NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF GEOLOGICAL SCIENCES

CRUISE REPORT

North East Irish Sea Investigations
August-September, 1967

Preliminary results of geophysical investigations

by R.McQuillin.M.Sc., and M.C.Tully.B.Sc.

Geophysical Division

Preliminary results of geological investigations

by J. H.Hull.M.Sc. and G.H.Rhys.B.Sc.

Continental Shelf Unit 1

CONTENTS

	page
INTRODUCTION	1
GEOPHYSICAL INVESTIGATIONS	1
Ship and personnel	1
Aims and methods	2
Position fixing and navigation	2
GEOPHYSICAL EQUIPMENT	3
Power supplies	3
Installation system	3
Transit Sonar equipment	3
Wimpey/Alpine seismic profiling equipment	4
E.G. and G. seismic profiling equipment	4
Elsec proton magnetometer	4
PRELIMINARY RESULTS	5
Sea floor sediments	5
The top seismic layer	5
Structures beneath the top seismic layer	5
GEOLOGICAL INVESTIGATIONS	5
Personnel	5
Navigation	6
Programme of work	6
Sampling	6
SAMPLING EQUIPMENT	6
Shipek Grab	6
Gravity corers	6
Vibracorer	6
Rock Drill	8
PRELIMINARY RESULTS	8
Sea floor sediments	8
Boulder clay and more recent sediments	8
Solid rock	8
FURTHER RESEARCH	8
REFERENCES	10
APPENDIX 1. Geophysics; synopsis of daily log.	10
APPENDIX 2. Geology; synopsis of daily log.	11

LIST OF TEXT FIGURES

		page
Figure 1	Area surveyed	1
Figure 2	150 - joule sparker traverses	2
Figure 3	10 000 - joule sparker traverses	2
Figure 4	Magnetometer traverses	5
Figure 5	Probable areas of solid rock at relatively shallow depth below sea floor	5
Figure 6	Sampling localities with supplementary Transit Sonar traverses	7
Figure 7	Sea floor deposits	9

INTRODUCTION

During 1966 the Institute of Geological Sciences began a programme of geophysical and geological investigation of the British Continental Shelf, and geophysical surveys were undertaken in the North Minch and in the Moray Firth (Annual Report for 1966, Institute of Geological Sciences. 1967. pp. 102-3). These shipborne surveys had limited objectives but provided valuable experience as well as useful new geophysical data. In 1967 a more ambitious project was planned utilizing a range of geophysical and geological tools to study an area of about 2000 sq miles in the north-east Irish Sea between the Isle of Man and the coasts of Cumberland and Lancashire. The M.V. 'Moray Firth IV' was used for the geophysical investigations and the geological work was done from the M.V. 'Olna Firth'. These operations are described separately under the appropriate sections of this report.

This survey was the first large scale marine operation by the Institute of Geological Sciences and for a number of reasons the north-east Irish Sea was thought to be a particularly suitable area for study. The results of aeromagnetic (Aeromagnetic Map of Great Britain, Sheet 2. 1st Edition, 1965) and gravity surveys (Bott, 1964) were already available and anomaly patterns indicated that the regional geological structure would be varied without being too complex. Good geological and geophysical control is available from land surveys around the area. Furthermore, the area was selected as one where conditions are promising for the discovery of economically valuable materials at or below the sea bed. Geological and geophysical evidence suggests the presence of a sedimentary basin, similar, though on a smaller scale, to parts of the North Sea.

The main objective of the surveys, both geological and geophysical, was to interpret and map the geology of the sea bed of this part of the Irish Sea. This project being the first of its type undertaken by the Institute, it was realized at the outset that this main objective was not likely to be completely attained and an important though secondary objective was to gain experience of techniques and a better understanding of the problems posed by work of this type.

The area in which work was carried out is shown in the plan (Fig. 1) which shows lines of geophysical traverses and sites on a regular grid from which geological samples were obtained. It was decided to engage the services of a contracting company to to operate a range of geophysical and geological sampling equipment and to provide, if necessary by sub-contract, a ship for the work. After consideration of a number of tenders submitted on this basis, a contract was awarded at the end of June to George Wimpey & Co.

The geophysical survey lasted from 6th to 31st August most of the period being spent at sea undertaking continuous day and night observations. Douglas harbour proved to be the most convenient port for provisions, shelter and for maintenance and installation of equipment. The geological sampling programme commenced on 17th August, mobilization of the 'Olna Firth' having been carried out in Garston Dock, Liverpool, and terminated on 28th September.

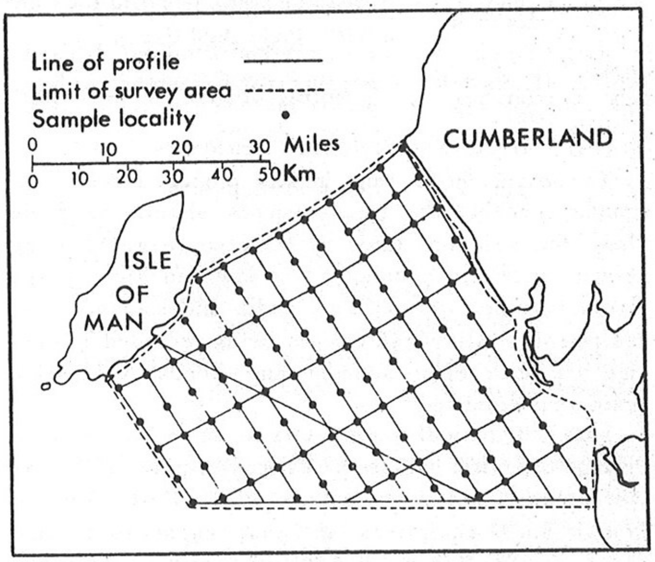

Fig. 1. Area surveyed.

