Metamorhic petrology as a tool to understand subduction initiation

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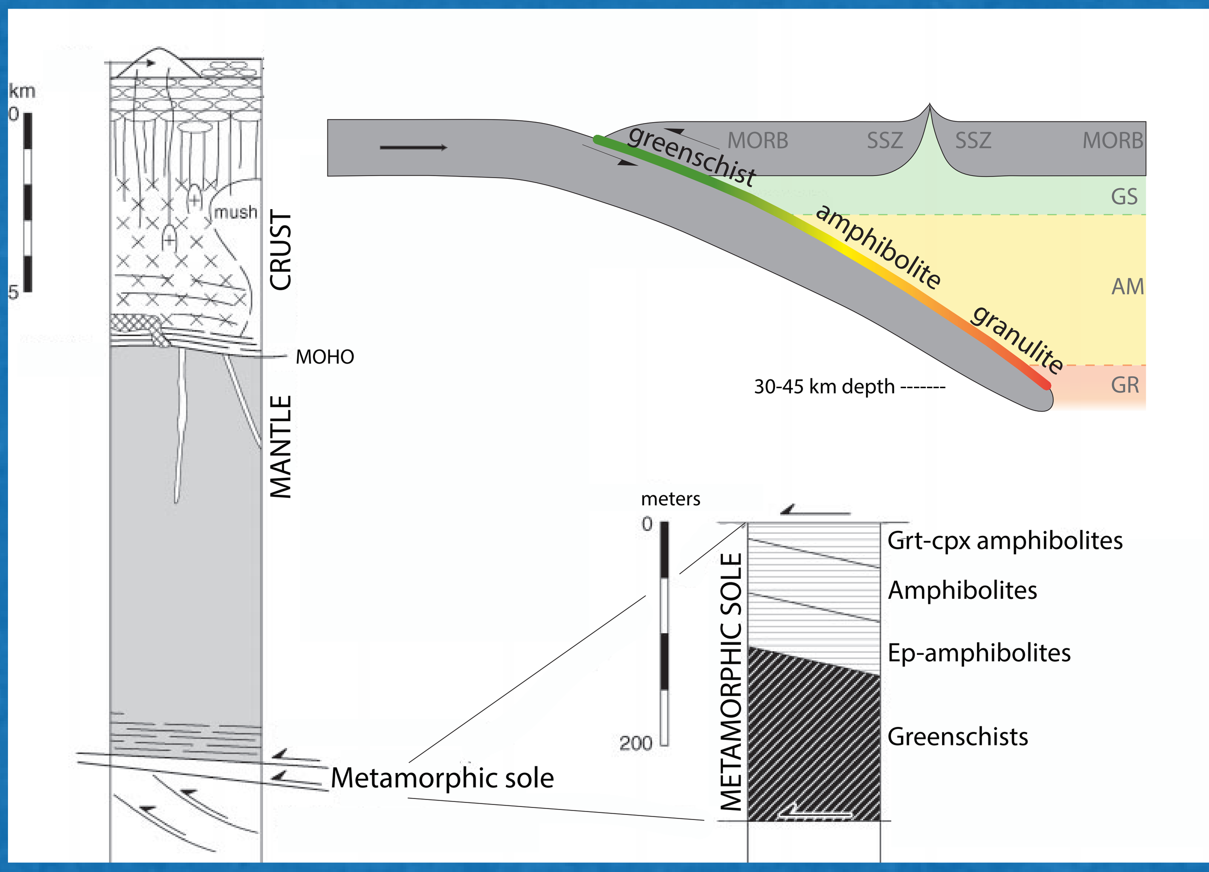
WHAT & WHY?

Metamorphic soles - how can they help to better constrain the physics of subduction initiation?

Metamorphic soles are intensily sheared, metamorphosed basalts and pelagic sediments that are welded to the mantle section of ophiolites with a so-called supra-subduction zone (SSZ) geochemical signature. They are interpreted to form at the top of a nascent oceanic subducting slab. These metamorphic rocks have a thickness of a few hundred meters and typically preserve an inverted metamorphic (field) gradient with P-T conditions up to 10-15 kbar (~30-45 km depth) and 875˚C.

