GEOTHERMAL EXPLORATION ADVANCEMENT IN DJIBOUTI

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ABSTRACT

The Republic of Djibouti is located within an exceptional geodynamic situation, the Afar Depression, an emerged triple junction of the Red Sea, Gulf of Aden and East African rifts, where volcanic and tectonic activity occurs since 30 My, and numerous current and past hydrothermal activities are identified mostly in the Western part of the country. Twelve prospects are recognized from which there are Asal rift, lake Abhe and others.

Although geothermal explorations began from the early 1970s, the generation of the geothermal energy is still at the stage of programming.

Given that energy is a key sector for the economical and social development of the country to alleviate poverty, the Government of the Republic of Djibouti is strongly committed in developping as much as possible the geothermal resources. Over the years 2000, Djibouti conducted a significant policy of capacity building of CERD, the national research center, in order to give the capability to prepare faisability studies reports for the geothermal prospects. As a results CERD has launched such studies on the Djibouti aquifer thermal anomalies and the prospect of Nord-Goubhet.

In addition, being active for the promotion of the geothermal energy, private sector has been involved on different geothermal prospects: Asal rift and lake Abhe.

INTRODUCTION

Two main phases are identified for the geothermal exploration in the Republic of Djibouti over the last thirty years but the underground geothermal energy has not yet reached the stage of exploitation. However, today a new era can be considered within the frame of the third phase where several prospects are under study to prepare the faisability phases with exploration drillings.

The commitment of the Government of Djibouti to tackle the energy sector with geothermal energy as a priority has led to this new phase with the involvment of private sectors and the capacity building at all levels of the national research institution, CERD.

After a short review of the past activities, the paper describes the advancement of the geothermal exploration sector in the Republic of Djibouti.

BRIEF SUMMARY OF THE PAST ACTIVITIES

The geothermal exploration can be divided in two main phases. The first phase concerns the exploratory survey conducted by BRGM (1970), which showed possible potential geothermal areas as Lake Asal, Lake Abhé, Allols, Nord-Ghoubet, Arta and Obock to be prospected by drillings (fig. 1). The two initial drillings in the rift of Asal in 1975 (BRGM) recognized a deep reservoir at 1000 m depth with a high mineralisation (180 g/l) fluid and 260°C. The low production of the well Asal 1, located in the Southern area of Asal rift, decreased relatively quickly because of mineral deposits in the wellbore casing and in the surface tubings.

The second phase beginning in 1981 (AQUATER) delt with the exploration of Hanlé-Gaggadé area, recent tectonic basins, located between Abhé and Asal. Results from Hanlé plain drillings reported a good permeability aquifer but containing a low temperature fluid (AQUATER 1989). The fresh water underground flow from the downstream Awash river valley would explain the low temperature of the reservoir. With respect to the new drilling capacities the exploration continued in the Asal area with four new wells. Although Asal 3 located nearby Asal 1, revealed a maximum well head pressure of 21 bars and a maximum discharge rate of 350 ton/h, it is still accompanied by scaling and also by decreasing of the discharge rate. Except Asal 6 located in Asal 3 area, the other wells located toward the axial rift area, did not recognized the reservoir.

If technical solutions to exploit the deep Asal reservoir are still to be found, there exist an alternative geothermal resource with the low depth reservoir in the Asal area. The latter has not been tested but the preliminary data (50 g/l;

130°C to 190°C) of the fluid and the extension of the reservoir as it has been recognized by all Asal wells, gives the possibility of a geothermal resource development using binary systems.

