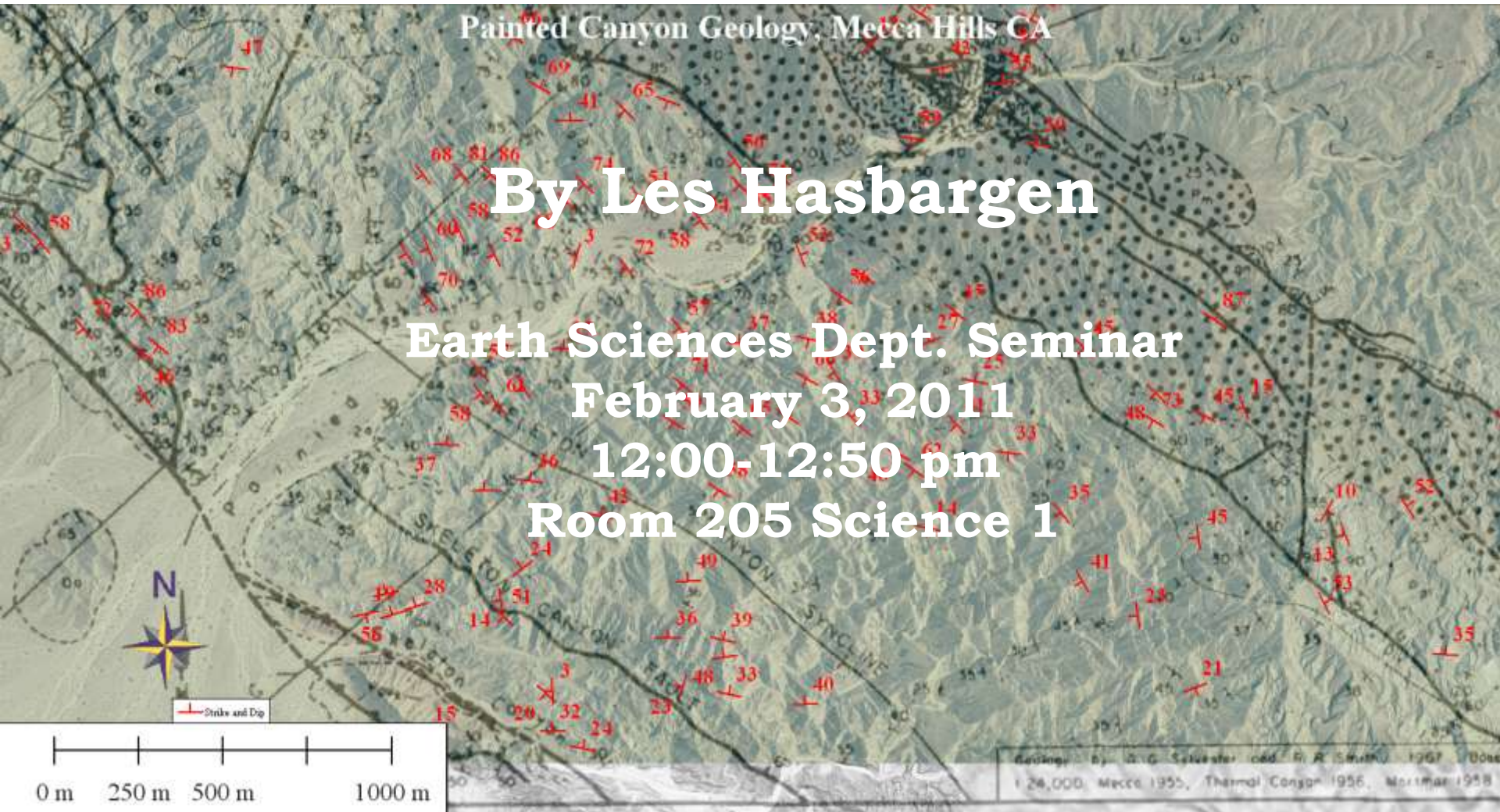


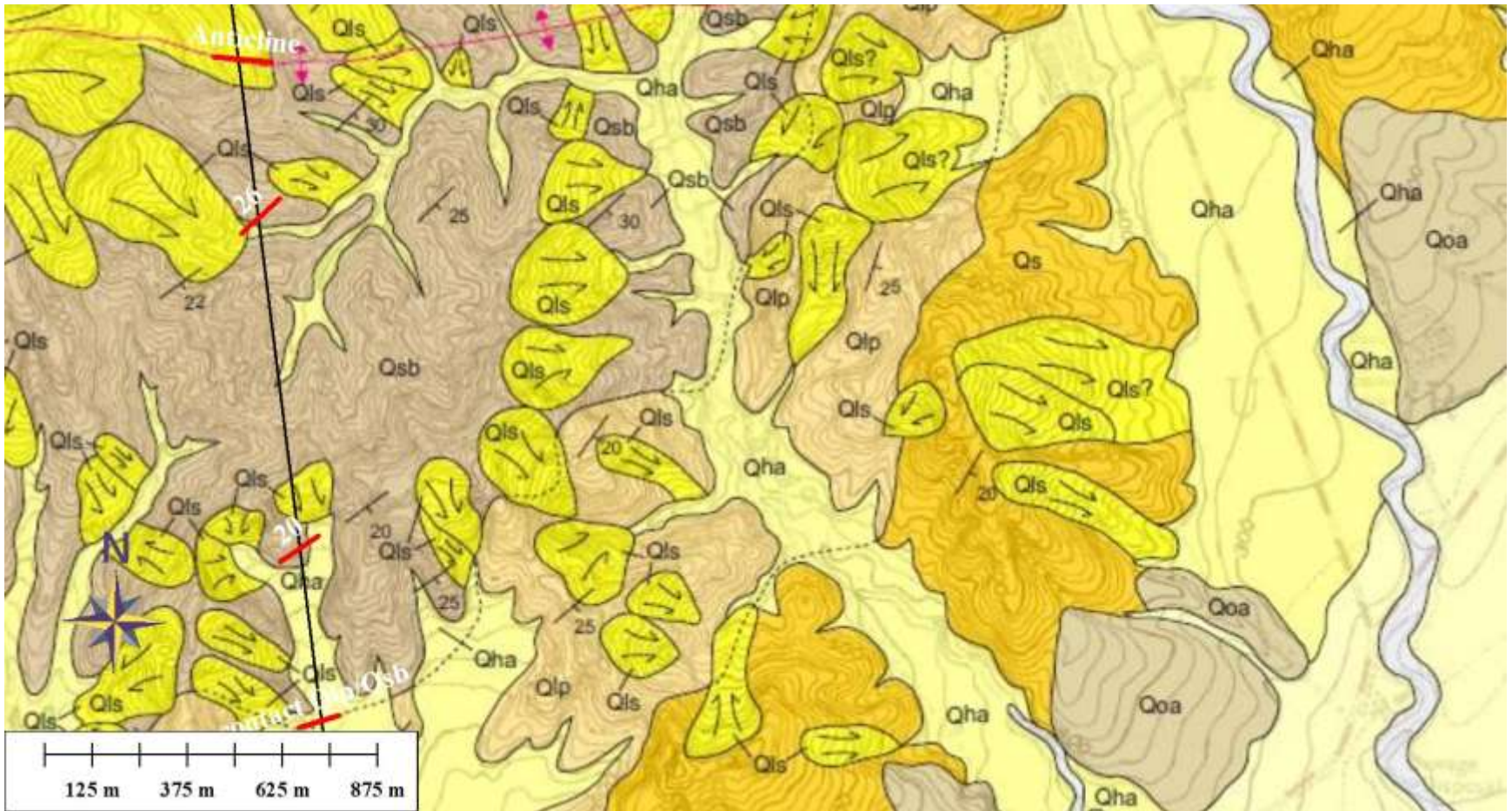
GEOLOGIC MAPPING IN A VIRTUAL WORKSPACE



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 ASTER GDEM

• Aerial Imagery

— High resolution

• Web Mapping Services (WMS): data at your

finger tips

Select Online Data Source to Download

Select Data Source

- MILITARY MAPS
- PA LIDAR
- TERRAIN DATA
- U.S. DATA
 - DOQ - USGS Digital Ortho-Quadrangle (Grayscale aerial imagery) [MSRMAPS.COM]
 - DRG - USGS Digital Raster Graphics (Topographic Maps) [MSRMAPS.COM]
 - USGS 10m Elevation Data (10m Resolution) [Use http://seamless.usgs.gov/ if fails]
 - USGS 30m Elevation Data (30m Resolution) [Use http://seamless.usgs.gov/ if fails]
 - USGS 1:250,000 Scale Topographic Maps (USGS)
 - US Land Parcel Data from CoreLogic [PREMIUM CONTENT]
 - United States Elevation Data (NED) (10m Resolution) [Use http://seamless.usgs.gov/ if fails]
 - United States Elevation Data (NED) (30m Resolution) [Use http://seamless.usgs.gov/ if fails]
 - USGS Aerial - High Resolution Digital Transfer for Selected Areas in the US [MSRMAPS.COM]
 - USGS Wetland Data

Buttons: Add WMS/DSM/TMS Source... Remove Source Delete Cached Files... Add Sources from File...

