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National Spatial Data Infrastructure

Public Review Draft – Digital Cartographic Standard for Geologic Map Symbolization

Geologic Data Subcommittee
Federal Geographic Data Committee

April 2000

Federal Geographic Data Committee

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1. INTRODUCTION

1.1 Objective

This new draft standard is intended to provide to the Nation's producers and users of geologic map information a single, modern standard for the digital cartographic representation of geologic features. The objective in developing this national standard for geologic map symbols, colors, and patterns is to aid in the production of geologic maps and related products, as well as to help provide maps and products that have a consistent appearance.

1.2 Scope

This new draft standard contains descriptions, examples, cartographic specifications, and notes on usage for a wide variety of symbols that may be used on typical digital geologic maps or related products such as cross sections. The standard is scale-independent, meaning that the symbols are appropriate for use with geologic mapping compiled or published at any scale. It is designed for use by anyone who either produces or uses digital geologic map information.

1.3 Applicability

This new draft standard applies to any geologic map information published by the Federal Government, whether released as hard-copy (in either offset-print or plot-on-demand format) or electronically (as either Portable Document Format (PDF) files or for computer-monitor display only). Non-Federal agencies and private companies that produce geologic map information are urged to adopt this standard as well.

1.4 Related Standards

This new draft standard will supersede any existing U.S. Geological Survey (USGS) formal or informal cartographic standards for geologic map information.

During preparation of this new draft standard, its relation to other standards or standards-development activities was assessed, and no significant conflicts were found. For example, the International Organization for Standardization (ISO) Standard 710, Parts 1–4, describes a general schema for graphical display of a selected set of geologic map symbols. Although similar to some that are included in this new draft standard, they were found to have limited applicability. In addition, similar standards have been developed in other agencies of the Federal Government, including the U.S. Forest Service (in the geology component of their Terra database) and the U.S. Army Corps of Engineers (in the geology component of their Tri-Service CADD-GIS Spatial Data Standards). These were found to be somewhat specialized and limited in their coverage of geologic map features. Conversely, this new draft standard provides comprehensive coverage of symbology for a broad range of geologic map features.

1.5 Standards Development Procedures

This new draft standard has been developed by members of the USGS Geologic Division's Western Publications Group and National Geologic Map Database (NGMDB) project. It draws heavily upon previous work by USGS geologic and cartographic personnel (U.S. Geological Survey, ca. 1975, 1995a, 1995b), and the standards-development group gratefully acknowledges their contributions.

In 1995, a proposed standard was informally released by the USGS (U.S. Geological Survey, 1995a, 1995b). In 1996, this proposed standard was formally reviewed by geologists and cartographers in the USGS, the Association of American State Geologists (AASG), which represents the state geological surveys, and the Federal Geographic Data Committee's (FGDC) Geologic Data Subcommittee (GDS), which is composed mostly of representatives from Federal agencies that produce or use geologic map information. That review (Soller, 1996) indicated the need for some revision to the proposed standard prior to its consideration by the FGDC for adoption as a Federal standard.

In 1996, plans were outlined to create a revised and updated Federal standard, and the standards-development group was formed. A proposal to develop the revised standard was submitted by the FGDC's GDS (see http://ngmdb.usgs.gov/fgdc_gds/mapsymbprop.html), and the FGDC accepted that proposal in 1997. Later that year, the standards-development group produced a preliminary, beta version of the draft standard, which was circulated among selected USGS and state geological survey personnel for review. Comments were incorporated and, in 1999, the revised draft standard (Working Draft) was submitted to the FGDC's GDS for consideration. Upon review and subsequent approval by the GDS, the Working Draft was submitted to the FGDC Standards Working Group, which approved the document for public review, pending adoption of minor changes. The changes were made, and this new draft standard document (Public Review Draft) is now available to the public for review and comment.

Upon completion of the 120–day public review period, comments to the Public Review Draft will be considered, and any necessary revisions will be made. The revised draft standard document then will be submitted to the FGDC for formal approval as the Federal standard for geologic map symbolization.

After the standard is formally approved by the FGDC, the intention is that it will become a “living” standard—that is, it will be maintained and revised as needed to reflect new mapping disciplines or evolving usage conventions. The initial release of the FGDC–approved standard document will be available in printed form and supplemented by an electronic (PDF) version. Thereafter, updates to the standard document will be reflected in an online version, which will become the authoritative reference.

To help users maintain an up-to-date hard-copy version of the standard document, the initial release will be printed in “loose-leaf” format. Subsequent updates to the standard document will be made available in PDF format only, which could then be printed on a local output device and inserted where appropriate into a loose-leaf binder.

Because this new standard is intended for use with digital applications, an electronic implementation of the Public Review Draft has been prepared in PostScript format, and it is informally released as a USGS Open-File Report (USGS, 1999). This PostScript implementation will enable reviewers to directly apply the standard to geologic maps or illustrations prepared in desktop illustration and (or) publishing software. As the formally approved standard evolves, the PostScript implementation will be updated as well. Additionally, partial work on an ArcInfo (v. 7x) implementation has been completed, and this implementation may also be informally released as a USGS Open-File Report in the future. Information regarding updates to these and other implementation efforts will be posted on FGDC's GDS website (http://ngmdb.usgs.gov/fgdc_gds).

The Public Review Draft document is available in both printed and PDF formats. For information on the review mechanism and the deadline for submittal of review comments, as well as on how to obtain copies of the Public Review Draft, please see FGDC's GDS website (http://ngmdb.usgs.gov/fgdc_gds). Questions or comments may be addressed by e-mail to mapsymbol@geology.usgs.gov or, if preferred, by regular mail to Map Symbol Review, c/o David R. Soller, National Geologic Map Database project, U.S. Geological Survey, 908 National Center, Reston, Virginia, 20192.

1.6 Maintenance Authority

On behalf of the FGDC, the USGS will maintain the Federal standard; the responsibility for coordinating Federal geologic mapping information is stipulated by Office of Management and Budget Circular A–16 (see http://www.whitehouse.gov/omb/circulars/a016/a016.html). The Geologic Mapping Act of 1992 (and subsequent reauthorizations) stipulates a requirement for standards development under the auspices of the National Geologic Map Database (NGMDB). Under this authority, the NGMDB project will function on behalf of the USGS as coordinator of this maintenance activity (see http://ngmdb.usgs.gov/info/standards/general.html). Maintenance will be conducted in cooperation primarily with the AASG, which is the USGS’s partner in the Geologic Mapping Act.

