FORTRAN Program of Preparing Contour Maps for Geologic Use

by

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Abstract

A computer program was designed for preparing contour maps by the "Polyhedron Method". The program was written in FORTRAN for FACOM 230-60/75 by utilizing CALCOMP X-Y plotter Model 770/763. It can be easily modified for other computers which have more than 41 K words (or 164 K bites) of core memory.

The procedure of automatic contouring and the operating instructions of the program are described, and several test examples for geologic use are presented. The source list of the program is also carried in the appendix.

Introduction

A contour map is one of the most common ways of displaying geological quantitative areal data. Many mapping procedures (Bishop, 1960 for example) and their applications have been developed. They are isopachous maps (Merriam, 1955; Krumbein, 1962; Kanto Loam Research Group, 1965), isolith maps (Krumbein, 1962) and trend-surface maps (Krumbein, 1962; Merriam and Harbough, 1964; Schramm, 1968) in stratigraphy, and structure contour maps (Merriam, 1955; Kakimi et al., 1973; Robinson and Charlesworth, 1969) and beta diagrams (Robinson, 1963; Noble and Eberly, 1964) in structural geology, for example. Besides, contour maps are generally used in display of many geophysical data, e.g. magnetic and gravitational ones.

However, it consumes time and cost to prepare contour maps by hand method. The quality of contour maps, when they are prepared by hand method, depends on an operator's technique and on his interpretation of data to be mapped. For the reasons mentioned above, most maps have been prepared only for data required specially to be displayed in contour maps, and they are nothing more than the illustrative maps. Consequently, not a few informations from collected data have been left to be used.

The computer has enabled to prepare standardized contour maps inexpensively and promptly, and the several procedures have been developed for computer contouring (HARBough and MERRIAM, 1968, p. 32; COTTAFAVA and MORI, 1969;
There are two kinds of output media for contour maps which can be prepared by a computer; the one is a lineprinter and the other an X–Y plotter or drafter. A contour map made by a lineprinter is shown as a characters pattern in which the same characters are printed on the places where the values fall within the same ranges (YAMAMOTO, 1973). Therefore, it requires either raw or processed data regularly and densely spaced. Although it easily and promptly makes a contour map, it can not make any accurate one. It may be suitable for mapping functional surfaces. On the other hand, an X–Y plotter or a drafter has an advantage in that they can make much more precise and detailed ones. Besides, it can make a contour map directly even from irregularly spaced data.

The present program was designed for plotting a contour map by using an X–Y plotter in order to make the map from data irregularly spaced as well as from regularly spaced ones. It includes many options for geologic use.

The basic principle used in the program is the “Polyhedron method” described by HARBOUGH and MERRIAM (1968). The permission for using the principle is given from one of the authors (D. F. MERRIAM).

The program was made as one of the developing programs of Data Processing Center, Kyoto University (PROBLEM NO. 5001EY044 and 5001DY045). Any one who uses the program is required to have the permission from the present authors or Data Processing Center, Kyoto University.

Acknowledgement

The authors wish to thank Prof. Dr. Keiji Nakazawa of this Institute for encouraging them during the study. They are indebted to Prof. Dr. Daniel F. Merriam of Syracuse University for readily permitting them to use the contouring principle. The manuscript has benefited from the critical review of Dr. Shinjiro Mizutani of Nagoya University, whom they thank for his comments. The authors also wish to thank Mr. Kenichi Harada of this Institute for his help to prepare the manuscript, and the staffs of Data Processing Center, Kyoto University for their helps in programming and computation.

General Description of Program

This program produces a contour map from regularly or irregularly spaced data by using an X–Y plotter. The arrangement of a map on a plotting paper is shown in Fig. 1. This program is written in FACOM 230–60/75 FORTRAN (Fujitsu, 1970) which corresponds to IBM 360 FORTRAN IV (GERMAIN, 1967) using FACOM 230–60/75 SSL (Scientific Subroutine Library; FJITU, 1972) and CALCOMP routines (Yoshizawa Business Machines, 1969a and 1969b), and requires about
41K words (or 164 K bites) of core memory and 75 cm (29.5 inches) plotter. Many options are provided for geologic uses; input data selection, insertion of geographic data as a referring map and so forth (see b. Input options and c. Processing options).

a. Contouring procedure

By assuming that a surface to be mapped is represented as a polyhedron surface of triangular elements (named faces) each of which is defined by its peak points in a three dimensional space (Fig. 2), contour lines in a triangular element can be contoured.

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Fig. 1. Arrangement of output map on the plotting sheet. The contour map is drawn in the frame of broken line. The unit of length is expressed in cm.

Fig. 2. Tetrahedron model illustrating the contouring procedure. The tetrahedron is constructed by triangular faces. Broken lines are contours.
obtained by interpolation as shown in Fig. 3 (Harbough and Merriam, 1968, p.34). Conjunction of contour lines for all the elements yields a contour map of the surface to be mapped.

In this program, faces are automatically defined even if face definition is not directly given as input.

b. Input options

The following three kinds of data can be read as input:

1. Irregularly spaced data with face definition
2. Irregularly spaced data without face definition

A specified area to be mapped is derived into rectangular grid units, and the units are sequentially numbered. The value at a given grid point (named the grid value) is computed by approximation of the observations in the specified area. Observations in hatched area are used to estimate the grid value at point P. The area should be specified as input using the number of units. In this case, the number is 2.
number of units around the grid point (Fig. 4). As a result, regularly spaced data are completed (see to Harbough and Merriam, 1968, p. 35). (The more number of units are specified as the area in which observations are, the map will be more smoothed.) Then each unit is subdivided into two triangular elements (faces), and the elements are automatically defined by using grid point numbers given before.

