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**MEETING ON HIGH PRESSURE - LOW TEMPERATURE METAMORPHISM OF THE OCEANIC AND CONTINENTAL CRUST IN THE WESTERN ALPS**

# EXCURSIONS TO THE GRUPPO DI VOLTRI, SESIA-LANZO ZONE AND VALTOURNANCHE

**26 - 29 september 1976**

The Genova Meeting was followed by an excursion to some significant areas of the Western Alps showing eclogitic assemblages both in the oceanic and in the continental crust.

The excursion begun with the Voltri meta-ophiolites on Sept. 26; the Sesia-Lanzo Zone was visited on the 27th and 28th and the Valtournanche metamorphic ophiolites on the 29th. Owing to bad weather stops *a*) and *b*) of the excursion to the Gruppo di Voltri had to be inverted; for the same reason stops B4, 5, 6 and 7 of the Sesia-Lanzo excursion, and C2 and 3 of the Valtournanche excursion were omitted.

# EXCURSION TO THE METAMORPHIC OPHIOLITES OF THE GRUPPO DI VOLTRI

GUIDE BOOK

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## 1. General outlines

The term « Gruppo di Voltri » is referred to the widest metamorphic ophiolite complex in the Western Alps; it spreads over an area lying between Genova and Savona (Western Liguria) and represents the connection between Alps and Apennines.

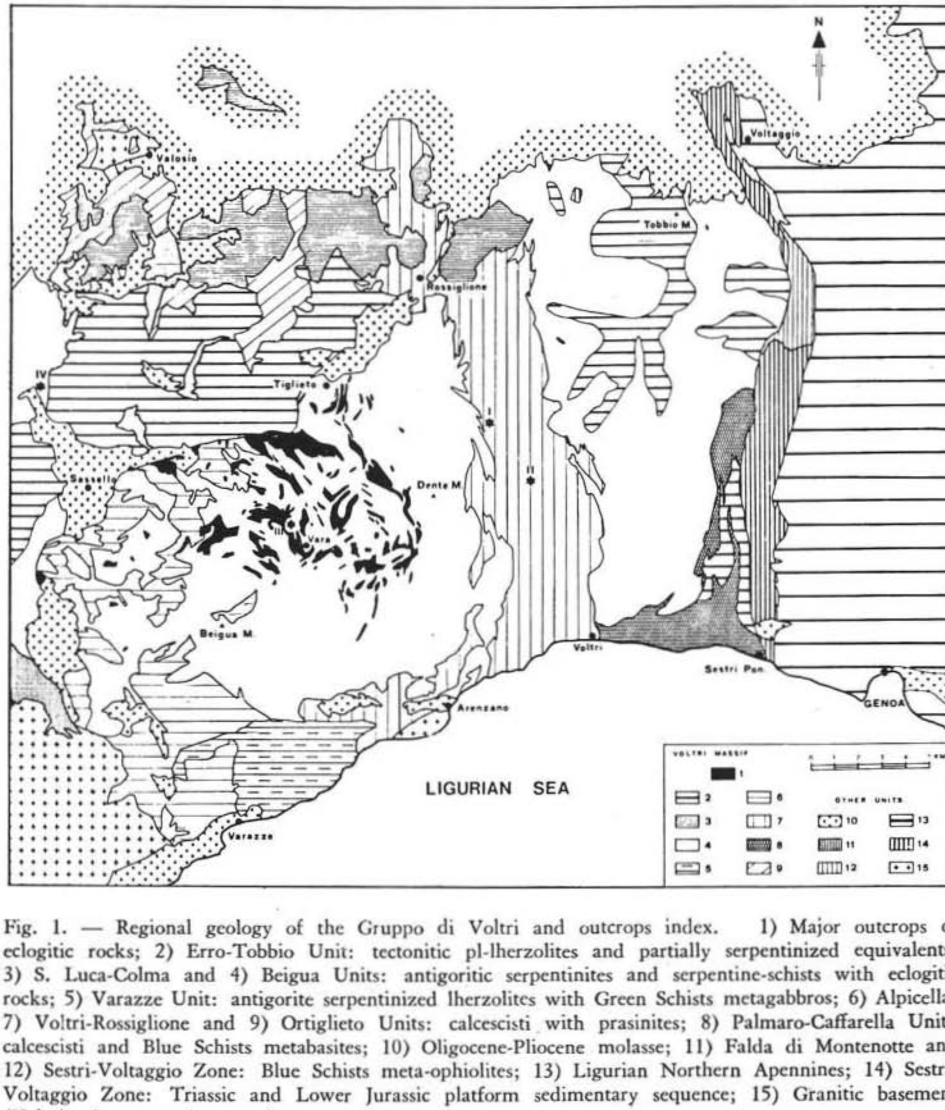


Fig. 1. — Regional geology of the Gruppo di Voltri and outcrops index. 1) Major outcrops of eclogitic rocks; 2) Erro-Tobbio Unit: tectonitic pl-lherzolites and partially serpentinized equivalents; 3) S. Luca-Colma and 4) Beigua Units: antigoritic serpentinites and serpentine-schists with eclogitic rocks; 5) Varazze Unit: antigorite serpentinized lherzolites with Green Schists metagabbros; 6) Alpicella; 7) Voltri-Rossiglione and 9) Ortiglieto Units: calcescisti with prasinites; 8) Palmaro-Caffarella Unit: calcescisti and Blue Schists metabasites; 10) Oligocene-Pliocene molasse; 11) Falda di Montenotte and 12) Sestri-Voltaggio Zone: Blue Schists meta-ophiolites; 13) Ligurian Northern Apennines; 14) Sestri-Voltaggio Zone: Triassic and Lower Jurassic platform sedimentary sequence; 15) Granitic basement (Valosio, Savonese, Arenzano).

The Gruppo di Voltri lithotypes mostly consist of ultramafics (more or less serpentinized) with associated minor metabasites, and of calcescisti with prasinites (Foglio 82, *Genova*, Carta Geologica d'Italia, and Note illustrative; Chiesa et Al., 1975, with references) (Fig. 1).

This ophiolitic complex acquired its metamorphic characters during the phases of Alpine orogenesis, preceding the Oligocene transgression of the Piedmont Tertiary Basin.

