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Forced subduction initiation in Oman revealed by ophiolite-sole couple geochronology

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Subduction zones are unique to Earth and fundamental in its evolution, yet the processes responsible for subduction initiation (SI) remain enigmatic. Numerical modeling indicates that SI either results from far-field forcing or spontaneous lithospheric gravitational collapse, but unequivocal geological proof of one or the other remains elusive. A fundamental diagnostic prediction of the two models is the time lag between nucleation of the subduction plane and ensuing upper plate extension. During spontaneous SI, area consumed by subduction must immediately be balanced by area gain through upper plate extension, resulting in a short or nil time lag. In contrast, upper plate extension following induced SI must be generated by the growing slab after a period of underthrusting, resulting in a time lag. Constraining such time lag requires chronological data from both rocks that recorded formation of the incipient subduction thrust, and that formed at the onset of upper plate extension.
Suprasubduction zone ophiolites such as the archetypal Semail ophiolite of Oman and its associated metamorphic sole expose remnants of the upper and lower plate of an incipient subduction zone. The age of extension and crustal accretion in the Semail ophiolite has been estimated by U-Pb dating of zircon from gabbros and plagiogranites, interpreted to have formed below a spreading ridge between 96.1-95.5 Ma. On the other hand, the age of initial burial of the lower plate under the Semail ophiolite was estimated from 40Ar/39Ar hornblende or mica dating from the metamorphic sole and U-Pb dating of zircons from melt segregations. The resulting 96.16-92.6 Ma metamorphic ages coincide or slightly postdate the ages of the magmatic crust of the overlying ophiolite, suggesting that there is no time lag between initial burial of the lower plate and upper plate extension. This synchronicity is typical of most if not all ophiolite-sole couples, hinting that spontaneous SI could be a process inherent to suprasubduction zone ophiolite genesis. The meaning of this coincidence in terms of sole formation is nevertheless debated. Both geochronological methods may date post-peak conditions rather than burial of the sole.
A promising technique in this regard is Lu-Hf dating of garnet. This method allows reliable time constraints on the growth of garnet, a petrological indicator of burial and heating in metamorphosed rocks. Here, we apply this approach to garnet from the metamorphic sole of the Semail ophiolite of Oman — specifically on the garnet-clinopyroxene amphibolites of the upper sole section — to date the early stages of sole development. The results are supported by textural observations, trace element mineral chemistry, and new U-Pb zircon and titanite data. The comparison of our new 104 Ma Lu-Hf garnet growth ages in the metamorphic sole and published 96.1-95.5 Ma extension ages in the overlying ophiolite constrains a minimum time lag of 8 Myr between initial lower plate burial and incipient upper plate extension, consistent with an induced SI. Consequently, the causes for the onset of convergence in the Cretaceous Neo-Tethys must be sought after prior to 104 Ma, in the far-field.