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A GUIDE TO THE PRODUCTION OF SHOTPOINT LOCATION MAPS USING A DIGITIZING TABLE AND COMPUTER

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F. D. Atkinson, Commonwealth Government Printer

SUMMARY

A procedure for the automated production of shot-point location maps has been developed. It involves two essentially independent steps: the first in digitizing seismic shot-points on a digitizing table from whatever maps are available as a source of information; and the second in running a series of computer programs to convert the table output into the maps required by the user.

Seismic shot-points are digitized at BMR using a GRADICON digitizing table integrated with a Hewlett-Packard HP2100 computer system. This combined system provides the user with an extended range of capabilities. Data files can be saved directly on disc, so avoiding the inefficiencies of paper tape or card output. The data can be edited and the corrected file output onto magnetic tape in computer-compatible form. As the digitizing follows a general procedure, any digitizing system can be used with little program modification. At present the programs can handle data from either GRADICON or D-MAC digitizing systems.

Control points for the conversion of table coordinates into geographical coordinates are provided by systematically digitizing the latitude-longitude graticule on each map. Each seismic line is digitized separately with data input manually to identify the survey and line number. To minimize this manual input of data, a semi-automatic procedure is used to generate the shot-point numbers. The user provides the increment between consecutive shot-points and the starting shot-point number only. Shot-point numbers are then assigned automatically within the program to the digitized shot-point locations.

The digitized data is processed using computer programs written in Fortran IV which are presently implemented on the Cyber 76 system at the Division of Computing Research, CSIRO. The major program DIGMAP converts the digitized data into shot-point number, latitude, and longitude. The control points are adjusted to the true grid by a least-squares technique which at the time minimizes the effects of irregularities caused by folds in the source map, stretching of dyeline prints, and the like. The user is provided with an estimate of the accuracy of the conversion to geographic coordinates. Data are output in the file form standard for BMR marine surveys.

Using this basic data file, program TRAKMAP plots the shot-point location maps at any specified scale and projection. Facilities exist to plot the track between consecutive shot-points for data density maps, to plot the track and annotate at specified intervals for regional maps, and to plot and annotate each shot-point for detailed maps.

1. INTRODUCTION

During preliminary compilation of seismic data from the Eromanga Basin region, it became apparent that a composite map of shot-point locations would be required. Location maps were available for individual surveys but these were on different scales and projections and thus were not easily merged. The two approaches usually tried are photographic reduction, which cannot overcome several inherent mapping problems, and manual scaling and replotting, which is a once-off effort that must in general be repeated for later projects. Instead a computer-based method developed in the Marine Gepphysics Group was adopted because of its greater flexibility and accuracy. Some of the reasons for this choice are outlined below.

Various map scales have been used over the years by the different exploration companies, ranging from 1:63 360 (1 inch to 1 mile) to 1:250 000. Simple reduction to a common scale would have resulted in greatly varying line weight and character size, and would have encountered problems with the variable legibility of the original maps. Reduction to a scale of 1:1 000 000 or smaller would have made the map illegible.

Most maps were plotted using the Transverse Mercator projection and difficulties occur when merging east-to-west across zone boundaries. To further complicate matters, maps drawn for a particular survey region sometimes used a non-standard zone to give the least distortion locally. On other maps, the projection used could not be identified or the graticule provided was completely inadequate for defining latitudes and longitudes.

Difficulties are exaggerated by the way in which most data maps are made available as dyelines. The dyeline printing process often introduces a differential shrinkage of up to 5 percent in the map dimensions, and the direction in which this occurs depends upon how the print was passed through the dyeline machine. Folding of the copy to fit within a report creates yet more distortion, and the quality of the copy deteriorates with time.

An attempt was made to use photographic reduction but the several inherent problems discussed above coult not be overcome. Maps had to be matched as well as possible because of the projection incompatibilities and distortion effects. It was found that many maps could not take a 5 to 10 times reduction without causing almost total illegibility. Extension of the compilation to a larger region would have exacerbated such difficulties.

A superior result using manual methods could be possible by scaling positions from the original maps and then replotting at compilation scale. At least in this way the maximum positional accuracy could be maintained. In the final result it suffers from the same limitations as any other manual method; the information cannot be displayed at another scale or projection without repeating much of the previous work.

A possible hybrid solution considered is reduction of the maps to a common scale and lifting off shot-points at specified intervals onto a transparent base map. While probably the quickest method for the study in question, it involves a considerable amount of manual effort. The final product is a map restricted to the scale and projection used at compilation, and giving only approximate shot-point locations.

On the other hand, the computer-based technique adopted involves about the same level of manual effort, but avoids many of the shortcomings of the manual approach. Maps are digitized at original scale using a digitizing table to give the best positional information available. Effects of irregularities in the digitized map (e.g. folds, dyeline stretching, poor graticule preparation) are minimised in the computer program used to convert the raw information to geographic co-ordinates. From that point onwards there are no problems in merging information from different sources within the limits of accuracy of the method.

The basic positional information is saved as a digital data file of shot-point number, latitude, and longitude. At any later date using a variety of computer programs available within the Marine Geophysics Group, maps covering any part of the area can be rapidly prepared from this data file at any scale or projection without repetition of the manual effort.

One obvious application is the integration of shot-point locations with seismic time-depth data to automate the production of time-depth structure and horizon isochron contour maps. With the input of velocity-depth data, the more tedious task of preparing true depth and isopach maps could be done by computer also.

Much use is made in the computer field of jargon that is unfamiliar to many people. In particular the word file has several connotations generally made clear by the context in which it is used. In order to avoid confusion here, its use is restricted to that of a block of data which is processed as a unit by a computer program. Similarly the unit of storage which may consist of one or several files is called a document to help differentiate between the two. A user may wish to process one or more files of data within a document which is sequentially searched to first identify and then extract the unit of information.

2. AN OUTLINE OF THE PROCEDURES INVOLVED

The work involved in the automated production of shot-point location maps can be conveniently divided into two essentially independent steps: the first in digitizing seismic shot-points on a digitizing table from whatever source maps are available; the second in running a series of computer programs to convert the table output into the maps required by the user. While the techniques described in this report can be applied using any suitable devices, it is simplest to present them in terms of the equipment available to the BMR Seismic Sub-Section, namely the GRADICON digitizing table within BMR (integrated into a Hewlett-Packard HP2100 computer system) for the first step, and the Control Data Corporation Cyber 76 computer at CSIRO in Canberra and the Calcomp plotters at BMR for the second step. A flowchart for these steps is shown in schematic form in Figure 1.

Procedure at BMR

The best available shot-point location maps are located and extracted for digitization. Some preparatory work may be required to ensure that there is an adequately sized systematic graticule and to decipher different survey lines if several surveys are portrayed on the map. Isolated lines from older surveys are commonly incorporated on a map and this can lead to duplicate digitization if the user is not careful. The digitizing requirements should be clearly laid out in advance so that the task on the digitizing table is as simple and mechanical as possible to minimize mistakes.

The map is digitized using the procedures detailed in Chapter 4 and the data file saved as a document in the HP system. The digitized output consists of blocks of data of two types. The first type contains the graticule data used to control the conversion from digitizer co-ordinates to latitudes and longitudes, while the second type consists of a sequence of seismic shot-points. Information is input manually to identify the data type and control the later processing. It is desirable, but not essential, that all seismic traverses lie within the limits of the graticule as the accuracy of conversion decreases rapidly for points outside the graticule.

This document is then listed for editing purposes. Data input manually are checked for logical order or missing information, and any obvious errors made during digitizing are corrected. The person digitizing should keep note of blunders by manually entering suitable messages to aid in the editing, eg. DELETE ABOVE BLOCK, DELETE 10 LINES. In this way mistakes are more readily identified when checking through the listing.

The edited data file can then be saved on an archival tape to await further digitization for the desired region and avoid accidental flushing of the document from the HP disc system. Archiving is carried out on request by the HP2100 computer operator. When all required maps are digitized, the archival tape is converted by the operator into a card-image magnetic tape in a format compatible with the Cyber 76. This tape is then sent to CSIRO.

Procedure at CSIRO

The magnetic tape containing perhaps several files of basic digitized data, one per map area, is read by the Cyber 76 computer at CSIRO and saved within the system as a document. The shot-point location maps are generated from this document via a series of FORTRAN programs. A basic aspect of the process is the creation of a digital data file of locations in geographic co-ordinates. Any later digitized data may then be used to update the file. In this way, a master file of shot-points may be maintained in digital form and used to rapidly prepare location maps for any specific purpose from a detailed study to a regional investigation.

Two main programs are used: DIGMAP which converts the digitized data into shot-point number, latitude and longitude; and TRAKMAP which plots the location map at a specified scale and projection. Other programs used are for file management and editing: LISTAPE produces a numbered listing of every card image in a data file; NEXFILE merges editing corrections with the main file to produce an updated file, of the digitizer output in this case; see Whitworth (in prep.) for a more detailed explanation of the handling of card image files (Appendix 7). These programs are available in the program libraries maintained by the Marine Geophysics Group on its discpack (at present, Serial Number DMR1345). The instructions for the use of these libraries are given in Appendix 4.

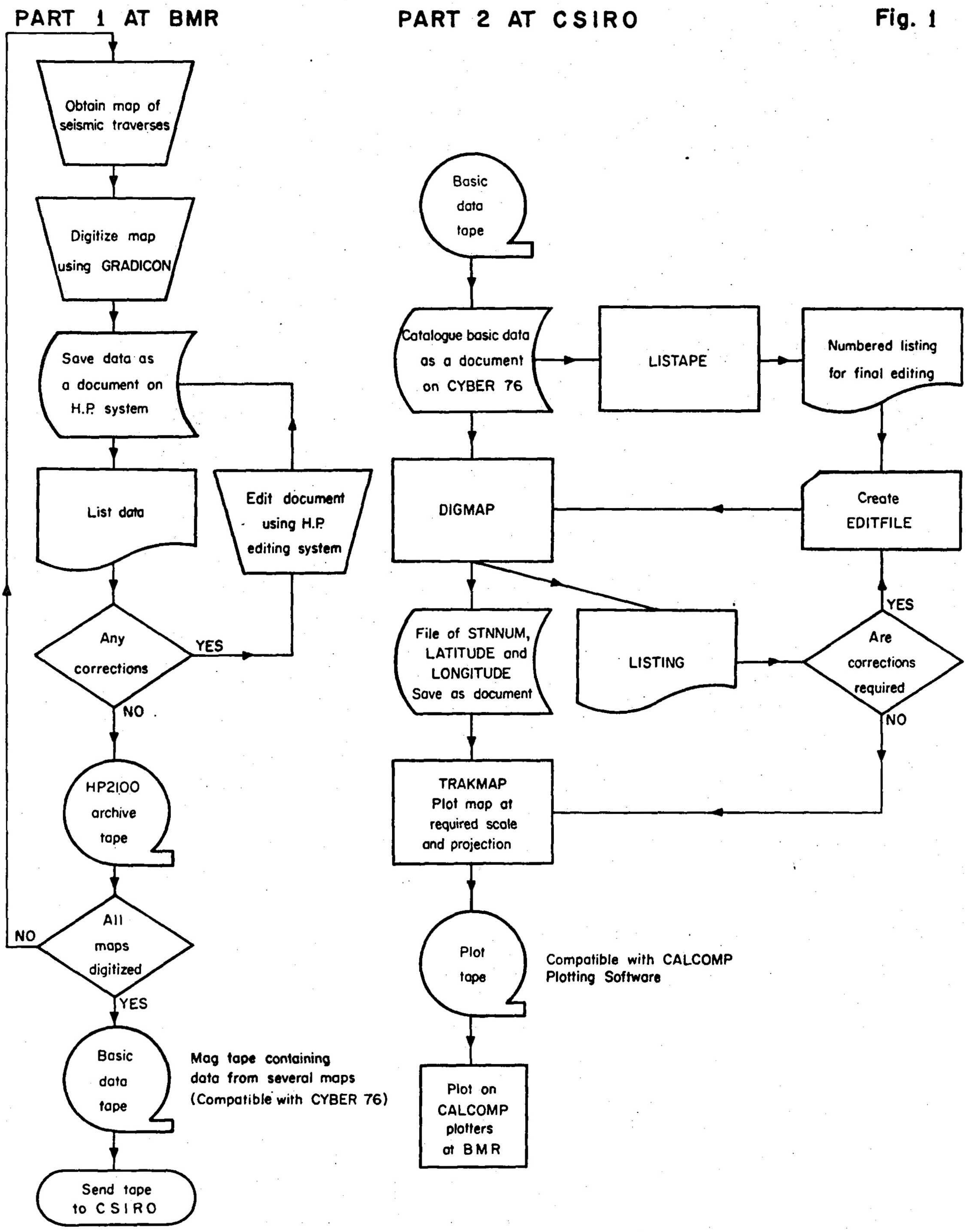
Because mistakes, however minor, are almost inevitable the first step on the Cyber 76 is the production using program LISTAPE of a numbered listing of the card images in each file that is to be processed. As it is generally found that several passes through the processing system are needed to eliminate the mistakes, on-line editing is used; that is, corrections are made to the input file as it is read into a program but the file itself remains unaltered. This means the user needs only to produce the numbered listing at the beginning of the process and work out corrections relative to the original file.

Program DIGMAP is then run to convert the digitizer output into shot-point number, latitude, and longitude. The program printout is inspected for irregularities, and the cause found by reference back to the numbered card-image listing. Major errors are usually associated with mistakes in one of the manual entries or in digitizing of the map graticule. Edit additions and modifications are punched onto cards and added to the existing cards in the edit file. Usually it is best to continue processing even though errors may be present in the output file as repeated runs of DIGMAP can be costly and lead to excessive amounts of printout. If a portion of the original file contains major errors, DIGMAP can be rerun on this part of the file and checked as before. When satisfied the user saves the converted data as a buffered file in the standard survey data file format used by the Marine Geophysics Group.

Consideration should be given to producing large outputs from DIGMAP in microfiche form. As this is primarily a checkout phase, there is no need to keep the printout once the user is satisfied that the conversion has worked properly.

Program TRAKMAP is then executed using the survey data file as input, and maps are produced for comparison, with the same scale, projection, and area as the maps digitized. The plotted maps are overlaid on the originals and checked for incorrect positioning, missing shot-points, incorrect shot-point numbers or any other irregularity between the two maps. Further edit corrections to the digitizer output file may need to be punched at this stage and the steps repeated.

Fig. 1



GENERALIZED FLOWCHART FOR THE PRODUCTION OF SHOTPOINT LOCATION MAPS

Record No. 1976/65

G465-21A

When all corrections have been determined, program NEXFILE is used to merge the edit file and the main file into an updated digitizer output file. The printout from LISTAPE then becomes redundant and any further modifications will require the production of a new numbered listing for the updated file.

Now program DIGMAP can be used to produce the final shot-point location file. This file and the file produced by NEXFILE are saved for any future applications. Program TRAKMAP may be run at any time to provide an integrated map at the required scale with shot-points posted at a specified interval. Usually standard map areas at 1:250 000 and 1:1 000 000 will be plotted.

3. GRADICON-HP2100 DIGITIZING SYSTEM

The GRADICON digitizing table was designed as a stand-alone system capable of a significant amount of control and formatting by hardware (INSTRONICS, 1975). However, it had two short-comings, its output rate was low, and recording on digital magnetic tape was not possible. To overcome these limitations it has been integrated with the Hewlett-Packard HP2100 system operated by the ADP Group. There are four pieces of hardward of interest to the user: the digitizing table itself, the console that controls accuracy and formatting, the keyboard for manual entry of information, and an NCR terminal for communication with the HP system.

The table has an operating area of 160 by 130 cm, and outputs digitized positions relative to a local origin, the ABS option, or incremental or relative to the preceding digitized point, the DELTA option. The values output may be scaled with ratios of 1:1, 1:2, and 1:4 by setting the scale switch on the console (Fig. 2); with it set to 1:1 the readings are in millimetres with a precision of 0.01 mm. At greater scales, the precision in millimetres falls. All work is done with a ratio of 1:1. The user may choose POINT mode digitization where one value is output each time the cross-hair follower is pressed, TIME mode where values are continuously output with time at a frequency selected by the RATE control on the console, or INC mode where values are continuously output with distance along the axes at a frequency selected by the VARIABLE INC/INC AXIS SELECT controls.

