A NATIONAL PROGRAM FOR DIGITAL CARTOGRAPHY

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ABSTRACT

Since 1977, the U.S. Geological Survey has been planning and developing the components that are now merging into the Digital Cartography Program. This Program undertakes the development of several types of digital cartographic data to meet the needs of Federal and State agencies and other users. In addition, the data are being collected so that increasing automation of the mapping process will be possible as improvements in technology occur. It is expected that the Program will be supported through a revolving fund on a self-sustaining basis. For the Program to be effective, it is essential that the products developed address the needs of the user community and are easily usable. To insure this, various coordination mechanisms are in operation to provide feedback on the suitability of the products. There are presently four main types of products available to the public. An active research and development program is also underway to examine new products and more efficient means of data production.

INTRODUCTION

Digital cartography has many faces. For some it is the use of automated techniques to produce a finished map from a digital data base. For others it is the automation of the mapping process to achieve greater efficiences of production. It can mean the availability of base information in digital form that permits the quick and easy preparation of thematic maps. For those in resource managing agencies, it often means the availability of digital data that enables the modeling or analysis of complex spatial problems that, in some cases, could not otherwise be undertaken. For the U.S. Geological Survey (USGS), digital cartography means all of these things. Only by recognizing and understanding the full range of uses and applications of these data can a program to construct a National Digital Cartographic Data Base be successful.

In order for the digital cartography program to be effective, USGS has established the following objectives:

- Create, manage, utilize, and distribute the national cartographic and geographic digital data base for multipurpose needs.

- Assist Geological Survey Divisions, other Federal and State agencies, and others in developing and applying spatial data.

- Coordinate digital cartographic and geographic activities and provide leadership to the Federal government in the development and application of spatial data.

- Implement digital techniques in cartographic and geographic operations.

- Establish a major capability for digital geographic and cartographic research and development.

US GEODATA

One of the major interests for the user community is the growing availability of cartographic data in digital form. Whether the data are to serve as a base for the graphic presentation of other data or to serve as the principal input for spatial analyses, digital cartographic data are valuable to a wide community of users.

The Geological Survey is now producing a number of digital cartographic products including elevation data, planimetric data, and land use and land cover data. These products are available at a variety of scales ranging from 1:24,000 to 1:250,000. The USGS has selected the term "US GeoData" to provide an overall identity to these varied products. While any individual product must still be identified by its type and scale, all digital cartographic and geographic data distributed by USGS will be known as US GeoData. This should create a more coherent image of the Digital Cartography Program and provide a clearer context for the array of products from the Geological Survey.

Information on current USGS digital products can be obtained through the National Cartographic Information Center (NCIC) headquartered in Reston, Virginia. They can provide information on the specific coverage of available data and their costs. User guides are available that describe the data content, formats, and coding schemes. NCIC will also handle orders for any categories of data that are available.

Current digital products can be summarized under three headings:

1. Geographic Names Information

2. Digital Elevation Models (DEMs)
   a. 1:24,000-scale DEM data
   b. 1:250,000-scale Defense Mapping Agency digital terrain data

3. Digital Line Graphs (DLGs)
   a. 1:24,000-scale topographic series
   b. 1:250,000-scale land use and land cover series
   c. 1:2,000,000-scale planimetric information

The creation of these products reflects the present capabilities of USGS for data production and the expressed requirements of major users, especially Federal agencies. In the future, the list of products can be expected to grow and change as capabilities develop and as the requirements for digital cartographic data expand. Even at this present level, the products represent a considerable base of information for users that is worth examining in more detail. However, today, particular attention should be given to a new digital cartographic data base covering the entire Nation at 1:2,000,000 scale.

1:2,000,000-SCALE DATA BASE

The Geological Survey, in responding to increasing user needs for up-to-date cartographic data and products on a nationwide basis, is introducing a digital cartographic data base at 1:2,000,000 scale. A major emphasis of the USGS has been the development of a digital cartography program applying automated techniques to the cartographic process. This approach offers the attractive features of reduced manual effort, quick response, high precision, and the versatility to generate products of various scales, projections, feature combinations, and output media. Until now, there has not been a suitable data set available for user applications at a regional or national scale in the United States.

Existing digital cartographic data bases that include the United States are the CIA's World Data Bank I and World Data Bank II, and the DIMECO files. Some of the limitations associated with these data sets are the very small scale of the source material used for the original digitization, the limited range of features digitized, the lack of currency of information, inaccurate source documents, and the limited flexibility for merging these files with thematic data available in digital form from various organizations.

