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Fossil oceanic core complexes recognized in the blueschist metaophiolites of Western Alps and Corsica☆

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A B S T R A C T

Tethyan ophiolites show an apparent poorly organized association of ultramafic and mafic rocks. By contrast to the complete mantle-crustal sections of Semail-type ophiolite sheets, Tethyan ophiolites are characterized by a smaller amount of mafic rocks (gabbros and basalts), by the absence of any sheeted dyke complex and by the frequent occurrence of oceanic sediments stratigraphically overlying mantle-derived peridotites and associated gabbroic intrusions. Therefore, they are considered as typical remnants of oceanic lithosphere formed in slow-spreading environment or in ocean–continent transition at distal passive margins. In the very first models of formation of the Tethyan ophiolites, in the years 1980, the geodynamical processes leading to mantle unroofing were poorly understood due to the paucity of data and concepts available at that time from the present-day oceans. In particular, at that time, little work had focused on the distribution, origin and significance of mafic rocks with respect to the dominant surrounding ultramafics. Here, we reconsider the geology of some typical metaophiolites from the Western Alps and Corsica, and we show how results from the past decade obtained in the current oceans ask for reassessing the significance of the Tethyan ophiolites in general. Revisited examples include a set of representative metaophiolites from the blueschists units of the Western Alps (Queyras region) and from Alpine Corsica (Golo Valley). Field relationships between the ophiolitic basement and the metasedimentary/metavolcanic oceanic cover are described, outlining a typical character of the Tethyan ophiolite lithological associations. Jurassic marbles and polymictic ophiolite metabreccias are unconformably overlying the mantle-gabbo basement, in a way strictly similar to what is observed in the non-metamorphic Appennine ophiolites or Chenaillet massif. This confirms that very early tectonic juxtaposition of ultramafic and mafic rocks occurred in the oceanic domain before subduction. This juxtaposition resulted from tectonic activity that is now assigned to the development of detachment faults and to the formation of Oceanic Core Complexes (OCCs) at the axis of slow spreading ridges. This fundamental Plate Tectonics process is responsible for the exhumation and for the axial denudation of mantle rocks and gabbros at diverging plate boundaries. In addition, field relationships between the discontinuous basaltic formations and the ultramafic–mafic basement indicate that this tectonic stage is followed or not by a volcanic stage. We discuss this issue in the light of available field constraints.

Contents

☆ This work is dedicated to the memory of Bruno Lombardo. As a scientist and as a person, Bruno gave a lot to the study of Alpine ophiolites. The results discussed in this work also benefit from his work and his great passion for geology in general.

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1. Introduction

Metaophiolites exposed in the internal units of the Western Alps and Corsica were subducted during the closure of the Piemont–Ligure ocean, a segment of the Jurassic Tethys located between the Eurasian and the Apulian–African continents (Bernouilli et al., 1979; Beccaluva et al., 1984; Ricou et al., 1985; Pognante et al., 1986; Lemoine and Trümpy, 1987; Weissert and Bernoulli, 1985; Stampfli et al., 1998; Schmid et al., 2004; Handy et al., 2010, and references therein). In contrast with the thick sections of large ophiolite sheets such as the Semail Nappe in Oman, the Western Alps and Corsica metaophiolites are characterized by a relatively small amount of mafic rocks (metagabbros and metabasalts), by the absence of any sheeted dyke complex and by the frequent occurrence of oceanic sediments stratigraphically overlying variably hydrothermalized mantle-derived peridotites and associated gabbroic intrusions. These associations, which do not fit the "Penrose" three-layer model (Anonymous, 1972), also characterize the ophiolites of the Appennine belt as recognized by many geologists since 1960 (e.g., Decandia and Elter, 1969, 1972; Elter, 1972; Cortesogno et al., 1975; Barrett and Spooner, 1977; Abbate et al., 1980; Molli, 1996). During the last 30 years, authors have highlighted the strong affinities between the Tethyan ophiolites of the Alpine blueschist units and the oceanic lithosphere emplaced at present-day slow spreading ridges (Lombardo and Pognante, 1982; Tricart and Lemoine, 1983, 1991; Lagabrielle and Cannat, 1990; Lagabrielle and Lemoine, 1997). In the mean time, similar observation highlighting the processes of mantle and lower crustal section exhumation were reported from the Northern Apennine ophiolites (Molli, 1995, 1996; Tribuzio et al., 1997). Alternatively, based on the occurrence of continent-derived remnants such as micaschists and granitoid clasts in the sedimentary cover of some of these metaophiolites (e.g., Caby et al., 1971; Polino and Lemoine, 1984), an origin from the lithosphere formed at the ocean-continent transition (OCT) of the ancient Tethyan margins has also been proposed. The model of "distal-continental margin" environment for the emplacement of the serpentinized mantle has been applied to the Alps as well as to the Appennine and Corsica (Lemoine et al., 1987; Froitzheim and Manatschal, 1996; Manatschal and Nievergelt, 1997; Marroni et al., 1998, 2001; Boillot and Froitzheim, 2001; Desmurs et al., 2002; Manatschal and Müntener, 2009; Vitale Brovarone et al., 2011; Meresse et al., 2012; Masini et al., 2013; Beltrando et al., 2014). Therefore, it is now established that the Tethyan ophiolites have been sampled from different regions of the Tethys ocean, including the distal, hyper-extended passive margins and the more internal (ultra-?) slow-spreading center (see review in Lagabrielle (2009)).