(3) Regularly spaced data

This kind of data should be grid data regularly spaced as mentioned above. The units formed by grids are subdivided into triangular elements, and they are automatically defined as in (2).

c. Processing options

The following three kinds of processings can be optionally performed:

(1) Insertion of referring point(s), line(s) and/or map scale.
(2) Plotting of data points with their numbers and values.
(3) Specification of blank unit(s), i.e., rectangular one(s), in which no contours are to be drawn; valid in the input cases of b-(2) and b-(3).

d. Input medium

Cards and an alternative tape can be used an input medium for source data input.

e. Limitations

(1) # of peaks, NOP \leq 1000.
(2) # of faces, NOF \leq 2000.
(3) # of rectangular units, NNN \leq 1000.
(4) # of referring points, NUMBER \leq 100.
(5) # of referring lines, NLINE \leq 10.
(6) # of control points on a referring line, 3 \leq NPFOLN \leq 100
(7) Others: refer to Input Instructions.
(8) Map size: width (x-direction) and length (y-direction) are less than 68 cm and 88 cm respectively in the case of using Data Processing center, Kyoto University (refer to Fig. 1 for the map arrangement and to Fig. 7 for the coordinate system).

f. Output

(1) List of processing specifications
(2) Input
(3) Tracing informations of processing
(4) Error messages
(5) Contour map

g. Error treatment

Error checks are carried out on the following items, and error meassages are printed out, if any errors are detected:
(1) Kind of input data:
If any code other than FDEF, SMTH, REGS are detected, the processing will be stopped with a message “ILLEGAL DATA KIND” (refer to Input Instructions-B-c).

(2) Computed results of grid values:
If a grid value is not normally obtained, a message “GAUELS ERROR, APPROXIMATING PLANE WAS NOT DETERMINED” will be printed out, and any contours will not be drawn in all the units concerned with the grid point.

(3) Specification of blank unit(s):
If any illegal specification is detected, the processing is stopped with a message “BLANK AREAS DEFINITION ERROR” (refer to Input Instructions-B-(g.)).

(4) Repetition times number of main repeating operations:
Amount checks are carried out on the items in Tab. 1. If an amount exceeds its limitation, it will be printed out in the form “**ERROR** CONTROL VALUE IS ILLEGAL........” and the processing will be stopped.

(5) # of contour lines:
If contour lines are to be too densely drawn in a triangular element, the lines which exceed the limitation (100 lines) will not be drawn, and a message “LINES TO BE DRAWN OVER 100” will be printed out.

**Processing Procedure**

The processing is performed according to the following flow of steps (Fig. 5, Process flow chart).

**Step 1.** Data and task specifications are read as input from cards.

The program control proceeds to step 2, 3, or 4 according to the kind of source data; to Step 2, when they consist of peak and face definition data, to Step 3, when only peak ones, and to Step 4, when regularly

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**Tab. 1. Check list of main iteration numbers.**

<table>
<thead>
<tr>
<th>#</th>
<th>Code</th>
<th>Limitation</th>
<th>Test Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MAP$^a$</td>
<td>10</td>
<td># of sets of regularly spaced data in a tape</td>
</tr>
<tr>
<td>2</td>
<td>MAXX</td>
<td>200</td>
<td># of grids in x-direction</td>
</tr>
<tr>
<td>3</td>
<td>MAXY</td>
<td>200</td>
<td># of grids in y-direction</td>
</tr>
<tr>
<td>4</td>
<td>NOP</td>
<td>1000</td>
<td># of peaks</td>
</tr>
<tr>
<td>5</td>
<td>NOF</td>
<td>2000</td>
<td># of faces</td>
</tr>
<tr>
<td>11</td>
<td>RPO$^a$</td>
<td>100</td>
<td># of referring points</td>
</tr>
<tr>
<td>12</td>
<td>PLN$^a$</td>
<td>10</td>
<td># of referring lines</td>
</tr>
<tr>
<td>13</td>
<td>RLP$^a$</td>
<td>100</td>
<td># of control points on a referring line</td>
</tr>
<tr>
<td>14</td>
<td>MARK</td>
<td>200</td>
<td># of marks on a map scale</td>
</tr>
</tbody>
</table>
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Fig. 5. Process flow-chart of program.
spaced ones.

Step 2. After input of peak and face data, it proceeds to Step 7.
Step 3. Peak data are read as input. After completion of grid values, it proceeds Step 5.
Step 4. Regularly spaced data are read as input.
Step 5. Triangle definition is performed.
Step 6. (Optional) Blank unit(s) is/are defined according to input from card(s), if required.
Step 7. Contour lines are drawn.
Step 8. (Optional) Data points and their numbers and values are plotted, if required.
Step 9. (Optional) A referring map is drawn, if required.

**Input Instructions**

A. Order of cards in deck

An example is shown in Fig. 6 in FACOM 230–60/75 cases. Cards indicated by items of letter enclosed in parentheses are optional.

a. System cards*
b. Problem/data name card
c. Task and data specification card–a
d. Input format cards
e. Task and data specification card–b
f. Data input cards if data are recorded on cards.
g. Blank unit(s) specification card(s)
h. Referring map data input cards
i. System cards*

```
$NO
$KJOB
COND=500
$PORTLINK
program deck
$PLOTMAX MAX=100
data deck
[$FD F08,FILE=(OLD, CKA367.XXX),UNIT=DD0, VOL=(SPEC, PP5014)]
If all input data are to be read from cards, this system card is not required. The underlined
are the file name and volume name.
$POUT
$JEND
```

Fig. 6. Setup example of card deck. The statements with marks “$” indicate system cards. The
one in the bracket is necessary to define an input file which is alternative to input data cards.

