Making a geologic map using ArcGIS

Created for Penn State Geosciences Field School

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Overview

This is a bare-bones primer for geologic mapping in ArcGIS, tailored for the exercises in the 2017 Penn State Geosciences Field School, and assumes no prior knowledge of ArcGIS. We have tried to be as precise as possible with the language and terminology, so please read carefully (and report any errors or typos please!). The mapping database was created using the NCGMP09 database toolbox from the USGS (downloaded March 2017) and modified.

The general workflow is as follows:

1. Geologic fieldwork
    - A draft map is constructed in the field using a paper topographic contour basemap and pencils.
    - Navigation and positioning is accomplished using PSU-supplied iPhone 6s+ mobile devices loaded with Avenza PDF Maps. Basemaps and waypoints are transferred between iPhone and computer via a communal DropBox account.
    - Strike and dip measurements of geologic features are measured using either the Move Clino iPhone app or a Brunton pocket transit. Measurements are recorded by hand in field notebook, and linked to either paper map location or waypoints in Avenza PDF Maps.
2. Digital mapping
    - At the end of each field day, draft field maps are digitized using ArcGIS, and refined using air photos and topographic context.
    - First, linework (contacts and faults) is transferred, indicating appropriate level of uncertainty. Map unit polygons are then constructed from the completed linework.
    - Strike and dip measurements are manually added to the map from field notes, guided by any geologic stations exported from Avenza PDF Maps.
    - Ornamentation such as fold axes or geomorphic mapping is added separately from the main linework and polygon topology that defines the mapping units.
3. Cross section generation
    - Once mapping is complete, a geologic cross section is constructed along a provided cross section line using the ArcGIS Cross Section Toolbox from Evan Thoms (USGS).
4. Final geologic map presentation
    - Using the provided ArcGIS mapping template, an 11”x17” map sheet is generated as a high-resolution (300 dpi) pdf file. This map sheet will include a geologic map and cross section at a predetermined scale and extent, and a description of mapping units. Legends, scale bars, north arrows, and general layout are fixed by the instructor, and should not need adjusting.

It should be noted that the above workflow is highly streamlined from a typical project workflow building a geologic map from scratch, and so many steps involving geodatabase construction and layout are purposefully left out.

1. Opening and setting up the ArcMap workspace

1.1 Opening ArcMap and customizing toolbars and windows

Navigate to and open the file “ElkBasin2017.mxd”, which is the ArcGIS map document for Exercise 2 (Elk Basin). ArcGIS map documents provide a structure and layout “shell” within the program ArcMAP, and point to the actual mapping data contained in separate file geodatabases or file folders. ArcMAP should open to a layout view or print preview of the Elk Basin map, showing just a base topographic map with no geologic mapping (yet!).

Before getting started, it will be necessary to go through a few setup steps as described below (you should only need to do this the first time you open ArcMap on a computer).

Because we will be working with gridded raster data, you will need to activate both the **3D Analyst** and **Spatial Analyst** extensions. Pull down the **Customize** menu, select **Extensions…**, make sure the boxes for **3D Analyst** and **Spatial Analyst** are checked (Fig. 1), and click **Close**.

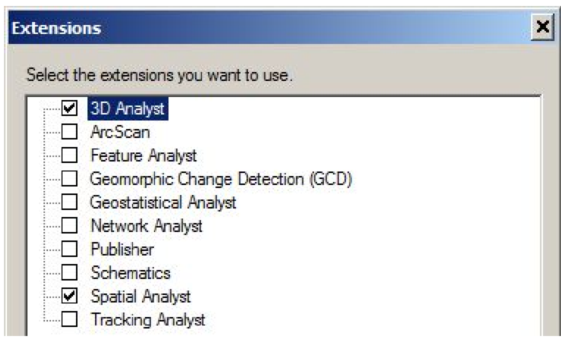

Figure 1. Adding extensions in ArcMap

Next, right click anywhere on the toolbar, and make sure the following toolbars are loaded:

3D Analyst   Advanced Editing   Editor   Layout   Standard   Tools   Topology

You can move these around wherever they are most helpful to you.

There are also a number of windows besides the main window that can be turned on or off depending on what tasks are being conducted. The quickest way to do this is through the following shortcut buttons on the **Standard** toolbar (Fig. 2).

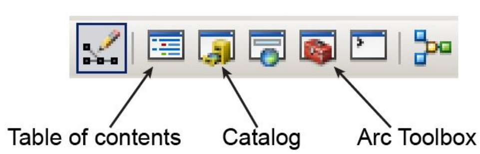

Figure 2. Icons on the Standard toolbar

The **Table of Contents** window shows you which datasets are currently loaded, the **Catalog** window shows you the file system of your machine and enables you to navigate to or load datasets, and the **ArcToolbox** window contains the library of tools that we will use to analyze these datasets. For now, we only need the Table of Contents window to be open, and your screen should look something like Fig. 3 below. Now is a good time to save your .mxd file. Do this early and often!

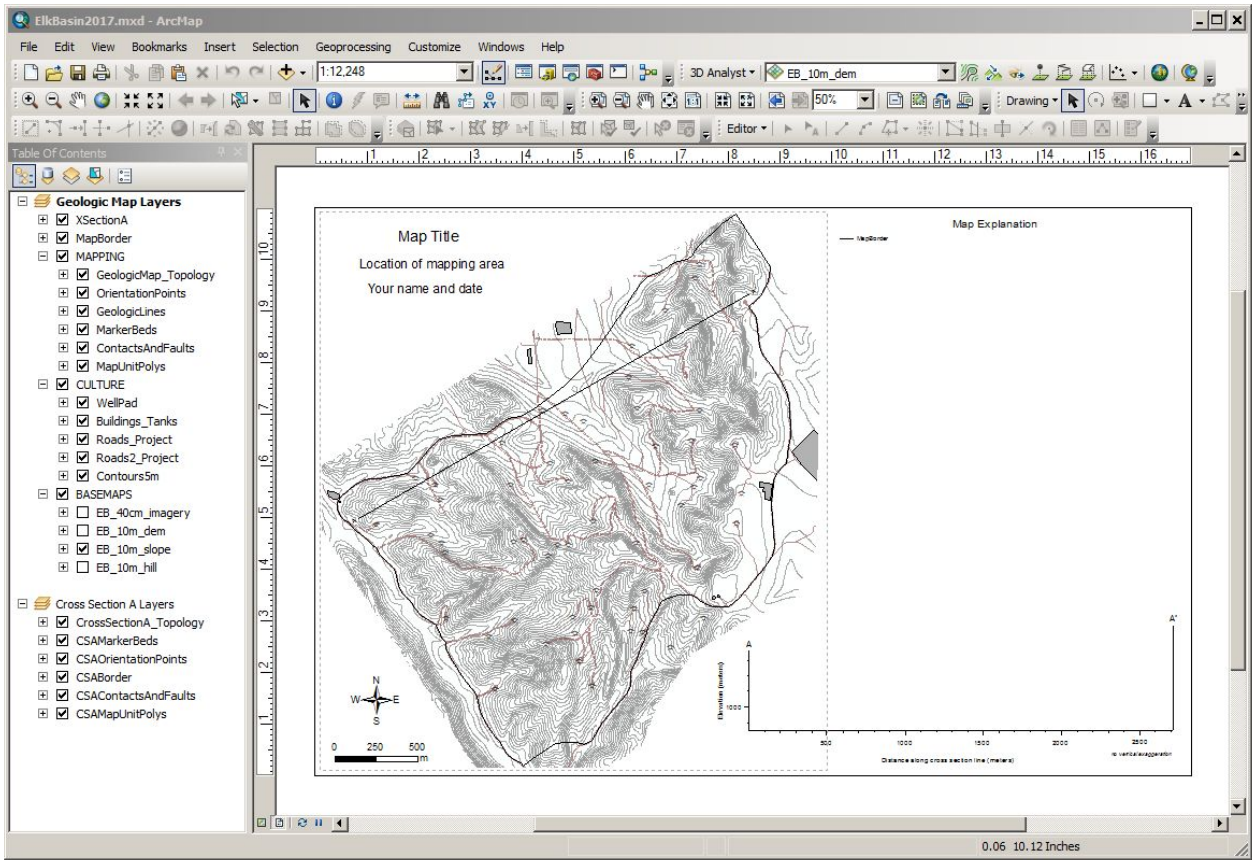

Figure 3. Window and toolbar layout.

1.2 Layout view

At this point, a print preview of the map document should be visible in the main window, as we are in **layout view**. In this view, individual **data frames** containing **layers** appear as objects that can be moved around on the page layout, and linked to north arrows, legends, scale bars, and other annotation. It is important to note that this is a *dynamic* layout, such that changing the content of a Data Frame will change the north arrows, legends, and scale bars appropriately.

To make your lives easier, much of the layout, design, and annotation has been pre-populated in your map document (you will still need to add your name and map unit descriptions, as described in section 4). As you begin mapping, a legend will be automatically generated containing only the symbology that you use on your map.

You may notice there are two different navigation toolbars. The **layout toolbar** contains tools for panning and zooming the actual page layout (Fig. 4), and the **tools toolbar** contains tools for navigating within an individual **data frame** (Fig. 5).

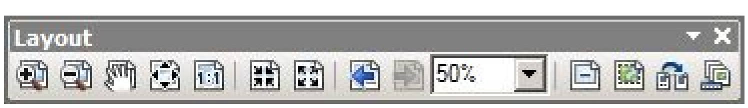

Figure 4. Layout Toolbar showing page navigation tools.

Figure 5. Tools Toolbar showing data frame navigation and measuring tools.

For the final layout, **bookmarks** for both the Mapping and Cross Section data frames have been provided, and allow for quick navigation to the final scale and extent (Fig. 6). Note that these bookmarks are unique to each data frame.

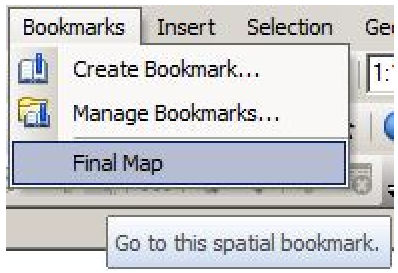

Figure 6. Bookmarks tab, showing predefined scale and extent for final map.

1.3 Data view

Except for the preparation of your final maps, you will be working mainly within **data view**, focusing on a single data frame (either your map or cross section). You can switch to data view by navigating to and selecting **View\Data View**\ from the menu bar, or by selecting the shortcut button at the bottom left corner of the main window.

