I.O.S.

SEABED CONDITIONS WEST OF THE OUTER HEBRIDES.

NEIL H KENYON and COLIN D PELTON

Report No 95

1979

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Prepared for the Wave Energy Steering Committee.

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SUMMARY

Mapping with side-scan sonar proves that the rugged topography of the Lewisian gneiss complex of the Outer Hebrides extends out beneath the sea, as far as 75 km from the coast. Mooring of structures would probably need to be by direct fastening into the rock unless the small flat areas of sand are preferred. Rock hummocks, in many places over 5 m high with steep slopes and jagged surfaces, make this a particularly inhospitable area for the laying and repairing of cables. However further reconnaissance may reveal sand floored passages running in towards the coast.

Profiles and trends of the topography are analysed in the hope that they will allow equivalent bed roughness, and its effect on wave attenuation, to be estimated.

INTENTION

A geological reconnaissance of the sea floor is a useful pre-requisite in the planning of major offshore engineering projects. To this end maps of geological hazards have been prepared for the northern North Sea (Fannin, 1979) and for the Celtic Sea (Langhorne and Kenyon, 1979). Side-scan sonar with its ability to rapidly map relief trends and roughness contrasts has proved to be an ideal tool for such a task. This report is based largely on an analysis of side-scan sonar data obtained by IOS between 1965 and 1979 and it is hoped that the report will be taken into account in the selection of potential sites for wave energy devices, prior to the making of more detailed site surveys. (The significance of the wide range of easily recognised bedforms found on the continental shelf is shown by Belderson et al. (1972) in their picture atlas "Sonographs of the seafloor".)

A measure of roughness characteristics should be possible from the high resolution profiles provided.

METHODS AND DATA

There is very little published information on solid geology, superficial sediments or topography from the continental shelf west of the Outer Hebrides. The present work, which to some extent covers all of these topics, was originally done as part of the investigation of the geological processes of continental margins by the geology group of IOS at Wormley. It included a particular study of shelf sediment transport (Kenyon and Stride, 1970).

Most of the data analysed (Figure 1) was taken by the R.R.S. Discovery hull-mounted side-scan sonar, which had a frequency of 36 KHz and a range of 1 km. Some is by the new 2 way-looking hull-mounted equipment operating at a range of 500 m to each side of the ship. One long range sonograph (12 km) taken by the 6 KHz GLORIA Mk I equipment proved useful in mapping the rock boundary (Rusby and Revie, 1975). The most valuable data for the accurate measurement of roughness was produced by the IOS telesounder, a high resolution side-scan sonar having multiple beams, the principle of which is described by Stubbs et al. (1974). It has a frequency of 250 KHz, a horizontal beam width of 1° and a vertical beam width of 35°, enabling relief that is at least as small as about 1 m to be resolved when the sea is calm; as it was during its use in this area. Other side-scan sonar coverage was obtained on cruises of the R.R.S. Challenger.

About 150 grab samples have been looked at, taken at stations distributed evenly over the shelf west of the Outer Hebrides. They were collected by Dr. J.B. Wilson as part of his study of carbonate rich sediments on the Scottish Shelf and have

proved useful in giving confidence to the interpretation of the sonographs.

OUTER SHELF PLATFORM

The outer shelf platform is believed to be underlain by younger rocks of Mesozoic and Cainozoic age. It is relatively level at depths of between 120 m and 140 m but has some broad shoal areas near the shelf edge that are between 10 m and 20 m high (Figure 2). On some of these low rises there is a small scale relief of a few metres, that is attributed to the ploughing action of icebergs (Belderson et al. 1973). These shoal areas are subject to winnowing by occasional current action that has swept them almost completely free of sandy sediments, leaving rounded lithic fragments of cobble, pebble, and gravel size covered by a few thin patches of locally derived shell sand. An extensive pavement of this rock gravel is also found across most of the width of the shelf, west of Lewis, at about 58°30'N.