Using World Data Bank II as an example, source documents were digitized at scales of 1:1,000,000 to 1:4,000,000; digitizing was performed from 1973 through 1977; and only coastlines, islands, lakes, rivers, and international and State boundaries are available for the United States. Past experience with these data sets has shown that, while they most likely met the objectives for which they were designed, their content is not sufficiently comprehensive for many common cartographic applications.

The current 1:2,000,000-scale digital data base is intended to address several of these shortcomings. The cartographic source materials used for digitizing (the general reference maps of The National Atlas of the United States of America)

are at a scale of 1:2,000,000--the only exception being the Alaska drainage manuscript which were originally compiled at 1:1,000,000. The content of the data base includes political boundaries (State and county level), Federal lands, transportation networks (roads and railroads), hydrographic features (streams and water bodies), and populated places. The National Atlas source materials were updated immediately before the digitizing phase, thus providing the most current information available. The inclusion of more data categories and the more accurate digitization has also resulted in a larger data base. For comparison, World Data Bank I contained about 20,000 points and World Data Bank II had 1.5 million points to cover the entire world, while the 1:2,000,000-scale data base has some 15 million points to cover the United States.

These data were digitized using digital line graph procedures. The term "digital line graph" (DLG) has been selected to describe planimetric map data collected by USGS. All these data are digitized in a topologically complete, arc-node structure; identifying beginning and ending nodes and areas left and right. This procedure avoids duplicate digitizing and permits the use of software to perform topological verification resulting in more consistent and accurate data.

The classification system was designed for distinguishing not only the broad categories of map features but also the subcategories of an individual feature. The coding scheme is organized to allow the selection of specific classes of features appropriate for a map, given its scale and intended use or purpose. The various features are assigned a numerical rank based on the significance of that feature relative to other features of similar type. The evaluation of a feature's significance is based on criteria established for a given set of features and varies among different sets of features. For example, railroads are classified by annual tonnage; roads, by designation (Interstate, U.S., etc.). This will permit plotting procedures to delete features automatically, based on the relationship between the size or area of the particular features and the scale of map being produced. These 1:2,000,000-scale DLG data files represent the first full national digital data coverage with a significant improvement over World Data Bank II.

The data are available in two formats. One is a topologically structured data set which will provide a useful geographic reference system for displaying a wide range of thematic data, allow for various types of spatial analysis, and furnish a means of automatically producing patterned or solid-fill plates for reproduction. The second is a graphically oriented data set which will be compatible with the Cartographic Automatic Mapping (CAM) program. The data are distributed in a sheet format with 21 sheets covering the United States with three layers of information for each sheet: boundaries, transportation, and hydrography. The data are now available through NCIC.

RESEARCH DIRECTIONS

To maintain the viability of any major program, especially in such a high technology field, it is essential to have an ongoing research program providing new techniques, examining new technologies, and developing enhanced capabilities. The USGS is committed to a major program of research and development to expand existing capability, improve efficiency, and develop new applications.

A primary focal point is the automation of the mapping process. As budgets shrink and personnel ceilings drop, it is critical for the USGS to make the maximum use of automation. The Geological Survey is strongly committed to the incorporation of automated techniques in the mapping process. The implementation of such procedures is aimed not only at the development of digital products, but also at improved efficiencies and economies of operation. A system has been developed that permits the efficient collection of digital data directly at the stereocompilation stage. A key task now is to develop effective procedures for the digital revision of maps. Only as that process moves into production will the real efficiency of a digital cartographic data base emerge. In the area of the map finishing process, there remains considerable research and development to establish an economical system for the digital production of standard topographic maps. The time has not yet arrived where a press of a button will yield a map full of the complex levels of information expected of a topographic map.

However, it must not be forgotten that there is a growing community of users for digital cartographic data. They have a need for data today and expect it to be more accurate and expect a lot more of it than yesterday. To meet those needs as well as internal needs, it is necessary to build the data base as fast as possible. To do this, USGS is developing a major capability in raster scanning. There is a backlog of 40,000 maps in graphic form that must be addressed. This development effort is examining not just scanning techniques, but the entire production process including the attribute tagging and editing functions as well as effective quality control procedures. As the data base grows it will become one of the largest ever and will raise new problems of data management. USGS is already conducting tests of new mass-storage devices and conducting research on spatial data base management systems to insure that these facilities will be available when needed.

