U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

COMPUTER PROGRAMS TO DISPLAY AND MODIFY DATA IN GEOGRAPHIC COORDINATES AND METHODS TO TRANSFER POSITIONS TO AND FROM MAPS, WITH APPLICATIONS TO GRAVITY DATA PROCESSING, GLOBAL POSITIONING SYSTEMS, AND 30-METER DIGITAL ELEVATION MODELS

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ILLUSTRATIONS

ABSTRACT

Computer programs were written in the Fortran language to process and display gravity data with locations expressed in geographic coordinates. The programs and associated processes have been tested for gravity data in an area of about 125,000 square kilometers in northwest Nevada, southeast Oregon, and northeast California. This report discusses the geographic aspects of data processing. Utilization of the programs begins with application of a template (printed in PostScript format) to transfer locations obtained with Global Positioning Systems to and from field maps and includes a 5-digit geographic-based map naming convention for field maps. Computer programs, with source codes that can be copied, are used to display data values (printed in PostScript format) and data coverage, insert data into files, extract data from files, shift locations, test for redundancy, and organize data by map quadrangles. It is suggested that 30-meter Digital Elevation Models needed for gravity terrain corrections and other applications should be accessed in a file search by using the USGS 7.5-minute map name as a file name, for example, file "40117_B8.DEM" contains elevation data for the map with a southeast corner at lat 40° 07' 30" N. and lon 117° 52' 30" W..

INTRODUCTION

The U.S. Geological Survey (USGS) has used geographic coordinates in digital format to express locations of gravity data since the 1960's (for example, Plouff, 1966). The principal purpose of this report is to explain a template method to transfer locations expressed in geographic coordinates between locations obtained from Global Positioning Systems (GPS) and maps. In addition, computer codes related to the geographic aspects of processing gravity data for the USGS are described. Copies of programs and auxiliary files described in this report can be obtained via a file transfer program (ftp) or from a USGS Web Site at http://wrgis.wr.usgs.gov/docs/gump/gump.html.

A computer program to "draw" templates to interpolate geographic coordinates (fig. 1), was written in 1974 (Barnes and Plouff, 1984). The primary application of templates was superseded by the availability of digitization hardware and software until GPS instruments were used to determine locations of data points in the field. Prior to GPS technology, data points were manually located on field maps by using references to cultural features and topography, vehicle odometers, altimeters, surveying, compass resection, and paced distances. Templates now are used in the field to determine geographic coordinates of the next data point to enter as input to GPS devices and to plot GPS locations on field maps.

Computer programs to draw templates originally created output files to drive pen plotters. Pen plot methodology, however, no longer is efficient because of the need for operator control of pen plotters, the need for photographic copy processes, and the need to re-program changes of software and computer platforms. The current template-drawing program, **drawgeog.f**, creates output files that direct drawing commands in the PostScript language (Adobe Systems Incorporated, 1990) to plotters or printers. PostScript programs **drawutm.f** and **draw30.f** draw templates to overlay Universal Transverse Mercator metric coordinates shown on most USGS maps. PostScript program **mapscale.f** draws map scales or estimates scales not shown on published maps so that template overlays can be prepared for determining geographic coordinates at selected locations. Program **calnevhp.for**, which plots data within the borders of California and Nevada, is discussed as an application of map plotting, but this pen-plotter application has been superseded by more general programs. Program **cutoln.f** reduces the number of points along a polygonal boundary consistent with the scale of the map to be plotted.

Other programs described in this report apply to geographic-based data formats specialized for gravity data collected by USGS, but the format, with one-record-per-data-point, easily can be adapted to other applications. Program **staelplt.f** draws—in PostScript format—data point locations and associated information on a geographic-based coordinate system. Program **geogrange.f** prints the geographic range of data in a file. Program **chnglocs.f** adds a constant geographic location shift to data. Program **pullrect.f** extracts data from inside or outside a rectangular geographic boundary. Program **surround.f** extracts data from inside or outside a polygonal boundary with vertices specified in geographic coordinates. Program **inventpf.f** displays the number of data points located in each 2.5-minute square of a study area. Progam **mapindex.f** prints a list of arbitrarily-defined 7.5-minute map names associated with data points. PostScript file **FLDFORM.PS** (output from progam **fldform.f**) prints a proposed field data sheet that includes map names as digital entries. Program **cntmaps.f** lists the number of data

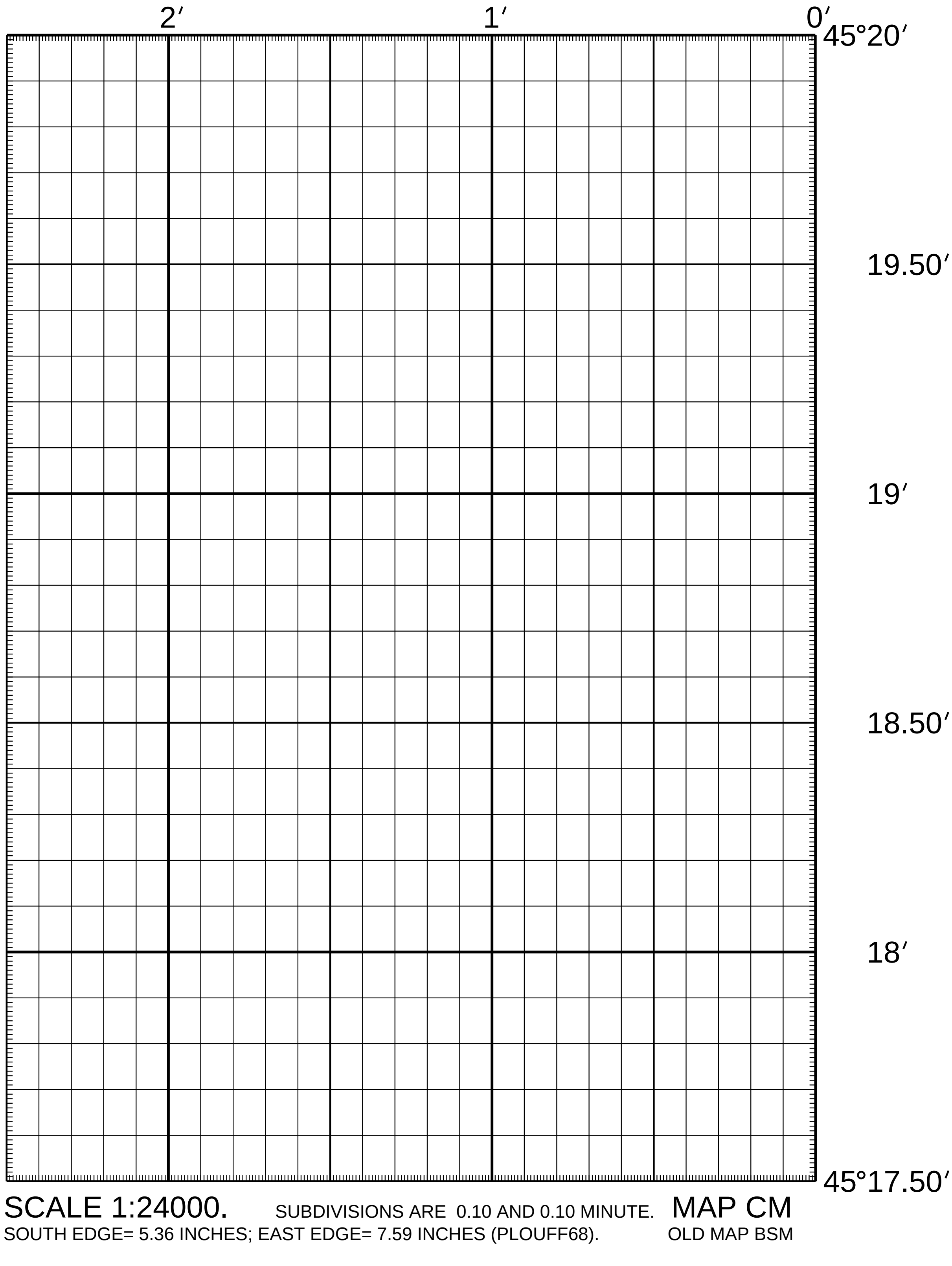


Figure 1.--Template at scale of 1:24,000 to interpolate geographic coordinates.

points in each 7.5-minute map. Program **prephtc.f** is an example of using the abbreviated output of map and station names from progam **mapindex.f** to insert auxiliary information into a data file. Program **substute.f** inserts auxiliary information into a data file by matching unique data point names.

The computer programs are written in the Fortran-77 language and are compiled and executed in a UNIX (trademark of American Telephone and Telegraph Co.) system. Fortran-77 is a scientific programming language, which is commonly referenced, for example, in algorithms published by the Association for Computing Machinery (ACM) Transactions on Mathematical Software. For convenience of conversion to computer algorithms, Fortran notation is used to express most equations rather than standard mathematical notation in Snyder's (1987, p. ix) manual on map projections. The Fortran language also is used for many other USGS geophysical applications (for example, Godson, 1974; Cordell and others, 1992; Blakely, 1995). The generic level of Fortran coding and self-documentation by extensive prompting would simplify adaptation of programs discussed in this report to other platforms and conversion of the codes to other languages. The programs perform essential tasks for which they are designed, but comprehensive testing has not been done for a full range of input data.

ACKNOWLEDGMENTS

John H. Healy initiated extensive use of geographic coordinates in digital format for gravity data processing by suggesting and supporting the development of a terrain correction system based on a grid system of geographic coordinates. Alf Janssen, Water Resources Division, encouraged development of the California base map program as a model for other states and distributed the program to other agencies. David F. Barnes encouraged me to write the template-drawing program and enthusiastically promoted the application. Robert F. Sikora tested one of the first sets of templates. David A. Ponce encouraged the use of standard geographic-based names to label maps and field tested the GPS application of the page-size templates. Robert Morin and David A. Ponce provided test cases for applying geographic file names to Digital Elevation Models. Carter W. Roberts used his knowledge of the GPS system to supply field data to test the difference between the 1927 and 1983 horizontal datums and confirmed the usefulness of page-size templates in the field. Michael Linck supplied the data base for the conversion between the 1927 and 1983 horizontal datums. John F. Waananen provided a Fortran program based on Snyder's (1987) formulas to convert between UTM and geographic coordinates. Allen H. Cogbill, Los Alamos National Laboratory, supplied an algorithm to identify data points inside, outside, or along the border of a polygon.

DEVELOPMENT OF TEMPLATE METHOD

Geographic coordinates for gravity data points first were obtained by drawing lines between geographic registration marks on maps and interpolating coordinates with the aid of engineers' scales, ten-point dividers, or variable-scale devices. The tedium and uncertainty of those techniques commonly led to significant errors, including reversed digits, at as many as 5 percent of the data points in a data set. Therefore, locations obtained by two persons sometimes were combined to minimize errors. Geographic-based (Plouff, 1968) computer programs were developed to plot data points and associated values (appendix 1). The plots were used to display data coverage and to identify location and elevation errors and, at the last processing stage, to hand-contour gravity-anomaly values.

D.F. Barnes used hand-drawn templates to separately interpolate latitude and longitude coordinates for Alaska (Barnes and Plouff, 1984). D.F. Barnes also devised circular slide rules to calculate gravity anomalies in the field. D.F. Barnes supported the concept of writing a computer program to draw templates that interpolate latitudes and longitudes for any user-selected latitude and map scale. After the program was written and tested, Barnes and Plouff (written commun., 1974) distributed a memorandum with the title "Cheap and rapid method of measuring geographic coordinates." Examples of templates and an order form keyed to computer program entry were included with the memorandum. The "height" of most templates was the full north-south latitude extent of maps, and "widths" were the narrowest longitude extent of geographic registration-marks. The smallest subdivisions of templates usually are multiples of decimal minutes (6 seconds), but subdivisions in multiples of 5 arc seconds also were requested. George VanTrump obtained the source code in 1978 and consequently published transparent page-size templates to span Alaska (Campbell and VanTrump, 1982a; 1982b). The demand for templates was greatly diminished when digitizing devices and associated software became available to obtain geographic coordinates. Templates are still useful to manually obtain coordinates for a few points per map and to identify and correct doubtful locations (for example, Plouff, 1996, p. 4).

Template formats (fig. 1) essentially are unchanged since 1974, but the computer program and drawing techniques often needed to be changed in response to changes of computers, plotters, and software. "CalComp" subroutines (California Computer Products, Inc., 1976) were called to drive pen plotting: PLOT (raise, lower, or drag pen and shift origin); SYMBOL (LETTER in some systems); NUMBER; and NEWPEN. Maintenance of code related to SYMBOL was difficult because of changing requirements to transmit variable names and variability of font definitions needed for different computers and software libraries. HPINIT or PLOTS (initialization or message to plotter operator) were needed for some systems. A "repeat point" (fig. 9) was drawn to indicate if registration was lost during plotting due to roller slippage or due to over-used 9-track plot tapes. Programs were written so that plot time/cost and lifting the pen from the drawing surface was minimized. Thick lines were obtained by drawing slightly separated lines with normal thickness or by commands to change pens. Templates drawn on translucent media were vulnerable to shrinkage or expansion and, therefore, needed to be copied to transparent stable-base material soon after plotting by means of contact photographic processes. Plotting was faster and pen problems were eliminated by using electrostatic plotters, but distortion due to variable calibration and speed of the roller drive was unacceptable, and the electrostatic medium was less reproducible.

Computer-driven pen plotters were used to draw templates until increasing use of Global Positioning Systems required faster production of page-size templates for field use. The time, expense, drawing problems, reproduction problems, and the need to link to specialized plot libriaries in order to create templates with pen plotters were solved by writing a computer program, **drawgeog.f**, to output ASCII files in PostScript format (Adobe Systems Incorporated, 1990) to drive inkjet and laser printers and plotters. PostScript format yields different line thicknesses with uniformly quality—without saw-tooth-shaped diagonal lines—and can print or plot on many media.

PROGRAM TO DRAW TEMPLATES WITH GEOGRAPHIC COORDINATES

Program **drawgeog.f** (appendix 2) prompts for the name of a print file to record the session, plot paper size, paper scale factors if needed, the map projection, and map scale. Template designs are suggested, which depend on the requested paper size and map scale. The user also may design a template. The program then prompts for the coordinates of the south and north edges that bound a swath of templates to be plotted. The ouput is a set of geographic-based file names, each of which plots one or more templates. One character-matching command (asterisk convention) can print/plot all the templates.

Scale factors in the north-south and east-west directions may be input in order to compensate for printer/plotter error, map stretch, or superposition on maps with an unknown map projection. Scale factors to compensate for printer or plotter error are determined by verifying dimensions printed on templates or by printing or plotting squares with known dimensions, for example, by plotting **ploten.for** for a 10-inch square or printing PostScript file **PLOT5.PST** for a 5-inch square. Dimensions printed for a selected range of templates were verified to 0.01-inch accuracy by comparison with UTM distances obtained from a computer program by John F. Waananen (written commun., 1997), which is based on Snyder's (1987) formulas.

PROJECTIONS, SPHEROIDS, COORDINATES, AND HORIZONTAL DATUM SHIFTS

Plouff (1968) published algorithms to convert from geographic coordinates to map projection coordinates with an accuracy sufficient for computer-plotting (appendix 1). The Polyconic projection was used by USGS for decades (Snyder, 1987, p. 1) for maps at scales of 1:125,000 to 1:24,000. The Transverse Mercator projection generally has superseded the Polyconic projection for maps at scales of 1:24,000 and is commonly used for for maps at scales of 1:100,000 and 1:250,000 and for maps at scales of 1:63,360 in Alaska. Transformations of geographic coordinates to map projection coordinates for these programs are based on the Clarke spheroid of 1866 (Snyder, 1987, p. 12). Key parameters that define spheroids for areas outside the conterminous United States, for example, the Bessel spheroid of 1841 for the Former Soviet Union (Plouff, 1968; Snyder, 1987, p. 12), are the assumed equatorial and polar radii of the Earth and derivative parameters such as polar flattening (Plouff, 1964, p. 156) and eccentricity (Snyder, 1987, p. 13). Map projections for the Hawaiian Islands (International Ellipsoid; Snyder, 1987, p. 58) and other areas may not be based on Clarke's spheroid of 1866, but slight differences in shape can easily be accomodated by application of scale factors in program **drawgeog.f**.

Rectangular coordinate systems for map projections commonly are defined so that distances increase toward the top (Y, nominally north) and toward the right (X, nominally east) edges of map sheets. The Universal Transverse Mercator (UTM) System consists of 60 zones with widths of six degrees, which encircle the Earth in a longitudinal direction. UTM zone number 1 extends from 174° to 180° and UTM zone number 30 extends from 0° to 6° west longitude in the northern hemisphere (Snyder, 1987, p. 62). Zone numbers are the same for longitude intervals in the southern hemisphere, but the numbers are negative. Within a UTM zone, X distances ("eastings") are relative to an origin at the central meridian, but a "false" 500,000 m is arbitrarily added to avoid negative distances. UTM distances in the Y direction ("northings") are large numbers that reflect the projected distance from the Equator, with a false northing of 10,000,000 m added for locations in the southern hemisphere (Snyder, 1987, p.58).

Geographic coordinate systems commonly are defined so that latitudes increase northward from the Equator and longitudes increase eastward from the Greenwich meridian. Therefore, west longitudes are expressed as negative numbers (Snyder, 1987, p. ix). Many computer programs and master data files, however, have been developed for U.S. locations with longitudes that increase westward (for example, Plouff, 1977). The positive west convention originated from other geodetic definitions and from the convenience of table entry. If longitudes are expressed with degrees, minutes, and seconds, it is impractical to carry the negative sign with each of the components. Exchanges between the two sign conventions typically are treated near the input/output level outside cores of progams, or, for example, algebraic signs of distances relative to map-based central meridians are reversed. If longitudes are expressed only in decimal degrees, there may be too many significant figures to determine distances, with the basic 7-digit (or slightly less) inherent "single" precision of most computers. Calculations of the distance between data points with constant distances per geographic unit are done with minimum loss of accuracy for a given computer precision by subtracting the degree portions of latitudes and longitudes, expressed as integer numbers, and separately subtracting the decimal minute and second portions.

