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The contents are provisional and will be superseded by a paper in the DMT'11 Proceedings.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

Appendix V: Instructions for Digitizing Geologic Cross-Sections and Stratigraphic Columns**

1.) Scan original cross section or strat column in grayscale (or indexed color if in color) at 400 dpi. (If necessary, crop out cross section/column diagram from overall map layout in Adobe Photoshop and save as a separate .tif file. Maps, cross-sections or strat column images should all be georeferenced individually for best accuracy.)

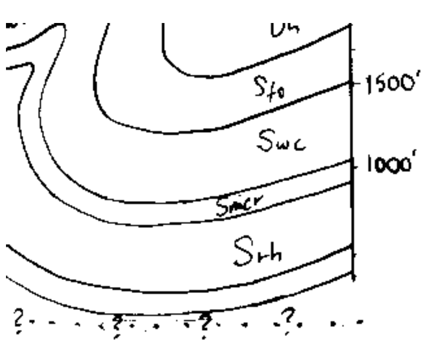
2.) In Photoshop, perform any needed image sharpening, brightness/contrast, rotating, cropping, collar erasing, etc that may be needed *before* georeferencing. (Once an image has been georeferenced, it should not be edited again in Photoshop!)

3.) **Measure cross-section *location* line**, i.e., the A-A' line, off of the geologic map to an accuracy of at least one-hundredth of an inch (0.01 inches) using a scale/drafting ruler, or measure the line off the scanned tif image of the map in Photoshop using the Measurement Tool (right click on the Eyedropper to find this tool. Look for "D1" along the toolbar at the top of the Photoshop window for the measurement). DO NOT measure the horizontal axis of the cross section itself, it MUST be the location line *from the map*.

4.) Write this measurement on the *Geologic 7.5' Quad Digitizing Checklist* for your quadrangle in the cross-section checklist space provided, to keep a record of it.

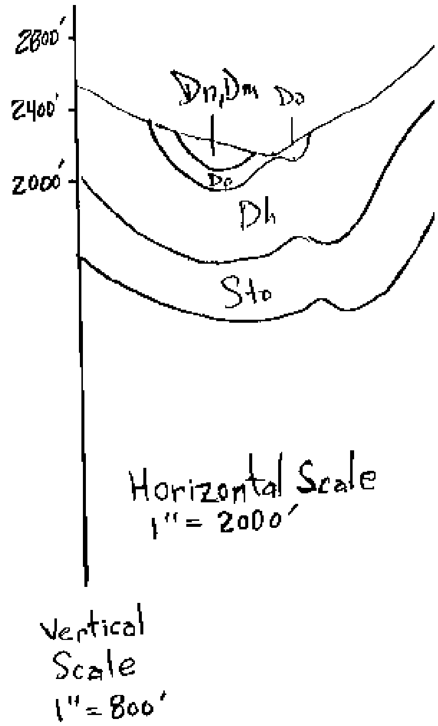
5.) **Convert** the real-world paper measurement of the cross section location line into ArcMap inches by multiplying the measurement by 24,000. This will be the at-scale length of the cross section horizontal axis in ArcMap. Note this figure on the checklist. For example, a cross-section line measuring *25.685* inches off the paper or in Photoshop *X 24,000* will be *616,440* inches in ArcMap units.

6.) **Examine** the vertical axes of the cross section and note the vertical exaggeration which should be stated on the diagram. Measure the vertical axes and/or figure out how tall they *should* be on paper *if they were drawn perfectly*. Note the "perfect" figure (adjusted to correct errors) for the final height in inches of the vertical axes on the checklist. Do NOT just trust that axes are drawn perfectly, always scrutinize them for the following types of problems!:



Note the vertical axis of this cross section example to the left has not been completely drawn by the author. The axis line will need to be extended from where it ends by at least another 1000 feet to enclose the bottom of the diagram. Also the tic marks are not evenly spaced.

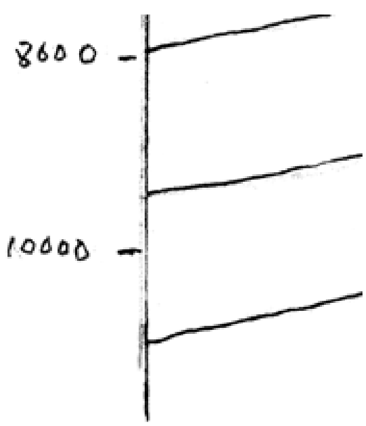
This will be corrected by building the "perfect" frame in Arc and warping the image to the frame.



