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GEOTHERMAL DEVELOPMENT IN REPUBLIC OF DJIBOUTI: A COUNTRY UPDATE REPORT

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ABSTRACT

The aim of this paper is to highlight the vision of future perspective of new geothermal development strategies. Djibouti has a long history of geothermal resource exploration since 1970, as the country is endowed with numerous geological structures. ODDEG (Office Djiboutien de Developpement de l'Energie Geothermique), the newly created specialized agency is the expression of the strong political commitment of the government to achieve the goal of achieving a development of this affordable energy. Djibouti's location at the junction of three main active geological structures, and the presence of numerous surface geothermal manifestations with hot springs and fumaroles, gives the country the potential to develop geothermal energy. With an important commitment of the government over this period, intense studies throughout the country have been initiated, which enabled the discovery of an important potential estimated to around 1000 MW. However, after having carried out several drill holes, it was discovered that high temperature resources were difficult to identify away from active magmatic heat sources (as shown at Hanlé), and that some factors such as salinity limited the exploitation of the resource (in the well identified Asal high temperature geothermal site) at that current state of technology. The Government of Djibouti, strongly committed to exploit the resource, asked financials partners to perform additional studies to help finding solutions to these limiting factors. In the last 10 years, the country took the initiative to drastically reduce fossil fuel dependence for power generation by importing electricity of hydro source from Ethiopia and promoting development of its own geothermal potential according to the 2035 vision. In order to develop sustainable geothermal sector, important initiative has been taken for the equipment and capacity building for the manpower with specialized support from several partners like United Nations University Geothermal Training Program and other bilateral partners (Iceland, Japan, and German government agencies). Several exploratory studies have been already started in the Lake Abhe with the technical support from ISOR, Hanle-Garabayiss with technical support from JICA and Sakalol prospect jointly carried out by ODDEG with CERD.Also, the country raised around 31 Million USD for exploration drilling in the Asal-Fiale geothermal field with the financial ofthe World Bank, Afdb, OFID, AFD, with the Djibouti government participation. In order to establish, the first step, i.e. a feasibility study of a 50 MW geothermal power plant, to be extended to 150 MW if the potential will be enough in that area and surroundings.

1. INTRODUCTION

The Republic of Djibouti is located in the northern extremity of East African Rift Valley (EARV)system (a continental rift),where the geology is also influenced by the rifting phenomenon of the Red Sea and the Gulf of Aden oceanic rift system resulting from the NE separation of the Arabian plate from Africa.

In this geodynamic context, a huge quantity of energy is dissipated from a very shallow anomalous mantle to the surface. The Afar triangle and Iceland are the only two regions in the world where an oceanic ridge is accessible off shore for geological investigations and geothermal exploitation.

This exceptional geodynamic setting gives the country its geothermal potential. Since 1970, thirteen (13) geothermal prospective areas were identified. Several studies carried out in the past, in many prospective areas, ranging from surface exploration to exploratory drilling, have estimated the geothermal potential of the country to be around 800 MW. However, the only potential resources confirmed yet is the Asal-Ghoubhet field, but its development was until now limited due to factors that inhibit optimum exploitation.

Over the last 10 years, high-level political commitment was set up to promote and develop the geothermal sector in a sustainable way, in view of reducing drastically the fossil fuel consumption for power generation. In fact, thanks to imports of hydroelectricity from Ethiopia, fossil fuel accounts for 50% of the electricity production in the country which leads to the high electricity costs.

To achieve this objective the government set up in January 2014 a new entity called ODDEG (Djibouti Office for Geothermal Energy Development) in charge to stimulate a rapid geothermal development, and to ensure this sustainable development.

This paper presents the current energy situation, the current active potential fields and the foreseen development of this sector in the future.

2 STATUS OF ELECTRICITY PRODUCTION

2.1. Electricity sector

The electricity sector was highly developed over the last 5 years. Thermal energy represented the most important part of the power generation. A solar plant and an interconnection line from Ethiopian power company (EEPCO) were added to the energy offer in 2011.

The Ethiopia-Djibouti interconnector provides an additional electricity source, based on renewable (hydro), ranging from 180 to 300GWh per year. It is therefore covering between half and two-thirds of the demand. The line terminates at a 220/63/20 kV substation, 12 km west of Djibouti-Ville, where the voltage is stepped down to 63 kV for interconnection with the existing transmission system. The transmission system is currently limited to a 63 kV inter-connector between the main stations, and two 20 kV transmission circuits from Djibouti-Ville to Arta, some 40 km away. There is also a 20 kV circuit between Dikhil and Ali Sabieh in the south of the country. The distribution system comprises 20 kV radial circuits emanating from the main substations. Most customers are supplied at low voltage (LV) via distribution substations.

More projects using renewable energy, including geothermal energy, are planned in the near future. Table 1 presents the proportion of different energy sources used.

Table1: Installed capacity and production for electricity generation from Edd (Edd[1], 2013).

Electricity generation	Thermal power	Solar power plant	Hydro-electricity (Imported)	Total
Installed capacity(MW)	120 MW	0.30MW	42MW[2]	173MW
Production(MWh)	66637MWh[1]	522MWh[3]	354901 MWh[1]	422 060 MWh

[1] Electricite de Djibouti (Edd).

[2]Average Imported Electricity from EEPCO.

[3] Production in 2012, CERD.

2.2. Electricity generation cost in Djibouti

Electricity generation from diesel and heavy fuels represent important cost for operation and maintenance of power plants. Hot weather can also lead to rapid fatigue of the mechanical components.

The cost of electricity was decided to assure an optimum service and to prevent electricity shortages. Government legislate the price of the electricity. The Government initiate in 2012 and in 2014, a decrease of the cost of energy for the lowest and middle class.

Table 2 describes the different cost of the electricity (Edd, 2011).

Customer	Price per kWh
Social tariff (1kVa)	15c$/kWh
Residential customer	55c$ to 40c$/kWh
Industrial customer	34c$ to 42c$ /kWh

2.3 Projects planned in the energy sector

Over the next 10 years, the country has a good and ambitious program to develop and expand its energy provision, to satisfy the local demand and increase the energy access in rural areas. Renewable energy utilization represents a part of this energy development strategy including in the 2035 development vision. Renewable Energy available like solar, wind and geothermal energy are the most important resources of Djibouti.

In the solar energy sector, the government has several projects in the pipeline, for providing rural areas with access to electricity, financed by donors and development agencies. Also a first solar PV plant of300MW is planned to be built in the central part of the country with private funds. Wind energy is available with wind speed ranging between 5to 10m/s, in the north-eastern part. The first wind farm with 60 MW power is planned to be built on 2017 supported by Qatar Electric.

However, due to the stability on the electrical grid, and high resource availability, geothermal energy is the best resource to ensure a sustainable development. To start with ,the first plant in Asal-Fiale is planned for commission in 2018[1]with an installed capacity of about 30 to 50 MW extensible to 100 MW. Also other private initiatives are on discussion to exploit potential site for electricity production like gas pipeline project between Djibouti and Ethiopia.

