UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Review of USGS Open-file Report 95-525 ("Cartographic and digital standard for geologic map information") and plans for development of Federal draft standards for geologic map information

by

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Open-file Report 96-725

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This report summarizes a technical review of USGS Open-file Report 95-525 "Cartographic and digital standard for geologic map information" and OFR 95-526 (diskettes containing digital representations of the standard symbols). If you are considering the purchase or use of those documents, you should read this report first. For some purposes, OFR 95-525 (the printed document) will prove to be an excellent resource. However, technical review identified significant problems with the two documents that will be addressed by various Federal and State committees composed of geologists and cartographers, as noted below. Therefore, the 2-year review period noted in OFR 95-525 is no longer applicable. Until those problems are resolved and formal standards are issued, you may consult the following World-Wide Web (WWW) site which contains information about development of geologic map standards:

URL: http://ncgmp.usgs.gov/ngmdbproject/home.html

If the WWW is not available to you, or if you have a specific question regarding the use of the document, send e-mail (drsoller@usgs.gov) or write to:

Executive Secretary, Geologic Data Subcommittee
USGS
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Reston, VA 20192

Background

The practice of geologic mapping, and representation of geologic information in digital databases and on maps, must be supported by standards if we are to witness increased utility for our information in support of societal issues. It is essential that such standards be developed collaboratively, with mutual agreement of the need for, and content of, a standard. Unfortunately, collaboration on USGS Open-file Report 95-525 was minimal. Cooperators on the report were the USGS, the Association of American State Geologists (AASG), and the Federal Geographic Data Committee's (FGDC) Geologic Data Subcommittee (GDS).

The document had been intended for release as a FGDC draft Federal standard, through the GDS. Under Executive Order 12906, which established the National Spatial Data Infrastructure, the FGDC has responsibility for assuring development of standards necessary to promote the dissemination and use of information produced by the Federal government and, with their cooperation, by the states. A rigorous technical review of this document was essential, to determine whether the document was acceptable to its cooperators and to the geologic mapping community in general.

The technical review was conducted in 1996 (see Appendices). Comments were sought from the state geological surveys (20 states provided comments), from mappers and cartographers in the USGS Geologic Division, from the USGS Water Resources Division, and from the FGDC Secretariat. Some private companies also responded. Many of the reviews are excellent, and provide valuable insight to the technical issues of geologic mapping -- for their efforts, I extend my appreciation. I used their guidance to help prepare this report.

The authors of the standards document also certainly deserve appreciation for their efforts. The geoscience community needs various standards for managing and presenting data in digital form

and on maps, and this document deserves credit for addressing some of those standards. Many reviews expressed their appreciation to the USGS and the document's authors, and noted the critical need for such standards. However, the most thorough reviews also identified significant shortcomings to the document. Because I am charged through the FGDC with development of Federal standards for geologic information, and because standards must be developed through general consensus among all parties, this report focuses on the need for the document's revision.

The document contains two parts -- a general discussion of geologic mapping procedures and cartographic design ("Part I") and the collection of proposed standard symbols, colors, and patterns ("Parts II and III"). These two parts are separately discussed below. My conclusions are supported by reviewer's quotes. To minimize controversy, I have chosen to omit attribution to the quotes. However, a list of the reviewers is appended.

Part I -- general discussion of geologic mapping procedures and cartographic design

The title of this document is most welcome -- it suggests a standard for digital map information that is badly needed by the geoscience community. The transition from traditional paper-based map products (destined for application through visual inspection of the map) to digital databases (destined for analysis using statistics and GIS techniques as well as output to paper maps for visual inspection) has been difficult and expensive for geological surveys around the world. Regardless, the opportunity to prepare our information in a format more useable for societal decisionmaking, and the potential analytical power of the technology, have hastened the transition.

Unfortunately, this document does not address a comprehensive digital standard:

> "The original title suggests to me that there is a digital standard for geologic information. That is to say, there is a standard for computerized geologic databases, or at least certain kinds of geologic data. This is clearly not the case, as there is no such model even suggested. ... The assumption that the printed (plotted) map is the most important information source is clearly rooted in the past, not the future."
>
> "This report consistently treats digital geologic maps as digital copies of our current paper maps."

