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Neogene brittle detachment faulting on Kos (E Greece): implications for a southern break-away fault of the Menderes metamorphic core complex (western Turkey)

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Abstract: The southern limit of the Menderes metamorphic core complex has recently been proposed to be formed by an Oligocene–early Miocene top-to-the-north breakaway detachment fault, the Datça–Kahle fault running across the Lycian nappes in southwestern Turkey. Proving a breakaway detachment fault as opposed to a 'simple' local high-angle normal fault is generally hampered by absence of a metamorphic contrast between hanging wall and footwall. The island of Kos lies close to the inferred southern breakaway fault. It exposes Permo- Carboniferous anchi-metamorphic rocks, intruded and contact-metamorphosed at upper crustal levels by a 12 Ma old monzonite during or close to peak-burial conditions. Here, we show that exhumation of these rocks occurred along a top-to-the-north brittle extensional detachment fault underneath upper Mesozoic and Palaeogene non-metamorphic carbonates after 12 Ma, and that any (undocumented) earlier extension did not lead to significant exhumation of the Permo-Carboniferous rocks. Kos should thus be placed within the Cyclades–Menderes extensional province since 12 Ma. The age of exhumation is younger than the proposed activity of the breakaway fault, the existence of which we cannot corroborate. We conclude that the brittle detachment of Kos cannot be straightforwardly correlated to any ductile-to-brittle detachments of the Menderes or eastern Cycladic metamorphic core complexes further to the north and may represent a relatively isolated structure.

Metamorphic core complexes have since long been recognized to form due to exhumation along low-angle extensional detachment faults that juxtapose high-grade metamorphic rocks in the footwall against upper crustal rocks in the hanging wall (Crittenden *et al.* 1980; Wernicke 1981, 1995; Davis 1983, Lister *et al.* 1984; Lister & Davis 1989; Fig. 1). Recent modelling of formation of metamorphic core complexes suggests that core complexes form in two stages: in the first stage, symmetric boudinage of the crust leads to a graben at the surface and lower crustal flow into the extending region, followed by a second stage where a mid-crustal shearzone at depth links with one of the brittle graben-bounding faults in the upper crust to form an sigmoidal extensional detachment along which a metamorphic dome is exhumed to the surface (Tirel *et al.* 2008, 2009).

Due to the asymmetric structure of a metamorphic core complex, its boundaries on either side are markedly different: on one side they are easily recognizable by the existence of a ductile-to-brittle extensional detachment with a sharp metamorphic contrast between the lower metamorphic grade hanging wall and higher metamorphic grade footwall. On the opposite side, the metamorphic grade of the footwall will more gradually decrease and eventually the detachment will lack a ductile history, juxtaposing only upper crustal, low-grade metamorphic rocks in footwall and hanging wall in an area between the exhumed metamorphic rocks and a break-away fault (Fig. 1). This break-away fault can be considered to be the boundary of the metamorphic core complex (Dorsey & Becker 1995; Otton 1995; van Hinsbergen & Meulenkamp 2006).

The Menderes core complex in western Turkey (Fig. 2) is one of the largest in the world and formed as a result of *c.* north–south extension in the Aegean backarc since the late Oligocene (Bozkurt & Park 1994; Hetzel *et al.* 1995*a*, *b*; Bozkurt & Satir 2000; Bozkurt & Oberhänsli 2001; Gessner *et al.* 2001). Multiple extensional detachment faults with both top-to-the-north and top-to-the-south sense of shear have been recognized in the Menderes massif, and a clear structural asymmetry on the scale of the whole massif is not evident (Hetzel *et al.* 1995*a*; Gessner *et al.* 2001). Recently, however, Seyitoğlu *et al.* (2004) postulated that an Oligocene–lower Miocene 'Kahle–Datça fault zone' in the central part of the Lycian nappes of southwestern Turkey (Fig. 2) formed a break-away fault of the Menderes metamorphic core complex, thus suggesting that in the early

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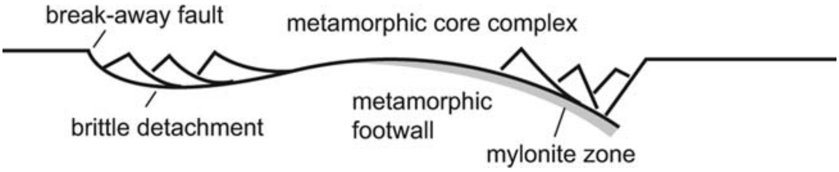

Fig. 1. Schematized cross-section of a metamorphic core complex, indicating the relationship between the break-away fault and the position of the metamorphic core (modified after Lister & Davis (1989)).

stages of exhumation, top-to-the-north unroofing was the dominant process of exhumation. Proving that the Kahle–Datca fault zone is indeed a break-away brittle detachment fault, as opposed to a relatively small-displacement normal fault is difficult, since the most obvious criterion for an extensional detachment fault – a metamorphic contrast between hanging wall and footwall – is absent.

