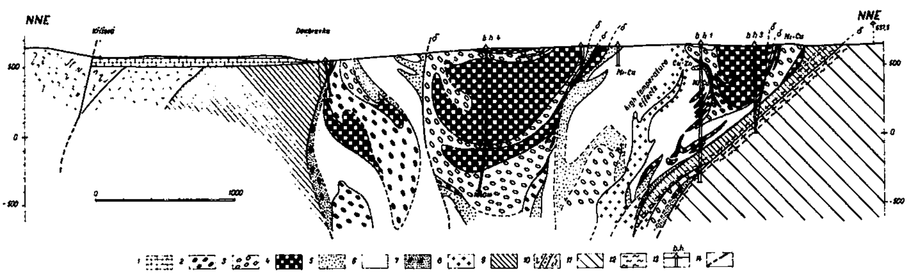

FIG. 2. Geological section through the Ransko massif. 1. Cretaceous sediments. 2. Troctolite. 3. Plagioclase-rich peridotite. 4. Peridotite. 5. Olivine gabbro. 6. Gabbro. 7. Gabbro contaminated with xenoliths. 8. Quartz diorite. 9. Mica schists and gneisses. 10. Phyllites with quartz albite porphyry. 11. Moldanubian gneisses and migmatites. 12. Younger mylonites and blastomylonites. 13. Bore hole. 14. Fault.

(Mísař 1971). There, the process of magmatic differentiation continued along with contamination by country rocks and the crystallization of ultramafic rock members until enveloped by gabbroic intrusions related to a slightly later geotectonic event. At this time, single blocks of the semi-solidified dunite–peridotite–troctolite series were carried by the gabbroic magma closer to the surface, to a depth of about 15 km. Pyroxene gabbro apophyses in ultrabasic rocks, xenoliths of metamorphic rocks in gabbros, contact phenomena in the country rocks of the massif, and mixed olivine–pyroxene gabbros strongly support this idea (Fig. 3). The emplacement of the Ni–Cu sulfide deposits coincides very probably with the end of this period.

The rocks of the Ransko massif can be divided into five principal lithological groups as follows: I. The dunite–peridotite–troctolite rock group in which olivine (Fo$_{79-85}$), calcic plagioclase (An$_{86-88}$) and spinels (Fig. 4) are present as major constituents; relatively rare are orthopyroxene (En$_{80-82}$) and clinopyroxene (salite–endiopside). The spinels in the peridotite–troctolite rocks belong mainly to the chromite–hercynite spinel group and at least four generations of

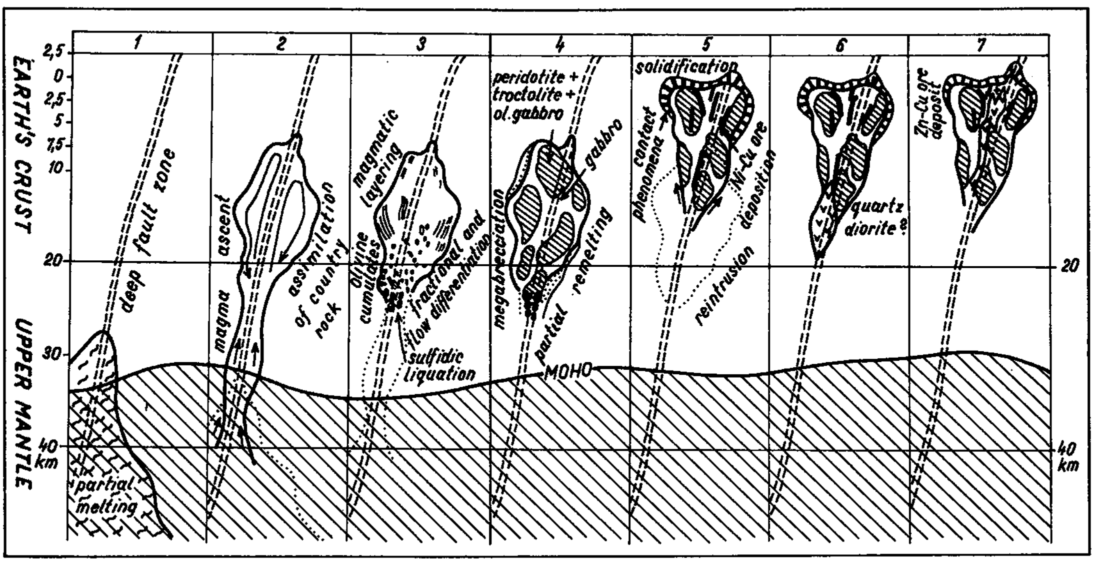

FIG. 3. Hypothetical model of the generation, differentiation and emplacement of the Ransko gabbro–peridotite massif (Mísař 1971). 1. Generation of the parent magma by partial melting. 2 – 4. Stages of the transitory magma chamber. 5. Final emplacement stage with complete solidification and Ni–Cu mineralization. 6 – 7. Postsolidification stages and geological position of quartz diorite and Zn–Cu ore deposit.

