Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

Geochemical and Petro-Physical Characteristics of the Kenyan Rift Basalts for CO_2 Mineralization Potential (Case Study Olkaria Geothermal Field)

Christine N. Katana[1,2]*, Guðmundur H. Guðfinnsson[3], Iwona M. Galeczka[3], Guðni Axelsson[2]
KenGen[1]*, GROGTP[2], Haskoli Islands[3]
Ckatana@kengen.co.ke *

INTRODUCTION

Rising levels of anthropogenic CO_2 and the ongoing climate change have intensified global calls for carbon emissions reduction. The global atmospheric CO_2 concentration reached 422 ppmv in 2024 which is about 51% higher than pre-industrial levels. To mitigate emissions while meeting energy demands, strategies like carbon capture and storage (CCS) are being promoted. Basalt formations are gaining popularity as viable CCS sites due to their ability to permanently mineralize CO_2, as demonstrated by the Carbfix project in Iceland (Gislason et al., 2010).

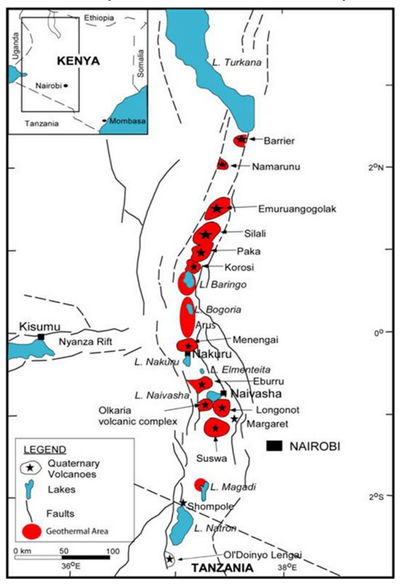


Figure 1. Map of the Kenyan rift system showing the location of Olkaria geothermal field and other volcanoes (Ofwona et al., 2006).

Geothermal power plants in Olkaria geothermal field located within the southern sector of the Kenyan rift, shown on Fig. 1, emit around 68,916 tCO_2e annually, despite being renewable.

The region's basaltic formations found in Olkaria geothermal field show promise for CO_2 mineralization. However, properties of these basalts and their long-term potential remain under-researched. This study aims to assess the mineralogical, chemical, and petrophysical properties of the Olkaria Basalt unit, shown on Fig. 2, using rock cuttings from four reinjection wells, to better estimate its CO_2 storage capacity and support effective onsite carbon mitigation strategies.

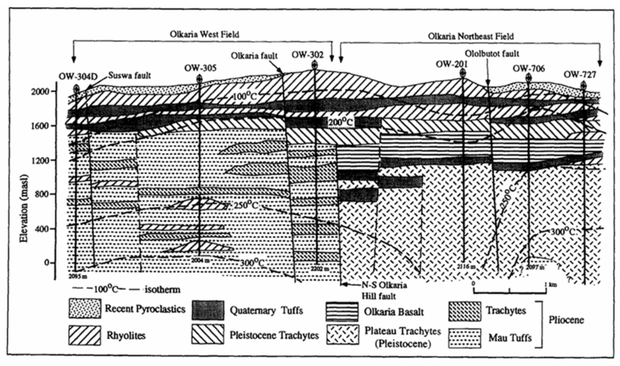


Figure 2. General lithostratigraphy of the Olkaria geothermal area with temperature distribution. Modified from Omenda (1994), includes data from Browne (1984) and Muchemi (1992) (Omenda, 1998)

MATERIAL AND METHODS

Materials: Drill cuttings from 4 reinjection wells as shown on Fig. 3 and Fig. 4 respectively.

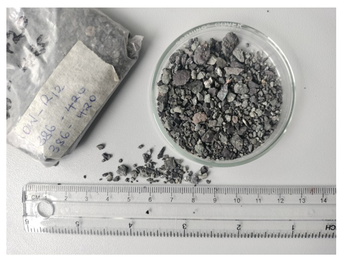


Figure 3. Rock cuttings

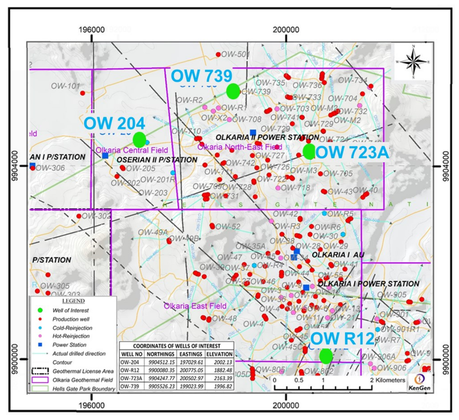


Figure 4. Location map of wells OW-204, OW-739, OW-723A, & OW-R12

Methods:

1. Binocular Analysis
2. Petrographic Analysis
3. ICP-OES Analysis - 10 major elements
4. Porosity estimation using SEM images and ImageJ software to quantify void spaces
5. Estimation of theoretical CO_2 Storage Capacity (Zhang et al., 2023)

$mCO_2=\sum \rho r.fi/ni.nCO_2$,.....Eq1

$MCO_2=mCO_2.A.H(1-\phi)$,.....Eq2

Where: ρr=rock density, fi = mass fraction, ni = molecular weight, nCO_2 = molar weight of CO_2, i= CaO,MgO,FeO, A = reservoir area (at 0.5 km radius), H = thickness , (ϕ) = porosity as a fraction

- mCO_2 =theoretical CO_2 storage capacity per unit volume of rock.
- MCO_2=total mass of CO_2 stored in a given volume of the reservoir.

