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Photongaya (Geopower) to Our Atlantic Esmeralda

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ABSTRACT

Fernando de Noronha archipelago is the biggest oceanic island of Brazil, located about 360km off the northeast coast. With 3 thousand inhabitants and 1.9 MWe of running capacity, it has received the nickname of 'Esmeralda do Atlântico' (Atlantic Esmeralda) because of its beauty. The electricity is generated by a diesel plant and a small wind turbine. Tourism and fishing are the principal economic activity, so there is concern about sustainability to preserve this fragile ecosystem.

Originating from igneous activity that lasted until 1.7 Ma ago, it has no superficial hydrothermal manifestation, neither is it known from the geological record, but the islands are above sea level today because of its internal heat. Even with little geothermic data, its geology points to the possibility of implementation of EGS to supply the electricity needs of the island. Enhanced or Engineering Geothermal Systems allow electricity generation in non-volcanic areas like Australia, France and Switzerland, harvesting the huge potential of crustal heat. Binary plants could operate at temperatures as low as 100^{o}C. Keeping in mind these technical advances, a new assessment of Brazil's geothermal potential must be performed, since the last national survey was published 20 years ago, when said techniques were only in their initial development.

1. INTRODUCTION

Last year, Tupi and its pre salt reserves received a great deal of attention as the biggest oil province discovered in the last 30 years; in 2007, Brazilian expertise with biofuels was recognized as one possibility of minimizing the terrible future painted by many specialists, with the menace of global warming to our species.

In addition to the pre salt and ethanol, Brazil has a very large hydropower potential, and solar and wind can contribute to meeting energy demand. The virtually inexhaustible resource that is often ignored as an energy source is the heat from the deep earth.

People used to say that geothermal energy is not possible in Brazil because it has no active volcanoes. As the older volcanoes are about 20 million years old, there are no geysers, but some heat remains in areas affected by Tertiary alkaline volcanism, as pointed out by Hamza et al (2005), existing a lot of places were hot water has balneology applications. In some places like Caldas Novas at Goiás state, central Brazil, no one really knows from where the heat comes, as thermal water occurred at aquifers as old as one billion years.

2. GEOTHERMAL ENERGY USE IN BRAZIL

Hamza et al (2005) presented an updated report of geothermal energy development in Brazil at last World Geothermal Congress. The Resource Base is 2.4 x 10^{25} Joules, and according to them, '*high temperatures geothermal systems appear restricted to Fernando de Noronha and Trindade*'. There is no geothermal electric generation in Brazil, and most applications are related to balneology, with very few and punctual industrial uses.

Technical innovation in geothermal use permits electricity production from low to intermediate quality resources (less than 150^{o}C, IEA 2006), made possible using binary turbines, where a working fluid with a lower boiling point produces steam. As it circulates in a closed loop, controlled pressure changes can be exploited, and fluid leaks to the outside environment can be avoided. Binary plants like those constructed by Ormat, Cryostar, Raster, and others can operate at temperatures as low as 100^{o}C (Bronicki 2007).

EGS allow geoelectricity to be generated even in non-volcanic areas like Australia, France and Switzerland (Wyborn 2007, Tenzer 2005).

By applying hydraulic stimulation, a very common technique in the petroleum industry to augment the productivity of the reservoir, a subsurface "heat exchanger" is built connecting production and injection wells; the optimum configuration is the triplet (Tenzer 2005). Water is injected and produced to the surface heat exchanger, where the heat is transferred to the working fluid of the binary plant.

In the 80's, the experiments at the first demonstration project in Fenton Hills (USA) showed the technical feasibility of the HDR (Hot Dry Rocks) concept. But an abrupt price fall in 1986 ended the petroleum crises of the 70's and was followed by long lasting low oil prices.

Since then, other experiments extended the Fenton Hills discoveries, like the geothermal European initiative in Soultz-sous-fôret in France (Tenzer 2005), and the Habanero project in Australia (Wyborn 2007). Another project in Basel received media attention because of an induced earthquake. All of them are close to producing electricity this year; until now just steam was produced due to engineering of the subsurface heat exchanger.

Those technical advances impose a new interpretation of our geothermal potential, as the resource assessment depends in the way the heat mapped can be used. When Brazil's national survey was performed 20 years ago (Hamza et al 1987), neither binary plant technology nor EGS was technical feasible, so those technological improvements were not considered.

Subsurface temperature is a very important tool when looking for oil, but it is often ignored as an energy resource. Petrobras drilling activity has shown temperatures high enough to produce electricity with binary plants (Figure 1) so a better evaluation of our potential should be performed.

