Proceedings, 7th African Rift Geothermal Conference
Kigali, Rwanda 31st October – 2nd November 2018

Geohazard In Geothermal Development: Case Of Comoros

Faouzia Ibrahim Abdallah

Geological Bureau of Comoros

M'Dé Ex-CEFADER Moroni Comoros

ibrahimfaouzia@gmail.com

Keywords: Geothermal, Ballistic, Lahar, Phreatomagmatic, Effusive eruption, Hazard, Volcanic, Distal eruptive fissure, Earthquakes

ABSTRACT

Any geothermal project requires a thorough study of the targeted area. One of the studies conducted in the Comoros during geothermal exploration is the study of volcanic hazards.

By having a Hawaiian-type shield volcano, the hazard study was necessary before any action following the eruptions observed every seventh year. The hazards that can influence potential areas of geothermal development are defined in three activities: phreatomagmatic activities, effusive eruptions and distal eruptive fissures. Each activity has its own specific hazards (Ballistics, Lahars, The lava flows…etc.) that can interfere with any activity.

Volcanic hazards can have a direct or indirect impact on any geothermal facility or pipeline. But also, can affect virtually any area of the edifice making any permanent infrastructure on the volcano vulnerable to activity.

This study allowed us to discover possible mitigation measures and potentially safer regions which can be identify near the target areas for future infrastructures.

This will allow us to plan long-term sustainable geothermal development in Comoros.

1. INTRODUCTION

For several years, the Comoros have serious energy problems. To overcome this problem, the Comorian government gives priority to the development of geothermal energy in the Comoros. Surface exploration studies began in October 2014.

The Karthala volcano is a basaltic shield volcano with a very active hydrothermal system. It is the southern part of the island of Grande Comore. The Karthala has an upper caldera 3,500 m long and 2,700 m wide, formed by successive eruptions and extended by fault zones extending from the summit towards the directions NNO and SE. Its caldera includes two

active craters: Choungou Chahale (center of the caldera) and Choungou Chagnoumeni (north of the caldera). Both flaring and explosive eruptions can occur in any location, in fault zones (lateral eruption), or on low-lying flanks (eccentric eruption).

The lava flows are the most frequent hazard for the Karthala and determine the greatest threat to the population of Grande Comore and any infrastructure.

Other hazards including toxic volcanic gases (CO2, H2O, SO2 ...), products of lava fountains, explosives eruptions of the phreatic and phreatomagmatic type are also characteristic of karthala activity.

The danger posed by these hazards is mainly related to the destructive effects.

This paper shows the compilation of information on volcanic hazards that may affect the development of geothermal energy on / near Mount Karthala in Grande Comore.

2. CONTEXTS

Being a young and active volcano similar to that found in the Hawaiian Islands where there is a functioning geothermal power station and a large identified geothermal energy resource, the Karthala is experiencing several eruptions, the last of which was in 2007 (Table 1).

Year	**Location**	**Eruption type**	**Covered area ($100m^2$)**	**Seismicity felt**	**Damage**
2007 (January 12-15)	Crater Chagnouméni	Magmatic	Yes	Yes	0 Dead
2006 (May 28-June 3)	Main crater	Magmatic	Yes		
2005 (Nov 24-Dec 8)	Main crater	Phreatomagmatic	Yes		
2005 (16-18 April)	Main crater	Phreatomagmatic	Yes		
1991 (11 July)	Main crater	Phreatic	Yes	Yes	
1977 (April 5-10)	Southwest flank	Eccentric Magmatic	1.8	Yes	Yes
1972 (8 Sep-5 Oct)	Caldera	Magmatic	2.5	-	-
1965 (12th of July)	Caldera and Crater free	Magmatic	0.05	-	-
1952 (Feb. 10)	Main crater	Magmatic	-	-	-
1948 (April 22-June 16)	Crater free	Magmatic			
1948 (February 10 to 14)	Main crater	Magmatic and Phreatomagmatic	16	Yes	
1918 (June 13-16)	Main crater	Phreatic	25	Yes	Yes
1918 (April 22 to May 4)	North zone rift	Lateral Magmatic	2.7	Yes	-
1904 (August 11 to 13)	North zone rift	Lateral Magmatic	11	Yes	Yes (1 Dead)
1903 (August 25 to 26)	Southeast rift zone	Gaseous Emissions	-	-	Yes (17 Deads)
1880 (February 25 to April)	Southeast rift zone	Lateral Magmatic	2.4	Yes	Yes
1876	Southeast rift zone	Lateral Magmatic	4	-	-
1872	North zone rift	Lateral	1.6	-	-

