STRUCTURAL CONTROL OF RUNGWE VOLCANIC PROVINCE AND ITS IMPLICATION ON GEOTHERMAL SYSTEM

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ABSTRACT

Rungwe volcanic province is marked by Plio/Pleistocene to recent eruptive and tectonic events. It is located at southern triple junction of the East Africa Rift System (EARS) in Mbeya region, southern Tanzania. The province is dominated by three major volcanic centres, namely; The Main Rungwe volcano, Kiejo volcano and Ngozi volcano. This paper describes structural influences on volcanism and hydrothermal systems in the area based on field observations. Structurally Rungwe Volcanic Province is characterised by presence of Rungwe caldera, Ngozi caldera, caldera ring structures, the dominant NW trending structures including the Mbaka fault, Mbeya front escarpment, Ifisi fault, Mbalizi fault and Lupa fault system, which follow the regional NW trending structural corridor largely influenced by Neogene Nyasa rifting and Rukwa rifting. It is observed that underlying structures may have not only influenced the locations of these three volcanic centres but also the hydrothermal system associated with them. Rungwe being the main volcanic system and underlying basement structure may have enabled magma conduits to the north and south resulting in Ngozi and Kiejo eruptions.

1 INTRODUCTION

Rungwe Volcanic Province (RVP) is located in Mbeya region and parts of Njombe region, SW Tanzania, lying mainly between latitudes 8° 45´ and 9° 35´ and longitudes 33° 10´ and 34° 0´ in the southern highland of Tanzania. The area is accessible by all season tarmac road from Mbeya (Mbeya – Malawi border road) and is characterised by mountainous terrain largely influenced by Volcanism. Rungwe Volcanic Province is accommodated at southern triple junction of East Africa Rift System (EARS) between NE trending Usangu rift to the North East, NW trending Nyasa rift to the South and NW trending Rukwa rift to the North West (Figure 1).

