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COMPUTER MAPPING SOFTWARE AT THE LAWRENCE BERKELEY LABORATORY

Peter M. Wood and William H. Benson

June 1978

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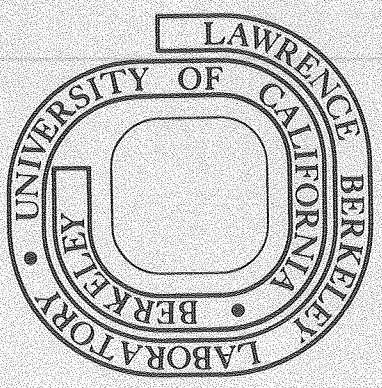

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COMPUTER MAPPING SOFTWARE AT THE LAWRENCE BERKELEY LABORATORY

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ABSTRACT

A number of FORTRAN programs useful for computer mapping are supported by the Computer Science and Applied Mathematics Department for preparing base files and displays of statistical data. Digitizing and editing of geographic base files is maintained by the programs MAPEDIT and ZING. Display of statistical attributes of discrete points, lines, or areas in two dimensions is done by the program CARTE. Display in three dimensions or of surfaces is accomplished using subroutines from the Integrated Data Display System. All the programs use a device independent graphics system, GRAFPAC.

DOE Contract No. W-74505-eng-48

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INTRODUCTION

A set of computer software has been developed at the Lawrence Berkeley Laboratory which facilitates the generation of maps by computer. This software has been useful in the digitization and editing of geographic base files as well as in the display of thematic data referenced to the base files. Base file preparation is done using the programs MAPEDIT and ZING. Display of geocoded point, line, or areal entities in two dimensions is done by the program CARTE. (These three programs were initially developed together and emphasize usability by non-programmers.) Display of surfaces or in three dimensions is done using subroutines from IDDS (Integrated Data Display System). This requires some programming knowledge. All these programs are interfaced to a device independent graphic system called GRAFPAC. Although there are other mapping related software packages available for use at the laboratory, only those mentioned above will be reviewed in this paper.

Program Name: MAPEDIT

Authors: Harvard Holmes, Bill Benson

Address: Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720

MAPEDIT is a FORTRAN program designed to support a variety of mapping operations. It allows the combination of maps and selection of subsets of a map according to several attributes. In this regard, it performs an intelligent copying function, allowing the selection of records to be copied in a convenient, map oriented manner. Second, it provides changes in projection (equirectangular, conic, etc.) and changes in format (the standard NICKEL (polygon), BCD listing, and a dime-like format). Third, it provides specialized data processing steps which are used primarily with raw digitizer input. These steps include data compression (using a straight line recognition algorithm), corner detection, fiducial analysis, error checks, fitting routines, and common boundary matching.

MAPEDIT uses a device independent graphics package (GRAFPAC, q.v.) supporting a variety of hardcopy devices and interactive terminals. Some operations, such as map composition, can be done better interactively, while for many others COM or pen plotter output generated in batch mode is more suitable.

MAPEDIT expects two files as input - a data file containing the map or maps to be worked on, and a file of commands describing the operations to be performed. MAPEDIT produces a listing of the operations, a data file of map items selected, and a plot file. MAPEDIT runs on the CDC 6000 or 7000 series machines, making use of up to 250,000 words of large core memory on the 7000 series machines, and using the disk for random access memory on the 6000 series.

The standard NICKEL format treats each map item as a separate polygon. No adjacency information is kept for boundaries. Each item is a separate logical record on tape or disk. Each item has an array length and an array of geocodes, four words for minimum and maximum coordinate limits, an array length and an array of cosmetic labels, and the number of points followed by the list of points. This format can be read by one FORTRAN READ statement. Coordinates are usually in west longitude and north latitude in degrees. Since each map item is separate, they may be in any order on the data file. There may be an unlimited number up to tape or disk capacity. There are typically less than 2000 points per polygon. Statistical or thematic data is not possessed by this program, but may linked to cartographic base files via common geocodes.

The format for operations to be performed consists of lines or cards of three types -

1) commands and options or parameters (identified by an asterisk in column 1)
2) a string of geocode and coordinate limits (identified by a slash in column 1)
3) inputs particular to a specific command (identified by the lack of an asterisk or slash)

Each command is followed by a list of 0 to 20 geocode strings, followed by command specific inputs. As many commands as desired may be used. A geocode string may use as many selectors as desired and in any order. A map item will be selected if all of its available geocodes match those in the string. Geocodes not supplied for the map item or not specified in the string are ignored.

Sample run:

From a US by county data file in NICKEL format (previously staged to the standard map input file), the following commands read counties 43 and 45 from state 6 (California) and plot a map of polygon boundaries.

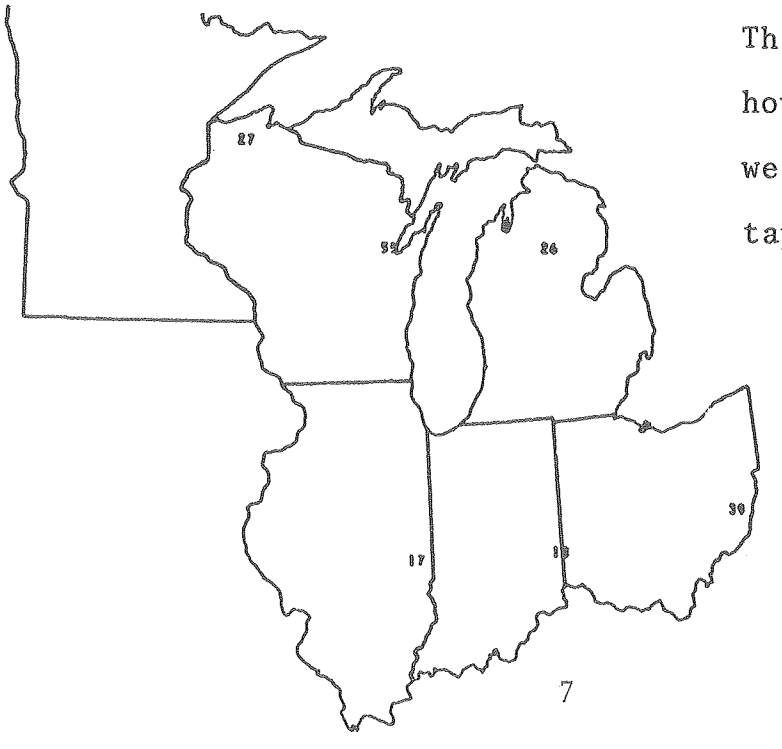
```
*append map
/state=6,county=43
/state=6,county=45
*plot
*quit
*quit
```

A list of commands executed, polygons selected, and number of points read is listed on the standard output file.

Availability:

This program may be obtained from Bill Benson at Lawrence Berkeley Laboratory. There is no charge at present, but the requestor must supply a magnetic tape. For non-CDC installations, the cource code can be written in either ASCII or EBCDIC on 9-track tape. Parts of this software are in use at Lawrence Berkeley Laboratory, Brookhaven National Laboratory, and Los Alamos Scientific Laboratory. The initial distribution was in 1973. There is a users' guide available.

```
@A M
/SI=17,SM=0
/SI=18,SM=0
/SI=26,SM=0
/SI=27,SM=0
/SI=39,SM=0
/SI=55,SM=0
   2.489  -9.142      18       0       0       0          18
   2.101  -8.707      27       0       0       0          27
   2.271  -8.818      55       0       0       0          55
   2.322  -9.155      17       0       0       0          17
   2.401  -8.700      26       0       0       0          26
   2.553  -8.863      26       0       0       0       0      0       0       0       0
   2.665  -9.081      39       0       0       0          39
GLOBAL LIMITS        1.92050733      -9.34850907       2.78014854       -8.50458097
APCLV        7, PTS IN        0, PTS OUT     2407
@PLOT
```



This example shows how six state outlines were extracted from tape.

Program Name: ZING

Author: Harvard Holmes

Address: Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720

ZING is an interactive map editor used to correct and update the geographic base files produced by the MAPEDIT system. The production of geographic base files passes through several stages -- selection of maps, photo reduction, automatic digitization, data compression and reformatting, joining insets together, and a manual review and correction of remaining errors. ZING is used for the manual review and correction process. This is accomplished at an on-line graphics console using commands to change points and lines, rename polygons, or create new ones.

ZING has been matched to the particular requirements of polygon editing. It is able to edit several polygons in parallel, moving several points belonging to several polygons at the same time. It also allows an individual polygon to be edited in context, that is, while adjacent polygons are displayed.

ZING uses a device independent graphics package (GRAFPAC, q.v.) supporting a variety of interactive terminals. ZING takes advantage of a vector refresh device, if available, by re-drawing only those parts of the picture that change. Otherwise, as with storage tube devices, the

entire frame is re-drawn after each edit operation.

For editing, ZING expects one file as input- the map to be edited (in the standard NICKEL (polygon) format). Edit operations are directed from the terminal by menu selection for commands, and cursor or light pen hits from the polygon display area for coordinate input.

The procedure for operating ZING is as follows. The display is divided into three parts -- the data, which occupies the central portion of the screen, the comments which appear at the top of the screen, and the commands, which appear at the right hand edge of the screen. The data portion displays the current map or a list of polygon names when the editor is in select mode. The comments are to inform the user what the editor is doing and what the user should do next. The commands are a list of actions available to the user. The general idea is to select a point on the map, and then execute some command using that point. Some commands require no data as input. Other commands are implicit, that is, something happens immediately upon selection of a point.

