# *Science motivations for LiDAR (high resolution topography)*


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Outline

- Introduction and motivation
- Technology overview
- Tectonic geomorphology application
- Ecological applications
- Volcano deformation application
- Terrestrial Laser scanning (TLS)

ASU Arizona State University

OpenTopography Portal

www.opentopography.org

SDSC

# Introduction:

- Landscape development a combination of many processes:
  - Tectonic
  - Hillslope
  - Fluvial
  - Biologic
  - Anthropogenic
- High-resolution representation of landscape is central to qualitative and quantitative study of process.
- Aerial photography traditional tool for geomorphic studies
- 2D representation
- Qualitative tool

***Crosby, MS 2006***

# Introduction:

- Digital topography provides 2.5D representation of landscape

- Widely avail. digital topography (digital elevation models - DEMs) are too coarse to provide representation of small geomorphic features / process.

- USGS 30 m DEM = best available national coverage

# Introduction:

- Digital topography provides 2.5D representation of landscape

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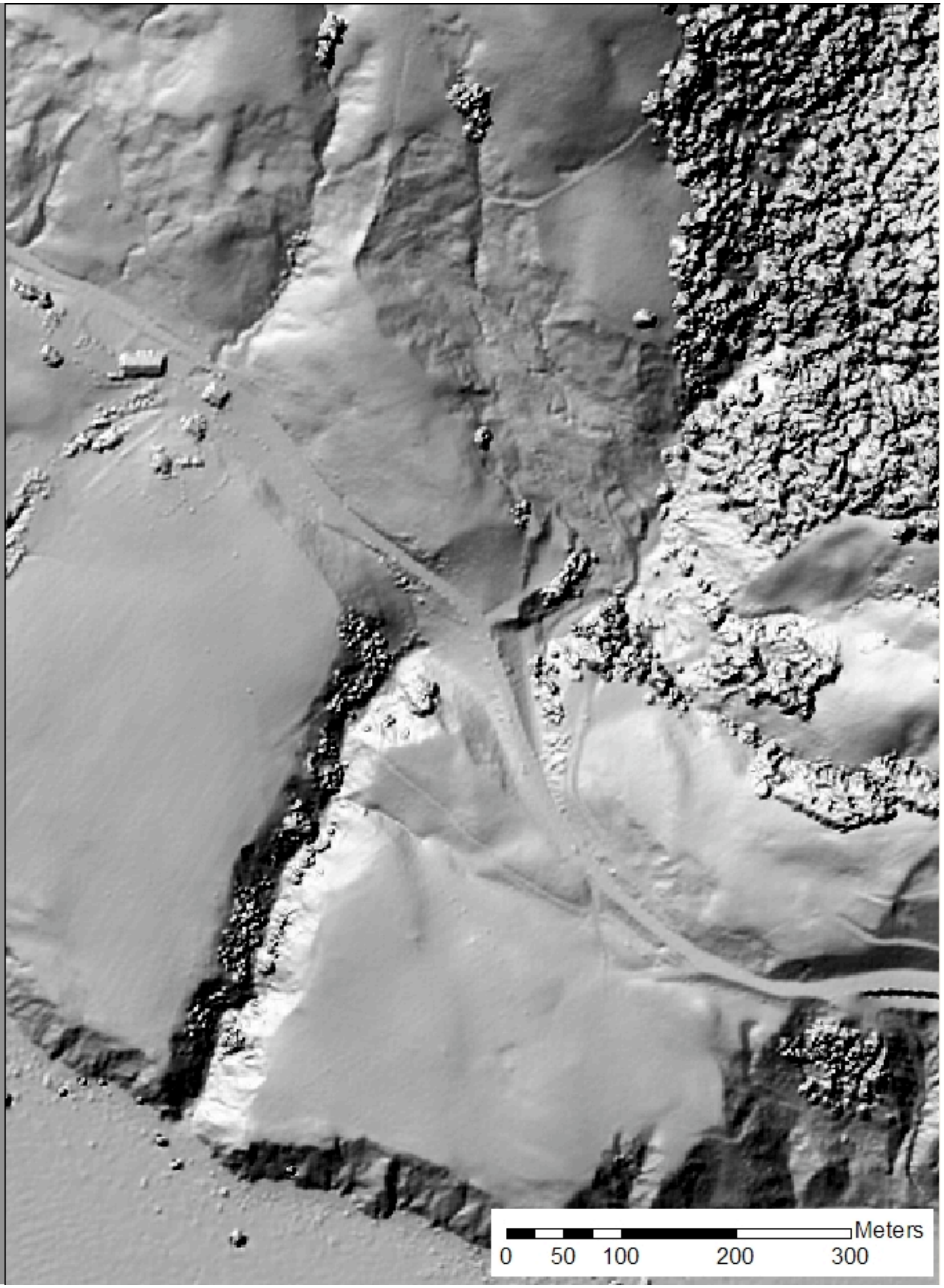
- USGS 10 m DEM

# Introduction:

- LiDAR / ALSM data
- DEMs at resolutions not previously possible.
  - sub-meter resolution
- Applicable to:
  - Geomorphology
  - Landslide & flood hazards
  - Forestry/Ecology
  - Civil Engineering
  - Urban planning
  - Volcanology
- One of the hottest tools in the Geosciences

***Crosby, MS 2006***



# A Problem

$$H(x,y,t) = H_0(x,y) + U(x,y,t,H) + V(x,y,t,H)$$

**Current elevation** | **Original elevation** | **Tectonic displacement** | **Geomorphic displacement**

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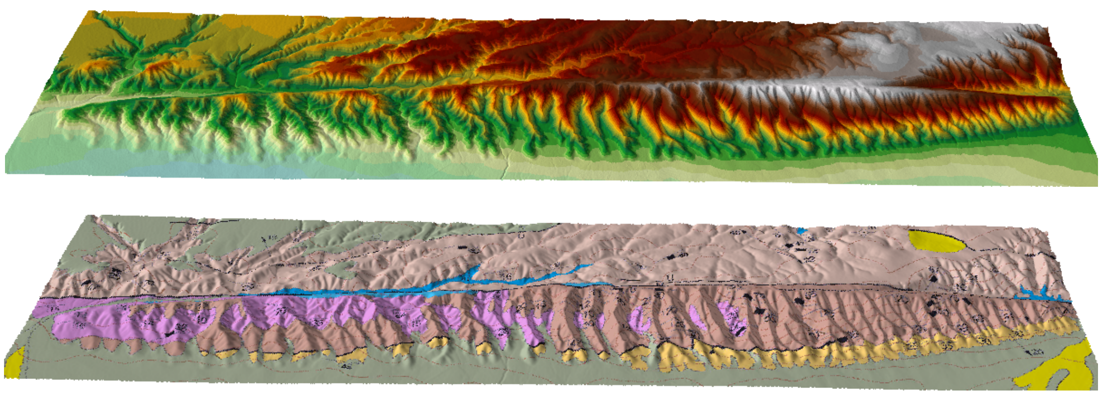
**Elevation change with time** $\frac{\partial H}{\partial t} = \frac{\partial U}{\partial t} - \nabla Q_s$ **Divergence of sediment flux and rock uplift rate**

*Surface processes act to change elevation through erosion and deposition while tectonic processes depress or elevate the surface directly.*

LiDAR/imagery fusion: 4 cm pixel balloon aerial photo merged with 25 cm B4 DEM.



Dragon's Back 1 m DEM and geological mapping

(Hilley and Arrowsmith, *Geology*, 2008)

## WORKSHOP ON STUDYING EARTH SURFACE PROCESSES WITH HIGH-RESOLUTION TOPOGRAPHIC DATA

**Boulder, Colorado, 15-18 June 2008**

**Report to the National Science Foundation**

**Workshop Organizers**


Dorothy Merritts, Department of Earth and Environment, Franklin and Marshall College, Lancaster, PA

George Hilley, Department of Geological and Environmental Sciences, Stanford University, CA

J Ramon Arrowsmith, School of Earth and Space Exploration, Arizona State University, Tempe, AZ

Bill Carter, Department of Civil and Coastal Engineering, University to Florida, Gainesville, FL

William Dietrich, Department of Earth and Planetary Science, University of California, Berkeley, CA

Jennifer Jacobs, Department of Civil Engineering, University of New Hampshire, Durham, NH

Stephen Martel, Department of Geology and Geophysics, University of Hawaii, Honolulu, HI

Josh Roering, Department of Geological Sciences, University of Oregon, Eugene, Oregon

Ramesh Shrestha, Department of Civil and Coastal Engineering, University to Florida, Gainesville, FL

Noah P. Snyder, Department of Geology and Geophysics, Boston College, Chestnut Hill, MA

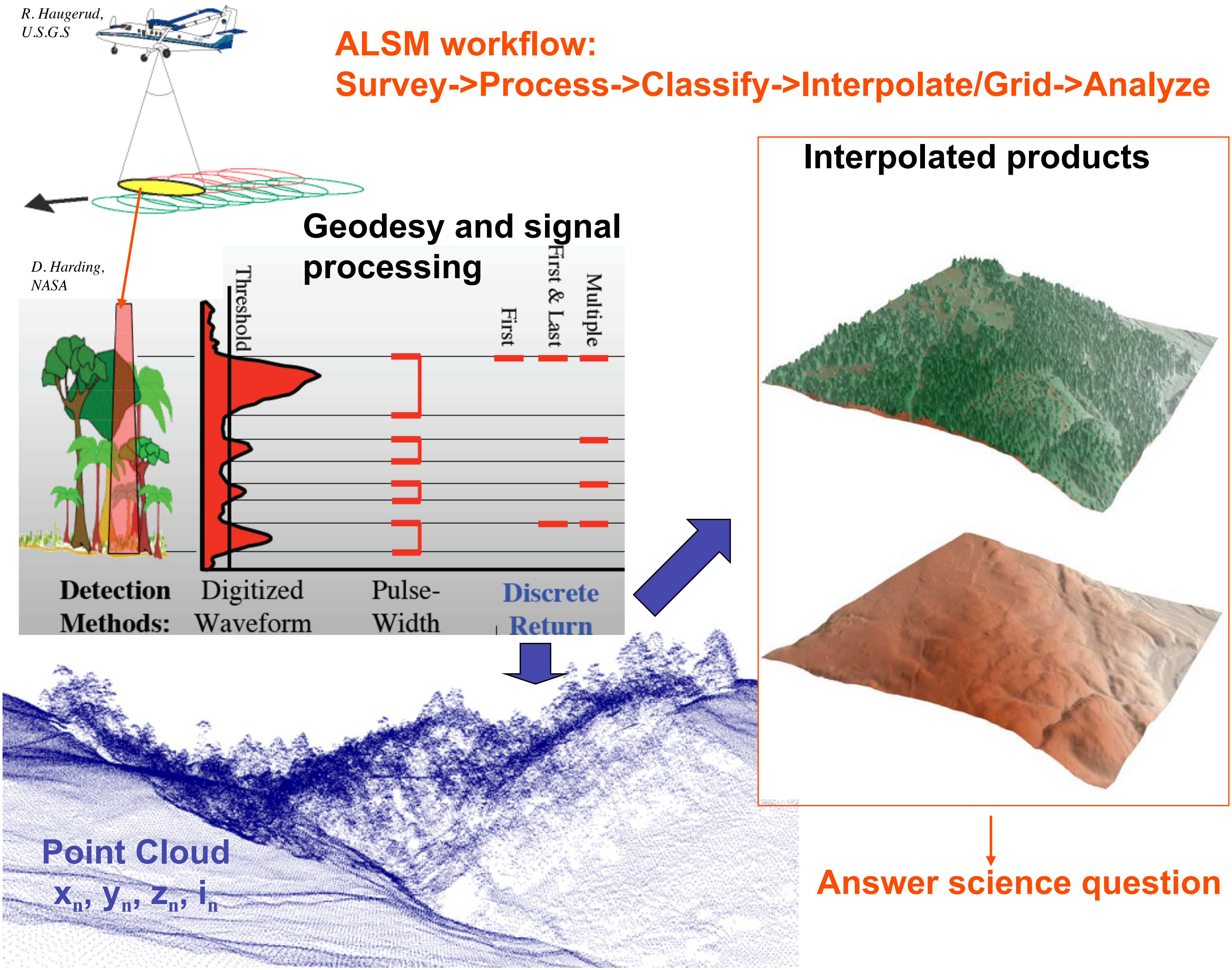

http://www.opentopography.org/index.php/blog/2009/04/

## Major themes

- Identifying and extracting topographic features
- Coupling tectonic and climatic processes with landform evolution
- Testing landscape evolution models
- Detecting landscape change
- Feedbacks between life and topography
- Routing water and sediment through watersheds
- Linking structural geology to geomorphology

