Intro to exercise: Mapping landforms with applications to geomorphology and earthquake geology

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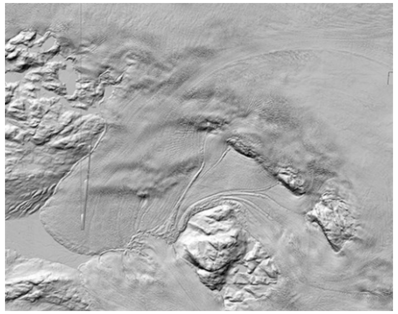
Exercise on simple mapping for landforms along active faults

- Designed as in class exercise; pencil and paper ok if you can print it out and then take pictures of the result to turn in. Or, use a drawing program.
- I am sorry that I did not yet build an example for normal faults, but the lessons on strike-slip and reverse faulting related landforms hopefully point the way

Getting the right coverage in time, space, and resolution for the question

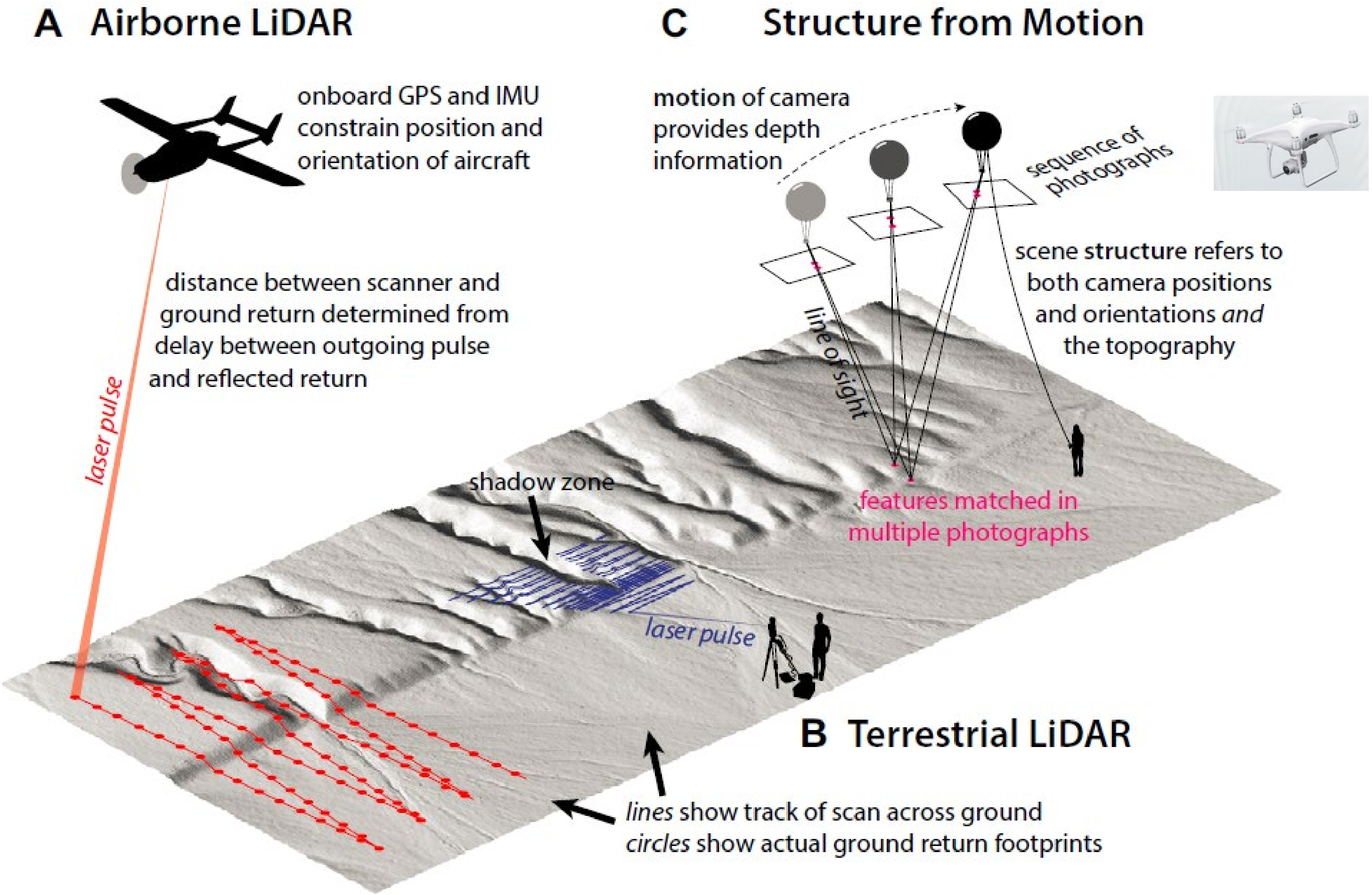
Global and regional topography/bathy (10s-100s m/pix)

+ASTER



Stereo-Photogrammetric Elevation Model (Polar Geospatial Center)

Local to site scale topography (dm to m / pix)



Johnson, K., Nissen, E., Saripalli, S., Arrowsmith, J R., McGarey, P., Scharer, K., Williams, P., Blisniuk, K., Rapid mapping of ultra-fine fault zone topography with Structure from Motion, Geosphere, v. 10; no. 5; p. 1–18; doi:10.1130/GES01017.1, 2014.

Digital Elevation Models

- Digital representation of topography / terrain
  - “Raster” format – a grid of squares or “pixels”
  - Continuous surface where Z (elevation) is estimated on a regular X,Y grid
  - “2.5D”

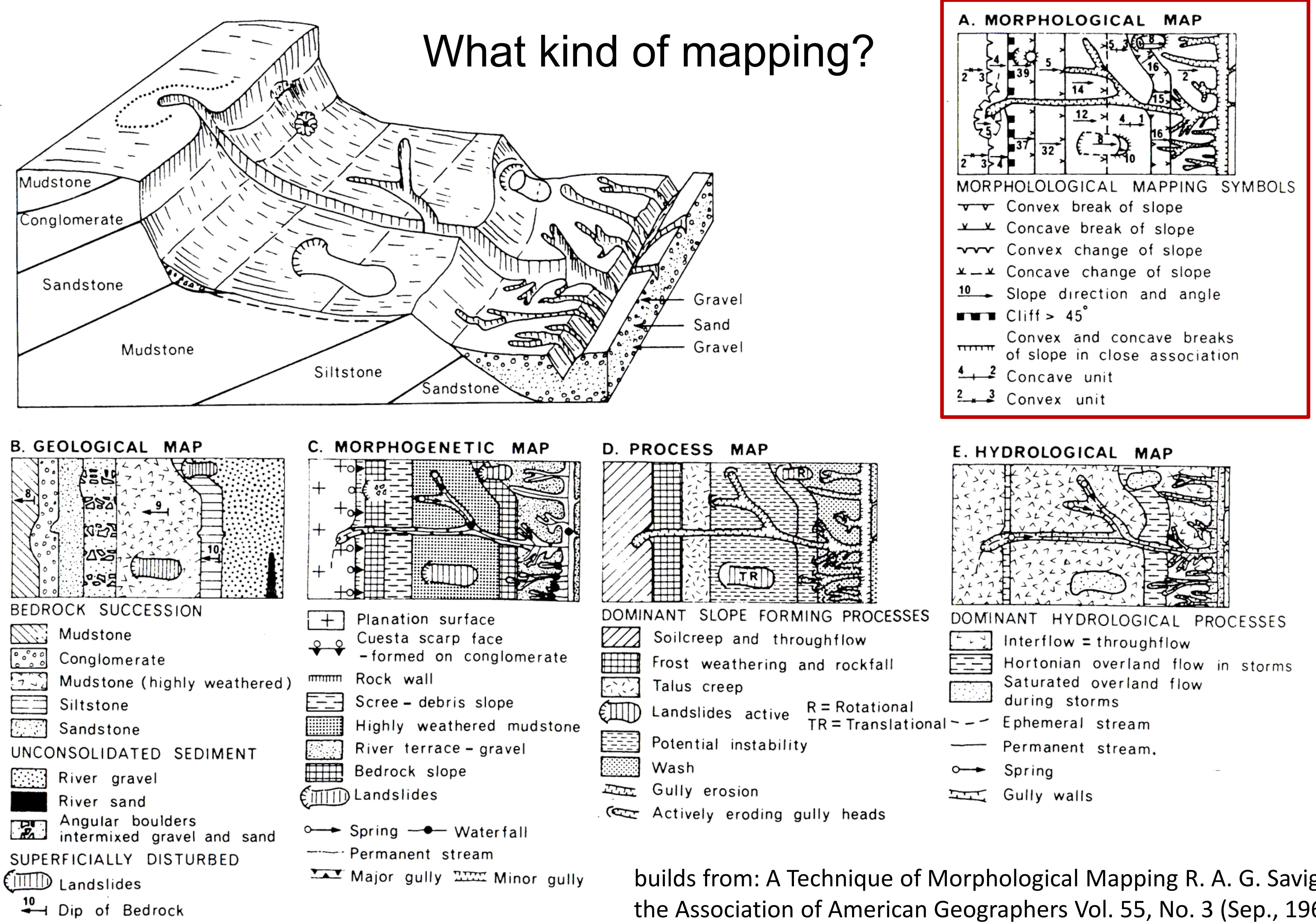
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	0
0	50	100	100	100	100	100	100	100	100	100	100	100	100	100	50	0
0	50	100	150	150	150	150	150	150	150	150	150	150	150	100	50	0
0	50	100	150	200	200	200	200	200	200	200	200	200	150	100	50	0
0	50	100	150	200	250	250	250	250	250	250	250	200	150	100	50	0
0	50	100	150	200	250	300	300	300	300	300	250	200	150	100	50	0
0	50	100	150	200	250	300	350	350	350	300	250	200	150	100	50	0
0	50	100	150	200	250	300	350	400	350	300	250	200	150	100	50	0
0	50	100	150	200	250	300	350	350	350	300	250	200	150	100	50	0
0	50	100	150	200	250	300	300	300	300	300	250	200	150	100	50	0
0	50	100	150	200	250	250	250	250	250	250	250	200	150	100	50	0
0	50	100	150	200	200	200	200	200	200	200	200	200	150	100	50	0
0	50	100	150	150	150	150	150	150	150	150	150	150	150	100	50	0
0	50	100	100	100	100	100	100	100	100	100	100	100	100	100	50	0
0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: http://www.ncgia.ucsb.edu/giscc/extra/e001/e001.html

