Geomorphic Indicator Ranking System (GIR) Part 1

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What is the GIR?

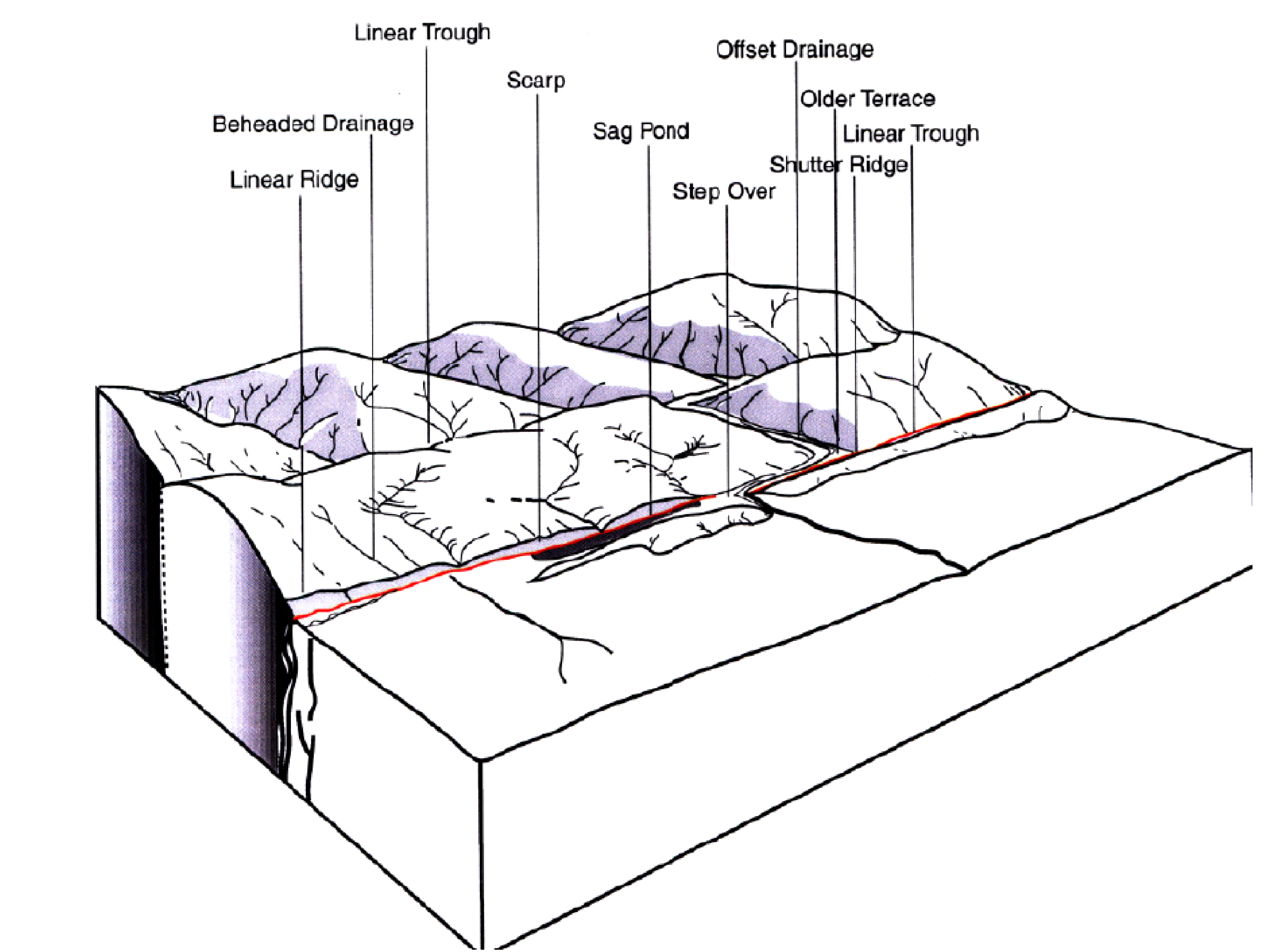
- The Geomorphic Indicator Ranking System (GIR) is a system to quantify geomorphic indicators that form as result from surface faulting

What does the GIR do?

- Provides a systematic and repeatable way to rank the mappers' confidence of a fault trace location from the available evidence along possible surface traces

- Helps mappers rely less on preconceived notions about an area and more on observable evidence to make conclusions

Geomorphic Indicators



Block diagram showing landforms produced along recently active strike-slip faults (modified from Vedder and Wallace, 1970 by Jeri Young).

Geomorphic Indicators (cont.)

- Alluvial fan between two mountain ranges

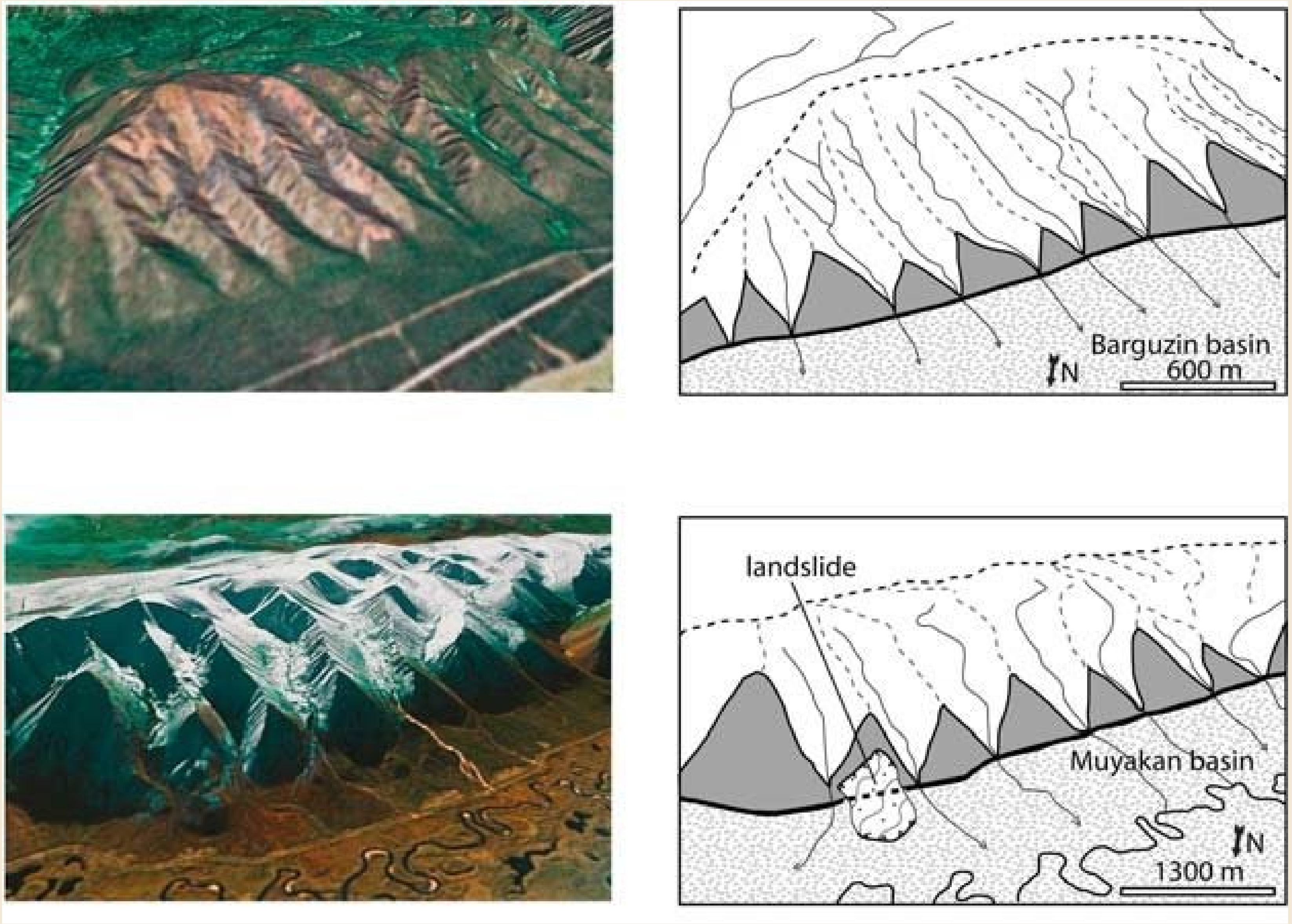
- What could cause this kind of activity?