* These cards are required to control a job. The forms depend on the convention of each computer
center. Consult to your computer center.
B. Card preparation
   b. Problem/data name card
      Col. 1–80  Alphanumeric problem/data name; characters only in 1–40 columns are plotted on the output map.
   c. Task and data specification card–a
      Col. 1–4  FDEF: if face definition data are to be read as input.
                 SMTH: if only peak data are to be read as input.
                 REGS: if regularly spaced data are to be read as input.
      10  Input device logical # for peak or regularly spaced data (1 to 4 and 8 available); if not specified, 5 (card reader) is used as a default value.
      15  Input device logical # for face definition data (1 to 4 and 8 available; must be not the same as that for peak data); default is 5 for a card reader.
      16–18  YES: if a referring map is to be plotted; otherwise leave blank.
      21–30  YES: if blank unit(s) specification is/are to be performed; otherwise leave blank.
      26–28  YES: if peak points are to be plotted; otherwise leave blank.
      31–35  Skip # for plotting peak points; when 1, all points will be plotted.
      36–40  # of digits of the decimal part to be plotted as peak values. If it is punched in a negative number, peak values are not plotted.
      41–50  Base value of contours; real with a decimal point.
      61–70  Scaling factor for plotting; if it is left blank, the map is automatically scaled.
      71–75  0: if only a map scale is to be plotted.
             1: if only referring point(s) is/are to be plotted.
             2: if only referring line(s) is/are to be plotted.
             3: if referring point(s) and line(s) are to be plotted.
             Note: if the map scale is also to be plotted in the case of 1, 2, 3, negative number should be punched, i.e. \(-1, -2, -3\).
      76–78  YES: if input format(s) is/are to be specified; otherwise leave blank.
   (d.) Input format cards (Optional)
      If input format(s) for peak and/or face definition data is/are to be specified, both of two format cards for peak and face definition should be
prepared. If input of face definition data is unnecessary, leave the second card blank.

Card 1. For peak data input:

(1) If regularly spaced data are to be read as input, this specifies the format of values (z) at regularly spaced points (i.e. at grid points). If not specified, the format (8(6X,E10.4)) is used as a default one.

(2) If irregularly spaced data are to be read as input, this specifies the format of a peak #, its location (x,y) and value (z) (see Fig. 7 for the coordinate system). The default is (2(I5,3F10.0, 5X)) for two peaks in a card.

![Fig. 7. Coordinate system. All the input data should be measured according to the system.](image)

Card 2. For face definition data input:

If face definition data are to be read as input, this card should be punched; otherwise leave blank. In the case of to be read, this specifies the format for arbitrary # of face definitions, each of which consists of three peak numbers to define a triangle.

The default is (4(3I5, 5X)) for four faces in a card.

e, f. Task and data specification card–b, and data input cards.

All data input cards should be punched according to the formats specified on the input format cards or to the default formats. If source data are to be read from an alternative tape, they should be also written to the formats. In the case of using an alternative tape, task and data specification card–b should be prepared.

The following three types of data (see General Description of Program) can be chosen as the source data:

(1) Peak and face definition data (The task and data specification card–b is Card 1).
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Card 1. Col. 1–5 # of peaks
6–10 # of faces

Card 2. Peak data: peak #, coordinate of location (x,y).

Card 3. Face definition data; see the explanation of (d) Card 2.

(2) Peak data without face definition (The task and data specification card—b is Card 1).

Card 1. Col. 1–5 # of peaks
6–10 # of units for the computation of grid values (see General Description of Program); if autoextension is necessary, punch in a positive number, and if not, in a negative one.
11–20 Boundaries of the mapping area in the original coordinate system; x-under, upper, and
21–30 y-under, upper respectively; real with a decimal
31–40 point (see Fig. 4).
41–50 Side lengths of a unit in the original scale;
51–60 x and y directional ones, respectively (see Fig. 4).
61–70

(3) Regularly spaced data

If the data are to be read from an alternative tape, see Note.

Card 1. Col. 1–10 Pitch of data points in x-direction
11–20 Pitch of data points in y-direction
21–25 # of data points in x-direction
26–30 # of data points in y-direction

Card 2. Values (z): punched according to the specified or default format.

Note: If the source data are to be read from an alternative tape, an ID-card in which ID-code and # are written in the format (A4, I5) is required instead of Card 1 described above. A data set whose ID-code and # coincide with the ones of ID-card is read as input. The data in the tape should be written in the following forms:

Section 1. File code and # of data sets in the file should be written in the format (A4, I5).

Section 2. ID-code, # and pitch and #s of data points in x, y-directions are written in the format (A4, I5, 2F10.0, 2I5).

Section 3. Values (z): in the specified or default format. Sections 2 and 3 make a data set. As many sets as # of data sets

written in Section 1 should be stored in the tape.

(q.) Blank unit(s) specification card(s)

16 sets of data can be punched on a card at most. Each set of data consists of unit # (4 columns) and a delimiter (1 column); blank, comma, hyphen, or slash. If a blank or comma is punched as a delimiter, only the unit which corresponds to the # in the set is defined as a blank unit. If a hyphen is punched as a delimiter, all the units from the one of the #s punched in the set to the one of the #s punched in the next set. But this type of specification should be kept in the same card. The delimiter of slash indicates the end of the specification. An example is shown in Fig. 7.

(h.) Referring map data input cards

(1) Referring point(s) input cards
Card 1. Col. 1–5 # of referring point(s)
Card 2. Prepare one card for a referring point.
   Col. 1–10 x-coordinates of a referring point; real with a decimal point
   11–20 y-coordinates of a referring point; with a decimal point
   21–30 Size of a referring point (cm); real with a decimal point
   31–40 Size of referring point name (cm); real with a decimal point
   41–60 Name of a referring point
   61–70 Symbol code (numeric) of a referring point

(2) Referring line(s) input card
Card 1. Col. 1–5 # of referring lines
Card 2. Col. 1–5 # of control points on a line
   6–15 Size of line name (cm); real with a decimal point
   16–25 Inclination of the name (degrees anti-clockwise) from y-direction; real with a decimal point
   26–45 Line name

Card 3. Prepare as many as desired for a line. Four sets of coordinates (x,y), i.e. eight values, can be punched on a card at most; real with a decimal point.

