# SIGNIFICANCE OF SANDSTONES INTERBEDDED IN THE JURASSIC BASALTS OF THE BALAGNE OPHIOLITIC NAPPE (CORSICA, FRANCE)

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ABSTRACT

The Balagne Nappe which includes a thick ophiolitic succession, has an isolated external western position and is underlain by Eocene rocks over the autochthonous Corsican basement. The nappe consists, from base to top, of: 1) basaltic pillow lavas up to 1 km thick, 2) oceanic sediments (radiolarites, limestones showing diverse facies, particularly pelagic, pelites with interbeds of "Palombini"-type limestones, and 3) detrital formations ranging from the Albian-Cenomanian to Middle Eocene. The trace element content of the basalts of the Balagne Nappe s.l. is characteristic of enriched mid-oceanic ridge basalts (E-MORB). In contrast, lavas of the more eastern Ligurian Units, such as the Inzecca Unit (Upper 'Schistes lustrés'), have an N-MORB character. We can thus define a marginal "Balagne-Ligurian domain".

In their lower part close to the gabbroic substratum, near Piana di Castifao, the Jurassic basalts have a level of feldspathic and micaceous quartzitic sandstone with calcareous cement (Baud, 1975). This level, 3 m thick, is intercalated within two 8-m layers of basaltic breccia (exploded pillows), sandwiched between flows of pillow lavas in places showing normal polarity. This rules out a tectonic hypothesis for the contacts at the base and top of the sandstones, as both contacts are clearly stratigraphic. The top of the sandstones is coarse grained, with lithic debris of continental origin and basalt fragments. The heavy minerals originate either from the oceanic or continental material. Zircons are particularly abundant and well preserved, which indicates limited transport. The typological study, according to Pupin's diagram (1980), reveals that zircons plot in the field overlapping that of zircons from calc-alkaline granites (s.l.), highly abundant in the Corsican-Sardinian batholith.

The Piana di Castifao sandstone interbed is the only known example in the Corsican Ligurian ophiolites. A similar thin bed has been described from the top of the ophiolitic sequence of the "Lago Nero-Replatte Nappe" to the east of Briançon in the French-Italian Alps. Similarly, in the Queyras region West of Mount Viso were reported sands and gravels with granite clasts, here there are underlying pillow basalts extruded over a serpentinite substratum. In both cases (east of Briançon and Queyras), no geological nor geochemical indications were found to constrain the position of the continent that supplied the detrital material.

The detrital material originated from a continental source similar to that of Piana di Castifao. The Balagne-Ligurian domain of the Ligurian Ocean must therefore have been situated, during the Jurassic, relatively close to the Western European continental margin, as indicated by the geochemical facies of the E-MORB, the basement fragments within the San Colombano supra-ophiolitic limestones, and the Piana di Castifao quartzitic interbed. The eastern margin of the Ligurian Ocean was also characterized by continental detritus as shown in the Cretaceous External Ligurides in the Northern Apennines.

## INTRODUCTION

The presence of terrigenous clasts in the Balagne ophiolitic succession has contributed to provide information on the nature of the ancient margin of the Jurassic Ligurian paleo-ocean.

## GEOLOGICAL SETTING

The Balagne ophiolitic nappe (Durand Delga et al., 1978; Nardi et al., 1978), derived from the Ligurian domain, did not suffer notable Alpine metamorphism in contrast to most of the other nappes from the same domain, which are considered together within the "Schistes lustrés" (SL) Nappe.

The main Alpine structural pattern was slightly disturbed from the end of the Early Miocene, by the formation of major N-S-trending antiforms (Cap Corse, Tenda) and synforms (Nebbio, Balagne).

The Balagne Nappe (Fig. 1) crops out over some 100 km to the southeast of Ile Rousse and is preserved in the westernmost synform. It comprises (Fig. 2) a pile of superposed subunits that, to the west, thrust Eocene silicoclastic formations of the western autochthonous basement. To the east, the nappe is isolated from the N-S-trending Tenda antiform, showing outcrops of reworked Variscan basement, by a main NNW-SSE-striking fault (Ostriconi Fault). Both this basement and its cover underwent Alpine metamorphism and deformation, and plunge eastwards beneath the SL Nappe.