- Grid resolution is defined by the size in the horizontal dimension of the pixel
  - 1 meter DEM has pixels 1 m x 1m assigned a single elevation value.

Hillshade is artificial illumination (usually actually from the NW: 315)

What kind of mapping?



builds from: A Technique of Morphological Mapping R. A. G. Savigear Annals of the Association of American Geographers Vol. 55, No. 3 (Sep., 1965), pp. 514-538

Fig. 10.3. Maps are some of the most common landscape models. These maps show various features and interpretations of one landscape represented in a block diagram. Such maps are very useful for recording field observations. (Modified and extended from Brunsden *et al.* 1975.)

I. Mapping the San Andreas Fault (SAF) near Wallace Creek California

Goals--After completing this exercise, you should have these basic skills:

- Use large scale aerial photography, topographic maps, and other topographic data to delineate landforms.
- Identify tectonic landforms along a strike-slip fault system and estimate offsets if appropriate.
- Interpret simple logs of excavations (trenches) to determine the ages of landforms.
- Estimate the slip rate along the San Andreas Fault and consider the implications for earthquake timing.

I. Mapping the San Andreas Fault (SAF) near Wallace Creek California

Tasks:

- Make a morphologic and geomorphic map of the site
- Identify major tectonic landforms along strike slip faults
- Measure offset channels
- Interpret trench logs
- Compute slip rate

Wallace Creek area airphotos draped over 0.5 m digital elevation model

Wallace Creek area airphotos draped over 0.5 m digital elevation model

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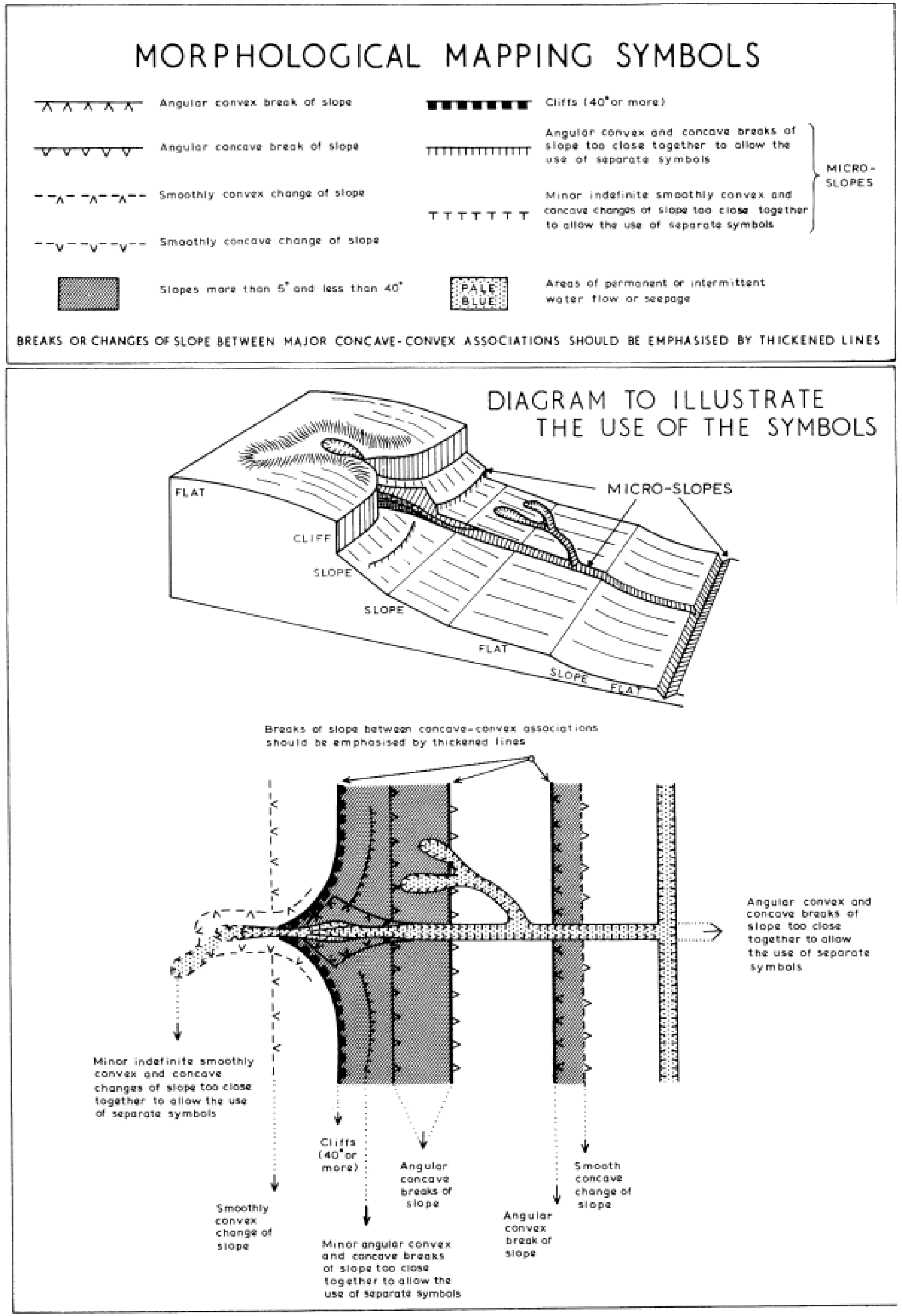
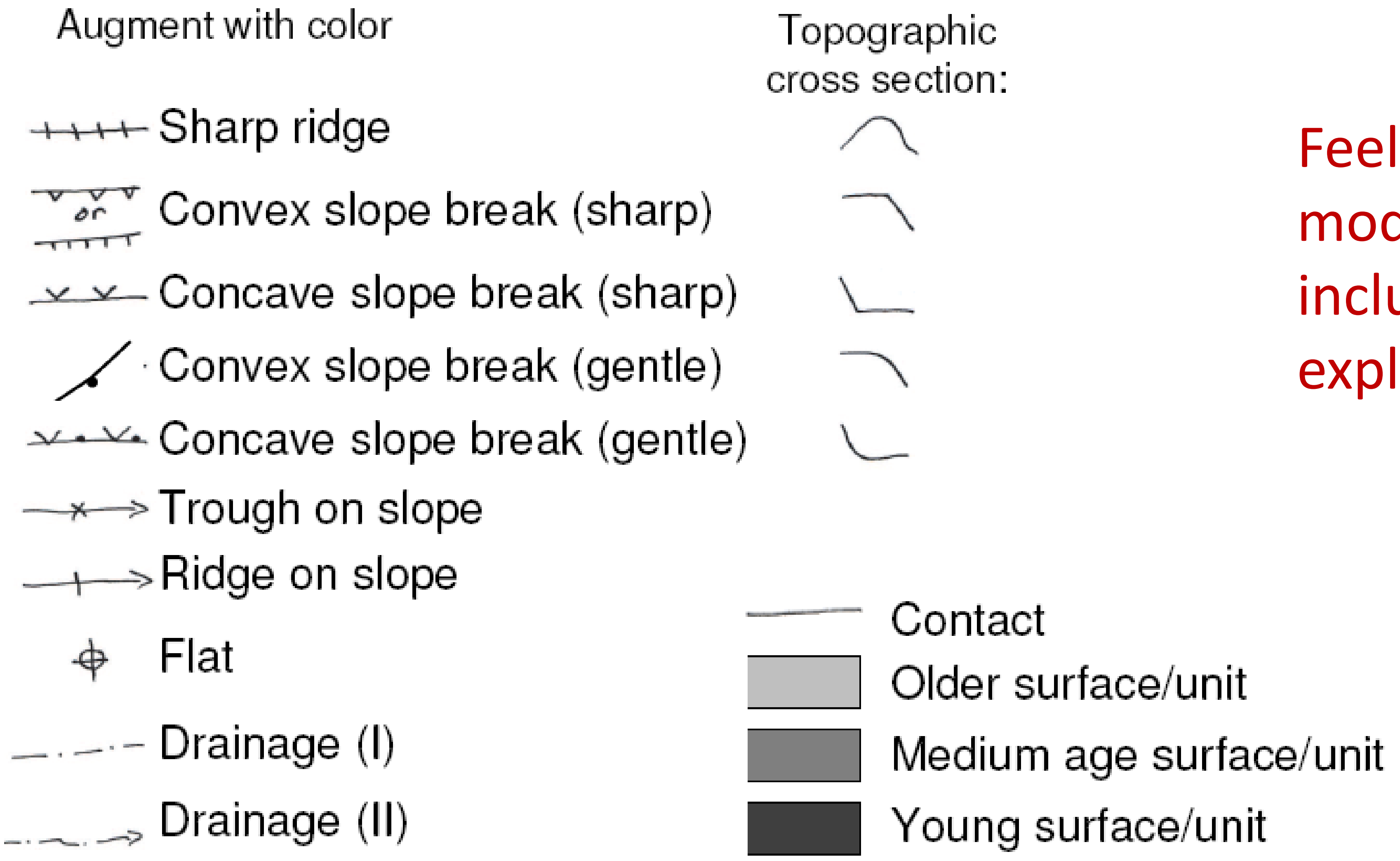
Wallace Creek area airphotos draped over 0.5 m digital elevation model



