Eclogae geol. Helv.	Vol. 76/3	Pages 611–629	7 figures in the text	Basle, November 1983

Serpentinite oceanic bottom in south Queyras ophiolites (French Western Alps): record of the incipient oceanic opening of the Mesozoic Ligurian Tethys

By Pierre Tricart[1]) and Marcel Lemoine[2])

RÉSUMÉ

Les nombreux petits massifs ophiolitiques du Queyras permettent de reconstruire la structure du substratum océanique (ophiolitique) d'une partie du segment ligure de la Téthys mésozoïque. On décrit ici deux massifs de serpentinite, où les contacts primaires magmatiques, tectoniques et sédimentaires d'âge jurassique ont été particulièrement bien conservés malgré la tectonique compressive alpine ultérieure. On peut y distinguer trois ensembles lithologiques superposés: 1. substratum ophiolitique (serpentinites traversées par des filons de gabbros); 2. brèches ophiolitiques (ophicalcites) et basaltes en coussins; 3. série pélagique normale, débutant parfois par les radiolarites du Malm inférieur, plus souvent par les calcaires du Malm. Ces résultats sont en accord avec ce que l'on sait par ailleurs des autres massifs ophiolitiques du secteur: au moment même de l'ouverture, le substratum océanique qui est apparu le premier entre les deux marges continentales européenne et apulienne était constitué de serpentinites avec quelques corps gabbroïques, ces derniers parfois déjà déformés et métamorphisés (gabbros foliés); l'apparition soudaine de ce fond serpentineux et gabbroïque susceptible de recevoir des sédiments, sa tectonisation (escarpements dus probablement à des failles normales ou décrochantes), suivis par le dépôt rapide des brèches ophiolitiques, correspondent à un événement tectonique majeur. Cet événement s'insère ici entre deux épisodes magmatiques de la genèse de l'association ophiolitique, puisqu'il est postérieur à la mise en place des gabbros et antérieur aux épanchements basaltiques. Il enregistre ici le tout début de l'ouverture océanique téthysienne à travers le continent pangéen.

ABSTRACT

In the Queyras mountains (French Western Alps), several small overthrust ophiolitic massifs allow reconstruction of the early structure of at least a part of the Tethyan Mesozoic oceanic basement. The two serpentinite massifs here described provide large and continuous outcrops where the primary ("oceanic") magmatic, tectonic, and sedimentary structures of Jurassic age are generally well preserved notwithstanding the later Alpine, late Cretaceous and Tertiary, compressional events. Three main groups of rocks are superposed, viz.: 1. ophiolitic basement (serpentinites cut by gabbro dykes), 2. ophiolitic breccias (ophicalcites) and basaltic pillow lavas, and 3. the normal pelagic sediments (upper Jurassic radiolarian cherts, often lacking; upper Jurassic limestones; lower Cretaceous shales and limestones). These data fit well with those from other neighbouring ophiolite massifs. From them the following can be deduced: a) At the very time of the continental break-up, the first oceanic bottom which appeared between the European and Apulian continental margins was made up of ultramafites associated with minor gabbro bodies; at that time parts of the latter were already deformed and metamorphosed (foliated gabbros). b) The sudden appearance of this basement and its tectonization (fault scarps), followed by relatively rapid deposition of the breccias, marks a major tectonic event. This event cuts the

[1]) Faculté des Sciences et Techniques, Sfax (Tunisia).

[2]) Institut Dolomieu, F-38031 Grenoble.

generation of the ophiolite suite into two successive magmatic events, since it postdates the emplacement of the gabbros, and predates the basaltic outflows. It appears as the record of the very moment of continental break-up in this part of Pangea.

Introduction

Ophiolites of the Western Alps, of Corsica, and of the Northern Apennines, are now regarded as remnants of the oceanic "crust", or better of the oceanic basement, of the ligurian segment of the Mesozoic Tethyan ocean (BERNOULLI & LEMOINE 1980). The oceanic opening of this part of the Tethys occurred across Pangea during middle Jurassic times (150-160 m.y. approx.), bringing about partition between Europe and Apulia-Adria. This event was more or less coeval with the partition between North America and Africa, i.e. with the oceanic opening of the Central Atlantic segment of the Tethys (BERNOULLI & LEMOINE 1980).

Indeed, these ophiolites comprise the three main components of the celebrated "Steinmann trinity" (whose "locus typicus" is precisely the Northern Apennines), namely, ultramafites, gabbros plus basalts, and radiolarian cherts (STEINMANN 1926). Nevertheless, the mutual relationship between these rock categories as well as their relationships with the overlying oceanic sediments are not "classical" ones. In fact, the basaltic layer is often missing, so that the sediments may directly overlay gabbros, serpentinites, and the associated ophiolitic breccias (LEMOINE 1980; LAGABRIELLE et al. 1982; LAGABRIELLE et al. 1983).

As will be seen further on, both the reconstructed structure of the Ligurian Tethys oceanic basement, and the corresponding geodynamic processes, do not at all fit the classical or fashionable models of the structure and generation of oceanic crust, whether derived from present day ocean data, or from study of certain classical ophiolitic belts.

In order to give an idea of the problem, we have chosen to describe here examples of the relationships between an ultramafic-gabbroic bottom and its sedimentary cover, which are particularly well preserved in two serpentinite massifs of the southern part of the Queyras area (Fig. 1, 2), and to discuss the possible origin of such an "abnormal" oceanic basement.

Of course, the ophiolitic and sedimentary rocks here described underwent several successive episodes of synmetamorphic folding during late Cretaceous-Tertiary times (see, e.g., CARON 1977; TRICART 1973; TRICART 1980): therefore, all the rocks described here are metasediments, metabasalts (the so-called "prasinites"), metagabbros, etc. Indeed, these Alpine compressive events of late Cretaceous and Tertiary age may have partly obliterated certain primary (Mesozoic) sedimentary and magmatic mutual relationships between all these rocks. Nevertheless, such relationships, especially the primary sedimentary contacts, may at some places be surprisingly well preserved.

I. Description of the serpentinite massifs

The two serpentinite massifs here described mainly outcrop in the mountain crests between the Aigue-Blanche, Cristillan and Ubaye valleys (Fig. 1 and 2). As a

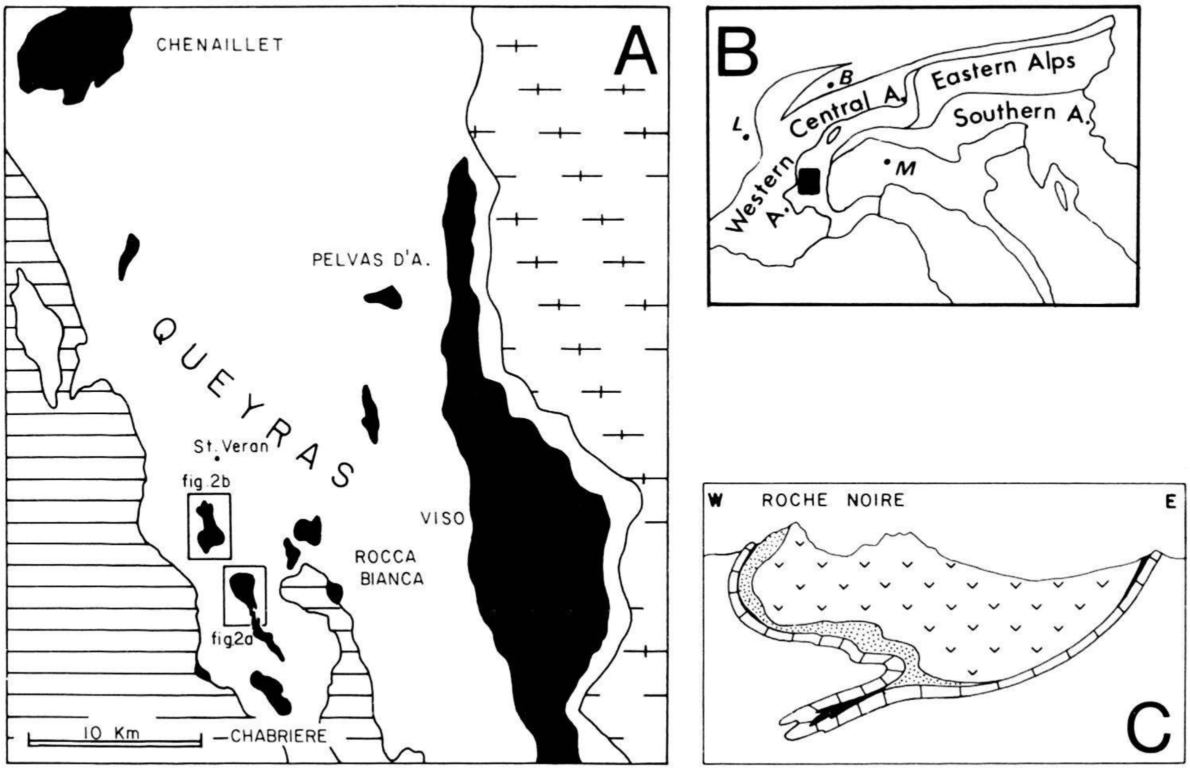


Figure 1. Location and structure of the serpentinite massifs.
B = location of map A in the Alpine chain. B = Bern. L = Lyon. M = Milano.
A = sketch map of the Queyras and neighbouring areas. Hatched = Briançonnais zone; white = Piemont "Schistes lustrés" (mesozoic metasediments); black = main ophiolite massifs; crosses = Dora-Maira Piemontese massif.
C = schematic cross section of the Roche Noire synform (modified after TRICART 1974). Symbols as in Figure 2a.

