The National Geologic Map Database Project – 2007 Report of Progress

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Development and management of geologic map databases for support of societal decisionmaking and scientific research is a critical need. The National Geologic Mapping Act of 1992 (*http://ncgmp.usgs.gov/ncgmpabout/ngmact/ngmact1992*) and its subsequent reauthorizations mandate the creation and maintenance of a National Geologic Map Database (NGMDB, *http://ngmdb.usgs.gov*) as a national archive of spatially referenced geoscience data, including geology, paleontology, and geochronology. The Act further stipulates that all new information contributed to the NGMDB must adhere to technical and science standards that are to be developed as needed under the guidance of the NGMDB project. Development of a national database and its attendant standards is a daunting task that requires close collaboration among all geoscience agencies in the U.S., at the State and Federal levels. The Act, therefore, creates the environment within which the USGS and the Association of American State Geologists (AASG) can collaborate to build the NGMDB and also serve the needs of their own agencies.

From the guidelines in the National Geologic Mapping Act, and through extensive discussions and forums with the geoscience community and with the public, a general strategy for building the NGMDB was defined in 1995. Based on continued public input, the NGMDB has evolved from a concept to a set of resources that substantially help the Nation's geological surveys provide to the public, in a more efficient manner, standardized digital geoscience information.

The NGMDB is designed to be a comprehensive reference tool and data management system for spatial geoscience information in paper and digital form. It consists of the following: 1) a Map Catalog containing limited metadata for all paper and digital geoscience maps and book publications that contain maps (including maps of any part of the Nation, published by any agency), online viewable images of paper and digital maps, and links to online data; 2) the U.S. Geologic Names Lexicon; 3) the Mapping in Progress Database; 4) nationwide geologic map coverage at intermediate and small scales; 5) an online database of geologic maps (predominantly in vector format; planned as a distributed system); 6) a set of Web interfaces to permit access to these products; and 7) a set of standards and guidelines to promote more efficient use and management of spatial geoscience information. The NGMDB system is a hybrid – some aspects are centralized and some are distributed, with the map information held by various cooperators (for example, the State geological surveys). Through a primary entry point on the Web, users can browse and query the NGMDB, and obtain access to the information wherever it resides.

The Congressional mandate for state-federal collaboration has proven invaluable, facilitating progress on many technical issues that would otherwise have been much more difficult to achieve. The NGMDB's long record of accomplishment owes a significant debt to its many collaborators, and to the institutions with which it interacts (Appendix A). Each year in these Proceedings, and at numerous meetings and presentations, technical plans and progress are reported. In order to minimize repetition in this report, I have limited the background and explanatory information, which are contained in previous reports of progress (Appendix B; in particular the 2005 report).

PROJECT ORGANIZATION

The project consists of a set of related tasks that will develop, over time, a NGMDB with increasing complexity and utility. This is being accomplished through a network of geoscientists, computer scientists, librarians, and others committed to supporting the project's objectives. **Phase One** of this project principally involves the building of a comprehensive Geoscience Map Catalog of bibliographic records and online images of all available paper and digital maps, and many books, guidebooks, and journal articles that either include maps or describe the geology of an area; although the project's name refers only to maps, the Catalog contains information

related to the numerous earth-science themes specified in the National Geologic Mapping Act of 1992. Critical to this first phase is the design and development of the U.S. Geologic Names Lexicon (Geolex), the Mapping in Progress Database, and the National Paleontology Database. **Phase Two** addresses the development of standards and guidelines for geologic map and database content and format. **Phase Three** is a long-term effort to develop a distributed database containing nationwide geologic map coverage at multiple map scales, populated according to a set of content and format specifications that are standardized through general agreement among all partners in the NGMDB (principally the AASG and USGS); this database will be integrated with the databases developed in Phase One. The NGMDB project's technology and standards development efforts also are coordinated with various international bodies, including the Federal Geographic Data Committee, ESRI, the North American Geologic Map Data Model Steering Committee (NADM), the U.S. National Science Foundation's database management and interoperability projects, the IUGS Commission on the Management and Application of Geoscience Information ("IUGS CGI"), the IUGS Commission on Stratigraphy, the IUGS-affiliated Commission for the Geological Map of the World, and the International Association of Mathematical Geology (IAMG).

