Proceedings, 6th African Rift Geothermal Conference
Addis Ababa, Ethiopia, 2nd – 4th November 2016

GEOTHERMAL DEVELOPMENT IN THE COMOROS AND RESULTS OF GEOTHERMAL SURFACE EXPLORATION

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Key words: Geothermal development, Energy crisis, results of surface studies.

ABSTRACT

Comoros constantly is going through an energy crisis. This crisis is due to the difficulties that the company of Water and Electricity encounters. On total capacity of 21.5Mw installed only 12MW are available. The cost of producing 1KWh is still high compared to the sale price of 1KWh. This explains the dire situation that the company is facing for more than twenty years. Each 1KWh sold the company is recording a loss. To solve these problems, the ministry of Energy is prospecting solutions and among them, the development of geothermal energy remains suitable, clean, lasting and less expensive. The Government of the Union of the Comoros through the Geological Bureau of Comoros and the partnership help of the African Union, the Government of New Zealand and UNDP, surface studies were conducted. These define the first stage of the project. In November 2014, geochemical studies were conducted. In July-August 2015 these studies were supplemented by performing 80 magnetotelluric measurements and 208 gravity measurements. The results are more encouraging and satisfactory, Geothermal potential is highlighted. It extends over an area of 4.1km2 in the northeast of the caldera. After interpretation of geochemical and geophysical data, geothermal potential was estimated at a value greater than 40Mw. Initially, three exploratory drillings were carried out on two wells identified sites. The goal is to confirm the feasibility of resource exploitation. The use of geothermal energy will have a direct impact in the cost of electricity and solve the energy crisis in the country. The advantage of this program for the economy is obvious. In addition, electricity will be produced, the direct use of geothermal energy will thus be developed, tourist uses, drying agricultural products and fishing.

1. INTRODUCTION

Development of geothermal energy in the Comoros remains among the Priority Programs which concern to the Government of the Union of Comoros. The surface exploration studies define the first phase of the program activities and were supported by the Consortium Formed by the Government of Comoros, the Government of New Zealand which provided technical assistance and the United Nations Development Program for (UNDP). The surface exploration studies were implemented in two stages. On the first time Geological and geochemical studies were executed by the Geological Bureau of the Comoros (BGC) and Jacobs from New Zealand. In addition to this, we carry out geophysical surveys (magnetotelluric and gravimetry). This phase of surface exploration Was financed largely by the Geothermal Risk Mitigation Facility (GRMF), a program from African Union. This program supports the development of geothermal energy in East Africa.

Karthala volcano is a basaltic shield volcano with an active hydrothermal system on its flanks (Savin et al., 2001). It has multiple nested calderas at the top (Strong and Jacquot, 1970) and heartbreak aligned to the NNW and SE in which are eruptive fissure (Bachelery and Coudray 1993). The presence of a system of eruptive fissure fracture with associated with a major shield volcano is similar to that operated by the Puna Geothermal Project in Hawaii (Speilman et al., 2006) and could therefore accommodate thermal activity at suitable depths drill targeting. The presence of fumaroles, hydrothermal alteration and solfatara on the northern flank of Karthala top of the rift support the hypothesis of the existence of geothermal resources.

2. GEOLOGICAL SETTING

The constructionn of the archipelago can be designed in the following way:
Comoros are built as a result of a major volcanic phases separated by periods of rest during which the erosion could act. It should be noted that the volcanic activity still persists in the islands of Ngazidja especially in the West with a period of 11years. Mainly due to its volcanic nature, the archipelago of the Comoros (Figure1) presents a high geothermal potential.

