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The very beginning of the Ligurian Tethys: Petrological and geochemical evidence from the oldest ultramafite-derived sediments in Queyras, Western Alps (France)

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ABSTRACT

The first indisputable post-ophiolitic sediments of the Ligurian Tethys are older than the paleontologically dated Upper Oxfordian in the St Veran area, Queyras, France. These sediments are represented by chaotic breccias reworking the classical ophicalcites, overlain by graded-bedded sedimentary serpentinites with turbiditic facies. Their major and trace element composition and mineralogy imply the entirely ultramafic nature without any noticeable terrigeneous and gabbro-basaltic contribution. The signature of sea-water alteration is significant. The basaltic contribution suddenly appeared slightly before the onset of radiolaritic sedimentation together with Mn-Fe-PO_4 crusts. It is concluded that these very peculiar ultramafic sediments seal the initial exposure of ultramafic rocks of the oceanic bottom excavated in the form of lherzolitic protrusions during the Late Triassic–Early Jurassic. We propose the geodynamic context of a rift zone similar to that of the Red Sea.

RÉSUMÉ

Les premiers dépôts post-ophiolitiques de nature sédimentaire indubitable qui sont antérieurs à l'Oxfordien Supérieur daté comprennent des brèches chaotiques d'ecroulement surmontant les classiques ophicalcites. Il leur succède des serpentinites sédimentaires granoclassées (microbrèches, grès, silts) de caractère turbiditique. Leur chimisme et leur minéralogie traduisent la nature exclusivement ultramafique du matériel et l'absence de toute contamination terrigène et gabbro-basaltique importante, et souligne le rôle important de l'altération dû à l'eau de mer. Ce n'est qu'à la base des radiolarites qu'apparait soudainement une contribution basaltique. On conclut que ces premiers sédiments ultramafiques très particuliers cachettent la première mise à l'affleurement du fond océanique au Trias supérieur–Lias sous forme de protrusions ultramafiques, bien avant les premières éruptions basaltiques sousmarines. On envisage un contexte de rift similaire à celui de la Mer Rouge, la différence principale portant sur l'immersion importante des marges continentales à cette époque.

Introduction

Ophiolites of the Piemont Zone, Western Alps, are generally regarded as remnants of the Piemont–Ligurian oceanic crust of the Mesozoic Tethys (BERNOULLI & LEMOINE 1980; LEMOINE 1983; Fig. 1). In contrast with large ophiolitic masses of the Inner Piemont Zone (i.e. Zermatt–Saas Fee Zone, Voltri etc. ...), ophiolitic massifs from the External Piemont Zone do not exceed 10 km^2 in area. Yet, there is a general agreement to consider

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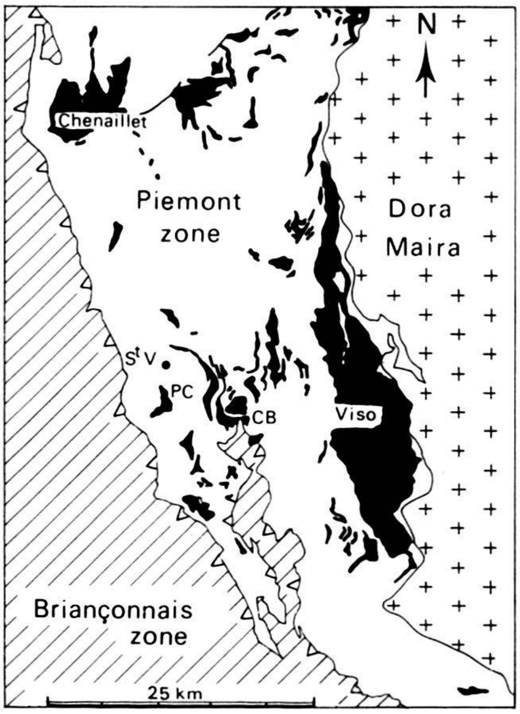
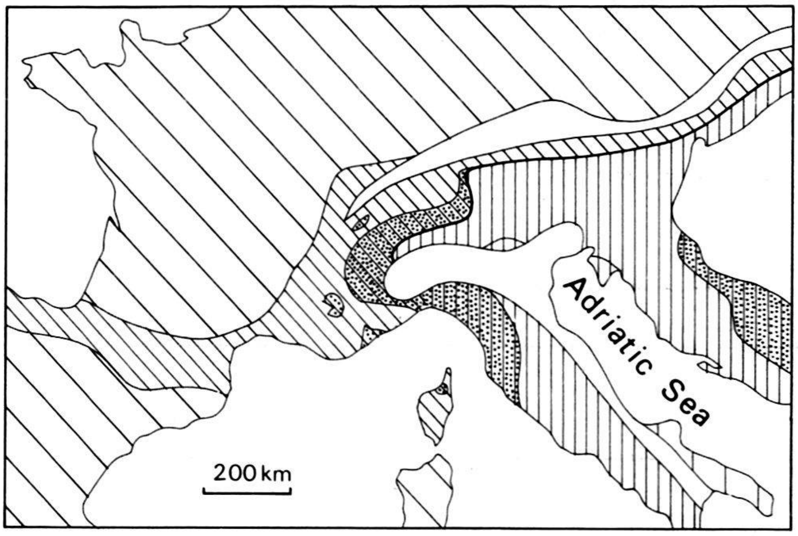


Fig. 1. A schematic geological map of the Piemont Zone and adjacent areas. Inset B: structural sketch-map of the Alpine fold belt s.l. Inset C: hypothetical palinspastic map (Jurassic). Inclined hatching: Europe and European margin. Vertical hatching: Adria and Adrian margin. Dotted: Oceanic terranes (B and C from LEMOINE 1983).

B



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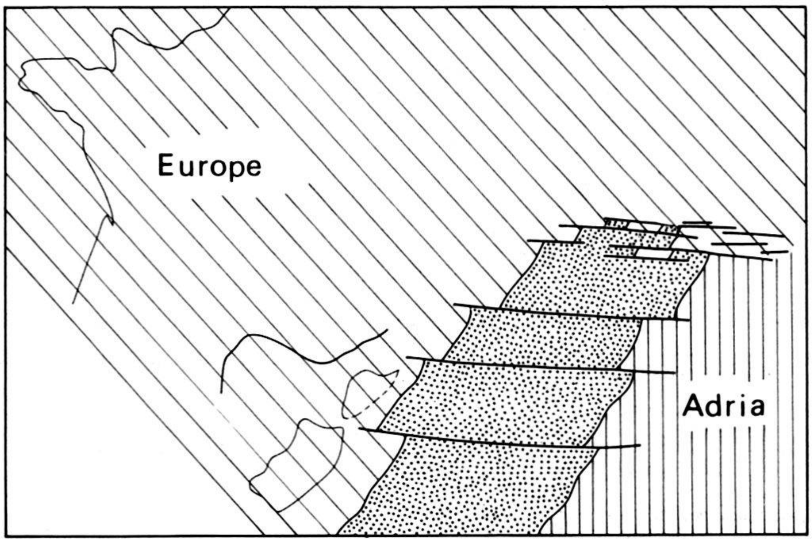

them as fragments of the early Mesozoic oceanic crust generated at the same time as the oldest Central Atlantic crust (LEMOINE 1980, 1983, 1985).

