Plumes, Plates, and Crust Formation in the Early Earth

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Understanding the role of arc magmatism in the formation of Earth's earliest continental crust requires identification of "fingerprints" of ancient arc magmatic processes that are appropriate for early earth systems. One oft cited difference between the modern earth and the early earth is higher radiogenic heat flux (3-6x), which contributed to higher mantle potential temperatures, which led to shallower subduction angles, which led to voluminous slab melts of TTG and/or adakitic compositions, which exhibit the normalized trace element distributions typical of modern arc magmas (i.e., LIL-enriched spidergrams with negative anomalies of HFSE). In modern systems, hydrous melting is thought to contribute to the development of these signatures and there is little reason to doubt this analogy is a reflection of hydrous melting in arc systems throughout geologic time. In particular, Mesoarchean TTG rocks from the northern Wyoming Province exhibit these elemental characteristics and have been interpreted to indicate 2.8-2.9 Ga subduction and arc magmatism. Enriched isotopic signatures in the Rb-Sr, Sm-Nd, and U-Pb systems, however, indicate that this arc was not the equivalent of an Archean intra-oceanic subduction system. Pb isotopes in particular show that this arc was built on pre-existing crust that was not the product of pre-Mesoarchean arc magmatism, but more likely was the product of anhydrous melting in a plume-like system. This conclusion is based on the Mesoarchean TTG rocks exhibiting a crustal Pb-paradox that requires the pre-existing crust to have a range of U/Pb ratios far higher than expected for arc-related magmas (av. U/Pb of the Mesoarchean rocks < the depleted mantle). The length of time this older crust existed is model dependent, but the presence of detrital zircons up to 4.0 Ga suggests it existed for at least a billion years. This combination of elemental and isotopic systematics in the Mesoarchean TTG suite suggests a multi-stage process of crust formation that began with a plume-like (LIPS-like) proto-continent and ended when its current configuration was established by arc magmatism 2.8-2.9 Ga ago. This crust and its deep (>250 km) mantle root have remained unaltered since the Mesoarchean and its seismic profile contains an extensive, fast, lower crustal layer similar to those reported for modern arcs such as IBM and the Aleutians.