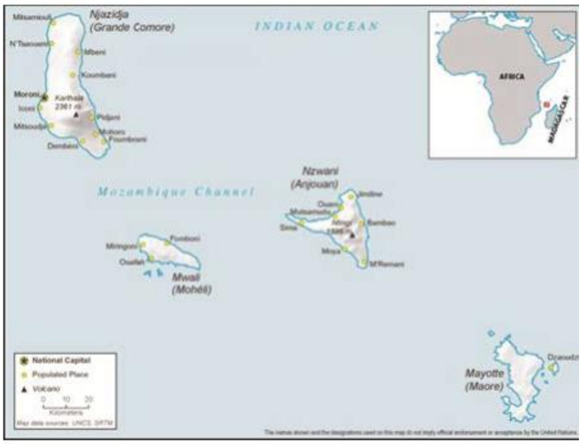

Figure 1: Comoros archipelago map

Comoros are formed from the migration of lithospheric plate of Somalia over a relatively a relatively stationary and active hot spot during the last 1 million years. Volcanism of Comoros is probably controlled by a complex regional constraints in relation to the separation of Madagascar and the African continent (Flower, 1970).

The following figure (Figure2) shows the geological map of Grande Comore, the island where the project is set up.

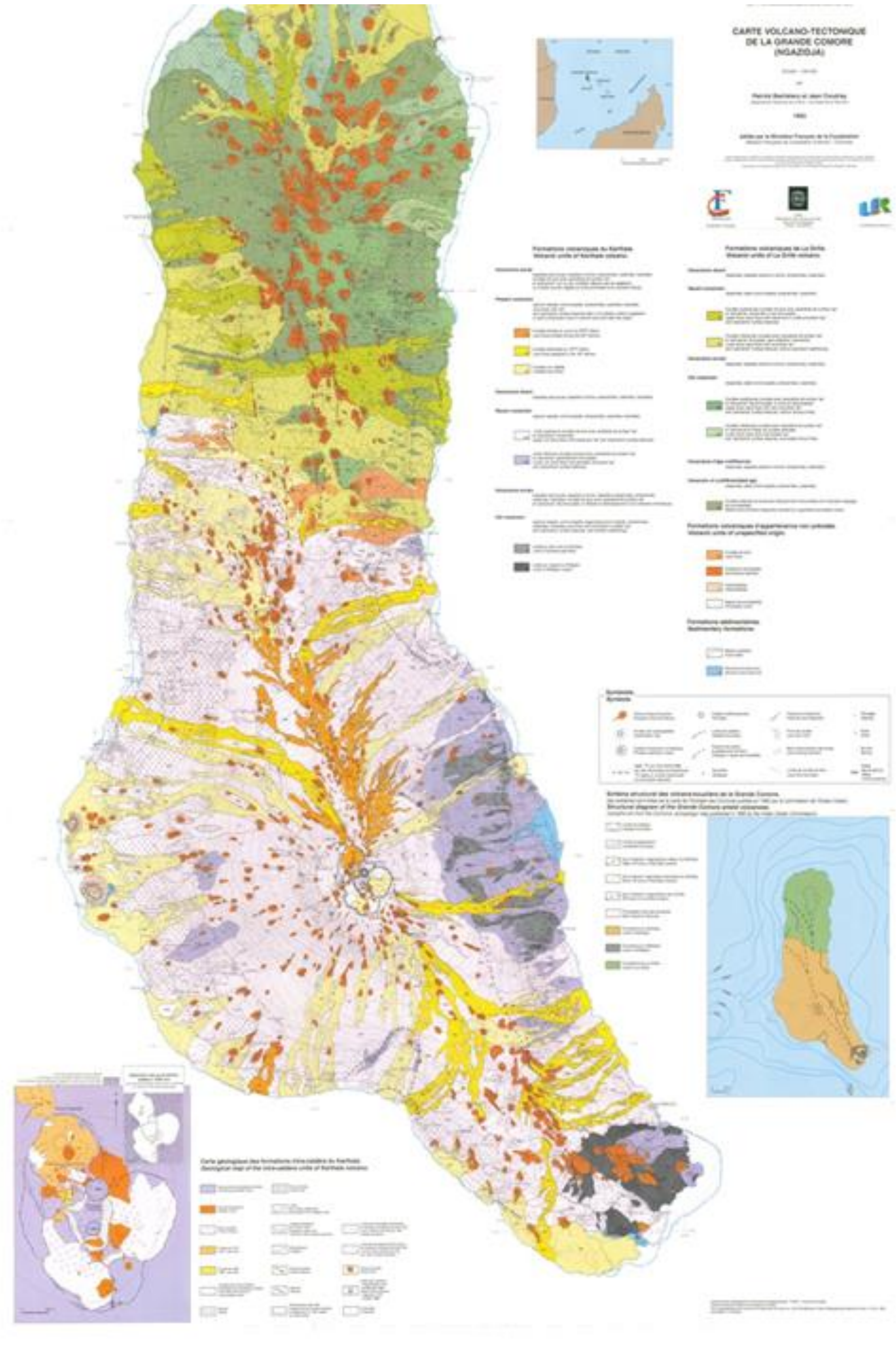

Figure 2: Geological map of Grande Comore (from Bachelery and Coudray 1993)

3. SURFACE THERMAL ACTIVITY

Different thermal manifestations exist in Grande Comore Island. In the La Soufriere region, we can find the most impressive thermal activities, located in the upper part of the northern rift zone, where several fumaroles and extensively altered ground are located. These features are emplaced along fractured basaltic lava flows, which were erupted during the 20th century. Thermal features are aligned ~N15°W, which agrees with the main direction of the rift zone in the northern flank of Karthala (NNW).