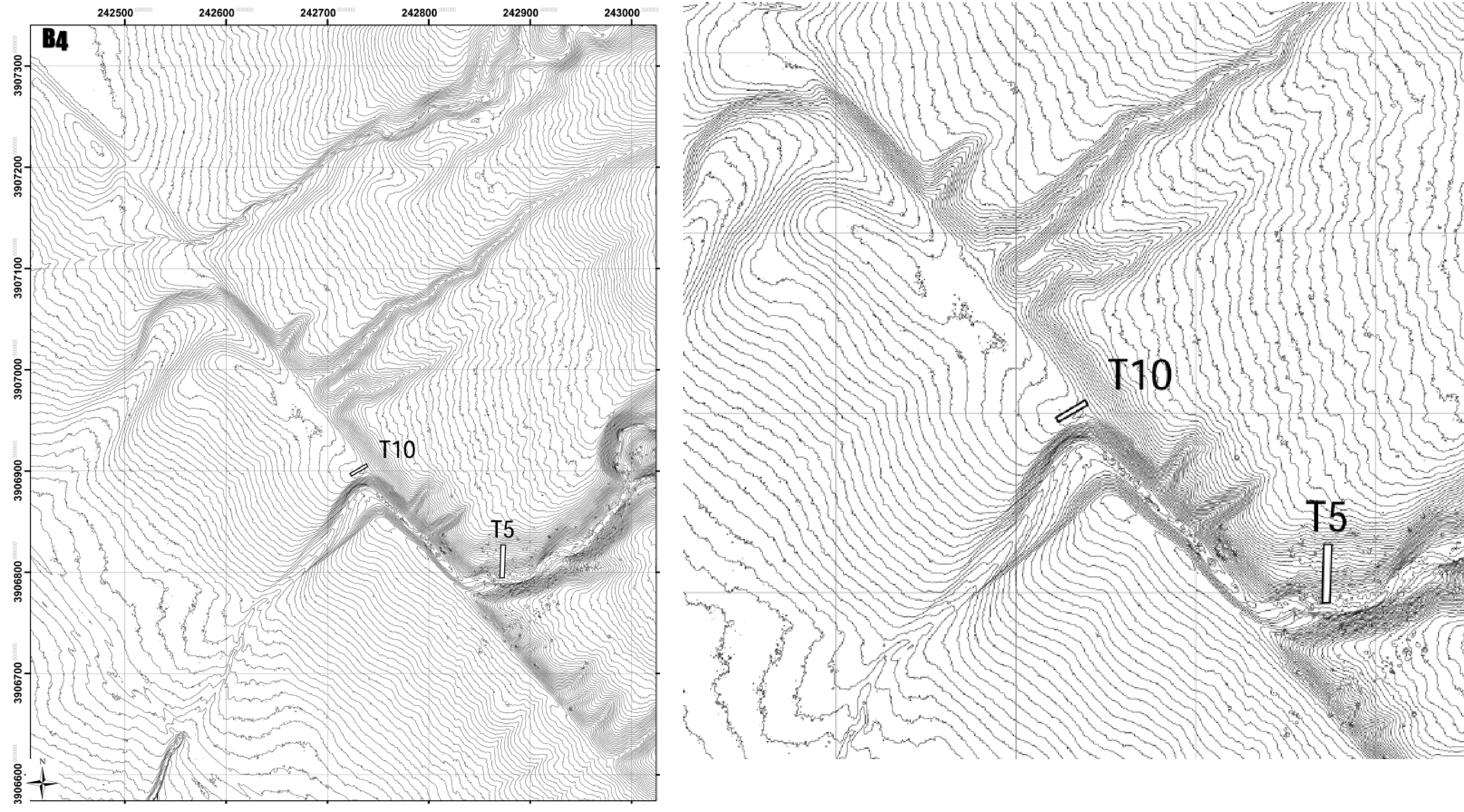
-Savigear, 1965

Suggested morphologic mapping symbology



Feel free to modify! Just include an explanation

Suggested morphologic mapping symbology. Use this mapping "language" to indicate the positions and extents of the morphologic elements that comprise the landforms. Feel free to create new ones as you need; just be consistent and put it on an explanation for the map. Use colors where you can for emphasis.

