A short course on

Making digital geologic maps with the NCGMP09 database schema

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Introduction

There are several ways to use the NCGMP09 schema while creating a geologic map. Each path implies its own workflow, set of tools, and problems. Among these paths are:

1. Heads-up digitizing an existing analog map (map image) into the NCGMP09 schema
2. Creating a new map by heads-up interpretation and digitization of source data (field maps, aerial photographs, topographic images, other remote sensing images) within your GIS using the NCGMP09 schema
3. Translating an existing GIS database into the NCGMP09 schema

These exercises demonstrate these three paths.

Prerequisites

This course assumes you have the use of ArcGIS (version 10.1 or higher) and a reasonable familiarity with both ArcGIS and geologic mapping.

Typography

Computer file and folder (directory) names are shown in bold proportional serif font: **C:\ArcGIS**. Objects (feature datasets, feature classes, rasters) within a geodatabase are shown in the same font.

Window, menu, sub-menu, and textbox names are in bold san-serif font; an inequality sign (>) is used to separate menu > submenu, e.g., **File > Save**, or <right-click> **> Copy**.

Text you type, either in a textbox or at the command prompt, is denoted by bold mono-spaced serif font, e.g., to save a file under a new name in MSWord, click **File > Save As** and in the **File Name:** textbox enter **`MyNewFilename.doc`**

Setup

It is convenient to have additional resources in your ArcGIS installation. Install the following sets of files, all available in the **Resources** folder of the course disk:

USGS Symbols.style	I recommend this file be placed in **ArcGIS\DesktopNN.n\Styles**
GSC_FGDC-style	See contents of this folder. Install **FGDC_GSC_20100414.style** into **ArcGIS\DesktopNN.n\Styles**. Install 5 TrueType fonts (*.ttf) by right-clicking on each and selecting **Install**.
NCGMP09v1.1-Tools3_arc10.1	Copy the entire directory to, perhaps, **\ArcGIS\DesktopNN.n\NCGMP09v1.1-Tools3_arc10.1**, but can be anywhere.

Exercise 1. Digitize 1:100K-scale geologic map of the Purcell Mtn, WA 7.5' quadrangle

We start with Washington Division of Geology and Earth Resources Open-file Report 87-16 by Hank Schasse. You will need the following source materials, all available in the Resources folder of this exercise:

ContactsAndFaults100K.lyr	*ArcMap lyr file set up for digitizing 1:100K scale linework*
DMU_export.dbf	*Prepared DMU table in dbase format, for import into your DescriptionOfMapUnits table*
PurcellMtn.png	*screen capture of part of WaDGER OFR87-16*
wa_ger_ofr87_16_ plt1.pdf	*map sheet of WaDGER OFR87-16 in pdf format*
wa_ger_ofr87_16_text.pdf	*text of WaDGER OFR87-16 in pdf format*

You will create the following:

PurcellMtn.gdb	*an NCGMP09-format geodatabase*
PurcellMtn-TopologyReport.html	*output of TopologyCheck tool*
PurcellMtn-Validation.html	*output of ValidateDatabase tool*

A page-size paper map made from **PurcellMtn.gdb**, scale 1:100K, using FGDC symbols, with mapunit colors given in **PurcellMtnDMU.dbf**

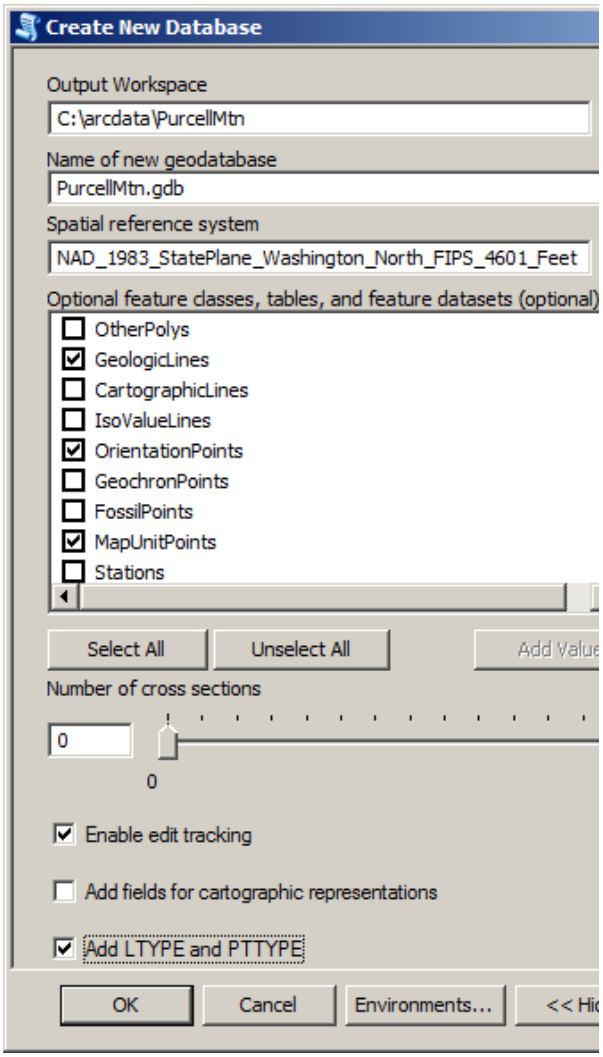
0. Start ArcMap and install the NCGMP09 toolbox

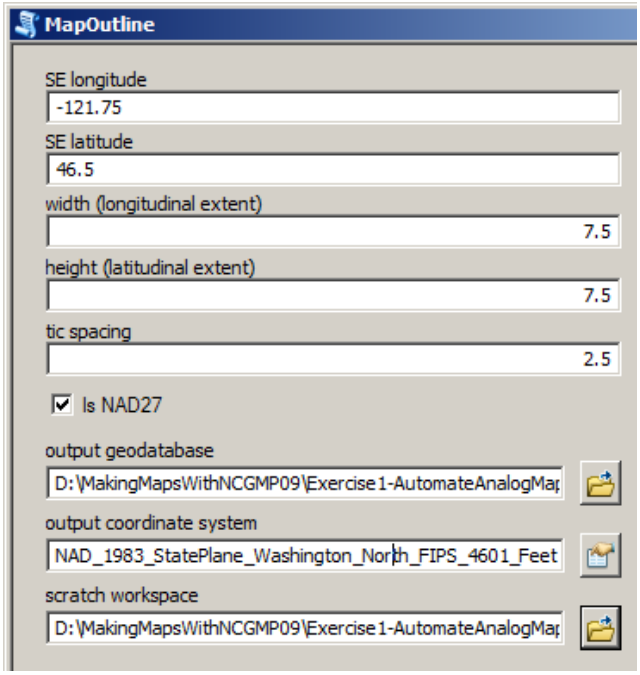
Start ArcMap. When offered an existing project, **CANCEL** to start with an empty map composition. Open the **ArcToolbox** window. Right-click on an empty part of the **ArcToolbox** window and select **Add Toolbox...** In the **Add Toolbox** window that opens, navigate to your **NCGMP09v1.1-Tools3_arc10.1** directory and select **NCGMP09v1.1_Toolbox3_Arc10.1.tbx**. <Right-click> again on an empty part of the **ArcToolbox** window and **Save Settings > To Default**.