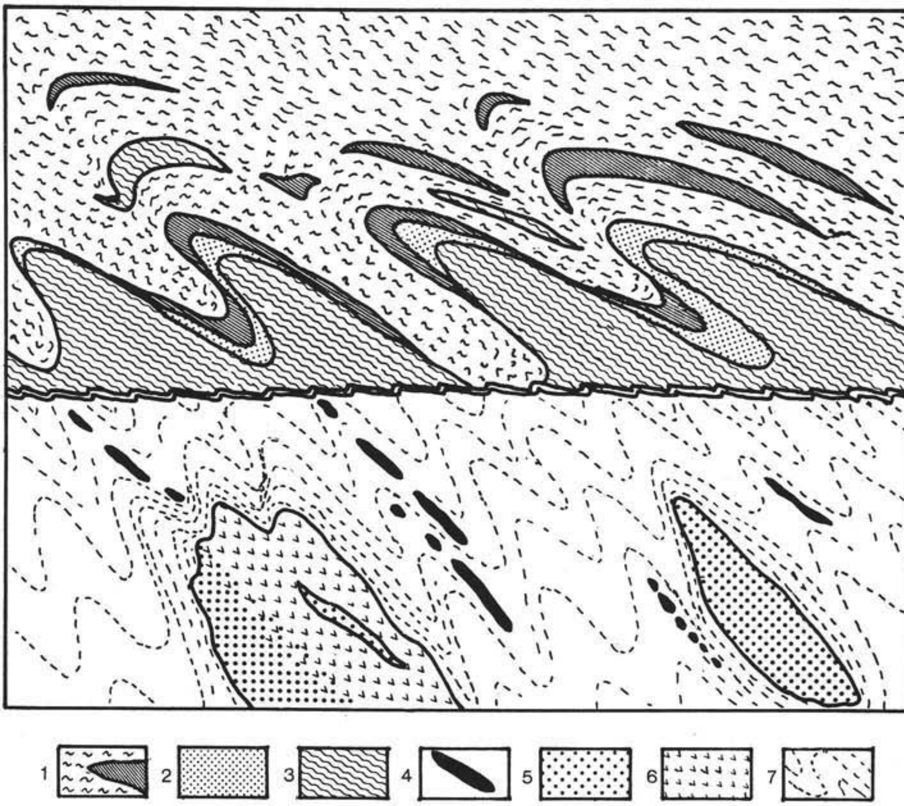


Fig. 2. — Inferred stratigraphic sequence for the polymetamorphic ophiolitic terrains of the Gruppo di Voltri. 1) Calcescisti, phyllitic-calcareous levels and limestones layers; 2) Quartz-schists; 3) Prasinites; 4) Rodingites; 5) Eclogites; 6) Metagabbros; 7) Antigoritic serpentine-schists.

The grouping into lithological associations of the rocks types occurring in the area, on the basis of both structural relationships and metamorphic characters (after Chiesa et Al., 1975), can be synthetized as follows:

— tectonitic ultramafics, more or less serpentinized (lizardite), and relic-bearing serpentinites;

— relic-bearing antigoritic serpentinites, massive or slightly sheared, and metagabbros in Green Schists facies;

— sheared antigoritic serpentinites and serpentine-schists, associated with eclogites and metagabbros with HP assemblages, more or less reequilibrated in Green Schists facies;

— calcęscisti, calcareous-dolomitic marbles and quartz-schists with Mn-bearing minerals, associated with prasinites;

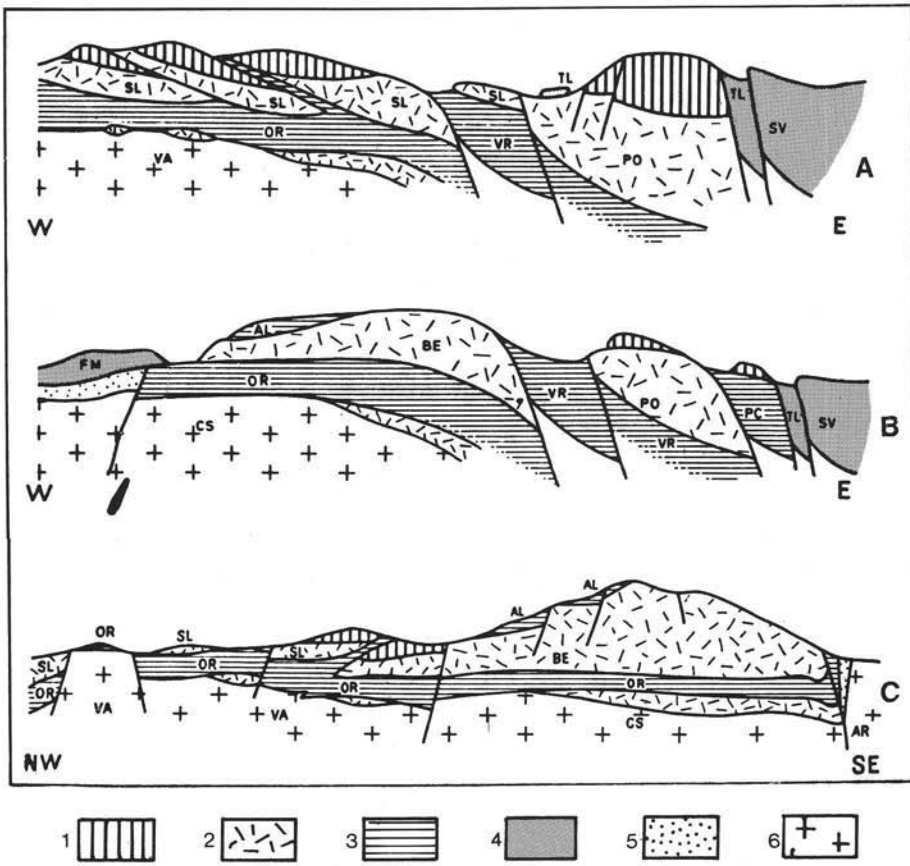


Fig. 3. — Interpretative geological sections across the Gruppo di Voltri. (A) E-W section in the northern area; (B) E-W section in the central-southern area; (C) N-S section in the western portion. 1) Tectonitic lherzolites complexes (Erro-Tobbio Unit); 2) Serpentinitic complexes (SL = S. Luca-Colma Unit; P = Ponzema Unit; BE = Beigua Unit); 3) Calcescisti-prasinites complexes (OR = Ortiglieto Unit; VR = Voltri-Rossiglione Unit; AL = Alpicella Unit; PC = Palmaro-Caffarella Unit); 4) Ligurian and Insubrian Zone (TL = Triassic-Liassic Units; SV = Sestri-Voltaggio ophiolitic Units and Ligurian Units; FM = Falda di Montenotte); 5) Brianconaise cover; 6) Pennidic continental crust (VA = Valosio Massif; CS = Savonese Massif; AR = Arenzano).

— calcescisti and crossite-bearing quartz-schists associated with HP metagabbros and glaucophane-schists;
— blasto-psefitic and blasto-psammitic quartzites associated with dolostones and phyllitic schists.

