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MAJOR PALEOGEOGRAPHIC, TECTONIC AND GEODYNAMIC CHANGES FROM THE LAST STAGE OF THE HELLENIDES TO THE ACTUAL HELLENIC ARC AND TRENCH SYSTEM

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Abstract

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 southwestwards 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 paleogeographic reconstructions of the Hellenic arc and surrounding areas show the shortening of the East Mediterranean oceanic area, following the slow convergence rate of the European and African plates plus the localised shortening following the rapid Hellenic subduction rate. The result is that the frontal parts of the accretionary prism developed in front of the Hellenic arc have reached the African continent in Cyrenaica whereas on the two sides the basinal parts of the Ionian and Levantine basins are still preserved before their final subduction and closure. 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.

Key words: *oceanic subduction, continental subduction, upper plate extension, orogenic arc evolution, arc parallel structures, arc transverse structures.*

1. Introduction

The Hellenides are a segment of the Tethyan Alpine Orogenic Belt developed along the European active margin, resulted from plate convergence between the Eurasian plate in the north and the African plate in the south, with longlasting subduction of the Tethyan basins and platforms underneath the European margin (e.g. Papanikolaou et al, 2004; Van Hinsbergen et al, 2005). Convergence between the two plates has started since Jurassic and produced successive orogenic arcs that gave birth to the orogenic systems of the Hellenides until Miocene (e.g. Aubouin, 1974; Jacobshagen et al, 1978; Papanikolaou 1986;

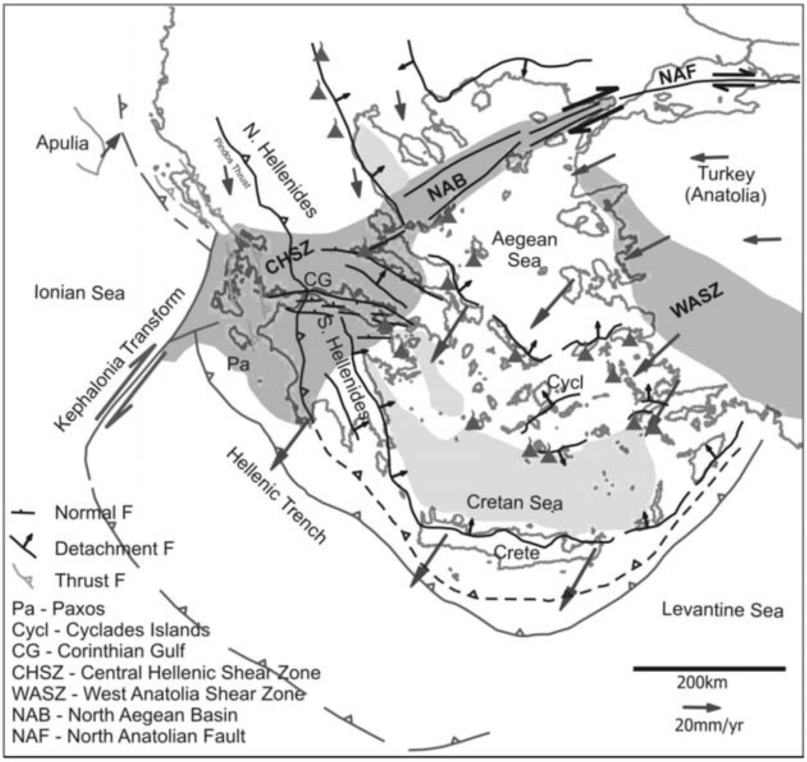

Fig. 1: Tectonic sketch of the Hellenides and the actual Hellenic arc and trench system. Bending of the thrusts in the southern segment is shown by the Pindos thrust and Late Miocene thrusts within the Ionian unit. The Late Miocene volcanic arc is shown in comparison to the Quaternary volcanic arc, developed only in the southern segment. Representative GPS rates are included together with the CHSZ and WASZ. Major detachments and normal faults of Late Miocene – Present are indicated.

1993). However, convergence is still going on today with an average rate of 1 cm/year (e.g. Reilinger et al, 1997; Kahle et al, 2000) in the eastern Mediterranean, including the Hellenides, whereas collision has occured at the western Mediterranean since early Miocene and at the Arabia – Caucasus transcet since middle Miocene (e.g. Cavazza et al, 2004). Thus, subduction of the last remnant of the oceanic basin of the Eastern Mediterranean, developed at the northern part of the African plate, occurs along the actual Hellenic arc and trench system, which is limited between the Amvrakikos Gulf in the northwest and the Rhodos transect in the southeast, forming the Aegean microplate (Fig. 1). The differentiation of the present day Hellenic Arc and trench system from the previous structure of the Hellenic fold and thrust belt necessitates the distinction of the Northern Hellenides and the Southern Hellenides on both sides of the Amvrakikos Gulf (Papanikolaou & Royden, 2007).