		Magmatic			
1860	Southeast rift zone	Lateral Magmatic	5.5	-	-
1859	Rift	Lateral Magmatic	3.9	-	-
1858 (December)	Caldera and Rift	Lateral Magmatic	12.5	-	-
1857	caldera and Rift zone Southeast	Lateral Magmatic	10	-	-
1848	South-East Flank	Eccentric Magmatic	3	-	-
1830	-	Magmatic	-	-	-
1828	-	Magmatic	-	-	-
1821	-	Magmatic	-	-	-
1814	-	Magmatic	-	-	-
1808	-	Magmatic	-	-	-

Table 1: Chronology of eruptions, Source OVK November 2008

These types of eruptions can influence potential areas of geothermal development. What prompted Jacobs (New Zealand) hired GNS (Science International Limited) in 2015 to identify the volcanic hazards of the Karthala volcano in the geothermal exploration area defined by Jacob (Figure 2.1 and 2.2).

Figure 2.1: Grande Comore (Ngazidja). The white rectangle indicates the main study area. Singani(1977 lava flow). Credit: modification of Google Earth.

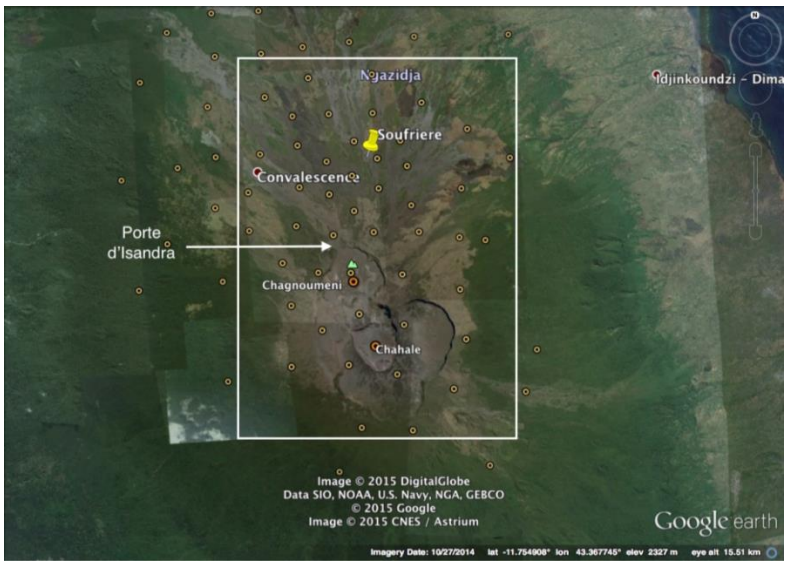

Figure 2.2: Summit area of the Karthala volcano. The two main active craters (Chahale and Chagnoumeni) and the Itsandra Gate (where lava flows over the Chagnoumeni crater to the north). The white rectangle indicates the general study area, with Soufriere. Yellow circles indicate the planned magnetotelluric sites (MT). Credit: modification of Google Earth.

Volcanic risk is defined as the product of hazard and vulnerability. According to IAVCEI, major volcanic hazards are divided into two groups:

- Direct major hazards, related to the direct impact of the products of an eruption (lava flows, pyroclastic flows, aerial fallout, gas ...)
- Indirect major hazards, related to the secondary consequences of an eruption (mudslides, land movements, tidal waves ...).