To assist in its maintenance efforts, the NMGDB project will coordinate a standing committee that, as needed, will review comments and suggestions for revisions, additions, and deletions to the standard. Committee membership will be drawn from, among others, the NGMDB project, the USGS scientific staff and Publications Groups, the AASG, and the academic community. This standards-maintenance mechanism will be tested by forming the committee before completion of the FGDC public review period, so that the committee might both help the GDS evaluate the comments received and assist in preparing the final version to be submitted for formal approval by the FGDC.

2. BACKGROUND

2.1 Relation to Previous U.S. Geological Survey Standards

For many years, mapmakers within the USGS relied on a set of technical specifications given in the informally named "Technical Cartographic Standards" volume (U.S. Geological Survey, ca. 1975). This informal standard was available to USGS cartographers and editors as a set of green, loose-leaf notebooks that allowed pages to be replaced as the standard evolved; this informal standard was maintained until the mid-1980s. The technical specifications were devised to serve the needs of cartographers at a time when maps were conventionally prepared for offset printing using hand-placed type, hand-scribed linework, and peelcoats. This informal standard served the USGS well, but it was not commonly available to other producers of geologic maps nor was it formally recognized as a standard by the Nation's geoscience community.

Beginning roughly in the mid-1980s, digital technologies for mapmaking were both rapidly evolving and becoming more widely available. The gradual adoption of digitally based mapmaking methods necessitated the development of new standards that would address the requirements of the new technology, both for the digital production of negatives for offset printing and for the preparation of digital files for plot-on-demand or online publications. In response to the steady increase in mapmaking using digital technology and the accompanying concern about the difficulties in preparing high-quality, consistently produced digital maps, the U.S. Geological Survey informally released in 1995 a proposed standard entitled "Cartographic and digital standard for geologic map information" (U.S. Geological Survey, 1995a; see also, 1995b). As was noted above, subsequent review of that document by the USGS, the AASG, and the FGDC's GDS (Soller, 1996) indicated the need for some revision prior to its consideration by the FGDC for adoption as a Federal standard.

2.2 Changes from Previous Standards

In this new draft standard (contained in (normative) appendix A), descriptions, examples, cartographic specifications, and notes on usage are provided for a wide variety of symbols that may be used on typical digital geologic maps or related products such as cross sections. In the preparation of this standard, every effort was made to retain the original symbols and their specifications from the 1995 USGS proposed standard (U.S. Geological Survey, 1995a); however, many updates have been incorporated into this new version. The number of symbols has increased significantly, from about 800 to almost 1200. Symbols are more logically grouped; some sections have been combined with others, and a few new sections have been added.

Many symbols, particularly lines, have been redesigned slightly so that they would more successfully translate to digital applications. For instance, in the old "Technical Cartographic Standards" volume (U.S. Geological Survey, ca. 1975), as well as in the 1995 USGS proposed standard (U.S. Geological Survey, 1995a), the lineweight for contacts was specified as .005 inches (.125 millimeters). However, experience has shown that .005–inch lines do not always plot well when digitally output by high-resolution imagesetters. Therefore, the minimum lineweight for contacts, as well as for most other stroked-line symbol elements, has been increased to .006 inches (.15 millimeters) in this new draft standard. In addition, the dash and gap lengths for many line symbols have been adjusted so that their dash-gap templates can be more easily defined electronically.

A newly revised chart that shows a wide range of CMYK colors has been included (plate A); an offset-print version of this chart has been in use at the USGS for many years, and the variety of colors has proved to be sufficient for portraying complex geology shown on most maps, regardless of the output medium. In addition, a chart that shows commonly used geologic patterns has been added (plate B); the patterns themselves are similar to what was in the 1995 USGS proposed standard, but most have undergone lineweight changes to facilitate digital output at high resolutions. The old pattern numbers have been revised and the patterns are now organized into seven geologically relevant series. A few new patterns have been added, and some have been eliminated. Both the color chart and the pattern chart display new numbering systems that may be used with generic lookup tables in digital applications.

Also included in this new draft standard is a diagram showing suggested stratigraphic-age and volcanic map-unit colors, and a new geologic age symbol font has been added. In addition, three new sections that address map marginalia have been included: (1) a variety of bar scales, as well as calculation tables that show how to convert between inches, miles, and kilometers; (2) a series of mean declination arrows, showing magnetic north both east and west of true north; and (3) quadrangle location maps for each of the 50 states (and District of Columbia, Guam, Puerto Rico, and U.S. Virgin Islands), as well as a map of the 48 conterminous states (so that quadrangle locations covering more than one state can be shown).

A few new informational sections have been added to the introductory material in this draft standard. The section entitled "Guidelines for Symbol Usage" provides general information about some of the symbol categories in the draft standard. The section entitled "Guidelines for Color Design" provides useful information on color selection and the use of patterns. The section entitled "Guidelines for Map Labeling" provides recommendations on placement of text on a map.

In response to reviewer's comments (Soller, 1996), much of the first part of the 1995 USGS proposed standard has been abandoned because it was not pertinent to this standard (for example, the sections on map accuracy, geologic map content, metadata, and geocoding). In addition, no attempt has been made in this new standard to provide definitions for the geologic features represented by the various symbols. For such information, please refer to one of a number of reference books available; an excellent source is the American Geological Institute's Glossary of Geology (Bates and Jackson, 1987, 3rd ed.; Jackson, 1997, 4th ed.).

2.3 Preparers of This Draft Standard

This new draft standard document was prepared by members of the USGS Geologic Division's Western Publications Group for submittal to the FGDC as a Federal standard. Principal contributors to its preparation (which, unless otherwise noted, consists of both the Working Draft and the Public Review Draft) include the following individuals:

David R. Soller (USGS; Chief, National Geologic Map Database)—Coordinator, FGDC draft standard development.

Taryn A. Lindquist (USGS; Digital Map Specialist, Western Publications Group)—Editor and compiler, FGDC draft standard document; coordinator, PostScript and ArcInfo implementations; designer, line symbols for PostScript and ArcInfo implementations.

Sara Boore (USGS; Publication Graphics Specialist, Western Publications Group)—Designer, FGDC draft standard document, point and line symbols, color charts and patterns for PostScript implementation.

F. Craig Brunstein (USGS; Geologic Map Editor, Central Publications Group)—Technical reviewer, FGDC Working Draft.

Alessandro J. Donatich (USGS; Geologic Map Editor, Central Publications Group)—Technical reviewer, FGDC Working Draft.

Kevin Ghequiere (USGS; Cartographer, Western Publications Group)—Designer, patterns for PostScript implementation.

Richard D. Koch (USGS; Digital Map Specialist, Western Publications Group)—Designer, point symbols for ArcInfo implementation, geologic age symbol font.

Diane E. Lane (USGS; Geologic Map Editor, Central Publications Group)—Technical reviewer, FGDC Working Draft.

