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Stress amplification around weak inclusions in the dry and strong subducting oceanic lithosphere

Giovanni Toffol[1], Jianfeng Yang[1], Manuele Faccenda[1], Marco Scambelluri[2], and Giorgio Pennacchioni[1]

[1]University of Padova, Department of Geosciences, Padova, Italy (giovanni.toffol@phd.unipd.it)

[2]University of Genova, Department of Earth, Environment and Life Sciences, Genova, Italy

Intermediate-depth subduction seismicity is still hiding most of its secrets. While plate unbending is recognised as the main stress loading mechanism, the processes responsible for earthquake nucleation are still unclear and depend upon the question whether failure occur in a wet dehydrating slab or in a completely dry lithosphere. The recent observation of subduction-related pseudotachylytes (quenched frictional melts produced during seismic slip along a fault) in the dry ophiolites of Moncuni (Lanzo Massif, W. Alps)[1], an exhumed example of the actual intermediate-depth seismicity, and the interpretation of seismic data from various double-plane seismic zones in subducting slabs[2] suggest that the seismogenic portions of subducting oceanic slabs can be dominantly dry. In absence of a fluid-mediated embrittlement (i.e. dehydration embrittlement), a dry and strong slab requires extremely high differential stress for brittle failure to occur.

Here we investigate with numerical simulations the potential of a subducting dry oceanic slab of building up the high differential stress required for failure. We performed pseudo-2D thermo-mechanical simulations of free subduction of a dry slab in the asthenosphere considering a visco-elasto-plastic rheology. We tested both a homogeneous dry plate and a dry plate with scattered weak circular inclusions representing domains of partial hydration in the first 40 km of the slab.

The stress field in the unbending portion of the slab describes two arcs, the outer one in compression and the inner one in extension, in agreement with the two planes of seismicity. For the homogenous plate the maximum values of differential stress are around 1 GPa, i.e. not high enough for triggering earthquakes. The presence of weak inclusions induces a stress amplification, which can be of several folds if elastic properties of the inclusions are sufficiently degraded, but still maintaining a high viscosity. For inclusions with a shear modulus decreased by 60-70% relative to the surrounding material, but similar viscosity, stress values in excess of 4 GPa are obtained, high enough for brittle failure at 100 km of depth. This inclusion rheology is compatible with that of a slightly hydrated and serpentinized meta-peridotite. These meta-peridotite domains are likely to be found in the oceanic lithosphere around faults related to slab bending which represent the main pathways for fluid infiltration in the slab.

We conclude that extremely high deviatoric stresses can be achieved in dry and strong subducting plates in presence of scattered domains of meta-peridotite acting as local stress amplifiers. These

previously unreported stress values may explain brittle seismic failure at intermediate depth conditions.

References:

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