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PAKA VOLCANO IN THE NORTHERN KENYA RIFT: VOLCANIC EVOLUTION, PETROLOGY AND INSIGHTS INTO ITS GEOTHERMAL SYSTEM

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ABSTRACT

This paper describes a PhD research proposal to be undertaken at Paka volcano in the northern Kenya Rift. The Kenya Rift spreads from Lake Turkana to northern Tanzania. A marked variation in the structural orientation style has led to the division of the Rift into three main segments i.e. the northern, central and the southern sector. Volcanism is prominent in the northern and central sectors and to lesser extend in the south sector. This is ascribed to the numerous volcanoes in both sectors of the rift with a clear distinction in volcanism culminating in the bimodal character of rocks in the north rift. This research focuses on Paka Volcano, a low lying multivent volcano located in the northern sector of the Kenyan Rift. The geological history of Paka as earlier outlined was largely hampered by scarce radiometric data, comprehensive sequence of volcanic events therefore has inherent inconsistencies. This leads to uncertainty in the assessment and understanding of its volcanic evolution. On the other hand, geochemical studies lack isotope data and complete trace element analysis and therefore some aspects of a petro genetic model cannot be fully explained. The genetic relationship of the multiple vents in the area is yet another important aspect that is unexplored. Additionally, the knowledge of the subsurface is mainly through indirect data leading to generated conceptual models that may have fundamental inaccuracies. In this study the first ever available direct data from of drill cuttings will be presented. This project seeks to fill in the aforementioned data and knowledge gaps by carrying out detailed study through surface mapping in a new stratigraphic framework to generate and present a series of time-reconstructed eruptive maps of Paka caldera so as to develop a volcanological model outlining pre-caldera, syn-caldera and post-caldera events and also provide baseline data for geohazard assessment. Additionally, trace element and isotope geochemistry will be applied to model petrogenesis and magma processes in Paka and in the assessment of whether the multivents in the area are cogenetic or otherwise. Finally, direct data in terms of drill cuttings will be analysed petrographically and through chemical analytical techniques to understand the underlying rocks of Paka, relationship of surface and subsurface rocks, determine the base of the volcano, establish an alteration mineral structure of Paka and develop a model to constrain the available geophysical data. Through this study, therefore, best approaches for development, utilization and monitoring of the geothermal resource can be generated. This will enhance the pace of geothermal development, hence socio-economic improvement of the surrounding communities in Kenya. It will also contribute to the knowledge of the geothermal and geoscience community. The project is supported by a United Nation University fellowship and the Geothermal Development Company.

1. INTRODUCTION

The Kenya Rift spreads 900 km longitudinally from Lake Turkana to northern Tanzania (Dunkley et al., 1993).The Nyanzian Rift is subordinate to the main N-S Rift and trends in an E-W orientation (Smith and Mosley, 1993) within the Archean basement. A marked variation in the structural orientation style (Figure 1) has led to division of the Rift into three main segments i.e. the northern, central and the southern sector (Dunkley et al., 1993; Williams et al., 1984). The northern sector arises from Menengai to Lake Turkana area and displays a NNE-SSW structural orientation style. At 0° 35'N, this Northern sector forms a double graben structure comprising the Elgeyo escarpment to the west and the main Rift to the east. The central Rift cuts the area between Menengai and Suswa and constitutes the peralkaline volcanic province (White et al., 2012) whilst the southern sector tracks from Suswa to Magadi area. Volcanism is prominent in the northern and central sectors ascribed to the numerous quaternary central