With the exception of the last association, which is to be related to platform Triassic sedimentary sequences, these rocks can be referred to three main primary associations:
— gabbro-peridotite complexes;

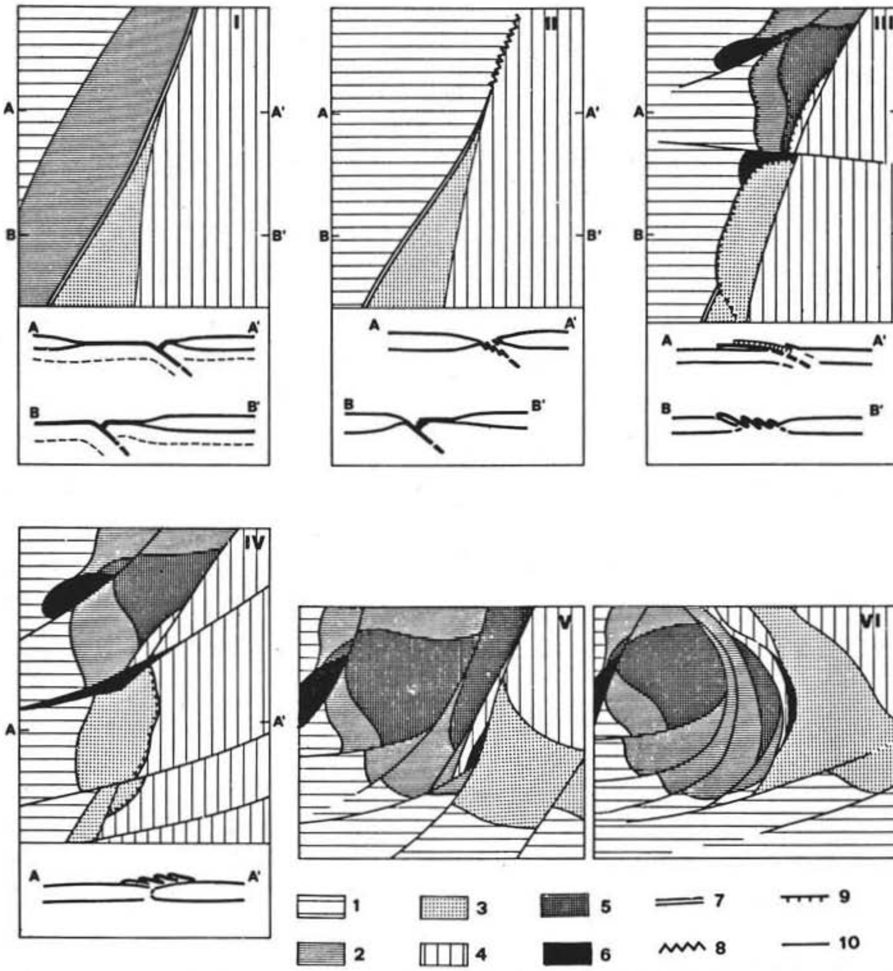


Fig. 4. — Geodynamic evolution of the Gruppo di Voltri from Upper Cretaceous to Oligocene. 1) European continental crust; 2) Subducted oceanic crust of the European plate; 3) Insubrian oceanic crust; 4) Insubrian continental crust; 5) Insubrian sub-continental upper mantle; 6) Oceanic Insubrian plate margin, involved in the subduction processes; 7) Trace of the subduction plane; 8) Margins in collision; 9) Edges of thrust Units; 10) Main tectonic lines.

— vulcanic-sedimentary sequences;
— tectonitic lherzolites.

As for as can be inferred beyond the complex metamorphic evolution of the gabbro-peridotite and volcanic-sedimentary associations (Fig. 2), it must be remarked the coexistence, within the Voltri meta-ophiolites, of tectonitic lherzolites (with minor harzburgites and dunites), gabbroic intrusions, ocean-floor tholeiitic volcanites (Mazzucotelli et Al., 1976) cherts (Chiesa et Al., 1976) and calcareous-pelitic sedimentary sequences, closely resembling Northern Apennines ophiolitic terrains.

The petrological characters, together with the absence of a strongly depleted mantle section and of well developed diabase sheeted complexes, point out that remarkable differences exist between the Ligurian ophiolites (Gruppo di Voltri and Northern Apennines) and the oceanic sections produced along active ridges (PICCARDO & RICCIO, 1975).

The tentative conclusion has been drawn that the Ligurian ophiolites originated during an early phase of the basin evolution, when the depleted astenospheric mantle material had not yet reached the uppermost levels and the melted fractions (ocean-floor basalts) intruded and extruded over a lithospheric poorly depleted upper mantle (PICCARDO, 1976).

The slabs of plagioclase-bearing tectonitic lherzolites emplaced in the Gruppo di Voltri, being not affected by the same polymetamorphic evolution as the other associations, should therefore represent the peri- or sub-continental upper mantle which underwent low pressure reequilibration during the early phase of continental rifting and drifting (MESSIGA & PICCARDO, 1974; CHIESA et Al., 1975).

For what concerns the tectonic setting, few main tectonic units (Fig. 1), named after local toponims, have been recognized in the Gruppo di Voltri, with the support of structural relationships and metamorphic evidences:

— Beigua (S. Luca - Colma and Ponzema) Unit: antigoritic serpentinites and serpentine-schists with eclogites and eclogitic metagabbros;

Fig. 5. — Main metamorphic assemblages and evolutive trends of Western Liguria Units.

I) Trend of the eclogitic rocks (mainly meta-Fe-gabbros) and Na-cpx - garnet - rutile - bearing metagabbros of Beigua, S. Luca - Colma and Ponzema Units: (A) precynematic eclogitic stage, (B) postcynematic eclogitic stage, (C) Na-amphiboles stage, (D) barroisitic hornblende stage, (E) albite + epidote + actinolite stage (after ERNST, in press; CORTESOGNO et Al., 1976).

II) (not represented in the diagram) The metamorphic trend of the metabasites associated to the Voltri-Rossiglione, Alpicella and Ortiglieto calcescisti (MAZZUCOTELLI et Al., 1976; CORTESOGNO, MESSIGA & PICCARDO, unpublished data) shows relics of a high pressure early stage (Na-pyroxene + garnet + rutile), probably related to (A) and (B) stages of eclogites; a later better preserved glaucophane stage might correspond to (C) stage. In the Ortiglieto Unit the barroisitic stage is well developed, while (E) stage is dominant in the Voltri-Rossiglione Unit.

III) Metamorphic trend of the Palmaro-Caffarella metabasites (CORTESOGNO, unpublished data). (★) Small lenses of jadeite + glaucofane - bearing metagabbros are not clearly related to the more common metabasites (stage a), characterized by aegirinic cpx + Na-amphibole + albite + lawsonite ± ± pumpellyite + chlorite ± rutile ± sphene. A later partially developed equilibration is visible, developping (stage b) albite + Na-amphibole + epidote + chlorite + sphene, followed by a slightly developed overprint in Green Schists conditions.

IV) Metabasites of the HP Unit of the Sestri-Voltaggio Zone (CHIESA et Al., 1975; CORTESOGNO, unpublished data) and the Falda di Montenotte (BOY et Al., 1976): metagabbros, meta-Fe-gabbros, meta-Fe-diorites and metadiabases. The HP metamorphic assemblage is mainly represented by Na-pyroxenes + lawsonite ± glaucophane, followed by a slightly developed equilibration at shallower depth.

V) Metabasites of the intermediate pressure Units of the Sestri-Voltaggio Zone and Falda di Montenotte (CHIESA et Al., 1975; CORTESOGNO, unpublished data). The metamorphic assemblage is mainly characterized by pumpellyite ± lawsonite ± prehnite + Fe-epidotes + albite + chlorites ± actinolite ± stilpnomelane + sphene.

VI) Savonese continental basement (Western Liguria) (CIMMINO et Al., 1976; MESSIGA et Al., 1975): gneiss and amphibolites, granites, pre-mesozoic sedimentary cover and volcanites. The alpine metamorphic assemblages are mainly represented by pumpellyite ± lawsonite + albite + chlorite + Na-amphibole + actinolite ± stilpnomelane + sphene.

