Analysis of the 2018 Mw 7.5 Papua New Guinea Earthquake Using the Sub-pixel Offset Method

DEPARTMENT OF GEOLOGY

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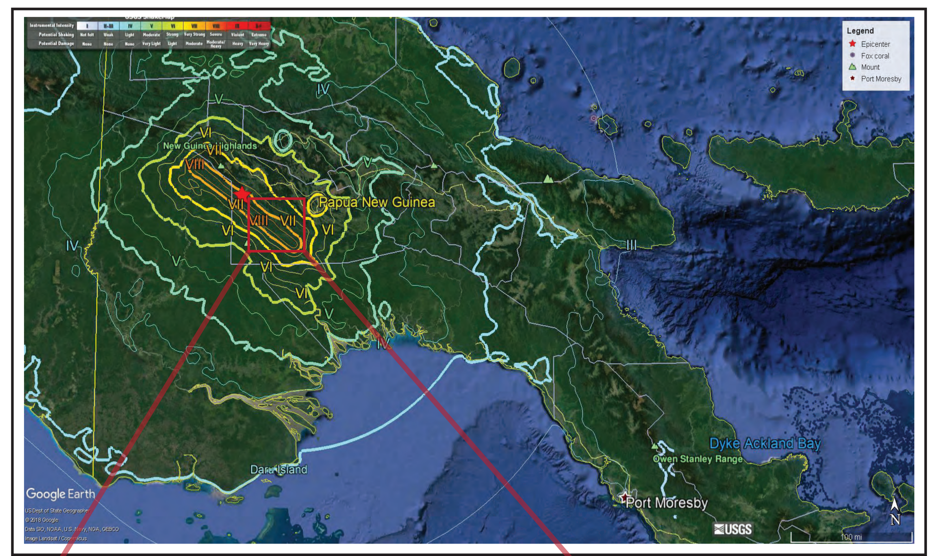
Introduction

On the 25th of February 2018, a Mw 7.5 earthquake struck the Southern Highlands of the fold-and-thrust belt in Papua New Guinea (**Figure 1**). This was the largest magnitude earthquake that was recorded in the Southern Highlands using the moment magnitude scale. This study uses a satellite geodetic method known as the sub-pixel offset method (or Synthetic Aperture Radar offset) to analyze the crustal deformation during the earthquake (coseismic) of the mainshock in the Southern Highlands of the fold-and-thrust belt.



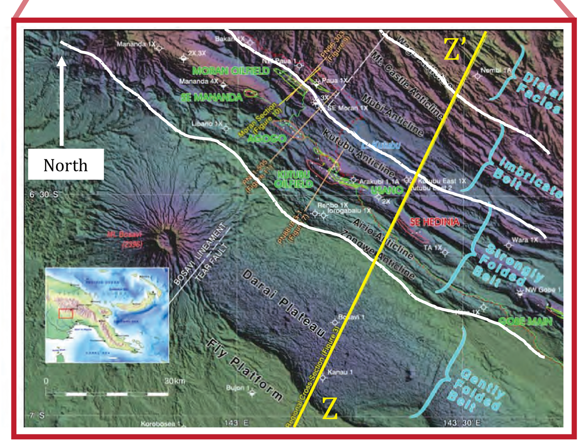


Figure 1: (Up) Shaking intensity map from USGS with red star indicating the location of the 25th February 2018 mainshock. (Left) Geological map of the area of interest (Hill et al., 2010)

Methods

The sub-pixel offset method tracks the pixel offsets of Synthetic Aperture Radar (SAR) images by Sentinel-1A before and after the mainshock (**Figure 2**). The pixel resolution is ~5 x 20 meters. 3D displacement was produced by combining ascending and descending tracks. The fault model was constructed by estimating fault parameters (strike, dip, rake, depth, and size) that were constrained from the sub-pixel offset displacement. The best-fit fault parameters was selected based on the lowest observed residual displacement.

