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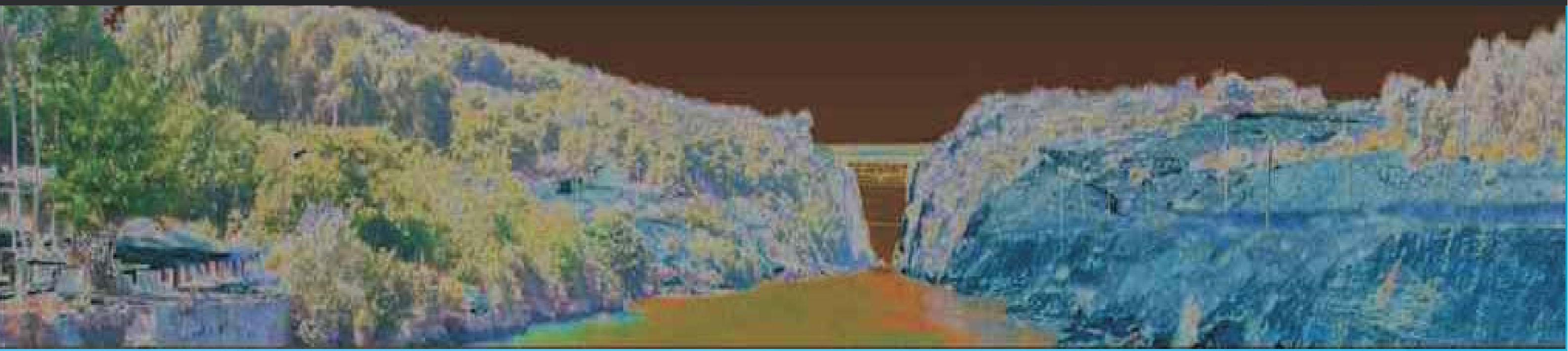

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NEOTECTONIC AND ACTIVE DIVERGING RATES OF EXTENSION IN THE NORTHERN AND SOUTHERN HELLENIDES ACROSS THE CENTRAL HELLENIC SHEAR ZONE

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Abstract (Neotectonic and active diverging rates of extension in the Northern and Southern Hellenides across the Central Hellenic Shear Zone): *Present day location and geometry of the Hellenic arc and trench system is only a small portion of the previously developed Hellenic arc that created the Hellenides orogenic system. The timing of differentiation is constrained in Late Miocene, when the arc was divided in a northern and a southern segment. This is based on: a) the dating of the last compressive structures observed all along the Hellenides during Oligocene to Middle-Late Miocene, b) on the time of initiation of the Kephalonia transform fault, c) on the time of opening of the North Aegean Basin and d) on the time of opening of new arc parallel basins in the south and new transverse basins in the central shear zone, separating the rapidly moving southwestward Hellenic subduction system from the slowly converging system of the Northern Hellenides. The driving mechanism of the arc differentiation is the heterogeneity produced by the different subducting slabs in the north (continental) and in the south (oceanic) and the resulted shear zone because of the retreating plate boundary producing a roll back mechanism in the present arc and trench system. The extension produced in the upper plate has resulted in the subsidence of the Aegean Sea and the creation of several neotectonic basins in southern continental Greece in contrast to the absence of new basins in the northern segment since Late Miocene. Crustal thickness, structural profiles, earthquake mechanisms and GPS rates are compared in the two segments, showing significant extension in the Southern Hellenides.*

***Key words**: Hellenides, neotectonic extension, slab roll-back*

INTRODUCTION

The active portion of the Hellenic orogen is an arcuate belt reaching from the central Adriatic Sea southwards and eastwards to western Anatolia (McKenzie, 1978; Le Pichon and Angelier, 1979; Picha, 2002; Reilinger et. al., 2006). Within the northwest-trending portion of the Hellenic belt, two segments can be distinguished by subduction rate (slow in the northwest, fast in the southeast) and water depth of the foreland lithosphere (shallow in the northwest, deep in the southeast; e.g. Dewey and Sengor, 1979; Finetti, 1982; McKenzie, 1978; Le Pichon and Angelier, 1979, Fig. 1). These segments, dextrally offset from one another near the island of Kephalonia, have been referred as the Northern and Southern Hellenides (Papanikolaou and Royden, 2007; Royden and Papanikolaou, 2011).