Most historical eruptions occurred along the fault zones, while more recent eruptions occurred mainly inside the caldera and outside the caldera in the 21st century. The most dangerous areas are therefore close to the caldera, which is the target area for the installation of the geothermal site.

3. OBJECTIVES

The main objective of this study was to identify the hazards that could be detrimental to the geothermal development project in order to carry out volcanic hazard mapping. The latter will allow considering options that will avoid or reduce the danger for the realization of the geothermal development project.

4. TYPES OF HAZARDS

The risks likely to influence the potential zones of geothermal development are the volcanic risks (Figure 3) which are listed in 3 activities:

4.1 <u>Phreatic and Phreatomagmatic activities</u>

The main risks listed in Grande Comore are:

4.1.1 Ballistics

Those are fallout rocks that can be emitted during an explosive eruption. The projection is up to 3 km from the main event Choungou Chahalé crater.

4.1.2 Ashes

Ashes affect radically different areas depending on the emission rate and wind conditions. Any explosive eruption of the crater Choungou Chahale and Choungou Chagnoumeni has the potential to deposit one to several tens of centimeters of ash on any existing infrastructure.

4.1.3 Lahars

They can affect all the flanks of the volcano, so a large target area. They can be up to 1-2m thick in the Karthala areas and have enormous destructive power.

Note: Lahars may occur years after the end of the eruption.

4.2 Effusive eruptions

Lava flows are the main potential hazards. The volcanic edifice of Karthala is built almost entirely by lava flows, making it the most visible volcanic hazards on the island.

4.3 Distal eruptive fissures

Although most of the eruptions occurred recently in the summit caldera region, there are distal eruptive fissures observed at a distance of 10 to 25 km from the summit. This explains the probability that such an event may occur in or near the target areas.

NB: Most of the volcanic hazards mentioned above are associated with a rash. However, periods of volcanic agitation, even if they do not lead to an eruption, could generate risks that could have an impact on the target areas.

4.4 Non-eruptive risks

Most likely are: seismic activity and gas emission:

Since the 1990s, the OVK (Volcanological Observatory of Karthala) has recorded significant seismic activities outside eruptive periods. These earthquakes can be felt by the population more than 20km from the summit, which means they are felt more strongly near the hypocentre, so close to the target areas of the geothermal project.

With regard to the emission of gas, it is persistent between the eruptions of the main crater or fumarolic zones, as in the soufriere.

