Longevity of metamorphism in metamorphic soles

implicatins for subduction initiation

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Metamorphic soles - do they form at the same moment as the overlying oceanic crust?

The initiation of subduction is key to the formation and recycling of tectonic plates. The best geological archive to study subduction initiation can be found underneath many supra-subduction zone (SSZ) ophiolites as a metamorphic sole. Metamorphic soles are interpreted to represent the upper part of a downgoing slab at the onset of subduction, when the mantle wedge has not yet cooled down. They consist of metamorphosed oceanic crust and pelagic sediments that are accreted to the mantle section of supra-subduction zone (SSZ) ophiolites.

Metamorphic soles typically show an inverted metamorphic field gradient, ranging from greenschist facies at the bottom to granulite facies at the top with peak metamorphic conditions up to ~850°C and 10-15 kbar (Jamieson, 1986; Dilek and Whitney, 1997; Hacker and Gnos, 1997; Wakabayashi and Dilek, 2000; Guilmette et al., 2008; Myhill, 2011).

The metamorphic history of the soles is typically investigated using 40Ar/39Ar hornblende chronology These age data consistently overlap with the crystallization age of their overlying SSZ ophiolites. This synchronicity could indicate that subduction started spontaneously (Stern, 2004). Nevertheless, 40Ar/39Ar data may in fact date cooling after a history that is not yet known.

What is the time difference between formation and cooling of the metamorphic sole?

Case study: petrology and multi-mineral chronology of Pınarbaşı metamorphic sole - Turkey

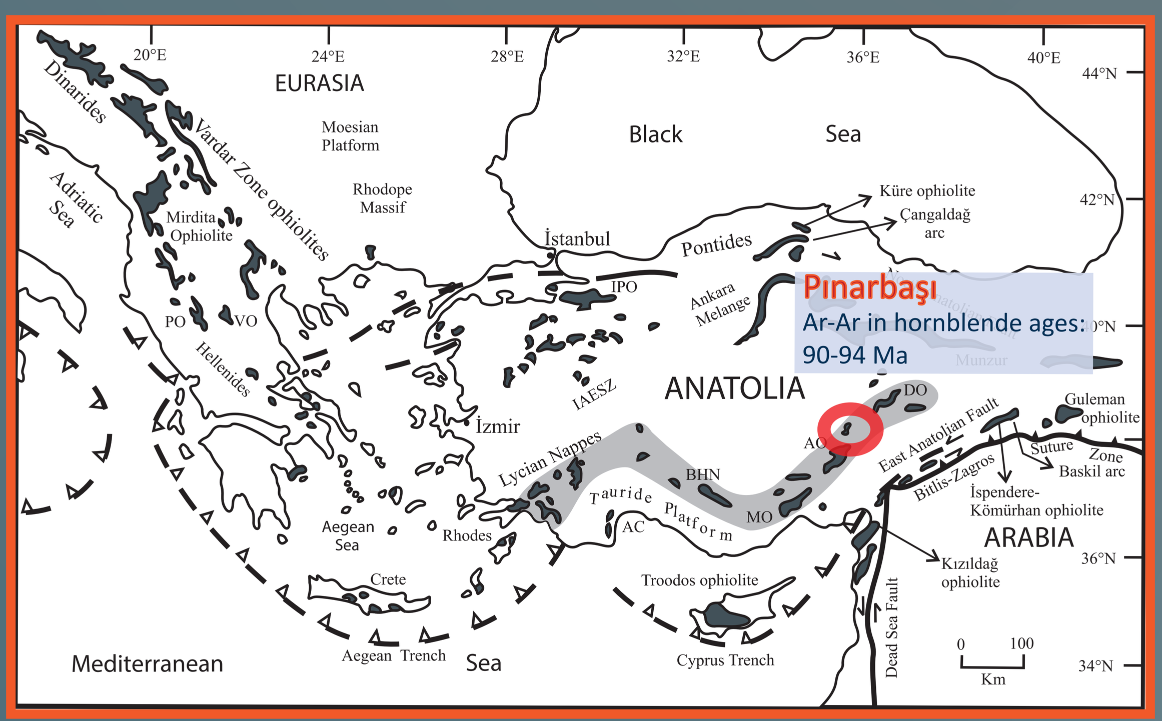


Figure 1. Distribution of Neotethyan ophiolites in the Eastern Mediterranean region, after Parlak (2006). 40Ar/39Ar ages for the metamorphic soles from Parlak (2016) and references therein.

