Northern Tanzanian Earthquakes: Fault orientations, and depth distribution

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1.0 Introduction

Earthquakes in the continental crust deeper than about 20 km are rare, but recent studies in northern Tanzania suggest that in this particular location these deep earthquakes may be occurring (Nyblade & Langston 1996). In this project I investigate a cluster of earthquakes in northern Tanzania to better define the location of the earthquakes, in particular the depth at which these earthquakes occur, and the nature of the fault that ruptured to produce these earthquakes. The area of study is located in a region where there are no visible faults. There are only visible faults relatively close to the region. The results of this study will enhance our knowledge and understanding of the rheology of the continental crust and also the tectonic development of the rift system in east Africa.

Data collected between May 1994 and May 1995 from a network of 20 seismic stations set out across Tanzania have been used in this study. Seismograms from many earthquakes from this study have been analyzed using well-established methods for determining source locations and fault mechanisms.

In this report I begin with a background section that includes a brief review of the geologic setting of the area studied, and the previous work on the seismicity, and a full description of the problem addressed in this study. A section describing the data and methods follows, and in the last section the results of this study are presented.

2.0 Background

The Archean Tanzanian Craton, and the Proterozoic mobile belts surrounding it characterize the geology of Tanzania (Figures 1 & 2). The Tanzanian Craton is a very large solid portion of earth that lies mostly in Tanzania, and stretches north into Kenya and Uganda. It is made up mostly of granites, gneisses, and amphibolites (Nyblade, 2002). Some greenstone belts
lie in a region to the north. To the east of the Tanzanian Craton lies the Mozambique belt, the Ubendian belt to the southwest, and the Kibaran belt to the west. The Mozambique belt has mainly north to south strike slip faults (Nyblade, 2002), while the Ubendian and Kibaran belts consist of normal, or dip slip faults. These belts make up the East African rift system, which is made up of the Eastern and Western Rifts. The Western Rift is composed of the Kibaran and Ubendian belts, while the Mozambique belt makes up the Eastern rift (Figures 1 & 2) (Nyblade, 2002).

![Figure 1: Geology of Tanzania, East Africa. Red Circles are previous locations of events. Triangles show seismic station locations.](image)

3.0 Data & Methods

3.1 The Tanzanian Broadband Seismic Experiment

In May 1994 20 broadband seismic stations were deployed in two 1000-km long arrays spanning Tanzania from east to west and northeast to southwest. The space between the stations were anywhere between 50 to 200 km. The arrays were placed so they could best record the
propagation of surface waves throughout East Africa. The sites crossed the craton and the mobile belts that surround the craton. The seismic stations consisted of broadband sensors, data loggers and a one-gigabyte hard drive. The stations went online June 10, 1994, and were set to record three different types of data streams, a one sample per second continuous stream, a twenty sample per second continuous stream, and a forty sample per second phantom trigger steam that only recorded event triggers (Nyblade et al., 1996).

**3.2 Methods**

The process of determining the depth of the source of an earthquake, and discovering the nature of the fault begins with picking the arrival times for the primary and secondary waves (Figure 3). The process for picking the primary and secondary wave arrival times involved using a program called SAC, Seismic Analysis Code. The program displays a seismogram for a particular station and allows the user to place markers approximately where the primary and secondary waves begin. After the arrival times for the primary and secondary waves have been picked the location program Hypoellipse was used to locate the position and depth of the
earthquake. Hypoellipse uses the primary and secondary wave picks from the Seismic Analysis Code program and creates a best-fit line for each. An initial location is determined by where the two lines converge, and the program then iterates that point to improve the location.

Figure 3: Example seismogram from an actual event. A=Primary wave beginning T1=Secondary wave beginning

Determining the fault orientation (focal mechanisms) requires different programs. The first of two programs uses the location provided by the Hypoellipse program and the primary wave picks provided by the Seismic Analysis Code to calculate and produce a synthetic waveform to compare to the waveform of the actual data. We input different source depths for the program to run for every station. The waveforms were displayed together, and we analyzed the two waveforms and discarded those that were not similar. The program also produced a file that told us the error for every depth. The error is calculated by calculating the mismatch between the actual waveforms and the synthetic waveforms (Figure 4). The goal was to get the
error under 0.5; to do this we had to continue discarding the waveforms that did not compare well to each other (Brazier et al., 2005)

![Waveform Comparison](image)

**Figure 4: Example comparison of actual wave waveforms (top) and synthetic waveforms (bottom) Event #1**

When an error of less than 0.5 was achieved one last program was run to create the focal mechanisms, or “beach balls” that represent the focal mechanism, and to figure the actual depth. The orientation of the fault is determined by the way the “beach ball” looks. If a certain portion of a particular region is shaded, then a certain type of fault is being displayed. The shaded regions of the “beach ball” vary with the type of fault that is being displayed. The focal mechanisms are then placed on a graph where the x-axis is depth and the y-axis is the error. The correct depth for the earthquake is determined by the “beach ball” with the lowest error.

4.0 Results and Discussion

4.1 Location
The cluster of events that were investigated is located at latitude and longitude. Within this cluster we found earthquakes occurring at a variety of depths (Figure 5). Most of the events occur between 10 and 20 km, but I was able to find some earthquakes occurring deeper than 20 km. When comparing my locations to the locations from previous investigations, we have found that my improved locations are not as widely dispersed, and occur in more centralized areas.

I have been able to locate earthquakes ranging from the surface of the crust down to 40 km deep. I located close to 80 earthquakes and about 10% of these have occurred lower than 20 km. The deepest event I was able to locate was at 40 km, but after using the focal mechanism to improve the depth, it was actually 29 km deep. Continuous depth distribution indicates movement along a buried fault; therefore the prospect of a volcano can be dismissed.

Figure 5: Latitude and Longitude versus depth.
Figure 6: White circles represent previous located events; black circles represent events located in this study. Focal mechanisms included for certain events.

We also discovered the orientation of the faulting that is occurring (Figure 7). Of the events I was able to obtain a focal mechanism for most of them, and they have an oblique dip-slip movement to them. The events were not quite strike-slip, but they were not exactly normal faulting either.
Figure 7: Focal mechanisms for events 1(e), 2(c), 3(b), 4(a), 9(b)
5.0 Conclusion

Approximately 10% of the earthquakes located occurred lower than 20 km, with the deepest at 29 km. Most models describing where earthquakes occur indicate that earthquakes should not occur this deep in the crust. Either the models describing the depth distribution of seismicity that exist now should be reevaluated, or this particular area in Tanzania is anomalous with respect to continental crust in other places (Nyblade & Langston 1996). A possibility of a magma chamber close to the area is not likely due to the even distribution of events through the earth’s crust, therefore a new fault is likely forming. More research is required on these earthquakes to confirm these results.
References Cited


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