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Remarks on the Nickel Deposits of the Western Alps (Italy)

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Summary

The nickel-mineral resources in the Italian Western Alps are considered. They are referred to three different types of mineralizations with respect to mineralogical, geo-lithological, and morphological characters. The first two types exemplify classic deposits (there are many occurrences, limited in importance and not yet exploited). The third one is a potential resource for the future, the practical interest being related to the research presently performed on nickel recovery.

The following types are examined:

- Fe-Ni(Cu) mineralization, within mafic and ultramafic rocks of the Ivrea-Verbano unit; the characteristic paragenesis is pyrrhotite-pentlandite-chalcopyrite (Sudbury type);
- Ni-Co-As(Fe) vein mineralization, within ophiolite rocks of the Piedmont zone; the characteristic paragenesis is smaltite-chloanthite and safflorite-rammelsbergite;
- Fe-Ni mineralization in serpentinites (particulary in the asbestiferous ones), formed by tiny disseminations of various minerals, as the native nickel-iron (of the josephinite type), and sulphides (pentlandite, heazlewoodite, bravoite, millerite, etc.).

1. Introduction

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We will summarize the peculiar characters for any of this type.

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2. The nickel-bearing pyrrhotite deposits of the Ivrea-Verbano Zone

This concerns a group of mineralizations (NATALE and ZUCCHETTI, 1976), situated in the provinces of Vercelli and Novara, precisely in the Sesia Valley and its branches and in the Strona di Omegna Valley, in altitudes also higher than 1.000 meters.

The mines (a dozen in total) were particulary active during the second half of the last century, then closed and reopened during the present one; however any activity ceased soon after the Second World War.

The geological context of these deposits is the "diorito-kinzigitic" complex (Ivrea-Verbano Zone), a unit of the crystalline basement of the Southern Alps, formed by a kinzigitic complex of pelitic and semipelitic metasediments of high degree, with subordinate intercalations of marbles and amphibolites, and by a complex of mafic rocks, essentially in granulitic facies, including limbs of ultramafic rocks and subordinate metasediments (BORIANI and SACCHI, 1973).

The tectonics is more or less complex, according to the interpretation of several authors; the metamorphic evolution being the consequence of the superimposition of two thermic events at least, referred respectively to the Caledonian and Hercynian cycles.

The mafic and ultramafic rocks, referred in the past to Hercynian post-metamorphic intrusions, today are considered, at least in part, as more ancient metamorphic rocks, in amphibolite or granulite facies, with a structural evolution of a degree equal to the one of the surrounding rocks (PEYRONEL PAGLIANI and BORIANI, 1967).

To these mafic and ultramafic rocks are linked the above mentioned mineralizations, which are localized both in the main mafic mass and in ultramafic rocks, contacting or not with the normal mafic ones, and also, subordinately, in mafic lenses within the kinzigitic rocks.

The mineralized bodies generally have a lenticular or irregular shape, with various dimensions; instead, sometimes they are stratiform, as real and proper regular layers (RIVALENTI et al., 1975). The metallic minerals are there minutely disseminated or they occur in the little veins and lenses, closely associated with lithoids.

The metallic paragenesis – as already mentioned in the preface – is the typical one of the pyrrhotite-pentlandite-chalcopyrite mineralizations of the gabbro-noritic affiliation (Sudbury type).

The pyrrhotite generally occurs as an immiscible association, formed, according to several interpretations, either by troilite plus intermediate pyrrhotite (OMENETTO and BRIGO, 1974), or hexagonal pyrrhotite plus monocline pyrrhotite (RAMDOHR, 1969), or α and β pyrrhotite (BERTOLANI, 1952, 1964). The pentlandite, sometimes of the cobalt-bearing type, is distributed in the pyrrhotite, also as typical flamelike exsolution product, and here and there it is transformed in bravoite. The chalcopyrite occurs in plates into the pyrrhotite or as minute dissemination in the lithoid minerals.

Among the accessories we mention mackinawite, ilmenite, magnetite, chromite, sphalerite, sperrylite (RAMDOHR, 1969).

As an example, with reference to the most important deposit (the one of Campello Monti, in the Strona Valley) (NATALE and ZUCCHETTI, 1976), it is contained in a large mass of ultramafic rocks, represented for the greatest part by pyroxenites, sometimes olivinic, here and there more or less strongly serpentinized and/or talcized in the picture of the Alpine retrograde metamorphism.

