

## **Digital Cartographic standards for 1:50,000 Geologic map: some important considerations.**

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### **Abstract**

Geologic maps are extremely complex interpretive documents. Additional complexity is introduced by the lack of consistency at different levels. Important issues like interpretive, complex nature of geologic map, scale of original survey, basemap content, presentation of structural features, adherence to international conventions and media of map presentation has to be addressed before postulating a national standard for map presentation. Consistency has to be maintained in original surveying, in descriptive information, attributes codes and in compiling maps. Unless these prerequisites are fulfilled, any effort to prepare a digital cartographic standard will be futile.

### **Introduction:**

A geologic map is the principal tool that geologists use to convey information about the structure and stratigraphy of the earth's surface, the location and type of geologic hazards and earth resources. The most powerful and useful aspect of geological maps (especially large-scale) is the correct representation of rocks in three dimensions (areal extent and height and depth information) with added information of time (geological age). A geological map is thus a four-dimensional information system on a horizontal reference plane, which is crucial in understanding not only where earth resources and characteristics are located, but also how and when these earth features were formed.

The primary objective of geological map is to reconstruct the geological evolution of the area. A geologist understands the geometries of the rock bodies and their lateral and vertical relationships from the map. Idea about the three dimensional nature of the rocks and their relative ages is obtained from this information which in turn helps in interpreting the geological history of the area. Having acquired this knowledge, the geologist can then apply his understanding in solving problems related to earth resources, hazard assessment, and land-use planning.

Geological maps are produced by various government, private and academic agencies, according to various locally developed guidelines. They are extremely complex documents with many different types of information displayed. Additional complexity is introduced by the lack of consistency at different levels, starting from original surveying to design of GIS databases and in the products derived from them. Consistency from one map to another is not a primary concern when users are focused on local problems. As geologic maps are used for larger, regional studies, consistency of data representation becomes more important (Johnson et al, 1997). Implementation of standards for data generation, database designing and presentation can facilitate the sharing of information within an organization and between organizations.

Geological Survey of India has been publishing hard copy geological maps at scales 1:250,000, 1:1,000,000 and 1:5,000,000. While doing so GSI has been using international (CGMW) and national standards for map presentation. Field survey has always been done at a larger scale (1:50,000 and 1:25000) than the published maps. GSI is participating as a contributor agency of

the NSDI and has committed 1:50,000 geologic maps as the agency layer to NSDI. Accordingly it has become a prime necessity to develop national standards for geologic map presentation at a scale of 1:50,000 (Croswell, 2000).

The presentation of geological information on maps (both print and electronic media) must be supported by standards in order to increase the utility of the information. Development of digital cartographic standards is necessary to promote the dissemination and extensive use of the information. There should be consensus on necessity and content of the standard. Such standards should be developed collaboratively (involving national, state, academic, private agencies) and should be acceptable to the collaborators and the geoscience community in general.

Descriptions of geologic features, relevant examples, cartographic specifications and notes on how to use the symbols should accompany a map symbolization standard. The standard should aim to be scale dependent, implying their usability with maps compiled or published at any scale. It should be applicable to both print and web media. While developing such a standard the following issues have to be taken into consideration beforehand.

1. Interpretive nature of Geologic map
2. Complexity of Indian geological set up
3. Scale of original survey
4. Basemap content
5. Presentation of structural features
6. Adherence to international conventions
7. Media of presentation

In the following sections each of these issues are discussed in detail.

### **Interpretive nature of geologic map:**

In bedrock geologic map, the extent of exposure and the character of the **map units** (Formations in case of 1:50,000 map) control the accuracy of the map. Often it is difficult to find natural rock units of suitable thickness for mapping at the intended scale and composed of an easily identifiable rock type. This implies that the identification of map units are not always objective and is fraught with uncertainty. Typically large portions of the map area reveal no **outcrops** (exposed bedrocks or surficial materials on the land surface). Consequently outcrop information must be extrapolated to cover the entire map. This extrapolation is based on understanding of the structure, and stratigraphy of the area (Spencer, 1993; Maltman, 1998). Mapping thus proceeds by observation, formulating hypothesis, testing further observation and so on. The final product is a mixture of recorded observations and the hypothesis that the field geologist considers to best connect those observations. The observations almost always reflect the present state of geologic knowledge. This is the major reason that advances in geologic knowledge commonly necessitates remapping of regions. Proper understanding of the stratigraphy of the area is needed so that the field lithology units can be translated into map units. Standard symbology for map unit display can only be prepared when standard definitions for the geologic features have been specified. A unified stratigraphic legend is a primary requisite to achieve this purpose. The intended standard document should specify the characteristics (lithological, structural, etc.) by which the field units can be assigned to respective map units.

