Real-time Mapping of Laser Rangefinder to Photograph in ArcMap

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Overview

- LaserSketch is an ArcMap/ArcScene extension which provides real-time mapping (or offline mapping) of point measurements by a laser or total station on a vertically oriented structure to their proper location on a photograph of the structure.
- Requirements:
  - One time distortion characterization of the camera
  - Laser with XYZ encoder or total station
  - For real-time plotting: Bluetooth, USB, or serial link between laser/total station and laptop computer running ArcMap and LaserSketch
  - For offline plotting: computer running ArcMap and LaserSketch
  - Identify a minimum of four tiepoints between the photograph and the XYZ coordinates from the laser/total station. Tiepoints are graphic markers placed on the photograph in ArcMap.

Examples of Laser Systems

Laser Rangefinder

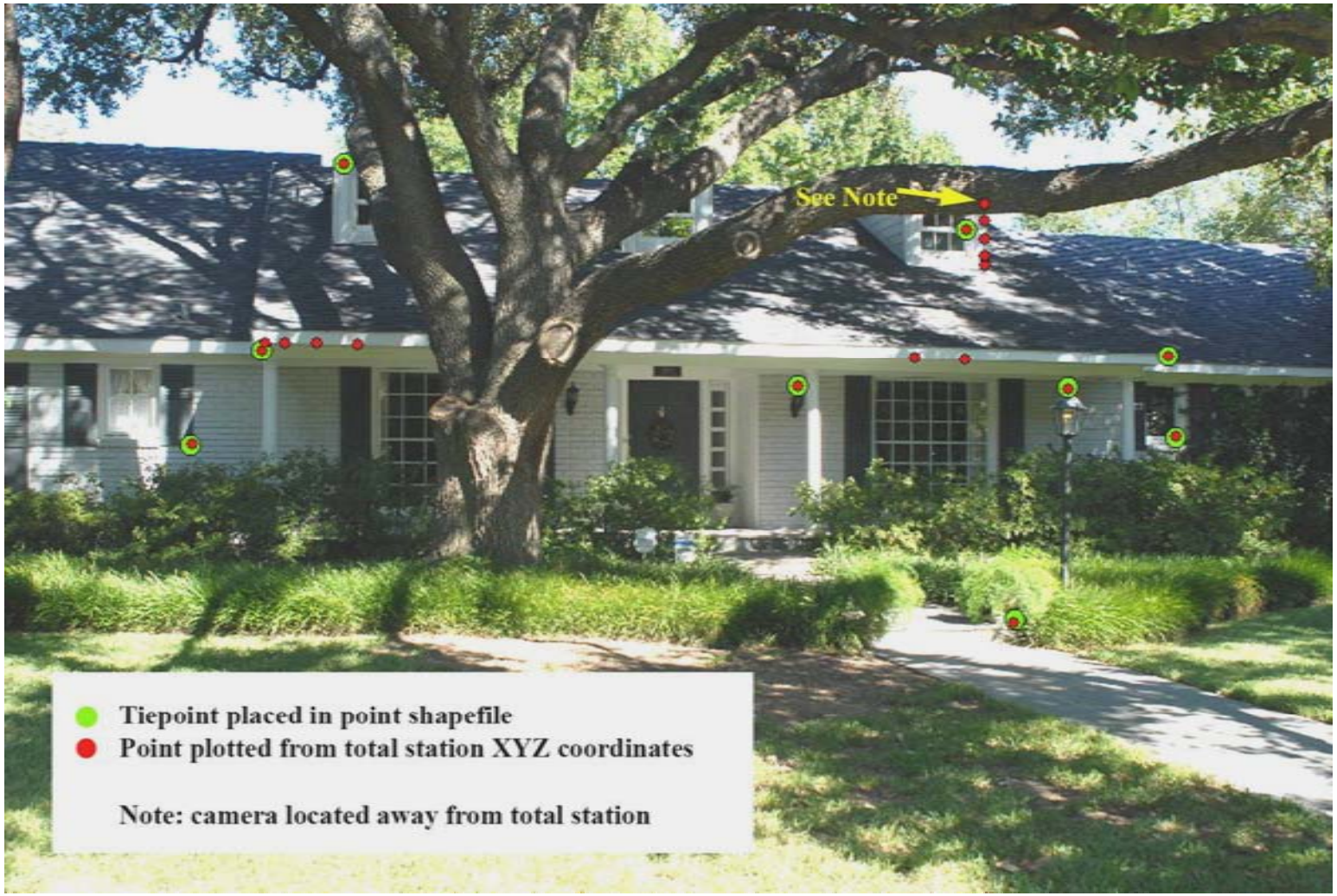
Total Station

Examples of Application

1. Matching of laser points to photograph in real-time
2. Construction of hallway from laser rangefinder (Points to polygons and polyline shapefiles)
3. Mapping and analyzing natural (geologic) features

Matching of laser points to photograph in real-time

Dimensions of Residential Structure



CloseUp of Tiepoints

Tiepoint placement to measured points are within 1.5 pixels of each other.

Subsequent points plotted on photo are within a couple of pixels of true location on the structure.

Process Flow

- One time distortion characterization of camera and lenses. Each camera/lens combination must have a separate set of distortion parameters
- Take photograph of target
- Load photograph in ArcMap/ArcScene
- Identify a tiepoint in ArcMap/ArcScene with graphic marker and shoot XYZ location with laser/total station
- Repeat until at least four points have been selected
- Calculate 3D => 2D transformation parameters, repeat process if residuals are unsatisfactory
- All subsequent XYZ points which are shot will be plotted on the photograph in real-time. Points can be named and attributed at time of capture

Transformation Parameters

- Six transformation parameters are needed to map the 3D coordinates to the 2D coordinates of the photograph. Three rotation parameters (Ω, Φ, K) and three translation parameters (ΔX, ΔY, ΔZ) are used.
- A least squares method for solving for the transformation parameters is used requiring four tiepoints.
- Rotation parameters are used to construct the rotation matrix

Transformation Equation

$$Xp = \frac{m11*(Xs+\Delta X)+m12*(Ys+\Delta Y)+m13*(Zs+\Delta Z)}{m31*(Xs+\Delta X)+m32*(Ys+\Delta Y)+m33*(Zs+\Delta Z)}$$

