COMPUTER PRODUCED PROFILES OF MICROTOPOGRAPHY AS A SUPPLEMENT TO CONTOUR MAPS

by Paul J. GRIM (*), George H. KELLER, and Robert J. BARDAY (**)

Atlantic Oceanographic and Meteorological Laboratories
Miami, Florida

ABSTRACT

The principal products of deep sea bathymetric surveys are contour maps depicting the relatively larger features of the floor. Unfortunately, however, these maps cannot display most of the small scale features (microtopography) that are recorded on fathograms. Knowledge of this microtopography and some means of displaying it are increasingly important as man develops a greater need for utilization of the sea floor. Since future surveys are likely to be automated for data reduction, an economical and quickly produced supplement to contour maps can be computer produced profiles that clearly display the details of the bottom topography. Illustrations based on a recent narrow-beam echo sounder survey clearly point out the benefit from presenting bathymetric data in other than map form.

INTRODUCTION

Man is rapidly developing his technology to the point where exploitation of the sea floor will be a common occurrence in all depths of the oceans. One of the tools most needed for this will be an accurate knowledge of the undersea topography. This must be known if man is to lay pipelines and cables, construct bottom mounted structures or conduct sea floor mining activities. However, bathymetric contour maps of large portions of the deep ocean do not show the exact nature of the sea floor because these areas are often characterized by small scale features (here referred to as microtopography) having lateral dimensions much less than the separation of the survey tracklines. A knowledge of the nature of

(*) Currently at the National Geophysical Data Center of NOAA's Environmental Data Service.

(**) Currently at the Department of Oceanography, Oregon State University, Corvallis, Oregon.

this microtopography is the very information that will be most valuable for some aspects of man's utilization of the sea floor.

The purpose of this paper is to point out that in many oceanic areas, bathymetric profiles showing the microtopography are valuable supplements to contour maps. With the use of computers and automatic X-Y plotters, these profiles can be produced rapidly and economically since it is likely that most deep sea soundings collected in the future will be digitized for computer processing.

The profile presentation of bathymetry is particularly meaningful if, when conducting the survey, a narrow beam echo sounder is used. Such a sounding system obtains a much greater degree of detail than is normally possible with a conventional wide beam sounder (see, for example, KRAUSE and KANAEV, 1970) thus providing a very close approximation of the sea floor relief even in the roughest terrains.

EXAMPLES FROM A SURVEY SOUTH OF PANAMA AND COSTA RICA

To develop the argument presented in this paper, bathymetric data selected from a recent deep-sea survey are used. These data serve to illustrate: (1) the character of typical microtopography as shown by narrow beam echo sounder fathograms, (2) the difficulty or near impossibility of showing in a meaningful manner the nature of the sea floor in certain areas with contour maps based on the trackline spacing that will likely be used in future deep sea surveys of significantly large regions of the ocean floor and (3) how the microtopography can be shown with computer-produced profiles quickly and economically if digital methods are used for reducing the survey data.

The survey was conducted in the equatorial Pacific Ocean (figure 1) in August 1969 by the National Ocean Survey ship *Oceanographer*. Approximately 11 200 kilometres (6 000 nautical miles) of trackline data were obtained with satellite navigational control centered on the Panama fracture zone, a seismically active fault zone trending north-south between 82° and 83°W (MOLNAR and SYKES, 1969). The basic survey pattern was a grid with tracklines oriented north-south and east-west at one quarter degree intervals (about every 28 kilometres, or 15 nautical miles). Bathymetric and magnetic results of this survey, including data reduction techniques, have been discussed by GRIM (1970a). All depths have been corrected for variations of sound velocity using Matthews' tables (1939).

The trackline density of this survey is about the same as that which has been used in the past, and proposed for future systematic surveys in the deep ocean. See, for example, the coverage of NOAA's north Pacific SEAMAP survey given by RYAN and GRIM (1968).

