Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Geothermal Exploration Opportunities in Eritrea

Michael Abraha

Ministry of Energy and Mines, Department of Mines, P. O. Box 272, Asmara, Eritrea

m_abraha2002@yahoo.com

Keywords: Alid, Eritrea, Geothermal Prospect, Geothermal Law, Investment Proclamation, Independent Power Producer

ABSTRACT

The Government of Eritrea is entirely dependent on imported oil for the production of its electricity. As a result, the production of geothermal electricity will decrease foreign exchange expenditures, provide energy security, and decrease GHG emissions.

The Government has established a conducive environment for IPPs and investors. It sees its role as bringing project opportunities to the point where private sector companies and investors will become involved, carry them through to completion and ensure long term operation and sustainability.

As a result of previous work carried out by the Ministry of Energy and Mines of Eritrea and the US Geological Survey (with the financial support of USAID) at the Alid Volcanic area. The Government of Eritrea wishes to pave the way for geothermal-based rural electrification through the installation of a pilot geothermal power plant at Alid and the identification of new prospects for additional geothermal plants in the future.

The Government feels the best way to do this is to pursue a two pronged program that builds on the earlier work at Alid and includes (A) siting, drilling between 1-3 geothermal exploration wells and carrying out the related resource analysis and modeling at Alid and (B) implementing a regional geothermal reconnaissance survey to outline potential geothermal resources throughout the eastern lowlands of Eritrea (along the Red Sea) where five geothermal manifestations (hot springs and fumaroles) have been identified. The regional survey should include appropriate geological, geochemical, and geophysical surveys.

1. INTRODUCTION

Eritrea is located in the Horn of Africa and is bordered on the northeast and east by the Red Sea, on the west and northwest by Sudan, on the south by Ethiopia, and on the southeast by Djibouti. The country has a high central plateau that varies from 1,800 to 3,000 meters (6,000-8,000 feet) above sea level. A coastal plain, western lowland and some 300 islands comprise the remainder of Eritrea's land mass.

The climate is temperate in the mountains and hot in the lowlands. Asmara, the capital, is about 2,300 meters (7,500 ft.) above sea level. Maximum temperature is 26^{o} C (80^{o} F). The weather is usually sunny and dry, with the short rainy season occurring during February-April and the longer rainy season beginning in late June and ending in mid-September.

Eritrea's 3.5 million citizens belong to nine major ethnic groups, and are part of three distinct linguistic families - the Cushitic (or Hamitic), the Semitic, and the Nilotic languages.

2. STATUS OF ENERGY SECTOR

The Eritrea Electric Authority (EEA) had approximately 50 MW of diesel-fired generating firm capacity in 2001 excluding the new 84 MW Hirgigo power plant, which was commissioned early 2003.

Around 21% of Eritreans have access to electricity, but only 2% of the rural population are estimated to have the access. Averaged over the whole population, per capita electricity consumption has improved from as low as 16 kWh in 1991 to 60 kWh in 2001.

Over 66% of the energy consumption is obtained from biomass and 34% is obtained from imported oil.

The country's biomass energy resource is being used unsustainable contributing to the degradation of the ecosystem - a factor that has prompted quite extensive afforestation and reforestation as well as soil and water conservation programs.

Present and projected power demand – power use profiles

To extend the supply of electricity to an increasing number of locations and customers, international, regional or national power companies, local or foreign Independent Power Producers (IPPs) and Independent Power Distributors (IPDs) are encouraged to invest in the required infrastructures. The Government will soon establish an Electricity Regulatory Board and a System Operator with whom the IPPs and the IPDs will interact. The IPPs have the option to generate power from sources like the renewables wind and solar, geothermal, or using state of the art conventional energy technologies. In principle importation or exportation of electricity and thus regional integration of power are permissible subject to the approval by the Government. In particular national companies and electric membership co-operatives are highly encouraged to enter in the market of rural electrification either by extending the national grid or through a self contained system of generation and distribution.

One of the major constraints in the rehabilitation and development efforts in Eritrea is the acute shortage of Energy.

Being aware of the importance of Energy in the nation building, the Government of the state of Eritrea has given a great attention to the study and development of indigenous energy resources.

3. ENERGY POLICY

Diversify primary energy resources through appropriate study of the indigenous energy resources.

Electrify rural areas, take appropriate measures to conserve energy and encourage private sector's involvement.

4. GEOTHERMAL POTENTIAL IN ERITREA

Proper Geothermal assessment was not carried out to date.

