



P·A·P·G

Pittsburgh Association of
Petroleum Geologists

An AAPG Affiliated Society

www.papgrocks.org

Mapping with Lidar Based DEMs – a Geologist's New Tool

Thomas G. Whitfield, P.G.

Pennsylvania Geological Survey

www.dcnr.state.pa.us/topogeo

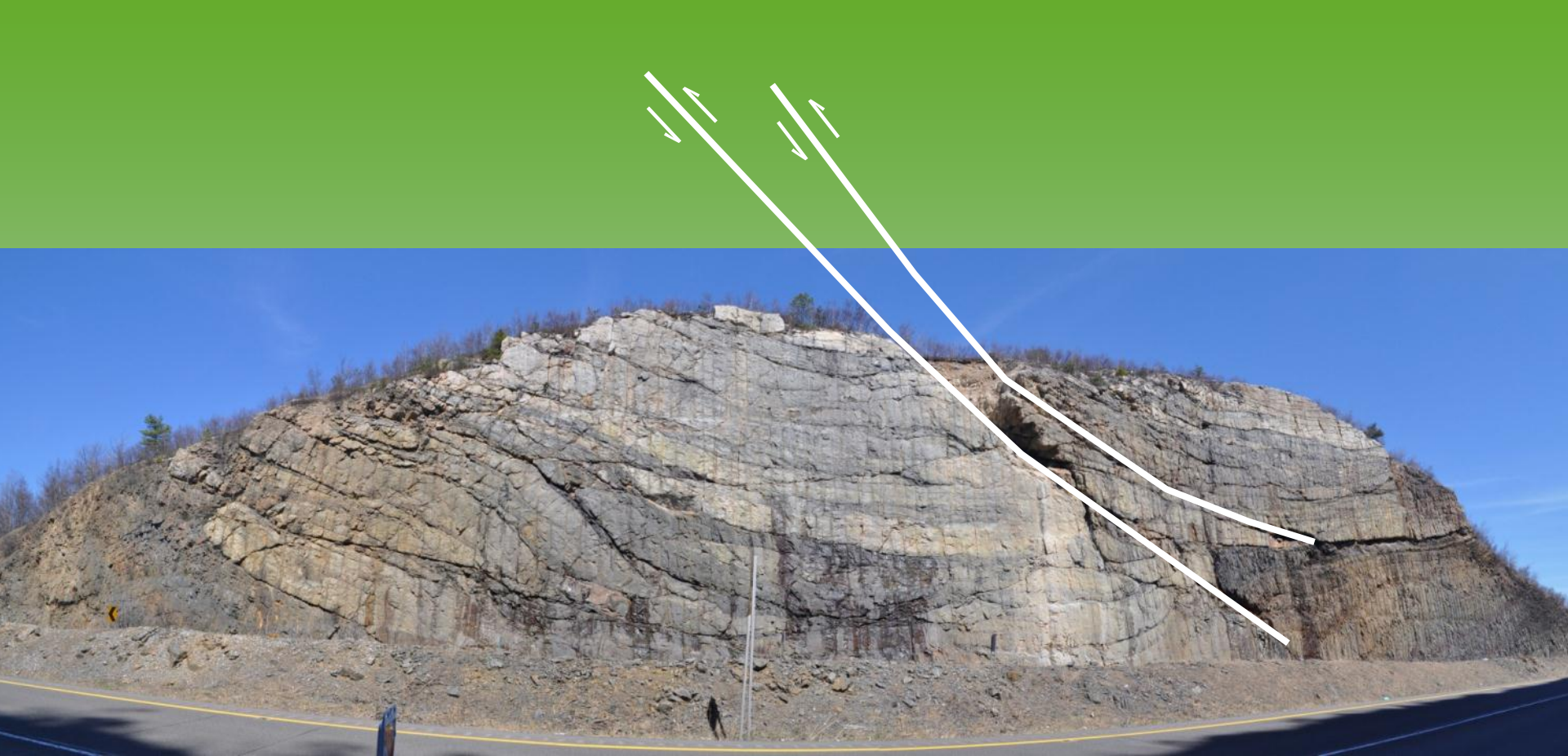








Bedding is readily apparent in some sedimentary rocks.



Spring Mountain
syncline and reverse faults
exit 39, I-81 at McAdoo, PA



Epler Fm. (Oe), Lehigh Co., PA

Complex folding – Rose Hill (Srh) and Tuscarora (St) fms.
Rt 322 W roadcut at Macedonia, opening of the Lewistown Narrows.





BIG HORN FM →
ORDOVICIAN
430—500 MILLION YRS

12



Up close and personal...

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Pressure from management...

George E.W. Love, P.G.
Pennsylvania State Geologist

Geologist's Toolbox

- Topo map
- Aerial photography
- Boots-on-the-ground field work
- Previous work
- Digital imagery
- Digital DEM derivatives
- GIS software

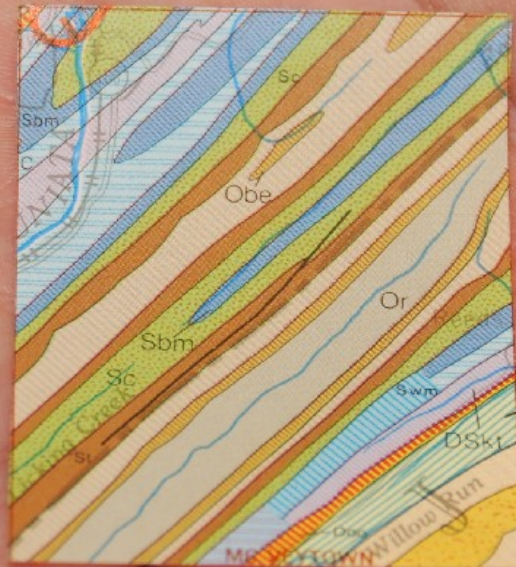
Geologist's Toolbox cont.

- One thing computers cannot do is duplicate geological thinking.
- It is ability of the geologist to think in 3-D, look at the “big picture”, analyze difficult concepts, and use logical thinking to derive a model that make sense...
- ...for now.

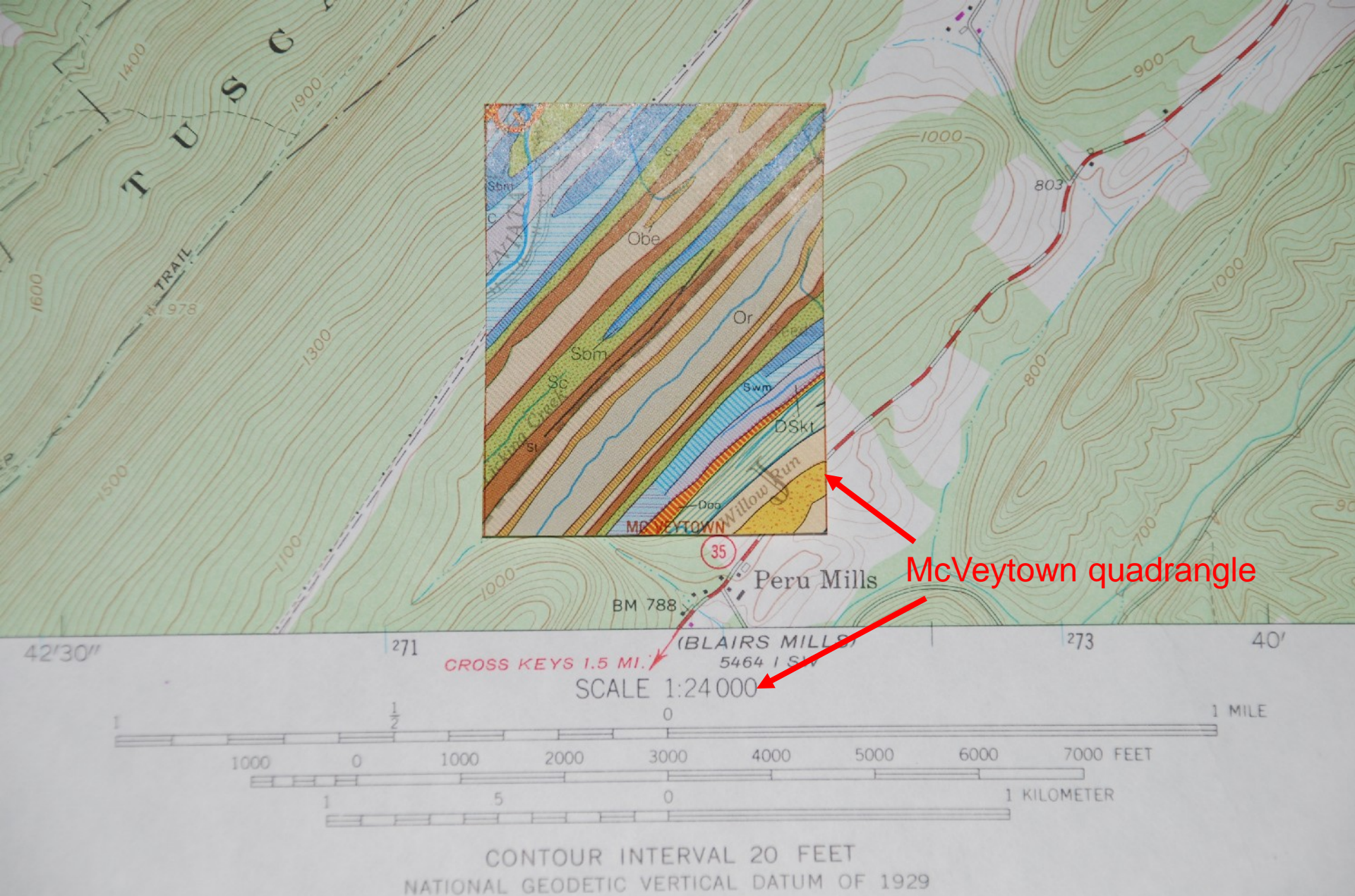
Combining geology and GIS

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The McVeytown quadrangle geology @ 1:250,000 from Pennsylvania Map 1

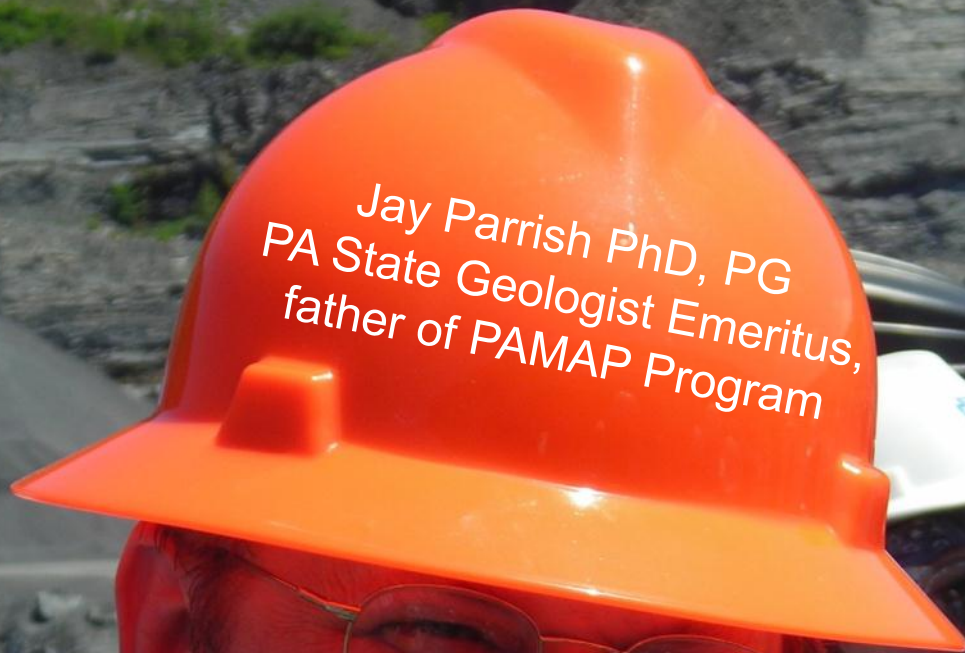


A GIS pitfall – mixing scales



- Thou shall not commit accuracy scale sacrilege.
- 1:250,000 geology is not accurate beyond 1:250,000.

Jay Parrish PhD, PG
PA State Geologist Emeritus,
father of PAMAP Program



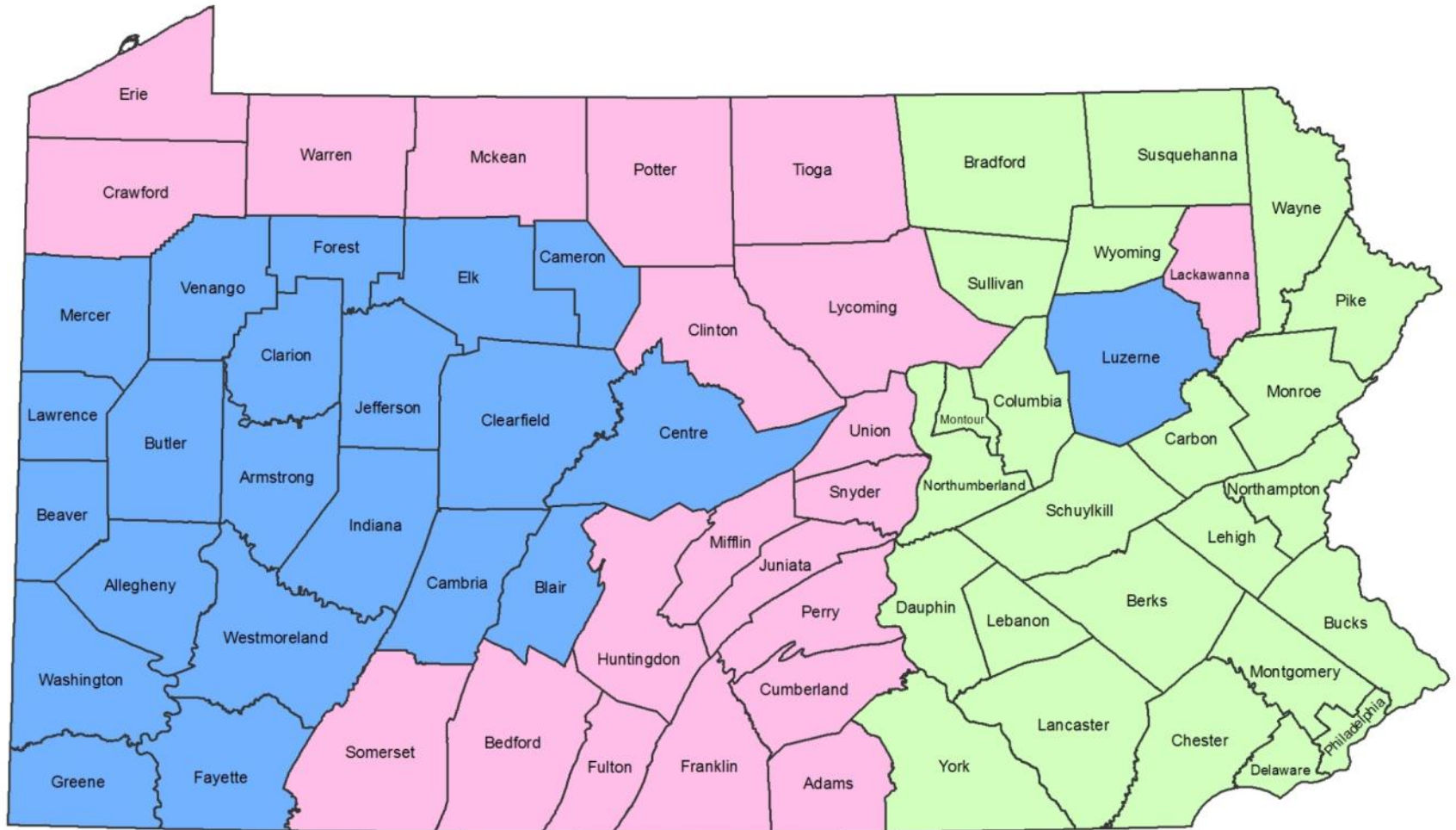
PAMAP program – another tool

- Statewide program
- Fly high-resolution lidar and full color aerial imagery at the same time
- Generate a very detailed DEM (digital elevation model)
- Generate high-resolution color orthoimagery
- Use a 10,000-foot grid tile for whole state



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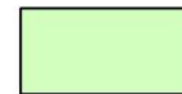
PAMAP Lidar Acquisition



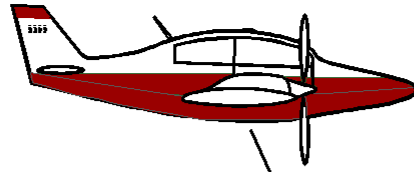
2006



2007



2008



Basics

~4,000 feet altitude

Differential GPS control

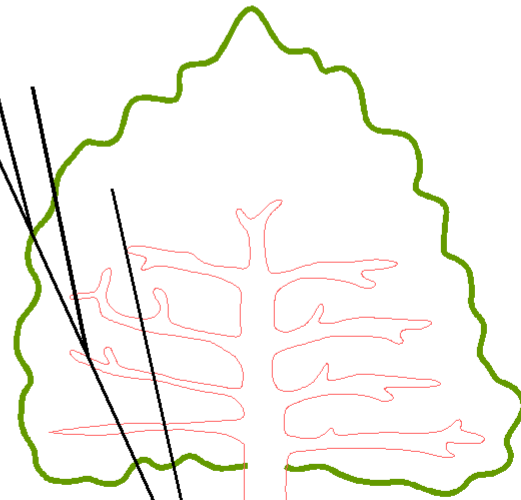
30° sweep angle

Lidar – Light (laser)
Distancing and
Ranging

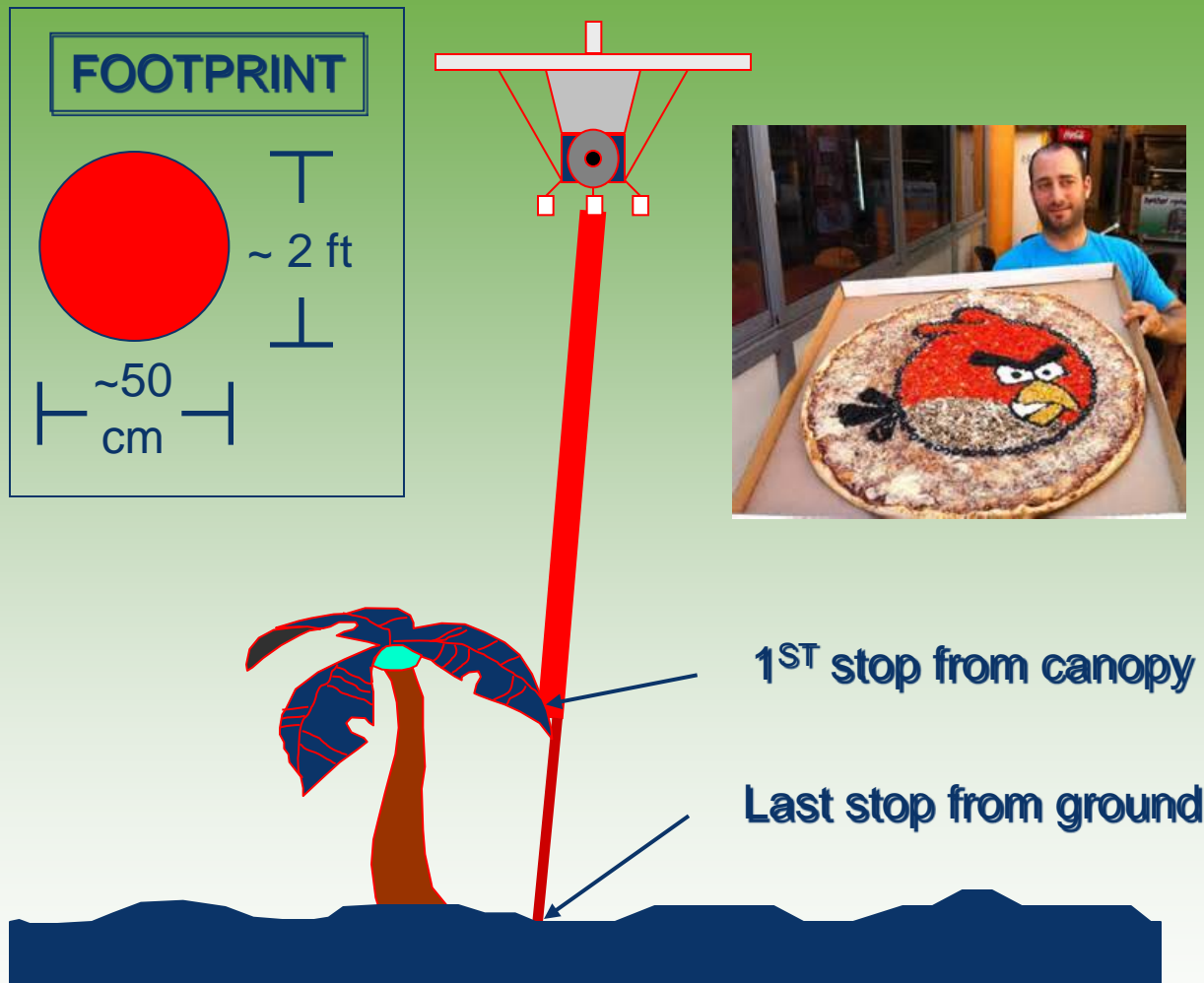
Up to 150,000 pulses per second

Multiple returns

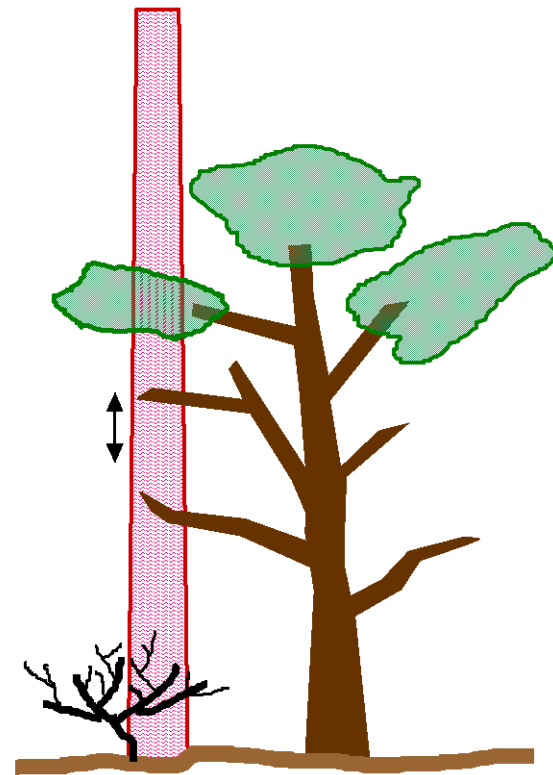
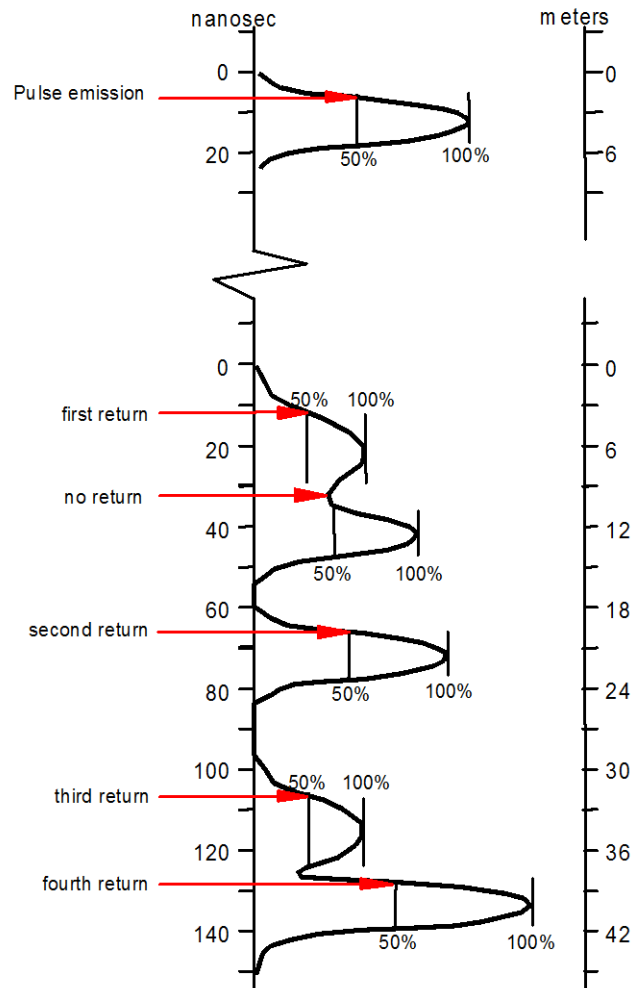
Enough time one pulse to go out, all
returns back – before next pulse is out



Lidar 1st and Last Return



Multiple Return Theory



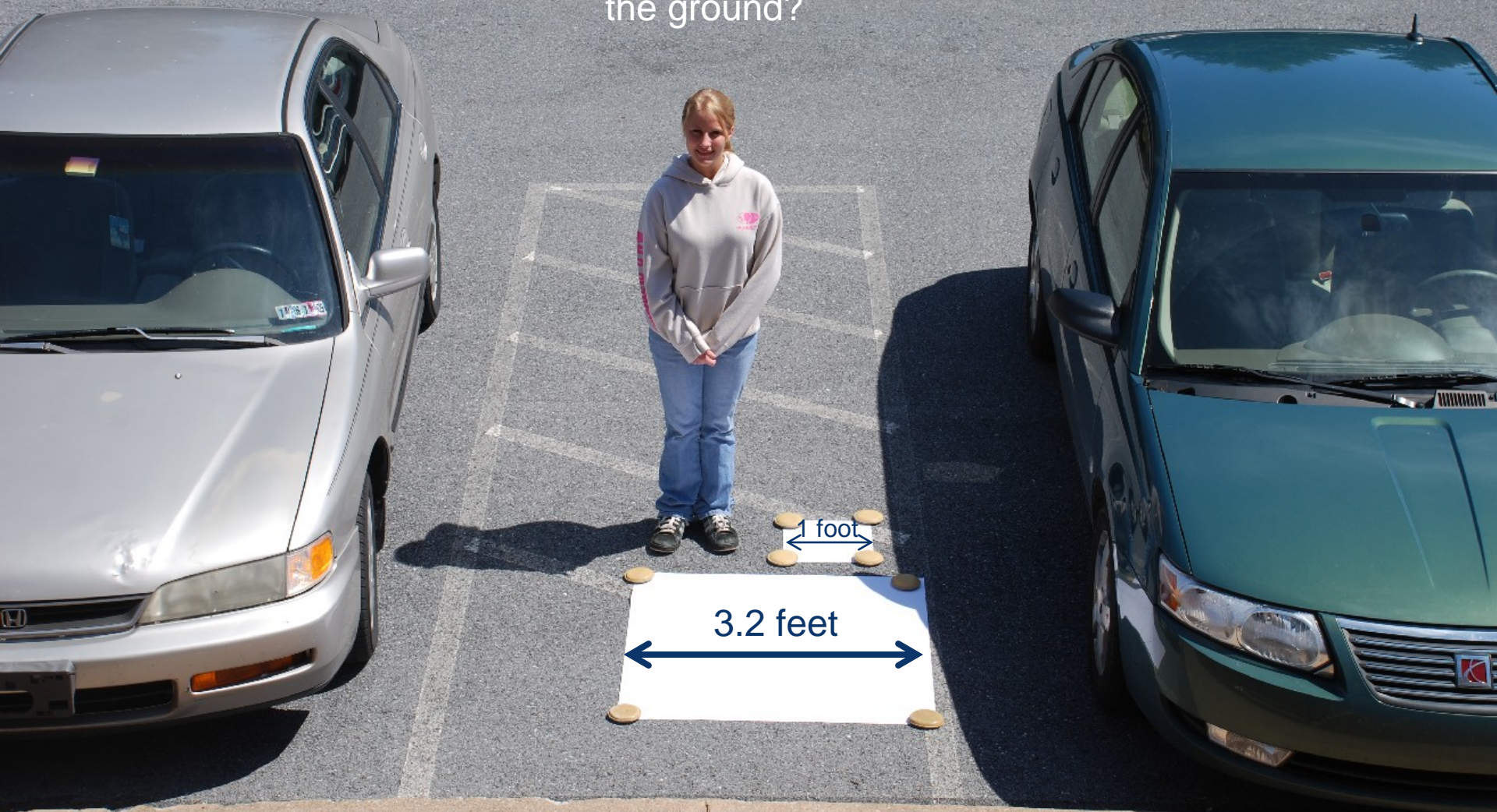
Lidar processing

- One year of processing and filtering
- Multiple derivative products
- Lots of uses
- “Bare earth” or “last returns” model
- Our lidar derived DEM is a 32-bit, floating point GRID with 3.2-foot pixel resolution

PAMAP Lidar Accuracy

- X, Y, and Z point in point cloud
- X, Y position in range of 0.4 to 1.5 feet.
- Z elevation in range of 0.3 to 1.0 feet.
- Along with 1-foot pixel orthoimagery

What does mean on
the ground?

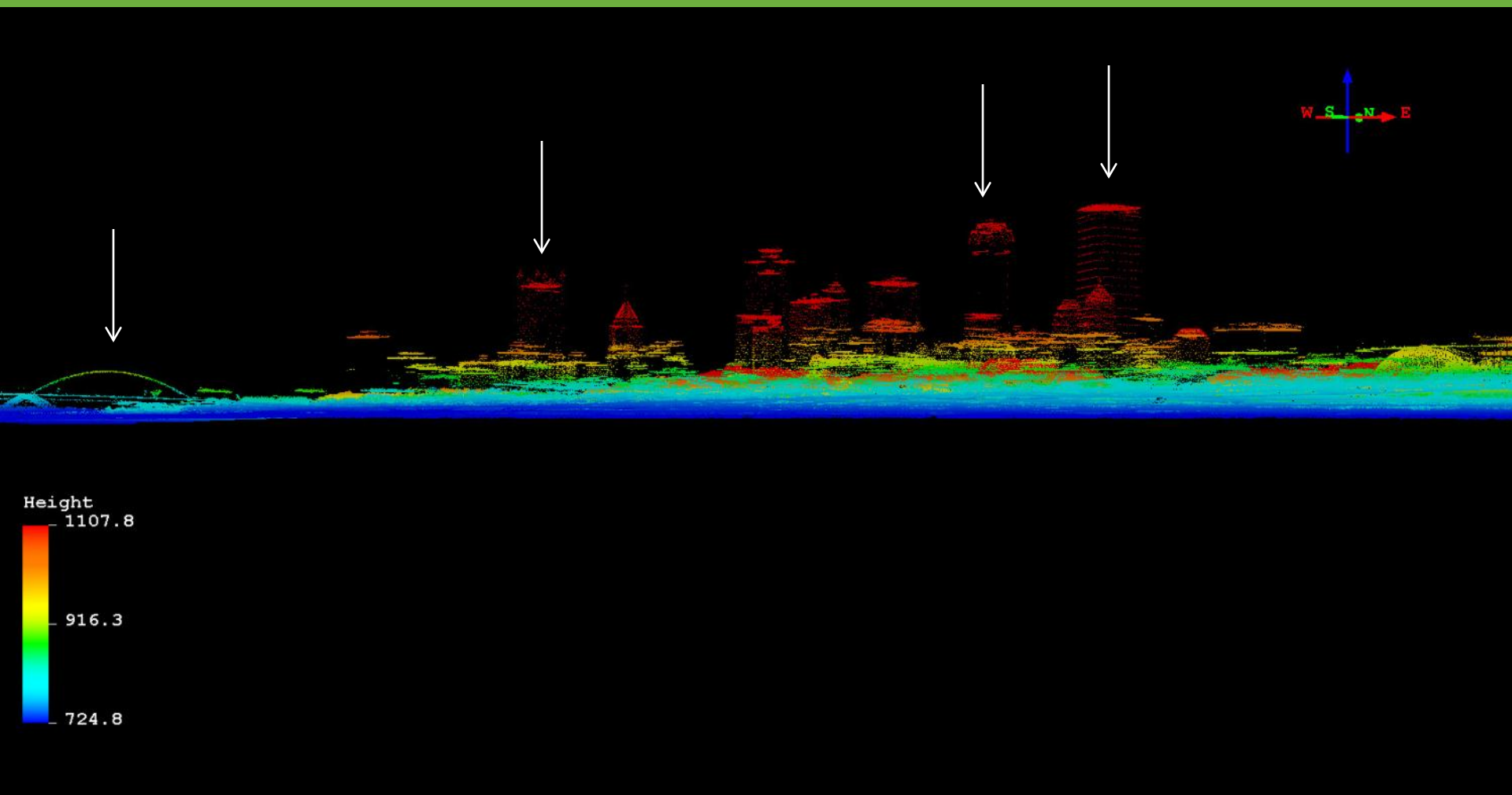




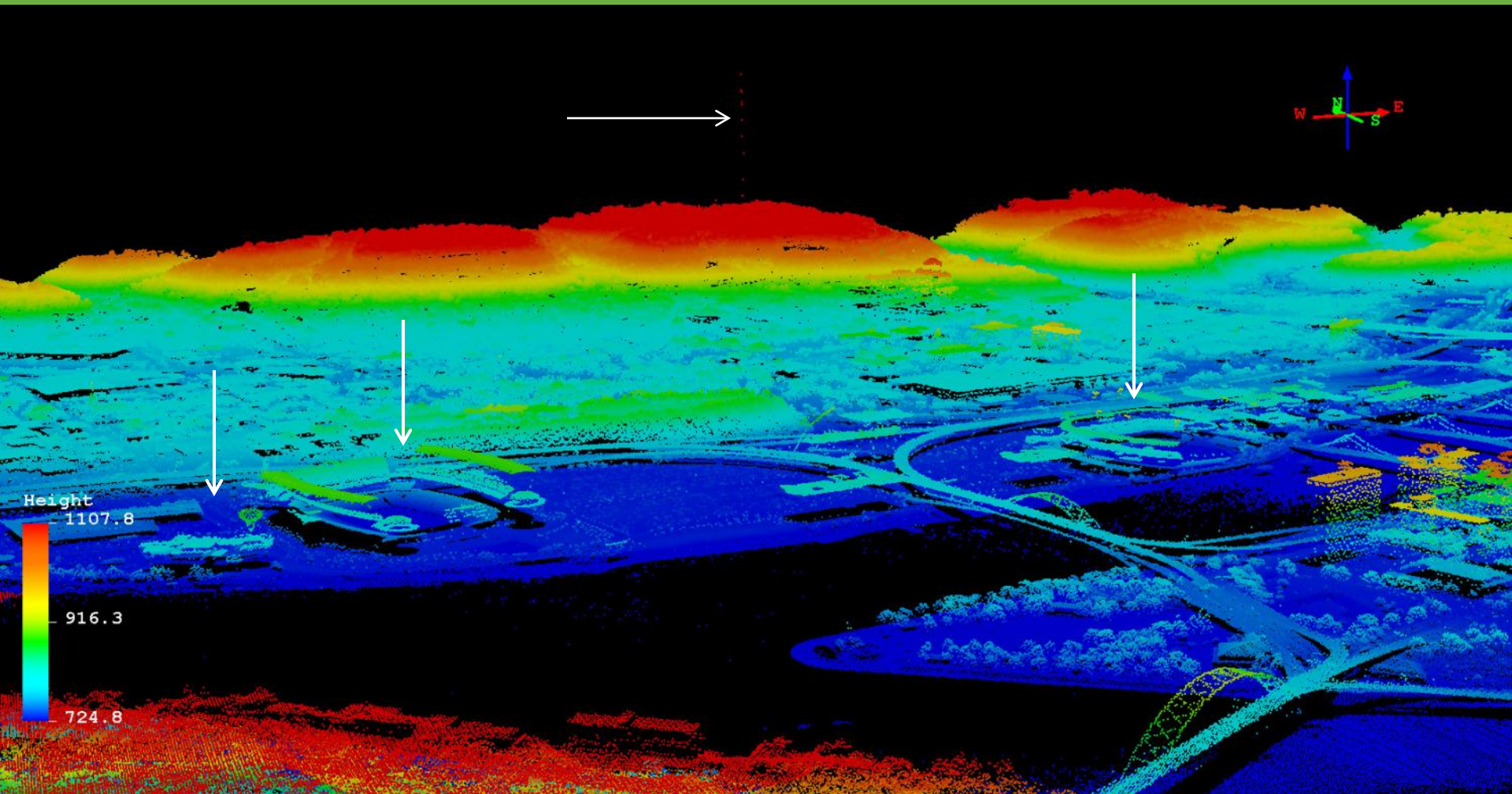
www.dcnr.state.pa.us/topogeo



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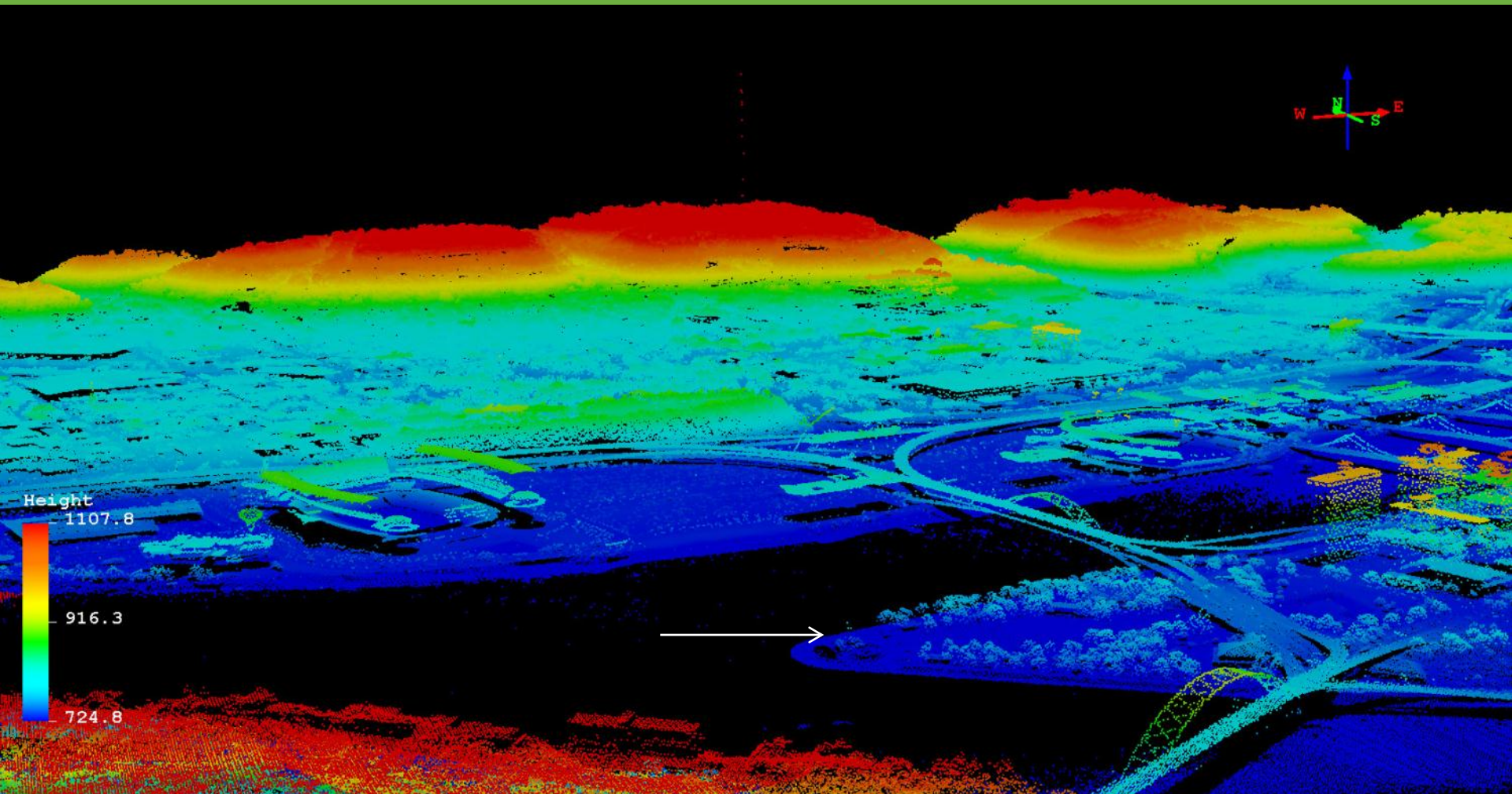


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What's available?

