ELSEVIER

Lithos 65 (2002) ix–xiii

LITHOS

www.elsevier.com/locate/lithos

Preface

Europrobe–Pancardi Symposium "Eastern Mediterranean Ophiolites: Magmatic Processes and Geodynamic Implications"

It is now some 30 years since the overall importance of ophiolites for unravelling the tectonic development of orogenic belts was fully appreciated. At that time, it was believed that the vast majority of ophiolites formed at mid-oceanic ridges. Nowadays, with an increasing knowledge based on geological, petrological, geochronological and geochemical data from various tectonic environments, it is widely accepted that many ophiolites, perhaps the majority, were instead generated within suprasubduction zone settings. The subduction-related model needs to be carefully tested with well-documented case studies. Tethyan ophiolites, especially those of the Eastern Mediterranean region, have played a key role in understanding of genesis and evolution of oceanic crust and mantle preserved today as ophiolites.

Recent years have seen the publication of numerous papers concerning individual Eastern Mediterranean ophiolites, dispersed throughout many journals and books. However, since publication in 1984 of the benchmark volume "The Geological Evolution of the Eastern Mediterranean" (edited by Dixon and Robertson, 1984), no specific publication has been dedicated to a comprehensive coverage and synthesis of the ophiolites of the Eastern Mediterranean region. The review paper by Smith (1993) focussed on the Hellenic–Dinaric ophiolites. It therefore seemed timely to us to focus again on the Eastern Mediterranean ophiolites and their role in the geotectonic evolution of the former Tethys Ocean. Accordingly, a symposium on this topic was held in 1999 at the 10th Meeting of the European Union of Geosciences in Strasbourg. The symposium was sponsored by the European Science Foundation Project "EUROPROBE–PANCARDI". The participants contributed information and interpretations from many research fields, including igneous and metamorphic petrology, geochemistry, geochronology, geophysics, structural geology, sedimentology, palaeontology, tectonics and geodynamics.

Our main aim was to use the various ophiolites and related units to shed new light on the fundamental processes that lead to the formation and emplacement of the Eastern Mediterranean ophiolites. As a result, the tectonic settings, geochronology, metamorphic evolution and palaeogeographical settings of the ophiolites were key concerns. However, there was also considerable discussion of more general aspects of Tethyan evolution, including the implications from palaeontology, stratigraphy and sedimentology of the associated sedimentary units.

The symposium demonstrated the overall progress in ophiolite-related geology in southeast European countries, including Turkey, Greece, Albania, Yugoslavia, Croatia, Macedonia, Romania, Bosnia and Hercegovina, Hungary, Slovakia and Austria.

Following the meeting, eight papers were included in this issue of LITHOS as the proceedings of the symposium. The geographical distribution of the papers is shown in Fig. 1. The first paper by Robertson gives a general overview of the geological setting of the Eastern Mediterranean ophiolites. This was the keynote paper at the meeting and forms the introduction to this issue (this paper covers the whole Eastern Mediterranean region and is therefore not shown on Fig. 1).

Robertson focuses on the different origins and tectonic settings of the various Eastern Mediterranean ophiolites. He argues that the widespread occurrence of depleted basalts, andesites and boninitic lavas

0024-4937/02/$ - see front matter © 2002 Elsevier Science B.V. All rights reserved.
PII: S0024-4937(02)00159-7

