



The Oligocene ophiolite-derived breccias and sandstones of the Val Marecchia Nappe: Insights for paleogeography and evolution of Northern Apennines (Italy)

Vincenzo Perrone ^{a,*}, Sonia Perrotta ^b, Kathleen Marsaglia ^c, Angelida Di Staso ^a, Valentina Tiberi ^a

^a Department of Earth, Life and Environmental Sciences, University of Urbino, Campus Scientifico "Enrico Mattei", Località Crocicchia, 61029 Urbino, Italy

^b Badley Ashton and Associates Ltd., Winceby House, Winceby Horncastle, LN9 6PB Lincolnshire, United Kingdom

^c Department of Geological Sciences, California State University Northridge, 18111 Nordhoff Street, Northridge, CA 91330-8266, USA

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ABSTRACT

Ophiolite-derived debrites, microbreccias and olistoliths are interbedded in the Monte Morello and *Argille Varicolori* Formations of the Val Marecchia Nappe, constituting the highest tectonic unit of the north-eastern Apennines and usually considered as having originated from the External Ligurian Domain.

The ophiolite-derived clastic rocks were supplied exclusively by an oceanic sequence, consisting of peridotite, gabbro, basalt, radiolarite, pelagic limestone and shale. They are interbedded within a succession made up of fine-grained carbonate and siliciclastic turbidites, and of pelagic claystones.

Petrographic and sedimentological features of the ophiolite-derived breccia and sandstone units testify to an intrabasinal source area for these clastic rocks rather than an extrabasinal origin from subaerially exposed oceanic crust, forming the inner flank of the basin, as previously suggested. Due to their Oligocene–earliest Miocene age, the deposits in which debrites and olistoliths occur, are related to Early Neo-Alpine tectonic events that caused reactivation and/or inversion of old normal/transform faults. Unstable fault escarpments provided a preferential path for submarine landslide and turbidite emplacement. Debrites, microbreccias and olistoliths, therefore, were added to the basin fill of fine-grained turbidite and pelagic deposits.

This study suggests that the Val Marecchia Nappe succession was deposited on an oceanic substratum. Stratigraphy and age of the succession of this nappe can be well framed only in the evolution of the Sub-ligurian Domain, whereas they conflict with the interpretation of the Val Marecchia Nappe as a nappe originated from the External Ligurian Domain, as suggested previously by most authors. This interpretation also requires an oceanic substratum for the Sub-ligurian Domain, i.e. the existence of an oceanic belt external to the Ligurian Domain, which was deformed only in the Early Miocene. The Sub-ligurian Domain, therefore, would be an eastern branch of the Central Tethys and would represent the extension in the Northern Apennines of the Maghrebian–Lucanian oceanic realm, as recognized in the Betic Cordillera, Maghrebian Chain and Southern Apennines.

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1. Introduction

The history of ancient ocean basins consumed during subduction and continental collisions can be partly recorded in the marine sedimentary units preserved within resulting orogens. This study is focused on the nature of ophiolite detritus, which is the key but sometimes understudied component of such orogenic successions, to help unravel the complex history of a segment of the Northern Apennines Orogen.

The Northern Apennines are characterized by a nappe stack consisting of oceanic and continental units; the upper nappes originated from the Central Tethys Ocean (Ligurian Units), the lower nappes were derived from the margin of the Adria Plate (Tuscan and Umbro–

Marchean Units; Fig. 1a and b). The Sub-ligurian Canetolo Complex, deposited on the thinned continental crust of the westernmost margin of the Adria Plate, is discontinuously sandwiched between the Ligurian and Tuscan Nappes (Abbate et al., 1970b, 1994; Elter, 1973, 1975, 1993; Zanzucchi, 1980, 1988; Abbate and Sagri, 1982; Fig. 1a and b). Within the oceanic nappes, two groups of units have been distinguished: Internal Ligurian Units, in which the oceanic substratum is preserved, and External Ligurian Units, where stratigraphic successions are detached from their pre-Cretaceous substratum. In the latter, ophiolitic rocks occur as slide-blocks, breccia layers or clasts mainly in Cretaceous sedimentary melanges, together with blocks of continental crust (Elter et al., 1966; Elter, 1993; Abbate et al., 1980; Elter and Marroni, 1991; Marroni et al., 1998, 2001, 2002; Principi et al., 2004, among others).

