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The Asal Geothermal Site, Djibouti Republic (Model Update, 2012)

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ABSTRACT

The aim of this paper is to provide an account of the present knowledge and a vision of future perspectives, based on a geothermal model that we can ascertain on the eve of an important deep drilling exploration program led by the Ministry of Energy, Water Resources and Natural Resources of Djibouti Republic with the financial support of an international banking consortium led by the World Bank.

The proposed model is based on the results gained from several successive phases of geothermal exploration undertaken on the site since 1970, with 3 major steps : the initial studies (1970-1975) run by BRGM, including 3 deep wells (Asal 1 to 3), the successive works by Aquater (1986-1988), and the present stage from which we draw new data and a model established by ISOR for REI (2008), as well as recent geophysical studies (Doubre et al. 2007, Manighetti et al. 2007) and successive interpretations (Doubre et al. 2009).

Whereas a pretty high geothermal gradient (18°C/Km) is provided by the active spreading of the Asal-Ghoubbet ridge itself, with a hot (1300°C) anomalous mantle of a low velocity zone at 7km depth and above along the rift axis, a supplementary heat source is provided by the shallow magma chamber located underneath Fiale, that is a former lava lake located right on the rift axis which generated the 1978 tectonic event (a few meter wide opening of the rift) and the Ardoukoba basaltic eruption. The infilling and development of the Fiale magma chamber which resulted from the 1978 event, was achieved 10 years ago, and locally induced an even higher geothermal gradient (up to 60°C/Km) consistent with the presence of a 2km deep magma chamber at Fiale (Vergne et al. 2012)

The difficulty encountered in the previous steps did arise from two major problems:

- The lack of permeability of the volcanic formations crossed by the (vertical) deep exploration wells; and
- The salinity of the fluid encountered at Asal1, the most productive well which was plugged by metallic sulfides and silica deposits at the flash level of the 240g/l brine.

We believe that these difficulties will be solved in the coming months with the following steps:

- Drilling deviated wells with an orientation perpendicular to the rift axis in order to cross the normal faults and open fissures observed in the axial part of the rift and benefit from a high permeability and productivity of the wells.
- Locating the wells in the vicinity of the shallow magma chamber, in order to cross a superficial reservoir displaying suitable temperatures for industrial productions (200-300°C).

The major challenge – to be solved by further MT-EM geophysical works - will be finding suitable deep deviated wells location to cross through a fractured reservoir benefiting from the vicinity of this shallow heat source without touching the magma itself!

This is going to be achieved during the next phase of the program, financed by a public banking consortium led by the World Bank (with the OPEP fund, ADB, GEF and AFD). Evidence of 4 deep deviated wells and long lasting tests of the reservoir(s) will be necessary in convincing investors to further develop the geothermal power production there up to 50MW, in response to the present needs of the base load of Djibouti town.

1. INTRODUCTION

A pluriannual research program financed by the French CNRS and the Italian CNR and led by G.Marinelli and H.Tazieff for the geological exploration of the Afar triangle started in 1967. It involved a dozen of researchers from various earth science disciplines. The program lasted 10 years and facilitated the mapping of the whole area now located in Eritrea, Ethiopia and Djibouti Republic. Whereas the main objective of the research was basic geosciences - volcanology, petrology and tectonics - and the most spectacular result was the discovery of the presence of the Red Sea – Gulf of Aden oceanic ridge crossing through this part of the African continent, another consequence was the launching, in 1970, of geothermal exploration programs under UNDP in Ethiopia and BRGM in Djibouti.

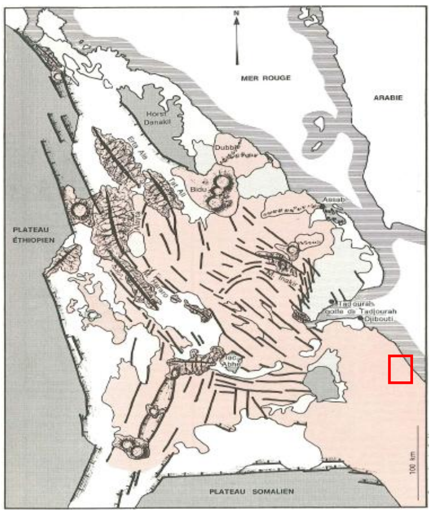

Figure 1 : Sketch map of the Afar triangle (from J.Varet, 1975), with the location of Axial ranges, the active spreading segments linking the Red sea rift to the Gulf of Aden ridge, with the location of the Asal-Ghoubbet range (red square).