The main petrological differences with other ophiolites (i.e. Eastern Mediterranean, Oman, etc. ...) are 1) the lack of sheeted dike complexes and 2) the marked predominance of spinel and plagioclase lherozolites (BECCALUVA et al. 1984; ISHIWATARI 1985). Some authors therefore consider that these small ophiolites may have been generated by incipient separation of continental crust (LOMBARDO & POGNANTE 1982). From mineral chemistry and petrological considerations, ISHIWATARI (1985) has suggested that Alpine ophiolites were the product of a rather low degree of partial melting in the mantle, and has also concluded that they were generated in an early Mesozoic rift zone between paleo-Europe and Africa.

The undetached post-ophiolitic cover generally begins with metaradiolarites, of Upper Oxfordian to Middle Kimmeridgian age (DE WEVER & CABY 1981) but in some places it begins with Upper Jurassic marbles or Cretaceous calcareous schists (LEMOINE 1980).

This study deals with sedimentological, petrological and geochemical investigations on the oldest ophiolite-derived sediments that underlie radiolarites of Upper Oxfordian age near Saint Veran, Queyras (Fig. 1). The history and evolution of the Piemont–Ligurian ocean at its inception is discussed in the light of these new results, and a geodynamic model for the 210–165 My period is proposed.

Geological setting of the Queyras ophiolites

Most of the ophiolitic massifs from the External Piemont Zone in Queyras are overturned. Strong penetrative alpine deformation is lacking in many plutonic rocks, in spite of a high pressure-low temperature metamorphism (glaucophane + lawsonite + jadeite). According to ISHIWATARI (1985), serpentinites are mainly derived from plagioclase and spinel lherzolites. Harzburgites with a well defined high temperature foliation are also present, as well as undeformed cumulates (BERTRAND et al. 1982). In the investigated area, dikes and pods of undeformed pegmatitic websterite intrude deformed peridotites (AYOUB 1984). Gabbros from the Saint Veran area form small bodies and dikes emplaced in peridotites. «Euphotide» gabbros, with a well developped agmatitic texture and diabase cement are common, suggesting their emplacement at shallow depth together with crystallization of trondjhemites and plagiogranites. Fission track zircon dating from gabbros and trondjhemites has given Late Triassic ages (192±6 My to 212±8 My) which are interpreted as crystallization ages (CARPENA & CABY 1984).

LAGABRIELLE et al. (1984) have advocated an intraoceanic structuration of a normal-type oceanic crust to account for the variable nature of the oceanic bottom below the cover: serpentinite, gabbro, basaltic breccias and ophiolite-derived sediments. Direct evidence for intraoceanic tectonics and cold diapirism of ultramafics have also been reported by TRICART et al. (1985 a). LAGABRIELLE et al. (1984) have postulated a major break between the magmatic crystallization of plutonic rocks and pouring of basalts, the later being sometimes as young as the onset of radiolaritic sedimentation. Undisputably ophiolite-derived sediments have been reported in several localities from Queyras (TRICART et al. 1982; TRICART & LEMOINE 1983; LAGABRIELLE et al. 1984; TRICART et al. 1985 a and b; LE MER et al. 1986, etc. ...). Some of these occurrences seem to be the

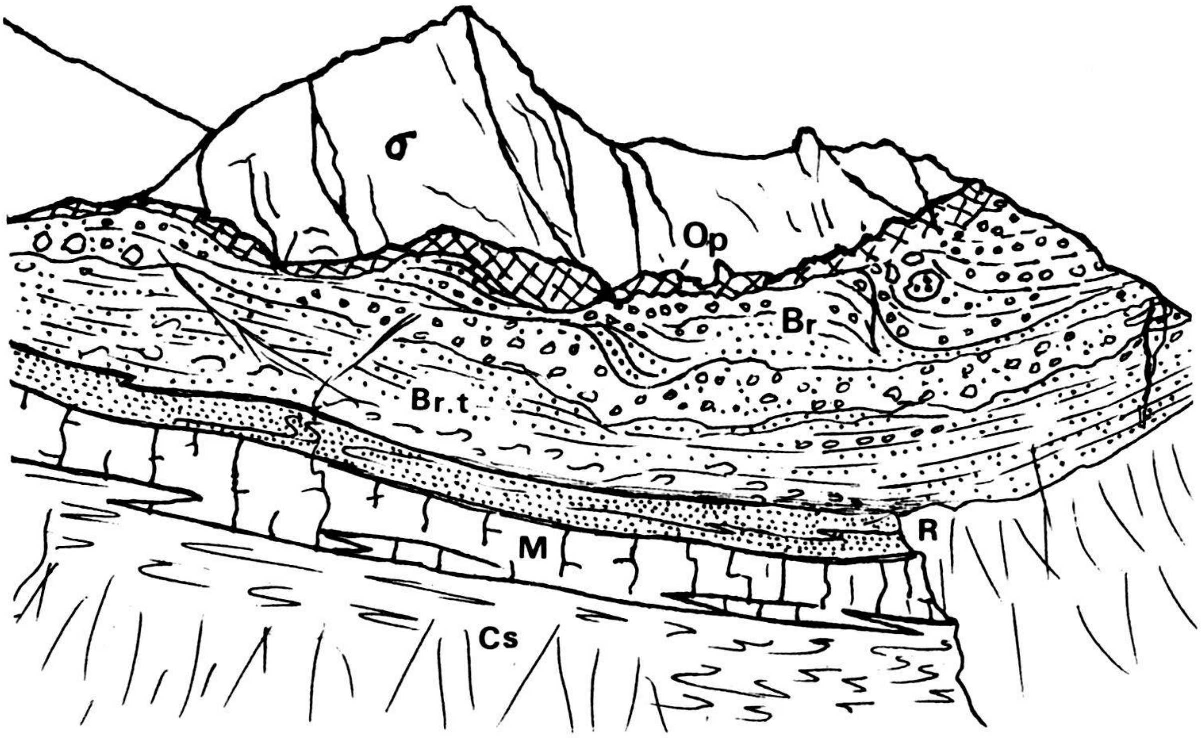

Fig. 2. The east face of Pic Cascavelier (loc. 1) (drawing after a photograph) showing the undetached series (upside down). 6: ultramafic basement; Op: Ophicalcitic breccias; Br: clast supported breccias, with blocks up to several meters across, interpreted as avalanche deposits; Br.t.: turbiditic finer grained arenites, with load and slump structures on top, grading through metasilt of basaltic composition into meta-radiolarite (R) overlain by Upper Jurassic marbles (M) and calc-schists (Cs).

metamorphic equivalents of ophiolitic sediments from the Appennines (see LAGABRIELLE et al. 1984 for references) and Swiss Alps (WEISSERT & BERNOULLI 1985).