The display manipulation commands allow the selection of magnifications up to 100X of any area of the map. Having selected a magnification and a area, one may then step the display in any of four directions by half a screen width at a time. This is ideal for stepping around

a boundary at very high magnification.

The standard NICKEL format treats each map item as a separate polygon. No adjacency information is kept for boundaries. Each item is a separate logical record on tape or on disk. Each item has an array and an array of geocodes, four words for minimum and maximum coordinate limits, an array length and an array of cosmetic labels, and the number of points, followed by the list of points. This format can be read by one FORTRAN READ statement. Coordinates are usually in west longitude and north latitude in degrees. Since each map item is separate, they may be in any order on the data file. There may be an unlimited number, up to tape or disk capacity. There are typically less than 2000 points per polygon. Statistical or thematic data is not processed by this program, but may be linked to cartographic base files via common geocodes.

ZING is written in FORTRAN and runs on the CDC 6000 series machines.

Sample run:

Figures 1 and 2 illustrate the move points command.

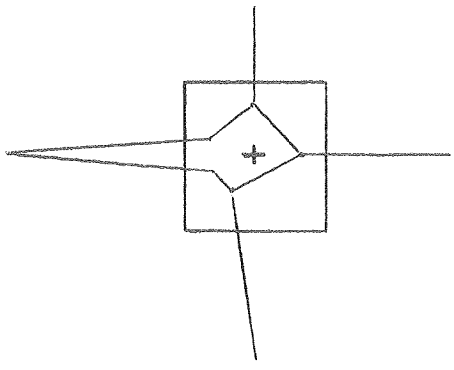


Figure 1. A typical corner at the intersection of four polygons. The cross shows the last position read by the program and the square outlines the area affected by the current command.

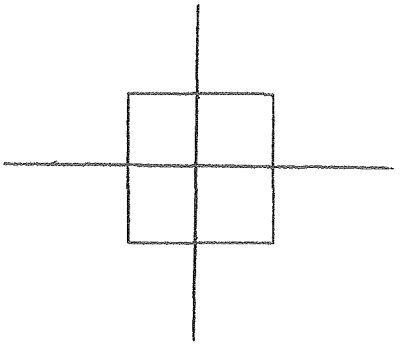


Figure 2. The points within the square have been moved to the cross.

No tabular output is produced.

Availability:

This program may be obtained from Bill Benson at Lawrence Berkeley Laboratory. There is no charge at present, but the requestor must supply a magnetic tape. For non-CDC installations, the source code can be written in either ASCII or EBCDIC on 9-track tape. The software is in use only at Lawrence Berkeley Laboratory. The initial distribution was in 1974. There is a users' guide available.

Program Name: CARTE

Author: Peter M. Wood

Address: Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720

CARTE is a program which helps a user combine statistical data with geographic base files to produce a thematic map. It is designed to assist the planner/analyst in both quick visual exploration and analysis of geocoded data as well as in the preparation of maps for wider distribution. Originally developed to assist in Department of Labor and Department of Energy applications, it can be used to display any statistical or nominal attribute of geographic entities that can be referenced to geographic base files (see Figure 3).

A flexible set of directives helps the user design and format the maps. Points may be symbolized by scaled or shaded user-defined symbols. (If shaded symbols overlap, they may be clipped.) Linear features may be symbolized by differences in line width, and areas by character symbols, textures or colors. Additional information such as titles and figures can be added to complete a map. Zooming on subsets of a base file, arithmetic expressions of attributes, and multiple maps (several insets or attributes on one frame) are also allowed. The actual display depends upon which device is being used. While resulting displays are sometimes not identical, the interface is standardized through the use

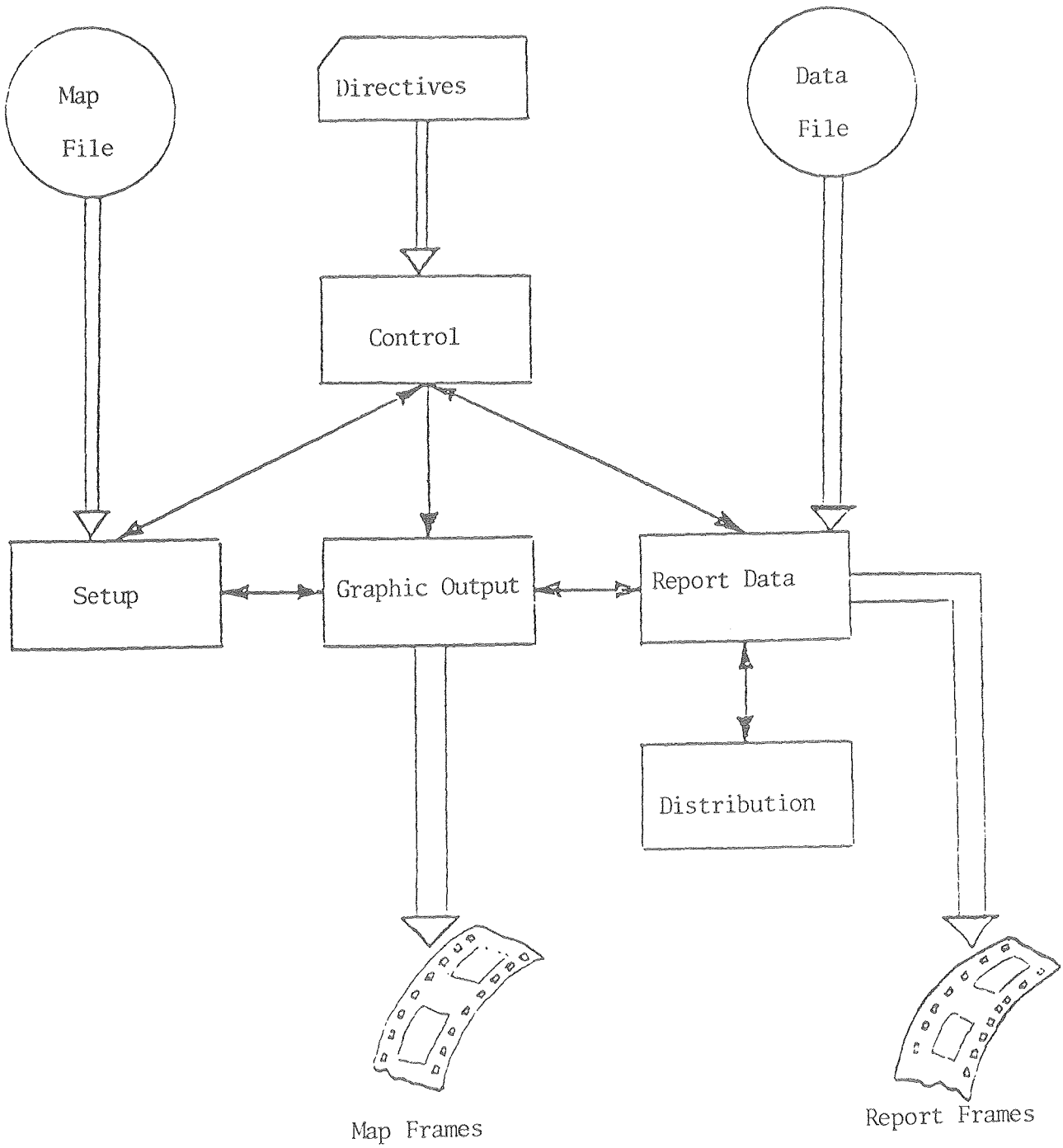


Figure 3. DIAGRAM OF PROGRAM STRUCTURE AND FLOW OF CONTROL

of the device drivers supported by GRAFPAC.

Cartographic data is read from a file that is usually prepared by MAPEDIT. This is structured so that all information for an entity can be read in one FORTRAN read statement. Each record contains -- map geocodes, bounding rectangle, labels, and points. For areas the points define a closed polygon, with no explicit adjacency information, but with points of islands or holes included. Lines and points are input using the same basic structure, although points can also be input with the data set.

Thematic data is input in two conceptual parts, a tabular data file and a data definition file which describes the structure and size of the data. The body of the data is a table, with geocodes and attributes for an entity comprising a row.

These two are related to each other by geocode matching. Thus the two files can be in any order, and more than one map entity can apply to one data record. The user can decide which elements to match although there are some commonly recognized geocodes, e.g. FIPS.STATE, FIPS.SMSA, and FIPS.COUNTY.

Figure 4 summarizes the inter-relation of map and data files. Map files are maintained in the standard form with a dictionary built to facilitate random access to the map.