As Petrobras is one of the biggest Brazilian electricity producers, it is possible to recover waste heat from produced fluids for power generation in our facilities, even in a small scale. Binary turbines would be used because the resources are low to intermediate grade.

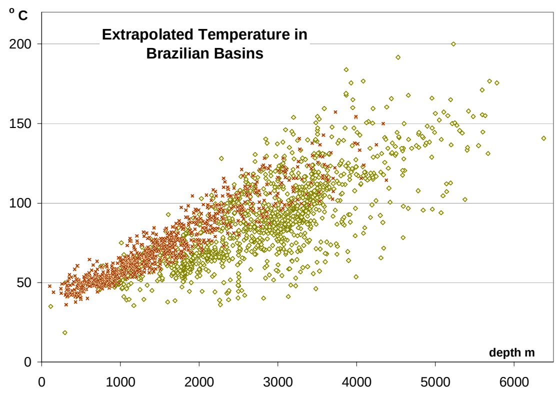

Figure 1: Extrapolated Temperature in onshore wells (brown) and offshore (light green), showing the cooling effects of deep waters.

3. FERNANDO DE NORONHA CASE

Fernando de Noronha archipelago, located about 360km off our northeast coast, has the biggest Brazilian oceanic island with an area of less than 17 km^2 And a population of 3 thousand inhabitants. It is named of 'Esmeralda do Atlântico' (Atlantic Esmeralda) because of its natural beauty. A National Park was created in 1988 incorporating both onshore and offshore portion until 50m isobath. In 2001, UNESCO recognized it as Natural Patrimony of humanity.

The national survey by Hamza et al (1987) classified volcanic islands of Fernando de Noronha and Trindade as intermediate to high enthalpy resources, the best quality geothermal areas in Brazil (Figure 2).

3.1 Operating Power System and Renewable Options

Fernando de Noronha power needs are supplied by a diesel feed system and a 225 kW wind turbine, comprising 1.9 MWe of running capacity. Renewable energy represents just 2% of power generation (Lodi, 2008, Ely 2008).

With current technologies and electricity prices, wind power could account for 39% of island electricity generation, as shown by Lodi (2008), or 28% according to Ely (2008), both using Homer software.

Considering wind availability and diesel prices, the most attractive option is pure diesel power generation (Lodi 2008). Diesel supplemented by wind has a slightly higher cost, with 9% clean power and a diesel economy of 73 m^3 by year (annual consumption about 3654 m^3). Under appropriate conditions, wind power generation could reach 39% with 274 m^3 diesel burning economy. The best case considers a wind velocity of 12 m/s (mean is about 9 m/s), and a US$2 to the diesel consumed (Lodi 2008). A wave power demonstration project was considered in the study, but not geothermal energy.

The island's small area is a strong constraint on solar and even wind resources. Ely (2008) predicted 200 wind turbines in his best scenario.

Diesel electricity generation is the most feasible way to provide island inhabitants with electricity. Improving renewable resources use is a great concern in a place like Fernando de Noronha, where nature is a major source of income, but burning diesel is currently more economically feasible.

This dilemma raises a major question related to financing green projects: what price should be paid for a Carbon Free economy?

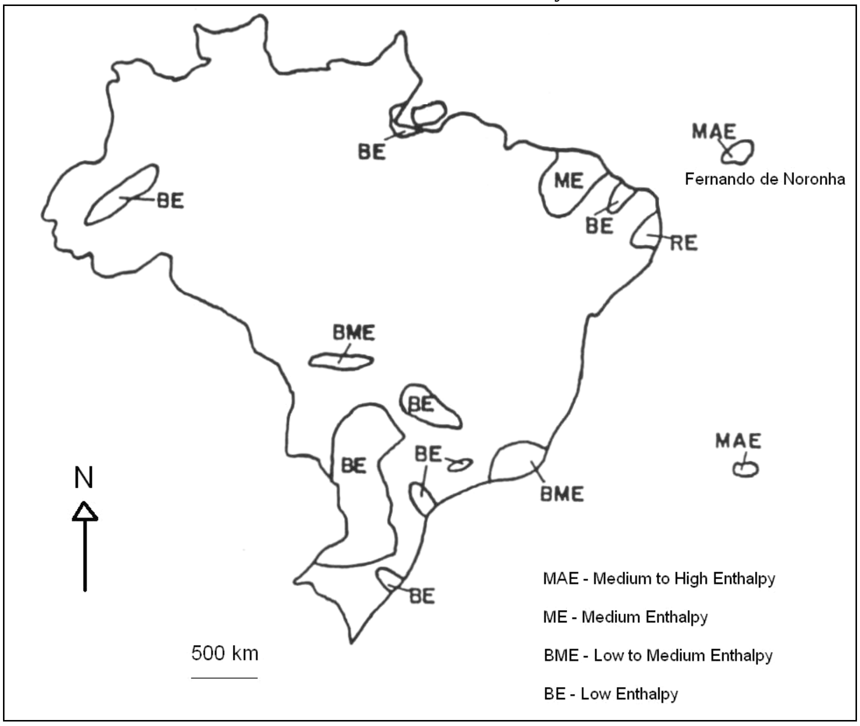

Figure 2: Brazilian Geothermal resources classification (Hamza et al., 1987)

