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# Timing of tectonic emplacement of the ophiolites and terrane paleogeography in the Hellenides

Dimitrios Papanikolaou

*Department of Geology, University of Athens, Panepistimioupoli Zografou, 15784 Athens, Greece*

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ABSTRACT

The timing of tectonic emplacement of the ophiolites is analyzed in the four oceanic terranes of the Hellenides ($H_2$, $H_4$, $H_6$, $H_8$). The criteria for this analysis are based on: a) the post-emplacement sedimentary cover or intrusive rocks, b) the syn-emplacement tectonostratigraphic formations and c) the youngest rocks involved in the structure of the autochthon and the allochthon unit in each case. The timing becomes younger towards the more external tectonic units of the Hellenides with: (i) Late Eocene–Oligocene age in the external ophiolite belt of the Pindos–Cyclades oceanic terrane $H_2$, (ii) Late Jurassic–Early Cretaceous age in the internal ophiolite belt of the Vardar/Axios oceanic terrane $H_4$ , (iii) Post-Liassic–pre-Late Jurassic age in the ophiolites of Lesvos–Circum Rhodope oceanic terrane $H_6$ and (iv) Pre-Late Jurassic age in the ophiolites of Volvi–Eastern Rhodope terrane $H_8$. An ophiolite obduction model can be applied, with the ophiolitic nappes always emplaced on top of pre-Alpine continental terranes with Mesozoic shallow-water carbonate platforms. The geometry of the continental terranes drifting during the Mesozoic within the Tethys Ocean controls the number and dimensions of the Tethyan oceanic basins. Where a continental terrane dies out, the two adjacent oceanic basins merge into one larger basin. This seems to be the case of the Pelagonian terrane ($H_3$), which is terminated north of Skopje, where the Pindos oceanic basin ($H_2$) merges with the Vardar/Axios oceanic basin ($H_4$).



## 1. Introduction: the ophiolite belts and the Tethyan oceanic basins of the Hellenides

The Hellenides represent a characteristic segment of Tethyan paleogeography and have been used as a model for the development of geosynclines in early geotectonic syntheses (e.g. Aubouin, 1965). Their paleogeographic organization has been rather complex with alternation of ridges, comprising shallow-water carbonate platforms and furrows with pelagic sediments and volcano-sedimentary formations including mafic rocks. The presence of ophiolites has been considered during the "pre-plate tectonics" period as the documentation of the axial zones of the eugeosynclinal area on both sides of the Pelagonian metamorphic massif in the so-called Sub-Pelagonian zone along the external western margin and the Vardar/Axios zone along the internal eastern margin. Nevertheless, the Vardar/Axios ophiolites have been considered as the main axial zone dividing the Hellenides/Dinarides orogenic system to the west from the Alpidic system of the Balkanides and the Carpathians in the east (e.g. Kossmat, 1924).

Since the development of the plate tectonics theory and the interpretation of the ophiolites as ancient oceanic crust the Hellenic ophiolites have been re-evaluated as major paleogeographic elements dividing oceanic basins within Tethys (e.g. Smith, 1971; Dewey et al., 1973). The complexity of Tethys with more than one ophiolite belt occurring within the pelagic sediments, alternating with shallow-water carbonate platforms was evident from the beginning of the application of the new theory and it was obvious that the simple Atlantic type oceanic model with two passive continental margins could not be accepted in the eastern Mediterranean. Several tectonic and paleogeographic models have been proposed with a different number of oceanic basins along the belt and also different types of geodynamic settings such as ophiolites formed within spreading centers along a mid-ocean ridge or above supra-subduction zones etc. (for extensive reviews and discussion see Robertson and Dixon (1984), Smith (1993), Robertson (2002, 2004), and Smith and Rassios (2003).

The concept of tectonostratigraphic terranes has been applied in the eastern Mediterranean aiming to locate the micro-continents existing within the Tethyan belt. Pre-Alpine continental crust of Precambrian and/or Paleozoic age covered by Mesozoic–early Cenozoic shallow-water carbonate platforms occurring within the Tethyan belt form the continental terranes. The ophiolites and related pelagic sediments of the intermediate oceanic basins separating the micro-continents have been sutured and their obducted relics of oceanic crust form the evidence for the oceanic terranes. Both continental and oceanic terranes have been analyzed and mapped at 1/2500 000 scale during 1987–1995 within IGCP project 276 (Papanikolaou and Sassi, 1989; Papanikolaou and Ebner, 1997).

The timing of tectonic emplacement of the ophiolites is a characteristic feature of each oceanic basin that may be related to its closure. Additionally, the timing helps to correlate major tectonic

*E-mail address:* dpapan@geol.uoa.gr.

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events along neighboring segments of the Tethyan belt (e.g. Dinarides/Hellenides–Pontides/Taurides) by correlating the timing of formation of ophiolite suture zones and of the closure of adjacent oceanic basins. The available data on the timing of tectonic emplacement for each oceanic terrane in the Hellenides are presented in this paper, following their relative position from south to north, together with a discussion of the long-lasting processes of alternative periods of plate convergence and (micro-) collision between Eurasia and Africa.