3. STATUS OF GEOTHERMAL DEVELOPMENT IN THE COUNTRY

3.1 Geology

The geology of the country is affected by the junction of the Aden gulf, the Red sea oceanic ridge, and also by the East African Rift Valley (EARV) system which constitute the triple junction system. The Afar depression (Figure1)is the region where crustal extension occurred caused by the separation ofthe Arabian, Nubian and Somlian plates. This establishes the connection between the current oceanic ridge in the Redsea,and the Gulf of Aden system, and the EARV intra-continental rifts.

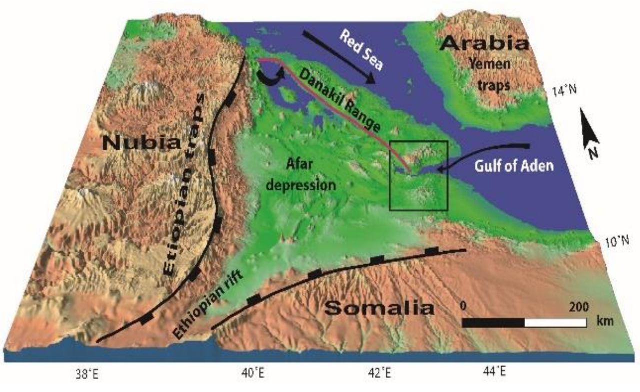


Figure 1: The rifting system and Afar depression

[1]A target that will not be achieved before 2020 due to delays encountered in the implementation of the project.

The Aden gulf and the Red sea ridge are the most active geological system, with an average spreading rate of 1, 5 cm/year.in addition with the EARV system (5 to 6 mm/y), this lead to important tectonic and magmatic activities over the last 20 to 30Ma.

Almost all of the Afar depression is covered by basalt strata bound, eventually partially hidden by sediments infilling in the grabens, and were created by the early stages of proto-oceanic rifting (Barberi and Varet, 1977) 3.5 to 1My ago. Almost all the rock composition in the country is basaltic like Dalha basalts (8-4 My), Somali basalts (5 to 3 My), Stratoid basalts (3.5 to 1 My) etc, as shown in Figure 2.

Located in the eastern part of the Afar depression, the Republic of Djibouti has been the place of an important tectonic activity since the Oligo-Miocene period until today. All stages of rifting developed from continental to oceanic rifting as deduced from the various volcanic units studied in Djibouti Republic.

The seismicity assessment in the emerged part of the rifting system describes an important movement collected in the Asal-Ghoubbet rift, the area of the country with the highest identified potential.

Recent volcanic formations built along identified active rift structures of oceanic type are located in two sites in Djibouti Republic: the Asal rift and the Manda Inakir range.

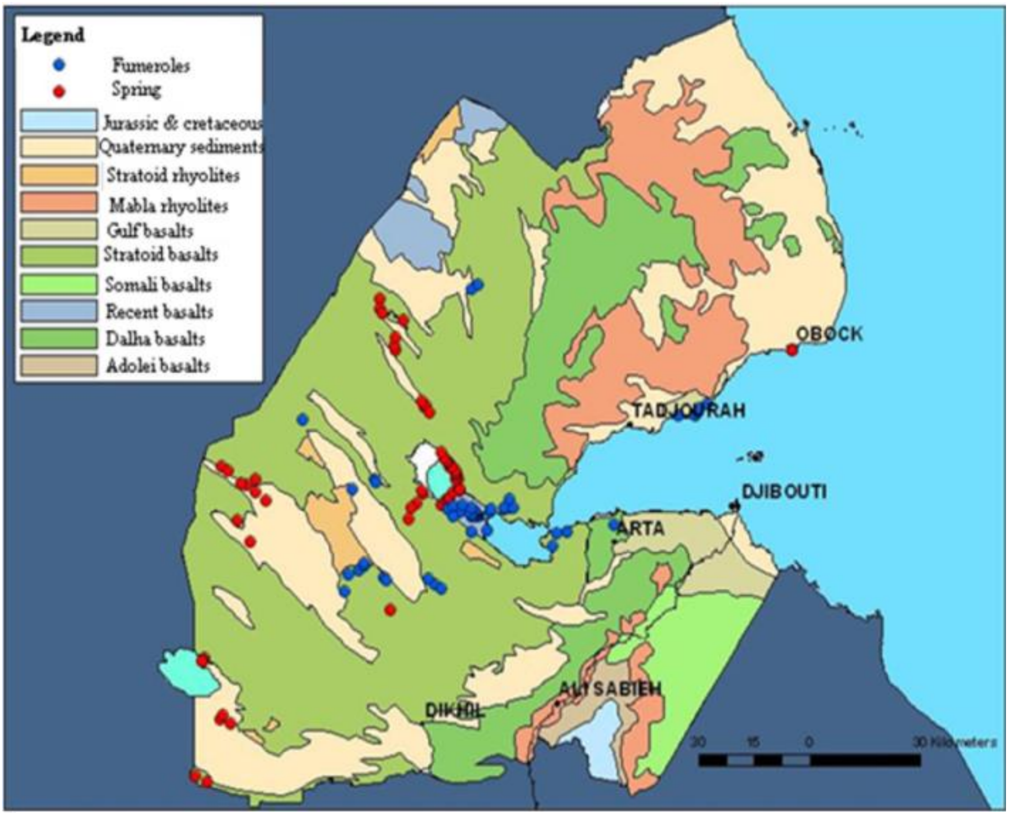


Figure 2: Geological Maps of Djibouti (CERD)

Figure 2 shows in dots, the surface manifestation located mainly on the Asal-Ghoubbet rift (SW-NE trend): red dots represent the numerous hot springs and the blue dots show the fumaroles[2].

3.2 Previous study

Since the years 1970's, several surface studies were done in the country which located at least13 potential areas for geothermal interest. The main location of the most promising prospects is along the main NW-SE

[2]Note that fumarole sites are more numerous than reported on this map

active axis of spreading crossing through the country from the Gulf of Tadjoura to Manda Inakir. The preliminary studies found an important potential area in the Asal-Ghoubhet zone, confirmed by drilling in 1975, and after new studies, exploratory drilling were undertaken in the year 1987 in the Hanle graben and in the Asal prospect.

Table 3 show all the studies carried out between 1975 to 1990 from surface exploration to deep drilling in different prospects.

Geothermal Site	Exploratory Stage				Surfaces Manifestations	
	Geology	Geochemistry	Geophysics	Exploratory drilling	Hot springs	Fumaroles
Lake Asal	+ +	+ +	+ + +	+ + +	+ +	+
North-Goubhet	++	++	++		+	+
Lake Abhe	+ +	+ +			++	++
Obock	+	+ +			+	+ +
Sakalol-Alol-	+ +	+	+ +		++	+
Gaggadé	+ +	+ +			+	+++
Hanlé	++	+ +	+ +	++	++	
Arta		++				++

Table 3: Geothermal studies undertaken in different prospects in the years 1975-2005.

3.3 Asal geothermal field

The Asal geothermal field is located in the Asal-Ghoubhet rift which extends north to the Asal Lake. This area isthe most explored geothermal field in the country.

