L5 Late Archean plate tectonics

< deep ocean, hotspot ophiolites, island arc terranes, subduction >

What evidence is there of plate tectonics during the Late Archean, 2.5-3.1 Ga? [1]

The great thickness of Archean pillow lavas indicates that the ocean was present and deep. Associated with the pillow lavas, but volumetrically much less, are graded bedded graywackes. Huge volumes of Archean rhyolitic clastics are in places superincumbent on the basaltic pillow lavas. In some of these places deformation and erosion has preceded the accumulation of the rhyolite. Late Archean granites intruded as stocks and bathotliths and granite-gneiss diapirs, are differentiates from a mafic basement that leave a more basic behind, or are of remobilized older Archean granitoid crust.

Modern analogues: 1) Great thicknesses of pillow lavas are submarine hotspot outpourings. In the northwest Pacific, such outpourings, dated Cretaceous in age, thickly cover mid-ocean ridge basalt (MORB) originating oceanic crust of Jurassic age. This thickening to 20 km or more of the otherwise 4-8 km thick oceanic crust does not prevent it from being subducted and (as exampled by northwest rim of the Pacific) andesitic island arcs are the result. 2) In the way that India tucked its northern edge under the continent of Asia, New Guinea is currently tucking itself under the thickened crust of the northwest Pacific and presently could become a terrane with siliceous rock beneath mafic rock. This terrane would be too buoyant to sink and in time radiometric heating would likely cause the rise of granite-gneiss diapirs and the concurrent sagduction of the overlying mafics as synclinoria between. Before then, subduction could begin along its northern edge and add island-arc material to it.

The variety of plate tectonic island-arc themes are many and these would have operated in the Archean. The only variables that are certainly different today are: Earth's cooler body, a decreased amount of radioactivity within Earth, a greater degree of differentiation of sial from sima and, as a result of this differentiation, a concentration radioactive elements in the sial and the depletion of these in the sima. Lithosphere plates of the hotter early Earth would have been thinner and likely they subducted at shallow angles. Possibly back-arc opening was not a feature of Archean plate tectonics. Compressive subductions bought terranes together.

Modern-style subduction during the late-Archean has been imaged by seismic profiling across the boundary of the Abitibi and Opatica subprovinces (terranes) of the Superior province (***Figure L5.1***). Similar has been imaged at other collisional boundaries of terranes of all ages back to 3.0 Ga.[2]

High-pressure, low-temperature metamorphic minerals indicative of a strong lithosphere, mid-Archean, subduction has been found in the Barberton terrain, South Africa.[3]

Crustal composition estimates assume, as a first approximation, that the bulk composition has been that of "andesite" volcanic arcs. But these have only been typical of crustal accretion in the last 2 billion years. In the Archean, "rhyolite" volcanic arcs are typical. The higher heat flow during the Archean could have caused subducted basalt to reach melting temperatures at shallow depths and at pressures that were too low to cause dehydration before melting. Partial melting of hydrated basalt leaves a hornblende-garnet residue and produces a sweated-out sodium rich granitic magma.

Continental accretion is an ongoing process. The volume of the continental crust by the end of the Archean was probably 30-40 % of what exists today.

Compared to post-Archean (more differentiated) crust, Archean continental crust has a bulk composition, according to Stuart Ross Taylor, of 75% sodium-rich felsic plutonics and 25% andesite. This model is supported by the sedimentary record that gives us a sampling of the Archean crust and reveals it to have had europium in the amounts predicted by little differentiation and much lesser amounts of light rare-earth elements (***Figure L5.2***).[4] ❑

Figure L5.1 [5] Geologic map and seismic profile (interpreted) across the boundary of the Abitibi (AB) greenstone belt and the Opatica gneissic belt. A dêcollement (detachment structure, indicated by D and arrows), and possibly a subducted plate, shows in the section.

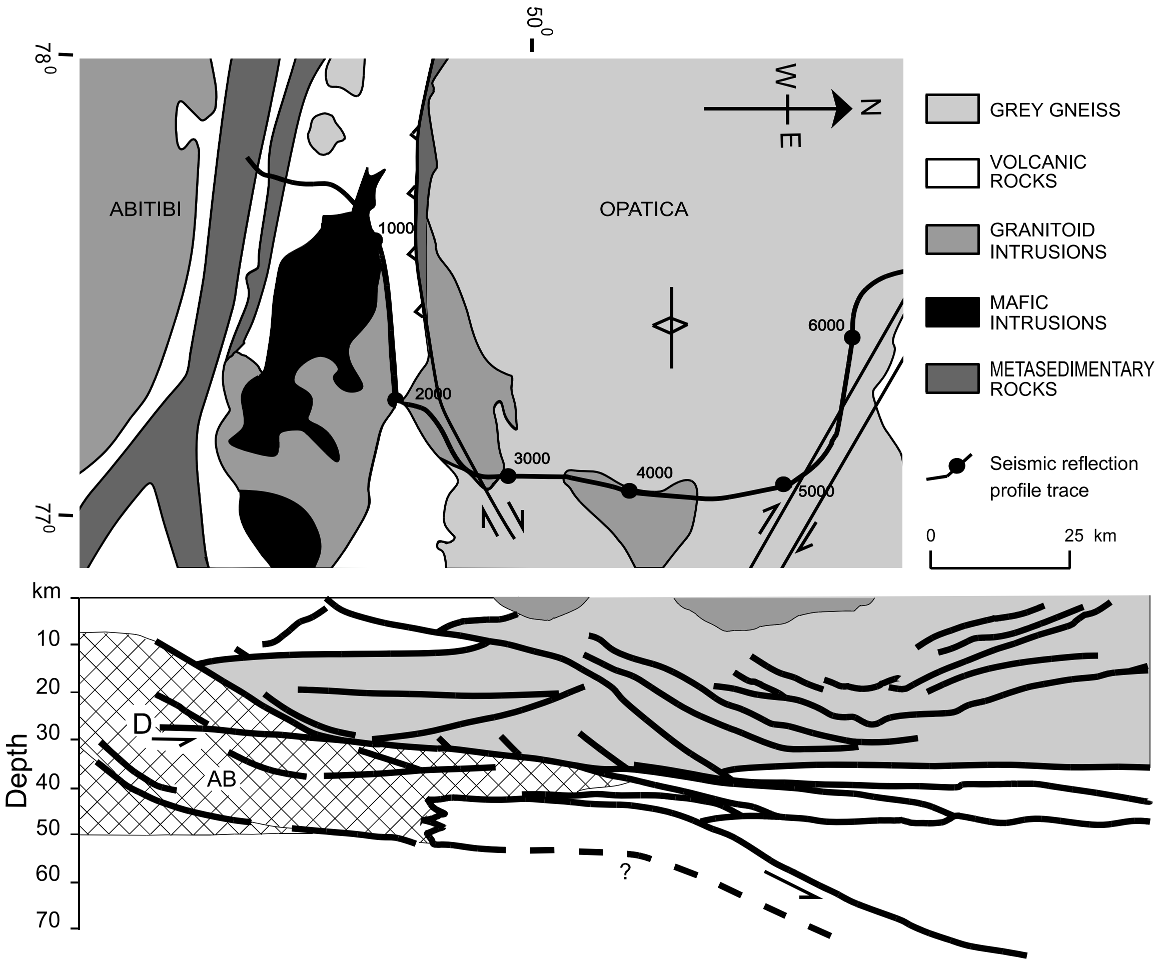

Figure L5.2 [6] Europium (Eu) in post-Archean graywackes is much depleted by comparison to its amount in Archean graywackes.