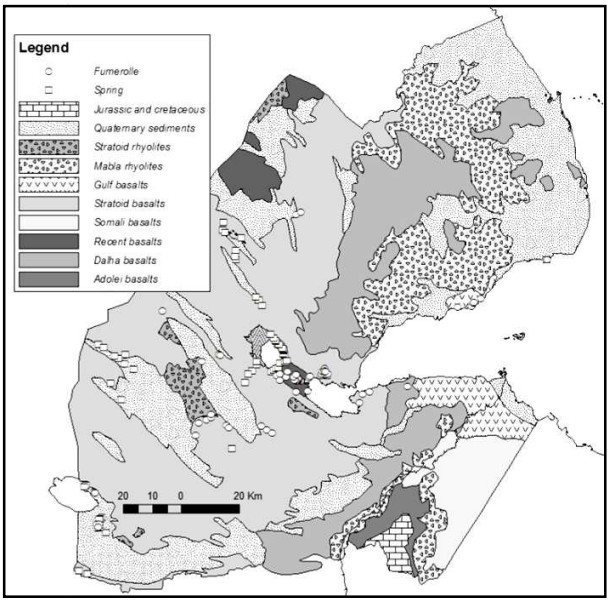

Figure 1. Geothermal surface manifestations in Djibouti

ASAL RIFT GEOTHERMAL PROSPECT

Since the last exploration by drillings in 1988 and other few studies by the 1990 on the corrosion and scaling in the Asal rift geothermal prospect new exploration activities have taken place only by 2008. Such activities were initiated by the cooperation of Djibouti and Iceland Governments and the involvement of a private sector, Reykjavick Energy Invest, REI. Within the frame of this new exploration phase, agreements including general agreement, the head of terms of the document project and the head of terms of the power purchase agreement were signed.

The programme realized a new and complete geophysical coverage of the Asal rift using TEM and MT methods. From this 106 TEM and 102 MT soundings were executed. In addition a tectonic/structural survey was conducted based on aerial and satellite images and field works (fig. 2).

The analysis of the results brought REI to propose a more targeted area of exploration within the Asal rift, known as Fiale and represented by a collapsed large caldera. The previous explored area of the well Asal 1 is located close to the Southern margin of the Asal rift. Based on those results, a faisability study programme was prepared including deviated exploratory wells.

An Environmental Impact Assessment study has been also undertaken by the programme of REI for the Asal rift region.

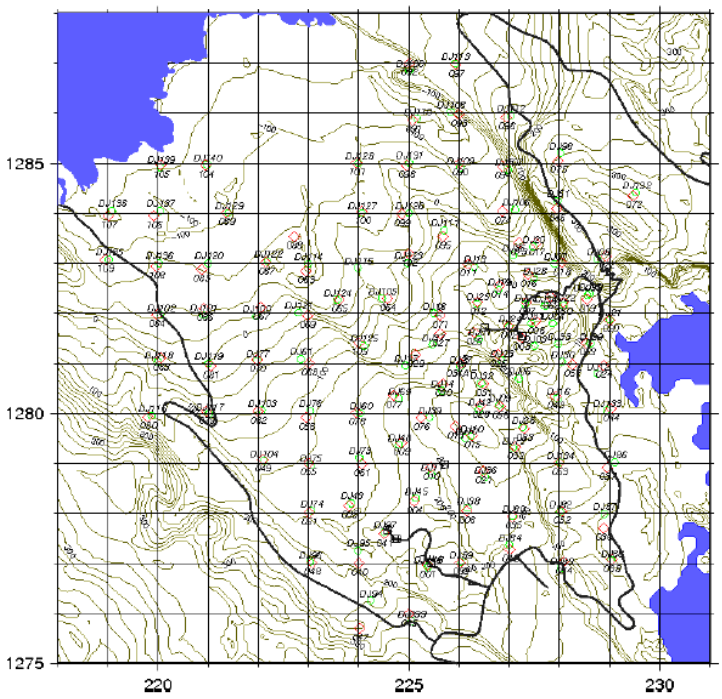

Figure2: TEM and MT surveys of Asal rift (REI-ISOR 2008)

Given the complex Asal geothermal reservoir with the presence of brine a modeling project has been undertaken. The PhD-project (Daher 2010) involves the study of the Asal geothermal resources based on the analysis of existing and new field data collected by REI. The principal tool used is a detailed numerical reservoir modelling, while other methods of reservoir analysis are used as well as interpretation of underground resistivity data. Chemical data also provide input for the project. The aim of the study is to:

- Significantly improve understanding of the nature of the complex Asal brine geothermal system. Asal geothermal reservoir capacity assessment between 115 and 329 MWe with 95% interval confidence is done by using the Volumetric method.
- Develop a conceptual model of the system on the basis of all available old and new data (geological logs, hydrothermal alteration, chemical analyses, well production). The resistivity data collected from October to December 2007 are of major importance here.
- Develop a numerical model of the Asal system based on forward modelling with TOUGH2. TOUGH2 is a numerical simulator for non-isothermal flows of multicomponent, multiphase fluids in one, two, and three-dimensional porous and fractured media (fig. 3). It is widely used and considered the most advanced and powerful geothermal reservoir simulator available.
- Inverse modelling with iTOUGH2 is applied, which helps in the development of the conceptual model. This inverse modelling software was developed for the non-isothermal, multiphase, multicomponent numerical simulator TOUGH2 to facilitate automatic history matching and parameter estimation based on data obtained during testing and exploitation of geothermal fields. The iTOUGH2 code allows one to estimate TOUGH2 input parameters based on any type of observation for which a corresponding simulation output can be calculated.
- Underground resistivity is incorporated in the modelling study, during forward modelling, and is attempted during the inverse modelling phase.
- The numerical model will furthermore be used to select the most appropriate region for future reinjection.