- Everything is in the same edge-matched 10,000 by 10,000-foot tiling scheme
- 3.2-foot pixel, bare-earth, DEMs
- Classified Lidar LAS (point cloud) data
- GIS Break-line vector files
- 2-foot derived surface contour lines
- 1-foot pixel color orthoimagery

What's the catch?

- DEM is ~ 25 MB/tile
- Lidar LAS file is ~ 80 MB/tile
- 1-foot pixel orthoimagery is ~ 250 MB/tile
- For state – LAS and DEMs ~ 2.5 TB
- For state – Orthoimagery ~ 7.1 TB

How Much?

Most PAMAP funding
came from various
Federal, State, and
Local sources...

...all public data.

www.dcnr.state.pa.us/top



Freely downloadable from
Pennsylvania Spatial Data Access
(PASDA) website

<http://www.pasda.psu.edu>



Want the entire state?

Contact me or PASDA to make arrangements.

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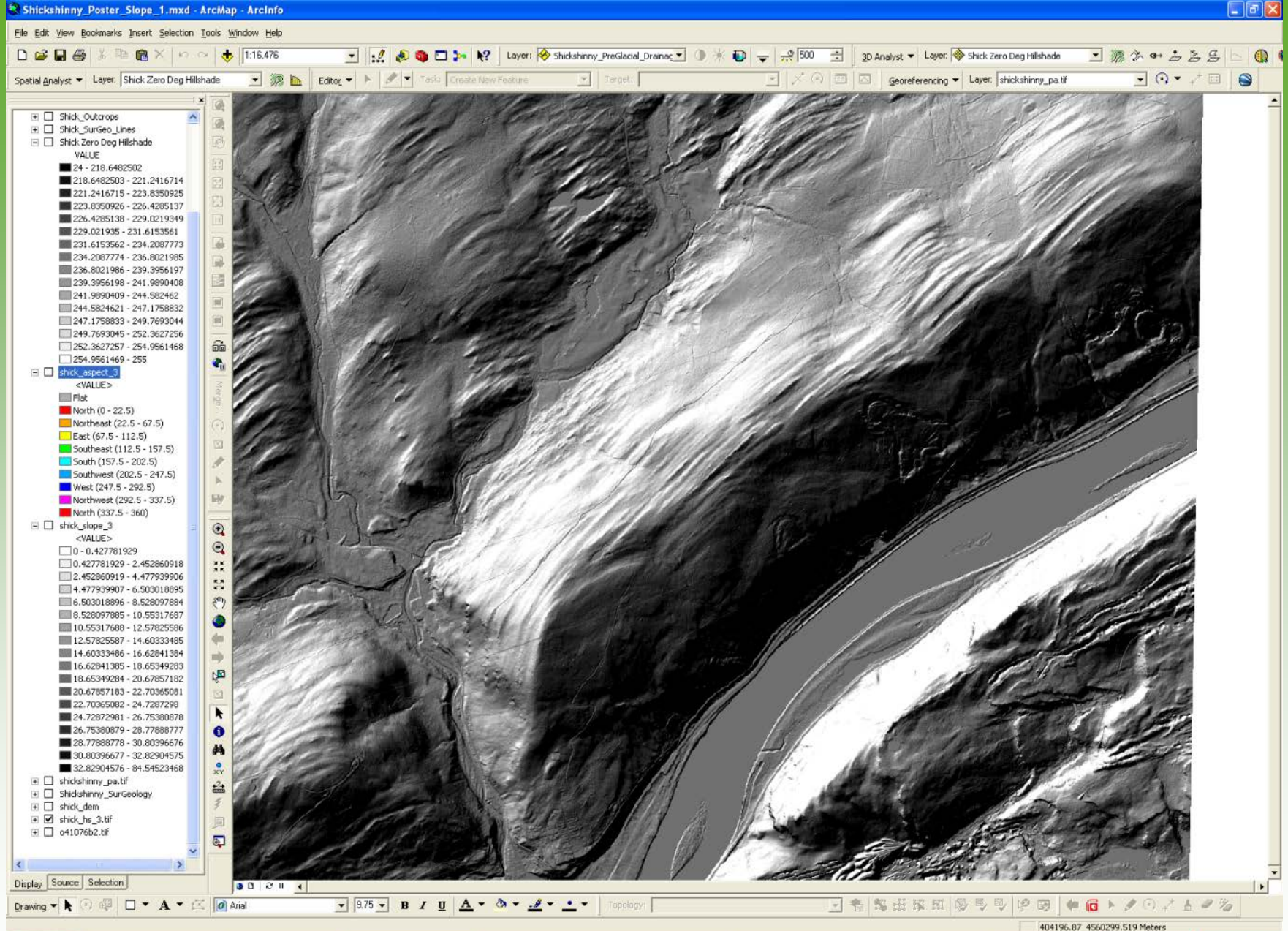


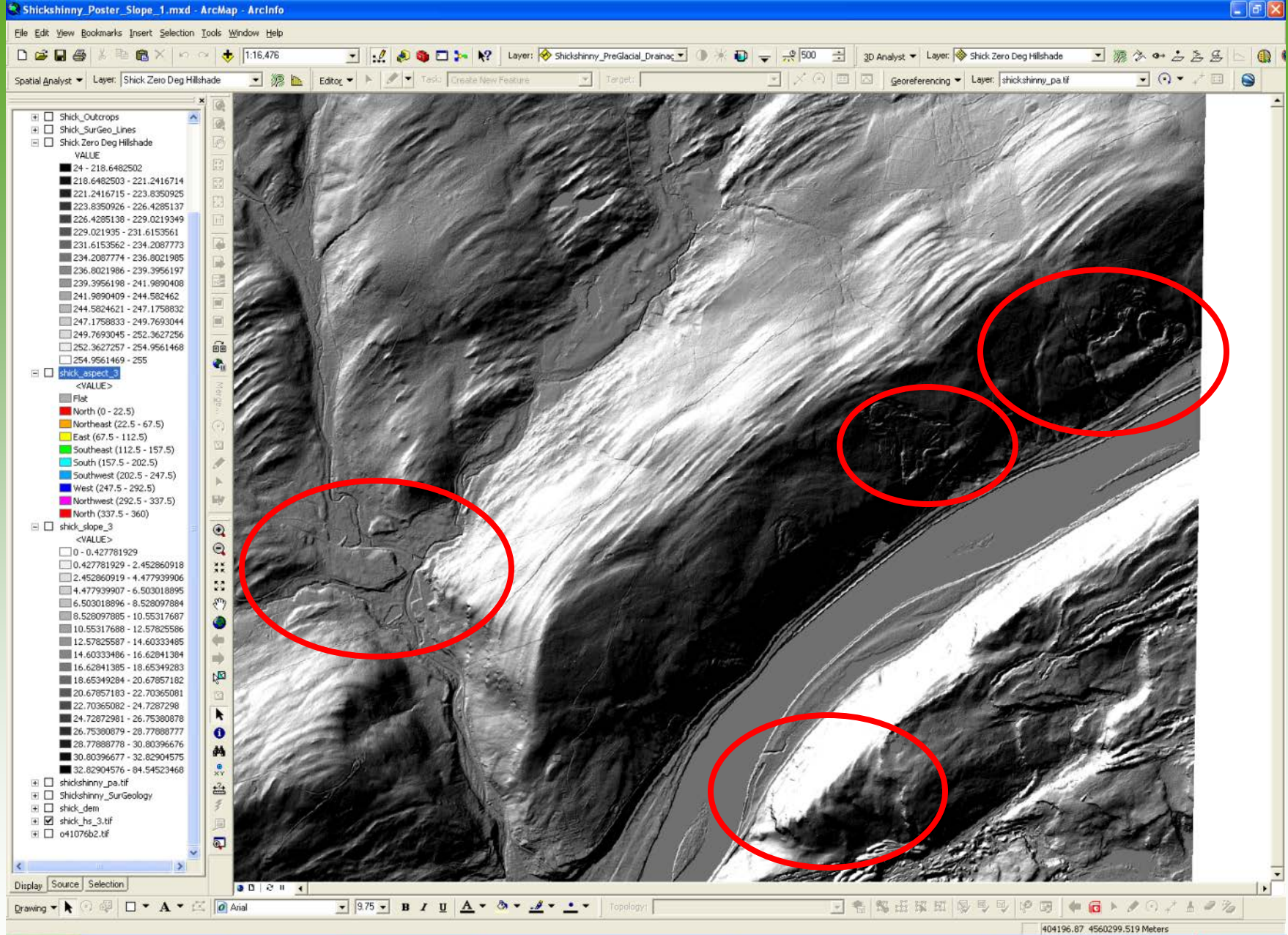
Two most used DEM derivatives

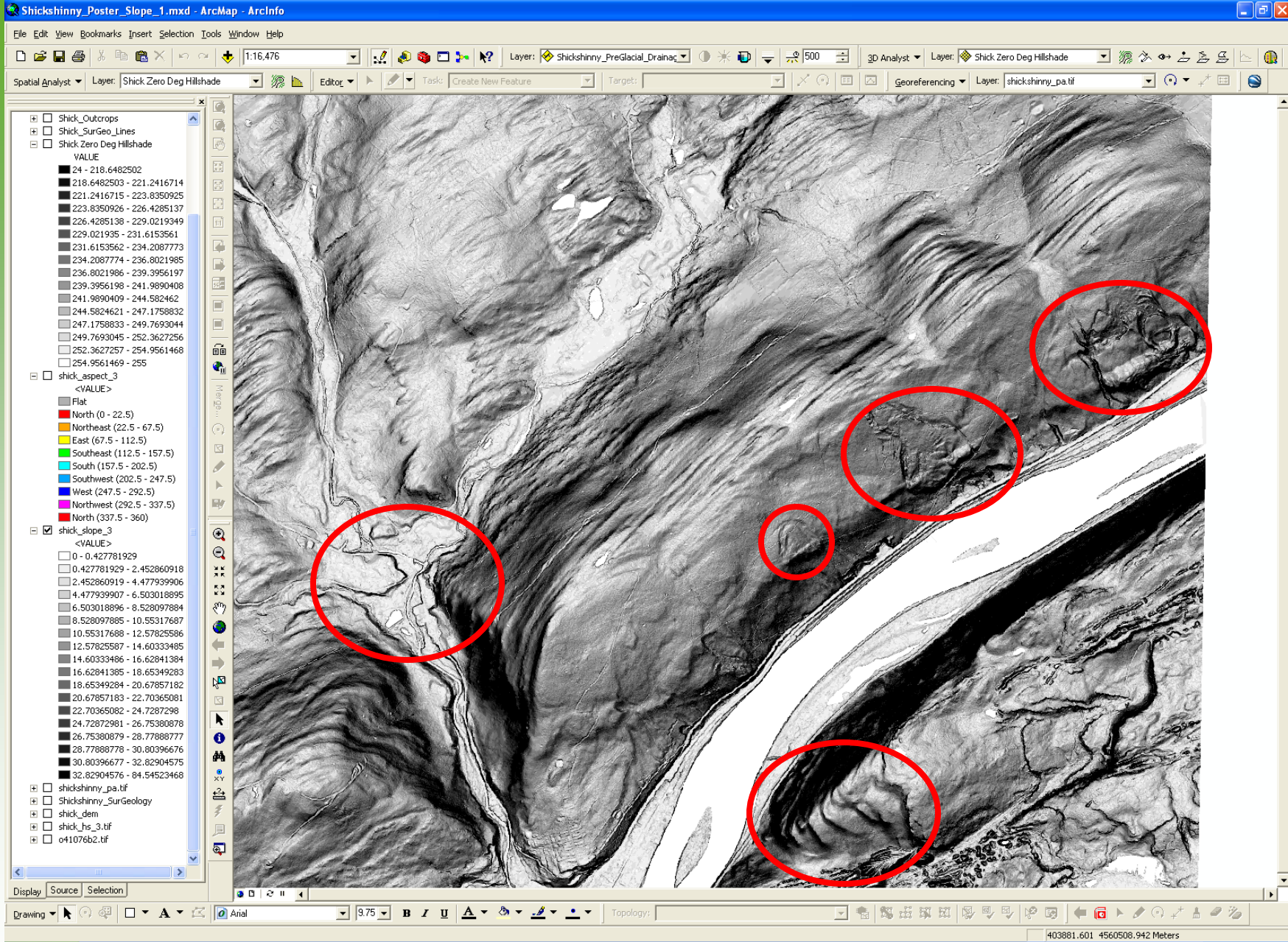
- Hillshade model – pseudo solar illumination based on sun angle of 45° and never occurring sun azimuth of 315° (NW)
- Slope – the rate of maximum change in z-value from cell to cell.
- Slope-shape is a display schema of a slope raster

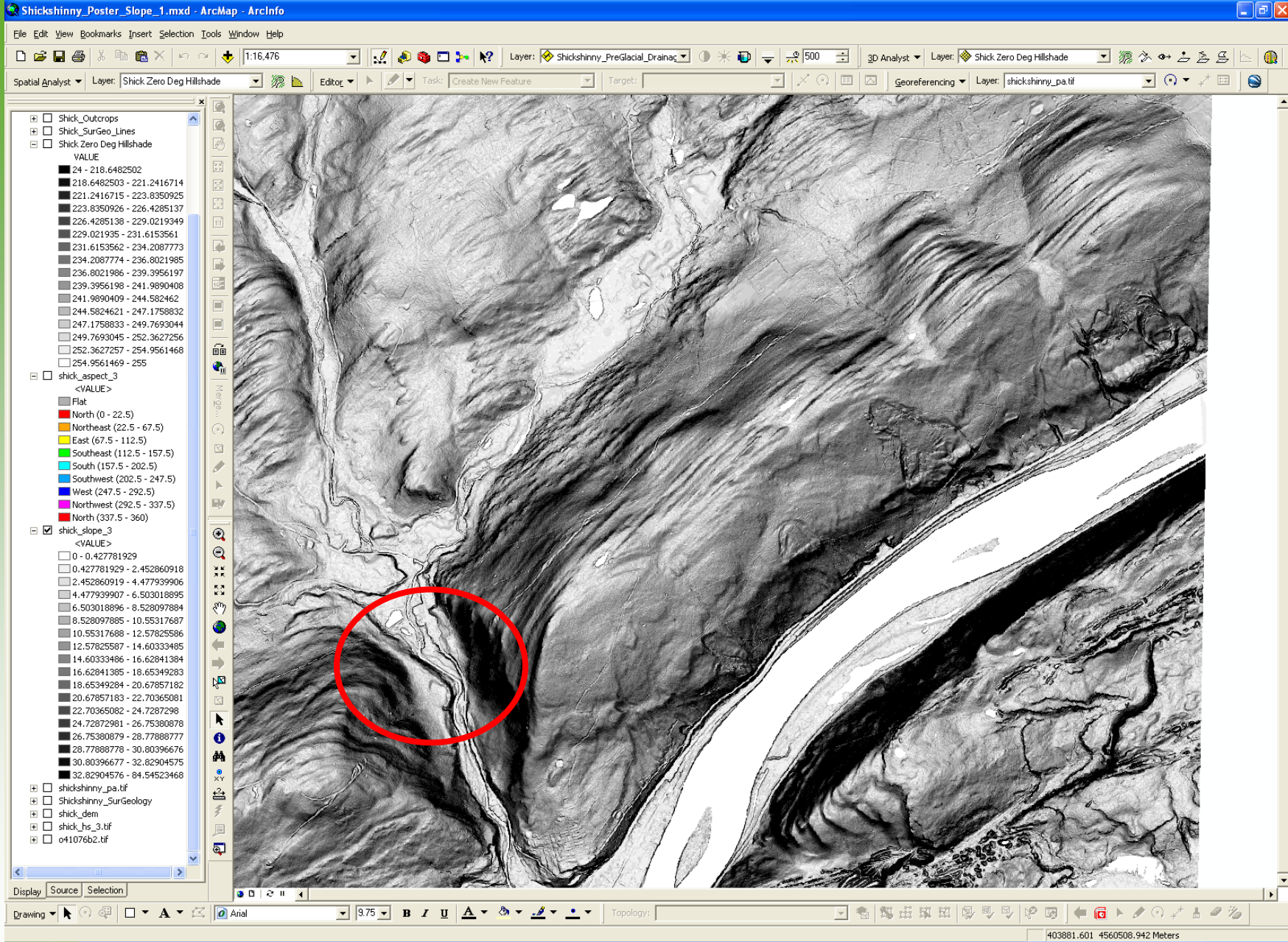
Technical page

- $$\text{Hillshade} = 255.0 * ((\cos(\text{Zenith_rad}) * \cos(\text{Slope_rad})) + (\sin(\text{Zenith_rad}) * \sin(\text{Slope_rad}) * \cos(\text{Azimuth_rad} - \text{Aspect_rad})))$$
- $$\text{slope_degrees} = \text{ATAN} (\sqrt{ ([\text{dz}/\text{dx}]^2 + [\text{dz}/\text{dy}]^2) }) * 57.29578$$



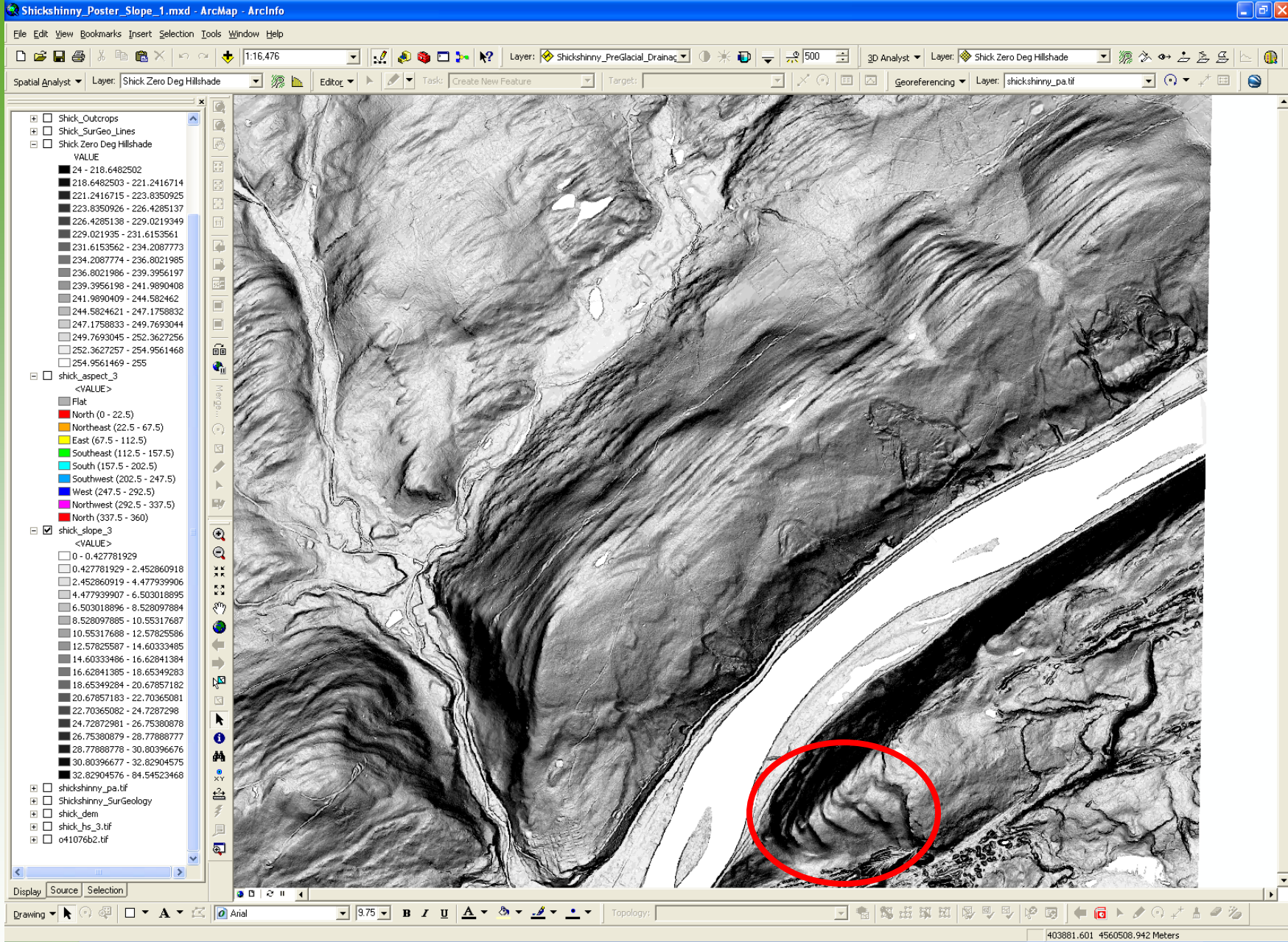






Looking SSE







The slope caveat page.....

- We do not have “sun and shadow” effects
- We lose the sense of “up and down”
- Without visual clues – sometimes cannot tell high points from low points
- We are looking strictly at downward slope angle

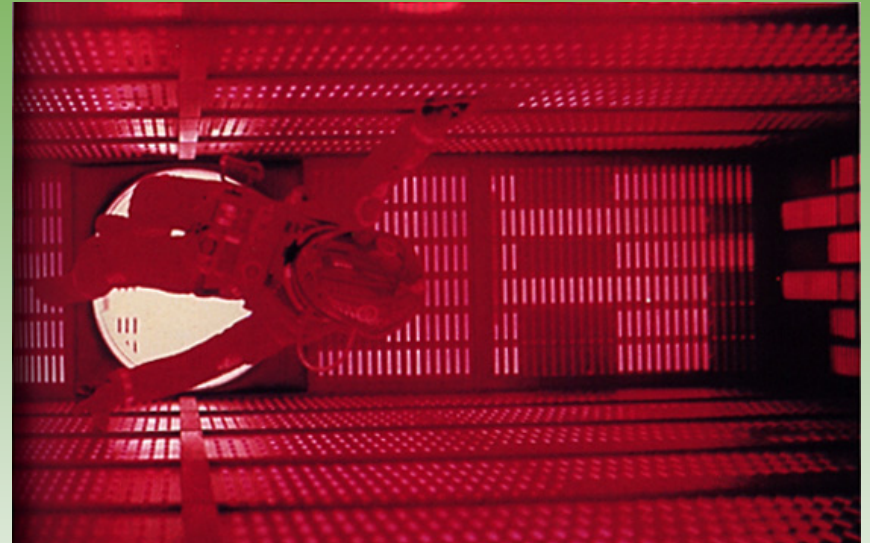


Creating a Slope-Shape for Geologists

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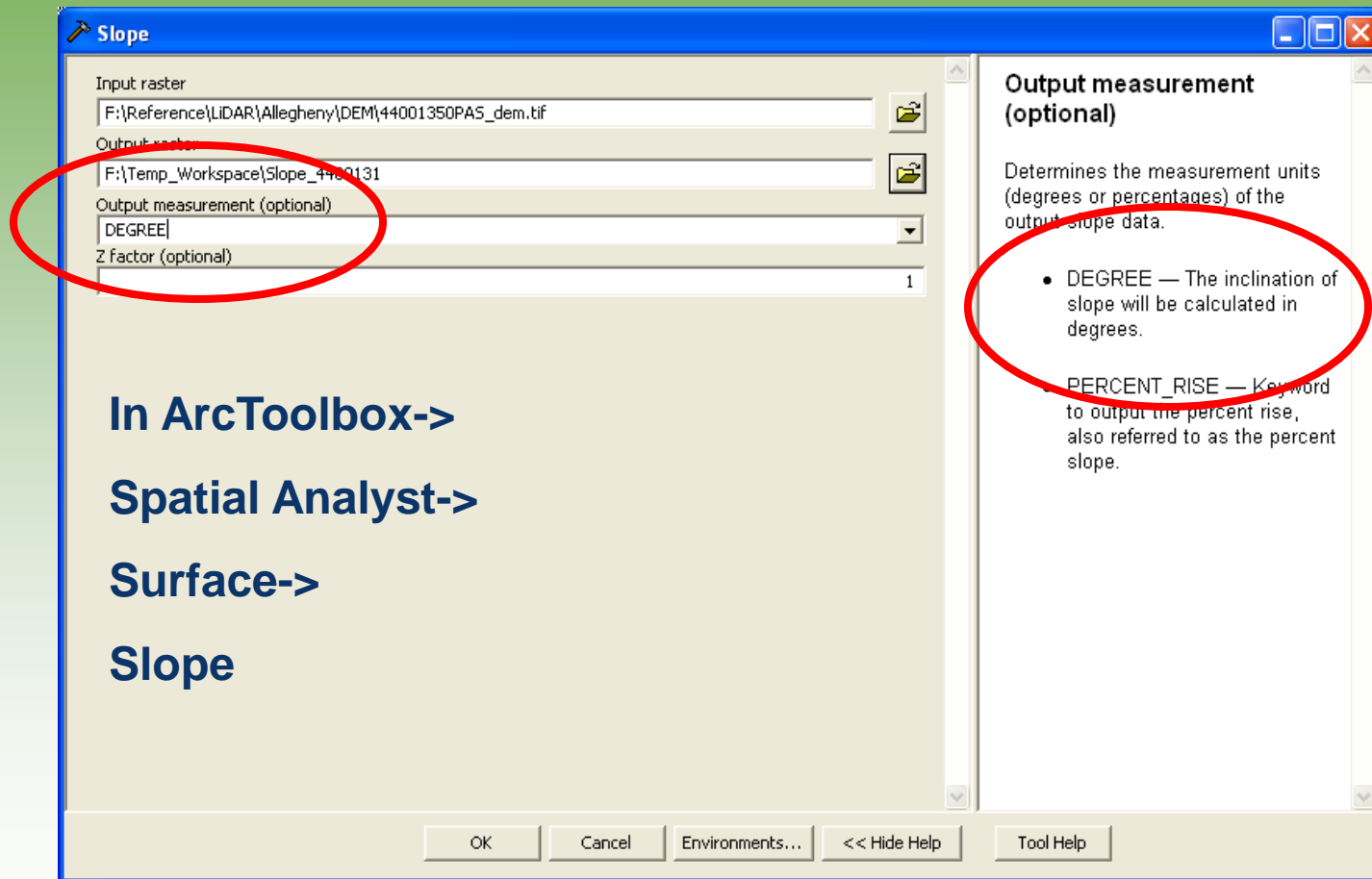
Slope-shape – “How to’s”

- Ain’t rocket science
- Easy to create
- Easy to display – most important part
- Easy to interpret
- One grid to track
- No right way, no wrong way, but there is always the.....