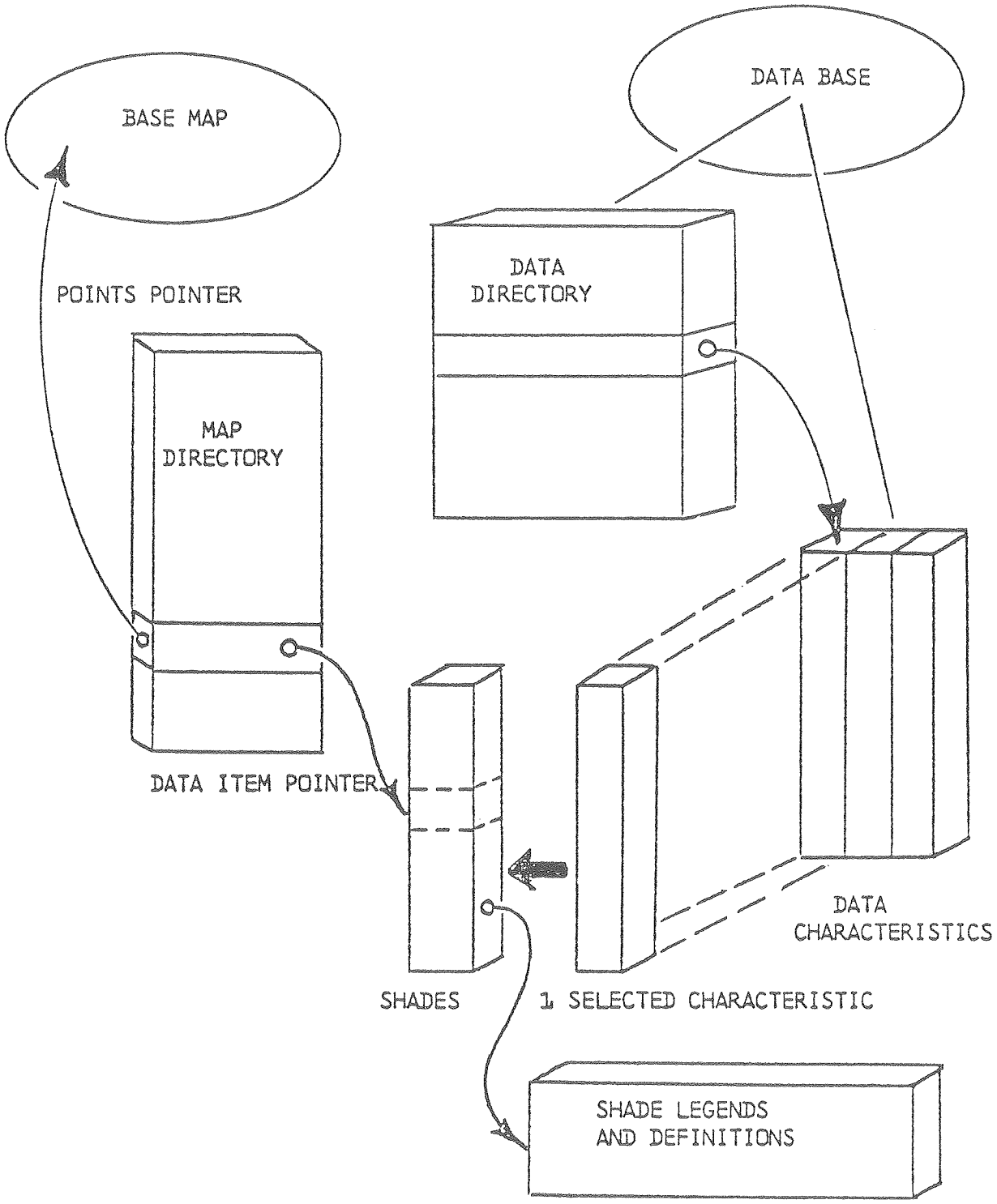


Figure 4 - Basic Map Data Structure

Data sets are transformed so that one attribute for all areas is easily retrieved. This is currently performed by a data management system.

Data volume and type problems are minimal. Routines are parameterized and algorithms structured to minimize data volume problems. Runs have been made with 3300 polygons, with up to 1200 points per polygon, and up to 100 attributes. Any data that can be referenced to a geographic location and transformed into an appropriate input format can be mapped. Data is usually located through geocode matching with existing base files. (Base files exist at LBL for census tracts, SMSAs, counties, states and BEA regions of the United States and for the countries of the world.) Point data whose location is embedded in the data set does not need to be geocoded.

There are two styles of command language for CARTE depending upon whether operation is in batch or interactive mode. The two styles are typed keyword/parameter as is used in MAPEDIT, and keyword selection through graphic input as is used in ZING.

Batch commands are indicated by an asterisk followed by a keyword (which may be abbreviated to one character) which in turn may be followed by its parameters.

*go indicates that the map is fully specified

More complex directives, may allow several lines of input, e.g. title input.

```
*titles,2
<index number>,<number of lines>,<location on page>
<Text of a title>
1,1,0,1000,0,1000
Text of a title
```

For interactive work, a menu of commands is displayed to the user. At each step the user selects one and the program will either a) prompt the user for needed parameters, b) perform the indicated operation and display the result, or c) display the menu of commands available to implement the one chosen. This can greatly facilitate positioning of map components, e.g. title location, and increases speed and reliability of map design and data analysis.

The main output of CARTE is thematic maps. It can also produce tabular reports of the input data, with multi-line titles, column headers, and footnotes. The sample runs which follow illustrate only making maps, one in batch mode and the other in interactive mode.

EXAMPLES

A FIRST MAP

A FIRST MAP

A map of gasoline consumption in Arizona is desired. Data is available at the county level from the Brookhaven Energetics Model. So the data set is prepared using a retrieval program, REAP. A base map of Arizona, composed of its counties, is prepared using MAPEDIT. Then the map is designed. Page 26 shows the map blocked out on a grid. Next, the directives are prepared.

First the general directives are made. The county numbers are the second key in the data set prepared and the fourth key in the nickel file produced by MAPEDIT. Thus the second key from the data and the fourth key from the map form a key pair. No other key pairs are needed because each county number for Arizona is unique. The maptype must also be selected. Although a multi-color map is desired, it is preferable at this stage to make cross-hatch maps because the whole map will be on one frame. Thus it will be easier to assess the impact of the map as a whole. The directive file so far is --

```
*keys,2=4
*maptype,hatch
```

Next directives describing the data are prepared. In this case, the default values are sufficient. The data set from REAP was prepared in CARTE's default format, the third data value from this first data set is to be mapped, and, since the distribution of the data is unknown, the program will be allowed to generate the division points for the data.

Now the map is described. The picture space units are set as 0 to 1200. The map is centered in the picture space, but room is left around the edges for titles and a legend. The titles and the legend are also translated into directives. Thus added to the directive file are --

```
*picture space,0,1200,0,1200
*xymap space,200,1000,200,1000
*legend,1,0,200,0,500
1,1
by county
*titles,4
1,1,4,0,1200,1100,1200 (centered horizontally on
                        the screen)
map one
2,1,4,0,1200,1000,1100
btu per capita gasoline consumption
3,1,3,600,1200,100,200 (centered in the right half
                        of the screen)
Brookhaven Energy Atlas
```

4,1,3,600,1200,0,100

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The map has been completely specified. With the addition of a *go directive, the first pass map of Phoenix can be produced. Figure 5 shows the complete job necessary to generate this map.

An Example of Map Design

A Square Picture Space Ranging From 0 to 1200 is Defined

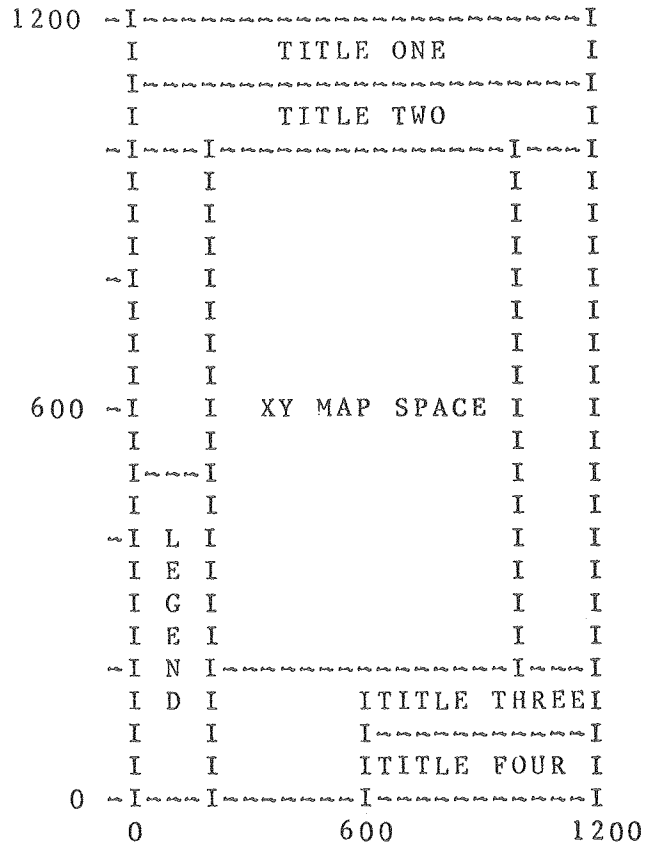

Figure 5. Deck setup for a first cross-hatch map

```
map,,,70000.acctno,name
fetchmt(data,libno)
fetchmt(map,libno)
fetchps(carte,carte,cartlgo)
carte.
dispose(film=mf,m=me)
7/8/9
*keys,4 8
*maptype,hatch,choropleth
*picture space,0,1200,0,1200
*xymap space,200,1000,200,1000
*legend,1,0,200,0,500
1,1
by  county
*titles,4
1,1,4,0,1200,1100,1200
map one
2,1,4,0,1200,1000,1100
btu per capita gasoline consumption
3,1,3,600,1200,100,200
Brookhaven Energy Atlas
4,1,3,600,1200,0,100
```

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*go

6/7/8/9

This ends the example of map-making in batch mode.

