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Things You Used to Hate About Map Layout in Arc Have Changed: Attractive and Complete Maps Are Possible in ArcGIS!

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Introduction

Cross-section and stratigraphic column diagrams are important accessory information to many geologic maps. These diagrams are often included for illustrative and interpretive purposes, but their size and scale dimensions must match the geologic maps they accompany and, in order to be useful reference material, the diagrams must plot out on the final paper map at the exact size and scale intended. The authors decided to use the projected-space functionality of geographic information (GIS) software, namely Esri’s ArcMap, to achieve this goal without having to employ any external illustration software. The map layout shown in figure 1, including all diagrams and insets, was constructed entirely in ArcMap (version 9.3). The cross sections are the same scale as the geologic map, which is 1:24,000, and print out on the paper map at the exact size at which they were intended to be shown. Similarly, the stratigraphic column prints out at its correct size and scale (1 inch = 100 feet (ft)).

Cross Sections

Step 1: Measure Cross Section and Build Frame to Scale in Arc

This method builds an idealized, mathematically “perfect” frame and corrects for several types of drafting errors, omissions, and inconsistencies that can be made by authors. It can also be used to change the scale and (or) vertical exaggeration of a cross section drafted on paper into a new one. For example, a diagram drawn at 1 inch:800 ft scale can be converted to the more standard 1 inch:2,000 ft, or a diagram drafted on paper with a vertical exaggeration of 2X for drafting convenience can be rescaled and then digitized with no vertical exaggeration to appear at true 1:24,000 scale on the finished map. The following directions are excerpted from Gooding, 2010 (S.E. Gooding, ed., Digital Open-File Geological Maps of West Virginia National Park Service Mapping Project Handbook (unpublished): West Virginia Geological and Economic Survey):

Horizontal Axis:

Measure cross-section location line (for example, the A-A′ line highlighted in red on the map layout shown in figure 1) on the geologic map to an accuracy of at least one-hundredth of an inch (0.01 inch) using a scale/drafting ruler or measure the line on the scanned, full-size tif image of the map in Photoshop. DO NOT measure the horizontal axis of the drafted cross section itself; it MUST be the location line from the map. Otherwise any drafting errors in the length of the cross section will be perpetuated.

Convert the real-world paper measurement of the cross-section location line into projected-space “ArcMap inches” by multiplying the measurement by 24,000. This will be the true length of the cross-section horizontal axis in ArcMap. For example, a cross-section line measuring 25.685 inches on the paper map or in Photoshop, when multiplied by 24,000, will be 616,440 inches in ArcMap-projected space.

Begin digitizing the cross-section frame in Arc:

1. Left click to start drawing the line of the horizontal axis.
2. Right click and choose “Direction/Length” from the floating menu.

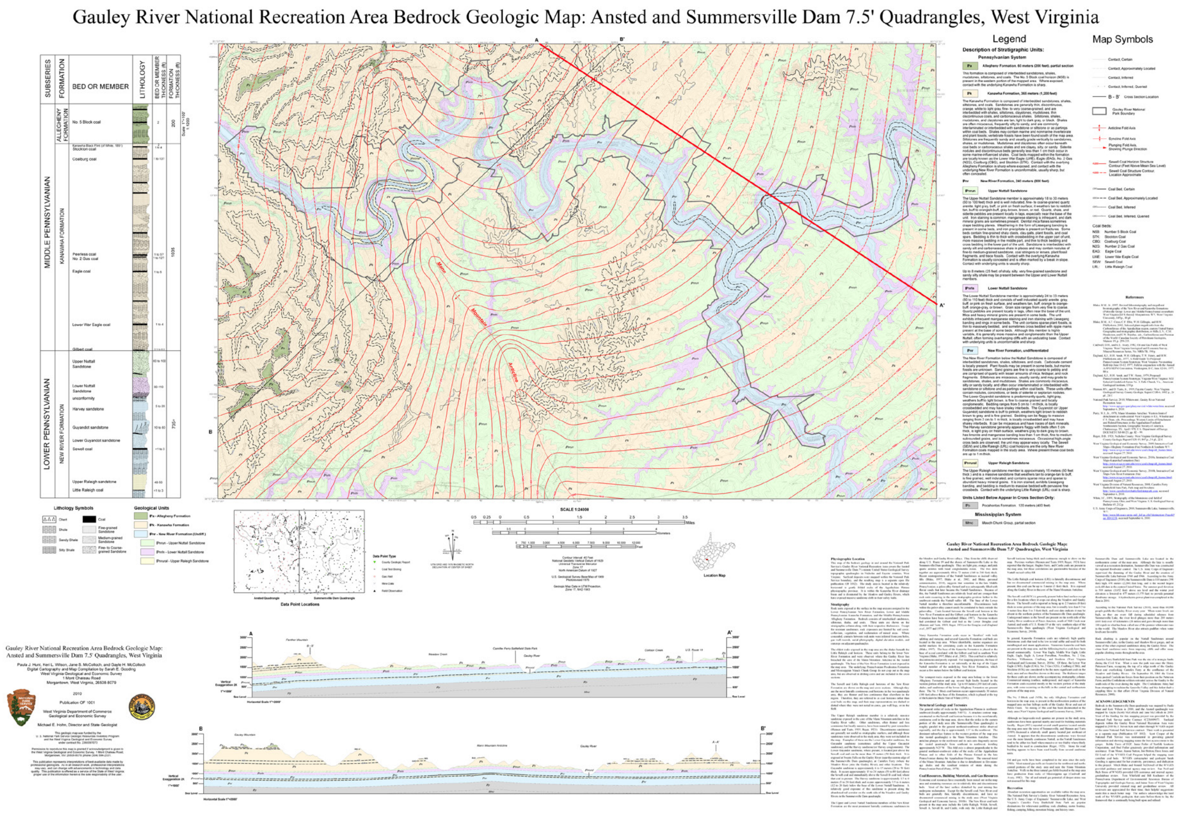

Figure 1. Low-resolution image of *Gauley River National Recreation Area Bedrock Geologic Map* (Hunt and others, 2010) layout, showing cross section A–A' highlighted in red for example of cross section digitizing process and overall layout construction and final cartography.

