Thematic set:
Tethyan Ophiolites and Tethyan Seaways

JGS
Journal of the Geological Society

Published Online First
https://doi.org/10.1144/jgs2018-099

Structural architecture of the Western Alpine Ophiolites, and the Jurassic seafloor spreading tectonics of the Alpine Tethys

Gianni Balestro[1*], Andrea Festa[1] & Yildirim Dilek[2]

[1] Dipartimento di Scienze della Terra, Università di Torino, Via Valperga Caluso, 35, 10125 Torino, Italy
[2] Department of Geology & Environmental Earth Science, Miami University, Oxford, OH 45056, USA
G.B., 0000-0001-5215-4659; A.F., 0000-0001-5325-0263; Y.D., 0000-0003-2387-9575
* Correspondence: gianni.balestro@unito.it

Abstract: We present a regional synthesis of the structural architecture and tectonic evolution of the Western Alpine Ophiolites (WAO), exposed in NW Italy. The WAO represent the remnants of Alpine Tethys (Ligurian–Piedmont Ocean) that opened between Europe and Adria, and developed in four stages from the Middle Jurassic to Early Cretaceous. Emplacement of gabbroic intrusions into the extending lithospheric mantle of Europe–Adria marked the main magmatic event (Stage 1). Coalescent shear zones in the fossil upper mantle form lithospheric-scale detachment faults, which led to the exhumation of upper mantle peridotites and gabbros on the seafloor, and extensive serpentinization (Stage 2). Detachment faults, and serpentinized peridotites–gabbros in their footwalls, represent preserved fossil oceanic core complexes within the WAO. Emplacement of ophiolitic breccias and basaltic lava flows marked the syn-extensional phase (Stage 3). Radiolarian chert and limestone were deposited unconformably on this syn-extensional volcanic–sedimentary sequence, marking the post-extensional phase (Stage 4). Magmatic ages of gabbroic intrusions and mafic–felsic dykes, and depositional ages of post-extensional sequences in the WAO constrain the timing of the opening of the Ligurian–Piedmont Ocean to the Middle Jurassic (*c.* 170–168 Ma), followed by a tectonic quiescence stage in the Late Jurassic–Early Cretaceous.

Received 16 May 2018; **revised** 13 February 2019; **accepted** 18 February 2019

The Western Alpine Ophiolites (WAO) have contributed to the ophiolite concept significantly since the 19th century, wherein the early Alpine geologists described the spatially associated, tripartite serpentinite–diabase–chert assemblages in the Alps and Apennines as an 'ophiolite', and interpreted them as ocean floor representatives for the deep axial parts of geosynclines (Brogniart 1821; Steinmann 1905; Argand 1911; Elter 1971; Bernoulli *et al.* 2003). Although the definition of a typical ophiolite sequence has changed considerably since these early studies (for an overview see Dilek 2003), careful observations made by the early ophiolite geologists in the Western Alps and the Northern Apennines still remain valid. However, the WAO and their time-equivalent counterparts in the Northern Apennines (Ligurian ophiolites *sensu stricto*) are fundamentally different from those Penrose-type and subduction-influenced suprasubduction-zone (SSZ) ophiolites, such as the Troodos (Cyprus), Semail–Oman (Oman) and Mirdita (Albania) massifs in terms of their internal structure, igneous stratigraphy, geochemical makeup and inferred emplacement mechanisms (Decandia & Elter 1972; Dilek *et al.* 1990, 2007; Tankut *et al.* 1998; Dilek & Flower 2003; Dilek & Furnes 2009, 2014; Dilek & Thy 2009; Pearce & Robinson 2010; Goodenough *et al.* 2014; Piccardo *et al.* 2014; Saccani *et al.* 2015, 2018; Capponi *et al.* 2018). The WAO and the Ligurian ophiolites were derived from the oceanic lithosphere of the Liguria–Piedmont Ocean, whereas the SSZ ophiolites in the Neotethyan realm to the east originated from the upper plate of a subduction zone within Neotethys (Dilek 2003; Dilek & Robinson 2003; Dilek & Furnes 2011, and references therein). Therefore, the WAO provide a unique opportunity to examine in four dimensions the structure and stratigraphy of a fossil, subduction-unrelated oceanic lithosphere (*sensu* Dilek & Furnes 2011), and to investigate the seafloor spreading tectonics of an embryonic ocean basin.

In this paper, we present new structural and lithostratigraphic observations from the WAO exposed in the Western Alps, and synthesize the available geochronological (i.e. U–Pb dating of zircons) and biostratigraphical (i.e. radiolarian ages) information on these ophiolites in the extant literature. We also present a comprehensive model for a multi-phase development of the WAO and the seafloor spreading evolution of the Ligurian–Piedmont Ocean. Our work in the WAO has focused on a systematic, comparative documentation of the internal structure and lithostratigraphy of the main ophiolite complexes, in which we identified remnants of key stratigraphic unconformities and major oceanic shear zones that are reminiscent of those documented for detachment faults from *in situ* oceanic core complexes along the slow-spreading Mid-Atlantic and Southwest Indian ridges (Karson & Dick 1983; Blackman *et al.* 1998; Tucholke *et al.* 1998; Escartín *et al.* 2003, 2017; Boschi *et al.* 2006; Cannat *et al.* 2006; Ildefonse *et al.* 2007; Miranda & Dilek 2010; Bonnemains *et al.* 2017). Using these key structures and their timing of development, we have reconstructed a common architecture of the ophiolites that reflects their pre-alpine evolution. The reconstructed structure and stratigraphy of the WAO and our interpretation of the evolution of the Ligurian–Piedmont Ocean, involving the seafloor spreading of a restricted ocean basin and post-extensional deposition stages, took *c.* 25–30 myr between the Middle Jurassic (*c.* 170–168 Ma) and the tectonic quiescence in the Late Jurassic–Early Cretaceous.

Regional geology of the Western Alpine Ophiolites

The Alpine orogenic belt developed as a result of the collision between Adria in the upper plate and Europe in the lower plate as the intervening Ligurian–Piedmont Ocean (Alpine Tethys) closed in the Early Cenozoic (Dal Piaz *et al.* 1972; Ricou & Siddans 1986; Coward & Dietrich 1989; Laubscher 1991; Dilek 2006; Handy *et al.* 2010). The Ligurian–Piedmont Ocean evolved after the Late Triassic–Early Jurassic rifting between these two continents, followed by the Middle to Late Jurassic seafloor spreading. It has