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MINERALIZATION IN WESTERN MEDITERRANEAN OPHIOLITES

MINERALIZZAZIONI NELLE OFIOLITI DEL MEDITERRANEO OCCIDENTALE

Abstract — In the Western Mediterranean area, Tethyan ophiolites occur in the Alps, Apennines and northern Corsica. Various types of ophiolite related mineralization, both ores and non-metallic raw materials, formed during the evolution of the ophiolite complexes. The mineralization is different in the major geologic divisions which include, in a generalized column of unmetamorphosed ophiolites, mantle ultramafics followed upward by gabbros, basalts and sediments. In metamorphosed ophiolites, extensively occurring in the Alps, either similar geologic divisions are recognized, or original volcano-sedimentary sequences originated in a non-oceanic environment are represented.

Key words: Mineral deposits, Ophiolites, Western Mediterranean.

Riassunto breve — *Nel Mediterraneo occidentale ofioliti affiorano nelle Alpi, negli Appennini ed in Corsica. Nel corso della evoluzione dei complessi ofiolitici si sono formati numerosi giacimenti di minerali metallici e non metallici. Le mineralizzazioni sono differenti nei principali complessi geologici che, nella successione generale delle ofioliti non metamorfiche, comprendono dal basso in alto: ultramafiti del mantello, gabbri, basalti e sedimenti di copertura. Nelle ofioliti metamorfiche, diffuse nelle Alpi, si riconoscono gli stessi complessi ed anche successioni vulcanoclastiche di ambiente non oceanico.*

Parole chiave: *Giacimenti minerari, Ofioliti, Mediterraneo occidentale.*

Introduction

In the Western Mediterranean, Tethyan ophiolites of Jurassic-Early Cretaceous age are present in the Alps, Apennines and Corsica (fig. 1). Different mineralization, including ores and non-metallic mineral deposits, occur in the various members of the ophiolitic suite. Metallic mineral deposits are mainly represented by stratabound Fe and Fe-Ni deposits in ultramafics, by stratiform copper deposits in basic,