## 2. The ophiolites within the terrane tectonostratigraphy of the Hellenides

The paleogeographic organization of the Hellenides comprises four oceanic and five continental tectonostratigraphic terranes (Papanikolaou, 1989a, 1997; Papanikolaou et al., 2004) (Fig. 1). The symbols $H_1$–$H_9$ characterize each of the terranes of the Hellenides (H) and the odd numbers correspond to the continental terranes ($H_1$, $H_3$, $H_5$, $H_7$, $H_9$) whereas the even numbers to the oceanic terranes ($H_2$, $H_4$, $H_6$, $H_8$). The present day remnant of Tethys Ocean in the Eastern Mediterranean, which is being subducted below the Hellenic arc during the past few millions years, is the southernmost Tethyan oceanic basin adjacent to the African passive margin that can be regarded as a future sutured terrane ($H_0$). The four oceanic terranes of the Hellenides are: Pindos–Cyclades $H_2$, Vardar/Axios $H_4$, Lesvos–Circum Rhodope $H_6$ and Volvi–Eastern Rhodope $H_8$. They form ophiolite suture zones within the Hellenide nappe structure and represent allochthonous fragments of former oceanic basins that closed throughout Mesozoic and Cenozoic time. The distinction and location of the ophiolite outcrops of Greece for the four oceanic terranes is given on the map of Fig. 2. The classification of some ophiolite outcrops is not certain in cases where the available information is not conclusive due to lack of age determination, cover by recent sediments, younger tectonism destroying primary structures etc.

Continental blocks with pre-Alpine basement rocks covered by thick shallow-water carbonate platforms of Mesozoic to lower

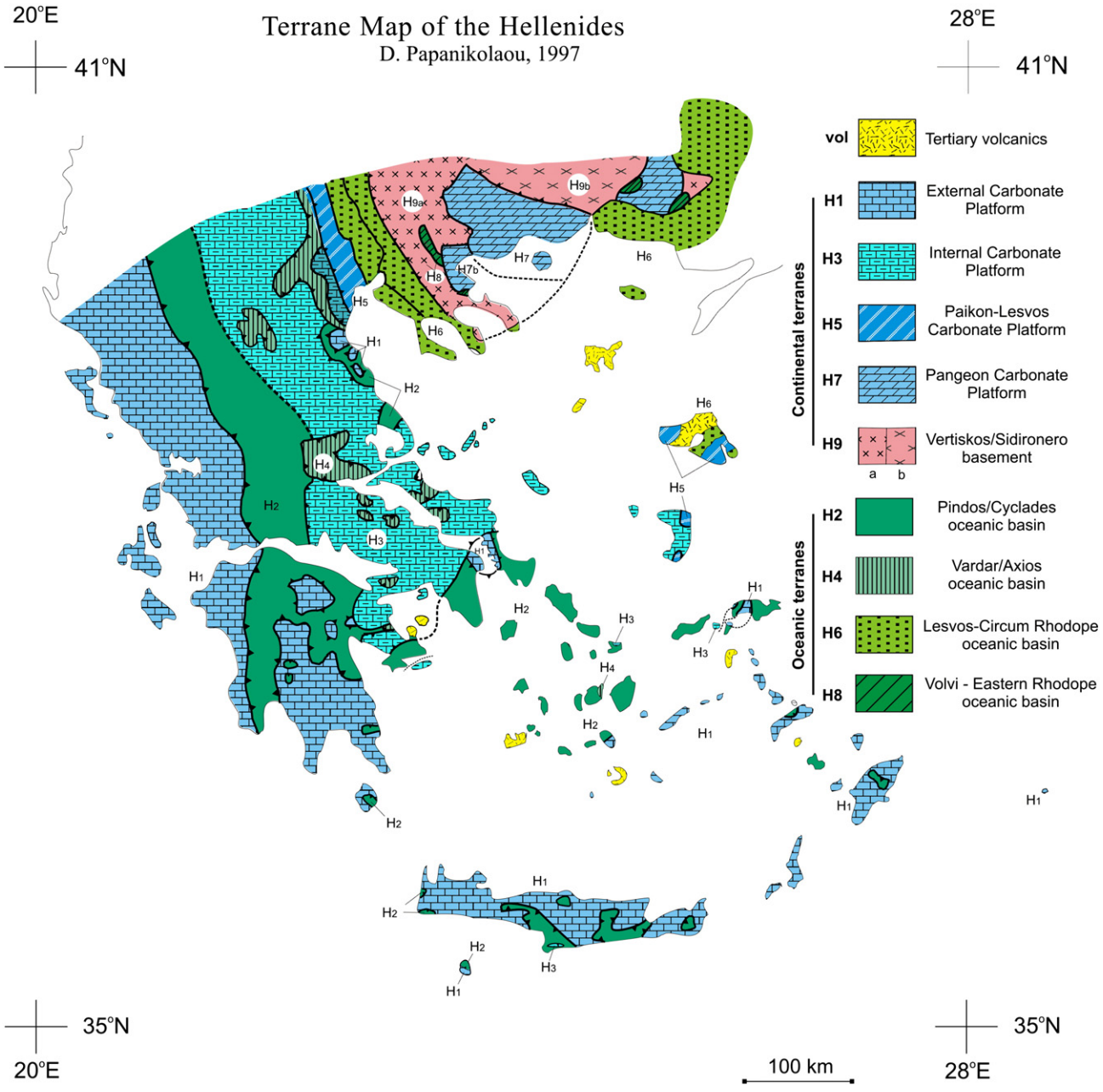


**Fig. 1.** Terrane map of the Hellenides (after Papanikolaou, 1997, modified).