THE COMMONER FORAMINIFERA OF THE ENGLISH CHANNEL FROM THE HAND DEEPS TO START POINT, AT OR NEAR THE THIRTY-FATHOM LINE.

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(Read at Totnes, August, 1900.)

[*Nomenclature, geographical distribution, and range in depth*, H. B. Brady, Foraminifera, *Challenger Reports IX*.

Notes in brackets after name of species are extracted from the same author's "Synopsis of the British Recent Foraminifera," *Journal Royal Microscopical Society, November*, 1887, and have reference to distribution round the British Isles.]

THIS paper, like last year's on the bottom-deposits, arises out of the work of the Marine Biological Laboratory at Plymouth. Its range is confined to the commoner species found in the area examined, and its intent is rather to provide material toward a knowledge of the conditions and surroundings most favourable to each species, than to add to the knowledge of its general distribution.

It is a grave difficulty in discussing the influence of the surroundings on the prevalence of any given species, that so many foraminifera should seem absolutely indifferent to variations in temperature or depth. For instance, *Miliolina seminulum* and *Truncatulina lobatula* may both be found in all latitudes, all seas, and all depths, from the shore pools to 3,000 fathoms. While *Lagena lævis* is distributed from the Arctic seas to the Equator, and thence to the Antarctic seas, it occurs in shore pools, and has been taken at the depth of 2,435 fathoms, its geological history commencing in the Upper Silurian. These are but some instances among many.

An indifference and independence more absolute cannot be suggested than that of any organism which, descending unchanged from Palæozoic time, is found to-day apparently indiscriminately scattered through all seas. Apparently indiscriminately, for within its wide range there are localities it affects in preference to others, and while rarely if ever absent over any area, it is much more numerous in some.

It is probably the same with all foraminifera, however wide their distribution; each species has preferences, as shown by its varying prevalence on adjacent grounds.

So little is known of the life-history of the family that we are at a loss to tell what features in any locality are likely to affect the distribution of the various species.

It appears probable that some species should prefer sandy and others muddy bottoms, while adherent species may have prejudices in favour of certain locations or hosts. Arenaceous foraminifera would require suitable material from which to build their tests, but so fine are the particles most usually employed, that a supply exists almost everywhere, except possibly in the deepest seas. Some species would seem ill adapted to localities where wave-action is considerable, notwithstanding which extremely delicate forms are found in shore pools.

Each species would no doubt flourish best, other conditions being equal, where its food-supply is most abundant; but little or nothing is known as to the food especially affected by any one foraminiferan, or, indeed, whether all is not very literally fish which comes to the net of any.

The only means of solving the problem of distribution lies in constantly noting the conditions under which each species is found, in hope that from many observations it may be possible to sift out those features which are essential from those which are neutral.

Within the area covered by the dredgings described last year there are considerable variations in numerical representation of the various commoner species of foraminifera, and it is these variations which are now to be recorded, side by side with a statement of as much as is known of the local conditions in each case.

As explained in last year's paper, samples of the bottom-deposit were dredged from various localities, and the material obtained was divided by sieves into various grades according to the size of the constituent grains. Only Grades VI., VII., and VIII. are of interest in this connection. Of these, Grade VI., known as the "medium sand," consists of particles over 0·5 mm. and under 1 mm. in diameter; Grade VII., the "fine sand," consists of particles under 0·5 mm. in diameter, and which, when stirred up in sea-water, settle in one minute; Grade VIII., the "silt," remains in suspension at the end of one minute.

It is in these three grades that practically all the foraminifera are found. Grades VI. and VII. were examined in every case, and Grade VIII. in most instances.

The examination was always made after the sieving and drying had been completed; accordingly no living foraminifera were observed, but the skeletons only.

The chart published in "Bottom-Deposits" is re-inserted here, and the position of each haul referred to will be found indicated by its distinguishing number within a circle.

As to the Relative Frequency of Foraminifera of all Species.