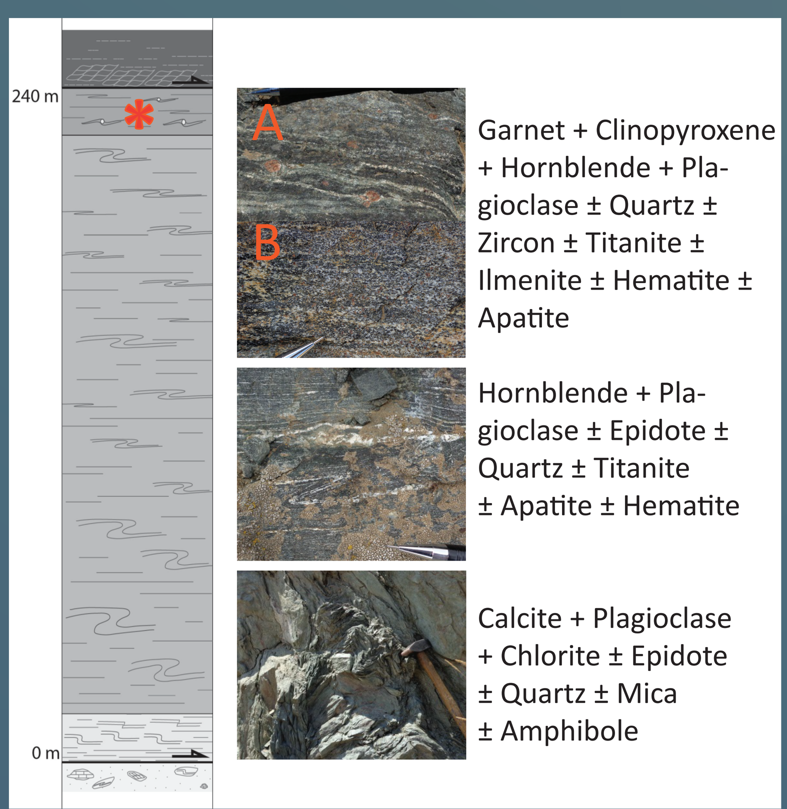
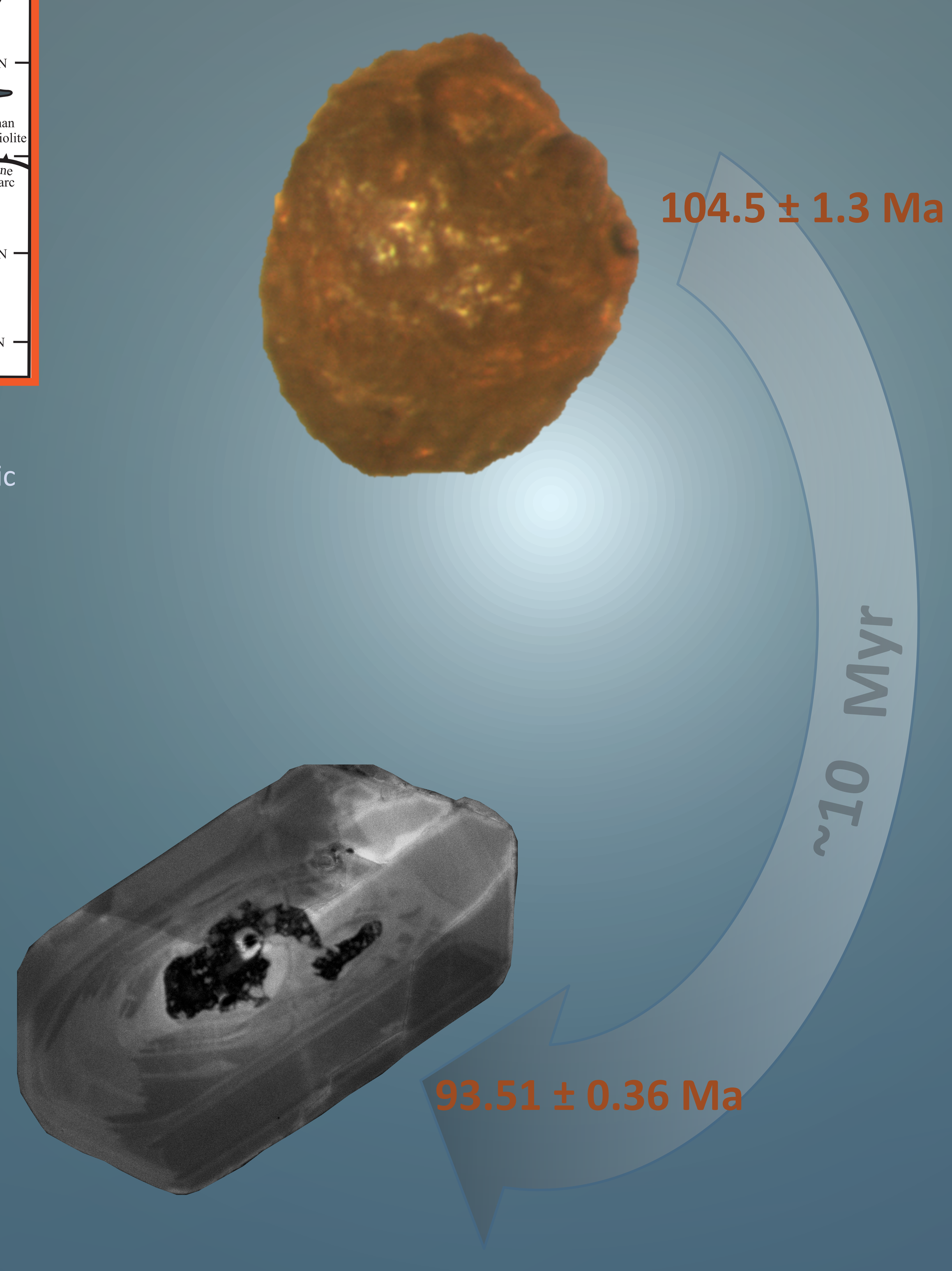