1. Make an empty NCGMP09 geodatabase specific to this project and add map tics and map boundary

Start ArcMap if it is not already open. Open the **ArcToolbox** window.

A. Run the **NCGMP09 Tools for Arc10 > Create New Database** script to make an empty geodatabase
   a. Make a new folder for your output workspace. I recommend a location such as **c:\arcdata\PurcellMtn or c:\users**\<username>**Documents\PurcellMtn**.
   b. Name the new geodatabase **`PurcellMtn.gdb`**.
   c. Set the projection to **Projected Coordinate Systems > StatePlane > NAD83 (USFeet) > Washington North FIPS 4601**. We choose this projection to match the lidar data we will use later. *This is not the projection of the source map. Why is it OK to do this?*





   d. Make optional feature classes GeologicLines , OrientationPoints, and MapUnitPoints.
   e. You can enable edit tracking—or not. Don't add fields for cartographic representations. Check "Add LTYPE and PTTYPE". **OK**.

B. Run the **NCGMP09 Tools for Arc10 > MapOutline** script.
   a. SE corner of Purcell Mtn 7.5' quad is at 46°30' N, 121°45' W. *Note that west longitudes are negative. SE longitude can be entered as* `-121.75` *or* `-121 45` *(degrees minutes or decimal degrees). SE latitude can be entered as* `46 30` *or* `46.5`.
   b. Leave **IsNAD27** checked. (*Why?*)
   c. Tic spacing can be set to 7.5 minutes or left at 2.5 minutes.
   d. Use your newly-created **PurcellMtn.gdb** as the output geodatabase.
   e. Set output coordinate system to **Projected Coordinate Systems > StatePlane > NAD83 (USFeet) > Washington North FIPS 4601**.
   f. **OK**.
   g. Look at the catalog for your new geodatabase. You should see feature classes MapOutline and tics at the top level.
   h. Add the tics feature class to your map composition.

C. Save the map composition to your PurcellMtn workspace as PurcellMtn.mxd.

2. Georegister scanned map image

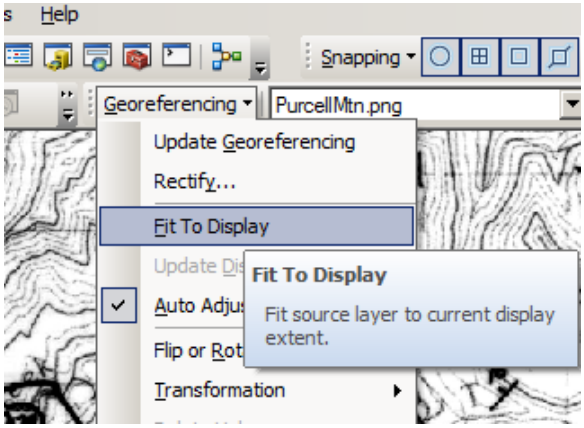
If you have not completed step 1, make a new working folder, copy the contents of folder **Exercise1-AutomateAnalogMap\2-GeoregisterScan** *into this folder, and double-click on* **2PurcellMtn.mxd** *to start ArcMap.*

A. Copy file **PurcellMtn.png** from the **Resources** directory to your working folder.

B. Add **PurcellMtn.png** to the map composition. You should get a warning message about missing spatial reference information. **OK**. Save!

C. Go to **Customize > Toolbars** and ✓ **Georeferencing**. **Snapping** should also be checked.

D. Ensure that PurcellMtn.png shows in file window on the **Georeferencing** tool bar. Tap the **Georeferencing▼** dropdown and select **Fit to Display**. Check **Auto Adjust** also.



E. Add links for the 4 corner tics. *The tics are hard to see. The lower tics are marked by the intersection of half-length vertical bars with the map margin and are inside the map boundary. The SE corner (just above 45' on lower right of map image) will be easiest to find and add first. The upper tics are full crosses +*

   i. **Snapping▼ Use Snapping** should be checked.
   ii. Click on the **Add Control Point** button on the **Georeferencing** toolbar
   iii. Zoom into a tic in the map image.
   iv. Click on the tic location in the map image.
   v. Zoom out if need be. Click on the corresponding tic point symbol.
   vi. Repeat for remaining tics.

F. Check residuals on the link table (**View Link Table** button on the **Georeferencing** toolbar). Because we are fitting 4 points—only 1 point of redundancy—the residuals should be excellent (less than 10 ft, or 0.03 mm at 1:100,000 map scale).

G. If you are satisfied with your results, go back to **Georeferencing▼** dropdown and click **Update Georeferencing**. This will write a world file (**PurcellMtn.pgwx**) that describes the transformation from image coordinates to map coordinates and allows ArcMap to place the image in the correct place any time the image is loaded into a data frame with the correct coordinate system.

H. Disable the Add Control Point tool by clicking on another icon, perhaps the **Select Elements Tool**. Turn the Georeferencing toolbar off: **Customize > Toolbars > Georeferencing**.

I. Save (floppy-disk symbol) your map composition.

3. Setup for digitizing

If you have not completed step 2, make a new working folder, copy the contents of folder **Exercise1-AutomateAnalogMap\3-SetupForDigitizing** *into this folder, and double-click on* **3PurcellMtn.mxd** *to start ArcMap.*

A. Do you have the necessary toolbars? I usually work with **Advanced Editing**, **Editor**, **Snapping**, **Standard, Tools**, and **Topology** enabled

B. Load the MapOutline you made into the ContactsAndFaults feature class.

i. Open the **Catalog** window, navigate to **PurcellMtn.gdb/GeologicMap** ***in your current workspace***, right click on **ContactsAndFaults**, and **Load▶Load Data…** The **Simple Data Loader** will open.

ii. Click on the folder symbol to open the **Open GeoDatabase** window and navigate to **PurcellMtn.gdb** ***in your current workspace*** and select **MapOutline**. Click **Open**, **Add**, **Next>**, **Next>**, **Next>**, **Next>**, and **Finish** to load the data in **MapOutline** into the **ContactsAndFaults** feature class.

C. Add ContactsAndFaults to the map composition.
One of the challenges in working with the NCGMP09 schema is that most lines have multiple attributes. **ContactsAndFaults100K.lyr** *sets up a four-fold view of ContactsAndFaults, such that attributes LTYPE (optional, not required by the NCGMP09 schema), ExistenceConfidence, IdentityConfidence, and LocationConfidenceMeters are all symbolized, so that you can see what the values of these attributes are.* **ContactsAndFaults100K.lyr** *also provides a set of templates that—when a template is selected and a line is created—set appropriate values for these attributes and the attribute Type.*

i. Click the **Add Data** button, navigate to the **Resources** folder in the course CD, and **select ContactsAndFaults100K.lyr**. **Add**.

ii. In the **Table of Contents**, expand ContactsAndFaults100K if necessary. Right-click on LTYPE, move down to **Data**, and select **Repair Data Source…** Set the data source to **PurcellMtn.gdb/GeologicMap/ContactsAndFaults** ***in your current workspace***. This should also fix data sources for sublayers ExistenceConfidence, IdentityConfidence, and LocationConfidenceMeters. *You should now see a red line that is the boundary of the Purcell Mountain 7.5-quadrangle.*

D. Tap the **Snapping▼** dropdown and ensure **Use Snapping** is checked. **Intersection Snapping**, **Midpoint Snapping**, and **Tangent Snapping** should all be enabled.