A full realization of the project's third phase is not assured and will require a strong commitment among the cooperators as well as adequate technology, map data, and funding. The project will continue to assess various options for development of this database, based on realistic funding projections and other factors. During the development of these phases of the NGMDB, extensive work will be conducted to generate Web interfaces and search engines and to continually improve them, and to develop the data management and administrative protocols necessary to ensure that the NGMDB will function efficiently in the future. The NGMDB's databases and project information can be found at *http://ngmdb.usgs.gov*.

PROGRESS IN 2007

Phase One

A wealth of geoscience information is available in various paper and digital formats. With the emergence of the Internet and Web, the public has come to expect rapid, easy, and unfettered access to government data holdings. Geoscience data must therefore become widely available via the Web, and the concepts presented in its products must be understandable to the public. If our information is more readily available to the public, and if tools are offered to help integrate and provide access to that information, its utility may be greatly increased.

However, providing effective public Web access to our products presents a real challenge for each geoscience agency, because of new and rapidly evolving technology, restricted funding, new requirements from the user community, and the somewhat confusing array of websites at which various types and quality of information can be found. To help address these challenges, Phase One focuses on providing simple, straightforward access to a broad spectrum of geoscience information, and forms the stable platform upon which the other NGMDB tasks and capabilities are based.

Specific accomplishments in 2007 include:

1. Expanded the Geoscience Map Catalog by about 3700 records, to a total of about 78,000 records. This includes 37,500 USGS publications in map, book, and open-file series, 27,000 state geological survey publications, and 13,500 products by other publishers. About 4700 existing records were updated; these mostly consisted of links to newly-online versions of the publication.
2. Engaged 49 states in the process of entering Map Catalog records. This resulted in the addition of about 2700 new records for state geological survey publications.
3. Increased the number of links from the Map Catalog to online publications, including map images, from about 10,000 to 15,000.
4. Continued to expand and revise Geolex (U.S. Geologic Names Lexicon), with a major update completed in mid-year. This update included the addition of ~1500 synopses, 500 references, and 70 geologic units.
5. Significantly revised the Geolex web interface to: a) allow more flexible search of geologic names; b) provide search results that include units related to that name; and c) provide forms for users and project personnel to assist in making additions and corrections.
6. Engaged 12 state geological surveys in a systematic review of Geolex, partly in cooperation with the USGS Energy Resources Program.
7. Under agreement with the USGS Publications Warehouse (PW), obtained 7000 map images scanned by the PW, and have processed 3200 for direct service via the Map Catalog image viewer. The agreement was undertaken to minimize duplication between the two systems, integrate them, and provide to the user the image viewer most appropriate for the publication format (e.g., MrSID format for large-format maps via NGMDB, and DjVu format for multi-page documents via PW).
8. Configured a 7-TB computer for short-term storage of map images and for image processing. Loaded to this computer 4.1 TB of images scanned by NGMDB or obtained from cooperators.

9. Received approval by USGS National Cooperative Geologic Mapping Program (NCGMP) and their Federal Advisory Committee for a plan to make images of selected EDMAP-grant deliverables publicly available via the Map Catalog (e.g., *http://ngmdb.usgs.gov/Prodesc/proddesc_81551.htm*). Unpublished GIS files of these maps will be archived and password-protected in the NGMDB, for later use by researchers.

10. Completed a significant effort to include in the Map Catalog a geographic search (see *http://ngmdb.usgs.gov/ngmdb/ngm_compsearch.html*). This new function allows the user to visually define the geographic boundary of their search. In a future redesign of the entire site, the geographic search is expected to serve a central, organizing role.

11. Created a set of monthly web statistics that identify the extent to which state geological survey publications are accessed via the Map Catalog. These statistics will be provided to each state geologist.

12. Evaluated user response to a prototype application that generates a file to display Map Catalog search results in Google Earth. Based on public comments received, this application will be further developed.

