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Pre-orogenic tectonic framework of the northern Apennine ophiolites

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Key words: Ligurian Tethys, northern Apennine ophiolites, rifting, history, pre-orogenic shear zones, structural geology

ABSTRACT

The results of a structural investigation of the Northern Apennine ophiolites are presented focusing on different generations of shear zones developed both in the mantle and in the intruded gabbros during their uplift. Relationships between continental crust rocks and ophiolites are also discussed. The overall sets of data can be coherently inserted in models of passive rifting as recently proposed by different authors. A brief discussion on the evolution of the northern Apenninic/Corsica-Briançonese continental margins points to a rifting history progressively changing from symmetric (or slightly asymmetric) to asymmetric and ending up with mantle-gabbro denudation on the 'ocean' floor.

RIASSUNTO

Sono qui presentati alcuni risultati di uno studio geologico-strutturale sulle ofioliti dell'Appennino settentrionale ed in particolare sulla loro evoluzione pre-orogenica, testimoniata da differenti generazioni di zone di taglio che si sviluppano sia all'interno delle porzioni di mantello che nei gabbri in esse intrusi. Viene inoltre discusso il possibile significato delle relazioni tra rocce di crosta continentale ed ofioliti osservabili in alcuni settori dell'Appennino. Tutti i dati raccolti possono essere inseriti nei modelli di rifting passivo proposti negli ultimi anni da differenti autori. Una breve analisi di alcuni caratteri dell'evoluzione dei margini continentali nord-Appenninico/Corso-Brianzonese indica un'evoluzione che si modifica con il tempo da rifting simmetrico (o debolmente asimmetrico) ad asimmetrico con denudamento finale del basamento ultramafico/gabbrico a costituire il fondo ‹oceanico›.

Introduction

Since the early Seventies the northern Apennine ophiolites have been utilized as a reference for the study of the features of the Mesozoic Ligure-Piemontese oceanic domain, thanks to their very low grade orogenic metamorphism (prehnite-pumpellyte in metabasic rocks) associated with a deformation at high structural levels, which allowed an accurate reconstruction of the primary features of the ophiolites (Decandia & Elter 1969; Abbate et al. 1980; Barrett 1982; Cortesogno et al. 1987 and bibl.).

Their peculiar characteristics have been soon recognized as being shared by other Ligurian Tethys-derived ophiolites (Lemoine et al. 1970; Dal Piaz 1971; Elter G. 1971; Amaudric du Chaffaut et al. 1972; Trümpy 1975) and quoted as a typical feature of the former oceanic basin.

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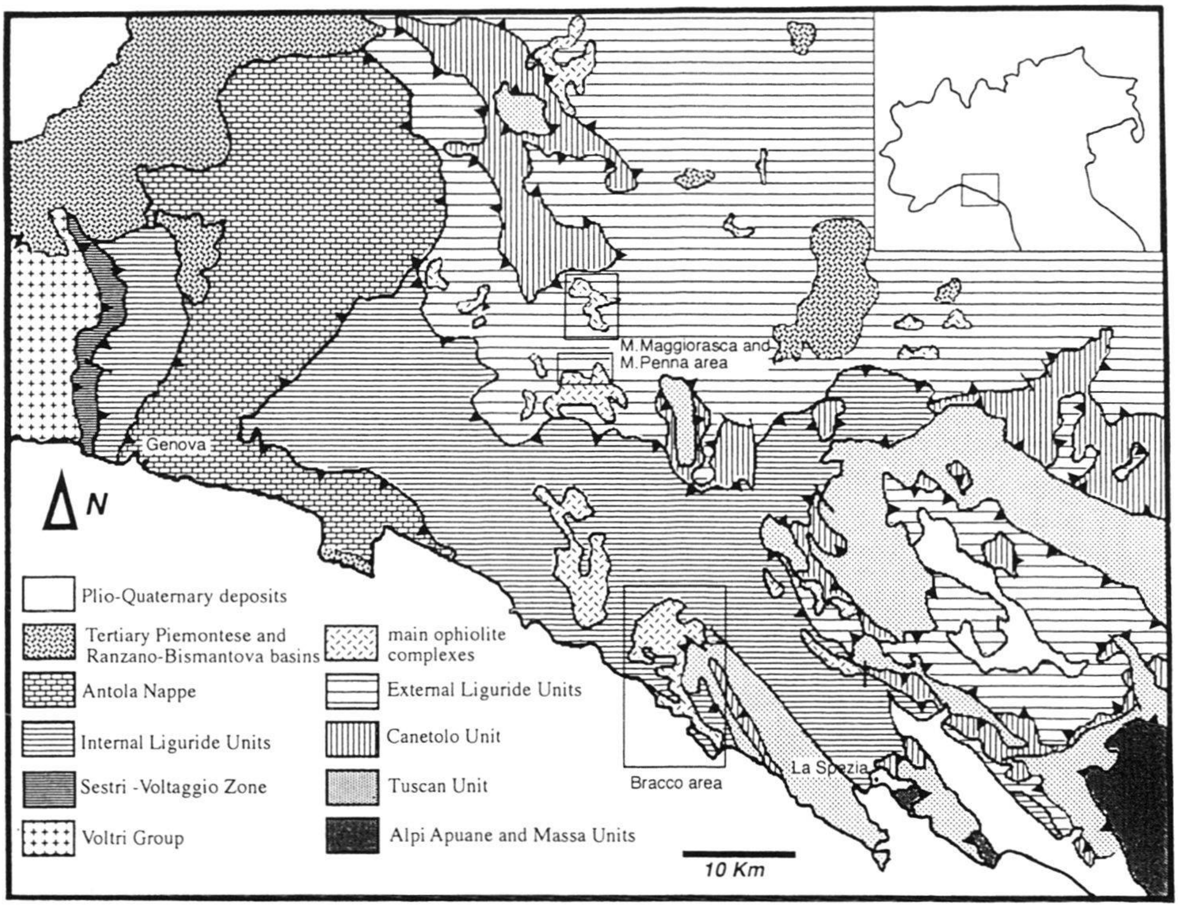


Fig. 1. Geological sketch map of the Northern Apennine with location of the areas quoted in the text.

