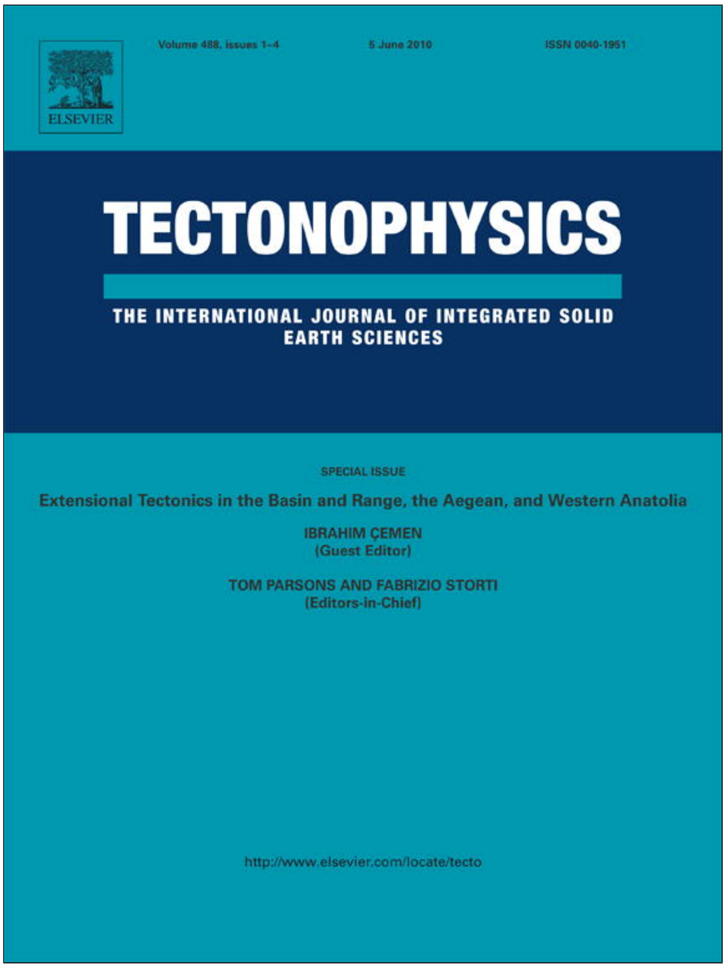
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# Strain development and kinematic significance of the Alpine folding on Andros (western Cyclades, Greece)

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ABSTRACT

The general trend of both fold axes and stretching lineation in the Cycladic Blueschist Unit is NE–SW to NNE–SSW. This orientation forms a large angle (almost perpendicular) with respect to the Hellenic trend that is inferred from the main thrusts on mainland Greece. Thus, the kinematic significance of the stretching parallel folding in the Cycladic Blueschist Unit is non-trivial. Since within the western Cyclades, the NE-trending folds are best exposed on the island of Andros, it is a key locality for understanding the timing, style and kinematic significance of folding. Here we show that the NE-trending folds on Andros formed within the stability field of glaucophane, after the peak high-pressure metamorphism and simultaneously with the early stage of retrogression. The axes-parallel stretching was non-rotational; it started during the NE folding at blueschist-facies conditions, and continued long afterward and well into the retrograde greenschist overprint. Furthermore, we present the result of a finite strain calculation which shows that the large NE folds could not have been reoriented at ~90° as previously thought. Instead it is suggested that these folds formed under constrictional strain regime during regional NE–SW extension, and represent coeval transverse NW–SE shortening and vertical thinning. This implies that NE extension and southwest directed rollback of the active margin prevailed in the western Aegean between the Eocene and early Miocene.



## 1. Introduction

The Cycladic Blueschist Unit (CBU), exposed at the center of the Aegean Sea (Fig. 1), was metamorphosed at high-pressure conditions during Alpine orogenesis in Eocene times (Altherr et al., 1979; Wijbrans et al., 1990; Bröcker et al., 1993; Tomaschek et al., 2003; Putlitz et al., 2005; Bröcker and Franz, 2006). Structures in the CBU, both fold axes and mineral lineations, most commonly trend NE–SW to NNE–SSW (Papanikolaou, 1978; Blake et al., 1981; Rodgers, 1984). This trend is almost perpendicular to the general structural trend of the Hellenides on mainland Greece, which is parallel to the present Hellenic trench (Le Pichon and Angelier, 1979; Papanikolaou, 1987). The kinematic significance of the fold orientation and the parallelism between fold axes and mineral lineation in the Cyclades are a long standing question. Blake et al. (1981) interpreted the NE–SW trending folds in the Cyclades as recording Eocene deformation between NW–SE converging blocks, decoupled from convergence in the Hellenides (Fig. 1). In contrast, Rodgers (1984) suggested that the present direction of the fold axes has been attained through regional reorientation of folds that were originally oriented parallel to the 'Hellenic trend', and that both lineation and fold axes represent the direction of tectonic transport.