Geographic locations of gridmarks on most USGS maps are based on the 1927 North American Datum (NAD27). Global Positioning Systems, however, commonly refer to the North American Datum of 1983 (NAD83). Current USGS maps show dashed lines near each map corner where the *predicted* location of those coordinates are in the NAD83 system, and offset distances, in meters, are printed beneath the southwest corner of maps. Offsets *later determined* between the two datums, expressed in meters and geographic units, were printed by the United States Geological Survey (1989) at 7.5-minute intervals in and adjacent to the United States and territories. NAD83-minus-NAD27 offsets, which were obtained in digital format from Michael Linck (written commun., 1997), closely agree with the published values (figs. 2-4). To agree with GPS positions expressed by NAD83, positions of templates would need to be moved to register with the NAD83 offsets, or a readout of coordinates expressed in NAD27 should be selected for GPS positions.

PROGRAMS TO DRAW TEMPLATES BASED ON UTM COORDINATES

UTM coordinates may be used to specify locations of USGS field samples. The advantages of the UTM system for sampling compared to the geographic system is that equal areas may be statistically represented if needed, the decimal system of subdivision is simpler than subdivision by 60's, and only one easily drawn template fits all maps at the same scale. Disadvantages are that a zone number must be included, data in an adjacent 6° zone are complicated to relate, longer numbers—requiring double precision or integer numbers if processed by a computer program—lead to a greater chance for recording errors, and USGS or foreign maps may not show UTM coordinates. Current USGS maps at a scale of 1:24,000 show UTM lines spaced at 1-km intervals. Earlier USGS maps showed UTM registration marks and associated distance labels only along edges of maps. Therefore, in order to determine UTM coordinates, either lines were drawn to connect registration marks on opposite sides of maps, or templates were drawn to cover the largest map at a given scale. The experience gained in programming **drawgeog.f** was applied to prepare program, **drawutm.f**. Program **drawutm** input is via interactive prompting and output is in the PostScript format (fig. 5; appendix 3). Program **drawutm** similarly was extended to prepare program **draw30.f**, which draws templates with grid intervals of multiples of 30 m for 30-m UTM Digital Elevation Models (fig. 6, appendix 3).

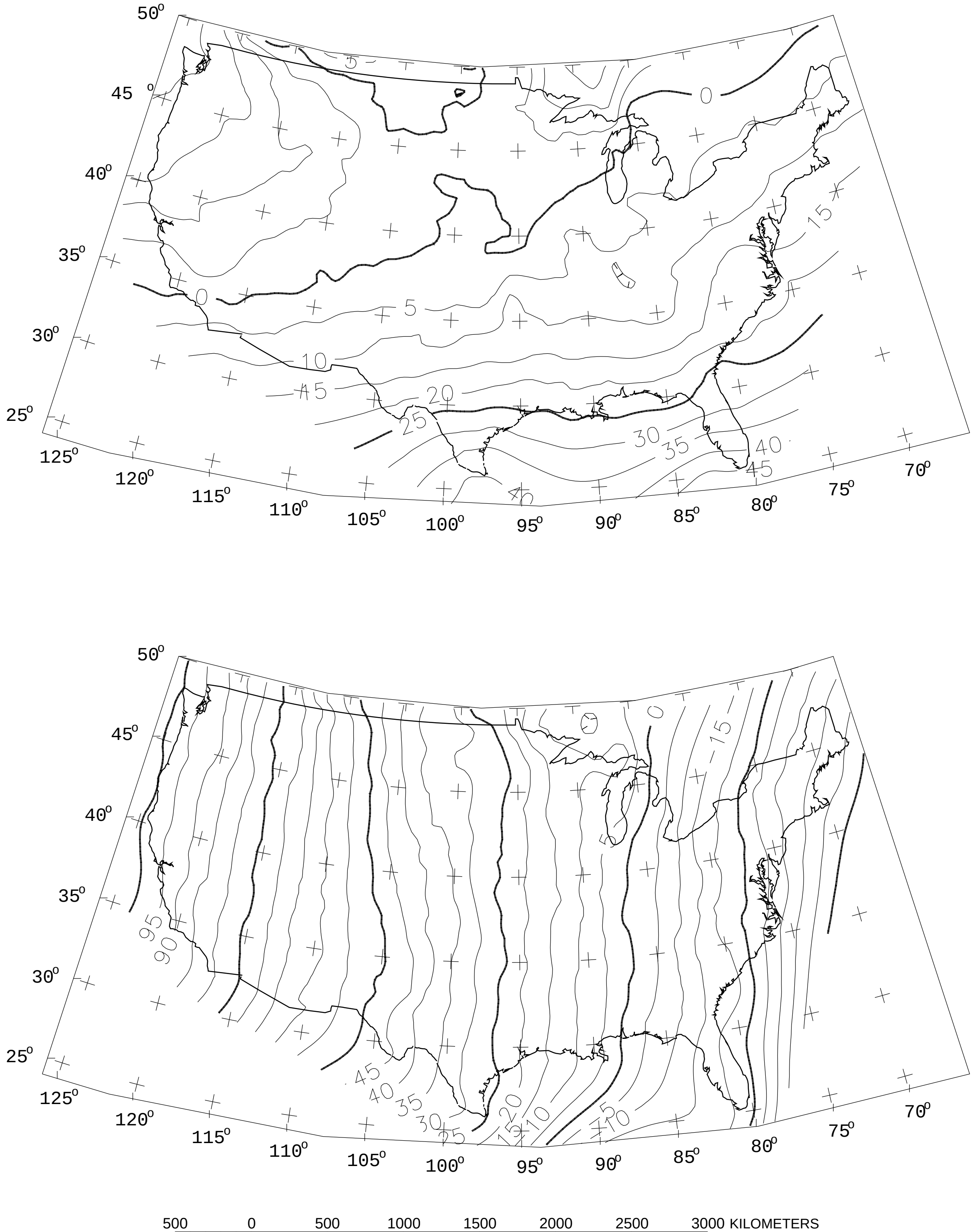


Figure 2.--Distance in meters between 1927 and 1983 datums for conterminous United States. Contour interval, 5 m. Upper drawing shows distance to add to the latitude component of the 1927 location, with negative numbers to south; negative distances in western U.S. are not labeled. Lower drawing shows distance to add to the longitude component, with negative numbers to east.

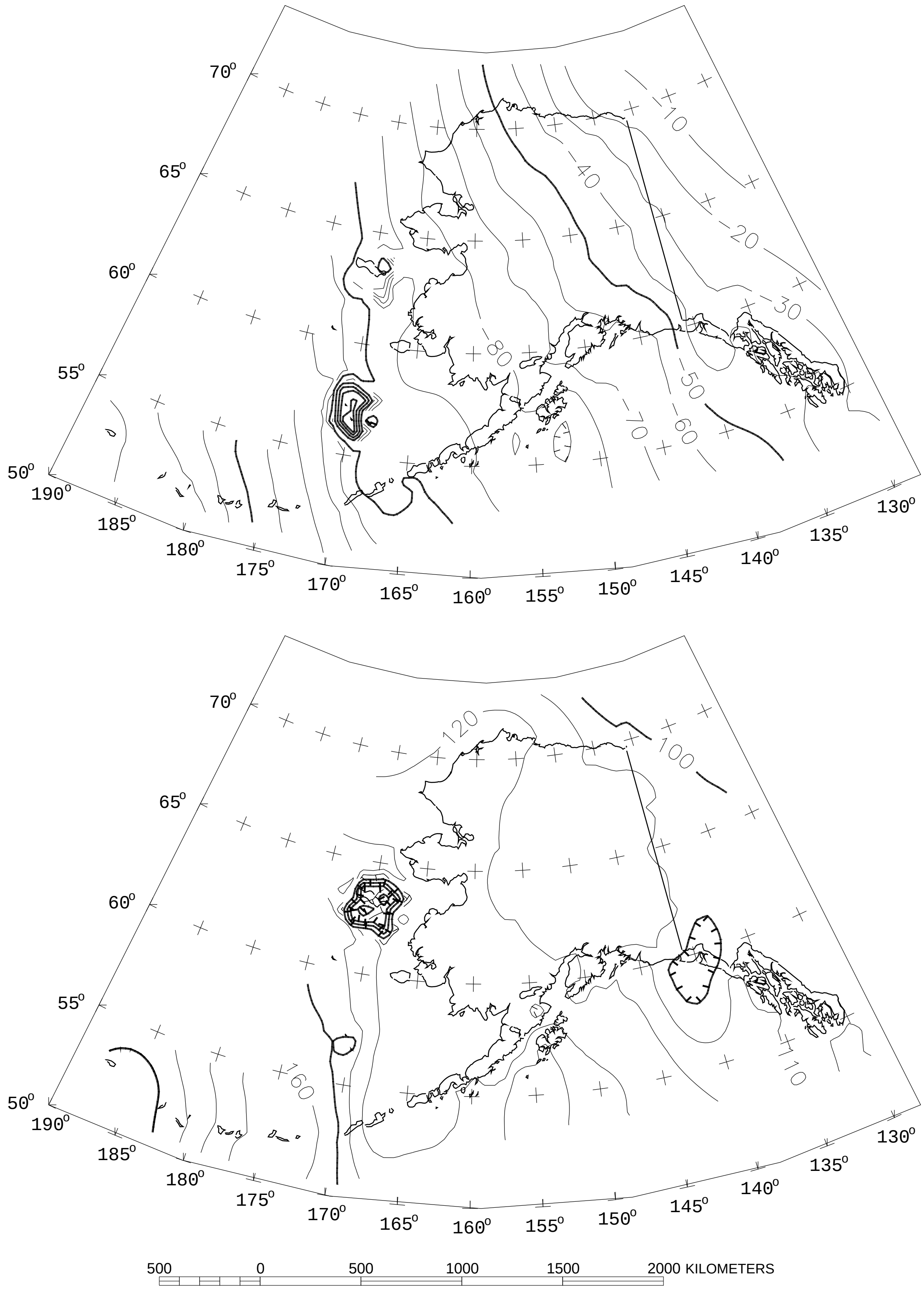
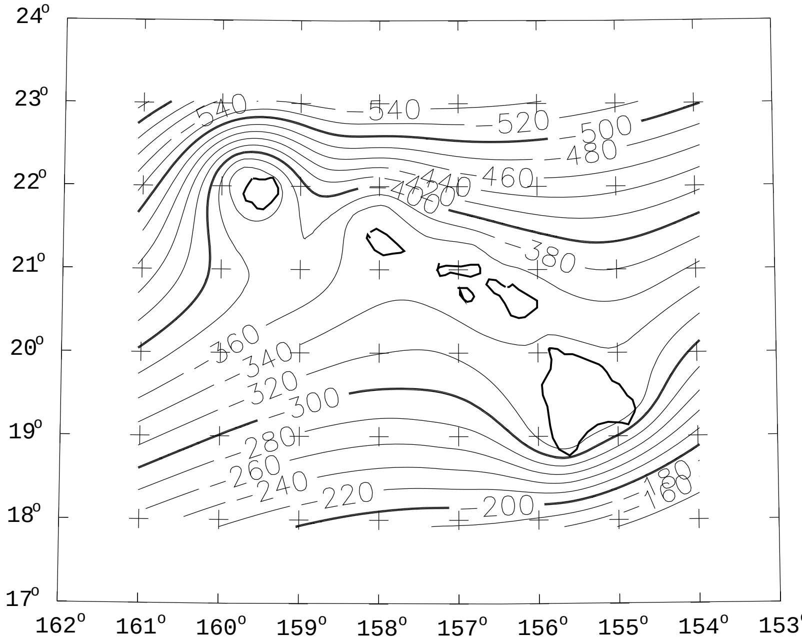


Figure 3.--Distance in meters between 1927 and 1983 datums for Alaska. Contour interval, 10 m. Upper drawing shows distance to add to the latitude component of the 1927 location, with negative numbers to south; positive distances in southwestern Alaska are not labeled. Lower drawing shows distance to add to the longitude component, with positive numbers to west.



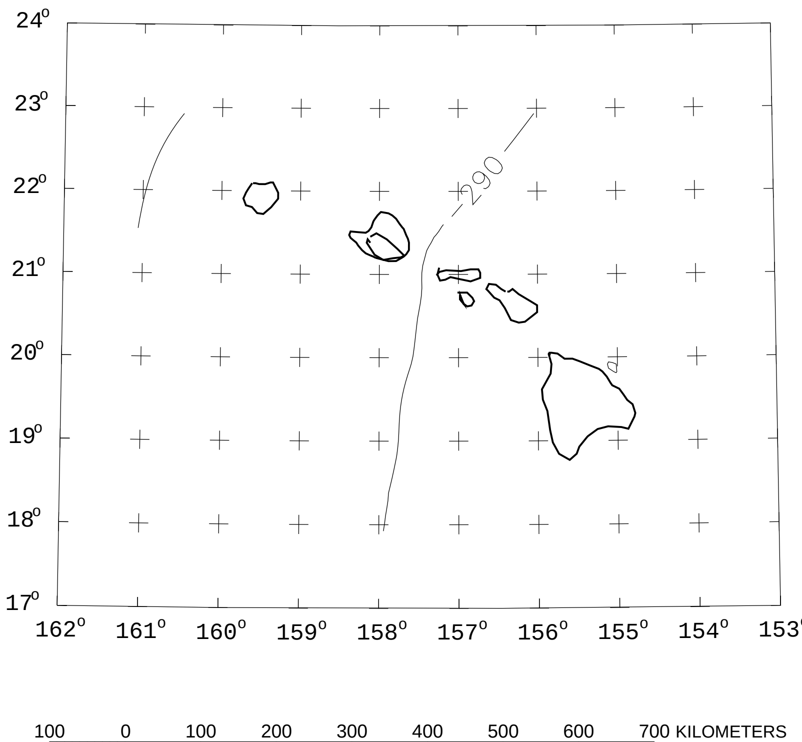


Figure 4.--Distance in meters between 1927 and 1983 datums for Hawaiian Islands. Upper drawing shows distance to add to the latitude component of the 1927 location, with negative numbers to south; interval, 20 m. Lower drawing shows distance to add to the longitude component, with negative numbers to east; interval, 5 m; contour "-285" not labeled.

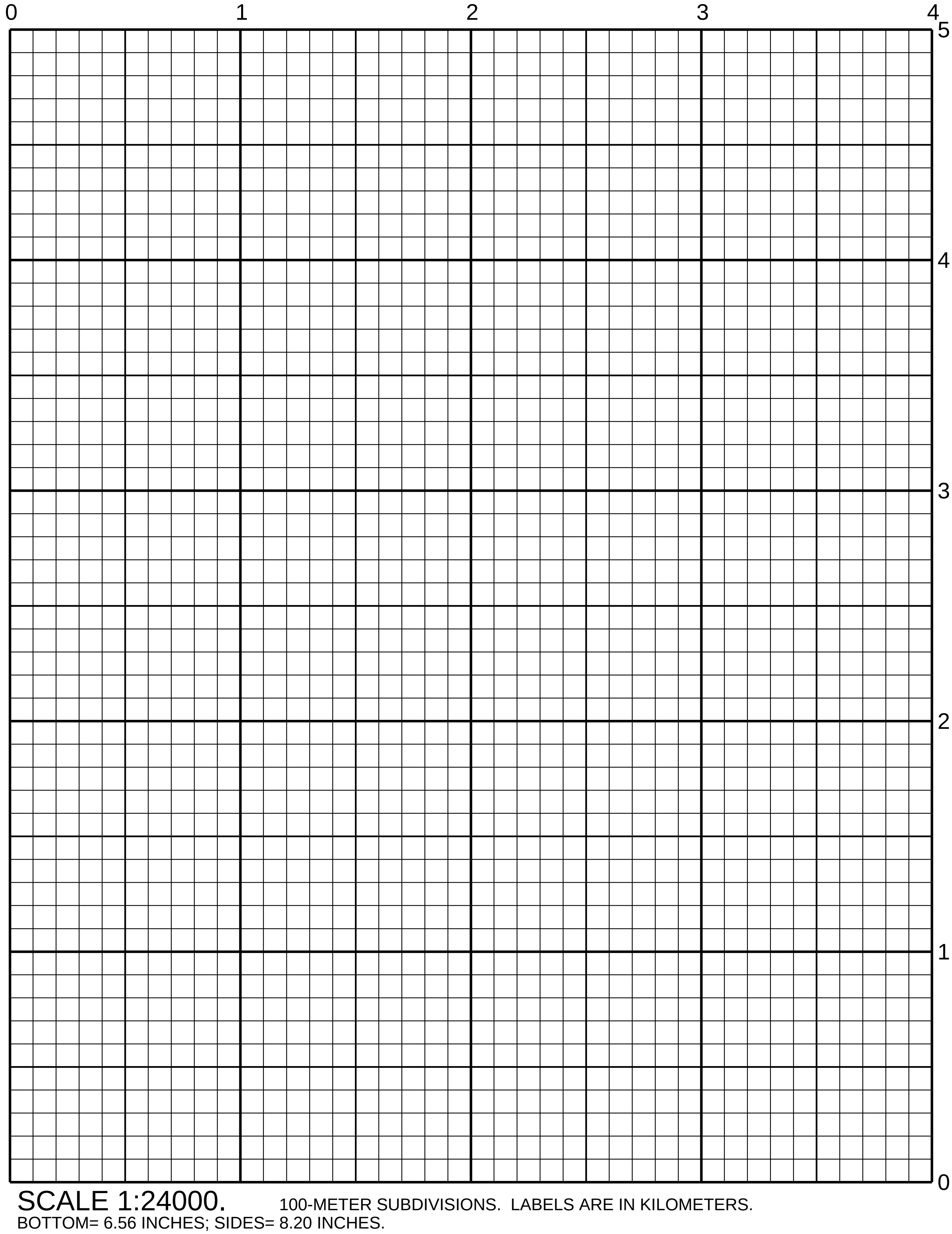


Figure 5.--Template at scale of 1:24,000 to interpolate UTM coordinates.