In this paper I will present data relative to the pre-orogenic structural history affecting ultramafic and gabbroic rocks before the intrusion of basaltic dykes and radiolarian sedimentation, as well as discuss its possible significance. Some details of the analysis have already been presented elsewhere (Molli 1994; Molli 1995), but their general implications have not yet been examined, nor has the meaning of the outcrops showing relationships between ophiolites and continental basement rocks been considered.

All our data can be coherently inserted in models of ocean opening in a 'passive' rifting setting as recently proposed by different authors for the evolution of the Ligurian Tethys.

Geological setting

In the Apennine the Liguride Units occupy the highest position in the nappe pile. On the basis of stratigraphic and structural features, they have been subdivided into two main systems (Elter & Pertusati 1973): the Internal Liguride Units and the External Liguride Units (Fig. 1).

The Internal Liguride Units are characterized by the presence of ophiolites and their sedimentary cover (cherts, Calpionella limestone and Palombini shales) associated with a thick turbiditic sequence evolving through time from distal to proximal (Lavagna shales, Gottero sandstones and Bocco/Colli-Tavarone shaly-complexes, Abbate et al. 1980; Casnedi 1982; Treves 1984; Marroni 1990). They are considered as remnants of the Ligure-Piemontese ocean which, starting from Paleocene (age of the youngest sedimentary melanges, Bocco/Colli Tavarone shaly-complexes), was involved in an 'alpine' accretionary wedge (reviews in Van Wamel 1987; Marroni 1990; Galbiati 1990; Hoogerduijn Strating 1994).

On the other hand, the External Liguride Units are distinguishable for the presence of the typical Cretaceous-Paleocene calcareous-dominant sequences (Helminthoid Flysch) associated with complexes or pre-flysch formations called 'basal complexes'. According to their stratigraphic differences, two main groups of units can be recognized: those associated with ophiolites and in some cases with relicts of their original sedimentary cover, and others without ophiolites and associated with fragments of mesozoic sedimentary sequences and conglomerates with austro-southalpine affinity (cfr. Elter et al. 1966; Elter 1975; Zanzucchi 1988).

The origin of the 'basal complexes' can be linked with an Early (?) to Late Cretaceous deformation of the original paleogeographic External Ligurian Domain due to transpressive tectonics affecting the southern part of the ocean as well as the adjacent continental margin (cfr. Bertotti et al. 1986; Zanzucchi 1988).

Pre-orogenic history of the ophiolitic sequences in the Internal Ligurian Domain

The Internal Liguride Units represent a classical area for the study of the Apenninic ophiolites and their general features are well known (Passerini 1965; Abbate 1969; Decandia & Elter 1972; Piccardo 1977; Abbate et al. 1980; Barrett 1982; Cortesogno et al. 1987). They consist of ultramafics, generally covered by ophicarbonate breccias (ophicalcite), gabbroic complexes, in which the most abundant lithotype is represented by Mg-gabbros. Fe-gabbros are also present although never showing primary relationships with Mg-gabbros (Serri 1980).

Plagiogranitic differentiates (diorites, quartz-diorites and trondhjemites) occur as dykes and veins, mainly intruding gabbros but also massive and pillow lavas (Serri 1980). Ultramafic and gabbroic rocks are locally covered by ophiolitic sedimentary breccias interleaved with MORB-type basaltic flows (Abbate et al. 1980). The sedimentary cover consists of cherts (Callovian-Oxfordian), Calpionella Limestone (Berriasian) and Palombini shales (Berriasian-Aptian) (Cobianchi et al. 1994).

The peculiar characteristics of the Apenninic ophiolites can be summarized as follows: 1) the ultramafics, showing widespread serpentinization, represent the most diffuse ophiolite member. According to Piccardo et al. (1992 and bibl.), they are constituted by depleted mantle rocks, i.e. cpx-poor lherzolites (fractional melting $< 10\%$, Rampone, 1992 and bibl.). On the other hand, Rösli (1988) described within serpentinized ultramafics from the Bracco area, clinopyroxenes showing features referable to undepleted mantle rocks (cfr. LOT ophiolites in Nicolas 1989); 2) the main paleotectonic discontinuity is between the ultramafic/gabbroic rocks and the thin and discontinuous basaltic flows which, interlayered with radiolarian cherts, constitute part of the volcano-sedimentary cover; 3) a true sheet dyke complex is absent; 4) ophiolitic breccias are present in locally large amounts and 5) direct stratigraphic juxtaposition of the pelagic sediments over the ultramafic and gabbroic rocks can be locally observed.

In the ultramafic and gabbroic basement the presence of a pre-orogenic metamorphic and tectonic evolution is also well known and has been described since the early seventies (Cortesogno et al. 1975; Piccardo 1976).

Based on field data, mainly collected around the Bracco area, in this pre-orogenic history the following steps can be recognized:

A) D1 shearing in the mantle section with local development of peridotite tectonites. Judging from the meso- and microstructural similarities, this kind of deformation may have the same significance as the first generation of shear zones described by Vissers et al. (1991) in the Voltri Group (Ligurian Alps). In the Internal Liguride peridotites the pressure and temperature conditions of this deformational event have not yet been well constrained; nevertheless the event may be placed before the reequilibration in the plagioclase stability field for which temperatures of 900–1000 °C and pressure of 0,5–0,7 GPa are reported (Rampone 1992 and bibl.).

B) intrusion of gabbros within mantle rocks; the maximum pressure of crystallization can be placed at less than 0,7–0,5 GPa (Cottin 1984; Piccardo 1994; Tribuzio et al. 1995) corresponding to a depth minor than 15–20 Km.

C) after this magmatic event the ultramafic and gabbroic rocks were deformed from high temperature to 'ocean' floor conditions. D2 deformation is witnessed by different generations of shear zones developed from granulite/upper amphibolite to greenschist facies conditions.

