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Unlocking Geothermal Potential in Northern Tanzania: Preliminary Geoscientific Exploration of the Natron Prospect

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ABSTRACT

Unlocking geothermal resources in Northern Tanzania is pivotal to advancing sustainable energy development within the East African Rift System (EARS). The Natron Geothermal Prospect, located in the Natron Magadi rift basin, has been prioritized by Tanzania Geothermal Development Company (TGDC) for its potential to generate 60MWe. In 2024, TGDC undertook preliminary geoscientific investigations including geological mapping, geochemical sampling, and geophysical surveys to evaluate the geothermal system. The studies revealed fluvial and lacustrine sediments, volcanoclastic deposits, and basement rocks structurally controlled by NNE–SSW and NW–SE fault systems. The Gelai dyke, extending 10 km NE, is interpreted as a likely magmatic heat source. Hydrothermal manifestations include alkaline hot springs (pH ~9.1) with discharge temperatures up to 52.8 °C, spatially aligned with major fault structures. Magnetotelluric (MT) surveys delineated a low-resistivity clay cap sealing probable reservoirs at ~2 km depth, with estimated temperatures of 125–174 °C and NaCl–HCO_3 fluid chemistry. Soil CO_2 flux and shallow temperature anomalies further mapped permeable pathways, confirming fault-controlled fluid migration. Collectively, these findings indicate a medium- to high-enthalpy geothermal system, capped by lacustrine sediments and young volcanic units, with permeability dominated by fracture networks. This integrated dataset provides the first comprehensive geoscientific evidence of Natron's geothermal potential, guiding the siting of resource confirmation wells and subsequent development phases. The study underscores the strategic importance of preliminary exploration in unlocking Northern Tanzania's geothermal resources and advancing regional energy resilience.

1 INTRODUCTION

The Natron geothermal prospect, located within the Natron–Magadi basin of the East African Rift System (EARS). This area is recognized as one of the most prospective geothermal targets in northern Tanzania. This region forms part of the Northern Tanzanian Divergence (NTD), a geodynamically complex segment of the rift characterized by active faulting, volcanism, and sedimentation processes (Ebinger et al., 1997; Dawson, 2008; Albaric et al., 2013). The tectonic evolution of this area reflects the interaction between magmatic intrusions and crustal deformation, which plays a fundamental role in the development of geothermal systems (Himematsu and Furuya, 2015; Roecker et al., 2017; Reiss et al., 2022).

Northern Tanzania hosts a series of active volcanic centers, including Oldoinyo Lengai, the only active natrocarbonatite volcano globally, whose eruptive dynamics and magmatic processes have significant implications for regional heat flow and geothermal potential (Kervyn et al., 2010; Beeckmans, 2014). In addition, large-scale carbon degassing associated with rifting processes has been documented in the region, indicating deep fluid circulation and mantle contributions to geothermal systems (Lee et al., 2016).

As part of Tanzania's national energy strategy aimed at diversifying energy sources and enhancing sustainability, geothermal resources have been identified as a key component of future power generation (Decon-Sweco, 2005; JICA, 2010; JICA, 2013). In this context, the Tanzania Geothermal Development Company (TGDC) has prioritized the Natron prospect, with an estimated generation capacity of approximately 60 MWe.

Previous regional and reconnaissance studies have highlighted the geothermal potential of the Natron area; however, detailed subsurface characterization has remained limited. To address this gap, TGDC conducted integrated geoscientific investigations in 2024, including magnetotelluric (MT) surveys, soil gas measurements, and shallow temperature assessments. These methods are widely applied in geothermal exploration to

delineate subsurface structures, identify permeable zones, and constrain thermal anomalies (Chiodini et al., 1998; Bjarnason, 2010; Parkhurst and Appelo, 2015).

In this study, newly acquired MT data were processed and interpreted using one-dimensional (1D) resistivity inversion to derive the electrical structure of the subsurface. The resulting resistivity models were integrated with soil CO_2 flux and temperature datasets to improve the understanding of fluid pathways, heat sources, and reservoir characteristics. This integrated approach provides a more robust assessment of the geothermal potential of the Natron prospect and supports future exploration and drilling strategies. The spatial distribution of MT stations acquired during the 2024 survey is presented in Figure 1, illustrating the extent of geophysical data coverage across the study area.

