

CAPTAIN COOK AND THE CRUMPLED ECHOGRAM

by Camille MAGEAU

Canadian Hydrographic Service, Ottawa

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ABSTRACT

Although navigation and surveying techniques have evolved since the days of sextants and azimuth compasses, two aspects of contemporary surveys have undergone little change :

1) the storage of documents collected at sea has not kept pace with technical developments in the field of data collection and manipulation ; and,

2) few hydrographic cruises are only slowly returning to the multi-disciplinary mentality which prevailed in earlier times.

Echograms and seismic records are essential tools in the interpretation of bathymetric data and the production of bathymetric and morphologic maps. Negligence in their care and preservation results in their deterioration and/or loss. It is proposed that these documents be copied onto 35 mm microfilm and the original documents granted archival status. The cost of this operation is minimal when compared to cruise costs.

Pre-season briefings, a greater participation by scientists in cruises and familiarization of hydrographers with all scientific aspects of the cruises are suggested. This would result in a greater scientific return and closer co-operation between scientists and hydrographers.

INTRODUCTION

The early explorers set out, not to unravel the mysteries of nature but rather to find the riches of the world and claim them for their sovereigns. Their successes were measured more in terms of treasure-laden galleons and exotic spices than in scientific revelations.



FIG. 1

In August of 1768, James Cook set sail on H.M. Bark *Endeavour* on what was to be one of the first scientific voyages of the eighteenth century. The development of the reflecting quadrant, the sextant, the astronomical quadrant, azimuth compass, theodolite and chronometer provided the eighteenth century explorer with the tools required to conduct accurate coastal surveys. The advances marked the beginning of a new era in hydrography and an age of intense activity in sea-borne commerce and, unfortunately, warfare.

Although Captain Cook's voyages have often been cited as examples of fine hydrographic surveying they were also seminal in that his goals were



FIG. 2. — Physiographic diagram of the sea floor after HEEZEN and THARP.

not simply to survey the ocean. Much emphasis was placed on the scientific pursuit of knowledge and both crew and officers were involved in this quest according to their interests and abilities. It is speculated that this was one of the reasons the crew enlisted time and again in spite of the perilous nature of these voyages. In this respect, eighteenth century cruises were fore-runners of the later naturalist cruises of the *Challenger*, *Meteor*, *Discovery* and *Galathea*.

Precise instrumentation and specialized techniques in chart construction were developed as the art of navigation and marine surveying evolved. One of the most important instruments in marine surveying, the echosounder, was developed early in the twentieth century. Whereas previous surveys had, for the most part, restricted themselves to the potentially dangerous coastal waters, offshore charting became possible with the advent of this new instrument. Over the years, the continuous use of the echosounder resulted in the accumulation of much topographical information about the sea floor. This increase in the knowledge of the configuration of the ocean floor led to the development of the bathymetric map which is different from the hydrographic chart. The bathymetric map seeks to represent the actual shape of the ocean floor as closely as possible, while the hydrographic chart instructs the mariner as to the dangers to surface navigation, particularly within coastal waters. To construct hydrographic charts, the shallowest depths recorded on the echogram are emphasized to stress the navigational hazards. Bathymetric maps, however, are based on the totality of the data recorded on the echogram and seek to interpret these values based on an understanding of geological processes which mould

the topography of the ocean. Professeur VANNEY (1976) summarizes this concept in his recent book stating :

‘La carte bathymétrique est la traduction explicative des sondages et diffère selon les auteurs ; elle constitue déjà le prime jalon de l’interprétation morphologique’.

In this respect, a bathymetric map is analogous to a scientific paper, the scientific data and its interpretation being presented pictorially rather than by the written word.

DISCUSSION

1. Data Interpretation

As our knowledge of the physiography of the ocean floor has increased, so has the realization of the complexity of the forces which have moulded

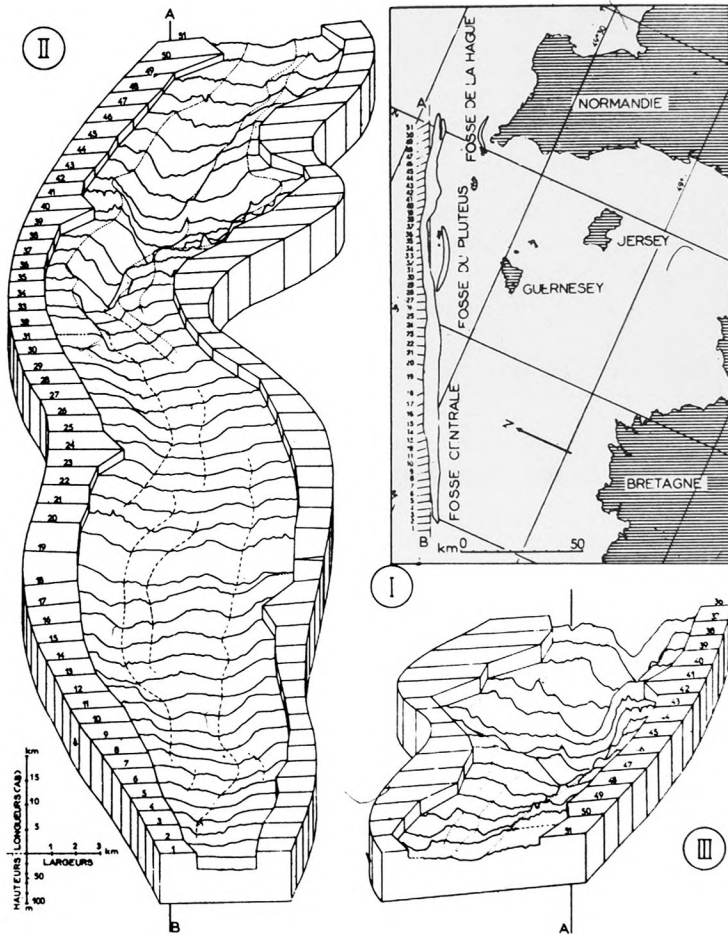


FIG. 3. — Sequence of bottom profiles.

it and of the processes which modify its profile. Oceanographers, fishermen, marine geologists, engineers and legists need particular knowledge of the composition, structure and morphology of the ocean floor and the processes which affect it. The development of these different disciplines in the marine sciences, their specific requirements and the limitations of the contoured bathymetric maps have resulted in the development of several other methods of portraying the ocean floor. HEEZEN and THARP (1959) extrapolated from bathymetric contours and echograms to draw their physiographic diagrams of the sea floor (fig. 2), while BOILLOT (1963) used sequences of bottom profiles (fig. 3) and MONAHAN (1971) presented an oblique view of contours to illustrate the sea floor (fig. 4).