Note: A set of a Card 2 and Card 3 as many as desired should
be prepared for a line. Prepare those sets as many as the \# of referring lines specified in Card 1.

(3) Map scale input card

Col. 1–10 Length of the map scale (cm); actual length on the marks output map; real with a decimal point (see Fig. 8)

11–15 \# of marks in the map scale: include both of side (see Fig. 8).

16–23 Actual distance of the map scale (alphanumeric): plotted on the right shoulder of the map scale (see Fig. 9).

Fig. 8. Example of blank unit specification data. This example specifies the units \#1 and \#5 to \#20 to be blank units.

Fig. 9. Map scale to be plotted in the output map.

Processing Examples

A. Test examples

(1) Irregularly spaced data

The data are concerned with the water depth of the Pacific off Hachinohe, Northeastern Japan, and derived from Hydrographic Department, Maritime Safety Agency, Japan. Two kinds of contour maps were prepared; the one from both peak and face data, and the other only from peak data. The input and the output maps for the former are shown in Fig. 10, those for the latter in Fig. 11. The contour lines in Fig. 11 are more smoothed than those in Fig. 10. The contour values can be obtained from the peak values in the former case and from the grid values printed in the output list in the latter case.

(2) Regularly spaced data

Two kinds of processing were performed on the regularly spaced data; the one with and the other without the blank units specification. The input and the output maps are shown in Figs. 12 and 13. The contour values can be obtained from the grid values in the input.

B. Application

Isopacous map of the Imaichi Pumice Bed. Fig. 14a is by this program and Fig. 14b is in "The Kanto Loam". The pumice bed was supplied from the mountain of Nantaisan, which is one of the Quarternary volcanos in the Kanto district, Japan. Data from Kanto Loam Research Group (1965).
Kaichiro Yamamoto and Niichi Nishiwaki

**JKOR 5Oe0W0?YAMAMOTO.KAI+$00331;**
**CORI=ADLK.+L P=6000**
** fibre=FILE=CKA367,CMPP=VOL=PF5005**
**EK#WKR=MAX=100**

**BFLIFF OF SEA BOTTOM, NO. 1 (HACHINOHE)**

<table>
<thead>
<tr>
<th>FEFF</th>
<th>YES</th>
<th>YES</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.5</td>
<td>-3</td>
</tr>
<tr>
<td>550</td>
<td>468</td>
<td></td>
</tr>
<tr>
<td>001</td>
<td>4.7</td>
<td>1.7</td>
</tr>
<tr>
<td>000</td>
<td>7.4</td>
<td>2.7</td>
</tr>
<tr>
<td>005</td>
<td>10.5</td>
<td>1.4</td>
</tr>
<tr>
<td>125</td>
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</tr>
<tr>
<td>233</td>
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<td></td>
</tr>
<tr>
<td>327</td>
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<tr>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>799</td>
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<td></td>
</tr>
<tr>
<td>989</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>18.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Relief of sea bottom off Hachinohe, Northwestern Pacific. This contour map was prepared from peak and face definition data derived from Hydrographic Department, Maritime Safety Agency, Japan. |

(a) Input data: title card, control cards, peak data (two sets in a card each of which consists of peak #, coordinates and depth of the point), face definition data (four sets in a card each of which consists of three peak point $s$), and data for referring points, line and a map scale.

Fig. 10. Relief of sea bottom off Hachinohe, Northwestern Pacific. This contour map was prepared from peak and face definition data derived from Hydrographic Department, Maritime Safety Agency, Japan.
(b) Output map: shoreline, and data points with their $s$ and values (depth) are plotted; contour values can be obtained from peak values.

Fig. 10  (continued)
(a) Input data: the same that of Fig. 10 except for without face definition data.

Fig. 11. Relief of sea bottom off Hachinohe, Northwestern Pacific. This contour map was prepared only from peak data which are also used in Fig. 10.
(b) Output map: the grid data each of which was estimated using the peak data around the grid point by least squares method; blank areas are due to scarcity of the peak data around the grid points; shoreline and data point with their $\Delta$s are plotted; contour values can be obtained from the grid values in the output list.

Fig. 11. (continued)
(a) Input data: title card, control cards, grid data, and blank unit definition data.

(b) Output map: blank areas are due to the blank unit definitions; contour values can be obtained from the grid values in the input.

Fig. 12. Processing example of regularly spaced data with blank unit definitions. The data are arbitrarily prepared for the test processing.
(a) Input data: the same that of Fig. 12 except for without the blank unit definition data.

(b) Output map.

Fig. 13. Processing example of regularly spaced data without blank unit definitions.
(a) Smoothed contour map drawn by the program: peak data, data for referring points and a map scale are used, all of which are from Kanto Loam Research Group (1965).

Fig. 14. Isopacous map of the Imaichi Pamice Bed (Late Quarternary), the Kanto district, Japan.

Fig. 14. (continued) Both of the maps show the distinct trend that the thicker the bed the nearer to the mountain of Nantai-san. The latter is more generalized, while more detail changes are expressed in the former.

References


Fujitsu (1970), FACOM 230-60 FORTRAN, File no. SP-061-4-4. (in Japanese)


SCHRAMM, M. W., Jr. (1968), Application of trend analysis to Pre-Morrow surface, southeastern
Appendix: Computer Program

This program is constructed in a simple structure, not overlayed. In this program, FACOM 230–60/75 SSL (Scientific Subroutine Library) and CALCOMP routines (basic and functional ones) are used. They are marked "*" and "**" respectively in the explanations below.

a. Call tree

Main- and sub-programs are connected with each other as shown in Appendix-fig. 1.