GOV'T WAY

Create a slope grid



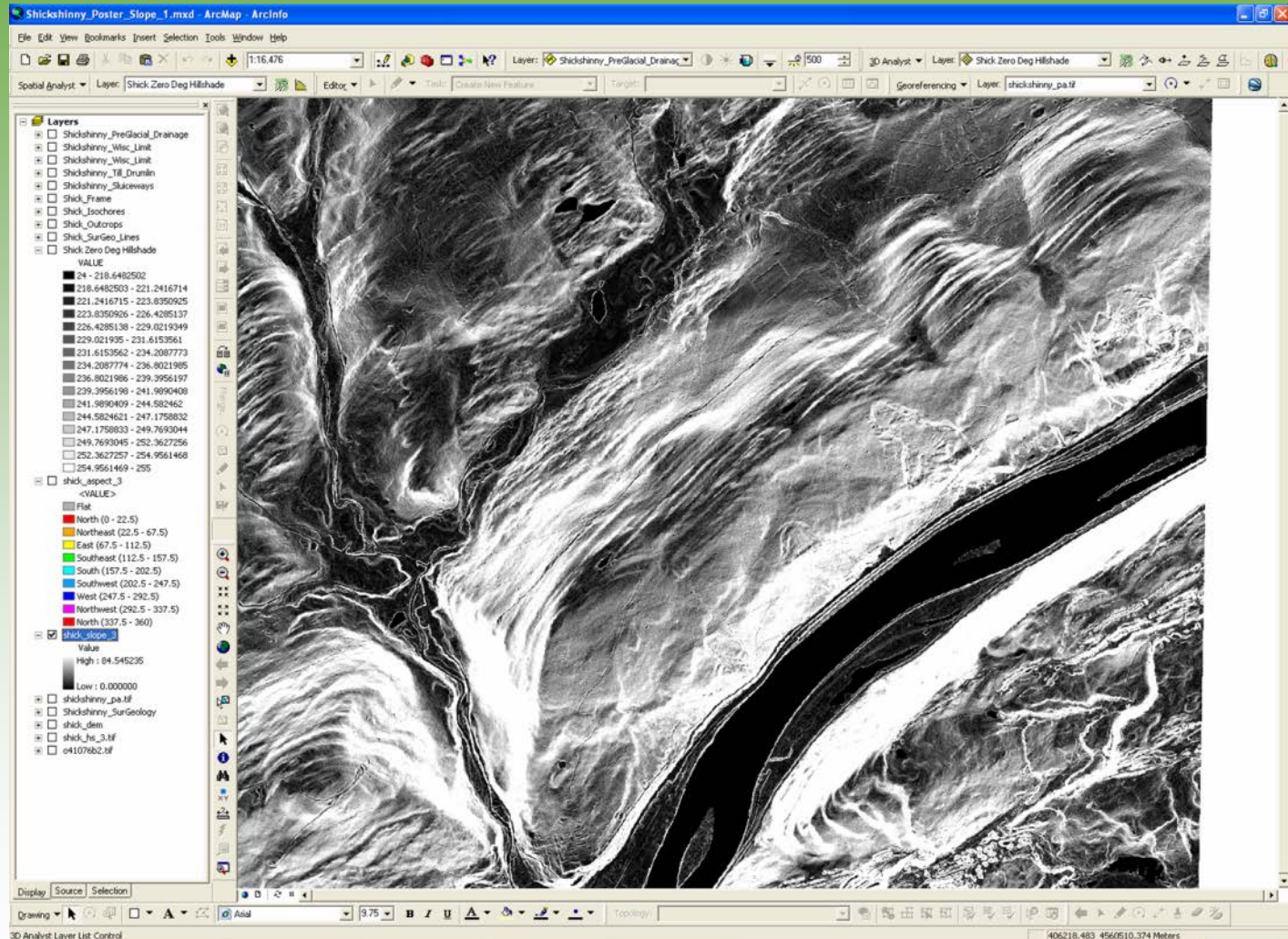
In ArcToolbox->

Spatial Analyst->

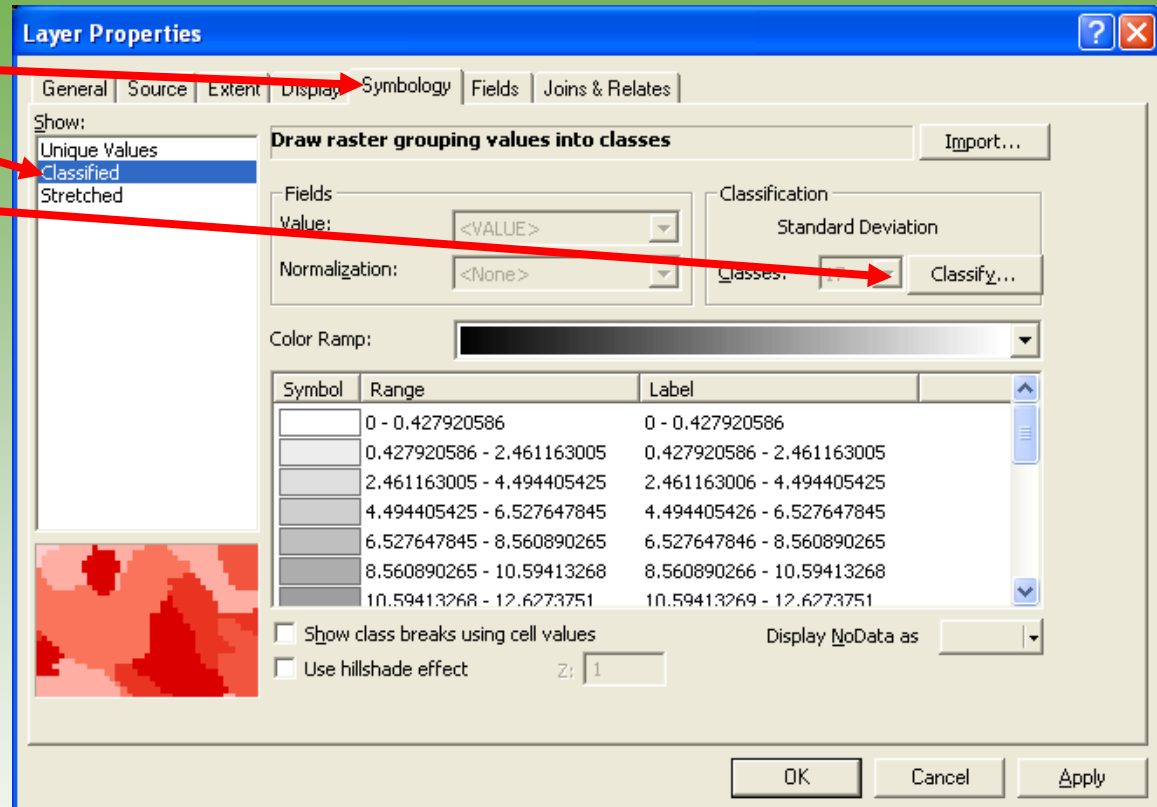
Surface->

Slope

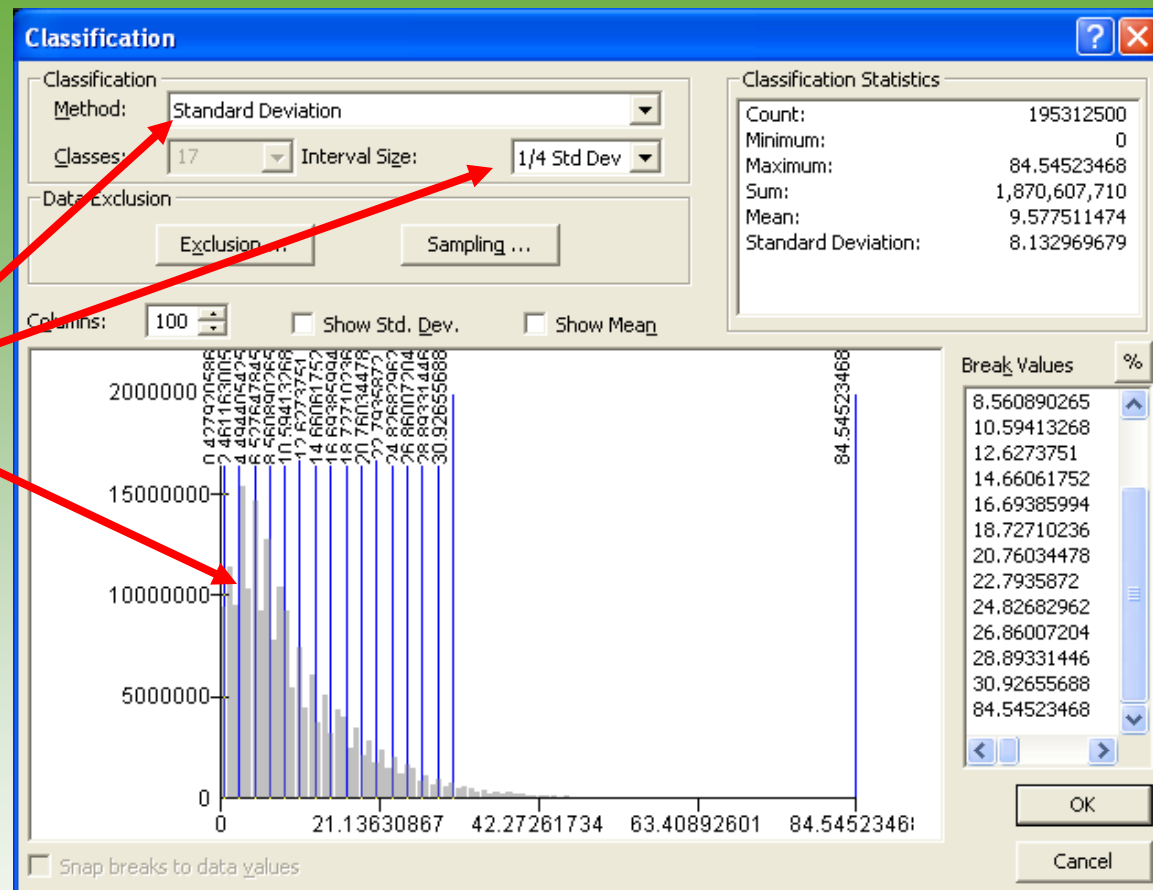
Not a pretty result – but that's okay



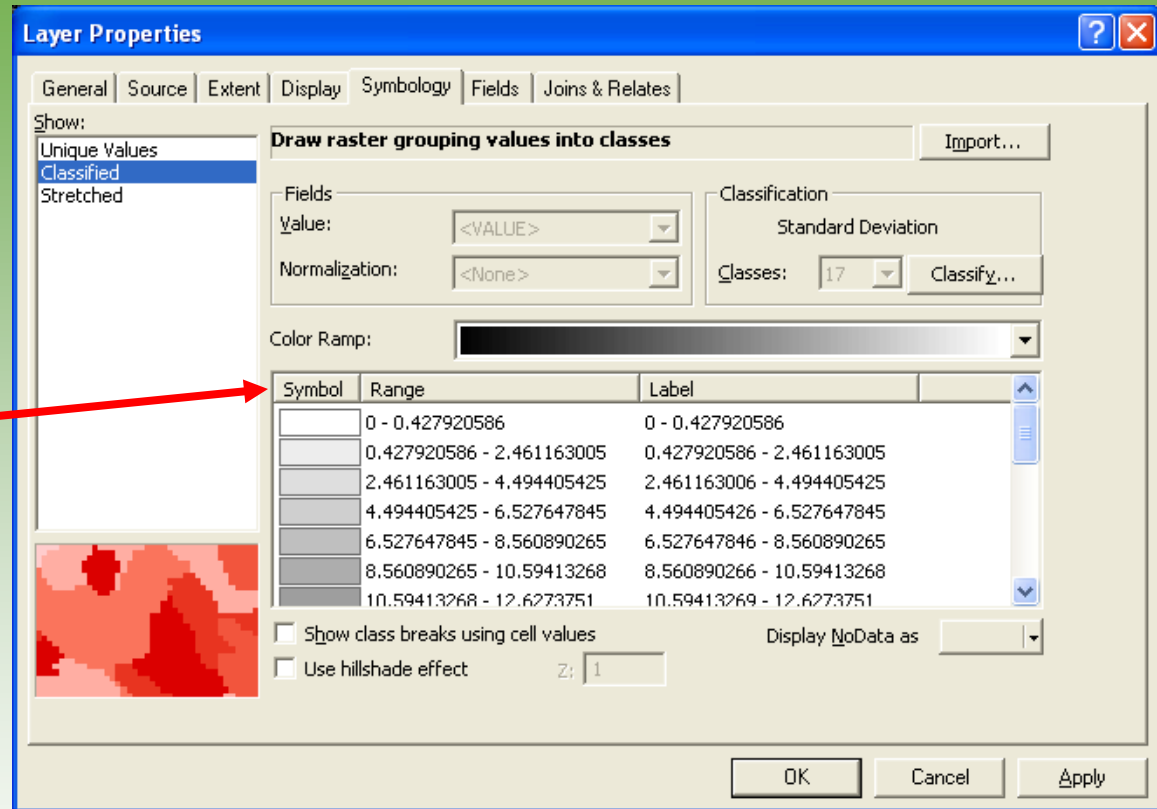
Under symbology –
go to classify
options.

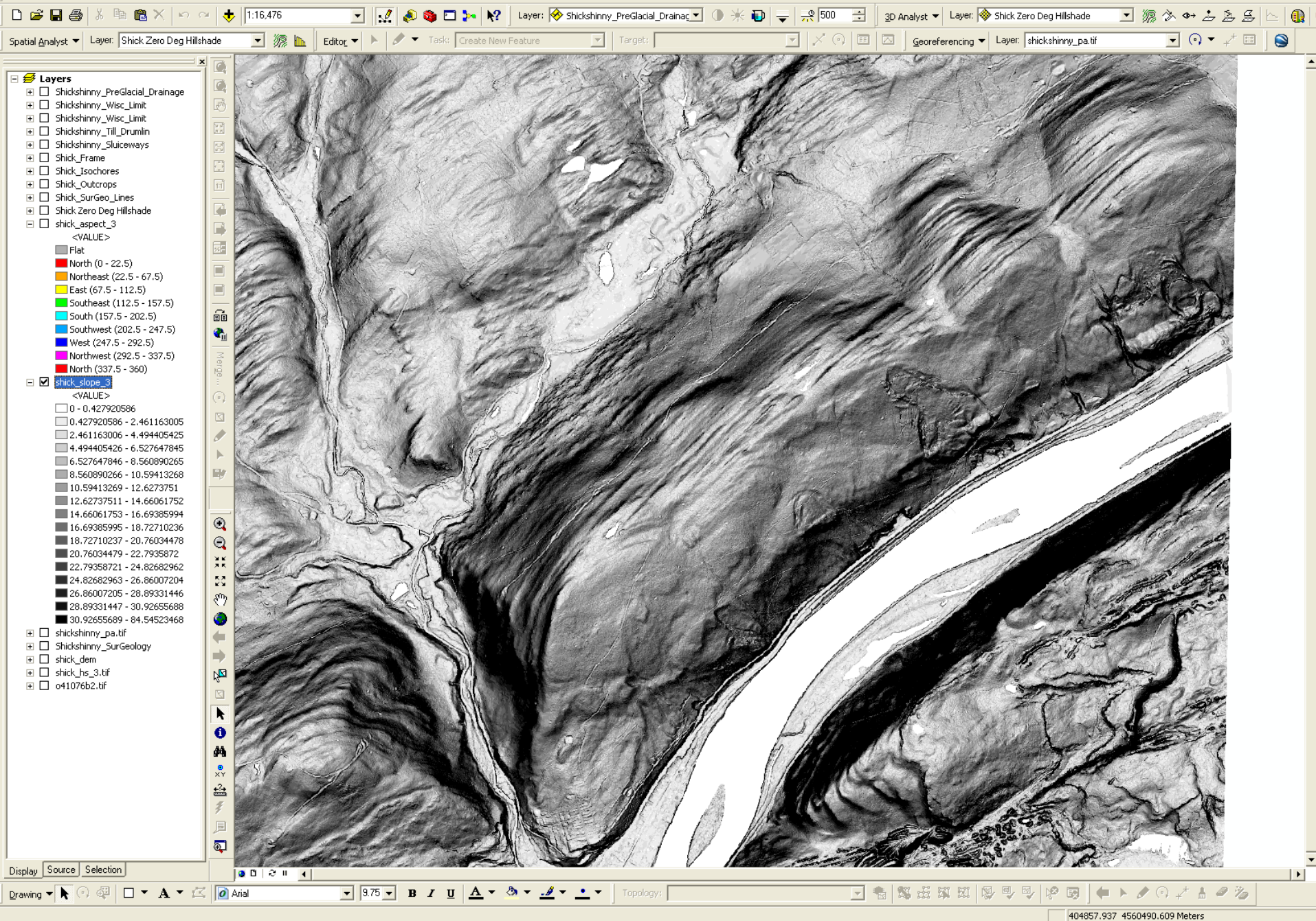


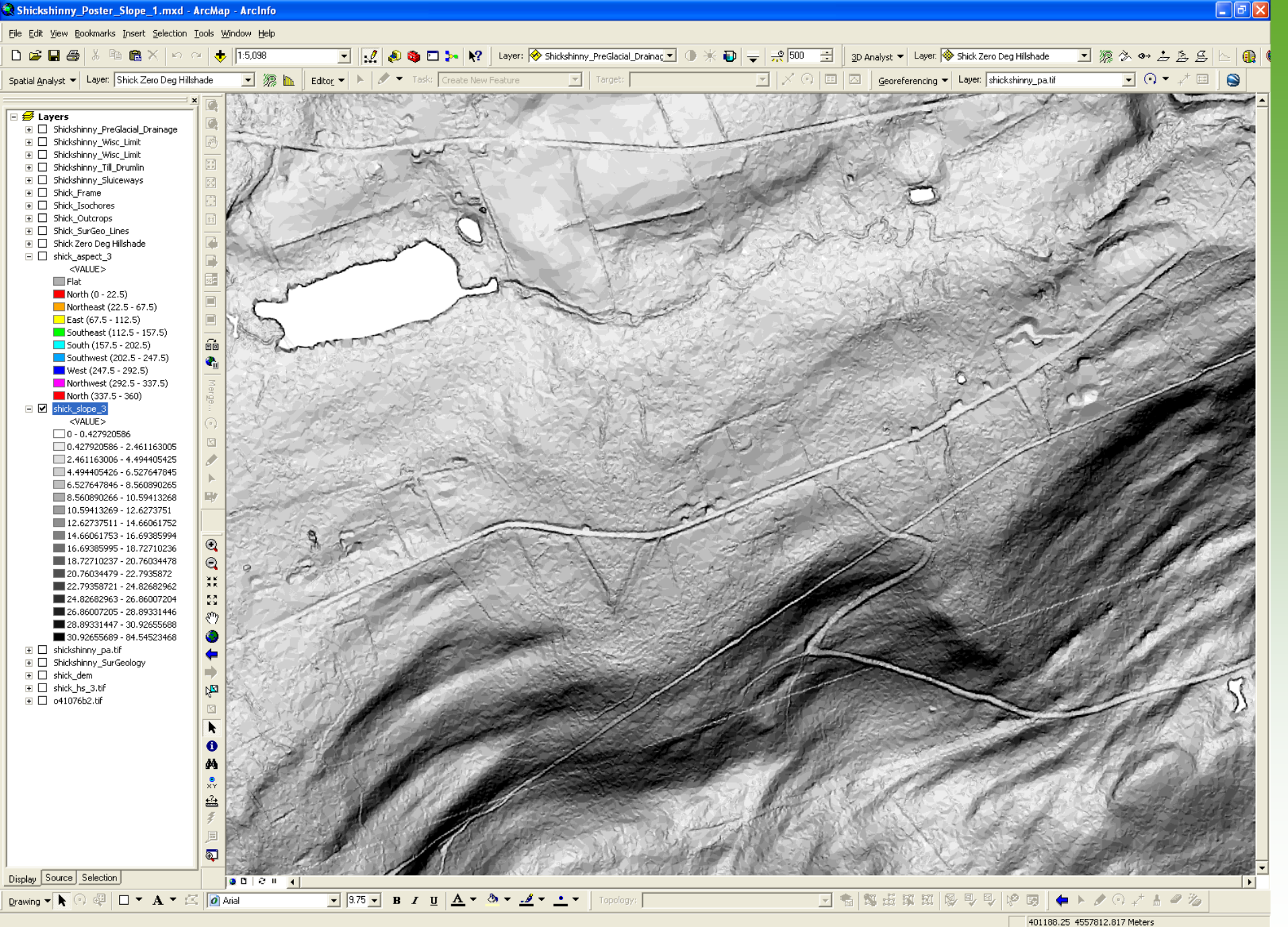
A standard deviation and 1/4 interval size gives a nice spread over the histogram



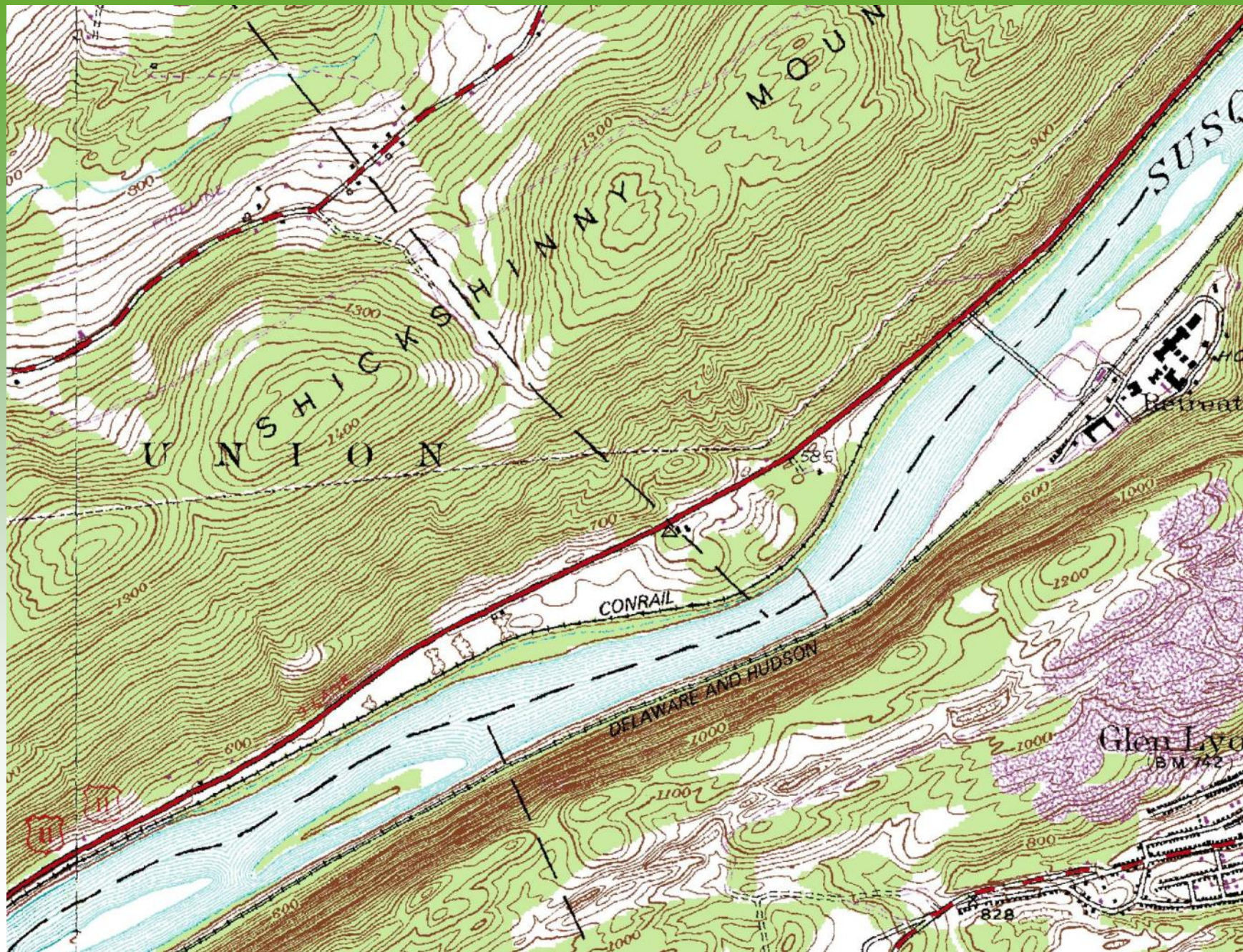
If necessary, invert the color ramp so white is flat and low angles progress in gray



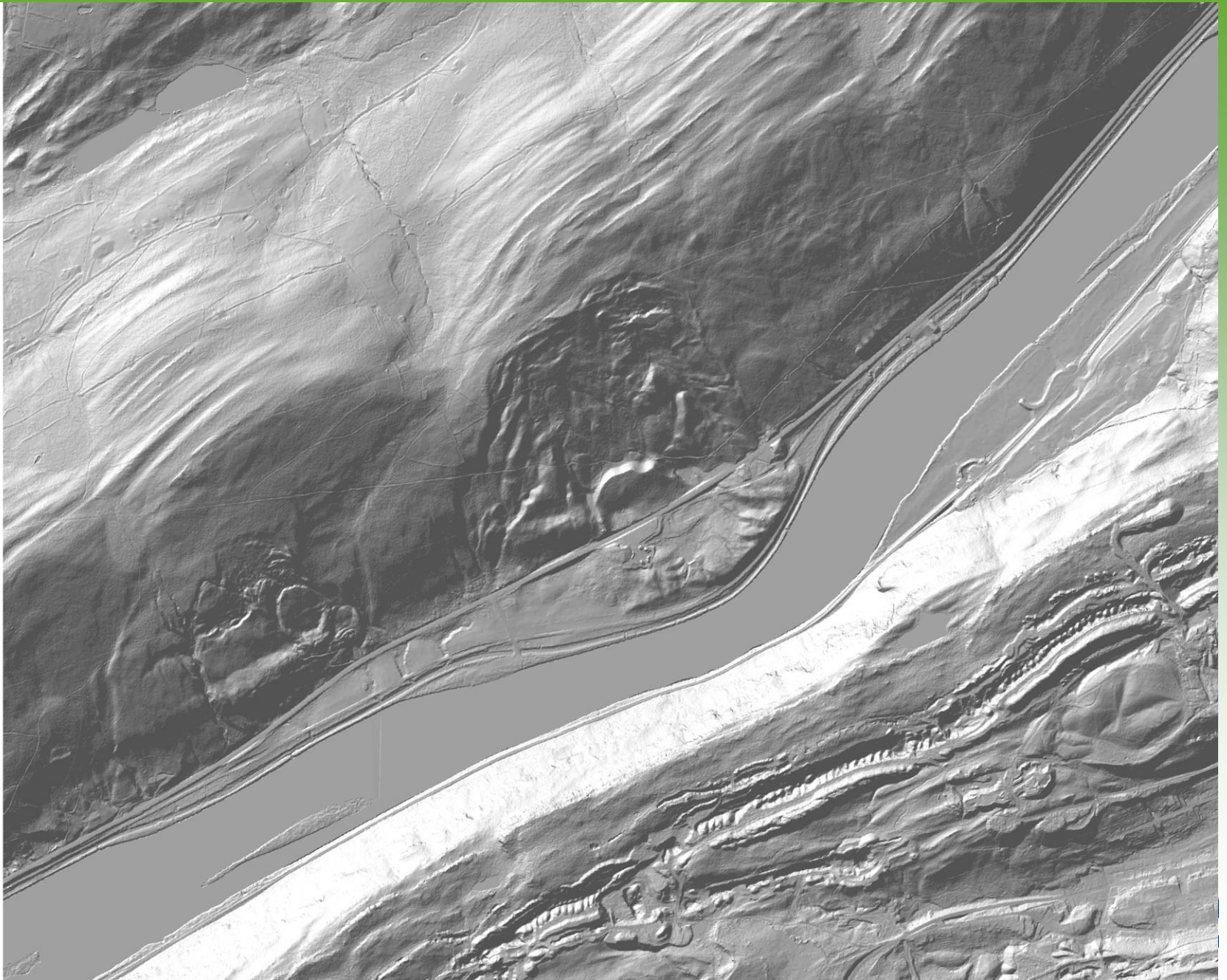


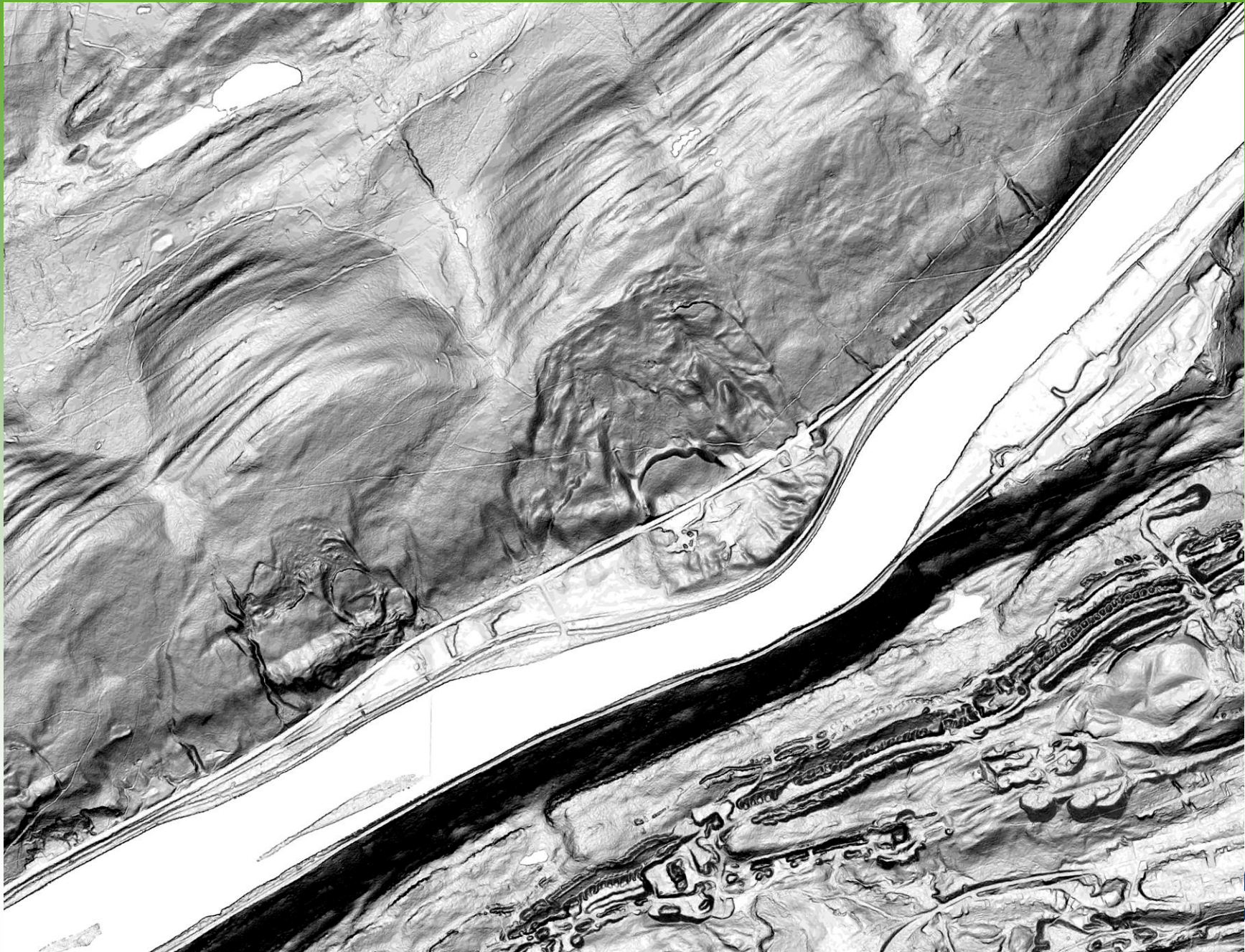


Examples –
Do you see what I see...?



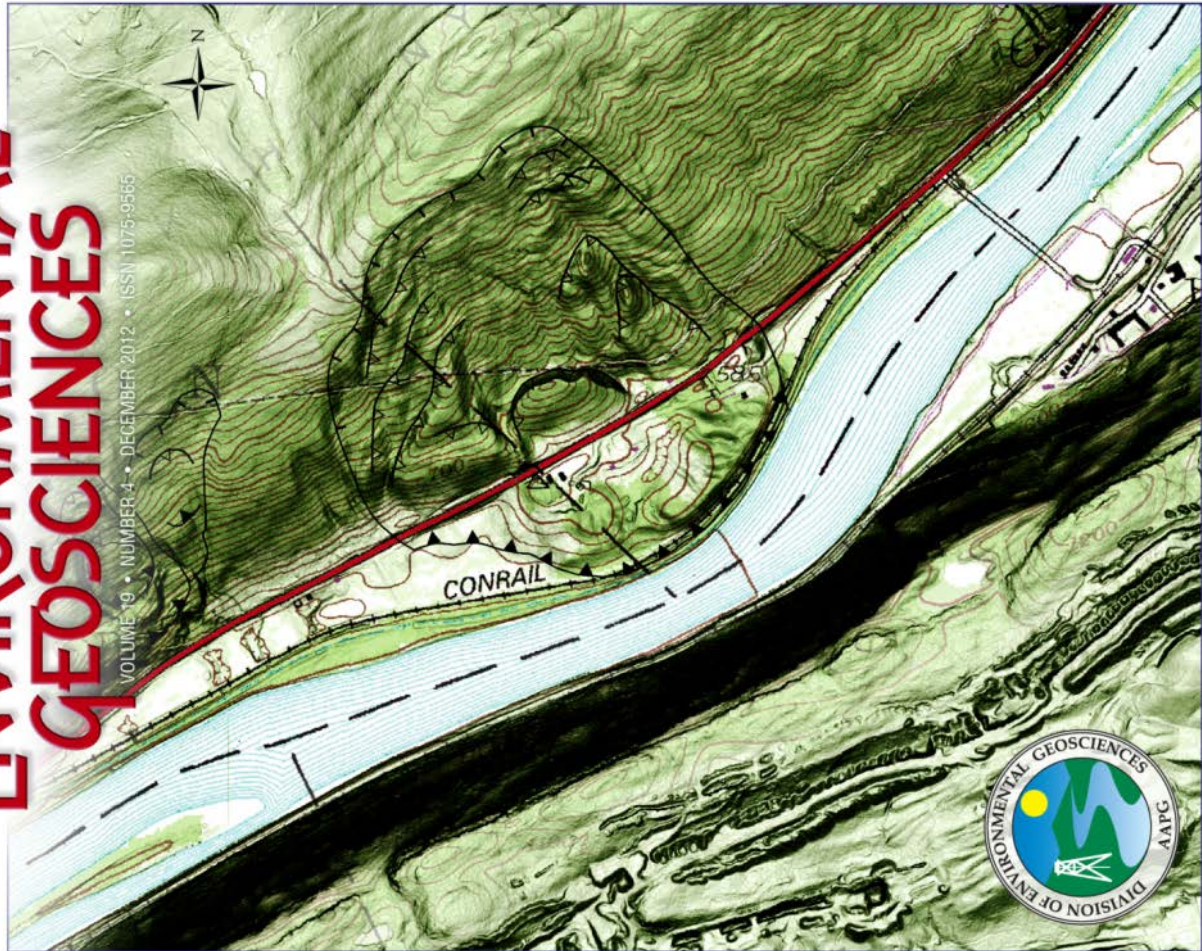






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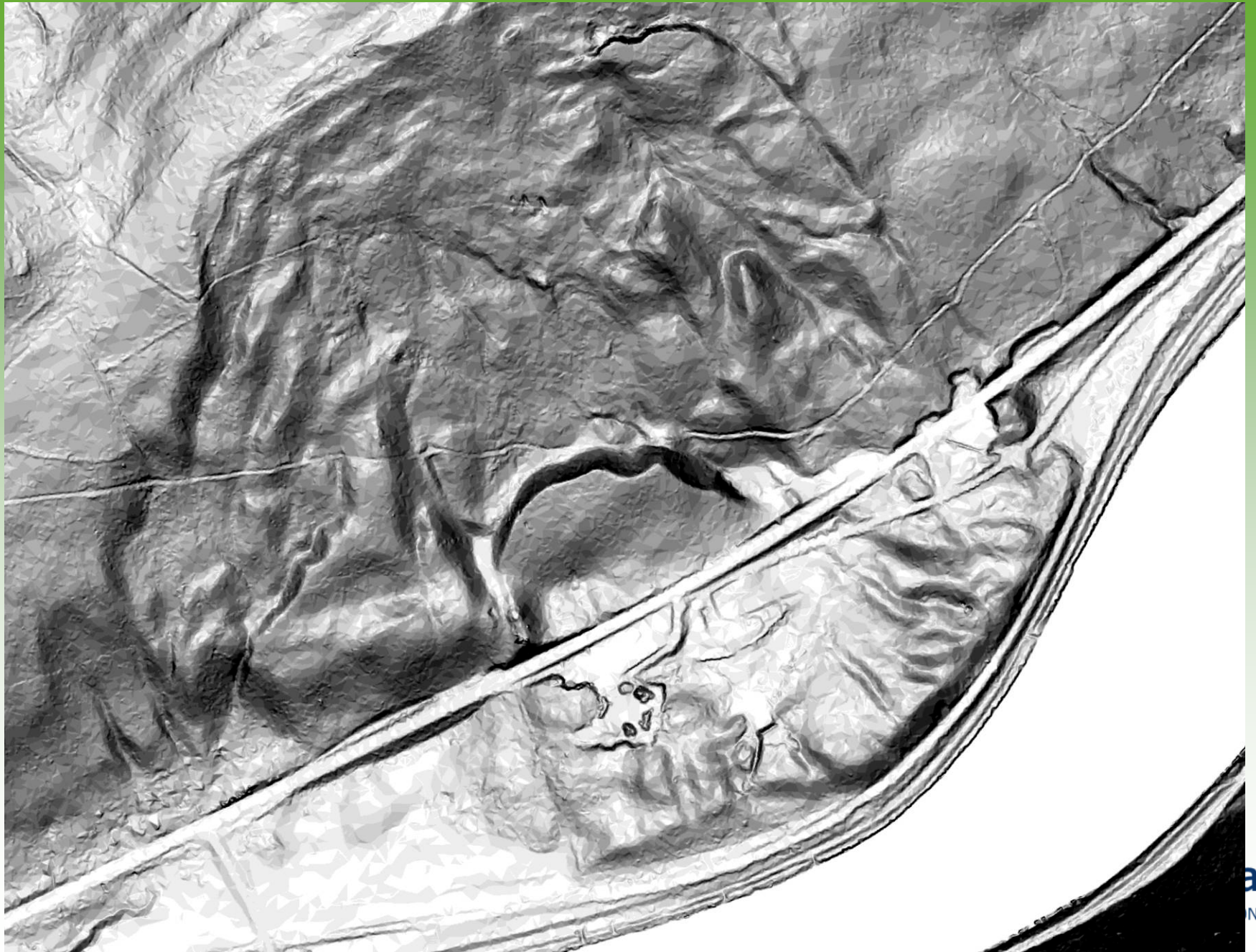
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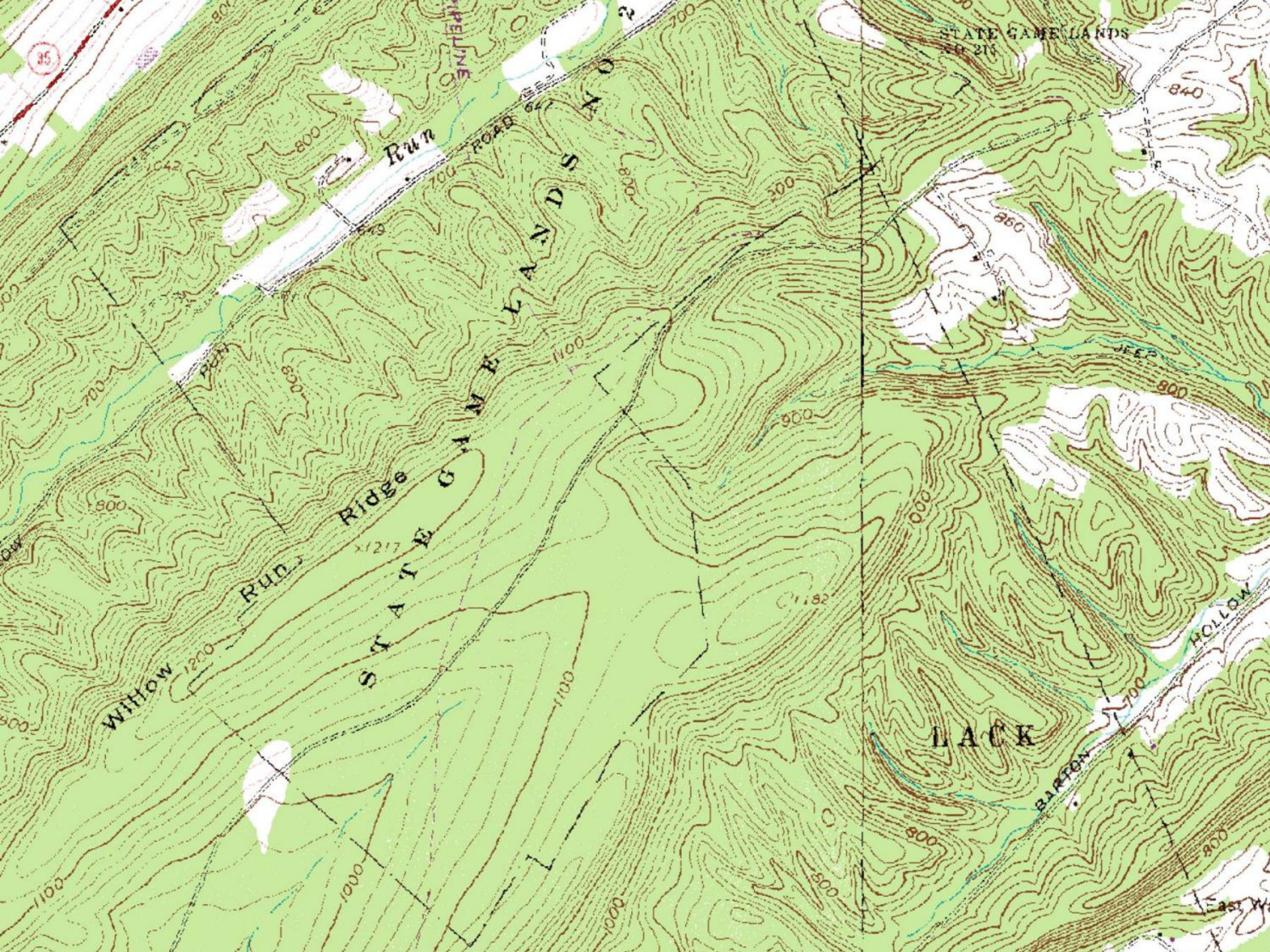