The origin may be set wherever the user desires by pressing the X and Y reset buttons. However, it is important to establish the origin on the scribed cross-hair at the bottom left-hand corner of the table as this readily allows the user to check whether the origin has shifted. The origin should be checked at the end of the digitizing run and at any convenient points during the work as the origin occasionally changes because of electrical faults with the GRADICON system or by accidental pressing of the origin reset buttons.

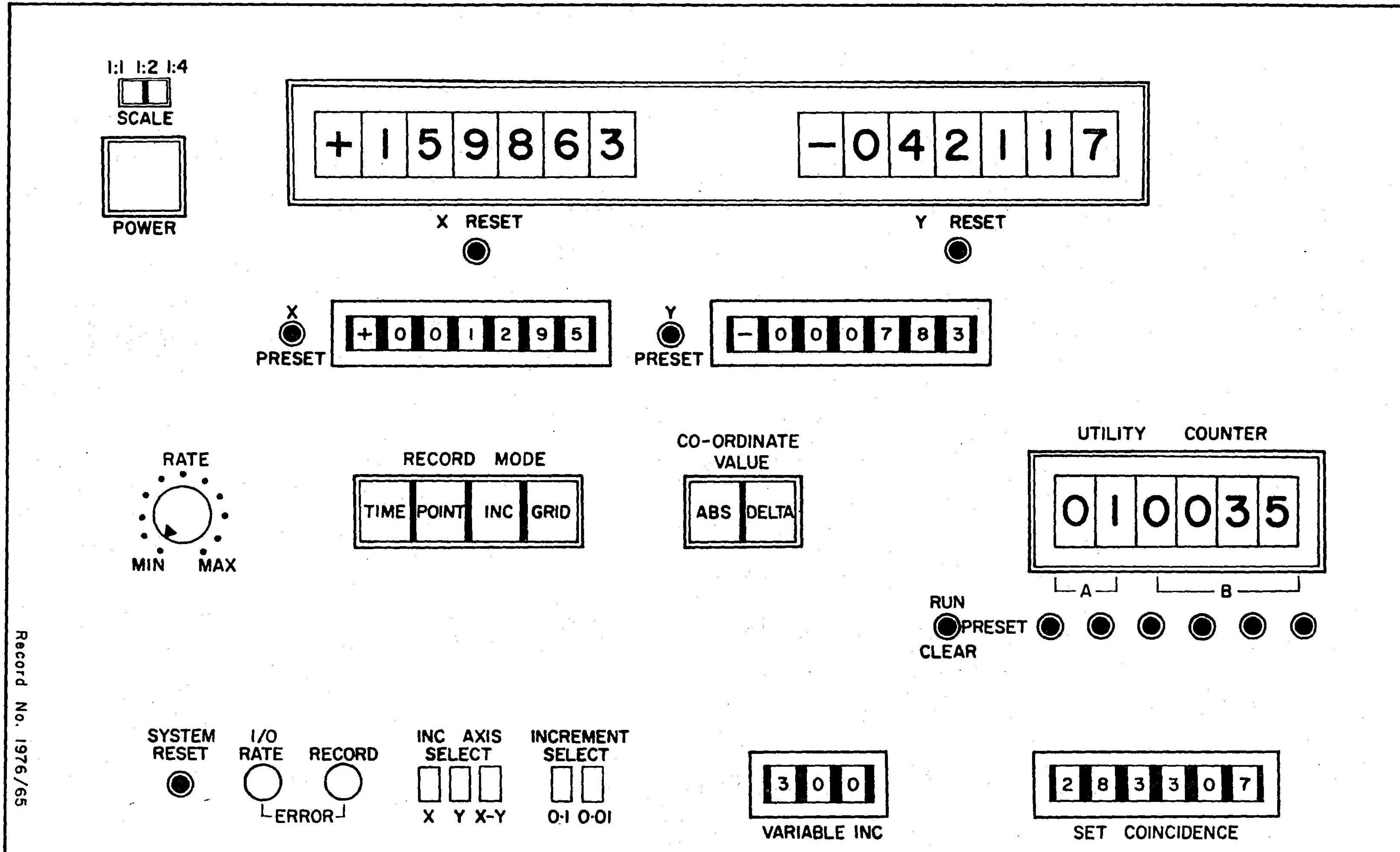
Information that the user wishes to insert manually is entered through the GRADICON keyboard. This is used in a variety of ways, depending upon the format chosen by the user as described in more detail elsewhere (ADP Group, 1974a). A limited degree of communication with the Hewlett-Packard system is allowed via the keyboard by entry of special messages that are recognized as commands. These commands are all prefixed with a period (.) and include:

- .ALTER - change the format and printing options (in our case suppress data printout after digitizing the map graticule)
- .EØP - to insert a software END-OF-PARTITION in the output file
- .EØF - to insert a hardware END-OF-FILE in the output file
- .END - to terminate run when digitizing is complete.

The NCR terminal allows the user to access the digitizer data acquisition program GRADI on the HP2100 system. To commence digitizing the user logs into the program by typing into the terminal

*LG, GRADI

and then answering a series of questions asked by the computer to establish the mode of operation and the format required for the digitized data. Appendix 1 show the questions asked by the computer and the answers necessary for seismic shot-point digitization.



GRADICON : FRONT PANEL CONTROLS

Fig. 2

Record No. 1976/65

G465-20A

The user defines the format he needs via the F2 option query. The co-ordinate data are packed into 80-character card image records (four X-Y readings per card image) if option 0 (zero) is chosen. This is the most efficient packing possible and is used to minimize the length of the output file. It also automatically converts each manual entry into a separate card image which makes identification straightforward.

Point mode digitization is used for seismic shot-point locations. This also requires the POINT and ABS buttons to be depressed on the digitizer console. In this mode a single X-Y value is sent from the table to the HP system each time the button on the cross-hair follower is pressed.

When the digitizing is complete the user finishes by typing .END and saves the document on the HP disc (see Appendix 1). The user can then obtain a numbered listing of the card-image digitized data for checking purposes, by typing
*LI, document header
The listing is output on the electrostatic printer in the HP computer room. The printout is scanned for errors or omissions in the manually entered data, and also for any spurious X-Y values that have been output by the digitizer. The data file is edited using the HP inter-active editor (ADP Group, 1974b) which is similar to the TED editing system on the Cyber 76 at CSIRO but not as powerful.

To edit, the user types the following commands on any available terminal:

*GF, filename	- get file called filename
*ED	- turn on editor

Edit file using appropriate instructions

MF	- make file and terminate editor
*RF, security code, filename	- replaces old filename with edited version

When all editing is finished the computer operator will archive the data to await other data from surveys within the same area. After all maps have been digitized the operator will write the digitized data onto a magnetic tape in CYBER 76 display code. This tape can be sent to CSIRO and read into the computer.

The GRADICON digitizing table at BMR is usually used to digitize the shot-point location maps, but data from the D-MAC digitizing table at CSIRO can be handled equally as well.

4. DIGITIZING SHOT-POINT LOCATIONS

The main source of seismic shot-point maps are the company reports held by the Subsidy Section of BMR. These location maps are usually at a scale of 1:100 000 and are drawn using the Transverse Mercator projection. The older surveys are often at 1:63 360 (1 inch to 1 mile) or 1:126 720 (2 miles to 1 inch). Regardless of source, scale, or projection the best available map should be obtained as the accuracy of the digitized positions depends upon the quality of the original map.

The map is almost invariably a dyeline copy that has been folded to fit into a report. Errors are introduced by the folds and differential shrinkage in the dyeline process, both of which increase the difficulty of obtaining accurate locations. The latitude-longitude graticule on the map is often drawn by hand with concomitant limitations in accuracy. Sometimes the parameters used in the projection are inadequately defined or the projection itself may not be specified. These limitations can be circumvented to some extent in the processing if adequate precautions are taken in the digitizing.

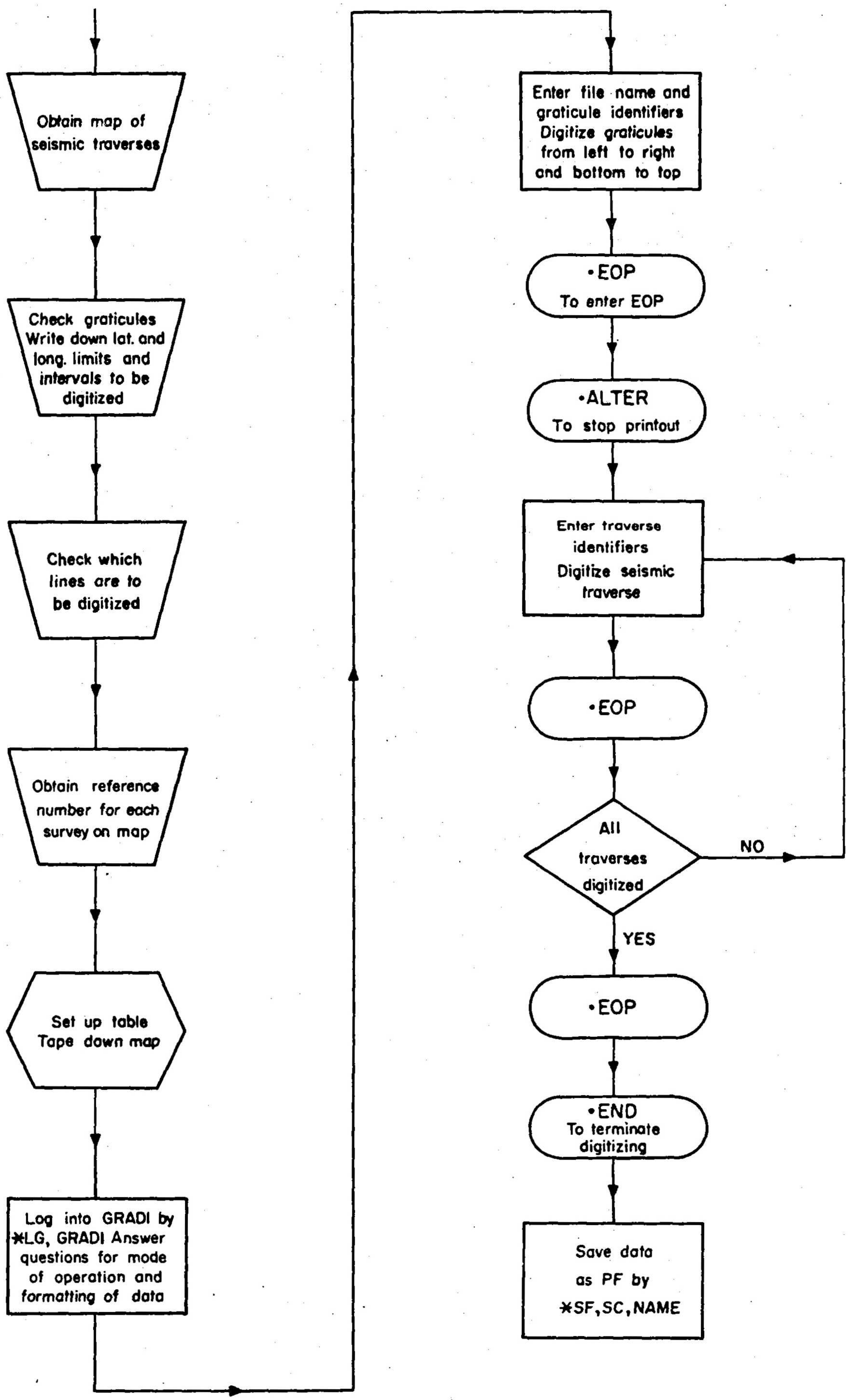
After the map has been taped down as flat as possible on the digitizing table, the latitude and longitude limits and spacing of the graticule to be digitized must be written down for later reference. These values are required in program DIGMAP to convert tho digitized shot-point data to geographic co-ordinates. The spacing must be constant in either direction but does not need to be the same for latitude and longitude. A flowchart of the preparation and digitization of the map is shown in Figure 3.

The user starts by inserting three messages manually on the GRADICON keyboard. The first is the file name, an 80-character free-format label, by which the file will be identified and located during the processing to follow. The next card image identifies the following data as being the digitized map graticule. This includes a free-Format map label which is used to identify the data within program DIGMAP. The third message gives the dimensions of the graticule. The graticule is then digitized row by row from left to right in longitude, starting at the bottom left-hand corner and moving upwards in latitude as each row of points is completed. The block of data is terminated by a manual entry of an End-of-Partition (or EØP).

In summary the block of graticule data is in the form:

file label	- label of file for identifying and locating
Mmap label	- M identifies map graticule block; followed by free-format map label
Glxm	- G identifies grid size information; l, m are number of longitude, latitude points in graticule
X .... X .... X	- digitized graticule points
.EØP	- insert EØP to mark end of graticule block

Following the map graticule block are one or more data blocks containing digitized seismic shot-point locations, one for each seismic line. The user first inserts several messages mainly to allow semi-automatic identification of the shot-point numbers. The first message identifies the



PREPARATION AND DIGITIZATION OF MAP

following data block as a run of location data and includes survey and line number and a free-format label. The next gives the interval between sequential shot-point numbers. This message is unnecessary if the interval is 1. Then comes a message giving the number of the first location. The shot-points are then digitized in numerically increasing order. As long as the shot-point numbers increase uniformly, they can be constructed from the information provided. Whenever there is a break in the sequence, a message giving the shot-point number following the break can be manually inserted and the sequence restarted.

The digitized shot-point locations are in the form:

Rssll. line label	- R identifies following as run of digitized locations; ss, II survey and line number; followed by free-format line label
Im	- I identifies interval information; m is interval between consecutive shot-points
Nnnnn	- N identifies number of first shot-point; nnnn is up to 4 digit number
X .... X .... X ....)	- digitized shot-point locations
Nnnnn	- new number following jump in sequence
X .... X	
.EØP	- insert EØP to terminate block

This sequence of messages and digitized locations is followed for each seismic line digitized. Note that while it is possible to break a traverse into two or more blocks to simplify checking, particularly if it contains a large number of locations, it is impossible to digitize two lines in one block because of the way the line number is provided.

A sample of digitized output is shown in Appendix 2. The first card image is the user's identifier for his digitizing job required by the Hewlett-Packard system. This will disappear when the file is written onto magnetic tape. The next card image is the file name, in this case
WEST BLACKALL
by which the file will be identified and located during the processing to follow. The next two are the graticule identifier,
MWEST BLACKALL
and the graticule dimensions,
G4x6. Twenty-four graticule points then follow and are terminated by a .EØP.

Following the graticule data block is the run data block containing the digitized locations of the seismic shot-points. The first card image contains the run identifier, the traverse number and label, in this case
R3101. WEST BLACKALL LINE WB1.
The next card image is the value of the first shot-point number,
N1
As no I identifier is present, the interval between consecutive shot-points is one. Eighty-five shot-points have been digitized, that is the shot-points range from number 1 to number 85. The block is terminated by a .EØP.

After digitizing all of the required seismic lines on the map, the file is terminated by a final EØP, i.e. two consecutive EØPs will have been inserted via the keyboard. Another map may then be digitized, or preferably the file is saved as a document within the Hewlett-Packard system. This will minimize accidental loss caused by overflow of the work space allotted to the GRADICON digitizer or failure of the system before transfer from temporary to permanent storage.

Files may be checked, edited, and concatenated before being written out in card-image form on magnetic tape for transfer to the Cyber 76.

For a quick and ready reference, a summary of the digitization procedure has been included in this report (Appendix 8).

5. PROGRAM DIGMAP

The primary aim of the program is to convert the digitizer output into station number, latitude, and longitude in a form suitable for retention in a digital data file. It can be used to process seismic traverses, ships' tracks, coastlines, photo-centre plots and other similar line information. A listing of the source program, execution deck, and a sample output printout are given in Appendices 3 to 5 respectively.