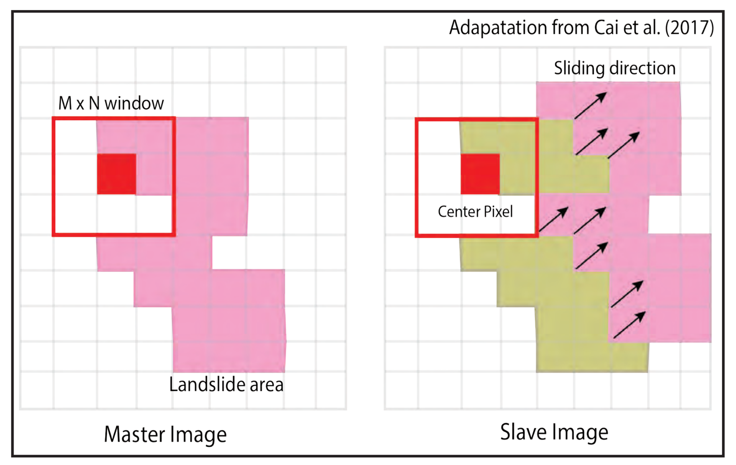


Figure 2: Example of the sub-pixel offset method. Pink pixels in slave images indicates movement, brown pixels indicate newly exposed region.

Hypothesis

There are at least two faults that were involved in this earthquake; contrary to the single fault model constrained by USGS using teleseismic data.

Results

Two surface rupturing faults were identified trending at a ESE-WNW direction. Surface rupture of Mubi Fault has an estimated length of ~35 km and surface rupture of Mananda Fault was estimated around ~22 km. Peak vertical displacement of Mubi Fault is ~2.1± 0.34 meters and Mananda Fault exhibits ~1.1 ± 0.34 meters (**Figure 3**). Peak north-south displacement showed that Mananda Fault has ~3 ± 0.63 meters of southward displacement compared to Mubi Fault with ~2 ± 0.63 meters. Both faults indicated about 2 ± 0.46 meters of peak westward displacement (**Figure 4**). A detachment fault with a length of 130 km was used to connect the Mubi and Mananda Fault (**Table 1**). The fault model indicated a peak slip of ~6 meters at the top 6 km of the Mananda Fault (**Figure 6**). Checkerboard test indicated the Mananda Fault has good recovery up to 8 km. The vertical displacement of the modeled faults have similar trend with observed displacement (**Figure 4**).