Fig. 1. Localisation et structure générale des massifs de serpentinite.
B = localisation de la carte A dans la chaîne alpine.
A = esquisse du Queyras et des environs. Hachures = zone briançonnaise; blanc = «Schistes lustrés» piémontais (métasédiments mésozoïques); noir = principaux massifs ophiolitiques; croix = Massif cristallin piémontais de Dora-Maira.
C = coupe schématique de la synforme de Roche Noire (modifié d'après TRICART *1974). Symboles: voir figure 2a.*

matter of fact, both massifs display synform structures (TRICART 1974). More precisely, the Roche Noire massif is a synform whose eastward vergence (Fig. 1) results from the latest tectonic movements; on the other hand, the Cascavelier-Marcel massif has a well-preserved lower limb (inversed series), and is overlain at its top by complex slices which derive from the former upper limb (TRICART 1974). As a consequence, the ophiolites occur mainly in the higher parts of the mountains, whereas the sediments outcrop below.

Unfolding of these synforms allows both the structure of the Jurassic oceanic (ophiolitic) basement and its relationships with its sedimentary cover, to be reconstructed (see paragraph II and Fig. 7), provided that the contact between both groups of rocks be of sedimentary origin, as will be shown further on.

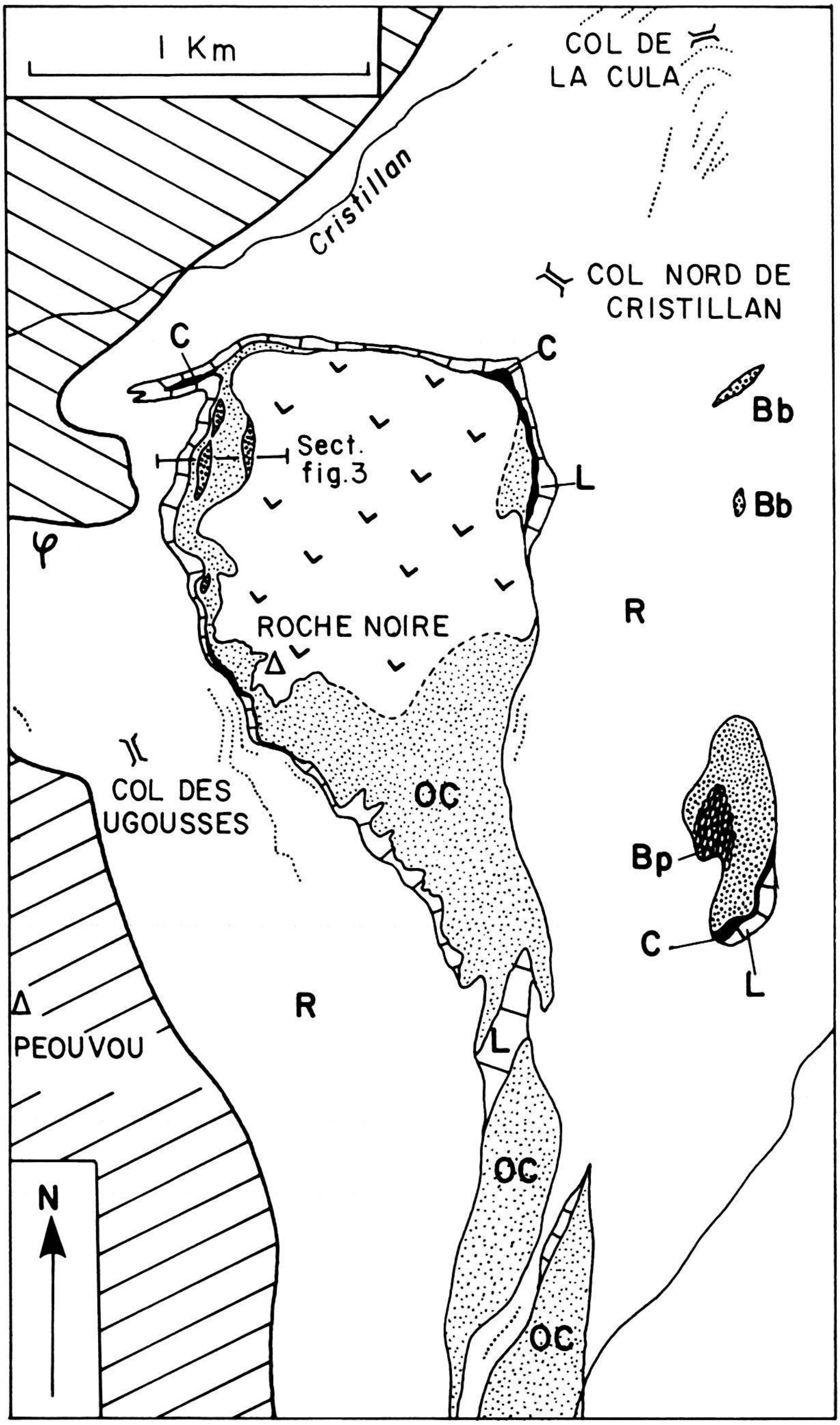


Fig. 2. Simplified geological maps of the South Queyras serpentinite massifs.

a = Roche Noire massif.

b = Cascavelier-Marcel massif. Explanation of symbols: see legend of Figure 7.

Dotted lines = ophiolitic detrital beds in the Replatte formation (R). φ : thrust contacts with other Piemontese units.