It was shown at that time (Tazieff et al. 1972, Barberi et al. 1970) that the Afar region was cut by axial basaltic ranges, where the present spreading mechanism was concentrated, i.e. from NW to SE: Erta Ale, Alayta, MandaHarraro, MandaInakir and Asal (Figure 1). Therefore, in Djibouti, the geothermal exploration program engaged by BRGM (1970, 1973) with the supervision of Tazieff and Marinelli facilitated the quick identification of the Asal Rift as a target of major interest for geothermal exploration. Detailed geological, petrological, and tectonic studies by Stieltjes as well as hydrogeology and fluid geochemistry by Lopoukhine, followed by geophysical surveys provided a basis for proposing a geothermal model in which the shallow anomalous hot mantel along the Asal-Ghoubbet Rift was to provide an efficient heat source with additional supply from a shallow magma chamber underneath the central part of the Asal Volcano (Figure 2).

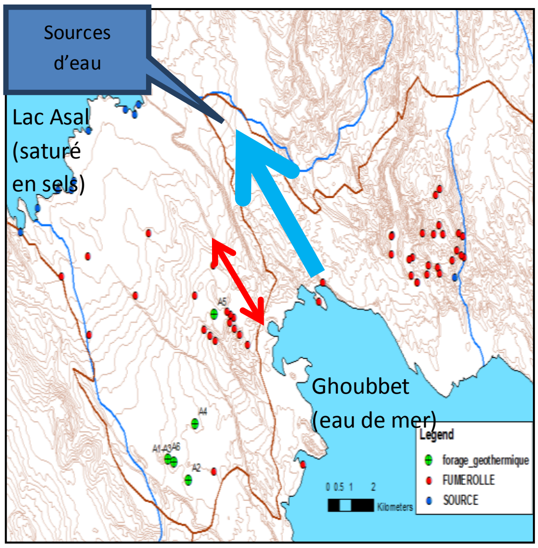

Figure 2: Location of the drilled sites (in green, numbered) and main fumaroles of the Asal rift on the topographic map. The first wells (A1 to A3) and later A4 et A6 were drilled on the SE side of the rift, at a fair distance from the active volcanic axis of the rift (double red arrow) as well as from the sismo-tectonically active along which an important ground sea water flow cross through from Ghoubbet to lake Asal (blue arrow)

The aim of this paper is to present the geothermal program presently run by the Ministry of Energy, Water and Natural Resources (MEERN) of the Republic of Djibouti, with the support of a public banking consortium led by the World Bank. The program is designed to release the remaining risks before a commercial program of electricity production can be implemented under PPP under good economic conditions. The objective is to drill up to 4 deep exploration wells in order to ascertain that the geothermal resource will be adequate to support a 50MW geothermal plant to cater for the present basic needs of Djibouti capital located 120km away from the site (World Bank, 2011).

2. GEOTHERMAL WORK UNDERTAKEN AT ASAL

2.1 Geological Setting

The active nature of the Asal volcanic and tectonic range, displaying a continuous basaltic activity in the recent quaternary period, with a magmatic evolution by crystal fractionation (Stieltjes et al.1976) and a typical rift in rift structure location of the present activity along the axis, was taken as the indication of the presence of a magmatic heat source at shallow depth, the last expression of which was found in the lava lake at Fiale (Figure 3, Stieltjes, 1976). Detailed quantitative geodetic surveys coupled with field work and age determination showed that the Asal shield volcano was built since 300.000 years and was subjected to successive rifting episodes with an equilibrium established between extension - of 17 to 29 mm / year along a 40° North direction - and magma injection (De Chabalier. &Avouac 1994, Figure 4). The 1978 eruption of Ardoukobba, which followed the rifting episode with up to 2m opening along the axis of the Asal-Ghoubbet(Ruegg et al., 1979) confirmed the active nature of this magmatic-tectonic rift segment (Demange et al. 1979). This was followed for several years by the reactivation of the Fiale caldera, newly replenished with magma at shallow depth. Several episodes of magma injection were observed from seismic sources in the period 1998-2001 (Doubre et al. 2007).