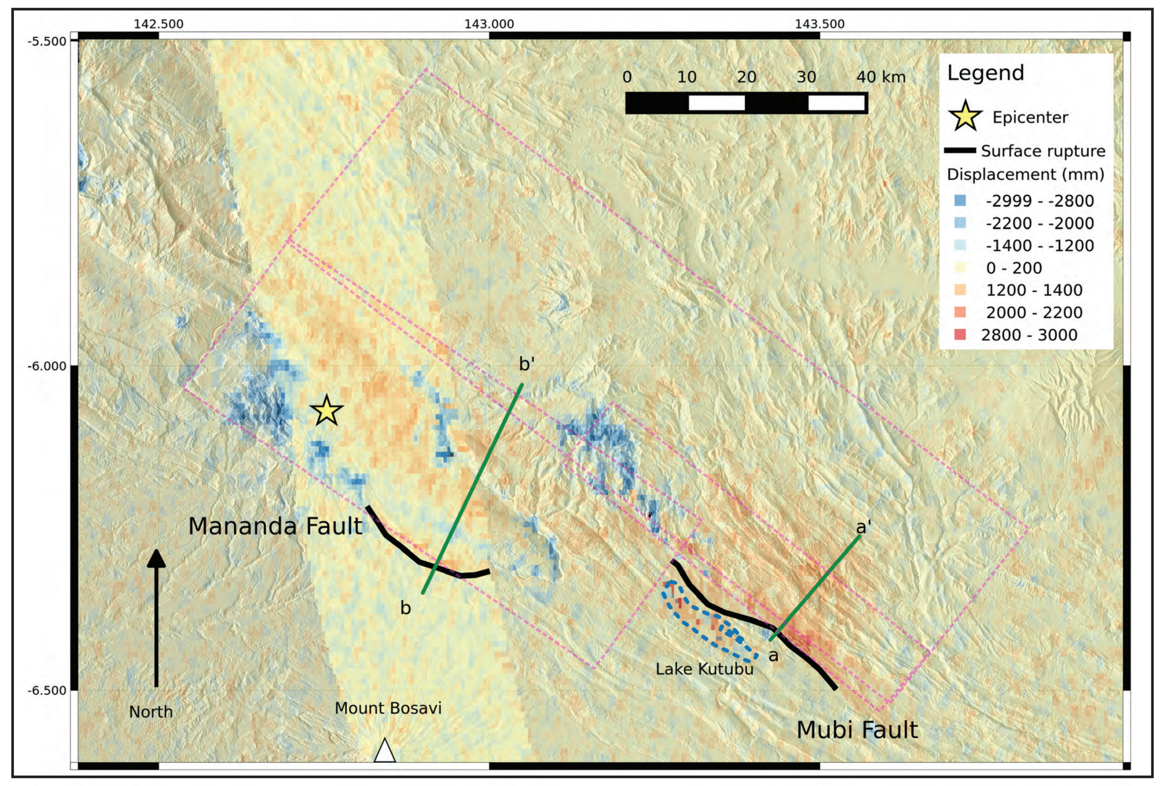


Figure 3: Vertical displacement of the combined tracks. Warm colors indicates uplift and cool colors indicates subsidence. Surface ruptures are marked with black lines. Pink dotted lines indicate the expected faults.

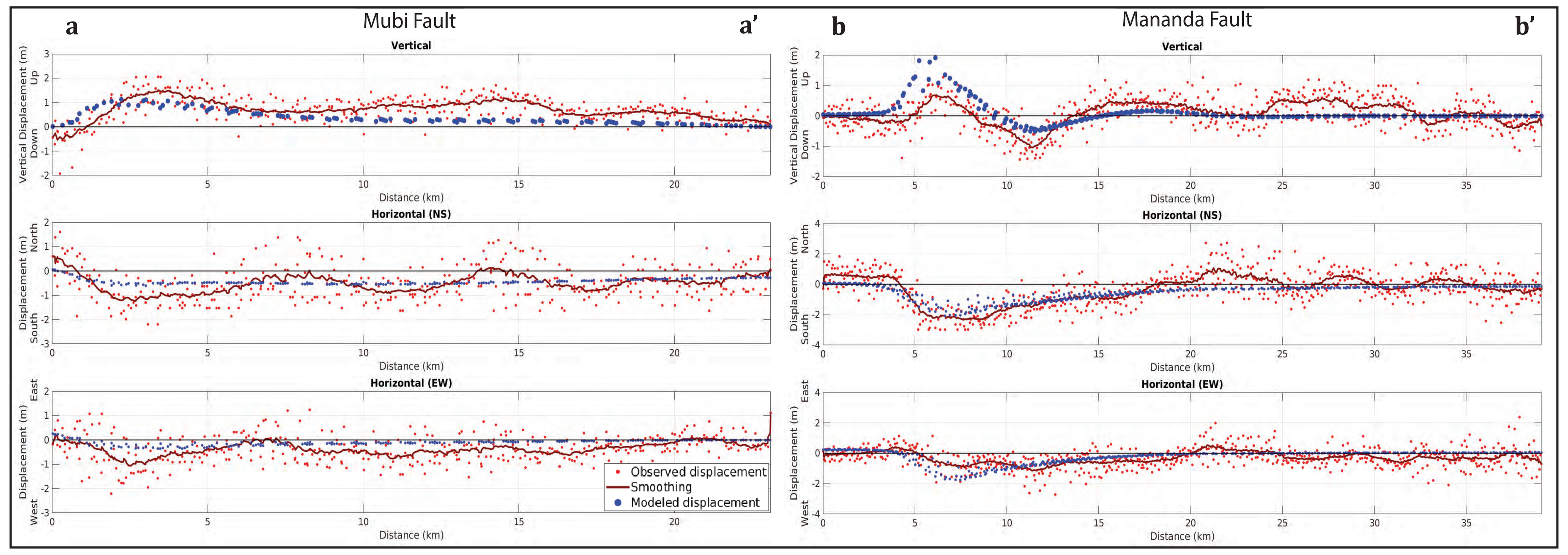


Figure 4: Surface displacement of the observed and modeled displacement data across the transects of Mubi Fault and Mananda Fault. Red dots indicate observed data, red lines indicate smoothing, and blue dots indicate modeled displacement.