Susan E. Mayfield (USGS; Publication Graphics Specialist, Western Publications Group)—Designer, FGDC draft standard document, color charts and patterns for PostScript implementation.

Kathryn Nimz (USGS; Digital Map Specialist, Western Publications Group)—Designer, patterns for PostScript and ArcInfo implementations.

Glenn Schumacher (USGS; Publication Graphics Specialist, Western Publications Group)—Designer, bar scales, mean declination arrows, and quadrangle location maps.

Stephen L. Scott (USGS; Publication Graphics Specialist, Western Publications Group)—Designer, FGDC draft standard document, point symbols and line symbols for PostScript implementation.

Will Stettner (USGS; Cartographer, Eastern Publications Group)—Technical reviewer, FGDC Working Draft.

José F. Vigil (USGS; Motion Graphics Specialist, Western Publications Group)—Designer, geologic age symbol font.

Jan L. Zigler (USGS; Geologic Map Editor, Western Publications Group)—Technical reviewer, FGDC Working Draft.

3. TECHNICAL SPECIFICATIONS USED IN PREPARATION OF THIS STANDARD

The new draft standard (contained in appendix A) consists of geologic line and point symbols, geologic map-unit colors and patterns, a geologic age symbol font, and related map marginalia. This section provides some technical discussion regarding preparation of the draft standard and its implementations in PostScript and ArcInfo formats.

3.1 Units for Lineweights, Lengths, and Distances

In this draft standard, as well as in the 1995 USGS proposed standard, the cartographic specifications for lineweights, lengths, and distances are given in millimeters, in accordance with the Federal standard for metrification. For ease of use, lengths have been specified in whole- or half-integer values whenever possible, and lineweights and distances have been rounded to the nearest .05 mm or, in some cases, .025 mm.

The millimeter specifications were converted from those given in thousandths of an inch in previous standards (for example, U.S. Geological Survey, ca. 1975). In these older versions, the thousandths-of-an-inch specifications corresponded to the widths of the engraving tools used to scribe the linework. A chart showing values used when converting from inches to millimeters has been included (table 1).

In the ArcInfo implementation of this new draft standard (in preparation), the original thousandths-of-an-inch specifications were retained when designing digital versions of the symbols, because ArcInfo requires lineweights and such to be specified in inches. In the PostScript implementation, however, lineweights were specified in points (see table 1 for conversion values from inches to points). This is because the preliminary, beta version of the draft standard document was prepared using Adobe Illustrator 6.0, which required lineweights to be specified in points. Although the Public Review Draft document was prepared using Adobe Illustrator 8.0, which allows lineweights to be specified in inches, the lineweights were still defined electronically in points. This is mainly because Illustrator 8.0 displays in its Stroke dialog box the values rounded to three significant figures; for example, a lineweight of .005 inches shows as 0.01 inches, and a lineweight of .004 inches shows as 0 inches. In reality, Illustrator 8.0 retains internally the original lineweight specifications to four or more significant figures; only the values shown in the dialog box are rounded to three figures. Nevertheless, to avoid any confusion when using the PostScript implementation, the lineweight specifications as originally defined in points were retained.

As an example of this unit-conversion process, consider the symbol for contacts (see p. A–1–1, appendix A). As was stated above, the lineweight for contacts was increased to .006 inches, and this value was converted to millimeters. The exact conversion of .006 inches is .152 millimeters (table 1), which was rounded to .15 millimeters as the cartographic standard. However, when preparing the preliminary, beta version of this draft standard document, the .15–millimeter lineweight was defined electronically in Adobe Illustrator 6.0 as .432 points (table 1). Therefore, in the PostScript implementation, the lineweight displayed (in the Stroke dialog box) is 0.43 points; in the ArcInfo implementation (in preparation), however, the original value of .006 inches is retained as the lineweight specification for contacts.

Complications from unit conversion arise not just when designing line symbols but also when creating point symbols and patterns, as most symbols are made of stroked lines. When creating symbols for a particular application, the user should choose whichever units work best in an application and then use the conversion table (table 1) to convert to those units.

Table 1. Chart showing conversion values from inches (in) to points (pts) to millimeters (mm).