## Opportunities

- understanding effects of human-induced changes in landscape characteristics
- discovering new ways of extracting landscape features from the topographic data, identifying new methods to quantify topographic trends
- developing new physical and mathematical descriptions of the landscape
- bringing these data into the classroom and informal science education opportunities


R. Haugerud, U.S.G.S
ALSM workflow:
Survey->Process->Classify->Interpolate/Grid->Analyze
Interpolated products
Geodesy and signal processing
D. Harding, NASA
Threshold
First
First & Last
Multiple
Detection Methods:
Digitized Waveform
Pulse-Width
Discrete Return
Point Cloud
$x_n, y_n, z_n, i_n$
Answer science question

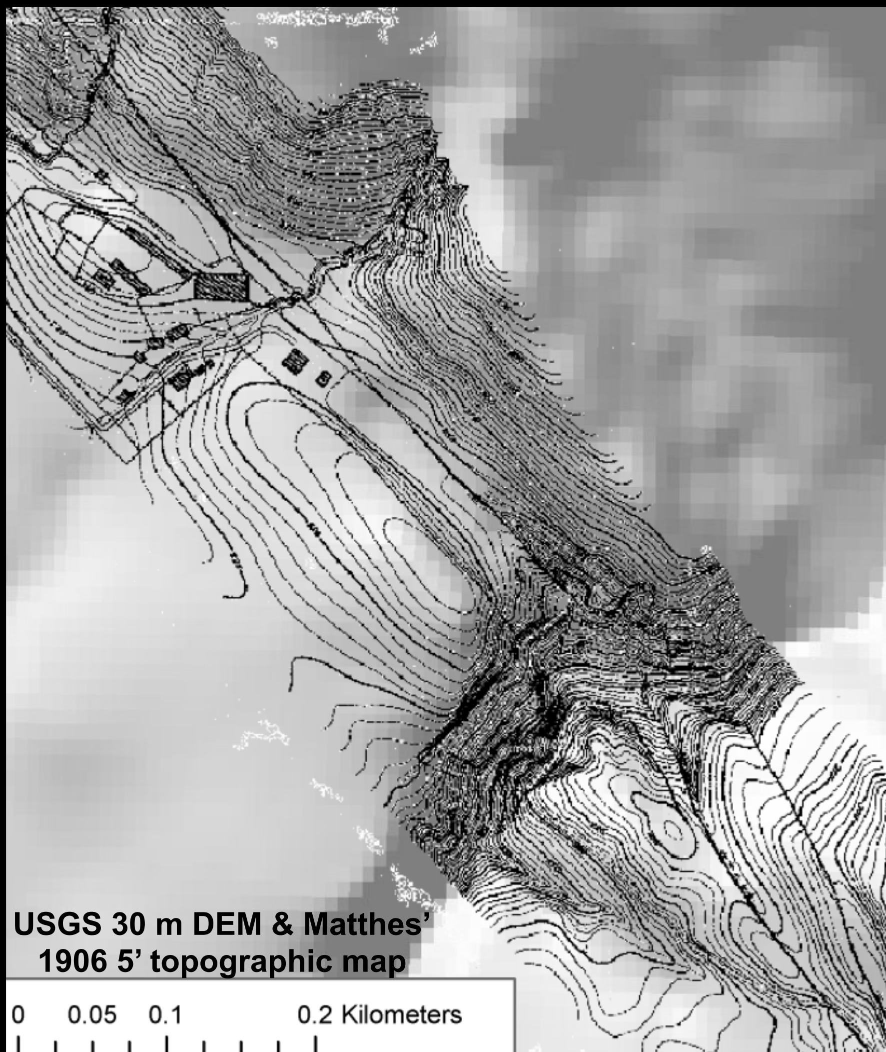
# Comparisons of Techniques for measuring surfaces and detecting changes in surfaces*

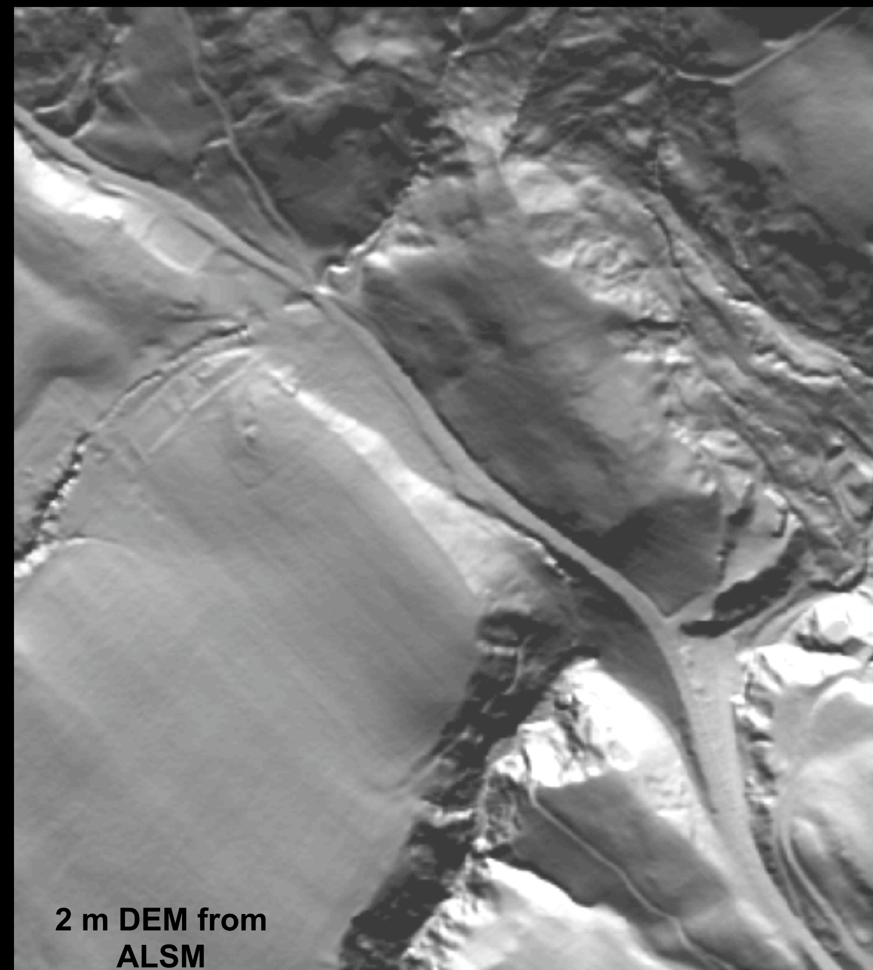
| | GPS | InSAR | ALSM | TLS |
|---|---|---|---|---|
| Sample Density | 1 site/10 $km^2$ | 10,000 pixels/ $km^2$ | 1-10 hits/ $m^2$ | 1000 hits/ $m^2$ |
| Position Precision | 1-20 mm | 2-3 m | 5-15 cm | 0.6-5 cm |
| Change Detection | 1 mm | 1-2 cm | 10 cm | 1 cm |
| Scale | Global | 100 km | 10-100 Km | 1 km |

* Ball park numbers for typical applications

-Phillips, Meertens, and Jackson, UNAVCO

# New Looks at Active Faults: Tectonic Geomorphology using Airborne Laser Swath Mapping (ALSM)

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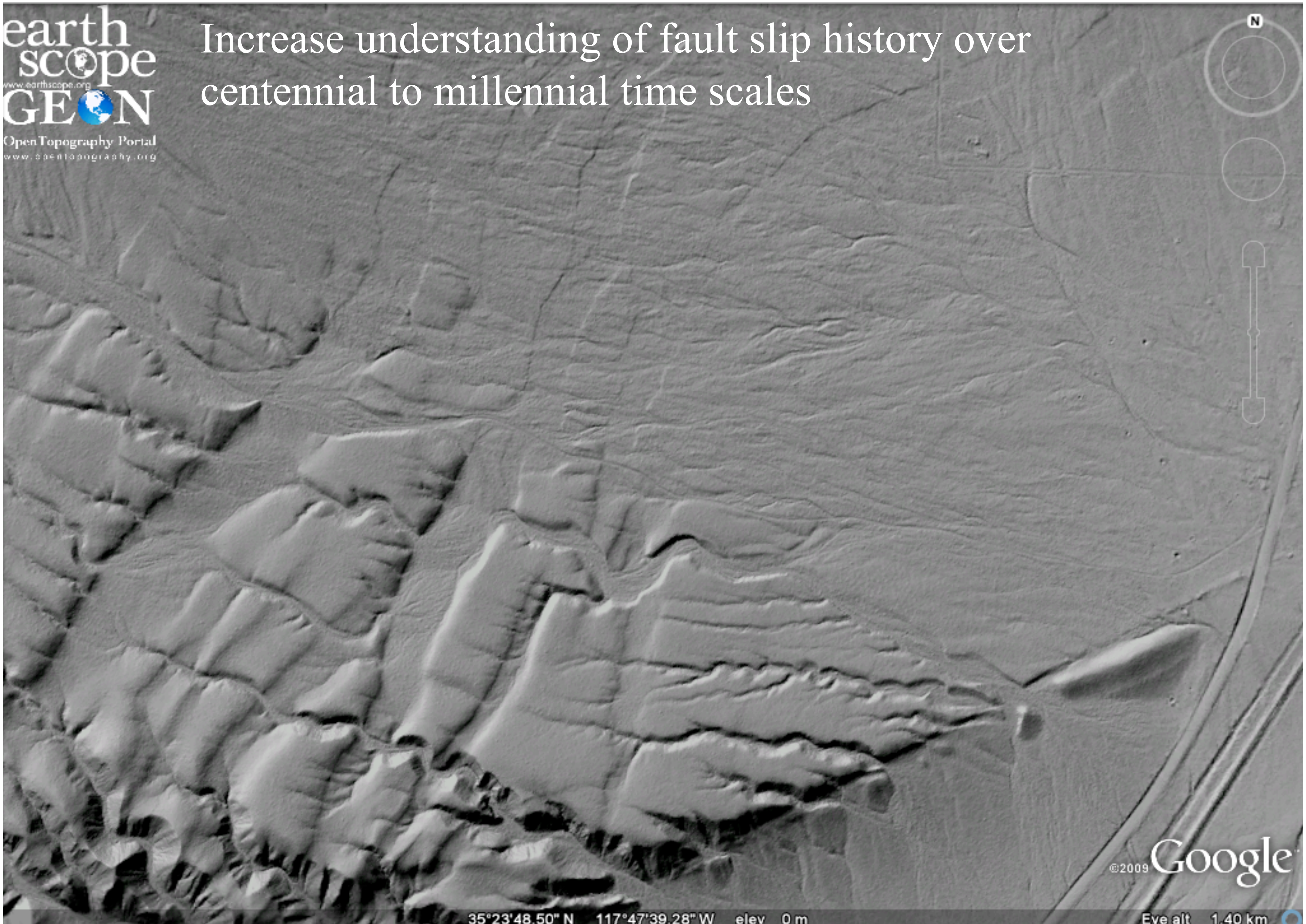
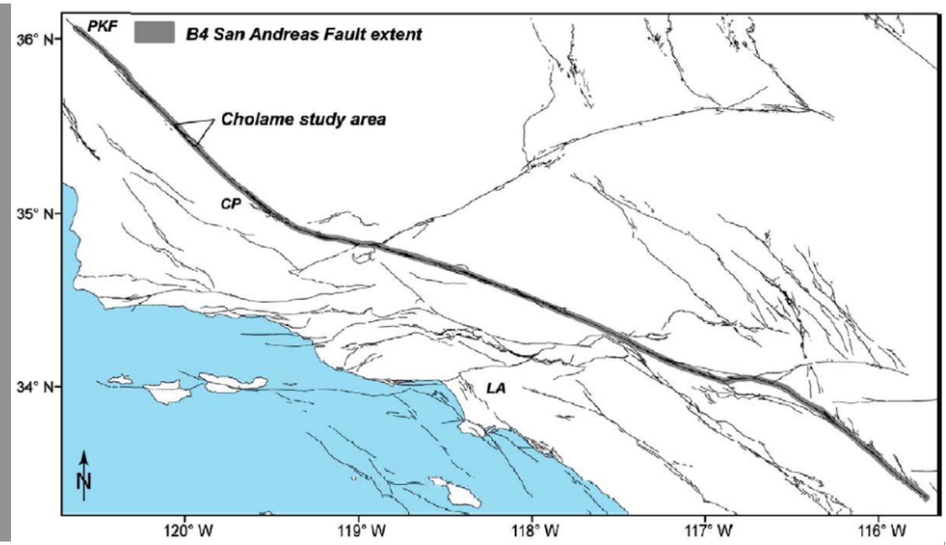
# Increase understanding of fault slip history over centennial to millennial time scales