3. Enter "0" for Direction (straight horizontal) and "616,440 in" for Length in the dialog box. Be sure to type "in" for inches or it will default to units of the data frame, which in UTM projection would be meters.
4. Hit Enter and F2 keys to end the line (fig. 2).

Measure and Calculate the Vertical Axes:

Examine and measure vertical axes of the original diagram. Use idealized axes to account for and repair drafting errors, and perform any necessary re-scaling or changes in vertical exaggeration. Convert to projected-space "ArcMap inches" for the vertical axes and build an idealized frame in Arc-projected space to enclose all parts of the diagram, extending vertical axes up and (or) down if necessary to correct any drafting errors by the author.

For example, a cross section with no vertical exaggeration and an idealized vertical axis of 5,000 total vertical feet (add above and below sea level tics to get total feet) should measure 2.5 inches high on paper.

5,000 feet at 1 inch:2,000 feet = 2.5 inches high

Then, convert to ArcMap inches by multiplying by 24,000:

2.5 inches x 24,000 = 60,000 "ArcMap inches"

Draw Vertical Axes:

1. Left click to start drawing the line of the vertical axis. Snap to "End" of horizontal axis line.
2. Right click and choose "Direction/Length" from the floating menu.
3. Enter "90" for Direction (Straight Vertical) and "60,000 in" for Length in the dialog box.
4. Hit Enter and F2 keys to end the line.
5. Repeat for other vertical axis (fig. 2).

STEP 2: Create the Elevation Tic Marks

Use the "Divide" (now called "Split" in Arc v. 10) function on the Editor Toolbar to divide the vertical axis lines into equal segments for the elevation tics based on how many elevation tics will be needed. For example, the cross section shown in figure 3 uses five line segments.

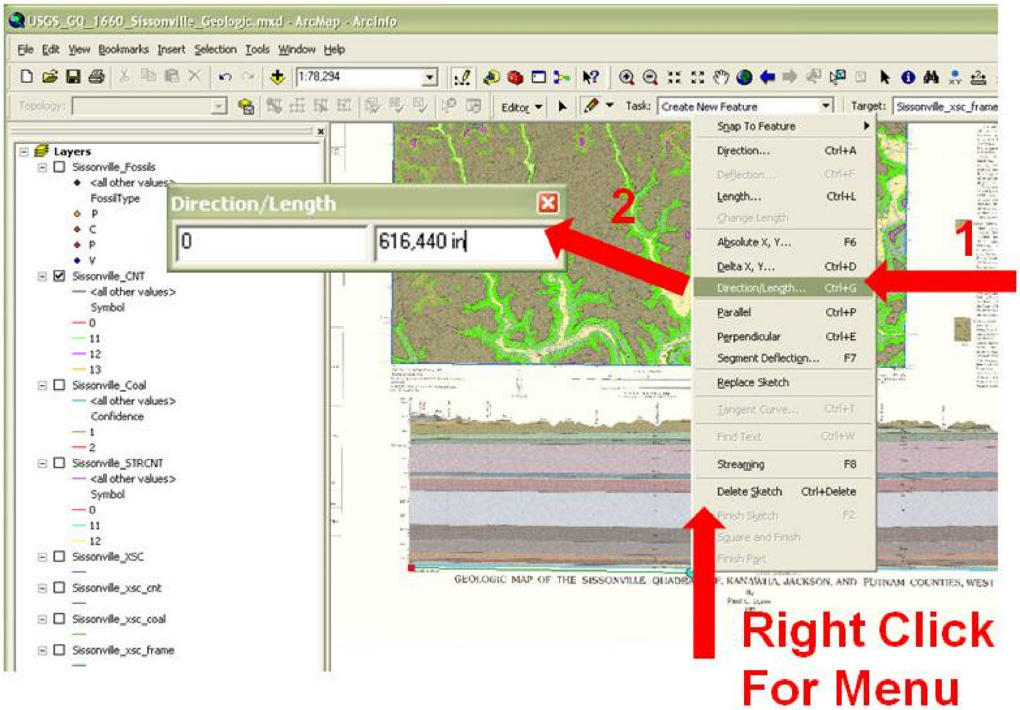

Figure 2. Cross sections, Step 1: Building the horizontal and vertical axes of the cross-section frame in Arc.