Note that only one data frame can be active in data view at a given time (indicated by the bold data frame name in the table of contents). To activate a different data frame, right click on the desired data frame and select **Activate** from the drop down menu (Fig. 7)

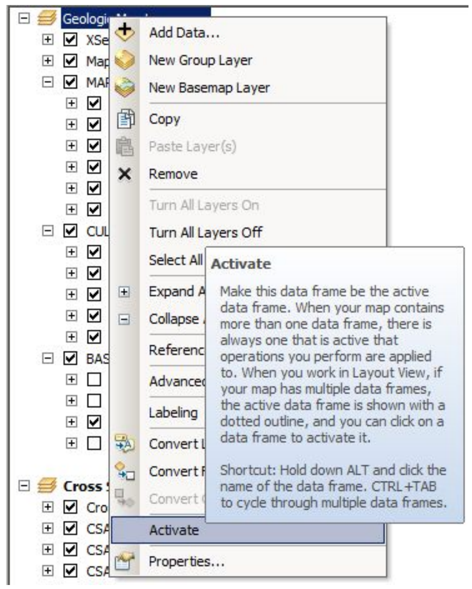

Figure 7. Activate data frame.

Within data view, you will see the layers contained in the dataframe drawn in the order they are listed, with the top layers at the top, and similar layers collected into group layers for organization. If you like, the draw order, transparency, and symbology can all be modified. ***However, for our exercises the default layer properties will be sufficient and only the turning on and off of layer visibility (using the checkboxes) will be needed*** (note that unchecking layers that are not needed can help speed up drawing times).

1.4 Exploring data

Take some time to explore your data a bit. You can zoom in and pan around with your mouse, and if you get lost, click the little blue globe on the **Tools** toolbar to get you back to the maximum extent (Fig. 5). The **Measure** icon allows you measure distances, perimeters, and areas, which are displayed using the units defined in the **Data Frame** properties. Also on the **Tools** toolbar is the **Info** icon that will give you layer information where clicked. You can spot-check an elevation, get the info from a geologic map, etc.

One incredibly helpful tool is the **Profile Graph** tool on the 3D Analyst toolbar (Fig. 8). This allows you to extract the information of a raster dataset along a linear or segmented profile.

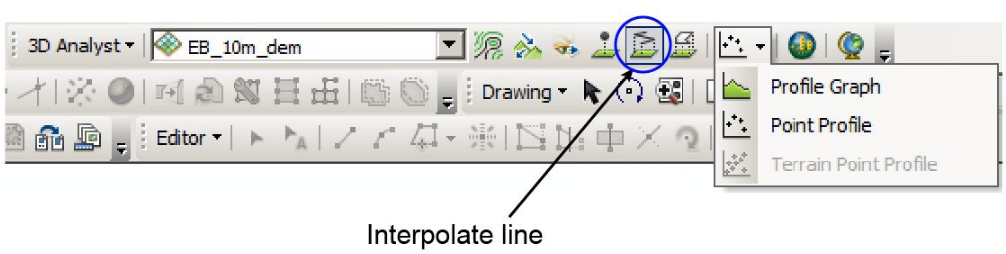

Figure 8. 3D Analyst Toolbar and the interpolate line tool.

First, select the raster dataset you wish to draw a profile of (here we'll use the digital elevation model, or DEM). To draw your line, use the **Interpolate Line** button and start clicking out a path. Double click the last point to finish, and then select **Profile Graph** to plot your profile. It will look something like Fig. 9 below:

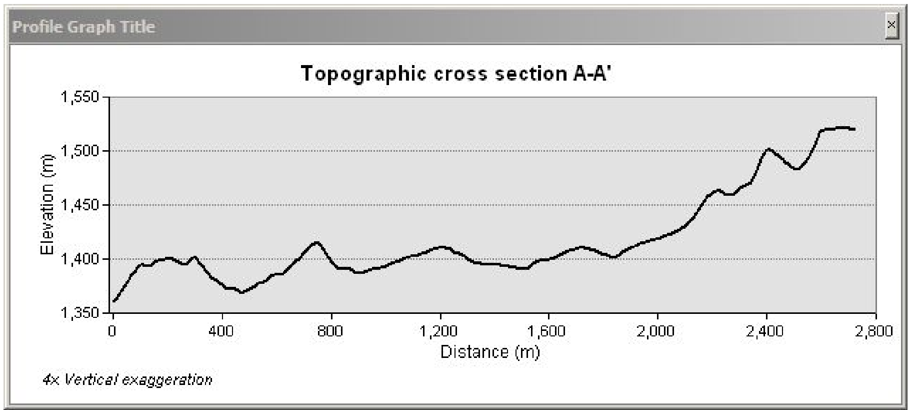

Figure 9. Profile graph of elevation, showing vertical exaggeration and location of cross section.

Note that the y-axis here shows elevation in meters, and the x-axis shows distance in meters. Be sure to note and be aware of any **vertical exaggeration** on your plot, which is simply the ratio of the horizontal scale to the vertical scale. Using Fig. 9 as an example, 1" corresponds to 800 m on the horizontal axis, but only 100 m on the vertical axis, thus the vertical exaggeration is 4x. You can edit the axes, labels, etc. by right clicking anywhere on the chart and choosing **Advanced Properties**.

A common pitfall is to accidentally plot a profile of a different raster, such as the mean rainfall, slope, or hillshade. Use common sense, and if something looks weird (like elevations ranging from 0-70), you probably made a mistake somewhere!

These profiles are NOT required for your final maps (as opposed to the geologic cross section described in section 3), but can be useful for interpreting the geology as you write your reports.

2. Mapping

In this section you will learn how to edit the feature classes within your mapping geodatabase to construct a professional looking geologic map.

General philosophy and tips

- Start by drawing linework and then use these to define polygon boundaries - do NOT start by drawing polygons. It will make things difficult and messy.
- Be vigilant with snapping. Do not leave gaps or dangles in your contact topology.
- Save your edits early and often!

2.1 Editing session overview

Mapping in ArcGIS is achieved through editing various point, line, and polygon features in what is termed an **Editing Session**. In order to create or edit features, you first need to Start Editing by navigating to the drop-down menu on the **Editor** toolbar (Fig. 10).

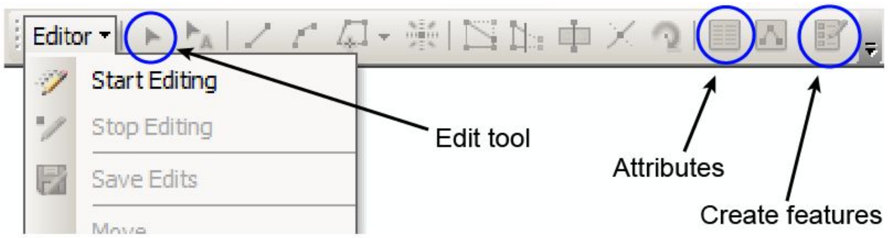

Figure 10. Editor toolbar showing key buttons.

When starting an editing session, you must choose the file geodatabase in which you want to edit (Fig 11). As all of the mapping features are contained within a single geodatabase (ElkBasin2017.gdb for this exercise), choosing any geologic mapping feature will do (e.g., ContactsAndFaults).

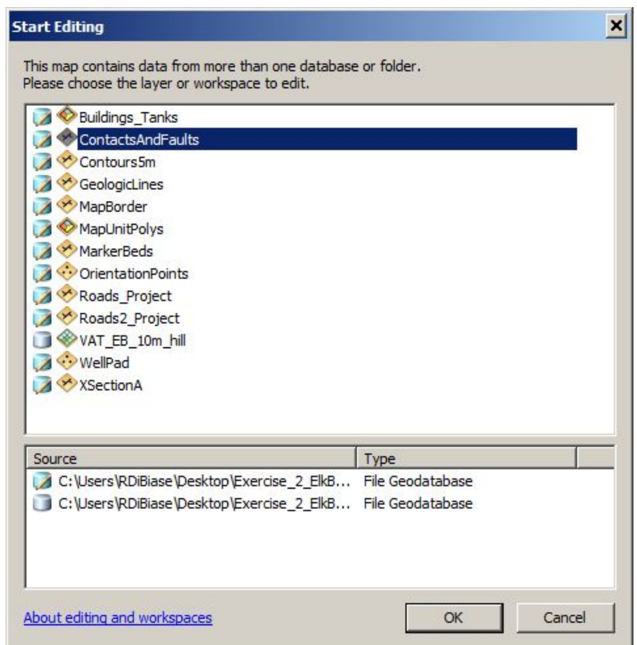

Figure 11. Start editing dialog box showing selection of geodatabase in which to edit.

As you start editing, be sure to periodically **Save Edits** (Fig. 10). This will limit frustration in case ArcMAP crashes, which is not uncommon. A good mantra is to save your edits "early and often".

When you are finished, go to the Editor toolbar and select **Stop Editing** (Fig. 10). Note that while an editing session is open, all files in the geodatabase are locked, and may cause issues if trying to access them from elsewhere (i.e., cross-section toolbar). Also note that the editor toolbar only tells you whether an editing session is open in the current data frame. Check all data frames for open editing sessions if you are running into problems!

2.2 Snapping

To ensure that your line work is topologically correct (i.e., no gaps or dangles), it is necessary to use snapping so that your mouse jumps to a pre-existing feature when it gets close. While you are in an open editing session, open the Snapping Environment window (Fig. 12) by navigating to and selecting **\\Editor\Snapping\Snapping Window** from the Editor toolbar (**note: if this does not show up, it is likely that "classic snapping" needs to be enabled by navigating to **\\Editor\Options\Use Classic Snapping**). Once the Snapping Environment window is open, select the layers you wish to include in the snapping environment (MapBorders and ContactsAndFaults for our purposes).

