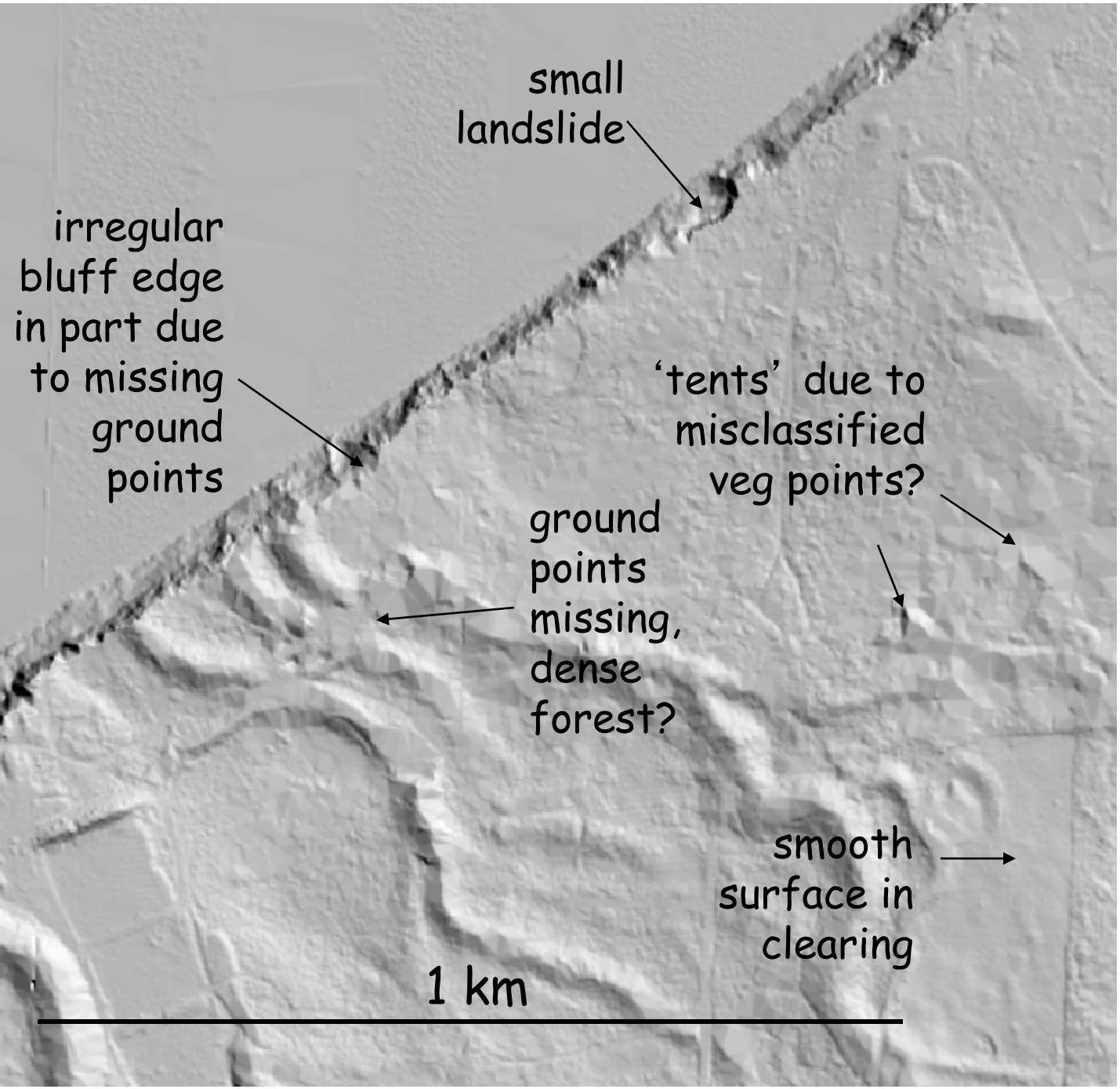
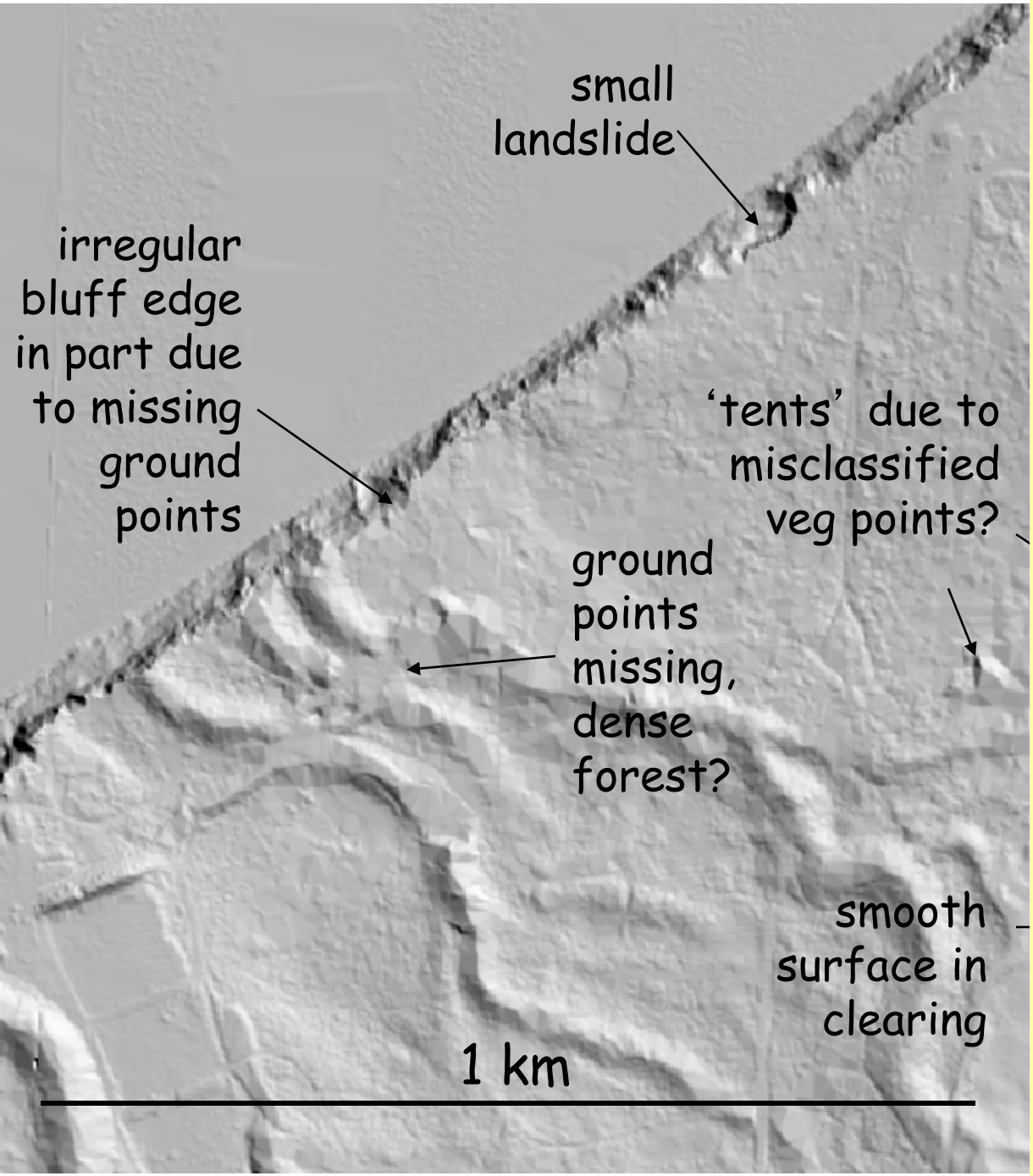
October 2009, Geological Society of America Annual Meeting, Portland, Oregon

A bestiary of lidar errors

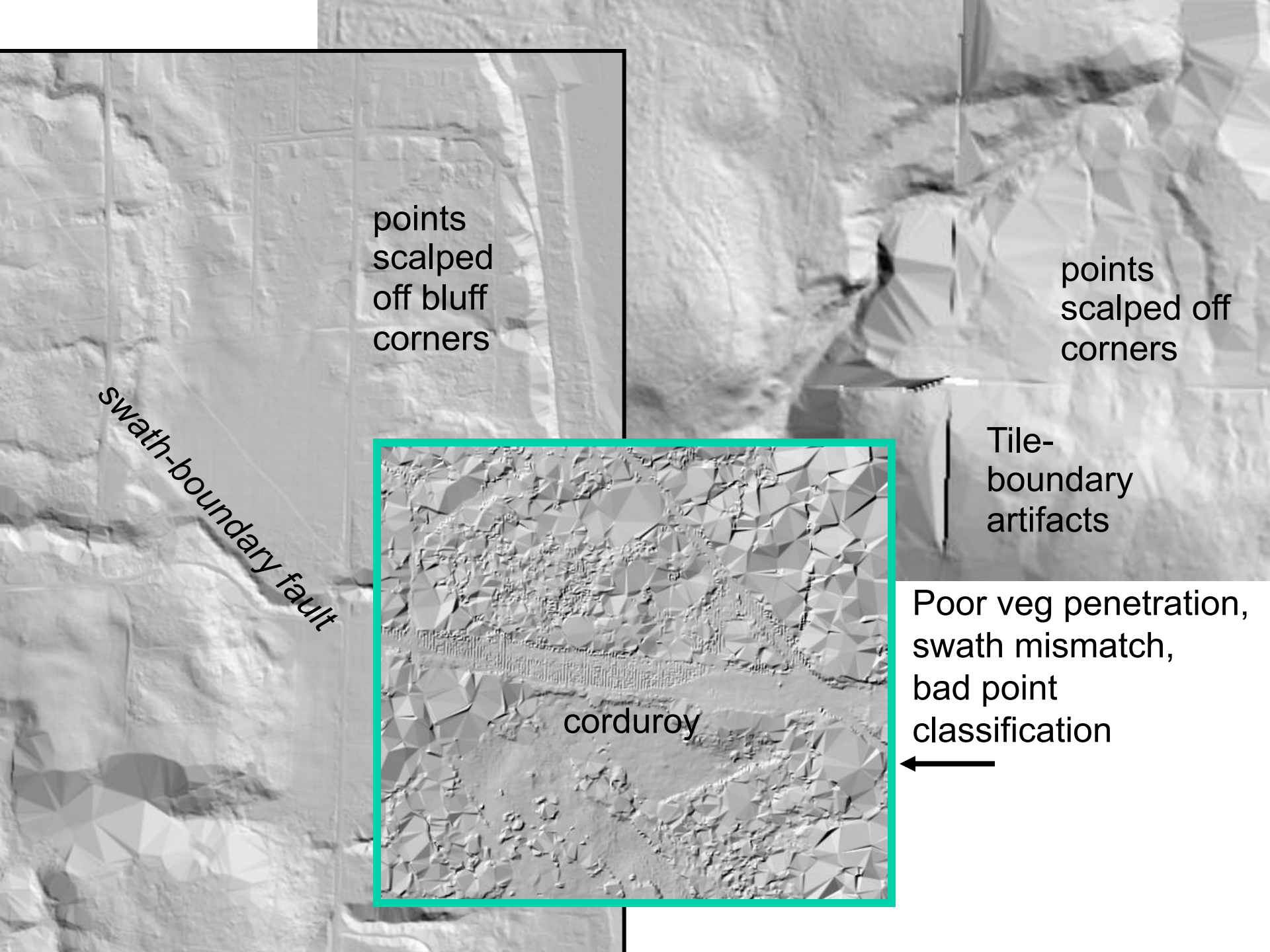
The following images illustrate some of the defects that may be found in lidar-derived bare-earth models. The images also illustrate the power of simple visual inspection in the evaluation of lidar data sets.