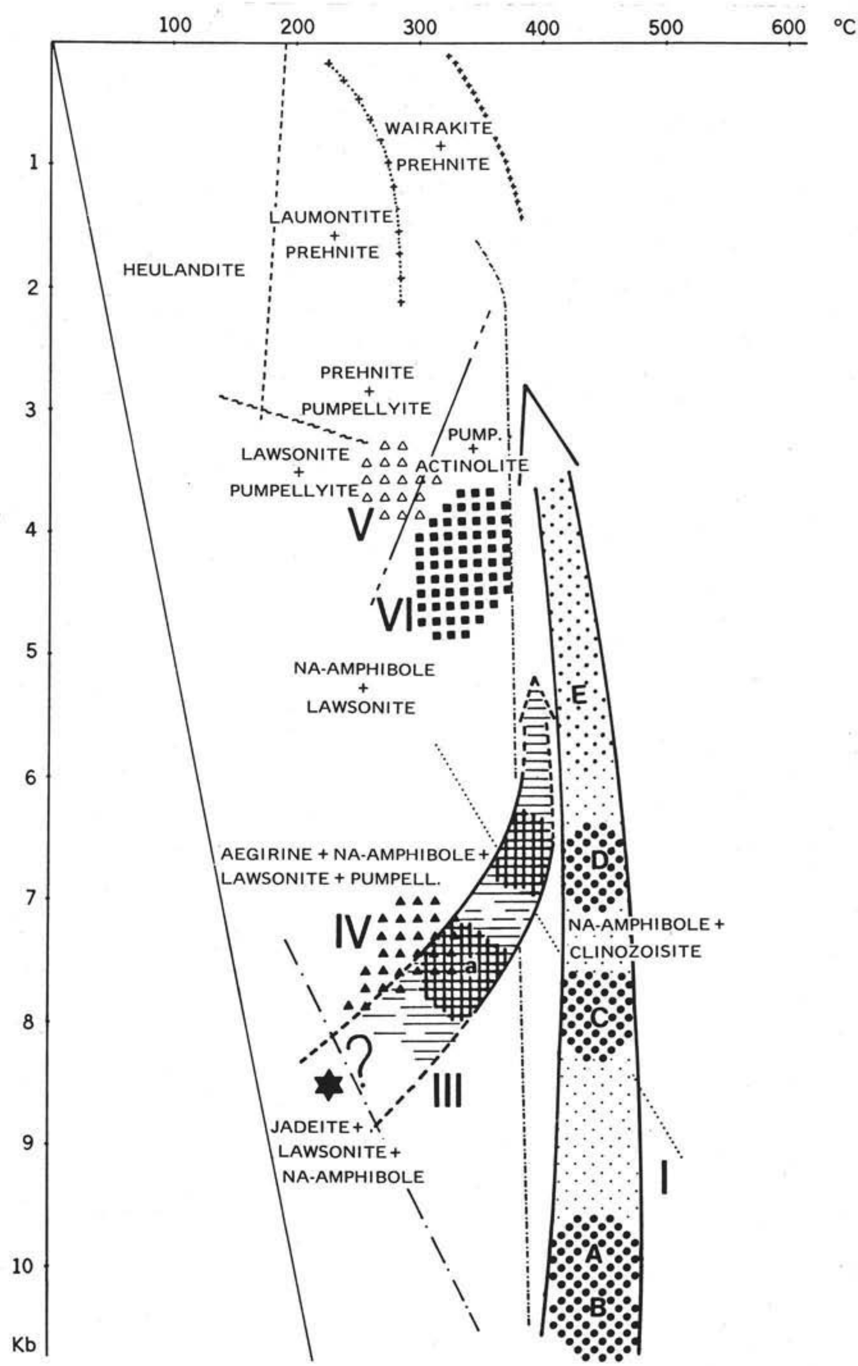
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Fig. 5.

— Erro - Tobbio Unit: tectonitic lherzolites and relic-bearing serpentinites;
— Calcescisti Units (Ortiglieto, Palmaro - Caffarella, Voltri - Rossiglione and Alpicella): calcescisti associated to prasinites, with different metamorphic characters.

As recently discussed by CHIESA et Al. (1975), on the whole, according to the field observation and interpretation, the main tectonic features of the Gruppo di Voltri are represented by the overthrust of slabs of oceanic lithosphere and sub-continental mantle over the margin of the paleo-European continent (Fig. 3).

Such feature must have characterized the whole massif and its present partial obliteration is due to later tectonic events which upset the primary arrangement by means of compressive and transcurrent effects, along more or less vertical faults, formerly with E-W direction and gradually changing to the more evident N-S direction.

The ultimate result of such events is represented by a differential counterclockwise displacement of the Gruppo di Voltri with respect to the Savona granitic massif, of the Eastern Voltri Units with respect to the Western ones, and of the Ligurian Apennines Units with respect to the Gruppo di Voltri (Fig. 4).

The reconstruction of the geodynamic evolution of the Gruppo di Voltri rests on the hypothesis that the Gruppo di Voltri and the Eastern Liguria ophiolitic Units occupied non-adjacent positions along their respective European and Insubric plate margins.

The trend of the trace of the Benioff plane, diverging southward from the continental margin of the Insubrian plate, is assumed to be the most significant factor for the coexistence of two main different metamorphic domains within the ophiolite sequences of the Ligurian area: the first one due to subduction zone conditions, the other one to conditions of weak metamorphism of low gradient.

Meta-ophiolites and pl-lherzolites constituting the Gruppo di Voltri are interpreted, respectively (Fig. 5), as oceanic material submitted to subduction metamorphic conditions and as slabs of pericontinental Insubrian upper mantle, emplaced by thrust-faulting over the paleo-European margin as a consequence of the continental collision.

The Eastern Liguria ophiolitic Units should represent, on the contrary, the oceanic section lying east of the Benioff zone, still preserved in the southern part of the basin after the northern one had already undergone a complete shrinkage; they will later be emplaced over the Insubrian-Tuscan margin.

The adjoining of the Ligurian Units to the Gruppo di Voltri has been referred to later transcurrent movements, assumed to give rise to a general roto-translational pattern of dislocations changing in direction from E-W to S-N, a trace of which should be represented by the Sestri - Voltaggio Zone.

The Oligocene transgression generally seals the main tectonic discontinuities of the Gruppo di Voltri, while later E-W faults, probably already active during the Oligocene, involve all the system, by now rigid, with events of subsidence along the Po-plain and Liguria edges.

To such tectonic events the cropping out of the Valosio massif (Forcella et Al., 1973) is referred; this granitic body, with hercinian metamorphism, would represent the sialic crust underlying the ophiolitic nappes of the Gruppo di Voltri.

## 2. The excursion

### 2.1. *The Voltri - Rossiglione Unit*

This Unit consists of a belt of calcescisti lying N-S, which separates the two major masses of ultramafites constituting the Gruppo di Voltri.

It is characterized by a set of isoclinal folds with sub-vertical axial planes, striking N-S and dipping E, which are cut by a system of inverse faults, generally parallel to such planes (Chiesa et Al., 1975; Chiesa & Rossi, in preparation).

