Passive Seismic Network: A Diagnostic Tool to Discover Geothermal Activity

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ABSTRACT

Geothermal resources can be studied by deploying various techniques based on geology, geochemistry and geophysics. These techniques have been guided by geomorphological observations and surface manifestations. Successful confirmation of the resources has been achieved especially in young volcanic environments and high heat flow zones. The same conventional techniques have been deployed in rift zones with some success in the East African Rift. Equally notable however, is the lack of success in some cases making high uncertainties for continuity of geothermal projects.

Geologically the evolution of the geothermal systems is characterised by tectonism, heat-flow and volcanism. Tectonic and volcanic processes cause stress build up and changes in the geological structures in the subsurface and allow heat to flow by conduction in rock units and convection in fluids. The movements of fluids and energy changes generate seismic signals that are detectable by special seismometers. Seismometers installed in form of an array of passive seismic networks equipped with neural technologies can precisely diagonise and map geothermal activity in complex geological formations where little information is known.

1. INTRODUCTION

Geothermal resource exploration, development and exploitation needs a holistic approach of techniques for information gathering and interpretation. The results from the data interpretation are interrelated using robust computing platforms to infer the drilling targets to establish the geothermal reservoir for development. Before coming to the development stage, exploration is undertaken using appropriate techniques based on the general knowledge of the area and its characterisation of geological processes such as hot (thermal) springs, passive seismic activity and other surface manifestations. Geothermal resources therefore can be studied by deploying various techniques based on geology, geochemistry and geophysics because the evolution of the geothermal systems is characterised by tectonism, heat-flow and volcanism. Tectonic and volcanic processes cause stress build up and changes in the geological structures in the subsurface which allow heat to flow by conduction in rock units and convection in fluids. The movements of fluids and energy changes generate seismic signals that are detectable by special seismometers. Seismometers installed in form of an array of passive seismic networks equipped with neural technologies can precisely diagonise and map geothermal activity in complex geological formations where little information is known. This paper presents the Passive Seismic techniques as a diagnostic tool in geothermal exploration and reservoir characterisation since the geothermal resource exploration techniques based on mining industry may be inadequate. However, the development of the resource and exploitation as a hot fluid can adopt from oil and gas with modifications for higher temperatures.

2. METHODOLOGY

Seismic methods are divided into two: (a) Passive seismic methods deal with the detection and recording of natural seismicity and induced seismicity due to ground fracturing associated with geothermal fluid extraction or injection. The seismic activity gives information about active faults and therefore permeable zones in geothermal systems. (b) Active seismic methods are concerned with seismicity generated by artificial wave sources. The propagation of the generated waves is used to study the geological structures and strata. Only passive seismic technique is presented.

Passive Seismic Network Methodology

The passive seismic technique has proved useful in investigation of fault system, seismotectonics and seismogenic zones for crustal studies. The data is processed in various stages and presented in 3D models for P-wave velocity and S-wave velocity leading to the P-wave/ S-wave ratio distribution maps and cross sections. The steps followed in the data processing are summarised in fig. (2) below.