Before digitizer co-ordinates can be converted to geographic positions, it is necessary to determine four unknown parameters. These are the orientation of the map on the digitizer, differential paper shrinkage in the dyeline paper (two components), and skew in the digitizer table (Fig. 4). The first avoids the need to accurately position the map grid parallel to the digitizer axes, a difficult job even when great care is taken. The second and third allow for the paper shrinkage which is caused partly by the dyeline process itself and partly by the history of treatment of the map. The last allows for non-orthogonality of the digitizer axes, which can prove significant and, if left uncorrected, introduces systematic errors in the conversion process.

As the relation between the variables is non-linear, an iterative least-squares procedure is used within the program to solve for the variables. The method is based upon the technique described in Whittaker & Robinson (1944) and a more mathematical treatment is given in Appendix 9. The variable parameters are adjusted iteratively to reduce the residuals between the digitized graticule and its theoretical counterpart to a minimum in the least-squares sense. Ten iterations are computed and the values of the parameters and the mean and RMS residual are printed out at each iteration. The user may assess the stability of the solution, and if dissatisfied may take corrective action. Otherwise the final values are applied in the conversion from digitizer co-ordinates to latitude and longitude.

An estimate of the overall accuracy of the digitized data can be obtained from the differences between theoretical graticule and the digitized graticule after conversion to geographic co-ordinates. Any gross errors usually arise from an erroneous digitized value: either a mistake in digitizing or spurious data causing a decoding error. Systematic variation in the residuals of either latitude or longitude is most likely to be caused by incorrect identification of the projection used for the base map. However, an inadequate number of points in the graticule can cause instability in the iterative solution, resulting in poor definition of the variable parameters. A 3 by 3 graticule is the minimum desirable.

A significant advantage of the approach adopted is that, by and large, the effects of systematic errors are minimized. Folding of the map introduces errors that are averaged out via the shrinkage scaling factors. Uncertainty in the scale of the map is treated as the equivalent of extreme shrinkage; in fact a scale of 1:100 000 has been mistakenly input for a 1:250 000 map and the program has correctly identified the scale by calculating a scaling factor of 2.5 (Fig. 4). If the projection used in the map is unknown, adoption of Traverse Mercator often gives surprisingly small errors. Over small regions orthogonal projections differ mainly in scale between latitude and longitude, and again the scaling factor copes remarkably well. As long as there are enough points in the graticule to give a reasonable statistical estimate of the remaining errors, the user can decide whether or not the solution is accurate enough for his task.

No further use is made of the graticule data, once the four variable parameters and other ancilliary constants have been determined. Conversion of positions to geographic co-ordinates can then be carried out using these constants only. Each block of position data is processed, co-ordinates computed, a station number constructed from the parameters inserted manually, and the data saved in buffered form on a scratch file. Should there be more than 1440 stations in a single input block, the output is broken up into two or more blocks. Each block input initiates a new block on output. When all the input file has been processed, an index of the output file is created, and index and output blocks are copied out sequentially from the scratch file.

A word of caution is needed when DIGMAP is used to handle seismic traverse data. Each location is assigned a unique station number of the form SSLL.NNNN, where SS is an assigned survey number, LL is the line number, and NNNN is the shot-point number which is treated as sequential. By way of contrast a marine station number is of the form SS.DDHHMM where the part following the decimal point represents time in days, hours, and minutes. The differentiation in the format of the station number is important as both programs DIGMAP and TRAKMAP must correctly identify the data type to carry out their functions properly.

Appendix 5 gives a sample of the output printout of DIGMAP. First the input graticule data are listed, followed by the iterative solution to the variable parameters using those data. Then the errors at each of the graticule points are tabulated to give the user an appreciation of the accuracy of conversion and any systematic errors remaining. For each survey line processed a list is given of the station number constructed, the actual digitized values (U and V), and the converted positions. Following this is a message giving the number of stations saved for the line. With small numbers of points, a complete listing is desirable. The example given is a compressed printout where only the data from every tenth station are listed, to avoid excessive quantities of printout. If very large data files are handled it is best to "annihilate" the printout in which case only those messages needed for the user to be sure the process is working properly are listed.

Messages from the program are self-explanatory and are either informative or caused by errors in the input file. Errors nearly always result from incorrect manual input or problems in decoding the digitized data. The most common error message is

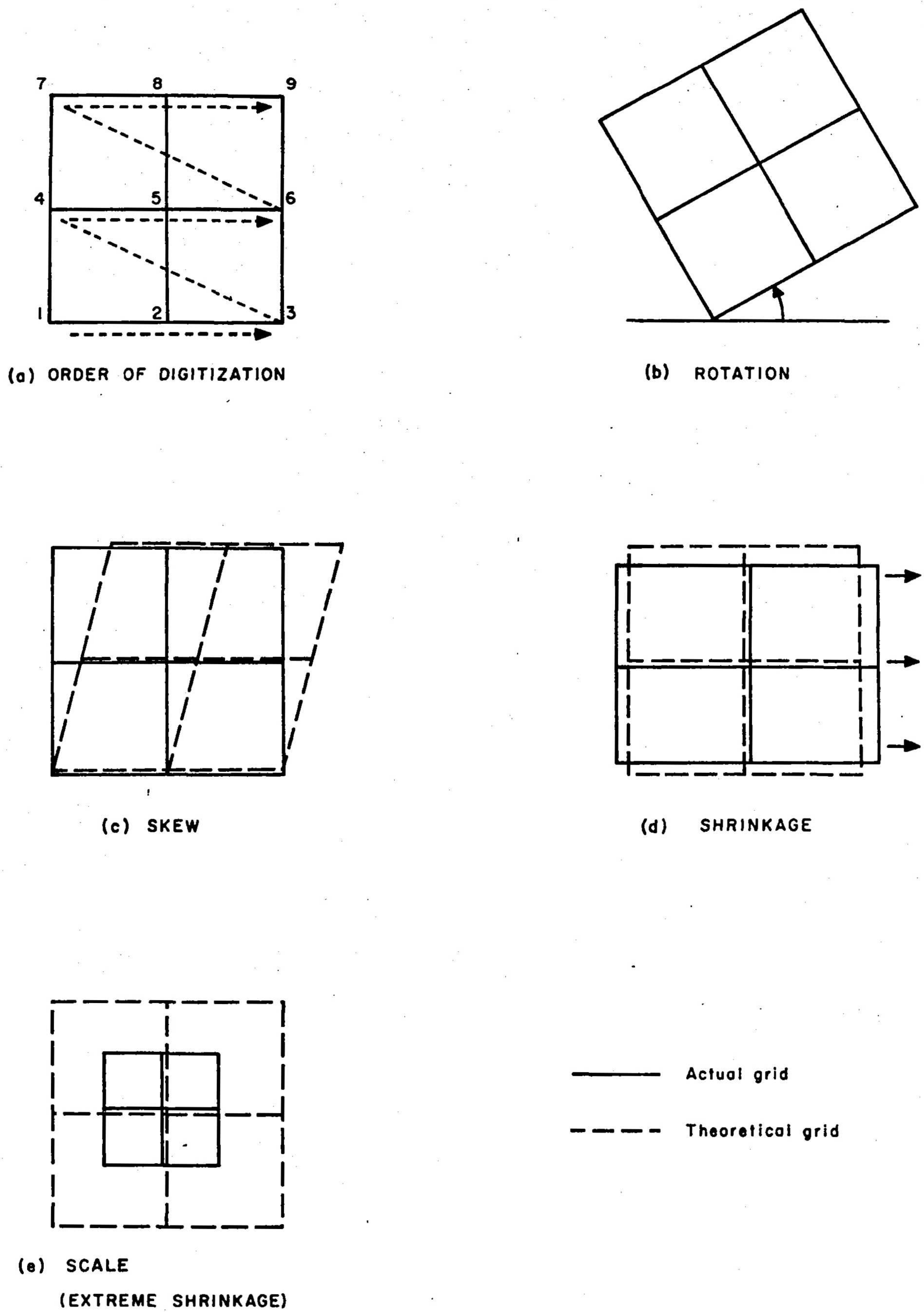
********** NON-NUMERIC INFORMATION IN RUNDATA AT KOUNT nn

followed by the card-image in which the error occurred. After location of the error, correction cards can be added to the edit file ready for the next run.

The converted data are output in buffered form in a format compatible with the survey data files used within the Marine Geophysics Group. This data file contains an index, together with one buffered record for each survey line.

A detailed description of the output file format can be found in the program documentation report by Whitworth (in prep.).

Fig. 4



PARAMETERS SOLVED FOR IN DIGMAP

Data Cards for Digmap: (See Appendix 4)

Card	Type	Format
1.	OUTPUT FILE LABEL	(8A10)
2.	*MAPGRID	(A10)
3.	MAP CARD - STANDARD CARD	(2(2A10,A4), A10, A2, 4(I3, F2.0))
4.	SPHEROID CARD - STANDARD CARD	(3A10, F10.0, F10.2, 2F5.0, F10.0, 2F5.0)
5.	PRINTOUT COMPRESSION CARD - OPTIONAL	(A10)
6.	INPUT FILE LABEL	(8A10)

Cards 2 to 6 are repeated for every map digitized.

Explanation of Cards:

1. OUTPUT FILE LABEL

This card is a free format label up to 80 characters in length.
e.g. GALILEE BASIN

2. *MAPGRID

This card and the following two cards cause the theoretical graticule corresponding with the digitized graticule to be calculated.

3. MAP CARD

This card contains the latitude and longitude limits of the digitized graticule, and has the form:

Description	Format	Columns	Example
Name of Map to be plotted	3A10	1-30	BMR Lake Galilee
Northern latitude boundary	(I3, F2.0)	61-65	2200
Southern latitude boundary	(I3, F2.0)	66-70	2230
Western longitude boundary	(I3, F2.0)	71-75	14545
Eastern longitude boundary	(I3, F2.0)	76-80	14645

4. SPHEROID CARD:

This card contains the information on the spheroidal parameters required to convert the X-Y co-ordinates to latitude and longitude. The standard spheroid card for the Transverse Mercator projection is given below. Other projections having slightly different card format can be found in Whitworth (in prep.).

Description	Format	Columns	Example
Name of Spheroid	3A10	1-30	Australian National Spheroid
Equatorial Radius (metres)	F10.0	31-40	6378160.0
Reciprocal of flattening	F10.2	41-50	298.25
Origin of zones (decimal degrees)	F 5.0	51-55	-183.
Width of zones (decimal degrees)	F 5.0	56-60	6.
Reciprocal of map scale	F10.0	61-70	100000.
Latitude spacing of digitized graticule (mins)	F 5.0	71-75	15.
Longitude spacing of digitized graticule (mins)	F 5.0	76-80	15.

5. PRINTOUT COMPRESSION CARD

This card is optional and is used to compress the output printout to avoid unnecessary printout for large data files. If this card is missing, all data will be output.

Two options are available:

a) *COMPRESS - causes every tenth station to be printed out
b) *ANNIHILATE - suppresses the printout for station data.

In both cases the grid data and the total stations saved are still printed out.

6. INPUT FILE LABEL

This card is an 80-character label which is used to locate the input file. The label on the card must be identical to the header card on the input file; otherwise the file will not be located.
e.g. BMR LAKE GALILEE.

If editing of the input file is required the INPUT FILE LABEL (Card 6) is replaced by a sequence of cards:

*EDITFILE
INPUT FILE LABEL
Edit Instructions
- - - - END OF SECTION FOR CYBER 76 - - - -

Edit instructions and explanation are given in Appendix 7.

6. PROGRAM TRAKMAP

This program is used to plot the seismic shot-point locations using the survey data file output from DIGMAP. The user can specify the scale and area to be covered by the map and the projection to be used. Only one projection may be used in each computer run, but a single map may be plotted at various scales within a run. The frequencies at which station symbols are plotted and station numbers posted, and their size, can be selected.

All stations within the file are checked by the program, and should two consecutive stations identifying numbers differ by more than a defined limit, the pen is lifted between the two locations. If the limit is set at zero, isolated station symbols are plotted, while if the limit is greater than the normal station number interval a continuous track is obtained. Thus individual stations or coastlines for example can be handled by the same program.

A standard station symbol is plotted each time the station number (converted to integer form) is divisible by the number supplied by the user. In this way, every station, each tenth station or any other frequency of plotting can be obtained. Similarly the station number can be posted at any frequency. However, posting is allowed only if the station symbol has already been plotted.

The user may specify a border zone around the map, outside which stations are completely ignored. Within the border, locations are used for two purposes: one is to allow a continuous track to be drawn to the edge of the map when one station is on and the other off the area being displayed; the other is to define the direction of traverse between two consecutive stations so that posting can be made perpendicular to the line automatically. This procedure gives satisfactory labelling in all but exceptional cases . even with a high station density along the traverse. In either case the border needs to be wider than the average station spacing.

Lastly the user has the option of over-riding the internally defined heights for symbols and posting, 0.04 and 0.07 inches respectively. In the former case the height supplied should be a multiple of four times the increment size of the plotter, the latter a multiple of seven times. This ensures the neatest symbols at any angle, consistent with the limitations of an incremental plotter. As the increment sizes on the CALCOMP 745 flat bed and 715 drum plotter are 0.0001 and 0.001 inches respectively, the limitation on the user is minor.

<u>Data Cards for Trakmap</u>: (see Appendix 6)

Card	Type	Format
1.	*MAPPLOT	(A10)
2.	TYPE CARD	(A10)
3.	MAP CARD	(2(2A10,A4),A10,A2,4(I3,F2.0))
4.	SPHEROID CARD	(3A10,F10.0,F10.2,2(F3.0,F2.0),F10.0,2F5.0)
5.	*TRACK	
6.	PLOT FREQUENCY CARD	(5I10,F10.1,2F10.2)
7.	INPUT FILE HEADER	(8A10)
8.	- - - END OF SECTION FOR CYBER 76 - - - - -	
9.	MAP TITLE CARD	(4A10,4A10)
10-18	Repeat of cards 1-9 for second map to be plotted	
19.	*ENDPLOT	

Cards 1-9 are repeated for each map to be plotted. The same map can be plotted at various scales or various plot and annotation frequencies, but only one projection can be used at each computer run.

Explanation of data cards:

1. *MAPPLOT

This card causes the MAPPLOT routine to be executed and draws a map graticule using the parameters from the following three cards.

2. TYPE CARD

This card is either *STANDARD MAP or *EXTENDED MAP. It is used to provide extra checks on required map and will cause job to abort if punching errors or unreasonable requests are made.

*STANDARD MAP indicates plot is equivalent in size to the standard 1:250 000 map sheets, approximately 17" by 24".

*EXTENDED MAP is used for any non-standard or large maps. Checks are made to ensure map fits on the flat-bed plotter, a maximum of 45" by 100".

3. MAP CARD

This card is similar to that for the DIGMAP program but instead of being the limits of the digitized graticules, it is for the limits of the graticule to be plotted and is not necessarily the same. It is of the form:

Description	Format	Columns	Example
Name of map to be plotted	(2A10,44)	1-24	NORTHERN EROMANGA BASIN
The map area, state	(2A10,A4)	25-48	QUEENSLAND
Identifying number for map	(A10,A2)	49-60	SF54
Northern latitude boundary	(I3,F2.0)	61-65	2000
Southern latitude boundary	(I3,F2.0)	66-70	2400
Western longitude boundary	(I3,F2.0)	71-75	14100
Eastern longitude boundary	(I3,F2.0)	76-80	14700

4. SPHEROID CARD

This card is the same as for the DIGMAP program. However the latitude and longitude spacing parameters now refer to the spacing of the regular graticule to be plotted. Any projection parameters may be used but they must correspond to the projection subroutine attached in the control cards (See Appendix 6). The most common projections are the Transverse Mercator, Simple Conic, and Lambert Conformal. The Transverse Mercator spheroid card is given in the data cards for DIGMAP. The Simple Conic and Lambert Conformal cards are identical to that for Transverse Mercator except for columns 51-60 where the latitudes of the two standard parallels replace the origin and width of zones.
i.e. Latitude of Northern standard parallel (deg. & mins) (F3.0,F2.0) 51-55

Latitude of Southern standard parallel (deg. & mins) (F3.0,F2.0) 56-60

5. *TRACK

This card causes the execution of the TRACK routine which plots the shot-point locations on the specified map base.

