Fossil mantle-sediments interface recognized in the Western Alps metaophiolites: a key to unravel the accretion mechanism of the Jurassic Tethys ocean

Published version:

DOI:10.3301/ROL.2015.179

Tartarotti, P., Festa A., Benciolini, L., Balestro, G. (2015) – Rendiconti online della Società Geologica Italiana, v.37, 68-71

doi: 10.3301/ROL.2015.179

Rend. Online Soc. Geol. It., Vol. 37 (2015), pp. 68-71, 1 fig. (doi: 10.3301/ROL.2015.179)

Fossil mantle-sediments interface recognized in the Western Alps metaophiolites: a key to unravel the accretion mechanism of the Jurassic Tethys ocean

Paola Tartarotti ([a]), Andrea Festa ([b]), Luca Benciolini ([c]) & Gianni Balestro ([b])

(a) Dipartimento di Scienze della Terra, Università degli Studi di Milano, via Mangiagalli, 34, 20133, Milano, Italy. Corresponding email: paola.tartarotti@unimi.it
(b) Dipartimento di Scienze della Terra, Università di Torino, via Valperga Caluso, 35, 10125, Torino, Italy.
(c) Dipartimento di Chimica, Fisica e Ambiente, sezione Georisorse e Territorio, Università di Udine, via del Cotonificio, 114, 3310, Udine, Italy.

Document type: Short note.
Manuscript history: received 5 October 2015; accepted 30 October 2015; editorial responsibility and handling by Bernardo Cesare & Carlo Doglioni.

ABSTRACT

In the southern Aosta Valley (Italian Northwestern Alps), meta-ophiolites are mainly composed of serpentinized mantle-derived peridotites intruded by gabbros and rodingitic dykes, well exposed in the Mount Avic area, and of smaller amounts of mafic rocks and metatrondhjemite. This rock assemblage recalls the "slow-spreading" lithosphere created at modern mid-ocean ridges. Meta-ophiolites show a dominant early Alpine subduction-related metamorphic imprint under eclogite/blueschist facies conditions, variously retogressed under greenschists facies conditions. In the high Champorcher Valley (SW of Mount Avic) serpentinites are directly covered by a serpentinite mélange followed by flysch-like calcschists with detrital ophiolitic interbeds. Despite the pervasive Alpine tectonic deformation and metamorphic recrystallization through subduction-related stretching and boudinage and collision-related folding, the mélange internal fabric still retains records of a block-in-matrix structure, well consistent with mass-transport processes related to an active oceanic tectonic setting in which mantle rocks were progressively and continuously exhumed by faulting. The products of mass-transport processes and faulting are unconformably sealed by flysch-type calcschists embedding cm-sized clasts of actinolite/tremolite-schists interpreted as detrital ophiolitic material. The serpentinite mélange is interpreted as syn-extensional sedimentary rocks produced at the mantle-sediments interface on the Jurassic Tethys ocean floor and subsequently overprinted by subduction zone tectonics.

KEY WORDS: meta-ophiolite, serpentinite mèlange, Western Alps.

INTRODUCTION

The Western Alps meta-ophiolites have been emplaced during the closure of the *Ligure-Piemontese* basin, a segment of the Jurassic Tethys ocean interposed between the European and African plates. Since 1980s to early 1990s, after many decades of investigations conducted on the Alpine meta-ophiolites, and particularly since the advances in marine geology techniques favouring a better knowledge of modern oceanic crust, the scientific community has become increasingly aware of the fact that the Tethyan ocean lithosphere did not fit the conceptual model of a "normal" or layered oceanic crust, as defined by the Penrose Conference (Anonymous, 1972; Lagabrielle & Cannat, 1990). Instead, Tethyan meta-ophiolites are characterized by dominant mantle-derived (mostly serpentinized) peridotites associated with gabbro intrusions, and by less amounts of mafic rocks deriving from lava flows, pillow lavas, and gabbros. Such internal architecture recalls the structure and composition of modern "magma-poor" (e.g., Dick et al., 1981; Mével et al., 1991) or "slow-spreading ridge" (e.g., Cannat, 1993) oceanic crust.