The first geothermal investigation was undertaken in 1970, by the French geological survey (BRGM).These investigations lead to the discovery of the high enthalpy geothermal reservoir. With the financial support of the World Bank and UNEP an additional 3, totalizing 6 deep boreholes drilled in this field.

Table 4 resumes the characteristics of these wells drilled in the Asal field.

Wells	Depths (m)	Temp max (°C)	Gradient temperature (°C/100 m)	Date
Asal 1	1145	261	18	1975
Asal 2	1554	235	14,3	1975
Asal 3	1316	280	15,51	1987
Asal 4	2013	345	15,2	1987
Asal 5	2105	360	15,2	1988
Asal 6	1761	280	12,75	1988

However, the exploration drilling showed also the high salinity of the geothermal resource, which caused scaling and corrosion of the wells. In fact, the recharge of the reservoir is ensures by seawater from the Ghoubbet, with salinity around 37 g/l and the Asal Lake, due to intense evaporation, the second most saline place on the earth.

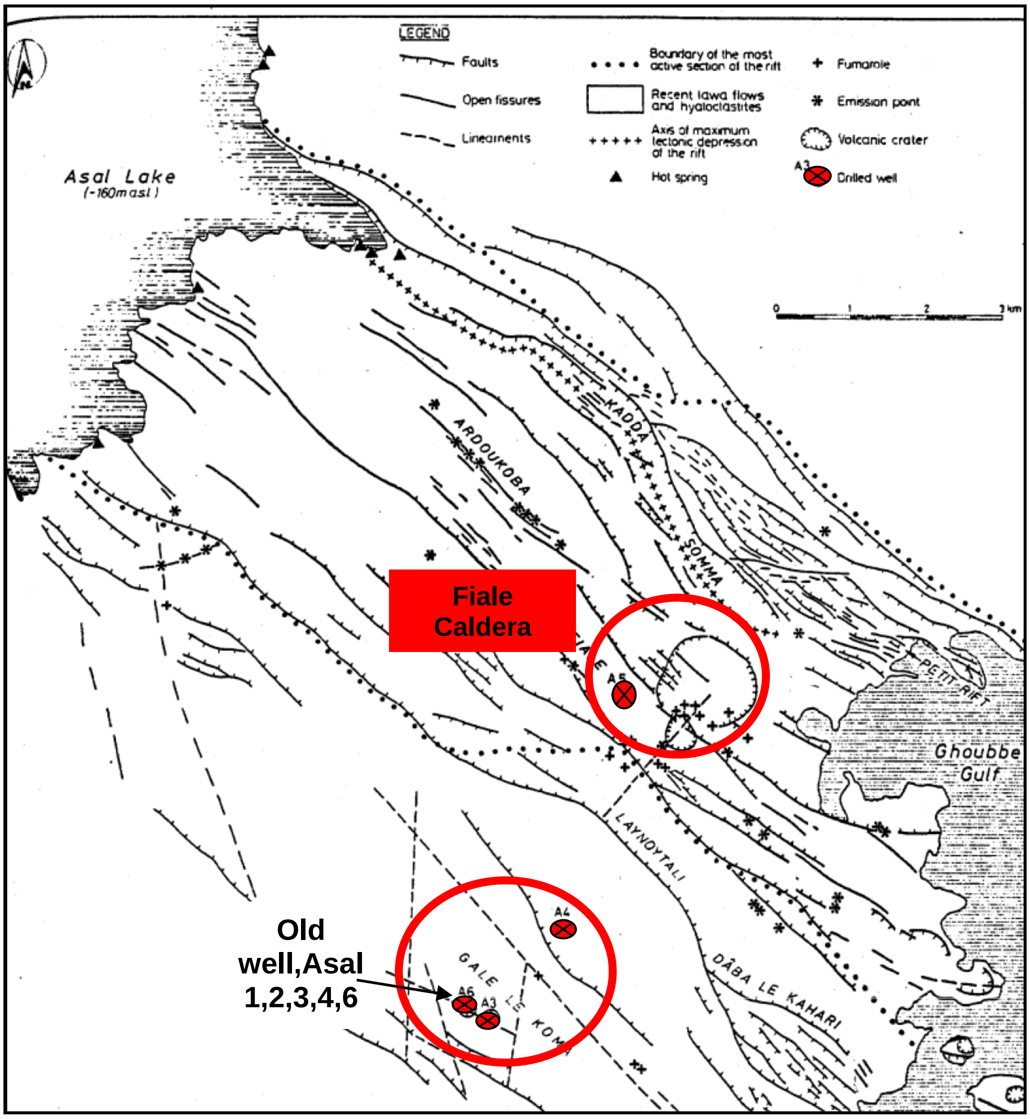


Figure 3: Structural Maps of Asal field

To avoid this salinity problem, the study expected to find in the Asal-Fiale caldera a better geothermal resource regarding the recharge and therefore less saline than the previous reservoir.

In 2008, geophysical measurements were carried out in this zone which confirmed the presence of geothermal resource. Figure 3 shows the location of the Asal-Fiale geothermal field. Geophysical measurement was conducted using 106 TEM and 102 MT soundings and additional tectonic survey was conducted based on aerial and satellite images and field work data (ISOR, 2008)

The resistivity maps in the figure 4 show a low resistivity zone around the caldera of Fiale, which demonstrates the presence of hot body in the zone.This map also report the seismicity measured in the period 1978-2002 in the Asal rift (Doubre et al., 2006), showing a high concentration of seismic activity in the Fiale caldera at shallow depth (3-5 Km) interpreted as direct magma-water interaction in the upper part of the uprising magma chamber (Varet, 2014).

An Environmental Impact Assessment was already done in 2008 by Reykjavik Energy Invest (REI) for the Asal-Fiale zone.

This zone was the area with the most potential in the country and the previous assessment predicted a maximum reservoir capacity of about 300 MWe. The previous project (the Asal project)with the Icelandic company Reykjavik Energy Invest could not proceed as originally envisaged due to economic crisis experienced in Iceland in 2008.

