

The Depth Distribution of Seismicity at the Northern End of the Rwenzori Mountains: Implications for Heat Flow in the Western Branch of the East African Rift System in Uganda

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Abstract. Data from a six-month deployment of seismic stations around the northern end of the Rwenzori Mountains have been used to investigate the depth extent of seismicity and its implications for heat flow in the Western Branch of the East Africa Rift System in Uganda. Previous seismicity studies of the Western Branch in Uganda show earthquake nucleation at depths greater than or equal to 40 km suggesting that heat flow from the rift is not elevated. However, heat flow elsewhere in the Western Branch (e.g., western Tanzania and Lakes Kivu and Tanganyika) is elevated, similar to the elevated heat flow in the Eastern Branch of the East African Rift System in Kenya.

Keywords: East Africa Rift System, Western Branch, seismic stations

1. Introduction

Welcome to The 2010 International Conference on Chemical Engineering and Applications (CCEA 2010). The Conference is a primary international forum for scientists and technicians working on topics relating to Chemical Engineering and Applications. It will provide an excellent environment for participants to meet fellow academic professionals, to enhance communication, exchange and cooperation of most recent research, education and application on relevant fields. It will bring you new like-minded researchers, fresh idea. It also provides a friendly platform for academic and application professionals from crossing fields to communication together. To investigate further the depth extent of seismicity in the Western Branch, seismological data were collected and analysed to obtain accurate hypocenters using both standard and double difference location algorithms. Focal mechanisms were also obtained to place constraints on the local stress regime. Results show that seismicity is concentrated along the major border faults of the Rwenzori horst, suggesting an eastward dip on the Ruimi-Wasa Fault and a northwestward dip on the Toro-Bunyoro Fault. Fault motions are predominantly normal, with possible strike slip motions between the Ruimi-Wasa and Toro-Bunyoro Faults. The number of earthquakes increases with depth, peaking at 16 km and falling sharply by 22 km. Strength envelope models indicate that heat flow in the range of 54 mWm^{-2} to 66 mWm^{-2} is required to explain this result. A heat flow of 54 to 66 mWm^{-2} is similar to heat flow in other mobile belts in East Africa away from major rift valleys, and therefore heat flow around the Rwenzori Mountains does not appear to be elevated. This finding does not preclude the possibility of a deep seated (i.e., mantle) thermal anomaly beneath the rift, which may not have had sufficient time to reach the surface.

In this study, data from a six-month deployment of seismic stations around the northern end of the Rwenzori mountains have been used to investigate the depth extent of seismicity and its implications for heat flow from the Western Branch of the East African Rift System (EARS) in Uganda. Previous seismicity studies of the Western Branch in Uganda show earthquake nucleation at depths greater than or equal to 35

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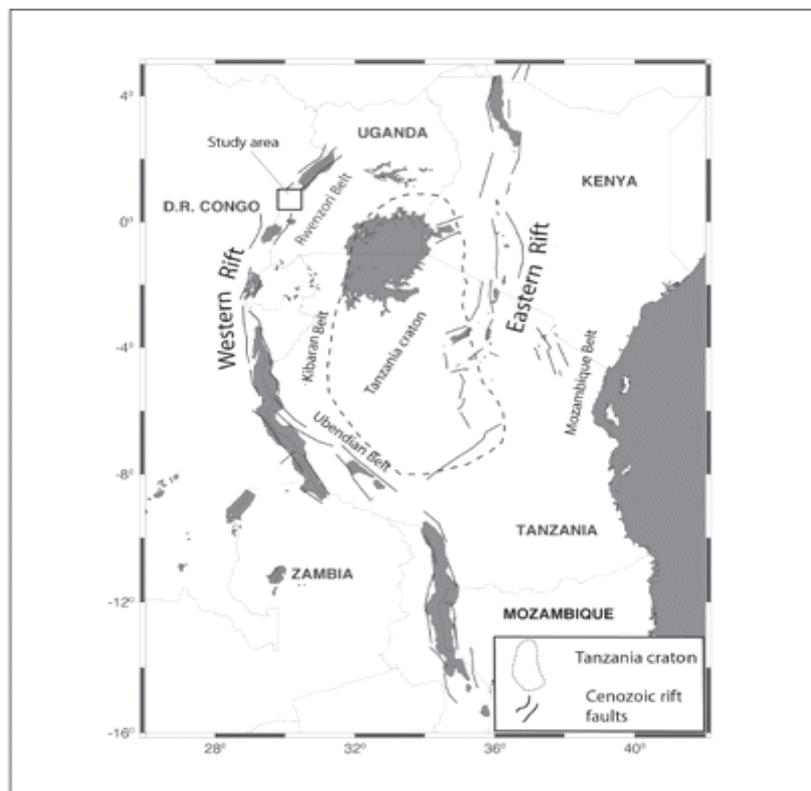
km (Albaric et al., 2008; Maasha, 1975; Ochman et al., 2007), suggesting that heat flow from the rift is not elevated. The average heat flow in Proterozoic mobile belts in East Africa away from the rift valleys is 63 mWm^{-2} (Nyblade, 1997), and Nyblade and Langston (1995), using a rheological model for the crust with a brittle upper crust and ductile lower crust (Brace and Kohlstedt, 1980; Byerlee, 1968; Ranalli 1987), showed that for a heat flow of 63 mWm^{-2} , brittle deformation, and therefore seismicity, can extend to crustal depths of ~ 30 to 35 km .