As an example of this bias, I refer you to the document's item 1.0.1.2:

> "This paragraph permits a point of observation to be moved on the map for the sake of cartographic clarity. I firmly believe that one should never be permitted to move an observation point."

Several reviewers suggested that Part I should be a guidelines document, not a standard:

> "...much of the "standard" is not a standard at all, but rather is a style manual for USGS authors and draftsmen. Unless everyone agrees that the only acceptable geological maps are those that are stylistically identical to USGS maps, most of the detail in Part I is irrelevant."

Other reviewers questioned whether they would, or could, adhere to the standards:

> "Because we have always viewed USGS cartographic standards such as these as guidelines, some of our comments concern areas where we have found these standards to be impracticable. It should be recognized that [we] and other state geological surveys may have developed (or may need to develop) standards better suited to their specific GIS or digital capabilities."

Similar concern was also expressed by USGS mappers:

> "We believe that the draft goes too far in defining standards that are difficult or impossible to apply in all situations or that have little scientific utility in some terranes."

Particularly common were questions about the document's standard for locational accuracy. Because of the rigorous use to which analysts may apply our digital data, resolution of this issue is even more important than in the past. A standard or guideline for locational accuracy must be addressed, collectively, before public release in a document such as this.

> "The discussion of locational accuracy in section 1.0.1 is seriously flawed and is not acceptable under the requirements of the ... FIPS standard for exchange of digital cartographic data. ... Federal standards require that the accuracy of features on a digital cartographic product must be specified, along with an *explicit* statement of how the accuracy has been determined. ... The USGS either has to test the positional accuracy of a wide variety of geologic maps and publish the results, which they can then cite, or they will have to explicitly acknowledge that the positional accuracy of features on their geologic maps are not known but are subjectively believed to be thus-and-so."

Resolution of comments:

The USGS could choose to submit this document as a Federal standard, which by definition need not be applied by the states [even this strategy may be somewhat murky, as some reviewers questioned whether participants in the STATEMAP component of the National Cooperative Geologic Mapping Program must adhere to a Federal standard]. We will instead coordinate the development of standards through broad consensus, among the state, academic, private, and federal geologic mapping community. The following actions will be taken.

1) Part I will not be revised for submittal to the FGDC, but may be used to develop specific standards or guidelines as described in 2 and 3, below.

2) Some of the reviewers comments are pertinent to the activities of USGS/AASG standards working groups and will be forwarded to those groups, to consider in their deliberations. [In August, 1996, five USGS/AASG working groups were formed to address a variety of standards and guidelines needed to support the National Geologic Map Database. These working groups address: 1) Metadata, 2) Guidelines for Digital Geologic Map Publication, 3) Data Capture Techniques, 4) Spatial Accuracy, and 5) a Geologic Data Model. For more information on the Database project and these working groups see the WWW site (URL: http://ncgmp.usgs.gov/ngmdbproject/home.html).]

   Because many issues related to preparation of digital geologic maps and databases are complex and not yet resolved, each issue must be thoroughly discussed and implemented after careful testing, perhaps through pilot studies. The USGS/AASG working groups will develop guidance or standards for technical issues that underlie digital mapping. In certain cases, these efforts are planned to culminate in a proposed FGDC standard; for example, a draft standard for a geologic data model.

   > "Now that the Geologic Data Subcommittee has developed standardized geologic symbols for making maps and thereby documenting what is known very precisely, the Subcommittee should turn its attention towards the more difficult subject of

developing digital standard geologic data. ... It is in this area [development of a geologic data model] that the FGDC might make its most important contribution."

