Geoscience Frontiers xxx (2016) 1–12

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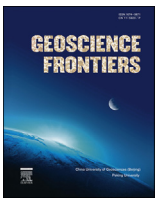
Geoscience Frontiers

journal homepage: www.elsevier.com/locate/gsf



Research paper

Analysis of heterogeneous characteristics in a geothermal area with low permeability and high temperature

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ARTICLE INFO

Article history:
Received 4 March 2015
Received in revised form
20 September 2016
Accepted 20 October 2016
Available online xxx
Handling Editor: H.M. Rajesh

Keywords:
Los Humeros geothermal field
Reservoir performance
Hot rock
Enthalpy
Permeability
Recharge

ABSTRACT

An analytical methodology for reservoir characterization was applied in the central and southwestern zones of Los Humeros geothermal field (LHGF). This study involves analysis of temperature, pressure, enthalpy and permeability in wells and their distribution along the area. The wells located in the central western side of the geothermal field are productive, whereas those located at the central-eastern side are non-productive. Through temperature profiles, determined at steady state in the analyzed wells, it was observed that at bottom conditions (approximately 2300 m depth), temperatures vary between 280 and 360 °C. The temperatures are higher at the eastern side of central zone of LHGF. A review of transient pressure tests, laboratory measurements of core samples, and correlation of circulation losses during drilling suggest that permeability of the formation is low. The enthalpy behavior in productive wells shows a tendency of increase in the steam fraction. It was found that productivity behavior has inverse relation with permeability of rock formation. Further, it is observed that an imbalance exists between exploitation and recharge. It is concluded from the results that the wells located at central-eastern area have low permeability and high temperature, which indicates possibility of heat storage.

1. Introduction

The central zone of Los Humeros geothermal field (LHGF) shows contrasting results; the wells drilled at the west side are productive whereas those on the east side are unproductive. To evaluate this contrasting behavior a methodology was developed. Through this methodology it is possible to estimate the initial conditions of the reservoir, its reserves, useful life, and operation policies, among other aspects (Schatzinger and Jordan, 1999). In order to apply the optimal production techniques for improving productivity, the reservoir characterization models are used to simulate the behavior of the fluids under different sets of circumstances.

The LHGF is located inside the Plio-Quaternary volcanic caldera complex with less than 500 ka of age. This complex is located in the eastern part of the Mexican Volcanic Belt (Gutiérrez-Negrín and Izquierdo-Montalvo, 2010). The location of the field is at the border between Puebla and Veracruz states, approximately to 220 km of Mexico City, with latitude 19.68°N and longitude 97.45°W (Lorenzo-Pulido, 2008). The topographical level of the field varies between 2800 and 2900 masl and the average temperature at the surface (INEGI, 2013) is between −2 °C (in winter) and 15 °C (in spring). A location map of the LHGF within the Mexican Republic is shown in Fig. 1. Inside the main caldera three geological features are distinguished: the “Potreros” collapse, a semi-circular rim known as “Collapso Central” (CC) at the north of the field, and the “Xalapasco” crater at the south.

41 wells have been drilled since 1981, among which 18 of them are producers and 3 are injectors (Flores-Armenta et al., 2014). The wells drilled in the “CC” and in the “Xalapazco” areas are producers and because of this, new exploration drillings in the central part of the field were projected. Wells 23, 24, 25, 26 and 27 were drilled in the central area of the field. In these wells, average static temperature was determined close to 290 °C but at greater depths than those drilled at the “CC”. High temperature and low permeability were determined in all these wells of the central eastern zone of the field (Torres, 1995). However, the wells in central-eastern area of

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Peer-review under responsibility of China University of Geosciences (Beijing).

