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SHORT NOTE

THE BARGONASCO - UPPER VAL GRAVEGLIA OPHIOLITIC SUCCESSION, NORTHERN APENNINES, ITALY

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INTRODUCTION

The Northern Apennines ophiolitic successions pertain to the Ligurian orogenic units, which were thrust onto the Adria continental margin (Tuscan and Umbrian Units) and show two different types of stratigraphic settings (Fig. 1) (Abbate et al., 1980):

a- as "oceanic basement" of the Vara Supergroup, one of the higher units of the tectonic pile ("Internal Ligurides");

b- as olistoliths of variable sizes, accompanied by ophiolitic breccias, included in the Upper Cretaceous - Eocene terrigenous successions of the "External Ligurides" tectonic units.

The Val Graveglia-Bargonasco area represented in the map, is located in eastern Liguria, on the northwesternmost side of the Northern Apennine, where most and more complete ophiolitic sequences of type a- crop out (the "Mt. Porcile Unit, Fig. 1). They consist of mantle peridotites (from clinopyroxene-poor lherzolites to harzburgites) and gabbros, which form the "oceanic basement", metamorphosed and tectonically denudated before the volcano-sedimentary cover (ophiolitic breccias, basalts, cherts, carbonate and carbonate-shaly pelagites, and finally siliciclastic turbidites) was deposited.

The tectonic scheme (Fig. 1, partially modified from the "schema tettonico" of the geologic map) shows that the Porcile Unit, object of our study, includes seven subunits separated by minor thrusts, i.e., from west to east, Mt. Domenico, M. Bianco, Rio Gromolo, Mt. Ciazze, M. Bocco, Rivo Orti, Mt. Tregin Subunits. The stratigraphic successions of all the Subunits pertain to the Vara Supergroup (see the stratigraphic Scheme on the geologic map).

This short note summarises a more extensive one, about the geologic evolution of this same area, which will be published in the Atti Ticinensi di Scienze della Terra, Pavia, Italy, 2004. We decided to write this short summary to advertise the map of this key area for understanding the geology of the Northern Apennine ophiolites.

STRATIGRAPHY

The "Schema stratigrafico" on the map shows the distribution and thicknesses of the formations of the Mt. Porcile Unit. In some subunits the succession includes almost all the formations described below ("complete successions"; e.g., Mt. Alpe Subunit), in others the succession is extremely reduced ("reduced successions"; e.g., Montedomenico Subunit).

Mt. PORCILE UNIT

The Basement

Serpentinites from mantle peridotites
("***Serpentiniti a relitti di strutture tettonitiche***" in the map)

The serpentinites (from clinopyroxene-poor lherzolites to harzburgites), are dark green, intensely fractured, and generally have abundant pyroxenes and rare spinels and, sometimes, allotriomorph plagioclases, included in a serpentinitic mass. On top of Mt. Fucisa, fresh lherzolites with a compo-