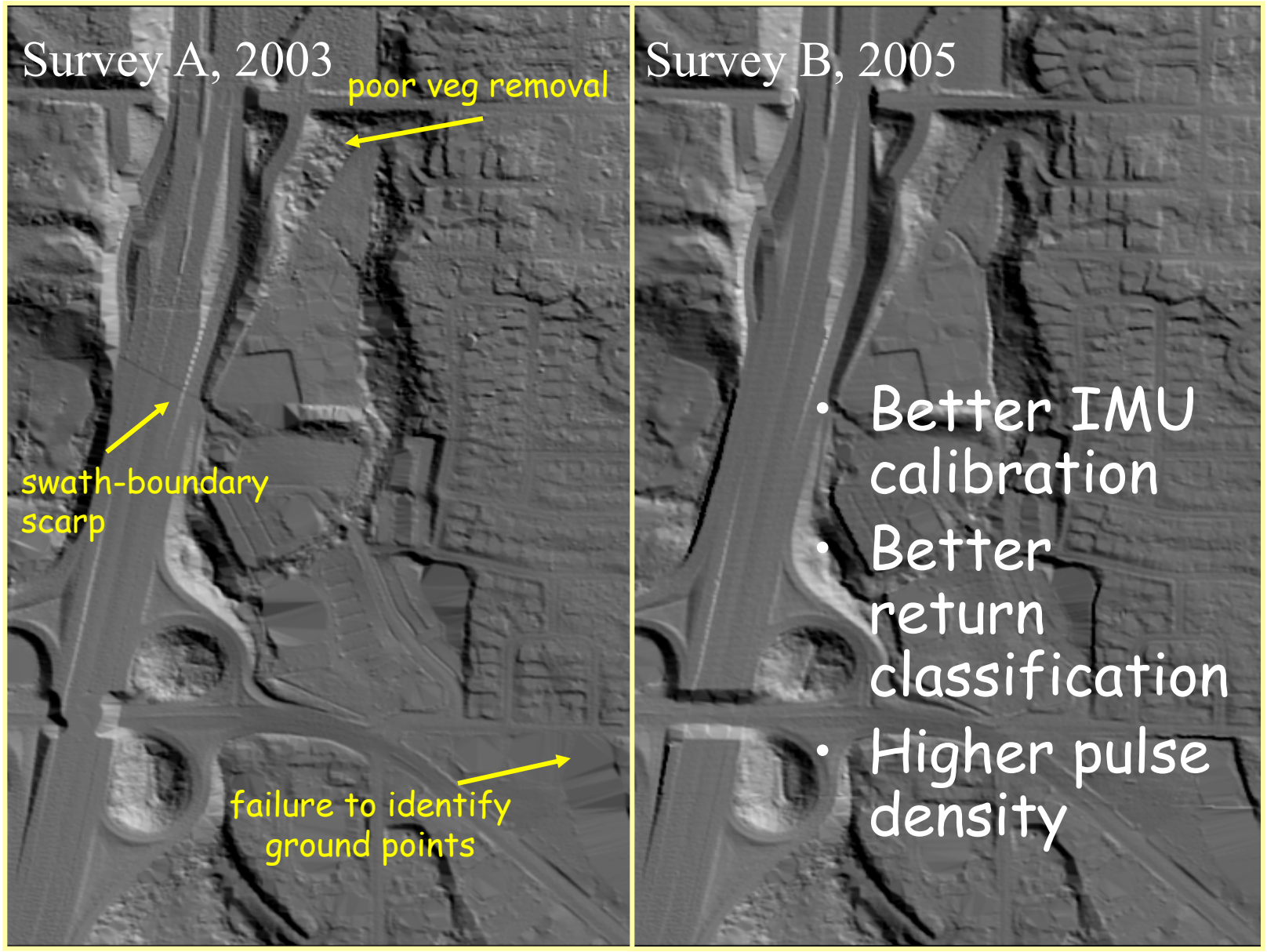
Ralph Haugerud
U.S. Geological Survey
c/o Earth & Space Sciences
University of Washington
Seattle, WA 98195
rhaugerud@usgs.gov / haugerud@u.washington.edu

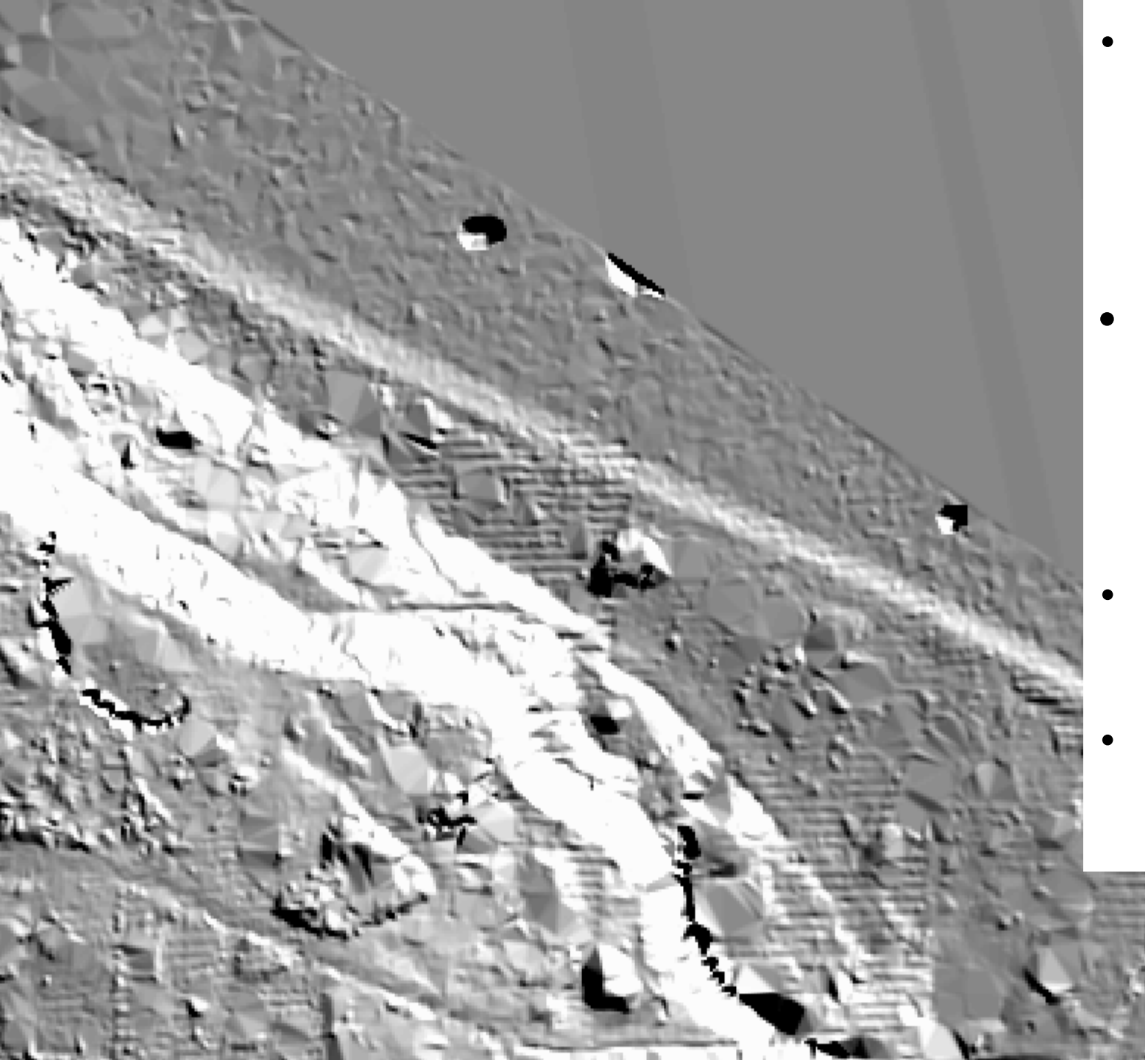

small landslide
irregular bluff edge in part due to missing ground points
'tents' due to misclassified veg points?
ground points missing, dense forest?
smooth surface in clearing
1 km



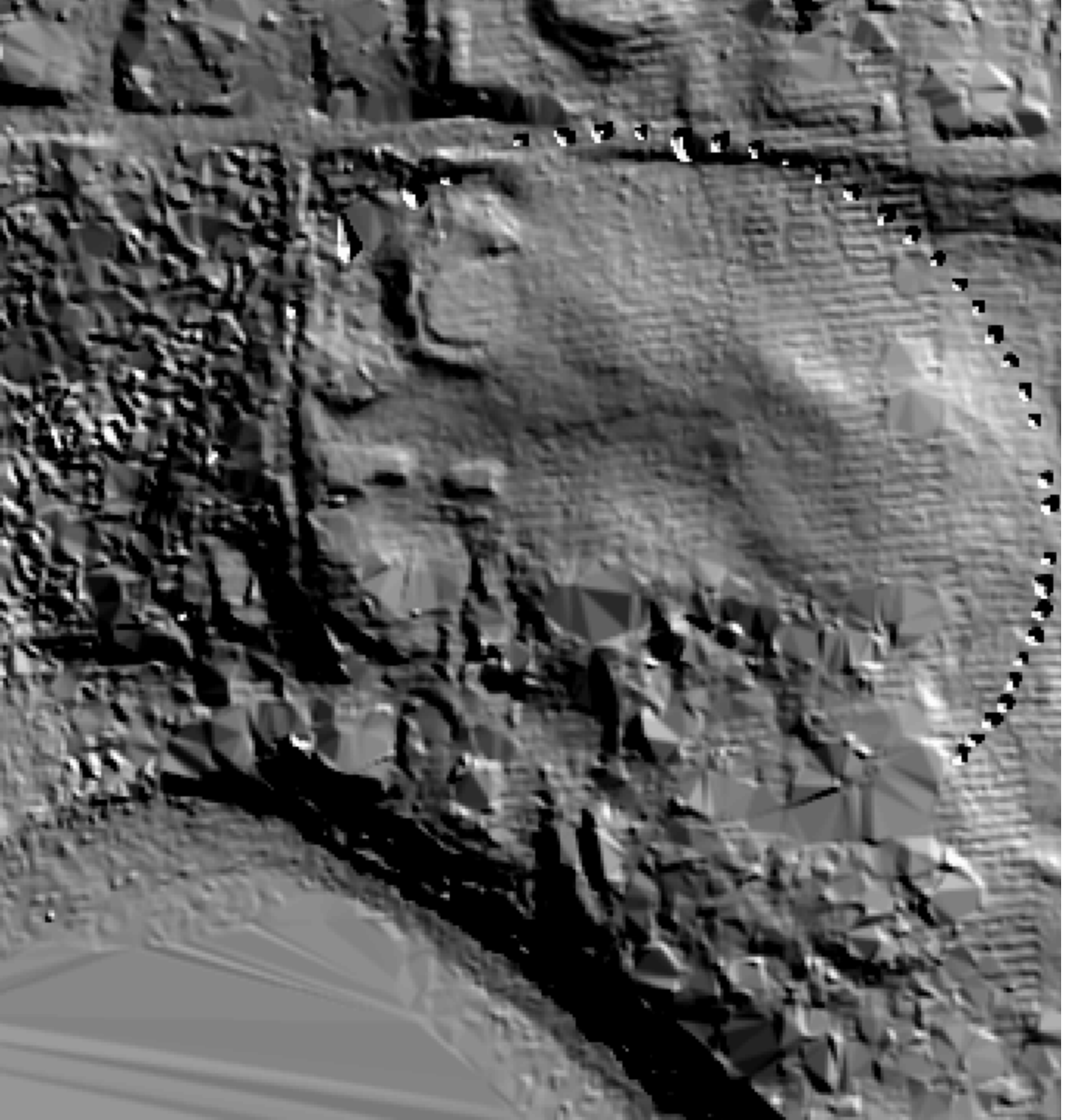
- DEM is point-based, via TIN (**T**riangulated **I**rregular **N**etwork)
- Quality is spatially variable
- Variations in quality are explicit
- Not smoothed by human contouring, thus more objective than most contour maps
- Noisier than most contour maps


points scalped off bluff corners
swath-boundary fault
points scalped off corners
Tile-boundary artifacts
corduroy
Poor veg penetration, swath mismatch, bad point classification