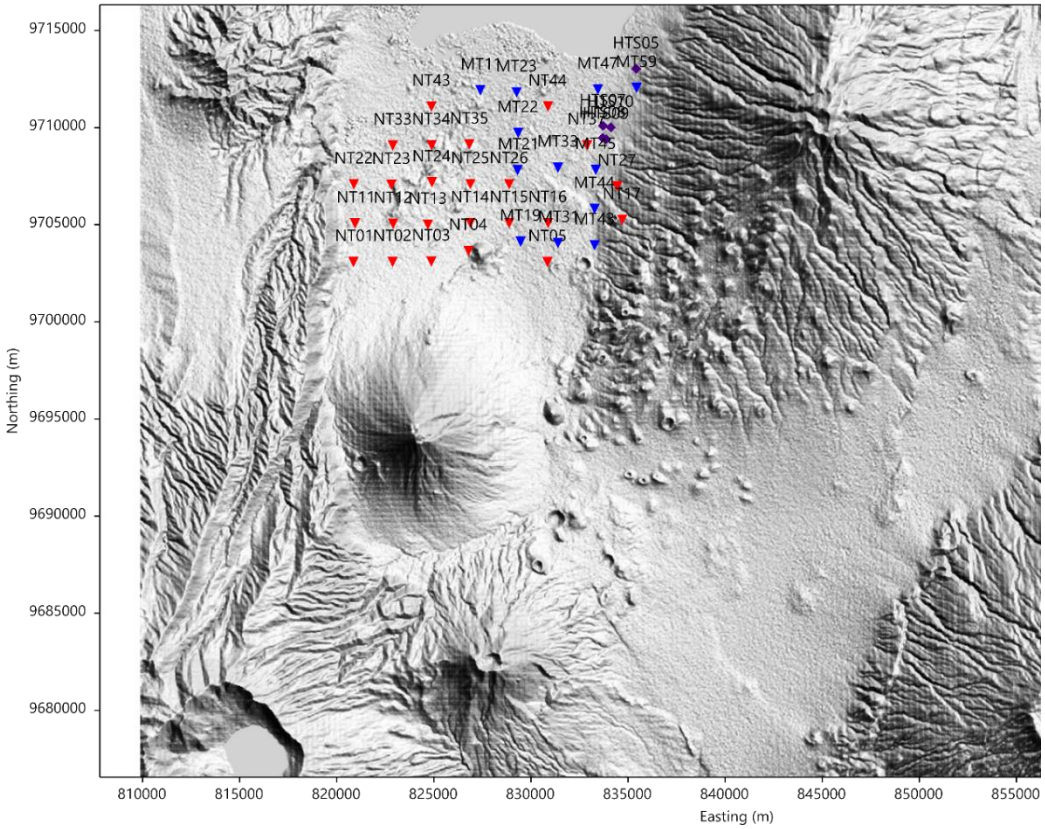


Figure 1: Locations of MT survey stations during the 2024 survey. The spacing between the stations was 2 km along the profiles.

1.1 PROJECT DESCRIPTION AND LOCATION

Natron geothermal prospect is situated in the Northern Tanzanian Divergence zone (NTD) within the eastern arm (Gregorian rift) of the East African Rift System (EARS) or Natron rift which has recorded the complex history of faulting, sedimentation and volcanism. The heat source for Natron is associated with rifting magmatism most likely the Gelai Volcano and the 10 km long dyke which is found in the Eastern part of the prospect area as shown in Figure 2.

Topography of Natron prospect is largely controlled by its geological location which includes volcanic eruptions and rifting/tectonic movement. It is regionally located in the NTD zone of the EARS (Figure 2) which developed due to complex tectonics. The region is associated with the second highest point in Tanzania (Meru volcano) in the Southeast and Oldoinyo Lengai in the Southwest (Figures 2 and 3).