The island of Kos (Fig. 2), however, may provide a case to test the existence of a brittle extensional detachment between the Kahle–Datca fault and the metamorphic complex of the Menderes. Kos is located only about 15 kilometres NW of the Datça fault, and *c.*15 km SW of the Bodrum peninsula, where the southernmost metamorphic rocks flanking the Menderes massif were found (Rimmelé *et al.* 2003). The Dikeos Window in southeastern

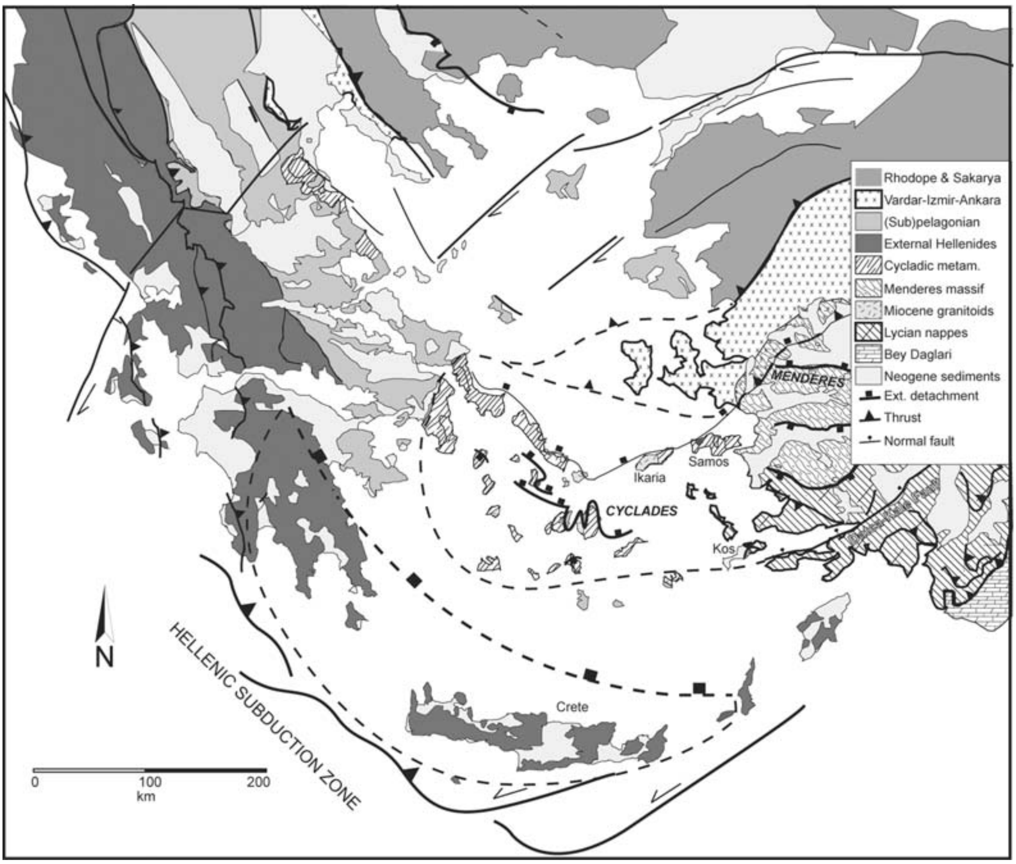

Fig. 2. Geological map of Greece and western Turkey, modified after Jolivet *et al.* (2004) with the position of the Datça–Kahle fault, postulated by Seyitoğlu *et al.* (2004) to form the Oligocene–lower Miocene break-away fault of the Menderes metamorphic core complex.