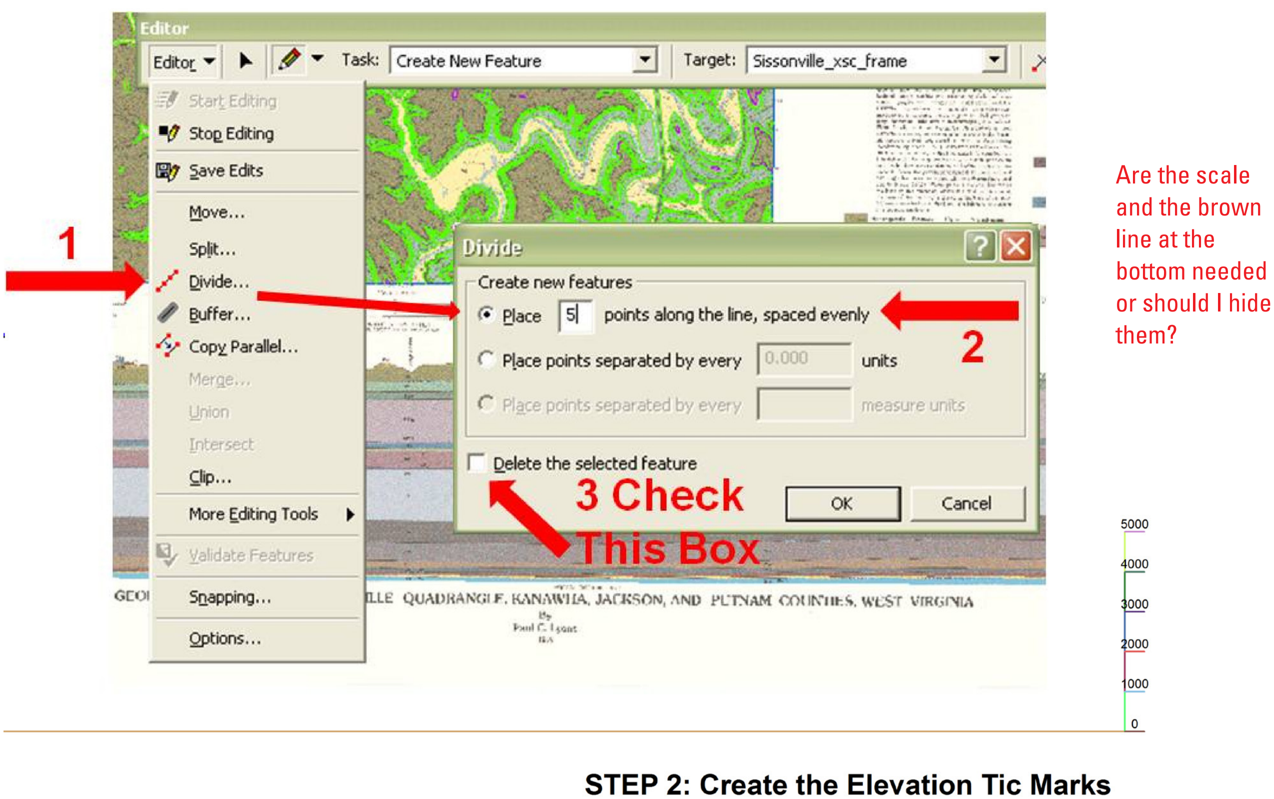

Figure 3. Cross Sections, Step 2: Creating the elevation tic marks on the vertical axes.

Digitize the Elevation Tics: Use the "Direction/Length" floating menu option to digitize short tics at the end of each segment of the vertical axis, including the very top and bottom of the axis, so it looks like the example in figure 3. Use a direction of 180 for the tics on the left side of the frame and 0 on the right side. Use a length of 150 for all tics (go with default ArcMap units, not inches in this case).

Attribute all tic lines with the correct elevation. Use "0" for sea level. Use negative numbers for elevations below sea level. I used "–9999" for all other frame lines that did not need an elevation value, but a "NULL" value could also be used for labeling purposes on the final map.

STEP 3: Georeference Source Material and Digitize the Cross-Section Contact Lines and Label Points

Georeference a scanned image of a traditionally drafted cross section like the one shown in figure 4, using the matching elevation tics from the frame and the image. Then digitize the lines by hand or use raster-to-vector conversion tools.

Other ways to generate the cross-section linework include:

1. Bring in unscaled vector linework in Cartesian coordinates from CADD or Illustrator-type graphic programs and use Spatial Adjust tools to make the linework fit the frame in the same manner as the stratigraphic column example shown later in this paper.

2. The topographic profile for the cross section (fig. 5) shown on the map in figure 1 was constructed using the Cross Section Tool from Thoms (2005) written for ArcGIS. A shapefile containing the cross-section line, a digital elevation model of the topographic surface, and the geologic contact polygons from the map were input into the tool. The resulting shapefile is a to-scale polyline of the topography broken into segments representing each geologic unit at the surface. The rest of the cross-section lines were then digitized in Arc without first being drafted on paper, using known unit thicknesses, dip, fold axis locations, coal bed elevations, and other geologic information.