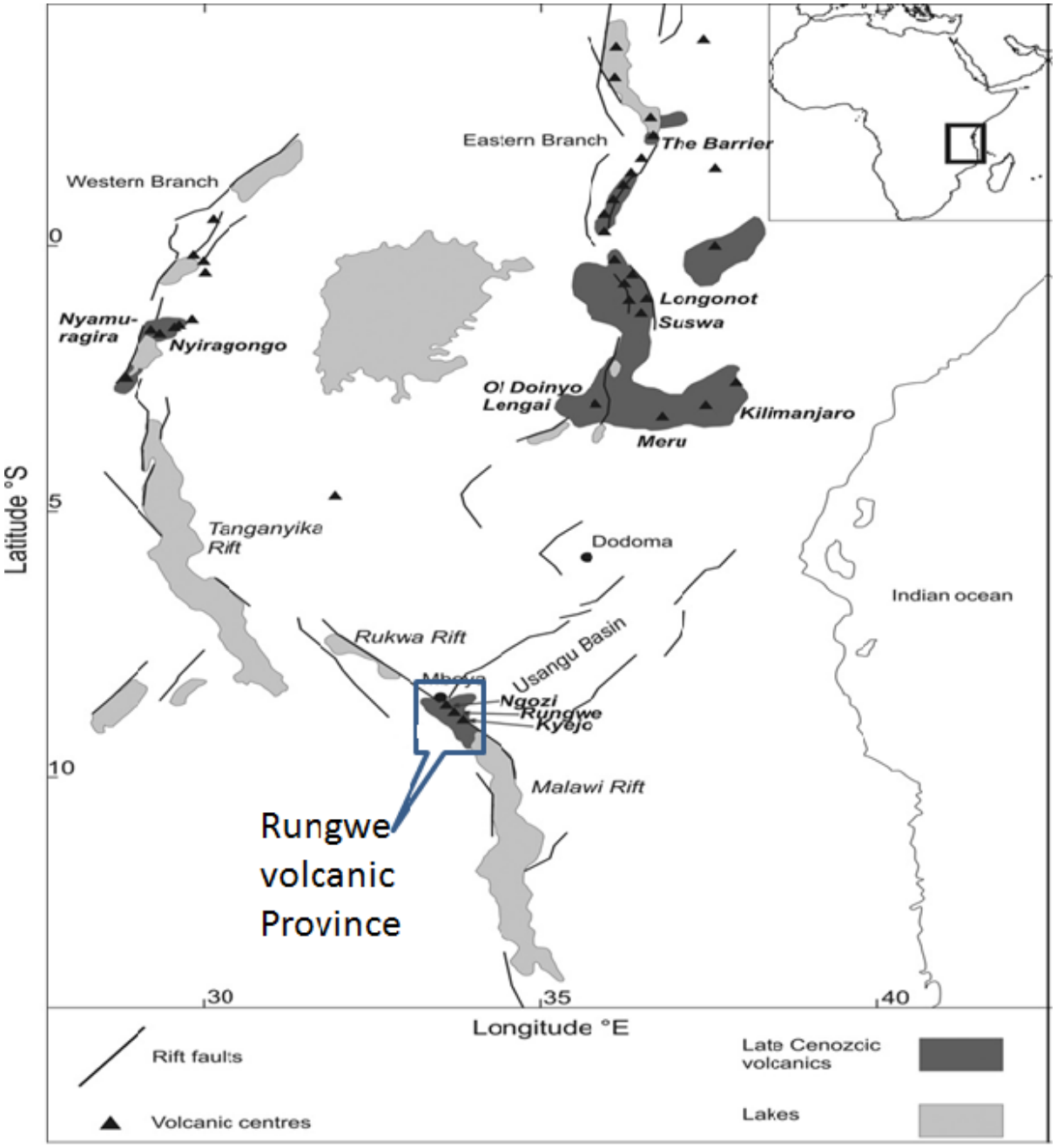

Figure 1: The location of Rungwe volcanic province at the southern triple junction of East Africa Rift System (EARS) modified after Fontijn, 2012.

2 GEOLOGY AND TECTONIC SETTING

Rungwe volcanic province is located at triple junction of EARS characterized by Neogene to recent volcanic eruptions, overlying the Cretaceous red sandstone and Karoo sediments, accommodated between reactivated NW trending Rukwa rift, NW trending Nyasa rift and NE trending Usangu rift. The Cretaceous red sandstone and Karoo sediments are confined to the western margin of Rukwa and Nyasa rift. (Figure 2)

Alkaline magmatism started during the late Miocene and occurred until present day with series of eruption from Ngozi, Rungwe and Kiejo during Holocene and early historical (Delalande, 2015, Harkin, 1960). The province has tens of small scale eruptive volcanic center but the dominant are the

three main volcanic centers, namely Rungwe, Kiejo and Ngozi Volcano; Rungwe being the main centrally volcanic center. Rungwe and Ngozi volcano has had a Plinian style eruption in the Holocene past (Fontijn et al, 2012). The province is marked by Neogene (Plio/Pleistocene to recent) eruptive and tectonic events. Both Nyasa and Rukwa rifts are bordered by deep NW trending Livingstone scarp fault and Lupa fault to the East, respectively and these faults seems to fade towards each other as Volcano pile is approached.

Volcano pile has arisen at the triple junction of Nyasa, Rukwa and Usangu (previously referred as Ruaha) rift system, where the North westerly structural trend is present in the Precambrian basement. This structural trend is followed by most of rift faulting and is reflected as the dominant control in the alignment of Volcanological features in the Rungwe Volcanic Province (Harkin, 1960)

