AAPG/SPE/SEG HEDBERG CONFERENCE
"ENHANCED GEOTHERMAL SYSTEMS"
MARCH 14-18, 2011 – NAPA, CALIFORNIA

Quantify Spatial and Temporal Changes in EGS Reservoirs Using Double-Difference Waveform Tomography

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Reliable quantification of spatial and temporal changes in enhanced geothermal systems (EGS) is critically important for optimizing the operation of injection and production wells and the placement of new wells. Fluid injection/migration and alternation of temperature in an EGS reservoir can cause changes in geophysical properties, leading to differences in seismic scattered data. Therefore, time-lapse seismic data contain information of EGS reservoir property changes. The conventional imaging of time-lapse seismic data to detect reservoir changes is to carry out an independent imaging process for each dataset and subtract the results of time-lapse datasets to obtain image changes. This procedure can result in spurious image artifacts in addition to the anticipated image changes due to the actual time-lapse reservoir property changes.

To improve the imaging of spatial and temporal changes in EGS reservoirs with time-lapse seismic data, we develop a double-difference waveform tomography method to invert for geophysical property changes directly from time-lapse seismic data. The method employs time-lapse datasets to jointly invert for reservoir property changes. We use time-lapse velocity models constructed from an EGS site in Nevada to validate the double-difference waveform tomography method. The models contain several steep faults. We conduct double-difference waveform tomography using synthetic time-lapse seismic data from the models, and compare the result with that obtained from independent waveform inversions of the time-lapse seismic data. Our double-difference waveform tomography image gives much more accurate time-lapse velocity change in the EGS reservoir than that obtained from two independent waveform inversions. In addition, our double-difference waveform tomography image contains much less image artifacts than the image of the conventional waveform inversions of time-lapse seismic data. Our numerical examples demonstrate that double-difference waveform tomography has great potential for reliably quantifying geophysical property changes in EGS reservoirs using time-lapse seismic data.

Acknowledgement: This work was supported by the Geothermal Technologies Program of the U.S. Department of Energy's Office of Energy Efficiency & Renewable Energy through contract DE-AC52-06NA25396 to Los Alamos National Laboratory.