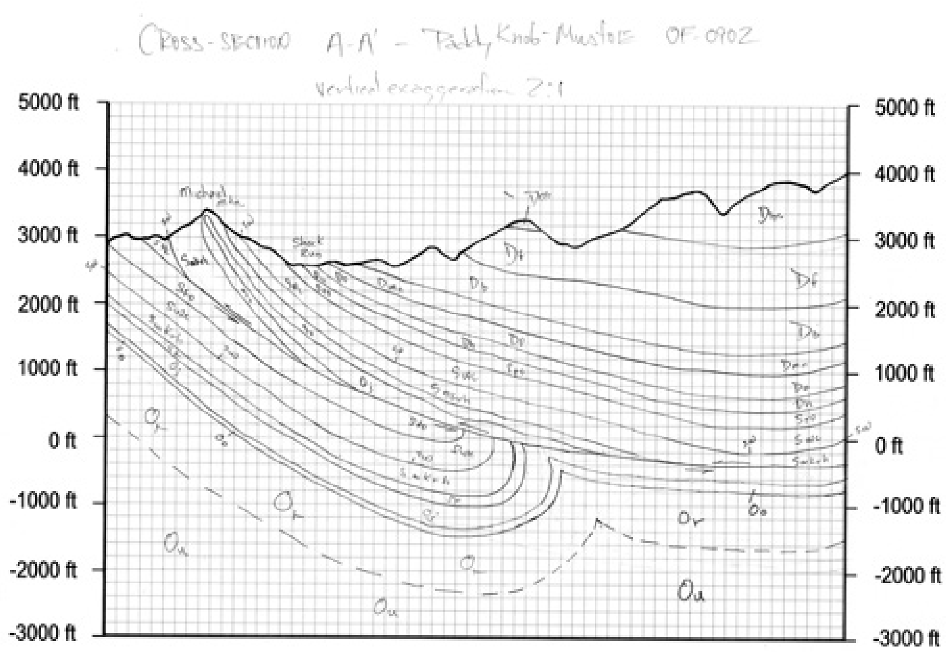

Figure 4. Cross Sections, Step 3(a): Example of a traditionally drafted cross section that has been scanned at high resolution and will be georeferenced in Arc to the frame built in Steps 1 and 2 for digital conversion.

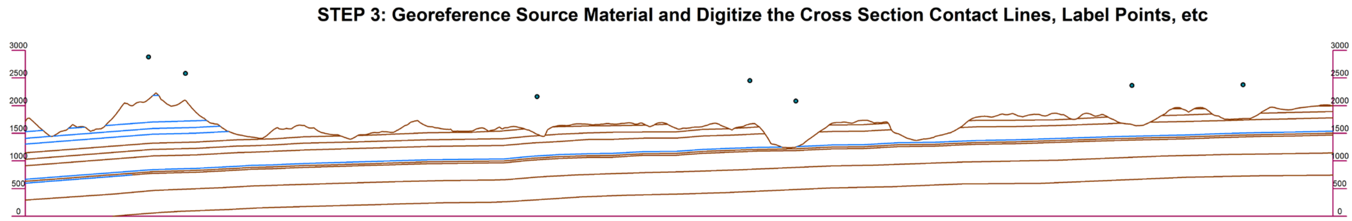

Figure 5. Cross Sections, Step 3(b): The digitized cross section, showing digitized lines for contacts (brown) and coal beds (blue), and digitized points for hovering topographic and structural labels. Line of section shown in figure 1.

This particular cross section in figure 5 also includes noncontact-forming coal beds as another line layer. Coal beds that DO form geologic unit contacts are included in the contact line layer of the cross-section geodatabase and will be used to form polygons in the next step. Lines in the contacts feature class are given attributes for whether they are a contact or fault and any unit abbreviation that may apply, such as coal bed name. Points for labeling cultural and structural features that “hover” over the cross section are also digitized during this phase in a “pointlabels” feature class (fig. 5).

Next, generate polygons from linework using “Line to Polygon” tools in Arc. The frame and contact lines feature classes are used to generate the polygons. It is recommended to create and verify Topology to make sure that there are no polygons that failed to form because of digitizing errors. Then add attributes for geologic units that match the accompanying geologic map, as shown symbolized in figure 6.

STEP 4: Cartography

Symbolize the geologic units, contacts, and coal beds with the same symbols used on the geologic map, with the exception that units which are only shown in the cross section are symbolized in shades of gray. Hovering point labels are symbolized with an appropriately sized italic font and a small white point symbol that will disappear against the paper on the map layout. Frame axis elevation tics are labeled and then converted into annotation that can be placed more appropriately on the map layout. Text blocks are placed on the map layout containing vertical and horizontal scale information. Figure 6 shows the finished cross section A–A’ at full scale, with all cartographic elements completed, as it appeared in the final publication (Hunt and others, 2010, shown in figure 1), in its own Data Frame on the map layout, locked at 1:24,000 scale.

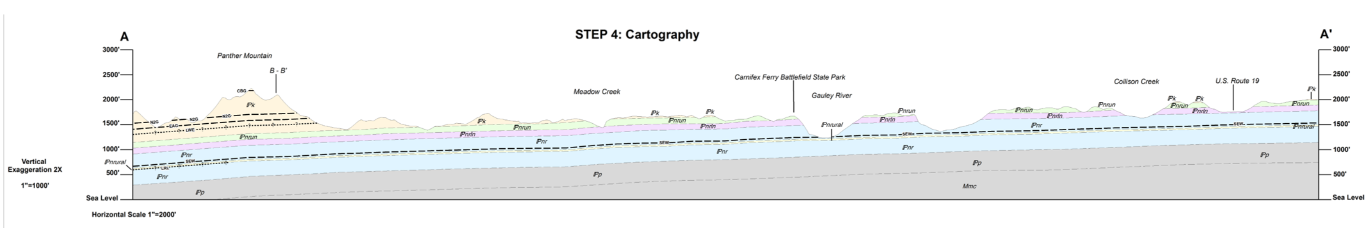

Figure 6. Cross Sections, Step 4: Generated polygons are given geologic unit attributes and symbolized to match the geologic map. Other digitized cross-section layers are shown here with final symbolization and cartography completed as it appeared in the final publication.

Stratigraphic Column

STEP 1: Build Frame, Georeference/Scale Source Material

First, a frame is built in Arc to the exact size of the desired finished stratigraphic column, following a similar procedure outlined for the cross sections. The projected space for the frame shapefile or geodatabase layer used should match the accompanying geologic map, for example, UTM NAD83, Zone 17, and the scale of the data frame should match that of the rest of the map layout, in this case 1:24,000.