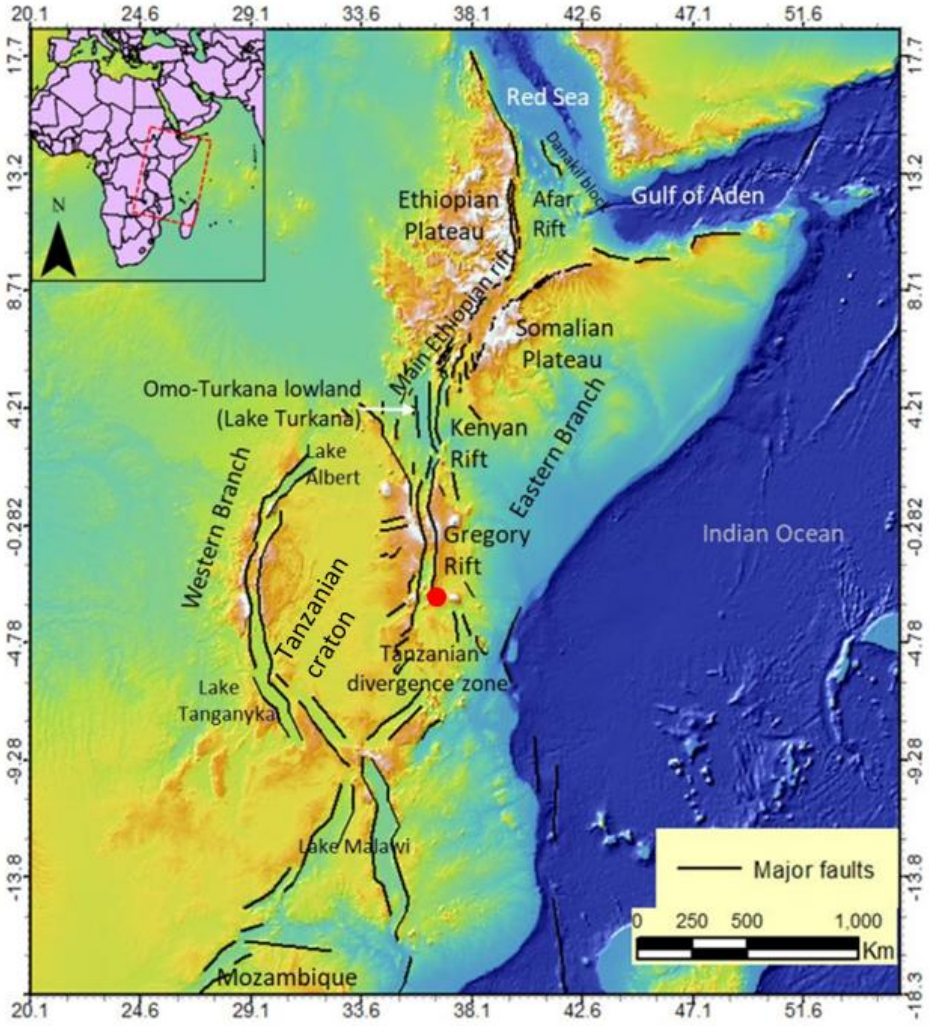


Figure 2: Digital elevation map of the Eastern Africa showing the East African Rift System (EARS) (From Josephat, 2023). The location of the study area is in Gregory Rift.

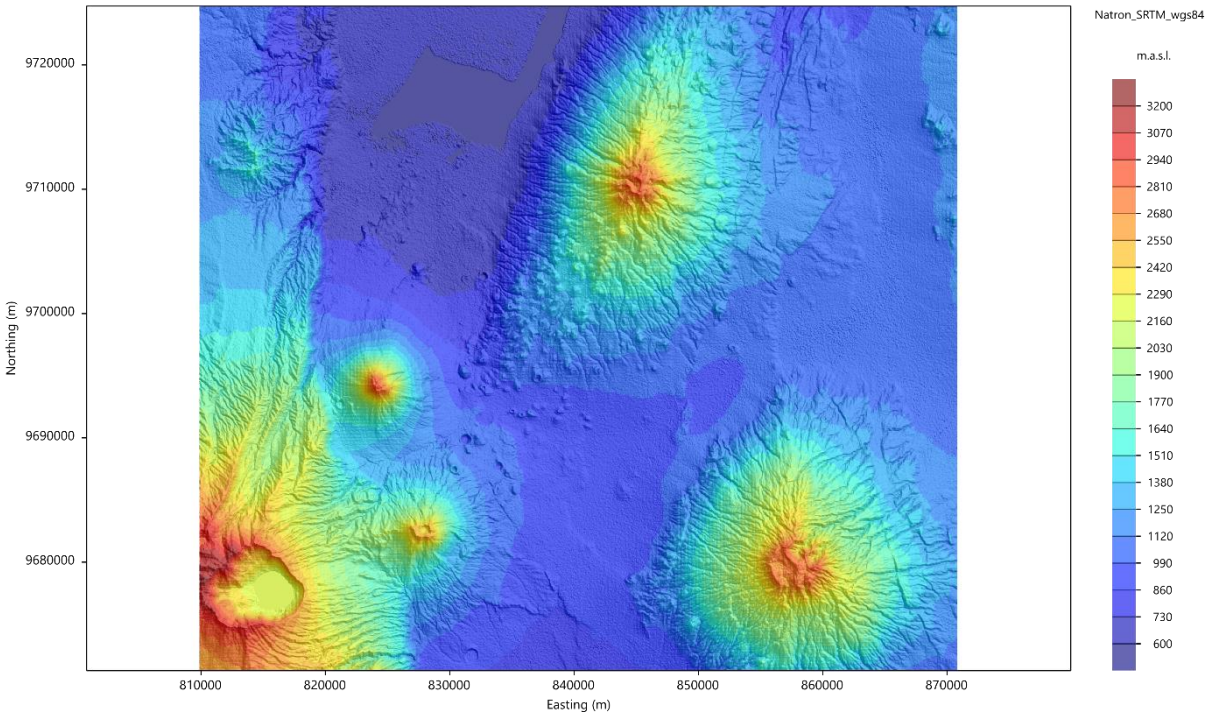


Figure 3: DEM showing Topography of Natron Prospect and the surrounding areas

1.2 Objective of the paper

The main objective of this paper is to reveal the preliminary investigation results at Natron. Through this work, it has shown possibilities to conduct a detailed geoscientific investigation as the area seemed to have a viable geothermal potential

2. GEOLOGICAL SETTING

Natron geothermal prospect is located within the eastern sector of the East African Rift System (EARS) or Natron rift. The region is characterized by active volcanoes and a group of eruption centres including small craters and tuff cones. Surface geology of the prospect is largely dominated by pyroclastic, tuffs, soda ash, trachyte, agglomerates, nepheline-carbonatite lava and olivine-basalt lava. The widespread volcanoclastic deposits were either effusively (Figure 4) or explosively ejected from the prominent Oldonyo Lengai volcano located SW of the prospective area (Figure 3).