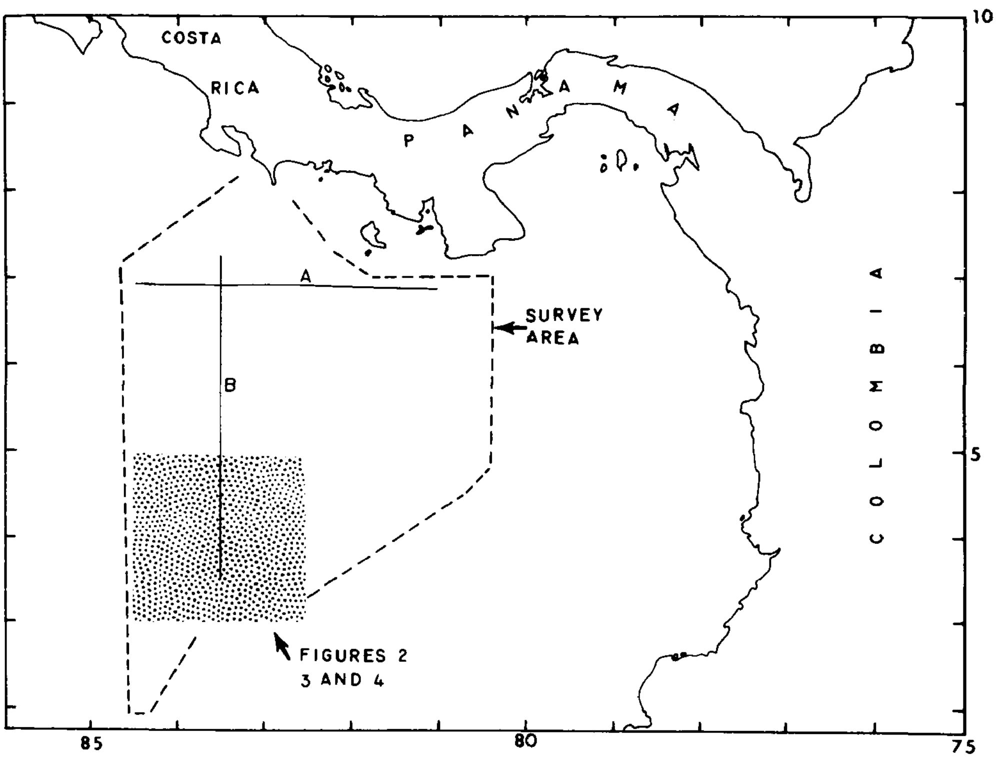
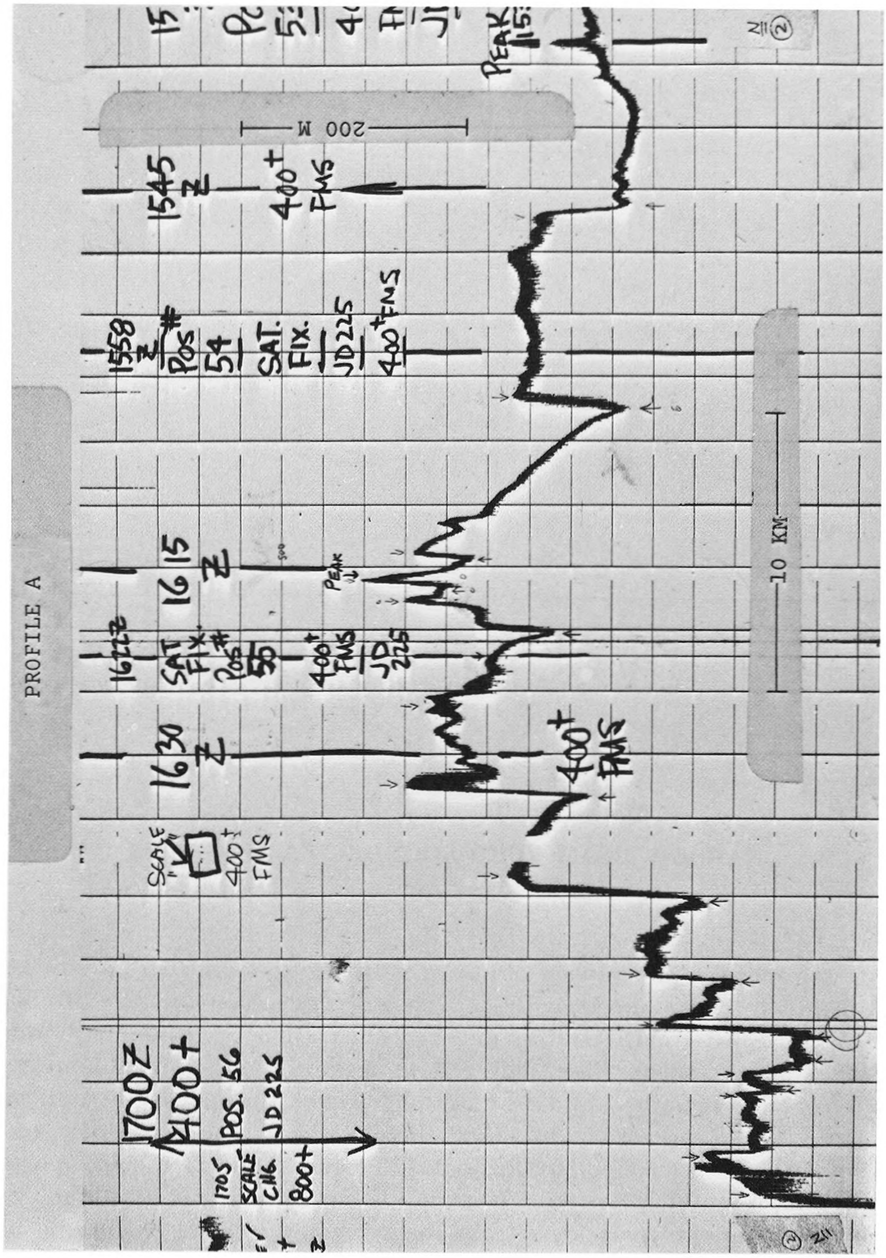