The thermal areas at the summit of Karthala are entirely steaming grounds (Figure5). Steaming grounds are located in the central part of Choungou-Chagnoumeni crater and along the eastern rim of Choungou-Chahalé crater. These thermal features are aligned in both zones ~N15°E, which agrees with the main direction of the rift zone in the northern flank of Karthala (~N-S). The temperature of the steaming grounds varies between 40 and 80.2°C, which is much lower than the boiling temperature of pure water at 2300 m a.s.l. (~92.5°C). A common characteristic to all steaming grounds at the summit is the absence of both a smell of sulphur (H2S) and native sulphur deposits, which are both present at La Soufriere.

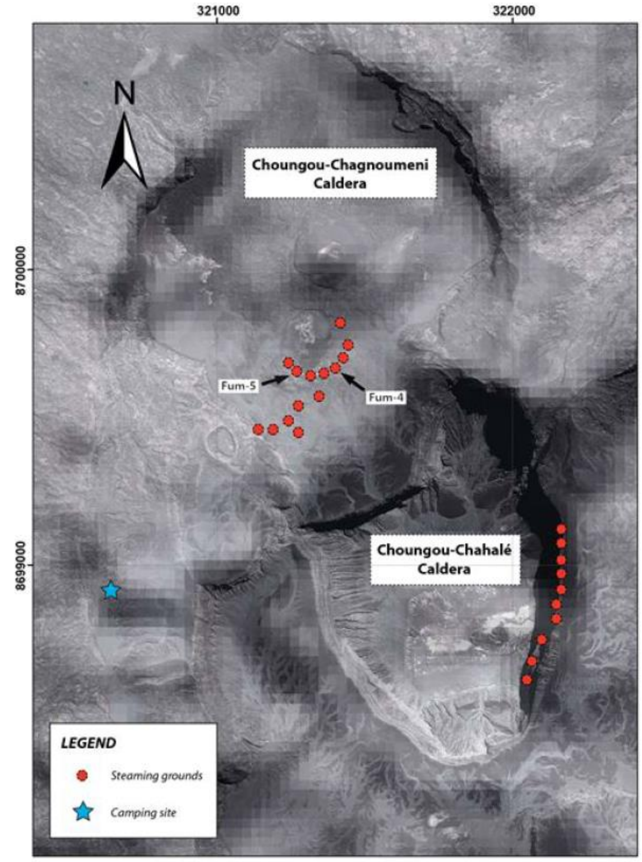

Figure 3: Thermal activity location in the calderas

4. GEOCHEMISTRY

The surface fluid chemistry at Grande Comore includes HCO3-rich cold springs, saline Na-Cl waters from cold bores located near the coast, and fumaroles and steaming ground associated with Karthala volcano (figure6). The chemistry and the isotopic composition of the HCO3 (up to 190 mg/kg) waters along with low temperatures (<24.7°C) indicates that they are groundwater (Shvartsev, 2008). Some of the temperatures are possibly slightly higher than ambient.