Convergence rate between the present day Hellenic arc and Africa, expressed by the ongoing Hellenic subduction, is about 4 cm/year (e.g. Reilinger et al, 1997; Kahle et al, 2000; Hollenstein et al, 2008), which is several times more than the convergence rate between Europe and Africa. This difference between the Africa – Eurasia plate convergence rate and the Hellenic subduction rate is producing extension in the Aegean upper plate and opening of the North Aegean Basin (Papanikolaou & Royden 2007). North of the Amvrakikos Gulf the convergence rate between Apulia (part of the Adria plate) and the Northern Hellenides is around 8 mm/year and there is no arc and trench system developed other than a compressional seismically active thrust belt (Baker et al, 1997). The lateral differentiation of more than 30 mm/year convergence rate north and south of Amvrakikos is accommodated by the Kephalonia transform fault. In the area of continental Greece and the Aegean the different kinematic motion between the Aegean microplate in the south and the European plate in the north produces a vertical shear zone – the Central Hellenic Shear Zone (CHSZ) (Papanikolaou & Royden 2007) comprising strike-slip, oblique-slip and normal faults (Fig. 1). Another shear zone - the West Anatolian Shear Zone (WASZ) - is developed at the eastern boundary of the Aegean microplate along the western coastline of Minor Asia, because of its differential motion with respect to the Anatolian microplate.

This paper is focused on a review and discussion concerning: 1) The timing of initiation of the present day geometry, from a previous homogeneous geodynamic regime along the Hellenides across the Kephalonia transform, the CHSZ and the North Aegean Basin. 2) The different tectonic and paleogeographic elements, that are considered as key points for understanding the complex evolution of the area. 3) The driving mechanism(s), that produced the observed present day differentiation of the Aegean microplate from the rest European margin. 4) A synthesis, where the overall conclusions are displayed in a series of paleogeographic sketches of the area over the last 34 million years (Oligocene – Present).

2. Timing of differentiation of the Hellenic Arc

The data regarding the timing of differentiation of the Hellenic arc can be grouped in four sets: 1) At the front of the fold and thrust belt along the subduction zone on either side of the Kephalonia transform. 2) Along the CHSZ and on either side of it in the continental part of Greece. 3) In the North Aegean Basin between the northern margin of the Aegean Sea at Macedonia and Thrace and the central and southern Aegean Sea. 4) An overall study of the arc geometry in different periods, before and after the differentiation.

The migration of the Hellenic thrust and fold belt from the internal part of the Hellenides in the Aegean Sea to the external part in the Ionian Sea throughout Eocene – Miocene is well known longtime ago (Philippson, 1959; Aubouin, 1959; 1965; Jacobshagen et al, 1978; Papanikolaou, 1986). The last compressional structures related to the front of the Hellenic fold and thrust belt have been reported from the Ionian islands of Kephalonia and Zakynthos, involving Pliocene or even Early Pleistocene sediments (Mercier et al, 1972; 1979; Underhill, 1989). However, the above structures are localised and rather exceptional with respect to the dating of the latest structures all along the western coast of continental Greece and the rest Ionian Islands, where the latest sediments involved in the compressional structures are of Late Miocene – Early Pliocene age (around 5 million years) including also the well known, all over the Mediterranean Basin, Messinian evaporites (e.g. Zakynthos and Parga) (IGSR & IFP, 1966; B.P. 1971; Hsu et al, 1978). North of the Amvrakikos Gulf there is no evidence of Plio-Quaternary compressional structures and the tectonic trend of the Miocene folds and thrusts is dextrally offset by several tens of km with respect to its location south of the gulf. The overall dextral offset of the Kephalonia transform fault is about 100 km, judging from the location of the northern edge of the Hellenic trench/plate boundary south of the Kephalonia transform and its approximate location north of the Kephalonia transform in the area west of the Paxos and Corfu islands, determined on the basis of bathymetric and geophysical data (e.g. Monopolis & Bruneton, 1982).

In continental Greece, the difference of the distribution of Plio-Quaternary basins north and south of the CHSZ is impressive, with almost no Plio-Quaternary basin formed in the Northern Hellenides in contrast to five basins developed in the southern Hellenides along the transect from Western Messinia in southwestern Peloponnese to southern Evia in the central Aegean (Fig. 2). These basins form neotec-

