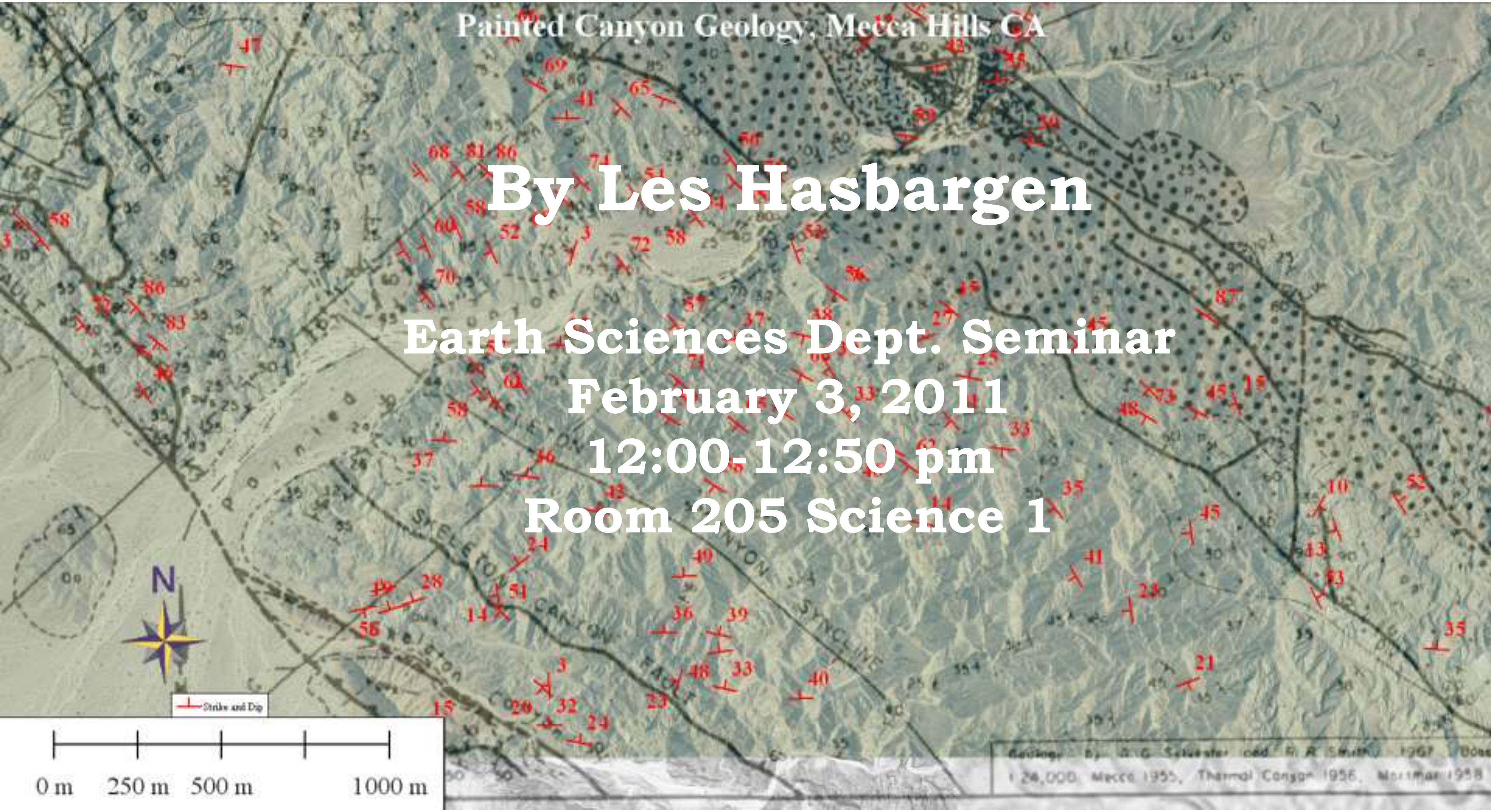
Geologic Mapping in a Virtual Workspace



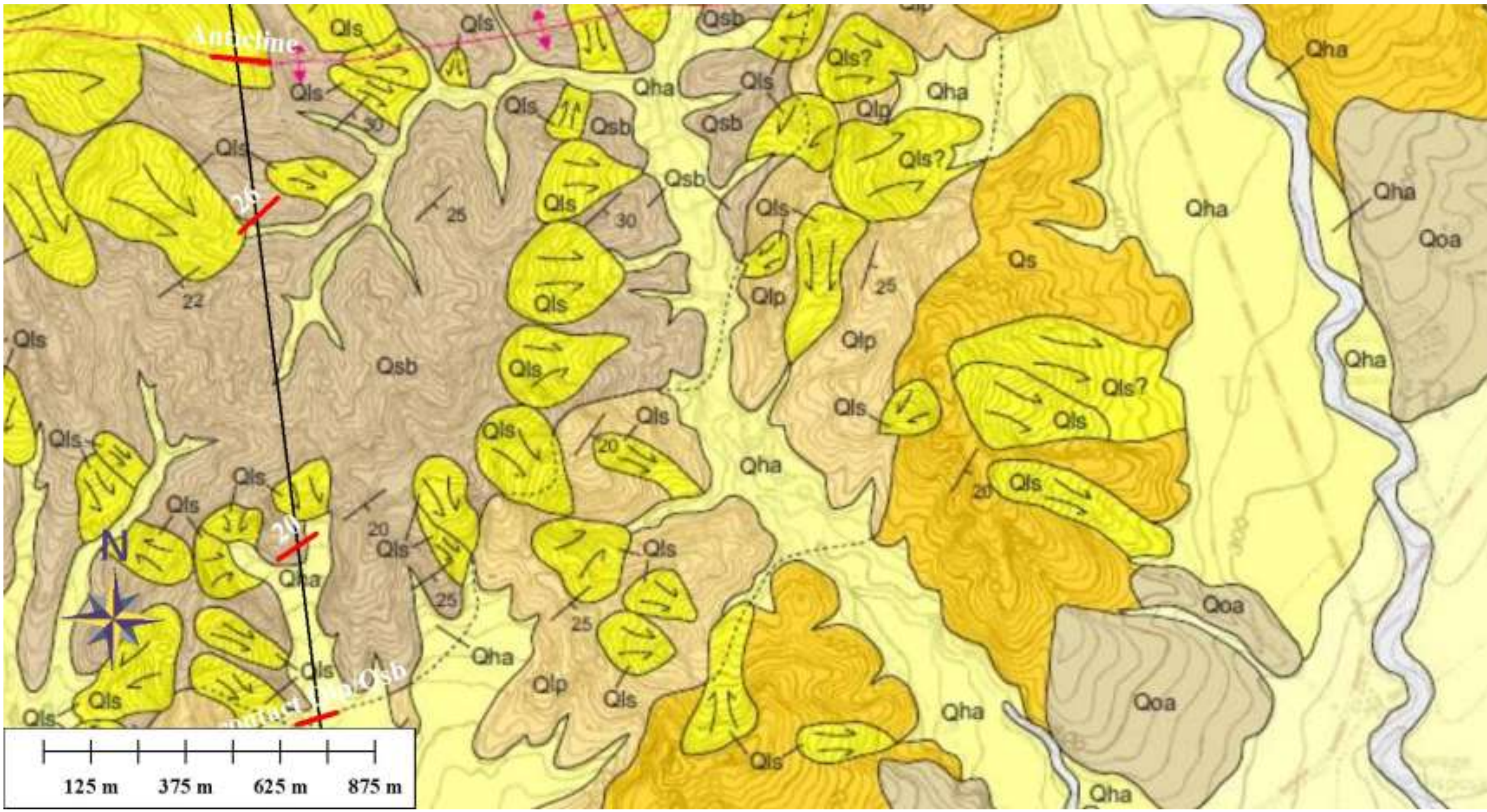
By Les Hasbargen

Earth Sciences Dept. Seminar
February 3, 2011
12:00-12:50 pm
Room 205 Science 1

Mapping this talk…