However, as considerable portion of the State of Eritrea is located within the World's Geothermal Provinces, it is believed that the country is well endowed with geothermal energy.

5. POTENTIAL FOR GEOTHERMAL POWER GENERATION AND DIRECT USES

The study by the Ministry of Energy and Mines in collaboration with US Geological Survey (USGS) of the Alid Volcano area represents Eritrea's first attempt to evaluate and promote the use of a geothermal resource. See below for details.

Based on geological, geochemical and hydrothermal studies done in the eastern lowland, other thermal springs, which need further follow-up exist along the Asmara-Massawa highway and in the Henab area 170 km north of Massawa.

There is high demand for geothermal energy in the region for applications like:

- Improve quality of life through better illumination, better air quality, improve access to information and telecommunications as well as being a stimulus to business development,
- Manufacturing plant (Cement, Fish, Refrigeration, distillation plants and water desalination)
- Resort area (the gulf of Zula has got a high potential for tourist attraction (historical remains, animal parks, diving and fishing, hot springs and fumaroles etc.,)
- Enhanced oil recovery;
- Coastal development in line with the newly constructed Massawa-Assab road etc.,

A well developed geothermal power generation that is connected to the national grid will have a proportionate influence in reducing imported oil and thus has the global benefit of mitigating greenhouse gas emissions.

6. GEOTHERMAL ENERGY EXPLORATION IN ERITREA.

Alid Geothermal Prospect:

Alid area had been identified as a prospect since 1901-02 when Angelo Marini from the Italian Institute for Military Geography undertook a detail study of Alid and its surroundings. A number of papers were published by researchers since then. A reconnaissance survey was carried out by UNDP in 1973 as part of the geothermal resources development program. In 1992, the late Prof. Giorgio Marinelli and a staff member from the Department of Energy visited Alid area and prepared proposal for detail study.

Geological and geochemical studies were conducted by USGS and MEM in 1996.

The Alid volcanic area is felt to be the highest near-term potential geothermal prospect in the country. It is located about 120 km south of Massawa, Eritrea's dominant port city. (Figure 1)

Alid rises about 700 meters above the floor of the Danakil Depression, a crustal spreading center that traverses the eastern lowlands of Eritrea. This mountain is a structural dome that formed as a result of local intrusion(s) of silicic magma into the upper crust. Intrusion of this magma domed Precambrian rock and an overlying sequence of late Cenozoic sediments and lava flows. The sediments are fine-grained clastic deposits typical of a shallow inter-tidal environment. Some contain marine fossils. The lava flows include basalt, andesite and rhyolite. Some basalt is pillowed, indicative of emplacement underwater, but most of the lavas are emplaced in a subaerial environment. (Figures 2 and 3).

The age of the Alid structure is unknown, though geologic and geomorphic relations suggest that uplift and rhyolite eruption occurred between about 50 and 200 ka.

Fumaroles and thermal pools are found in at least 11 small (about 1-2 ha) sites over about 10 km^2 in the depressed summit region and northern flank of Alid. Most of these zones are clay-altered and are covered by sublimates of various NH_4-, Ca- and K- sulfates. The thermal areas went through a variety of lithologies, including rhyolites, siltstones and a small block of Pre-Cambrian mica schist that crops out in a deep canyon cut into the central part of the uplift. There are no obvious structural controls on the distribution of fumaroles. Thermal pools contain mixtures of shallow groundwater and fumarolic condensate. Hot or cold springs unrelated to fumaroles were not found.

Results of aforementioned Previous studies strongly suggest that an upper crustal magmatic and/or hot plutonic body is present beneath Alid Mountain.

A variety of gas geothermometers all yield high parent reservoir temperatures, up to and over 250° C. The geologic structure and tectonic environment of Alid were considered highly favorable for producing and maintaining substantial fracture permeability beneath the mountain and perhaps even extending north and south somewhat from the mountain's base. The overall temperature and permeability conditions seemed sufficiently favorable for the existence of an electrical grade geothermal resource for the team to recommend that exploration drilling to depths of 1.5 to 2 km take place.

However, before such deep drilling is undertaken, additional tasks were suggested in order to select specific drill sites.

7. PROPOSAL FOR DETAIL SURVEY IN ALID GEOTHERMAL PROSPECT

The following additional detail survey is recommended to be carried out before drilling exploratory wells:-

- Detailed hydrogeological and fracture pattern study to determine the recharge area.
- Geophysical study to delineate the reservoir and confirm the presence of local heat source.
- Drill temperature gradient wells to determine the heat flow direction and thereby the up-flow zone.
- Carry out the study of carbon dioxide and radon in soil gas to help locate zones of high permeability.

