Elastoplastic Deformation in a Wedge-Shaped Plate Caused By a Subducting Seamount

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Abstract

The goal of this investigation is to test a conceptual hypothesis that a subducting seamount might generate a complex fault system in the upper plate [Wang and Bilek, 2011]. The fault system and its stress state are envisioned to evolve with time due to the geometrical movement of the seamount. We conducted a static numerical modeling to investigate the characteristic of the fault system caused by subducting seamounts at different depth, subduction angles, and plastic failure criteria. We used COMSOL 4.3 to simulate the 2D elastoplastic deformation and plastic strain in a wedge-shaped upper plate above a subducting interface, part of which is forced to move to simulate the movement of a subducting seamount (Figure 1). A series of numerical experiments were carried out to investigate how the upper plate mechanical failure changes as a function of (1) material properties of the upper plate, i.e., elastic, elastoplastic Von Mises and Mohr-Coulomb failure criteria; (2) the seamount depth to the surface; and (3) dipping angle of the subducting interface. In particular, we calculated the durations of seamount movement, T1-T4, that is required for the fault-like shear zones (refer to as faults) to cut through the entire upper plate. The modeling results revealed that a pair of conjugate normal faults would first appear in the thinner part of the plate. Subsequently, a second pair of conjugate thrust faults would form in the thicker part of the plate (Figure 2). The durations of the seamount movement required for these faults to cut through the entire plate, T1-T4, are longer for deeper seamounts, greater dipping angles of the plate, and for the Mohr-Coulomb than the Von Mises criterion. Our models provide a quantitative way to investigate the time-dependent lithospheric deformation and fault formation processes during seamount subduction.

Reference

1. K. Wang and S. L. Bilek, Do subducting seamounts generate or stop large earthquakes?, Geology, 39, 819 –822 (2011).

Figures used in the abstract

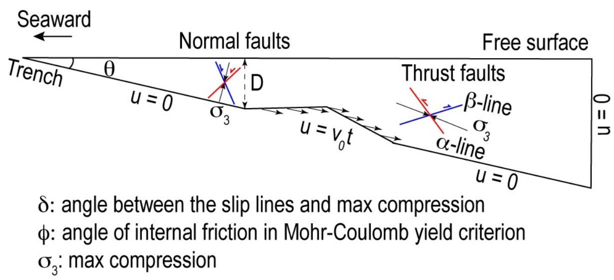

Figure 1: Model set-up and anticipated stress field. Our modeling domain is the upper plate, while a rigid upward-pointing triangular notch represents the seamount. The top surface of the model is assumed to be stress free, while the right side and the subduction interface are assigned fixed displacements. Due to the seamount movement, the section of the subduction interface between the seamount and the upper plate is subjected to a displacement vector parallel to the plate dipping direction, u = v0t, where t is the time duration of seamount movement from the beginning of the process, and v0 is the seamount movement velocity. The left (thinner part of the plate) and right (thicker part of the plate) sides of the seamount are in different stress state. The maximum compression stress is vertical left of the seamount, where normal faults are anticipated. By contrast the maximum compression stress is approximately horizontal right of the seamount, where thrust faults are anticipated. The alpha-slip lines and beta-slip lines are defined by the right-lateral and left-lateral sense of maximum shear, respectively, at counterclockwise and clockwise angles to the maximum compression direction. The vectors along the slip lines indicate the slip directions.

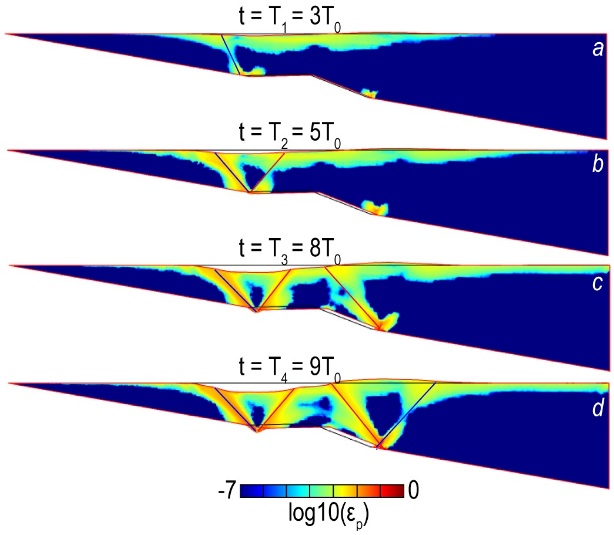

Figure 2: Snapshots showing a sequence of faults cutting though the entire plates: (a) right-dipping normal fault; (b) left-dipping normal fault; (c) right-dipping thrust fault; and (d) left-dipping thrust fault. ep is the second invariant of the plastic strain tensor, with dark blue color indicating elastic regions. Results are for the case with the plate dipping angle of 10 degrees, the seamount depth of 10 km, and Von Mises failure. Characteristic time defined as T0 = 0.001 D/v0. Deformation of the model domain is exaggerated by a factor of 50.