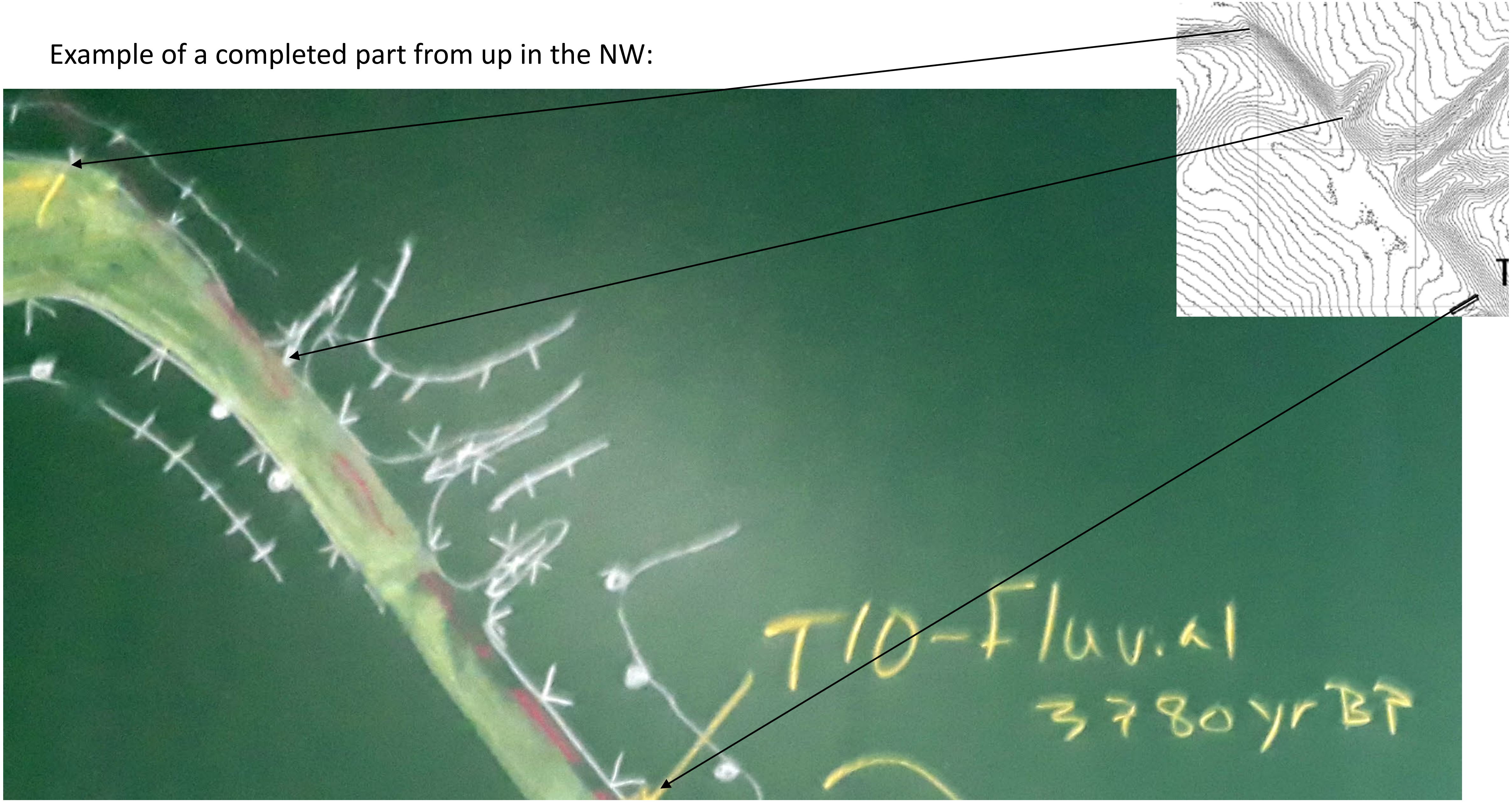

B4
242500
242600
242700
242800
242900
243000
3907300
3907200
3907100
3907000
3906900
3906800
3906700
3906600
N
T10
T5
T10
T5

Line work guided by topographic breaks

Line work only

Additional interpretation (valley floor) and fault zone

Example of a completed part from up in the NW:



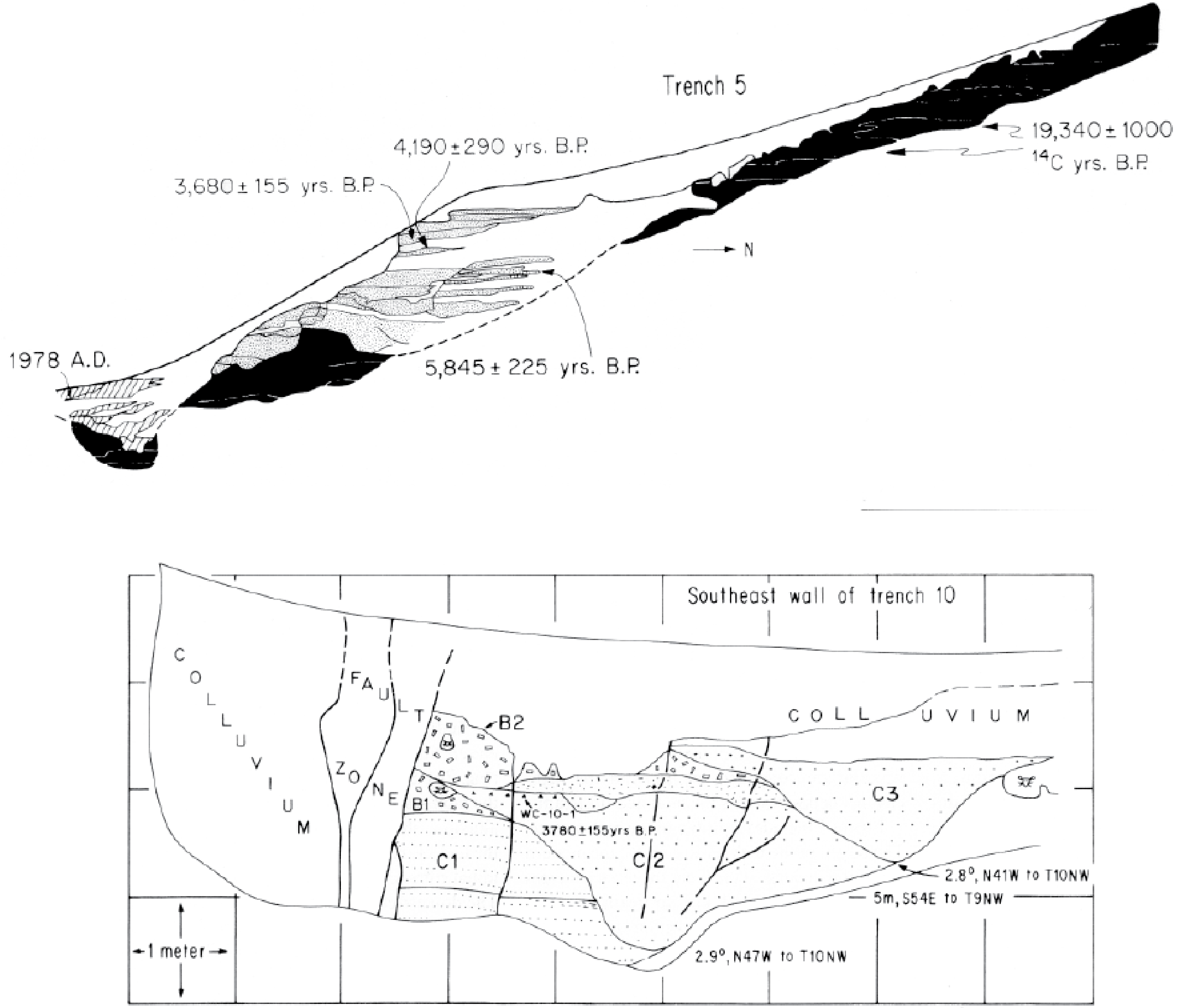


Figure I.6: *Logs from trenches 5 and 10 from Sieh and Jahns 1984. Use these ^{14}C ages to estimate the time of* <u>*last*</u> *deposition of these materials and hence the ages of the surfaces they are associated with. Note their locations on Figure 3. Units B1-B2 are scarp derived colluvium. C1-C3 are fluvial sands and gravels.*

Hints:

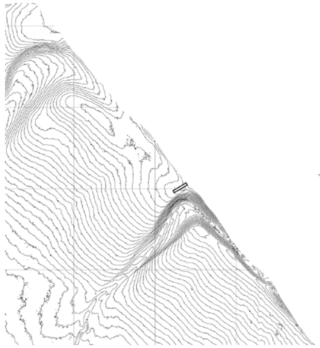
T5 exposes "bedrock" (black) overlain by a fluvial terrace deposit.

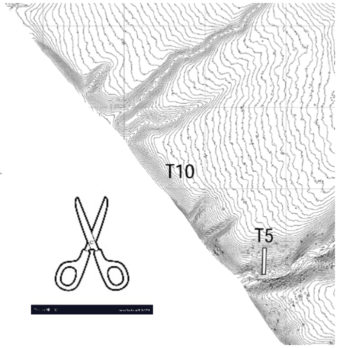
T10 exposes fluvial units (C1, C2, C3; paleo flow parallel to the fault) overlain by colluvium.

Sedimentary characteristics suggest that T5 fluvial units correlate to T10 channel units

*Assume youngest fluvial ages in the terrace/abandoned channel = age of abandonment = age of modern Wallace Creek

Upstream feature (type/location)	*Downstream feature (type/location)*	*Offset measurement (m)*	*Age (Years BP)*	*Slip rate (offset/age)*





https://www.vectorstock.com/royalty-free-vector/scissors-cartoon-vector-21843654

II. Examining an uplifting landscape: Wheeler Ridge, California

Goals--After completing this exercise, you should have these basic skills:

- Use high resolution topographic data to delineate tectonic landforms over an active fold.
- Given ages of deformed landform elements, estimate the surface uplift rate where possible.
- Interpret the pattern of fold growth.