13. In response to NCGMP and AASG requests, and in part to address NCGMP performance metrics required by the Office of Management and Budget, provided: a) index maps showing areas in the U.S. that have been geologically mapped at various scales and time periods, and b) computations including the number of square miles geologically mapped at intermediate and more detailed scales (see Soller, 2005).

14. Worked with NCGMP to improve their data-entry procedure for the Mapping in Progress database, focusing on database redesign and adding information most useful to NCGMP management.

15. Gave numerous project presentations to scientists and managers at USGS, AASG, and other scientific meetings, whereby details of the project were explained and participation in building various NGMDB standards and databases was increased.

16. Completed several hundred productive interchanges with Map Catalog and Geolex users, via the NGMDB feedback form and other mechanisms. These users vary widely in interest and background, and include school children, homeowners, local government planners, and professional geologists.

Phase Two

Geoscience information increasingly is available in digital format. Within an agency, program, or a project, there are standard practices for the preparation and distribution of this information. However, widely accepted standards and/or guidelines for the format, content, and symbolization of this information do not yet exist. Such standards are critical to the broader acceptance, comprehension, and use of geoscience information by the non-professional and professional alike. Under the mandate of the National Geologic Mapping Act, the NGMDB project serves as one mechanism for coordinating and developing the standards and guidelines that are deemed necessary by the U.S. and international geoscience community.

The NGMDB project leads or assists in development of standards and guidelines for digital database and map preparation, publication, and management. This activity is a challenging one that entails a lengthy period of conceptual design, documentation, and test-implementation. For example: 1) a conceptual data model must be shown to be implementable in a commonly-available GIS such as ESRI's ArcGIS; 2) a data-interchange standard must be demonstrated to be an effective mechanism for integrating (e.g., through the NGMDB portal) the many and varied data systems maintained by the state geological surveys, USGS, and others; and 3) a map symbolization standard must be implemented in, for example, Postscript or ArcGIS before it can be used to create a map product. Then, of course, each proposed standard must become widely adopted; otherwise, it isn't really a standard. Internationally, the NGMDB participates in venues that help to develop and refine the U.S. standards. These venues also bring our work to the international community, thereby promoting greater standardization with other countries.

Specific accomplishments in 2007 include:

1. Coordinated work on the new Federally-endorsed (FGDC) geologic map symbolization standard, especially preparation of the printed version of the standard, and the Postscript implementation, which will be a USGS publication. Responded to inquiries and comments from users. Redesigned the FGDC Geologic Data Subcommittee website, and posted the PDF version of the standard there (*http://ngmdb.usgs.gov/fgdc_gds/*).

2. Served as Chair of the FGDC Geologic Data Subcommittee.

3. Organized and led the eleventh annual "Digital Mapping Techniques" workshop. Developed the agenda, solicited presentations, and worked to prepare the workshop proceedings. Edited and prepared for publication the workshop Proceedings from the previous year's meeting (DMT '06, Columbus, OH). These meetings have helped the geosci-

ence community to converge on more standardized approaches for digital mapping and GIS analysis.

4. Served as committee Secretary and as member of the U.S. Geologic Names Committee. Assisted in proposal of geologic time scale and color scheme that was adopted by the USGS (*http://pubs.usgs.gov/fs/2007/3015/*).

5. Served as Coordinator of the North American Geologic Map Data Model Steering Committee (NADMSC) and managed the NADM website (*http://nadm-geo.org/*).

6. Served as U.S. representative to DIMAS, the global standards body serving the Commission for the Geological Map of the World (*http://www.geology.cz/dimas*). Provided technical information and guidance on data model and science terminology standards under development in North America, and participated in DIMAS initiatives to develop global standards.

7. Served as the U.S. Council Member to the IUGS Commission for the Management and Application of Geoscience Information ("CGI", *http://www.cgi-iugs.org/*).

8. Participated in the IUGS CGI's Interoperability Working Group (*https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/InteroperabilityWG*). Helped to develop consensus for international standards for a geologic data model. Contributed to development of the GeoSciML schema, which is proposed as an international data-exchange standard for geoscience information.