$$Yp = \frac{m21*(Xs+\Delta X)+m22*(Ys+\Delta Y)+m23*(Zs+\Delta Z)}{m31*(Xs+\Delta X)+m32*(Ys+\Delta Y)+m33*(Zs+\Delta Z)}$$

Xp, Yp are coordinates on the photograph
Xs, Ys, Zs are 3D coordinates on the structure

Rotation Matrix

$$\begin{bmatrix} m11 & m12 & m13 \\ m21 & m22 & m23 \\ m31 & m32 & m33 \end{bmatrix}$$

Results of Transformation Calculation

```
Focal Length = 24.99   Solution:  1.54801706  3.56885707  -0.00938988  -0.108  -0.658  -0.106


-------------------------------------------------------------
Transformation created by LaserSketch
   Date: 5/13/2009   Time: 10:30:11 AM   execution time = 0 min   8 sec
                  Tiepoint Data
  point  weight    U         V                X                  Y                  Z
-------------------------------------------------------------------------------------------
     C01    1    -7.13252  +1.61971         +10.6764          -11.7421           +1.4466
     C02    1    -5.66417  +4.99690         +11.4119          -14.1733           +4.1375
     C04    1    +5.62192  +3.77949          +4.3675          -19.8008           +3.6180
     C05    1    +9.44444  +0.03516          +1.5477          -21.1500           +0.5614
     C06    1    +9.32573  +1.50950          +1.4349          -18.3332           +1.5561

Residual analysis for each tiepoint
                residual(mm)                residual(pixels)
 point      X        Y    vector      X         Y      vector
-------------------------------------------------------------
   C01  +0.0003  +0.0017  0.0017   +0.04     +0.27      0.27
   C02  +0.0007  -0.0031  0.0032   +0.12     -0.50      0.51
   C04  -0.0025  +0.0059  0.0064   -0.41     +0.94      1.03
   C05  -0.0005  -0.0030  0.0030   -0.07     -0.48      0.49
   C06  +0.0015  -0.0015  0.0021   +0.24     -0.24      0.34

Number of unique solutions = 6  Total number of solutions = 62      rms       camera-scanner
    omega        phi        kappa        dx        dy        dz    residual(mm) distance(m)
-------------------------------------------------------------------------------------------------
+1.54798052 +3.56882448 -0.00940651    -0.105    -0.665    -0.105    0.0037         0.681    **
-1.59361213 -0.42723182 +3.13218614    -0.105    -0.665    -0.105    0.0037         0.681
-1.73236019 -0.44284027 -0.05549126   -15.333   +33.438    -3.220    1.0794        36.927
+4.55082512 -0.44284027 -0.05549126   -15.333   +33.438    -3.220    1.0794        36.927
+1.40923247 +3.58443292 +3.08610139   -15.333   +33.438    -3.220    1.0794        36.927
+1.40923247 +3.58443292 -3.19708392   -15.333   +33.438    -3.220    1.0794        36.927
```

