Standardizing and Automating Digital Geologic-GIS Map Symbolization

James R. Chappell[1], Stephanie A. O'Meara[1], James R.H. Winter[1], Ronald D. Karpilo Jr.[1] and Timothy C. Henderson[2]

Colorado State University, Department of Geosciences [1]Poster Author, [2]Co-Presenter

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Introduction

To date the GRI has produced approximately 800 digital geologic-GIS maps. For each of these maps the depiction or symbolization of geologic features (actual, observed, or measured) has been primarily derived from a feature's source map (see Figure 1 for an example of a geologic map legend/ explanation).

As a result of this approach the symbolization of geologic features are not fully standardized, and thus the symbolization of a geologic feature on one map may differ from the symbolization of that same feature on another map. In addition, the process of assigning map symbols to geologic features has utilized non-standard and often incomplete ESRI symbology stylesheets (e.g., Geology 24K or Mining), and is often time-intensive and inefficient.

In an effort to standardize how geologic map features are symbolized on digital geologic-GIS maps the GRI has recently developed a geologic map symbolization standard that is based on the Federal Geographic Data Committee (FGDC) Digital Cartographic Standard for Geologic Map Symbolization. The process for producing geologic map symbolization has also been automated through GRI-developed custom tools that efficiently and accurately produce geologic feature symbolization.

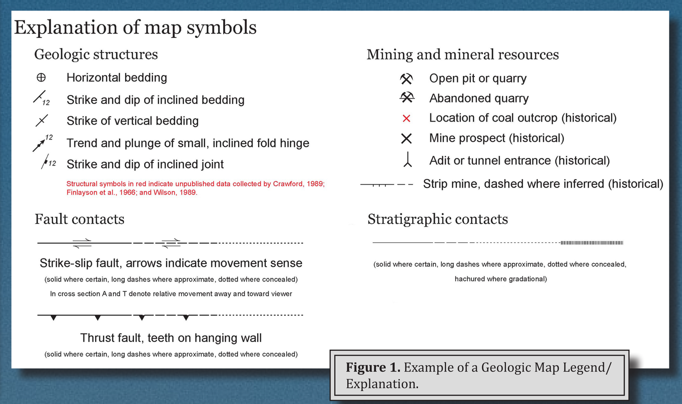


Figure 1. Example of a Geologic Map Legend/ Explanation.

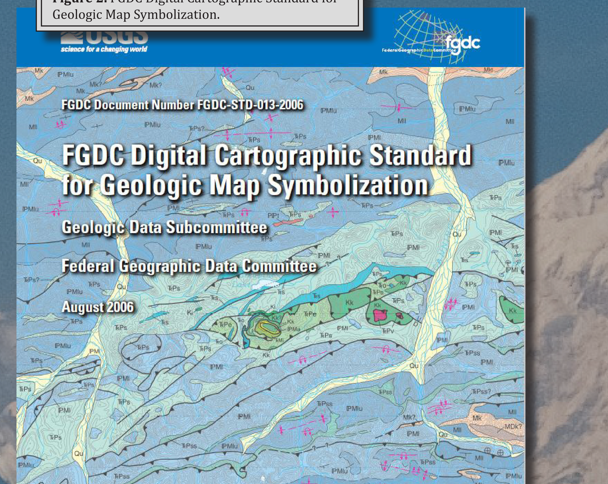
The FGDC Digital Cartographic Standard for Geologic Map Symbolization

The FGDC Digital Cartographic Standard for Geologic Map Symbolization is a standard put forth by the committee as the national standard for the digital cartographic representation of geologic map features. The standard contains cartographic specifications for a wide variety of symbols that may be present on a typical geologic map, and was designed to be useful to anyone who either produces or uses geologic map information (see Figure 2).

The standard implements a system where geologic features are assigned a reference number (abbreviated REF NO. in the standard).

A few agencies such as the Geological Survey of Canada (GSC) and the Alaska Division of Geological & Geophysical Surveys (AKDGGS) have developed digital ESRI ArcGIS stylesheets based on the FGDC standard. However, these stylesheets utilize special fonts, and as such users of GIS data symbolized using stylesheets with these special fonts must have these fonts installed on their operating system otherwise these symbols won't draw correctly.

Figure 2. FGDC Digital Cartographic Standard for Geologic Map Symbolization.