Appendix-fig. 1. Call tree. The routine marked "*" and "**" are FACOM 230–60/75 SSL (Scientific Subroutine Library) routine and CALCOMP ones respectively.

b. Function of main- and sub-programs

1. **Main program**: reads control, source and blank unit specification data, computes grid values, and automatically defines triangular elements as well as the control of the processing flow.
2. **DRAW**: draws contour lines in each element.
3. **APPEND**: normally terminates the job, after plotting data points, if required.
4. **REFMAP**: reads referring map input data and draw a referring map.
5. **TEST**: checks the repetition times of the main repeating operations.
6. **ERROR**: detects errors.
7. **SCALP**: scales plotting data.
(8) **GAUELS***: solves a linear system by Gaussian elimination method (SSL).

(9) **PLOTS****: opens a file in which plotting data are to be stored (CALCOMP routine).

(10) **PLOT****: linearly removes a plot-pen, and in the case of CALL PLOT (0.0, 0.0, 999) close the file (CALCOMP routine).

(11) **SYMBOL****: plots symbol(s) (CALCOMP routine)

(12) **NUMBER****: plots a number (CALCOMP routine)

(13) **FLINE****: draws a smooth line through specified points (CALCOMP routine).

c. Common blocks

Relations among common blocks and main- and sub-programs are shown in Appendix tab. 1.

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**Appendix-tab. 1. Common blocks.**

<table>
<thead>
<tr>
<th>MAIN &amp; SUBROUTINE</th>
<th>COMMON BLOCKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIN</td>
<td>PNI (for peak # and value)</td>
</tr>
<tr>
<td></td>
<td>OPT1 (for face definition)</td>
</tr>
<tr>
<td></td>
<td>OPT2 (for blank unit definition)</td>
</tr>
<tr>
<td></td>
<td>PRB (for problem/data name)</td>
</tr>
<tr>
<td>DRAW</td>
<td>PNI, OPT1, OPT2, PRB,</td>
</tr>
<tr>
<td></td>
<td>AREA (for mapping area specification)</td>
</tr>
<tr>
<td>REFMAP</td>
<td>AREA, PRINT (dummy)</td>
</tr>
<tr>
<td>APPEND</td>
<td>not used</td>
</tr>
<tr>
<td>TEST</td>
<td>not used</td>
</tr>
<tr>
<td>ERROR</td>
<td>not used</td>
</tr>
<tr>
<td>SCALP</td>
<td>not used</td>
</tr>
</tbody>
</table>

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d. Program source list
C ***** CONTOUR MAP PROCESSING PROGRAM NAME...CMPP *****
C
COMMCM /FN/ X(1000), Y(1000), Z(1000), NPEK(1000)
1 /OPT/ HDVF(3-2000)
3 /OPT/ NAME(20)
DIMENSION NOFM(20), X(1000), Y(1000), Z(1000), AA(3,4), WWK(3)
1 PNP(10), PNP(20), IFMF(20)
1 DATA NVJS, /2000*YES/, /
1 IFMF /12(1,'5.3F0.10,','5.3F0.16)/,
1 IFMF /14(3, '15.5I0.12,17)/,
C
C ***** INPUT, CONTROL DATA *****
READ (S,1001) NAME
1001 FORMAT (1044)
READ (S,1002) EDATA,IND, IDF, NOPT3, NOPT4, NOPT5,
1002 FORMAT (4A1, 5X=3(A4, 13, 2=3F10.4, 15, A4))
IF (NOPT3 .NE. YES) NOPT3=NO
IF (NOPT4 .NE. YES) NOPT4=NO
IF (NOPT5 .NE. YES) NOPT5=NO
IF (IFSP .NE. YES) IFSP=NO
IF (IND .EQ. 0) IND = 5
WRITE (6,2001) NAME, IFSP, IND, NOPT3, NOPT4, NOPT5,
2001 FORMAT (10H1///, 10X=CONTouro MAP PROCESSING/1///
1 IF (IND .LE. 5) IND=5
1 IF (IND .EQ. 0) GO TO 40
1 IF (IND .EQ. 5) GO TO 80
C **** INPUT, REGIONS REGULARLY SPACED DATA ****
1 IF (IND .LE. 5) GO TO 40
1 IF (IND .EQ. 5) GO TO 80
1003 FORMAT (4A1, 10=12, 15=15, 10=15, 10=15)
1004 FORMAT (4A1, 53)
CALL TEST (1, NOHP=10, 'MAP')
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GO TO 43
43 READ (IND,1013), PX,PY,MAXX,MAXY
4013 FORMAT (2F10.0,2I5)
NOMAP = 1
43 DO 60 I = 1,NOMAP
IF (IND,J.EQ. 5) GO TO 44
READ (IND,1005), XL(1:101),PY,MAXX,MAXY
1005 FORMAT (2F10.0,2I5)
NTEM = MAXX-MAXY
44 IF (IFS,P .NE., "YES") GO TO 45
READ (IND,1FMP) (Z(J),J=1,NTEM)
GO TO 48
45 READ (IND,1006), (X(J),J=1,NTEM)
1006 FORMAT (2F10.0,2I5)
44 CONTINUE
WRITE (6,2002) (X(J),Y(J),Z(J),J=1,NTEM)
2002 FORMAT (2F10.0,3I5)
CONTINUE
STOP 'DATA SET WAS NOT FOUND IN THE FILE'
70 IF (IND,J .NE., 5) REWIND IND
GO TO 200
C ***** INPUT & PROCESSING OF FACE DEFINITION DATA *****
80 IF (KDATA,N .EQ., "FDEF") GO TO 100
READ (5,1007) NOP,NOF,BOUND
1007 FORMAT (2I5,2F10.0)
IF (NOP .NE., 5) REWIND IND
90 IF (KDATA,N .EQ., "FDEF") READ (IND,1FMP) (NPEK(I),X(I),Y(I),Z(I),J=1,NOP)
1008 FORMAT (2I5,3F10.0)
READ (1FMP) (NSDF(I,J),I=1,NJ,1=NOP)
1009 FORMAT (3I5,5F5.3)
WRITE (6,2003) (NPEK(I,J),Z(I,J),I=1,NJ,1=NOP)
2003 FORMAT (2I5,3F10.0)
WRITE (6,2004) (NSDF(I,J),I=1,NJ,1=NOP)
2004 FORMAT (2I5,3F10.0)
CALL PLOT5
CALL DRAW(NOF,NOP,MAXX,MAXY)
CALL APPEND(NOP,NOP,NOP,NOP,NOP,NOP,NOP,NOP,NOP,NOP,NOP)
CALL VAX(NOF,1015,SCALE,1,NOF)
CALL SEV(NOF,1015,SCALE,1,NOF)
C ***** INPUT: PEAK DATA WITHOUT FACE DEFINITION *****
100 CONTINUE
STOP 'ILLEGAL DATA KIND'
READ (5,1010) NOP,NUNI,BOUND,FX,FY
1010 FORMAT (2I5,2F10.0)
IF (NOP .NE., 5) REWIND IND
READ (IND,1FMP) (NPEK(I,J),Z(I,J),I=1,NJ,1=NOP)
1050 FORMAT (2I5,3F10.0)
IF (NOP .NE., 5) REWIND IND
READ (IND,1FMP) (NSDF(I,J),I=1,NJ,1=NOP)
1050 FORMAT (2I5,3F10.0)
WRITE (6,2055) NOP,NUNIT,BOUND,PIX,PIY,IX(J),IY(J),IZ(J),J=1,NOP)

