

Making a Geologic Map with ArcGIS

By Mike Oskin – November 23, 2009

PART 1. Setup of ArcGIS project

Important! Many functions in ArcGIS are based on antiquated unix-style subprograms. These subprograms fail when given filenames that violate the rules (below). Pathetically, the default directory “My Documents” violates three of the four rules! You may not encounter problems right now, but following the rules now saves you from mysterious crashes later.

The ‘Rules of Names’

1. **Filenames must be 12 characters or less**
2. **No spaces in the filename or path**
3. **No capital letters in the filename or path**
4. **No filenames or directory names may start with a number**

Programs & Subprograms:

ArcCatalog: ArcCatalog is a general-purpose data management utility that comes as a part of the ESRI ArcGIS package. Most of our setup steps for parts one and two will be conducted in this program prior to working with the LiDAR data in ArcGIS. Start ArcCatalog by clicking on its icon (a yellow file cabinet) under the ArcGIS subfolder of the Start menu.

ArcMap: ArcMap is the program where you will spend most of your time. It acts as a portal into your data, allowing you to visualize and edit maps. ArcMap also has a ‘layout’ mode where you can make finished maps for exporting or printing.

ArcToolbox: ArcToolbox is a collection of ArcGIS scripts, arranged in a tree-style menu system. It is available to you in ArcCatalog and ArcMap from the red toolbox icon.

Workspace: A Workspace is a location on the file system where you keep all of your map data for a project. This location must be named so that it obeys the rules of names, above. For example, the common default working directory for ArcGIS is C:\workspace.

To begin your project, navigate to the workspace folder in ArcCatalog using the tree view on the left side of the screen. You may also set up a folder in the root directory (C:\ or D:\ or possibly Y:\ if you are using Parallels on a Mac). Right click in a blank area on the right side of the screen and select New->Folder. Name this folder anything you want so long as it is **less than 12 characters, no spaces, does not start with a number, and contains no capital letters!** Double click this new folder to navigate to your new workspace.

PART 2. Georeference a Base Map

This section is for preparing a field map for digitizing in ArcGIS. If you are mapping directly from satellite imagery you can skip to the next part of the tutorial.

Step 1: Scan your field map

The easiest way to accomplish this is to use Photoshop on a computer hooked up to a scanner. After you have scanned your map, rotate it so that north is up. Save it in TIFF format, with the options selected for 'RGB' color, 'IBM-PC' byte order, and 'No Compression.'

Step 2: Prepare a scratch ArcMAP project for georeferencing

Start ArcMAP and select 'new project' from the window. We will use this project to georeference your map and digitize the map data. For georeferencing it is important to define the projection ahead of time. For example, if your map is UTM zone 11 WGS84 datum select View->Data frame Properties->Coordinate System and navigate to the 'projected coordinate systems,' 'UTM,' and 'WGS84' then select the appropriate zone.

Press the yellow 'add data' button to bring in your field map tiff (or tif) file. Right now it is unprojected. If you hover over the file you will see that the coordinates are below '10 meters'. These are actually units of inches from the scanner.

Step 3: Use the Georeferencing Toolbar

To prepare to georeference your map, select View->Toolbars->Georeferencing to bring up the georeferencing toolbar. You should see your file in the drop down box. Choose **three** coordinates near the edge of your map and **not in a straight line** and write down the X and Y coordinates ('X' is the smaller number in UTM). Record these numbers very carefully! If you enter the wrong number of digits on accident ArcMap may crash.

To georeference your scanned map, you will click points on the map with known coordinates with the 'double-cross-hair button,' located on the georeferencing toolbar. Click on one of the three points, and then right click anywhere on the map and select 'input X and Y.' Type in the UTM coordinate of the point you recorded earlier. After you do this, your map will disappear because ArcMap has moved it to the position you just entered. To find your map, right click on the map name in the legend and select 'zoom to layer.'

Now go and enter the second point. The map will now zoom in because the scale is close to correct. Use 'zoom to layer' again to zoom out to the map extent, then find and add the third point. By this point, the guess that ArcMap makes for the coordinate should be pretty close. Once you have completed entering points and are satisfied with how the map coordinates match the ArcMap project coordinates you are ready to finish georeferencing your map. Select Georeferencing->Rectify and give the rectified map a new name.

PART 3. Prepare a Geodatabase

We will now build a geodatabase to contain a geologic map data. The geodatabase will eventually contain the following:

1. Polygon feature class, units, with an attribute for unit name
2. Line feature class, contacts, with an enumerated attribute for line type
3. Point feature class, bedding, with attribute for strike
4. Topology, with rules defining relationships between units, contacts, and bedding

Step 1: Create a New Personal Geodatabase

Open ArcCatalog and navigate to your workspace. Right click in the contents menu and select New->Personal Geodatabase. Name the database something very general (like the name of your field area).