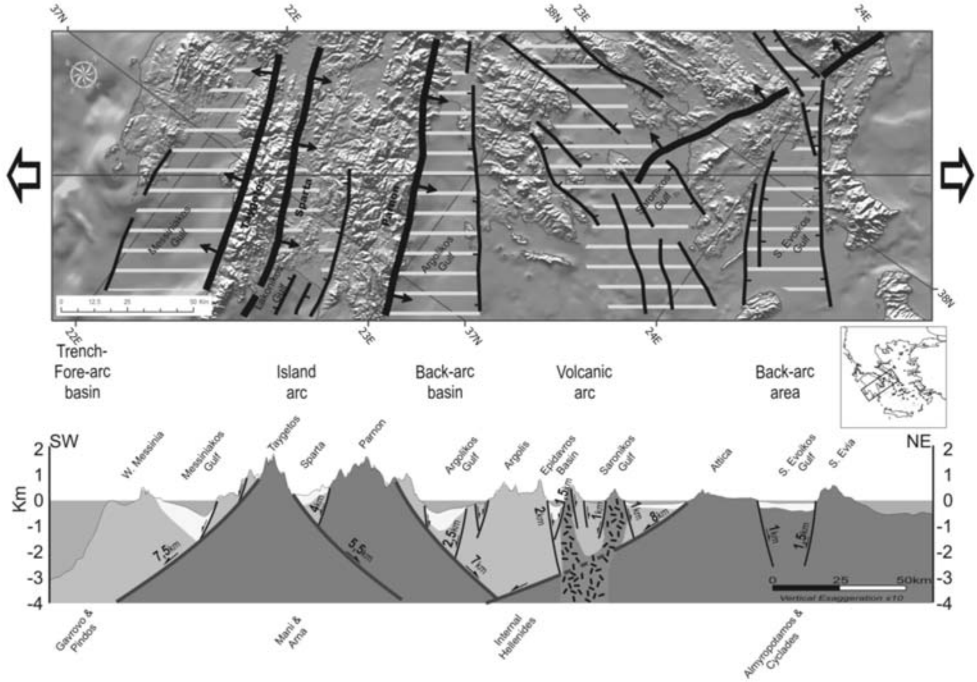

Fig. 2: Schematic neotectonic map and profile across the arc parallel basins/grabens of the Southern Hellenides, developed within Late Miocene – Present under an extension in the ENE-WSW direction (modified after Papanikolaou et al, 1988). A decrease of the deformation is shown by the estimated magnitude of fault throw along the profile.

tonic grabens filed with marine and/or continental sediments onshore and actual marine sedimentary basins offshore, developed within the successive gulfs of Messiniakos, Lakonikos, Argolikos, Saronikos and Southern Evoikos. These basins correspond to neotectonic grabens bounded by neotectonic horsts forming the mountainous regions of Western Messinia, Taygetos/Mani, Parnon, Argolis, Attica and Southern Evia. This alternation of neotectonic horsts and grabens in the NNW-SSE direction shows a WSW-ENE directed extension that forms arc-parallel structures within the Aegean upper plate. The intensity of deformation as expressed by the topographic relief, the sedimentary thickness and the fault displacement values shows a decrease from the external part of the arc in the southwest towards the internal part in the northeast (Papanikolaou et al, 1988). The minimum extension estimated across the above profile is 35 km, considering a mean 45^{o} dip of the normal faults forming the marginal faults of the basins. Within the CHSZ the accomodating structures are mainly the basins of Northern Evoikos Gulf, Beotikos Kiffissos and Corinth Gulf. These basins are transverse or oblique with respect to the arc geometry, with prevailing E-W trend controlled by normal faults which are seismically very active. They are filled with continental sediments mainly of Late Miocene – Pliocene age with some marine influence only during Middle - Late Pleistocene. North of the CHSZ, the latest neotectonic basins / grabens occur east of the Mesohellenic molassic basin with Late Miocene – Pliocene continental deposits. The latest sediments in the continuous molassic sequence of the Mesohellenic basin are of Late Miocene (Tortonian) age marking the end of marine sedimentation in central-northern continental Greece.

The opening of the North Aegean Basin has occurred sometime in Early Pliocene judging from its geometry, sedimentary thickness, fault displacements and differences in the present day GPS rates observed

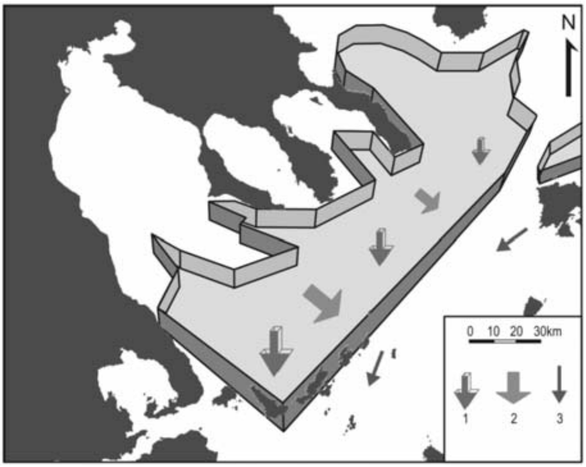

Fig. 3: Block stereo-diagram showing the overall geometry and kinematics of the North Aegean Basin (after Papanikolaou et al, 2002). 1: vertical subsidence, 2: horizontal opening, 3: GPS slip vectors.

