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On the Origin of Cratonic Sag Basins: Did They Sag?

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Cratonic sag basins are regions of long-lived, extremely slow (∼20-30 m/Myr) shallow water and terrestrial sediment accumulation that have no striking signs of tectonic activity (cf. Allen and Armitage, 2012). In their evolution, hundreds of Myr-long periods of slow sediment accumulation are separated by unconformities. The mechanisms for their formation resist geodynamic characterization by other common hypotheses for basin subsidence because of their extremely slow subsidence and lack of evident tectonic activity. I propose their dynamics are better understood within the geodynamic context of continental cratons that ride over a ∼250km-deep sub-asthenospheric mantle with lateral temperature variations between a few wide and persistent 1000s-km broad ∼1400C 'superplume' upwelling mantle structures (e.g. currently beneath S. African Atlantic and French Polynesia) and prevalent surrounding ∼1150C average temperature sub-asthenospheric mantle. When continents pass over typical mantle plumes, buoyant plume material tends to drain beneath the continent along junctions between cratons where the lithosphere is relatively thin, keeping the lithosphere over regions where plume material drains hotter than the average temperature of ∼250km-deep mantle. (e.g., the Cameroon Line.) Regions where melting of plume material occurs during decompression associated with either plume ascent or lateral drainage beneath continents are associated with the addition of a buoyant rind of more depleted mantle to the continent. In addition, regions where plume material can pond in a relatively thin sub-lithospheric 'anti-basin' beneath a continent, or that stay stationary for long times over super plumes will heat to a lithospheric basal temperature of ∼1400C instead of ∼1150C, with ∼700m of associated uplift. (e.g., Southern Africa). In this scenario (cf. Yamamoto, Morgan, and Morgan in "Plumes, Plates, and Paradigms"), it is the relative plume-passage-induced uplift of arches between cratonic sag basins, and relative coldness of the base of the cratonic lithosphere beneath sag basins that is the origin of the obvious 'sag' in the interiors of cratonic sag basins. The thermal time-scales of these plume-related processes can account for both the slow background subsidence of cratonic sag basins linked to cooling of a cratonic root following its (rare) incubation over a superplume, and faster subsidence pulses linked to more transient plume-related (or subduction-linked dynamic topography) effects. In this framework, the flexure in cratonic sag basins is not due to anomalous sag in their interior, but rather 'anomalous' push-up of their margins. A final interesting consequence is that the deposition of thick sequences of sediments with higher-than-average radiogenic production can – again after ∼100s of Ma – change the long-term sub-basin temperature profile, hence the relative elevation of the basin's center. Simple thermal models are discussed to quantify and illustrate these implications.