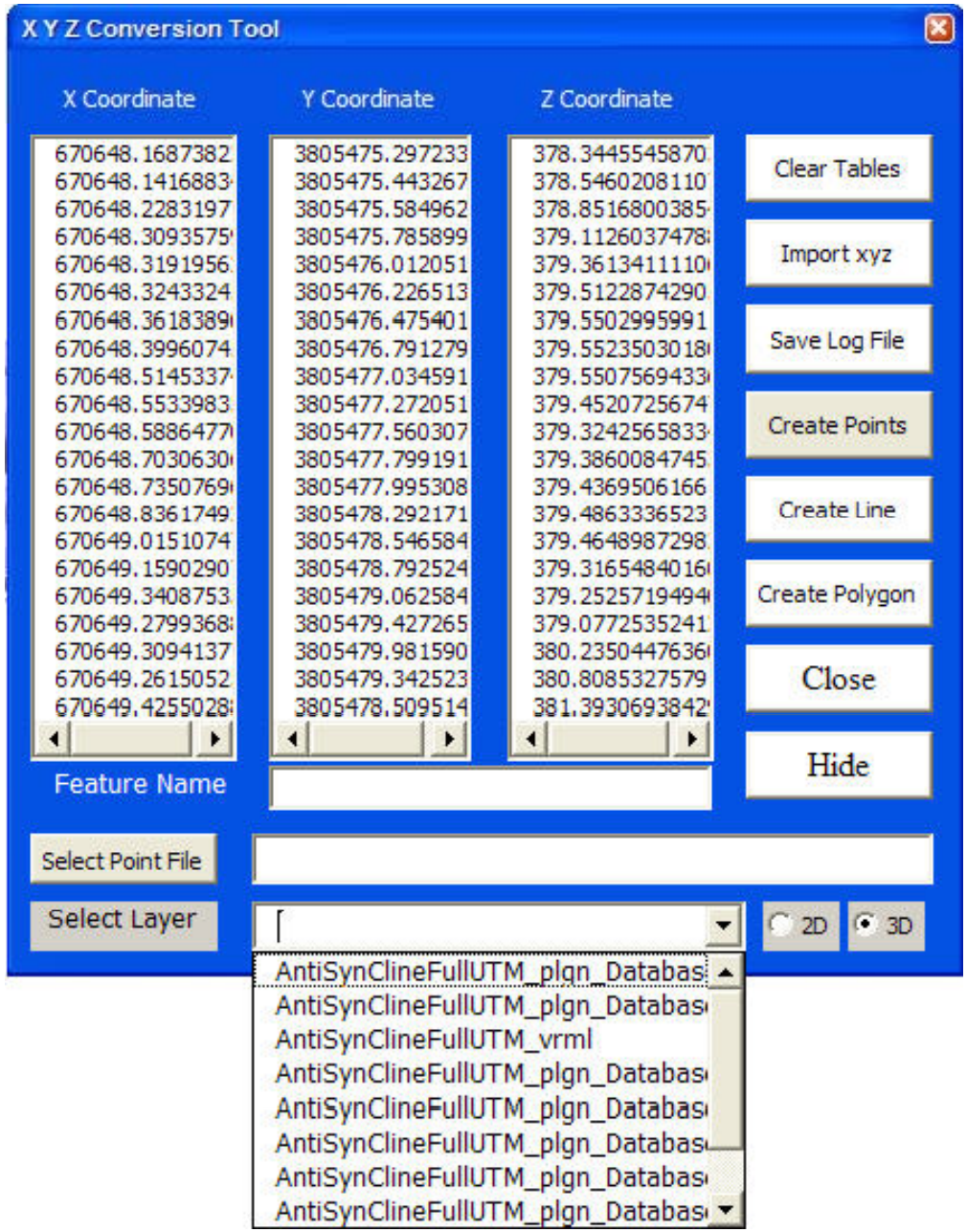
Construction of hallway from laser rangefinder