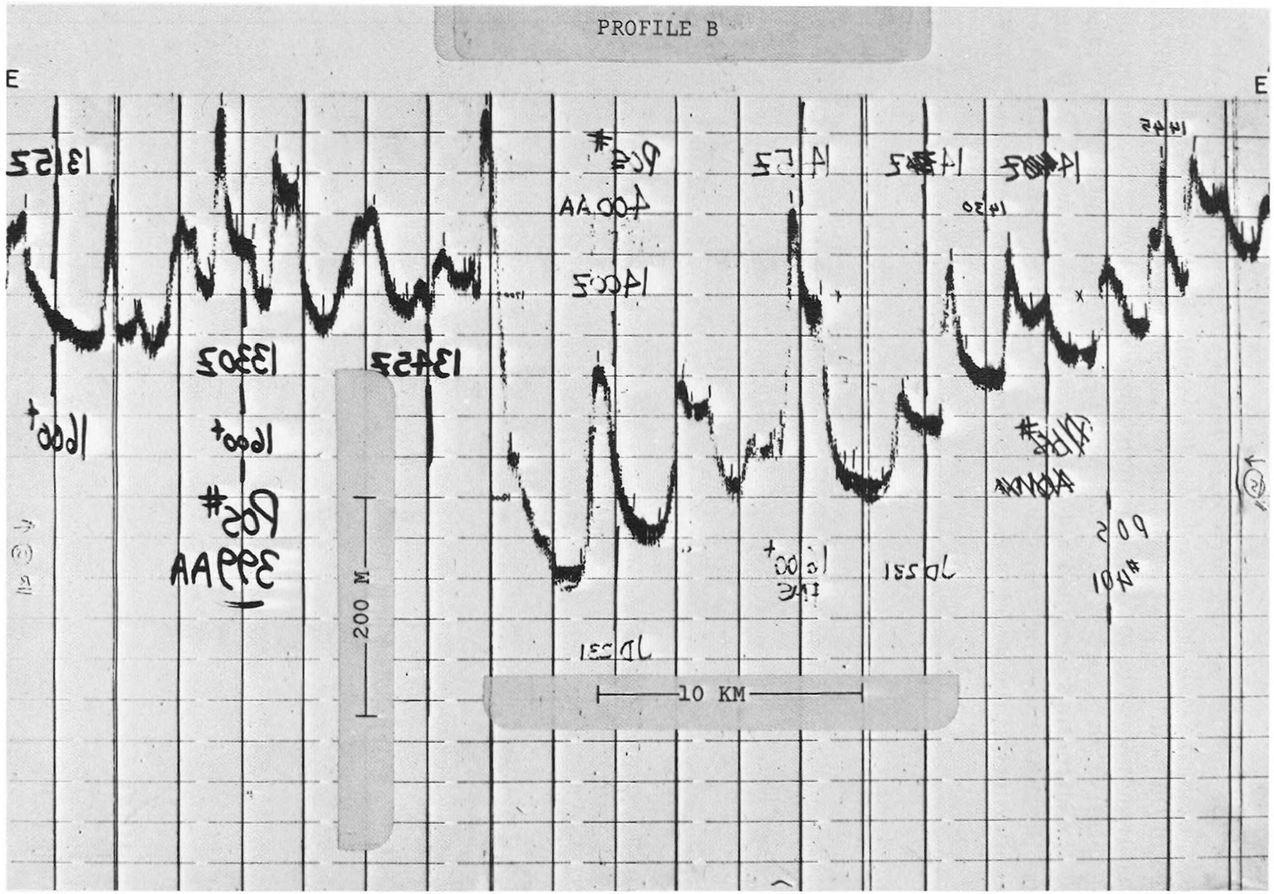


