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AN INVESTIGATION OF A SANDWAVE FIELD AT THE SOUTH WESTERN END OF SANDETTIÉ BANK DOVER STRAIT

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ABSTRACT

A critical examination has been made of four repeat surveys, covering a period of three years, in an area which is of vital importance to the safety of navigation by deep draught shipping. Replotting of the bathymetry from ship's echo traces at a large scale has been rigidly controlled by Hifix. Large symmetrical and asymmetrical sandwaves have been found with amplitudes of up to 16 metres and wave lengths of up to 270 metres with a fairly high degree of stability over the three year period.

INTRODUCTION

Much work has been done on sandwaves in the North Sea and this has been usefully summarised by STRIDE (1973). From the time of the early work of Van VEEN (1935) there have been various theories advanced concerning the formation and evolution of sandwaves. None of these theories can be regarded as universally proved or accepted. However, there does seem to be fairly general agreement that sandwaves may be expected in areas where the tidal stream pattern is strongly rectilinear, with stream rates in excess of about 1 knot, where there is a plentiful supply of sand and where the depth of water is sufficient to protect the sea bed from violent wave action. Symmetrical waves are considered by some workers to represent conditions of zero net transport between the flood and ebb streams, whereas asymmetrical ones are thought to be the result of a net transport in either the flood or ebb direction, the steep slope facing the direction towards which the sandwave is thought to be moving. On the vital question of mobility of the sandwaves there is less agreement. Generally it seems that the more accurate the survey work and the more careful the analysis, the smaller the amount of movement that is found. Thus LANGERAAR (1966) and TERWINDT (1971) both found displacements off the Dutch coast, over a period of 2½-3 years, which were less than the positional errors involved in the survey methods. LANGHORNE (1973) found little overall movement in the sandwave field at Long Sand Head in two years. Some unpublished work by HMS *Fawn* in 1971 found negligible movement in waves east of South Falls over a period of seven months.

It is really only with the advent of a position fixing system such as Hifix that it is possible to do repeat surveys of sufficient precision to make reliable measurements of sandwave movement or to prove non-mobility. The operation of Hifix in the North Sea has been well studied (BRADLEY, 1970). LANGHORNE (1973) claims a positional accuracy in the Long Sand Head area of better than 10 m, the work by HMS *Fawn* in 1971 already referred to claimed ± 5 m in the area east of South Falls, CLOET (1970) gives ± 3 m.

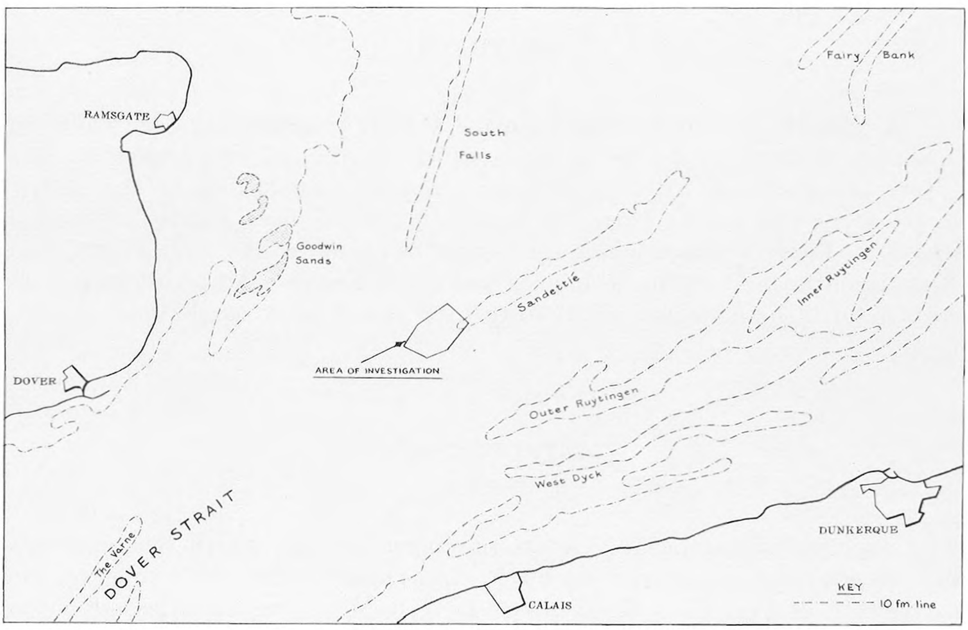


FIG. 1. — Location diagram.

The work described in this paper was undertaken in a known sandwave area of the southern North Sea (see fig. 1). The purpose of the work was a practical one, that is assessing the necessary re-survey programme in support of safe navigation for deep draught shipping, the special needs of which have been described by WINSTANLEY (1970). The study was made possible by the existence of four (a fifth was received while the investigation was in progress) accurate repeat surveys of the area at approximately annual intervals 1971-5.

SURVEY DATA

All the surveys examined in this study were on a scale of 1:25 000 and controlled by the South Rijnmond Hifix Chain, the first two in the Thorpe Ness/Dungeness configuration, the last three in the Thorpe Ness/South Foreland configuration. Examination of the calibration corrections given in the reports of survey confirmed that horizontal positioning was better than ± 10 m. Tidal reductions were from observed readings at Dover or Margate and co-tidal chart number 5059, and are considered to be correct to within ± 0.5 m.

The first survey examined was by HMS *Fawn*, 1-13 November 1971. The sounding lines were run on pattern II of the Hifix, south-southeast to north-northwest and are thus not at right angles to the sandwave crests. The lines are spaced at about 120 m apart in ground distance.

The second survey was by Wimpey Laboratories Ltd, 1-12 June 1972. The sounding lines were run in the same direction as the 1971 survey. The spacing is about 100 m with interlining in the most complicated part of the sandwave area. The Hifix chain was calibrated off Dover and the whole lane count was carried from the Pier Light to Sandettié SW buoy, flood and ebb positions.

