Advanced Structural Geology, Fall 2022

Carefree Fault DeBrief and assignment

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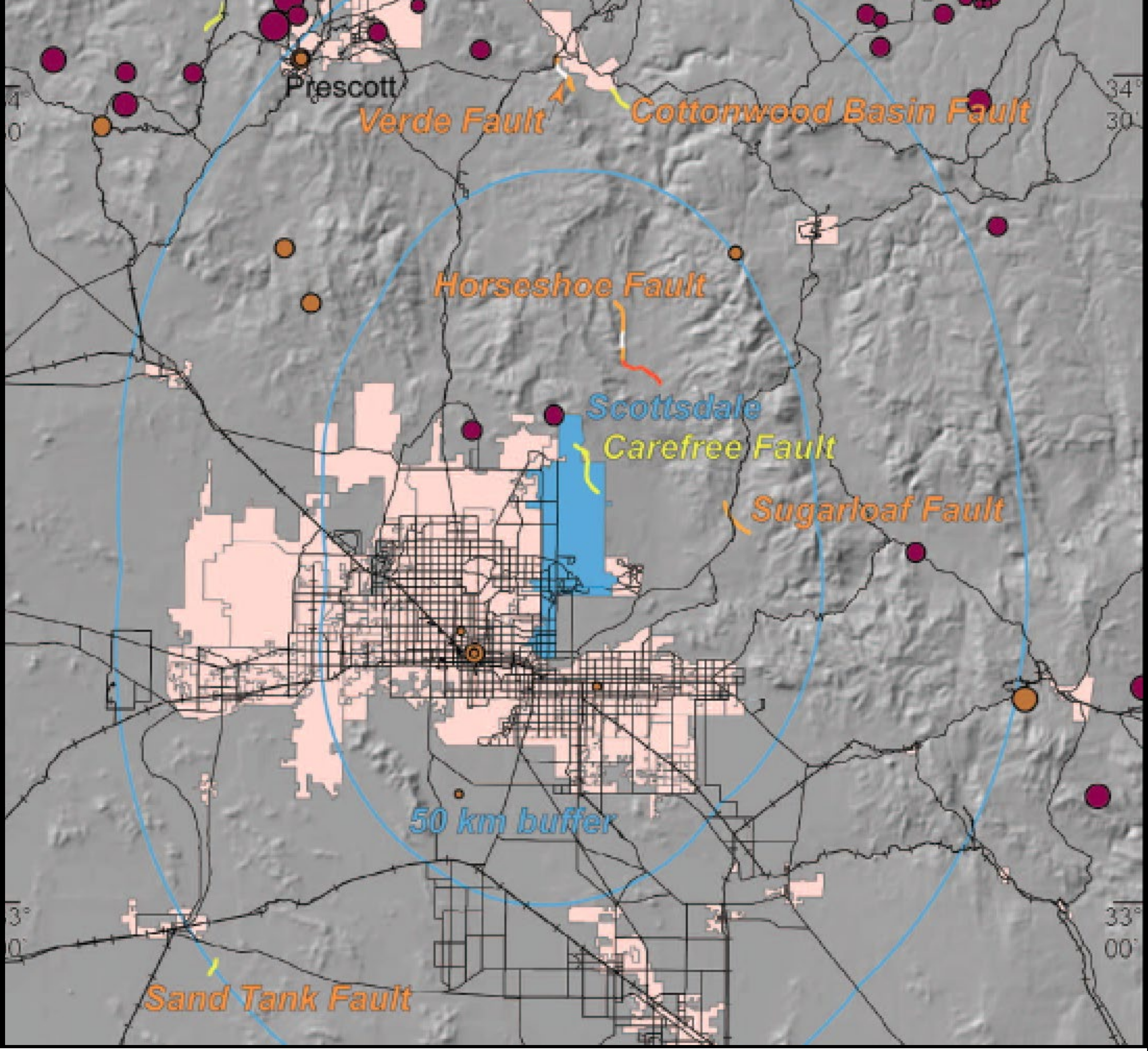
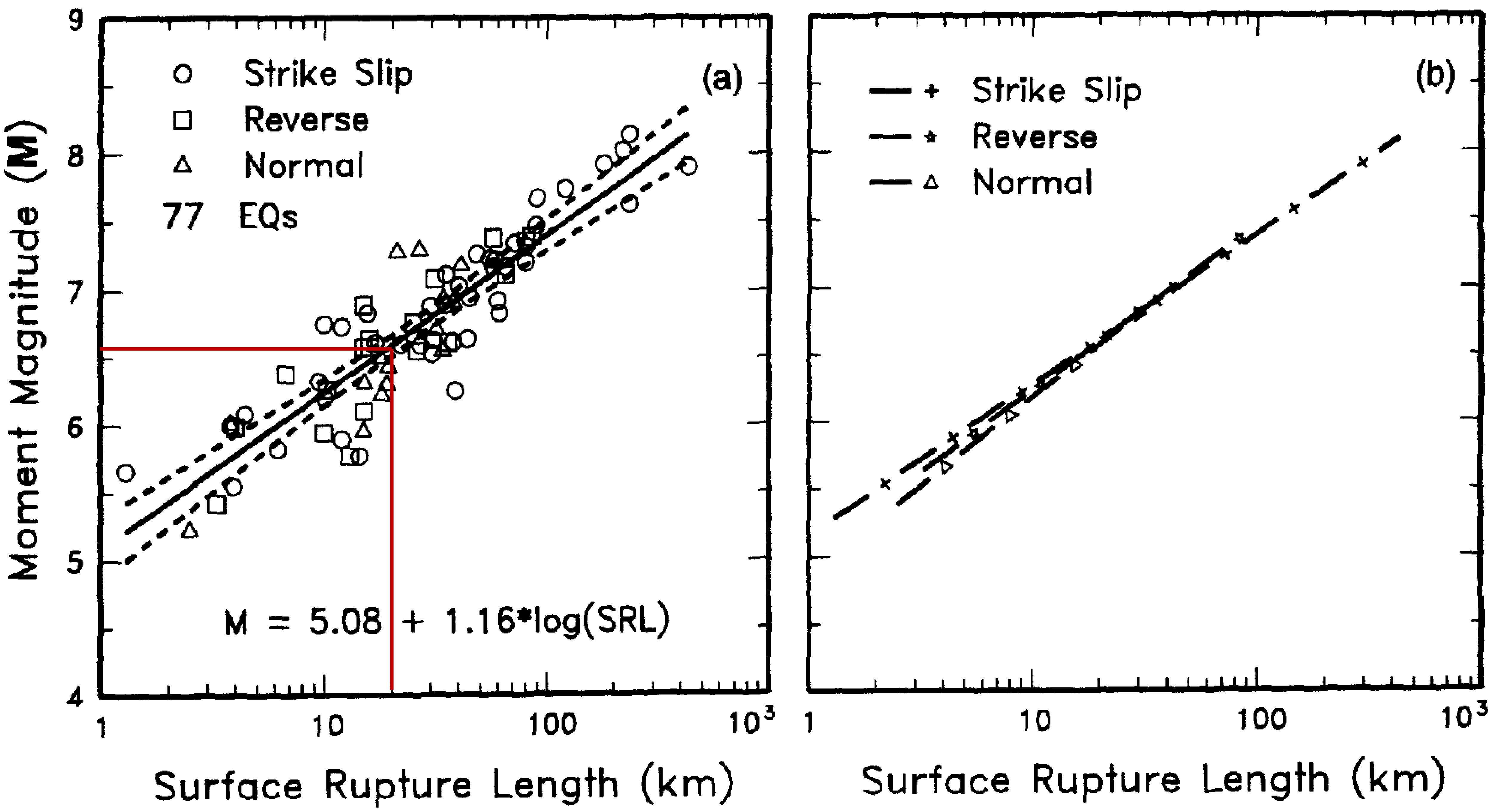
Ghanat, S. T., Kavazanjian, E., Arrowsmith, J R., Seismic Source Characterization for Greater Phoenix Area Earthquake Hazard, Environmental and Engineering Geoscience, Vol. XXI, No. 3, pp. 211–222, August 2015.

Detailed source characterization for Phoenix



Fault Sources	Length (km)	Age of Latest Movement	Slip Rate (mm/yr)	M_{max}
Horseshoe	20	Late Quaternary (<130 ka)	0.01–0.03	6.6
Carefree	11	Middle & Late Quaternary	0.01	6.3
Verde	10	Late Quaternary	0.01–0.02	6.2
Sugarloaf	9	Late Quaternary	0.01–0.02	6.1
Cottonwood	5	Middle & Late Quaternary	0.002–0.003	5.9
Sand Tank	5	Late Quaternary	0.01–0.03	5.9



Moment Magnitude (M)
Strike Slip
Reverse
Normal
77 EQs
(a)
M = 5.08 + 1.16*log(SRL)
Surface Rupture Length (km)
(b)
Strike Slip
Reverse
Normal
Surface Rupture Length (km)

Geologic Map of the Wildcat Hill Quadrangle, Maricopa County, Arizona

by

Steven J. Skotnicki, Robert S. Leighty, and Philip A. Pearthree

Arizona Geological Survey
Open-File Report 97-2

July, 1997

Arizona Geological Survey
416 W. Congress, Suite 100, Tucson, AZ 85701

Includes 17 page text and 1:24,000 scale geologic map.

Funded by
the Environmental Protection Agency through the State Indoor Radon Grant Program,
Grant #K1009544-07-0,
the US. Geological Survey through the STATEMAP Program,
Agreement no: 1434-HQ-96-AG-01474,
and the Arizona Geological Survey.

This report is preliminary and has not been edited
or reviewed for conformity with Arizona Geological Survey standards

We will update and make more detailed the mapping along the fault zone

UNIT DESCRIPTIONS

Quaternary Deposits

Piedmont Deposits

- Qy Holocene alluvium (<10 ka)
- Ql Late Pleistocene alluvium (10 to 250 ka)
- Qml Middle and Late Pleistocene alluvium, undivided (10 to 7
- Qm Middle Pleistocene alluvium (250 to 750 ka)
- Qm2 Younger member of the middle Pleistocene alluvium
- Qm1 Older member of the middle Pleistocene alluvium

Late Tertiary Deposits

- Tsy Younger sedimentary basin-fill deposits
- Tsyl Lower unit of the younger sedimentary basin-fill deposits

Middle Tertiary Units

- Tsl Lacustrine deposits
- Tb Basalt
- Trp Crystal-rich rhyolite dikes
- Tt Tuff
- Tfi Felsic to intermediate volcanic rocks
- Tl Latite
- Tcv Volcaniclastic conglomerate
- Tc Conglomerate (granitic clasts)

Proterozoic Intrusive Rocks

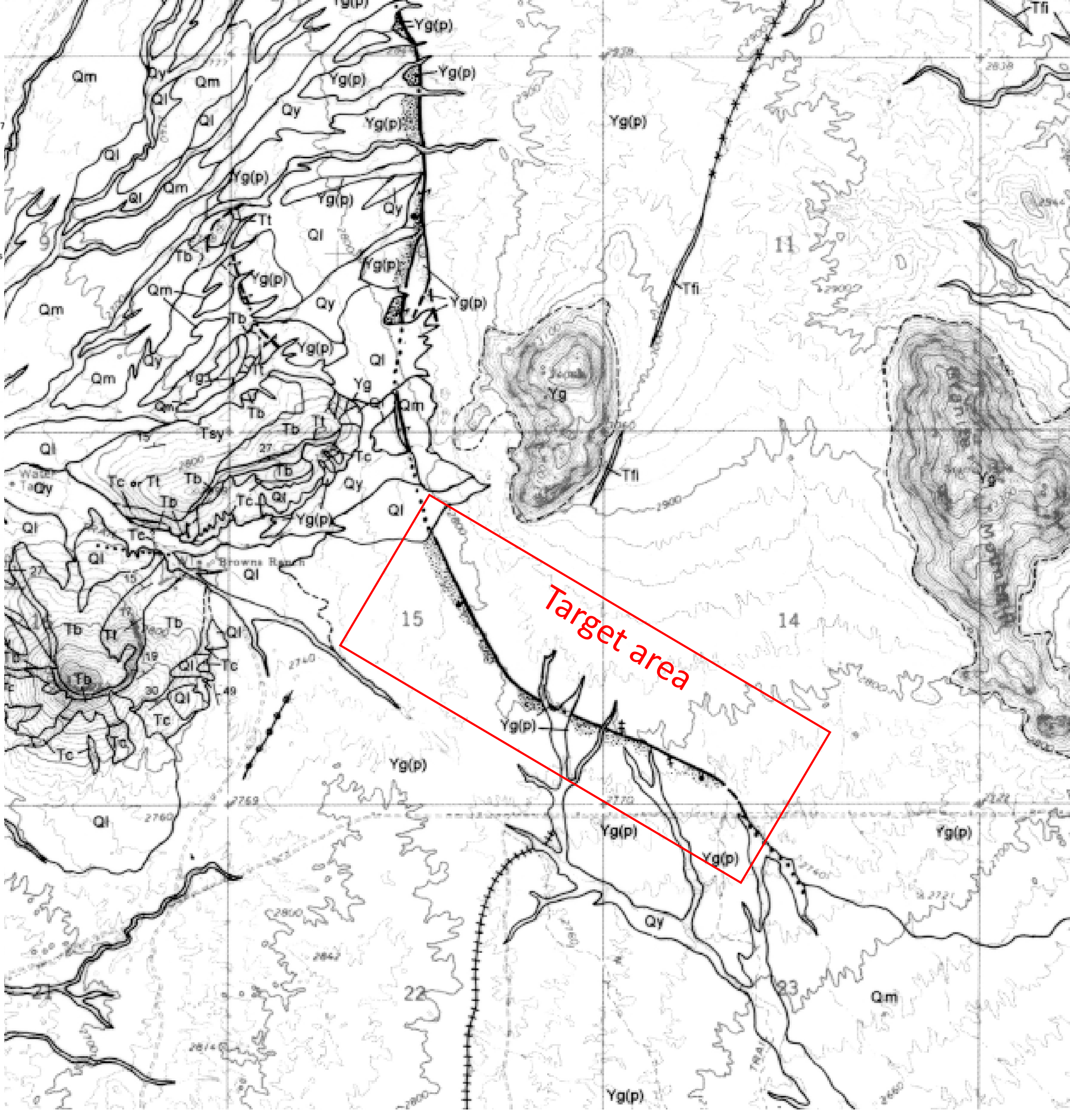
- Yg(p) Granite pediment
- Yg Granite
- Ygd Granodiorite
- Yd Diorite

Proterozoic Meta-sedimentary Rocks

- Xr Rhyolite
- Xq Quartzite
- Xsp Pelite
- Xsps Psammite
- Xc White chert

Map Symbols

- bedding
- overturned bedding
- vertical bedding
- graded bedding, arrow points up-section
- cross-bedding, arrow points up-section
- metamorphic foliation, with lineation
- vertical metamorphic foliation
- flow foliation in felsic intrusive rock
- contact, dashed where approximately located
- fault, with attitude and lineation, dashed where uncertain, dotted where concealed
- felsic dikes
- mafic dikes
- chalcedony-filled fractures or faults
- crystal-rich rhyolite dikes
- carbonate along fault