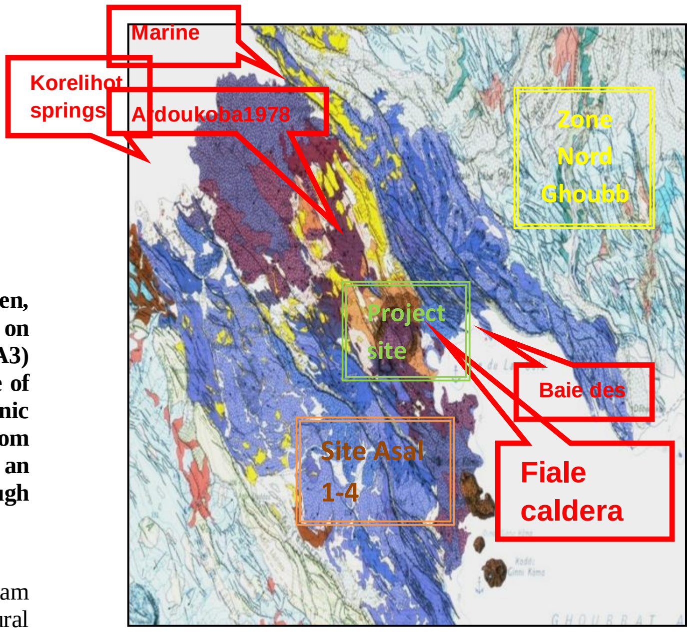

Figure 3: Geological map of the Asal Rift (Stieltjes, ed. BRGM, 1978); hyaloclastites are in orange, recent basalts in deep blue and violet whereas early rift basalts (300.000 - 100.000 y.) are in pale blue; the stratoid series (3 to 1 My) is in very pale blue colour. Lacustrine deposits (diatomite) in yellow.

2.2 Geochemical Origin of the Springs and the Geothermal Reservoirs of Asal

Several groups of springs are identified in the Asal area: the Manda springs located on the eastern side of the lake emerging from recent basaltic flows, the Korili spring emerging from the southern major fault system on the lake side, Wadi Kalou springs south of the lake, and Alifita and

Eadkorar spring areas on the northern side of the lake. Geochemical studies were undertaken in order to understand the origin of these springs in terms of the nature and behaviour of their hydrogeologic system and geothermal reservoirs fluids characteristics (Lopoukhine, 1973, Bosch et al. 1974, Fouillac et al. 1983; Fontes et al. 1989, Sanjuan 1990).

It was noted that a major hydrogeological feature of the Asal system is the important flow of sea water from the north-western shore of Ghoubbet pass into the south-eastern shore of the Asal Lake, thanks to open faults and fissures characterizing the northern side of the axial rift. This observation was a major indication that drilling in this part of the rift where the system may have been kept cool at depth should be avoided (see Figure. 2). The analysis of the correlation between major elements and further detailed studies of trace elements such as lithium, strontium, bromine and borum, in addition to strontium isotopic analysis showed that all fluid compositions can be explained by the interaction of sea water with the basalt at high temperature and by evaporation (Sanjuan 1990). The absence of anomaly in the bromine/chloride ratio excluded evaporate dissolution. A vapour dominated geothermal reservoir can be supported by the low value of the bromine/chloride ratio.

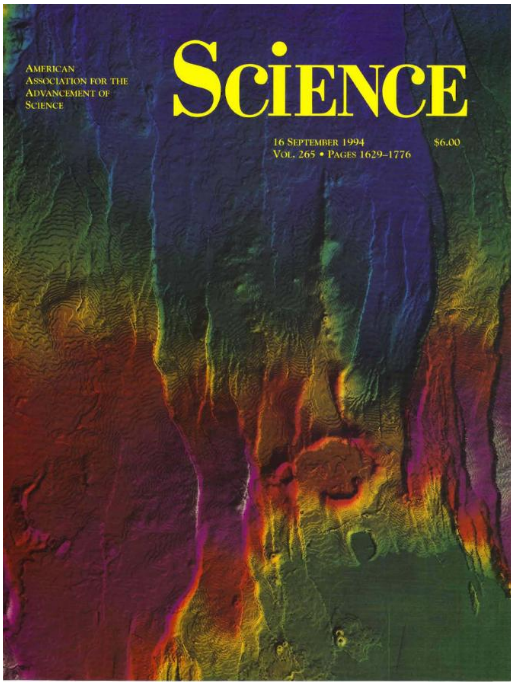

Figure 4: Shaded topography of the 12km long Asal rift. Colors indicate elevations, from -150 bsl (dark blue) to +350m above sea level (purple). The topography results from the dismemberment over the past 100.000 years of a large shield volcano formed stride the rift zone 300.000 to 100.000 years ago. Reconstruction of the volcano by Chabalier&Avouac (1994) indicates a spreading rate across the rift of 17 to 29 mm/y. cover page of Science. The Fiale Caldera and the baie des requins crater are well visible, as well as the axial ridge of Ardoukoba 1978 eruption.

Except for the Wadi Kalou located emerging from major border faults in the southern part of the lake, a continental water that has reacted with basalts at high temperature, all the springs show a sea water component with geothermometer maxima at 100°C, very close to the emergence temperature. Kalou and Korili groups of springs show a mixing of sea water with Lake Asal's brine showing that these also contribute to the reservoir fluids. This data was taken as the basis for locating the first exploration wells in A1 site area, that is on the top of the shield volcano, not far from Wadi Kalou springs, and at a certain distance from the rift axis in order to avoid seismo-volcanic hazards and the influence of cold sea water circulations.