Summarizing, the Balagne ophiolitic nappe which results from the westward obduction of a Ligurian-Piedmont ocean fragment, is preserved in the highest structural position on the western Corsica autochthonous basement. In its southern half, the Balagne Nappe is essentially composed of ophiolitic basalts topped by oceanic sediments typical of the Ligurian Units: Upper Dogger - Malm radiolarites, limestones from the Jurassic-Cretaceous boundary, Lower Cretaceous clayey pelites with interbeds of "Palombini"-type limestones (San Martino Formation). In its northern half, the nappe is mainly made up of continental-derived formations, predominantly detrital, Mid-Cretaceous to Middle Eocene in age: Albian-Cenomanian lydites (cf. Marino et al., 1995), the Alturaja Formation (Late Cretaceous to Paleocene?), the Annunciata Formation (Eocene). Most of the lithologies identified in western autochthonous Corsica are thus present within the detrital formations.

The Balagne basalts are essentially pillow lavas, apart from the local intercalation of columnar flows along the Lagani River (Baud, 1975). In the absence of recognized tectonic repetition, the thickness of the basalts is estimated as at least several hundred metres and may be as much as 1 km. Gabbros and serpentinites (ancient olivine gabbros or plagioclase peridotites? according to Baud (1975) crop out locally from beneath the basalts as discontinuous slices, particularly to the northeast of Moltifao.

South of the Balagne Nappe, erosion by the Asco River along its W-E course and its tributaries has exposed the autochthon: *i.e.* detrital Eocene sediments overlying a granitic substratum (cf. 1:50,000-scale Corte map, Rossi et al., 1994). Along the southern bank of the river near Ponte-Leccia, some scattered nappe outliers have ophiolites. Their high tectonic position and lithological composition suggest that they belong to the southern continuation of the uplifted Balagne allochthon. The Pineto-Tribbio Unit (Durand-Delga, 1984) is the best example, mainly along the eastern bank of the Golo River between Ponte-Leccia and the area surrounding Francardo. This unit is essentially composed of gabbros (Franconi, 1967; Ohnenstetter and Ohnenstetter, 1975 and Rossi et al., 1994). To the south and east they are troctolites with intercalations of serpentinized dunites; to the north and west, thick magnesian, locally pegmatitic, "euphotide" gabbros. These rocks are remarkably well preserved, showing slight Alpine greenschist metamorphism, as in the Balagne. Their thickness, impossible to identify precisely, could be as much as 1 km. At the northwestern limit (Testa a l'Ortone) along the left bank of the Golo River, the euphotide gabbros are in direct contact with their sedimentary cover, comprising red radiolarites overlain by upper Berriasian Calpionellid Limestones, "Palombini" Shales, and finally, a younger (Cretaceous?) calcareous-sandy flysch (Durand-Delga, in Rossi et al., 1994). In this area, between gabbros and radiolarites, the basaltic pillow lavas are absent or reduced to only a few metres.