6. PLOT FREQUENCY CARD

This card provides the information on station and posting frequency and other plotting control: The format is:

			Columns
PLTFREQ	-	frequency of station symbol plotting (I10)	1-10
STNFREQ	-	frequency of station number posting (I10)	11-20
MAXINT	-	maximum station number interval (I10) before pen lifted	41-50
BORDER	-	border needed in minutes of arc (F10.0)	51-60
CHARNEW	-	height of characters posted in inches (optional) (F10.2)	61-70
SYMBNEW	-	height of symbols posted in inches (optional) (F10.2)	71-80

If either PLTFREQ or STNFREQ are left blank (i.e. zero) then no symbols or numbers are plotted. In the sample deck given PLTFREQ is 1, that is every station is plotted, while STNFREQ is 10, so every tenth shot-point is labelled. With MAXINT blank (i.e. zero) only the symbols are plotted and there is no track between them. The BORDER has been left blank (i.e. zero) as there are no data outside the map area.

7. INPUT FILE HEADER

This is the header label of the input file and must be identical to the label used in program DIGMAP when producing the output file of shot-point locations e.g. GALILEE BASIN

8. END-OF-SECTION CARD

This terminates search of the input document. If any other files are needed the appropriate header cards must all appear in front of the E-O-S in the order the files occur on the input document as search is strictly sequential.

9. MAPTILE CARD

This card contains the map title to be drawn on the map in two forty column blocks. The title should be centred on columns 20-21 and 60-61 for aesthetic reasons. e.g. NORTHERN EROMANGA BASIN
SHOTPOINT LOCATIONS

7. APPLICATIONS

The major difference between the computer-based approach discussed in this report and manual methods is the creation of a digital data file containing shot-point numbers, latitudes, and longitudes. Data in this form can be readily retrieved for use in a variety of projects. The simplest is perhaps the preparation of integrated shot-point location maps as shown in Figure 5. This is a one-third size plotter reduction of all seismic work falling within the MUTTABURRA 1:250 000 map sheet. Similar maps can be prepared for a particular area of interest, given the data in digital form, at any suitable scale and projection.

A straightforward extension is the creation of a digital file of shot-point numbers and seismic reflection times to interpreted horizons and merging of this file with the geographic location files. Techniques and programs exist within the Marine Geophysics Group for the conversion of digitized seismic sections to time-depth data, and resampling to regular intervals, in this case shot-point numbers, in basically the same format as the location data (Tilbury & Karner, in prep.). Merging of the two data files is a minor task.

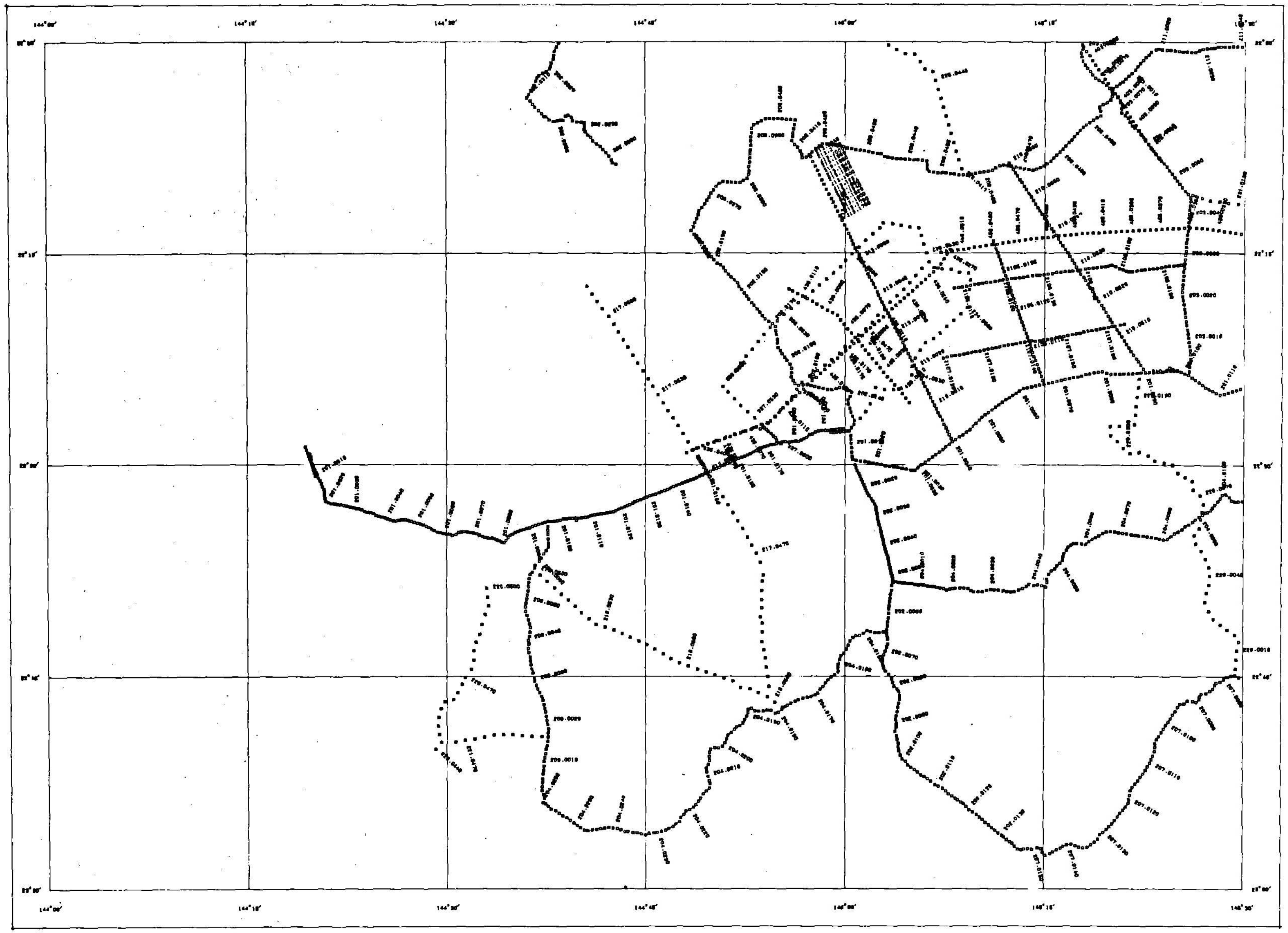
Contouring on a particular horizon or isochrons for specified stratigraphic intervals requires little further development of techniques most of which are already understood. Only two difficulties can be foreseen. One is when a horizon does not exist, or conversely has not been interpreted; how does one cope with lack of information? The other is when the horizon is so disturbed that computer contouring cannot adequately handle the information. In this case a base map can be produced with the required data values posted upon it which can then be hand contoured.

The conversion of seismic time-depths to true depths and thicknesses involves the application of velocity functions. This is quite tedious when done manually, for even simple functions, and rapidly becomes impracticable for complex varying functions. With a clear definition of an acceptable protocol to be observed when certain horizons are missing, interpolation of the functions between velocity determinations and computation of the converted time-depths presents little difficulty. Plotting of the converted data is basically the same task as when plotting time data.

PLOTTED 30/09/75

1:250 000

MUTTABURRA



AUSTRALIAN NATIONAL SPHEROID
TRANSVERSE MERCATOR PROJECTION
ZONE 55 (AUSTRALIA SERIES)

MUTTABURRA

MUTTABURRA

SHOTPOINT LOCATIONS

Fig. 5

Record No. 1976/65

F55/B3-118.A

8. REFERENCES

* A.D.P. Group, 1974a - Gradicon - HP2100 Digitizing System. HP2100 Computer System Documentation Report.

* A.D.P. Group, 1974b - Terminal Operating System, TEROS. HP2100 Computer System Documentation Report.

INSTRONICS LTD, 1975 - Gradicon: Graphic to Digital Convertor. Operator's Manual.

TILBURY, L.A. & KARNER, G. (in prep.) - A guide to digitizing Stripchart Profiles and Seismic Sections. Bur. Miner. Resour. Rec.

WHITTAKER, E.T. & ROBINSON, G., 1944 - The Calculus of observations: treatise on numerical mathematics. Blackie, London (4th ed.).

* WHITWORTH, R. (in prep.) - A guide to the Marine Group processing system. Computer Program Documentation Report.

* References with asterisks are not published reports but are available in computer printout form on request.

APPENDIX 1 : DIGITIZER QUESTIONS AND ANSWERS

```
 *LG,GRADI
GRADI ON


                ** GRADICON-HP2100 DIGITIZING SYSTEM **
                                                      REV 2 -29/4/1975

DIGITIZER DATA ID?
!!LT
XY OR X OR Y CO-ORDINATES?
!!XY
F2 OPTION?
!!0
POINT MODE OR INCREMENTAL MODE?
!!POINT
PRINT DATA?
!!YES
READY - START DIGITISING
     1 LT
```

After typing .END on Gradicon keyboard computer replies with:

```
*EOT
OUTPUT ON MT PF OR MAKE SCRATCH FILE?
!!SCR
REMEMBER TO SAVE OR OUTPUT YOUR DATA!
 *SF,800,NAME
NAME SAVED
LENGTH: 1 RECORDS,  100 WORDS
```

```
PK
WEST BLACKALL
MWEST BLACKALL
G4X6
X+0857.45 Y+0059.76 X+1026.98 Y+0060.92 X+1195.80 Y+0061.12 X+1365.67 Y+0061.59
X+0857.38 Y+0244.03 X+1026.00 Y+0245.04 X+1148.71 Y+0245.19 X+1365.60 Y+0246.17
X+0856.76 Y+0429.12 X+1025.92 Y+0429.74 X+1195.16 Y+0430.04 X+1365.44 Y+0430.97
X+0856.64 Y+0614.04 X+1025.73 Y+0614.86 X+1195.34 Y+0615.42 X+1365.38 Y+0615.98
X+0855.81 Y+0798.02 X+1025.87 Y+0799.56 X+1194.96 Y+0799.41 X+1365.36 Y+0800.76
X+0856.06 Y+0983.22 X+1025.50 Y+0984.53 X+1195.85 Y+0984.92 X+1365.34 Y+0984.67
.EOP
R3101  WEST BLACKALL LINE WB1
N1
X+1358.84 Y+0706.01 X+1352.36 Y+0706.57 X+1346.54 Y+0706.89 X+1340.42 Y+0707.83
X+1334.56 Y+0708.32 X+1328.08 Y+0709.31 X+1322.52 Y+0709.87 X+1316.93 Y+0710.84
X+1310.99 Y+0711.43 X+1304.29 Y+0712.25 X+1299.59 Y+0712.52 X+1294.25 Y+0713.61
X+1289.07 Y+0714.14 X+1284.43 Y+0714.48 X+1279.44 Y+0715.36 X+1273.34 Y+0715.77
X+1267.32 Y+0716.53 X+1261.94 Y+0717.23 X+1257.55 Y+0718.19 X+1252.30 Y+0718.73
X+1245.59 Y+0719.59 X+1240.67 Y+0719.93 X+1235.11 Y+0720.54 X+1230.16 Y+0720.97
X+1225.31 Y+0722.13 X+1219.38 Y+0722.51 X+1214.27 Y+0723.33 X+1208.69 Y+0723.76
X+1204.15 Y+0723.98 X+1200.53 Y+0726.74 X+1195.90 Y+0729.10 X+1190.97 Y+0732.16
X+1186.61 Y+0734.23 X+1182.21 Y+0736.81 X+1177.47 Y+0739.52 X+1172.85 Y+0742.44
X+1168.50 Y+0744.74 X+1163.56 Y+0747.54 X+1159.22 Y+0750.34 X+1154.62 Y+0752.29
X+1149.46 Y+0756.64 X+1144.84 Y+0758.91 X+1140.61 Y+0761.87 X+1136.26 Y+0764.70
X+1131.47 Y+0767.60 X+1126.85 Y+0770.43 X+1121.79 Y+0773.02 X+1116.74 Y+0775.66
X+1112.35 Y+0778.71 X+1106.26 Y+0781.53 X+1101.95 Y+0784.23 X+1097.45 Y+0787.24
X+1092.67 Y+0790.00 X+1088.07 Y+0792.75 X+1083.49 Y+0795.47 X+1079.32 Y+0797.86
X+1074.60 Y+0800.57 X+1070.56 Y+0803.41 X+1066.02 Y+0805.56 X+1061.07 Y+0808.17
X+1056.18 Y+0810.75 X+1051.66 Y+0813.72 X+1047.15 Y+0816.86 X+1042.24 Y+0819.27
X+1037.61 Y+0822.06 X+1032.86 Y+0825.39 X+1027.78 Y+0828.22 X+1023.55 Y+0830.45
X+1018.94 Y+0833.53 X+1013.50 Y+0836.48 X+1008.94 Y+0839.31 X+1004.47 Y+0842.85
X+0999.86 Y+0844.49 X+0994.93 Y+0847.71 X+0990.00 Y+0850.03 X+0985.77 Y+0853.15
X+0980.92 Y+0855.83 X+0976.69 Y+0858.16 X+0972.31 Y+0861.32 X+0967.98 Y+0863.80
X+0963.32 Y+0866.44 X+0958.73 Y+0868.92 X+0953.93 Y+0872.02 X+0949.25 Y+0874.55
X+0944.30 Y+0877.58
.EOP
R3102  BLACKALL LINE WB2
I6
N1
X+0935.73 Y+0141.76
N3
X+0938.04 Y+0141.75 X+0946.32 Y+0142.20 X+0955.04 Y+0142.43 X+0963.64 Y+0143.04
X+0971.65 Y+0143.11 X+0980.63 Y+0143.49 X+0988.40 Y+0143.34 X+0996.59 Y+0143.39
X+1004.45 Y+0143.24 X+1012.65 Y+0143.12 X+1020.88 Y+0143.23 X+1029.03 Y+0142.94
X+1037.68 Y+0142.87 X+1045.74 Y+0143.10 X+1053.50 Y+0142.67 X+1061.69 Y+0142.49
X+1069.70 Y+0142.58 X+1077.76 Y+0141.99 X+1085.57 Y+0142.73 X+1093.30 Y+0142.37
X+1102.16 Y+0142.30 X+1110.53 Y+0142.34 X+1118.32 Y+0142.15 X+1126.46 Y+0142.10
X+1134.73 Y+0141.89 X+1142.66 Y+0141.83 X+1150.68 Y+0141.80 X+1158.56 Y+0141.82
X+1166.66 Y+0141.59 X+1174.67 Y+0141.85 X+1183.01 Y+0141.50 X+1191.14 Y+0141.36
X+1199.08 Y+0141.64 X+1206.97 Y+0141.29 X+1210.42 Y+0140.34 X+1214.91 Y+0140.82
X+1223.08 Y+0141.36 X+1231.15 Y+0141.33 X+1239.18 Y+0141.44 X+1247.45 Y+0141.17
X+1256.06 Y+0141.17 X+1263.72 Y+0140.67 X+1271.69 Y+0141.02 X+1279.92 Y+0141.27
X+1287.88 Y+0140.62 X+1295.64 Y+0140.71 X+1303.69 Y+0139.43 X+1311.57 Y+0140.17
X+1319.80 Y+0140.27 X+1327.95 Y+0140.23 X+1336.52 Y+0140.40 X+1344.79 Y+0139.97
```

```
X+1352.78 Y+0139.81 X+1360.95 Y+0140.05
.EOP
R3104  BLACKALL LINE WB4
I6
N1
X+0935.29 Y+0317.98
N7
X+0943.22 Y+0319.18
N15
X+0954.26 Y+0321.16 X+0962.25 Y+0322.31 X+0969.90 Y+0323.28 X+0978.10 Y+0325.01
X+0986.35 Y+0326.13 X+0994.14 Y+0327.36 X+1002.26 Y+0328.96 X+1010.58 Y+0330.41
X+1018.71 Y+0331.69 X+1026.84 Y+0333.03 X+1035.38 Y+0334.54 X+1043.28 Y+0336.11
X+1051.23 Y+0336.63 X+1059.28 Y+0338.31 X+1067.46 Y+0340.01 X+1075.74 Y+0340.96
X+1084.24 Y+0342.07 X+1091.49 Y+0343.53 X+1099.46 Y+0344.55 X+1106.86 Y+0345.50
X+1114.78 Y+0347.32 X+1122.60 Y+0348.59 X+1130.55 Y+0349.28 X+1137.97 Y+0350.91
X+1145.96 Y+0351.19 X+1153.48 Y+0352.63 X+1161.91 Y+0354.20 X+1169.08 Y+0355.33
X+1177.70 Y+0357.00 X+1185.72 Y+0357.67 X+1193.56 Y+0357.73 X+1202.00 Y+0358.43
X+1210.50 Y+0359.20 X+1218.16 Y+0360.10 X+1226.36 Y+0360.51 X+1234.64 Y+0360.97
X+1242.71 Y+0361.75 X+1250.07 Y+0361.87 X+1259.22 Y+0363.10 X+1266.42 Y+0363.90
X+1274.71 Y+0363.91 X+1282.20 Y+0364.68 X+1290.41 Y+0364.94 X+1298.88 Y+0365.94
X+1306.58 Y+0366.18 X+1314.38 Y+0366.55 X+1322.39 Y+0367.20 X+1330.78 Y+0367.94
X+1338.63 Y+0368.98 X+1346.74 Y+0369.31 X+1354.34 Y+0369.18 X+1363.24 Y+0370.29
N326
X+1369.27 Y+0369.86
.EOP
.EOP
```