The relative high Cl/B molar ratios of the Na-Cl waters (up to 1210) and their Na-K-Ca-Mg proportions indicate that these waters are a mixture of seawater (<5%) and meteoric water (>95%), without the participation of any geothermal or magmatic components. Air free analyses could only be obtained from fumaroles in the La Soufiere solfatara. The gas (other than atmospheric) from the steaming ground in the caldera is mainly CO2.

The air free fumarole chemistry is consistent with a geothermal resource at depth, but with more reducing conditions than that for andesitic type systems addressed by Giggenbach (1987). Thus, the D'Amore and Panichi (1980) geothermometer has been used rather than the Giggenbach (1991) Ar based geothermometers, to calculate a reservoir temperature of around 300°C.
Condensate samples collected from the caldera steaming ground and La Soufriere areas have pH's higher than 4 and low Cl and F contents, indicating that magmatic acid forming gases (SO2, HCl and HF) are not present; at least at the surface.

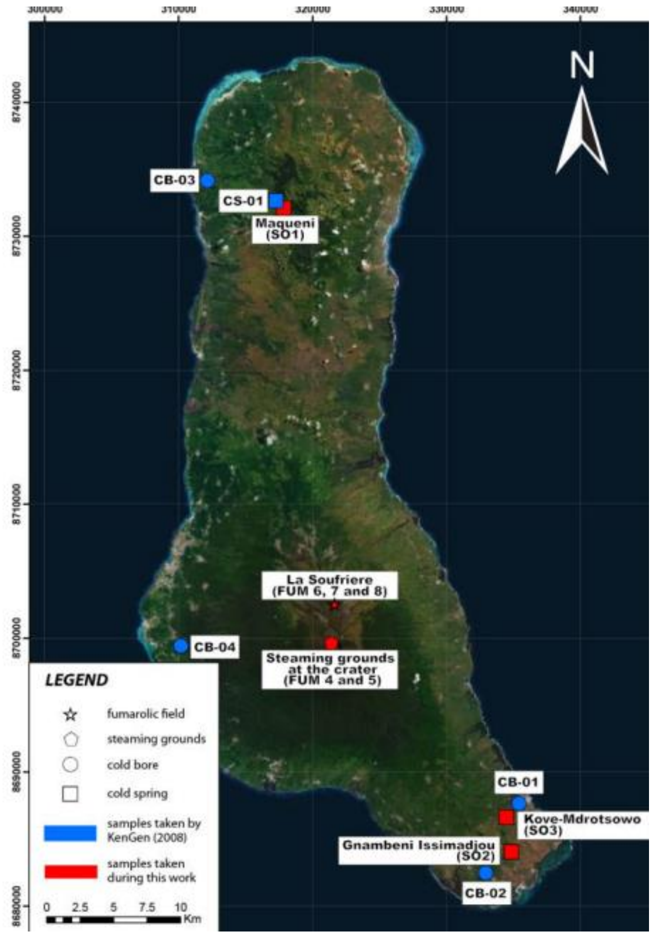

Figure 4: Distribution of geochemical sampling points.

4.1 CO_2 Flux Survey

Comparison of CO2 flux and soil temperature at Karthala showed that higher CO2 fluxes and soil temperatures were only measured in areas with known thermal features (fumaroles and steaming grounds) and decrease rapidly with distance from each feature. Thermal features and, therefore, high CO2 fluxes and soil temperature, are spatially controlled by fractures that were recognised in the field. These fractures have a main orientation coinciding with the direction of the proposed rifting system affecting the northern flank of Karthala volcano. The observation of localised high CO2 flux suggests that structural permeability is controlling surface emissions at Karthala.