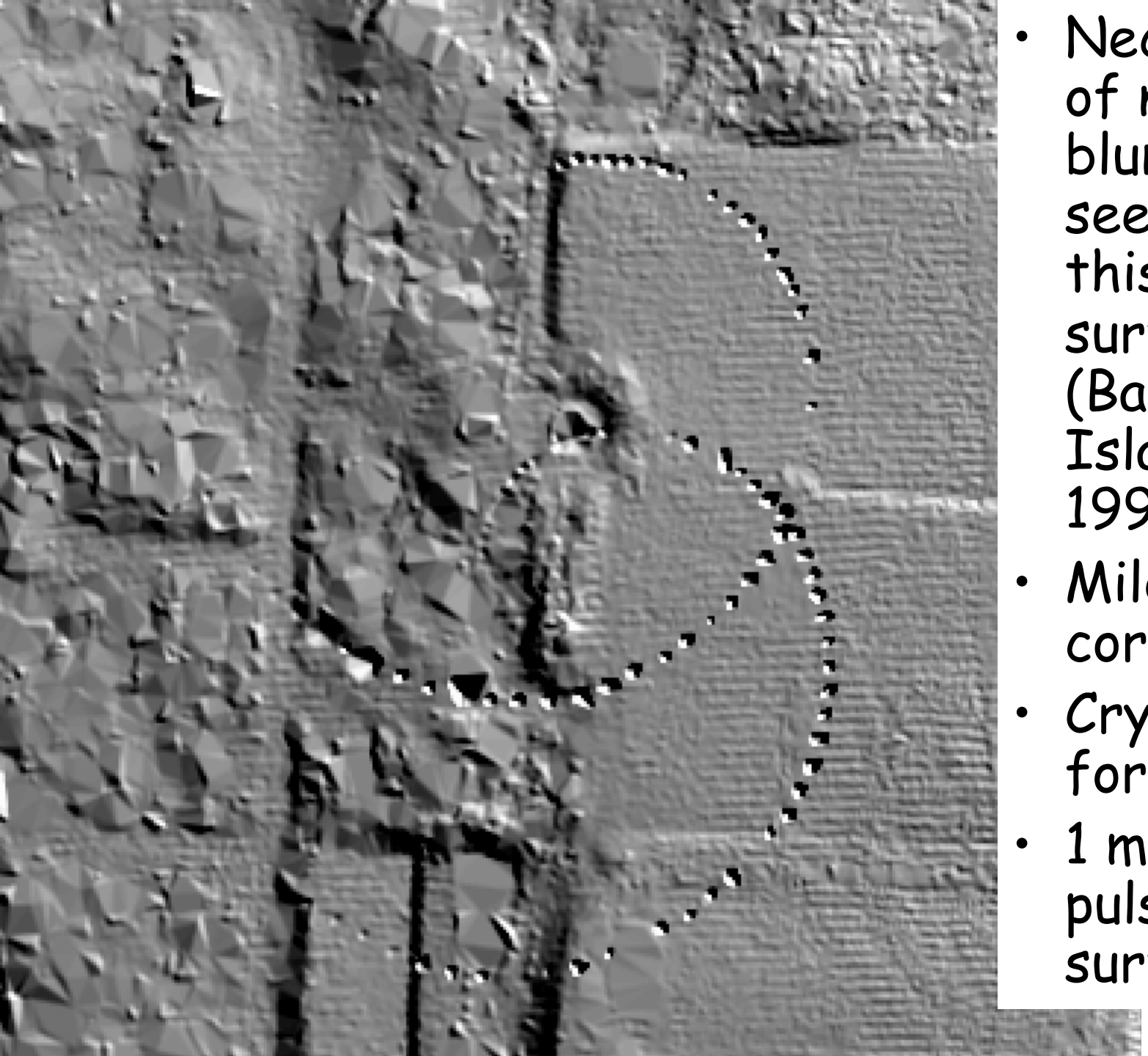

Survey A, 2003
poor veg removal
swath-boundary scarp
failure to identify ground points
Survey B, 2005
• Better IMU calibration
• Better return classification
• Higher pulse density



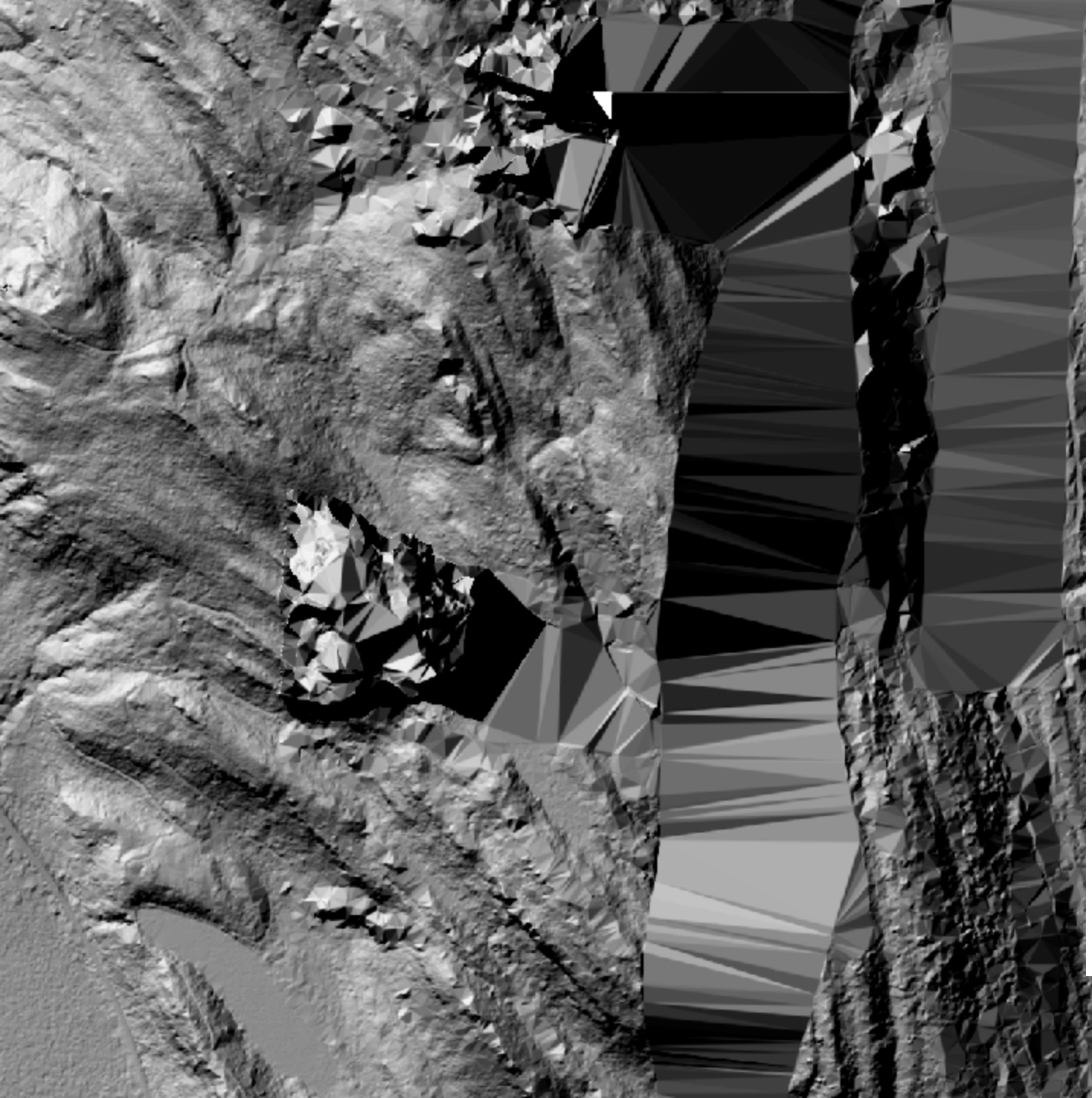
- 1 m grid of 1 pulse/m^2 survey
- "Bomb craters": negative blunders
- Mild corduroy
- Crystal forest



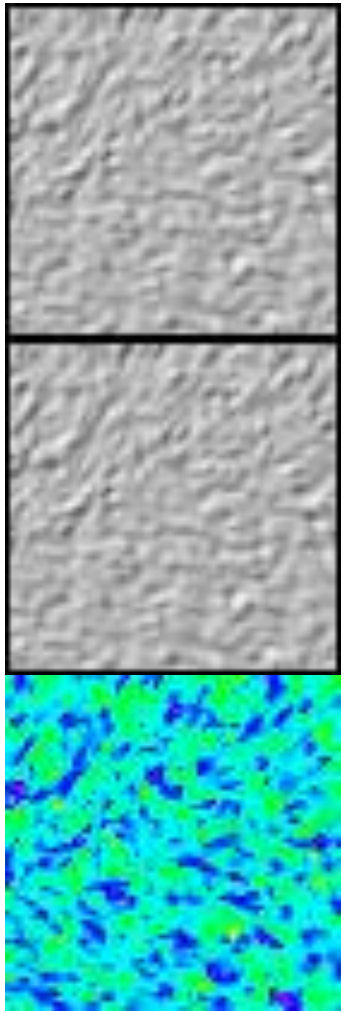
- Necklace of negative blunders—seen only in this one survey (Bainbridge Island, early 1997)
- Mild corduroy
- Crystal forest
- 1 m grid of 1 pulse/m^2 survey



- Necklaces of negative blunders—seen only in this one survey (Bainbridge Island, early 1997)
- Mild corduroy
- Crystal forest
- 1 m grid of 1 pulse/m^2 survey



- Wart in center is 4,000 feet higher than surrounding landscape; are these returns from a cloud?
- Note N-S data gaps (missing flight lines?) at right of image