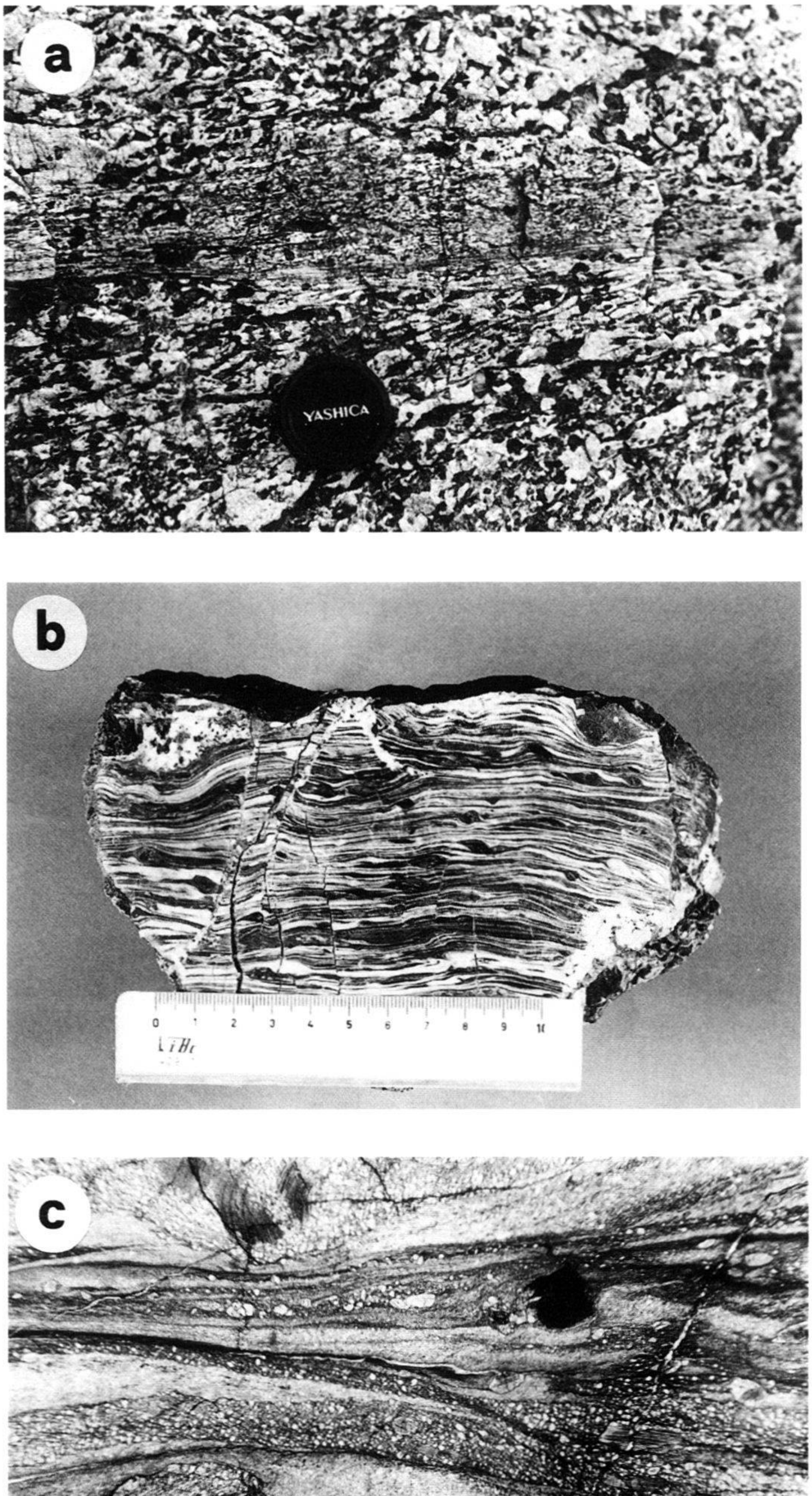
D) emplacement of basaltic dykes and lava flows.

In the ultramafics, the evidence of D2 deformation is found in the uppermost part of the bodies, within the ophicalcite levels which can be considered as polyphasic fault rocks (cfr. Cortesogno et al. 1980; Hoogerduijn Strating 1988). A later brittle polyphasic deformation overprints three generations of plastic shear zones, whose features can be only partially observed and whose study is hampered by a diffuse and complex serpentinization history (cfr. Cortesogno et al. 1980).

From the microstructural point of view, the relicts of the first generation of structures are represented by peridotitic mylonites (D2.1) (olivine + clinopyroxene + brown hornblende + plagioclase). These structures are followed by serpentinite mylonites associated with serpentine + tremolite + magnetite ± chlorite (D2.2) and later serpentine + magnetite + chlorite (D2.3) assemblage in banded microstructures (cfr. ribbon textures in Maltam 1978).

Also in the gabbroic rocks it is possible to recognize three generations of shear zones. The oldest (D2.1, Fig. 2) are represented by metagabbro mylonites characterized by plagioclase (An50/55) + diopside-rich clinopyroxene + red/brown hornblende + ilmenite and attributed to 700–800 °C, 0,4–0,5 GPa conditions.

Fig. 2. a) D2.1 shear zone in metagabbro, field appearence; b) D2.1 metagabbro mylonite; c) D2.1 metagabbro mylonite in microscopic view, showing a millimetre scale alternation of pyroxene-rich and plagioclase rich layers. Asymmetric clinopyroxene porphyroclasts can be observed, scale bar 1.4 mm.