Metasediments overlying meta-ophiolites consist of metaquartzites, marble, and calcschists (with various proportions) which directly cover metabasalts or, alternatively, mantle rocks and gabbros. Field evidence for mantle rocks exposition on the Tethyan seafloor are constrained by the occurrence of ophicalcites and ophicarbonate breccias interposed between the ophiolitic basement and the metasedimentary cover (e.g., Driesner, 1993; Tartarotti et al., 1998; Dal Piaz, 1999, for the northwestern Alps). In present-day oceans, mantle peridotites and gabbros have been recovered within a variety of tectonic settings including transform faults, the walls of mid ocean ridges, ridge-transform intersections (e.g., Karson et al., 1987; Mével et al., 1991; Bonatti et al., 1990; Blackman et al., 1998). Exposure of mantle rocks on the seafloor and mantle denudation mechanism have important tectonic and geochemical implications for lithospheric extension and subduction process (e.g., Lemoine et al., 1987; Deschamps et al., 2013; Schwartz et al., 2001). Therefore, informations from modern oceans are fundamental for understanding the geodynamic evolution of the Tethyan lithosphere.

Here we focus on a portion of the Western Alps meta-ophiolites where serpentinized mantle peridotites are directly cover by ophicarbonate breccias and calcschists. On the basis of lithostratigraphic and petrographic features this contact is interpreted as a fossil basement-cover interface. Inferences on the paleo-topography and physiography of the Tethys ocean seafloor are then discussed.

REGIONAL GEOLOGY

The study area is located in the southern Aosta Valley (Northwestern Alps, to the south of the Aosta-Ranzola fault system) and comprises metamorphic ophiolites comparable to the Zermatt-Saas (ZS) unit (e.g., Bearth, 1967; Dal Piaz & Ernst, 1978). The ZS unit consists of antigorite-Ti-clinohumitemagnetite-bearing serpentinites, Fe-Ti- and Mg-metagabbros, metabasalts, covered by metasedimentary rocks showing a dominant early Alpine metamorphic imprint under eclogite-blueschist-facies conditions, partially retogressed under greenschists facies conditions.

Meta-ophiolites exposed in the southern Aosta Valley are mainly composed of serpentinized mantle-derived peridotites intruded by gabbros and rodingitic dykes, well exposed in the Mount Avic area (Fontana et al., 2008; Fontana et al., 2015), and of smaller amounts of mafic rocks and metatrondhjemite (Dal Piaz et al., 2010; Novo et al., 1989). These meta-ophiolites show a dominant early Alpine subduction-related metamorphic imprint under eclogite-blueschist-facies conditions of Eocene age, variously retogressed under greenschists facies conditions (e.g., Baldelli et al., 1985; Benciolini et al., 1988; Martin & Tartarotti, 1989; Dal Piaz et al., 2001).

Two main types of metasedimentary successions are recognizable in the southern Aosta Valley: one succession comprises metaradiolarite, marble, calcschists s.s., and flysch-like calcschists. This suite generally occurs on top of mafic rocks, as in the St. Marcel Valley (Martin & Tartarotti, 1989; Tartarotti et al., 1986, 2014; Tartarotti & Caucia, 1993), where metabasalts and metasediments are also associated with sulphide- and Mn-rich ore deposits (Martin et al., 2008; Martin & Tartarotti, 1989; Rebay & Powell, 2012; Tartarotti & Caucia, 1993; Tumiati et al., 2005, 2010). This ophiolitic sequence likely refers to the shallowest part of the Tethyan oceanic crust created near the ridge axis where hydrothermal fluid circulation was active and covered by pelagic sediments. The other type of metasedimentary succession consists of ophicarbonate breccias which directly lie upon serpentinized mantle peridotites, followed by flysch-like calcschists with ophiolitic interbeds (Tartarotti et al., 2015). We here describe the second type of metasedimentary succession which occurs in the high Champorcher valley (SW of the Mount Avic serpentinite massif), in the Lac Miserin area.