2.3 Geophysical Surveys of the Asal Rift

The MELOS EM method was applied by BRGM (1973). Although its investigation depth was low, it pointed out a superficial elongated conductor anomaly on which the first Asal1 well was located successfully. This anomaly correlates with several hyaloclastite complexes located along a main fracture zone in the southern part of the rift. Other conductors were also identified close to the rift axis. Gravimetric surveys point out several heavy body anomalies with different dimensions (CFG 1993). Those located in the central part of the rift are correlated with the injection of magmatic chamber and the caldera collapse. Locally small anomalies could be the result of an intensively fractured zone. The comparison of the aeromagnetic data and the gravimetric modelling, with the help of geothermal data, was used in mapping the basement of the recent quaternary basalts, represented by the Dalha series, split into several compartments delimited by intensive fractured zones. MT survey was carried out by Ballestracci and Benderitter (1979) followed with AMT survey, in order to complete at shallow depth, but faced the difficulty of distinguishing between the deep geothermal reservoir and the shallow reservoir BRGM (Barthes et al. 1980, Abdallah et al. 1981). However, the interpretation of AMT data provided a good correlation with previous methods in determining the Dalha and stratoid series interface. Later on, EM survey was also limited to penetration to few hundred of meters (ORKUSTOFNUN 1988). Whereas the previous surveys covered the whole rift, this one focused on the eastern-central part near well Asal 5. The top of the conductor body delineates the ground sea water flow gradient from Goubbet toward Lake Asal, with an "upflow" in the Fiale area. This follows a form of the heavy body identified by gravimetric survey except in the wells area. Later on two magneto-telluric methods - MT5EX and low frequency - were engaged on a limited number of stations and appeared to provide useful complementary data to the electrical method (CFG 1993).

Seismic reflexion and PSV methods (Hirn et al. 1988) confirmed that the geothermal reservoir identified in Asal 1 was located on the intersection of main faults and was of fractured type. Numerous and significant anomalies correspond to the top of a geothermal reservoir on Asal 5 location, with observed seismicity concentrated in the Fiale area in the 2500-3000m depth interval. This activity could be explained by the interaction of water circulations with the top of a magma chamber (Doubre et al. 2007). More recently, Vergne et al. (2012) did show that the magma chamber underneath the Fiale caldera could be as low as 2000m depth.

A new geophysical survey combining TDEM and MT methods engaged (Reykjavick Energy Invest 2008), enabled the elaboration of a new conceptual model taking into consideration other available data including the results from the deep drillings. This allowed for the locating of new wells in the central part of the rift axis, in Fiale caldera and surroundings for the next feasibility phase.

2.4 Previous Deep Drillings Results

Altogether six deep wells with depths ranging from 1137m to 2105m were drilled at Asal in two major campaigns (BRGM 1975a,b; AQUATER 1989). A1, A3 and A6 are in the same area, located on the SW block inside the rift but away from the active volcanic axis and present sea water circulation. A4 and A5, located toward the central part of the rift, encountered the superficial underground sea water flow toward Asal between 250m and 280m. The stratigraphic logs and the resulting geological cross section are in good accordance with the geological model. A complete sequence down to the Dalha basalts is observed and Mabla series may even appear down A4 (CFG 1988). The hydrothermal mineral assemblage is in good agreement with the measured temperatures in all wells (Zan et al. 1990), except A5 in the rift centre, which does not allow any easy correlation. Two pleistocene and plioceneclayey layers mark the separation of the three principal stratigraphic units (recent Asal flows, stratoid series and Dalha basalts).

A3 and A6 temperature profiles are almost similar (Figure 6), with one intermediate medium temperature reservoir and one deep high temperature reservoir, while no deep reservoir was reached by A4 and A5. The deep high temperature reservoir was tapped by A3 at 1075m and between 1225m and 1250m, and in A6 between 1100m and 1300m, with bottom hole temperatures of 263.5°C and 280°C respectively. At higher depths, low permeability was exhibited by A4 between 1725m and 1775m, as well as between 1950m and 2000m and by A5 between 2000m and 2050m with bottom hole temperatures at 345°C and 359°C.