The third survey was again by Wimpey, 14-18 June 1973. The Hifix chain was calibrated off Calais and lane counts again carried to Sandettié SW buoy. Sounding lines were run on pattern I of the Hifix, southwest to northeast. Although the change in direction made it difficult to compare with earlier work, it is highly desirable to run the lines approximately at right angles to the sandwave crests. The two later surveys have followed this pattern, which can now be regarded as the norm for this area. The sounding lines are about 150 m apart with interlining in the sandwave area.

The fourth survey was by HMS *Bulldog*, 26 February-1 March 1974. The Hifix was checked at Tongue Sand Tower and tidal corrections taken from readings at Margate. Sounding lines (southwest-northeast) are at 60 m intervals throughout the sandwave area.

The fifth survey was by HMS *Fawn*, 25 February-7 March 1975. The Hifix was checked at Tongue Sand Tower and the flood and ebb positions of buoys in the survey area established. Tidal reductions were taken from readings at Dover. Sounding lines (southwest-northeast) are at 60 m intervals in the sandwave area.

For each of the above surveys the ship's deckbook containing full details of each fix, the echo traces and ship's track plot are available. A cursory examination of this data showed clearly that the plotting scale of the survey (1:25 000) was far too small for accurate comparison work in such a complex area. It was therefore decided to work direct from the echo traces and Hifix data of the fixes, and plot at a horizontal scale of six times the drawn survey scale. The graphs described below are therefore at a horizontal scale of about 1:4 000 and vertical exaggeration of 20:1.

Tidal stream observations are held for a position 51°09'.5 N, 01°44'.1 E, which is just on the south western extremity of the sandwave field, for a period of 25 hours on the 9/10 June 1936. These observations were by HMS *Kellet* and include three sets of hourly observations, a surface logship, a 32 foot floating pole and a logship at 5 fathoms. The surface observations had already been analysed and inserted on the published charts, but those for 5 fathoms depth have been analysed in this study and are described below.

METHOD OF ANALYSIS

The latest survey (available when the investigation was started), by HMS *Bulldog* in February 1974, was taken as the standard to which the other surveys were to be compared.

Accordingly a selection of *Bulldog*'s sounding lines (about every third line) was plotted out in cross section form. All the fixes on the selected lines were plotted out at six times survey scale and checked against the Hifix coordinates (fig. 2). All peaks and troughs were then plotted relative to fixes, and sufficient other depths added to complete the profile. The vertical scale of 1 m = 0.5 cm gave a vertical exaggeration of about 20:1. Widespread minor ripples on the traces with amplitudes of up to 1 m were smoothed out in plotting.

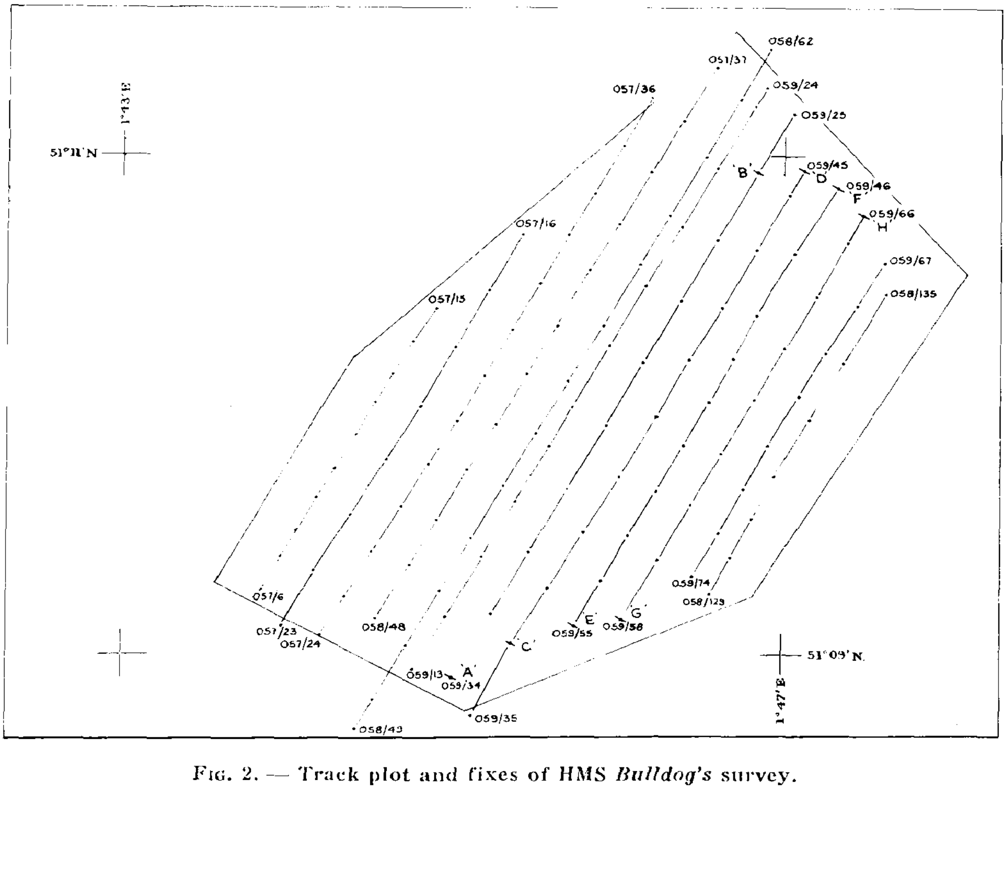


FIG. 2. — Track plot and fixes of HMS *Bulldog's* survey.

