The following was presented at DMT'11 (May 22-25, 2011).

The contents are provisional and will be superseded by a paper in the DMT'11 Proceedings.

See also earlier Proceedings (1997-2010)
http://ngmdb.usgs.gov/info/dmt/

ILLINOIS STATE GEOLOGICAL SURVEY
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Tools and Techniques for 3D Geologic Mapping in ArcScene: Boreholes, Cross Sections, and Block Diagrams

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Introduction

In the life cycle of a geologic mapping project, a mapper is likely to use 5 or more different software packages, from borehole logging programs (WellCAD and LogPlot), to database programs (Microsoft Access), to GIS programs (ArcGIS), to specialized modeling software (RockWorks, Surfer, gOcad, GSI3D), to web-based tools (Google Maps, Google Earth). Beyond that are graphics programs such as those of the Adobe Creative Suite (Illustrator, Photoshop, and InDesign), that are required for cartographic and production work.

Though there is some overlap among software packages, there is no one-stop solution for geologic mapping. For a given task in the mapping process, one program might be better suited than others. The choice of software is often a matter of personal preference and convenience as well as functionality. All programs have their strengths and weaknesses.

This poster focuses on the functionality of ArcScene for 3D mapping. I discusses techniques for creating and editing 3D boreholes and cross sections, using custom tools as well as out-of-the-box functionality in ArcScene 10. Examples from mapping projects at the Illinois State Geological Survey (ISGS) demonstrate how these fit into broader mapping workflows. The customization of ArcScene with VBA has played a key role in making ArcScene efficient and practical for geologic mapping.

Advantages of ArcScene

- The interactive 3D environment that ArcScene provides is critical for understanding geologic relationships in the subsurface.
- The 3D navigation tools are relatively intuitive and easy to use.
- With ArcScene users can take advantage of existing data storage formats and workflows already developed for ArcGIS without having to convert data.
- Data in a standalone Access database can be read or imported with minimal processing.
- Multiple options exist for customizing and automating tasks: Geoprocessor scripting with Python, Add-ins with ArcObjects, and Model Builder. Help and information about customization techniques are well documented by ESRI and an active user community.