Parameters	Mubi Fault	Mananda Fault	Detachment fault
Strike, Dip, Rake	308, 35, 90	305, 15, 85	307, 6, 90
Size (along strike, dip) in km	70 km, 18 km	86 km, 34 km	130 km, 40 km
Subfaults (strike, dip)	35, 9	43, 17	65, 20
Starting depth	0.8 km	0.7 km	8.9 km

Table 1: The expected fault parameters for Mananda Fault, Mubi Fault, and the detachment fault.

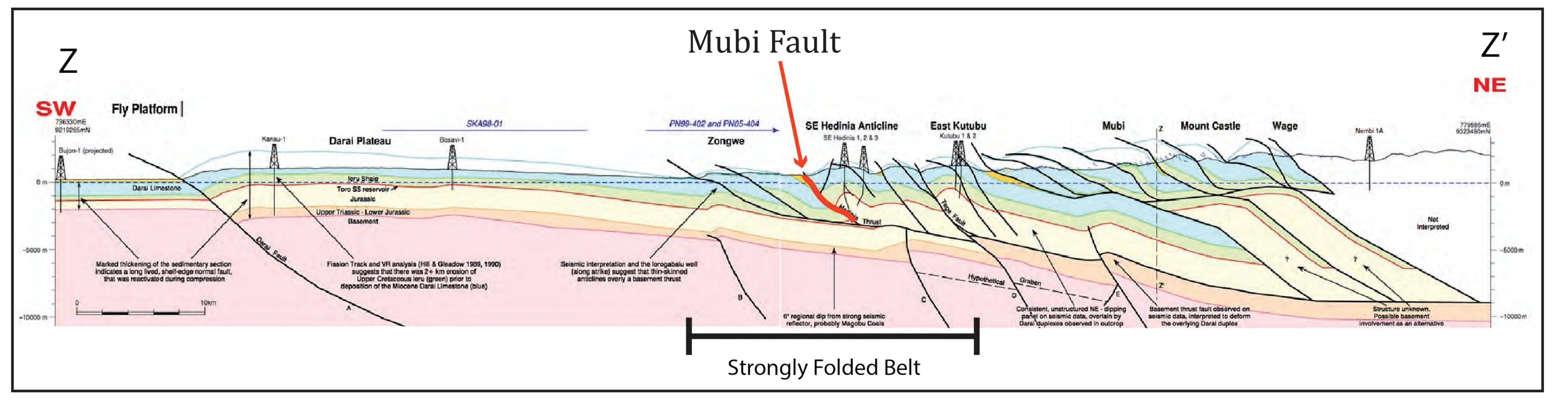


Figure 5: Cross-section view of the geological setting across Mubi Fault (**Figure 1**) from Hill et al. (2010).