The method of adding the data from HMS *Fawn*'s 1975 survey and Wimpey's of 1973 was the same. *Bulldog's* fixes were superimposed on those of the other two surveys. Where there were identical lines on the other surveys (not uncommon since all three surveys were controlled by the same Hifix chain) the fixes were plotted relative to those of *Bulldog* and depths then inserted as before. Where there was no line corresponding to *Bulldog's*, the nearest lines on either side were taken, depths read off both, and an interpolated depth plotted on the graphical sections.

With the Wimpey survey of 1972 and earlier surveys, some other method had to be devised as the sounding lines were in a different direction. In view of the amount of work involved, only the Wimpey 1972 survey has been used so far in this investigation. The Wimpey traces were replotted in plan at six times the survey scale with depths in figures. This drawing was then contoured at 0.1 metre intervals. The *Bulldog* track plot was then enlarged photographically six times and superimposed on the contoured survey. Depths could then be read off at and between the *Bulldog* fixes. Considering the subjective element involved in close contouring this large scale drawing between the sounding lines, the degree of agreement with the other three surveys is thought to be remarkable.

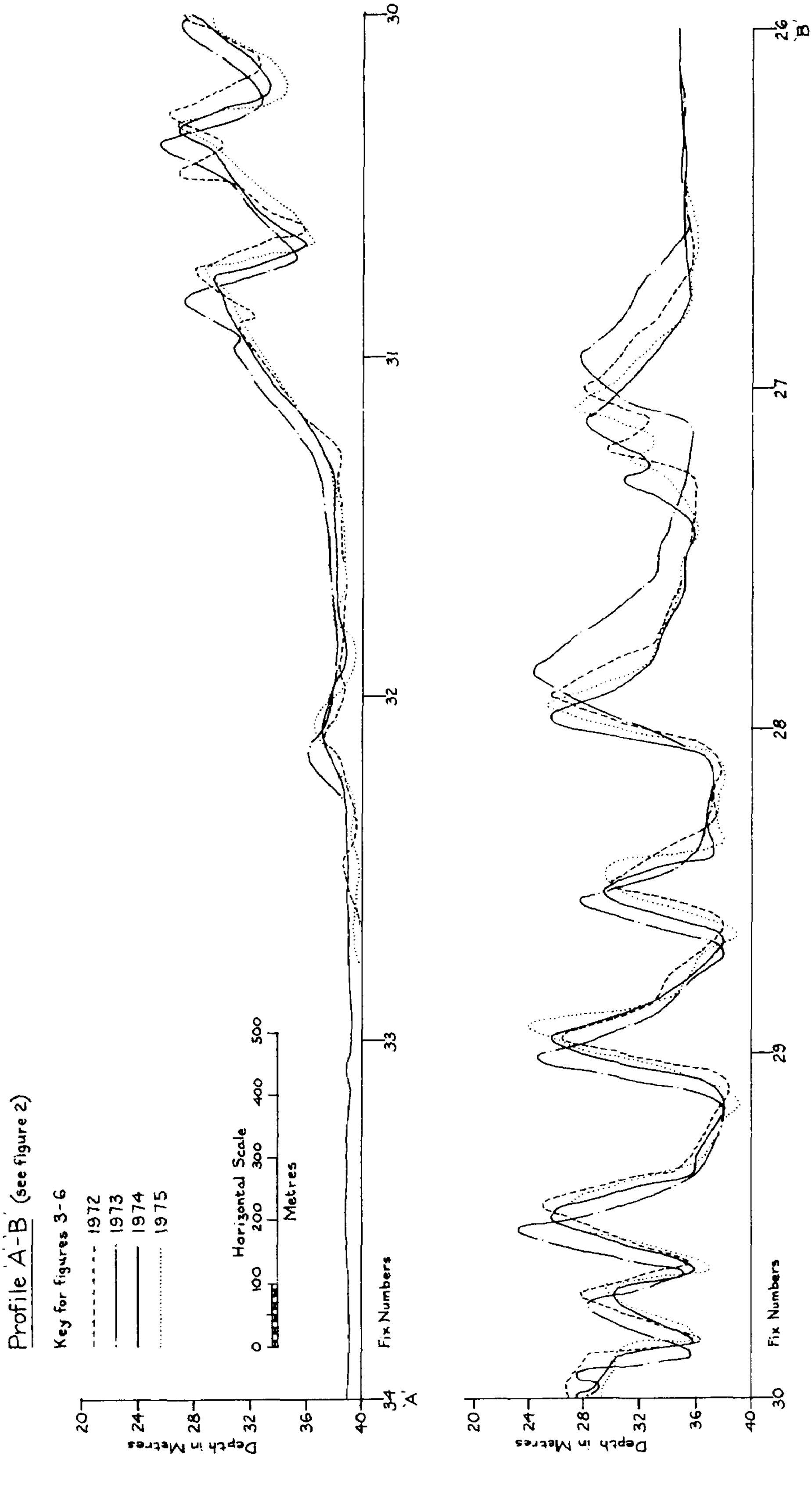
A selection of the lines with all four profiles superimposed is reproduced, at a reduced scale, in figs. 3-6. In view of the above, the 1972 profiles should be regarded as the least accurate of the four.

RESULTS

Figs. 3-6, which show the four lines, marked AB, CD, etc., on figure 2, illustrate the largest waves found. These have an amplitude of 12-16 m and a wavelength of 200-270 m. The waves in the central part of the field are very symmetrical. Towards the northeast the waves become slightly asymmetrical with the steeper slopes towards the southwest. At the southwestern side of the field the tendency is reversed and the steeper slopes are to the northeast. On the basis of some sandwave theories therefore, this should be an area of bed convergence. However, there is no evidence, over this three year period, of any build-up of material in the central parts of the field.