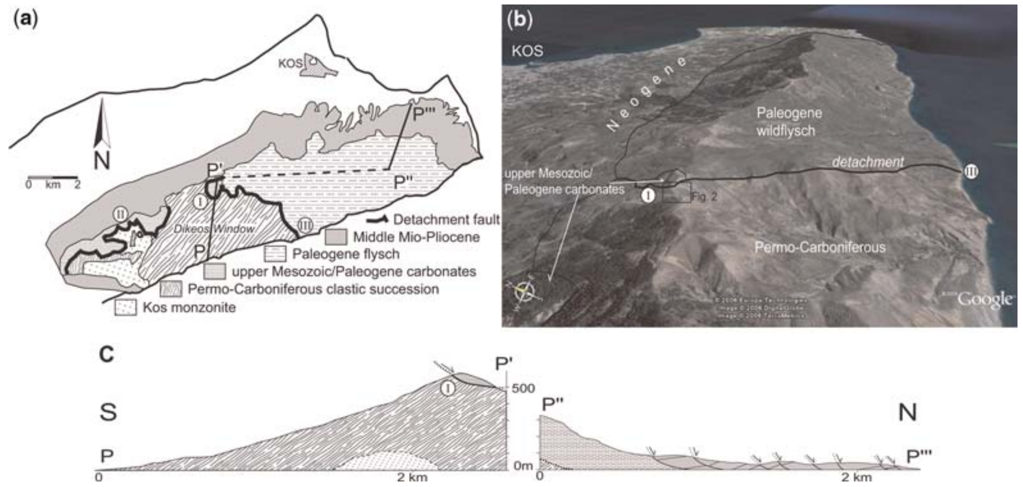

Fig. 3. (**a**) Geological map of eastern Kos, modified after Böger *et al.* (1974) and Altherr *et al.* (1976); Figure 6 shows field photographs of location II near Paleo Pili. (**b**) Google Earth image of the topography and satellite image of eastern Kos looking eastward, with the outline of the Kos detachment. Locations I and III described and discussed in the text are indicated at their field positon. Pictures and drawings in Figure 4 are located at Location I. (**c**) Schematic geological cross-section PP‴, partly modified after Böger *et al.* (1974). For location of cross section see Figure 3a.

Kos exposes Permo-Carboniferous sedimentary rocks which were intruded and metamorphosed at shallow crustal levels by the Kos monzonite around 12 Ma (Altherr *et al.* 1976; Kalt *et al.* 1998). A brittle fault zone separates these rocks from isolated occurrences of upper Mesozoic and lower Cenozoic carbonate units and Palaeogene wildflysch with olistoliths (Desio 1931; Altherr *et al.* 1976, 1982; Gralla 1982; Henjes-Kunst *et al.* 1988; Kalt *et al.* 1998; Papanikolaou & Nomikou 1998; Fig. 3). In this paper we present new information concerning the nature of the contact between the Kos monzonite and surrounding contact-metamorphosed Permo-Carboniferous series, and the overlying upper Mesozoic to Palaeogene carbonates with Palaeogene flysch and discuss these results in light of the kinematic evolution of the Menderes metamorphic core complex and the postulated existence of a southern breakaway fault.

Geological setting

Menderes metamorphic core complex

The Menderes region of western Turkey (Fig. 2) exposes a large-scale complex of Pan-African basement and Palaeozoic to Cenozoic metasedimentary and igneous rocks (Schuiling 1962; Bozkurt & Park 1994, 1999; Hetzel *et al.* 1998; Bozkurt & Oberhänsli 2001; Glodny & Hetzel 2007). It exposes metamorphosed parts of the northern Tauride–Anatolide block that underthrusted below the Izmir–Ankara suture zone during Palaeogene African–Eurasian convergence (Şengör & Yılmaz 1981; Jolivet *et al.* 2004). The protolith of the Menderes basement terrain formed lateral palinspastic units to those of the neighboring Cyclades in central Greece, which share a history of late Palaeozoic to Palaeogene sedimentation and Palaeogene underthrusting and metamorphism (Ring *et al.* 1999; Bozkurt & Oberhänsli 2001; Jolivet *et al.* 2004). To the south, the Menderes Massif is overlain by the Lycian nappes, the northern part of which underwent a HP/LT metamorphic history (Rimmelé *et al.* 2003, 2005). The Lycian nappes consist of thrust sheets of Permo-Triassic clastic sediments and Mesozoic to Palaeogene carbonates and flysch, overthrusted by an ophiolitic mélange and serpentinised peridotites (Bernoulli *et al.* 1974; Okay 1989; Collins & Robertson 1997). Within the Menderes metamorphic core complex, Neogene postorogenic extension was accommodated along several extensional detachments both with top-to-the-north (Hetzel *et al.* 1995*a*; Ring *et al.* 1999*a*; Bozkurt & Sözbilir 2004; Isik *et al.* 2004) and top-to-the-south sense of shear (Bozkurt & Park 1994; Hetzel *et al.* 1995*b*; Bozkurt 2001, 2004, 2007; Gessner *et al.* 2001; Lips *et al.* 2001), which led Hetzel *et al.* (1995*a*) and Gessner *et al.* (2001) to propose bivergent extension of equal importance in the exhumation history of the Menderes region. Low-temperature geochronology has shown that cooling of the metamorphic rocks, attributed to exhumation along the extensional detachments, continued until approximately 8–5 Ma (Gessner *et al.* 2001; Ring *et al.* 2003).

A top-to-the-north break-away fault to the Menderes-Lycian nappes detachment system formed by the Datça–Kahle fault, such as that postulated by Seyitoğlu *et al.* (2004) would however imply that the early Neogene stages of exhumation for the Menderes-Lycian nappes system were accommodated along a dominantly top-to-the-north extensional detachment system.

