Microearthquake Survey at the Buranga Geothermal Project, Western Uganda

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The BGR supports the Government of Uganda in the geoscientific investigations at the Buranga geothermal prospect since 2004. The objective of the project is to raise the development status of Buranga (Fig. 1) by geoscientific investigations to reach a pre-feasibility status in the future which is the base for planning of exploration wells and further developement.

Figure 1. The Buranga hot springs consist of 37 springs with an overall flow rate of ca. 30 l/s and temperatures up to 98.4°C.

The Buranga hot springs are situated in the Albertine Rift (western branch of the East African Rift) in the Semliki National Park in Bundibugyo district to the west of the Rwenzori Massif. The national park extends to the north and west to the Semliki River, which is the borderline to the Democratic Republic of Congo. The springs are situated in a swamp in the tropical rain forest a few hundred meters westerly of the Bwamba fault, which forms the western flank of the Rwenzori and the eastern scarp of the rift respectively.

The observation that after strong earthquakes local displacements of the hot springs as well as changes of the individual flow rates had occurred suggests that the activity of the Buranga hot springs is very much related to an active fault system and that these tectonically active faults might provide the migration paths for the hydrothermal water.

In the region of the Albertine Rift, where Buranga is located, no geological surface indications for volcanic activity or intrusive dikes were found so far which could act as a heat source for the thermal water.

However, from carbon isotopic composition of CO2 a first indication of a mantle source for the gas released at Buranga hot springs was found. This was confirmed by He isotopic analyses indicating a contribution of >30% mantle He. These findings imply that a still hot actively degassing magma body exists in the subsurface of Buranga area. This magmatic body serves most likely as the heat source of the hot springs. Hence the task of active ground geophysics was detecting and delineating this magmatic intrusion. The known high seismicity (about 300 local earthquakes per month) suggested that Buranga provides excellent requirements to apply seismology (Fig. 2).

