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I.O.S.

A LONG-RANGE SIDE-SCAN SONAR SURVEY OF THE MERIADZEK TERRACE, BAY OF BISCAY

BY
N.H. KENYON AND P.M. HUNTER

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NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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WORMLEY

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This report was originally commissioned by British Telecom

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INTRODUCTION

TAT-8, the first Transatlantic fibre optic cable, is scheduled to be completed in 1988. The route of the cable is planned to cross the canyoned continental slope of the northern Bay of Biscay, taking advantage of one of the few relatively smooth areas of sea-floor, known as the Meriadzek Terrace. The American end of the cable will split into two on the Meriadzek Terrace, one branch going to the UK and the other to France. There is a history of failure for cables crossing this continental shelf break and slope that is, at least in part, attributed to their being suspended across the steepest and most rugged topography.

The survey was carried out using the long-range sidescan sonar (GLORIA) in order to determine (1) whether there are any obstacles such as steep slopes along the planned route, and (2) what room there is for future cables.

THE GLORIA SYSTEM

A review of sidescan sonar, both its history and the acoustic and technical factors affecting sonar design, is given in Somers & Stubbs (1984). Technical details of the GLORIA Mark-II system are to be found in Somers et al. (1978). The GLORIA-II system (Geological Long-Range Inclined Asdic) was designed and built at IOS, Wormley. Dual sidescan transducer arrays are towed in a neutrally buoyant vehicle, about 400m behind the ship and at a depth of about 40m. The vehicle is launched from a specially designed launching cradle in an operation that takes about 20 minutes. Launching and recovery can be carried out in relatively rough seas and interpretable data has been obtained in all sea states up to Force 10. The main restriciton on operations in bad weather is a limitation on the direction of travel, because constant pitching can damage the cable.

The transducers operate at a frequency of 6.5 kHz. The ranges that can be obtained depend on the properties of the sea water but are typically about eight times the water depth.

The signals received are tape-recorded and then photographically anamorphosed (stretched) to correct for changes of ship's speed.

PRECISION ECHO SOUNDER

The IOS precision echo sounder, which operates on a frequency of 10 kHz, was used to give slope gradients and soundings. Gradients steeper than about 25° cannot be measured accurately.

NAVIGATION

The Pulse/8 system, operated by Racal-Decca, gave a positioning accuracy that is much greater than our usual operations which rely on Loran and/or satellite navigation. Fixes were taken every six minutes.

CRUISE NARRATIVE

The RV Farnella, a 65 m long deep-sea trawler owned by J. Marr & Sons of Hull, sailed from Concarneau, France, at 0700, 16 September 1984. The PES and GLORIA were launched a few hours before the survey area was reached. Tracks were run approximately up and down the slope (Plate 1) with the separation of the survey lines fixed at 13 nautical miles at the southern end of the area and six nautical miles at the northern end. This allowed for between 10% and 30% overlap depending on sound propagation conditions which limited the range obtained on parts of the upper slope to three nautical miles.

At the end of the survey the ship ran parallel to the planned route for the UK branch of the cable. The whole survey lasted from 2200, 16 September to 2200, 18 September and, during these two days, 2700 square nautical miles were completely covered. Eight minutes of sidescan record were lost due to an electronic fault but this was over ground that was being looked at for the second time. A hand-made mosaic was made on board and was taken off the ship by British Telecom personnel at 0700 on 19 September.

Those involved in the project included:

Christopher Knight	BT
Brian Squelch	BT
Charles Rogers	BT
Stuart Crawford	STC

Michael Quain	ATT	
Paul Rabbett	Racal-Decca	
Neil Kenyon	IOS	Geologist, in charge of survey.
Michael Somers	IOS	Head of GLORIA project.
Malcolm Harris	IOS	GLORIA project manager.
Peter Hunter	IOS	Cartographer
Roy Hadgraft	J. Marr & Sons	Master

INTERPRETATION

Sidescan sonar interpretation is an art. Errors and distortions on sonographs cannot be avoided; however, some of them can be reduced or even removed by proper interpretation. Potential errors and distortions can occur due to:

1. A 'lay-back' effect because the fish is 400m behind the navigation system.
2. A 'lay-over' effect caused by looking down obliquely at steep slopes. For instance, the top of a ridge will appear to be slightly nearer to the bottom of a ridge than it would be if mapped in true plan.
3. A decrease in resolution with increasing distance from the fish arising from the increase in the beam width. A point target at far range will appear as a bar on the record.
4. Artefacts due to propagation problems in stratified water. Some spurious returns due to this were seen at the north-east corner of the survey (Plate 2).
5. Loss of signal or false waviness due to roll and yaw of the fish.
6. A 'minimum' in the sonar receptivity at close range, resulting in some loss of data.
7. Usually sidescan sonar records have a distortion that is greatest in the near-range but, in this case, it has been partially removed before anamorphosing. However, some distortion will remain because an average value for depth has been assumed.

It must be borne in mind that the images in Plate 2 are a map of the strength of acoustic backscattering from the sea-floor. This backscattering strength will vary according to the direction in which a relief feature is viewed. Thus stronger signals will be received when travelling parallel to a relief feature than when transverse to it. Errors in the position of features, arising from one or a combination of these effects, could be as much as 500m.

It is useful to think of two sorts of backscatterer. Firstly, there are the major relief features which give strong reflections (whiter tones) from large slopes facing towards the ship and weaker reflections (grey tones) or shadows (black) from slopes facing away from the ship. At the other end of the spectrum of reflections come small-scale roughness elements which can cause dramatically different values of backscattering. Stronger than average returns could come from the rough surfaces of exposed rocks, biological features such as corals, shells or burrows and small, current-induced bedforms such as ripples. Even changes in sediment type should be detectable by sidescan sonar; for instance, muds should absorb more sound than sand.

DATA REDUCTION

The GLORIA records were interpreted (Plate 3) after first measuring and plotting slope angles from the PES profiles. Plate 2 has been made into a mosaic in such a way that the sonographs match in tone wherever possible. However, some of the larger slopes, lying between the tracks, will appear differently when viewed from opposite directions and thus a tonal match is not always easy to achieve. Careful post-cruise signal processing should be able to correct this cosmetic problem.

The bathymetric map (Plate 4) has been drawn from soundings compiled at IOS. Sources include IOS research cruises, which use precision echo sounders, and cruises by the CNEXO ship Jean Charcot using the multibeam system, SEABEAM. All of this data is fixed by satellite navigation. Most of the SEABEAM data is from the canyoned areas to the east and west of the Meriadzek Terrace and some has been published by Groupe CYMOR (1982). The final contouring was drawn using the GLORIA interpretation as a guide. Plate 4 is very much more accurate than previous bathymetric maps for this area.

DESCRIPTION OF THE GROUND

Meriadzek Terrace

The few strips of smooth sea-floor on the continental slope in the Bay of Biscay were recommended as potential routes for undersea cables by Belderson &

Kenyon (1976). The Meriadzek Terrace is one of the largest of these strips of smooth floor. It can be seen to be divided into an Upper Meriadzek Terrace and a Lower Meriadzek Terrace by a prominent escarpment which will be called here the Petrock Escarpment (Petrock of Bodmin, besides having a suitably geological name, was a Cornish Saint, as was Meriadzek). Both parts of the Terrace appear to be free from any relief features or other strong acoustic targets and have gradients of less than 2°.

Slump folds and slump faults

The Meriadzek Terrace is bounded by steeper slopes except at the narrow corridor linking it to the Celtic Sea shelf. As the gradients increase to between 3° and 5° the characteristic wavy shape of slump folds and slump faults are detected on some parts of the Terrace. These are due to a downslope creep of the sediments, resulting in slope parallel ridges, several kilometres in wavelength and up to 50m high. A large arcuate feature bordering the east side of the Lower Meriadzek Terrace is probably the surface trace of a shear failure along a concave upward shear plane in the sediments. Similar features have been described from elsewhere on the Northwest European Continental Slope by Kenyon et al (1978). It is not known whether they are still active. The immediate cause of such mass movements is an increase in steepness of the slope, due to either an increase in the rate of deposition of sediment or to movement on the deep-seated faults that underlie the slope. As neither seem likely to be occurring at the present time in the geological history of this region, catastrophic failure would seem to be unlikely.