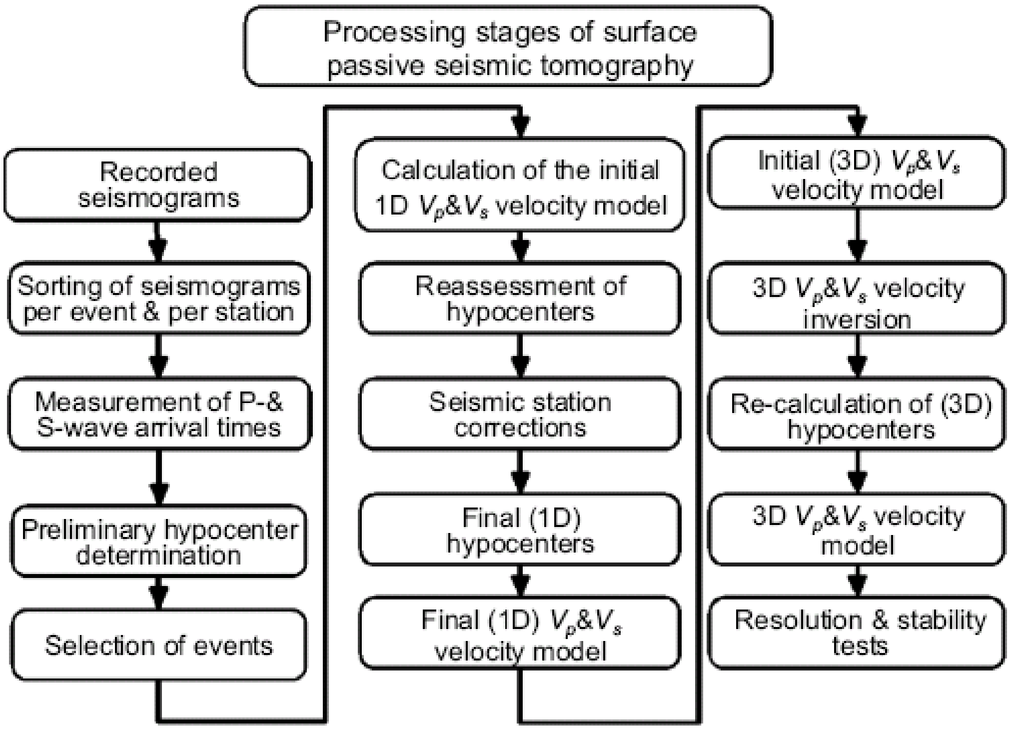
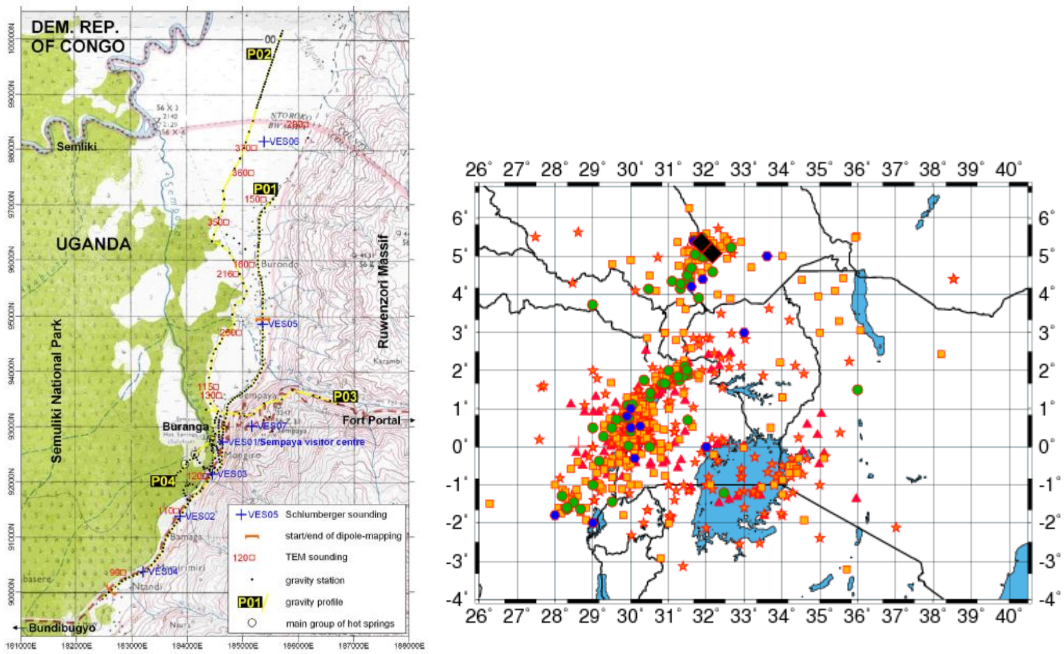


Fig2. Flow chart presenting the data processing in Passive seismic tomography (adapted from Tselentis et .al , 2007).