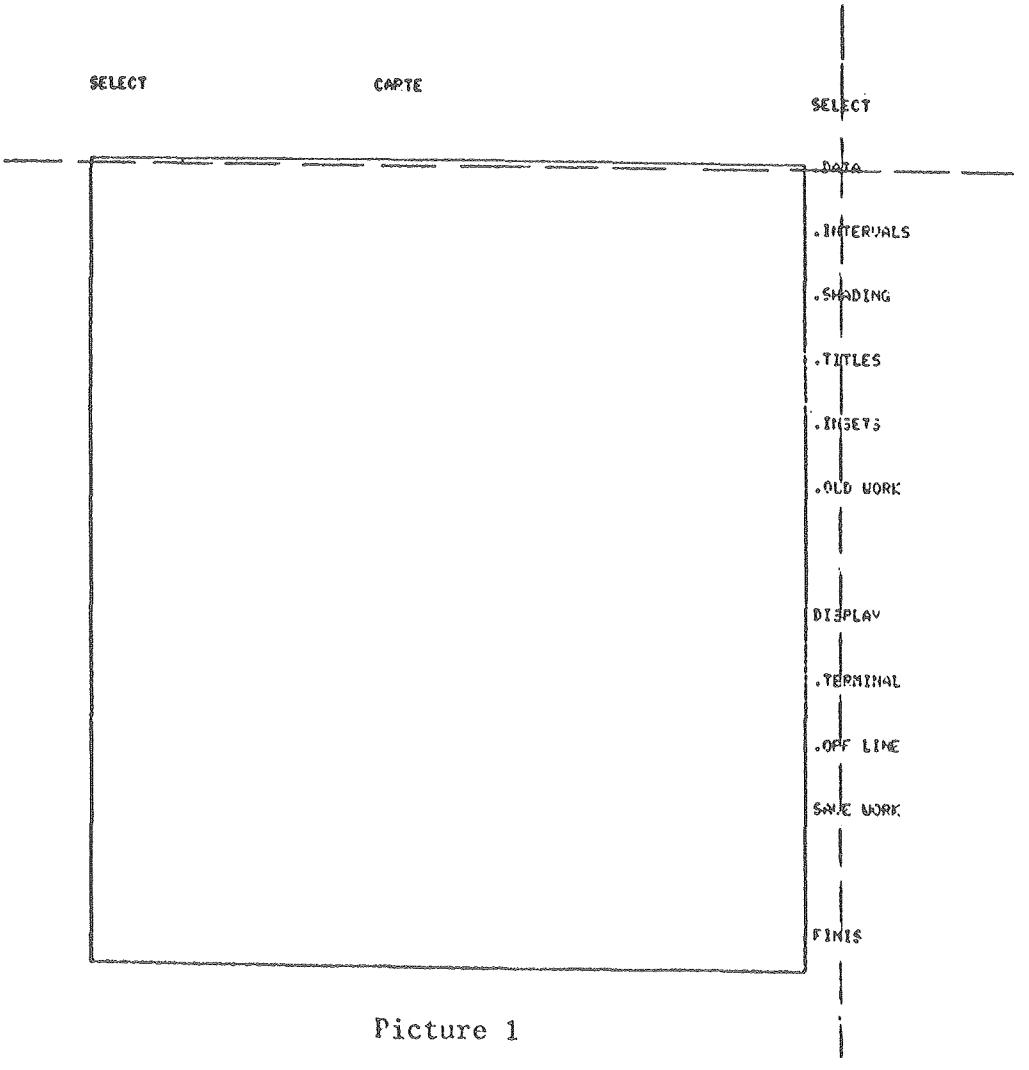
The following example shows the commands required to draw a first map interactively. The five "Pictures" that follow are reproductions of the screen image (Tektronix 4014 model) in the map-making process. They are extracted from Workbook III, Computer Mapping Systems, Programs MAPEDIT, DOBEDO, and CARTE, LBL-6439.

Simple Design Sequence

..DATA - Data File Display

Execute the .DATA directive by centering the cross-hairs (represented by the dotted lines in Picture 1) on the word .DATA, now hit the space bar and then the Carriage Return key.

The User has an option with the DATA directive to do simple arithmetic on the data base characteristics.

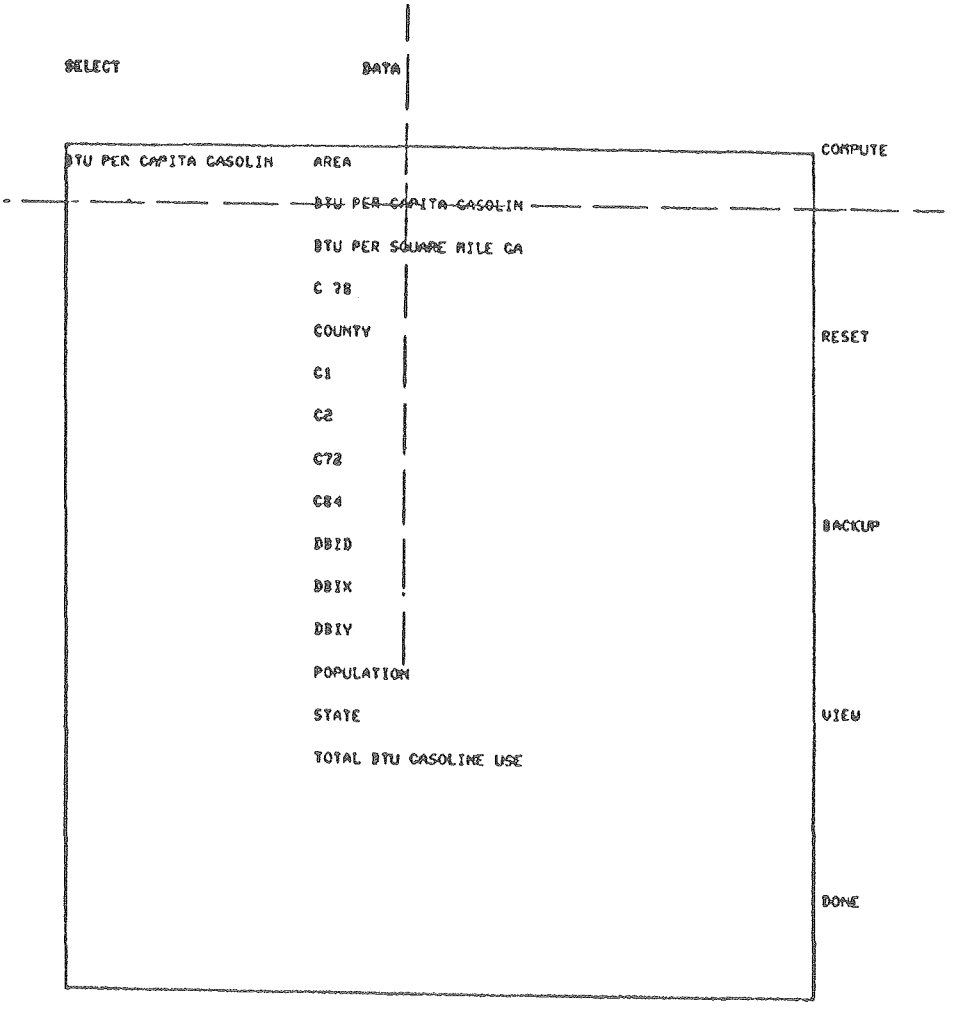


Picture 1

Begin this shortened map making procedure with the DATA directive. Select a data characteristic by centering the cross-hairs on the name, hit the space bar and Return.

The characteristic just selected will appear in the upper portion of the workspace (see below).

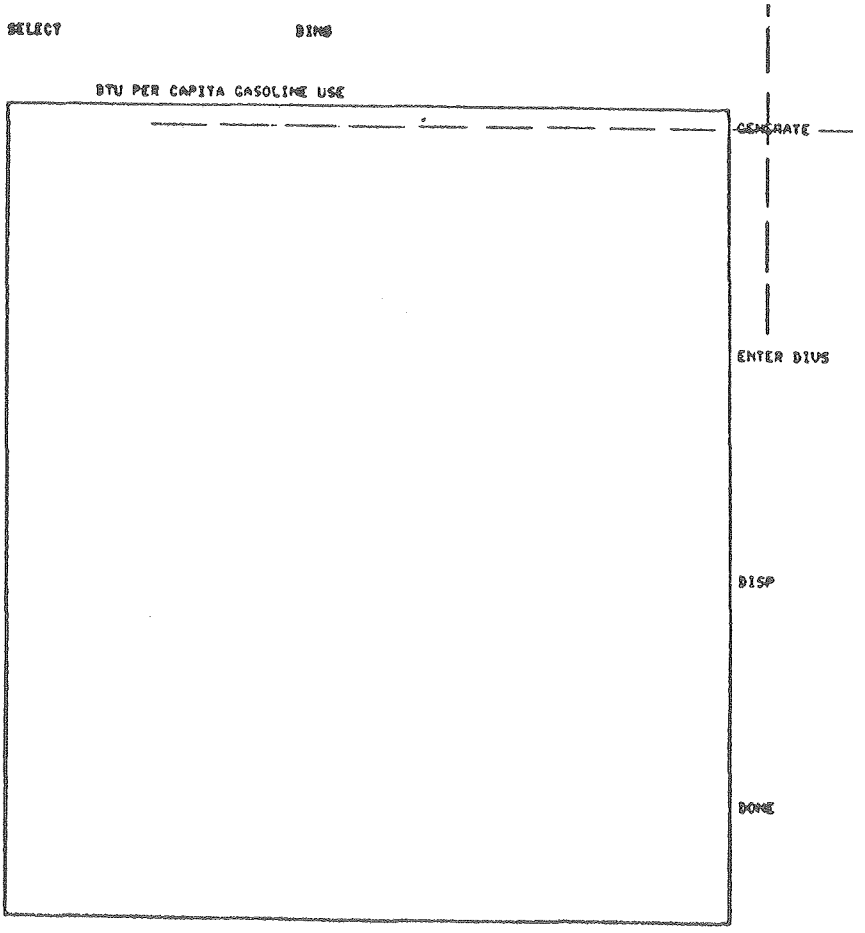
NOTE: Only 1 data characteristic per DATA run can be chosen in this mode.



