GEOTHERMAL ENERGY DEVELOPMENT OF L. ABBE AND CDM FOR DJIBOUTI

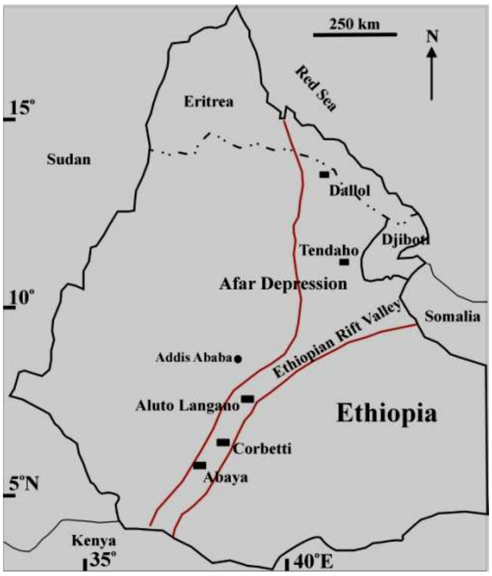
D Chandrasekharam[1,2] and Varun Chandrasekhar[2]
[1.] *Department of Earth Sciences, Indian Institute of Technology Bombay, India*
[2.] *GeoSyndicate Power Pvt. Ltd., Mumbai*

ABSTRACT

Lake Abbe geothermal province is located within the Afar depression and is one of the active geothermal provinces in Djibouti. The lithological and tectonic configuration of Lake Abbe geothermal systems appears to bear strong similarity to Tendaho geothermal systems located in the Ethiopian Rift, towards NE of Lake Abbe. Lake Abbe is part of ther Awash river basin and the entire surface run off of Awash discharges in to this lake. The geochemical signature of the Lake Abbe geothermal waters is similar to the surface thermal springs and bottom hole thermal waters of Tendaho geothermal province. A conservative estimate of 15 to 20 MWe for the thermal province reported. By using tapping all the geothermal provinces, Djibouti can become energy independent and improve the socio-economic condition of the rural as well as urban population and earn about 9 million euros under certified emision rate through clean development mechanism

INTRODUCTION

The Republic of Djibouti occupying an area of 23180 sq.km is located above the 'Horn of Africa" adjacent to the Red Sea (Fig 1a) It is occupies a strategic position in the East African Continent due to the presence of natural harbour. The essential commodities to all the East African countries land in Djibouti port and transported over land. The population density of the country is about 14 persons/km^2, most of them concentrated in Djibouti town. The country is bordered by Ethiopia and Somalia in the SE. Although the coastal plain is ~ 25 km wide, Ghoubet Kharab bay at Gulf of Tadjoura separates the sea from SE-NW depression land. This part of the land is 155 m below the sea level. The western part of the country is dominated by several SE-NW trending ridges formed due to linear faults that rsulted due to the tectonic configuration of the AFAR triangle and are dominated by basaltic flows. The only river basin in Djibouti is the L Abbe, located toward the south western part of the country that receives drainage from Awash river (Fig 1b).



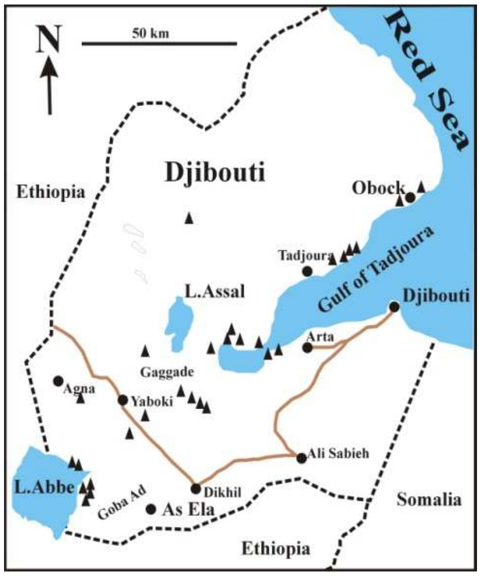


Figure 1: **a).** Map showing the major geothermal fields in the East African Rift valley and **b)** geothermal springs in Djibouti.

The main source of electric power in Djibouti is diesel, imported from the developing countries. The unit cost of electric power is about US 20 cents. Djibouti, being located within the East African Rift system, is endowed with excellent high enthalpy geothermal energy resources. The country can be energy independent if the geothermal resources are utilized both for power production and space heating and cooling. The socio-economic status of the rural communities in the country can be uplifted through this energy source.