On the mid-shelf extensive sheets of carbonate rich shell sands and shell gravels are deposited in the slightly deeper ground stretching south from St. Kilda. These sands have a small mud content in places, particularly in the area around St. Kilda. The shelly sands and gravels form a complex mosaic of patches that are seen as light and dark tones on the sonographs. Some rock pebbles are found in places close to rock outcrops. Although these carbonate sands and gravels are relatively well sorted, only a limited amount of transport is expected to take place. This is likely to be on the occasions when the weak tidal currents are enhanced by currents generated during the passage of long period storm waves and storm surges (Kenyon and Stride, 1970).

The thickness of these shell sand sheets is unknown but it is probably greater than 1 m, except where they thin out at their boundary with the rocks and rock gravel.

ROCKY RIDGES

Older, more resistant rocks form the core of the three elevated ridges on which lie the three groups of islands of St. Kilda, the Flannan Islands and the Outer Hebrides. Between the Flannan Islands and the Outer Hebrides there is a linear deep, elongated NE-SW, that is considered to be a river valley overdeepened by glacial action (Ting, 1937) and now partially floored by sandy sediments.

The outer limit of rock outcrops, which can be readily mapped from sonographs, is one of the main contributions of this report (Figure 3). It roughly coincides with the 100 m contour. The Outer Hebrides rocky ridge extends at least 50 km southwards from Barra Head. The limit here is taken from an Institute of Geological Sciences map (Binns et al. 1974) with slight modification from an IOS long range sonograph. The rock limit is about 40 km west of the coast of South Uist and about 50 km from the coast of North Uist. Rocks outcrop almost continuously across the 75 km from the Outer Hebrides to just west of St. Kilda. Off north west Lewis the rock limit is between only 2 km and 5 km from the coast.

The area of rugged bare rock is one of the most extensive on the continental shelves of Europe. This is essentially because these are among the oldest and most resistant rocks of Europe, namely the Lewisian gneiss complex of north-west Scotland. The distinctive appearance of the submarine topography can best be described by reference to the landscape found on the islands of

the Outer Hebrides. This landscape has invited such local descriptive terms at "bossy" or "knock and lochan" topography. As seen from the ground the landscape is "a jumble of hills and mounds of roche moutonnée form alternating with an absolute maze of small lakes and peat filled depressions". If we substitute carbonate sands for the lakes and peat in the depressions one has an adequate description of the submarine topography (Figures 4 and 5).

Part of the Flannan Islands ridge has a coarse superficial sediment cover and a smooth but hummocky relief. This is perhaps a cover of morainic material over Lewisian rocks, such as is found masking a part of northern Lewis. But for the most part the Lewisian rock cover is continuous within the rock boundary of Figure 3. Some locally derived shell sands, shell gravels and gneissic cobbles partly fill the deeper of the narrow gullies that have been etched out along lines of weakness. These flat, sediment floored hollows are well seen on the telesounder record (Figure 4), and are more common near the outer limit of rock in deeper water.

BED ROUGHNESS

The height of the rock hummocks is extremely variable. The tallest peak to trough height measured on our records is 35 m. In order to allow estimates of roughness to be made (for the purpose of calculating the effect of the rock relief on wave energy), heights from peak to trough were measured along two lines at right angles to each other in depths of between 20 m and 90 m. These lines (parts of which are shown in Figure 6) were west of South Uist but they are thought to be typical for the whole area of rock outcrop. A peak of over 10 m high was

found every 1.7 km on average, whereas a peak of over 5 m high was found every 300 m on average. It is estimated that peaks over 1 m high will be found about every 30 m. The bed roughness has not been measured in depths less than 20 m, but it is thought that it will not be much less than the roughness in the deeper water because many rocks are charted just off the coast.