Petrock Escarpment

The terrace is subdivided by a slope that, at its eastern end, is 1400m high with a gradient of up to 14° and, at its western end, 500m high with a gradient of 5°. At its foot there is a series of deeps. Such a configuration is in keeping with this being the site of a large deep-seated fault in the rocks of the continental margin. Although sedimentation processes have not had time to fill in the deeps, movement on this fault is not likely. Few large earthquakes occur on the margins of the Atlantic and there have been none in the northern Bay of Biscay over a period of 15 years from 1965-1979. The Escarpment continues to the east across the canyoned slope to at least as far as 7°45'E. It appears to have been considerably eroded by the canyon-forming processes. To the west, the trend of the Escarpment coincides with the trend of the lower Shamrock Canyon.

Canyons

The canyons trend roughly north-south down the overall slope to the east of the Terrace but, to the west of the Terrace, the Shamrock Canyon is the most prominent of a number of oblique trending features. The oblique trends are believed to be due to deep-seated lines of weakness in the rocks of the continental margin. There are numerous small branching gullies running into the canyon axes, especially near the heads of the canyons. Thus the topography is rough and resembles that of the badlands in the arid, mountainous parts of the western USA. The canyon walls usually slope at greater than 7° and, in places, exceed 25°, which is the limit to which slopes can be measured by our precision echo sounder. The lower walls and the floors of the canyons correspond to strong reflectivity on the sidescan records. Submersible traverses across the walls and floor of a branch of the Shamrock Canyon by the Group CYMOR (1981) showed that, as well as rock outcrops, there were signs of erosive activity including small overhanging cliffs and piles of boulders.

SEDIMENT PROPERTIES

There is little available data on the surface sediments although sands are known to be present down to at least 200 m. Bouysse et al. (1979) show a tentative boundary between 'coarse sand' and 'very fine sand' in depths of about 500 m, near the head of Black Mud Canyon. Auffret & Sichler (1982) describe diverse types of surface sediments in depths of between 2000 m and 3000 m on the southwestern end of the Lower Meriadzek Terrace and on the Aegis Ridge. Although the sediments are dominantly muddy foraminiferal oozes, some samples contain up to 90% sand, much of it derived from shallower water. On the basis of the sediment type, Auffret & Sichler (1982) predict the occurrence, in depths of 3000m on the Aegis Ridge, of relatively strong bottom currents, reaching 30 to 50 cm/sec, whereas much weaker currents prevail in the shallower, 2000 m, depths. The sediments of the Upper Meriadzek Terrace do not appear to have been sampled but at some, as yet unknown, depth the surface sediments should change from dominantly sandy in the shallower water of the shelf to dominantly muddy on the upper slope. This 'mud line' is related to a decrease in the hydrodynamic activity. Hydrodynamic activity is usually relatively strong and complex near shelf breaks.

CONCLUSIONS

1. The GLORIA system has rapidly mapped the major features in the area and aided in the drawing up of an improved bathymetric map (Plate 4). The strongly-reflective areas (white) of Plate 2, in most cases correspond to slopes that are steeper than 10°. It is suspected that some backscattering of sound from these slopes is due to their being free of the cover of mud that is usually found on the continental slope and in the deep ocean. These strongly reflective areas ought to be avoided.

2. The Upper and Lower Meriadzek Terrace has gentle slopes, free from large obstacles. However, boulders or wrecks, although unlikely to be present, are too small to be resolved by GLORIA. The Terrace narrows upslope to a neck of only 4 km at a depth of 300 m.

3. The sediment type along the planned route is little known. It is suspected that medium-sized sands will give way to muddy sand and mud at depths of somewhere between 200 m and 500 m.

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PLATE CAPTIONS

Plate 1. Tracks used in the analysis. The continuous lines are those along which precision echo-sounder profiles have been used, the R.V. Farnella survey tracks are those with hour marks. The dashed lines are isolated tracks for which Seabeam data is available and the shaded areas have complete Seabeam coverage (by courtesy of J-C. Sibuet and the Centre Oceanologique de Bretagne). The plates have been drawn on a Standard Mercator Projection with a Standard Latitude at 38°N. The projection is based on the 1967 International Spheroid, semi-major axis 6378160.0 and semi-minor axis 6356775.0.

