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Architecture and evolution of the Kivu rift within the western branch of the East African rift system: Implications for seismic hazard Assessment

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Abstract. The Kivu rift, in the middle of the western branch of the East African Rift system, has a particular setting within the African continent. It represents the most recent (late Cenozoic) evolution of the Mesoproterozoic Karagwe-Ankole Belt of the Great Lakes Region in Central Africa. Its architecture and evolution have been profoundly influenced by the tectonic framework inherited from the Kibaran and Pan-African orogenic events. In order to build a new detailed seismic hazard map, we have compiled regional geological and neotectonic maps and re-examined the tectonic evolution, investigated the brittle structures and determined the paleo-stress field evolution. The Kivu rift appears heterogeneous and complex. It probably started as an isolated segment that progressively linked with the adjacent segments of the Western Rift Branch. Its architecture and structural inheritance are reflected in the seismic activity and the current stress field. This results in a marked lateral variability of the Gutenberg-Richter parameters and seismic hazard estimates.

Keywords: East African Rift, Kivu Rift, Tectonic structure, Neotectonics, Seismic hazard assessment

1 Introduction

The Kivu rift, in the middle of the western branch of the East African Rift system, has a particular setting within the African continent. It represents the most recent (late Cenozoic) evolution of the Mesoproterozoic Karagwe-Ankole orogenic belt of the Great Lakes Region in Central Africa (Fig. 1). Its architecture and evolution have been profoundly influenced by the tectonic framework inherited from the Kibaran and Pan-African orogenic events.

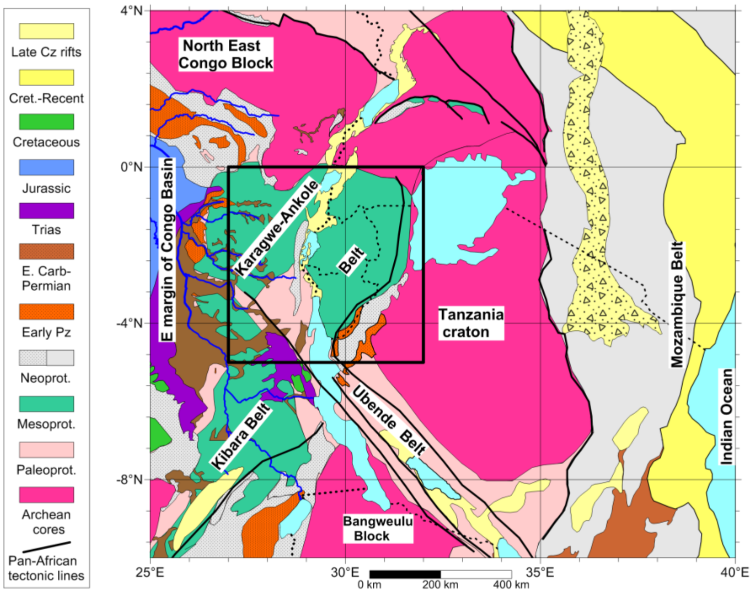

Fig. 1. Location of the Kivu rift region within the Mesoproterozoic Karagwe-Ankole orogenic belt. It forms the central part of the western branch of the East African Rift System (from [2]).

2 Geological and neotectonic evolution

In order to build a new detailed seismic hazard map for the Kivu rift region, we first compiled regional geological and neotectonic maps of the region surrounding the Kivu rift and re-examined the tectonic evolution, investigated the brittle structures and determined the paleo-stress field evolution.

The neotectonic setting, related to the evolution of the late Cenozoic rifting has been highlighted by mapping the fault pattern from combined interpretation of the topography from the NASA Shuttle Radar Topography Mission (SRTM) at 30m resolution, existing geological maps and additional field work [1]. We also added the known thermal springs, quaternary volcanic centers and seismic epicenters [2]. The Kivu rift appears heterogeneous and complex, influenced by pre-rift tectonic heterogeneities (faults and shear zones, shown in black in Fig. 2).

It probably started as an isolated segment that progressively linked with the adjacent segments of the Western Rift Branch. Two dominant fault trends have been recognized: an older NE-SW trend (in yellow in Fig. 2) and a younger N-S trend (in red). In the Kivu rift basin, the two directions are superimposed while south of it, the older NE-SW trend formed the Kamituga rift which is now abandoned (but still seismically active) and was connected to the central part of Lake Tanganyika by the Namoya-Kalemie NW-SE depression. More recently, probably in the Quaternary, the active rift migrated eastwards to connect directly the northern tip of the Kivu basin with the northern extremity of the Tanganyika rift basin (Fig. 2). Its architecture and structural inheritance are reflected in the seismic activity and the current stress field.