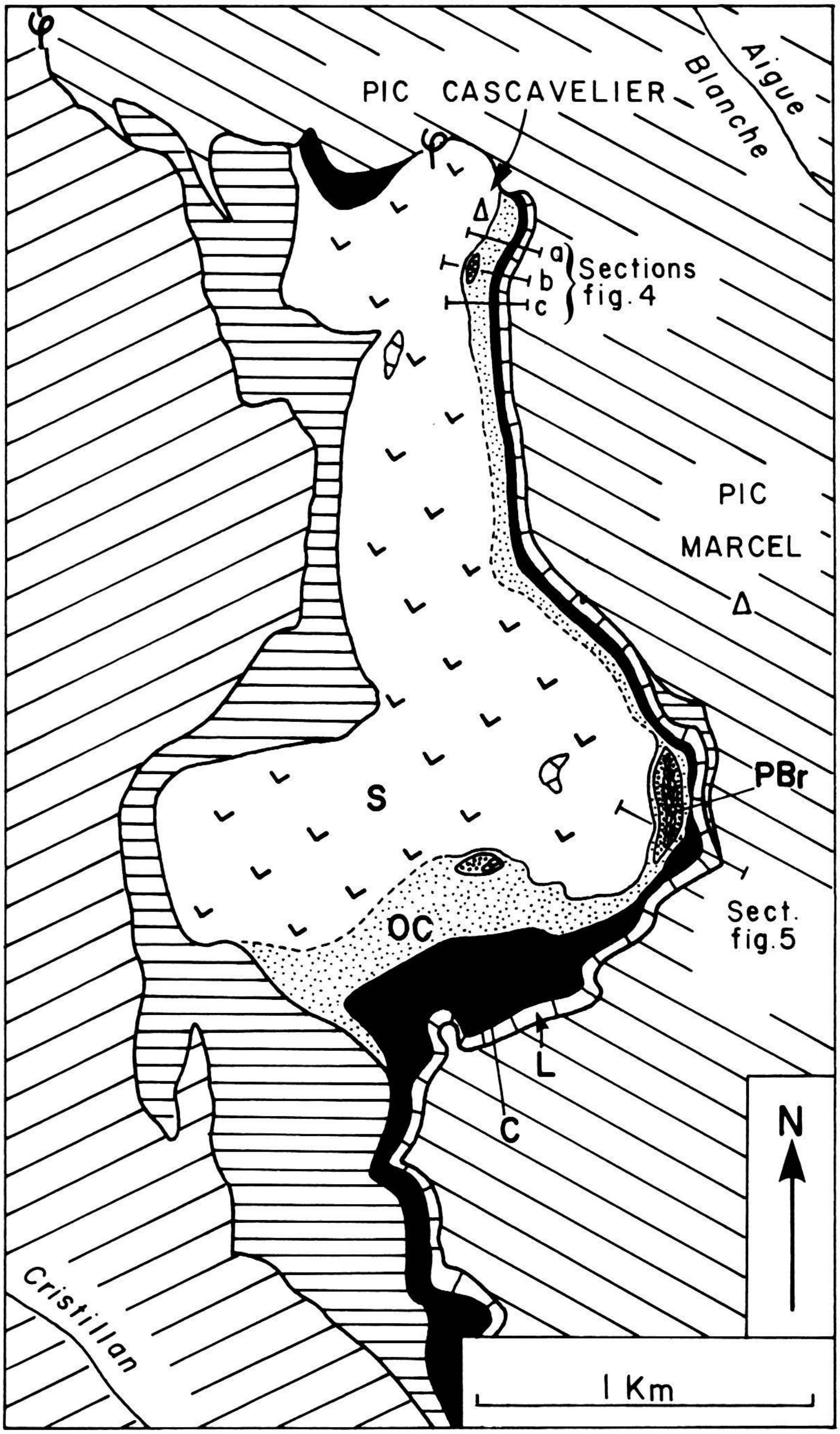


Fig. 2. Cartes géologiques simplifiées des massifs serpentineux du Sud Queyras.

Explication des symboles: voir légende de la figure 7. Lignes pointillées: intercalations détritiques à matériel ophiolitique dans la formation de la Replatte (R). φ : contacts anormaux avec d'autres unités piémontaises.

In fact, three superposed rock groups can here be distinguished, namely: 1. Ophiolitic basement (mainly serpentinites), 2. ophiolitic breccias and basaltic flows, and 3. oceanic pelagic sediments (radiolarian cherts, limestones, etc.)

1. The ophiolitic basement: serpentinites and gabbros

Ultramafites build up the main part of both ophiolitic massifs. These are mainly serpentinized peridotites, which often exhibit an undisturbed layering of the pyroxene crystals: this leads to the conclusion that great parts of these ultramafites were surprisingly little, or not at all affected by Alpine compressive deformations, apart from some narrow shear zones where the serpentinites may become schistose.

The serpentinite groundmass is cut at some places by *dykes of magnesian gabbros ("euphotides")* which range in thickness from a few centimeters to a few meters, and even, at one place, to several tens of meters. Dykelets a few centimeters thick are frequent, e.g. in the northwest cliff of Roche Noire where they are remarkably isopach and planar (Fig. 3, 6a): this supports the idea that the surrounding serpentinites are little affected by Alpine deformation. Near Pic Cascavelier and Pic Marcel, the dykes, a few meters thick, are clearly oblique (30–60°) with respect to the boundary surface between rock groups 1 and 2, i.e. to the oceanic bottom, and may sometimes be cut by this surface. Near Pic Marcel (Fig. 7), a 100 × 200 m body of undeformed gabbro occurs to the north of the dykes.

It is important to notice here how the late Cretaceous and Tertiary Alpine compressive deformation acted upon these gabbros: the dykelets are little affected; the greater dykes display pinch and swell structures; but apart from some narrow foliated margins, they did not suffer any pervasive Alpine deformation, whether flattening or stretching. These facts are in good agreement with the oceanic (ante-alpine) nature of some foliations of the gabbros (see below).

The upper part of the serpentinite mass, a few meters below the overlying breccias, may at some places be brecciated, i.e. intricately cut by white calcareous veins: such rocks are *a first variety of the so-called ophicalcites.*

2. The ophiolitic breccias and the associated basalts

a) *Serpentinite breccias* are largely predominant. They are mainly made up of fragments of serpentinite embedded in a calcitic matrix: this *another variety of ophicalcite,* quite different, both in aspect and in origin, from the first variety[3]). Their *sedimentary (detrital) origin* is supported by their general aspect (see below) and also by the fact that these breccias fill very irregular and deep depressions of the top of the ultramafic basement. In addition, analogous breccias are clearly stratigraphically interbedded in the supra-ophiolitic pelagic sediments (TRICART et al. 1982). Therefore all these serpentinite breccias can no longer be regarded as resulting from Alpine (i.e. late Cretaceous and/or Tertiary) tectonic frictions in the

[3]) Both types of ophicalcite were exploited as "marbles" during the past century: small abandoned quarries can still be seen in the high mountains of the upper Cristillan, Aigue-Blanche and Ubaye valleys.

heart or at the periphery of the main serpentinite bodies. Obviously, alpine shear zones do exist, either in serpentinites (see above), or in ophicalcites; but they clearly are restricted to narrow schistose zones where the ophicalcites take a planar texture. Elsewhere, the bulk of the breccias is little or not affected by Alpine deformation; therefore their sedimentary features are generally well preserved.

In the general case, the breccias comprise isodiametric, subangular clasts embedded in a more or less abundant calcareous matrix (Fig. 6b); these clasts are generally not sorted; they range in size from a few millimeters to several centimeters, even sometimes up to a few tens of centimeters. The main mass of these breccias exhibits no clear-cut stratification. Nevertheless, at some places, incipient stratifications result from a rough variation in mean grain size: for instance, near Pic Cascavelier (Fig. 4), arenite or gravel layers a few meters thick alternate with breccias; but in general the main character of the breccias is the lack of sorting of the mixed sand grains, gravels, and blocks.

Large blocks ("olistoliths") up to some ten meters in size, made up either of serpentinite or of gabbros, occur at some places in the serpentinite breccia.

b) *Other varieties of ophiolitic breccias* are much less frequent:

— A breccia with major gabbro and minor basaltic clasts occurs in the slope north of Roche Noire (Fig. 3); this breccia is cut by small basaltic dykes.

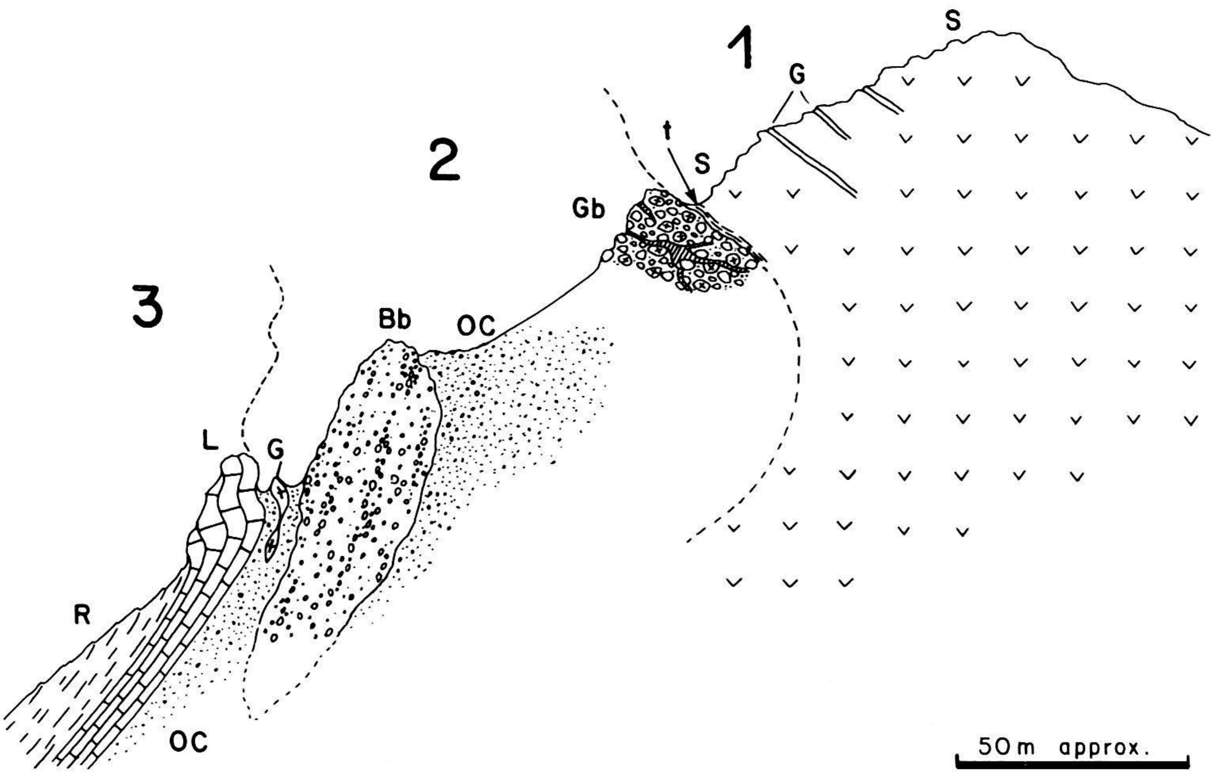


Fig. 3. Detailed section, north of Roche Noire summit.
Location: see Figure 2a. Explanation of symbols: see legend of Figure 7. In addition: t = talcschist.