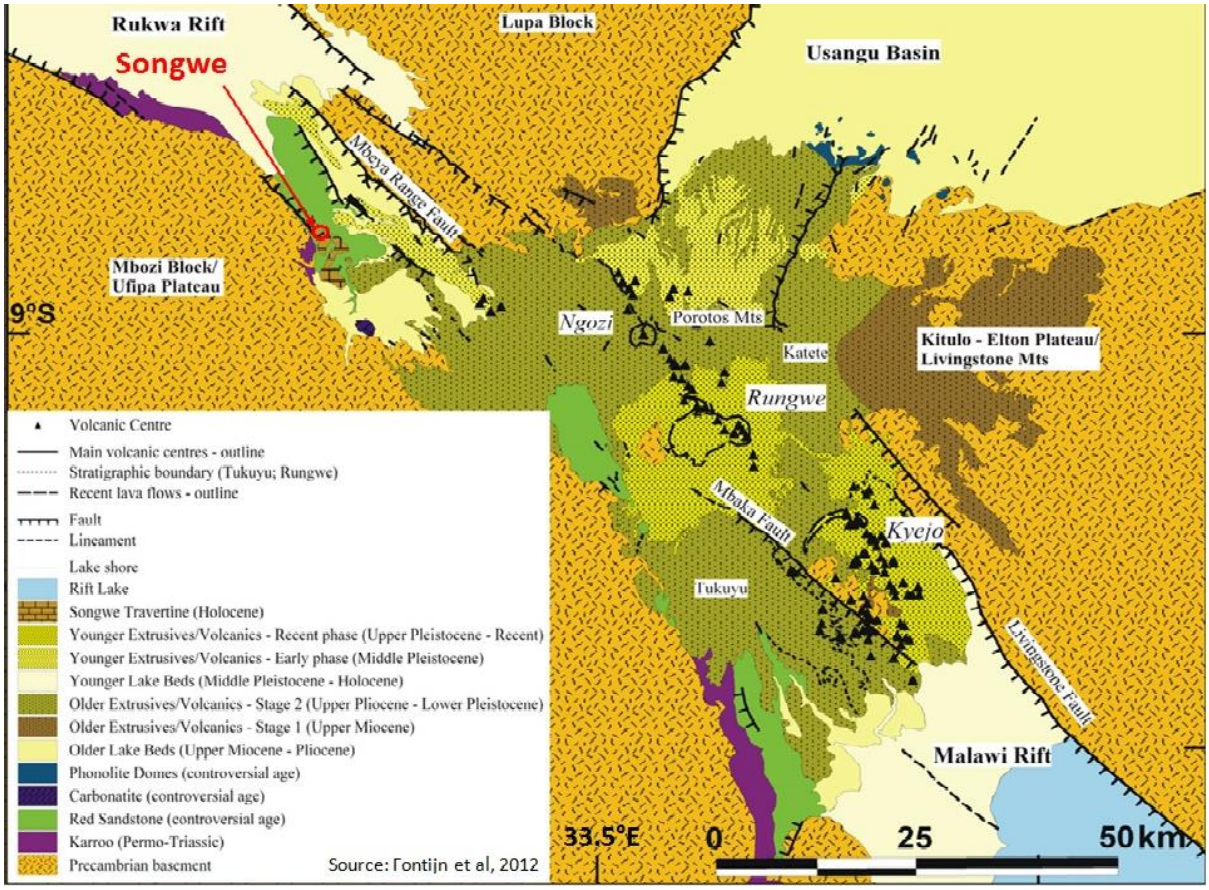

Figure 2: The geological map of the Rungwe volcanic province, showing Precambrian basement confining the volcano pile.

3 THERMAL MANIFESTATION

The geothermal activity in the Rungwe Volcanic province has been related to the volcanic activity and as a result of tectonic accidents, allowing heat volatiles and deep water uprising. (Delalande, 2015, Delvaux et al 2010, Harkin 1960)

3.1 Caldera and Volcanic centers

The Ngozi caldera provides a clue of the thermal activity associated with it. The bathymetric survey conducted back in 2010, showed existence of three hot spots beneath the caldera lake with temperature ranging from 65°C to 89° C (Geothermal II: Geothermal Energy as an alternative source of energy for Tanzania. BGR – Final Technical Report, 2013). Geophysical survey conducted during the recent field work shows the existence of low resistivity, cap layer beneath ngozi geothermal area, which confirm that at one point the heat flow from the magma chamber baked the rock to form a cap layer. Apart from the three main volcanoes in the region, there are host of volcanic eruption centers which seems to make a general trending NNW structural alignment and which are associated with thermal activity (refer figure 3).