Figure 2. Tectonostratigraphic column and field photographs of the Pınarbaşı metamorphic sole, with serpentinised peridotite at the structural top and tectonic mélange underneath the metamorphic sole. Structural position of samples containing garnet and zircon indicated with a red star.



Lu-Hf in garnet: prograde metamorphism

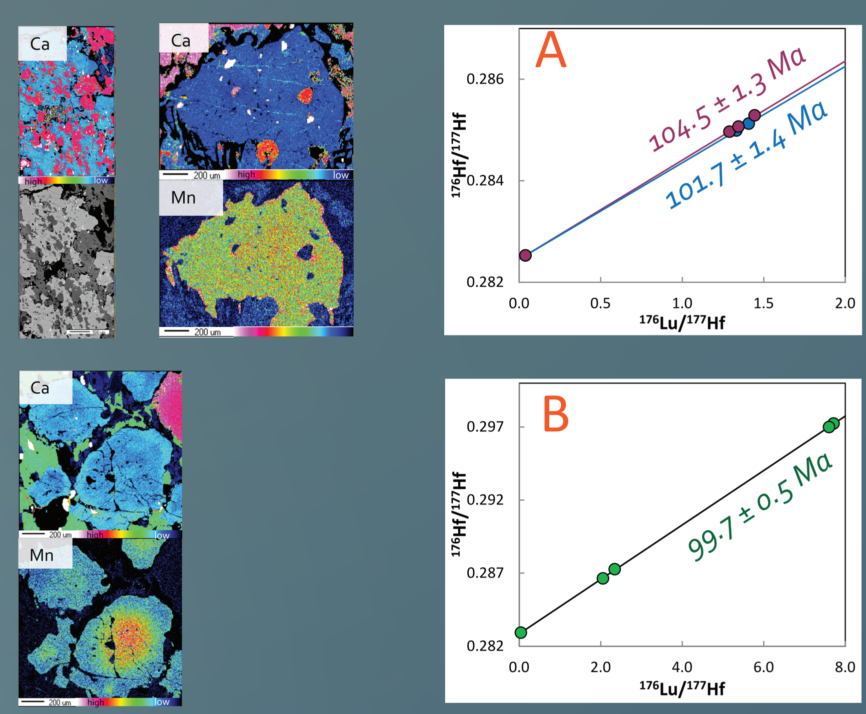


Figure 3. Ca and Mn element maps of garnet grains, and Lu-Hf garnet age of granulite facies garnet-amphibolite (A and B, see also figure 2), of the Pınarbaşı metamorphic sole.