E. Optional: enable **Snap To Sketch**.
If you build polygons in bulk, using the NCGMP09 toolbox Make Polygons script, it is convenient to be able to digitize small polygons as a single arc—that is, to snap the endpoint of an arc to its own start point. This is "Snap to Sketch".
If you build polygons piecemeal, using the Construct Polygons tool on the Advanced Editing toolbar, it may be undesirable to have single-arc polygons, as every time you later build an adjoining polygon, using the shared bounding arc, you will create a copy of the initial polygon which must be deleted.
You must have an active edit session to enable **Snap To Sketch**. In **Table Of Contents**, right-click on LTYPE (under ContactsAndFaults100K), scroll down to **Edit Features**, and click on **Start Editing**. Then tap the **Snapping▼** dropdown and click **Snap To Sketch**.

F. Add some data to the **DescriptionOfMapUnits** table in **PurcellMtn.gdb**. *For description of the DMU table, see the NCGMP09 documentation on the course CD. I have prepared a list of map-unit codes, map-unit labels, names, ages, hierarchy codes, and symbols (colors) as spreadsheet file* **PurcellMtnDMU.dbf***, largely so we can readily color map-unit polygons*.

i. Open the ArcMap **Catalog** window. Navigate to **PurcellMtn.gdb/DescriptionOfMapUnits** ***in your current workspace***. Right-click on DescriptionOfMapUnits and scroll down to **Load > Load Data…** In the **Simple Data Loader** window, click on the folder icon to bring up the **Open GeoDatabase** window. Navigate to the **Resources** folder on the course CD and select **PurcellMtnDMU.dbf**. **Open**. **Add**.

ii. **Next> and Next>** to bring up a field mapping table (headings "Target Field" and "Matching Source Field") in the **Simple Data Loader** window. Fields MapUnit, Label, Name, and Age should already be matched. Scroll down to HierarchyKey, click on

<None> in the second column, and scroll down to select HierarchyK.

iii. **Next>**, **Next>**, and **Finish**.

G. Add **MapUnitPolys** to the map composition. Click the **Add Data** button, navigate to **PurcellMtn.gdb/GeologicMap** in your current workspace, and select **MapUnitPolys**. **Add**.

H. Join feature class **MapUnitPolys** to table **DescriptionOfMapUnits**. In the **Table of Contents** window, right-click on MapUnitPolys, scroll down to **Joins and Relates**, and **Join…** In the **Join Data** window that opens, "Join attributes from a table" (top list-box) should already be selected.

i. **1. Choose the field**… Select "MapUnit".

ii. **2. Choose the table…** Select **DescriptionOfMapUnits** from **PurcellMtn.gdb** ***in the current workspace***.

iii. **3. Choose the field …** Select "MapUnit".

iv. **Join Options**: Select **Keep all records**

v. **OK**. You will get an error message about the joined table having no rows. 'Tis OK.

I. Set labeling and make MapUnitPolys semi-transparent.

i. Double-click on MapUnitPolys to open the **Layer Properties** window. Tap the **Labels** tab. Check **Label features in this layer**. **Method:** should be "Label all the features the same way" (this is the default value). At **Label Field:**, hit the drop-down arrow and scroll down to and select the second occurrence of "Label". Change **Text Symbol** color to red.

ii. Still in the **Layer Properties** window, tap the **Display** tab. Set **Transparent:** to 50%.

iii. **OK**.

J. ***Save (floppy-disk symbol) your map composition.***

4. Digitize arcs and make polygons

If you have not completed step 3, make a new working folder, copy the contents of folder **Exercise1-AutomateAnalogMap\4-Digitize** *into this folder, and double-click on* **4PurcellMtn.mxd** *to start ArcMap. You may have to change the source of PurcellMtn.png. (In* **Table of Contents***, right-click on PurcellMtn.png, tap Source tab, click Set Data Source…, navigate to your workspace for step 3, or to* **Exercise1-AutomateAnalogMap\3-SetupForDigitizing***, and select* **PurcellMtn.png***.)*

A. Digitize ContactsAndFaults.

i. Right-click on ContactsAndFaults100k/LTYPE and navigate to **EditFeatures > Start Editing**. If feature templates do not appear, go to the ArcMap toolbar, tap the **Editor▼** dropdown, and navigate to **EditingWindows > CreateFeatures**.

ii. Pick an LTYPE template and click away. Double-click or F2 to terminate a feature. Repeat.

iii. **Save Edits** (available **at Editor▼** dropdown) ***frequently!***

Snapping: *You **really** want to ensure that lines join precisely, without undershoots or overshoots. It is possible to fix such problems later, using various editing tools, but much more efficient to avoid them from the get-go. Do this by (1) setting the Snapping environment properly (see ArcGIS Help if you are unfamiliar with this), (2) digitizing at the appropriate scale (so snapping works as you wish it to), and (3) taking a modicum of care while digitizing.*

Working scale: *If Windows is configured to properly recognize your monitor and monitor resolution, the scale statement on the ArcMap toolbar will be approximately correct. In general, I find it best to work at a somewhat larger scale than the intended final display scale AND to adjust the working scale so that edges are well defined (fuzzy features get sharper as they are shrunk).*

Choice of template: *Use the working scale as a guide to setting LocationConfidenceMeters, i.e.,*

if a working scale of 1:10,000 gives moderately well-defined edges, select LocationConfidenceMeters to be 10. If you are digitizing at 1:100,000 scale, select LocationConfidenceMeters of 100; a value of 30, or 10, is certainly not appropriate. It's OK to use approximate or rounded numbers for LocationConfidenceMeters. This attribute is a real (floating point) number ***not*** *because we know it precisely but because we use it to denote a real-world quantity. Integers are for counting, reals are for measuring.*

Strategy: *Work from youngest to oldest. This eases snapping to correct line positions and gives the cleanest, most continuous lines and best symbolization. First create the map boundary. Then digitize Recent contacts (water boundaries, margins of modified land and artificial fill). Then digitize older Holocene arcs (young landslides, young alluvium, etc.). Continue into the past.*

Line direction: *Some arcs, particularly low-angle faults, have ornaments that lie to one side of the arc. Typically such ornaments are on the right side of the arc, thus we digitize low-angle faults with the hanging wall to the right. An arc can be flipped after the fact: while editing, and with the Edit Tool active, double-click on the arc, right-click on the arc, and select Flip.*

Managing multiple attributes: *A properly-built, relatively small set of templates greatly eases the task of managing the multiple line attributes of the NCGMP09 schema. However, it is unlikely that any usable set of templates will allow you to specify all attributes of all arcs. For example, the templates in ContactsAndFaults100K.lyr do not create faults that are queried because their identity (e.g., contact versus fault, or strike-slip fault versus normal fault) is uncertain. Nor do the templates set DataSourceID values (was this arc digitized from an analog map, interpreted from aerial photographs, or walked in the field while creating a GPS tracklog?). Think about your map, build appropriate templates, hand-calculate some values, and use the edit-tracking attributes to identify arcs that were created or modified during the same edit session and thus (probably have a common data source.*