The CO_2 fluxes measured in other areas, such as further along the proposed major rift zone and where inferred lineaments were mapped, are in the range of CO2 flux values produced by biologic activity. This could be explained by the very low permeability of the lithology that composes the volcanic structure at Karthala (i.e. basaltic lava flows, ash deposits), which prevents the CO2 from escaping to the surface. The latter does not exclude the possible existence of fault-fracture meshes in these areas at depth, but if the faults exist they are not open conduits for transport of deep degassing to the surface.

5. GEOPHYSICAL STUDIES

A geophysical survey was carried out to complete the geological and geochemical studies. 208 gravity measurements and 80 magnetotelluric (MT) measurements were implemented. The following map (figure 5) shows all measurement stations.

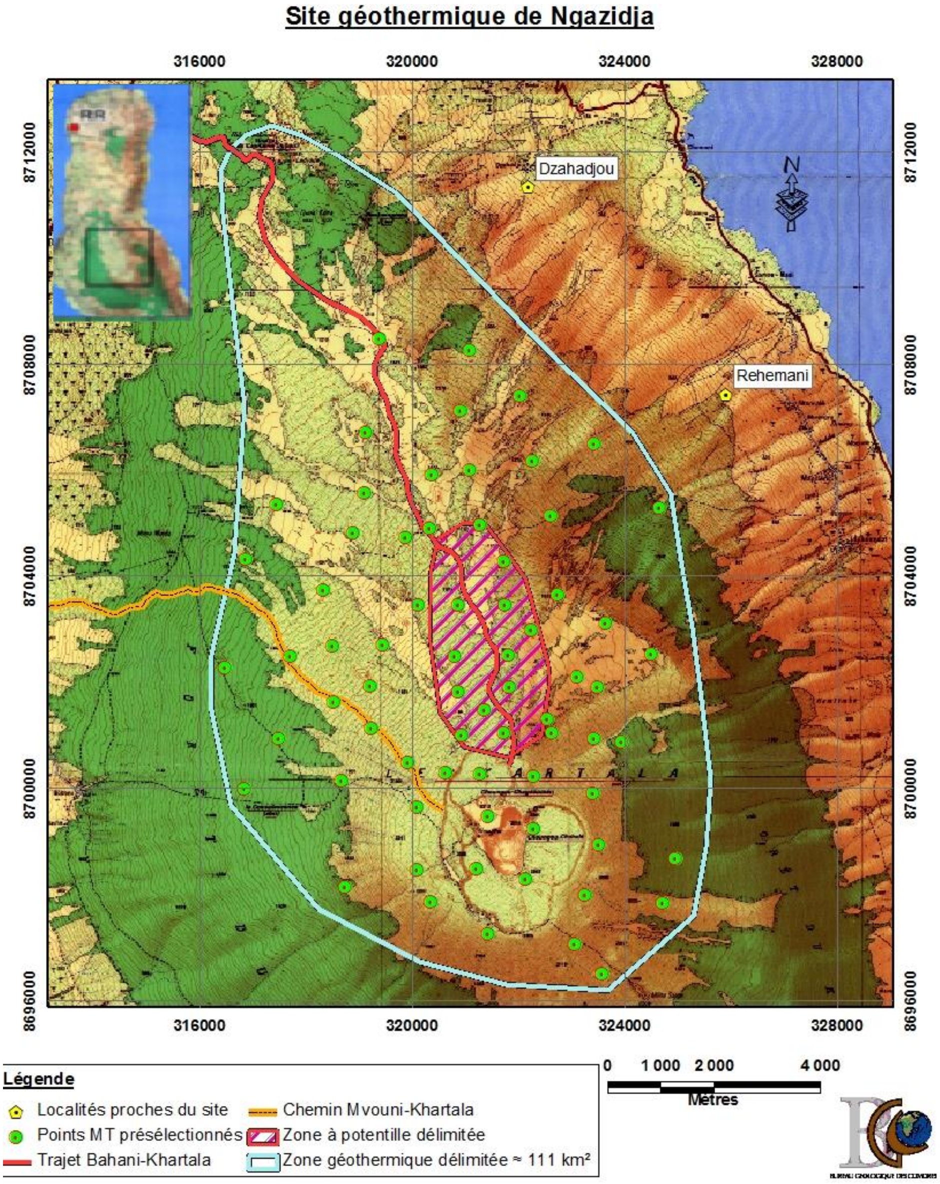

Figure 5: Exploration programme perimeter and final MT survey layout (80 stations, in green) showing the location of surface thermal features