The linear patterns of rock relief seen on the sonographs are due to gullies lying along lines of fracture. An analysis of the most prominent of these (see the rose diagram inset in Figure 3), whose relief is greater than about 5 m, shows that there may be a tendency for them to have two preferred directions, NE-SW and NW-SE. The criss-crossing fracture pattern divides the rock into square, rectangular or diamond shaped lumps with steeper lower slopes than upper slopes. The smaller roughness elements, less than 5 m, rarely exhibit any obvious regional lineation. When viewed from above the relief often approximates to the shape of a tray of rectangular loaves with a very rough top crust. Thus, it is thought that for estimates of bed roughness over the general area of rock outcrop the relief can be assumed to be isotropic. However in certain localities there will be some preferred lineation.

CONCLUSIONS

1. The shelf west of the Outer Hebrides consists of a sediment floored outer shelf platform and three large rocky ridges topped by islands.

2. The outer shelf platform is divisible into shoaler areas covered in winnowed rock gravel, and slight hollows filled with carbonate sand sheets, sometimes with some mud content. There are none of the bedforms indicative of high mobility of sand.

3. The very extensive rock areas have the same rugged relief as is found on the Outer Hebrides. They are probably nearly all hard, metamorphic rocks of Pre-Cambrian age. The rock hummocks are often over 5 m high with steep slopes and jagged surfaces.

4. Mooring of structures within 40 km or more of the west coast of the Outer Hebrides would probably need to be by direct fastening into the rock unless the small flat areas of sediment are preferred. Cable laying and repairing will be difficult unless further reconnaissance reveals some sand floored passages running in to the coast.

5. It is hoped that an equivalent bed roughness can be estimated from the profiles and measurements given. (One cannot refrain from making the observation that because the sea bed west of the Outer Hebrides is extremely rough, the resulting attenuation of the storm waves could favour the formation of the Machair, the remarkable sandy coastal zone, rather than the shingle beaches that one might expect to find in such an exposed situation. We will not speculate on what effect further extraction of wave energy will have on the sediments of the coastal zone.)

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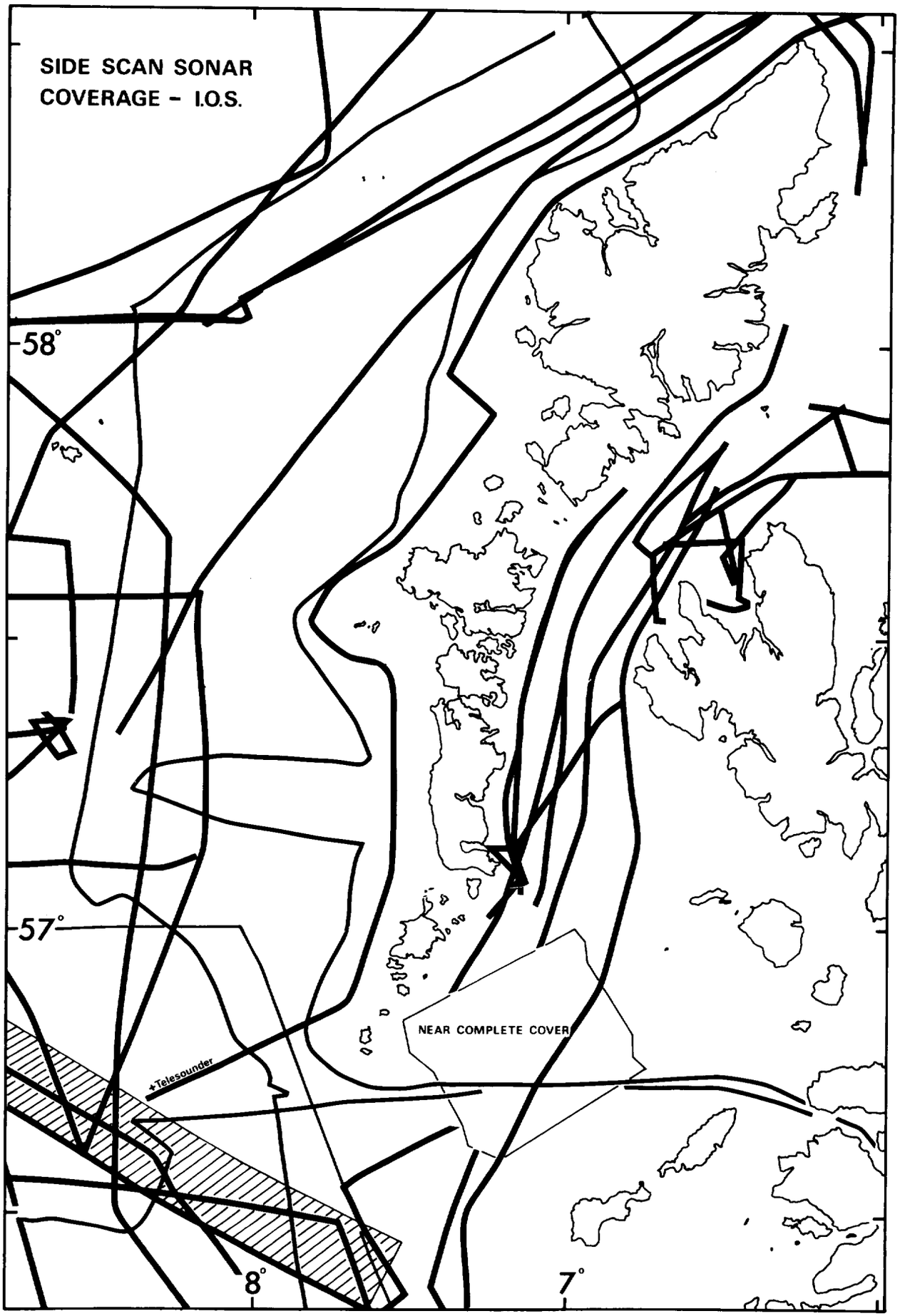


