Exploring the Plumbing of the Truth or Consequences, New Mexico Geothermal System by using Magnetotelluric Surveys, Fracture Analysis, and Aquifer Testing

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We combined forward hydrothermal modeling with magnetotelluric (MT) and transient electromagnetic (TEM) geophysics to image a deep (4 to 10 km) crystalline basement-hosted groundwater flow system that is associated with the Truth or Consequences (T or C) geothermal resource along the central Rio Grande rift of New Mexico, USA. Previously published hydrothermal models indicate that the effective hydraulic permeability of the crystalline basement in the T or C watershed must be unusually high (10^{-12} m^2) to explain measured hot-spring temperatures (41°C), geothermometer reservoir temperature estimates (170°C), vertical specific discharge rates (3 to 6 m/yr), and mean uncorrected carbon-14 groundwater residence times (7,000 yr). We further evaluate this conceptual model using electrical resistivity, fracture analysis, and aquifer testing. Regional subsurface resistivity patterns imply the presence of a single-pass and deeply circulating regional groundwater flow system between the upland recharge area to the west and the T or C hot-springs district near the Rio Grande to the southeast. The resistivity of the crystalline basement is observed to be between 100 and 200 ohm-m to depths of 10 km, which is typical of altered, fractured and saturated igneous and metamorphic rocks and is much more conductive than typical intact crystalline rocks. Regional faults do not appear to compartmentalize the groundwater system but may serve as conduits for upwelling fluids. There is also a conductive (50 ohm-m) feature at 6 to 10 km depth below the T or C hot-springs district that may represent upwelling brackish geothermal fluids. This feature is reproduced well by hydrothermal groundwater models that we use to infer electrical resistivity patterns. Aquifer testing carried out within the T or C hot-springs district estimate local crystalline basement permeability to be on the order of 4×10^{-10} m^2. Preliminary analysis of fractures in surface exposures of Proterozoic basement rocks in the Mud Springs Mountains and on the south side T or C reveals local variability in both rock type and fracture density. Rock types include folded metasedimentary and metavolcanic rocks intruded by nonfoliated granite that, in places, contain large xenolithic blocks of the older metamorphic rocks. The T or C outcrops north and west of the Rio Grande have the highest fracture densities (20 to 50 fractures/m). Outcrops in the Mud Springs Mountains commonly have low densities (2 to 10 fractures/m) with local zones of higher density. Interestingly, very few of the fractures observed in the Proterozoic rocks in the Mud Springs Mountains continue above the “Great Unconformity.” Fractures in the Mud Springs Mountains predominantly strike northwest. The orientations of fractures in T or C are more variable. Overall, these results indicate the likely presence of permeable crystalline rocks on a regional scale that permit geothermal groundwater circulation to depths of up to 10 km within this geothermal system. This work provides evidence that seismically active rift settings with prolonged tectonic histories may contain extensive regions of highly-fractured crystalline rocks that facilitate groundwater circulation to great depth.

Keywords:

Truth or Consequences, geothermal system, fracture measurement, magnetotelluric data