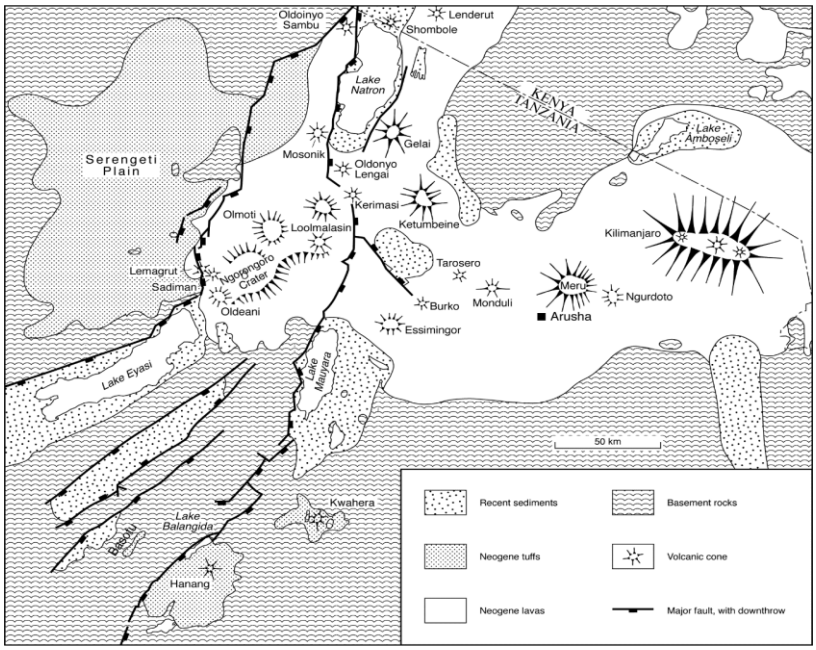


Figure 4: Map showing volcanoes and tectonic lineament in the Northern Tanzania Divergence Zone (Foster et al., 1997).

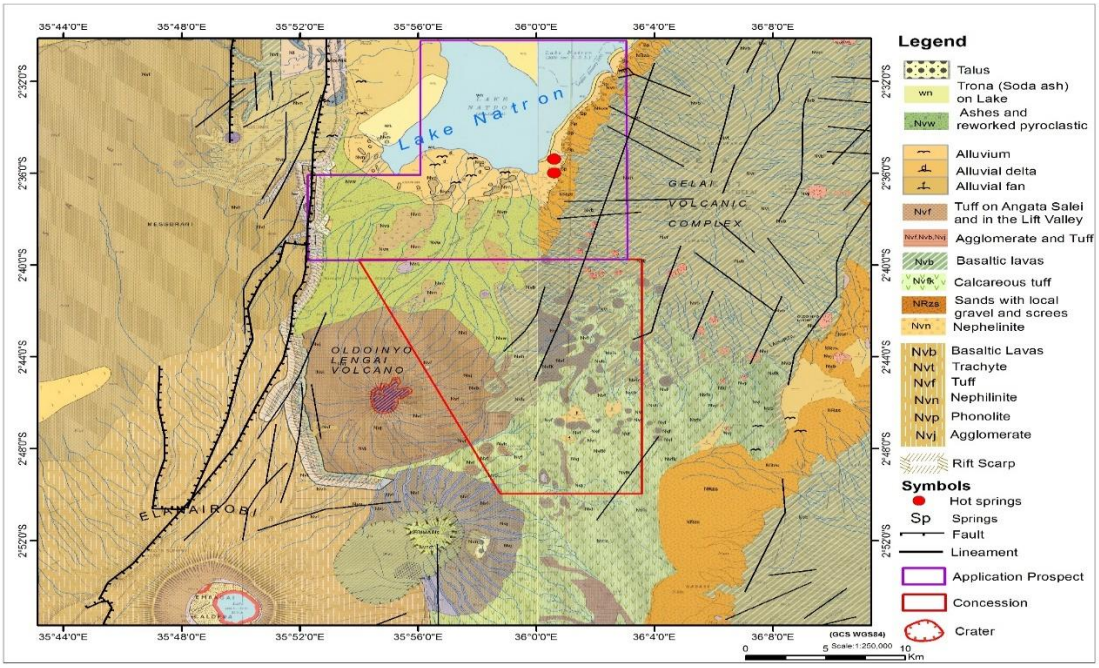


Figure 5: Geological map of Natron Prospect.

3. METHODOLOGY

An integrated, multidisciplinary approach was employed to evaluate the geothermal potential of the Natron prospect:

3.1 Geological and Structural Mapping

Detailed field mapping was conducted to identify lithological units and structural features. Attention was given to fault orientations (NNE–SSW and NW–SE), volcanic centers, and surface manifestations, which are critical for understanding fluid flow pathways.

3.2 Soil CO_2 Flux Measurements

Diffuse soil CO_2 emissions were measured using portable accumulation chamber techniques. These data were used to identify zones of enhanced degassing, which are indicative of permeable structures and active geothermal processes.

3.3 Soil Temperature Survey

Ground temperature measurements were collected at a depth of 15 cm using a calibrated thermocouple. Spatial variations in temperature were analyzed to detect anomalous heat flow linked to subsurface geothermal activity.