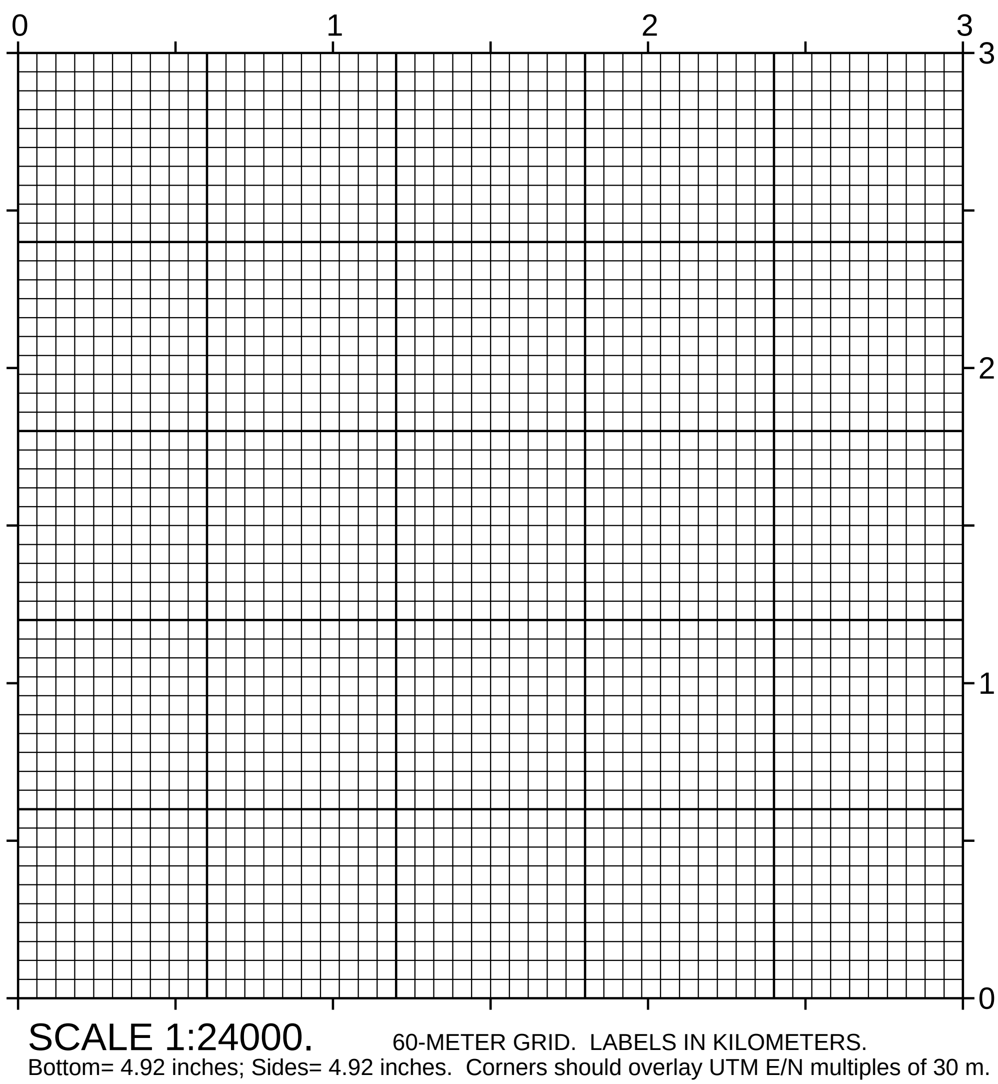


Figure 6.--Template at scale of 1:24,000 to interpolate multiples of 30-m UTM coordinates.

PROGRAM TO DRAW MAP SCALES

Program **mapscale.f** draws map scales (figs. 2, 3, 4, 8, and 9) or estimates scales not shown on published maps so that template overlays can be prepared for determining geographic coordinates at selected locations. The program writes a PostSript file in response to user prompting (appendix 4).

GEOGRAPHIC-BASED DATA FORMATS

A simple format for digital lines that represent roads, geologic faults, geologic contacts, or other boundaries consists of a series of connected data points/records, each of which has four free-field numbers separated by spaces or commas: 1) longitude degrees (negative for west longitudes); 2) longitude minutes (no algebraic sign); 3) latitude degrees; and 4) latitude minutes. A simple delimiter record to indicate that the end of each connected line segment in an "other-lines" file has been reached is "-999.0 0 -999.0 0.0." Borders shown in figures 2-4 are expressed in this digital format. To save storage space and processing time, program **cutoln.f**, which takes into account the scale of the map to be plotted, reduced the number of data points needed to portray the 42-segment border of the conterminous U.S. (fig. 2) in an other-lines file from 14,099 to 2,216 points (appendix 5).

A user group in Menlo Park, Calif., defined data input and output formats for the digital gravity terrain correction program by Plouff (1977, p. 8-14). The 80-column "plouff" output format has 8-digit gravity station names that consist of a 3-digit project name followed by the 5-digit input name, for example. Numerical values do not include decimal points, and elevations are expressed to tenths of feet. Program **pulldma91.f** converts gravity data obtained from the National Geophysical Data Center (1991) to the plouff format by combining a 4-digit source code with a 4-digit sequence code to form the 8-digit station name. The "gravity" or "denver standard" format defined by the Branch of Geophysics (1989, p. 11-14), consists of three lines of identification and program parameters followed by data records with 8-digit station names, no decimal points, geographic coordinates expressed in degrees and minutes with either algebraic sign for longitudes, and elevations in meters.

The plouff gravity data format generally is referred to in this report. Conversions to and from other formats can be done with simple programs or spreadsheet methods. Program **geogrange.f** prints the geographic range of data in a file (appendix 6). Program **chnglocs.f** adds a constant geographic location shift to data (appendix 7). Program **pullrect.f** extracts data from inside or outside a rectangular geographic boundary (appendix 8). Program **surround.f** extracts data from inside or outside a polygonal boundary with vertices specified in geographic coordinates (appendix 9). Program **surround.f** was used to assign 2-digit State names and an arbitrary 2-digit name along the border between California and Nevada (Plouff, 1982, p. 40-105) and to limit data compilation to a smoothly-defined envelope around a large study area (fig. 7). Program **redund.f** lists data points that are within a user-prescribed geographic distance from other data points in a data file, and program **redundel.f** deletes data points in one data file that are near data points in another data file (appendix10). Programs **countdma.f**, **combpair.f**, and **compare2.f** further implement the process. Identifying redundant stations is especially important for analyzing data from the National Geophysical Data Center (1991), which includes data from many sources. Program **inventpf.f** displays the number of data points located in each 2.5-minute cell in a study area. The output of program **inventpf.f** can be edited to highlight areas of special interest (fig. 7; appendix 11).

CONVERTING PEN PLOT COMMANDS TO POSTSCRIPT COMMANDS

Programs to call pen-plot subroutines such as PLOT and SYMBOL can be modified to create PostScript commands by appending subroutines that have the same pen-plot names but perform the equivalent commands in the PostScript language. The following conversions can be applied, for example. PLOT (X,Y,3) with the pen up is replaced by "x y move." PLOT (X,Y,2) with the pen down is replaced by "x y lineto." PLOT (X,Y,-3) origin shift is replaced by "x y translate." PLOT (0,0,999) to complete plots is replaced by "showpage." SYMBOL (X,Y,HEIGHT,ALPHAMERIC,0,N) to print a horizontal name or number is replaced by "x y moveto (alphameric) show." Inasmuch as transferring variable alphameric values between subroutines is platform dependent, programming the equivalent PostScript command for SYMBOL is simpler. Plot initialization PLOTS (,,) is replaced by opening a plot file and writing a PostScript prologue