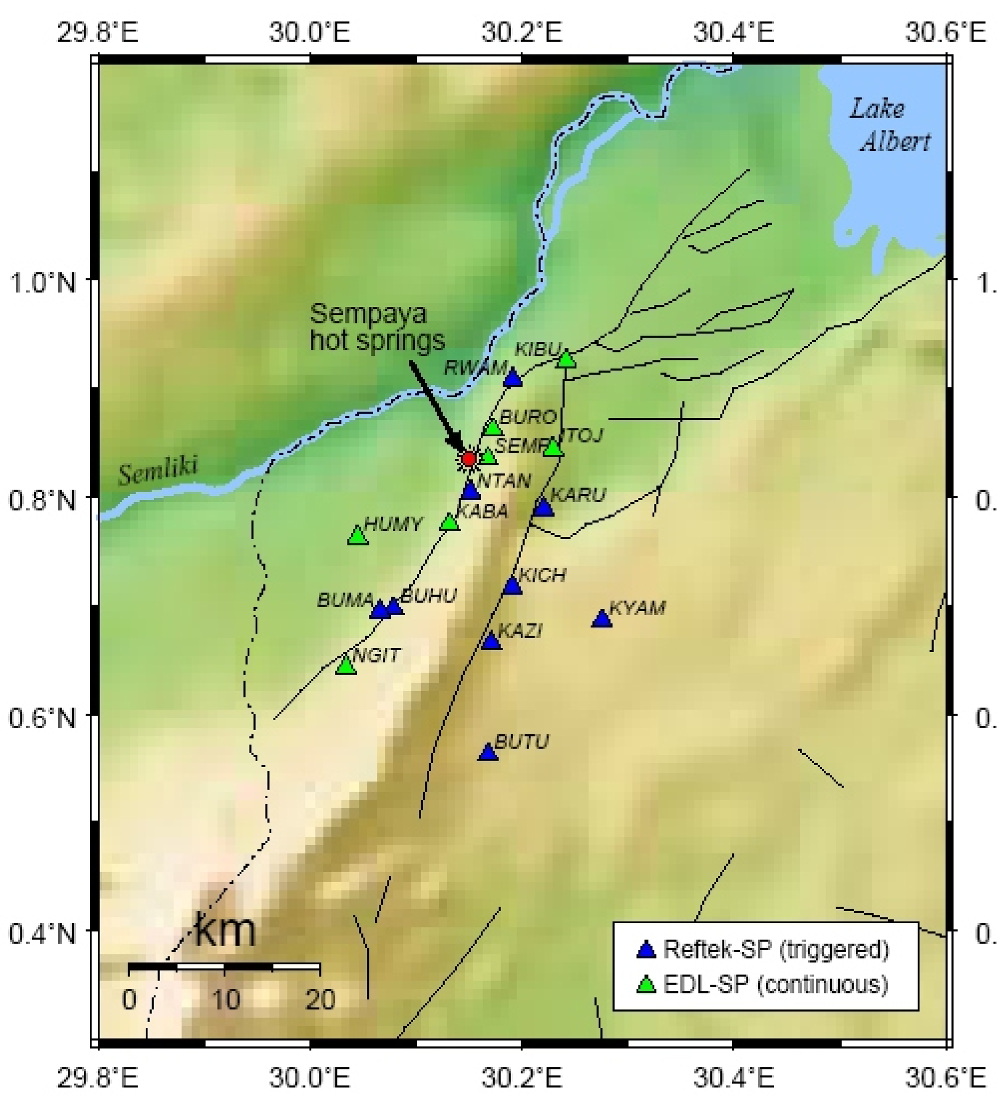

Figure 2. Map showing the distribution of deployed recording stations (triangles). Note, when the project started in April 2005 only 3 sites were occupied. During the following months the number of stations was gradually increased to 15. Surface faults (black lines) were taken from existing Geological Maps.

Fig. 3 shows the epicenters of 4185 earthquakes that have been recorded in 2006 (Jan. - Aug.). The majority of events exhibit a focal depth between 10 and 30 km; the deepest events occur at depths of about 55 km. The program HYPOCENTER was used for hypocenter localization. Obviously, few earthquakes occur within the northern part of the Rwenzori block; most events occur outside of the surface expressions of the main marginal faults.