Fig. 3. Coupe détaillée au nord du sommet de Roche Noire.

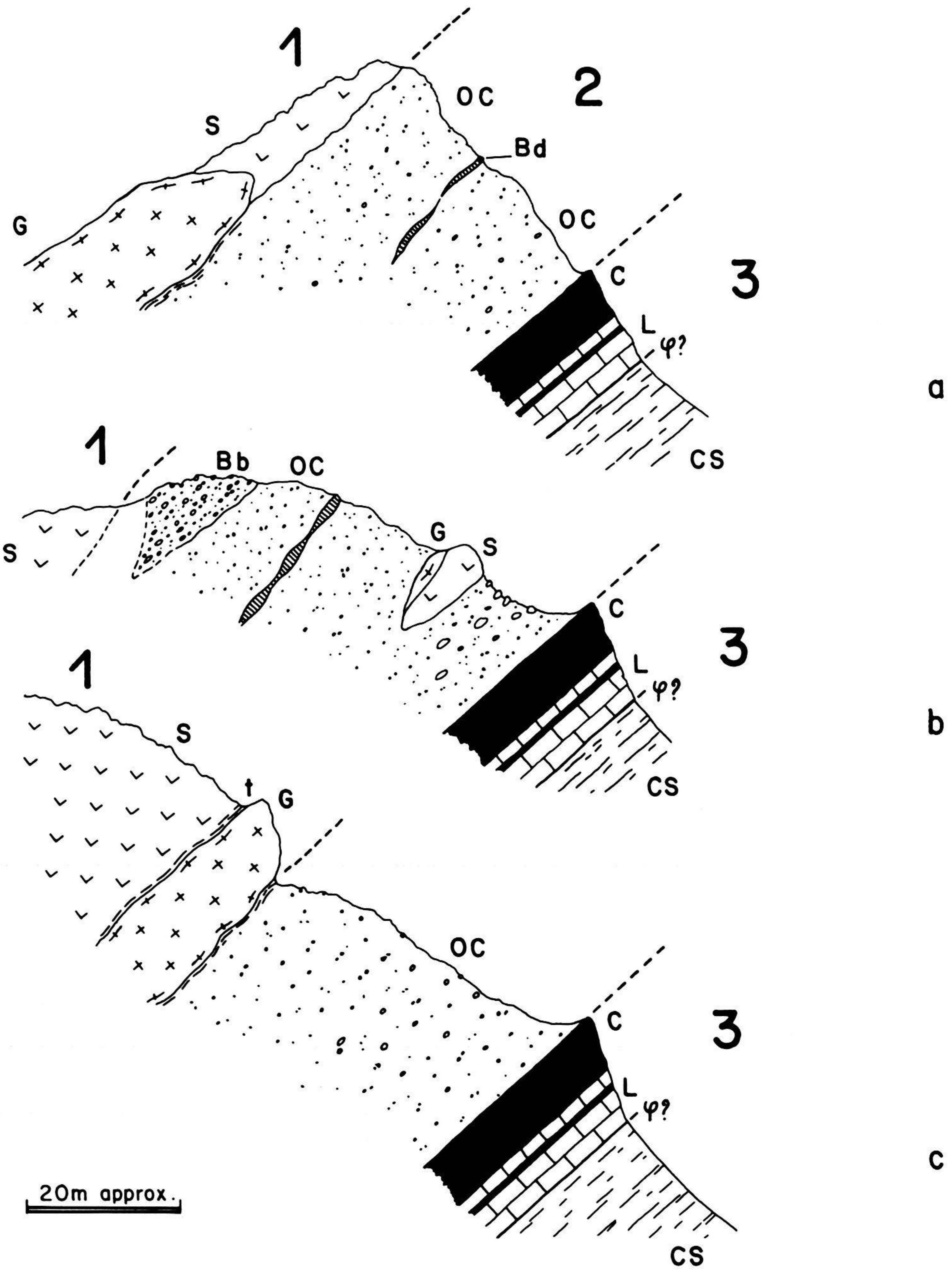


Fig. 4. Detailed sections, south of Cascavelier Peak.
Location: see Figure 2b. Explanation of symbols: see legend of Figure 7. In addition: cs = calcschists.

Fig. 4. Coupes détaillées au sud du Pic Cascavelier.
Localisation: figure 2b. Légende: voir figure 7. cs = calcschistes.

— Monogenic basaltic breccias also occur, as lens-like bodies in the serpentinite breccias, (Fig. 3, Fig. 4b); some clasts obviously originate from variolitic external crusts of pillows; hence, the question of the origin of these breccias, whether sedimentary, or volcanic, is still pending. If sedimentary, they obviously derive from very nearby volcanic flows; if volcanic, they may be either frontal or lateral margins of submarine volcanic flows. They may also represent large olistoliths derived from brecciated lava flows.

— A special case is that of a ten meters thick *polygenic breccia with both ophiolitic and quartzo-feldspathic clasts* (CABY et al. 1971), which occurs on the main crest south of Pic Marcel (Fig. 5). The clasts are: 1. either massive or variolitic basalts (hence originating from pillows), 2. gabbros of various compositions and textures (including *already foliated* gabbros), and 3. igneous quartzo-feldspathic rocks. Whether the latter originate from a continental crust of from plagiogranites or related rocks, remains to be settled. The clasts, with sizes up to 20 cm, lie in an arenaceous and gravelly matrix of the same lithologic composition as the clasts; an incipient layering results from the more or less basic composition of the matrix. Some narrow basaltic dykes cut across the breccia.

c) *Basaltic rocks* are much less abundant than the other ophiolitic rocks, even than the gabbros. Obviously they postdate here the deposition of the major part of the ophiolitic breccias.

Basaltic dykes cut across the serpentinite breccias near Pic Cascavelier (Fig. 4a, 4b) as well as across the polygenic breccia south of Pic Marcel (Fig. 5) and across the gabbro breccia north of Roche Noire (Fig. 3).

Basaltic flows are very rare in this area. South of Pic Marcel (Fig. 5), a 20 m thick lava flow is mainly made up of pillows, with pillow breccias at its top and bottom.

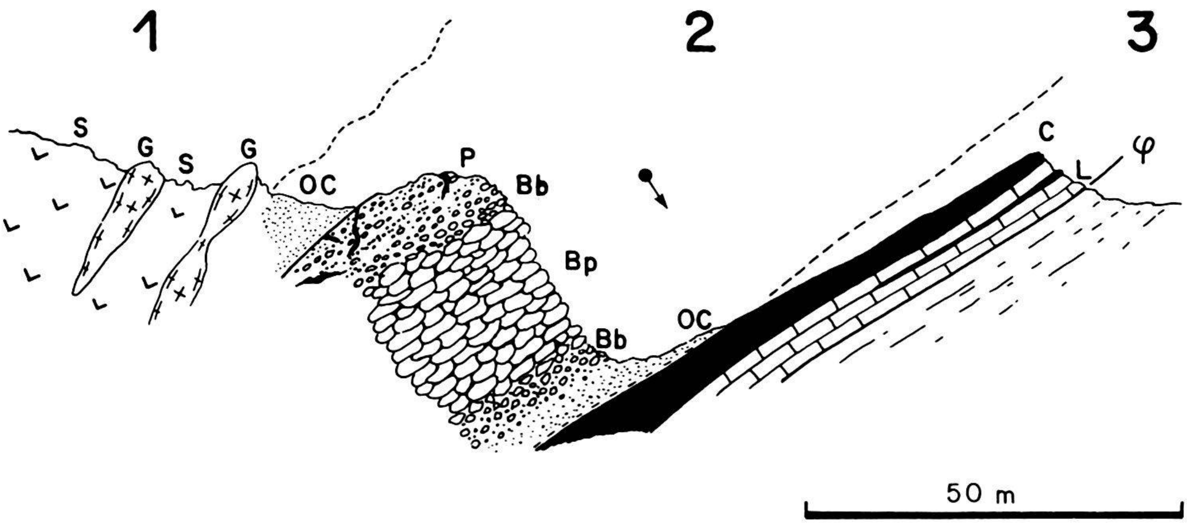


Fig. 5. Detailed section along the main crest, south of Pic Marcel.
Location: see Figure 2b. Explanation of symbols: see legend of Figure 7.