Garlock fault zone high resolution topography

# Fault zone mapping from ALSM—a major application

## Arrowsmith and Zielke, 2009
## Cholame case study




A) Explanation for fault strip mapping

*Vedder and Wallace, 1970*

- Local features with annotation
- Regional features
- Recently active breaks, certain
- Recently active breaks, less obvious
- Ponds and lakes

*Stone and Arrowsmith*

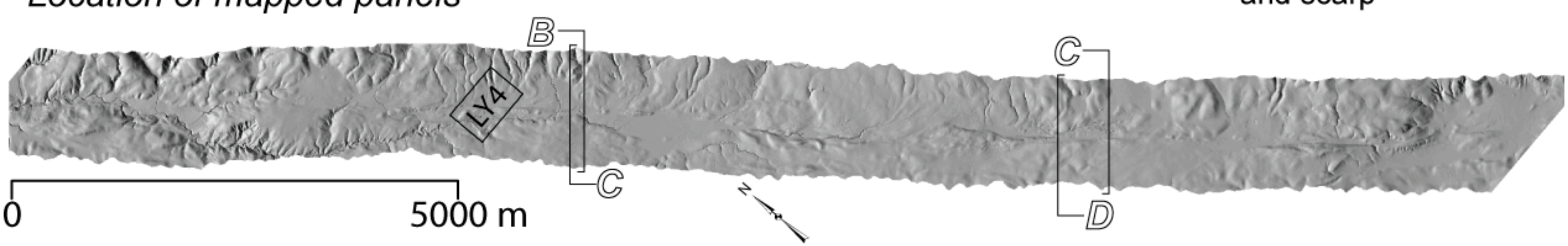
- Fault trace
- Fault trace, concealed
- Fault trace, inferred
- Lineament
- Landslide deposit
- Landslide scarp
- Sag

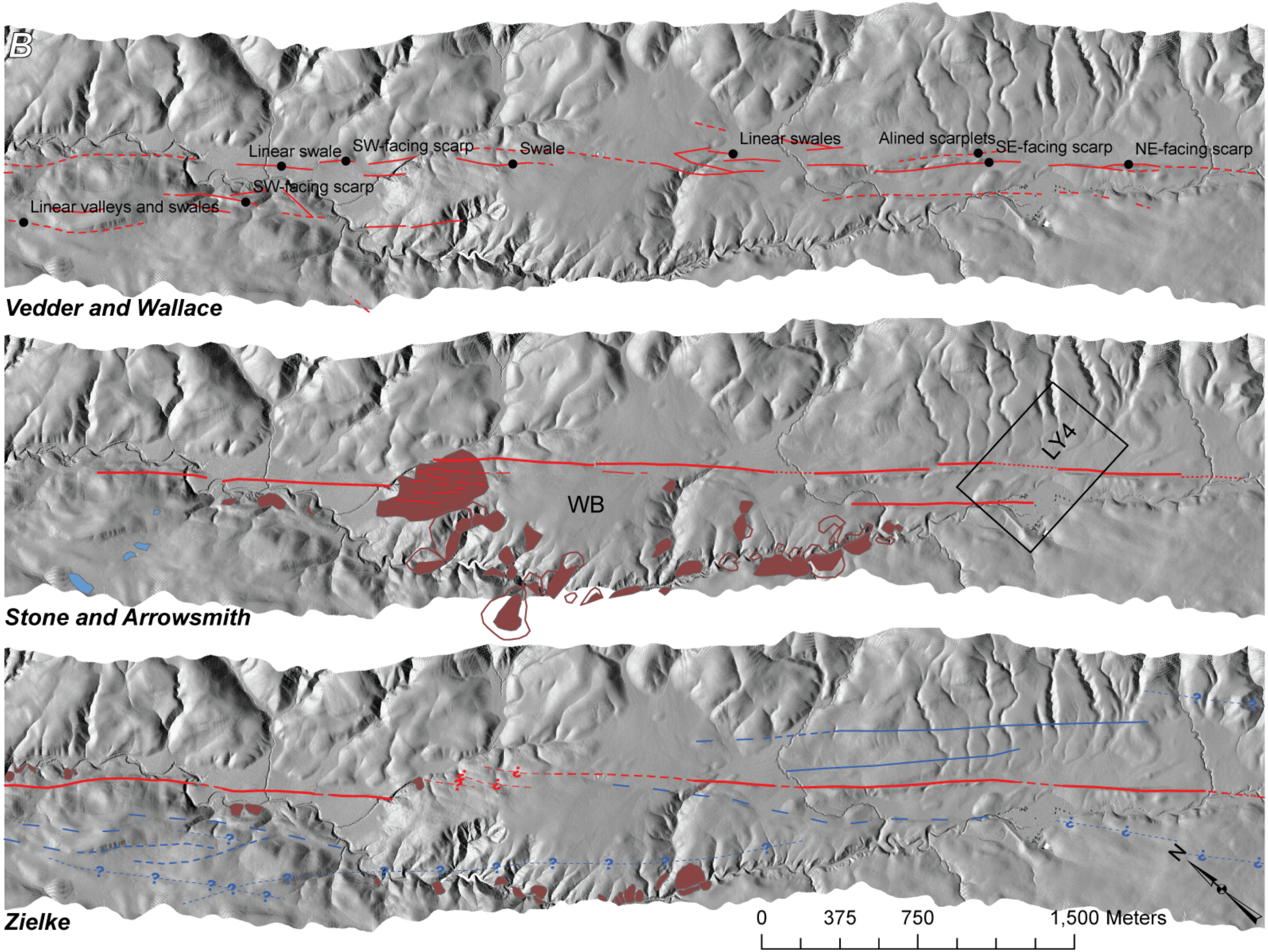
*Zielke, this study*

Fault traces: red for main trace, blue for secondary traces

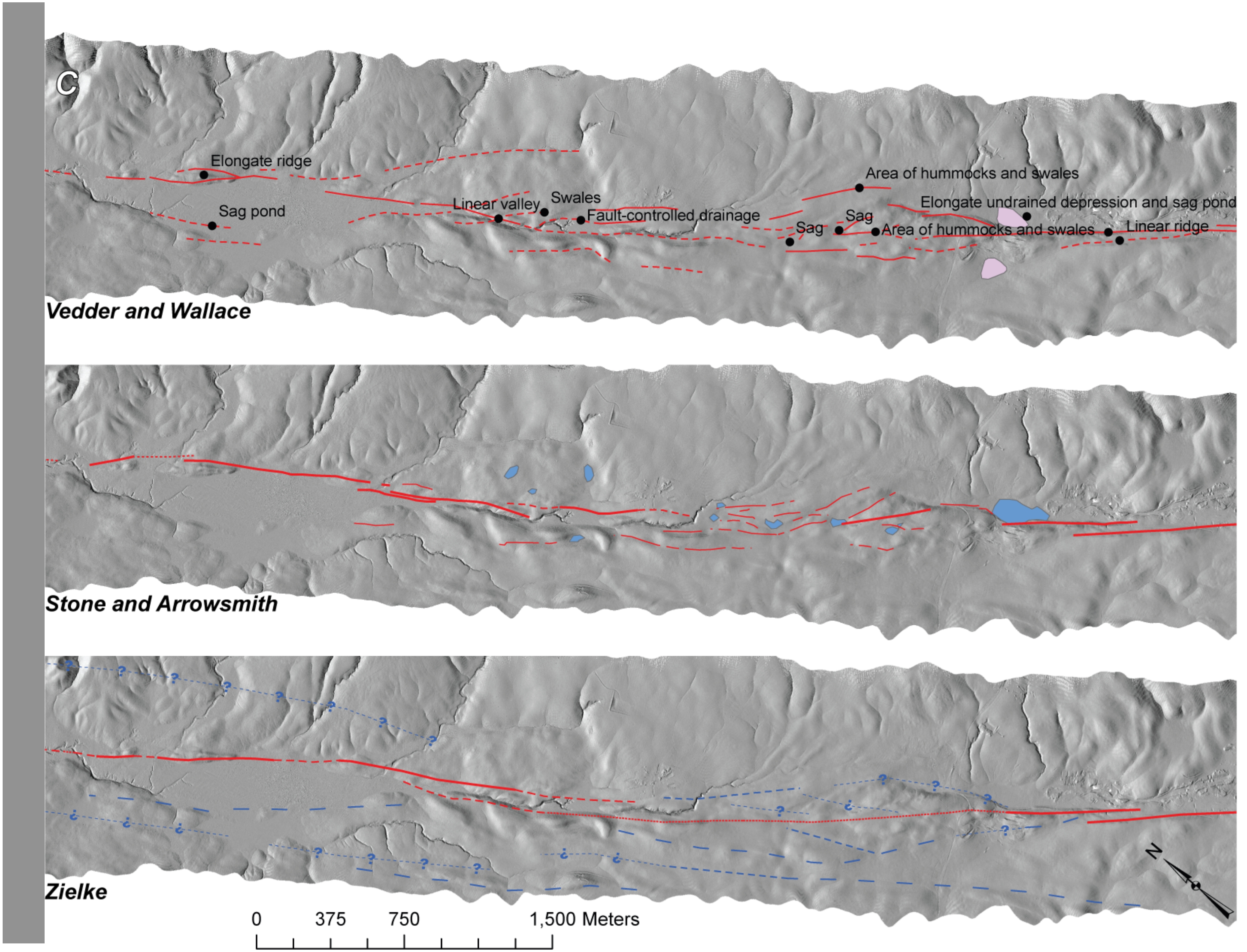
- Fault trace, certain
- Fault trace, inferred
- Fault trace, queried
- Fault trace, uncertain
- Landslide deposit and scarp