- This alluvial fan has a significant **surface unit offset** (tonal difference) and uphill facing **scarps**

- The original deposition order of the quaternary units is disrupted

An alluvial fan between the Kunlun and Altun mountain ranges that form the southern border of the Taklimakan Desert in China. (B.A.E. Inc. / Alamy Stock Photo)

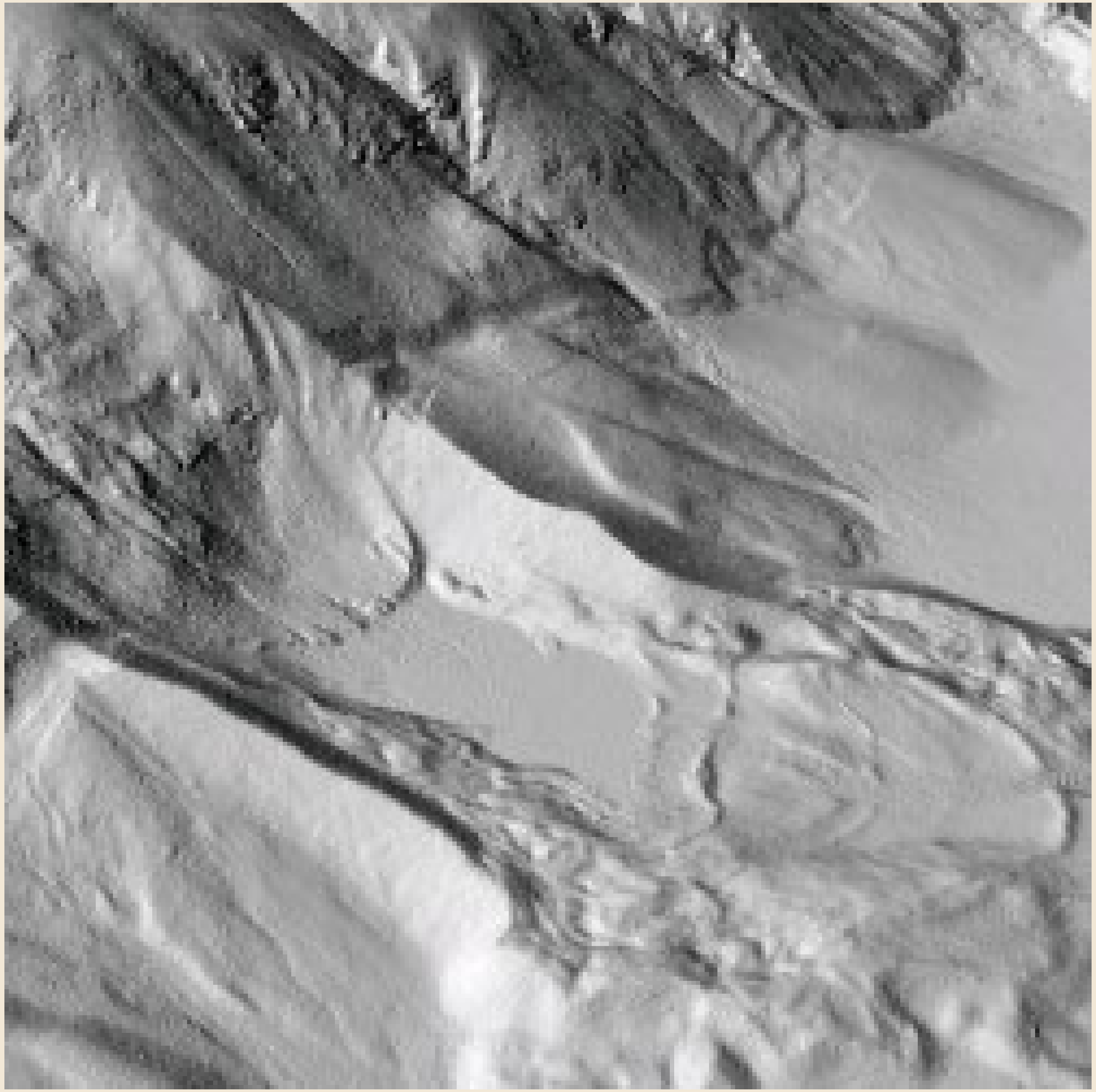
Geomorphic Indicators (cont.)



Oblique views of three triangular facet-bearing scarps of the North Baikal Rift in the (top) south Barguzin, (bottom) Muyakan,. Google Earth imagery (Petit et al., 2009)

- **Triangular facets** are formed at the base of mountain ranges
- Can form scarps where the fault plane has dropped the base of the front
- Quality of facet varies with age and erosion
- Can be formed by faulting but also found on the sides of river valleys if there is some lateral erosion and downcutting

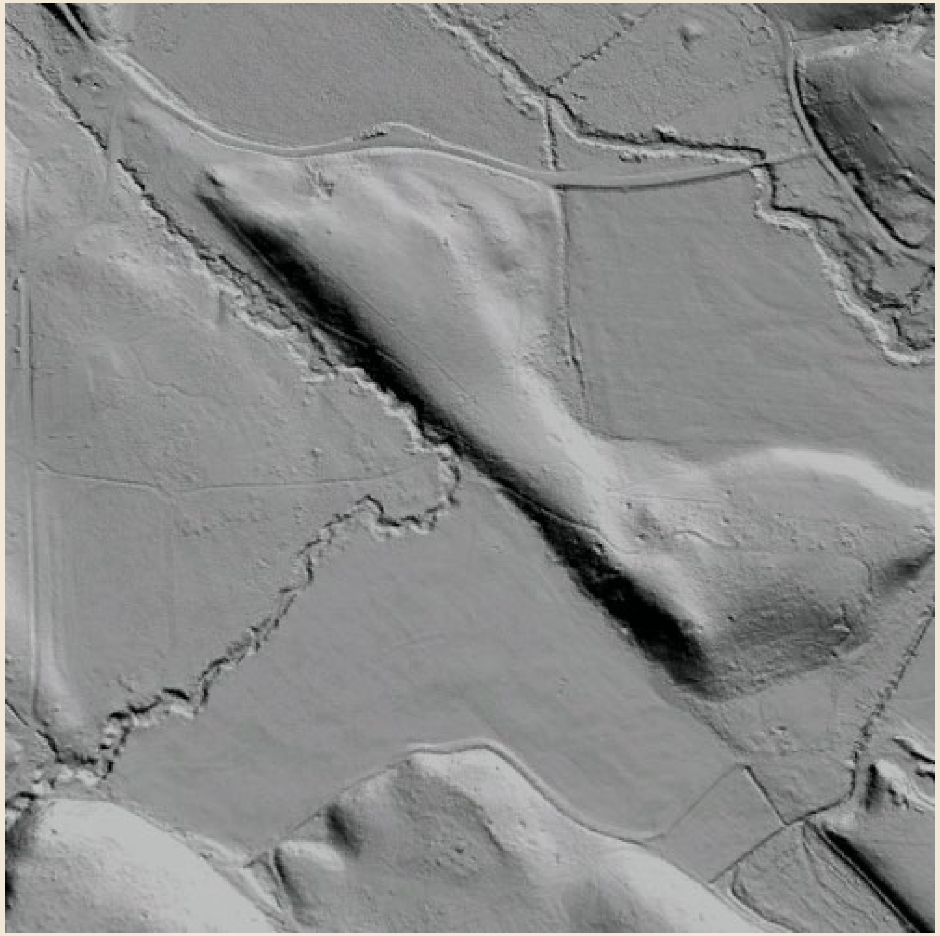
Geomorphic Indicators (cont.)