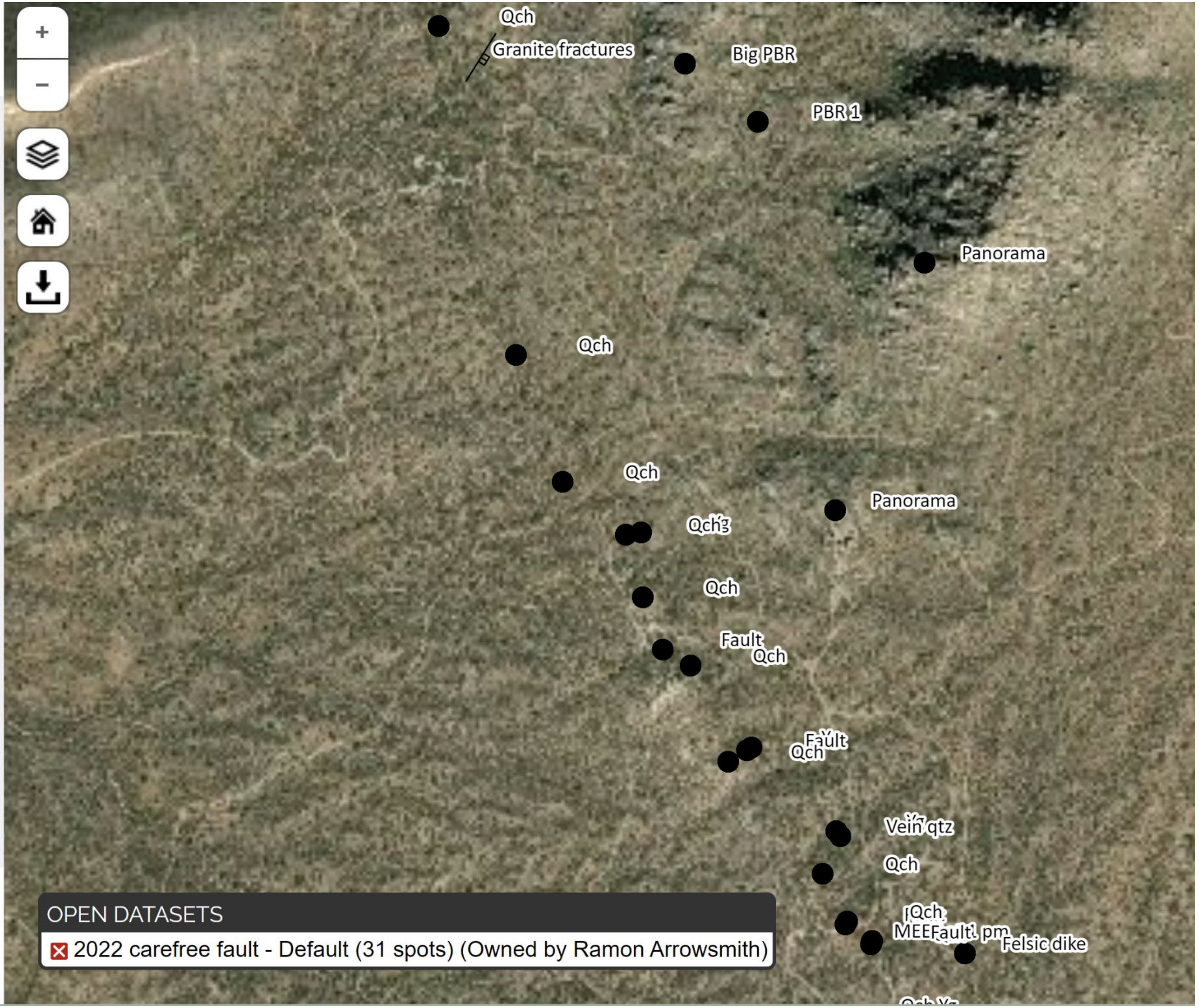
STRABO SEARCH

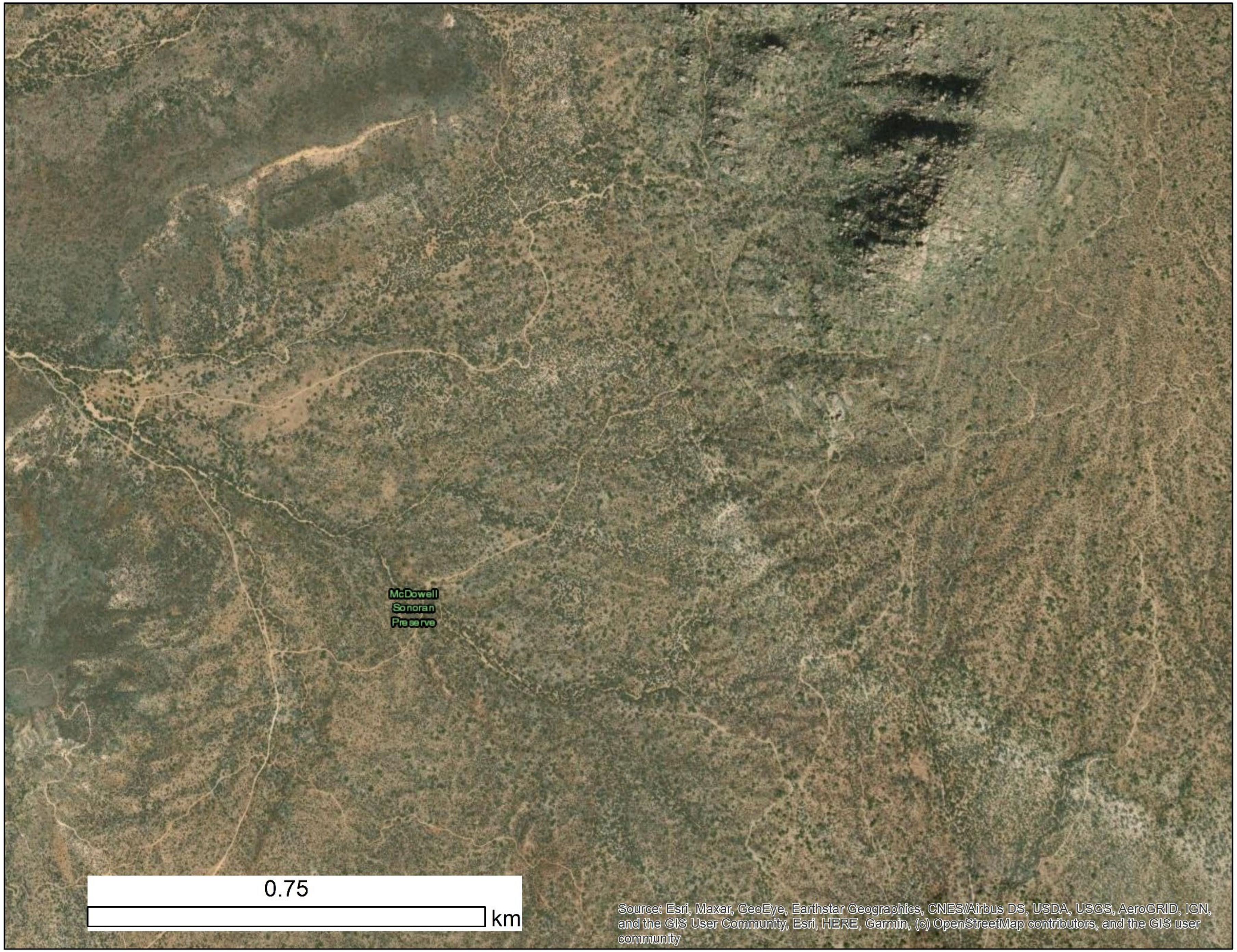
Search Criteria:

select...