Step 2: Create a Feature Dataset

A feature dataset is a container to hold related map data. Feature datasets hold related geographic information, such as all of the features that comprise a single geologic map. These are necessary so that you can relate information such as lines to polygons. This is sort of like a 'subdatabase' within the larger geodatabase. In ArcCatalog, double click on the geodatabase to get to its contents window. Next, right click in the contents window and select New->Feature Dataset. Name this data set 'geology'. In the next window you will define the projection of the feature data set. For example, if your map is in UTM zone 11, select Projected Coordinate Systems->Utm->Wgs 1984->WGS 1984 Zone 11N. The next window asks for a vertical coordinate system, which may be ignored for now. The last window is for precision. Usually the defaults are more than adequate. Hit 'Finish' to complete this step.

Step 3: Create line and point classes

Double click the new feature data set. You will now make features inside of this set. **It is very important that you create these features inside your feature data set!** Next, right click in the blank area and select make a new feature class. Make this first one a point feature class called 'bedding'. Don't forget to change the geometry from 'Polygon' to 'Point.' Add a short integer field called 'azimuth' and another short integer called 'dip.'

Next, make a line feature class called 'contacts.' In the data definition window, change the Geometry Type to 'line.' Add a field named 'linetype' as a short integer field. Give this field a default value of '0.' Set the allow NULL values to 'No.' Hit the finish button.

Step 4: Set up line sub-types

Next we will use this linetype field to define a special enumerated data type for the contacts. In ArcCatalog, double click 'contacts' to bring up its properties. Under the 'subtype' heading, select 'linetype' as the subtype field. Next, fill out the table below with the following:

0	undefined
1	contact certain
2	contact uncertain
3	contact inferred
4	fault certain
5	fault uncertain
6	fault inferred
7	fault covered
8	map border

Step 5: Create a topology class

Finally, we need to define some topology rules so that our polygons will be easy to create later in the project. In the ArcCatalog window, right-click and select New->Topology. Hit next on the first window that appears. In the next window, name the topology 'contact_topology.' Ignore the cluster tolerance. Hit next to continue.

The contact_topology will apply to the contacts only, so check the box next to contacts in the next box and hit next. Ignore the next window (ranks) and hit next again. Another window will show up with a blank list of rules. Hit the add rule button. A new window will appear. We want to add a rule for 'contacts,' which should be selected in the upper box. In the middle box, select 'Must Not Intersect Or Touch Interior' as the rule. Hit OK. Now add a second rule, 'Must not have Dangles.' After this rule is added, hit Next and the Finish to complete the topology. Ignore the warning box about 'no new features' that shows up after hitting 'finish.'

PART 4. Create an ArcMAP Project

Step 1: Load imagery and map data sets

Start ArcMap and select a new blank map. Hit the yellow '+' button and navigate to your workspace. Select the imagery data set (either a satellite image or your scanned base map) to begin. Once loaded you will see the data set show up on the screen and in the column on the left side (the 'table of contents'). Repeat this process for any other background data sets, such as topography, hillshade images, or contour maps.

Next you will load your new, empty feature dataset. Hit the yellow '+' button again and double-click on your personal geodatabase. This will open up its contents. Click once to highlight the feature dataset, and then click 'open.' This should bring all of its contents (lines, points, and topology) into your map.

Step 2: Customize map symbology

ArcMap will load the data with a default (usually ugly) line type, polygon fill, or symbol. You will have to change all of these to make a useful map. Each data type contains several varieties, such as different units for the polygons and different symbols for the structural data. Double click each data set in the table of contents to change its symbology. On the symbology tab, use the 'categories' style with 'unique values' to get a separate symbol for each linetype. Double click each type to set its symbology. Use the 'properties button' to fine-tune the line. The 'cartographic line' style has many options for thickness and dashes. Sometimes the 'marker line' is useful for dotted contacts (e.g. covered faults). I recommend using something thick and obvious (yellow 2pt?) for the 'undefined' type – that way you know which lines need to be attributed.

For the symbols, you will need to load the 'Geology 24k' symbol set prior to selecting the symbol for 'bedding.' To get the symbols to rotate into the correct dip, select rotation from under the 'advanced' button in symbology and rotate the symbol geographically according to the 'azimuth' attribute.' The symbol should have an initial angle of 270 degrees in order for the rotation to work correctly. Set the symbol size to 36 pts.

Now is a good time to save your work. Do it now, and do it often (ArcMAP will crash).

PART 5. Digitize your Geologic Map

In ArcMap, open the editor toolbar (pencil and 3 dots button). Select Editor->Start Editing and select the geology geodatabase as the target. Hit OK.