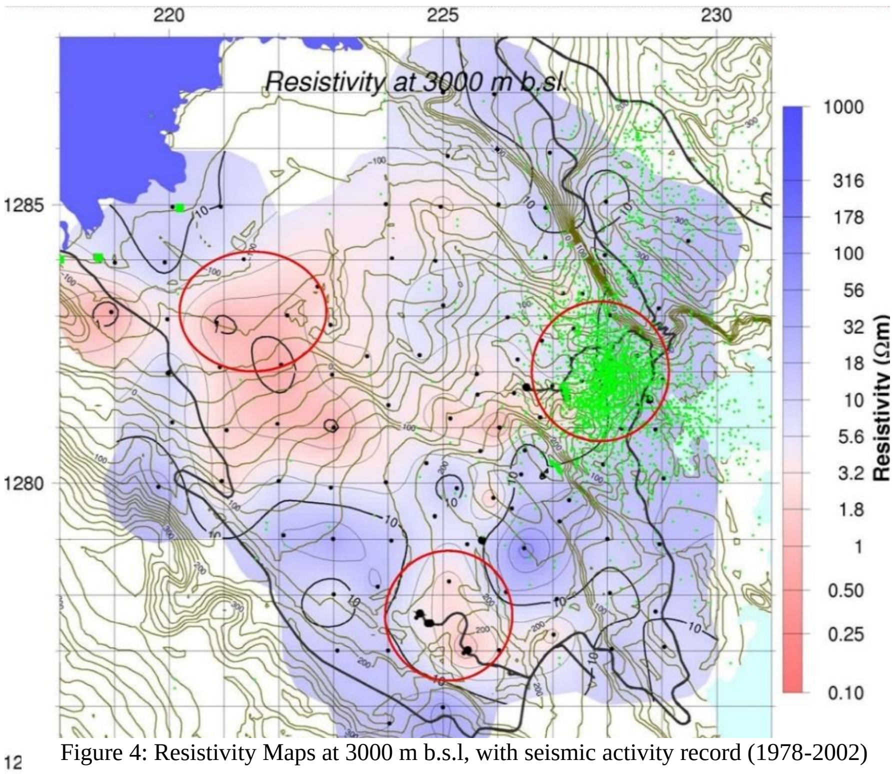


Figure 4: Resistivity Maps at 3000 m b.s.l, with seismic activity record (1978-2002)

Due to these difficulties, the Asal concession acquired by REI expired and the Djiboutian Government decided to develop the potential of the areas.

In 2011, the Government of Djibouti was committed to financing and mitigating the high risk in the drilling of at least 4 wells. A group of public banks led by the World Bank (WB) are the principle financial partners in the project, with the drilling costs estimated to be around 30Million USD.

The objective of this project is to quantify the technical and financial feasibility of the Asal-Fiale geothermal resource for large scale (50MW) power generation. This project was designed to implement exploration drilling program through which three to four full size production wells (9 5/8) at depth of 2500m are planed tobe drilled. This will be done in the Fiale Caldera, on the active rift axis, using derivate drilling techniques in order to reach good permeability conditions while crossing the vertical faulting.

At the present time the geothermal consulting company has been selected, the drilling contractor identified and field activities focused on civil engineering works, acces road, and preparation platform for drilling.

The question of the target of the exploration drilling is a matter of debate. The project geothermal consultant at present privilege a hypothetical reservoir at 2.500m depth, as temperature inversion was observed in the A5 well drilled in 1988 on the NW flank of Fiale caldera. According to Varet (2004), the temperature inversion observed at Asal 5 should at present be reinverted due to the magmatic injection at shallow depth documented by the 1998-2002 seismic crisis, and a high temperature reservoir should exist in the Fiale area at a depth interval as shallow as 600 to 1200m, whereas nothing indicate the presence of a geothermal reservoir at 2500m, but rather the top of the magma chamber.

3.4 Asal -Gale Le Koma geothermal field

Since June 2016, ODDEG undertook intensive field activities in the Asal rift area in the area called "**Gale Le Koma**" where the first success drilling was undertaken in 1975 (See Figure 3). All wells drilled in the area encountered a shallow geothermal reservoir that was not really studied. In this context ODDEG in collaboration with Petrotek elaborated a program for exploration drilling for 4 drill holes at shallow depth, using purchase rig CF 2000for the purpose of identifying the characteristics of this shallow reservoir.

The objective of this program is to quantify this shallow reservoir discovered during the geothermal exploration drilling evidenced by earlier drillings in 1975, and confirmed by further wells drilled from January 1987 to July 1988.

Taking into account the importance of the development geothermal energy this program is financed exclusively by the government of Djibouti and the executing agency is ODDEG, national institution dedicated to geothermal energy development in Djibouti.

The final output is to carry out some tests for evaluating the potential of this shallow reservoir, then proceed to install a small modular unit for electricity generation. The result obtained will be presented to the investors in order to cover the financial aspect of this important project.