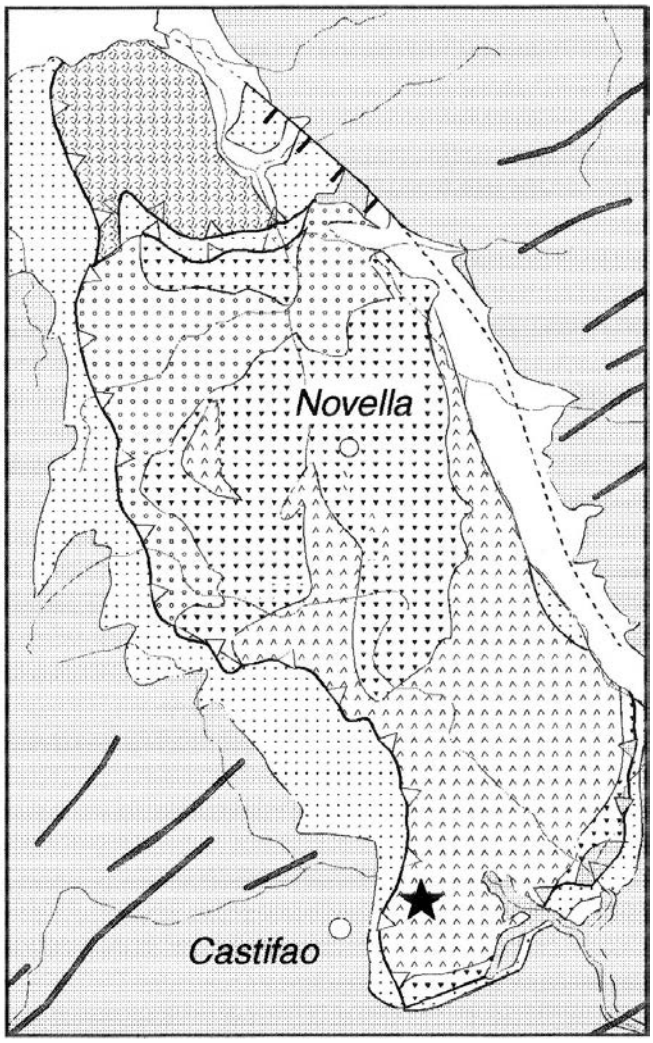


Fig. 1 - Location of the Piana di Castifao sandstone outcrop in the Balagne Nappe. White: Quaternary formations; grey: basement and dike swarm; ^: ophiolites; triangles: Cretaceous conglomeratic formations; small dots: Eocene autochthonous formations; open dots: Eocene allochthonous formations; grey dots: "bas-Ostriconi Nappe" (Late Cretaceous); star: Piana di Castifao outcrop.

In conclusion, the remains of an allochthonous ophiolitic unit ("Balagne Nappe" s.l.) are identifiable between the Francardo region in the south and the Mediterranean shore in the north. Possibly composite, it shows the two following major characteristics:

1. The Balagne oceanic basalts have a similar composition to enriched mid-oceanic ridge basalts (E-MORB) based on their trace-element distribution (Venturelli et al., 1981; Ohnenstetter, 1993; Durand-Delga et al., 1997). This indicates relative proximity of a continent, after a rifting stage, at the beginning of ocean formation in the Late Lias to Dogger. Conversely, the ophiolites of the more internal Corsican Ligurian Units belonging to the "Schistes lustrés" zone, such as the Inzecca Unit, show a N-MORB character, i.e. oceanic basalts emplaced without continental influence.
2. From Albian to Cenomanian, the supra-ophiolitic sediments of the Balagne Units are laden with continental detritus (sandstones, conglomerates, olistoliths), coming from rocks indistinguishable from those known in western Corsica (granites, Permian volcanic, metamorphic basement …). We can thus define a "Balagne-Ligurian" domain (Durand-Delga et al., 1978) having a marginal position in the Balagne Nappe, probably close to the western European continent.