Fig. 1. — Survey area. The stippled part of the area is characterized by extremely rugged topography. Computer produced bathymetric profiles are given for tracklines A and B in figures 5 and 6.

NARROW BEAM ECHO SOUNDER FATHOGRAMS

Depth measurements were obtained with a gyro-stabilized narrow beam echo sounder (20 000 hertz with a 3° beam width between −3 dB points and 6° between −15 dB points) and recorded on a precision bathymetric recorder. The records were digitized at 5-minute intervals (about every 2.3 km, or 1.25 n. miles) and at additional times (peaks, deeps, and slope changes) judged necessary to show the details of the sea floor on the subsequently produced computer plots. Plates 1 and 2 display portions of the survey fathograms which reveal areas of highly irregular relief. These fathograms clearly show that the very abrupt changes in the topography are faithfully recorded with a narrow-beam sounder. With conventional wide-beam echo sounding equipment the straightness of the scarps and the existence of the narrow deeps would not be seen. Discussions of directional echo sounding and how these results compare with those of wide beam sounders can be found in Cohen (1959) and Krause and Kanaev (1970).


PROFILE A
200 M
10 KM



PLATES 1 and 2
Portions of narrow beam echo sounder fathogram records corresponding to parts of profiles A and B in figures 5 and 6 respectively. Vertical exaggeration about 35/1. Vertical black lines were made automatically every 5 minutes and at fix times and other events. The fathogram in plate 2 is printed in reverse so that its orientation is the same as profile B in figure 6.

LOSS OF TOPOGRAPHIC DETAIL ON A CONTOUR MAP

In portions of the survey area it is difficult or impossible to contour accurately the sea floor because of the microtopography. Such a terrain is located in the southern part of the survey area. The complicated nature of the bathymetry owing to such microtopography is clearly shown by the series of profiles in figure 2. Each trackline plot represents the average depth of the soundings obtained along that particular segment. With one exception these averages lie between about 2 900 metres and 3 300 metres (the exception being the short east-west segment at 3.5°N between 83.5°W

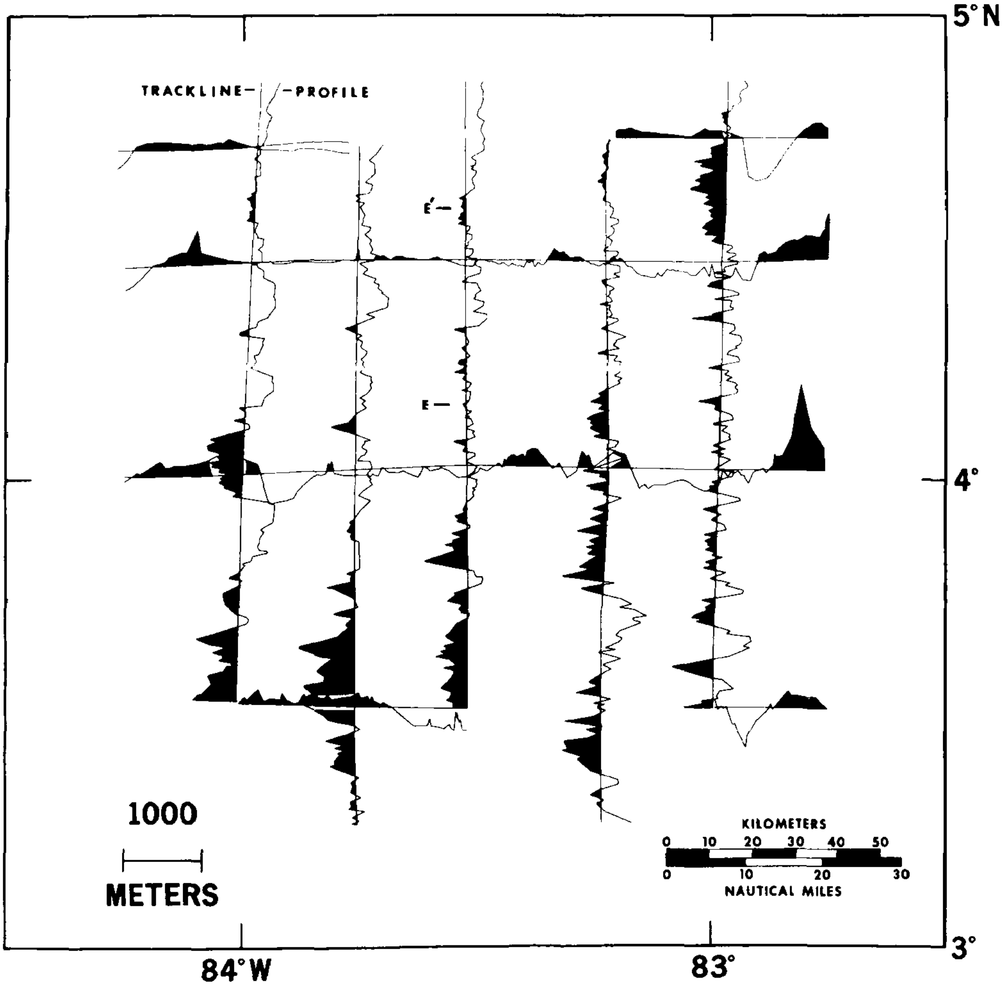


FIG. 2. — Bathymetric profiles from southern part of survey area presented along tracklines (see figure 1). The blackened portions of the profiles represent depths shoaler than the average depth along each trackline segment. Vertical exaggeration for each profile is about 20/1. Relief of the microtopography is given by the 1 000-metre scale. The fathogram record between E and E′ is shown in plate 2.