However, heat flow elsewhere along the Western Branch is elevated ($\sim 109 \text{ mWm}^{-2}$ in western Tanzania; 73 mWm^{-2} and 67 mWm^{-2} in Lakes Kivu and Tanganyika, respectively; Nyblade et al., 1990), similar to the elevated heat flow (100 mWm^{-2}) in the Eastern Branch of the EARS in Kenya (Wheildon et al., 1994). And for a heat flow of $\sim 100 \text{ mWm}^{-2}$, it is unlikely that brittle deformation and therefore seismicity would extend much deeper than about 10 km .

To investigate further the depth extent of seismicity in the Western Branch, seismic data were collected and analysed to obtain accurate hypocenters from the northern part of Rwenzori Mountains. Events were located using both standard and double difference algorithms, and focal mechanisms were obtained to place constraints on the local stress regime. Results show that seismicity, which is concentrated along the major border faults of the Rwenzori horst, extends to lower crustal depths. This result is analysed using strength envelope models to place new constraints on heat flow from the Western Branch in Uganda.

2. Background information

The EARS is a classic example of an active continental rift and represents the incipient stages of continental break up (Fairhead and Stuart, 1982). The Eastern Branch of the EARS extends from the Afar Depression in Ethiopia, through Kenya and into Tanzania (Gregory, 1921; Sikes, 1936) (Figure 1). The Western Branch of the EARS extends from southern Sudan through western Uganda, Rwanda, Burundi and Tanzania along the boundary with the Democratic Republic of Congo (Figure 1).



View larger version:

Figure 1. Tectonic map of East Africa showing the major Precambrian terrains and rift faults of the Cenozoic East African Rift System. The small box in western Uganda shows the location of this study.

The EARS formed within the Precambrian basement of East Africa, which consists of the Archean Tanzania craton in the centre of the region surrounded by a number of Proterozoic mobile belts (Figure 1). The formation of the two branches of the EARS may have begun at different times but both branches experienced significant tectonic activity in the late Cenozoic (Chorowicz, 2005; Ebinger, 1989; Maasha and Molnar, 1972).

The main geological feature within the study area is the Rwenzori Mountains, a large horst block about 120 km long and 65 km wide. The mountain range consists of late Archean and early Proterozoic basement rock uplifted 5,000 m above sea level (Tanner, 1973). The western side of the mountain range is bounded by the Bwamba Fault, a steeply dipping normal fault (Ebinger, 1989). The eastern side is more gradual, except for the north-northeast trending Ruimi-Wasa and Toro-Bunyoro Faults, which define the narrow northern nose of the mountain range (McConnel, 1972) (Figures 2 and 3). The Pleistocene-Holocene Kicwamba volcanic field lies just east of the Ruimi-Wasa Fault. Pleistocene-Holocene sediments, locally known as the Kaiso-Kisegi beds, occupy the rift valley floor in the Semuliki basin, with thicknesses reaching 4000 to 6000 metres (Figures 2 and 3).

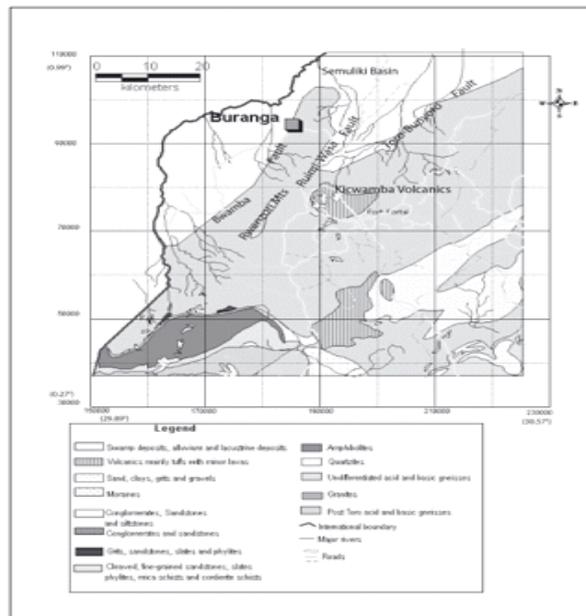


Figure 2. Geology of northern Rwenzori Mountains adapted from an open report from the Department of Geological Survey and Mines, Uganda.