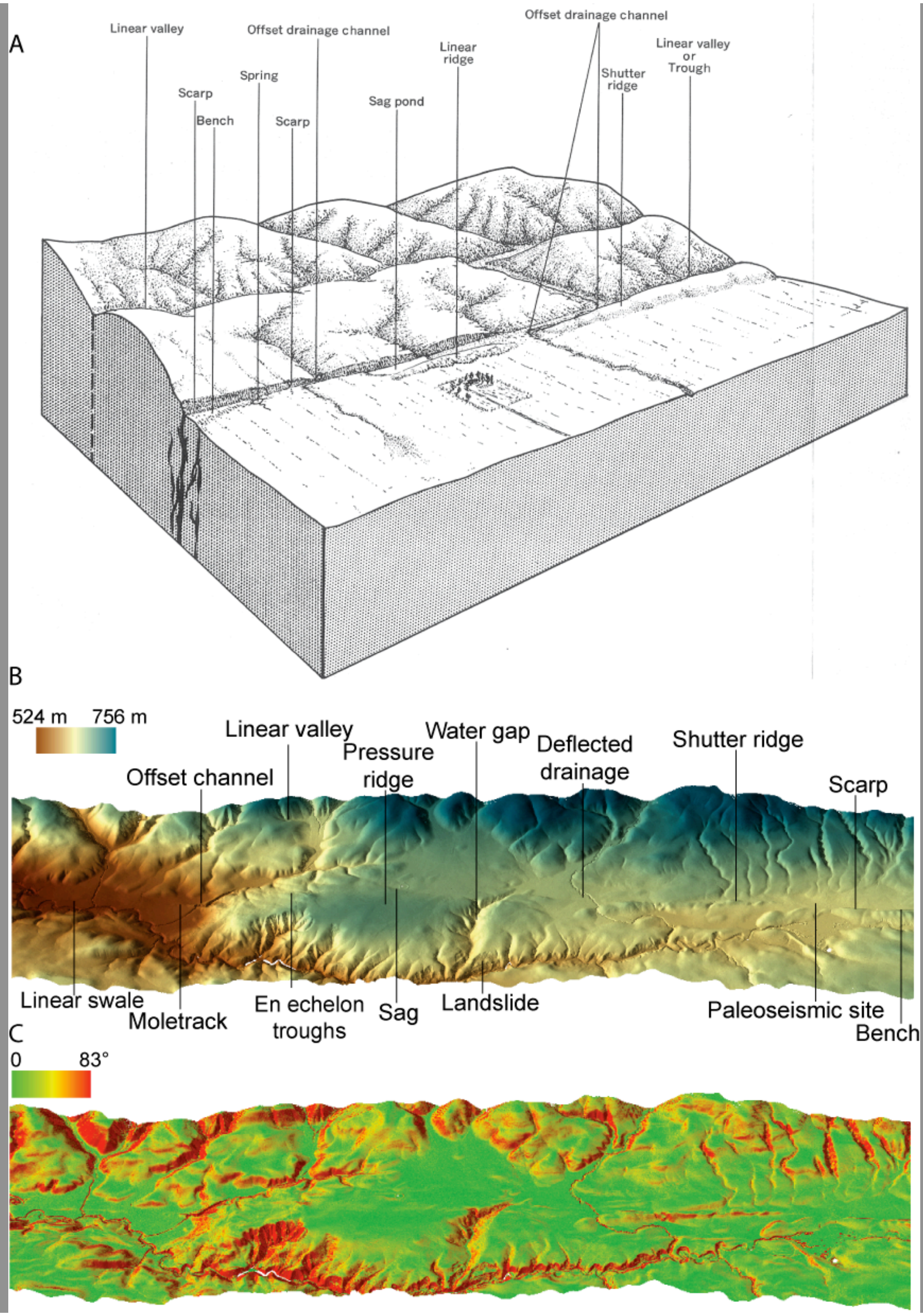
*Location of mapped panels*





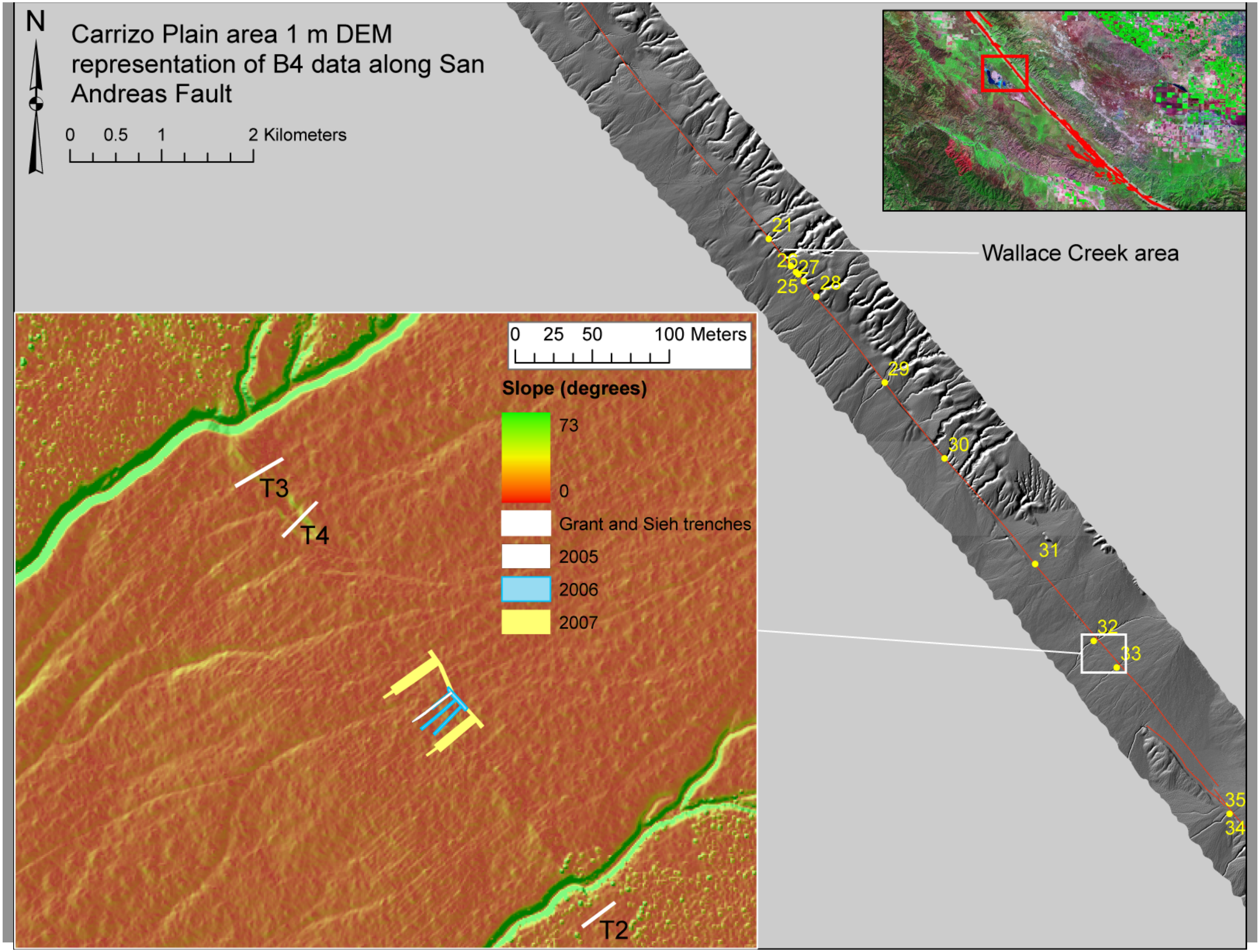
B
Linear swale
SW-facing scarp
Swale
Linear swales
Alined scarplets
SE-facing scarp
NE-facing scarp
SW-facing scarp
Linear valleys and swales
Vedder and Wallace
WB
LY4
Stone and Arrowsmith
Zielke
0
375
750
1,500 Meters
N


C
Elongate ridge
Sag pond
Linear valley
Swales
Fault-controlled drainage
Sag
Sag
Area of hummocks and swales
Elongate undrained depression and sag pond
Area of hummocks and swales
Linear ridge
Vedder and Wallace
Stone and Arrowsmith
Zielke
N
0
375
750
1,500 Meters