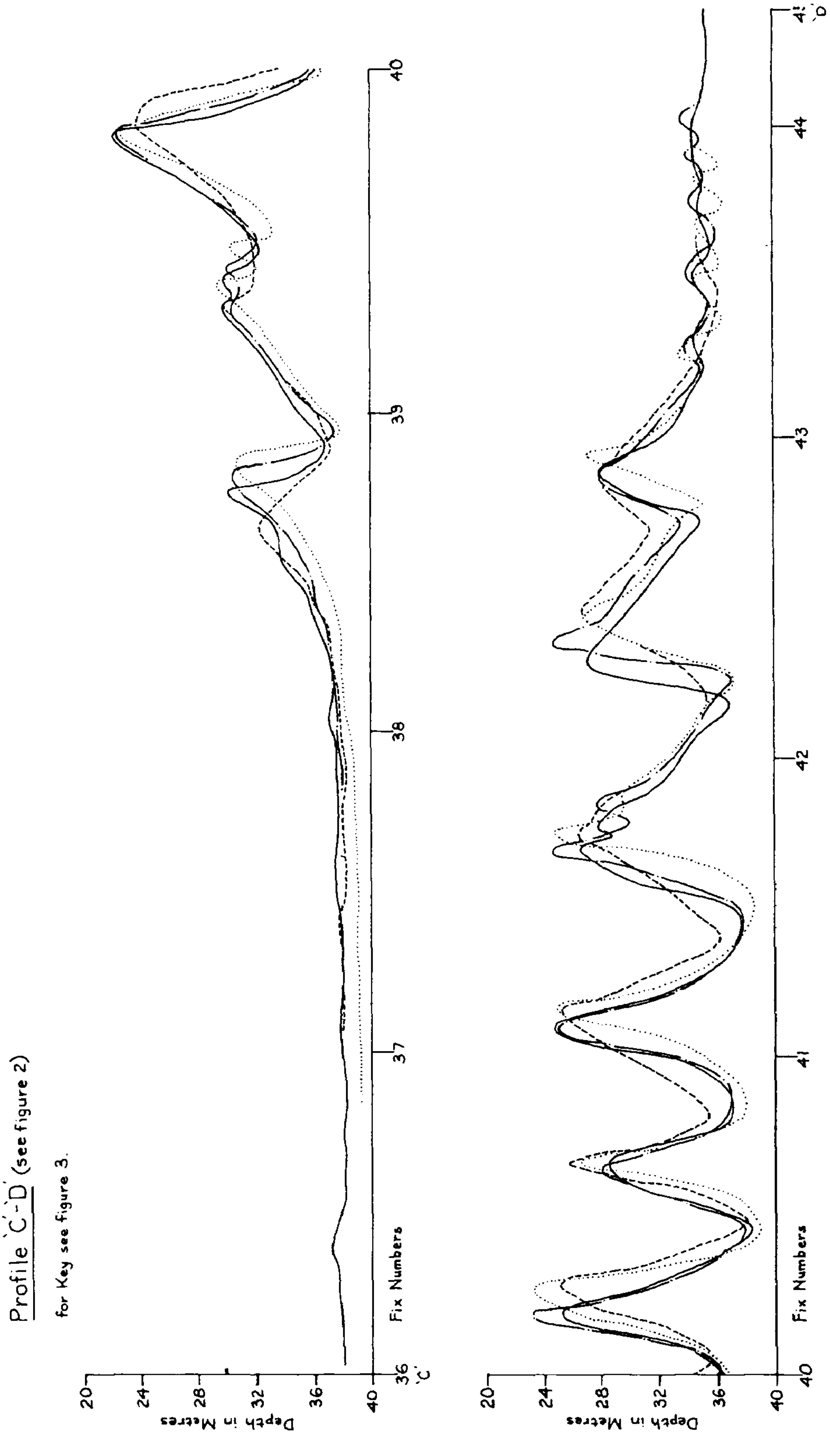
The horizontal and vertical displacements of all the sandwave crests of over 5 m in amplitude were measured and analysed in several ways statistically. The results are tabulated below. Several different sequences of measuring were tried but a straightforward time sequence was found to be best, and this had the added merit of showing whether there was any consistent movement with time. The reason that there are fewer readings for 1972/3 is that a number of the crests did not appear on the 1972 data, probably due to the method of analysis as already described.

Inspection of the profiles shows that there is not a single case of a systematic movement in one direction, either horizontally or vertically, with time. We are therefore dealing either with real, but fairly small, oscillatory movements, or are just recording small discrepancies in the surveying and analysis techniques.