Picture 48

The screen will clear and a new set of directives will appear, along with the name of the data characteristic at the top of the work space.

Continue the default process by centering the cross-hairs on GENERATE, hit the space bar and Return.



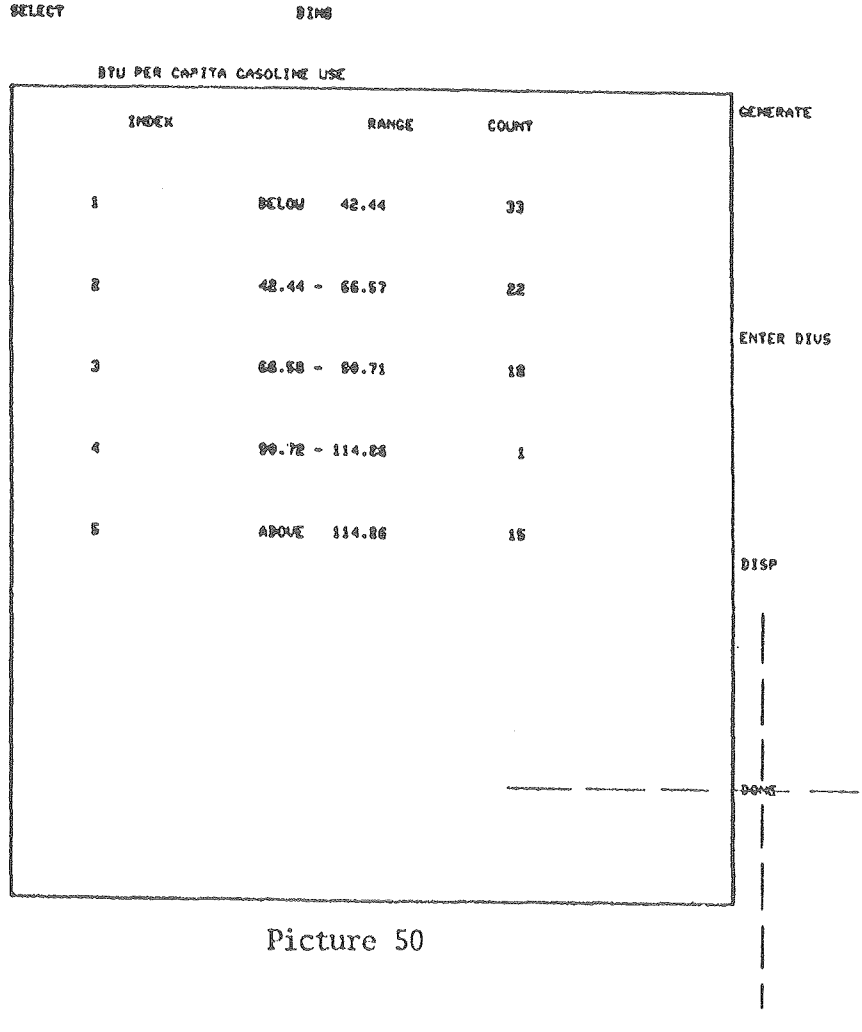
Picture 49

The range of data values are calculated and then printed in the workspace. If dissatisfied with the automatic binning process, new values can be entered with ENTER DIVS.

Again, the User is cautioned that these additional steps defeat the quick mapping process.

If the binning is acceptable, execute DONE.

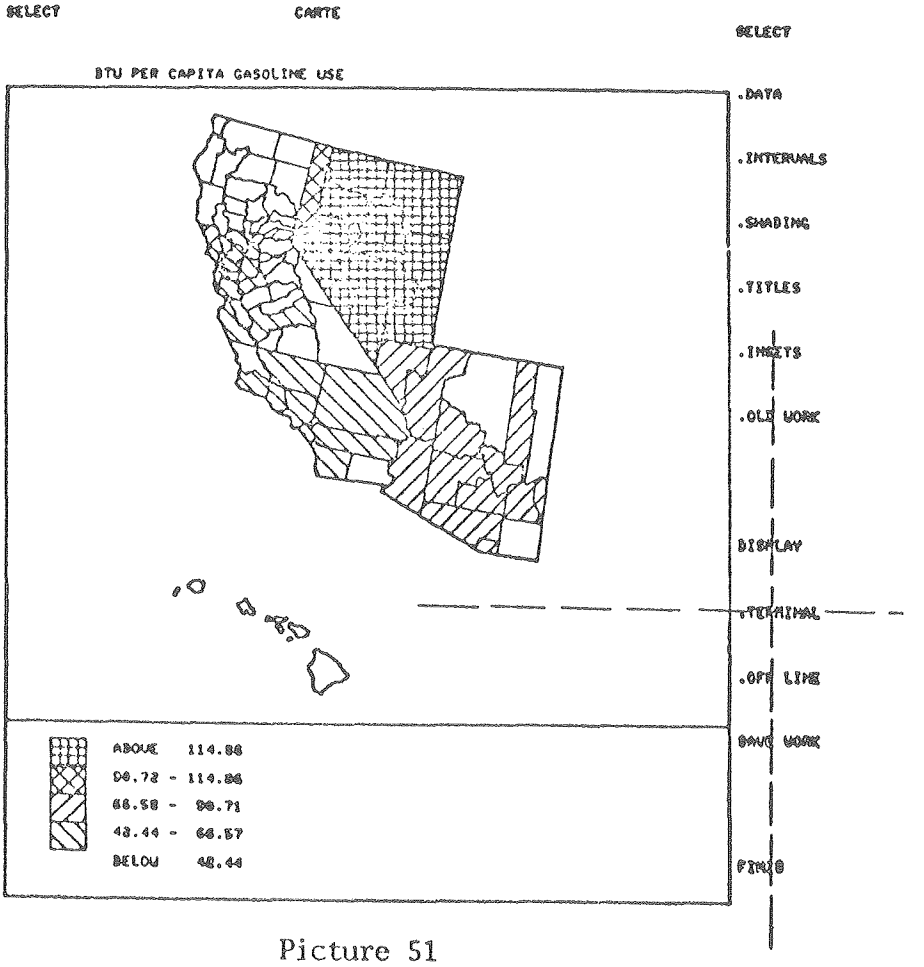
Continue to Picture 51.



Picture 50

The default map is printed in full with the TERMINAL command.

The program has called precalculated cross-hatch patterns to display the five data range values. The Legend prints these values and their patterns. The data characteristic name remains at the top of the work space. The map may now be printed off line on film, but not saved on PSS (an archival storage system). The User may return to the data directive and map another characteristic.



Picture 51

The program is written in FORTRAN and has been implemented on 60-bit machines, i.e. CDC 6400, 6600, and 7600. Implementing on a smaller word size would require some data declaration and access modifications. It is available from the author for the cost of reproduction and has no constraints on its distribution. The program as a whole is in use only at LBL although some of its subroutines have been distributed. Users Manuals are available from LBL in

SEEDIS Workbook III, by P. Wood and B. Burkhart. LBL-6439

Technical Documentation includes the following --

CARTE: A Thematic Mapping Program, LBL-3073, P. M. Wood and D. M. Austin, July 1974. Also in Computers and Graphics, Vol. 1, No. 1.

Interactive Thematic Mapping -- A Report. LBL-3496, P. Wood, August 1976.

Interactive Display of Polygonal Data. LBL-6490, P. Wood, October 1977.

MANPOWER INDICATOR ATLAS FOR REGION IX

300 color maps and corresponding tables of Federal Region IX by county showing socio-economic-demographic data extracted from the 1970 census.

ADMINISTRATIVE ATLAS

18 black and white cross-hatched maps and corresponding tables of Federal Region IX by county indicating dollars and manpower slots authorized by the U. S. Department of Labor for contracts active March 31, 1973.

PILOT LAND USE INFORMATION SYSTEM: PART III, VOLUME V

13 black and white cross-hatched and color maps showing property values of about 500 parcels of land about a quarter-mile radius around a rapid transit station in Walnut Creek, California.

MANPOWER INDICATOR ATLAS - DENVER/BOULDER SMSA

57 color maps and 19 corresponding tables showing socio-economic-demographic data extracted from the 1970 census; for each of the 19 data items selected there are 3 maps; one of the entire Denver/Boulder SMSA by census tract, one Denver area inset by census tract, and one Boulder area inset by census tract.

