The Geology of the Cyclades

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Having explored the islands of Antiparos, Paros and Milos as a geologist for over 20 years (mainly during holidays), I have observed numerous rocks and structures. I recently compiled (May 2025) a pdf file on the geology of Antiparos based on my observations and various areas of interest. The pdf file is here :
http://apreat.ovh/wp-content/uploads/2025/05/0.pdf

In addition to these observations, which anyone can discover when walking on the islands, an important question is how the Cyclades islands formed? I have never studied this problem, but being intrigued by the many structures observed on the field, I turned to the bibliography.
And there, the first observation is that there are numerous studies, conducted over more than 100 years, carried out by professionals including sedimentologists, structuralists, geochemists, mineralogists, geophysicists, metallogenists, etc.

All these disciplines were necessary as the formation of the Cyclades is extremely complex, from the smallest to the largest spatial and temporal scales.

I have therefore selected articles dealing with the formation of the Cyclades and illustrated them with informative diagrams. I have mentioned the source (in the form of a web link), and in the texts I have removed the numerous bibliographical references used by the authors, so as not to make the reading too heavy. Everyone will be able to find these references thanks to the web links.

Finally, I would like to emphazise that the geology of the Cyclades is complex, even for a geologist! I hope that this simplified overview will encourage some of you to explore the subject further by reading the articles mentioned in the text.

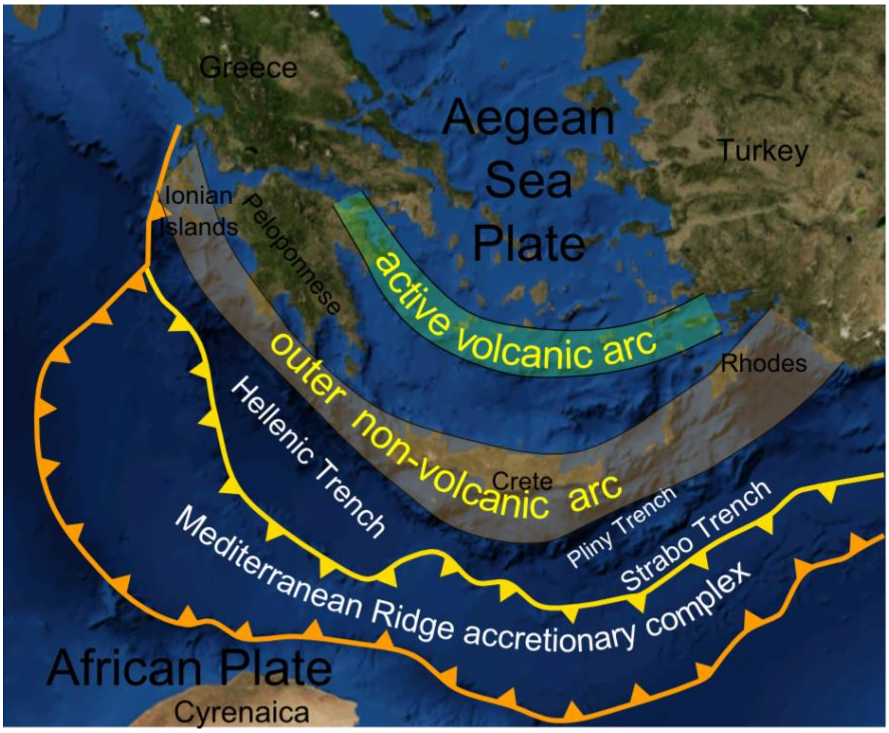
Nb: A geological time scale is available here : https://stratigraphy.org/chart

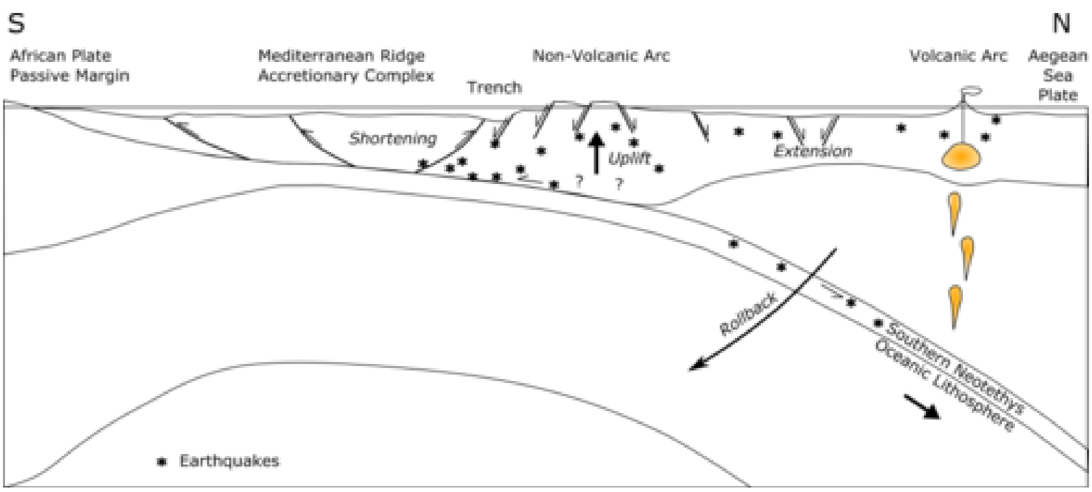
1. The Hellenic Subduction Zone (HSZ)

https://www.sciencedirect.com/science/article/abs/pii/S0012821X17305629 (2017)
The Hellenic subduction zone is characterized as a complex tectonic region resulting from the interaction between Africa and Eurasia convergence, the SW motion of Anatolia, and the large extension affecting the Aegean due to the slab retreat (see figures below). **The African plate moves northwards at a rate of 1 cm yr^{-1} and subducts along the Hellenic trench forming an active volcanic arc.** The associated seismicity delineates a Wadati–Benioff zone extending down to a depth of 180 km.

https://en.wikipedia.org/wiki/Hellenic_subduction_zone (accessed in 2025)
The **Hellenic subduction zone** (HSZ) is the convergent boundary between the African plate and the Aegean Sea plate, where oceanic crust of the African continent is being subducted north–northeastwards beneath the Aegean. The southernmost and shallowest part of the zone is obscured beneath the deformed thick sedimentary sequence that forms the Mediterranean

Ridge accretionary complex (*see figures below*). It has a well-defined Wadati–Benioff zone of seismicity, which demonstrates the relatively shallow dip of its southern part, which increases markedly to the north of the non-volcanic part of the Hellenic arc. The descending slab has been imaged using seismic tomography down to the top of the mantle transition zone at 410 km depth.





The Aegean volcanic arc (Piocene to Recent) is located 130–140 km directly above the Benioff plane, 200–250 km behind the subduction front.

There is evidence that more than 1500 km of Neotethyan oceanic crust (*see 'Southern Neotethys on the figure, above*) has been subducted along this structure or earlier versions of it. **Broadly northward subduction of Neotethys beneath Eurasia was already established in the Late Cretaceous**. This proceeded by the progressive closing up of different parts of Neotethys with the accretion of intervening continental areas to Eurasia. **This involves backstepping of the subduction zone southwards across each microcontinent,** so maintaining a continuous slab, as suggested by the tomographic results.