Implementation

To implement the FGDC Digital Cartographic Standard for Geologic Map Symbolization geologic features were first matched or "cross-walked" with their reference number (REF_NO) in the standard. As an example, a "strike and dip of inclined bedding" feature has a reference number value of 6.2 in the standard (see Figure 3).

To store reference numbers in GRI digital geologic-GIS data a Symbology (SYM) field was added to all feature GIS attribute tables. Reference numbers stored in the field are "zero-padded" for numbers between 1 and 9. This enables references numbers, represented as text/string values, to sort as intended. In the example of a "strike and dip of inclined bedding", the feature's GRI reference number would be "06.02". Furthermore, Feature Type (FTYPE) and positional accuracy (POS) field domain values, feature properties that dictate feature symbolization, are appended after underscores to a zero-padded reference number.

In the above example for a strike and dip of inclined bedding, the Symbology (SYM) field would be assigned a value of "06.02_1_1". The first "1" denotes the feature's Feature Type (FTYPE) coded domain value (FTYPE 1 = strike and dip of inclined bedding), whereas the second "1" denotes its Positional Accuracy (POS) coded domain value (POS 1 = known or certain).

To store matched (cross-walked) feature types and/or positional accuracy values with their corresponding reference numbers the GRI developed a GRI-FGDC symbology Excel spreadsheet. The reference number of any feature can be looked up by first selecting the tab of its feature class or data layer, then looking up the feature's Feature Type (FTYPE) and/or Positional Accuracy (POS). In addition to the spreadsheet, the GRI has also developed an ESRI stylesheet based on the FGDC standard.

One significant issue with fully implementing the FGDC standard, however, has been that many features present on GRI digital geologic-GIS maps are not found within the standard. To address this issue the GRI has assigned new reference numbers to features not found in the standard and where possible has adhered to standard naming and organization conventions. For features where no existing feature group exists within the standard (e.g., map symbology) new groups are added. New feature groups are simply assigned the next available group-level number, starting with the first number after the standard's last group number.

A significant change in implementing the standard "as is" is that the GRI controls some discrete line-related properties such as fold symbols and fault displacement symbols (e.g., lateral movement, bar-and-ball, and "U" and "D") by representing these as points. This allows these symbols to be located and rotated as desired (true to the source map), and not as a component of line symbology where their placement and rotation generally can't be fully controlled. Another difference in implementation is the GRI does not use patterns for area feature or unit symbology. The primary reasons being that the GRI report team found it difficult to match patterns when producing graphics displaying map units (e.g., a stratigraphic column), and that patterns present negative complexities that affect the display of area features.

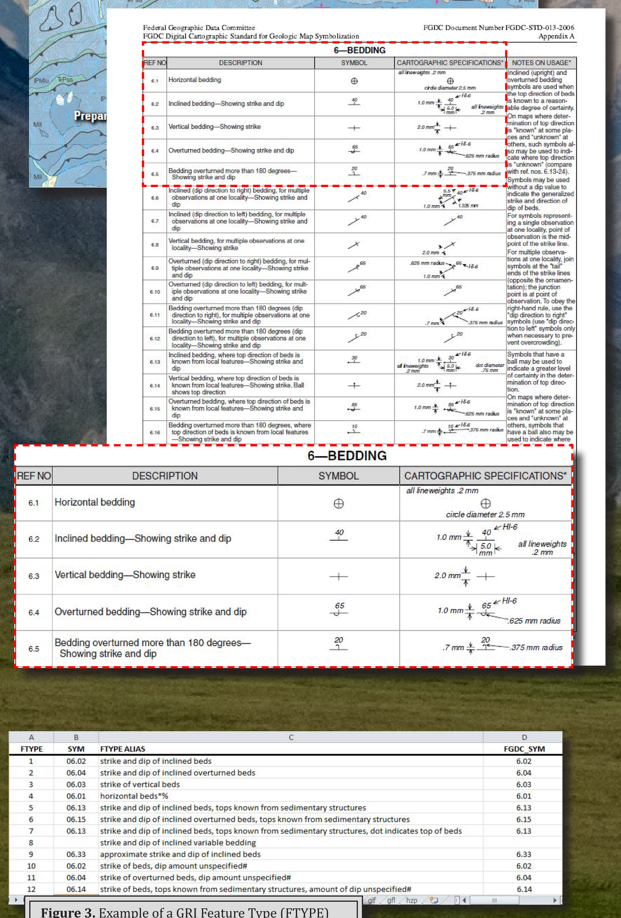


Figure 3. Example of a GRI Feature Type (FTYPE) "cross-walk" to FGDC Reference Numbers (REF_NO).

