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THE GENERATION OF A PROTOTYPE USGS 1:24,000-SCALE TOPOGRAPHIC MAP FROM DIGITAL LINE GRAPH DATA

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Summary

In an effort to modernize the production of graphic maps, the U.S. Geological Survey is investigating the development of automated methods for the production of standard topographic maps using Digital Line Graph (DLG) data. This paper describes the development of processes that led to the production of a fully symbolized color composite proof of the 1:24,000-scale Bombay, New York - Quebec quadrangle from Digital Line Graph data archived in the National Digital Cartographic Data Base. The project was developed to include the use of existing hardware and software for production, to maximize the automation of production procedures wherever possible, to minimize the use of interactive editing, to create symbols that meet established 1:24,000-scale map series standards, and to produce publication-quality output.

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INTRODUCTION

The U.S. Geological Survey (USGS) is investigating the development of automated methods for the production of standard topographic maps and thematic graphic products. Efforts to produce graphic products from digital data were recently organized into a development activity known as Modernization - Product Generation (MPG). The primary goal of the MPG activity is to complete the development necessary to produce both standard and nonstandard graphic products in an automated fashion using commercially available hardware and software. Initial investigations into the automated production of various graphic products have already been conducted.

The primary goal of this research was to produce a fully symbolized color composite proof of a 1:24,000-scale quadrangle from archived Digital Line Graph (DLG) data. A secondary goal included automating the production processes wherever possible. An outline of the production workflow developed to generate graphic products from DLG data is included in Figure 1.

In addition to describing the production workflow, this paper focuses on the problems encountered in converting DLG attribute codes into map symbols. Although the production process was executed on a specific combination of systems, the basic problems experienced in converting a DLG into a symbolized map will be inherent in any similar production process involving DLG files. The insights that were gained from a data users perspective are among the most valuable results of this project. They are presented in some detail here, and are intended to assist the DLG user, regardless of the type of equipment being used.

Working Parameters

The Bombay, New York - Quebec data set was selected because the moderate level of detail was appropriate for developmental testing and all data categories were archived in the National Digital Cartographic Data Base (NDCDB). The data sets, or overlays, included hypsography, hydrography, surface cover, nonvegetative surface features, boundaries, survey control and markers, other significant manmade structures, and transportation.

Several decisions were made about how the Bombay data set would be handled. The 1:24,000-scale data set would be used to produce a 1:24,000-scale graphic; the data would not be adjusted or generalized. The final graphic was to reflect the true character of the digital data, and the data would not be edited in any way. Attribute codes indicating that a feature was photorevised would be ignored in the production process.

