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Exploring the Morphology of oceanic ridges with experiments using colloidal dispersions

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Mid-ocean ridges exhibit significant changes in their structural, morphological, and volcanic characteristics with changes in lithospheric thickness and/or spreading velocity. However, to separate the respective roles of those two partly correlated effects is difficult with only field data. We therefore designed a series of laboratory experiments using colloidal silica dispersions as an Earth analogue. Saline water solutions placed in contact with these fluids, cause formation of a skin through salt diffusion, whose rheology evolves from purely viscous to elastic and brittle with increasing salinity. Applying a fixed spreading rate to this pre- formed, brittle plate results in cracks, faults and axial ridge structures. Lithospheric (skin) thickness at a given extension rate can be varied by changing the surface water layer salinity. Moreover, the mechanical properties of the skin can also be independently controlled by changing the type of colloid. We focus here on cases where the spreading direction is perpendicular to the ridge axis.

For a given dispersion and salinity, we observe four regimes as the spreading rate increases: (1) at the slowest spreading rates, the spreading axis is composed of several segments separated by non-transform offsets and has a fault-bounded, deep, U-shaped axial valley. The axis has a large sinuosity, rough topography, and jumps repeatedly. (2) At intermediate spreading rates, the spreading axis shows low sinuosity, overlapping spreading centers (OSC) , a smooth axial morphology, and very few to no jumps. The axial valley is shallow and shows a V-shape morphology. The OSCs have a ratio of length to width of 3 to 1. (3) At faster spreading rates, the axis is continuous and presents an axial high topography. (4) At the fastest spreading rates tested, the spreading axis is again segmented. Each segment is offset by well developed transform faults and the axis has a sinuosity comparable to those of regimes 2 and 3. Rotating and growing microplates are also observed in regimes 3 and 4.

These four regimes, as well as the decrease in sinuosity with increasing spreading rate (regime 1) down to a critical value (regimes 2 to 4), present strong similarities with natural cases. This is predicted by a new dimensionless number Π_F comparing the maximum fracture length attainable without plasticity to the axial thickness. Slow spreading, fault-dominated ridges and fast spreading, dike-dominated ridges on Earth and in the laboratory are separated by the same critical Π_F value. Moreover, our results suggests that the fraction M of spreading rate accomodated by magmatic dyke opening is closely related to Π_F.