Limitations of ArcScene

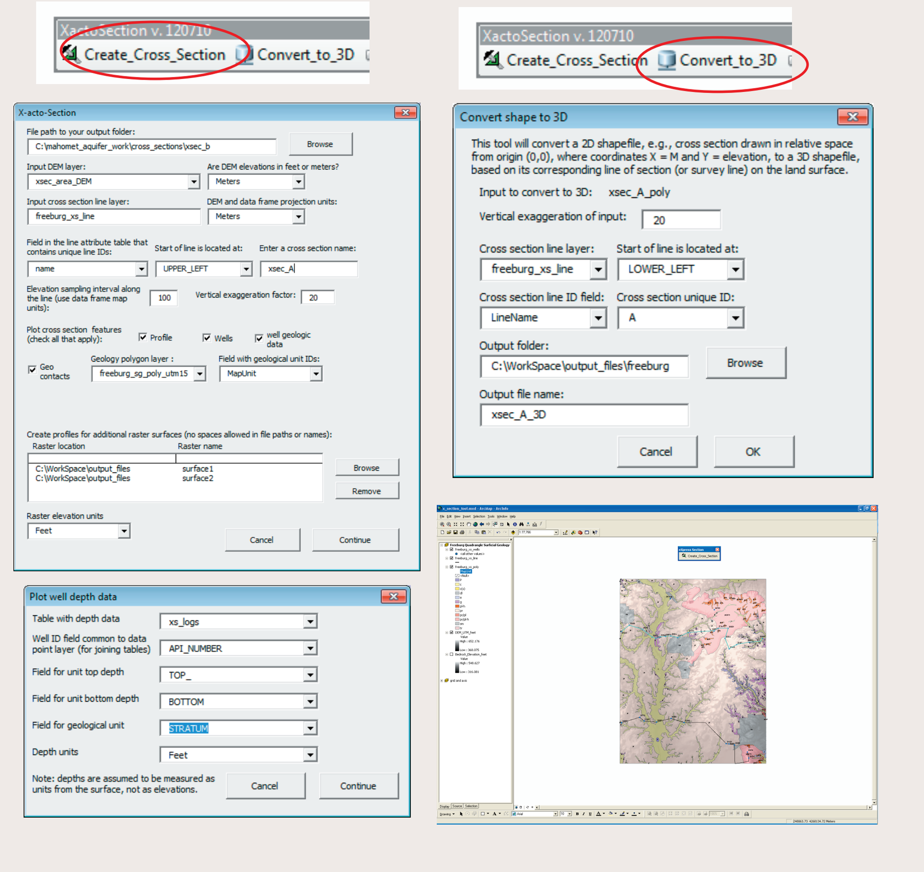
- Texture mapping of vertical surfaces, e.g. draping an image of a cross section on a vertical wall, is still not possible out-of-the box. ArcScene still seems to have trouble with vertical surfaces in general.
- When dealing with the large volumes of data often required by geologic mapping, memory can get used up quickly, causing slow performance and hang-ups. The workaround has been to divide data into smaller geographic areas.
- ArcScene 10's new 3D geoprocessing tools might work for simple multipatches representing buildings, but they tend to crash when 3D geologic volumes are input.
- Anything beyond simple layer-cake modeling requires some level of customization to make the multi-step workflows manageable.
- Custom tools developed over the past 4 years with VBA now need to be rewritten because VBA will be discontinued as of the next release of ArcGIS.
- There is still no labeling of features in ArcScene.
- The new out-of-the-box 3D geometry-editing capabilities touted by ESRI are still limited and don't always work, especially with the vertical surfaces of boreholes and cross sections. Digitizing in 3D space requires you to snap new features to existing data layers. However, you cannot snap to the face of a vertical areal feature such as a cross section wall.
- The geometry of complex multipatches, such as those generated by extruded surfaces, cannot be edited.

Acknowledgments

The geologic data shown in the screen shots represent the works of ISGS geologists Steve Brown, Brandon Curry, Andrew Stumpf, and Drew Phillips. The Adventures of Geo Man was made possible by Microsoft clip art.

From 2D Cross Sections in ArcMap and Illustrator to 3D Cross Sections in ArcScene

The Xacto Section tools:



Program inputs

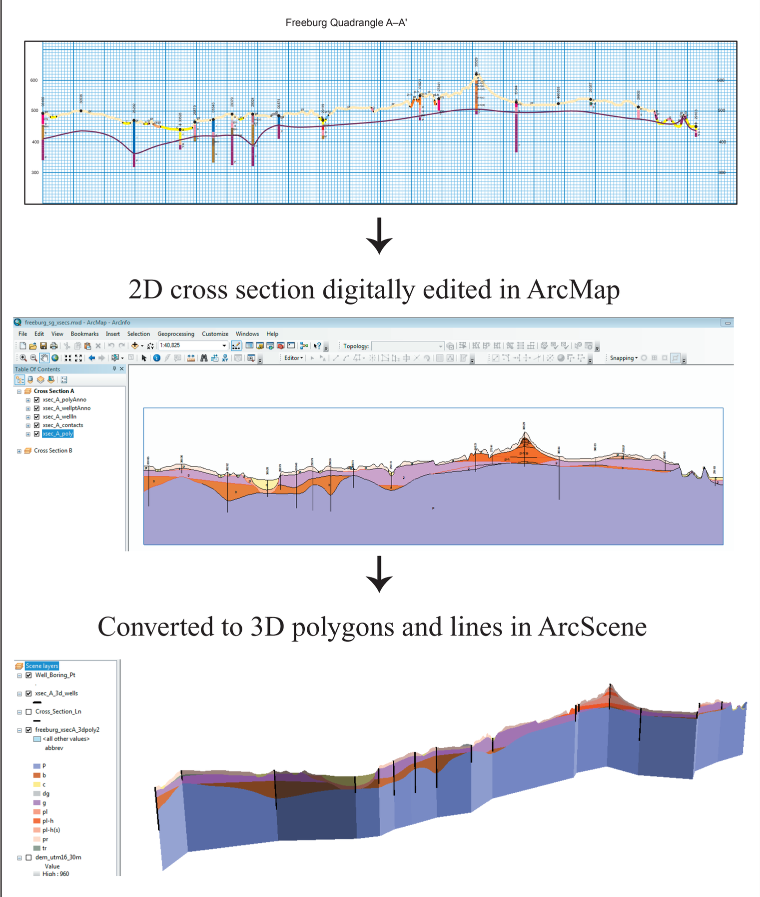
- Elevation raster (Esri Grid)
- Cross section line
- Geology polygons
- Well and boring points
- Additional subsurface rasters
- Well log data table (.dbf)