The panels to the right of this panel focus on the GRI's efforts to automate standardized digital geologic-GIS symbolization (Panel 2), as well as present additional considerations pertaining to utilizing symbolization for data production (digitization) and quality assurance (Panel 3).

The Geologic Resources Inventory

The Geologic Resources Inventory (GRI) is one of twelve inventories funded under the National Park Service (NPS) Natural Resource Challenge. The goal of the GRI is to increase understanding of the geologic processes at work in parks and provide accurate geologic information for use in park decision-making. Sound park stewardship relies on understanding natural resources and their role in the ecosystem, of which geology is the foundation. The GRI program is a partnership between the NPS and Colorado State University (CSU), and relies heavily upon the U.S. Geological Survey, individual state geological surveys, and other organizations in developing its source map products. CSU research associates work side-by-side with NPS GRD GRI staff to facilitate a scoping meeting that identifies park mapping needs, as well as park-specific geologic issues, features, and processes.

Overview of GRI Products

In addition to the geologic-GIS data the GRI also produces a basic cartographic layout and a geologic report. The layout displays a park's geologic map complete with prominent features and localities within and around the park. The report is a comprehensive document that presents a park's: (1) geologic significance, (2) geologic history, and (3) discusses prominent geologic features, processes and issues, and presents this in a scientific format directed at park resource managers.

To ensure that GRI digital geologic-GIS data is accessible to a variety of users, from basic users to advanced GIS users, the GRI now publishes digital geologic-GIS maps in multiple GIS product formats. These product formats are: 1.) ESRI file geodatabase and accompanying ESRI map document and layer files for use with ESRI ArcGIS software, 2.) ESRI file geodatabase and accompanying ESRI map file and layer files for use with ESRI ArcGIS Pro software, 3.) Open-source GeoPackage with an accompanying (for most maps) open-source map file for use in open-source software, 4.) KML/KMZ file for use with Google Earth software, and planned 5.) an ESRI map service for use in ESRI ArcGIS Online (AGOL) and other online web service applications.

To achieve producing multiple GIS data formats the GRI first produces its digital geologic-GIS data in ESRI ArcGIS, a file geodatabase and ArcMap document, then utilizes custom GRI-developed tools and scripts developed in vb.NET and Python, as well as a few ArcGIS out-of-the-box tools to produce the other supported GIS product formats.

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GRI FGDC Style

The GRI-FGDC Style (see Figure 4) is a custom ESRI Style modeled from the Geological Survey of Canada- (GSC) FGDC Style with regards to symbol reference number, naming, and organization. The GRI-FGDC Style, in contrast to the GSC-FGDC Style, was developed from fonts available within a standard ArcGIS install and thus requires no custom fonts to deploy and install. The GRI-FGDC Style is a work in progress where new symbols are added as they are needed for newly identified features that aren't yet represented in the Style. Symbols that are not present in the FGDC standard are added to the GRI-FGDC Style using the source map for symbol specifications. Figure 5 shows the ArcGIS Symbol Property Editor which is used to create symbols.

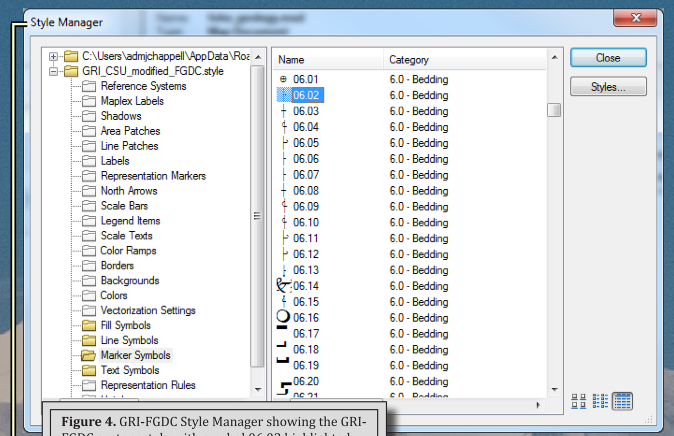

Figure 4. GRI-FGDC Style Manager showing the GRI-FGDC custom style with symbol 06.02 highlighted.