GEOPHYSICAL INVESTIGATIONS

Ship and personnel

Under a sub-contract a coastal cargo boat the 'Moray Firth IV' was chartered from Gillie and Blair of Newcastle-upon-Tyne. for use as the survey vessel. Specifications of this ship are as follows :-

Length overall	:	182 ft
Beam	:	29 ft

Draught loaded	:	12 ft 9 in
Tonnage	:	816 tons, deadweight

Under the charter arrangement, the ship was manned by four officers, three crew and two cook/stewards. Scientific personnel consisted of five geophysicists and two hydrographic officers from George Wimpey & Co. as well as either two or three scientific staff from the Institute. Mr. R. Gardener acted as party chief for the contractor and Mr. R. McQuillin for the Institute. Mr. C. McCann from the Marine Science Laboratories, Menai Bridge, joined the survey for five days, when equipment on loan from the Laboratories was being used.

Aims and methods

It was hoped that the results of the geophysical survey would provide data on :-

(i) Localities where solid rocks crop out on the sea bed or where superficial deposits are thin; these localities to be sampled by coring devices.

(ii) Thickness, structural and lithological variations in the superficial unconsolidated deposits.

(iii) Structure in solid rock formations.

To obtain these data it was proposed that continuous geophysical measurements should be made along the selected lines of traverse (Fig. 1) using seismic profiling equipments at low and high energy levels together with oblique asdic and magnetometer equipments; all measurements being recorded in conjunction with echo sounder and Decca Navigation System observations.

The geophysical survey was made in two stages. During the first stage a Wimpey/Alpine 150-joule sparker was used in conjunction with a Kelvin Hughes Transit Sonar equipment, an Elsec magnetometer and and a Kelvin Hughes M.S.26 echo sounder, and the lines shown in Fig. 2 were surveyed. During the second stage the lines shown in Fig. 3 were surveyed using an E.G. and G. 10 000-joule sparker system in conjunction with magnetometer and echo sounder. Details of the progress of the survey are summarized in Appendix 1. Before the survey commenced it had been anticipated that good records could not be obtained using high and low energy sparkers simultaneously and this required the execution of the work in two stages. Experience during Stage 2 of the survey suggested that the high energy sparker pulse can cause excessive interference on both Transit Sonar and echo sounder records. Echo sounder traces were less affected and could generally be regarded as acceptable when detailed information on the sea bed topography was not a primary survey requirement.

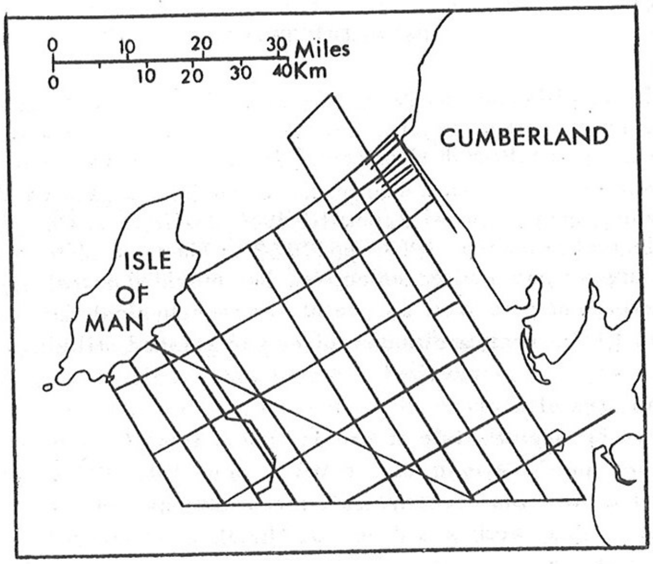

Fig. 2. 150 -joule sparker traverses.

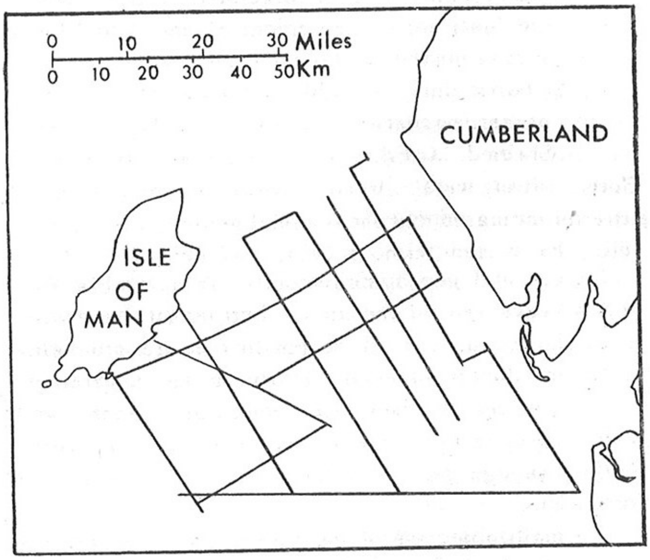

Fig. 3. 10 000 - joule sparker traverses.

Position Fixing and Navigation

Positions of all geophysical lines were fixed using the Decca Navigation System, North West British Chain. Lines were pre-plotted on Decca track-plotter charts and with track-plotter and automatic pilot in use on the bridge it was possible to keep accurate courses even at the slow surveying speed of 4–5 knots. At 10 minute intervals, fiducial marks were registered on all records and at the same time deccometer readings were logged. These fixes were plotted on 1in-to-1mile Decca Charts which had been specially prepared by Decca on the British National Grid projection. It was possible to work a 24-hr day using Decca Navigation with occasional interruptions due to instability, usually in association with thundery weather.

Geophysical Equipment

Two important factors which can greatly affect the quality and efficiency of a marine geophysical survey are the provision of an adequate and versatile power supply system and the adoption of a well-planned installation system for the geophysical equipment.