Features and tectonic evolution of the Ligurian oceanic area are debated. Lithospheric remnants are characterized by a clear predominance of

* Corresponding author. Tel.: +39 0722 304289; fax: +39 0722 304306.
E-mail address: vincenzo.perrone@uniurb.it (V. Perrone).

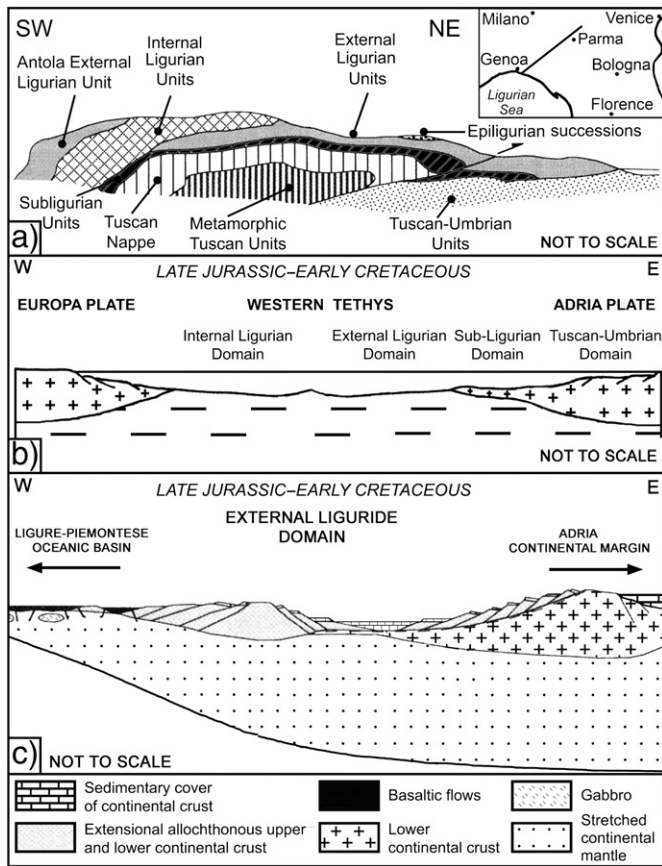


Fig. 1. a) Schematic cross-section of the Northern Apennines (after Elter, 1972). Box indicates the location of section along a Genoa–Parma alignment; b) schematic Late Jurassic–Early Cretaceous paleogeographic section of the North-Apenninic domains; c) Late Jurassic paleogeographic section of the External Ligurian Domain according to Marroni et al. (2001).

ultramafic rocks, absence of sheeted dikes, scarcity of basalt, abundance of ophiolitic breccias, and deposition of pelagic sediments directly on serpentinized peridotite. These features have been variably interpreted as originating by: 1) mantle delamination in a rifted passive margin setting (Decandia and Elter, 1972; Piccardo, 1977, 2003; Vissers et al., 1991; Molli, 1996), 2) mantle upwelling and peridotite diapirism along a transform zone (Galbiati et al., 1976; Abbate et al., 1980, 1986; Cortesogno et al., 1987), or 3) rifting in a slow-spreading mid-oceanic ridge, where peridotites and gabbros were exposed (Barrett and Spooner, 1977; Lagabrielle and Lemoine, 1997; Bortolotti et al., 2001). More recently, Principi et al. (2004) interpreted the ophiolites of the Northern Apennines as having originated in an oceanic area characterized by both transform fault zones and a slow spreading ridge, similar to the model proposed by Tucholke and Lin (1994). Other studies (Molli, 1996, 2007; Montanini and Tribuzio, 2001; Marroni et al., 2002; Piccardo, 2003; Marroni and Pandolfi, 2007; Piccardo et al., 2009) suggest that the Ligurian Domain was likely the result of asymmetric rifting, which led to the opening of an oceanic area to the west, proximal to the European–Corsican margin, and to stretching the Austroalpine–Southalpine (Adriatic) Margin, to the east (Fig. 1c). The resulting Internal Ligurian ophiolites are structurally and compositionally similar to those characterizing the slow or ultra-slow spreading oceanic basins, whereas the External Ligurian Units, representing a fossil continent–ocean transition, are very similar to present-day magma-poor passive margins, such as the Galician Margin (Boillot et al., 1987; Whitmarsh et al., 2001). The stretched Adriatic Margin, in particular, is made up of subcontinental mantle peridotite (Piccardo et al., 2004,

2009), tectonically associated with slices of continental crust (granulites, gneiss, schists), considered as remnants of extensional allochthons (Marroni et al., 1998; Montanini and Tribuzio, 2001; Fig. 1c).