Geology of Kos

The eastern Greek island of Kos is located only about 15 km NW of the Datça fault (Fig. 2), and *c.*15 km SW of the Bodrum peninsula, where the southernmost HP/LT metamorphic parageneses are found in the Lycian nappes (Rimmelé *et al.* 2003; Fig. 2). It has thus a position in the region where a brittle detachment fault has been postulated by Seyitoğlu *et al.* (2004). In southeastern Kos, the Dikeos window exposes Permo-Carboniferous anchimetamorphic sediments which were folded and then intruded and contact-metamorphosed by the Kos monzonite around 12 Ma (Altherr *et al.* 1976; Gralla 1982; Kalt *et al.* 1998). These are separated by a brittle fault zone from upper Mesozoic and lower Cenozoic carbonate units and Palaeogene wildflysch with olistoliths (Desio 1931; Altherr *et al.* 1976, 1982; Gralla 1982; Henjes-Kunst *et al.* 1988; Kalt *et al.* 1998; Papanikolaou & Nomikou 1998; Fig. 3). The age of folding of the Permo-Carboniferous rocks of Kos cannot be constrained better than between their deposition and the intrusion of the Kos Monzonite, but is likely related to the Alpine folding and thrusting history. Upper Mesozoic recrystallized limestones also occur on the Kefalos peninsula of western Kos (Papanikolaou & Nomikou 1998). The age and lithology of the Kefalos limestones suggest they are correlatable with the limestones overlying the Dikeos window, although the recrystallized nature of the Kefalos limestones led Papanikolaou & Nomikou (1998) to suggest that they may share a burial history with the Dikeos Permo-Carboniferous rocks. Kalt *et al.* (1998) provided Palaeobarometry estimates for the Kos monzonite and surrounding contact-metamorphosed Permo-Carboniferous sediments. Al-in-hornblende barometry yielded pressures of 3.1–5.1 kbar, but Kalt *et al.* (1998) indicated that this is likely an overestimation and render pressure estimates obtained from mineral parageneses in the contact metamorphic aureole of 1.5–2.5 kbar more reliable. The very low metamorphic grade of the Permo-Carboniferous sediments outside the contact metamorphic aureole (Altherr *et al.* 1976; Gralla 1982; Kalt *et al.* 1998) indicate that the Kos monzonite intruded close to or during peak-burial conditions of the Permo-Carboniferous metapelites, corresponding to *c.*1.5–2.5 kbar, or *c.* 5–7.5 km of depth. The anchimetamorphic sediments consist of carbonate, shale and sandstone with sedimentary ages ranging from Ordovician to Permian (Desio 1931; Altherr *et al.* 1976). The clear contact metamorphic aureole in the Permo-Carboniferous rocks is absent in the overlying carbonate succession (Altherr *et al.* 1976; Kalt *et al.* 1998). Altherr *et al.* (1976) therefore suggested that the contact between the Kos monzonite and the upper Mesozoic and Palaeogene carbonates postdates intrusion and cooling of the monzonite and these authors interpreted this contact as a thrust fault. Fission track cooling ages suggest cooling of the monzonite below *c.* 100 °C around 7 Ma (Altherr *et al.* 1982). To date, no structural information has been available for this contact fault zone.

The Neogene sedimentary cover of Kos consists of lower Miocene molassic sediments on western Kos unconformably overlying the Mesozoic carbonates (Papanikolaou & Nomikou 1998), and north of the Dikeos window ranges from middle Miocene to Pleistocene shallow marine to terrestrial deposits (Böger *et al.* 1974; Altherr *et al.* 1976; Willmann 1983). It dips southward as a result of north-dipping normal faults that separate the sediments from the pre- Neogene basement (Böger *et al.* 1974; Fig. 3).

Contact between the Dikeos Permo-Carboniferous and Cretaceous rocks

The contact between the footwall (contact-metamorphosed Permo-Carboniferous clastic sediments and the Kos monzonite) and the hanging wall (non-metamorphosed upper Mesozoic and Palaeogene carbonates and Palaeogene flysch) is exposed in three areas along the northern side of the Dikeos window (Fig. 3). In one of these outcrops clear kinematic criteria have been obtained (location I) at the contact between the contact-metamorphosed Permo-Carboniferous sequence and the non-metamorphic upper Mesozoic and Palaeogene carbonate unit. At location II, near Paleo Pili, the upper Mesozoic and Palaeogene carbonates overlie the Kos monzonite with a brittle fault zone as contact, from which we have not obtained conclusive kinematic criteria. In the east (location III) the Permo-Carboniferous is overlain by the Palaeogene flysch, which forms a chaotic fault zone. In all three cases, the contact is of tectonic origin. The footwall is dome-shaped, and the contact fault zone is dipping northwesterly in the west, and northeasterly in the east (Fig. 3). Upper Mesozoic and Palaeogene carbonates are not laterally continuous, and appear as isolated klippen on