Along the western margin of the belt, these faults are often marked by the occurrence of tectonic slabs of sheared serpentinites.

The limits between the Voltri - Rossiglione and the adjoining ultramafics are marked by compressive faults more or less parallel to the major discontinuities characterizing the Unit itself; such situation is disturbed by later faults striking SW-NE.

The rock types occurring in this Unit are represented by calcescisti, quartz-schists and prasinites: the last two types often occur as nuclei of tight antiforms.

Within this Unit dolomitic limestones and quartzitic rocks of different derivation also occur.

Where the tectonic events have not obliterated the primary relationships between different rock types, it is possible to recognize the originary sequence: prasinites - quartz-schists - calcescisti (Chiesa et Al., 1976; Mazzucotelli et Al., 1976; Chiesa & Rossi, in preparation).

The prasinites of the Voltri - Rossiglione Unit show a remarkable homogeneity as for schistosity, banded structure and typical porphyroblastic texture of albite.

Rare relics of Na-pyroxene (aegirinic augite), garnet and rutile testify for an earlier facies of HP conditions and comparatively low gradient, followed by a phase of strong deformation which produced isoclinal folds and probably the banded structures (Mazzucotelli et Al., 1976).

Following phases of metamorphic evolution with progressively decreasing pressures are shown by the blastesis of glaucophane and, later on, of blue-green amphibole, which form at expenses of the preexisting mafic minerals, and by reaction of garnet.

A second phase of deformation, characterized by a more open folding often of concentric style, involved these associations; the development of the most recent paragenesis (pistacite, actinolitic amphiboles, chlorites, porphyroblastic albite) is in many cases posterior to this event (Fig. 6).

The geochemical characters, on the basis of the trace elements which are believed least mobilized during metamorphic events like Ti, Cr, P, Zr, Y and Nb (Tab. 1,

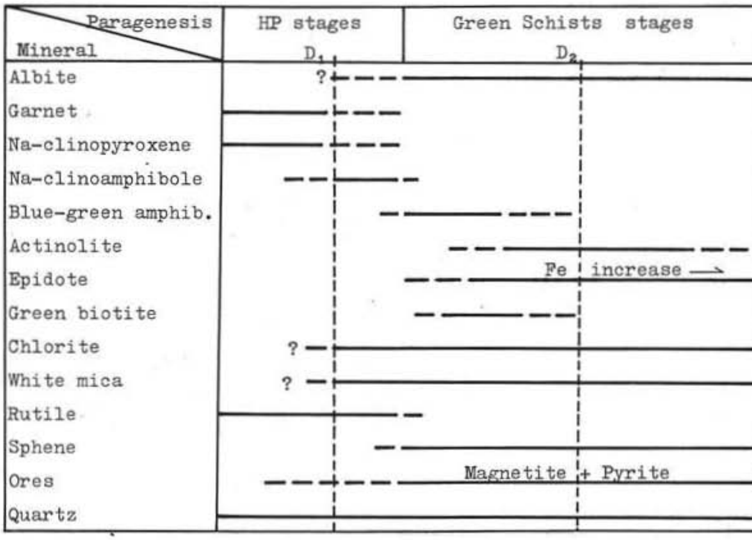


Fig. 6. — Metamorphic assemblages of Voltri-Rossiglione prasinites. $D_1$ and $D_2$ represent the main deformation events.

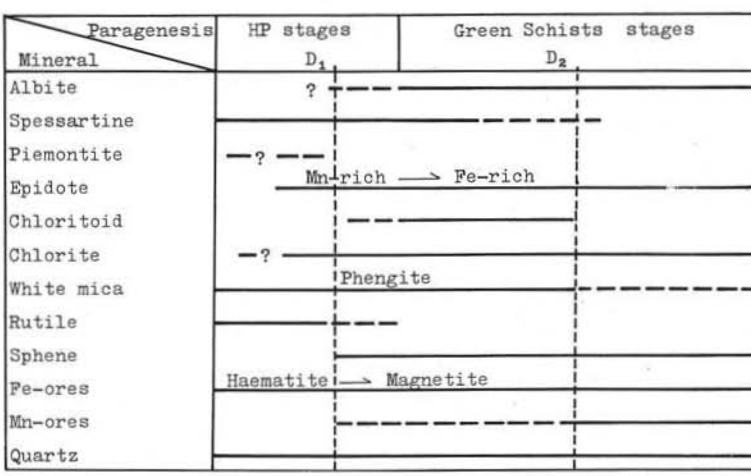


Fig. 7. — Metamorphic assemblages of Voltri-Rossiglione qz-schists. $D_1$ and $D_2$ represent the main deformation events.

and Fig. 8), show, for the parental volcanites, ocean-floor tholeiitic affinity, quite comparable with that of the slightly metamorphosed basalts of Northern Apennines ophiolitic suites.

The quartz-schists generally occur as two lithological types remarkably different at the outcrop scale (CHIESA et Al., 1976).

TABLE 1

*Trace elements average values of prasinites of the Voltri - Rossiglione Unit* (MAZZUCOTELLI et Al., 1976). *I) and II) represent tholeiitic basalts of Northern Apennines ophiolites* (BECCALUVA et Al., 1975, and FERRARA et Al., 1976, respectively)

| | Prasinites | | | Tholeiitic basalts N Apenn. ophiolites | |
|---|---|---|---|---|---|
| | $\bar{x}$ (39) | σ | range | $\bar{x}^{II}$ | $\bar{x}^{I}$ |
| $TiO_2$ | 1.55 | 0.37 | 1.06 - 2.41 | 1.53 | 1.78 |
| Ti | 9302 | 2273 | 6354 - 14447 | | |
| $P_2O_5$ | 0.22 | 0.08 | 0.11 - 0.40 | 0.24 | 0.23 |
| Cr | 223 | 76 | 103 - 400 | 259 | 256 |
| Zr | 132 | 35 | 60 - 200 | 154 | 163 |
| Y | 40 | 12 | 22 - 73 | 41 | 54 |
| Nb | 3 | 1.2 | 2 - 5 | 3 | 6 |

Elements are in ppm. Y/Nb ratios show relatively high values, the mean value being 14, the range 4.4 - 27.

The first type is fine-grained and homogeneous, with sparse quartz nodules and marked cleavage; it is characterized by the abundance of white micas, epidotes, garnets and opaques and often it presents concentrations of a dusty Mn-mineral (todorokite).

The second type exhibits a structure characterized by nodules and thin bands of quartz, due to folding and boudinage of quartz veins during different phases.

Its paragenesis consists of quartz, phengitic micas, chlorites, spessartine garnet and pistacitic epidote often with enclosed Mn-rich epidote preserved as armoured relics (Fig. 7).

Among the accessory phases there is abundance of tourmaline, apatite, sphene (rarely preserving rutile cores) and magnetite; chloritoid (often ottrelite) is generally rare but it may become abundant in some cases.

The mineralogy and, most of all, the high content of Mn-bearing minerals point out the equivalence of quartz-schists with cherts of Eastern Liguria sequences; the less transformed qz-schists of the Palmaro - Caffarella Unit show evident textural relics of radiolaria (CORTESOGNO, unpublished data).