[See also: https://www.researchgate.net/publication/370907437_A_Review_of_the_Dynamics_of_Subduction_Zone_Initiation_in_the_Aegean_Region (2023)].

The onset of subduction of southern Neotethys was diachronous, starting in the east in the latest Eocene (ca. 35 Ma), beneath Crete in the early Miocene and in the Pliocene (ca. 4 Ma) at the western end of the HSZ beneath the Ionian Islands. The initially near planar slab began to fold **in the latest Oligocene (25–23 Ma), associated with differential slab rollback and trench retreat**, causing major clockwise rotation of western Greece. From mid-Miocene times (ca. 15 Ma) the slab curvature became more pronounced and southwestern Turkey began to rotate anticlockwise. During the period a major tear developed between the main part of the HSZ and the Western Cyprus zone, forming a slab window in the deeper part of the slab.

Currently, the rate of movement along the HSZ is estimated to be about 35 mm per year. However, the overall convergence between the African and Eurasian plates is only about 5 mm per year. This discrepancy is consistent **with continuing slab rollback** (*see previous figure*) and relatively fast southward movement of the Aegean Sea plate, accompanied by **ongoing extension** within that plate.

https://ui.adsabs.harvard.edu/abs/2024EGUGA..26.9789P/abstract (2024)
During slab rollback, segments of the middle-lower crust may undergo heating and partial melting due heating of thinned lithosphere by the asthenosphere and the migration of the magmatic arc. Alternatively, after accretion of radiogenic crust, the lower parts of the crust may relax through radiogenic decay. In both scenarios, the heating of the middle-lower crust reduces crustal strength, resulting in the development of **metamorphic core complexes** (MCC, see below). **The timing of lower crust heating is crucial for understanding the switch over from lithospheric shortening to extension**. The Hellenides in the eastern Mediterranean constitute an arcuate orogen located north of the present-day active Hellenic margin, marking the site of NNE-ward subduction of the African plate beneath Eurasia. **The Aegean Sea region in the Hellenide is a world-class example of large-scale continental extension above a retreating subduction zone.** In the Cyclades, the Hellenide orogeny began in the early Cenozoic, causing subduction and sustained high-pressure (HP) metamorphism between approximately 53 and 30 Ma. The timing of slab rollback is subject of intense debate. A decrease in the convergence rate was interpreted to suggest that slab rollback initiated at around 35-30 Ma, during or even after the waning stages of HP metamorphism.

The Cycladic islands are located in the central Aegean Sea (Greece) forming a partly submerged plateau separated into two parts: the eastern shallower one (**Andros, Tinos, Mykonos, Naxos, Paros, Syros, Ios, Sikinos, Folegandros**) which formed one big island (6.978 km^2) at the end of the last glacial period, the western islands (**Kea, Kythnos, Serifos, Sifnos, Milos**) which remained separated during the same period. The eastern islands constitute an erosional plateau which is the end product of a Neogene palaeosurface that was partially submerged due to thinning of the crust during the Quaternary. The presence of numerous Neolithic sites both on land and submerged indicates the existence of an advanced civilization in the area for thousands of years. The location of the lost Atlantis could be found in this area probably between Naxos, Paros and Antiparos.

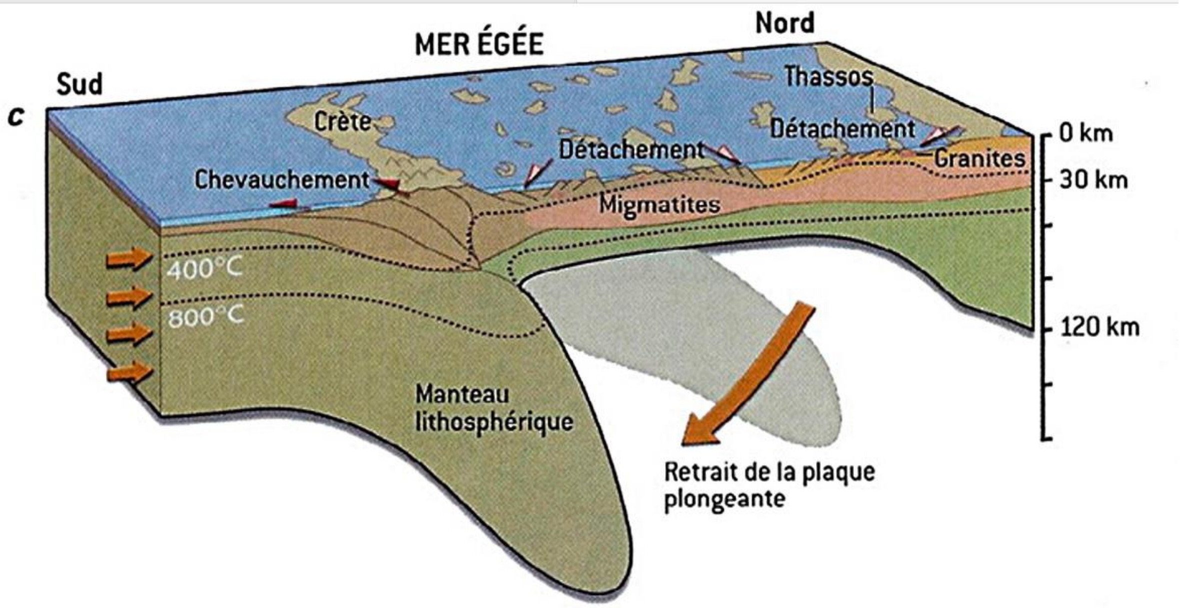
2. The Aegean domain

2.1. Geotectonic Setting

The structures of the Aegean domain are the result of an extension that followed a previous thickening caused by a continental collision. The extension could only begin once the collision was complete, and it was the warming induced by the crustal thickening following the collision that allowed the rheological softening necessary for the development of **metamorphic complex cores (MCC)**. **The extension began in the Cyclades in the Lower Miocene.**

The result is a two-stage evolution of the Aegean domain, with a collision lasting until the Oligocene followed by a back-arc-type extension linked to the rollback of the Hellenic subduction zone, which is still active today.

https://planet-terre.ens-lyon.fr/ressource/ile-Naxos.xml *(2018)*



Nb: Retrait de la plaque plongeante = slab rollback related to the trench retreat (subduction).

In https://www.researchgate.net/publication/251094915_Palaeogeographic_Evolution_of_the_Cyclades_Islands_Greece_During_the_Holocene *(2009)*

The geology of the Cycladic area consists mainly of metamorphic rocks such as micaschists, marbles, gneisses, amphibolites, glaucophane schists and plutonic rocks. **The main metamorphic events are of Tertiary age (Eocene, Lower Miocene**) as documented by radiometric studies. The structures in the metamorphic rocks are dominated by isoclinal folding, thrusting and refolding during Eocene – Oligocene.