In Queyras, ophiolite-derived sediments are always present close to the basal part of the sedimentary cover regardless of its age. In several cases they are interfingered with calc-schists of the post Jurassic «schistes lustrés» (TRICART et al. 1985 a and b). The Saint-Veran area offers a classical section of the post-ophiolitic cover locally dated by radiolarians of Upper Oxfordian–Middle Kimmeridgian age (DE WEVER & CABY 1981; TRICART & LEMOINE, 1983).

I. Lithostratigraphy and sedimentological data on the oldest detrital serpentinites from Saint Veran and neighbouring localities

1. *The Cascavelier area (Section 1, Fig. 2):* A 40 m thick clastic unit entirely composed of sedimentary serpentinites is outcropping in the eastern face of the peak, stratigraphically overlying the ultramafic basement (overturned section) (see also TRICART & LEMOINE 1983, Fig. 1–3). The serpentinized lherzolite progressively passes upward into fragmented and calcite-infiltrated serpentinized lherzolite grading into the classical ophicalcites (Fig. 3). Vertical and lateral transitions to clast-supported breccias with sedimentary features can be observed. The earlier clast-supported breccias are chaotic (Figs. 4–6), interfingered with finer grained-breccias and arenites with a very poor sorting. Serpen-

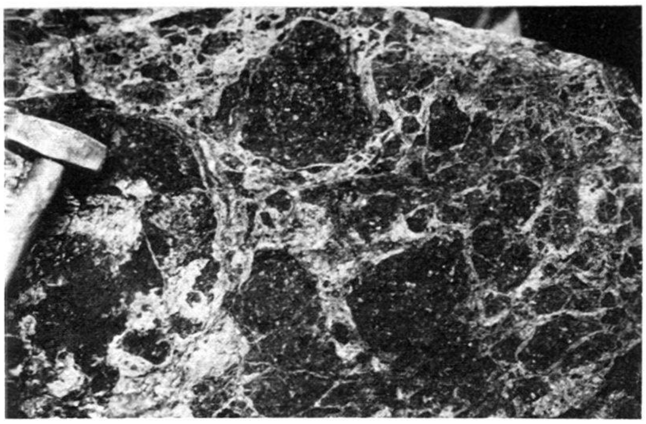

Fig. 3. Fragmented and calcite infiltrated serpentinized lherzolite (= ophicalcitic breccia) close to the interface with sediments. Note both the puzzle texture, and the replacing veins.

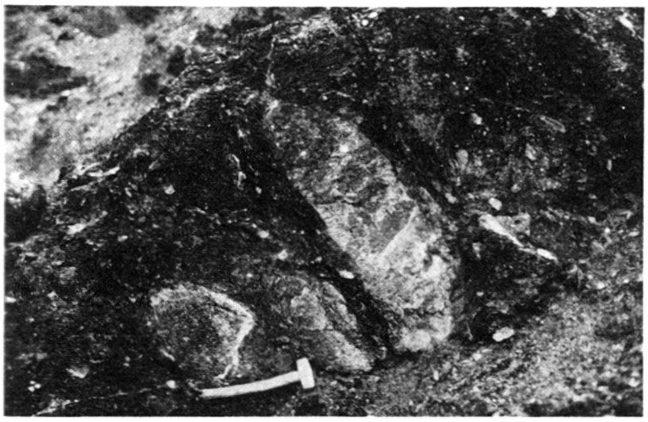

Fig. 4. Clast-supported polygenic breccia with big blocks of ophicalcitic breccia.

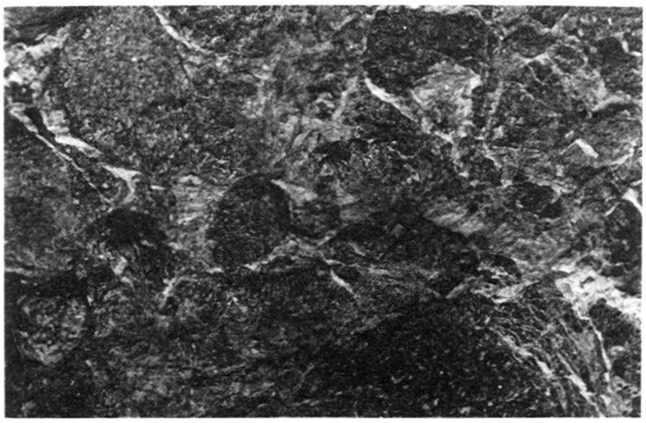

Fig. 5. Clast-supported polygenic breccia with cobbles of various ultramafic rocks. Note the late (alpine) veinlets of calcite + asbestos cuting through elements.

Fig. 6. Clast supported arenite of ultramafic composition with dispersed blocks and contorted bedding (hammer is 40 cm long).

tinite lenses and sub-spherical blocks up to 1 m in diameter are also scattered within arenites. Textures and grain size of ultramafics allow to recognize both monogenic and polygenic breccias. The former is essentially composed of serpentinized lherzolite similar to that of the substratum, whereas the later consists of clast of various types of peridotites, ultramafic cumulates, including pegmatitic websterite, but also rare marble and ophibreccias. Sedimentary features are in agreement with deposition of this oldest material as proximal rockfall deposits along a scarp, as reported from the Mid-Atlantic ridge (Bonatti et al. 1973) and the Gorringe Bank (Lagabrielle & Auzende 1982).

The upper part of the succession is regularly layered with alternating beds of microbreccias, sandstones and silty layers. Normal graded bedding is frequent in the coarse-grained arenites, whereas finer-grained sediments display thinly banded parallel laminations (Figs. 7–8). Structureless silty layers do not exceed a few cm in thickness and are sometimes reworked as mud pebbles in coarse-grained arenites.

Post-depositional structures include slumpings up to 1 m in size, load structures and synsedimentary normal faulting.

Though no sedimentological analysis has been done, mutual relationships and geometry of beds may suggest that these layered sediments are turbidites, with possible A, B and E terms of the Bouma's sequence.

