

# The ESRI Geologic Mapping Template

By Charlie Frye and Janel Day

Esri  
380 New York Street  
Redlands, CA 92373  
Telephone: (909) 793-2853  
email: [cfrye@Esri.com](mailto:cfrye@Esri.com); [janel\\_day@Esri.com](mailto:janel_day@Esri.com)

## Introduction

An ArcGIS implementation of the Federal Geographic Data Committee (FGDC) Digital Cartographic Standard for Geologic Map Symbolization (“Standard”), the Geologic Mapping Template, provides a standardized set of the most commonly used geologic and supporting cartographic symbols.

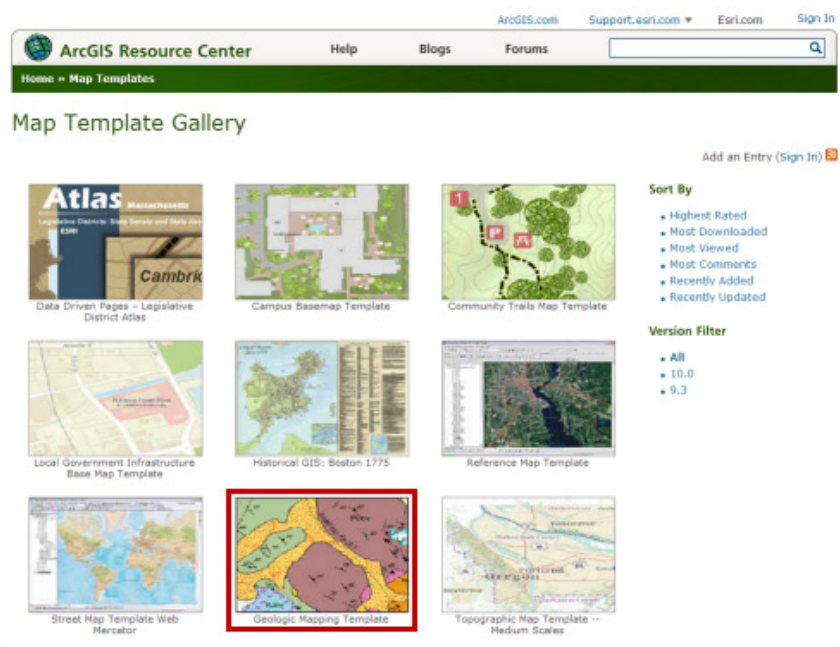
The Standard developed out of the need to “support efficient production of geologic maps and related products, as well as to improve their consistency in both appearance and underlying database content.” Preparation of the Standard by the U.S. Geological Survey (USGS) on behalf of the FGDC began in the late 1990s, with the final publication released about 10 years later in August 2006 (FGDC, 2006; [http://ngmdb.usgs.gov/fgdc\\_gds/](http://ngmdb.usgs.gov/fgdc_gds/)).

The idea of the Geologic Mapping Template came to fruition in early 2009, but the work leading up to the template began a few years earlier. In late 2005, the USGS and ESRI began discussing the creation of symbols that met the complex specifications contained in the Standard. Cartographic Representations, a new functionality added to ArcGIS around this time, provided the means to produce the symbols that would meet those specifications. For 4 years, ESRI followed the guidance of the USGS and the Standard to develop over 1,000 of the 3,000 symbols in the Standard, focusing on the most frequently used symbols from Sections 1 – 18. By the time the development of the symbols neared completion, ESRI began publishing map templates, leading to the Geologic Mapping Template (GMT).

## Map Templates

ESRI began publishing map templates in early 2009. The templates are designed as a resource for the ArcGIS user community, delivering a cartographic specification for a particular map purpose.

The templates typically consist of ArcGIS files, sample data, symbology, geoprocessing tools, documentation, and Web map applications when appropriate. They can be downloaded from the ArcGIS Resource Center Map Templates Gallery and saved on your local or network directory (fig. 1; <http://resources.esri.com/maptemplates/>).



**Figure 1.** Map Template Gallery on the ArcGIS Resource Center. The Geologic Mapping Template .zip file can be downloaded from this site.

## The Geologic Mapping Template

An ArcGIS 9.3.1 implementation of the Standard, the GMT is a complete solution for storing, managing, and symbolizing geologic map data. The Template contains a geodatabase with symbols and tools, a documented workflow, and an example map document and database with GIS data for the Geologic Map of the Mount Baker 30' x 60' Quadrangle by Tabor and others (2003) (fig. 2). It is available for download at <http://resources.esri.com/mapTemplates/index.cfm?fa=codeGalleryDetails&scriptID=16317>.

The example map and data-rich database demonstrates the result of taking data from the native format and pushing it through the 11 steps of the Getting Started document, included with the template. The template is scalable and flexible by design.

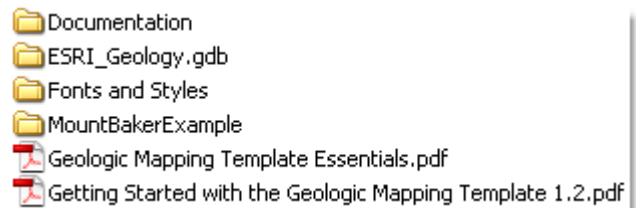
### Template Geodatabase

The GMT includes a geodatabase with a feature dataset, symbols, reference tables, and geoprocessing tools (fig. 3). The geodatabase schema is modeled after Appendix A of the FGDC Standard.