Power Supplies

Decca receiver and track-plotting units were powered by the ship's 24-volt d.c. supply. All other power requirements were met using three diesel generating sets (7½kVA, 7½kVA and 9kVA). These requirements consisted of :-

(i) A 24-volt d.c. supply for echo sounder, Transit Sonar and magnetometer. A 10-amp 0–35 volt stabilized power supply unit was used, in some cases floated across batteries.

(ii) 220-volt and 115-volt, 60-Hz supplies for sparker equipments. These supplies were obtained direct from the generating sets.

These arrangements were in general satisfactory, but the following improvements are suggested :-

(i) Each generator should be wired to a main switch-board having main switch, pilot light, fuses and a number of appropriately rated output sockets to which any equipment can easily be plugged, as well as providing sockets for auxiliary equipment such as extra lighting, test equipment and maintenance tools.

(ii) The magnetometer functions poorly if stray electrical noise is derived via its power supply and an independent supply should be used if possible.

Installation System

The space available on the ship for geophysical equipment consisted of a small chart-room behind the bridge, a hut which was lashed to the deck abaft the funnel, and a large area in one of the holds. Ballast occupied only part of this hold. During Stage 1 of the survey the hold was not used, but during Stage 2 all the E.G. and G. equipment was installed there, and this proved to be a very satisfactory arrangement. Transit Sonar and echo sounder were installed in the chart-room together with Decca equipment, except for the track-plotter which was housed on the bridge for use by the navigating officer. Magnetometer and Wimpey/Alpine sparker were installed in the portable hut. Space here was less than desirable but the hut had the advantage of being at the stern of the ship and was therefore conveniently sited when towed equipment was to be handled.

Outboard installations were relatively simple. Transducers for echo sounder and Transit Sonar were rigged on steel pipes which slotted into special frames welded to the sides of the ship, about midships, one frame on each side. Transducers could be rigged in a few minutes once the ship was stationary. With the Transit Sonar transducer in the water, the ship's speed was limited to about 6 knots; higher speeds would probably have damaged the mounting assembly. The hydrophone array, spark units and magnetometer fish were all towed astern of the ship.

A more detailed assessment of the performance of the geophysical equipment is now given.

Transit Sonar Equipment

The Transit Sonar equipment used is an oblique asdic device manufactured by Kelvin Hughes Ltd. Its general specification is as follows :-

Type	:	M.S.43 Mk. 1
Frequency	:	48kHz
Pulse length	:	1 millisecond
Ranges	:	0–300 yd and 0–600 yd
Beam angles	:	Horizontal – 1.5° to 3db points
		Vertical – 51° to 3db points

A 600-yd range was used throughout the survey and in most depth and bottom conditions reflections were detected over the whole range. Poor records in unfavourable sea conditions were due mainly to the effects of pitch and roll on the rigidly mounted transducer. Useful records were obtained in sea conditions associated with force 4–5 winds but not in more severe weather. The records are presented on 6-in wide dry paper giving at 5 knots an approximately true-to-scale representation of sea bed features (1 in = 100 yd). The recording system is very reliable but the records need careful handling if smudging is to be avoided. The papers available for use in this recorder appear to have too limited a dynamic range, and it is proposed to experiment with the equipment using alternative recording systems to test whether the quality of the records can be thus improved.

Wimpey/Alpine Seismic Profiling Equipment

The seismic equipment, which was used during Stage 1 of the survey, is a nominal 100-joule sparker high resolution seismic profiling equipment manufactured by Alpine Geophysical Associates, Inc. of New Jersey, U.S.A. This equipment has been modified to give 150-joule pulses at a quarter-second firing rate. Resolution is limited to about 10 ft and penetration to up to about 700 ft below the sea bed in favourable conditions. The system is made up of the following units :-

(i) Power pack/capacitor bank.
(ii) Sparker. ⅜-in spark gap towed 100 ft behind ship.
(iii) Hydrophone array. 10 elements, two chains in parallel of five H.P.1 (Halls–Sears) pressure sensitive hydrophones.
(iv) Preamplifier.
(v) Band pass filter. Krohn–Hite Inc.
(vi) Modified Mufax Recorder.

Records are produced on an 18-in wide electro-sensitive paper. A quarter-second sweep time was used throughout the survey.

During the whole of Stage 1, the equipment functioned satisfactorily, working non-stop for periods of up to a week and with only short stoppages for maintenance. Useful records were obtained in sea conditions associated with winds force 4–5, but in very calm sea, resolution improved and reflecting horizons were detected at much greater depths.

E.G. and G. Seismic Profiling Equipment

During Stage 2 of the survey, see Fig. 3, a nominal 10 000-joule seismic profiling system manufactured by Edgerton, Germeshausen and Grier Inc. was installed in the vessel. This was tried at full power but a combination of long pulse length and bottom multiples obscured much of the record. In this part of the Irish Sea, using the 10-element Wimpey/Alpine hydrophone array (see above), best results were obtained using a 3000-joule pulse energy fired once per second. Operated at this power, the system is made up of the following units :-

(i) Five Type 254 power supply units.
(ii) One Type 233 capacitor bank.
(iii) One Type 231 capacitor and trigger unit.
(iv) One Sparkarray unit–3 electrodes.
(v) One Wimpey/Alpine hydrophone array (described above).
(vi) One Type 254 Recorder with included trigger pulse, filter and processing circuitry.

The E.G. and G. recorder can be operated over a range of sweep speeds, continuously variable from 1 to 1000 r.p.m. of the helix blade, as well as having a switched helix control giving a number of fixed sweep speeds. This makes the recording system much more versatile than the Wimpey/Alpine system which can operate at only 4-sec, 1-sec or ¼-sec sweep speeds.

