DNAG Geologic Map of North America GIS Implementation: Overview and Progress

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PURPOSE[1]

When plans for the Geologic Map of North America (GMNA) were being made, the notion of geologic map databases was in its infancy. At that time, and for many years thereafter, few geologists were familiar with the design and use of databases to manage geologic map information. In 1998, the Geological Society of America (GSA) and the United States Geological Survey (USGS) National Geologic Map Database project agreed to cost-share the digital preparation of this map. The plan was to digitize the hand-drawn, author-prepared geologic compilations for the four map quadrants, in order to provide digital data for two purposes: (1) to allow GSA to print the map, and (2) to permit the National Geologic Map Database project to develop a prototype database for this map. When the map was printed, the National Geologic Map Database project began to design and implement the GMNA for use in a Geographic Information System (GIS), based on certain assumptions regarding the anticipated content of, and uses for, the map database as it gradually evolved from the printed map. In mid-2006, a GIS prototype of the GMNA (Garrity and Soller, 2006) was provided to the organizations principally responsible for map compilation (GSA, USGS, Geological Survey of Canada, and Woods Hole Oceanographic Institute), in order to initiate discussion and decisions on how the map database would be designed, managed, and served to the public and cooperators. These discussions were successfully concluded, and in 2007 construction of the database began. The first version of this database will contain the geologic information observable from the printed map and accompanying explanation sheet. It will serve as the fundamental entity from which products of the map can then be derived. These products may be interpretive, or they may be future editions of the map.

To produce any future editions of the map, the database will incorporate all map revisions that are necessitated by detection of compilation errors and by new regional mapping and interpretations. Further, the geologic unit descriptions shown on the printed map can be supplemented in the database by more richly attributed information derived from the many sources that were used to compile the map. This capability to revise the printed map and to include additional descriptive information for map units is one of the primary reasons for building the database; the other reason is, of course, the analytical capabilities made possible by providing the map in a digital, GIS compatible format.

The creation of this database and its enhancement to include new mapping and more richly attributed information is a daunting task that will require a significant amount of time and effort. Recognizing that a group of dedicated and knowledgeable scientists is essential to make this database useful and to keep its content up to date, GSA will develop a consortium of geological agencies to manage the database.

DATABASE DESIGN

The design of this first version of the GMNA database reflects the information structure of the printed map. As the database evolves, data attributes will be modified to make the database more comprehensive and useful. Also, future versions of the GMNA database may incorporate elements of the North American Data Model (*http://nadm-geo.org/*) and be harmonized in content with the International Geological Map of Europe (*http://www.bgr.de/karten/IGME5000/igme5000.htm*). Figure 1 shows the geologic features found

[1] Modified from Soller, *in* Reed et al. (2005)