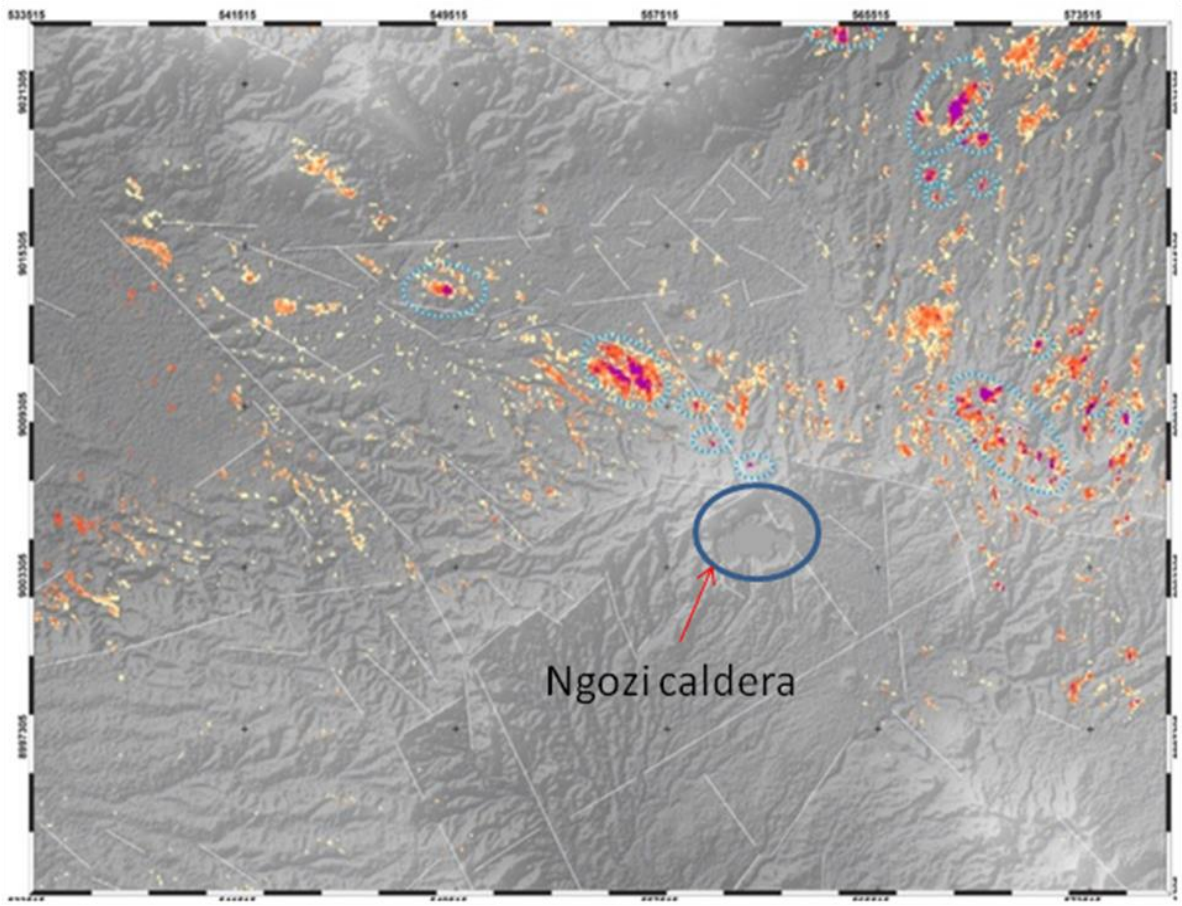

Figure 3: Thermal anomaly map showing the possible thermally active areas North West and north eastern part of Ngozi caldera

3.2 Hot and warm springs

A number of hot spring and warm spring exist in the region with temperature ranging from 30° C to 89° C, from the southern end to northern end of the Rungwe Volcanic province. These warm springs are mostly found out flowing from river banks around ngozi area here there is huge blanket of pyroclastic ash and high precipitation. There could be mixing effect with infiltrated cold water which results into low temperature springs, here referred as warm spring. These hot spring are out flowing from structures which are dominantly trending NW, largely influenced by rifting faulting