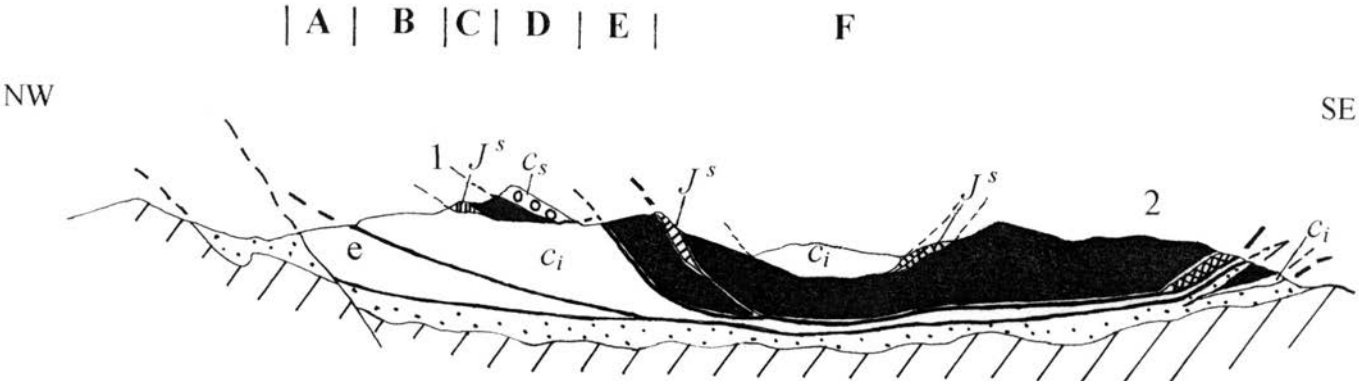


Fig. 2 - Schematic cross section of the Balagne Nappe. Autochthon, oblique stripes: Variscan basement; dots: Middle to Upper Eocene. Nappe, A: Annunciata Sub-unit; B: Toccone Sub-unit; C: San Colombano Sub-unit; D:; $J^s$: Middle Jurassic to Berriasian; *Ci*: Early Cretaceous to Cenomanian; *Cs* Early(?) Cretaceous; e: Eocene.

## THE PIANA DI CASTIFAO SECTION

Near Piana di Castifao, at the southwestern point of the Balagne Nappe (Fig. 1), a quartzitic sandstone is intercalated in the basaltic pillow lavas. The bed is near the base of the stacked basaltic lavas, probably near the gabbroic substratum. In fact, nearby, to the east of Castifao, gabbros and associated serpentinites crop out without a major tectonic hiatus. However, at Piana, near the basal contact of the Balagne Nappe, the position of the sandstone bed within the primitive ophiolitic sequence has not been identified.

The outcrop is intersected by the D 457 road embankment, about 50 m southeast of the Tartagine bridge, not far from the access road to Piana. Discovered by Baud (1975), the sandstones, which can be traced for some 15 m, must continue westwards over a similar distance beneath a scree cover. The sandstone interbed is approximately 3 m thick (Fig. 3) with a dip of 20-30 to the southeast.

The Piana di Castifao section shows, from bottom to top:

1. Pillow lavas (50 cm to 1 m in diameter), poorly exposed, overlain by 8 m of basaltic pillow breccia ("exploded pillows with hyaloclastites").
2. The sandstones interbed (3 m thick) with some mm-thick bands of black micaceous pelites, representing the only trace of stratification in the sandstone. Its coarser upper part contains rhyolitic quartz, probably derived from the Permian volcano-sedimentary formations, micaschist debris and, at the very top, basaltic fragments heralding the upper lava flow.
3. A lava flow with a further 8-9 m of basaltic pillow breccia at the base with hyaloclastite beds; higher up, a thick formation of normal pillows, commonly with a variolitic rim, clearly indicates normal polarity.

The sandstone (Fig. 4) is coarse grained, slightly feldspathic and commonly laden with white mica flakes; the calcareous cement contains rare organic fragments, among them crinoids and foraminifers sections (B. Peybernès et al., in press). A detailed inventory, after crushing and magnetic and density separation, has made it possible to identify the following heavy minerals: zircon, pyroxene, green amphibole, biotite, chlorite, garnet (almandine-andradite), chrome spinel, hematized pyrite, hematite, tourmaline and apatite. The supply was thus both oceanic (chrome spinel, pyroxene, green amphibole) and continental, particularly the zircon.