on both sides of its margins (Lalechos & Savoyat, 1979; Le Pichon et al, 1984; Armijo et al, 1999; Papanikolaou et al, 2002; 2006). The opening of the basin is more pronounced in the western part (40 km) than in the eastern (20 km) and so is the depth (1600 m in the west and 950 m in the east) (Fig. 3). The location of the basin at the western prolongation of the North Anatolian Fault and its seismotectonic characteristics, implying a dextral strike-slip motion, have been the main argument for an induced basin because of wrench tectonics along the European margin, following the continental collision in the Caucasus area during the Middle Miocene and the subsequent lateral escape of Anatolia (Brunn, 1976; Dewey & Sengor, 1979; LePichon & Angelier, 1979; Armijo et al, 1999; McNeill et al, 2004; Kreemer et al, 2004).

The understanding of the transition period between the last stage of the Hellenides, viewed as a continuous orogenic arc involving all the characteristic parts, and the present day geometry of the Hellenic arc and trench system was based on an analysis of the paleogeographic position of the arc segments by comparing the geometry of the Burdigalian period with that of the Messinian and of the Plio-Quaternary period (Papanikolaou & Dermitzakis, 1981; Dermitzakis & Papanikolaou, 1979; 1981) (Fig. 4). The main features of the arc that have changed in Messinian are: 1) The uplift and ending of marine sedimentation in the Mesohellenic and the Cycladic molassic basins. 2) The opening of a new molassic basin in the area of the Cretan Sea between the Cyclades and Crete. 3) The termination of the volcanic arc activity in the segment of the Northern Hellenides and the continuation of the arc volcanism only in the segment of the Southern Hellenides. During the Plio-Quaternary, the volcanic arc continued its migration towards the more external zones of the Hellenic arc until its present location along the southern margin of the Cycladic plateau at a 60-80 km distance away from the location of the Late Miocene volcanic arc (see also Fig. 1). 4) The initiation of opening of the North Aegean Basin in the North Aegean Sea at the western prolongation of the newly formed North Anatolian Fault (see also Fig. 3). 5) The beggining of subduction of the last remnant of the Tethyan oceanic crust of the Eastern Mediterranean Basin along the arcuate segment formed between the Amvrakikos Gulf and Rhodes. 6) The initiation of the Kephalonia transform fault at the level of the Amvrakikos Gulf. 7) The migration of the fold and thrust belt towards the Ionian islands south of the Kephalonia transform fault, with Plio-Quaternary compressional structures at a distance of several tens of km away from the Late Miocene structures. 8) The disruption of the Late Eocene - Miocene fold and thrust belt and the relative westward displacement of the Hellenides nappes in the southern segment. Thus, the Pindos thrust is observed today at the front of the nappe system in southwest Peloponnese and Kythira Island up to Gavdos Island south of Crete, adjacent to the trench, whereas in the Northern Hellenides it rests along the western slopes of the Pindos chain at a distance of 90-120 km away from the

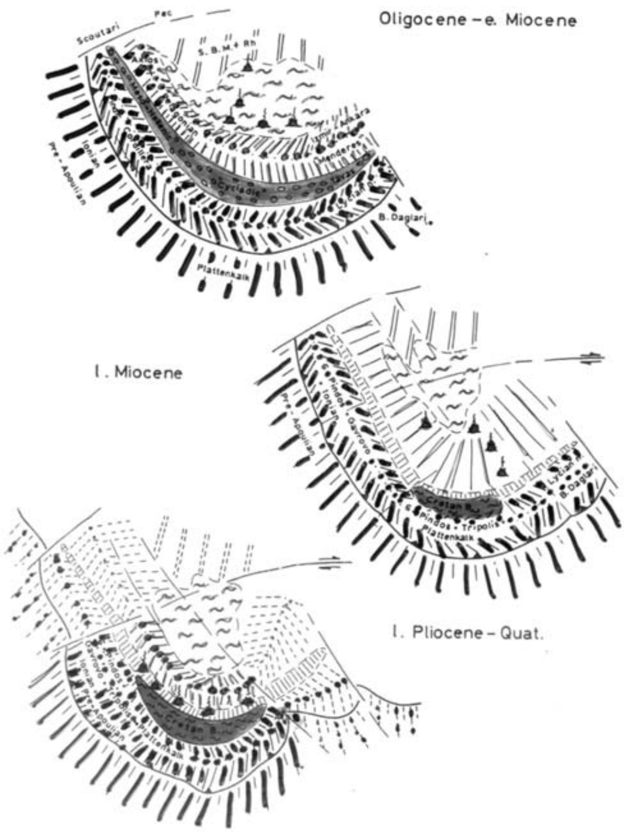

Fig. 4: Paleogeographic and paleogeodynamic sketches of the Hellenic arc from the last stage of the Hellenides (Oligocene – Early/Middle Miocene to a reorganisation period in Late Miocene and to the actual Hellenic arc and trench system (Plio-Quaternary) (after Papanikolaou & Dermitzakis, 1981).