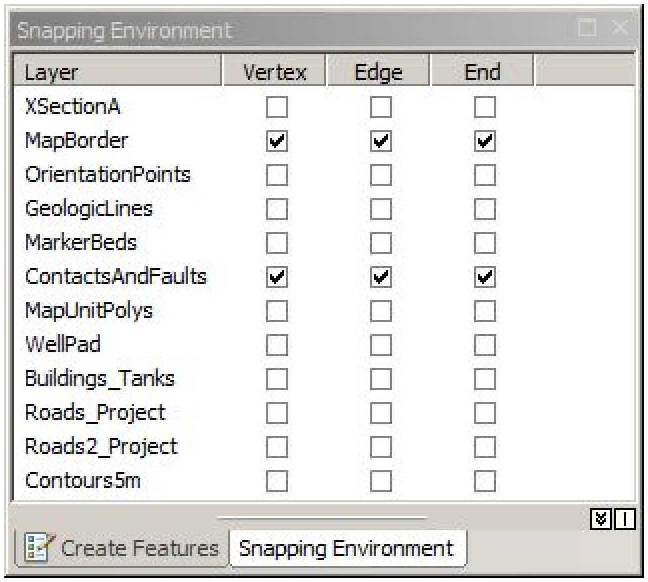

Figure 12. Snapping Environment window, showing the layers used for snapping. Be sure to only snap to the MapBorder layer and the ContactsAndFaults layer.

Next, make sure the snapping tolerance is set appropriately, by navigating to and selecting **\\Editor\Snapping\Options** from the Editor toolbar (Fig. 13). The ideal tolerance will depend a bit on what scale you are mapping at, but 5 pixels is usually a good balance between precision and frustration.

Figure 13. Snapping tolerance (classic snapping).

2.3 Create features (linework)

Before mapping, it is necessary to open the Create Features window by clicking on the appropriate button on the Editor toolbar (Fig. 10) while in an open editing session. The Create Features window (Fig. 14) will show the templates for all visible, editable layers (select the checkbox in the Table of Contents for any layers you want to edit that aren't showing up).

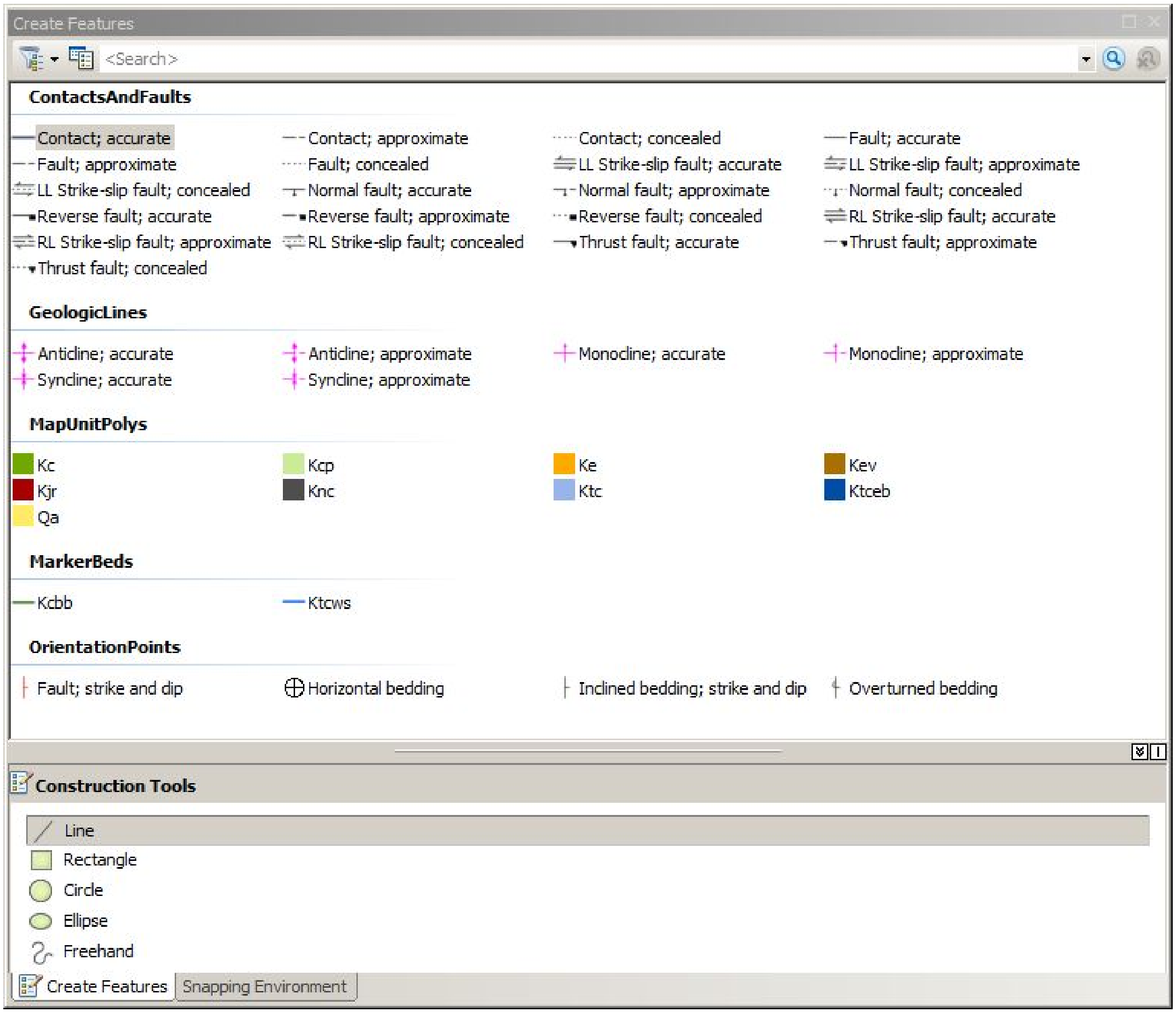

Figure 14. Create features window, showing feature templates and construction tools.

To start mapping, choose a representation (e.g., "Contact: accurate" from the feature class "ContactsAndFaults") and a construction tool (e.g., "Line") and begin clicking out your feature (double-click to finish). **Note that although there are a number of different construction tools, use only the "Line" tool for drawing linework.** Resist the temptation to use the "Freehand" tool, as it can be challenging to edit and correct mistakes later on.

Often, it is useful to fine tune a line feature after you have created it. To do this, double-click the line using the Edit tool (Fig. 10) to open the Edit Vertices toolbar. Here you can move, create, or delete vertices (Fig 15). If you want to delete an entire feature, simply select it with the Edit tool (Fig. 10) and press delete.

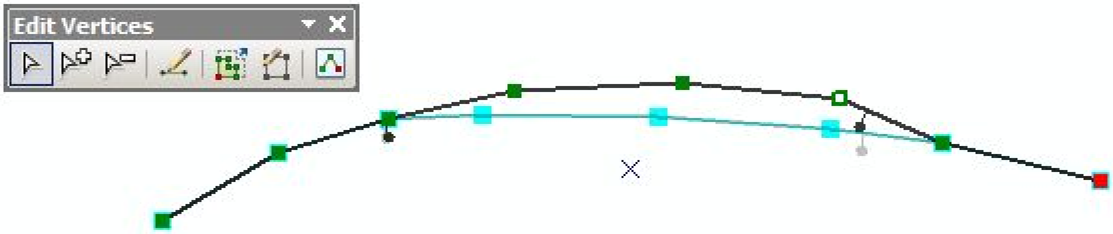

Figure 15. Edit vertices toolbar, showing feature modification.

You will be spending a lot of time creating lines. One of the MOST IMPORTANT things to remember about creating lines is that all of your contact lines (including fault contacts) should follow a clean topology, and finish at either a contact or a fault (no dangling contacts!).

When mapping an enclosed unit, the topology does not like a single line feature to close on itself. Use the Split tool on the editor toolbar, or draw two separate lines to close the loop.

Changing line direction: There is a directionality to your lines that determines which side line decorations (e.g., thrust barbs) fall on. This directionality can be switched by right clicking on the line feature class while in edit vertices mode (Fig. 15), and selecting flip.

2.4 Constructing polygons

Once most of the linework has been completed, it is time to start filling in the areas with polygons that reflect our geologic mapping units using the **Construct Polygons** tool on the **Advanced Editing** toolbar (Fig. 16).

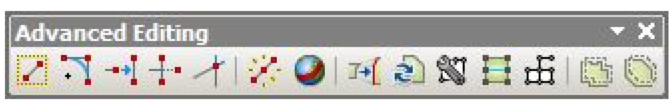

Figure 16. Advanced editing toolbar.

In order to construct a mapping polygon using the existing linework, select the boundaries of the polygon you wish to map using the Edit tool on the Editor toolbar (Fig. 10). To select multiple lines, hold the shift key while selecting. Once you have selected a properly enclosed (i.e., no gaps) set of bounding lines, use the "wrench" on the Advanced Editing toolbar (Fig. 16) to open the Construct Polygons dialog box (Fig. 17). Choose the appropriate template and then click OK (Fig. 17). If this fails, it is likely because there is a small gap somewhere that evaded your best snapping efforts. It can be a bear to track these topology errors down, so best to avoid in the first place with careful attention to snapping. You can check **Use existing features in target** to avoid generating overlapping polygons, but sometimes this feature can be buggy. If possible, it will make things easier to first construct polygons for interior "islands" before the surrounding area (Fig. 18).

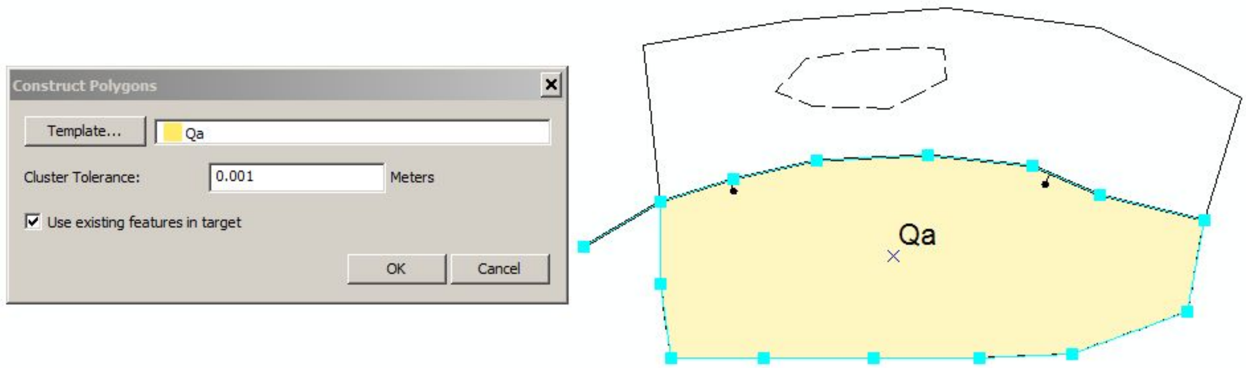

Figure 17. Construct polygon dialog box for simple polygon construction.