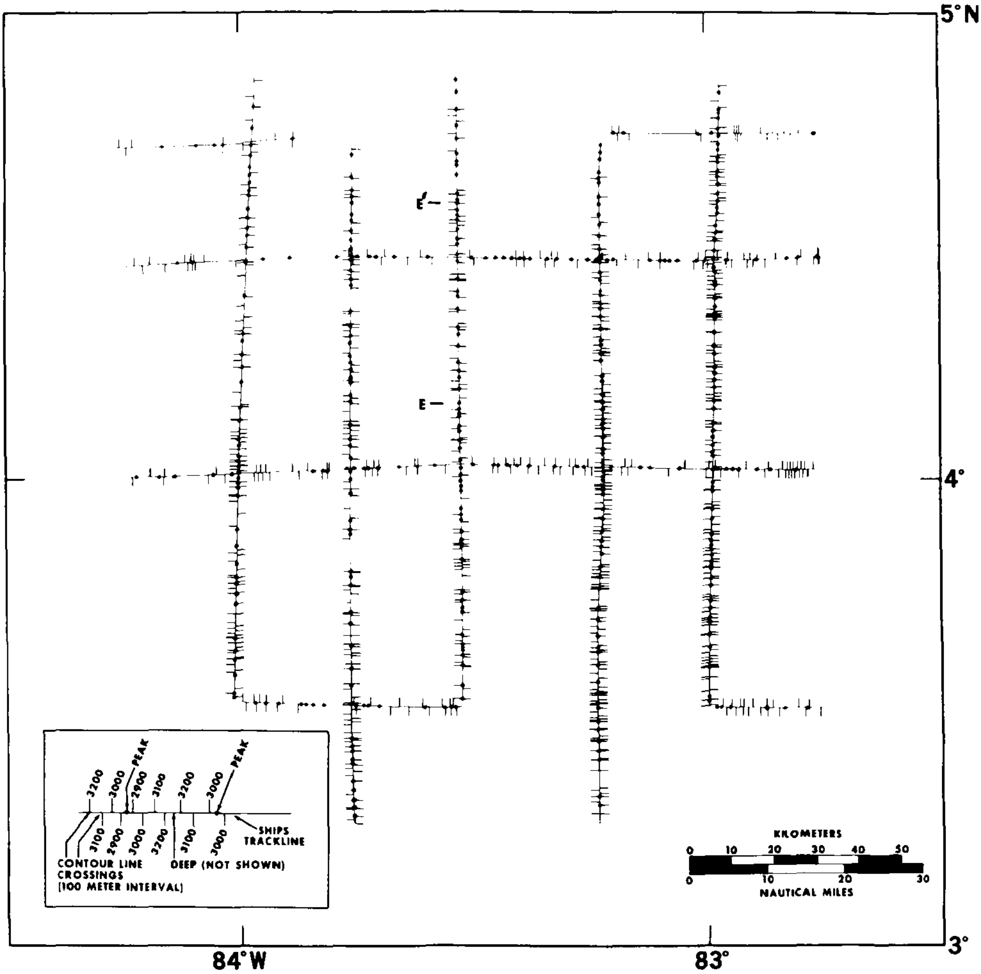


FIG. 3. — Alternating ticks normal to the tracklines indicate locations of 100-metre contour lines. Dots show locations of bathymetric peaks. Deeps are not indicated (see inset and text for explanation).

and 84°W which has an average depth of about 2 700 metres). The portions of each profile shoaler than the average depth are blackened.

Most of the depths within the area of figure 2 are between 2 600 and 3 800 metres. West of 83°W the grain of the topography (i.e. the trend of the ridges and troughs) is east-west as seen by the correlation of some of the larger features across several north-south traverses. This is consistent with the observation that the topography along the north-south tracklines shows more peaks and deeps than that along east-west lines (i.e. the north-south lines have a shorter topographic "wavelength"). However, most of the smaller peaks and deeps cannot be correlated across the north-south lines showing that they lose their identity (for example, by bifurcating or merging with other ridges and troughs) over the spacing of the tracklines.

