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Flat Slab Subduction, Trench Suction, and Craton Destruction: Comparison of the North China, Wyoming, and Brazilian Cratons

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We define and test a unifying plate tectonic driving mechanism that explains the characteristics of the destruction of cratonic lithospheric roots. We document and model the relationships between flat slab subduction, trench suction, and craton destruction, using examples from the North China and Wyoming cratons, each of which locally lost approximately 100 km of their lithospheric roots in the Cretaceous and which show spatio-temporal relationships with episodes of flat slab subduction in the mantle transition zone associated with deep mantle hydration, coupled with slab rollback and concomitant influx of fertile mantle material to accommodate the space created by slab roll-back. A similar process has more recently operated along the western side of the Brazilian craton where it is thrust beneath the thickened crust of the Andes in an area of trench rollback. The importance of the mutual interaction between these processes for destruction of cratonic roots may be greater than currently perceived. Together with the other processes of subduction erosion and arc subduction, larger amounts of continental lithosphere may have been subducted or otherwise returned to the sub-lithospheric mantle than previously appreciated.

When oceanic lithosphere subducts, it hydrates the upper mantle beneath an arc from well-known dehydration reactions. However, some hydrous phases (e.g., Phase A, Phase E, and –γt and β-phase olivine) are stable to much greater depths and dehydrate even when a slab is in the mantle transition zone. It is estimated that 40% of the water subducted in hydrated oceanic crust, mantle, sediments, and subducted continental material reaches the mantle transition zone between 410 and 660 km. For instance lawsonite may contain up to 11% water, and is stable up to 11 GPa or about 300 km and serpentinites can contain up to 13% water and are stable up to 7 GPa, and after conversion to denser hydrous phases such as β-phase olivine they can be stable up to 50 GPa, well past the mantle transition zone. With increasing temperature (i.e., more time in the transition zone for deep flat slabs) these phases decompose to less hydrous wadsleyite and ringwoodite with 2.2-3.3 wt % water, releasing water to the deep mantle, which rises and hydrates the overlying mantle. During flat slab subduction dehydration reactions therefore add water to the overlying mantle wedge. As the subducting slabs roll back, they suck in mantle material to infill the void space created by the slab roll back, and this fertile mantle becomes hydrated. The roll-back causes concomitant lithospheric thinning of the overlying craton so the flux of newly hydrated mantle material inevitably rises causing adiabatic melting, generating new magmas that gradually destroy the roots of the overlying craton through melt-peridotite reactions. Calculated fluxes of new mantle material beneath cratons that have lost their roots range from 2.7 trillion to 70 million cubic kilometers, which is sufficient to generate enough melt to completely replace the affected parts of the destroyed cratons. Cratonic lithosphere may be destroyed in massive quantities through this mechanism, warranting a re-evaluation of continental growth rates with time.