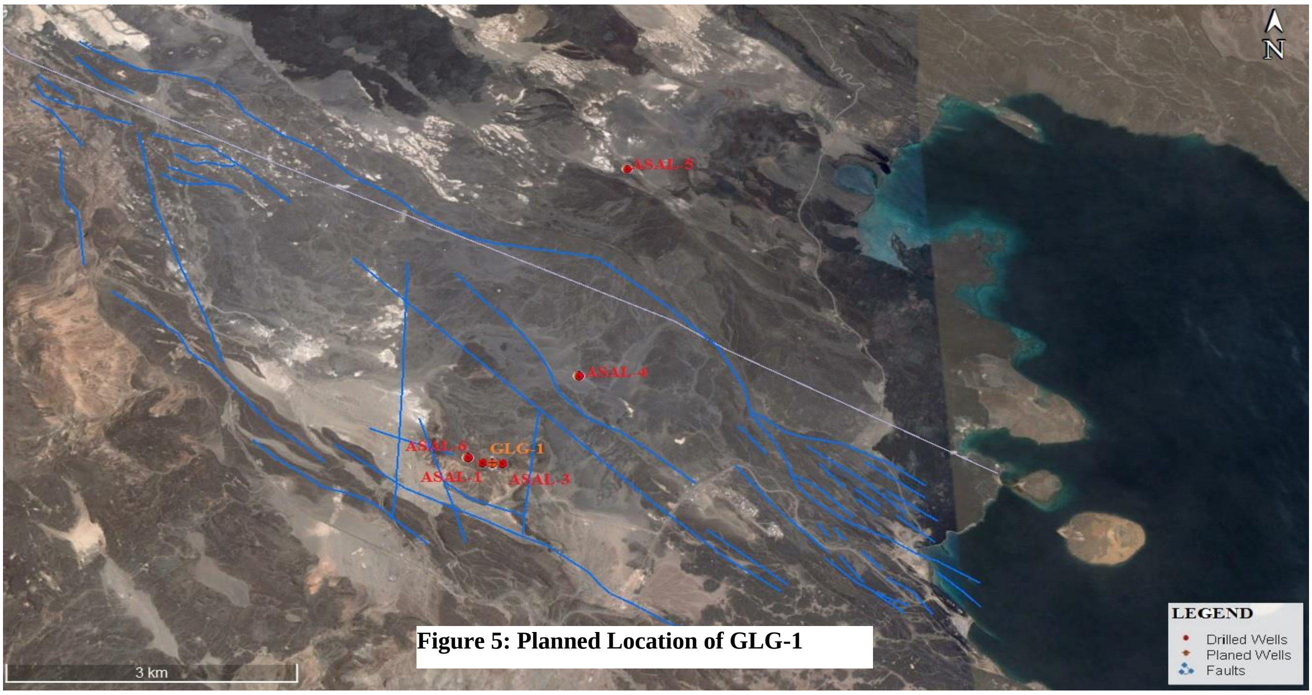
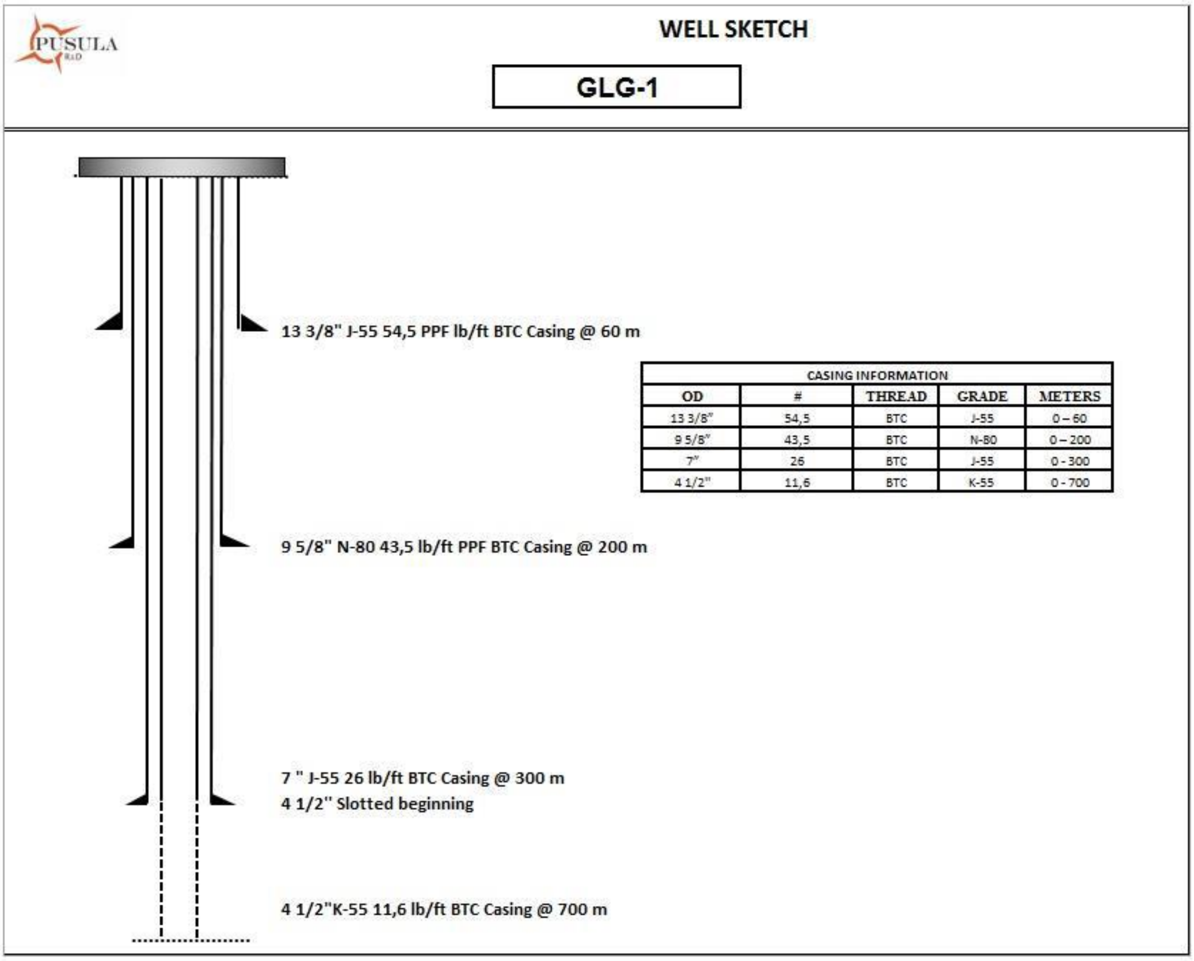


Figure 5: Planned Location of GLG-1



OD	#	THREAD	GRADE	METERS
13 3/8"	54,5	BTC	J-55	0 – 60
9 5/8"	43,5	BTC	N-80	0 – 200
7"	26	BTC	J-55	0 - 300
4 1/2"	11,6	BTC	K-55	0 - 700

Figure 6: GLG-1 Well Design

3.5 North -Ghoubhet Geothermal field

The North–Ghoubhet geothermal field is located close to the Asal Geothermal field in the northeastern part of the country. The area islimited to the north by the Goda mountain and the by the Ghoubbet sea (westernmost extension of the Aden ridge) in the southern part, within elevation around 0to 600 m.a.b.s.l.

The geological structure is composed mostly of deeply faulted, tilted and eroded basaltic rocks from Dalha covered in discordance by the more recent, nearly flat-lying basalt from Gulf. The tectonic activities of the zone are controlled by complex fracture networks from NW to SE following the Asal rift with other directions resulting from the transform fault system linking the Ghoubbet rift segment to the Tadjoura rift segment (Fig.7.). Surface manifestations are mostly fumaroles along the valley of the Oued (Fig 7).

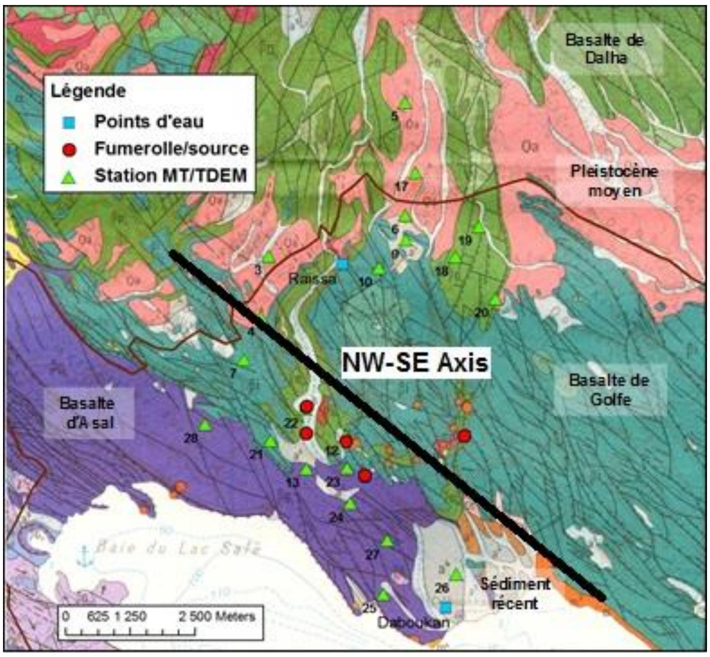


Figure7: Geological maps (CERD, 2010) *made of gulf basalts (pale blue), passing to the west to Asal Rift younger basalts (deep blue and violet). The Dahla basalts (7 to 3 M y) in deep green are intensively faulted and eroded.*

Gravimetric measurements were done by the French geological survey (BRGM) in 1983 and lead to the discovery of heavy anomalies in different points delimited by the linear trend associated to the tectonic activity zone. Geophysical measurements using the electrical AMT were also done at the same time by BRGM, revealed three main zones, the southern Asal rift, the northern part where heavy gravity anomalies were identified, and the central part along the trend NW-SE.

To fulfill the previous study, the CERD (Center of Research of Djibouti), startedan exploration study in 2010.The CERD geophysical team completed 30 MT sounding and 26 TDEM stations with geophysical measurements using MT and TDEM measurements.