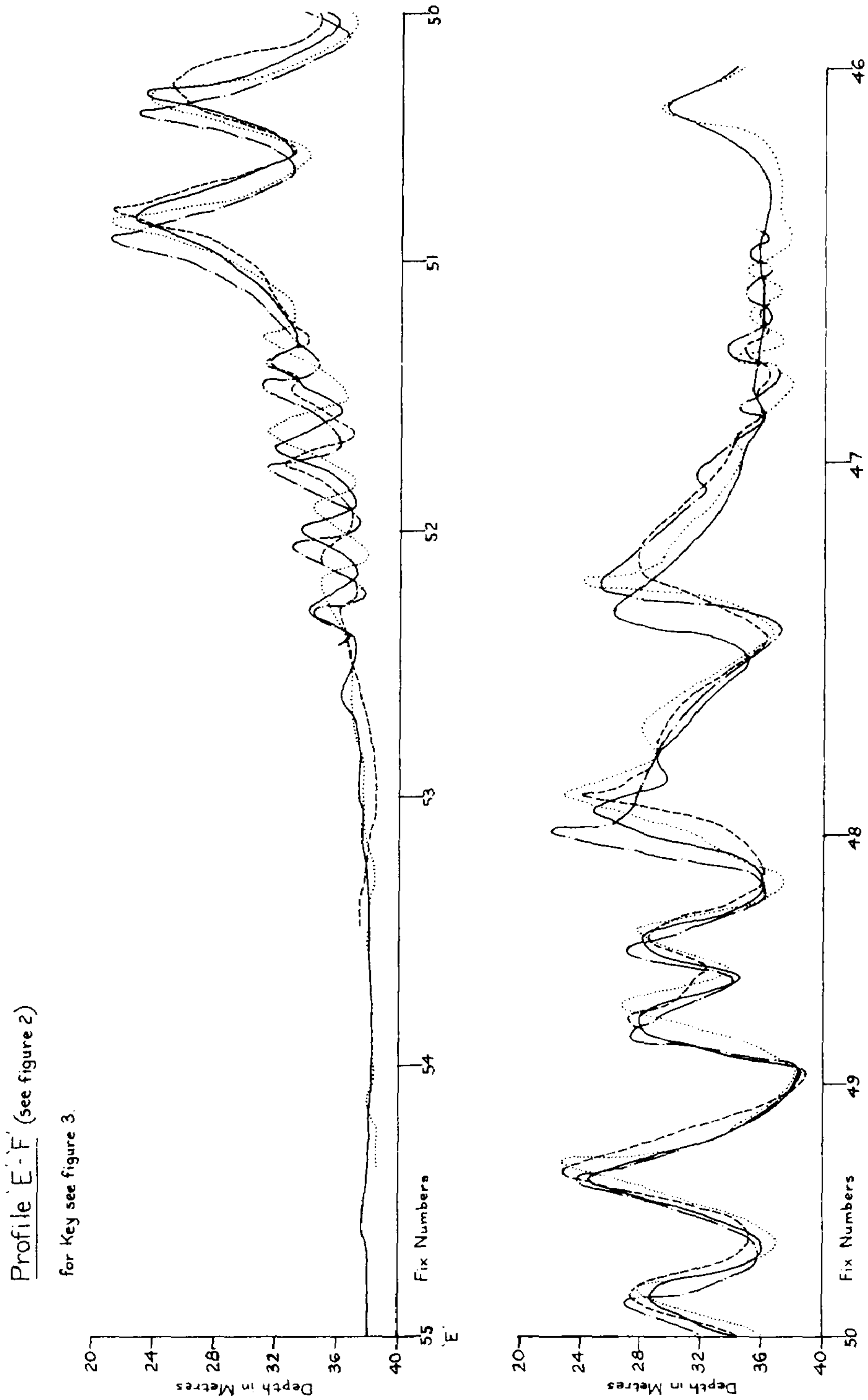
Profile 'A'-'B' (see figure 2)
Key for figures 3-6
1972
1973
1974
1975
Horizontal Scale
0 100 200 300 400 500
Metres
Depth in Metres
20 24 28 32 36 40
Fix Numbers
34 33 32 31 30
'A'
30 29 28 27 26
'B'

FIG. 3



Profile 'C'-D' (see figure 2)
for Key see figure 3.
Depth in Metres
20
24
28
32
36
40
Fix Numbers
'C'
36
37
38
39
40
Depth in Metres
20
24
28
32
36
40
Fix Numbers
40
41
42
43
44
45
'D'

FIG. 4



Profile 'E'-'F' (see figure 2)
for Key see figure 3.
Depth in Metres
20
24
28
32
36
40
Fix Numbers
55
'E'
54
53
52
51
50
Depth in Metres
20
24
28
32
36
40
Fix Numbers
50
49
48
47
46
'F'