THE LAC MISERIN SERPENTINITIC MÉLANGE

In the Champorcher Valley, meta-ophiolites are made of metabasalt, metagabbro, and serpentinite (Dal Piaz & Nervo, 1971; Nervo & Polino, 1976; Dal Piaz et al., 1979). Serpentinites are extensively exposed in the huge Mount Avic massif (on the left side of the Champorcher valley) and in small outcrops in the Lac Miserin area (right side of the high Champorcher Valley). These latter are interpreted as tectonic slices transposed from the Mount Avic serpentinite. In the Lac Miserin area, serpentinites are directly covered by a serpentinite mélange followed by flysch-like calcschists with detrital ophiolitic interbeds. Upon massive to veined and brecciated serpentinite, sealed by metasomatic rocks rich in tremolite and carbonates, the mélange starts with white marble and carbonatic calcschist alternating with decimeters-thick horizons of serpentinite metabreccia and metagraywacke, including isolated metric blocks of serpentinite (Figure 1). The sequence continues with rounded to irregularly-shaped blocks of serpentinite, cm-to several dm in size, randomly distributed within a matrix of foliated impure marbles and calcschist. It is then unconformably covered by flysch-like calcschists embedding cm-sized clasts of actinolite/tremolite-schists, interpreted as detrital ophiolitic material.

The serpentinite mélange has been severely overprinted by Alpine tectonic deformation and metamorphic recrystallization through subduction-related stretching and boudinage and collision-related folding. At least four Alpine deformation phases were recognized in the field which produces isoclinal folds followed by asymmetric folding overprinted by wide open folds and late S-C structures. Rootless and isoclinal folds constrain the timing of the serpentinite mélange emplacement to the pre-Alpine or early Alpine history. Despite this intense tectonic reworking, the mélange internal fabric still retains records of breccia and block-in-matrix structures, well consistent with mass-transport processes related to an active tectonic setting in which mantle rocks were progressively and continuously exhumed by faulting.

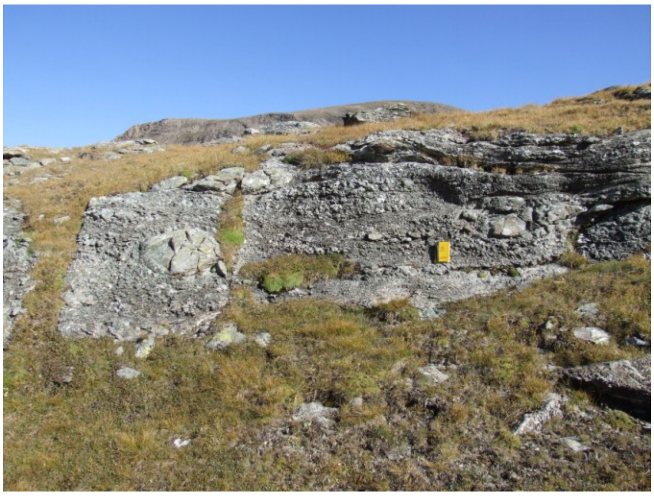

Fig. 1 - Outcrop of the Lac Miserin serpentinite mélange showing serpentinite metabreccia and metagraywacke and serpentinite blocks (Foto P. Tartarotti)

In conclusion, the serpentinite/calcschists juxtaposition in the Lac Miserin area is separated by an interposed serpentinite mélange which thus corresponds to a fossil mantle-sediments interface established in the Jurassic Tethys ocean. We infer that the serpentinite mélange corresponds to syn-extensional sedimentary rocks produced at the mantle-sediments interface on the Jurassic Tethys ocean floor and subsequently overprinted by subduction zone tectonics.

This scenario has profound implications for the physiography of the Tethys Ocean. Our results indicate that the Tethyan seafloor should have been characterized by extensive regions of active faulting and mass wasting responsible for the formation of a serpentinitic rugged seafloor. Serpentinite metabreccia and metagraywacke of the Lac Miserin mélange may represent talus breccias accumulated at the base of fault scarps, then indurated by carbonate sediment (ooze?), whereas larger blocks of serpentinite randomly distributed within foliated impure marbles and calcschist may be interpreted as coarse, poorly sorted blocks deposited by mass wasting. Similar deposits have been extensively observed and sampled in the Atlantic Ocean (e.g., Karson & Lawrence, 1997). Ophicarbonate rocks resting upon the serpentinite basement indicate that the upper mantle peridotites were already exhumed on the seafloor prior to the onset of subduction zone tectonics within the ocean basin. Finally, flysch-like calcschists are here interpreted as a post-extensional sedimenatry sequence sealing the serpentinite-mélange interface.

ACKNOWLEDGMENTS

I thank the organizing Committee of the Meeting “Geologia delle Alpi” for inviting me to give a contribution in honour of Prof. G.V. Dal Piaz and F.P. Sassi.

