Solid Earth Discuss., 4, C258–C268, 2012
www.solid-earth-discuss.net/4/C258/2012/

Solid Earth Discussions

SED

4, C258–C268, 2012

Interactive Comment

Interactive comment on "Seismicity at the Rwenzori Mountains, East African Rift: earthquake distribution, magnitudes and source mechanisms" *by* M. Lindenfeld et al.

M. Lindenfeld et al.

lindenfeld@geophysik.uni-frankfurt.de

Received and published: 29 June 2012

We thank the referees for their constructive comments and critical remarks on our paper.

A) Comments to referee 1:

Referee 1: As authors claimed, the depth distribution of earthquakes shows clear maximum of activity at 16 km in Fig. 7. However, this depth of 16 km corresponds to a velocity jump in assumed velocity model to relocate earthquakes (Table 1). Horizontal concentrations of earthquakes near a velocity boundary are frequently caused by an insufficient coverage of seismic network. Indeed, sharp concentrations of earthquakes are clear at transects C1-C2, D1-D2 and E1-E2, where the seismic network is sparse. Thus, I wonder that the horizontal concentration of earthquakes at 16 km depth (velocity boundary), that is interpreted to be a stripe, is apparent due to insufficient coverage of the seismic network. It is needed to check how the depth-distribution of hypocenters changes if you employ different sets of velocity models including a simple half-space velocity model.

Reply: We agree that discontinuities of the velocity model may induce earthquake concentrations at the depth of the velocity jump, especially in regions with spare station coverage. For this reason we have checked the stability of our locations by relocating the events with as simple constant velocity model. The start depth was systematically increased from 5 km to 25 km with an increment of 5 km and the solutions with minimum RMS residual times were finally selected. The resulting hypocentral depth distribution confirms the previous locations (Fig.1). The maximum of seismicity is still in 14-16 km depth. For this reason we are convinced that the hypocentral depths are reliable, at least in the central region of our network were most of the presented vertical section are situated.

Referee 1: You discuss that the seismicity seems to trace the upper and lower edge of a low velocity zone (LVZ) that was identified by receiver function inversion in Figure 9 (E1-E2). Show a histogram of travel-time differences between S and P-waves for the upper and lower edge seismicity at almost the same epicentral distance. The histogram having two peaks against depth strongly supports the author's model.

Reply: As suggested we derived a histogram of differential P and S travel-times at stations in almost the same epicentral distance. For this purpose we selected a subset of events located at the southern part of profile E, where we observe a clear separation of seismic activity in 15 km and 20-25 km depth. Closer inspection of the dataset revealed that most of the seismograms were recorded at epicentral distances between 20 km and 25 km and therefore the ts-tp statistic was calculated for this distance range. The histogram (Fig.2) clearly indicates two maxima: a large one at ts-tp=3.4 s, corresponding to events in about 15 km depth and a smaller one at ts-tp=4.0 s, corresponding to the deeper events. A rough estimate for an epicentral distance of 23 km yields ts-tp = 3.4 s for a focal depth of 15km, and ts-tp = 4.0 s for focal depth of 23 km, assuming vp = 6.0 km/s and vp/vs = 1.74. This estimate agrees well with the two peaks of the observed ts-tp histogram.

Referee 1: Along C1-C2 section, there is no significant change of Moho depths between NGIT and KASS (25 km and 24 km, respectively), while the depth distribution of seismicity shows lateral change corresponding to the rift system. It is possible to reinterpret the Moho depth at NGIT, as well as SEML? If no, why can you re-interpret the Moho-depth at SEML? Detailed explanations about the re-interpretation of Moho depth should be added.

Reply: Moho depths were derived by Wölbern et al (2010). The discontinuities are identified by clear signals in teleseismic receiver functions, as described by Wölbern et al. (2010). The re-interpretation at SEML was done by Wölbern (pers. comm.) on the basis of additional data. The Reviewer states that the Moho depth *between* NGIT and KASS is constant, whereas seismicity shows lateral variation. However, Moho depths were determined directly *beneath* stations NGIT and KASS, and there is no information about crustal thickness between these stations. All profiles show a strong lateral heterogeneity of the seismicity and in several regions we observe large variation of Moho depths within short distances (compare SEML and KABE on Profile A, or SEMP and ITOJ on Profile B). Therefore, there is no discrepancy between Moho depths and seismicity on profile C. It is conceivable that the Moho follows the seismicity between NGIT and KASS, however we have no data to proof this assumption.