The cause of the relatively high pressures is uncertain since the present-day overburden of the overlying ophiolite, cannot account for such high pressures. In addition, according to a geothermal gradient of 10˚/km for a mature subduction zone, we would expect temperatures of 300-450˚C at at 35-40 km depth. However, we find higher temperatures, implying that the metamorphic sole formed at the onset of subduction close to a ridge where the mantle has not cooled yet.

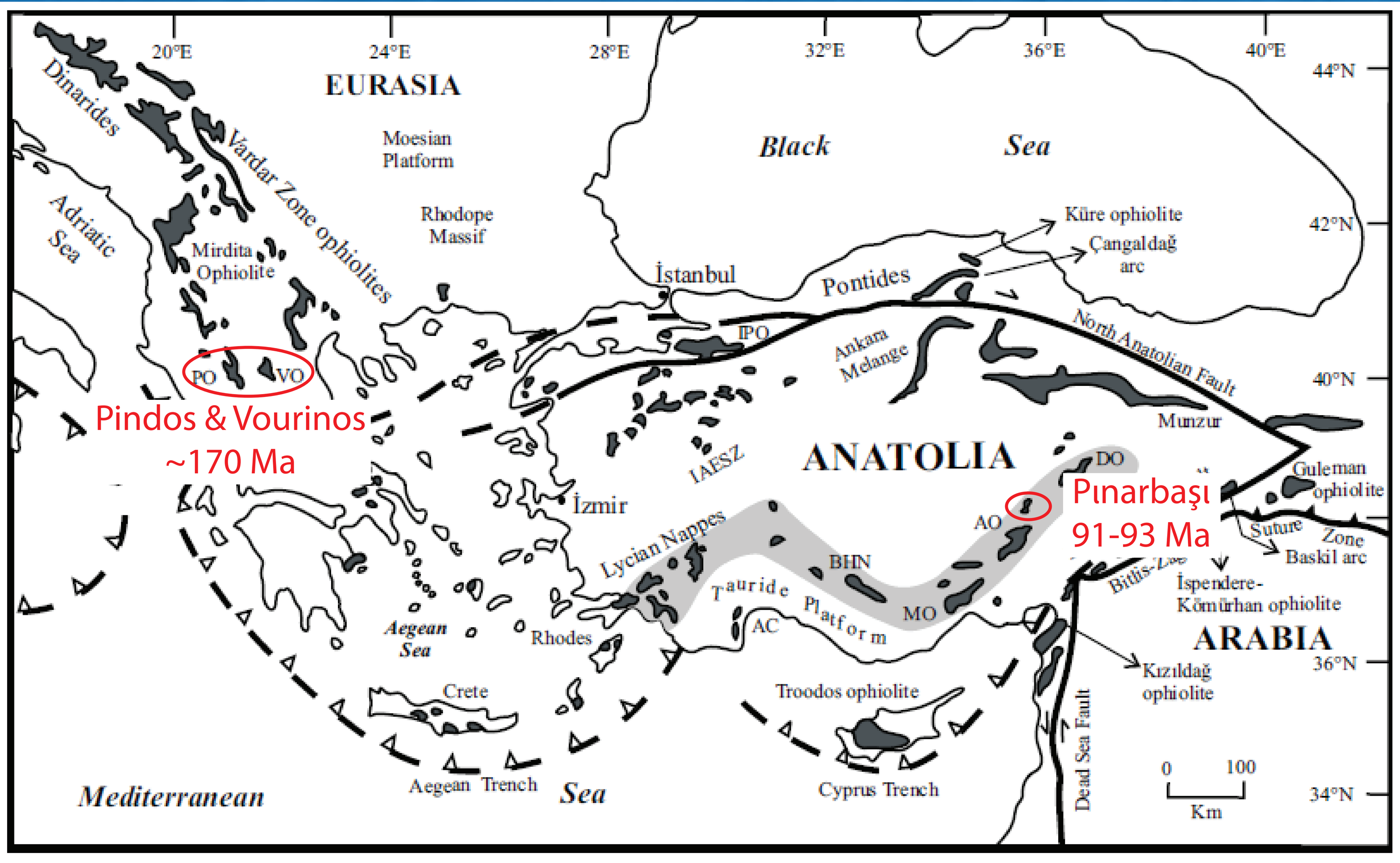
What is the formation mechanism of metamorphic soles?