plate boundary (see also Fig. 1). 9) The maximum uplift of the nappe pile in the southern Hellenides, producing the arrival at the surface of the higher mountains of south Peloponnese of the basal metamorphic unit of Mani and of the overlying metamorphic unit of Arna. 10) The development of a number of arc-parallel extensional neotectonic basins in the Southern Peloponnese and of transverse neotectonic basins in the Northern Peloponnese and Sterea Hellas (see also Fig. 2).

In conclusion, the timing of differentiation of the Hellenic arc and its subdivision in the Northern and the Southern Hellenides is constrained in Late Miocene. Tortonian is the last period of the previous uniform Hellenic arc and Messinian is the re-organization period whereas already by the beginning of Pliocene the new subdivision and arc geometry has been established.

3. Sedimentary basins and tectonics

The post-Oligocene sedimentary basins and associated neotectonic structures developed within the upper plate during the migration of the Hellenic orogenic arc can be distinguished in the following three categories.

1) The first category concerns all the arc parallel structures occurring within the orogenic arc from the

front of the fold and thrust belt at the fore-arc basin, to the back-arc area behind the volcanic arc. This category involves compressive structures developed from Late Eocene - Oligocene (e.g. Pindos and Tripolis units) to middle - late Miocene (e.g. Ionian and Paxos units) all along the frontal zone of the Hellenic arc in the paleo-trench and the external zone of the paleo-island arc. It also involves extensional structures related to the opening of the molassic Mesohellenic Basin and its probable continuation in the Cycladic molassic basin to the south. The tectonic trend remains constant in the NNW-SSE direction for both compressive and extensional structures. The sedimentary sequences deposited in the above structures are deep marine clastic sediments of flysch type in the frontal compressional zone and of molassic type in the internal extensional zone. Continental sedimentation is generally rare, such as the Early Miocene Aliveri basin in central Evia and the Strymon basin in Eastern Macedonia.

2) The second category concerns the arc parallel structures occuring within the Late Miocene to Plio-Quaternary Hellenic arc and trench system in the Southern Hellenides. The Parnon and Taygetos extensional detachments in Peloponnese are characteristic arc parallel features together with the other NNW-SSE trending normal faults, described earlier along the transverse profile of Fig. 2. The dominant facies of these basins involve deep marine clastic sedimentation of molassic type, such as the Cretan Basin, and less deep marine sedimentation in the other neotectonic basins. In the case of the Itea – Asmfissa detachment the extensional deformation started in Middle Miocene (Papanikolaou et al, 2009). A middle Miocene age of the detachment faulting resulting in the opening of the Cretan Basin in the north and the Messara Basin in the south was also reported from Crete (Papanikolaou & Vassilakis, 2009). The orientation of the detachments in Crete is following the arc curvature and the general trend is E-W. In the Northern Hellenides the Plio-Quaternary neotectonic basins occur at the previously existing NNW-SSE oriented Late Miocene basins with lignite bearing continental deposits (Burchfiel et al, 2008). No new Plio-Quaternary basins were formed within the Northern Hellenides.

3) The third category concerns the arc transverse structures within the CHSZ developed since Late Miocene. These structures show strike-slip motions combined with normal and oblique faulting (Pavlides et al, 1990; Sokoutis et al, 1993; Koukouvelas & Aydin, 2002), related to the strike-slip faults of the Northern Aegean Sea, where oblique extension can describe better the overall tectonics (Papanikolaou et al, 2002; 2006) (Fig. 2). The dextral strike-slip motion of the CHSZ is expressed mainly by two transverse fault zones with structural trend in the ENE-WSW direction. These strike-slip fault zones are crossing the North Aegean Sea and enter mainland Greece along the Maliakos Gulf and along the Skyros – Aliveri – Northern Attica lineament (Papanikolaou & Royden, 2007). The middle Miocene age of the Kymi Basin and the Oxylithos volcanic rocks (Xypolias et al, 2003) imply the beginning of transverse strike-slip tectonics earlier in the internal part of the Hellenic arc. The general trend of the Plio-Quaternary transverse structures is E-W, overprinting the previous NNW-SSE tectonic trend of the arc parallel structures. The different fault pattern of the Plio-Quaternary neotectonic structures and basins in the CHSZ and south of it in the Southern Hellenides was described by Mariolakos & Papanikolaou (1981, 1987) and Mariolakos et al (1985) who emphazized also the fact that the E-W younger faults are seismically active structures in contrast to the NNW-SSE faults, which are less active (Fig. 5). Within the CHSZ the new structures developed during Plio-Quaternary disrupt the previous arc parallel structures as this is shown on both sides of the Corinth Gulf (Papanikolaou & Royden, 2007). In the case of the Itea – Amfissa detachment, the NNW-SSE oriented arc parallel structure has been active throughout Middle – Late Miocene and was disrupted by the Late Pliocene – Pleistocene E-W faults, bordering the northern margin of the Corinth Gulf (Papanikolaou et al, 2009). The same pattern was observed in the Northern Evoikos Gulf, where the NNW-SSE Aghios Konstantinos detachment was disrupted by the E-W normal faults of the Arkitsa system (Papanikolaou & Royden, 2007).