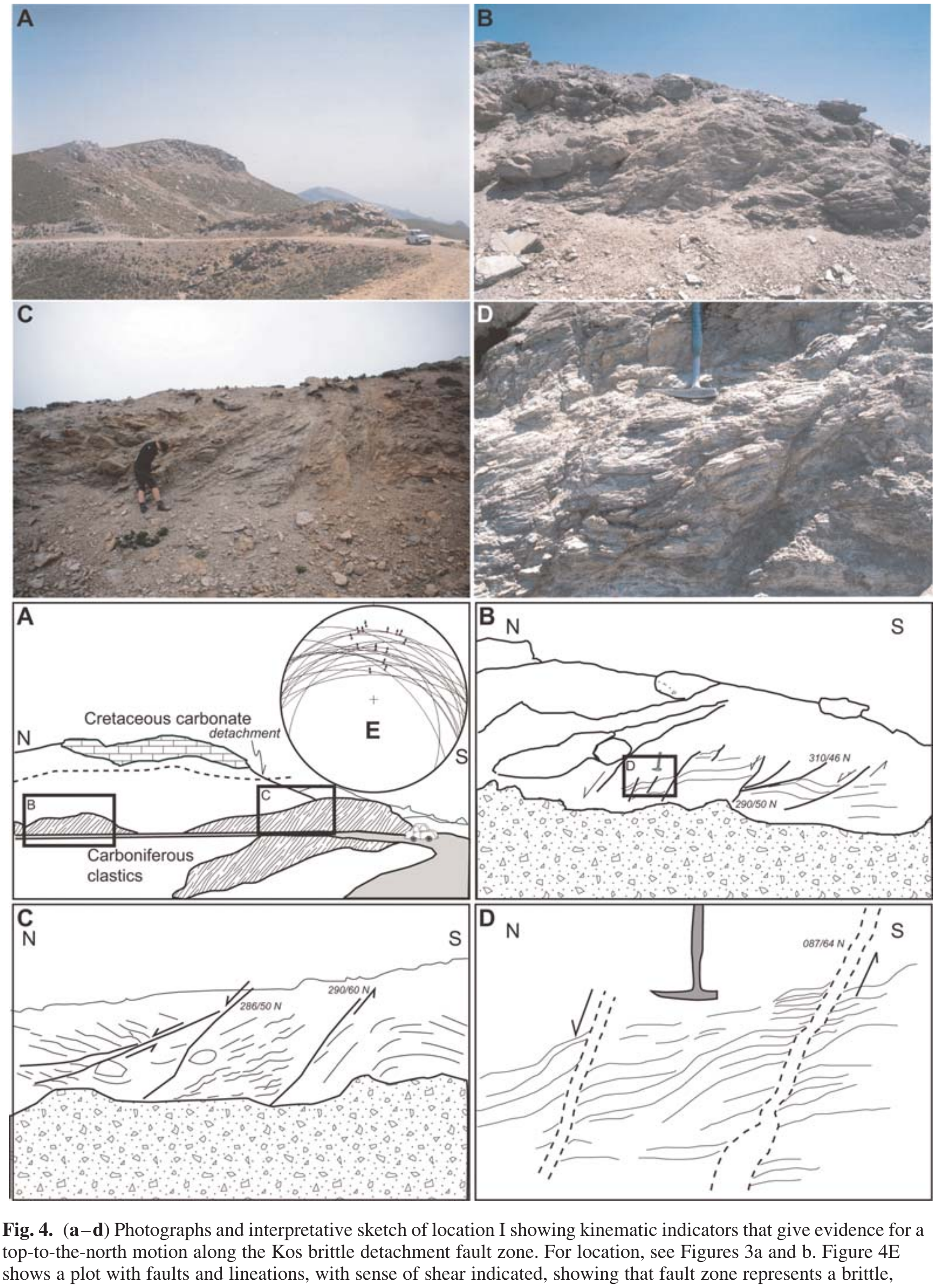

Fig. 4. (**a**–**d**) Photographs and interpretative sketch of location I showing kinematic indicators that give evidence for a top-to-the-north motion along the Kos brittle detachment fault zone. For location, see Figures 3a and b. Figure 4E shows a plot with faults and lineations, with sense of shear indicated, showing that fault zone represents a brittle, top-to-the-north extensional detachment fault. The overall SE dipping main foliation is deflected and deformed by the top-to-the-north normal fault zones that form the detachment. This fault exhumed the Permo-Carboniferous succession and the Kos monzonite from underneath upper Mesozoic and Palaeogene successions and overlying middle Miocene and younger basin sediments since 12 Ma (see text for further details).

top of the Permo-Carboniferous series and the Kos monzonite (Fig. 3). They are heavily brecciated but do not contain clear individual shear zones.

Location I

Location I exposes the contact between the upper Mesozoic and Palaeogene carbonates and the Permo-Carboniferous rocks over a north–south distance of *c*. 200 m (Fig. 4a). The Permo-Carboniferous sequence consists of anchimetamorphic phyllites and quartzites, and minor carbonates. The dominant structure is a foliation which is here southeasterly dipping. The foliation is well developed in phyllitic parts, whereas the quartzites are boudinages within the foliation plane. Some of these boudins show isoclinally folded thin-bedded quartzites and quartz-veins, which provide clear evidence for at least two phases of tight to isoclinal folding (Fig. 5). The fold-axial plane of F2 folds trends subparallel to the enveloping surface of the main foliation, which renders it likely that the latter is an axial plane cleavage.