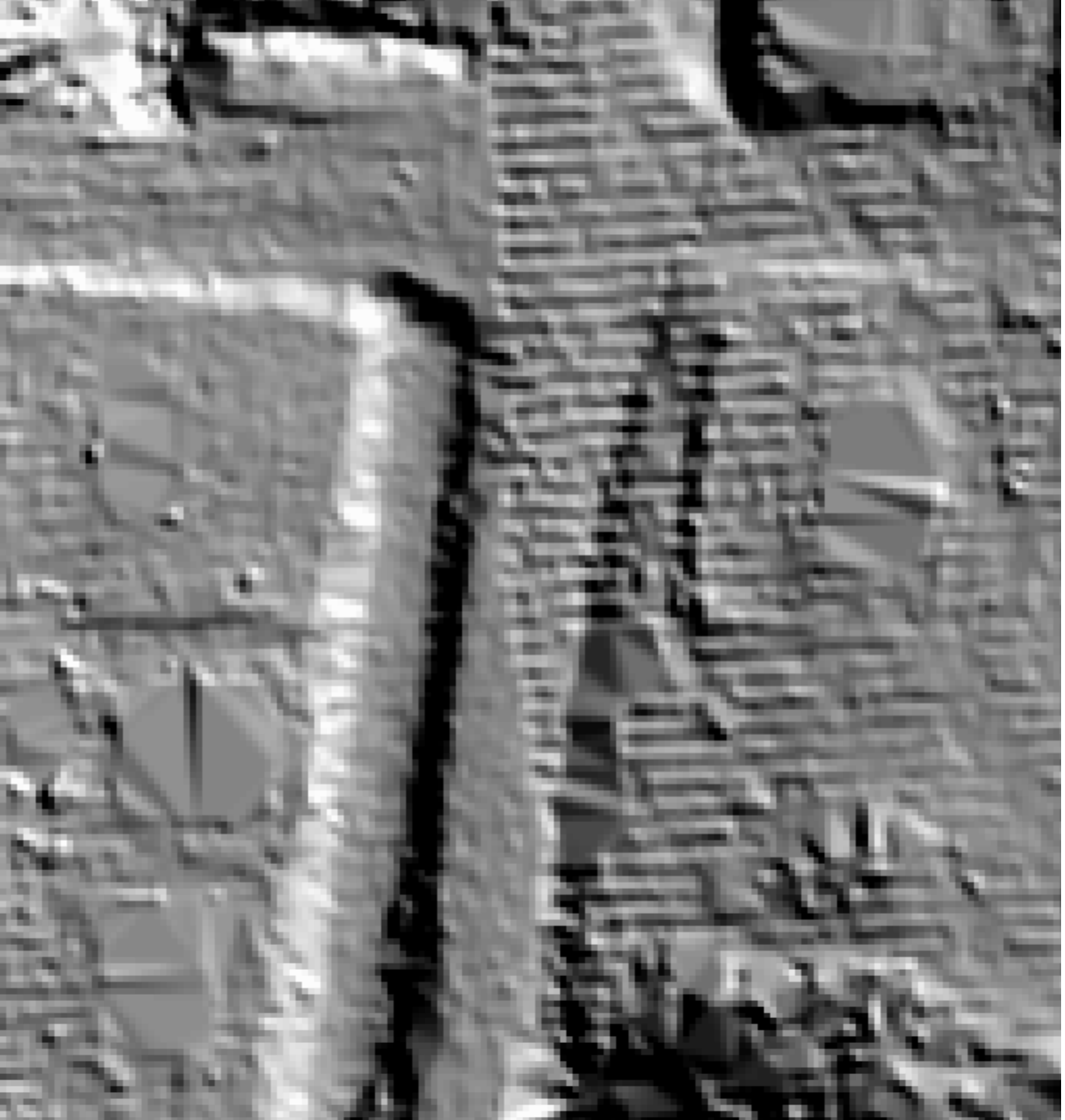


Runway surface, 1st and last returns.
Illuminated from NW, 5X vertical exaggeration.
Area is approximately 50 m x 50 m in size.

Departures from smooth surface:
surface minus low-pass filtered surface.
Illuminated from NW, 5X vertical exaggeration

Color map of departures from smooth surface.
Cyan = no departure, blue = +6 cm,
green = -6 cm.

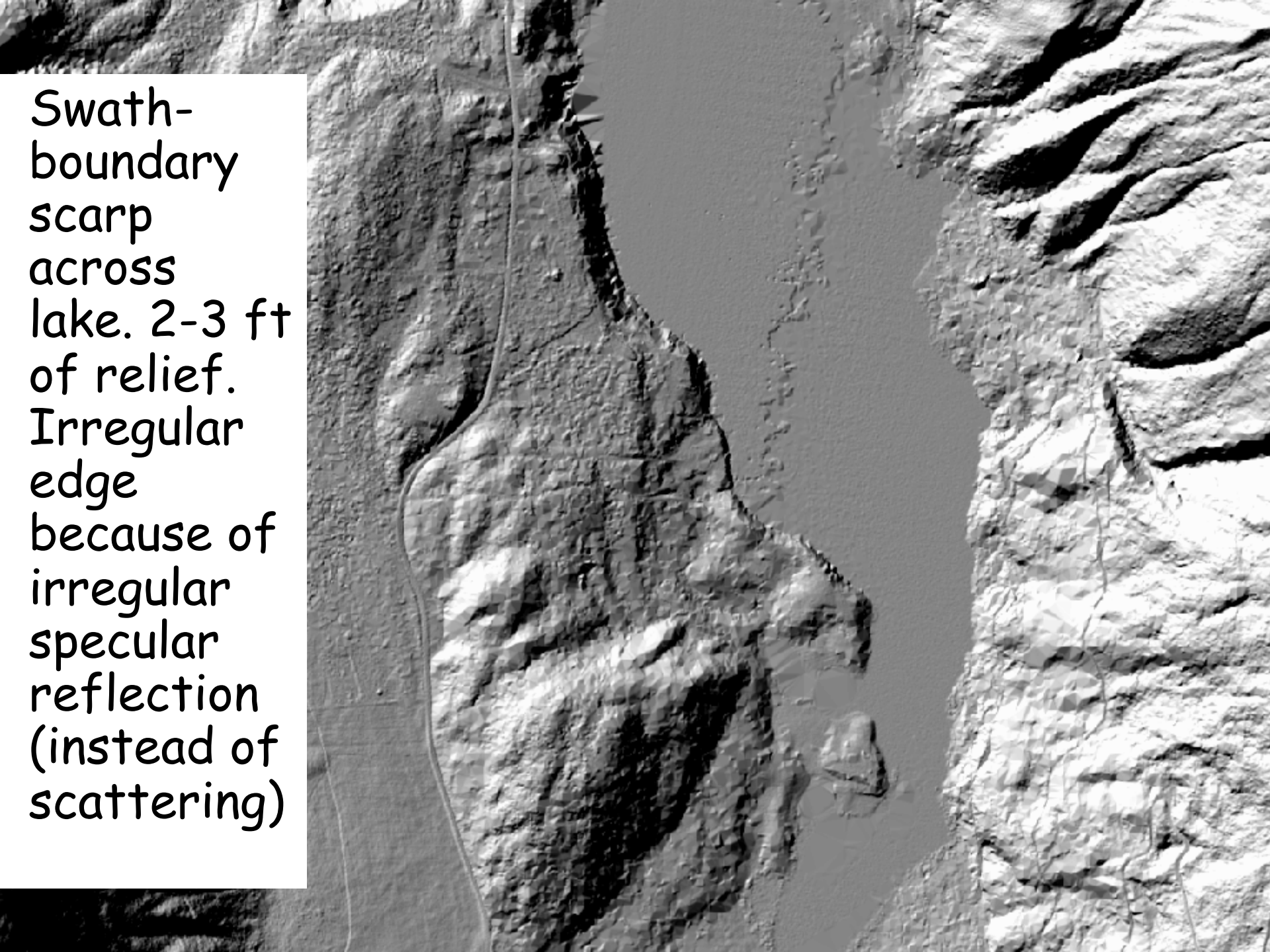
Images calculated from data from a single swath obtained during a fraction of a second (circa 0.4 sec if the instrument was pulsed at 10 KHz). It is thus unlikely that GPS or IMU drift has contributed to the scatter. Any bias stemming from poor IMU or scanner calibration should be removed by subtracting the low-pass-filtered surface. Departures from a smooth surface range from +13.2 to -13.4 cm, with an average departure (standard deviation) of 3.3 cm. The wavelength of this variation is on the order of a few meters, thus I infer that very little of it is due to roughness of the runway surface.

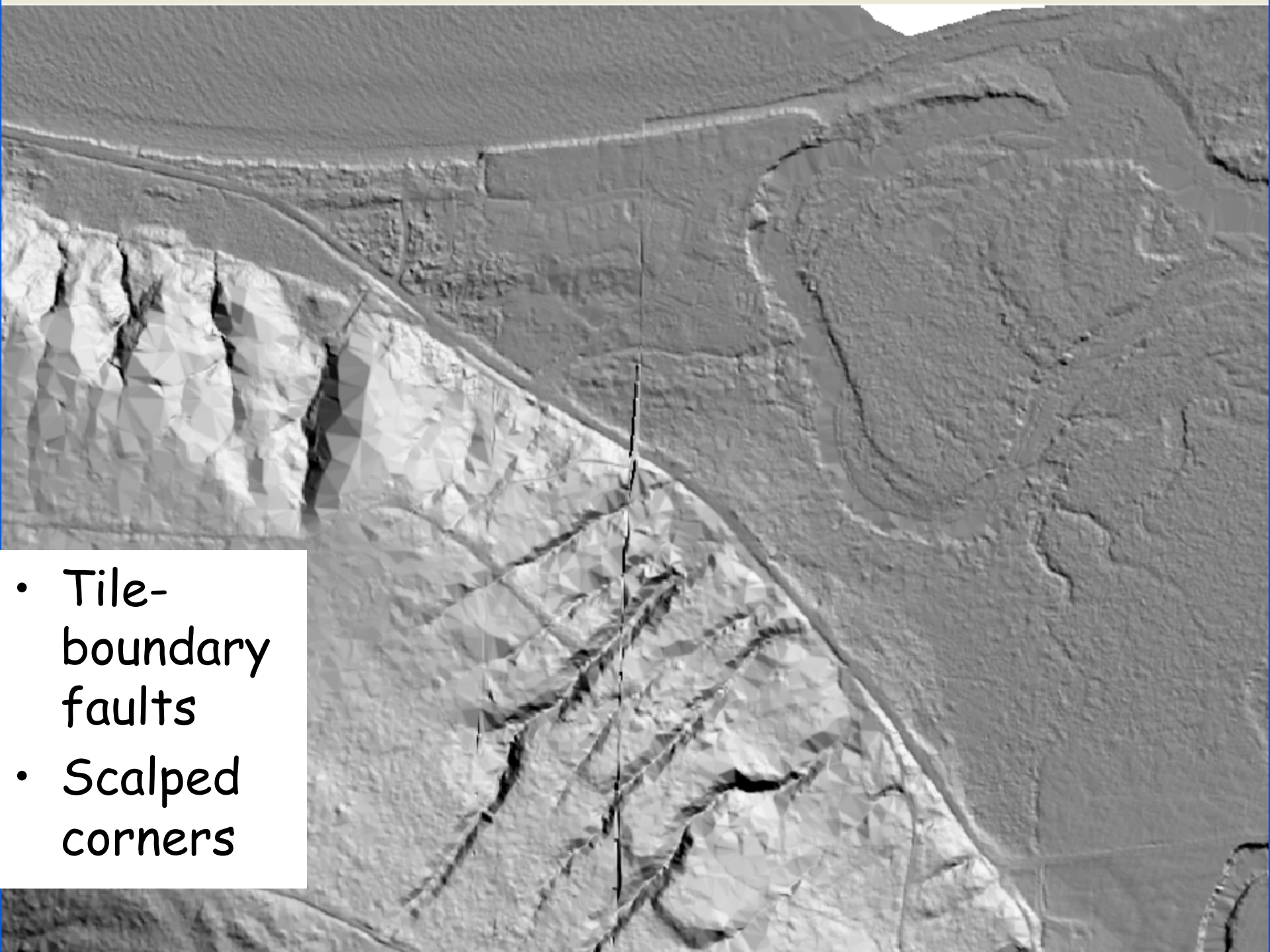


- Mild corduroy (~1/2 ft relief) and swath-margin scarp
- 1 m grid of 1 pulse/m^2 survey