TECTONIC SETTING OF THE GEOTHERMAL SYSTEM AROUND L. ABBE

The Afar Depression is loci of active volcanism and tectonism and extends SW in to Ethiopia as the East African Rift. Afar and the EAR host a large number of thermal springs that resulted due to active magmatic activity. This region is one of active spreading ridge since 30 Ma represented by a series of volcanic flows of age ranging from Recent to > 4 Ma (Barberi and Varet, 1977, Varet and Gasse,1978) has given a detailed account on the geological information on the Afar (including EAR and Djibouti). A geological cross section of the lithological Formations across the EAR extending from West of Tendaho to the western banks of Lake Abbe is shown in figure 2.

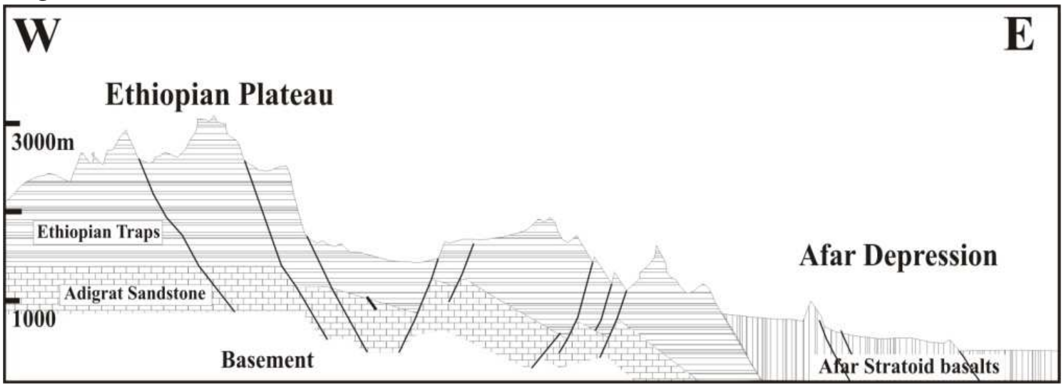


Figure 2: Lithological section across the Ethiopian plateau (Western flank of the rift valley) and Afar depression (up to western bank of Lake Abbe). Modified from (Barberi and Varet, 1977, Varet and Gasse, 1978).

Although Djibouti and Ethiopia are divided politically, the geologically the stratigraphic sequence found on either side of L. Abbe is same and a part of this sequence is shown in figure 2. The Ethiopian Plateau basalts on the western side of L. Abbe continue towards East of the lake and form the oldest basalt sequence in Ali Sabieh horst in Djibouti. Pre-Tertiary sandstone (Adigrat Formation) and limestone Formations underlying below the Ethiopian Plateau basalts continue towards East and lie below the Afar Stratoid basalts extensively outcropping around L. Abbe. All the basalts are dissected by series of parallel NW-SE trending faults. Being within the zone of a spreading zone, the entire L. Abbe zone experiences very high heat flow represented by a large number of boiling thermal springs and fumaroles. Considering the location of the Tendaho geothermal field and the stratigraphic configuration of litho units and drainage systems, the L. Abbe geothermal field is no way different from that of the Tendaho system located a few kilometres away from the L Abbe geothermal field. In fact, as seen from figure 3, the L. Abbe geothermal systems appears to be a part of the Tendaho geothermal system, considering the surface and subsurface geology, tectonic setting and surface manifestations.

GEOCHEMICAL SIGNATURE OF L. ABBE GEOTHERMAL PROVINCE

The L. Abbe geothermal province hosts more than 20 thermal springs with issuing temperature varying from 70 to 98 °C with a flow rate varying from 40 to 45 L/s. Majority of the springs are characterised by tall travertine mounds, aligned parallel to the regional structural trend (figure 3). The fumarolic activity is seen at the top of several travertine mounds (Figure 4) deposited over boiling springs.

The geochemical signature of the L Abbe area is very similar to the thermal springs around Tendaho as shown in figure 5a. On the Giggenbach's Na-K-Mg diagram (Figure 5b) the L. Abbe thermal springs fall near the Tendaho Thermal springs area within the partial equilibrium field.