### **Complexity of Indian Geology:**

India is one of the rare subcontinents where, rock units ranging the entire time scale, from Archaean to Quaternary are exposed. Correlation between the diverse spatio-temporal geological sequences is an enormous problem. The complexity further aggravates due to the fact that evolution and disposition of the different geological units are not similar throughout the region. Some headway, however, could be made by considering the three physiographic domains, namely, the

- i) Peninsular shield,
- ii) Extra-peninsular shield and
- iii) Indo-gangetic alluvial tract.

These physiographic domains have distinctive geological evolutionary history. Again each of these physiographic domains has their inherent dissimilarities and complexity. For example, the Peninsular shield is a mosaic of four major cratonic domains- the Southern Indian Craton (SIC), the Central Indian Craton (CIC), the Eastern Indian Craton (EIC), and the western Indian Craton (WIC). These cratons have evolved from Archaean through Proterozoic, but their evolution is not exactly similar in the sense that, while the Archaean greenstone sequences are more widespread and prominent in the SIC, are not remarkable in the other three cratons. The linear to curvilinear Proterozoic fold belts that are identifiable in WIC (Delhi, Aravalli), CIC (Mahakoshal, Sakoli) and EIC (Singhbhum) are not identifiable in SIC. Similarly, the mildly deformed cover sequences, such as, Bijawar, Gwalior, and Abujmar sequences which are present in CIC, are rare in other three cratonic domains. Therefore, stratigraphic correlation and subsequent standardization of map units even within a single physiographic domain is a difficult job, leave alone the correlation between different physiographic domains. However, post Mid-Proterozoic, the evolutionary history of the Peninsular shield is more or less uniform, except for the fact that, the terrestrial facies covers of linear grabens (Gondwana) are present in all the cratonic domains barring the WIC.

The extrapeninsular belt comprises a huge volume of reworked shield elements, but due to the reworking during the Himalayan orogenesis, the original characters of these elements are so much obliterated that their correlation with their peninsular counterpart is yet to be achieved.

Constructing unified stratigraphic legends for each of the physiographic domains can be an optimal solution; if necessary the different cratonic domains can be treated separately also. These stratigraphic legends that represent a taxonomic type classification (having major-minor code system) can be used to formulate the hierarchical map unit symbols, or in other words a unified color and/or pattern code for all the Supergroups, Groups and Formations. Currently no such hierarchical symbolsets are in vogue in any of the GIS or CAD packages. It is imperative that this approach will demand creation of hundreds of symbols, which has to be significantly different from each other in order to distinguish nominal categories. Moreover, if lots of color are used for certain domains, the choice of color remaining available for the other domains will be much too limited for satisfactory discriminations.

#### **Scale of original survey:**

Field geologists tend to map geological features depending upon the scale of survey. What is definite at small scale may be only inferred at larger scale. The nature of the administrative boundary does not change with map scale; the cartographer only applies graphical generalization if at all necessary (large scale to small scale). It is commonly defined and observed with a resolution with much greater precision than it is plotted. Geologic objects are commonly defined

and observed with a resolution that is near the intrinsic resolution of the map (Haugerud, 1998). Symbols (continuous or dashed lines) are used to denote whether an object is located as well as or more poorly than can be depicted at that scale.

Geologic data models should be consistent enough so that any geologic feature may be represented as one or more geometric shapes (volumes, surfaces, areas, lines) depending on the type and scale of the map. For example, rock units are not confined to a volume (in 3D geometry) or area (in 2D geometry). At a smaller scale, thin rock units may appear as surfaces (represented as lines or line segments in two dimensions) and small, but significant units may be represented as points. Similarly, veins, dikes, fault zones, etc. may change representational geometry with changes in scale. In the present case the scale of systematic mapping and scale of map presentation is same (1:50,000), so if the consistency of original surveying, and the data model is maintained then map compilation and presentation will prove to be an easier task.

### **Basemap content:**

Representing relief information is of utmost importance in geologic maps, but has to be done without compromising clarity. The purpose of using basemaps in thematic mapping is mainly to provide locational information and to some extent explanation for the thematic features observed. Geologic data are recorded and presented on a base, most commonly a topographic map. It is very important to represent relief in the base map and the most effective method of representation is by topographic contour lines (Maltman, 1998; Spencer, 1993). It is easy to construct topographic profile from contour lines (which is necessary for constructing a cross-section). An experienced map-reader can also gain idea about the attitude and disposition of rock units from the relationship between the contour lines and the contacts of different rock bodies. Drainage is also used, as it tends to follow the fracture pattern in the rock bodies. Next to contour lines, also roads and towns are used as base map features (for location).