9. Served as IUGS CGI liaison to the Multi-Lingual Thesaurus Working Group. This group is enabling global exchange of geoscience information by developing a common science vocabulary that is translated into many languages.

10. Served as USGS technical representative to the international "OneGeology" project (*http://www.onegeology.org/*). Provided technical guidance and support to the project.

11. Participated in USGS-AASG meetings on "Geoinformatics", intended to identify common ground for building the infrastructure needed to support projects such as the NGMDB.

12. Continued to interact with ESRI regarding: a) collaboration on an ArcGIS Geology Data Model that could be compatible with the NGMDB data model now under development; and b) ESRI implementation of the FGDC geologic map symbolization standard.

Phase Three

It is a commonly held vision that the National Geologic Map Database will be a repository of geologic map and related information, managed in a system distributed among the USGS and State geological surveys. The system would offer public access to complex, attributed vector and raster geoscience data, and allow users to perform queries, create derivative maps, and download source and derived map data. To realize this vision requires: 1) close collaboration among the partners; 2) a flexible and evolving set of standards, guidelines, and data management protocols; 3) a clear understanding of the technical challenges to building such a system; and 4) an adequate source of funding. Phase Three is designed to foster an environment where the distributed database system can be prototyped while these requirements are being addressed by the partners. The NGMDB is prototyping a system with two components: 1) a centralized database containing digital geologic map coverage for the U.S. at selected intermediate and small scales, and 2) distributed access to a more comprehensive set of map data held by the NGMDB collaborators (principally the state geological surveys). All information in the system would retain metadata that clearly indicates its source (e.g., who created the source map and, ideally, details on the origin and modifications to a particular contact, fault, or map unit attributes).

This is a long-term effort whose fully realized form is, at this time, difficult to predict. Because it is a complex task that depends on data availability, technological evolution, skilled personnel (in high demand and, therefore, in short supply), and the ability for all participants to reach consensus on the approach, the scope and details of Phase Three are systematically explored and developed through prototypes. Each prototype addresses aspects of the database design, implementation in GIS software (e.g., ArcGIS), standard science terminologies, and software tools designed to facilitate data entry. Each prototype is presented to the participants and the public for comment and guidance. The focus of new prototypes is guided by the comments received.

For example, in FY01 the NGMDB completed a major prototype in cooperation with the Kentucky Geological Survey, the Geological Survey of Canada, the University of California at Santa Barbara, and the private sector (Soller and others, 2002). The principal goal was to implement the NADM draft standard logical data model in a physical system, and to demonstrate certain very basic, essential characteristics of the envisioned system. That prototype was demonstrated and discussed at numerous scientific meetings, and its data model contributed to development of the North American conceptual data model. The project then considered plans to improve that system by adding more complex geologic data and software functionality. However, it would have required significant new funding at a time when technology and geoscience community ideas on database design were rapidly evolving. Therefore, a more limited approach is being pursued in the current prototype, in which draft NGMDB science

terminologies, a NADM-based database design, and data-entry tools were devised in order for the project to develop a Map Data Portal that offers public access to a simplified view of GIS data held by various cooperating agencies.

Specific accomplishments include:

1. Significant advances were made in design of the NGMDB prototype Map Data Portal. Components developed in previous years (e.g., a NADM-derived data model (Richard and others, 2004 and 2005), a Data-Entry Tool, and NADM-derived science terminologies) were brought together to demonstrate for USGS and AASG consideration a system model in which the full richness and variability of map information content is managed by the publishing agencies or other repositories, with a subset of the information made available via the NGMDB data portal for browsing and querying and, on a limited basis, for downloading in formats such as Arc shapefiles and GeoSciML. Our overall philosophy is to provide through this Portal a simplified view, a glimpse, of the maps and, as in the Map Catalog, to then direct the user to the source (the publishing agency) to obtain the actual data. Because the information provided through this Portal uses standardized, controlled science terms, it presents a somewhat unified or harmonized view of the source maps, which should assist users in understanding the basic aspects of a region's geology.