- Geologic mapping: rock location and orientation, and structures
- What's new? Data sources and access
- Math provides the tool to streamline the process

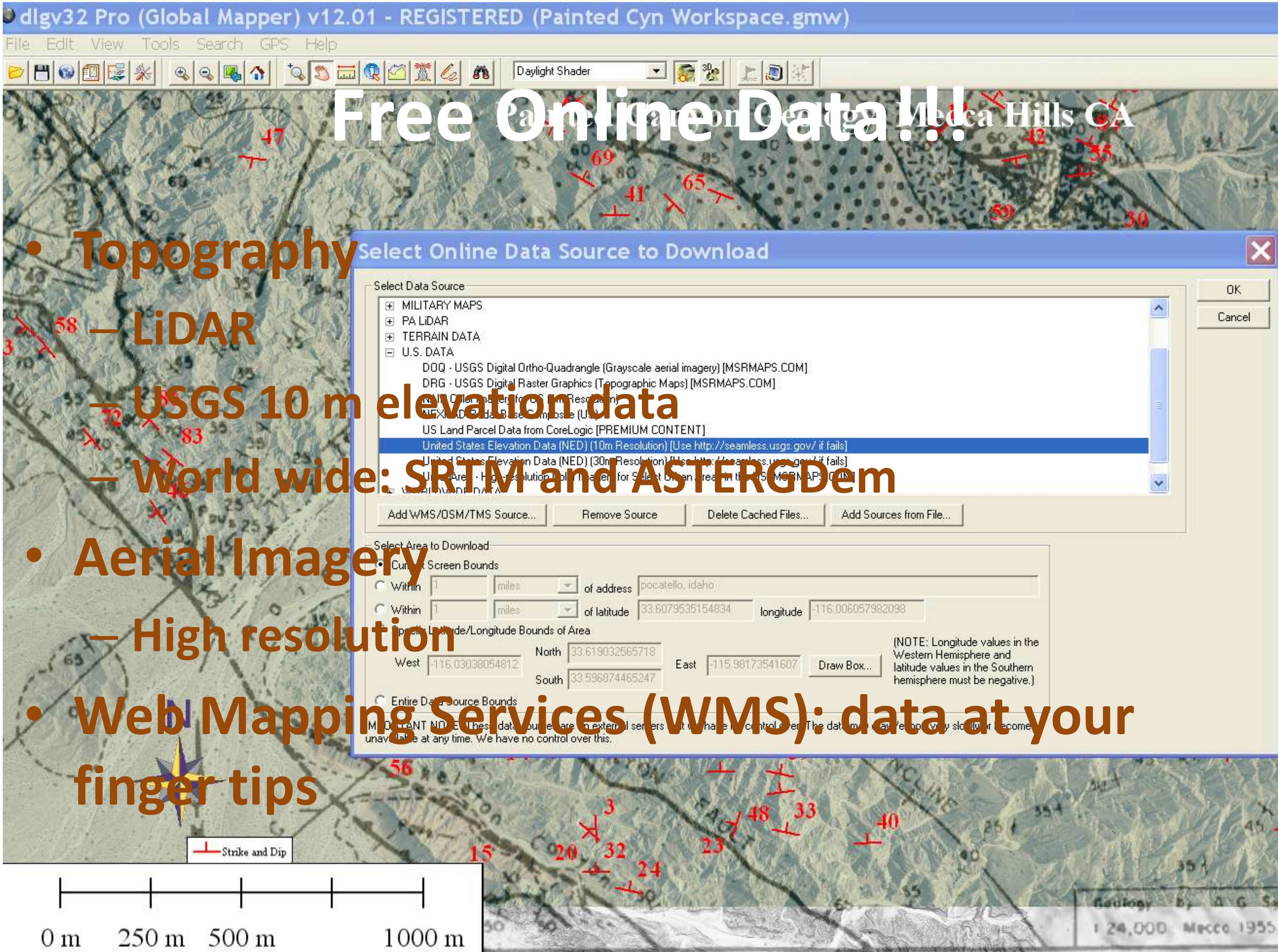
Geologic Maps



Geologic map excerpted from Siang S. Tan, Kevin B. Clahan and Anne M. Rosinski, 2004.