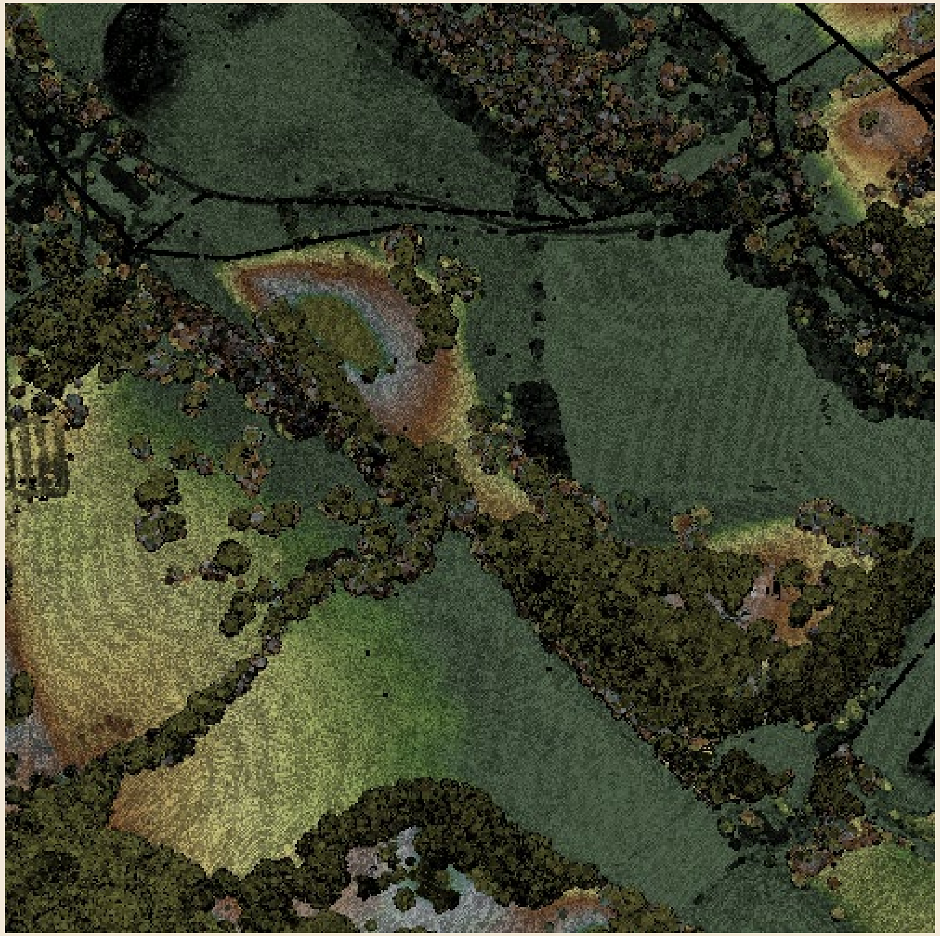


A normal fault scarp at the base of the Teton Mountain range in Wyoming. (EarthScope Intermountain Seismic Belt LiDAR Project, OpenTopography)

- **Scarps** are linear cliff-like slopes or faces that break a younger(quaternary) or older (bedrock) surface.
- If identified correctly, is almost certainly a result of active faulting
- Can form in other environments besides faulting (erosion) and seen as a sharp slope break

Geomorphic Indicators (cont.)





- A **shutter ridge** is a topographic ridge that has been "carried" by movement on a strike-slip fault to block an existing topographic valley, deflecting a drainage or stream

Geomorphic Indicators (cont.)

Bedrock Scarp	Offset or cut Alluvial Fan Complex	Shutter ridge
Beheaded Drainages	Offset Terraces	Spring
Bench	Over-steepened range front	Surface Unit Offset
Deflected Stream	Pressure ridge	Spring
Depression/Sag Pond	Quaternary Scarp	Topographic Hills
Fissures	Rangefront sinuosity	Triangular Facet
Horst and grabens	Sackung	Unit Offset
Offset drainage channel	Single Offset or cut Alluvial fan	

Feature Ranking

Ranking	Explanation
4	Strongest evidence for faulting. Features with this ranking are almost unequivocally a result from tectonic activity.
3	Strong evidence for faulting. These features more than likely indicate active faulting
2	Moderate evidence for faulting. Features with this ranking can be a result of active tectonics but are hard to stand alone as an indicator.
1	Little evidence of faulting. Features with this ranking can be a result of tectonic activity but may also be a result of other geomorphic processes.

Modifiers

- Some features on the surface may indicate faulting if they appear with other strong features, but they are not enough on their own to indicate active faulting

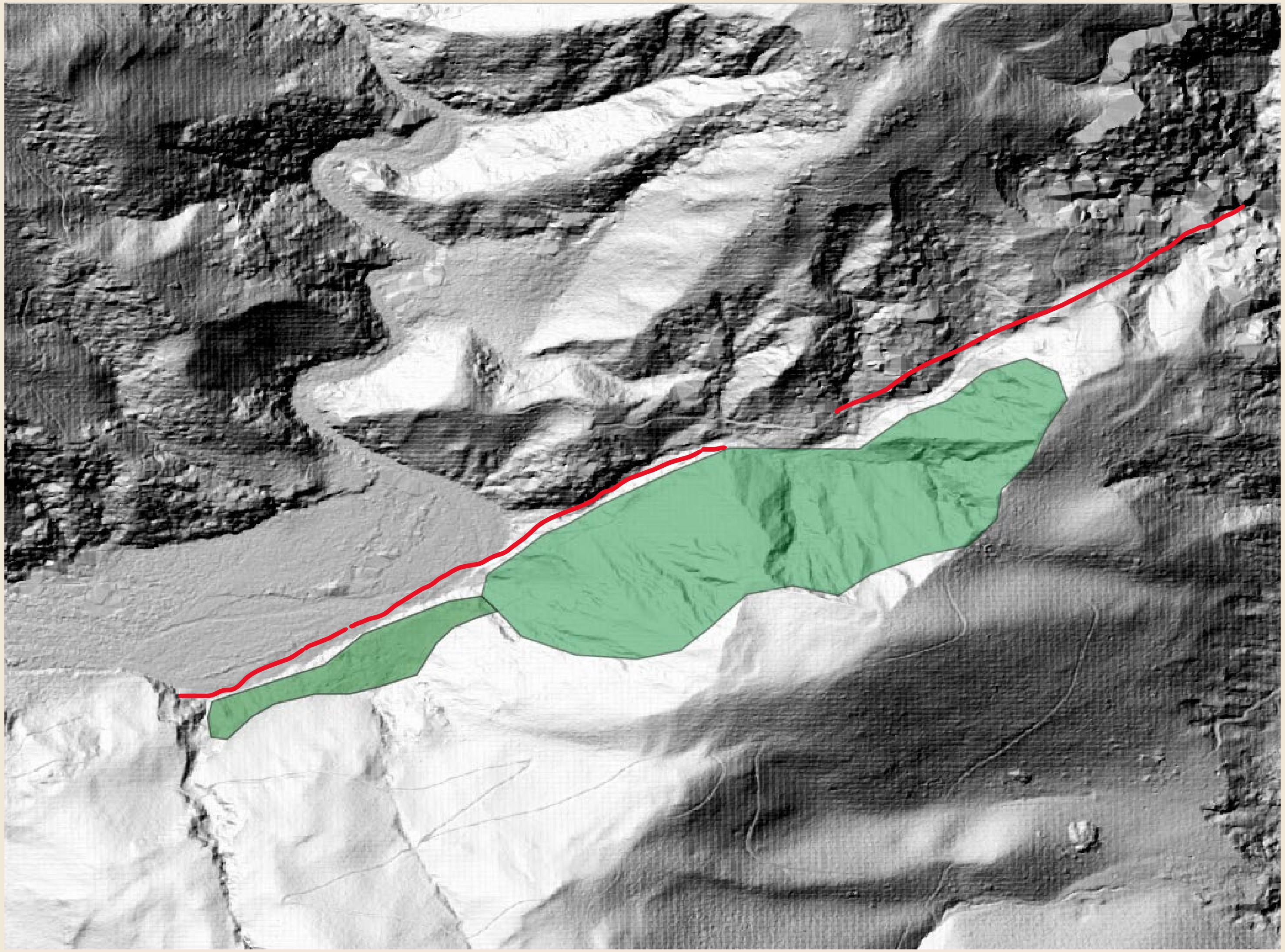
- These features are given a +/- 1 score and should only be mapped when they are in junction with a feature from the main GIR