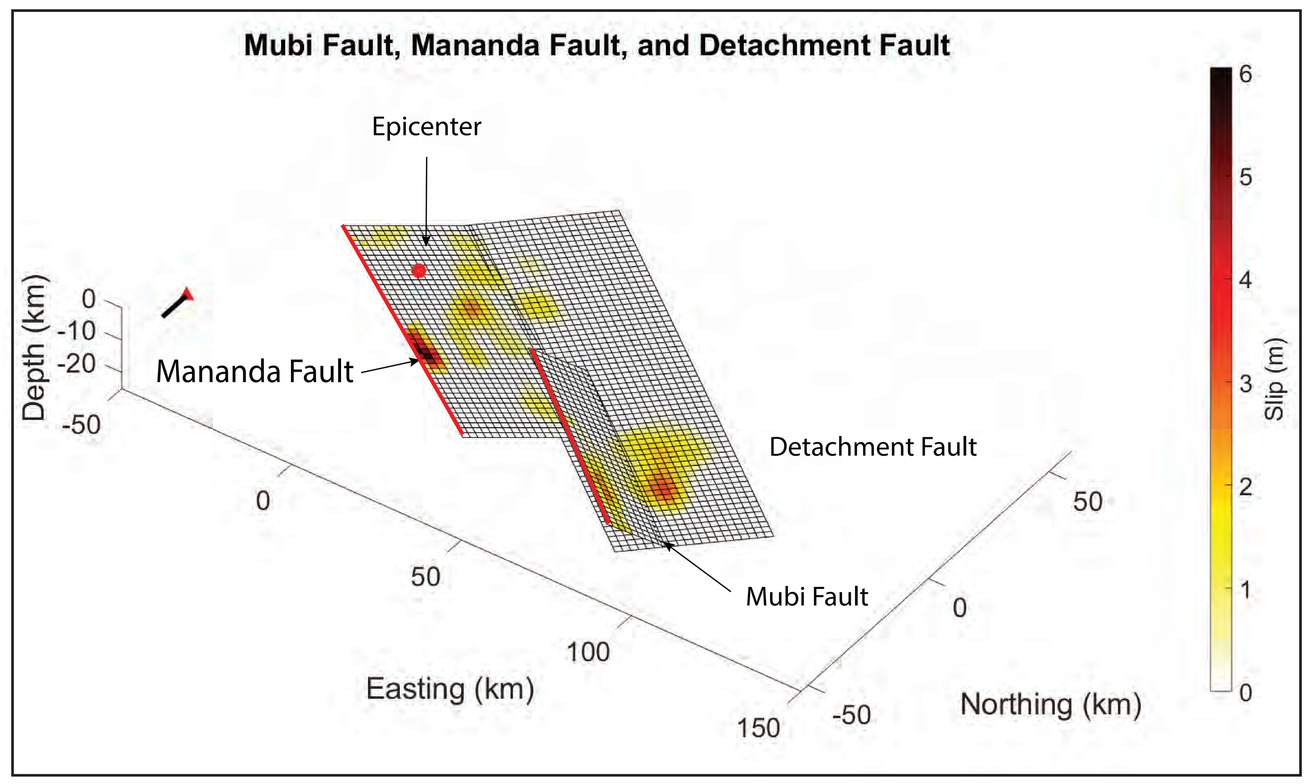


Figure 6: 3D view of the expected faults that were involved in the earthquake. Darker color indicates higher amount of slip. The subfaults (squares) are discritized into 2 by 2 km. Mananda Fault and Mubi fault are not in contact with each other.

