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Geological structures and analogue permeability studies in Los Humeros geothermal system

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Caldera-related superhot geothermal reservoirs are in many cases underexploited. Primary exploration and production challenges, closely tied to investment risk, are predicting the reservoir and targeting the drilling. Our focus in this contribution is assessing the role of fractures in outcrops and their utility as analogues to the fractures in the geothermal reservoir. Our case study is the Los Humeros geothermal fields in the Central Mexican volcanic belt, as part of the H-2020 GEMex project (EU-MEX collaboration) to improved understanding of subsurface conditions.

Los Humerous are recent caldera (<3.8 Ma) characterized by high heat-flow related to granitoids intruded into the Jurassic-Cretaceous limestone basement. The Los Humeros reservoir lies below about 1300 m depth and consists of fractured lavas and ingimbrites and underlying limestone. The present caldera land surface is composed of volcanic edifices, tuffs and lavas. The reservoir lithologies are influenced by pre- and syn-caldera extreme temperatures and deformation, post-caldera burial, and pre-caldera to present hydrothermal alteration/metamorphism and magmatic intrusion.

Our database includes most of the lithologies present in the reservoir. Data were acquired using fracture scan lines and 3D quantitative outcrop models. Conventional interpretation and analysis were extended by stochastic fracture modelling to generate analogue 10-m scale "fracture boxes". From these we infer relative fracture permeability based on fracture size, orientation, connectivity and spatial frequency. For application to the reservoir fluid flow modelling, we group these fractured-rock volumes into three categories: A) fault-related; B) background deep burial; and C) background shallow burial.

Fault-related fracture systems (A) are typical of damage zones along faults, in relays, and near fault intersections. Recently-active regional to intra-caldera faults cross-cut numerous caldera lithologies and some influence the caldera shape. These faults and their representative "fracture box" volumes are characterized by high fracture frequencies in lithified "tight" reservoir-analog lithologies (welded tuff/ignimbrite, lava, intrusive, metamorphic). Outcrops representative of deeply buried sections of syn-caldera faults (i.e. reservoir) typically show high grade alteration in the form of hydrothermal fracture fill and metamorphism (combined seal conduit systems).

Background fracture systems (B) in outcrops of granodiorite and marble (skarn) are inferred to have been generated under deep burial conditions similar to the reservoir. The low fracture frequency (0.1-0.3 f/m) indicates low network permeability. The typical fracture system consists of orthogonal regular-spaced joints of non-tectonic origin, including near-subsurface unroofing joints, cooling joints and hydrothermal veins.

Sedimentary and extrusive volcanic rocks (C) display a much higher fracture frequencies than deep-burial category. For syn- to post-caldera deposits these fractures formed in the near surface have been progressively buried to reservoir depths. For pre-caldera deposits this history is overprinted by caldera-related deformation. In general andesites and basalts show fracture characteristics consistent with good permeability and mostly high fracture connectivity both in background levels and in faults. Mesozoic limestone basement may also be present in the reservoir has a tight fracture network inherited from Laramide-age folding and thrusting followed by the uplift and unroofing during TMVB development.

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