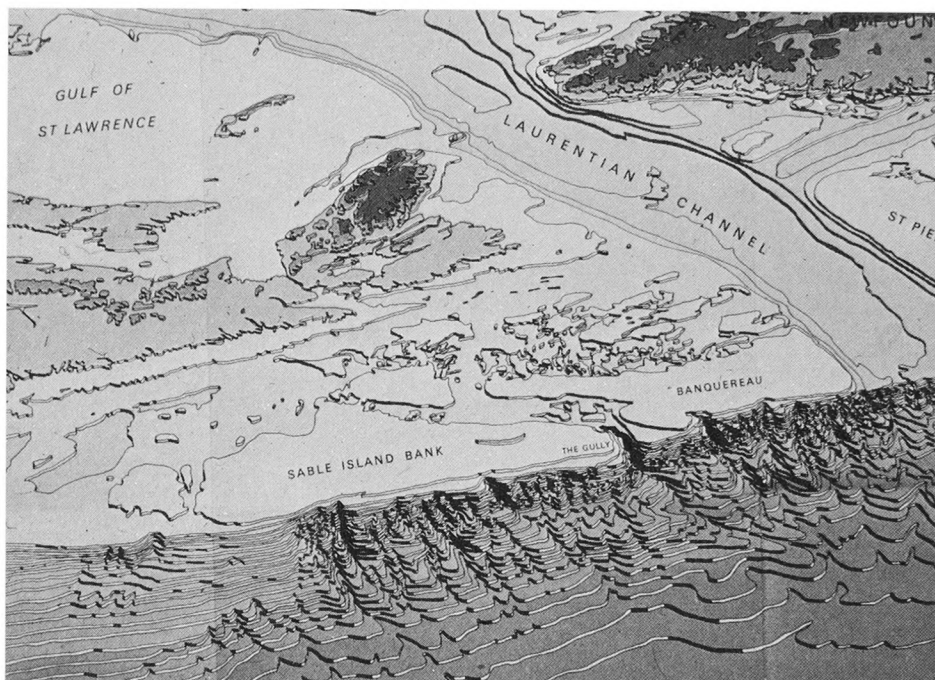


FIG. 4. — Three-dimensional representation of submarine relief.

Block diagrams, colour-coded bathymetric maps and sounding sheets are three of the most extensively used means of representing the sea floor. To complement the use of colour-coded bathymetric maps, the Geoscience Mapping Unit of the Canadian Hydrographic Service (C.H.S.) also employs medium scale morphology maps (MONAHAN and MACNAB, 1974). These maps combine the physical outline of features, their spatial distribution and permit identification of features too small to be reflected by the contours.

The typical procedure to generate a bathymetry/morphology map follows. The profile of the ocean bottom as actually measured by the echosounder and displayed on the echogram is examined prior to contouring the data points numerically represented on the field sheets. After correcting vertical and horizontal scale exaggerations induced by changes in ship

speed, paper speed and phase changes, the profile of the ocean bottom is redrawn on a clear plastic overlay (fig. 5).

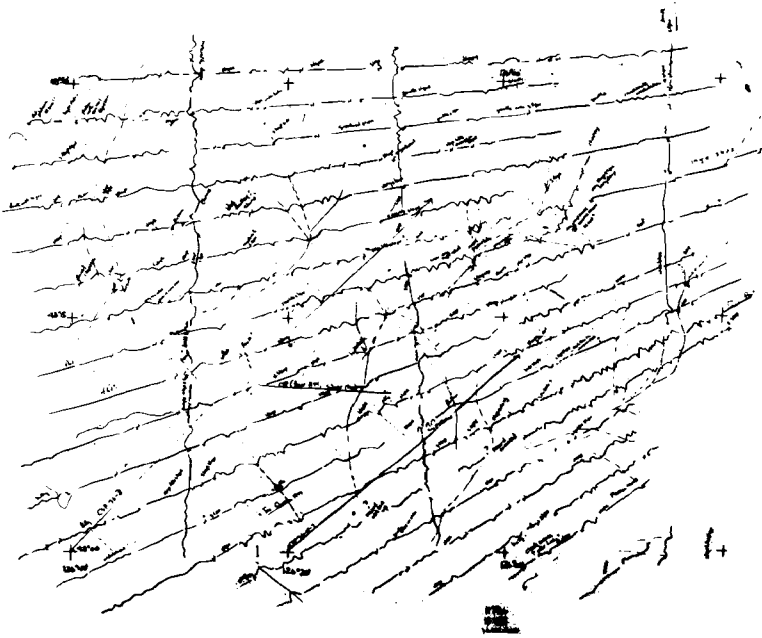


FIG. 5. — Trace of bottom profiles along the ship's tracks.