THE SEPARATION OF THE NORTHERN AND SOUTHERN HELLENIDES BY THE CENTRAL HELLENIC SHEAR ZONE

Several years of GPS measurements indicate a convergence rate of ~5-10 mm/yr across the Northern Hellenic subduction boundary, as measured between stations on the subducting plate (Apulia) and on the over-riding plate in northern Greece (Hollenstein et al., 2008; Bennett et al., 2008; Vassilakis et al., 2011) and seismic activity and focal solutions for local earthquakes attest to continuing convergence in this region (e.g. Louvari et al., 1999; Papazachos et al., 2000). Based on evidence from seismology, morphology and industry seismic data, the active thrust front of the Northern Hellenides lies just west of the Ionian islands of Corfu and Paxos (Monopolis & Bruneton, 1982; Vassilakis et al., 2011) (Fig. 1).

Even though gravity data indicate that the basement is flexed downward beneath the thrust front and the resulting depression filled with sedimentary foredeep deposits (Moretti and Royden, 1988), no trench is present in the bathymetry along the Northern Hellenides. For ease of reference we will refer to this zone of convergence as the Northern Hellenic trench, despite the fact that the trench has been entirely filled with sediments. The lithosphere entering the Northern Hellenic trench is continental or transitional in character, with a crustal thickness of ~25-30 km (Morelli et al, 1975; Marone et al, 2003, Cassinis et. al., 2003). Modern water depths near the thrust belt are generally ~1 km or less and overlie a shallow water sedimentary sequence of Triassic through Pliocene age (Jacobshagen et al., 1978).

On the contrary the same GPS data indicate a convergence rate of ~35 mm/yr across the Southern Hellenides, as measured between Africa and points in the over-riding (Aegean) domain (McClusky et al., 2000; Reilinger et al., 2006). Behind the Southern Hellenides, a Benioff zone reaches to ~150 km depth (e.g. Papazachos et al., 2000) and an active volcanic arc is present ~200 km behind the trench (Fytikas et al., 1984). The zone along which basement is subducted beneath the Hellenides lies ~50 km west of the southwestern coast of the Peloponnesus, passing beneath the deepest portions of the Hellenic trench (Fig. 1). Here, earthquake hypocenters and gravity data indicate that the depth to basement is ~12-15 km depth (Royden 1993; Hirn et al., 1997; Clément et al., 2000; Sachpazi et al., 2000). Thrust faults and folds also occur within the accretionary prism outboard of the trench, over a width of several hundred kilometers to the Mediterranean ridge (Kopf et al., 2003), but thrusting here involves only sedimentary cover detached above the basement. The crust beneath the Ionian Sea is almost certainly oceanic, probably Triassic or Jurassic in age, and consists of approximately 8 km of crystalline crust overlain by 6-10 km of sedimentary cover (Makris, 1985; Kopf et al., 2003). The water depth throughout much of the Ionian Sea region is 3-4 km, with the deepest depths of up to 5 km occurring along the Southern Hellenic Trench.

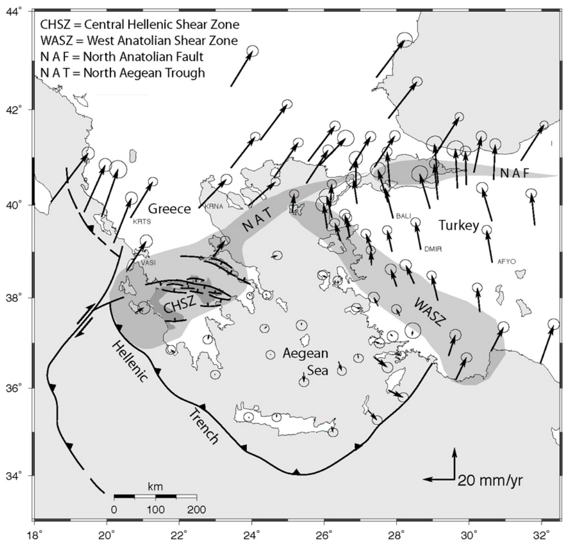

Fig. 1: Selected GPS velocities from McClusky et al. [2000] in a reference frame that minimizes velocities in the Aegean region. Some data were omitted in areas where high data density obscured the velocity pattern, mainly near the North Anatolian Fault zone. Shading indicates the zones of active oblique extension that bound the northwestern and northeastern margins of the largely undeforming Aegean domain.