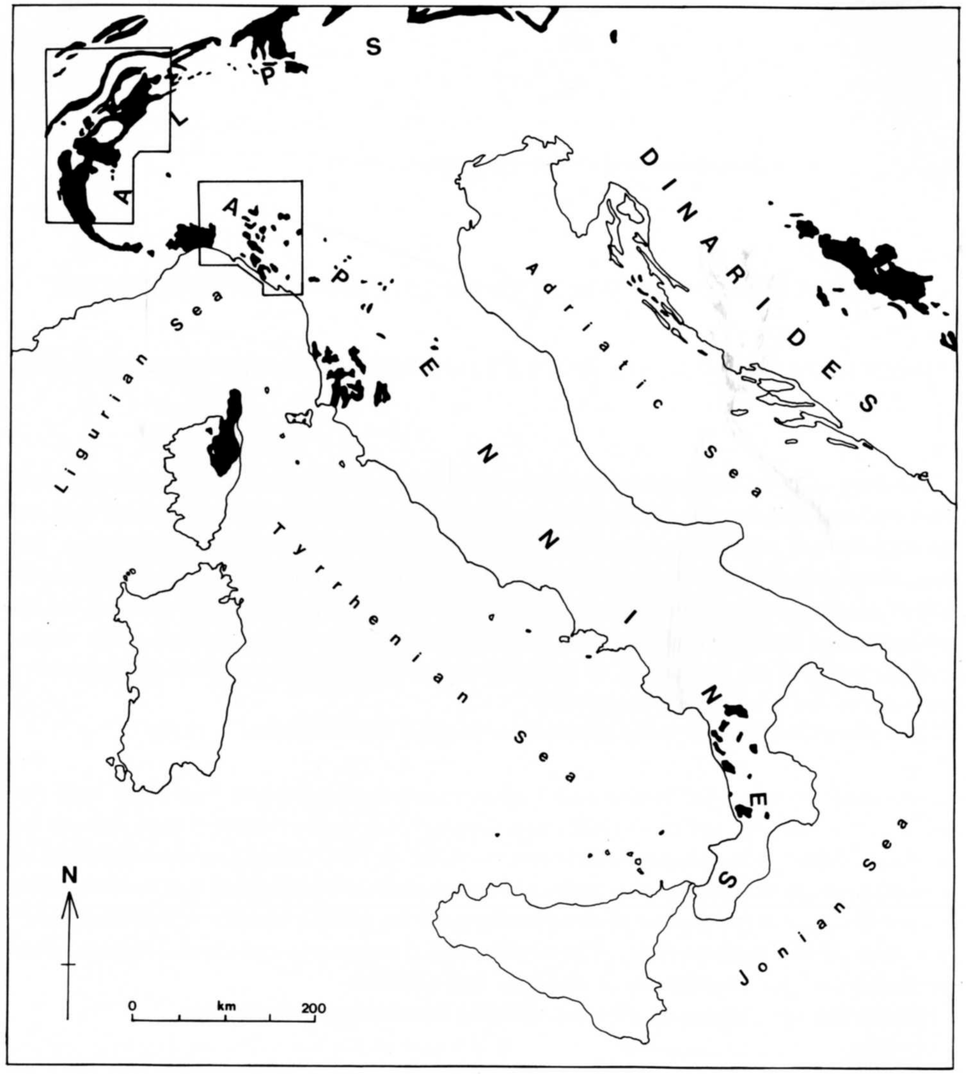

Fig. 1 - Distribution of Tethyan ophiolites (black areas) in the Western Mediterranean realm. The areas represented in figs. 6 and 7 are indicated.
- *Distribuzione delle ofioliti (aree nere) nel Mediterraneo occidentale. Sono indicate le aree rappresentate nelle figg. 6 e 7.*

mostly extrusive, ophiolites, and by some Fe-Mn deposits in the sediments on top of the basalts (MASTRANGELO et al., 1976; GLOM, 1977; FERRARIO & GARUTI, 1980; CASTELLO, 1981). Economic deposits of non-metallic raw materials, mainly chrysotile

asbestos, included in ultramafics are also to mention (NATALE, 1972; MASTRANGELO et al., 1976). The ophiolite related mineralization shows many similarities with that occurring in other Tethyan ophiolites, particularly of the Eastern Mediterranean (Yugoslavia, Albania, Greece, Turkey) with respect to parageneses and stratigraphic relations. It differs, however, in the negligible importance of chromite deposits, which, on the contrary, are conspicuous in the East Mediterranean area. Futhermore, in metamorphosed ophiolites from original volcano-sedimentary sequences, Fe-Cu-Zn deposits containing in addition Pb and Mo minerals and graphite are represented (BRIGO et al., 1976).

In the present paper, mineral deposits occurring in the different stratigraphic units of the Western Mediterranean ophiolite suite are briefly described in terms of their chemistry and relation with the host rock. Implications with the identification of the original tectonic setting of the ophiolites are discussed.

Geological framework

The Western Mediterranean ophiolites display strongly different features, both in structure and metamorphic history. They include in fact relatively coherent to highly disrupted ophiolites, which either underwent a complex polyphase Alpine metamorphism (Cretaceous to Paleogene in age), or were feebly affected by it. Two main domains are recognized: an Apenninic and an Alpine domain. The first one includes ophiolites either unaffected, or showing very low-grade Alpine metamorphism inprint. They are well represented in the Ligurian and Tuscan-Emilian Apennines by relatively coherent (Internal Ligurids) to highly disrupted (External Ligurids) allocthonous complexes (SESTINI, 1970; ABBATE et al., 1980). The Apenninic domain includes also a part of the ophiolites occurring in the Southern Apennines (Calabria and Lucania: LANZAFAME et al., 1979) and Northern Corsica (GLOM, 1977).

In the Alpine domain, which extends mainly in Western and Central Alps and includes also some of the Corsican and Calabrian ophiolites, the inprint of the Alpine metamorphism, dominated by the eo-Alpine (Cretaceous) phase under high-temperature and low-pressure conditions is shown (DAL PIAZ, 1974).

The stratigraphy of the ophiolite complexes shows many similarities in both domains, and is similar to that of the present-day oceanic lithosphere, although not easily identifiable as such. The tectonic setting, in fact, is still debated, although a mid-ocean ridge basalt (MORB) to transitional MORB affinity of the extrusives is suggested by geochemical data.

In the Apenninic domain, the ophiolite sequences include (fig. 2) a lower unit of mantle ultramafics, mainly lherzolites, a poorly developed intermediate unit con-