Where there are only occasional irregularities on the sea floor, bottom categories are established and colour-coded, and individual features such as ridges, valleys and major faults are indicated. The relative intensity and the frequency of the occurrence of certain features and general bottom conditions are noted in order to establish the areal extent of the bottom categories. As each echogram is examined, interpretations of the individual features are made, regarding their mode of formation and their relationship to the geological history of the area. Adjoining echograms are compared to trace the progression of individual features, such as the lateral extent of a ridge, to determine if it bifurcates, broadens into a plateau or slowly slopes to the ocean floor. Continuous seismic profiles (CSP), side scan sonar, gravity and magnetic data, as well as additional information obtained from the geological literature are used to assist in the interpretation of the echograms. The location of suspected faults, trends of features, the composition of bottom samples collected by the hydrographers and sedimentological data inferred from the echograms (KING, 1966) and seismic lines (STOLL, 1977) are plotted on the overlay (fig. 6).

The first step in the production of morphology and bathymetry maps, therefore, consists in producing a working copy on which the locations of features, and pertinent geological information are indicated. Areas exhibiting similar morphology are outlined, labelled and described according to their dominant characters. The relief provinces of the final morphology map are defined by these areas (fig. 7).

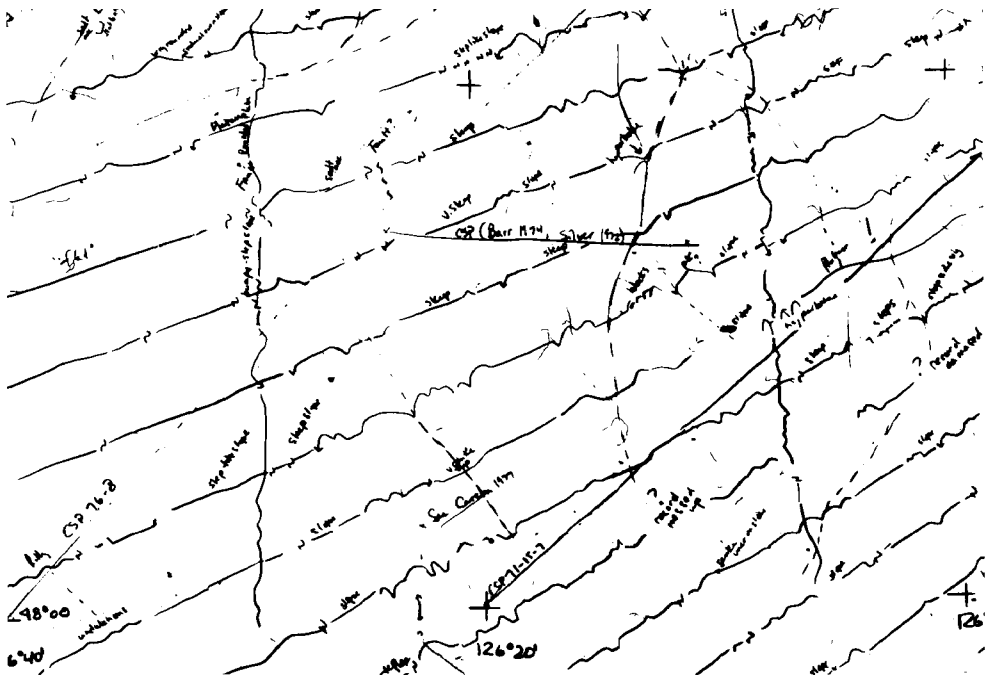


FIG. 6. — Plot of bottom profiles, location of CSP lines, key references, suspected fault traces, etc.

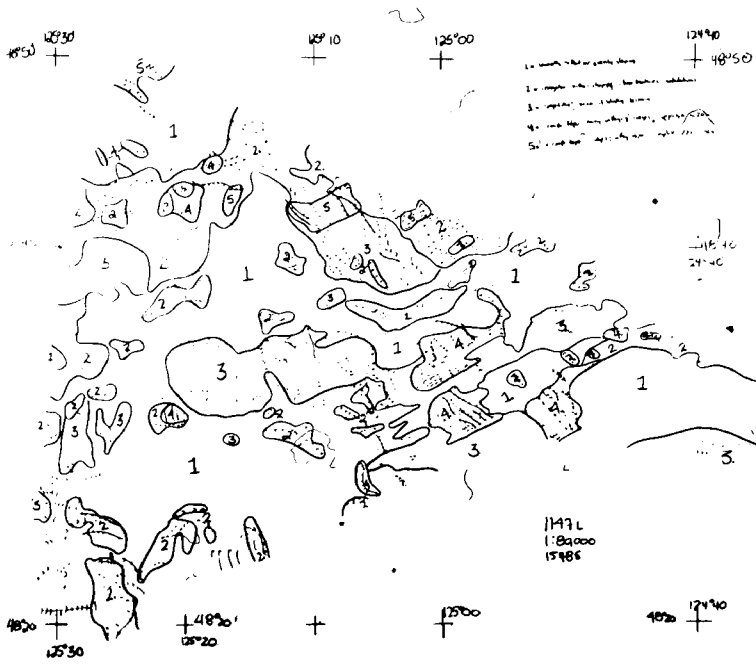


FIG. 7. — Outline of morphological provinces, categories and dominant features.

The numerically coded provinces, the trend of features, variations in valley shapes, angularity of elevations and degree of continuity of slope are depicted on the morphology map by the use of appropriate symbols (fig. 8).