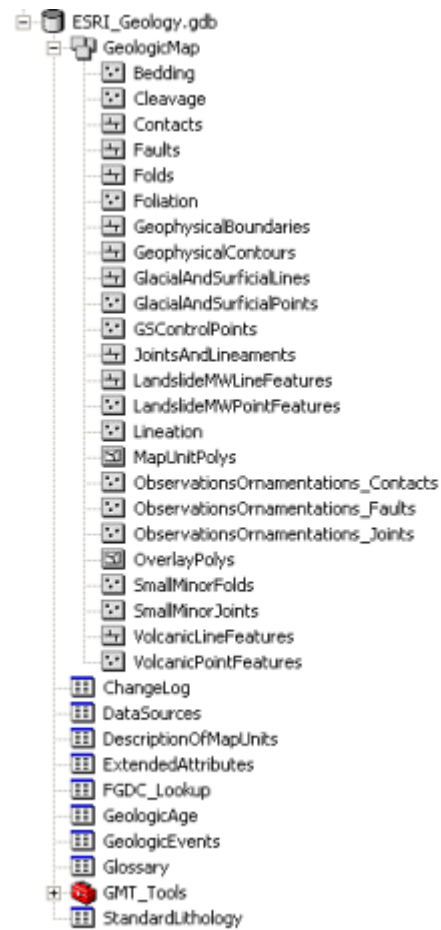
### Feature Dataset

The GeologicMap feature dataset contains 24 feature classes that are organized by the major symbol (representing feature) type classifications defined in Appendix A of the Standard, including:

1. Contacts, Key Beds, and Dikes
2. Faults
3. Boundaries Located by Geophysical Surveys
4. Lineaments and Joints
5. Folds
6. Bedding
7. Cleavage
8. Foliation
9. Lineation
10. Geophysical and Structure Contours
11. Fluvial and Glaciofluvial Features
12. Periglacial Features
13. Lacustrine and Marine Features
14. Eolian Features
15. Landslide and Mass-Wasting Features
16. Volcanic Features
17. Natural Resources



**Figure 2.** Contents of the Geologic Mapping Template (folder view) after the downloaded file has been unzipped.



**Figure 3.** The Geologic Map Template file geodatabase.

WGS84 is the defined geographic coordinate system for the template dataset.

### Feature Class Representations (Symbols)

Each feature class in the GeologicMap dataset contains a corresponding set of symbols that is managed with what is known as a representation class. For example, the Faults feature class has a representation class that contains the symbols for the different types of faults, the Bedding feature class has a representation class that contains the symbols for the different types of bedding features, and so on.

Each representation class is composed of a set of rules, with a unique rule for each symbol. Each unique rule is given a unique identifier known as a Rule ID. Each rule also has a unique name. For the GMT, the rule name corresponds to the reference number (REF NO) for the symbol in the Standard (fig. 4). Cartographic Representations is the term that describes this entire symbol management system within the geodatabase.

The ability to store the symbology with the features in the geodatabase is essential for storing, managing, and sharing geologic map data. Whereas the traditional paper map represents a complete, interpretive geologic story, digital data only represent half of the story. A thrust fault representation, for example, has a complete and an incomplete story, depending on whether it is a symbol drawn on a map or is a feature in a geodatabase.

On a map, a thrust fault is represented by a line with little triangular-shaped teeth that repeat at regular intervals. The orientation of the teeth along the line indicates the direction of thrust. As data, a thrust fault is simply a line feature that has a 'thrust fault' attribution and unless the feature has been digitized following the right-hand rule as defined in the Standard, there is no guarantee that this feature will be properly represented when plotted in ArcMap. The teeth could plot on either side of the line representing the fault trace, or on both sides, offering an incoherent and inaccurate representation of the geologic feature (fig. 5).

The GMT offers a solution to bridge the gap between the data and its proper representation. Recall that the GMT is an ArcGIS implementation of the Standard. Therefore, the symbols follow the right-hand rule as defined in the Standard. Assuming the thrust fault has been digitized following the right-hand rule, the teeth will fall on the proper side of the line when it is symbolized with the thrust fault symbol in the GMT. However, if the feature was digitized following a convention that differs from the Standard's right-hand rule, the feature may need to be flipped and (or) the symbol geometry edited to orient the teeth. Either way, the feature and symbol will be stored together in the database, assuring the data provider and the data user that the features will be properly symbolized when plotted in ArcMap.

For general information about cartographic representations, refer to ESRI's online help on the topic that can be found on the Resource Center (<http://resources.esri.com>). For working with the representations in the GMT, refer to the Tips and Tricks section.