For example, if the finished column on the map layout is desired to print out at 22 inches high, like the column shown in Hunt and others (2010) in figure 1, using a scale of 1:24,000 to match the map layout, multiply 22 in. by 24000 to get 528000 "ArcMap inches" and use this figure to construct the multiple parallel vertical axes of the column in Arc. Use the same formula to calculate the size of the horizontal frame lines, so they will print out at exactly 7 in. wide. 7 in. times 24000 will equal 96000 "ArcMap inches," and this figure will be used to construct the horizontal lines. Horizontal lines can be used at formation boundaries, as shown in figure 7, to serve as "tic marks" to help georeference the linework or images to the stratigraphic column frame.

Digitized linework from CADD, Illustrator, CorelDRAW, and other graphic programs with Cartesian coordinates can be imported and converted to a shapefile, and then "Spatial Adjust" tools can be used in Arc to fit the linework to the scaled, projected-space stratigraphic column frame. Bare, wire-frame linework should be imported, as shown in figure 7, to exclude or delete all vectorized fills and patterns. These will be replaced with polygon fill symbols at a later stage. Published or hand-drafted stratigraphic columns, such as the one used here from Englund and others (1986), can be scanned and imported as image files and georeferenced to the frame using formation boundary lines, known marker beds, or by using the scale bar on the diagram to re-scale the raster image to a section of the frame and then moving it into place. Complete or partial diagrams can be used for this, or a column can be compiled from multiple scanned diagrams or a mix of raster and vector source materials, as shown in figure 7.

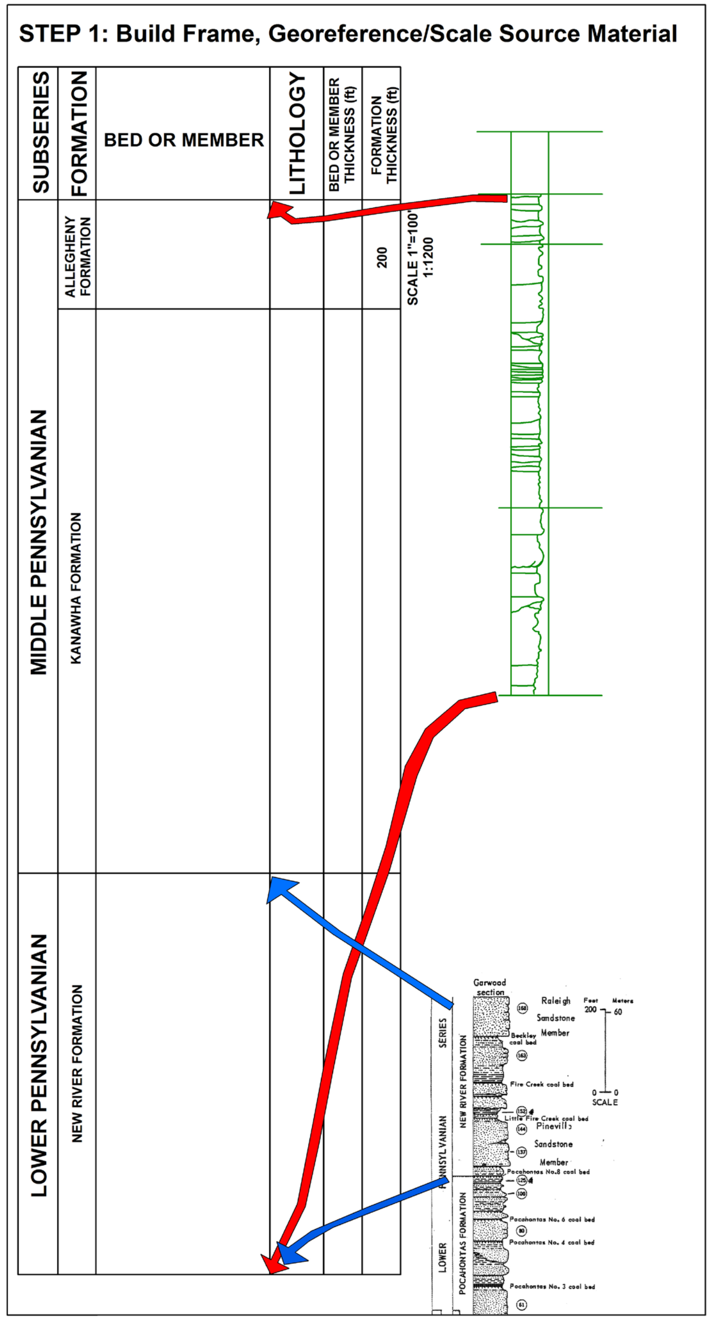

Figure 7. Stratigraphic Columns, Step 1: The column frame is built in Arc, so raster and vector source material can be georeferenced or Spatial Adjusted to it to compile a column specific to the accompanying geologic map.

STEP 2: Digital Linework and Points – Edit Spatial Adjusted Linework, Raster-to-Vector Conversion, and Regular Digitizing

Once the raster and (or) vector source material is scaled and georeferenced, the weathering profile and empty block outlines of the lithologic units are digitized and (or) edited to create the column, taking care to snap line ends to the frame and to each other, so that polygons will form correctly in the next step. Lines are given attributes for cartographic purposes, so that cross beds and other special features will have a different line style from unit contacts. Specialized symbology, such as cross-bed lines, unconformities, and the chert layer triangle symbols near the top of the column (fig. 8), had to be digitized literally, because no symbols for these exist in the Esri palettes.

Point features, such as fossils, could also be digitized at their locations along the column, and custom fossil point symbols could be used to symbolize these features. Point labels are also digitized in another point feature class at their correct locations in the "Bed or Member" and "Thickness" sections of the column and labeled with bed names and unit thickness to later annotate the column by converting into an Annotation Layer (fig. 8).

