Comment on “Neotethyan subduction ignited the Iran arc and back-arc differently” by Shafaii Moghadam et al. (2020)

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November 22, 2022

Abstract

Shafaii Moghadam et al. (2020) contribute important new data on Late Cretaceous-Tertiary subduction- related magmatism in Iran, but their plate convergence model, wherein Neotethyan subduction begins in mid-Cretaceous time (c. 100 Ma), overlooks well established facts relating to the tectonic history of Neotethys, in regard to global plate reconstructions, paleolatitude data, the regional stratigraphy, geochronology and geochemistry, and metamorphic history. Based on their model, Neotethys subduction beneath Eurasia began at ~100 Ma, meaning that the Neotethys was spreading and bounded by opposing passive margins during Jurassic and Early Cretaceous time, for ~100 Ma prior to their proposed onset of Neotethyan convergence. Consequently, their subduction model contradicts (1) the Indian Ocean spreading history derived from magnetic anomalies; (2) continental paleolatitude data from paleomagnetism; (3) sedimentary and igneous evolution of the Mesozoic continental margins in Arabia and southern Asia, (4) the age and geochemistry of Jurassic igneous rocks in southernmost Eurasia; and (5) the preservation of Early to Middle Jurassic eclogite metamorphism and exhumation on the northern side of the Arabia-Eurasia suture. Reconciliation of each of these omissions and contradictions of their model would be welcome, and perhaps an advisory that readers may wish to evaluate their concept of Cretaceous subduction initiation with due circumspection.

Comment on "Neotethyan subduction ignited the Iran arc and back-arc differently" by Shafaii Moghadam et al. (2020), Journal of Geophysical Research. doi:10.1029/2019JB018460

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Shafaii Moghadam et al. (2020) contribute important new data on Late Cretaceous-Tertiary subduction-related magmatism in Iran, but their plate convergence model, wherein Neotethyan subduction begins in mid-Cretaceous time (c. 100 Ma), overlooks well established facts relating to the tectonic history of Neotethys, in regard to global plate reconstructions, paleolatitude data, the regional stratigraphy, geochronology and geochemistry, and metamorphic history. Based on their model, Neotethys subduction beneath Eurasia began at ~100 Ma, meaning that the Neotethys was spreading and bounded by opposing passive margins during Jurassic and Early Cretaceous time, for ~100 Ma prior to their proposed onset of Neotethyan convergence. Consequently, their subduction model contradicts (1) the Indian Ocean spreading history derived from magnetic anomalies; (2) continental paleolatitude data from paleomagnetism; (3) sedimentary and igneous evolution of the Mesozoic continental margins in Arabia and southern Asia, (4) the age and geochemistry of Jurassic igneous rocks in southernmost Eurasia; and (5) the preservation of Early to Middle Jurassic eclogite metamorphism and exhumation on the northern side of the Arabia-Eurasia suture. Reconciliation of each of these omissions and contradictions of their model would be welcome, and perhaps an advisory that readers may wish to evaluate their concept of Cretaceous subduction initiation with due circumspection.

Global plate circuit. The Jurassic was the time of breakup of Pangea, when the spreading histories of the Atlantic and Indian oceans began. Once the Atlantic Ocean began spreading, there was subduction all along the western margin of the Americas, i.e., parallel to the nascent Atlantic mid-ocean ridge, to compensate for the increasing Earth surface area in the Atlantic. More closely related to the evolution of the Tethys, seafloor spreading began with rifting of Afro-Arabia from Antarctica to cause opening of the western Indian Ocean. The associated expansion occurring to the south of Africa was oriented north-south and required north-south convergence between Afro-Arabia and Eurasia. During the Jurassic and Early Cretaceous at the longitudes of the western Indian Ocean, the Neotethys was the Earth's only east-west trending ocean. Therefore, from a planetary perspective, subduction initiation must have begun in the Jurassic to balance the surface area increase and to complete the Mesozoic seafloor spreading circuit. Jurassic subduction in the Tethys was also a critical driving mechanism for the coeval Pangea breakup (Keppie, 2016). Indeed, Jurassic subduction initiation has long been a globally recognized scenario for the plate tectonic history of Neotethys, adopted by the Commission for the Geologic Map of the World (CGMW) (Dercourt et al., 2000) and all research institutions charged with evaluating and revising paleogeographic reconstructions of the system (e.g., Lawver et al., 2015; Scotese, 2017).

Continental paleolatitude data. The subduction model advocated in Shafaii Moghadam et al. (2020) contradicts paleomagnetic data available for the peri-Tethyan realms. A difference in timing of subduction initiation between the two models, c. 200 Ma versus 100 Ma, is wholly sufficient for testing the two models based on paleolatitudinal concordance through time. Paleomagnetic data show that the Cretaceous (ca. 100 Ma) ocean width was at least 10° less than the width in Jurassic (ca. 180 Ma) (e.g., Soffel et al., 1996; Besse et al., 1998; Gallet et al., 2000; Muttoni et al., 2009; Torsvik and Cocks, 2016), contradicting the 100 Ma initiation model (see, e.g., Fig. 11 in Müller et al., 2016; Fig. 7 in Hosseinpour et al., 2016). In support of their model, Shafaii Maghadam et al. (2020) cite the model of Golonka (2004), which -for Iran part- is at odds with the regional geology (elaborated below) by speculating that Paleotethys remained open at 225 Ma and proposing two Neotethys Oceans at the longitudes of Arabia and Iran, strongly disagreeing with more recent syntheses (i.e. Hassanzadeh and Wernicke, 2016; Müller et al. 2016; Torsvik and Cocks, 2016).