3) For material in Part I not already addressed by the above-mentioned working groups, reviewer comments will be forwarded to the USGS Chief Geologist, for a decision on whether to eventually revise it for re-release as a guidance document for cartographic preparation of geologic maps. Does the geoscience community, or perhaps just the USGS, need a standard or a guidelines document for the cartographic design of geologic maps, independent of whether a map is prepared digitally or conventionally? If so, the following issues should be addressed:

   a) Must a geologic map be supported by a topographic base, cross-sections, and stratigraphic columnar sections?
   "Several of us who have made maps of relatively uneroded, undeformed terrain have declined to show cross sections on our published maps because the sections would be meaningless."
   "Most maps of surficial geology don't have cross sections, therefore, by Table 1, they are not geologic maps."

   b) What is an appropriate guidance or standard to help describe a map's reliability? Can we have a nationwide standard to define "reconnaissance map" or "preliminary map" that is applicable at all scales and to all geologic terranes? In the reviews, the section on reliability diagrams was contentious, and needs debate before it is proposed as a standard or guideline.

   c) Can we sufficiently distinguish between "mapping" and "compilation" so that a standard is possible?
   "In many cases "new" geology is based on reinterpretation and synthesis of the old. Geologic maps are highly interpretive and as such the responsibility for authorship has to fall to the geologist; it can not be legislated in a standard."

   d) Can stratigraphic units be named on a geologic map? This question evoked several conflicting comments.

   Because Part I focuses on geologic mapping and cartography instead of digital data, the proposed guidance document should not address digital issues:
   "There is a heavy emphasis on geologic maps as opposed to digital geologic data and discussion of both is mixed together throughout the standard. I think it would be clearer and more useful to separate the cartographic from the digital standards."

Parts II and III -- the collection of proposed standard symbols, colors, and patterns

This section contains a proposed collection of standard symbols, colors, and patterns, most of which have been used by the USGS for decades. For each symbol, there is a cartographic specification and a unique code based on the Digital Line Graph 3 (DLG-3) standard coding scheme. The symbols are also available in 28 Encapsulated Postscript files as USGS Open-file Report 95-526; however, as noted below, these files are not useable for digital cartography.

There was widespread agreement that Parts II and III, and especially the symbols themselves, will be of great utility to the geoscience community. Reviewer comments on symbols, patterns, and colors will be useful in developing the final standard sets for submission to the FGDC. However, the attribute coding scheme for symbols is perhaps the most contentious issue in the document, and must be addressed before submittal.

> "The most significant problem with the proposed standard is expressed in this section [section 2.0.1], where it specifies a "major-minor" code system that requires a minimum of 7 digits to represent a feature, and may require as many as 28 digits. The coding scheme really is an exhaustive, taxonomic-type classification of map symbols, and while theoretically it may be unambiguous in all conceivable circumstances, it is unnecessarily cumbersome and impractical for actual use. It ignores current practice and is incompatible with coding schemes in the most widely used cartographic programs such as ARC/INFO and AutoCAD, as well as the coding procedures in graphic languages such as IGL, HPGL, and PostScript."

It should not be concluded that a coding scheme is unnecessary, only that significant discussion needs to occur among technical experts who must, upon acceptance of such a standard, implement it daily. Implementation is the important consideration -- are the symbols and the attendant coding scheme appropriate to the task of preparing a digital database and map, appropriate to the breadth of hardware and software used by the geoscience community, and appropriate to the standard data model now under development?

> "The need for an attribute code standard is without question. Data collected today needs to be useable many years from now. Will software be made available to link these new codes to the ARCDLG command in ARC/INFO? ... Is DLG the best choice, or should a completely new, less cumbersome, format be developed by a consortium of software developers, geologists, digital cartographers? We are going to have to live with this exchange standard for a long time. Therefore, the development of a standard needs to be thought out carefully and with ALL users in mind."

A coding scheme should be designed to most efficiently support database queries and analysis. For example, numeric fields are generally more amenable to sorting, reselection, and query than character fields. The proposed coding scheme does not adequately consider efficiency in the act of encoding a symbol or in the query of a map database.

> "Sorting operations appear tedious and time consuming. For example, under this coding structure multiple reselection iterations are required in order to sort for all faults. [Our] coding scheme uses an approach that is the reverse of the proposed USGS system. All faults are tagged by a primary variable; sorting of specific fault types is then conducted by reselection from the general fault population."

A further consideration is that some feature attribution, for example expressions of spatial uncertainty, may be scale-dependent:

> "Section 2.0.1 "Attribute Coding for Earth Science Features" has what I regard as a fundamental flaw. This is, the 1:24,000 and 1:100,000 data are lumped together with the same coding (as far as I can determine). That is, I can see no way of distinguishing data with different uncertainty other than "definite, approximate, and inferred." However, what is definite at 1:100,000 scale may be only inferred at 1:24,000 scale."