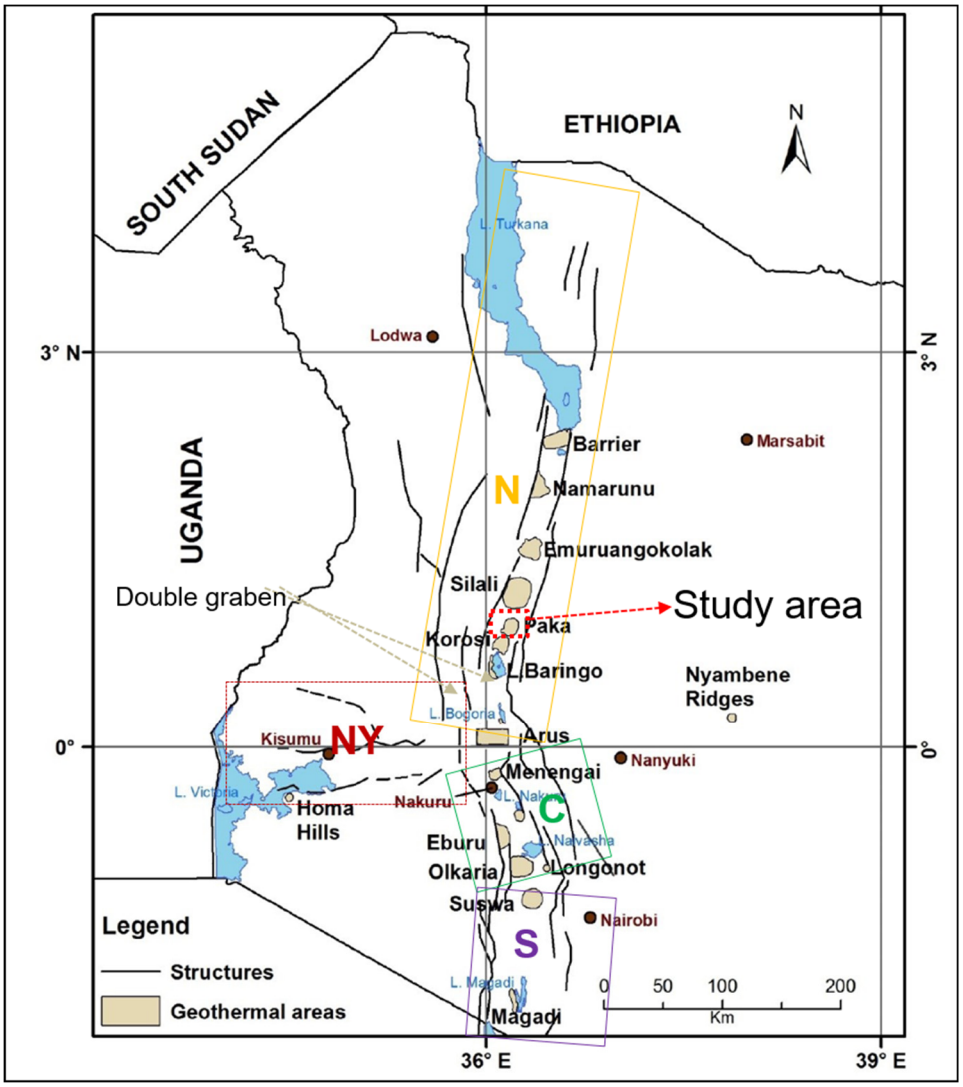

FIGURE 1: The Kenya Rift Valley; N - northern rift enclosing the study area, C - central rift, S - south rift, NY – the subordinate E-W Nyanzian rift; Note the double graben at Bogoria area

volcanoes with clear distinction in volcanism culminating in bimodal character of rocks in the northern rift as opposed to the central rift. The southern portion has less pronounced volcanoes resulting from the limited volcanic rocks emplaced in the area. This project focuses on Paka volcano located in the northern segment of the Kenyan rift where a total of nine axial volcanoes are located, the main ones include; Lake Turkana Islands, Barrier, Namarunu, Emuruangogolak, Silali, Paka, Chepchuk and Korosi (Dunkley et al., 1993).

2. REVIEW MATERIAL

This research project seeks to fill in data and knowledge gaps escalating from earlier research work. Review material comprises geological report by Sceal (1974), rock geochemistry data found in Sceal and Weaver (1971) which appears incomplete. Other principle references are the broad description of a range of volcanoes in the Kenya Rift including Paka volcano contained in Williams et al. (1984) and geological work by Hackman (1988). Geothermal energy exploration studies by the British Geological Survey (Dunkley et al., 1993) including (Darling et al., 1995) and those by KenGen and the Ministry of Energy and GDC and Omenda (2009), would also be used in addition to InSAR studies results by Biggs et al. (2009), and Friese et al. (2014), and the most recent geophysical study by Lichoro et al. (2017).

3. DESCRIPTION OF THE WORK

A detailed review of previous work in Paka identifies data and knowledge gaps which point to three key issues with implication to its geothermal system that remain unaddressed. These are:

a) Accurate volcanic evolution and volcanic model of Paka from a detailed assessment is absent;
b) The geochemistry and petrogenesis of Paka is based on incomplete data, two contrasting petrogenetic models exit, the relationship of the many surface volcanic eruption centres is not known;
c) Direct knowledge of the subsurface geology is missing due to lack of direct data; the geothermal models, stratigraphy and constrains to indirect data is lacking.

3.1 Research questions

The research will endeavour to answer the questions to unravel the three issues pointed out through; review of data, geological field mapping, petrology and geochemical analysis of both surface rock samples and drill cuttings from deep geothermal drilling in Paka volcano. The research questions synthesised for this project are query 1, 2(i) and (ii) and 3 highlighted in Figure 2 and listed below:

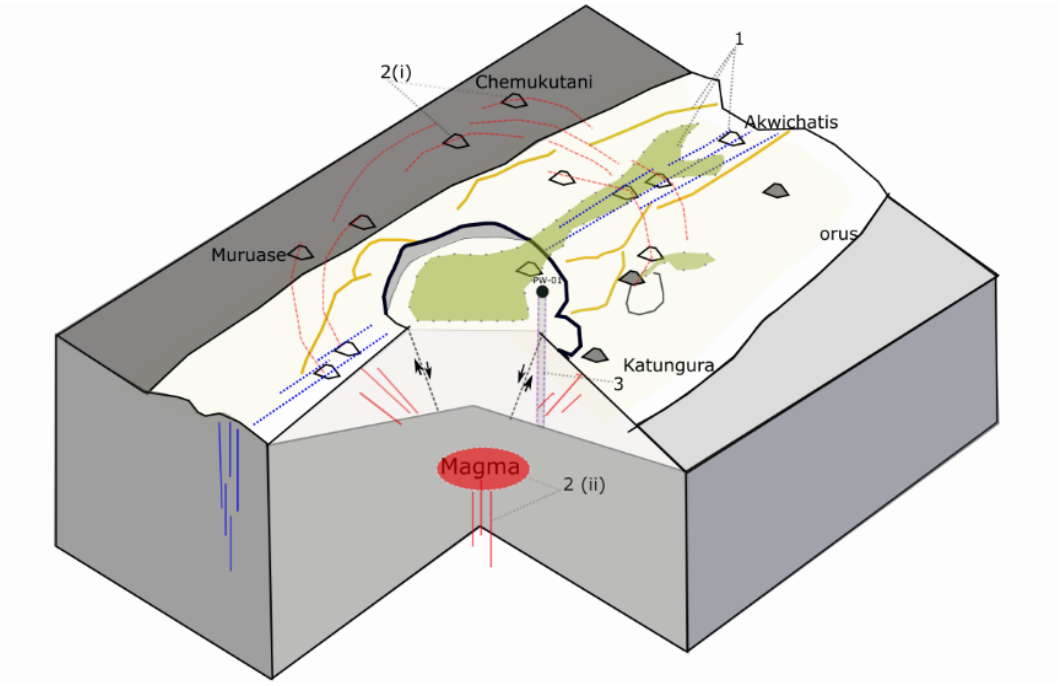

FIGURE 2: Research questions projected in a qualitative model: 1. Mapping in a new stratigraphic frame work - sequence of lava flow structures and eruptive events; 2.(i) geochemical correlation of eruptive centres; 2.(ii) magma sources and processes; and 3. subsurface geology

1. What are the sequence of volcanic events in the new stratigraphic frame work;
2. (i) What is the genetic correlation of eruption centres in Paka;
   (ii) Plumbing system, is magma from a single source or variable sources;
3. How is the lithostratigraphy correlating with the surface lavas.

3.2 Approach and methodology

This project seeks to carry out a detailed study through the approached of (Hutchison et al., 2016 and references therein). Surface mapping in a new stratigraphic framework will be used to generate and present a series of time-reconstructed eruptive maps of Paka caldera. This will help in illustrating the progressive development from pre-caldera, syn-caldera to the post-caldera period, and explicate eruptive dynamics, volcanic model and provide baseline data for geohazard assessment. Trace element and isotope geochemistry will be applied to model petrogenesis and magma process in Paka where Turkana basalt will used as parental/source composition. The geochemistry data will also assist in assessment of whether the multivents in the area are co-genetic or otherwise. In carrying out this study 177 samples will be used for interpretation. About 150 samples will be analysed during the present study, the additional data sets include those by Omenda (2009) and Sceal and Weaver (1971). Direct data in terms of drill cuttings will be analysed petrographically and through chemical analytical techniques to understand the underlying rocks of Paka, relationship of surface, subsurface rocks and determine the base of the volcano and also establishing alteration mineral structure of Paka.

3.3 Timelines and budget

The project proposal and course work in relevant requisite areas is being undertaken for eight months at the University of Iceland beginning in September 2017 to May 2018. Field work is expected to extend from May to September 2018 in Kenya - Paka volcano. The main fieldwork is expected to take about 3 months with a second fieldwork episode allocated 2 weeks for additional data collection deemed necessary after a thorough review of initial data collected. The laboratory data analysis and review is expected to be completed by June 2019. Two draft papers for publications are expected to be ready by August 2019 and final paper by February 2020.Thereafter the PhD thesis compilation is expected to commence and be completed by July 2020. The final PhD defence seminar is scheduled for August 2020.

4. RESULTS

The results of the work will result in publication of three papers in peer reviewed journal articles preferably (*Journal of Volcanology and Geothermal Research, Geothermics etc*.) and a few articles in conference proceedings. The results will be discussed at scientific conferences such as the Geothermal Resource Council, World Geothermal Conference expected in 2020 here in Iceland. All data will be made available in open access to the geothermal geoscience community and general public.

5. CONCLUSIONS

This PhD research work will be carried out under the supervision of Hjalti Franzson, Björn S. Hardarson from ISOR and Halldór Geirsson and Eniko Bali from the University of Iceland. The aim of the project is to answer questions related to volcanic and petrogenetic evolution of Paka while giving insights into the geothermal system in the area. The project will take three years and is divided into two components (i) Field work in Kenya, and (ii) Laboratory analysis, interpretation and paper publication in Iceland. The budgetary support is through the UNU-GTP scholarship announced in 2017.

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