Geological constraints: Zagros-SaSZ Mesozoic stratigraphy. Based on stratigraphic, igneous and structural records, the Neotethys Ocean began spreading between the Zagros and the SaSZ in the Permian (c. 275 Ma; e.g., Berberian and King, 1981; Hassanzadeh and Wernicke, 2016). Passive margin development on either side of the oceanic basin, now represented as the Zagros suture (Fig 1A in Shafaii Moghadam et al., 2020), led to Atlantic-type carbonate shelf deposition. The sedimentary records preserved in the Zagros-Persian Gulf and the SaSZ reveal isopachs trends disposed quasi-symmetrically on either side of the suture in Permian through Triassic time, indicating two facing passive margins, supported by subsidence analysis (e.g., Edgell, 1977; Stöcklin and Setudehnia, 1991; Figs. 2 and 6 in Hassanzadeh and Wernicke, 2016). These records show that shelf carbonate deposition continued throughout Permian and Triassic time on both margins, suggesting that the Neotethys was spreading during that interval (c. 275-200 Ma). Throughout the Jurassic-Early Cretaceous, carbonate deposition continued along the northeast-facing Arabian margin (e.g. Formations included in Khami and lower Bangestan Groups). In the SaSZ, however, sedimentation changed abruptly from shelf carbonate to volcanic-rich detrital deposits and volcanics (equivalent of Shemshak Formation) near the Triassic-Jurassic boundary (Stöcklin and Setudehnia, 1991; Hassanzadeh and Wernicke, 2016). If subduction had initiated in the mid-Cretaceous then obviously shelf carbonate deposition would have continued along the SaSZ passive margin through Jurassic-Early Cretaceous time, and there would be Khami-Bangestan-type limestone formations on the Eurasian side of the ocean as well, contradicting well established observations.

Geochemistry of the Jurassic magmatism. Shafaii Moghadam et al. (2020) have tied their mid-Cretaceous subduction initiation model to a Jurassic continental rift idea (Azizi and Stern, 2019) which contradicts numerous reports documenting the age and geochemistry of widespread Jurassic calc-alkaline magmatism along the length of the SaSZ. The rift model places emphasis on the A-type granite and alkaline geochemistry reported for minor magmatic rocks in the northwestern sector of the belt. A more viable model, accounting for the localized nature of these minor magmas, and still compatible with Jurassic global tectonics, is the local slab window hypothesis proposed by Zhang et al. (2018). Generally, extension and alkaline magmatism are not exclusive of “continental rifts” and both commonly occur in suprasubduction settings. Cretaceous subduction initiation also ignores the boninitic compositions already documented for various Jurassic rock associations in several parts of the SaSZ (Esna-Ashari et al., 2016 and references therein).

Subduction channel metamorphism. Eclogite facies metabasites, exposed near the Zagros suture in the central SaSZ, have recently been dated at 184 to 173 Ma (Early to Middle Jurassic) based on phengite $^{40}Ar/^{39}Ar$ ages (Davoudian et al., 2016). A felsic pegmatite formed by partial melting of the metamorphic host of these metabasites show overlapping U-Pb zircon ages of ~177 Ma and indicate rapid cooling immediately after high-pressure metamorphism in the subduction channel at ~200 Ma (Jamali Ashtiani et al., 2020). Cretaceous subduction initiation does not account for these observations.

In summary, the Cretaceous subduction initiation model of Shafaii Maghadem et al. (2020) for the Neotethys Ocean fails nearly every critical test in regard to plate circuit, paleomagnetic, stratigraphic, magmatic and metamorphic constraints, as predicted by the Wilson Cycle. A brief analysis of their summary tectonic figure (Fig. 11), which is difficult to match with their Figure 1, is instructive as it relates to the SaSZ. (1) The SaSZ in their Fig. 1 is not shown in Fig. 11, requiring the reader to ascertain that its location is on the Eurasian side of the Main Zagros Thrust, i.e. at the immediate northern margin of Neotethyan Ocean. (2) If the SaSZ was an intracontinental Jurassic rift, as stated in the paper, how did it find its way into the position inferred for Fig. 11? Based on Fig. 1, the SaSZ was in a forearc position during subduction initiation. Where is the other continental mass bisected by the supposed rift? (3) There is a supra-subduction oceanic forearc basin labeled "Zagros" in Fig. 11. Why is it attributed to the "Zagros"? The passive margin that is going to change into the Zagros 80 Ma later is on the southern margin of the Neotethyan Ocean, not the northern margin as shown. Because of this ca. 1000 km separation, is it not more reasonable to name this area the "SaSZ forearc"? Obviously, naming that arc element as "SaSZ forearc" was avoided, because it would necessitate a suprasubduction setting for the "SaSZ continental rift." (4) What would justify the pre-subduction rift? Do all modern continental magmatic arcs include such an element? (5) During ca. 80 Ma between intracontinental rifting and the onset of subduction, passive margin deposits would necessarily have formed on the southern edge of the SaSZ. No such Jurassic to mid-Cretaceous shelf carbonate successions are exposed anywhere along the length of the SaSZ. We observe instead a c. 1700 km-long belt containing and interval of volcanic sediments and volcanics, intruded by numerous calc-alkaline stocks and batholiths (e.g., Figs. 1, 5 and 7 of Hassanzadeh and Wernicke, 2016).

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