The calcescisti of the Voltri - Rossiglione Unit are represented (CHIESA et Al., 1972; CHIESA et Al., 1975) by metasediments, characterized by well developed cleavage, grey colour and brightness due to the abundance of micaceous minerals: the lithological associations are quite variable as for compositional and structural characters and generally range from marbles to mica-schists.

The strong differences within each association reflect both primary abrupt changes in sedimentation and the results of strong deformation events.

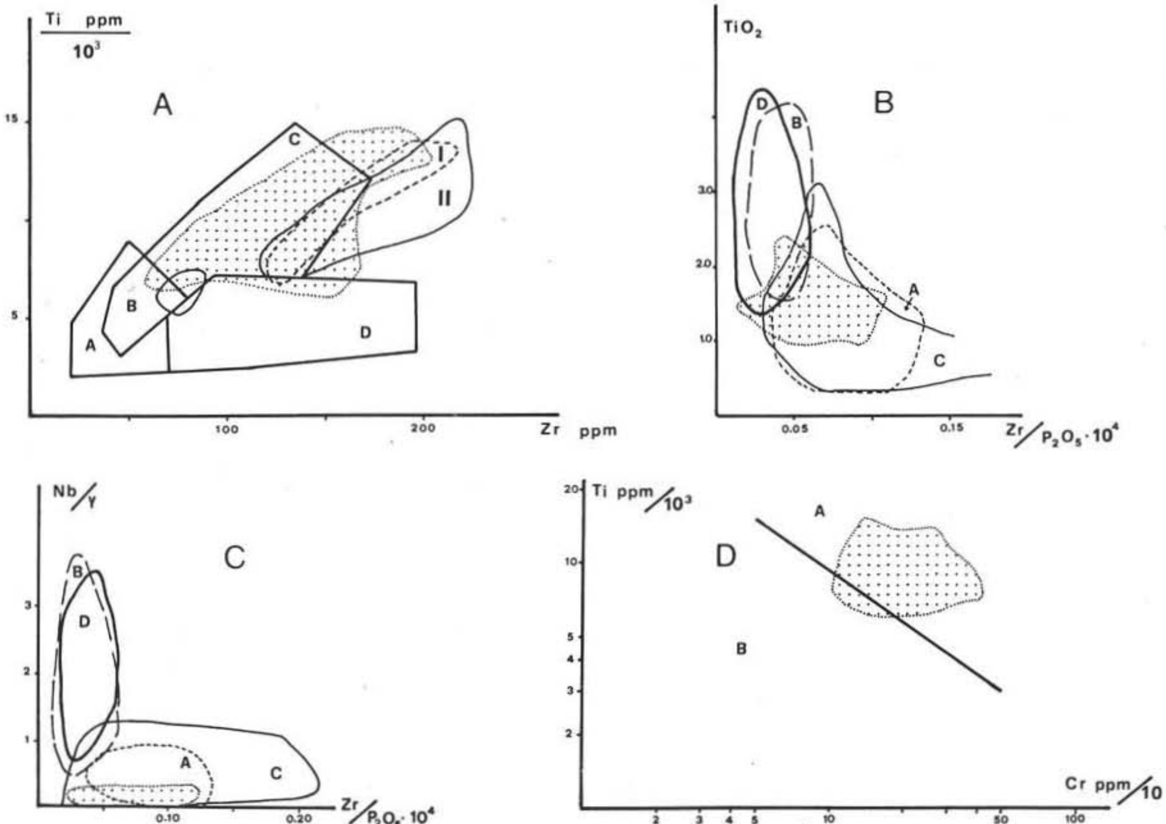


Fig. 8. — Trace elements plots: the dotted area represents the variation field of the Voltri - Rossiglione prasinites (MAZZUCOTELLI et Al., 1976).

A): Ti versus Zr plot (PEARCE & CANN, 1973). A and B fields = low K tholeiites; C and B fields = ocean-floor basalts; B and D fields = calc-alkali basalts. I) Tholeiitic basalts of Northern Apennines ophiolites (BECCALUVA et Al., 1975). II) Tholeiitic basalts of Northern Apennines ophiolites (FERRARA et Al., 1976).

B) and C): $TiO_2$ and Nb/Y versus $Zr/P_2O_5 \cdot 10^4$ plots (FLOYD & WINCHESTER, 1975). A = oceanic tholeiitic basalts; B = oceanic alkali basalts; C = continental tholeiitic basalts; D = continental alkali basalts.

D): Ti versus Cr plot (PEARCE, 1975). A = ocean-floor tholeiites; B = low K tholeiites.

Though transposed by such deformations, the interlayering of carbonates-rich levels with meta-pelitic ones must represent a primary depositional character, which therefore suggests a flyschlike deposition..

The mineral assemblage occurring in the most frequent types consists of carbonates (with prevailing calcite, sometime with variable dolomite content), phengitic, paragonitic and muscovitic micas, chlorites, albite, epidote, chloritoid, tourmaline, quartz, sphene, pyrite and rare green biotite.

The presence of paragonite (Liborio et Al., 1970) should testify for a metamorphic event in HP conditions, while the most important metamorphic phase is referable to conditions suitable for the stability of chloritoid.

Summing up, petrographic and stratigraphic characters of the prasinites - quartz-schists - calcescisti sequence of the Voltri - Rossiglione Unit show a substantial analogy with the oceanic volcanic-sedimentary sequence of Northern Apennines ophiolites.

The textural and paragenetic features of the different rock types lead to the identification of two main stages in their complex tectonic and metamorphic evolution (Figs. 6 and 7):

— an early phase in HP conditions;
— a following evolution in continuously changing conditions up to a general reequilibration in a PT field referable to Green Schists facies.

Outcrop *a*): *Masone* (Tav. MASONE, I SW Foglio 82, GENOVA): prasinites and calcescisti

Prasinites crop out as a lense within calcescisti, with tectonic contacts.

The green-greyish rocks show a banded structure, due to differential concentration of chlorites + amphiboles + epidotes and albite, respectively: such feature is probably related to tight similar folds of the earlier deformation event.

A second event of deformation is testified by open concentric folds; it is locally well evident the post-cynematic blastesis of the porphyroblastic albite.

Outcrop *b*): *Bric Picciu* (*Passo del Turchino*: tav. VOLTRI, II NW, Foglio 82, GENOVA): prasinites - quartz-schists - calcescisti

In the field the different rock types crop out as a fold with a nucleus of phyllitic-calcescisti and flanks of quartz-schists and prasinites: the primary sequence, slightly tectonized, is clearly recognizable.

Prasinites, deeply equilibrated in Green Schists assemblages with porphyroblastic albite, are generally strongly weathered.

Quartz-schists show both coarse lithotypes, with quartz-rich augens (often made of isolated hinges of folds), and fine-grained facies, with relatively abundant white micas, chlorites and spessartine.

Following the road toward W, the western limit of the Voltri - Rossiglione Unit is crossed: tectonic setting and relationships with the Beigua serpentinites (to the W) are locally well evident, by means of steeply dipping N-S faults accompanied by tectonic interfingering of sheared serpentinites within the Voltri - Rossiglione terrains.