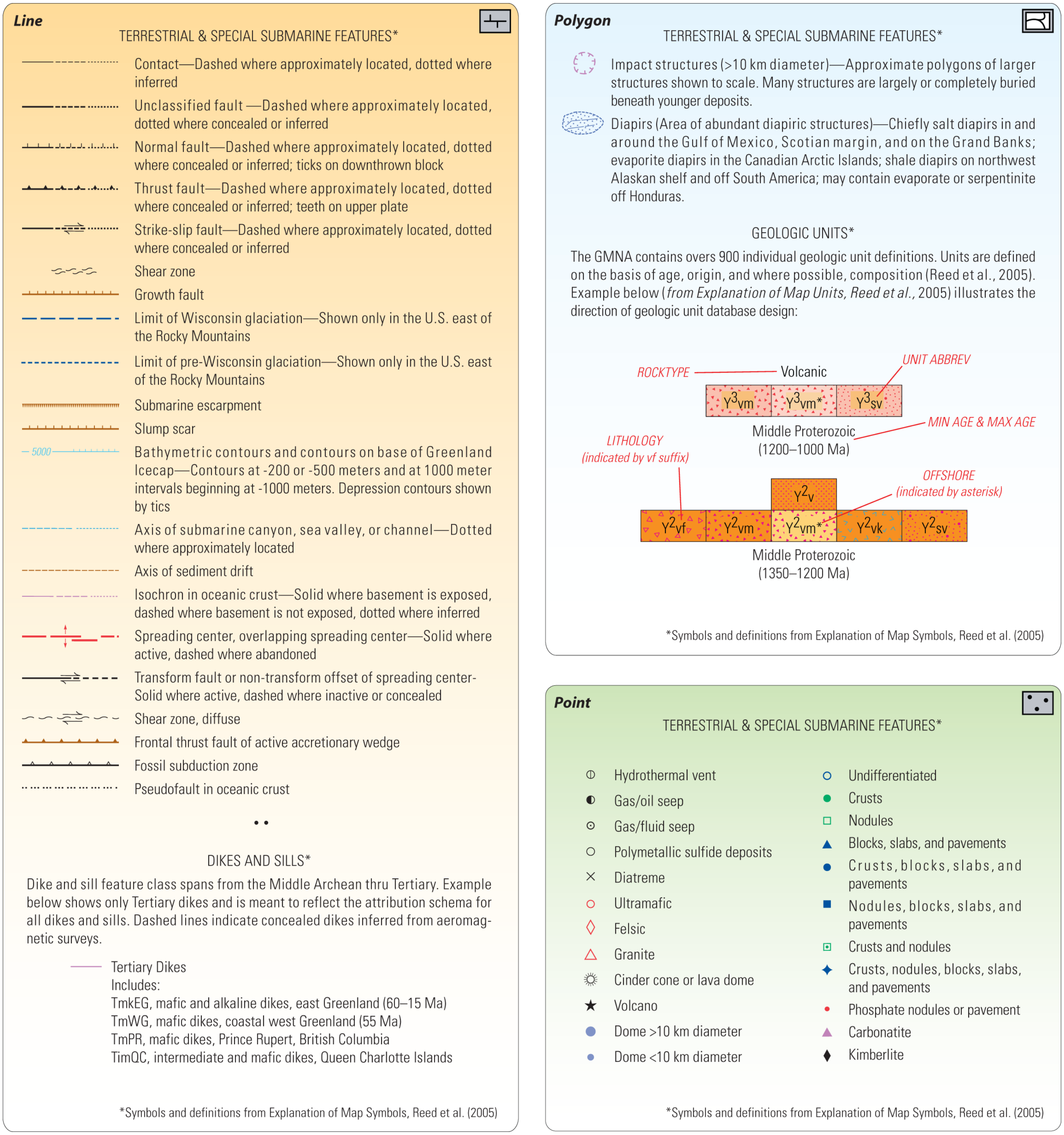

Figure 1. Features of the geologic map of North America grouped by feature geometry type.

on the printed GMNA, and how they are generally organized in the database. Figure 2 specifies the organization of these features in the ESRI Geodatabase structure.

GEOLOGIC UNIT ATTRIBUTES

For this first version of the database, we strove to capture the information exactly as it was depicted in the GMNA explanation sheet that accompanies the published map. For geologic map units, the database's attribute list includes:

GMNA GEODATABASE DESIGN

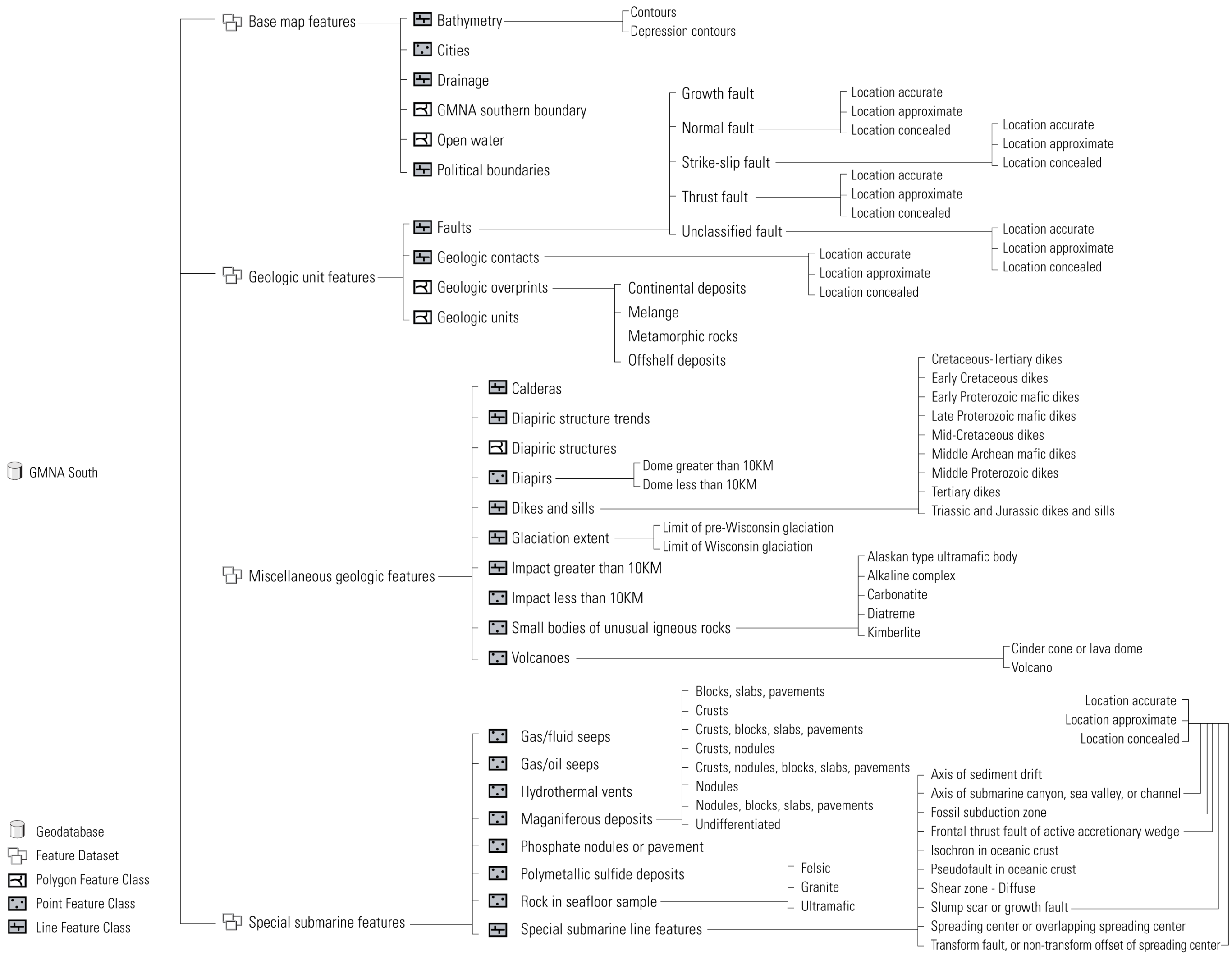

Figure 2. Database design of the Geologic Map of North America. Primary bracket includes feature datasets, secondary bracket includes features classes, tertiary and quaternary brackets include feature class subtypes.

- ROCKTYPE – the "top level" rock classification (sedimentary, plutonic, volcanic, metamorphic).
- LITHOLOGY – the simplified description included for each geologic unit on the explanation sheet of the GMNA.
- ROCK_UNIT_NOTE – special notes associated with certain units on the explanation sheet of the GMNA. For example, selected volcanic rocks are attributed "Basalt adjacent to active spreading centers", selected metamorphic rocks are attributed "Granulate facies metamorphism", and selected sedimentary rocks are attributed "Continental deposits".
- UNIT_UNCERTAINTY – a query following the map unit code indicates uncertainty about composition, or whether the rock was recovered in situ from the ocean bottom.
- MIN_AGE – minimum geologic age for the unit. Subdivisions of time-stratigraphic units are lower, middle, and upper (lower-case), and for plutonic rocks are Early, Middle, and Late
- MAX_AGE – see comments for MIN_AGE.
- MIN_AGE_CODE – code derived from the geologic age codes defined by the AAPG Committee on Standard Coding (1967)
- MAX_AGE_CODE – see comments for MIN_AGE_CODE.
- AGE_UNCERTAINTY – a query preceding the map unit label indicates uncertainty about the assigned age.
- MAP_UNIT_CODE – the GMNA map unit code
- MIN_MAX_RELATE – the relationship ("and", "or", "thru") between the MIN/MAX ages of units bounded by multiple ages.

PROCESSING STEPS

The following steps are taken to process the source digital files into the GMNA database:

1. Adobe Illustrator files containing linework used for the hard copy production of the Geologic Map of North America (GMNA) were obtained from USGS cartographers in Reston, VA. The two (northern and southern) Illustrator source files were massive, with layer counts totaling over 1,500 each.
2. Files were analyzed to determine if direct import of the entire Adobe Illustrator file to ArcGIS was possible. When observed at scales far more detailed than that of the printed map, the files showed numerous areas where problems in topological relationships existed. Common topological problems in these areas included polygons that overlapped or had gaps between them, overlying line layers (contacts, faults, etc.) which were not coincident with polygon boundaries, and line features that self-overlapped. Topological errors were estimated in the hundreds of thousands.
3. To avoid the time consuming process of correcting each topological error due to the direct import of all features from Adobe Illustrator to ArcGIS, only the non-geologic contact linework coincident with geologic unit boundaries was imported. For attribution purposes, each line type (inferred thrust fault, concealed thrust fault, etc.) was imported to ArcGIS individually.
4. The remaining linework (geologic contacts) was isolated in Adobe Illustrator and exported as a series of high-resolution (~600-1200 dpi) monochrome raster tiles. Export at lower resolutions resulted in "blobbing" of raster cells in areas where very intricate linework existed, making them undesirable for auto-vectorization purposes.
5. When computer generated graticules plotted on stable base media were overlain on the printed version of the GMNA, unsystematic registration shifts at latitude-longitude intersections were observed throughout the printed version of the GMNA. Although shrinking/swelling of base media may have contributed to the registration inconsistency, it is more likely that error was introduced in the numerous iterations (and numerous technological changes in cartographic production) of the GMNA over its twenty year history of compilation. As a result, the monochrome tiles exported from Adobe Illustrator had to be rubber sheeted to local geographic coordinate positions using control points in the DNAG projection (Snyder, 1987).
6. Georeferenced monochrome images were auto-vectorized using ArcScan. Gaps and overlaps between tiles due to rubber sheeting were rectified via raster painting tools.
7. Topology rules were set in ArcMap and line dangles in the newly vectorized layer were snapped to the nearest unit-bordering line features imported in process step 3. This resulted in a topologically clean layer.
8. Individual geologic unit layers were batch exported from Adobe Illustrator and used to overlay the feature class created in step 7. Through spatial querying, polygons in the new layer that had their center within a specific overlay layer were attributed based on the overlay's geologic unit abbreviation.
9. Remaining attribution for all other fields was completed quickly through VBA field calculator scripting based on the populated unit abbreviation field.
10. Feature class symbolization was created to closely resemble the printed version of the GMNA. Feature class symbology was exported to layer files.

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