Toe

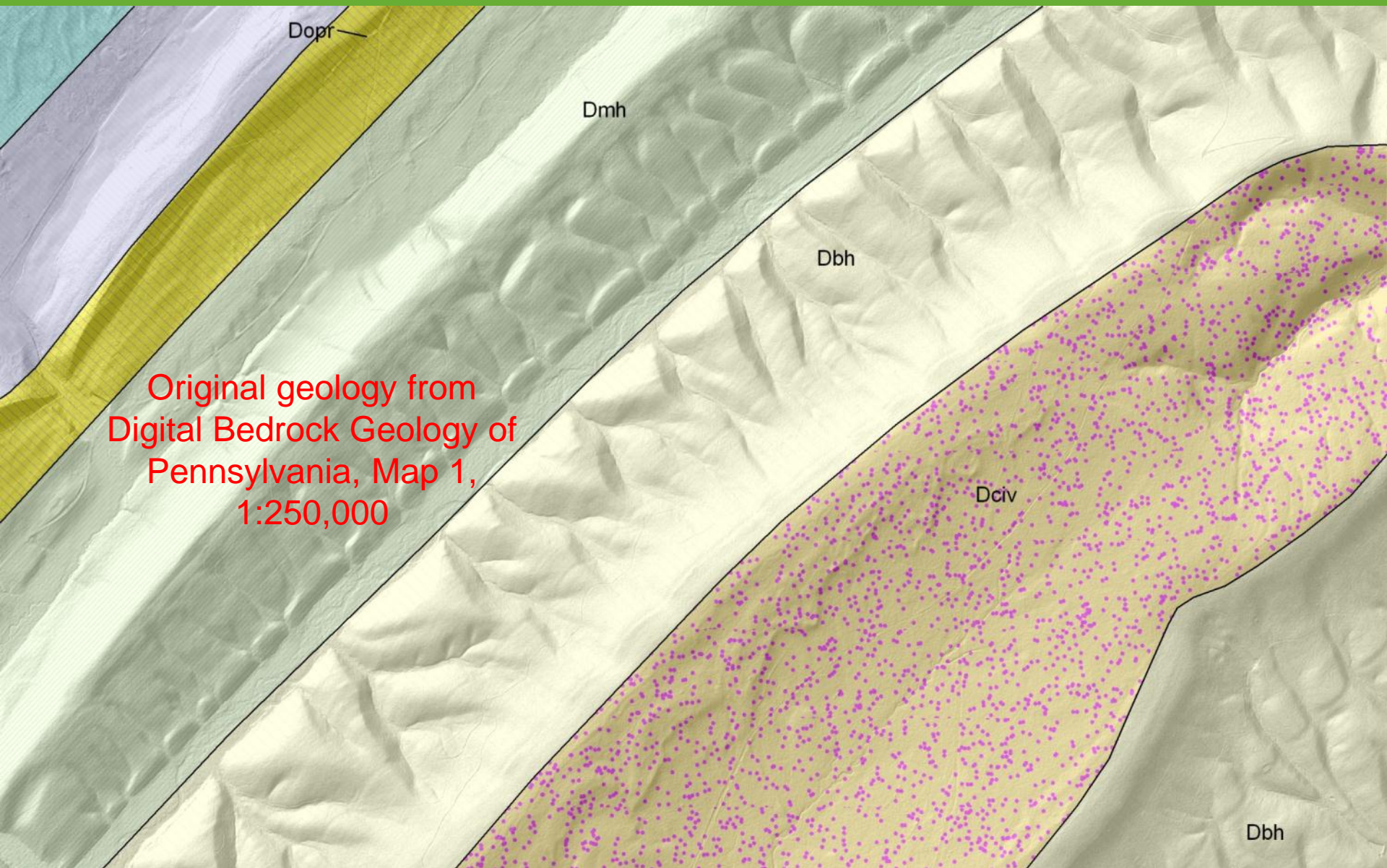


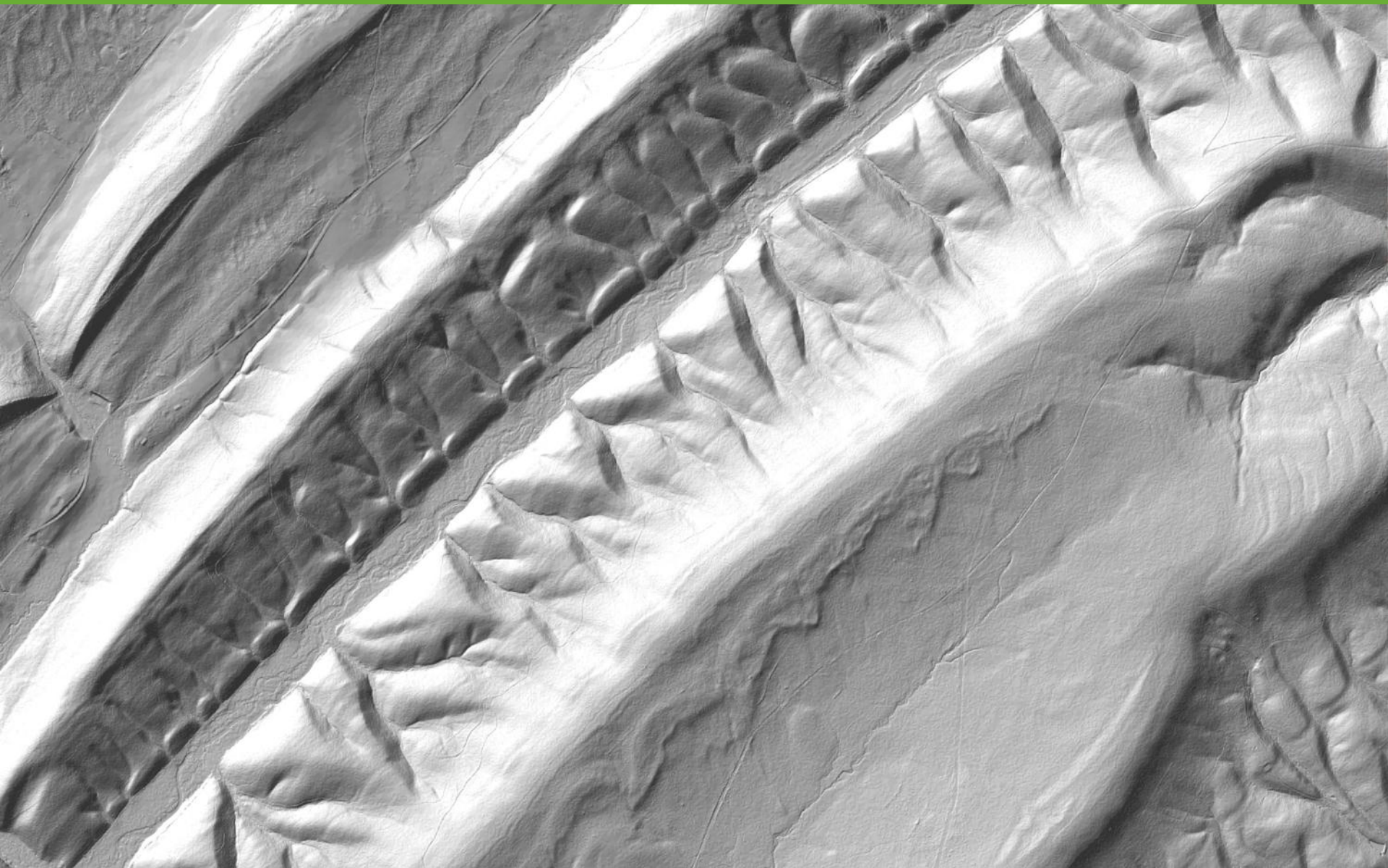


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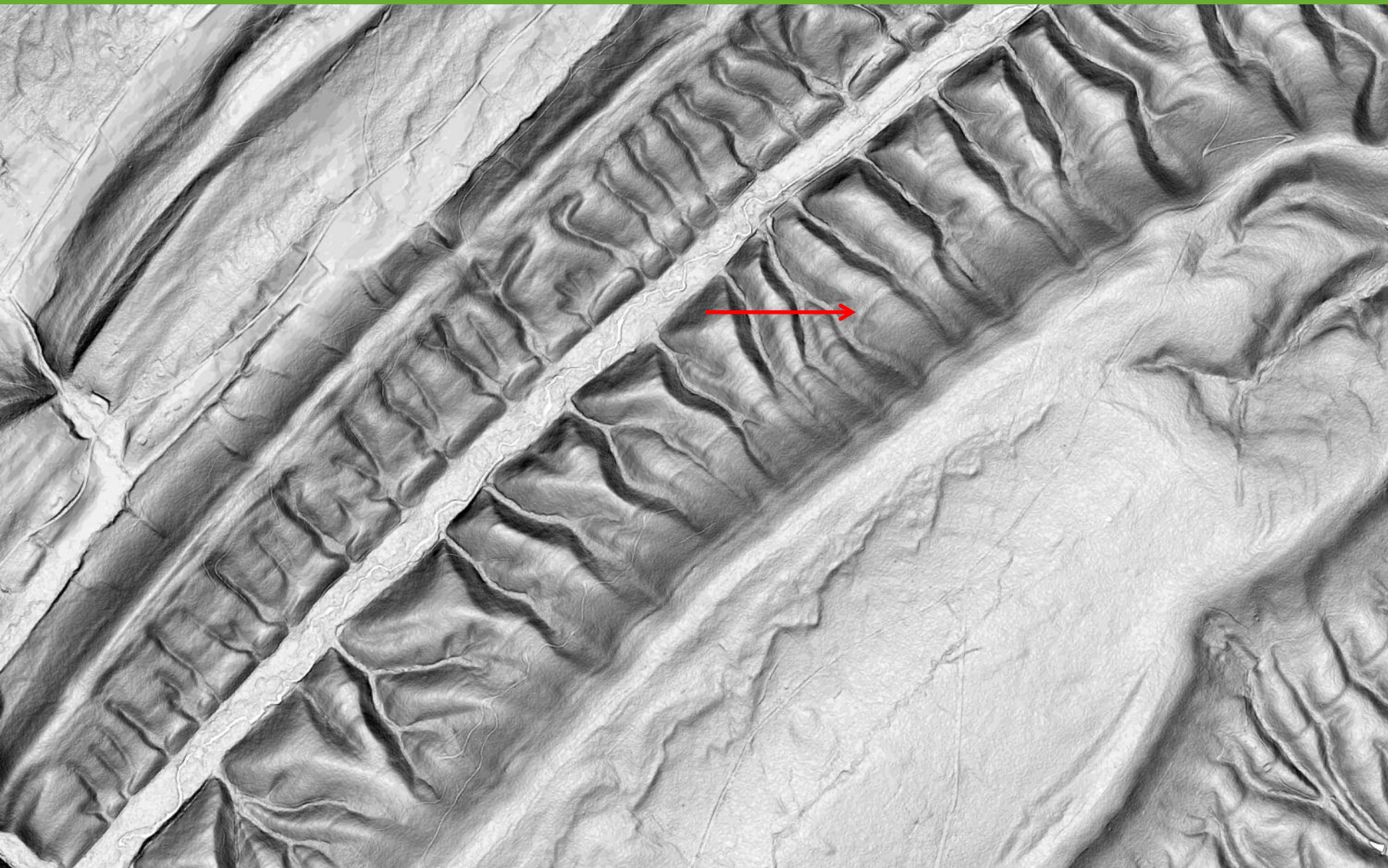




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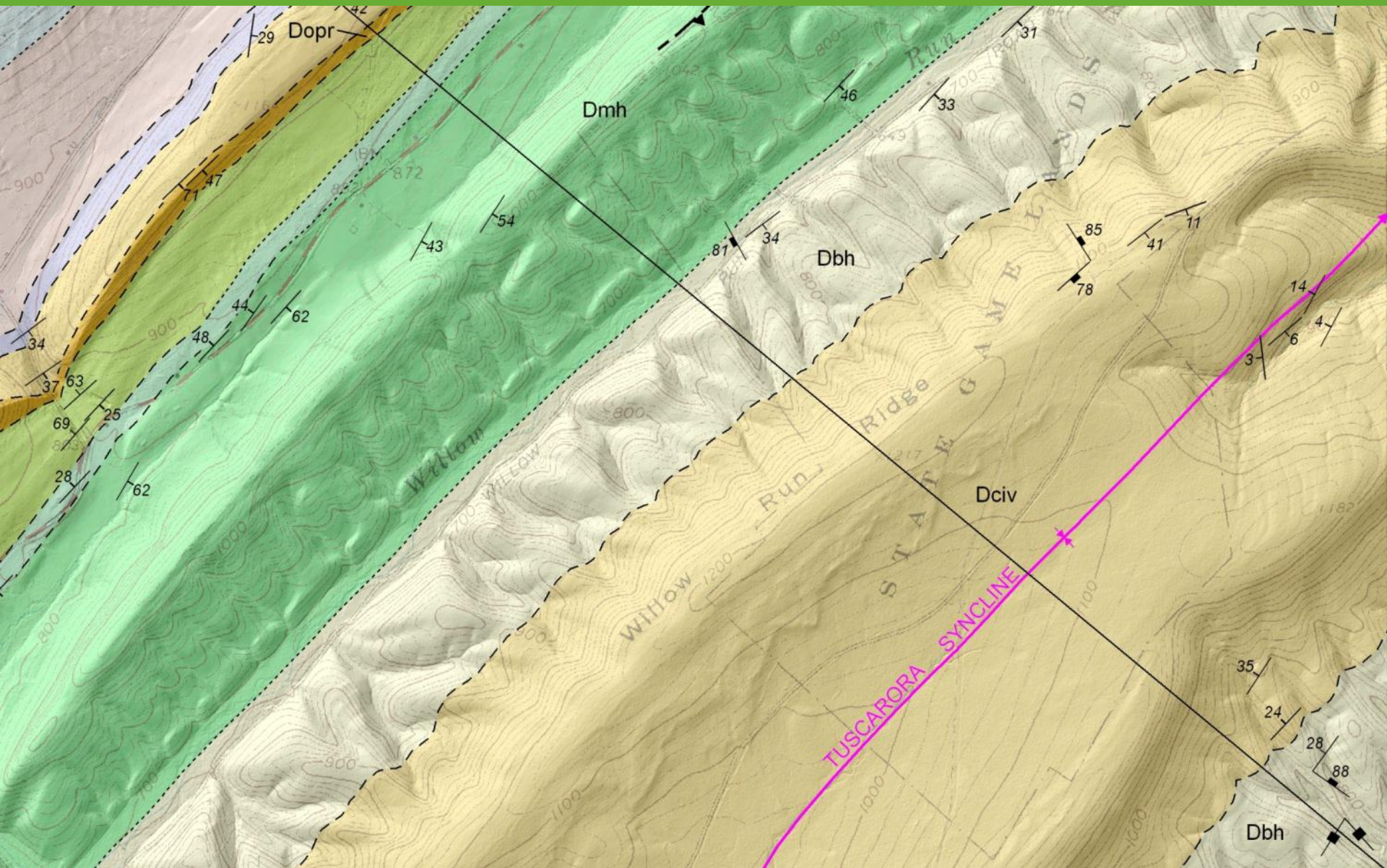


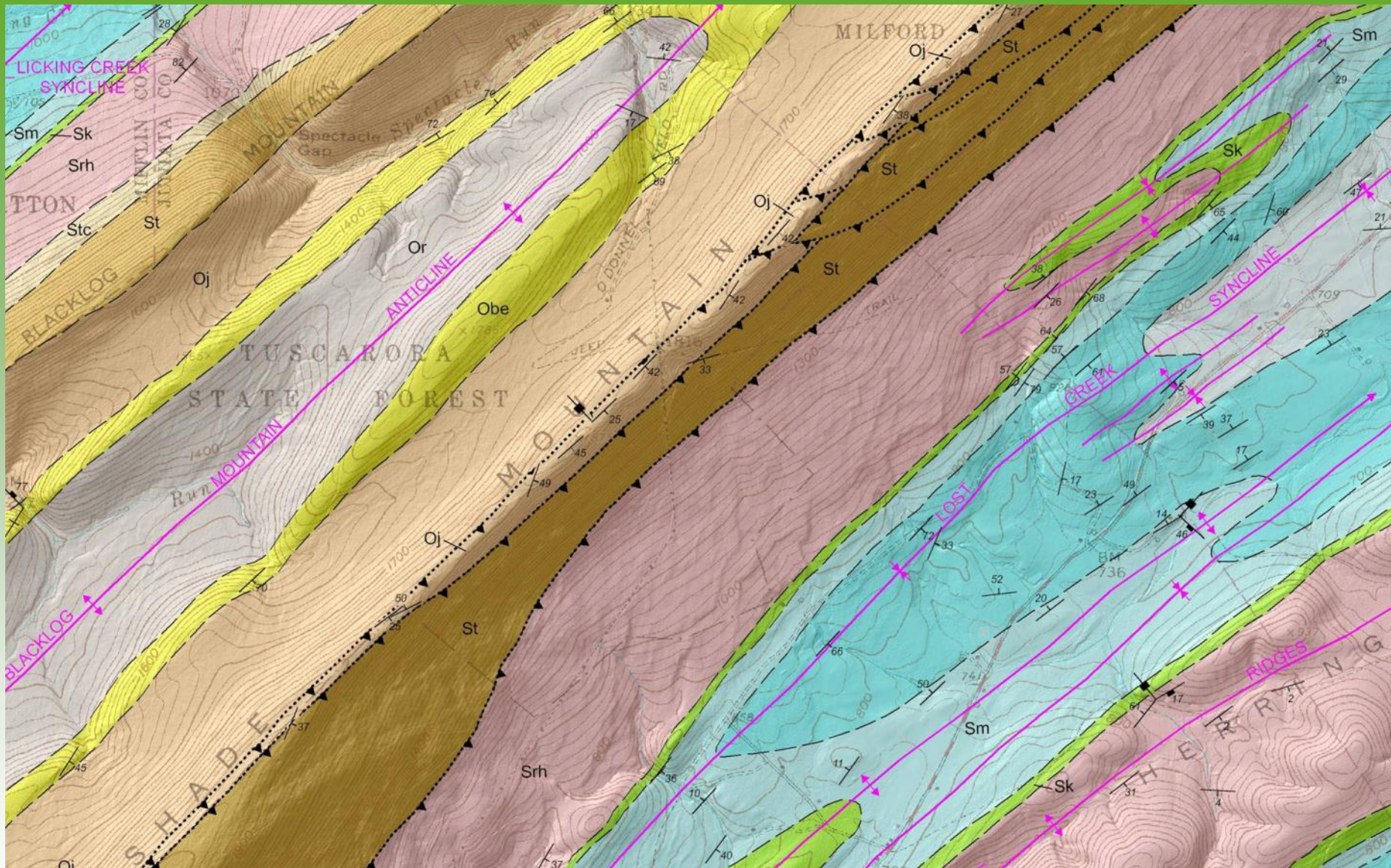
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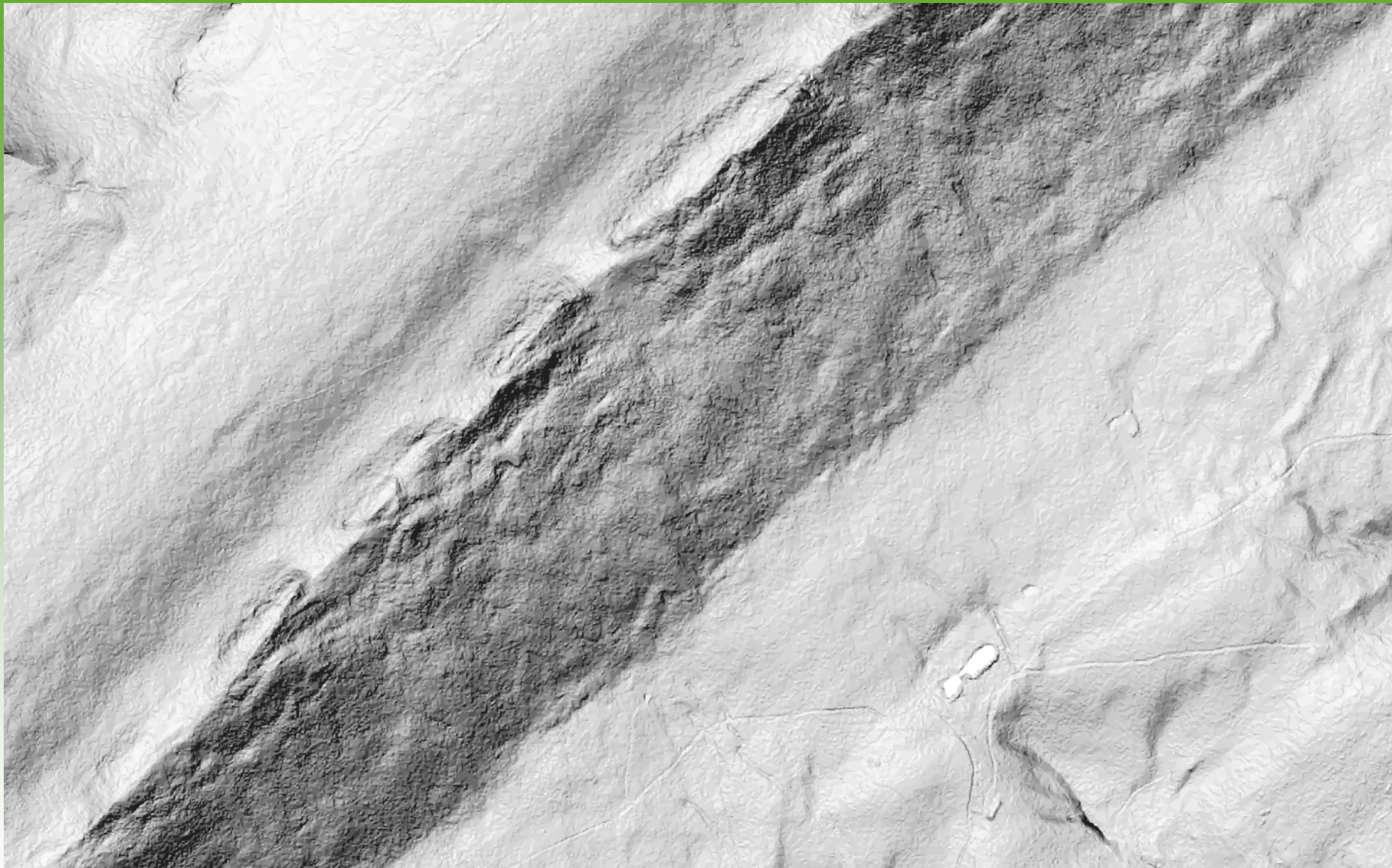
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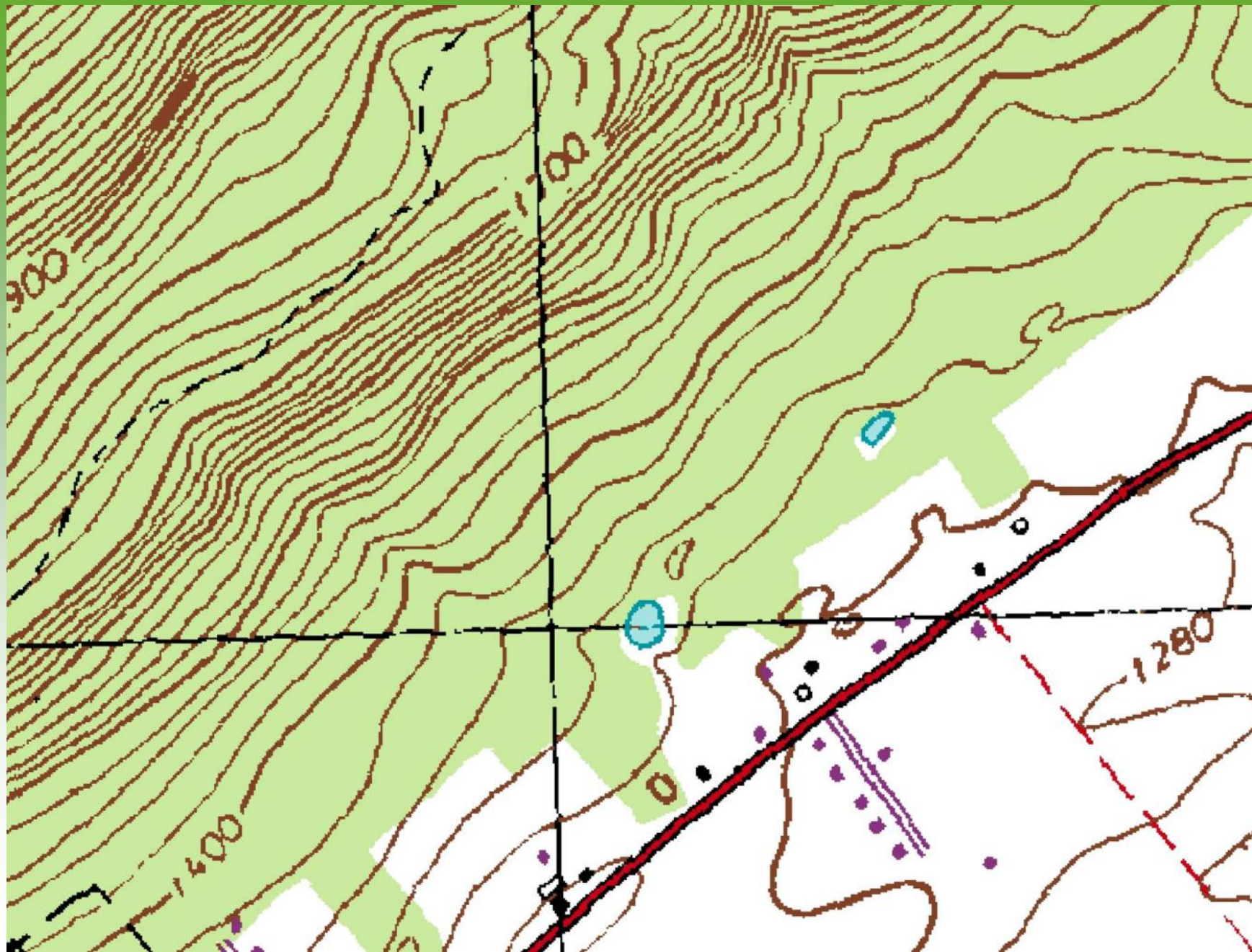
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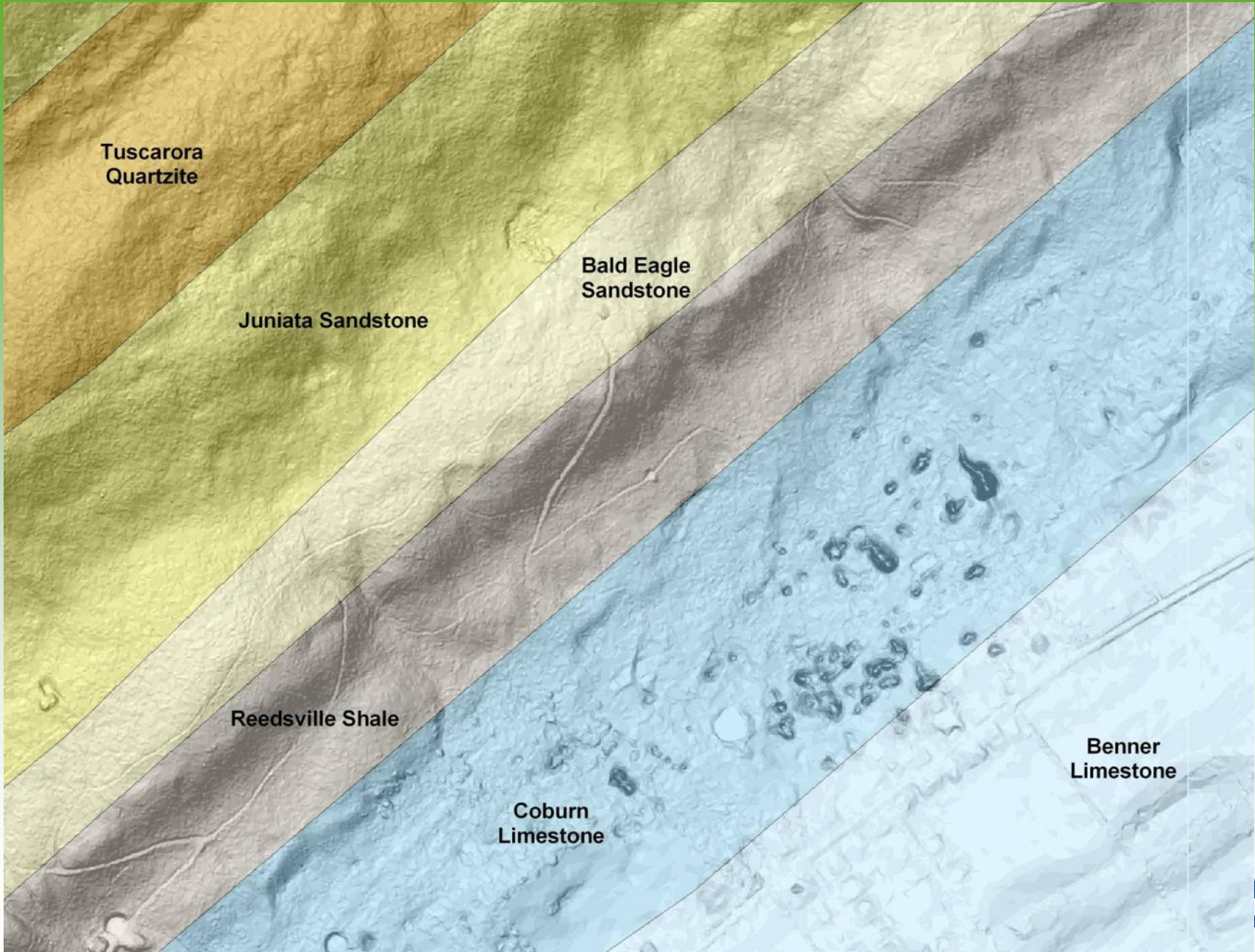