FIG. 5

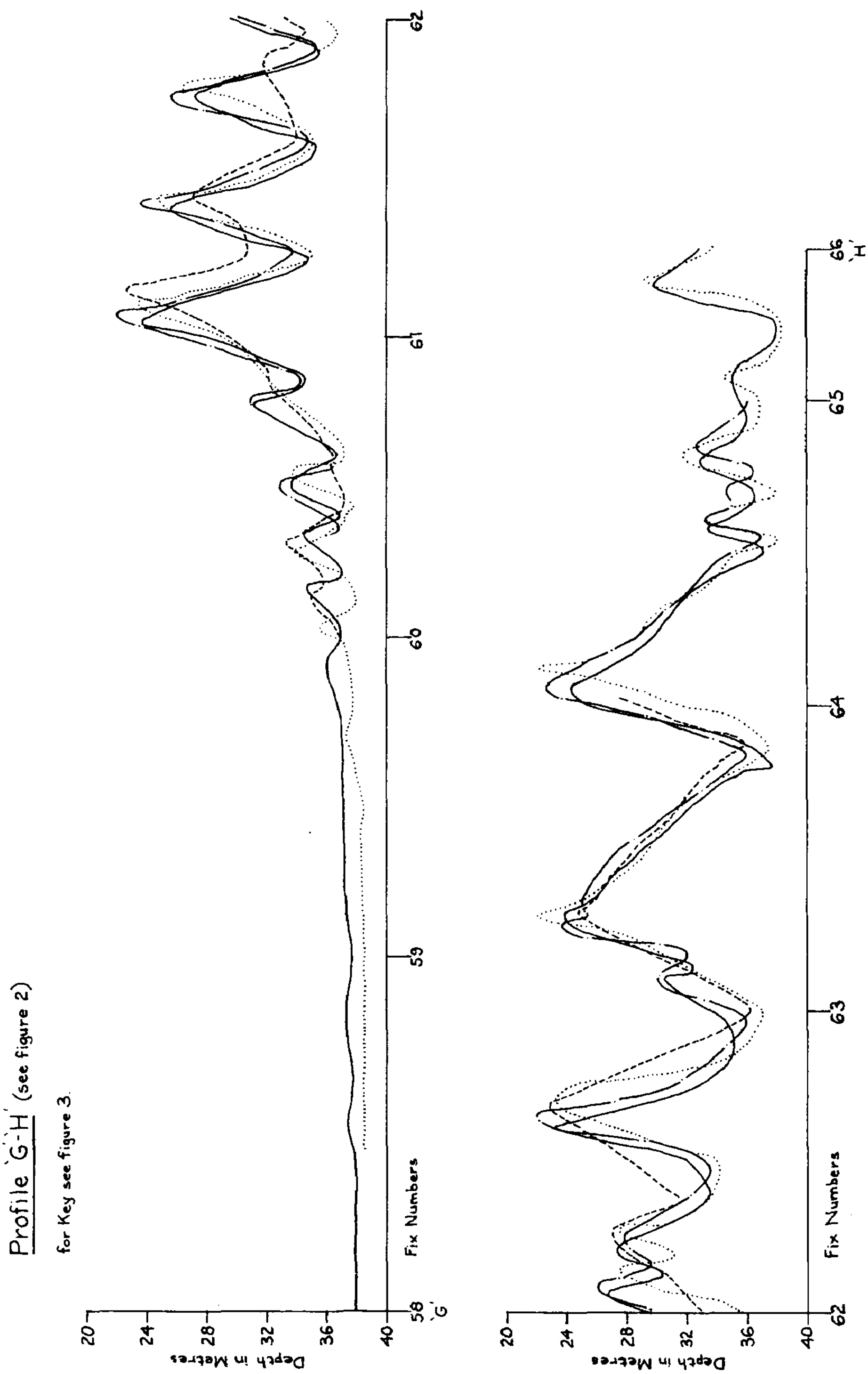

Profile 'G-H' (see figure 2)
for Key see figure 3.
Depth in Metres
20
24
28
32
36
40
Fix Numbers
58
'G'
59
60
61
62
63
64
65
66
'H'

FIG. 6

TABLE 1

Horizontal and vertical displacements of sandwave crests with time

(Movements to the northeast and upwards from the sea bed are considered positive, those in the reverse directions negative)

	1972/3	1973/4	1974/5
Horizontal			
Positive movements (number)	6	54	55
Mean displacement (m)	16.4	18.5	20.0
Negative movements (number)	68	29	30
Mean displacement (m)	29.9	16.0	12.5
No movement (number)	5	11	9
Arithmetic mean of all displacements (m)	28.3	17.4	17.1
Standard deviation	16.8	12.8	13.1
Vertical			
Positive movements (number)	54	4	74
Mean displacement (m)	1.3	0.3	1.1
Negative movements (number)	14	82	13
Mean displacement	0.4	1.2	0.5
No movement (number)	11	8	7
Arithmetic mean of all displacements (m)	1.1	1.2	1.0
Standard deviation	0.9	0.8	0.8

TABLE 2

Degree of scatter in sandwave crest movements

The table shows the number of observations which fall within each band

	1972/3	1973/4	1974/5
Horizontal			
No movement	5	11	9
01-10 m	8	24	30
11-20 m	16	28	23
21-30 m	16	17	20
31-40 m	19	9	7
41-50 m	10	5	4
> 50 m	5	0	
Vertical			
No movement	11	8	7
0.1-0.5 m	12	15	22
0.6-1.0 m	23	25	24
1.1-1.5 m	5	7	13
1.6-2.0 m	18	16	19
> 2.0 m	10	13	9

Considering the horizontal displacements in Table 1, the overwhelming movement in 1972/3 was towards the southwest and the average displacement was rather large at about 28 m. However, as explained above, results deduced from the 1972 survey should be used with caution. In both 1973/4 and 1974/5 the dominant movement was to the northeast although in both years about a third of the displacements were in the opposite direction. What is more interesting is the close agreement and relatively low figures for the two periods for the overall mean and the standard deviation from this mean. These figures are thought to be well within a combination of survey errors and inaccuracies in plotting and analysis (estimated to be ± 20 m). Later work in another area has shown that these difference figures can often be reduced by more exact interpolation procedures in cases where the lines being compared on successive surveys are not in exactly the same place. From Table 2 the peak number of observations for horizontal displacements in 1972/3 occurs at around 30 m, for the other two periods at between 10 and 15 m. The present evidence cannot be regarded as conclusive and the surveys of later years will be examined with critical interest. However, it seems probable that there is very little real movement in the horizontal plane over the years 1972-1975 and certainly no consistent movement in any one direction.

In the vertical plane the picture is rather different. Thus in 1972/3 (both surveys in June) most of the crests grew in height above the sea bed. In 1973/4 (surveys in June and February) there was lowering of virtually all the crests, which trend was reversed again 1974/5 (both surveys in February). There are thus either small real cyclical changes, which do not seem to be related to the seasons of the year, but might be explained by weather conditions, or there are small datum differences in the various surveys. On tidal reductions it is estimated that there are errors of ± 0.5 m, and the smoothing of the traces accounts for a further ± 0.5 m. The very close agreement in the arithmetic mean and standard deviation for all three periods is interesting. From Table 2 it is evident that there is a fairly random spread of observations throughout the whole band 0-2 m vertical movement. Again, further work is really required to determine whether these variations are real or not.

In the meantime the effect of changes in the vertical on the accuracy of charted depths has been examined carefully. On the largest scale charts there are only about thirty soundings in the whole area covered by this investigation. With this number of soundings it is quite impossible to represent such complicated submarine relief in any detail. Outside of the main area of Sandettié Bank itself the shoalest sounding charted is 20_1 m (11 fm). This sounding is in the middle of the area where the crests of the major sandwaves are found on all the four surveys analysed. Whilst in that exact spot slightly differing values are found from the various surveys, there are many similar depths on all surveys in the immediate vicinity. In fact, for the four years investigated there is no shoaler sounding in this area than 20_1 m. None of the four surveys therefore has produced depths which could be described as "unexpected" from a study of the chart. Further, the fact that the outer limit of the sandwaves can be mapped fairly positively and is remarkably constant over the four years (see fig. 7), again lessens the impact of these waves on the safety of navigation.