These geophysical measurements show that there is a conductive surface in the upper layer but in the deeper zone, at 1000 m.b.s.l, a heterogonous surface are found, with some conductive anomalies which may be associated with hydrothermal fluids.
Below the horst of Moudoueoud, the MT measurements confirmed low resistivity in the deeper zone.

Geochemistry measurements were also done from fumarole sampling and the unique hot spring of the area investigated (other hotsprings are reported to the east along the sea shore which were not sampled). The geothermometry gives a temperature range of 170°C to 220 °C for the reservoir. The chemistry of the condensate and the spring demonstrates low salinity of the fluid compared to the Asal field and the chemical mark of the fluid was bicarbonate.

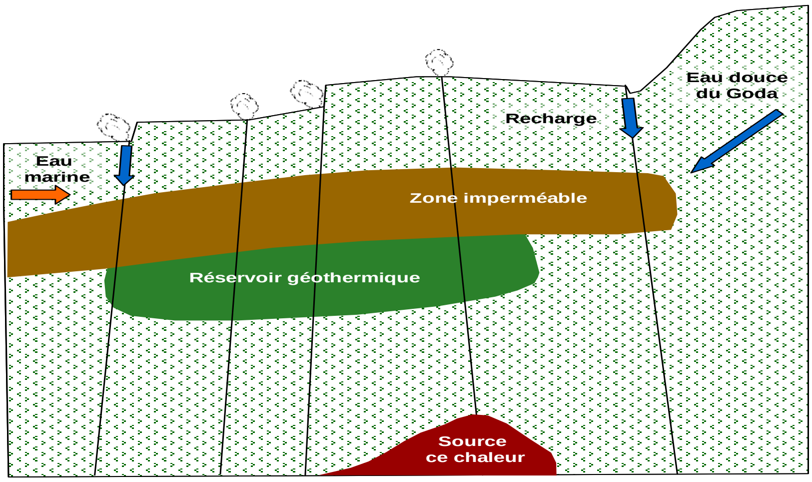


Figure 8: Conceptual model of the North-Ghoubhet field (CERD, 2010)

This is in coherence with the geological context showing possible recharge of the system by the rainwater from the Goda Mountain through intense faulting and detrital material accumulated at the foot of this 2000m escarpment under the Gulf basalts (Varet, 2012). The intrusion of seawater should also account for the reservoir feeding in this faulted environment.

This study has enabled the creation of a reservoir model of the geothermal system (Figure 8) to delineate a prospective area for exploration drilling around the horst of Moudoueoud and wells sitting for directional drilling. In the figure 8, the hot source (in red colour) is below the geothermal reservoir represented by the green color covered by impermeable zone in brown and the recharge water are displayed by the blue arrows from the Goda mountain and the marine intrusion. This hypothetical local magmatic body could add a supplementary heat source to the favorable context of the active Ghoubbet rift with identified active diking and central volcano at a short distance, at the submarine foot of the North Ghoubbet site.

At present, ODDEG is preparing a new field campaign in order to complete the investigation to the east and south until the sea shore over the whole N-Ghoubbet area, implying geological, mineralogical and structural investigation, with more attention paid on surface hydrothermal leakages along faults. These will be completed by supplementary geochemical and geophysical surveys in order to acquire an broader view of this eventually important low-salinity geothermal system.

3.6 Lake Abhe geothermal field

The Abhe Lake is the area with the second most geothermal potential of the country. Located in the southwest of the country, the Lake named Abhe is shared between Djibouti and Ethiopia.

The geological structures of the areas were composed by stratoid basalt limited by E-W faults. Surface hydrothermal manifestations are numerous around the lake along with a rich variety of fumaroles, hot springs and many travertine constructions. Some of the travertine was higher than 60 m.a.b.s.l.

The hot spring manifestations are mainly located in the bottom of the travertine with high temperatures of more than 90°C. The chemical profiles of the hydrothermal source are alkaline-chloride in general and some bicarbonate from the previous studies.

Figure 9: Field location

A complementary study has been carried out during November to December 2015 by ODDEG and ISOR, financed by the Icelandic International Development Agency (ICEIDA) and the Nordic Development Fund (NDF).Field work was focused on gravity and resistivity survey.

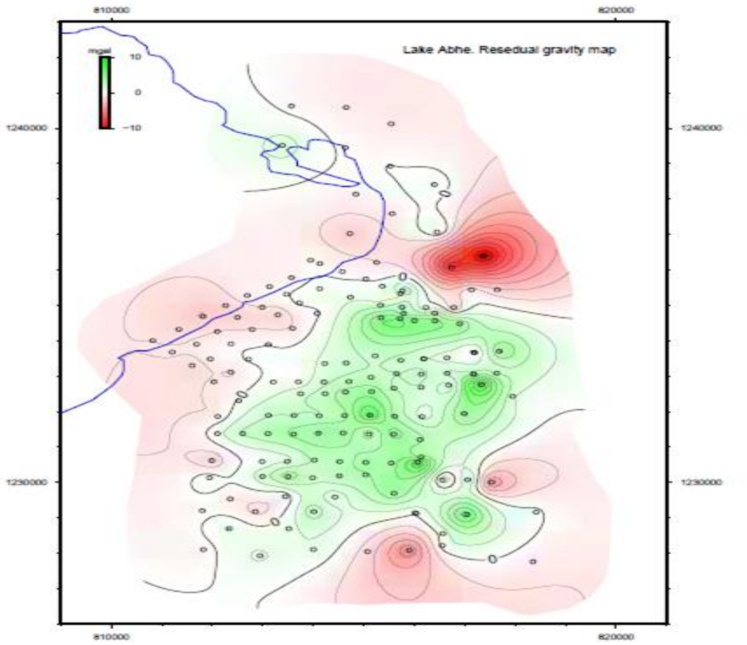


Figure 10:Residual Bouguer gravity anomaly map.

The relative gravity high observed in the central part can be associated at the omega-structure imaged by both 1-D joint inversion and 1-D inversion at 1500 m bsl until 3000 m bsl. This anomaly can be associated in term of geological by some less permeable stratoids basalts or some acid intrusion like rhyolitic structures.

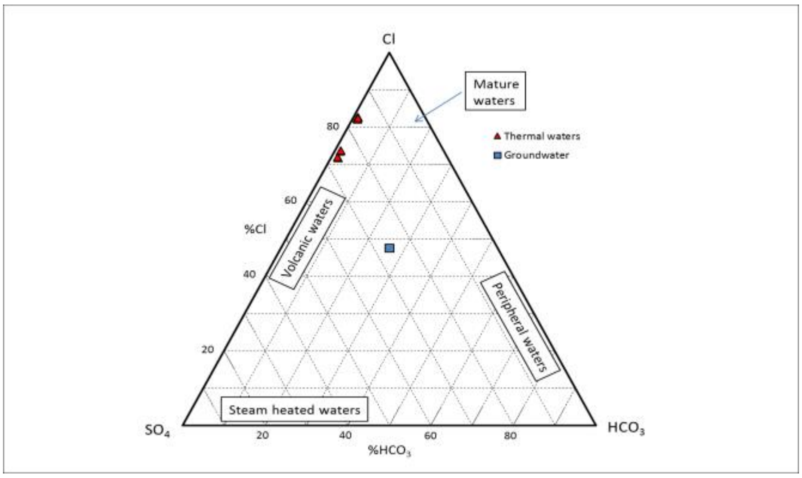
Regarding the chemistry of the hydrothermal manifestations, the sources of hot water was 2 classifications.