Fig. 1 The line width shows the area of ground covered.

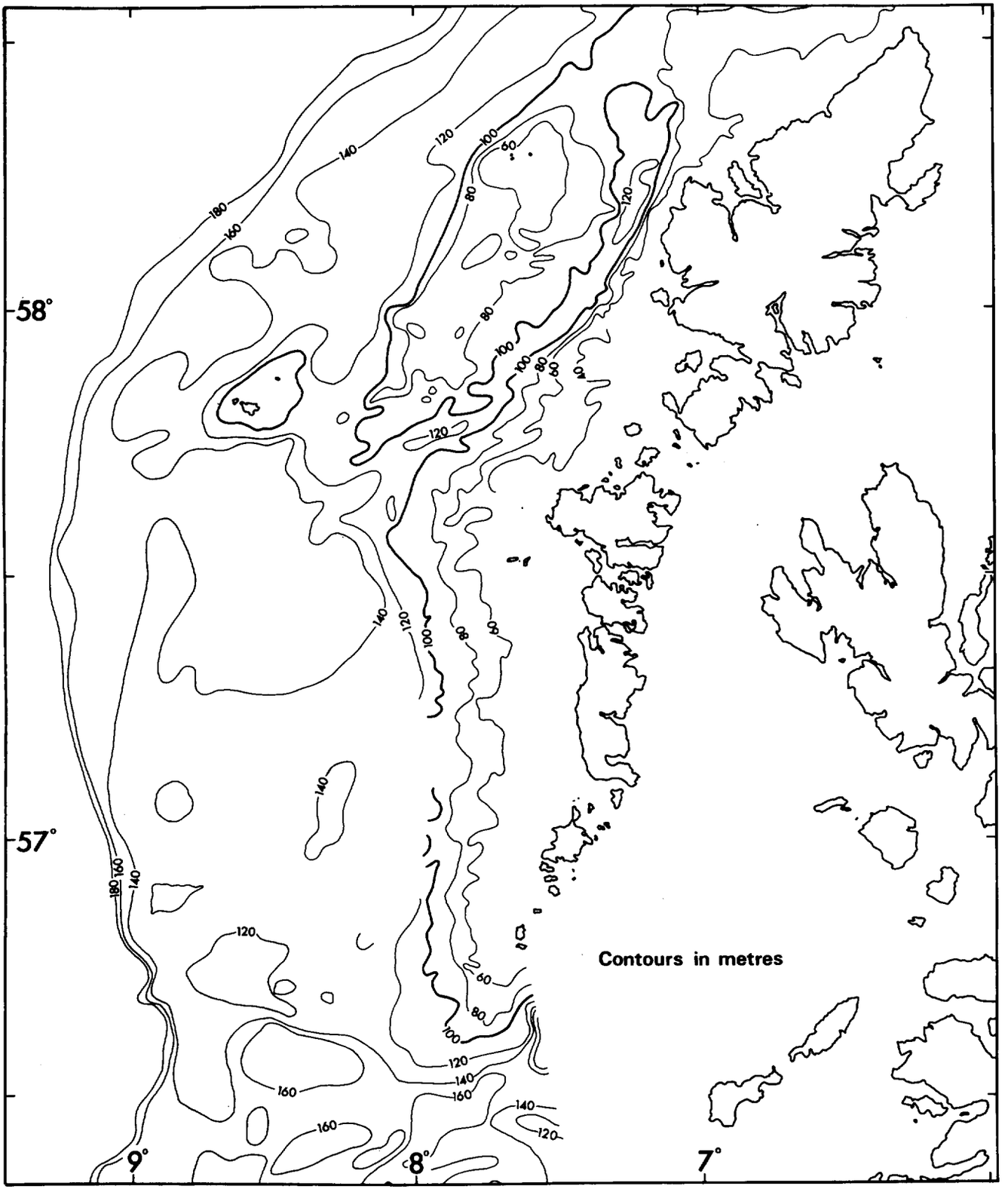


Fig. 2 Bathymetry based on Admiralty charts. The shelf is relatively flat below about 120 m, but there is a low rise near the shelf edge.