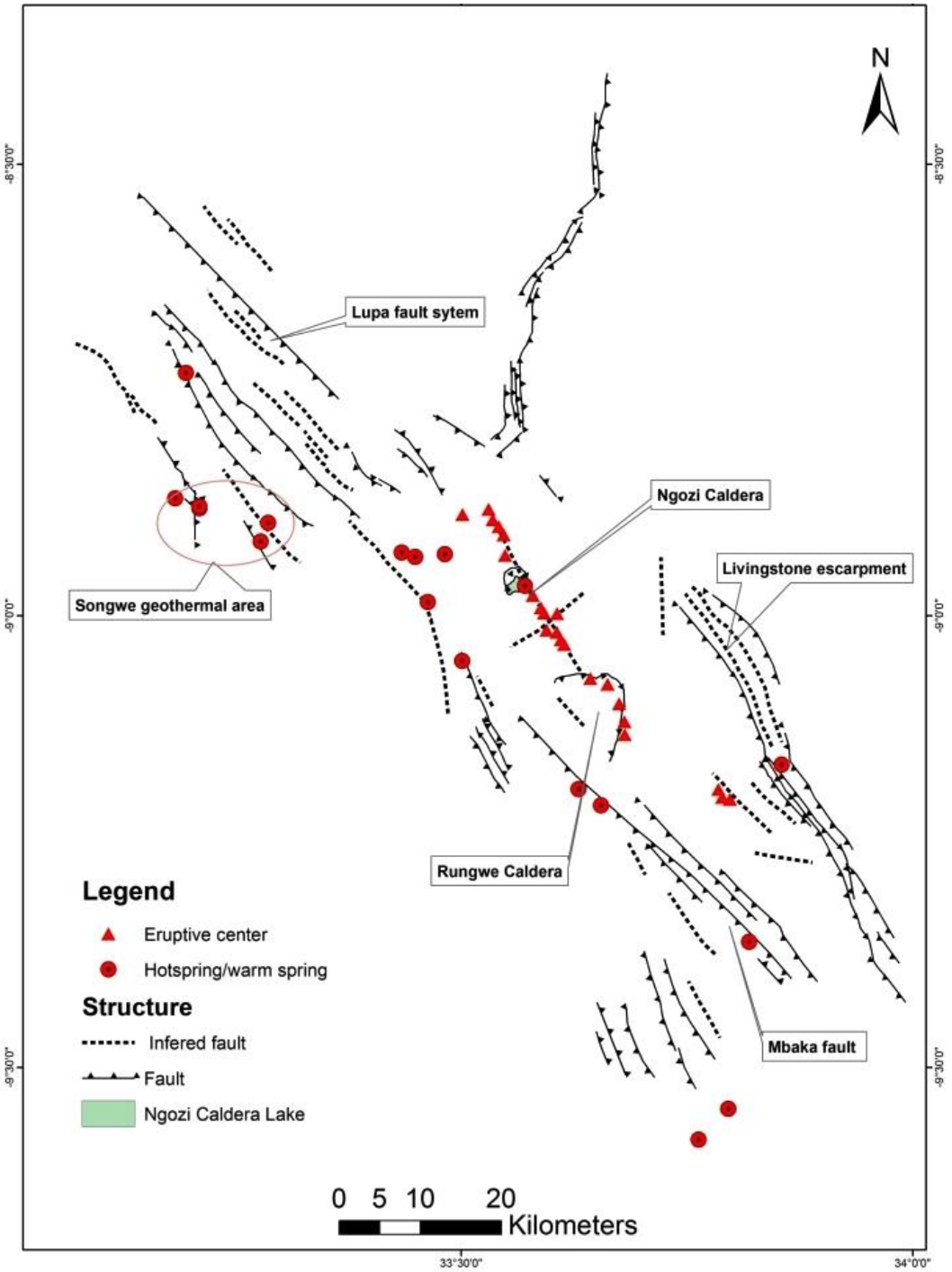

Figure 4: thermal manifestation map of Rungwe volcanic province, considering the main structures and volcanic center at a given scale. Structures were generated from remote sensing data.