Key input: Concentrations of CaO,MgO,FeO, thickness, porosity & reservoir area

RESULTS

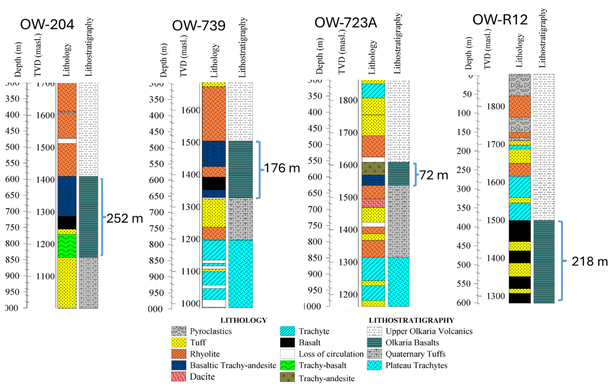


Figure 5. : Rock units observed within the Olkaria Basalt unit across the four wells

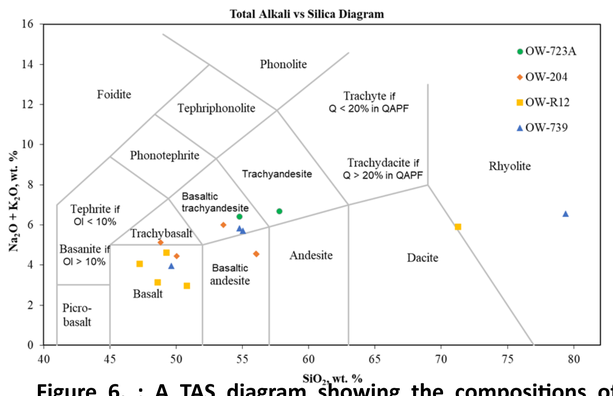


Figure 6. : A TAS diagram showing the compositions of the rocks from wells OW-723A, OW-R12, OW-204 and OW-739.

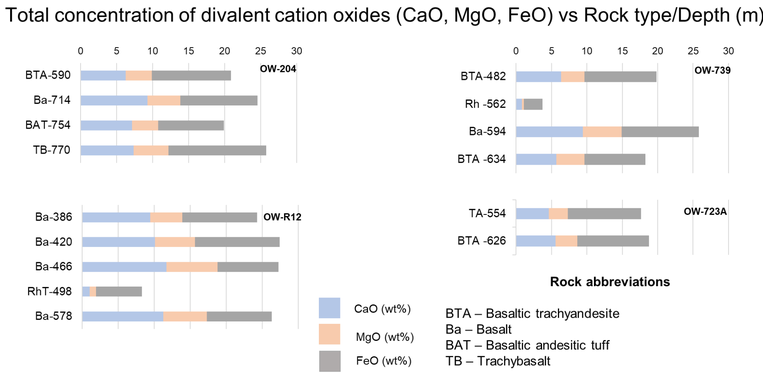


Figure 7. : Total concentration of the reactive oxides CaO, MgO, FeO (wt%) vs rock type/Depth (m), for OW-204, OW-R12, OW-739 & OW-723A.

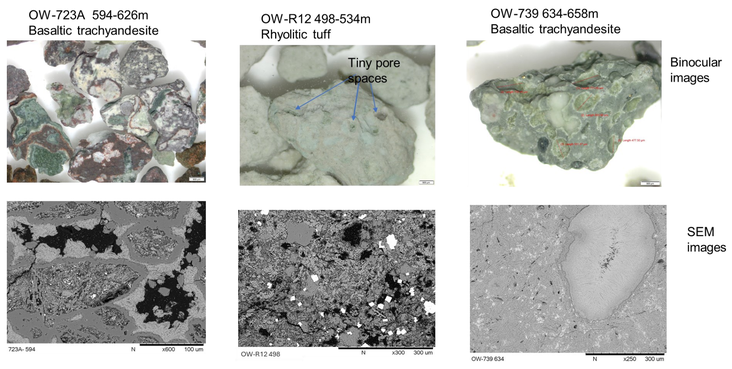


Figure 8. : Images of vesicle porosity. Binocular image and BSE image of porosity in wells OW-723A, OW-R12 and OW-739, showing how porosity has been affected by deposition of secondary mineral .