Fig. 5. Coupe détaillée sur la crête principale, au sud du Pic Marcel.
Localisation: figure 2b. Légende: voir figure 7.

This lava flow occurs at the top of the polygenic breccia, and is overlain by a serpentinite breccia, itself overlain in turn by radiolarian cherts. Basaltic breccias inserted near the top of the serpentinite breccias north of Roche Noire may represent a brecciated lava flow (compare Fig. 3 and 5).

d) *Primary (sedimentary) nature of the contact between the serpentinite-gabbro oceanic bottom (1) and the ophiolitic breccias (2):* Field data strongly suggest that the breccias were deposited directly upon the serpentinites. The contact is usually sharp. It appears as an irregular surface with knolls and depressions sometimes as much as 10 m deep. At some places however, the upper part of the serpentinite bottom is fractured and cut by calcitic veins, grading near the top into sedimentary breccias (i.e. transition from one variety of ophicalcite to the other one). Such a strongly irregular contact does not fit with the hypothesis of a late (Alpine) tectonic fragmentation of the serpentinite during Alpine thrustings and foldings. Therefore, we conclude that *the serpentinite breccias were laid down upon an irregular, fractured serpentinite bottom.*

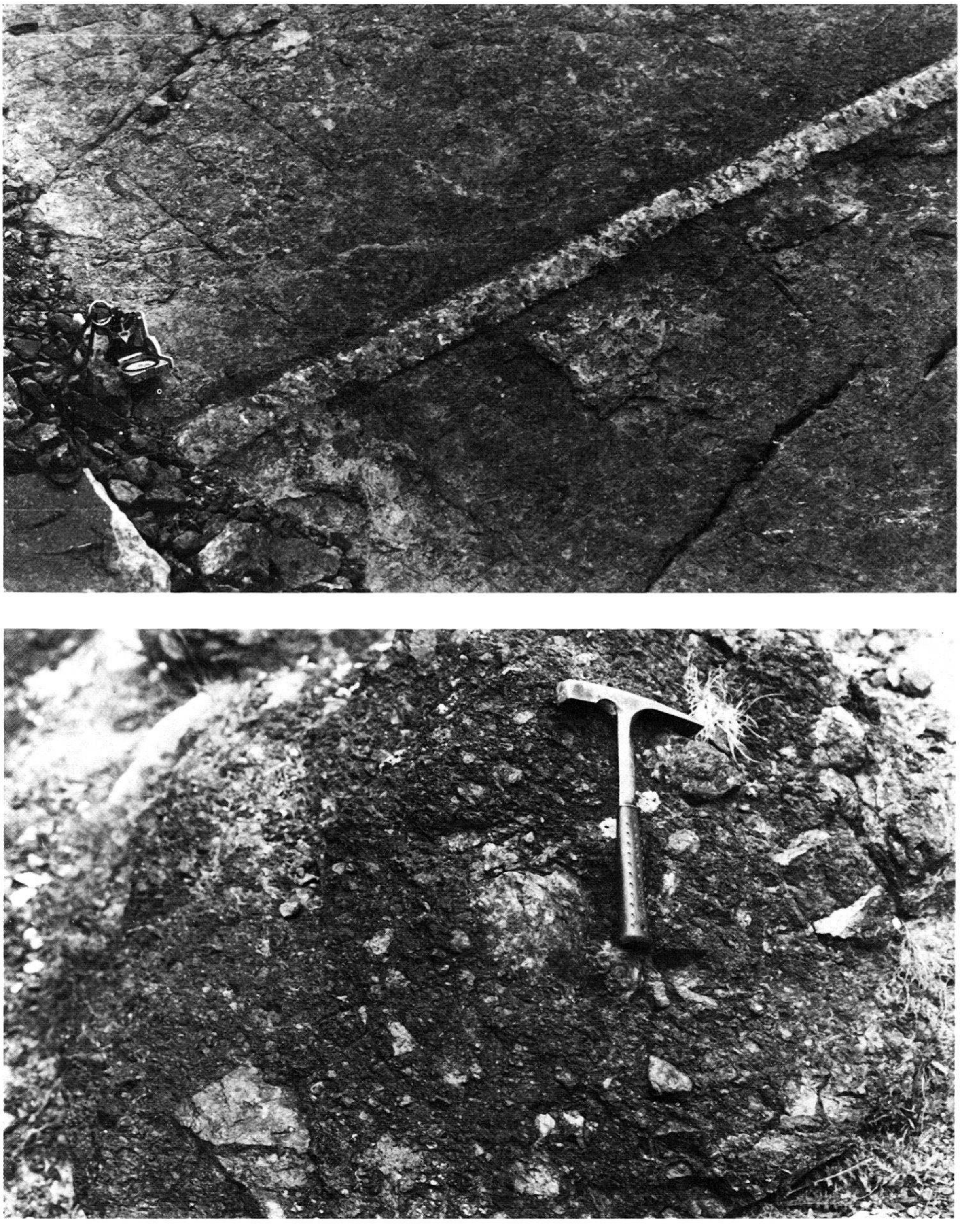
3. The pelagic sedimentary series

As in several other places, both in the Alps-Corsica and in the Apennines folded belts, a pelagic sedimentary series overlays the ophiolitic breccias and, if present, the basaltic flows as well.

Variously termed Chabrière series in the Western Alps (LEMOINE et al. 1970), Inzecca series in Corsica (AMAUDRIC DU CHAFFAUT et al. 1972) and Bracco series in the Northern Apennines (DECANDIA & ELTER 1971), it comprises four successive members, namely:

1. *Radiolarian cherts:* near Pic Cascavelier they bear a surprisingly well-preserved radiolarian fauna of late Oxfordian-middle Kimmeridgian age (DE WEVER & CABY 1981).
2. *Limestones:* by comparison with the Calpionella limestones of the Apennines, they are believed to be of late Jurassic-earliest Cretaceous age.
3. *Limestones and shales (Replatte formation),* or *calcschists,* equivalent of the Palombini formation of the Apennines (early Cretaceous).
4. *Shales and sandstones (Roche Noire formation)* analogous to the Val Lavagna shales of the Apennines (middle, and even late, Cretaceous).

Sedimentary nature of the lower contact of the pelagic series: When the ophiolite massifs of the whole Queyras area are considered, the radiolarian cherts rather seldom occur at the lower part of the sedimentary series: in fact, in most cases, the late Jurassic limestones lie directly upon ophiolitic breccias, and the contact appears, in the field, to be of sedimentary origin. Moreover, analogous relationships between ophiolites and ophiolitic breccias on the one side, and radiolarites or limestones on the other side, commonly occur in the Western Alps, in Corsica and in the Northern Apennines as well. Such a contact between the same formations over such an extensive area can hardly be interpreted as being of tectonic origin, all the more so, as examination of outcrops in these areas very often supports a sedimentary origin: therefore we definitely consider these relationships as primary ones, i.e. of sedimentary origin.



a

b

Fig. 6. Pictures of outcrops.

6a: Gabbro dykelet in serpentinite, Roche Noire massif.
6b: Unsorted serpentinite sedimentary breccia, near Pic Cascavelier.

Fig. 6. Photographies d'affleurements.

6a: Petit filon de gabbro dans la serpentinite, massif de Roche Noire.
6b: Brèche sédimentaire de serpentinite, près du Pic Cascavelier.

Ophiolitic arenites, breccias and olistoliths in the Chabrière series: Numerous ophiolitic detrital beds and olistoliths occur, at least in the Queyras area; they are interbedded at various levels of the Chabrière series (LEMOINE & TRICART 1979; LEMOINE 1980; LAGABRIELLE et al. 1982). In the area described here, they occur at different levels of the early Cretaceous Replatte formation (see Fig. 2a) as well as in the overlying Roche Noire Formation (TRICART 1974).

Comparison with other ophiolite massifs in neighbouring areas

Several ophiolite massifs of the Western Alps, especially those of the Queyras area and that of the Chenaillet massif east of Briançon (Fig. 1), display comparable features. The ophiolitic bottom may be for instance made up either 1. of serpentinites overlain by ophicalcites followed by the pelagic sedimentary series (e.g. Saint-Véran copper mine), or 2. of gabbros directly overlain by upper Jurassic limestones (e.g. Pelvas d'Abriès: LAGABRIELLE et al. 1982), or 3. even of gabbros and/or serpentinites overlain, without any intercalation of ophicalcites, by basalts followed by upper Jurassic limestones (e.g. Rocca Bianca: LAGABRIELLE et al. 1982). At several places, the gabbros are cut by basaltic dykes. Also noteworthy is the fact that certain gabbros exhibit a foliated structure (associated with metamorphism) which is certainly of early origin: in the Pelvas d'Abriès section, the upper Jurassic limestones lie unconformably (up to 30° or 45°) upon the foliated gabbros; in the Chenaillet massif, the foliated and metamorphosed gabbros are cut by undeformed basaltic dykes (MEVEL et al. 1978).