Free Online Data!!!

- Topography
  - LiDAR
  - USGS 10 m elevation data
  - World wide: SRTM and ASTERGDem
- Aerial Imagery
  - High resolution
- Web Mapping Services (WMS): data at your finger tips



The Data is there, and getting better… What do we do with it??!!

- Expand our mapping skills
- Take advantage of coordinate data
- Utilize 3-point method
- Make the computer do the math
- Make the computer plot the output

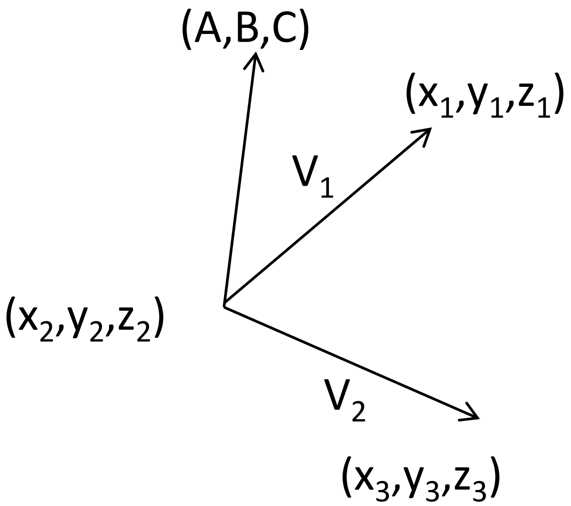
3-Point Problem

- Characterize a geologic surface as a plane
- Any three non-collinear points on that surface can define a plane
- Construct two vectors starting at the same point
- Find the cross product of the vectors (it’s a vector normal to the geologic plane)
- Determine strike and dip from the normal vector

The Cross Product

$$Ax + By + Cz = D$$

The equation of a plane, where A, B, C represent the vector normal to the plane.
First, construct two vector with the 3 points:



$$V_1 = (x_1 - x_2, y_1 - y_2, z_1 - z_2) = (a, b, c)$$

$$V_2 = (x_3 - x_2, y_3 - y_2, z_3 - z_2) = (d, e, f)$$

Then find the cross product of the two vectors:

$$V_1 \times V_2 = (b * f - e * c)\boldsymbol{i} - (a * f - d * c)\boldsymbol{j} + (a * e - d * b)\boldsymbol{k} = \boldsymbol{U_1}\mathbf{i} - \boldsymbol{U_2}\mathbf{j} + \boldsymbol{U_3}\mathbf{k}$$

$$\boldsymbol{U_1 i} = ((y_1 - y_2) * (z_3 - z_2) - (y_3 - y_2) * (z_1 - z_2))\boldsymbol{i}$$

$$-\boldsymbol{U_2 j} = -((x_1 - x_2) * (z_3 - z_2) - (x_3 - x_2) * (z_1 - z_2))\boldsymbol{j}$$

$$\boldsymbol{U_3 k} = ((x_1 - x_2) * (y_3 - y_2) - (x_3 - x_2) * (y_1 - y_2))\boldsymbol{k}$$

Then find determine the strike and dip. Note, mathematically, this is the most tedious part! Dang geologic conventions for characterizing a plane. It would be easier if we defined geologic surfaces with dip and dip direction…

Strike and Dip from the Normal

$$U_1 i = ((y_1 - y_2) * (z_3 - z_2) - (y_3 - y_2) * (z_1 - z_2))i$$

$$-U_2 j = -((x_1 - x_2) * (z_3 - z_2) - (x_3 - x_2) * (z_1 - z_2))j$$

$$U_3 k = ((x_1 - x_2) * (y_3 - y_2) - (x_3 - x_2) * (y_1 - y_2))k$$

This gives us the components of the pole to the plane

$$S = \{U_2, -U_1, 0\} = \{E, N, 0\}$$

This is the strike vector, consistent with right hand rule

$$\cos(\beta) = \frac{N}{\sqrt{E^2 + N^2}} \rightarrow \beta = \arccos\left(\frac{N}{\sqrt{E^2 + N^2}}\right)$$

This is the bearing of the strike line, clockwise from North

The following table resolves ambiguities between the pole extending above or below the plane