in	pts	mm	in	pts	mm	in	pts	mm	in	pts	mm
0.001	0.072	0.025	0.051	3.672	1.295	0.101	7.272	2.565	0.151	10.872	3.835
0.002	0.144	0.051	0.052	3.744	1.321	0.102	7.344	2.591	0.152	10.944	3.861
0.003	0.216	0.076	0.053	3.816	1.346	0.103	7.416	2.616	0.153	11.016	3.886
0.004	0.288	0.102	0.054	3.888	1.372	0.104	7.488	2.642	0.154	11.088	3.912
0.005	0.360	0.127	0.055	3.960	1.397	0.105	7.560	2.667	0.155	11.160	3.937
0.006	0.432	0.152	0.056	4.032	1.422	0.106	7.632	2.692	0.156	11.232	3.962
0.007	0.504	0.178	0.057	4.104	1.448	0.107	7.704	2.718	0.157	11.304	3.988
0.008	0.576	0.203	0.058	4.176	1.473	0.108	7.776	2.743	0.158	11.376	4.013
0.009	0.648	0.229	0.059	4.248	1.499	0.109	7.848	2.769	0.159	11.448	4.039
0.010	0.720	0.254	0.060	4.320	1.524	0.110	7.920	2.794	0.160	11.520	4.064
0.011	0.792	0.279	0.061	4.392	1.549	0.111	7.992	2.819	0.161	11.592	4.089
0.012	0.864	0.305	0.062	4.464	1.575	0.112	8.064	2.845	0.162	11.664	4.115
0.013	0.936	0.330	0.063	4.536	1.600	0.113	8.136	2.870	0.163	11.736	4.140
0.014	1.008	0.356	0.064	4.608	1.626	0.114	8.208	2.896	0.164	11.808	4.166
0.015	1.080	0.381	0.065	4.680	1.651	0.115	8.280	2.921	0.165	11.880	4.191
0.016	1.152	0.406	0.066	4.752	1.676	0.116	8.352	2.946	0.166	11.952	4.216
0.017	1.224	0.432	0.067	4.824	1.702	0.117	8.424	2.972	0.167	12.024	4.242
0.018	1.296	0.457	0.068	4.896	1.727	0.118	8.496	2.997	0.168	12.096	4.267
0.019	1.368	0.483	0.069	4.968	1.753	0.119	8.568	3.023	0.169	12.168	4.293
0.020	1.440	0.508	0.070	5.040	1.778	0.120	8.640	3.048	0.170	12.240	4.318
0.021	1.512	0.533	0.071	5.112	1.803	0.121	8.712	3.073	0.171	12.312	4.343
0.022	1.584	0.559	0.072	5.184	1.829	0.122	8.784	3.099	0.172	12.384	4.369
0.023	1.656	0.584	0.073	5.256	1.854	0.123	8.856	3.124	0.173	12.456	4.394
0.024	1.728	0.610	0.074	5.328	1.880	0.124	8.928	3.150	0.174	12.528	4.420
0.025	1.800	0.635	0.075	5.400	1.905	0.125	9.000	3.175	0.175	12.600	4.445
0.026	1.872	0.660	0.076	5.472	1.930	0.126	9.072	3.200	0.176	12.672	4.470
0.027	1.944	0.686	0.077	5.544	1.956	0.127	9.144	3.226	0.177	12.744	4.496
0.028	2.016	0.711	0.078	5.616	1.981	0.128	9.216	3.251	0.178	12.816	4.521
0.029	2.088	0.737	0.079	5.688	2.007	0.129	9.288	3.277	0.179	12.888	4.547
0.030	2.160	0.762	0.080	5.760	2.032	0.130	9.360	3.302	0.180	12.960	4.572
0.031	2.232	0.787	0.081	5.832	2.057	0.131	9.432	3.327	0.181	13.032	4.597
0.032	2.304	0.813	0.082	5.904	2.083	0.132	9.504	3.353	0.182	13.104	4.623
0.033	2.376	0.838	0.083	5.976	2.108	0.133	9.576	3.378	0.183	13.176	4.648
0.034	2.448	0.864	0.084	6.048	2.134	0.134	9.648	3.404	0.184	13.248	4.674
0.035	2.520	0.889	0.085	6.120	2.159	0.135	9.720	3.429	0.185	13.320	4.699
0.036	2.592	0.914	0.086	6.192	2.184	0.136	9.792	3.454	0.186	13.392	4.724
0.037	2.664	0.940	0.087	6.264	2.210	0.137	9.864	3.480	0.187	13.464	4.750
0.038	2.736	0.965	0.088	6.336	2.235	0.138	9.936	3.505	0.188	13.536	4.775
0.039	2.808	0.991	0.089	6.408	2.261	0.139	10.008	3.531	0.189	13.608	4.801
0.040	2.880	1.016	0.090	6.480	2.286	0.140	10.080	3.556	0.190	13.680	4.826
0.041	2.952	1.041	0.091	6.552	2.311	0.141	10.152	3.581	0.191	13.752	4.851
0.042	3.024	1.067	0.092	6.624	2.337	0.142	10.224	3.607	0.192	13.824	4.877
0.043	3.096	1.092	0.093	6.696	2.362	0.143	10.296	3.632	0.193	13.896	4.902
0.044	3.168	1.118	0.094	6.768	2.388	0.144	10.368	3.658	0.194	13.968	4.928
0.045	3.240	1.143	0.095	6.840	2.413	0.145	10.440	3.683	0.195	14.040	4.953
0.046	3.312	1.168	0.096	6.912	2.438	0.146	10.512	3.708	0.196	14.112	4.978
0.047	3.384	1.194	0.097	6.984	2.464	0.147	10.584	3.734	0.197	14.184	5.004
0.048	3.456	1.219	0.098	7.056	2.489	0.148	10.656	3.759	0.198	14.256	5.029
0.049	3.528	1.245	0.099	7.128	2.515	0.149	10.728	3.785	0.199	14.328	5.055
0.050	3.600	1.270	0.100	7.200	2.540	0.150	10.800	3.810	0.200	14.400	5.080

3.2 Type Specifications

In most cases, type is specified in this new draft standard as either Helvetica (sans-serif) font or Times (serif) font, two fonts that are commonly used and widely available; type sizes are given in points (see table 2 for abbreviations for type faces used in this standard). Geologic age characters have been specified as StratagemAge (sans-serif) font, a specialized font designed by the U.S. Geological Survey (see section 38, appendix A). Other fonts besides these three may be substituted, but consider that they may not be installed on all common output devices and thus may not plot correctly.

3.3 Color Specifications for Line and Point Symbols

Color has been specified as the cartographic standard for many line and point symbols in this new draft standard, either because of adherence to a long-established color convention or because using color for features such as folds and dikes may help them to stand out better from other full-black linework such as contacts and faults. In most cases, another color or black (especially on an otherwise black and white only map) may be substituted if the color specified as the standard would not be visible when printed over an underlying map-unit color.

Whenever possible, color has been specified as either cyan or magenta, two of the four process-color (CMYK, cyan/magenta/yellow/black) inks that are used both in inkjet plotters and for offset printing. However, in some cases it was not practical or preferable to specify cyan or magenta as the standard; for example, mineral resource assessment areas traditionally have been outlined in red (see p. A–19–1, appendix A). Although it is possible to make a non-process color such as red from two or more process-color inks, this should be avoided if the map is to be offset printed because of the difficulties in registering large, CMYK-separated negatives. Thus, in some cases a spot color (a single-ink, non-CMYK color) has been specified as the cartographic standard.

As a simple, general way of specifying spot colors, generic color names (for example, red and violet) have been used in this new draft standard. This is mainly because in Adobe Illustrator 6.0, which was used to prepare the preliminary, beta version of this draft standard, spot colors had to be chosen from a list of Custom Color names. And although the final version of the draft standard was prepared using Illustrator 8.0, in which Adobe changed the way spot colors are specified, the color names as originally chosen in Illustrator 6.0 have been retained herein. Specifying color as these generic color names, however, may not be appropriate for use with certain output media. Therefore, the user must choose a method of specifying color that is appropriate for a particular output device; table 3 shows suggestions for conversions of spot colors to other color models.

For output to an inkjet plotter, specifying a spot color as one of the generic color names is satisfactory because, during the plotter's RIP[1] of the file, the color will automatically be converted to the proper amounts of CMYK inks that will combine to make the CMYK equivalent of that color. For maps that are to be offset printed, however, a Pantone color (single-ink spot color) should be specified (table 3). Pantone colors are imageset onto separate pieces of film, thereby avoiding misregistration problems caused when a color converts to CMYK and then is color separated onto as many as four pieces of film. Misregistration is not a problem with single-pass inkjet-plotter output.