these spinels can be defined. Some of these spinels have a spectacular "emental cheese" structure. A second type of spinel is ceylonite. Zn–spinels are common in the Zn–Cu ore deposit (Watkinson *et al.* 1978). Generally, the spinels in the peridotite and troctolite are good indicators of mineralized gabbro–peridotite massifs (Johan 1976) and valuable petrogenetic indicators as well (Irvine 1965, 1967b).

The peridotite and troctolite of the Ransko massif locally display well-developed cumulate texture and magmatic layering. Olivine primocrysts are mostly surrounded by intercumulus plagioclase or enclosed in larger poikilitic plagioclase crystals. The relationship of clinopyroxene with early primocrysts of olivine is identical that of plagioclase with olivine. Conspicuous pyroxene–hornblende coronas on olivine in contact with plagioclase are commonly developed. Plagioclase in ultramafic rocks is usually pseudomorphed by thompsonite, calcite, clay minerals and amphiboles.

II. The mixed olivine-pyroxene gabbro is highly variable petrographically and chemically. The gabbro contains "corroded" primocrysts of olivine as ghost relics in a mass of plagioclase (An_{86}) and clinopyroxene (endiopside). The ratio of olivine relics to the plagioclase + clinopyroxene mass is variable.

III. Pyroxene and hornblende–pyroxene gabbros occur widely in the Ransko massif. Plagioclase and clinopyroxene are the main rock-forming minerals; spinel is ubiquitous, and very commonly hornblende and occasionally quartz and biotite can be found. The texture of the rock is gabbroic to ophitic.

IV. Hornblende gabbro and gabbroic diorite constitute small isolated lenses or dyke-like bodies in the massif. The rock contains plagioclase and hornblende as the main constituents. Biotite, quartz and in cases clinopyroxene occur as accessory minerals.

V. Gabbro pegmatite forms small dykes in troctolite and peridotite. Medium- to coarse-grained types with large hornblende crystals are usually strongly altered.

The other rocks of the Ransko massif, including the "metasomatic" quartzite and quartz diorite, do not belong to the primary differentiates of the massif. The quartz diorite (VI) and "metasomatic" quartzite may represent highly metamorphosed gabbro and peridotite in the neighborhood of the Zn–Cu ore deposits (Pokorný 1969, Holub & Pokorný 1970) or metamorphosed members of volcanogenic ore deposits (Watkinson *et al.* 1978). According to the reinterpretation of Watkinson *et al.* (1978), the quartz diorite is 330 m.y. (G. Bernard, (cordierite-bearing rocks) are metamorphic rocks older than the intrusive rocks of the Ransko massif. However, the age of the gabbroic rocks is Upper Proterozoic–Lower Paleozoic (Marek 1970) and the K–Ar age of the quartz diorite is 330 m.y. (G. Bernard, pers. comm.).