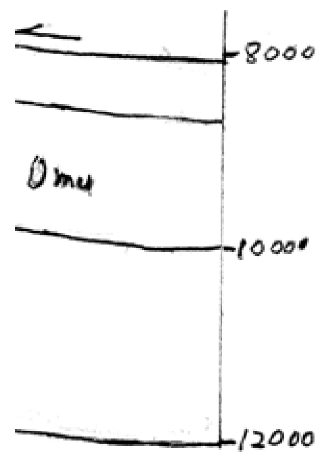
Note the vertical axis of this cross section example to the left has not been completely drawn by the author. The vertical axis is also a non-standard vertical scale of 1:800. This will need re-scaled to 1:2000 by building the frame to the required final vertical depth, and warping the image to the frame in Arc, using whichever tics will match, such as the "2000" ft tic mark.

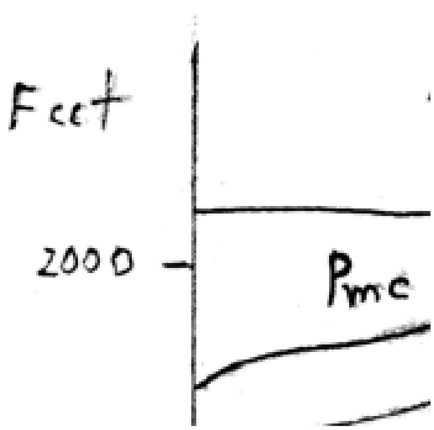
The Horizontal Axis has not been drawn at all. This will be corrected by building the frame in Arc.

The Vertical Axis lines were not drawn straight. This will be corrected by warping the image to the "perfect" frame in Arc.



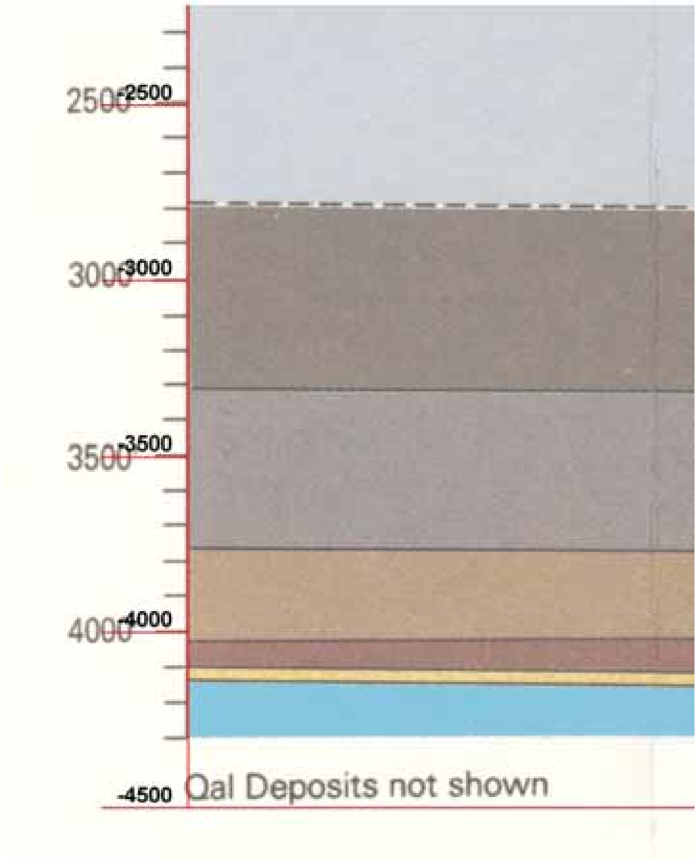
The vertical axes of the cross section example to the left and right are from the **same** cross section diagram. The axis on the left side is drawn to 10,000 feet, but the right side axis is drawn to 12,000 feet. The diagram also extends below the 12,000 foot tic mark. This will be corrected by extending the frame downwards in Arc by the amount required, in this case another 2000 feet, (for a total depth of 14,000 ft) to enclose the whole diagram without cutting any of it off.





The vertical axis of the cross section example to the left shows the topographic profile at the top of the diagram exceeds the highest vertical tic of the axis. This will be corrected by extending the frame upwards in Arc by the amount required, in this case by another tic unit of 2000 feet, (for a final height of 4000 feet) to enclose the whole diagram without cutting any of it off.

