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Did flat subduction occur in the early Earth?

Jeroen van Hunen
Durham University, Earth Sciences, Durham, United Kingdom (jeroen.van-hunen@durham.ac.uk, +44 191 3342301)

Around 10% of today's convergent margins show shallow flat subduction, where subducting lithosphere remains in or bends back to shallow, sub-horizontal positions for several 100's of km inland from the trench. As discussed below, shallow flat subduction is also commonly believed to have been the norm for early Earth subduction. To understand how this phenomenon can potentially be extrapolated to the Earth's distant past, a proper understanding of its dynamics is necessary. Most flat subduction is associated with the subduction of buoyant features due to an overthickened oceanic crust, with the subduction of the Nazca and Juan-Fernandez ridges below South-America as the prototype examples. Buoyancy of the subducting plate has therefore since long been suggested as a dominant mechanism for shallow flat subduction. Forced, low-angle subduction gives rise to suction forces in the mantle wedge that act to further reduce the subduction angle, providing a positive feedback mechanism for flat subduction. But dynamical modelling has indicated that these factors alone are probably not sufficient to create shallow flat subduction, and an active trenchward motion of the overriding plate was recognized as an additional mechanism. Recently, it has been proposed that the thickness variation of the overriding plate may play an additional role.

The hotter mantle in the early Earth probably led to more extensive melting, and Archaean oceanic crustal thickness (implicitly assuming plate tectonics operated) has been suggested to have been up to 20-25 km. Analogous to the flat subduction of modern buoyant features, shallow flat, buoyant subduction was proposed as the norm in the Archaean. It has also been invoked when discussing Archaean continental crust geochemistry: TTGs are proposed to be slab melts, analogous to modern adakites. However, TTGs often lack a mantle contamination component, and the absence of a mantle wedge in the flat subduction model provides an attractive solution. But such Archaean subduction dynamics model phases several dynamical difficulties. Modern flat subduction of oceanic plateaus is mostly driven by the density of the attached 'normal' oceanic plate (i.e. with a 'normal' 7-km-thick crustal thickness), which would be absent in the Archaean. Even if Archaean subduction was dominantly driven by overriding plate motion, then the weakness of the hotter Archaean mantle would not provide the torque to lift slabs into a horizontal position. Finally, most modern-day flat subduction regions are characterized by volcanic gaps, suggesting very little or no magmatism at all. Unlike popular belief, flat subduction was therefore less common in the early Earth than it is today.