3.4 Magnetotelluric (MT) Survey and Data Processing

A total of 41 MT stations (29 acquired in 2024 and 12 from earlier surveys) were analyzed. The data were processed and inverted using one-dimensional (1D) inversion techniques to derive subsurface resistivity structures. The resulting models were interpreted to identify key geothermal components, including conductive clay caps, resistive reservoirs, and structural controls.

3.5 Data Integration

All datasets were integrated to delineate the geothermal model. Correlation between resistivity anomalies, gas emissions, temperature data, and geological structures was used to constrain the geothermal system.

4. RESULTS AND DISCUSSION

3.1 Soil CO_2 Diffuse Degassing

The analysis of diffuse CO_2 degassing in the surveyed area reveals notable anomalous degassing forming trends oriented in northeast-southwest (NE-SW). Less dominant trends-oriented northwest-southeast (NW-SE), east-northeast to west-southwest (ENE-WSW) and WNW-ESE can also be observed in the area (Figure 6). The identified CO_2 degassing anomalies may be inferred to represent the concealed permeable geological structures which act as conduits for such gas on the southeastern flank of lake Natron (Josephat et al. 2024).

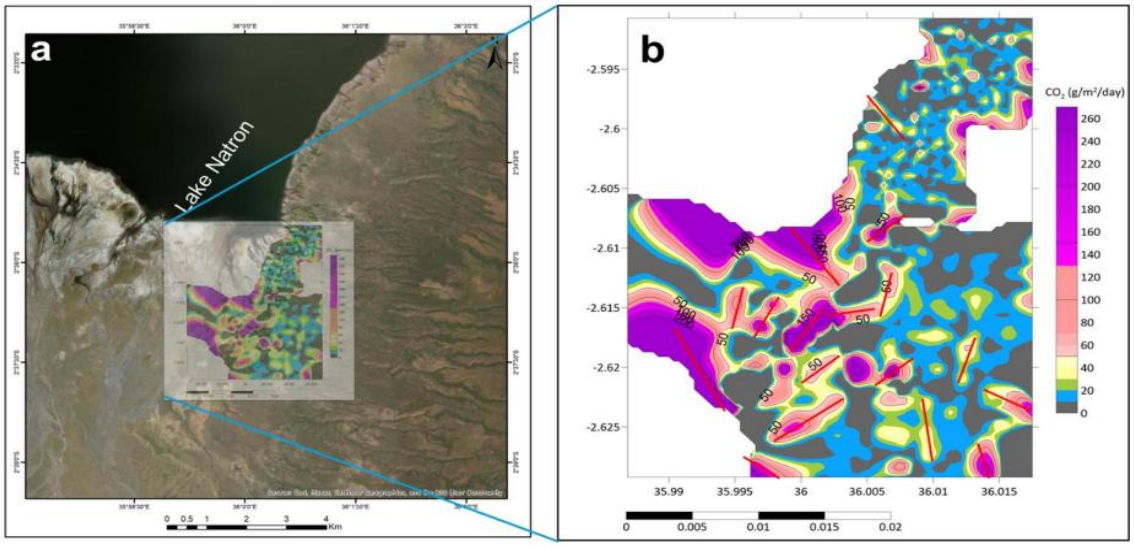


Figure 6: Map (a) showing Lake Natron and the spatial distribution of CO_2 flux from the soil on the southeast of Lake Natron. Map (b) indicates the spatial distribution of CO_2 flux and structures (red lines).

3.2 Soil Temperature

Flux Soil temperatures were recorded at a depth of 15 cm below ground level using a high precision thermocouple. The measurements revealed significant variations in temperature in different parts of the surveyed area in the Natron prospect. Ground temperature ranged between 24.1-51.9°C with average of 33°C while ambient temperature ranged between 21-47.4°C with average of 32°C. Although the surveyed area was wet in some parts, majority of the measured stations (55.46%) recorded temperatures exceeding the ambient temperature, suggesting the existence of deeper heat sources which may be contributing to high heat flux in the Natron area.