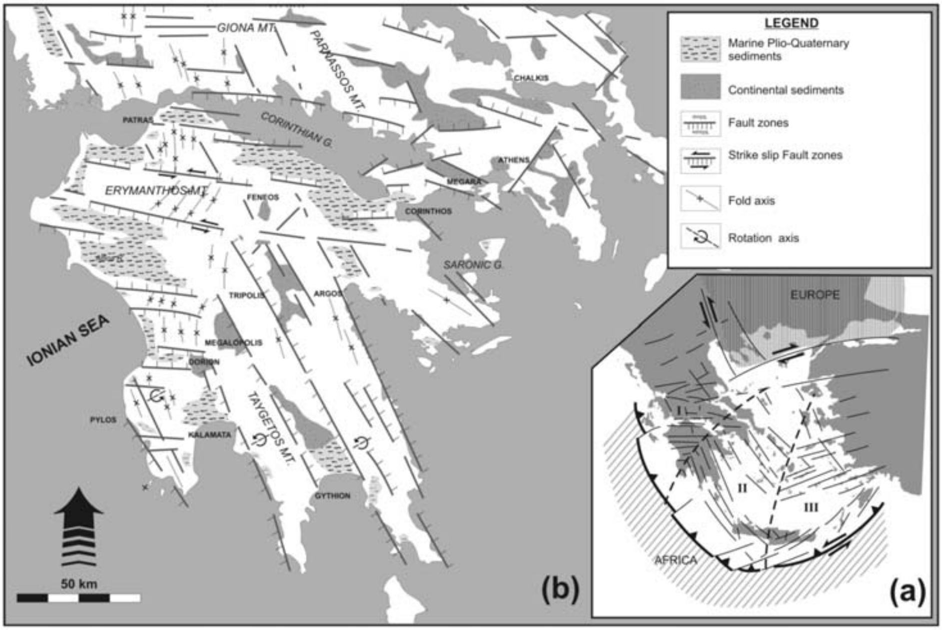

Fig. 5: Neotectonic sketch map of Sterea Hellas and Peloponnese (a) and of the Hellenic arc (b) (after Mariolakos & Papanikolaou, 1981). The distribution of the E-W oriented transverse faults within the CHSZ is confronted to the NNW-SSE arc parallel faults in the Southern Hellenides. The distribution of marine and continental sediments within the neotectonic basins helps to differentiate vertical motions with subsidence during the Pliocene and uplift during the Quaternary around the Peloponnesian coast.

In conclusion, the Hellenic arc exhibits a well pronounced arc parallel structure comprising compressive structures at the frontal zone and extensional structures at the back – arc zone throughout its tectonic evolution since Oligocene times. This arc parallel structure has been disrupted during Late Miocene – Present by transverse and oblique to the arc structures, involving dominantly strike-slip and normal faulting within the CHSZ, that separates the Northern Hellenides from the Southern Hellenides.

4. Driving mechanism(s)

Plate convergence between Africa and Europe has been the main driving force of the ongoing Hellenic subduction and related geodynamic features of the migrating orogenic arc throughout Late Cretaceous – Present. However, this subduction process has been interrupted by some distinct periods of micro-collision of the intermediate continental tectono-stratigraphic terranes of the Hellenides (Papanikolaou, 1989; 1997). Judging from present day GPS rates in the northern Hellenides and the southern Hellenides we can estimate a rate of convergence during the microcollision periods of 5-10 mm/year, similar to the rates observed today between Apulia and the Northern Hellenides and subduction rates of oceanic basins around 40 mm/year. Subduction rates may increase up to 70-80 mm/year judging from other actual subduction zones whereas rates of continental convergence seem to be of the order of a few mm/year worldwide (Sella et al, 2002; Funiciello et al, 2003; Lallemand et al, 2005; Royden & Husson, 2006).