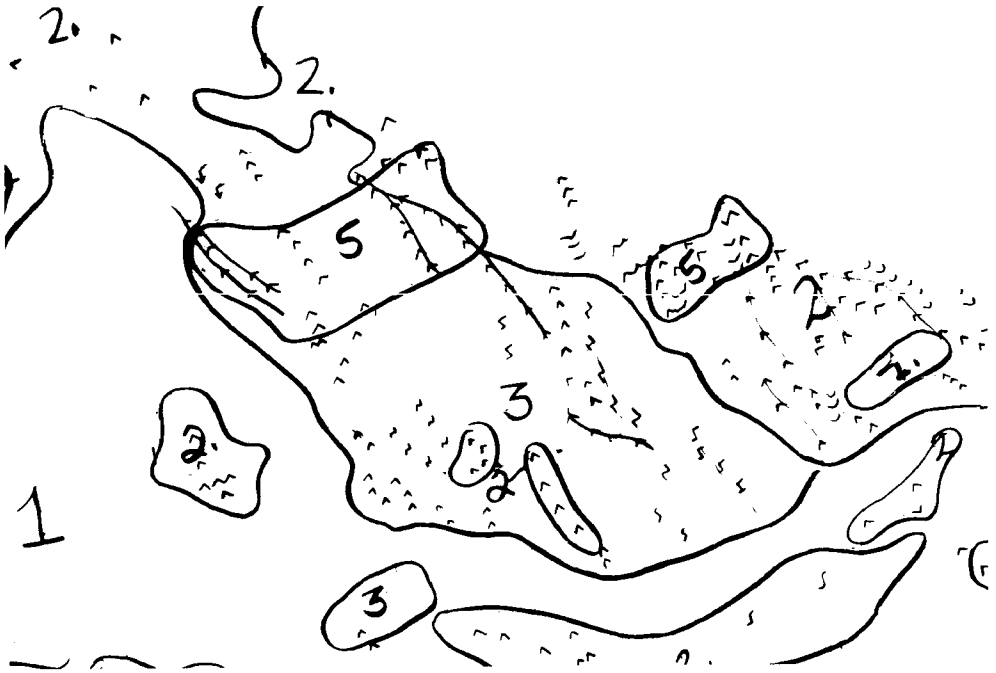


FIG. 8. — Enlargement of morphology map, symbols representing peaks, ridges, steps, breaks in slope. Numbers indicate morphological provinces.

The field sheet and the overlay are then superimposed and the field sheet contoured. These contours, however, are based not only on the numerical values as selected on board ship, but also on the geological and geomorphological information derived from the echogram analysis. By outlining trends of valleys and ridges, and complementing the bathymetric data with information obtained from different sources, additional information is extracted from the depth values. It is obvious that examination of the echograms becomes more important as the distance between sounding lines increases. Figures 9, 11, 13, depict the configuration of the preliminary contours based only on the numerical values. Some of the features outlined by the echograms are superimposed on the contours (fig. 11 and 13). It can be seen that the trend of some of the valleys and ridges differs somewhat from the trend outlined by the numerically based contours. Furthermore, by considering the general trend of the topography, it is possible to modify the contours that fall between soundings and sounding lines to present a more realistic solution. Figures 10, 12 and 14 illustrate the corrected contours and demonstrate the importance of the information not normally included in the data set recorded on the field sheet but revealed by the echogram.

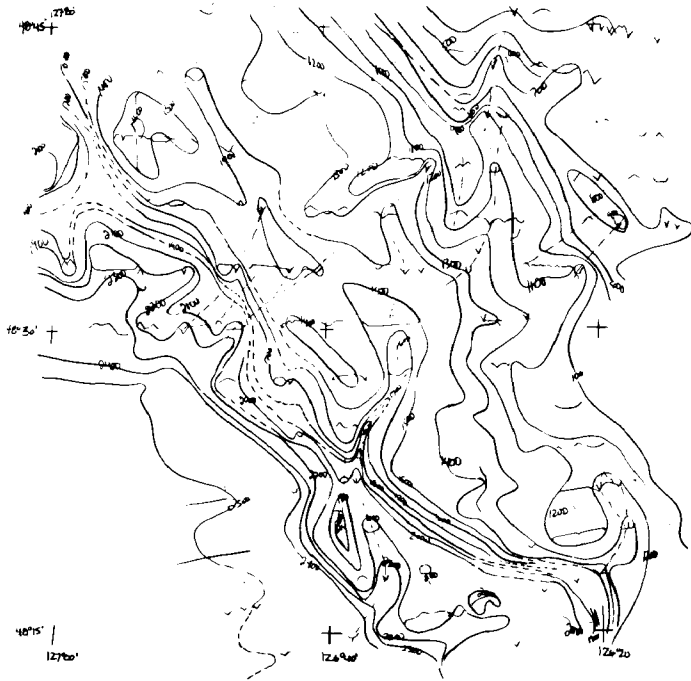


FIG. 9. --- Contours based on field sheet data only.

