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Stress evolution and fault stability during the Weichselian glacial cycle with special focus on the Fennoscandian endglacial faults

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At the end of the last glaciation, northern Fennoscandia experienced a dozen very large earthquakes, with estimated magnitudes reaching 8. These reverse faulting events ruptured the surface in throws of 10 to 15 m, leaving fault scarps up to 160 km length that are still visible today. Although the deglaciation process is widely accepted as the cause of the earthquakes, the underlying mechanics are still not well understood. In this study we investigate the effects of ice advance and retreat on the stability of faults during the glaciation. We use a recently developed 3D finite element model of the crust and mantle, coupled to the results of a dynamic ice sheet model of the Weichselian glaciation. Constrained by BIFROST GPS data, Fennoscandian tide-gauge data and relative sea-level data we select a few well fitting Earth models for further stability analysis. The models are based on the concept of multiple elastic layers overlying a two-layered viscoelastic mantle. In the assessment of fault stability, the pre-existing, background, stress field is of utmost importance. As the current tectonic stress state is unlikely to have changed markedly in the last 100,000 years, we construct models of the background stress state based on current stress estimates from inversion of earthquake focal mechanisms and deep boreholes. We study both reverse and strike-slip background stress states and show how these influence the time history and magnitude of fault stability during a glacial cycle. Using models with both flat elastic layers and elastic layer thickness that mirror the thickening of the lithosphere from the North Sea to central Finland, we see surprisingly small differences in the stability of faults at depths down to approximately 20 km. Hydrology at the base of ice sheets is a complex topic, but because pore pressure is very important in fault mechanics, we explore the effects of simple static end-member models of possible glacially induced pore pressures in the shallow crust. We find that in addition to the stress state, the parameters that most severely influence fault stability is the direction of the maximum horizontal stress in the background field, and the estimate of glacially induced pore pressures. Our models predict the correct timing and location for onset of instability, assuming a reverse stress field was well established in the area of the endglacial faults. Recent reflection seismic profiling across the Pärvie and Burträsk endglacial faults indicate that the faults dip 50-55 degrees to the east/southeast in the upper 2-3 km. We explore the implications of these steep dips on the mechanics of faulting and the background stress field.