SAMPLE DIGITIZER OUTPUT

```
      PRUGRAM DIGMAP(TAPE10,TAPE40,TAPE20,INPUT,TAPE60=INPUT,OUTPUT)

C**        THIS PROGRAM CONVERTS DIGITISED DATA FROM THE GRADICON OR
C**        D-MAC INTO STATION NUMBER, LATITUDE AND LONGITUDE.
C**        IT CAN BE USED TO PLOT SHIPS" TRACKS, SEISMIC TRAVERSES
C**        AND COASTLINES
C**        DATA IS OUTPUT IN BUFFERED FORM USING THE STANDARD FORMAT
C**        FOR MARINE SURVEY DATA FILES.
C**
C**        SUBROUTINES REQUIRED "MAPGRID","READIN","MAPDATA",
C**           "SCALER","MAPERR","EXTRACT","RUNDATA","INDEXER"

      DIMENSION NAME(8)
      COMMON/MASK/ MASK,NBITS(10)
      COMMON/DATAPLT/ SIZE,MAPNAME(3),MAPAREA(3),MAPNUM(2),MAPTITL(8)
      COMMON/XYCOORD/ SFEROID(3),MAPTYPE(9),SCALE,RLATINT,RLONINT
      COMMON/INPUT/ NWORD(8),NERRORS,GRIDU(20,20),GRIDV(20,20)
      COMMON/SCALE/ XSCALE,YSCALE,XSHIFT,YSHIFT,USHIFT,VSHIFT
      COMMON/ROTATE/ XSINROT,XCOSROT,YSINROT,YCOSROT,SINSKEW,COSSKEW
      COMMON/MAP/ L,M,GRIDLAT(20),GRIDLON(20),GRIDX(20,20),GRIDY(20,20)
      COMMON/RUNDATA/ RUNNAME(8),KOUNT,FOTO(200),U(200),V(200)
      COMMON/INDEX/LABEL(8),NSEGS,NSUM,ERRSUM(11),
     1   INDEX(8,200),STNSUM(200),ST(3,200),NERROR(11,200)
      COMMON/SEGMENT/SEGMENT(8),ISTNS,T(8),ERROR(11),STNDATA(12,1440)
      COMMON/CONST/MTOUT,MTSCR,LUNDOC,IBLANK,DUBIOUS,UNKNOWN,IDATE
      DATA (MTOUT=10),(MTSCR=20),(LUNDOC=40),(IBLANK=10H          )
      DATA (DUBIOUS=1.0E9),(UNKNOWN=1.0E10),(MASK=77B)
      DATA(IFORM =6H(8A10))
      DATA (NBITS=-54,-48,-42,-36,-30,-24,-18,-12,-6,0)

      CALL ERRSET(UU,1000)
      CALL TODAY(IDATE)
      REWIND LUNDOC   $   REWIND MTOUT     $   REWIND MTSCR

C*         READ IN OUTPUT FILE LABEL
      READ 20, LABEL
      LABEL(8) = IDATE
C*         READ IN METHOD, IF EOF END PROCESSING
   10 READ 20, METHOD
   20 FORMAT(8A10)
      IF (EOF(60))  200,30

C*         CALL MAPGRID TO SET UP LATITUDE AND LONGITUDE ARRAYS
   30 IF (METHOD.EQ.10H*MAPGRID  )  60,40
   40 PRINT 50
   50 FORMAT(/,10X,10(1H*),*  PROCESSING STOPPED AS NEW MAPGRID CARD CAN
     1NOT BE FOUND*)
      GO TO 200

   60 CALL MAPGRID

C*         READ NAME, IF *COMPRESS - COMPRESS PRINTOUT
C*                    IF *ANNIHILATE - SUPPRESS PRINTOUT
C*         LOCATE INPUT FILE, IF NOT FOUND STOP
      ILIST = 1    $   READ 20, NAME
      IF (NAME(1).EQ.10H*COMPRESS ) 61,63
   61 ILIST = 10    $   READ 20, NAME

      GO TO 67
   63 IF (NAME(1).EQ.10H*ANNIHILAT) 65,67
   65 ILIST = 1000000    $   READ 20, NAME
   67 CALL GETFILE(LUNDOC,NAME,2,NFLAG,60)
      IF (NFLAG.EQ.1)  STOP
      NERRORS= 0

C*         READ CARD-IMAGE FROM INPUT FILE
   70 CALL READIN(LUNDOC,IFORM,8,NWORD,IFEOF)
      GO TO (90,10)  IFEOF

   90 NCHAR = SHIFT(NWORD(1),-54).AND.MASK

C*         IF CARD IS MAPCARD, CALL ROUTINES TO SET UP GRID VERTICES,
C*         CORRECT FOR ROTATION AND SKEW OF GRATICULES, AND COMPARE
C*         THEORETICAL AND DIGITISED GRATICULES FOR ESTIMATE OF ERRORS.
      IF (NCHAR.EQ.1HM)  100,110
  100 CALL MAPDATA
      CALL SCALER
      CALL MAPERR
      GO TO 70

C*         IF CARD IS FILECARD, EXTRACT FILE NAME
  110 IF (NCHAR.EQ.1HF)  120,130
  120 CALL EXTRACT(79,NWORD,2,NAME,1)
      NAME(8) = IDATE
      GO TO 70

C*         IF CARD IS RUNCARD, CALL ROUTINES TO CONVERT DIGITISED DATA
C*         INTO STATION NUMBER, LATITUDE AND LONGITUDE, THEN SAVE DATA
  130 IF (NCHAR.EQ.1HR)  140,150
  140 CALL RUNDATA(ILIST)
      CALL INDEXER(MTSCR)
      GO TO 70

C*         PRINT MESSAGE IF ILLEGAL DATA BLOCK, SKIP TO NEXT EOF AND
C*         RESUME PROCESSING
  150 PRINT 160, NWORD
  160 FORMAT(/,10X,10(1H*),* UNRECOGNISED INITIAL CHARACTER AT BEGINNING
     1 OF DATA BLOCK*,/,20X,1H*,8A10,1H*)
      NERRORS = NERRORS+1
  170 CALL READIN(LUNDOC,IFORM,1,DUMMY,IFEOF)
      GO TO (170,70)  IFEOF

C*         AT END OF PROCESSING CALL OUTAPE TO PRODUCE FINAL OUTPUT
C*         IN REQUIRED FORMAT
  200 CALL OUTAPE(MTOUT)

      PRINT 210
  210 FORMAT(///,10X,10(1H$),10X,*END OF PROCESSING*)

      END
```

SOURCE PROGRAM DIGMAP

SUBROUTINE MAPGRID 76/76 OPT=1 FTN 4.4+R401 07/04/76 15.40.59 PAGE 1

```
      SUBROUTINE MAPGRID
C**        THIS SUBROUTINE COMPUTES THE LATITUDE AND LONGITUDE GRID
C**        VALUES USING THE LIMITS AND INTERVALS GIVEN ON THE MAP
C**        NAME AND SPHEROID CARDS, THE THEORETICAL X-Y COORDINATES
C**        OF THESE GRID VALUES ARE ALSO COMPUTED
C**
C**        SUBROUTINE REQUIRED "XYCOORD","MAPZONE"

      COMMON/DATAPLT/ SIZE,MAPNAME(3),MAPAREA(3),MAPNUM(2),MAPTITL(8)
      COMMON/MAP/ L,M,GRIDLAT(20),GRIDLON(20),GRIDX(20,20),GRIDY(20,20)
      COMMON/MAPPLOT/ TLAT,BLAT,WLONG,ELONG,SINROT,COSROT,XL,YB,XR,YT
      COMMON/XYCOORD/ SFEROID(3),MAPTYPE(9),SCALE,RLATINT,RLONINT

      TIMEINT = SECOND(UU)
      PRINT 20, TIMEINT
   20 FORMAT(1H1,///,10X,*DIGITISATION OF MAP COMMENCED*,F9.1,* SEC*,//)

C*         CALL MAPZONE TO READ MAP CARD AND ESTABLISH LIMITS OF MAP
      CALL MAPZONE

C*        CALL XYCOORDS TO SET UP CONSTANTS NEEDED LATER
      CALL XYCOORD(U,U,U,U)

C*         SET UP LONGITUDE GRID VALUES, INCLUDING EDGES OF MAP
      NERROR =0
      L = (ELONG-WLONG+0.0001)/RLONINT+1
      IF (L.LE.20)  GO TO 40
      NERROR = 1   $   GO TO 60
   40 DO 50   I=1,L
      GRIDLON(I) = WLONG+(I-1)*RLONINT
   50 CONTINUE

C*         SET UP LATITUDE GRID VALUES, INCLUDING EDGES OF MAP
   60 M = (BLAT-TLAT+0.0001)/RLATINT+1
      IF (M.LE.20)  GO TO 80
      NERROR = 1   $   GO TO 100
   80 DO 90   J=1,M
      GRIDLAT(J) = BLAT-(J-1)*RLATINT
   90 CONTINUE

C*         WRITE ERROR MESSAGE THAT LAT - LONG GRID TOO BIG AND STOP
  100 IF (NERROR.EQ.0)  GO TO 130
      PRINT 120, L,M
  120 FORMAT(10X,10(1H*),10X,I5,* X*,I5,* LATITUDE - LONGITUDE GRID TOO
     1BIG*)
      CALL ABORT

C*         DETERMINE X-Y COORDINATES OF LATITUDE-LONGITUDE GRID
  130 DO 150 I=1,L
      DO 140 J=1,M
      CALL COORDS(GRIDLAT(J),GRIDLON(I),GRIDX(I,J),GRIDY(I,J))
  140 CONTINUE
  150 CONTINUE

      RETURN
```

SUBROUTINE MAPERR 76/76 OPT=1 FTN 4.4+R401 07/04/76 15.40.59 PAGE 1

```
      SUBROUTINE MAPERR
C**        THIS SUBROUTINE COMPARES THE THEORETICAL AND DIGITISED
C**        GRATICULES AFTER CORRECTION FOR ORIENTATION OF MAP ON
C**        DIGITISER, DIFFERENTIAL SHRINKAGE OF PAPER, AND SKEW OF
C**        DIGITISER OR MAP, A TABLE IS OUTPUT OF THE ESTIMATES OF
C**        THE DIGITISING ERRORS
C**
C**        SUBROUTINE REQUIRED "XYCOORD"

      COMMON/INPUT/ NWORD(8),NERRORS,GRIDU(20,20),GRIDV(20,20)
      COMMON/MAP/ L,M,GRIDLAT(20),GRIDLON(20),GRIDX(20,20),GRIDY(20,20)
      COMMON/SCALE/ XSCALE,YSCALE,XSHIFT,YSHIFT,USHIFT,VSHIFT
      COMMON/DATAPLT/ SIZE,MAPNAME(3),MAPAREA(3),MAPNUM(2),MAPTITL(8)
      COMMON/ROTATE/ XSINROT,XCOSROT,YSINROT,YCOSROT,SINSKEW,COSSKEW

      TIMEINT = SECOND(UU)
      PRINT 10, MAPNAME,TIMEINT
   10 FORMAT(1H1,///,10X,*ESTIMATE OF ERRORS IN DIGITISING   *,1H*,3A10,
     1 1H*,*  FROM GRATICULE VALUES   -   COMMENCED*,F10.1,* SEC*,//,
     2 24X,*I    J*,6X,*LAT*,7X,*DLAT*,6X,*LONG*,6X,*DLONG*,/)

      SUMLAT = SUMLAT2 = SUMLON = SUMLON2 = 0.0
      DO 40  J=1,M
      LATD = GRIDLAT(J)+0.00083  $  RLATM =(GRIDLAT(J)-LATD)*60.0
      DO 30  I=1,L
      LONGD = GRIDLON(I) + 0.00083  $  RLONGM = (GRIDLON(I)-LONGD)*60.0
      UU = GRIDU(I,J)-USHIFT    $   VV = GRIDV(I,J)-VSHIFT
      UU = UU+VV*SINSKEW    $    VV = VV*COSSKEW
      X = XCOSROT*UU - XSINROT*VV + XSHIFT
      Y = YSINROT*UU + YCOSROT*VV + YSHIFT
      CALL POSITN(RLAT,RLONG,X,Y)
      DLAT=(RLAT-GRIDLAT(J))*60.0  $  DLONG=(RLONG-GRIDLON(I))*60.0
      SUMLAT = SUMLAT+DLAT    $ SUMLAT2 = SUMLAT2+DLAT**2
      SUMLON = SUMLON+DLONG    $    SUMLON2 = SUMLON2+DLONG**2
      PRINT 20, I,J,LATD,RLATM,DLAT,LONGD,RLONGM,DLONG
   20 FORMAT(20X,2I5,2(I7,F4.0,* *,F8.3,* *) )
   30 CONTINUE
      PRINT 35
   35 FORMAT(10X)
   40 CONTINUE

C*         COMPUTE AND PRINT MEAN AND SD OF LAT AND LONG ERRORS
      COUNT = L*M
      AVGELAT = SUMLAT/COUNT    $    AVGELON = SUMLON/COUNT
      SDLAT = SQRT(SUMLAT2/COUNT-AVGELAT**2)
      SDLON = SQRT(SUMLON2/COUNT-AVGELON**2)

      PRINT 50, AVGELAT,AVGELON,SDLAT,SDLON
   50 FORMAT(/,36X,*MEAN*,2(F10.3,*"*,10X),/,38X,*SD*,2(F10.3,*"*,10X) )

      RETURN

      END
```