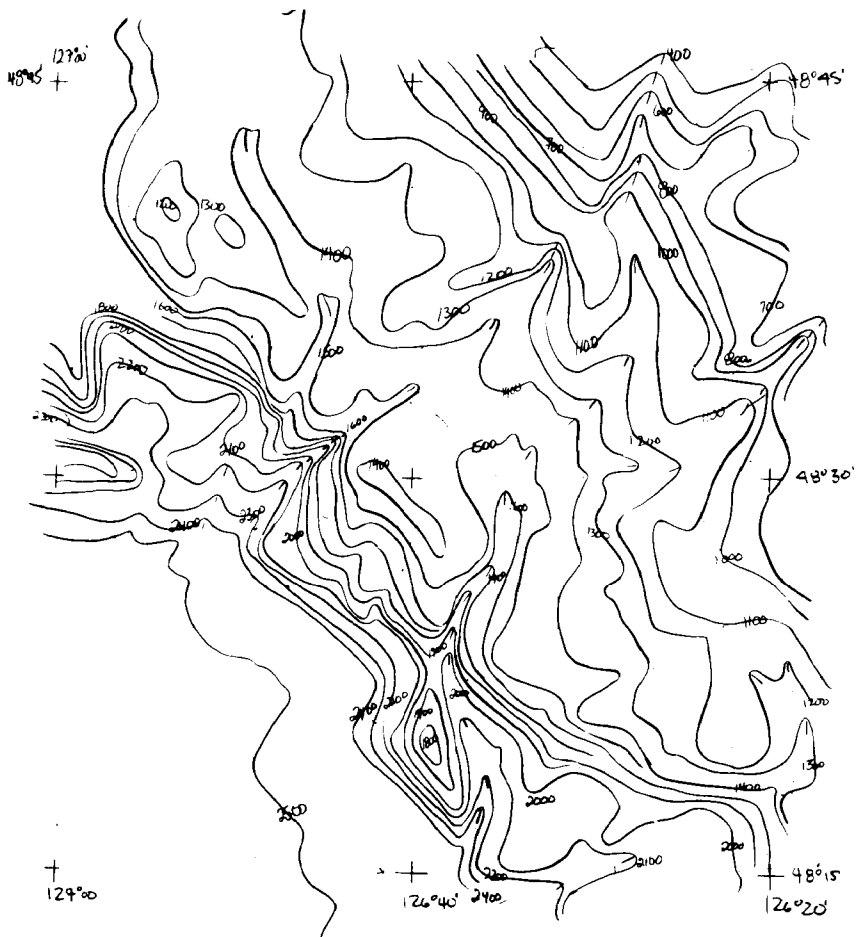


FIG. 10. --- Contours interpreted from echograms, seismic and geological data. (Corrected contours of fig. 9).

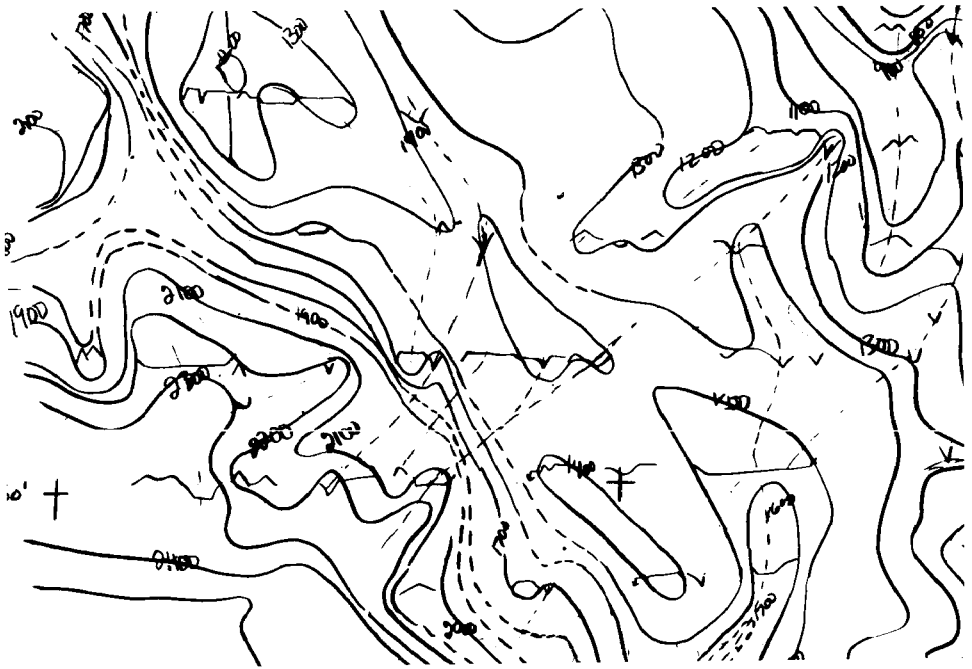


FIG. 11. — Disagreement between numerically generated contours and features, trends, delineated by the echograms.

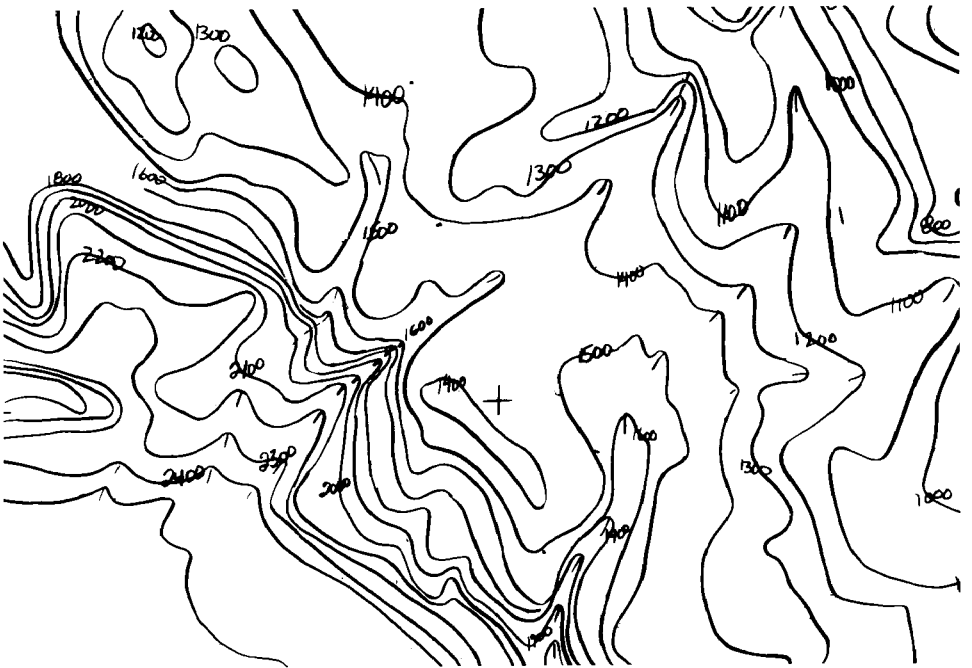


FIG. 12. — Configuration and trend of valleys and ridges interpreted from echograms, seismic records and geological data.
(Corrected contours of fig. 11).