Records produced by the two systems are on the same type of electro-sensitive paper, and differences in appearance of the records obtained from the two systems depend on the sweep velocities and filters used and more particularly on differences in the acoustic pulses. The E.G. and G. Sparkarray has three electrodes, and three sparks in line about 2 ft apart are produced on each explosion, whereas the Wimpey/Alpine spark is generated at a single spark gap. The E.G. and G. system operates at 3–4 kV as compared with the 6½–7 kV operating voltage of the Wimpey/Alpine system. Further, the E.G. and G. system was operated at much higher pulse energy levels, 3000 joule as compared with 150 joule. The E.G. and G. equipment was operated to give maximum penetration and under these conditions gave much poorer resolution than was obtained using the Wimpey/Alpine equipment; time was not available to test the E.G. and G. equipment at low power, and no comments can be made about comparison of the two systems when operated at low energy levels. Comparatively, the E.G. and G. equipment is much more versatile; with the equipment on the ship, operation at any energy level between 100 joule and 10 000 joule would have been possible.

Elsec Proton Magnetometer

A sea-borne proton magnetometer, provided by Wimpey Central Laboratory and manufactured by The Littlemore Scientific Engineering Co., Oxford, was used. Initially it was operated in conjunction with an analogue pen-recorder provided by the Institute, but this was found to be incompatible with the digital output system used by the Central Laboratory. The digital output system was made up of the following units :-

(i) An Elsec proton magnetometer.
(ii) An Elsec crystal control digital clock.
(iii) A Serializer unit.
(iv) A modified Addo 5–channel paper tape punch.
(v) A magnetometer fish towed 400 ft behind the ship.

First operations with the equipment were not successful and the trouble was wrongly diagnosed as a faulty Serializer unit. Eventually the incompatibility between pen-recorder and digital units was discovered and acceptable results were then obtained using only the paper tape output, from 19th August until completion of the survey. Lines surveyed using the magnetometer are shown in Fig. 4.

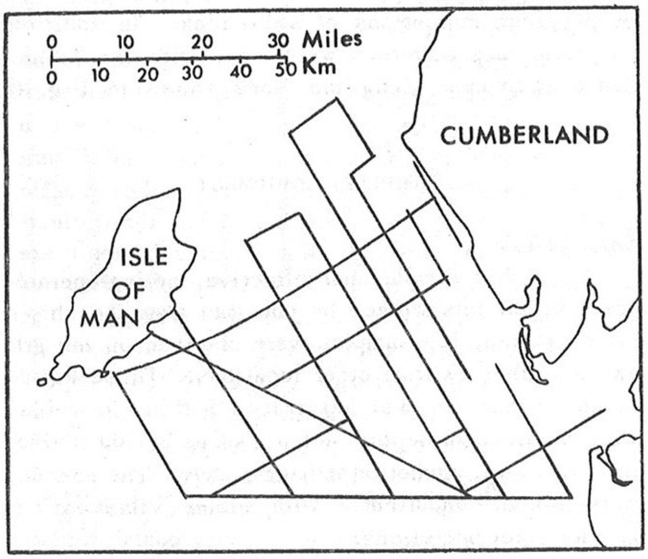

Fig. 4. Magnetometer traverses.

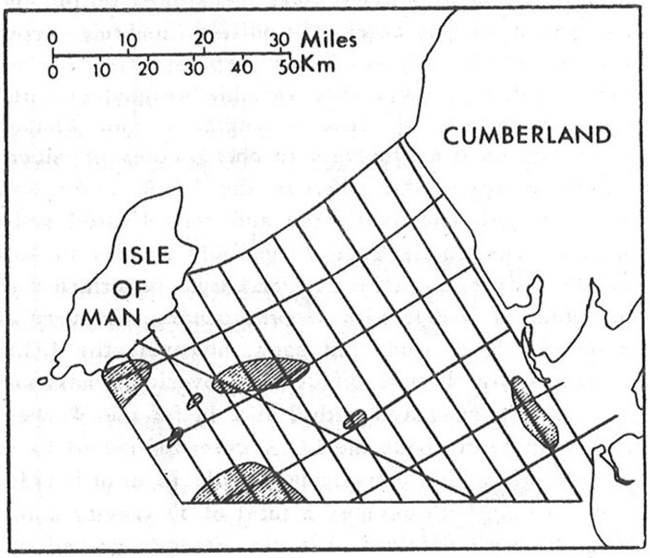

Fig. 5. Probable areas of solid rock at relatively shallow depth below sea floor.

PRELIMINARY RESULTS

Analysis of the results of the survey is incomplete and at the time of writing only preliminary results are available. On ship, as the survey progressed, a map was prepared showing areas where it was considered that the sampling devices available on the 'Olna Firth' might penetrate and obtain samples of solid rock formations (Fig. 5). This map was based on a thorough review of sparker and Transit Sonar records. When samples were taken it became evident that most of the area has a substantial cover of unconsolidated sediments which vary considerably in thickness. Other preliminary results are summarized below :-

Sea Floor Sediments

Study of the Transit Sonar records shows, in many places, good correlation between features displayed on these records and the distribution of sea floor sediments discovered by the geological sampling survey.

The top seismic layer

A top seismic layer has been discovered which covers most of the area surveyed. Thickness of this layer ranges up to about 250 ft but is mainly in the range 30–140 ft. Work is in progress on the preparation of maps of thickness contours of this top seismic layer, and of depths to rock head. These will be calculated assuming a velocity of 6000 ft/sec for the layer.

The sparker records show evidence of varied structure within the layer and of variations in the types of sediment of which it is composed. Its broadest division is between areas of approximately horizontally layered sediments often deposited on a fairly flat solid rock surface, and areas of irregularly layered, apparently heterogeneous materials usually deposited on an irregular rock surface.

Structure beneath the upper seismic layer

Structure in solid rocks beneath the upper seismic layer can be identified over most of the area using the sparker records. These are being analysed and a map is in preparation showing dip directions and values (along the ship's tracks). It is hoped that comparisons between profiles will permit an interpretation of some of the main structures. On individual profiles, structure varies from inclined bedding of low dip to that of tightly folded beds.

A further aid to the interpretation of geological structure at depth will be an analysis of the results of previous aeromagnetic surveys.