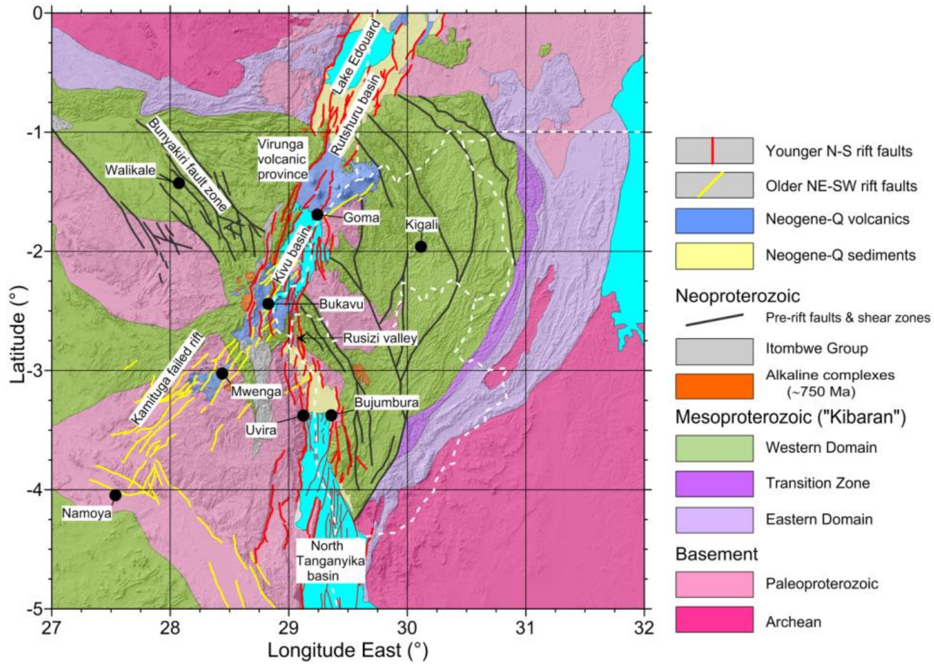

Fig. 2. Geology and neotectonics of the Kivu rift region, showing the older NE-SW rift trend with the Kamituga failed rift branch between Bukavu and Namoya, and the new N-S rift rend linking the Kivu basin to the North Tanganyika basin trough the Rusizi valley (from [2]).

3 Seismic hazard evaluation

The detailed methodology used for the seismic hazard evaluation is explained in [2] and we will here only summarize the most important points. To evaluate the seismic hazard for the Kivu rift region, we compiled a regional seismic catalogue based on the ISC reviewed earthquake catalogue, completed by data from BUL (until 1990), EAF (since 1991), ENT, NAI, PRE, LSZ, CGS, NEIC and GSHAP catalogues, spanning 126 years, with one thousand and sixty eight (1068) events. The magnitudes have been homogenized to Mw and aftershocks removed. It was subdivided into four sub-catalogues with a total of seven hundred and seventeen (717) data from 1931 to 2015 with various magnitudes of completion. The catalogue used for the seismic hazard assessment contains three hundred and fifty nine (359) data for the homogeneous part with a completion magnitude Mw= 4.4. from 1956 to 2015 (60 years) (Fig. 3).

The region of the Kivu rift was subdivided into seven seismic source areas based on the regional geological structure, neotectonic fault systems, basin architecture and distribution of thermal springs and earthquake epicentres (Fig. 3).

The seismic hazard map (Fig. 3) was computed using the Gutenberg-Richter seismic hazard parameters determined by the maximum likelihood method and existing attenuation laws with the Crisis 2012 software (details in [2]). The PGA values obtained (475 years return period) are higher than previous estimates [3]. They vary laterally in function of the geological setting, being highest in the non-magmatic part of the rift (Southern Lake Kivu and Rusizi zones), intermediate in the volcanically active Virunga zone, and lowest in the rift flanks.

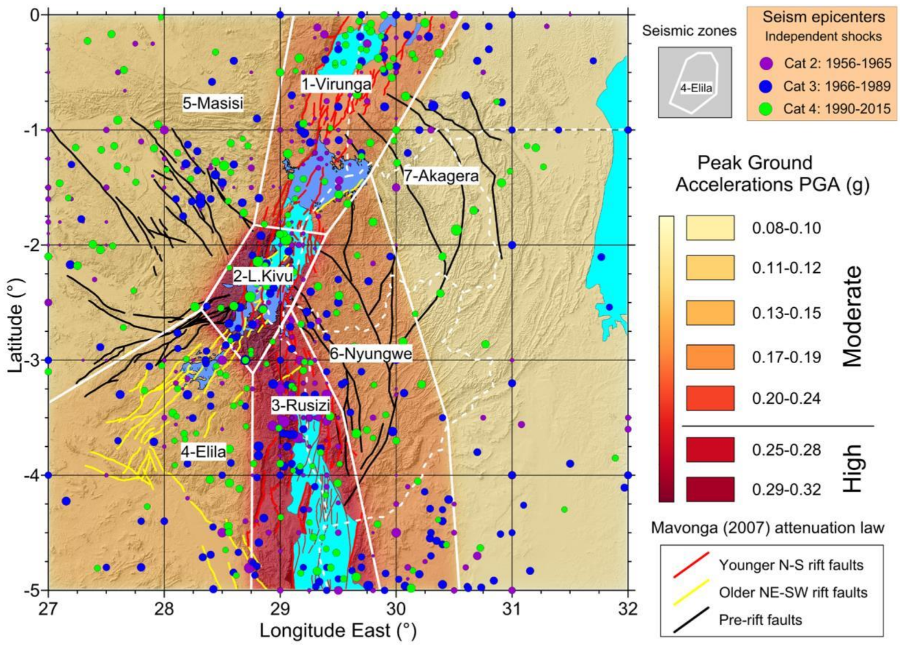

Fig. 3. Seismic hazard map.

4 Discussion/conclusion

Compared with the previous estimations, our model provides a finer seismic zonation using a longer earthquake catalogue, but it can still be improved using more realistic attenuation laws in a logic tree approach. We observed a marked lateral variability of the Gutenberg-Richter parameters and seismic hazard estimates which reflect the heterogeneity of the rift and its location within the African continental plate. The same region has been incorporated in the new seismic hazard model for the East African Rift [4], overlying five (5) different seismic zones.

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