Tectonostratigraphic column of the Oman ophiolite and metamorphic sole, modified from Searle and Cox, 2002. Schematic cross section of the tectonic setting of formation of the metamorphic sole, indicating at what levels the different metamorphic facies are formed.

HOW TO USE METAMORPHIC PETROLOGY?

Fieldwork: sampling and mapping of three metamorphic



Distribution of Neotethyan ophiolites in the Eastern Mediterranean region (Parlak et al., 2006; after Dilek and Flower, 2003).

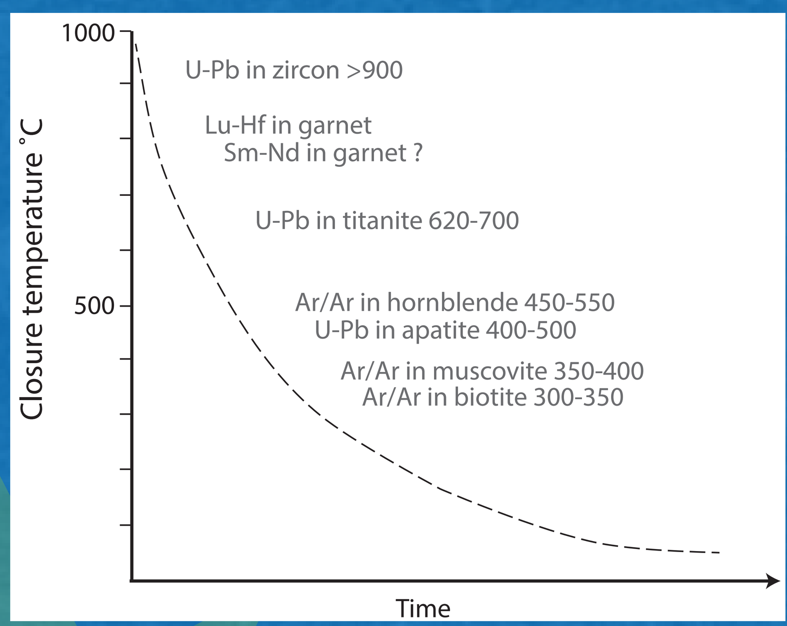
Analytical work

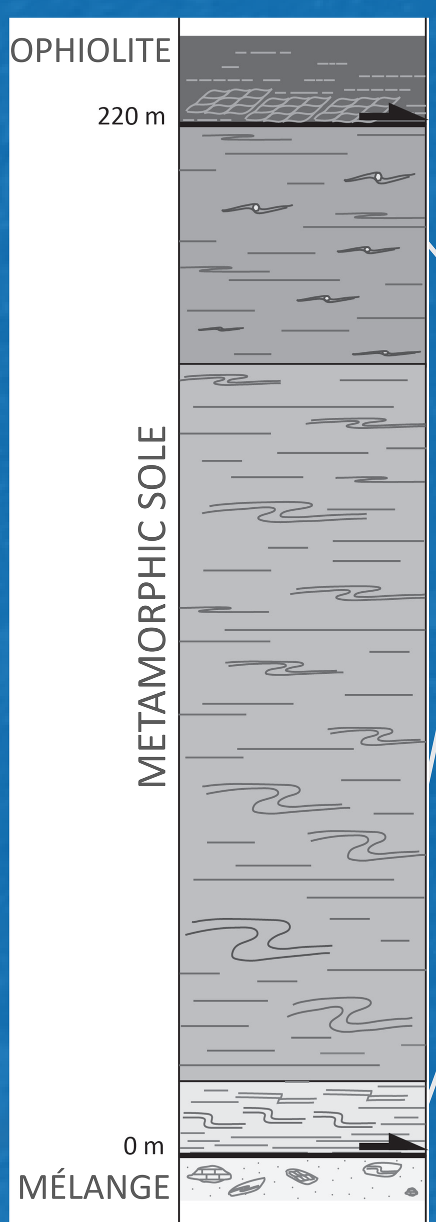
Electron microprobe analysis (EMPA): chemical composition of minerals
→ geothermobarometers: pressure or temperature conditions for a specific mineral reaction
→ solid solutions and zoning of minerals