GEOLOGICAL INVESTIGATIONS

Ship and personnel

The work was carried out from the M.V. 'Olna Firth', owned by Messrs. Williams and Gillespie of Garston Dock, Liverpool and manned by a master, Capt. N. Gillespie, three officers, two stewards and four crew. The specifications of the ship are as follows :-

Length overall	:	182 ft
Beam	:	28 ft 6 in
Draught	:	11 ft to 12 ft 6 in
Tonnage	:	780 tons, deadweight

The Wimpey party consisted of a driller and five men under a party chief, Mr. M. Dawes. I.G.S. was represented by Messrs. G. H. Rhys and J. H. Hull, assisted from time to time, by other members of the Leeds, London and Edinburgh offices of the Institute, there generally being three I.G.S. officers aboard at any one time.

Navigation

The navigation of the ship from one sampling locality to another, which was the responsibility of I.G.S. staff, was effected by a Decca Mark 12 system with an associated automatic track plotter and using Decca-prepared charts for north–south traverses and alternate east–west traverses. The positioning errors involved in the use of this system are greatest in the eastern part of the area, where errors of up to 360 yards appear possible. A further error in the actual position of a sampling locality depends upon the amount of difficulty encountered in bringing the ship to anchor over the selected point; on average this error may be as much as 100 yards.

Programme of work

On 17th August, 1967, the M.V. 'Olna Firth' sailed from Garston Dock to commence the survey, though mobilization was not quite complete. In Appendix 2 a synopsis of the ensuing daily log is given up to demobilization in Heysham Harbour on 28th September, 1967. The intervening 41 days of the survey can be broken down as follows :-

(i) Days sampling and traversing – 28
(ii) Days lost, or in harbour – 13

The second item can be broken down as follows :-

(a) Repairs to drilling equipment – 2 days
(b) Personnel changes and minor repairs – 2 days
(c) Defects in ship – 1 day
(d) Cessation of work due mainly to bad weather – 8 days

Sampling

The main network of sampling localities (Fig. 6) was sited at the intersections of geophysical traverses. The intention, subsequently achieved, was to drill a Vibracore hole and to take a grab sample at each site and subsequently to use the rock drill and I.G.S. gravity corer at localities where there were geological and geophysical indications of solid rock. In addition, supplementary traverses were made with the Transit Sonar equipment along the lines shown in Fig. 6.

Sampling Equipment

Shipek Grab

Using this simple, but effective, spring-operated grab, which was worked by one man from the ship's after capstan, 105 samples were obtained on the grid and a further 17 from other locations. These bottom sediment samples, which averaged 5–6 lbs in weight, were obtained in depths of water of up to 200 ft when the ship was at anchor or drifting slowly. The samples were taken concurrently with either Vibracore or gravity corer operations.

Gravity Corer

Two types of gravity corer were used during the survey. A Wimpey corer, of modified Cambridge type, with a fixed barrel, weight and separate bits, and an I.G.S. Hull-type corer with variable weights and detachable barrels of various lengths. The Wimpey corer was used exclusively to obtain cores of unconsolidated sediments, whereas the I.G.S. corer was used on both unconsolidated and consolidated sediments. The corers gave comparable results in soft muddy sediments, achieving maximum penetration of the order of 7–8 ft with a corresponding recovery of about 3½ ft of mud. In sand, however, the I.G.S. corer was slightly more effective recovering a maximum of 3 ft 2 in compared with 1 ft 1 in for the Wimpey corer. In harder beds the I.G.S. corer recovered 15 in of Manx Slates but a maximum of only 12 in of boulder clay. Using both devices a total of 55 gravity cores (Fig. 6) were obtained, but six attempts proved unsuccessful.

Vibracore

The rig, 25½ ft long with tripod legs 13 ft across, was powered by a compressor which vibrated the head, hammering the 20-ft core-barrel into the sea bed. The amount and rate of penetration, were independently recorded in graphic form through a potentiometer incorporated in the drilling head. Using this rig 105 holes were drilled on the main network, together with two supplementary holes. The average core recovered