- Positive modifiers are meant to fortify the presence of a fault, but not serve as stand-alone evidence

- Negative modifiers are used when the feature reduces the mapper's confidence to the fault location or obscures evidence of faulting

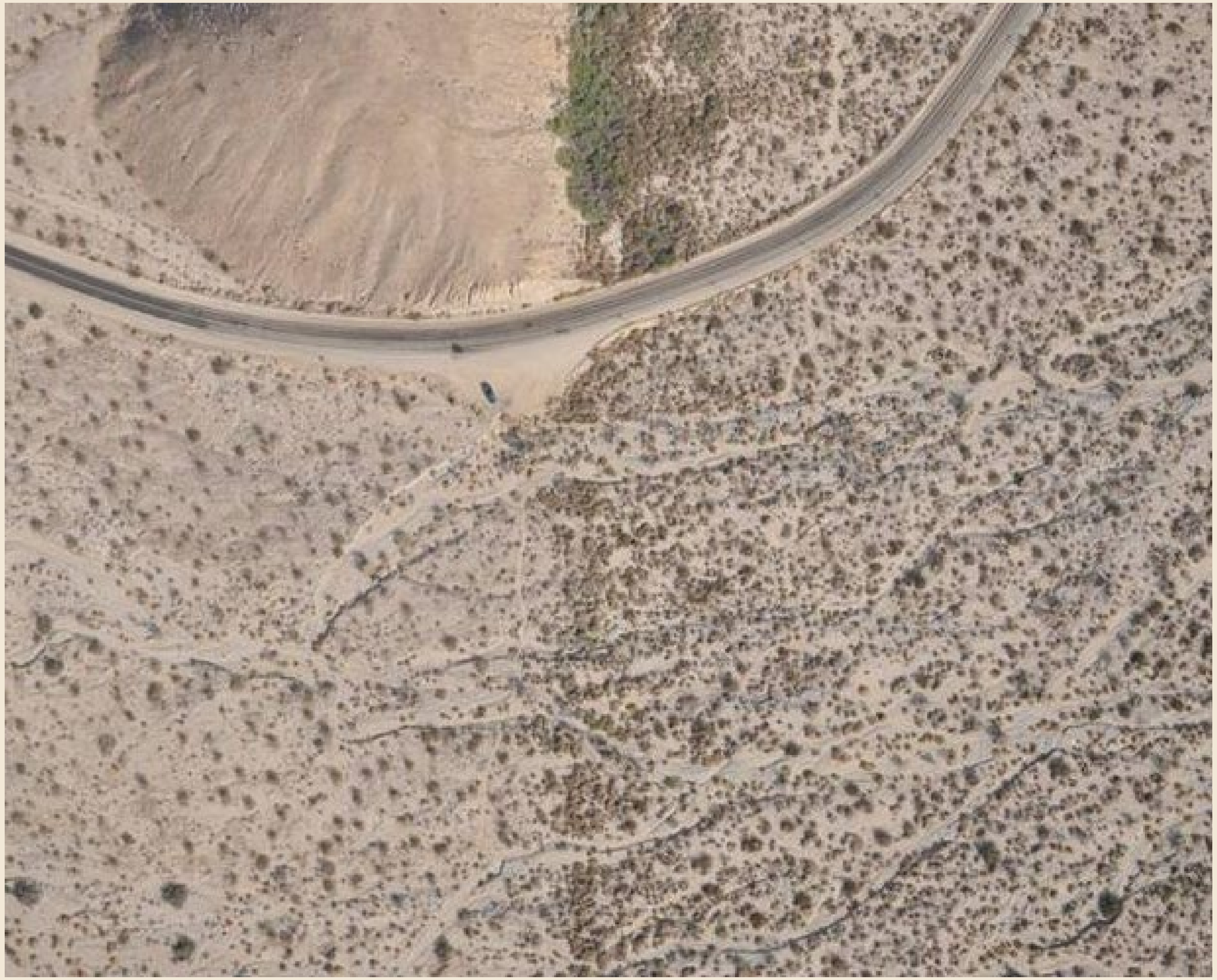
Alignment	Landslides	Stream Knickpoint
Anthropogenic Alteration	Landslides	Vegetation lineament
Colluvial Cover	Linear Valley/Drainage	Wineglass canyons
Cross cut	Morphologic elements	
Erosion	Pirated Channel	
Saddle	Proximity to active water	

Modifiers



- **Landslides** form from coseismic shaking and can indicate a nearby fault
- They can also obscure evidence of a fault trace if the landslide covers other geomorphic evidence of faulting

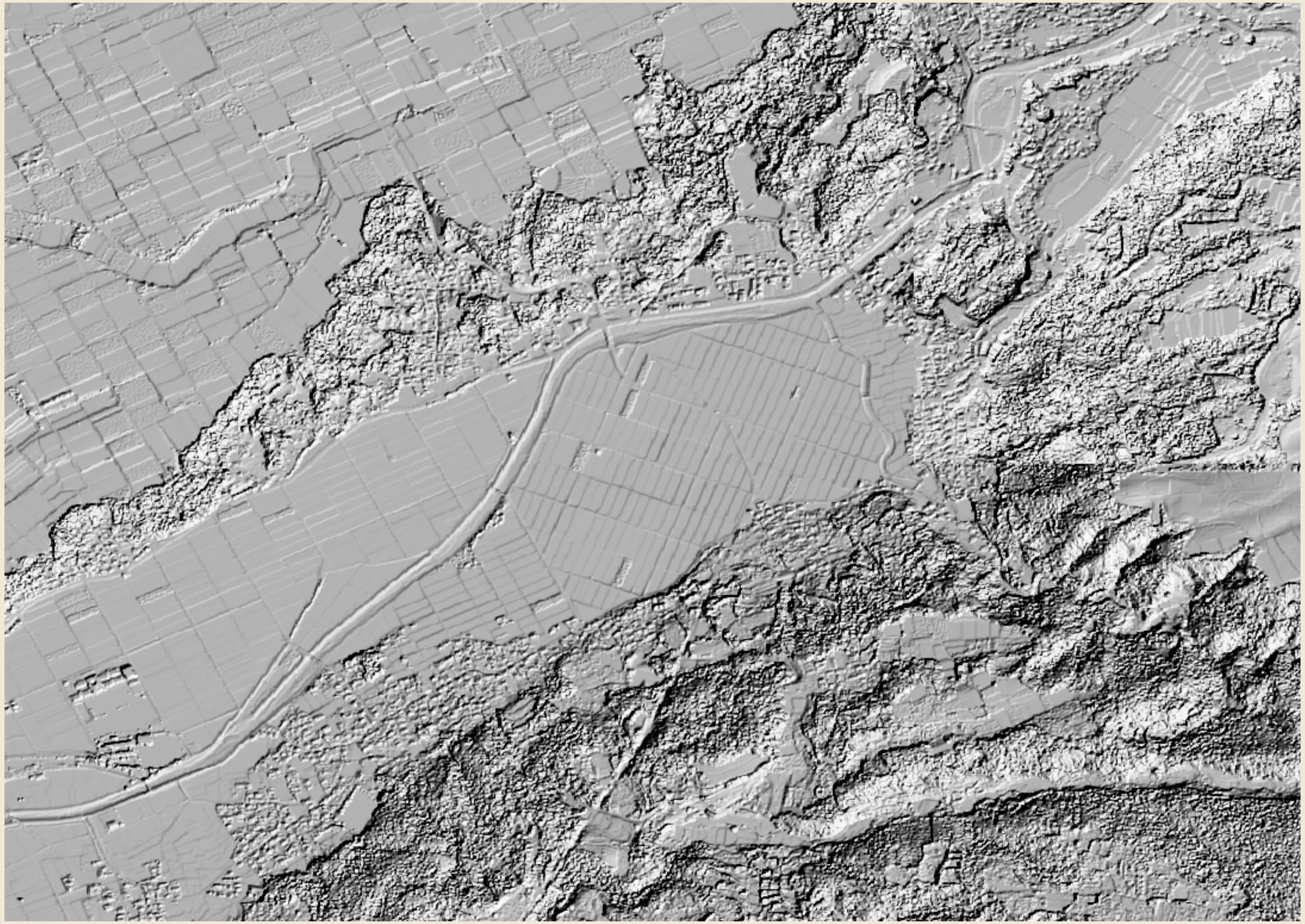
Modifiers (cont.)