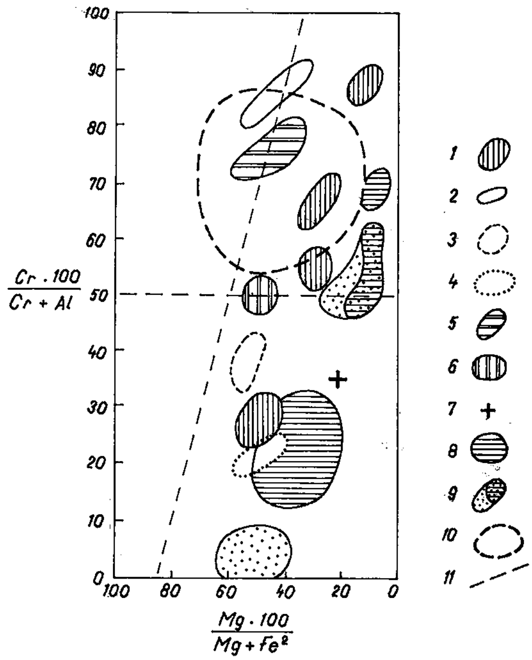

FIG. 4. Spinels of the Ransko gabbro–peridotite massif as compared with those of other basic and ultrabasic rocks. Diagram after Irvine & Findlay (1972) and Coleman (1977). 1. Spinels of the peridotite in the inclusion in leptinitic rocks of the Moldanubicum – Horní Bory. 2. Spinels of lherzolites of the Gander River complex (Malpas & Strong 1975). 3. Spinels of lherzolites of the Lanzo massif (Boudier 1972). 4. Spinels of lherzolites of the Bay of Islands ophiolite (Malpas & Strong 1975). 5. Spinels of harzburgites of the Bay of Islands ophiolite (Malpas & Strong 1975). 6. Spinels of dunites of the Bay of Islands ophiolite (Malpas & Strong 1975). 7. Spinels of lamellar clinopyroxene of the Higashi-Akaishi massif (Yokoyama 1975). 8. Different spinels of troctolite (with sulfides) of the Ransko gabbro–peridotite massif. 9. The main spinels (chromite–hercynite and ceylonite) from peridotites of the Ransko massif. 10. The field of chromite spinels of stratiform intrusions (Coleman 1977). 11. The variation trend of spinels in metamorphic peridotites (Coleman 1977).

Nickel-Copper Mineralization

Shortly after prospecting began in 1957–1960, a mineralized zone with nickel–copper sulfides was discovered. The zone contains several ore deposits and crosses the massif in a NE–SW direction. It is 3 km long and about 1 km wide (Fig. 5). The structural position of the deposits is controlled by the dominant strike of the zone, by the internal structure of the massif and by the rock boundaries.

The richest Ni–Cu mineralization was found at localities with alternating troctolite - olivine gabbro and pyroxene gabbro. The most representative deposits are the Jezírka and near-contact types (Fig. 6). At the Jezírka ore deposit the mineralization follows NE–SW striking zones in troctolite and olivine gabbro alternating with many apophyses of pyroxene gabbro. The Ni–Cu sulfides are not confined to a particular rock type but cross the rock boundaries. In the near-contact type deposit, which is related to the Jezírka type, the sulfide mineralization follows approximately the contact between the peridotite and the plagioclase peridotite with the troctolite.

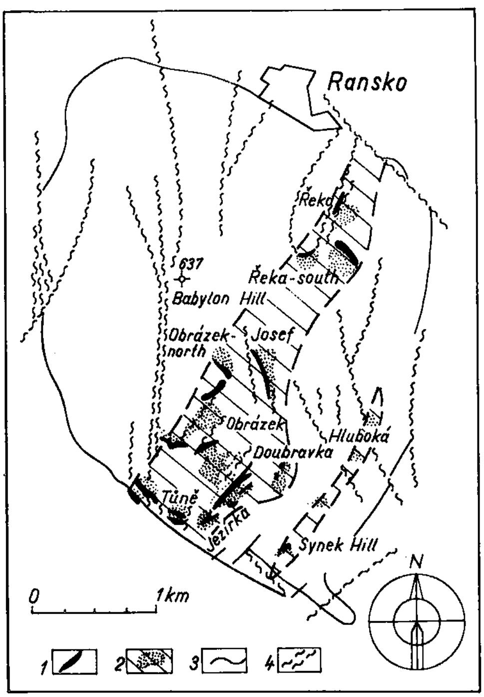

Fig. 5. Map of the sulfide ore deposits in the Ransko gabbro–peridotite massif with local ore deposit names. 1. Outcropping disseminated Ni–Cu ores. 2. Subsurface parts of the ore bodies. 3. Boundary of the massif. 4. Tectonic lines.

The other type of Ni–Cu sulfide deposits in the Ransko gabbro–peridotite massif consist of importance. The Reka mineralization is characterized by several thin ore zones dipping to the SE. The host rocks are pyroxene and olivine-poor gabbro (Fig. 7).