Select Area to Download

Current Screen Bounds

Within [] miles of address [pocatello, idaho]

Within [] miles of latitude [33.6079535154834] longitude [-116.006057982098]

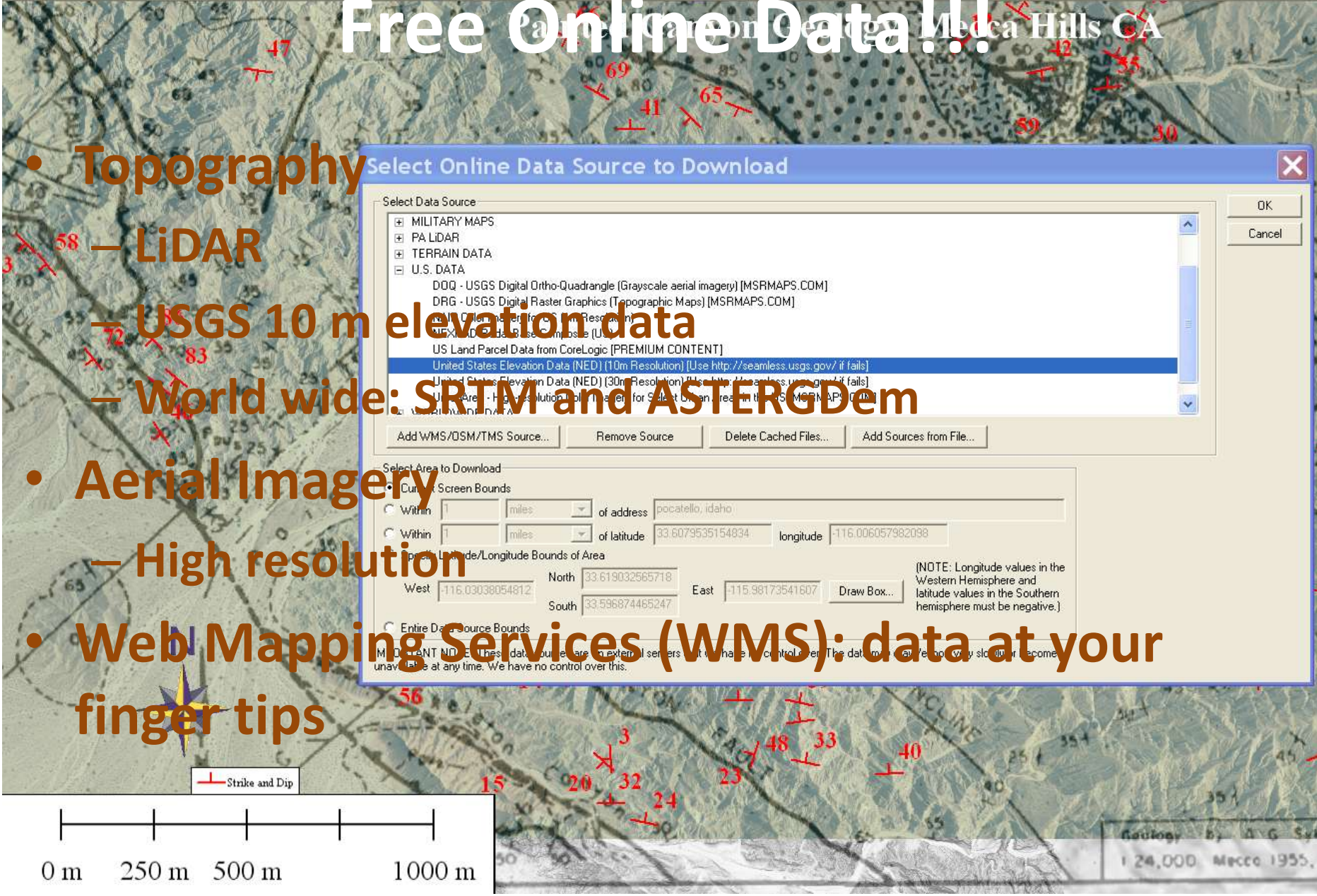
Specify Latitude/Longitude Bounds of Area

West [-116.03038054812] North [33.619032565718] East [-115.98173541607] South [33.596874465247]

Buttons: Draw Box... (NOTE: Longitude values in the Western Hemisphere and latitude values in the Southern hemisphere must be negative.)

Entire Data Source Bounds

IMPORTANT NOTE: These data sources are on external servers that we have no control over. The data may not be available or become unavailable at any time. We have no control over this.