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**Tuscarora
Quartzite**

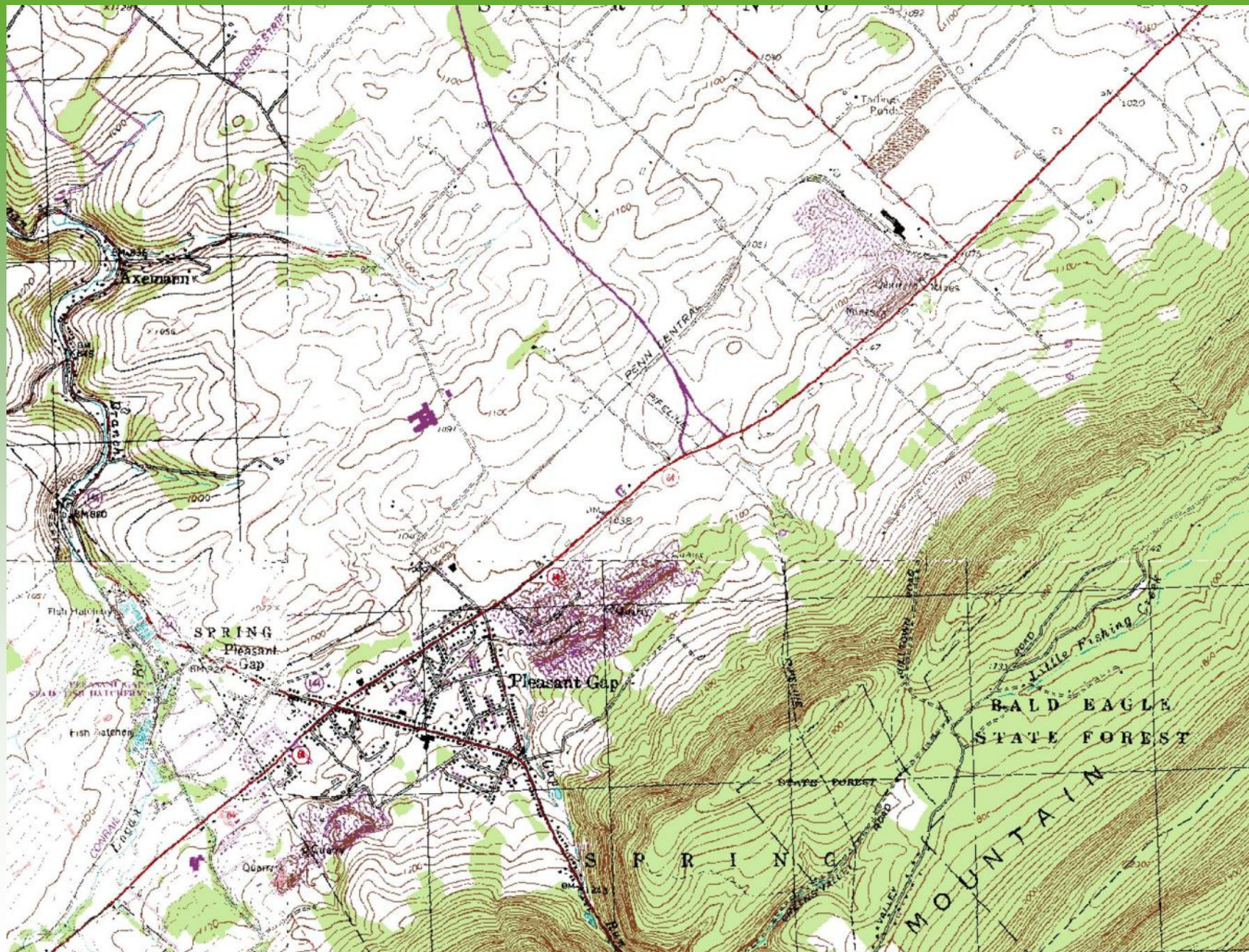
Juniata Sandstone

**Bald Eagle
Sandstone**

Reedsville Shale

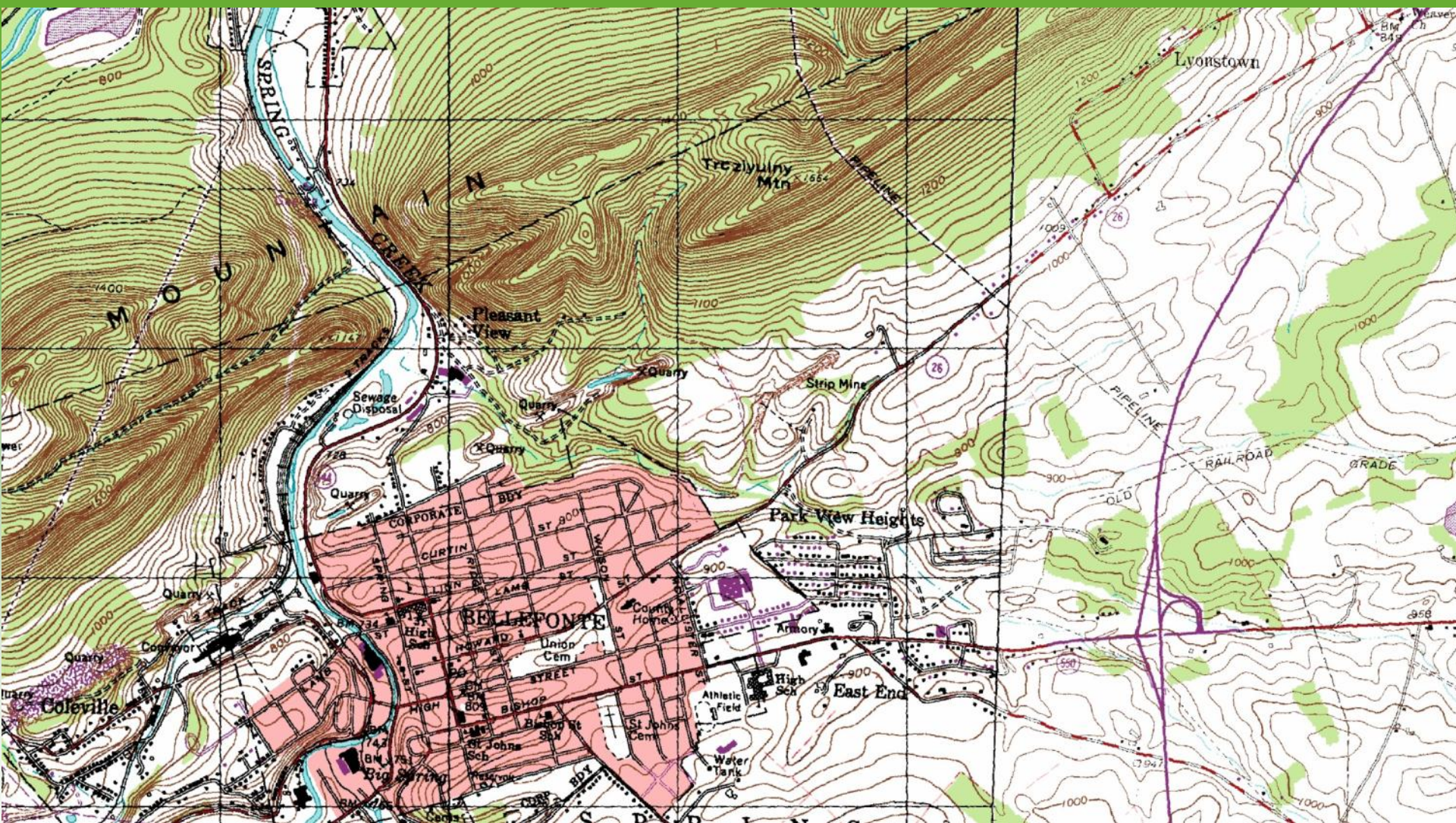
**Coburn
Limestone**

**Benner
Limestone**









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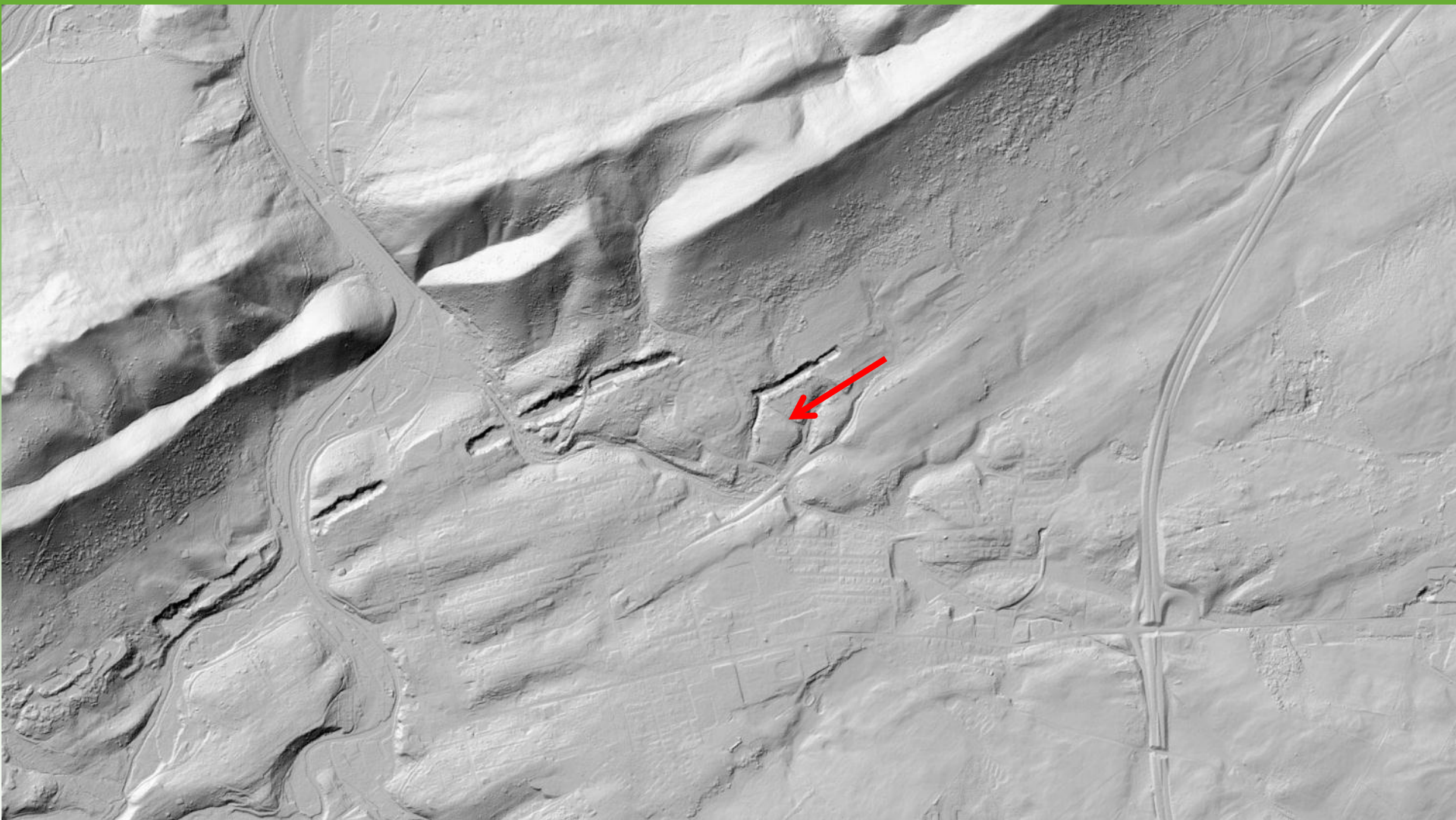
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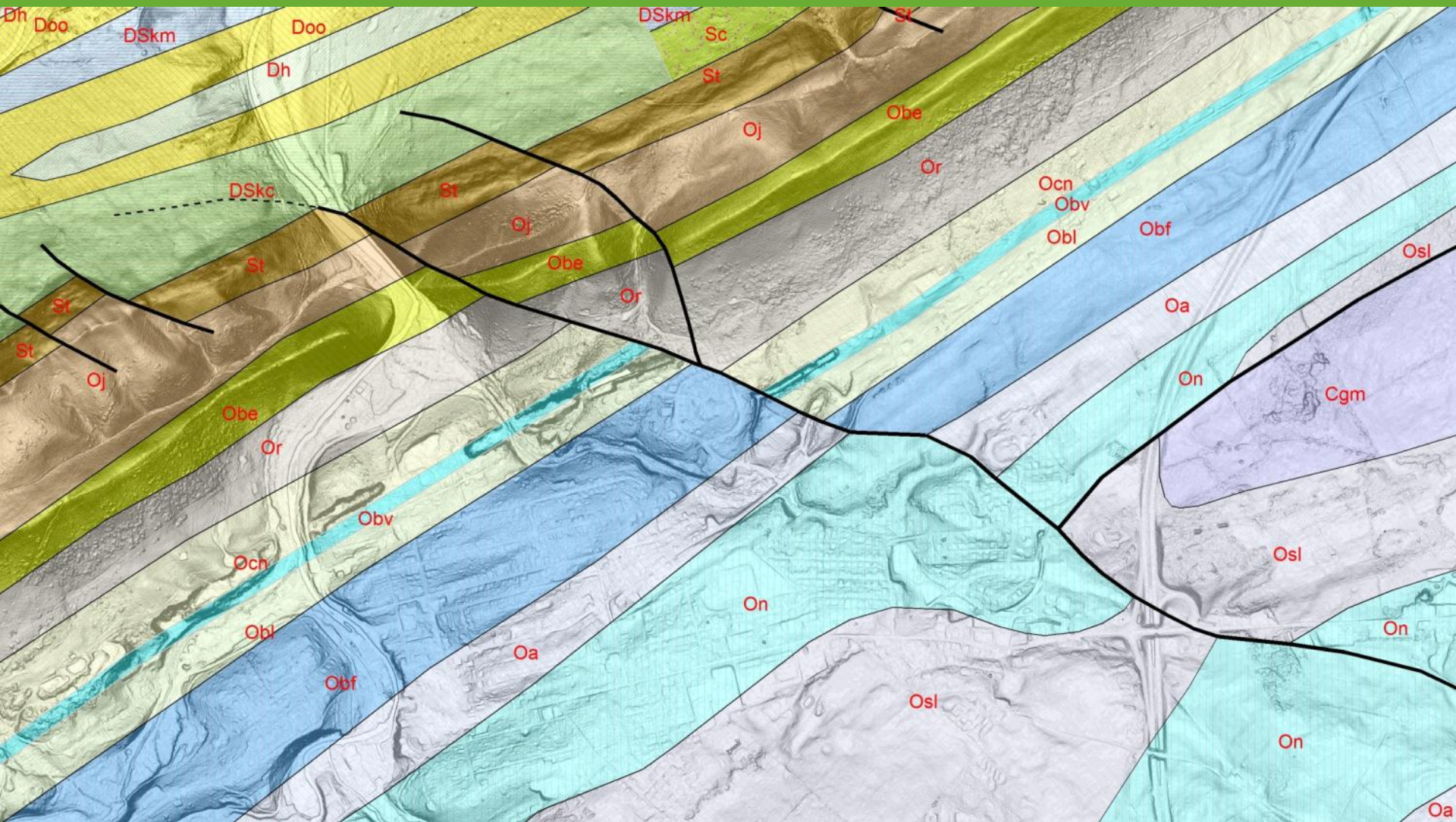
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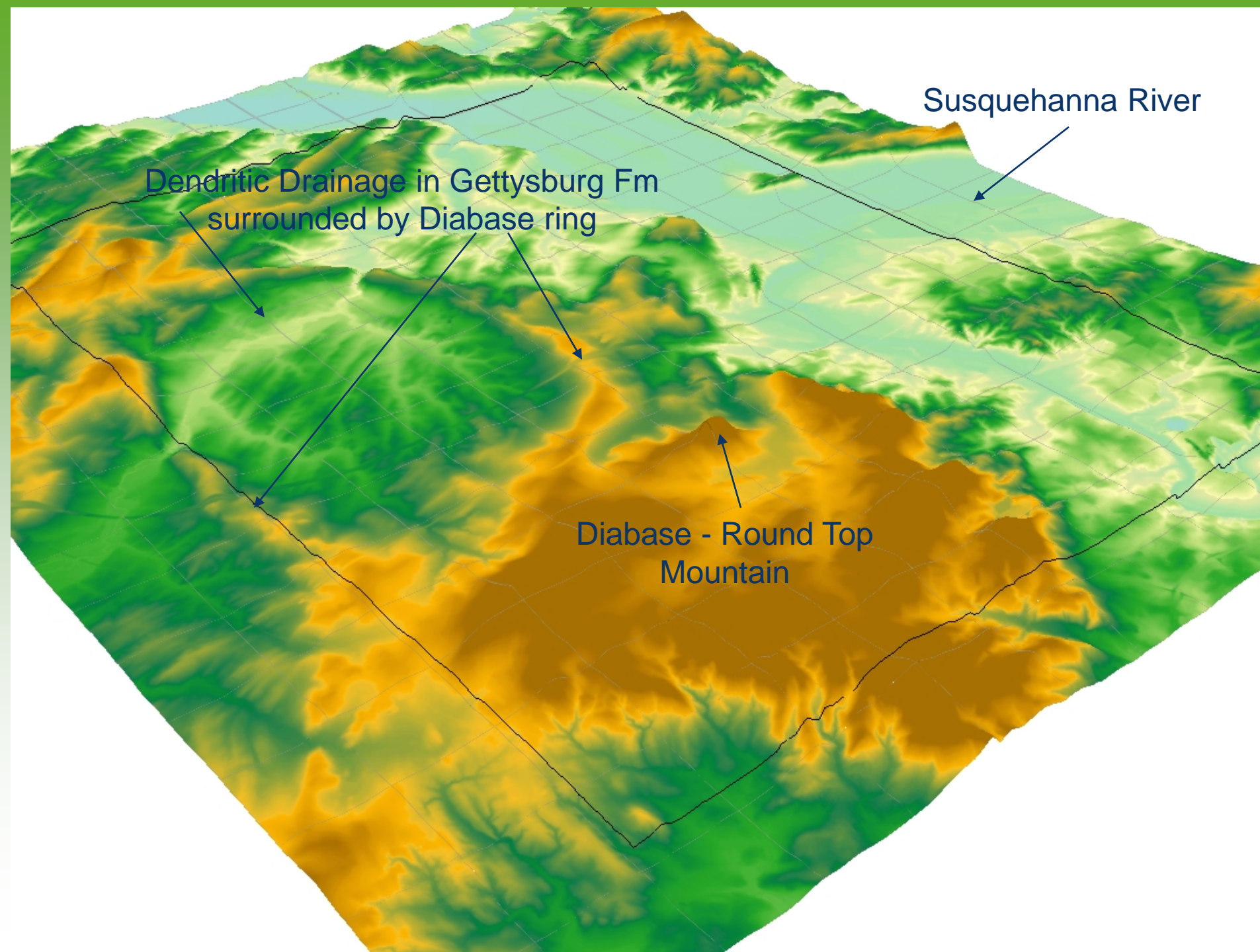


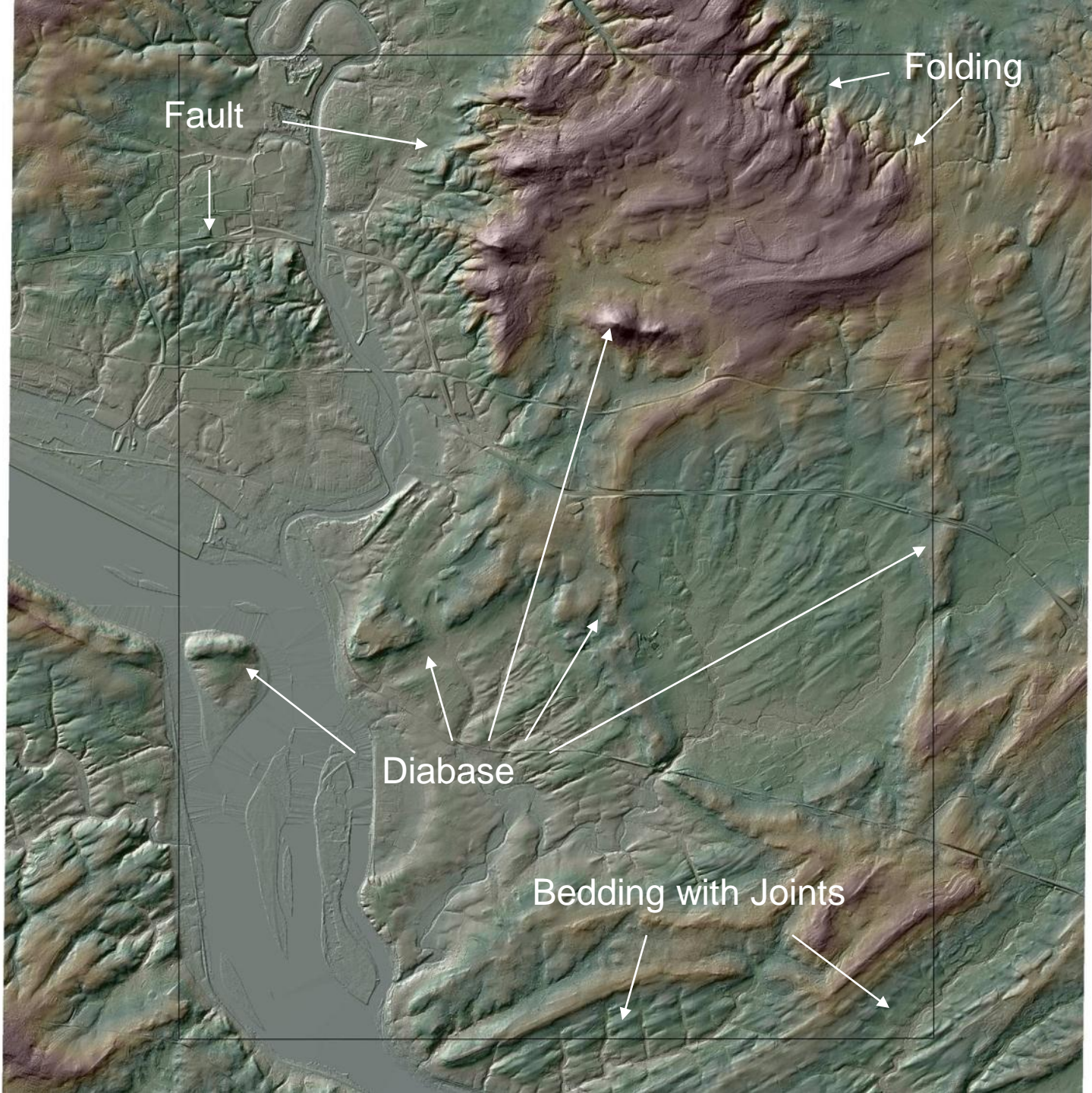
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Susquehanna River

Dendritic Drainage in Gettysburg Fm
surrounded by Diabase ring

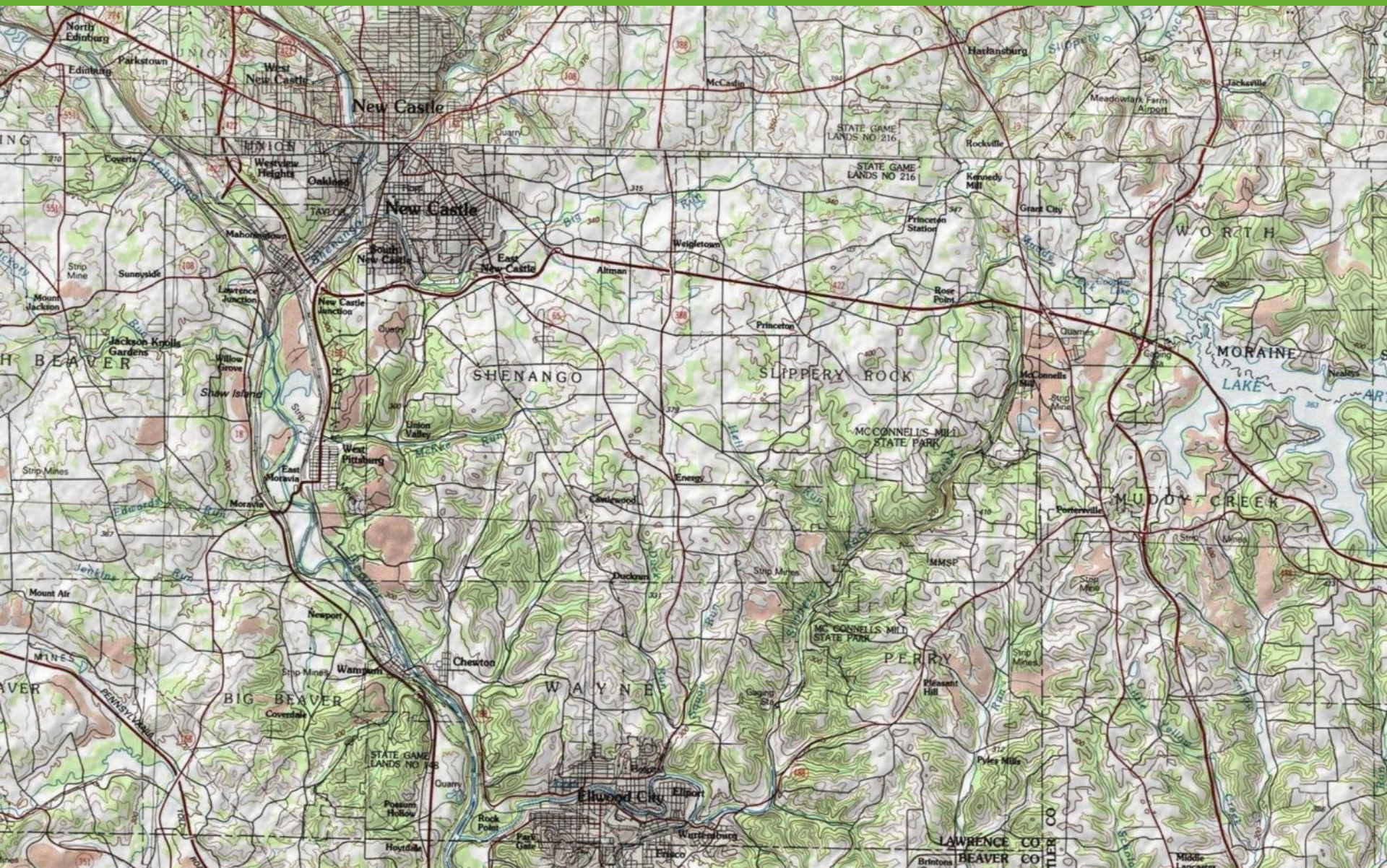
Diabase - Round Top
Mountain





Surficial Features

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Distinct texture change...

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Quick glacial boundary.

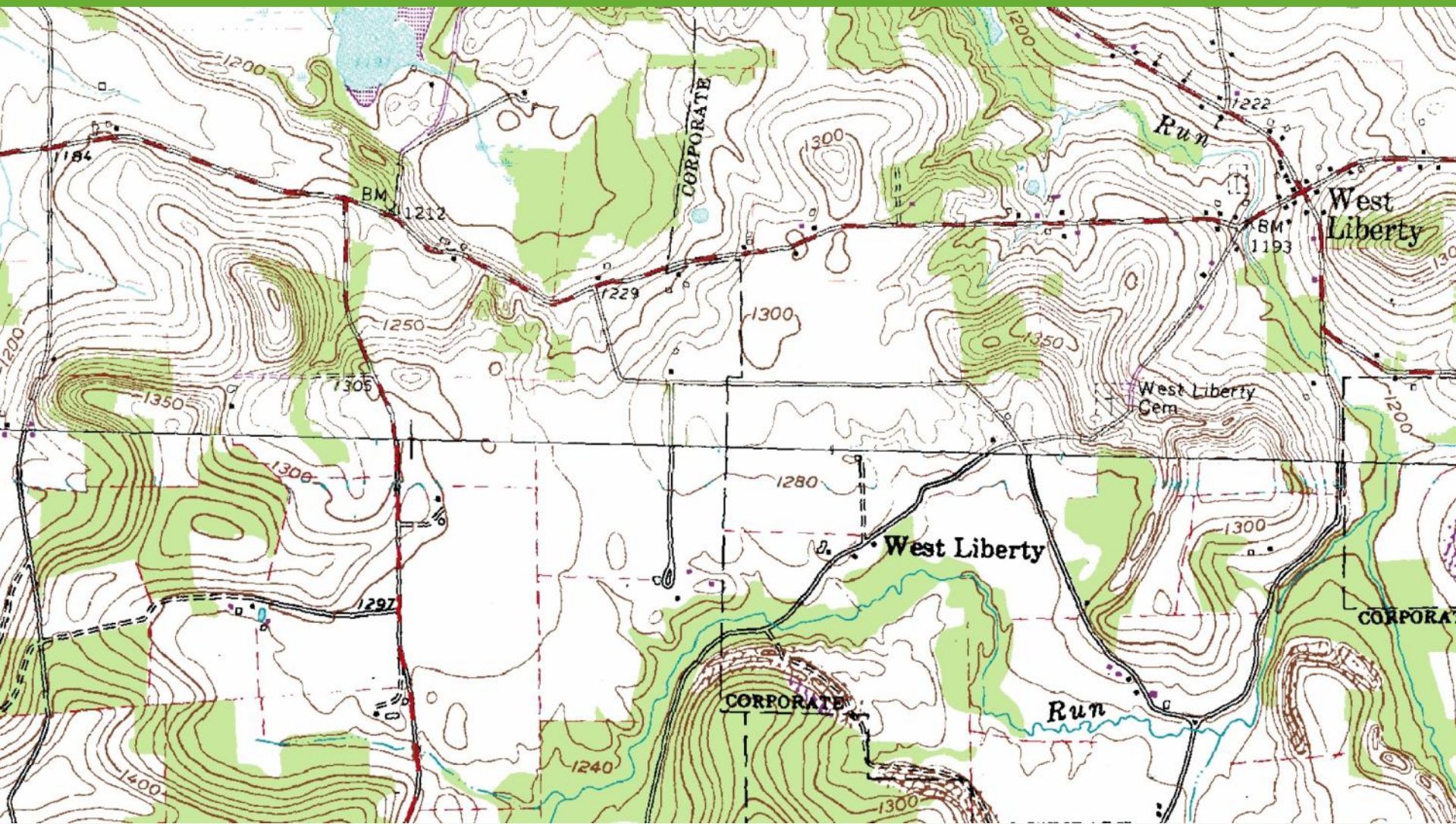
A grayscale topographic map of a landscape. A prominent, winding, light-colored ridge runs diagonally from the upper right towards the lower left. The ridge has a distinct, repetitive scalloped or bedded appearance. To the left of this ridge, the terrain is more rounded and less defined. To the right, the terrain is more rugged with more pronounced ridges and valleys. A solid blue line is drawn across the upper portion of the map, starting from the top left and extending towards the right edge, passing above the main ridge.

Bedding in the Slippery
Rock Gorge.

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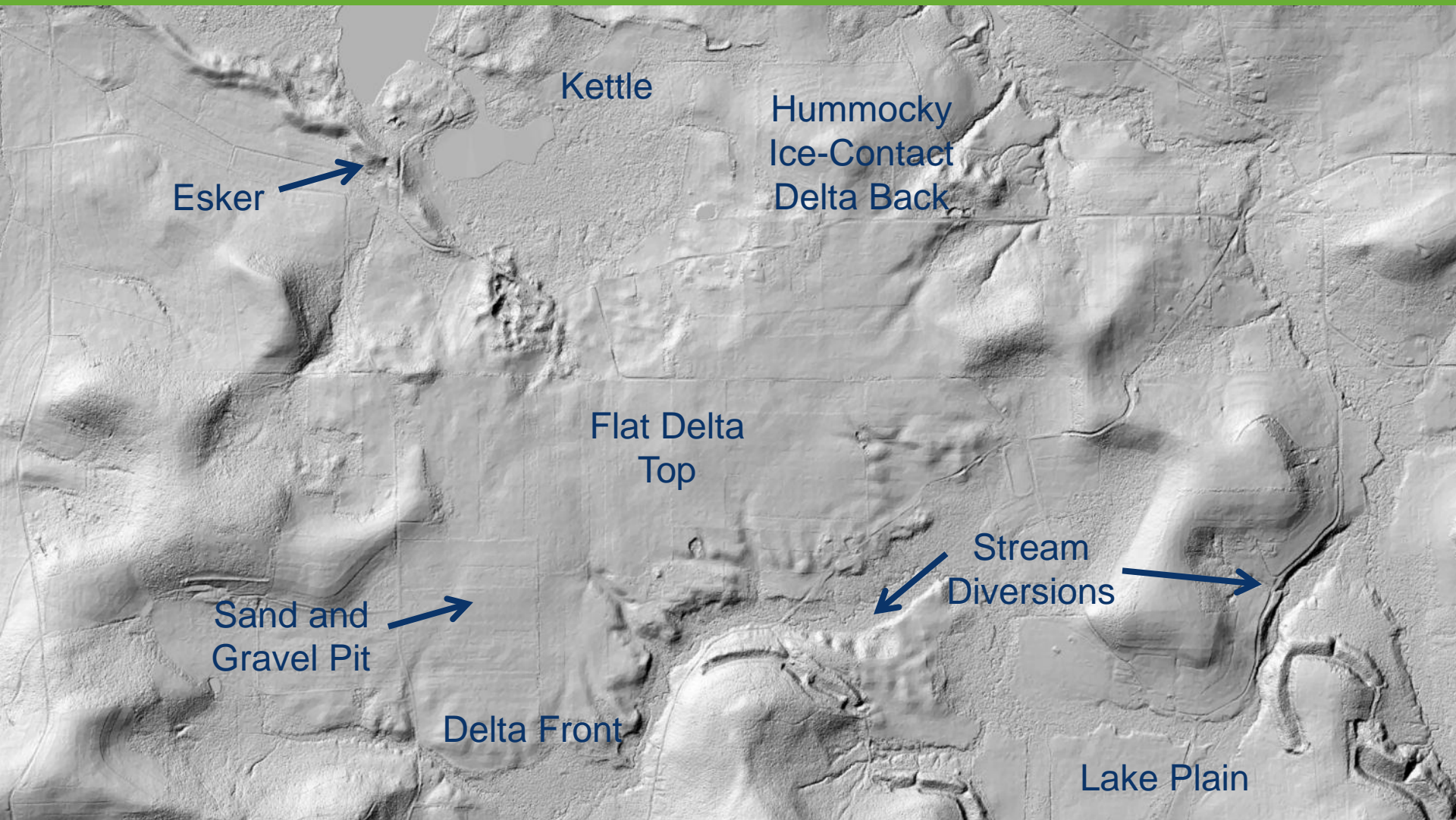
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Bill



...and the famous,
rarely seen, Pleistocene
hummingbird!

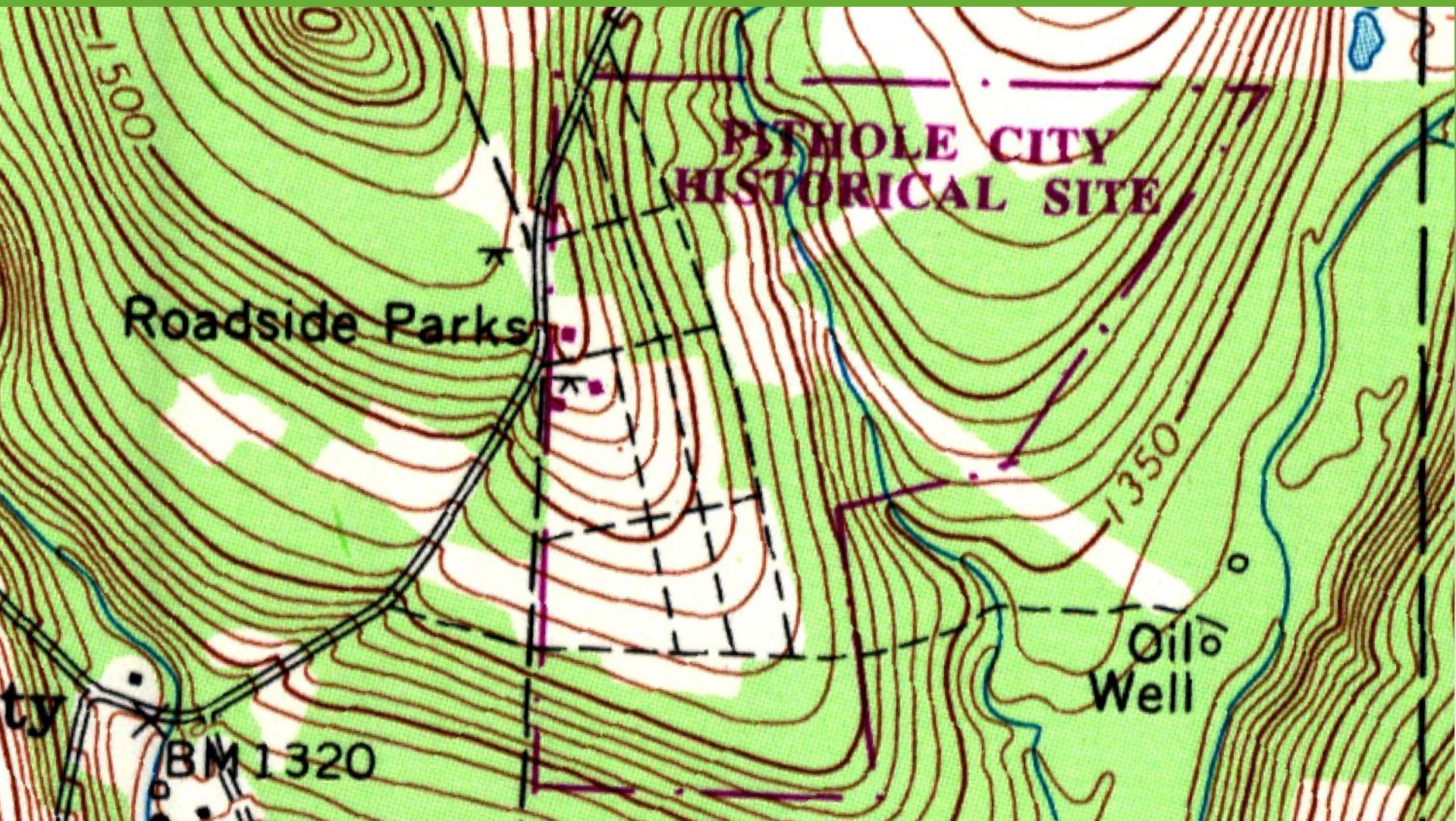
Geo-archeology

(Some interesting stuff)

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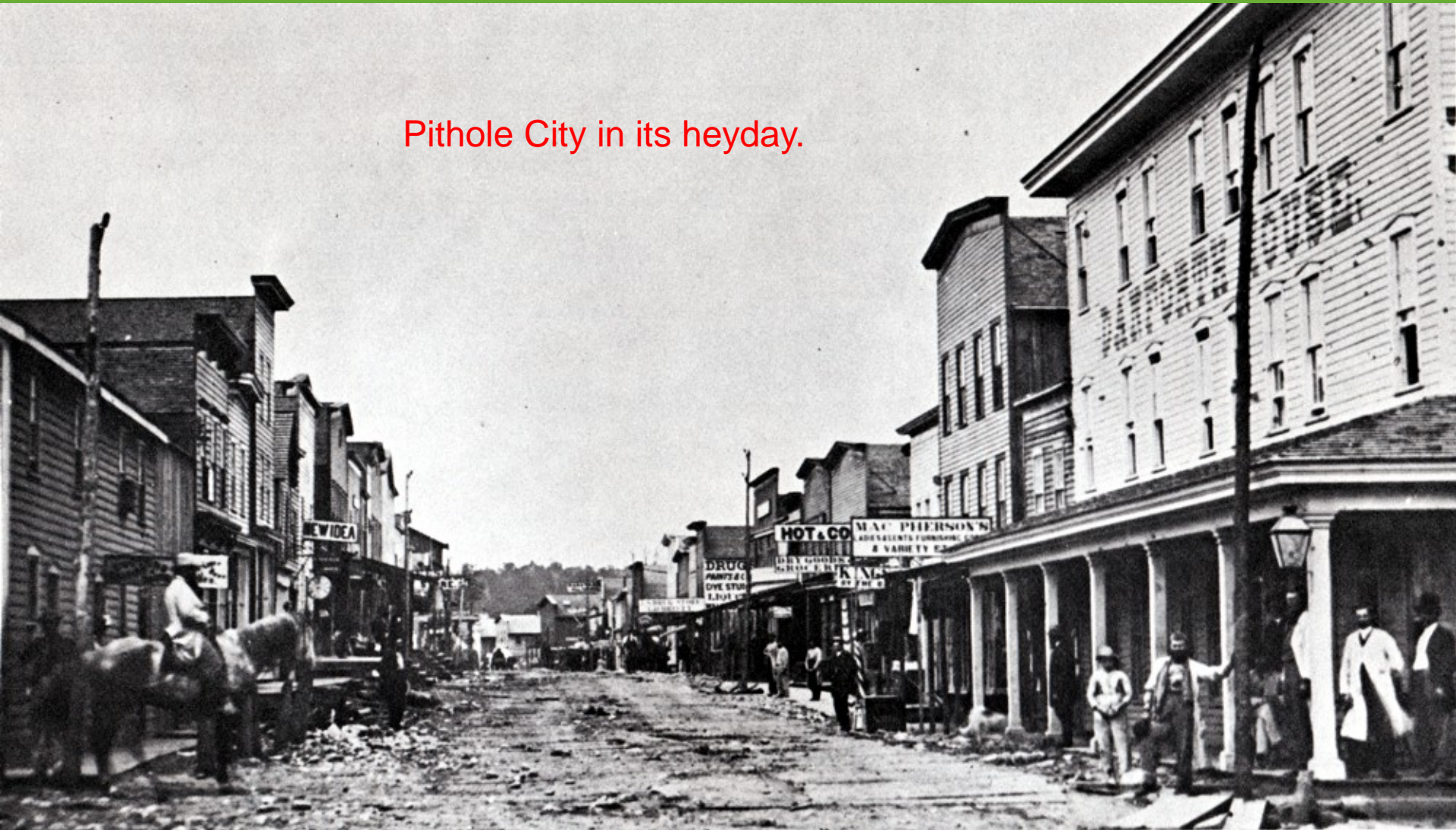


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Pithole – near Titusville, PA

- 1864 first oil well drilled
- Jan 1865 – 250 Bbl/day, population 2,000
- Sept 1865 – 6,000 Bbl/day, 15,000 people
- Jan 1866 – 4,000 people
- 1870 – population 281
- 1879 – town sold for \$4.37

Pithole City in its heyday.