The sulfides in the nickel–copper deposits in the Ransko gabbro–peridotite massif consist of pyrrhotite, chalcopyrite and pentlandite, with lesser amounts of cubanite, pyrite, and magnetite. Both mackinawite and valleriite are also reported in trace amounts (Pokorný 1969). The sulfide concentration depends on the character and structure of the host rocks. Pentlandite + chalcopyrite + pyrrhotite in the troctolite, olivine gabbro and plagioclase peridotite are distributed and concentrated rather irregularly. In the troctolite, sulfide minerals that replace plagioclase completely surround altered olivine crystals in a typical sideronitic structure. In peridotite and unaltered troctolite the sulfide minerals are interstitial. In uralitic gabbro, veinlets of pyrrhotite and pentlandite passing into fine sulfide impregnations are common. In portions of the deposits that did not undergo metamorphism, the sulfides either surround grains of pyroxene, plagioclase or olivine or penetrate into them along fine fissures and cracks.

The composition of the sulfides is controlled by the petrochemical character of the host rocks (Pokorný 1969). The absolute nickel and copper contents are variable. Generally, they are low, rarely exceeding 0.5%. The richest ore deposit contains up to 2% Ni+Cu. The average Ni/Cu ratio is 0.97 in the troctolite, 0.87 in the olivine gabbro, and 0.77 in the pyroxene gabbro. A decreasing Ni/Cu ratio with depth at the Jezírka deposit (Pokorný 1969) is a function of rock type. At the surface, the ratio in troctolite is 1.6, at a depth of 150–200 m in olivine gabbro it is 1.1, and at a depth of 250 m in pyroxene gabbro the ratio drops to 0.4.

The concentration of the Ni–Cu sulfide mineralization in a distinct zone, the transgressive character of some lode horizons, and the textural and structural features of the ore deposits all suggest an epigenetic origin for the Ransko Ni–Cu sulfide deposits. The mineral assemblage of the deposits is typical for Ni–Cu mineralization and shows a clear affinity to the basic intrusion. The parent sulfide melt was probably fractionally separated in the early