The diagram will be georeferenced to the frame using the highest tic *on the image*, which in this case is the 2000 foot tic mark.



The vertical axis of the cross section example to the left appears to be perfect, but beware!! The labeled tics are all regularly spaced at 500 foot intervals until 4000 ft Below Sea Level (BSL). Then the last three unlabeled tics below 4000 are intervals of 100 ft each, for a total depth of 4300 ft! You will not be able to divide the vertical axis into equal segments in Arc without extending the frame to the next 500-foot increment, which is 4500 feet BSL.

This will be corrected by extending the frame (shown in RED, at left) downwards in Arc by the amount required, in this case another 2 units of 100 feet, extending the axis down to 4500 ft BSL. This will allow you to be able to divide the axis by equal segments in later steps of building the frame.

The diagram will be georeferenced to the frame using the lowest labeled tic *on the image*, which in this case is the 4000 foot tic mark. The diagram will be drawn as shown on the original image, if the author does not approve extending the lowermost unit to the bottom of the frame. In this case, the lowermost unit after the blue unit will be a polygon with a value of <blank>, so as not to imply the blue unit is twice as thick as it really is.

7.) Use the following tables and information to help you convert the vertical axis "perfect" total height in feet *to* inches on paper *to* ArcMap inches at 1:24,000 scale:

No Vertical Exaggeration = 1:1 or 1:2000 or 1 inch=2000 feet or 1:24000 scale

2X Vertical Exaggeration = 2:1 or 1:1000 or 1 inch = 1000 feet or 1:12000 scale

- For example, for a cross section with no vertical exaggeration, at 1:2000 (which is the standard), and a vertical axis of 5000 *total* vertical feet (add up above and below sea level to get total feet!) should measure 2.5 in high on paper. Convert to ArcMap inches by multiplying by 24,000:

<u>No Vertical Exaggeration (1:2000):</u>	<u>2X Vertical Exaggeration(1:1000):</u>
4000 ft = 2 in high = 48,000 ArcMap inches	4500ft = 4.5in high = 108000 Arc inches
5000 ft = 2.5 in high = 60,000 ArcMap inches	5000ft = 5 in high = 120,000 Arc inches
6000 ft = 3 in high = 72,000 ArcMap inches	
10000 ft = 5 in high = 120,000 ArcMap inches	and so on.

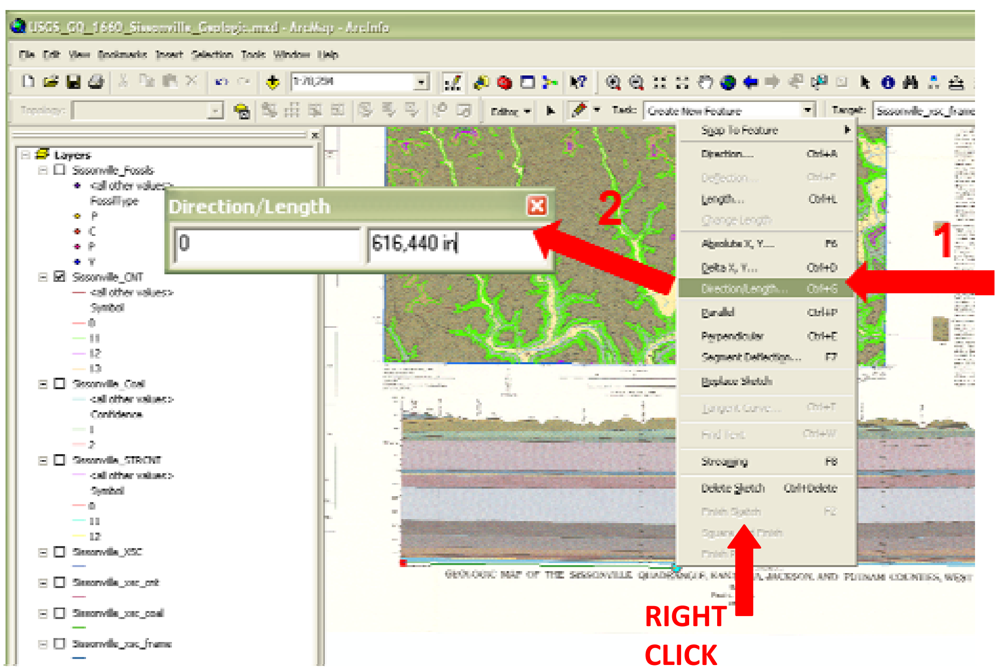
Be sure and note these figures on the Digitizing Checklist in the Cross Section area!

