New zircon radiometric U/Pb ages and Lu-Hf isotopic data from the ultramafic-mafic sequences of Ranau and Telupid (Sabah, east Malaysia): Time to reconsider the geological evolution of Southeast Asia?

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Cullen and Burton-Johnson (2021) offer a reinterpretation of our zircon age data (Tsikouras et al., 2021), providing some highly arguable statements. We take this opportunity to confirm that the Ranau peridotite (RP) is not genetically associated with the Telupid ophiolite (TO). There is abundant evidence that the RP includes subcontinental lithospheric mantle (SCLM) peridotites, impregnated by magmatic fluids (Tsikouras et al., 2021). We consider that most likely the melt-rock reactions in these rocks followed rifting and extension. The Miocene zircons in our study derived from two very different sources: (1) the RP SCLM, in which the zircons are interpreted as a phase crystallized from impregnating fluids; and (2) the TO basalt and diabase (i.e., typical magmatic rocks). Only the TO is interpreted as the westernmost end of the Sulu Sea spreading. A major population of zircons from both suites yielded similar Miocene ages, clustering at around 9.2–10.5 Ma, because they formed during the same extensional phase. The Miocene zircons show similar Lu-Hf isotopic characters and εHf ranges, likely indicating that melts percolating in the RP were contemporaneous with basaltic melts of the TO. Distinguishing magmatic from metasomatic zircons is not always an easy task, but there are several lines of evidence which strongly support the magmatic origin of our dated zircons. Metasomatic zircon crystals show the following morphological features (Corfu et al., 2003): (1) irregular patterns and/or bent prisms; (2) other mineral inclusions and/or inherited cores; (3) curved or diffused zoning, which does not follow the crystal outline; (4) high-U margins as emplacements in low-U areas; and (5) homogenized patterns. No zircon from other mineral inclusions and/or inherited cores; (3) curved or diffused zonings (see the Supplemental Material of our paper). In contrast to the claim by Cullen and Burton-Johnson of crust thicker than 35 km beneath Sabah, Pilia et al. (2021) reported passive-seismic data and thermomechanical simulations which demonstrate significant variations in crustal thickness with crust >50 km thick beneath the Trusmadi Mountains, <35 km in Ranau, and <30 km in the Telupid area. The thicker crust is the result of Early Miocene collision, which was subsequently thinned by Late Miocene extension. Apart from the above, the five points of Cullen and Burton-Johnson can be easily refuted:

(1) We do not deny Cretaceous rocks in the Chert-Spilite Formation (CS) in fault contact with the TO (Tsikouras et al., 2021). However, we do not consider these to date the TO. In the area between Telupid and Tongod, Kirk (1968) demonstrated that intrusive basaltic and gabbroic rocks are separate units from the CS and reported Miocene limestones intercalated in basalts (Kirk, 1968, p. 37); in later maps, these basalts were assigned to CS Formation despite their Miocene age.

(2) Newton-Smith (1967) mapped ultrabasic conglomerates as parts of the CS in the Bidu-Bidu Hills. Hutchison and Surat (1991) speculated that the undated ultrabasic rocks should be assigned to the Oligocene Kulapis Formation. In the same area, Newton-Smith (1967) reported ultramafic plutons with presumed Paleocene to Late Miocene ages.

(3) There are many northeast-southwest-oriented faults in Sabah, which despite their steep dips have commonly been interpreted as thrusts. Wang et al. (2017) showed that the 2015 Sabah earthquake resulted from the rupture of a steep northeast-southwest normal fault. Lai et al. (2021) reported that moment tensor solutions from shallow earthquakes suggest northwest-southeast extension. Cullen and Burton-Johnson’s figure 1 shows a misleading map allegedly with our interpretation of the spreading axis of the Sulu Sea transecting the whole of north Borneo. We suggested extension of the spreading axis only few kilometers onshore into Sabah consistent with data from Pilia et al. (2021).

(4) The free-air gravity anomaly map of Bai et al. (2020) shows a negative anomaly at the extension of the Sulu trench in Sabah. This could be an indication of significant crustal thinning and asthenosphere upwelling similar to the Sulu and South China Seas, in accordance with our interpretation.

(5) The seismic data presented by Linang et al. (2021) indicate an average crustal thickness in Sabah of 35 km, but the variations of crustal thickness are almost exactly the same as those in Pilia et al. (2021).

We find it ironic that Cullen and Burton-Johnson suggest we have misrepresented our new zircon ages to fit a tectonic model when they continue a pattern of ignoring, misinterpreting, or disregarding information that does not support a Cretaceous age for ophiolites and “ophiolitic basement” (Hutchinson, 2005) of Sabah. This reinforces the question of our title: “time to reconsider the geological evolution of Southeast Asia?”

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