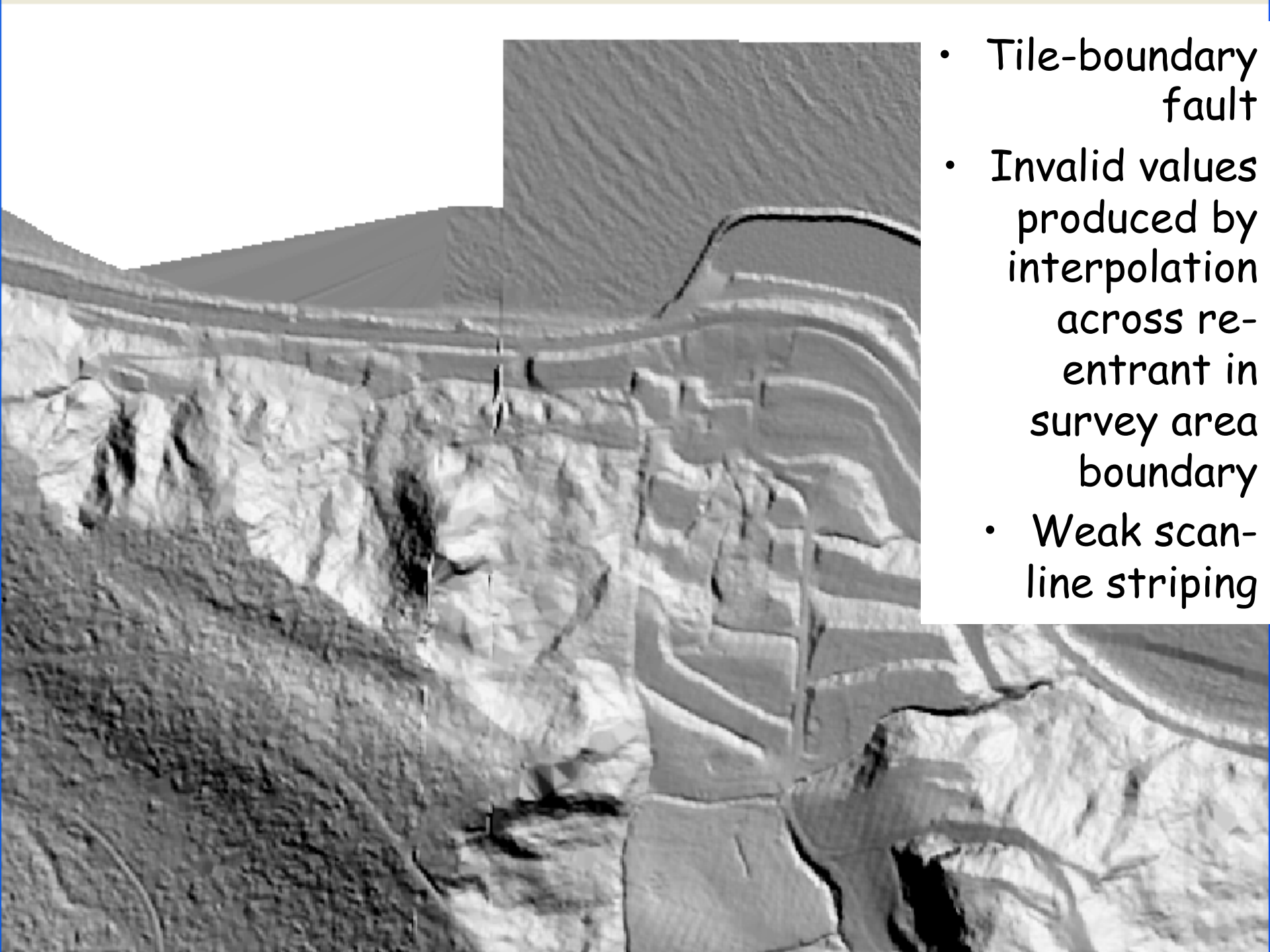
- Same image, 6 ft grid


Swath boundary faults
poor calibration

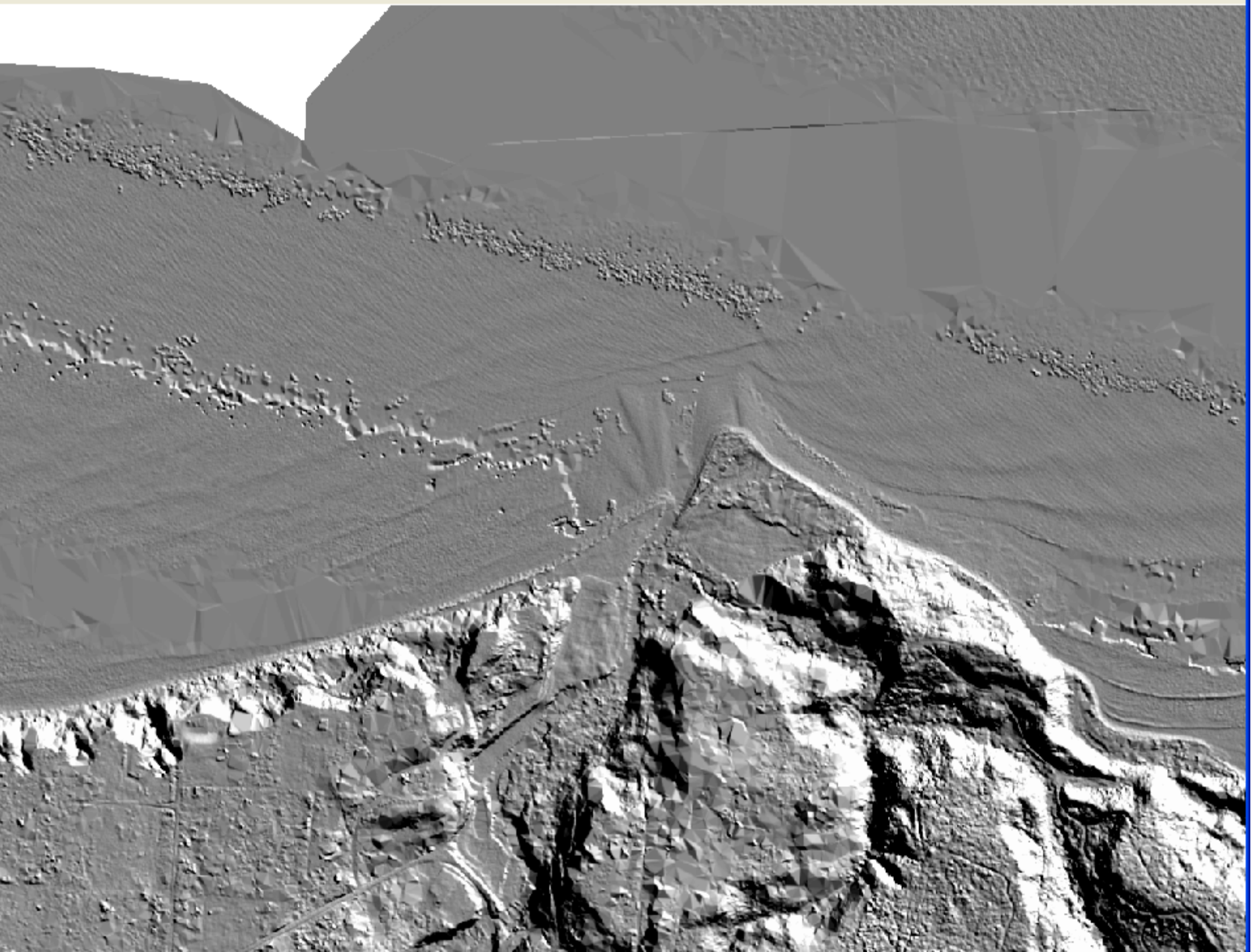

Swath-boundary scarp across lake. 2-3 ft of relief. Irregular edge because of irregular specular reflection (instead of scattering)



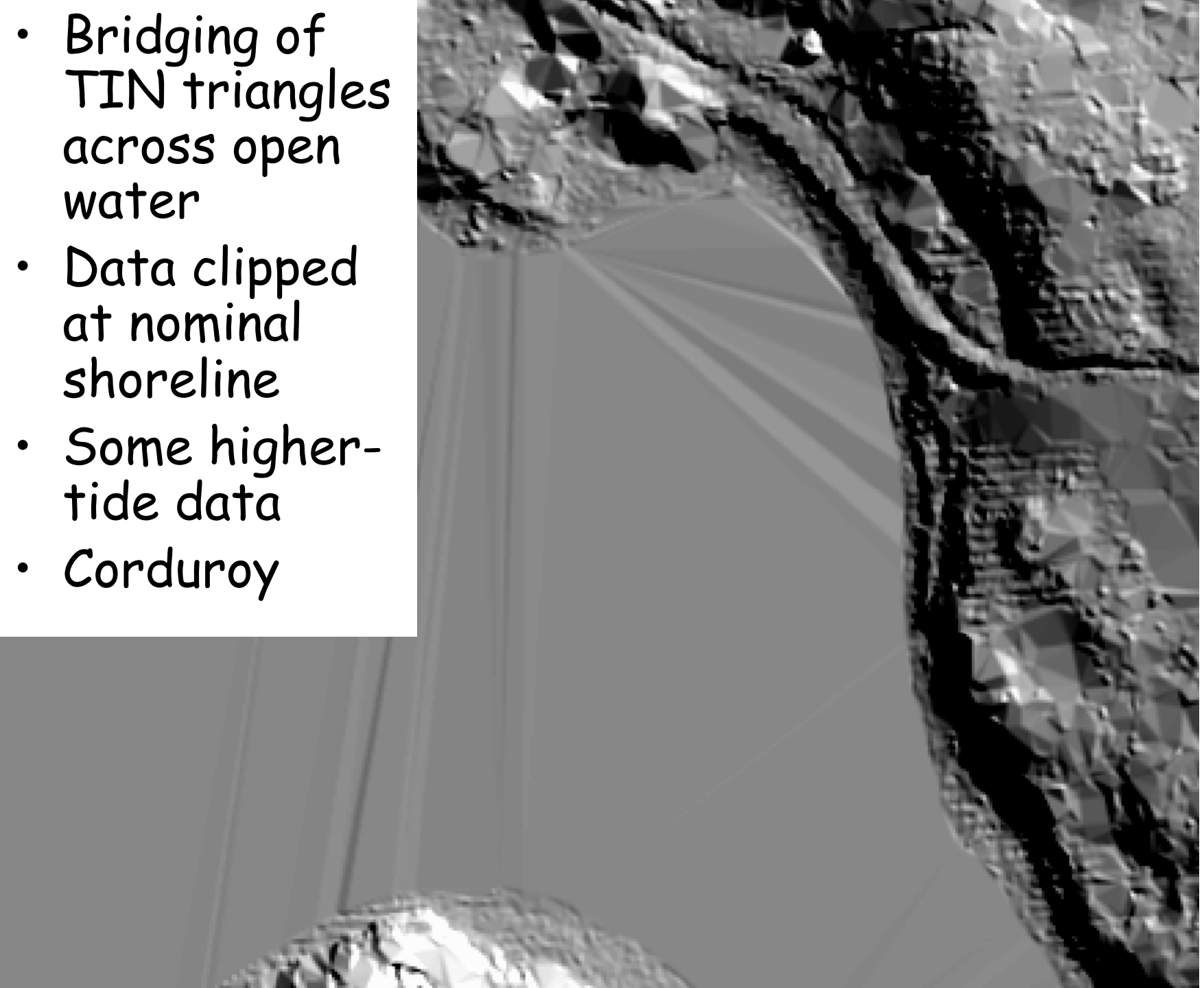
- Tile-boundary faults
- Scalped corners



