Motivation and Background

Strike-slip faults produce distinctive landscape features such as shutter ridges and offset streams. Continental lateral offset on a fault can produce a cycle of stream lengthening and capture, as shown in Figure 1. These features and processes have been used to determine activity and slip rates of faults. (Wallace, 1988, Hubert-Ferrari et al., 2002)

This cycle of stream lengthening and shortening induces ongoing transience in the landscape, causing knickpoints in channels and beheaded channels and wing gaps visible in plan form. However, stream captures shorten stream offsets, reducing the first-order “landscape signature” of a strike-slip fault. When viewing a landscape at a single moment in time, it can be difficult to find conclusive evidence of stream capture, and thus to determine whether observed stream offsets are the direct result of offset on a fault or whether they have been altered by capture. (Walker and Allen, 2012)

In real-world settings, the landscape signature of strike-slip faults is often not very dramatic. Walker and Allen (2012) note that on the Kuh Banan Fault in Iran, offsets are not as long as expected. In our field area, the right-lateral Marlborough Fault System in New Zealand, channel offsets are relatively short and often not present (Figure 2).

Model Setup

- We investigate the role of shutter ridges, which are areas of high relief transported laterally on the downhill side of the fault. Is relief in this area necessary to create stream offsets? Without shutter ridges, does stream capture happen more often and erase offsets?
- We use CHILD to build a 200 x 2000m, one-sided mountain range.
- We develop a steady state, a strike-slip fault is created through the range while maintaining the differential uplift.
- We track individual shutter ridges through time and recorded the number of stream capture events that breached each one.
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- A higher shutter ridge is more of an obstacle to stream capture.
- When relief downhill of the fault is greater, stream capture happens less often and stream offsets are longer.
- Stream capture happens less often around longer shutter ridges and stream offsets are longer.
- Longer shutter ridges effectively increase the drainage spacing near the fault, causing adjacent streams to be juxtaposed less often. However, shutter ridge length has less of an effect on stream capture frequency than shutter ridge height does.

Results

Figure 4. The number of stream captures occurring around shutter ridges of different heights in 500,000 years, the time it takes the fault to slip 500m.

Figure 5. The number of stream captures occurring around shutter ridges of different lengths.

Comparison to Field Sites

Figure 7. Shutter ridges are a common feature in the Marlborough Fault System of New Zealand, but they are not ubiquitous.

Discussion

Shutter ridges are important for generating the long channel offsets that are considered characteristic of strike-slip fault zones. In the absence of shutter ridges, or where they are not high-relief features, stream capture is frequent and channels can re-arrange often. This situation can dampen the landscape signature of the fault. Many real-world landscapes still show even fewer and shorter stream offsets than we have been able to produce in the model. The presence or offset of channel offsets does not necessarily reveal a fault’s activity or slip rate. Future work on this project will compare the effectiveness of different types of shutter ridges in creating long channel offsets. Many of the shutter ridges in the Marlborough Fault System are lithologically controlled – does an erodibility contrast create a more effective shutter ridge?

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References