The report of the first mission of exploration (geological and geochemical) indicated the presence of a resource. The previous map (figure5) indicates the area concerned by the exploration program. Data from MT surveys have located potential sites and possible depths for exploration drilling (see Figure 6).

All data acquired in the surface exploration phase (geological , geochemical and geophysical) were used to develop drilling plans.

The 3D processing and modeling carried out by Jacobs, GNS and CGG helped to develop a structural model of the basement with a Schematic conceptual model (see Figure 6), depth and associated structures .These results indicate that drilling will be located at altitudes over than 1,500 meters and reach depths of about 2500 meters, and will be located a few kilometers north of Soufriere . In all, three normal exploratory drilling is planned.

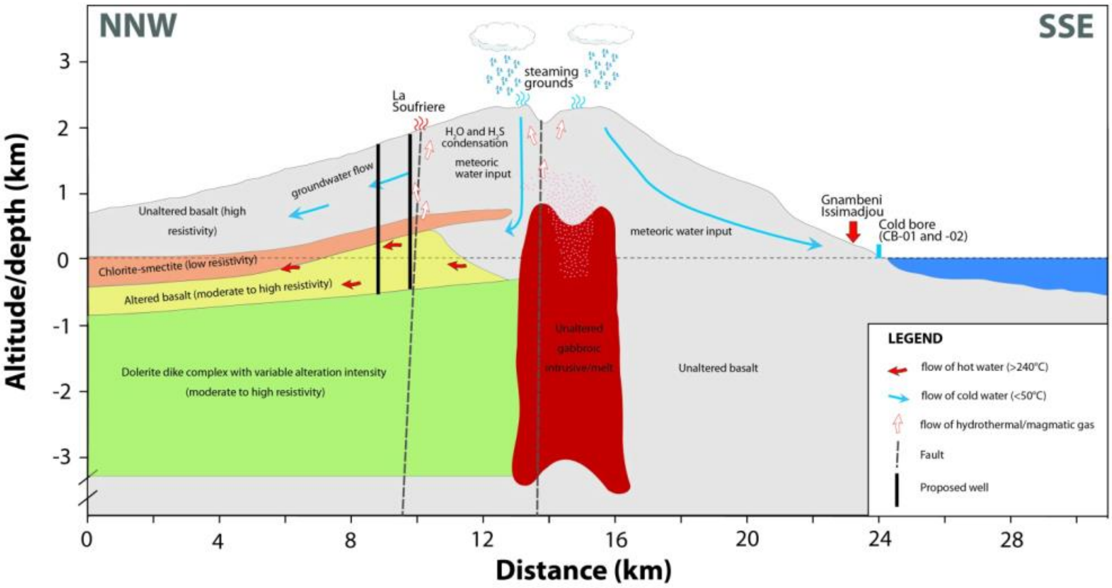

Figure 6: Schematic conceptual model along the rift hosting known thermal activity

The data acquired during the magnetotelluric survey are good quality .

5.1 Geophysical interpretation

Two very clear and very conductive anomalies of limited extent are shown in the vicinity of the surface thermal features in the northern part of the crater and at La Soufriere (see Figure 7).These anomalies are distinct and present from very near the surface down to an elevation of approximately 800masl. At this elevation, they appear to coalesce into one and join with the conductive zone present on the northern and western slopes of Mt Karthala. These features are very likely to be the result of the presence of hydrothermal clays produced along zones of upflow of geothermal fluids, and they give an indication of the extent of the shallow upflow near the surface features on Karthala.