The recent structural history of the Cycladic complex starts with the alpine orogeny during the Eocene when a period of compressional tectonism was dominant. **A group of rocks was metamorphosed under high pressures (HP) and low temperatures (LT) and became** known as **blue schists**. The compressional period changed to tensional during Oligocene or Miocene times in the form of shallow normal faults. During the Miocene the Central Aegean was a very shallow domain with extensive emerged regions and small elongated basins, as a consequence of prolonged intense compression which resulted in the formation of steep graben faults that rapidly uplifted the blue schists. In this period lower pressures metamorphosed a new group of rocks which formed the green schists. There followed the intrusion of plutonic rocks (granites) through the old faults which reached the surface of the Cycladic mass after the faulting has ceased. **About 5 million years ago, the south Aegean volcanic arc was formed** and extended from the Corinth area (Sousaki) to the island of Nisyros (Dodecanese islands). In the area of Cyclades volcanism occurred mainly in the islands of Milos and Thera. The crust in the Cycladic area is rather thinner than normal. The Cycladic plateau which is generally less than 200 meters deep lies mostly underwater because of the thinner crust.

The thinning is a result of the widespread Neogene and Holocene speading of the crust of this area as well as the westward extrusion of the Anatolia block. This area is presumably under an extensional tectonic regime behind the modern volcanic arc at the centre of the Aegean plate and possesses a relatively thin continental crust of about 28–30 km. **Recent studies have found that the crustal thickness is 25 km underneath the Cyclades** and less (22–23 km) southwest of the islands. This is owed to two factors, the gravitational collapse of the Aegean crust due to the southward retreat of subduction front during the Cenozoic and westwards extrusion of the Anatolian block in the Aegean during the Neogene. The relative motion of the Cyclades during the Holocene is towards the south and south-west with a rate of about 3 cm per year. The general trend of the major submarine fault tectonism is from east to west, exhibiting a curved shape and coinciding with the volcanic and back arc Cycladic area. In recent years several major offshore faults have been identified suggesting the presence of tectonic depressions with horsts.

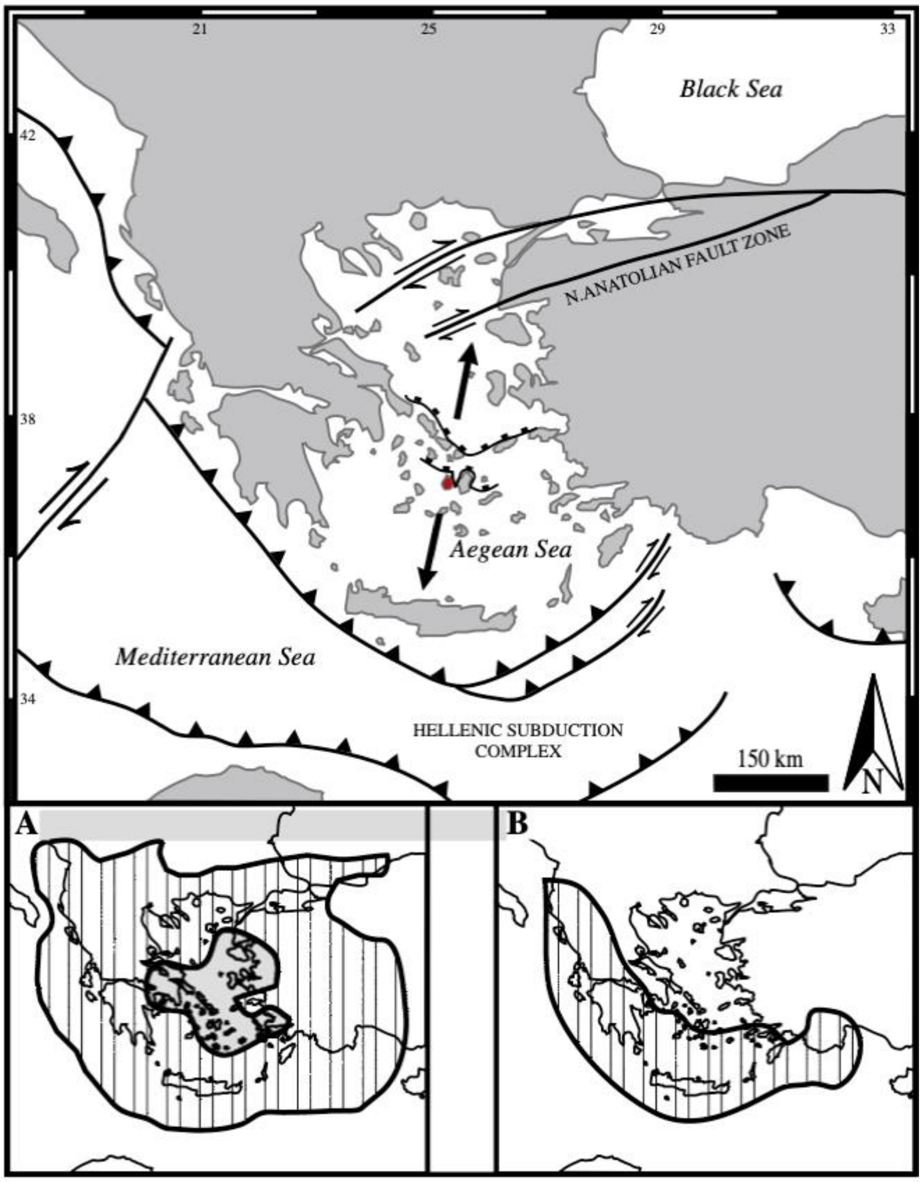


Fig. 1. Simplified regional tectonic map for the greater Aegean region. The Hellenic subduction ***complex structures*** *are from Papanikoloau et al. (2004), the North Anatolian Fault Zone location from Armijo et al. (1999), the Paros–Naxos extensional detachment location from Gautier et al. (1993), and the North Cycladic Detachment System location from Jolivet et al. (2010). Black arrows indicate the regional extension direction.* ***The island of Paros is highlighted in red****. [****A****] Hatched area shows the distribution of active earthquakes in the greater Aegean region occurring from 0 to 35 km depth and magnitude ≥4. The central Aegean (shaded light gray) is currently aseismic. [****B****] Hatched area shows the distribution of active earthquakes in the greater Aegean region occurring from 35 to 300 km depth and magnitude ≥4. Earthquakes deepen northward toward the limit of seismicity related to the downgoing Africa. Fig.1 from https://www.sciencedirect.com/science/article/abs/pii/S0040195112004325?via%3Dihub (2013).*

• Extension in the central Aegean province has been ongoing since fossils have been recovered from low-grade marbles of the Dryos Unit the latest Oligocene to earliest Miocene;

• Cenozoic development and southward retreat of the Hellenic subduction zone and the collapse of the Alpine Orogeny resulted in back-arc extension which was accompanied by widespread plutonism and volcanic activity that followed the migrating arc southward;

• Total extension of up to ~ 580 km has resulted in crustal thinning from an orogenic (> 50 km) to an attenuated lithospheric thickness of ~ 26 km in the central Aegean and is locally

manifested by low-angle normal faulting and in some cases, MCC development (see below);

