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Diamond Tectonics and Geotectonics – How do they intersect in the Archean?

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Aside from its universal appeal as a gem stone and its extreme physical properties, natural diamond is one of our most useful tectonic indicator minerals. Its distribution on the world's Archean cratons, its ages as well as its peridotitic and eclogitic inclusion and host rock parageneses suggest a multi-stage tectonic history of primary diamond deposits that is intricately linked to craton evolution. Diamond explorers are aware that the highest concentrations of "cratonic" diamond are found in kimberlites that have sampled the subcontinental lithospheric mantle under Mesoarchean parts of Archean cratons (e.g., Kimberley Block of the Kaapvaal craton, Tokwe segment of the Zimbabwe craton, Central Slave superterrane of the Slave Province) interpreted as continental nuclei with deep lithospheric roots. Diamond- and xenolith-based Archean tectonic models date the onset of plate-tectonic-like interactions between these nuclei at or before 3 Ga and suggest that recycling of crustal material by subduction contributed significantly to the formation of the lithospheric roots and to at least parts of the diamond parageneses [1,2]

Although geoscientists working in Archean terrains have assembled compelling evidence for some form of plate tectonics operating in the Archean [3], a debate still persists whether plate interactions, as known today, were possible on the early Earth. Of particular interest has been the question as to what form of subduction, if any, was viable in the Archean [4]. A common argument against Archean subduction is the apparent absence in Archean terrains of "robust" field criteria for identifying paleo-subduction zones, such as subduction melanges, blueschists and ultra-high pressure metamorphic belts. A lack of Archean ophiolites is seen as evidence that obduction of seafloor rocks onto continental crust did not occur. Furthermore, theoretical arguments against Archean subduction hold that higher Archean heat flow would prevent eclogitization of mafic oceanic crust thus preventing it from achieving the negative buoyancy necessary for subduction initiation.

Although there are many real differences between Archean and post-Archean terrains, some may be overstated. While the lack of ophiolites is commonly interpreted as evidence that Archean seafloor did not survive, greenstone belts are abundant and are composed mainly of submarine mafic flows. A number of greenstone belts have been viewed as Archean analogues to ophiolites and, indeed, ca. 85 % of greenstone sequences are now classified as subduction-related ophiolites [5]. Hypotheses that Archean seafloor was not subducted, now falsified also in the surface geological record [6], are contradicted by an ever growing body of evidence from studies of the kimberlite-borne diamond- and xenolith-based upper mantle sample. It can be stated with some confidence that tectonic hypotheses without invoking Archean subduction have ceased to be viable, and the argument must move on to discussions about possible mode(s) of subduction. In the talk I will outline probable plate tectonic scenarios resulting from melding Archean surface geological settings on different cratons with the constraints provided by their Archean upper mantle sample. Implications for diamond exploration will be discussed.

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