REFERENCES

Anonymous (1972) - Penrose field conference. Ophiolites. Geotimes, 17 (2), 24-25.

Baldelli C., Dal Piaz G.V. & Lombardo B. (1985) – Ophiolite eclogites from Verres, Val d’Aosta, Western Alps, Italy. Chem. Geol., 50, 87-98.

Bearth P. (1967) - Die Ophiolithe der Zone von Zermatt-Saas Fee. Beitr. Geol. Karte Schweiz, N.F., 132, 130 pp.

Benciolini L., Lombardo B. & Martin S. (1988) – Mineral chemistry and Fe/Mg exchange geothermometry of ferrogabbro-derived eclogites from Northwestern Alps. N. Jahrb. Miner. Abh., 159 (2), 199-222.

Blackman D.K., Cann J.R., Janssen B. & Smith D.K. (1998) - Origin of extensional core complexes: Evidence from the Mid-Atlantic Ridge at Atlantis Fracture Zone. J. Geophys. Res., 103 (B9), 21, 315-21,333.

Bonatti E., Seyler M., Channell J., Giraudeau J. & Mascle G. (1990) - Peridotites drilled from the Tyrrhenian sea, ODP Leg 107. In: Kastens, K. A., Mascle, J. et al., Proceedings of the Ocean Drilling Program, Scientific Results, vol. 107, 37-47.

Cannat M. (1993) - Emplacement of mantle rocks in the seafloor at mid-ocean ridges. J. Geophys. Res., 98, 4163-4172.

Dal Piaz G.V. (1999) - The Austroalpine-Piedmont nappe stack and the puzzle of Alpine Tethys. Memorie di Scienze Geologiche Padova, 51, 155-176.

Dal Piaz G.V. & Nervo R. (1971) - Il lembo di ricoprimento del Glacier-Rafray (Dent Blanche l.s.). Boll. Soc. Geol. It., 90, 401-414.

Dal Piaz G.V. & Ernst W.G. (1978) - Areal geology and petrology of eclogites and associated metabasites of the Piemonte ophiolite nappe, Breuil-St. Jacques area, Italian western Alps. Tectonophysics, 51, 99-126.

Dal Piaz G.V., Cortiana G., Del Moro A., Martin S., Pennacchioni G. & Tartarotti P. (2001) - Tertiary age and paleostructural inferences of the eclogitic imprint in the Austroalpine outliers and Zermatt-Saas ophiolite, western Alps. Int. J. Earth Sciences, 90, 668-684.

Dal Piaz G.V., Nervo R. & Polino R. (1979) - Carta geologica del lembo del Glacier-Rafray (Dent Blanche s.l.) e note illustrative. Centro studio problemi orogeno Alpi occidentali, CNR Torino, ed. n. 2, 24 pp.

Deschamps F., Godard M., Guillot S. & Hattori K. (2013) - Geochemistry of subduction zone serpentinites: A review. Lithos, 178, 96-127.

Dick H.J.B., Thompson G. & Bryan W.B. (1981) - Low angle faulting and steady state emplacement of plutonic rocks at ridge-transform intersections. Eos, 62, p. 406.

Driesner T. (1993) - Aspects of petrological, structural, and stable isotope geochemical evolution of ophicarbonate breccia from ocean floor to subduction and uplift: an example from Chatillon, middle Aosta valley, Italian Alps. Schweiz. Mineral. Petrogr. Mitt., 73, 69-84.

Fontana E., Panseri M., Tartarotti P. (2008) - Oceanic relict textures in the Mount Avic serpentinites, Western Alps. Ofioliti, 33(2), 105-118.

Fontana E., Tartarotti P., Panseri M., Buscemi S. (2014) - Geological map of the Mount Avic massif (western Alps Ophiolites). Journal of Maps, http://dx.doi.org /10.1080/17445647.2014.959567.

Lagabrielle Y. & Cannat M. (1990) - Alpine jurassic ophiolites resemble the modern central atlantic basement. Geology, 18, 319-322.

Lemoine M., Boillot G. & Tricart P. (1987) - Ultramafic and gabbroic ocean floor of the Ligurian Tethys (Alps, Corsica, Apennines). In search of a genetic model. Geology, 15, 622-625.