B. Make Polygons. Two methods for creating polygons from linework are the NCGMP09 **Make Polygons** script and the Advanced Editing **Construct Polygons** tool.

   i. **NCGMP09 toolbox > Make Polygons** is an enhanced wrapper for the Feature to Polygon (Data Management) script provided with ArcGIS. **Make Polygons** creates polygons from all arcs in **ContactsAndFaults** and labels these polys with both a) existing poly attributes and b) attributes of any **MapUnitPoints** label points. Make Polygons also creates ancillary feature classes that identify unlabeled polygons, polygons with multiple label points, label points that are multiples within a single poly, and the polygons that border each arc segment. Its scope is the entire feature dataset.
   You can use **Make Polygons** to make unlabeled polygons that you later select and attribute with MapUnit, or you can add points to feature class **MapUnitPoints** that you attribute with MapUnit, and these values will be transferred to the created polygons.

   ii. Use the **Construct Polygons** tool to create polygons from selected arcs. Advantages of using this tool are (a) its limited scope and (b) its immediacy, including feedback on digitizing quality. The primary disadvantages are that (c) it is easy to create duplicate polygons that must be deleted, (d) not all conceivable polygons will be created, and (e) polygons must be labeled after they are created; any label points are ignored.

   iii. I typically create label points (**Make Polygons** method) or select newly created polygons (**Construct Polygons** method) and attribute these with MapUnit only, leaving all other attributes null—except that if the polygon label has a query (e.g., "Tva2?"), I set MapUnit = "Tva2" and IdentityConfidence = "questionable". I later open the attribute table of MapUnitPolys, select all polys with IdentityConfidence <> "questionable", and calc IdentityConfidence of those polys to be "certain". I set Label and Symbol values later.

C. **Editor▼ Save Edits**. **Editor▼ Stop Editing**.

D. Set polygon symbolization. In the **Table of Contents** window, double-click on MapUnitPolys to open the **Layer Properties** window. Select the **Symbology** tab.
   i. Under **Show:** (left side of window), select **Categories > Match to symbols in a style**
   ii. Set **Value Field** to the second occurrence of Symbol in drop-down list.
   iii. **Match to symbols in Style**—tap **Browse…** and navigate to and select **USGS Symbols.style**. *Remember where you put it?*
   iv. **Match Symbols**. **OK**.

   Symbolization can be set before all polygons are labeled. And set again.

E. Make and inspect topology. To create an unambiguous map, and to allow certain sorts of queries, it is important that contact and fault arcs not overlap, contact and fault arcs not intersect themselves, polygons not overlap, that there be no gaps between polygons, that there be no dangling unconcealed contacts (dangling concealed contacts and dangling faults are typically OK), and that all polygon boundaries are coincident with an unconcealed contact or fault.
   i. Check that you do not have an open edit session.
   ii. Open **ArcToolbox**. In the **ArcToolbox** window, open **NCGMP09 Tools for Arc10**. Double-click on **Make Topology**. For **Input feature dataset**, navigate to and select feature dataset **PurcellMtn.gdb/GeologicMap** ***in your current workspace***. **OK**.
   iii. Open the Catalog window and navigate to PurcellMtn.gdb/GeologicMap in your current workspace. Add **GeologicMap_topology** to your map composition. You will be asked whether you also want to add participating feature classes. Answer **No** (they should already be present).
   iv. Start editing (right-click on MapUnitPolys and **Edit Features > Start Editing**). Look at the map for errors, and (or) open the **Error Inspector** window and check for errors. Note that ArcMap will tag dangling fault arcs as errors, but we accept them. You may mark them as exceptions. Fix any errors that you find. Re-validate the topology. Repeat until there are no errors. *Your map should have one dangling fault arc.*

F. **Editor▼ Save Edits**. **Editor▼ Stop Editing**. **Save** your map composition.

5. Digitize orientation points and geologic lines

If you have not completed step 4, make a new working folder, copy the contents of folder **Exercise1-AutomateAnalogMap\5-DigitzeOrientationPointsAndGeologicLines** *into this folder, and double-click on* **5PurcellMtn.mxd** *to start ArcMap. (You may have to change the source of PurcellMtn.png. In* **Table of Contents***, right-click on PurcellMtn.png, tap Source tab, click Set Data Source…, navigate to your workspace for step 3, or to* **Exercise1-AutomateAnalogMap\3-SetupForDigitizing***, and select* **PurcellMtn.png***.)*

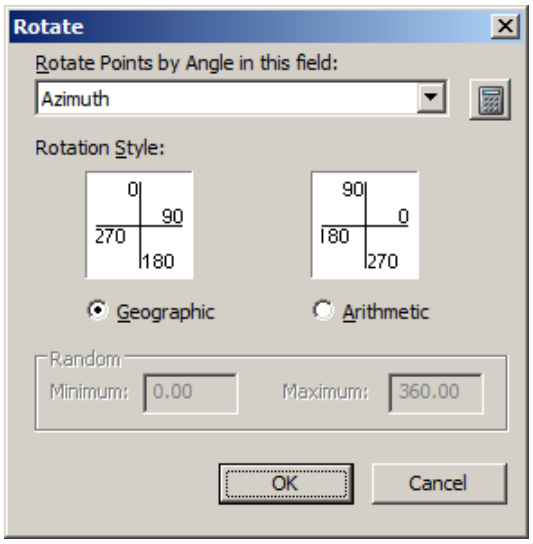
We digitized lines using feature templates to set the multiple attributes that characterize NCGMP09-style data. Our source map has only one flavor of orientation point ("bedding") and two flavors of geologic line ("anticline axis" and "anticline axis, concealed"). We will manage without prepared feature templates—instead, we will digitize generic point and line features and manually set the relevant attributes. If you are digitizing a variety of OrientationPoints Types (e.g., bedding, upright bedding, foliation, joint, stretching lineation) or GeologicLine Types, you will probably find it useful to create a palette of feature templates similar to that in ContactsAndFaults100K.lyr.

A. Square your map with the world. We do this to have on-screen rotation = geographic rotation. At the ArcMap main menu, **View > Data Frame Properties…** In the **Data Frame Properties** window, tap the **General** tab and adjust **Rotation:** until the map is square with the world. *I find that a value of* `0.75` *works for this region and map projection*.

B. While you are at the **General** tab of the **Data Frame Properties** window, set **Reference Scale:** to 1:100,000.

C. Add **OrientationPoints** and **GeologicLines** to your map composition.
   i. Open the **Catalog** window.
   ii. Navigate to **PurcellMtn.gdb/GeologicMap** in your current workspace. Expand the **GeologicMap** feature dataset.
   iii. Drag **OrientationPoints** and drop it into the Table of Contents window. Repeat with **GeologicLines**.