C Estimation of grid values

2055 FORMAT (6,1X,N3,1X,INPUT FOR OPTION=1)/
   1 N8*10X# OF OBSERVATIONS ....1,1/;
   2 N8*10XBOUNDARY.x,1,3,4....4,12,4,
   3 N8*10X*PITCH, y=PICTCH ....*212,4/
   4 N8*10X*Y,J,1,2/;
   5 N8*10X*Z(J),1,2/)

CALL TEST (4,NOP,1000,'NOP)
CALL TEST (2,MAXX,200,'MAXX')
CALL TEST (3,MAXY,200,'MAXY')
DO 180 J=1,MAXY
   YTEMP = BOUND(J) + PY*FLOAT(J-1)
   DO 170 I=1,YAXX
      NNN = IABS(NUNIT)
      XTEMP = BOUND(I) + PX*FLOAT(I-1)
      X1 = XTEMP + PX*FLOAT(J)
      Y1 = YTEMP + PY*FLOAT(J)
      X2 = XTEMP + PX*FLOAT(J)
      Y2 = YTEMP + PY*FLOAT(J)
      DO 110 M=1,3
         AA(M,N) = AA(M,N) + AA(M,N)
      END
      DO 120 M=1,4
         AA(M,N) = AA(M,N) + AA(M,N)
      END
      DO 110 M=1,3
      END
      DO 120 M=1,4
      END
      IF (X1(L) .LT. XI(CL)) AA(M,N) = AA(M,N) + WW(H)WW(N)
      AA(N,N) = AA(N,N)
      AA(M,N) = AA(M,N)
      AA(N,N) = AA(N,N)
      AA(M,N) = AA(M,N)
      AA(N,N) = AA(N,N)
      GO TO 140
   110 CONTINUE
   120 CONTINUE
   130 CONTINUE
140 CONTINUE
   IF (NPPL .LT. 5) GO TO 130
   CALL GAUELS(4A,3,4,1,0E+00,YLL)
   IF (YLL .NE. 0) CALL ERRUI1(2)
   X111 = XTEMP
   Y111 = YTEMP
   AA(1,4) = AA(1,4) + XTEMP*AA(2,4) + YTEMP*AA(3,4)
   GO TO 170
   IF (NUNIT .LT. 0) GO TO 160

CMPI01070
CMPI01080
CMPI01090
CMPI01100
CMPI01110
CMPI01120
CMPI01130
CMPI01140
CMPI01150
CMPI01160
CMPI01170
CMPI01180
CMPI01190
CMPI01200
CMPI01210
CMPI01220
CMPI01230
CMPI01240
CMPI01250
CMPI01260
CMPI01270
CMPI01280
CMPI01290
CMPI01300
CMPI01310
CMPI01320
CMPI01330
CMPI01340
CMPI01350
CMPI01360
CMPI01370
CMPI01380
CMPI01390
CMPI01400
CMPI01410
CMPI01420
CMPI01430
CMPI01440
CMPI01450
CMPI01460
CMPI01470
CMPI01480
CMPI01490
CMPI01500
CMPI01510
CMPI01520
CMPI01530
CMPI01540
CMPI01550
CMPI01560
CMPI01570
CMPI01580
CMPI01590
CMPI01600
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27

160 IF (CN(1) .EQ. 'YES') GO TO 250
   CONTINUE

170 IF (CN(1) .EQ. 'NO') GO TO 210
   CONTINUE

180 CONTINUE

190 CONTINUE

200 CONTINUE

210 CONTINUE

220 IF (CN(1) .EQ. 'YES') GO TO 250
   CONTINUE

230 CONTINUE

240 IF (CN(1) .EQ. 'NO') GO TO 250
   CONTINUE

250 CONTINUE

260 CONTINUE

C ****** TRIANGLE ELEMENTS DEFINITION ******

270 CONTINUE

C ****** BLANK UNITS SPECIFICATION ******

280 CONTINUE

C ****** DRAWING BASE INITIALIZATION ******

290 CONTINUE

C ****** PLOTTING ******

300 CONTINUE

C ****** APPEND ******

310 CONTINUE

END
C ***** CONTOUR DRAW NAME...DRAW *****

C SUBROUTINE DRAW(NOF, NAME, SCALE1, NOP)
COMMON /PP/N, NAME(10)
1 /MDF/ X(1000), Y(1000), Z(1000), NPEP(1000)
2 /MTP/ NPDP(3, 1000)
3 /MTP/ NIS(1000)
3 /MDF/ NAME(20)
2 /AREA/ BOUND(4)
3 DIMENSION X(10), Y(10), Z(10)