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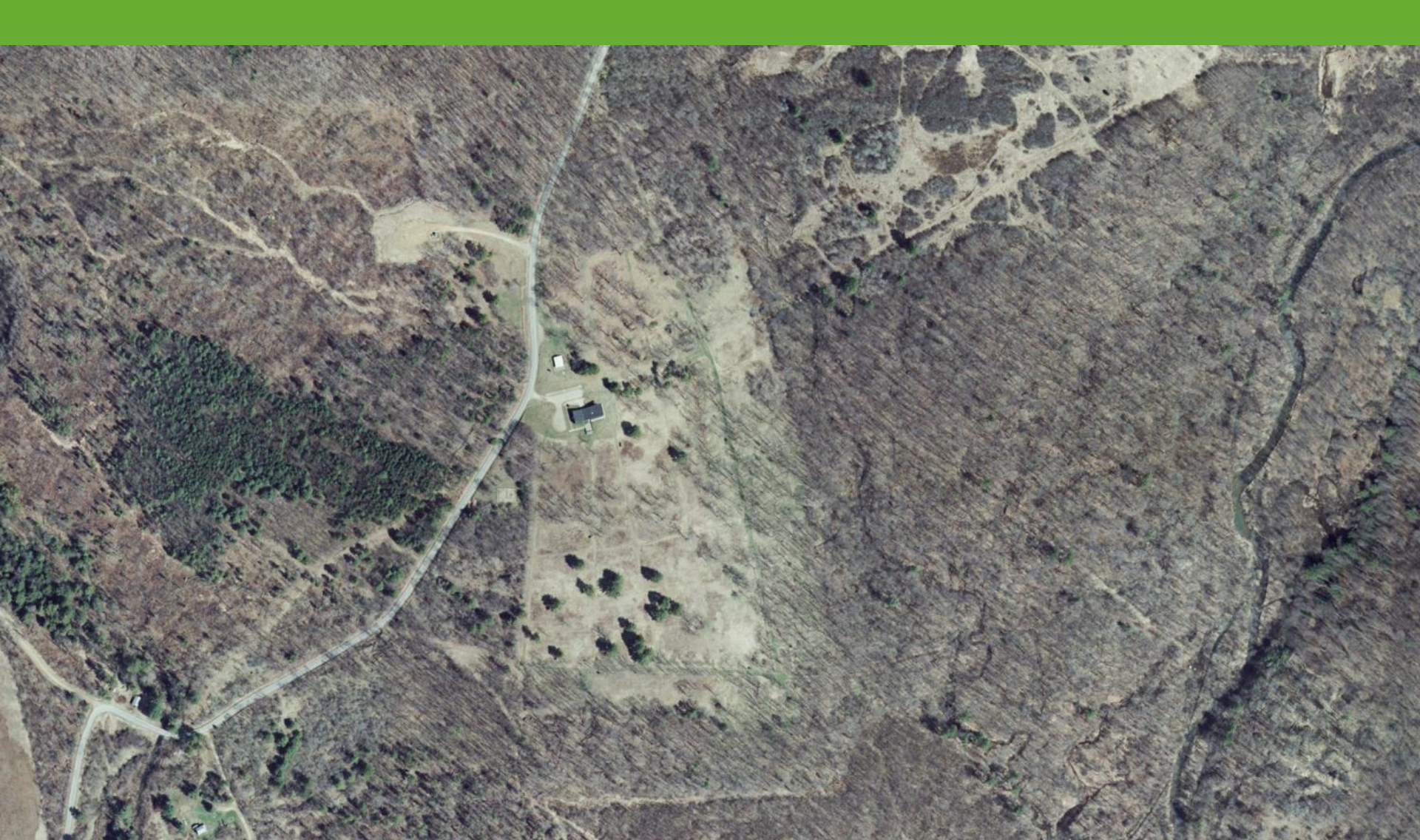
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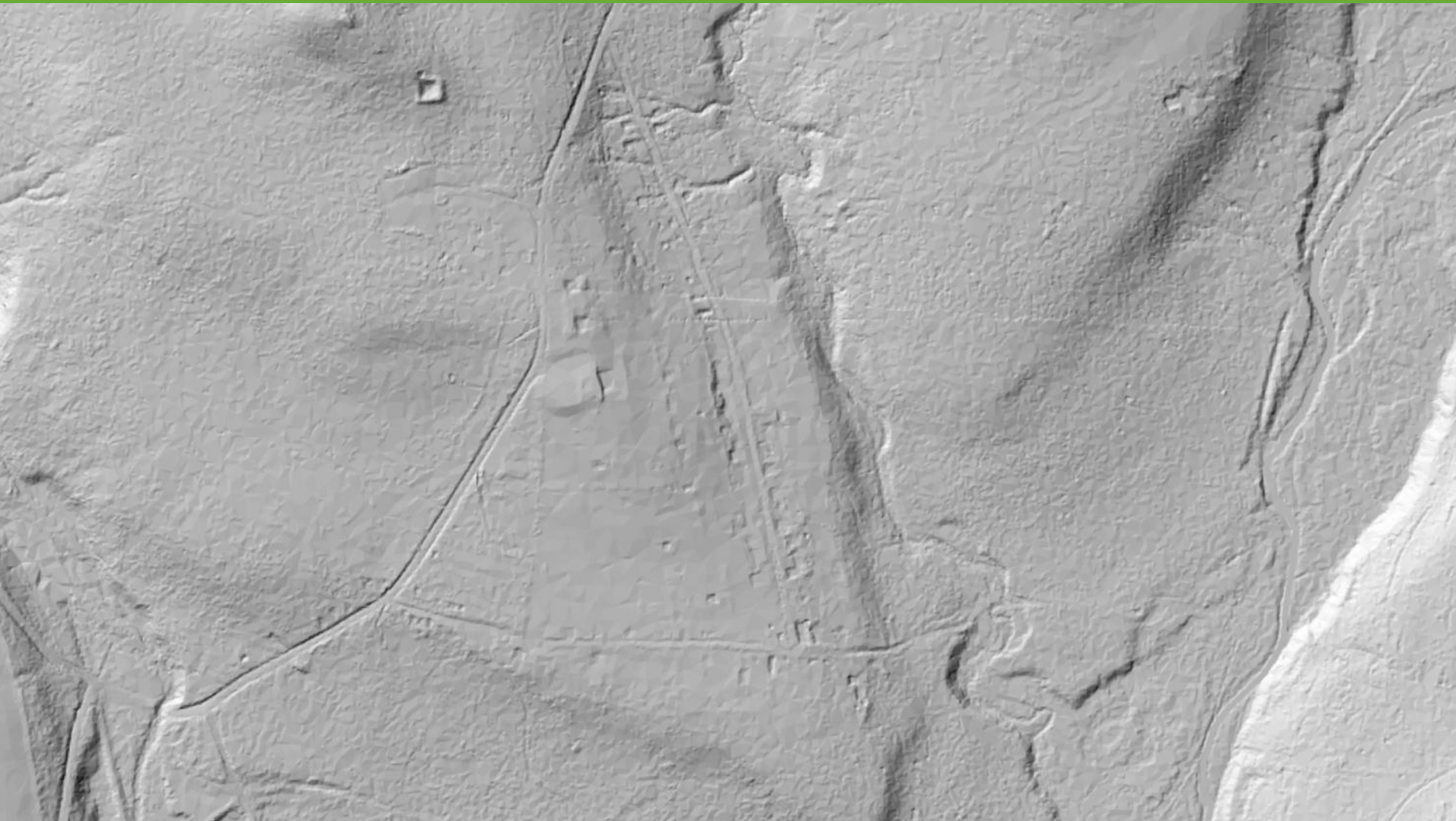
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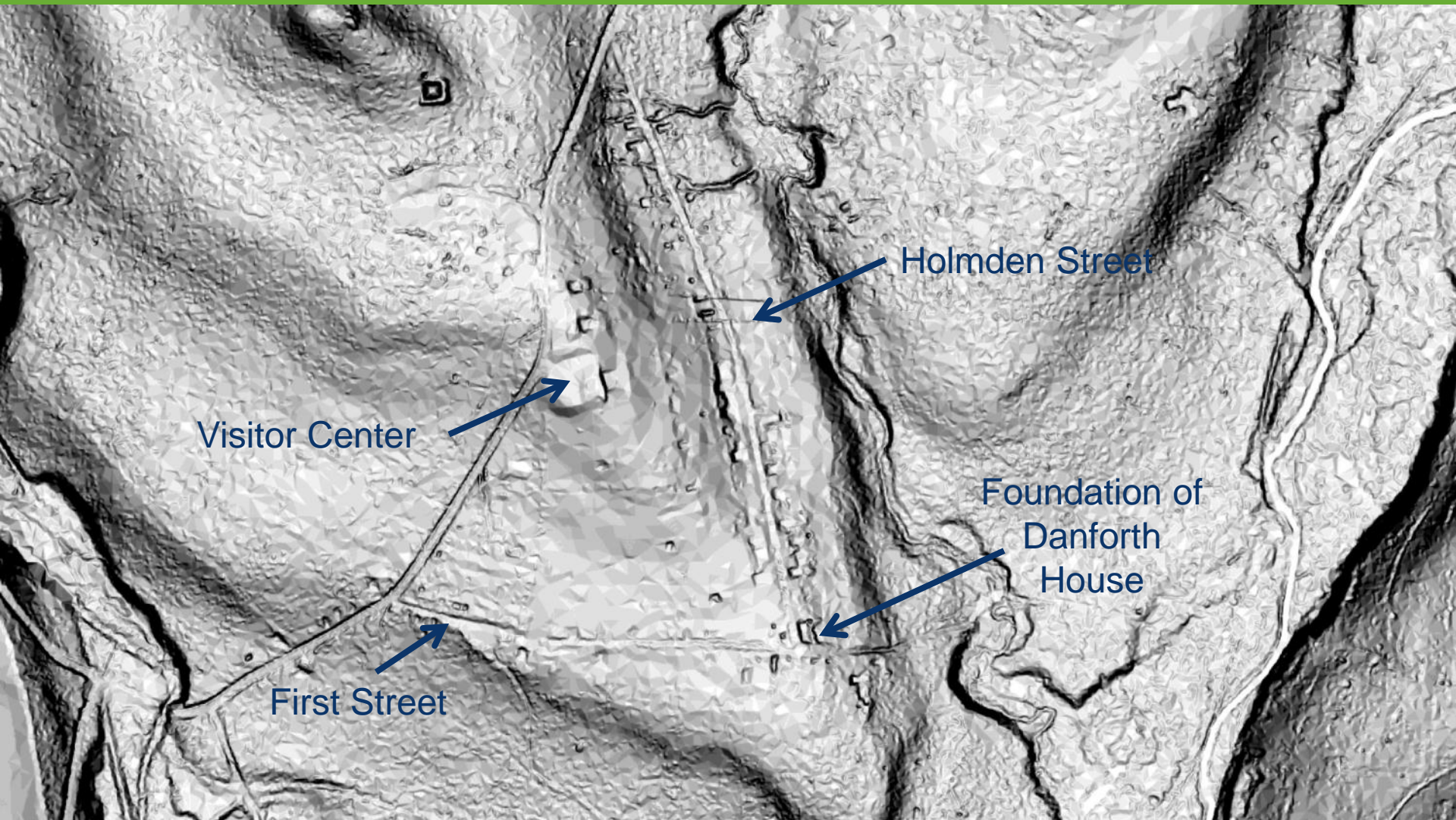
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Visitor Center



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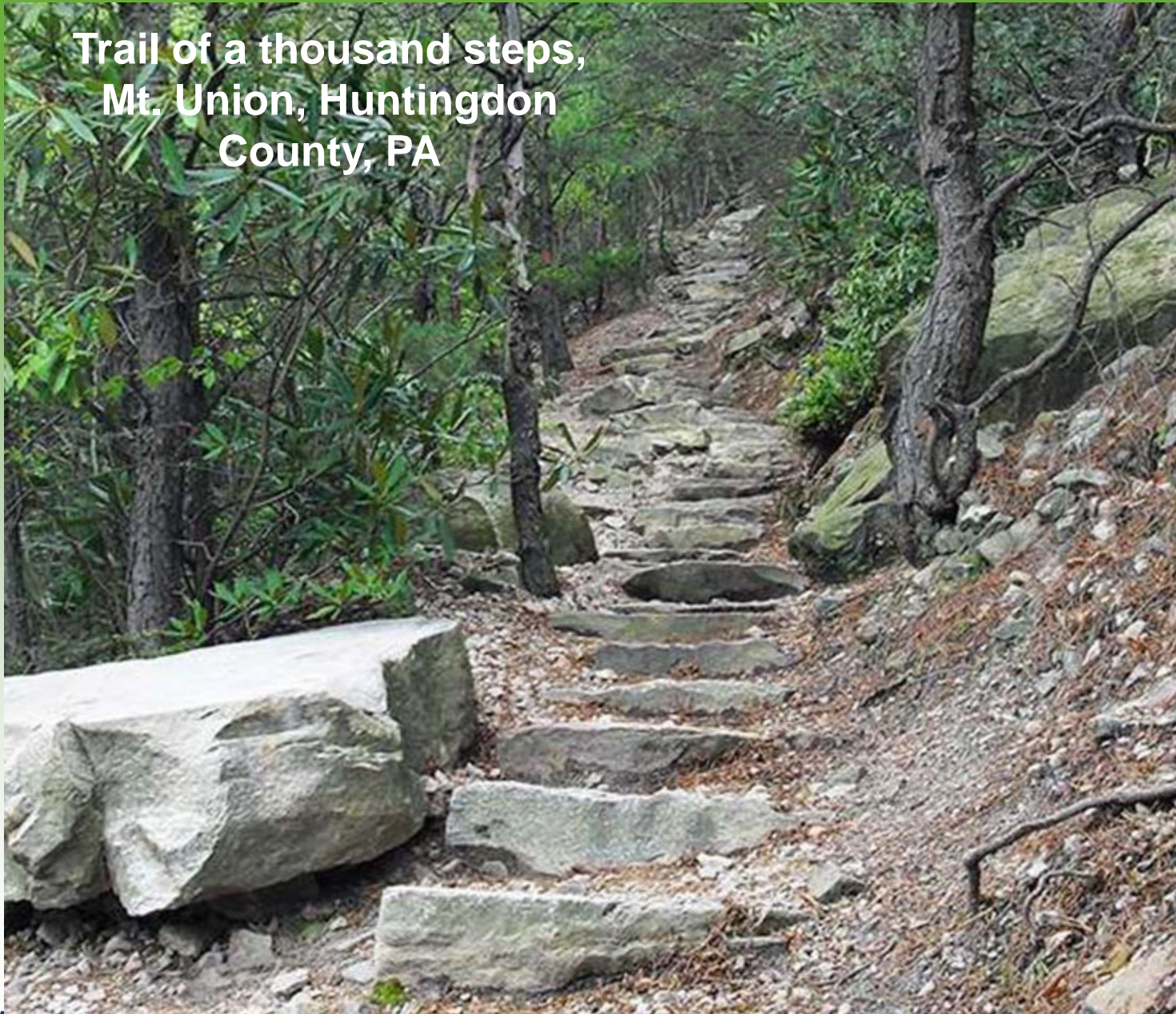


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Holmdem Street at Danforth
House looking north

**Trail of a thousand steps,
Mt. Union, Huntingdon
County, PA**





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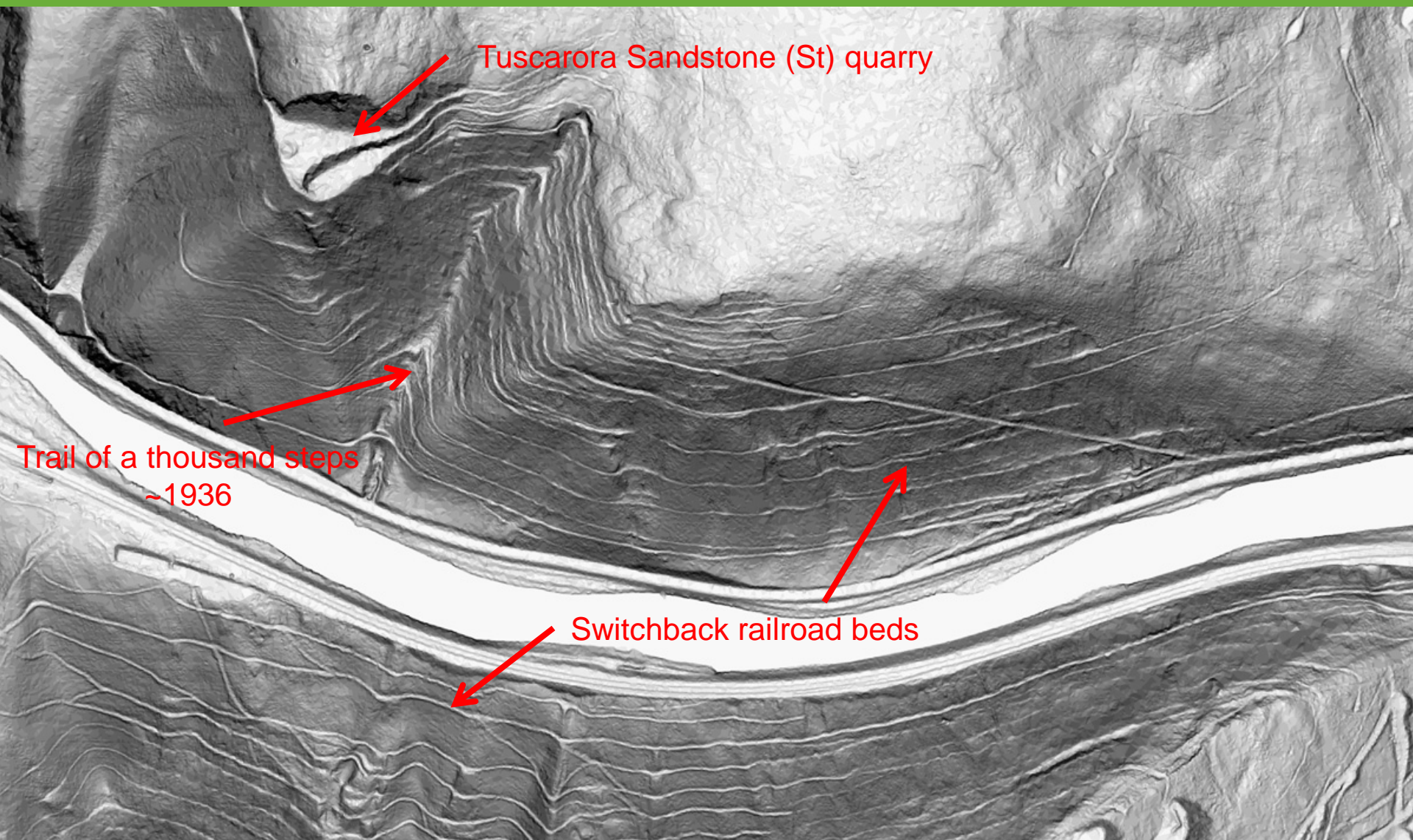
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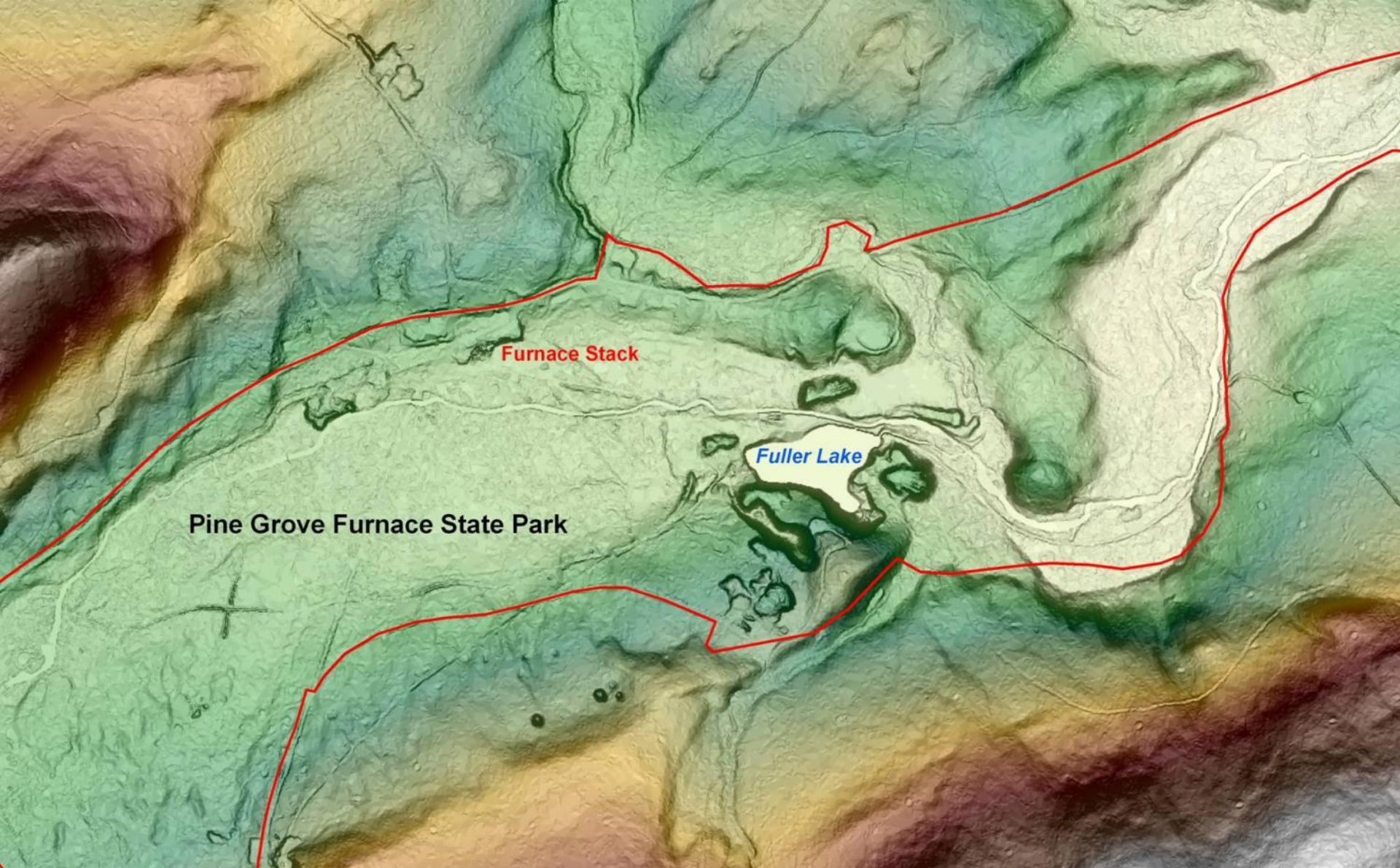
Tuscarora Sandstone (St) quarry

Trail of a thousand steps
~1936

Switchback railroad beds

Cold-blast iron furnace at
Pine Grove Furnace State Park
Cumberland County, PA



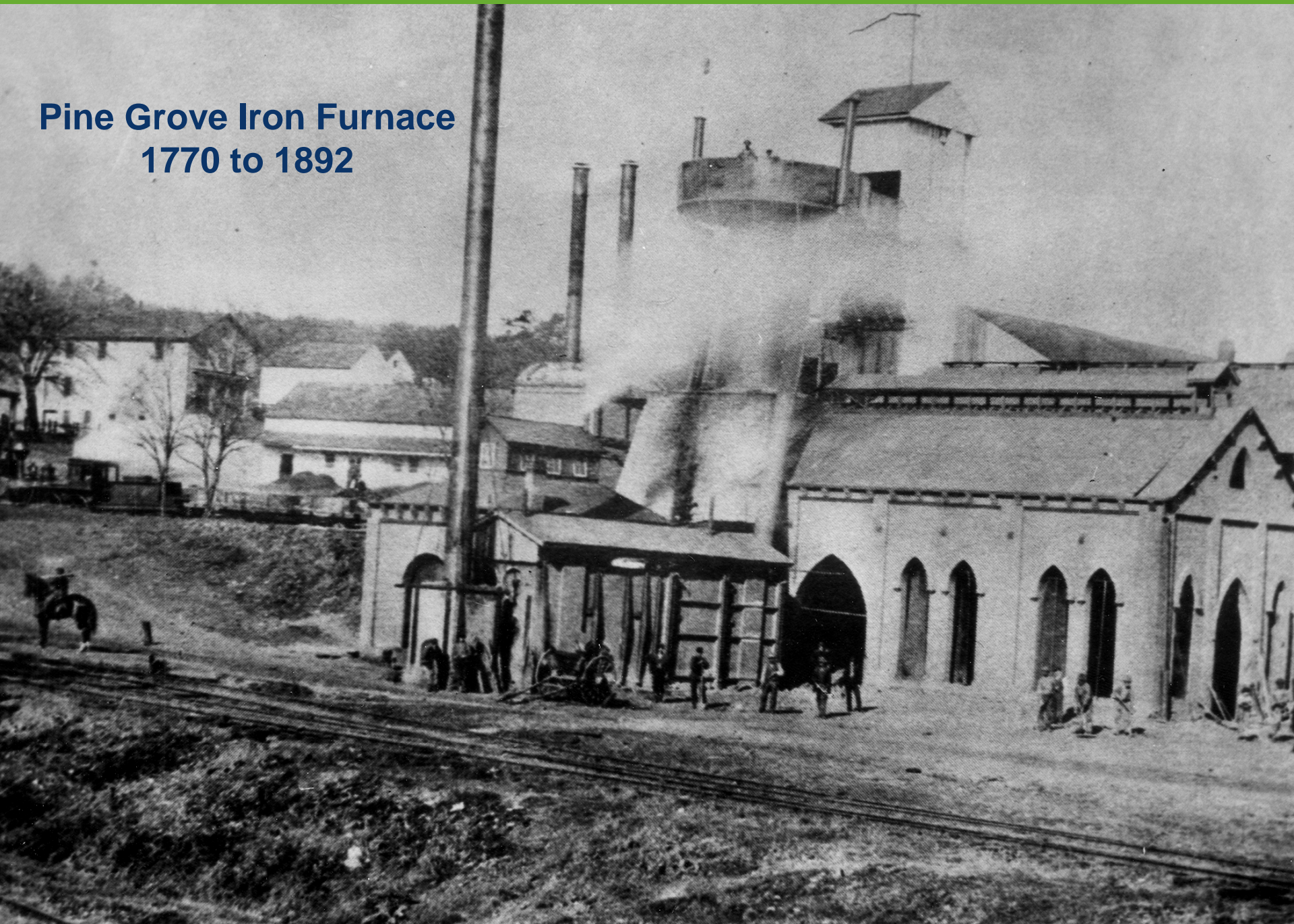


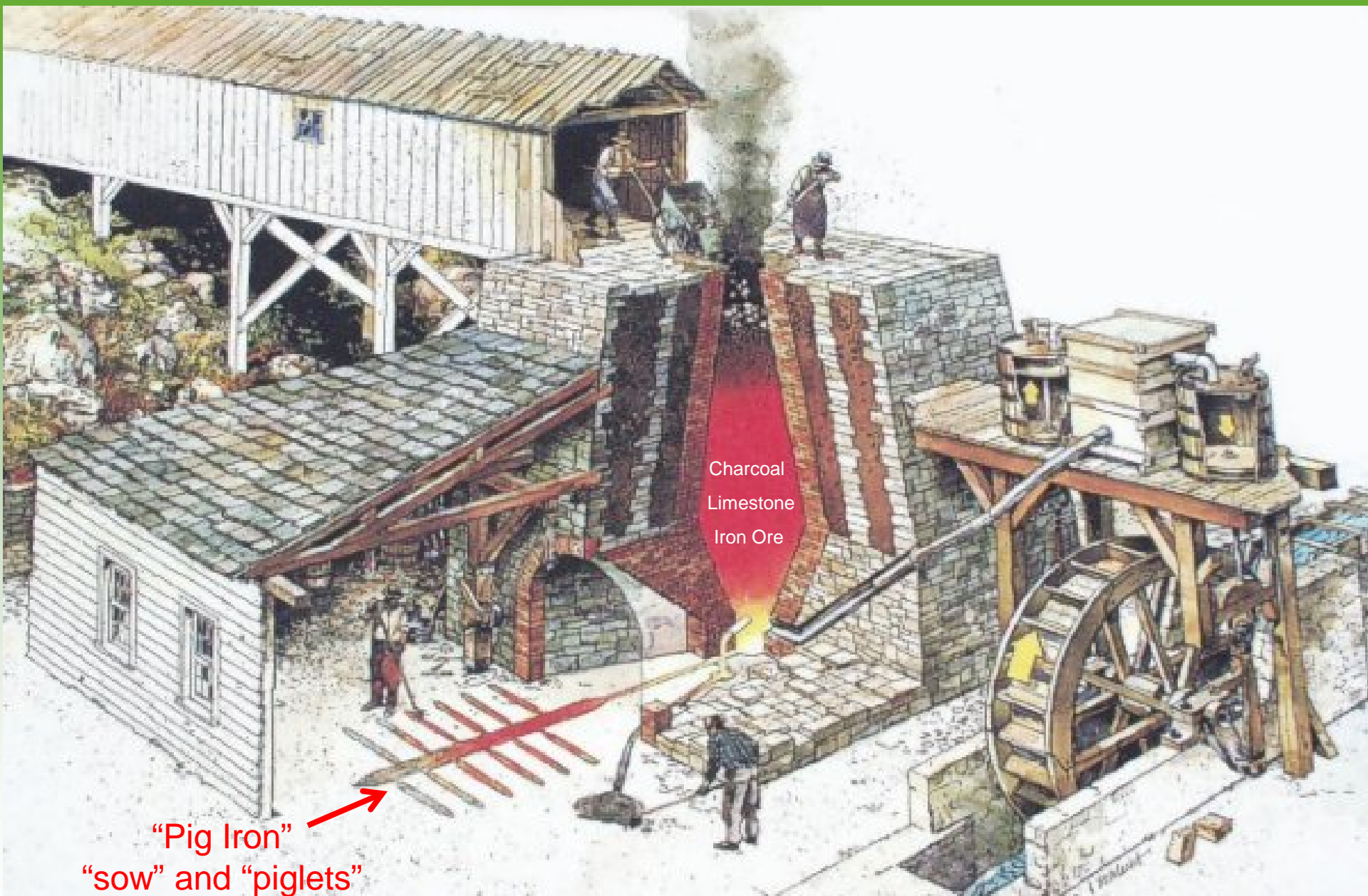
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**Pine Grove Iron Furnace
1770 to 1892**





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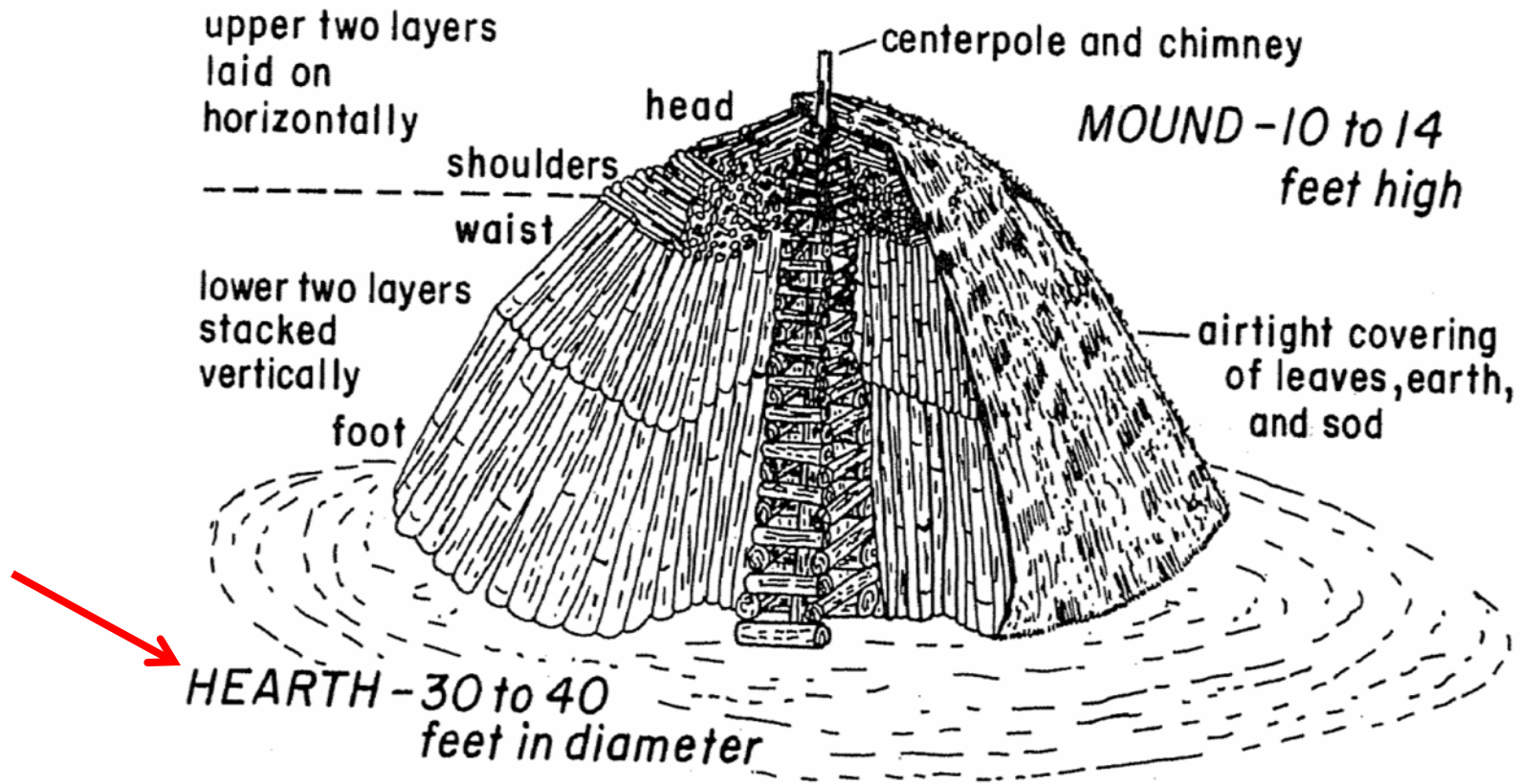
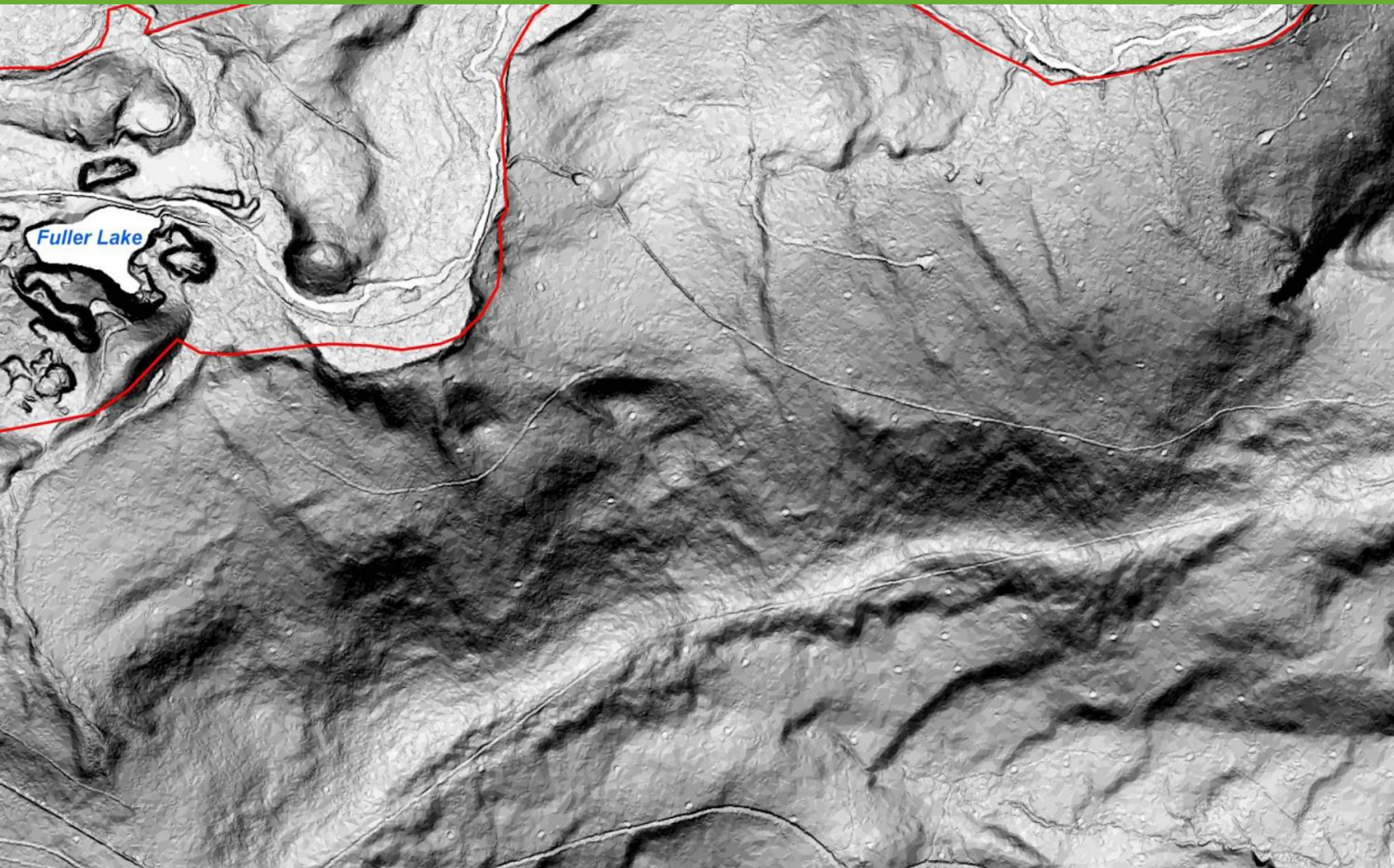


Figure 38. Sketch of a charcoal pit where timbers cut into 4-foot lengths are piled and "coaled." Charcoal produced in this manner was used as fuel for furnaces and forges of the area (Way, 1986, Figure 6-3, p. 12).