Output 2D shapefiles

- Surface profile, split at contact points
- Geologic contact points on the cross section
- Well and boring points on the cross section
- Wells extruded as lines into the sub surface, coded with geological attri butes
- Additional subsurface profiles

Output 3D shapefiles

- True 3D features can be symbolized and attributed with standard editing tools

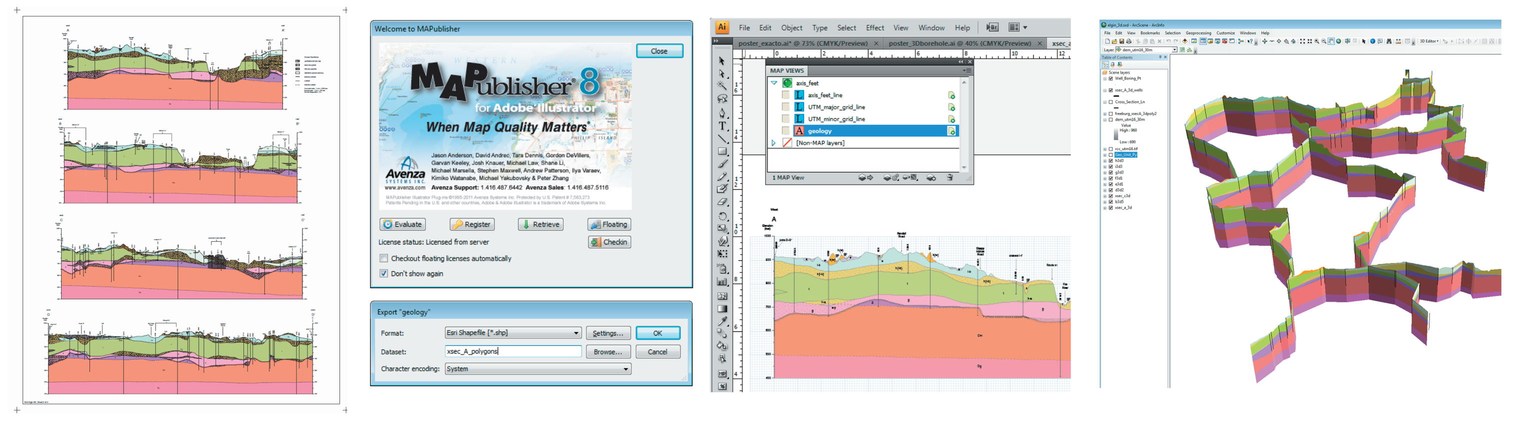


Visual Basic for Applications (VBA) was used to develop a custom cross section tool called Xacto Section within ArcMap. The tool generates a 2D cross section profile as a collection of polyline and point shapefiles. The shapefiles can be digitially edited in ArcMap and/or exported to Adobe Illustrator for finishing. Completed cross sections can be exported as 3D vector features for viewing and editing in ArcScene.

In addition to creating cross sections from scratch, the tool can be used in combination with the MaPublisher plug-in for Illustrator to convert legacy cross section vector graphics into 3D georeferenced shapefiles. In this way simple "spaghetti" graphics can be restored to valuable quantitaive geologic data.

The .mxd containing the toolbar is available on the ArcGIS Resources web site.