In volcanic areas, the water can simply be heated (Giggenbach, 1991), which is commonly used for classifyingby direct contact with the magma.

For non-volcanicwaters of different origin, shows that the thermal waters are areas, the water is heated by a convection, or the rockmature, and possibly slightly volcanic temperature increases with depth (geothermal gradient) if water penetrates deep it will be heated by the hot rocks. Most of the hot springs are concentrated at the feet of travertine and near the lake, their temperature varies between 70 ° C and 100 ° C. in some cases the hot springs have a slight smell of sulfur and fate with a lack of pressure, it is estimated their water flow is 0.5L / s.

A detailed presentation of the area is provided by another paper (Kaireh and al).

Figure 11: *Cl-SO_4-HCO_3 ternary diagram. According to the temperature is 99.8 ° C and geological map with the* ***diagram*** *all the samples from thermal hot-springs are of distribution of hot springs.mature, possibly slightly volcanic, waters.*



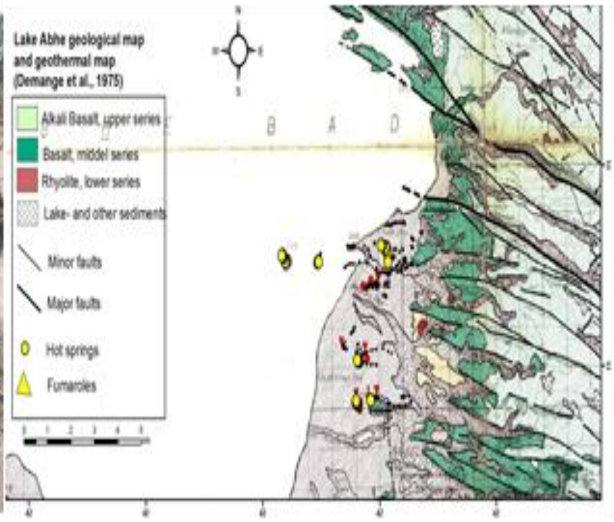


Figure 12 *Source of hot water that boils with a flow rate 1 L/ s*

3.7 Hanle-Garrabayis geothermal field

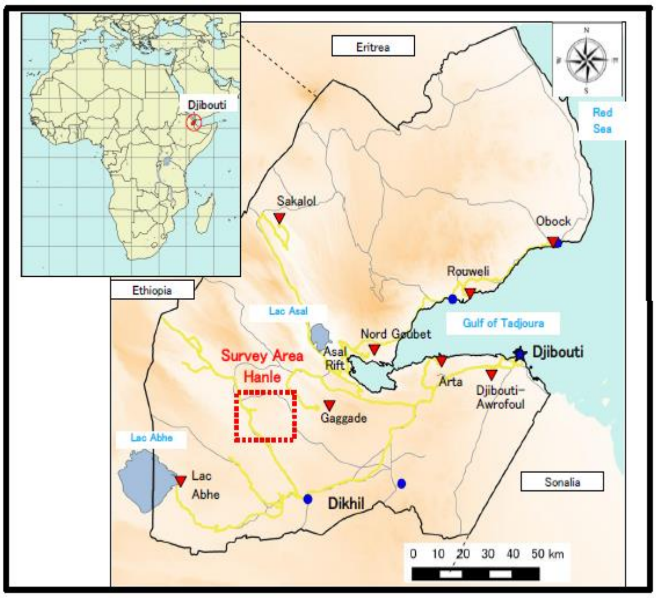


Figure 13: Full Site Hanlé-Garabbayis

A geothermal study was conducted in the region Dikhil, more precisely called Hanle graben (southwest of the Republic of Djibouti), in the years 1981 to 1987, with the assistance of the Italian government and the World Bank.

After creating the ODDEG in 2014, and with the assistance of Japan International Cooperation Agency (JICA), ODDEG carried out in 2014 a data collection survey to summarize and analyze all geological and geochemical information on thirteen geothermal sites in order to prioritize the development of the country.

Geochemical and geophysical studies were conducted in April and May 2015. The geothermometry gave a high T C of the reservoir.

		2014/06/06	2015/04/07
H_2/Ar	Shallow	72 °C	74 °C
CO_2/Ar	Intermediate	159 °C	121 °C
CH_4/CO_2	Deep	266 °C	234 °C
Reservoir		230-260 °C	

This survey allowed to conduct geological, geochemical and geophysical together with socio-environmental surveys in order to select exploration drilling location sites.

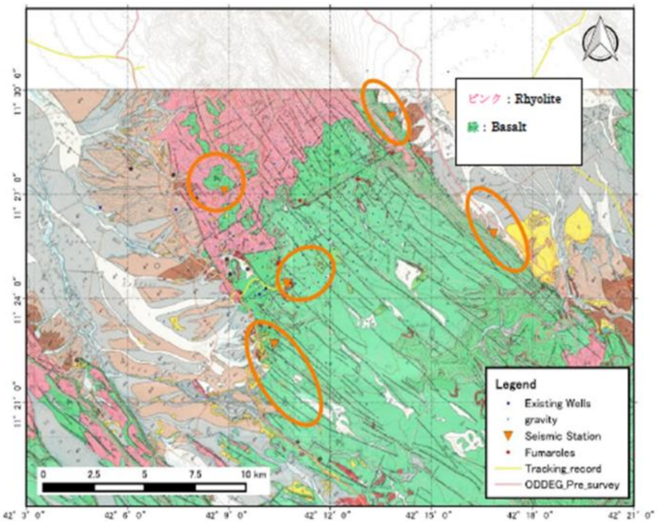


Fig 14: Locations of micro-seismic stations

As part of this additional study, geophysical methods used magneto telluric (MT), time-domain electromagnetic (TDEM), as well as gravity and micro seismicity.

Results acquired at present did not allow to identify a high temperature reservoir in this area where no recent volcanic activity is observed. The a-magmatic geothermal model imply convective hydrothermal fluid ascent along faults that still need to be mapped at depth in order to locate the plumbing system to be targeted by further exploratory drillings.

3.8 Sakalol Geothermal field

As part of the national geothermal research program undertaken by ODDEG, a geothermal reconnaissance studies campaign was conducted in the Sakalol sector focused in a first step on geological and geochemical studies. Following this recognition campaign, geophysical exploration investigations will becarried out for the first time in this area.

This study of Geothermal Exploration is carried out by ODDEG with the support ofCERD scientific teams.