In the case of the Hellenides, the difference between the northern segment and the southern segment corresponds to the ongoing microcollision and continental subduction of the Apulia shallow-water carbonate platform, developed over the Adria continental crust, beneath the external Hellenides nappes in the north against the subduction of the oceanic crust of the East Mediterranean Basin beneath the southward continuation of the same external Hellenides nappes. The change of the southern segment from continental subduction to oceanic subduction occured sometime in Late Miocene, when the last marginal parts of the External Platform of the Hellenides, known as the Paxos Unit, were subducted. The external carbonate platform of the Hellenides constitutes the external terrane H_1 (Papanikolaou, 1989; 1997) separating the Pindos oceanic basin (terrane H_2) in its internal margin from the East Mediterranean basin (terrane H_0) in its external margin. Subduction of the external platform started in Late Eocene, when flysch sedimentation started in the more internal parts of the platform, comprising the tectonic units of Olympos, Amorgos, and Gavrovo – Tripolis and ended in Late Miocene when the more external parts, represented by the Paxos (known also as Pre-Apulian) unit, have been deformed and uplifted at the front of the Hellenic belt. North of the Kephalonia transform fault the external parts of the external carbonate platform are detected offshore in the Ionian Sea and continue up to the outcrops of the recently uplifted Apulia peninsula.

In conclusion, the creation during Late Miocene and the following evolution up to the present day Hellenic arc and trench system is the result of lateral inhomogeneity of the Hellenic subduction system with continental subduction and micro-collision in the north against oceanic subduction in the south. This produced a very slow convergence in the north, with a rate of 5-10 mm/year, without developing the characteristics of an arc and trench system and a rapid subduction with a rate of 40 mm/year, that created the Hellenic arc and trench system. The transition from slow continental subduction in the late Miocene to rapid oceanic subduction in the Plio-Quaternary in the southern Hellenides was driven by a roll back mechanism occuring at retreating plate boundaries, observed when subduction rate is higher than convergence rate (Royden, 1993; Ten Veen & Postma, 1999).

The above conclusion, as far as the mechanism controlling the differentiation of the Hellenides orogenic belt since Miocene times is based on subduction dynamics and confronts previous models proposing a mechanism based on lateral escape of the Anatolian microplate, following continental collision between the Arabian and Eurasian plates in the Caucasus. In this escape model, the Hellenic arc and trench system obtained its differentiated kinematics, curvature, geometry and internal deformation under the push from the Anatolian microplate, itself been pushed away from the collision zone of Arabia and Eurasia (Brunn, 1976; Mercier et al, 1979; LePichon & Angelier, 1981). This model has not taken into consideration the geodynamic situation and changes of the plate boundary at the front of the Hellenic arc in the west but only the plate dynamics in the east. A major point of concern has been the absence of a strike-slip fault zone through central continental Greece as postulated by the early plate tectonics model of the area (McKenzie, 1972). However, the GPS measurements obtained in the area of the Eastern Mediterranean during the 90's showed that the Anatolia rate is much less than the Aegean rate (20 mm/year versus 35-40 mm/year) (e.g. Reilinger et al, 1997). Thus, instead of push, the relation between Anatolia and Aegean is pull! The analysis of the GPS measurements considering the Aegean area as stable showed the existence of two vertical zones of shear along the northern (CHSZ) and the eastern (WASZ) boundaries of the Aegean microplate with a strike-slip and transtentional character (Papanikolaou & Royden, 2007). The E-W oriented transverse to the arc basins of Corinth, Beotikos Kiffissos and Northern Evoikos in central continental Greece are the result of the CHSZ and the E-W oriented basins of Western Anatolia are the result of the WASZ.

5. Paleogeographic synthesis

The paleogeographic reconstruction of the Hellenic arc during the last 34 million years (Eocene/Oligocene boundary to present) can be understood by taking into account:

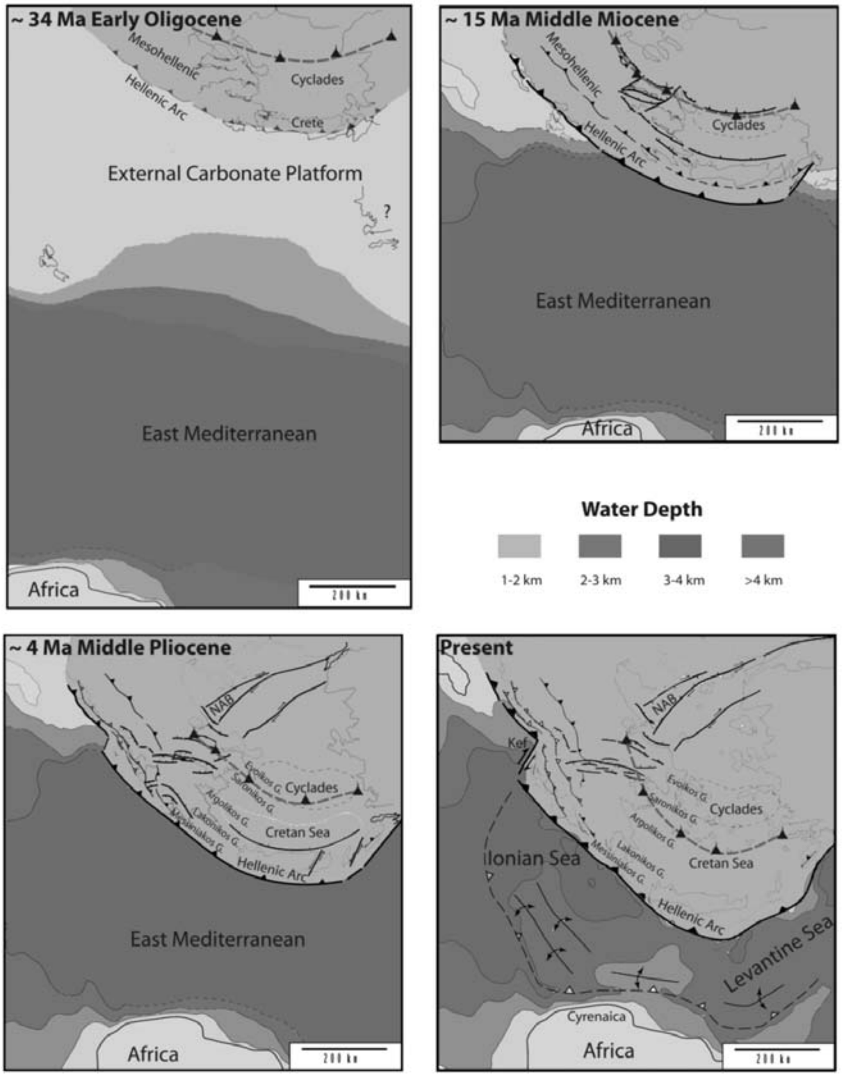

Fig. 6: Paleogeographic sketches of the Hellenic arc and its evolution to the present day Hellenic arc and trench system (modified after Royden & Papanikolaou, manuscript).

1) The estimated average Africa – Europe convergence rate (10 mm/year).

2) The Hellenic subduction rate (at present 35-40 mm/year), after its differentiation from the convergence rate of the rest European margin with an important increase during Late Miocene.

3) The internal deformation of the Aegean microplate, undergoing arc parallel extension at its central segment and horizontal shear with strike-slip faulting along the two marginal zones (CHSZ and WASZ).

4) The migration of the Hellenic arc and its internal subdivision together with the major paleogeographic changes, based on the dictribution and facies of the sedimentary basins (see for Dermitzakis & Papanikolaou, 1979).

The above computations resulted in four paleogeographic sketches corresponding to 34, 15, 4 and 0 million years given in Fig. 6. The northern boundary of the area, approximately along the North Aegean coastal zone was considered stable in the frame of reference. Thus, the difference of the distance from the North Aegean to the coast of the Cyrenaica peninsula in Africa in each sketch shows the amount of convergence between Africa and Europe. The Kephalonia transform fault, separating the Northern from the Southern Hellenides, is shown to increase in the two younger sketches. The opening of the Cretan Basin in the south is shown to develop as an arc parallel extensional basin in late Miocene whereas the North Aegean Basin is shown in the north along the new microplate boundary separating the Aegean from northern continental Greece. The other minor basins (Corinth, Evoikos, Maliakos etc) are developed within the CHSZ. The external carbonate platform of the Hellenides enters the subduction zone 34 million years ago, after the closure of the Pindos basin. At the 15 million years period the more external parts of the external platfrom are shown during their final stage of subduction in the Ionian islands when oceanic subduction of the East Mediterranean basin was established in the southern part of the arc in Crete. The bending of all previous structural trends (pre-Late Miocene) on both sides of the Kephalonia transform is depicted in the last two sketches (e.g. the Pindos thrust). The formation of the east Mediterranean rise is shown at the last sketch, when the Hellenic subduction zone has approached the African passive margin of Cyrenaica and collision is under way at the frontal part whereas subduction pertains in the Ionian and Levantine basins (Finetti et al, 1991).

6. Conclusions

The differentiation of the Hellenic arc occured in Late Miocene separating a northern segment where continental subduction continued from a southern segment where oceanic subduction started. The development of the present Hellenic arc and trench system is the result of oceanic subduction of the East Mediterranean Basin. The geometry of the Hellenic arc has been characterised by arc parallel structures both compressive at the front and extensive in the back throughout its evolution since early Tertiary. The subdivison in Northern and Southern Hellenides was accompanied by the development of the CHSZ, which created strike-slip faults and oblique to normal faults transverse to the arc with a general E-W direction in continental Greece. The extension of the Aegean upper plate produced the subsidence of the Aegean area and the creation of the North Aegean Basin and the arc transverse basins of Corinth, Beotikos Kiffissos, Northern Evoikos and other minor neotectonic basins.

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