Referee 1: To determine focal mechanisms using SV/P amplitude ratios, it is better to take some station corrections of SV/P amplitude ratios into account (e.g., Hardebeck and Shearer, 2002). Do you include the station correction terms?

Reply: The basis of all presented fault plane solutions are P-polarities. SV/P – ampli-

SED

4, C258–C268, 2012

Interactive Comment

tude ratios were only used to improve the less-well constrained P-solutions. We did not apply station corrections because there is not yet enough information on local site conditions. However, we picked the P and S-amplitudes strictly on the same seismogram component (Z) rather than using vertical P-amplitudes and horizontal S-amplitudes. This technic should minimize the influence of site effects. Hardebeck and Shearer (2002) systematically investigate the influence of the velocity model and variations in hypocentral depth on the fault mechanisms that were derived by P-polarities. We did a similar check for a small sample of events by shifting the hypocentral depth within $\pm$ 3 km which is a typical value for the vertical location error. There were no significant deviations from the initial solutions.

Referee 1: The authors documented that 2% of the analyzed events are pure thrust faults. Where are they located in the rift- system? Are they clustered?

Reply: In total there are 7 events with thrust faults. They are not clustered. All are east of the Rwenzori range. Five of them are located between 0.0° and 0.4° latitude.

Referee 1: Interestingly, a similar little seismicity in the top upper curst has been reported from the ancient rift system buried beneath the thick sedimentary basin (Kato et al. 2009). Thick sedimentary layer may show aseismic deformation, resulting in little seismicity in the top upper crust. The seismicity in Rwenzori Mountains area is similarly argued to relate to rift structure.

Reply: We will include this reference in the revised version of the manuscript.

Technical corrections:

Referee 1: State the location errors for horizontal and vertical directions independently.

Reply: Errors are slightly larger than horizontal errors, we will list them independently.

Referee 1: What is meaning of “a crustal root”? Please explain it in the text. It is better to add some discussions about the crustal root.

SED

4, C258–C268, 2012

Reply: We will add some discussion concerning the "crustal root".

Referee 1: In each cross-section in Figure 9, add horizontal locations of the rift valley and rift shoulders, to make reader easily identify these locations.

Reply: We will modify Figure 9 accordingly.

B) Comments to referee 2:

Referee 2: The title should include the period during which the seismicity has been analyzed: “Seismicity from February 2006 to September 2007 at the Rwenzori Mountains, East African Rift: earthquake distribution, magnitudes and source mechanisms.

Reply: We will modify the title accordingly.

Referee 2: Dataset. Presenting a diagram reporting the statistics of the number of earthquakes [by magnitude range] recorded in function of the number of seismic stations [and, or measured P- and S-waves] could help the reader to have a better idea of the global dataset quality and importance.

Reply: We have derived a diagram as proposed by the referee, presenting the number of recording stations for 4 different magnitude classes (Fig.3). As expected the number of evaluated stations increases with the size of an earthquake. The smallest events (ML < 1.0, grey histogram) are located with typically 4-5 stations. Events with magnitudes from 1.0 – 2.0 (red) are located by up to 13 stations. For the strongest events (green and blue) we could use up to 20 stations. Only in few cases recordings of the complete network (27 stations) were available.

Referee 2: The authors mentioned the occurrence of a ML=5.1 earthquake. It should be clearly identified on figures 2, 8 and 10.

Reply: We will mark the epicenter of this event on these maps.

SED
4, C258–C268, 2012

Referee 2: Magnitude distribution. The magnitude frequency distribution is used by the authors to formulate a hypothesis on the cause of the seismic activity. The computed b-value [1.1] is very close to the one for typical tectonic earthquakes. Therefore, I found the argument for "magmatic processes" very weak. First, the authors should provide a good analysis on the b-value uncertainty. Secondly, I 'am not against formulating the hypothesis "magmatic processes", but it should be discussed more carefully and in parallel with other scientific evidence(s) if possible.

Reply: The b-value was computed by a least squares algorithm. With a value of 1.1 it is indeed very close to the one for tectonic events and not a significant indication for magmatic processes. In the revised version we will state that this b-value of 1.1 does not allow to discriminate between tectonic and magmatic processes.

