An Oceanic Subduction Origin for Archean Granitoids as Evidenced by Silicon Isotopes

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A major question in geosciences is whether Earth started in a non-plate tectonic regime similar to Mars, and if it did, when did the transition to the modern style regime take place. While studies on Archean granitoids, detrital sediments and Hadean zircons have suggested some sort of subduction since 3.5-4.0 Ga, there are also contemporary studies arguing that plate subduction did not start until 2.5-3.0 Ga. Here we report Si isotopic data for 4.0-2.8 Ga tonalite-trondhjemite-granodiorite (TTGs), Phanerozoic granites, and modern adakites that have been generated by partial melting of mafic crust at various pressure-temperature conditions. Integrating mineral-melt Si isotopic fractionation factors derived from previous density functional theory calculation into a batch melting model, we show that at similar melting pressures, TTGs have Si isotopic compositions heavier than those of granites and adakites. This is best explained if Archean TTGs have been produced by partial melting of a subducted (oceanic) mafic crust that was enriched in sedimentary silica from interaction with seawater. Before emergence of organisms at 0.5-0.6 Ga that could fix biogenic silica, the Archean oceans were close to Si saturation, which led to extensive deposition of sedimentary cherts on the seafloor. It is no longer the case in modern oceans as silica biomineralization maintains the dissolved Si at low concentrations. Eventually, Archean oceanic crust acquired a heavy Si isotopic composition that was later transferred to Archean TTGs via a subduction-like process. This implies that horizontal tectonics has been active at least locally as early as 4 Ga, and it was likely responsible for the fomation of felsic rocks on emerging lands.