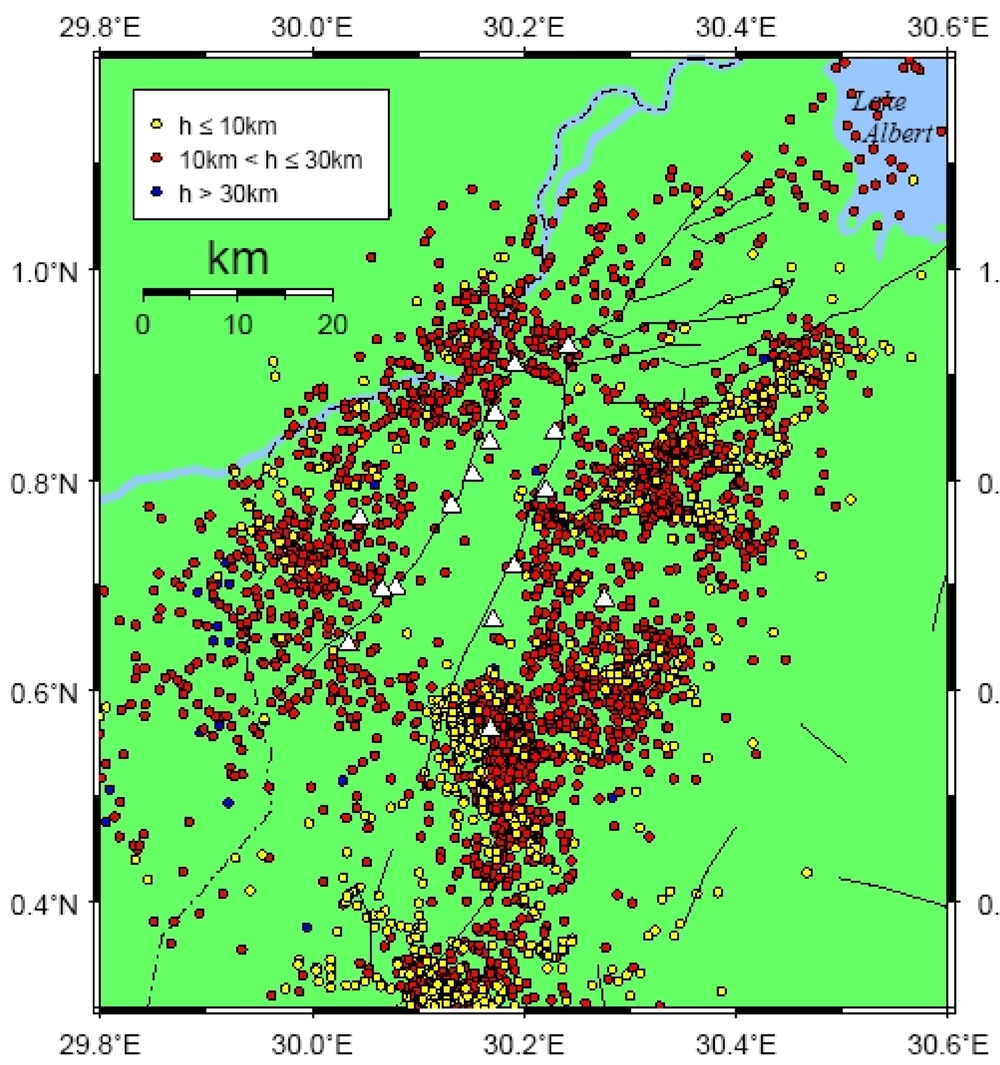

Figure 3. Results of the determination of 4185 hypocenters recorded in 2006. Stations are marked by triangles. Different colours of epicenters indicate different focal depths. Black solid lines indicate locations of surface faults.

The microearthquake activity around Rwenzori was observed to delineate an assumed magmatic intrusion. Travel time residuals are used to calculate the involved velocity perturbations in the crust (Fig. 4). Minimization of these residuals are achieved using an iterative procedure for earthquake relocation and simultaneous determination of the velocity structure (tomographic inversion method).

The velocity contrast between the Precambrian crust and an assumed magmatic intrusion is hard to estimate because many parameters (ascension temperature, age, pressure, volume…) are unknown. A rough mean velocity attenuation of 100m/s per 100°C may be appraised.

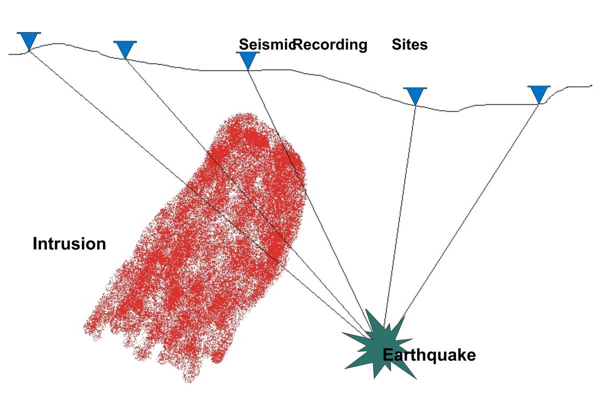

Figure 4 Seismic rays traveling from an earthquake source to recording sites at the surface can exhibit early or late arrival times depending on the velocity anomalies they have passed.

Results of the tomographic inversion method are presented in two figures. Fig. 5 shows vertical sections of the p-wave anomalies in the vicinity of the Buranga hot springs, while Fig. 6 displays a quasi 3-D section of the same.