Credit: Universities Space Research Association

- **Vegetation lineaments** are natural boundaries between high and low vegetation growth
- Can be formed by multiple mechanisms
- If formed by faulting (as shown here in Thousand Palms along SAF), the fault plane will disrupt the soil below and impede water flow so one side of the fault grows more vegetation than the other

Modifiers (cont.)



Location: Kumamoto, Japan

- **Erosion** can obscure the quality of other, stronger geomorphic indicators
- **Anthropogenic Alteration** includes roads, buildings, farming, urbanization
- Both can obscure faulting evidence

Primary vs. Secondary

Primary	Secondary
• Continuous trace	• Broken trace
• Multiple identifiers	• Few identifiers
• Follows similar strike to other primary faults	• Can deviate from the main fault strike
• Can be found en echelon, parallel sequence	• Can be found in singular, stray locations
• Large scarp or multiple scarp appearances	

- Geomorphic ranking wasn’t applied to determine whether the trace would be classified as primary or secondary
- Instead, general analysis using above identifiers were used to distinguish the types of faults

GIR Recap w/ Steps

1. Map each geomorphic feature and modifier along the proposed fault location in the GIR that you believe occur from the active faulting

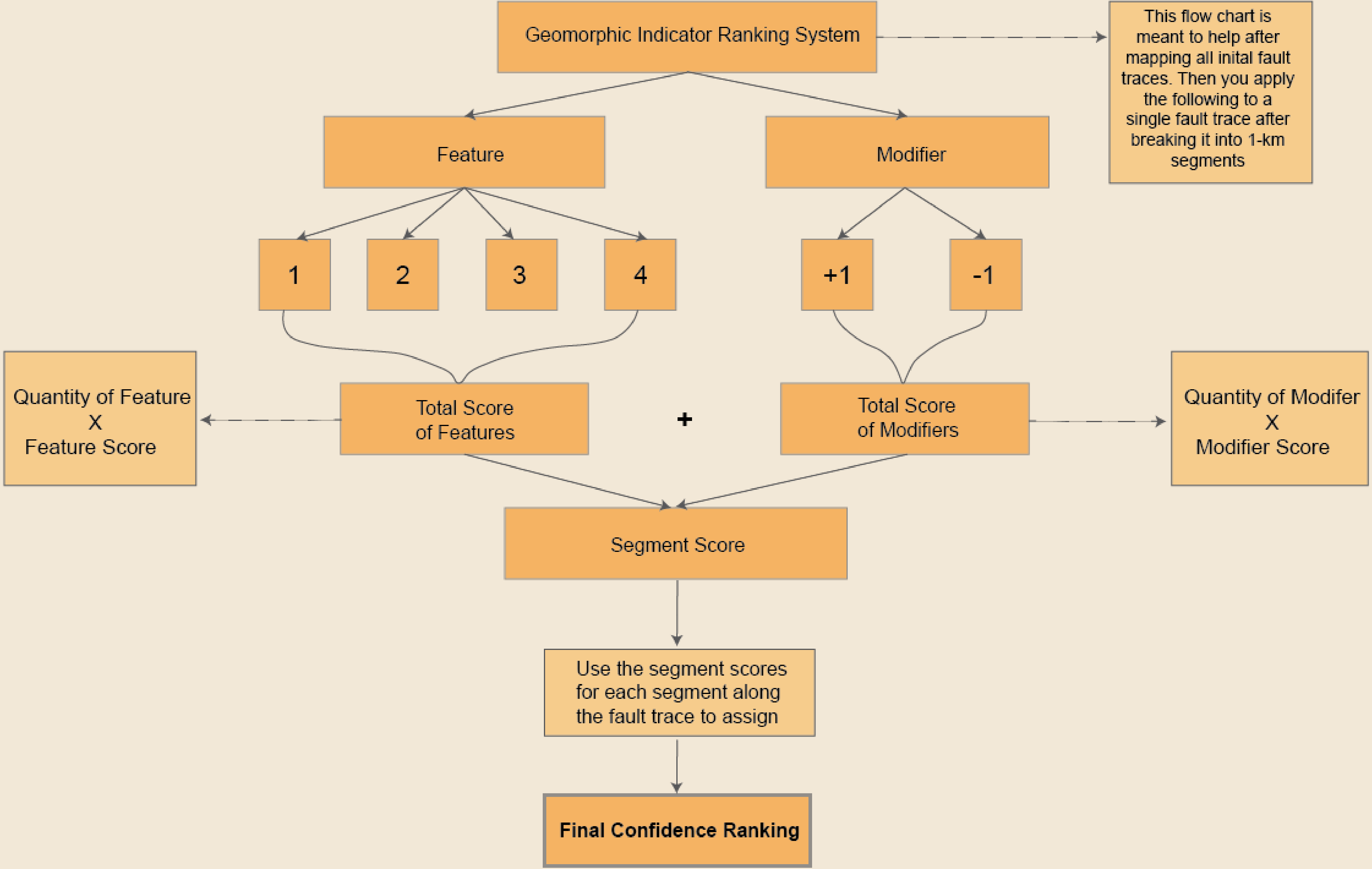
2. From the mapped features, draw a general fault trace line,