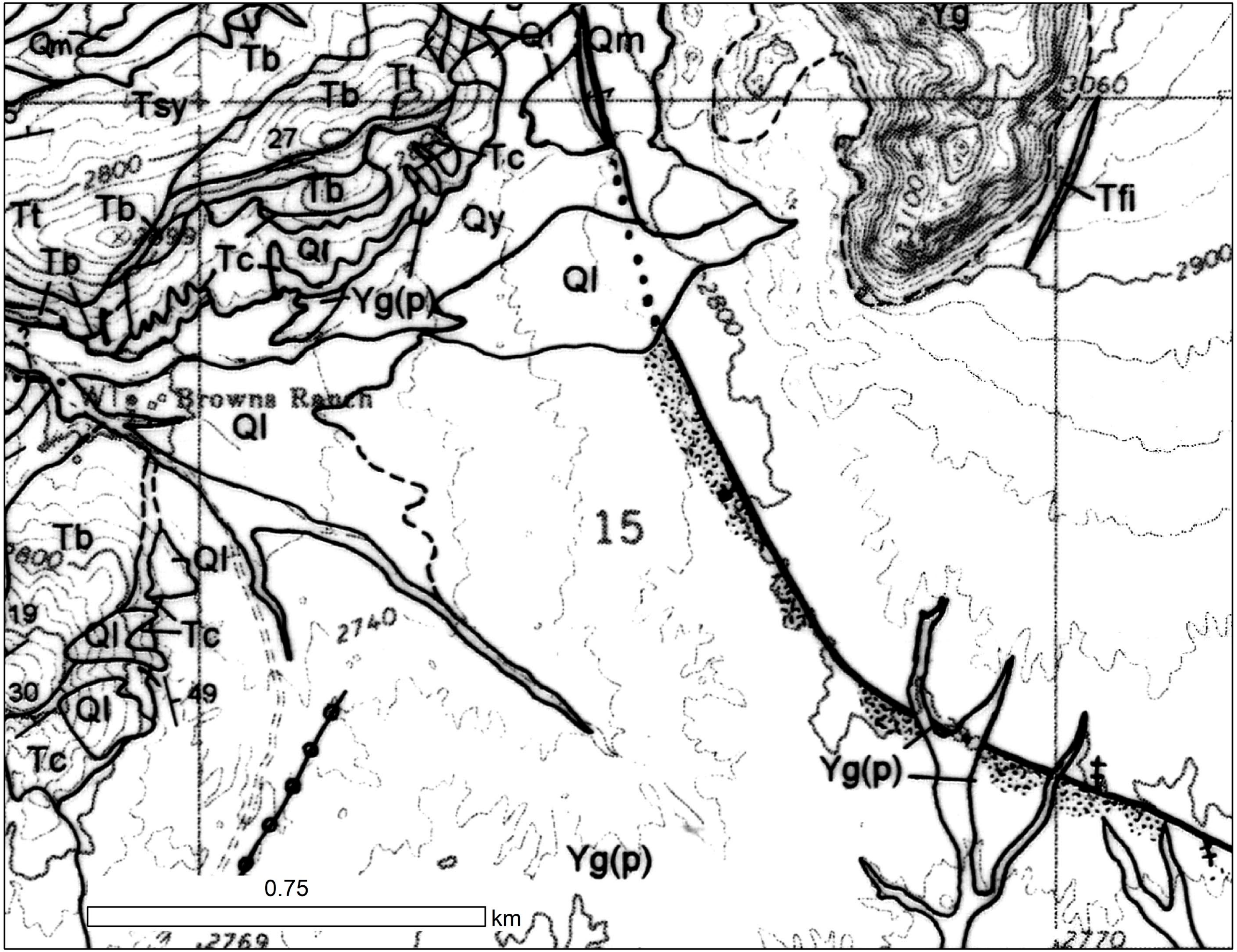
Uploaded to StraboSpot

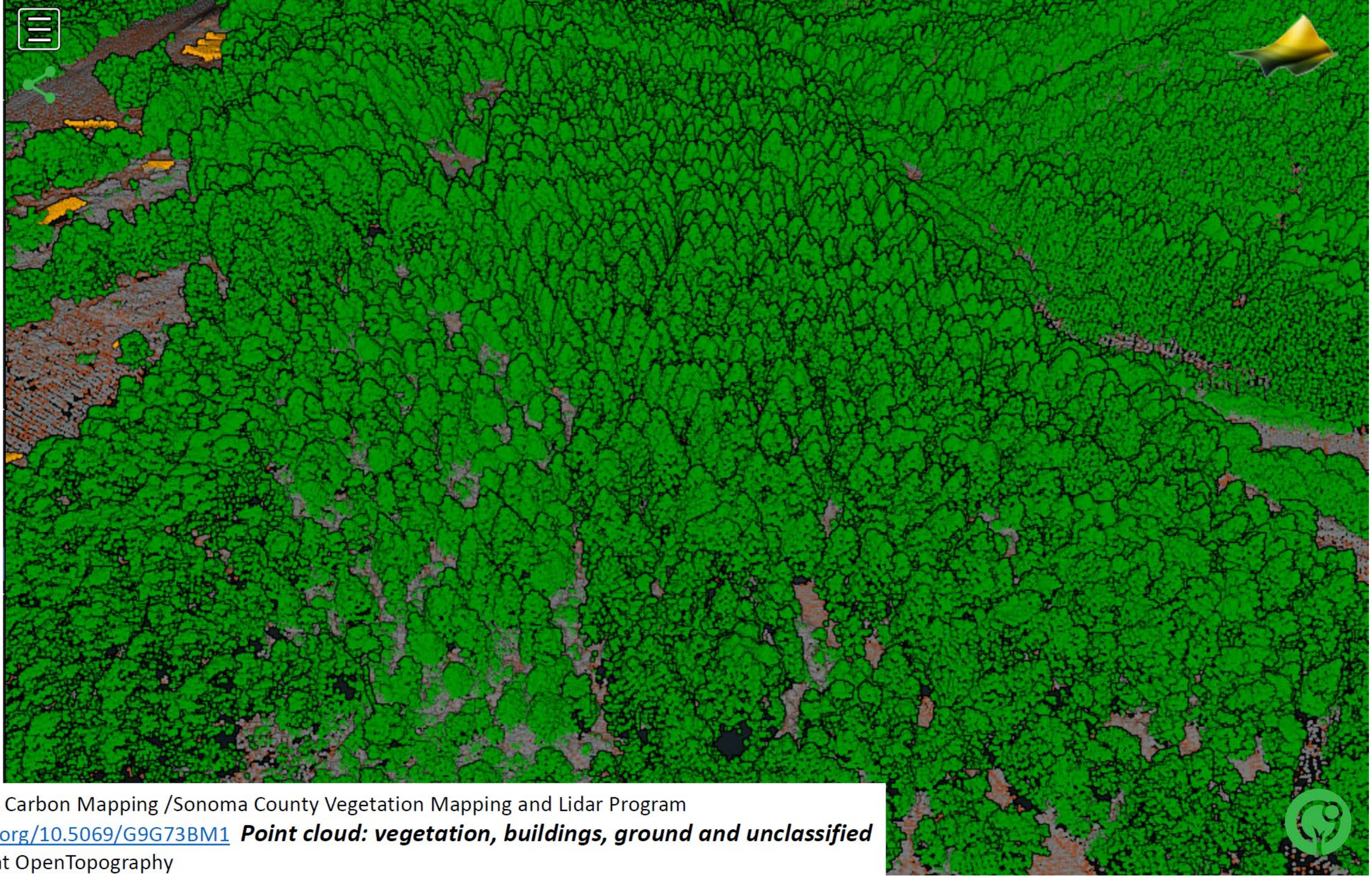
Download



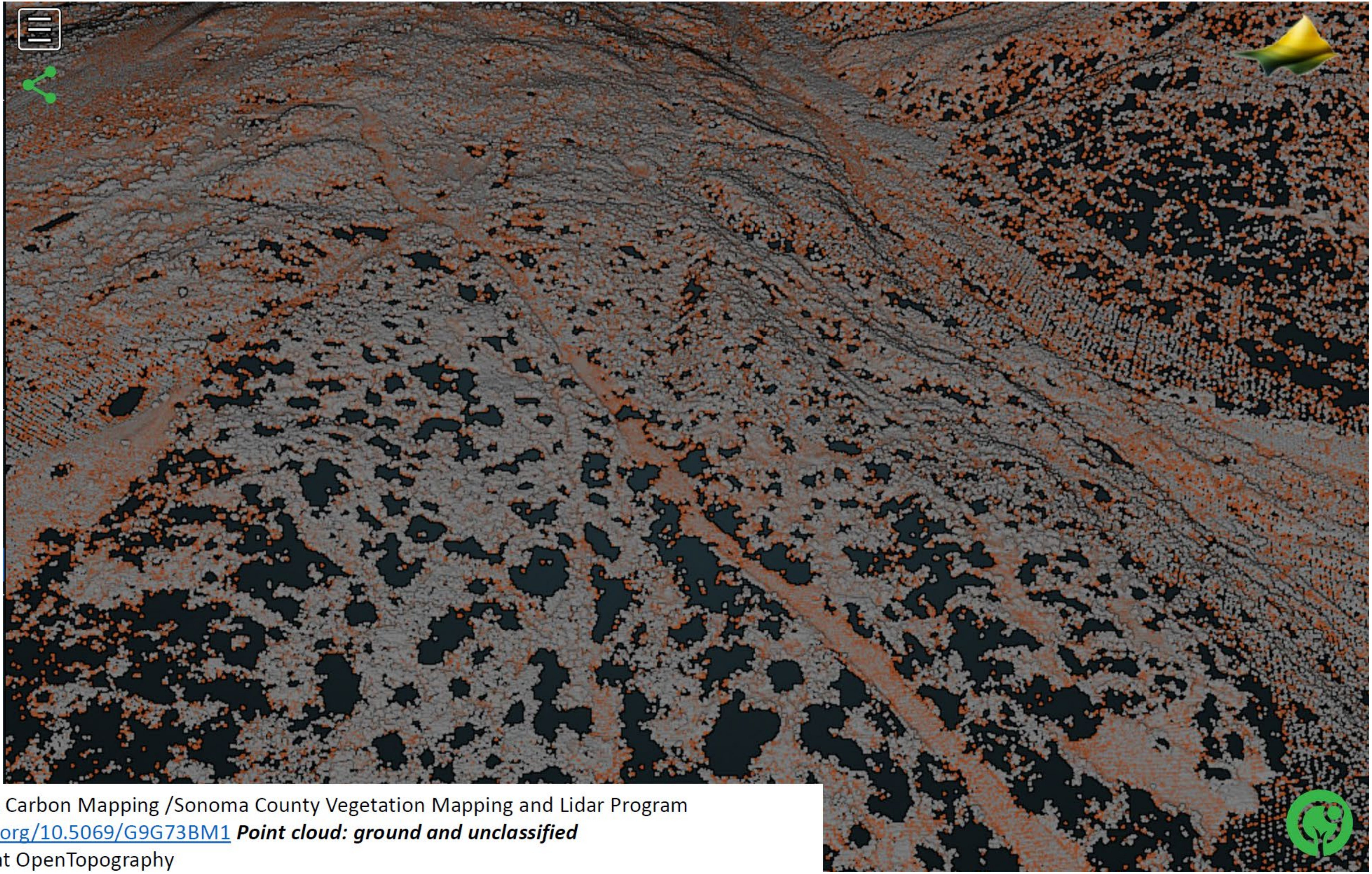

McDowell
Sonoran
Preserve
0.75
km
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community, Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

AZ GS OFR 97-02





UMD-NASA Carbon Mapping /Sonoma County Vegetation Mapping and Lidar Program
https://doi.org/10.5069/G9G73BM1 ***Point cloud: vegetation, buildings, ground and unclassified***
Processed at OpenTopography



UMD-NASA Carbon Mapping /Sonoma County Vegetation Mapping and Lidar Program
https://doi.org/10.5069/G9G73BM1 ***Point cloud: ground and unclassified***
Processed at OpenTopography

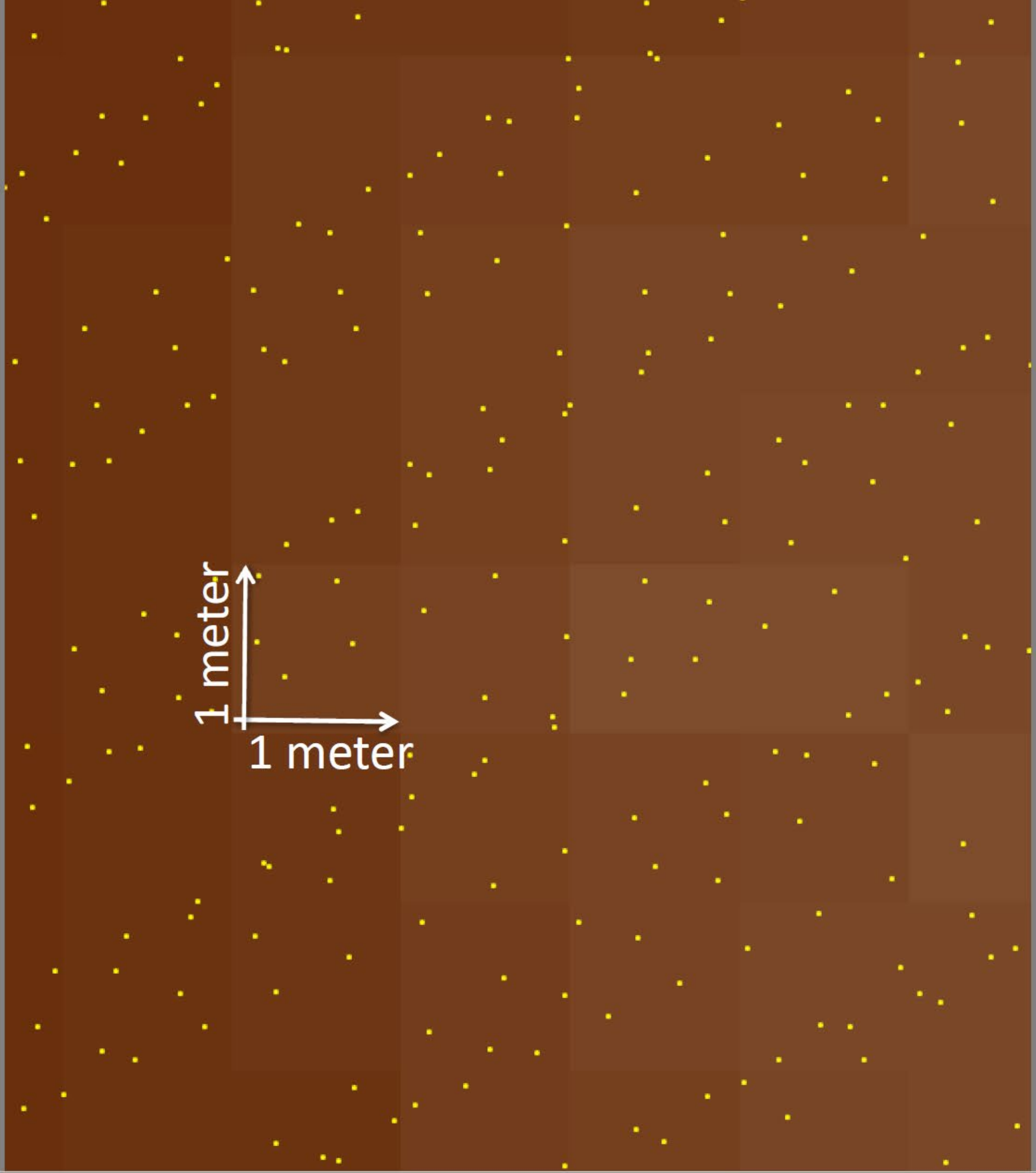
- 1 meter grid

- LiDAR returns from EarthScope data collection

- Example from flat area with little or no vegetation so ground is sampled approx. 5+ times per square meter

- How do we best fit a continuous surface to these points?
    - Triangular irregular network, splines/kriging, local min/max/mean, etc.

- Ultimately wish to represent irregularly sampled data on a regularized grid.



Digital Elevation Models

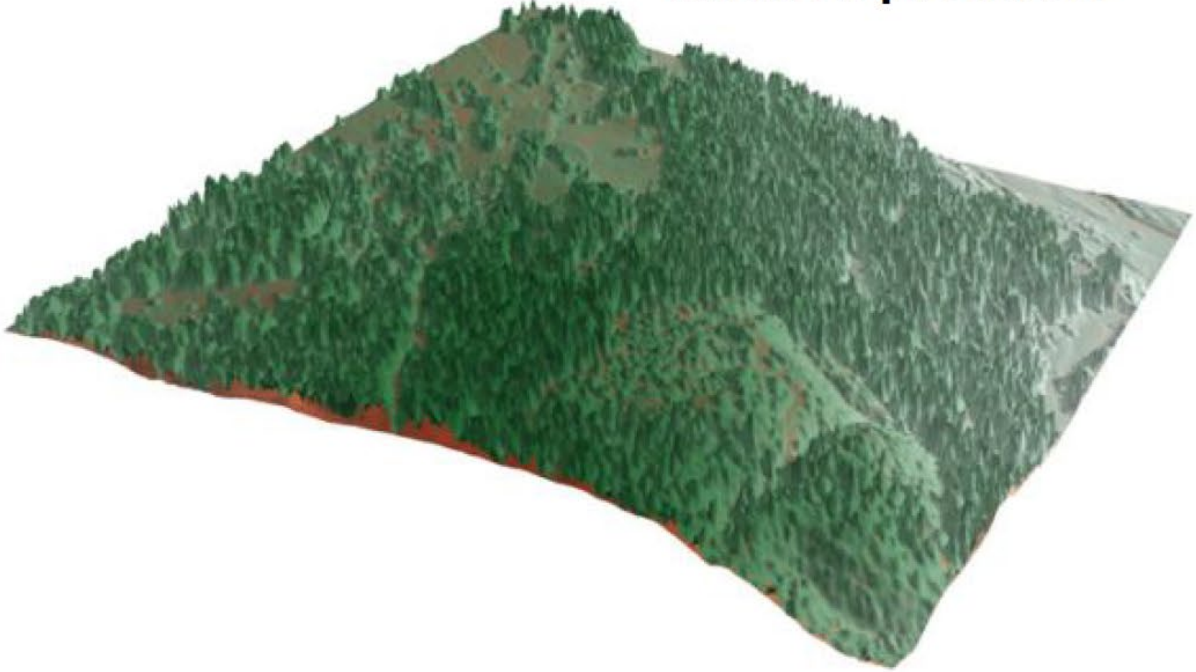
- Digital representation of topography / terrain
  - "Raster" format – a grid of squares or "pixels"
  - Continuous surface where Z (elevation) is estimated on a regular X,Y grid
  - "2.5D"

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

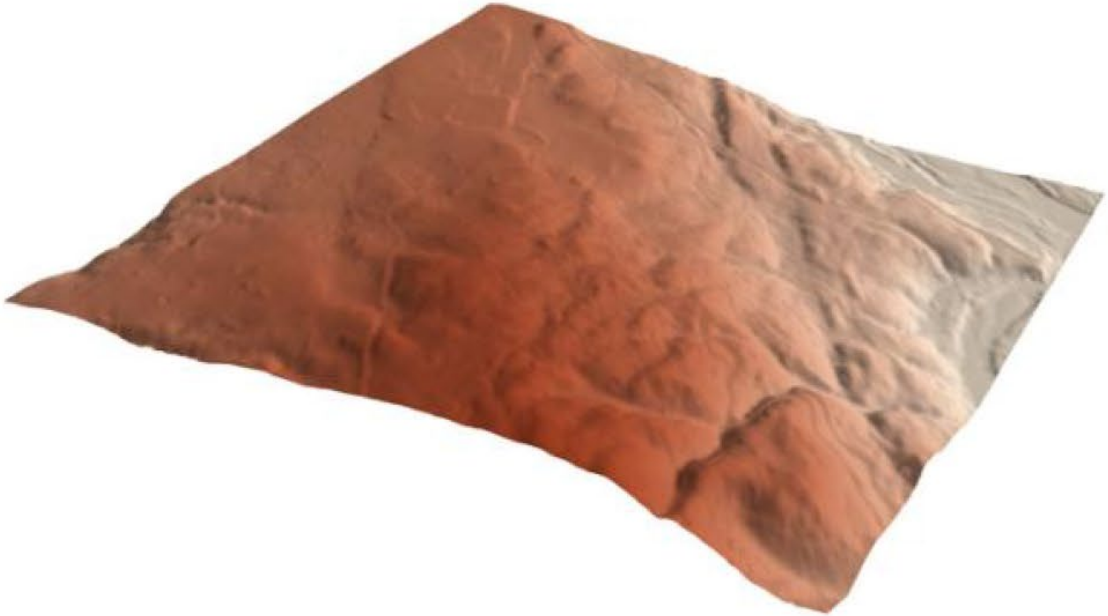
Source: http://www.ncgia.ucsb.edu/giscc/extra/e001/e001.html

- 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.