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

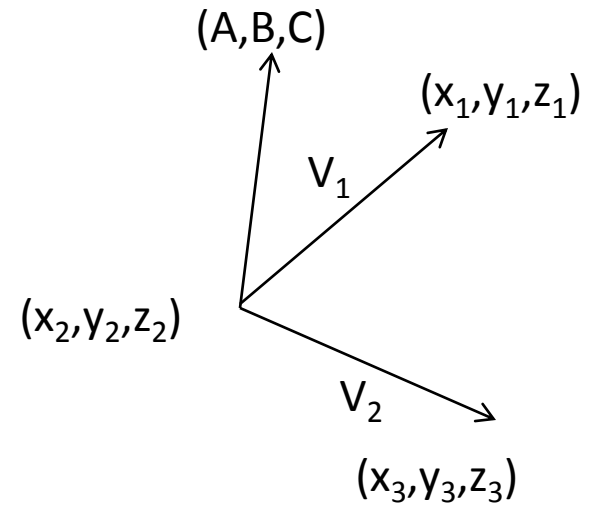
$$Ax + By + Cz = D$$

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:

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

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

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

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

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

‡

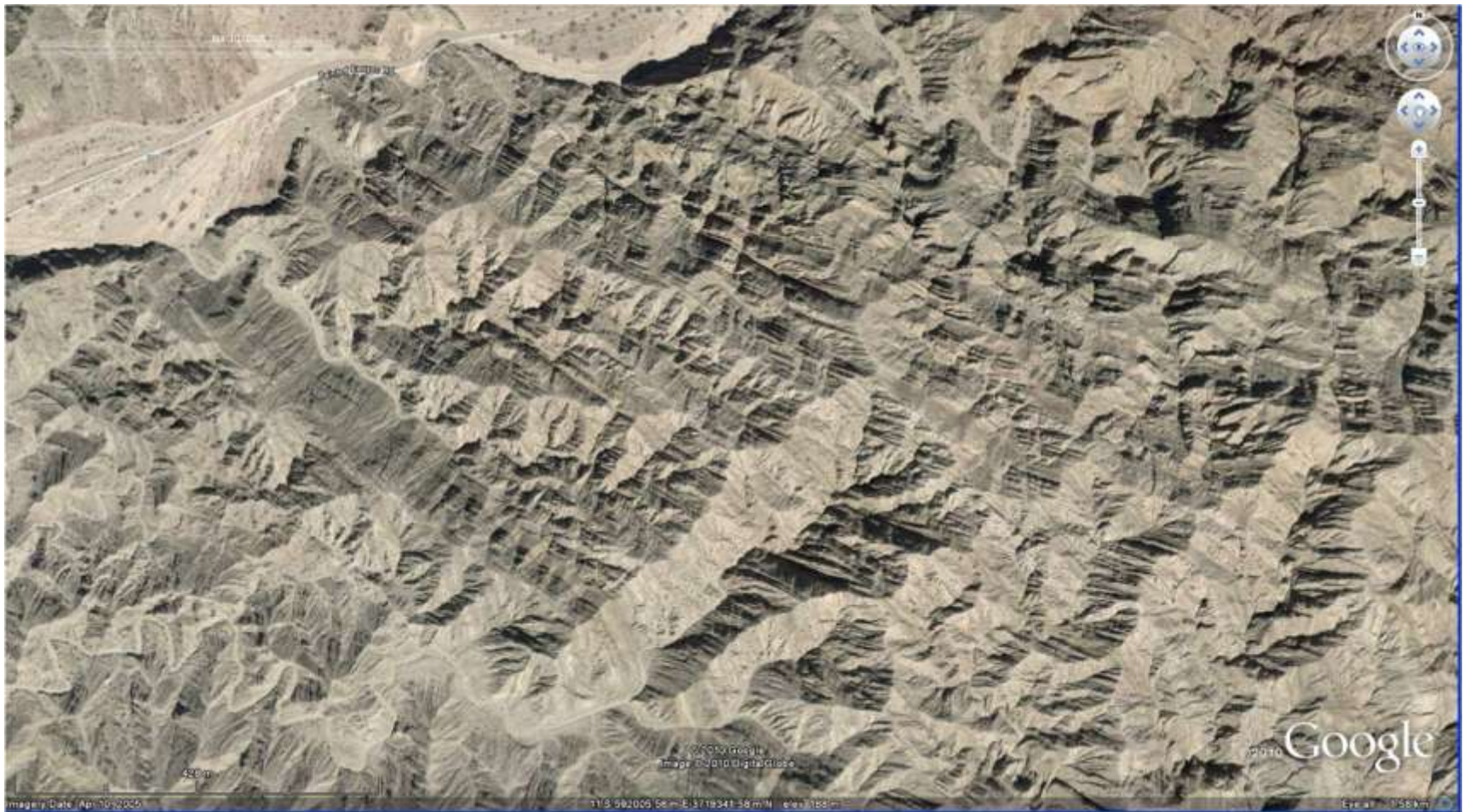
Easting	Northing	Quadrant	Formula: Radians → Degrees
$E > 0$	$N > 0$	0-90	$=\beta * 180/\pi$
$E > 0$	$N < 0$	90-180	$=\beta * 180/\pi$
$E < 0$	$N < 0$	180-270	$=360 - \beta * 180/\pi$
$E < 0$	$N > 0$	270-360	$=360 - \beta * 180/\pi$