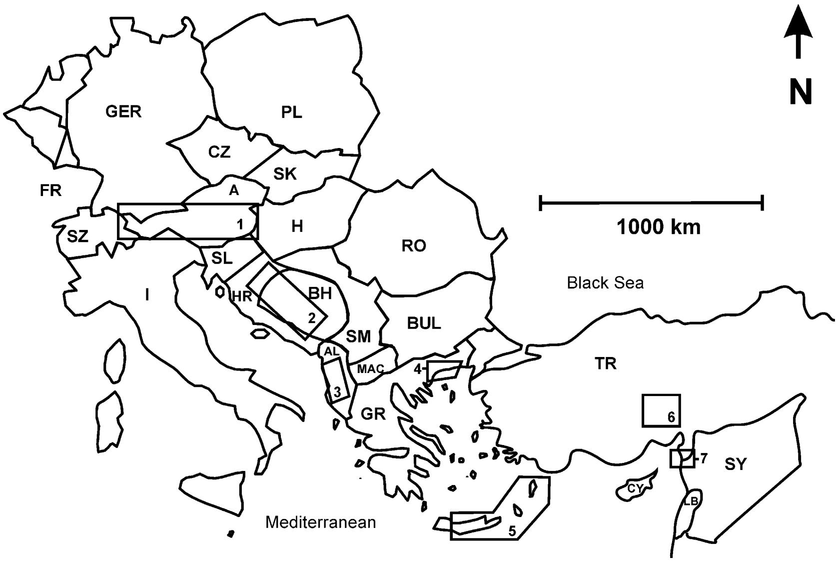

Fig. 1. Distribution of countries surrounding the Eastern Mediterranean. The inserts and numbers refer to the papers in this volume. FR—France, SZ—Switzerland, I—Italy, GER—Germany, CZ—Czech Republic, PL—Poland, A—Austria, SK—Slovakia, SL—Slovenia, H—Hungary, HR—Croatia, BH—Bosnia and Hercegovina, SM—Serbia and Montenegro, RO—Romania, AL—Albania, MAC—Macedonia, BUL—Bulgaria, GR—Greece, TR—Turkey, SY—Syria, LB—Lebanon, CY—Cyprus.

favours the formation of most of the large, relatively intact ophiolites in the Eastern Mediterranean region above subduction zones rather than mid-ocean ridges. Such ophiolites probably formed by spreading during the initial stages of intraoceanic subduction, prior to the emergence of any major related oceanic arc. MOR-type ophiolites are locally preserved, as for example in the Jurassic Western-type Albanian ophiolites. Large areas of MOR-type oceanic crust were subducted, now recorded mainly as dismembered thrust sheets or blocks in ophiolitic mélange. Volcanic-sedimentary units of mainly Triassic age, including alkaline to MOR-type extrusives and radiolarites record rifting, transitional to spreading of Neotethyan ocean basins. Back-arc, intracontinental marginal basins of Triassic and Late Jurassic age developed within the northerly (Eurasian) continental margin. Several ophiolites formed in these basins were exposed by uplift, without significant transport. Transform-influenced ophiolites are occasionally preserved. The Eastern Mediterranean subduction-type ophiolites, of both Jurassic and Cretaceous age, were rooted in several coeval Neotethyan oceanic basins, separated by microcontinents, and cannot be interpreted entirely as vast, far travelled thrust sheets derived from a single palaeogeographically simple Tethyan oceanic basin.

The following papers are ordered geographically so that the reader is guided from the Eastern Alps, i.e. the paper by Melcher et al., to the Dinarides and Albania, discussed in the papers by Pamić et al. and Hoeck et al.

In the Eastern Alps, Melcher, Meisl, Puhl and Koller (No. 1 in Fig. 1) report a heterogeneous pile of pre-Mesozoic and Mesozoic nappes that were emplaced during specific orogenic events. Exclusively metamorphic ultramafic rocks are preserved within these nappes; these are now located variously within the pre-Mesozoic basement units of the Penninic Tauern Window, in the Austroalpine basement complexes, within Mesozoic units of the Penninic windows and also within the overlying Lower Austroalpine units.

Metamorphic peridotites and clinopyroxene-rich pyroxenites are distinguished in the Cambro–Ordovician Stubach Group and in the Habach Group of the Tauern Window. Both ophiolite occurrences developed in inferred back-arc and volcanic arc settings, respectively, along the northern margin of Gondwana.