a
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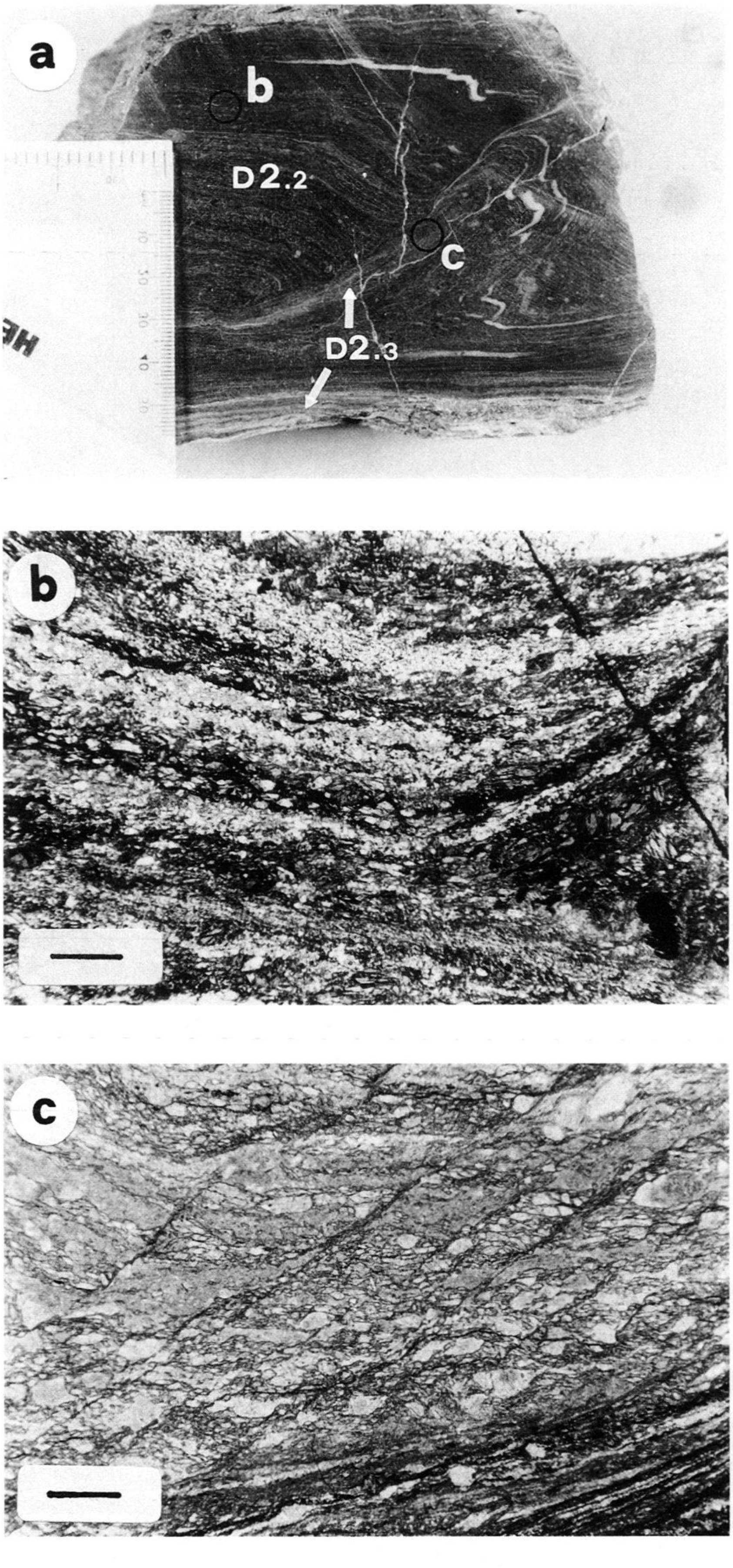
a
b
D2.2
c
D2.3
b
c

These structures range in width from a few decimetres to several tens of metres. The widest can be up to several metres in length. The shear zones locally occur in groups, where they can be observed forming anastomosing patterns (of deformation areas) around lenses (shape ratios on X/Z plane between 3/1 and 7/1) of undeformed host rocks.

The second generation (D2.2, Fig. 3) of shear zones is testified by amphibole-bearing gneissic mylonites with Mg-hornblende + plagioclase (An35–44) + oxides locally cross-cut by lower-temperature structures (D2.3) with actinolitic hornblende/actinolite + plagioclase (An 24–28) + oxides ± chlorite. These later structures are less frequent with respect to D2.1 structures in the gabbros of the Ligurian Apennines, although they are relatively diffuse in different types of ophiolitic breccias (Abbate et al. 1980) testifying their original large scale presence. A tentative correlation between D2 structures in the gabbros and in the ultramafics is supported by petrographic (cfr. Cortesogno et al. 1979; Cortesogno et al. 1987) and structural evidence.

In the Bracco area, D2 (in particular D2.1) structures in the gabbros are suitable for geometric and kinematic studies (Hoogerduijn Strating 1988; Molli 1995). Orientation data of foliation and lineation have been restored to their presumed original orientation utilizing the magmatic layering (considered as paleohorizontal) as a datum plane and all the elements accordingly rotated (see Molli 1995 for a discussion on restauration problems).

The main results of this analysis are shown in figure 4, where the total distribution of the foliation poles is represented. Two main systems (possible conjugate) are defined, showing a low to medium angle with respect to the paleohorizontal. The principal system is 20–30° southwest-dipping. The lineations show a predominant down-dip orientation and the shear sense is generally extensional.

For D2.2 and D2.3 structures patchy observations have revealed geometries and kynematics consistent with D2.1 structures, representing their evolution under decreasing temperature and pressure conditions.

D2 deformation ends up with the exposure of basement rocks (mantle ultramafics and intruded gabbros) on the 'ocean' floor. The deformation predates almost all leucocratic differentiates (diorite and plagiogranites) and basaltic dykes, as indicated by cross-cutting relationships between D2 structures and undeformed and unmetamorphosed intrusions (cfr. Cortesogno et al. 1987).

Figure 5 shows a schematic representation of the earliest deformation geometries based on the data collected around the Bracco area (Fig. 1). The deformational structures in the gabbros have been interpreted as formed in order to accomodate local strain incompatibilities, developed during the uplift of mantle portions. The main movement zones have been accordingly located within the ultramafics, where several generations of structures can be recognized as contributing to mantle denudation according to "core com-

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Fig. 3. a) decimetric sample of D2.2 amphibole-bearing gneiss mylonite cross-cut by lower temperature D2.3 shear zones (arrowed); b) micrograph of D2.2 fabric, showing a millimetre scale alternation of hornblende and oxides-rich and plagioclase-rich layers. In the right part it is possible to observe a tail zone of an asymmetric hornblende porphyroclast, scale bar 0,6 mm; c) detail of D2.3 shear zone, with shear bands defined by fine grained actinolites, scale bar 0.5 mm.

