Deciphering Evolution of Extensional Fault Systems from Transient Behavior of Bedrock Channels: An example from the Incision of the Ethiopian Plateau

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Investigation of fault system evolution in an active tectonic setting can be difficult due to the preservation potential of suitable marker beds affected by faults, especially, if the region is still undergoing significant uplift and incision like the Ethiopian Plateau. In these cases, transient response of modern channels can provide new insights in reconstructing fault-slip variation and thus building fault zone architecture.

The deeply incised Ethiopian Plateau, situated on the flank of the extensional zones of the Main Ethiopian Rift and Afar Depression, is characterized by an array of normal faults, the evolutionary style and slip of which are poorly constrained. A network of bedrock channels draining across and around these faults have incised into the plateau, exposing Neoproterozoic to Recent metamorphic, sedimentary, and volcanic rocks that have been variably deformed by extensional faults.

Our goal is to investigate fault dynamics that control morphology of these channel long-profiles. In a previous study, we used SRTM DEM (90 m spatial-resolution) to map major channel knickpoints with >200 m relief that are unaffected by faults. In this study, we used 15 m spatial-resolution ASTER DEM data to quantify transient behavior of fault-crossing (<30 m slip) channels using stream power model to constrain fault behavior in northern, central and eastern parts of the plateau.

Quantitative stream power-law models for bedrock channel profiles reveal transient signals, which are preserved as numerous, upstream-propagating knickpoints (<100 m relief). We mapped knickpoint relief and distribution, and correlated them with the spatial distribution of fault slip. Broad convex zones in channel profiles are also interpreted to correlate with fault slip/offset zones. These irregularities in channel profiles indicate a non-steady state condition, which is also evidenced in the channel slope vs. drainage-area plots. Our preliminary 3D structural models show that the spatial distribution of knickpoints is a function of upstream drainage-area and slip-variation of normal faults.