8. OTHER GEOTHERMAL PROSPECTS

Aside from Alid, geological, geochemical and hydrothermal studies done in the eastern lowland have documented the existence of other thermal springs along the Asmara-Massawa highway, near the Gulf of Zula and in the Henab area 170 km north of Massawa. The thermal springs along the Asmara-Massawa highway are on a section of the middle to lower levels of the western escarpment of the Red Sea graben. Surface temperature and chemical analyses have been carried out at the Ali Hasa, Dongolo Basso, Sabarguma and Ailet spring areas. The hydrothermal features at these areas are classified as warm and hot springs (defined based on their temperatures being lower or higher than 50° C). They issue near-neutral waters with low chemical contents. All of the springs are of low energy exhibiting quiet flow with no steam separation or gas evolution.

9. PROPOSED RECONNAISSANCE SURVEY

Other than Alid reconnaissance survey is needed to assess the geothermal energy potential of the country. The proposed study area includes the Eastern escarpment where low enthalpy geothermal springs are manifested and stretches SSE crossing the Zula bay up to Erireaa-Djibouti border.

The study is proposed to include:

- Interpretation of aerial photos, satellite images, Regional Geological mapping, Hydrogeological mapping, Geochemistry and Geophysics.

10. GEOTHERMAL LAW

Geothermal resources are governed under mineral mining laws (section III, article 18(3) of Proclamation No.68/1995).

Key policies upon which the Mining Law (including geothermal exploration) is based include:

- The duty of the Government to ensure the conservation and sustainable development of mineral resources (which are public property) for the benefit of the Eritrean people;
- The right to exploit any commercial discoveries made pursuant to a valid exploration license.
- A simple and fair taxation system which recognizes the risky nature of mining investments, and hence allows:
- Write-offs of exploration expenditure incurred anywhere in the country;
- Generous reinvestment deduction (5% of gross income); No dividend tax;
- A nominal rate of import duty (0.5%) on all inputs necessary for mining operations.
- Equitable foreign exchange regulations permitting:
- Free and unrestricted repatriation of earnings;
- Retention of a portion of foreign currency earnings abroad in external accounts;
- Maintenance of foreign currency accounts in banks in Eritrea.

Eritrea has an ample supply of artisans and semi-skilled craftsmen, although technical experts and highly skilled professionals and managers are in short supply. The Government and international donor agencies are trying to remedy the situation with domestic and external training courses. As the government improves infrastructure and as foreign investment increases, skilled professionals of the Eritrean Diaspora are likely to begin to return home in greater numbers.

Eritrean legal documents ask contractors to give preference to the employment of Eritrean nationals to the fullest extent possible, provided, such nationals have the required qualifications and experience. If an Eritrean national cannot be found with qualifications and skills suitable to fill a position the licensee may employ a qualified foreign national (Mining law article 29(1)).

The process of investor certification has been centralized under the authority of the Eritrean Investment Center. The Investment Proclamation specifically requires the center to issue certification within ten days from the completion by the investor of the required formalities. The Investment Proclamation eliminates the requirement for joint ventures or acquisition of Eritrean partners. Projects can be wholly owned by private foreign companies. Projects are examined to ensure they include training Eritrean staff to replace expatriate workers and that projects will not negatively effect the environment or local conditions.

Official approval authorization for private projects is vested with the Eritrean Investment Center. In practice, large-scale projects are usually reviewed and approved by the appropriate minister or Office of the President.

Foreign investors are offered further protection as a result of the Government of Eritrea seeking appropriate bilateral and multilateral investment protection or guarantee treaties, specifically MIGA (Multilateral Investment Guarantee Agency) and ICSID (International Center for the Settlement of Investment Disputes), or the Washington Convention.

On May 1, 1998 the National Bank of Eritrea adopted a free-floating exchange rate. According to the regulation each bank will set the exchange rate at which anyone can convert *Nakfa*, the Eritrean currency, to hard currencies.

The Investment Proclamation maintains that investments are protected from nationalization, confiscation, seizure, or expropriation. Foreign investors are offered further protection as a result of the Government of Eritrea seeking appropriate bilateral and multilateral investment protection or guarantee treaties, specifically MIGA (Multilateral Investment Guarantee Agency) and ICSID (International Center for the Settlement of Investment Disputes), or the Washington Convention.

11. INDEPENDENT POWER PRODUCER

The newly drafted legal frame-work which is soon to be promulgated will have positive impact on the private sector.