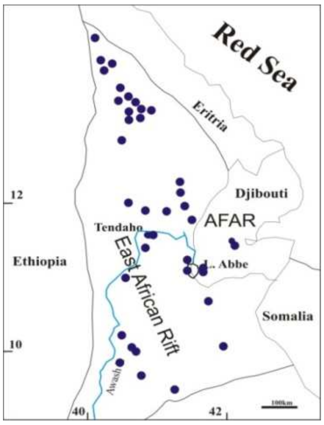


Figure 3: East African Rift and Afar showing the location of thermal springs and the Awash River (modified after Ali, 2001).

Figure 4. Travertine mounds around Lake Abbe and fumarolic activity over the Travertine mound.

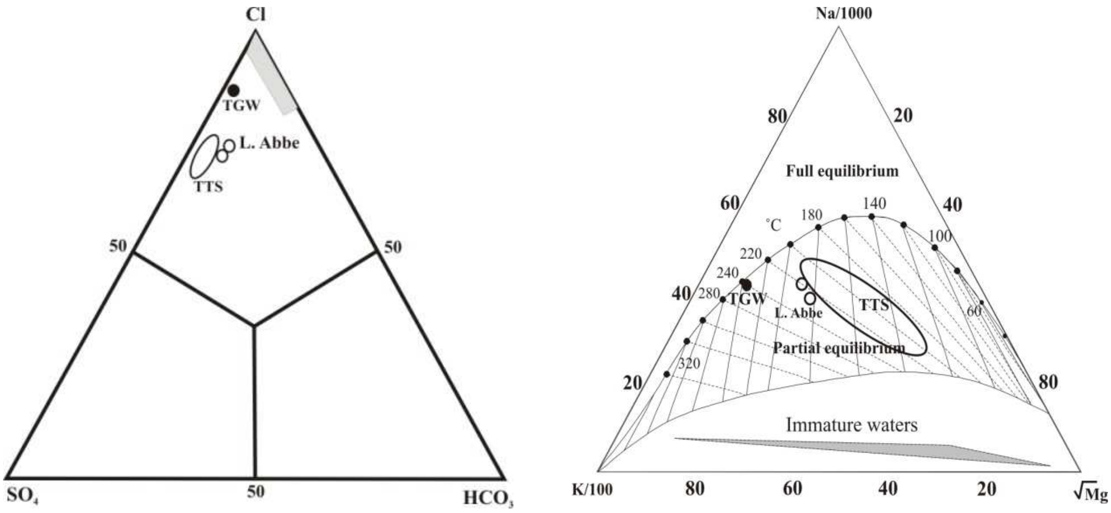


Figure 5 a) Position of Lake Abbe thermal waters with respect to Tendaho thermal springs and Tendaho geothermal well and **b)** position of Lake Abbe geothermal waters on the Giggenbach's (Giggenbach, 1988) Na-K and Mg diagram indicating the reservoir temperatures. TGW: Tendaho geothermal well; TTS: Tendaho thermal springs

DISCUSSION

The Afar Triangle, that hosts Lake Abbe geothermal field, is a part of the active East African Rift system, extending from the Gulf of Tadjoura to Lake Victoria, curing the entire Ethiopian country. The Assal rift extending from the Red sea through the Gulf of Tadjoura, is spreading at the rate of 30 mm/year and is propagating westwards (Courtillot et al., 1980,1984.). The Afar Triangle encloses several active tectonic elements such as normal faults open fissures associated with basaltic volcanism extending age from 1 to 4 Ma (Corti, 2009, Wolfendenm et al., 2004). The NW trending Tendaho rift is a part of the Erta Ale Manda active rift system that extend to the Lake Abbbe geothermal province. Lake Abbe, falling within this rift is filled with lacustrine and alluvial sediments followed by the Afar Stratoid basalts. The Awash River, originating from the elevated SW region (~ 1700 m above mean sea level) of the Ethiopian rift floor, flows towards lower regions in the NE discharging in to Lake Abbe.