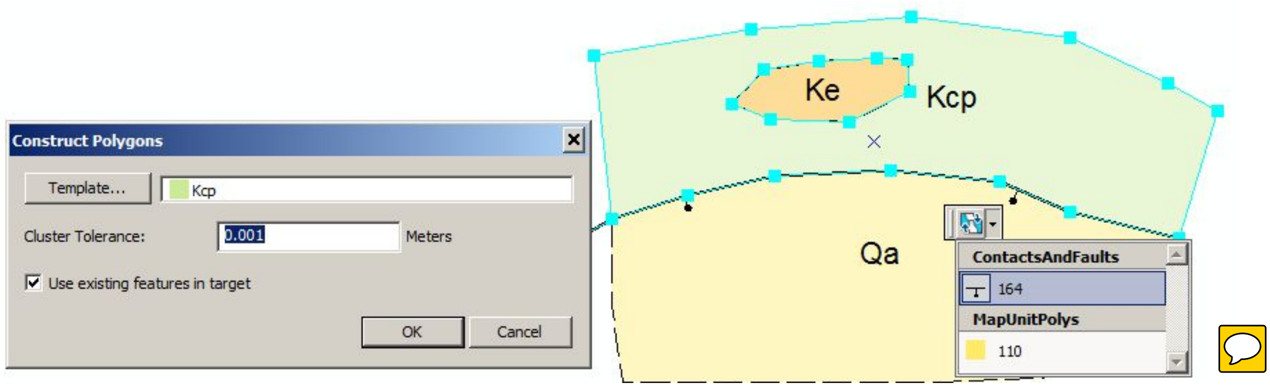

Figure 18. Construct polygon box for slightly more complex situation. Here, polygon Ke was constructed first, followed by Kcp. The fault was isolated by using the drop-down menu to avoid also selecting the Qa polygon.

As you progress, it is unavoidable that you will select polygons as well. You can deselect the polygon features by selecting somewhere in their interior, or use the dropdown box to choose the linework only (Fig. 18). This same drop-down menu can be used to delete unwanted, overlapping polygons. Continue mapping until no blank spaces remain in your mapping area (remember to use your map border as a boundary for constructing polygons where appropriate).

If you want to reclassify a mapped polygon, you can change the geologic unit by selecting the desired polygon and opening the **Attributes** window from the **Editor** toolbar (Fig. 10). Scroll down to the attribute “MapUnitPolys_ID”, click the ellipses on the right to open the **Choose Symbol Class** window, and select the correct mapping unit (Fig. 19).

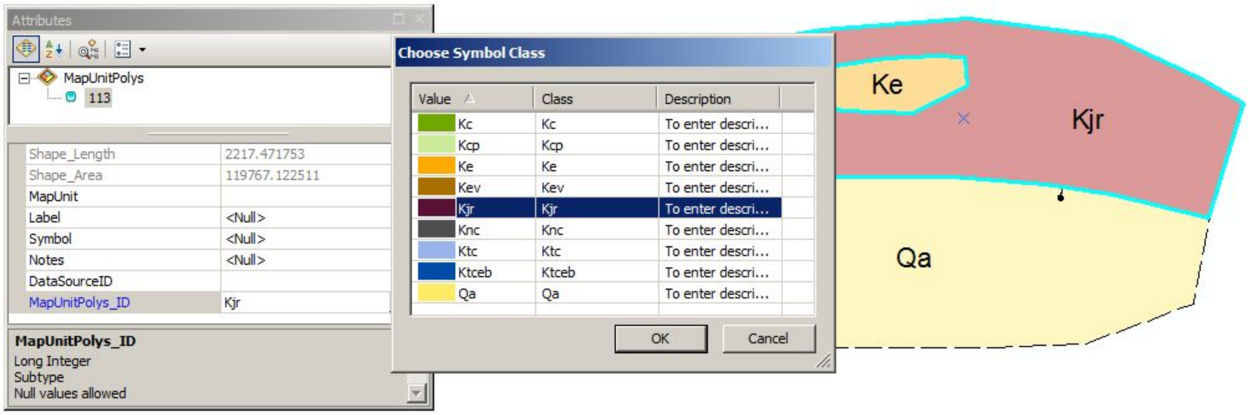

Figure 19. Attribute window used to change the mapping unit for a previously constructed polygon.

2.5 Editing shared features

If you make a mistake, or change your mind on the location of a contact, you can edit the linework and polygons concurrently using the **Topology Edit** and **Modify Edge** tools on the **Topology** toolbar. You can see which features are shared by opening the **Shared Features** window from the Topology toolbar. After clicking Topology Edit (second button from the left), select the boundary you wish to modify (it will turn magenta). Next, click Modify Edge, and adjust the boundary using the Edit Vertices toolbar (Fig. 15, Fig. 20). When finished click anywhere on the map to complete the changes (Fig. 21).

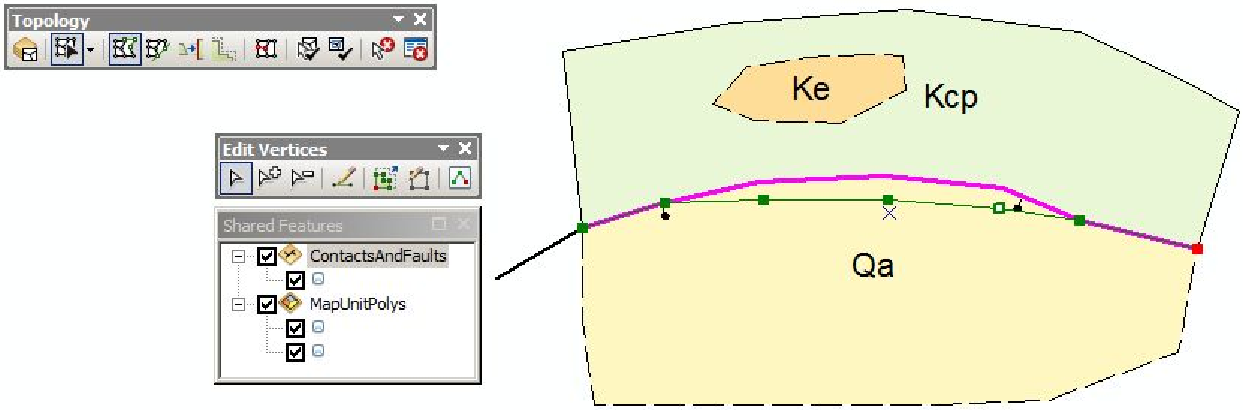

Figure 20. Topology editing of shared feature using modify edge.

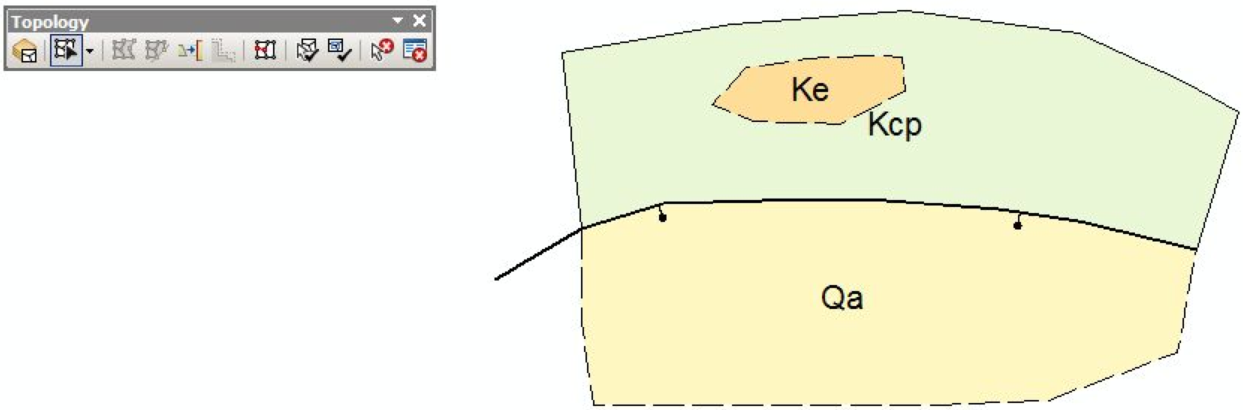

Figure 21. Finished modification of shared feature.

2.6 Adding strike and dip measurements

While still in an open editing session, bring up the **Create Features** window (Fig. 14), and select the type of measurement you wish to record (e.g., fault plane or bedding). Then, click on the map where you would like to place the measurement (you can turn on snapping to your "geology stations" layer downloaded from your iPhone if you wish to align directly to GPS points captured in the field).

To enter the strike and dip information, open the **Attributes** window from the **Editor** toolbar (Fig. 10) and enter the strike, dip, and azimuth (dip direction) into the appropriate cells (Fig. 22). Note that the azimuth is the strike direction plus 90 degrees (subtract 360 for values greater than 360). The strike is used for plotting the symbol on the map, and the azimuth information is used to calculate apparent dip using the cross section toolbar (section 3).

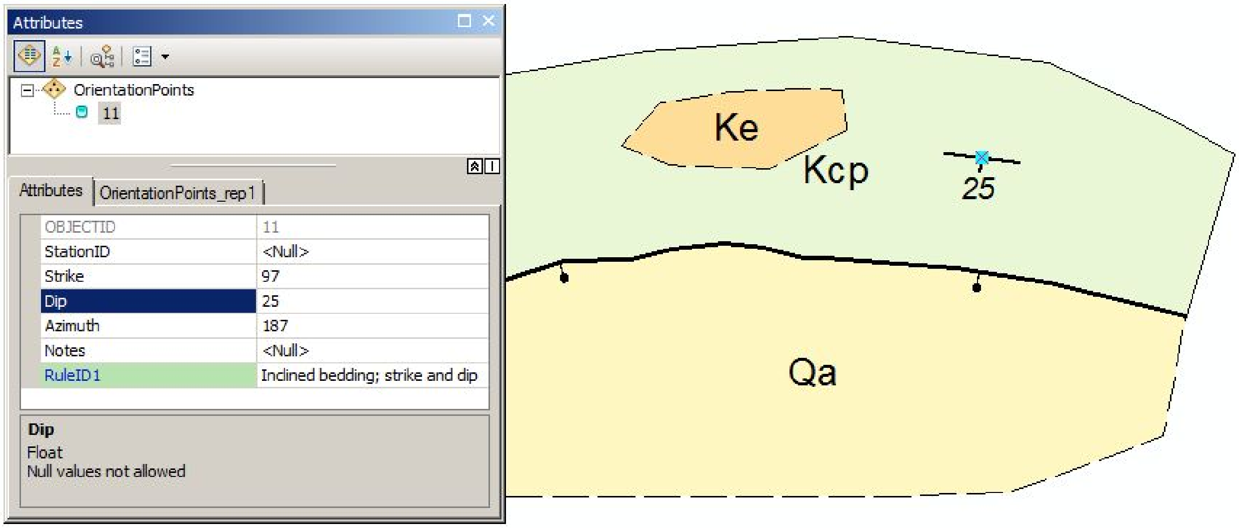

Figure 22. Attributes window showing proper entry of strike, dip, and azimuth information.