• Regional, top to the N–NE, Holocene extension rates have been estimated to range between 12 and 60 mm/yr although up to 2–3 cm/yr of geodetic movement has been reported between the Aegean region and stable Eurasia

References for the four points above are in https://www.sciencedirect.com/science/article/abs/pii/S0040195112004325?via%3Dihub

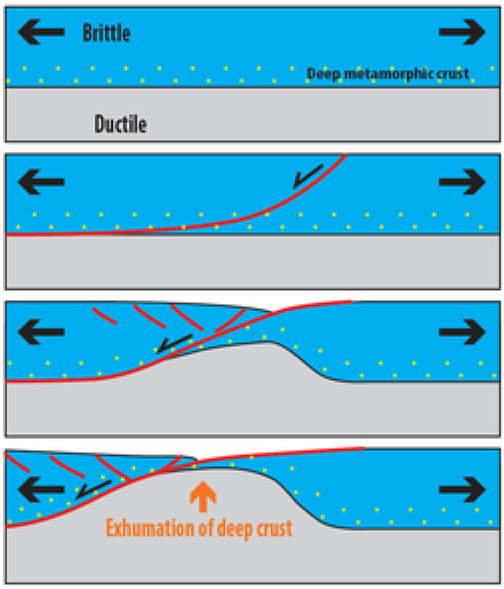
https://storymaps.arcgis.com/stories/023abb16eaee4a4ab09ad5c51d297879 (2023)
As slab rollback was accelerated by a tear in the subducting slab, the Eurasian plate moved with the African plate, which caused the Eurasian plate to thin and extend. This extension was accommodated by normal faults in the Eurasian plate. As these normal faults occurred, the asthenospheric mantle underneath the Eurasian plate swelled and rose in response to the decrease in overlying pressure and weight. This is known as isostatic rebound. **This swelling ultimately led to the exhumation of dome-shaped islands at or near the extensional normal faults that are known as metamorphic core complexes.**

2.2. Metamorphic core complexes

(from Wikipedia)
Metamorphic core complexes (MCC) are exposed areas of deep crust brought to the surface by crustal extension (stretching). They form, and are **exhumed**, through relatively fast transport of middle and lower continental crust to the Earth's surface in the form of uplifting welts of hot rock and magma. **The resulting doming causes the overlying rock to gravitationally collapse, sliding down and usually away from the uplift along low-angle detachment faults**. Brittle, faulted cover rock above the detachment surface lies in direct contact with the ductile middle-lower crust below.

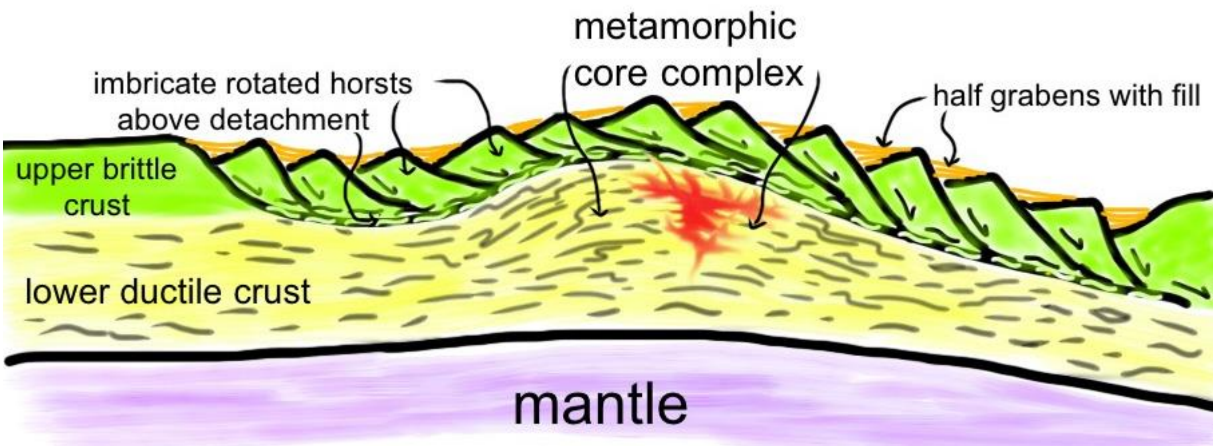
High-grade metamorphic rocks (eclogite-, granulite- to amphibolite- facies) are exposed below the detachment faults (and mylonitic shear zones). Amphibolite- to greenschist-facies, syndeformational metamorphism, and ductile-brittle to brittle deformation are shown on the upper-side (hanging-wall), with tilted geometries.

They range from several miles to over 50 miles across, and usually exhibit several miles of vertical uplift. They are common in areas of localized crustal extension in otherwise thickened fold-thrust belts The origin of the low angles of the detachment faults were a subject of debate as of 2022.

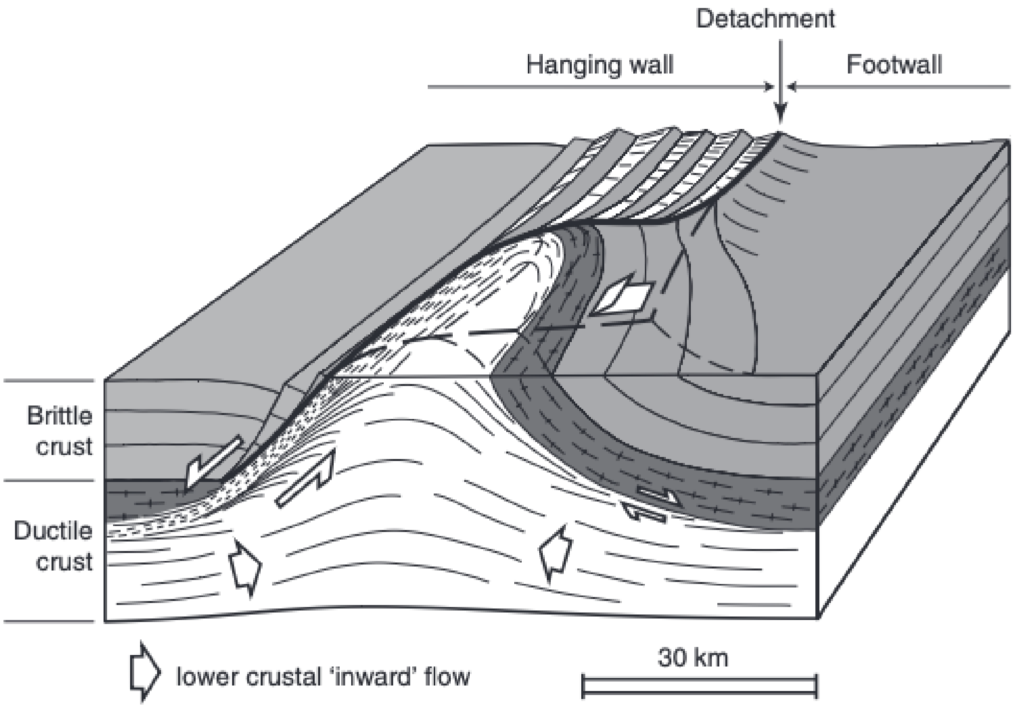


Formation of a metamorphic core complex (in Wikipedia).
MCC are formed by metamophic series