Technical and management involvement in Portal development, and the datasets served therein, was obtained from the geological surveys of Washington, Oregon, Idaho, and Arizona, and from Portland State University and the University of Arizona. The NGMDB Map Data Portal was demonstrated at the GSA Geoinformatics'07, DMT'07, and AASG'07 annual meetings – the response from management and technical staff was highly favorable, encouraging development to proceed.

The Portal's general design and workflow are shown in Figure 1. Map data are incorporated into the Portal's database by means of a data-import tool that facilitates attribution of map units with controlled vocabulary terms. The tool, which manages the map data in a local copy of NGMDB's database design, then exports it to an interchange format for loading into the Portal's PostGIS database. Presently, we are using Shapefiles as the interchange format, but envision using GeoSciML when it

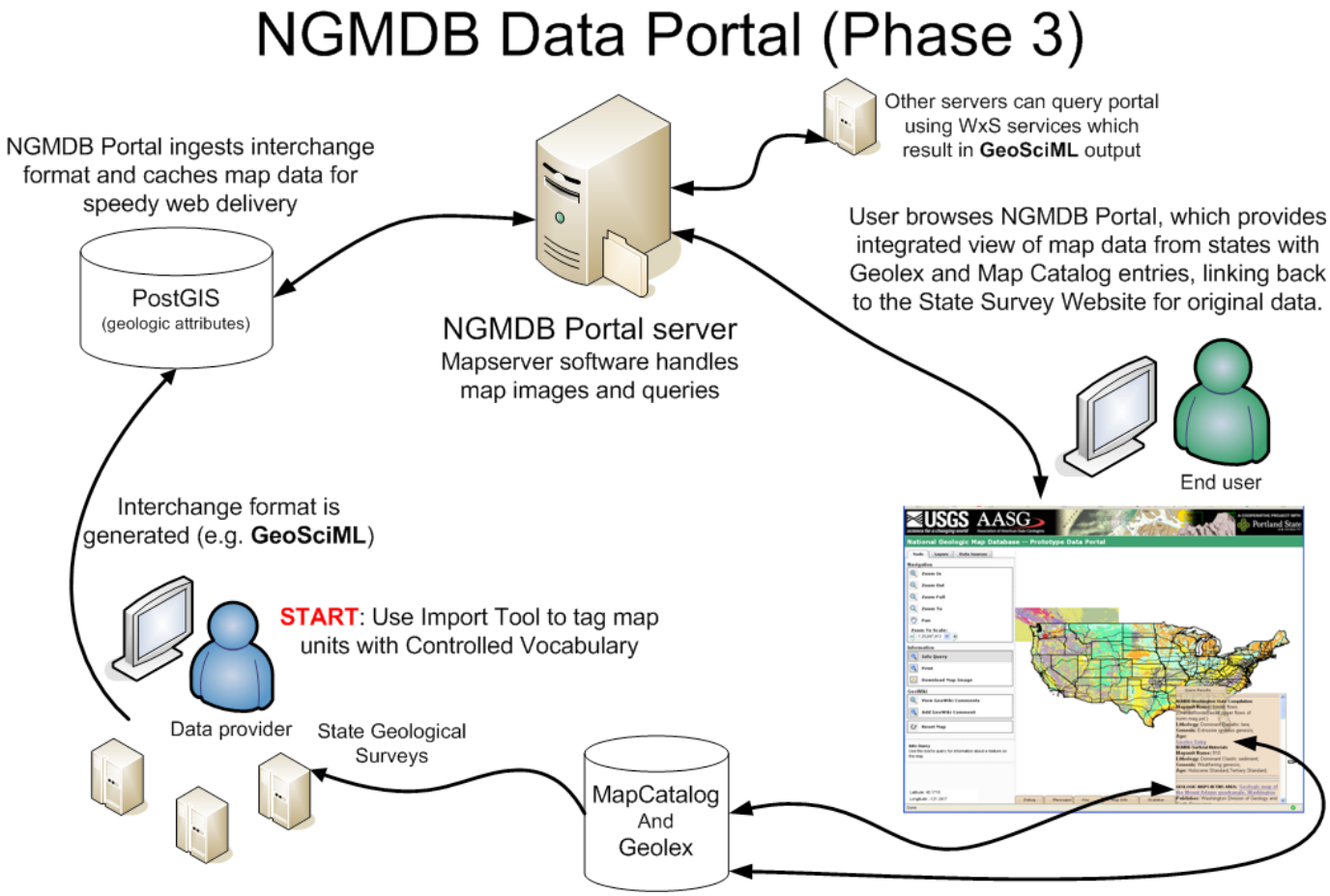

Figure 1. The NGMDB prototype Map Data Portal – general design and workflow. See text for explanation.