The silty bands are also ultramafic in composition and may represent redeposited muds, whose genesis will be discussed later. The last serpentinite silty layers also display convolute and slump features up to 5 cm in size. They include very fine-grained layers

Fig. 7. Ultramafic arenite grading upward to thinly laminated ultramafic sandstone.

Fig. 8. Thinly banded sandstone and silts with parallel laminations sharply overlain by coarser grained arenite.

with more than 80% of cryptocrystalline secondary blue amphibole and contain badly preserved phosphatized radiolarians.

On top of this detrital sediments lenses of peculiar breccia marbles are outcropping. These matrix dominated breccias contain highly serpentinized lithic fragments, and frequently a high amount of recrystallized pink Fe-rich calcite. In addition, their mineralogy can also be dominated either by Cr-aegyrine or blue amphibole.

2. *In section 2,* located 1,7 km south of section 1, a brecciated plutono-volcanic complex (CABY et al. 1971) is interlayered with meta-arenites (Fig. 9). The younger detrital beds overlie pillowed metabasalts and pillow breccias. These sediments differ from those of section 1 by the abundance of brown amphibole of the pargasite group and titaniferous gabbroic clasts, mixed with ultramafic clasts and chromite grains, with a carbonate matrix (Fig. 10). More sensitive to alpine metamorphism than those of ultramafic composition, these sediments were recrystallized into tremolite and/or glauco-

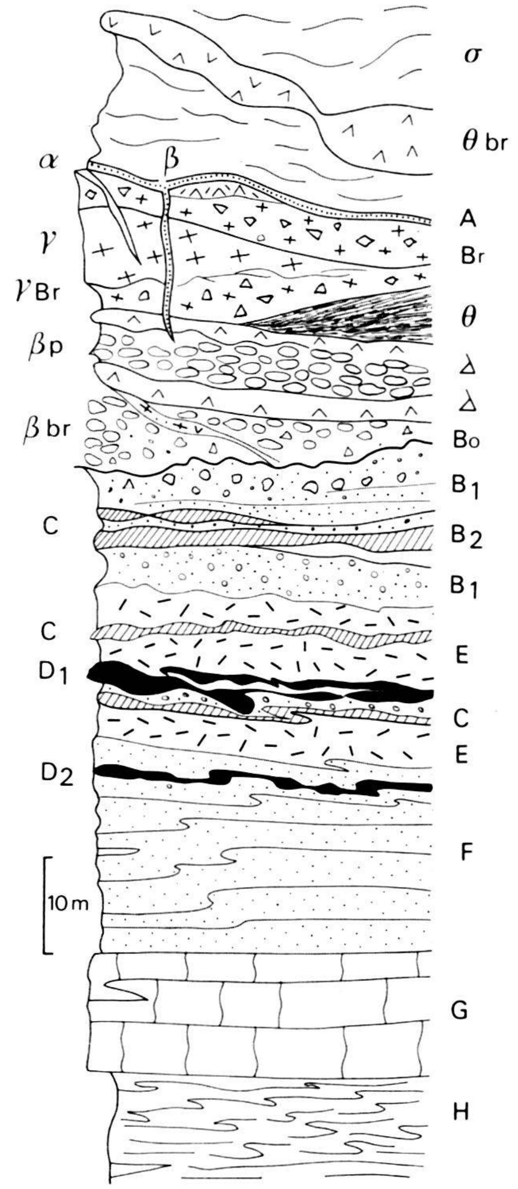

Fig. 9. Locality 2: The ultramafic basement (σ), mostly serpentinized lherzolites, is cut by gabbroic dikes with agmatitic texture (θbr). A: meta-arenite layer (ultramafic, pargasite-clinopyroxene gabbroic and marble lithic fragments) makes the transition with the plutono-volcanic complex, which comprises: Fe-Ti amphibole-Cpx dolerite sills (θ) with frequent breccia texture, intrusive in A and in Br, which is a polygenic breccia with predominant trondjhemite – granite elements (see Caby et al., 1971); a sheet of coarse-grained Na rich granite (γ) cut by albitite veins (α); layered Fe–Ti metagabbros (λ) with numerous sodic allanite-zircon rich aplitic veins and associated biotite schlieren, pillowed basalts (βp) grading upward into pillow breccia (βbr), and possible feeder dikes (β) which cross cut acidic rocks.
The sedimentary cover overlying the plutono-volcanic complex starts with glaucophanites derived from basaltic metatufs (B_0) overlain by meta-arenites (B_1) with ultramafic boulders up to 1 cubic meter, grading upward into tremolite-blue amphibole-rich metasiltites and meta-arenites (B_2); lenses of impure marbles (P, Cr, Mn, serpentine ± glaucophane ± aegyrine bearing): C; laminated Mn crust with primary Mn oxides, dialogite, phosphate and radiolarians, secondary Mn silicates and garnet (D_1), mixed up with red shale (D_2); ophicalcitic marble (E); banded metaradiolarite (F); Upper Jurassic marbles (G); Cretaceous calcschists (H).

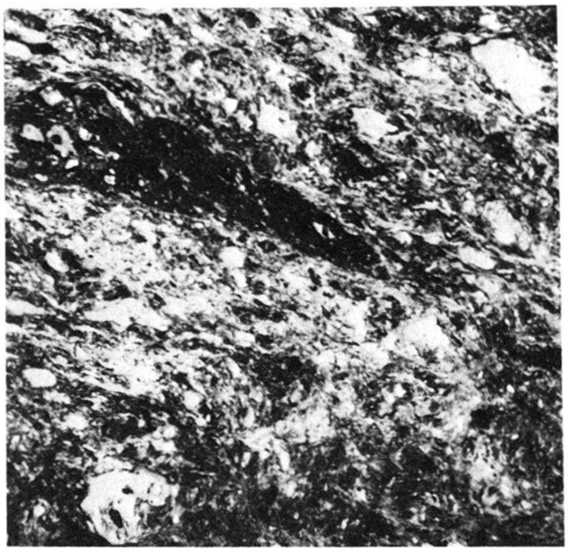

Fig. 10. Deformed meta-arenite with lithic clasts and minerals derived both from an ultramafic and a gabbroic source (loc. 2).

phane schists and calc-schists. Moreover, Mn-PO_4-rich crust horizons with some poorly preserved radiolarians and other undetermined organic rests are interlayered together with impure marbles rich in pink calcite. The Saint Veran stratabound copper-orebody (Ayoub 1984) lies at the same stratigraphic horizon and underlies the metaradiolarites. Radiolarians tests preserved in sulphides attest for the early emplacement of Cu, Fe and associated metals (Ayoub 1984).