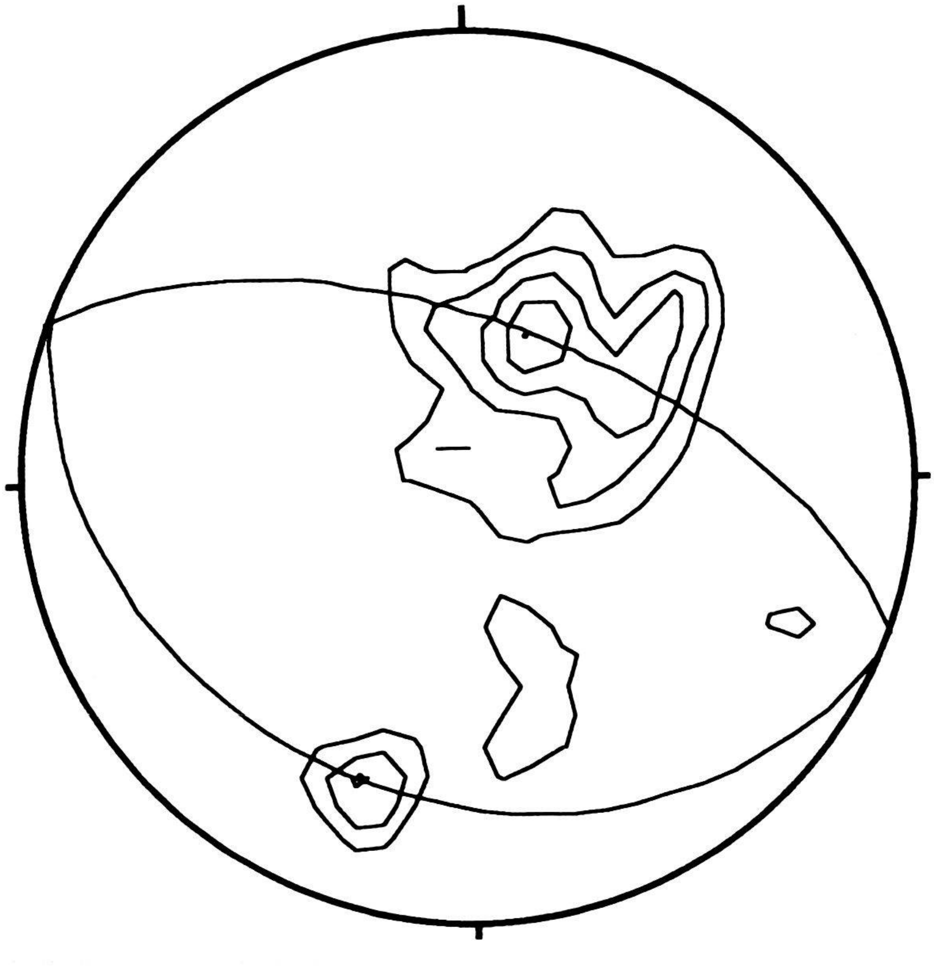


Fig. 4. Plot of the overall restored foliation poles (m. 200). Two main systems are defined at 90–100° to each other, the main system dipping 20–30° towards SW (equal area projection, lower hemisphere contours at 2–3 etc. times unit).

plex"-type deformational geometries. Relicts of a part of this structure can be found within the uppermost portions of the ultramafics, in the ophicalcite levels interpreted as polyphasic fault rocks which may locally represent the remnants of a detachment fault. On the basis of collected data we cannot infer whether the local system was directly related to the master fault(s) or part of a complex conjugate, although the latter hypothesis is to be preferred. This evolution is brought to an end by development of high angle faults, dyke intrusions and basaltic flows, all contributing to morphological instability associated to the formation of different types of sedimentary breccias.

The presented tectonic history has not yet been well constrained from the geochronological point of view; in particular, a key point is represented by the age of the Bracco-type plutonic complex, still to be determined.

The available data are relative to: 1) Sm/Nd model ages of partial melting affecting (? some part of) the mantle rocks at 290–270 Ma (Rampone 1992; Piccardo et al. 1995); 2) zircon fission track ages from leucocratic differentiates (diorite and plagiogranites) spanning from 185 to 161 Ma (Bigazzi et al. 1973); 3) U/Pb data of plagiogranites with a crystallization age of 153 Ma (Bosi 1995); 4) $^{40}Ar/^{39}Ar$ dating on ferrodiorites at 152 Ma (Bortolotti et al. 1990) and basaltic dykes at 158 Ma (Bortolotti et al. 1991).

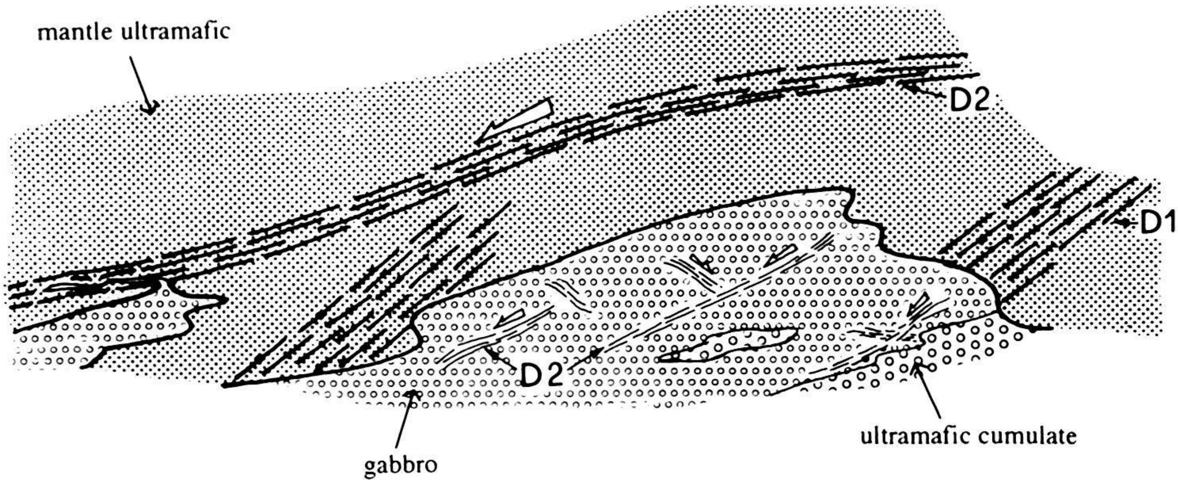


Fig. 5. Idealized and schematic representation of the earliest deformation geometries based on the interpretation of field data in the Bracco area.