X-ray fluorescence (XRF): bulk-rock composition
→ pseudosection modelling: stability fields for different equilibrium mineral assemblages

Geochronology:
Using different isotope systems to date the formation and cooling of all levels in the metamorphic sole

→ timing of metamorphic events

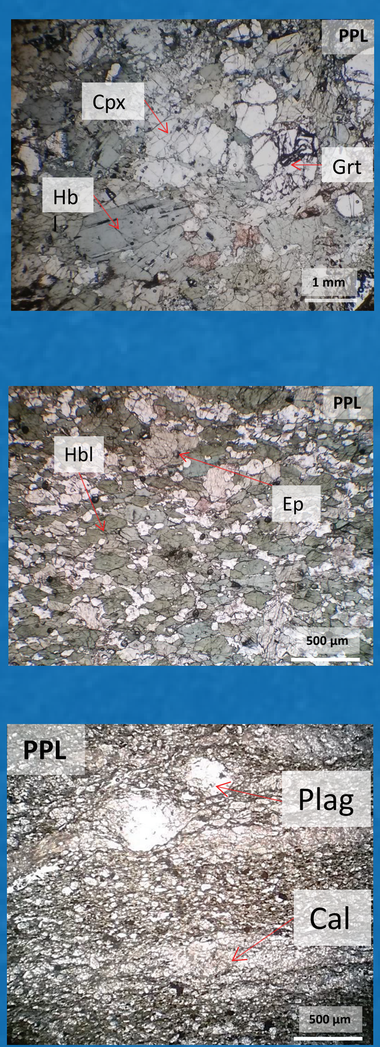




Tectonostratigraphic column of the metamorphic sole of the Pınarbaşı ophiolite (Turkey).