Although standard symbology is important for map display, utility of the geologic database and map requires that we first specify standard definitions (a "content" standard) for the geologic features that we would symbolize.

> "[In section 2.0.1.0.4] the standard comes somewhat close to articulating what is required for digital content standards by saying: "Feature points are represented by a point having attributes in a digital data base." It's the features and their attributes that need to be defined and standardized. In doing so you are defining what information is important; the map is just a means used to represent that information."

Some reviewers questioned whether they had the resources needed to implement the coding scheme. Although a standard need not specifically address issues of implementation, they must be explicitly considered as the standard is being developed.

> "It is not clear how the metadata and properties identification is expected to be accomplished. If every item on every map we produce needs to be coded for attributes with both major and minor codes, then we'll need to hire additional staff or expect maps to take orders of magnitude longer to produce. The expectations of how this system is to be applied needs to be realistic and needs to be defined more clearly."

Because of the general lack of digital standards and the stature of organizations cited as collaborators on this document, testing and implementation of the standard has already begun in some agencies.

> "I have found in the past that ... attributing, as recommended in ... OFR 95-525, is extremely cumbersome to use in a map database. It is designed (apparently) to be able to lump any sort of data into a single database file, mostly aimed at storing cartographic information, not necessarily geologic information. Given the variety of data that needs to be included in a useful geologic database, it makes a lot more sense to me to put the data in a number of coverages and files, following the Arc/Info logic of putting data in layers that make sense. I'm including a rough draft of the data structure design we're presently using. The attribute coding follows that laid out in OFR 95-525 to the extent that I thought that worked. As much of the useless overhead as possible was removed to make data storage more efficient and coding easier to figure out."

Implementation of the symbol standards in a digital environment, with output to plotters of various resolution and design, to film writers, and to display terminals, requires extensive forethought and development costs. Unfortunately, the digital symbols in OFR 95-526 will not serve as the basis for a digital implementation of the standard.

> "[It] simply contains a series of Adobe Illustrator files, each one corresponding to a page in Sec. 2.1. It is possible to ungroup an illustration, select a particular symbol, and enlarge it to any desired size. However, you then discover that is consists only of strokes, identical in nature to the line-drawn symbols in the old Bureau of Standards Hershey fonts or to IGL symbols. Since the symbols are not drawn as outlines, their graphic representations cannot be used to define PostScript or other scalable symbols, and the precision with which they can be printed is dependent upon the original drawing and not on the resolution of the output device. ... The specifications for symbols are adequate only for creating stroked symbols, not scalable outlines, and so are not appropriate for use with modern high-resolution graphics devices."

Resolution of comments:

1. The standard collection of symbols, colors, and patterns will be revised, and submitted to GDS for comment as a draft Federal standard. As GDS Executive Secretary, I will resolve these problems as best I can and submit the draft to the FGDC; additional comments from a broader audience can then be heard through the FGDC review process. The following actions will be required to prepare the draft standard:

    a. Replace the coding scheme with a more practical one
    b. Provide a more comprehensive standard set (especially for the patterns), based on recommendations of USGS and State Publications Groups
    c. Resolve specific comments from reviewers, especially for the symbols (for example, some symbols are new and unfamiliar, and some are inadequate to describe the geology, especially in complex structural terranes)
    d. Remove the symbols for non-geologic features (the document now includes some hydrologic and base cartographic symbols, which are within the purview of other FGDC thematic subcommittees)

    The draft standard will be prepared electronically and produced as a paper document for FGDC review. It will also become available in electronic format. Preparation of the draft standard will proceed as quickly as possible with available resources. Until the draft is available for comment through the FGDC review process, the symbols, colors, and patterns in OFR 95-525 should serve as a valuable reference.