Gridded products

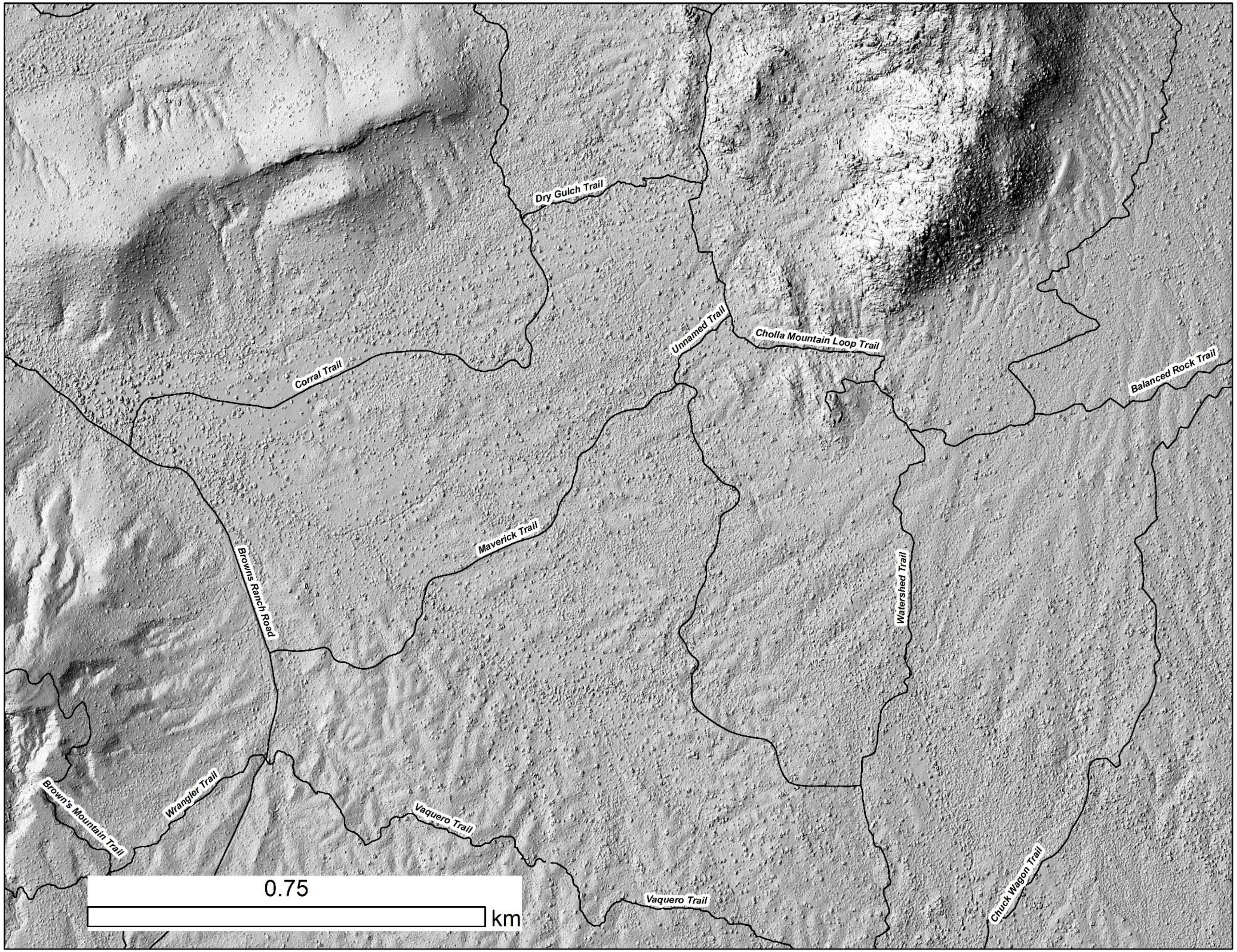


Digital surface model—Mostly what we are getting in SfM



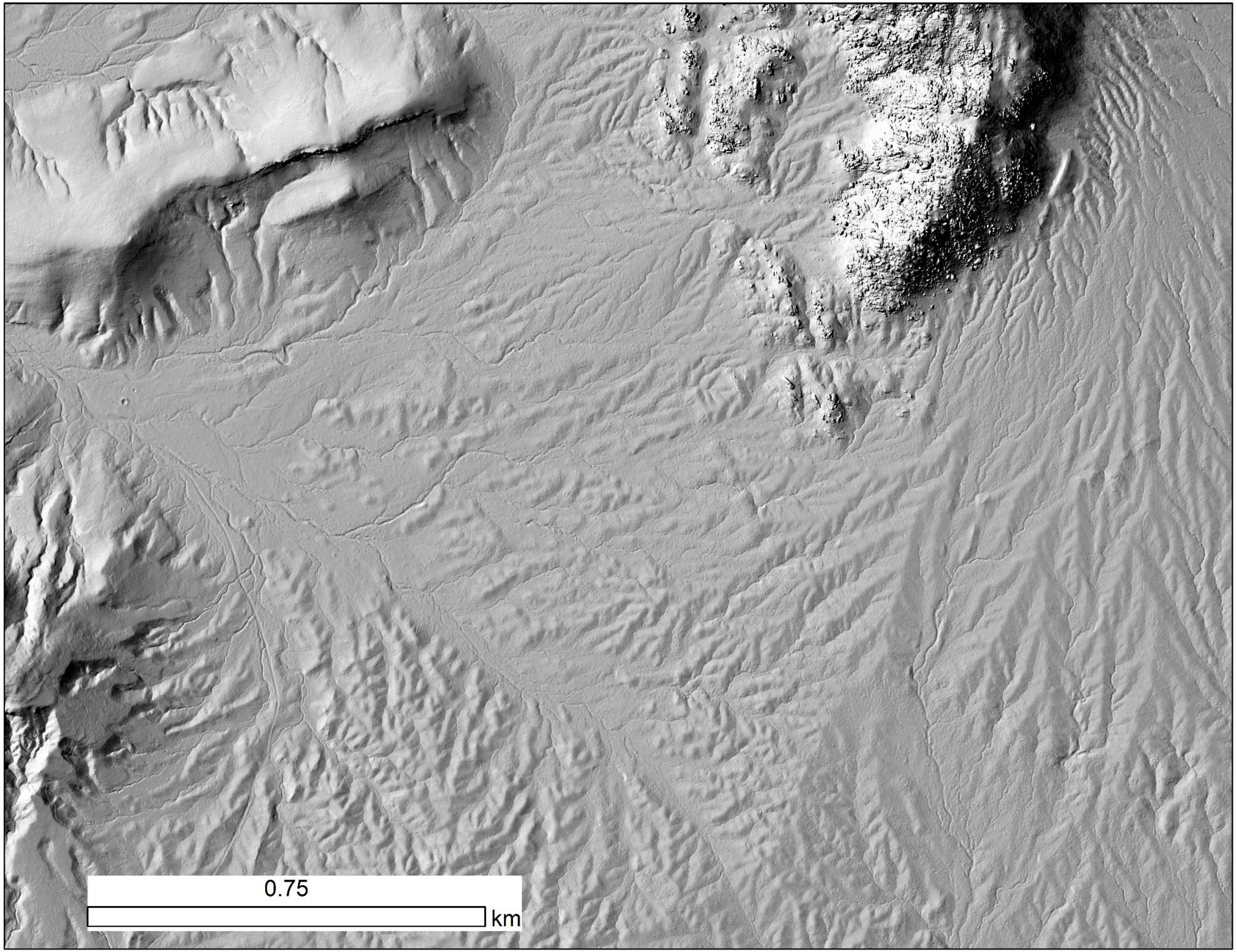
Digital terrain model

USGS 3DEP 1 m DSM + All_Trails_ Nov_2019



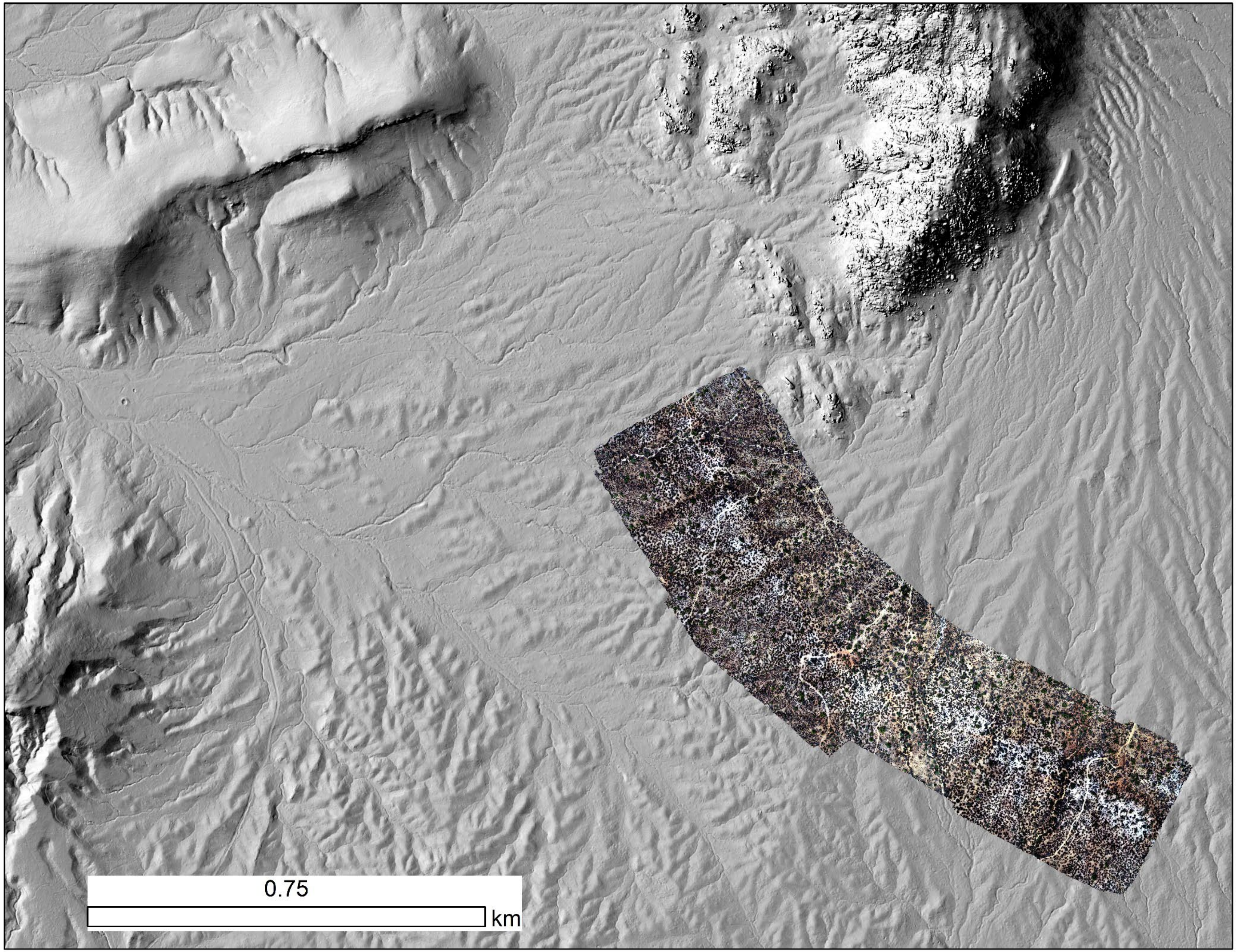
https://portal.opentopography.org/usgsDataset?dsid=AZ_MaricopaPinal_1_2020