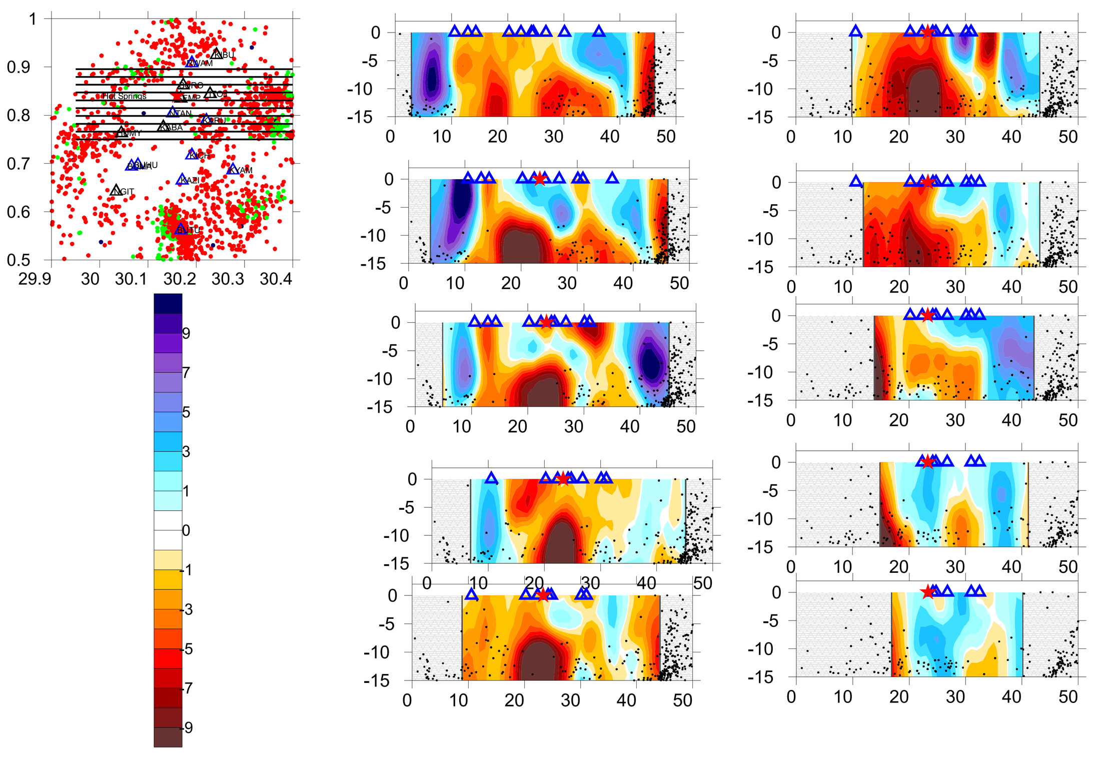

Figure 5. The anomalies of P-velocities presented in vertical sections. The East-West sections are marked on the map in the upper left corner. The projected position of the hot springs is marked with a star and section 6 closely traverses the springs position. Blue triangles indicate seismological stations projected into the vertical plane. Black dots mark neighbouring hypocenter locations projected into the vertical plane.

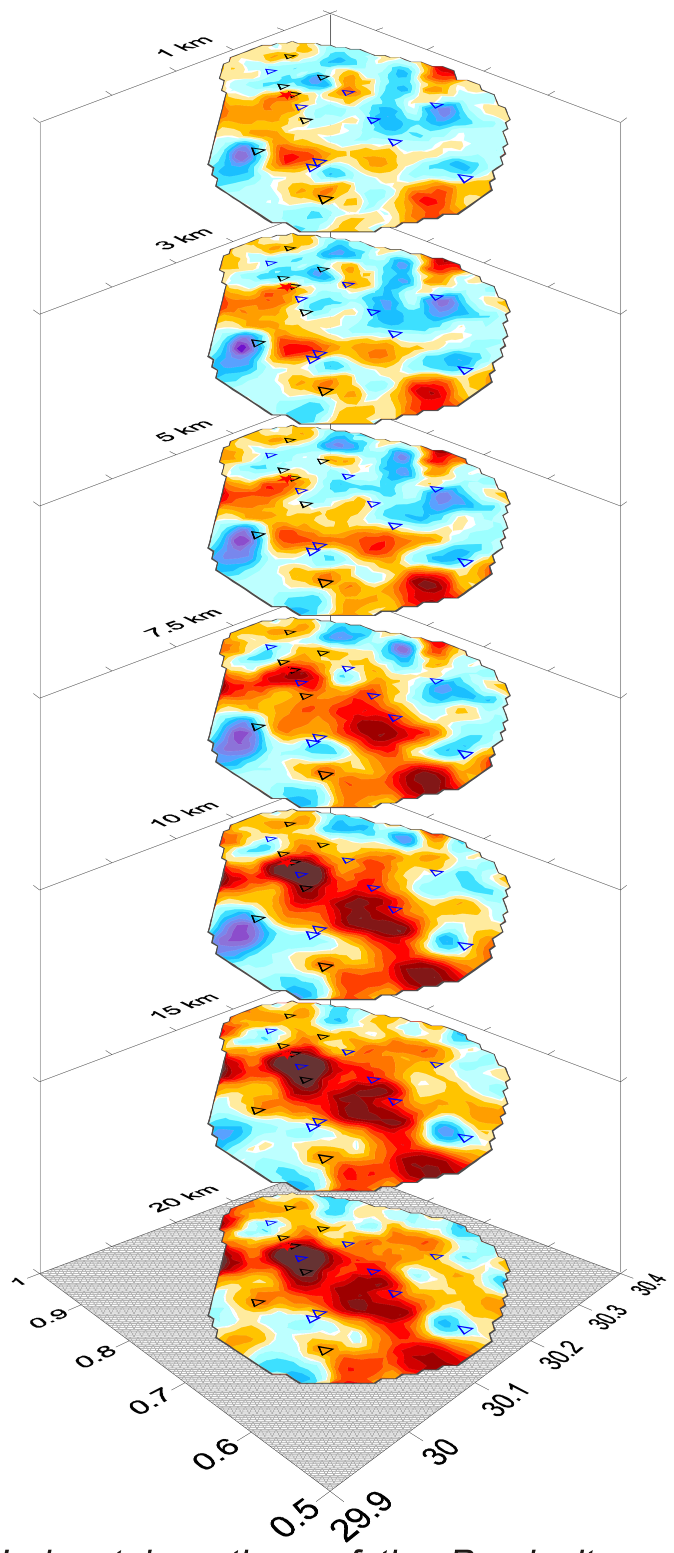

Figure 6. Horizontal sections of the P-velocity anomalies in different depth levels. Blue (red) colours indicate regions of relatively high (low) velocities with respect to the initial velocity model. A relatively hot magmatic intrusion near the surface is expected to exhibit a negative velocity anomaly. The color bar of Fig. 5 applies accordingly.