3. Creating a cross-section using the cross-section toolbar

4.1 Introduction

Traditionally, geologic cross sections have been drafted either by hand, or using vector drawing programs such as Adobe Illustrator or Inkscape. This often requires tracing or exporting topographic profiles, determining locations of contacts and faults along the cross section, and projecting strike and dip measurements into the plane of the cross section (being careful to calculate apparent dips). All while being faithful to the vertical exaggeration typically needed to communicate the interaction between topography and geologic structure.

Here, we will be using a series of Python scripts developed for **ArcGIS by Evan Thoms at the USGS (https://github.com/evanthoms/Cross-Section)**. These tools automatically extract the surface expression of your geologic map along a topographic profile, the appropriate projection of nearby bedding measurements and vertical exaggeration, and the location of contacts and faults.

For this exercise, the cross section is placed in a separate data frame and occupies a corner of your map. While there is no defined 'projection' information, the X-axis is distance in meters along the profile line and the Y-axis is elevation (times vertical exaggeration, if any). Use the 'measure' tool to measure out distances in either direction if desired.

The cross-section toolbar is extremely useful for accurately defining the placement of contacts and faults, and the projected orientation of any bedding/fault/lineation measurements.

4.2 Installing the Cross Section Tools toolbox

In your ArcMap project, open the ArcToolbox window (Fig. 23).

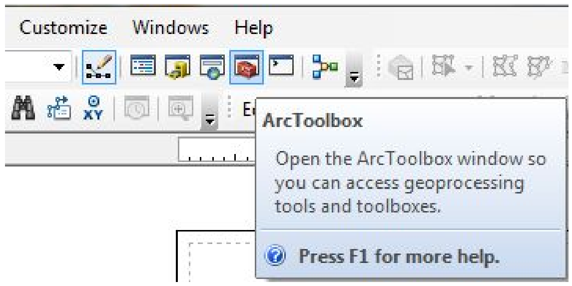

Figure 23. Opening ArcToolbox.

There should be a toolbox called **Cross Section Tools 10.2** with three steps listed below (Figure 24). If this toolbox does not show up you need to add it right click on the white space in the ArcToolbox window, select **Add Toolbox**, navigate to the location of the downloaded cross-section toolbox (ask Faculty/TA if you are unsure of the location) and select **open**. *Note that we have simplified the Cross Section tools 10.2 created by Evan Thoms and downloaded from GitHub to appear as shown in Figure 24.

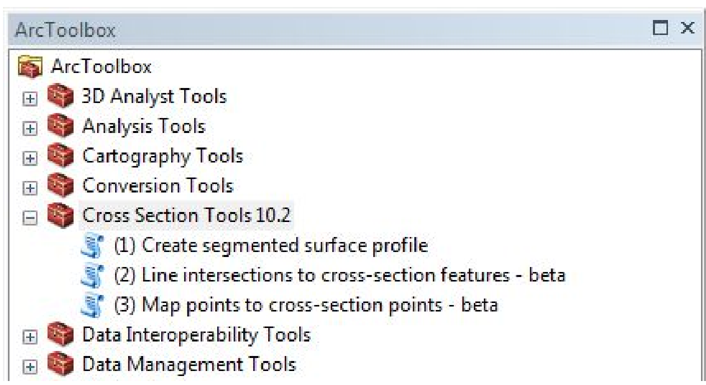

Figure 24. Cross Section Toolbox.

4.3 Extracting a segmented surface profile

Here you will extract the topographic surface expression along a cross section line. The line generated by this toolbar will be segmented according to the different surface geology that you mapped (i.e., MapUnitPolys). In this way, you can accurately determine the locations of contacts between different geologic mapping units along the cross section line.

The following are the main culprits that will give you errors when using the cross-section toolbar. Therefore, before beginning make sure that:

- the geologic mapping data frame is **activated** (Fig. 7)
- editing sessions in all data frames are closed
- the names of the files listed in the Table of Contents in ArcMap are identical to the name of the associated feature class in your geodatabase (rare problem)
- Spatial Analyst extension is activated (Fig. 1)

Step 1: Activate the **Geologic Map Layers** data frame (it will be in **bold** if activated; if not, right click on the name and select **activate** - see Fig. 7).

Step 2: Open ArcToolbox in ArcMap (if not already open) and navigate to the **Cross Section Tools 10.2** and select ***(1) Create segmented surface profile*** (Fig. 25).

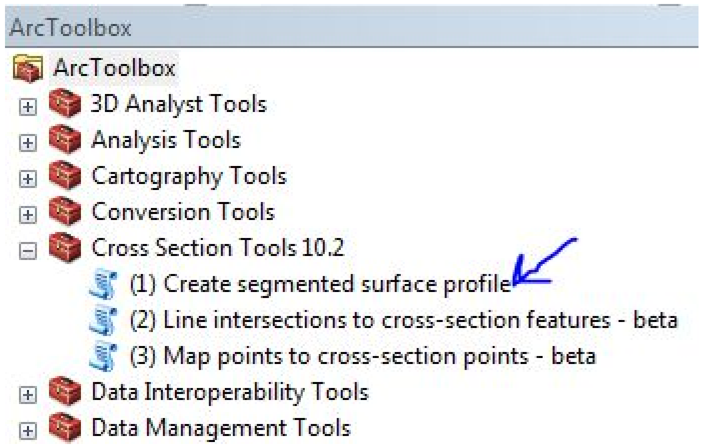

Figure 25. Opening Cross Section Tools in ArcToolbox

Step 3: Enter the parameters exactly as described below and in Fig. 26. Click OK when done to generate the segmented profile line.

- **Cross section line layer:** your cross section line is called **XSectionA**
- **DEM layer:** *the name will differ for each project but will contain 'dem' in the name
- **Begin measuring lines from:** defines the start of the cross section line. Enter southwest for this tutorial.
- **Geology polygon layer:** contains your mapped polygons representing your geologic units; called "MapUnitPolys" for all exercises.
- **Vertical exaggeration:** Ask your professor if you should add any vertical exaggeration.
- **Output feature class (option):** Navigate to your project database, open the CrossSectionA dataset and name the file **csa_segline** (see Fig. 26)
- **Existing feature class (optional):** leave grayed out
- **Add to data frame (optional):** Select **Cross Section A Layers** - This will put your new segmented line file into the Cross Section A Layer data frame.

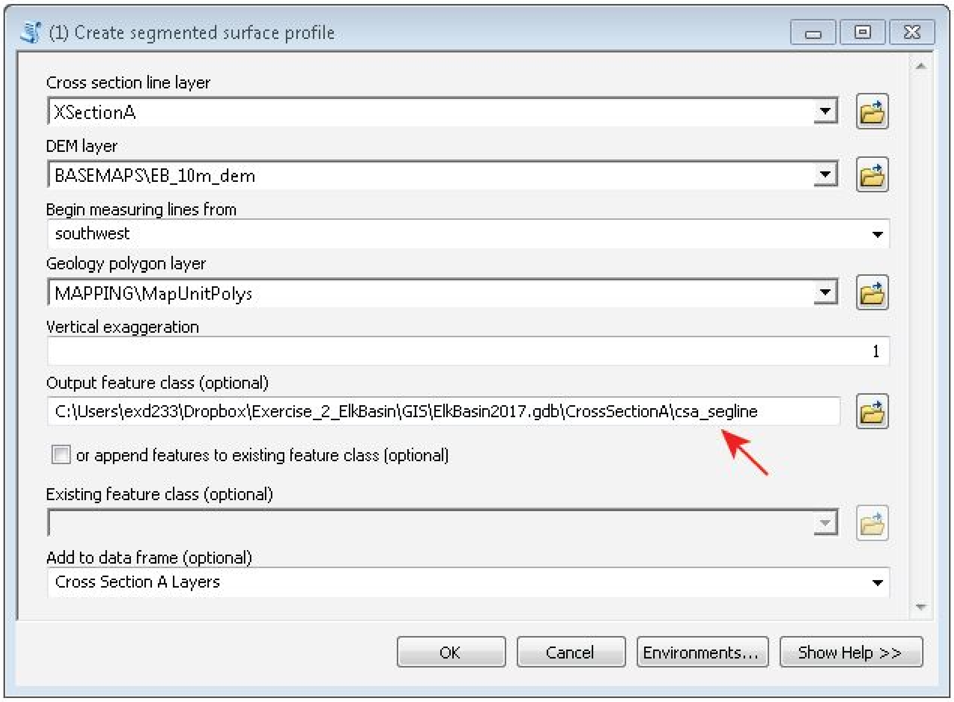

Figure 26. Create segmented surface profile dialog box.

Step 4: Click OK. If successful you should a solid profile line called csa_segline appear in the Cross Section A Layers Data Frame. Activate that data frame.

Step 5: Now we are going to assign colors to each segment of the profile line to help with interpreting the geology along your cross section. To do this we need to modify the layers symbology. Double click on the csa_segline layer and click on the **Symbology** tab. We have set up a file for you to point to that will assign the appropriate mapping color (based on your MapUnitPolys) to each line segment from your geologic map. YEAH!

To assign these colors to your line segments open the **Symbology** tab, select **Import** and click on the yellow folder. Navigate to a the GIS folder in your project, in it will be a folder called **layers**, open and select a layer called **csa_segline** (Fig. 27). Click **Add** then **OK**. Make sure that the MapUnitPolys_ID in the value field match each other (Fig. 27) and click **OK**. Your profile line should now be color coded identical to your MapUnitPolys. See Figure 28 for an example.

