Distribution of faults and volcanic centers in the early stages of continental breakup: Natron Basin, Tanzania

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1 Introduction

We present preliminary findings of a study characterizing faults and volcanic products in the 1 Ma Natron Basin. The nature and behavior of these faults has implications for how strain is accommodated during a continental breakup and will define insights into the evolving contributions of magmatic and tectonic processes during an early-stage rift. The current study looks to address:

1) The distribution and nature of faulting
2) Apportion relationships between faults and volcanic centers
3) The distribution of observable (i.e., fault throw) vs. sub-horizonal (sub-volcanic) faults
4) The relative timing of volcanic and intra-volcanic faulting
5) Potential geological influences on fault behavior

Figure 1: Location map of the Natron Basin and North Tanzania Rift, Tanzania. Base map is a topographic map of the eastern arm of the East African rift.

2 Methods

Fieldwork: Fault swarms were identified and examined, and disturbed line and other volcanic deposits were sampled for Ar-Ar dating currently being analyzed at Rutgers University, New Jersey. Broad-scale fault mapping: Mapping was performed using a combination of topographic imagery (12 m resolution), high-resolution aerial photos, and Google Earth. Faults are defined on the early available ASTER GDEM v2 (horizontal resolution of 30 m, vertical accuracy of 8 m) (LE90).

Strain analysis: Fault throws have been analyzed using a novel technique combining AST/STM DTM with a widely deployed fault-mapping program. The program measures fault throws using a depth-based method at ~600 intervals along fault traces.

3 Field Observations and Fault Data

3.1 Distribution

Table 1: Faults data obtained from northern and southern faults (modified from Fig. 4, Ages from Le Guillou et al. 2008, and references therein)

<table>
<thead>
<tr>
<th>Faults</th>
<th>Age</th>
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<tbody>
<tr>
<td>Northern Faults</td>
<td>20 Ma</td>
</tr>
<tr>
<td>Southern Faults</td>
<td>20 Ma</td>
</tr>
<tr>
<td>Northern Faults</td>
<td>2 Ma</td>
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<tr>
<td>Southern Faults</td>
<td>2 Ma</td>
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Northen faults general appearance in the field

The northern fault array extends approximately 10 km east and 60 km north of Ol Doinyo Lengai (Fig. 4). The faults are arranged on faults, both herb and sub-terraced segments, and the footwall of faults typically expose shallow slopes. Northern faults observed in the field have steep slopes and are generally younger and more prominent. Northwest-southeast trending faults differ in mean length, form, and spacing from north-south trends. Table 1 shows the fault data obtained from northern and southern faults.

3.2 Stress Field

Figure 2: Photo of a typical northern fault observed in Ol Doinyo Lengai volcanoes.

4 Interpretation of intra-rift pattern faults

The short length and right cleavage of the northern faults is suggestive of a zone of bended magnetic (7) strike-slip faulting on the lithosphere. Strike slip is predominantly located at the center of the fault array (Fig. 3), indicating potential transition from border fault to an over-riding fault system. Further, however, we need to consider how strain from the active faults due to the fault activity has influenced the distribution of faulting in the north.

The general length and throw values exhibited by the southern faults highlight the potential influence of stress or pre-faulting processes, which have significantly altered faulting processes. In the southern region, these faults are either elongated pre-existing basement fractures (Le Guillou et al., 2008), or accommodating the thermal widening of the rift south into the Tanzanian Mountains.

5 Distribution of fault-related strain and magmatic centers: observations and implications

Five broad observations from our preliminary strain analysis are:

1) Correlation of faults to the present-day surface features of the study region has been surprising and consistent with the idea of a transition from border to over-riding fault.

2) Faults are not parallel, as would be expected in a simple extensional environment.

3) Some faults show evidence of strike-slip motion.

4) The relative timing of volcanic and intra-volcanic faulting.

5) Potential geological influences on fault behavior

Figure 3: Location map of the Natron Basin and North Tanzania Rift, Tanzania. Base map is a topographic map of the eastern arm of the East African rift.

6 Conclusions

- There is a shift in the nature and distribution of faults from north to south. This transition is likely related to a change in the mechanical properties of the crust. Northern faults are forming in a thermally weakened environment, whereas the southern faults are likely controlled by tectonic, structural controls.

- The distribution of faults and volcanic centers indicates a possible interplay between magmatic and fault-related strain accommodation in the Natron rift basin.

- The observed presence of strain in the central rift is suggestive of a transition to a rift with border-dominated strain accommodation, and the potential termination of border fault activity.

7 Future Work

- A review of volcanic deposits related to faults to better constrain the timing and evolution of the fault sub-phases.

- Focusing the automated fault mapping program and performing more analysis.

- Estimate the contribution of external forces on the distribution of faulting.

- An analysis of faults in Magadi Rift using similar approaches.

8 Acknowledgments

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References

Le Guillou, J., Bousquet, P., Binet, J., Bernet, M., Fallés, H., Monna, Norrel, M., Al


Figure 4: Photo of a typical southern fault observed in Ol Doinyo Lengai volcanoes.

Figure 5: Illustration of fault-related strain measured from observable fault throw, extension, and the present velocity of the movement (in mm/year) based on the drone survey. The extension is driven by the movement of the African plate and the motion of the plate's boundary.

Figure 6: Illustration of fault-related strain measured from observable fault throw, extension, and the present velocity of the movement (in mm/year) based on the drone survey. The extension is driven by the movement of the African plate and the motion of the plate's boundary.