The character of the External Ligurian Domain

The only direct information about the features of the External Ligurian Domain derives from the analysis of the Cretaceous 'basal complexes' of the Helminthoid Flysch, in which fragments (up to plurikilometric in size) of the original paleodomain can be studied. These fragments are considered either as giant olistolites or slide blocks within the sedimentary melanges (Elter et al. 1966; Abbate et al. 1980; Naylor 1982; Terranova & Zanzucchi 1984) or offscraped slices of the original basement (Plesi et al. 1994).

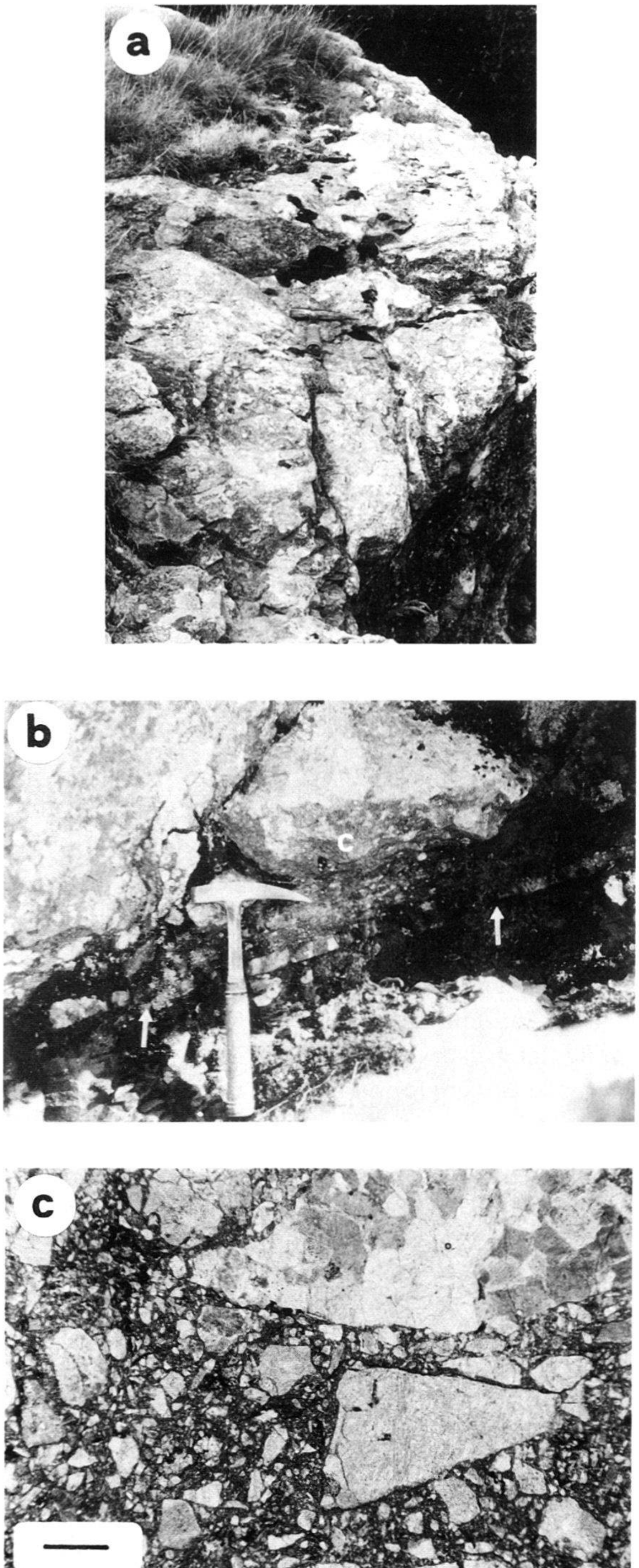
On the basis of their features the western part of the External Ligurian Domain can be considered as formed by:

- ultramafics, mainly represented by undepleted spinel-plagioclase lherzolites, interpreted since the early seventies as subcontinental lithospheric mantle (Piccardo 1976; Piccardo et al. 1992; Rampone 1992). Deformed rocks are the most frequent lithotypes, comparable on the basis of meso- and microstructural similarities to the 'low' and 'high strain' tectonites described in the Voltri Group (Ligurian Alps) by Drury et al. (1990). This correlation is confirmed also by petrological evidence (Piccardo 1983; Piccardo et al. 1992), therefore the tectonic evolution proposed for the Erro/Tobbio peridotites can be accepted also for the External Ligurian peridotites (cfr. Hoogerduijn Strating et al. 1993; Piccardo et al. 1995);
- gabbros are present in pluridecametric scattered outcrops. Locally abundant, they can be also found as metric, or decimetric to centimetric clasts in Cretaceous breccias. The most abundant lithotype is coarse-grained Mg-gabbro, but plagioclase-bearing ultramafic cumulates, melatroctolites and leucocratic differentiates are also described (Casnedi et al. 1993). Deformed rocks showing structures and mineral paragenesis similar to that of the Internal Liguride Units can be found;
- basalts are locally abundant and mainly constituted by pillow lavas, in some cases associated with monogenic basaltic breccias, whose Jurassic age is witnessed by cross-

cutting undeformed basaltic dykes (Terranova & Zanzucchi 1984). N and T-MORB as well as alkaline affinities are reported (Capedri et al. 1977; Beccaluva et al. 1980);