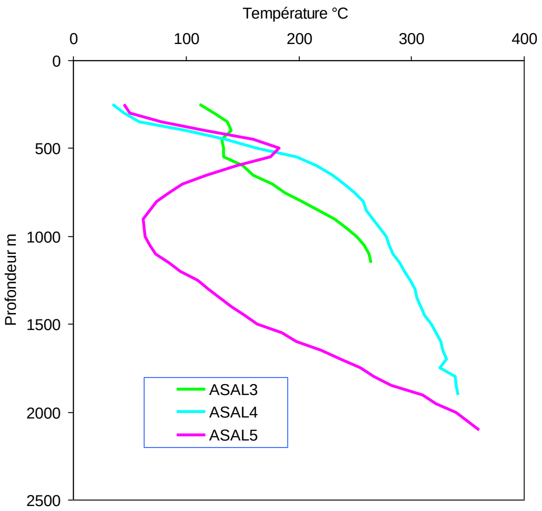

Figure 5: Temperature profiles measured in the Asal wells A3 to A5. Note the inversion of temperature observed in the A5 well located along the rift axis (Source: Jaludin, 2003).

An important temperature inversion is observed at A5 confirming the fear that the superficial underground marine water flow towards the lake can penetrate deep into this part of the rift that is affected by numerous active open faults. The higher temperature encountered at intermediate depths is most likely fed by convective geothermal fluid along faults bordering the central part of the rift. It could also be linked to magmatic intrusion at shallow depth, as gradient would fit with a magma chamber at 2km depth (Figure 7), a figure resulting from the latest geophysical surveys (Vergne et al. 2012).

The objective of the geothermal drillings was to reach a high enthalpy reservoir. Therefore the intermediate geothermal reservoir, although showing high permeability, was not tested. It appears in the six well logs, at depths ranging from 240m to 600m. The geophysical data correlates with the well log in suggesting a certain continuity of that intermediate reservoir in the whole rift area, which is not the case for the deep reservoir (CFG 1993; ENEL 1990; ORKUSTOFNUN 1988; Hirn 1988; Jalludin 1992). Comparing chemical and temperature data, it was noted (ENEL 1990) that this intermediate reservoir at 140 to 190°C was thermally protected, with salinity around 50g/l.

The deep liquid-dominated reservoir was produced three times for more than nine months in total at A3.The first test provided 360 t/h of fluid at 12.5 bars at the well head with a production temperature of 265°C and a vapour fraction of about 35%, that would allow to produce 10MWe(AQUATER, 1989). The total dissolved solids were 116 g/l with 1700 ppm non-condensable gases (mainly CO_2). The production data showed an important decrease in the output, the bottom hole pressure drop by 3.5 bars whereas scaling was observed in the wellbore and the surface equipment. Sample analysis showed metallic sulphide deposits (PbS, ZnS) at high pressure and amorphous silica with Mn and Fe at low pressure (BRGM 1975; VIRKIR-ORKINT 1990). Some calcite deposits were also detected. A 10 mmthick scaling was measured by caliperin the flash zone and up to 6-8 mm in the wellhead. Reservoir engineering studies (Battistelli et al. 1991) concluded that the Asal 3 output decline was due to wellbore scaling - certainly the major handicap of Asal deep reservoir - but that a decrease in average pressure could also result from the limited extension of the reservoir due to fault boundaries in this fractured reservoir as already pointed out by BRGM (1981).

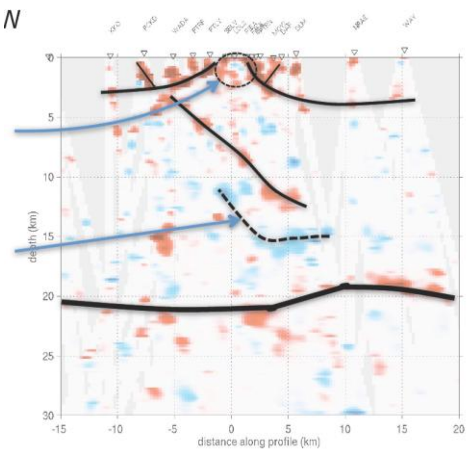

Figure 6: crustal structure across the rift according to seismic profile obtained by Vergne at al (2012), showing that the magma chamber may be as low as 2km in the rift axis (Fiale caldera)

3. A NEW APPROACH BASED ON RECENT VIEWS OF ACTIVE GEOTHERMAL SITES

3.1 The Icelandic Approach

A 20 years interval separated the drilling and corrosion/scaling tests in the late 1980s from new exploration undertaken in 2008 through cooperation between the two small Republics of Djibouti and Iceland, with the involvement of a private enterprise, Reykjavik Energy Invest. A new and complete geophysical coverage of the Asal Rift using TEM and MT methods was conducted by ISOR. 106 TEM and 102 MT soundings were obtained and analysed in light of complementary tectonic/structural survey based on aerial and satellite images and field works (Figure 8).

Figure 7: TEM and MT surveys undertaken by ISOR for REI (REI-ISOR 2008).