Notes:

- *The the black border (Fig. 28) is your cross section border; a set of lines that we created. You will be interpreting the geology within this border.*
- *When you finalize your cross section, it is important to return the symbology to a uniform thin black line (0.5 thickness).*

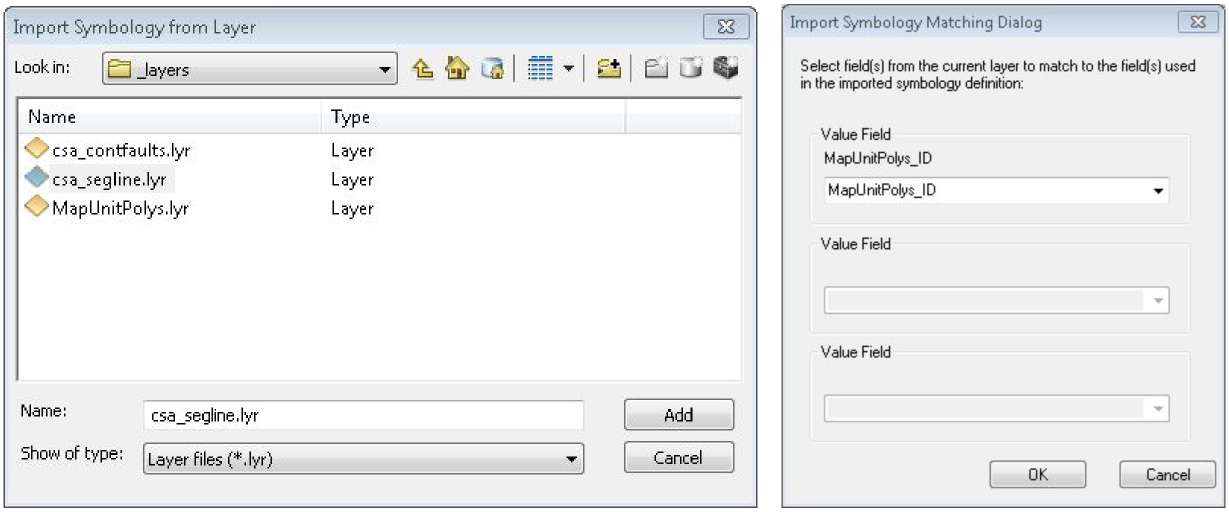

Figure 27. Assigning colors to segments in cross section profile line.

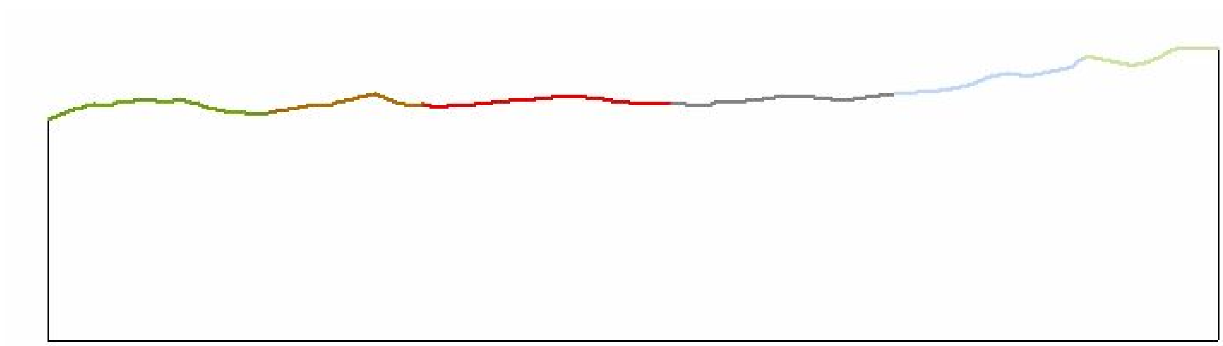

Figure 28. Segmented profile line color coded by mapping units.

4.4 Projecting line features onto the cross section

Here we will use the Cross Section toolbox to project the position of all contacts and faults that intersect with the cross section line.

Step 1: Activate the **Geologic Map Layers** data frame by right clicking on it in the table of contents and selecting **Activate** (Fig. 7).

Step 2: Open the Cross Section Tools 10.2 in ArcToolbox (Fig. 25) and select ***(2) Line intersections to cross-section features***. Fill in the information as shown in Fig. 29. In **Create new feature class** make sure to name your new file **csa_contfaults**. Also remember that the vertical exaggeration may differ between exercises so check with your instructor. Click OK when you are done to generate the contacts and faults lines.

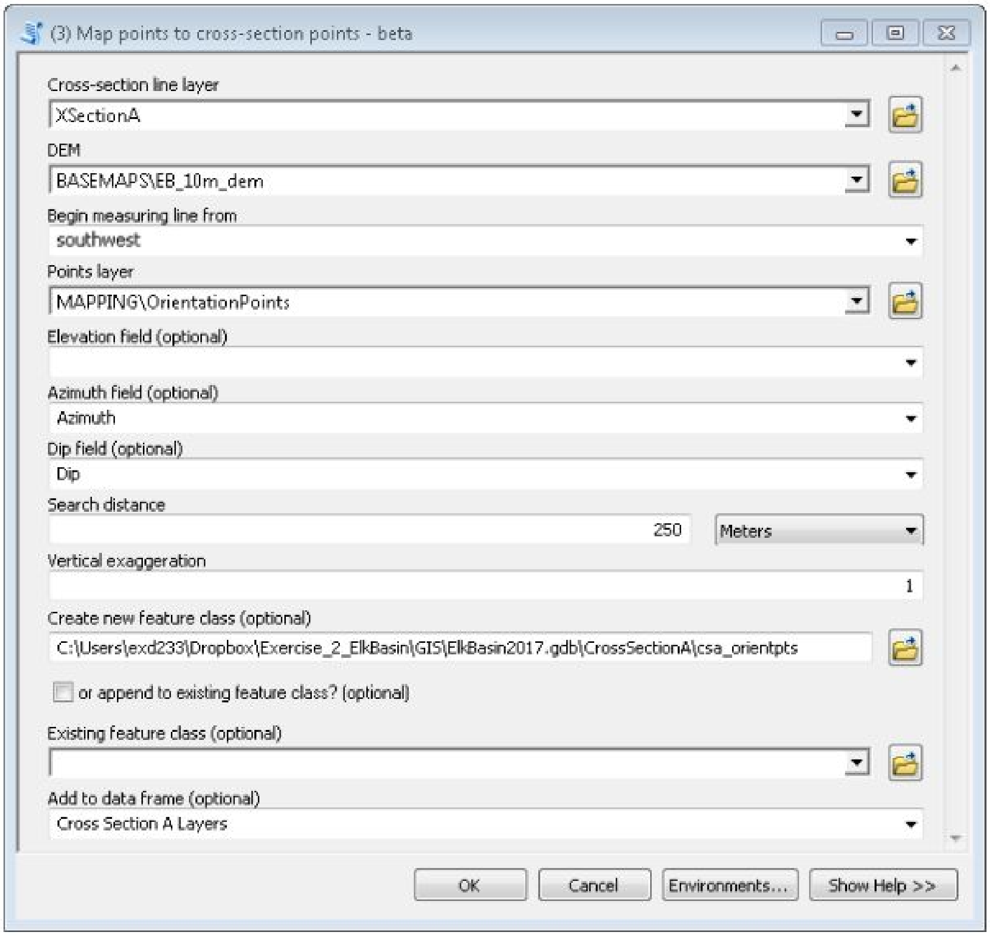

Figure 29. Using Field Calculator to create a column of dip direction values.

Step 3: You should now see a series of lines created along the profile line, one at each location of a contact or fault. All of the lines will appear in the same color by default (regardless of the line type (contacts, faults, etc)). Therefore, we are going to assign different colors to each line type so that you have an easier time discriminating between faults and contacts when interpreting your cross section.

To do this we need to modify the layers symbology exactly as we did above in **4.3**, but we will point to a different layer file. Double click on the **csa_contfaults** layer, click on the **Symbology** tab, select **Import** and click on the yellow folder. Navigate to a folder in your GIS project called **layers**, open, select **csa_contfaults**. Click **Add** then **OK**. Make sure that the **RuleID1** in the value field match each other and click **OK**. You should now have color coded lines as shown in Fig. 30: contacts_accurate are solid gray lines, contacts_approximate are gray and dashed, contacts_concealed are dotted, and all faults are red.

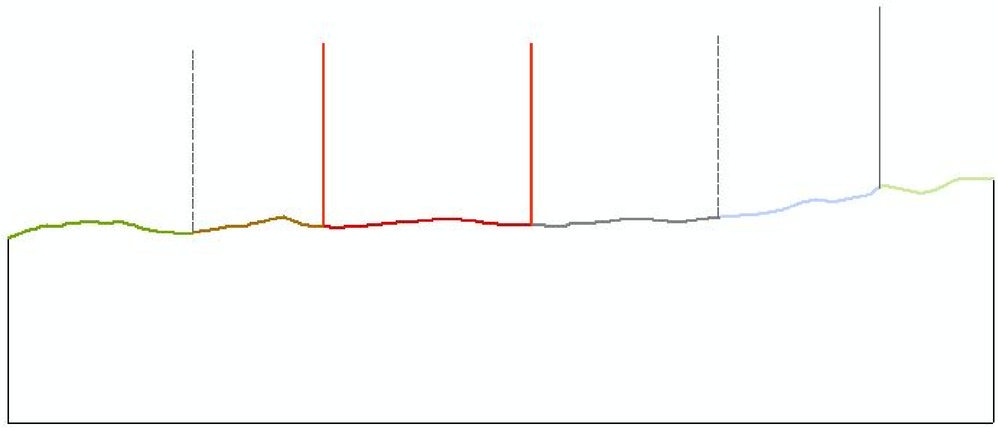

Figure 30. Segmented profile line with contacts (vertical gray lines) and faults (vertical red lines)

4.4 Projecting orientation points onto the cross section

Now we are ready to create some tadpoles on the cross section that will show the location and apparent dip of orientation points (primarily strike and dip measurements).

Step 1: Activate the **Geologic Map Layers** data frame by right clicking on it in the table of contents and selecting **activate**.