II. First conclusion: a preliminary geodynamic calendar

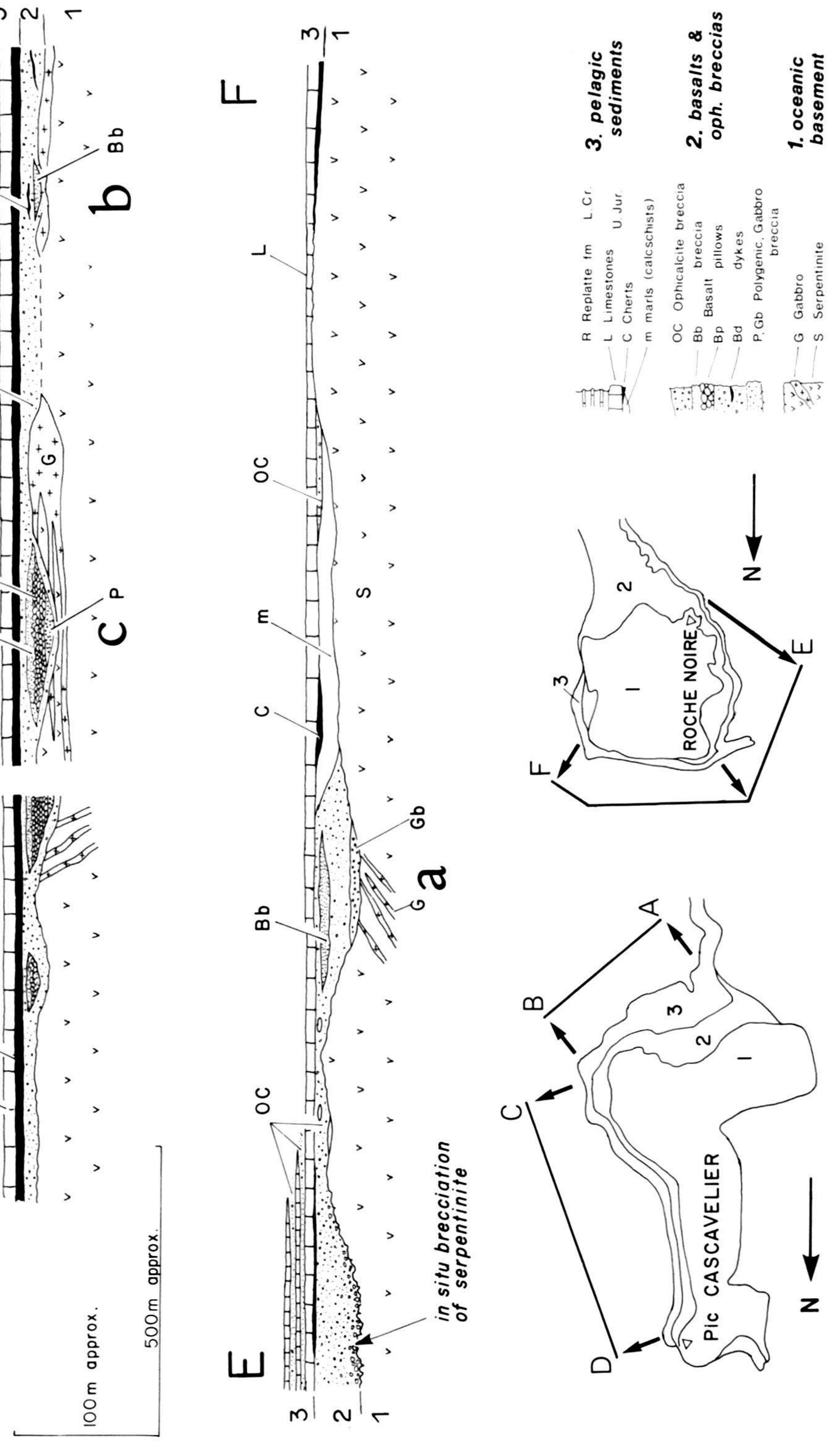
1. Preliminary remark: oceanic crust, oceanic basement, oceanic bottom

It must be recalled that one cannot speak here of "oceanic *crust*": this terms refers to a mainly mafic, mostly basaltic, body, a few kilometers thick (layers 2 and 3) which is assumed to occur in present-day oceans above the ultramafic upper mantle rocks. Since the basalts are here either absent or rather thin, we chose to speak of "oceanic *basement*" to designate the mainly ultramafic (and partly gab-

---

Fig. 7. Reconstitution of the primary relationships between the oceanic basement (1) and its sedimentary and volcanic cover (2: breccias and basaltic flows, and 3: pelagic sediments), from field observations in the Roche Noire and Cascavelier-Marcel massifs. Sections A–B and C–D from northeastern and southeastern slopes of the Cascavelier massif. Section E–F from northern and western slopes of the Roche Noire massif.
a, b, c: location of sections of figures 3, 4, 5.

Fig. 7. Reconstitution des relations primaires entre le socle océanique (1) et sa couverture sédimentaire et volcanique (2: brèches et coulées basaltiques; 3: sédiments pélagiques), d'après des observations sur le terrain dans les massifs de Roche Noire et du Pic Cascavelier.
Sections A–B et C–D: projection des versants nord-est et sud-est du massif de Cascavelier. Section E–F: projection des pentes nord et ouest du massif de Roche Noire.
a, b, c: localisation des coupes des figures 3, 4, 5.



Pic Cascavelier
A
B
C
D
a
b
c
L
C
Oc
Bb
Bp
P
G
Bd
E
F
OC
m
S
Gb
in situ brecciation of serpentinite
100m approx.
500m approx.
R Replatte fm L.Cr.
L Limestones U.Jur
C Cherts
m marls (calcschists)
OC Ophicalcite breccia
Bb breccia
Bp Basalt pillows
Bd dykes
P,Gb Polygenic, Gabbro breccia
G Gabbro
S Serpentinite
3. pelagic sediments
2. basalts & oph. breccias
1. oceanic basement
ROCHE NOIRE
Pic CASCAVELIER
N

broic) rocks which occured at the site of the incipient Tethyan ocean when the continental margins began to separate from each other. Finally, the term "oceanic *bottom*" is here restricted to *a surface*, more precisely, to a submarine surface; later on this surface became the interface between the oceanic basement and the either sedimentary or volcanic rocks which were deposited upon it. This distinction is necessary since certain petrogenetic, as well as tectonic, processes leading to the structuration of the oceanic basement in-being might possibly occur before any oceanic bottom appears.

2. Main results inferred from field data

First, the above-described field date allow three main conclusions to be drawn.

a) As soon as the first continental break-up occurred, *the first oceanic bottom which appeared between the European and the Apulian continents was made up of submarine outcrops of ultramafites associated with minor gabbro bodies.*

b) *Two magmatic events* at least occurred successively: the *first event* led to the emplacement of the *gabbros* in the ultramafites; whether this first event also resulted in submarine lava outflows, or not, cannot at present be deciphered. The *second event* resulted in *basaltic dykes* into the gabbros. In fact, these two events were *separated by a certain time span,* during which an oceanic bottom came into being and was subsequently eroded, and a certain amount of ophiolitic breccias deposited.

c) Moreover, at first glance, one cannot escape the conclusion that the first magmatic event, leading to emplacement of the gabbro dykes, might have occurred before - however shortly - the formation of the serpentinitic and gabbroic oceanic *bottom.*

3. A preliminary calendar

The geodynamic events would therefore have occurred in the following order:

1. The *intrusion of gabbros* in the ultramafites, as well as the *foliation* and metamorphism in the amphibolite to greenschist facies of part of them would have occurred first.

2. Then, the already associated ultramafites plus gabbros make their appearance, when the continental break-up occurs; hence the formation of an *oceanic bottom* susceptible to be covered by sediments. Obviously this bottom became rapidly rugged.

3. The deposition of the *ophicalcitic breccias* then occurred. They filled up depressions of the oceanic bottom; at some places, which probably were highs of the rugged bottom, no deposition occurred. Here and there, tholeiitic submarine outflows took place, followed or not by deposition of ophicalcitic breccias.