- granulites: the presence of lower continental crust rocks associated with the External Liguride ophiolites has been reported since the seventies (cfr. Braga et al. 1975). They are mainly represented by basic granulite (plagioclase + orthopyroxene + clinopyroxene + spinel ± olivine ± amphibole) and pyroxenites (clinopyroxene + orthopyroxene + spinel) but also by acid granulites (quartz + plagioclase + garnet ± white micas) (Marroni & Tribuzio 1994; Montanini 1995). Deformed rocks (mylonites and ultramylonites) testifying a complex retrograde tectonic and metamorphic evolution are present. Petrographic similarities (Braga et al. 1975; Marroni & Tribuzio 1994, Montanini 1995) supported by recent radiometric data (Montanini 1995) point out the affinity with the intrusive complex of the Ivrea zone (see also Braga et al. 1975);
- continental granites: they can be found as exposures up to pluridecametric lenses as well as clasts locally associated with gneiss, micaschists and quarzite, metric to centimetric in size, relatively abundant within breccias of Cretaceous age (Elter et al. 1966; Terranova & Zanzucchi 1984). Particularly significant are the presence of basaltic dykes within the granites (cfr. Braga & Marchetti 1969) and their primary relationships with the basalt flows testifying the outpourings of lava onto the continental crust slices (Fig. 6a). An important outcrop (north of M. Penna, 44° 29'25''9°29'40'' of the National coordinate grid) described for the first time by Pagani et al. (1972) shows a stratigraphic contact between granitic rocks and radiolarian cherts (Fig. 6b). In detail, in this exposure it is possible to observe, in overturned sequence, a decametric wide granite body (quartz + plagioclase + K/feldspar + white mica + garnet + apatite + zircon) characterized by an upper part (few decimeters) formed by granitic cataclasite (Fig. 6c). The top of the cataclasite is irregular and grades into a sedimentary breccia (Pagani et al. 1972) formed by granitic clasts in an arenitic/siltitic matrix in transition with 'granitic' sandstones (sub-arkose: quartz, white-micas and subordinate feldspars) with radiolarian skeletons and radiolarites overlain by basaltic flows.
  Granite and cataclasite are cross-cut by faults pre-dating the 'granitic' clastic deposits, the radiolarian sedimentation and the basaltic effusion.
  The available radiometric data (Rb/Sr and K/Ar on biotite and muscovite) of the granites (Eberhardt et al. 1962) suggest their hercynian age (310/272 Ma) but also reveal the presence of a younger age (229/222 Ma) whose possible significance will be discussed later;
- Radiolarian cherts, Calpionella Limestones and Palombini shales represent the original Upper Jurassic to Lower Cretaceous sedimentary cover of the above mentioned lithotypes.

Fig. 6. a) Tholeiitic dyke cross-cutting hercynian continental granites. North of M. Maggiorasca. b) North M. Penna: primary contact between continental granites and radiolarian cherts. The sequence in overturned position shows in the original uppermost part a granitic cataclasite (c) cross-cut by later faults pre-dating the radiolarian cherts (arrow) uninvolved in it; c) microscopic appearence of uppermost cataclastic granite, scale bar 0,8 mm.


a
b
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c

For the eastern part of the External Ligurian Domain, the presence of ophiolitic basement can be ruled out, whereas fragments (also pluridecametric in width) of a Triassic-Jurassic sedimentary sequence with austro-southalpine affinities (Braga 1957; Zanzucchi 1961; Elter et al. 1966; Carraro & Sturani 1972; Dallagiovanna et al. 1991) as well as the composition of Late Cretaceous conglomerates (Salti del Diavolo conglomerates) strongly support the idea of an original stretched continental basement, interpreted as the southern prolongation of the Canavese Domain (Sturani 1973).

The Ligurian Domain: main features and interpretation

On the basis of the above quoted features, we propose the following reconstruction (Fig. 7). The 'ocean' floor is mainly built up by mantle portions (mostly tectonite lherzolites with subcontinental affinities), scattered gabbro bodies and dykes, subordinate basalts occurring in structurally controlled morphological depressions and slices of continental granites (and subordinate lower continental crust rocks) associated with the 'oceanic' lithosphere before the intusion of the basaltic dykes and the radiolarian sedimentation.

The western part of the External Ligurian Domain (B in Fig. 7) is here considered (see also Manatschal & Molli 1994) as the transitional realm between the continental and the 'oceanic' crust domain, being interposed between the Bracco-type 'oceanic' crust (A in Fig. 7) and the southern stretched continental margin i.e. eastern part of the External Ligurian Domain (cfr. 'dominio Ligure orientale', Sturani 1973; 'solco Emiliano', Zanzucchi 1988).

The petrological and structural features of the mantle section (Piccardo 1977; Rampone 1992; Hoogerduijn Strating et al. 1993; Piccardo et al. 1995) in the western part of the External Ligurian Domain strongly support the idea of a tectonic denudation of the peridotites in a passive rifting setting. The structural history reconstructed for the ophiolitic basement of the Internal Ligurian Domain (whose age, on the basis of the available radiometric data, can be considered older than 185/170 Ma, and therefore significantly older than the early radiolarian sedimentation and lava flows) can be coherently fitted in with this evolution (Hoogerduijn Strating 1988; Drury et al. 1990; Molli 1995). The coupling of the continental crust with the ophiolites in the External Ligurian Domain could be also considered as having formed during the rifting stage. The slices of the cristalline basement may be considered as 'extensional allochthons' which, locally covered by synrift sediments and radiolarian cherts and showing a brittle polyphasic deformation (post 220 Ma and pre radiolarites sedimentation), recall similar situations (Bric Filia, in the Canavese Zone and the Platta nappe) originally located along the southern tethyan margin at the border between 'ocean' and continent.

A similar reconstruction has been proposed for different parts of the Ligure-piemontese ocean by various authors (cfr. Trümpy 1982; Tricart & Lemoine 1991; Weissert & Bernoulli 1986; Manatschal et al. 1995) and in other cases older radiometric ages (212/192 Ma) of ophiolitic gabbroic intrusion (Carpena & Caby 1984) call for this regional setting.