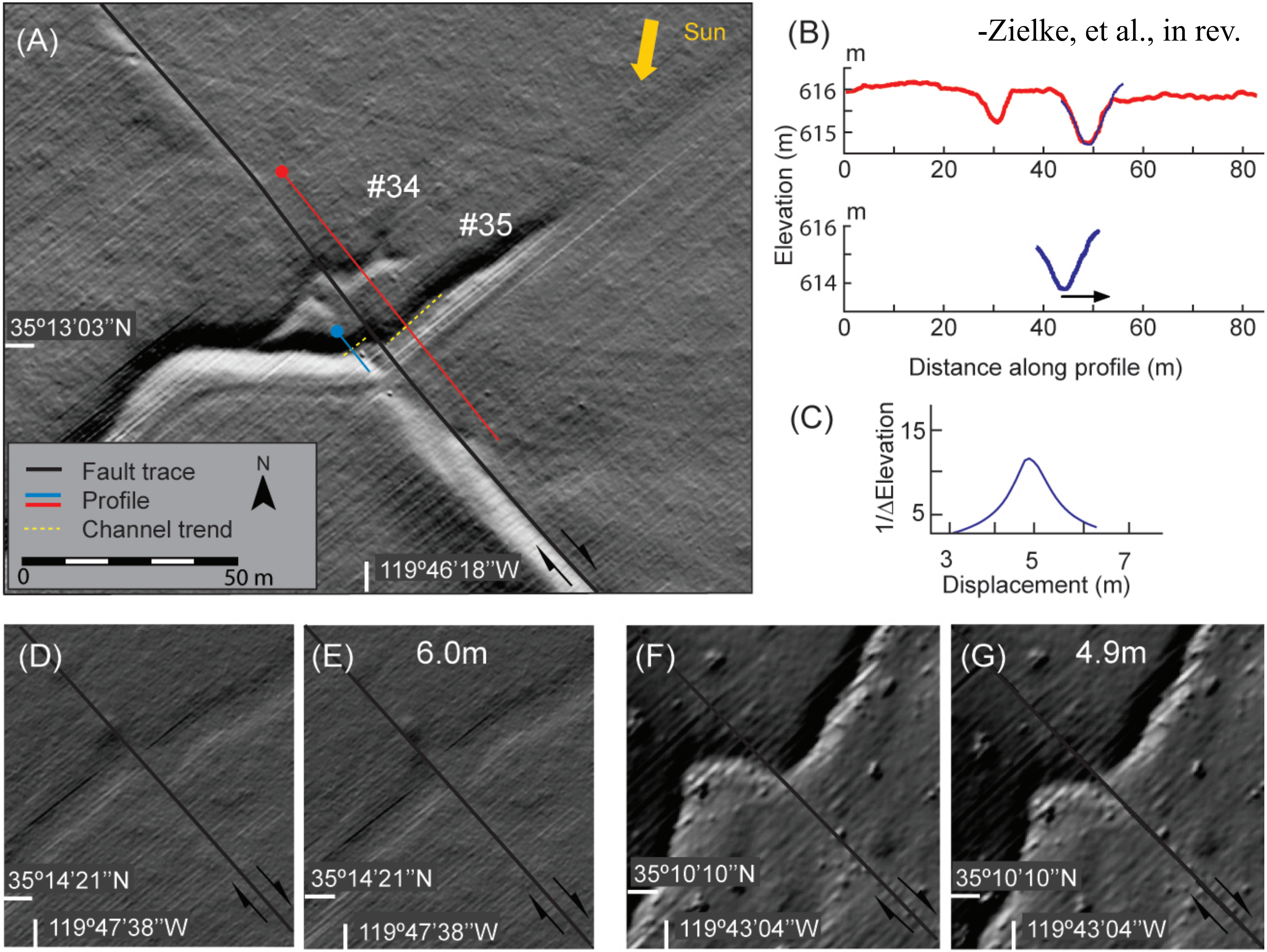



# A new view of fault zone tectonic landforms

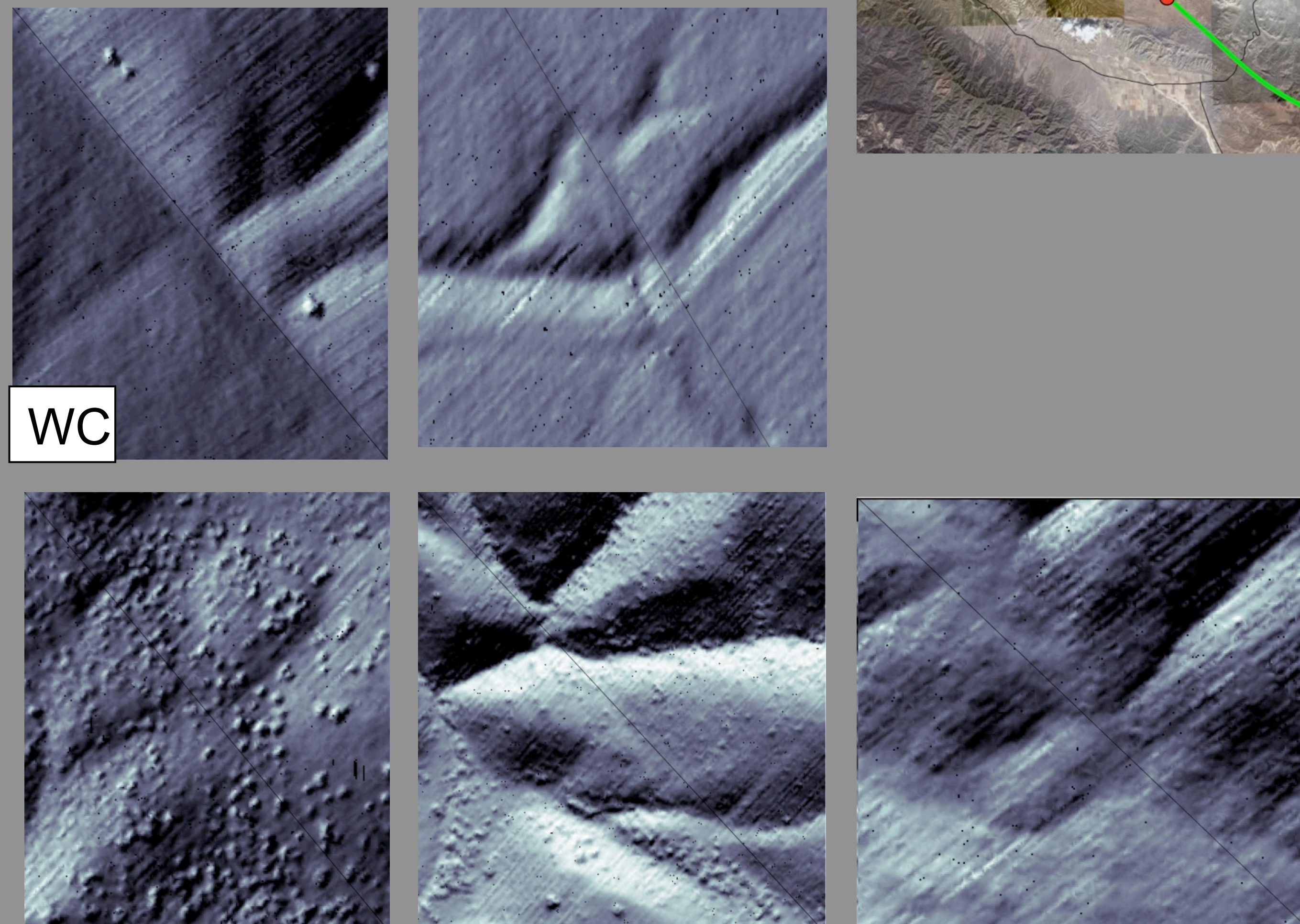
Arrowsmith and Zielke, 2009



N
Carrizo Plain area 1 m DEM representation of B4 data along San Andreas Fault
0 0.5 1 2 Kilometers
Wallace Creek area
21
26
27
25
28
29
30
31
32
33
35
34
0 25 50 100 Meters
Slope (degrees)
73
0
Grant and Sieh trenches
2005
2006
2007
T3
T4
T2

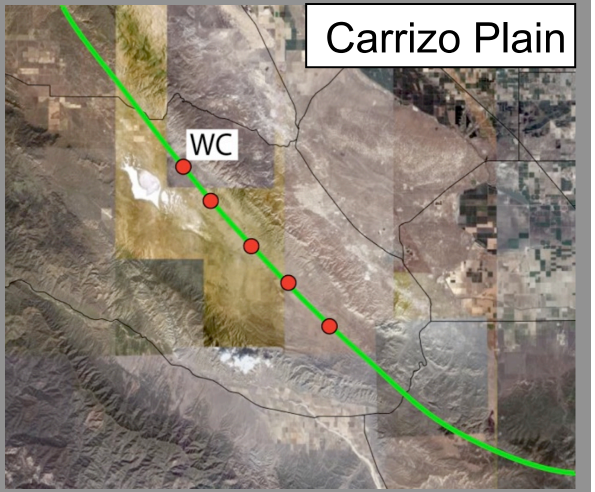

-Zielke, et al., in rev.
(A)
Sun
#34
#35
35°13'03"N
119°46'18"W
Fault trace
Profile
Channel trend
N
0
50 m
(B)
m
616
615
Elevation (m)
0
20
40
60
80
m
616
614
Distance along profile (m)
(C)
1/ΔElevation
15
5
3
5
7
Displacement (m)
(D)
35°14'21"N
119°47'38"W
(E)
6.0m
35°14'21"N
119°47'38"W
(F)
35°10'10"N
119°43'04"W
(G)
4.9m
35°10'10"N
119°43'04"W

