Transformational Faulting as a Deep-Focus Earthquake Mechanism: Correlating In-Situ Acoustic Emission Locations at High P-T with Post-Mortem Fault Imaging Using Synchrotron X-Ray Microtomography in Controlled Deformation Experiments

*Yanbin Wang[1], Lupei Zhu[2], Feng Shi[1], Tony Yu[1], Mark L Rivers[1], Alexandre Schubnel[3], Nadege Hilairet[4], Fabrice Brunet[5]

1.Center for Advanced Radiation Sources, University of Chicago, Chicago, IL, USA, 2.Department of Earth Sciences, St. Louis University, St. Louis, MO, USA, 3.Laboratoire de Géologie, CNRS UMR 8538, Ecole Normale Supérieure, Paris, France, 4.Université des Sciences et Technologies de Lille, Lille, France, 5.CNRS-ISTerre, Université de Grenoble, Grenoble, France

One of the possible mechanisms responsible for deep-focus earthquakes occurring at depths below 350 km is faulting induced or triggered by phase transformation from metastable olivine to its high-pressure phases (wadsleyite and ringwoodite, both are related to the general spinel structure) in the mantle transition zone. We have studied transformational faulting from olivine to spinel in Mg_2GeO_4, a close analog of the silicate olivine $(Mg,Fe)_2SiO_4$, using a high-pressure deformation apparatus in conjunction with in-situ acoustic emission (AE) monitoring [1]. Synchrotron X-ray microtomography (XMT) [2] was used to image the samples recovered from high-pressure deformation experiments, with spatial resolution of ~0.005 mm. In this study, we establish spatial correlations between AE events observed during in-situ deformation experiments and faults imaged by XMT post-mortem. The nature of high-pressure experiments limits the sample size to the order of 2 mm in linear dimensions, and the acoustic system we used has a maximum sampling rate of 50 MHz (i.e., 20 ns between adjacent sampling points), which limits spatial resolution of AE locations to about 0.3 mm. This makes it difficult to locate AE events accurately. A well-developed double-difference cross-correlation (CC) algorithm (hypoDD –[3]) developed for seismological studies has been successfully adapted in the analysis of AE locations, improving AE allocation spatial resolution by a factor of ~10. This algorithm also helps separate events with various waveforms, which are related to different fault planes and faulting directions. The CC algorithm classifies AE events into various groups. Events within each group share common characteristics and may be considered occurring within the same faulting mechanism. These groups of events display excellent correlations with faults imaged by XMT, with two major groups of AE events correlating well with two conjugated faults in XMT images. Furthermore, time sequence of AE events can be examined to investigate details of formation of macroscopic faults from the micro AE events. These results help understand the dynamic process of transformational faulting.

References:

[1] A. Schubnel *et al.*, Deep-Focus Earthquake Analogs Recorded at High Pressure and Temperature in the Laboratory. *Science* 341, 1377 (2013).
[2] M. L. Rivers, Y. Wang. (2006), Recent developments in microtomography at GeoSoilEnviroCARS, in: *Developments in X-Ray Tomography V*, U. Bonse (ed.), *Proc. SPIE* vol. 6318, pp. 63180J-63180J-15
[3] F. Waldhauser, W. L. Ellsworth, A Double-Difference Earthquake Location Algorithm: Method and Application to the Northern Hayward Fault, California. *Bulletin of the Seismological Society of America* 90, 1353 (2000).

Keywords: Deep-focus earthquakes, High P-T deformation, Acoustic emission, Synchrotron x-ray diffraction and imaging, Earthquake mechanisms