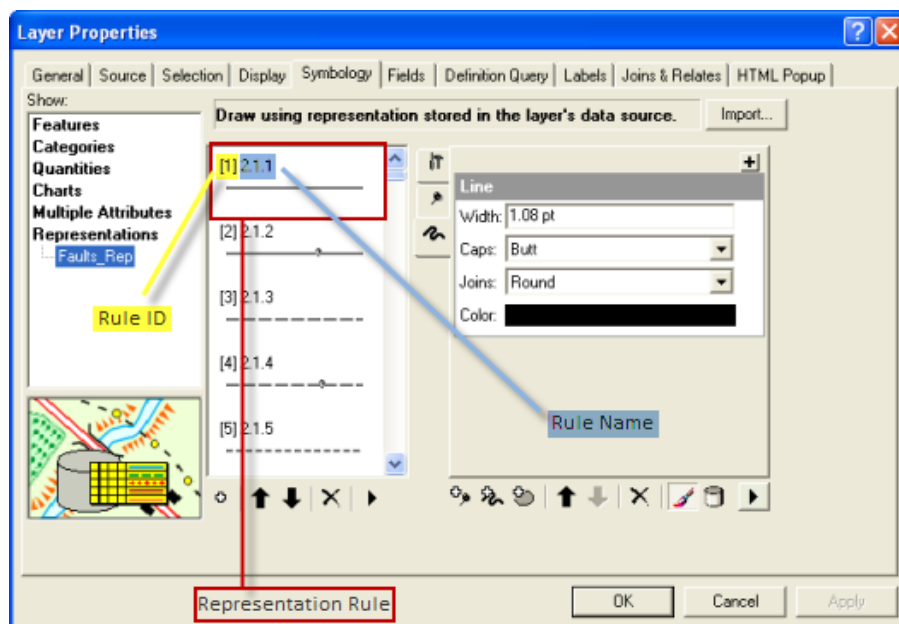
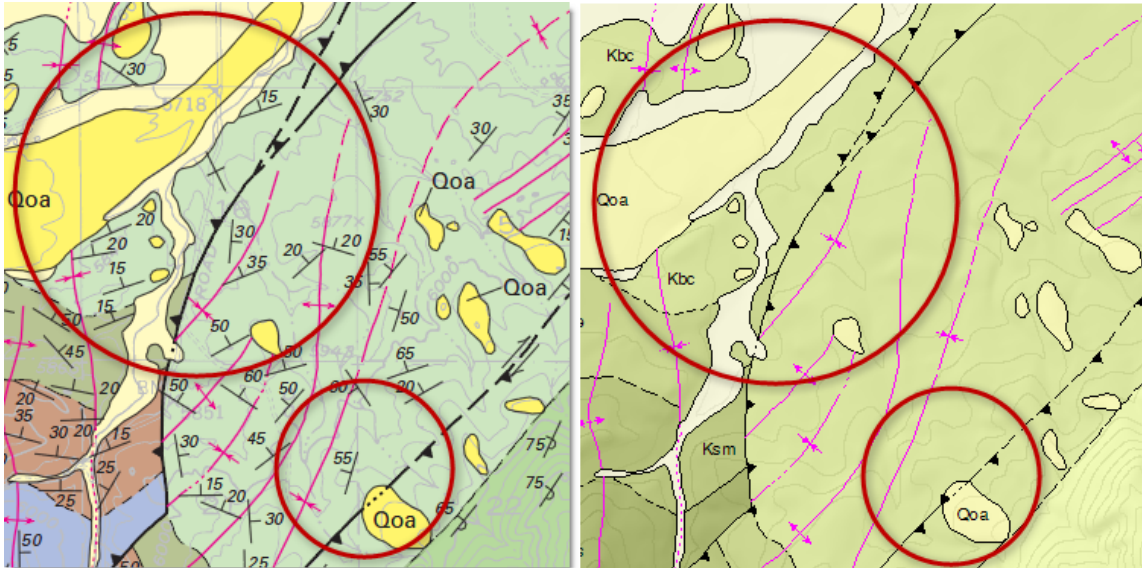


Figure 4. ArcMap Layer Properties Symbology view of cartographic representations.



**Figure 5.** Comparison of thrust faults shown on printed map (to left) and symbolized from GIS data (to right). Map is the Sedan quadrangle, Gallatin and Park Counties, Montana (Skipp and others, 1999). Note incorrect symbolization from the GIS data.

## Tables

The GMT geodatabase contains several tables. Some tables have no data but are designed to hold the supporting geologic information contained in your data, including data sources, description of map units, additional attributes, and standard lithology. The other tables include the GeologicAge table and the FGDC\_Lookup table. The GeologicAge table holds the geologic age names and their age ranges, based on the Divisions of Geologic Time – Major Chronostratigraphic and Geochronologic Units (U.S. Geological Survey Geologic Names Committee, 2007) diagram. The FGDC\_Lookup table (fig. 6) contains the symbols' reference numbers, symbol descriptions as defined in the Standard, and corresponding Rule ID values.

## Toolbox

The tools in the GMT Tools toolbox (fig. 7) help bring everything together. The tools facilitate the creation of a project database with the appropriate projection, the migration of data from the native format into the project database, and the calculation of fields as described in the documented workflow.

## Documentation

The GMT includes a set of documentation files that describe the structure of the template geodatabase schema, the sample map, and geodatabase contents, as well as a documented workflow.

## Documented Workflow

The document “Getting Started with the GMT” outlines a step-by-step process for working with the template. “Geologic Mapping Template Essentials” serves as a companion document and provides more detailed information about the ArcGIS implementation of the standard, including an overview of the overall design of the template and an introduction to working with cartographic representations.

## Example Map and Database

The complexity of the geology and the thoroughness of the publication “Geologic Map of the Mount Baker 30' x 60' Quadrangle” (Tabor and others, 2003; and fig. 8) proved to be an excellent example for testing the GMT. This became the example map and database that was released with the GMT.