Folds with axes parallel to the maximum stretching direction were reported in several other orogenic belts (Ridley, 1986; Ellis and Watkinson, 1987; Malavielle, 1987; Dietrich, 1989; Kleinschrodt and Voll, 1994; Yang and Nielsen, 1995). Like in the Cyclades, the formation and kinematic significance of these folds are not completely clear. Several mechanisms were proposed to account for parallelism between folds and maximum stretching. Under simple-shear strain linear structures such as fold axes and mineral lineations rotate towards the direction of maximum stretching (Ramsey, 1967, 1980; Escher and Watterson, 1974; Bell, 1978). Such rotation can bring folds and lineation into approximate parallelism and may account for the large angle between these structures and the orogenic trend (Escher and Watterson, 1974). Passive amplification of deflected planes in high simple-shear strain may develop sheath folds with axes parallel to stretching direction (Cobbold and Quinquis, 1980). Since the rate of fold growth is proportional to fold initial amplitude (Biot, 1961), passive amplification of non-cylindrical folds (i.e. fold amplitude varies along strike) under pure-shear strain may also result in extension parallel to fold axes (Dietrich, 1989). Thus under pure-shear strain, parallelism between folds and maximum stretching is attained through reworking of existing structures. Folds parallel to maximum stretching may also develop from an undeformed rock. Differential displacement rates within a shear zone may result in sub-parallelism between fold axes and stretching lineations at the frontal and lateral tips of a shear zone (Coward and Potts, 1983; Ridley, 1986).

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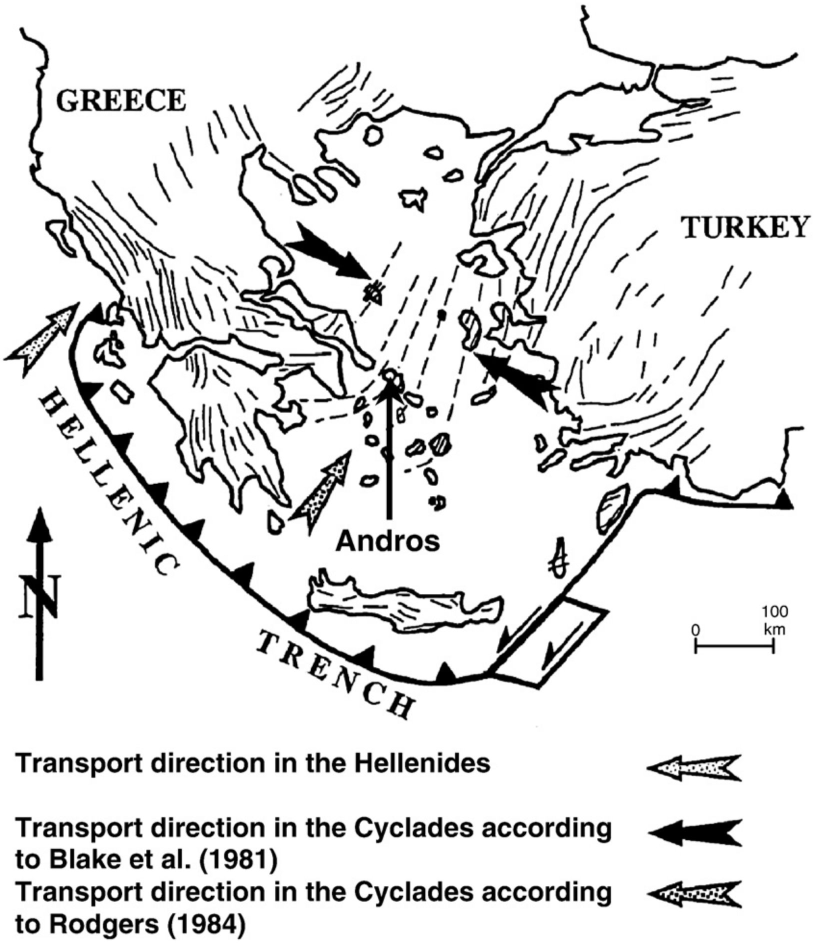


**Fig. 1.** Map showing the main structural lineaments in the Aegean Sea and the surroundings (after Jacobshagen, 1986). Also shown are the transport directions proposed by Blake et al. (1981) and Rodgers (1984), and the Hellenic transport direction as is inferred by the trend of the main thrusts on mainland Greece. The location of Andros is indicated.

Folds may nucleate parallel to the direction of maximum stretching in coaxial strain regime, either under plane strain with the intermediate principle strain perpendicular to layering (Watkinson, 1975), or under pure constriction with maximum stretching parallel to layering (Kobberger and Zulauf, 1995).

Based on a quantitative finite strain analysis and a petrographic study on Andros (western Cyclades; Figs. 1 and 2), where NE-trending megafolds are best exposed, we show here that the large NE-trending folds could not have been reoriented at ~90°. Instead we argue that these folds formed during regional NE–SW extension, and represent coeval transverse NW–SE shortening and vertical thinning. Extension-parallel folds have been shown to develop in a similar fashion during and after Early Miocene high-temperature metamorphism in the central Cyclades (Naxos and Paros; Avigad et al., 2001). Our observations on Andros, however, show that glaucophane bearing assemblages were stable during extension-parallel folding. This suggests new constraints on the timing of folding and the initiation of NE extension in the western Cyclades.

## 2. Geological setting

The Cycladic Massif is a poly-metamorphosed segment of the Alpine orogenic belt of the Hellenides (Fig. 1). The Cycladic Blueschist Unit (CBU; Lower Unit), the dominant tectonic unit of the Massif, underwent regional eclogite- and blueschist-facies metamorphism during the Eocene (M1). It was overprinted by greenschist (western Cyclades) and amphibolite (Naxos and Paros)-facies assemblages during exhumation at the early Miocene (M2) (Wijbrans et al., 1990; Keay et al., 2001; Putlitz et al., 2005). This paper focuses on the system of NE-trending folds that characterizes the CBU throughout the western Cyclades. Since within the western Cyclades, the NE-trending folds are best exposed on the island of Andros (Fig. 2), it is a key locality for understanding the timing, style and kinematic significance of folding.

