Fracture Modeling applied to the geothermal system potential reservoir of Rosario de La Frontera (La Candelaria Ridge, NW Argentina)

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INTRODUCTION

Discrete fracture network (DFN) models are three-dimensional stochastic or combined stochastic/deterministic representations of natural fracture systems. They represent an important tool to investigate pathways for fluid flow in geothermal reservoir. Fractures not only improve the hydraulic conductivity of many reservoirs, but also induce significant permeability anisotropy due to the geometry and the type of the discrete fracture network. Thus, fracture system characterization represent an important tool to predict the anisotropy of the hydraulic conductivity in a geothermal reservoir and its effect on fluid flow.

We used this computer modeling approach to study the geothermal reservoir of *Rosario de La Frontera*, in the Salta province. Therefore, detailed field measurements of outcropping reservoir and seal were conducted to get a quantitative description of the DFN (e.g. fracture orientation, fracture length, fracture spacing and effective hydraulic aperture; e.g. LEE AND FARMER, 1993; PRIEST, 1993; MARCHEGIANI *et alii*, 2006). In this abstract we present the DFN models elaborated for the deep reservoir and for the seal of this active geothermal system. The purpose of this modeling is to create simulation fracture properties (such as porosity, permeability, connectivity) with the aim to predict the reservoir and seal behavior in prospect evaluation and reservoir management.

GEOLOGICAL SETTING

The study area lies within the structural province of the *Santa Barbara System*, in the Sub-andean foreland thrust belt, dominated by a thick-skinned compressive deformation (ALLMENDINGER *et* alii, 1983; JORDAN *et alii*, 1983; KLEY AND MONALDI, 1998; SEGGIARO AND HONGN, 1999). This province is characterized by predominantly broad, low-amplitude folds generated by mainly westward-vergent thrusting (ALLMENDINGER *et alii*, 1983) that represent the reactivation of normal faults generated during the Cretaceous rift (BIANUCCI *et* alii, 1982; GRIER *et alii*, 1991; SALFITY *et alii*, 1993; KRESS, 1995; CRISTALLINI *et alii*, 1997).

La Candelaria Ridge represent one of this broad anticline structures, uplifted by fault planes dipping to the west with a top-to-the-east sense of transport. It crop out in the province of Salta and Tucuman, elongated for ca.60 Km N-S and strongly plunging for both north and south directions. It exposes low grade metasedimentary Precambrian strata that are unconformably overlain by a thick sequence of predominantly continental Cretaceous to Paleogene strata (Salta Group) related to the rift stage (SALFITY AND MARQUILLAS, 1981, 1994). The Salta Group strata are capped by a thick continental foreland basin fill that was shed from Early Miocene to Recent time.

The thermal area of *Rosario de La Frontera*, characterized by several hot springs with temperatures at surface ranging between 50°C and 99°C, is located to the north of *La Candelaria Ridge*, in the Salta province. The permeable levels of the Salta Group represent the reservoir of this geothermal fluids that occur close the city of *Rosario de La Frontera*, in correspondence of the thermal area known as *Los Baños*, where syn-orogenic clastic sediments crop out. The post-rift and syn-orogenic impermeable levels provide the cap rock of the geothermal system.

METHODOLOGY

The sampling technique applied for the observation of the fracture network has concerned the acquisition of data along scan-lines and on scan-areas on the outcropping reservoir rocks in order to define the requested parameters needed to generate the DFN. In addition, these characterization was done in different

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areas of the studied anticline, along the forelimb, backlimb and plunging northern nose in order to relate, if possible, the fracture system characters to the folding process.

Discontinuities observed, such as fractures, joints, veins, etc., were investigated in terms of kinematics, orientation, dimension, spatial distribution, and surface texture. Mentioned data were used as statistical input data to generate a DFN model in 3-D volume of the deep geothermal reservoir. The volume of the potential reservoir was reconstructed from the geological model, based on geological maps and seismic-reflection profiles crossing the studied area. The seismic profiles were interpreted and depth converted, and the results integrated to the superficial data. The workflow was done using the software Move 2012 (Midland Valley).

PRELIMINARY RESULTS

Most of the structural analysis was carried out in the syn-rift sedimentary fractured strata of the Pirgua subgroup (conglomerates and sandstones), and in the syn-orogenic siltstones strata (Anta Formation). Fracture orientations result relatively complex with different trends N-S, NE-SW, NNW-SSE and E-W.

N-S and E-W trending fractures are present mainly in correspondence of the northern plunge of the anticline where occur several hot springs and Anta Formation (the main seal of the geothermal system) extensively crops out. The E-W trending fractures network seems to exert a structural control on the thermal springs distribution and geochemical characteristics producing a compartmentalization of the system.

NNW-SSE and NE-SW trending fractures are predominately visible in the reservoir rock outcropping in the eastern and western limbs of the anticline, respectively. Within the reservoir unit, fractures show a typical spacing of approximately 30 cm and apertures which ranges from 3mm up to 1 cm.

In addition, density values (number of fractures per meter) were obtained from quantitative analysis in order to elaborate a three-dimensional representation of the fractures network that characterize the deep reservoir. Furthermore, an upscaling phase was necessary to generate permeability and porosity properties distribution in order to compare the obtained data to other geophysical investigations, such as soil gas surveys, audiomagnetotelluric surveys, to better constrain the reservoir extension.

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