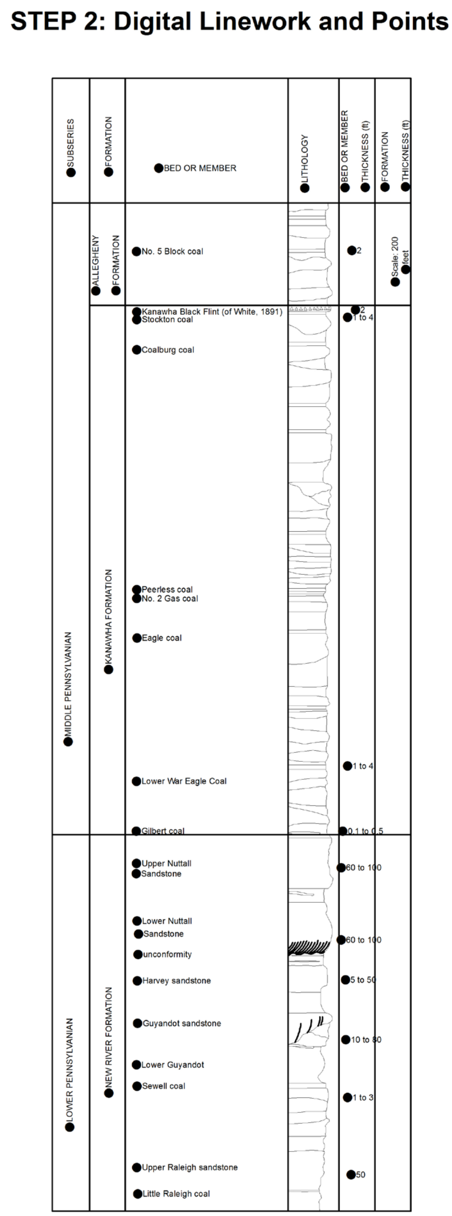

Figure 8. Stratigraphic Columns, Step 2: Linework is edited from vector source material, or digitized from raster sources, and given attributes for desired line style. Points are digitized for labels for frame, bed names, thicknesses, other notations, and fossil symbols.

STEP 3: Polygons and Attributes: Generate Polygons From Lines

Once linework for the column is completed, polygons are generated for the lithologic units and assigned attributes for geologic unit (for example, Pnr, Pk) and lithology (for example, shale, sandstone, coal). Three types of shale and three types of sandstone were used as attributes to increase the visual interest of the stratigraphic column (figs. 9 and 10).

STEP 3: Polygons and Attributes

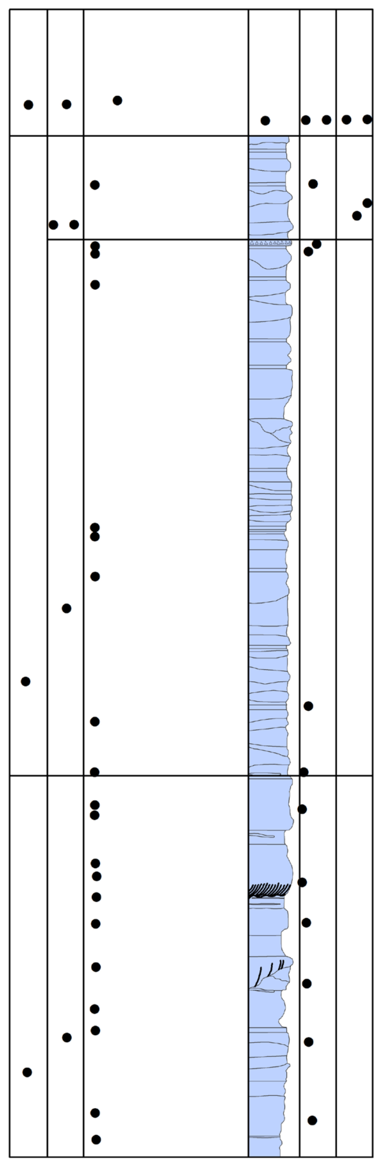

Figure 9. Stratigraphic Columns, Step 3(a): Polygons were generated (shown in blue) and given unit attributes to match the accompanying geologic map and lithology attributes for lithology polygon fill symbols.

Attributes of GARI_StratCol_Poly

OBJECTID	SHAPE *	Symbol	Unit_Abbrv	Name	Lithology
1	Polygon	31	Pnr		SHALE_1
2	Polygon	1	Pnr	Little Raleigh Coal	COAL
3	Polygon	23	Pnrural	Upper Raleigh Sandstone	SAND_3
4	Polygon	31	Pnr		SHALE_1
5	Polygon	42	Pnr		SANDY_SH_2
6	Polygon	21	Pnr		SAND_1
7	Polygon	42	Pnr		SANDY_SH_2
8	Polygon	31	Pnr		SHALE_1
9	Polygon	1	Pnr	Sewell Coal	COAL
10	Polygon	21	Pnr		SAND_1
11	Polygon	1	Pnr		COAL
12	Polygon	42	Pnr		SANDY_SH_2
14	Polygon	31	Pnr		SHALE_1
15	Polygon	23	Pnr	Harvey Sandstone	SAND_3
16	Polygon	1	Pnr		COAL
17	Polygon	1	Pnr		COAL
18	Polygon	31	Pnr		SHALE_1
19	Polygon	22	Pnrln	Lower Nuttall Sandstone	SAND_2
20	Polygon	1	Pnr	Iager B Coal Horizon	COAL
21	Polygon	42	Pnrun		SANDY_SH_2
22	Polygon	22	Pnrun	Upper Nuttall Sandstone	SAND_2
23	Polygon	31	Pnrun		SHALE_1
24	Polygon	1	Pk	Gilbert Coal	COAL
25	Polygon	31	Pk		SHALE_1
26	Polygon	42	Pk		SANDY_SH_2
27	Polygon	22	Pk		SAND_2
28	Polygon	31	Pk		SHALE_1

Record: 1 Show: All Selected Records (0 out of 92

Figure 10. Stratigraphic Columns, Step 3(b): A screen capture of the attribute table for the stratigraphic column unit polygons, showing attribute fields for Symbol, Unit Abbreviation, Name, and Lithology.