□

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

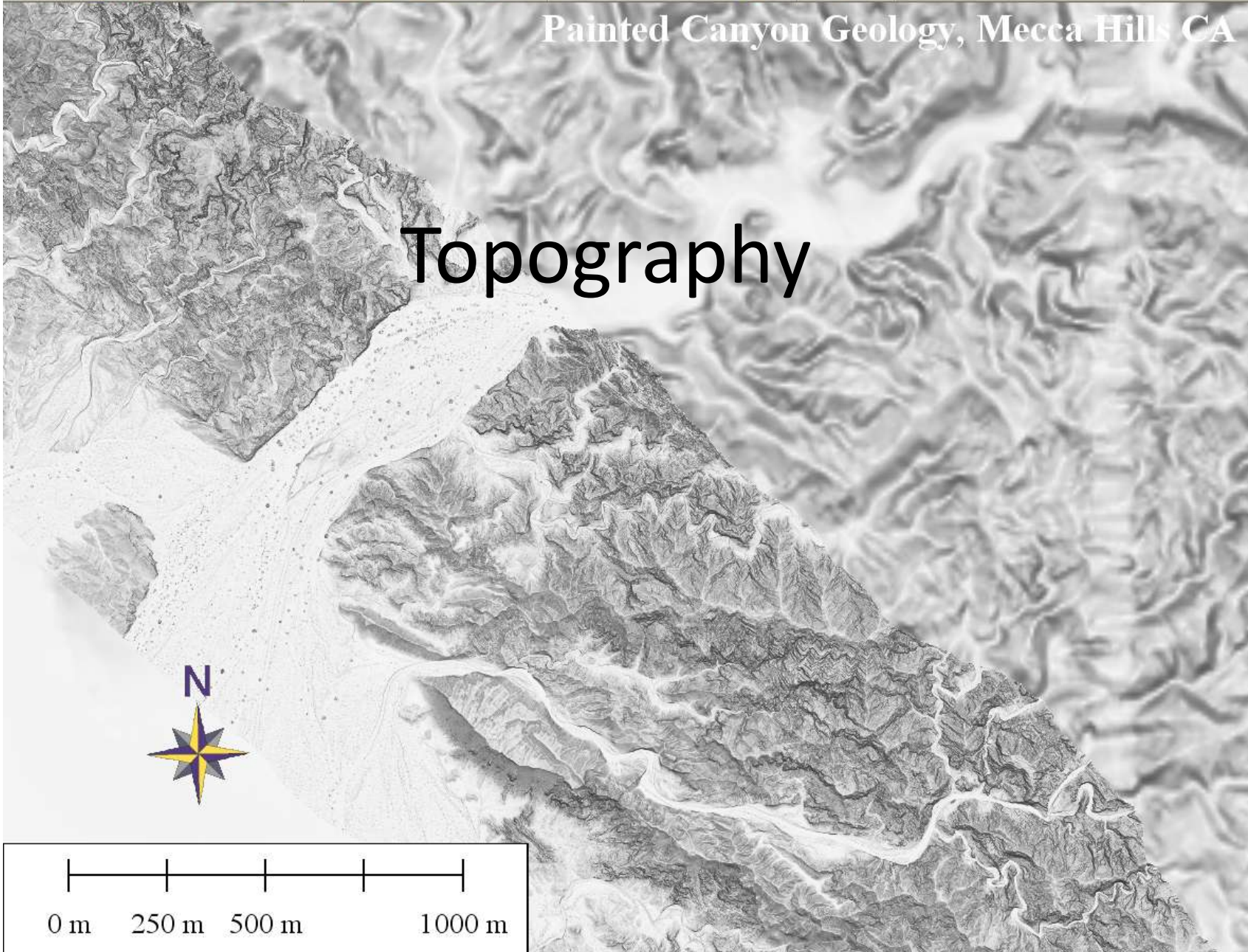
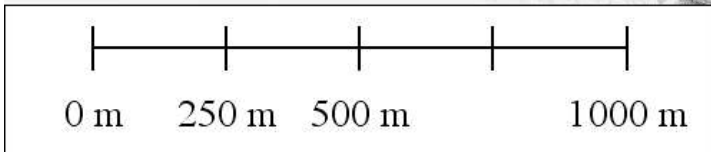
$$\sin(\delta) = \frac{\sqrt{U_1^2 + U_2^2}}{\sqrt{U_1^2 + U_2^2 + U_3^2}} \rightarrow \delta = \arcsin\left(\frac{\sqrt{U_1^2 + U_2^2}}{\sqrt{U_1^2 + U_2^2 + U_3^2}}\right)$$