At shallow depth (1-3 km) the results show that a large low-velocity anomaly exists in the north-western section of the region under investigation. It is interesting to note that the Buranga hot springs are located at the boundary of this anomaly at the transition between slow and fast regions. The low-velocity anomaly broadens at greater depths (> 5 km) and their position is dislocated towards the centre of the northern Rwenzori block. The anomalies tend to become stronger at depth.

The resuts of the tomography clearly reveal definite low velocity anomalies. Taking into account the evidentiary findings of geochemistry, which clearly proved that mantle helium and volcanic CO2 are released at Buranga hot springs, the most plausible conclusion for the observed velocity reductions are high temperature anomalies. These temperature anomalies could be a result of a hot actively degassing magma intrusion, which may serve as a heat source of the hot springs.

Together with structural geological interpretation of satellite images and further findings a conceptual model for the Buranga geothermal prospect is presented in Fig. 7. It has to be considered that the section is vertical, although the fault has a dipping angle (ca. 60°W at Buranga).

The recharge area for the thermal water is located in the high Rwenzori region (proven by isotope hydrological investigation). Several km along its migration path the water is heated up through the magmatic heat source and reaches temperatures of ca. 160°C at depth. The convectively rising thermal water emanates with temperatures of up to 98°C at the Buranga hot springs.

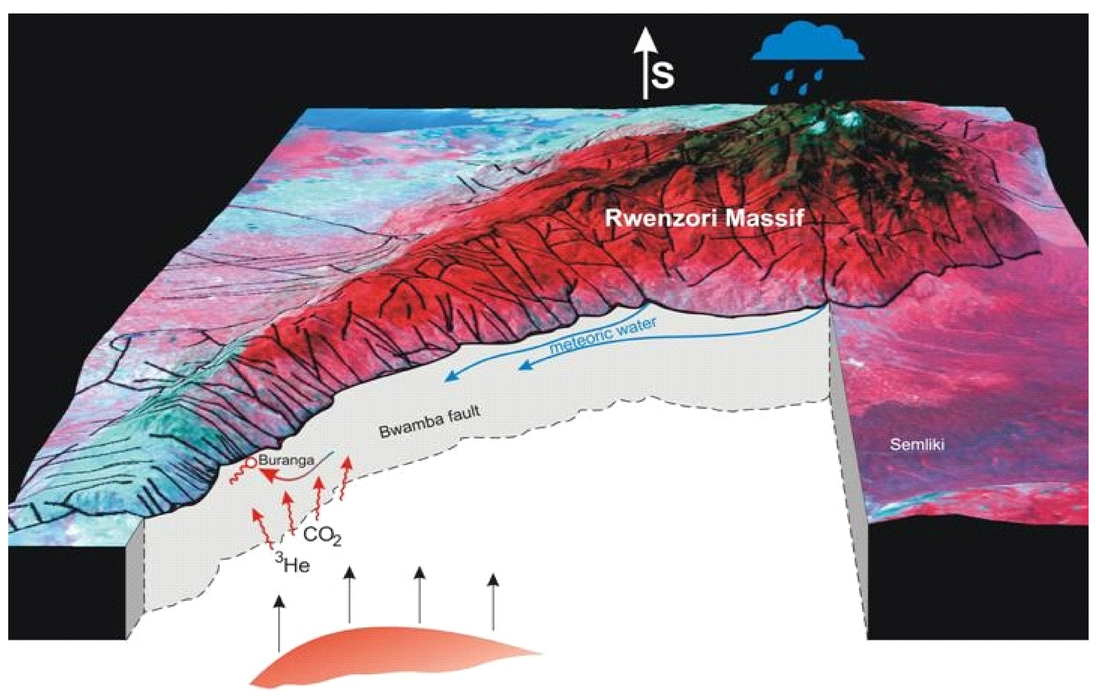

Figure 7. 3-dimensional view of the Rwenzori Massif from space as seen from the North overlain by a lineament pattern and integrated conceptual model of the Buranga geothermal prospect (not to scale).

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