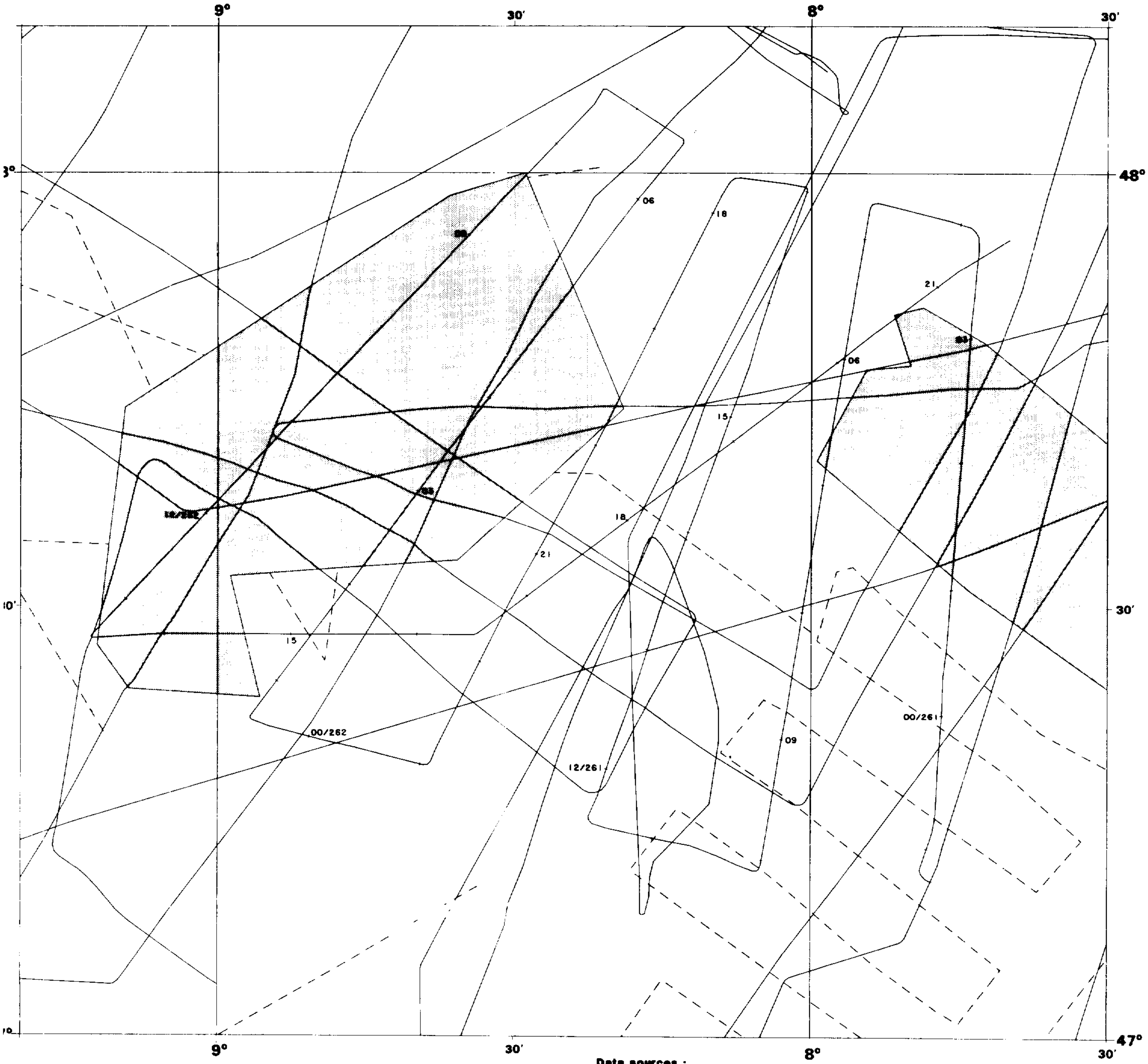
Plate 2. GLORIA sonograph mosaic.