Since the CBU on Andros mostly consists of pervasively overprinted greenschist-facies sequences, *P*–*T* conditions during M1 metamorphism on Andros are not well constrained. Nevertheless, within the Lower Unit of Andros blueschist-facies relicts are locally preserved including glaucophane–epidote–garnet assemblages and jadeite-rich clinopyroxene (Reinecke, 1986; Dekkers et al. unpub. data; Buzaglo-Yoresh et al., 1995). Pressure–temperature conditions for peak M1 metamorphism on Andros were estimated as ≥10 kbar and 450–500 °C based on epidote blueschist-facies assemblages in ferromanganoan metasediments (Reinecke, 1986) and metabasites (Buzaglo-Yoresh et al., 1995). Dekkers et al. (unpublished) devised, however, a *P*–*T* path for the CBU on Andros that included an initial eclogite-facies stage at ~11–13 kbar and 450–500 °C followed by equilibration at lower pressures and temperatures in the epidote blueschist-facies field. Best *P*–*T* estimates for the greenschist-facies overprint are 350–450 °C at 5–6 kbar (Reinecke, 1982; Bröcker and Franz, 2006). Rb–Sr phengite ages of the CBU rocks on Andros are well within the age range determined elsewhere in the Cyclades: 45 Ma for high-pressure rocks (M1) and 23–21 Ma for their greenschist-facies derivatives (Bröcker and Franz, 2006).

Extensional tectonics overprinted the Alpine orogen in the Cyclades since the early Miocene (Avigad et al., 1997). Extension in the Aegean is considered post-orogenic as indicated by 23–16 Ma cooling ages of ductile-extended metamorphic rocks throughout the

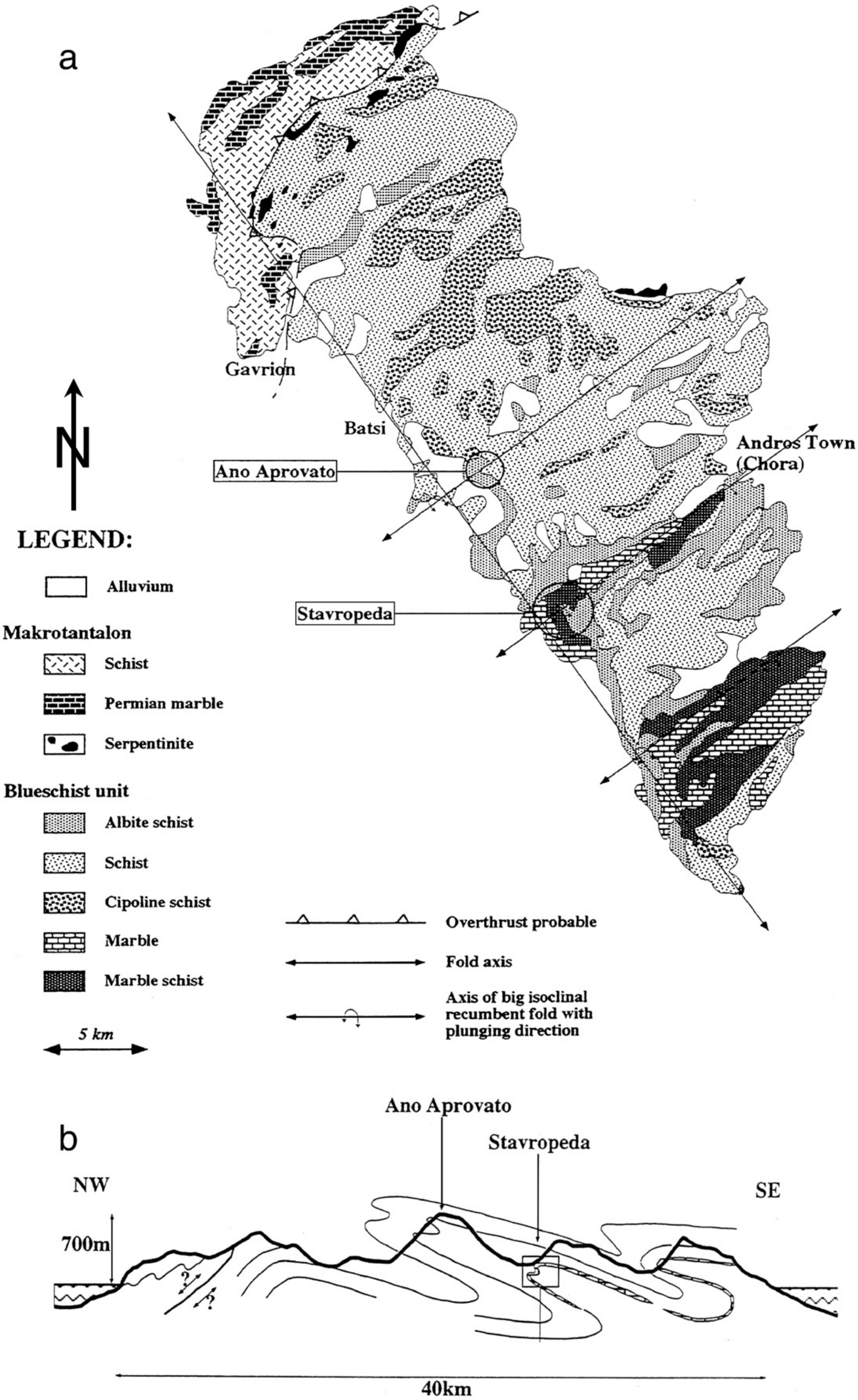


**Fig. 2.** a. Geological map of Andros (after Papanikolaou, 1978). b. Schematic cross section of Andros (after Papanikolaou, 1978). Note that Ano Aprovato and Stavropeda are located in the axial zone of Andros' largest recumbent fold.