Step 2: Make sure that you filled in the **azimuth** field for all of your measurements. You can double check by right clicking on the **OrientationPoints** layer and select **Open attribute table**. Fill in any blanks by taking your strike measurement and adding 90, if over 360 add remaining to zero (300 degrees strike = 30 degrees Azimuth)

Step 3: Open the Cross Section Tools 10.2 in ArcToolbox (see Fig. 25) and select ***(3) Map points to cross-section points***. Fill in the information as shown in Fig. 31. In **Create new feature class** make sure to name your new file **csa_orientpts**. Click OK when you are done to generate orientation points. The points will appear as 'tadpoles' marking the location of the measurements along the profile line and the apparent dip (Fig. 32). Use these measurement to guide your mapping as described below in section **4.5**.

Notes: Ask your instructor for the Search Distance value, and the vertical exaggeration for the exercise.

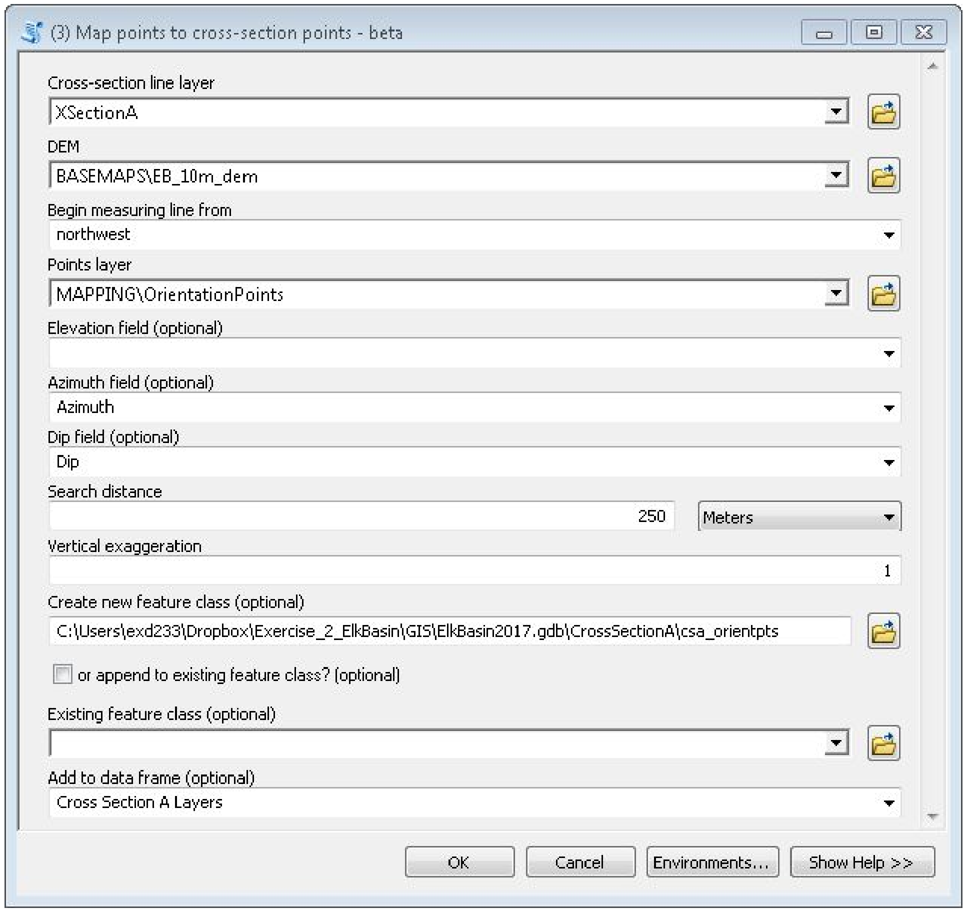

Figure 31. Projecting orientation points to the cross section line.

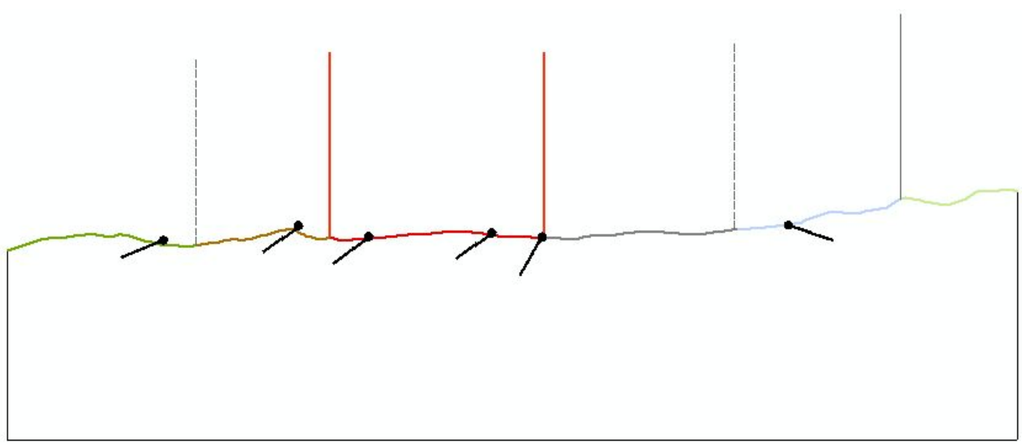

Figure 32. Tadpoles showing bedding/fault attitude on cross-section line.

4.5 Mapping in cross section

Now we are set to start mapping.

Step 1: Activate the the Cross Section A Layers data frame. Start **Editing.** *You will receive an error message saying 'Spatial reference does not match data frame" - this is fine, just hit **Continue**.* In the editing pull down menu select **Snapping** and then **Snapping Window**. In the snapping window put three check marks next to **CSABorder, CSAContactsAndFaults, and csa_segline** and exit this window (as in Fig. 12). Go back to Snapping and select **Options** and check that this is set for 5 pixels (Fig. 13).

Step 2: You will now interpret the geology in your cross section. As you did in your map, start by creating lines. There are only 4 line types to choose from, including faults. As you are mapping in the geology remember to use the segmented profile line, the locations of contacts and faults, and the orientation of any beds or faults (tadpoles) to inform your mapping. You will create lines (using the CSAContactsAndFaults layer), and then polygons from those lines.

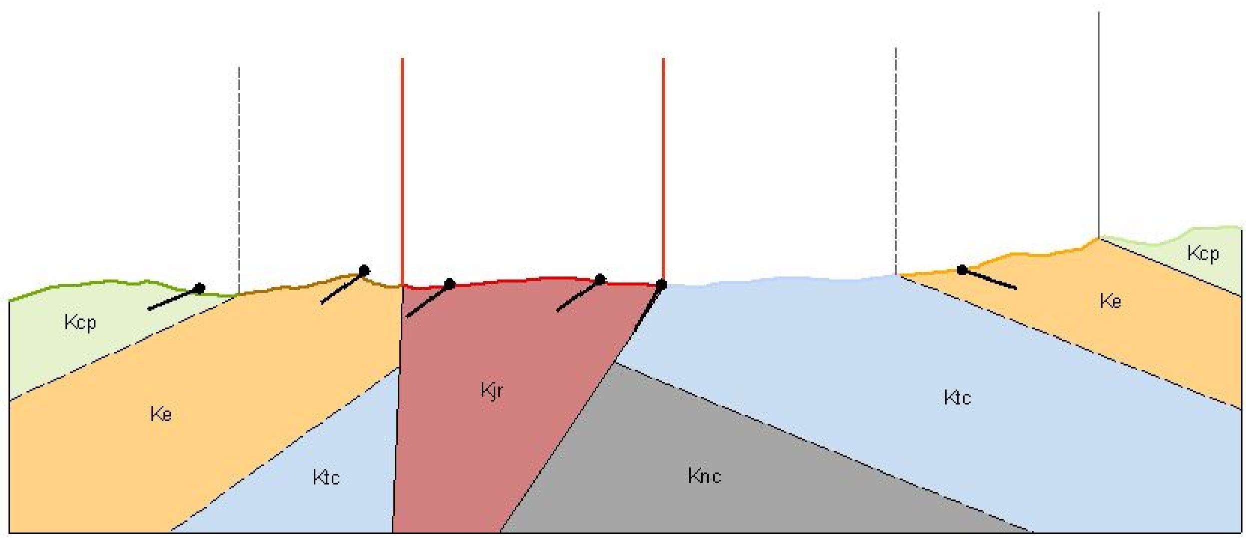

Figure 33. Interpreting geology along cross section.

Step 3: You now need to show the direction (using arrows) of any faults on your map. To place arrows on fault lines, start Editing, and under **CSAOrientationPoints** in the Create Features Window, select the correct arrows you need to show fault displacement and add a point directly on the line. Unfortunately, as you notice, the arrows will not automatically rotate to appear parallel to the fault line. You must rotate this by hand. To do that, open the attribute table for the point, modify the **Inclination** field until your arrows parallel your fault line (Fig. 34).

Step 4: Go back and change the color of the csa_segline to black with a thickness of 0.5. To do this, go to the layer properties, open the symbology tab, select **Features** and change the symbol to a 0.5 black line (see Fig. 34).

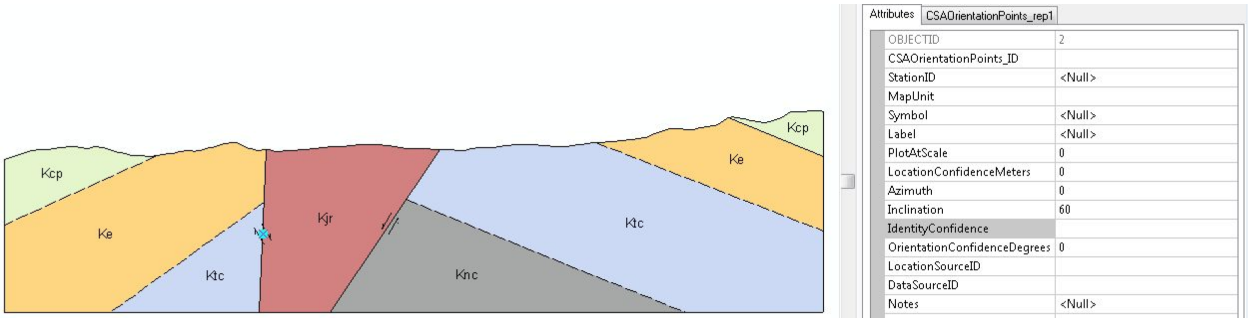

Figure 34. Finished cross section showing appropriate annotation (rotating arrows).