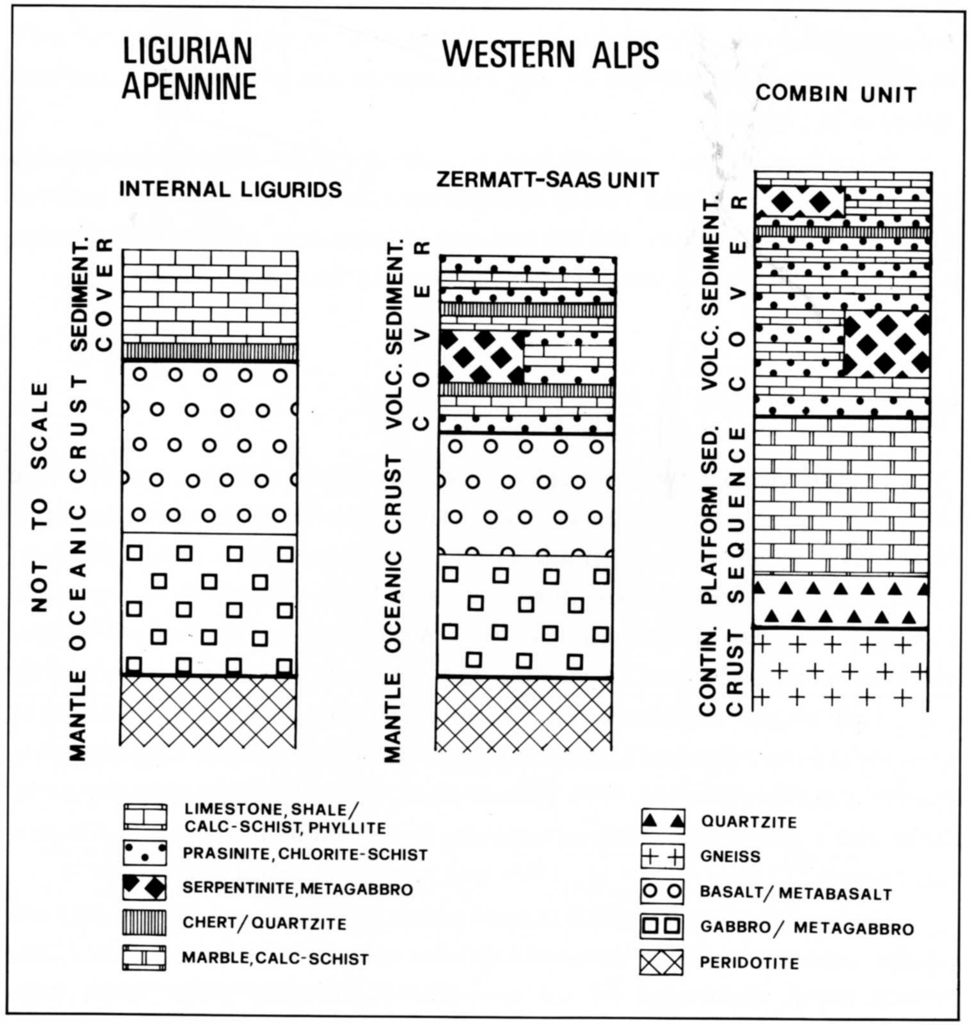

Fig. 2 - Schematic interpretative geologic columns of ophiolites from the Northern Apennines and the Western Alps.
- *Schema interpretativo della successione geologica delle ofioliti dell'Appennino settentrionale e delle Alpi occidentali.*

sisting of gabbros grading to cumulus peridotites, and an upper unit consisting of basalts capped with sediments. Layers of sedimentary breccia, including both monogenic (with gabbro or serpentinite clasts) or polygenic (with intrusive and volcanic rock detritus) types are present (ABBATE et al., 1980). They occur at different levels in the geologic column: on top of serpentinized peridotites or of gabbros, or interlayered within the volcanic section (fig. 3).

In the Alpine domain, a typical peridotite - gabbro - basalt - sediment sequence can ben reconstructed, in spite of deformation and strong metamorphic alteration