D. Create temporary symbology for OrientationPoints
   i. In **the Table of Contents**, expand OrientationPoints. Double-click on the symbol (probably a dark-colored dot) to bring up the **Symbol Selector** window. Next to **Search:**, tap the radio button for "**All Styles**". Type "`bedding`" into the search window and hit <Enter>. Select symbol 06.02 from FGDC_GSC_20100414. Click on **the Color:** ▼ dropdown and change the color of the symbol to something highly visible like bright red. **OK** to exit.
   ii. In the Table of Contents, double-click on "OrientationPoints" to summon the **Layer Properties** window. Click on the **Labels** tab. Check "**Label features in this layer**". Set **Label Field:** to Inclination. Set **Text Symbol** color to match your bedding symbol. Click **Placement Properties...**, click the **Placement** tab, and select **Place label on top of the point**. **OK**.
   iii. Select the **Symbology** tab in **the Layer Properties** window. Click on the **Advanced**▼ dropdown and select **Rotation...** Click the dropdown for **Rotate Points by Angle in this field:** and select "Azimuth". Ensure that **Rotation Style:** is Geographic. **OK**. **OK**. Save your .mxd again.



E. Digitize orientation points.
   i. You may need to right-click on OrientationPoints in the **Table of Contents** window and re-start editing (**Edit Features▶ Start Editing**). If the Create Features window is not available, click **Editor**▼ and navigate to **Editing Windows > Create Features**. Go to the **Create Features** window and select the OrientationPoints template.
   ii. I find it quickest to first place all bedding points and then set their attributes:
      a. Zoom into the map. Select the OrientationPoints template from **the Create Features** window. Click on the center of a bedding attitude that is shown on the map. This will place an OrientationPoints marker with Azimuth = 0, Inclination=0, and labeled with Inclination. Go to the next attitude and repeat until you've added points for all bedding attitudes. **Editor▼ Save Edits**!
      b. Select the **Edit Tool** on the **Editor** toolbar. Select a bedding symbol. Select the **Rotate** tool on the **Editor** toolbar. Grab an end of the bedding symbol and rotate it until it is aligned with the bedding attitude shown on the map. Go to the **Attributes** window and key in the inclination value shown on the map. Repeat until all bedding values are set. **Editor▼ Save Edits**!
      c. In the **Table of Contents**, right-click on OrientationPoints and **Open Attribute Table**. In the **OrientationPoints** window that opens, right-click on the Type column then navigate to and click **Field Calculator...** Set Type = "bedding". Then **OK** to set all

Type values to "bedding". Repeat for PlotAtScale = 120000, LocationConfidenceMeters = 100, IdentityConfidence = "certain", OrientationConfidenceDegrees = 5, LocationSourceID = "DAS1", and DataSourceID = "DAS1". **Editor▼ Save Edits**! Close the attribute table.

F. Digitize geologic lines.
   i. Go to the **Create Features** window and select the GeologicLines template. On the map, digitize the exposed (continuous) anticline axis as one arc, then the concealed (dotted) anticline axis as a second arc.
   ii. In **the Table of Contents** window, right-click on OrientationPoints and **Open Attribute Table**. Highlight (click on left margin) one row. Is this dotted line on the map? If so, type `Y` into IsConcealed. Or `N` if not. Enter the appropriate value for the other row. For both rows, calculate Type `= "anticline"`, ExistenceConfidence = `"certain"`. IdentityConfidence = `"certain"`, LocationConfidenceMeters = `200`, and DataSourceID = `" DAS1"`. **Editor▼ Save Edits**! **Editor▼ Stop Editing**. Close the OrientationPoints attribute table.

The GeologicLines feature class is a hold-all for linear features that are present in the real world—that is, they may be concealed and they may have uncertainty in their position, identity, and existence—but they and their kin do not participate in the map topology. If there are a large number and variety of such lines it may be appropriate to create one or more additional feature classes for some of these features. See the NCGMP09 documentation.

6. Add Metadata

If you have not completed step 5, make a new working folder, copy the contents of folder **Exercise1-AutomateAnalogMap\6-AddMetadata** *into this folder, and double-click on* **6PurcellMtn.mxd** *to start ArcMap.*

The NCGMP09 schema requires a significant internal feature-level metadata. You created some of this (e.g., values of LocationConfidenceMeters) as you digitized features. Now add the remainder.

A. Back up the geodatabase. You are going to make significant, wholesale modifications to the geodatabase. Best to keep a copy, in case you screw things up.
   i. Open the **ArcToolbox** window. Expand **NCGMP09 Tools for Arc10** and double-click **Compact and Backup**. For **Input Geodatabase**, tap the folder symbol and navigate to **PurcellMtn.gdb** ***in your current workspace***. **OK**.
   ii. Look at your current workspace, either with a directory window or via the **Catalog** window. Note that the backup copy of the geodatabase.

B. MapUnitPolys, IdentifyConfidence=certain. You have probably already noted which polygons have uncertain identities. You now need to specify IdentifyConfidence for the remainder. In the **Table of Contents** window of ArcMap, right-click on MapUnitPolys and navigate **to Open Attribute Table**.
   i. Select some rows.
      a. At the upper left corner of the **Table** window, click the **Table Options▼** dropdown and **Select by Attributes...** In the **Select by Attributes** window, build an SQL expression:
         1. **Method:** should be Create a new selection (the default).
         2. Double-click on MapUnitPolys.IdentityConfidence. *The field name is compound because MapUnitPolys is joined to DescriptionOfMapUnits*.
         3. Click on **<>**.
         4. Click on **Get Unique Values**.
         5. Double-click on 'questionable'.
      b. **Apply**.

c. All rows in the MapUnitPolys feature attribute table should be highlighted except those with IdentityConfidence = "questionable".

ii. Calculate values.
   a. Right-click on the IdentityConfidence column heading and navigate to **Field Calculator…**
   b. In the text window **MapUnitPolys.IdentityCOnfidence =**, enter `"certain"`.
   c. **OK**.
   d. Clear the selection: **Table Options▼ Clear Selection**.
   e. **Editor▼ Save Edits**!

C. Calc DataSourceIDs.
   i. In the MapUnitPolys attribute table, right-click on the heading of column DataSourceID and navigate to **Field Calculator…** In the text box **MapUnitPolys.DataSourceID =**, type `"DAS1"`. **OK**. Close the attribute table.
   ii. Open the attribute table for **ContactsAndFaults** (right-click on ContactsAndFaults100K/LTYPE). Calc DataSourceID = `"DAS1"`. Close the attribute table.
   iii. You have already set DataSourceIDs for **OrientationPoints** and **GeologicLines**. But you could check. *Note that OrientationPoints has both LocationSourceID and DataSourceID, as location and orientation may have separate sources. For this transcription, both should be "DAS1".*
   iv. **Editor▼ Save Edits**!