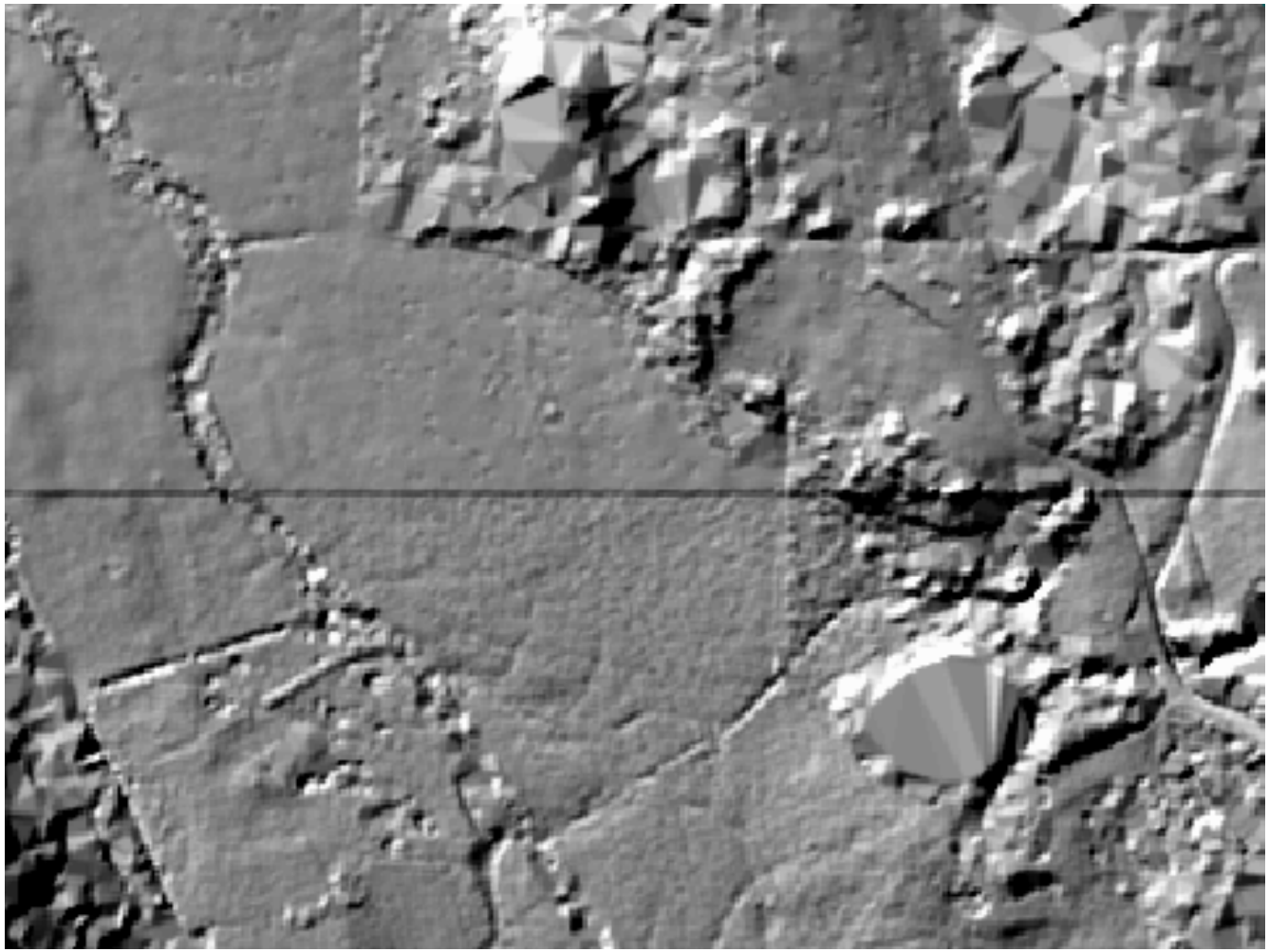
- Tile-boundary fault
- Invalid values produced by interpolation across re-entrant in survey area boundary
- Weak scan-line striping



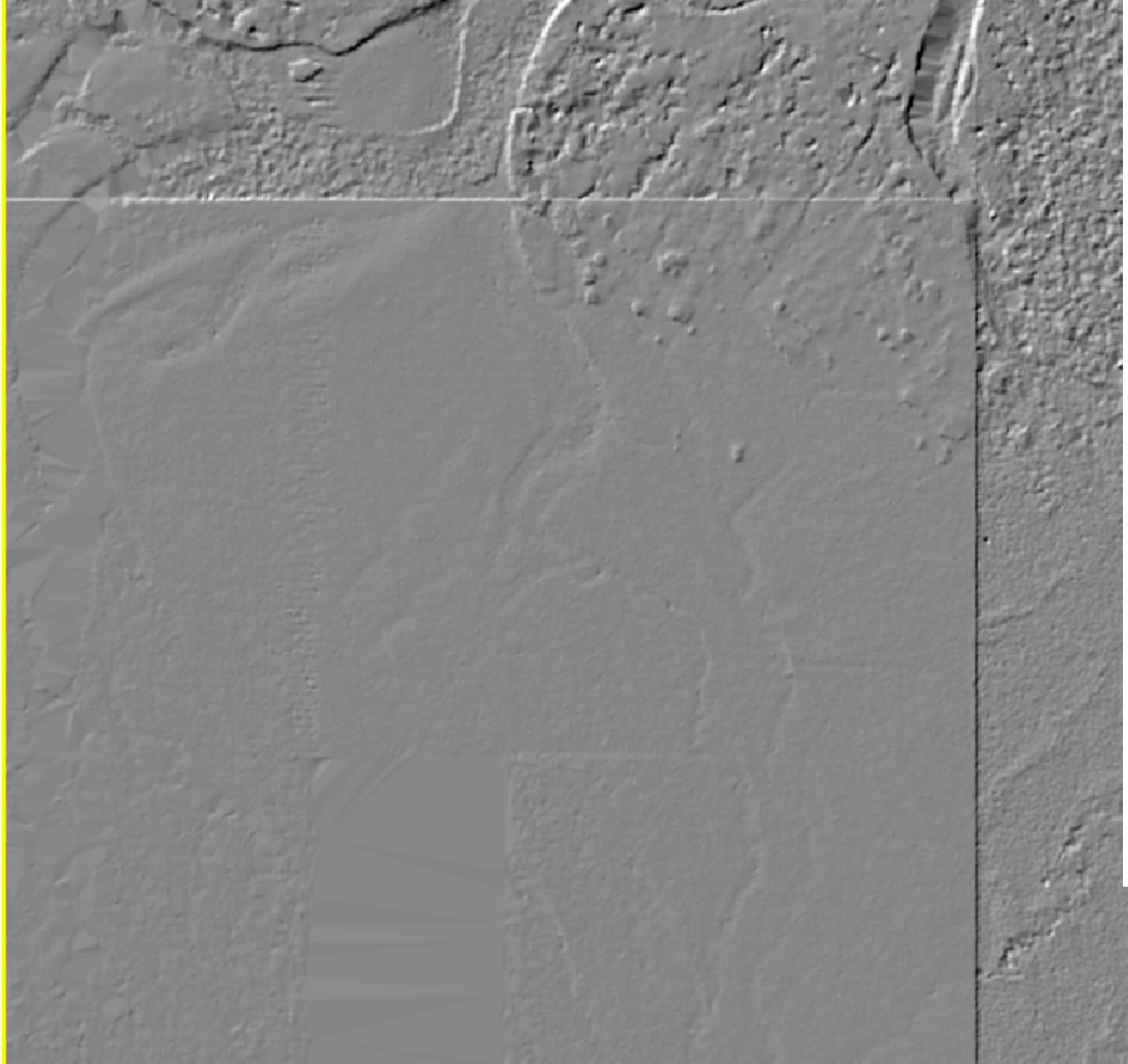
- Bridging of TIN triangles across open water
- Data clipped at nominal shoreline
- Some higher-tide data
- Corduroy



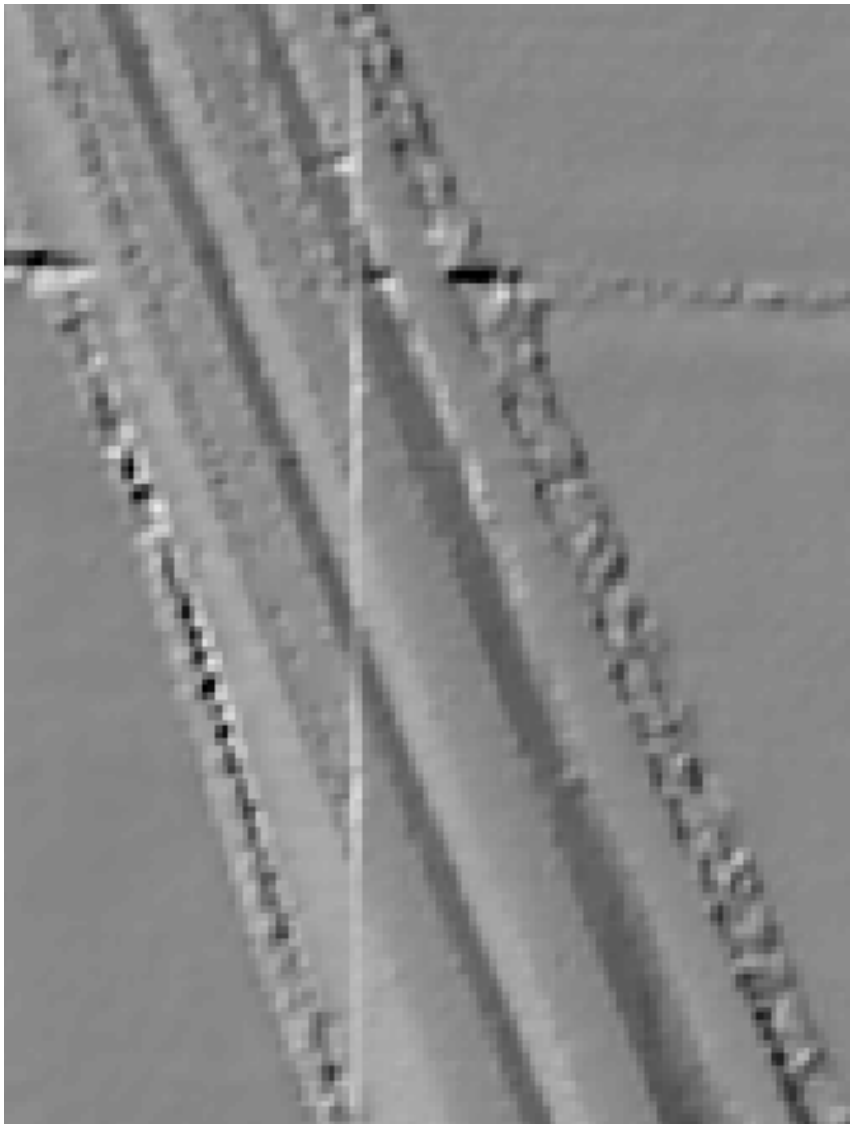
- 2 to 4 ft step in freeway coincides with a tile boundary
- Multiple calibrations
- Irregular, lumpy, freeway surface in western part of image
- Locally, uncompensated range walk