2. The USGS and the geoscience community need digital versions of these standards, in formats compatible with commonly used software, and in digital specification that will produce high-quality, scalable output on commonly-used output devices. The following steps will be coordinated by me, through interaction with interested experts in the USGS, the states, and private industry:

    a. Identify the requirements for hard-copy output (on which plotting and printing devices do we want to implement the standards?)
    b. Identify the digital formats in which the standard set will be developed (this decision will be based on the software most commonly used by the USGS and, if additional funding can be identified, other formats used by a sufficient number of state geological surveys)
    c. Develop strategies for converting the standard to digital formats.
    d. Identify funding sources and/or establish a Cooperative Research and Development Agreement (CRADA) with a private company.
    e. Develop the digital files
    f. Pending negotiations with a CRADA partner, release the files to the public on CD-ROM and at a WWW site.

3. The cartographic standard should be accompanied or preceded by standard definitions for the geologic features that they represent (for example, what is the generally-accepted, standard definition for a disconformity, a thrust fault, a pingo?). Standard definitions could be developed by the USGS/AASG Data Model Working Group or the USGS Geologic Division; discussions will be held with those groups to ascertain interest.

Summary:

* Persons intending to use OFR 95-525 or 95-526 should read this report first. For some uses, OFR 95-525 may still be appropriate. However, technical review identified significant problems with that document which will be addressed by various Federal and State groups composed of geologists and cartographers, as noted below.

* Contents of the document's Part I (general discussion of geologic mapping procedures and cartographic design) will not be revised for submittal to FGDC.

* Many of the issues discussed in Part I have begun to be resolved by standards working groups formed in August, 1996 under guidance of the USGS National Geologic Map Database project and the Association of American State Geologists (AASG) Digital Geologic Mapping Committee. Those working groups are the appropriate forum in which to resolve those issues and to propose standards to the FGDC, and pertinent review comments will be forwarded to them.

* Parts II and III (the standard collection of symbols, colors, and patterns) will be revised and submitted to GDS for comment as a draft Federal standard. This work will require technical advice from mappers and publications groups in the USGS and State geological surveys.

* The standard symbols, colors, and patterns should be developed into digital files for use with widely-used output devices and GIS and graphics software. Federal government Cooperative Research and Development Agreement (CRADA) partners may be sought to accomplish this. The files could be released through the CRADA partnership or as a USGS product, on CD-ROM and at a WWW site.

* The cartographic standard should be accompanied or preceded by standard definitions for the geologic features that they represent (for example, what is the generally-accepted, standard definition for a disconformity, a thrust fault, a pingo?). This activity may be supported by a USGS/AASG Working Group.

Appendix 1. List of reviewers. In parentheses, I note all reviewers I could identify from the correspondence received. In some cases, the respondent noted that various unnamed persons had reviewed the document. I thank all who took the time to provide comments.

Arizona Geological Survey (Stephen Richard)
Arkansas Geological Commission (John McFarland)
California Division of Mines and Geology (various staff members)
Florida Geological Survey (Jon Arthur, Jackie Lloyd)
Idaho Geological Survey (Loudoun Stanford)
Indiana Geological Survey (Todd Thompson)
Iowa Geological Survey Bureau (Bernard Hoyer)
Kansas Geological Survey (John Davis)
Maryland Geological Survey (Lamere Hennessee)
Minnesota Geological Survey (G.B. Morey)
Missouri Division of Geology and Land Survey (Mark Middendorf)
Montana Bureau of Mines and Geology (Karen Porter)
Nevada Bureau of Mines and Geology (various staff members)
New Jersey Geological Survey (various staff members)
North Carolina Geological Survey (Kathleen Farrell, Carl Merschat, Leonard Wiener)
Oregon Department of Geology and Mineral Industries (Paul Staub)
Utah Geological Survey (Bill Lund)
Vermont Agency of Natural Resources (Laurence Becker)
Virginia Division of Mineral Resources (Ian Duncan)
Wyoming Geological Survey (Gary Glass)
USGS

- FGDC (Denise Perreca)
- Geologic Division (Greg Green, Mike Machette, Dave Sherrod [with assistance from Ed Wolfe, Richard Waitt, and Willie Scott], Ron Stanton [with assistance from Debbie Carter, John SanFilipo, and Peter Warwick], Don Swanson)
- Publications Groups (Craig Brunstein, Simon Cargill, Alex Donatich, Gene Ellis, Jim Estabrook, Laurie Hodgen, Liz Koozman, Diane Lane, Kate Schindler, Randy Schumann, Will Stettner, Sean Stone, Julia Thomas)