Field observations

Optical microscopy



Mineral assemblages

garnet - clinopyroxene hornblende - plagioclase ± titanite, ilmenite, hematite

old granulite facies overprinted by amphibolite

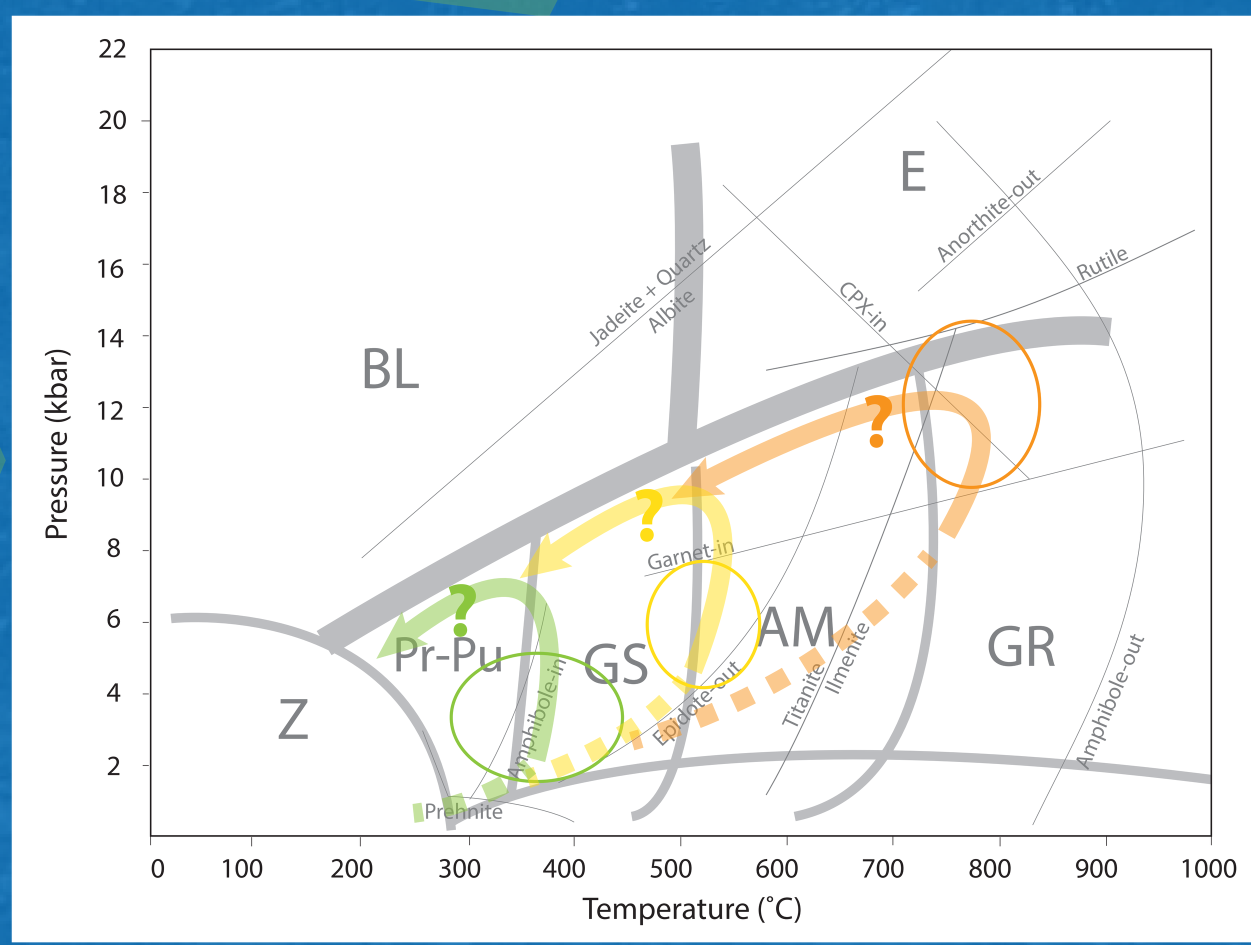
hornblende - epidote - plagioclase ± titanite, hematite, apatite

epidote-amphibolite facies

plagioclase - quartz - epidote - calcite

greenschist facies

Result: pressure - temperature - time (P-T-t) path

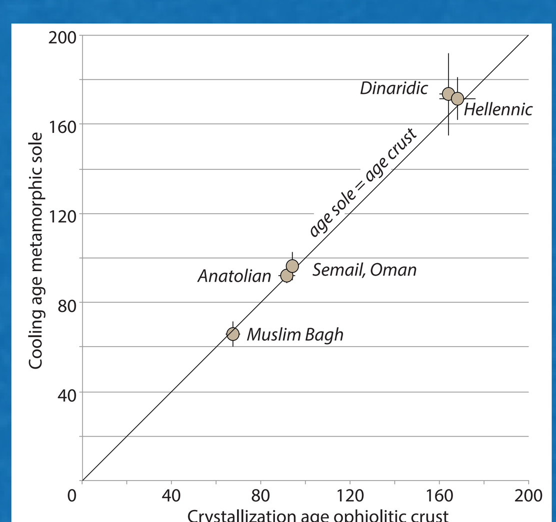


Pressure-temperature diagram (modified from Guilmette et al., 2008), showing the metamorphic facies (after Winter, 2001) and reaction curves of some index minerals. Inferred stability fields for the different levels in the metamorphic sole, based on stable mineral assemblages, indicated in coloured circles. Suggestions for P-T paths for the different levels in the sole are given, but they are not yet confirmed by analyses.

OUTLOOK

Metamorphic sole vs ophiolite

How are the metamorphic sole (top of a nascent subducting slab) and the overlying SSZ ophiolite (overriding oceanic lithosphere) related? We know that the metamorphic sole cooled (and formed?) during SSZ oceanic crust crystallisation, but many questions remain: How and when are the high-grade metamorphic sole rocks welded to the overlying oceanic lithosphere and exhumed to the surface? What are the P-T conditions of the ophiolite, and are pressures in the mantle section as high as in the top of the sole? We expect that (micro)structural observations, petrological- and chemical analysis could help to better define the relation between the sole and the ophiolite.



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