Characterizing Fractures in Geysers Geothermal Field by Micro-seismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy

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Abstract

The project is a joint effort by USC, Calpine Energy and Lawrence Berkeley National Laboratories. We acknowledge important contributions from Mark Wallers and his team at Calpine, as well as Ernie Major, and Leon Thompson of UBNL. We also acknowledge contributions from our US colleagues: Raj Erashghi, Don Paul, Muhammad Sahimi and Charles Sammis.

Introduction

Developing improved methods to better characterize fractures in Enhanced Geothermal System (EGS), new methodologies to characterize geothermal reservoirs north-west part of the Geysers and gain better knowledge of their porosity, permeability, fracture density, fracture orientation, fracture spacing and reservoir discontinuities (stubs and shear-zones) is the main objective of our research team. This will be accomplished by developing a 3-D seismic velocity model of the field using the microseismic data. Exploiting the microseismic data and the nature of the rocks gives better understanding the fracturing mechanisms. In addition soft computing is used for processing and analyzing the passive data.

Predicting characteristics of fractures and their orientation prior to drilling new wells, also determining location of fractures, spacing and orientation during drilling, as well as characterizing open fractures after simulation help identify the location of fluid flow pathways within the EGS reservoir. These systems are created by injecting water, and stimulating fracture development in hot water and geothermal rocks. The fracturing thus created enhances the permeability of the hot rock formations, thus enabling better circulation of water for the purpose of producing the geothermal resource. Better understanding the mechanisms for fracture stimulation can be used to obtain more information for a better exploitation of geothermal resources of the Geysers field (Sonoma County, California) and other similar fields.

Micro-seismic data analysis both for compressional waves and shear wave using soft computing, anisotropic inversion and fracture can be used and tested to develop new data analysis calculation techniques. This enables us to analyze and interpret micro-seismic data and create velocity fields using tomography. Neural-fuzzy approach can be used to create a hybrid MEQ event picking.

Geologic Cross-Sections of the Geysers

The seismicity is overlaid with an approximate temperature distribution. The more pronounced distibution of seismicity below and around the injection wells is noticeable.

Field observations (Clark, 2003) and geomechanical modeling (Butler and O’Connor, 2007) have concluded that injection- induced seismicity at the Geysers geothermal field is the result of shear fracture mechanisms; critical stress changes cause the reduction of normal areas associated with thermal contraction. It follows that a spatial analysis of the observations, sizes, and source mechanism of induced events can reveal the mechanism of different rock types present in the reservoir. The basic assumptions are that the hypocenters are located on the fractures, that larger events occur on larger fractures, and that the source mechanism constrains the orientations of the activated fractures.

Collaborating with the geomechanical group at Berkeley to use their models to simulate the expected response of a fractal network to the thermal stresses generated by injection.

Scheduled Tasks

1. Use of the augmented receiver network in the NW Geysers
2. Develop a 3-D seismic velocity model beneath the largely undeveloped 10 sq. mi. area of NW Geysers where Cajon is proposing further development.
3. Use 3-D velocity field, constructed based on them, to create a fracture map and monitor low-level micro-seismicity occurring in response to deep, low-rate water injection, in order to precisely locate and characterize fracturing occurring in response to injection into deep reservoirs.

Use of Soft Computing to analyze passive seismic data

Soft computing (including neural networks, fuzzy logic and genetic algorithms) has been used extensively in geosciences and energy related applications. Yet very few applications have been found for exploration and exploration of geothermal resources, seismology and soft computing is less commonly used in geothermal and mineral exploration and development, but has great potential for growth pioneering work has proven valuable in mapping mineral deposits. The next goal is to work on soft computing applications to seismic data from the petroleum industry, adapting and applying techniques to explore and exploit geothermal energy. This goal can also be achieved by trained engineers, scientists and students.

Directional events in selected seed points will be used as the training set for the neural-fuzzy auto-picker. The results are compared against the current auto-picker being used by USL as well as the picks by human. We expect our hybrid approach will improve both in ability to pick the subtle events and the efficiency of the process.

Geometric and Geophysical Observations

The location of MEQs events may delineate the locations of new subsurface fractures and reservoirs. The location of these MEQs depends upon an accurately known distribution of subsurface seismic velocities (both P and S). These velocity fields must include accurate distributions of seismic anisotropy. For this purpose the following steps should be performed:

1. Form initial velocity field for subsurface using seismic velocities, AMOCs and data.
2. Define a set of fracture density maps.
3. Define a set of fracture orientation maps.

Given the usually poor quality of microseismic data, simultaneous analysis of S and P wave data to deduce information on shear wave splitting from fracture reservoir is usually difficult. Hence a hybrid approach is needed. This includes using both conventional anisotropic imaging techniques and shear wave splitting analysis.

Figure 3 shows the fuzzy nature of the velocities for different rock categories. And also demonstrates the impact of fuzziness in P wave velocities and its relation to phase velocities of different rock types according to their respective S and P wave impedances. Developing a “fuzzy” velocity field and anisotropy map and validate the velocity field from microseismic data measurements by using a large number of well data from the existing wells, in conjunction with the analysis of MEQ data. Reservoir characterization with fuzzy velocities can be examined.

Utilizing various neural network based approaches can be applied to better understand the fracturing system, as applied to the NE and SE cross sections as shown in Figure 2.

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References