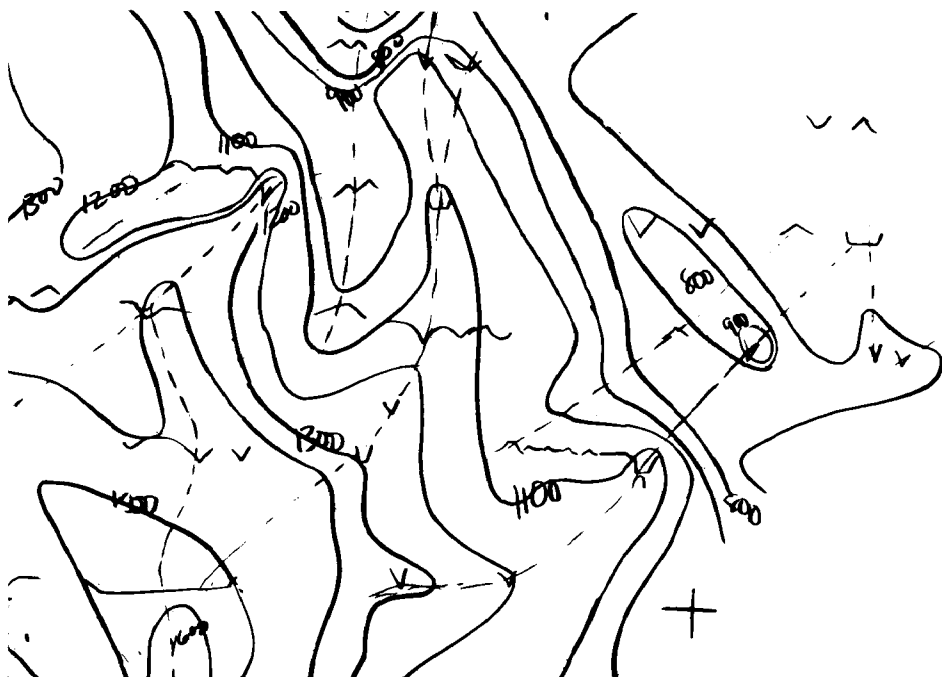


FIG. 13. — Geologically unrealistic contours based on field sheet data only.

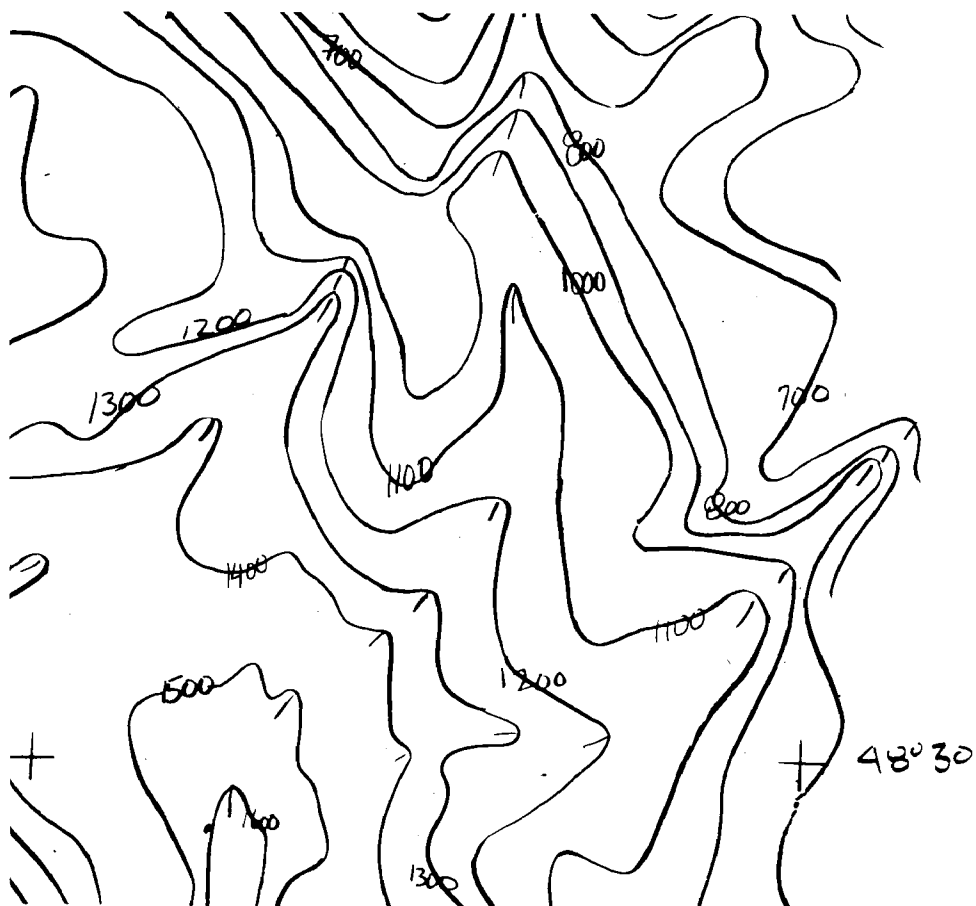


FIG. 14. — Interpretation of contours between soundings and sounding lines.
(Corrected contours of fig. 13).

RECOMMENDATIONS

Archival Importance of Echograms

The interpreter is greatly dependent on the quality of annotation and physical state of the echograms. In the view of the interpreter, the ideal echogram consists of a clearly and consistently annotated profile that indicates the times, dates, changes in ship speed, changes in paper speed, changes in phases, ship's course, sea state and reasons for unusual artifacts on the records. These details are necessary to accurately position the echogram ; to correct for distortions and enable a more realistic interpretation of the data. Omission to annotate changes in the operation of the echo-sounder may lead to interpretation errors. For example, adjusting of the gain to give a strong first arrival will prevent subsurface geomorphological information from being recorded digitally or on the echogram. This will give rise to incomplete information as to the nature of the bottom and perhaps cause an erroneous interpretation.