Cyclades and by the age of sedimentation in extensional basins in the region (Jolivet and Patriat, 1999; Jolivet and Faccenna, 2000). Several islands in the Cyclades have been described as metamorphic core complexes (Lister et al., 1984; Faure et al., 1991; Gautier and Brun, 1994). The Aegean core complexes, like their Cordilleran equivalents, include a normal-sense detachment that juxtaposed sedimentary and low-pressure metamorphic rocks ('Upper Units') on top of exhumed and overprinted rocks of the CBU. The earliest detachment was observed on Tinos, where both units were intruded by an 18 Ma granite (Avigad and Garfunkel, 1989).

A vertical tectono-stratigraphic section characteristic of the Aegean core complexes was also described on Andros. Papanikolaou (1978) identified two different units on the island: The CBU, which consists of a thick meta-sedimentary and -volcanic series, is overlain at the northernmost part of the island by the Makrotantalon Unit composed of meta-sedimentary sequence including fossiliferous marbles of Permian age (Fig. 2). Unlike the CBU, the Makrotantalon Unit was not affected by Eocene HP metamorphism, but both units yielded 23–21 Ma Rb–Sr phengite ages (Bröcker and Franz, 2006). Juxtaposition by normal-sense movement along the serpentinite-marked contact between the units should thus have been accomplished by 21 Ma. The detachment surface, best exposed along the NE coast of Andros, was studied in detail by Mehl et al. (2007) to clarify the transition from ductile to brittle deformation as deep rocks were being progressively exhumed towards the surface. These authors also described earlier ductile structures in well preserved and overprinted blueschists along the SW coast of Andros, away from the detachment, and concluded that folds and lineations formed by greenschist-facies deformation. Mehl et al. (2007, p.48) wrote: 'Because both the stretching lineations and the fold axes show a consistent NE–SW trend, it is difficult to ascertain the chronology of folding, stretching and shearing.' In the following section such chronology is established and convincing evidence for the evolution of folds and lineations at blueschist-facies conditions is given.

## 3. Deformation and re-crystallization in Andros blueschists

The entire stratigraphic column of the CBU on Andros is folded by a system of recumbent folds with a wavelength of about 10 km (Fig. 2b). Superimposed on these megafolds are parasitic folds of various wavelengths and amplitudes. Deformation–re-crystallization relations were thoroughly examined in two locations, near the village of Ano Aprovato and in Stavropeda (Fig. 2). In Ano Aprovato a blueschist-facies assemblage of glaucophane–epidote–garnet is well preserved, whereas in Stavropeda greenschist-facies assemblages are dominant. Both sites are located, however, along the axial plane of the same megafold (Fig. 2b), and the folding in both sites is equally intense.

The earliest fabric preserved on Andros is the penetrative layer-parallel schistosity, S1. In places, blue-amphiboles lineation, L1, is developed on S1 surfaces. The layer-parallel S1 schistosity is deformed by a system of NE-trending cylindrical folds, F2. Although folds earlier than the F2 set are quite scarce on Andros, interference patterns between F2 and an earlier F1 can be observed near Ano Aprovato (Fig. 3). Inspection of these interference patterns reveals that S1 is an axial plane cleavage of F1 sheath folds, and thus the formation of S1 and F1 is coeval (Fig. 3a). Some of the blue amphiboles are aligned parallel to F1 hinge line (Fig. 3c). Such parallelism between stretching and hinge lines is expected if the F1 sheath folds were formed during intense shear strain of older cylindrical fold axes with shear strain magnitude that varies along the pre-existing axes.

In addition to the L1 stretching lineation that is aligned parallel to the F1 hinge line and exhibits deformed lineation loci with respect to the F2 axes (Fig. 3c), two other stretching lineations can be observed. The second, L2, lineation consists of blue-amphibole needles aligned parallel to the cylindrical F2 axes. In places where greenschist overprint is strong (i.e., Stavropeda), a third, L3 lineation, is also