NOTE: Unless otherwise indicated, Atlases are out of print or not available.

MANPOWER INDICATOR ATLAS - PHOENIX SMSA

Similar to the Denver/Boulder atlas, 24 color maps and 12 corresponding tables.

NORTHWEST REGIONAL PROFILE

14 color maps and corresponding tables of Federal Region X by county showing socio-economic-demographic data extracted from the 1970 census.

CETA ADMINISTRATIVE MAPS

5 color maps: two U. S. by state, one U. S. by county, one U. S. by SMSA, and one for Federal Region IX by county. Corresponding tables show the allocation of fiscal year 1974 Federal funds under the terms of the Comprehensive Employment and Training Act (CETA) of 1973, Title II.

ENVIRONMENTAL IMPACT STUDY MAPS

A seris of 37 black and white cross-hatched maps for the U. S. Army Corps of Engineers showing selected socio-economic-demographic data for SMSA's from 5 states and combined county corridor areas bordering the upper Mississippi and Illinois rivers.

NOTE: Unless otherwise indicated, Atlases are out of print or not available.

ENERGETICS ATLAS OF THE UNITED STATES

A series of 31 color maps, U. S. by county, describing the U. S. energy system. Characteristics include demographic and economic variables, production and uses of fuels, electric and refinery capacities, and emissions of air pollutants from fuel use. Available through NTIS, BNL 50501-R

ENDANGERED SPECIES STUDY

A series of 7 color maps showing endangered species by county in the U. S. Maps include an inventory of mammals, fish, birds and a total map of endangered animal species. In production. C. Calef Biomedical and Environmental Assessment Division, Brookhaven National Laboratory.

ENERGY AND ENVIRONMENT REGIONAL STUDIES PROJECT: ERDA

A series of black and white cross-hatched maps, state by county, showing projections of water requirements, power plant emissions and energy requirements for California, Nevada and Hawaii. Data will eventually be plotted for Air Quality Control Regions and Hydrologic Study Areas.

Power plant siting criteria will also be studies with the aid of computer generated maps.

NOTE: Unless otherwise indicated, Atlases are out of print or not available.

CERCDC: CALIFORNIA ENERGY RESOURCE CONSERVATION AND DEVELOPMENT COMMISSION

A State of California project to study energy related impacts of the present 1976-1977 drought: factors to be considered include, reduction of hydroelectric generating capability and increased pumping requirements of agricultural areas. Black and white maps will be presented by hydrologic study area.

BACKCOUNTRY USE PATTERN STUDY

A series of line and symbol black and white maps for the Forestry Department of the University of California showing the various alternative use patterns from changing constraints in a linear programming model of back country use.

PARAP: POPULATIONS AT RISK TO AIR POLLUTION PROJECT

An EPA sponsored project that includes a series of black and white maps by county: SAROAD air quality data characteristics, cancer mortality rates and survey data, and various 1970 census socio-economic-demographic characteristics. These are planned activities for 1977.

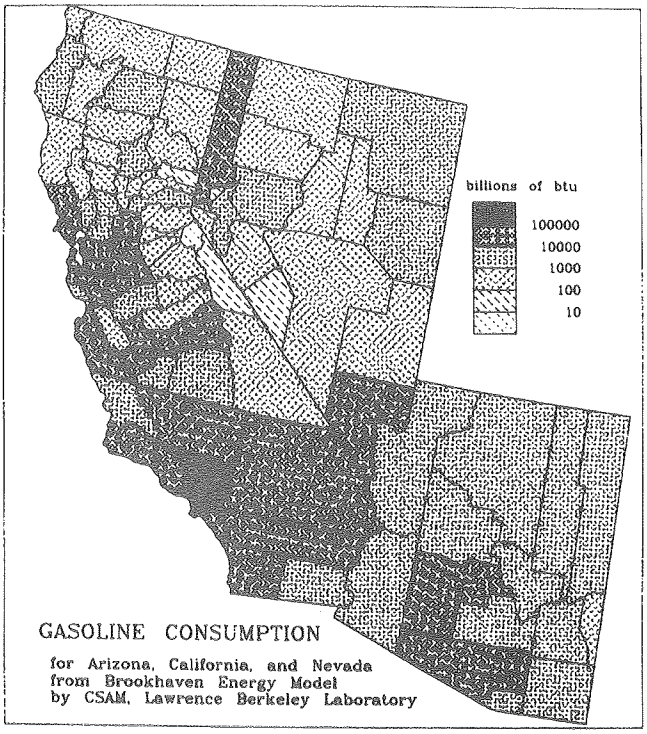
NOTE: Unless otherwise indicated, Atlases are out of print or not available.

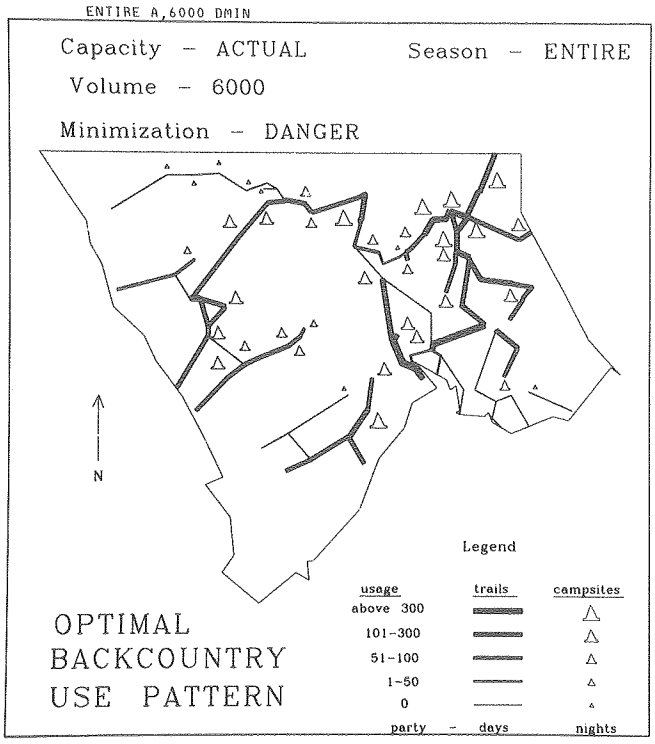
The creation of an integrated data base of air pollution and pollutants, morbidity and mortality statistics, and other socioeconomic and demographic characteristics will also be completed.

URBAN ATLAS

12 color maps, 17x22, for each of the 65 largest SMSA's from the 1970 Census. The maps show the spatial distribution of selected census socioeconomic characteristics. Map insets are provided for the larger SMSA's. The project sponsored by the Census Bureau, Department of Labor and LBL. Available through NTIS.

NOTE: Unless otherwise indicated, Atlases are out of print or not available.