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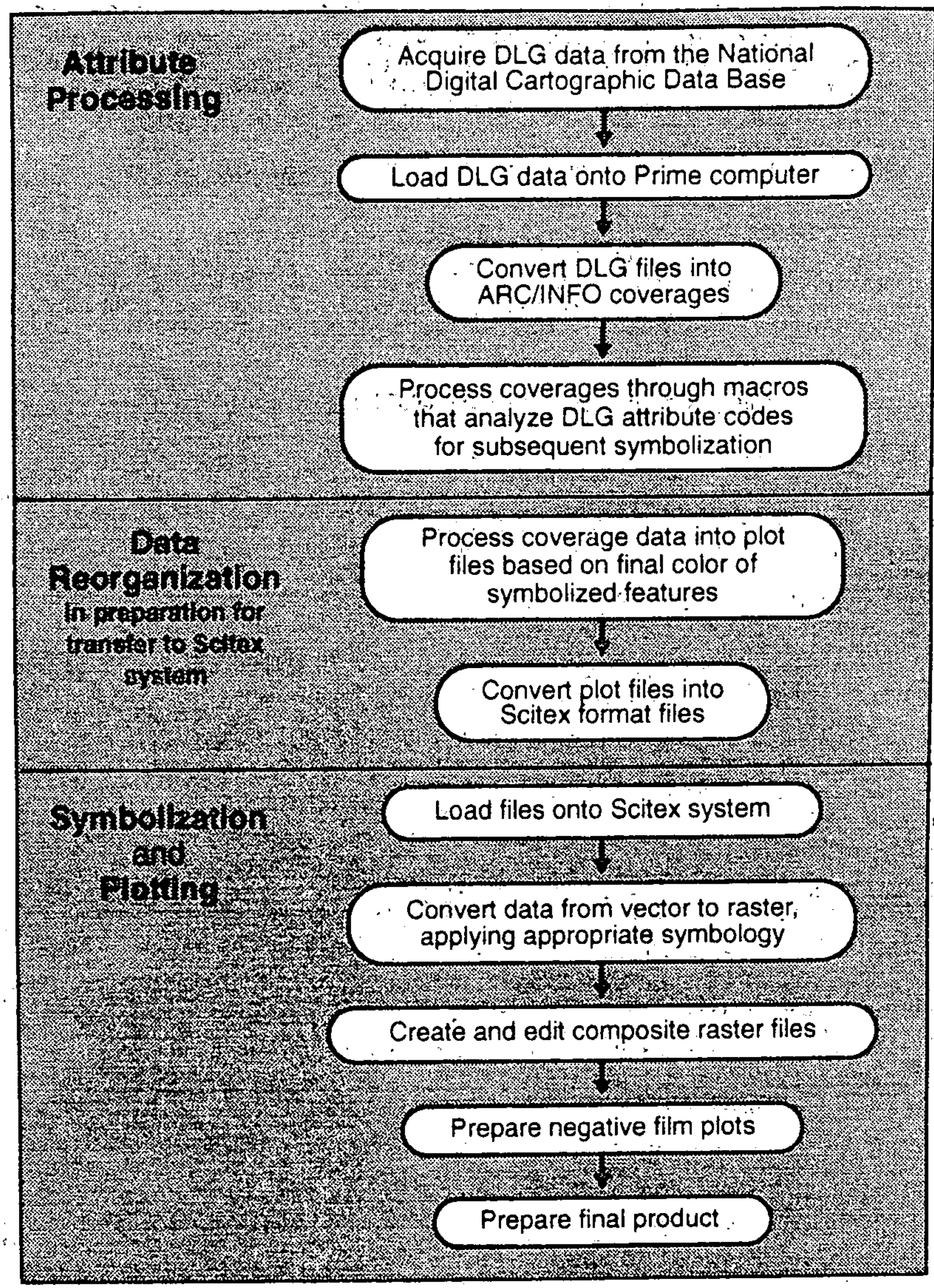

Figure 1. Outline of the process developed to generate graphic products from Digital Line Graph data.

The symbols for this project were to be of publication quality, as defined in USGS graphic standards. The graphic standards selected for the production of the Bombay quadrangle were the "Standards for 1:24,000 and 1:25,000-Scale Quadrangle Maps, Part 5, Publication Symbols (Metric Unit Maps)" (USGS 1984), also known as the Part 5 specifications. The Part 5 specifications were selected because they are oriented toward digital production and are the most recently published of the 1:24,000-scale topographic map standards.

The hardware and software for this project were ARC/INFO (version 5.0.1) on a PRIME 9955 computer and the Scitex Response-280 System (version 6.83). All work was done on the Scitex and ARC/INFO systems except the production of a projection and UTM grid and projection labels. USGS projection and plotting software was executed on an Encore 32/9780 computer, and plotting was done on a Gerber 1232 plotter.

CONVERSION OF DLG ATTRIBUTE CODES INTO MAP SYMBOLS

Producing map symbols from the DLG attribute codes was not a straightforward process. The first step was to identify and analyze the attribute codes in the data set and to relate those codes and code combinations to graphic symbols in the Part 5 specifications. The second step was to produce map symbols on automated equipment to meet the standards in the Part 5 specifications.

Relating Attribute Codes to Symbols

One attribute code does not necessarily represent one map symbol. In many cases, multiple attribute codes represent one graphic symbol. For example, a narrow gauge multiple track railroad is represented by three attribute codes: 180 0201 (railroad), 180 0606 (narrow gauge), and 181 XXXX (number of tracks).

There are no technical instructions that link the digital standards as defined in the "Standards for Digital Line Graphs, Part 3, Attribute Coding" (USGS, 1985) to the graphic standards in the Part 5 specifications. To establish a relationship between the two, tables were prepared that included every map feature and its graphic and digital representation.

In addition to relating a graphic symbol to its digital attribute code(s), a column was added to the tables for the TEST number, a value assigned to each feature based on its graphic representation. The use of TEST numbers effectively compresses the DLG attribute codes to a single value. In the preparation of the attribute tables, discrepancies between the digital standards and the graphic standards were encountered. The discrepancies occurred because the attribute coding system was not designed specifically for product generation. In addition, the graphic standards and the digital standards were written at different times, and some of the resulting differences have not been reconciled. Therefore, the two sets of standards have not been fully integrated.