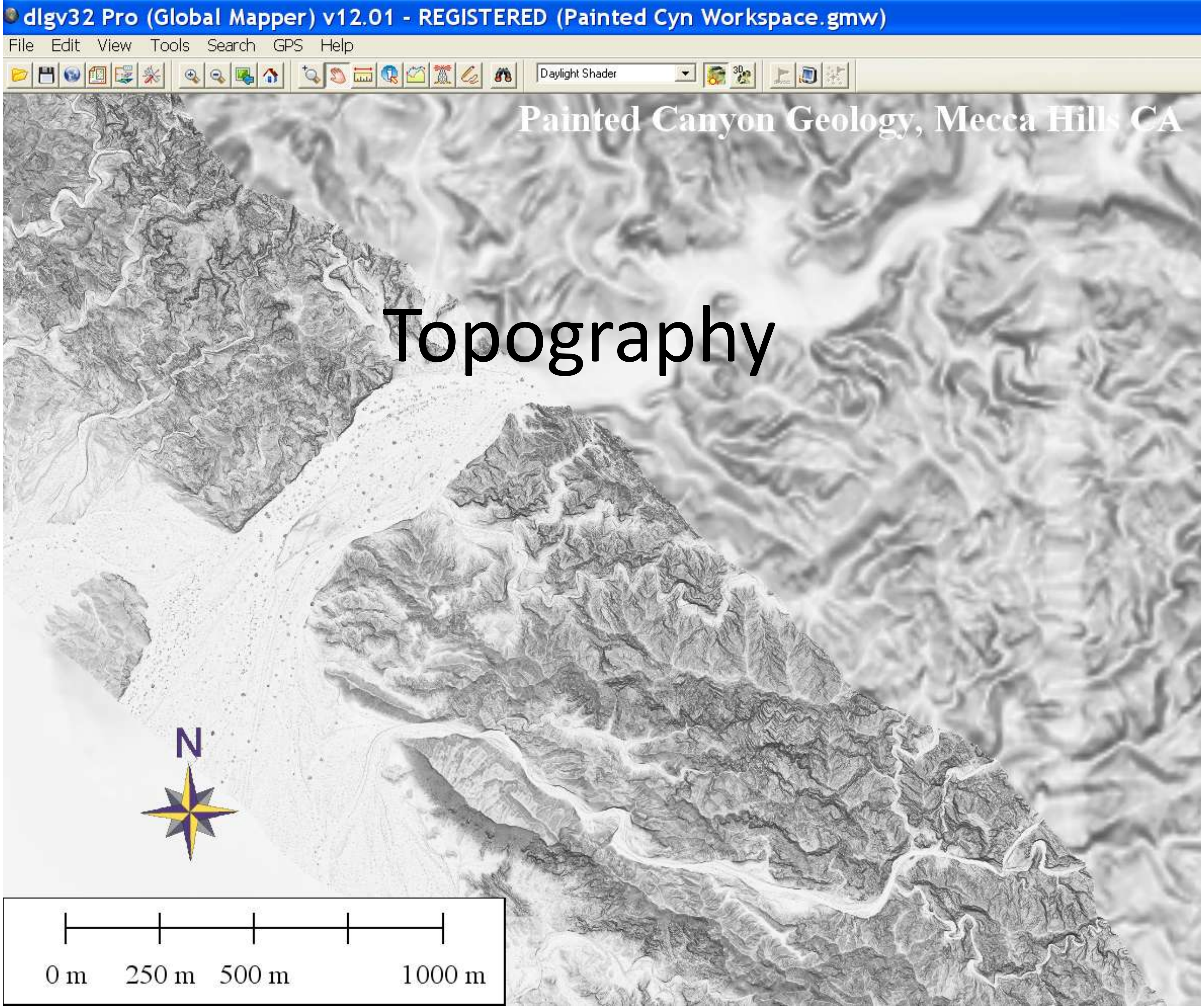
Easting	Northing	Quadrant	Formula: Radians→Degrees
$E > 0$	$N > 0$	0-90	$=\beta * 180/\pi$
$E > 0$	$N < 0$	90-180	$=\beta * 180/\pi$
$E < 0$	$N < 0$	180-270	$=360 - \beta * 180/\pi$
$E < 0$	$N > 0$	270-360	$=360 - \beta * 180/\pi$

Getting the dip angle from the components of the pole to the plane

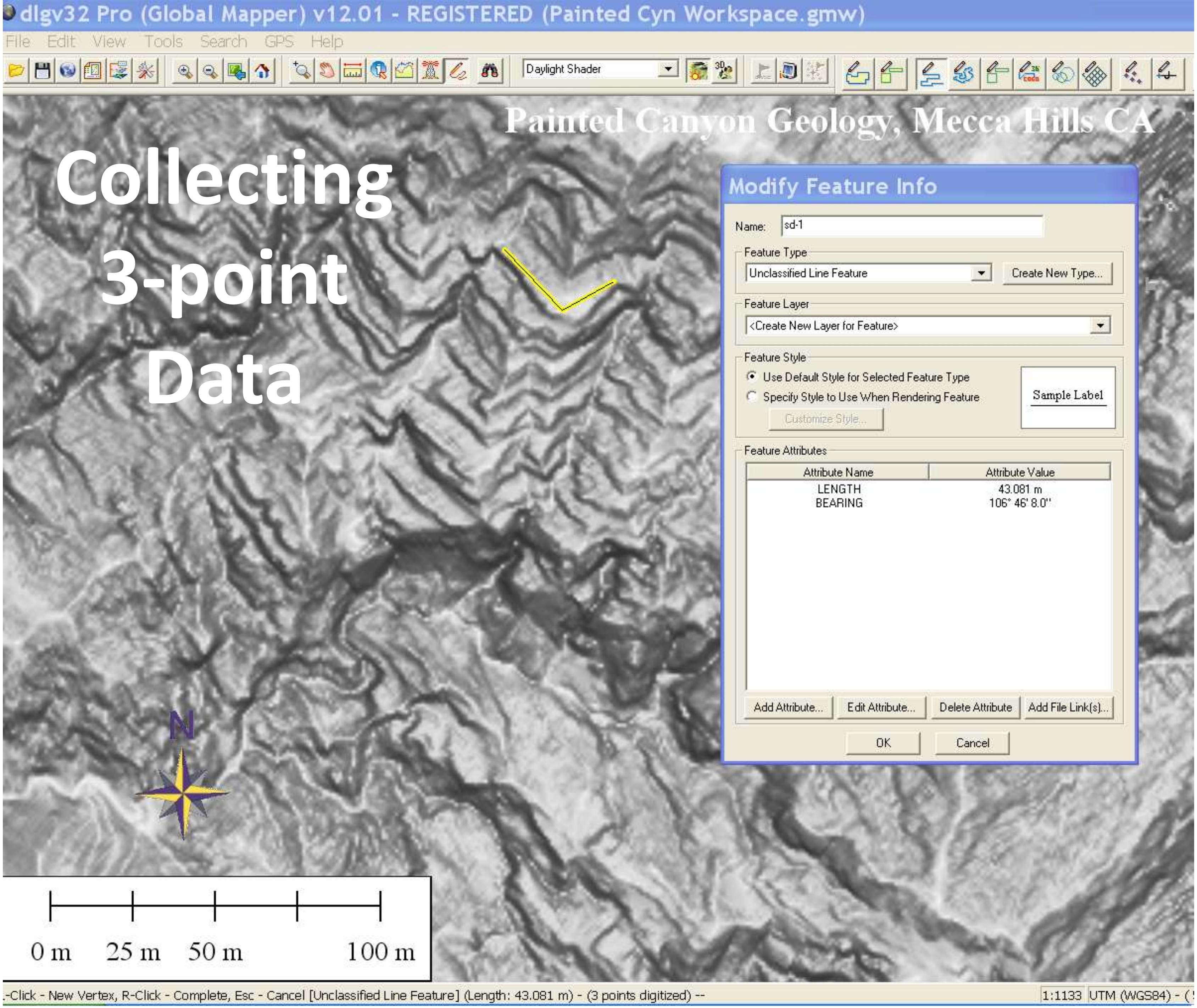
$$\sin(\delta) = \frac{\sqrt{\boldsymbol{U_1}^2 + \boldsymbol{U_2}^2}}{\sqrt{\boldsymbol{U_1}^2 + \boldsymbol{U_2}^2 + \boldsymbol{U_3}^2}} \rightarrow \delta = \arcsin\left(\frac{\sqrt{\boldsymbol{U_1}^2 + \boldsymbol{U_2}^2}}{\sqrt{\boldsymbol{U_1}^2 + \boldsymbol{U_2}^2 + \boldsymbol{U_3}^2}}\right)$$