4. GEOLOGY AND GEOTHERMICS

Fernando de Noronha's geology was first described by Almeida in 1955. It comprises two volcanic Tertiary age units, Vila dos Remédios and Quixaba. The Vila do Remédios Formation is made up of intrusive rocks like the phonolite that shapes Morro do Pico, with ages from 9 to 12 million years. The Quixaba Formation basalts are younger, at 6.3 until 1.7 million years old. Those ages was determined by Cordani (1970).

Muñoz & Hamza (1996), remember that the Northeastern Heat Flow Anomaly (Figure 2) is contiguous with the westward extension of the Fernando de Noronha oceanic lineament, known for its recent volcanic and magmatic activities (Almeida, 2006). Lima Neto (1998) and Mizusaki et al (2002), among others, proposed the relationship among Tertiary volcanic rocks at Northeastern Brazil to the impingement of a mantellic plume in the region. Almeida (2006) discusses the implication of this model and the controversies about it.

In a Hot Spot model, high temperature materials come deep from the core mantle boundary in some cases. As it reaches the base of lithosphere, it spreads away in a large disk, resulting in an overall mushroom shape.

The base of the lithosphere is thermally defined, so it goes up or down if heated or cooled. At the surface, uplift, volcanic activity, geyser activity, or nothing at all could occur. The hot spot track manifests as aligned seamounts and guyouts, extending from Fortaleza to the east at the present day location of Fernando de Noronha.

Fernando de Noronha Hot Spot is a small plume, hot enough to introduce strong modifications to regional geology with uplifts and several volcanic activities widespread in northeast Brazil.

Considering the hot spot hypotheses, the plume impinges an older and much cooler oceanic lithosphere. The island and seamounts result from the plume, but the plume itself stays at the lithosphere asthenosphere boundary. There is no sight of the plume today by bathymetric changes, and the island has remained quiet for almost 2 million years.

Fernando de Noronha archipelago is just a small portion of a huge amount of igneous rocks that rise from a 4000 m deep ocean floor (Figure 3). It was formed during at least 10 million years of igneous activity. Apparently the island is the remnant of a caldera that exploded less than 2 million years ago.

The archipelago and seamount complex are very heterogeneous, with more than 10 million years of activity as suggested by existing data. Geothermal resources come from that rock volume, dominantly basaltic rocks. Its low thermal conductivity limits thermal exchange between the complex interior with the cold oceanic waters. Fractures eventually could allow some infiltration, but there is no sign of hydrothermal process.

We do not know how much heat is preserved, but it is enough to keep the construction above sea level. Considering worldwide data, heat flow in oceanic crust older than 10 million years could be as high as 150 mW/m^2 (Wei and Sandwell 2006).

The unique known information comes from a shallow well where a 50^{o}C/km gradient was determined according to Hamza (personal communication 2008).

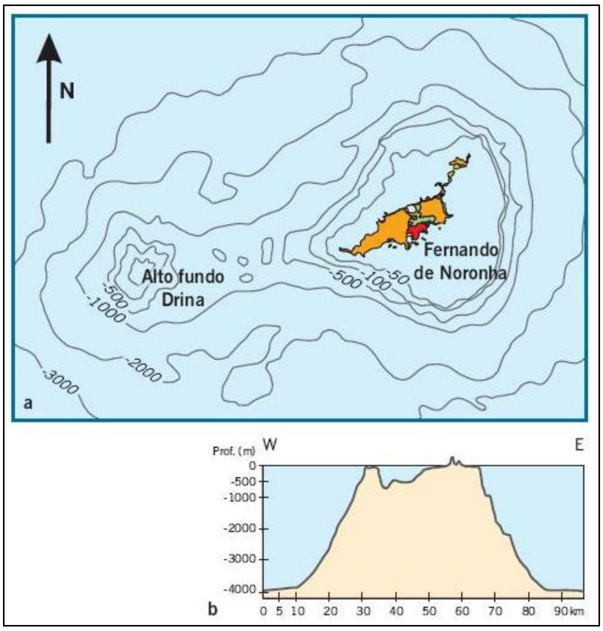

Figure 3: Bathymetry of Fernando de Noronha Archipelago (Almeida 2006)

5. PHOTONGAYA CONCEPT

Fernando de Noronha Geothermal project is a concept demonstration that called PHOTONGAYA (from ***Photon*** meaning light and ***Gaya***, the Earth Divinity of Greek mythology). It is technically feasible, but not profitable due to high costs.