Metamorphic harzburgite and dunite, veined by metagabbroic dykes, occur in the Austroalpine Silvretta crystalline basement nappe. In the Austroalpine basement east of the Tauern Window, highly depleted metamorphosed harzburgite and dunite are found in association with amphibolite and eclogite in the Proterozoic (ca. 800 Ma old) Speik Complex. These lithologies formed from an already depleted mantle in an inferred suprasubduction zone setting.

In the Mesozoic units of the Penninic windows (Lower Engadine, Tauern and Rechnitz windows), highly serpentinised ultramafic rocks of harzburgitic composition are associated with metagabbro, metabasalt, radiolarite and ophicarbonate. Serpentinised lherzolites are also exposed in the Matrei Zone, in the Lower Austroalpine Reckner Complex and in a body (of unclear tectonic affinities) located at the southern margin of the Lower Engadine Window. The harzburgites are interpreted as remnants of a residual mantle and form part of the (incomplete) Mesozoic ophiolite sequences of the restored Ligurian–Piemontais Ocean. The lherzolites are attributable either to an Early (Permian?) rifting episode during break-up of Pangea, or represent subcontinental mantle from the Adria plate that were tectonically incorporated into Neotethyan units.

Proceeding from the Alps towards the south Pamić , Tomljenović and Balen (No. 2 in Fig. 1) consider two dismembered ophiolite belts. The first, the Dinaride Ophiolite Zone (DOZ) is attributed to an open-ocean Tethyan setting, whereas the second, very dismembered ophiolites of the Vardar Zone (VZ) are viewed as a Tethyan back-arc basin. Ophiolites of both DOZ and VZ consist predominantly of mantle tectonites, represented mainly by fertile spinel lherzolite in the western and central parts of DOZ and VZ, and by depleted harzburgites in their southeastern parts. Rare cumulate ultramafics and gabbros are in some places overlain by massive or sheeted dyke complexes, in turn capped by basaltic pillow lavas. Metamorphic soles of the ophiolites are represented by various amphibolites with subordinate pyroxenite schists and scarce eclogites with ultramafic interlayers.

K–Ar and Sm–Nd ages have yielded a Jurassic age (174 ± 14 to 136 ± 15 Ma) for the ophiolites of the DOZ, but a Cretaceous age (109.6 ± 6.6 to 62.2 ± 2.5 Ma) for the ophiolites from the VZ. The bulk of oceanic crust is believed to have been generated during Late Triassic to pre-Late Jurassic/Early Cretaceous time when oceanic subduction processes were active. Generation of oceanic crust continued during the Cretaceous–early Palaeogene in a reduced Dinaridic Tethys within an inferred back-arc setting. The Dinaridic Tethys finally closed in Eocene time, accompanied by a second emplacement of VZ ophiolites and related tectonic events in the Dinarides.

Hoeck, Koller, Meisl, Onuzi and Kneringer then focus on the Voskopoja ophiolite in southern Albania, which forms an important, but hitherto poorly known, part of the MOR-type western ophiolite belt (No. 3 in Fig. 1). This consists predominantly of lherzolites, with minor harzburgites and dunites in the mantle section. Above come ultramafic and mafic cumulates including wehrlites, troctolites and olivine gabbros. The volcanic section is dominated by basaltic breccias, including megablocks with sheeted dykes, pillow lavas and isolated dykes. The basaltic breccias grade upwards into sandstones, in turn, interlayered with argillites and cherts of Jurassic age.

Different geochemical groups are delineated, several with MOR-type characteristics, and one of SSZ type. The former groups are comparable to “high-Ti ophiolite extrusives” of the western ophiolite belt of northern Albania. Basalts of the SSZ-type are, in turn, widespread in the volcanics of the eastern ophiolite belt. A comparison of the ultramafic–mafic cumulates and the basaltic volcanics with those in the northern part of the western belt in Albania and the Pindos ophiolite in northern Greece indicates that there is a systematic variation in petrography and geochemistry from north to south in the western belt, with an increasingly distinct SSZ-type signature towards the south. Ultramafic and mafic cumulates as well as basalts from the Shebenik massif in the eastern belt are similar to those of Voskopoja ophiolite, implying a genetic relationship.