U-Pb in zircon: peak metamorphism

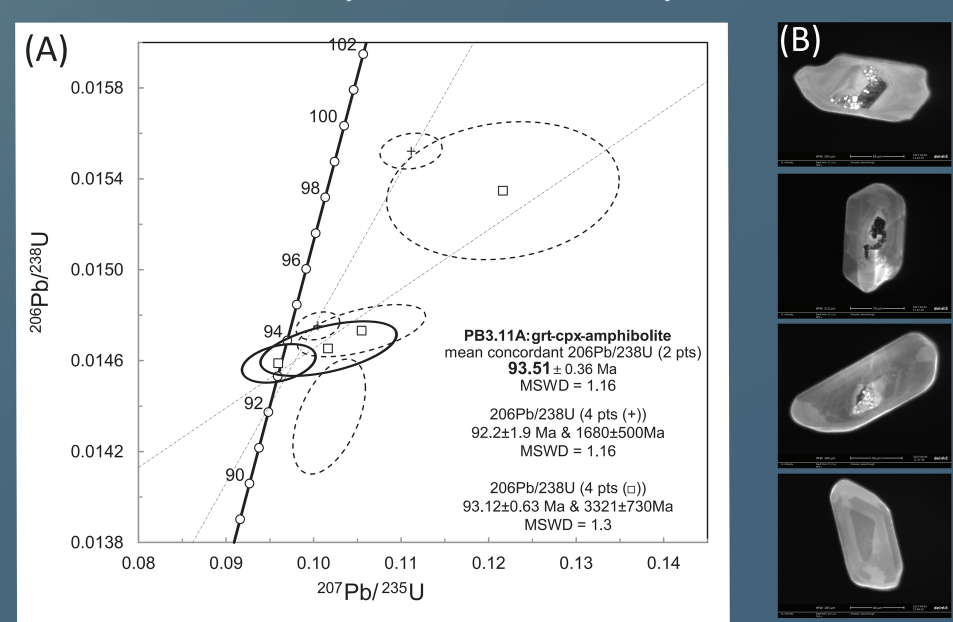


Figure 4. (A) Concordia diagram displaying U/Pb ages for zircon grains from the Pınarbaşı metamorphic sole. Ellipses indicate the 2σ uncertainty. MSWD = mean square of weighted deviates.
(B) CL images of zircon grains used for dating; grainsize 90-120 µm.

Results demonstrate that the highest grade rocks from the Pınarbaşı metamorphic sole (Turkey) started to undergo metamorphism around 104 Ma (Lu-Hf garnet chronology), earlier than our c. 94 Ma U-Pb zircon ages and published 40Ar/39 Ar cooling ages (90-94 Ma). The Lu-Hf in garnet age reflects the timing for burial and decoupling of the sole from the downgoing slab, and can be interpreted as the earliest documented timing of subduction initiation. The U-Pb in zircon age most likely indicates zircon crystalization from a partial melt within the sole at peak temperatures (Guilmette et al., 2018). From that time on, the metamorphic sole started to exhume, as indicated by published 90-94 Ma Ar-Ar in hornblende ages from metamorphic soles in the Tauride ophiolites (Parlak, 2016). Around 90 Ma, extension in the upper plate led regionally to the formation of SSZ ophiolitic crust (Van Hinsbergen et al., 2016).

The ~10 Myr age difference between the Lu-Hf in garnet ages, and the U-Pb in zircon and Ar-Ar in hornblende ages demonstrates that there is a significant time lag between the formation of the sole and cooling of the sole and upper plate extension in Pınarbaşı. Such a time lag provides evidence for far-field forced subduction initiation.

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