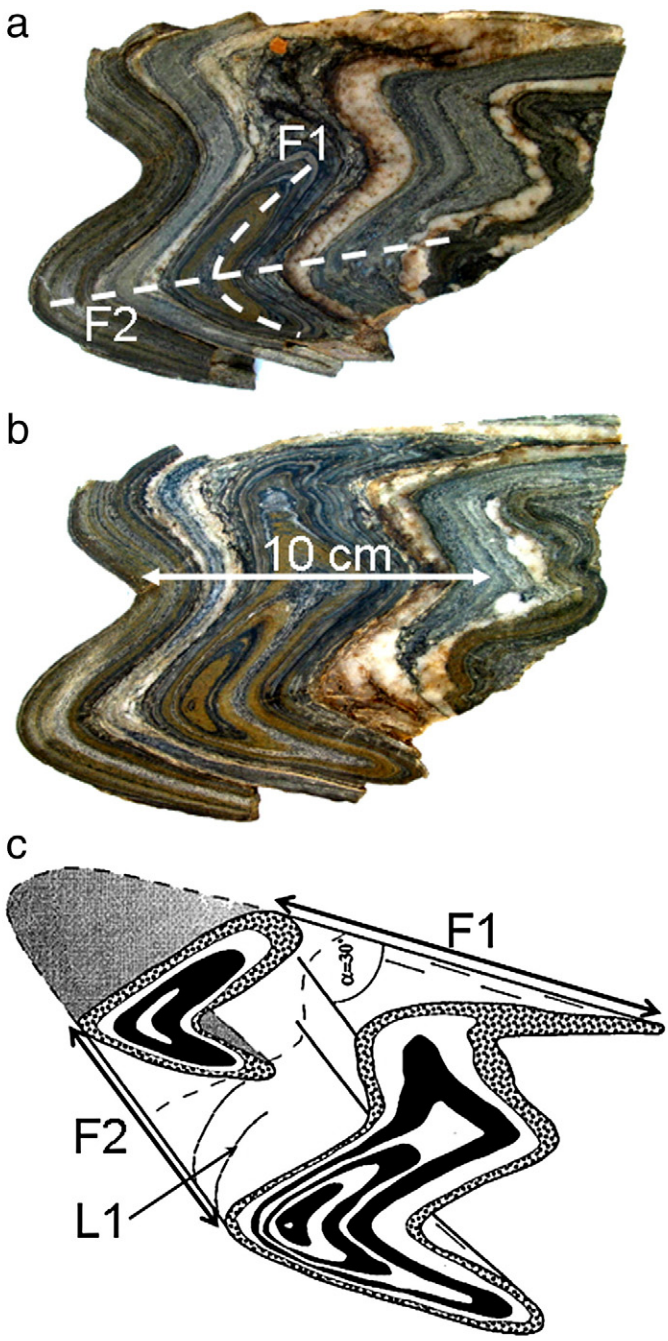


**Fig. 3.** Rock specimen sampled near the village of Ano Aprovato, containing an interference pattern between F2 and an earlier F1 sheath fold. a.–b. Photographs of either face of the rock specimen. c. Schematic sketch showing the 3D structure of the interference pattern. Note the deformed lineation loci of L1 with respect to the F2 axis.

present. The L3 lineation may either appear in the form of coaxially boudinaged L2 blue amphiboles, with albite and/or chlorite filling the inter-boudin gaps (Fig. 4d–e), or it may consist of stretched albite crystals, often containing small inclusions of L2 lineation (Fig. 4f). Note that the L2 boudins are not rotated, and that the albite long axes are aligned parallel to the L2 inclusions. Thus, the L3 lineation is of the same orientation as that of the L2 lineation.

Three generations of blue amphiboles can be recognized. Small idiomorphic blue-amphibole crystals that are axial-planar oriented with respect to F1 and are tightly folded by F2, belong to the first generation. The second generation consists of large blue-amphiboles crystals, zoned from faint blue (Mg-rich) cores to dark blue (Fe-rich) rims. Most of the crystals belonging to this generation are oriented