They have a typical granoblastic structure and are constituted by pyroxene (bronzite and diopside), amphibole (referred to paragasitic type), spinel (hercynite), olivine (eventually), with accessories plagioclase, biotite and opaque minerals. The last ones are represented by the above mentioned sulphides and oxides, nickel-bearing or not, which are disseminated as tiny grains in the rock. The content of nickel of these pyroxenites generally is very low (0.1–0.2%).

Here and there the pyroxenites gradually change, with alternations of listed texture, to rocks of gabbroic appearance and composition (amphibolic "gabbros"), constituted by a granular association of plagioclase, basaltic hornblende and pyroxene.

All these characters discovered in these pyroxenites (as the geologic environment, gradual change to melanocratic granulites, texture, structure, mineralogic composition, etc.) induce to suppose they are "metaultramafites", more precisely, ultramafic granulites.

For what concerns the deposit, this is formed by portions of pyroxenites of various forms and sizes, with rate of nickel about 1%, with irregular richer strips (with rates of some units per cent).

The metallic paragenesis of the mineralized bodies is the one already mentioned and, like the lithoidal one, it appears in the whole as the result of the succession of two main minerogenetic events: one older, fundamental, granulitic; the other of retrometamorphic type and presumably of Alpine age.

In conclusion, some considerations can be made on the genesis and the age of these deposits.

They show, due to their paragenetic composition and petrologic affinity with the mafic (or ultramafic) rocks, the pertinent characters of the mineralizations with Fe-Ni-Cu associated with differentiated mafic complexes linked, in several parts of the world, with Precambrian formations or Hercynian orogenetic areas. The analogy with the deposits of Ontario and Manitoba, with some of Norway, Finland, USSR, Australia, with the South-African ones is evident; furthermore the analogy with metamorphosed stratiform complexes of Greenland can be emphasized (Rivalenti et al., 1975).

The mafic and ultramafic rocks and the mineralizations show to have partaken the same metamorphism of all the series. For this event, on the base of the determination of the absolute age (Buchs et al., 1962; Chessex, 1964), a surely pre-Carboniferous age is ascertained, assignable to the Lower Paleozoic or the Upper Precambrian. Therefore the original mineralizations could be connected with a metallogenesis of Precambrian age, similarly with the greatest part of deposits of this type.

3. The deposits linked to ophiolites of the Piedmont Zone

3.1. The Ni-Co-As-bearing deposits

This concerns some deposits situated in the province of Turin, precisely in the Susa and Lanzo Valleys, in altitude near or also higher than 2,000 meters (Mastrangelo et al., 1976).

Their elevation has undoubtedly made difficult their exploitation, in effect the extractive activity has been performed for a few years during the last two centuries, especially in the last one.

The mineralizations are linked to ophiolites of the Piedmont Zone, precisely to epidotic-amphibolic prasinites, sometimes with abundant chlorite ("ovarditi"), or they also occur partly in prasinites and partly in schistose serpentinites.

The mineralized bodies have typical vein form, very different sizes, but generally conspicuous enough; the ones of the Lanzo Valley represent a parallel field of a dozen of main veins, with developments in direction from 200 m as far as 3 km and thickness from several decimeters as far as 5–6 m (Fenoglio, 1928); in the Susa Valley there is instead a vein about 1 m thick, 50 m deep and followed in its direction for the same length by two crossing veins of much more reduced size (Fenoglio and Fornaseri, 1940).

The minerals are chiefly represented by carbonate gangue (siderite, mesitite, calcite, dolomite), with subordinate quartz and small quantities of metallics. In the Lanzo Valley, associated with these large poor veins, the are also numerous little veins, with thickness from 1 cm as far as 30 cm, much richer of useful minerals and with predominant quartz gangue.

The paragenesis is the typical one of the Ni-Co-As (without Ag) mesothermal deposits: smaltite-chloanthite, safflorite-rammelsbergite, with various sulphides (tetrahedrite, chalcopyrite, arsenopyrite, pyrite, pyrrhotite) (PIEPOLI, 1934). The smaltite-chloanthite occurs in crystalline aggregates, often with the typical zoned microstructure. Chemical analyses performed by different authors (FENOGLIO e FORNASERI, 1940; RAMMELSBERG, 1973) on the minerals of the various deposits have demostrated that smaltite-chloanthite of the Susa Valley is richer in nickel than in cobalt (Ni = 11.15%, Co = 2.77%), while the contrary is found in the deposits of the Lanzo Valley (Ni = 4.22 e 4.37%; Co = 7.65 e 7.31%).

