Relocation and Comparison of the 2010 M4.1 and 2011 M5.6 Earthquake Sequences in Lincoln County, Oklahoma

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Abstract

On February 27, 2010, a magnitude 4.1 earthquake occurred in southeastern Lincoln County. 111 aftershocks of this earthquake were recorded through May 31, 2011. At the start of the sequence, the seismic network consisted of six Oklahoma Geological Survey seismic monitoring sites distributed across the state. IRIS Transportable Array coverage of Lincoln County was reduced by the inclusion of the state, and NetQuakes instruments -4km to the west. Over the remainder of 2010, the coverage of the Transportable Array gradually expanded to include the whole state of Oklahoma. Consequently, part of the 2010 M4.1 aftershock sequence had poor station coverage, particularly at the beginning of the sequence, and events could not be precisely located. On Nov. 6, 2011, a M5.6 occurred in the same region. Aftermaths of this event have been well-recorded with a dense network of temporary local, OGS, and TA stations. Using VELEST, we inverted for a 1-D velocity profile using the P and S-wave plots for 212 earthquakes from the well-resolved 2011 M5.6 earthquake sequence. Sonic logs from nearby wells were used as a prior information to constrain velocity inversion. The well-located M5.6 2011 sequence and the M4.1 2010 sequence were located together using HypoDD. The earthquake locations and associated uncertainties for the 2010 M4.1 2010 earthquake sequence improved dramatically through joint location. The relocated earthquakes for the M4.1 2010 sequence occurred in approximately the same location and delineate a zone with the same orientation as the larger Nov. 6, 2011 earthquake sequence.

Velocity Analysis

A Vp/Vs ratio was calculated for each layer and a weighted average based on layer thickness was determined to be 1.816. The p-wave and S-wave velocity models were inverted for separately. The shallow velocity model derived from the western sonic logs had a westerly dip of the fault zone. The southwest portion of A-A’ illustrates a linear fault plane and shallow rupture, but the northeast segment has shallow and deep ruptures and a more complex fault zone.

Double-Difference Relocation

Right: Locations of relocated earthquakes, scaled by magnitude. Focal mechanisms for the largest event of the 2010 sequence (blue) and for the three largest events of the 2011 sequence (red) are plotted. Most of the focal mechanisms across both sequences are consistent with an east dip. The 2011-11-28 M4.7 event, shown, was left lateral strike-slip. Focal mechanisms generally coincide with the observed seismicity pattern and nearby vertical strike-slip faults. The mapped fault (1987) at the base of the Pennsylvanian and the seismicity within the Precambrian basement both suggest fault complexity within the Wilzetta Fault system near the epicenter of the larger 2011 earthquakes. Focal Mechanisms from USGS/CGS.

Conclusions and Further Work

Relocated earthquakes strongly delineate a fault zone striking SSW with a steep northwesterly dip, and both sequences appear to have occurred on the same structure. Focal mechanisms for the 2010 and 2011 earthquake sequences are high-angle single-slip faults. The 2011 earthquake sequence consistently exhibits right lateral strike-slip, but the fault appears to bifurcate in at least two locations where different focal mechanisms are observed. The 2011 earthquake sequence shows an aforesaid decay consistent with Omori’s Law. Prior to 2010, while representing an increase from background seismicity, does not follow Omori’s Law. The vast majority of ruptures occurred in the Precambrian granitic basement. Additional data from temporary OGS and PASSCAL RAMP stations, which can help elucidate the complexity of the Wilzetta Fault system, will be presented by Katie Keranen Wednesday at 3:30 p.m. 111 aftershocks of the 2010 sequence, while representing an increase from background seismicity, does not follow Omori’s Law. The vast majority of ruptures occurred in the Precambrian granitic basement. Additional data from temporary OGS and PASSCAL RAMP stations, which can help elucidate the complexity of the Wilzetta Fault system, will be presented by Katie Keranen Wednesday at 3:30 p.m.