Abstract
Until the last few decades, the mechanism by which deep-focus earthquakes (i.e., seismicity below 350 km depth) formed was still largely a mystery. Conventional brittle-fracturing cannot occur at these depths because rocks tend to become ductile and fluid-like. One hypothesis for deep-focus earthquakes is phase transformation induced embrittlement in mineral olivine, which is abundant in the upper mantle. Below ~350 km depth, olivine transforms into spinel (ringwoodite) or spineloid (wadsleyite) phases at high pressure and temperature. The high-pressure phases are fine-grained and superplastic and form shear localizations, which ultimately self-organize into large-scale fault zones. In our experiments at GSECARS (sector 13 of APS), we used the deformation DIA apparatus to deform analog olivine Mg2GeO4 within the spinel stability field at high pressure and temperature. We used x-ray diffraction to determine stress and radiography to measure strain. Six acoustic emission (AE) transducers were used to detect rupture events during deformation. This poster details the process of manually picking P-wave first arrivals (the times at which the sensors detect acoustic emissions) and how it is then possible to engage in cross-correlation of the individual events’ waveforms to understand how fault zones are produced during transformational faulting.

Hypothesis
Olivine-spinel phase transformation is one of a number of proposed theories: others include dehydration embrittlement and thermal shear. One argument for transformational faulting is the depth of deep-focus earthquakes correlates with the spinel stability field (Figure 1).

Work Scope
To conduct laboratory simulations under controlled pressure, temperature, stress and strain rate conditions to help seismologists to understand how earthquakes nucleate. To investigate sources of errors and uncertainties in first arrival determination of the events, we conducted manual picking of ~1500 events in one experiment. The results will be further analyzed by cross-correlating waveforms to help evaluate and refine autopicking algorithms.

Methods
During experiments, six anvils, 2 polycrystalline diamond and 4 tungsten carbide (see Figure 2), compress a cylindrical sample of Mg2GeO4 olivine, an analog of silicate olivine. Fastened to the rear surface of each anvil is a piezoelectric transducer capable of detecting AE events resulting from fracturing in the sample in situ.

Data Analysis
Figure 3 displays an example of waveforms recorded by all six channels for one event. First arrivals are marked by the blue lines. The transducers, which convert mechanical energy to electric energy, will only register the shockwave as an event when the amplitude of the waveform (volts) exceeds a pre-determined threshold. Once the software detects an event, it will include time before and after, meaning that background noise (i.e., apparatus movement, electronic noise) will show up.

After all events are manually picked, a 3D model event distribution can be created (Figure 4) based on the first arrival time data. Each sphere represents one event, color-coded by magnitude. This process is similar to that of detecting hypocenters of earthquakes.

Accurate manual picks allow us to obtain focal mechanisms (Figure 5) of all events, which reveal how the fractures progressed. Each sensor can detect if the AE event is moving towards or away from it, allowing software to get a better idea of how the crack originated and developed.

Conclusions
The 3D data (Figure 4) clearly shows several events outside the cylinder representing the sample. The scatter reflects both the noise in the system and uncertainties by manual picking of first arrivals. These data will be further analyzed using advanced seismological algorithms.

References:
1Li, Ziyu, 2021, A Nanoseismological Study on Acoustic Emission Events in High-Temperature and High-pressure Rock Deformation Experiments.