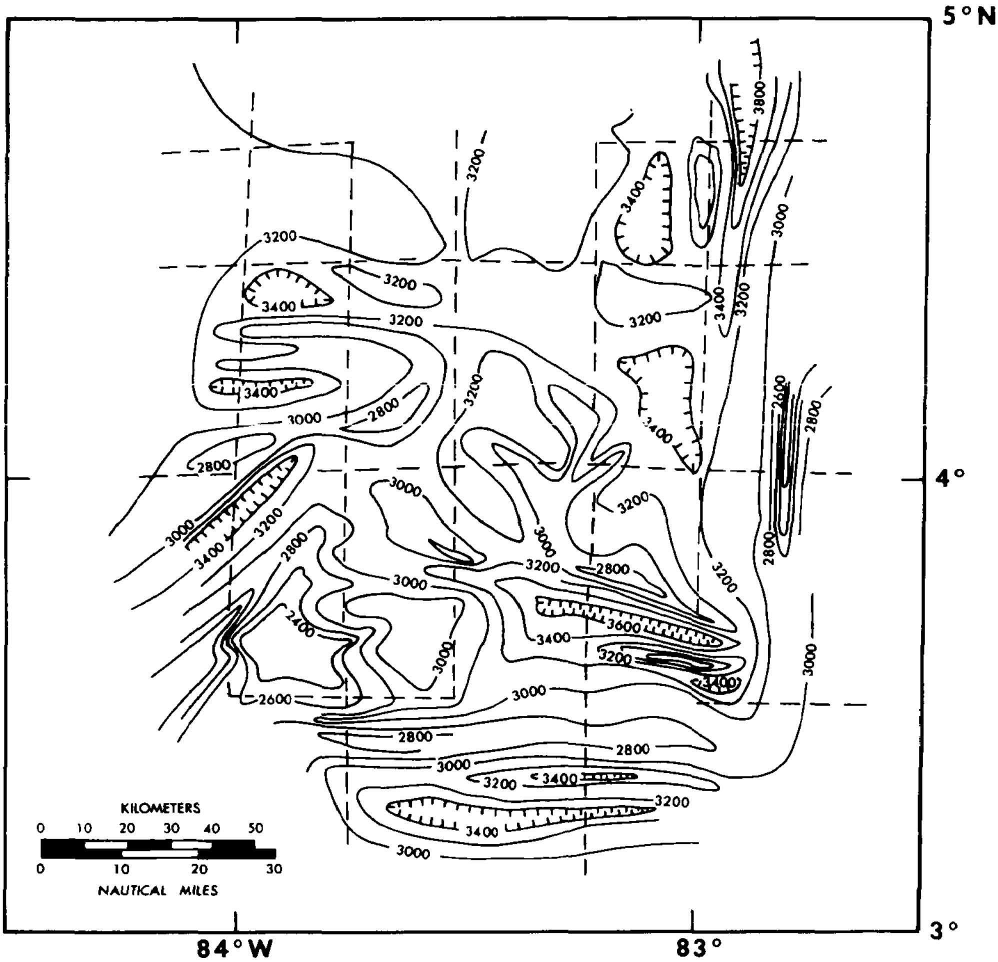


FIG. 4. — Generalized contour map (200-metre interval) of area shown in figures 2 and 3. Contours are also based on a single northeasterly trending trackline which is not shown here or in figures 2 and 3 for clarity of presentation.

The most noticeable aspect of figure 2 is the ruggedness of the sea floor although it has about the same general depth throughout the area. Abrupt changes in depths of hundreds of metres with slopes of 15° to 20° or more are common.

It is difficult to evaluate the problems in contouring such an area on the basis of the profiles. Figure 3 shows in map form how complex the area is for one attempting to contour it with a 100-metre contour interval. This figure was made by using all of the depths digitized from the sounding profiles. The intersections of the tracklines with the 100-metre isolines (i.e., where 100-metre contour lines would cross) are indicated by alternating tick marks normal to the track (this does not necessarily imply that the contours trend normal to the trackline). Minimum depths (peaks seen on the fathograms) are indicated by dots along the trackline. For clarity of presentation the values of the individual contour crossings at each tick are not given and the deeps that exist between the peaks are not shown.

This figure demonstrates the problems in showing the actual sea floor relief in this area with a contour map. If such deep sea areas are to be contoured, the tracklines will have to be spaced much closer than those of this survey and an appropriate map scale used. In spite of these difficulties, bathymetric contour maps in area similar to this are essential to provide some indication of the general depths. Such a map is given in figure 4. The contours of this map were drawn after subjectively smoothing the depth profiles. By comparing this figure with the profiles in figure 2, some of the larger features are seen to be clearly shown by the contours, although there is no indication of the great amount of microtopography present in this area. It should be emphasized that if this area were contoured by other workers using the same data, it is likely that the contour lines in much of the area would be drawn quite differently from the presentation given here.

COMPUTER PRODUCED PROFILES

In figures 5 and 6 computer-produced profiles from the survey are given as examples of how the profiles might be presented (although it is probably desirable to publish the profiles at a larger scale than given in the pages of this review). These profiles were made by an offline X-Y plotter using a computer program (GRIM, 1970b) which accepts reduced bathymetric data as input and produces annotated plots of bathymetry at any scale and vertical exaggeration desired. The profiles were made on the plotter in ink and are suitable for publication with very little additional labeling.