For the GMT's example map and database, GIS data for the Mount Baker map were downloaded, and the 11 steps outlined in the Getting Started document were followed. One of the first steps in working with the template database is to project the GeologicMap dataset in the template database to match the local projection. In the Mount Baker case, the WGS84 geographic coordinate system had to be projected to Washington State Plane South. A tool is provided in the GMT toolbox to create a new database that follows the template geodatabase schema and a GeologicMap dataset that has a suitable projection for the mapped region (fig. 9).

RepRuleID	FGDC_REFNO	FGDC_DESC
1	1.1.1	Contact—Identity and existence certain, location accurate
2	1.1.2	Contact—Identity or existence questionable, location accurate
3	1.1.3	Contact—Identity and existence certain, location approximate
4	1.1.4	Contact—Identity or existence questionable, location approximate
5	1.1.5	Contact—Identity and existence certain, location inferred
6	1.1.6	Contact—Identity or existence questionable, location inferred
7	1.1.7	Contact—Identity and existence certain, location concealed
8	1.1.8	Contact—Identity or existence questionable, location concealed
9	1.1.9	Internal contact—Identity and existence certain, location accurate
10	1.1.10	Internal contact—Identity or existence questionable, location accurate

Figure 6. The FGDC\_Lookup table.

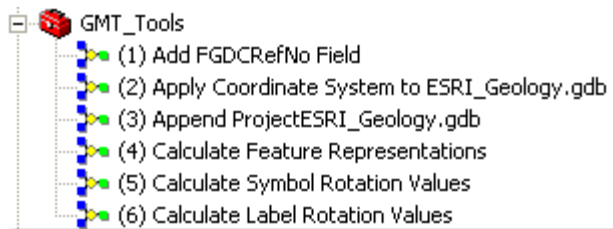


Figure 7. Geologic Mapping Template Tools.

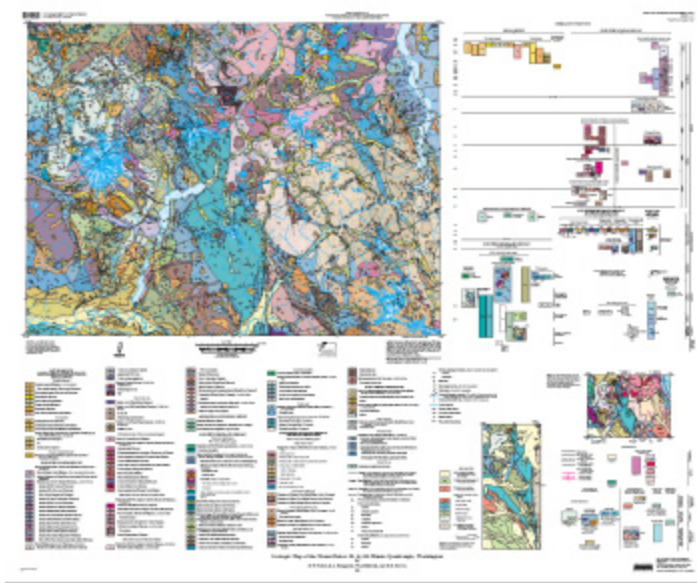


Figure 8. Image of the published Geologic Map of the Mount Baker 30' x 60' Quadrangle (Tabor and others, 2003).



Figure 9. Mount Baker example map, reprojected in the Geologic Mapping Template.

## Exceptions to the Rule

The GMT is designed to be flexible. If additional fields are needed to store additional data, simply add them to the feature classes in the template database. If additional feature classes are needed, add those to the template database. If you want to add cartographic representations from the template database to your own database schema, one option is to follow the steps below:

- a. Load the “Faults” feature class from the “ESRI\_Geology” (GMT folder) feature dataset into a new ArcMap document.
  - b. Open Layer Properties.
  - c. On the Symbology tab, select representations. Click ‘Apply’.
  - d. Select, for example, the thrust fault symbol (2.8.1) .
  - e. Click the ‘Rule Options’ arrow below the symbol window.
  - f. Select ‘Save Rule’ (fig. 10).
  - g. In the “Save Rule to Style” window (fig. 11), make sure the symbol has a name and category. You can opt
- for the default or rename the symbol. For example, instead of naming it by the Reference Number (2.8.1 in this case), you can name it ‘Thrust Fault, identity and existence certain, location accurate’ to follow the convention of the Standard. The representation rule is saved to your personal style.
  - h. Repeat this procedure for each symbol/representation rule needed.
  - i. Add your existing feature class to a blank map document.
  - j. If they don’t already exist, create representations. Right-click the layer and select ‘Convert Symbology to Representation. . .’ (fig. 12).
  - k. Right-click the layer (now with representations) and select ‘Properties’.
  - l. Click the ‘Rule Options’ black arrow again and select ‘Load Rule’ (fig. 13).
  - m. Scroll through the symbol window (fig. 14) until you find the thrust fault symbol (2.8.1). Select the symbol and add the name of the symbol to the Rule ID field.
  - n. Repeat for each additional symbol.