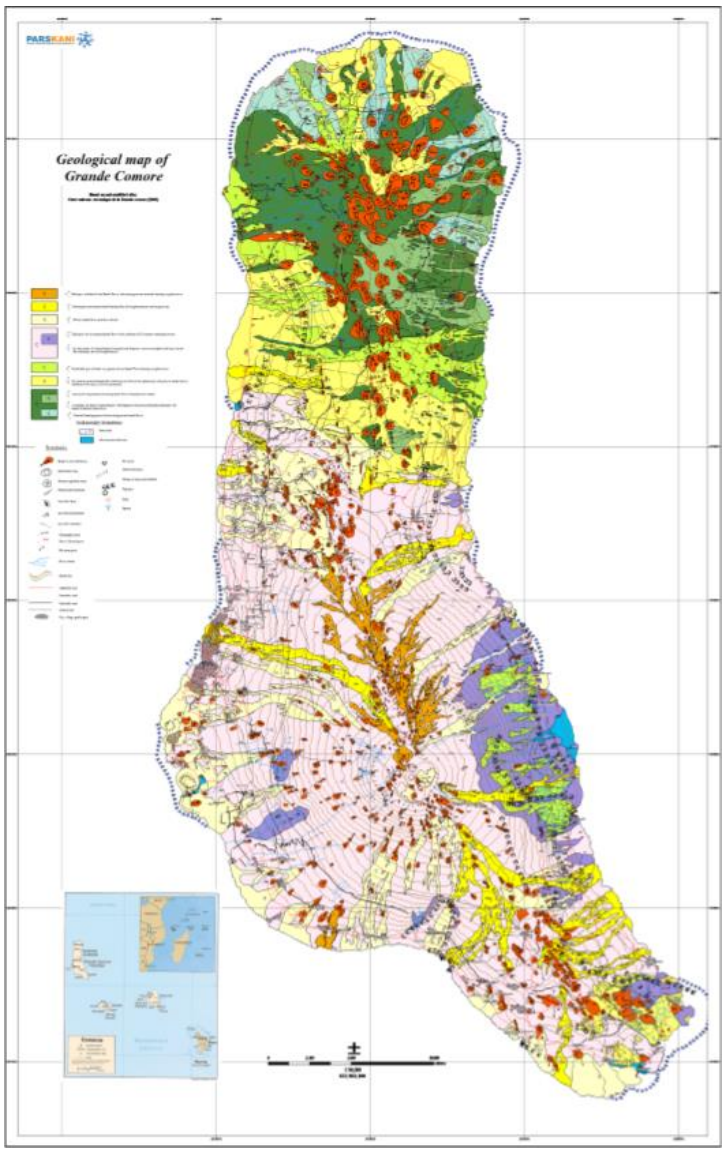

Figure 3: Geological maps of Grande Comore. There are orange and yellow lava flows north of the summit caldera. The south-east trench (southeast of the summit caldera) is mainly represented by yellow lava flows. The multiple vents all around the building are indicated in red. Credit: Bachelery and Coudray (1993) Volcano-tectonic map of Grande Comore (Ngazidja),

5. METHODOLOGY

Following the risk assessment carried out in order to know the possibility of already devastated areas as well as the nature of the phenomena at the origin of the disaster; we find that the deposits are confined in / on the beam of the caldera. That is, within 1.8 km of the main crater.

To map the volcanic hazards, the method of Kauahikaua et Al. (1995) was essential. This method takes into account the recovery rate and the probability that a lava flow will occur in a given region and in a given time interval.

On the other hand, the use of the recovery rate was difficult for a Karthala risk assessment, due to the lack of dates and valleys to allow for their enumeration. They had to be content with eruptions recorded from the year 1808.

6. ATTENUATION MONITORING

Due to the lack of an accurate eruption recording beyond the last 200 years, it is impossible to determine with certainty the most likely scenario for the next eruption. Based on recent history, it seems that activity is concentrated around the crater of the current summit. Focusing on the target areas, the most likely scenario is probably the lava flows emitted in the summit crater; and perhaps overflow to the north through the Isandra Gate. In case of explosive activity (for example, Choungou Chahale crater), the ballistic can wait up to 3 km from the vent, and a significant ashes fall (for example, several tens of centimeters) could fall on the target areas. This implies that a geothermal infrastructure installed in the proposed target area is likely to be impacted by at least one eruption.

On the basis of the foregoing, high level recommendations can be drawn following the associated risks:

- Ballistics: Any infrastructure must be developed outside a radius of 3km (most likely Choungou Chahale figure 4).
- Lava flows: Infrastructure construction must be outside the North Rift Zone. It should be at an area of 200-700m directly to the west or east of the Soufrière (Figure 4).
- The ash fall: An emergency plan must be put in place for all continuous operations (cleaning procedure, ventilation method and protection of water tanks ...).
- During the 2005 eruption, an increase in the heat flux in the subsoil is assumed to have dried the hydrothermal system in the northern part of the caldera. For this kind of threat, it is necessary to have good monitoring of the volcano, and this is where the OVK intervenes.

