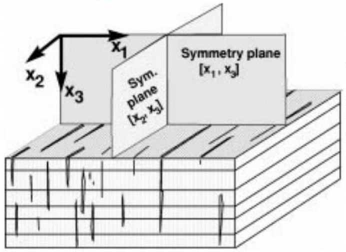
U.S. DEPARTMENT OF ENERGY

SPE Orthorhombic Seismic Modeling

SAND2018-6218C

Modeling SPE experiments with 3-D orthorhombic elastic full waveform simulations

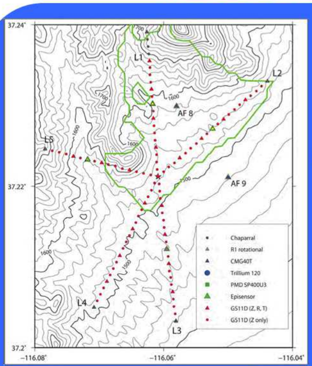
Background/State of the Art



A physical mechanism leading to orthorhombic anisotropy. From Tsvankin, 1997, *Geophysics*.

- Typically, full waveform modeling assumes isotropy for simplicity, computational speed, and because anisotropic parameters are usually poorly known
- Linear seismic source inversions usually use isotropic models, which may erroneously map anisotropic structure or other effects into the source function

Innovation



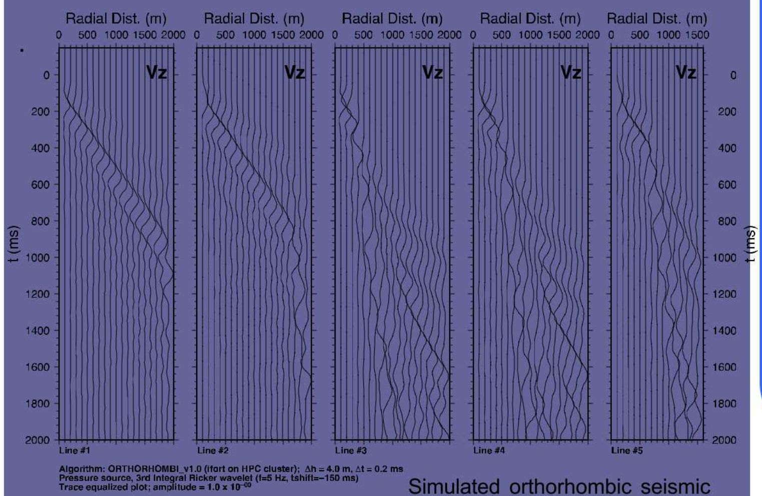
Map of SPE phase-1 modelling area.

- Develop 3-D orthorhombic linear elastic modeling algorithm (complete)
- Model seismic data from SPE experiments and use comparisons to improve modeling capabilities (underway)
- Provide linear seismic source equivalents for SPE and define their limitations

Approach, Metrics and Outcomes

MAIN ACHIEVEMENT

- Modeling SPE sources and seismic data within uncertainties



Simulated orthorhombic seismic traces of SPE-1.

HOW IT WORKS

- Explicit time-domain 3-D finite-difference using 4th order spatial and 2nd order temporal accuracy
- Built off existing isotropic elastic 3-D code with improved absorbing boundary conditions.
- Comparisons with SPE seismic data will provide a real-world validation of the code capabilities

ASSUMPTIONS AND LIMITATIONS

- Limited by the accuracy of the orthorhombic earth model parameters, which are usually poorly known
- Computational effort increases rapidly as frequencies increase
- Assumes linear seismic wave motion. Thus, permanent deformation, fracture, etc., are not modeled

Impact

- The 3-D orthorhombic code is generally applicable to any seismic full waveform simulation scenario, including non-proliferation, tunnel detection, source characterization. Many stakeholders in the DOE, DoD, and others could benefit.
- Understanding the limitations on using linear seismic source models have application in non-proliferation and forensics, etc.

TRLs (start and finish) Starting TRL: 3, Final TRL : 6

Publications

Jensen, R., and L. Preston, Finite-Difference Algorithm for 3D Orthorhombic Elastic Wave Propagation, *Seis. Res. Lett.*, 89(2B), doi:10.1785/0220180082, 2018.

Goals/Action Plan

Current FY

- Build 3-D orthorhombic model of SPE phase-1 site using information provide by LLNL
- Massively parallelize orthorhombic code
- Simulate SPE phase 1 experiments
- Predict DAG-1 waveforms

Future FY

- Model and predict DAG experiments, using past comparisons to improve modeling
- Investigate limitations of using linear seismic source models using SPE data

Team

SNL with collaboration from LLNL

Defense Nuclear Nonproliferation R&D

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