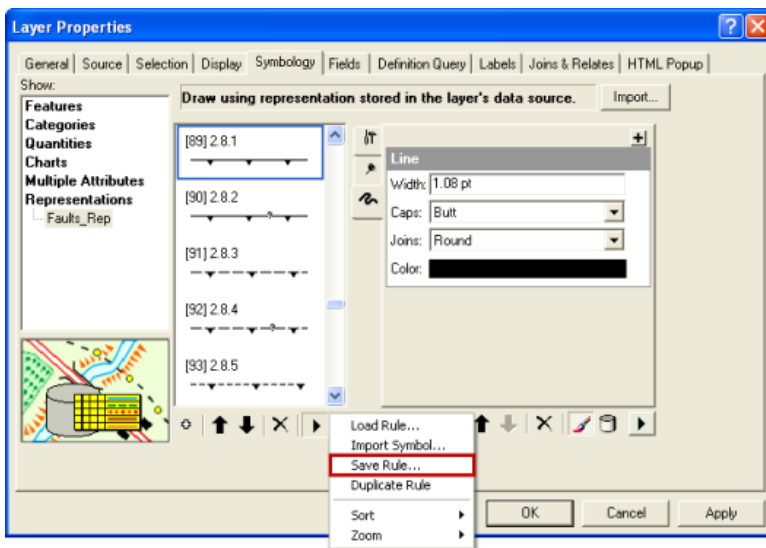


Figure 10. Saving a representation rule.

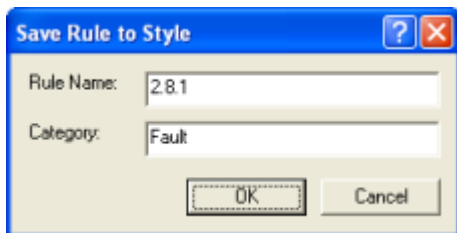


Figure 11. Naming and Categorizing a saved representation rule.

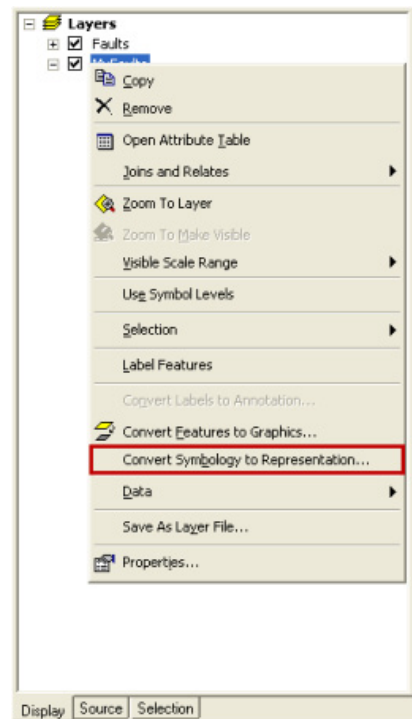


Figure 12. Converting symbology to representations.

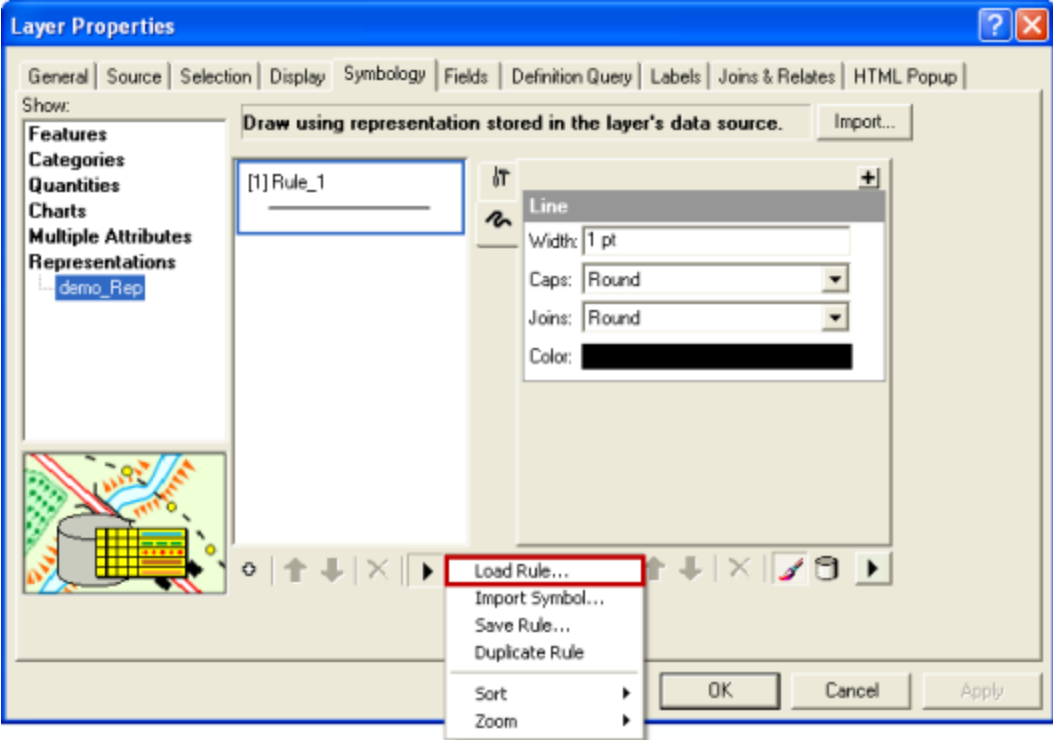


Figure 13. Loading a representation rule.