GSI has decided to use triangulation points, spot heights, motorable roads, highways, drainage, important localities and administrative boundaries as the supportive basemap content. Contour lines though of prime importance will be omitted because of restrictive government policies. Thus decided the symbols for representing these basemap features can be generated in such a way such that they do not obscure the primary content of the map.

### **Presentation of structural features:**

A geological map not only exhibit the spatial distribution of rock units in three dimension but also reflects a wide spectrum of earth science database, in which the most significant element is the meso and the megascopic structural feature. These features can be broadly grouped into primary and secondary type, which play vital role in the following studies.

1. Environment of deposition as well as syndepositional tectono-magmatic episode
2. Stratigraphic and tectonic order of superposition
3. Reconstruction of tectonic history and postulation of regional framework
4. Delineation of economically potential zone and hazard prone areas

All these studies are carried out to formulate a near factual model for which the standardized database has to be the basic premise to start with.

In case of GSI's map, structural data have to be standardized both in regard to quality and quantity. Lack of the standardization exists in the maps of all geological terrain because of

workers, having different bias and objectives, mapped adjacent area of the same geological domain. In addition studies carried out during widely separated years present data sets in accordance with the prevailing status of knowledge at a particular time. These have resulted in existence of non-uniform data sets leading to problem of map compilation as follows:

1. Arbitrary use of symbols for structural features leads to difficulty in correlation of fabrics of adjacent areas.
2. Presence of detailed data in one area, in contrast to area with scanty data make it difficult to extend a particular structural domain in space.
3. Non-standardized data creates the main hindrance to postulate unequivocal tectonic framework of a belt and to establish its relation with presently juxtaposed areas.
4. Proper delineation of economically potential and hazard-prone areas is also not possible.

Establishing unified structural legends for regional and local structure prior to symbol design and formulating map compilation standards for structural data particularly for areas having detailed data set in one sector and scanty data in the other can overcome these problems.

Generalization of structural features (extremely pressing but unresolved issue) ideally depends on scale of presentation, the generations of structural features involved, the type of structure as well as the regional tectonic framework. Average structural trends can be obtained by constructing **stereograms** (a diagram used to represent 3D orientation data in a 2D graphical form through stereographic projection (McClay, 1987; Maltman, 1998)) but that again require extensive analysis and understanding of the structure of the area.

It is worth mention here that although the structural features have an ordinal character; they are represented with an associative perception in the map. The ordinal character of the data is reflected in the legend where a younger structural feature is placed above the oldest one. In fact, the ultimate aim of geologists is to understand the geological history of the area, and that understanding is always reflected in the legend. The legend of geological maps is always constrained by the age relationships (ordinal character). Generally "Value" as a visual variable is not used to depict the ordinal character, as that would make the map difficult to read.

#### **Adherence to international conventions:**

As far as possible the national standards should conform to international standards (FGDC, 2000) and conventions in order to facilitate global sharing. Before attempting to construct a brand new digital cartographic standard, the existing international standards should be studied thoroughly to gain insight, as well as to maintain parity.

Color for symbols has to be judiciously chosen such that features could stand out clearly. For example, folds and dikes should be distinguishable from other line features such as contacts and faults. In doing so, adherence to long-established conventions should not be ignored, for example faults have always been drawn with red color; thrusts have been represented by asymmetric ornamented lines (sawteeth); structural features have been represented by asymmetric geometric symbols unique to geology; orange and red have been reserved for igneous rocks, pink for metamorphic rocks and so on. In addition to color, each map unit is normally assigned a code to symbolize it on the map. The code is a combination of an initial one or two capital letters (sometimes in Greek alphabets; representing the age of the map unit) followed by one or more small letters (representing the lithology). This is a convention followed by the geologic

community of the world, to make the map more readable, and should be an integral part of the standard.

It is understandable that each country or region could be geologically distinct and thus demands exclusive standards for their own use, but in doing so the purpose of facilitating easier exchange and sharing will be defeated.

### **Media of presentation:**

The rapid advances in information technology in recent years have revolutionized the way spatial information is collected, stored and presented. Now there is possibility of disseminating spatial information using electronic media apart from the traditional paper maps. The rapid growth of Internet and related technologies over the years has provided many more options to the modern mapmaker. The coming together of Internet and GIS has revolutionized the way users can access and interact with maps (Saha, 2002).

According to Kraak (2001), web maps can be classified into static maps and dynamic maps. Both of these categories can be subdivided into “view only” and “interactive interface and/or contents”. View only maps use symbols similar to conventional maps whereas in case of interactive maps the map design is defined by the navigational and interactive function. Also to hold the user’s attention a map should not only be functional, but also attractive from an aesthetic point of view (van den Worm, 2001).

Interactive web maps let one query the data in order to derive more useful information in comparison to traditional maps that are static. The incorporation of interaction in the display of maps may be considered as a major accomplishment of the computer-era in cartography (exploratory cartography) because in this way the user is in control of the resultant map.