Points to polygons and polyline shapefiles

GeoConverter

Capabilities:

- Export XYZ for each point to ASCII file.
- Import any XYZ ASCII file
- Create 2D or 3D point, polyline, polygon or multipatch shapefile
- Input feature name for each feature



Model construction from laser points of manmade structure

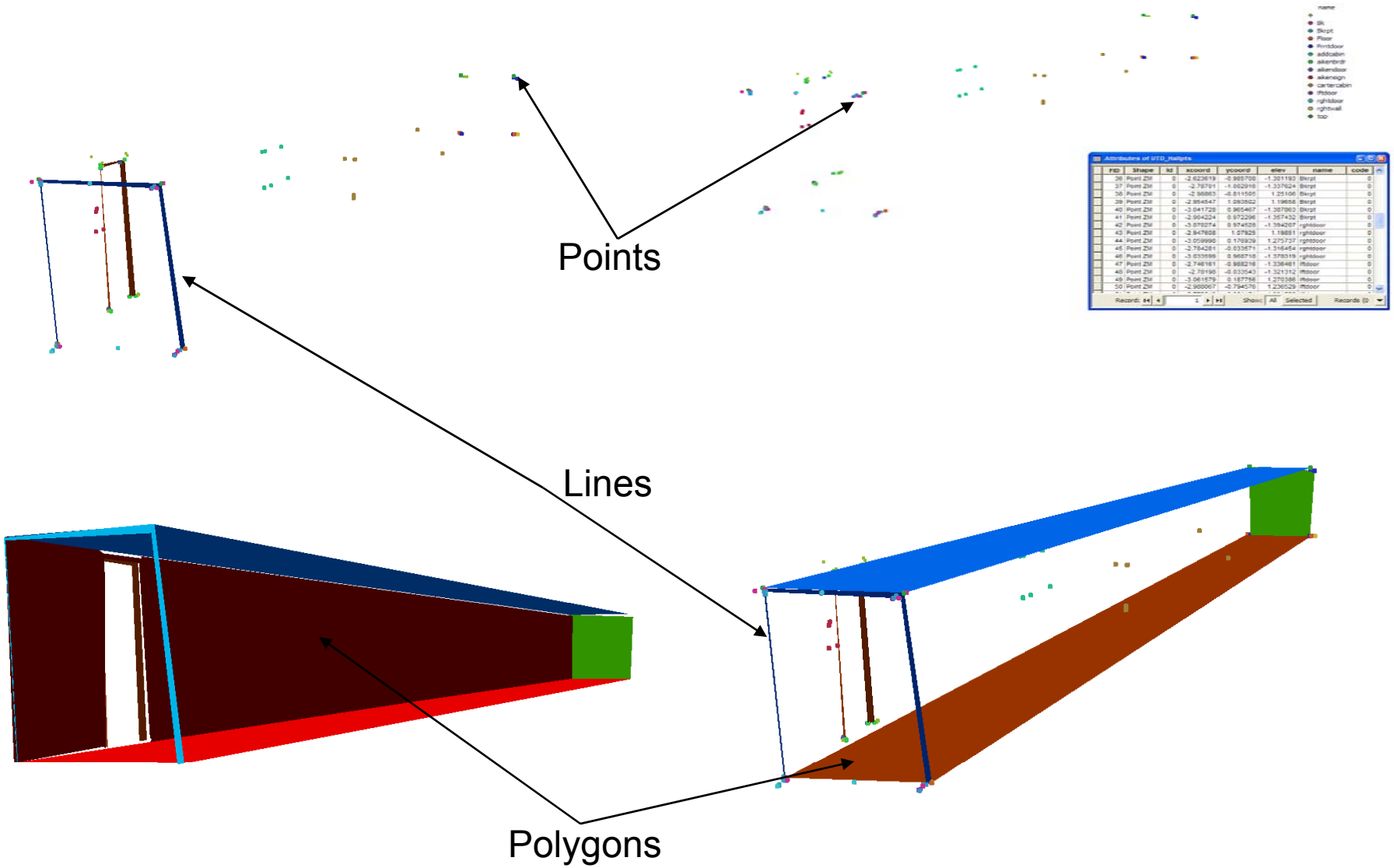
Shoot key features:

1. Walls
2. Corners
3. Door frames
4. Floor
5. Ceilings

→

Convert points to polylines and polygons

Founders building corridor, UTD



Mapping and analyzing natural (geologic) features

Model construction from laser points of natural features

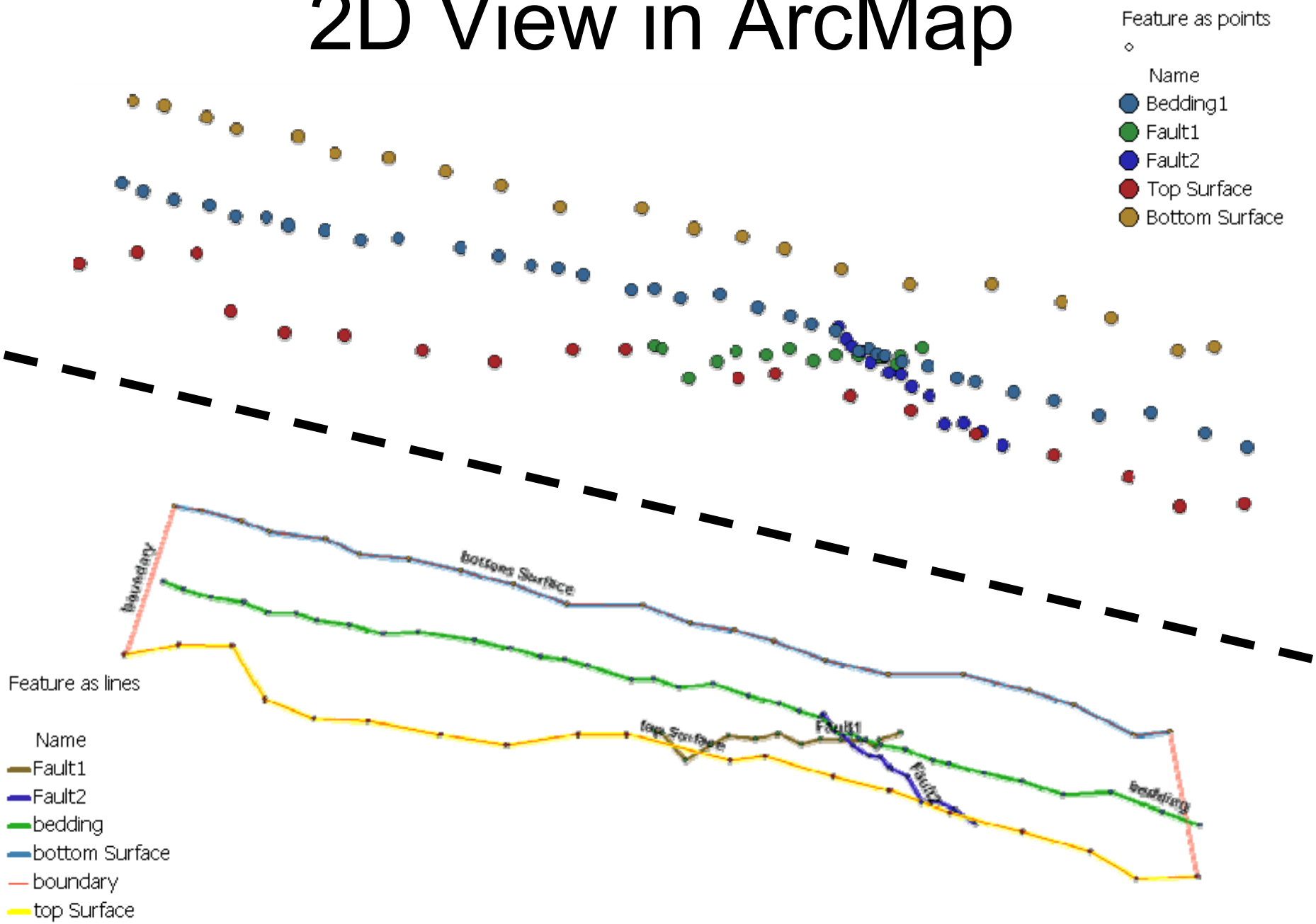
Shoot key features:

1. Faults
2. Bedding
3. Top surface
4. Bottom Surface

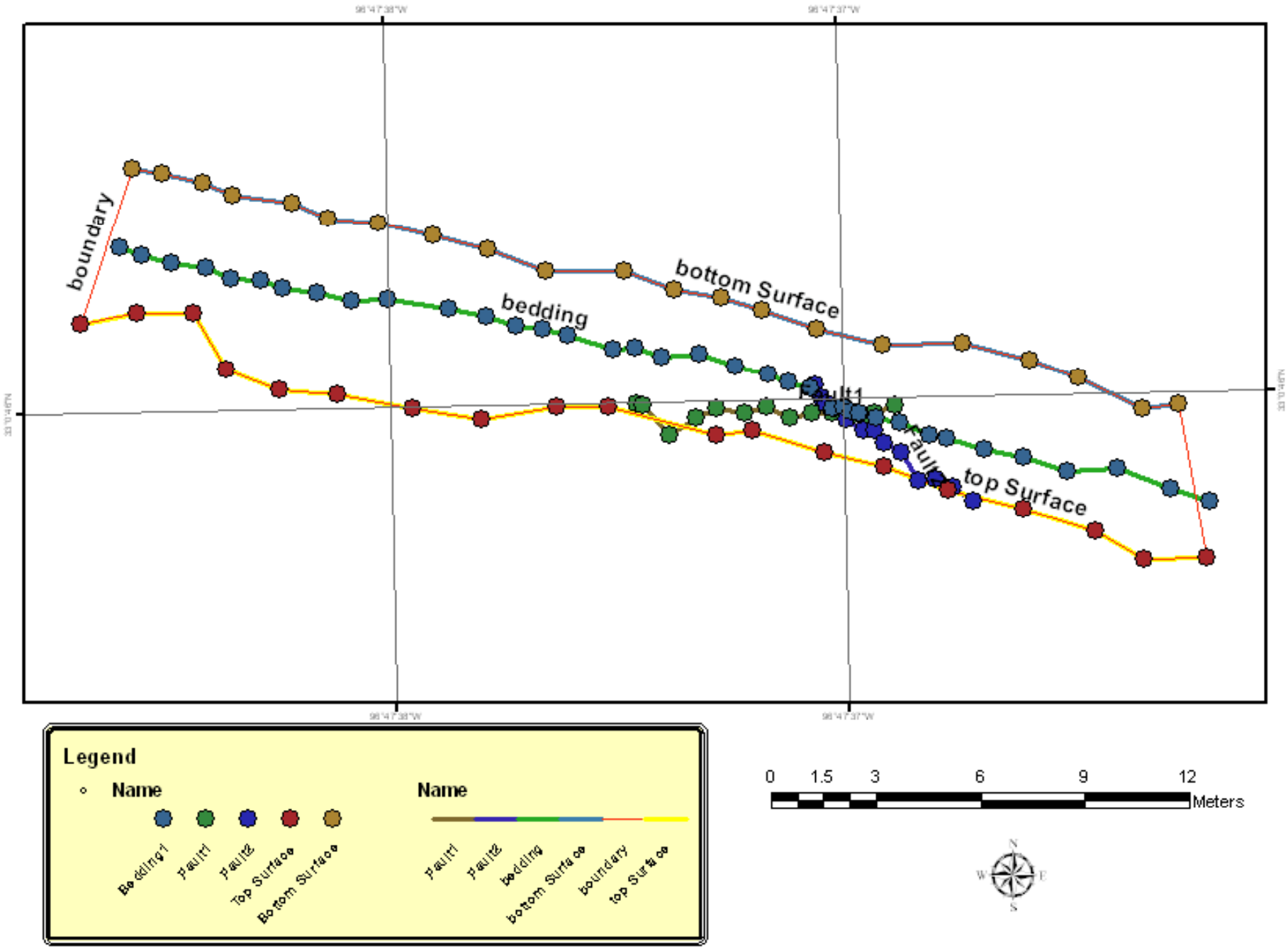
→

Convert points to polylines and polygons

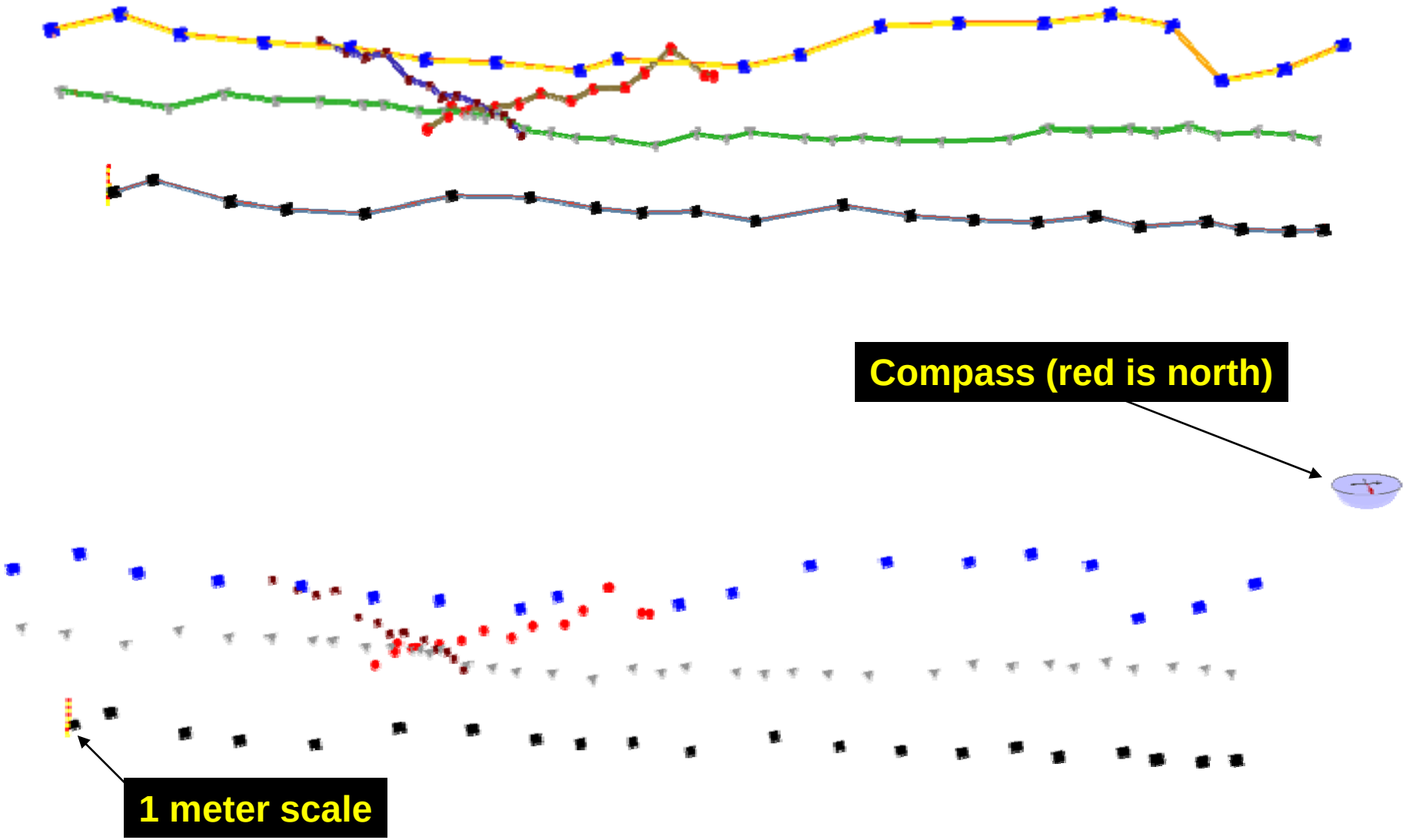
