Geophysical observations reveal dehydration-modulated small-scale convection beneath oceans

*Zhitu Ma[1], Colleen A Dalton[1]

1. Brown University

Understanding the thermal evolution of the oceanic lithosphere is key for developing a complete formulation of plate tectonic theory and constraining the Earth's heat budget and ocean volume throughout its history. To first order the evolution is described by simple conductive cooling of a half space (HSC), but observations of seafloor bathymetry require the supply of additional heat to the base of tectonic plates older than ~70 Myr. However, the physical mechanism that delivers the extra heat has remained an enigma, despite three decades of study. Here we provide evidence showing that small-scale convection in which the onset time is controlled by the thickness of a shallow high-viscosity layer is the most likely mechanism. We analyzed seismic velocity and bathymetry independently along 824 trajectories that track the evolution of each piece of seafloor since its formation at the mid-ocean ridges in the Pacific and Atlantic Oceans. We identified the age at which HSC fails to satisfy the observations along each trajectory. HSC failure happens at a broad range of ages- in some cases not at all- in the Atlantic and a narrow range in the Pacific. In addition, HSC failure is roughly symmetric across the Mid-Atlantic Ridge and occurs earlier along trajectories where the ridge is underlain by colder mantle. This variation is best explained by rheological stratification created by melting at mid-ocean ridges, with a colder mantle generating a thinner high-viscosity lid and therefore an earlier onset time for small convection. Our results reveal the considerable influence that melting at the ridge has on the fate of the lithosphere and, by extension, the volume of ocean basins and rate of heat loss from the mantle over geological time.

Keywords: Lithosphere, Asthenosphere, Small scale convection