3. Break the trace into 1-kilometer segments in order to count the geomorphic features

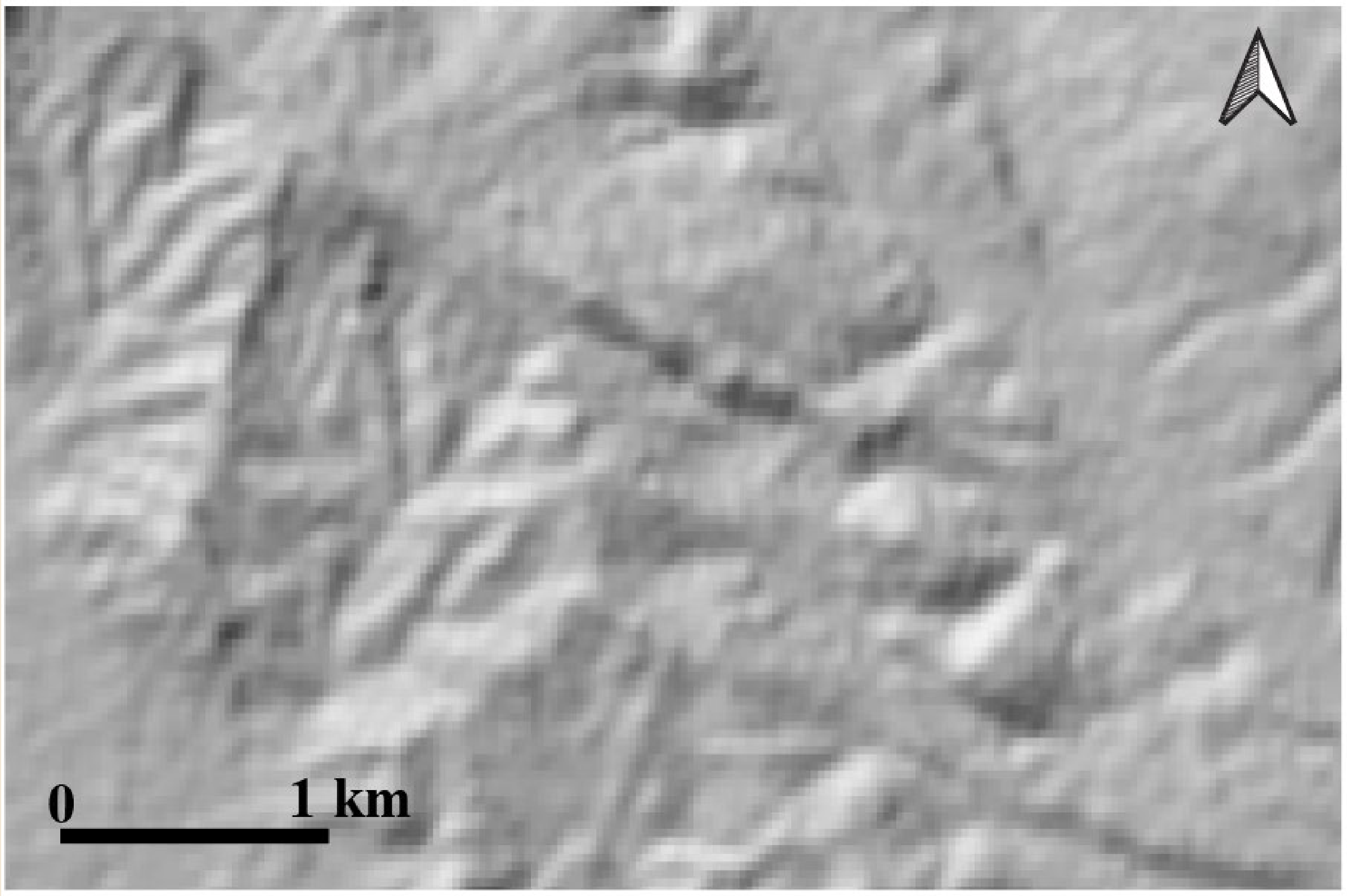
4. Add all the features together with their respective ranking to get the ‘Segment Score’

5. Use the total scores of each segment to assign a **Final Confidence Ranking** for each segment

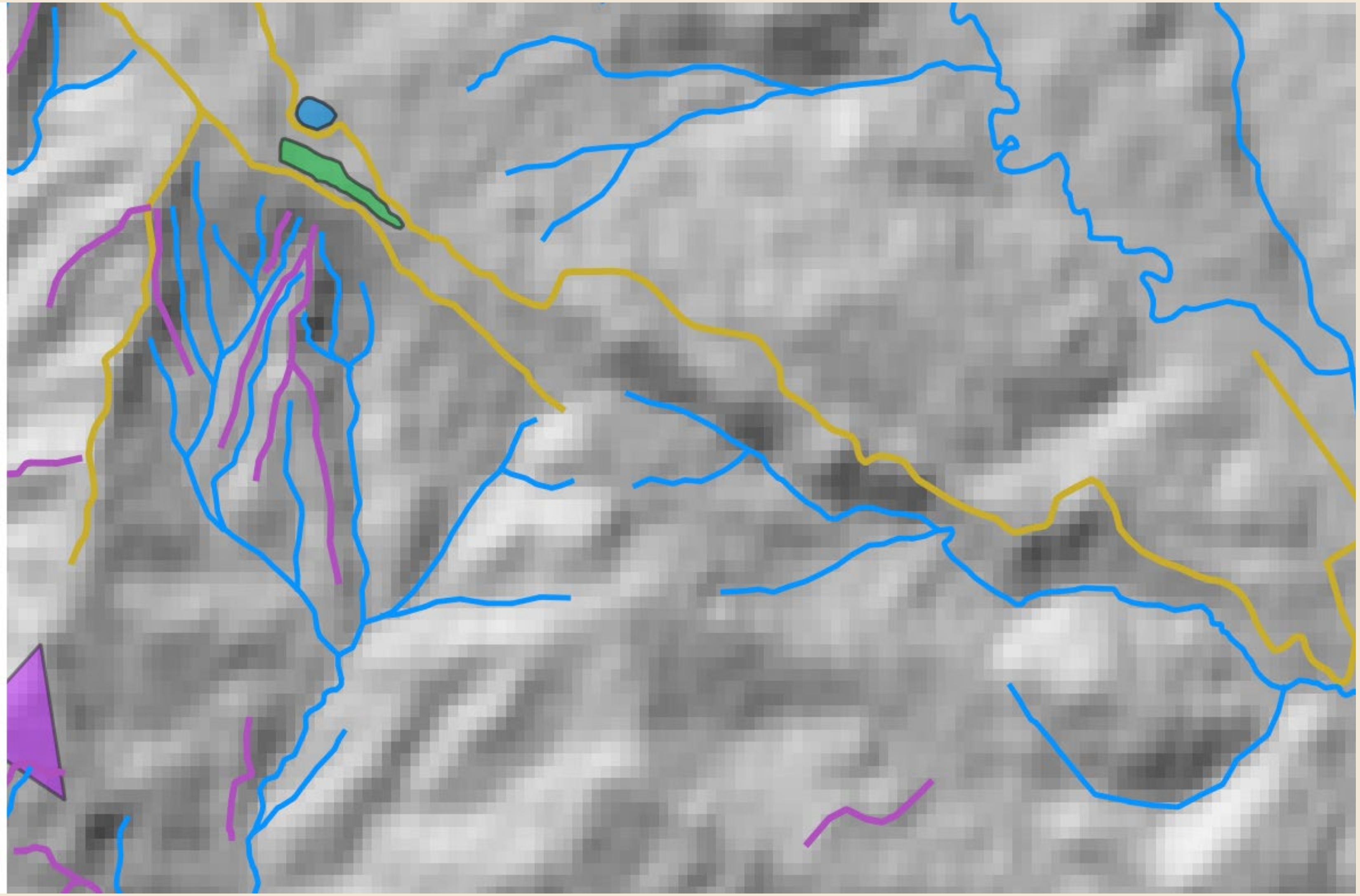
6. Adjust the fault trace to map each segment according to your final confidence