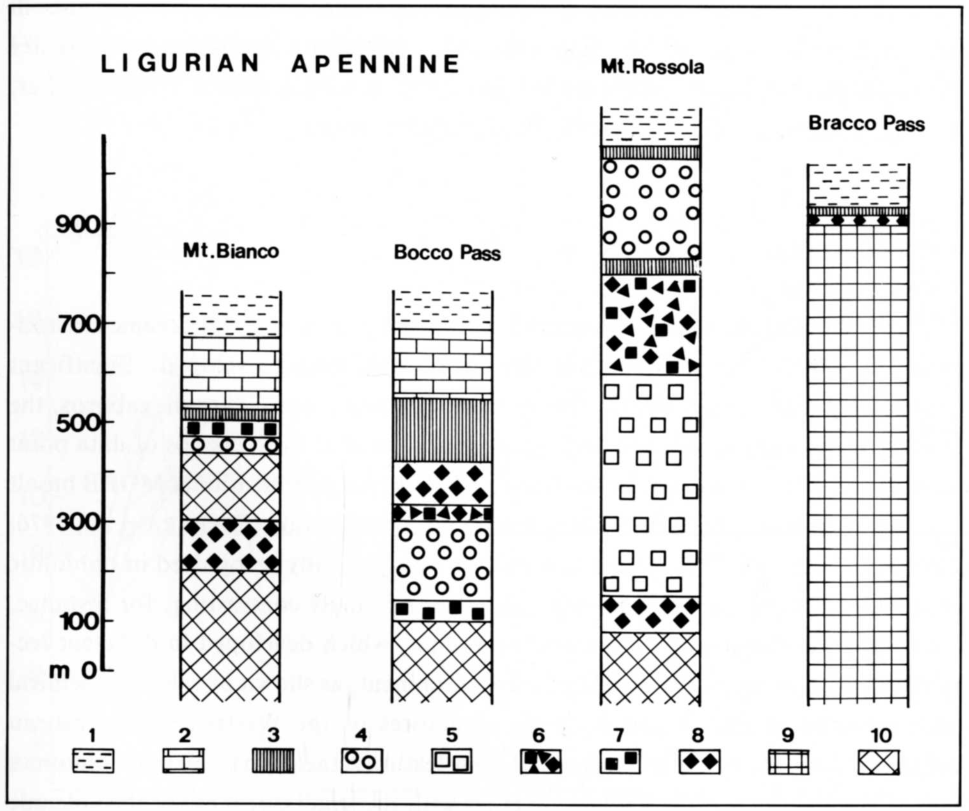

Fig. 3 - Stratigraphic columns of ophiolite sequences from Ligurian Apennine. Legend. 1: shale, 2: limestone, 3: chert, 4: pillow basalt, 5: massive basalt, 6: polygenic breccia, 7: gabbro breccia, 8: serpentinite breccia, 9: gabbro, 10: lherzolite.
- *Successione stratigrafica delle ofioliti dell'Appennino Ligure. Legenda. 1: argilliti, 2: calcari, 3: selci, 4: basalti a pillow, 5: basalti massicci, 6: brecce poligeniche, 7: brecce di gabbri, 8: brecce di serpentiniti, 9: gabbri, 10: lherzoliti.*

of the rocks. It is similar to that of the Apennine area, even in the occurrence of some breccia layers (fig. 2). Besides Liguride-types sections, sequences characterized by an upper section of interlayered sediments and volcanics (probably volcanoclastic rocks) also occur. In the Western Alps these sequences are represented in two ophiolitic units (Zermatt-Saas and Combin units: fig. 2) which strongly differ in their stratigraphy (BEARTH, 1967; DAL PIAZ and ERNST, 1978). The former (Zermatt-Saas Unit) consists of an oceanic-type basement overlain by a volcano-sedimentary sequence. The latter (Combin Unit) has a non-oceanic pre-ophiolitic basement (continental rocks overlain by platform sedimentary rocks of Triassic to Jurassic age) covered with a volcano-sedimentary sequence. The volcano-sedimentary sequence in both units includes calc-schists, quartzites and phyllites with interlayered metabasites (probably tuffites, hyaloclastites and sills in origin), and metagabbros or serpentinites. The latter occur as slices, probably of olistolithic origin.

Tectonic setting

Most petrological and stratigraphical data point to an original oceanic environment in which the Western Mediterranean ophiolites developed. Significant petrological data include mainly the pattern of crystal fractionation in gabbros, the lineage of magma evolution in both gabbros and basalts. Both groups of data point to an origin of the mafic ophiolites from a MORB-type or transitional MORB basalt and to low-pressure conditions during fractional crystallization (FERRARA et al., 1976; BECCALUVA et al., 1980). These features are non generally recognized in ophiolitic complexes, also in the Tethyan ones. They are strikingly contrasting, for instance, from those or Eastern Mediterranean ophiolites, which developed in different tectonic settings, in most cases in island-arc environment, as shown by selected chemical data reported in figs. 4 and 5. Some pecularites of the Western Mediterranean ophiolites can be however emphasized. A first feature is the paucity of mafic plutonics and of sheeted dikes. This feature, together with the small thickness of the volcanic section, seems to indicate an uncompletely developed oceanic crust, and is consistent with the undepleted character of the mantle ultramafics, which are mostly lherzolites instead of harzburgites. Different interpretations are proposed: either an origin in a narrow oceanic basin, or in a fracture zone, or, finally, a development of the ophiolites near a continent. The latter statement can be supported by some sedimentological data: the hemipelagic character of the sediments on top of basalts, and the occurrence of abundant continental material in early ophiolite-bearing flyschs and mélanges.