The Survey has recognized that, in addition to providing map base category data in graphic and digital form, there will be a growing need to interface the basic map data with other types of data, often collected by other agencies (Federal, State, and local). These data will include additional base categories, thematic data of various kinds, and administrative support data. In response to these emerging needs for data analysis and use and in an attempt to improve the current cartographic processes, the idea of an expanded data base as now conceived would serve as the source for preparation of standard graphic products, such

as the 7.5-minute quadrangle maps, as well as supply customized map products to meet low volume but important needs.

Also, digital data files, both standard and customized, could be made available to various government and non-government agencies for the purpose of conducting automated geographic analysis. The National Mapping Division of the Survey is currently proposing to move in several stages from essentially manually based cartographic processes (Figure 1) to an integrated digital cartographic and geographic data base. Under the existing system, standard maps prepared by mainly manual processes are subsequently used as the source material for the digital products. We are currently proposing to expand our use of computers and associated equipment to move toward a digitally integrated system to produce standard map products, standard digital data files for geographic analysis, and customized graphic and digital products (Figure 2). Under this plan, data would be either collected directly by digital recording devices (substantially replacing fieldwork and traditional aerial photography), or converted to a digital representation as early in the cartographic processes as possible. The data, then in digital form, can be edited, checked for quality, and stored. From the digital data base the various products will be derived. One clear emerging trend is the need to be able to combine map base-category data with other data, often collected by another agency, to build a data base specific to a particular problem. A cartographic/geographic data base in digital form will present the opportunity to collect and store a great variety of data to meet these needs. These data may be collected by other agencies according to standards developed by the National Mapping Division. These standards will probably be variable, depending on data category (base categories, thematic map data, administrative type data, etc.), and all data entered into the data base will be tagged with appropriate descriptive information (source of data, accuracy, etc.). When the data are subsequently retrieved for use, the user will know the relevant characteristics of the data, and can, at that time, make the decision as to whether or not the data are suitable for his application. Obviously, it would be ideal to store only the highest quality data, but this is impracticable from a cost standpoint, and often less than perfect data is better than no data at all as long as the user is aware of the data limitations.

STANDARDS

For digital cartography to develop on a sound foundation that will effectively serve the wide range of users that are emerging, it is essential that appropriate standards be developed. Recognizing the necessity for standards, the USGS has taken a leadership role in their development as an extension of its existing responsibilities for map standards.