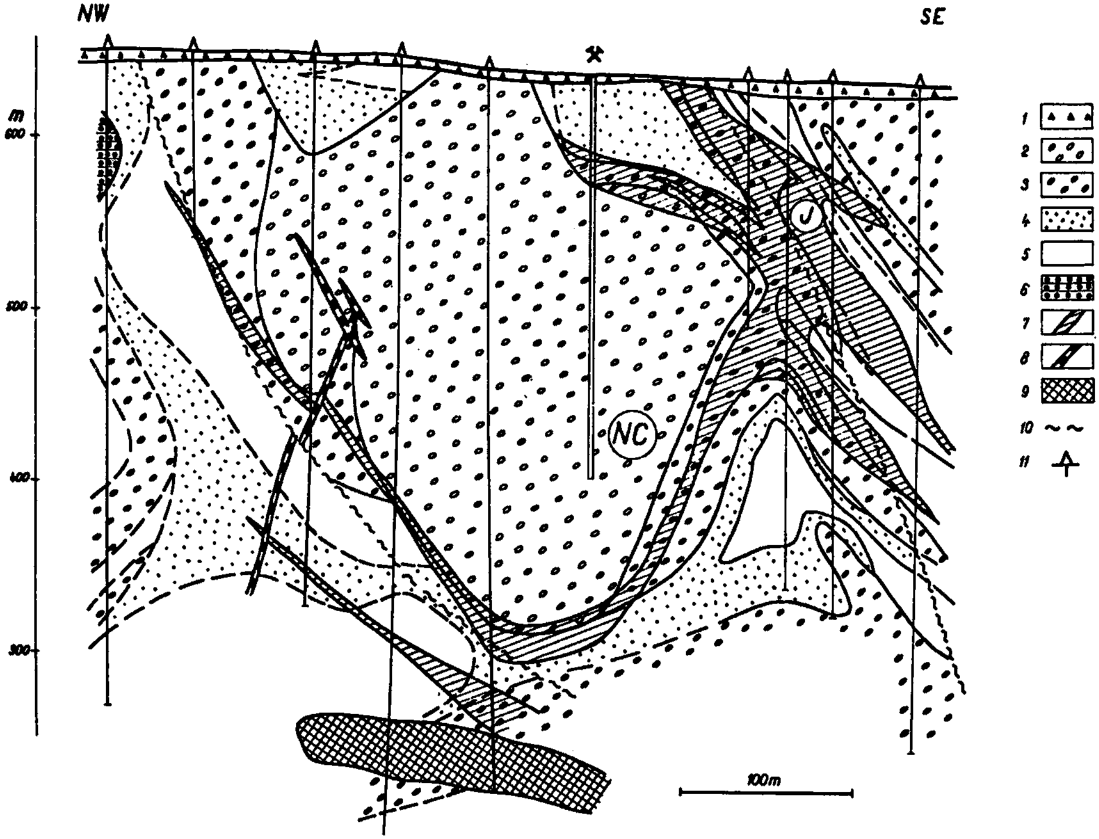

FIG. 6. Cross sections of the Jezírka (J) and near-contact type (NC) ore deposits. 1. Rock debris. 2. Plagioclase-rich peridotite. 3. Troctolite. 4. Olivine gabbro. 5. Gabbro. 6. "Metasomatic" quartzite. 7. Disseminated Ni–Cu ores. 8. Porphyry. 9. Xenoliths of amphibole hornfels. 10. Fault and mylonite zone. 11. Bore hole.

stage of the magmatic history in a transitory magma chamber and left behind after the gabbro intrusion (Fig. 3). After the final emplacement of the massif the dense liquid sulfides were squeezed upward and emplaced in suitable structures and host rocks. However, some nickel–copper sulfide droplets in dunite and peridotite may represent an immiscible material trapped *in situ*.

Zinc–Copper Mineralization

The zinc-copper mineralization is economically the most important mined in the Ransko massif. The first occurrence was discovered by chance during the exploration work on the Ni–Cu mineralization. The Zn–Cu ore deposit called Obrázek lies at a depth of 85–200 m under the surface near a N–S fault zone. The deposit is up to 200 x 300 m in horizontal section with a maximum vertical thickness of about 70 m. The main concentration of Zn–Cu sulfides with barite occurs in "metasomatic" quartzites. However, dispersed uneconomical mineralization can be also found in the surrounding gabbro and troctolite.

The Obrázek ore deposit is not homogeneous. It is divided into several flat-lying horizons consisting of high-grade sphalerite–chalcopyrite ore in which pyrite, pyrrhotite and barite are abundant. Regular veinlets of sphalerite occur towards the hanging wall of a particular ore horizon and veinlets of chalcopyrite and pyrite can be seen towards the footwall. In the vicinity of the rich horizons, lower concentrations of pyrrhotite, chalcopyrite, pyrite and sphalerite occur in "metasomatic" quartzite and gabbros.

Morphologically and mineralogically the Zn–Cu mineralization of the Ransko massif includes

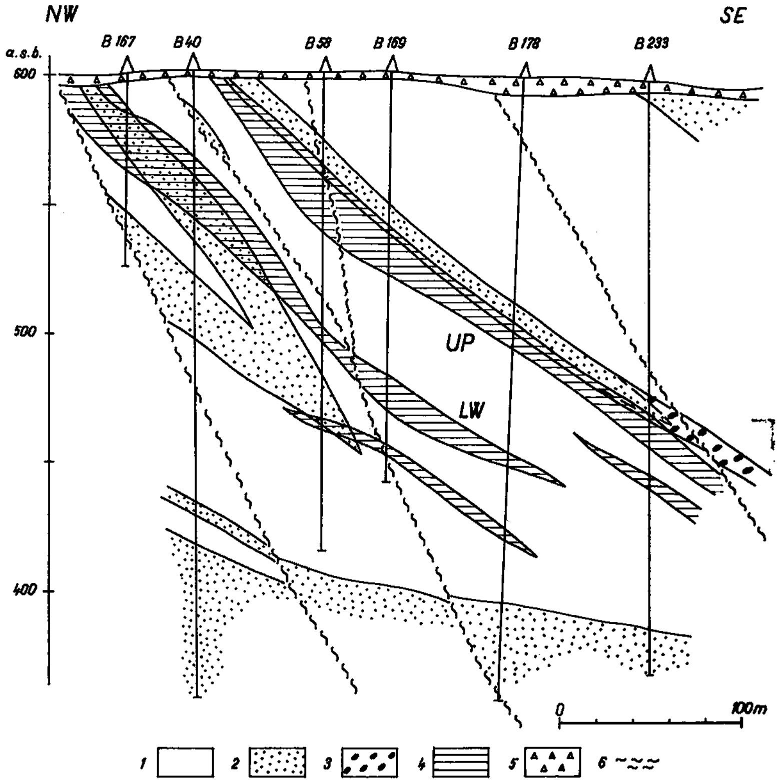

FIG. 7. Geological cross sections through the Řeka ore deposit. 1. Gabbro. 2. Olivine gabbro. 3. Troctolite. 4. Ni–Cu ore deposits, 5. Quarternary. 6. Sheared zone. UP: Upper lode horizon. LW: Lower lode horizon.

two types. The first type, high-grade sphalerite ore, occurs as streaks and nest-like to irregular platy accumulations with poly- to monomineralic sulfide and commonly with considerable amounts of barite. Such aggregates are sometimes parallel-structured and their boundaries against gabbro are irregular and lobate (Pokorný 1969). Dark brown sphalerite replacing older sulfide minerals dominates in this type of mineralization; the proportions of chalcopyrite, barite, pyrite and pyrrhotite vary.