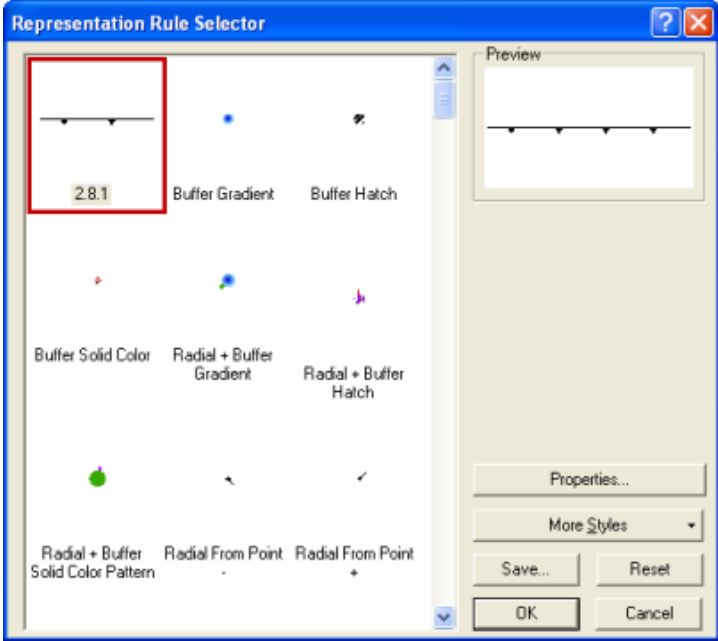


Figure 14. Selecting a saved representation rule.

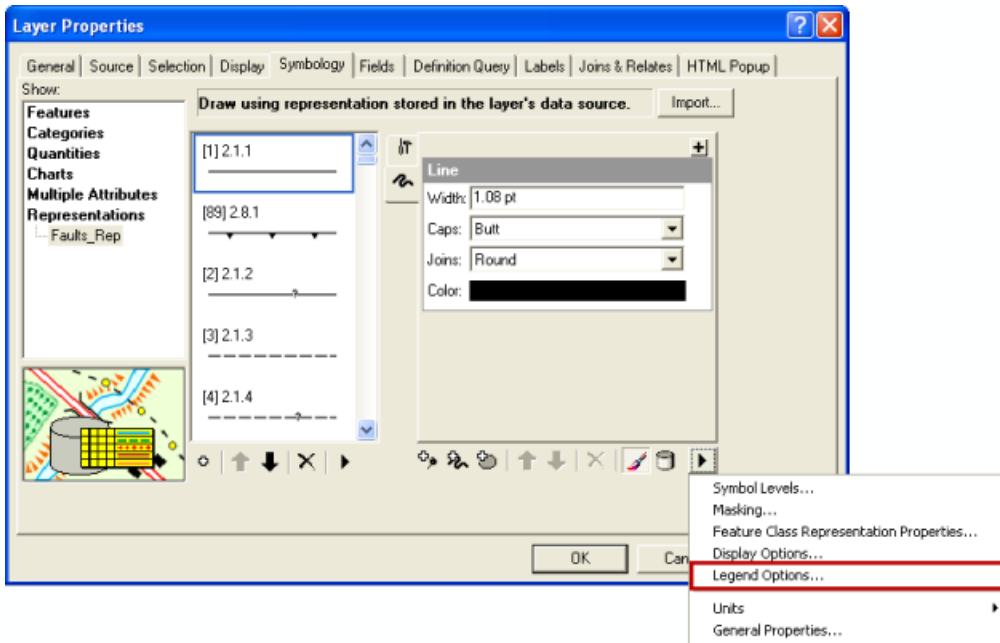
## Tips and Tricks

Cartographic representations are fairly new to ArcGIS Desktop, being released with ArcGIS 9.2. Since cartographic representation functionality differs from traditional methods of symbolizing features in ArcMap, this section offers three tips and tricks for working with cartographic representations efficiently in the template. The examples provided herein can be applied to any feature class.

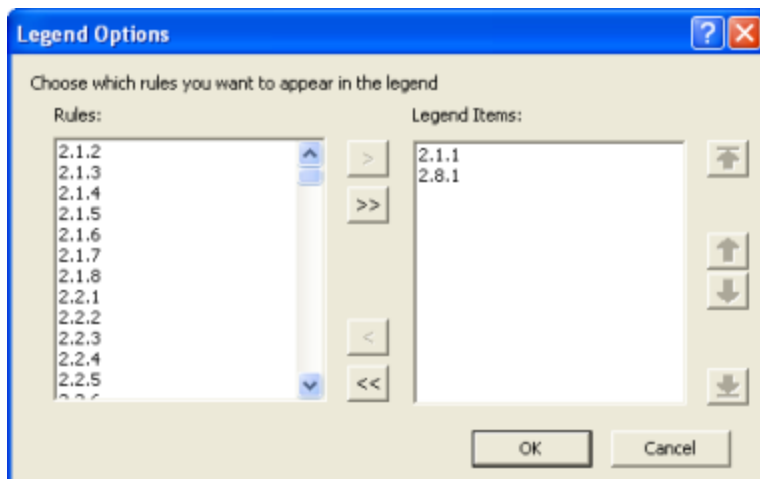
### Tip #1: Limit the number of symbols that draw in the ArcMap Table of Contents and in the map legend

The Faults feature class in the GMT, for example, has several hundred representation rules for each unique symbol type found under the Faults section of the Standard. However, only a subset of these symbols will be needed for any given map. Cartographic representations allow you to select the subset of symbols you would like to appear in the ArcMap Table of Contents and the map legend.