As our knowledge of the Alpine ophiolite geology was increasing, fundamental progresses were also being made in our understanding of the formation of the lithosphere at slow- and ultra-slow-spreading ridges. In particular, the concept of oceanic core-complexes (OCC) now explains how mantle rocks and gabbros are exposed on the seafloor by large detachment faults (e.g., Escartín et al., 2003, 2008; Smith et al., 2008; MacLeod et al., 2009; Escartín and Canales, 2011). This provides clues to decipher the significance of some puzzling Tethyan ophiolite associations in regions where the Alpine deformation was regarded as the major cause of ophiolite dismembering. In this article, we show how our knowledge of the OCC architecture helps in understanding the apparent poorly organized association of metagabbros, serpentinites and metabasalts forming the oceanic basement of blueschist units of the Western Alps and Corsica. A similar comparison has been successfully conducted in the Chenaillet Ophiolite in the Franco-Italian Alps, which represents a well-preserved ocean-floor sequence that was only weakly overprinted by Alpine metamorphism during its emplacement in the Alpine nappe stack (Manatschal et al., 2011). Lithological similarities with slow spreading ridges were also reported from the Northern Apennine ophiolites (Tribuzio et al., 1999, 2000; Principi et al., 2004).

2. The metaophiolites of the Western Alps blueschists units: a case study in the Queyras region

2.1. Regional geology, age of metamorphism

The Alpine ophiolites form discrete tectonic bodies scattered within the most internal units of the Alpine belt (Fig. 1). They were emplaced following the closure, subduction and exhumation of some remnants of the Piemonte-Ligurian ocean. Their metamorphic overprint developed during subduction and collision events at various metamorphic conditions, from low-pressure (prehnite–pumpellyite–facies) and medium-pressure (blueschist-facies) to high-pressure (HP) (eclogite-facies) conditions. The blueschist-facies ophiolite bodies are small-sized and are included within large volumes of oceanic metasediments : the Schistes Lustrés (s.s.). By contrast, the eclogite-facies metaophiolites, such as the Monviso, Lanzo and Zermatt units are more voluminous, and are associated with restricted volumes of metasediments.

The Schistes Lustrés tectono-stratigraphic complex hereafter the Schistes Lustrés complex is composed of a stack of units comprising dominant oceanic metasediments (Schistes Lustrés s.s.) and their metaophiolite basement rocks in various proportions (Deville et al., 1991; Lemoine, 2003). In the Southwestern Alps, the blueschist-facies terranes of the Schistes Lustrés complex are well exposed in the Queyras region (Fig. 2). The Queyras units lie structurally above the eclogite-facies Monviso metaophiolites, which in turn overlies the Dora-Maira internal crystalline massif representing the eclogitized distal European margin and including ultra-HP slices. U/Pb ages of coesite-bearing rocks from the Dora-Maira massif (Tilton et al., 1991; Gebauer et al., 1997; Rubatto and Hermann, 2001) suggest that crystallization occurred at 35 Ma under PT conditions of more than 30 kbar and 700 °C (Chopin, 1984). Fission track data (Gebauer et al., 1997) show that these Ultra-HP rocks attained 250 °C at ca. 29 Ma, implying very rapid cooling and decompression (see also Rubatto and Herman, (2001)). The (ultra-) HP metamorphism in the Dora-Maira massif occurred about 10 Ma later than the eclogitic peak in the Monviso units. The age of the eclogitization of the Monviso ophiolite is estimated to be 49 ± 2 Ma using the Ar/Ar method (Monié and Philippot, 1989) and the Lu/Hf method (Duchêne et al., 1997), and 62 ± 9 Ma using the Sm/Nd method (Cliff et al., 1998). The contact separating the blueschist Queyras units from the eclogitic Monviso units is a polyphased