D. Add information to metadata tables **DataSources** and **Glossary**.
   i. Open Catalog window. Navigate to **PurcellMtn.gdb** ***in your current workspace***. Add tables **DataSources** and **Glossary** to your map composition.
   ii. In the **Table Of Contents** window, right-click on DataSources and **Open**.
   So far, all the information in PurcellMtn.gdb has a single source: Washington DGER Open-file Report 87-16, by Hank Schasse, transcribed by you. You need to add an entry to describe this source.
      a. In table DataSources, in column DataSources_ID, enter `DAS1`.
      b. In column Source, enter an appropriate modification of the following (copy and paste works): `Geology of the Mount Rainier quadrangle, Washington, compiled by Henry W. Schasse, Washington Division of Geology and Earth Resources Open File Report 87-16, 1987, map scale 1:100,000. Digitized and interpreted by Ralph Haugerud in September-October 2014.`
      c. In the Notes field, you might enter an appropriate modification of the following: `Values of LocationConfidenceMeters, ExistenceConfidence, IdentityConfidence, and OrientationConfidenceDegrees assigned by Haugerud on the basis of source map scale, source map symbolization, and his experience. These values may not coincide with the intent of the author of the source map.`
      d. Close Table **DataSources**. **Editor▼ Save Edits**.
   iii. In the **Table Of Contents** window, right-click on Glossary and **Open**.
   Table **Glossary** contains definitions of the terms used in an NCGMP09 geodatabase. All terms used in a Type field or a Confidence field should be defined here. *We will later run a script to check that the list of terms defined in* **Glossary** *is complete. For now, we add a few that we can remember.*
      a. In table Glossary, in the Term column, enter `contact` <return>. Continue to enter, in successive new rows of the Term column, `fault`, `bedding`, `anticline`, `certain`, and `questionable`.
      b. We leave Glossary_ID empty for now.

c. You have several choices for definitions. You may write your own. You may paraphrase definitions from your favorite dictionary or geology text. Or you may paraphrase definitions from the American Geological Institute's Glossary of Geology (recommended).

Note that **certain** and **questionable** are not defined in the AGI Glossary; the best definition for their meaning in this context that I am aware of is that on pages 16-17 of the FGDC Geologic Map Symbolization standard (FGDC-STD-013-2006).

d. In another document, draft your definitions. Copy and paste them into the appropriate Definition field in table **Glossary**.
e. For each unique source of definitions, create a new DataSourceID value and enter it in the DefinitionSourceID field. If all definitions have the same source, all DefinitionSourceIDs will be the same (e.g., **DAS2**).
f. Close Table **Glossary**. **Editor▼ Save Edits**.

iv. For each new value of DefinitionSourceID that you created in **Glossary**, create a corresponding entry in table **DataSources**. *See step ii, above*.
v. Add information to **DescriptionOfMapUnits**. In the **Table of Contents** window, right-click on DescriptionOfMapUnits and **Open**. You are going to provide additional attributes for each map unit identified in the DMU, but not for those rows that correspond to DMU headings.
vi. Select rows that correspond to map units.
    a. In the **Table** window, tap the **Table Options▼** dropdown at the upper left corner of the window.
    b. **Select By Attributes…**
    c. In the **Select By Attributes** window, **Method:** should be Create a new selection (the default). In the list of fields below, double-click on "MapUnit". Tap **<>**. Tap **Get Unique Values**. In the list of unique values, double-click ''.
    d. **Apply**. All rows of DescriptionOfMapUnits that have non-null values of MapUnit should now be highlighted.
vii. FullName. Some map-units, on some maps, have names like "sandstone member" that are not informative until you know that this is the "sandstone member of the XYZ Formation." Fullname is a field for storing the latter, compound name that might be used in a flyout that appears when a user's cursor hovers over a map-unit polygon in a web display of the map.
    a. For this map, FullName can be the same as Name. Right-click on the FullName heading and open the **Field Calculator…**
    b. In the **Field Calculator** window, in the **Fields:** box, double-click on Name.
    c. **OK**. Values of FullName for all rows should now be the same as values of Name.
viii. Description. In a better world our source-map text would not be a scanned image and we could copy map-unit descriptions from the source map and paste them into the DMU table. Unfortunately this is not possible
    a. Open file **Resources/OCR/MapUnitDescriptions.docx** in the course CD. Read the introduction on how this file was created.
    b. Copy map-unit descriptions and paste into appropriate places in Table DescriptionOfMapUnits.
ix. DescriptionSourceID. Our descriptions all come from OFR 87-16.
    a. Right-click on the DescriptionSourceID heading and open the Field Calculator…
    b. In the Field Calculator window, in the DescriptionSourceID box, type "DAS1". OK.
    c. Close **Table DescriptionOfMapUnits**.
    d. **Editor▼ Save Edits**.

x. GeneralLithology
    a. Open the NCGMP09 documentation (**Documentation/ usgs_of2010-1335_NCGMP09.pdf**) and the text for OFR 87-16 (**Resources/ wa_ger_ofr87_16_text.pdf**). Scroll to Appendix A. Lithology and Confidence Terms for GeneralLithology in the NCGMP09 documentation (p. 125 and following).
    b. For each map unit in table **DescriptionOfMapUnits**, find the GeneralLithology term that you think best fits. Copy and paste the GeneralLithology term into the appropriate row of the GeneralLithology column in **DescriptionOfMapUnits**. Also add the GeneralLithologyConfidence term (High, Medium, Low; page 134) that you find appropriate. *It is <u>OK</u> if no GeneralLithology term fits well—find the best-fitting term, either a general term that is uninformative or a specific term that omits some lithologies within the map unit—and set the corresponding value of GeneralLithologyConfidence to High, Medium, or Low as appropriate.*
    c. **Editor▼ Save Edits**. **Editor▼ Stop Editing**.
    d. Close **Table DescriptionOfMapUnits**.

E. Set ID values. Except for DataSources _ID and related DataSourceID values, you have not set any _ID or ID values. These can be created with an NCGMP09 toolbox script that creates new values for any missing values and preserves existing relations.
    i. Open the **ArcToolbox** window. Open **NCGMP09 Tools for Arc10** and double-click **on (re)Set ID values**. In the **Input NCGMP09-style geodatabase field**, click on the folder symbol and navigate to **PurcellMtn.gdb** ***in your current workspace***. Select it and **Add**.
    ii. **OK**. When script has completed, **Close**.

7. Check topology, symbolize, and validate your database.

If you have not completed step 6, make a new working folder, copy the contents of folder **Exercise1-AutomateAnalogMap\7-CheckSymbolizeValidate** *into this folder, and double-click on* **7PurcellMtn.mxd** *to start ArcMap.*

A. Check topology. Beyond requirements that lines not cross or dangle and that polygons neither overlap nor have gaps (step 4E above), there are other aspects of map topology that can be checked to guard against digitizing errors and implausible map relations.
    i. Run NCGMP09 **Topology check** script. Input geodatabase **is PurcellMtn.gdb**. Check the box to validate the topology of all feature datasets—you only have one, **GeologicMap**. Set map scale to 100000. You shouldn't need to change any other input values. **OK**. *Note that the Topology check script is a work in progress.*
    ii. Look at output file PurcellMtn_TopologyReport.html. You should see one **Line and point topology** error:

        errors_GeologicMapTopology_line

        ```
        1   Must Not Have Gaps   esriTRTAreaNoGaps
        ```

        You may also have an **End-points of fault arcs that may need flipping** error, which in this case (these fault lines are not directional) may be ignored.
        Note the tables showing how many arcs, and what cumulative length of arc, there are in the classes "Concealed contacts and faults", "Contacts (not concealed)", and "Faults (not concealed)". These can be useful in identifying digitizing errors. One might imagine that for a large, complex map these might even teach you something about the stratigraphy of the map (is it layer-cake or not? What are the significant unconformities?)