These faulted contacts, characterized by important mylonitization and lack of metamorphic reactions, are to refer to late vertical and transcurrent movements: they upset the former tectonic setting of the main Units of the Gruppo di Voltri.

The mountains to the W (reaching 1000 m a.s.l.), deeply eroded along the southern side, consist of antigoritic serpentine-schists of the Beigua Unit.

### 2.2. *The Beigua Unit*

The Beigua Unit represents one of the major structural elements of the Gruppo Voltri and consists of antigoritic serpentine-schists often embodying lenses of metabasites, mainly consisting of eclogitic rocks (Chiesa et Al., 1975).

The western edge of this Unit is partially covered by calcescisti and prasinites of the Alpicella Unit, while in the southern zone calcescisti of the Ortiglieto Unit seem to dip underneath.

The northern and western edges are characterized by important faults, with average stike E-W, some of which preceded or accompanied the Oligocene sedimentation, while others followed it.

The serpentine-schists show an evident foliated structure, not always implying fissility, and several phases of deformation can be recognized.

The metamorphic assemblage consists of antigorite, magnetite, titanclinohumite and, rarely, calcite and tremolite.

Within the serpentinites, boundins and lenses of rodingitized basic rocks, sometimes preserving the primary dyke-like setting, can be found.

The primary textures are generally obliterated by the polyphasic recrystallization of granditic hydrogarnet, diopside, pennine, sphene, pistacite and idocrase.

The metabasites embodied within the serpentine-schists mainly consist of eclogitic rocks: the petrographic features are quite variable, mostly according to the different degree of reequilibration reached during their metamorphic evolution (Bocchio & Mottana, 1974; Messiga & Piccardo, 1974; Mottana & Bocchio, 1975; Cortesogno et Al., 1975; Cortesogno et Al., 1976; Ernst, in press).

In some outcrops the presence of relict textures and, more rarely, of paragenetic relics (Na-pyroxene pseudomorphs, coronitic garnet and interstitial plagues of Ti-ores) allows to recognize the intrusive character of the primary rock: its original mineral composition might have been Ti-augitic clinopyroxene, plagioclase and Ti-magnetite or ilmenite, in agreement with the magmatic assemblage of the Fe-gabbros of Northern Apennines ophiolites.

More often strong deformations have caused the eclogitic rocks to assume foliated structures, related to isoclinal folds, sometimes recognizable on the field, and blastomylonitic textures.

Several metamorphic phases are recorded in the eclogitic rocks and some outcrops preserve the whole paragenetic sequence.

The different stages of evolution can be synthetized as follows (after CORTESOGNO et Al., 1976; ERNST, in press):

— Stage A): blastesis of chloromelanitic pyroxene, garnet and rutile, with frequent pseudomorphic textures, occurred in static conditions;

— Stage B): strong deformation and clastesis of the first eclogitic paragenesis, accompanied and followed by recrystallization of Na-pyroxene and garnet, often with blastomylonitic textures;

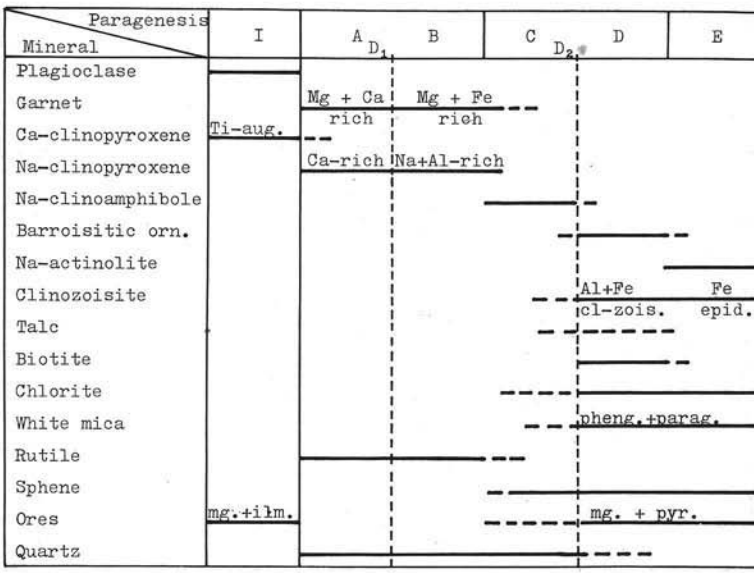


Fig. 9. — Metamorphic assemblages of Beigua eclogites (after CORTESOGNO et Al., 1976; ERNST, in press): these stages of metamorphic evolution are mainly referred to eclogitic rocks derived from Fe-gabbroic protoliths. I) Igneous assemblage; A) Precynematic eclogitic stage; $D_1$) First event of deformation; B) Mainly postcynematic eclogitic stage; C) Glaucophanitic stage; $D_2$) Second event of deformation; D) Barroisitic stage; E) Green Scists stage.

— Stage C): replacement of pyroxene by glaucophanic amphibole, while garnet probably still recrystallizes; a phase of deformation marks the separation from the following stage;

— Stage D): development of barroisitic blue-green hornblende, at expenses of glaucophane, together with epidote, sphene (by reaction on rutile) and interstitial albite;

— Stage E): late blastesis of actinolitic amphiboles, epidotes, chlorites and albite, as well developed porphyroblasts.

TABLE 2

*Average chemical composition of eclogites from the Gruppo di Voltri* (BOCCHIO & MOTTANA, 1974; CORTESOGNO et Al., 1975; CORTESOGNO et Al., 1976, in press)

| | $\overline{x}$(64) | σ | range |
|---|---|---|---|
| $SiO_2$ | 45.46 | 2.41 | 50.05 - 39.90 |
| $Al_2O_3$ | 10.55 | 1.48 | 16.40 - 7.89 |
| FeO tot. | 17.03 | 2.19 | 23.29 - 10.53 |
| MgO | 6.47 | 1.40 | 10.78 - 2.33 |
| MnO * | 0.26 | 0.06 | 0.47 - 0.13 |
| CaO | 9.14 | 1.46 | 17.22 - 6.35 |
| $Na_2O$ | 3.72 | 0.79 | 6.05 - 2.00 |
| $K_2O$ | 0.07 | 0.07 | 0.29 - 0.01 |
| $TiO_2$ | 4.42 | 1.52 | 7.30 - 0.50 |
| $P_2O_5$ ** | 0.40 | 0.33 | 1.92 - 0.10 |
| Cr ppm * | 118 | 35 | 350 - 79 |
| Ni ppm *** | 27 | 32 | 175 - 2 |

* average of 60 analyses; ** average of 41 analyses and *** average of 36 analyses (CORTESOGNO et Al., 1975; CORTESOGNO et Al., 1976).

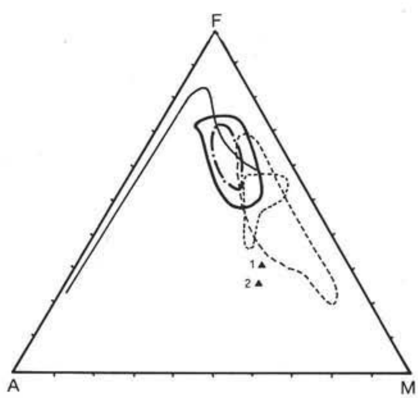


Fig. 10. — AFM diagram.