In summary, MCCs are metamorphic domes that have developed through extension and can exceed 100 km in width. The core of the dome consists of metamorphic rocks (middle crust, see above)and is surrounded by upper crustal units that may constitute the substrate of sediments deposited during the formation of the dome. **MCCs are typical structures in region made of highly extended continental lithosphere.**



https://maps.unomaha.community/Maher/plate/week3/MetamorphicCoreComplexes.html



Simplified skectch showing the main features of a metamorphic core complex
https://www.researchgate.net/publication/252739859_Sequential_Development_of_Interfering_Metamorphic_Core_Complexes_Numerical_Experiments_and_Comparison_to_the_Cyclades_Greece *(2009)*

MCCs are typical structures in region made of highly extended continental lithosphere.
They constitute metamorphic domes capped by one or several low-angle normal-sense shear zones or 'detachment' zones that separate a highly faulted hanging wall made up of superficial rocks from a footwall made up of rocks exhumed from the middle or lower crust and recording a extensional strain on the scale of the crust.

2.3. Metal occurrences

https://www.sciencedirect.com/science/article/pii/S0169136817304043#f0005 *(2018)*
The Cyclades MCC hosts a large number of metal occurrences albeit with minor metallogenic significance and the fragmentary exposure of outcrops on scattered islands, suggesting favorable conditions for metal deposition . Most of mineralization consists of (1) porphyry Mo(-Cu) and Fe-rich skarn deposits observed in the Lavrion peninsula and Serifos island , (2) Pb-Zn(-Ag-Cu) veins and manto-type carbonate replacements, including the Lavrion ore field and (3) Au(-Ag) quartz veins and breccias located close to crustal-scale detachments or within the detachment plane itself (i.e. on Tinos, Mykonos and Sifnos islands). Magmatic fluids are generally evoked to transport metals while surface-derived meteoric fluids and/or seawater seem to contribute to metal deposition at shallow depth (i.e. ≤1 km). No absolute dating has been performed on alteration minerals in the Cyclades. However, structural relationships and geochronological constraints on related intrusions (U-Pb dating on zircon) indicate a late Miocene age for hydrothermal activity, during the late exhumation stage of the Cyclades MCC. More recently, intermediate-sulfidation epithermal Au-Ag(-Mn-Pb) deposits formed along the Pliocene-Quaternary Aegean volcanic arc (e.g. Milos island).

3. Geology of Paros and Naxos

https://www.sciencedirect.com/science/article/abs/pii/S0040195112004325?via%3Dihub (2012)
Paros is unique among the central Cyclades in that it exposes a nearly complete succession of footwall rocks and hanging wall sediments. In the footwall, Cycladic basement rocks of Paros are composed of highly deformed Carboniferous ortho- and paragneisses and less-deformed, S-type granites. A low-angle detachment fault separates the high-grade MCC foot-wall from the hanging wall sediments, which are mainly exposed along the coast in NE Paros.

A classic metamorphic core complex is located on the island of Naxos in the Aegean Sea and numerous high-quality structural and microfabrics data have been published. Naxos is the largest island of the Cyclades in the western Aegean Sea**. The exhumation/uplift resulted in a north-south trending elongated dome**. The main structure of the Naxos MCC is a migmatite-cored gneiss dome that is structurally overlain by a ductile low-angle normal fault in the east and a steep strike- slip-type fault zone in the west, the latter located in an N-S trending topographic depression. Within the MCC, continental basement, probably of Variscan age, is capped by a high-grade metamorphic cover succession of Mesozoic carbonates, fine-grained siliciclastic and tuffaceous rocks.

The Naxos-Paros ductile low-angle fault, located along the northern margin of Naxos, is part of **the North Cycladic Detachment System**. A rolling hinge top-N displacement was proposed in recent models. Exhumation of the Naxos MCC was contemporaneous with migmatization and granitoid intrusion in the center of the dome. The Naxos migmatite contains subdomes, which formed by combination of upper crustal extension and deep crust contraction. The vast majority of the deformation in the migmatitic core is characterized by melt-present deformation conditions and microstructures show recrystallization at high-temperature. Melt-present deformation clearly was the key deformation process in the core of the dome throughout its history.

https://planet-terre.ens-lyon.fr/ressource/ile-Naxos.xml#Vanderhaeghe (2009)
Naxos and Paros, like all the Cyclades, therefore bear traces of intense stretching. This extension actually affects the whole of mainland Greece and western Anatolia, and continues today, as evidenced by GPS measurements . On the Greek and Turkish mainland, this is superficially reflected in a series of grabens bounded by normal faults, such as the Corinth Graben, which separates Attica and Boeotia on the northern side of the Peloponnese, south of the Corinth Canal. In the Aegean Sea and further north, in the Rhodope Mountains, **the stretching is expressed by a 'bulging' of the brittle upper crust, fragmented into pieces separated by upwellings of the ductile lower crust, as in Naxos and Paros**. According to seismic data, the thickness of the crust is reduced to 25 km in the Aegean, and barely more for the lithosphere, due to the strong geothermal gradient that considerably reduces the mantle portion of the lithosphere. This stretching accompanies the southward retreat of the Aegean subduction trench, now located south of Crete. The causes of this significant retreat of the trench and this deformation by buckling of the Aegean crust are still the subject of active research and seem to be related both to the rheology of the Aegean continental lithosphere before stretching (an already 'hot' and fairly ductile) and asthenospheric movements caused by the rupture of the panel plunging beneath Anatolia.

https://ui.adsabs.harvard.edu/abs/2024EGUGA..26.9789P/abstract (2024)

The formation of extensional sedimentary basins and radiometric dating of extension-related mylonite place rollback at approximately 23 Ma, distinctly after the final stages of HP metamorphism.Between about 30 Ma and 20 Ma, isobaric heating during the exhumation of some HP rocks has been proposed on some islands (Syros, Tinos, Andros, and Naxos). However, the precise timing and duration of this isobaric heating remains largely unconstrained. **On Naxos, previous geothermobarometry estimates indicate isobaric heating occurred from 500 to 550°C from a middle segment of the nappe stack**. Garnet chemical zonation formed during exhumation allows for a heating timescale to be estimated via diffusion chronometry. We conducted Monte Carlo diffusion simulations to determine the best-fitting timescale based on Chi-square statistics, assuming three different heating paths. **Diffusion model results for a heating path from 500 to 550°C indicate a 10 Myr timescale.** A lower temperature path (from 400 to 450°C) requires heating over an unreasonable geological timescale (>100 Myr). Conversely, a higher temperature path (from 600 to 650°C) requires a timescale of <1 Myr. This higher temperature path corresponds to temperatures recorded near the migmatite core at the bottom of the Naxos nappe stack. At such temperatures and within a 10 Myr period, chemical heterogeneities in garnet would have relaxed, as observed in most garnets near the migmatite core. The results of this approach indicate that the heating of the lower crust occurs over a 10 Myr period, suggesting that the heating may result from radiogenic decay during the Oligocene before the slab roll during the Miocene.