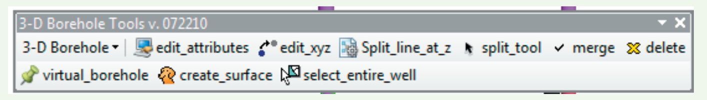
Converting "dumb" 2D graphics into 3D spatial data with MaPublisher and Xacto



Archived graphics files (.ai, .eps, .pdf)... can be georeferenced to a spatial layer in Illustrator and exported as 2D shapefiles... then converted into 3D shapefiles.

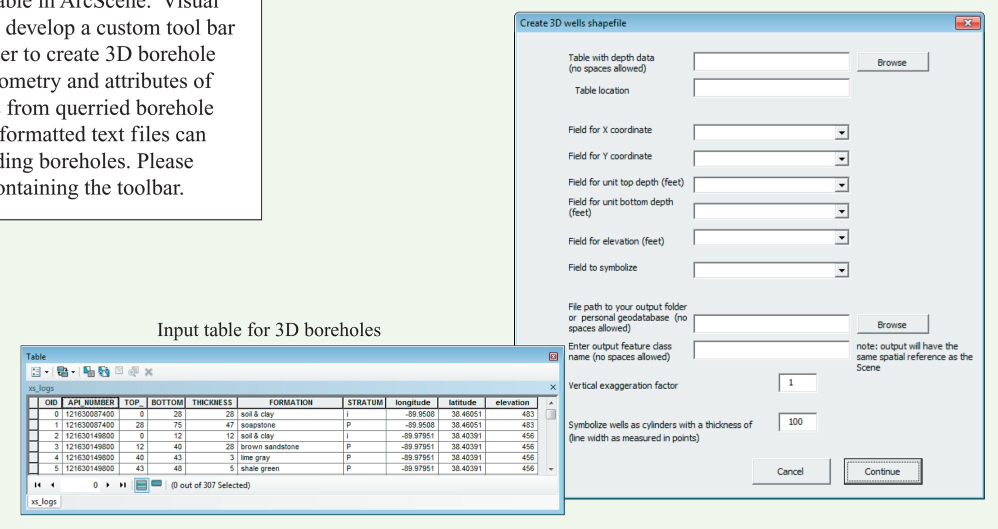
Creating and Editing 3D Boreholes with the 3D Borehole Toolbar

The ability to view, zoom, rotate, and fly through borehole data in 3 dimensions is vital to understanding geological relationships in the subsurface. ArcScene provides a relatively easy and familiar interface for these tasks. A limitation, however, has been that prior to ArcGIS 10, editing tools were not available in ArcScene. Visual Basic for Applications (VBA) was used to develop a custom tool bar in ArcScene. Its 14 tools that allow the user to create 3D borehole features from tabular log data, edit the geometry and attributes of those features, and quickly create surfaces from querried borehole intervals. Geophysical logs data as .LAS-formatted text files can also be plotted as graphs along corresponding boreholes. Please contact the author for a copy of the .sxd containing the toolbar.