has matured and stabilized. When the map attributes and geometry are loaded into PostGIS, various map portrayals (e.g., geologic materials, geologic age) are prepared and cached as images. This pre-processing is essential in a portal of this type, because we intend to only provide the user with a quick overview of the geology rather than serving as a platform for in-depth query and analysis – for those needs, we link users to the source data, as shown along the bottom of the Figure. Mapserver software and an open-source interface (Map-Fu) provide the user with map display and simple queries such as "identify" a map unit. For that query, the displayed information includes links to the source map (in the NGMDB Map Catalog) and to geologic name information (in Geolex). These links provide the mechanism to direct users to the agency that published and maintains the source map data, and is our first step in tying this Portal to the Phase One databases. The Portal also will provide access to the map data through one or more OGC-compliant Web Services (hence "WxS" in Figure 1); this is intended to promote direct user access to the database, as well as access by other portals.

2. Concluded work for the Database Interoperability Testbed #2, which was sponsored by the IUGS CGI's Interoperability Working Group; this testbed demonstrated among eight agencies worldwide a limited implementation of the draft international geoscience data-interchange format, GeoSciML. This is a vitally important activity for the NGMDB, and for the USGS and AASG in general. The NGMDB contribution involved the USGS, Arizona Geological Survey, Portland State University, Oregon Department of Geology and Mineral Industries, and the University of Arizona. Began work on enhancements to GeoSciML, in preparation for release of a new version to support Testbed #3, which will be conducted in 2008.

3. In order to create modern, small-scale, consistent geologic map coverage for the U.S., the NGMDB project is converting the recently published Geologic Map of North America (GMNA) to digital format. This is a daunting task, and so an area was selected in which a prototype map database would be developed (it included part of the U.S., Canada, and the Pacific Ocean). The prototype map database was created and subjected to peer review at the DMT'06 meeting (Garrity and Soller, 2007). This prototype demonstrated the feasibility of converting the enormously complex map files from Adobe Illustrator to ArcGIS.

ACKNOWLEDGMENTS

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Appendix A. Principal committees and people collaborating with the National Geologic Map Database project.

Geologic Data Subcommittee of the Federal Geographic Data Committee:

Dave Soller (U.S. Geological Survey and Subcommittee Chair)
Jerry Bernard (USDA-Natural Resources Conservation Service)
Mark Crowell (Dept. of Homeland Security, Federal Emergency Mgmt. Agency)
Jim Gauthier-Warinner (U.S. Forest Service, Minerals and Geology Management)
Laurel T. Gorman (U.S. Army Engineer Research and Development Center)
John L. LaBrecque (National Aeronautics and Space Administration)
Lindsay McClelland (National Park Service)
Jay Parrish (State Geologist, Pennsylvania Geological Survey)
George F. Sharman (NOAA National Geophysical Data Center)
Dave Zinzer (Minerals Management Service)

Map Symbol Standards Committee:

Dave Soller (U.S. Geological Survey and Committee Coordinator)
Tom Berg (State Geologist, Ohio Geological Survey)
Bob Hatcher (University of Tennessee, Knoxville)
Mark Jirsa (Minnesota Geological Survey)
Taryn Lindquist (U.S. Geological Survey)
Jon Matti (U.S. Geological Survey)
Jay Parrish (State Geologist, Pennsylvania Geological Survey)
Jack Reed (U.S. Geological Survey)
Steve Reynolds (Arizona State University)
Byron Stone (U.S. Geological Survey)