Step 1: Digitize Contacts

On the editor toolbar, change the target to 'contact certain.' The Task should be set to 'Create New Feature.' Select the pencil button to start adding contacts. In the main window, click with the mouse to start making lines. Double click or hit F2 to finish a line. Right-clicking will bring up an options menu. To snap the edge of another line, select 'Snap to Feature' from the options menu and select Edge. You may also use these keys to aid with snapping:

Snap to End Point:	Ctrl F5	<i>line ends or junctions</i>
Snap to Vertex:	Ctrl F6	<i>good to target a particular bend</i>
Snap to Midpoint:	Ctrl F7	<i>not too useful for geology</i>
Snap to Edge:	Ctrl F8	<i>very useful</i>

Try to manage the topology (how lines join together) as you go by snapping line end points and preventing lines from crossing. Eventually you will create a line that does not join correctly. The topology tool bar can fix this. Access the toolbar from Editor->More Editing Tools->Topology. To fix topology (such as breaking up a line at a new intersection), select the lines to fix (use the shift key for multiple lines) and hit the 'wrench' button.

Step 2: Digitize Bedding

This is much more simple than digitizing lines. Just select bedding as the target and use the pencil tool to add points. Click on your map where you would like to add a strike & dip data point. To adjust the azimuth and dip, select the bedding and hit the 'Attributes' button (it looks like a little table). You can enter in the strike of the bedding here and watch the symbol rotate in response. To make the dip value show up on the map, double click the feature class in the menu and select 'dip' under the 'labels' tab.

Step 3: Check & Fix Topology

Closing your lines is a prerequisite to making polygons from your line data. The topology helps you make sure that your lines are closed correctly. To search for errors, use the 'Validate Entire Topology' button in the topology toolbar. This will fix many errors for you (such as incomplete intersections) and highlight any endpoint errors. The 'Fix topology' tool may be used to select features that show errors. Right click the selection to use the split tool to fix the error (this is the most common type).

PART 6. Create a Polygon Feature Class:

Save your edits in ArcMap and SAVE AND CLOSE THE PROJECT. This next step will not work if your project is not open!

Step 1: Create a Polygon Feature Class

Open up ArcCatalog and navigate to your feature data set. Right click in the contents window and select New->Polygon Feature Class from the menu. Name this class 'units' and select the 'contacts' feature class to contribute lines. Hit OK. Right click the new units feature class, go to the Fields tab, and add a 'name' integer field.

As with the line feature class, you will use the name field to add subtypes for each unit on your map. In ArcCatalog, double click 'units' to bring up its properties. Under the 'subtype' heading, select 'name' as the subtype field. Next, fill out the table with a list of numbers (one for each unit) and a map symbol (e.g. Qal for alluvium, etc.). It's helpful to set zero as 'undefined' so it's easy to locate these on the map.

Step 2: Label and color your polygons

Re-open your ArcMap project (.mxd file). Use the 'add data' (yellow plus) button and navigate into your feature data set to bring your polygons into the project. All of the units should show up as subtypes in the table of contents. Go through each subtype and assign colors. You may also want to adjust the transparency of the polygons so you can see your image as you work. To do this, right click 'units' in the table of contents and select 'Properties.' The transparency can be adjusted under the 'display' tab.

To attribute the polygons you need to first 'start editing.' Now simply select a polygon (or a set of polygons with the shift key) and use the 'attributes' window to name the unit (note that you have to use the top item of the list to name all polygons of a selected set at once).

Don't forget to save your edits!

PART 7: Create a Map Layout

ArcMap works under two different 'views' – data view and layout view. Until now you have been using the data view. Change to layout view under the view menu. You will see a page with your map in the center drawn at some arbitrary scale that fits on the page. Make the map a fixed scale of (e.g. 1:20,000) under the view->data frame properties->data frame dialog box.

Next, adjust the layout box on the page so that it just encompasses the whole map. You are now ready to finish the map by adding the scale bar, north arrow, legend, map grid, and explanatory text. Scale bar, north arrow, and map legend are available from the 'insert' menu. The grid may be added under the View->Data frame properties->Grids dialog box. Add a 'graticule grid' with appropriate intervals (30 seconds or 1 minute for a large-scale field map).

The legend will look kind of ugly at first. To fix it, right click, select 'convert to graphics,' right-click again, select 'ungroup,' right-click yet again, select 'ungroup' again. Now the individual elements of the legend can be edited or deleted as needed.

Don't forget to add the title, map scale, map projection, and datum information as explanatory text. Explanatory text may be added using the text button ('A').

When everything is arranged, print out your layout or use File->Export map to make a PDF file for printing. You can also export the map to Adobe Illustrator for further tweaking or incorporation into a figure.