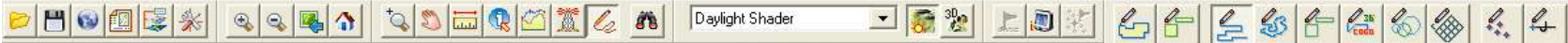
A case study: Painted Canyon, CA



Painted Canyon Geology, Mecca Hills CA

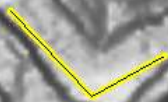
Topography





Painted Canyon Geology, Mecca Hills CA

Collecting 3-point Data



Modify Feature Info

Name:

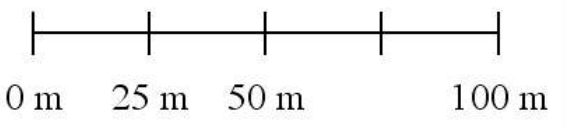
Feature Type:

Feature Layer:

Feature Style:
 Use Default Style for Selected Feature Type
 Specify Style to Use When Rendering Feature

Feature Attributes

Attribute Name	Attribute Value
LENGTH	43.081 m
BEARING	106° 46' 8.0"



Implementing the solution in a spreadsheet

Strike-Dip Calculator 3 Point Problem.xls [Compatibility Mode] - Microsoft Excel

Home Insert Page Layout Formulas Data Review View Developer

Clipboard Font Alignment Number Styles Cells Editing

1 This worksheet calculates the strike and dip, given 3 points on a plane. *Last modified: Jan 11, 2011 by LEH*

2 The calculation finds the pole to the plane by computing the cross product of two vectors constructed between 3 pts on a plane.