STEP 4: Cartography: Putting it All Together...

Polygons then were symbolized based on lithology, using standard USGS symbol polygon pattern fills available in the Esri symbol palettes. The chert symbol and legend patch had to be created by hand since there was no symbol for this in the Esri palettes. Polygons were also symbolized based on geologic unit color to match the accompanying geologic map. The color layer was placed under the pattern fill layer, and the pattern fill layer was given transparent backgrounds so the color would show through the pattern.

Point labels were converted into an Annotation Feature Class for advanced label placement and font formatting. Fossil point locations were given fossil symbols imported as bitmaps from the Federal Geographic Data Committee (FGDC) symbol files that accompany the FGDC's *Digital Cartographic Standard for Geologic Map Symbolization* (FGDC, 2006).

Figure 11 shows the finished stratigraphic column at full scale, with all cartographic elements completed, as it appeared in the final publication. The final stratigraphic column is inserted into the overall map publication layout in its own Data Frame, locked at 1:24,000 scale (fig. 1).

Text and Legend

Large text blocks are first formatted in Microsoft Word, then inserted into the Arc layout as objects. This allows advanced text formatting to be used, such as employing different fonts, text sizes, and styles in a single block of text, using multiple text columns and hanging indents, and formatting individual paragraphs in different ways. There is a maximum single-page size limit of 13 x 13 inches for the Word object that Arc will accept, so this large block of text in figure 1 is

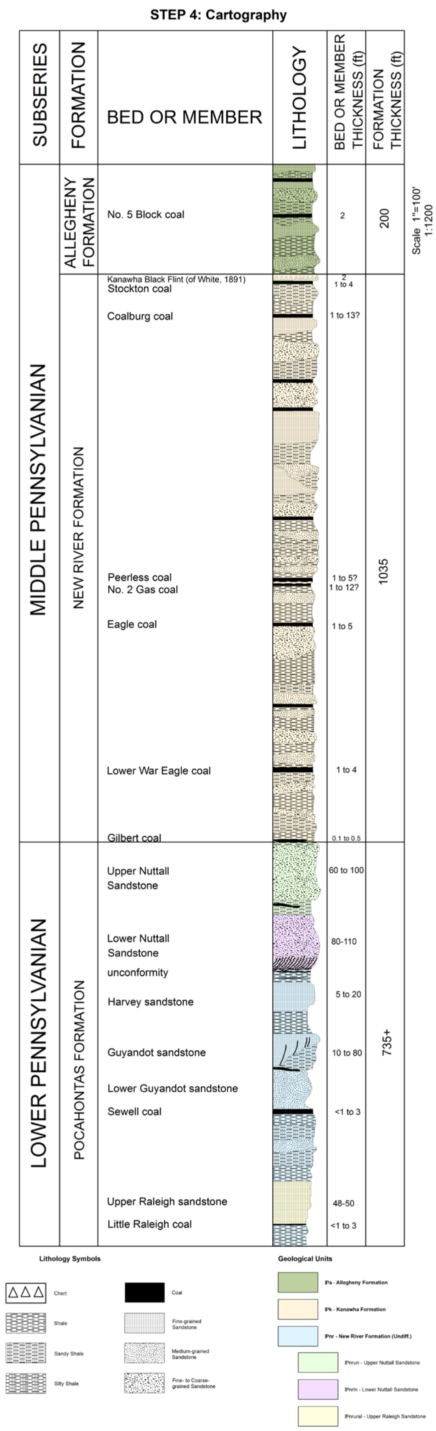

Figure 11. Stratigraphic Columns, Step 4: This shows the finished stratigraphic column with all cartographic elements completed, as it appeared in the final publication. Column units have been symbolized for both geologic map unit (color) and lithology (pattern). Labels have been converted into an Annotation layer for advanced placement and formatting.

actually two objects placed side by side in the map layout. A live link is maintained to the inserted text object, so any edits made to the text in Word will also immediately appear on the Arc layout once the document is saved.

Standard Arc legend tools were used to create the overall legend, then it was converted into graphics, and individual components were edited and arranged separately. Blocks of formatted text were copied and pasted in for the geologic unit descriptions. Standard Arc scale bars and text objects were used (fig. 1), and three separate Data Frames contain the Location Map, Data Point Locations inset map, and a custom-drawn north arrow showing the magnetic declination of the topographic base map.

A full-sized version of this map was shown during "Map Blast" at DMT'11 (see figure 12). It also is available as a publication from WVGES (Open File 1001) (Hunt and others, 2010) or from the National Park Service (GRI Source Map 75478 GARI). The full set of instructions for measuring and constructing cross sections (Gooding, 2010) can also be downloaded from the DMT Web site (*http://ngmdb.usgs.gov/Info/dmt/DMT11presentations.html*) or is available from the author upon request.