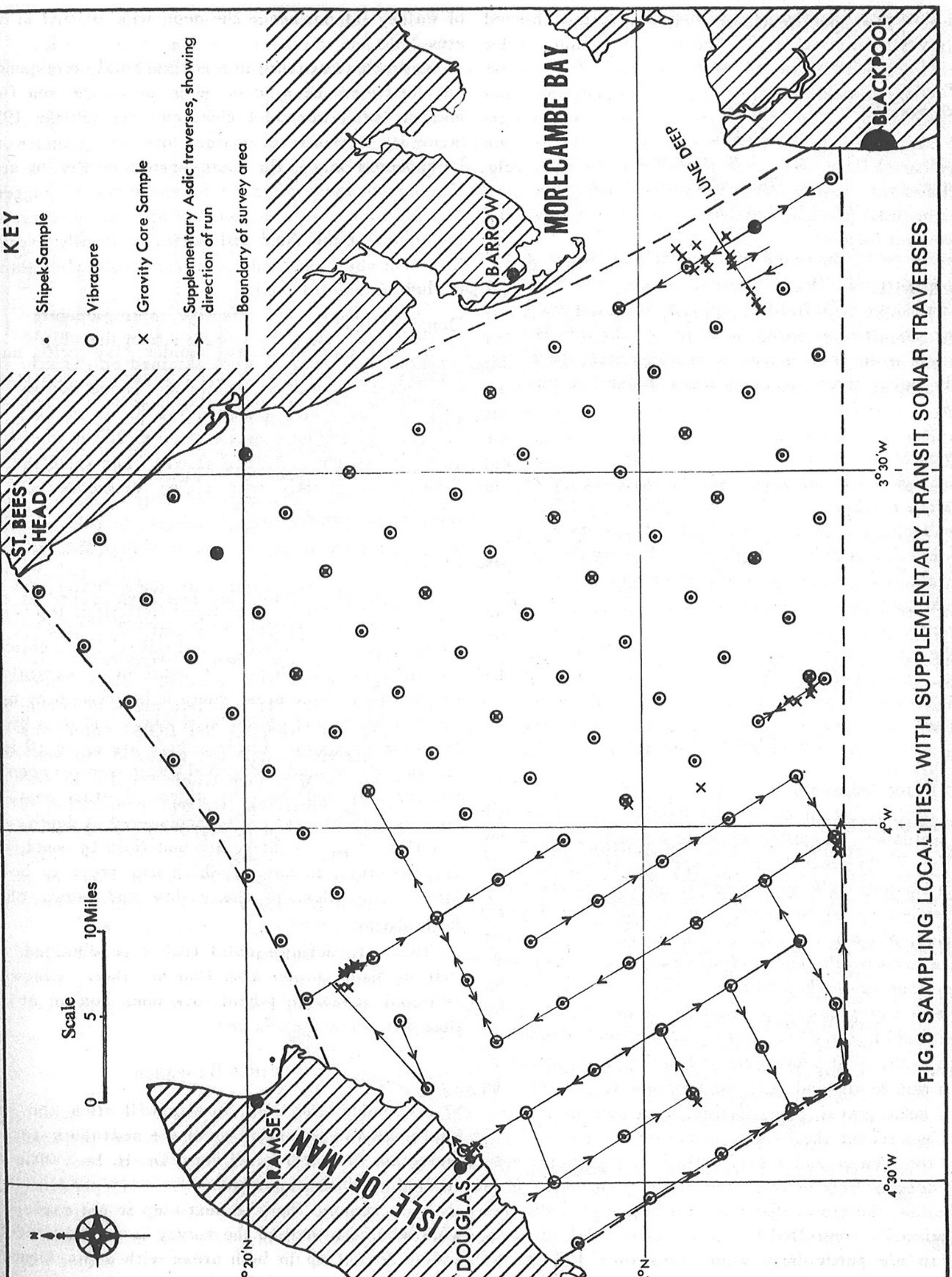

FIG.6 SAMPLING LOCALITIES, WITH SUPPLEMENTARY TRANSIT SONAR TRAVERSES

per hole was just over 8 ft, but a number achieved recovery of almost 20 ft. The rate of drilling, under ideal conditions, varied with lithology from about 38 ft/min through mud to 7 in/min through sand and boulder clay. The core produced was removed from the core barrel together with the expendable perspex core-barrel liner. The core appeared to be relatively undisturbed apart from compaction under its own weight, wall friction, and disturbance to the upper and lower few inches.

Rock Drill

The rock drill is hydraulically powered, is 25 ft long overall and carries a 20-ft core barrel. It was tested in 40 ft of water in Douglas Bay, at a site where up to 2 ft of sand were thought to overlie Manx Slates. After 20 minutes drilling the penetrometer (similar to that of the Vibracore) indicated that the drill had cut 2 ft of soft superficial sediment, and about 15 in of hard rock; the recovery was 1 ft 5 in of Manx Slates.

Subsequent attempts to use the rig at sites suggested by the geophysical survey proved unsuccessful. Six attempts were made in all, but the maximum penetration achieved was only about 9 ft. None of these attempts penetrated solid rock and, apart from the Douglas Bay samples, the only recovery was from a boulder bed near the Lune Deep.

Preliminary Results

Sea Floor Sediments

The distribution of sea floor deposits, as determined by preliminary visual observation in the field is shown in Fig. 7. In general terms, there is an elongate area, with its long axis approximately parallel to the Cumberland–Lancashire coast, in which there is a deposit of mud, which includes some fine sand. This deposit has a maximum thickness of at least 20 ft and contains a number of marked shelly horizons. There is in general a progressive increase in the grain size of the sediments from the centre of the area of mud deposition, both to the west-south-west and to the east-north-east, from mud to silt and silty sand through to coarser sand with some gravel; locally this latter deposit is overlain by a recent shell sand. It can be seen from Fig. 7 that the area of mud deposition does not coincide with the deepest part of this area of the Irish Sea. It is possible, therefore, that the distribution of sediments is primarily controlled by the effect of tidal currents. These are particularly weak (less than 1 knot) off the coast between St. Bees Head and the southern end of Walney Island, hence the deposition of mud in this area.

Assuming that there is a geographical correspondence between the type of sediment on the sea floor and the peak speed of tidal currents (Pratje 1950; Stride 1963), relatively coarse sand with gravel would be expected only in the south-western part of the area. The presence elsewhere of this type of deposit suggests that it is not solely the product of tidal currents, and the fact that the sand and gravel is locally overlain by recent shell sand indicates that it is a relict glacial or fluvio-glacial deposit.

Boulder Clay

A stiff reddish brown boulder clay, with small erratics and locally with shell fragments, was proved beneath the sea floor deposits along the coastlines of both the mainland and the Isle of Man and also in the south central part of the area. The lithology of the deposit would appear to be similar to that proved in Morecambe Bay and exposed near Heysham Head; there is insufficient data, however, to make a correlation with the boulder clays of the Isle of Man (Mitchell 1965).

Though the boulder clay has been proved at only a few sites it is thought to be present throughout the surveyed area. In addition to the localities mentioned above, it was also found at depth in the central and western part of the area, where it is overlain by up to 14 ft of brown and yellow silty clays and then by the sea floor deposits. Locally there are up to 10 in of red and brown sand and gravel interposed between the boulder clay and the silty clays. Farther east, the boulder clay has yet to be encountered at depth. The sea floor deposits, here, are underlain by sand, dark grey to brown in colour, which may prove to be the lateral equivalent of the yellow and brown clays.

Solid Rocks

The only definite solid rock core obtained was that of Manx Slates from Douglas Bay. Elsewhere it would appear that hard rock does not lie at less than 8 ft below the sea bed.