Tethyan rifting and ocean building from an Apenninic perspective: a discussion

The stratigraphic and structural features of the Northern Apennine ophiolites, shared by most of the western Tethys ophiolites (e.g. Abbate et al. 1984; Lagabrielle et al. 1984),

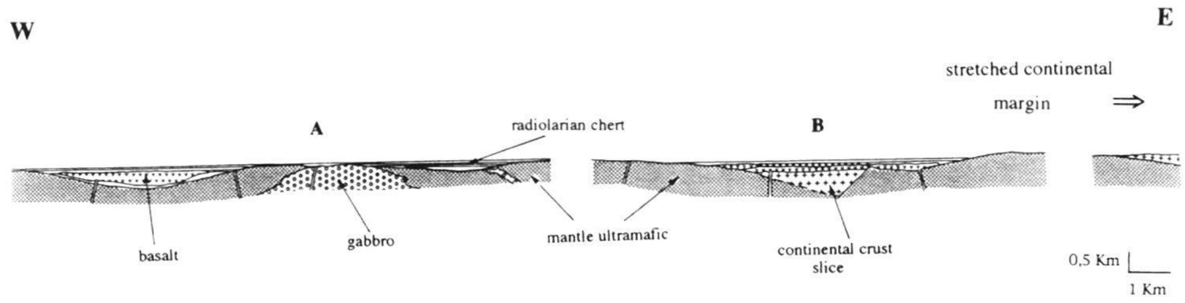

Fig. 7. Schematic representation of the Ligurian Domain as derived by field relationships in the Northern Apennine ophiolites. Section A derives from the Bracco area and surroundings (Internal Ligurides), whereas section B from field evidence in the Ligurian/Emilian Apennine (External Ligurides).

e.g. the absence of a sheet dyke complex and continuous basaltic and gabbroic layers, the existence of a large amount of mantle rocks in some places directly covered by a sedimentary sequence, as well as the locally important presence of ophiolitic breccias, represent a key point for any interpretation of the former oceanic domain.

These general features have been claimed to be linked to transform faults (Gianelli & Principi 1977 and review in Abbate et al. 1980) on the basis of their similarity with the actualistic oceanic settings; nevertheless the structural studies performed in recent years both in the mantle (Nicolas 1989 p. 197; Drury et al. 1990; Hoogerduijn Strating et al. 1993) and in the crustal section (Hoogerduijn Strating 1988; Molli 1995) do not well agree with the transform fault model.

On the other hand, the same features have been interpreted by different authors as due to slowly spreading oceanic ridge segments (Barrett & Spooner 1977). This hypothesis has been recently reproposed by Lagabrielle & Cannat (1990) for the Western Alps ophiolites and it is the object of various ongoing studies. Although some petrological and structural evidence may support this model (Abbate et al. 1992; Piccardo 1994; Cortesogno et al. 1995; Tribuzio et al. 1995; Molli 1995), for the Apennine ophiolites the overall available data undermine it. In particular:

a) the petrological and structural evolution of the mantle section for the External Liguride peridotites (Piccardo 1977; Hogerduijn Strating et al. 1993; Piccardo et al. 1995) strongly supports their tectonic denudation in a pre-oceanic rifting setting;
b) the available radiometric ages, in the Internal Liguride ophiolites, suggest gaps between 1) the mantle partial melting, for which are proposed Sm/Nd model ages 290–270 Ma (Rampone 1992; Piccardo et al. 1995), 2) the intrusion and the polyphasic deformation in the gabbros (pre-dating 185/170 Ma) and 3) the later leucocratic differentiates, the basaltic dykes and lava flows at 160/152 Ma (Bigazzi et al. 1973; Bortolotti et al. 1990; Bortolotti et al. 1991; Borsi 1995) pointing to a genetically independent relationship between the three ophiolitic members, stress out that, though spatially associated, they can be hardly considered as different parts of a single coeval oceanic cross-section (cfr. Piccardo et al. 1995; Malod et al. 1993; Schärer et al. 1995 for a possible actualistic analogue);

c) the presence of a well developed centre of oceanic accretion (implied in the slow-spreading ridge model) is not supported by field evidence, the latter suggesting, on the contrary, that the spreading phases must have been sporadic and diffuse and not localized (Bortolotti et al. 1976; Knipper et al. 1986; Hoogerduijn Strating 1991; Cortesogno et al. 1995).

The overall sets of available data rather support a 'passive' rifting model (Decandia & Elter 1969, Piccardo 1977, Vissers et al. 1991), in which localized mantle shear zones controlled the geometry of deformation and finally produced denudation of mantle-gabbros in association with the slicing of the continental crust forming 'extensional allochthons'. The ophiolitic basement and the relics of stretched continental crust have been injected, later on, by basaltic dykes and lava flows related to diffuse and sporadic magmatic activity due to local mantle melting a depth.

On the basis of the comparison between the tectono-sedimentary and the magmatic evolution of the paired continental margins, the deep geometries of extension and the type of mechanism (symmetric vs. asymmetric) related with the general strain, pure vs. simple shear, can be inferred tentatively (e.g. Mc Kenzie 1978; Wernicke 1985; Lister et al. 1986; Coward 1986).

Different asymmetric models of rifting have been recently proposed for the Jurassic evolution of the Alpine Tethys (e.g. Lemoine et al. 1987; Froitzheim & Eberli 1990; Vissers et al. 1991; Favre & Stampfli 1992; Trommsdorff et al. 1993; Froitzheim et al. 1994) with some authors suggesting an asymmetric history starting already from the Permian (Dal Piaz 1993; 1994; Piccardo et al. 1995).

The analysis of the conjugate northern Apenninic and Corsica-Briançonese continental margins reveals a complex history with an early gross symmetry (cfr. Vanossi & Gosso 1983) during the Middle Triassic, subsidence and alkaline volcanism in the Tuscan Domain i.e. Punta Bianca basin – whose associated thermal event can be possibly linked to the rejuvenation age of granites in the External Ligurian Domain – and in the Ligure Briançonese-Corsica realm (Elter & Federici 1964; Martini et al. 1986 and bibl.; Caby & Galli 1964; Vanossi & Gosso 1983 and bibl.) to the Trias/Lias boundary (coeval uplift of the Briançonese and External Tuscan Domain, Vanossi et al. 1985 and bibl.; Carmignani et al. 1987 and bibl.) and an asymmetric evolution starting only at the end of the Early Jurassic as testified by the uplift of the European continental margin (Briançonese) in opposition to the general subsidence of the northern Apenninic one (Bernoulli et al. 1979). This argument, joined with the presence of a well defined 'break-up unconformity' (a typical upper-plate feature) only on the European successions (Lemoine & Trümpy 1987) and the possible outcrops of lower continental crust rocks in the western part of the External Ligurian Domain, suggests a role of upper-plate for the European and of lower plate for the southern continental margin.

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