II. Examining an uplifting landscape: Wheeler Ridge, California

Tasks:

- Make a morphologic and geomorphic map of the site
- Identify major tectonic landforms over the feature
- Measure uplifted features
- Interpret age control
- Compute uplift and propagation rate

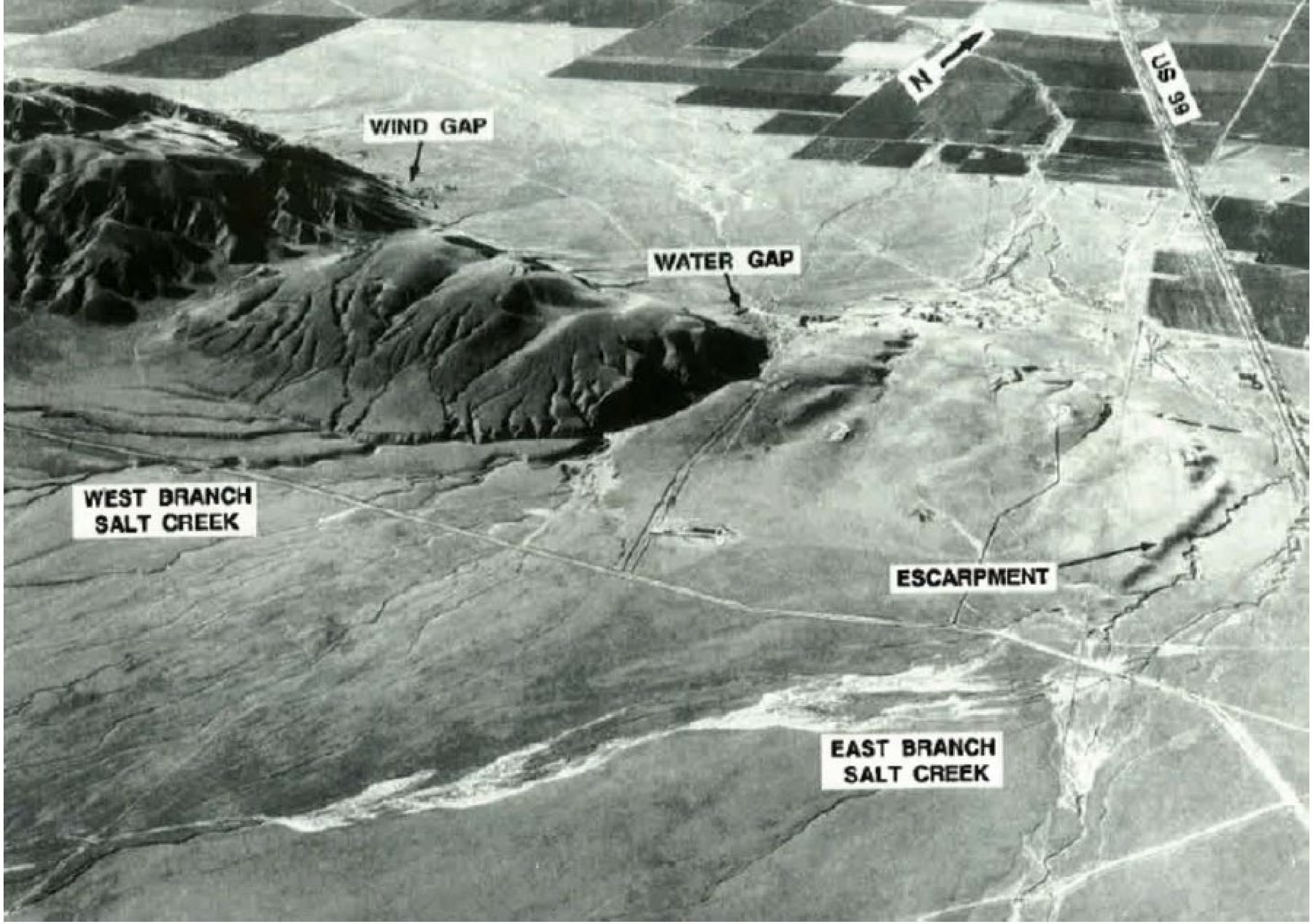
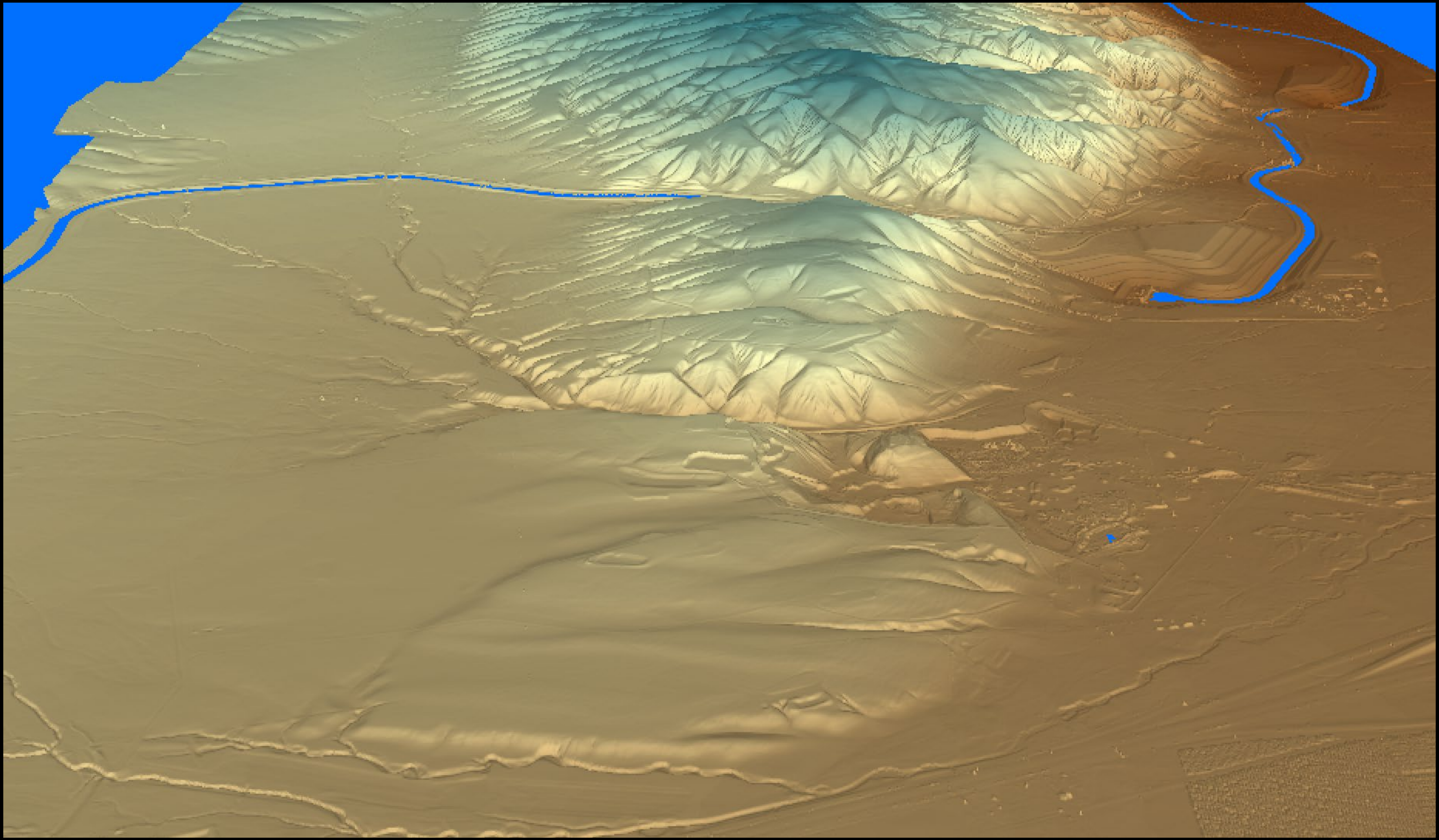


Figure II.2. *Low angle aerial photo from Shelton (1966) over the eastern portion of Wheeler Ridge pointing out the wind and water gaps and their positions relative to the northward flowing branches of Salt Creek. View to the northwest.*