——— Skaergaard trend. ------- Oceanic gabbros of the middle-Atlantic Ridge (THOMPSON, 1973). ▬▬ Eclogites of the Gruppo di Voltri. ——— Fe-gabbros of the Northern Apennines (BOY et Al., 1976). ▬ - ▬ Fe-metagabbros of the Falda di Montenotte (BOY et Al., 1976). 1 ▲ Eclogitic metagabbros of the Gruppo di Voltri (average of 2 analyses, CORTESOGNO et Al., 1975. 2 ▲ Gabbros (pl + di ± ol) of the Northern Apennines ophiolites (average of 25 analyses, BECCALUVA et Al., 1976).

The eclogitic rocks, and especially those sections which underwent little reequilibration after the first eclogitic paragenesis, developed in anhydrous conditions and probably without important exchanges, show, for what concerns their chemical composition, peculiar features (BOCCHIO & MOTTANA, 1974; CORTESOGNO et Al., 1975; CORTESOGNO et Al., 1976).

Disregarding Ca, Na and K, which can easily be mobilized, eclogites are characterized by higher content of $FeO_{tot.}$, $TiO_2$, MnO, and a lower one of $Al_2O_3$,

$SiO_2$ (and often MgO) in comparison with the clinopyroxene- and olivine-bearing gabbros, which represent the most common intrusive rocks of the Northern Apennine ophiolites (Tab. 2).

On the contrary remarkable similarities in the chemical characters are shown in comparison with the Fe-gabbros of Northern Apennines and the Fe-metagabbros of the Falda di Montenotte, whose magmatic paragenesis consists of augitic clinopyroxene, andesinic plagioclase, Fe- and Ti-ores and, not rarely, apatite and zircon (Cortesogno et Al., 1975; Beccaluva et Al., 1976; Boy et Al., 1976) (Fig. 10).

Such compositional characters, together with relics of paragenesis and texture, confirm Fe-gabbroic protoliths, for this kind of eclogites, quite comparable with the most differentiated types of the Mid-Atlantic Ridge gabbros (« titanomagnetite-bearing gabbros of Thompson, 1973) (Bocchio & Mottana, 1974; Boy et Al., 1976).

Outcrop *c*): *Vara* (Tav. URBE, III NE Foglio 82, GENOVA):
eclogites and antigoritic serpentine-schists with rodingites

Along the road it crops out a huge lense of eclogite, embodied in serpentine-schists.

The dark coloured eclogitic rock shows foliated and banded structures and generally fine-grained blastomylonitic textures.

Major porphyroclasts (up to 4-5 mm in size) are rarely preserved and consist of precynematic pseudomorphs of chloromelanitic pyroxene.

The former HP metamorphic parageneses (Na-pyroxene + garnet + rutile) are partially replaced by glaucophane and barroisite + epidotes assemblages: this equilibration is deeply developed near to the contacts with enclosing serpentinites.

In the outcrop this contact runs more or less orizontal for several tens of m, and it is marked by a reaction zone characterized by fibrous serpentine and chlorites, and sometimes talc and tremolitic amphiboles.

The antigoritic serpentinites show green colour with black patches, due to magnetite concentrations: tremolite is rarely present, while titanclinohumite is generally confined in brownish bands.

Serpentinites are strongly laminated along the contact with eclogitic bodies: for their easy cleavage these rock types are locally quarried and utilized as building material.

Within the serpentinites rodingitized gabbroic dykes are sometimes well preserved: their main assemblage consists of granditic garnet, idocrase, diopside, sphene, magnetite and chlorites.

They show a dark reaction zone against the enclosing ultramafites, mainly made of chloritic material.

From Vara to Sassello and then to Ponte Erro the road runs across the Oligocene sequences, transgressive on the Voltri terrains.

Between Vara and Sassello the « Formazione di Molare » (Note illustrative al Foglio 82, GENOVA, Carta Geologica d'Italia, with references) is mainly represented by conglomerates with beds of sandstones, marls and siltites: elements mainly consist of serpentinites, metabasites and calcescisti; locally coralline limestones and lignite are found.

Near Prato Vallarino eclogitic rocks crop out under the cover of Oligocene molasse.

At the Sassello village the lowermost section of Oligocene sediments is represented by conglomerates and sandstones, referred to a brackish environment: they are followed upwards by sandstones and marls of marine sedimentation.

Along the road from Sassello to Ponte Erro Oligocene molasse lie on lherzolites and serpentinites of the Erro - Tobbio Unit.

### 2.3. *The Erro - Tobbio Unit*

The lherzolites and serpentinites masses, cropping out as uppermost structural elements above the S. Luca - Colma and Ponzema Units (antigoritic serpentine-schists with eclogites), are ascribed to this Unit.

They consist of tectonitic lherzolites, with minor harzburgites and dunites, and rarely pyroxenitic bands: the different rock types locally show well developed banded structures.

The main mineral assemblage is represented by prevailing forsteritic olivine, various proportions of enstatitic orthopyroxene and diopsidic clinopyroxene, and few percents of Al-chromian spinel.

This spinel-bearing facies generally reacted and reequilibrated in plagioclase-bearing assemblages, mainly testified by growth of plagioclase rims around the spinel grains.

Locally a strongly developed deformative effect, followed by recrystallization of olivine-pyroxenes - plagioclase assemblages, originated gneissic and blastomylonitic textures.

A first stage of serpentinization, always present and sometimes completely developed, produced lizardite and Fe-ores and was accompanied by chlorites replacement on pyroxenes and saussurite on plagioclase.

Later on antigorite developed in connection with faulted and shear zones related to the relatively recent tectonic evolution of this ultramafic Unit.

Small lenses and dykes of cpx-gabbros are present within the ultramafites: these basic intrusions present poorly developed rodingitic and Green Schists assemblages, but show no evidence of having passed through an eclogitic stage.

As a whole the metamorphic characters and tectonic relatioships of the Erro - Tobbio lithological associations point out their different evolution in respect to the other ultramafic Units of the Gruppo di Voltri.

Outcrop *d*): *Ponte Erro* (Tav. BANDITA, IV SW Foglio 82, GENOVA): relic-bearing serpentinites with small gabbroic dykes; Green Schists metabasites

In this outcrop serpentinized ultramafics of the Erro - Tobbio Unit show a tectonic contact, by means of more or less vertical N-S faults, with metabasites of the formerly underlying metamorphic ophiolitic Units.

Ultramafics mainly consist of deeply serpentinized lherzolites with well preserved textural and paragenetic relics: small gabbroic dykes, slightly rodingitized, are visible in the outcrop.

Metabasites, locally foliated and deeply reequilibrated in Green Schists assemblages (chlorites, epidote, albite and actinolitic amphibole), show a gabbroic origin and relics of a former HP recrystalization.

Siliceous and sulfides mineralizations, genetically related to zeolitic associations, are often present along the faults and within the basal sections of the Lower Oligocene molasse.

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