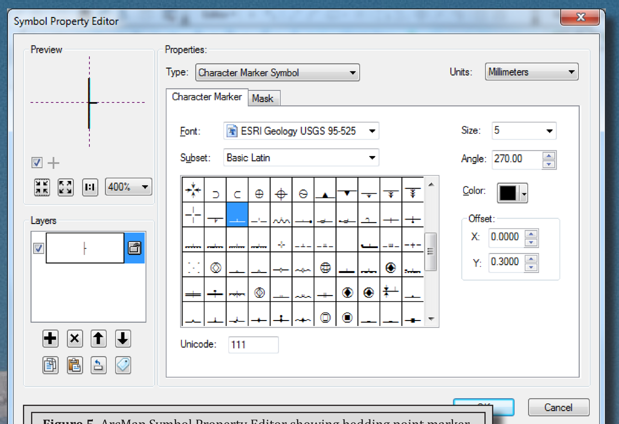

Figure 5. ArcMap Symbol Property Editor showing bedding point marker design for symbol 06.02 in the GRI-FGDC Style.

GRI Symbology Tools

A pair of custom ESRI AddIns were developed by the GRI to automate the standardization and creation of feature symbology. Both AddIns were developed with ArcObjects and VB.Net. The tools run only on visible layers in an ArcMap document. This enables layer by layer processing with the ability to exclude layers from processing. Both tools are designed to be iterable so that layer symbology can be refined if needed.

Update Sym Field AddIn

The Update Sym Field Addin populates each feature's Symbology (SYM) field based on unique Feature Type (FTYPE) and/or Positional Accuracy (POS) values. The tool searches through each layer identifying available Feature Type (FTYPE) and/or Positional Accuracy (POS) values and cross-walks them to the corresponding FGDC reference number in the GRI-FGDC Symbology Spreadsheet. The resulting Symbology (SYM) field value is a concatenation of the FGDC reference number and the Feature Type (FTYPE) and/or Positional Accuracy (POS) field values.

Update Layer Symbology AddIn

The Update Layer Symbology Addin reads in feature Symbology (SYM) field values and updates layer symbology, based on the FGDC reference number, with the corresponding symbol from the GRI-FGDC style. Additionally, this tool reads in geologic symbol, name, age, and RGB color information from the unit sorting spreadsheet and updates geologic unit labels and symbology.