Mineralization associated with Western Mediterranean ophiolites

Metallic mineralizations typically linked with ultramafics, eiter mantle or cumulus peridotites, are scarce and unimportant in Western Mediterranean ophiolites. Significant Cr deposits are particularly absent. The following mineralizations occur rather frequently in ultramafics:

— Fe deposits (magnetite), which compose huge bodies in meta-serpentinites from the W Alps (COMPAGNONI et al., 1979);

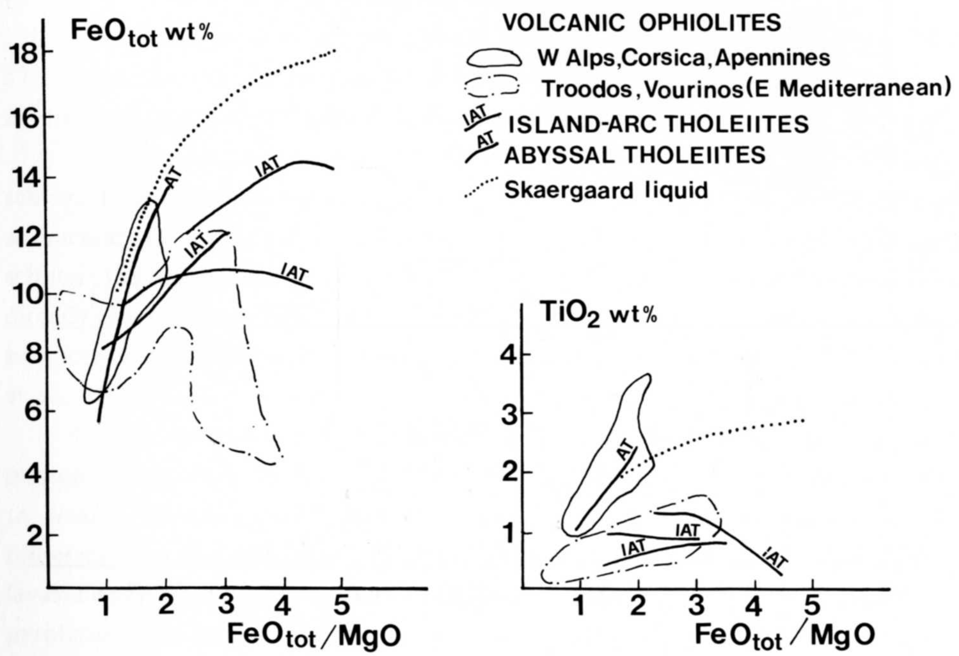

Fig. 4 - FeO_{tot} vs FeO_{tot}/MgO and TiO_2 vs FeO_{tot}/MgO diagrams for basaltic ophiolites from the Mediterranean realm. Data from BECCALUVA et al., 1980; 1983.
- *Diagrammi FeO_{tot} su FeO_{tot}/MgO e TiO_2 su FeO_{tot}/MgO per le ofioliti basaltiche del Mediterraneo occidentale (dati da* BECCALUVA *et al., 1980; 1983).*

— Fe-Ni and Ni-Co deposits mostly in the form of disseminations in serpentinized ultramafics from both Alpine an Apenninic domains (ZUCCHETTI, 1969; FERRARIO & GARUTI, 1980);

— copper mineralization represented by stratabound Fe-Cu-Ni ores and Cu-Fe sulphides epigenetic veins in serpentinized ultramafics from the Ligurian Apennine (FERRARIO & GARUTI, 1980).

Economic deposits are to mention among non-metallic mineralization. The most important consists of chrysotile asbestos occurring in serpentinites at Balangero (fig. 7), which is the greatest asbestos deposit in W Europe. Talc and magnesite mineralizations are also represented and sometimes economically important: they are linked with metamorphosed serpentinites from the Western Alps (MASTRANGELO et al., 1976).