4. Layout

The final stage of preparing a geologic map is to add a descriptive legend and all appropriate annotation (e.g., north arrow, scale bar, title, author). The best way to get a sense of what is needed is to look at geologic maps published by the USGS (Fig. 35).

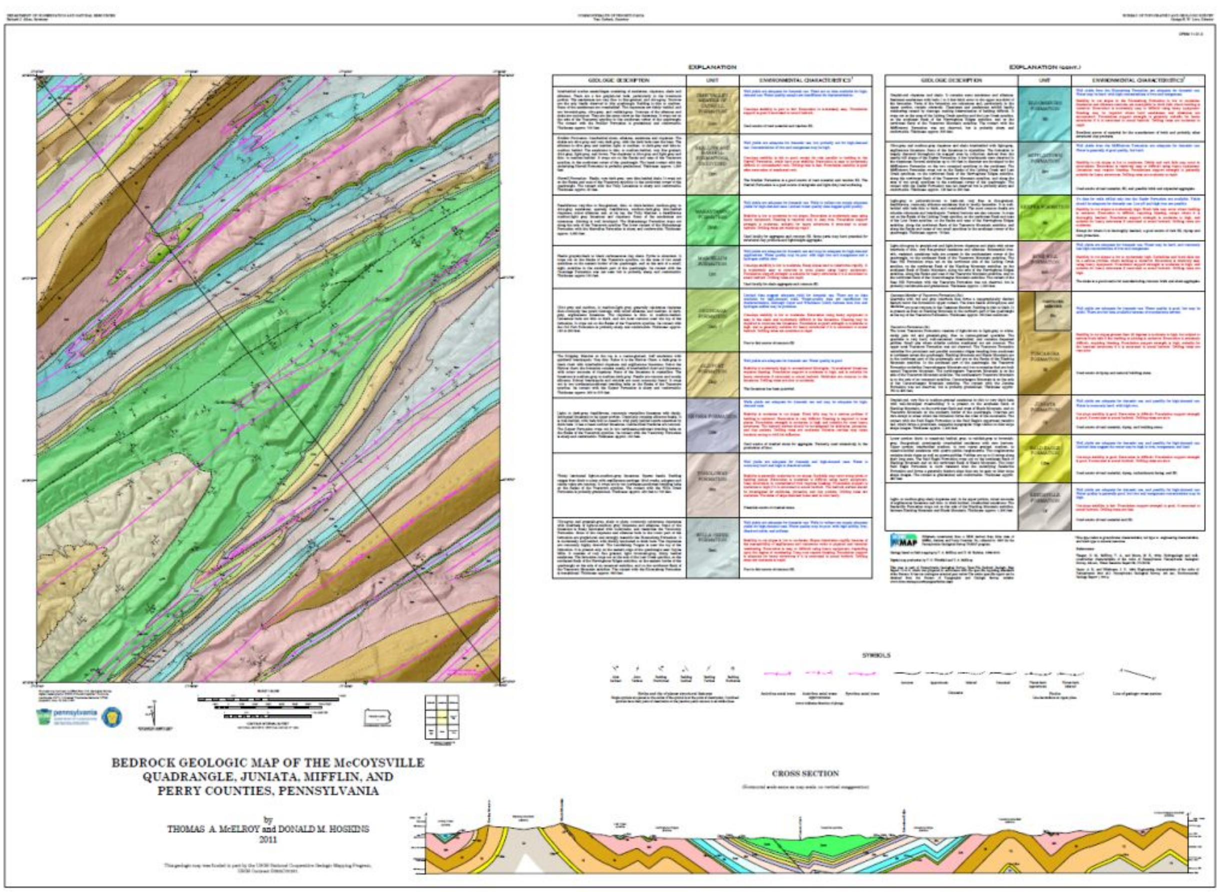

Figure 35. Bedrock geologic map of the McCoysville quadrangle, PA ([link]()). Note the brief descriptions of mapping units in stratigraphic order, the description of all symbols used on the map, and a geologic cross section with the same scale as the map.

While a bit clunky at times, it is possible to do all of the layout within the ArcMap program using the Layout View (Fig. 3). In some cases it may be easier to make fine scale edits using an external vector drawing program, such as Adobe Illustrator or Inkscape. **For this class, all of the layout decisions have been made for you, and items such as scale bars, north arrows, and legends have been setup for automatic generation.** Thus, there are only a few things you will need to do:

4.1 Add your name and title to map

Double click on the title and name to edit the text appropriately. No need to reposition the text.

4.2 Adding map unit descriptions

First, you will add a short (fewer than 30 words or so) description to each of your map units. This is done through the Symbology tab of the Layer Properties window of the feature class MapUnitPolys. Here you should see your mapping units listed in stratigraphic order (youngest at the top), with their corresponding symbol (color), value (e.g., 0, 1, 2...), and Label (e.g., "Qa, Kjr, Kcp..."). For each unit, right click on the label and select Edit Description (Fig. 36). This will bring up a dialog box where you can type or paste the description you wish to include, which will show up in the legend.

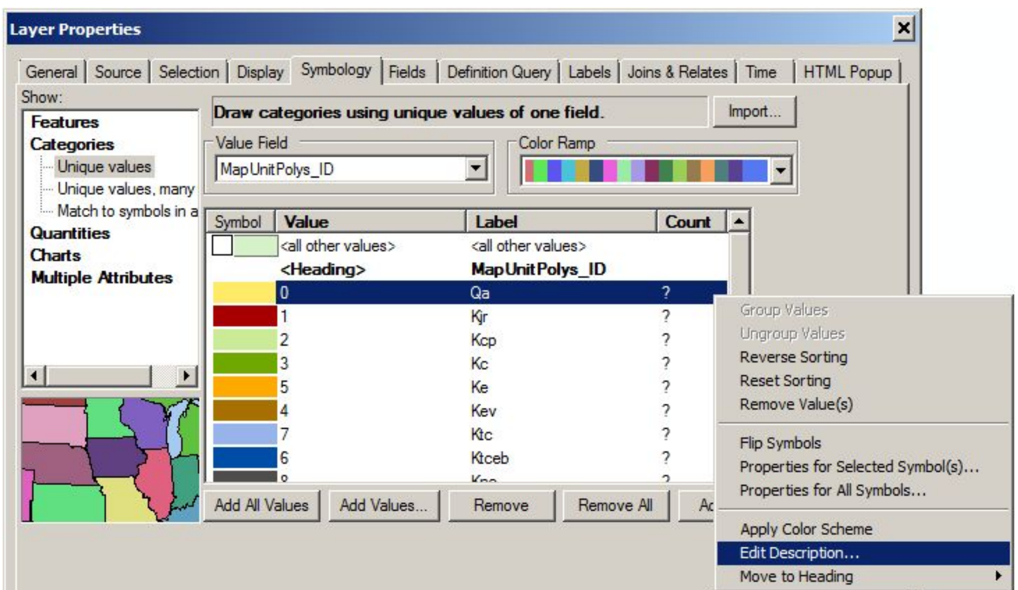

Figure 36. Edit description option in the Symbology tab of the Layer Properties dialog box.

4.3 Using Bookmarks

The scale and extent of your final map has already been chosen by the instructor. As you have undoubtedly panned and zoomed to a different extent in both of your data frames over the course of your mapping, it will be necessary to reset the extent using the provided Bookmarks (Fig. 6). Activate each data frame in Layout View, and then go to the final bookmark for each. Be sure not to pan or zoom in the data frame after you have done this (i.e., do this step just before you export/print)!

4.4 Exporting your map to pdf

To publish your map as a pdf file for sharing and printing, go to **File\Export Map** from the menu bar and save as type "PDF". Be sure to to use 300 dpi resolution, and "best" image quality (Fig. 37). Give your map an appropriate name, like "LastName_Exercise3_map.pdf", and click save!

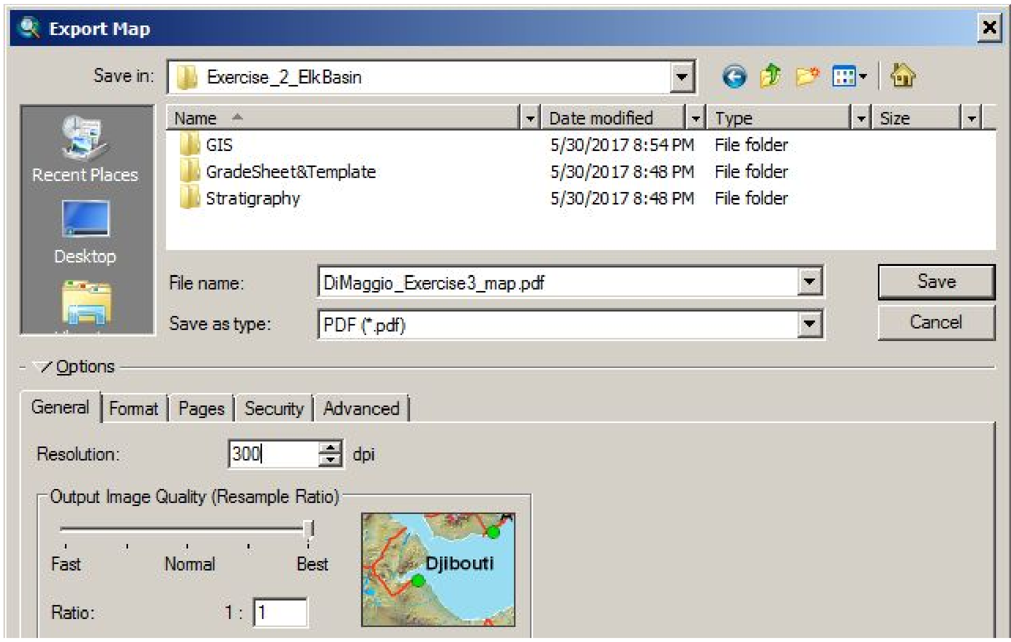

Figure 38. Export dialog

4.5 What happens if I mess up the layout?!?!?

There is a significant probability that during the course of frantic editing you will accidentally bump or delete a critical item in the map layout. If this happens, you can always copy and paste a fresh version of the original mapping document (.mxd file) to your working directory just before you submit. The new .mxd file should point to your completed mapping geodatabase, with a layout as good as new!