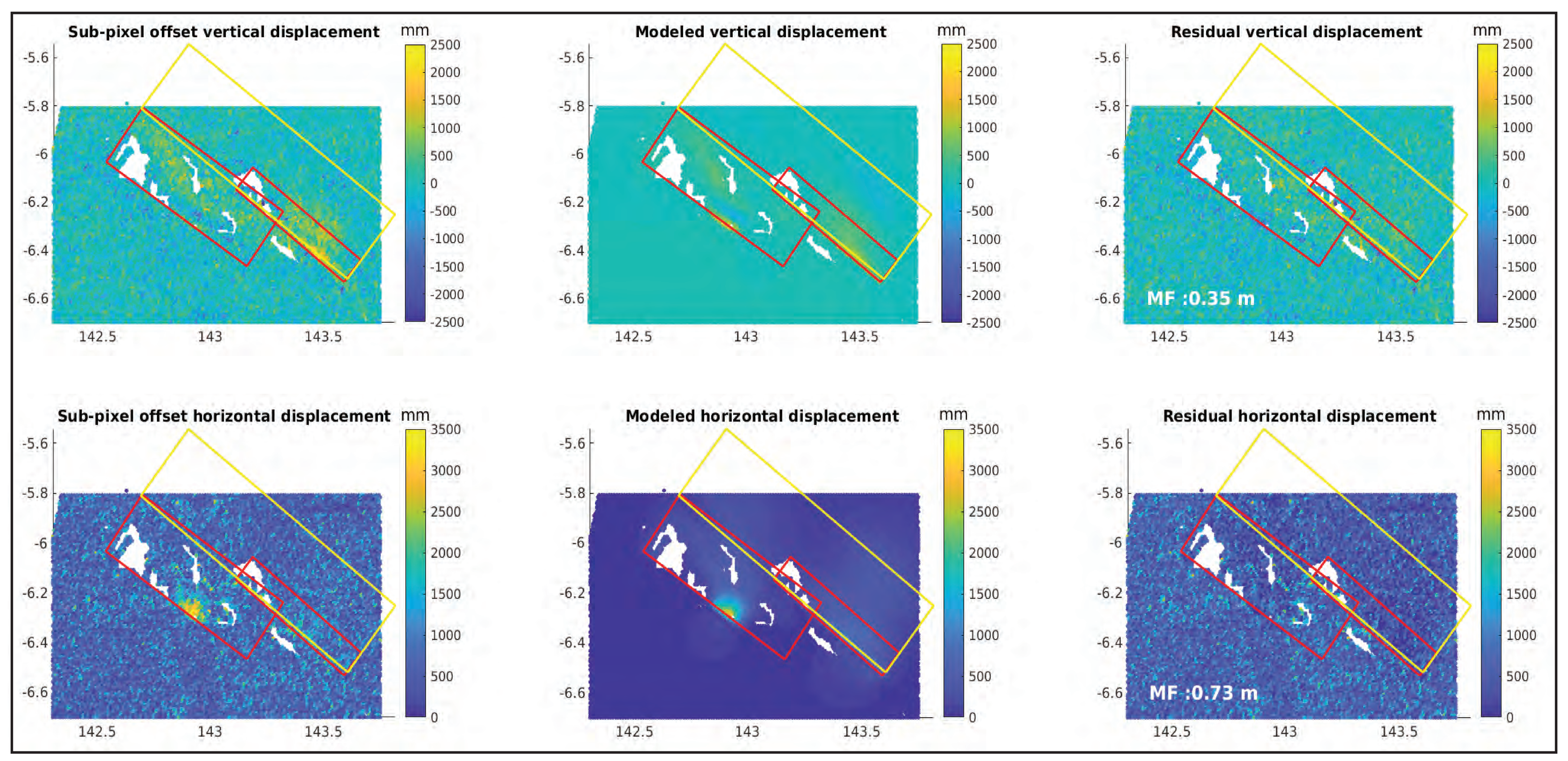


Figure 7: Surface displacement of the observed and the modeled. The residual is the difference between the observed and the modeled displacement. MF indicates the misfit between the model and observed displacement.

Discussion

- Two surface rupturing faults located at different parts of the fold-and-thrust belt
- A detachment fault was used to explain the transfer of slip (**Figure 6**)
- There is a possibility of a steeper fault located on Mananda Fault (**Figure 9**)
- Surface ruptures tend to trend with the topography (**Figure 10**)
- Landslide can also be detected using the sub-pixel offset method

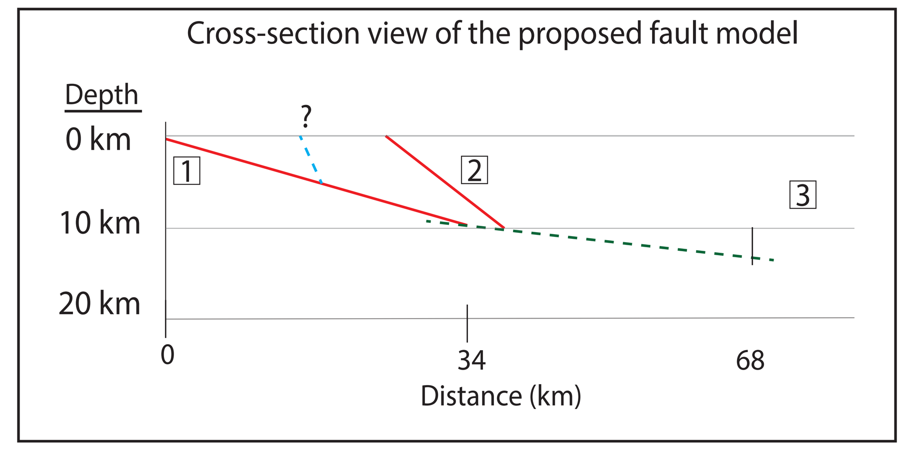


Figure 9: (Top) Cross-section view of the fault model with the proposed fault above the Mananda Fault 1.