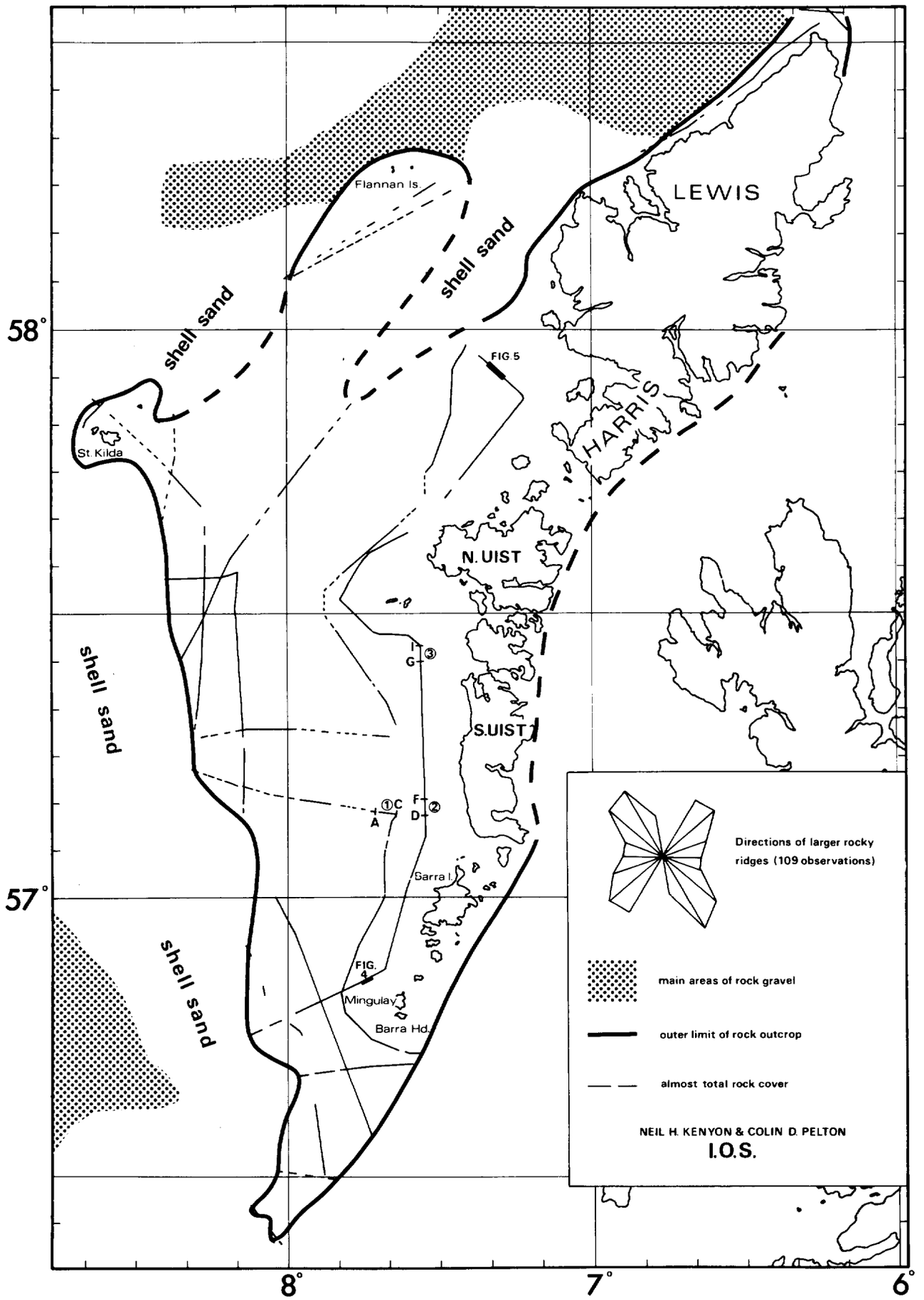


Fig. 3 The rock limit is plotted from sonographs and bathymetry.

Fig.4 I.O.S. Telesounder (width exagg. ×3·5)

