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Extension in the Aegean nappe-stacks: numerical modelling and their geological validation

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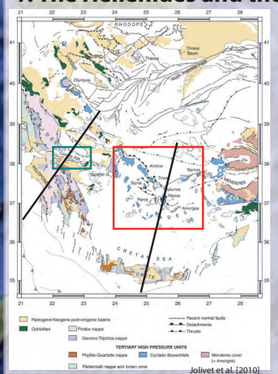
Abstract The Aegean region is being stretched in a back-arc position for the last 30-35Myr. At large scale, the deformation is distributed but at smaller scale, field observations show that the extension has been localised along detachments as the Aegean slab was retreating with time. In all the cases, extension has been and is still reworking the initial nappe stack accreted within the accretionary prism of the subduction. In this contribution, we present attemps of modelling the effect of this structural inheritance at different scales in the crust. In all the cases, different dataset have been used to validate the models.

Since all the studied areas are representative of the same process with very similar initial conditions, it is possible to use the example of the Gulf of Corinth has an active analogue for the initiation of the Cycladic detachments and oppositely to use the exhumed Cycladic MCCs has a field analogue for the lower crust of the Gulf of Corinth. Thanks to those parallel histories, it is possible to use more datasets to validate the mechanical models of the crust and therefore to retrieve the effective rheology of the crust and the lithosphere.

1. The Hellenides and the Aegean domain



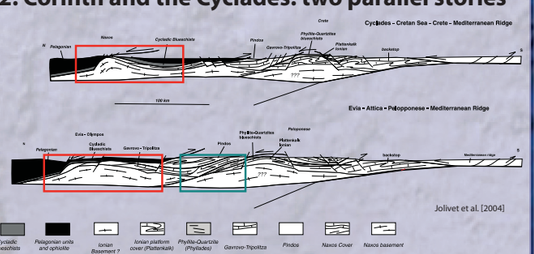
Jolivet et al. [2010]

The Hellenides are the result of convergence between Africa and Europe since the late Cretaceous.

Thickening has been achieved by stacking of successive units coeval with HP-LT metamorphism:
- Eocene in the Cyclades,
- Miocene in Crete and Peloponese.

Retreat of the African slab induced lithospheric stretching in the back arc:
- Oligo-miocene MCCs in the Cyclades,
- Mio-quaternaty Gulf of Corinth in the Peloponese.

2. Corinth and the Cyclades: two parallel stories



Jolivet et al. [2004]

The Gulf of Corinth reworks and roots in the Cretan HP-LT metasediments (Phyllite-Quartzite nappe).

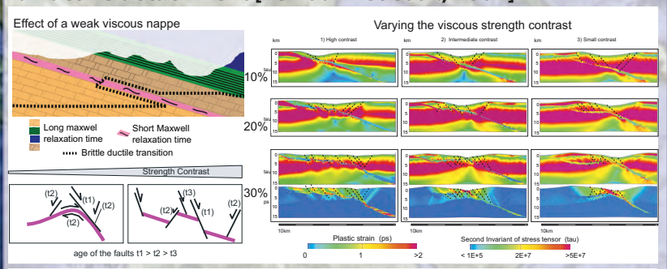
The Cycladic detachments exhume the HP-LT Attic-Cycladic Blueschists and Cycladic Basement.

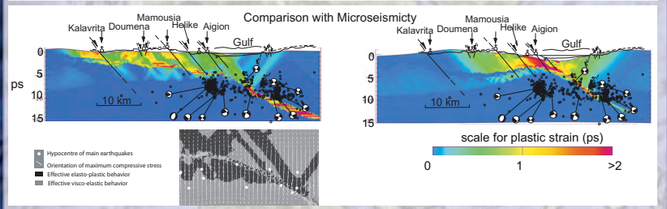
The Cycladic MCCs open windows in the deformation of the lower crust below the Gulf of Corinth

3. A large dataset to constrain the models

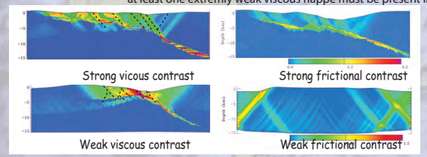
The models are constrained by a large set of natural data:
- structural geology in the Gulf of Corinth and the Cycladic islands,
- microseismicity in the Gulf of Corinth,
- microstructure within the gouges of Mykonos detachments,
- P-T paths and exhumation rates of the metamorphic units exposed in the Cycadic MCCs,
- kinematics of the ductile deformation in the footwall of the detachments.

4. Structural inheritance in the Gulf of Corinth: an active detachment [Le Pourhiet et al., 2004]





In order to reproduce natural data set available in the Gulf of Corinth at least one extremly weak viscous nappe must be present in the basement

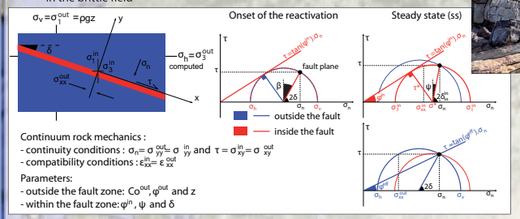


Accounting for a weak fault the friction must be very close to zero in order to explain the faulting pattern

What Can be the cause for such weakness at the brittle ductile transition ?