Various types of mineralizations are associated with the extrusive ophiolites

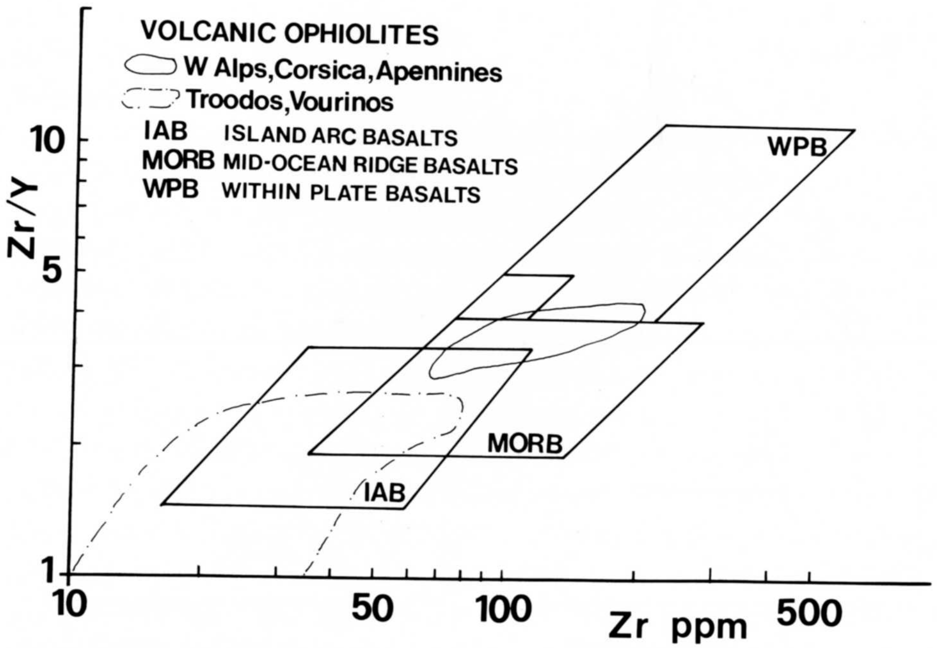

Fig. 5 - Zr/Y vs Zr diagram (after PEARCE and NORRY, 1979) for basaltic ophiolites from the Mediterranean realm. Data from BECCALUVA et al., 1980; 1983; DESMONS et al., 1980.

- *Diagrammi Zr/Y su Zr (*PEARCE *e* NORRY*, 1979) per le ofioliti basaltiche del Mediterraneo (dati da* BECCALUVA *et al., 1980; 1983;* DESMONS *et al., 1980).*

in the Apenninic and the Alpine domains: in both areas copper deposits are the most important. On the basis of paragenetic and structural features two main groups are distinguished (BRIGO et al., 1976):

— Fe-Cu-Zn mineralizations occurring in different stratigraphical positions, mostly linked with weakly metamorphosed basalts and breccias in Ligurian Apennine;

— Fe-Cu-Zn-Au-C mineralization associated with metabasites from the volcano-sedimentary sequence on top of the Combin Unit in the Western Alps.

The first group of copper deposits includes stratabound ores (massive, disseminated and stockwork) occurring: a) in basal breccias (serpentinite and gabbro breccias); b) within pillow-lava and pillow-breccia sequences; c) at the boundary between pillow lavas and capping sedimentary rocks, mostly chert (FERRARIO & GARUTI, 1980).

In metamorphosed ophiolites from the Alpine domain similar deposits, mineralogically and structurally reworked during the Alpine metamorphism, are recognized (DAL PIAZ et al., 1978; DE CAPITANI et al., 1981).

The second group of copper deposits is also represented by stratabound ores. Their mineralogy is characterized by the occurrence of unusual phases in ophiolite-related deposits, notably galena, molibdenite, and graphite.

These deposits occur: a) as thin bands and lenses interlayered within chlorite-schists, prasinites, calc-schists and quartzites, mostly interposed between meta-sedimentary and meta-igneous beds; b) as disseminations within prasinites and chlorite-schists; c) as lenses and thin bands interlayered within volcano-sedimentary sequences directly overlying metamorphosed gabbros, or gabbro-ultramafic complexes, which have the characteristics of oceanic crust (DAL PIAZ and OMENETTO, 1966; BRIGO et al., 1976).

Finally, the manganese deposits occurring within cherts and their metamorphosed derivatives from the sedimentary cover of basaltic ophiolites are mentioned. In weakly metamorphosed ophiolite sequences from the Apennines, they are represented by disseminations or bands within thin-bedded cherts on top of pillow-lavas. Fe and Zn minerals are usually associated with the dominant Mn phases (mostly pyrolusite). Mn deposits occurring in the Western Alps within quarzites (meta-cherts) are similar either in morphology and mineralogy, and doubtless represent the metamorphosed equivalents of the former.

The areal and stratigraphical distribution of the main ophiolite related deposits in the Northern Apennines and Western Alps are shown in figs. 6, 7 and in tab. 1.

