マントル剪断帯における加水反応に起因したレオロジー弱化：海洋プレートの沈み込み開始との関係
Rheological weakening via hydration reactions in a mantle shear zone: Implications for the initiation of oceanic plate subduction

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Plate tectonics on Earth is essential for mantle geochemistry and planetary habitability; however, its initiation remains controversial and previous geodynamic models require a preexisting zone of weakness (average stress less than 30 MPa) in the oceanic lithosphere. Although the operation of grain-sensitive creep (e.g., diffusion creep) causes a reduction in stress, fault strength near the brittle–ductile transition (BDT) remains remarkably high (1500 MPa), even when assuming olivine diffusion creep with an anomalously small grain size (1 μm) and a slow strain rate (10^{-15} s^{-1}). Although the oceanic lithosphere is considered to be dry, infiltration of seawater into a preexisting fault zone (e.g., fracture zones) will lead to the formation of hydrous phyllosilicates (e.g., amphibole, serpentine, and talc). To investigate hydration-induced rheological weakening effects on preexisting faults in intra-oceanic settings, we conducted high-pressure friction experiments on peridotite gouge under hydrothermal conditions. We find that increasing strain and reactions lead to the development of localized talc-rich shear zones, which induce an order-of-magnitude reduction in stress. The rate of reaction is strongly dependent on the degree of cataclastic deformation, rather than time.
Our laboratory experiments demonstrate that the operation of frictional–viscous flow, controlled by pressure-solution-accommodated frictional sliding on weak hydrous phyllosilicates, leads to a drastic reduction (down to 40 MPa) in the high stresses near the BDT within the oceanic lithosphere. Our results also suggest that the existence of oceans is a prerequisite for the initiation of plate tectonics on terrestrial planets (e.g., Earth); otherwise, stagnant lid convection operates in the mantle (e.g., Venus).

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