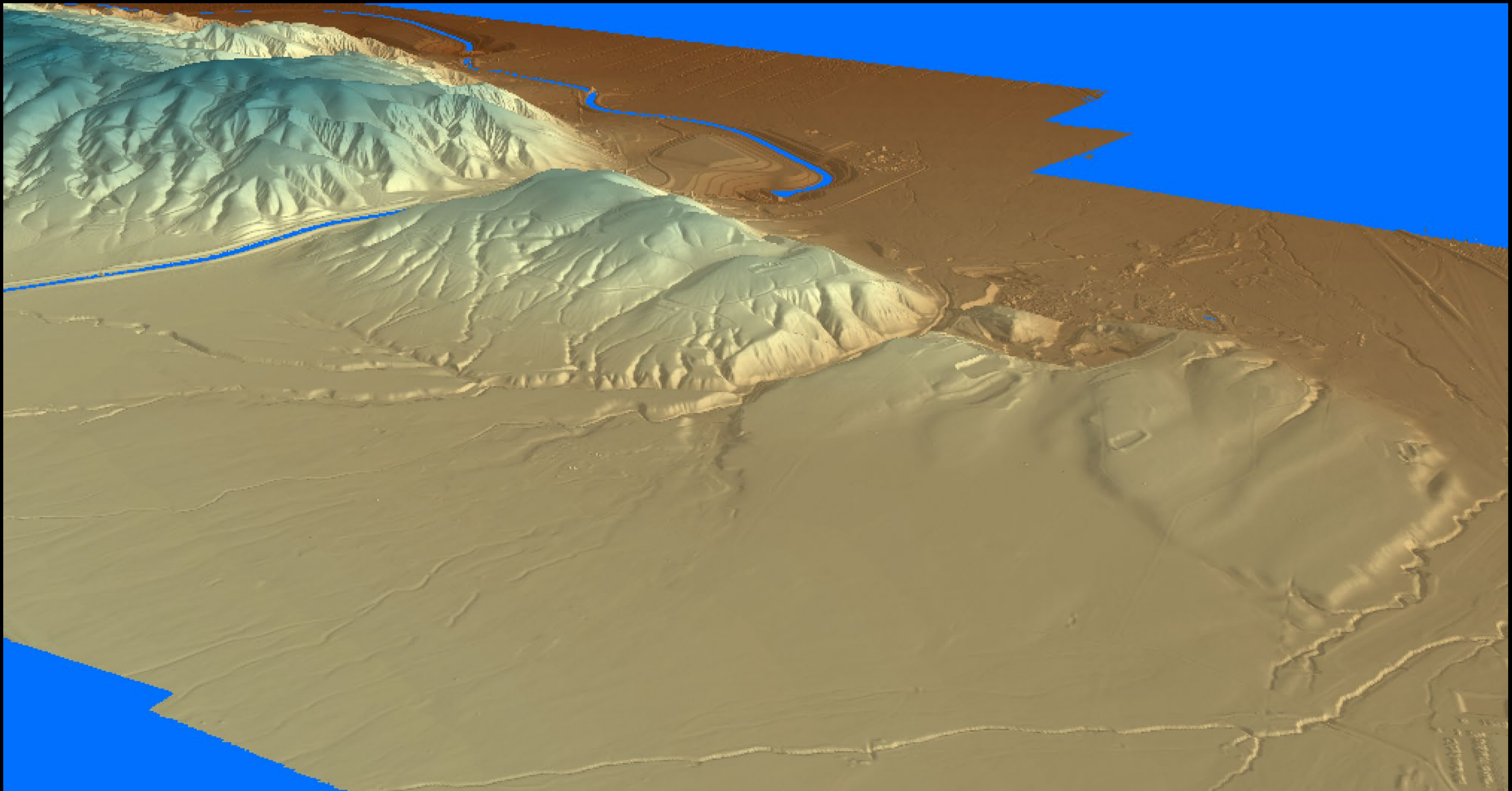
Wheeler Ridge 1 m digital elevation model

Wheeler Ridge 1 m digital elevation model

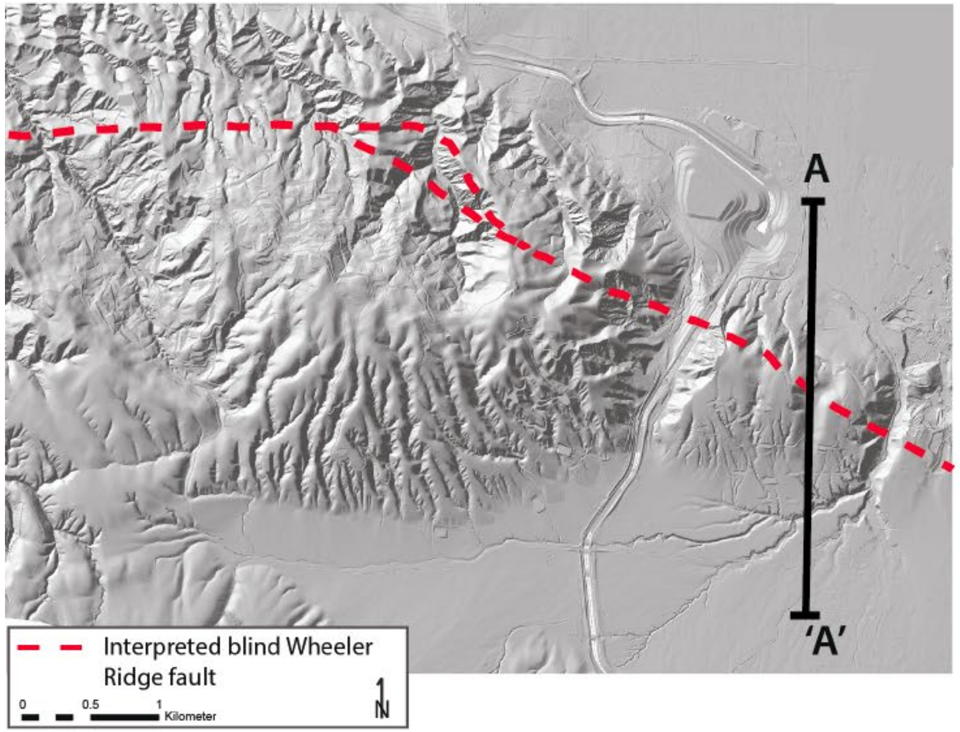
Wheeler Ridge 1 m digital elevation model