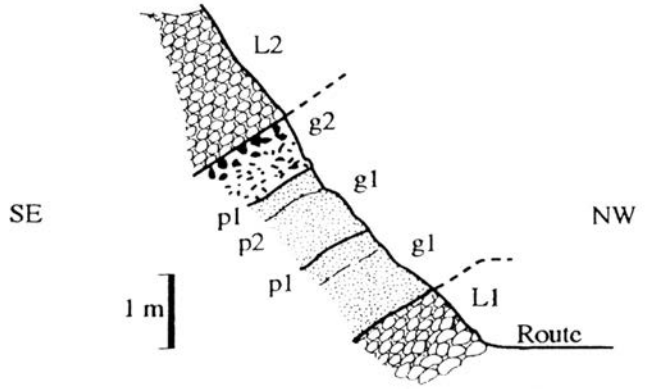


Fig. 3 - Section of the sandstone interbed (g1, g2) at Piana di Castifao. L1, L2: pillow-breccia; p1:pelites (cm beds); p2: thin pelitic layer.

## ZIRCON STUDY

The excellent preservation of the zircons combined with their abundance have allowed a typological study, which revealed four population types (Fig. 5):

- a first population (12% of the total) of very dark, zoned zircons, commonly with an even darker core that cannot be indexed;
- a second population (7% of the total) of colourless to pale-coloured (pink) zircons, commonly rounded or ovoid, and locally showing pitted surfaces;
- a third population (5% of the total) of very dark zircons, ovoid or rounded.
- a fourth population (76%) of zircons that can be indexed, some colourless, others dark and zoned commonly with an obvious darker core.

The average index of the fourth population (A,T = 472.36-593.42), characterizes zircons derived from magnesian-potassic and calc-alkaline granites; according to Pupin's diagram (1980), the plotted field overlaps that of zircons from the calc-alkaline granites of the Corsican Batholith. The absence of populations characteristic of alkaline complexes is notable.

It could be emphasized that the Piana zircons show a marked difference from those of plagiogranites from the Inzecca ophiolites (Ohnenstetter et al., 1981).

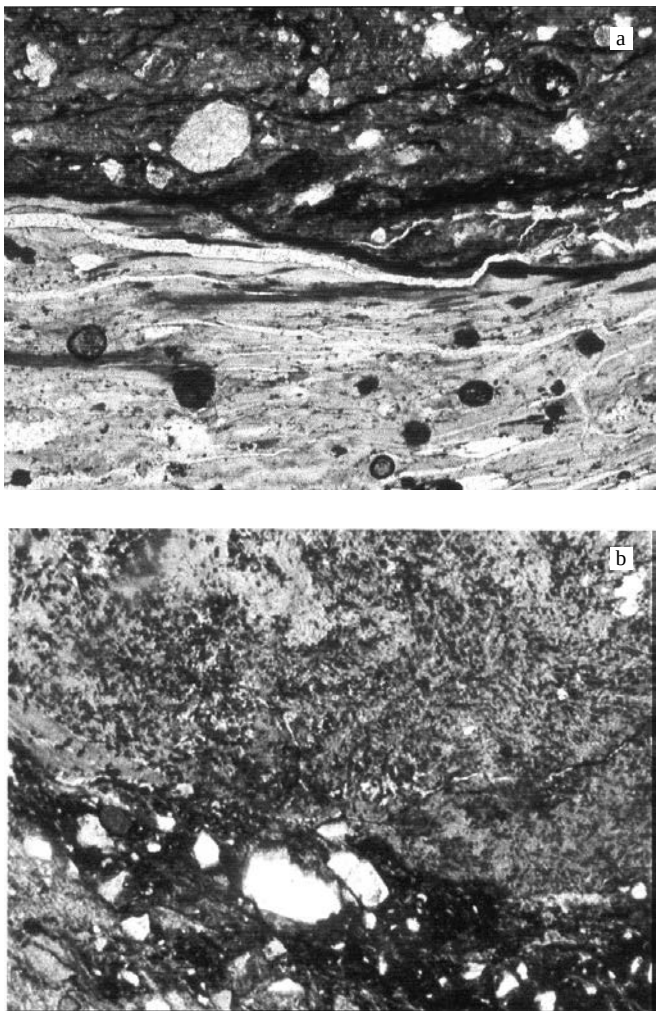


Fig. 4 - Base (a) and top (b) of the sandstone interbed at Piana di Castifao.