Under 'Legend Options' on the Layer Properties Symbology tab, select the subset of representation rules for the Table of Contents and map legend based on the symbols you need for a particular map (figs. 15 and 16). By selecting the two rules that will appear in the table of contents and in the map legend, these two rules are prioritized and appear at the top of the list in the Representations Layer Properties Symbology view (fig. 17). These rules are the only two rules that appear in ArcMap's Table of Contents (fig. 18).



**Figure 15.** Navigating to Legend Options.



**Figure 16.** Selecting representation rules that will appear in the ArcMap Table of Contents and legend.



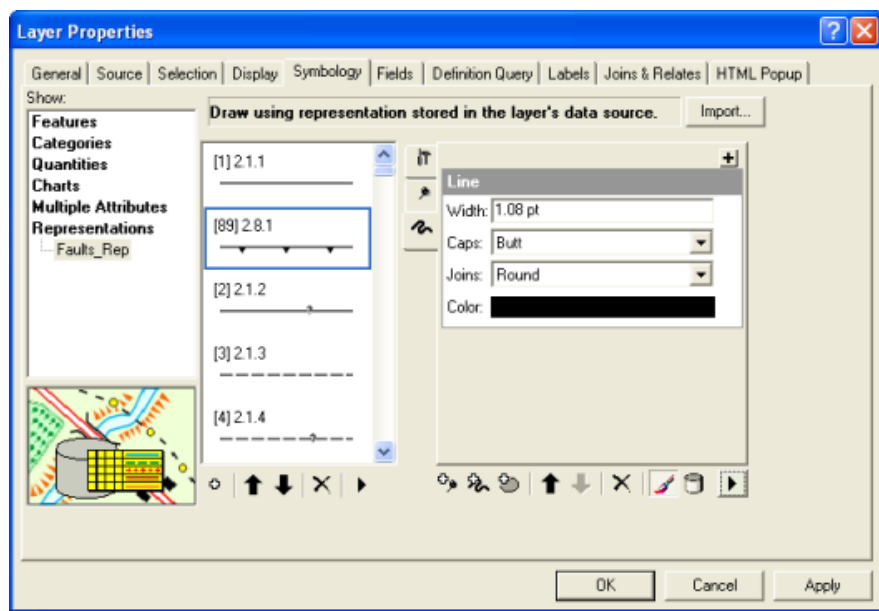


Figure 17. Selected legend items will move to the top of the representation symbology list.

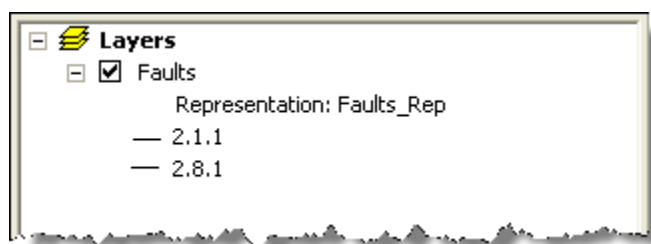


Figure 18. ArcMap Table of Contents view after setting the legend items.

## Tip #2: Renaming representation rules

All of the symbols in the GMT are named by the Reference Number from the Standard. For example, “2.8.1” is the Reference Number that corresponds to the symbol representing a ‘Thrust Fault, identity and existence certain, location accurate’. “2.8.1” is also the symbol name for Rule ID 89. However, this name can be changed. To change it, click in the field next to the Rule ID (the number in brackets, “[#]”) on the Layer Properties Symbology tab and type a new name. You might replace the name with the full name, or a derivation of this name, something like ‘Thrust fault - certain, accurate’ (fig. 19). The new name will appear in the ArcMap Table of Contents (fig. 20) and in the map legend.

## Tip #3: Keep data in the database without drawing the data in ArcMap

A scratch boundary is a good example of a feature that may be maintained in the database, but should not be symbolized on the map. With cartographic representations, this feature would be assigned a <null> Rule ID. When this layer is symbolized with representations in ArcMap, there is an option to not draw the feature, accessible through ‘Display Options’ on the Layer Properties Symbology tab (fig. 21). Uncheck the box next to “Draw representations that have an invalid or null Rule ID” to disable the drawing of those features (fig. 22).

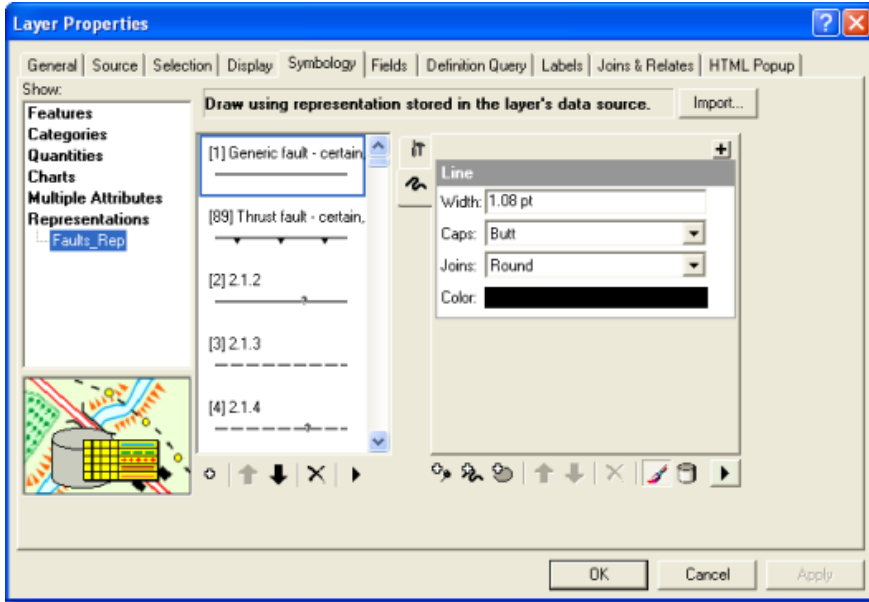


Figure 19. The representation rules, renamed.