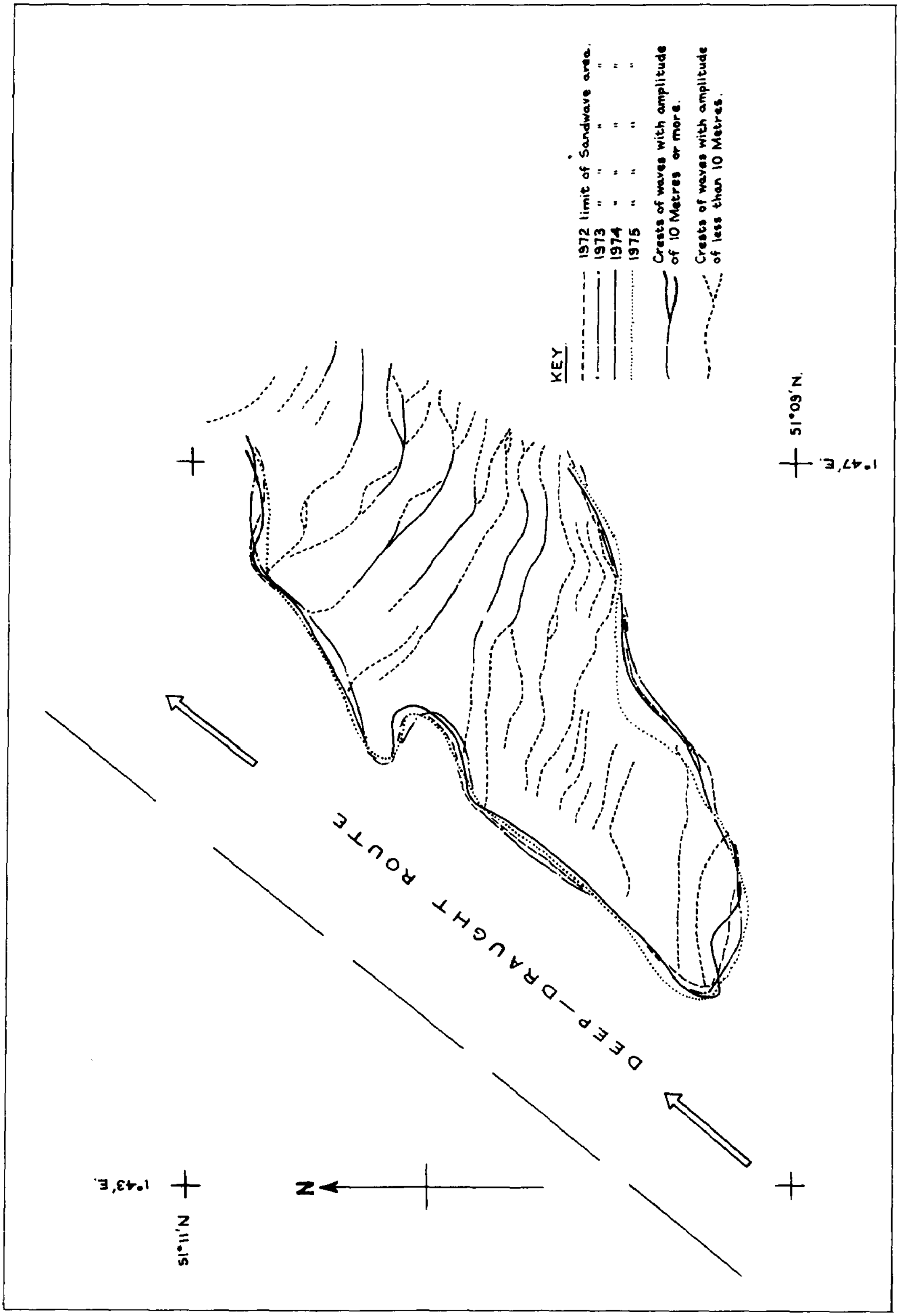

KEY
1972 limit of Sandwave area.
1973
1974
1975
Crests of waves with amplitude of 10 Metres or more.
Crests of waves with amplitude of less than 10 Metres.
DEEP-DRAUGHT ROUTE
51°09'N.
1°47'E.
51°11'N.
1°43'E.
N

TABLE 3

Tidal stream observations by HMS Kellet, *9/10 June 1936*

Logship at 5 fathoms, with surface float, position 51°09'.5 N, 01°44'.1 E. High Water at Dover 14.41 on 9/6/1936 and 03.11, 15.25 on 10/6/1936.

Hours		Observed		Interpolated Rates	
		Direction	Rates	Springs	Neaps
Before HW Dover	6	223°	0.90	1.02	0.57
	5	213°	2.15	2.43	1.35
	4	212°	3.07	3.47	1.93
	3	207°	2.87	3.24	1.80
	2	202°	2.20	2.49	1.39
	1	105°	1.03	1.16	0.65
	HW	045°	1.67	1.89	1.05
After HW Dover	1	033°	2.25	2.54	1.42
	2	041°	2.53	2.86	1.59
	3	022°	1.92	2.17	1.21
	4	015°	1.31	1.48	0.82
	5	142°	0.38	0.43	0.24
	6	243°	0.67	0.76	0.42

The tidal stream observations at 5 fathoms depth were analysed by the semigraphical method given in the Admiralty Manual of Hydrographic Surveying, Volume II, Chapter II, p. 104. The averaged readings of the two tidal cycles observed and replotted relative to HW at Dover are given in tabular form above. These values, plotted in polar coordinate form, show that the stream pattern is strongly rectilinear (fig. 8). Maximum rates at spring tides approach 3.5 knots. There is a residual movement on the observed data of 0.18 kn, in direction 179°, which converts to 0.20 kn at springs, 0.11 kn at neaps. The maximum flow rates are strongly concentrated on an axis which is exactly at right angles to the trend of the sandwave crests. The flood and ebb flows are fairly well balanced, the small residual movement being almost due south. The finding of large symmetrical sandwaves in this location therefore supports the general theories already quoted. No satisfactory reasons can at present be adduced for asymmetry in the waves towards the edges of the present area of investigation.