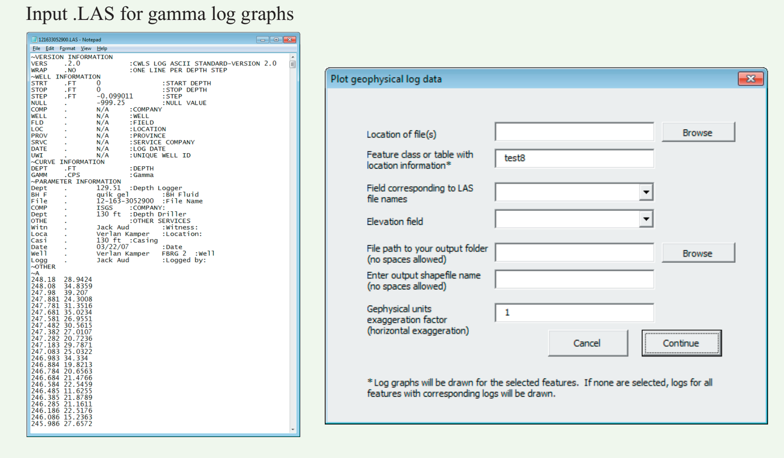
The 3D Borehole Tools

The **"Create_3d_lines"** tool takes a table (.dbf or geodatabase) of well log data--x, y, top, bottom, unit-- and creates a 3D polyline shapefile. The shapefile is symbolized as a 3D tube. When dealing with several thousand borehole segments, rendering performance can be increased by converting the 3D lines to polygons, though the ability to edit the feature's geometry will be lost.



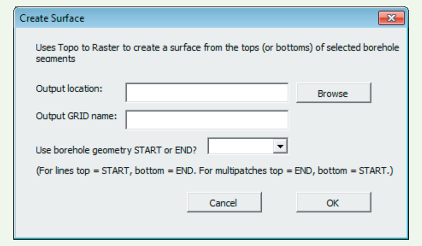
Input table for 3D boreholes

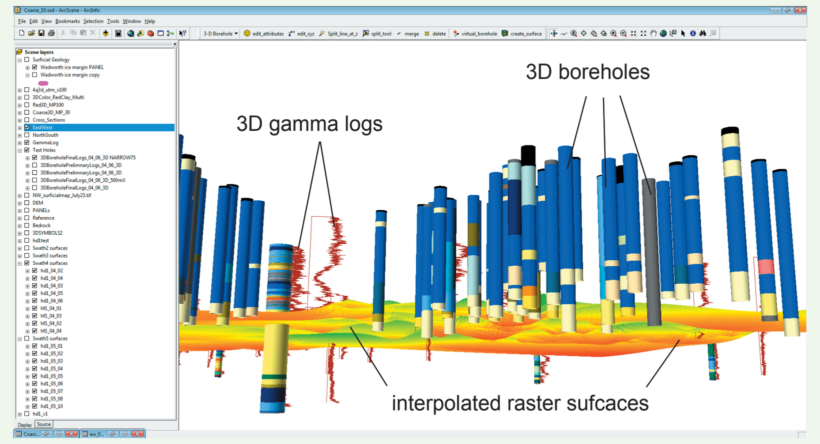
The **"Plot_gamma"** tool reads geophysical logs (text files formatted to the .las standard) from a designated folder and for each log plots a graph alongside the borehole whose ID matches the log file name. The output is a line shapefile.



Input .LAS for gamma log graphs

The **"Create surface"** tool provides a quick interface to the Topo to Raster interpolation tool. It automatically extracts either the top or bottom point of each selected borehole segment and feeds it into Topo to Raster. The output raster is automatically symbolized with a default color ramp, and base heights are automatically applied to the layer. This tool is useful for creating exploratory test surface patches in the process of interpreting and reclassifying log data.