C X = 1

C ***** MAP LABEL PLOTTING *****
CALL SYMD (E, 1, 0.0, 1.5, NAME, 90.0, X)
CALL PLTD (E, 10.0, 9.0, X, 10.0, X)
WRITE (6, 1) (1)

C CALL FORMAT (1)
CALL TST (4, NOP, 1000, 'NOP')
CALL TST (5, NOP, 2000, 'NOP')

C ***** SCALING OF DATA (X,Y,Z) *****
CALL SCALF (X, 0.0, NOP)
CALL SCALF (Y, 0.0, NOP)
CALL SCALF (Z, 0.0, NOP)
IF (SCALE1 < 0.0) GO TO 20
SCALE1 = 0.0

C GO TO 20

C 20 CALL SCALF (X, 0.0, NOP)
C CALL SCALF (Y, 0.0, NOP)
C CALL SCALF (Z, 0.0, NOP)
C IF (SCALE1 < 0.0) GO TO 20
C SCALE1 = 0.0

C CONTINUE
BOUND(1) = (X(1) = (X(1) - (X(NOP) + 1) / SCALE1)
Y(1) = (Y(1) - Y(NOP)) / SCALE1
Z(1) = (Z(1) - Z(NOP)) / SCALE1
CONTINUE
BOUND(3) = (X(1) = (X(1) - (X(NOP) + 1) / SCALE1)
BOUND(3) = (Y(1) - Y(NOP)) / SCALE1
BOUND(3) = (Z(1) - Z(NOP)) / SCALE1
CONTINUE

C ***** CONTOURING START *****
DO 250 I = 1, NOP
IF (NVRIS(I) > 1000) GO TO 250
DO I = 1, NOP
IF (NPEP(I) > 3000) GO TO 250

C DO 240 I = 1, NOP
IF (NVRIS(I) > 1000) GO TO 250

C DO 250 I = 1, NOP
IF (NVRIS(I) > 1000) GO TO 250

C DO 240 I = 1, NOP
IF (NVRIS(I) > 1000) GO TO 250

C CONTINUE
MDF = J
ZM(NO) = Z(1)
CONTINUE
B16 = Z(I)
DO 30 J = 1, 3
IF (ZM(J) < B16) GO TO 30
ZM(J) = Z(I)
B16 = Z(I)
MTM = MDF
MDF = M(J)
MTM = TSM
CONTINUE
IF (ZM(J) < B16, ZM(I)) GO TO 30

C END
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```fortran
BIG = 2M(3)
ZM(3) = ZM(2)
ZM(2) = ZM(1)
MTEM = MO(3)
MO(3) = MO(2)
MO(2) = MTEM

60
CON = BASE + (INT(FLOAT(INT((ZM(3) - BASE) / CINT)) * 1.0)

MAK = 100

DO 210 JM = 1, MAK

16 = J - 1

IF (CON .GT. ZM(1)) GO TO 220
LNM = 1

XI1 = ZM(3)
M1 = MO(3)
Z12 = ZM(2)
M2 = MO(2)

70 IF (CON .GT. XI1 AND CON .LE. Z12) GO TO 80

GO TO 90

CONTINUE

LNM = LNM + 1

XT(MNM) = X(M1) + (X(M2) - X(M1)) * (CON - XI1) / (Z12 - XI1)
Y(MNM) = Y(M1) + (Y(M2) - Y(M1)) * (CON - XI1) / (Z12 - XI1)

90 IF (LNM .EQ. 2) GO TO 110

IF (LNM .EQ. 3) GO TO 200

IF (LNM .GT. 3) GO TO 100

Z11 = ZM(3)
Z12 = ZM(2)
M1 = MO(3)
M2 = MO(2)
LNM = LNM + 1

GO TO 70

100

Z21 = ZM(3)
Z22 = ZM(1)
M1 = MO(3)
M2 = MO(1)
LNM = LNM + 1

GO TO 70

C

***** PLOT A LINE *****

110 CONTINUE

CALL PLOT(YT(1), XT(1), 3)
CALL PLOT(YT(2), XT(2), 3)

