# *High Resolution Topography of Normal Faults in the Volcanic Tablelands, near Bishop in Eastern California, April 2019*


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Introduction: We present high resolution topography data and orthomosaic imagery along three normal fault scarps in the Volcanic Tablelands of Eastern California. In the Volcanic Tablelands, normal faults create prominent scarps that offset the Bishop Tuff. This area has been the focus of a number of studies on fault zone structural geology and geomorphology.

In this survey, we collected uncrewed aerial vehicle (UAV) imagery over three fault scarps each with length of 2-4 km. We produced point clouds, digital surface models (DSMs), and orthomosaics using structure-from-motion (SfM) techniques.

Personnel

- PIs: Chelsea Scott, Tyler Scott, Ramon Arrowsmith
- Field staff: Cassandra Brigham, Simone Bello, Jianhong Xu, Federica Ferrarini, Christopher Milliner, Andrea Donnellan

**Site Conditions:**

Conditions varied between sunny and partially cloudy. Wind was mild and the temperature was comfortable. We spent almost a full day imaging each of the three faults. For Faults 1 and 2, we started at the southern end of the fault in the morning and progressed northward throughout the day. While we tried to minimize sudden changes in light conditions by gradually working northward, there is a gradient in light conditions along fault strike. Along Fault 3, we reimaged portions of the fault with a different camera angle throughout the day.

**Dates of Collection:**

Fault 1: April 11, 2019
Fault 2: April 12, 2019
Fault 3: April 13, 2019

**UAV Equipment and Data Collection Methods:**

We used a Phantom 4 Pro UAV and a Phantom 4 UAV to collect the aerial photographs. We used the Phantom 4 Pro UAV to begin each day's surveys and until the batteries in the controller lost their charge. We then switched to the Phantom 4 UAV for the remaining flights. We used Pix4DMapper to plan the flight missions. We flew the UAV ~110 m above ground level. The camera was pointed 0-30° from nadir. We used flight overlaps of ~70% along and perpendicular to the UAV flight track.

**Processing:**

We processed the photographs collected by the UAV into point clouds, DSMs, and orthomosaics using AgisoftMetaShape. We processed each of the three faults individually. We optimized the sparse cloud and camera models using the georeferenced positions (see below). We produced the sparse and dense point clouds using a combination of "Medium" and "High" settings in Metashape. We used the suggested resolution to generate the DSMs and orthomosaics.

**Resolution:**

| Fault Number | Fault Position (either base station or target) | Point Cloud (pts/$m^2$) | DSM (m/pix) | Orthomosiac (m/pix) |
|---|---|---|---|---|
| 1 | -118.4416, 37.4466 | 242 | N/A | 0.21 |
| 2 | -118.4903, 37.4311 | 278 | 0.041 | 0.020 |
| 3 | -118.5029, 37.4833 | 255 | 0.065 | 0.016 |

**Georeferencing:**

All data (point clouds, DSMs and orthomosaics) are in NAD83 UTM zone 11N (EPSG: 26911). The heights are orthometric in NAVD88 (computed using GEOID12B, EPSG: 5703).

We georeferenced the point clouds using ground control points (GCPs). The GCPs are black targets with white crosses. We used 6-10 GCPs for each fault. To measure the location of the GCPs at Faults 1 and 2, we used postprocessing kinematic (PPK) GNSS positions. The base station was a Leica AX1209GG with an INTUICOM antenna. We used a RX1200 rover. At each fault, we had over 6 hours of occupation time. For fault 3 we used Septentrio Altus APS-3G base and rover stations. The base station broadcasts corrections to the rover using a coarse position solution. We surveyed iron cross survey targets, which have a black and white checkered cross diagonally from corner to corner of the target. Positions of the targets relative to the coarse base station are stored on the handheld unit connected to the rover and are downloaded after the survey. The base station logs data for the duration of the kinematic survey, which are then downloaded for post processing.

The accuracy of the measured GCP positions is typically better than 0.01 m in both the horizontal and vertical. At a few GCPs, the rover was not able to make the connection with the base station, leading to errors of~2 m and ~3 m in the horizontal and vertical coordinates, respectively.

We corrected the base station position using the Online Positioning User Service (OPUS) available from the National Oceanic and Atmospheric Administration (NOAA). The rover positions are the adjusted relative to the precise base station position.

We manually marked the location of the GCPs on the aerial photographs. Most GCPS are in 10-15 photographs. Errors between the marked and processed GCP vary by fault. Along Fault 1, the error for the 8 GCPs that made the base station-rover connection is ~10 cm. Along Fault 2,the Metashape estimated errors in position are ~2 cm for the 6 GCPS where the rover connected to the base station and are ~2 m when the connection was not made. Along Fault 3, the Metashape estimated errors in position are ~12-30 cm for all of the 10 GCPS that all made the base station to rover connection.

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