5. Structural inheritance on Mykonos island: an exhumed detachment [Lecomte et al., in press]

Setup: extensional reactivation of a shallow-dipping inherited heterogeneity in the brittle field

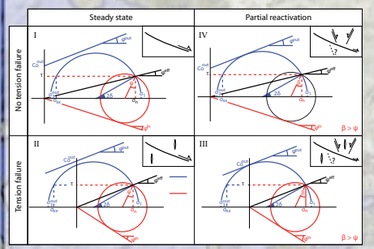


Continuum rock mechanics :
- continuity conditions : $\sigma_n = \sigma_{ij}^{out} = \sigma_{ij}^{in}$ and $\tau = \sigma_{xy}^{in} = \sigma_{xy}^{out}$
- compatibility conditions : $\varepsilon_{xx}^{in} = \varepsilon_{xx}^{out}$

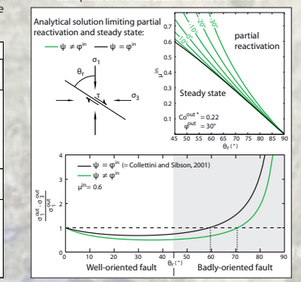
Parameters:
- outside the fault zone: Co^{out}, φ^{out} and z
- within the fault zone: φ^{in}, ψ and δ

Mykonos island, Cyclades

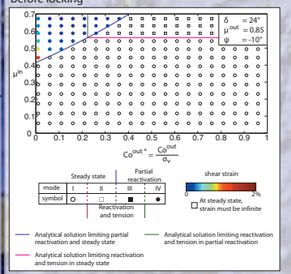
Four modes of reactivation possible including a complete or partial reactivation of the shear zone with or without tensile failure in the surrounding medium.



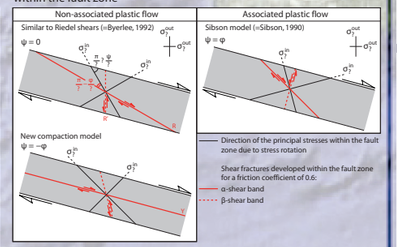
Comparison to the classical brittle models



Plastic strain rate obtained in partial reactivation before locking

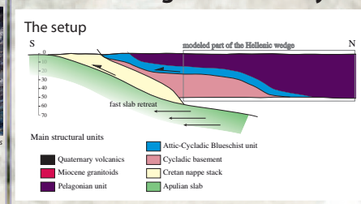


Predicted newly formed micro/meso-structures after the stress rotation within the fault zone

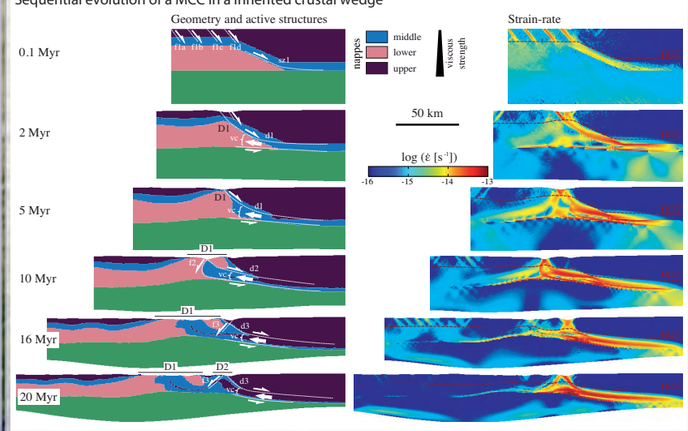


6. Structural inheritance in the Cycladic: a crustal wedge reworked by MCCs [Huet et al., subm.]

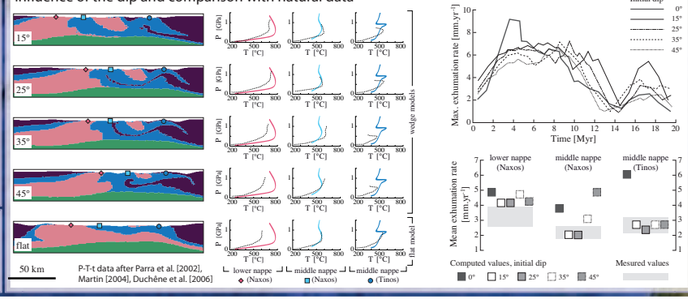
The setup



Sequential evolution of a MCC in a inherited crustal wedge



Influence of the dip and comparison with natural data



50 km

P-T-t data after Parra et al. [2002], Martin [2004], Duchêne et al. [2006]

7. Conclusions

Structural inheritance is present at all scale in the Aegean. Including geological knowledge of the initial complexity of the crust in the set up of mechanical or thermo-mechanical models allows to get more realistic results and therefore to use more data in order to validate quantitatively the models.

Inherited dipping heterogeneities such as a 1km thick mica-schist layer (Gulf of Corinth), and inherited weak fault zone (Mykonos) or a several km thick layer of meta-sediments (Cyclades) impose some complexity in the kinematics that allows explaining out of sequence faulting at crustal scale, the distribution of the seismicity at depth and the slip lines within kilometre scale fault zone or the reheating of material during the exhumation without introducing complex parametrisation of the rheology in the models. With this approach, we can use simple rheological models in order to asses effective rheological behaviour of the rocks in situ.

Since the boundary conditions have not changed that much and plenty of todays active graben of the Aegean are located in similar geological context as were the Cycladic MCCs during the early Miocene Times, we were able to use similar model set up to model exhumed MCCs, the microstructures in exhumed detachments or an active rift such as the gulf of Corinth. This allows to gather more dataset together in order to constrain the rheology of the crust at different scale across the brittle-ductile transition.

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