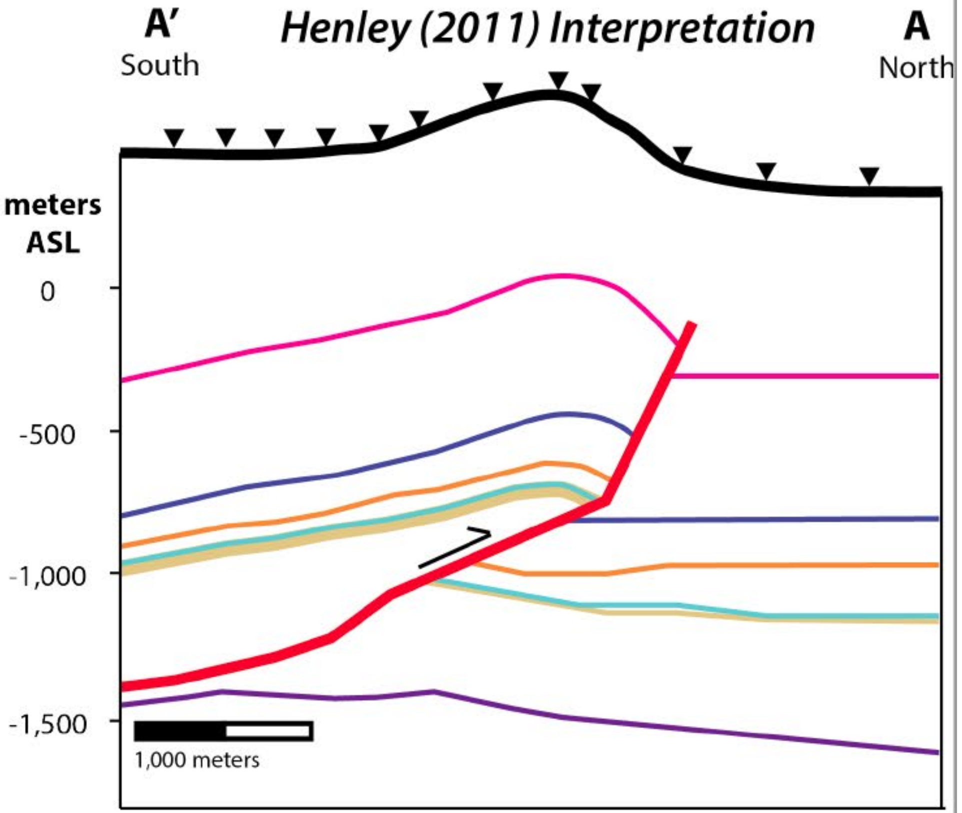


Wheeler Ridge 1 m digital elevation model



Previous work- Oil well data and interpretations

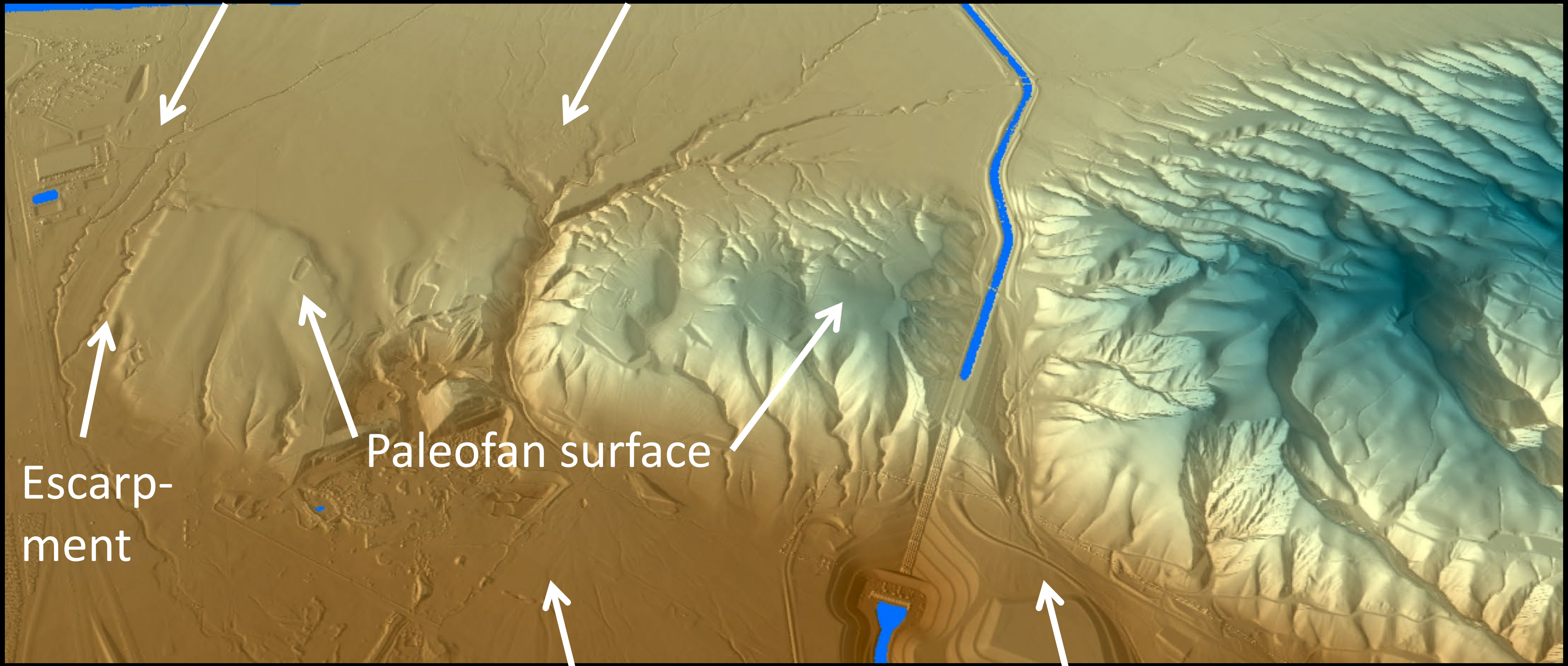


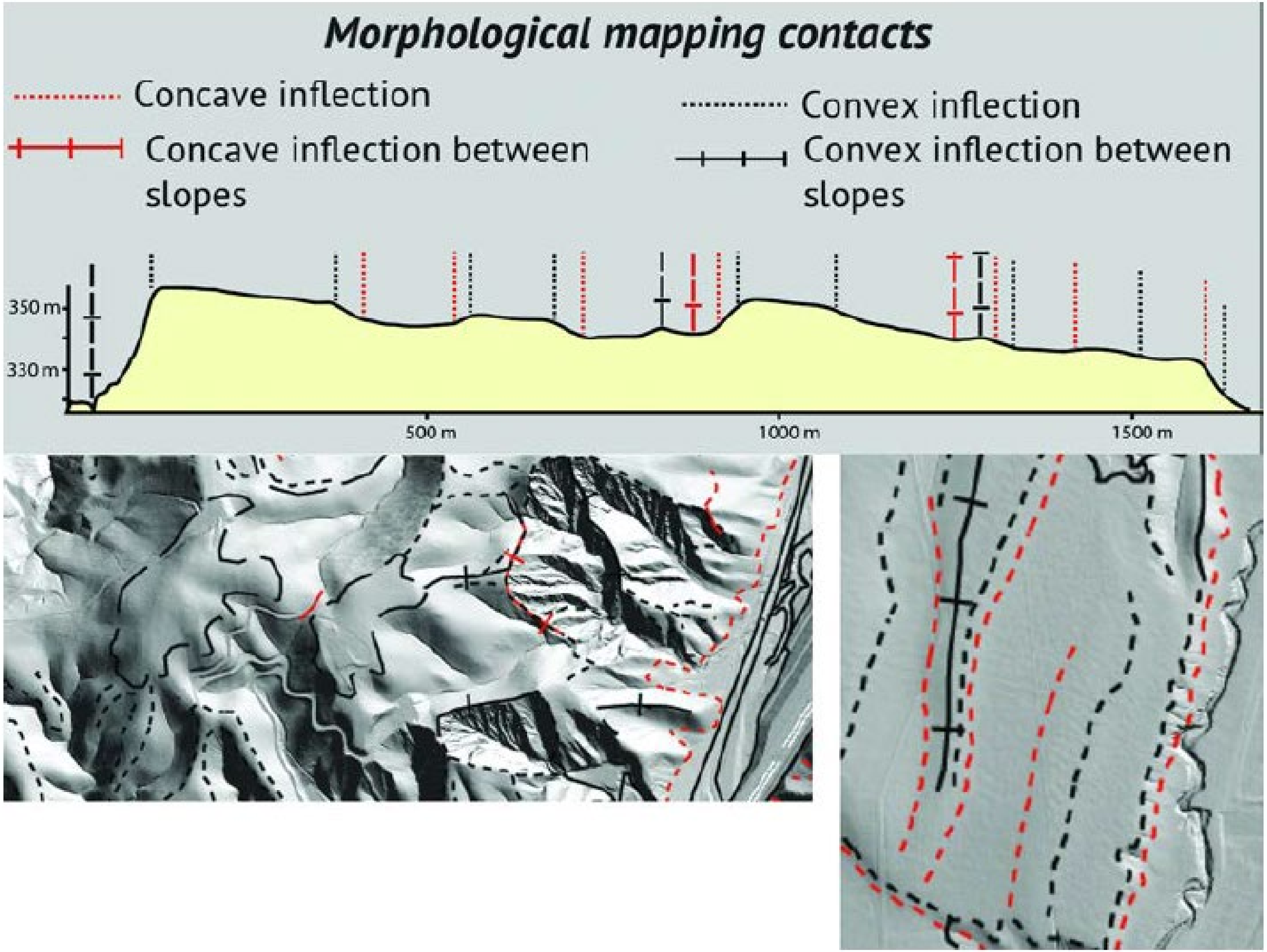


- Oil and gas exploration yields some constraints on the fold geometry.
- Based on measured structural relief, Uplift rate: 3.2 mm/yr