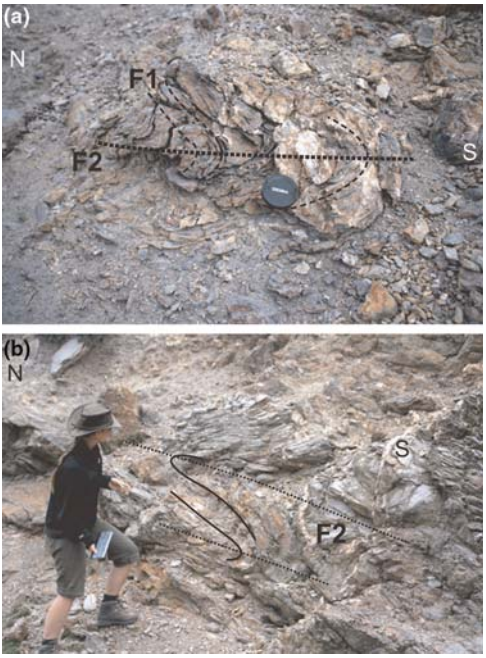

Fig. 5. (**a**) Field photograph at location I showing intensely folded Permo-Carboniferous sandstones, in a boudin within the detachment zone. At least two tight folding phases affected the Permo-Carboniferous rocks in the Dikeos window. (**b**) Tight F2 folds in the Permo-Carboniferous sandstones of location I. Note that the F2 fold axial trace trends subparallel, dipping SE, to the enveloping surface of the main foliation in the outcrops of Fig. 4b and c.

The Permo-Carboniferous series here is cross-cut by brittle to semi-brittle north-dipping fault zones, which deflect the foliation to northerly dips (Fig. 4b–d). Slickenside lineations in these fault zones are consistently north-dipping (Fig. 4e) and the asymmetric tectonic fabric formed by beds that are dragged along north-dipping faults. The fabric in tandem with the consistenly north-dipping lineations on the *c*. east–west trending fault surfaces between the north-dipping faults indicates dip-slip, top-to-the-north motion along the fault zone between the Permo-Carboniferous series and the upper Mesozoic and Palaeogene carbonates (Fig. 4). In the next section, we will combine this with the available information on the metamorphic, geochronologic and stratigraphic information to determine the extensional or contractional origin of this fault zone.

Location II

The contact between the Kos monzonite and the upper Mesozoic and Palaeogene carbonates at location I near Paleo Pili is a brittle fault zone of typically 100 m wide, which is developed as north dipping gouge zones in the monzonite (Fig. 6). The deformation zone is several tens of metres thick, below which the monzonite and xenoliths of the Permo-Carboniferous series, here metamorphosed into muscovite-biotite bearing schists is undeformed. The fault zone consists of anastomosing cataclastic zones of typically up to several tens of centimetres wide. These zones are strictly brittle in nature, clearly evidenced by fragmented K-feldspar crystals which are abundant in the monzonite. The cataclasites are furthermore characterized by small dark brown anastomosing bands of typically several millimetres thick consisting of very fine grained fault gouge. We did not observe any slickenside lineations within these cataclastic zones and absence of markers within the monzonite hampers determination of a sense of shear along this fault zone. The cataclasites are generally east–west striking, with highly variable dips varying from shallow northerly dipping to subvertical. The overall enveloping surface determined by the contact between the monzonite and the upper Mesozoic and Palaeogene carbonates can be clearly determined by the 3D exposure in the valley of Paleo Pili and strikes east–west, with a *c*. 40° northerly dip.

Location III

The contact in the east at location II, between the flysch and the Permo-Carboniferous series (Fig. 4) is a mélange of brittly deformed rocks of hundreds of metres thick, dipping at approximately 40° to

