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Searching for the origin of plate tectonics, leaving no grain unturned

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The physical cause, or origin, or generation of plate tectonics, especially how it arises from a convecting mantle on Earth (and not apparently on our solar system's other terrestrial planets) is one of the big questions in geophysics, and has haunted (or taunted) the author for the last 30+ years. Although he's tried to drive the question to basic physical causes for plate boundary formation in a cold stiff lithosphere, he's certainly taken his share of wrong turns. His earliest attempts to understand these processes from fluid lab experiments (while a postdoc at WHOI) only achieved (1) making gallons of fluids that look much like mucus, and (2) proof that he was a lousy experimentalist. But in the intervening decades, he's burrowed deeper into smaller and smaller scales to understand how microscale physics of mineral grains influence plate boundary formation at large scales. This led to the most recent theory of grain damage that allows for formation of weak boundaries, corresponds to field and laboratory observations of mylonitic behavior, and has applications from the onset of early plate tectonics, to passive margin collapse, to slab segmentation and necking. The most recent theory incorporates how mineral phases (olivine and pyroxene) mix with each other at the grain scale, and this has allowed a close comparison to new rock deformation experiments on grain mixing and shear localization, which opens up many new questions and predictions for more experiments and observations.