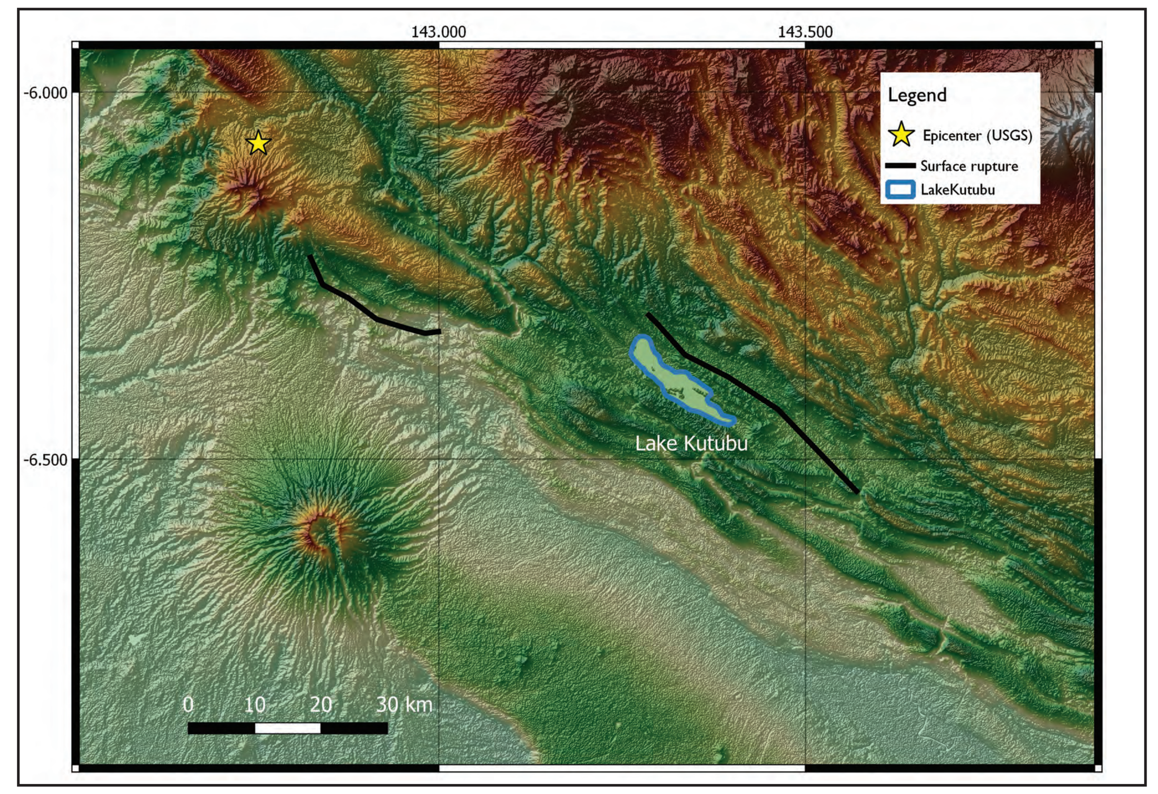


Figure 10: Topography map of an area between the two faults. Surface rupture tends to follow the topography.

Broader Impact

This method can be used by rescue operations to determine accessibility and/or assess damages over a larger region in a cost and time efficient way compared to aerial surveys. Furthermore, sub-pixel offset method is not affected by cloud cover, weather, and daylight.

Link to video of the fault models

Reference

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Hill, K.C., Lucas, K., and Bradey, K., (2010), Structural styles in the Papuan Fold Belt, Papua New Guinea: constraints from analogue modeling, *Geological Society London,* 348, 33-56, doi:10.1144/SP348.3/