The next two papers are devoted to several aspects of the Jurassic ophiolites of Greece. Magganas (No. 4 in Fig. 1) describes the incomplete Jurassic–Lower Cretaceous Evros ophiolite in Thrace, NE Greece. He concludes, based on geochemical investigations, that the geotectonic setting of this ophiolite was a volcanic arc-marginal basin system in the Vardar Ocean. Massive and pillow lavas with a few tuffaceous rocks and lava breccias forming the uppermost levels of the ophiolitic sequence are then overlain by volcanic and pyroclastic rocks of tholeiitic composition. The protoliths of the upper lavas are boninitic, believed to have been produced in a forearc area by about 30% partial melting of an already depleted mantle source. The depleted mantle source of the upper lavas is seen as the residue of an earlier partial melting event that had generated the magma of the lower volcanic protoliths in an extensional regime.

The following paper by Koepke, Seidel and Kreuzer (No. 5 in Fig. 1) is concerned with the southern Aegean islands of Crete, Karpathos and Rhodes. These form a critical transition between the exposures of the Jurassic ophiolites of the Dinarides, Albanides and Hellenides, and the Cretaceous ophiolites of Turkey, Cyprus and Syria. The ophiolites exposed on the Aegean Islands do not form a continuous belt. However, there are significant differences in composition and age between the ophiolites of Crete in the west and those of Karpathos and Rhodes in the east. On Crete, the serpentinites were derived from lherzolites representing primitive, undepleted mantle material, suggesting an origin at a slow-spreading ridge. The peridotites are intruded by gabbroic dykes ranging in composition from pyroxene gabbros to hornblende diorites and plagiogranites. The dominance of hornblende in these rocks and the geochemical signature imply a subduction-related origin for these dykes. Hornblendites associated with the peridotites are regarded as metamorphic ferrogabbros, which were probably overprinted within high-temperature shear zones. K–Ar dating of the hornblendites yielded ages around 160 Ma (Middle to Late Jurassic), indicating that these ophiolites are a part of the more westerly, Jurassic ophiolite belt. By contrast, in Karpathos and Rhodes, the serpentinites were originally harzburgites. These ultramafics are intruded by dolerite dykes with a geochemical signature of island arc basalts. Both the depleted nature of the peridotites and the geochemistry of the dykes are typical of inferred suprasubduction zone ophiolites. K–Ar dating of hornblendes from the dolerites yielded an early Late Cretaceous minimum age (around 90 Ma) for the ophiolites of the two islands. The age and clear similarities in composition and structure with ophiolite occurrences in southern Turkey demonstrate that the ophiolites of Karpathos and Rhodes belong to the more easterly Cretaceous ophiolite belt of the Eastern Mediterranean and the Middle East.

Following the general geographic line from north to south and from west to east, the final two papers by Parlak et al. and Al-Riyami et al. concentrate on the Cretaceous ophiolites in Turkey and Syria.

Parlak, Höck and Delaloye (No. 6 in Fig. 1) discuss the Pozanti–Karsanti ophiolite (PKO), one of a number of discontinuous remnants of Late Cretaceous oceanic lithosphere within the eastern Tauride belt of southern Turkey. This is characterized by mantle tectonites, ultramafic and mafic cumulates, isotropic gabbros, sheeted dykes and volcanics. Well-preserved crustal cumulate rocks are mainly composed of dunite ± chromite, wehrlite, olivine clinopyroxenite, clinopyroxenite, olivine websterite and low-Ti gabbro. The mineral chemistry of the ultramafic cumulates forming the basal portion of the plutonic section of the PKO is not consistent with crystal-liquid fractionation of primitive mid-ocean ridge basalts at low pressures. The presence of highly magnesian clinopyroxene and orthopyroxene together with the absence of plagioclase as early fractionating phases indicates medium-to high-pressure crystal fractionation of primary basaltic melts. Mineralogical and geochemical data suggest that the ultramafic cumulates are distinct from rocks in mid-ocean ridge and back-arc basin ophiolites. They are instead inferred to represent a part of the plutonic core of an intraoceanic island arc/suprasubduction zone tectonic setting.