200

CON = CON + CINT

210 CONTINUE

WRITE (6,2004) MAK

220 WRITE (6,2007) (NPDF(K+1),K = 1,3) + ZM,M0,IL

230 CONTINUE

2002 FORMAT (1H -5X,15J,3X,'X=').S35,5X,'X=').S35,5X,'X=').S35,5X,# OF LINES',
1X,')

2004 FORMAT (1H -10X,'ALL CONTOUR LINES DRAWN')

RETURN

END
```
C ***** PLOT REFERENCE POINTS/LINES, NAME...RFMAP *****
C
SUBROUTINE RFMAP(KIND,SCALE)
C
COMMON /PRINT/, MOUT
C
DIMENSION XR(100), YR(100), NNAMEP(100), SIZEP(100),
2 NPFOLN(10), AL(10), XL(10), YL(10), NNAMEL(10),
3 NNAMEL(10), SIZEL(10), NAMEL(10), XL(10), SIZEL(10),
4 NAMEP(10), AX(10), YY(10), NVALUE(10)
C
IF (KIND .EQ. 0) GO TO 250
1 KKK = IABS(KIND)
2 GO TO (10,50,10), KKK
C
***** INPUT, REFERING POINT(S) DATA *****
10 READ (5,1001) NUMBER
20 FORMAT (15,1002) X(1), Y(1), SIZE(1), NAME(1)
30 CONTINUE
40 CONTINUE
50 IF (KKK .EQ. 1) GO TO 90
C
***** INPUT, REFERING LINE(S) DATA *****
60 READ (5,1003) NL
70 FORMAT (15,1004) XNL(1), YNL(1), NLX(1), NLY(1)
80 CONTINUE
90 CONTINUE
C
GO TO (100,200,100), KKK
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C ***** PLOT, REFERING POINT(S) *****
100 DO 120 I=1,NUMSER
   DO 110 J=1,NUMTEM
      NAMEPO(I,J) = NAMEPO(I,J)
110 CONTINUE
   NAMTEM(J) = NAMEPO(I,J)
   YTEM = (XP(I)-BOUND(1))/SCALE
   XTEM = (YP(J)-BOUND(2))/SCALE
   CALL SYMBOL(XTEM,YTEM,SIZEP(I,1),NFOM(I),90,O,.1)
   XTEM = XTEM + SIZEP(I,1) + SIZEP(I,2)
   CALL SYMBOL(XTEM,YTEM,SIZEP(I,2),NFOM(I),90,O,2)
120 CONTINUE
WRITE(6,2005)
IF (K==1) GO TO 250
200 CONTINUE

C ***** PLOT, REFERING LINE(S) *****
DO 240 J=1,NLFOLN
   DO 220 K=1,NFLAT
      NAMELN(J,K) = NAMELN(J,K)
220 CONTINUE
   DO 220 K=1,NLFOLN(J-1)
      YTEM = YTEM + FLAT(J,K)
      CALL SYMBOL(XTEM,YTEM,SIZEL(1),NFOM(1),90,O,S)
   220 CONTINUE
WRITE(6,2006)

C ***** INPUT & PLOT, MAP SCALE *****
IF (END .GT. 0) RETURN
READ (3,1006) DIST,MARK,NVALUE
1006 FORMAT (F10.0,F15.2A4)
WRITE(6,2007)

255 WID = 0.0
DL = WID/40.0
PIA = 10.0
PI = DIST/FLOAT(MARK=1)
XTEM = MARK
CALL TEST(XTEM,MARK)
DO 260 I=1,MARK
   CALL PLOT(XTEM,PIA)
   CALL PLOT(XTEM,PIA)
   CALL PLOT(XTEM,MARK)
   PIA = PIA + PI
260 CONTINUE
XTEM = MARK
YTEM = 10.0 + DIST
DO 270 X=1,20
   CALL PLOT(XTEM,YTEM)
   CALL PLOT(XTEM,YTEM)
   CALL PLOT(XTEM,10.0)
   XTEM = XTEM + DL
270 CONTINUE
RETURN
2005 FORMAT (/IM ,10X,'REFERING POINTS PLOTTED'//
   ,10X,'REFERENCE LINES PLOTTED'//
   ,10X,'MAP SCALE PLOTTED'//
   ,10X,'END')
C ***** DATA POINTS PLOTTING AND JOB TERMINATING ROUTINE; NAME... APPENDAP000030
SUBROUTINE APPEND(NOP,NL,2,H,N3,0,L,LMK,SY,0,L,KNREF,SCALE) APDO00030
C
DIMENSION X(NOP),Y(NOP),Z(NOP),LMK,NPEK(NOP)
       IF (NL .NE. 'YES') GO TO 100
       IF (N.S. 'ES', 0) = '
       DO 50 I = 1,NOP
          CALL SYMBOL(Y(I),X(I),0.5,2,90,0.012)
          YTEM = Y(I)
          XTEM = X(I) + 0.5
          TEMP = MPEK(I)
          CALL NUMBER(YTEM,XTEM,0.3,TEMP,90,0.012)
          IF (L .LT. 0) GO TO 50
          YTEM = YTEM + 0.5
          CALL NUMBER(YTEM,XTEM,0.3,TEMP,90,0.012)
      50 CONTINUE
      WRITE(6,200) 'DATA POINTS PLOTTED'
      C... REFERING MAP PLOTTING...
      IF (NL .NE. 'YES') CALL REFMAP(KNREF,SCALE)
      C Normally TERM:NATE THE JOB *****
      CALL PLOT(0,0,0,0,999)
      STOP 'NORMAL END OF JOB'
      END

C ***** AMOUNT TEST ROUTINE; NAME... TEST TSTO0020
SUBROUTINE TEST ITTEM,NV,MT,NAME) TSTO0020
       IF (NV .GT. 0. AND. NV .LE. LIMIT) RETURN TSTO0030
       ITEM"15", (A",") VALUE -,,L12",L:M:T,.I6",) TSTO0040
      STOP TSTO0050
      ENO TSTO0060
C***** ERROR ROUTINE; NAME... ERROR ERR00030
SUBROUTINE ERROR A(I) ERR00030
       CALL PLOT CO,O,O.O,999) ERR00040
       IF (A(I) .LT. SMAV SHAL) ERR00050
      20 CONTINUE ERR00060
      STOP 'ERROR referring: aplane was not detennineb, ERROR ERR00070
      ENO ERR00080

G:6:8:E,?:;LP(A;W•NtM) gE;g81 1g
s:G.Aa) . scpoeolo
sMALss(v sCpoao4o
D0 20 Itl,N,M • SCPOO050
IF .(A(1) .LT. 0) 20;G.5MAL) SCPOO060
50 CONTINUE SCPOO070
RETURN SCPOO080
END SCPOO10
Supplement figure. Output example of the revised program: map is framed and contour values are written at ends of every two lines.
Supplement

The program was revised. The revised one can frame the output map and write their values along the contours as shown in the supplement figure in which the values are written every two contours. (Supplement figure)