The deformation history of the Ligurian Domain has also been debated. According to the most widely accepted hypothesis (Boccaletti et al., 1980; Elter and Marroni, 1991; Elter, 1993; Marroni et al., 2002; Molli, 2007 and references therein), this domain was subjected to a Europe-vergent deformation in the Late Cretaceous–Middle Eocene. Later on, the oceanic accretionary wedge was involved in the build-up of the Apennine Chain which, starting from the Oligocene, developed with an Adriatic vergence. In contrast, other authors suggest that both the deformation of the Ligurian Domain and the build-up of the Apennine Chain resulted only from a Europe-dipping subduction (Principi et al., 2004 and references therein).

Tectonic breccias (ophicalcites), occurring at the top of the mantle peridotites (Decandia and Elter, 1972), large olistoliths (slide blocks) of mafic and ultramafic rocks and lenses of ophiolite-derived mono- and polymictic sedimentary breccias and sandstones, fed exclusively by magmatic and sedimentary oceanic rocks, or showing both continental crust and ocean-derived blocks and pebbles, are widespread in both Internal and External Ligurian Units (Bortolotti, 1961, 1962a; Decandia and Elter, 1972; Elter, 1993; Montanini, 1997; Principi et al., 2004, among others). Bonatti et al. (1971, 1974) were the first to relate some ophiolitic breccias of Northern Apennines to the ultramafic-carbonate breccias of the Equatorial Mid-oceanic Ridge (Romanche and Vema fracture zones), followed by Barrett and Spooner (1977). Abbate et al. (1980), Bortolotti (1992) and Principi et al. (2004) interpreted these breccias as gravity flow deposits derived from ultramafic topographic highs associated with transform fault discontinuities offsetting low-spreading-rate ocean ridge segments. All these breccias, therefore, have been related to initial opening of the Western Tethys during Late Jurassic–Early Cretaceous. They were successively involved in the early phase of the Alpine subduction (Upper Cretaceous sedimentary melanges of the Monte Penne–Casanova Complex; Elter and Marroni, 1991; Elter et al., 1991), and in the building of Paleogene accretionary wedges (Upper Paleocene breccia units within the Colli-Tavarone and Gaiette-Bocco Formations; Elter, 1993). Finally, the youngest ophiolite-derived clastic rocks, considered to be of Eocene age, were recognized in the Val Marecchia Nappe, cropping out in the Tuscan–Romagnan Apennines.

This paper is focused on these ophiolite-derived breccias and olistoliths, interbedded in a succession of distal calcareous turbidites (Monte Morello Formation) and pelagic claystones (*Argille Varicolori* Formation). In the early 1960s these rocks were recognized by Bortolotti (1961, 1962a, 1962b, 1962c) and considered to be extrabasinal deposits of Late Cretaceous–Middle Eocene age, fed from accretionary complexes forming the western margin of the basin in which the Val Marecchia Nappe succession deposited. Later, Principi et al. (2004) pointed out that breccia clasts are quite similar to rocks of some Internal Ligurian units, so confirming the interpretation that breccias were extrabasinal deposits related to the closing of the Ligurian oceanic area and the collision between the North-Apenninic paleochain and the Adriatic Margin.

Herein, field, litho- and biostratigraphic, petrographic and textural features of these rocks have been studied in order to check their origin and sedimentary history. The occurrence of coarse breccias and olistoliths in successions consisting of pelagic and fine-grained turbidite calcareous rocks is peculiar and difficult to insert in the up-to-now proposed paleogeographic and tectonic evolution of Northern Apennines.

2. The Val Marecchia Nappe: previous studies

The Val Marecchia Nappe (Ruggieri, 1958, 1970; Ricci Lucchi, 1987; de Feyter, 1991; Conti, 1994), cropping out in the upper Tiber, Savio, Marecchia and Foglia valleys, constitutes the highest tectonic unit of the North-eastern Apennines, overthrusting both Tuscan and Umbro-

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