Similar care must be exercised when drafting the boat boards, for this is the only means of relating the time events recorded on the echograms to actual positions on the earth's surface. Morphological symbols derived from the analysis of the echogram, must be properly positioned in order to supplement information given by the soundings. Colour-coding of days on the boat-board should be consistent throughout the survey area and the fixes should be labelled with indelible markers. Annotations of the boat-boards must include the location of the beginning and ending of sounding lines and co-ordination of reference marks between field sheets and boat-boards as well as between adjoining boat-boards. All of these criteria are outlined in field manuals for hydrographers, but it would seem that with the advent of automated systems of data collection, plotting and storage these time-consuming and laborious tasks may be overlooked. There is a danger of relying too heavily on the computer-generated records. In the eventuality of a computer malfunction discovered after a cruise, the hydrographer should be able to correct the discrepancies by referring to well annotated echograms. If the echograms have not been well annotated during the field season, the losses incurred in terms of finance and manpower are considerable.

Given the important role played by echograms in the production of bathymetric and morphologic maps and the fact that these echograms constitute the only tangible product of a hydrographic cruise, it is surprising that they are not treated with proper and due care. In spite of the archival importance of echograms, the monetary cost (i.e. tax dollars) and human costs (i.e. loss of internal equilibrium), the need for better preservation methods has received very little attention. Crumpled, dried out, rolled and unrolled, sent hither and yon, the echograms deteriorate to a point where they are illegible (fig. 15).

The proposal which follows represents the first step in the move to preserve these documents. Several scientific institutions in the United

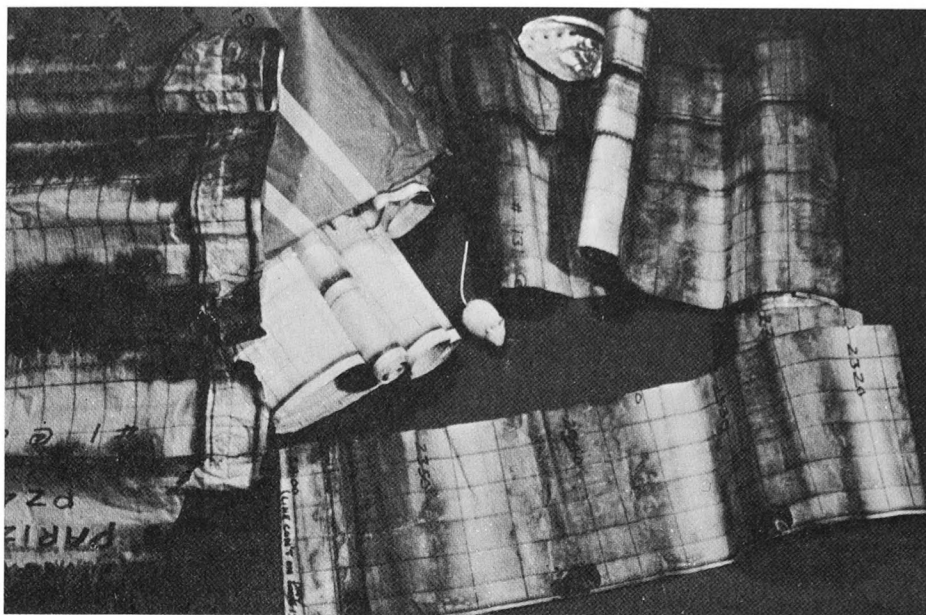


FIG. 15. — Echograms collected in 1975 — brittle, water-stained and torn.

States and Canada have undertaken to transfer their seismic records and echograms systematically onto continuous reels of 35 mm microfilm. These reels can be examined by use of a microfilm reader which displays the information on a screen and from which photocopies of the documents can

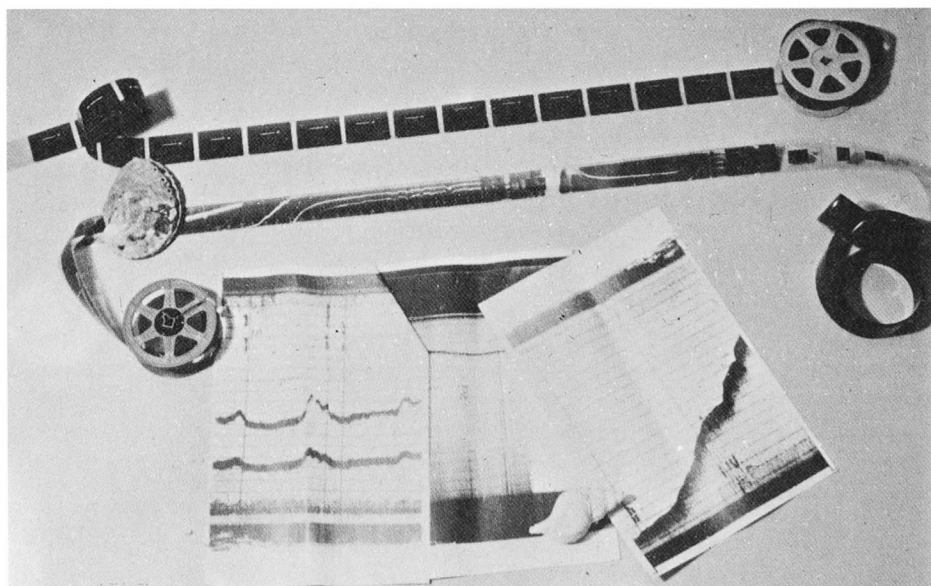


FIG. 16 — 35 mm microfilm reels of echograms photographed as a continuous strip, and as overlapping sections. Photocopies obtained from these microfilms by use of a "Reader-printer".

be obtained (fig. 16). This microfilming method would present advantages in storing, handling and shipping of the echograms. It would also result in an increase in the ease of retrieval and reproduction of these echograms and hence increase the value of the survey. For archiving purposes it might also prove wise to preserve boat-boards and field sheets in negative form or include them on the microfilm as some institutions have done. These improvements in the storage methods can be justified if the prospective users of these documents are considered : marine geologists, who produce bathymetric, morphologic and sediment distribution maps ; pleistocene geologists concerned with glacial deposits ; petroleum companies involved in drilling and dredging operations ; economic geologists looking for mineral deposits ; marine engineers ; fishermen and legists.