If graphical map elements are to be published as part of a web page on the World Wide Web, colors should be chosen from a browser-safe, 8-bit color palette (216 colors) to avoid unwanted dithering on monitors that display only 256 colors (Weinman, 1996). To aid in doing so, an attempt was made to provide the browser-safe color equivalents of the spot colors given in the new draft standard (table 3). These browser-safe colors are made up of the RGB (red/green/blue) values that are as close as possible to the directly converted RGB-equivalent colors (table 3). However, with only six possible RGB values from which to choose (000, 051, 102, 153, 204, and 255), it proved to be impossible to exactly reproduce the directly converted RGB-equivalent colors. Incidentally, industry opinions on Web-safe color may be changing, owing to the large number of monitors now in use that can display more than 256 colors; Chris

[1] Raster-image processing, a process that runs on all plotters, printers, and imagesetters and converts data (in either raster or vector format) to printer dots to produce an image.

Table 2. Abbreviations used in this draft standard.

A. Color and pattern names

ABBREVIATION	MEANING	EXAMPLE OF USAGE	REF NO
B	brown	422-B (pattern)	Plate B
C	cyan	502-C (pattern)	Plate B
CMYK	cyan/magenta/yellow/black	CMYK Color Chart	Plate A
DO	dropout	204-DO (pattern)	Plate B
K	black	101-K (pattern)	Plate B
M	magenta	317-M (pattern)	Plate B
R	red	121-R (pattern)	Plate B
RGB	red/green/blue	RGB-equivalent color	Table 3
Y	yellow	CMYK Color Chart	Plate A

B. Measurements

ABBREVIATION	MEANING	EXAMPLE OF USAGE	REF NO
cm	centimeter(s)	measurement equivalent of distance	Sec. 35
ft	foot (feet)	measurement equivalent of distance	Sec. 35
in	inch(es)	measurement equivalent of distance	Sec. 35
km	kilometer(s)	measurement equivalent of distance	Sec. 35
m	meter(s)	measurement equivalent of distance	Sec. 35
mi	mile(s)	measurement equivalent of distance	Sec. 35
mm	millimeter(s)	.15 mm (contact lineweight)	1.1.1

C. Type styles and sizes

ABBREVIATION	MEANING	EXAMPLE OF USAGE	REF NO
H-8	Helvetica, 8 point type	GOLDEN FAULT (fault name)	2.1.8
HI-6	Helvetica Italic, 6 point type	*40* (dip value)	6.3
S-8	StratagemAge, 8 point type	Ŧg (unit label containing geologic age character)	31.8
TBI-12	Times Bold Italic, 12 point type	***A–A'*** (cross section label)	31.6

MacGregor (*in* Dennis, 1999) recently stated that non–Web-safe colors may be acceptable to use in detailed areas, although she still recommends using Web-safe colors in large areas.

3.4 Color Specifications for Map-Unit Areas

Color is routinely added to geologic maps to help distinguish individual map units. Color can be added to map-unit polygons either as color fill, as pattern fill, or as patterns over color fill. See subsection below entitled "Guidelines for Color Design" for information on color and pattern selection.

To maintain control of color output, color fills for map units should always be specified using process-color (CMYK) inks, regardless of the intended output medium. If not, then the output device (be it plotter or imagesetter) will automatically convert the non-CMYK values to CMYK during the RIP, and unwanted color shifts often will take place. To aid in the selection of color fill for geologic map units, a chart showing a wide variety of CMYK colors has been included herein (plate A).

Table 3. Spot color specifications and their equivalent colors in other color models.

[Abbreviations: CMYK, cyan/magenta/yellow/black color model (C, cyan; M, magenta; Y, yellow; K, black); RGB, red/green/blue color model (R, red; G, green; B, blue)]

Color name in draft standard[1]	Process color (CMYK) equivalent		RGB equivalent[4]	Pantone color equivalent[5]	Web-safe color equivalent[6]	Example in draft standard
	Exact CMYK conversion[2]	Suitable color on CMYK chart[3]				
red	C 15 M 100 Y 100 K 0	C 0 M 100 Y 100 K 0	R 217 G 0 B 0	485 U	R 204 G 0 B 0 (CC0000)	Section 1.2, p. A–1–3
50% red	C 7.5 M 50 Y 7.5 K 0	C 0 M 50 Y 50 K 0	R 233 G 124 B 95	485 U (screened 50%)	R 255 G 102 B 102 (FF6666)	Section 19.5, p. A–19–6
green	C 100 M 20 Y 100 K 0	C 100 M 0 Y 100 K 0	R 0 G 109 B 44	346 U	R 0 G 102 B 51 (006633)	Section 19.5, p. A–19–6
50% green	C 50 M 10 Y 50 K 0	C 50 M 0 Y 50 K 0	R 127 G 181 B 120	346 U (screened 50%)	R 102 G 153 B 102 (669966)	Section 19.5, p. A–19–6
violet	C 45 M 90 Y 0 K 0	C 30 M 70 Y 0 K 0	R 140 G 23 B 136	Purple U	R 153 G 51 B 204 (9933CC)	Section 21, p. A–21–1
brown	C 50 M 85 Y 100 K 0	C 30 M 70 Y 70 K 0	R 127 G 30 B 2	470 U	R 102 G 51 B 0 (663300)	Section 26.1, p. A–26–1

[1] Name of Custom Color, or spot color, as first specified in Adobe Illustrator 6.0.
[2] Value after direct conversion of spot color to CMYK by Adobe Illustrator 8.0.
[3] Value of comparable color on CMYK Color Chart (plate A).
[4] Value after direct conversion from CMYK to RGB by Adobe Illustrator 8.0.
[5] Value of closest Pantone color for offset printing on uncoated paper.
[6] RGB value (hexadecimal value in parentheses) closest to RGB-equivalent value.

The CMYK Color Chart was designed in Adobe Illustrator 8.0 to reproduce the offset-printed color chart entitled "Printing Colors and Screens in Use by the U.S. Geological Survey for Geologic and Hydrologic Maps" (yellow/magenta/cyan version), which has been in use for many years at the USGS. On this new version, however, the color codes were inverted so that the values now read as cyan/magenta/yellow (instead of yellow/magenta/cyan), in order to conform to the industry standard of CMYK (with K=0). Note that the color chips themselves have not changed, only the coding system has changed.

In addition, a diagram showing suggested stratigraphic-age and volcanic map-unit colors has been included (see section 33, appendix A). This diagram was designed in Adobe Illustrator 8.0 to reproduce something similar in the old USGS Technical Cartographic Standards volume (U.S. Geological Survey, ca. 1975); in this new version, however, the range of colors was modified slightly, a few new colors were added, and the color codes were converted to cyan/magenta/yellow (from yellow/magenta/cyan).

3.5 Pattern Specifications

The old USGS Technical Cartographic Standards volume (U.S. Geological Survey, ca. 1975) contained no cartographic specifications (lineweights, dot sizes, or size and spacing of pattern elements) for its patterns. The volume dates back to a time when maps were conventionally prepared using hand-scribed linework and peelcoats. In those days, patterns were preprinted onto large sheets of film, which were photomechanically combined with the various peelcoats to make the CMYK negatives.