B. Set symbolization. *One of the strengths of GIS, and of the NCGMP09 schema, is that symbolization may be almost entirely divorced from semantic content—that is, unlike with a paper map,* ***heavy***

`black line` *need not equal* ***`fault`****. We choose to set symbolization separately from the Type, ExistenceConfidence, and other attributes of a feature. One advantage of this is that we can easily re-symbolize as we change the scale at which map data are to be displayed. Zoom out, so that 1:24,000 scale becomes 1:100,000 scale, and many dashed contacts should be shown as continuous. You can pick line weights and colors that are appropriate for your display medium. And so on.*
If you choose to use FGDC symbology (FGDC Digital Cartographic Standard for Geologic Map Symbolization, FGDC-STD-013-2006, available on the web at ngmdb.usgs.gov), you may find the NCGMP09 **Set Symbol Values** script helpful.

i. Run the NCGMP09 **Set Symbol Values** script. Open the **ArcToolbox** window, expand **NCGMP09 Tools for Arc10**, and double-click on **Set Symbol Values**.
   a. Set **Feature dataset** to **PurcellMtn.gdb/GeologicMap** ***in your current workspace***.
   b. Set **Map scale denominator** to `100000`.
   c. Accept defaults for the remainder of the script parameters.
   d. **OK**.

ii. **Set Symbol Values** uses a dictionary file ***that you can edit*** to set *Symbol* values. This file, **Type-FgdcSymbol.txt**, lives in the **Scripts** folder of the NCGMP09 toolbox and lists *Type* values and a corresponding symbol identifier from the GSC implementation of the FGDC cartographic standard.
   a. For many line types (e.g., contact, fault) there are eight (2^3) line symbols defined in the FGDC cartographic standard for all combinations of is or is not concealed, location confidence (certain versus approximate,) and existence/identity confidence (queried or not). These line types are listed in the dictionary file under the heading **Eight-fold Lines**.
   b. Some structural orientation symbols have different forms depending on whether the orientation is known exactly or approximately—that is, whether *OrientationConfidenceDegrees* is less than some critical value. These, and other structural orientation symbols that do not have different forms, are listed under **Two-fold Orientation Points**.
   c. Other symbols are invariant once *Type* is given. *Type*-to-symbol mapping for such symbols is given under **My Symbols**.

   By default (but you can choose not to) **Set Symbol Values** also calculates some attribute values for polygons in **MapUnitPolys**. *Symbol* is set equal to *DescriptionOfMapUnits.Symbol*. *Label* is set to *DescriptionOfMapUnits.Label*, except for polygons for which *IdentityConfidence* <> `certain`, for which "?" is appended to the label.
   By default (but again you can choose not to), if this is the **GeologicMap** feature dataset and there is an **OrientationPoints** feature class, **Set Symbol Values** will create a new feature class **OrientationPointLabels**, add points to this class with attribute *Inclination*, position these points according to the dictates of the FGDC standard, and add a layer to your map composition that draws these labels with the font and size specified by the FGDC cartographic standard. You may find this a good start towards correctly positioned dip numbers.

C. Validate your database and fix errors that are identified.

i. First, **Compact and Backup** your database with the script in the NCGMP09 toolbox.

ii. Run the NCGMP09 **Validate Database** script.
   a. Open the output file PurcellMtn-Validation.html. What errors are identified? Likely problems include:
      1. Excess fields. You enabled error tracking on all feature classes and tables. While extensions to the schema are not errors, you are likely to choose not

to retain this information in the final, public, version of the database. In the **ArcCatalog** window, navigate down to **PurcellMtn.gdb/GeologicMap** in your current workspace, expand, right-click on each feature class, navigate down to **Manage**, and **Disable Editor Tracking**. **OK**. In the **Table Of Contents** window, right-click on the corresponding layer, open the attribute table, navigate to the editor tracking fields, and delete them. Repeat for all feature classes in **GeologicMap**. Repeat for tables **DataSources**, **DescriptionOfMapUnits**, and **Glossary**. *Here is a script that needs to be written!*

2. Unneeded feature classes. **MapOutline** and **tics** (at the root level of the geodatabase) are excess. Delete them. You have not used **GeologicMap/MapUnitPoints** and it is optional. Delete it.
3. Missing **Glossary** entries. Validate Database almost certainly will have identified several terms that should be defined in the Glossary table.
    a. Open the **Glossary** table for editing and add the missing terms.
    b. You also need to add values of *Glossary_ID* for each new term, either manually or by running the NCGMP09 **(re)Set ID values** script when you are done editing **Glossary**.
    c. GeneralLithology and GeneralLithologyConfidence terms are defined in Appendix A of the NCGMP09 standard. ***These terms should not be redefined!*** As a convenience to the users of your database, copy and paste the relevant definitions into Glossary. Add the appropriate value of DefinitionSourceID.
    d. **Editor▼ Save Edits**. **Editor▼ Stop Editing**.
4. **Validate Database** is not smart enough to identify missing definitions, missing map unit descriptions, or lousy descriptions of data sources. However, it does list the contents of tables **DataSources**, **DescriptionOfMapUnits**, and **Glossary**. Scan these. Fix that which needs fixing.

iii. Re-run the **Validate Database** script. Fix any remaining errors. Repeat until done.

8. Make a map image and print it.

A. Go **to View > Data Frame Properties...** on the ArcMap menu bar. Under the **General** tab, ensure that **Reference Scale:** = `1:100,000`.

B. Add unadorned **ContactsAndFaults** to your map composition. Either open the ArcCatalog window and drag, or click the Add Data icon and Add Data… Uncheck ContactsAndFaults100K.

C. Go back to **Table Of Contents**. Symbolize layers OrientationPoints, GeologicLines, and ContactsAndFaults with the FGDC cartographic standard.
    i. In the Table Of Contents window, double-click on OrientationPoints. In the **Layer Properties** window, click on the **Symbology** tab. In the **Show:** box, select **Categories > Match to symbols in a style**. For **Value Field**, select `Symbol`. For **Match to symbols in Style**, click the **Browse...** button and scroll down and select **FGDC_GSC_20100414.style**. **Open**.
    ii. Back at the Layer Properties window, click **Match Symbols**. Uncheck `<all other values>`.
    iii. For OrientationPoints ***only***, click the **Advanced▼** button and select **Rotation...** Set **Rotate Points by Angle in this field:** to `Azimuth`. Ensure that the **Geographic** radio button is selected. **OK**.
    iv. **OK**.
    v. Repeat for ContactsAndFaults and GeologicLines.