Appendix 2. Excerpts from a letter to Thomas Berg (State Geologist of Ohio), asking for the state geological surveys to conduct a formal review of USGS Open-file Report 95-525:

December 5, 1995

Thomas Berg
Chair, AASG Data and Standards Committee

Tom --

Based on our telephone conversations with you and with Walter Schmidt, the Federal Geographic Data Committee's (FGDC) Geologic Data Subcommittee (GDS) requests that the AASG conduct a technical review of USGS Open-file Report 95-525, entitled "Cartographic and digital standard for geologic map information." Symbology represented in that report are released in digital form in USGS Open-file Report 95-526; therefore, a review of that document is also requested. Because the AASG was listed as a cooperating entity in 95-525, it is appropriate that they have the opportunity for a technical review. Likewise, the USGS will be conducting a technical review.

The GDS does not wish to constrain your review because there may be technical issues or difficulties with implementing this standard that cannot be foreseen prior to technical review. We do offer some issues for your consideration, partly based on preliminary reviews of the document:

-- do you agree with the general philosophy and approach as stated in the introductory pages?
-- does Part 1 (Geologic map information) adequately address the subject?
-- are the digital symbols useful? Do various plotters, with different file formats, reproduce the symbols adequately?
-- is the DLG-type attribute coding scheme adequate? Is it restrictive? Can it be translated into SDTS format?
-- is the color scheme adequate and useable?
-- is the standard incomplete?

We do not expect each person to review the entire document with a consistent level of attention throughout, but rather to concentrate on those aspects of the document which are most pertinent to their expertise. Because this document can be subdivided into discrete topics (e.g., symbology, coding scheme, or geologic map content), we do not require that all aspects of the document be readied for FGDC release at the same time. If the entire document is acceptable, then it can be released in its present form. If not, we can submit for FGDC approval those parts of the document that we all agree are worthy and non-controversial; if the review identifies any controversial sections, those could be held back for further discussion without delaying the remainder of the document.

We are mailing you at least 50 copies of the document, and one copy of the floppy disk containing Report 95-526. However, for reviewers who want to examine the digital version of the symbols (separately released as USGS Open-file Report 95-526, but not widely available), it may be easier for them to obtain a copy from Soller's workstation. There you will find twenty-eight EPS graphics files and a WP5.1 (export) version of the documentation. You will also find a

compressed tar file. Take your pick. The graphics were developed in Adobe Illustrator. All graphics files are uncompressed and DOS-compatible. On the Mac, the EPS files can be opened in Adobe Illustrator.

If your review identifies specific elements of the standard that would benefit from revision by technical experts and/or managers, the GDS and USGS will work with AASG to resolve those concerns. Thank you for assisting the geoscience community in this endeavor.

John F. Sutter
Chair, FGDC Geologic
Data Subcommittee

David R. Soller
Exec. Secretary, FGDC Geologic
Data Subcommittee

TO CUSTOMERS INTERESTED IN PURCHASING OFR 95-525 or 95-526:

The U.S. Geological Survey (USGS) Open-file Report (OFR) 95-525 ("Cartographic and digital standard for geologic map information") and the accompanying diskettes (OFR 95-526) have been reviewed by the USGS, the State Geological Surveys, and the Geologic Data Subcommittee of the Federal Geographic Data Committee. The review, published as USGS OFR 96-725, describes flaws in those reports and explains the plan for preparing a revised set of cartographic standards for geologic maps.

Before you purchase either 95-525 or 95-526, you may want to read the review document; if you like, we will send it to you (free of charge, except for postage) or you may read it on a USGS Web site (see URL: *"http://ncgmp.usgs.gov/ngmdbproject/standards/carto/OFR95-525review.html"*). For more information about the standards development activities underway at the USGS, see the Web site *"http://ncgmp.usgs.gov/ngmdbproject/home.html"*.

If you decide to purchase OFR 95-525, the cost of reproduction is as follows: 1) text b&w with color reproduction of pages showing map symbols, colors, and patterns -- $159.75; 2) text b&w with color reproduction of pages showing map symbols (pages showing colors and patterns would be b&w) -- $96.75; or 3) all pages b&w -- $37.50.