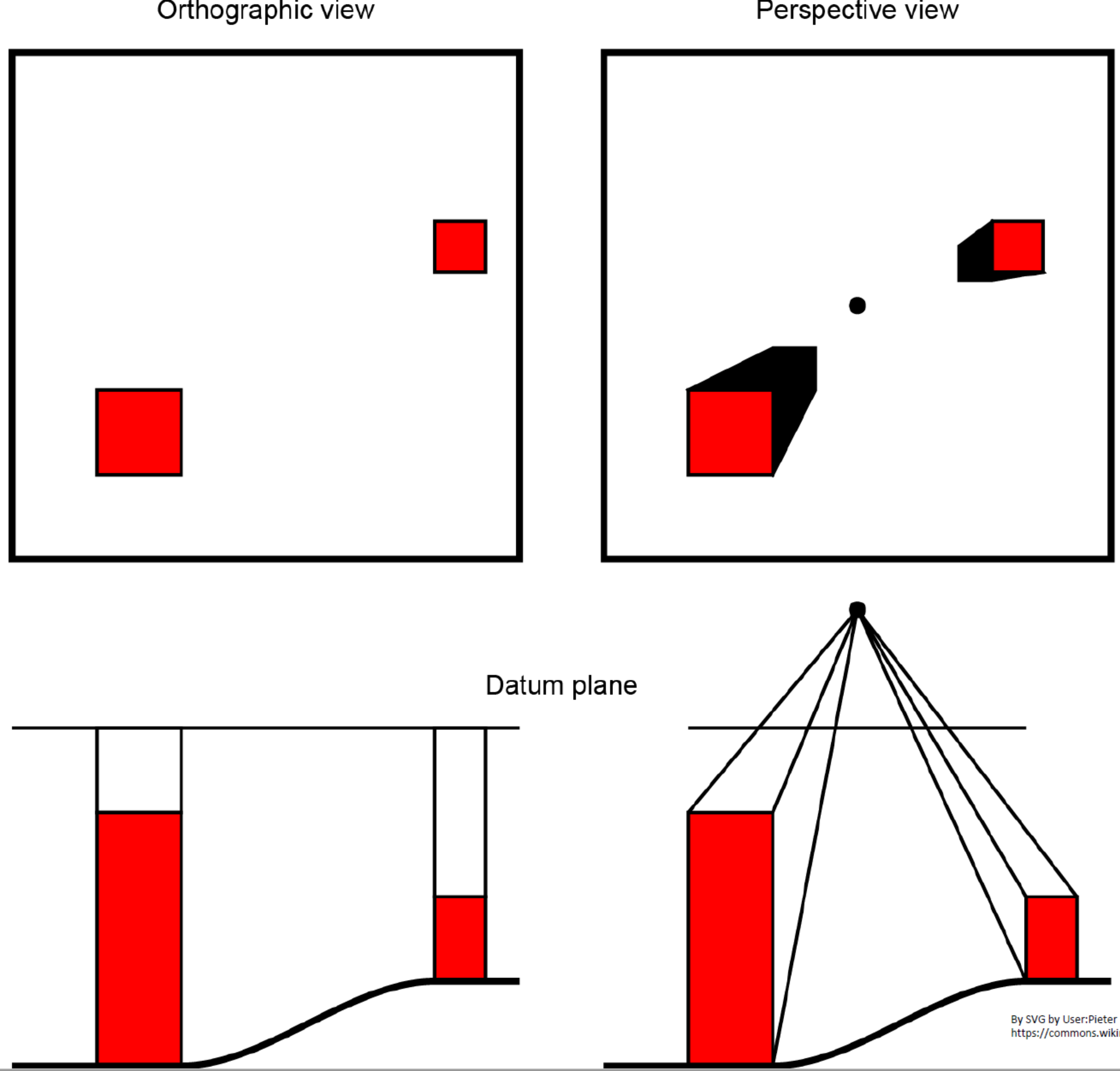
USGS 3DEP 1 m DTM



https://portal.opentopography.org/usgsDataset?dsid=AZ_MaricopaPinal_1_2020

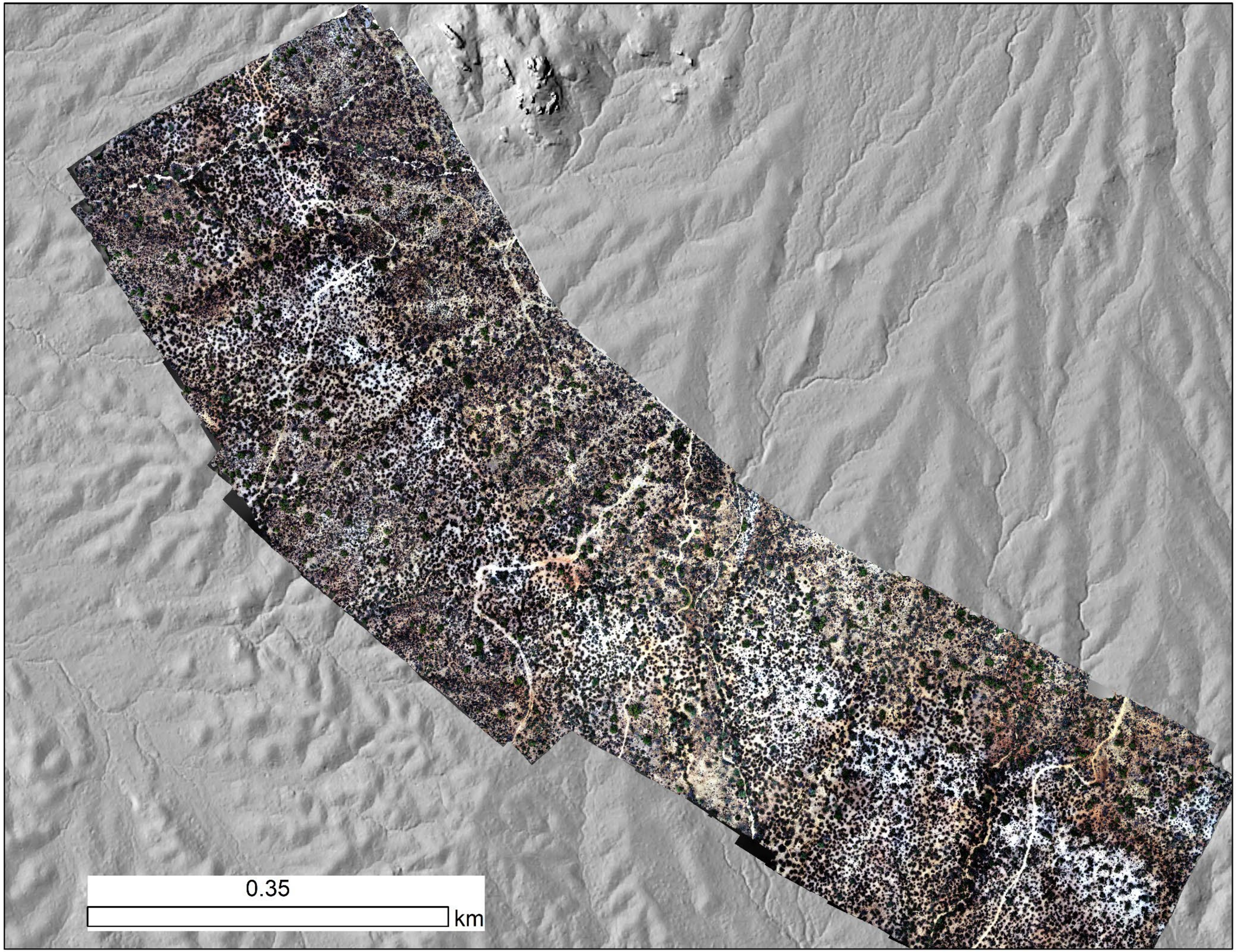
SfM
5 cm/pix
Orthoimage



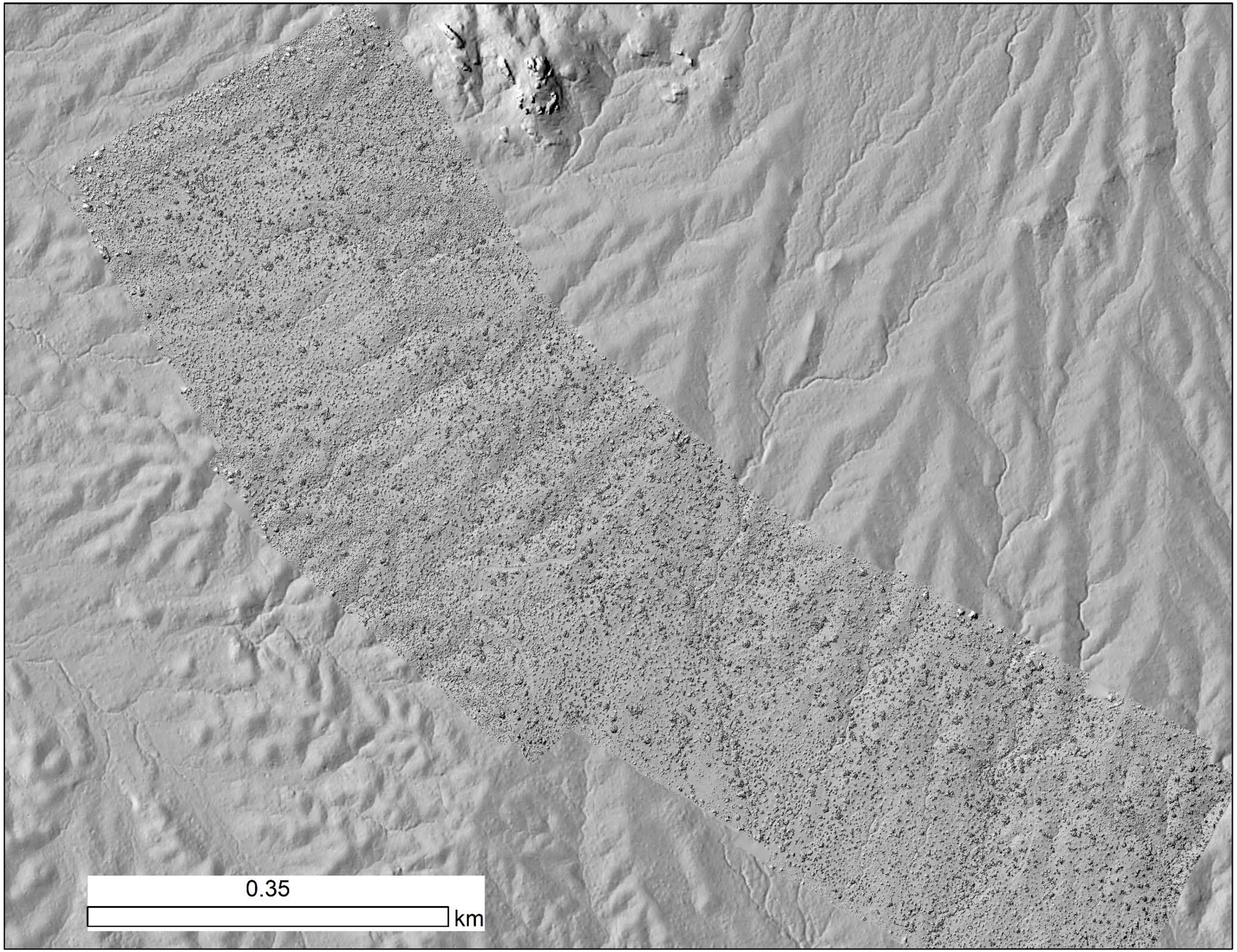


An orthophoto, orthophotograph or orthoimage is an aerial photograph or satellite imagery geometrically corrected ("orthorectified") such that the scale is uniform: the photo or image has follows a given map projection. Unlike an uncorrected aerial photograph, an orthophoto can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief,[1] lens distortion, and camera tilt.

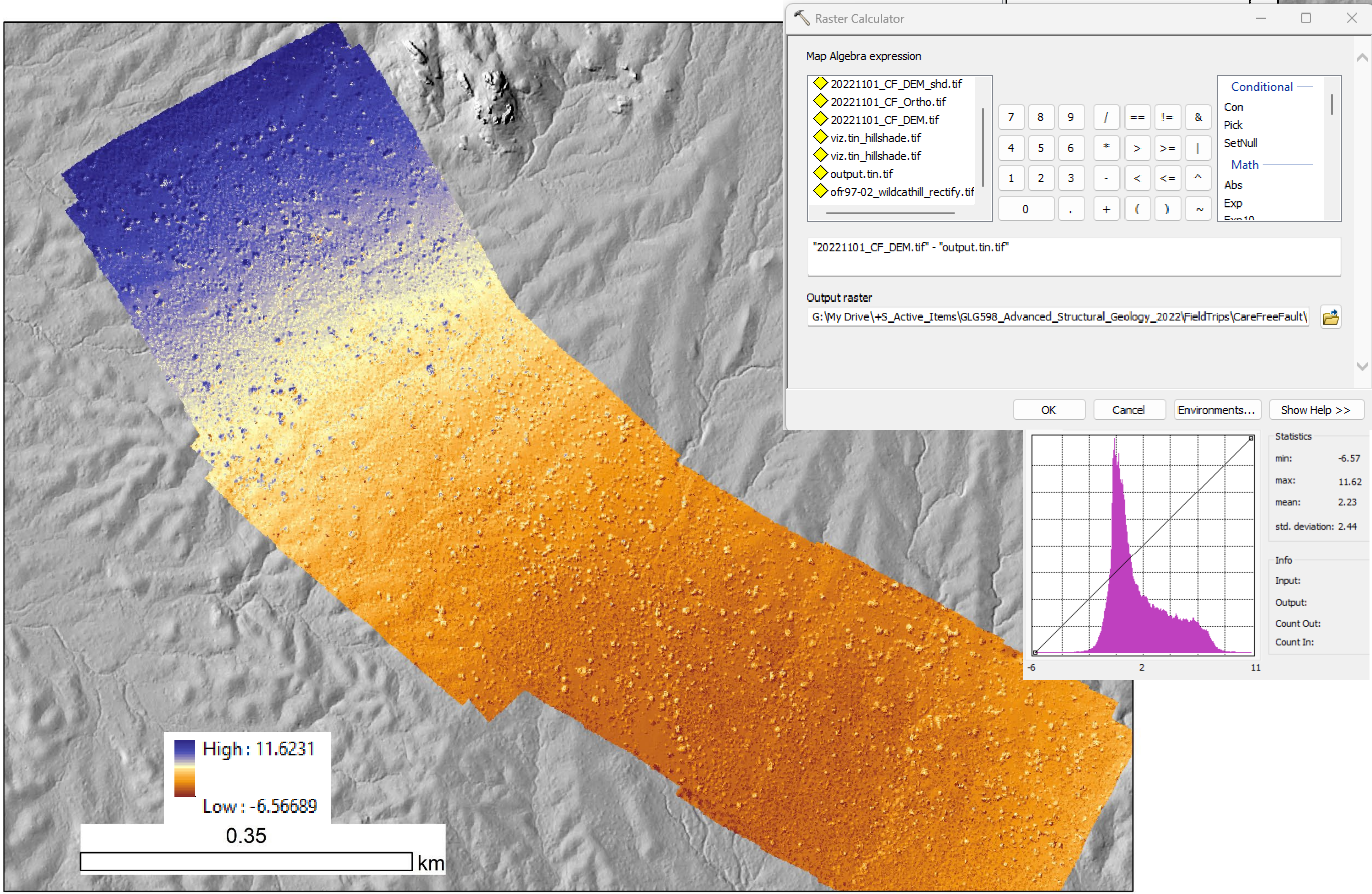
SfM
5 cm/pix
Orthoimage



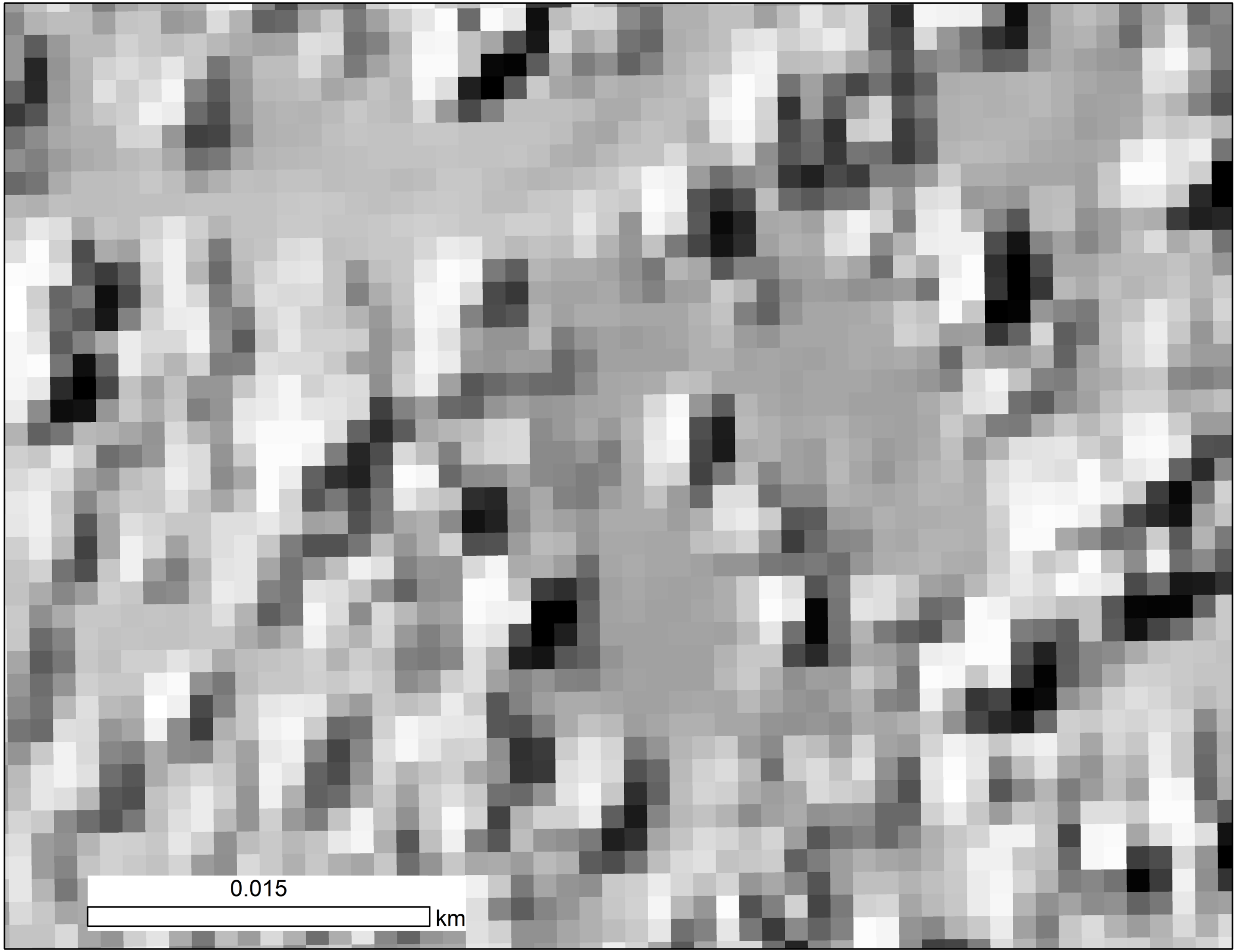
SfM
5 cm/pix
DSM



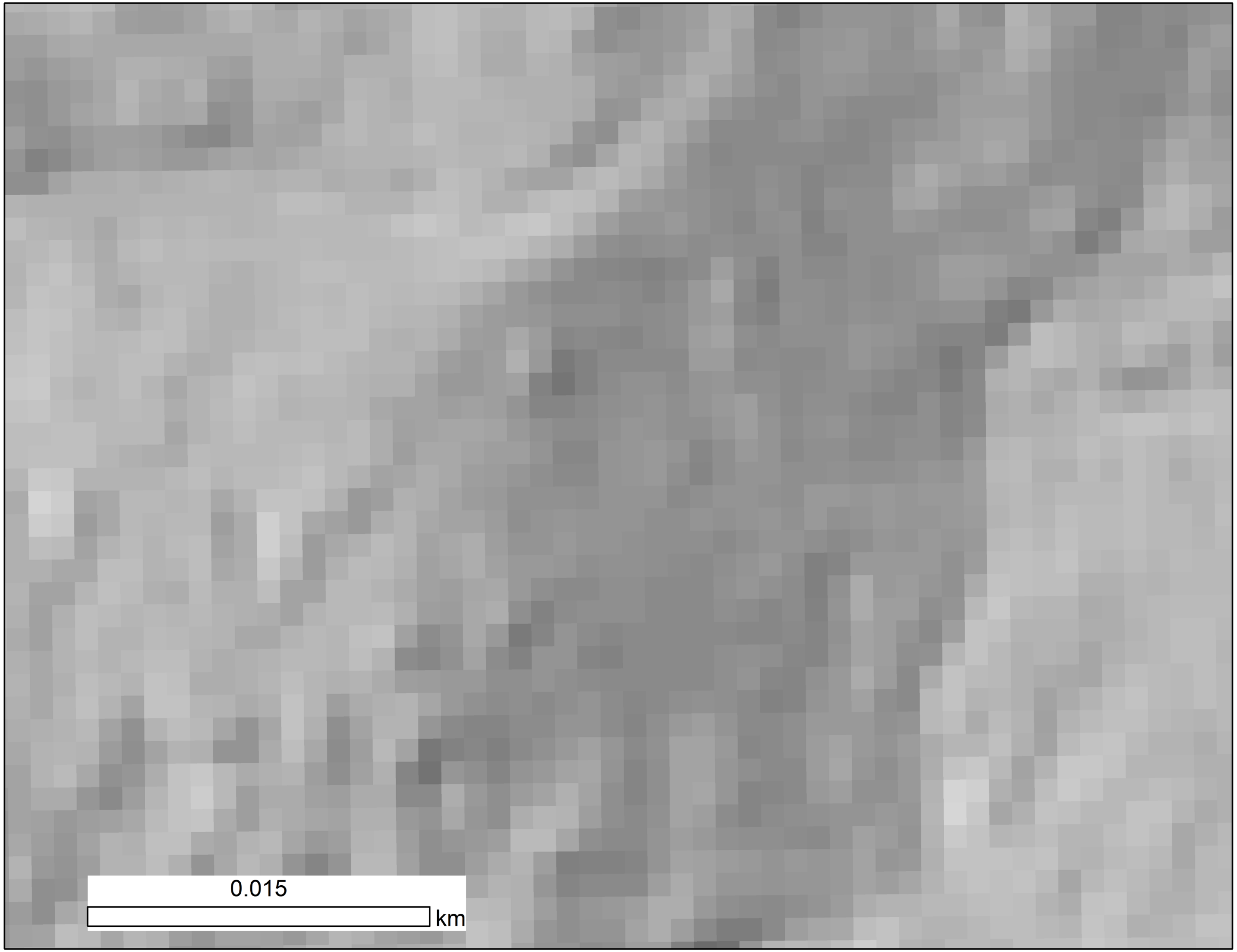
SfM – Lidar DSM: SfM longer wavelength artefacts



