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African cratonic lithosphere carved by mantle plumes

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Cratons are the ancient, stable, highly depleted nuclei of the continents. Seismic tomography yields information on the present state of the lithosphere and unveils complex structural patterns within the continental upper mantle. Our new waveform tomography of Africa, performed with massive new datasets, reveals fine structure of the African continental lithosphere. Even though the vast majority of Africa's tectonic blocks are Precambrian, the cratonic keels beneath the continent are smaller and more fragmented than, for example, beneath Eurasia or North America. Crustal Archean terranes in Africa often show a greater lateral extent than do the roots of the cratons in the mantle, suggesting probable erosion of the cratonic keels. Kimberlite and lamproite data offer evidence on the existence of thick, cold cratonic lithosphere in the past, at least up to the time of their eruption. We show that most diamondiferous kimberlites and lamproites in Africa are located, at present, not atop thick, cold lithosphere normally associated with stable cratons, but in regions where the lithosphere is thinner and warmer. These regions also display traces of mantle plume activity (West Africa - Central Atlantic Magmatic Province; Kalahari - Karroo; Congo - Paranà-Etendeka; Tanzania - Afar). Although the same plume-induced melting that gives rise to flood basalts cannot be the source of the (very different) kimberlitic magmas, the thermo-chemical heterogeneity created by plumes can account for the kimberlite eruption. This is especially likely because we can rule out the two main alternative models for the origin of African kimberlites. Firstly, there was no subduction in Africa over the last few hundred million years, when almost all presently known African kimberlites erupted. Secondly, kimberlites, as we show, are not located preferentially near the boundaries of the cratonic lithosphere. The complex shape of the fragmented keels beneath the cratons of Africa, resolved by our tomography, is a result of evolution that continues to this day, with the Tanzania cratonic lithosphere being eroded at present. Taken together, the evidence of the present lithospheric structure from tomography, the evidence of its past structure from kimberlites, and the evidence of plume-related magmatism suggests that it was the mantle plumes that eroded, carved and shaped the African cratonic lithosphere through time.