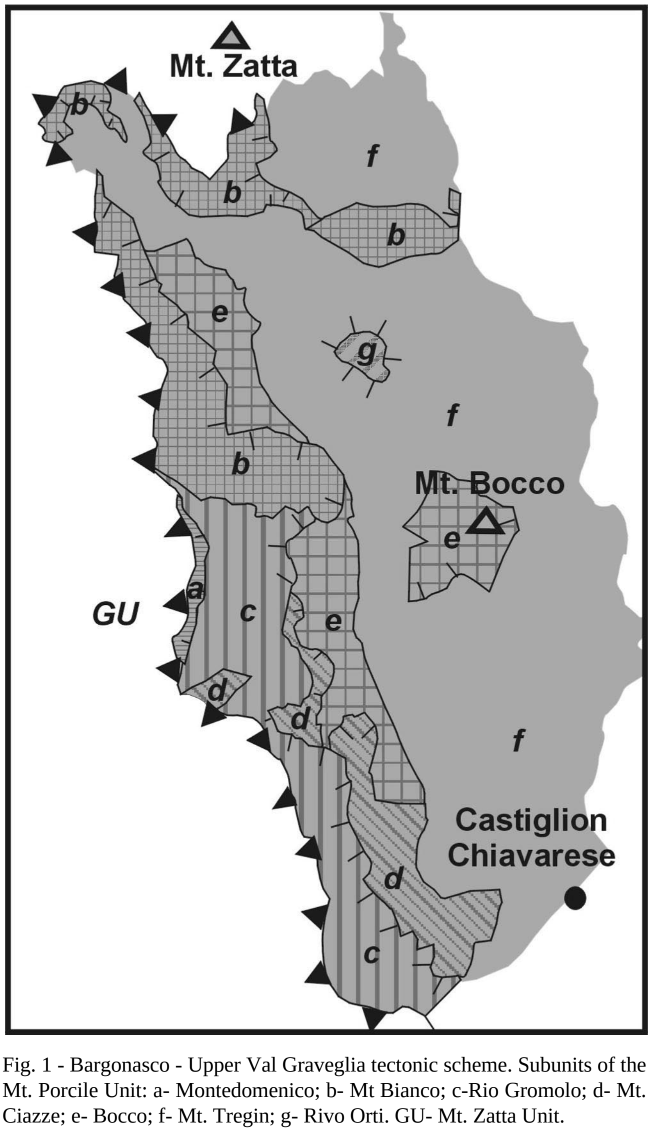

Fig. 1 - Bargonasco - Upper Val Graveglia tectonic scheme. Subunits of the Mt. Porcile Unit: a- Montedomenico; b- Mt Bianco; c-Rio Gromolo; d- Mt. Ciazze; e- Bocco; f- Mt. Tregin; g- Rivo Orti. GU- Mt. Zatta Unit.

sitional tectonic banding are present.

The structure is blastomilonitic; serpentinisation (lizardite and crisotile) is generally intense and pervasive. These rocks are spinel peridotites partially re-equilibrated to plagioclase lherzolites with rare dunites (Beccaluva et al., 1980; 1984).

Peridotites and gabbros suffered a polyphase retrograde oceanic metamorphism, of which serpentinisation and rodingitisation occurred in the last step (see later).

The serpentinites either grade into the Ophicalcites or are covered by the Casa Boeno and Mt. Capra Breccias.

In the study area the contacts with gabbros are always tectonic, but nearby, in the Bracco area, intrusive contacts of gabbros into the serpentinised peridotites are visible (Cortesogno et al., 1987).

Gabbros (“*Gabbri*” in the map)

Coarse- and middle-grained Mg-gabbros (from leucogabbros to gabbros and olivinic gabbros) occur as isotropic masses, often intensely wheatered. They have either a layered structure, sometimes with wherlitic bands near the base, or a granular ipidiomorphic, rarely pegmatitic texture (Beccaluva et al., 1980).

Three phases of retrograde oceanic metamorphism affected gabbros and peridotites: a- an amphibolitic facies (550-700°C and 2-5 kb), b- a greenschist facies (300-500°C and ~ 1 kb); c- a prehnite - pumpellyite facies (230-350°C and 1-1.5 kb). Phases b- and c- are present also in the basalts (see below).

An age of 164±14 Ma (Sm/Nd) has been determined by Rampone and Hofman (1998), and probably corresponds to the Bajocian-Bathonian.

The gabbros are covered by basalts through thin levels of ophiolitic (mainly gabbroic) breccias.

The Cover

At the top of the serpentinite-gabbro “basement”, volcano-sedimentary successions, both complete or reduced crop out. The complete ones include some ophiolitic breccia levels (“Lower” and “Upper” Breccias, with respect to the basalts), basalts, cherts and calcareous and calcareous-shaly pelagites; the reduced successions are characterised by the lack or the extreme thinness of basalts and breccias, and sometimes also of the calcareous pelagites.