Referee 2: Source mechanisms. I 'am not convinces that "the combination of P-polarities with SV/P ratios enables to derive more reliable fault plane solutions". The addition of a more continuous probability density function will allow defining a minimum of the "misfit" function, but the reliability of the solutions will be given by the extension of the fiducial regions on the diagram. Therefore, for this issue, I also follow the comment of reviewer 1 on the necessity to be careful to use this kind of information. I recommend computing the mechanisms only with the SV/P ratios and P-first motions for the stations for which the ratio is available. If parts of the minimums of the misfit function are coherent with the one considering only the whole P-waves first motion dataset, the combined solution will have some sense. If it is not the case, the combined solution has no real sense.

Reply: We are aware that the use of amplitude ratios to construct fault mechanisms bears some problems. The FOCMEC program that we used to determine the solutions does not supply a measurement of the data "misfit". However, it is possible to allow for errors of P-polarities and amplitude ratios. In all cases we did not allow for any P-polarity but we set a larger tolerance for the amplitude ratio error which is defined as the deviation of the measured ratio from the theoretical one. This implies that the major constraints for an individual focal mechanism come from the P-polarities whereas the amplitude ratios have a weaker influence. To estimate the reliability of the method we compared these results with the mechanisms obtained with P-polarities alone. The distribution of source types as presented in Figure 13 of the discussion paper is nearly the same for both methods. Using only P-polarities leads to the following results (in brackets are the numbers for the combination of P-polarities and SV/P ratios applied to the same database):

Solutions in total: 197 (304). Pure normal faulting: 60% (49%). Normal faulting with strike slip component: 19% (23%). Pure strike slip: 3% (8%). Pure reverse faulting: 3% (2%). Reverse faulting with strike slip: 2% (4%). Odd mechanisms: 14% (14%).

We think that this comparison shows that the use of amplitude ratios does not cause a systematic bias on our results, but it enables us to derive more solutions than with P-polarities alone.

Referee 2: The authors mentioned that they were able to determine a focal mechanism for 40% of the selected earthquakes with P-wave first motions. They should give some examples, including the mechanism of the recorded ML=5.1 earthquake.

Reply: If it is considered as useful we would include more examples like that of Figure 12 in the final version. However, it was not possible to derive the mechanism of the ML=5.1 event. At that time (May 2006) only 7 stations of our network were working – not enough to calculate a stable fault plane solution. However, the HRVD CMT solution indicates normal faulting with the orientation of the tension-axes similar to those observed in most of our fault-plane solutions (Fig.4).

Interactive comment on Solid Earth Discuss., 4, 565, 2012.