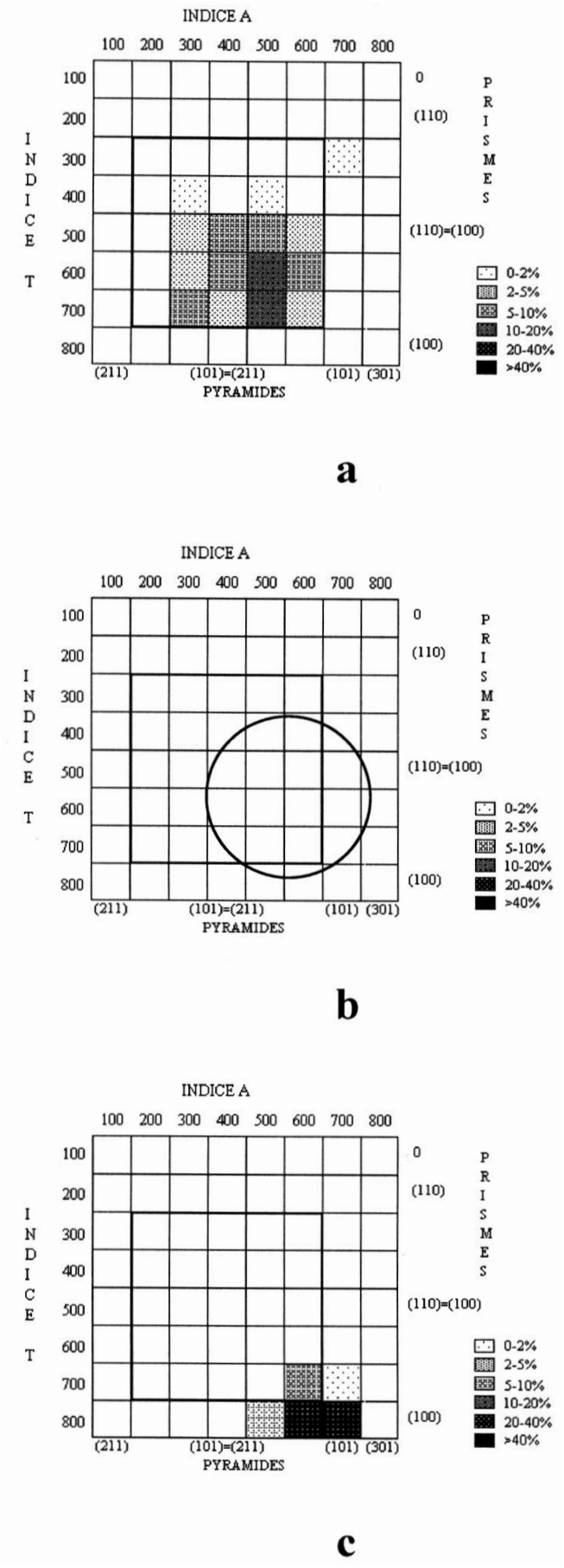


Fig. 5 - Zircon typology according to Pupin's diagram (1980). a- Piana di Castifao sandstone; b- Hercynian calc-alkaline granites from western Corsica; c- ophiolitic plagiogranites from Inzecca.

## COMPARISONS AND CONCLUSIONS

The observation of association of ophiolites and continental material from the "Schistes lustrés" nappe in Corsica, can be compared to those of the French-Italian Alps, the Apennines and Calabria.