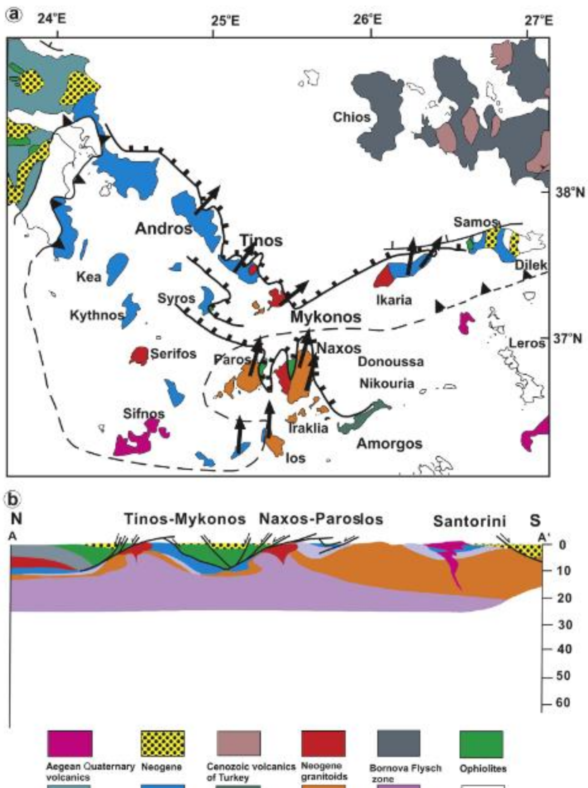


Fig. 2. (a) Schematic geological map within the context of the North Cycladic Detachment System. The arrows indicate the sense of ductile shear in the lower plate (modified after Jolivet et al., 2010; Huet et al., 2011). (b) Detail of N–S cross-section of the Aegean region centered on the Cyclades archipelago (modified after Jolivet et al., 2010).

In https://www.sciencedirect.com/science/article/pii/S0191814113001193?via%3Dihub (2013)

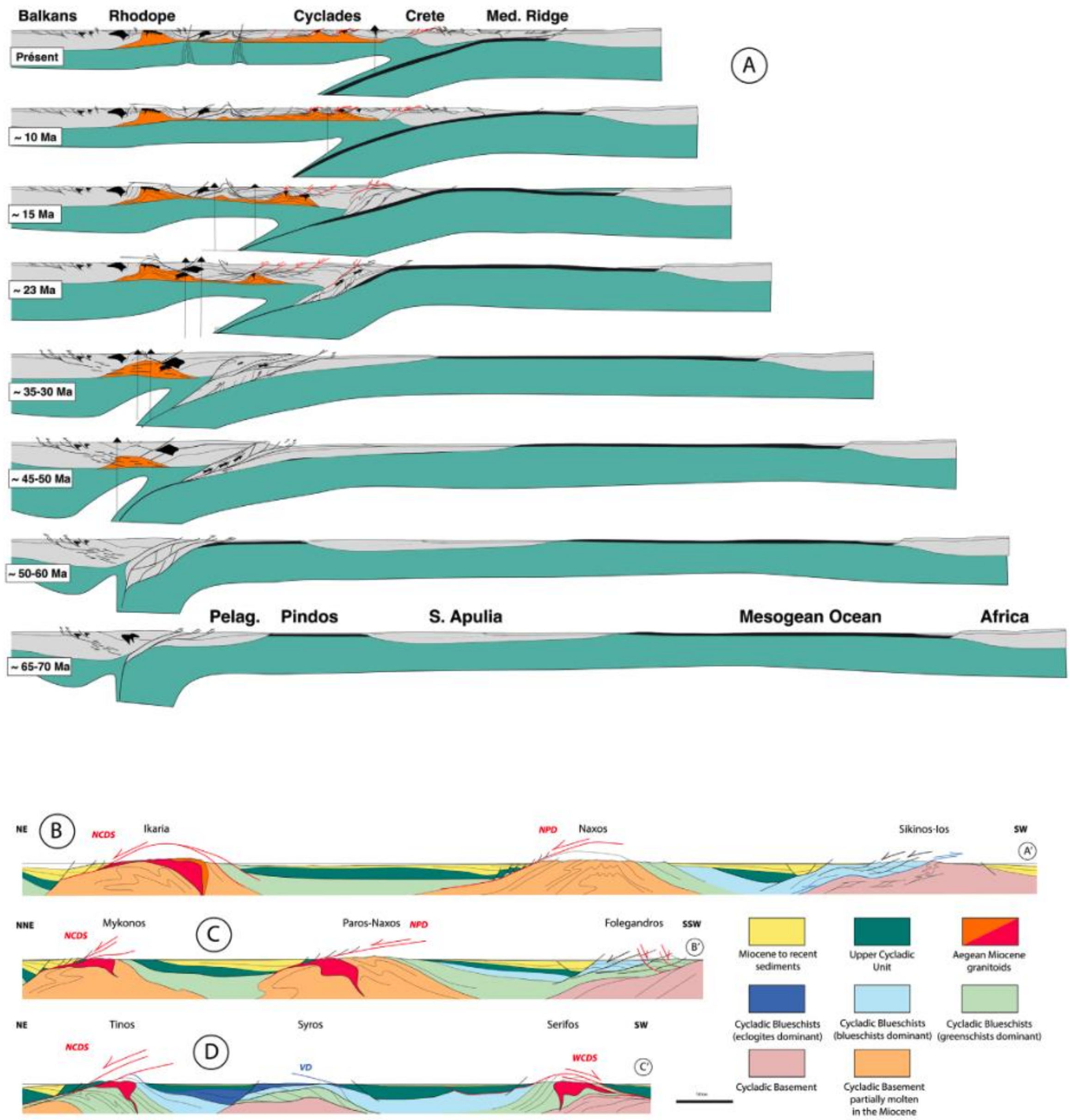


Fig. 3. Cross-sections of the Aegean domain. A: Evolution of the Aegean domain along a N–S section from the Balkans to the northern margin of Africa, from Jolivet and Brun, 2010. B, C and D: three cross-sections across the Cyclades (see location on Fig. 2C), from Jolivet et al. (2015b).

https://www.researchgate.net/publication/327840563_Extensional_crustal_tectonics_and_crust-mantle_coupling_a_view_from_the_geological_record (2018)

Extension in the Aegean domain developed in the back-arc region of the Hellenic subduction zone from the Eocene to the Present. In a first period, it was localized in the Rhodope Massif duringthe Eocene and then migrated in the Aegean Sea and Menderes Massif after the Late Eocene . The history of magmatism shows that during the first period, the magmatic arc was initially limited to the Balkans and Rhodope, while it subsequently migrated at 2–3 cm/yr toward the south, suggesting that slab retreat was faster, which is compatible with the thinner crust observed in the Aegean Sea. **Several metamorphic core complexes were exhumed during these two distinct phases, including the Rhodope Massif itself and the different MCCs of the Cyclades** (see Fig.3A,B above).