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  2 1 1  2|313  3     21  11 1 2   |  2 3   1111  1 2 1 1444|2343311 111   31 1     1| 1
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      5595 |   7222321121  1214123  |1167223 2 3  1 1  3412 1|11 316512121222131223  1|  32
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 1    269K|7    117 133232111374211|3  44         11    2   2474|421131 1125243 13 134 1 |2  1
      3674|  1 11525 1122122AC2 21|   8DA2     1    1 1      2|3313 12 21311 1 12  3    |32
 1 1   1582|1     14 223212322447131|123222     2 2     21  14 |2342  142421 1 1241 3 11| 323
      1352|      252 42111321 58111| 3          1 11  222  322|25411 1252 1    1316216  |111
 1       85|3     242  233214111323 |13          2  2    12411311|312    123113 111 EB12225| 1
  1  1  32|1  1 1 5   3222331113622|12       11 1 1212521434 1|21331 1151221 2    15712 |1 21
    1    1|211    14   3  1332222221|12       22212321213613 2 | 1132 157522  11 114523 |411
  1       1 | 121  353221  1 12 33212|1 2    111211  2321 3     |      22 1 11112  1644172|  1
 1111       |  12331    1          134D|  2     11 2    1   3 31 1 |224 214 1 112    11  12 4|
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  2 11  11|        12     5ETGFEB898|        111 121             | 13331351 1 214  1332221| 24
   11 112 |          11  1 EZJZN6525| 211112  1     1 1 1      |1  12111 2 13 11221422  | 121
   12131 1|       1   1  1JYMQT9778|1     111      1 1         1|111 21312416231311115  2|121
    11 111|   1        1  1 CKDF7  |1  1 1     21        1    1 1|11112 3  111321114 13131|12 1
      1111 | 1111       322  35JF93   |1       1 11  332422122   |121 2115  1 1  111175352| 11
        221|  1311    31  15PJA221   |       1  2        1 132211 |212 13252  12 1432641 33|3 31
       2112|11 1 2   3   13MV95 4    1|     133331  1   2  24231 |1 11 44KP821123455 23122|131
        1 1|3 1  3232 1   1 341 3 1  |1  13   2   1   22344121 11|2 11 3BMZ6121  454 1 111|231
          1|24 131   1   1  1   3    |1 34    1    11 5542 111 1|1112135GQG211   423311153|
         11|11332    1     1 2    14  | 12  1 2    123 42531     |  12 1142G61 22234634272|1
           | 1141     1  1 2 212152 | 5  1  21    1 121     1 |21 1 1 1 31114211 1434853|
           |11 3     1  1222 523  3 3|26 212 2    1    315 12443|112    1 23 1 4556155443 |
           | 1122  1  1 57413 21 2 2| 153 331     11 11 1  21 |  1     113 11B8765443   |
           | 1213  1  1 85641121312 |131  412        2121111124|1 2 111131    128E46E42   |
           |   113  111121  441424211|11 1    13    1 3311 22 2 |          641  12424481  |
           |      4121121    2 34 1   |4      21121143 1    1     1|  1 1 24  11    1 1 2    |
           |     31  1 111   2 3241   |311       121 334321311  1|  2 4214   2231 113 1    |
           |   11412        1   41    |3 1  1   1 2434313242  1 |  3323351   58 21121      |
           |       54      1 21    1331|312    321 12212 3 423    |333 121223E63 2  1       |
           |       22     11 11  1 111|1221    21112233      42522|43 1 15877212241 1       |
           |         3     3 1         1|  1223232 2331     1111 1 |1 11253211111232         |
           |          2    2 1 1   1   1|111   11    212 231 2 11 | 1  862 122  14           |
40° ------------------------------------------------------------------------------------
           |         1 3  212   2351614|31231212  11 433   122 11| 313 11  11 132          |
           |             5  124 4122   41|3222  511 1242211 121 22| 33465442    2          |
           |           2533   231 411251|1  11221131 2232   3    23|53343441 1311           |
           |              123481 41 153| 131 3111    21     3 11 4|1  12   1               |
           |             1 1137355 1 14|112223       1 11   31 134| 33421                   |
           |               1 341141   11| 211 2       1   2 3   2543|4 1                     |
           |                  15151 112|334   3   2   12   312 121 |                         |
           |                11442 5 21 |21221323  1222 1721       |                         |
           |               111435161   2|2111211111 2242            |                         |
           |                13233452311|2 2113 14211               |                         |
           |                  1 2443834|12 3 2 11                  |                         |
           |                   11331184|3133                        |                         |
           |                   2 1 1 31|                            |                         |
```

Figure 7.--Index map showing distribution of gravity data in study area. Numbers and letters indicate number of data points in 2.5-minute cells that include their south and east edges. Blank spaces indicate no data. For example, A indicates 10 data points, I and O are skipped, Y indicates 31 data points, and Z indicates 32 or more data points. **Bold print** indicates location that includes data points without map verification. North-south distances are exaggerated about 1.3 times east-west distances.

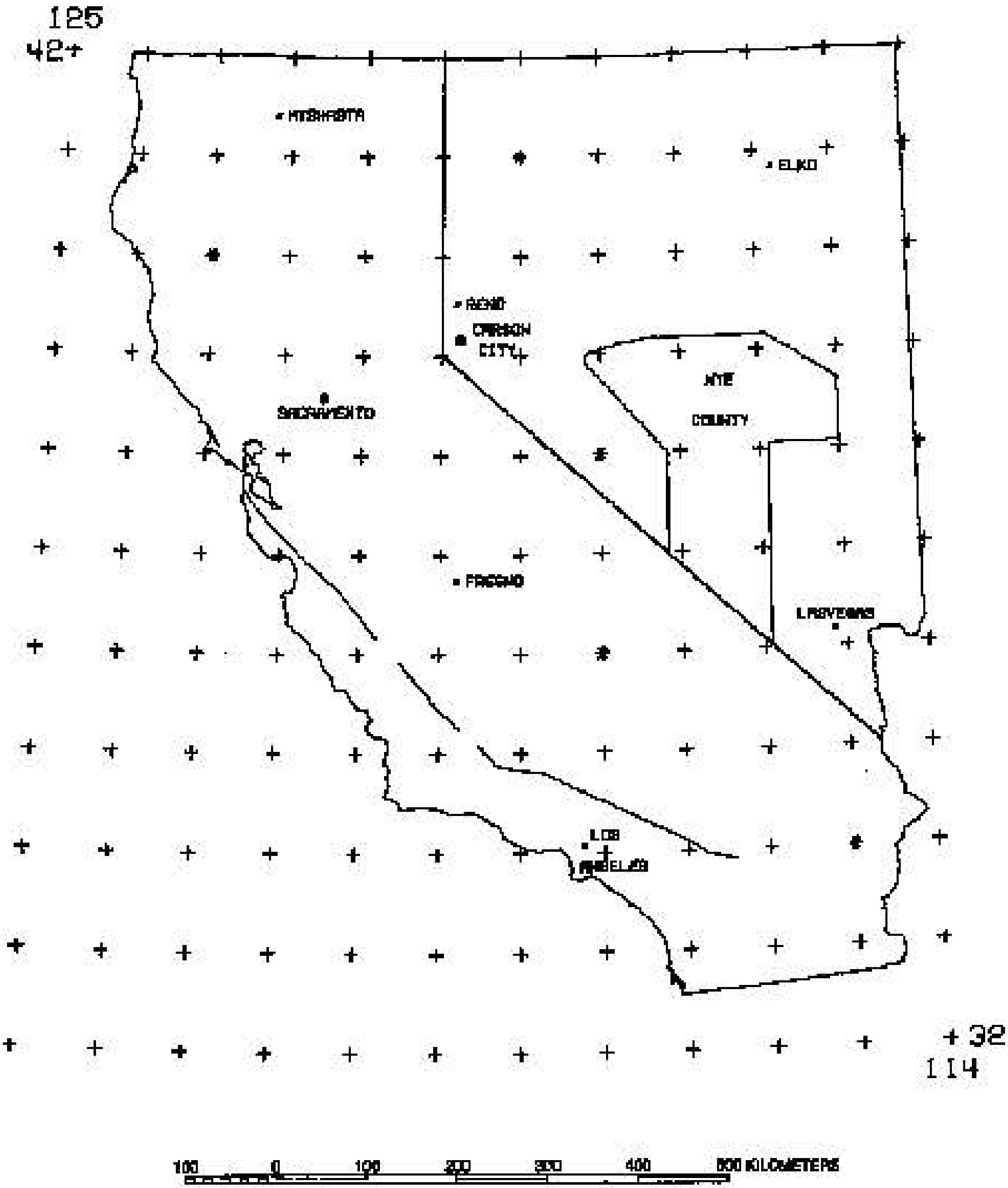

Figure 8.--Map of California and Nevada from program calnevhp. Lines and names were obtained from input data. Asterisks are "X" superimposed on "+" to test symbol centering. Grid interval, one degree. Lines show approximate locations of San Andreas fault and Nye County.

that consists of the line "%!PS-Adobe,", assignment of paper size ("BoundingBox") if needed, user-defined abbreviations, font type/size, line thicknesses, conversion of points to inches, and a translation. Rex Sanders (written commun., 1993) called attention to a library of CalComp-to-PostScript conversion subroutines which includes most CalComp commands, but the PostScript programs described in the present report were either written before 1993, or subroutines were tailored to fit the requirements of individual programs.

PROGRAMS TO PLOT DATA ON MAP OVERLAYS

Program **calnevhp.for** was developed in 1970 to draw lines, locations, and associated information on maps of California and Nevada (fig. 8; appendix 12). The maps are based on the Lambert Conformal Conic map projection with standard parallels at 33° and 45° latitude, which is commonly used as a base for State maps (Plouff, 1968; Snyder, 1987, p. 104-110). Although superseded by later computer programs that include choices of many projections and border lines, the program serves as an example of a self sufficient method to store state borders as data, to rotate maps, and to position borders that meet the requirements of different sheet sizes and scales. If the approach of program **calnevhp.for** is to be adapted, interactive choices and supplementary files should replace formatted input parameters, and pen-plot subroutines should be replaced by the equivalent PostScript commands.

Program **staelplt.f** draws gravity data point locations and associated information on a geographic-based coordinate system (fig. 9; appendix 13). PostScript prints or plots from program **staelplt.f** are registered to maps by printing on transparent media or by using light tables. If the mapscale of the map to be overlain is not known, program **mapscale.f** can be used to determine the scale and to provide a scale in PostScript format (appendix 4). Program **staelplt.f** evolved from separate programs to display data based on Polyconic and UTM projections by using pen plotters. These programs were written to rapidly calculate projected locations and to minimize the distance the pen moves, but improved central processor speeds and conversion to vector-to-rastor PostScript plotting nullify these advantages. The last application before PostScript plotting was to draw data point identification and associated elevations directly on topographic maps. That method was implemented by setting the mechanical pen origin on a point drawn on the map and alining a line parallel to the bottom of the map. Alexander Wagini (written commun., 1984; Wagini, 1985) plotted locations—with station identifications and elevations—for all previously established gravity data in a 1° by 2° area so that corrections, including discarding redundant and doubtful data points, could be made. The ability to draw directly on maps, however, was not implemented by the author for current software and has been superseded by other mainframe computer programs. Selner and others (1986; Kork, 1991; Selner and Taylor, 1993, p. 256-257) described a microcomputer (IBM PC and compatible) system to draw geographic-based information directly on topographic maps or stable base maps by first interactively registering a sighting device or pen to corners of a map.

MAP LABELING CONVENTIONS

The USGS subdivided regions of the conterminous United States into 1- by 2-degree study areas for interpretation and publication at a scale of 1:250,000 (Snyder, 1987, p. 57; for example, Oliver, 1980). The maps are 1- by 3-degrees in Alaska. Inasmuch as Alaska has few towns and prominently named physiographic features, maps commonly are named with a system defined by the letters A-D in 15-minute increments from south to north and the numbers 1-9 in 20-minute map increments from east to west. For simplicity of filing field and office maps that cover large areas, rather than referring to local map names, the Alaskan system has been adapted by D.A. Ponce (oral commun., 1992) and others to subdivide 1- by 2-degree maps into 15-minute increments in the conterminous United States: A-B-C-D for latitudes and 1-2-3-4-5-6-7-8 for longitudes. Therefore, the 15-minute quadrangle in the southeast corner of the Reno 1- by 2-degree map is identified as R-A1 and the northwest quadrangle is R-D8. Letters NE, NW, SE, or SW are appended as a suffixes to include 7.5-minute map subdivisions witin a 15-minute map.

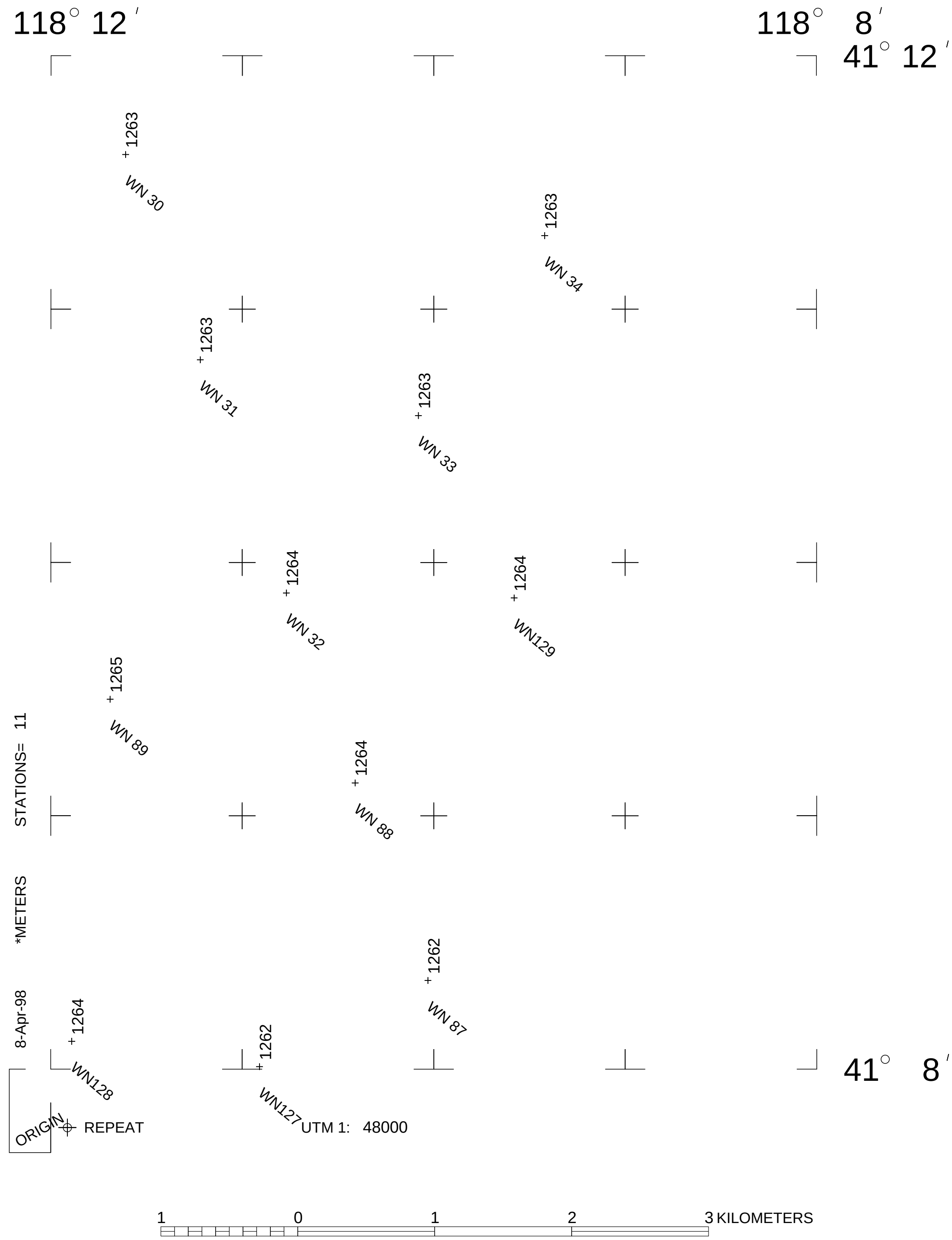

Figure 9.--Plot from program staelplt. Plot shows station numbers and elevations in meters.

START:
LUNCH:
STOP:
TOTAL:

PROJECT ________________ DATE (1-8) ________ DATA SHEET ______

GRAVITY METER/CALIB ________________ LAST NEW STATION ______

TIME ZONE ______ OPERATOR ____________ RECORDER ____________

T.C. RING ____________

ODO-METER	STATION 1-5	R ? 6	TIME 7-10	READING 11-18	TIDE-TEMP CORR-READ	ELEVATION /INCREMENT 19-24	M ? 25	ACC. 26-28 T.C. 29-31	STATION DESCRIPTION	MAP 32-36

LINE WITH ALL NINES AFTER LAST READING

D. PLOUFF 7-86 FORM

Figure 10.--Field data sheet with map names based on subdivisions of 1- by 2-degree quadrangles. A map name of "RB5NW," for example, also can be expressed as "39119D2" or simply "99D2."

Utilization of this map-based system has substantially improved processing of large masses of gravity data at all stages from field data entry to final compilation. A digital format for field data sheets has been tested, which includes map names (fig. 10) so that copies of data sheets with geographic information in addition to other key information frequently can be mailed to the headquarters as insurance against loss of maps or data sheets. A program "reads" map names typed as part of the data so that, for example, maps with new data to be digitized can be listed. To avoid ambiguity or duplication of map names, data points should not be located along edges of 7.5-minute maps.

The USGS prints a unique identification nomenclature below the southeast corner of most maps. "N4100—W11715/15," for example, designates a 15-minute map with a southeast corner at lat 41° 00' N. and lon 117° 15' W.. "40117-B8-TF-024" identifies a 7.5-minute map at a scale of 1:24,000 with a southeast corner at lat 40° 07' 30" N. and lon 117° 52' 30" W.. The first four or five numbers of the 7.5-minute system identify the latitude (40) and longitude (117) of the southeast corner of the hypothetical one-degree quadrangle in which the map is located. Similar to the Alaskan system, the two digits, B8 in the example, reflect 7.5-minute map increments from the southeast 1-degree corner: A-B-C-D-E-F-G-H for latitudes and 1-2-3-4-5-6-7-8 for longitudes. Only a single latitude letter is needed to label geographic templates with this convention. Another letter is appended for page-size templates—S, M, or N—to account for the three 2.5-minute portions of 7.5-minute maps (fig. 1). The USGS map labeling system also can be used to name files of 7.5-minute Digital Elevation Maps (DEMs) with 30-m spacing. The DEM file name can be "40117_B8.DEM" for map "40117-B8-TF-024." Therefore, a processing program can search a master directory of DEM files by file name for geographic coverage needed to process data, and, for example, the gravity effect of topography in a 7.5-minute quadrangle can be processed without copying about 1.2 megabytes per DEM file to a user directory.

PROGRAMS TO UTILIZE A SYSTEM BASED ON 7.5-MINUTE QUADRANGLES

Program **mapindex.f** reads the geographic coordinates of data points and outputs 7.5-minute map names associated with each data point (appendix14). Redundancy or ambiguity can be avoided by having unique station names and by not locating data points along edges of 7.5-minute maps. Program **pullring.f** extracts data that lack inner gravity terrain corrections (TCs). Programs **cntmaps.f** and **mapstas.f** list the number and station names of data points for each map. Output data from **mapindex.f** is sorted by map name, to be prepared for input to program **prephtc.f**, which inserts new TCs. Progam **substute.f** iinserts new information from program **prephtc.f** into the original data set by matching unique station names.

PROGRAMMING TECHNIQUES

An initial goal was to reduce time and costs of computation and plotting while retaining sufficient accuracy. Most programs were written in a modular style so that later improvements are simplified. The first programs had punchcard input to batch processing. Therefore, program documentation consisted of comments within the source code, printed output, and informal notes. Programs were self-documenting since the availability of interactive input (prompting). Most programs operate quickly, so that VAX/VMS (Digital Equipment Corporation) command files or UNIX scripts with answers to anticipated questions are not needed. Typical prompts have default responses, that is, a carriage return (or pressing the Enter key), a "y," or a "Y" signify a response of "yes," and "n" or "N" signifies a "no." Questions are phrased in such a way as to protect against overwriting existing files by saying "Do you want to save the file that will be overwritten?" to stop program execution. To avoid system errors, the INQUIRE function is used in programs to first determine if files to be opened for reading or writing exist. Requests for numerical values are answered by the user by typing numbers separated by blank spaces or commas ("free-field" format). Tests for permitted or reasonable values within the programs avoid system errors and lead to stops or repeated questions. Fortran phrases such as "bz" (set blank spaces to zero), "err=," and "end=" also avoid system errors. Some programs may require compilation with the VAX/VMS option "-lV77" to implement library non-standard routines such as DATE() and TIME() and file-OPEN functions such as CARRIAGECONTROL="list," READONLY, and SHARED.

Although PostScript plotting makes the approach less relevant, the strategy for pen plotting was to keep ink running by keeping the pen down and minimizing the total path of pen movement. Pen traverses in program **staelplt.f** (appendix 13) were designed to weave right-to-left and then left-to-right along the shortest path of six tested strip widths. Duplicate pen movements were made for repeat points plotted at

the beginning and end of plots to help ink flow. Drawing centered symbols such as squares and plus signs was done rather than calling a system-dependent SPOT subroutine, but slight system-dependent shifts of print fonts for numbers or names printed near centered symbols were ignored. The PLOT (x,y,-3) origin shift command is interpreted as a relative or absolute origin shift in different systems. Lines related to the PostScript "BoundingBox" function may need to be included or excluded, depending on the language version. A ten-line "Setup" section for an advanced version of the PostScript language can be deleted by editing a print file, if it causes an "offending command" error from the language processor of an older printer. PostScript ASCII files were edited with a simple word processor to print captions and page numbers and to move positions of contour plots and map scales in figures of this report.

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APPENDIX 1

MAP PROJECTION FORMULAS

The following formulas from Plouff (1968) were obtained to maximize computational speed without diminishing accuracy. References at that time were made to formulas in publications by Adams (1918), the U.S. Coast and Geodetic Survey, 1935), and Thomas (1952). See Snyder (1987). who referenced the same publications, for further discussion of these map projections.

Definitions of symbols

A radius of Earth at the equator—6,378,206.4 m for Clarke spheroid of 1866 (Snyder, p. 12)

B radius of Earth at the pole—6,356,583.8 m for Clarke spheroid of 1866

e^2 $=(A^2 - B^2)/A^2$, square of eccentricity of the Earth—0.006768658 for Clarke spheroid of 1866. For comparison, the current accepted "GRS 80" value is 0.0066943800 (Snyder, p. 13).

λ variable longitude of point to be plotted, in radians increasing to west. This sign convention is opposite to the commonly used convention of negative west longitudes.

Λ constant longitude of arbitrary map reference point, usually at map center to maximize precision and to define this as a central meridian parallel to the left and right edges of a map plot

$\Delta\lambda$ $=(\Lambda - \lambda)$, in radians increasing to the east

φ variable latitude of point to be plotted, in radians increasing to north; c=cosine(φ); s=sine(φ)

ϑ constant latitude of arbitrary map reference point, usually at map center to maximize precision; C=cosine(ϑ); and S=sine(ϑ)

$\Delta\varphi$ $=(\varphi - \vartheta)$, in radians, increasing to the north; $\Delta\varphi^o$ for degrees increasing to the north

M length, in meters, of a degree of the meridian at a latitude of $\varphi_m = 0.5\ (\varphi + \vartheta)$. Approximately,

$M = 111{,}132.09 - 566.05\ cos(2\ \varphi_m) + 1.20\ (cos\ 4\ \varphi_m)$

$= 111{,}699.34 - 1{,}141.70\ cos^2\ \varphi_m + 9.60\ cos^4\ \varphi_m$ (U.S. Coast and Geodetic Survey, 1935, p. 4)

Q scale of map

x variable west-to-east coordinate, in meters, of point to be plotted; location usually is relative to the a constant map reference point.

y variable south-to-north cordinate, in meters, of point to be plotted

Polyconic projection

From U.S. Coast and Geodetic Survey (1935, p. 4),

$$x = QL\ sin(\theta), \text{ and}$$

$$y = Q\ [M(\Delta\varphi^o) + 2L\ sin^2(\theta/2)],$$

where

$$L = Ac/[s(1 - e^2 s^2)^{1/2}\ ], \text{ and}$$

$$\theta = s(\Delta\lambda).$$

For an accuracy of 0.4 m on a 30-minute quadrangle,

$$x = QA(\Delta\lambda)\ [C - S(\Delta\varphi) + 1/2\ e^2\ S^2\ C], \text{ and}$$

$$y = Q\ [(\Delta\varphi^o)\ (111{,}699.34 - 1{,}141.70\ C^2 + 9.60\ C^4) + 1/2\ ASC(\Delta\lambda)^2].$$

For a given map plot, all terms except x,y, $\Delta\lambda$, $\Delta\varphi$, and $\Delta\varphi^o$ are constant.

Transverse Mercator projection

Formulas for the transverse Mercator projection are modified from Thomas (1952, p. 2):

$$x = 0.9996\ \mathrm{Q}Gc(\Delta\lambda)\ [1 + 1/6\ c^2(\Delta\lambda)^2\ (1 - T^2 + Ec^2)$$
$$+ 1/120\ c^4(\Delta\lambda)^4\ (5 - 18\ T^2 + T^4 + 14\ Ec^2 - 58\ Es^2)],\ \text{and}$$
$$y = 0.9996\ \mathrm{Q}\ \{M(\Delta\varphi^o) + Gcs(\Delta\lambda)^2\ [1/2 + 1/24\ c^2(\Delta\lambda)^2\ (5 - T^2 + 9\ Ec^2 + 4\ E^2c^4)$$
$$+ 1/720\ c^4(\Delta\lambda)^4\ (61 - 58\ T^2 + T^4 + 270\ Ec^2 - 33\ Es^2)]\},$$

where

$T = s/c$,
$E = e^2/(1 - e^2)$ (=0.006814784 for the Clarke spheroid of 1866), and
$G = \mathrm{A}/(1 - e^2s^2)^{1/2}$, approximated by
$G = \mathrm{A}\ (1 + 1/2\ e^2s^2 + 3/8\ e^4s^4 + 5/16\ e^6s^6)$.

For an accuracy of 13.6 m on a map with a north-south dimension of less than 1.6°,

$$x = 0.9996\ \mathrm{Q}G\ (\Delta\lambda)\ [C - S\ (\Delta\varphi)],\ \text{and}$$
$$y = 0.9996\ \mathrm{Q}\{(\Delta\varphi^o)\ [111{,}699.34 + (1141.70 - 9.60\ C^2)\ (SC(\Delta\varphi) - C^2)]$$
$$+ 1/2\ GSC(\Delta\lambda)^2\},$$

with

$$G = \mathrm{A}\ [1 + 1/2\ e^2S^2\ (1 + 3/4\ e^2S^2 + e^2SC(\Delta\varphi)].$$

For a given map plot, all terms except x,y, $\Delta\lambda$, $\Delta\varphi$, and $\Delta\varphi^o$ are constant.

Conformal conic projection

The Lambert conformal conic projection typically applied to States in the conterminous United States has two standard parallels, φ_s, 33° N. lat, and φ_n, 45° N. lat., with $S_s=\sin\varphi_s$, $C_s=\cos\varphi_s$, $S_n=\sin\varphi_n$, and $C_n=\cos\varphi_n$. From Adams (1918, p. 6-8),

$$x = \mathrm{Q}R\ \sin(L\Delta\lambda)\ \text{and}\ y = \mathrm{Q}R\ \cos(L\Delta\lambda).$$

A map plot is rotated on a sheet by adding a constant angle to ($L\Delta\lambda$). Parameters are defined as

$$R = K\left[\tan\left(z/2\right)\right]^L,$$

$$L = \frac{\ln\left[\dfrac{C_s}{C_n}\sqrt{1-\dfrac{e^2\left(S_n^2-S_s^2\right)}{1-e^2S_s^2}}\right]}{\ln\left[\dfrac{C_s}{C_n}\,\dfrac{S_n+\sqrt{S_n^2+(A/B)^4C_n^2}}{S_s+\sqrt{S_s^2+(A/B)^4C_s^2}}\right]},$$

$$K = \frac{aC_s}{L\sqrt{1-e^2S_s^2}\left[\tan\left(z_s/2\right)\right]^L},$$

and

$$\tan\left(z/2\right) = \frac{C}{(B/A)^2S+\sqrt{C^2+(B/A)^4S^2}}.$$

The last equality is a tangent definition for variable latitude φ or for standard parallels φ_s and φ_n. The value for K had a typographical error in Plouff (1968). For standard parallels 33° N. lat and 45° N. lat., K=12,452,660 m and L=0.6305 for the Clarke spheroid of 1866 (Adams, 1918, p. 10).

APPENDIX 2

DRAWING GEOGRAPHIC-BASED TEMPLATES

The following computer session for program **drawgeog.f** was used to prepare the template shown in figure 1. Note that the default parameters for templates at a scale of 1:24,000 could have been selected by a carriage return but were typed to illustrate the method for special cases. Typed responses are in bold print. Additional comments not in the original session are bracketed in italics.

drawgeog [*CALL PROGRAM*]