CONCLUSIONS

An area of large sandwaves exists off the southwestern end of Sandettié tail, which is very close to the recommended routes for deep draught shipping. The largest waves have amplitudes which are of the order of 50 % of the prevailing navigational depths in the deep draught routes. The sandwaves have been mapped with as much care and accuracy as existing survey data will allow. Over a three year period the main waves have been fairly stable both in position and in height. Whilst the smaller peripheral waves may be less stable, their maximum extent has not varied appreciably. Provided shipping keeps to seaward of their outer limit there need be no danger to deep draught navigation. Further work is required to establish whether the relatively small variations that have been found are real or not. However, it does not seem necessary to continue with a complete annual re-survey to ensure safety of navigation.

TIDAL STREAM OBSERVATIONS
H.M.S. Kellet 9/10 th. June 1936
Position 51°09'30"N. 01°44'06" E. Depth 5 fathoms.

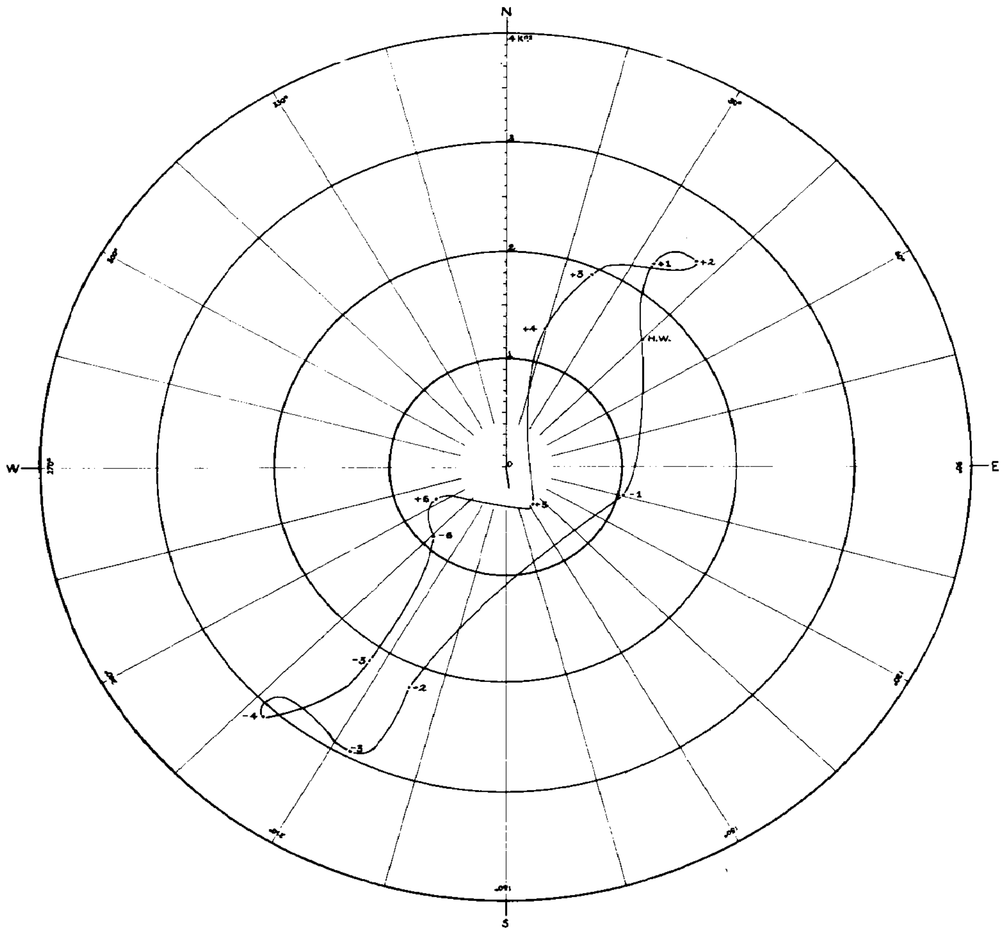


FIG. 8. — Residual current 0.18 knot (0.20 knot at Springs) 179°.

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SEA OF SARDINIA, 100 B.C. : HOW DEEP IS THE OCEAN ?

Ever since men had been sailing the open sea, they must have wondered about its depth. But they had to battle or at least work like galley slaves to make their way from port to port, and there was little opportunity to find out.

The only early record of sounding the deep sea that I have been able to locate was that of Herodotus in the 400s B.C., and I do not know what depth was found.

About 100 B.C. one of the startling discoveries of the ancient world was made, an important discovery for oceanography. Lowering a line into the dark sea, just as fishermen had done for centuries, sailors lowered and kept lowering the line till they had measured a depth of over a mile, or 6 000 feet. It was the first time men ever had discovered any such depth.

Strabo, who was a contemporary of Christ, reported it : "The sea of Sardinia, than which a deeper sea has never been sounded, measuring, as it does, according to Posidonius, about 1 000 fathoms".

What Posidonius was talking about was the first recorded sounding of the deep sea, away from shore, anywhere. Besides diving for oysters, sponges and pearls, man's exploration of the depths started right here, with the unknown sailors of whom we are told by Posidonius through Strabo.

From *Men who Dared the Sea*, by Gardner Soule (Crowell, New York, 1976).