We thus interpret the Mn-PO_4 and Fe-Cu deposits as deep-sea crusts generated on the oceanic bottom by nearby hot brines, and mixed with ultramafic-gabbroic detritus. Relationships of detrital sediments with basalts and beginning of radiolaritic sedimentation suggest that the Cascavelier detrital serpentinites of section 1 represent the oldest sediments in the area.

3. *The Col Blanchet ultramafic sediments* (loc. 3, Fig. 11) comprise an elongate boudin with no internal deformation, enclosed in Cretaceous (?) calc-schists with no trace of any ophiolitic detritism.

The boudin is composed of lenses of breccias and microbreccias alternating with sandstone and siltstone layers. The fine-grained material displays a thinly layered structure (cm and dm scale). Both well sorted sandstones with normal graded bedding, and poorly sorted layers with a bimodal grain size distribution are present. Silty layers display regular parallel laminations. Slumps up to 10 cm thick and injection features possibly due to fluid-escape processes have also been observed. Coarse-grained breccias with no internal bedding nor sorting constitute irregular beds and lenses, with cut and fill structures at their base and onlap of the overlying deposits. Ultramafic clasts up to 20 cm include ultramafic silt and sandstone. We interpret these breccias as debris flows sharply interupting finer grained turbiditic sedimentation at a base of slope system.

II. Petrography of detrital serpentinites

Arenites and sandstones are composed of both lithic and mineral fragments often angular in shape (Figs. 12–16). According to habitus of grains and the nature of their alteration products, it is possible to recognize in thin section the following detrital phases:

Olivine → network of fibrous serpentine with opaque granules, Orthopyroxene → «bastite» or talc-chlorite, Clinopyroxene → tremolite + carbonate, calcic plagioclase → cryptocrystalline chlorite. Many serpentinite flakes with internal veinlets testify that many elements were serpentinized before deposition. Serpentine elements frequently display a pronounced brown pleochroism (probable lizardite and clinochrysotile). Brown spinel is more abundant close to the bottom of graded bedded layers. Brown amphibole is only found on top of section 2, and is also present in the sedimentary serpentinites from the Chenaillet (Figs. 12 and 13). In the fine-grained sandstones and silts, scarce igneous minerals only can be recognized in thin section.

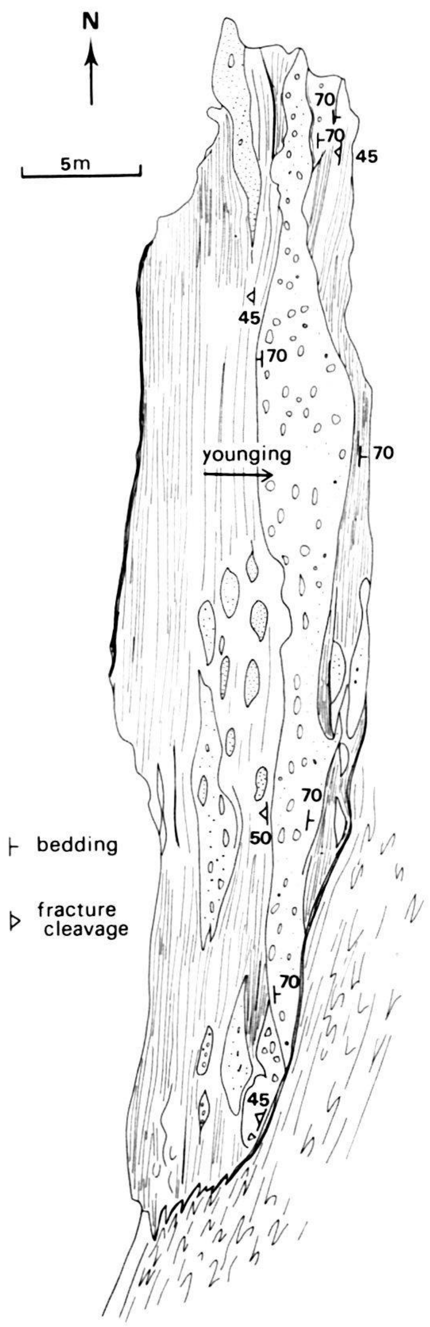

Fig. 11. Detailed map of sedimentary serpentinites located 250 m east of Col Blanchet (Italy). This outcrop is interpreted as a tectonic boudin enclosed in Cretaceous calc-schists (contact in the southern corner). Explanation in text.

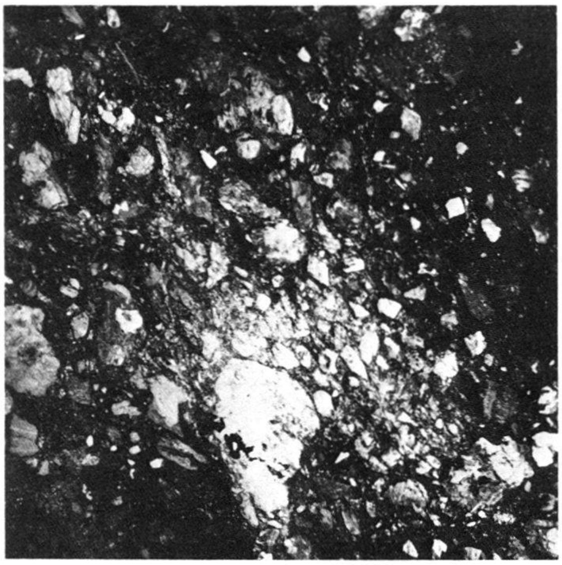

Fig. 12. Ultramafic microbreccia with more than 50% of calcite matrix. Angular grains are entirely serpentinized and calcite impregnated (Chenaillet).

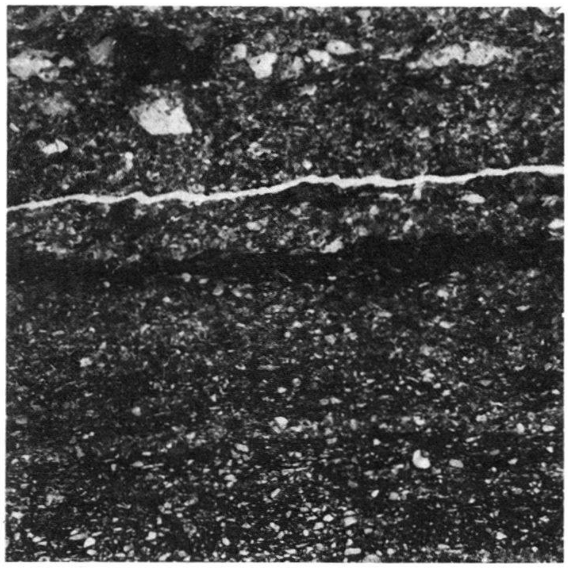

Fig. 13. Ultramafic silt from the Chenaillet. Most of the angular elements were entirely replaced after deposition by carbonate, except some fresh clinopyroxene, talc and serpentine flakes. More than 20% of hydrogrossular (in black) cements the clasts.