3 A chart for plotting the strike line is given at right.

4 You can copy-paste the formulas in Columns 11-17 for additional points that you add.

5 Row 10 provides an example...

6 Or use the macros to read/write Global Mapper data.

7 Paste coordinates of your points for a geologic feature below in columns 2-10.

8

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32

Geologic Feature ID

Eastings, Northings, Elevations

Point 1 Point 2 Point 3

UTM Coordinates

Calculated Values

Strike vector

Strike, Dip, start x, end x, start y, end y, Strike, Dip, degrees

sd-1

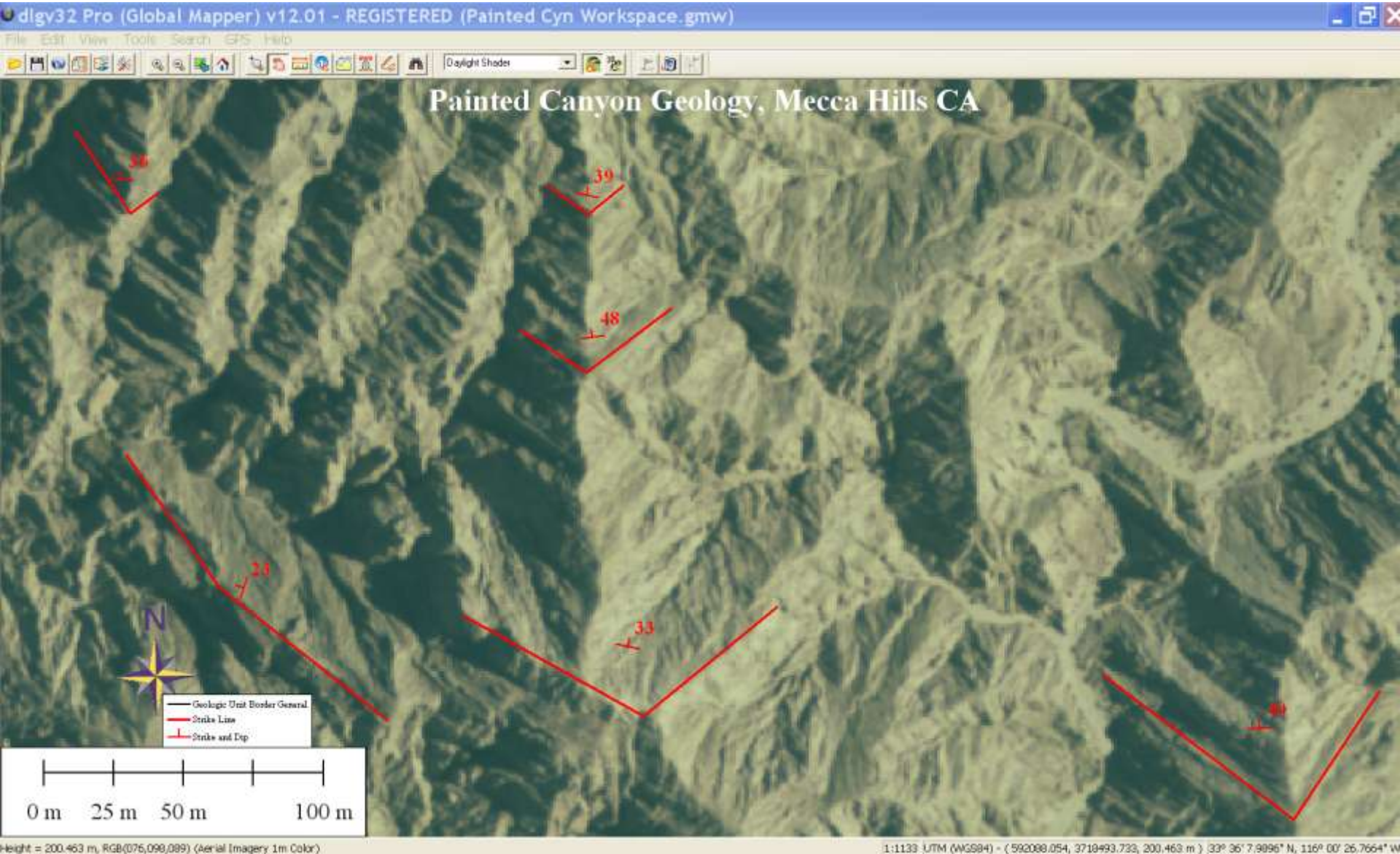
DESCRIPTION=Str

591506 3719215 89 591530 3719201 102 591534 3719187 96 -279 -209 284 209 -279 143 51 0 0.600214 0 -0.79984 143

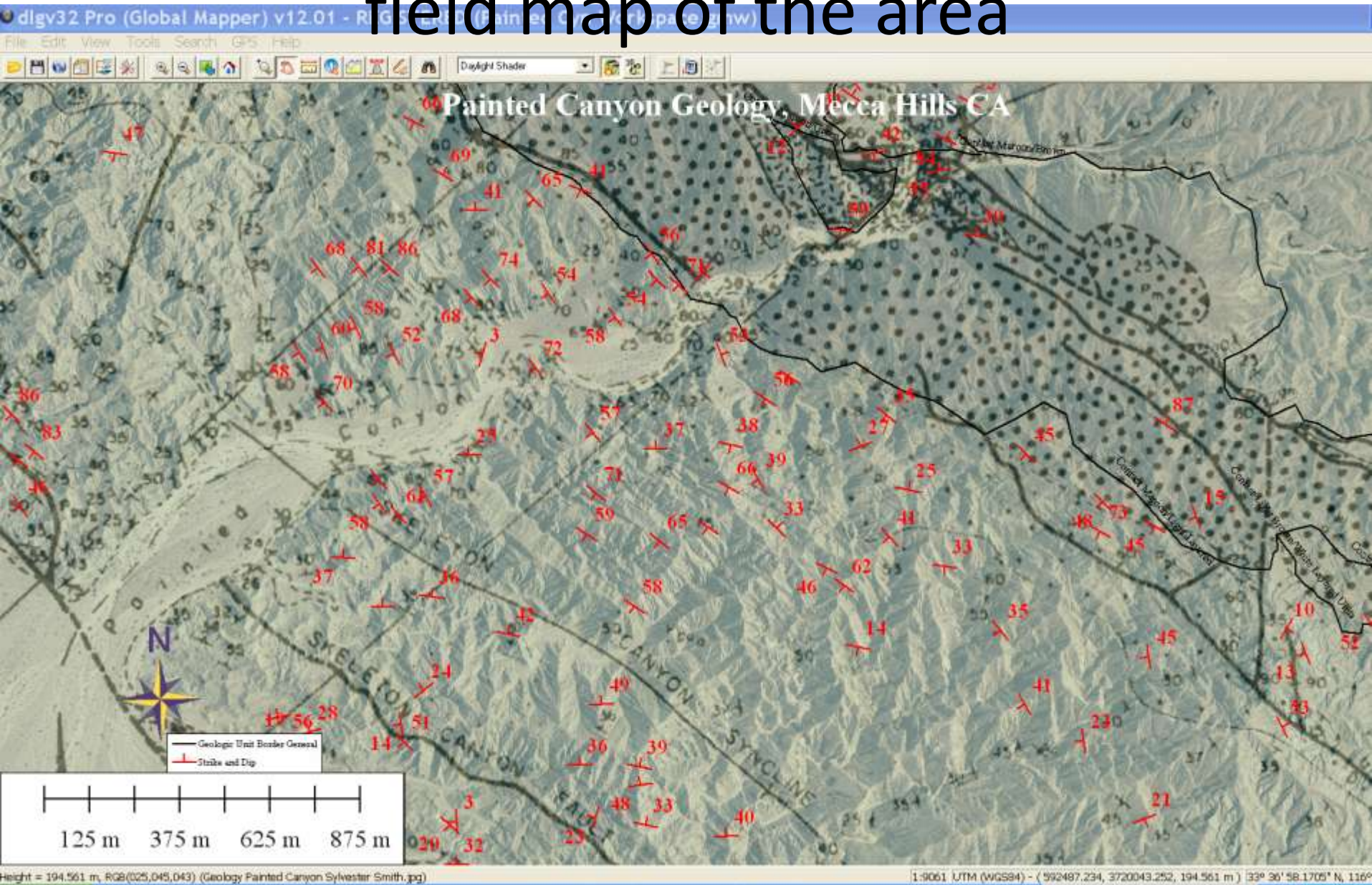
591409 3719204 116 591429 3719152 80 591493 3719108 114 3378 3004 -2550 3004 -3378 138 61 0 0.664467 0 -0.74732 138