4. Finally, the deposition of the pelagic sedimentary series took place; this deposition began either with late Oxfordian-early Kimmeridgian radiolarian cherts, or with late Jurassic pelagic limestones.

III. Discussion and conclusions: new constraints and new problems

Such field data are known not only from the Western Alps, but also from Corsica, and more especially from the Northern Apennines (BARRET 1982; BARRET & SPOONER 1977; BRUNACCI & MANGANELLI 1980; CORTESOGNO et al. 1981, etc.). This implies that the Ligurian oceanic bottom, at least at the beginning of its history, calls for a different explanation than the "classical" present day oceans, such as the Atlantic ocean.

1. Possible actualistic models from present-day oceans

Beside the fact that a continuous, thick basaltic layer seems to occur over extensive areas of the present-day oceans, serpentinites and even gabbros nevertheless do actually outcrop in some places, especially in the Atlantic ocean basement. In this respect, at least two kinds of occurrences may be taken into consideration.

a) First, the *transform zones of the Equatorial Atlantic*, or even the *Gorringe bank* east of the Azores (LAGABRIELLE et al. 1981), can be compared with the Western Alps and Apennine ophiolitic basement (GIANELLI & PRINCIPI 1978; LEMOINE 1980). There, serpentinites as well as gabbros (even foliated and amphibolitized gabbros) and ophicalcitic breccias have been either dredged or directly observed (diving saucer) along "transverse" crests and scarps. Such conditions may have prevailed in the Ligurian segment of the Tethys ocean, whose early evolution very likely was governed by the left-lateral strike-slip relative motion of Africa and Apulia with respect to Europe (LEMOINE 1980, 1983).

b) But one may also consider some oceanic areas distant from important transform faults; in such areas, the birth and early evolution of the oceanic basement was governed by pure distensional movements. At the present state of our knowledge, two examples may be selected:

- In the Central Atlantic ocean close to the M.O.R., holes 556 and 558 of DSDP Leg 82 (BOUGAULT et al. 1983) have shown that the basaltic layer may locally be as thin as 100 m and lie upon serpentinites or gabbros, or even upon detrital beds made up of serpentinite and/or gabbro clasts.
- At the foot of the Iberian margin of the North Atlantic, close to the inferred continental crust-oceanic crust boundary, serpentinites has been dredged from an elongated hill (the so-called "5100 hill") which runs more or less parallel to this boundary (BOILLOT et al. 1978).

2. Early denudation or the serpentinite-gabbro oceanic bottom: possible models

Several models can therefore be set up to explain the sudden appearance of a serpentinite or gabbroic sea bottom as early as the very time when Apulia began to separate from Europe (150-160 m.y.).

First, when referring to the above-mentioned actualistic models, one may point out that the occurrence of serpentinitic submarine hills has been interpreted (BONATTI 1976) as resulting from "protusions", i.e. from something like a *serpentinite diapirism.* Such a process can act either in association with strike-slip movements (case of the transform zones) or in association with incipient distensional movements (case of the 5100 hill at the foot of the Iberian margin).

Another model, not an actualistic one, has been proposed by LOMBARDO & POGNANTE (1982) for the Western Alps ophiolites; it suggests a kind of *tectonic uncovering of the upper mantle rocks* as a result of stretching and break-up of the continental crust, coupled with differential sliding along the boundary between the latter and the upper mantle (see also DECANCIA & ELTER 1972).

In both categories of models, since we deal here with the earliest appearance of an oceanic basement between two continental blocks which begin to separate from each other, two main conclusions arise, namely: 1. The ultramafites may originate from a "sub-continental" mantle (see BOILLOT et al. 1980 and KORNPROBST et al. 1981 for the 5100 hill serpentinite). 2. Partial melting and subsequent gabbroic intrusions might have occurred below the continental crust during its stretching (LOMBARDO & POGNANTE 1982), i.e. before the first appearance of an oceanic *bottom.* Such possibility may perhaps explain some radiometric ages of ophiolitic rocks (CARPENA 1983) which appear as "too early" with respect to the *stratigraphic* age of the first sediments deposited upon the ophiolitic *bottom.*

Whatever the case, we believe that the selection of a model, whether it concerns the Ligurian Tethys only, or also other oceanic areas as well, calls first for further research.

3. The ophicalcitic and volcanic basal complex (2) seen as the recording of a major geodynamic event

Whatever the geodynamic model we attempt to build, one must take into account the existence of *a major geodynamic transitional event* which has been accompanied by the deposition of the ophiolitic breccias.

Prior to this deposition, several events took place, viz.: partial melting of the upper mantle in the course of rising, intrusion of gabbros, foliation of some of these gabbros, which evolved from amphibolite to greenschist metamorphic facies, serpentinization of the ultramafites during the end of their progressive uplift (LOMBARDO & POGNANTE 1983, CORTESOGNO 1980), and, finally, either denudation or diapiric uplift of the serpentinites leading to the birth of the first oceanic bottom.

After this deposition, another sedimentary regime took place, with deposition of the pelagic Chabrière series, interrupted from time to time by sudden, short detrital episodes.

The here considered event in fact corresponds both to the deposition of the ophicalcite breccias and to the outpouring of some tholeiitic lava flows, both displaying some special features.

a) In the here described sector, the tholeiitic *basalts* are poorly developed, and occur as relatively thin layers in the upper part of the breccia member. Nevertheless, clasts of basalts are known also from the basal parts of this member. Moreover, in other sectors of the Queyras area, in the Chenaillet massif, and elsewhere, the basaltic outflows may be somewhat thicker (locally up to a few hundred meters), and may occur close to the base of the breccias. Therefore, it seems likely that volcanism occurred sporadically all during the whole period of deposition of the breccias.

b) The O^{18} and C^{13} isotopic ratios of the calcitic matrix of the ophiolitic breccias suggest the presence of hot water; these breccias may also be associated with, or laterally replaced by, copper sulfur ores (e.g. Saint Véran mine), so that it has been proposed, as a working hypothesis, that the here investigated event may have been accompanied by a certain *submarine hydrothermalism* (LEMOINE et al. 1983).

c) When dealing with the *sedimentology of the breccias*, the following must be emphasized: these breccias are very poorly sorted, and little or not bedded. Moreover, neither internal hiatuses (such as, for instance, manganese crusts) nor internal erosions (channels, etc.) have yet been reported. All these data suggest a rapid deposition of mass flows along short, probably steep, slopes, from the foot of submarine cliffs towards depressions of the ophiolitic bottom. Such phenomena were very likely of short duration, whereas the overlying radiolarian cherts and pelagic limestones, even if perhaps redeposited at some places, correspond to a much slower sedimentation rate. Also, since the ophiolitic breccias are not interrupted by any pelagic episode, however thin, one must admit that *the ophicalcite event was of rather short duration*, being perhaps even "instantaneous" on the geological scale. This is also the case of the other ophiolitic detrital interbeds or olistoliths which occur at different levels of the overlying pelagic series: they also appear as quasi-instantaneous submarine rock slides or avalanches.

d) The rugged nature of the oceanic bottom, the brecciation of its upper part (first variety of ophicalcites) and the sudden and rapid detrital sedimentation (second variety of ophicalcites), all strongly suggest that these sedimentary events resulted from an *important tectonic activity:* normal and/or transcurrent fault-scarp generation associated or not with diapir rising, and even other tectonic processes.

To conclude, this *ophicalcitic and basaltic basal complex* records an event both relatively brief and highly intricate. Whatever the actual geodynamic processes involved, they accompanied *a tectonic-magmatic climax which heralds the very break-up of the continental crust in this part of Pangea.*

Acknowledgments

Many thanks are due to M. Gidon, G. Mascle and R. Trümpy for citical reading of the manuscript, and to J. Girault for language corrections.

REFERENCES

AMAUDRIC DU CHAFFAUT, S., CARON, J.M., DELCEY, R., & LEMOINE, M. (1972): Données nouvelles sur la stratigraphie des Schistes lustrés de Corse: la série de l'Inzecca. Comparaison avec les Alpes occidentales et l'Apennin Ligure. - C.R. Acad. Sci. (Paris) (D) *275*, 2611-2614.

BARRET, T.J. (1982): Review of stratigraphic aspects of the ophiolitic rocks and pelagic sediments of the Vara Complex, North Apennines, Italy. - Ofioliti *7*, 3-46.

BARRET, T.J., & SPOONER, E.T.C. (1977): Ophiolitic breccias associated with allochthonous oceanic crustal rocks in the East Ligurian Apennines, Italy - a comparison with observations from rifted oceanic ridges. - Earth and planet. Sci. Lett. *35*, 79-81.