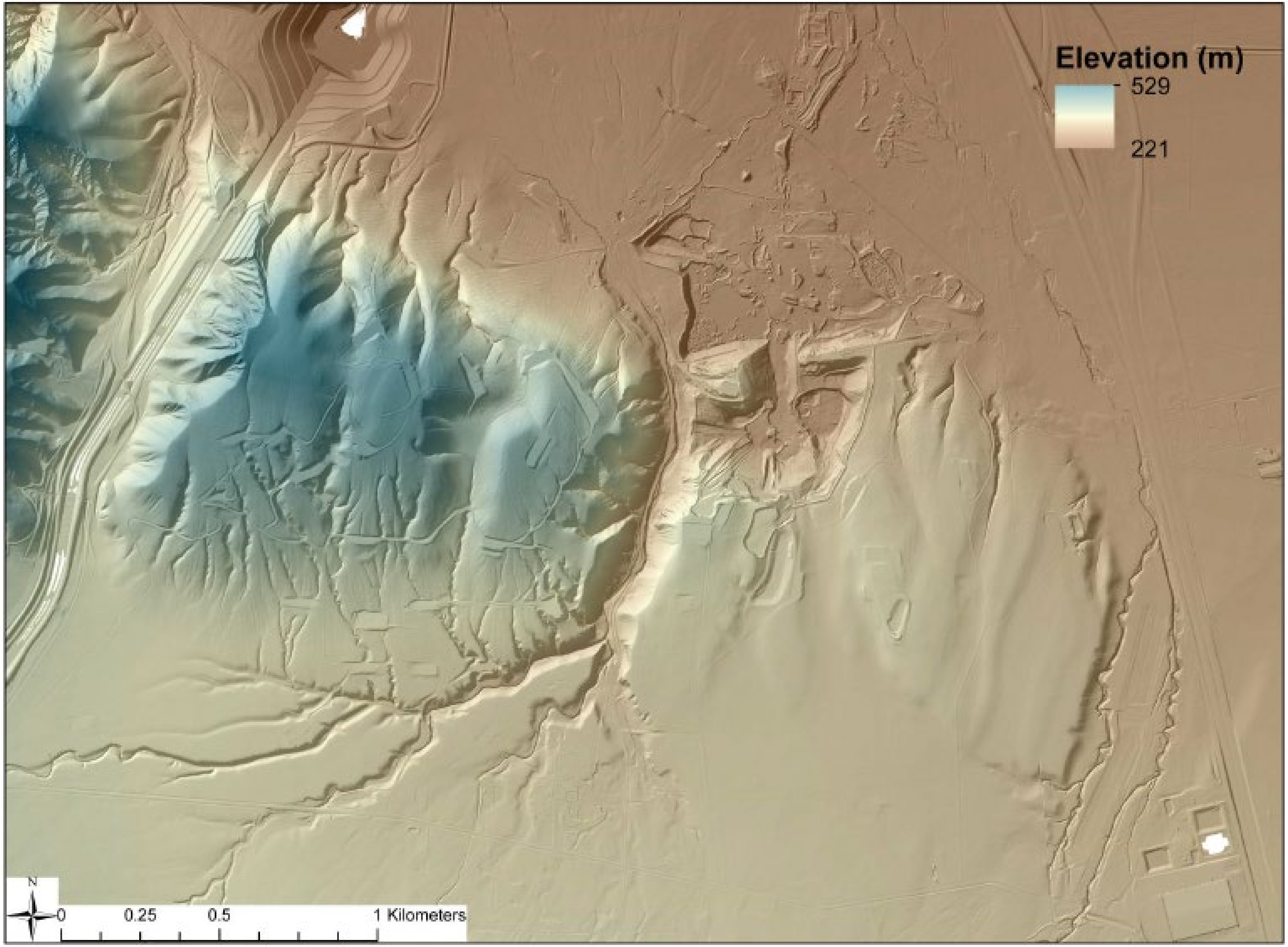
-E. Kleber, MS defense, 2015

Identify features

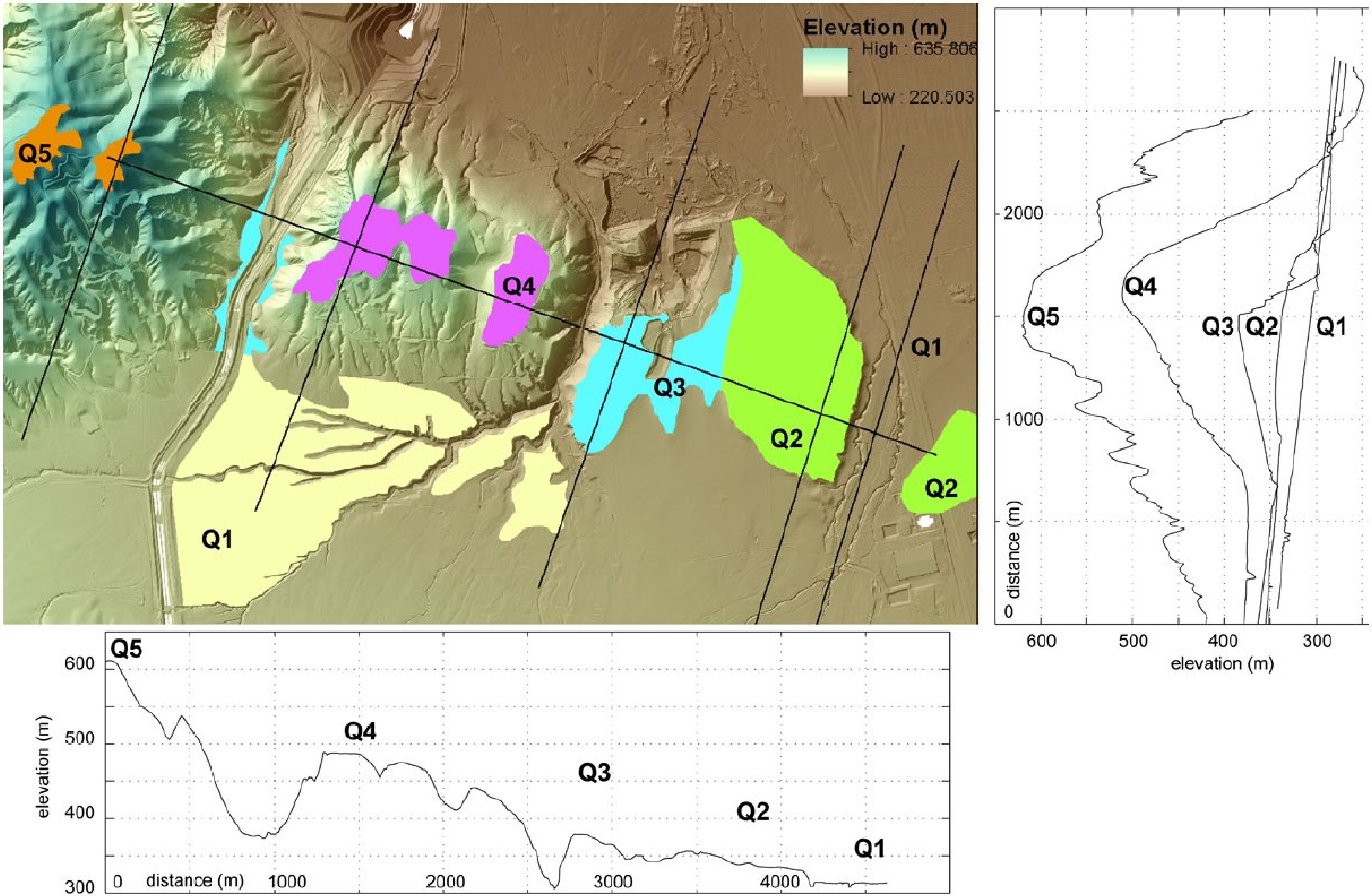




Feel free to modify! Just include an explanation



Draw on this figure



Elevation (m)
High : 635.806
Low : 220.503
Q5
Q4
Q3
Q2
Q1
Q2
Q1
elevation (m)
distance (m)
0
1000
2000
3000
4000
300
400
500
600

WHEELER RIDGE SOIL CHRONOSEQUENCE

Geomorphic surface*	Solum thickness (m)	B Horizon Type	Moist color†	Texture	Structure	Clay films	Carbonate stage§	Approx. elevation (m)	Approximate age of deposits (ka)
Q1	0.5–0.8	AC to Cambic B	10YR 3/3	Sandy to sandy loam	Primary fluvial stratification to massive	None	Weak I	295–299	Holocene#
Q2	2.4+	Argillic	10YR 4/4	Sandy loam	Moderate coarse subangular blocky	Many thin and moderately thick on pebble-matrix interfaces	I–III	318–335	17**
Q3	2.7+	Argillic	10YR 4/4	Loam to sandy loam	Weak medium subangular blocky	Many moderately thick on pebble matrix interfaces	II–III	335–378	60††
Q4	3.1+	Argillic	7.5YR 4/6	Sandy loam	Massive breaking to fine subangular blocky	Continuous thick on pebble-matrix interfaces	III	425–500	105 or 125§§
Q5	N.A.	B horizon stripped and/or engulfed by carbonate					Strong IV	600–650	185##

Note: N.A.—not available.
*We assume that the geomorphic age is approximately the age of the deposits.
†Color terms follow Munsell Color Company (1975) notation.
§Carbonate stage terms follow Gile et al. (1966) and Bachman and Machette (1977).
#Based on soil development and ^{14}C.
**Based on ^{14}C and uranium-series.
††Based on extrapolation of fold propagation and soil development.
§§Based on uranium series.
##Based on rate of fold propagation—may be as old as 400 ka.

6. Adjacent to the Figure II.6 map are topographic profiles parallel (below) and perpendicular to the fold axis. They should be used to estimate the surface uplift (hint: use Q1 as the reference undeformed shape and measure the vertical distance to the current elevation of the paleosurface). Using the table below fill in the vertical uplift you have just measured and the age of the surface in kiloyears before present (Table II.1). Compute the vertical uplift rate for each surface.

Quaternary surface	*Surface uplift (m)*	*Surface age (ka)*	*Surface uplift rate (m/kyr)*
Q1			
Q2			
Q3			
Q4			
Q5			

7. Using the surface ages and the distance along the fold (parallel profile on Figure II.6) compute the horizontal propagation rate of the fold (hint. Assume that the tip of the fold is now at Q1 on the parallel topographic profile and that it was in an equivalent position at the time of activity—the age—of the other surfaces).

Quaternary surface	*Horizontal distance (m)*	*Surface age (ka)*	*Horizontal propagation rate (m/kyr)*
Q1			
Q2			
Q3			
Q4			
Q5			