The most common map found in WWW is the static view only map. Often these web maps are original cartographic products, which are scanned and put as bitmaps on the Web. The viewing environment or the WWW as medium dictates that the web map should not be too large in both image and file size (Kraak, 2001). This puts constraint on the map content as well and implies that graphic and information density should be low. This handicap can be overcome by using interaction; all additional information can be put behind the map image.

Using interactive techniques can be of great use in most of the cases, but may prove to be less effective in case of structural features. The interactive symbols may fail to provide an overall idea about the geological setting of the area (showing type localities may alleviate the problem to some extent). Depicting all the structural symbols on the map image is also problematic. The low resolution of the display device does not permit that. Maps are supposed to bring out trends, patterns in data, that objective may not be fully realized in these approaches (Saha, 2002).

The Web offers both limitations and opportunities, which cartographers should take into consideration when producing web maps. Cartographers have to take into account the disadvantages such as the end-user environment, the speed of data transfer and the impatience of the general Web-user. On the other hand cartographers should take advantages of the interactivity and easy update facility the Web has to offer. Standard specifications should vary depending upon whether the presentation is intended for print or electronic (web) media.

Color specifications could be in CMYK for inkjet plotting, but if the map is to be offset-printed then spot colors (single ink, non-CMYK) can be specified. It is also necessary to get the same colors on screen and on the final printed map. To achieve that, it is necessary to produce color charts (Brown and Feringa, 1999). The purpose of these color charts is to judge in advance what the colors on the screen will look like when printed (Kraak and Ormeling, 1996)

If graphical map elements are to be published as part of a web page on the WWW, colors should be chosen from the web-safe, 8-bit color palette (216 colors) to avoid unnecessary dithering on devices that can display only 256 colors (Brown and Feringa, 1999). The web-safe color equivalents of the spot colors or CMYK colors has to be given. These web-safe colors are made up of RGB values that are as close as possible to the directly converted RGB-equivalent colors. The problem is that with only 6 possible RGB values to choose from (000, 051, 102, 153, 204 and 255 known as 00, 33, 66, 99, CC and FF in hexadecimal notation), it would be impossible to exactly replicate the entire gamut of colors needed for all the map units (FGDC, 2000) Fortunately, recent increase in use of monitors, which can display more than 256 colors, calls for a rethink. The problem of image size though remains. Fonts, their size and style used should be different for print and web media. It is better to use sans serif fonts for the electronic media. Apart from these, new techniques like shadow and transparency effects have to be considered while constructing symbols for web maps.

#### **Discussion and conclusion:**

Geologic maps and spatial data differ from other maps and spatial data in significant ways. In response to the steady increase in digital mapmaking and the need for having high-quality consistent maps it is necessary to prescribe digital cartographic standards. Many experiments are needed before prescribing an optimal standard. One of the great advantages of digital era is the ease with which data can be transferred, transformed and merged with other data sets. This ease is obtained only if data conform to common standards for format and content. GSI encourages such experimentation while creating some measure of standardization. The objective in developing this national standard for presentation of geologic features is to help in the production of geologic maps and related products that have a consistent appearance.

Consistency from one map to another is not a big issue when the focus is on local problems. As geologic maps are used for larger, regional studies, consistency of data representation becomes more important. Prior to creating such data presentation standards three levels of consistency has to be addressed: consistency of original survey (standardized data collection), consistency of descriptive information (standardized data model) and consistency of coding (Johnson et al, 1997). Standardized data collection format and a standard data model can only be realized after considering the interpretive and complex nature of geologic map. If the requirements of the first two levels of consistency are met, it is usually an easy task to automate the process of converting all attributes to a common coded representation. Unless these consistency levels are attained, any effort to create a digital cartographic standard for geologic maps will be unproductive.

The problem in case of GSI (as well as other survey organizations) is that, data is being collected and stored without any standardization from time immemorial. There exists disparity in both quantity and quality of data. Any new data model standardization effort has to take into account the great volume of data already collected. GSI has implemented 1: 50,000 map database in 1997 and standard data format is since being used for data collection. A process of refining and populating the database is currently on. The next step would be to formalize the map compilation guidelines and finally formulate the digital cartographic standards for map presentation.

The issue of implementing the cartographic standard is also important and should be addressed simultaneously. The requirements for hard-copy output (plotting and printing devices) and soft copy display have to be identified. Decision about the digital formats in which the standard set will be developed (based on the software most commonly used by GSI) has to be taken. Digital files for use with widely used output devices and GIS and graphics software can be developed at a later stage.

The standard should be dynamic- that is it should be maintained and updated as necessary to reflect the evolution in knowledge of geologic mapping.

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