```
DRAWGEOG, Plouff 5-98.  Program to draw templates with labeled lines of
 equal latitude and longitude, which coincide with geographic gridmarks
 on maps.  Graphical output is in PostScript format (laser, etc.).
Do you want to skip the explanation of how templates are designed?     n
All lines on the templates are drawn as straight lines.  The minimum span of
lines of equal longitude is the smallest geographic gridmark interval printed
 on the map to be overlain, and, to the extent plot paper is available, the
 maximum length can be the full height of the map.   Inasmuch as projected
 parallels of latitude curve, the span of longitudes should equal or exceed
 the smallest geographic gridmark interval marked on the map to be overlain.
The span of the smallest geographic gridmark interval commonly fits on an
 8.5- by 11-inch sheet.  Larger plot sheets, for which templates are
 plotted side by side until the paper width is exceeded and a new file is
 started, are needed to span the north-south extent of maps.  Only the
 Polyconic and the common Transverse Mercator projections are available,
 but scale factors might be adjusted to fit other projections.
DO YOU WANT TO CONTINUE?     y
A carriage return is a yes and the letter n is a no throughout the program.
Questions will be repeated if your response is not understood.
Print PostScript files PLOT5.PST or PLOT5DAV.PST (advanced language) with a
 5-inch square to test if you need to apply scale factors.
DO YOU WANT TO STOP TO CHECK?      n
The name of the file that will record your session is DRAWGEOG.PNT.
DRAWGEOG.PNT already exists.
 DO YOU WANT TO STOP TO RENAME IT RATHER THAN BEING OVERWRITTEN?             n
Do your templates fit on 8.5- by 11-inch sheets (a marked grid interval)?    y
Are plotter/printer scale factors okay and maps undistorted?                 y
Do the maps to be overlain have the typical Transverse Mercator projection?  y
Do want to print superseded A-D 15-minute names as well as A-H 7.5 minutes?  y
DO NOT TYPE DECIMAL POINTS OR COMMAS FOR THE REMAINING REQUESTED NUMBERS.
TYPE the reciprocal of the map scale (integer number):                 24000
The finest intervals are designed for interpolating either decimal minutes
or seconds.
Do you want decimal minutes?       y
The subdivisions are multiples of 6 seconds.
Your scale permits no more than the standard 2.5-minute gridmark span.
The standard template setup is: 0.1 minute between fine lines
 and 0.5 minute between thick lines, to cover the 2.5-minute span.
Is this acceptable?          n     [A carriage return would bypass 6 questions]
You will type (in integer seconds) the geographic size of the smallest
 subdivision, the thick line separation, and total length of the template.
Rarely would geographic subdivisions differ in the directions of  longitude
 and latitude.  Templates greater than page size generally have a longer
 total length in latitude than longitude; page size generally are equal.
The finest interval should be a multiple of 6 seconds.
DO YOU WANT TO EXIT THE PROGRAM?                                       n
TYPE the distance (seconds) between the finest latitude lines of the template: 6
The same interval between longitude lines?                             y
The distance between thick lines usually is a multiple of 30 seconds.
TYPE the distance between thick latitude lines (integer seconds):      30
The same interval between longitude lines?                             y
TYPE the latitude height of your templates (minutes, seconds):         2  30
```

```
 The longitude width of the templates usually equals the smallest gridmark
  interval of the map.
 For example 300 seconds for 1:62,500 maps, and 150 seconds for 1:24,000.
 TYPE the longitude width of your templates (minutes, seconds):        2  30
 Do you want tickmarks at an interval of 0.01 minute marked along the edges?  y
 One or more templates can be printed to cover a range of latitudes.
  Type 3 integer numbers (without decimal points) separated by spaces.
 TYPE the latitude of the south edge of southmost template (deg,min,sec):45 15 0
 TYPE the latitude of the north edge of northmost template (deg,min,sec):45 22 30
 A total of   3 templates will be prepared.  If this is not acceptable,
  the request for the south edge will be repeated.
 IS THIS ACCEPTABLE?                           y
 Excluding a 1.5-inch east-west gap, each template occupies  6.3 inches or
  less in the east-west direction and  8.2 inches in the north-south
  direction with  1 templates per paper width (and per file).
 Template(s) file  1 is named T4515.00
 South edge of template  1 is 45D 15M  0S
 Template(s) file  2 is named T4517.50
 South edge of template  2 is 45D 17M 30S
 Template(s) file  3 is named T4520.00
 South edge of template  3 is 45D 20M  0S
 A total of  3 sheets were plotted.
 If the edges of your template are not plotted, you must: increase numbers
  0.40 and 0.40 for line 27 (translate command) in file DRAWGEOG.PST for the
  left or bottom edges, respectively; request shorter distances for the right
  or top edges; or change complicated lines 2 (BoundingBox) or bracketed
  numbers in lines 20 and 24.
```

[*Print file DRAWGEOG.PNT*]

```
DRAWGEOG, Plouff 5-98.  Draws lines of equal latitude and longitude with a
  PostScript plotter.  The templates overlay maps with geographic registration.
 Page-size templates are selected.
 Scale factors: 1.0000 N-S 1.0000 E-W.
 Maps have the Transverse Mercator projection.
 Scale selected is 1:  24000
 The finest template interval is to interpolate decimal minutes.
 Tickmarks at an interval of 0.01 minute will be drawn along the edges.
  Latitude units.  Finest:  0.10M; coarse:  0.50M; template: 0D  2.50M
 Longitude units.  Finest:  0.10M; coarse:  0.50M; template: 0D  2.50M
    3 templates will be prepared.
  The latitude range is 45D 15M  0S to 45D 22M 30S.
 Excluding a 1.5-inch east-west gap, each template occupies  6.3 inches or
  less in the east-west direction and  8.2 inches in the north-south
  direction with  1 templates per paper width (and per file).
 Template(s) file  1 is named T4515.00
 South edge of template  1 is 45D 15M  0S
 Template(s) file  2 is named T4517.50
 South edge of template  2 is 45D 17M 30S
 Template(s) file  3 is named T4520.00
 South edge of template  3 is 45D 20M  0S
 A total of  3 sheets were plotted.
 If the edges of your template are not plotted, you must: increase numbers
  0.40 and 0.40 for line 27 (translate command) in file DRAWGEOG.PST for the
  left or bottom edges, respectively; request shorter distances for the right
  or top edges; or change complicated lines 2 (BoundingBox) or bracketed
  numbers in lines 20 and 24. phoenix% lpr -PAiry T4517.50
```

lpr -PAiry T4517.50   [*PRINT COMMAND DIRECTED TO ANY POSTSCRIPT MEDIA*]

Templates are stored in the sequence of increasing latitude. For field use with daylight background, templates can be held or taped over or under field maps while transferring geographic coordinates.

APPENDIX 3

DRAWING TEMPLATES WITH UNIVERSAL TRANSVERSE MERCATOR COORDINATES

PROGRAM DRAWUTM

The following computer session for program **drawutm.f** was used to prepare the template shown in figure 5. Note that the default parameters for templates at a scale of 1:24,000 could have been selected by a carriage return but were typed to illustrate the method for special cases. Typed responses are in bold print. Additional comments not in the original session are bracketed in italics.

```
drawutm                                                      [CALL PROGRAM]
 DRAWUTM, Plouff 8-97.  Program to draw templates with equally-spaced lines
  to interpolate distances between gridmarks for Universal Transverse Mercator
  (metric) or State Plane (english) coordinates.
 Graphical output is in PostScript format (laser, etc.).
 Do you want to skip the explanation of how templates are designed?          n
 Templates can cover the smallest gridmark interval shown on maps.
 For example, 1,000 meters UTM squares (1.64-inch separation) may be shown or
  can be drawn between map edges on 7.5-minute maps.  If UTM or State Plane
  registration marks along edges are insufficient to obtain 1,000-meter
  squares, templates need to be large enough to span a short distance beyond
  the map.
 DO YOU WANT TO CONTINUE?                y
 A carriage return is a yes and the letter n is a no throughout the program.
 Questions will be repeated if your response is not understood.
 Print PostScript files PLOT5.PST or PLOT5DAV.PST (advanced language) with a
  5-inch square to test if you need to apply scale factors.
 DO YOU WANT TO STOP TO CHECK?           n
 The file that will record your session is DRAWUTM.PNT.
 Print file DRAWUTM.PNT already exists.
  DO YOU WANT TO STOP TO RENAME IT RATHER THAN OVERWRITING IT?               n
 Do your templates fit on 8.5- by 11-inch pages?                             y
 Are plotter/printer scale factors okay and maps undistorted?                y
 DO NOT TYPE DECIMAL POINTS OR COMMAS FOR THE REMAINING REQUESTED NUMBERS.
 TYPE the reciprocal of the map scale (integer number):                24000
 Distance intervals can be shown in either the metric (meters/kilometers)
  or the english (feet/kilofeet) system.
 Do you want the metric system?                                              y
The metric system is selected.
 The standard template setup is 100 m between fine lines and 500 m
  between thick lines, to cover a 4- by 5-km area.
 Is this acceptable?                                                         n
 You will type (integer meters) the size of the smallest subdivision,
  the thick line separation, the total width/length of the template,
  and label spacing.
 DO YOU WANT TO EXIT THE PROGRAM TO PREPARE THE DESIGN?                      n
 The smallest subdivision should be a number rounded  to hundreds in the
  range of about   100 to   200 meters
 TYPE the distance (integer) between the finest lines of the template:       100
 The distance between thick lines must be an integer multiple of the
  smallest interval.
 TYPE the distance (integer) between thick lines:                            500
 The maximum distance spans covered by the template must be multiples of the
  thick line interval.
        5500 meters=longest bottom-to-top distance available
        4500 meters=longest left-to-right distance available
 TYPE the maximum bottom-to-top distance covered by the template (integer):  5000
 TYPE the maximum left-right distance covered by the template (integer):     4000
Spacing of labeled thick lines must be an integral multiple of a thousand.
 TYPE the spacing of labels:                                                 1000
```

```
The PostScript file to print is named M24.0
   If the edges of your template are not plotted, you must: increase numbers
 0.40 and 0.40 for line 22 (translate command) in PostScript file for the
 left or bottom edges, respectively; request shorter distances for the right
 or top edges; or change complicated lines 2 (BoundingBox) or bracketed
 numbers in lines 15 and 19.
```

Analog versions of templates that spanned field maps first were used by the U.S. Geological Survey to record geochemical sample locations at distant field locations such as Alaska. Office applications originally were to record locations of mineral occurrences for a database, but the data were usually were recorded as alphameric text rather than digital data to be read and processed by later computer programs.

PROGRAM DRAW30

To quickly assure that a corner of the template (fig. 6) prepared in the following session correctly overlays 30-m Digital Elevation Model coordinates, the sum of digits for marked 1-km UTM Northings and Eastings at the corner should be integer multiples of three. Default parameters were selected with carriage returns for the most useful template at a scale of 1:24,000 (fig. 6) in the following session, but other scales and sizes can be selected. Typed responses are in bold print. Additional comments not in the original session are bracketed in italics.

```
draw30                                                     [CALL PROGRAM]
 DRAW30, Plouff 2-98.  Program to draw templates with lines spaced at
  multiples of 30 meters to iterpolate UTM locations for 30-m Digital
  Elevation Models.  Graphical output is in PostScript format (laser, etc.).
 A carriage return is a yes and the letter n is a no throughout the program.
 Questions will be repeated if your response is not understood.
 Print PostScript files PLOT5.PST or PLOT5DAV.PST (advanced language) with a
  5-inch square to test if you need to apply scale factors.
 DO YOU WANT TO STOP TO CHECK?                                            n
 The file that will record your session is DRAW30.PNT.
 Print file DRAW30.PNT already exists.
  DO YOU WANT TO STOP TO RENAME IT RATHER THAN OVERWRITING IT?            n
 Do your templates fit on 8.5- by 11-inch pages?
 Are plotter/printer scale factors okay and maps undistorted?
 DO NOT TYPE DECIMAL POINTS OR COMMAS FOR THE FOLLOWING REQUESTED NUMBERS.
 TYPE the reciprocal of the map scale (integer number):                   24000
 Distances are expressed in meters.
 The standard template setup is 60 m between fine lines and 600 m
  between thick lines, to cover a 3- by 3-km area.
 Is this acceptable?
 The PostScript file to print is named D24.0
    If the edges of your template are not plotted, you must: increase numbers
  0.40 and 0.40 for line 22 (translate command) in PostScript file for the
  left or bottom edges, respectively; request shorter distances for the right
  or top edges; or change complicated lines 2 (BoundingBox) or bracketed
  numbers in lines 15 and 19.

                              [Print file DRAW30.PNT]
 DRAW30, Plouff 2-98.  Draws templates with multiple of 30-m grid to
  interpolate DEM/UTM coordinates.  Must register with UTM multiples of 30m.
 Page-size templates are selected.
 Scale factors: 1.0000 bottom-top 1.0000 left-right.
 Scale selected is 1:  24000
 The standard template setup is 60 m between fine lines and 600 m
  between thick lines, to cover a 3- by 3-km area.
 The PostScript file to print is named D24.0
 If the edges of your template are not plotted, you must: increase numbers
  0.40 and 0.40 for line 22 (translate command) in PostScript file for the
  left or bottom edges, respectively; request shorter distances for the right
  or top edges; or change complicated lines 2 (BoundingBox) or bracketed
  numbers in lines 15 and 19.
```

APPENDIX 4

DRAWING MAP SCALES

The following computer session for program **mapscale.f** was used to prepare and position the scale shown at the bottom of figure 2. Typed responses are in bold print. A carriage return can be substituted for the answer "yes" (y). Additional comments not in the original session are bracketed in italics. Note that the default condition suggests a fine interval of 10 km and a coarse interval of 100 km. With that condition and the fact that the fine intervals are incorporated in one coarse interval to the left of the zero mark, the rightmost mark would be 3400 km to fit within the pre-determined margin. However, printing indicated that the fine interval was needlessly close for the nature of the illustration. The most confusing element needed for the design is the "span" (3500) that is the sum of the leftmost (500) and rightmost (3000) labels rather than simply the rightmost label. To incorporate the scale into a PostScript figure with a caption and page number below, the default distance of one inch from the bottom of the page was changed to 2.0 inch. Later, the caption and page number were inserted as PostScript text into file **scale40m** before drawing the map scale**.**

```
mapscale                                                        [CALL PROGRAM]
 MAPSCALE, PLOUFF, 7-94. Program to create a PostScript file for a map scale.
  If you do not know the scale, it will be calculated from your measurements.
 Default units of miles or kilometers will be provided unless the scale is
  too large.  A default scale occupies about 3.75 inches, is centered on a
  8.5-inch page width, and starts 1.00 inch from the bottom of the page
  (varies slightly with printer).
 TYPE a name for a PostScript file:                             scale40m.
 TYPE the reciprocal of the map scale (0, if unknown):          40000000
 Are your distance units kilometers?                            y
 The scale extends  3.44 inches to a maximum span of  3500 kilometers
 The right end of the scale is marked 3400 kilometers
 Fine intervals are 10.0 ( 0.010 inch) and coarse are 100 ( 0.10 inch) kilometers
 Are these values okay?                                         n
 If fine intervals are not wanted (rarely), type 0.
 TYPE the length of a fine interval (units, decimal number):    100
 The coarse interval is the length of the total number of fine intervals.
 TYPE the coarse interval (units, no decimal point, non-zero):  500
 The requested maximum distance includes the fine intervals.
 TYPE the span of the scale (units, no decimal point):          3500
 The lower left corner of the scale is 1.0 inch from the bottom of the paper
  and 2.23 inches from the left edge.
 Are these values okay?                                         n
 TYPE the distance in inches from the bottom:                   2.0
 TYPE the distance in inches from the left edge:                2.23
 If this PostScript file is combined with a plot, delete the first %!PS line,
  delete the last showpage line, and insert after line one %!PS in the plot
  file.  Rotated plots and slight translation shifts of paper origins will
  need special treatment.
```

To add the caption and page number, the following lines were inserted into the map scale file after the "72 72 scale" line for converting units of points to inches. Asterisks indicate missing words.

```
/Times-Roman findfont 0.16 scalefont setfont
0.8 1.40 moveto
(Figure 2.--Distance in meters between 1927****United States.  Contour) show
1.0 1.21 moveto
(intervals, 5 m.  Upper drawing shows distance****of the 1927 location,) show
1.0 1.02 moveto
(with negative numbers to south; negative****labeled.  Lower drawing) show
1.0 0.83 moveto
(shows distance to add to the longitude****negative numbers to east.) show
4.2 0.50 moveto
(7) show
```

To prepare a map scale for an existing map that does not have a scale, answer 0 (zero) when the map scale is requested. To determine the scale, prompting will request the latitude (degrees, minutes) of two positions along the same meridian on the map and the distance in inches. That scale could be rounded for a separate execution or for plotting data points later. Scales for both english and metric units can be combined into one plot file in a word-processing editor by appending two map-scale files, deleting %!PS and introductory definitions for the second scale, and adjusting a coordinate translation. The PostScript contour plots in figures 2-4 were appended after captions and scales to form one PostScript file.

APPENDIX 5

REDUCING THE NUMBER OF POINTS THAT DEFINE A POLYGONAL GEOGRAPHIC BOUNDARY

"Other-lines files" consists of records with longitude degrees, longitude minutes, latitude degrees, and longitude minutes separated by spaces or commas ("free field" format) to express the geographic coordinates of each point. Although west longitude degrees must have negative signs, the associated minutes do not have negative signs. If this format is converted from a format with decimal degrees, zeroes must be inserted in the positions of minutes. Delimiters between connected line segments are "-999.0 0 -999.0 0." Program **cutoln.f** discards points that are closer than 0.01 inch at the scale to be plotted, thus saving storage and processing time. An interval of 0.01 inch is sufficient to delineate connected lines on plots although the resolutions of most printers are less than 0.01 inch. The following computer session for program **cutoln.f** deleted redundant points along the United States boundary for figure 2. Note that an initial working scale of 1:25,000,000 was requested rather than the scale of 1:40,000,000 in figure 2. Typed responses are in bold print. Additional comments not in the original session are bracketed in italics.