1. In the Corsican "Schistes lustrés" nappe, the Morteda-Farinole Unit (Lahondère and Lahondère, 1988) includes eclogitic metaconglomerates containing continental pebbles within ophiolitic formations affected by blueschist metamorphism (Lahondère and Caby, 1989).
2. In the French-Italian Alps, the following examples of continental sands associated with ophiolites of the Ligurian Units exist (references hereafter).
   a) In the Chenaillet Massif to the east of Briançon, the "Lago Nero-Replatte Nappe" (Cirio and Lemoine, 1996) occupies the westernmost part of the "Schistes lustrés" zone. The supra-ophiolitic sediments here are affected by blueschist metamorphism. Directly overlying a serpentinite mass, capped by ophicalcites and a thin basaltic breccia, are (Polino and Lemoine, 1984): radiolarites, a bed of marble (several metres thick), and a Cretaceous pelitic unit with the "Replatte Formation" at the base. The succession overlying the radiolarites can be compared with the "Palombini" type one such as the Corsican Erbajolo Formation.
   A thin detrital layer of continental material locally overlies the basaltic breccia south of Mount Corbioun. This quartzo-feldspathic layer is laden with a variety of minerals (white mica, chlorite, biotite, apatite, sphene, and zircon; R. Polino, written comm., 1997) derived from the erosion of rocks similar to biotite granites, of which this layer contains pebbles. This sandy layer occupies the same level as the radiolarites overlain by the marbles marking the Jurassic-Cretaceous boundary and is overlain by the marbles marking the Jurassic-Cretaceous boundary. According to Polino and Lemoine (1984), the continental source is either a) one of the two continental margins (European or Apulian) of the Ligurian Tethys, or b) a continental intraoceanic block .
   b) In the Queyras region (Marcel Peak), approximately 25 km to the south-southeast of the Chenaillet area, sands and gravels containing granite fragments are interbedded in the lower part of a polygenic breccia within a tectonically overturned ophiolitic succession (Saby et al., 1988). The breccia is separated from its serpentinite substratum by ophicalcites and is stratigraphically overlain by pillow basalts, and then by a sedimentary cover. The zircon typology and trace-element distribution prove the calc-alkaline nature and continental origin of the granites in this sandy layer. Saby et al. (1988) concluded in favour of erosion of one of the two continental margins during the initial opening of the Western Tethys.
   For the Balagne Nappe, the lithology of the sediments has revealed that the European continental margin, in particular the batholith of western Corsica, supplied the detrital material associated with the ophiolites (Durand-Delga et al., 1997). Indeed, 8 km to the north-northwest of Piana di Castifao, overlying the radiolarites (which age is between Late Dogger and Kimmeridgian) capping the pillow lavas, the San Colombano Limestones (dated as Kimmeridgian by a rich microfauna) contain variably rounded debris of a

rock assemblage known in western Corsica. The fragments, up to 0.5 m in size, not only include very abundant calc-alkaline granites and Permian-Carboniferous lavas, but also rocks petrographically specific to western Corsica, such as rare Permian hypersolvus granites. The question thus arises as to whether the continental detritus at the top of the ophiolites of the Lago Negro-Replatte Unit and at the base of the pillow basalts of Marcel Peak of the Western Alps can be assigned to a similar framework, thus representing further evidence of the proximity of the European continent to the western part of the Ligurian Ocean.

3. In the Southern Italian Apennines (Spadea, 1982), blocks of low pressure-high temperature granulitic gneisses (kinzigites) presumably derived from the "African margin" are included in the ophiolites, suggesting that the oceanic crust developed on a thinned and/or dilacerated continental crust. These same ophiolites are directly overlain by terrigenous sediments testifying the proximity of a continent (Lanzafame et al., 1978).
4. Blocks of "felsic granulites" (quartzo-feldspathic rocks of metasedimentary origin and quartz-free charnockites) and Hercynian granitoids (ranging from biotite-rich granodiorites and tonalites to per-aluminous two-mica granites) have been revisited (Marroni et al., 1997) in the Upper Cretaceous sedimentary "mélanges" of the External Ligurides of the Northern Apennines. For Marroni et al. (1997), these detritus come from the eastern margin of the Jurassic ocean *i.e.* the "Insubrian" continent.

The presence of the underlying kinzigite basement (in slices, or as clasts within the ophiolites), and the continental sediments interbedded within or directly overlying the same ophiolites, suggest that these relics of the Ligurian Ocean constituted the transitional area to its continental margin.

According to the previous cited authors, the remnants of continental material are related to both the European (1-2) and the Adriatic or Apulian (3-4) paleomargins.

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