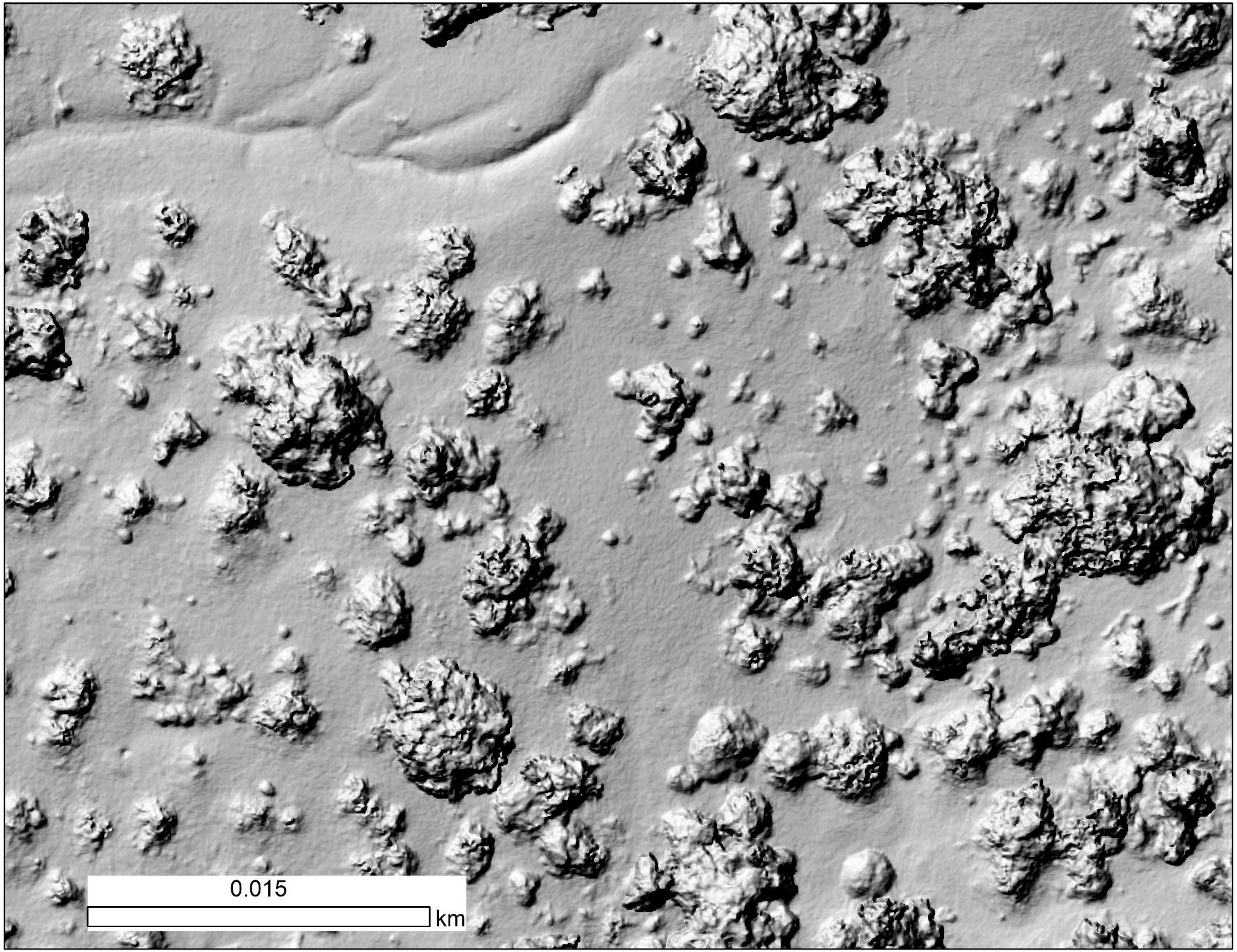
USGS 3DEP
1 m DSM



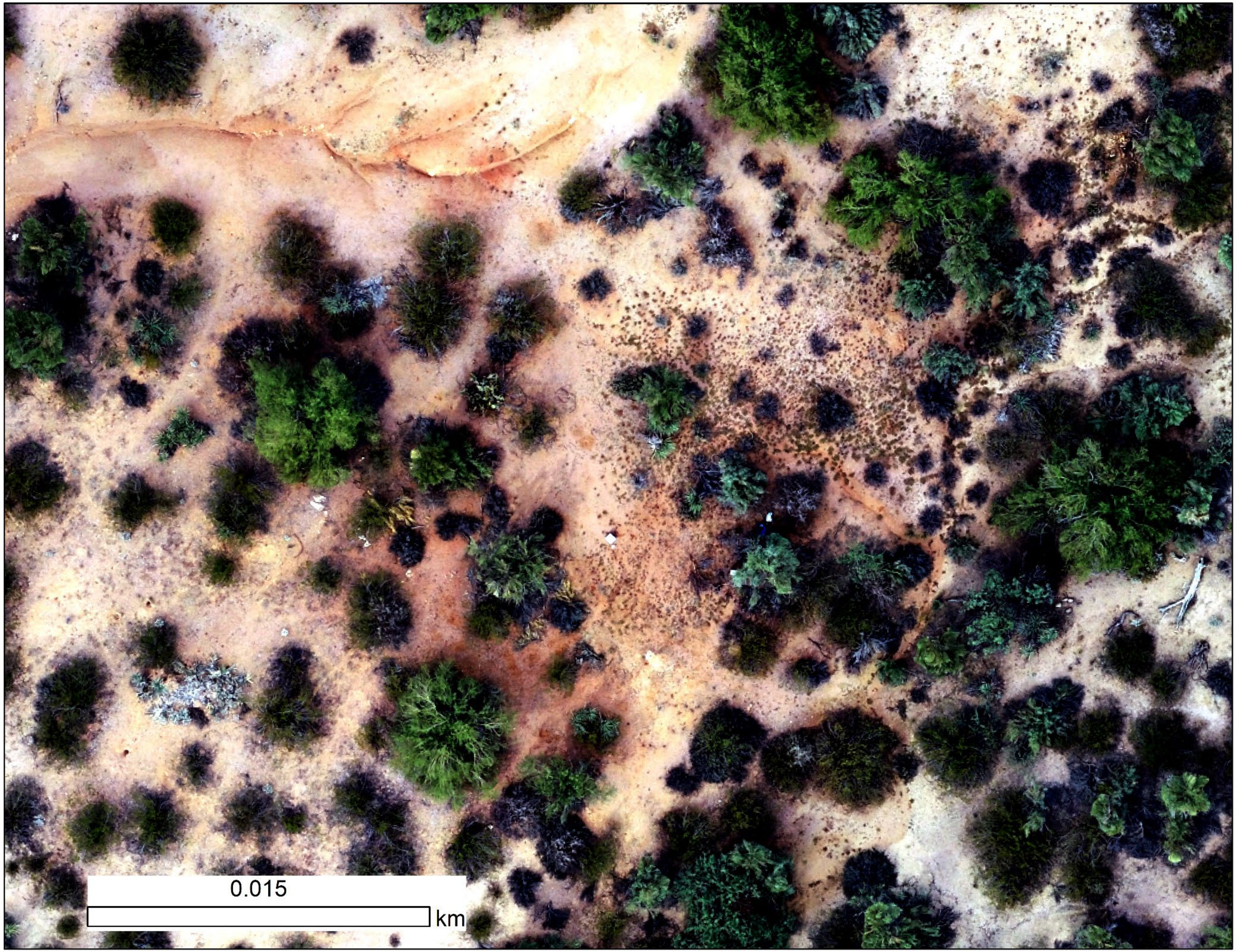
USGS 3DEP
1 m DTM

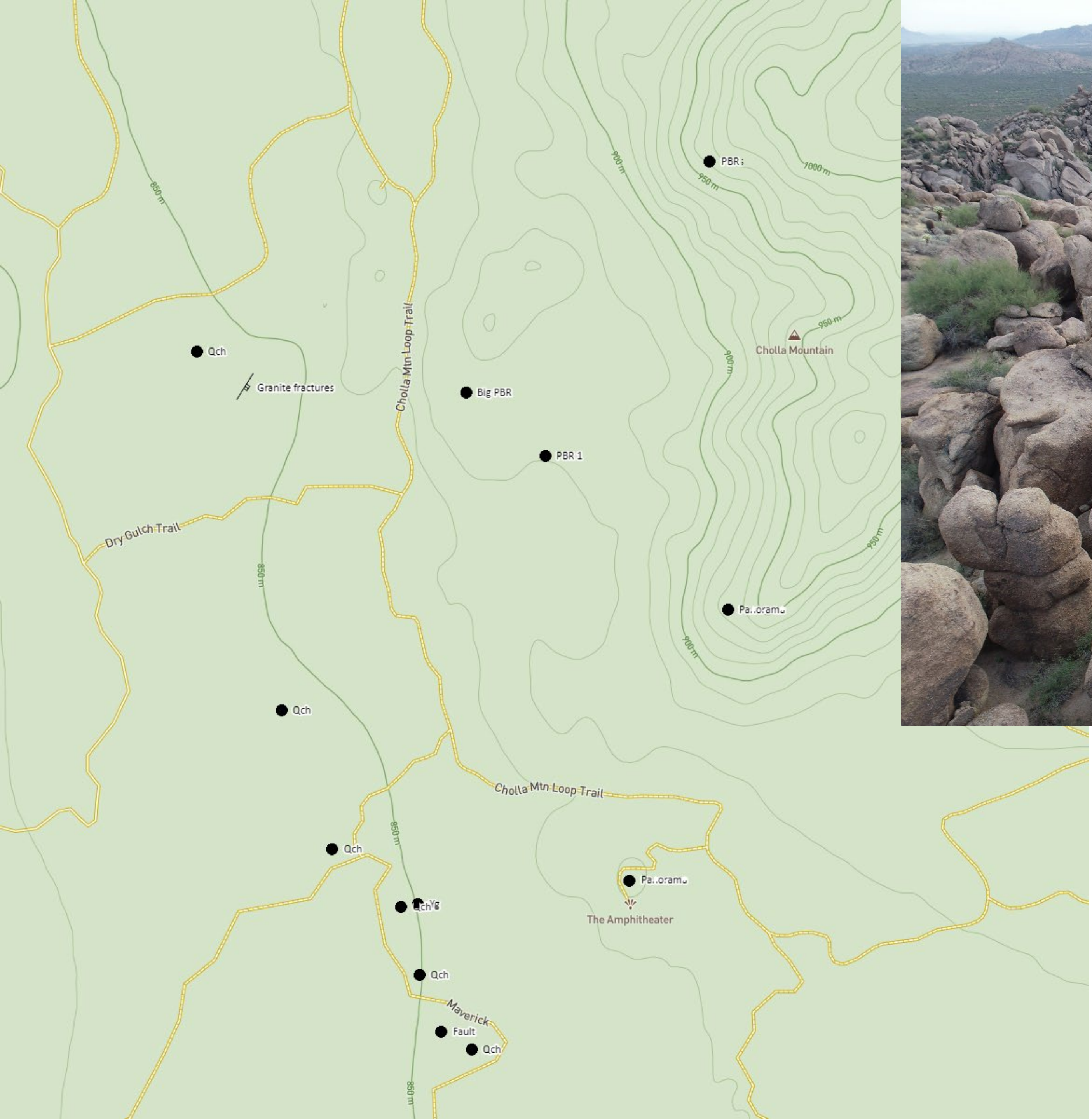


SfM 5 cm DSM



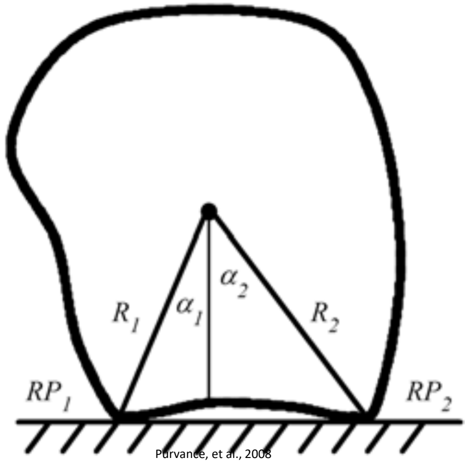
SfM
5 cm/pix
Orthoimage



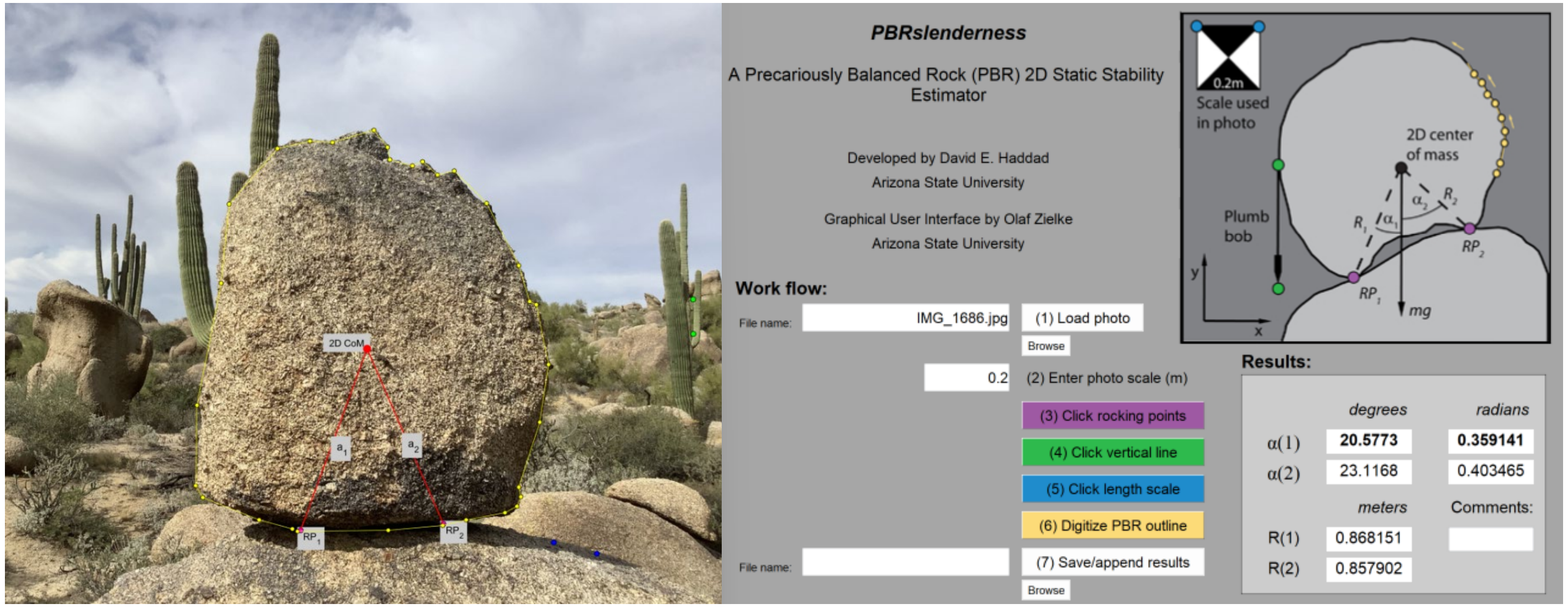


Precariously Balanced Rocks: negative indicators of strong ground motion

Precariously Balanced Rocks: negative indicators of strong ground motion

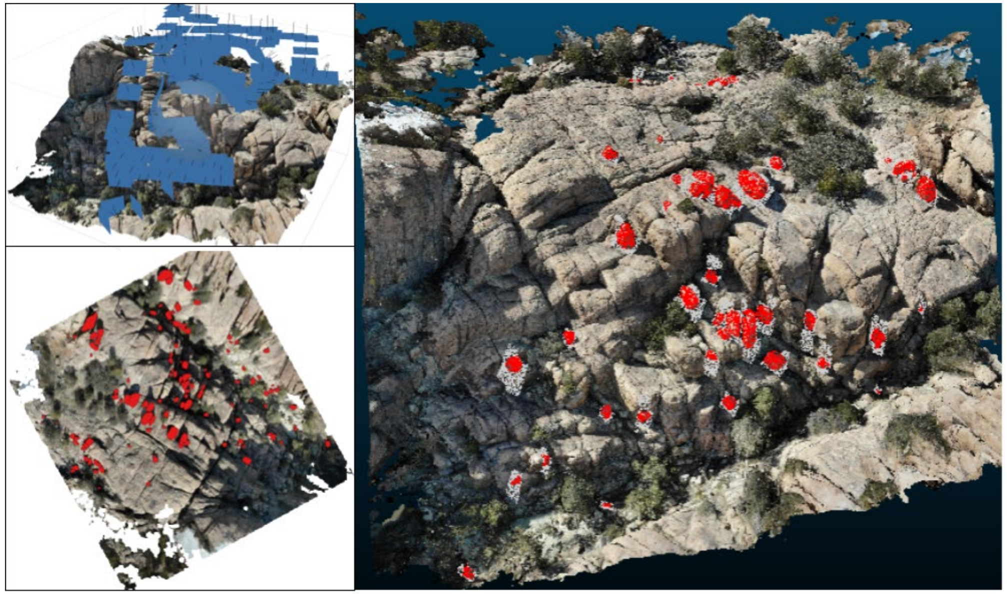


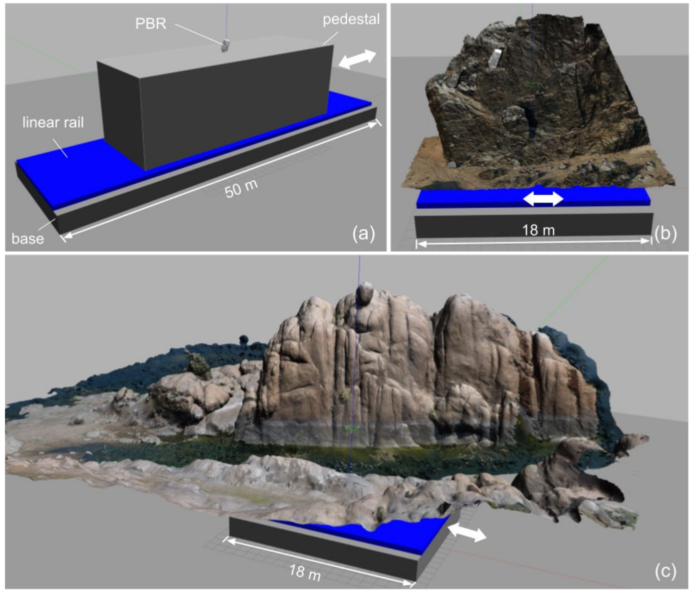
*Dynamic overturning ~1.3*tan(α_{min})*



Method of Haddad, D. E., Zielke, O., Arrowsmith, R., Purvance, M. D., Haddad, A. M., Landgraf, A., Estimating two-dimensional static stabilities of precariously balanced rocks from unconstrained digital photographs, *GeoSphere*, doi:10.1130/GES00788.1, 2012

Autonomous PBR Detection and Virtual Shake Robot (Chen, et al.)





TopoToolbox

MATLAB-based software for topographic analysis

Download

Direct download link from Github

TopoToolbox is plat-form independent but requires MATLAB and the Image Processing Toolbox. Some function also require the Mapping Toolbox. TopoToolbox 2 has been developed using Matlab Versions R2016b and TopoToolbox requires this or a later version. Note that some functions require the Optimization Toolbox or the Statistics and Machine Learning Toolbox. Some functions take advantage of the Parallel Processing Toolbox.

Downloads

Download here latest work-in-progress copy of TopoToolbox (**recommended**).