BERNOULLI, D., & LEMOINE, M. (1980): Birth and early evolution of the Tethys: the overall situation. - 26th Int. Geol. Congr., Paris 1980, Coll. C5, p. 168-179.

BOILLOT, G., GRIMAUD, S., MAUFFRET, A., MOUGENOT, D., KORNPROBST, J., MERGOIL-DANIEL, J., & TORRENT, G. (1980): Ocean-Continent boundary off the Iberian margin: a serpentinite diapir West of the Galicia bank. - Easrth and planet. Sci. Lett. *48*, 23-34.

BONATTI, E. (1976): Serpentinite protusions in the oceanic crust. - Earth and planet. Sci. Lett. *32*, 107-113.

BOUGAULT, H., CANDE, S., et al. (1982): On Leg 82. Elements traced in the Atlantic. - Geotimes, July 1982, 21-23.

BRUNACCI, S., & MANGANELLI, V. (1980): Geologia della zona ofiolitifera compresa tra Murlo e Pari (Prov. di Siena e di Grossetto). - Ofioliti *5*, 161-194.

CABY, R., MICHARD, A., & TRICART, P. (1971): Découverte d'une brèche polygénique à éléments granitoïdes dans les ophiolites métamorphiques piémontaises (Schistes lustrés du Queyras, Alpes françaises). - C.R. Acad. Sci. (Paris) (D) *273*, 999-1002.

CARON, J.M. (1977): Lithostratigraphie et tectonique des Schistes lustrés dans les Alpes cottiennes septentionales et en Corse orientale. - Mém. Soc. géol. Strasb. *48*.

CARPENA, J. (1983): Ophiolite fission track ages in the French occidental Alps. - Terra Cognita *3*/23, 183 (Abstract).

CORTESOGNO, L. (1980): Il metamorfismo giurassico nelle ofioliti dell'Appenino settentrionale: due distinti cicli metamorfici in ambiente oceanico. - Ofioliti *5*, 5-18.

CORTESOGNO, L., GALBIATI, B., & PRINCIPI, G. (1981): Descrizione dettagliata di alcuni caratteristici affioramenti di brecce serpentinitiche della Liguria orientale ed interpretazione in chiave geodynamica. - Ofioliti *6*, 47-76.

CORTESOGNO, L., GALBIATI, B., PRINCIPI, G., & VENTURELLI, G. (1978): Le brecce ofiolitiche della Liguria orientale: nuovi dati e discussione sui modelli paleogeografici. - Ofioliti *3*, 99-160.

DECANDIA, F.A., & ELTER, P. (1982): La «zona» ofiolitifera del Bracco nel settore compreso fra Lavanto e la Val Graveglia (Apennino Ligure). - 66th Congr. Geol. Soc. ital., Pisa, p. 37-64.

GIANELLI, G., & PRINCIPI, G. (1977): Northern Apennine ophiolite: an ancient transcurrent fault zone. - Boll. Soc. geol. ital. *96*, 53-58.

KORNPROBST, J., OHNENSTETTER, D., & OHNENSTETTER, M. (1981): Na and Cr contents in clinopyroxenes from peridotites: a possible discriminant between "sub-continental" and "sub-oceanic" mantle. - Earth and planet. Sci. Lett. *53*, 241-254.

LAGABRIELLE, Y. (1981): Les Schistes lustrés à ophiolites du Queyras (Alpes franco-italiennes): données nouvelles et précisions lithostratigraphiques. - C.R. Acad. Sci. (Paris (II) *292*, 1405-1408.

— (1982): Ophiolites et croûte océnique; tectonique et environnement sédimentaire: apports des données océaniques à l'interprétation géologique des séries ophiolitifères du Queyras (Alpes franco-italiennes). - Unpubl. thesis, Univ. Brest.

LAGABRIELLE, Y., & AUZENDE, J.M. (1982): Active in situ disaggregation of oceanic crust and mantle on Gorringe Bank: analogy with ophiolitic massives. - Nature *297*, 490-493.

LAGABRIELLE, Y., NERVO, R., POLINO, R., & DUTTO, F. (1982): Sedimentary cover of some ophiolites of Cottian Alps. - Ofioliti *7*, 339-350.

LAGABRIELLE, Y., AUZENDE, J.M., CORNEN, G., JUTEAU, T., LENSCH, G., MEVEL, C., NICOLAS, A., PRICHARD, H., RIBEIRO, A., & VANNEY, J.R. (1981): Observations par submersible de croûte océanique affleurant sur le banc de Gorringe (SW Portugal): évidence de processus de démantèlement des gabbros en milieu sous-marin. - C.R. Acad. Sci. (Paris) (II) *293*, 827-832.

LAGABRIELLE, Y., POLINO, R., AUZENDE, J.M., BLANCHET, R., CABY, R., FUDRAL, S., LEMOINE, M., MEVEL, C., NERVO, R., OHNENSTETTER, M., ROBERT, D., & TRICART, P. (1983): Les témoins d'une tectonique intra-océanique dans le domaine téthysien: analyse des rapports entre les ophiolites et leur couverture métasédimentaire dans la zone piémontaise des Alpes franco-italiennes. - Ofioliti in press.

LEMOINE, M. (1971): Données nouvelles sur la série du Gondran près Briançon (Alpes cottiennes). Reflexion sur les problèmes stratigraphiques et paléogéographiques de la zone piémontaise. - Géol. alp. (Grenoble) *47*, 181-201.

— (1980): Serpentinites, gabbros and ophicalcites in the Piemont-Ligurian domain of the Western Alps: possible indicators of oceanic fracture zones and associated serpentinites protusions in the Jurassic-Cretaceous Tethys. - Arch. Sci. Genève *33*, 103-116.

— (1983): Rifting and early drifting: Mesozoic Central Atlantic and Ligurian Tethys. - Init. Rep. Deep Sea Drill. Proj. *76*.

LEMOINE, M., STEEN, D., & VUAGNAT, M. (1970): Sur le problème stratigraphique des ophiolites piémontaises et des roches sédimentaires associées: observations dans le massif de Chabrière en Haute-Ubaye (Basses-Alpes, France). - C.R. Soc. Phys. Hist. nat. Genève [N.S.] *5*, 44-59.

LEMOINE, M., & TRICART, P. (1979): Une partie des Schistes et des ophiolites du Queyras (Alpes occidentales françaises) résultent-ils de sédimentations et d'écroulements au pied d'un escarpement de faille océanique? - C.R. Acad. Sci. (Paris) (D) *276*, 705-708.

LEMOINE, M., BOURBON, M., GRACIANSKY, P.C. DE, & LETOLLE, R. (1983): Isotopes du carbone et de l'oxygène de calcaires associés à des ophiolites (Alpes Occidentales, Corse, Apennin): indices possibles d'un hydrothermalisme océanique téthysien. - Rev. Géogr. phys. Géol. dyn. in press.

LOMBARDO, B., & POGNANTE, U. (1982): Tectonic implications in the volution of the Western Alps ophiolites metagabbros. - Ofioliti *7*, 371-394.

MEVEL, C., CABY, R., & KIENAST, J.R. (1978): Lower amphibolite facies conditions in the oceanic crust: example of amphibolitized flasergabbros and amphibolites in the Chenaillet ophiolite massif. - Earth and planet. Sci. Lett. *39*, 98-108.

STEINMANN, G. (1926): Die ophiolitischen Zonen in den Mediterranen Kettengebirgen. - Int. Geol. Congr., Madrid *2*, 637-667.

TRICART, P. (1973): Tectoniques superposées dans les calcschistes piémontais du Haut-Cristillan (Queyras, Alpes franco-italiennes). - C.R. Acad. Sci. (Paris) (D) *276*, 705-708.

— (1974): Les Schistes lustrés du Haut-Cristillan (Alpes cottiennes France): lithostratigraphie, architecture et tectogenèse. - Géol. alp. (Grenoble) *50*, 131-152.

— (1980): Tectoniques superposées dans les Alpes occidentales, au Sud du Pelvoux: évolution structurale d'une chaîne de collision. - Unpubl. thesis, Univ. Strasbourg.

TRICART, P., BOURBON, M., & LAGABRIELLE, Y. (1982): Révision de la coupe Péouvou-Roche Noire (zone piémontaise, Alpes franco-italiennes) bréchification synsédimentaire d'un fond océanique ultrabasique. - Géol. alp. (Grenoble) *58*, 105-113.

WEVER, P. DE, & CABY, R. (1981): Datation de la base des Schistes lustrés postophiolitiques par des Radiolaires (Oxfordien supérieur-Kimméridgien moyen) dans les Alpes cottiennes (Saint-Véran, France). - C.R. Acad. Sci. (Paris) (D) *292*, 467-472.