DIGMAP SUBROUTINES : MAPGRID AND MAPERR

```
SUBROUTINE MAPDATA    76/76    OPT=1                    FTN 4.4+R401       07/04/76  15.40.59        PAGE     1

              SUBROUTINE MAPDATA

      C**          THIS SUBROUTINE EXTRACTS THE DIGITISED GRATICULE VALUES,
      C**          CHECKS DATA FOR CONSISTENCY AND STORES GRID VALUES IN INCHES
      C**          IN ARRAYS "GRIDU" AND "GRIDV"
      C**
      C**          SUBROUTINE REQUIRED "EXTRACT","READIN","XYCODE"

            DIMENSION LABEL(3)
            COMMON/INPUT/ NWORD(8),NERRORS,GRIDU(20,20),GRIDV(20,20)
            COMMON/MASK/ MASK,NBITS(10)
            COMMON/MAP/ L,M,GRIDLAT(20),GRIDLON(20),GRIDX(20,20),GRIDY(20,20)
            COMMON/DATAPLT/ SIZE,MAPNAME(3),MAPAREA(3),MAPNUM(2),MAPTITL(8)
            COMMON/CONST/ MTOUT,MTSCR,LUNDOC,IBLANK,DUBIOUS,UNKNOWN,IDATE
            DATA(IFORM =6H(8A10))

      C*           CHECK MAPNAME WITH LABEL - IF DIFFERENT PRINT MESSAGE
            CALL EXTRACT(30,NWORD(1),2,LABEL(1),1)
            DO 70  K=1,3
            IF (MAPNAME(K).EQ.LABEL(K))  70,80
         70 CONTINUE
            GO TO 100

         80 PRINT 90, MAPNAME,LABEL
         90 FORMAT(/,10X,10(1H*),* ERROR IN MAPSHEET LABEL - SHOULD BE      *,
           1 1H*,3A10,1H*,/,46X,*NAME INPUT       *,1H*,3A10,1H*)
            NERRORS = NERRORS+1

      C*           READ CARD IMAGE FROM INPUT FILE
        100 CALL READIN(LUNDOC,IFORM,8,NWORD,IFEOF)
            GO TO (120,100)  IFEOF
        120 NCHAR = SHIFT(NWORD(1),-54).AND.MASK
            IF (NCHAR.EQ.1RG)  GO TO 150
            PRINT 140, NWORD
        140 FORMAT(/,10X,10(1H*),* UNRECOGNISED INITIAL CHARACTER IN MAPGRID I
           1NFORMATION - SHOULD BE GRID SIZE STARTING WITH "G"*,/,
           2 20X,1H*,8A10,1H*)
            NERRORS = NERRORS+1

      C*           EXTRACT GRID DIMENSIONS (LXM)
        150 IMAX = JMAX = KOUNT = 0
            DO 210  K=2,10
            K1 = K+1
            NCHAR = SHIFT(NWORD(1),NBITS(K)).AND.MASK
            IF (NCHAR.EQ.1RX)  220,190
        190 IF (NCHAR.EQ.1R )  210,200
        200 IMAX = IMAX*10+(NCHAR-1R0)
        210 CONTINUE
        220 DO 240 K=K1,10
            NCHAR = SHIFT(NWORD(1),NBITS(K)).AND.MASK
            IF (NCHAR.EQ.1R )  240,230
        230 JMAX = JMAX*10+(NCHAR-1R0)
        240 CONTINUE

      C*           CHECK IF GIVEN GRID VALUES EQUAL TO CALCULATED GRID VALUES
      C*             - IF NOT PRINT MESSAGE
            IF (IMAX.NE.L.OR.JMAX.NE.M)  250,270

        250 PRINT 260, IMAX,JMAX,L,M
        260 FORMAT(/,10X,10(1H*),I10,* X*,I3,* MAPGRID VERTICES SAID TO BE PRE
           1SENT - THERE SHOULD BE*,I5,* X*,I3)
            NERRORS = NERRORS+1

      C*           EXTRACT X-Y COORDS OF GRATICULE
      C*           STORE VALUES IN GRIDU AND GRIDV IN INCHES
        270 PRINT 280
        280 FORMAT(///,17X,*COUNT*,7X,*VERTEX*,7X,*U*,9X,*V*,/)
        290 CALL READIN(LUNDOC,IFORM,8,NWORD,IFEOF)
            GO TO (310,380)  IFEOF
        310 CALL XYCODE(UU,VV,NWORD,IFERROR,IFEND)
            KOUNT = KOUNT+1
            JMAX = (KOUNT-1)/L+1    $    IMAX = KOUNT-L*(JMAX-1)
            GO TO (360,320) IFERROR
        320 PRINT 330, NWORD
        330 FORMAT(/,10X,10(1H*),* NON-NUMERIC INFORMATION IN MAPGRID DATA*,/,
           1 20X,1H*,8A10,1H*)
            NERRORS = NERRORS+1
            GRIDU(IMAX,JMAX) = GRIDV(IMAX,JMAX) = UNKNOWN
            GO TO(310,290) IFEND

        360 PRINT 370, KOUNT,IMAX,JMAX,UU,VV
        370 FORMAT(10X,2I10,I5,2F10.2)
            GRIDU(IMAX,JMAX) = UU/2.54
            GRIDV(IMAX,JMAX) = VV/2.54
            GO TO(310,290) IFEND

      C*           IF INSUFFICIENT GRID VALUES FOR CALCULATED GRID PRINT MESSAGE
        380 IF (IMAX.NE.L.OR.JMAX.NE.M)  390,410
        390 PRINT 400, IMAX,JMAX,L,M
        400 FORMAT(/,10X,10(1H*),I10,* X*,I5,* MAPGRID VERTICES DIGITISED - TH
           1ERE SHOULD BE*,I5,* X*,I3)
            NERRORS = NERRORS+1

        410 RETURN

            END
```

DIGMAP SUBROUTINE : MAPDATA

```
      SUBROUTINE SCALER

C**       THIS SUBROUTINE COMPUTES AN ITERATIVE LEAST SQUARES SOLUTION
C**       OF FOUR PARAMETERS (XSCALE,YSCALE,ROTATION,SKEW) USING THE
C**       METHOD OUTLINED BY WHITTAKER,E.T. AND ROBINSON,G. ,1940
C**       "THE CALCULUS OF OBSERVATIONS: A TREATISE ON NUMERICAL MATHS"
C**
C**       SUBROUTINE REQUIRED "MATINV"

      DIMENSION A(4,4),B(4)
      COMMON/INPUT/ NWORD(8),NERRORS,GRIDU(20,20),GRIDV(20,20)
      COMMON/SCALE/ XSCALE,YSCALE,XSHIFT,YSHIFT,USHIFT,VSHIFT
      COMMON/ROTATE/ XSINROT,XCOSROT,YSINROT,YCOSROT,SINSKEW,COSSKEW
      COMMON/MAP/ L,M,GRIDLAT(20),GRIDLON(20),GRIDX(20,20),GRIDY(20,20)
      DATA(EPSILON=1.0E-10)

C*        COMPUTE MEAN VALUES AS LOCAL ORIGIN (TO KEEP NUMBERS SMALL)
      COUNT = L*M
      SUMX = SUMY = SUMU = SUMV = 0.0
      DO 110  J=1,M
      DO 100  I=1,L
      SUMX = SUMX+GRIDX(I,J)   $   SUMY = SUMY+GRIDY(I,J)
      SUMU = SUMU+GRIDU(I,J)   $   SUMV = SUMV+GRIDV(I,J)
  100 CONTINUE
  110 CONTINUE
      XSHIFT = SUMX/COUNT   $   YSHIFT = SUMY/COUNT
      USHIFT = SUMU/COUNT   $   VSHIFT = SUMV/COUNT

C*        SET UP INITIAL PARAMETERS
      KOUNT = 0
      XSCALE = YSCALE = 1.0   $   ROTATE = SKEW = 0.0
      SINROT = SINSKEW = 0.0   $   COSROT = COSSKEW = 1.0

      PRINT 10
   10 FORMAT(//,22X,*XSCALE*,14X,*YSCALE*,14X,*ROTATE*,14X,*SKEW*,
     1 17X,*AVGE*,16X,*RMS*,/)

C*        COMPUTE CORRECTED "U" AND "V" USING LATEST ESTIMATE FOR
C*        UNKNOWN PARAMETERS AND CALCULATE RESIDUAL ERRORS
   50 KOUNT = KOUNT+1
      SUMDR = SUMDRSQ = 0.0
      CALL MEMSET(0.0,A,16)
      CALL MEMSET(0.0,B,4)
      DO 210  J=1,M
      DO 200  I=1,L
      XX = GRIDX(I,J)-XSHIFT   $   YY = GRIDY(I,J)-YSHIFT
      UU = GRIDU(I,J)-USHIFT   $   VV = GRIDV(I,J)-VSHIFT
      USKEW = UU+VV*SINSKEW   $   VSKEW = VV*COSSKEW
      UROT = -VSKEW*SINROT+USKEW*COSROT
      VROT = VSKEW*COSROT+USKEW*SINROT
      DX = XSCALE*UROT-XX   $   DY = YSCALE*VROT-YY
      DRSQ = DX**2 + DY**2   $   DR = SQRT(DRSQ)
      SUMDR = SUMDR+DR   $   SUMDRSQ = SUMDRSQ+DRSQ

C*        IF DR SMALL, SET SIN AND COS TO AVOID DIVISION BY ZERO
C*        THEN CALCULATE DIFFERENTIAL COEFFICIENTS CORRESPONDING
C*        TO "U" AND "V"
      IF (DRSQ.GT.EPSILON)  GO TO 190
      COSA = 0.0   $   SONA = 1.0
      GO TO 195
  190 COSA = DX/DR   $   SINA = DY/DR
  195 C1 = COSA*UROT   $   C2 = SINA*VROT
      C3 = -(COSA*XSCALE*VROT - SINA*YSCALE*UROT)
      C4 = COSA*XSCALE*(VROT-UU*SINROT) - SINA*YSCALE*(UROT-UU*COSROT)

C*        CREATE COEFFICIENTS FOR SIMULTANEOUS EQUATIONS IN FORM A(X)=B
      B(1) = B(1)+C1*DR   $   B(2) = B(2)+C2*DR
      B(3) = B(3)+C3*DR   $   B(4) = B(4)+C4*DR
      A(1,1) = A(1,1)+C1**2   $   A(1,2) = A(1,2)+C1*C2
      A(1,3) = A(1,3)+C1*C3   $   A(1,4) = A(1,4)+C1*C4
      A(2,2) = A(2,2)+C2**2   $   A(2,3) = A(2,3)+C2*C3
      A(2,4) = A(2,4)+C2*C4   $   A(3,3) = A(3,3)+C3*C3
      A(3,4) = A(3,4)+C3*C4   $   A(4,4) = A(4,4)+C4**2
  200 CONTINUE
  210 CONTINUE

C*        COMPLETE SYMMETRIC MATRIX; FIND SOLUTION AND CHECK IF SINGULAR
      A(2,1) = A(1,2)   $   A(3,1) = A(1,3)
      A(4,1) = A(1,4)   $   A(3,2) = A(2,3)
      A(4,2) = A(2,4)   $   A(4,3) = A(3,4)
C*        SOLVE MATRIX
      CALL MATINV(A(1,1),4,B(1),1,DET,IRR)
      IF (IRR.EQ.1)  GO TO 520

C*        COMPUTE ADJUSTED VALUES USING WEIGHTING FUNCTION TO AVOID
C*        OSCILLATION IN ADJUSTMENTS
      ALPHA = 0.5 + 0.5/KOUNT
      XSCALE = XSCALE-ALPHA*B(1)   $   YSCALE = YSCALE-ALPHA*B(2)
      ROTATE = ROTATE-ALPHA*B(3)   $   SKEW = SKEW-ALPHA*B(4)
      AVGEDR = SUMDR/COUNT   $   RMSDR = SQRT(SUMDRSQ/COUNT)
      PRINT 300, XSCALE,YSCALE,ROTATE,SKEW,AVGEDR,RMSDR
  300 FORMAT(10X,6F20.10)
      SINROT = SIN(ROTATE)   $   COSROT = COS(ROTATE)
      SINSKEW = SIN(SKEW)   $   COSSKEW = COS(SKEW)

C"        QUIT AFTER 10 ITERATIONS AND PRINT SOLUTION
      IF (KOUNT.LT.10)  GO TO 50

  520 ROTATE = ROTATE*57.295
      SKEW   = SKEW*57.295
      PRINT 530, XSHIFT,YSHIFT,USHIFT,VSHIFT,ROTATE,SKEW,XSCALE,YSCALE
  530 FORMAT(//,24X,*XSHIFT =*,F10.2,* INCHES*,/,24X,*YSHIFT =*,F10.2,
     1 * INCHES*,///,24X,*USHIFT =*,F10.2,* INCHES*,/,24X,*VSHIFT =*,
     1 F10.2,* INCHES*,///,22X,*ROTATION =*,F10.2,* DEGREES*,
     3 /,22X,*SKEW     =*,F10.2,* DEGREES*,//,24X,
     4 *XSCALE =*,F10.3,/,24X,*YSCALE =*,F10.3)

C*        COMPUTE PARAMETERS REQUIRED IN OTHER SUBROUTINES
      XSINROT = XSCALE*SINROT   $   XCOSROT = XSCALE*COSROT
      YSINROT = YSCALE*SINROT   $   YCOSROT = YSCALE*COSROT

      RETURN

      END
```

DIGMAP SUBROUTINE : SCALER

```
SUBROUTINE RUNDATA    76/76   OPT=1                FTN 4.4+R401      07/04/76  15.40.59      PAGE    1

                 SUBROUTINE RUNDATA(ILIST)
          C**        THIS SUBROUTINE EXTRACTS THE DATA FOR EACH DIGITISED TRACK
          C**        VALUES ARE STORED IN INCHES IN ARRAYS "U" AND "V"
          C**
          C**        SUBROUTINE REQUIRED "EXTRACT","READIN","NUMCODE","TRACKER"

                 COMMON/INPUT/ NWORD(8),NERRORS,GRIDU(20,20),GRIDV(20,20)
                 COMMON/CONST/MTOUT,MTSCR,LUNDOC,IBLANK,DUBIOUS,UNKNOWN,IDATE
                 COMMON/MASK/ MASK,NBITS(10)
                 COMMON/RUNDATA/ RUNNAME(8),KOUNT,FOTO(200),U(200),V(200)
                 INTEGER FOTOLAB,FOTO
                 DATA(IFORM =6H(8A10))

                 ISTART = KOUNT  = 0
                 INC = 1

          C*         EXTRACT AND PRINT RUNNAME
                 CALL EXTRACT(79,NWORD,2,RUNNAME,1)
                 IF (ILIST.LT.10000)  PRINT 40
              40 FORMAT(1H1,/)
                 PRINT 45, RUNNAME,TIMEINT
              45 FORMAT(//,10X,*DIGITIZATION OF RUN  *,1H*,8A10,1H*,4X,
                1 *COMMENCED*,F6.1,*SEC*)
                 IF (ILIST.LT.10000)  PRINT 50
              50 FORMAT(//,17X,*COUNT*,4X,*LABEL*,6X,*U*,9X,*V*,/)

              10 CALL READIN(LUNDOC,IFORM,8,NWORD,IFEOF)
                 GO TO (20,10) IFEOF

          C*         EXTRACT AND PRINT INCREMENT VALUE
              20 NCHAR = SHIFT(NWORD(1),-54).AND.MASK
                 IF (NCHAR.EQ.1HI)30,135
              30 CALL NUMCODE(NWORD,1,INC,IFLAG)
                 IF (IFLAG.EQ.1) 400,420

             400 PRINT 410, NWORD
             410 FORMAT(/,10X,10(1H*),* ERROR IN DECODING INCREMENT VALUE *,/,
                1 20X,1H*,8A10,1H*)
                 INC = 1

             420 PRINT 430, INC
             430 FORMAT(/,10X,10(1H$),10X,*INCREMENT VALUE = *,I4,/)

             110 CALL READIN(LUNDOC,IFORM,8,NWORD,IFEOF)
                 GO TO (130,380)  IFEOF

             130 NCHAR = SHIFT(NWORD(1),-54).AND.MASK
             135 IF (NCHAR.EQ.1RN) 140,60

              60 IF (ISTART.EQ.0)  90,200
              90 PRINT 100, NWORD
             100 FORMAT(/,10X,10(1H*),* UNRECOGNISED INITIAL CHARACTER AFTER RUN LA
                1BEL-SHOULD BE PHOTO NUMBER STARTING WITH ?N?*,/,
                2  20X,1H*,8A10,1H*)
                 NERRORS = NERRORS+1
                 ISTART = 1
                 NFOTO = 0   $   FOTOLAB = IBLANK   $   GO TO 200

          C*         EXTRACT RUN NUMBER TO BE USED AS FRACTIONAL PART OF STATION NO
             140 NCHAR = SHIFT(NWORD(1),-48).AND.MASK
                 IF (NCHAR.EQ.1R+) 1130,1140
            1130 NFOTO = NFOTO + 1
                 ENCODE(10,240,FOTOLAB) NFOTO
                 ISTART = 1
                 GO TO 110

            1140 NFOTO = 0   $   FOTOLAB = IBLANK
                 DO 190  K=2,10
                 NCHAR = SHIFT(NWORD(1),NBITS(K)).AND.MASK
                 IF (NCHAR.EQ.1R )  190,180
             180 NFOTO = NFOTO*10+(NCHAR-1R0)
                 FOTOLAB = SHIFT(FOTOLAB,+6).AND..NOT.MASK
                 FOTOLAB = FOTOLAB.OR.NCHAR
             190 CONTINUE
                 ISTART = 1
                 GO TO 110

          C*         EXTRACT X-Y COORDS OF DIGITISED TRACK - STORE IN INCHES IN
          C*         ARRAYS "U" AND "V", AND CREATE PHOTO NUMBER
             200 CALL XYCODE(UU,VV,NWORD,IFERROR,IFEND)
                 KOUNT = KOUNT+1   $   IF (KOUNT.GT.200)  300,205
             205 GO TO (280,210)  IFERROR
             210 PRINT 220, KOUNT,NWORD
             220 FORMAT(/,10X,10(1H*),* NON-NUMERIC INFORMATION IN RUNDATA AT KOUNT
                1 *,I5,/,12X,1H*,8A10,1H*)
                 NERRORS = NERRORS+1
                 U(KOUNT) = V(KOUNT) = UNKNOWN
                 FOTO(KOUNT) = 10HMISTAKE
                 GO TO 295

             280 IF((KOUNT/ILIST)*ILIST.EQ.KOUNT) PRINT 290,KOUNT,NFOTO,UU,VV
             290 FORMAT(10X,2I10,2F10.2)
                 U(KOUNT) = UU/2.54
                 V(KOUNT) = VV/2.54
                 FOTO(KOUNT) = FOTOLAB
             295 NFOTO = NFOTO + INC
                 ENCODE(10,240,FOTOLAB) NFOTO
             240 FORMAT(I10)
                 GO TO (200,110)  IFEND

          C*         TRUNCATE AND SAVE DATA IF MORE THAN 200 RECORDS
             300 KOUNT = KOUNT-1
                 PRINT 310
             310 FORMAT(/,10X,10(1H$),10X,*MORE THAN 200 RECORDS IN RUN - LIST TRUN
                1CATED AND SAVED*)
                 CALL TRACKER(ILIST)
                 KOUNT = 1   $   TIMEINT = SECOND(UUU)
                 IF (ILIST.LT.10000)  PRINT 45, RUNNAME,TIMEINT
                 GO TO 285

             380 CALL TRACKER(ILIST)

                 RETURN
```