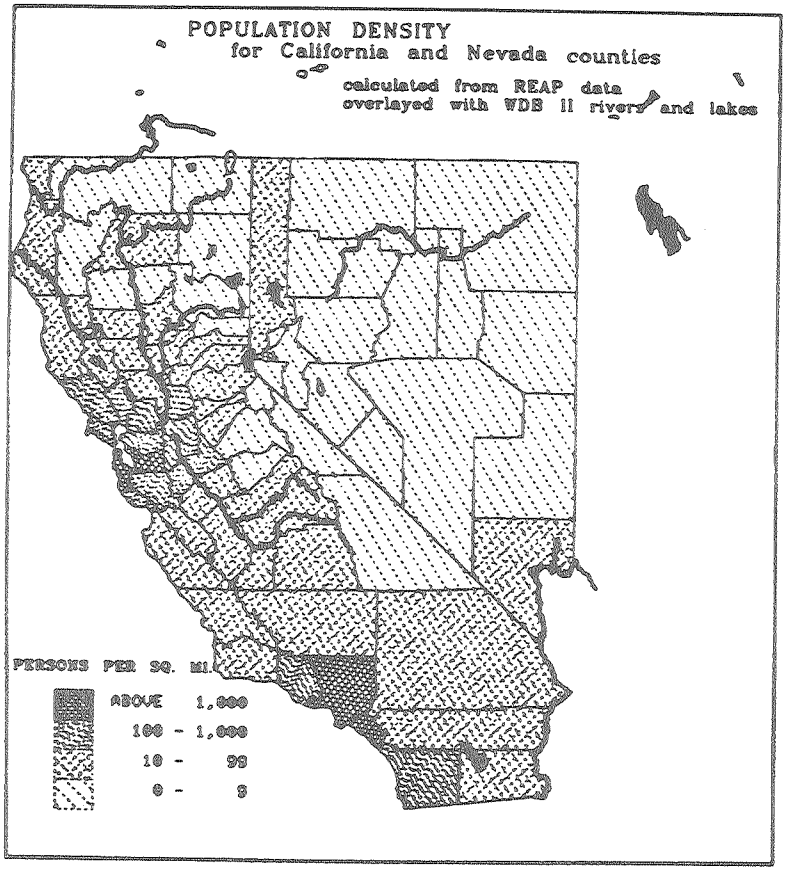




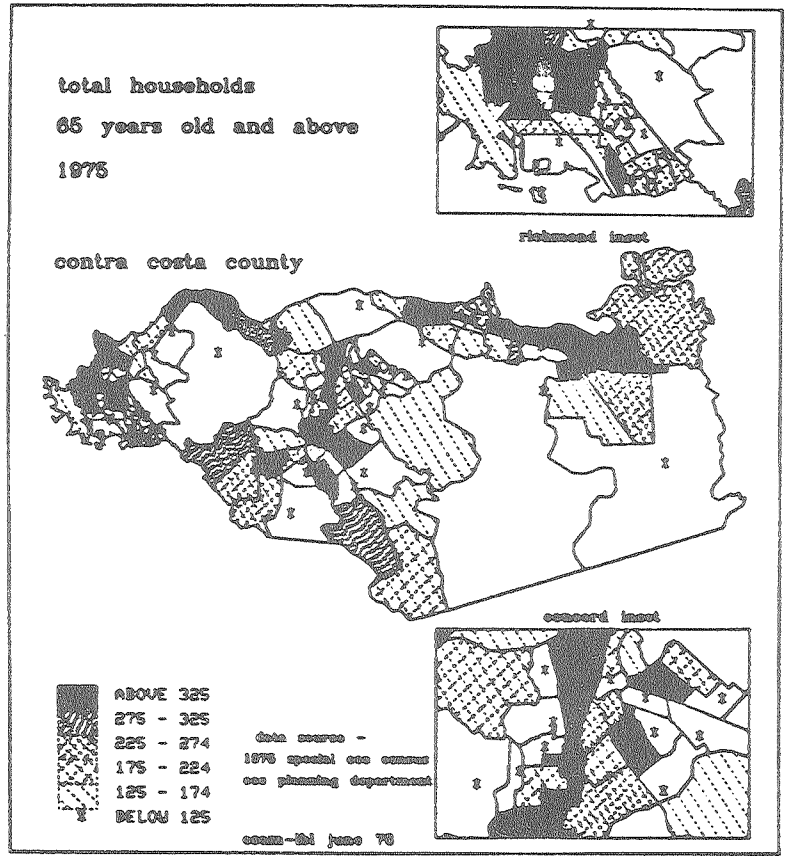
XBL 772-7596

Examples of Maps Made with CARTE

This map showing population density in 1970 for the counties of California and Nevada were calculated on-line, overlaid with major lakes and rivers (enlarged in width) from World Data Bank II, and titled with vector characters.



A map showing census tract level data from a special census for Contra Costa County in California, uses multiple insets to enlarge two small areas of interest.



Program Name: IDDS

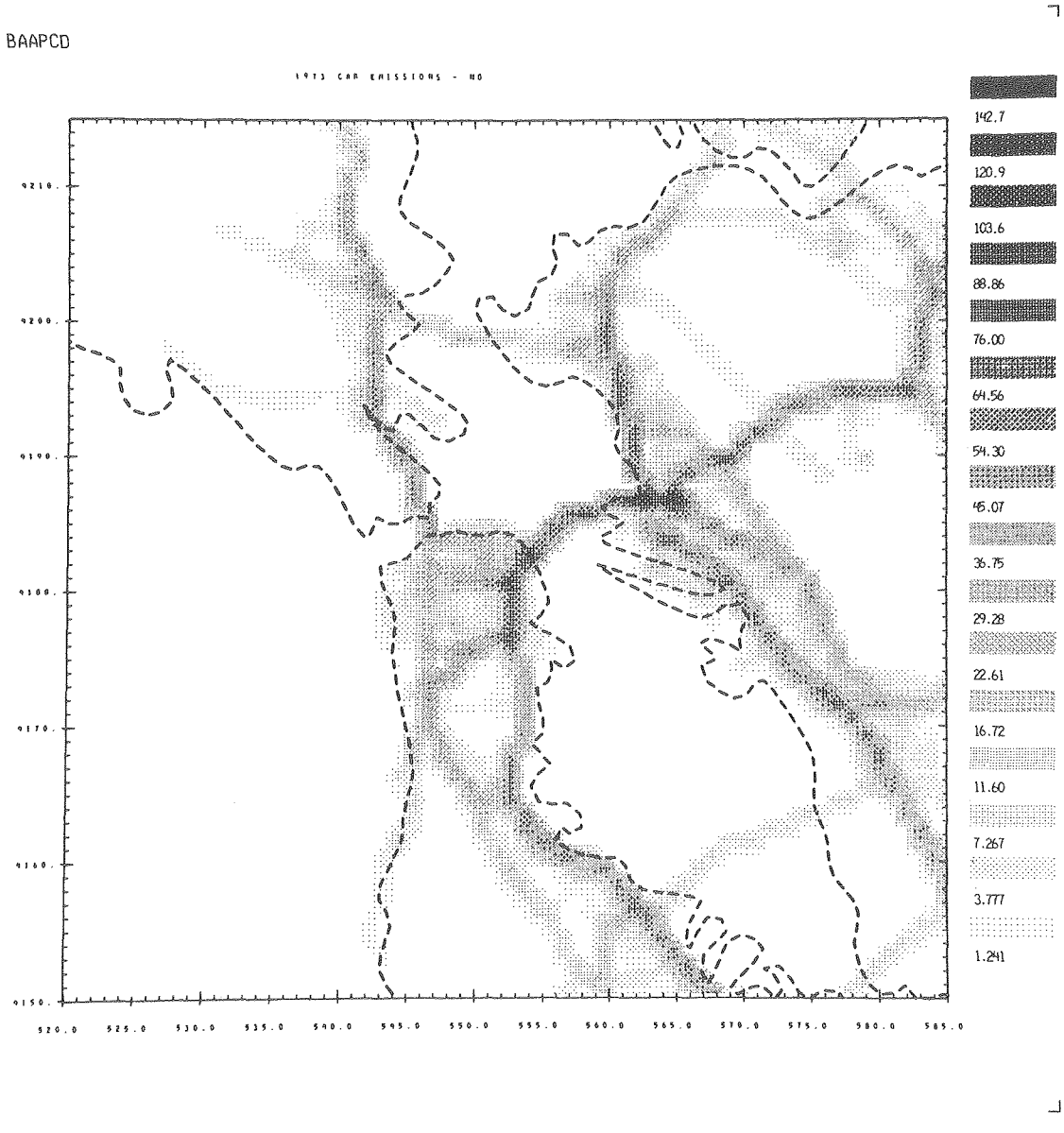
Author: William Johnston

Address: Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720

IDDS is an integrated set of subroutines used to graphically display data. It is used much in environmental modeling by research scientists. Its main type of displays related to computer mapping are the grey scale, streamline, contour, and perspective maps. Its great advantage is that the same series of operations can be applied to all data and can be easily overlayed.

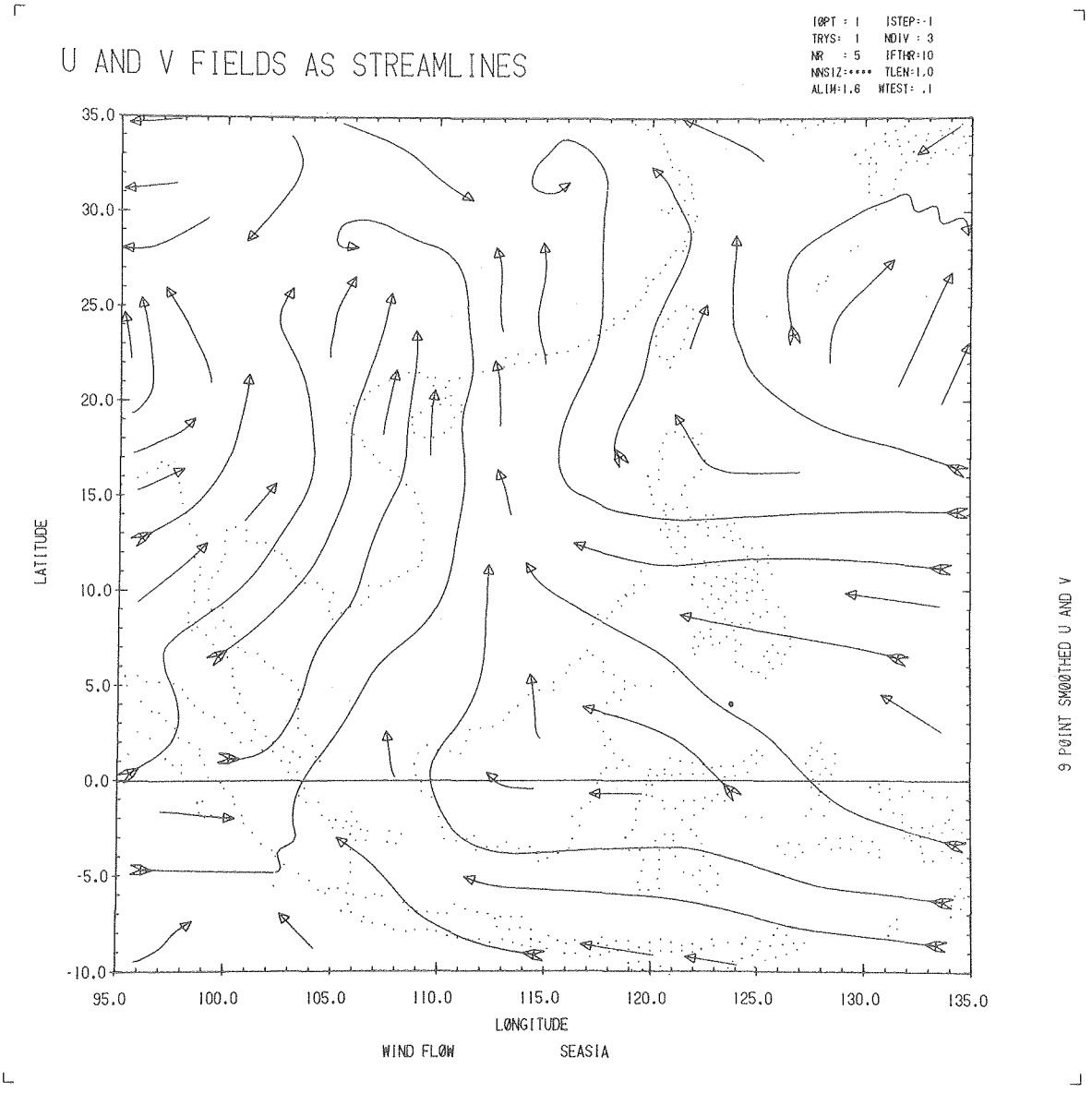
Its input requirements are supplied by the users's programs; a knowledge of FORTRAN is required for its use. For surfaces to be displayed, all data has to be put into a regular grid. Several subroutines are available to assist users in doing this. Part of the software has been implemented only on 60 bit machines at NCAR and LBL.