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 over long 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



1192 m

© 2010 Google

Image USDA Farm Service Agency

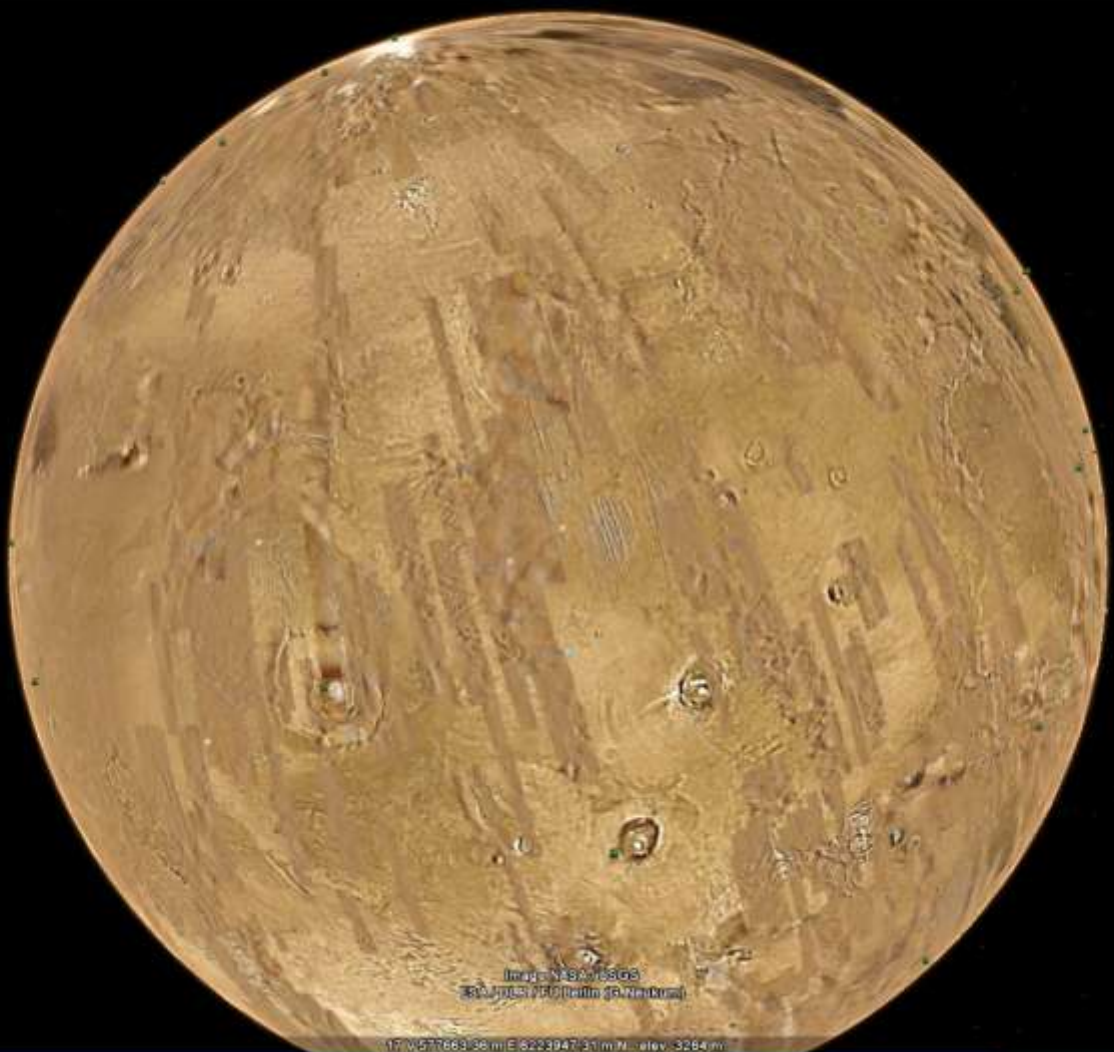


Image © NASA/JPL/USGS
Data © 2001-2010 (all rights reserved)

17° W, 57° 56' 38" E @ 223947.31 m N, elev. 3294 m

Questions?