The safflorite-rammelsbergite appears as aggregates with radial and/or zoned structure, sometimes in rhythmical deposition with the other arsenides.

Nothing in particular must be added in regard to the other metallics and the genetic link between the mineralizations and the ophiolites.

3.2. The mineralizations with native nickel-iron and sulphides in the serpentinites

It is known that the serpentinites linked to the Piedmont Zone have ample development, outcropping in large zones along all the arc of the Italian Western Alps and that, in some cases, they are the place of more or less important asbestos mineralizations (Aosta, Lanzo and Varaita Valleys) (MASTRANGELO et al., 1976).

Years ago I announced (ZUCCHETTI, 1967) the presence of nickel-bearing minerals disseminated in the asbestos serpentinite of Balangero deposit, in province of Turin – the most important one of the Western Europe with regard to dimension, production and plants – and subsequently in the one of Sampeyre deposit, in province of Cuneo, then in fibreless serpentinites of numerous other places situated in the Susa, Lanzo and Aosta Valleys (ZUCCHETTI, 1970).

The picture of the metallic minerals (particularly the nickel-bearing ones) found in all the serpentinites examined is uniform enough to be in the position of giving a unitary description of the several mineralizations, though we have to take into consideration the differences of the several zones for what concerns the frequency, distribution, sizes, forms, associations and relations of the several minerals.

The metallics, for the majority nickel-bearing, found in the several serpentinites studied, are:

- magnetite, native nickel-iron, pentlandite, present practically in all the samples in any zone;
- heazlewoodite, bravoite, present in several samples of almost all the zones;
- mackinawite, pyrrhotite and probable chalcopyrrhotite, present in few samples of some zones;
- millerite, cobalt-pentlandite, valleriite, present in some samples of Balangero deposit.

The native nickel-iron – which at Balangero appeared to be of the josephinite type, with composition close to Fe (Ni, Co)$_3$ and rate Ni/Co equal to about 38 – is spread with uniformity in the several serpentinites, in small grains, with maximum size about two millimeters, with flat form and with almost always irregular, winding and frayed borders and, subordinately, in small crystals with idiomorphic habit.

The nickel-iron elements are often found isolated in the rock, not associated with other metallic minerals; but very often they are intimately linked with one or more nickel-bearing sulphides or, less often, with magnetite or very rarely pyrrhotite. Similar evidences appear for the nickel-bearing sulphides.

Upon the data already observed, the following considerations can be formulated:

- the nickel on the studied serpentinites is not only linked exclusively with silicates, as it has been thought in the past, but, at least partially, with the many metallic minerals observed;
- the native nickel-iron and pentlandite are to be considered as normal accessories of these serpentinites, both in the presence of asbestos or not;
- the other nickel sulphides are spread in a less uniform way and, sometimes, occasionally;
- in many peridotites examined, little or not serpentinized at all, the nickel-iron and other nickel metallics are practically missing;
- about the genesis, the native nickel-iron and other metallics are linked with the serpentinization process, since we must admit interdependence relations among them, as already pointed out by other authors (RAMDOHR, 1950–52; QUERVAIN (DE), 1963; KRISHNARAO, 1964).

In conclusion, it is convenient to underline the practical interest of what described, for what concerns the problem of the recovery of nickel from serpentinites, particularly from the ones with asbestos, considered since long in Italy, but not yet solved on the industrial basis, also for the inadequate knowledge acquired on the nature of the nickel-bearing minerals contained in them.

We must bear in mind that the calculation of the cubic volume performed on the asbestos serpentinite deposit of Balangero demonstrated more than 50 Mt the quantity of mineralized rock on the surface, of which the average rate of Ni is known, already estimated by previous studies of about 0.17–0.18% and that, in relation with the average output of the mine (of more than 3 Mt a year of worked rock) can be estimated more than 5,000 tons per year the quantity of nickel thrown away in the dump.

Therefore the discovery of the native nickel-iron and of the other nickel-bearing minerals and the definition of their general characteristics and occurrence, not only represents a real contribution to a better knowledge of the distribution of the nickel in the serpentinites, but can give useful data for the researches intended to recover economically at least a part of the metal, in the picture of the most various problems concerning the valorization of the poor minerals.