8.) In ArcCatalog, create shapefile or feature class layers for the cross section frame and contact layers (and coal layers if required), following the naming conventions and attribute fields in the data model. _Naming Conventions:_ These cross section diagram layers have the lowercase “xsc” in the name to differentiate them from the cross section *location line* map layer with “XSC” in the name in all-caps. Give the xsc layers the same coordinate system as the parent geologic map.

9.) Open ArcMap and add the xsc layers and the scanned cross section image tif file to the digitized geologic map working document. You will draw the cross section at a short distance below the geologic quad map, so that they can be displayed in the same frame in ArcMap if needed. Be sure to allow enough space below the geologic map for the estimated height of the cross section, plus some white space. (**Stratigraphic columns should be drawn to the left side of the geologic map. Be sure to allow enough space for the width of the column, plus some white space.)

10.) **Draw the horizontal axis** for the cross section frame as follows:

a. Left click to start drawing the line of the axis on the lower left side.
b. Right click and choose “Direction/Length” from the floating menu.
c. Enter “0” for Direction (Straight Horizontal), and “XXXXXX in” for “Length”, where XXXXXX is the length of the horizontal axis converted to ArcMap inches that you calculated in Step 5. Using the previous example from Step 5, you would enter “616,440 in”. Make sure you enter the “in” for inches in the box, or it will default to whatever map units are set for the data frame, and you will get the wrong results!
d. Hit the Enter Key and the line will be drawn automatically to the exact specifications you entered. Hit the “F2” button to end the line.

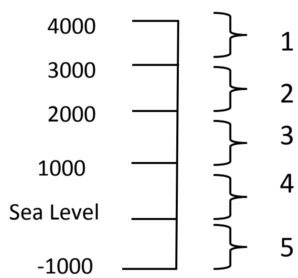


11.) **Draw the vertical axes** for the cross section frame as follows:

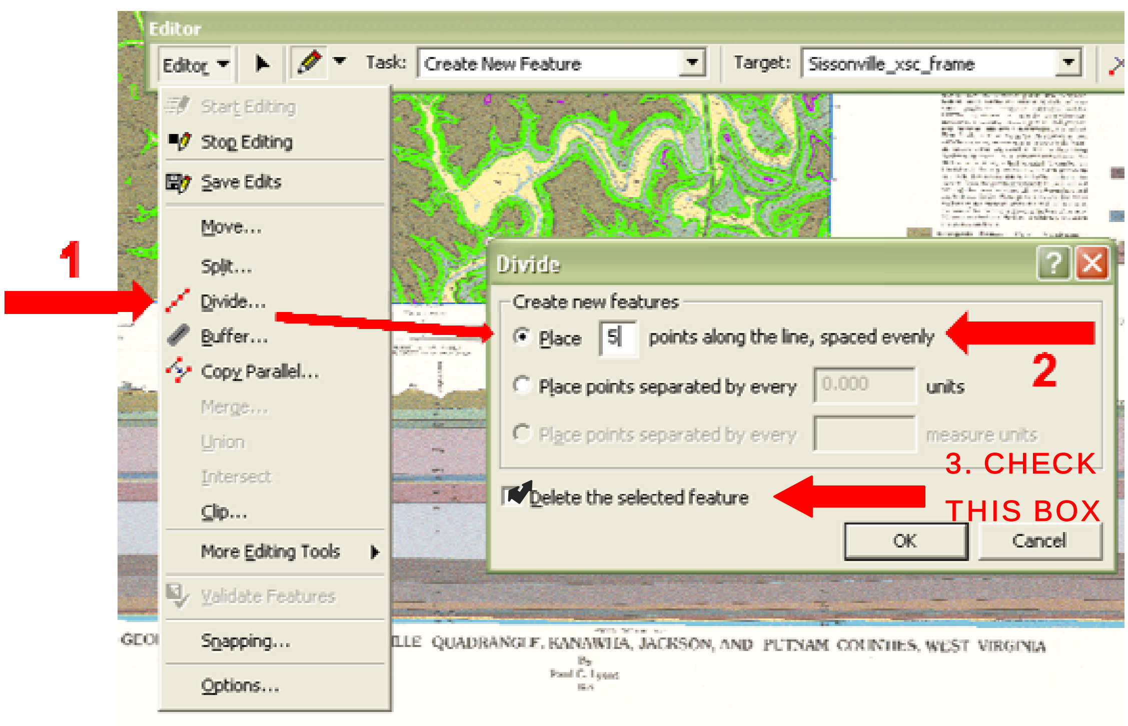
a. Set “Snapping” to “End” for the xsc_frame layer.
b. Start the line for the left side **vertical axis** line by snapping to the left end of the horizontal axis line.
c. Again right click, and choose “Direction/Length” from the floating menu.