For this new draft standard, the patterns were recreated by scanning the old pattern sheets and then tracing the pattern elements in Adobe Illustrator 8.0. In many cases, lineweights and dot sizes for the black patterns were increased to facilitate digital output. A few pattern tiles were scaled to accommodate the increased lineweights, and some of the lined patterns were dropped because an increased lineweight would fill in the pattern, and an increase in scale would cause the pattern to be too similar to other patterns in the patternset.

In addition to the black versions of the patterns, cyan and magenta versions of the patterns were created, as well as dropout versions (yellow versions were not created because yellow patterns are not visible over color fill). The lineweights and dot sizes for the color and dropout versions were increased even more than for the black versions, to help them show more clearly on maps. Glacial and hydrologic patterns were created only in cyan and black, as it is unlikely that magenta or other colors would be used for these types of patterns. Also, if red or brown patterns were specified as the cartographic standard for a particular feature, then they were added to the patternset. All patterns were renumbered and suffixes indicating color were added so that all versions of the same pattern are referenced by the same number.

3.6 Geologic Age Symbol Font

A digital font named StratagemAge has been created, in which 23 special geologic age characters have been substituted into positions of normal keyboard characters. These characters can be typed either directly or with the Shift key; no Option, Control, or Alt keys are needed to type these characters (they are all in lower-order ASCII positions that have character ID numbers below 128). This was done to allow the same character positioning to work on different computer platforms without interfering with special control key sequences.

4. GUIDELINES FOR SYMBOL USAGE

This section provides some guidelines regarding the use of the symbols contained in this new draft standard.

4.1 Line Symbols

On a geologic map, line symbols can represent traces of either planar features such as contacts, faults, or dikes, or linear features such as rivers and boundaries. The accuracy of location and (or) certainty of existence of various types of lines is shown graphically by the pattern of the line symbol on the map and is indicated by the following terminology used to describe symbol types:

Certain (solid)	Trace observed in field and accurately located
Approximately located (long dashed)	Trace observed in field but may not be accurately located
Inferred (short dashed)	Existence and location inferred from indirect evidence
Concealed (dotted[2])	Trace projected to surface from beneath mapped surficial unit, water, or ice

Queries may be added to indicate local uncertainty of a trace, either within a line segment or at its end(s). Queries should not be added to solid lines to indicate uncertainty of location; an "approximately located" dashed line should be used instead.

This new draft standard does not provide quantitative definitions of the locational precision terms listed above, as decisions related to the positional certainty of a line are beyond the scope of this standard. Such issues should be addressed by professionals responsible for establishing mapping procedures for various organizations and (or) for a particular geologic setting.

[2] In reality, dotted lines can be difficult to produce, and so a very-short-dashed line has long been used as the cartographic standard.

4.1.1 Contacts

Contacts can be used to show either abrupt or gradual changes in lithology. Annotations and (or) line symbol decorations may be added to indicate where a particular feature such as dip or lineation has been observed in the field.

Sometimes because of poor exposure or lack of accessibility, all contacts on a map can be considered as "approximately located." In these cases it may be best to draw all contacts as solid, non-broken lines but describe them as "approximate contact" in the explanation and (or) the database.

Scratch boundaries are boundaries of areas of color or pattern around which no line is drawn. For example, they may define a patterned area that overprints other geologic units, such as an observed zone of a particular metamorphic facies. Because, by definition, no line symbol is used, scratch boundaries have been omitted from this draft standard. This does not preclude them from being used, however.

4.1.2 Faults

Relative offset along faults is shown by various kinds of line symbol ornamentation. Some types of ornamentation are within the line symbol, such as evenly spaced sawteeth along a thrust fault. Other types of ornamentation are placed along a fault to indicate the general character of that fault segment, such as a "ball and bar" symbol to show normal offset. Annotations and (or) line symbol decorations may be added to indicate where a particular feature such as dip or lineation has been observed in the field.

4.1.3 Folds

A fold structure can be represented by either the trace of its axial surface (as it intersects the ground surface) or the traces of its crest (highest point) and trough (lowest point) lines. The trace of the axial surface is preferred, but crest and trough lines may be substituted if specified in the map explanation and (or) the database. In rare cases both may be shown if fully documented and explained.

Arrow symbols are added perpendicular to fold traces to indicate the different types of folds. These should not be added where a particular observation has been made but, rather, should be placed roughly in the center of a line segment to indicate its general character. Arrowheads may be added to a fold trace, usually but not always at its end(s), to indicate direction of plunge.

4.2 Point Symbols

Point symbols can represent either single features that result from one observation or multiple features observed at one locality. Point symbols may also be used to represent generalized areas or groups of points.

Point symbols may be combined if necessary. If two or more types of symbol are combined, an example of each type should be shown separately and described in the map explanation and (or) the database.

The point of observation for symbols representing planar features is located at the midpoint of the strike line where it intersects the tick indicating direction of dip. If several observations are made at one locality, the various point symbols are joined at their endpoints at the point of observation.

For linear features, the point of observation can either be in the middle of the arrow, at the end of the arrow, or at the tip of the arrowhead, depending on preference. Whichever is preferred, it is important to specify which method has been used in the map explanation and (or) the database.

4.3 Geologic Time and Ages of Rock Units

The USGS has published a scheme for the major divisions of geologic time, the age estimates of the boundaries, and the symbols to be used on geologic maps (Hansen, 1991). This particular scheme was adopted after a 1980 meeting of the Geologic Names Committee of the USGS (Hansen, 1991). In addition, several other schemes of geologic time boundaries have been published (see, for example, Harland and others, 1982; Palmer, 1983; Snelling, 1985), each of which is based on different assumptions, techniques, and (or) data. Any formally published age scheme may be used for a particular map, as long as the author specifies which was used.

4.4 Color and Patterns

Many factors can influence the decision as to how to best portray the geology on a map. Separate sections on color design and map labeling are included below to provide general guidelines for the effective use of color and (or) patterns in map units.

5. GUIDELINES FOR COLOR DESIGN

The goal in color design is to enhance the legibility of the map, as well as to lend meaning to the data presented by helping to focus attention on a particular map feature or group of features. Colors and patterns should not, however, be so visually dominant as to distract from the purpose of the map. A well-balanced color design can greatly improve the presentation of scientific information.

5.1 Factors that Influence Color Selection

5.1.1 Purpose of Map

Color is used differently on different types of maps. For example, on geologic maps, color is primarily determined by age and type of rock, although other rules may apply for terrane maps or maps that portray only one age group or type of rock. In addition, some map units, because of their geologic or economic importance, may need to be emphasized.