http://dx.doi.org/10.1016/j.gsf.2016.10.007

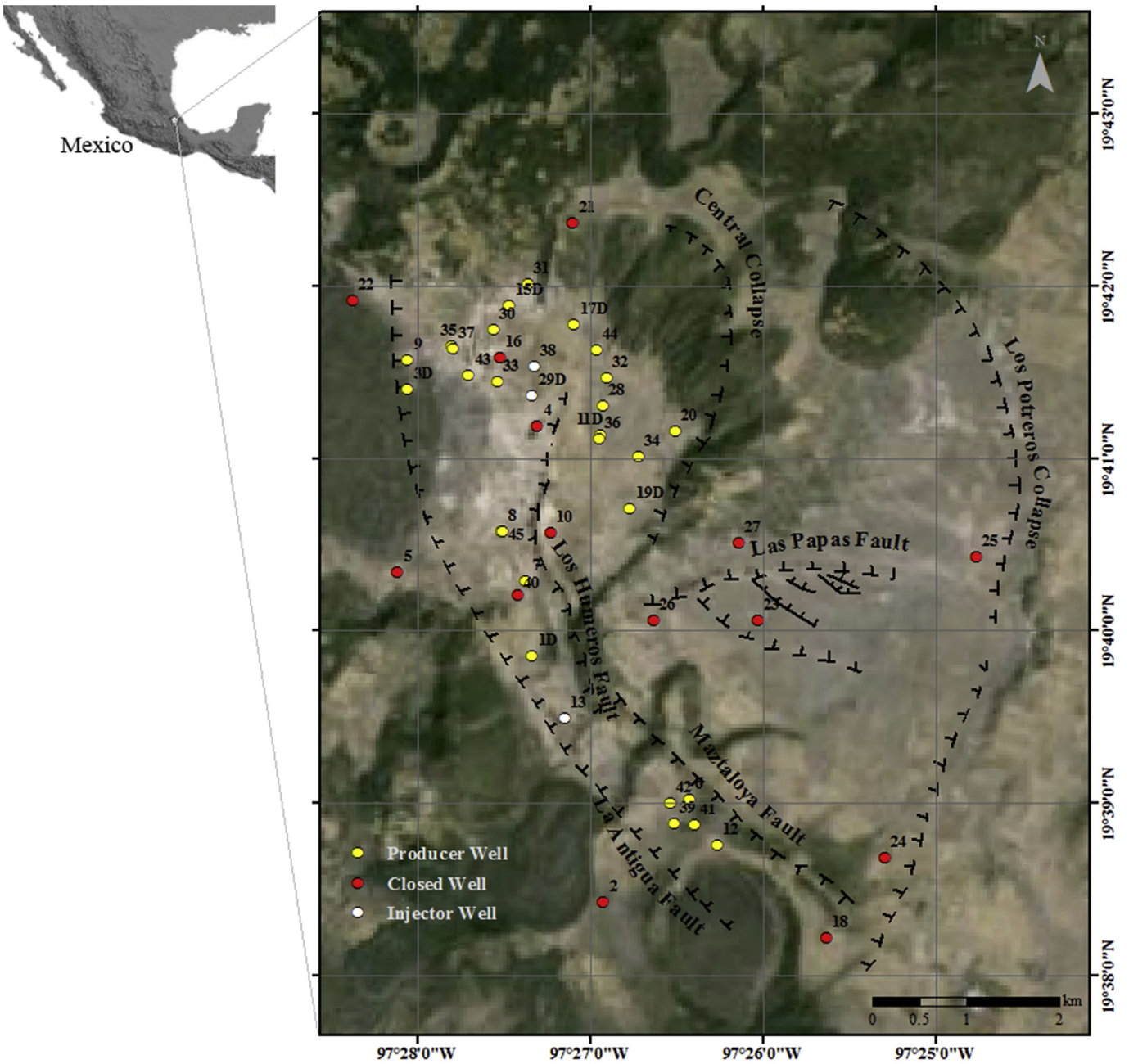

Figure 1. Location map of Los Humeros Mexico, geothermal field (LHGF) and existing wells; the producers with yellow mark, the closed (non-producers) with red mark, reinjection wells with green (the map was downloaded from Google earth and were included the wells and geological faults).

LHGF did not produce geothermal fluid, hence they were closed/abandoned. Due to low permeability conditions, and corrosion problems by acid condensed fluids, no more wells were drilled in this zone.

Permeability is a measure of the easy movement of fluid flow through rock. The permeability of rock results from pores, fractures, joints, faults, and other openings which allow fluids to move. High permeability implies that fluids can flow rapidly through the rock. Permeability and, by consequence the flow of fluids tend to decrease with depth because of the openings in the rocks are compressed from the weight of the overburden. According to Cedillo-Rodríguez (2000), the distribution of low permeability in rocks (granites and limestone) around Los Humeros caldera, combined with annular faults, isolates the geothermal reservoir from regional recharge. The recharge to the reservoir mostly occurs from rainfall transmitted through the fault system and fractures (Gutiérrez-Negrín et al., 2010a).

Based on updated data of the discharged fluids of the wells, reservoir fluids show enthalpy values greater than 2400 kJ/k, hence the field has been referred as a high enthalpy system (Arellano et al., 2003) and the values correspond to a thermodynamic steam dominated state (Tello, 2005). The exploitation from the wells of the field, except well 1, started with vapor dominated flow. As the operation time progressed, the steam fraction in the wells increased and gradually changed to dry steam. In this study, the mean values of main production characteristics of wells located in the central and southwestern zone of the field were considered. Significantly, this steam phenomenon in a geothermal reservoir can

Please cite this article in press as: Aragón-Aguilar, A., et al., Analysis of heterogeneous characteristics in a geothermal area with low permeability and high temperature, Geoscience Frontiers (2016), http://dx.doi.org/10.1016/j.gsf.2016.10.007