- 1-ft step at tile boundary
- Multiple calibrations

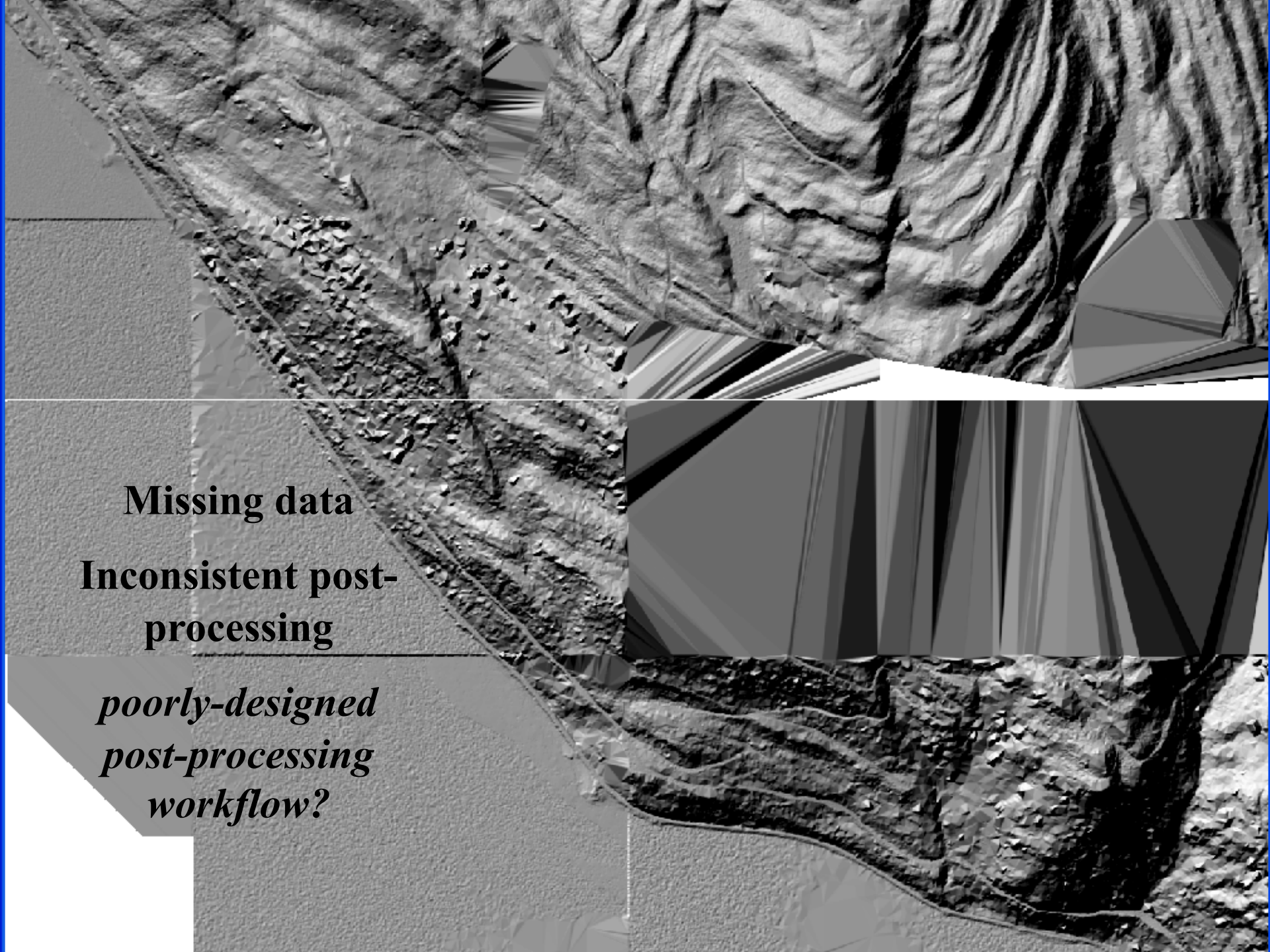


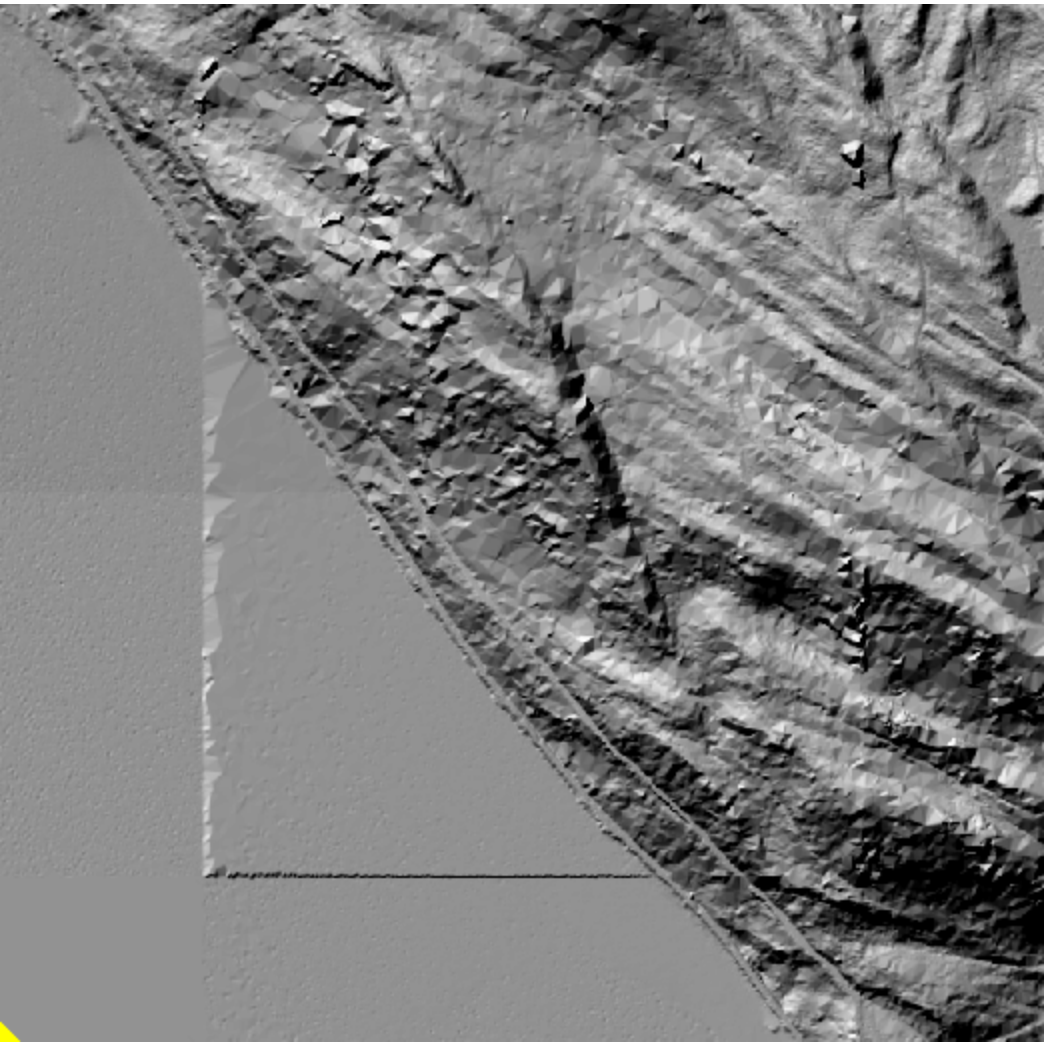
- Tile is $2\frac{1}{2}$ feet higher than surrounding tiles.
- Multiple calibrations
- Missing data
- Variably compensated range-walk?



3 ft step in freeway at tile boundary

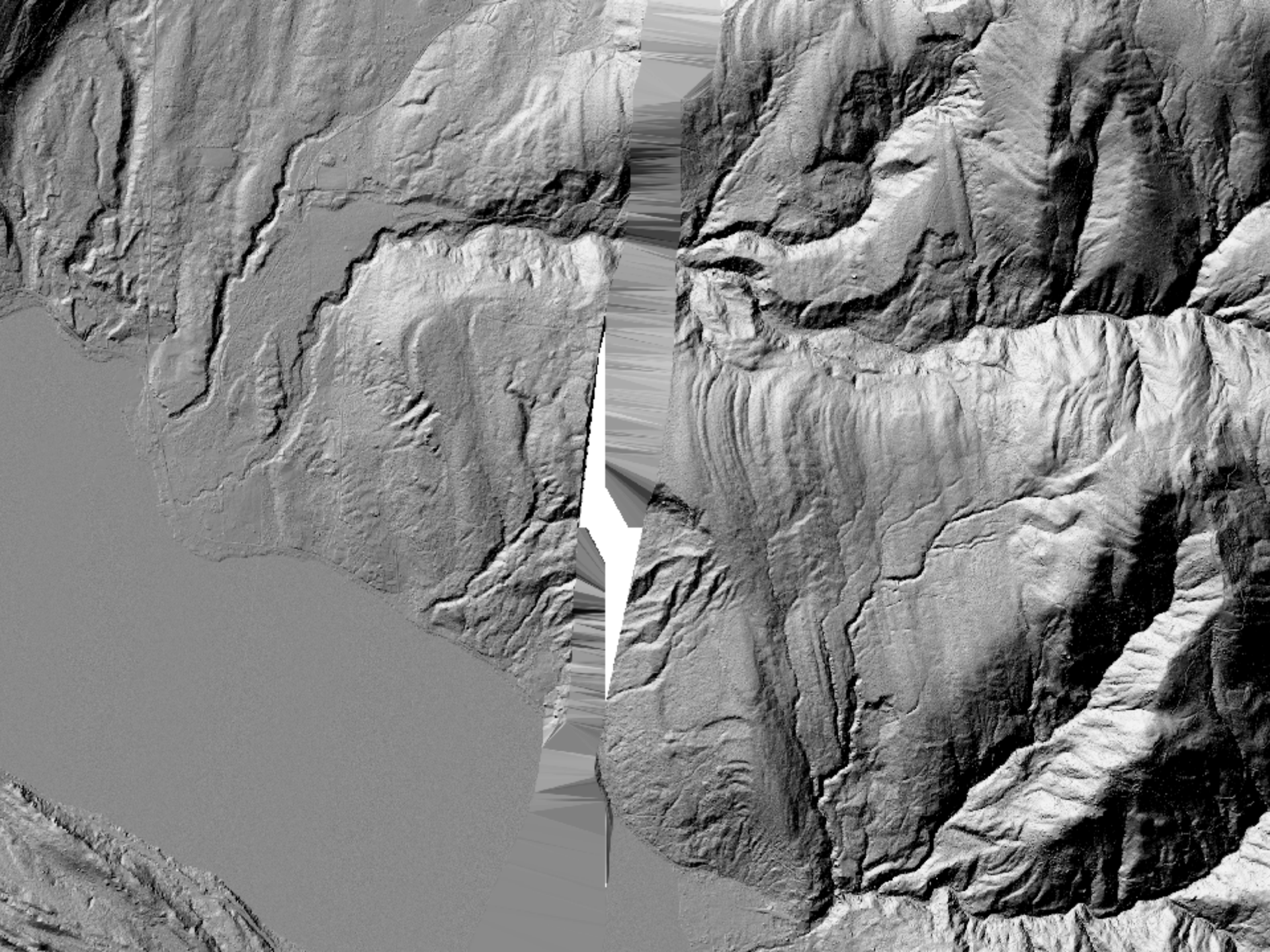
- Steps at tile margins: multiple calibrations
- Scalping of railroad embankment

