# Transformation-induced, melt-enhanced faulting in orthoenstatite: implications for global intermediate-depth earthquakes

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Intermediate-depth earthquakes, which occur at ~50-300 km depths and account for ~90% of all deep earthquakes between 50 and 700 km, are ubiquitously observed along convergent plate margins and post great hazards in many regions of the world. Earthquake-depth distribution in oceanic subduction zones exhibits a prevalent secondary seismicity peak between 180 and 240 km, where major dehydration reactions are expected to have completed [1, 2]. This secondary seismcity peak is a direct manifestation of earthquake activities in the lower plane of the double seimic zone [3]. One of the main constituents of oceanic slabs is harzburgite, which consists mainly of olivine and orthoenstatite (OEn) [4]. The latter transforms to high-pressure clinoenstatite (HP-CEn) at ~120 –210 km depths, depending on aluminum content and slab temperature [5, 6]. We conducted deformation experiments on OEn at conditions corresponding to ~ 40 –250 km depths. Within its stability field, OEn deforms plastically; no brittle failure is detected with acoustic emission (AE) monitoring. In the HP-CEn stability field, metastable OEn generates numerous AEs generated, and fails by macroscopic faulting between ~773 and 1373 K. Outside this temperature range, metastable OEn flows plastically again with no AEs detected. Recovered failed samples contain large conjugated faults, with ultrafine-grained gouge layers containing melts that are more Al-rich. OEn grain boundaries are decorated with fine grained (grainsize < 1 micron) garnet and clinoenstatite (CEn). The latter is interpreted as back-transformed HP-CEn upon pressure release. Within large OEn grains, finer-grained garnet forms thin lamellae preferentially parallel to the OEn (100) twin planes. These results suggest that micro-ruptures start in metastable OEn by syn-deformational transformation, which, aided by exothermic latent heat production, results in exsolution lamellae of garnet and CEn, both along the OEn (100) planes, associated with intragranular ruptures. These micro-ruptures conglomerate along weakened grain boundaries to form intergragular faults consisting of ultrafine grained reaction and shear zones, which, through adiabatic heating and local melting, self-organize into macroscopic faults. We propose that in harzburgite, the observed OEn instability triggers shear localization in olivine, resulting in adiabatic instability, a mechanism hypothesized on theoretical grounds [7, 8] and recently observed in laboratory experiments [9].

*References*:

[1] Hacker, B.R., Peacock, S.M., Abers, G.A., Holloway, S.D., 2003. J Geophys Res 108, 2019.
[2] Syracuse, E.M., van Keken, P.E., Abers, G.A., 2010. Phys Earth Planet In 183, 73–90.
[3] Brudzinski, M.R., C.H. Thurber, B. R. Hacker, E.R. Engdahl, Science, 316, 1472-1474.
[4] Ringwood, A.E., Irifune, T., 1988. Nature 331, 131–136.
[5] Gasparik, T., 2003. Phase diagrams for geoscientists. An Atlas of the Earth's Interior.
[6] Akashi, A.,et al., 2009. J Geophys Res 114, 322.
[7] Ogawa, M., 1987. J Geophys Res 92, 13801-13810.
[8] Hoobs, B.E., Ord, A., 1988. J. Geophys Res 93, 10521-10540.
[9] Ohuchi, T., et al., 2017. Nature Geoscience 10, 771.

 