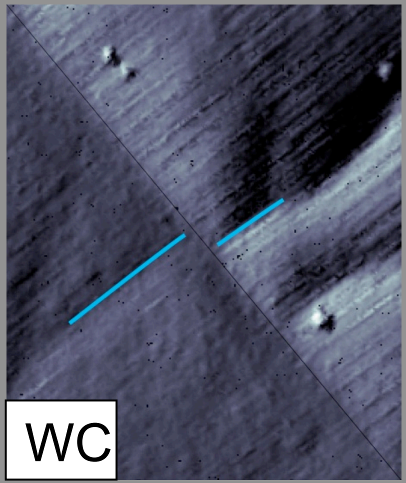
# Carrizo Plain, 1857 Offsets

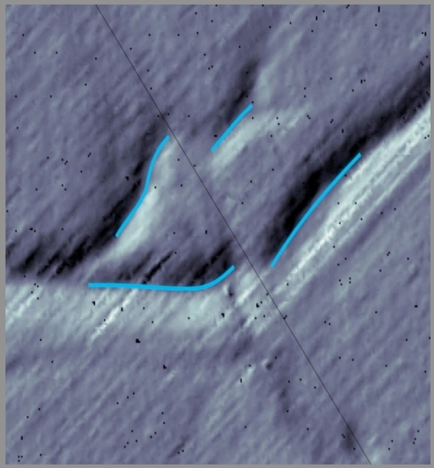



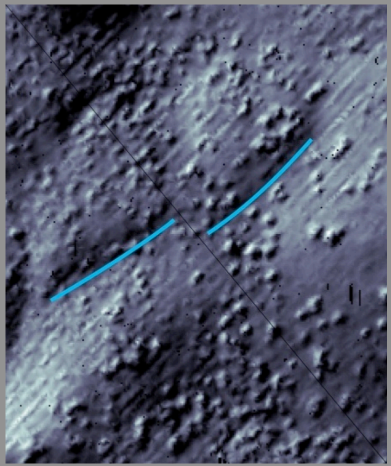

Zielke, 2009

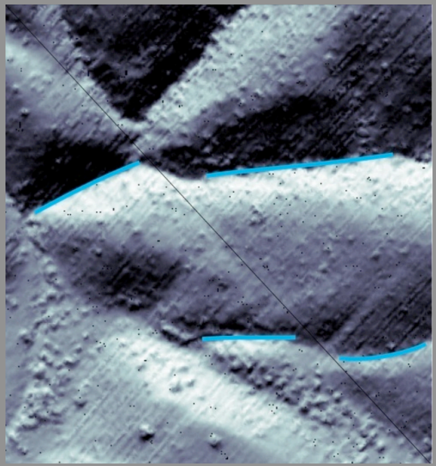
# Carrizo Plain, 1857 Offsets

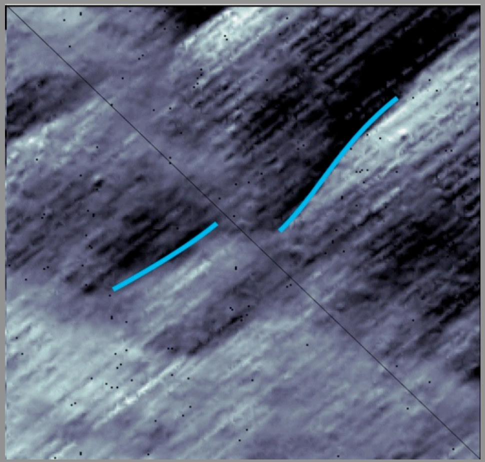








Zielke, 2009

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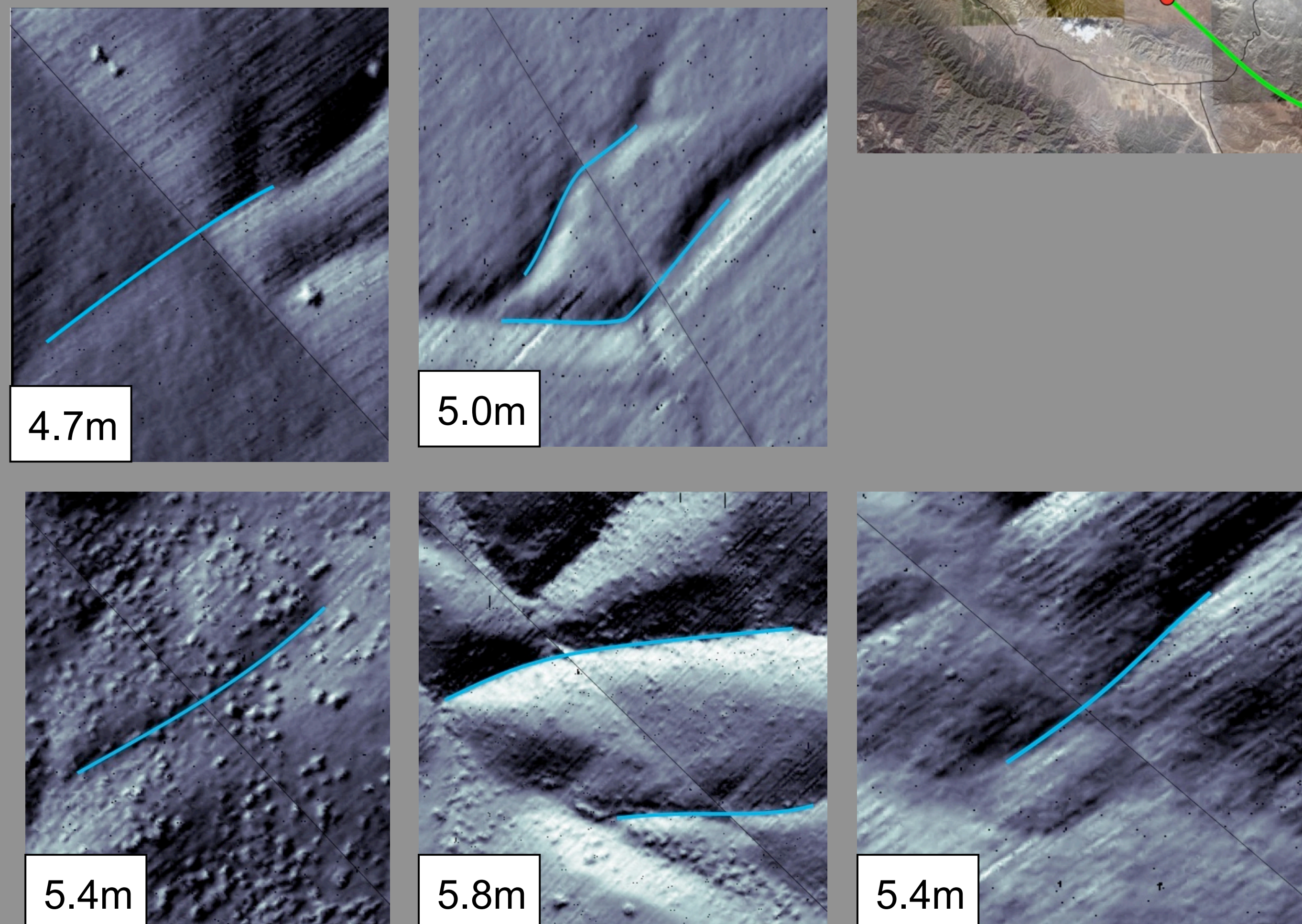
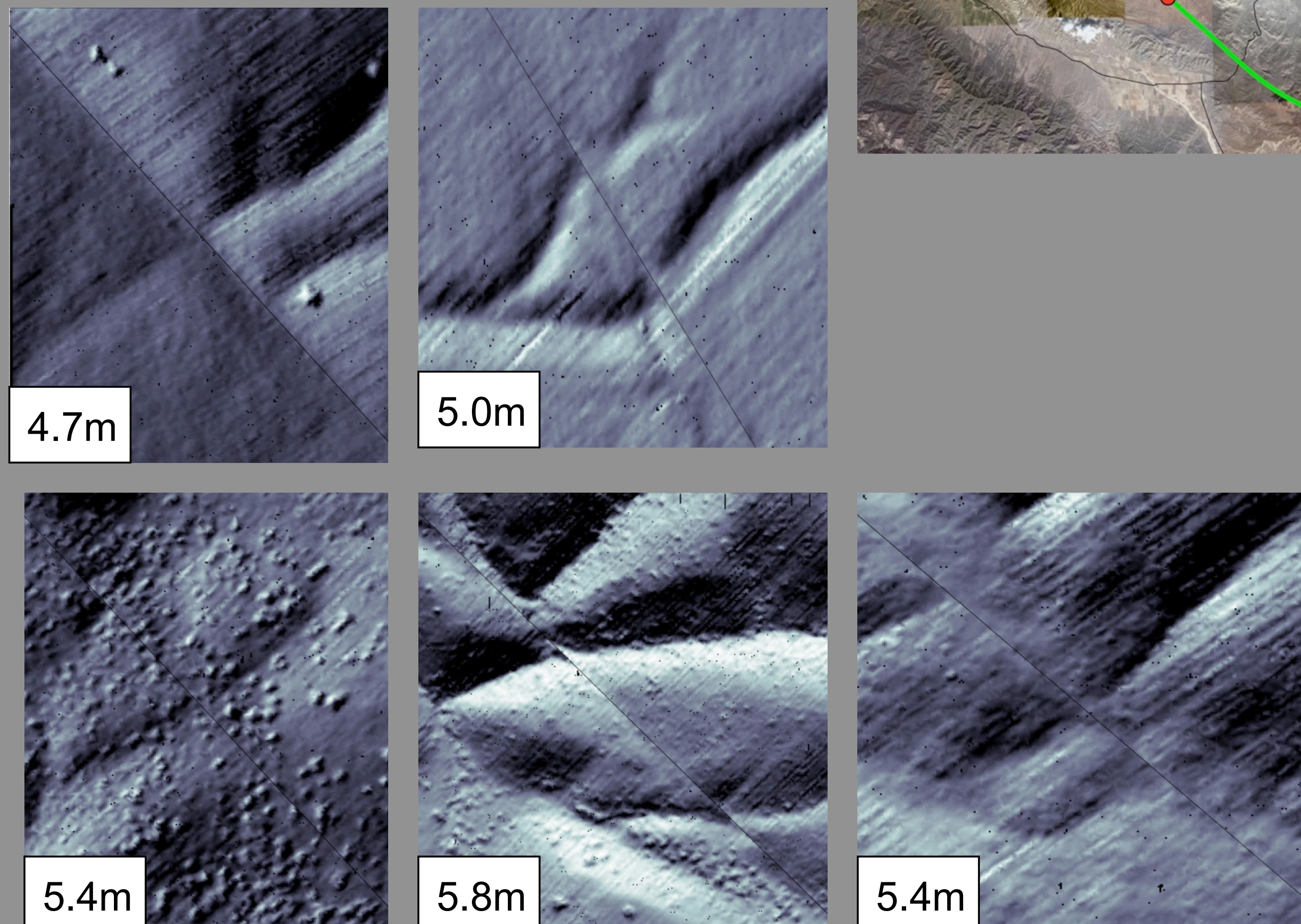
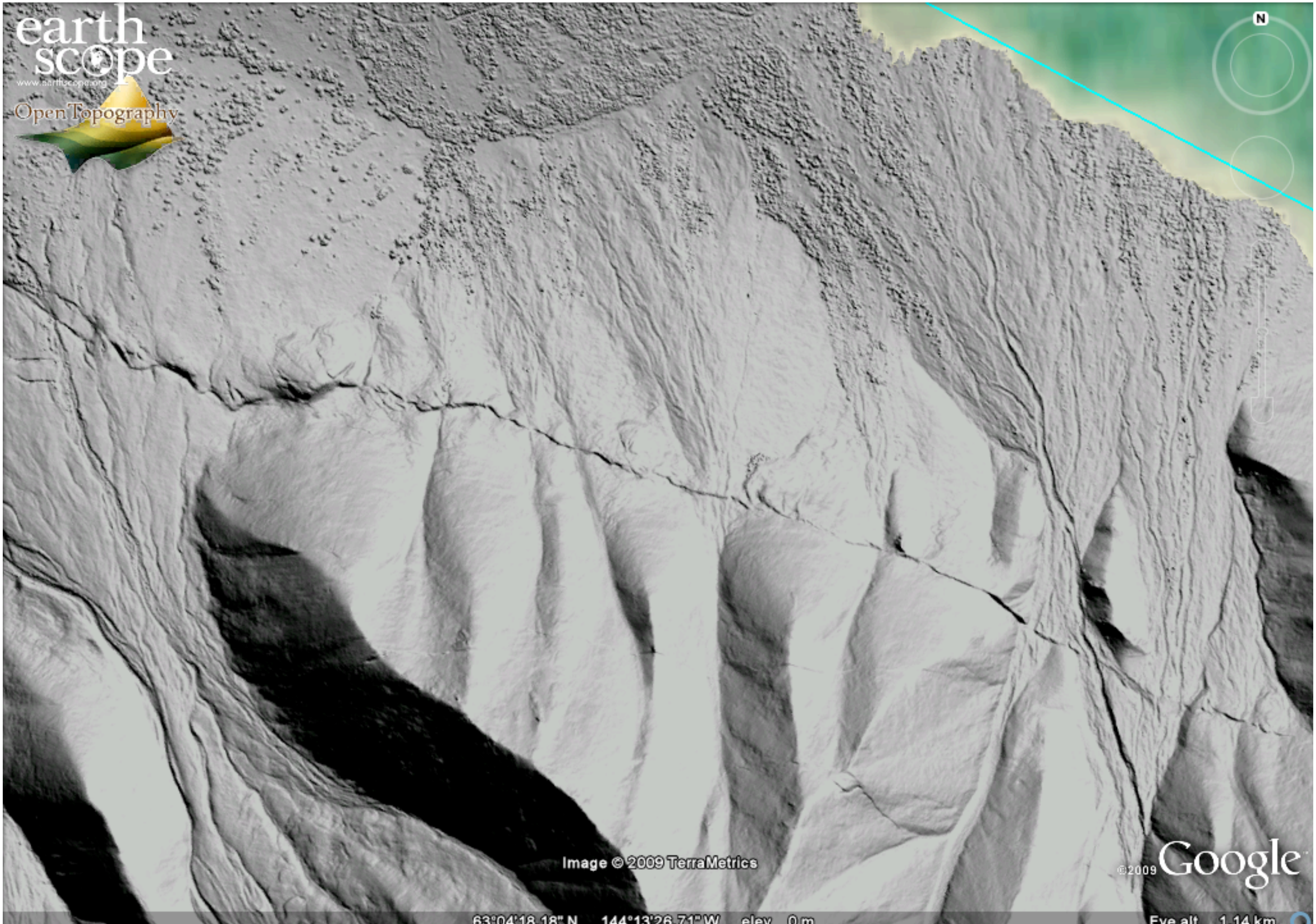