Al-Riyami, Robertson, Dixon and Xenophontos (No. 7 in Fig. 1) then consider the Baer–Bassit ophiolite, of inferred Late Cretaceous age, which was emplaced from the south-Tethys ocean onto the leading edge of the Arabian continental margin in latest Cretaceous time. Dismembered sequences in different thrust sheets can be correlated to produce a complete ophiolite sequence, with a metamorphic sole at the base, overlain, in turn, by upper mantle tectonite, rare cumulates, massive and layered gabbros, localized high-level plagiogranites, sheeted dykes, basic extrusives and minor Fe–Mn sediments (umbers). The restored ophiolite sequence is similar to that of the more intact Troodos and Hatay ophiolites, but dissimilar to Oman. The Baer–Bassit extrusives are magnesian and strongly depleted, comparable to primitive island-arc tholeiites and some boninitic lavas, which favours a subduction-related origin. During tectonic emplacement, the front of the ophiolite was tectonically imbricated and overthrust by the main ultramafic slab (Bassit massif). Following covering by Late Maastrichtian–Palaeogene marine calcareous sediments, the area was subjected to mid-Tertiary regional folding. This was followed by Neogene dominantly left-lateral, strike-slip deformation along the African–Eurasian plate boundary, extending from south of Cyprus to the Dead Sea transform fault. As a result, the originally emplaced thrust sheets were dissected into three main composite units (Baer, Bassit and the southeastern units), separated by strongly faulted and sheared ophiolitic blocks and unmetamorphosed volcanic-sedimentary mélange.

Special thanks go to the following colleagues, whose thoughtful reviews helped greatly to improve the papers. The reviewers are in alphabetical order: V. Bortolotti, K. Burgath, P. Burg, E. Dachs, M. Delaloye, H. Downes, P. Floyd, Sz. Harangi, O. Parlak, E. Rampone, C. Şengör, P. Spadea and G. Stampfli.

References

Dixon, J.E., Robertson, A.H.F., 1984. The Geological Evolution of the Eastern Mediterranean. Spec. Publ. Geol. Soc. London, vol. 17, 824 pp.

Smith, A.G., 1993. Tectonic significance of the Hellenic–Dinaric ophiolites. In: Prichard, H.M., Alabaster, T., Harris, N.B.W., Neary, C.R. (Eds.), Magmatic Processes and Plate Tectonics. Spec. Publ. Geol. Soc. London, vol. 76, pp. 213–243.

Volker Hoeck*
Cestmir Tomek[1]
Institute of Geology and Palaeontology,
University of Salzburg, Hellbrunnerstr. 34, A-5020
Salzburg, Austria
E-mail addresses: volker.hoeck@sbg.ac.at (V. Hoeck),
cestmir.tomek@sbg.ac.at (C. Tomek)

Alastair Robertson[2]
Department of Geology and Geophysics,
University of Edinburgh, West Mains Road,
Edinburgh EH9 3JW, UK
E-mail address: alastair.robertson@glg.ed.ac.uk

Friedrich Koller [3]
Institute of Petrology, University of Vienna,
Geozentrum, Althanstr. 14, A-1090
Vienna, Austria
E-mail address: Friedrich.Koller@univie.ac.at

---

* Corresponding author. Tel.: +43-662-8044-5405; fax: +43-662-8044-621.

[1] Tel.: +43-662-8044-5405; fax: +43-662-8044-621.

[2] Tel.: +44-131-650-8546.

[3] Tel.: +43-1-4277-533-40; fax: +43-1-4277-533-41.