SED
4, C258–C268, 2012

Interactive Comment

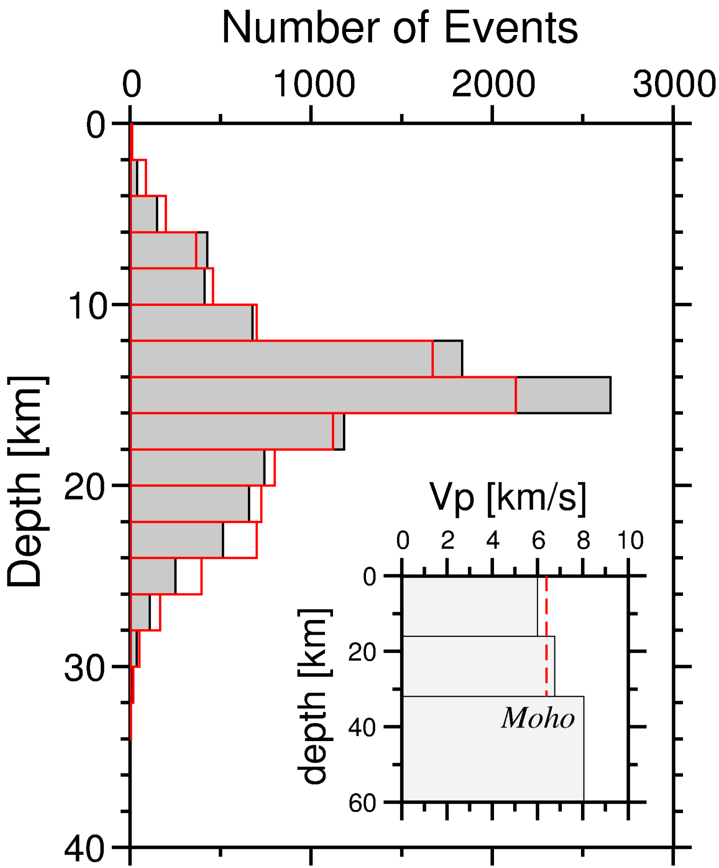

Fig. 1. Hypocentral depth distribution derived from the BRAM model (grey bars) and from a model with constant P-velocity within the crust (red lines).

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

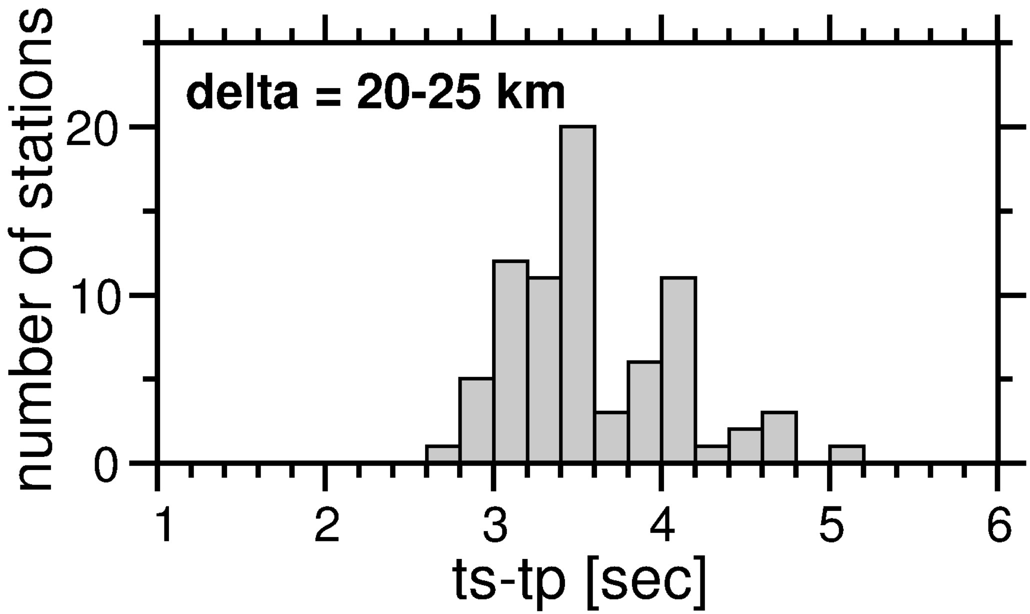

Fig. 2. Histogram of S-P travel-time differences of events on profile E observed at stations with epicentral distances between 20 and 25 km.