The northern and southern segments of the Hellenic subduction boundary are separated by the Kephalonia transform zone (e.g. Dewey and Sengor, 1979; Finetti, 1982; Kahle and Muller, 1998; Kahle et al., 1995; Hollenstein et al., 2008), across which GPS data indicate ~25 mm/yr of dextral motion (Fig. 1). The Kephalonia transform separates the slowly subducting, continental foreland of the northern Hellenides from the rapidly moving upper plate of the southern Hellenides. Focal solutions from earthquakes located along the Kephalonia transform show right-slip on steep southwest-striking fault planes and also thrust faulting along northeast-striking fault planes.

The Kephalonia transform coincides closely with a change in foreland water depth from ~1 km in front of the Northern Hellenides to ~3-4 km in front of the Southern Hellenides, particularly near the west coast of mainland Greece (Fig. 1). Here the Hellenic subduction boundary (trench) appears to be dextrally offset by ~100-150 km across the Kephalonia transform zone, although the precise offset is difficult to determine due to north-south variations in water depth and sediment thickness and due to the fact that some of the offset of the northern and southern segments is taken up by clockwise rotation of crustal units adjacent to the south side of the transform (Vassilakis et al., 2011). Northeastward, the Kephalonia transform zone extends into mainland Greece to merge with the broadly defined zone of dextral and extensional deformation in the Central Hellenic Shear Zone (Papanikolaou and Royden, 2007; see also discussions by Goldsworthy et al., 2002; Armijo et al., 1996; Roberts and Jackson, 1991).

Global P-wave tomography indicates a northeast-dipping zone of high P-wave speeds beneath the Southern and Northern Hellenides (Spakman et al., 1993; van der Hilst et al., 1997; Karason and van der Hilst, 2001; Wortel and Spakman, 2000; Suckale et al., 2009). Behind the Southern Hellenides, the subducted lithosphere appears to reach to the base of the upper mantle, perhaps deeper. A northeast-dipping zone of high P-wave speed also exists north of the Kephalonia transform zone, but here the velocity contrast with the surrounding mantle is not as large as beneath the Southern Hellenides.

COMPARISON OF TECTONIC STRUCTURES AND DEFORMATION RATES BETWEEN THE NORTHERN AND SOUTHERN HELLENIDES

The difference of the tectonic structure and of the deformation rates in the Northern and Southern Hellenides can be studied in two time periods: the recent neotectonic period of the last 5 million years during the Pliocene-Pleistocene and the active deformation of the last 14000 years during the Holocene incorporating also the actual observations and measurements. The main points showing the diverging rates of extension in the two segments of the Hellenides are the following.

1) The width of the Hellenic peninsula from the Ionian sea at the west to the Aegean Sea at the east, is longer approximately by 60 km across the southern profile which corresponds to the offset of the trench across the Kephalonia transform since the Aegean coast is rather rectilinear from the Olympus foothills to the Southern Evia and Andros-Tinos-Mykonos Cycladic islands.

2) The crustal thickness in the Southern Hellenides is much thinner (less than 25 km) than in the Northern Hellenides (up to 45 km) (Makris, 1977; 1985).

3) The tectonic structure of the Southern Hellenides is characterised by the occurrence of the External Tectonometamorphic Belt in Peloponnesus in the form of tectonic windows, which resulted from extensional detachments during Miocene

(Papanikolaou and Royden, 2007; Papanikolaou et al., 2009). Thus, the structure in the Northern Hellenides is rather simple with a regular nappe emplacement from the area west of the Olympus tectonic window up to the Ionian Sea in contrast to the more complex structure in the Southern Hellenides, where there are new metamorphic geotectonic units (such as the Mani and Arna units) appearing below the non metamorphosed nappes (such as the Tripolis and Pindos units) (Papanikolaou and Vassilakis, 2010).

4) A number of arc parallel extensional neotectonic basins oriented NW-SE occur along the transverse profile of the Southern Hellenides (e.g. in Southern Peloponnesus) as described by Papanikolaou et al. 1988 (Fig. 2). In contrast, no neotectonic basins are developed in the transverse profile of the Northern Hellenides with the exception of the Ioannina basin (the only extensive Plio-Quaternary structure west of the Oligo-Miocene Mesohellenic basin). The difference of extension in the two segments within the upper plate is more than 20%.