The Icelandic experience in similar active rift systems and in particular the analogy with Krafla encouraged REI to target the feasibility in the axial portion of the Asal rift, in theFiale caldera (Figure10). Based on the new data and revised earlier models, a feasibility programme was proposed including deep deviated exploratory wells, and an preliminary Environmental Impact Assessment study was undertaken.

3.2 Since 2011: A New Public Banking Involvement

The financial crisis that affected Iceland, had an impact on the project and a public banking consortium lead by the Word Bank offered to finance the high risk phase of drilling for feasibility before the site is offered for development to industrial partners, with the objective of building a power plant to produce 50 MW to cover the present base load needs of Djibouti capital. The wells are to be drilled in the Fiale Caldera and its immediate surroundings; that is, right on the active volcanic rift axis along which the Ardoukoba eruption occurred in 1978. It is along this axis that most of the seismic activity continued in the last years (especially in the 1996-2001 period, according to Doubre et al, 2007, Figure 9), in relation to magma injections, underneath the Fiale Caldera and down to the small explosion crater of baie des requins.

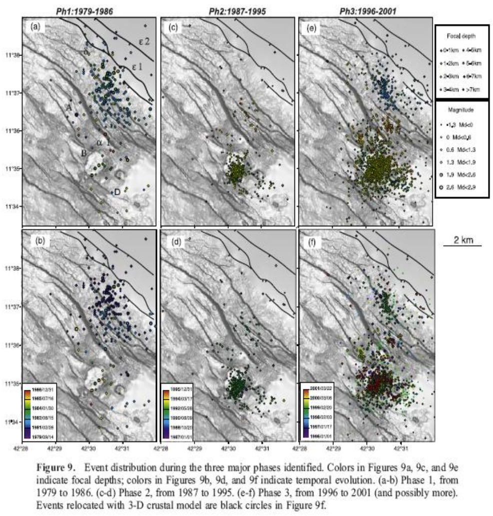

Figure 8: Event distribution during the three major phases identified. Colors in Figures 9a, 9c and 9e indicate focal depths; colors in Figures 9b, 9d and 9f indicate temporal evolution. (a-b) Phase 1, from 1979 to 1986. (c-d) Phase 2, from 1987 to 1995. (e-f) Phase 3, from 1996 to 2001 (and possibly more). Events relocated with 3-D crustal model are black circles in Figure 9f. From Doubre et al. 2007.

3.3 Discussion

Considering the importance of the sismo-teconic event of 1978 (2m wide opening of the Asal-Ghoubbet rift), one can think that such events are of centenary occurrence (2 cm per year average but really 2m per century). The seismic activity is particularly well documented thanks to the Arta seismic observatory jointly run by CERD with the Paris Institut de Physique du Globe. The intense seismic activity observed underneath the Fiale Caldera in the period 1986-2001 was interpreted as linked to successive magma injection following the 1978 crisis. Such phenomena have been observed in Iceland and more recently in the Manda-Harraro crisis (2006-2011).

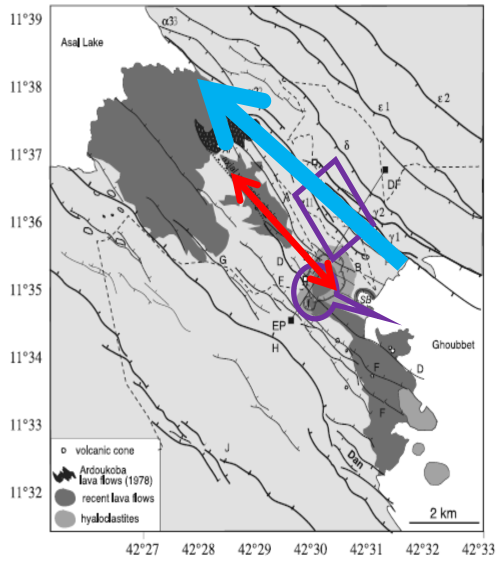

Figure 9: Location map of the proposed future drilling sites (G. Hjartarson et al. 2010) in and around theFiale caldera with its hyaloclastite ring and recent basaltic flows infilling the « lava lake » (Fi). Fiale is located along the active volcanic rift axis (in red) on which the Ardoukoba eruption occurred in 1978 (Ar). Present sismic activity (surrounded in violet), resulting from the interference of hot magma (1200°C) with sea water invasions concentrate under this calera in the 2 to 4 depth interval, as well as along the faults bording this caldera and extend SE towards Ghoubbet down to the baie des requins crater (SB). Seismic activity also develop, without any apparent relation with the magmatic axis along the tectonic axis located north, where the most important sea water flow streams down to lake Asal. The major sea water pass id underlined by aa blue arrow (base map after Doubre et al. 2001).