4 STRUCTURAL CONTROLS

Regionally Rungwe volcanic province is dominated by NW trending steep faults (Nyasa-Rukwa rift trend) as observed in figure 2 and 4 above, which in turn have impacted the orientation of thermal manifestation in the region. During the field work few measurements were taken on exposed structures but most of the area has been covered by volcanic pile hence blanketing the structures.

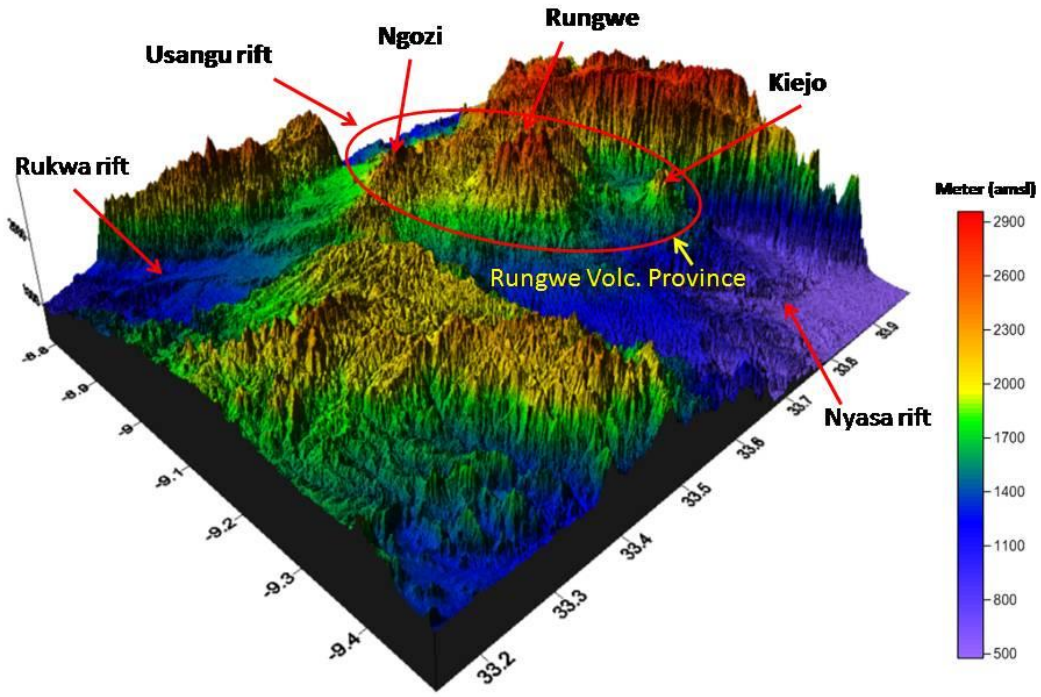

Figure 5: The digital elevation model of the rift triple junction, showing the tectonic of Rungwe volcanic province and elevated blocks on rift 'banks' as possible recharge area of the thermal system

4.1 Local structural control, a case study of ngozi area

Ngozi area, specifically the caldera lake has been of interest for geoscientific studies by different scientists for quite some time. It has proved to be a potential geothermal resource. Bathymetric survey conducted by a joint team of scientists from BGR, GST, TANESCO and Ministry of energy and Minerals (GEOTHERM II: Final Technical report, 2013) identified three 'hot spots' within the lake, and it is here considered to be the thermal manifestation.

High $^{3}He/^{4}He$ ratios at Ngozi lake water provide an unambiguous evidence for the inflow of mantle derived fluid into the lake (Delalande et al, 2014). Recent geochemical, geological and geophysical field work, with the help of remote sensing desktop work has tried to unlock the structural control of the ngozi geothermal system. The subsurface resistivity image has shown the faulting on the eastern margin of lake ngozi associated with the *Rungwe line* (structural corridor where eruptive center are aligned from Rungwe through ngozi to north of ngozi) as the main structural control of the system, and this structural line has contributed to the formation of path of the thermal fluid from deep reservoir into the caldera lake.