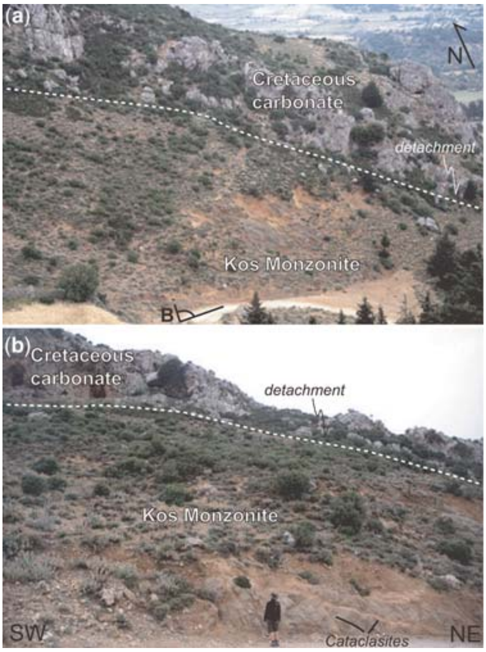

Fig. 6. (**a**) Exposure of the contact between the Kos monzonite and the overlying, non-metamorphosed Cretaceous carbonates at location II, near Paleo Pili. The contact is an anastomosing brittle fault zone developed within the Kos monzonite. This zone is approximately 100 metres thick, below which the monzonite is undeformed. (**b**) Detail of Fig. 6a. Note the cataclastic zones in the monzonite, which are typically *c*. 20 cm wide, and anastomose with an overall enveloping surface with an east–west strike and a *c*. 40° northward dip. Lineations within the cataclastic zones are absent and kinematic indicators are lacking. In conjunction with location I (see Fig. 4), as well as the fact that the Cretaceous carbonates are unconformably overlain in the west of the island by lower Miocene sediments (Papanikolaou & Nomikou 1998), i.e. the same age as the Kos monzonite, we argue that this fault zone accommodated the exhumation of the Kos monzonite and can be regarded as a brittle detachment fault cutting away a vertical crustal section of 5–7.5 km (see text for further explanation).

the NE. The chaotic character of hanging wall and footwall prevails determining a conclusive sense of shear. The flysch is much more deformed than the underlying Permo-Carboniferous unit, although part of this deformation may be the result of a nappe stacking episode and soft-sediment deformation.

Discussion

Six issues are essential in determining the extensional or contractional nature of the fault zone between the non-metamorphosed upper Mesozoic and Palaeogene carbonates and the Kos monzonite and surrounding contact-metamorphosed Permo-Carboniferous series: (1) The hanging wall of the fault zone juxtaposes younger over older; and (2) non-metamorphosed over metamorphosed rocks. (3) The kinematic criteria obtained from location I shows a top-to-the-north normal fault motion, with a comparable shear sense and strike as the basin faults that bound and deform the Neogene stratigraphy (Böger *et al.* 1974). Moreover, (4) the middle Miocene to Pliocene stratigraphy on Kos was deposited during and after intrusion, exhumation and cooling of the Kos monzonite between 12 and 7 Ma (Böger *et al.* 1974; Altherr *et al.* 1976; Willmann 1983), unconformably overlying upper Mesozoic to Palaeogene carbonates on western Kos (Papanikolaou & Nomikou 1998). This, in combination with (5) the pressure conditions of 1.5 to 2.5 kbar during the intrusion of the Kos monzonite (Kalt *et al.* 1998), shows that approximately 5 to 7.5 km of exhumation of the Dikeos window with respect to the sedimentary basins occurred since 12 Ma. Based on these facts we argue that the contact studied in this paper represents a top-to-the-north fault zone that exhumed the Kos monzonite and Permo-Carboniferous series from underneath the upper Mesozoic and Palaeogene series and overlying lower Miocene and younger sedimentary basins. The previously proposed thrust-nature of this contact (Altherr *et al.* 1976) is an unlikely scenario, not in the last part since (6), thrusting of the upper Mesozoic carbonates would require that they formed a coherent block during emplacement, unlike their present-day fragmented nature as isolated klippen on the Dikeos window. It would not be logical to fragment the hanging wall during sediment acquisition on top of it in the Neogene basin. More likely, these isolated blocks form extensional klippen comparable to those observed in the middle to upper Miocene Cretan supradetachment basin (van Hinsbergen & Meulenkamp 2006). This combination of facts strongly supports an extensional nature for the fault zone.

We therefore argue that this fault zone represents a brittle extensional detachment fault that accommodated *c*. 5–7.5 km of exhumation since 12 Ma. Moreover, since the crystallization depth of the Kos monzonite likely corresponds to the maximum burial depth of the surrounding anchimetamorphic Permo-Carboniferous rocks (Kalt *et al.* 1998), any pre-12 Ma extension and basin formation that may have affected Kos (Böger *et al.* 1974; Papanikolaou & Nomikou 1998) did not lead to significant exhumation of the footwall to the Kos detachment.

Placing this interpretation into the regional geological context requires correlation of the pre-Alpine rocks of the Dikeos window to those of the Kefalos peninsula, and the pre-Alpine rocks of Kos to the nappes of Greece and western Turkey, which is not straightforward. The recrystallized limestones of late Cretaceous age on the Kefalos peninsula are unconformably overlain by lower Miocene molassic sediments with olistoliths (Papanikolaou & Nomikou 1998). The recrystallized nature of the limestones led Papanikolaou & Nomikou (1998) to suggest that they may share a burial history with the Dikeos Permo-Carboniferous rocks.

However, the lower Miocene unconformable cover of the Kefalos carbonates shows that the Kefalos Cretaceous carbonates have been near the surface throughout the intrusion and exhumation history of the Kos monzonite, and it supports correlation to the Mesozoic rocks in the hanging wall of the Kos detachment. Two models can be postulated to place the pre-Alpine rocks of Kos in their regional tectonostratigraphic context. The main difficulty in correlation is the old age of the Kos Permo-Carboniferous rocks, which is not known from elsewhere in the Aegean or western Anatolian region (Papanikolaou & Nomikou 1998).