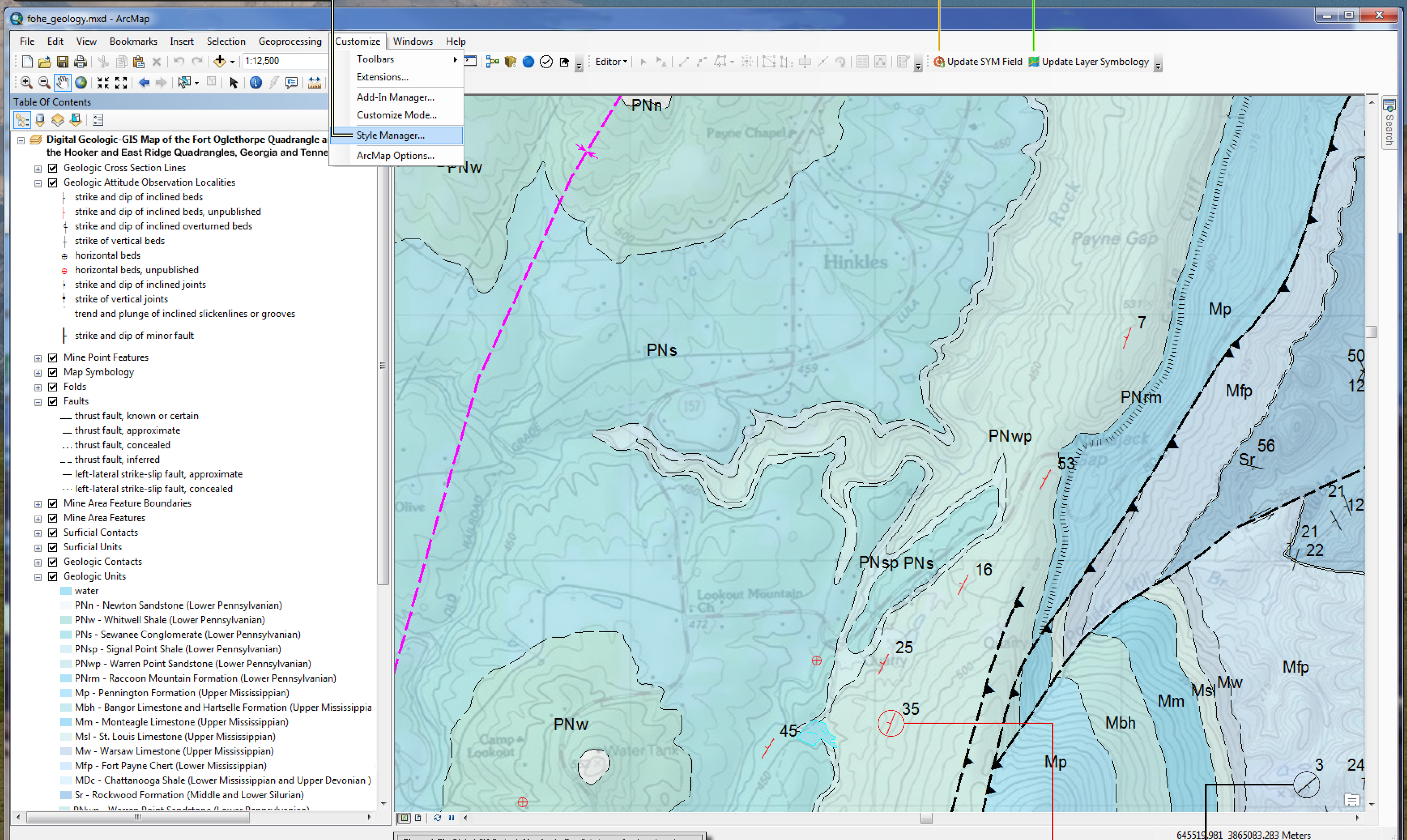

Figure 6. The Digital-GIS Geologic Map for the Fort Oglethorpe Quadrangle and parts of the Hooker and East Ridge Quadrangles in ArcMap showing GRI-FGDC symbology.

GRI Unit Sorting Spreadsheet

The GRI Unit Sorting Spreadsheet is a park project's central repository for geologic unit name, symbol, age, and relative sorting information. The spreadsheet is used to develop a sorting of units, primarily based on age, but also to serve as a source for other GRI product derivative unit information including unit colors for use with unit symbolization. A symbology tab containing ArcMap legend alias information, calculated from unit information contained in the spreadsheet, and associated RGB color values is then used in the symbolization process (see Figure 7). The Update Sym Field AddIn reads from this tab, updates the ArcMap legend, and assigns RGB color values to each geologic unit.

	Unit Name	Sort Number	Red	Green	Blue
2	Qal - Alluvial Deposits (Quaternary)	1	248	245	174
3	PNn - Newton Sandstone (Lower Pennsylvanian)	2	243	248	252
4	PNw - Whitwell Shale (Lower Pennsylvanian)	3	179	225	223
5	PNs - Sewanee Conglomerate (Lower Pennsylvanian)	4	167	224	235
6	PNsp - Signal Point Shale (Lower Pennsylvanian)	5	208	236	247
7	PNwp - Warren Point Sandstone (Lower Pennsylvanian)	6	202	233	236
8	PNrm - Raccoon Mountain Formation (Lower Pennsylvanian)	7	157	221	246
9	Mp - Pennington Formation (Upper Mississippian)	8	168	225	252
10	Mb - Bangor Limestone (Upper Mississippian)	9	168	220	270
11	Mbh - Bangor Limestone and Hartselle Formation (Upper Mississippian)	10	188	229	235
12	Mh - Hartselle Formation (Upper Mississippian)	11	188	240	220
13	Mm - Monteagle Limestone (Upper Mississippian)	12	149	216	245
14	Msl - St. Louis Limestone (Upper Mississippian)	13	218	239	242
15	Mw - Warsaw Limestone (Upper Mississippian)	14	199	217	239
16	Mfp - Fort Payne Chert (Lower Mississippian)	15	206	230	254
17	MDc - Chattanooga Shale (Lower Mississippian and Upper Devonian)	16	217	240	254
18	Sr - Rockwood Formation (Middle and Lower Silurian)	17	159	200	232
19	Os - Sequatchie Formation (Upper Ordovician)	18	199	198	229
20	Ona - Nashville Group, undivided (Middle Ordovician)	19	185	210	200
21	Ocy - Catheys Formation (Middle Ordovician)	20	182	198	232
22	Ocycn - Catheys Formation and Cannon Limestone, undivided (Upper and Middle Ordovician)	21	190	200	200
23	Ocycnh - Catheys Formation, Cannon Formation, Hermitage Formation, undivided (Upper and	22	160	190	215
24	Ocn - Cannon Limestone (Middle Ordovician)	23	217	218	238
25	Ocnhsr - Cannon Limestone, Hermitage Formation and Stones River Group, undivided (Middle	24	175	195	220
26	Oh - Hermitage Formation (Middle Ordovician)	25	136	158	205
27	Och - Chicamauga Limestone, undifferentiated (Middle Ordovician)	26	210	180	200
28	Osr - Stones River Group, undivided (Middle Ordovician)	27	212	165	204
29	Oca - Carters Limestone (Middle Ordovician)	28	209	199	224
30	Olb - Lebanon Limestone (Middle Ordovician)	29	182	161	204