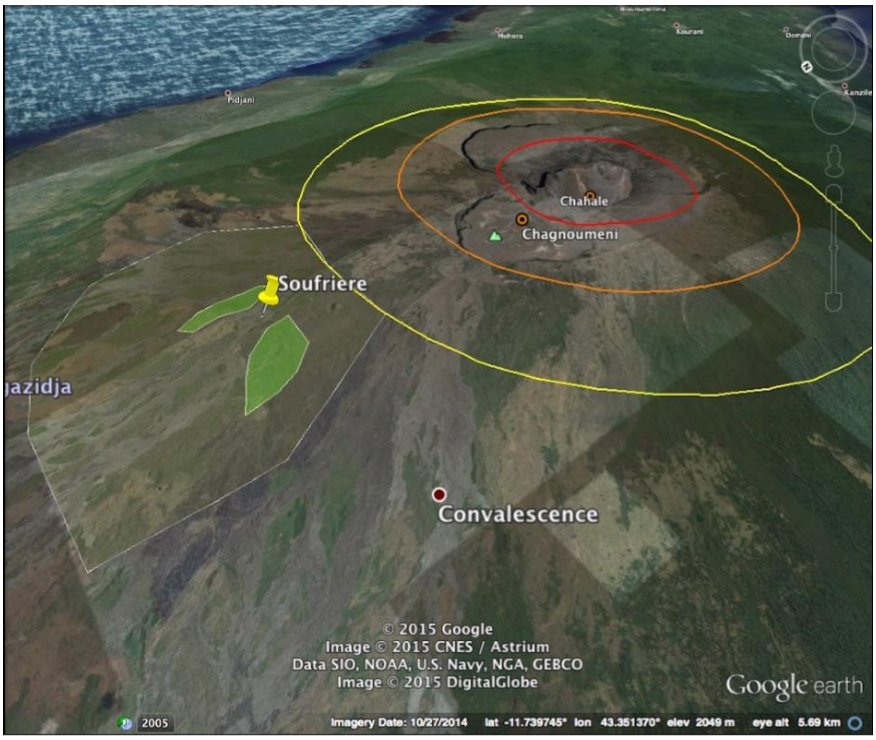

Figure 4: The less vulnerable areas (green) are around the Soufriere, seen from west to north. The three circles centered on the Choungou Chahale crater indicate the 1, 2 and the radius distance of 3 km (red, orange and yellow circle, respectively) from this conduit. Ballistics associated with the eruptions of 2005 was observed in the 2-3 km area. The installation of any permanent infrastructure further than 3 km from Choungou Chahale would significantly reduce its vulnerability to ballistics. The largest gray area around the Soufriere indicates the area less likely to be affected by the Choungou Chahale's ballistics or lava flows from Choungou Chagnoumeni (crater to the north). Both green spaces have not been affected by substantial lava flows for the last 100 years, so could be good candidates for all proposed facilities. Credit: modification of Google Earth.

7. CONCLUSIONS

The Karthala is an active volcano with eruptions that occur on average every eight years; the last occurred in 2007. This basaltic shield volcano has a very active hydrothermal system. In addition, the presence of a ditch associated with an active volcano is the key to a potentially exploitable geothermal system on the island of Grande Comore. This led the Comorian Government to prioritize the development of geothermal energy in the Comoros.

Surface exploration studies began in October 2014. However, volcanic hazards can affect virtually all areas of the volcano, making any permanent infrastructure on the volcano vulnerable.

To better consider the success of this project, it was necessary first of all to carry out a study which made it possible to identify and to register the various volcanic hazards succeptible to harm the project to better apprehend them and to act in prudence. This allowed to consider measures of attenuation.

Following this study, it was possible to identify mitigations and potentially safer areas that could be target areas for future infrastructure. These, with the support of the OVK, can enable long-term plans for geothermal development in the Comoros.

REFERENCES

Bachelery and Coudray (1993) Volcano-tectonic map of Grande Comore at 1: 50,000.

Geological Office of Comoros

GNS Science International Limited Consultancy Report (Volcanic hazard assessment at Karthala Volcano, Grande Comore, Comoros Islands) 2015/15 Octobre 2015

https://fr.wikipedia.org/wiki/Karthala

Nassor, H. (2001). Contribution to the study of the risk of large volcanoes Basaltic shields: Karthala and Piton de la Fournaise, University of Reunion (Saint Denis).

Volcanological observatory of Karthala (OVK)