In the future one of the steps in producing contour maps will probably be obtaining reduced data such as those used as input to the above plotting program. Thus, the profiles can be considered as an economically produced "spin off" in the process leading to the production of the final map.

Although most of the microtopography seen on the fathograms can be displayed with computer-produced profiles, some of the very smallest features (those with relief on the order of metres and lateral dimensions on the order of tens of metres) are difficult to show. If these features are deemed important enough to present on the profiles, then care must be taken, not only in scaling the depths at very short intervals on the fathograms but in the vertical exaggeration and physical size of the resulting plots

DISCUSSION

Small scale bottom features are becoming increasingly important as technological advances enable man to utilize greater and greater depths in

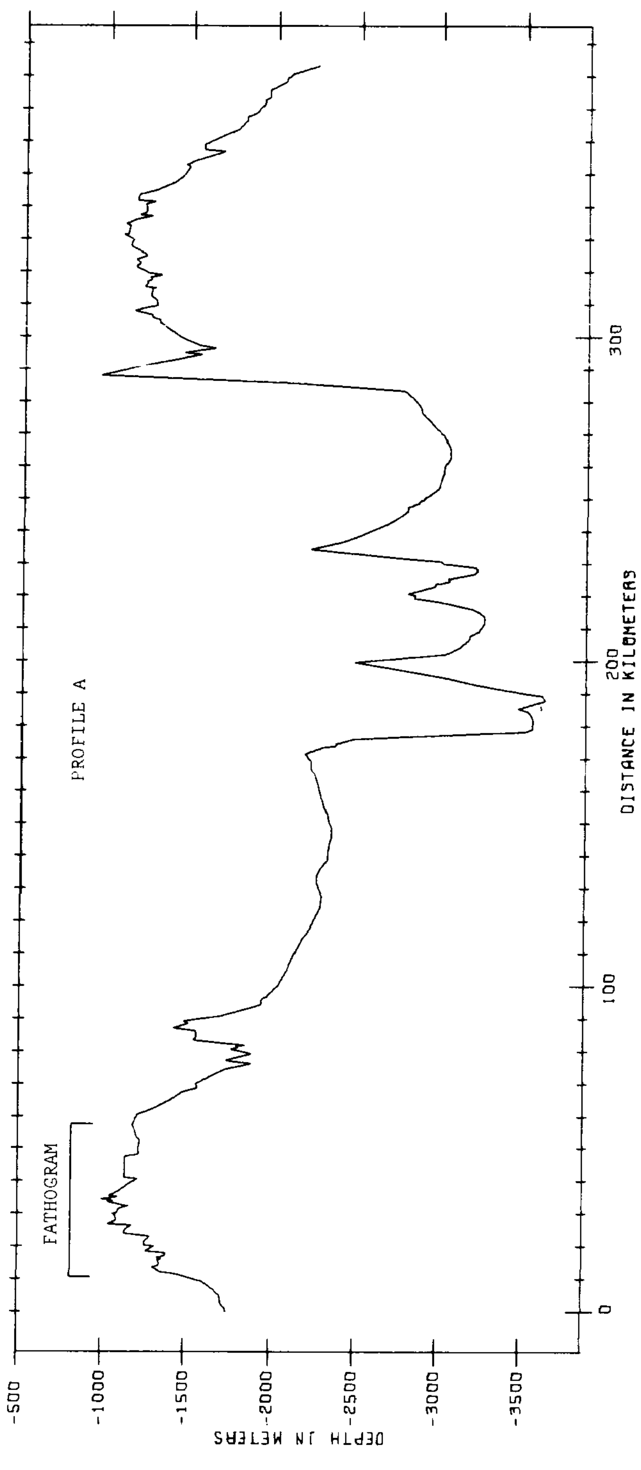


FIG. 5. — Computer produced bathymetric profile. See figure 1 for location. Vertical exaggeration 50/1. Plate 1 shows the fathogram record corresponding to *bracketed* part of the profile.