DIGMAP SUBROUTINE : RUNDATA

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SUBROUTINE TRACKER     76/76    OPT=1                    FTN 4.4+R401       07/04/76  15.40.59        PAGE    1

                 SUBROUTINE TRACKER(ILIST)

           C**        THIS SUBROUTINE USES THE CONVERSION PARAMETERS SET UP IN
           C**        SCALER TO CONVERT THE DIGITISED VALUES INTO GEOGRAPHICALS
           C**        AND STORES THEM IN ARRAYS IN STANDARD SURVEYFILE FORM
           C**
           C**        SUBROUTINES REQUIRED "EXTRACT","TODAY","XYCOORD"

                 COMMON/INDEX/LABEL(8),NSEGS,NSUM,ERRSUM(11),
                1  INDEX(8,200),STNSUM(200),ST(3,200),NERROR(11,200)
                 COMMON/SEGMENT/ SEGMENT(8),ISTNS,T(3),ERROR(11),STNDATA(12,1440)
                 COMMON/CONST/MTOUT,MTSCR,LUNDOC,IBLANK,DUBIOUS,UNKNOWN,IDATE
                 COMMON/SCALE/ XSCALE,YSCALE,XSHIFT,YSHIFT,USHIFT,VSHIFT
                 COMMON/ROTATE/ XSINROT,XCOSROT,YSINROT,YCOSROT,SINSKEW,COSSKEW
                 COMMON/RUNDATA/ RUNNAME(8),KOUNT,FOTO(200),U(200),V(200)
                 DATA IBLANK = 10H          )

           C*         EXTRACT TRACK LABEL AND CREATE SEGMENT HEADER
                 DECODE(5,70,RUNNAME(1))  TRACK
              70 FORMAT(F5.2)
                 CALL EXTRACT(74,RUNNAME,7,SEGMENT,1)
                 CALL TODAY(SEGMENT(8))
                 LAND = 0   $   IF (TRACK.GT.100.0)  LAND = 1

                 IF (ILIST.LT.10000)  PRINT 120, LABEL,SEGMENT
             120 FORMAT(///,10X,*POSITIONS OF SHIPS TRACKS ON  *,1H*,8A10,1H*,
                1 //,10X,*SURVEY, SHIP AND/OR CRUISE    *,1H*,8A10,1H*,///,
                2 15X,*RECORD*,4X,*TRACK*,6X,*LABEL*,9X,*X*,7X,*Y*,
                3 11X,*LATITUDE*,3X,*LONGITUDE*,/)

                 DO 190  I=1,KOUNT
                 IF (ISTNS.GE.1440)  CALL INDEXER(MTSCR)

           C*         COMPUTE STATION NUMBER AS TRACK LABEL PLUS RUN NUMBER
                 ISTNS = ISTNS+1
                 DECODE(10,135,FOTO(I))  POINT
             135 FORMAT(F10.0)
                 IF (LAND.EQ.0)  GO TO 140
                 STNNUM = TRACK + POINT*0.0001
                 GO TO 145
             140 STNNUM = TRACK + TSURVEY(POINT)
             145 IF(U(I).LT.DUBIOUS)  GO TO 150
                 RLAT = LATD = RLATM = RLONG = LONGD = RLONGM = UNKNOWN
                 GO TO 160

           C*         COMPUTE LATITUDE AND LONGITUDE FOR EACH DIGITISED POINT
             150 UU = U(I)-USHIFT   $  VV = V(I)-VSHIFT
                 UU = UU+VV*SINSKEW   $   VV = VV*COSSKEW
                 X = XCOSROT*UU - XSINROT*VV + XSHIFT
                 Y = YSINROT*UU + YCOSROT*VV + YSHIFT
                 CALL POSITN(RLAT,RLONG,X,Y)
                 LATD = RLAT+0.000083   $   RLATM = (RLAT-LATD)*60.0
                 LONGD = RLONG+0.000083   $   RLONGM = (RLONG-LONGD)*60.0

             160 IF((ISTNS /ILIST)*ILIST.EQ.ISTNS) PRINT 170,ISTNS,TRACK,FOTO(I),
                1 V(I),U(I),LATD,RLATM,LONGD,RLONGM
             170 FORMAT(I20,3X,F7.2,A10,4X,2F8.2,5X,2(I6,F6.2))

           C*         STORE DATA IN STANDARD SURVEY DATA PILE FORM
                 STNDATA(1,ISTNS) = STNNUM
                 STNDATA(2,ISTNS) = RLAT
                 STNDATA(3,ISTNS) = AMOD(RLONG+360.0,360.0)
                 DO 180 K=4,11
                 STNDATA(K,ISTNS) = UNKNOWN
             180 CONTINUE
                 STNDATA(12,ISTNS) = BLANK
             190 CONTINUE

                 RETURN
                 END
```

DIGMAP SUBROUTINE : TRACKER

```
*CY,CPDMRXSA,DIGMAP

DIGMAP(T20) .
COMMENT.          * * * * * *                                  * * * * * *
COMMENT.          * * * * * *  L A TILBURY  EXT 253            * * * * * *
COMMENT.          * * * * * *                                  * * * * * *
MOUNT(VSN=PMC502,SN=DMR1345)
ATTACH(A,EROMANGAONE,SN=DMR1345,ID=DMRXMD,MR=1)
COPY(A,TAPE40)
ATTACH(B,EROMANGATWO,SN=DMR1345,ID=DMRXMD,MR=1)
COPY(B,TAPE40)
REQUEST(TAPE10,*PF,SN=DMR1345)
ATTACH(LIB5,DIGITISINGBINARY,ID=DMRXMD,SN=DMR1345,MR=1)
ATTACH(LIB6,SERVICEBINARY    ,ID=DMRXMD,SN=DMR1345,MR=1)
ATTACH(LIB8,TRANSVERSEMERCATOR,ID=DMRXMD,SN=DMR1345,MR=1)
LIBRARY(*,LIB5)
LIBRARY(*,LIB6)
LIBRARY(*,LIB8)
MAP(PART)
DIGMAP.
CATALOG(TAPE10,NORTHEROMANGADIGMAP,ID=DMRXMD,XR=PASSWORD)
EXIT(U)
RETURN(TAPE10)
EXIT(S)
RETURN(TAPE10)
- - - - - END OF SECTION FOR CYBER 76 - - - - - - -
GALILEE BASIN
*MAPGRID
BMR LAKE GALILEE                                                     2200 22301454514645
AUSTRALIAN NATIONAL SPHEROID  6378160.0 298.25    -183.  6.  100000.  15.  15.
*COMPRESS
BMR LAKE GALILEE
*MAPGRID
BOWEN DOWNS MAP 10                                                   2045 21001440014505
AUSTRALIAN NATIONAL SPHEROID  6378160.0 298.25    -183.  6.  100000.   5.   5.
*ANNIHILATE
TOWERHILL MAP 10
*MAPGRID
BOWEN DOWNS MAP 1                                                    2100 21301440014500
AUSTRALIAN NATIONAL SPHEROID  6378160.0 298.25    -183.  6.  100000.   5.   5.
*ANNIHILATE
BOWEN DOWNS YARROWGLEN MAP 1
*MAPGRID
TOWERHILL MAP 2                                                      2100 21301450014600
AUSTRALIAN NATIONAL SPHEROID  6378160.0 298.25    -183.  6.  100000.   5.   5.
*ANNIHILATE
*EDITFILE
TOWERHILL MAP 2
*UPDATE          95
                                        ''''''''''''''''''''
*INSERT          96
X+1271.81 Y+0114.89
*UPDATE          98
''''''''''''''''''''
*INSERT          98
X+1233.33 Y+0100.96 X+1222.63 Y+0100.96 X+1211.83 Y+0098.36 X+1200.93 Y+0093.06
- - - - - END OF SECTION FOR CYBER 76 - - - - - - -
* * * * * END OF INFORMATION FOR CYBER 76 * * * * *
```

EXECUTION DECK : DIGMAP

DIGITISATION OF *BMR LAKE GALILEE * COMMENCED ,9 SEC

$$$$ FILE *BMR LAKE GALILEE * FOUND ON LUN 40
EDITFILE READ FROM CARD INPUT

COUNT	VERTEX		U	V
1	1	1	50,12	25,86
2	2	1	60,47	26,04
3	3	1	70,77	26,15
4	4	1	81,11	26,28
5	5	1	91,41	26,38
6	1	2	49,95	36,95
7	2	2	60,31	37,10
8	3	2	70,64	37,21
9	4	2	80,98	37,35
10	5	2	91,32	37,45
11	1	3	49,76	48,02
12	2	3	60,13	48,15
13	3	3	70,45	48,31
14	4	3	80,81	48,44
15	5	3	91,15	48,54

XSCALE	YSCALE	ROTATE	SKEW	AVGE	RMS
2,4881200151	2,4947007391	-,3105484864	,0046405070	9,3588706728	10,1109922887
2,3137783076	2,3158900413	-,0921135223	,0022640817	4,7324908177	5,1110234331
2,4471649154	2,4519002953	-,0383898179	,0020506902	1,7022490878	1,8367491781
2,4769142215	2,4820835583	-,0191963343	,0019449832	,5604248464	,6032653130
2,4860904912	2,4914373523	-,0120714666	,0018827582	,2103189866	,2251676812
2,4893404297	2,4948734337	-,0092305841	,0017685901	,0856964079	,0908877763
2,4907249816	2,4959373799	-,0080110554	,0016014191	,0381881312	,0403017885
2,4920054845	2,4976560352	-,0073583248	,0020121591	,0208135107	,0220043636
2,4919041741	2,4981719132	-,0075069855	,0015621565	,0168707499	,0184535863
2,4921216980	2,4992069533	-,0074113212	,0018010171	,0165887603	,0179607262

XSHIFT = -30,43 INCHES
YSHIFT = -968,80 INCHES

USHIFT = 27,81 INCHES
VSHIFT = 14,65 INCHES

ROTATION = -,42 DEGREES
SKEW = ,10 DEGREES

XSCALE = 2,492
YSCALE = 2,499

ESTIMATE OF ERRORS IN DIGITISING *BMR LAKE GALILEE * FROM GRATICULE VALUES - COMMENCED ,9 SEC

I	J	LAT	DLAT	LONG	DLONG
1	1	22 30,	,008	145 45,	-,034
2	1	22 30,	-,019	146 0,	-,000
3	1	22 30,	,016	146 15,	-,020
4	1	22 30,	-,001	146 30,	,013
5	1	22 30,	-,002	146 45,	-,008
1	2	22 15,	-,008	145 45,	,000
2	2	22 15,	-,008	146 0,	,027
3	2	22 15,	,032	146 15,	,018
4	2	22 15,	,002	146 30,	,027
5	2	22 15,	,011	146 45,	,026
1	3	22 0,	-,005	145 45,	,002
2	3	22 0,	,024	146 0,	,022
3	3	22 0,	-,009	146 15,	-,022
4	3	22 0,	-,017	146 30,	-,021
5	3	22 0,	-,024	146 45,	-,030
		MEAN	-,000'		-,000'
		SD	,015'		,021'

DIGMAP SAMPLE OUTPUT PRINTOUT

```
DIGITIZATION OF RUN  *1402, BMR LINE 2 LAKE GALILE  WELL                                   :*   COMMENCED   0,0SEC

       COUNT     LABEL        U           V

        10       1006      59.52       38.83
***   EOF WRITTEN AFTER CARD   47     *X+0594,16 Y+0381,67 X+0593,96 Y+0379,50                             *


POSITIONS OF SHIPS TRACKS ON  *GALILEE BASIN                                                1975/09/12*

SURVEY, SHIP AND/OR CRUISE     *BMR LINE 2 LAKE GALILE  WELL                                1975/09/12*

     RECORD    TRACK       LABEL          X        Y           LATITUDE   LONGITUDE

        10   1402:00       1006        15.29    23.43          22 12.63   145 58.92

$$$$$$$$$$          TOTAL OF    14  RECORDS SAVED IN SEGMENT ON SCRATCH LUN  20
$$$$$$$$$$          LABELLED   *BMR LINE 2 LAKE GALILE  WELL                                 1975/09/12*




DIGITIZATION OF RUN  *1401, BMR LINE A                                                      :*   COMMENCED   0.0SEC

       COUNT     LABEL        U           V

        10       1076      68.16       32.40
        20       1086      70.25       31.98
        30       1096      71.84       30.46
        40       1106      73.65       29.72
        50       1116      75.81       29.36
        60       1126      77.97       29.33
        70       1136      80.08       29.08
        80       1146      82.14       28.43
        90       1156      84.24       27.84
       100       1166      86.30       27.37
       110       1176      88.42       26.92