codeunit | PDF Unit Listing | PDF Unit Topics | Domains | Symbology

Figure 7. GRI Unit Sorting Spreadsheet showing Symbology tab containing ArcMap TOC description for geologic unit layers and associated RGB values.

Custom Symbolization

Customization of feature symbology is used to display specific features with non-standard symbology. For example, distinguishing published from non-published bedding points (see Figure 8). Customizations can be used to create custom symbology as per the source map. Customizations are stored in the Symbology (SYM) field and in the GRI-FGDC spreadsheet so that they can be tracked for use with future projects.

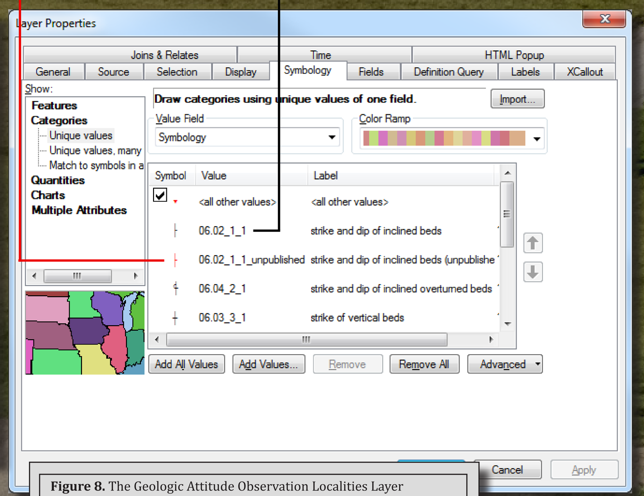

Figure 8. The Geologic Attitude Observation Localities Layer Properties dialog showing custom symbology for unpublished bedding points. Bedding points colored red on the source map were identified as coming from unpublished sources. Custom symbolization was utilized to symbolize these features differently from standard bedding points by modifying the Symbology (SYM) field value and coloring the respective symbol red.

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Utility in Map Digitization

Creating feature symbology can be a time-consuming process as this often involves searching for an appropriate symbol, then in many cases adjusting the symbol size, angle, color, rotation, and/or x/y offset. Additionally, errors made during this process are then propagated to the data during map digitization.

Figure 9 shows a strike and dip symbol that has not been rotated or centered properly during digitizing setup. As a result, every strike and dip symbol in the data has been rotated incorrectly and placed approximately 10 meters from its mapped location.

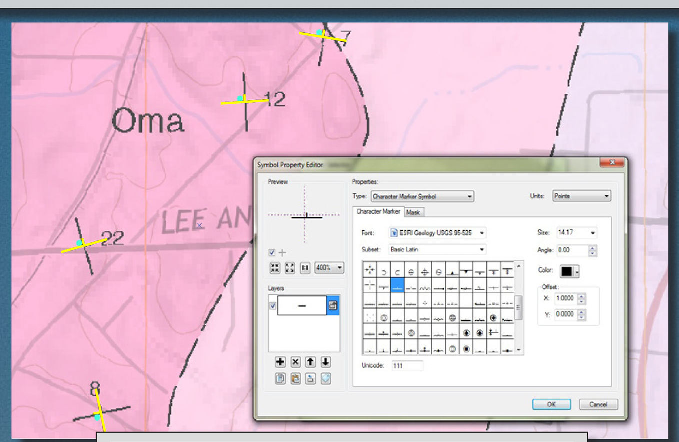

Figure 9. Example of an ArcMap document showing several strike and dip symbols and the Symbol Property Editor. The source map image features are shown in black and the digital data symbols are shown in yellow.

