When did subduction start - and how did it evolve?

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This key question for understanding the Early Earth and the history of subduction recycling is surprisingly difficult to resolve. Much of the evidence for subduction in the first billion years of Earth history is based on the identification of bonintes and adakites, both minor subduction-related rock types at the present day. Moreover, each has other explanations. In the case of boninites, the present-day petrogenetic requirements of mantle depletion by melt extraction during subduction initiation followed by addition of a subduction component can be replicated in the Archaean by melt extraction during komatiite genesis followed by further decompression melting and crustal interaction of the resulting magma. In the case of adakites, as a number of authors have pointed out, the present-day requirement of slab melting during hot subduction can be replicated in the Archaean by stacking of altered lava flows, delamination of thick volcanic crust or shallow underthrusting - to name but three alternatives to subduction. Recognition of subduction in boninites and adakites thus requires more precise fingerprinting. As will be demonstrated, this presently indicates a higher probablitity for non-subduction origins. In the second billion years of Earth history, there are more rocks resembling present-day arc volcanics but, even here, few are unambiguous. The usual criterion of negative-Nb anaomalies can be achieved even in the Phanerozoic in a number of ways that do not require deep subduction, the most important being crustal contamination of hot basic-ultrabasic magma and melting of enriched mantle during delamination or rifting. It is interesting that, if one also applies alteration-insensitive proxies for degree of melting (e.g. Y at 200ppm Cr) or oxygen fugacity (e.g. V-Y covariation), many Archaean 'arc' lavas do not satisfy present-day subduction criteria. Early examples best match the Cascades (relatively shallow subduction of hot lithosphere with inflow of hot, enriched mantle) in terms of the range of rock types present. Overall, a pattern of no subduction, followed by shallow subduction and, eventually, deep subduction is an attractive model that can be justified in part, though this does not take into account possible complex recycling when a magma ocean was active. In terms of the session theme, the implication of such a model is that the depleted components of the mantle will initially result from recycling of plume residues; only later will recycled subducted oceanic lithosphere become important. Interestingly, these two types of depleted mantle will have experienced melt extraction under different P,T conditions and may be distinguishable. Similarly, deep subduction recycling of crust, as opposed to burial-delamination recycling, may be more recent than commonly supposed.