2D View in ArcMap



Rail Road Cut, Plano, Texas



3D View in ArcScene

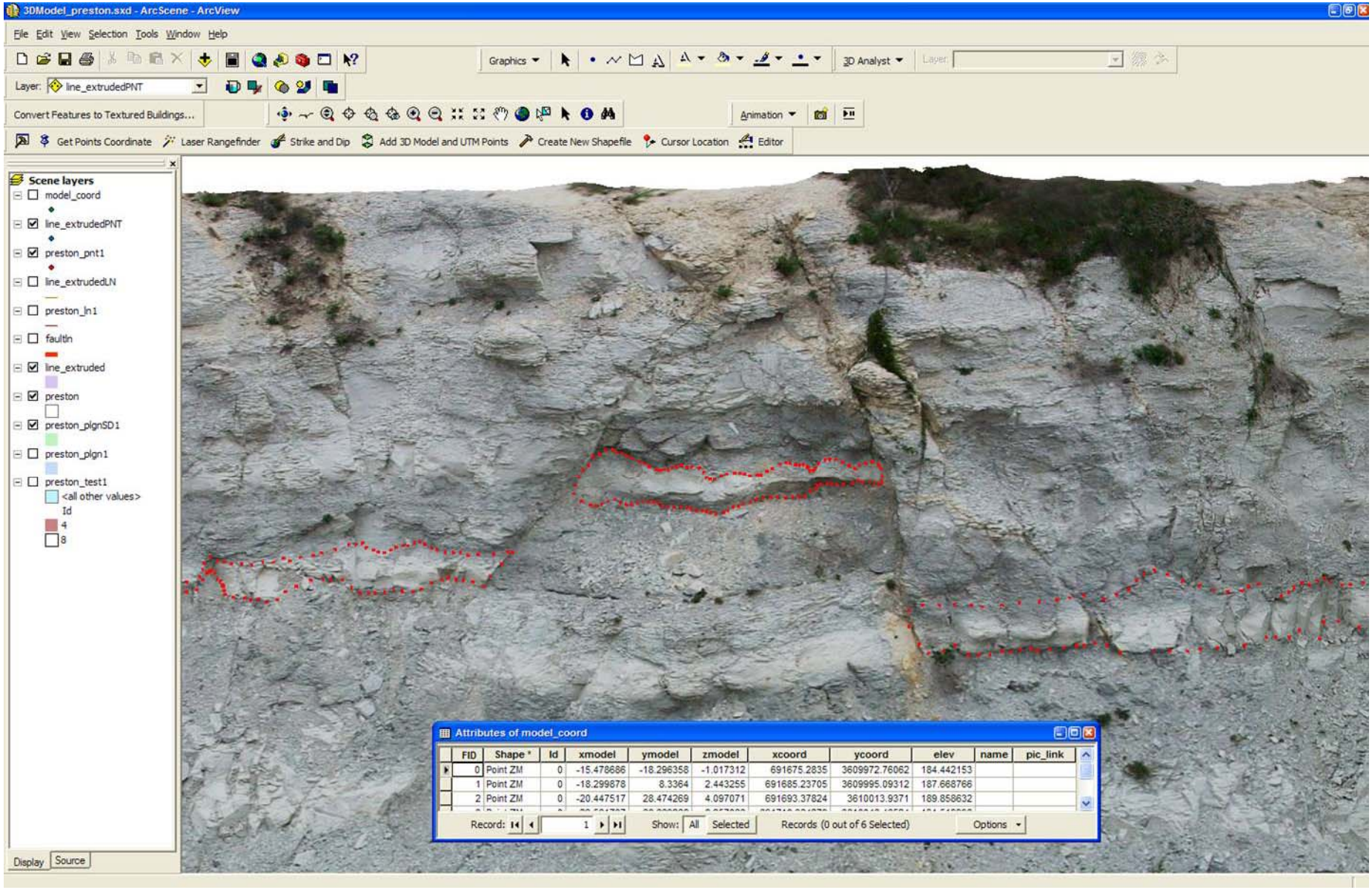


3D View in ArcGlobe

Location of the study area

Preston railroad cut, Plano, Texas

Comparison of laser points to 3D photorealistic model



Extracting Bedding in a Dangerous Environment (active railway)