Fig. 14. Graded-bedded ultramafic arenite from Pic Cascavelier with less than 5% of calcite cement (see text for description).

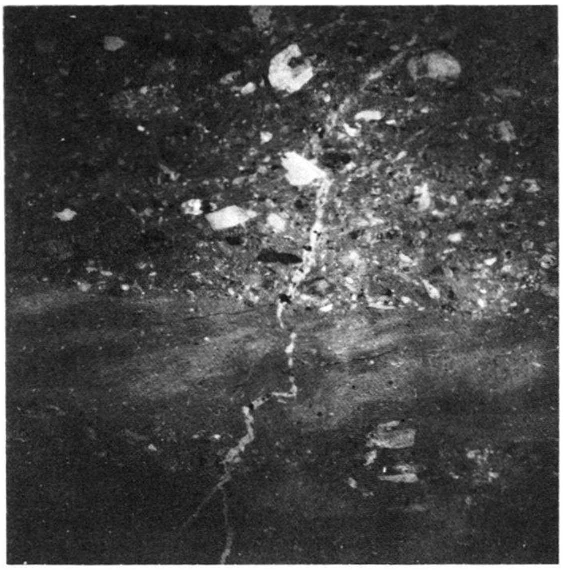

Fig. 15. Ultramafic meta-arenite of Col Blanchet (see Fig. 11) devoid of carbonate matrix. Note the incipient slaty cleavage in the ultramafic silty layers (an n° 9).

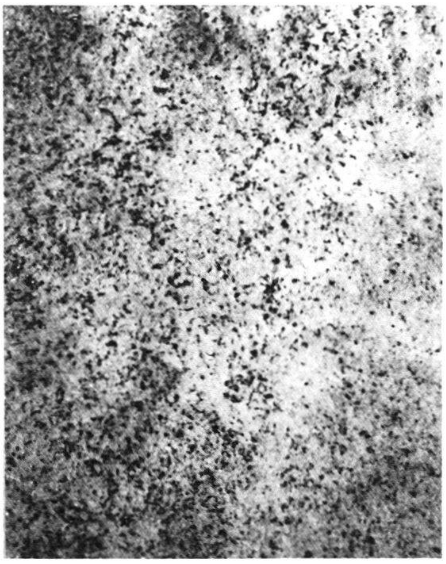

Fig. 16. Ultramafic meta-silt entirely recrystallized into serpentine, Mg-chlorite, calcite and magnetite without prefered orientation (Col Blanchet outcrop).

The matrix is absent in some of the finest grained rocks, but is common in most of the meta-arenites and clast-supported breccias. It is clearly recrystallized, migrating along grain boundaries and replacing minerals. The matrix is mostly calcite, but also Mg-chlorite, talc and serpentine. Hydrogarnet is very abundant (up to 20%) in the Chenaillet detrital serpentinites, as secondary phase replacing various elements (Pl. 3 B). Nevertheless, the primary nature of the carbonate cement in many samples is probable, and partly preserved organic rests have been observed. Direct evidence for a sedimentary origin of ophicalcites have been recently documented in Switzerland (BERNOULLI & WEISSERT 1985).

Alpine metamorphic minerals in variable amounts are represented by tremolite needles, cutting across grain boundaries and as intergrowths with calcite (asbestos), serpentine, magnetite, rare aegyrine and hydrogarnet in veinlets and tension gashes.

III. Sedimentological and petrographical notes on metaradiolarites and associated sediments from locality n° 1A

Metaradiolarites make up a thinly banded unit of 10 to 20 m thickness, affected by isoclinal, often curviplanar folds of any size. Essentially silicic bands alternate with pink and greenish metashales with a variable amount of quartz, carbonate and phengite. Synkinematic lawsonite, aegirine, blue amphibole and haematite are the other minerals which correspondingly indicate more calcic, iron-rich, and sodic compositions.

In addition to the fossiliferous rhodochrosite bands (De Wewer & Caby 1983), some cm-scale dark-red iron and phosphate enriched layers occur. We have also identified some dark green regular bands several cm thick with chlorite and serpentine as chief minerals, and numerous chromite grains surrounded by Cr-rich minerals (aegirine, chlorite, phengite, etc ...). These Cr-rich layers are interbanded with clast-supported microbreccias, containing fragments of already lithified radiolarite and impregnated by phosphate, haematite, jasper and/or rhodochrosite, still containing radiolarians. We therefore interpret these green Cr-rich layers as distal turbidites originating from an ultramafic terrain and that sharply interrupted the quiet radiolarite-red clay sedimentation which was itself probably controlled by turbidity and bottom currents like in the Apennines (Folk & Mc Bride 1978, Kälin et al. 1979).

Table 1: *Representative analyses.*

1–2: serpentinite blocks. 5-6-9-12-14: detrital serpentinites. 7-16-26: detrital serpentinites mixed with carbonates 20–28: turbidites and clays. 18–19: metasilt (basaltic + ultramafic derivation). 24–25: marbles. 23: radiolarite. 22: P-enriched red clay.