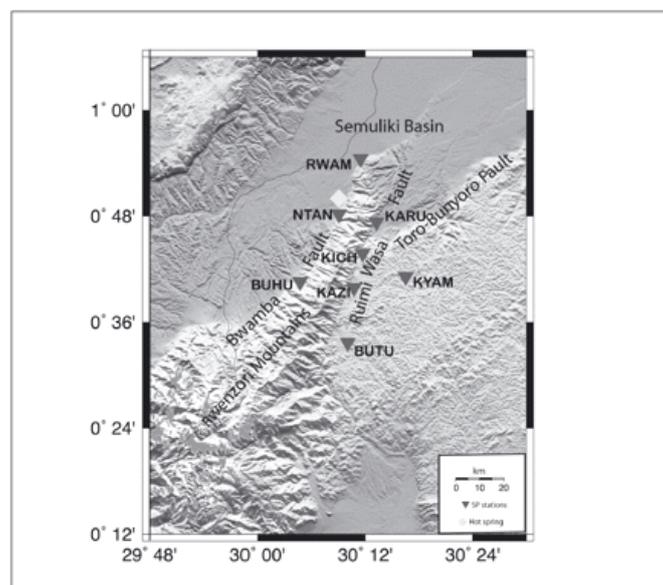


Figure 3. Topographic map of the study area showing major faults, the locations of seismic stations, and the Buranga hot spring. The background topography is from 30 sec SRTM data.

A previous seismicity study in the region was conducted by Maasha (1975), which employed four short period seismographs deployed at 28 different sites throughout the Rwenzori Mountains. The sites occupied at any one time formed a quadrangle. Distances between adjacent stations ranged from 5 to 20 km, and the stations were run for 4 to 20 days at each site. Fault plane solutions from this study indicate that the Rwenzori Mountains are bounded by normal faults (Maasha, 1975). The seismicity recorded was mainly associated with the Ruimi-Wasa Fault. Events located beneath the mountain range extended to depths of 25 to 40 km.

Seven moderate earthquakes in the region have been studied in detail using teleseismic data (Shudofsky, 1985; Shudofsky et al., 1987; Upcott et al., 1996). Earthquake focal mechanisms show that the rift faults bordering the Semuliki basin and the southern end of the Lake Albert rift valley are oriented nearly north-south or northeast-southwest. An exception to this general strike direction is the north-northwest to northwest striking Kisomoro Fault, along which a M 6.2 earthquake occurred in February 1994. Thus, the region appears to be under a state of east-west or northwest-southeast extension.

3. Results

The distribution of epicenters from HYPOELLIPSE . The seismicity pattern correlates with the Ruimi-Wasa and Toro-Bunyoro Faults on the eastern side of the Rwenzori Mountains (Figure 3¹). The greatest concentration of events is found along the Ruimi-Wasa Fault south of station BUTU. The seismicity to the west of the Rwenzori Mountains falls within the Semuliki Basin rather than along the Bwamba Fault. A cluster of events is seen north of the Buranga hot spring at the northern end of the Bwamba Fault.

4. Summary

In summary, seismicity at the northern end of the Rwenzori Mountains correlates well with the major border faults, suggesting an eastward dip on the Ruimi-Wasa Fault and a northwestward dip on the Toro-Bunyoro Fault. Fault motions are predominantly normal, with strike slip motions in between the Ruimi-Wasa and Toro-Bunyoro Faults.

The observed depth distribution of seismicity peaks at 16 km and falls off sharply by 22 km. Strength envelope models show that heat flow in the range of 54 mWm^{-2} to 66 mWm^{-2} is consistent with the depth distribution of seismicity. This heat flow range is similar to heat flow in other mobile belts in East Africa away from major rift valleys and is lower than the high heat flow ($\sim 70\text{--}100 \text{ mWm}^{-2}$) reported for the Eastern Branch in Kenya and the Western Branch in Tanzania. A heat flow of 54 to 66 mWm^{-2} is also consistent with average heat flow from Precambrian terrains globally. Therefore, heat flow in the Western Branch around the northern nose of the Rwenzori Mountains is not elevated.

5. Acknowledgments

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6. Footnotes

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