References

BERTOLANI, M.: Studio microscopico a luce riflessa sui minerali dei giacimenti cupro-nicheliferi della Valsesia. – Rend. Soc. Mineral. It. **8**, 67–86, Pavia 1952.

BERTOLANI, M.: Le manifestazioni metallifere della Valle Strona (Novara). – Atti Soc. Nat. Mat. Modena **95**, 3–26, Modena 1964.

BORIANI, A. & SACCHI, R.: Geology of the junction between the Ivrea-Verbano and Strona-Ceneri zones. – Mem. Ist. Geol. e Mineral. Univ. Padova **28**, 36 p., Padova 1973.

BUCHS, A. et al.: Ages "plomb total" déterminés par fluorescence X sur les zircons de quelques roches des Alpes. – Schweiz. Min. Petr. Mitt. **42**, 295–305, Zürich 1962.

CHESSEX, R.: Déterminations d'âge sur les zircons de roches des Alpes et des Apennins par la méthode des "radiation damage". – Schweiz. Min. Petr. Mitt. **44**, 27–42, Zürich 1964.

FENOGLIO, M.: Sui giacimenti di cobalto dell'alta Valle di Lanzo. – Atti Soc. It. Sci. Nat. **67**, 182–193, Milano 1928.

FENOGLIO, M. & FORNASERI, M.: Il giacimento di nichelio e cobalto del Cruvino in Val di Susa. – Per. Mineral. **11**, 23–52, Roma 1940.

KRISHNARAO, J. S.: Native nickel-iron alloy, its mode of occurrence, distribution and origin. – Econ. Geol. **59**, 443–448, Blacksburg 1964.

MASTRANGELO, F., NATALE, P., ZUCCHETTI, S.: Mineralizzazioni metallifere e litoidi associate a rocce ultrabasische delle Alp Occidentali. – Boll. Ass. Min. Subalp. **13**, 341–351, Roma 1976.

NATALE, P. & ZUCCHETTI, S.: Considerazioni sui giacimenti nicheliferi della formazione Ivrea-Verbano (con particolare riguardo al giacimento di Campello Monti in Valle Strona). – Boll. Ass. Min. Subalp. **13**, 181–190, Roma 1976.

OMENETTO, P. & BRIGO, L.: Metallogenesi nel quadro dell Orogene ercinico delle Alpi (con particolare riguardo al versante italiano). – Mem. Soc. Geol. It. **13/1**, 339–362, Roma 1974.

PEYRONEL PAGLIANI, G. & BORIANI, A.: Metamorfismo crescente nelle metamorfiti del "Massiccio dei Laghi" nella zona bassa Val d'Ossola-Verbania. – Rend. Soc. Mineral. It. **21**, 351–397, Pavia 1967.

PIEPOLI, P.: Studio micrografico di minerali complessi delle vecchie miniere di cobalto di Usseglio (Valle di Viù). – Per. Mineral. **5**, 141–153, Roma 1934.

QUERVAIN, F.: Die Erzmineralien des Serpentins von Selva-Quadrada (Puschlav). – Schweiz. Min. Petr. Mitt. **43**, 295–312, Zürich 1963.

RAMDOHR, P.: Über Josephinit, Awaruit, Souesit, ihre Eigenschaften, Entstehung und Paragenesis. – Mineral.-Mag. **29**, 374–394, London 1950–52.

RAMDOHR, P.: The ore minerals and their intergrowths. – Oxford, London: Pergamon, 1969, 1174 S.

RAMMELSBERG, C.: Untersuchung einiger natürlichen Arsen- und Schwefelverbindungen. – Z. Deutsch. geol. Ges. **25**, p. 284, Berlin 1873.

RIVALENTI, G., GARUTI, G. & ROSSI, A.: The origin of the Ivrea-Verbano basic formation (Western Italian Alps). Whole rock geochemistry. – Boll. Soc. Geol. It. **94**, 1149–1186, Roma 1975.

ZUCCHETTI, S.: Presenza e distribuzione di un ferro-nichel nativo del tipo della josephinite nel giacimento asbestifero di Balangero. – Rend. Acc. Naz. Lincei **43**, 233–241, Roma 1967.

ZUCCHETTI, S.: Ferro-nichel nativo ed altri minerali nicheliferi in serpentiniti anche asbestifere delle Alpi Occidentali. – Rend. Soc. It. Mineral. Petrol **26**, 377–397, Pavia 1970.