IPP will have the opportunity to negotiate for power purchase agreement.

The electricity tariff will be based on a reasonable Rate of Return.

12. GOVERNMENT COMMITMENT IN DEVELOPING GEOTHERMAL ENERGY

If a Private Company discovers geothermal energy and develops it, the Eritrean Electric Authority (EEA) can be a partner and willing to assist in developing the resource.

Transmission line from the geothermal power plant can be connected to the existing EEA grid system.

13. CONCLUSION AND RECOMMENDATION

- The legal frame-work for exploring geothermal energy is in place and encourages Private Sector involvement.
- The studies carried out have indicated the prospectivity of the geothermal energy in the country.
- The energy demand of the nation is high.

In order to move ahead with geothermal exploration and development in Eritrea, it is important to build on work already done and carry out further analyses which, if successful, should lead to exploratory drilling at one or more sites.

Since the geothermal resource at Alid is yet to be confirmed, further exploration and analysis is required.

Towards this end the Ministry of Energy and Mines invites interested Geothermal Companies and financiers to participate in geothermal exploration and development.

REFERENCES

Barberi, F., and Varet, J., 1970, The Erta Ale volcanic range (Danakil Depression), Northern Afar, Ethiopia: Bulletin Volcanlologique, v. 34, p. 848-917.

Beyth, M., 1994, A brief assessment of the Alid geothermal field: Report ES-10-94 of the Israel Ministry of Energy and Infrastructure, 11p.

Clynne, M.A., Duffield, W.A., Fournier, R.O., Woldegiorgis, L., Janik, C.J., Kahsai, G., Lowenstern, J., Mariam, K., Smith, J.G. and Tesfai, T. (1996a). *Geothermal potential of the Alid volcanic center, Danakil Depression, Eritrea*. Final Report to the U.S Agency for International Development. 46pp.

Marinelli, G., Quaia, R., and Santacroce, R., 1980, Volcanism and spreading in the northernmost segment of the Afar Rift (Gulf of Zula): Accademia Nazionale dei Lincei 47.

Souriot, T., and Brun, J., 1992, Faulting and block rotation in the Afar triangle, East Africa: The Danakil "crank-arm" model: Geology, v.20, p.911-914.

Figure 1: Alid geothermal project, location map.