Geophysical maps use several color schemes, depending on the purpose of the data being shown; usually a range of colors from dark to light is used. One such scheme is a graduated set of hues of similar value (for example, purple and magenta to orange and red). Another is a rainbow of hues in which the values alternate between full color and lightly screened color.

On slope-stability maps, the brightest colors are used on areas of highest instability. Similarly, on volcanic-hazard maps, areas of greatest hazard are shown in red, whereas areas of lowest hazard are shown in yellow.

Data on hydrologic maps are frequently shown in two or three colors. On maps showing depth to water table, color ranges from light blue at the shallowest depths to dark blue at the greatest depths. On maps showing dissolved-solids concentrations, color ranges from dark blue where concentration is lowest to dark red where concentration is highest.

5.1.2 Age and Type of Rock

Whenever possible, colors for ages and rock types on geologic maps should follow the scheme presented in the enclosed diagram showing suggested stratigraphic-age and volcanic map-unit colors (see section 33, appendix A). This color scheme has been in use at the USGS for many years, and it has been adopted by many geological surveys throughout the world.

On maps that cover a broad range of ages and rock types, relations between rocks within one age group can be shown by using similar colors, whereas relations between the same type of rock in different age groups can be shown by using patterns (for example, all volcanic rocks may have the same "v" pattern). Patterns should be used sparingly, however, as their use can create an overly busy appearance; use them only when the complexity of the map requires the diversity achieved by the use of patterns.

When it is not feasible to show map units in the suggested age color, such as on surficial maps, terrane maps, or on maps where most units are in one age group or consist of one rock type, other characteristics should be emphasized with color. On surficial maps, for example, it may be desirable to show all glacial deposits in one color, landslide deposits in another, lacustrine deposits in another, and alluvial deposits in yet another. On terrane maps, color may be used to show lithotectonic relations between various groups of rocks.

On maps that are mostly one age group, it is best to distinguish sedimentary rocks from volcanic rocks (usually shown in reds or other bright colors) and plutonic rocks (usually shown in pinks). On maps that are mostly one type of rock, differentiation between different rock sequences can be shown through the use of different colors.

Although it is preferable to follow the aforementioned guidelines, some rock types defy such guidelines because they traditionally have been shown in a particular color. For example, serpentinite and other ultramafic rocks characteristically are shown in purple; limestone usually is shown in bright blue; and glacial till often is shown in light green.

5.1.3 Size of Map Areas

In general, small map areas should be shown in darker colors and large areas should be shown in lighter colors. An exception to this may be in situations when numerous small bands of map units are shown; in this case it may be best to alternate light and dark colors. In the case of units that consist of both large and small areas, add labels and leaders to the smaller units to avoid confusion. See section below entitled "Guidelines for Map Labeling" for recommendations on placement of unit labels and leaders.

Because it is more difficult to clearly distinguish color in small areas, it is very important to choose as unique a color as possible for units that are present in only small areas. The minimum size of unit area that can show color is about two square millimeters; anything smaller will need to be labeled. In addition, exercise caution when using patterns in small areas because small areas may fail to show enough of the pattern to adequately identify a unit; about one square centimeter is the minimum size to clearly show patterns. If there can be any ambiguity in a unit area's identification, it is safest to add a label and leader.

5.1.4 Contrast

Adequate contrast enhances readability. A key factor is not so much the difference in hue, such as blue or green, but the difference in intensity. Contrast should not, however, be so great as to be glaring, but it should be significant enough for easy legibility. Units that need to be emphasized should be assigned colors that stand out and contrast well with the colors of less important units. In addition, greater contrast is required for small areas, whereas a more subtle contrast is sufficient for larger areas.

5.2 Specifying Color Values

Color values must be high enough to provide adequate contrast but not so great that they prevent the unit labels, structure symbols, and topographic base from showing clearly. Except in small areas, magenta and cyan should be used in intensities of 50% or less. A greater intensity of cyan might obscure drainage features (commonly shown in cyan), and a greater intensity of magenta might obscure magenta fold axes and dikes. As a general rule, use a combination of color values that, when added together, totals 100 or less (for example, 30% cyan/40% magenta/20% yellow; 30/40/20 = 30+40+20 = 90).

To maintain enough contrast between two colors, try to keep at least a 20% difference between one of the color values (for example, 30% cyan/8% magenta/20% yellow and 50% cyan/8% magenta/20% yellow). A small percentage (8% or 13%) of black can sometimes be added to create more color combinations.

There are a few colors that should not be used on a geologic map. Avoid using 8% yellow because it is too light and cannot easily be distinguished from white. In addition, it may be wise to avoid using 13% or 20% cyan, as these colors may look like a body of water.

On maps that are to be offset printed, it may be best to use a solid (100%) single-ink color such as cyan, magenta, yellow, or a particular spot color in very small areas to avoid misregistration problems. For example, 100% cyan may be used to show small limestone blocks in melange, or 100% magenta may be used to show thin rhyolite intrusions.

5.3 Use of Patterns

Patterns can be printed either in black, in color, or as a dropout. Ideally, patterns should be used sparingly and only when necessary for clarification, as they can add unnecessary complexity to a map. To select appropriate patterns for a map, both the type of rock and the size and (or) orientation of map-unit areas must be considered.

Although some flexibility exists in the use of patterns, some patterns are traditionally and exclusively used for certain rock types: for example, "+" patterns are used for plutonic rocks, and irregular "v" patterns represent volcanic rocks. For units that are present only in small areas, a tight, random pattern will fit more of the pattern elements into a particular area. Exercise caution, however, when choosing metamorphic patterns that display a strong directionality, as their use may imply a general orientation of metamorphic fabric that in reality is much more varied than the pattern may indicate.

5.3.1 Overprint Patterns

Black overprint patterns are less effective than color in most situations, as they can conceal base-map information or interfere with type or structure symbols. Thus, it may be best to restrict the use of full-black patterns to small, uncluttered areas; if a map-unit label is needed, it can be placed outside the area and leadered in. Black patterns can be screened to reduce their intensity, but be aware that doing so may lead to misregistration problems on maps being prepared for offset printing; this is because the color fill underneath such screened elements will most likely be masked out during the RIP.

Color overprint patterns are usually printed in either cyan or magenta, but sometimes a spot color such as red is used. For offset printing, it is best to use only one color for overprint patterns, as using more than one color can cause misregistration problems.

5.3.2 Dropout Patterns

Dropout patterns cause one or more of the CMYK colors that combine to make a unit color to be transparent, thus allowing the remaining color(s) to show through. Their use can be especially effective on a map that has a large amount of labeling or many structure symbols.