A case study: Painted Canyon, CA

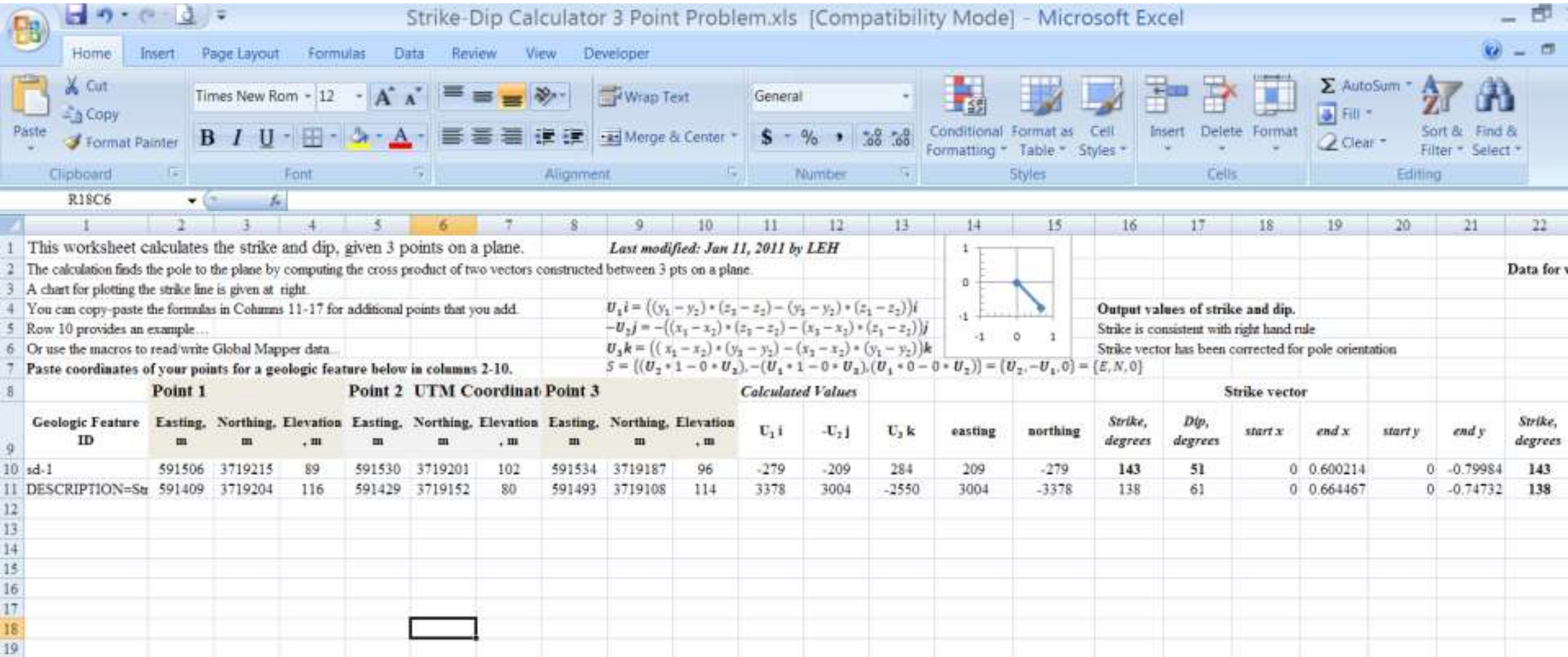
Topography


dlgv32 Pro (Global Mapper) v12.01 - REGISTERED (Painted Cyn Workspace.gmw)
File Edit View Tools Search GPS Help
Daylight Shader
Painted Canyon Geology, Mecca Hills CA
N
0 m
250 m
500 m
1000 m