	1	2	5	6	9	12	14	7	16	26	20	28	18	19	24	25	23	22
	7435	7436	7439	7440	7443	7446	7448	7441	7450	7460	7454	7462	7452	7453	7458	7459	7457	7456
SiO2	38.59	41.02	37.90	39.27	40.63	41.50	40.70	28.35	37.45	22.29	34.56	35.22	53.70	52.29	29.50	8.42	80.09	40.74
Al2O3	2.36	2.54	3.26	4.05	2.70	2.57	2.36	1.70	2.72	1.53	12.39	17.31	8.05	9.25	2.38	0.91	6.21	3.95
Fe2O3	8.60	8.72	7.59	11.42	8.44	8.11	8.03	5.90	10.89	5.38	16.04	16.89	11.50	10.53	7.94	3.76	5.96	12.82
MnO	0.17	0.09	0.15	0.18	0.09	0.09	0.12	0.21	0.14	0.42	4.50	0.28	0.17	0.15	0.36	1.70	0.23	0.50
MgO	33.50	33.54	31.44	31.39	34.40	34.36	32.59	21.42	16.04	16.50	13.13	10.10	16.10	16.13	8.72	4.59	2.72	2.72
CaO	1.78	0.55	4.05	0.25	0.18	0.32	1.79	18.78	18.20	25.97	4.03	5.59	0.82	1.04	26.10	43.11	0.21	19.54
Na2O	0.02	0.01	0.01	0.02	0.01	0.05	0.04	0.01	0.03	0.01	0.65	0.04	4.30	4.90	2.75	0.03	0.06	0.08
K2O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.69	1.79	0.02	0.01	0.01	<0.01	1.41	0.32
TiO2	0.08	0.06	0.09	0.10	0.11	0.06	0.09	0.08	0.09	0.02	0.42	0.57	0.48	0.51	0.05		0.26	0.06
P2O5	0.03	0.03	0.03	0.03	0.04	0.02	0.05	0.04	0.09	0.05	0.10	0.11	0.08	0.15	0.04	0.04	0.09	13.00
H2O+	0.71	0.49	0.31	0.67	0.48	0.22	0.52	0.39	0.21	0.30	0.20	0.26	0.25	0.22	0.29	0.03	0.05	4.80
H2O-	13.47	12.18	14.46	11.64	12.07	11.90	12.93	22.19	14.30	26.68	11.38	11.10	4.15	4.38	20.82	35.47	2.20	2.08
Total	99.35	99.28	99.32	99.04	99.19	99.25	99.27	99.08	100.21	99.19	98.12	99.31	99.64	99.60	99.00	98.09	99.52	100.64
Li	41	16	34	41	9	8	9	13	6	11	52	159	142	83	15	6	18	12
Rb	1	1		2		2	1	2	3	1	32	92	3	1	3	2	60	16
Sr	16	5	55	11	3	4	65	16	52	252	22	66	5	3	115	170	2	189
Ba	22		9							19	27	174					75	
V	94	116	91	116	92	96	87	84	49	36	301	198	170	146	85	19		131
Cr	3510	3567	3448	4798	2524	3263	2781	3552	737	1293	15716	2465	2250	710	2112	632		28
Ni	1623	1635	1238	1368	1358	1307	1324	1236	1207	825	1282	1123	978	326	1449	519		195
Cu	7	12	12	1	2		5	4	95	4	107	57	139	72	3	14		74
Zn	47	59	65	103	60	54	64	85	64	46	333	281	172	107	43	28		117
Y	5	13	5	11	7	4	6	6	5	5	25	19	19	22	4	4		329
Zr	7	7	11	9	16	9	18	11	19	8	22	113	64	88	7	7		14

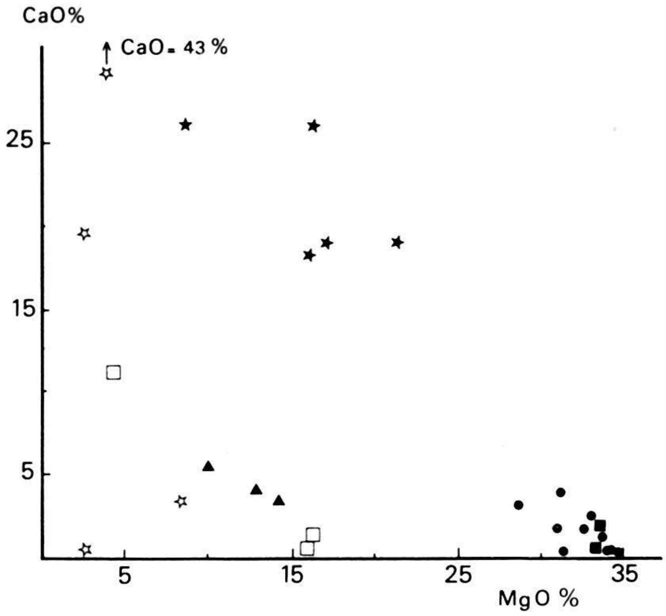

Fig. 17. CaO/MgO diagram. Circles: serpentinite boulders; dots: detrital serpentinites; crosses: idem, with carbonate cement; squares: meta-silt with composition of altered basalt (progressively grading upward into radiolarites at locality 1, see Fig. 2); triangles: ultramafic Cr-rich sitty layers (distal turbidites) interbanded with radiolarites from locality 1; stars: marble, radiolarite and clay.

IV. Geochemistry

28 samples have been analyzed for major and trace elements. They have been collected at locality n° 1, 1B. In addition, we have analyzed two detrital serpentinites from the Chenaillet massif, one Cr-phengite-rich layer interbanded with Upper Jurassic marbles and another Cr-rich schist of assumed Cretaceous age. The analyzed samples display large range of compositions. On the basis of SiO_2, CaO, MgO three groups may be distinguished (Fig. 17).

Ultramafic sediments (group I) have compositions similar to serpentinized ultramafic clasts (Tabl. 1) from the basal breccia. They resemble detrital seprentinites analyzed by LOCKWOOD (1971). Although some samples have compositions similar to alpine serpentinites of the Chenaillet massif (BERTRAND et al. 1982), they slightly differ from other alpine serpentinites by higher SiO_2, Al_2O_3 content and higher Si/Mg, Al/Mg and Cr/Ni ratios. These features associated with several correlations such as Al-Li and Ca-Sr may reflect the incorporation of clay minerals and authigenous and/or biogenous carbonates. On the other hand several negative correlations (e.g. Si-Al, Si-Ca) negate any contribution of basaltic components. Finally the large range of Cr content associated with various correlations (Cr-V, Cr-Zr) reflects the heterogeneous distribution of spinel among the samples, which is clearly due to gravitational sorting in graded-bedded layers.

Compared to the previous group, the group II has lower contents of most elements except for CaO and Sr. Thus it has suffered a strong dilution effect by incorporation of carbonate as shown on the Fig. 16).

Group III includes the other samples. Compositions of two Mn-poor samples of marble that overlie sedimentary serpentinites in section II indicate mixing with phase components of ultramafic origin. The blue amphibole-rich metasilts with slump structure grading upward into radiolarites have compositions close to that of oceanic floor basalts (samples n°18 and n°19). Their depletion of CaO is typical for oceanic alteration (HUMPHRIS & THOMPSON 1978), and it is generally agreed that Upper Jurassic radiolarites have been deposited below the calcite compensation depths (KÄLIN et al. 1979). Their relatively high Cr, Ni and MgO content implies the presence of some ultramafic component, while their enrichment in SiO_2 is related to the radiolarians.

The green Cr-rich layers of younger age (samples 20–28) have the highest content in Al_2O_3 and Fe_2O_3 and K_2O. Some of them (e.g. sample n° 20) are strongly enriched in Cr, V, Zn which reflect their abundance in the spinels.

All these groups are clearly individualized on the Fig. 17 where they are marked by lower Mg and CaO contents. They are interbedded with radiolaritic shales (sample n°23) and red clays sometimes strongly enriched in organic phosphate (sample n° 22). The positive correlation between Ca-Sr which probably reflects the variable proportion of calcareous component, is common among the oceanic sediments (KATO et al. 1983).