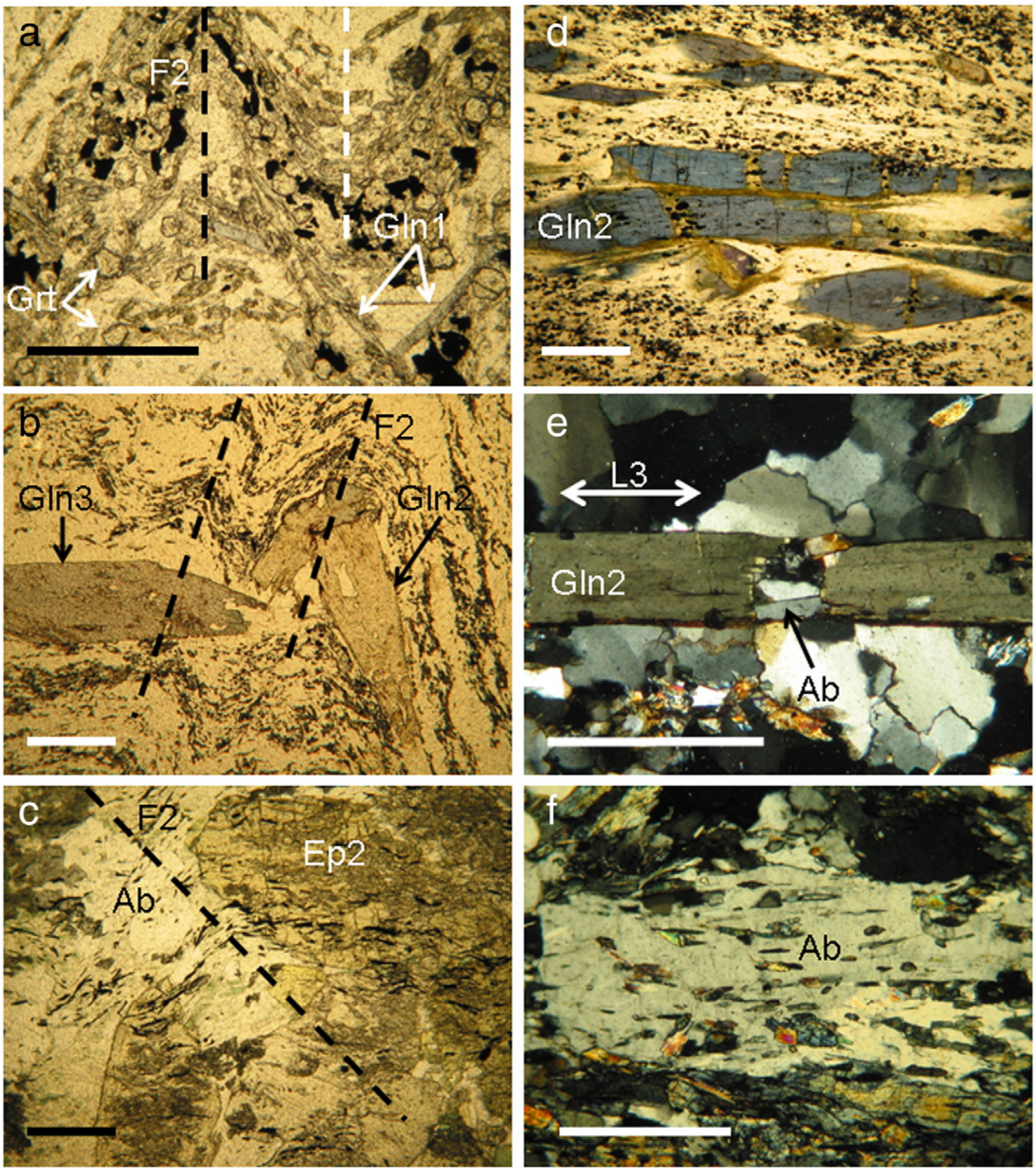


**Fig. 4.** Evolution and chronology of post-F1 folding, stretching and crystallization on Andros as observed in well preserved (Ano Aprovato) and strongly overprinted (Stavropeda) blueschists on Andros. The fold hinges exposed at both sites are within the axial zone of the same megafold (Figs. 1 and 2). Photomicrographs of axis-normal and axis-parallel thin section are shown on the left (a–c) and right (d–f) hand sides, respectively. a. Section perpendicular to F2 (blueschist, Ano Aprovato; PPL). Epidote and glaucophane are pre-kinematic with respect to F2. Epidote is ductilly folded, whereas glaucophane is fractured at fold hinges. Fine grained idiomorphic garnet also participates in folding. b. Section perpendicular to F2 (blueschist, Ano Aprovato; PPL). Fine grained epidote is tightly crenulated. Large crystals of blue amphibole are either slightly folded (Gln2) or undeformed (Gln3). c. Section perpendicular to F2 (greenschist, Stavropeda; PPL). Albite and epidote statically overgrow folded trails of inclusions of an earlier metamorphism. d. Section parallel to F2 (blueschist, Ano Aprovato; PPL). Glaucophane is boudinaged; gaps between boudins are filled with chlorite. Boudins are not rotated relative to each other. e. Section parallel to F2 (blueschist, Ano Aprovato; XPL). Boudinaged glaucophane with albite (twinned) filled gaps. f. Section parallel to F2 (greenschist, Stavropeda; XPL). Albite is stretched parallel to fold axis. Early lineation is preserved by trails of inclusions within the stretched albite, and is parallel to its long axis. For scaling we added 0.5 mm long horizontal bars at the bottom-left corner of each panel.

parallel to F2 axes (Fig. 4d–e), and some are slightly folded by the F2 axes, thus probably crystallized at a late stage of F2 (Fig. 4b on the right-hand side). Blue amphiboles belonging to the third generation are randomly oriented and are thus post-kinematic (Fig. 4b on the left-hand side). Two generations of epidote crystals were identified. The first appears in association with blue amphibole and garnet, and is tightly folded to crenulated (Fig. 4a–b). The second epidote generation appears in association with albite, and is clearly post-kinematic (Fig. 4c). Some epidote crystals of the second generation enclose folded inclusions, remnants of a previous metamorphic phase. Albite crystals are not deformed on sections normal to fold axes, and like the post-kinematic epidote, may enclose folded inclusions of a previous metamorphic stage (Fig. 4c).

The picture that emerges from these observations is that the dominant fabric i.e., the layer-parallel schistosity, was formed during the F1 folding. The F2 folding, on the other hand, did not cause much re-crystallization on the hinges. Both folding phases occurred within the stability field of glaucophane, but garnet crystallized only during F1. Thus F1 probably occurred closer to peak metamorphism and F2 was coeval with an early stage of retrogression. The NE stretching (both L2 and L3) was non-rotational. It started during the F2 folding, at blueschist-facies conditions, and ended during the retrograde greenschist overprint.

## 4. Quantitative implications of the reorientation model

We now present the result of a simple finite strain calculation that provides a lower bound on the amount of shear strain that is required in order to rotate fold axes, initially oriented perpendicular to the stretching lineation, into approximate parallelism with the direction of maximum stretching. Such material line rotation may either occur under pure-shear or under simple-shear strain, or under any combination of the two strain regimes. Since, however, the simple-shear strain is a more efficient mechanism than the pure-shear strain for material line rotations, and since we are interested in estimating the minimum amount of strain that would have been required had such reorientation occurred, below only the simple-shear mechanism is considered. In theory, the mapping of two non-parallel material lines into parallelism requires infinite amount of strain. In practice, however, since field measurements cannot discriminate an angular distance less than 5°, it is sensible to consider material lines as sub-parallel so long as their angular separation does not exceed 5°. The angular distance between two initially perpendicular lines as a function of the shear strain is shown in Fig. 5, for six representative pairs of lines separated by 15° in the pre-deformed state. Inspection of this plot shows that a minimum shear strain of about 4.5 is required in order to bring initially perpendicular lines, representing fold axes and stretching lineation, into a state of sub-parallelism. This corresponds to a shear angle of 77° and a maximum stretching of about 4.5.