5) The last onshore compressive structures in the Northern Hellenides are observed in Corfu and Parga areas, involving Late Miocene and early Pliocene sedimentary formations (including the Messinian evaporites) and in Kephalonia and Zakynthos islands in the Southern Hellenides with a dextral offset similar to the Kephalonia transform but somewhat smaller.

6) The transition from compression to extension as determined by earthquake mechanisms occurs in central Epirus in the Northern Hellenides and in the shallow marine zone between the Ionian islands and mainland Greece in the Southern Hellenides.

7) The rate of upper plate extension across the belt is ~3-5mm/yr in the Northern Hellenides and more than 30mm/yr in the Southern Hellenides.

EPILOGUE

All arguments displayed above point to the same conclusion of differentiation between the northern and southern Hellenides, regarding the amount of the extension both during the neotectonic period and the present day deformation. In many cases this differentiation can be quantified and the results are quite impressive showing that a major complex structure such as the Central Hellenic Shear Zone is acting as an oblique transform structure of the Hellenides by dividing the Hellenic peninsula and changing the present morphology.

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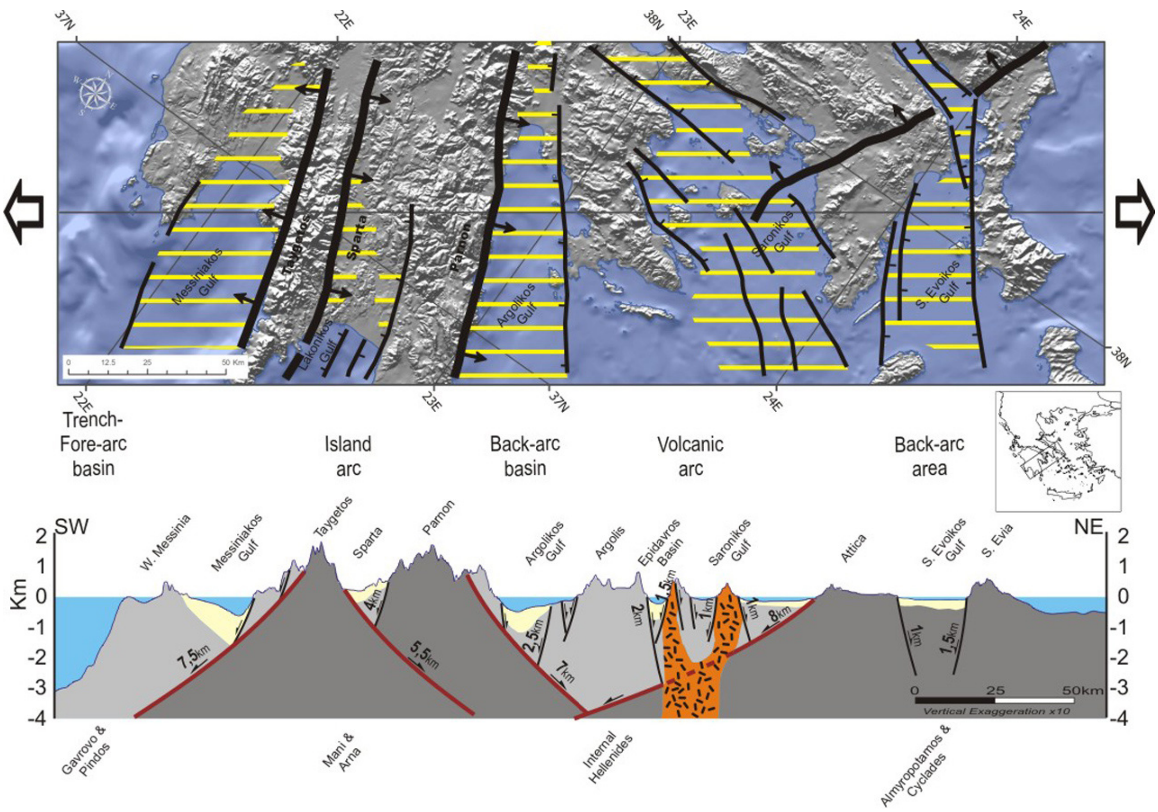

Fig. 2: In this vertically exaggerated (x10) SW-NE section across the Southern Hellenides the post-nappestacking extensional structures are indicated.

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