D. For MapUnitPolys, symbolize via **Match to Symbols in Style**, **Value Field** `Symbol`, and at **Match to symbols in Style**, **Browse…** to and select `USGS Symbols.style`. *This style file may not be present in your ArcMap installation. It is available in the Resources folder of the course CD.*

E. Adjust the labeling of MapUnitPolys.

F. Switch to Layout View and adjust. **Save**. **File > Export Map…** and **Save as type:** PDF (*.pdf). *Note that you may have to navigate to a different* **Save in:** *folder.*

G. Open the PDF with Adobe Reader and inspect. If everything is OK, print.

Exercise 2. Digitize newly-interpreted geology

Source materials

- Your final version of PurcellMtn.gdb and the accompanying .mxd file.
- Lidar data for part of the Purcell Mtn quadrangle and nearby areas, in geodatabase Lidar6ft.gdb in the Resources folder of the course CD. This geodatabase should be copied to your workspace.

1. Prepare lidar images

A. Calculate useful images

i. Open ArcMap with your most recent PurcellMtn .mxd.

ii. Load Data; navigate to Lidar6ft.gdb/PurcellMtn. Load this raster into your .mxd.

iii. Open the ArcMap Search window. Type "hillshade" into the search box and <ENTER>. Click on Hillshade and the Hillshade tool should pop open.
There may be licensing issues that govern whether you can access Hillshade (3D Analyst) and/or Hillshade (Spatial Analyst). You may have to go to Customize > Extensions... and enable 3D Analyst and/or Spatial Analyst.

iv. Make 3 hillshades.

Input raster	PurcellMtn	PurcellMtn	PurcellMtn
Output hillshade	Lidar6ft.gdb/ PurcellMtn_ne	Lidar6ft.gdb/ PurcellMtn_nw	Lidar6ft.gdb/ PurcellMtn_v10
Azimuth	45	315	315
Altitude	45	45	90
Z factor	1	1	10

i. The hillshades will be added to your map composition as you create them. Remove PurcellMtn_v10.

ii. Return to the search window. Type "mod" into the search box and <ENTER>. This should bring up Mod (Spatial Analyst). Click on the tool name.

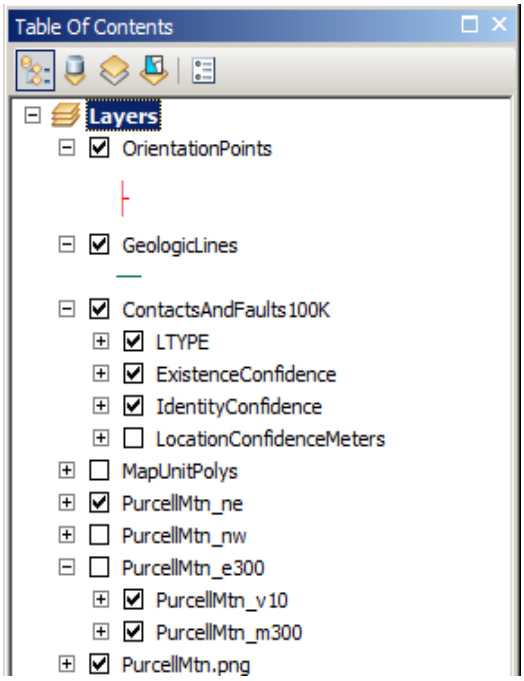
iii. In the Mod tool window, Input Raster or constant value 1= PurcellMtn, Input raster or constant value 2 = 300, and Output raster = Lidar6ft.gdb/PurcellMtn_m300. OK.

iv. Close the Search window.

v. Remove PurcellMtn_m300 from your map composition.

B. Go to Add Data and navigate to and add layer file PurcellMtn_e300.lyr, which is in the Resources folder of the course CD. You may need to repair the data sources. Uncheck raster layer PurcellMtn.

Your Table of Contents should now look something like the image at right.



2. Prepare to digitize

A. Look around. Change which lidar-derived image is visible and look some more.
How well does the 1:100K-scale geologic map depict the surficial geology in the area of lidar coverage? What's right? What's wrong? Can you see better interpretations? What Quaternary map units might you depict? Make a list (mental, scratch paper, short text file...). What distinguishes these map units? What defines their boundaries? How precisely can you pick these boundaries?

B. Enabling edit tracking for ContactsAndFaults. This will help you track which lines you digitized from OFR87-16 and which you interpreted from lidar topography.
   i. Open the Catalog window.
   ii. Navigate to PurcellMtnYI.gdb/GeologicMap/ContactsAndFaults. Right-click on ContactsAndFaults and navigate to Manage▶ Enable Editor Tracking...
   iii. Click "Yes"

3. Digitize new contacts

A. Uncheck ContactsAndFaults and check ContactsAndFaults100K.

B. In the Table of Contents, under ContactsAndFaults100K, right click on LTYPE and navigate to Edit Features▶ Start Editing.

C. Digitize new contacts that you interpret from lidar topography, using the lidar image(s) of your choice. What scale do you find is easiest to work at, where boundaries are well defined, you have a decent field of view, and yet your digitizing isn't cramped? As a general rule of thumb, divide the denominator of this scale by 1,000 and the result is the appropriate value of LocationConfidenceMeters. Pick the line template to match. *In this case, most of your lidar lines will be LTYPE = "contact 20m". A few contacts—e.g., between alluvial fans and valley-bottom alluvium—may be very difficult to locate precisely and "contact 200m" may be more appropriate.*

D. It is easier to preserve data lineage if you do not modify existing lines. Digitize new lines. Cut old, superceded lines at their junctions with new lines and delete them. In general it will be easier to digitize new contacts, e.g., Qal (valley bottom) against bedrock (hillside) entirely and later trim / extend the existing contacts to meet the new contacts.

E. **Editor▼ Save Edits** frequently.

4. Make topology and check for line errors. Build polygons

A. Once you have completed, more-or-less, revising the linework, **Editor▼ Stop Editing**. Create line topology with the NCGMP09 Make topology tool. Add the resulting GeologicMap_topology feature class to your map composition and inspect. Fix any overlaps, self-intersections, or unintentional dangles.

B. Make polygons. There are multiple ways to do this.
   i. Rebuild polygons with the NCGMP09 Make polygons tool. Attribute all new polygons,

perhaps in part with new map units.

ii. Or, use tools on the advanced editing toolbar to create, cut, and merge polygons.

C. If you have added new map units, you need to add these units to the DescriptionOfMapUnits table. **Editor▼ Save Edits**.

D. Check map topology with the NCGMP09 Topology check tool. Be particularly alert to the likelihood of bad nodes, now that the map has a more complicated digitizing-editing history. Fix any errors.

5. Fix metadata. Validate

A. Start editing. **Open Attribute Table** for LTYPE. Sort on *created_date* values. Select those records created in this edit session. Use the Feature Calculator to set *DataSourceID* = **"DAS7"** (or whatever value is appropriate).

B. If you modified existing lines (old or <Null> *created_date*, new *last_edited_date*, *DataSourceID* = **DAS1**), select these lines and calc *DataSourceID* = **"DAS8"** or whatever value is appropriate.

C. Open table DataSources. Make an entry *DataSources_ID* = **DAS7**, *Source* = **This report. Interpreted and digitized from 6ft lidar DEM by <yourname> on <thisdate>"** or similar. If needed, make a second entry **DAS8**, *Source* = **OFR 86-17, digitized with minor modifications by <yourname>** or similar.

D. **Editor▼ Save Edits**. **Editor▼ Stop Editing.**

E. Validate the database using the NCGMP09 **Validate Database** script. Fix significant problems.