Collecting 3-point Data

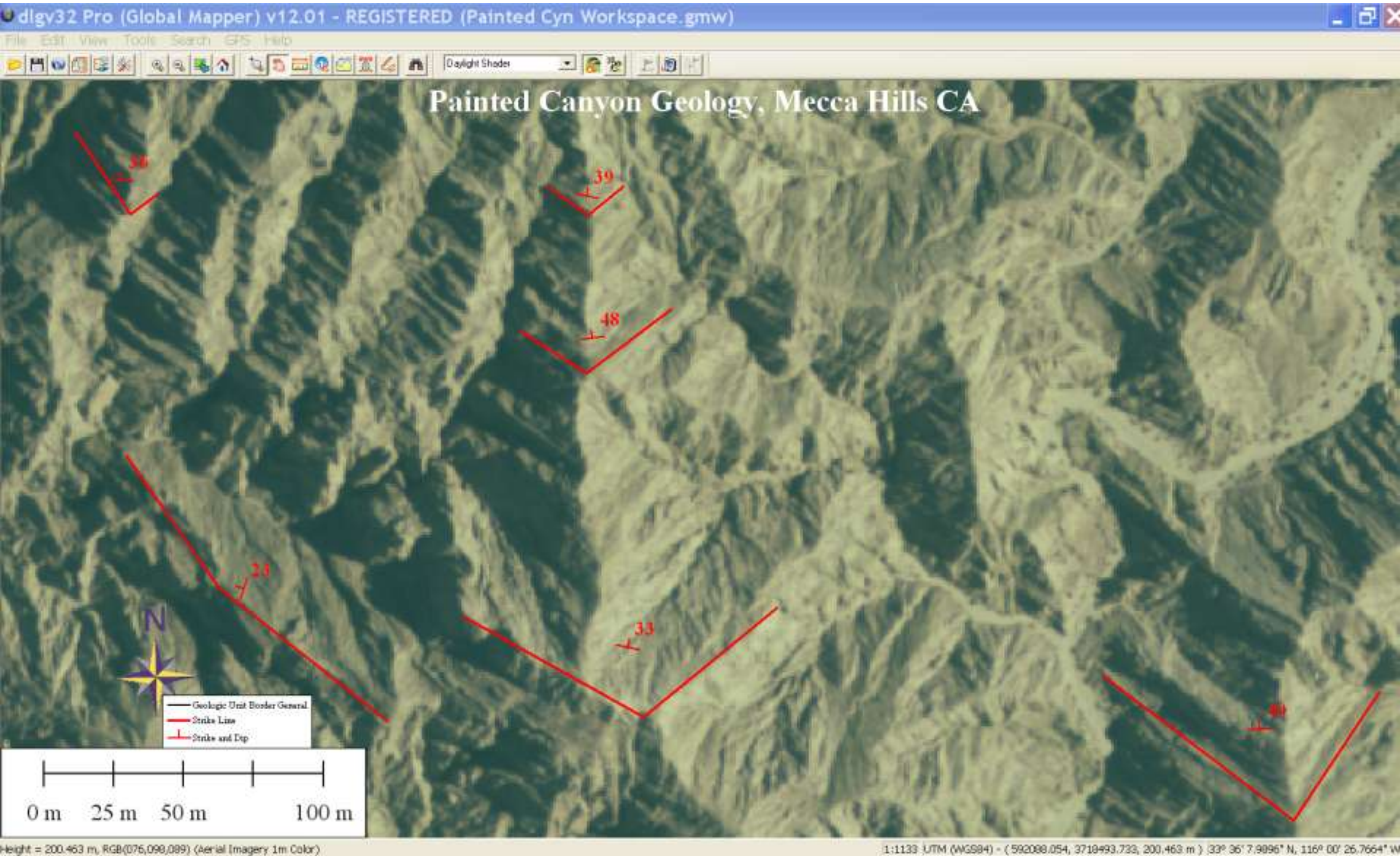


Implementing the solution in a spreadsheet

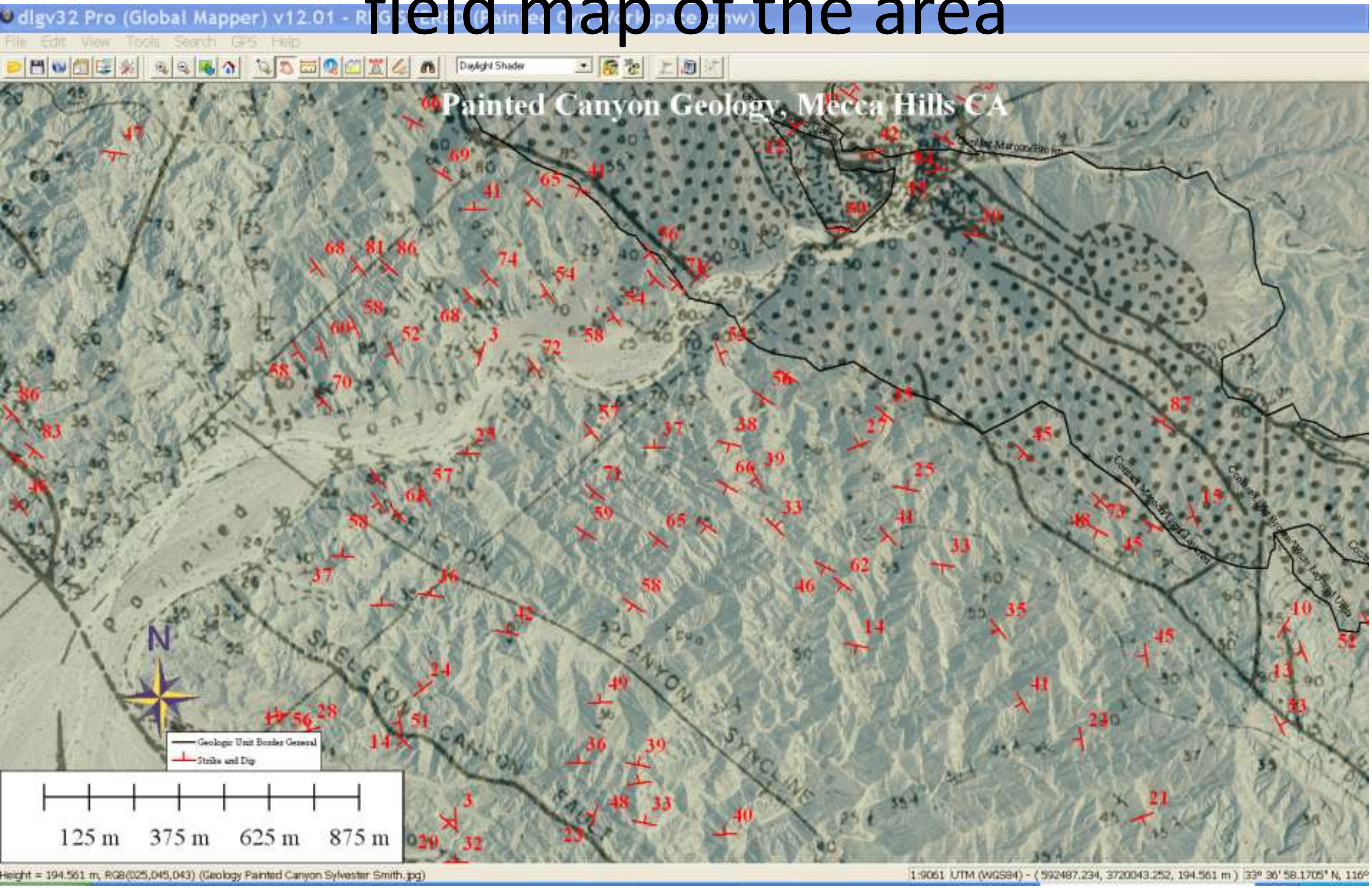


Getting the data into and out of the spreadsheet involves export/import of text files from the GIS. This can be automated with a macro in Excel. In fact, all of the calculations can be done off-screen, and written to a GIS-readable file, which then plots the strike dips for you…