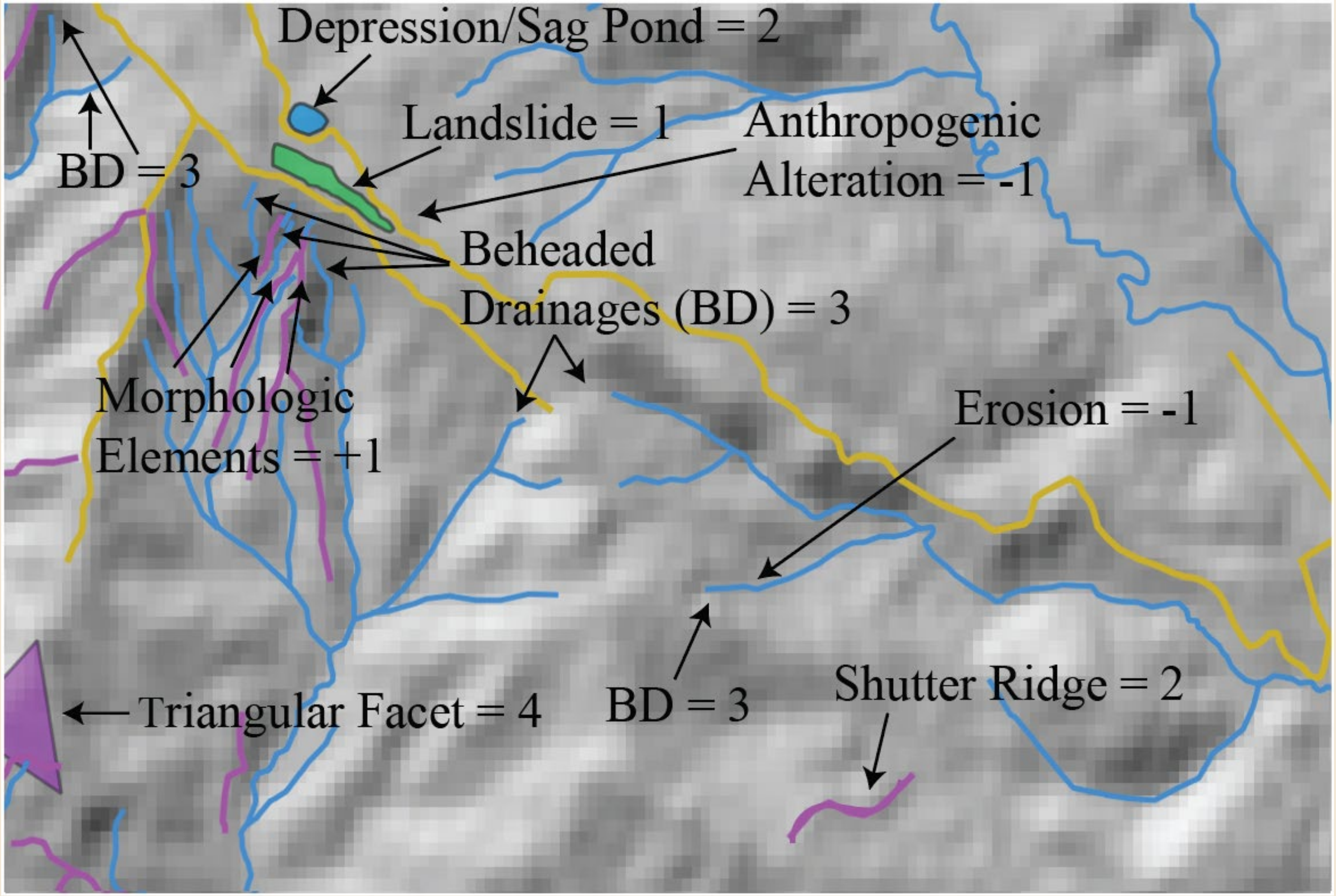

Geomorphic Indicator Ranking System
This flow chart is meant to help after mapping all inital fault traces. Then you apply the following to a single fault trace after breaking it into 1-km segments
Feature
Modifier
1
2
3
4
+1
-1
Quantity of Feature X Feature Score
Total Score of Features
+
Total Score of Modifiers
Quantity of Modifer X Modifier Score
Segment Score
Use the segment scores for each segment along the fault trace to assign
Final Confidence Ranking

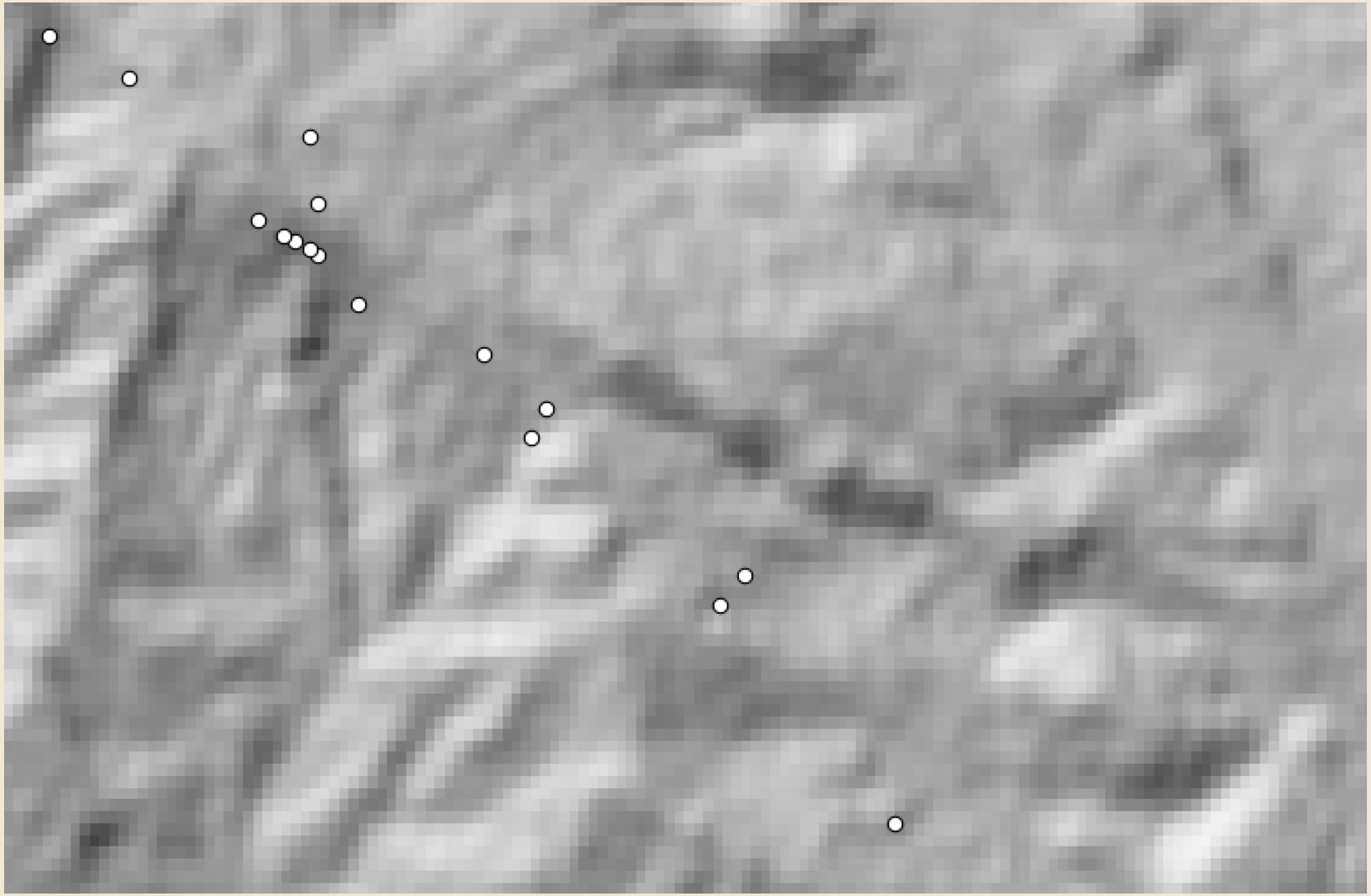
- Mapping area is from Parkfield, CA along the transitional zona of the San Andreas Fault.
- Pre-rupture mapping was done for the M6.0 earthquake on September 28, 2004
- This imagery is from the Landsat/Copernicus Satellite and is ~1.5 meters/pixel resolution