AASG/USGS Data Capture Working Group:

Dave Soller (U.S. Geological Survey and Working Group Chair)
Warren Anderson (Kentucky Geological Survey)
Rick Berquist (Virginia Geological Survey)
Elizabeth Campbell (Virginia Division of Mineral Resources)
Rob Krumm (Illinois State Geological Survey)
Scott McCulloch (West Virginia Geological and Economic Survey)
Gina Ross (Kansas Geological Survey)
George Saucedo (California Geological Survey)
Barb Stiff (Illinois State Geological Survey)
Tom Whitfield (Pennsylvania Geological Survey)

DMT Listserve:

Maintained by Doug Behm, University of Alabama

North American Data Model Steering Committee:

Dave Soller (U.S. Geological Survey and Committee Coordinator)
Tom Berg (Ohio Geological Survey)
Boyan Brodaric (Geological Survey of Canada and Chair of the Data Model Design Technical Team)
Peter Davenport (Geological Survey of Canada)
Bruce Johnson (U.S. Geological Survey and Chair of the Data Interchange Technical Team)
Rob Krumm (Illinois State Geological Survey)
Scott McColloch (West Virginia Geological and Economic Survey)
Steve Richard (Arizona Geological Survey)
Loudon Stanford (Idaho Geological Survey)
Jerry Weisenfluh (Kentucky Geological Survey)

IUGS Commission for the Management and Application of Geoscience Information:

Dave Soller (U.S. Geological Survey, Council Member)

Conceptual Model/Interchange Task Group (of the Interoperability Working Group of the IUGS Commission for the Management and Application of Geoscience Information):

Steve Richard (Arizona Geological Survey / U.S. Geological Survey, Task Group Member)

DIMAS (Digital Map Standards Working Group of the Commission for the Geological Map of the World):

Dave Soller (U.S. Geological Survey, Working Group Member)

NGMDB contact-persons in each State geological survey:

These people help the NGMDB with the Geoscience Map Catalog and GEOLEX. Please see *http://ngmdb.usgs.gov/info/statecontacts.html* for this list.

These groups have fulfilled their mission and are no longer active:

NGMDB Technical Advisory Committee:

Boyan Brodaric (Geological Survey of Canada)
David Collins (Kansas Geological Survey)
Larry Freeman (Alaska Division of Geological & Geophysical Surveys)
Jordan Hastings (University of California, Santa Barbara)
Dan Nelson (Illinois State Geological Survey)
Stephen Richard (Arizona Geological Survey)
Jerry Weisenfluh (Kentucky Geological Survey)

AASG/USGS Metadata Working Group:

Peter Schweitzer (U.S. Geological Survey and Working Group Chair)
Dan Nelson (Illinois State Geological Survey)
Greg Hermann (New Jersey Geological Survey)
Kate Barrett (Wisconsin Geological and Natural History Survey)
Ron Wahl (U.S. Geological Survey)

AASG/USGS Data Information Exchange Working Group:

Dave Soller (U.S. Geological Survey and Working Group Chair)
Ron Hess (Nevada Bureau of Mines and Geology)
Ian Duncan (Virginia Division of Mineral Resources)
Gene Ellis (U.S. Geological Survey)
Jim Giglierano (Iowa Geological Survey)

AASG/USGS Data Model Working Group:

Gary Raines (U.S. Geological Survey and Working Group Chair)
Boyan Brodaric (Geological Survey of Canada)
Jim Cobb (Kentucky Geological Survey)
Ralph Haugerud (U.S. Geological Survey)
Greg Hermann (New Jersey Geological Survey)
Bruce Johnson (U.S. Geological Survey)
Jon Matti (U.S. Geological Survey)
Jim McDonald (Ohio Geological Survey)
Don McKay (Illinois State Geological Survey)
Steve Schilling (U.S. Geological Survey)
Randy Schumann (U.S. Geological Survey)
Bill Shilts (Illinois State Geological Survey)
Ron Wahl (U.S. Geological Survey)

Appendix B. List of progress reports on the National Geologic Map Database, and proceedings of the Digital Mapping Techniques workshops.

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