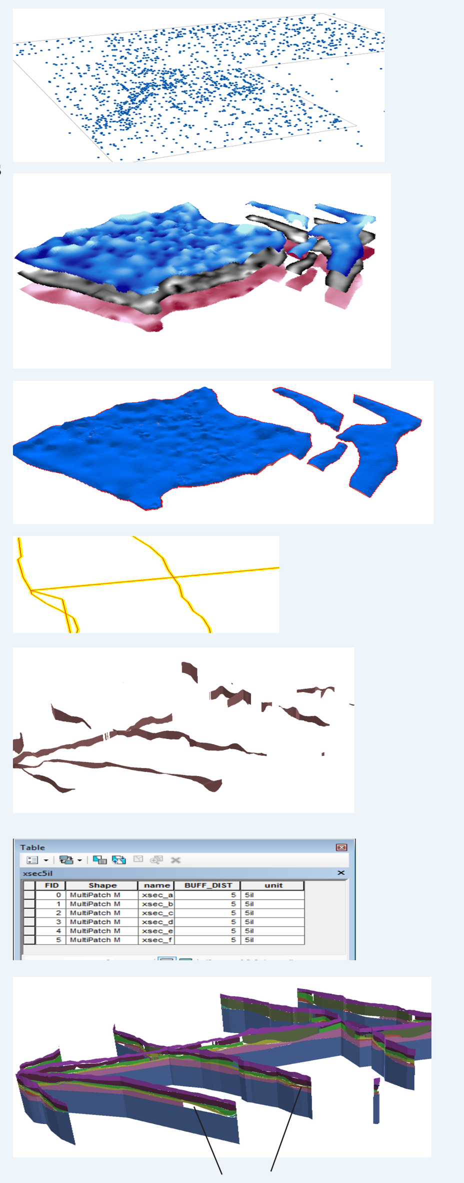


Creating 3D block diagrams and cross sections from raster surfaces

It is possible to create block diagrams from surfaces in ArcScene, though a fair amount of data processing is required if there are many surfaces in the geologic model. The workflow presented here could be automated using geoprocessing scripting with Python or using add-ins with ArcObjects.

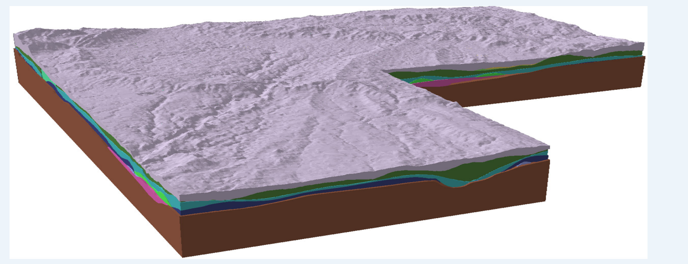
Input surfaces:
(1) Raster of unit top elevation and (2) raster of unit thickness, interpolated from points and/or contours

	Process	Tool or Method	Input	Output
1	Subtract the depth raster from top surface raster to generate a bottom surface for each unit	Spatial Analyst > Math > Minus	raster surfaces for top elevation and thickness	raster surface for bottom elevation
2	Convert the top and bottom surface rasters into TINs	3D Analyst Tools > Conversion > From Raster > Raster to TIN	unit top and bottom elevation rasters	unit top and bottom TINs
3	Create narrow buffer polygons for the cross section lines.	Analysis Tools > Proximity > Buffer	2D cross section polyline	2D polygon buffer of line
4*	Using the line buffers as bounding areas, extrude the top surfaces to the bottom surfaces. The output is a single multipatch feature for each extruded line, repeated for each geologic unit.	3D Analyst Tools > Terrain and TIN Surface > Extrude Between	unit top TIN, unit bottom TIN, 2D buffer polygons	3D multipatch feature
5	Because the output multipatches contain no attribute data, populate the multipatch attribute tables with the geologic unit name or ID.	Add Field, Calculate Field	multipatch features	multipatch features
6	Merge all multipatches into one shapefile or feature class.	Data Management Tools > General > Merge	separate shapefiles for each geologic unit	one shapefile containing all multipatches for all geologic units
7	To separate individual cross sections, query and export multipatches by cross section ID	Select by Attribute, Data > Export	all cross sections combined in one multipatch shapefile	separate shapefiles for each cross section



Gaps in the output reveal discrepancies among the input surfaces of the model

*The method shown above of buffering and extruding cross section lines was the only one that worked out of several tried. Other methods I tried were to extrude all top surfaces to a base height of 0. This produced multipatches with overlapping volumes when merged into a single layer. I then tried various 3D Analyst tools for 3D Features, newly available in ArcGIS 10 (Intersect 3D, Difference 3D, Union 3D) in an attempt to remove the overlapping volumes. All of these methods proved to be too much for ArcScene to handle, either resulting in ArcScene crashing or throwing errors citing lack of memory. It seems that the complicated multipatches created from TIN surfaces are are simply too much data for the geoprocessor. Decreasing the resolution of the input surfaces or working with smaller areas of a model may produce more successful results with these tools.



Block diagram created by extruding top and bottom TINs between a bounding polygon of the study area

The Bigger Picture: The life cycle of a geologic mapping project--in comics!