2.1 POTENTIAL APPLICATION OF PASSIVE SEISMIC NETWORK

The technique is very relevant in active zones with both seismic activity and geothermal. For it to be feasible the detection level needs to be low enough for microseismic activity to be detected and located which require and dense seismic network. The relative locations of earthquakes and fault plane solutions can be used to map individual faults and fracture and stress regimes can be computed to guide borehole planning for geothermal resource exploitation

2.1.1 Buranga Geothermal Prospect in Uganda



(a) (b)

Fig.3. (a): Topographic map of Buranga Geothermal prospect and ground geophysics coverage. Note the limited extent in coverage of the geophysical surveys (BGR,2007). (b): Earthquakes magnitude is shown in range by symbols: 1.0 ≤ M≤ 1.9 red cross; 2.0 ≤ M≤ 2.9 red triangle; 3.0 ≤ M ≤ 3.9 red star; 4.0 ≤ M ≤ 4.9 orange square; 5.0 ≤ M ≤ 5.9 green circle; 6.0 ≤ M ≤ 6.9 blue hexagon; 7.0 ≤ M ≤ 7.9 black diamond symbols (Tumwikirize , 2007).

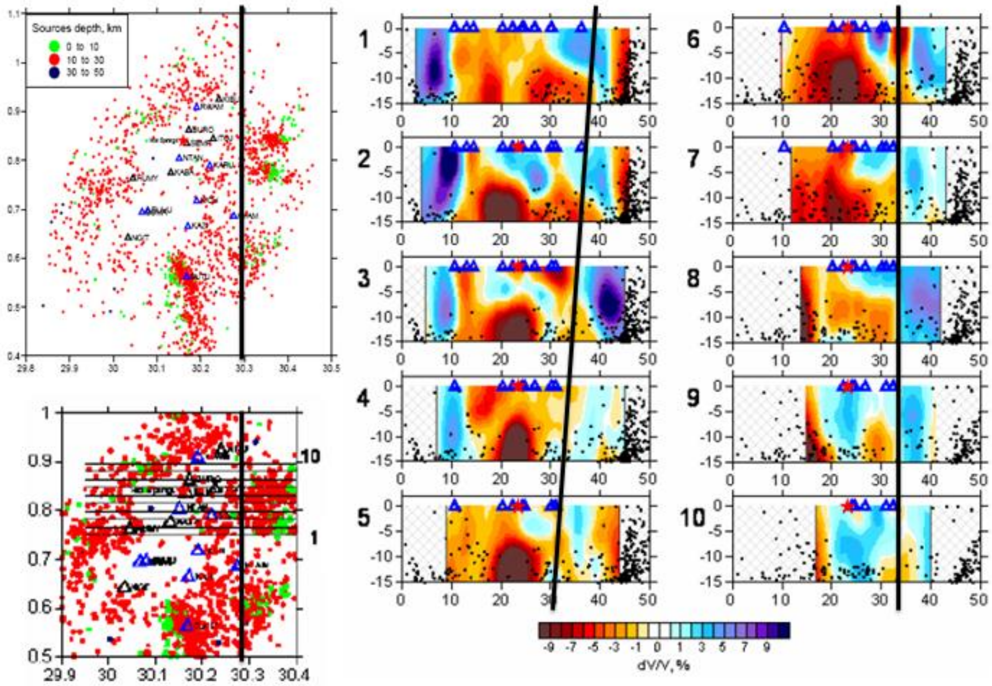


Fig 4. Seismic activity and vertical topographic sections numbered from top 1 to 10. The thick black line sets a boundary of network coverage and limitation of the ray path to resolve a representative model and most of the data was left out. Red star is the location of Buranga hot spring. Brown-red show low velocities due to high heat flow and blue cold rocks (BGR,2007).