3-Point lines and Strike-Dips



Add contacts, and compare to a real field map of the area

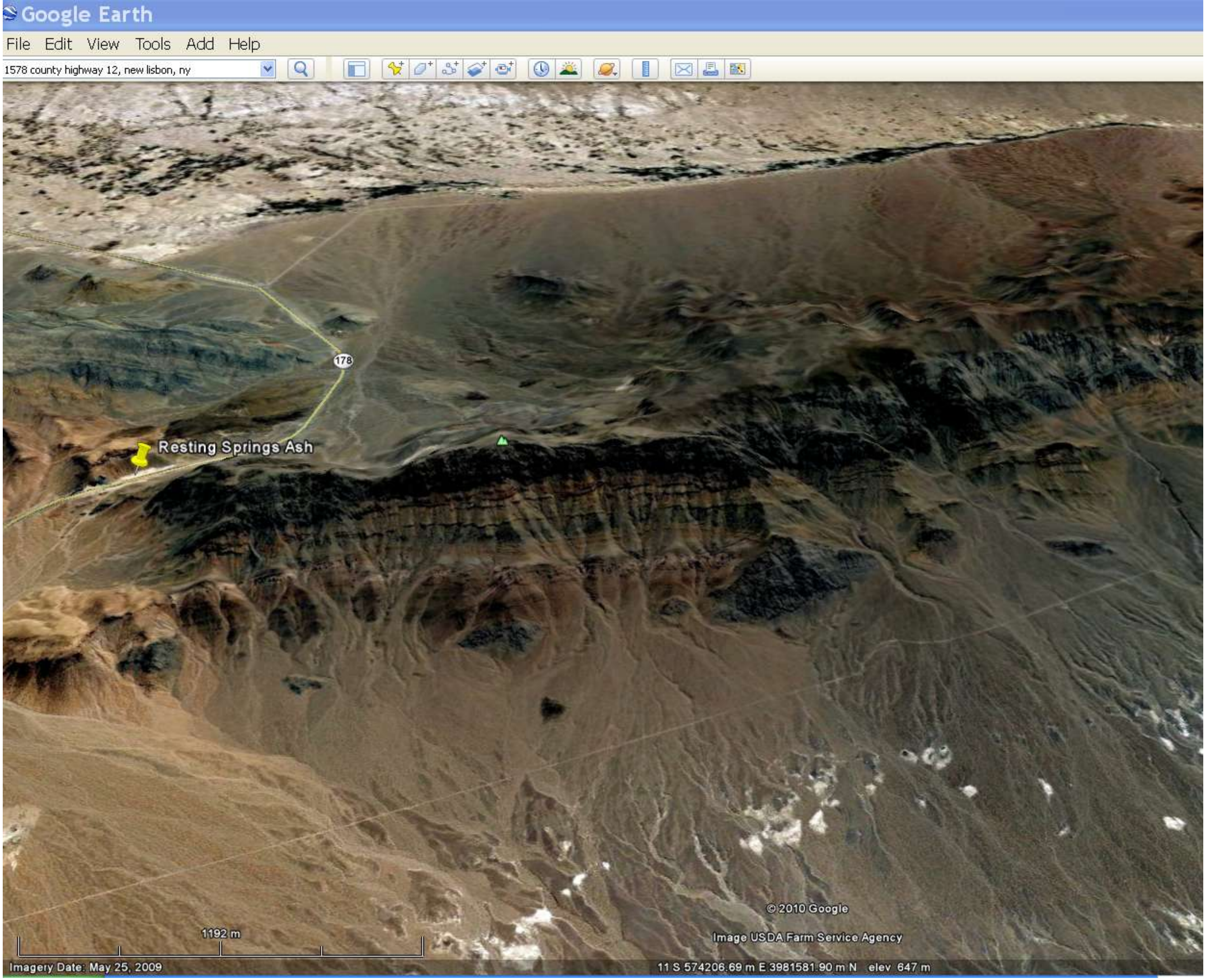


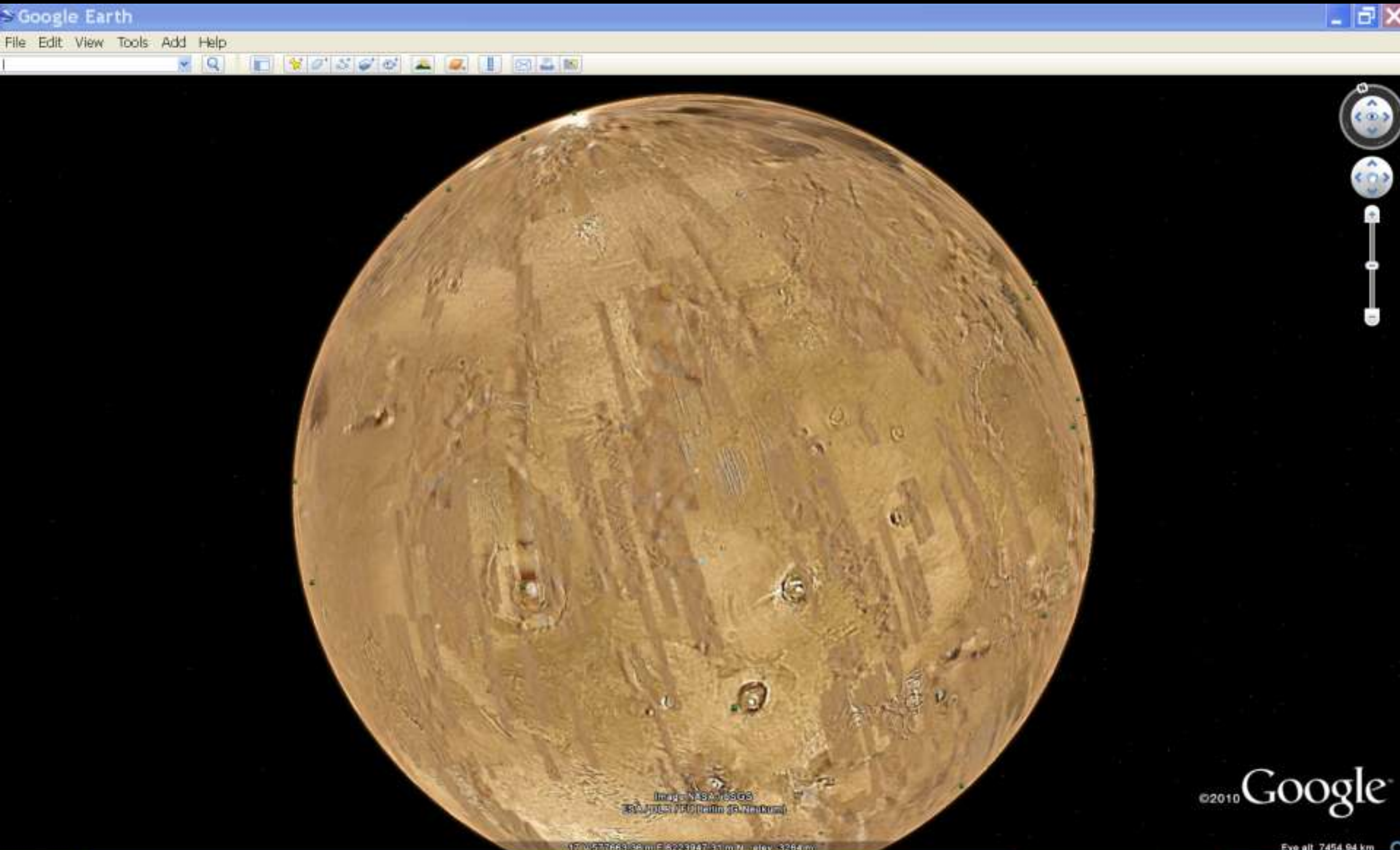
Problems

- Identifying bedding surfaces and contacts
  - Google Earth provides numerous photos under different lighting conditions—and it’s easy to get kmz files into Global Mapper
- Quality of the underlying topography makes a huge difference!
  - If one uses SRTM or ASTERGDem data, features must be continuous overlong distances, 400-500 m
  - Initial tests suggests USGS NED (1 sec and 1/3 sec) data compare moderately well with LiDAR (1 m spacing)

Applicability

- Limited only by data quality, in terms of resolution (spacing between points) and precision
- Can be applied to Afghanistan, Death Valley, the Moon, or Mars or??
- How reliable is it? We still need boots on the ground! But office mapping can provide an excellent framework to go test in the field


Google Earth
File Edit View Tools Add Help
1578 county highway 12, new lisbon, ny
178
Resting Springs Ash
© 2010 Google
Image USDA Farm Service Agency
1192 m
Imagery Date: May 25, 2009
11 S 574206.69 m E 3981581.90 m N elev 647 m


Google Earth
File Edit View Tools Add Help
©2010 Google
Eye alt 7454.94 km

Questions?