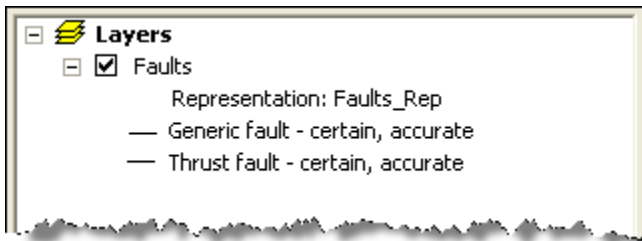


Figure 20. ArcMap Table of Contents view, after renaming the representation rules.

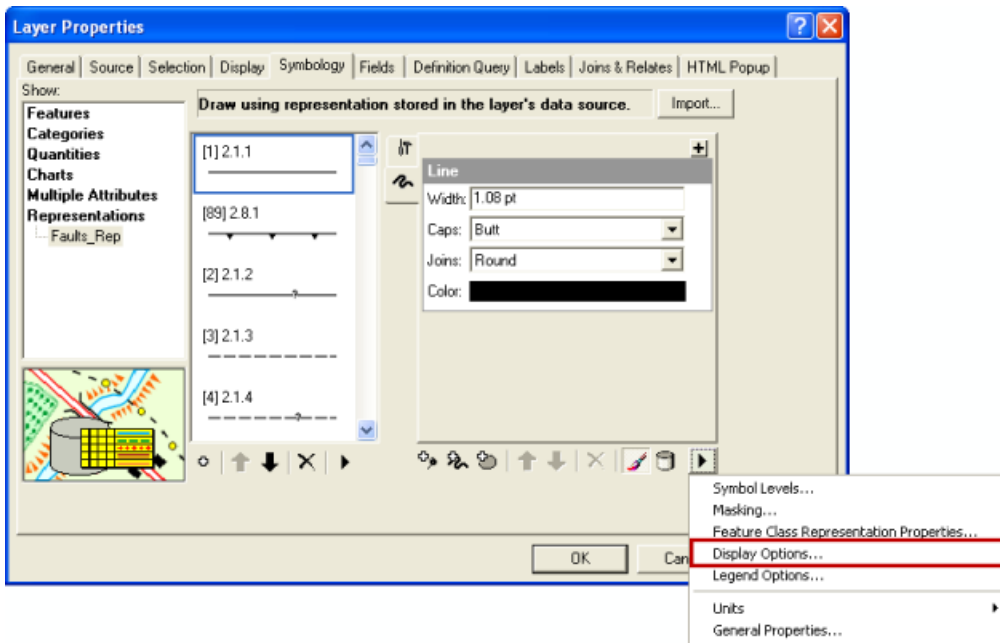


Figure 21. Navigating to Display Options.



**Figure 22.** Unchecking box to draw representations.

## Summary and Conclusion

The GMT is the first ESRI implementation of the FGDC Digital Cartographic Standard for Geologic Map Symbolization. It offers new opportunities and new challenges. For the first time, a standardized symbol set and documented workflow for creating a GIS-based geologic map exists, offering new opportunities in symbology continuity and the efficient production of geologic maps. Yet, there are still the obvious challenges associated with establishing new and appropriate workflows that take advantage of what the GMT offers and support existing mapping needs.

## References

- Federal Geographic Data Committee [prepared for the Federal Geographic Data Committee by the U.S. Geological Survey], 2006, FGDC Digital Cartographic Standard for Geologic Map Symbolization: Reston, Va., Federal Geographic Data Committee Document Number FGDC-STD-013-2006, 290 p., 2 plates, [http://ngmdb.usgs.gov/fgdc\\_gds/geolsymstd.php](http://ngmdb.usgs.gov/fgdc_gds/geolsymstd.php).
- Skipp, Betty, Lageson, D.R., and McMannis, W.J., 1999, Geologic map of the Sedan quadrangle, Gallatin and Park Counties, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-2634, scale 1:48,000, [http://ngmdb.usgs.gov/Prodesc/proddesc\\_23269.htm](http://ngmdb.usgs.gov/Prodesc/proddesc_23269.htm).
- Tabor, R.W., Haugerud, R.A., Hildreth, Wes, and Brown, E.H., 2003, Geologic map of the Mount Baker 30- by 60-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-2660, scale 1:100,000, [http://ngmdb.usgs.gov/Prodesc/proddesc\\_67595.htm](http://ngmdb.usgs.gov/Prodesc/proddesc_67595.htm).
- U.S. Geological Survey Geologic Names Committee, 2007, Divisions of geologic time—Major chronostratigraphic and geochronologic units: U.S. Geological Survey Fact Sheet 2007-3015, 2 p. [updated in 2010; <http://pubs.usgs.gov/fs/2010/3059/>].