The intersection of the *Rungwe line* and NE trending lineament south of Ngozi caldera could prove to be the potential area of the geothermal reservoir or the upflow zone, which is supported by the doming structure of the low resistive layer (cap rock) depicted during the geophysical survey; also from the soil gas survey, this is one of the area where high values of the CO_2 was depicted (Figure 6). This opinion though doesn't rule out the potential of having the reservoir or heat source beneath ngozi caldera.

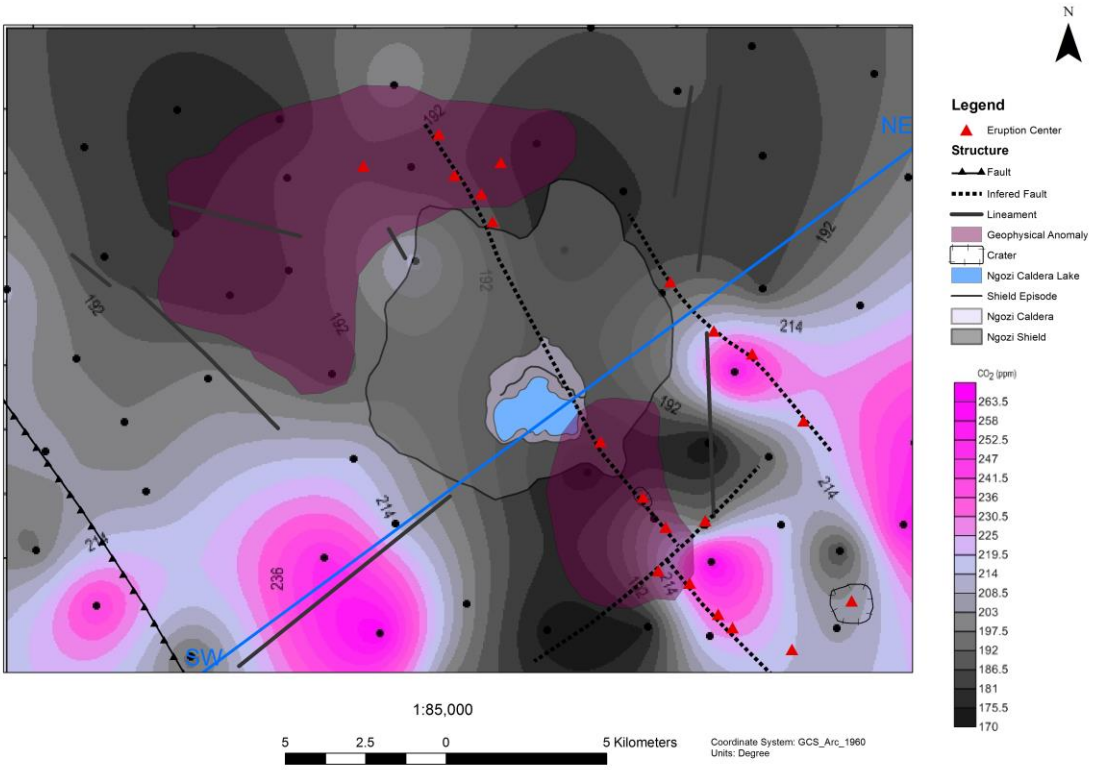

Figure 6: Sliced resistivity layer (bottom of clay cap), overlaid on soil gas anomaly map and geological structure. The blue line is the conceptual geological section line. The 'Rungwe line' trending SE - NW crossing the Ngozi caldera lake.

4.2 Conceptual Model

The conceptual model created based on the interpretation of available geological, geochemical and geophysical data, suggests that the geothermal resource at Ngozi is supported by deep upflow of geothermal fluids rising directly beneath the Ngozi caldera lake, presumably through fracture created by eruption as a result of a basement structure i.e. Rungwe line structural corridor which is passing through Ngozi caldera trending NNW (Figure 6). The depth to the basement at this point is not certain.

