Building continental crust top down

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The silicic continental crust (CC) is a unique feature of earth that has major influence on processes ranging from plate tectonics to biological evolution. The part of the CC we know best, the upper CC, has a composition virtually identical to that of convergent margin granitoids. Thus, understanding the process forming plutons, and ultimately batholiths such as the Sierra Nevada, is critical to understanding CC formation.

The igneous origin of granite (in general) was set by the seminal work of Tuttle and Bowen (1958) which showed that Earth's granites had compositions similar to the minimum melt in the SiO_2-$NaAlSi_3O_8$-$KAlSi_3O_8$-H_2O system. Their conclusion, that granites are igneous following controls by thermodynamic equilibrium, remains valid today. Yet the two most commonly cited differentiation mechanisms, partial melting and fractional crystallization, cannot explain this relationship in any reasonable way (the *conundrum*). In other words, do we think that the bulk composition of granites reflects a melt separated from a quartz-feldspar assemblage and then emplaced elsewhere? Thermal migration zone refinining (TMZR), combining a top down sill accretion process with an in situ temperature gradient process, has been proposed as an alternative mechanism for forming convergent margin plutons[1]. Thermal migration experiments using andesite + 4wt.% H_2O produce granite compositions at the cold end of a temperature gradient from a starting andesite that was not originally minimum melt. Thus TMZR is a process controlled by mineral-melt equilibrium which bypasses the conundrum—the Tuttle and Bowen (1958) observation is explained without a process needing mechanical separation of crystals and melt (PM or FC).

During TMZR, andesitic melts arrive at the base of the top-down growing pluton. If the mafic root stays attached to granite, then TMZR is simply an intracrustal differentiation process. However, TMZR results in net silicification of CC if the mafic base delaminates into the mantle. Based on experiments, the mafic root of TMZR transforms into garnet gabbro at 0.5 GPa; this root should be dynamically unstable and likely delaminate, increasing SiO_2 of the CC. Notably the size of a predicted TMZR delaminant is similar to the drip imaged geophysically beneath the southern Sierra Nevada[2]. TMZR with delamination may also provide an explanation for volcanic-tectonic cycling observed in the convergent margin geologic record and possibly geochemical changes of the CC such as Nb/Ta.

[1] Lundstrom (*GCA* **73**, 2009); [2] Zandt *et al* (*Nature* **431**, 2004).