Based on lithology, age and tectonostratigraphic context, they may correspond to either the tectonostratigraphically lowest central Aegean nappe formed by the Tripolitza unit, the Basal Unit and the Phyllite Quartzite, or to the structurally highest Lycian nappes. Blondeau *et al.* (1975) and Papanikolaou & Nomikou (1998) correlated the Mesozoic to Palaeogene carbonates of Kos to the Tripolitza and Pindos nappes of western Greece based on age and sedimentary facies. If this suggestion is correct, the Permo-Carboniferous of Kos could correlate to the HP/LT metamorphic Phyllite Quartzite unit exposed on Crete. Alternatively, the pre-Neogene rocks of Kos may belong to the Lycian nappes, which on nearby Turkish peninsulas expose Permo-Triassic clastic sediments and Mesozoic–Palaeogene carbonates and flysch (Bernoulli *et al.* 1974; Collins & Robertson, 1997). We advocate the latter correlation based on their non- to anchimetamorphic character and their position amidst rocks belonging to the Lycian nappes with comparable age and facies exposed on the Turkish peninsulas north and south of Kos.

The intrusion of the Kos monzonite and associated contact metamorphism provide a unique opportunity to show that in the south of the metamorphic rocks of the Menderes metamorphic core complex, top-to-the-north extensional detachment faulting has been active. This suggests that Kos has been a focused deformation site within the Cyclades–Menderes extensional province since 12 Ma. The top-to-the-north component of shear of the brittle Kos detachment is in line with the scenario of Seyitoğlu *et al.* (2004), which postulates that the Datça fault south of Kos is the Oligocene–lower Miocene break-away fault of the core complex. However, the thermodynamic reconstruction of Kalt *et al.* (1998) shows that the Kos monzonite intruded the Permo-Carboniferous series close to peak burial conditions, indicating that no significant exhumation occurred on Kos prior to 12 Ma. Seyitoğlu *et al.* (2004) suggested that the Datça breakaway fault was active during Oligocene to early Miocene times. This can only be valid if the rocks on Kos belong to the hanging wall of the Oligocene–early Miocene detachment system inferred by Seyitoğlu *et al.* (2004). We cannot corroborate the existence of a Oligocene–early Miocene brittle detachment on Kos and this makes the scenario of Seyitoğlu *et al.* (2004) unlikely. Moreover, seismic profiles of Kurt *et al.* (1999) and Ulug *et al.* (2005) cannot corroborate any on-land continuation of this fault zone and these authors instead suggested a much younger, late Miocene or Pliocene age of the Datça Fault. The existence of a brittle detachment on Kos does show that brittle detachment faulting exhumed upper crustal rocks from mid upper crustal depths south of the Menderes and eastern Cycladic metamorphic core complexes, but the Kos detachment appears to be a relatively isolated structure. Our new data indicate that there is no evidence that the Datca fault forms part of a southerly Oligocene to lower Miocene break-away fault of the Menderes core complex as suggested by Seyitoğlu *et al.* (2004). This renders the bivergent rolling-hinge scenario of Gessner *et al*. (2001) as a better fitting solution for the kinematic evolution of the Menderes core complex.

Conclusions

The Menderes metamorphic core complex western Turkey is clearly defined in the north by extensional detachments along which a sharp metamorphic contrast exists between hanging wall and footwall. The southern limit of the core complex is less well defined. An Oligocene–early Miocene breakaway fault has previously been postulated in the Lycian nappes in southwestern Turkey. Showing the existence of a breakaway detachment fault is difficult due to absence of a metamorphic contrast along the fault for those parts where only upper crustal rocks are exhumed. The island of Kos, just north of the inferred breakaway fault, exposes Permo-Carboniferous anchimetamorphic rocks, intruded and contact-metamorphosed by a 12 Ma old monzonite. Here, we show that exhumation of these rocks was accommodated along a top-to-the-north brittle extensional detachment emplacing them underneath non-metamorphosed upper Mesozoic to Palaeogene carbonates and Neogene basin sediments.

Previously published petrological constraints on the burial history of the Permo-Carboniferous series of Kos has shown that the Kos monzonite intruded close to peak-burial conditions, showing that any pre-12 Ma extension and basin formation on Kos has not led to any detectable exhumation of the Permo-Carboniferous series. We conclude that the island of Kos should be placed within the Cyclades–Menderes extensional province. However, the age of exhumation is younger than the proposed activity of the breakaway of the Menderes metamorphic core complex (Seyitoğlu *et al*. 2004), and the bivergent rolling-hinge scenario of Gessner *et al*. (2001) remains a better fitting solution. We conclude that the brittle detachment of Kos cannot be straightforwardly correlated to any ductile-to-brittle detachments of the Menderes or eastern Cycladic metamorphic core complexes further to the north and may represent a relatively isolated structure.

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