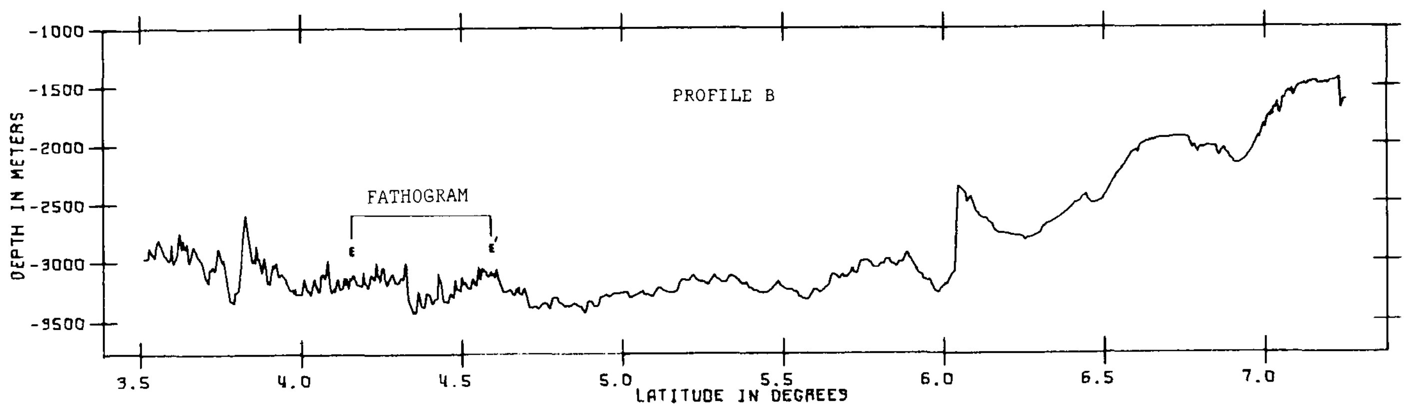


FIG. 6. — *Computer produced bathymetric profile. See figure 1 for location. Vertical* exaggeration 40/1. Fathogram record for E-E' given in Plate 2.

his exploitation of the sea floor. Properly annotated and presented bathymetric profiles are essential in locating sites for various ocean engineering projects and for planning such operations as the mining of manganese nodules or other mineral resources. The detail provided by such profiles is also required for search and rescue operations as well as various salvage programs.

In addition to the probability that such information will be of great practical use in the near future, these same data are of significant interest to the marine geologist in studying geologic processes that have affected the sea floor. Various features resulting from sedimentary processes show up very clearly on profiles. For example, the detail associated with submarine canyons, fan valleys, and deep sea channels that exist on continental margins and their adjacent abyssal plains can only be shown in such profiles. The nature of small lineations on the sea floor such as sand waves might be determined by comparing profiles based on results obtained from systematic survey tracklines. Other bottom features seen on profiles would include block faulting, the smoothing effect of sediment as a function of distance from a sediment source, and evidence for craters on seamounts or the flattening of their summits.

The idea of producing bathymetric profiles from deep sea tracklines is not new. This has been a standard technique for presenting bathymetric information in scientific journals for years but at scales which often omit the detail needed to evaluate the microtopography. More recently, data reports from bathymetric and geophysical studies based on profiles produced by automatic X-Y plotters have been published (e.g., HAYES *et al.*, 1969; LOWRIE and ESCOWITZ, 1969). However, almost all the tracklines of such scientifically oriented studies are not spaced closely enough to allow contouring of the data. This paper has shown that even when surveys are systematic and detailed enough to generate bathymetric contour maps, properly produced profiles are a valuable supplement to the maps because only with such profiles can the microtopography be delineated. It is especially important that the idea of publishing profiles be brought to the attention of survey organizations such as hydrographic offices that may not be research oriented but will probably conduct many of the deep sea surveys in the future. The traditional single product of a bathymetric survey made by such organizations is a contour map and the routine publishing of deep sea bathymetric profiles, such as suggested here, may be a novel concept.

Thus far only deep sea surveys have been considered. However, the ideas developed here can also be applied to surveys conducted on continental shelf and slope areas. Although such surveys are likely to have a trackline density sufficient to permit the construction of relatively accurate contour maps, the nature of features with scales of tens or hundreds of metres will still be difficult to show meaningfully on these maps.

Computer produced profiles could essentially be published as data reports (including trackline location charts) at the same time or at an earlier time than the contour map. These reports could be available months or even years before the maps since the profiles are simply a straightforward method of showing the basic data and would require none of the interpretation needed in contouring the depths. The physical size of the profile plots would depend on the roughness of the sea floor in the area surveyed, the accuracy of the navigational control, and the type and quality of the fathogram records. For example, the size of profiles from a survey conducted with a wide beam echo sounder with relatively poor control might be much smaller than the size of profiles based on a survey conducted with good control and a narrow-beam echo sounder. In general, both the profiles and the trackline location chart should be presented at a scale that allows the positions of individual features to be determined with an accuracy consistent with that of the navigational control.

In the future an increasing number of bathymetric surveys will use advanced echo sounders and will be automated for data reduction. The resulting contour maps of many oceanic areas can be supplemented by computer produced profiles quickly and economically by using the reduced bathymetric data. Such profiles will display much of the sea floor microtopography which cannot be shown adequately on contour maps but a knowledge of which may be very important as man acquires the ability to utilize the sea floor more fully.

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