The second type of Zn–Cu mineralization, the impregnation-veinlet type, is always related to "metasomatic" quartzite, metamorphosed gabbros and xenoliths of metamorphic rocks. It is characterized by the predominance of iron-bearing sulfides over sphalerite. The sulfide minerals of the impregnation-veinlet type in the "metasomatic" quartzite occupy the interstices between equidimensional grains of quartz and cordierite. Along the contact with sulfides, cordierite is clearly decomposed. Sulfides are either isolated or intergrown in complicated aggregates (Pokorný 1969). The Zn–Cu–Fe sulfides are rarer in the metamorphosed gabbros and xenoliths of metamorphic rocks, but their occurrence is similar to that in the "metasomatic" quartzite.

The origin of Zn–Cu mineralization has been discussed by Holub & Pokorný (1968) and in Mísař (1974b). They distinguished two significant stages of mineralization. During the older stage, higher-temperature ore fluids reacted with the silicates. Later, a mass crystallization of barite and sphalerite preferentially followed flat tectonic structures. In the reinterpretation of Watkinson *et al.* (1978), the Zn–Cu Obrázek ore deposit is supposed to be older than the Ransko complex, having been regionally metamorphosed at great depths prior to incorporation in the Ransko intrusion.

More detail work has to be done to understand the role of xenoliths, the processes of transformation of country rocks, the structural position of the deposit, and the origin of "metasomatic" quartzite and quartz diorite. Without making any definite conclusion, the author considers the Zn–Cu ore to be a special type of complex mineralization restricted to the Ransko pipe-like feeding channel. The age of the quartz diorite (330 m.y.), the specific geochemical character of the deposit, the concentrations of high-temperature phenomena only in the deposit and its surroundings, and the complex plutonic and volcanic features in the whole region seem to support this hypothesis.

Conclusions

The Ransko gabbro–peridotite massif represents an example of a concentrically zoned intrusion or an intrusion of polygenic type. It may have some relationship to the Upper Proterozoic plutonic and volcanic features in this portion of the Bohemian massif.

There are two main rock series. The peridotite–troctolite–olivine gabbro series was formed at an early stage and was rather passively brought up by the younger series of pyroxene gabbro. In the tectonic and magmatic history of the massif, the stage of the transitory magma chamber was probably the most important. The trapped primary tholeiitic magma differentiated and was probably contaminated by metamorphic rocks from the chamber walls.

The complex processes inside the magma chamber also resulted in the precipitation of a Ni–Cu–Fe sulfide immiscible melt. Geological phenomena such as the structural position of the Ni–Cu deposits and the varied petrological character of the host rocks strongly point to the theory that the sulfide melt was left behind after the pyroxene-gabbro intrusion. The emplacement of the ore took place at the end of the solidification process in suitable structures and host rocks. From this point of view, the remarkable zone of Ni–Cu mineralization striking NNE-SSW is one of the most promising areas for the location of an economic ore deposit. The emplacement of the sulfide mineralization followed practically and theoretically the principles described by Nesbitt (1971) or Skinner & Peck (1969).

The Zn–Cu sulfide mineralization of the Ransko massif is not well understood. According to the hypothesis of Holub & Pokorný (1970), the deposit is considered to be a high-temperature metasomatic type related to the alteration of the gabbro and troctolite. Watkinson *et al.* (1978) believe that the Zn–Cu ore deposit was produced by regional metamorphism of altered volcaniclastic sedimentary rocks associated with a volcanogenic Cu–Zn deposit. In this interpretation the deposit must be older than intrusions of gabbro. In the author's opinion, the Zn–Cu mineralization may be a product of volcanic processes in the Ransko pipe-like feeding channel. The origin and emplacement of the younger quartz diorite must be related to these same processes and channelway.

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