1 acre = 25 cords = enough charcoal for 1 day of operation

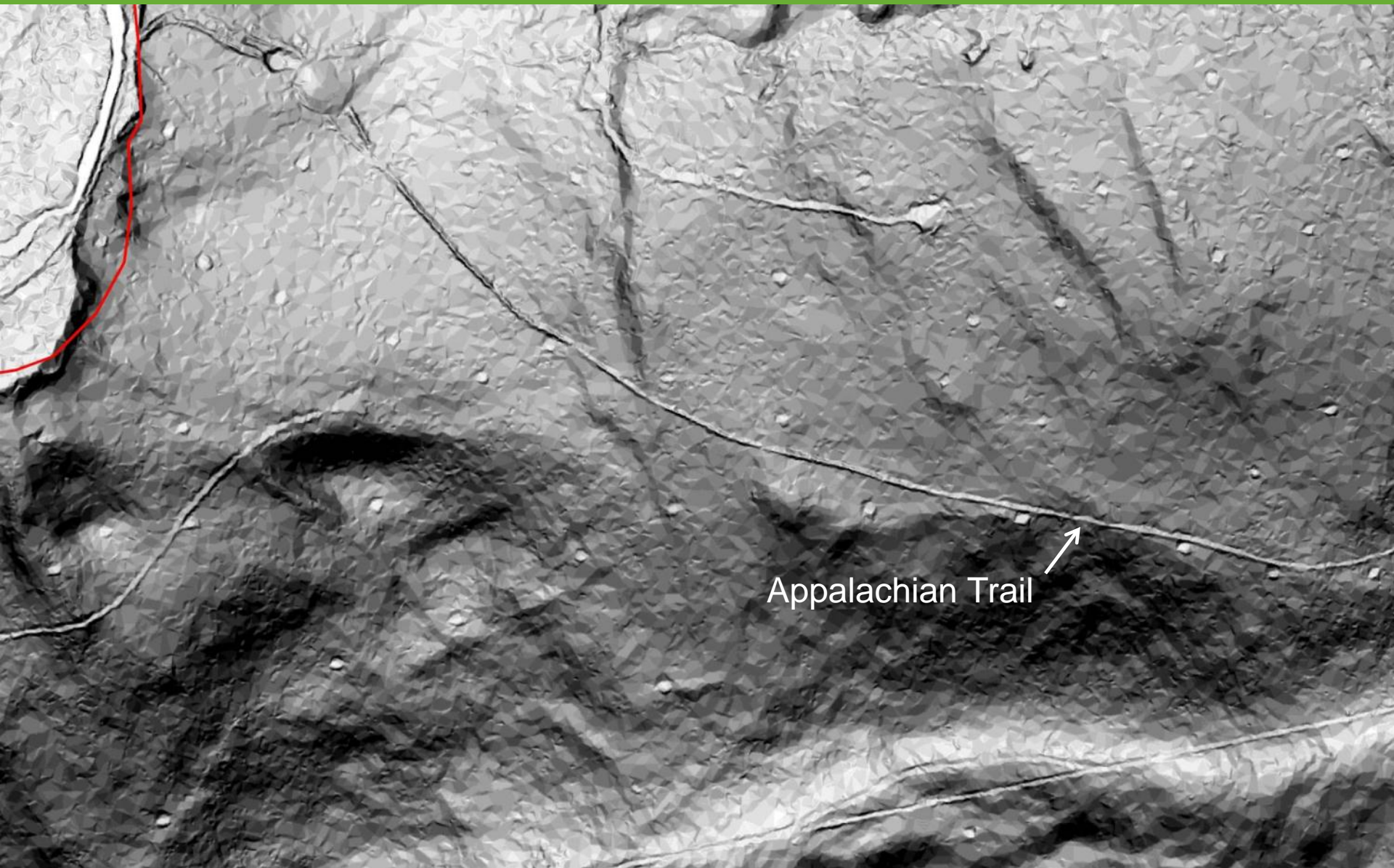
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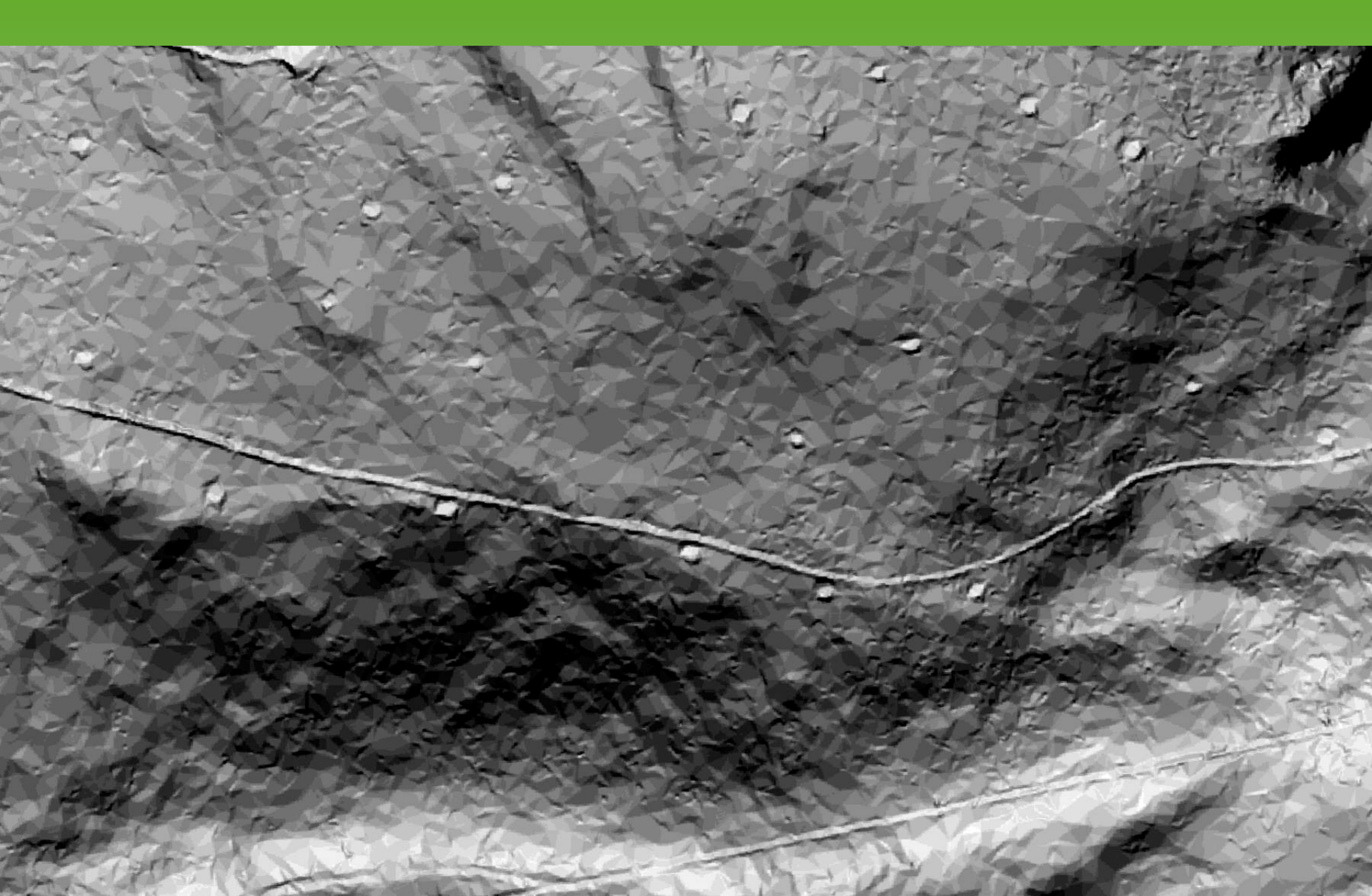


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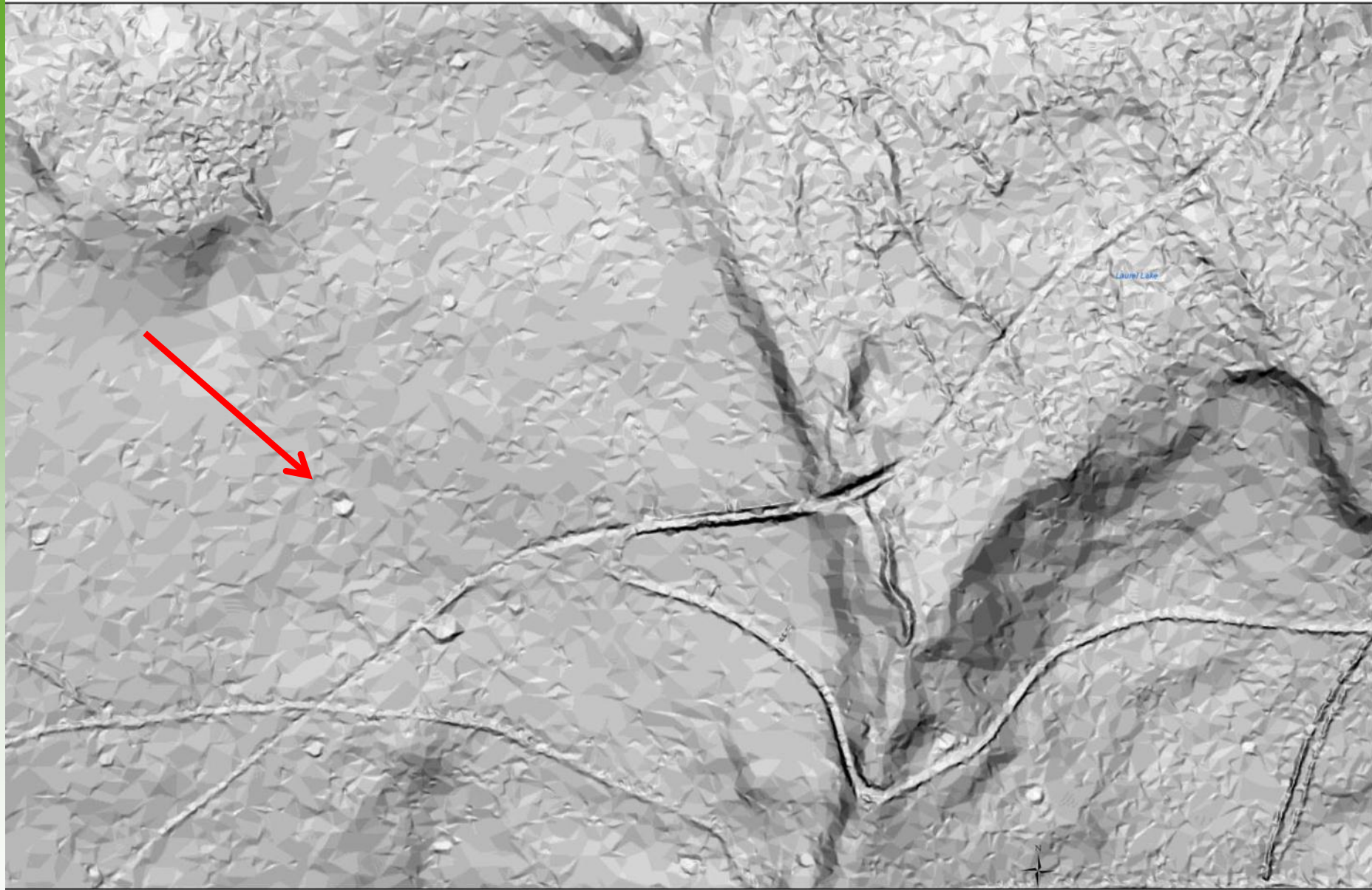




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Pine Grove Furnace State Park and vicinity
Cumberland County, PA
PAMAP orthoimagery and Lidar elevation data.

0 50 100 200 300
Feet



Pine Grove Furnace State Park and vicinity
Cumberland County, PA
PAMAP orthoimagery and Lidar elevation data.





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Riddle me this – Can we
locate old abandoned wells?



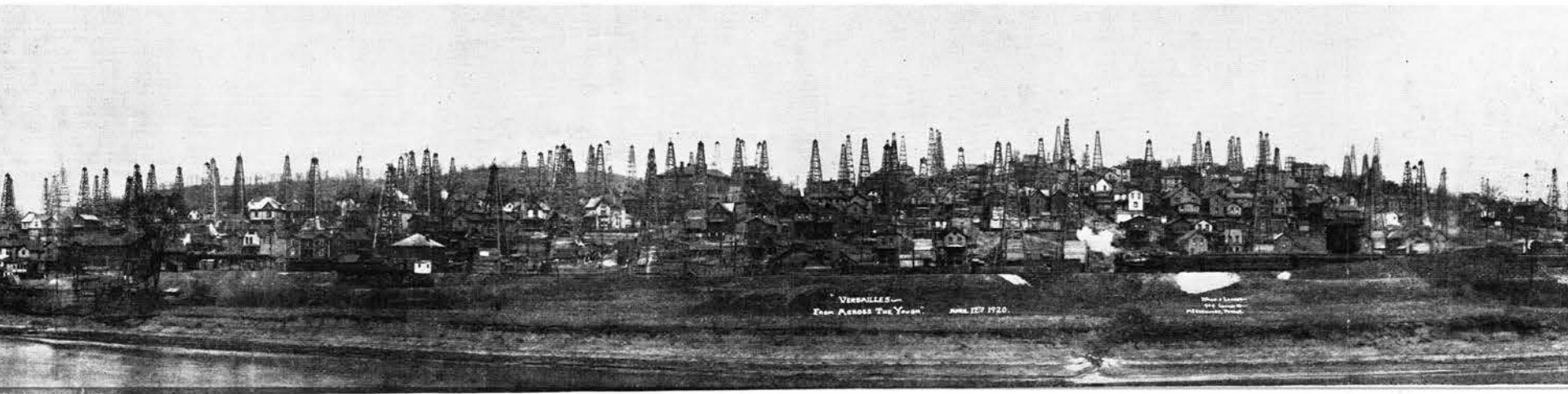
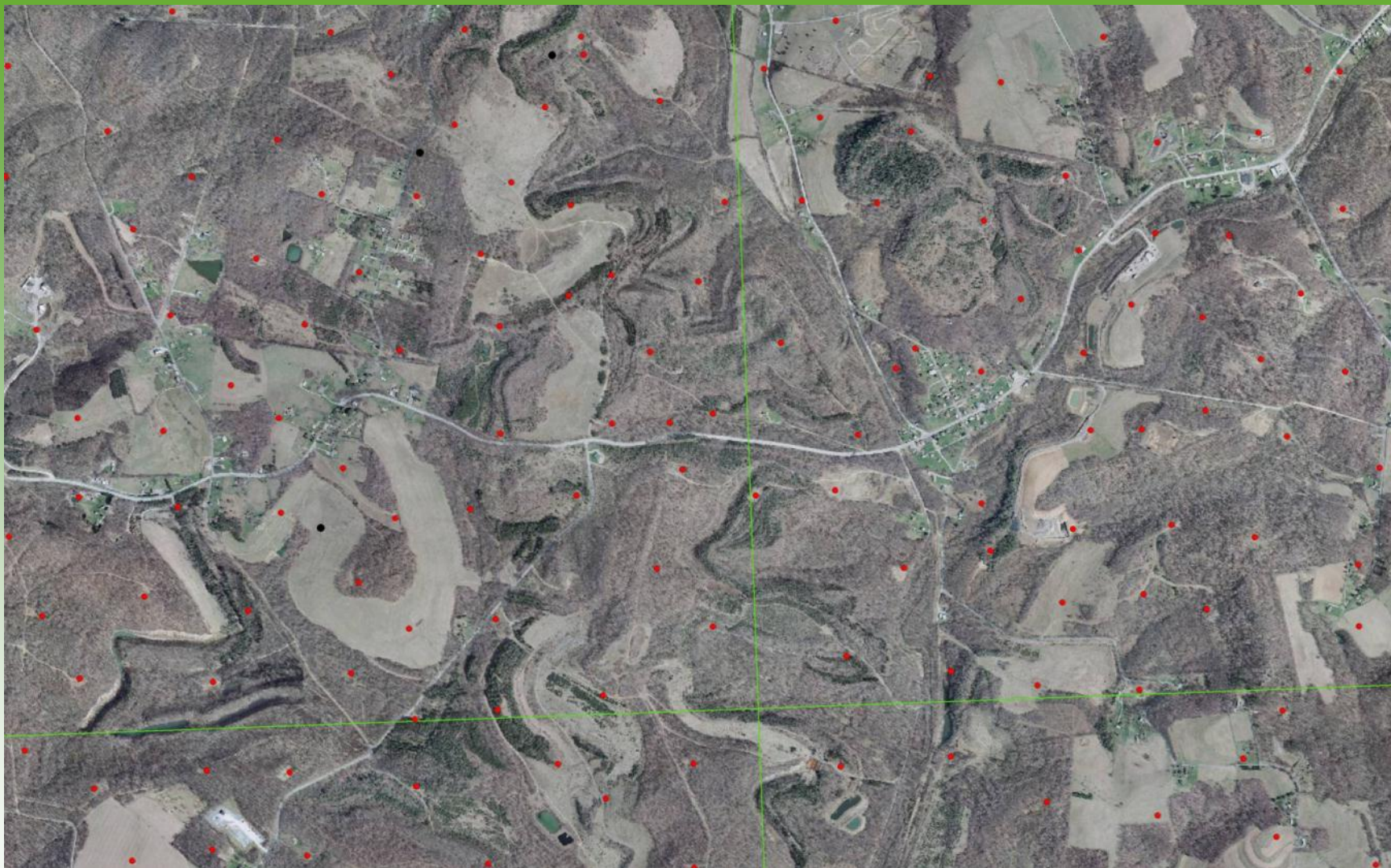


Plate XXIII. Panorama of McKeesport gas field taken when the gas boom was at its peak. This is the southern part of the field at Versailles. Seen from across Youghiogheny River.

Photogr

Versailles from across the Youghiogheny River, April 1920. South end of McKeesport gas field.



**Jacksonville, Indiana County
McIntyre Quad**

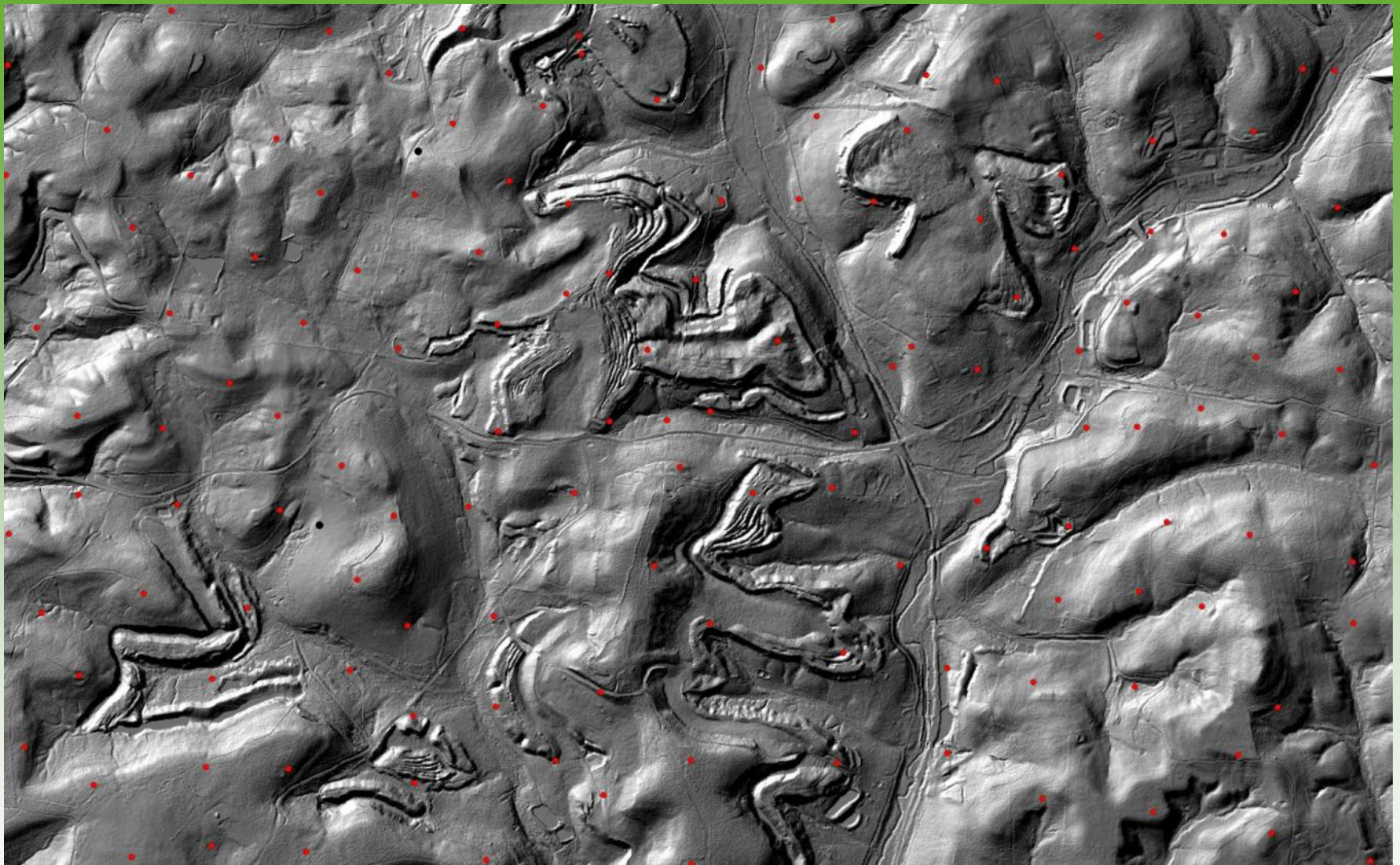
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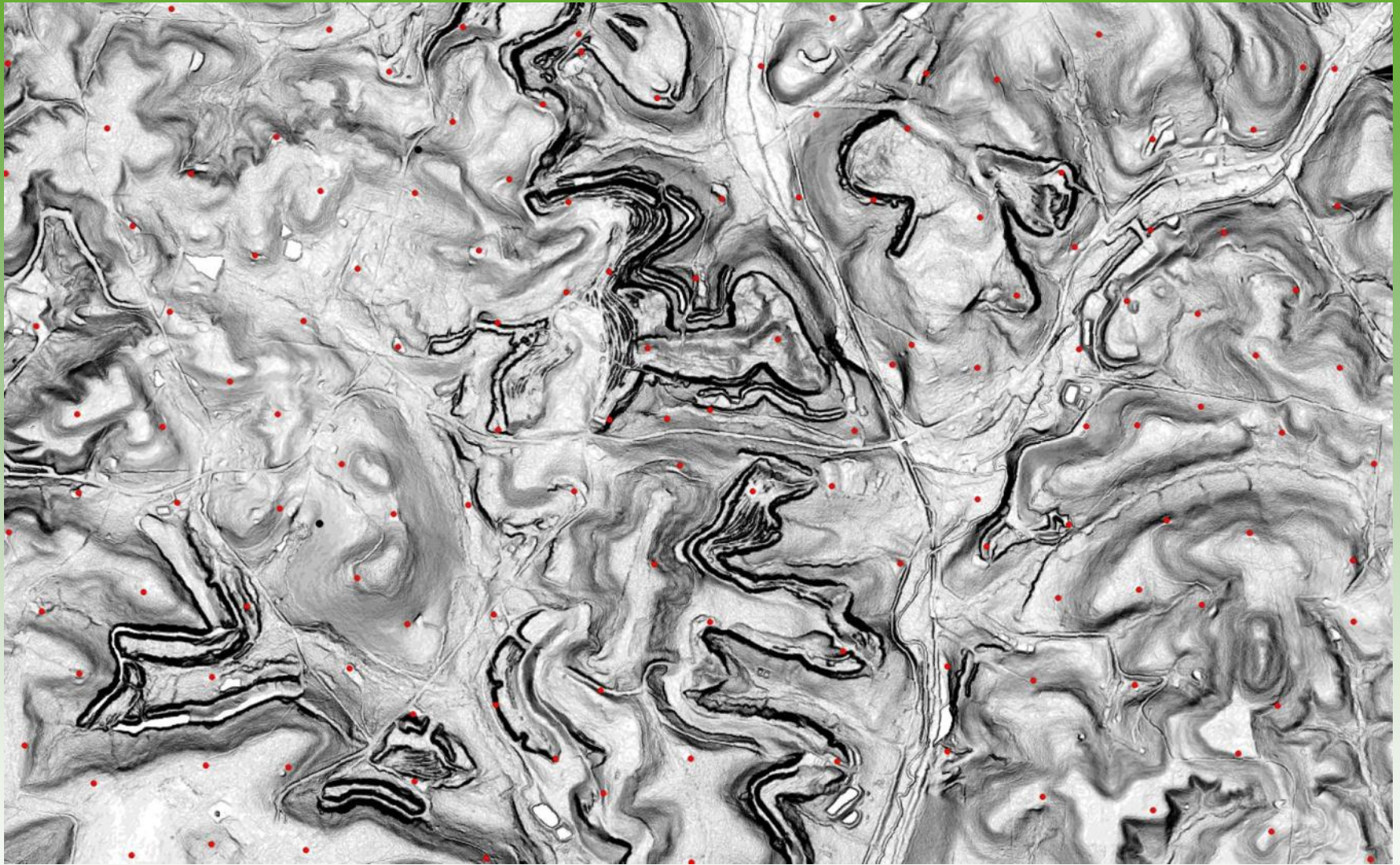
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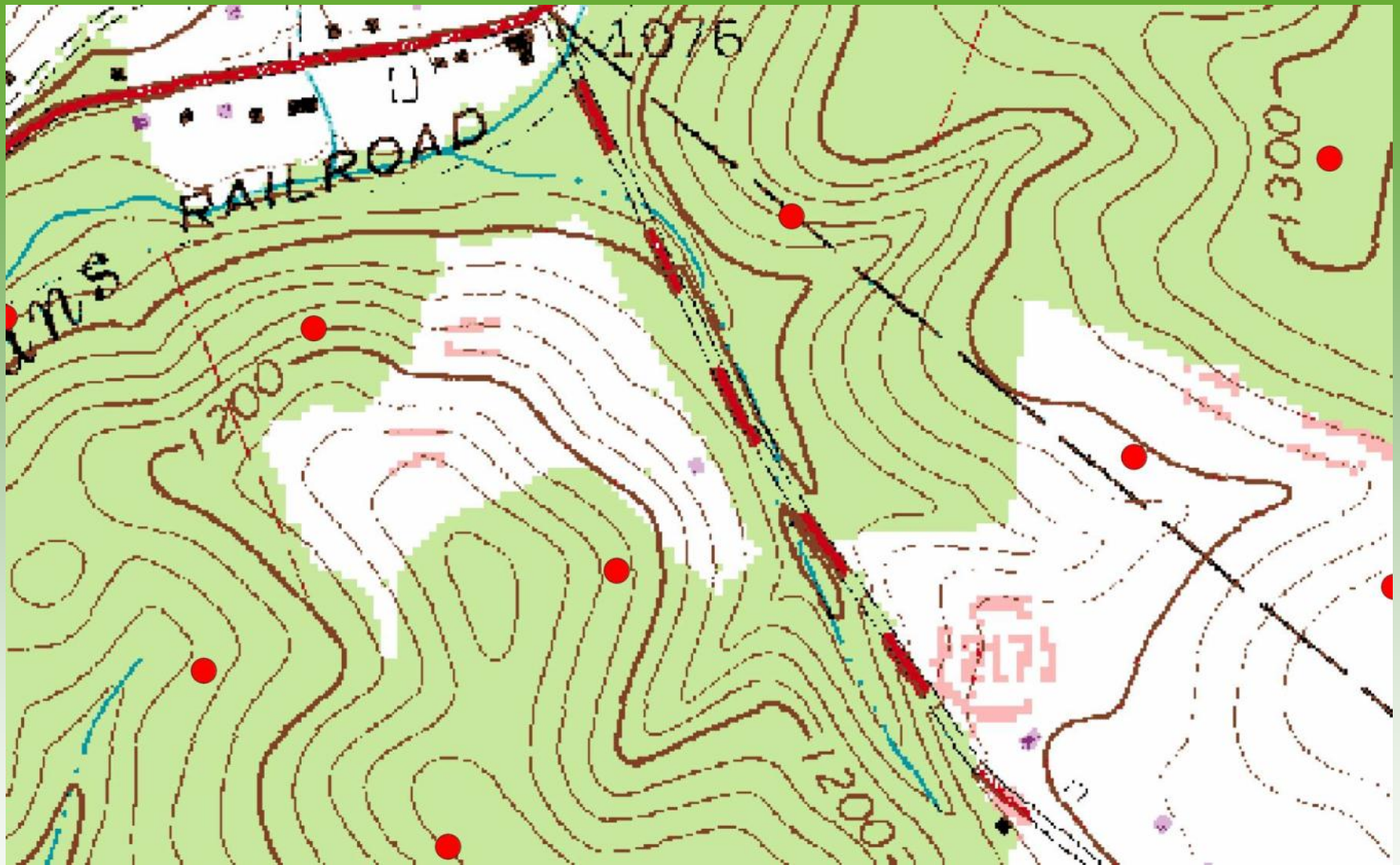
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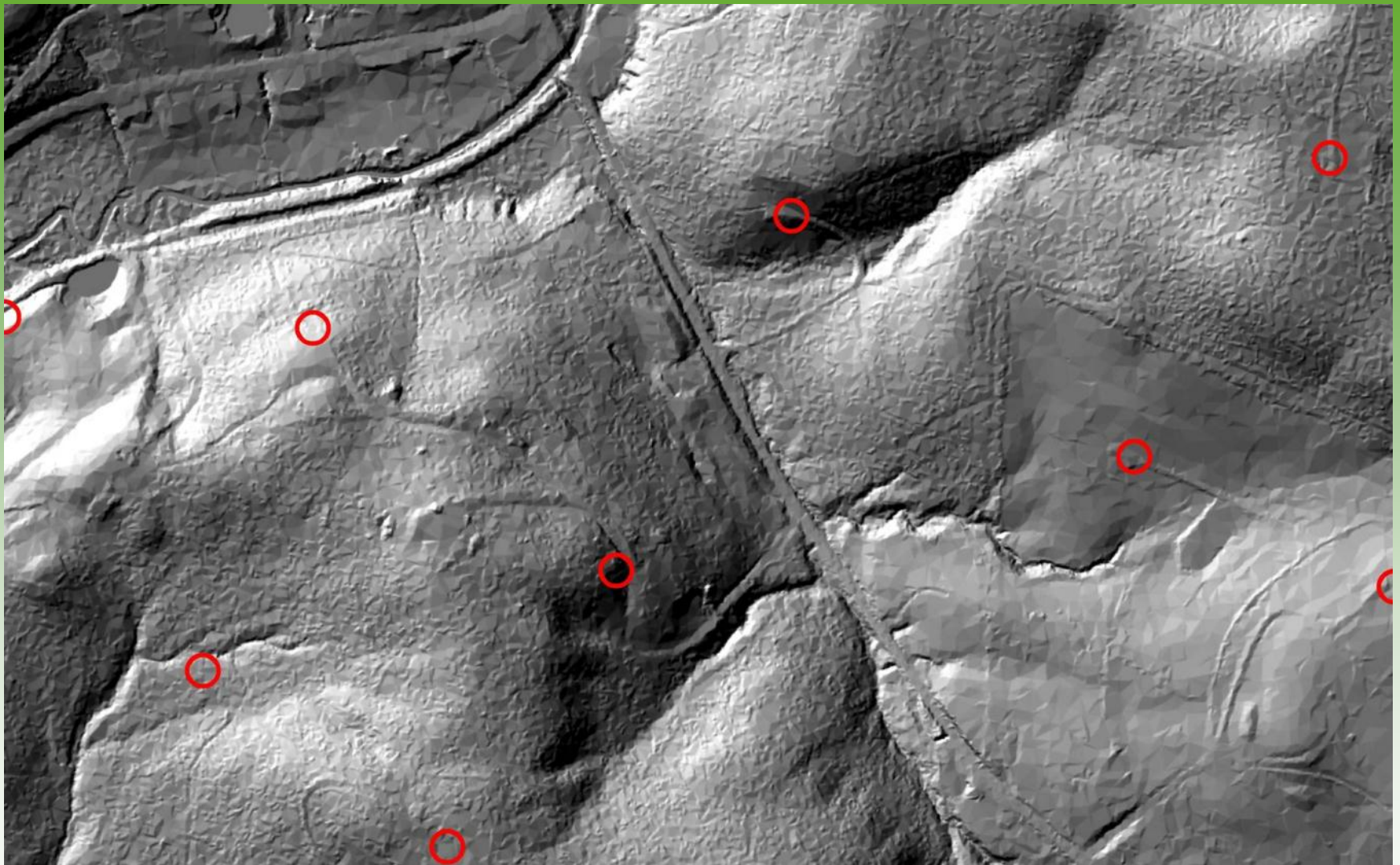
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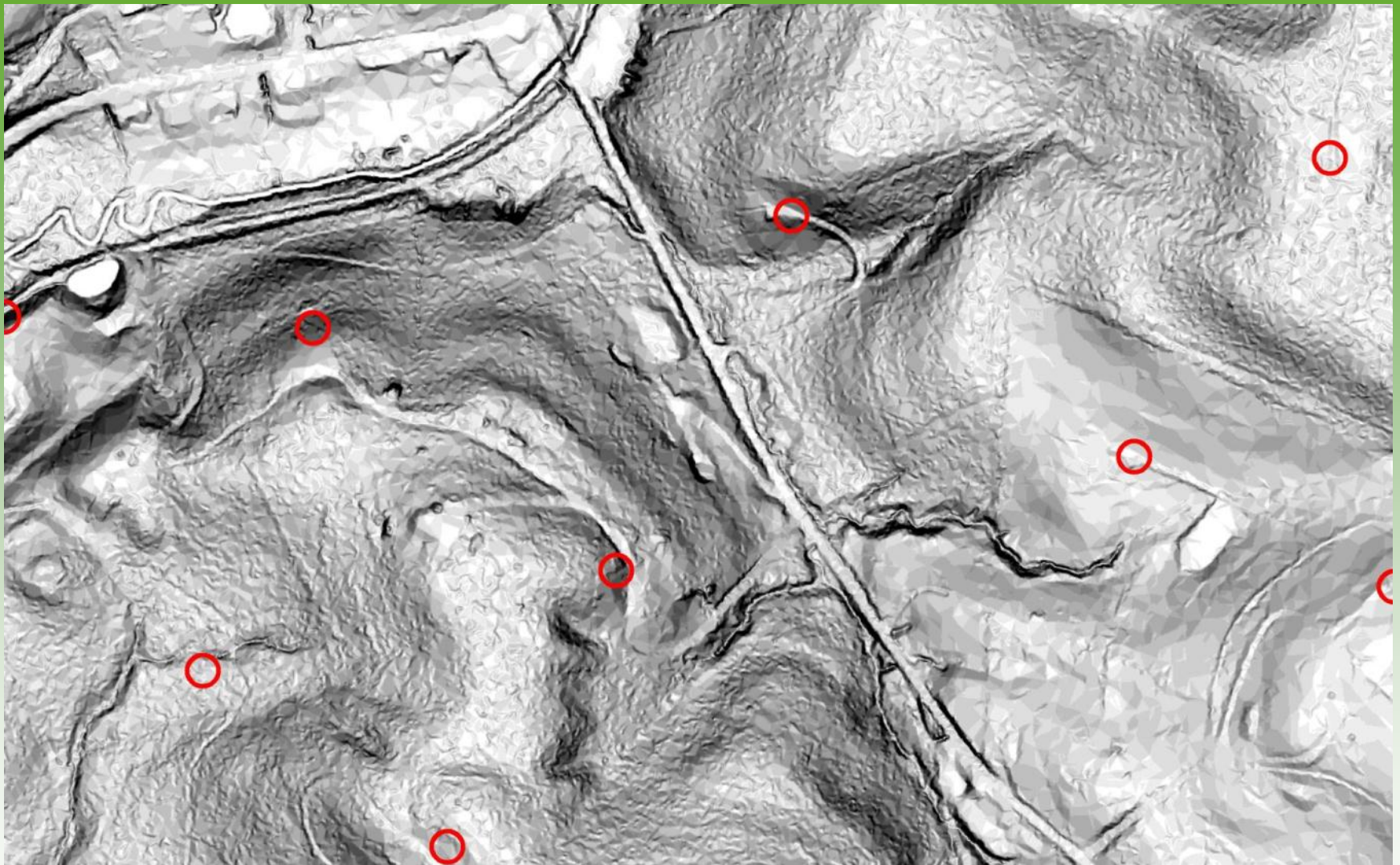
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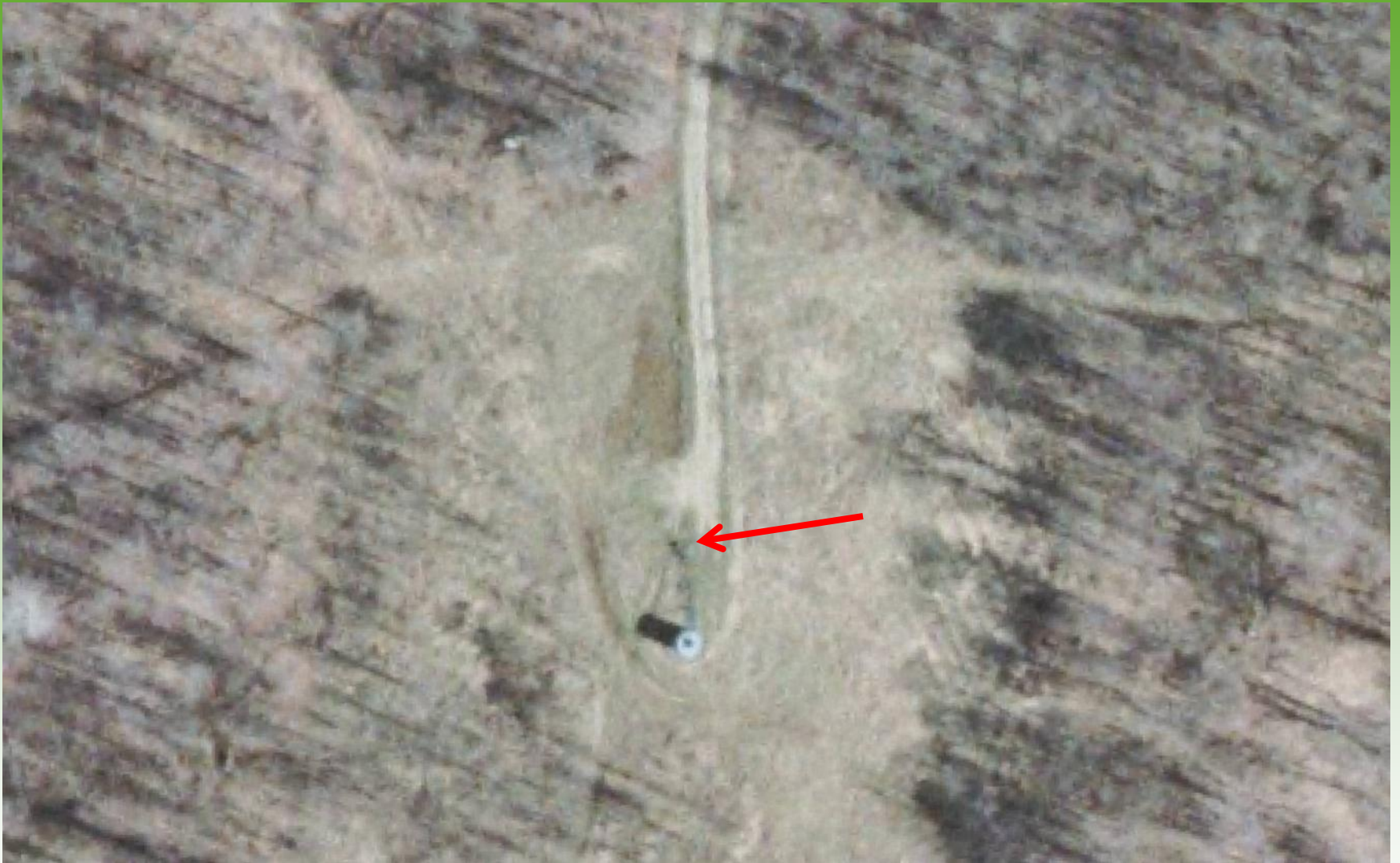
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aforesaid: *Provided*, That provisions of this act shall not apply to warrants issued prior to the year one thousand eight hundred and seventy-four: *And provided further*, That the provisions of this act shall not apply to cities of the first and second class.