Utility in Quality Assurance

Symbolizing a map can improve data quality by providing a direct visual comparison between the digital data and its source map image. Figure 10 illustrates how running the GRI Symbology Tools on an existing dataset helps identify errors in the digital data.

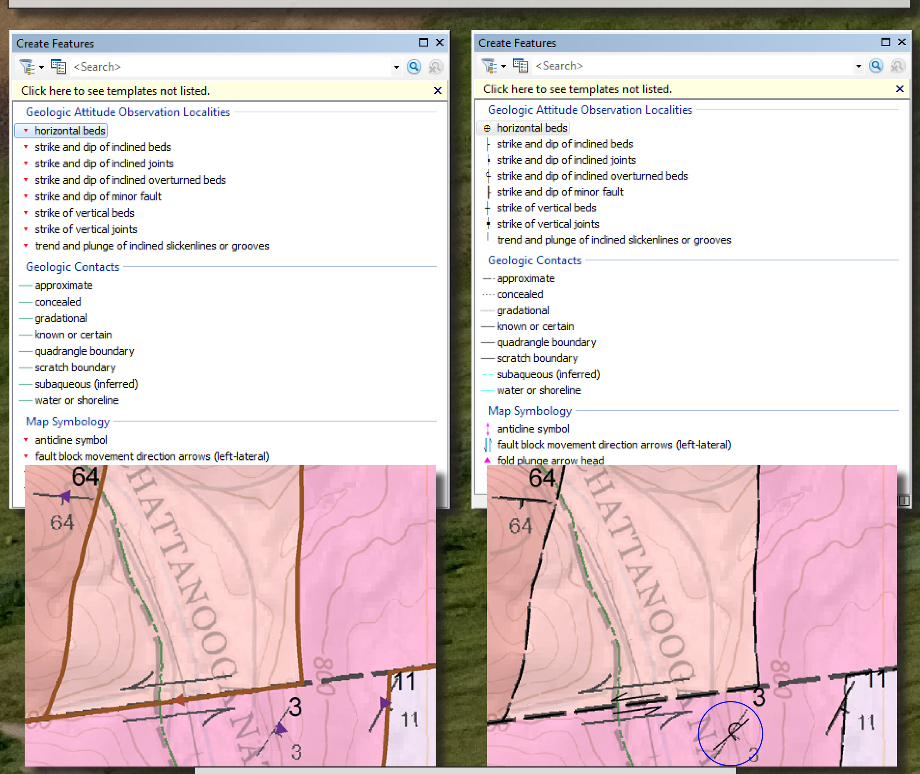

Figure 10. Example showing the Create Features dialog box and an ArcMap document before and after running the symbology tools. The blue circle on the right figure shows a feature that has an incorrect Feature Type (FTYPE) and Strike (ST) azimuth.

What about representations?

Representations are another way to symbolize data in ArcMap and ArcGIS Pro. They are composed of a set of representation rules that stipulate how features within a feature class are symbolized. Representations are unique because they can be used to alter the geometry of data through dynamic feature geometry and because representation symbology is stored with the data in an ESRI geodatabase.

When representations are added to a feature class, two fields are appended to its attribute table. The first field (RuleID) stores an integer (with a coded value domain) that is a reference to a representation rule. The second field (Override) stores feature-specific customizations to representation rules and can even store changes to the representation geometry of a feature.

Although representations may be a useful tool for creating certain cartographic products representations are not supported in shapefiles or other non-geodatabase formats which the GRI produces and presently there are no means to extract representation symbology for use with these formats. Additionally representations can be displayed in ArcGIS Pro, but not edited.

Conclusion

Before the creation of the GRI Symbology Tools the symbolization of geologic features was done manually and was derived as per the source map. This process was time-intensive and resulted in the same features being symbolized differently from map to map.

With the goal of standardizing map symbolization, the GRI developed a geologic map standard based on the Federal Geographic Data Committee (FGDC) Digital Cartographic Standard for Geologic Map Symbolization. Analogous to the FGDC standard, the GRI standard cross-walks geologic features to a reference number and stores them in a Symbology (SYM) field in feature GIS attribute tables. These reference numbers are then matched to the symbols in the GRI-FGDC stylesheet to symbolize a map. To implement this standard efficiently the GRI has developed a pair of ESRI custom AddIns that automate the process of map symbolization while insuring that geologic features are accurately depicted and standardized across maps.

Software and References

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