Table 1. : Measured porosity percentages of the rocks within the Olkaria Basalt unit .

Well	Depth (m)	Rock	Porosity (%)	Av. porosity (%)
OW-204	590-714	Basaltic trachyandesite	2.02	2.18
	714-754	Basalt	4.23	
	754-770	Basaltic andesite tuff	0.84	
	770-842	Trachy basalt	1.62	
OW-723A	554-594	Trachyandesite	2.19	2.59
	594-626	Basaltic trachyandesite	2.98	
OW-739	482-562	Basaltic-trachyandesite	1.19	1.28
	562-594	Rhyolite	1.16	
	594-634	Basalt	1.01	
	634-658	Basaltic-trachy andesite	1.77	
OW-R12	386-420	Basalt	4.23	3.83
	498-534	Rhyolitic tuff	6.05	
	578-604	Basalt	1.22	

Table 2. : Theoretically estimated CO_2 storage capacities for the different wells. A represents the reservoir area within a radius of 0.5 km, H represents the thickness of the Olkaria Basalt unit in the well and 1-ϕ represents the solid rock volume with reactive mineral phases within the rock matrix. .

Well	mCO_2 (t/m^3)	A (Km^2)	H (m)	1-ϕ	MCO_2eff (Mt)
OW-204	0.46	0.79	252	0.98	89.6
OW-R12	0.43	0.79	218	0.96	70.1
OW-739	0.40	0.79	176	0.98	54.3
OW-723A	0.42	0.79	72	0.97	23.2

DISCUSSION AND CONCLUSION

- The Olkaria Basalt unit lies between 1600–1100 m a.s.l. and consists of interbedded layers of basalt, tuff, rhyolite, basaltic trachyandesite, trachybasalts, and trachyandesite. It varies in thickness from 70 m in Olkaria Northeast to 250 m in Olkaria Central. Well data show textural changes with depth and regional variations in thickness and composition.
- Hydrothermal alteration is widespread and affects porosity and permeability. Secondary minerals like quartz, chlorite, calcite, and pyrite are observed, with epidote appearing only in OW-204, indicating temperatures of >240°C.
- Divalent cation oxide concentrations vary across rock types in the Olkaria Basalt unit. Mafic rocks like basalts have the highest values (24–27%), intermediate rocks have moderate concentrations (17–20%), while felsic rocks like rhyolite and rhyolitic tuff are least effective (3.7–8.2%) due to high silica content.
- Porosity is vital for CO_2 mineralization, but in the Olkaria Basalt unit, it is limited (1.3–3.8%) due to extensive alteration and secondary mineral deposition in vesicles and veins.
- The Olkaria geothermal field has an estimated CO_2 storage capacity of 23–89 Mt, enough to offset emissions for 160–600 years, even with projected increases as Kenya expands geothermal capacity from 799 MW to 1.6 GW by 2030.
- While rock composition and porosity determine capacity, factors like depth, temperature, pH, and pressure also affect storage efficiency. At Iceland's Carbfix2 site, CO_2 is injected into basalt at 750 m and 250°C (Snæbjörnsdóttir et al., 2018). Similarly, the high-temperature conditions at Olkaria suggest that even small-scale injection zones can support long-term CO_2 storage.
- With a storage capacity of 23–89 Mt, the Olkaria field presents a significant opportunity for CO_2 sequestration to help offset geothermal emissions in Kenya. However, effective implementation will require strategic planning and investment.

Acknowledgements

REFERENCES

Gislason, S., Wolff-Boenisch, D., Stefansson, A., Oelkers, E., Gunnlaugsson, E., Sigurdardottir, H., Sigfusson, B., Broecker, W., Matter, J., and Stute, M. (2010). Mineral sequestration of carbon dioxide in basalt: A pre-injection overview of the CarbFix project. International Journal of Greenhouse Gas Control, 4(3), 537–545.

Ofwona, C., Omenda, P., Mariita, N., Wambugu, J., Mwawongo, G., and Kubo, B. (2006). Surface geothermal exploration of Korosi and Chepchuk prospects

Omenda, P. A. (1998). The geology and structural controls of the Olkaria geothermal system, Kenya. Geothermics, 27(1), 55–74.

Snæbjörnsdóttir, S. Ó., Tómasdóttir, S., Sigfússon, B., Aradóttir, E. S., Gunnarsson, G., Niemi, A., Basirat, F., Dessirier, B., Gislason, S. R., Oelkers, E. H., and Franzson, H. (2018). The geology and hydrology of the CarbFix2 site, SW-Iceland. Energy Procedia, 146, 146–157.

Zhang, L., Wen, R., Li, F., Li, C., Sun, Y., and Yang, H. (2023). Assessment of CO_2 mineral storage potential in the terrestrial basalts of China. Fuel, 348, 128602.