Sakalol is located in the northwest region of the Republic of Djibouti in an area that may appear as a NW extension of the Asal rift system. This is an elongated graben produced by normal faulting affecting the stratoid series (3.5 to 1 My old). Although it is deprived of any recent volcanic activity, Sakalol was considered by JICA as part of the important sites in the Republic of Djibouti in terms of geothermal potential.

Field work focused mainly on:

-geological mapping, (CERD TEAM)

-geothermal surface manifestations mapping, (CERD TEAM)

-geochemistry of geothermal fluid, (CERD TEAM)

-gravity and resistivity survey, (ODDEG TEAM)

3.9 Arta Geothermal Site

The Arta geothermal prospect is one of the several geothermal prospects in Djibouti, and on the southern shore of Tadjourah gulf. The Tadjourah gulf is a young oceanic rift whose geology and tectonic activities have been investigated by several workers. Some of the units observed in the field include the 'Dalha' basalt and the 'Ribta' rhyolite which have been strongly altered by geothermal fluids and could constitute a sealing impervious formation, a possible explanation for the scarcity of surface thermal manifestation in the area. The most active faults direction are in the NW-SE and fumerolic manifestations are related to it on-shore, but more thermal output could be present in the of-shore portion of the field.

The prospect is the nearest active geothermal system to Djibouti town (situated about 40 km away). A good number of scientific investigations for geothermal resources were carried out in the area in the 1980.

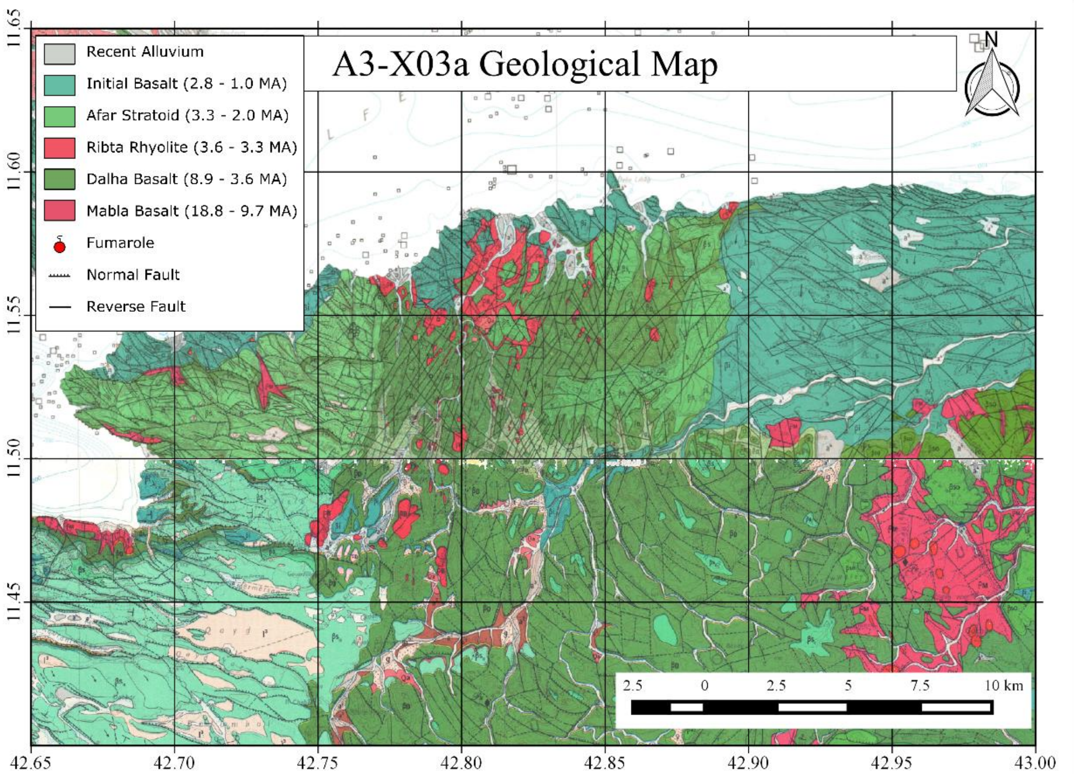


Figure 15: Geological Maps of Arta geothermal Site (JICA, 2014)

This site was submitted to the GRMF (Geothermal Risk Mitigation Facility) third round for a surface study programme and in 2015 this site was selected to receive the grant after application submission.

The plan survey will be including, geology, geochemistry, geophysics including environmental and social survey.

Now this site is on preparation for finalizing process with the GRMF committee to sign the grant agreement. Active work will start later on November after grant signing.

4. INSTITUTIONNAL ARRANGEMENT

Concerning the institutional aspects, the government of Djibouti has taken several initiatives to develop and promote its geothermal resource. A clear framework has been set up; regarding the EIA assessment under the Ministry of Environmental, and Mining code manage the concession of geothermal fields under the Ministry of Energy.

The energy sector was liberalized, the monopoly of EDD (Electricity of Djibouti) for electric production was replaced by facilities offered to private investors (IPP).

The Ministry of Energy in charge of Natural Resources is responsible for overall policy formulation in the energy sector. Within the framework of the policy defined by the Government, the new agency, ODDEG (Djibouti Office for Geothermal Energy Development), has these mains tasks:

- Identification of the various types of geothermal resources of the country
- The completion of exploration, reconnaissance and research work
- Conducting pre-feasibility studies and feasibility studies for the industrial development of these resources and the diversification of their uses
- The identification, with appropriate partners, public and private operators likely to ensure the development of geothermal energy, and any associated products

ODDEG is empowered to undertake all activities related to the geothermal resource development in order to make available geothermal resource for IPPs. This institution dedicated specifically for geothermal in Djibouti is under the direct umbrella of the Presidency of Djibouti.

5. PRIVATE SECTOR FACILITIES

The Republic of Djibouti is politically stable, and is located in a geostrategic position at the cross road of the three continents and has a favorable policy for investments.

The energy sector suffers high electricity costs in the region which enables the development of renewable energy projects and profitable businesses. The Government supports and assists the private developers (IPP) through the national investment agency (ANPI) at different step of the process. Many infrastructures like operational electrical grid, dispatching control center assures interconnection of different energy resources on the grid is in commission before the end of 2012.

6. CONCLUSION

The Republic of Djibouti has an important potential in geothermal energy, estimated to be around 1000 MW. Between 2011 up to now active work has been engaged to develop the geothermal sector aiming to achieve the government policy for green development (100% renewable planned for 2020). The creation of the Djibouti Office for Geothermal Energy Development (ODDEG) supports this policy according to the vision 2035. Practically, in the short term, ODDEG has to assess the huge geothermal potential available in the country through surface study and exploratory drilling. The first geothermal well engaged in the pipeline at Asal Gale le Koma with the technical expertise of Turkish drilling team using the recently acquired geothermal drilling rig machine of ODDEG, aside with the program engaged at Asal-Fiale with the support of an international banking consortium led by the WB thus demonstrate the government involvement to speed up the development of geothermal energy in order to enable the green energy development strategy of the country. The geothermal resource is foreseen be the key to the economic development of the country in the attainment of the MDG goal and it aims to play a major role in improving access to electricity and energy for all.

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