Problems encountered in translating attribute codes into map symbols are summarized below.

<u>Attribute codes do not completely describe a feature in a manner that allows for graphic representation of a symbol</u>. For example, churches are symbolized as

buildings with small crosses, but the digital codes do not include any information as to the positioning of the church cross in relation to the body of the symbol.

Thresholds specified in the digital standards do not match those in the graphic specifications. When minimum and maximum specifications do not match, it is impossible to translate a feature defined by digital codes into graphic representation precisely.

The manner in which a feature is coded necessitates additional work prior to symbolization. Boundary lines are not explicitly coded in the digital file. Most boundaries must be derived from the area attributes on either side of the boundary line.

Features described in the digital standards have no corresponding symbol specification in the graphic standards.

Features exist on the map that have no corresponding code in the digital standards.

Symbolization
Once digital attribute codes were associated with graphic symbols and resulting problems resolved, symbolization of the features began. Symbolization tests were conducted in ARC/INFO and on the Scitex system for producing publication-quality line, point, and area symbols. Each test was plotted on a Scitex laser plotter for evaluation. Most of the symbols were easily produced on Scitex or ARC/INFO. However, it was virtually impossible to create automated symbols for features that were areal in nature and required an irregular representative pattern. A coral reef, a braided stream, and a railroad yard are examples of these types of features. Selected symbols and a portion of the Bombay quadrangle (excluding screened data) are shown in Figure 2.

Line Symbolization. The creation of custom lines in ARC/INFO is limited because the symbolization software is not able to adjust the symbol cycle to the line. Symbol patterns stop abruptly at the end of each line segment. The symbol cycle then restarts at the beginning of the next line segment. The result of this mechanical application is often a poor quality, discontinuous line pattern. In addition, controlling line widths was difficult in the conversion from ARC/INFO to Scitex.

Line symbols produced on the Scitex Response-280 system were of very high quality. The Scitex has the capacity to generate line widths accurate to one-thousandth of an inch; therefore, all the nuances in the graphic standards were easily handled by the Scitex system. The major advantage of Scitex software is its capacity to automatically adjust symbol cycle to line segment. Another feature of Scitex symbolization is the ability to control line intersections. A priority of specific line symbols can be defined, which creates open intersections where cased roads meet. Line symbols can also be placed over other lines to create compound line symbols.