Zielke, 2009

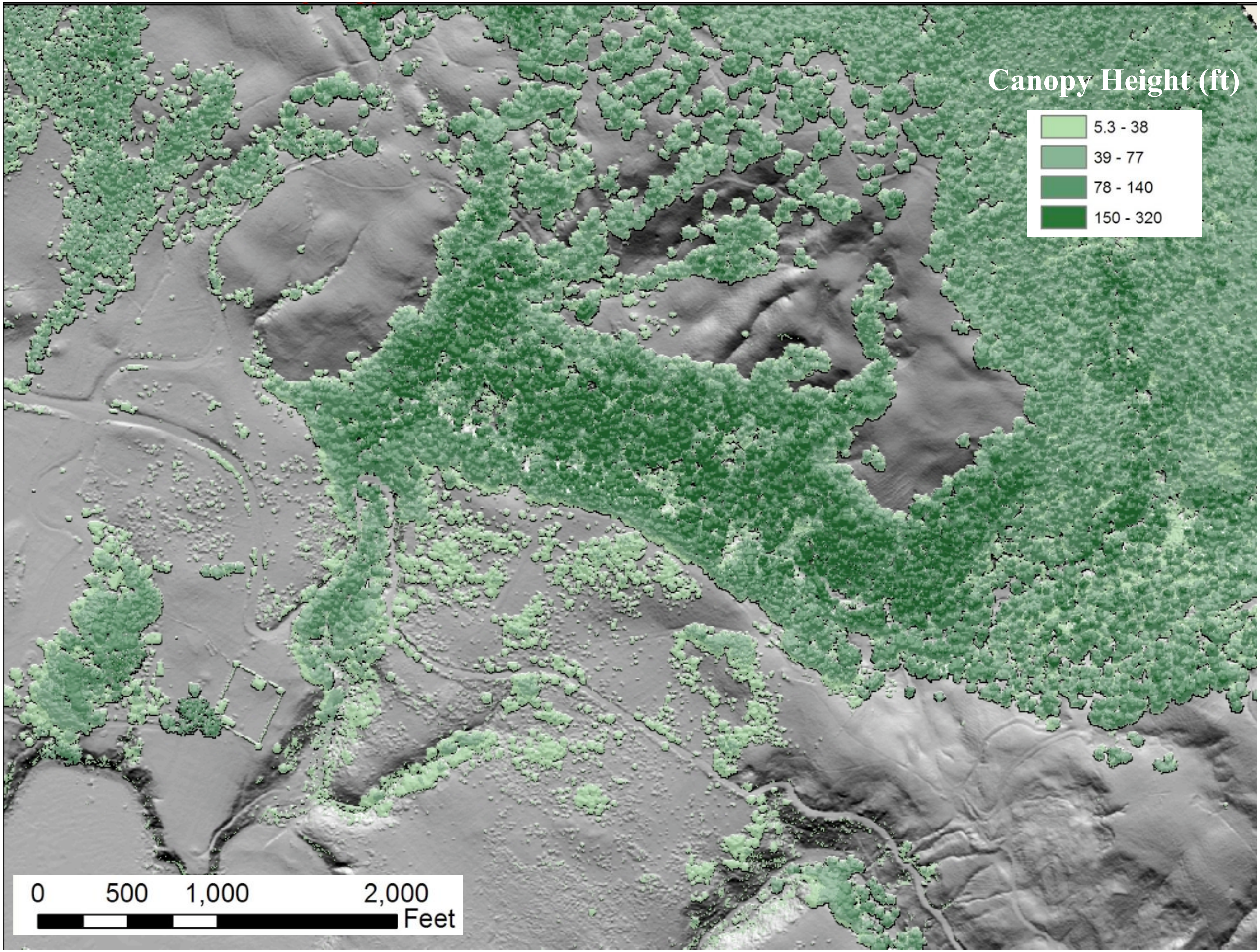
# Carrizo Plain, 1857 Offsets

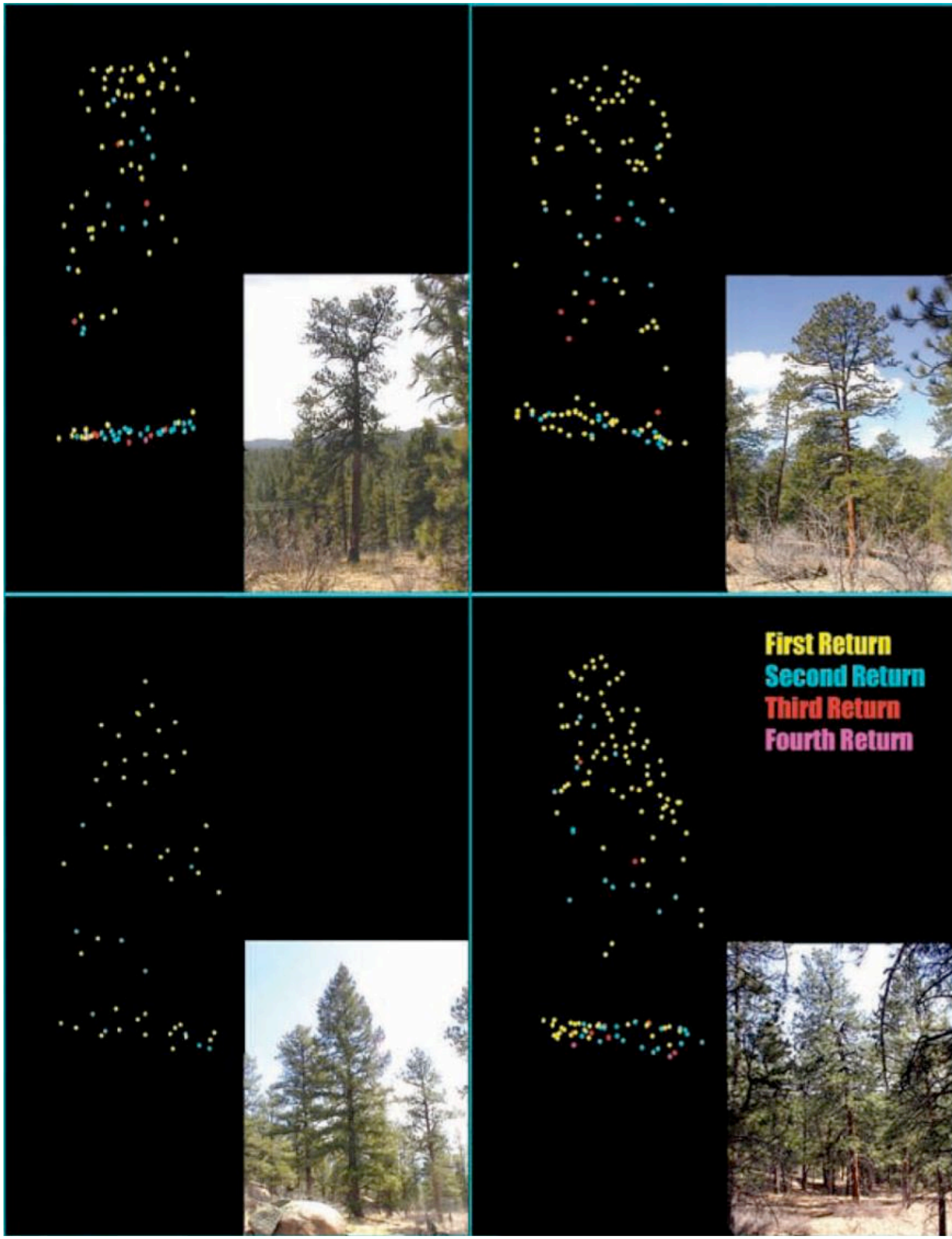




Zielke, 2009




Post earthquake laser scanning and repetition (B4, Hector Mine, Denali)


Canopy Height (ft)
5.3 - 38
39 - 77
78 - 140
150 - 320
0
500
1,000
2,000
Feet

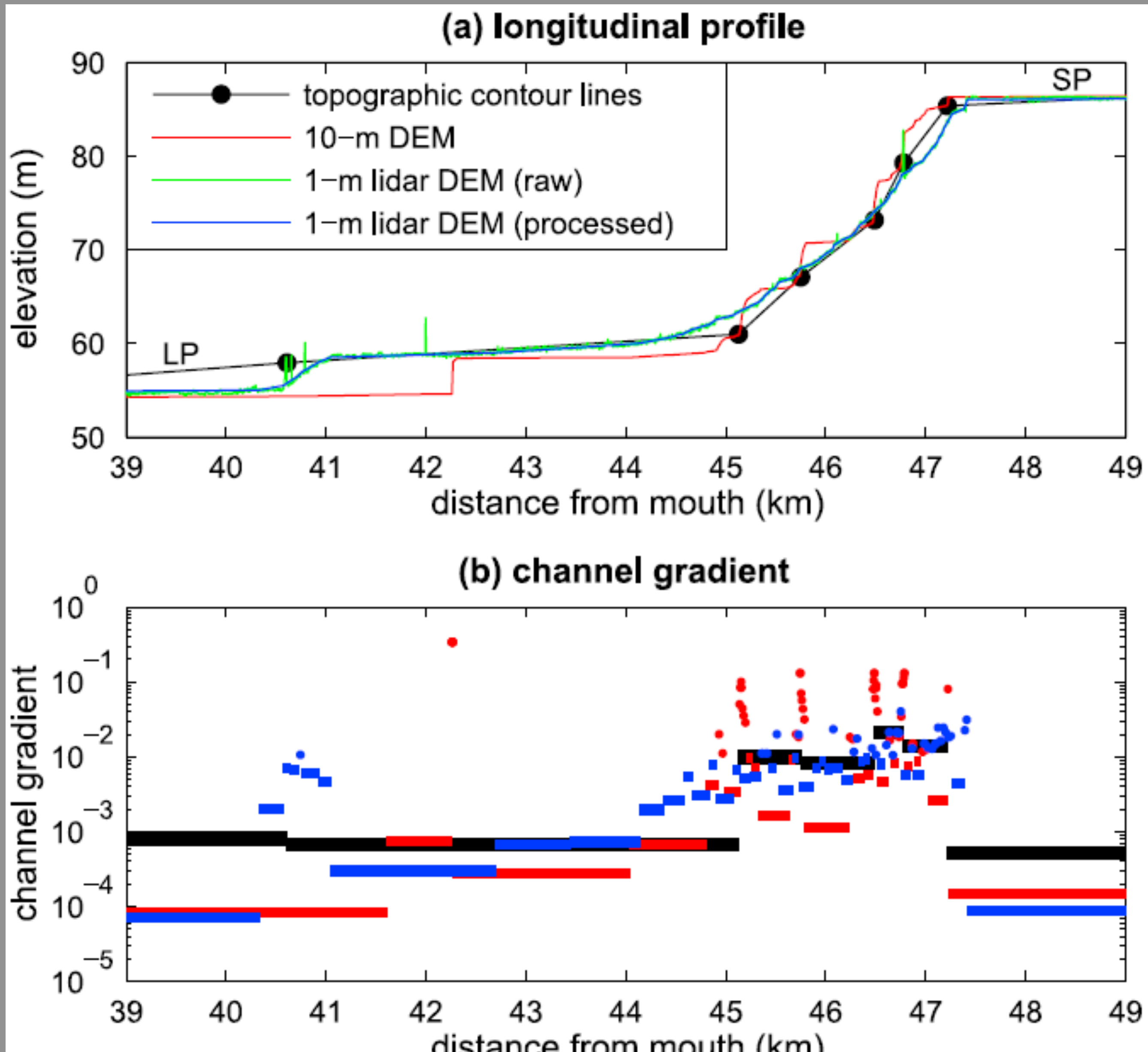



Ecology Applications:

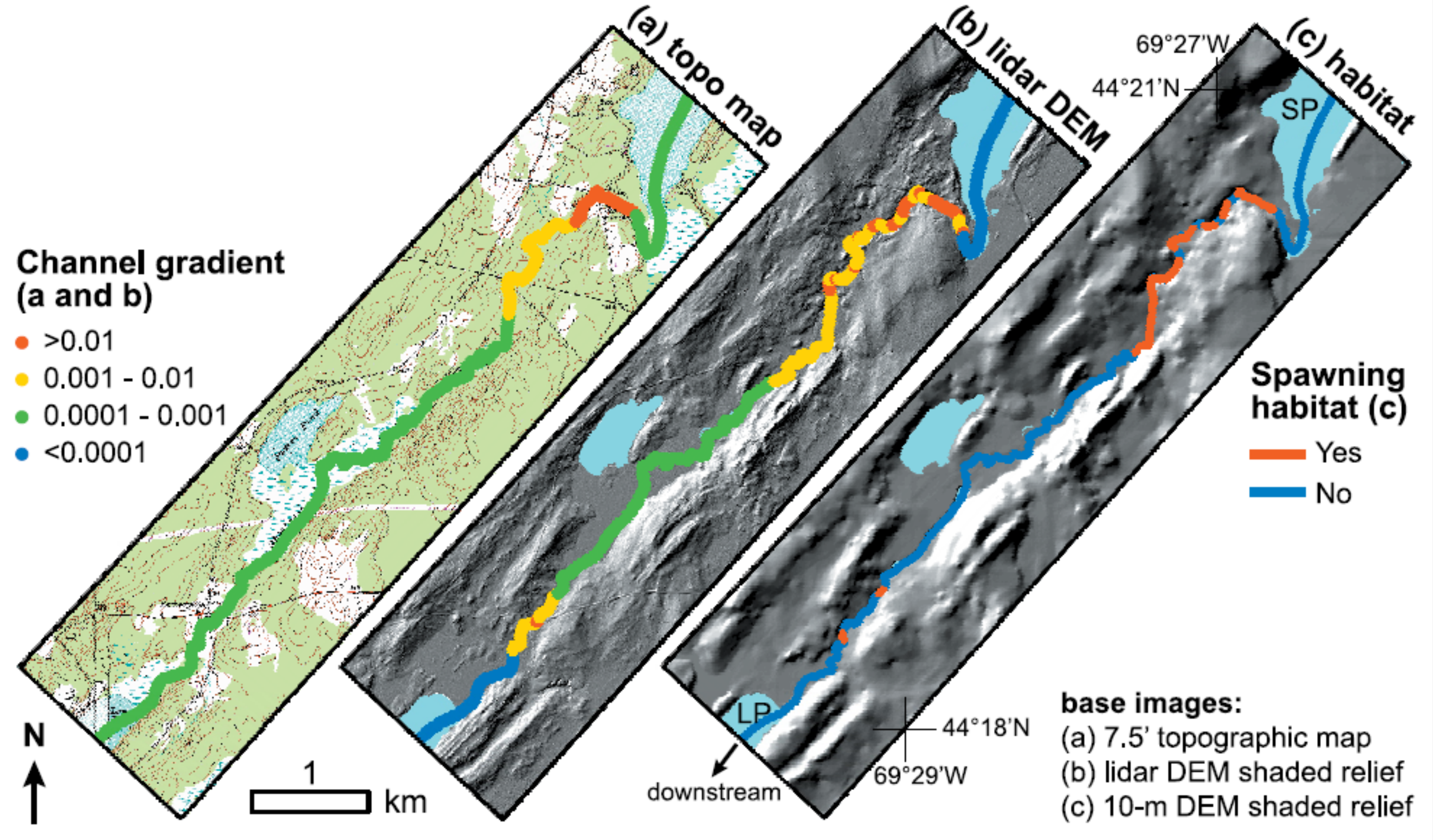
- 3D vegetation information & interactions between vegetation and topography
- 3D vegetation structure:
  - estimation of stand height
  - total aboveground biomass
  - foliage biomass
  - basal area
  - tree density,
  - canopy base height
  - canopy bulk density

*Stoker et al., 2006*

Snyder, N. P., 10 February 2009. Studying stream morphology with airborne laser elevation data, *Eos, Transactions, American Geophysical Union, v. 90, n. 6, p. 45-46.*



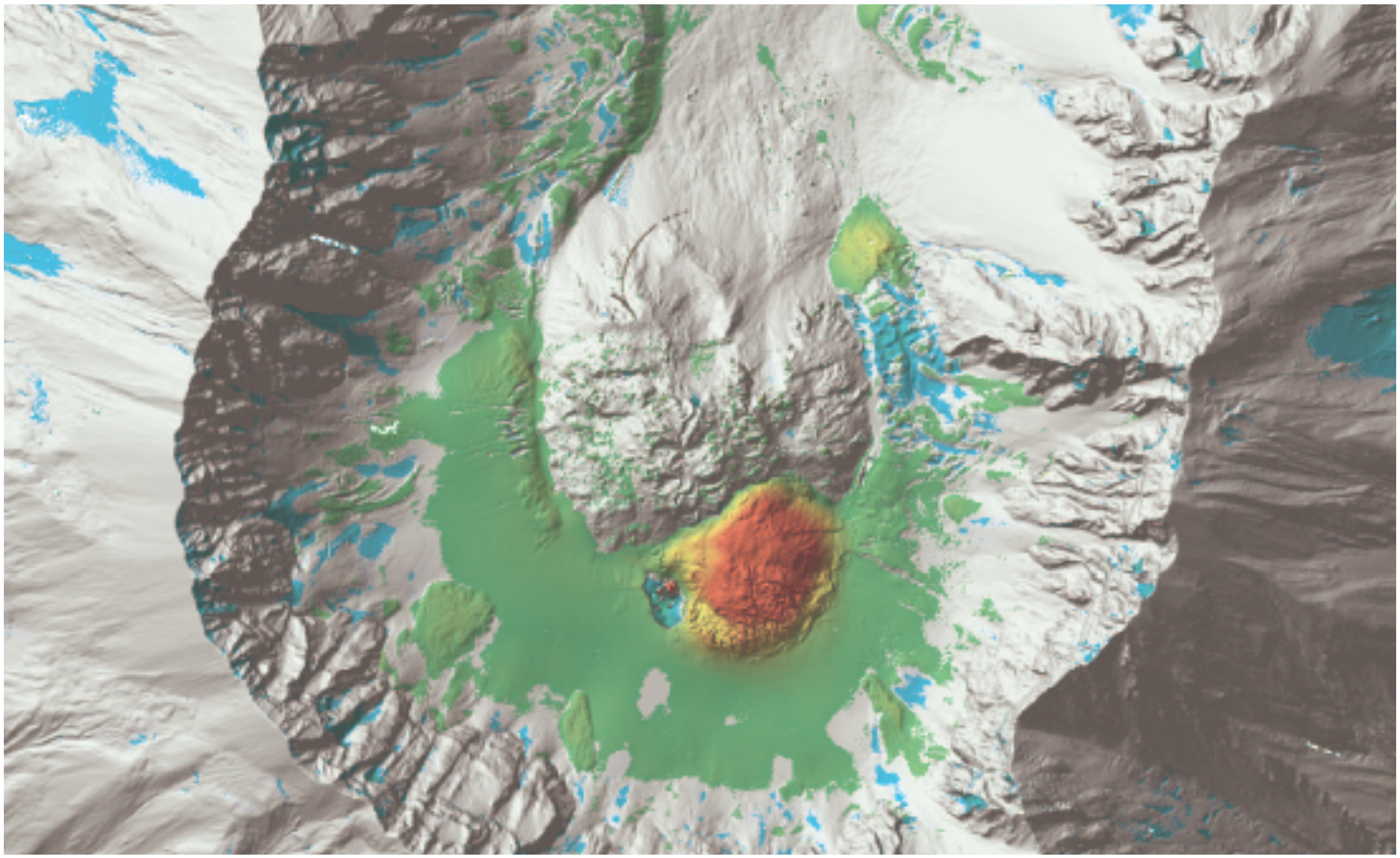

Sheepscot River, ME



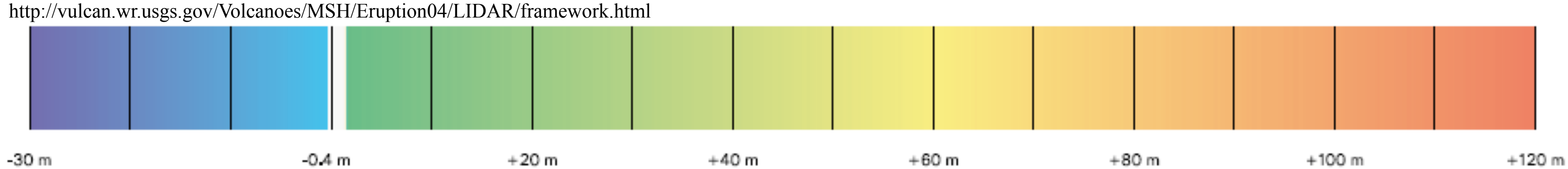

*Note the greater resolution provided by the lidar DEM image and profile (Figure 2b), and the correspondence of higher slope (Figure 2b) with spawning habitat (Figure 2c).*

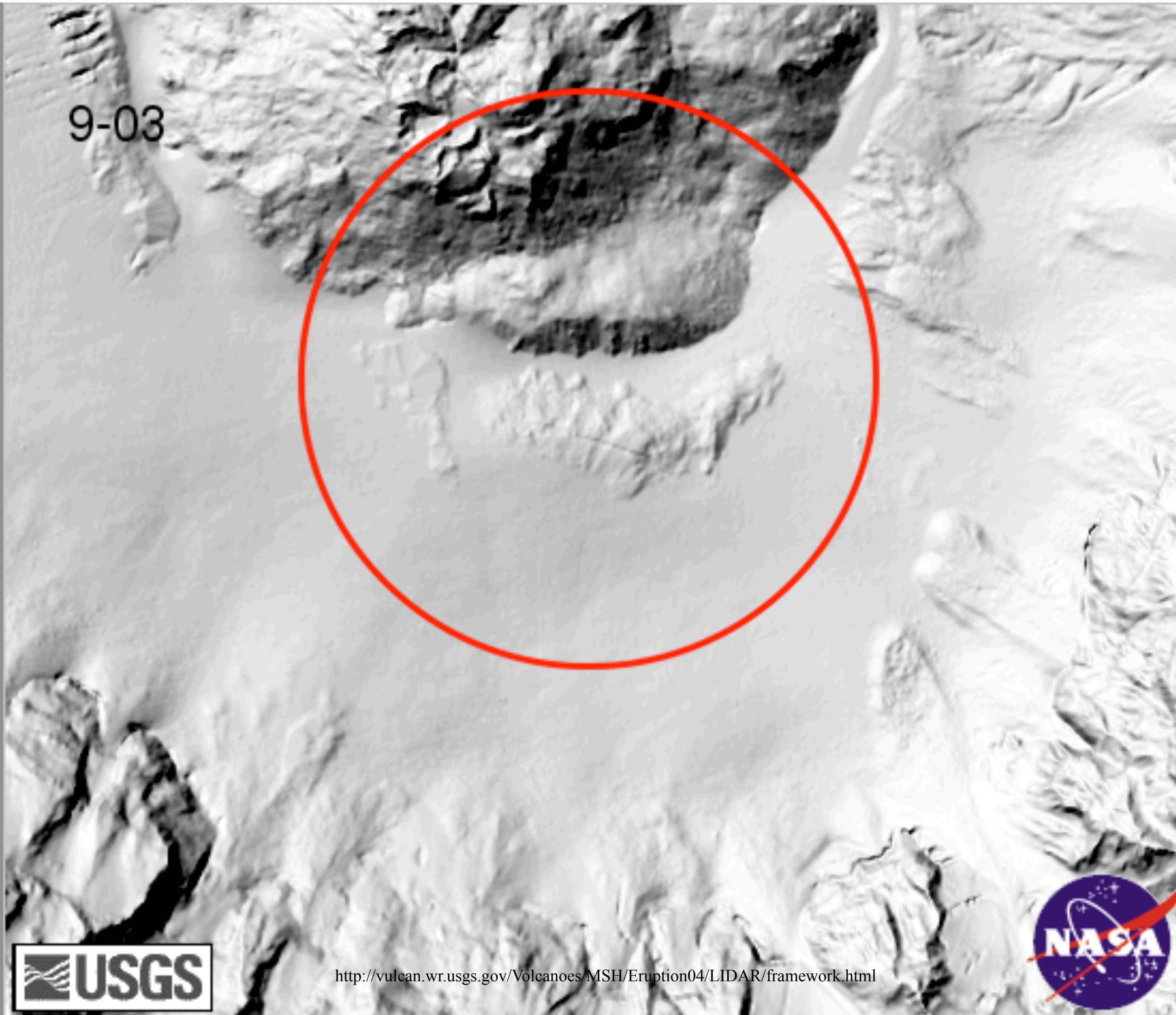
# Elevation change at Mt St Helens, September 2003 to October 4-5, 2004

Ralph Haugerud (USGS), David Harding (NASA), Vivian Queija (USGS), Linda Mark (USGS)



http://vulcan.wr.usgs.gov/Volcanoes/MSH/Eruption04/LIDAR/framework.html




9-03
USGS
http://vulcan.wr.usgs.gov/Volcanoes/MSH/Eruption04/LIDAR/framework.html
NASA