As evident from figure 5, the Lake Abbe geothermal waters are very similar to Tendaho geothermal field. The position of the lake Abbe thermal waters close to the Tendaho geothermal field in figure 6 indicates mixing of waters from both basalt as well as sandstone aquifers, like what has been documented for Tendaho region. Reservoir temperatures, as indicated by Na-K-Mg geothermometers (Figure 5b) around 200 °C. Considering the flow rate and estimated reservoir temperature for Lake Abbe, and the transmissivity of the sedimentary (10

m^2/h to 163 m^2/h) and Stratoid basalt aquifers (20 m^2/h to 800 m^2/h; Jalludin, and Razack, 2004) and assuming conditions similar to modelled Tendaho geothermal field (Battistelli et al., 2002) the Lake Abbe geothermal province should be able to generate minimum (conservative) of 15 to 20 MWe (~ 120 x 10^6 kWhr) per a group of 3 to 4 wells tapping both basalt and sedimentary geothermal aquifers. Although both sandstone and limestone aquifers lying below the Stratoid basalts are grouped as sedimentary aquifers, as evident from the volume of travertine mounds found around Lake Abbe, contribution of CO_2 by the limestone aquifer to the geothermal system appears to be greater relative to the sandstone and basalt aquifers.

Djibouti is currently generating about 260 million kWhr (50 MWe) of electricity through diesel thus emitting 1.76 million metric tons of carbon dioxide. For a small country like Djibouti this amount is quite large. The country's per day consumption of diesel is about 13 thousand barrels (http://www.estandardsforum.org). In addition to the existing diesel power generators, the country is planning to augment it electricity supply by installing four 5 MWe diesel generators shortly. The future demand may exceed 120 MWe

According to the preliminary estimates discussed above, development of Lake Abbe geothermal field alone can save about 120 x 10^6 kg of CO_2 there by earning over one million euros under CER (Certified Emission Rate; about 10 euros /tCO_2). Thus the country can geopower its rural regions and become power independent. Both socio-economic status of the rural Djibouti and economic status of the urban Djibouti can be augmented if all the geothermal resources are put to use. If the geothermal potential of Assal is also considered, which is estimated to be of the order of 100 to 150 MWe (Reykjavík Energy report-unpublished, 2008) then the country can generate both from Lake Abbe and Lake Assal geothermal fields ~900 x 10^6 kWhr thus earning about 9 million euros under CER. The country can also earn revenue by supplying electric power to neighboring countries like Somalia and Eritrea.

REFERENCES

Ali, S. 2001. Geochemistry of the Tendaho geothermal field, Ethiopia**.** Stanford Geothermal workshop

Barberi, F. and Varet, J., 1977. Volcanism of Afar: small-scale plate tectonics implications. Geol. Sot. Am. Bull., 88:1251-1266.

Battistelli,A., Yiheyis, A., Calore,C.,Ferragina,C. and Abatneh, W. 2002. Reservoir engineering assessment of Dubti geothermal field, Northern Tendaho Rift, Ethiopia. Geothermics 31, 381–406.

Corti, G. 2009. Continental rift evolution: From rift initiation to incipient break-up in the Main Ethiopian Rift, East Africa. Earth Sci. Rev., Earth-Science Reviews 96 (2009) 1–53

Courtillot, V., Galdenao, A. and Le Mouel, J.L. 1980. Propogation of an accreting plate boundary: a discussion of new aeromgnetic data in the gulf of Tanjurah and south Afar. Earth. Planet. Sci. Lett., 47, 144-160.

Courtillot, V., Acache, J., Landre, F., Bonhommet, N., Montigny, R. and Feraud, G. 1984. Episodic spreading and rift propogation: new paleomgnetic and geochronologic data from the Afar nascent passive margin. J. Geophy. Res, 89, 3315-3333.

Gigenbach, W. F. 1988. Geothermal solute equilibrium. Derivationof Na-K-Mg-Ca geoindicators. Geochim. Cosmochim. Acta, 52, 2749 - 765.

Jalludin, M. and Razack, M. 2004. Assessment of hydraulic properties of sedimentary and volcanic aquifer systems under arid conditions in the Republic of Djibouti (Horn of Africa). Hydrology Jour., 12, 159-170.

Salahadin Ali, 2001. Geochemistry of the Tendaho geothermal field, Ethiopia**.** Stanford Geothermal workshop

Wolfenden, E, Ebinger, C., Yirgu, G., Deino, A. and Ayalew, D. 2004. Evolution of the northern Main Ethiopian rift: birth of a triple junction. Earth Planet Sci. Lett., 224, 213– 228.

http://www.estandardsforum.org/system/briefs/250/original/brief-jibouti.pdf?1277490973