Line Symbols

National Boundary

State Boundary

Primary Highway

Primary Highway with centerline

Multiple Track Railroad

Narrow Gauge Railroad

Depression Contour

Point Symbols

Gravel Pit

Mine Shaft

Boundary Monument

Gaging Station

School Flag

Cemetery

Exposed Wreck

Area Symbols

Swamp

Class 1 Building

Inundation

Orchard

Sample from Bombay, New York-Quebec Quadrangle

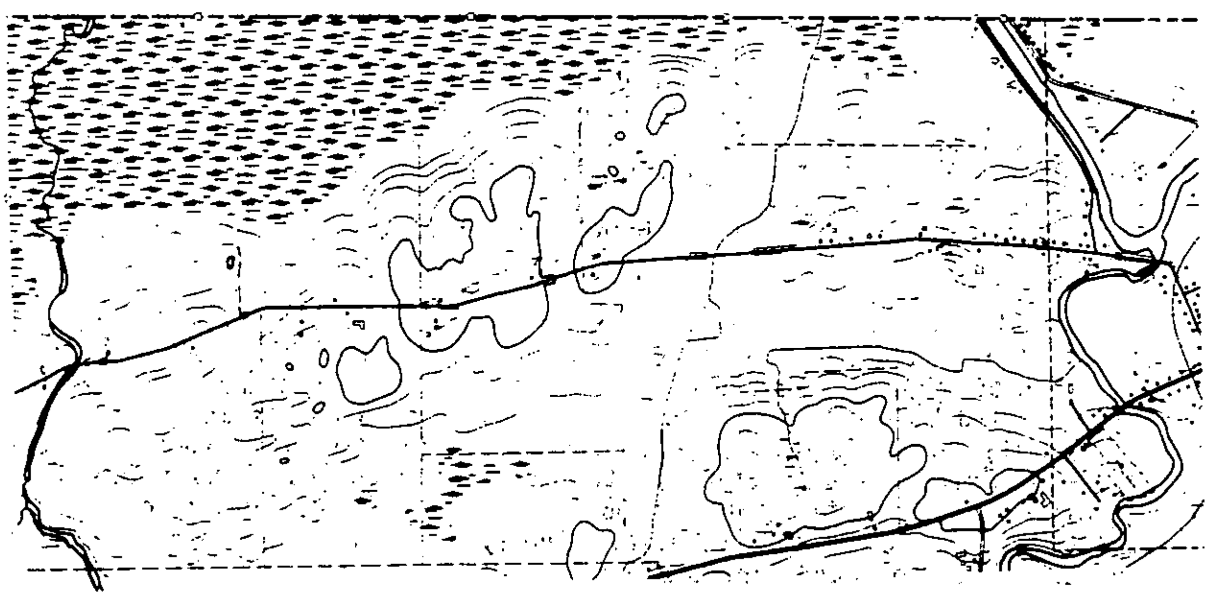

Figure 2. Examples of publication quality symbols.

Area Symbolization. The creation and application of custom area patterns was tested only on the Scitex system. Area pattern symbolization was not tested in ARC/INFO because the ARC/INFO program for creating custom area patterns was judged to be very limited. Small raster files, approximately 300 pixels square, were created and stored in the Scitex library. Initially, the area patterns were scanned, but it was discovered that they would have required considerable editing to make them useful. The scanned patterns were used as guides for creating new raster files, which were much cleaner than the scanned files. The raster patterns proved to be very successful and easy to apply using the Scitex area fill command.

Point Symbolization. Point symbolization was initially tested on the Scitex system. A small raster file was created for each point symbol. Symbols that did not require rotation were easily produced on the Scitex system. The placement of point symbols requiring rotation was more complicated and required some experimental work. Ultimately, rotated symbol placement was accomplished by using both the Scitex and the ARC/INFO systems. The symbols were created either by manual digitization or by keying in the specifications, and then rotated in ARCPLOT. They were passed to the Scitex system as vector data for symbolization and plotting. This two-system method of producing rotated point symbols was not without problems. It was difficult to control the overall dimensions of the point symbols, and occasionally the symbol shape was not reproduced accurately.

To summarize the final symbolization decisions, all line, point, and area features were ultimately symbolized on the Scitex Response-280 system. Line, area, and nonrotated point symbols were constructed entirely on the Scitex system. Point symbols that did require rotation were created and rotated in ARC/INFO and symbolized on the Scitex.

PRODUCTION WORKFLOW

Attribute Processing

The first step in the production process is to load the file from tape to disk and convert it into a set of ARC/INFO coverages. The file is output to a set of four coverages; an arc coverage containing lines, a polygon coverage, a point coverage containing attributed nodes, and another point coverage containing degenerate lines. During this conversion, topology is stripped from the DLG, and attribute codes are placed in an INFO file. It is then necessary to rebuild the topology according to ARC/INFO standards and to join the attribute file to the coverage. The item called TEST is added to the INFO files. The TEST item will be used to hold the subset of attribute codes for product generation.

The four coverages are now ready to be run through a series of attribute code processing macros. These macros assign a value to the TEST item based on the DLG attribute codes. The result is a subset of attributes necessary for graphic production. The attribute processing macros also call other macros when further processing of features is necessary. The function of this second tier of macros is to derive codes for uncoded features based on topological relationships.

The final step in attribute code processing is to unify line segments where necessary. This type of processing is carried out for major linear features found in the roads and trails and boundary files. Line segments are unified by removing unnecessary nodes, which allows the linear symbol to be applied more uniformly to each line segment.

Data Reorganization

In the next step of the production workflow, the data are reorganized in preparation for transfer to the Scitex system. A series of color separation macros convert the coverage data into plot files on the basis of the color of the final symbolized features. For example, all features that will appear in blue on the color proof are extracted from the original coverages and placed in a plot file. TEST values are used for this reselection process.

Data reorganization is conducted within the ARCPLOT software module of ARC/INFO. The files composed in ARCPLOT are later transferred to the Scitex system for plotting. While the DLG features are never actually plotted using this ARC/INFO plot format, the preparation of the plot file provides a linkage between DLG features and those files that define symbology in the Scitex system. In addition, a common set of registration marks is added to each plot file.

The link to the Scitex involves two additional types of ARC/INFO files: lookup tables and symbol set files. Lookup tables associate an arbitrary symbol number to each TEST value. The symbol number is translated into symbol specifications through the use of a symbol set file. Typically, symbol set files would define the symbols to be plotted. However, in this procedure symbol descriptions vary only in the parameter that defines color. The color number provides a link to specific symbol information on the Scitex.