Plate 3. Interpretation of the GLORIA sonographs and echo-sounder profiles obtained by RV Farnella.

Plate 4. Bathymetry at 100 m intervals, from uncorrected profiling data and sonographs.

MERIADZEK TERRACE : Track compilation

PLATE 1



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Data sources :

12/261 **Farnella track**

IOS track

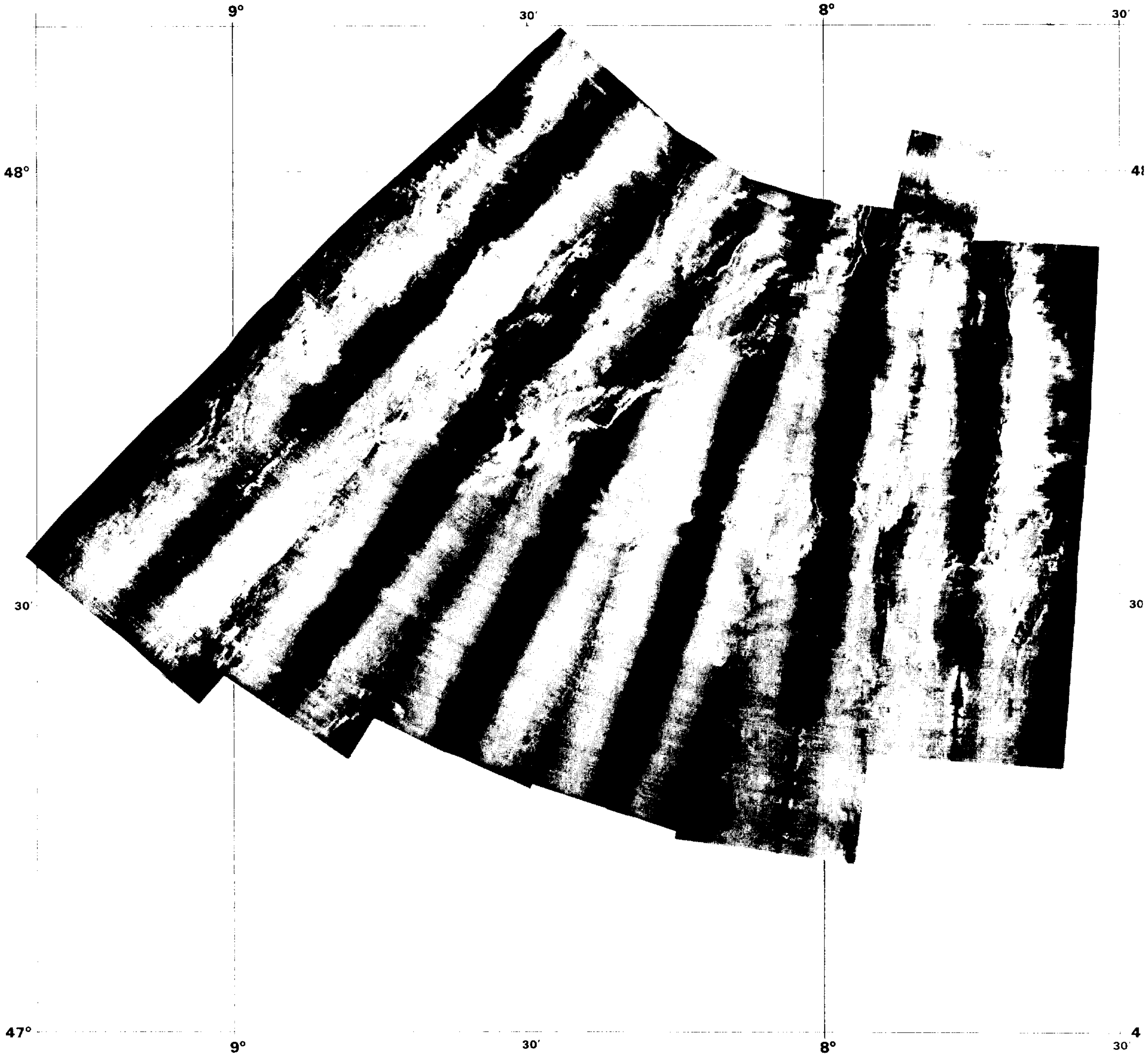
SEABEAM track

SEABEAM survey

October 1984

MERIADZEK TERRACE : GLORIA Mosaic

PLATE 2



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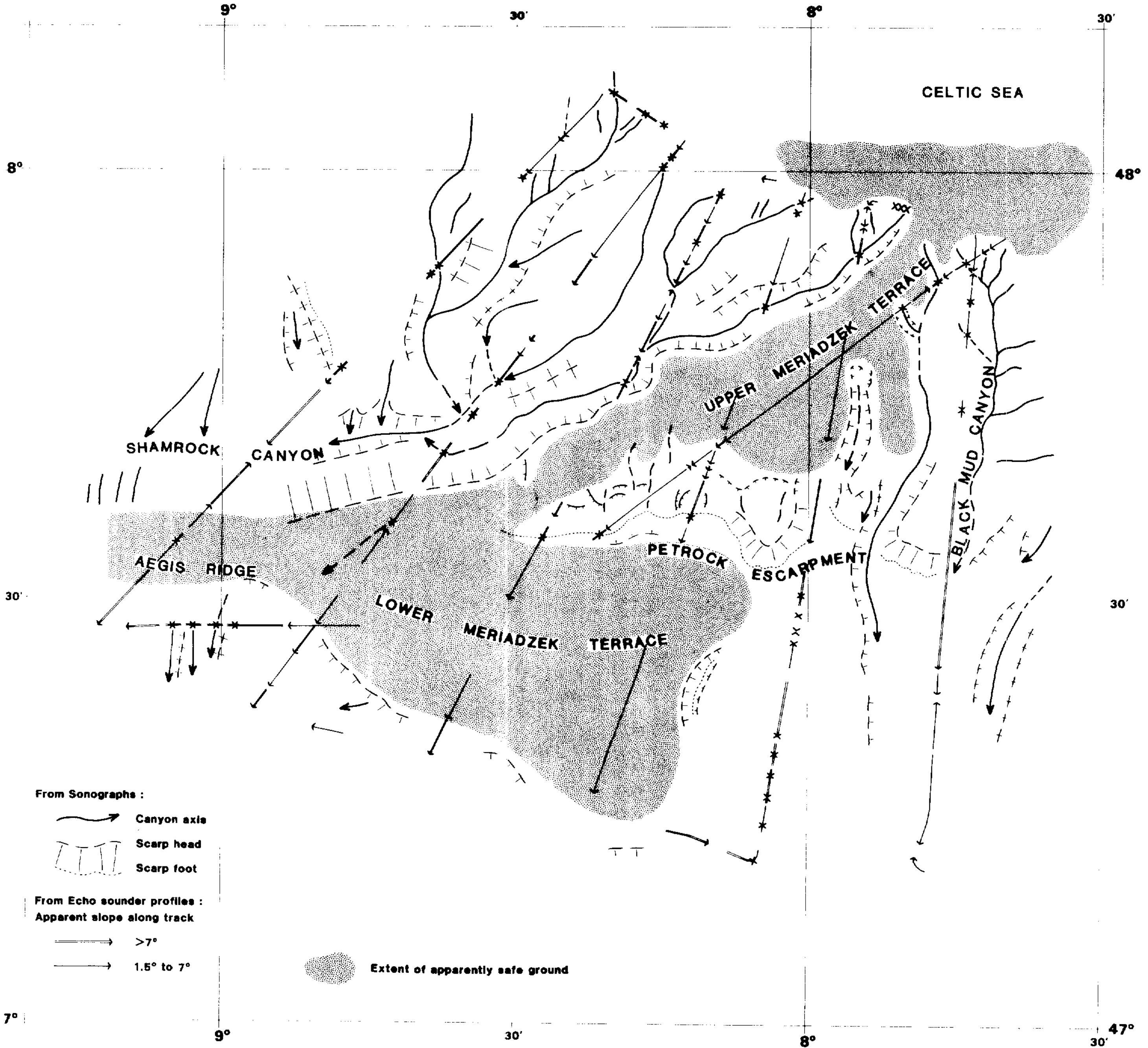
MERIADZEK TERRACE : Interpretation