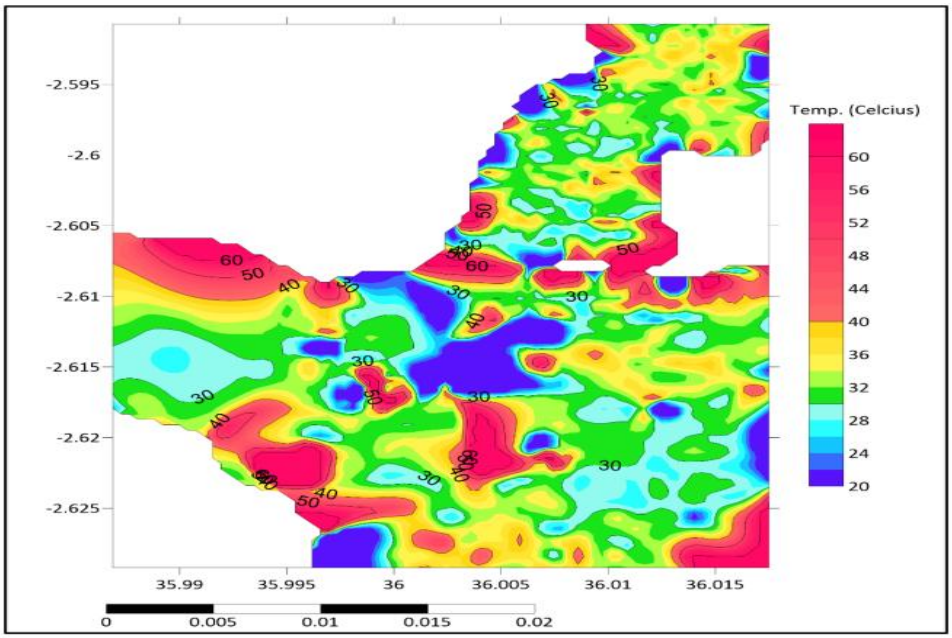


Figure 7: Maps showing spatial distribution of soil temperature on the southeastern flank of Lake Natron.

4.3 1d Inversion Results of MT Data Set

The work involved interpretation of 41 MT soundings in total, with 29 MT soundings acquired in 2024 and the previous 12 MT soundings acquired in 2018. The inversion result confirms Natron evolution complexity as documented by previous researchers. The resistivity structure comprises conductive circular features having resistivity values (<1 ohm-m) (Figures 8-10). We interpret these circular conductive bodies as sills of molten materials as has also been suggested by Reiss et al., (2022).

The distribution of resistivity at shallow depth reveals an NNW-SSE and NNE-SSW orientation apart from circular conductive anomalies. The dominant structural trend, the NNE-SSW and the NW-SE trends converge at the center of the study area where the circular feature of high conductivity is situated (Figure 9).

The resistivity results show high resistivity values (>150 ohm-m) in the East and West of Natron prospects at the hillside of Gelai and in the Rift Scarp respectively consistent with basement rocks. Moving from Gelai towards Lake Natron, resistivity gets considerably lower showing a higher electrical conductivity in the lake sediments than in the volcanic rocks at the slope.

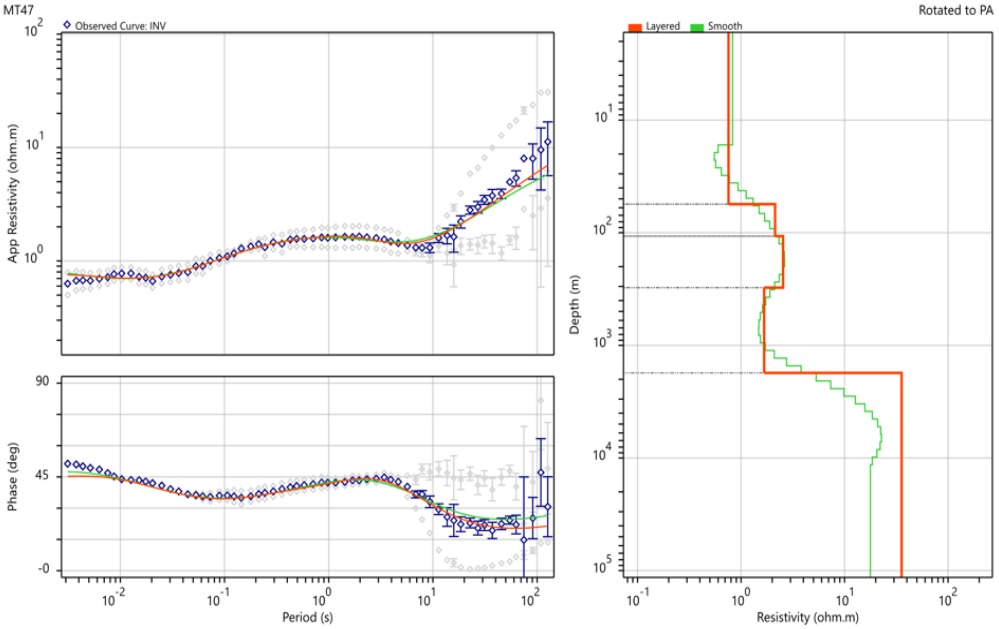


Figure 8: The invariant 1-D model indicating the electro stratigraphy of the Natron area. The observed resistivity values less than 100 ohm-m, are typical resistivity values in sedimentary basin settings.