Download here release 2.4. This release can also be installed using a single installation file (.mltbx-file).

Find here older versions of TopoToolbox.

Getting started

Before working with TopoToolbox the directories and functions must be on the search path of Matlab. Enter following code into the command line:

```
addpath(genpath('C:\path\to\wherever\you\installed\this\TopoToolbox-2'))
```

To remove .git-folders from the path, run

```
rmpath(genpath('C:\path\to\wherever\you\installed\this\TopoToolbox-2\.git'));
```

Type `doc` in the command line to open the main documentation page. You'll find the TopoToolbox documentation in the section Supplemental Software (see also this blog post). The documentation contains several user's guides that will help you getting started. In addition, TopoToolbox functions have extensive help sections (e.g. `help gradient8` or `help STREAMobj/modify`). An additional resource for code and examples is the TopoToolbox blog.

TopoToolbox

TopoToolbox is a MATLAB program for the analysis of digital elevation models (DEMs). It's free and open source (as long as you have MATLAB).

Search

Recent posts

TopoToolbox course at IIT Roorkee OCTOBER 10, 2022

Don't smear knickpoints when smoothing river profiles SEPTEMBER 20, 2022

The entire blog translated into Chinese JUNE 16, 2022

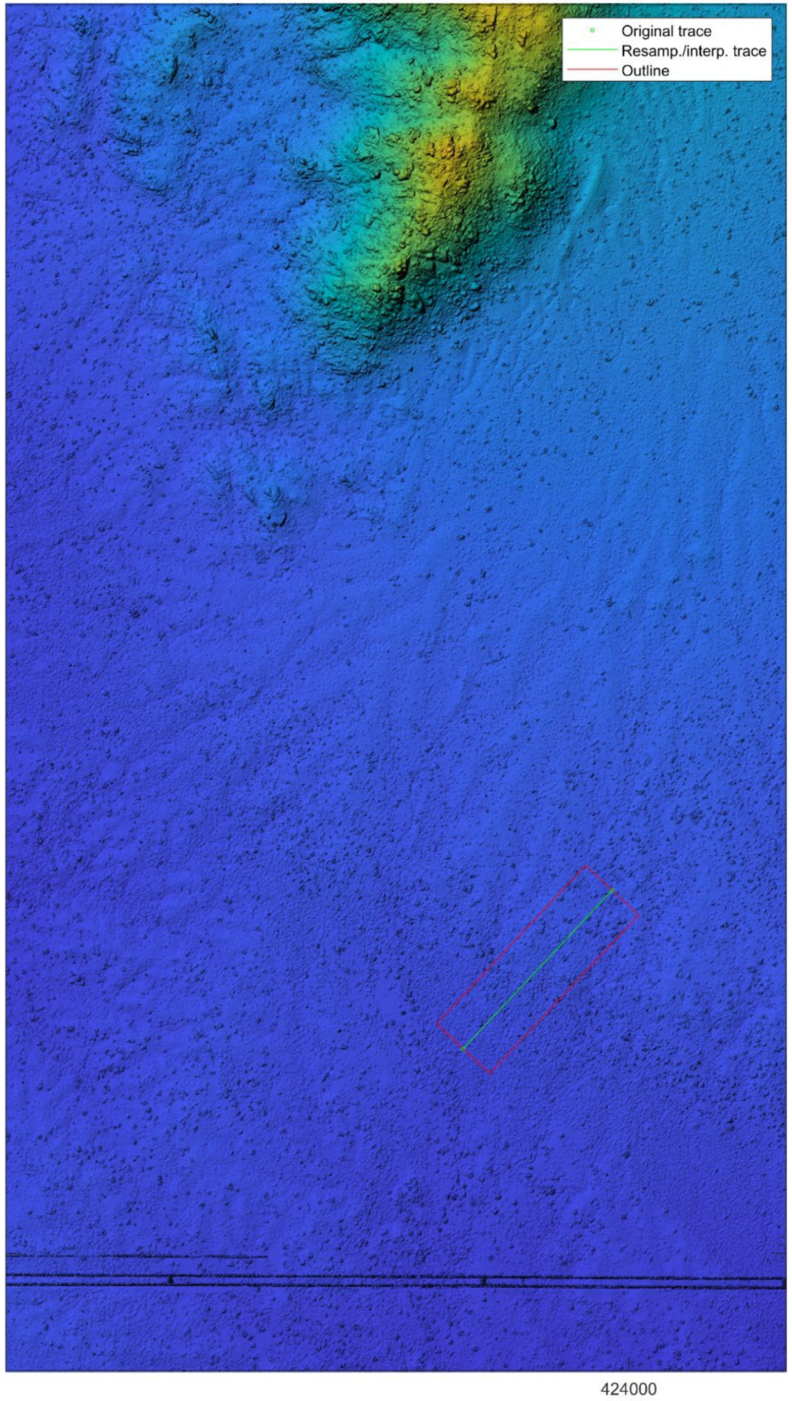
Stream burning – or how to convert a shapefile to a STREAMobj JUNE 1, 2022