PLATE 3



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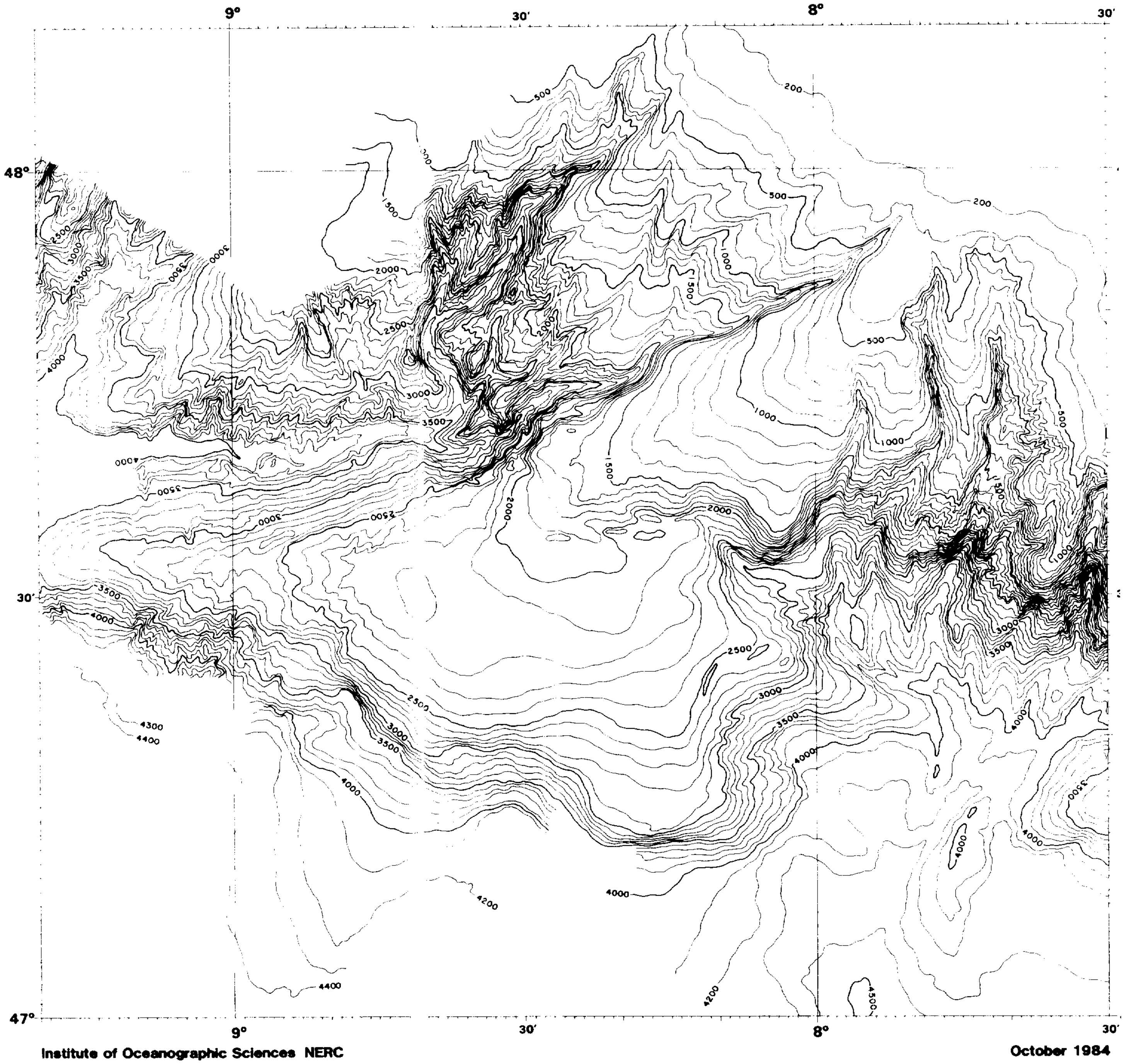
MERIADZEK TERRACE : Bathymetry

PLATE 4



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