```
cutoln                                                        [CALL PROGRAM]
 Plouff, 7-97, CUTOLN.  Program to reduce the length of an OLN file to be
  plotted by deleting points that are less than 0.01 inch from the last
  point.  The method depends on the scale to be plotted and previewing the
 file for the minimum latitude.
 TYPE the name of the OLN file (<66 characters):                USF.OLN
TYPE the reciprocal of the map scale (integer) (zero to stop):  25000000
An output file name for the trimmed data should include an indication of the
 scale for which it is intended (e.g., without last 3 digits.
 TYPE the name of the output OLN file (<66 characters):         US25000.OLN
The input file has   14099 points with   42 99-delimiters.
 Latitudes range from   25.120 to   49.372 degrees.
Longitudes range from -124.732 to  -66.958 degrees.
Conversion factors are 1.85 and 1.68 km/minute for latitude and longitude.
 0.01 inch is 0.05721 and 0.06284 degree at your scale. The output file will
 have 2 digits to the right of the decimal point for degrees and
  1 digits for minutes.
The output file has    2216 points and   42 de-limited segments.
```

In contrast to 2,216 points yielded by a scale of 1:25,000,000, a scale of 1:500,000 yielded 13,893 points from the original 14,099 points.

APPENDIX 6

PRINTING THE GEOGRAPHIC RANGE OF DATA

The following computer session for program **geogrange.f** recorded the geographic range of gravity data compiled to cover an area in northwest Nevada and northeast California (Plouff, 1996). The program is useful to identify data outside the area of interest (coordinates of zero, for example, identify an inadvertent blank line) and to establish boundary limits for plotting and contouring programs. Typed responses are in bold print. Additional comments not in the original session are bracketed in italics.

```
geogrange                                                         [CALL PROGRAM]
 Program to print range of geographic coordinates in a plouff-format file.
 TYPE the name of your file:                                 all96.isn
 Total stations in file is   7075
 Minimum  latitude is  39D 29.01M at station     P286
 Maximum  latitude is  42D  8.00M at station    I   2
 Minimum longitude is 116D 51.03M at station  CGMD43
 Maximum longitude is 120D 25.84M at station    AB101
 Print file GEOGRANGE.PNT for a record of these results.
```

File GEOGRANGE.PNT lists the input file name and prints the summary as above.

APPENDIX 7

ADDING A CONSTANT GEOGRAPHIC LOCATION SHIFT TO DATA

The following computer session for program **chnglocs.f** corrected a nearly constant location error for a set of gravity data tin northwest Nevada (Plouff, 1996, p. 9-10). Typed responses are in bold print. Additional comments not in the original session are bracketed in italics.

```
chnglocs                                                          [CALL PROGRAM]
 CHNGLOCS.  Plouff, 12-1994.  To add constants to latitudes and longitudes
  (plouff format).  19-Dec-94 16:41
 Print file CHNGLOCS.PNT already exists.
 Do you want to STOP to save it?                                  n
 TYPE the name of your plouff file to be revised:                 pvz.isn
 TYPE a name for your revised plouff-file:                        pvgchng.
 Your output file already exists.
 Do you want to STOP to save it?                                  n
 You will type constants to be added to the input coordinates, that is, to
  move the locations to the north and to the west for positive numbers and to
  the south and east for negative numbers.  Units are decimal minutes
 TYPE the northward latitude shift (minutes):                     0.14
 TYPE the westward longitude shift (minutes):                     0.71
 There are  177 stations in your plouff input file.
 A record of this session is in file CHNGLOCS.PNT
```

Printout of file CHNGLOCS.PNT

```
 CHNGLOCS.  Plouff, 12-1994.  To add constants to latitudes and longitudes
  (plouff format).  19-Dec-94 16:41
 Input file: pvz.isn
 Revised output file: pvgchng.
 Your constant shifts are  0.14 minutes north and  0.71 minutes west.
 There are  177 stations in your plouff input file.
```

Inasmuch as system date and time builtin subroutines were used, compilation of the program required a Sun FORTRAN-77 compiler option designated as "-lV77" for compatibility with the VAX/VMS FORTRAN language (Digital Equipment Corporation). If that option is not available, calls to the date and time functions must be modified or deleted.

APPENDIX 8

EXTRACTING DATA FROM A RECTANGULAR GEOGRAPHIC BOUNDARY

The following computer session for program **pullrect.f** extracts gravity data for theVya 1° by 2° quadrangle, Nevada-Oregon-California, from a large BLM study area (Plouff, 1996) for further study and extracts data from a 7.5-minute quadrangle that represents a small area around a doubtful data point to be studied for errors. Positive numbers are assumed for west longitude degrees in the data format. Typed responses are in bold print. Additional comments not in the original session are bracketed in italics.

```
pullrect                                                          [CALL PROGRAM]
 PULLRECT, Plouff, 3-98.  Retrieve data in plouff format (80 columns)
  from inside or outside a rectangle bounded by geographic coordinates.
 See program SURROUND for a polygonal boundary.
 TYPE the name of the file where the data are stored:                   all96.isn
 Do you want to select data from inside (not outside) a rectangle?      y
 TYPE the name of the file where the selected data are to be stored?    vya.isn
 Boundaries are expressed in decimal degrees and minutes.  You may type four
  edges for the boundary or half the span of a geographic window (<1 degree)
  followed by its center coordinates.
 The window flag is negative minutes for the half width span.
 Questions will be repeated if your response is unacceptable.
 TYPE the coordinates of the south boundary or window (deg, min):       41  0
 North edge (deg, min):                                                 42.0  0.0
 East edge (deg, min):                                                  118  0
 West edge (deg, min):                                                  120  0
  7075 data points are in input file: all96.isn
 1549 points in: vya.isn
 Do you want to extract more data from the same input file?             y
 TYPE the name of the file where the selected data are to be stored?    VAISE.isn
 Boundaries are expressed in decimal degrees and minutes.  You may type four
  edges for the boundary or half the span of a geographic window (<1 degree)
  followed by its center coordinates.
 The window flag is negative minutes for the half width span.
 Questions will be repeated if your response is unacceptable.
 TYPE the coordinates of the south boundary or window (deg, min):       0  -3.75
 TYPE center coordinate latitude (deg, min):                            41  3.75
 TYPE center coordinate longitude (deg, min):                           118  3.75
   8 points in: VA1SE.isn
 Do you want to extract more data from the same input file?             n
```

The above "window" option, is initiated, for example, by positioning a template over a location that has apparently inconsistent values on a contoured gravity map. The geographic coordinates are determined near the center of the anomalous area, are entered into program **pullrect.f**, and consequent suspicious data points are examined on topographic maps. For the next test, the part of a data set nominally located in Oregon (edge at about 42° N. lat) is extracted from a larger set. Note that the south, east, and west boundaries are extended outward to assure that all data north of 42° N. lat are extracted.

```
pullrect                                                          [CALL PROGRAM]
 Plouff, 3-98.  Retrieve data in plouff format (80 columns)
  from inside or outside a rectangle bounded by geographic coordinates.
 See program SURROUND for a polygonal boundary.
 TYPE the name of the file where the data are stored:             all96.is
 That file was not found.  Try once more.
 TYPE the name of the file where the data are stored:             all96.isn
 Do you want to select data from inside (not outside) a rectangle?      n
 Therefore, the data you select will be outside the quadrangle.
 TYPE the name of the file where the selected data are to be stored?    oregon.
 Boundaries are expressed in decimal degrees and minutes.  You may type four
  edges for the boundary or half the span of a geographic window (<1 degree)
  followed by its center coordinates.
 The window flag is negative minutes for the half width span.
 Questions will be repeated if your response is unacceptable.
 TYPE the coordinates of the south boundary or window (deg, min):       10  0
 North edge (deg, min):                                                 42  0
 East edge (deg, min):                                                  10  0
 West edge (deg, min):                                                  150  0
  7075 data points are in input file: all96.isn
  271 points in: oregon.
```

APPENDIX 9

EXTRACTING DATA FROM A POLYGONAL GEOGRAPHIC BOUNDARY

Gravity data were extracted from the data set of the National Geophysical Data Center (1991) within a rectangular geographic boundary to cover a large study area in northwest Nevada and northeast California (Plouff, 1996). That data set of 10,751 data points was trimmed to 7,991 data points within a smooth envelope that encloses an arbitrary polygonal boundary just outside the study area (fig. 7) by using the following computer session for program **surround.f**. Typed responses are in bold print. Additional comments not in the original session are bracketed in italics.

```
surround
 SURROUND, Plouff.  To extract stations from inside and outside a polygonal
geographic boundary.
 TYPE the name of the plouff input file:                          cover.blm
 You need a file with consecutive polygon corners.  Each line has 4 decimal
  numbers (separated by spaces or commas) consisting of longitude (d,m)
  followed by latitude (d,m).  The first vertex need not be repeated.
 TYPE the name of the polygon file:                               margin.lines
 Do you want the exterior stations to be saved in a file?               n
   8 corner coordinates read.
 Area center at 40D 48.0M latit 118D 38.5M longit
 10751 input stations
  7991 stations inside or on boundary are in file INSIDE.DAT
 (     0 stations on border)
 You may want to delete trailing blank spaces from INSIDE.DAT.
 Print file SURROUND.PNT for a record of this session.
```

[*File SURROUND.PNT*]

```
 SURROUND, Plouff,  6-Mar-98 09:51:28
 To extract stations from inside or outside a polygonal geographic boundary.
 Input file: cover.blm
 Your file of polygon corners is:    ../margin.lines
 Your file of stations inside the polygon is named INSIDE.DAT
 Corner:   1  42D  7.00M 120D 26.00M
 Corner:   2  42D  7.00M 116D 51.00M
 Corner:   3  40D 39.00M 116D 51.00M
 Corner:   4  39D 53.00M 117D 28.00M
 Corner:   5  39D 29.00M 118D 59.00M
 Corner:   6  39D 29.00M 119D 22.00M
 Corner:   7  41D  2.00M 120D 26.00M
 Corner:   8  42D  7.00M 120D 26.00M
   8 corner coordinates read.
 Area center at 40D 48.0M latit 118D 38.5M longit
          UNIVERSAL TRANSVERSE MERCATOR PROJECTION
 10751 input stations
  7991 stations inside or on boundary are in file INSIDE.DAT
 (     0 stations on border)
 You may want to delete trailing blank spaces from INSIDE.DAT.
```

[*File margin.lines]*

```
-120 26 42  7
-116 51 42  7
-116 51 40 39
-117 28 39 53
-118 59 39 29
-119 22 39 29
-120 26 41  2
-120 26 42  7
-999  0 -999 0
```

A file, **SURROUND.PNT**, to record the session and an output file, **INSIDE.DAT**, for points inside and along the border always are written. An output file, **OUTSIDE.DAT**, for points outside the border is written at the request of the user. Either or both of the last two lines in file **margin.lines** could have been omitted because the polygon is closed by program **surround.f** if a repeated origin is not provided, and the "other-lines" format (segment terminator line with -999) is not required. Either algebraic sign may be entered for longitude degrees in file **margin.lines**. Inasmuch as system date and time builtin subroutines were used, compilation of the program required a Sun FORTRAN-77 compiler option designated as "-lV77" for compatibility with the VAX/VMS FORTRAN language (Digtal Equipment Corporation). If that option is not available, calls to the date and time functions must be modified or deleted.

APPENDIX 10

FINDING AND UTILIZING REDUNDANT DATA

The criterion for redundancy is that the geographic distance between data points is less than a user-selected distance, in minutes of both the latitude and longitude component. Programs to identify redundant data are especially useful for processing data from the Defense Mapping Agency (DMA) Gravity Library, which is now maintained and administered by the National Geophysical Data Center (1991) in the United States and other areas. This function is useful both to delete superfluous—less accurate or repeated—data and to compare observed-gravity datums for repeated data. As indicated in Appendix 9, a total of 7,991 NGDC data points were obtained to cover a large study area in northwest Nevada and northeast California (Plouff, 1996). Typed responses in the following computer sessions are in bold print. Additional comments not in the original session are bracketed in italics. As previously discussed, some of the following programs, **countdma.f**, **redund.f**, **combpair.f**, **compare2.f** and **redundel.f**, include date and time functions which may need to be modified or deleted.

PROGRAM COUNTDMA

Based on analysis of the first four digits of 8-digit gravity station names, program **countdma.f** shows that sorted-by-station-name data set INSIDEDAT.SRT consists of 62 data sources (subsets). The output of the program is a list of DMA source codes and the number of data points with that source code.

```
countdma                                                     [CALL PROGRAM]
 COUNTDMA.F, Plouff 2-94.  Program to list the unique 4-digit names and how
  many occurences there are for the first four columns of every line in
  a file.  The intent mostly is to summarize the source code part of
  8-digit station names derived from DMA gravity data files (plouff, e.g.).
 The output of this program is a file of single lines with source codes followed
  by the total number of stations with that code (format 1x,a4,i5).
 Sorting by code and/or total number is suggested.
 The name of that output file is COUNTDMA.PNT (**overwrites).
 TYPE the name of your input file (<66 cols):                    INSIDEDAT.SRT
  62 source codes for 7991 stations
```

[*PARTIAL LIST OF OUTPUT FILE COUNTDMA.PNT*]

```
  483   11
  764    5
 1083   25
 2149   18
 2179  535
 2235  219
- - - - - - - -
 6948  134
 6976  169
 7358  770
 7567  178
 7838   33
 7942   41
```

PROGRAM REDUND

Program **redund.f** reads file INSIDEDAT.SRT, lists pairs of data points within a user-prescibed distance apart, and outputs those pairs for further comparison. To eliminate data sources which absorbed but did not reoccupy earlier an data subset, the prescribed distance should first be zero minutes in latitude and longitude for exact duplication. After deleting exact matching subsets with a program or in an editor, and possibly substituting unique names for the second four digits of the data point identification, larger distances can be tested. Different station names for matching points in the two data subsets does not preclude that a later compiler did not mistakenly rename the earlier data points.

```
redund                                                            [CALL PROGRAM]
 REDUND, 2-95, Plouff.  To list and output stations that are close to others
  in a plouff-format file.
TYPE the name of the file to be tested for redundant stations:    INSIDEDAT.SRT
 The test is based on closeness of geographic coordinates.  Do not select a
  distance that includes adjacent stations along a closely spaced profile.
 TYPE the redundancy distance in decimal minutes (geographic):                0
 Do want to create an abbreviated plouff-file of pairs of redundant stations
  for later testing?                                                          Y
 TYPE the name of that file:                                         red0.pairs
   578 pairs of closely spaced stations in file of  7991 stations.
 The results of this program are in a file named REDUND.PNT
```

[*PARTIAL LIST OF 1170-LINE OUTPUT FILE REDUND.PNT*]

```
  9-Mar-98 09:20:12
 REDUND, 2-95, Plouff.  To list and output stations that are close to others
  in a plouff-format file.
 List of redundant stations from gravity data in plouff-file: INSIDEDAT.SRT
Pairs of redundant stations are in file:  red0.pairs
 Geographic offset= 0.00 minute.
 Elevation differences in feet; CB1-differences to 0.1-mGal.
  Differences that are too large to print will be listed as nines.
 List of close pairs of stations:
 LINE   STATION LATIT   LONGIT   ELEV/ERR OBS.GRV/ERR    CB1/ERR   STATION
   395 21792248 41 4150 117 5940  45270    7988498           0    21792248 FIRST
  2300 47880229 41 4150 117 5940  45270  0 7988484  -14      0  0 47880229 MATCH
   574 21795188 39 5280 117 4370  40270    7976113           0    21795188 FIRST
  3441 50680789 39 5280 117 4370  40270  0 7976110   -3      0  0 50680789 MATCH
   573 21795187 39 5285 117 4380  39850    7976412           0    21795187 FIRST
  3442 50680790 39 5285 117 4380  39850  0 7976409   -3      0  0 50680790 MATCH
----------------------------------[OTHERS]--------------------------------
  2824 4999 SR1 39 4181 118 1761  42090    7973652           0    4999 SR1 FIRST
  7970 79420048 39 4181 118 1761  42090  0 7973699   47      0  0 79420048 MATCH
  2823 4999 SR1 39 4132 118 1612  47790    7970202           0    4999 SR1 FIRST
  7971 79420049 39 4132 118 1612  47790  0 7970261   59      0  0 79420049 MATCH
  2822 4999 SR1 39 4086 118 1585  50130    7968535           0    4999 SR1 FIRST
  7972 79420050 39 4086 118 1585  50130  0 7968594   59      0  0 79420050 MATCH
   578 pairs of closely spaced stations in file of  7991 stations.
```

The following session indicates that 1,421 data points are closer than 0.1 minute compared to 578 exactly coincident data points identified above.

```
redund                                                            [CALL PROGRAM]
 REDUND, 2-95, Plouff.  To list and output stations that are close to others
  in a plouff-format file.
 TYPE the name of the file to be tested for redundant stations:   INSIDEDAT.SRT
 The test is based on closeness of geographic coordinates.  Do not select a
  distance that includes adjacent stations along a closely spaced profile.
 TYPE the redundancy distance in decimal minutes (geographic):              0.1
 Do want to create an abbreviated plouff-file of pairs of redundant stations
  for later testing?                                                          Y
 TYPE the name of that file:                                        red10.pairs
```

```
  1421 pairs of closely spaced stations in file of  7991 stations.
 The results of this program are in a file named REDUND.PNT
```

[*BEGINNING OF 2842-LINE OUTPUT FILE* RED10.PAIRS]

```
 4830010 393086 1185650 402707972168
1083000  393090 1185640 402707972180
 7641704 42   0 1174280 443007990587
21791174 415990 1174290 442807990593
21791146 401210 1182850 398807977838
21794590 401214 1182852 399407977879
21794581 401305 1174990 491907972706
21795113 401295 1174995 491907972701
```

Note that the 0.1-minute test extracted closely-spaced profile of data points in data source "2179" as well as pairs of data points from different sources.

PROGRAM COMBPAIR

Program **combpair.f** provides a statistical summary of diferences between data sources. This information permits deletion of entire subsets as redundant and provides observed-gravity datum shifts to be applied to data sets that are less accurate than other sets or are tied to different observed-gravity datums.