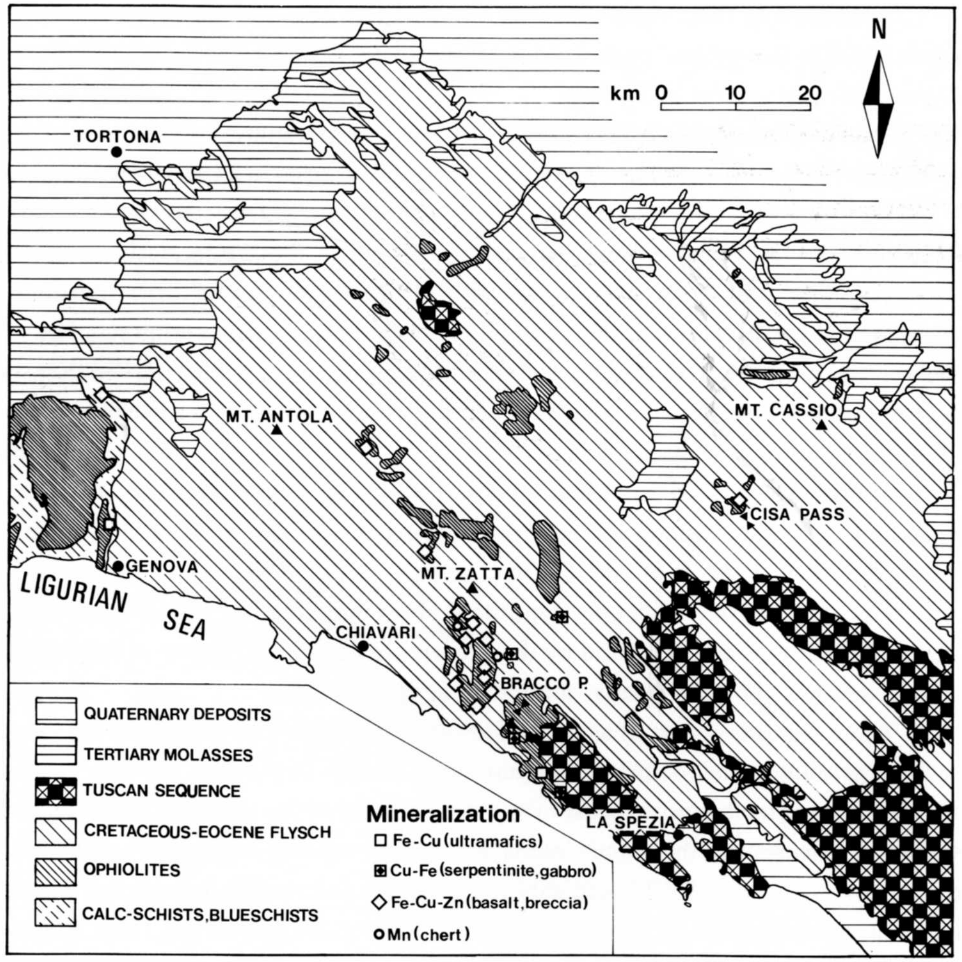

Fig. 6 - Simplified geologic map of the Northern Apennines and locations of ophiolite related mineral deposits.
- *Schema geologico dell'Appennino settentrionale e ubicazione dei giacimenti legati alle ofioliti.*

Concluding remarks

In the Western Mediterranean ophiolites, the major mineralization event is related to the basaltic volcanism from a spreading centre represented by the pillow-lavas on top of the magmatic sequence. An older mineralization event (or events)