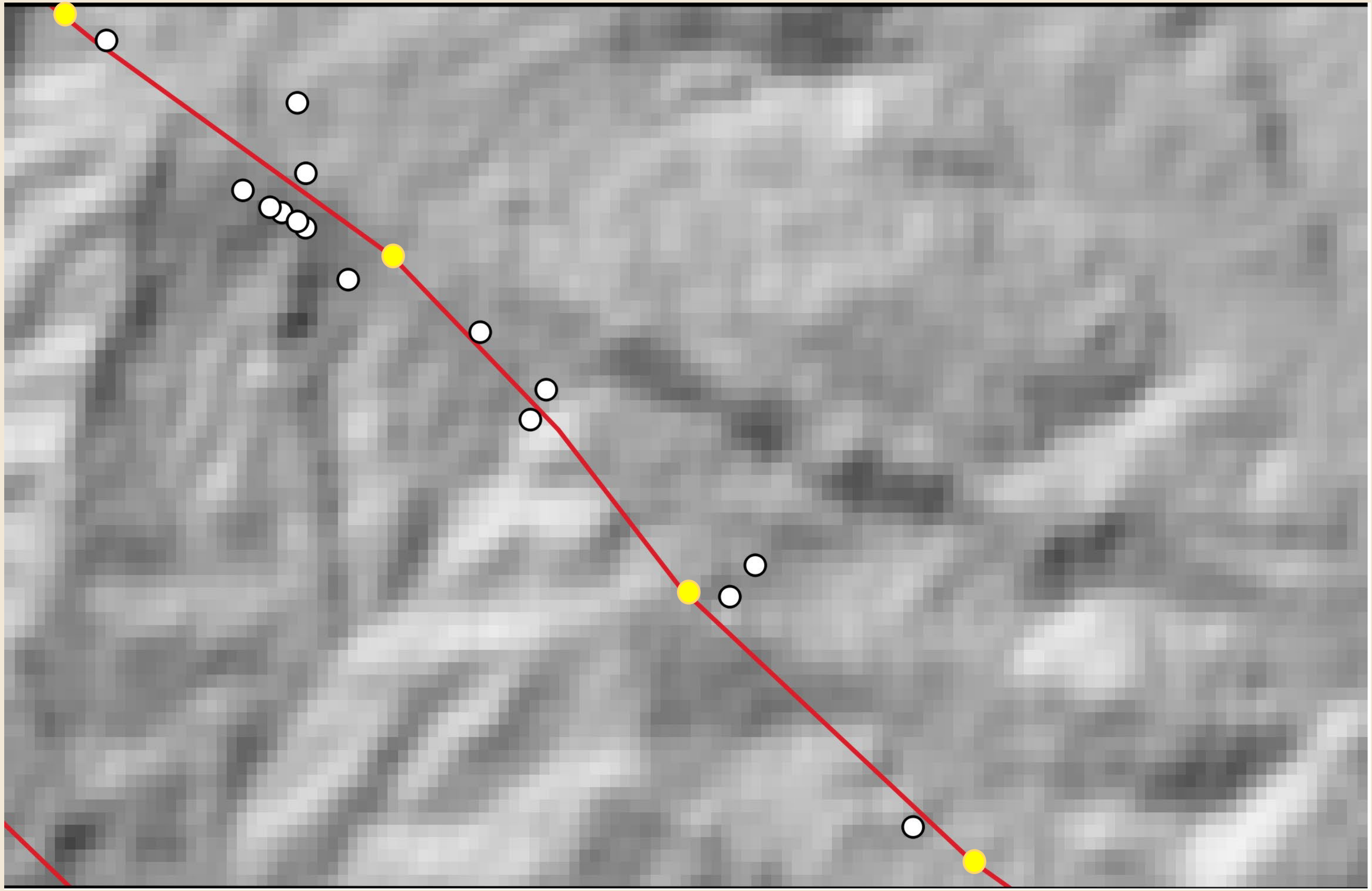


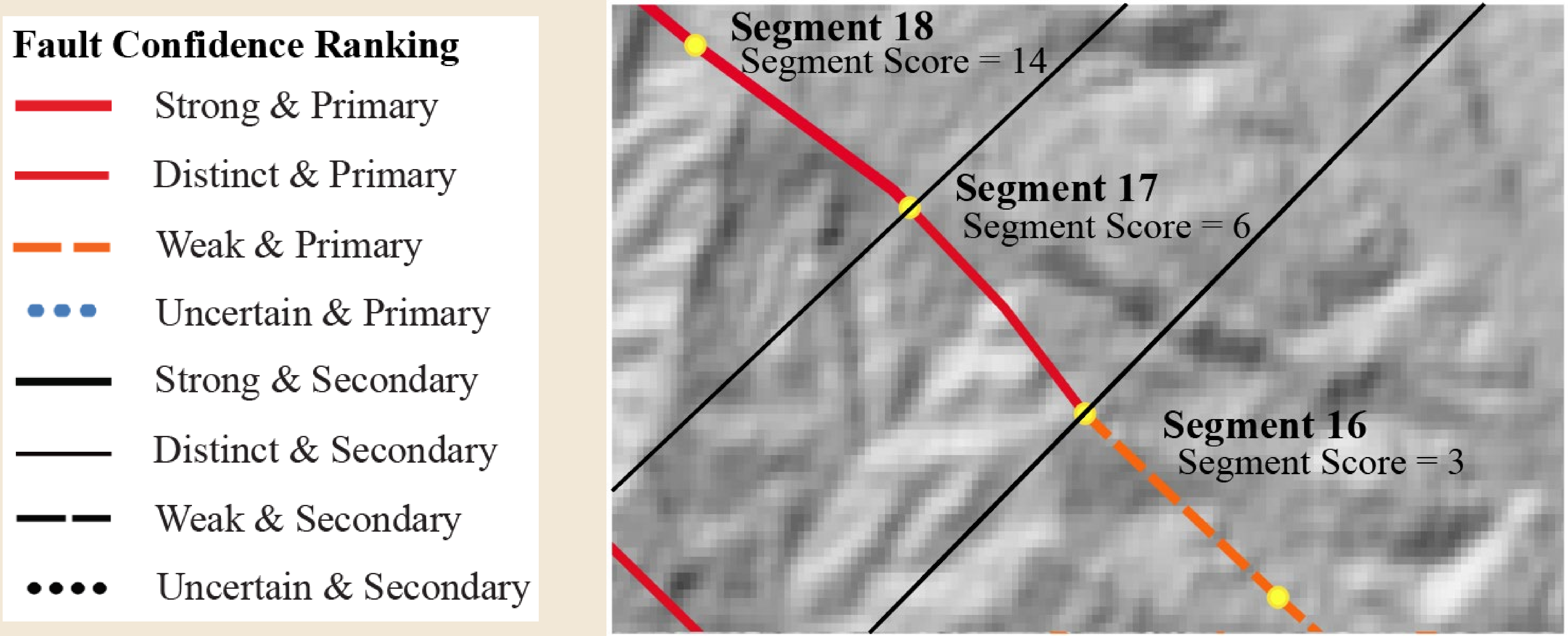
- This imagery is the same area but a 30-m DEM taken from the Nasa Shuttle Radar Topography Mission (SRTM)




Depression/Sag Pond = 2
BD = 3
Landslide = 1
Anthropogenic
Alteration = -1
Beheaded
Drainages (BD) = 3
Morphologic
Elements = +1
Erosion = -1
Triangular Facet = 4
BD = 3
Shutter Ridge = 2







Segment #	Geomorphic Features	Segment Score	Fault Confidence Ranking
18	**3** Beheaded Drainages (Score = 3), **1** Scarp (3), **1** Depression/Sag (1), **1** Land-slide (+1), **3** Morphologic Elements (+1), **1** Anthropogenic Alteration (-1)	16	Strong
17	**2** Beheaded Drainages (3)	6	Distinct
16	**1** Shutter Ridge (2), **1** Beheaded Drainage (3), **1** Erosion (-1)	4	Weak

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4. Add all the features together with their respective ranking to get the ‘Segment Score’
5. Use the total scores of each segment to assign a **Final Confidence Ranking** for each segment
6. Adjust the fault trace to map each segment according to your final confidence