Further Research

In London, Dr. D. S. Cronan will study the sedimentology and geochemistry of the sediments from the immediate sea floor; in Leeds, Dr. H. M. Pantin will study the Vibracore samples.

It is intended that the next step in the exploratory work will be to extend the survey in an adjacent area and to follow up in both areas with a programme of boreholes into the solid rock.

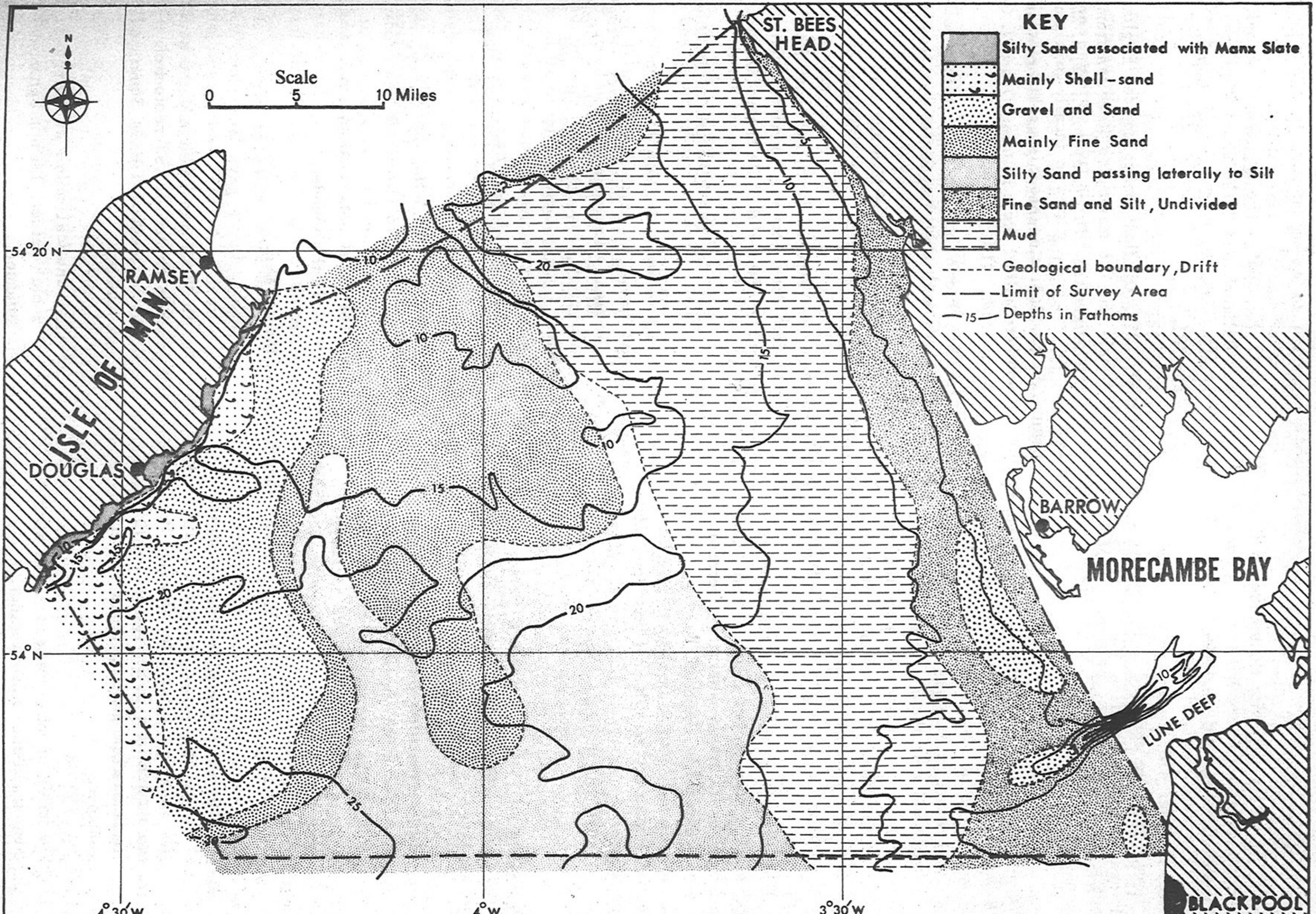

FIG.7 SEA FLOOR DEPOSITS

REFERENCES

Bott, M. H. P. 1964. Gravity measurements in the north-eastern part of the Irish Sea. *Quart. J. Geol. Soc. Lond.* **120.** 369-396.

Geological Survey. 1965. *Aeromagnetic map of Great Britain.* Sheet 2, 1st Edition. (H.M.S.O.)

Institute of Geological Sciences. 1967. *Annual Report* for 1966.

Mitchell, G. F. 1965. The Quaternary deposits of the Ballaugh and Kirkmichael districts, Isle of Man. *Quart. J. Geol. Soc. Lond.,* **121,** 359-381.

Pratje, O. 1950. Die Bodenbedeckung des Englischen Kanals und die maximalen Gezeitenstromgeschwindigkeiten. *Dtsch. hydrogr.,* **2,** 3, 201-5.

Stride, A. H. 1963. Current-swept sea floors near the southern half of Great Britain. *Quart. J. Geol. Soc. Lond.,* **119,** 175-199.

APPENDIX 1

Geophysics

Synopsis of Daily Log.

AUGUST 6 Mobilization complete. ship sailed from Garston Dock, Liverpool at 2315 hr.

7 76 nautical miles of survey – 150-joule sparker, Transit Sonar and echo sounder.

8 108 nautical miles of survey – 63 miles satisfactory, bad weather for remainder. 150-joule sparker, Transit Sonar and echo sounder.

9 88 nautical miles of survey – 150-joule sparker, Transit Sonar and echo sounder.

10 92 nautical miles of survey – 150-joule sparker, Transit Sonar and echo sounder.