Lower Ophiolitic Breccias
(“*Brecce Ofiolitiche Inferiori*” in the map)

These ophiolitic breccias include the Ophicalcites s.l., the Casa Boeno and Monte Capra Breccias. At the top of the serpentinites, serpentinitic breccias prevail; at the top of the gabbros, gabbroic breccias prevail. All the ages of the Lower Breccias have been deduced by radiolarian assemblages (Chiari et al., 2000, with bibl.)

Ophicalcites (“*Oficalciti*” in the map)

They are constituted by a basal tectonic level, the Ophicalcites s.s., called by Cortesogno et al (1987) *Levanto Breccia*, and by an upper sedimentary level, called by the same authors *Framura Breccia*. In the map these two levels are not separated.

1- *Levanto Breccia*

This breccia constitutes the carapace of the serpentinites cropping out in the ocean floor. It is a tectonic - hydrothermal breccia made of serpentinite blocks pervaded by many swarms of open fractures filled by sparry calcite, talc and, in the larger ones, also by serpentinite fragments in a micriti matrix (see Treves and Harper, 1994). It grades upwards to the Framura Breccia.

2- *Framura Breccia*

This is a sedimentary breccia consisting of serpentinitic, and very rarely gabbroic clasts, in an abundant micritic-serpentinitic matrix, somewhere hematitic.

The age is middle Bathonian - early Callovian.

This breccia can grade upwards to the Mt. Capra Breccia, Basalts or Mt. Alpe Cherts.

Casa Boeno Breccia (“*Breccia di Casa Boeno*” in the map)

This is a massive, sedimentary monogenic breccia made of serpentinite clasts in a more or less scarce sandy serpentinite matrix. It includes also some big serpentinite olistoliths. No fossils have been found; the age could be late Bathonian - early Oxfordian, according to a radiolarian association found at the top of these breccias some kilometres south of the study area (Abbate et al., 1986; Chiari et al., 2000).

This breccia lies on top of the serpentinites and has no stratigraphic cover.

Monte Capra Breccia (“*Breccia di M. Capra*” in the map)

This is a massive, polygenic breccia, with Fe-gabbro and minor Fe-basalt, plagiogranite, Mg-basalt and serpentinite clasts, in a scarce sandy gabbroic matrix.

The age, latemost Bajocian - early Callovian, is deduced from a radiolarian association in a cherty intercalation (Chiari, 2000).

This formation is covered by the Basalts.

Basalts (“*Basalti*” in the map)

The basalt flows are mainly pillowed, but rare massive basalts are present. In the pillow basalts, jaloclastites are often present as matrix or thin levels. The primary mineralogical phases are augite and plagioclase, with an ophitic structure. The spilitic chemistry shows affinities with the N- and T-MORB (Beccaluva et al., 1980, etc.).

The age of the basalts is comprised between the latemost Bajocian-early Callovian (age of the underlying Mt. Capra Breccia) and the middle Bathonian-early Callovian (age of the overlying Mt. Alpe Cherts).

The basalts can be covered by the Movea, Mt. Zenone, Mt. Bianco Breccias, or directly by the Mt. Alpe Cherts.

Upper Ophiolitic Breccias
(“*Brecce Ofiolitiche Superiori*” in the map)

These ophiolitic poligenic breccias include the Movea, Mt. Zenone and Mt. Bianco Breccias.

Also the ages of the Upper Breccias have been deduced by radiolarian assemblages (Chiari et al., 2000, with bibl.)

Mt. Bianco Breccia (“*Breccia di M. Bianco*” in the map)

This massive breccia is made up of serpentinite and ophicalcite clasts, with a very abundant sparry matrix, somewhere limonitised.

The age of this breccia is late Bajocian - early Callovian.

Movea Breccia (“*Breccia di Movea*”in the map)

This massive polygenic breccia, generally linked to the Mt. Zenone Breccia, consists of foliated gabbro, and minor pillow basalt and serpentinite clasts, with a sandy gabbroic cloritised matrix.

The age is late Bajocian - early Callovian.