SED
4, C258–C268, 2012

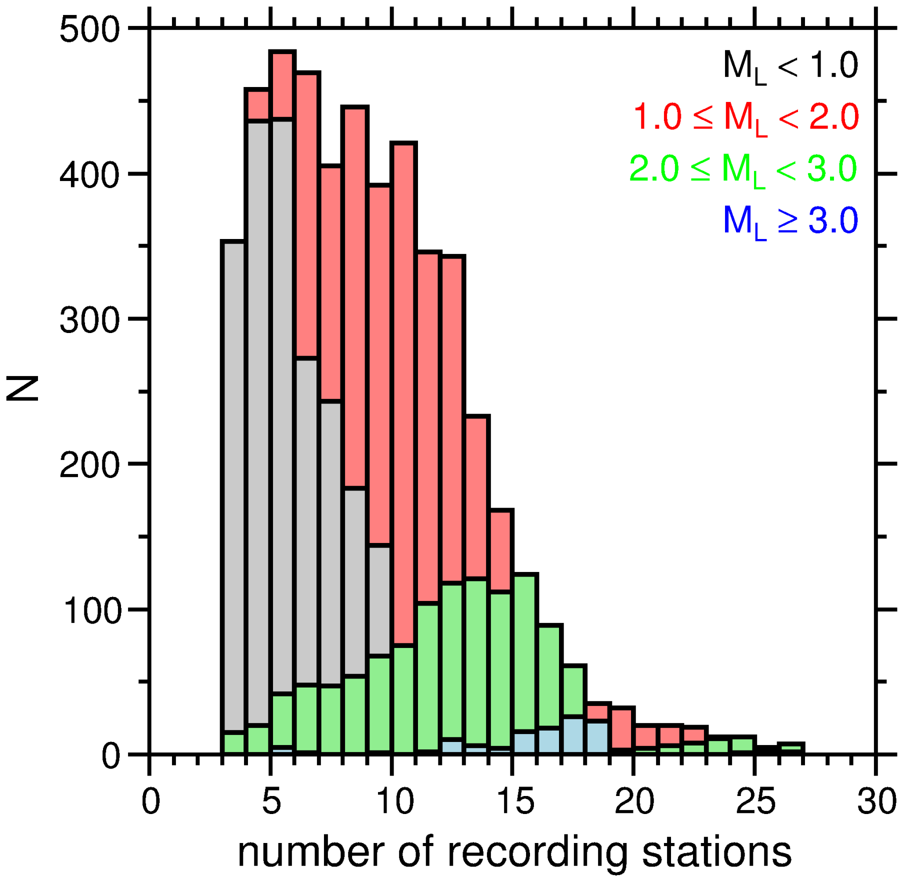

Fig. 3. Histogram of the number of stations used to locate an event, plotted for 4 different magnitude classes.

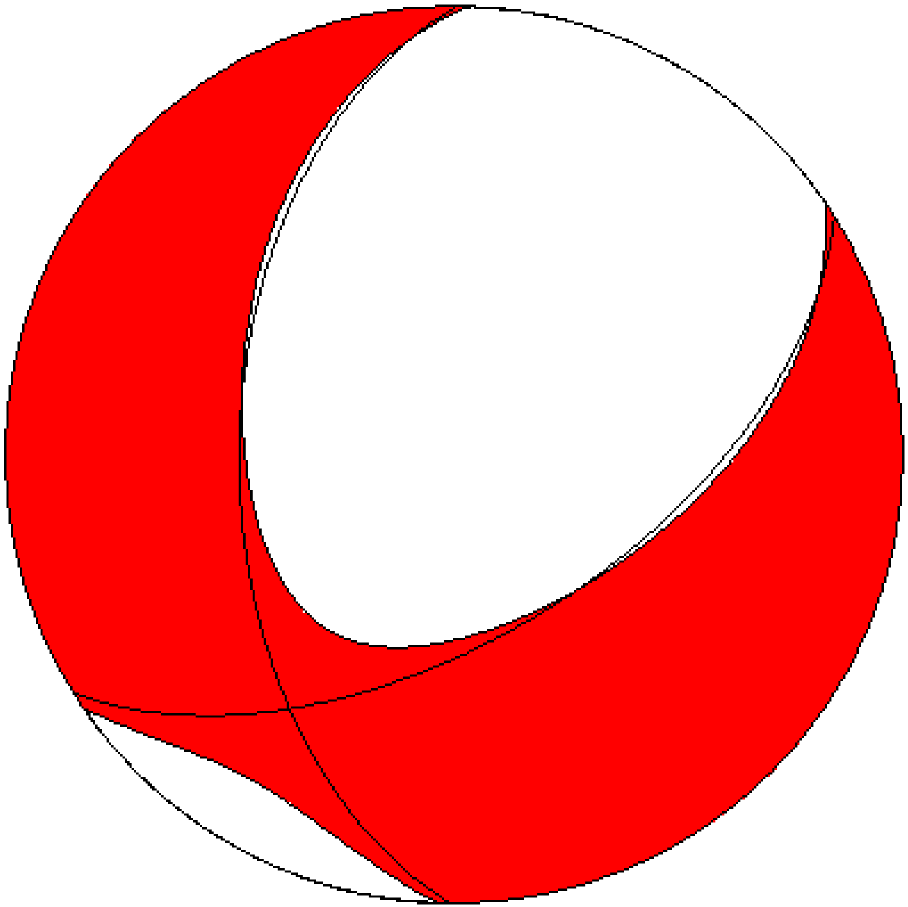

Fig. 4. HRVD CMT solution for the ML=5.1 event of 2006/05/29 15:30:36.12 (taken from ISC Bulletin).