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Magnitude and meaning of time lags between the formation and cooling of Neotethyan metamorphic soles from multi-chronology

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The initiation of subduction is key to the formation and recycling of tectonic plates. To investigate the mechanism of subduction initiation, we explore the history of metamorphic soles, which are 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. These conditions are uncommon in mature subduction zones and therefore metamorphic soles are interpreted to form at the onset of subduction as the top of the nascent slab that is in contact with the still hot overlying mantle wedge.
The metamorphic history of the soles is typically investigated using 40Ar/39Ar hornblende dating. The age data consistently overlap with the crystallization age of their overlying SSZ ophiolites. This synchronicity could indicate that spreading in the overriding plate and sole cooling are causally linked. Nevertheless, 40Ar/39Ar data may in fact date cooling after a history that is not yet known.

In this study, we conducted an integrated multi-mineral chronological analysis on the metamorphic soles of three Tethyan ophiolites: the Vourinos and Pindos belts in northern Greece and the Pınarbaşı ophiolite in Turkey. The Lu-Hf system provides reliable age constraints on the growth of garnet—a prime prograde index mineral that may reveal the early stages of sole formation. The Lu-Hf ages of garnet demonstrate that the Pınarbaşı metamorphic sole was undergoing metamorphism around 104 Ma. The ages are older than our U-Pb zircon ages (c. 94 Ma) and published 40Ar/39Ar cooling ages (94-90 Ma). The Vourinos and Pindos metamorphic soles yield garnet Lu-Hf ages of c. 171 Ma from the highest grade garnet-amphibolites in Vourinos, and 169 Ma for lower grade garnet-micaschists of the Pindos sole. These ages are both synchronous with published 40Ar/39Ar cooling ages on hornblende. Available kinematic reconstructions and geochemical affinities of the ophiolites show that subduction initiated in Greece in Jurassic times close to a spreading ridge, while the Cretaceous subduction in Turkey started closer to a continental margin.

The ∼10 Ma age difference between the formation and cooling of the metamorphic sole in Pınarbaşı, and rapid cooling of the metamorphic sole in Vourinos suggest that subduction initiation is not a uniform process, but may vary for different tectonic settings. We propose that the delay between subduction initiation and sole cooling could be a function of lithosphere thickness; the thicker (and older) the lithosphere in which subduction starts, the longer the time lag that may occur between the formation and cooling of the metamorphic sole.