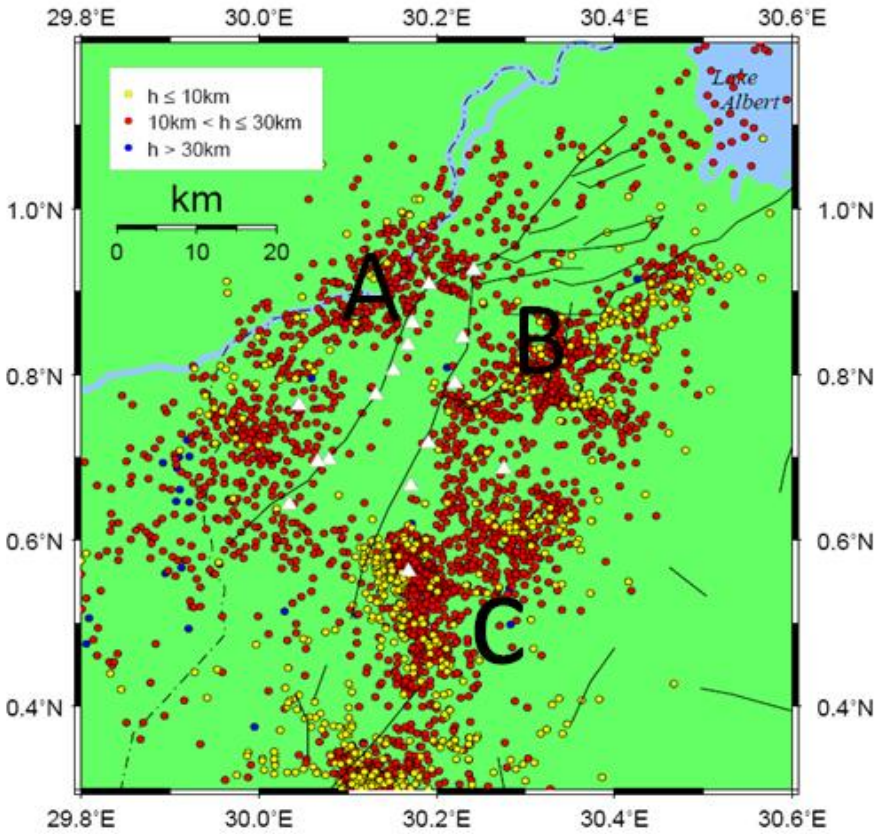
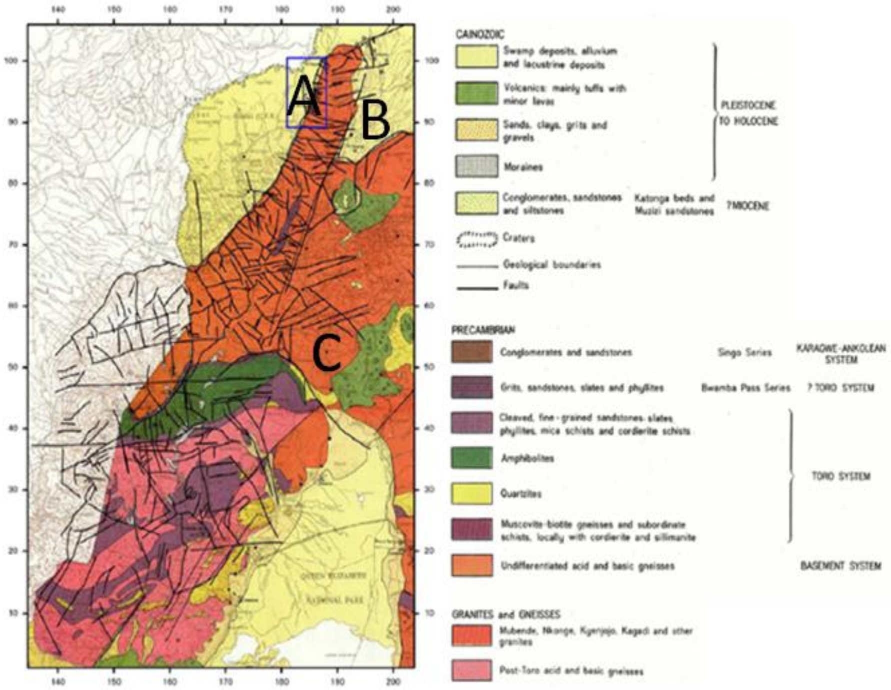


Fig. 5. Depth and Epicenters of natural earthquakes in Buranga (adapted from BGR, 2007 and modified).