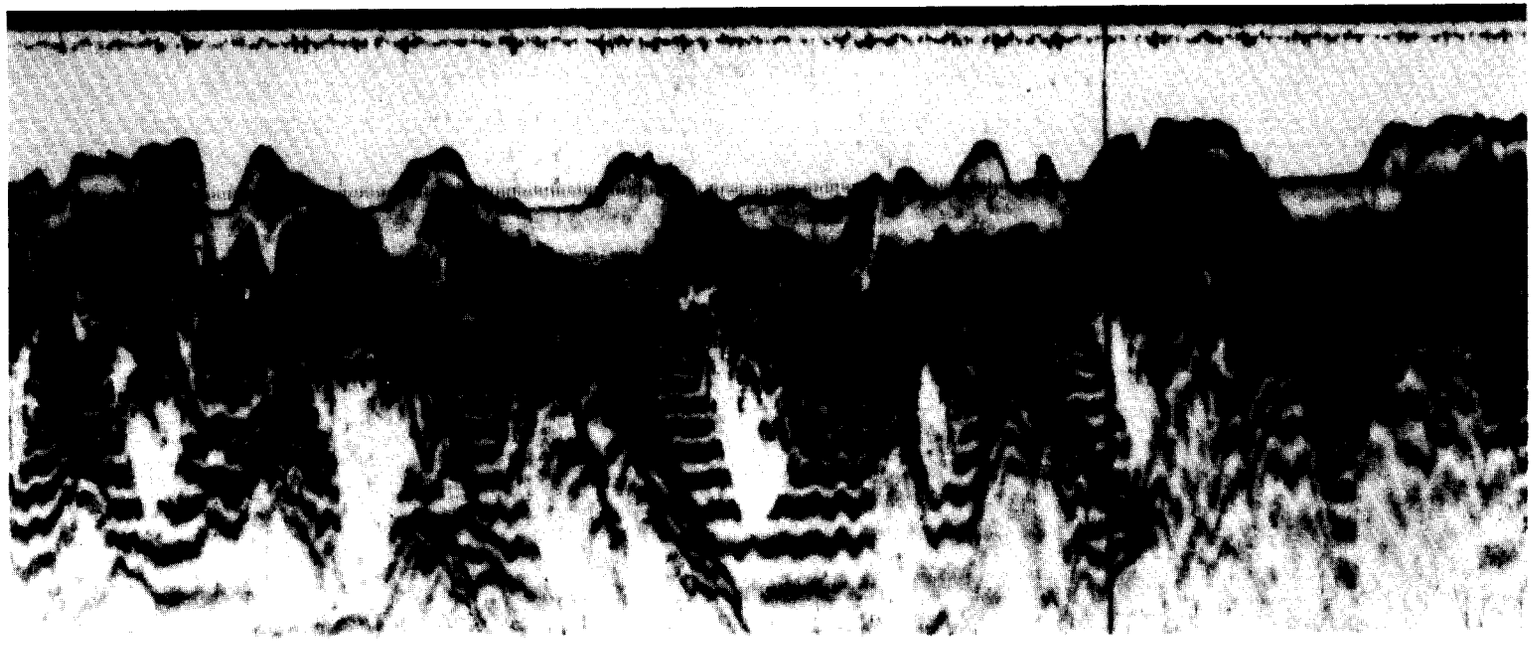
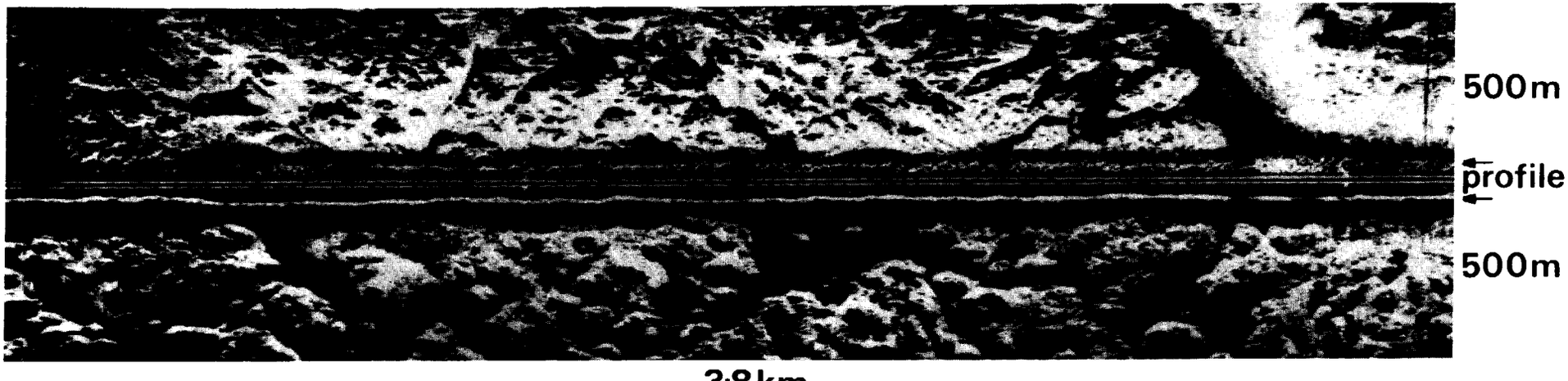


Fig.5 Dual channel side-scan sonar (true plan)