Although the novelty of this storage and display method may be unpopular with some users, the ability to photocopy relevant portions and to scan rapidly through the records will surely outweigh this factor. The quality of the microfilmed reproduction does not present a problem and the echograms can be viewed at several magnifications by simply replacing the objective lens of the reader-printer. It is proposed that the original documents be placed in archival storage and made available on an open file basis only.

The cost of microfilming material collected during a hydrographic cruise represents a minimal expenditure when compared to ship operating costs. The process of microfilming all of the echograms collected during a standard hydrographic survey represents approximately 0.01 % of the cruise cost if the echograms are photographed as a continuous strip, or 0.2 % if they are photographed as overlapping sections (see Appendix).

Considering the period of time that likely elapses before offshore areas are resurveyed and considering the cost of resurveying these areas because the computer tapes have been accidentally erased and the echograms have deteriorated or are lost, is it not wise to try and preserve these data in a better fashion ?

When reading accounts of Captain COOK's voyages it is difficult not to admire his meticulous nature and the accuracy and the care he gave his work. Would he have treated precious echograms with such disrespect and relegated them to some dark and damp section of the hull ? Would we hold this man up as a symbol of an accomplished explorer and hydrographer if he had allowed echograms, boat-boards and seismic records to crumble into oblivion ?

Multi-disciplinary Surveys

As mentioned earlier, it was the quest for knowledge of the sea which inspired his crew and himself to roam the seas. Artifacts, sketches and observations on the culture and character of the people and their lands were valued as highly as the charts of the waters which bound them. Only recently has this concept returned to our ships in the form of multi-disciplinary surveys. One aspect, however, is still missing to make our identification with the past complete, that is total co-operation toward

achieving the same goal. Unfortunately, all too often scientists descend upon a ship like a dreaded disease and are considered, and perhaps behave, as an interference. In spite of many seasons of co-operation, some field hydrographers and crew do not really understand why anyone could be interested in echograms, or care to know the nature of the sediments beyond its anchor holding capability. Could there not be an effort made to stimulate the curiosity of those on board to understand the full importance of the data they have collected? Perhaps by giving them the satisfaction of seeing the final product and explaining its uses, those responsible for the collection of the raw data would have the tools, experience, and knowledge to fully understand the importance of that which they are monitoring.

To achieve this co-operation it might be worthwhile to encourage scientists who gain by the collection of bathymetry to become involved both in cruise preparation and participation. This co-operation between marine scientists and hydrographers would result in a greater scientific return both from the hydrographic and scientific point of view. Finally, may I suggest that there be a pre-season briefing, outlining the general geology and oceanography of the survey area, the problematic areas, the questions to be answered and the type of information required to answer these queries. An understanding of the scientific problems of the survey area would enable the hydrographer to establish the location and orientation of the sounding grid and to select a bottom sampling interval to help satisfy the needs of the many users of these data. This could only result in a greater return of scientifically valuable data in addition to obtaining the required hydrographic data. It would also represent a financial saving by eliminating the necessity to return to this area.

Furthermore, close co-operation between related disciplines might initiate the return of that spirit of adventure and quest for knowledge which prevailed in Captain Cook's days, for it is stated in the hydrographer's bible, *The Admiralty Manual of Hydrographic Surveying* :

" The Surveyor should endeavour to collect any information likely to be of value to the advancement of scientific knowledge generally ; e.g. a record of meteorological conditions in the survey area, all types of oceanographical observations... He also has unique opportunities of studying and collecting fish, birds, mammals and insects, and will always receive advice and encouragement from the various museums on the subjects ".

Cook himself considered the task of marine surveying and exploration as inseparable : " The world will hardly admit of an excuse for a man leaving a coast unexplored he has once discovered " (SKELTON, 1954).

ACKNOWLEDGEMENTS

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APPENDIX

Case Study :

Parizeau cruise, April to October 1975

1. — Days of bathymetry collection assumed to be 79.
2. — Total of 37 128 km of sounding lines, of 469 km per day.
3. — Cost of ship time : \$ 7 000/day (in Canadian dollars) ; Cruise cost = \$ 553 000.

Microfilming reduction of echograms collected during this survey :

Echogram recorded at a paper speed of 3ft/hr will accumulate 72 ft of record/day.

— 1 day is represented by 4.5 ft of 35 mm film.

Therefore 4.5 ft. of film = 72 ft. of echogram = 469 km ; and 1 reel of microfilm holds 100 ft of film, which represents 22 days of bathymetry. Therefore, approximately $3\frac{1}{2}$ reels of 35 mm microfilm would be required to store the entire bathymetric data for this cruise.

Cost :

- a) Echogram recorded as one continuous strip on 35 mm film :
 - material and handling costs for 1 reel range from \$ 14.50 to \$ 20/100 ft reel which represents an expenditure of \$ 50 to \$ 70 for the entire cruise, or 1/100 of 1 % of the total cruise cost.
- b) Echogram recorded in overlapping sections 3ft in length on 35 mm film :
 - reduction from 3 ft section to 1 frame $1\frac{1}{2} \times 1\frac{3}{4}$;
 - cost of 1 frame varies from 35 cents to 45 cents ;
 - 1 day = 4.5 ft of film = approximately 30 frames ;
 - 79 days of bathymetry = 2 347 frames at a cost of :
 - 35 cents = \$ 821
 - 45 cents = \$ 1 056

Cost of microfilming the bathymetric data represents 0.2 % of the total cruise cost.

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DEMISE OF SEASAT A

Word has been received that the oceanographic satellite SEASAT A, described in a paper in the July 1978 *I.H. Review* by T.D. ALLAN, suffered a fatal power failure after 99 days of operational life. Although no replacement satellite is now programmed, SEASAT A in its short lifespan was able to collect a vast amount of data which will require substantial time to analyse.