```
combpair                                                                    [CALL PROGRAM]
 Plouff 1-89
 Program to read file of pairs of redundant stations from program REDUND and
  to print the number of pairs for each combination of 4-digit source codes.
 The original file usually was obtained from a DMA file and was sorted
  by station name.  The list of source codes (or first 4 digits of station
  names) is obtained from the output of program COUNTDMA with the file of pairs
  as input.
 TYPE the name of the .PNT file from the CNTSRC or COUNTDMA programs: COUNTDMA.PNT
 TYPE the name of the output pairs file from the REDUND program:        red0.pairs
 There is a total of 62 source codes.
 A total of  578 pairs were read.
 There are  30 different pairs of source codes.
 Some pairs may be repeated in reverse order if the original file was not
  initially sorted by station name.
 Printout of results are in a file named COMBPAIR.PNT
```

[*PARTIAL PRINT OF FILE COMBPAIR.PNT*]

```
  9-Mar-98 09:24:23
 Plouff 1-89
 Program to read file of pairs of redundant stations from program REDUND and
  to print the number of pairs for each combination of 4-digit source codes.
 The original file usually was obtained from a DMA file and was sorted
  by station name.  The list of source codes (or first 4 digits of station
  names) is obtained from the output of program COUNTDMA with the file of pairs
  as input.
 COUNTDMA program file of source codes:         COUNTDMA.PNT
 REDUND program file of pairs:                  red0.pairs
 There is a total of 62 source codes.
 A total of  578 pairs were read.
 A list of paired source codes follows.  The list includes the
  number of occurrences, the average difference of elevations in feet, the
  the standard deviation of the elevation difference, the average difference
  of observed gravity in milligals, and the standard deviation in milligals.
```

```
 CODE1 CODE2 NUMBER EL2-EL1 STD DEV  OG2-OG1 STD DEV
   483  5069     11     0.0     0.0    -0.05    0.00
  2149  5069     18     0.0     0.0    -0.03    0.00
  2179  5068     41     0.0     0.0    -0.03    0.00
  2179  5069     47     0.0     0.0    -0.03    0.00
  3598  5069      7     0.0     0.0    -0.04    0.00
  4787  6625     12   -14.0    32.5     0.02    0.00
  4788  5116      2     1.0     1.4     0.04    0.03
  4869  6625     30     0.0     0.0    -0.80    0.00
  4999  7942      3     0.0     0.0     0.55    0.07
  5068  5130     11     0.0     0.0     0.05    0.00
  5068  5163     10     0.0     0.0     0.05    0.00
  5069  5144     85     0.0     0.0     0.05    0.01
  5069  5163     25     0.3     1.6     0.05    0.00
 There are  30 different pairs of source codes.
 Some pairs may be repeated in reverse order if the original file was not
  initially sorted by station name.
```

The above list indicates that many data points in data sources "5068" and "5069" should be deleted, because they were copied from earlier data sets with small constant changes of observed gravity. Although the values of observed gravity are essentially the same for sources "4787" and "6625," one or more data points have elevation errors to be found. A constant observed-gravity datum shift should be accounted for when comparing sources "4869" and "6625."

PROGRAM COMPARE2

Program **compare2.f** compares the values of observed gravity for subsets within two sets of data. As with **combpair.f**, subsets are identified by the first four digits of the 8-digit station name. The following session compares data points in a one- by two-degree data set extracted from the final published data set **all96.isn** with data points that originally were available in file **INSIDEDAT.SRT**. The full data set, **all96.isn**, had too many apparent subsets—not based on the simple DMA naming convention—for program **compare2.f**. In practise, smaller geographic areas of data already in U.S. Geological Survey files were compared with **INSIDEDAT.SRT** or its subsets during the compilation process.

```
compare2                                                             [CALL PROGRAM]
 COMPARE2. Plouff,3-98.  Program to primarily summarize differences of
  observed gravity at nearly coincident stations in two plouff-format files.
  Differences are grouped into combinations matched with the first four
  digits of station names.  Files preferably should be sorted by station
  name and run through programs REDUND (no internally coincident stations)
  and COUNTDMA (no more than 80 unique 4-digit source-code names in files).
  Files must have no more than 9000 data points.
 The output of this program is in print file COMPARE2.PNT
 TYPE the name of one file:                                         lv.isn
 TYPE the name of the other file:                                   INSIDEDAT.SRT
 Data points from the two sets need not exactly coincide to be tentatively
  assumed to be at the same location.  The tolerance is expressed in
  geographic minutes (both longitude and latitude).  This program should
  first be run with zero tolerance, to test for copied data.
 TYPE the tolerance in minutes:                                     0.03
 File 1: lv.isn
  has 1716 data points and the following 72 unique source codes:
 ECGB] E CG] ELCG]   CG] L CG] LCGB]  CGB]  CGH] LCGH] ECGH] LCGL] LCGN]  CGN]
 LECG] LCGS]  CGS] ECGS]  CGT] LCGT] ECGT]    R]    G] L  G] L G1] EL G] 3891]
    K] L  K] L  Q]    Q] EL Q] EL H]    H] L  H] E  H]    X] EL X] L  X]     ]
 L   ] E   ]    S] L  S]   DB] L DB]   ge] L ge]   FR] 24FR] 25FR] 26FR] 27FR]
 28FR] 29FR] 30FR] 31FR] 32FR] 33FR] 34FR] 35FR] 37FR] 39FR] 41FR] 42FR] 43FR]
 44FR]    P] Q  P]    W] EL S] E  S]    B]
```

```
File 2: INSIDEDAT.SRT
 has 7991 data points and the following 62 unique source codes:
 483]  764] 1083] 2149] 2179] 2235] 2381] 2531] 2649] 2665] 2695] 2713] 2720]
2773] 3046] 3382] 3391] 3502] 3507] 3578] 3598] 3667] 3682] 3871] 3891] 3945]
3946] 4078] 4099] 4735] 4787] 4788] 4834] 4869] 4911] 4933] 4999] 5018] 5019]
5020] 5023] 5068] 5069] 5116] 5130] 5144] 5163] 5171] 5258] 5503] 5675] 5869]
5962] 6126] 6206] 6625] 6948] 6976] 7358] 7567] 7838] 7942]
There are   98 matched pairs of source codes.  1107 data points in file 1
 have points at the same location plus  42 extra matches in file 2.
Printout is in a file named COMPARE2.PNT, which has  134 lines.
```

Note that the first four digits for names in file **lv.isn** generally are variable. For plotting and purposes of recognition, letters were substituted for 4-digit DMA source numbers. Therefore, the following summary shows the equivalence of names (Plouff, 1996, table 2) and observed-gravity datum shifts that were derived after processing file **INSIDEDAT.SRT**. Letters L and E were added to prefixes to denote that locations and elevations,respectively, were changed from the original data points.

[*PRINT FILE COMPARE2.PNT*]

```
10-Mar-98 09:09:50
COMPARE2. Plouff,3-98.                    [REPEATS ABOVE THROUGH "copied data."]
You selected a tolerance of  0.03 minutes.
File 1: lv.isn           [SEE ABOVE LIST OF 4-DIGIT CODES]
A list of paired source codes follows.  The list includes the     [ABBREVIATED]
 number of occurrences, the average difference of elevations in feet, the
 the standard deviation of the elevation difference, the average difference
 of observed gravity in milligals, and the standard deviation in milligals.
CODE1 CODE2 NUMBER EL2-EL1 STD DEV  OG2-OG1 STD DEV
   CG  4999     19     0.0     0.1    -0.20    0.00
  CGH  4999      9     0.0     0.0    -0.20    0.00
    R  5503    438    -0.1     0.2     0.90    0.00
    G  2179     36     0.0     0.0     0.00    0.00
    K  5116     24     0.0     0.0     0.10    0.00
    Q  5130     15    -0.1     0.4     0.10    0.00
    H  5144     24     0.0     0.0     0.00    0.00
 L  H  5144      4     0.0     0.1     0.04    0.09
    X  5163     16     0.0     0.0     0.00    0.00
       5869    209     0.0     0.0     1.00    0.00
 L     4834      4     0.0     0.0     0.00    0.00
    S  2179      9     1.1     2.5     0.55    1.07
    S  2235     27     0.0     0.0    -0.35    0.00
    S  4834     32     0.0     0.2     0.00    0.00
    S  4999      3     0.0     0.0    -0.20    0.19
    S  5116      3   -16.7    28.9     2.81    4.43
    S  5130      2     0.0     0.0     0.44    0.32
    S  5144      6     0.0     0.0     0.10    0.24
 L  S  2179      5     0.0     0.0     0.14    0.10
 L  S  2235      6     0.0     0.0    -0.35    0.00
 L  S  5116      3     0.0     0.0     0.18    0.02
 L  S  5130      1     0.0     0.0     0.05    0.00
   DB  5018      9     0.0     0.0     0.00    0.00
   ge  5019     37     0.0     0.0     0.00    0.00
   FR  5020      6     0.0     0.0     0.00    0.01
    P  7838     26     0.0     0.2     0.00    0.00
 Q  P  7838      1     0.3     0.0     0.00    0.00
 EL S  2179      2     0.0     0.0     0.23    0.06
 EL S  2235      1     8.0     0.0    -0.35    0.00
There are   98 matched pairs of source codes.  1107 data points in file 1
 have points at the same location plus  42 extra matches in file 2.
```

PROGRAM REDUNDEL

Program **redundel.f** extracts from one file only data points that are needed to fill gaps in a second file. Observed-gravity datum shifts for the extracted data points, if needed, are determined by application of program **compare2.f**, for example. If the extracted points are added to the second file, the combination can be plotted with program **invent.pf** to show the true density of the combined coverage before further processing.

```
redundel                                                           [CALL PROGRAM]
 REDUNDEL, Plouff.  Deletes stations in a newly acquired file that are too
  close to stations in a reliable file (both plouff format).
 TYPE the name of your reliable file:                              all96.isn
 TYPE the name of your new file:                                   INSIDEDAT.SRT
 The test is based on closeness of geographic coordinates.
 TYPE the redundancy distance in minutes (geographic) (first try 0.0):  0.05
 TYPE the name of a file for stations from the new file that are not
  too close to stations in the old file:                           inside05.unq
 Do you also want to create a file of stations that were discarded?n
 There are  7075 stations in the old file.
  5379 redundant stations in new file of  7991 stations.
 There are 2612 remaining new stations for further redundancy testing in file:
     inside05.unq
 Your print file from this session is REDUNDEL.PNT.
```

[*PRINT FILE REDUNDEL.PNT*]

```
 REDUNDEL.  6-Mar-98 10:54:34
 Program to delete stations with locations in a new file:     INSIDEDAT.SRT
  that nearly coincide with presumed reliable stations in an old file:
     all96.isn
 Stations from the new file that are not redundant are stored in file:
  inside05.unq
 Geographic offset= 0.05 minute.
 There are  7075 stations in the old file.
  5379 redundant stations in new file of  7991 stations.
 There are 2612 remaining new stations for further redundancy testing in file:
     inside05.unq
```

APPENDIX 11

DISPLAYING A GEOGRAPHIC-BASED INVENTORY OF DATA

The following execution of **inventpf.f** was used to show gravity data coverage in a study area (fig. 7; Plouff, 1996, fig. 2). Output file **inventall.** later was edited in a word processor to insert selected bold numbers at data points without map validation (no accuracy code), a caption, and degree symbols. Locations without map validation were found by overlaying an **inventpf** plot with only those data points without accuracy codes.

```
 inventpf                                                          [CALL PROGRAM]
 INVENTPF.  Plouff, 4-94. Program to show regional gravity data coverage by
  printing the number of data points in 2.5-minute cells.
 TYPE the name of your data file (plouff format):                  all96.isn
 TYPE a name for a print file:                                     inventall.
   7075 stations are in the input file.
   Latitudes range from  39D 29.01M to  42D  8.00M
  Longitudes range from 116D 51.03M to 120D 25.84M
   7075 data points in the map.  Cells include south and east edges.
```

[*FIRST 10 LINES OF FILE INVENTALL., WITH RIGHT EDGE TRUNCATED*]

```
 INVENTPF.  Plouff, 4-94. Program to show regional gravity data coverage by
  printing the number of data points in 2.5-minute cells.
 Input file: all96.isn
   7075 stations are in the input file.
   Latitudes range from  39D 29.01M to  42D  8.00M
  Longitudes range from 116D 51.03M to 120D 25.84M
 Map covers 39D 27.5M to 42D 10.0M lat and 116D 50.0M to 120D 27.5M long
 Numbers and letters are the number of data points in a cell (no I, O; Z>32).
           120                        119                        118
            | 111              1   1 | 1       1 1        2 1 |   1     1   1
```

[*LAST 10 LINES OF FILE INVENTALL., WITH RIGHT EDGE TRUNCATED*]

```
            |            1 341141  11| 211 2      1  2 3  2543|4 1
                     |
            |               15151 112|334  3  2  12  312 121  |
            |             11442 5 21 |21221323  1222 1721     |
            |            111435161  2|2111211111 2242         |
            |             13233452311|2 2113 14211            |
            |               1 2443834|12 3 2 11               |
            |                11331184|3133                    |
            |                2 1 1 31|                        |
   7075 data points in the map.  Cells include south and east edges.
```

APPENDIX 12

PLOTTING DATA IN CALIFORNIA AND NEVADA

Program **calnevhp.for** was designed for 80-column punchcard batch processing, in which the program includes the boundaries of California and Nevada as block data, and the data file includes parameters to define the map and and the data to be plotted. The first application of the program was to plot data separated into one to four sheets—depending on map scale and paper size—that overlay maps of California (unpublished program in National Center for Earthquake Research library ,1970). Later applications were to prepare index maps for studies in California and Nevada (fig. 8). Inasmuch as the interactive mode is easier for users compared to a rigidly defined format for parameters, many borders are now available in data bases, and other programs provide choices of map projections, portions of the borders, and publication-quality formats, this progam is superseded. The source code, including numerous comments and print statements to explain the roles of parameters and plot strategy, however, is included in this report to document key parameters needed to obtain a computer-drawn map.

As indicated by the following record of UNIX compilation, program **calnevhp.for** requires changes before the program can be successfully compiled.

f77 calnevhp.for -o calnevhp -lV77

```
 MAIN:  line 46: Warning: ignoring unimplemented "readonly" specifier
        line 46: Warning: ignoring unimplemented "shared" specifier
 pts:   line 339: Warning: ignoring unimplemented: %REF() with CHARACTER argument
 cline; calc; constn; outlin; pbnd; param; calif; extrem; spotc
ld: Undefined symbols [subroutines]:    _symbol_    _plot_    _number_    _plots_
Compilation failed
```

[*DETAILS OF COMPILATION WARNINGS*]

```
    46        open (unit=15,file=infile,form='formatted',status='old',
    47       1 blank='zero',readonly,shared)
                            ^        ^
```

```
    49        READ (15,100) IREAD,XGAP,ZPAPR,ZPINC,XFACT,YFACT,IFVERS,NOTEN,IW
**** WARNING:  variable "ifvers" set but never referenced
   109      6 READ (IFAKE,IFMT,ERR=99) DENT(N),YDEG,XDEG,ISYM(N)
**** ERROR:  array "ifmt" referenced as format but set as integer*4 in
                 line #71
   131        CALL PLOTS (0,0,0)
**** WARNING:  undefined subprogram "plots"
   143     11 if (noten .ne. 0) go to 13
**** WARNING:  label "11" declared but never used
   146        CALL PLOT(XP,0.2,3)
**** WARNING:  undefined subprogram "plot"
   185        SUBROUTINE PTS(N,LTS,LTN,LNE,LNW,I,ZHT,XRIGHT,ZSIZE,IFPOST)
**** WARNING:  variable "xright" declared but never used
   279        CALL NUMBER(XP,YP,ZHT,YS,ZROT,-1)
**** WARNING:  undefined subprogram "number"
   339     12 CALL SYMBOL(XP,YP,ZSIZE,%REF(DENT(L)),ZROT,8)
**** WARNING:  undefined subprogram "symbol"
   339     12 CALL SYMBOL(XP,YP,ZSIZE,%REF(DENT(L)),ZROT,8)
**** WARNING:  ignoring unimplemented feature: %REF() with CHARACTER argument
   367        SUBROUTINE CLINE(I,MPTS,ZSTH,ZNTH,ZEAST,ZWEST,XRIGHT)
**** WARNING:  variable "i" declared but never used
**** WARNING:  variable "xright" declared but never used
   446        DATA X1/39000,
   447       *        23698,39022,23690,39129,23717,39202,23767,39355,23819,
                5
                ^
**** WARNING:  the symbols after 72 column are ignored
   826        CALL SPOTC(0.0,0.1,0.0,JPLUS,0.0,0.0,0.05)
**** WARNING:  possible argument #2 in "spotc" call is modified
**** WARNING:  possible argument #3 in "spotc" call is modified
**** WARNING:  possible argument #5 in "spotc" call is modified
                 See: line #917
   854        DATA X,Y,XMAX,XMIN/4*0.0/
**** WARNING:  variable "x" set but never referenced
Lines: 952; Commons: 7; Routines: 11 (MAIN: 1; Subroutines: 10)
Messages: 21 (Errors: 1; Warnings: 20)
```

APPENDIX 13

PLOTTING DATA TO SUPERIMPOSE ON PUBLISHED MAPS

Program **staelplt.f** outputs a PostScript plot of data points with associated station names and elevations or gravity anomalies (fig. 9). The most common application is to plot selected data points at a scale of 1:24,000 with a gridmark interval of 2.5 minutes so that locations and elevations can be verified on or transferred to topographic maps. In contrast to digitizing sets of newly established field data, templates can be used to obtain revised geographic coordinates for a few data points. Note that temporarily shortening station names by deleting common prefixes and plotting station names at an angle or 45 degrees along east-west profiles of closely-spaced data points minimizes overlap of names.

staelplt [*CALL PROGRAM*]