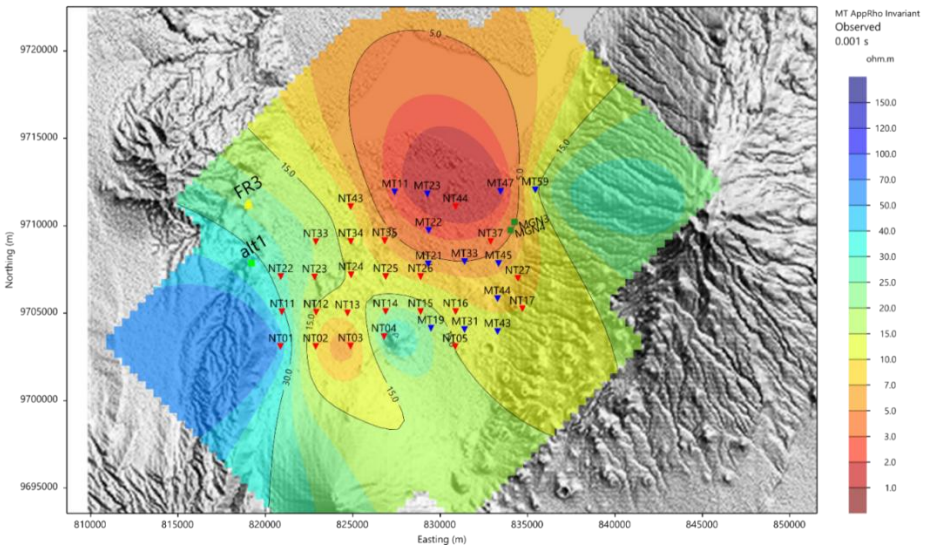


Figure 9: Observed apparent resistivity at 0.001s to depict shallow resistivity structures in Natron. MGN – Magadini hot springs: FR – location of fumarole at Natron escarpment: alt1 – a layer of green rock at Natron waterfall resembling an altered rock due to hydrothermal activities.

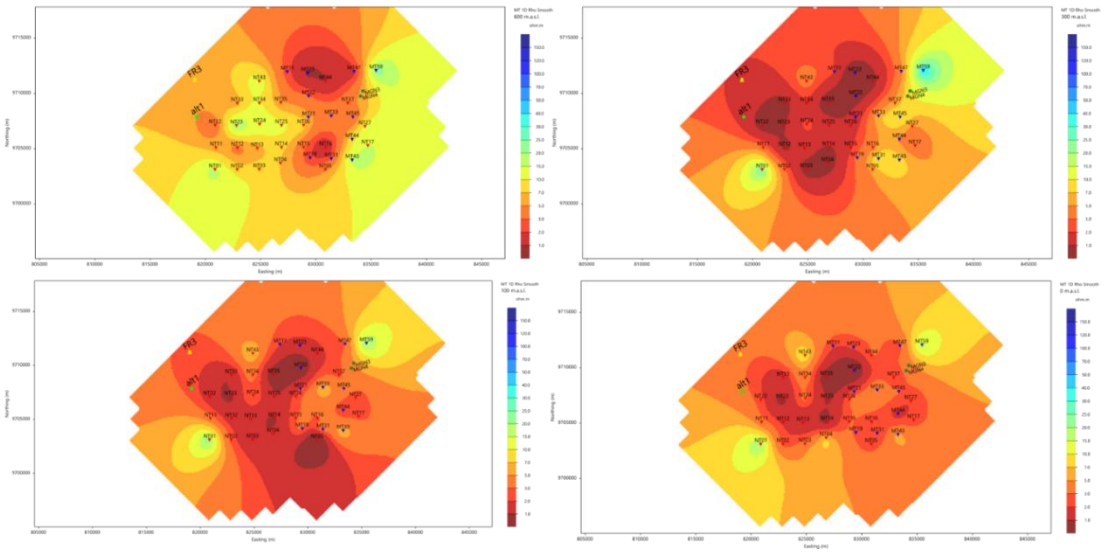


Figure 10: Depth slice maps from 600 m, 300 m, 100 m to 0 m above sea level indicating resistivity variation with depth.