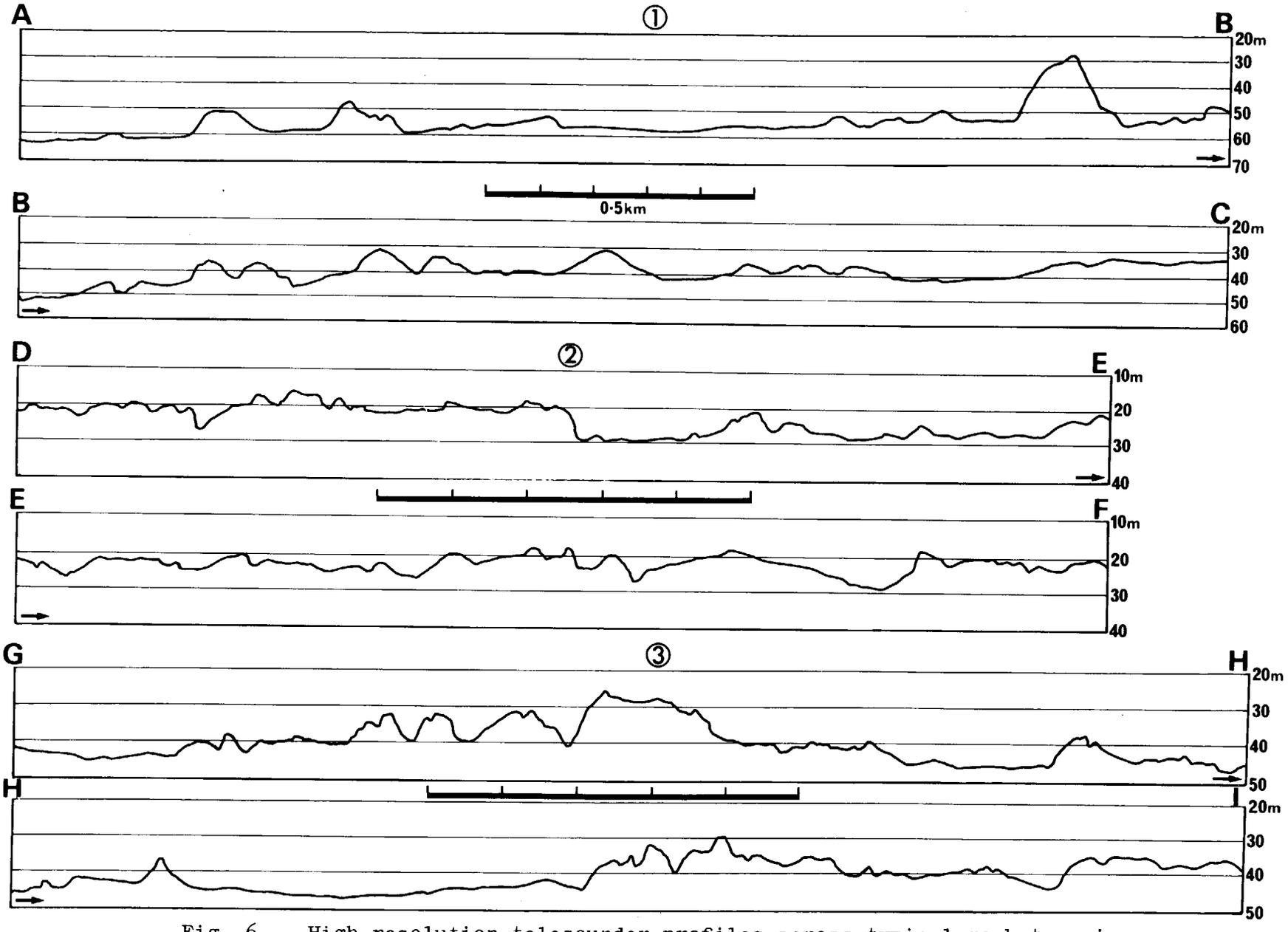


Fig. 6. High resolution telesounder profiles across typical rock terrain, located on Fig. 3. Line AC is at right angles to line DF.