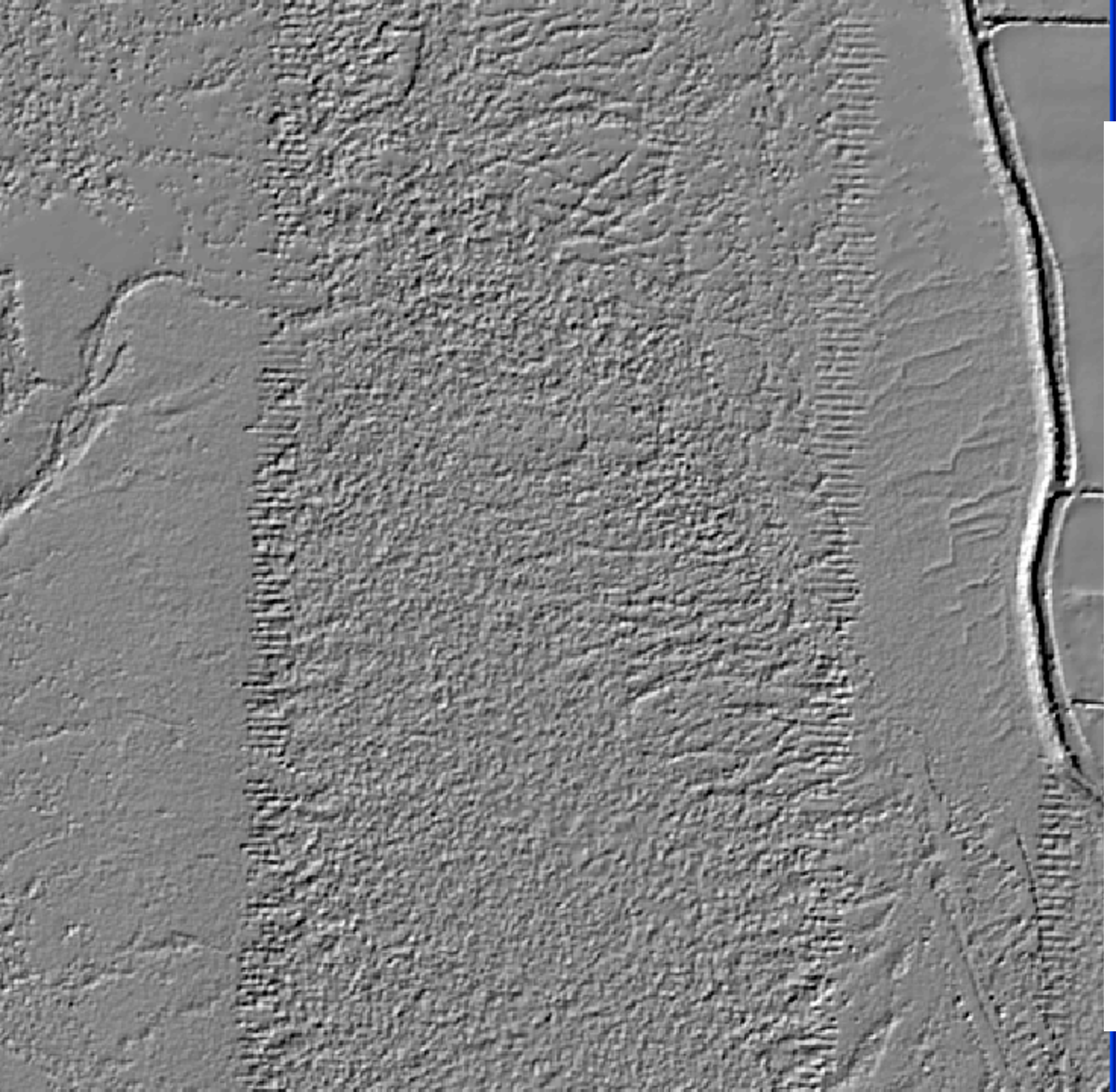

Missing data
Inconsistent post-processing
poorly-designed post-processing workflow?



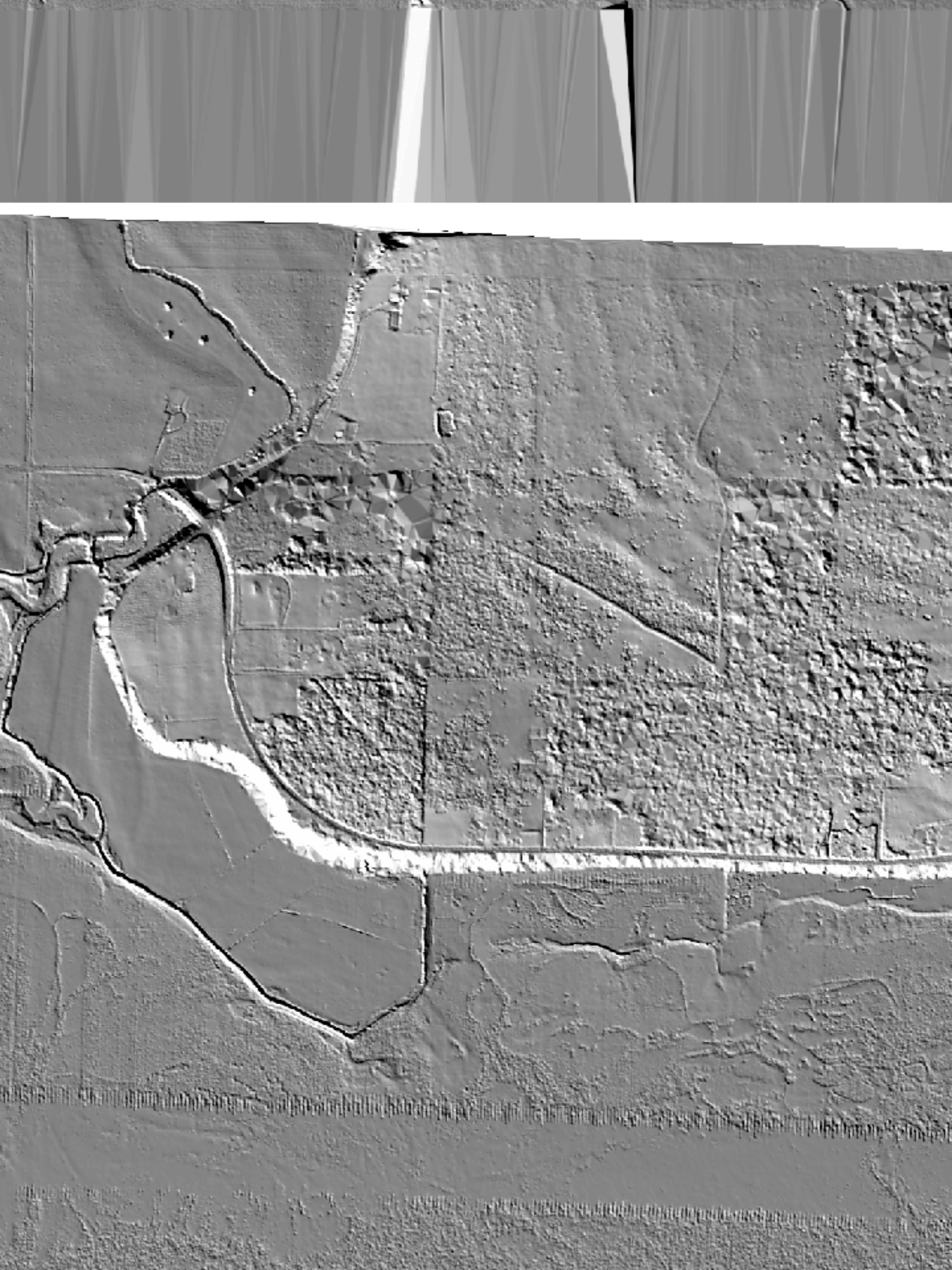
- Return classifi-cation somewhat improved

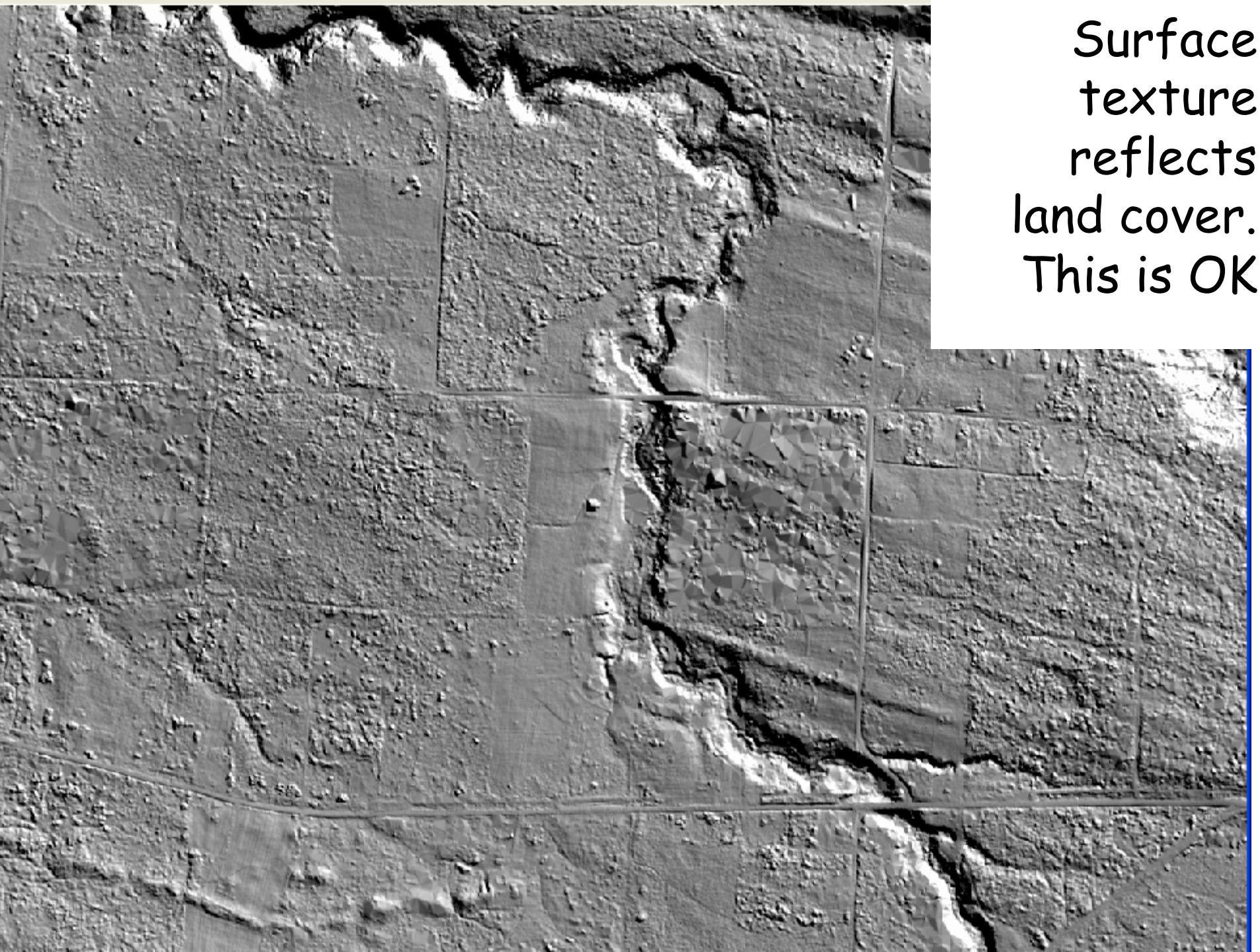
Buildings not removed from bare-earth model





- Corduroy across tideflat. Relief on corduroy is up to 3 ft





Surface texture reflects land cover. This is OK

- Burn piles along logging roads
- Invalid values produced by interpolation across re-entrant in survey area boundary