## 5. Discussion

### 5.1. The shortcoming of the reorientation model

The NE-trending folds were formed after the first generation of glaucophane crystallization, but still at epidote-blueschist-facies conditions. The static growth of greenschist-facies assemblage on the hinges of the NE-trending folds indicates that if these folds were indeed reoriented, this reorientation must have occurred during the interval between late Eocene and early Miocene, during which much of the decompression of the high-pressure rocks occurred. The finite strain calculation shows, however, that a penetrative shear strain of more than 4.5 to 1 would have been required in order to rotate fold axes into approximate parallelism with stretching lineation. Although it is likely that high shear strains have operated in the Cyclades after the late Eocene (cooling age of M1), it seems that on Andros they did

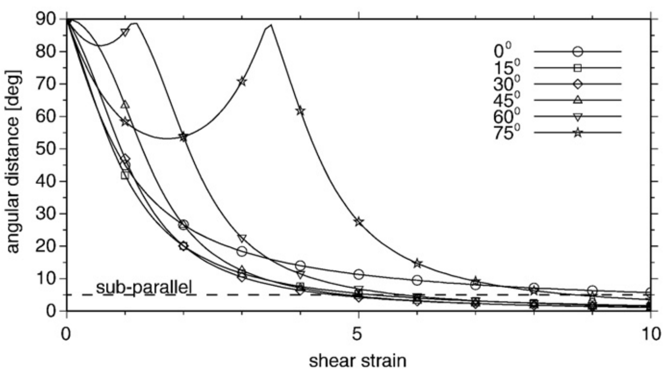


**Fig. 5.** Diagram showing the angular distance between two initially perpendicular lines as a function of shear strain, for six representative pairs of lines separated by 15° in the pre-deformed state. For reference we added a line indicating an angular distance of 5°. In practice, a pair of lines whose angular distance is less than 5° is considered as sub-parallel.

not penetrate the entire lithological section (see also Mehl et al., 2007). It is believed that penetrative ductile strain of the kind that is implied by the finite strain calculation should be accompanied by significant re-crystallization, and produces a new fabric that would erase or significantly overprint the previous fabric. Our observations, however, show that the formation of the NE-trending folds system did not cause much re-crystallization near the hinges. Thus, the lack of mylonite in association with the NE fold system is inconsistent with the reorientation concept.

### 5.2. Alternative model: simultaneous formation of fold axes and stretching lineation during pure constriction strain

The process of mountain building involves nappe emplacement and thrusting. Large simple shear is thus expected to be recorded in structures that formed during orogenesis. Although the NE-trending folds on Andros are asymmetric in a way that seems to indicate top-to-NW sense of shear, on a more regional scale, fold asymmetry varies. For example, while on Andros the fold vergence points to the NW (Papanikolaou, 1978), on Syros it points to an opposite direction (Ridley, 1982). Thus no systematic sense of shear may be inferred for the Cyclades (Papanikolaou, 1978). Apart from the fold asymmetry, the NE-trending folds do not show additional signs for high simple-shear strain. Furthermore, the megafolds on Andros are cylindrical on both outcrop and regional scales, whereas many field and experimental studies of non-coaxial deformation have shown non-cylindrical sheath folds to be the characteristic structure developed in shear zones (Rodes and Gayer, 1977; Cobbold and Quinquis, 1980; Henderson, 1981). It is thus concluded that significant simple shear was neither involved in the formation nor in the subsequent modification of these folds.

We suggest that a possible strain regime for the formation of the NE-trending folds is pure-shear constriction, i.e. $s_1 > s_2 = s_3$ (where $s$ signifies the principal stretching), with the long axis directed towards the NE. In addition to being consistent with our inference that no significant simple shear affected the formation of these folds, this model is also consistent with several other results: (1) Folds and axes-parallel stretching are coeval; (2) In addition to the horizontal shortening, this model includes an equal component of vertical shortening. Since the NE-trending folds were formed after peak metamorphism, during a de-compressive stage, such a vertical shortening is to be expected (see also Avigad et al., 2001); (3) Finally, it is expected that a planar preferred orientation be developed at right angle to the direction of maximum shortening, $s_3$. On Andros, however, such an axial-plane cleavage is not observed in association with the NE folds. This too is consistent with the idea that the strain ellipsoid during the folding did not posses a single minor axis, $s_3$, but instead $s_2 = s_3$.

