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Centrifuge Experiments of the Initiation of Self-Sustaining Subduction

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The post-Triassic age of all oceanic lithospheres indicates the efficiency and the sustainability of lithospheric subduction, which consumes the basaltic seafloor and recirculates it in the upper mantle. Since at present the initiation of subduction is very rare, comprehension of this cardinal process should be carried through modeling – numeric or analog. While deciphering processes through numeric modeling is commonly comprehensive, the analog models can determine major factor that constrain a tectonic procedure. Analog centrifuge experiments were applied to initiate self-sustained modelled subduction, trying to determine the critical factors that trigger its early stages.

Analytically we presumed that where densities of two lithospheric plates, juxtaposed across a weakness zone, exceed a critical value, then the denser lithosphere eventually will drive underneath the lighter one, provided the friction across the interface is not too high. Consequently, analog experiments were carried out in a centrifuge at acceleration of ca. 1000 g., deforming miniaturized models of three layers representing the asthenosphere, the ductile and the brittle lithosphere. The lithospheres were modeled to include lighter and denser components, juxtaposed along a slightly lubricated contact plane, where the density difference between these components was ca. 200 kg/m^3. No mechanism of lateral force was applied in the experiment (even though such a vector exists in nature due to the seafloor spreading at the oceanic ridges), to test the possibility of subduction in domains where such a force is minor or non-existent.

The analog experiments showed that the penetration of the denser modeled lithosphere under the lighter one led to extension and subsequent break-up of the over-riding plate. That break-up generated seawards trench rollback, normal faulting, rifting, and formed proto-back-arc basins. Lateral differential reduction of the friction between the juxtaposed plates led to the development of arcuate subduction zones. The experimental miniaturization, and subsequent numerical and analytical modeling, suggest that the observed deformation in the analog models could be meaningful to the planet as well.

Constraints of the analog experimentation setting did not enable the modeling of the subduction beyond the initial stages, but there is ground to presume that at depths of 40-50 km, metamorphic processes of the generation of eclogites would change the initial mineralogy on the subducting plate. Reactions with water would convert basalts into metamorphic serpentinites and schists.

Higher temperatures and pressures would melt parts of the subducted slab to generate felsic magmas, which would ascend towards the surface diapirically due to their lighter density. Alternately, low availability of H_2O would gradually alter the oceanic basalt and gabbro into eclogite, which would sink into the mantle due to its increased density.