Why Archaean TTG cannot be generated by MORB melting in subduction zones

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Abstract

Until recently it was assumed that the Archaean continental crust (made of TTGs: tonalites, trondhjemites, and granodiorites) was generated through partial melting of MORB-like basalts in hot subduction environments, where the subducted oceanic crust melted at high pressure, leaving a garnet-bearing amphibolitic or eclogitic residue. However, recent geochemical models as well as basalt melting experiments have precluded MORB as a plausible source for TTGs. Rather, geochemical and experimental evidences indicate that formation of TTG required a LILE-enriched source, similar to oceanic plateau basalts. Moreover, subduction is a continuous process, while continental growth is episodic. Several "super-growth events" have been identified at ~ 4.2, ~ 3.8, ~ 3.2, ~ 2.7, ~ 1.8, ~ 1.1, and ~ 0.5 Ga, which is inconsistent with the regular pattern that would be expected from a subduction-driven process. In order to account for this periodicity, it has been proposed that, as subduction proceeds, descending residual slabs accumulate at the 660-km seismic discontinuity. When stored oceanic crust exceeds a certain mass threshold, it rapidly sinks into the mantle as a cold avalanche, which induces the ascent of mantle plumes that in turn produce large amounts of magmas resulting in oceanic plateaus.

However, melting at the base of thick oceanic plateaus does not appear to be a realistic process that can account for TTG genesis. Modern oceanic plateaus contain only small volumes (≤ 5%) of felsic magmas generally formed by high degrees of fractional crystallization of basaltic magmas. The composition of these felsic magmas drastically differs from that of TTGs. In Iceland, the interaction between a mantle plume and the mid-Atlantic ridge gives rise to an anomalously (Archaean-like) high geothermal gradient resulting in thick basaltic crust able to melt at shallow depth. Even in this favorable context though, the characteristic Archaean TTG trace element signature is not being produced. Consequently, internal recycling of oceanic plateaus does not appear to be a suitable process for the genesis of Archaean continental crust.

A possible alternative to this scenario is the subduction of oceanic plateaus. This hypothesis is supported by a present-day analog. In Ecuador, the Carnegie ridge, which is an oceanic plateau resulting from the Galapagos hot spot activity, is being subducted beneath the South American plate. Not only are the resulting magmas adakitic (TTG-like) in composition, but the volcanic productivity is several times greater than in other parts of the Andean volcanic arc. Above the location where the plateau is subducted, the arc is wide and the quaternary volcanoes numerous (about 80 active edifices). The volcanic productivity of each individual volcano also is more intense than away from the subduction focal point with an average output rate of about 0.4–0.5 $km^3 \cdot ka^{-1}$ compared with only about 0.05–0.2 $km^3 \cdot ka^{-1}$ for production rates at volcanoes erupting in the rest of the arc. Consequently, we infer that occasional subduction of oceanic plateaus throughout Earth's history can account for the episodic nature of crustal growth. Additionally, the generation by this mechanism of huge volumes of TTG-like magmas would readily dominate the crustal growth record.

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