### 5.3. Long lasting NE extension in the Cyclades

The island of Andros was interpreted as a metamorphic core complex, where a detachment fault juxtaposed low-pressure metamorphic 'Upper Unit' on top of exhumed and overprinted rocks of the CBU (Jolivet and Patriat, 1999; Mehl et al., 2007). Rb–Sr phengite ages on either side of the detachment on Andros (Bröcker and Franz, 2006) indicate that it operated during the greenschist-facies overprint at the early Miocene. The superposition of semi-brittle onto precursory ductile structures (Mehl et al., 2007) indicates that movement along the detachment continued well after the early Miocene. The asymmetry of boudins and sigmoidal shear bands within the footwall indicate top to the NE sense of shear during core-complex formation (Mehl et al., 2007). The major conclusion of this study is that NE extension within the western Cyclades started much earlier, at blueschist-facies conditions and simultaneously with the formation of the NE-trending folds. This suggests that NE extension prevailed in the CBU between Eocene and early Miocene. Nonetheless, while the axes-parallel extension during early exhumation, as recorded by the axes-parallel L2 and L3 stretching lineation, was of coaxial nature, the NE extension associated with the core complex is of non-coaxial nature. Whether this reflects a radical change in the strain regime, or is merely a consequence of variable proximity of CBU rocks to the detachment is an open question.

### 5.4. Comparison with Syros

Prior to discussing the tectonic implications of our observations on Andros and applying it to the whole western Cyclades, it is instructive to compare the crystallization–deformation relations on Andros with those on other nearby islands. Whereas Andros mostly consists of pervasively overprinted greenschist-facies sequences, high-pressure rocks are best preserved to the south of Andros, i.e. on Sifnos and Syros. Some of the most spectacular and best studied outcrops are located on northern Syros, where peak metamorphic conditions ($T \leq 500$ °C; $P \sim 15$ kbar) and the timing of the ductile deformation events are well constrained (Dixon and Ridley, 1987; Rosenbaum et al., 2002; Keiter et al., 2004; Putlitz et al., 2005; Schumacher et al., 2008). While on Andros the F2 folds deform the dominant fabric, on Syros the dominant fabric is cogenetic with these folds, and previous fabric is preserved only within a few competent marble layers. Based on internally undeformed pseudomorphs after lawsonite, Keiter et al. (2004) inferred that the F2 folding ceased before or very close to peak high-pressure metamorphism at 50 Ma. Yet, given the very water-rich fluid phase ($X_{CO_2} = 0.01$) that coexisted with the high-pressure assemblages on Syros (including marbles), the pseudomorph forming reaction occurred at higher temperatures than those considered by Keiter et al. (2004), and thus S2 could easily have formed penecontemporaneously with peak metamorphism (Schumacher et al., 2008). In short, while on Andros the tightening of F2 folds deformed the dominant S1 fabric and ceased slightly after peak metamorphism during the early stage of exhumation, on Syros it produced a dominant S2 fabric and ceased just prior to exhumation. Thus provided that F2 on both islands is indeed contemporaneous, Syros was not only exhumed from a greater depth than Andros, but also entered the exhumation stage at a later time.

### 5.5. Tectonic implications

The major tectonic implication of the SW constriction model is that during the decompression of the CBU, the western Aegean Sea was subjected to a regional NE–SW extension, transverse NW–SE shortening, and vertical thinning. Since the relative motion in the Eastern Mediterranean region has been dominated during the past 110 Ma by the collision between several micro-continents (African fragments) and the southern margin of Europe, resulting in NE–SW shortening of about 1000 km (Biju-Duval et al., 1977), the NE–SW extension in the western Aegean Sea must have been accommodated by a greater amount of shortening elsewhere.

At the present time, SW extension in the Aegean Sea is being accommodated by the rollback of the active margin (ten Veen and Meijer, 1998; ten Veen and Kleinsphen, 2003; Meier et al., 2007), and to a lesser degree by shortening along the Hellenic trench (McKenzie, 1972; McKenzie, 1978; Le Pichon and Angelier, 1979). Previous researchers have shown that similar rollback of the active margin has played a central role in the Aegean since at least 30 Ma (Angelier et al., 1982; Thomson et al., 1998; ten Veen and Postma, 1999). Here we propose that the exhumation of the CBU on Andros occurred during long lasting SW stretching regime, which implies that SW retreat of the subducting slab may have already played an important role in the Aegean since Late Eocene. Although the age of the Hellenic trench is not well constrained, it is clear that subducting south of Crete did not start before 20 Ma (Spakman et al., 1988; Meulenkamp et al., 1994; Le Pichon and Angelier, 1979; McKenzie, 1978).

Thus, the active margin during the exhumation of the CBU must have been located north of the Hellenic Trench. Indeed, seismic images clearly reveal a subducting slab beneath the Aegean Sea that is at least 1700 km long (Spakman et al., 1993; Bijward et al., 1998; Bijward and Spakman, 2000). Using simple kinematic arguments, Meier et al. (2007) have shown that only 500–650 km of that slab is associated with the subduction since the shift of the plate boundary south of Crete about 20 Ma. They argue that the remaining 1000–1200 km long slab is composed of alternating sections of oceanic and continental lithosphere. It is thus clear that north directed subduction prevailed in the Aegean well into the Eocene, and it is probable that SW rollback of the subducting plate has played an important role in the exhumation of the CBU. In the previous section we concluded that Syros, which is located south of Andros, entered the exhumation stage at a later time. The delayed exhumation of Syros with respect to Andros is consistent with SW rollback of the active plate margin at that time.

Similar tectonic setting has been also inferred for the Menderes Massif in western Turkey, where NNE extension parallel folds are documented (Çemen et al., 2006). Monazite Th–Pb ages constrain the initiation of this extension to early Oligocene times (Catlos and Çemen, 2005). This suggests that the late Eocene to early Miocene SW constriction regime was not limited to the Cyclades Massif, but extended beyond that into western Anatolia.

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