A small geothermal power plant (<5 MWe) could provide enough energy to present day consumption in isolated systems according to Rybach (2002), and are competitive with burning diesel. He also states the need of incorporating other uses such as industrial heating and cooling processes for the geoheat.

Geoelectricity is produced at several places related with Hot Spot activity, like Hawaii, Azores and Iceland, in this case a plume captured by the middle Atlantic ridge. Those places show volcanic activity comprising a conventional resource setting with porous and permeable shallow reservoirs. In Iceland, very good reservoirs developed in basalts produces almost 15% of the country's electrical needs.

Geothermal reconnaissance must be done at first to better understand heat flow distribution at depth. An MT survey could identify hydrothermally altered zones and even hotter places; its inversion could provide an estimation of the temperature itself (Spichak et al 2007).

A geothermal exploration program must be modulated to use the resources as they are available. Shallower resources, too cold to generating electric power, can be applied to other uses, like desalination and refrigeration. A great portion of island's power demand refers to a desalination inverse osmoses plant that provides all the fresh water to population; important power consumption is also related with icing to fish activity.

Reducing electricity needs using renewable resources for direct use is also a way to 'produce' green power. Something similar to the Lindal Diagram must be constructed for a Noronha reality to better use available resources.

The shallow survey wells could be designed for future use as heat exchangers for non electrical uses focusing in cooling systems, such as those associated with solar thermal.

Those shallow wells will be laboratories to learn by doing to construct a deep heat exchanger by hydraulic stimulation to enhance heat recovery extraction before going deeper.

5.1 Ascension Island Drilling

The technical challenge of drilling a deep well in a South Atlantic oceanic island was performed in the 80's by people from Utah University to American Defense Department (Nielson 1996).

Utah University studies were performed in Ascension Island in 1988, where according to Nielson (1996), the presence of large volumes of volcanic rocks younger than 1 ma age could imply the existence of magma chambers. A complete study was done to locate a well (Nielson et al 1996), drill it (Nielson and Stigert 1996) and interpret their findings with the goal of finding the geothermal reservoir, a permeable portion of the igneous rock that formed the islands. Ascension Island has an area of 100 km^2, and is up 859 m above sea level. The geothermal gradient determined by the research project varied from 53.5^oC/km to 75^oC/km.

The research well was drilled to a 3126 m depth; fractures with fluids up 240^oC were intercepted at 2200 m (Nielson and Stigert 1996). But its productivity was not enough to feed a geothermal plant, so the well was closed and the project was postponed.

The published material does not discuss the option of fracturing the rock to provide an artificial man made reservoir. Fenton Hills was still testing those concepts at that time.

Noronha is not the same case, with an age of almost 2 million years. The onshore area is just one tenth that of Ascension Island, but the submerged massif has a similar area. Noronha is older than Ascension Island, with a lower relief and a thinner fresh water lens is expected.

Meteoric water infiltration is not enough to develop a groundwater circulation scheme because of the dry climate and a small capture area for the few raining days. This region has a very dry season, so fresh water is a great concern to their population.

The work to be done in Noronha is similar to that described by Nielson et al (1996): first a Exploration Survey to collect data for a pre-feasibility study, when an assessment of estimated potential could be made and targets to deep drilling located, after which the useful resources can be defined.

6. CONCLUSIONS: CHANGING AN ISLAND AT FIRST

In order to solve the dilemma of environmentally friendly energy consumption on Norona, which currently burns diesel for electricity, the geothermal option must be considered. According Rybach (2002), geothermal energy could be competitive with diesel price in electricity production.

Although there is an unknown heat potential and EGS technologies have not yet been tested, there exists technology to access the desired resource temperature and transform its heat content into electricity.

PHOTONGAYA is a concept of applying hydraulic stimulation and drilling technologies to create a subsurface heat exchanger and mine crustal heat. It is not cheap or economic, but it is possible. The main risk is related to underground reservoir construction. Photongaya is an ecologically concerned proposal, applying the highest technology for a better life of the people.

We must use geothermal associated in a consortium with all renewable resources, like solar, wind and wave power. Using electricity to heat domestic water and frozen fish and sea foods is huge waste of energy, and unnecessary GHG emission in Noronha's case.

Geothermal electricity must first be demonstrated in mainland Brazil before it can be applied to solve Noronha's needs.

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