The heat source in Ngozi is estimated to be 5 to 7 km below ngozi caldera; and is made up of trachytic magma chamber; which was replenished after the Ngozi Tuff eruption approximately 1,000 years ago. This is confirmed by the petrographical analysis of lithics sample collected around ngozi area. The cap rock of Ngozi geothermal area is made of volcanic rock which has been hydrothermally baked to create low resistivity smectite layer. (Figure 7)

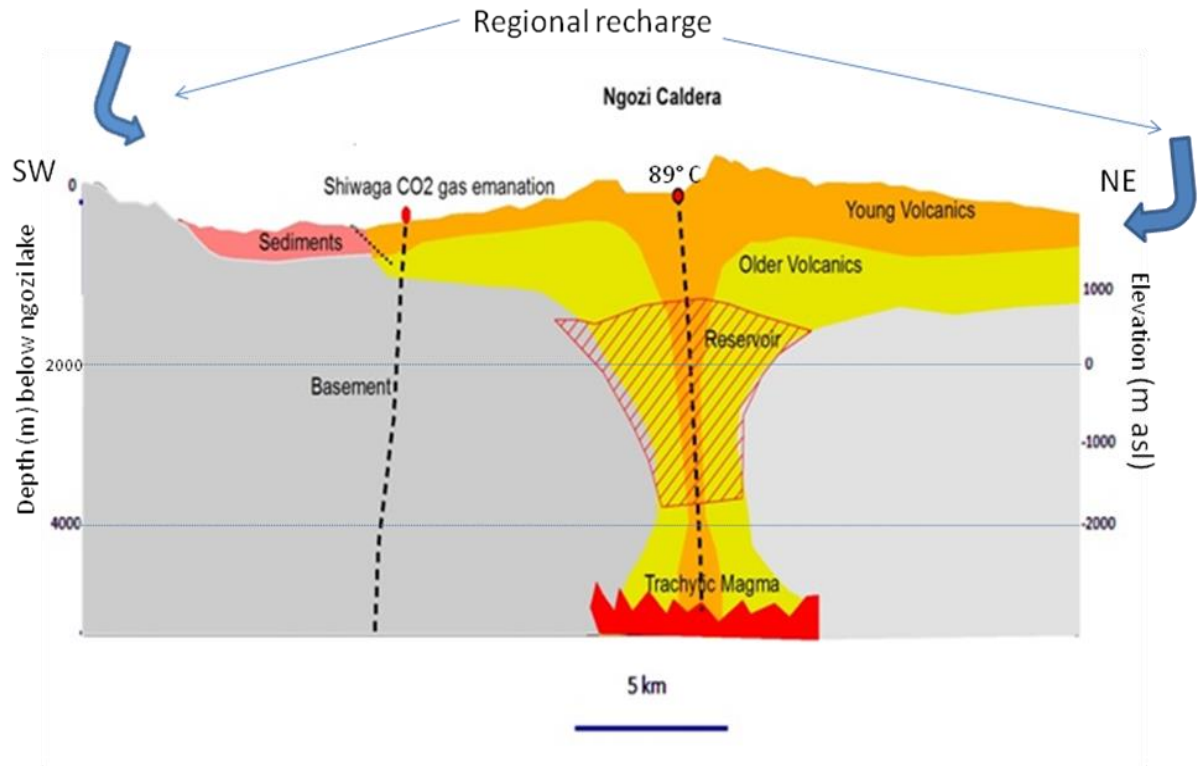

Figure 7: Schematic geological conceptual model for Ngozi volcano. The SW-NE cross section through Ngozi.

5 CONCLUSION

The Rungwe volcanic pile erupted at the junction of the Usangu and Rukwa – nyasa rifts, the later rifts having a dominant tectonic control of rift faulting and the alignment of the volcanic features, as observed in previous studies (Harkin, 1960). In light of the above geoscientific work, it is obvious the geothermal activity in the Rungwe volcanic province is very much related to the volcanic activity and tectonic events which have allowed the heat transfer and deep water movement to the surface, almost all hotspring are located in faults related to the rift formation. The Rungwe line structural corridor which is passing through Ngozi caldera towards NNW has played a major role in the formation volcanic eruptive center and in this case the presence of thermal activity around Ngozi and the volcanic province at large.

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