(a) Geological map of Rwenzori region and known faults

Fig.6: The seismic activity gives information about active faults and thus permeable zones in geothermal systems. However, in this case, there is no correlation between the known faults and the epicenter locations in (a). The observation may be due to geothermal activity in regions marked with A, B and C, because the seismic activity is clustered and diffuse (adapted from BGR, 2007 and modified).

2.1.2 Case study using Passive Seismic Method

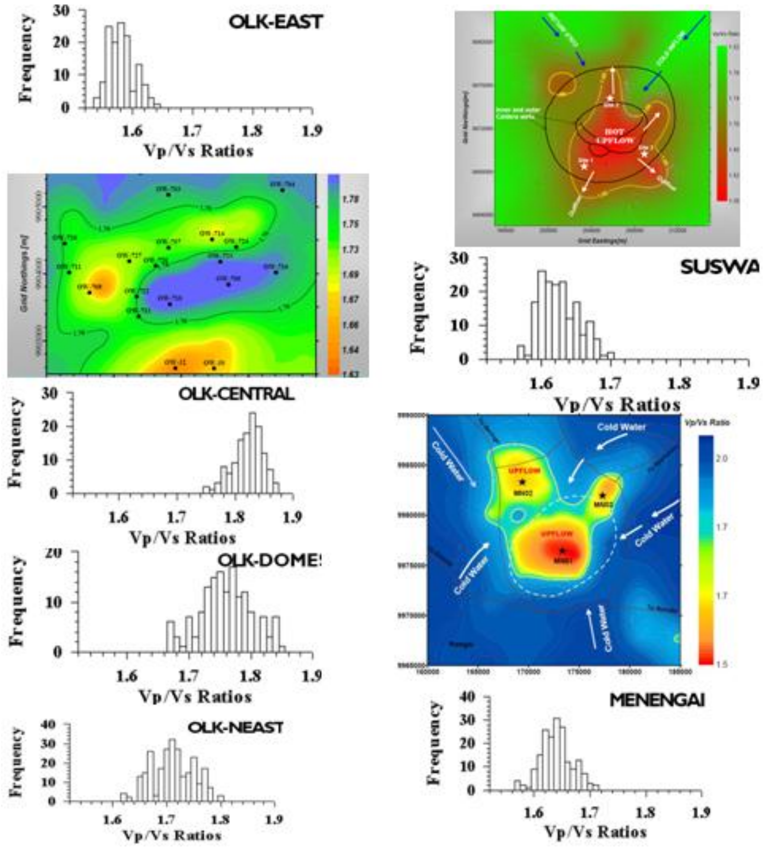


Fig 7. : P-wave and S-wave velocities ratios for Olkaria, Suswa and Menegai geothermal fields in Kenya Rift. Note a strong correlation of low velocity ratios with zones of high thermal anomalies (Simiyu, 1999)

3.0 CONCLUSION

Passive seismic technique is a powerful technique in geothermal studies. In the recent past, its application is being improved for tomography of the subsurface to infer the anomalies. The technique requires initial crustal structure in order to be able to constrain the earthquake solutions and fault geometry. In Uganda the technique was applied to study Buranga Geothermal prospect but covered small areas and geothermal resources seem to be extensive with deep seated heat source.

Previous studies indicate that the heat source is deep seated in all cases. The geothermal anomalies are not adequately resolved to warrant the drilling of deep wells.

The prospects need to be re-investigated using good Passive Seismic Network coverage for Seismic analysis. The results from such study can inform Gravity, TEM and MT techniques that can probe deeper to map the thermal anomalies for drilling. Passive seismic network -the proposed geophysical technique has proven to be the most successful in mapping the geothermal system for development into steam production making it a powerful diagnostic tool.

4.0 REFERENCES

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