```
 STAELPLT. Plouff, 8-95. Plot station names and elevations or anomaly 2 on
  topo maps.  Input data are in plouff format.  Default maps 7-1/2-minutes
  at scale of 1:24,000.  Map file names based on 15-minute naming convention
  (A-D south to north within a 1- by 2-degree quadrangle and 1-8 east to the
  west and NE-NW-SE-SW for 7.5 minutes) are suggested.
 Responses of y, Y, or a carriage return signify yes.
 TYPE the name of your input file (plouff format):                vya95isn.
 Do you want to plot station elevations (not CB2)?                     y
 Map plots must be with the transverse mercator or polyconic projection.
 Is your projection the common 'UTM' (transverse mercator)?            y
 1549 stations in input file.
```

```
Is this a conventional 1:24,000 map?                                       n
Is this a conventional 1:62,500 map?                                       n
TYPE the reciprocal of the map scale (INTEGER without commas) (e.g. 50000): 48000
TYPE the tickmark interval (INTEGER minutes, seconds) (e.g. 2 30):         1 0
TYPE the east-west map width (INTEGER minutes, seconds) (e.g. 7 30):       4 0
Is the north-south map width the same as the east-west?                    y
The southwest corner must be typed with INTEGERS (degrees/minutes/seconds)
 separated by blank spaces.
TYPE 999 for degrees to correct an earlier mistake.
TYPE the south edge of map (3 INTEGERS):                             41 8 0
TYPE west edge of map (3 INTEGERS):                                  118 12 0
A response to the following question provides several functions:
 [y] default--horizontal; numbers [1] to [8]--plot at 10 to 80 degrees SE;
 [-]--do not plot station names; [=]--only plot locations;
 [others]--plot at 45 degrees SE.
Horizontal station names OKAY?                                             4
Station names are plotted at 40 degrees.
Are elevations on this map expressed in feet (no=meters)?                  n
An appropriate plot file name for your map is A1.
Is this name acceptable?                                                   n
TYPE a plot file name for this map (<21 cols):                      va1nwse.ps
PostScript-2 printers require a BoundingBox specification.  The default
 size is 8.5 by 11 inches.  Others will be 11 by 17 inches (-tabloid).  The
 BoundingBox line number 2 in the output file can be edited to yield a size
 larger than 11 by 17 (1 inch = 72 points).
Is the size east 8.5 by north 11 inches okay?                              y
  11 stations on map.
Do you want to plot more maps?          [FROM THE SAME INPUT FILE]         n
   1 map files were written.
```

The "ORIGIN" in the lower left corner of figure 9 remains from an earlier pen-plot version of the program, which used this point to set the mechanical pen origin and to align the south edge of the plot with the plotter y=0 axis. The "REPEAT POINT" remains from an earlier pen-plot version of the program, in which paper slippage during plotting would cause the plus sign not to superimpose as a bullseye on the square. Page-centering, the scale (appencix 4), and the figure caption were added to the ASCII PostScript file later. Inasmuch as system date and time builtin subroutines were used, compilation of the program required a Sun FORTRAN-77 compiler option designated as "-lV77" for compatibility with the VAX/VMS FORTRAN language (Digtal Equipment Corporation). If that option is not available, calls to the date and time functions must be modified or deleted.

APPENDIX 14

USING GEOGRAPHIC-BASED MAP NAMES TO MODIFY DATA

After an initial gravity data set is prepared, further refinements are made. These refinements include substituting closein gravity terrain corrections (TCs), which are not accurately computed by digital terrain models digitized at a scale of 1:250,000 (Godson and Plouff, 1988), into the data set. Another refinement is to insert an accuracy code into the data set, which was not already inserted as part of a field survey, for each data point. Insertion is easiest to accomplish by first pencilling accuracy codes and values of easily estimated TCs near data point locations on 7.5-minute maps and then transferring the values into auxiliary data files in response to prompting without typing data point identifications ("station names").

The foundation of the method is to use program **mapindex.f** to create a file of lines that consist of a 4-digit map name followed by an 8-digit unique "station name." The 4-digit 7.5-minute map name is the system described in the section "Map Labeling Conventions," which is based on elements of one- by two-degree quadrangles. A more universal system based on one-degree squares with 7.5-minute map names of seven or less digits could easily be implemented. For example, the the name of the map Vya "A1SE" to be updated later would be replaced by the name "41118A1." Typed responses in the followint computer sessions are in bold print. Additional comments not in the original session are bracketed in italics.

PROGRAM PULLRING

Program **pullring.f** first was run to extract data points in the Vya quadrangle, which are not yet corrected for the gravity effect of nearby terrain. In the following session, the letter "Z" in column 63 of plouff format denotes inner TCs estimated only a coarse computer grid of 15 seconds (about 460 m along the latitude component of distance). Letters "F," "S," and "U" denote three distances, to which hand terrain corrections already were done. In other systems, no symbol in column 63 or zero in the position of inner gravity terrain correction could denote that an inner gravity terrain correction has not been done.

```
pullring
 Previous print file PULLRING.PNT will be overwritten.
 Plouff, PULLRING, 1-96.  Program creates separate files for stations with
  the same TC ring code within a plouff input file.
 Output file names will have the one-digit ring code as a suffix after a
  9-digit prefix (before decimal point) permitted for plouff input file name.
 TYPE the name of your plouff file:      vya.isn    [VYA 1° BY 2° QUADRANGLE]
 A total of 1549 input lines were read.
    0 lines had no TC code but file output.
   19 stations with ring code F are in file vya.F
 1016 stations with ring code S are in file vya.S
  512 stations with ring code Z are in file vya.Z                 [DESIRED SET]
    2 stations with ring code U are in file vya.U
 A record of this session is printed in file PULLRING.PNT
```

PROGRAM MAPINDEX

The following session creates a file that consists of lines with map names followed by a station mame for each data point. Sorting the output file organizes the data to be corrected in the order of 7.5-minute map names and, secondarily, station manes.

```
mapindex
 MAPINDEX, Plouff. Program to list in file MAPINDEX.PNT standard map names
  for gravity data in plouff format.  MAPINDEX.PNT presumably will be sorted
  by map name in a 1- by 2-degree quadrangle.
 DO you want an explanation of how map names are created?                  [y]
 Map names follow the style of 1:250,000 quads in Alaska (but 1x2D):
  First digit is A, B, C, or D for rows of 15-minute maps from south to north.
  Second digit is numbers 1 to 8 for columns of maps from east to west.
  For 7-1/2-minute maps, append NE, NW, SE, or SW.
 Stations along N or S edges of interior maps will be listed with the
  adjacent map.
 You can avoid printing data outside the desired quadrangle by first
  using program PULLRECT to select data.
 TYPE the name of your data file in plouff-format:                          vya.Z
 There is an option to read pairs of stations from program REDUND.
 Are there pairs of redundant stations in this file?                        n
 TYPE latitude (integer degrees) of south edge of the 1- by 2-degree sheet:   41
 TYPE longitude (integer degrees) of east edge of the sheet:                118
     512 input lines were read.
     512 stations are inside the quadrangle.
 To sort the output by map name, for example, TYPE:
     sort MAPINDEX.PNT -o MAPINDEX.SRT
sort  MAPINDEX.PNT  -o  vyazmap.srt
                      [PRINT OF FIRST 5 LINES OF FILE vyazmap]
   MAP  STATION LATITUDE LONGITUDE  ELEV
   MAP  STATION LATITUDE LONGITUDE  ELEV       [SORTING MOVES THIS LINE TO TOP]
  A1NE    WN 37 41 13.97 118  7.04  4169.0
  A1NE    WN 38 41 14.87 118  6.64  4159.1
  A1NE    WN112 41 14.85 118  1.58  4885.2
```

[*PRINT OF LAST 5 LINES OF FILE* vyazmap]

```
  D4SW    M1-13 41 47.03 118 52.56  4938.0
  D4SW    M1-15 41 46.96 118 52.98  5152.0
  D4SW    M1-17 41 46.94 118 53.43  5152.0
  D4SW    M1-18 41 46.83 118 53.84  5221.0
  Input file=vya.Z
```

PROGRAM CNTMAPS

Locations of data to be terrain corrected (file **vya.Z**) can be displayed with program **inventpf.f** (appendix 11). Program **cntmaps.f** lists the maps without inner TCs and the number of data points without inner TCs on each map, for example, in file **MAPINDEX.PNT**. Therefore, temporarily the user should not delete file **MAPINDEX.PNT** after sorting if this list is wanted.

```
cntmaps
 CNTMAPS, Plouff. 11-94.  Lists names of maps and number of occurrences in
  a file output from MAPINDEX (not pairs option).
 There are  49 unique map names.
 The input file has   3 lines without map names from a total of 515 lines.
 TYPE: sort CNTMAPS.PNT -o CNTMAPS.SRT
 if you want to create a file CNTMAPS.SRT that is sorted by map name.
phoenix% wc -l CNTMAPS.PNT
      51 CNTMAPS.PNT
sort  CNTMAPS.PNT  -o  VYAMAPS.SRT
```

[*PRINT OF FILE* VYAMAPS.SRT]

[*SEPARATE LINES WITH MAP NAMES AND NUMBERS ARE CONSOLIDATED HERE TO 7 PER LINE*]

```
      File CNTMAPS.* with map names and numbers of data points.
  Input file=vy.Z
 A1NE  15   A1NW  24   A1SE   5   A1SW  13   A2NE  14   A2NW   1   A2SE  15
 A2SW   1   A3NE   2   A3NW   1   A3SW   2   A5NE  21   A5NW   4   A5SE  53
 A5SW  10   A7SE   1   A8SE  10   B1NE  31   B1NW   8   B1SE  14   B1SW   3
 B2NE   7   B2NW   3   B2SE   4   B2SW   2   B3NE   2   B3NW   2   B3SW   2
 B4NE   9   B4SE  36   B4SW   3   B5NE   2   B5NW  17   B5SW  50   B7SW   1
 B8SW   1   C1NE   1   C1SE  14   C1SW   1   C2NE   5   C2SE   1   C2SW   4
 D3NE   6   D3NW  47   D3SE   2   D3SW   3   D4NE   2   D4SE  30   D4SW   7
```

PROGRAM MAPSTAS

After accuracy codes or inner TCs are obtained, the values can be copied from the map to a list of station names created by program **mapstas.f**, in preparation for prompting by program **prephtc.f**.

```
mapstas
 MAPSTAS, Plouff.  Program to list station names grouped by map.
 First run program MAPINDEX with a plouff file and sort the output.
 TYPE the name of your sorted file:                              vyazmap.srt
   512 stations are in the file.
 The name of your print file is MAPSTAS.PNT
```

[*PRINT OF FIRST 9 LINES OF FILE* MAPSTAS.PNT]

```
 MAPSTAS, Plouff.  Program to list station names grouped by map.
 First run program MAPINDEX with a plouff file and sort the output.
 List of stations from file:
    vyazmap.srt
 **   15 stations in map A1NE:
    WN 37    WN 38    WN112    WN116    WN131    WN132    WN133    WN134
    WN135    WN136    WN137    WN138    WN139    WN140    WN141
 **   24 stations in map A1NW:
    WN 26    WN 27    WN 28    WN 29    WN 30    WN 31    WN 32    WN 33
```

[*PRINT OF LAST 10 LINES OF FILE* MAPSTAS.PNT]

```
 **    2 stations in map D4NE:
    A28      A29
 **   30 stations in map D4SE:
    A30      A31      A32      A33      M1-11    M1-3     M1-5     M1-7
    M2-01    M2-03    M2-05    M2-07    M2-09    M2-10    M2-11    M2-12
    M2-13    M2-16    M2145    M3-01    M3-03    M3-05    M3-07    M3-09
    M3-11    M3-13    M3-15    M316+ L  A34   L  M1-9
 **    7 stations in map D4SW:
    A39      A44      A48      M1-13    M1-15    M1-17    M1-18
   512 stations are in the file.
```

New accuracy codes or terrain corrections are handwritten on a print of the above list.

PROGRAM PREPHTC

Program **prephtc.f** prompts for inner terrain corrections to be inserted in a file for selected data points. The units are hundredths of milligals.

```
prephtc
 Plouff, 11-94, PREPHTC.  Interactively  prepares a file of station names
  and associated hand TC's for input into program ADDTC, which updates plouff
  file.  The input into this program is the (sorted) output from program
  MAPINDEX.  You could either type TC's directly from a map or refer to a
  list, for example, superimposed on output from program MAPSTAS.
 You already have file PREPHTC.PNT that records this program.
 DO YOU WANT TO STOP TO SAVE THE FILE?                                     n
 TYPE the name of the output file from MAPINDEX:                 vyazmap.srt
 TYPE a name for an output file of TC's to be submitted to the ADDTC program:
vyamarch.tcs
 Type TC's in response to a prompt of a map name followed by station name.
 Typing a zero means to skip that station.  Typing a negative number means
   to select following options to stop or to skip ahead:
  1--Skip to a station name to be typed
  2--Skip to next map after this one
  3--Skip to next map name to be typed
  4--Stop process (can append later)
 Type hand TC's in units of 0.01 mGal without a decimal point.
    WN 37 (A1NE):       -1
 TYPE 1 (next sta #), 2 (go to next map), 3 (skip to later map), or 4 (stop): 2
    WN 26 (A1NW):       A1SE
 You typed something that was not an integer number.  Try again.
    WN 26 (A1NW):       -1
 TYPE 1 (next sta #), 2 (go to next map), 3 (skip to later map), or 4 (stop): 3
 TYPE next 4-digit map name you want to skip to:                           A1SE
    WN 71 (A1SE):  5
    WN 72 (A1SE):  3
    WN 73 (A1SE):  0    [TC NOT ESTIMATED OR NEEDS TO BE DONE BY OTHER METHODS]
    WN 74 (A1SE):  2
    WN 75 (A1SE):  8
    WN 70 (A1SW):  -1

 TYPE 1 (next sta #), 2 (go to next map), 3 (skip to later map), or 4 (stop): 4
 A total of   4 stations were provided TC's in file:   vyamarch.tcs
 Print file PREPHTC.PNT to see a record of the updated stations.
 To optimize merging with plouff file, sort PREPHTC output files.
```

[*PRINT OF FILE* PREPHTC.PNT]

```
 Plouff, 11-94, PREPHTC.  Interactively  prepares a file of station names
  and associated hand TC's for input into program ADDTC, which updates plouff
  file.  The input into this program is the (sorted) output from program
  MAPINDEX.  You could either type TC's directly from a map or refer to a
  list, for example, superimposed on output from program MAPSTAS.
```

```
 Your MAPINDEX file for input is:             vyazmap.srt
 Your output file of estimated TC's is:      vyamarch.tcs
 ***You stopped input after map A1SW, station    WN 70
 A total of   4 stations were provided TC's in file:  vyamarch.tcs
  STATION HTC  STATION HTC  STATION HTC  STATION HTC  STATION HTC  STATION HTC
    WN 71   5    WN 72   3    WN 74   2    WN 75   8

                 [PRINT OF FILE VYAMARCH.TCS; UNITS, 0.01 MILLIGAL]
   WN 71   5
   WN 72   3
   WN 74   2
   WN 75   8
```

PROGRAM SUBSTUTE

The following session for program **substute.f** creates a new master file, **vyanull.isn**, for the Vya quadrangle, in which null-data positions are held for four data points that are to be upgraded, and creates a file, **vtcin.**, into which will be substituted new terrain corrections from file **vyamarch.tcs**. If duplicate station names occur in the master file **vya.isn** or auxiliary file **vyamarch.tcs**, execution stops.

```
substute
 SUBSTUT, Plouff, 1-95.  Delete, replace, or nullify stations in plouff-
 format files with a search based on a match of unique station names.
 TYPE the name of the plouff file to be modified:                vya.isn
 Are data points to be replaced in the input file?               n
 Are stations to be deleted from the input file?                 n
 Therefore, the positions of the matched station names in the input file will
  be retained, but coordinates will be reset to zero (nullified).
 A supplementary file supplies station names or new data points.
 TYPE the name of the supplementary file:                        vyamarch.tcs
 TYPE the name of a revised file to be created:                  vyanull.isn
 TYPE the name of the file [.lft] to store unmatched data points from the
  supplementary file:                                            left.tcs
 Do you want to create a file for data points that were deleted, replaced,
  or nullified?                                                  y
 TYPE the name of that [.del] file:                              vtcin.
     4 stations in the supplementary file.
 1549 stations in input file.
    0 stations were deleted and    4 were replaced or nullified.

                                            [PRINT OF FILE vtcin.]
   WN 71 41 129 118 700 433337984918G633  -360 62493    0   63Z-15207   350WNBAS
   WN 72 41  96 118 605 465727983837G654  1653 62493    0  185Z-14182  1390WNBAS
   WN 74 41 227 118 399 456697984793C764  1565 62493    0   44Z-14102  1500WNBAS
   WN 75 41 217 118 612 430777985605C764   -45 62493    0   43Z-14824   745WNBAS

                            [PARTIAL LIST OF DATA POINTS IN FILE vyanull.isn]
   WN 70 41  23 118 848 420607985308G534 -1008 62493    0   49Z-15433   108WNBAS
   WN 71                                    [POSITION IS HELD FOR LATER SUBSTITUTION]
   WN 72
   WN 73 41 306 118 480 435047986002C754   621 62493    0   17Z-14331  1261WNBAS
   WN 74
   WN 75
   WN 76 41 161 118 815 417987984970G524 -1798 62493    0   17Z-16166  -627WNBAS
```

After the terrain corrections in file **vyamarch.tcs** are substituted for the zeroes in file **vtcin.** and their associated ring code is substituted for "Z," the data are re-processed through a digital terrain correction program and an isostatic reduction program to obtain new total terrain corrections and anomalies to be inserted into files **vyanull.isn** and the larger data base, **all96.isn**.