Extension in the Cyclades is taken up by a few large-scale structures such as the North Cycladic Detachment System (NCDS), the Naxos-Paros Extensional Fault System (NPEFS) or the West Cycladic Detachment System (WCDS).

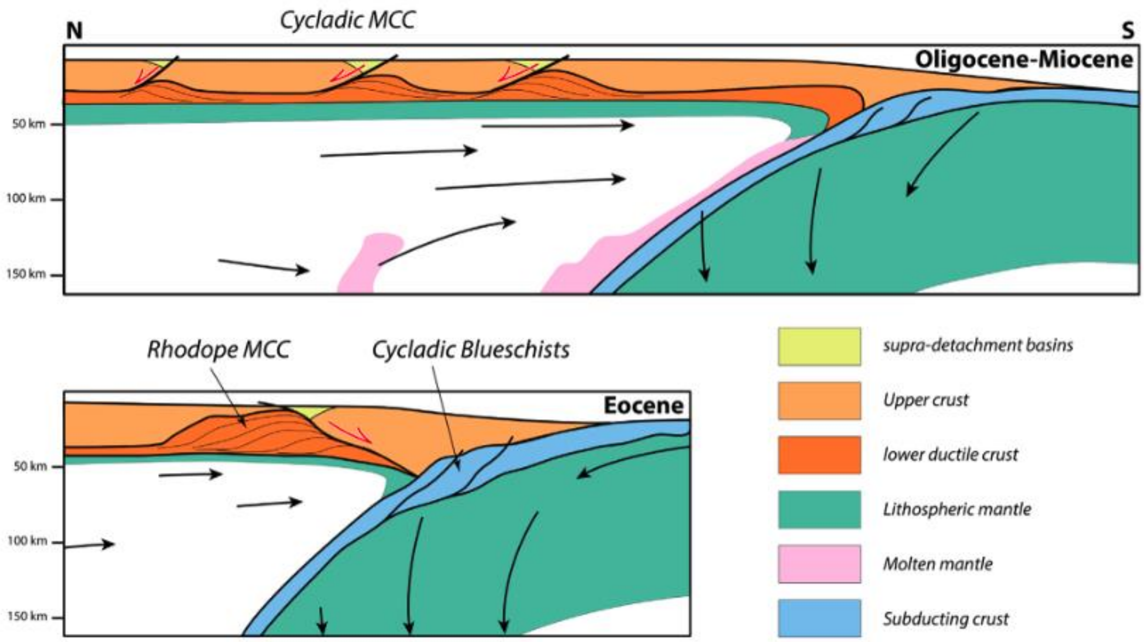


Fig. 4. Schematic cross-sections across the Aegean domain in the Eocene and the Oligo-Miocene showing the main active MCCs and detachments.

https://www.researchgate.net/publication/327840563_Extensional_crustal_tectonics_and_crust-mantle_coupling_a_view_from_the_geological_record (2018)

At the scale of the Aegean region, extension was thus first asymmetrical with one major MCC exhumed below a top-to-the SW detachment (the Rhodope in the Eocene) and then asymmetric with a top- to-the north or top-to-the NE in the centre of the Aegean Sea (The Cyclades in the Oligo-Miocene).

https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2017TC004697 *(2018)*

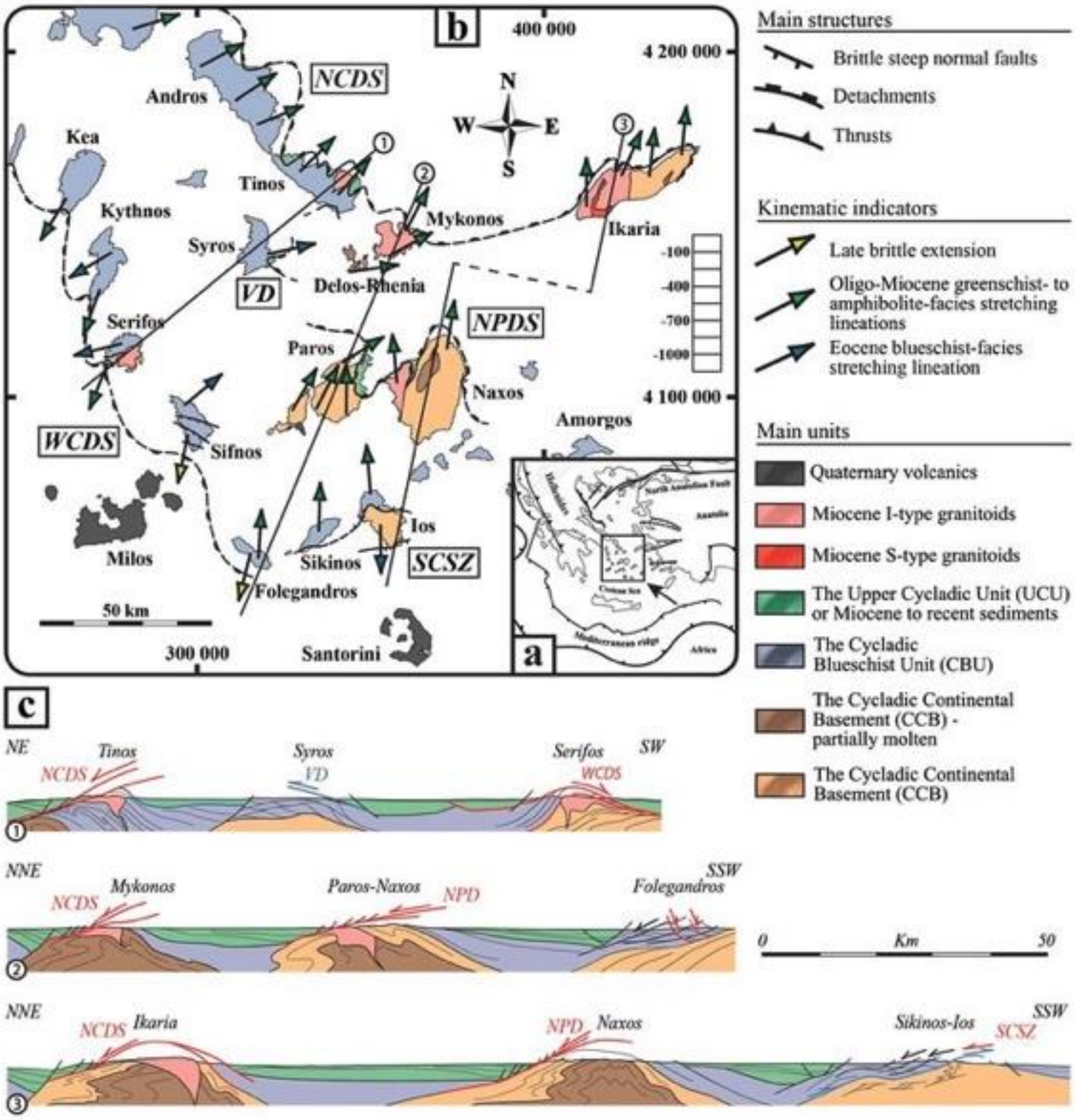


Figure 1. (a) Simplified tectonic map of the Aegean domain and location of the studied area. (b) Tectonic map of the Cyclades, modified after Huet et al. (2009), Jolivet et al. (2010, 2015), Grasemann et al. (2012), and Augier, Jolivet, et al. (2015). Coordinates on the map, including the following ones, are given in universal time meridian zone 35°N, World Geodetic System (WGS) 1984. At regional scale, note the spatial interaction between I-type granitoids (Tinos, Mykonos-Delos-Rhenia, Ikaria, Naxos, and Serifos Islands) and metamorphic core complexes together with their flanking detachments. (c) Cross sections through the Cyclades (1–3), modified after Augier, Jolivet, et al. (2015). Sections are roughly parallel to the tectonic transport and highlight the close interaction between granitoids and detachments. NCDS = North Cycladic Detachment System; NPDS = Naxos-Paros Detachment System; WCDS = West Cycladic Detachment System; SCSZ = South Cyclades Shear Zone; VD = Vari detachment.

