Analysis of surface rupture complexity sheds light on coseismic slip during the last earthquakes along the Bulnay-Tsetserleg fault zone (Mongolia)

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Context: a very slow deformation intraplate zone

**The 1905 Bulnay-Tsetserleg earthquakes**

The largest continental strike-slip sequence documented

Two M~8 left-lateral strike-slip earthquakes

- Starting along Tsetserleg fault in the N
- Second event 14 days later along Bulnay main fault + Teregtiyn and Dungen secondary branches

(Choi et al., 2018 – JGR)

https://doi.org/10.5194/egusphere-egu2020-5325
The Tsetserleg rupture: Questions and goals

(Choi et al., 2018 – JGR)

<table>
<thead>
<tr>
<th>Rupture width (km)</th>
<th>Rupture section</th>
<th>Length (km)</th>
<th>Slip (m)</th>
<th>MO X 1,027 (dyne cm²) with shear modulus of 30 GPa</th>
<th>Mw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tsetserleg rupture</td>
<td>114</td>
<td>2.57</td>
<td>0.879</td>
<td>7.26</td>
</tr>
<tr>
<td>10</td>
<td>Tsetserleg rupture</td>
<td>10</td>
<td>0.51</td>
<td>2.197</td>
<td>7.53</td>
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<td>25</td>
<td>Tsetserleg rupture</td>
<td>50</td>
<td>4.395</td>
<td>7.73</td>
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<tr>
<td>50</td>
<td>Tsetserleg rupture</td>
<td>80</td>
<td>7.032</td>
<td>7.86</td>
<td></td>
</tr>
</tbody>
</table>

- The seismological magnitude (Mw 8) is larger than the magnitude derived from coseismic geomorphic offsets
- How to explain this discrepancy?
  - May local offset measurements underestimate the total coseismic displacement?
  - Is there a vertical slip component?
  - Did the rupture extend more than what was mapped?
- Good preservation allows detailed analysis of the 1905 Tsetserleg surface rupture
  - Insight into rupture dynamics
  - Impact of fault geometry on surface rupture style and development
  - Preserved traces of previous earthquakes?

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**On the field (16/06 – 07/07/2019)**
- HR image acquisition with DJI Phantom 4 drone

**Back home**
- Image processing: photogrammetry (MicMac and Agisoft Photoscan softwares)
- Image analysis and measurements
  - Surface features mapping
  - Crack width projected along fault strike
  - Topographic profile extraction...

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Drone acquisition sites and datasets

<table>
<thead>
<tr>
<th>Site name</th>
<th>Fault section geometry</th>
<th>Number of photos used</th>
<th>Pixel size of orthomosaic</th>
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</thead>
<tbody>
<tr>
<td>SS1</td>
<td>Conjugate branch</td>
<td>164 photos</td>
<td>3 cm</td>
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<tr>
<td>Bul193</td>
<td>Fault bend</td>
<td>191 photos</td>
<td>4 cm</td>
</tr>
<tr>
<td>SP3</td>
<td>Restraining jog</td>
<td>75 photos</td>
<td>6 cm</td>
</tr>
<tr>
<td>SP4</td>
<td>Releasing bend</td>
<td>195 photos</td>
<td>3 cm</td>
</tr>
<tr>
<td>SP11_1701</td>
<td>Releasing bend</td>
<td>493 photos</td>
<td>4 cm</td>
</tr>
<tr>
<td>SP11_1706</td>
<td>Jog termination</td>
<td>133 photos</td>
<td>6 cm</td>
</tr>
</tbody>
</table>

DEM relative errors < 15 cm

Fault map from Choi et al. (2018)

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Horizontal slip from crack measurements

The mean value per site is close to the average slip deduced from offset markers.

All measured offsets fall in the range of projected crack width data.

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A vertical component?

24 cm resolution

East of SP3: local uplift of northern block in compressive area

No significant vertical offset on other sites

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Insight on 1905 rupture propagation

Similar features were reported on other ruptures (e.g. Klinger et al., 2005 BSSA on Kunlun)

Linked to faster propagation of the rupture front at depth -> surface cracks open first and later affected by strike-slip

2 m lateral offset of previously aligned, oblique cracks

Cracks crosscut by thrusts
Cumulative features of successive earthquakes

Network of smooth features from previous event(s), crosscut by last event

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Key points

• Performance of UAV image photogrammetry:
  • Acquisitions on fault sections between 0.15 and 0.65 km²
  • Best resolutions of 3 cm for output photomosaic, 12 cm for DEM
  • Relative vertical precision between 8 cm and 15 cm

• Revisiting the coseismic slip of the 1905 Tsetserleg earthquake
  • Offset markers and crack width measurements provide similar average slip values
  • No significant vertical slip component
  -> Possibility that surface rupture underestimates real faulting length

• Several generations of tectonic features are preserved
  -> Reconstruction of 1905 earthquake’s propagation
  -> Identification of previous earthquake markers
  -> Variability of rupture path through several earthquake cycles