Geophysical Research Abstracts
Vol. 21, EGU2019-7044, 2019
EGU General Assembly 2019

Using cluster analysis to understand patterns of volcano-tectonic seismicity in active continental rifts

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In active continental rifts, the volcano-tectonic setting leads to complex seismicity which has mixed-origins; with both tectonic processes and the migration of non-magmatic fluids triggering earthquakes within these regions. Therefore, our earthquake catalogue will consist of less- systematic swarms occurring synchronously with accelerating sequences and/or mainshock- aftershock sequences. When using earthquakes to forecast volcanic eruptions, we must be able to identify those events which are related to volcanic activity and one method of separating the volcanic events from the tectonic events is to use cluster analysis.

There are many different approaches that may be used to separate an earthquake catalogue into clusters. These clusters are defined as related events that have either been triggered by another in the same cluster, or those that have been triggered by the same underlying process, such as earthquakes generated during the intrusion of a dyke. Those which are found to be related are referred to as a 'cluster family'. However, the majority of current cluster methods have been developed using the Southern California Earthquake Catalogue (SCEC), a dataset which is predominately tectonic events that form mainshock-aftershock sequences. The exception is the CURATE method which uses the Central Volcanic Zone (CVZ) in the North Island of New Zealand, a contrasting dataset which will have swarm sequences. Both the SCEC and CVZ catalogue do not consist of mixed origin seismicity to the same extent as the Main Ethiopian Rift and hence current techniques do not correctly cluster and separate the volcanic and tectonic cluster families.

A new algorithm has been developed which uses the 2D spatial distribution of the inter-event times (IET) and inter-event distances (IER) to separate triggered, those events that are linked, and independent, background events. When IET is plotted against IER, two clear groups are seen on the graph, with one group consisting of events which are linked and the other consisting of independent events. We divide the two using an automated line plotting algorithm which removes the need for a priori assumptions in the clustering method, such as the time-distance windows and link strength seen in previous methodologies. From here, the linked events are sorted into their respective cluster families and the nearest-neighbour linked event is assigned to be the parent.

Having sorted the catalogue into its respective cluster families, further statistical analysis has been done to identify key differences between the tectonic and volcanic clusters. With forecasting volcanic eruptions in active continental rifts as the final aim, we can use the identifiers found to sort the clusters into their respective volcanic or tectonic origins. Furthermore, using real-time data, we can extend this to find only the earthquakes triggered by volcanic processes – excluding those which are tectonic in origin – and apply the well-established volcano forecasting methods to these.