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Ductile Deformation of Passive Margins: A New Mechanism for Subduction Initiation

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The onset of subduction at passive margins has been extensively investigated and debated in the literature. However, the force constellations and mechanisms that enable the development of a subduction system from a passive margin still remain unclear. We present new insights into the conditions and processes by which lateral density differences between oceanic and continental lithospheres in passive margins may lead to initiation of a low-angle subduction system. The presented study consists of
1. An analytical calculation of the evolving flow field generated by lateral density differences within a passive margins, and
2. Analogue experiments (performed in a centrifuge) of deformation of mature passive margins. The deformation is driven by lateral density differences between adjacent lithospheres, and also investigates the effects of density differences between the lithospheres and the underlying asthenosphere.
Both our analytical calculations and our analog experiments suggest that lateral density differences between oceanic lithosphere and continental lithosphere lead to flow fields that initiate subduction. The analytical formulation predicts temporal and spatial evolution of an interface between the oceanic and continental lithospheres, and demonstrates that oceanic underthrusting may occur by rotation of this interface. The analogue experiments agree with the analytical results, and show that incipient subduction may develop by ductile deformation within the lithosphere, involving no sliding along the ocean-continent interface, so that the frictional resistance between the plates need not be overcome. The force induced by the negative buoyancy of the oceanic plate with respect to the asthenosphere is found to be in some cases irrelevant to subduction nucleation. Our results rest upon recent indications that ductile deformation may indeed occur within the lower lithosphere. Results of both the analogue experiments and the analytical calculation are compared to the south-east Australian passive margin, and are shown to fit its geometry and stress distribution. The proposed mechanism is also suggested to explain the only two cases of subduction of Atlantic plates, the Lesser-Antilles and the South Sandwich subduction systems.