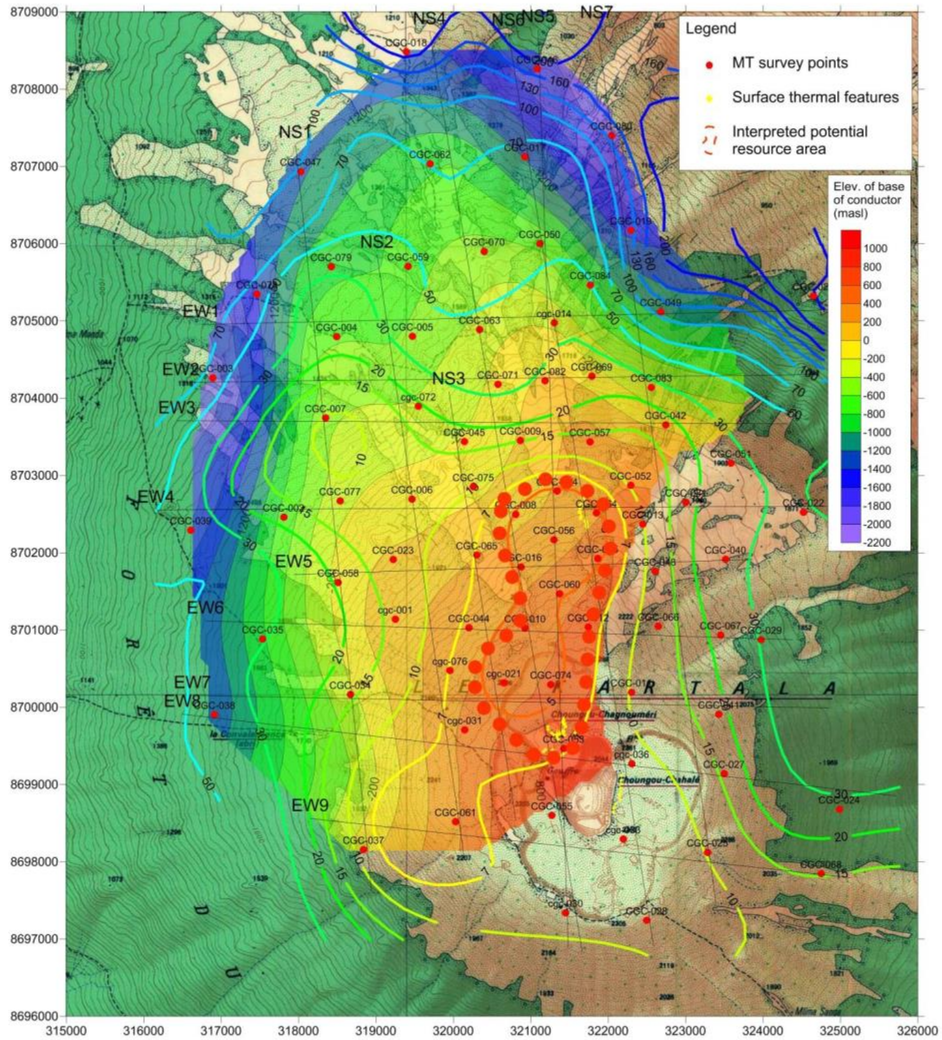

Figure 7: Interpreted potential 4km2 geothermal resource area (in red) shown with filled contours of the elevation of the base

We therefore interpret that this particularly conductive part of the conductive zone observed below the thermal features in the north of the crater and at La Soufriere, along the rift, is likely to be associated with a high grade geothermal upflow, which we interpret as outflowing preferentially towards the northwest. We highlighted this area of particularly low resistivity and interpret the resulting as a zone of elevated geothermal resource potential(in red area, see Figure 7).

6. CONCLUSIONS

Studies show the existence of the geothermal potential over than 40MWe, which spreads over an area of 4.1km2. The geothermal system around the Karthala volcano has probably exploitable temperatures average 280 ° C. Three exploratory drilling will be executed between the altitude 1700 and 1900metres (see Schematic conceptual model). To develop this potential, initially, 10MWe will be operated.

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