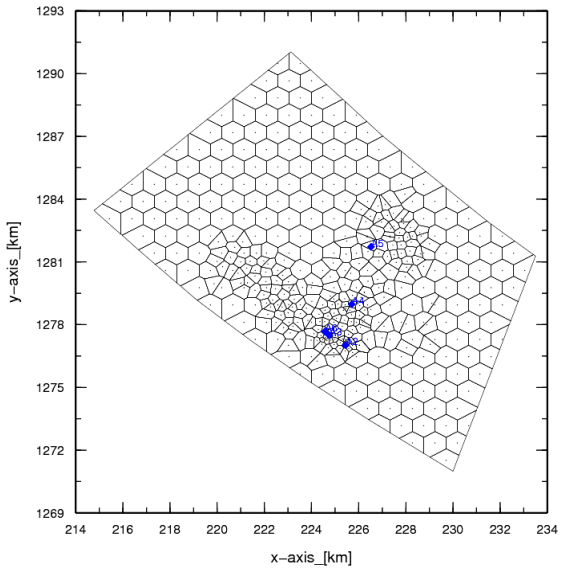

Figure 3: Mesh for the Asal rift geothermal system modeling

The next immediate step for the Asal rift prospect is the faisability study with at least three deviated wells in the Fiale area (REI 2008). Such exploration drillings might lead to the development of the geothermal energy with a minimum of 50 MW power plant.

NORD-GOUBHET

The Nord-Goubhet area is located North-Eastward but close to the Asal rift. Goda mountain and Makarassou region are found in the Northern part and the study zone is limited by the sea in the South. The geology is marked by the Dalha basalts outcrops covered by the more recent Gulf basalts and pleistocene sediments (fig. 4). The fracture network is well developped. The area is situated between different zones of different tectonic pattern and therefore is affected by several tectonic trends: Asal rift NW-SE faults, Makarassou N-S trends and old trends identified in the Goda mountain.

Along the scarped valleys of the wadis several fumaroles and one boiling spring are found at the bottom of the volcanic cliffs. Different methods applied to the chemical data from the condensate of the fumaroles give estimations for the possible reservoir temperature: 220°C and 170°C. Stable isotopes analysis of the fumaroles describe an assumption of the origine of the waters. Compared to the fumaroles of the Asal rift zone, Nord-Goubhet fumaroles have significantly lower Deuterium and Oxygene18. It is suggested that no primary steam from undiluted or diluted deep water exist in this zone. Fumaroles would be more likely the result of a secondary steam from previously condensated steam or boiling groundwater (Geothermica 1987).

Three geophysical surveys were conducted in the area of Nord-Goubhet: gravimetry, AMT and electric (rectangle method) (BRGM 1983). The gravimetric results point out several heavy and light anomalies not distributed regularly. Although these anomalies are of low amplitudes they are more or less clearly delimited by the different linear trends, correlated to the tectonic of the area. From their analysis, BRGM retain three main guidelines. First, the Southern Asal rift system delimits light anomalies. Parallel to it and Northward, a large axis comprises a succession of heavy and light anomalies. In the central part, a similar axis is identified along a NNW-SSE trend. It can be noticed that the major part of the hydrothermal activity is located between these two axis. Finaly, light anomalies cover the Eastern part of the prospect. The geoelectrical survey shows globaly low resistivities and three main zones can be observed. The first one is located on the Eastern part of the prospect. The second low resistivty area is located on the South-Westrn zone but higher resistivities are found along a NNW-SSE axis. The last and very conductive area is located in the North-Western part. It has been estimated that the bottom of the conductive zone

would reach around 1000 meters. The AMT survey identifies in the central zone of the prospect an uplifted conductive body. The results from the three geophysical surveys cannot be completely intercorrelated. However, findings from the gravimetric and the geoelectrical methods bring out interesting approach of the underground structures in relation with the surface hydrothermal activities that can guide a drilling exploration.