POSITIONS OF SHIPS TRACKS ON  *GALILEE BASIN                                                1975/09/12*

SURVEY, SHIP AND/OR CRUISE     *BMR LINE A                                                  1975/09/12*

     RECORD    TRACK       LABEL          X        Y           LATITUDE   LONGITUDE

        10   1401:00       1076        12.76    26.83          22 21.50   146 11.32
        20   1401:00       1086        12.59    27.66          22 22.10   146 14.35
        30   1401:00       1096        11.99    28.28          22 24.19   146 16.62
        40   1401:00       1106        11.70    29.00          22 25.23   146 19.24
        50   1401:00       1116        11.56    29.85          22 25.75   146 22.37
        60   1401:00       1126        11.55    30.70          22 25.82   146 25.50
        70   1401:00       1136        11.45    31.53          22 26.19   146 28.56
        80   1401:00       1146        11.19    32.34          22 27.10   146 31.54
        90   1401:00       1156        10.96    33.17          22 27.93   146 34.59
       100   1401:00       1166        10.78    33.98          22 28.59   146 37.58
       110   1401:00       1176        10.60    34.81          22 29.23   146 40.65

$$$$$$$$$$          TOTAL OF   113  RECORDS SAVED IN SEGMENT ON SCRATCH LUN  20
$$$$$$$$$$          LABELLED   *BMR LINE A                                                   1975/09/12*
```

DIGMAP SAMPLE OUTPUT PRINTOUT

```
*CY,CPDMRXSA,TRAKMAP

TRAKMAP(T50,ML1)
COMMENT.            * * * * * *                                    * * * * * *
COMMENT.            * * * * * *  L A TILBURY    EXT 253            * * * * * *
COMMENT.            * * * * * *                                    * * * * * *
STAGE(PLOT001,MT,HI,ST=IOS,POST)
LABEL(PLOT001,W,L=$EROMANGASHOTPTS$)
MOUNT(VSN=PMC502,SN=DMR1345)
ATTACH(TAPE1,NORTHEROMANGADIGMAP,ID=DMRXMD,SN=DMR1345,MR=1)
ATTACH(LIB4,PHASE4BINARY      ,ID=DMRXMD,SN=DMR1345,MR=1)
ATTACH(LIB6,SERVICEBINARY   ,ID=DMRXMD,SN=DMR1345,MR=1)
ATTACH(LIB7,PLOTBINARY      ,ID=DMRXMD,SN=DMR1345,MR=1)
ATTACH(LIB8,SIMPLECONIC      ,ID=DMRXMD,SN=DMR1345,MR=1)
LIBRARY(*,LIB4)
LIBRARY(*,LIB6)
LIBRARY(*,LIB7)
LIBRARY(*,LIB8)
MAP(PART)
TRAKMAP(PLOT001)
- - - - - END OF SECTION FOR CYBER 76 - - - - - - -
*MAPPLOT
*STANDARD MAP
NORTHERN EROMANGA BASIN                                   2000 24001410014700
AUSTRALIAN NATIONAL SPHEROID  6378160,0 298,25     1800 3600 1000000. 60.  90.
*TRACK
         1
GALILEE BASIN
- - - - - END OF SECTION FOR CYBER 76 - - - - - - -
         NORTHERN EROMANGA BASIN                        SHOTPOINT LOCATIONS
*MAPPLOT
*EXTENDED MAP
NORTHERN EROMANGA BASIN                                   2000 24001410014700
AUSTRALIAN NATIONAL SPHEROID  6378160,0 298,25     1800 3600 500000.  60.  90.
*TRACK
         1        10
GALILEE BASIN
- - - - - END OF SECTION FOR CYBER 76 - - - - - - -
         NORTHERN EROMANGA BASIN                        SHOTPOINT LOCATIONS
*ENDPLOT
* * * * * END OF INFORMATION FOR CYBER 76 * * * * *
```

```
*CY,CPDMRXSA,LISTAPE

LISTAPE(NL1,T30)
COMMENT.     L A TILBURY     X237
STAGE(TAPE40,PE,VSN=10293)
LABEL(TAPE40,R,L=$EROMANGADATA$)
MOUNT(VSN=PMC510,SN=DMR1345)
ATTACH(LIB5,SERVICEBINARY,ID=DMRXMD,SN=DMR1345,MR=1)
LIBRARY(*,LIB5)
LISTAPE(PL=10000)
DISPOSE(OUTPUT,ST=DADC8,*PR)
- - - - - END OF SECTION FOR CYBER 76 - - - - - - -
*INPUT FILE
         3
TOWERHILL MAP 10

BOWEN DOWNS MAP 12

BOWEN DOWNS YARROWGLEN MAP 1

* * * * * END OF INFORMATION FOR CYBER 76 * * * * *
```

EXECUTION DECKS : TRACKMAP AND LISTAPE

APPENDIX 7: <u>THE USE AND EDITING OF CARD IMAGE FILES</u> (after R. Whitworth, in prep.).

One of the main problems with the CDC 7600 system is the time taken to input large card files through the terminal. Repeated input is inefficient and creates unnecessary delays in turn-round for other users.

The policy has been adopted of creating card image files as documents on disc, either by direct input through the terminal, or as output from a program in lieu of punch cards. Multiple files within one disc document are allowed, but then the internal structure of the document must follow a consistent pattern if individual files are to be identified.

Each file has a card image header describing the file contents in free format. This header is not considered as part of the file, and usually contains the date of creation of the file in columns 71-80 in the format YYYY/MM/DD. A particular file is found by comparing a card supplied by the user with the file headers in the disc document.

For the system to be of much value, it must be possible to correct for mistakes in punching and erroneous data, and to carry out simple editing procedures. Editing is done in terms of card images, i.e. a whole card is deleted, inserted or replaced, and consecutive groups of cards can be treated in the same fashion. There is an option to delete or replace individual characters; but the program still works in terms of the card image. A numbered list of each card image file is required to allow identification of any particular card: the header is not included in this count. All marine programs that produce card-image output also provide the necessary listing.

A program is informed as to which file is required by the user supplying a card identical to the header of the card image file wanted. The multiple file is searched sequentially until agreement is reached between card and header. Forward search only is allowed, so should a series of files be needed, they must be requested in the correct order.

When editing of this file is needed, the single card header is replaced by:

```
*EDITFILE
CARD WITH HEADER OF INPUT FILE REQUIRED
EDITING CARDS
**************  CONTINUE
EDITING CARDS
.............................. END OF SECTION FOR 7600 ..............
```

The editing cards include instructions to the program, all of which commence with an asterisk, and data cards to be inserted or to replace existing cards in the file. The edit list is terminated by a single E-O-S card. There are five basic edit instructions which can operate on a single card or sequence of cards.

To delete a single card, N

```
*DELETE         N
```

To delete cards N1 to N2 inclusive

```
*DELETE         N1      N2
```

To insert an end-of-file after card N

```
*ENDFILE        N
```

To insert one or several cards after card N

```
*INSERT         N
```

Followed by data cards - ended by next * card or E-O-S card

To replace a single card N by one or more data cards

```
*REPLACE        N
```

Followed by data cards - ended by next * card or E-O-S card

To replace cards N1 to N2 inclusive by one or more data cards

```
*REPLACE        N1      N2
```

Followed by data cards - ended by next * card or E-O-S card

To update certain characters in card N

```
*UPDATE         N
```

Followed by a card containing the updated characters in their respective columns (other columns left blank). To insert a blank an up arrow ' ' is placed in the appropriate column.

The numbers N and N1 are right adjusted in columns 11 to 20 while numbers N2 are right adjusted in columns 21 to 30.

The main file and editing instructions are read in parallel by the program and the corrected file used within the program. This means that the main file is not altered in any way by the correction cards. The original numbered listing can be used to set up the edit cards for one or more runs until the user is confident that he has the information he wants.

APPENDIX 8: SUMMARY OF DIGITIZATION

1. Set up table, turn on power switches, reset origin on bottom left-hand cross-hair.

2. Tape down map on table.

3. Determine digitization limits and intervals.
Write these in note book

4. Log into GRADI, answer questions (XY, O, POINT, YES)

5. Digitize Graticule data block

```
         mapname       (LF)
M        mapname       (LF)
G lxm                              - l = no. of longitude points
                                     m = no. of latitude points
```

Digitize graticule points from left to right, bottom to top.

```
. EOP    (LF)                      - to close graticule block
. ALTER  -  optional to suppress printing
```

6. Digitize First Seismic line

```
Rssll.  Survey Name line no.   (LF)  - where ss = survey number
                                               ll = line number
Im       (LF)                      - Interval between consecutive shotpoints
Nnnnn    (LF)                      - First shotpoint number
```

Digitize shotpoints in increasing order

```
Nnnnn    (LF)                      - New shotpoint number following jump in
                                     sequence
. EOP    (LF)                      - to close seismic data
```

7. Repeat above block for each seismic line

```
Rssll.  Survey Name line no.  (LF)
Im  (LF)
Nnnnn  (LF)

. EOP                              - to close seismic data
```

Continue until all lines on map digitized

```
. EOP                              - to close data file
```

8. Exit from digitizer program GRADI by
.END

9. Save file in HP document region.

APPENDIX 9: DERIVATION OF FORMULAE USED IN LEAST-SQUARES TECHNIQUE

To provide control over the conversion of digitized data to latitude and longitude, a regular graticule of latitude-longitude points is digitized. The X-scale, Y-scale, orientation of the map relative to its theoretical counterpart, and skew in the axes of the digitizer are then determined that minimise the residual distances between observed and theoretical points. As the transformation is non-linear, the technique outlined in Whittaker & Robinson (1944, chapter IX, p.214) is used.

Approximate values are first adopted for the unknown parameters. The distance between each transformed point and its theoretical counterpart may then be calculated. From these, adjustments to the estimated parameters may be calculated that will minimize the distances. These adjustments are applied in an iterative loop which stops only when the adjustments fall below a specified value or ten iterations have been completed without reaching this value.

We must therefore set up equations relating the distances to the errors in the approximate values in the parameters

$$d = f(p,q,r,s)$$

where d is distance, p,q horizontal and vertical scale, r,s rotation and skew respectively.
If each variable is written as an approximate value plus an error term we have

$$d = f(\bar{p}+\Delta p, \bar{q}+\Delta q, \bar{r}+\Delta r, \bar{s}+\Delta s)$$

Following Whittaker & Robinson we assume the error terms to be small, and to first-order accuracy

$$d = f(\bar{p},\bar{q},\bar{r},\bar{s}) + \left(\frac{\delta f}{\delta p}\right)\Delta p + \left(\frac{\delta f}{\delta q}\right)\Delta q + \left(\frac{\delta f}{\delta r}\right)\Delta r + \left(\frac{\delta f}{\delta s}\right)\Delta s$$

Values for the four differential terms may be calculated using the approximate values for the variable parameters. To begin with these also are only approximate, but they become increasingly accurate as the iteration converges.

Suppose we now have a series of estimates of d, derived from observation, g say, which are liable to observational error. We need to find the most plausible values of p, q, r and s from a set of equations of the form

$$g = f(p,q,r,s)$$

With more equations than there are unknowns there will not be a unique solution. But an optimum solution can be found where the sum of the squares of errors in all the equations is a minimum, where the error is defined as:

$$e = \left(\frac{\delta f}{\delta p}\right)\Delta p + \left(\frac{\delta f}{\delta q}\right)\Delta q + \left(\frac{\delta f}{\delta r}\right)\Delta r + \left(\frac{\delta f}{\delta s}\right)\Delta s + f(\bar{p},\bar{q},\bar{r},\bar{s}) - g$$

Substituting C_1, C_2, C_3, C_4 for $\frac{\delta f}{\delta p}, \frac{\delta f}{\delta q}, \frac{\delta f}{\delta r}, \frac{\delta f}{\delta s}$

the above equation may be expressed as

$$e = C_1\Delta p + C_2\Delta q + C_3\Delta r + C_4\Delta s - \Delta l$$

where $\Delta l = g - f(\bar{p}, \bar{q}, \bar{r}, \bar{s})$ is the residual distance between the observed and estimated coordinates.
The sum of the squares of the errors is

$$t = \Sigma e^2 = \Sigma(c_1\Delta p + c_2\Delta q + c_3\Delta r + c_4\Delta s - \Delta l)^2$$

For t to be a minimum the following conditions must hold:

$$\frac{\delta t}{\delta(\Delta p)} = 0, \quad \frac{\delta t}{\delta(\Delta q)} = 0, \quad \frac{\delta t}{\delta(\Delta r)} = 0, \quad \frac{\delta t}{\delta(\Delta s)} = 0$$

Partially differentiating with respect to each variable we obtain:

$$\frac{\delta t}{\delta(\Delta p)} = \Sigma(c_1^2\Delta p + c_1c_2\Delta q + c_1c_3\Delta r + c_1c_4\Delta s - c_1\Delta l) = 0$$

$$\frac{\delta t}{\delta(\Delta q)} = \Sigma(c_1c_2\Delta p + c_2^2\Delta q + c_2c_3\Delta r + c_2c_4\Delta s - c_2\Delta l) = 0$$

$$\frac{\delta t}{\delta(\Delta r)} = \Sigma(c_1c_3\Delta p + c_2c_3\Delta q + c_3^2\Delta r + c_3c_4\Delta s - c_3\Delta l) = 0$$

$$\frac{\delta t}{\delta(\Delta s)} = \Sigma(c_1c_4\Delta p + c_2c_4\Delta q + c_3c_4\Delta r + c_4^2\Delta s - c_4\Delta l) = 0$$

Since the number of equations now equals the number of unknowns, a unique solution may be found to fit the least-squares condition. The solution is most easily found by matrix inversion. We may express the equations in the following matrix form:

$$\begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} \\ A_{21} & A_{22} & A_{23} & A_{24} \\ A_{31} & A_{32} & A_{33} & A_{34} \\ A_{41} & A_{42} & A_{43} & A_{44} \end{bmatrix} \times \begin{bmatrix} p \\ q \\ r \\ s \end{bmatrix}$$

where $B_i = \sum_k \Delta l\, c_{ik}$ and $A_{ij} = \sum_k c_{ik} . c_{jk}$

The adjustments $\Delta p, \Delta q, \Delta r$ and Δs that minimize the errors are added to the original estimate and the process repeated. Initially these adjustments are too large to be of sufficient accuracy considering the linear approximation made, but as the computation is repeated they progressively reduce until they become smaller than the precision desired of the variables. The values of the variables will then be of the required precision.

To obtain a solution using the above technique we must be able to calculate the coefficients $\frac{\delta f}{\delta p}, \frac{\delta f}{\delta q}, \frac{\delta f}{\delta r}, \frac{\delta f}{\delta s}$

Let u,v and x,y be the horizontal and vertical coordinates of a point on the digitizer and its counterpart on the scaled surface of the Earth; p,q the horizontal and vertical scaling factors; r,s the rotation of the map and skew of the digitizer respectively. Then applying the transformation step by step

$$x' = x + y \sin(s) \;; \quad y = y \cos(s)$$
$$x'' = y' \sin(r) + x' \cos(r)$$
$$y'' = y' \cos(r) + x' \sin(r)$$
$$\Delta x = px'' - x; \quad \Delta y = qy'' - y$$

the error in the transformed coordinates then becomes

$$\Delta l = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(px'' - x)^2 + (qy'' - y)^2}$$

We have to determine $\frac{\delta f}{\delta p}, \frac{\delta f}{\delta q}, \frac{\delta f}{\delta r}$ and $\frac{\delta f}{\delta s}$. With suitable differentiation we obtain:

$$\frac{\delta f}{\delta p} = u'' \frac{\Delta x}{\Delta l}; \quad \frac{\delta f}{\delta q} = v'' \frac{\Delta y}{\Delta l}$$

$$\frac{\delta f}{\delta r} = -\left(pv'' \frac{\Delta x}{\Delta l} - qu'' \frac{\Delta y}{\Delta l} \right)$$

$$\frac{\delta f}{\delta s} = p\left(v'' - u \sin(r)\right) \frac{\Delta x}{\Delta l} - q\left(u'' - u \cos(r)\right) \frac{\Delta y}{\Delta l}$$

A thing to note is that $\frac{\Delta x}{\Delta l}, \frac{\Delta y}{\Delta l}$ are the direction cosines of the residual distance vector Δl. If the residuals are small the vector will change direction very dramatically for small changes in p,q,r, and s. With few observations the resultant adjustments may fluctuate erratically and the solution becomes unstable. It has been found empirically that a minimum of nine grid points plus a reduction in weight of the adjustments as the iterations proceed avoids unacceptable oscillation in the solution in most cases.