Between the surface and 1800m depth, no seismic activity is observed. This is interpreted as being due to the numerous open faults filled with hydrothermal water at a temperature ranging from 100°C to 300°C. In fact, numerous steam vents are observed along the open fissure on the lava lake surface as well as along the faults bordering the caldera where the typical “Fiale” grass (which gave the name to the caldera) grows due to the humidity resulting from the condensation of the steam in the superficial soils that are associated with the hyaloclastite surface alteration. The hydrothermal alteration of the rock into clays and deposits certainly also play a role in reducing noisy faulting.

Between 1800m and 4000m, the brittle nature of the basalts and the dryer hydrothermal mineralization (epidote zone) allows the seismic events of low amplitude to appear as a result of interaction between hot rocks and superheated steam (from 300°C - 600°C). Of interest here is to discover whether this results from the interaction of the suoerheated fluid with hot rock or molten magma!

At a depth of more than 4000m, the magma chamber is found, filled with molten basalt at a temperature exceeding 1200°C. This silicate melt is produced by partial melting of the anomalous mantle, located at a depth increasing from 7km along the rift axis to 12km in the rift zone a few kilometers away from the axis.

4. PROGRAM PRESENTLY GOING ON (2011 – 2012)

Recently, the World Bank commissioned an impact assessment study as a prerequisite to the engagement of a new geothermal exploration phase. Administered by the Ministry of Energy, Water and Natural Resources (MEERN) in conjuction with the Ministry of Housing, Urbanism an Environment (MHUE), this study determined the social and environmental impact of the project that aims at producing electricity from a 50 MW geothermal plant located at Asal, 120km to the west of Djibouti capital. More precisely, the study concerns the first phase which implies the drilling of 4 deep exploration wells.
Considering that the choice of the drilling site was justified by sound scientific arguments (see above), the study also checked for the validity of the choice of the deep drilling in production size (full size of 9 inches), as the wells would be equally usable for production in the successive phase. The use of deviated wells was also validated due to the higher chance of cross the permeable zone in the axial area dominated by vertical open faults. Besides this, the lava lake was considered as a zone to be protected and hence drilling underneath was possible through deviated wells. Recalling that the objective of each of the 4 wells was to test the deep geothermal reservoir, it also retained that the test of the intermediate reservoir (at 240m to 600m) was a requirement.

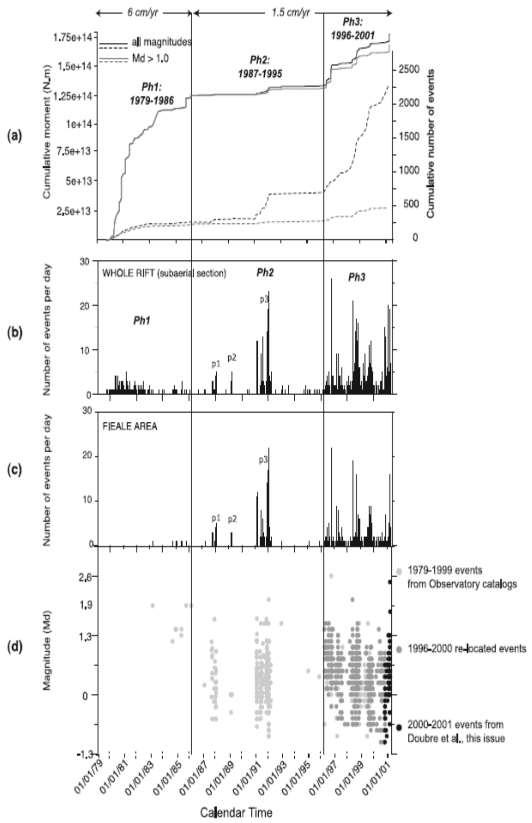

Figure 10: Intensity of the seismic activity in the Asal rift from 1978 to 2001 (from Doubre et al. 2007): the

period 1979-1986 immediately following the Ardoukoba eruption was the most active and was followed by a period of relative quiescence lasting nearly 20 years (1986-2006). A new phase of activity developed in the 2006-2011 period centered underneath the Fiale caldera (with depth of the seismic events from 2 to 4 Km), but also on the fault located north where events appear to be deeper (4 à 7km).