d. Enter “90” for “Direction” (Straight Vertical), and “XXXXXX in” for “Length”, where XXXXXX is the length of the “perfect” vertical axis converted to ArcMap inches that you calculated in Step 7. Using an example from Step 7, you would enter “60,000 in” for a vertical axis of 5000 total feet that would measure 2.5 inches on paper.
e. Hit the Enter Key and the line will be drawn to the exact specifications. Hit “F2” button to end the line.
f. Repeat for right side vertical axis line.

12.) Select one of the vertical axis lines. Use the “**Divide**” function on the Editor Toolbar to divide the vertical axis line into equal segments for the elevation tics. Check the “Delete the selected feature” box so the Divide Tool does not leave behind the original undivided line on top of the new, segmented ones. First figure out how many segments will be needed along the vertical axis (try to keep to units of 500 or 1000). For example:



This vertical axis will have 5 equal segments along the axis line.



13.) Repeat for the other vertical axis line.

14.) Attribute all frame axis lines drawn so far with the “-9999” attribute for “Elev” attribute field.

15.) **Digitize the Elevation Tics:** Snapping to the ends of the vertical axis line segments, use the "Direction/Length" floating menu option to digitize short tics at the end of each segment, including the very top and bottom of the vertical axis, so it looks like the example in Step 12 above. 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 this time). Hit "F2" to end each tic line.

16.) Attribute all elevation tic lines drawn along the vertical axes with the correct elevation attribute for each tic in the "Elev" attribute field. Include the minus sign for elevations below sea level. Use a value of "0" for Sea Level (This is a *Long Integer* type of field, so no text values are allowed).

17.) Save Edits and Stop Editing the cross section frame. In the Layer Properties box, turn labels "on" for this layer, using the "Elev" field. Now you should see the elevation of each tic mark displayed.

18.) Open the Georeferencing Toolbar, and choose the scanned cross section image as the target.

19.) **Georeference the scanned cross section** to the frame you just built, being careful to match the right vertical axis tics from the image to the correct (labeled) tics on the frame. Use 4 link points, the top and bottom of the vertical axis on both sides of the frame are the best points to use, but use whichever points seem best to get most accurate result. Make the image fit the frame. The frame is accurately measured, scaled, and mathematically generated; the paper diagram usually not so much.

20.) **Digitize the cross section** *contact line* (including topographic surface profile) and *coal bed/marker bed line* layers, snapping line "Ends" to the frame "Edge". The contact line layer for cross sections *contains* the fault lines, regular contacts are *Type*=1, faults are *Type*=2 as per the data model. Coal and/or marker beds will have the *Unit_Abbrv* attribute per the data model.

21.) Use the same procedure for **generating polygons** as you do for the geologic map *CNT* and *CNT_poly* layers, except use *<quad>_xsc_cnt* and *<quad>_xsc_frame* layers to create the polys. (See Appendix IV for instructions on this process.)

22.) Create and Validate Topology for the cross section contact, frame and polygon layers. Once topology confirms that all polygons were created, attribute the polygons as per the data model. (*You do **not** need to copy frame lines into the contact layer so ignore any errors related to frame boundary unless a polygon is not forming*)

****Stratigraphic Columns:** Use a similar procedure for creating the frame, georeferencing the scanned image, and digitizing the stratigraphic columns, except it will be a vertically-oriented frame instead of a horizontal one, and will meet the specific vertical and horizontal dimensions of the strat column. Strat columns should be drawn to the left of the geologic map, instead of below it. Draw the weathering profile as if it were a topographic profile, but vertically. Use a point feature class layer for any fossil symbols or other point-type features that may be symbolized in the column. Use the USGS lithology polygon fill symbol palette to fill the unit polygons with the correct lithology symbol, rather than digitizing these details.