It grades upwards to the Mt. Zenone Breccia.

Mt. Zenone Breccia (“*Breccia di M. Zenone*” in the map)

This is a monogenic massive breccia, with clasts of foliated (flaser) gabbros in a sandy gabbroic matrix.

The age is middle Bathonian - early Callovian, the same of the overlying Mt. Alpe Cherts (see later).

This breccia grades upwards to the Mt. Alpe Cherts.

Mt. Alpe Cherts (“*Diaspri di M. Alpe*” in the map)

This formation comprised red radiolarites, ftanites and siliceous shales. Near the base, manganiferous levels are present, which were exploited until the 1950’. Upwards, five litofacies crop out, from the base upwards: a- ophiolitic siltites with thin chert beds; b- thin stratified red radiolarites, porcellanites and siliceous shales; c- varicoloured cherts; d- greenish and red regularly alternating cherts; e- siliceous laminated red and green siltites.

The age of the base is late Bathonian - early Callovian (Chiari et al., 2000); the age of the top, more difficult to define, due to the lack of fossils, is deduced by the ages of the overlying formations, and seems to vary between late Tithonian and Berriasian.

The Mt. Alpe Cherts grade upwards to the Calpionella Limestones or directly to the Palombini Shales.

Calpionella Limestones
(“*Calcari a Calpionelle*” in the map)

Light grey, partly resedimented micritic limestones constitute the main lithology of the formation, which can be subdivided into four lithozones, from the base upwards: a- silicified micritic limestones alternating with red or varicoloured shales; b- whitish micritic limestones with very thin shale levels; c- whitish micritic limestones with very thin shale levels and detritic limestones; d- thin bedded grey micritic limestones.

The age is Tithonian at the base and Berriasian at the top (Cobianchi and Villa, 1992).

The Calpionella Limestones grade upwards to the Palombini Shales

Palombini Shales (“*Argille a Palombini*” in the map)

This pelagic formation consists of dark grey shales and minor marly shales, with grey micritic silicified limestone intercalations; in the upper portion of the formation the limestones diminish, substituted by siltstones and quartzarenites. The basal portion of the Palombini Shales pertains to the Mt. Porcile Unit; the upper one to the Mt. Zatta Unit, because it is crossed by a shear surface separating the Mt. Porcile Unit from the overlying Mt. Zatta Unit.

The age is comprised between the Valanginian and the Aptian top (Cobianchi and Villa, 1992; Cobianchi et al., 1994); in near areas the formation seems to reach the Santonian (Marroni and Perilli, 1990).

Mt. ZATTA UNIT

The Mt. Zatta Unit is constituted by a succession which comprises the upper portion of the Palombini Shales, the **Val Lavagna Formation** (a turbiditic alternance of siltites, silty sandstones and shales of Late Cretaceous age; “***Formazione della Val Lavagna***” in the map) and the **Mt. Gottero Sandstones** (a siliciclastic flysch of Late Cretaceous - Paleocene age; “***Arenarie del M. Gottero***” in the map).

In the southern study area, at the base of the Palombini Shales a thin level of Mt. Alpe Cherts crops out.

TECTONICS

The oceanic phases

The orogenic tectonic phases were preceded by a very long oceanic tectono-metamorphic history which, from the data collected in this area, can be summarised as follows:

a- The mantle peridotites show remnants of tectonitic structures (compositional banding) with parageneses of re-equilibration from spinel- to plagioclase-lherzolites, testify the uplift from deep zones of the mantle. The partial fusion was feeble.

b- A magmatic event which preceded the serpentinisation is shown by the rodingites cutting the peridotites, and probably formed the gabbro masses (164±14 Ma, Rampone and Hofman, 1998) in small oceanic magma chambers (e.g. in the near Bracco Massif, Cortesogno et al., 1987).

c- a metamorphic event followed, with high thermic gradients (~700°C) and formation of brown hornblende, augitic pyroxenes, and flaser to milonitic structures.