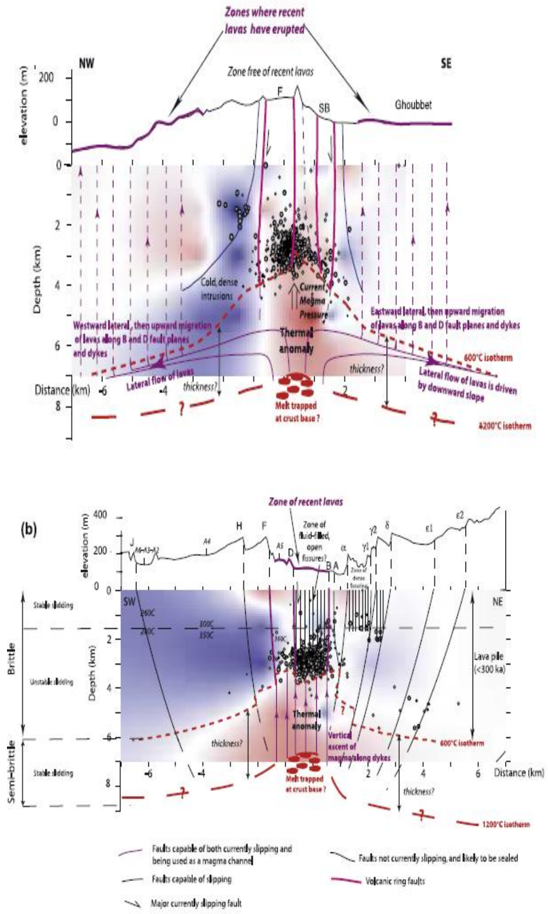

Figure 11. AG Rift crustal structure (subaerial section) in best agreement with all observations. Cross sections are Ax and P3 of Figure 5a. P wave velocity anomalies are from *Doubre et al.* [2007]. For clarity, only best constrained events are plotted (1996–2001). Names of faults and volcanic features are as before. A_i indicates position of drilled wells, with measured temperatures indicated [see *Abdallah*, 1997]. See text for discussion.

Figure 11: interpretative sections through the center of Fiale caldera, along the rift axis (above) and perpendicular to it (below). Isotherms were determined from the thermal profile of A5 geothermal well. 600°C and 1200°C isotherms are drawn, the last corresponding to liquid basaltic magma, rising at an average depth of 8,5 to10 Km and rising at less than 7km under the rift axis. The superheated area (with active diking) is at a depth of 4km (and eventually only 2 Km) under the rift axis. Sismic activity concentrates in this area at a depth of 2 to 4 Km.(From Doubre et al., 2007)

With temperatures ranging from 140°C to 180°C, this target is sufficient for commercial electricity production using binary technologies (ORC plant). In fact, this depth zone may be sufficient if the wells to be drilled behave like the upper part of A5, with a very high temperature gradient at shallow depth, provided that the drilling sites would be chosen in such a way that cold sea water inflow is avoided. Let us recall that if the magma chamber is only at a 2km depth underneath the Fiale Caldera, it could well be highly risky and eventually impossible to reach the 2500m targeted. The use of scaling inhibitors may be necessary in case the deep reservoir is reached and as salty as in the A3 area.

The project will be engaged under 3 primary contracts including:

- The selection of a geothermal expert to back the project team in structuring the program and in the proposal phase for the drilling consultant;
- The selection of a drilling consultant in charge of preparing the call for drilling enterprise, supervising the drilling and tests programs on site and contributing to the elaboration of the call for tenders for developers of the geothermal electric production plant; and
- The attribution of a service contract for undertaking the exploration drillings and well testing.

The requirements for the project include:

- Building an access road from the asphalted road (RN9) to the drilling sites;
- Opening one or several quarries for roads and platforms building;
- Preparing 4 drilling platforms 6.000 - 10.000m^2 each, with attached pools of 1000 - 2000m^3 respectively for drilling muds and fluid tests;
- Installing an area for storage and temporary housing of the drilling staff;
- The drilling works for the 4 wells (rotary drilling starting at 23 inches and ending with 9 inches production diameters; and
- Implementing the proper conduits for water feeding of the drilling system and geothermal fluids.

Complementary engineering studies will be necessary for implementing the well location, determining their final characteristics (deviation direction and angle, etc.), determining the precise sites for the platforms, optimal drilling fluids, the water source to be captured (sea water conduit from Ghoubbet or shallow production well on site), as well as the mode of evacuation or eventual processing of the geothermal fluid during tests. Lasting a total of 28 months, the following phases will be considered: conception and studies, site preparation (roads, platforms, basins, housing), then drillings, tests and interpretations (nearly 12 month), and finally, abandonment or call for development.

5. CONCLUSION

After 40 years of discontinuous efforts, the current program should allow for the development of the Asal geothermal site, by providing the model on which this new feasibility can be confirmed. The project will engage and train new staff in the geothermal energy sector, including engineers, technicians and workers. The population expects this project to be run on schedule and come to an end due to the fact that the development of this endogenous renewable energy resource is long over-due. It is a real challenge for the newly created MEERN to succeed in this project.

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