CURRENT PROCESS

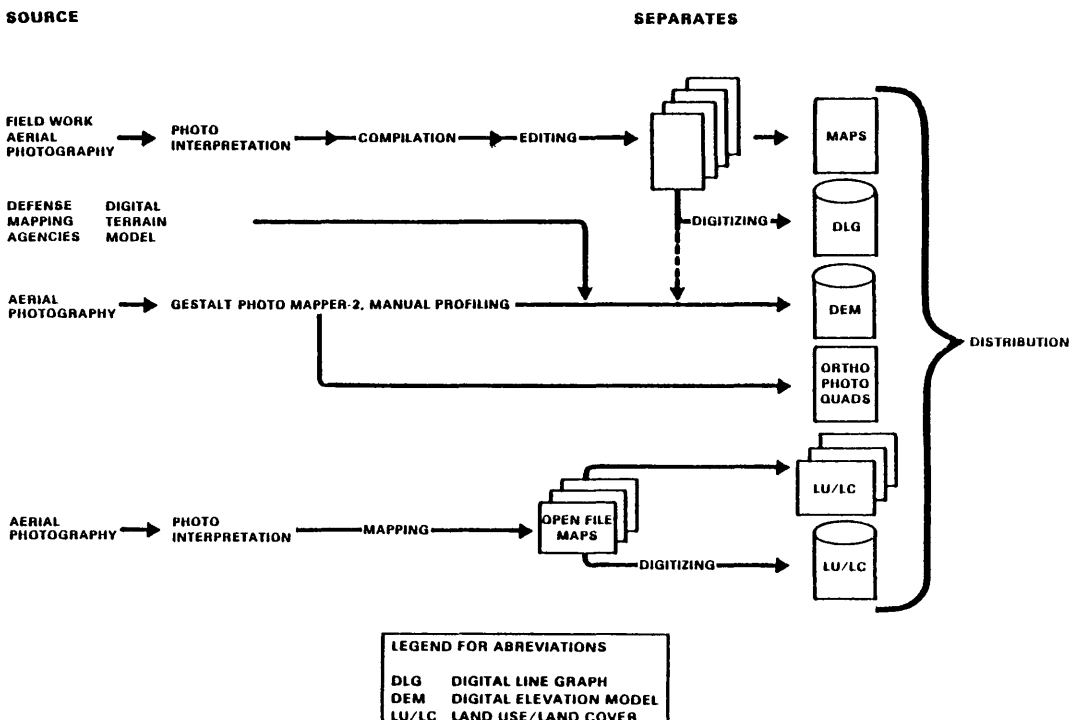

Figure 1. Current mapping process of the USGS National Mapping Division

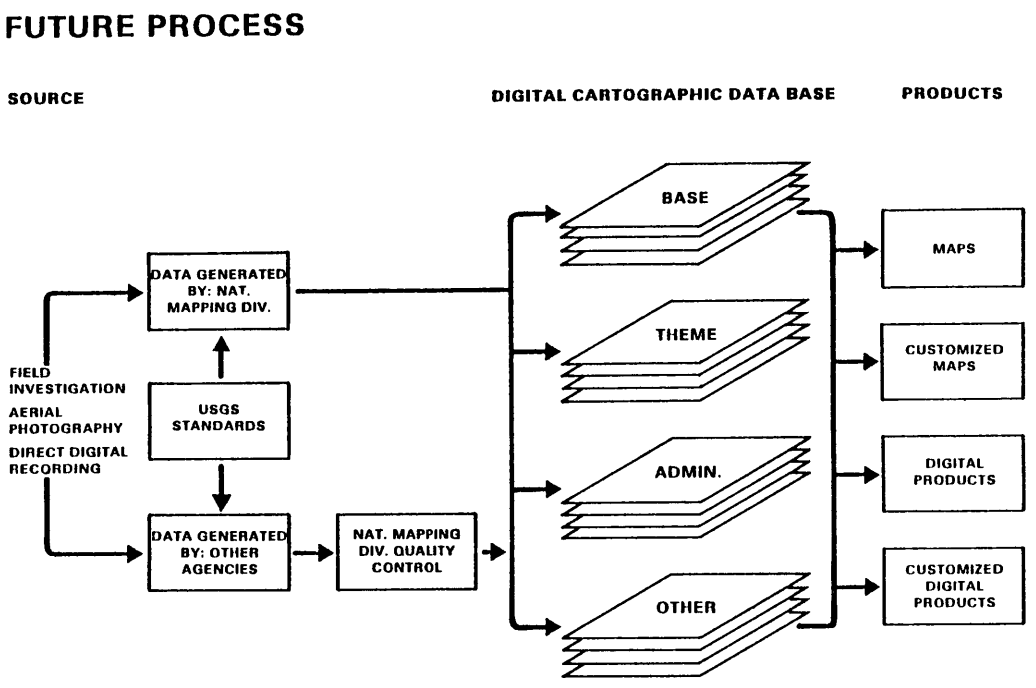

Figure 2. Proposed future mapping process of the USGS National Mapping Division

The setting of standards in digital cartography presents a number of complex problems that go far deeper into spatial data structures than the usual issues of ADP protocol and formats--issues usually discussed by computer scientists. In a very real sense the development of standards for digital cartography requires a completely fresh start in cartographic science unencumbered by current codes and specifications. The evolution of map standards and conventions over the past several hundred years is almost irrelevant in approaching the future requirements for automated geospatial analysis. The basic cartographic principles regarding accuracy, content, and currency will still be vital in understanding the new world of digital maps, but the codified standards for a graphic map do not translate directly into the computer environment.

The USGS has taken the first steps in the standardization process because the reliability and acceptance of the digital cartographic data base will thereby be enhanced. A procedure has been developed to process digital cartographic standards through the U.S. Bureau of Standards for eventual issue in the same form as many of the computer-related standards. An interagency committee has been developed at the Federal level to examine the requirements and needs of major users and to work towards the establishment of standards. The Survey has supported the establishment of the National Committee on Digital Cartographic Data Standards under the auspices of the American Congress on Surveying and Mapping with participation from across the field to coordinate the development of standards. A USGS staff section in the National Mapping Division has been established to develop and enforce standard procedures and quality control in the Divison's operations. But there is still much more to be done as the data user community develops and the role of the digital cartographic data base in relation to automated cartography and geographic information systems evolves.

CONCLUSION

The field of digital cartography is dynamic and challenging at this stage of development. The user community is steadily expanding and new applications are continually emerging that require more data and better software. It is an exciting era, and the Geological Survey is proud to play a leadership role in the field of digital cartography.