Martin S. & Tartarotti P. (1989) - Polyphase HP metamorphism in the ophiolitic glaucophanites of the St. Marcel valley (Aosta, Italy). Ofioliti, 14, 135-156.

Karson J.A. & Lawrence R.M. (1997) - Tectonic setting of serpentinite exposure on the Western Median valley Wall of the MARK area in the vicinity of Site 920. In: Karson, J.A., Cannat, M., Miller, D.J., and Elthon, D. (Eds.), Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 153.

Karson J.A., Thompson G., Humphris S.E., Edmond J.M., Bryan W.B., Brown J.R., Winters A.T., Pockalny R.A., Casey J.F., Campbell A.C., Klinkhammer G., Palmer M.R., Kinzler R.J. & Sulanowska M.M. (1987) - Along-axis variations in seafloor spreading in the MARK area. Nature, 328, 681-685.

Martin S., Rebay G., Kienast J.-R. & Mével C. (2008) - An eclogitised oceanic palaeo-hydrothermal field from the St. Marcel Valley (Italian western Alps). Ofioliti, 33, 49-63.

Mével C., Cannat M., Gente P., Marion E., Auzende J.-M. & Karson J.A. (1991) - Emplacement of deep crustal and mantle rocks on the west median valley wall of the MARK area (MAR, 23°N). Tectonophysics, 190, 31-53.

Nervo R. & Polino R. (1976) - Un lembo di cristallino Dent Blanche alla Torre Ponton (Valle d’Aosta). Boll. Soc. Geol. It., 95, 647-657.

Novo M., Accotto S., Nervo R., & Pognante U. (1989) - Jadeite-Quartz bearing metatrondhjemites from the Mt. Nero ophiolitic eclogites, Champorcher Valley (North-Western Alps). Ofioliti, 14 (1/2), 57-62.

Rebay G. & Powell R. (2012) - Eclogite-facies sea-floor hydrothermally-altered rocks: calculated phase equilibria for an example from the Western Alps at Servette. Ofioliti, 37, 55-63. doi: 10.4454/ofioliti.v37i1.405

Schwartz S., Allemand P. & Guillot S. (2001) - Numerical model of the effect of serpentinites on the exhumation of eclogitic rocks: insights from the Monviso ophiolitic massif (Western Alps). Tectonophysics, 342, 193-206.

Tartarotti P. & Caucia F. (1993) - Coexisting cummingtonite-sodic amphibole pair in metaquartzites from the ophiolite sedimentary cover (St. Marcel Valley, Italian western Alps): a X-ray structure refinement and petrology study. N. Jb. Miner. Abh., 165, 223-243.

Tartarotti P., Benciolini L. & Monopoli B. (1998) - Brecce serpentinitiche nel massiccio ultrabasico del Monte Avic (Falda ofiolitica piemontese): possibili evidenze di erosione sottomarina. Atti Ticinensi Sci. Terra, 7, 73-86.

Tartarotti P., Festa A., Benciolini L., Balestro G. (2015) - Mantle-cover sequence in the Western Alps metaophiolites: a key to recognize remnants of an exhumed Oceanic Core Complex (OCC). Rend. Online Soc. Geol. It., Suppl. n. 2 al Vol. 35 (2015), Società Geologica Italiana, Roma, p. 35.

Tartarotti P., Martin S. & Polino R. (1986) - Geological data about the ophiolitic sequences in the St. Marcel Valley (Aosta Valley). Ofioliti, 11 (3), 343-346.

Tartarotti P., Martin S., Monopoli B., Benciolini L., Schiavo A. (2014) - The Western Alps aphiolites and their cover rocks. A case study from the St. Marcel valley (Aosta). Rend. Online Soc. Geol. It., Suppl. n. 1 Vol. 31. Congresso SGI-SIMP, Milano, 10-12 settembre 2014.

Tumiati S., Casartelli P., Mambretti A. & Martin S. (2005) - The ancient mine of Servette (Saint-Marcel, Val d'Aosta, Western Italian Alps): a mineralogical, metallurgical and charcoal analysis of furnace slags. Archeometry, 47, 317-340.

Tumiati S., Martin S. & Godard G. (2010) - Hydrothermal origin of manganese in the high-pressure ophiolite metasediments of Praborna ore deposit (Aosta Valley, Western Alps). Eur. J. Mineral., 22, 577-594.