TopoToolbox Cheat Sheet in Chinese (and more) MAY 23, 2022

Archives

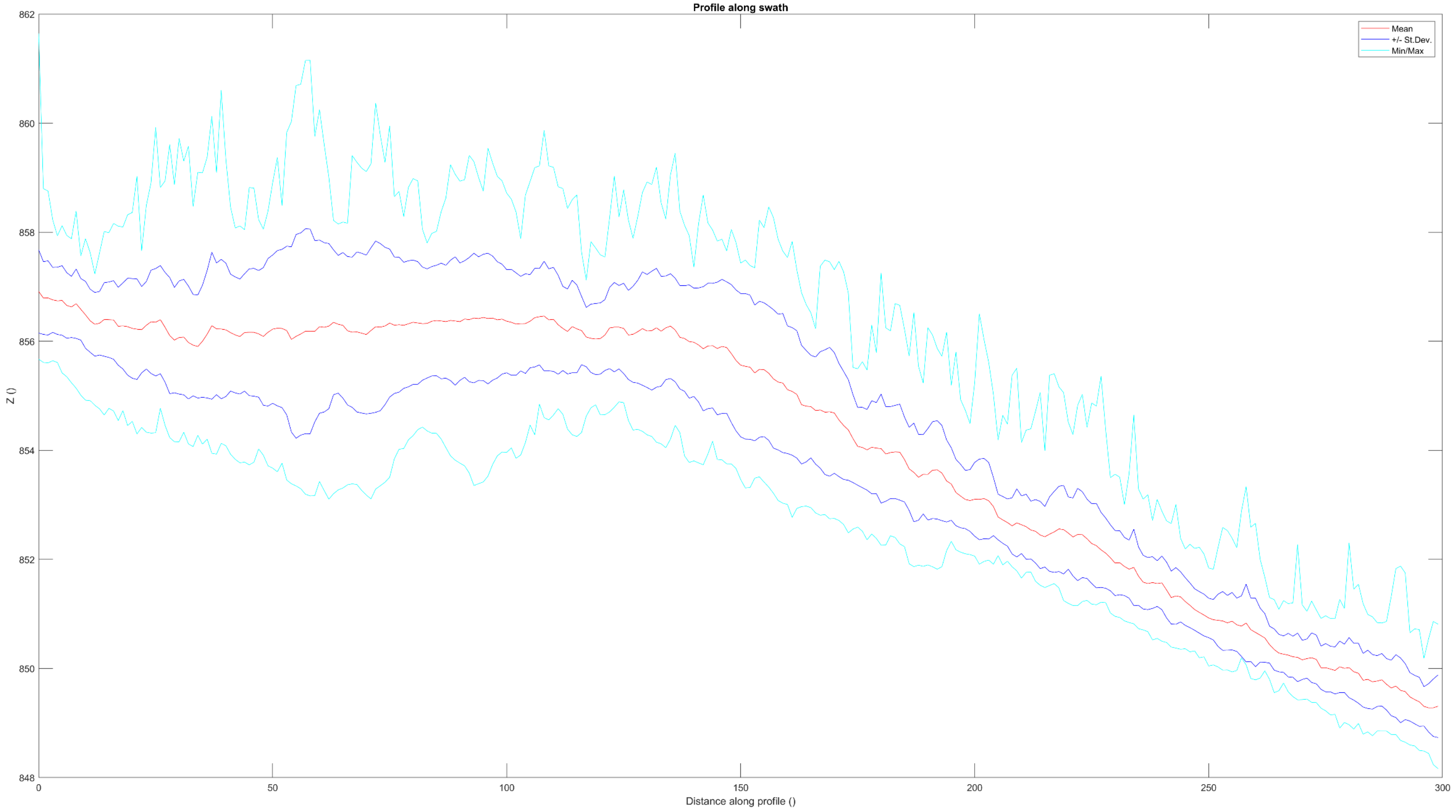
Select Month

DEM with swath location

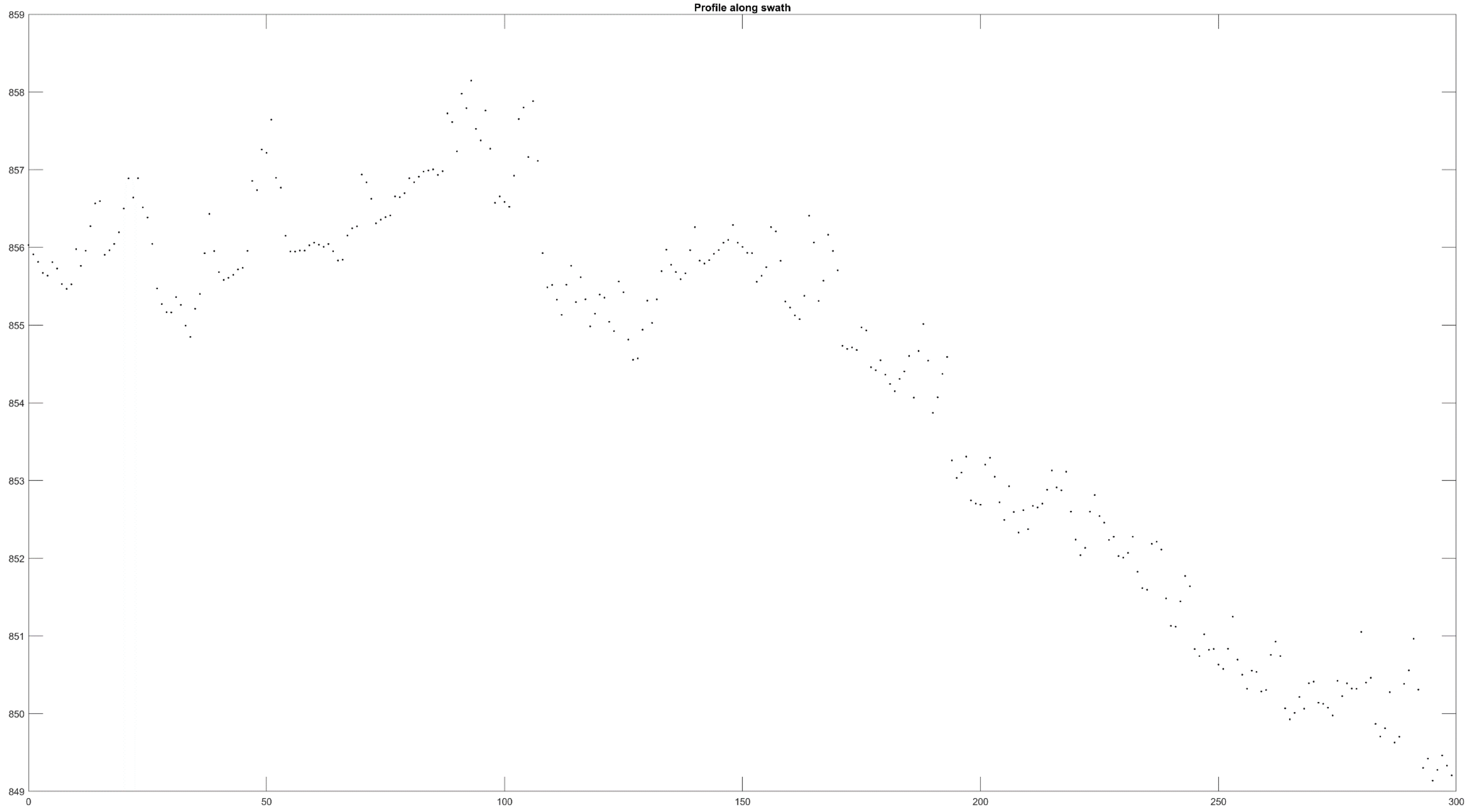



```
%script to produce swath profile and narrow swath profile
%Needs Topotoolbox
addpath(genpath('C:\Program Files\MATLAB\topotoolbox-master'))
%JRA April 2019
clear all
close all
%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
%set a few variables
dem_file_name='output.tin.tif'; %geotiff DEM
output_file_name='CareFreeTest'; %for output of narrow profile
swathwidth=100; %bigger swath width in meters
narrowswathwidth=1; %narrow swath width in meters
%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

%Here is a basic TopoToolbox set of commands to get started:
DEM = GRIDobj(dem_file_name); %Topotoolbox command to build gridobject
info(DEM) % everything's seems alright print out

%show the DEM with the swath location
figure(1)
imageschs(DEM,DEM,'ticklabels','nice','colorbar',false);
hold on
%these are the vertices of the swath profile:
[x,y]=ginput;
plot(x,y,'k-')

%Extract the broader swath along the x y path
SW = SWATHobj(DEM,x,y, 'width',swathwidth) %swathwidth wide swath
plot(SW)
title('DEM with swath location')

figure(2)
plotdz(SW)
title('Profile along swath')


%Extract a very narrow swath for scarp models
SW = SWATHobj(DEM,x,y, 'width',narrowswathwidth) %now do the swath again but just 0.2 m wide

figure(3) %shows the detailed map of the narrow swath
imageschs(DEM,DEM,'ticklabels','nice','colorbar',false);
hold on
plot(SW.X,SW.Y,'k.')
axis([min(min(SW.X)) max(max(SW.X)) min(min(SW.Y)) max(max(SW.Y))])

figure(4) %profile along swath (takes the average of each of the points in the narrowswath
plot(SW.distx,mean(SW.Z)','k.')
title('Profile along swath')

%write out the information
%first output the vertices of the profile in case we need them again
fileID = fopen(join([output_file_name "vertices" "txt"],"."),'w');
A=[x y];
fprintf(fileID,'%f %f\n',A');
fclose(fileID);

%now output the profile
fileID = fopen(join([output_file_name "profile" "txt"],"."),'w');
A=[SW.distx mean(SW.Z)'];
fprintf(fileID,'%f %f\n',A');
fclose(fileID);
```

100 m wide swath from lidar derived DSM



1 m wide swath from lidar derived DSM



Carefree Fault assignment (Due November 18, 2022)

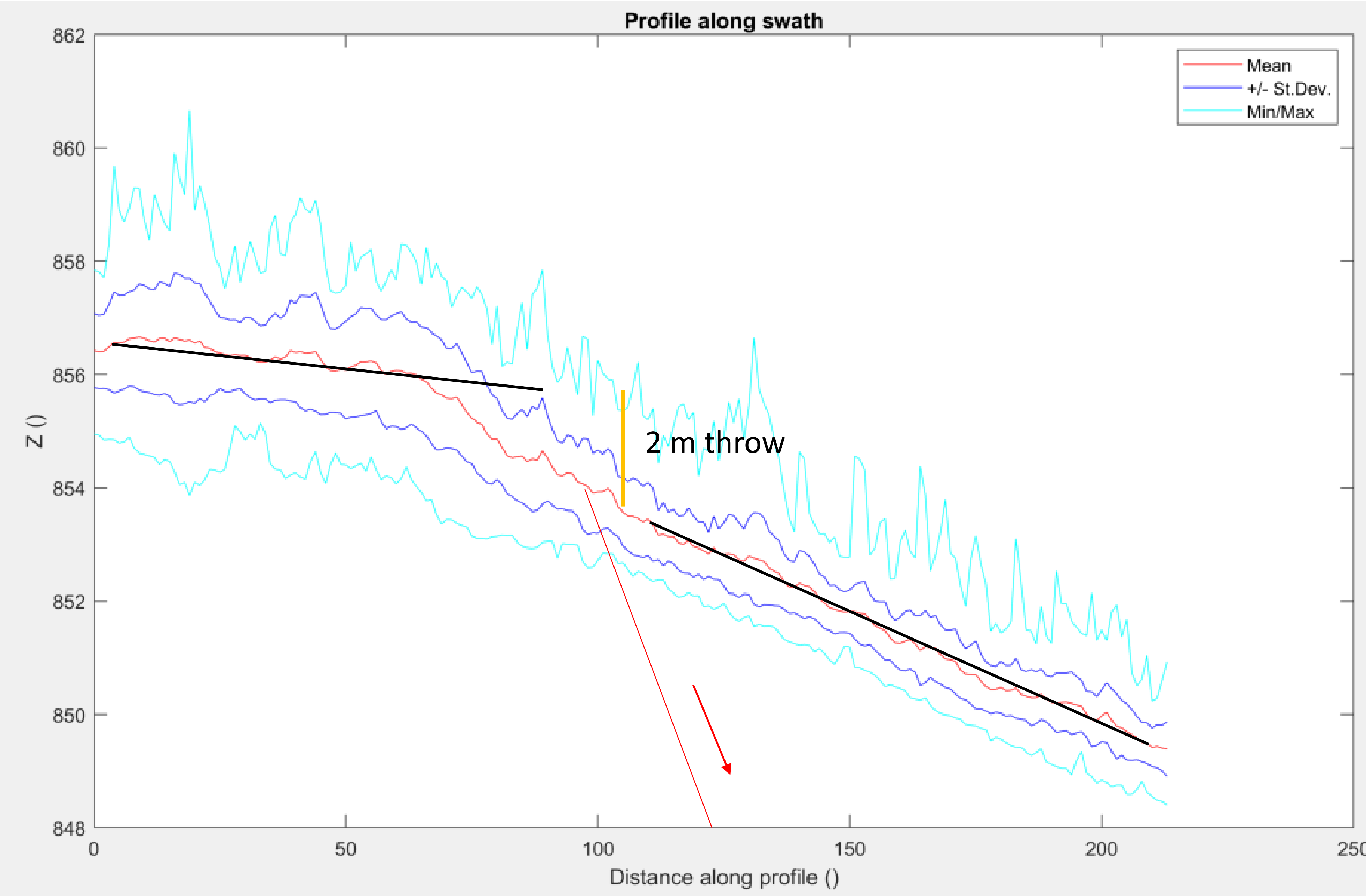
1) Review the USGS Quaternary Faults data for the Carefree Fault and estimate the FAULT LENGTH:
https://www.usgs.gov/programs/earthquake-hazards/faults Look for "Interactive Fault Map" link at the top
https://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=5a6038b3a1684561a9b0aadf88412fcf
What is that length and is it a maximum or minimum?
Using the Wells and Coppersmith, 1994 Empirical relation of Moment Magnitude and Surface Rupture Length (Figure 9), what is the expected Magnitude? Short paragraph answer

2) Using the AZ OFR 97-02 and your own field mapping and assessment of the lidar and SfM data, please make a geologic map along the Carefree fault zone (extent of the SfM coverage). PDF of map with explanation and scale

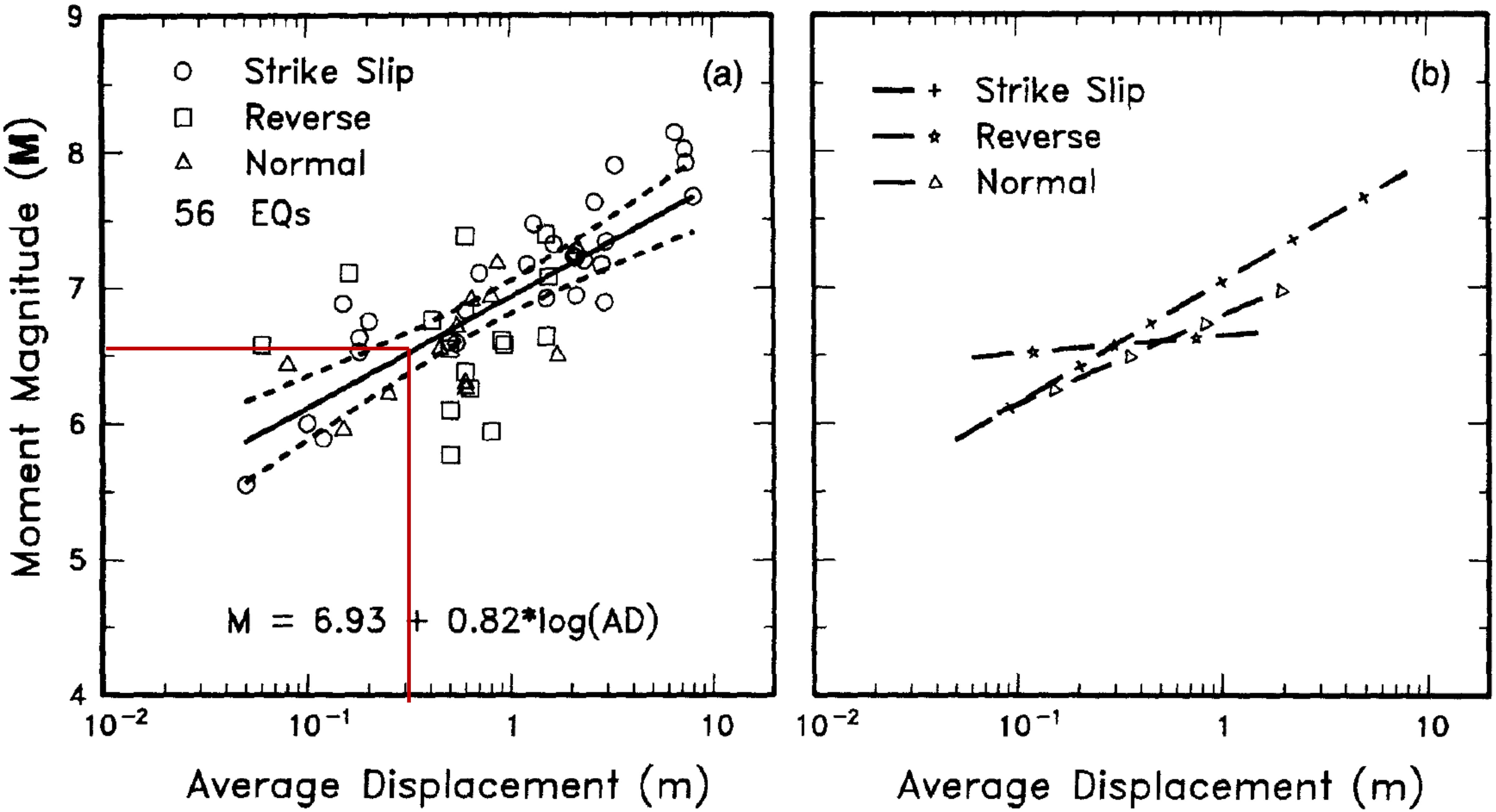
3) Using Topotoolbox and the DEMs, explore and produce a swath profile across the Carefree fault. What is a good swath width to represent the topographic signal of the faulting? Figure and short paragraph answer

4) Draw a simple geologic cross section (~300 m long) across the fault in your mapping area. Include the fault, the surficial and bedrock geology. Figure and short paragraph explanation

5) Fault throw rate and earthquake recurrence interval: Figure, simple computations, short paragraph discussion
Use your cross section to estimate the fault throw.
Looking at the geologic map and your mapping, what is the age of the surface that is offset?
What is the throw rate?
Using your estimated earthquake magnitude (step 1 above), determine average displacement for event (Wells and Coppersmith, 1994 Figure 11).
Assume that throw is the same as average displacement. Given your slip rate, what is the possible earthquake recurrence rate.



Profile along swath
Mean
+/- St.Dev.
Min/Max
2 m throw
Z ()
Distance along profile ()
862
860
858
856
854
852
850
848
0
50
100
150
200
250



Strike Slip
Reverse
Normal
56 EQs
(a)
Moment Magnitude (M)
Average Displacement (m)
M = 6.93 + 0.82*log(AD)
Strike Slip
Reverse
Normal
(b)
Average Displacement (m)

Throw rate (m/kyr) = throw (m)/age of surface (kyr)
Throw per earthquake (m) = average displacement (m)
Recurrence interval (kyr) = average displacement (m)/ Throw rate (m/kyr)