Past and present applications include the display of a wide variety of environmental data overlaid with base maps. For example, air quality data as grey scale and contour maps; meteorological data as streamlines; ground water data as surface plots; and geological data as contour maps. Future applications include an interface to World Data Bank II for base maps and general coordinate transformations to permit contour, grey scale, etc. overlays on large area base maps. A user's guide is available from the author.



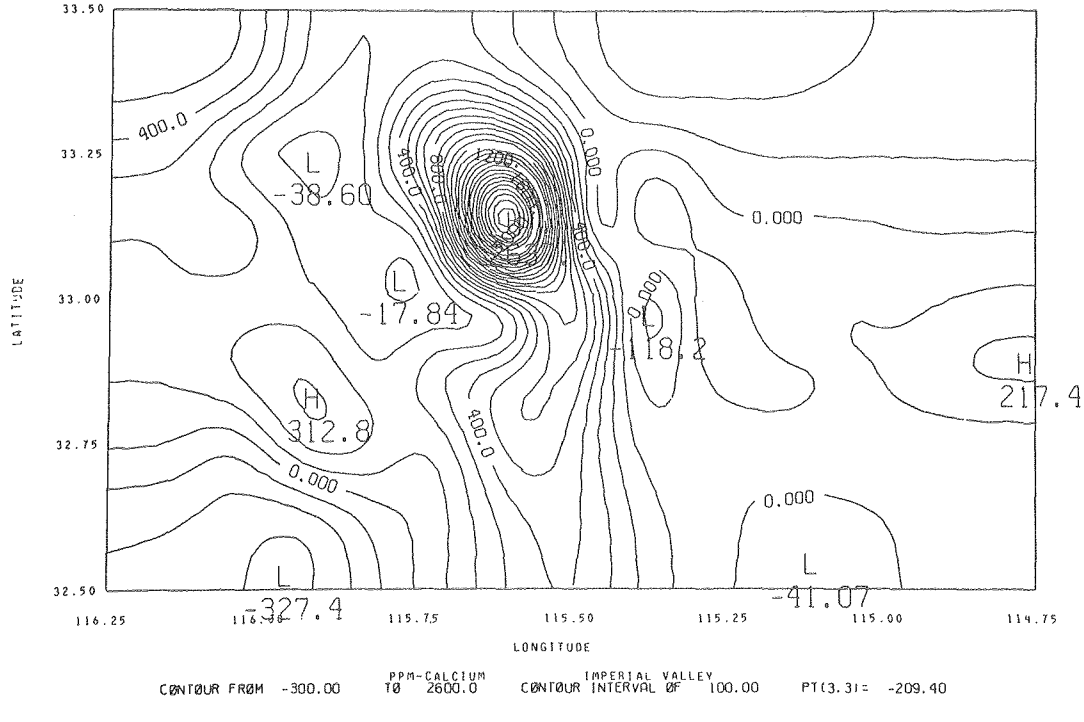
XBL 7710-10119

1973 rates for automobile nitrous oxide emissions as measured by the Bay Area Pollution District. Geography is measured in UTM local coordinates. The map has both polygonal and gridded data.



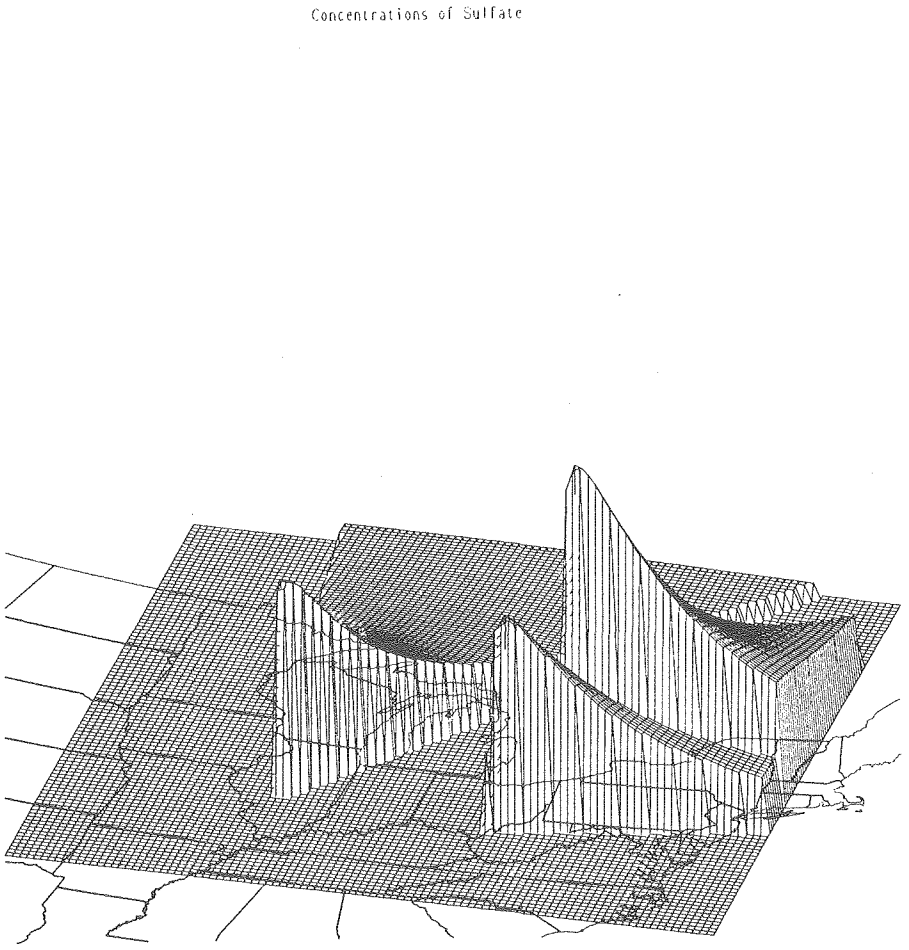
XBL 7710-10140

Gridded wind data displayed as streamlines overlaid on outlines of Southeast Asia.



XBL 7710-10113

A contour representation of waterwell calcium content after the data has been interpolated and integrated to an area of the California Imperial Valley.



XBL 7710-10169

3-D Display of Dispersion for Concentration of Sulfate Over the Central and Northeastern United States

Program Name: GRAFPAC

Author: Graphics Research Group

Address: Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720

GRAFPAC is the set of device independent graphics routines at the laboratory. It enables programs to run without change on different devices. It allows both direct use of a device and generation of an intermediate file for post-processing with a driver. It also allows switching between devices, e.g. from on-line to off-line, from within a program. GRAFPAC includes low level device drivers, a review package for post-processing, vector characters, and aids for interactive graphics.

This work was done with support from the U. S. Department Of Energy.

DEVICE INDEPENDENCE

Device Independence is achieved by having the routines for each device interpret only the parameters supported for that particular device. Thus, devices with only one character size will ignore KSIZE; devices with upper case only will ignore KASE; devices with only one intensity will ignore intensity. Each device is given a normalized plotting space of (0, 1.0) in X and Y. If the device surface is not square, then part of the surface will be unused. (This space can be recovered by advanced techniques.) TVSW and TVOPEN can be used to support multiple devices. GRAFPAC supports the following devices --

ONLINE

NAME	DEVICE
GT	GT40
TX	TEKTRONIX 4012
T6	TEKTRONIX 4006
TK	TEKTRONIX 4014
AN	ARPA NET PROTOCOL*
TT	TELETYPE PLOTS

OFF LINE

NAME	DEVICE
SC	STROMBERG CARLSON 4460
CC	CALCOMP PLOTTER
PR	PRINTER PLOTS
DD	DISK DRIVE FOR REVIEW
ZE	ZETA 30" COLOR PLOTTER

*Programs not yet implemented

GRAFPAC includes a set of low level routines to allow device independent graphic displays. Each member of the set produces display code for one particular device. Calling sequences and parameters are identical for all the devices. The routines produce graphic codes for frame advances, points, lines and characters. They attempt to use most of the hardware capabilities of each device.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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