d- a second event with lower temperatures formed hornblende, actinolite and oligoclase which filled the first fractures caused by uplift; serpentinisation begins at this stage.

e- in the mantle rocks approaching the ocean floor, tectonic and hydrothermal processes caused the serpentinisation of peridotites, rodingitisation of gabbro dikes and formation of the Levanto Breccias.

f- serpentinites and gabbros reached the ocean floor, forming steep slopes, bounded by active faults which shed clasts to submarine talus breccias like the thick massive sedimentary “lower ophiolitic breccias” formed.

g- a new magmatic phase formed the basalt cover in an uneven ocean floor, and contemporaneously the “upper ophiolitic breccias”.

h- a second metamorphic cycle, induced by basalt activity and accompanied by intense hydrothermal fluids circulation shows high gradient parageneses in the whole ophiolitic succession and affected also same “lower ophiolitic breccias”.

The oceanisation model

The field data emphasised the peculiarity of this thin and incomplete oceanic crust, very different from the “classic” one. Together with the succession of events just described (valid also for the nearby Bracco Massif ophiolites; Cortesogno et al., 1987), they led us, in the 1980, to propose an interpretative model based on the analogy between Apenninic ophiolites and present-day transform fault crust (Gianelli and Principi, 1977; Abbate et al., 1980; 1986). According to this model, the ophiolitic succession formed in a small oceanic domain (Western Tethys) dominated by large transform fault zones (linked to the strike-slip movement between Africa and Europe; Olivet et al., 1984) along which serpentinised ultramafites protruded. Successively, Abbate et al. (1994), in a paper on the oceanisation of Western Tethys, discussed three models: i- the transform fault zone; ii- the very slow spreading ridge, iii- the crustal delamination models. They concluded that the three hypotheses are not mutually exclusive, and could be applied to different stages and or to different sections of the Northern Apennines ophiolites. Recent observations on the Atlantic and Indian slow spreading ridges revealed characteristics very similar to those of the Northern Apennines ophiolites (Turcotte and Lin, 1994)

The orogenic phases

The ophiolitic succession of the Bargonasco-Val Graveglia area of the Mt. Porcile Unit suffered ductile and brittle deformations during the Apenninic orogeny.

The Rivo Orti, Mt. Bocco, Mt. Alpe, Mt. Ciazze, Rio Gromolo and, perhaps, Montedomenico Subunits are portions of a "megafold", successively sliced by some minor thrusts. As shown in the sections, the "megafold" is an eastwards vergent recumbent fold (see Decandia and Elter, 1972 and Braga et al., 1972), the main outcrops of which pertain to the reverse limb (Rio Gromolo, Mt. Ciazze and Mt. Alpe Subunits; the latter at its eastern termination, along the Mt. Coppello - Mt. Pu divide comprises the hing of the fold, with minor normal areas). Mt. Bocco s.s. Subunit peridotites constitute the core. Rivo Orti Subunit represents the only small outcrop of the lower normal limb. This structure, and the minor thrusts which successively separated the subunits, pertain to early Apenninic phases, probably of Paleocene-Eocene age. Subsequently, during the Eocene, both the Mt. Porcile and the overlying Mt. Zatta Unit of the Internal Ligurian Domain, were thrust onto the External Ligurides and, during the Late Oligocene - Early Miocene all the Ligurian Units were trust onto the Adria (Apenninic) continental margin (Tuscan and Umbrian Domains). The illite crystallisation index shows that in the study area the orogenic deformation developed in diagenetic conditions (Pacciotti, 2000).

In more recent times (Late Miocene - Quaternary), a brittle tectonic phase affected all the pile of units with a set of N-S high angle normal faults which created an horst sited in the central area, along the alignment Mt. Tregin - Mt. Roccagrande - Mt. Baralucco and probably caused gravity processes. In fact, mesostructural data show at least two phases: after the main compressive phase linked to the megafold, a second one, characterised by minor horizontal fold planes, could be linked to late gravitational collapse.

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