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Archean Subduction or Not? The Archean Volcanic Record Re-assessed.

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Methods of identification of volcanic arc lavas may utilize: (1) the selective enrichment of the mantle wedge by 'subduction-mobile' elements; (2) the distinctive preconditioning of mantle along its flow path to the arc front; (3) the distinctive combination of fluid-flux and decompression melting; and (4) the effects of fluids on crystallization of the resulting magma. It should then be a simple matter uniquely to recognise volcanic arc lavas in the Geological Record and so document past subduction zones. Essentially, this is generally true in the oceans, but generally not on the continents. Even in recent, fresh lavas and with a full battery of element and isotope tools at our disposal, there can be debate over whether an arc-like geochemical signature results from active subduction, an older, inherited subduction component in the lithosphere, or crustal contamination. In the Archean, metamorphism, deformation, a different thermal regime and potential non-uniformitarian tectonic scenarios make the fingerprinting of arc lavas particularly problematic. Not least, the complicating factor of crustal contamination is likely to be much greater given the higher magma and crustal temperatures and higher magma fluxes prevailing. Here, we apply new, high-resolution immobile element fingerprinting methods, based primarily on Th-Nb fractionation, to Archean lavas. In the Pilbara, for example, where there is a volcanic record extending for over >500 m.y., we note that lavas with high Th/Nb (negative Nb anomalies) are common throughout the lava sequence. Many older formations also follow a basalt-andesite-dacite-rhyolite (BADR) sequence resembling present-day arcs. However, back-extrapolation of their compositions to their primitive magmas demonstrates that these were almost certainly crustally-contaminated plume-derived lavas. By contrast, this is not the case in the uppermst part of the sequence where even the most primitive magmas have significant Nb anomalies. The magnitude of these anomalies is not sufficient to give an unambiguous result but the previously-proposed subduction origin carries the highest probability. If correct, Archean subduction in this case was likely a short-lived process, different from present day arcs in terms of melting and mantle flow processes, with a low r-value (subduction flux/mantle flux), not involving a high-temperature basaltic slab melt, and possibly not even involving oceanic lithosphere. The subsequent eruption of potassic lavas with high r-values is consistent with reactivation of a lithospheric subduction component in a post-subduction setting. Extending the methodology to published data for other parts of the Archean gives interpretations which best support models of episodic subduction in the form of short-lived, subduction-like events. We do not find good analogues of modern subduction processes in the Archean – the oldest that we can identify are at about 1900Ma in the Trans-Hudson Belt.