Four files are generated as a result of the data conversion from ARC/INFO to Scitex. They include a vector file, an area fill file, a symbol file, and a report file. The vector file contains line and poly partitions. The line partition contains the arcs, and the poly partition contains the polygon outlines. For the polygons in the plot files, an area fill file is generated that contains area fill points and fill codes to indicate symbology for each polygon. A symbol file contains point feature locations and the name of a symbol to be placed. A report file lists the results of the conversion process and is used to check for proper conversion of the file.

Symbolization and Plotting

Next, plot files are written to the Scitex system and converted from vector to raster format. During this conversion appropriate graphic symbols are applied. The rasterization process requires a font library for line symbols, raster pattern files for area patterns, and raster symbol files for point symbols. The linking of ARC/INFO and Scitex symbol information is accomplished through the use of tables in ARC/INFO, known as font and marker tables. These tables provide a systematic means of defining the linkages between the ARC/INFO and Scitex systems.

Certain point symbols need to be interactively rotated. Others must be interactively positioned, such as school flags or church crosses. This work is done on the Scitex workstation by using pixel coordinates for precision symbol placement or interactive placement for those items not directly encoded in the DLG.

Finally, the line, point, and filled polygon files are merged into a single file. The line file is first placed onto the filled polygon file. This allows symbolized lines that bound polygons to take precedence over the polygon information for overprinting purposes. Next the point symbols are merged. After the composite raster file is created, it is reviewed on the edit station. Corrections are made as necessary, and the raster file is then converted to the Scitex plot file format and plotted on the laser plotter. Film negative plots with the proper line screens are produced for color proofing. The negatives are hand-registered to the projection plate, and a color proof is made. A biangle screen is composited with an open-window negative of biangle features during the preparation of the proof, because the Scitex is unable to produce a biangle screen.

EVALUATION OF THE RESULTS

The goals set for this research project were met: a fully symbolized color proof was produced using off-the-shelf hardware and software, and the proof was judged to be of publication quality. The production processes were automated wherever possible through the use of 33 custom macros for ARC/INFO processing and 1 Scitex batch program. Minimal interactive editing was performed. The production of the color proof demonstrated the potential to produce a standard graphic product in an automated fashion. This effort marks the first time a standard product meeting publication specifications has been produced from DLG data.

The look of the color proof is remarkably similar to the original lithograph. A majority of the symbols produced met the specifications in the graphic standards. When the color proof was critically reviewed by experienced map editors, several categories of problems were identified. Most of the problems had been anticipated, as detailed earlier in this paper. These problems are summarized below.

Missing features. Features that were on the original graphic did not appear on the color proof because they were not encoded in the digital file. This error relates to omissions in the digital standards.

Errors on the original graphic were carried through the production process to the color proof.

Digitizing errors. Several features were digitized poorly, and the errors were reproduced on the color proof.

Poor quality linework. Some of the linework would have benefitted from the use of smoothing algorithms. This problem was particularly noticeable on long stretches of symbolized lines.

Poor registration. Corner registration marks generated in ARC/INFO were slightly different from those generated for the projection plate. All of the plots from the ARC/INFO to Scitex process registered precisely to one another. Preliminary investigations as to the source of the problem were made, but a definitive conclusion has not been reached.

Poor quality line symbols. Some of the nuances of manual application of the line symbol to a line were not easily duplicated in the digital production process. Minor problems were noted with irregular spacing and patterning of the line symbol, and patterned lines were not always turned on a dash but sometimes on a space or a dot.

Appearance of symbols that should be suppressed. In certain cases, the digital data provided information that was suppressed on the original graphic.

Improper classification of features. The automated classification of features did not always mimic the traditional methods of classification. The decision making processes of the cartographer are not easy to duplicate in the automated realm.

CONCLUSION

The research described in this paper contributes to the overall effort to modernize the production of graphic maps at USGS. It was a productive learning experience that provided insights into the processing of DLG attribute codes and how they relate to map symbolization from a data user's perspective. Strengths and weaknesses of the product generation capabilities of the ARC/INFO and Scitex systems were evaluated, and success in demonstrating the feasibility of automated generation of the 1:24,000-scale topographic map series was achieved.

This project represents a small part of the modernization program. Parallel research involving other standard map scales and hardware and software combinations continue to be explored.

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