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Why is the continental lithosphere (tectosphere) stable?

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Continental tectosphere is chemically depleted, thick lithosphere typically found beneath Archean crations (Jordan 1975). This special kind of lithosphere is believed to have been stable and not experienced major tectonic disruptions for the last two billions of years or so whereas other regions underwent intense tectonic episodes (e.g. Richardson et al. 1984). Although chemical buoyancy caused by the extraction of basaltic or komatiitic melts may be partly responsible for the stability of continental tectosphere (Jordan 1975), a number of geodynamical studies indicate that high viscosity is the most essential factor for the preservation of the thick lithosphere (Doin et al. 1 997; Shapiro et al. 1999; Lenardic and Moresi 1999; Sleep 2003). Water is preferentially partitioned into a melt phase during partial melting, and a relatively low water content is expected for the residual mantle. Pollack (1986) proposed that volatile loss due to magmatic events might have resulted in mechanical stiffness to stabilize the continental tectosphere.
Cratonic mantle xenoliths, however, usually point to water-rich environments, as suggested by the common presence of hydrous minerals such as phlogopites (Pearson et al. 2003). Moreover, the direct measurements of water content in cratonic xenoliths show a high amount of water, ~800 ppm H/Si in olivine (Bell and Rossman 1992; Kurosawa et al. 1997). The origin of these "wet" signatures is a key question regarding the bulk property of continental tectosphere. Usually, they are interpreted to be of a secondary origin, i.e., associated with metasomatic events prior to kimberlite magmatism that brought up those xenoliths to the surface.
In this study, we discuss water content to stabilize the thick continental lithosphere based on deformation fabric that is sensitive to water content within the deep mantle and a simple convective instability analysis incorporating xenolith data. Deformation microstructures such as lattice-preferred orientation indicate water-poor conditions (<200 ppm H/Si) during long-term plastic deformation in the continental tectosphere. The analysis of convective instability further constrains the water content to be less than 100 ppm H/Si. Consequently, we suggest that continental tectosphere as a whole must have a lower water content, at least one order of magnitude less than oceanic upper mantle, whereas the present-day water content of cratonic xenoliths most likely reflects localized metasomatism before eruption.

Keywords: tectosphere, rheology, water content, instability analysis, deformation fabric