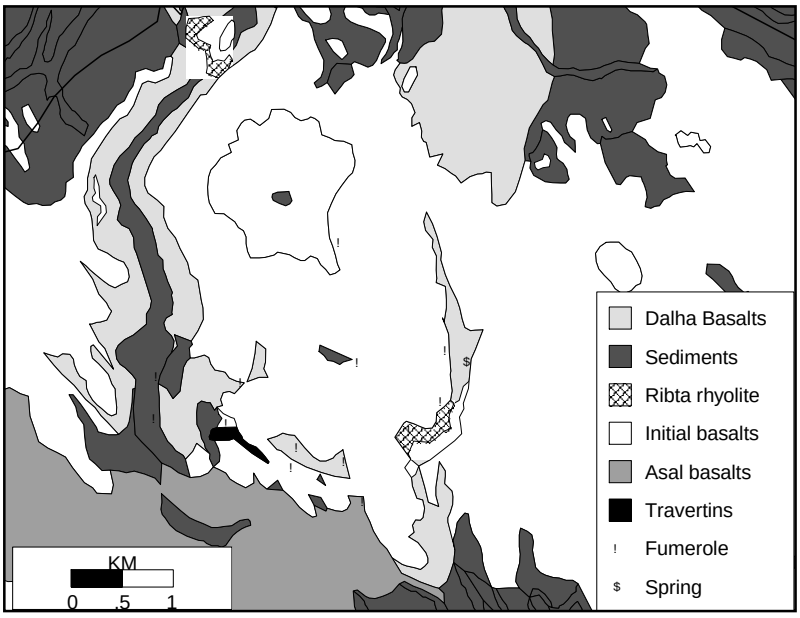

Figure 4. Nord-Goubhet prospect

A new phase of exploration is undergoing by CERD to complete the exploration with new data. This prospection comprise firstly a geophysical survey that applies TDEM and MT methods. Up to now 25 TDEM and MT stations were realized in the area of Nord-Goubhet. Surface manifestations as fumaroles and hot springs are also sampled for geochemical and isotopic analysis. A pecular analysis is undertaken of the surface manifestations and the weathered zones according to the geology and the structural features. These prospections will be completed by the environmental impact assessment of the study area in order to finalise the prefaisability study that will allow the exploration drilling in the frame of the faisability study.

LAKE ABHE AND DJIBOUTI PROSPECTS

Lake Abhé zone is located in the South-Western region of the country, on the border with Ethiopia. This hypersaline lake is the Western end of the Gobaad plain and the Eastern end of the dowstream valley of Awash river coming from the Ethiopian plateau. The geology is characterized by th stratoid basalts plateaus limited by E-W faults configuring the Gobaad plain, filled by quaternary and probably late pliocene sediments. The lake area is particularly rich of surface hydrothermal manifestations with fumaroles and hot springs but also travertine constructions, some of them being elevated at more than 60 m above ground level. The travertines are aligned on the main fracture trends. Fumaroles are located on those travertines and the hot springs occur at the bottom of these travertine chimneys. The temperature of resurgence of the hot springs is generaly higher than 90°C. Only geochemical preliminary studies cover this prospect and give mainly two types of waters. Most of the hot springs are alkaline-chloride-sulfated and few of them present also a bicarbonated type as a result of surface water mixing. The surface hydrothermal manifestations are spread over an area of about one hundred square kilometers. This observation suggest that in lake Abhé zone there exist an important thermal anomaly representing potential geothermal reservoir.

The lake Abhe prospect is under an agreement with the private sector, Hydrocarbon Co., since 2009. The environmental impact assessment study has been launched but the prefaisability study might begin in the next future.

The Djibouti prospect is represented by the aquifer of Djibouti exploited for fresh water supply to the town of Djibouti. It is located around the capital and extends over an area of about 500 km². The recent basalts of Gulf constitute the fractured and heterogeneous aquifer. There are no surface manifestation in this prospect but there are few thermal anomalies on the groundwater wells at Awrawsa and Wead in the Northern part of the aquifer. The temperatures between 100 meters and 150 meters reaches 60°C.

Therefore some preliminary studies were programmed and undertaken by CERD with the cooperation of University of Brest. Previous large grid MT and recently MT and TDEM methods results are under interpretation for the temperature anomaly zones.

CONCLUSION

The energy sector in Republic of Djibouti needs a clean and cheaper energy in order to boost the social and economical development of the country. However most of the geothermal prospects are not studied and slow down the resources evaluations. Therefore, the Government of Djibouti conducted an intensive programme and actions to build up the capacities of CERD, the national research center, to be able to undertake the prefaisability studies of the geothermal prospects.

Those studies are already in progress on the prospects of Nord-Goubhet and the Djibouti aquifer and the others will be covered progressively.

The commitment of the Government of Djibouti has brought private sectors on two main prospects, Asal rift and lake Abhe. Asal rift faisability programme with deviated exploration wells is on the stage to be launched. In the case of lake Abhe prospect prefaisability studies, surface studies, would start in the next future.

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