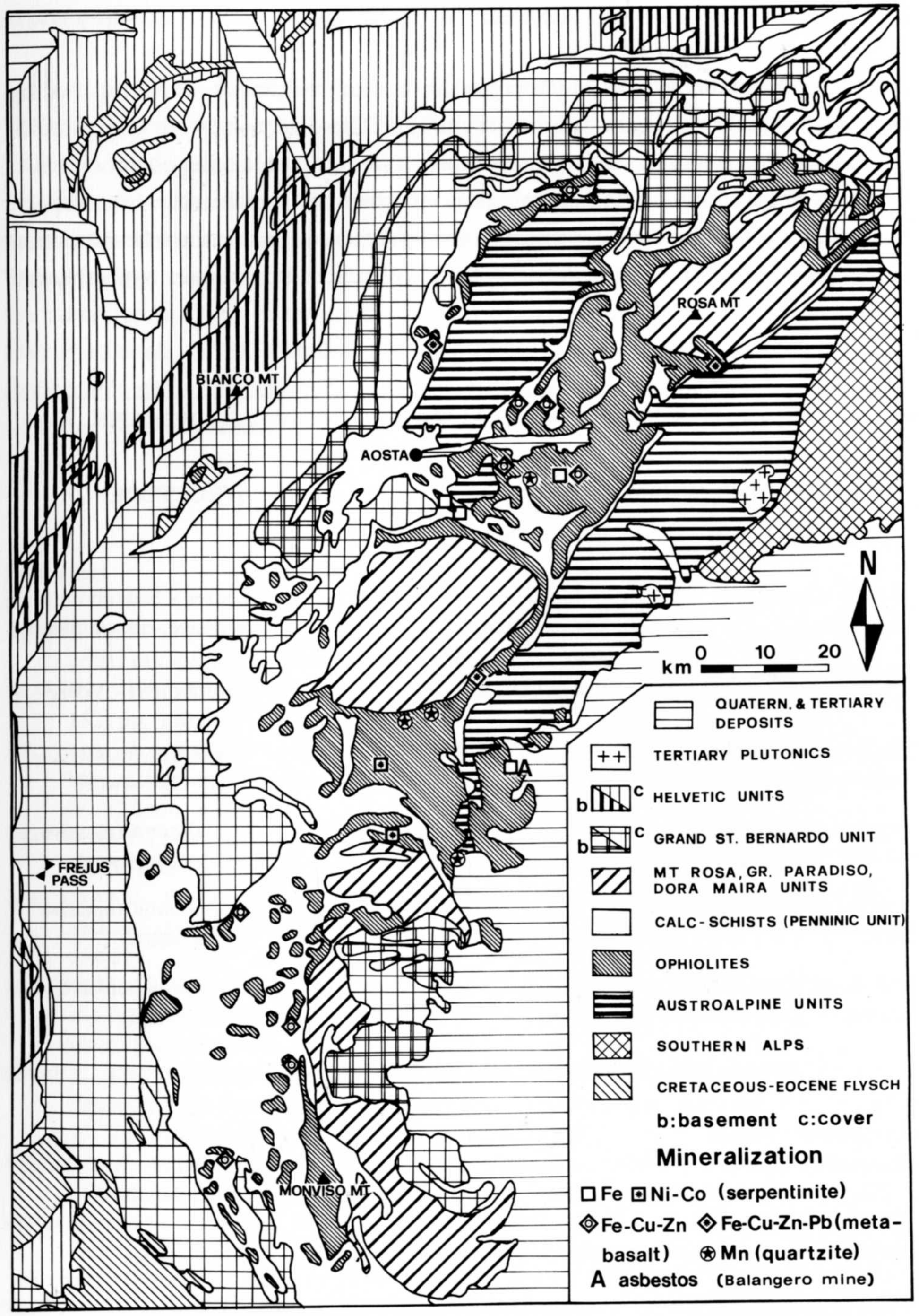

Fig. 7 - Simplified geologic map of the Western Alps and locations of ophiolite related mineral deposits.
- *Schema geologico delle Alpi Occidentali e ubicazione dei giacimenti legati alle ofioliti.*

related to magmatic activity which preceded the final volcanism is also testified by deposits in basal breccias of sedimentary origin. These deposits were originated in connection to erosion and sedimentation processes of oceanic lithosphere, or crust, along transform faults. The mineralogical, geochemical and structural features of the metalliferous deposits can ben explained by different genetic models: extraction and concentration of metallic minerals by deep circulating sea water hydrothermal

OPHIOLITE RELATED MINERALIZATION: METALLIC DEPOSITS

STRATIGRAPHIC UNIT (primary lithologies)	TYPE OF MINERALIZATION (main phases or metals)	STRUCTURE
Mantle ultramafics (lherzolite)	magnetite - Fe-Ni-Gold - (Fe-Ni-Co-As)°	Lenses - Stratabound (massive, disseminated)
Cumulus sequence (gabbro, peridotite)	(Fe-Cu sulphide)°	Stratabound - Veins
Basal breccias (gabbro, basalt, serpentinite clasts)	Fe-Cu-Zn sulphide	Stratiform (massive, diss.) - Stockwork
Massive and pillowed basalts	Fe-Cu-Zn sulphide	Stratabound (massive, diss.) - Stockwork
Volcano-sedimentary cover	Fe-Cu-Zn-Pb-Mo-Au-C- (Cu-Fe-Zn-Pb-Sn)°	Stratabound (massive disseminated)
Sedimentary cover (chert)	Mn-Fe-Cu minerals	Stratiform (massive, disseminated)

OPHIOLITE RELATED MINERALIZATION: NON-METALLICS

Serpentinized mantle ultramafics	chrysotile asbestos°°	Stockwork
	magnesite	Stockwork
	talc	Lenses-Bands

°Less important, °°Most important

Table 1 - Summary chart of mineralization related to Western Mediterranean ophiolites.
- *Carta riassuntiva dei giacimenti legati alle ofioliti nel Mediterraneo Occidentale.*

systems (a process which, according to many authors, e.g. SPOONER et al., 1976; SPOONER, 1976; BONATTI et al, 1976, could satisfactorily explain most ophiolite related sulphide mineralization); deposition by hydrothermal or exalative processes related to the volcanism (BRIGO and GARUTI, 1980). The presence of Pb, Mo and C minerals in some sulphide deposits linked with basic metaophiolites from the Western Alps, suggests other possible genetic models in which a contamination of the metalliferous fluids by the continental crust can be considered (BRIGO et al., 1976; DAL PIAZ et al., 1978). Metallogenesis in a tectonic environment similar to present-day oceanic spreading centres does not therefore represent the only model consistent with the observed features.

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