For output to a single-pass inkjet plotter, a dropout pattern may be applied to all of the CMYK colors that make up a unit color; the dropout pattern would then show as white. Be aware, however, that doing so may cause that unit to stand out more than is desired. For offset printing, only one color should be dropped out, as dropping out more than one will lead to misregistration problems; in general, the most dominant (the one with the highest value) color other than yellow should be the one dropped out.

6. GUIDELINES FOR MAP LABELING

Map-unit labels are the most common labels on geologic maps. Other labels include base-map information, feature names, and data items such as dip labels, gold concentrations, well depths, radiometric ages, and sample locality numbers. Before the use of digital technologies for mapmaking, labels and leaders were placed by either hand-drawing them or applying stick-up type. Nowadays, using digital mapmaking techniques, labels can be automatically plotted from information in a database; however, this often results in labels overprinting other map features, requiring them to be interactively repositioned or deleted. Regardless of the method employed, effective label placement is an important factor in producing a useful map.

For a map to be easily read, labels and leaders should be placed where they are clear and legible, with care taken to avoid overprinting of other labels or map features. They should not create an overly "busy" or cluttered appearance, which makes recognition of map patterns and shapes and map-element distribution difficult to discern. Enough features should be labeled so that the reader can identify all of the various map elements; no unlabeled map feature should leave the reader guessing.

Labels and leaders should be carefully placed to avoid overprinting of linework, symbols, or other labels. They should not obscure other map elements or make them difficult to read, nor should they obscure base-map features that are mentioned in the text or that are useful in locating places on the map.

6.1 Strategies for Map Labeling

Commonly, color or pattern can be used to identify an unlabeled polygon if a nearby polygon of the same unit is labeled. Therefore, color selection can be critical when deciding whether or not to label a particular polygon. Thus, it is important to complete the color and pattern design of the map before attempting to place and move unit labels, especially for complex maps or those that have many units.

There are no precise rules for which and how many of the polygons on a map should be labeled, but the following are some general guidelines. If a unit has a unique and clearly distinguishable color or pattern, it is not necessary to label every polygon of that unit. Color and pattern can carry the identification of a group of polygons of the same unit as long as some of them are labeled. Use judgment when deciding whether the color for that unit is distinctive enough and (or) whether a particular unlabeled polygon can be visually or logically associated with any nearby labeled polygons of the same unit. In small polygons, however, even the most distinctive color or pattern may be difficult to discern. If there might be any doubt, add a label and leader.

At least one polygon of every unit within a "normal field of view" should be labeled. This field of view is the area in focus when the map is viewed at a comfortable, readable distance. In uncluttered areas of the map or in areas of relatively simple geology, this field of view might have a radius of about two inches; in geologically complex or cluttered areas, it may be much smaller. The reader should not need to search across the map trying to find a labeled polygon that has a color that matches an unlabeled polygon.

In addition, maps that are to be downloaded from the Web will be sent to a plotter of unknown type, and there is no guarantee that colors that appear distinct when plotted on your plotter will also be distinguishable when plotted on other plotters. The more polygons that are labeled, the less chance of ambiguity and confusion.

6.2 Font Selection

When placing labels digitally, it is important to use the same font that will be used for final publication. The size and kerning (spacing of letters) of characters are different for different fonts, even those having the same point size. If labels have been carefully placed in tight areas using one font, but then another font is used for final publication, the labels may overprint other features because the new font may have longer character heights and string lengths. In addition, it is important to always use PostScript fonts, which are needed to ensure consistent final output for both print and digital publications.

In most cases, Helvetica, Times, or StratagemAge should be used. Other fonts besides these three may be used, but they may not plot correctly on all common output devices. The important thing to remember is to use the correct kind of font: use a sans-serif font like Helvetica or StratagemAge for most type on a map, such as unit labels, dip values, and fault names; use a serif font like Times for labels on cross sections. For base-map information, use a combination of serif and sans-serif fonts; the general rule is to follow the styles found on a published topographic map sheet.

6.3 Type Size and Style

The ideal size for map-unit labels is 8 pt, although labels as small as 6 pt may be substituted where space is tight. Fractional font sizes may be used if needed, and different sizes can be mixed on the same map. If unit labels contain subscripts or superscripts, the minimum unit-label size should be 7 pt; then the size for the subscript or superscript character would be 5 pt, two point sizes smaller than normal.

Other sizes and styles are used to label different features. In general, use 8 pt type for names of faults and major structures, for sample locality numbers and radiometric ages, and for fault (U/D, A/T) and contact (Y/O) ornamentation. Use 6 pt italic type for dip or plunge values. Use 11 pt italic type for cross-section labels. For labels of larger features, type size and (or) kerning (letter spacing) may be increased to improve legibility.

6.4 Label Placement

Labels for linear map features should be aligned along those features. Other labels should have a logical or comfortable orientation relative to the map. In rare cases it might be desirable to have labels run parallel to lines of latitude, but in general they should be oriented horizontally.

Unit labels and dip values should always be oriented horizontally. They should not overprint other map elements such as linework, point symbols, or any other dip values and labels, nor should they obscure base-map features that are referenced in text or are needed to orient the map in the field. Single labels can be used to identify more than one polygon; use multiple leaders where necessary.

Unit labels should not be placed in dark-colored units or in densely patterned areas, both of which would make the labels hard to read; instead, move labels outside such areas and add leaders. If a label must be placed in a dark-colored or densely patterned unit, it may be necessary to mask out the color or pattern around the label to help make it more legible.

6.5 Leader Placement

Leaders should be drawn as straight lines, not bent or curved. They should not stop at or outside polygon boundaries but should extend into unit areas. Leaders should cross polygon boundaries at as high an angle as possible; they should not cross through other units to reach a particular unit unless absolutely necessary. Multiple leaders emanating from a single label should not be joined at their "label" ends.

7. ACKNOWLEDGMENTS

This new draft standard owes its existence to the well-established cartographic traditions of the U.S. Geological Survey. In particular, the authors of this standard wish to thank the numerous cartographers and editors who contributed to the informal USGS Technical Cartographic Standards volume (U.S. Geological Survey, ca. 1975), as well as Mitchell Reynolds, James Queen, Richard Taylor, and others who were responsible for preparing the 1995 proposed standard (U.S. Geological Survey, 1995a), from which this standard has evolved. We also thank the many geologists, cartographers, graphics specialists, GIS specialists, editors, and others who reviewed either the 1995 USGS proposed standard (see Soller, 1996) or the preliminary, beta version of this draft standard and who provided invaluable comments and suggestions for revisions during the preparation of this Public Review Draft.

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