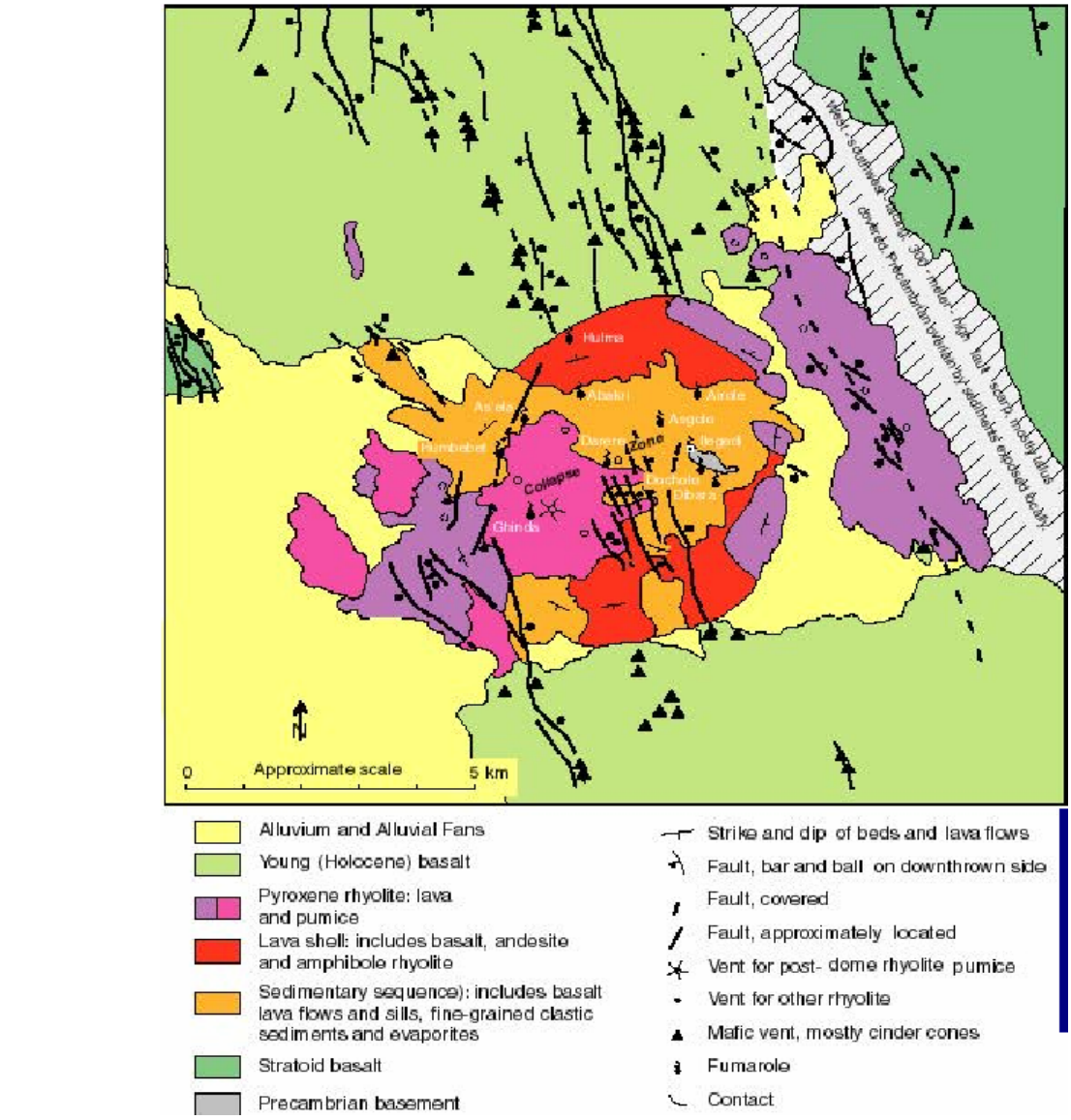

Figure 2: Generealized geologic map of Alid volcanic center (after Clynne et al. 1997).

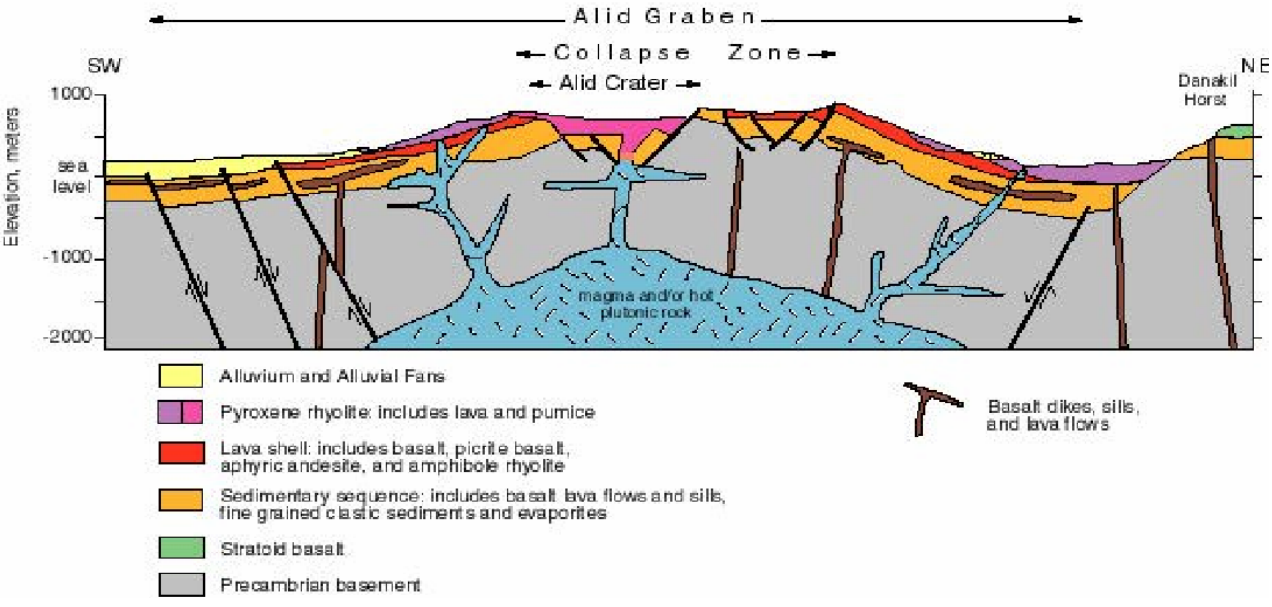

Figure 3: Schematic cross section of Alid volcanic center (after Clynne et al., 1997).

Figure 4: Overview of geothermal areas in Eritrea.