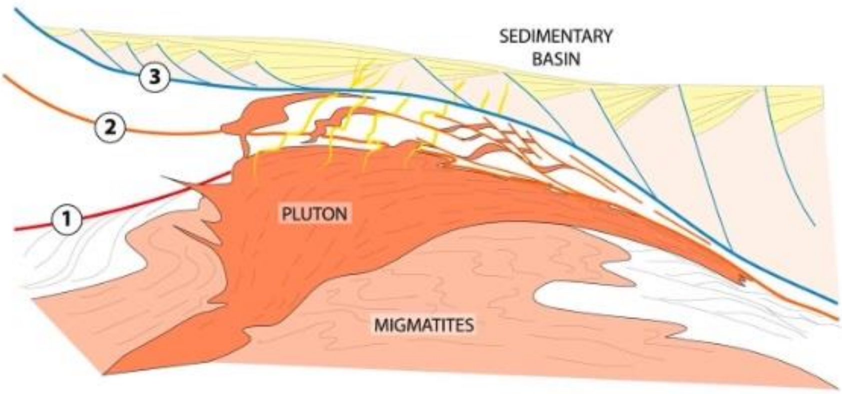


Figure 9. Cross section showing the sequentially developed detachment branches as resulting from the local interaction with a granitoid intrusion. This sketch can easily be used for each late exhumation history of metamorphic domes described in this study. The pluton intrudes an already active metamorphic core complex topped with a detachment (1) associated with or without a migmatite dome in its core. The early formed detachment can be the equivalent to the Tinos, Agios-Kirykos, Naxos, or Meghàlo Livadhi detachments. The intrusion inactivates the early detachment that is replaced by a new detachment (2) localizing along the upper contact of the pluton, similar to the Livada, Gialiskari-Fanari, Moutsouna, or Kàvos Kiklopas detachments. A shear zone develops within the pluton with a continuum of deformation from the comagmatic flow to subsolidus colder deformation and mylonitization below the new detachment. Finally, a third detachment may form above, strictly in brittle-cataclastic behavior, and its complete the exhumation of the metamorphic core complex, like the Mykonos detachment.

As further shown above, the present-day anatomies of the granitoid-cored metamorphic domes, however, imply somewhat more complex exhumation histories with the development of multiple detachments. Even if the exact onset of each MCC-bounding detachment remains uncertain through radiometric dating, some key elements reported in this review tend to demonstrate successively active detachments as a result of local and transient interactions with granitoid intrusions, rather than their concomitant existence, as shown in Figure 9 (above). All structural, kinematic, and geometrical constraints indeed converge upon a coherent model in which the exhumation of the granitoid-cored domes was systematically achieved below a single detachment that was inactivated at the time of intrusion and replaced by a new strain localization zone at the upper intrusive contact of the granitoids.

4. to conclude provisionally

https://www.fr.fnac.be/a2162942/Laurent-Jolivet-Geodynamique-mediterraneenne (2008)
The Mediterranean Sea as we know it today began its history 30-35 million years ago. Since then, very active dynamics on the surface and in the depths of the mantle have profoundly altered its appearance. It was during the Eocene/Oligocene transition that the oceanic lithosphere of a portion of the Tethys was isolated by a series of continental collisions to form the Mediterranean Sea. The geometry of the continental blocks led, during the Oligocene and Miocene, to a complex three-dimensional evolution in which subduction, the construction of mountain ranges and the opening of back-arc basins followed one another.

The typical tectonic pattern of the Mediterranean is therefore the classic one of a subduction (Hellenic)/back-arc extension couple. The diagram corresponds to an oceanic domain subducted beneath a continental arc and an accretionary prism where compressive deformations are recorded, and a back-arc basin in extension develops behind it.

The Hellenic arc (subduction) thus corresponds to a portion of the mountain range that has been reworked by post-orogenic extension. The same applies to the highly stretched continental substratum behind the arc. Extensive offshore MCCs then form, creating islands such as those in the Cyclades archipelago. **These MCCs are sometimes associated with granitic intrusions, as in Naxos. The back-arc extension recorded in these regions involves a significant retreat of the plunging panel over several hundred kilometres**. The resulting tectonic deformations are controlled by the relatively slow convergence of Africa and Eurasia, by the expulsion of Anatolia (= North Anatolian Fault) following the collision of Arabia and Eurasia, by the retreat of subduction zones, which induces back-arc extension, and by the collapse of certain mountain ranges under their own weight. It should be noted that the African lithosphere continues to subduct at the same speed into the mantle, but since Africa's movement relative to the mantle has slowed, a vertical component is added, involving a withdrawal of the plate to compensate. It is this change that causes the extension of the back arc. The weight of the subducting plate is the main driving force.

These processes depend on the movements of subducting plates in the mantle, and in each case it is necessary to establish a link between deep processes and surface tectonics.
In this tectonic setting**, the important question is that of the exhumation of HP-BT rocks (Cycladic blue schists) towards the surface**. Studies show that these rocks reached the upper levels of the crust fairly early, before post-orogenic extension began 30 Ma ago. They were therefore exhumed in the subduction zone and during the formation of the mountain range. From 30 Ma onwards, the rocks that were not completely exhumed in the Cyclades (Naxos, etc.) were heated in the back-arc domain and then exhumed in the core of the extensive HT MCCs**. It should also be noted that these rocks (MCCs) outcrop beneath series that are slightly or not at all metamorphic, from which they are separated by a fault and a low-angle ductile shear zone contemporary with the exhumation**. It is tectonics, and in particular faults and shear zones, acting as normal faults, that are responsible for exhumation.

The exhumation in the Cyclades is marked by the migmatitic dome of Naxos and the formation of granitic plutons in Tinos, Mykonos, Serifos, Naxos, Ikaria and Kos during the Miocene (between 20 and 10 million years ago).

One of the major features of the geology of the Cyclades therefore concerns the back arc continental extension with particular attention paid to the exhumation of metamorphic rocks, blue schists and MCCs, and their implication in the evolution of subduction since around 45 million years ago in the Aegean region. Finally the back-arc extension is a consequence of a retreat in subduction marked by a withdrawal of the trench at the end of the Eocene.

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