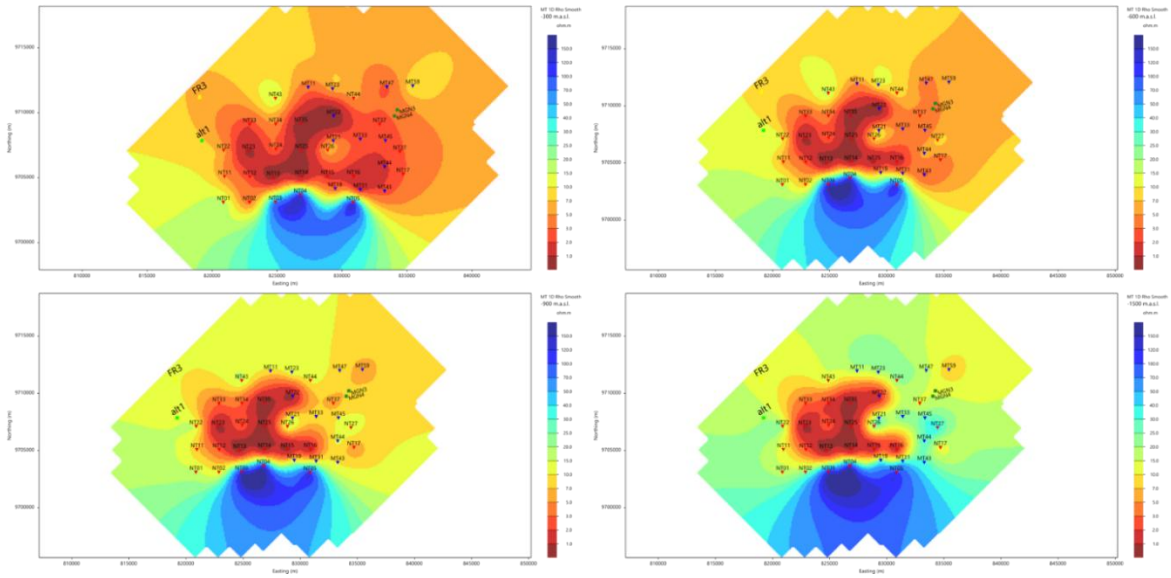


Figure 11: Resistivity at 300, 600, 900 and 1500 m below sea level

5. CONCLUSIONS

The heat source driving the geothermal system in Natron is probably the Gelai volcano. Natron prospect lies on the floor of the Natron basin where hot springs discharge on the Eastern and the Western sides of lake Natron, coinciding with the faults bounding the basin. Natron geothermal prospect is a medium to high enthalpy geothermal system with estimated subsurface reservoir temperature ranging from 125 °C to 174 °C, with a reservoir depth approximately 2 km.

Furthermore, lacustrine deposits and the young volcanic lava could function as system capping/cap rock sealing Natron geothermal reservoir. In addition, permeability in the Natron prospect is chiefly dominated by faults and fractures. The dominant structural trend in the area is the NNE–SSW to the N-S oriented structures. These structures run parallel on the Eastern and Western margin of the basin and are the major fault controlling fluid migration within the geothermal system. Other structures are the NW-SE trends which together make interconnection for fluid movement where heat is transported within the geothermal system toward the surface, where are manifested as hot springs.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this brief paper.

Data availability

The authors do not have permission to share data.

REFERENCES

DECON-SWECO, 2005: Technical Report on Geothermal Power. Tanzania Rural Electrification Study.

JICA, 2010: Situation Analysis Study on Geothermal Development in East Africa.

JICA, 2013: Data Collection Survey on Geothermal Energy Development in East Africa. Draft Final report (Tanzania).

Albaric, J., Déverchére, J., Perrot, J., Jakovlev, A., Deschamps, A, 2013: Deep crustal earthquakes in North Tanzania, East Africa: Interplay between tectonic and magmatic processes in an incipient rift, published in Geochemistry, Geophysics, Geosystems, Vol. 15, AGU Publication. pp. 374-394.

BEECKMANS, B, 2014: Volcanism in Tanzania, Thesis, Atlantic International University Honolulu, Hawaii.

Bjarnason, J.Ö: 2010: The chemical speciation program WATCH, version 2.4. ÍSOR – Iceland GeoSurvey, Reykjavik.

Chiodini G., Cioni R., Guidi M., Raco B., Marini L. 1998: Soil CO2 flux measurements in volcanic and geothermal areas, Appl. Geochem., 13, 543-552.

DAWSON, J.B. 2008: The Gregory rift valley and Neogene-Recent volcanoes of northern Tanzania, Geological Society of London Memoir 33, 112 p.

Ebinger, C., Djomani, Y. P., Mbede, E., Foster, A., & Dawson, J. B. (1997). Rifting Archaean lithosphere: The Eyasi-Manyara-Natron rifts, East Africa. Journal of the Geological Society, 154(6), 947–960. https://doi.org/10.1144/gsjgs.154.6.0947

Himematsu, Y. and Furuya, M. 2015: Aseismic strike–slip associated with the 2007 dike intrusion episode in Tanzania. Department of Natural History Sciences, Hokkaido University, N10W8, Kita-ku, Sapporo 060-0810, Japan.

Kervyn, M., Ernst, G.G.J., Keller, J., Vaughan, R.G., Klaudius, J., Pradal, E., Belton, F., Mattsson, H.B., Mbede, E., Jacobs, P. 2010: Fundamental changes in the activity of the natrocarbonatite volcano Oldoinyo Lengai, Tanzania, Bull. Volcanol. 72, 913–931.

Lee, H., Muirhead, J., Fischer, T., Ebinger, C., Kattenhorn, S., Sharp, Z., and Kianji, G. 2016: Massive and prolonged deep carbon emissions associated with continental rifting. Nature Geoscience Letters, PUBLISHED ONLINE: 18 JANUARY 2016 | DOI:10.1038/NGEO2622.

Parkhurst, D.L. and Appelo, C.A.J. 2015: Description of input and examples for PHREEQC, version 3 - A computer program for speciation, bath-reaction, one-dimensional transport, and inverse geochemical calculations. USGS, USA, computer software.

Reiss, M. C., De Siena, L., & Muirhead, J. D. (2022). The Interconnected Magmatic Plumbing System of the Natron Rift. Geophysical Research Letters, 49(15), 1–11. https://doi.org/10.1029/2022GL098922

Roecker, S., Ebinger, C., Tiberi, C., Mulibo, G., Ferdinand-Wambura, R., Mtelela, K., Kianji, G., Muzuka, A., Gautier, S., Albaric, J., & Peyrat, S. (2017). Subsurface images of the Eastern Rift, Africa, from the joint inversion

of body waves, surface waves and gravity: Investigating the role of fluids in early-stage continental rifting. Geophysical Journal International, 210(2), 931–950. https://doi.org/10.1093/gji/ggx220