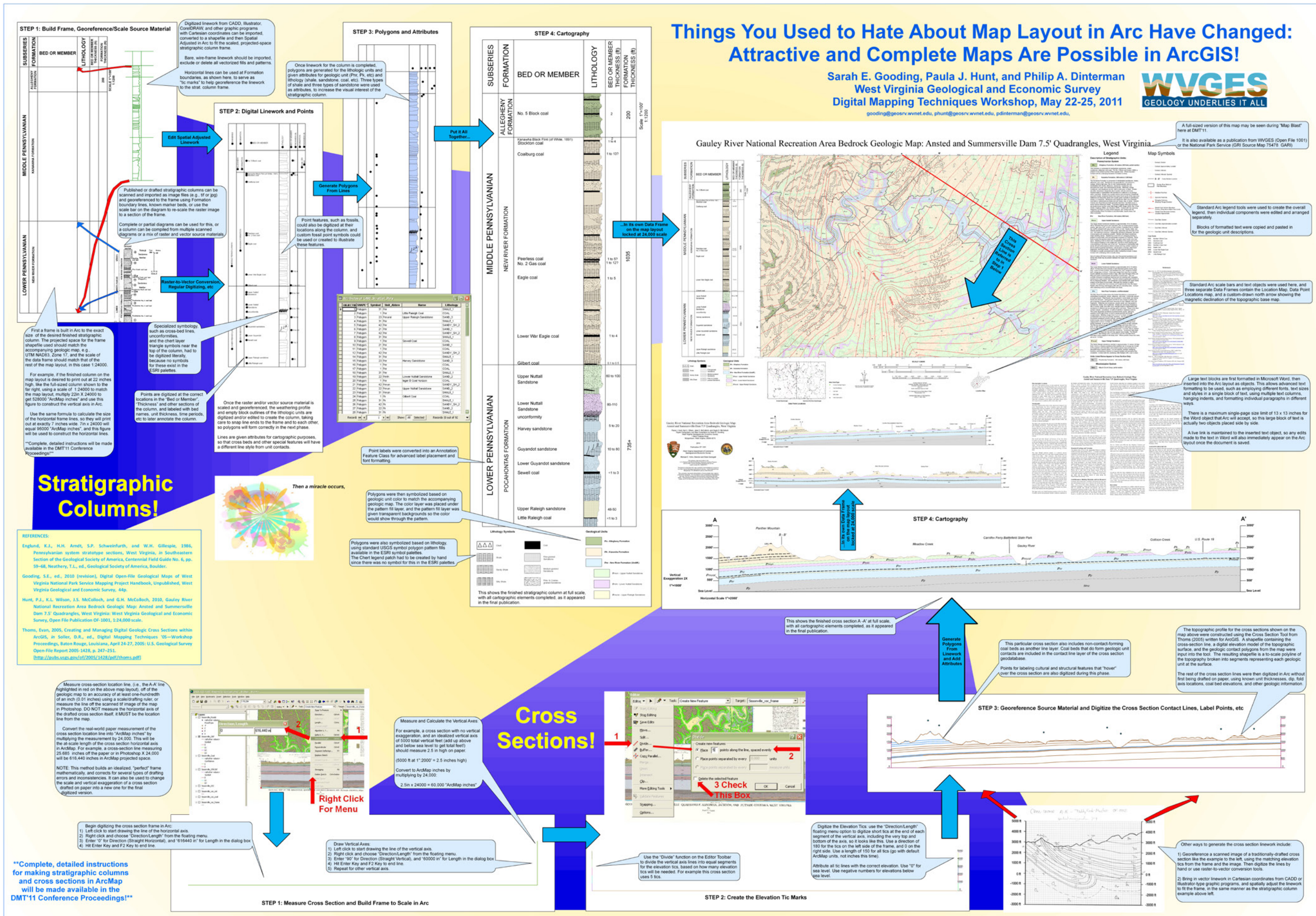

Figure 12. A page-sized version of the original poster as it appeared at the Digital Mapping Techniques '11 Workshop, May 22–25, 2011, in Williamsburg, Virginia. It can be downloaded from the DMT Web site, *http://ngmdb.usgs.gov/Info/dmt/DMT11presentations.html*.

References

Englund, K.J., Arndt, H.H., Schweinfurth, S.P., and Gillespie, W.H., 1986, Pennsylvanian system stratotype sections, West Virginia, in Neathery, T.L., ed., Southeastern Section of the Geological Society of America, Centennial Field Guide No. 6, p. 59–68: Boulder, Colorado, Geological Society of America.

Federal Geographic Data Committee (FGDC) [prepared for the FGDC by the USGS], 2006, FGDC digital cartographic standard for geologic map symbolization: Reston, Va., FGDC Document Number FGDC-STD-013-2006, 290 p., 2 pls., *http://ngmdb.usgs.gov/fgdc_gds/geolsymstd.php*.

Gooding, S.E., ed., 2010 (revision), Digital Open-File Geological Maps of West Virginia National Park Service Mapping Project Handbook (unpublished): West Virginia Geological and Economic Survey, 44 p.

Hunt, P.J., Wilson, K.L., McColloch, J.S., and McColloch, G.H., 2010, Gauley River National Recreation Area bedrock geologic map: Ansted and Summersville Dam 7.5' quadrangles, West Virginia: West Virginia Geological and Economic Survey, Open File Publication OF–1001, scale 1:24,000.

Thoms, Evan, 2005, Creating and managing digital geologic cross sections within ArcGIS, in Soller, D.R., ed., Digital Mapping Techniques '05—Workshop Proceedings, Baton Rouge, Louisiana, April 24–27, 2005: U.S. Geological Survey Open-File Report 2005–1428, p. 247–251, *http://pubs.usgs.gov/of/2005/1428/pdf/thoms.pdf*.