When and where
not to apply.

APPROVED—The 10th day of June, A. D. 1881.

HENRY M. HOYT.

Oil Well Plugging Act 101 of 1881

No. 101.

AN ACT

Regulating the mode of plugging abandoned oil wells, and providing a penalty for the violation thereof.

SECTION 1. *Be it enacted, &c.*, That whenever any well shall have been put down for the purpose of exploring for and producing oil, upon abandoning or ceasing to operate the same, the owner or operator shall, for the purpose of excluding all fresh water from the oil-bearing rock and before drawing the casing, fill up the well with sand or rock sediment to the depth of at least twenty feet above the third sand or oil-bearing rock, and drive a round, seasoned, wooden plug at least two feet in length, equal in diameter to the diameter of the well below the casing, to a point at least five feet below the bottom of the casing, and, immediately after the drawing of the casing, shall drive a round wooden plug into the well at the point just below where the lower end of the casing shall have rested, which plug shall be at least three feet in length, tapering in form and to be of the same diameter at the distance of eighteen inches from the smaller end as the diameter of the well below the point at which it is to be driven; after it has been properly driven shall fill in on top of same with sand or rock sediment to the depth of at least five feet.

Abandoned oil
wells to be
plugged.

SECTION 2. Any person who shall violate the provisions of this act shall be liable to a penalty of two hundred dollars, one half to be for the use of the informer and one half to the use of the school district in which such well may be situated, to be recovered as debts of like amount are by law recoverable.

Penalty.

SECTION 3. Whenever any owner or operator shall neglect or refuse to comply with the provisions of this section one of this act, the owner of, or operator upon any land adjoining that upon which such abandoned well may be, may enter, take possession of said abandoned well and plug the same as provided by this act, at the expense of the owner or operator whose duty it may be to plug the same.

Adjoining owner
may plug an aban-
doned well.

SECTION 4. All acts or parts of acts inconsistent herewith are hereby repealed.

APPROVED—The 10th day of June, A. D. 1881.

HENRY M. HOYT.

AN ACT

Regulating the mode of plugging abandoned oil wells, and providing a penalty for the violation thereof.

SECTION 1. *Be it enacted, &c.*, That whenever any well shall have been put down for the purpose of exploring for and producing oil, upon abandoning or ceasing to operate the same, the owner or operator shall, for the purpose of excluding all fresh water from the oil-bearing rock and before drawing the casing, fill up the well with sand or rock sediment to the depth of at least twenty feet above the third sand or oil-bearing rock, and drive a round, seasoned, wooden plug at least two feet in length, equal in diameter to the diameter of the well below the casing, to a point at least five feet below the bottom of the casing, and, immediately after the drawing of the casing, shall drive a round wooden plug into the well at the point just below where the lower end of the casing shall have rested, which plug shall be at least three feet in length, tapering in form and to be of the same diameter at the distance of eighteen inches from the smaller end as the diameter of the well below the point at which it is to be driven; after it has been properly driven shall fill in on top of same with sand or rock sediment to the depth of at least five feet.

Abandoned oil wells to be plugged.

SECTION 2. Any person who shall violate the provisions of this act shall be liable to a penalty of two hundred dollars, one half to be for the use of the informer and one half to the use of the school district in which such well may be situated, to be recovered as debts of like amount are by law recoverable. Penalty.

SECTION 3. Whenever any owner or operator shall neglect or refuse to comply with the provisions of this section one of this act, the owner of, or operator upon any land adjoining that upon which such abandoned well may be, may enter, take possession of said abandoned well and plug the same as provided by this act, at the expense of the owner or operator whose duty it may be to plug the same. Adjoining owner may plug abandoned well.

SECTION 4. All acts or parts of acts inconsistent herewith are hereby repealed.

APPROVED—The 10th day of June, A. D. 1881.

HENRY M. HOYT.



Warren County

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Farm Line map scans from SB 4, Oil and gas field property line maps of the Titusville (15-min) quadrangle, Pennsylvania, 1946, rp 1965, Pennsylvania Geological Survey – available on PAGS website.

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Source: Esri, DeLorme, USGS, Aero, GeoEye, IGN, Aerogrid, IGN, IGP, and the GIS User Community

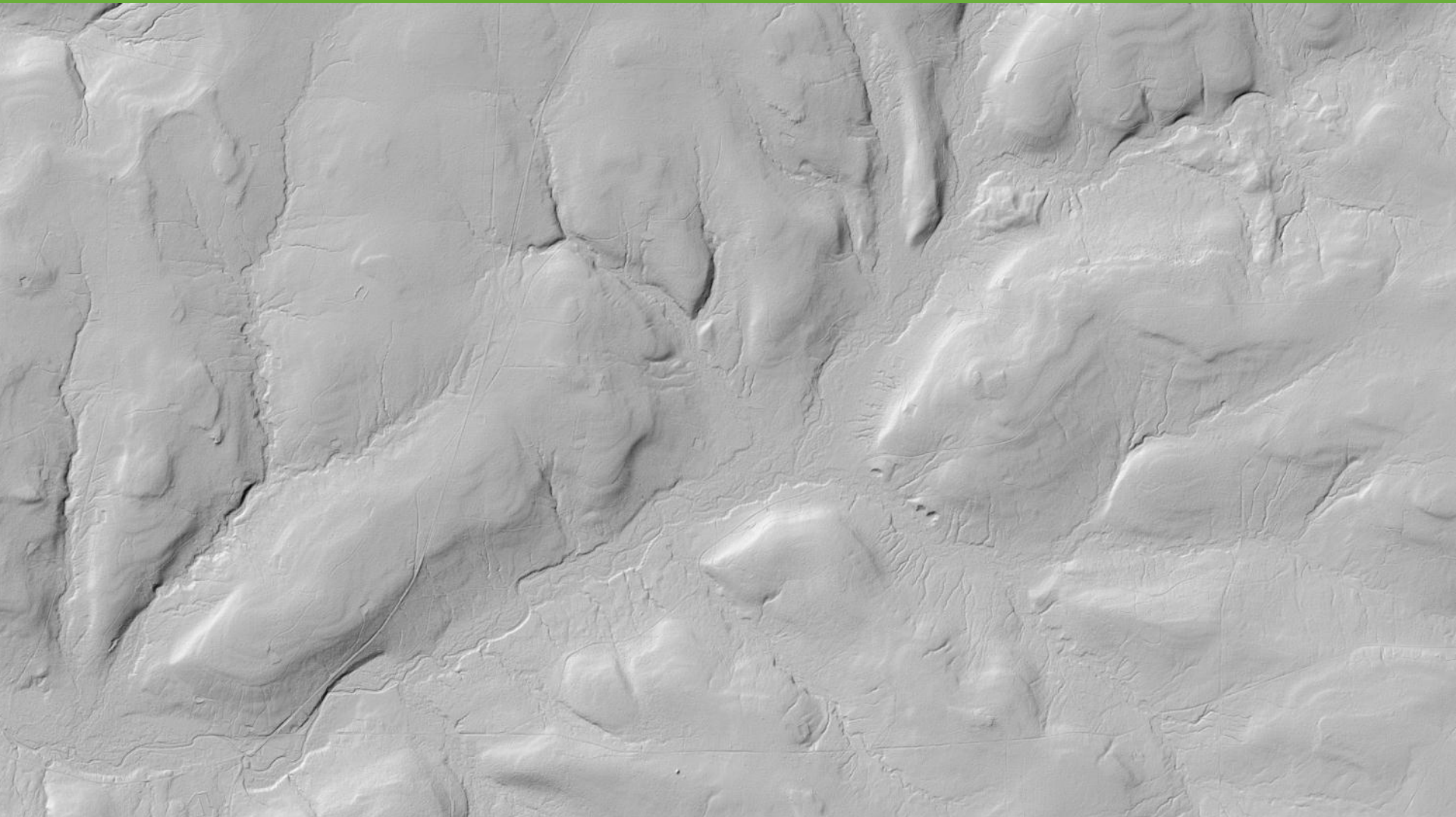
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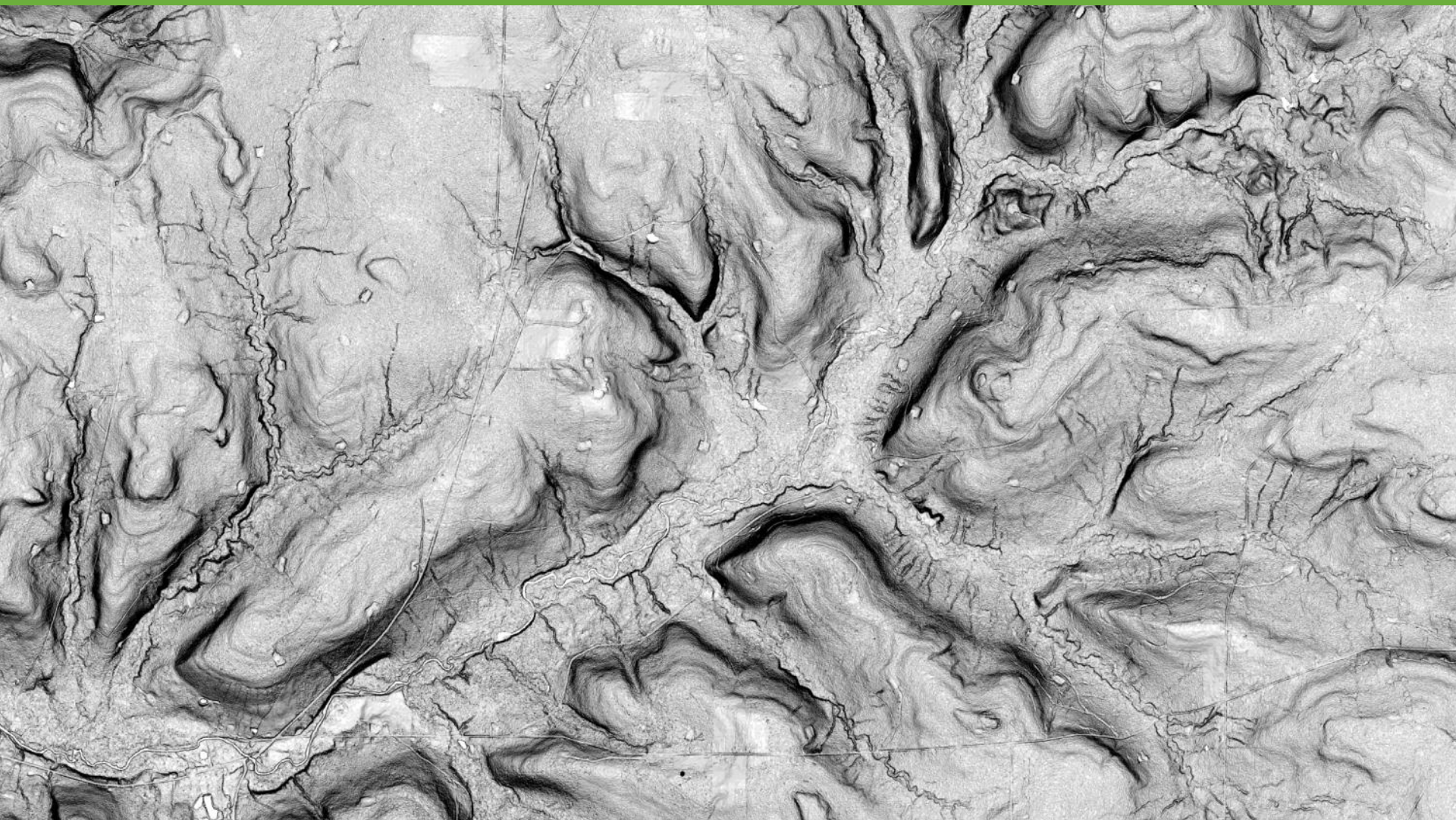


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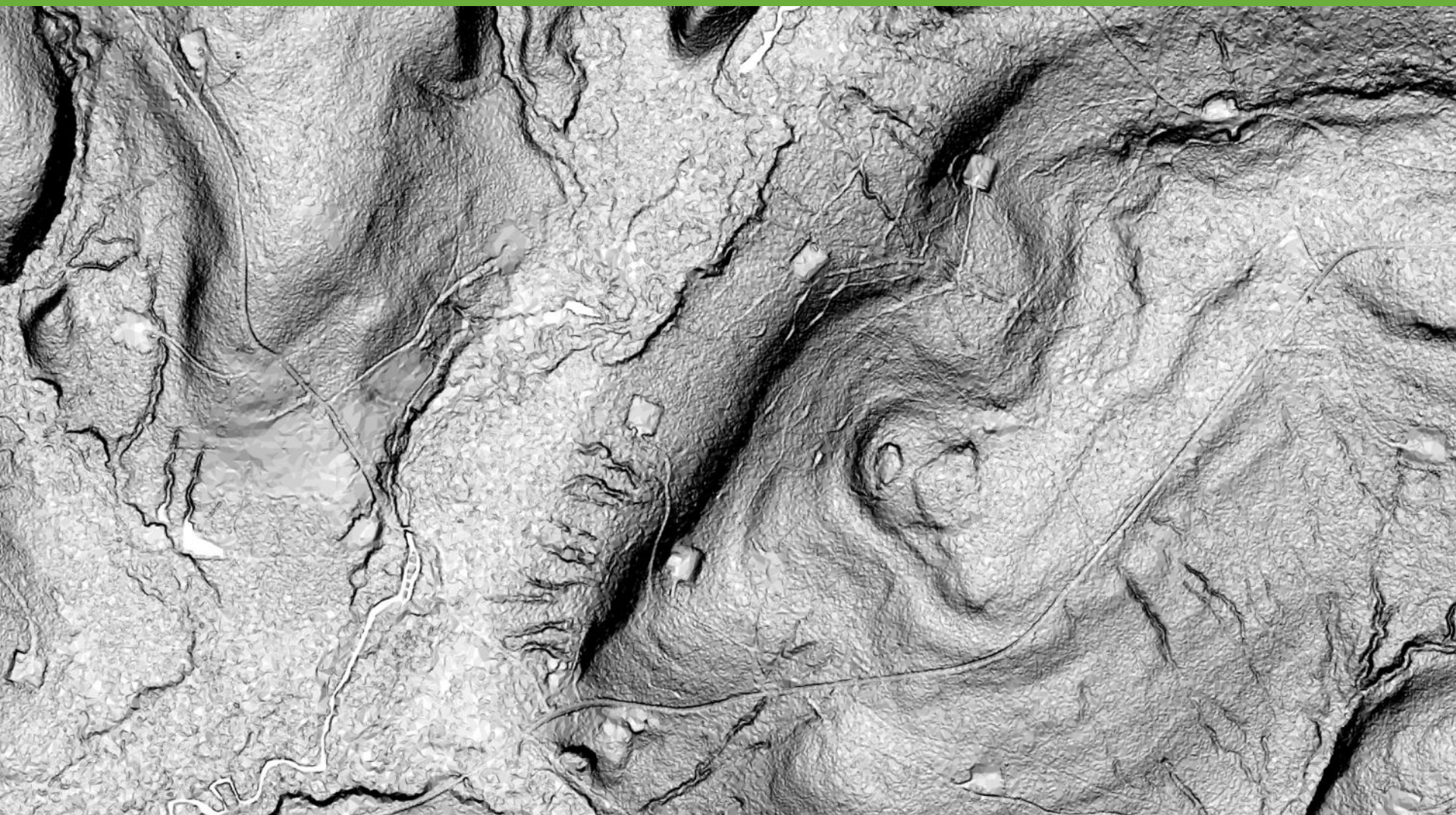
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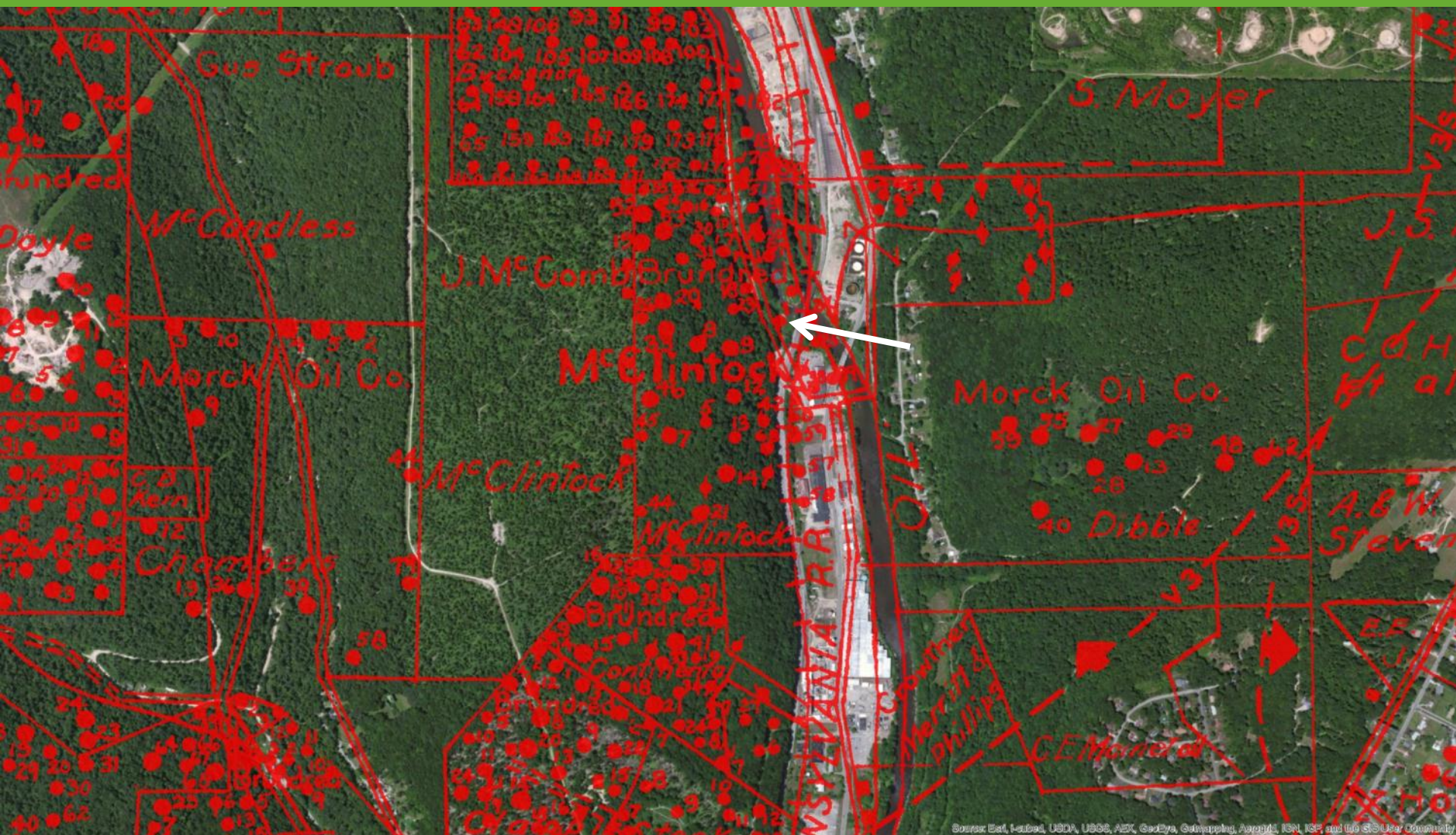
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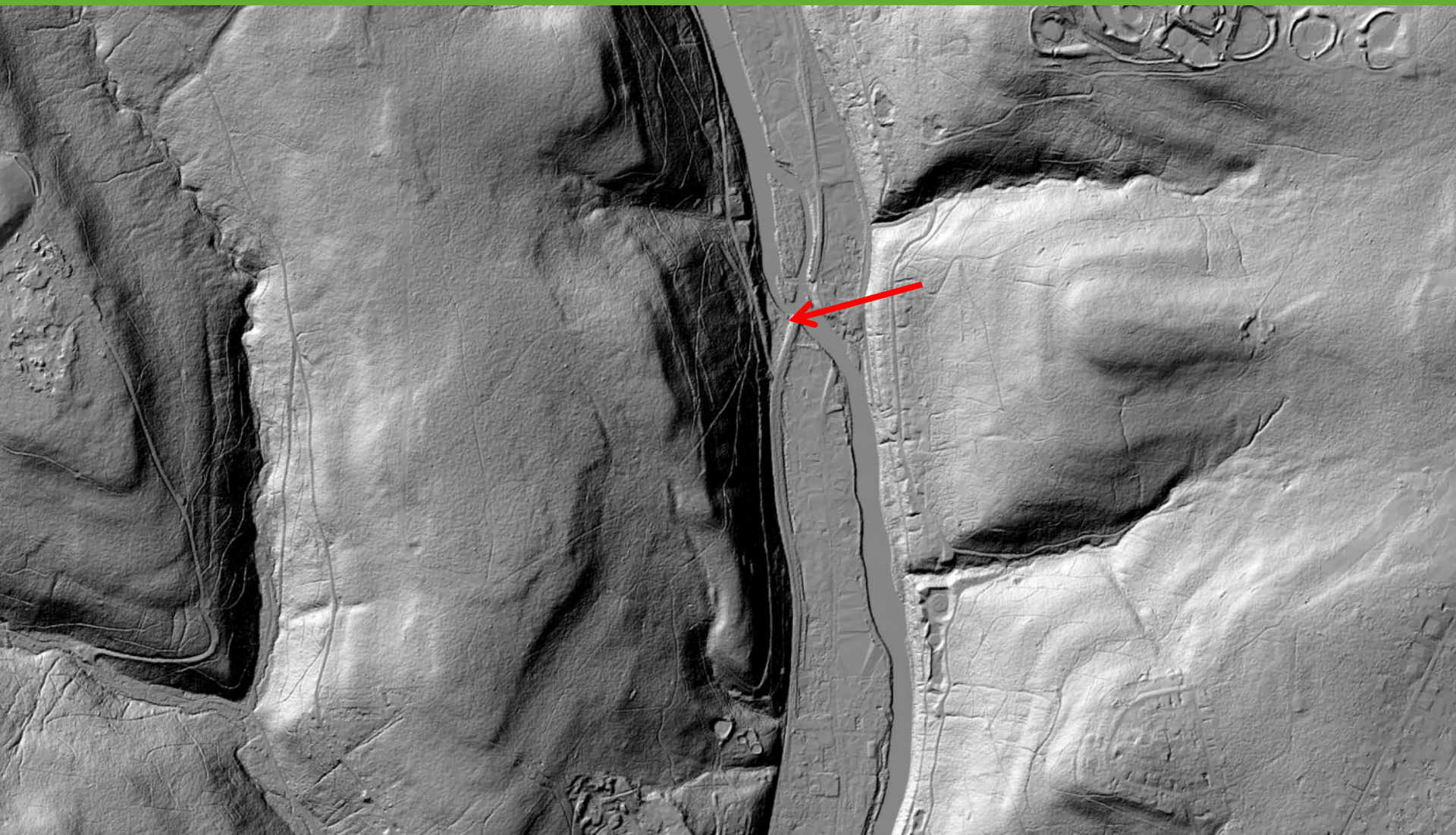


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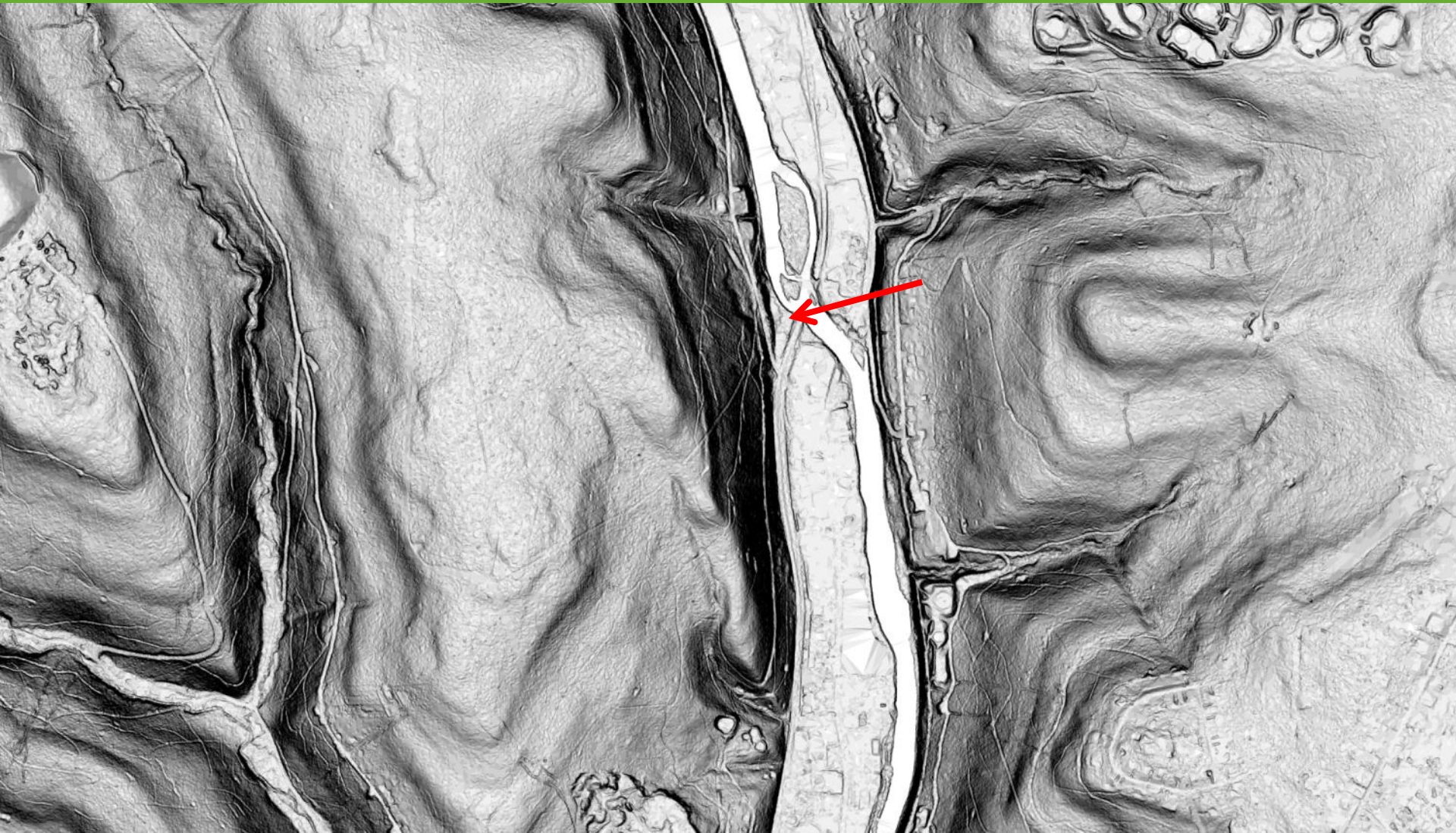


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Drake Well ~3,000 feet south



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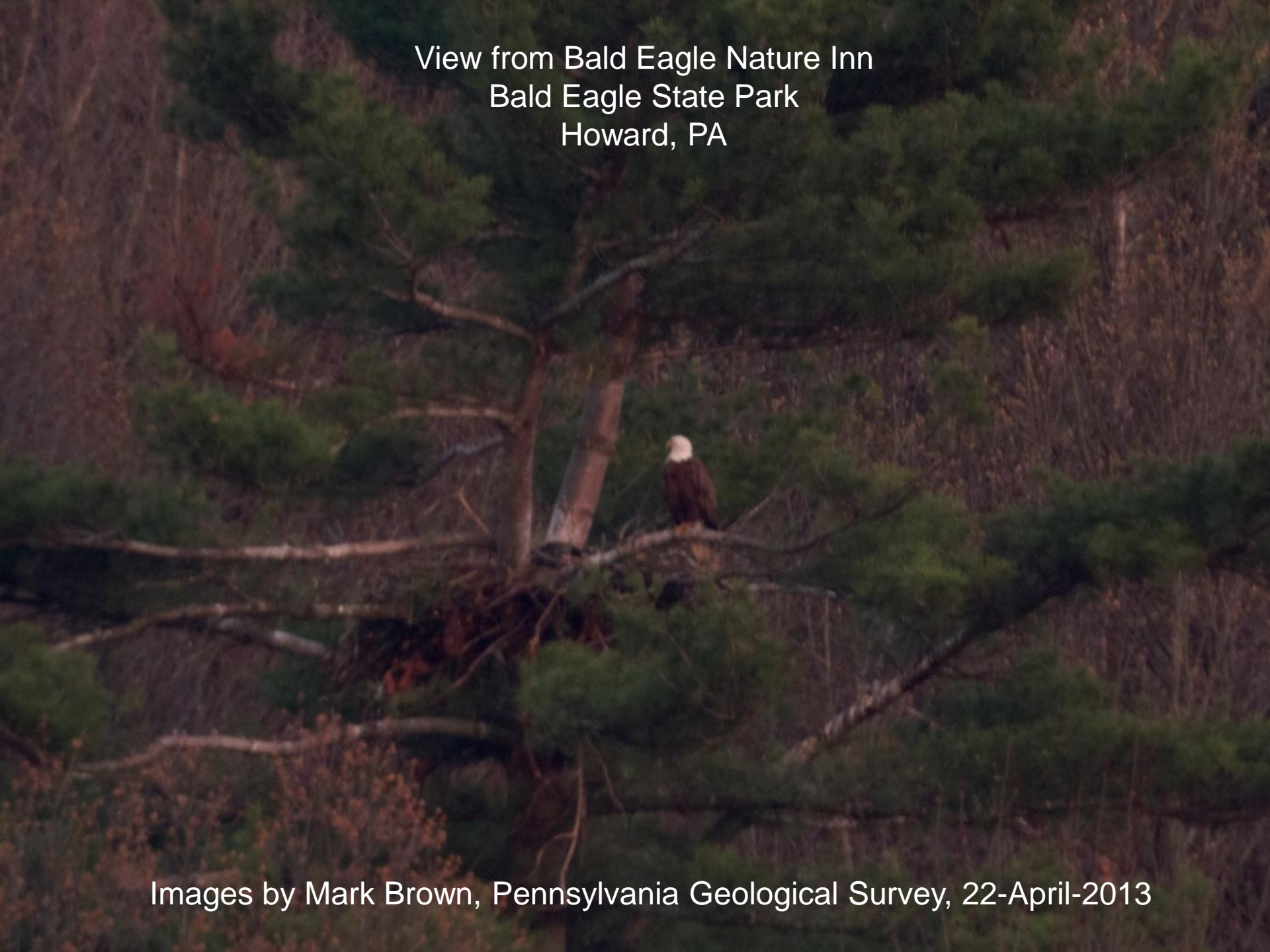
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View from Bald Eagle Nature Inn
Bald Eagle State Park
Howard, PA



Images by Mark Brown, Pennsylvania Geological Survey, 22-April-2013

Questions?



twhitfield@pa.gov

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