When K_2O is above the detection limit, the calculated K/Rb ratio remains rather low (175±5). It has been shown that sea water alteration may involve a drastic decrease of K/Rb (STAUDIGEL & HART 1983) and that carbonates forming veins in oceanic crust have very low K/Rb (RICHARDSON et al. 1980).

The Li content is high especially in samples which have Al_2O_3 higher than 4%. Such enrichment common in oceanic environment (SEYFRIED et al. 1984) is probably associated with the presence of pelagic marine clays.

The REE content (Fig. 18 and Tab. 2) is variable and especially high in P enriched sediments. The corresponding patterns marked by a distinct enrichments of heavy REE in detrital serpentinite are very similar to those of oceanic sediments and ocean water (MURPHY & DYMOND 1984).

Table 2: *Additional I.N.A.A. determinations (sample references as in the Table 1).*

Ref.	9	6	18	22
La	.91	1.9	13.7	135
Ce	1.99	7.1	32.2	207
Nd	1.24	3.7	14.1	122
Sm	.35	1.07	3.02	30.2
Eu	.094	.28	.81	8.4
Tb	.07	.23	.59	6.6
Yb	.54	.90	1.82	14.4
Lu	.09	.14	.29	2.15
Th	.5	<.1	4.3	1.0
Sc	12	14	17	3

Discussion

The oldest ophiolite-derived sediments which in section 1 directly overlie the ultramafic basement have compositions close to their ultramafic parental rocks. They are mixed with a calcareous component. Their variable chemical compositions reflect different proportions of primary magmatic minerals due to gravitational sorting (spinel).

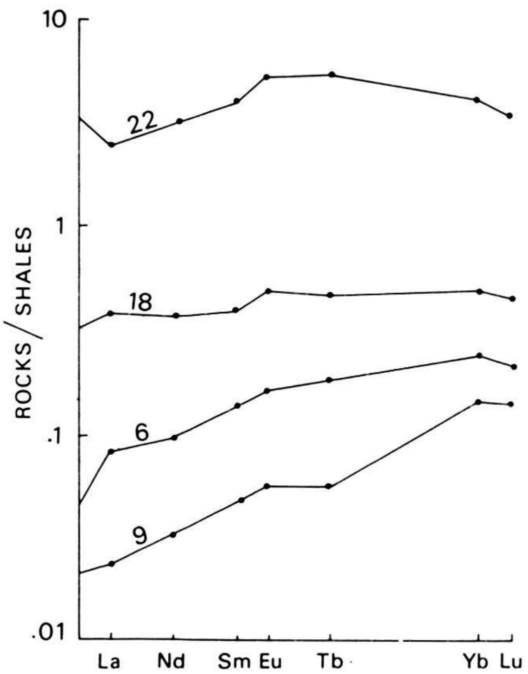

Fig. 18. Chondrite-normalized REE pattern.

Compositions denote the lack of both a gabbro-basaltic and a terrigeneous component. The high content of several elements (especially Li, Rb, HREE) reveals absorption and/or incorporation from sea water during deposition and diagenesis (pore water and adsorption by altered magmatic minerals in serpentine, Mg-chlorite derived from Mg-rich clays, etc.). In the upper part of Section 1. a basaltic contribution suddenly appears on top of ultramafic sediments. In contrast, the gabbro-derived sediments of section 2 directly overlie pillowed basalts and basaltic breccias. They are also interlayered with Mn-PO_4 deep sea crust sediments of hard-ground affinity with radiolarians, suggesting that this whole section is younger than section 1 regardless of the interpretation of the intercalated plutonic complex of Fig. 9 (intrusive bodies or olistoliths). It must also be pointed out that the meta-arenites of gabbroic composition described by LE MER et al. (1986) outcrop in areas where the radiolarites were not deposited. These authors have concluded that pouring of basalts and deposition of meta-arenites occured simultaneously.

The entirely ultramafic derivation of the oldest sediments may be interpreted in two ways: 1) it only reflects the local contribution of an ultramafic ridge; 2) it is a regional feature that reflects the essentially ultramafic nature of the oceanic bottom before the gabbros were exposed and before eruption of basalts.

Sedimentary features of coarse-grained clast-supported breccias support the first interpretation, but the presence of ultramafic silts may raise the question as how and where sorting of ultramafic material occurred. Following MELLIS 1958, and FOLK & MCBRIDE 1978, we suggest that this sorting may have necessarily been achieved by surficial exogenic processes along shore lines of an ultramafic island (such as St Paul Island in the South Atlantic Ocean).

TRICART et al. (1985) have described ultramafic-derived breccias and olistoliths within Cretaceous calc-schists, which imply that such a contribution was dependent on a rejuvenated ultramafic scarp.

These observations on a former ocean are consistent with the discovery of non-spreading crustal blocks of ultramafic nature that do exist in the Central Atlantic, plastered between much younger oceanic crust (BONATTI & HONNOREZ 1971, BONATTI 1976). Along the Vema fracture zone, these authors gave evidence for emplacement of such protrusive blocks in a narrow proto-Atlantic, with possible subsequent aerial exposition. Dating of associated gabbros from the Gorringe Bank at 197±9 My (CARPENA 1984) enhances the petrographic similarities between the Mid-Atlantic and the Queyras ophiolites, pointed out by MEVEL (1984). LEMOINE (1980), TRICART & LEMOINE (1983) and more recently BERNOULLI & WEISSERT (1985) have presented arguments for generation of the ligurian and Alpine ophiolitic masses in a transform setting. Petrological results also suggest that crystallization of plutonic rocks took place at the time of incipient separation of continental crust (LOMBARDO & POGNANTE 1982; ISHIWATARI 1985). Following AUZENDE et al. (1983) such topographic hights are likely to be obducted, in contrast to the normal (and younger) oceanic crust which would be subducted.

Our results rule out the contention that intraoceanic tectonism might have affected a normal-type oceanic crust, in which case basaltic components would be predominant in the oldest sediments. We suggest that the earlier ultramafic sediments investigated here are the record of the proto-Ligurian Tethys that generated contemporaneously with the proto-Atlantic during Late Triassic–Early Jurassic times, and before onset of basaltic volcanism. The lack of any terrigeneous contribution in these oldest sediments may reflect the large distance from emerged land masses, and possibly also the barrier effect of carbonate facies during this period. The proposed geodynamic setting of emplacement of the predominantly lherzolitic bodies and overlying detrital serpentinites of Queyras is thus similar to that of Miocene lherzolitic protrusions of the Red Sea, (BONATTI et al. 1981) which were emplaced during early rifting period (NICOLAS et al. 1987).

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