11 69 nautical miles of survey, 52 miles satisfactory, survey abandoned at 1950 hr, ship then headed for Douglas Bay to shelter from bad weather. – 150-joule sparker, Transit Sonar and echo sounder.

12 10 miles of survey attempted but work abandoned due to bad weather.

AUGUST 13 20 nautical miles of survey. Ship sailed from Douglas at 1820 hr. – 150 joule-sparker, Transit Sonar and echo sounder.

14 21 nautical miles of survey. Progress affected by bad weather. – 150-joule sparker, Transit Sonar and echo sounder.

15 Ship sheltered in Douglas Bay. Bad weather.

16 62 nautical miles of survey, results poor due to unsuitable sea conditions ship returned to Douglas Bay at 2230 hr – 150-joule sparker, Transit Sonar and echo sounder.

17 34 nautical miles of survey, results poor. Decca gave lane identification trouble. At 1615 hr returned to Douglas to rendezvous with M.V. 'Olna Firth' and change I.G.S. personnel. – 150-joule sparker, Transit Sonar and echo sounder.

18 34 nautical miles of survey – 150-joule sparker, Transit Sonar and echo sounder.

AUGUST 19 91 nautical miles of survey – 150-joule sparker, Transit Sonar, magnetometer and echo sounder.

20 93 nautical miles of survey, Transit Sonar fault developed at 1355 hr, some trouble with Decca – 150-joule sparker Transit Sonar, magnetometer and echo sounder.

21 82 nautical miles of survey – 150-joule sparker, magnetometer and echo sounder.

22 58 nautical miles of survey, Decca giving lane identification trouble, ship returned to Douglas at 1300 hr – 150-joule sparker, magnetometer and echo sounder.

23-24 Change of I.G.S. personnel. Installation in Douglas of the 10 000-joule sparker system. Repair made to Transit Sonar. Decca Mk 12 repaired by local Decca engineer.

25 32 nautical miles of Survey – 10 000-joule sparker, Transit Sonar, magnetometer and echo sounder.

26 105 nautical miles of survey – 10 000-joule sparker, Transit Sonar (part of time), magnetometer and echo sounder.

AUGUST 27 80 nautical miles of survey, transit sonar used but records often poor due to pick up from spark pulse. – 10 000-joule sparker, Transit Sonar, magnetometer and echo sounder.

28 85 nautical miles of survey – 10 000-joule sparker, Transit Sonar, magnetometer and echo sounder.

29 51 nautical miles of survey, ship hove to outside Douglas Bay to disembark one I.G.S. staff. – 10 000 joule-sparker, Transit Sonar, magnetometer and echo sounder.

30 40 nautical miles of survey, ship to Douglas Bay at 1030 hr to collect I.G.S. staff, returned to Douglas at 1810 hr survey completed. – 10 000-joule sparker, magnetometer, Transit Sonar and echo sounder.

31 Demobilization of 10 000 joule equipment in Douglas harbour, ship left Douglas at 1000 hr for Garston Dock, Liverpool and arrived at 2015 hr.

SEPTEMBER 1 Demobilization in Garston Dock.

APPENDIX 2

Geology

Synopsis of Daily Log.

AUGUST 17 Sailed from Garston to rendezvous with 'Moray Firth IV' at Douglas.

18 Vibracore sampling off Isle of Man. Berthed Douglas for night. I.G.S. crew change.

19–22 Vibracore sampling; attempts at rock coring; Transit Sonar and echo sounder traverses. Damaged Vibracore necessitated berthing Douglas for night.

AUGUST 23 Berthed at Douglas.

24–25 Vibracore, gravity corer and Shipek sampling; Transit Sonar and echo sounder traverses.

26 Failure of ship's generator. Shipek sampling late evening.

27–29 Vibracore, gravity corer and Shipek sampling. Transit Sonar and echo sounder traverses. Lost forward anchor.

30 Berthed at Douglas. Repairs to Vibracore. I.G.S. crew change.

31 & 1 Sept. Vibracore, gravity corer and Shipek samples. Transit Sonar and echo sounder traverses.

SEPT. 2–3 Gales, sheltered Douglas and Ramsey Bay.

4 Gales moderated, crossed to Heysham for bunkering and stores. Berthed for night at Heysham.

5–6 Storm, force 10. Berthed Heysham. Cores removed to Leeds. Trouble with ship's generator. Echo sounder mounting damaged in storm.

7–11 Vibracore, gravity corer and Shipek sampling. One dredge sample. Transit Sonar and echo sounder traverses. Berthed night of 11th at Heysham.

12 Repairs to gravity corer barrels. Change of I.G.S. personnel. Sailed from Heysham 1700 hours. Gravity corer and Shipek sampling.

13–14 Vibracore and Shipek sampling. Attempts at rock coring. Transit Sonar and echo sounder traverses of Lune Deep. Berthed at Heysham on night of 14th.

SEPT. 15 Change of I.G.S. personnel. Vibracore and Shipek sampling.

16–17 Vibracore and Shipek sampling. Forward anchor and 100 ft of wire lost.

18 Bad weather. Proceeded to Workington for new anchor and wire.

19–20 Berthed at Workington. New anchor fitted; sailed mid-day. One Vibracore sample. Big swell running. Transit Sonar and echo-sounder traverses.

21–22 Vibracore and Shipek sampling. Berthed night 22nd in Douglas. I.G.S. crew change.

23 Solid corer and gravity corer sampling in Douglas Bay. Proceeded Port Erin for shelter.

24 Weather unsuitable for drilling. Transit Sonar and echo sounder traverses.

25 Gales forecast. Sheltered in Heysham and collected core barrels and anchor wire.

26–27 Gravity coring and Transit Sonar and echo sounder traverses in Lune Deep area. Solid corer used on most promising site. Survey completed. Berthed at Heysham.

28 Samples and I.G.S. equipment off-loaded, I.G.S. personnel disembarked.