Using MT for understanding the formation of nonvolcanic geothermal systems: case study from Tsenkher geothermal area in Mongolia

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SUMMARY

Understanding the geological setting of nonvolcanic geothermal systems is vital to explaining the formation of geothermal reservoirs and their observable surface manifestations. The magnetotelluric method, used to determine the subsurface electrical conductivity distribution, is a common tool in geothermal exploration. In this study, we present an integrated interpretation of an electrical conductivity subsurface model, together with geological analyses and geochemical probes from a nonvolcanic, intermediate-temperature geothermal system in Mongolia. We conducted magnetotelluric (MT) and telluric-magnetotelluric (TMT) measurements at the Tsenkher geothermal area in the Mongolian Khangai dome during the summers of 2019 and 2020. The 20km*20km large area is characterized by three major hot springs with water temperatures up to 87°C. From a total of 196 MT and TMT stations, we obtained a 3-D electrical conductivity model of the subsurface. To interpret the data, we used a high-order finite-element electromagnetic modelling code (GOFEM) with locally refined hexahedral meshes that allows including accurate topography while ensuring high numerical accuracy with a sufficiently fine discretization of the inversion domain.

The best-fitting model provides essential insights into the subsurface structure of the Tsenkher geothermal area. The model is characterized by a strong vertical crustal conductor that appears south of the hot springs area and rises from depths of more than 10 km to the surface. We interpret this conductor as a remnant of past local volcanism and a zone of former magma ascent, indicating the potential source for the observed enhanced surface heat flow in the hot springs area around Tsenkher. Additionally, the model includes a prominent striking conductor beneath the hot springs at depths down to more than 3 km below the surface. The conductor is spatially aligned with a major fault that intersects the survey area, and is accompanied by several basaltic dyke intrusions. We interpret the fault-aligned conductor as the major area of deep fluid circulation and an accumulation zone for heated fluids. The interpretation agrees with theoretical concepts of topography-driven deep fluid circulation and local fault zones playing a major role in the transport of hot water from a reservoir to the surface. Inferred reservoir temperatures from geochemical fluid analyses are inagreement with interpretations of the maximum depth of fluid circulation inferred from the MT model.
Our MT subsurface model serves to better understand the formation of the Tsenkher hot springs in particular and intermediate-temperature geothermal systems in general.

Keywords: MT-TMT data acquisition, 3-D inversion, geothermal exploration, amagmatic geothermal systems, deep fluid circulation