The records on this point are not quite complete—indeed, a census was taken in nine instances only, out of a total of seventeen hauls.

The method adopted in census-taking was to spread 13 centigrammes by weight of Grade VII. of the sample to cover 13 square centimetres in such manner as to present a single layer of sand grains lying as nearly as possible side by side without overlap. The foraminifera present were then counted. The figures are as follows:—

Table I.

103 VII.,	13 cgrms.	by weight,	203	foraminifera.
90 VII.,	,,	,,	104	,,
83 VII.,	,,	,,	93	,,
87 VII.,	,,	,,	81	,,
91 VII.,	,,	,,	67	,,
97 VII.,	,,	,,	60	,,
102 VII.,	,,	,,	48	,,
105 VII.,	,,	,,	29	,,
106 VII.,	,,	,,	29	,,

The matter is more complicated than this table indicates, for in those cases where Grade VII. represented but a small percentage of the total haul the same number of foraminifera would form a much greater proportion of that grade than when Grade VII. was largely predominant in the total haul. In order, therefore, to obtain a fair comparison the numbers given in the table above should be reduced to the number of foraminifera in 13 cgrms. of all grades of each dredging.

This gives the following figures, which, it must be understood, are proportionate results only, the numerous foraminifera in Grades VI. and VIII. not being included in the computation; still the numbers found in VII. afford an accurate gauge of total relative frequency. The table also gives the percentage of Grade VIII. (silt) found in each haul, the total organic carbonate of lime expressed as a percentage of the whole, and the true description of the bottom-deposit in each case, founded on the nomenclature explained in the paper on "Bottom-Deposits," and abstracted from that paper.

TABLE II.

Distinguishing Number of Haul.	Number of Foraminifera in each 13 cgrms. of Grade VII., expressed as Number in each 13 cgrms. of Total Haul.	Percentage Grade VIII. (Silt) in Haul.	"Average Grade" of Haul.	Percentage $CaCO_3$ in Haul.	True Description of Bottom-Deposits.
90	72	6·8	6·561	22·91	Fine sand.
91	55	1·1	6·814	14·13	Fine sand.
102	41	1·7	6·849	14·86	Fine sand.
103	21	17·1	4·638	61·18	Medium gravel, sand & mud.
83	8	8·2	3·946	40·74	Medium gravel, sand & mud.
97	5	3·1	4·471	46·68	Fine gravel.
105	5	0·5	4·498	47·26	Coarse shelly gravel.
87	4	1·1	4·151	72·25	Medium shelly gravel.
106	2	0·3	3·803	52·77	Coarse shelly gravel.

The depths of water in which the dredgings were taken all lie practically between 25 and 35 fathoms, and variations between these limits are of no importance to the foraminifera.

The percentage of silt in the bottom-deposit apparently exercises little or no influence, at least within the limits here given. The "average grade" does, however, give a hint of the direction in which to look for the causes determining the frequency or otherwise of the foraminifera as a class; and when the "true description of bottom-deposit" is taken, it becomes evident that on the grounds under investigation the majority of these animals flourish best on fine sand, next best on gravel mixed with sand, next on fine gravel, and are least at home on a shelly gravel. Indeed, a coarser gravel with inorganic sand is somewhat more favourable to them than a slightly finer gravel with sand in greater proportion but derived from shells.

Notes made on other dredgings at the time when the hauls were examined, but omitted from the above table because the results were not numerically expressed, all bear out the foregoing conclusions.

As to the Relative Frequency of Individual Species.

In this matter the relative predominance of each species in each haul is taken, and not the number present in one haul as compared with all the other dredgings. Possibly both views should have been adopted; as it is, a given species may be but poorly represented numerically at a certain place, but if present in greater numbers than another species it is treated as predominant, and the conditions there obtaining are assumed to be more favourable to its existence. Comparative and not absolute frequency is chiefly relied upon. No doubt it would be better in future work to note both.

If the small specimens occurring in the silts are included, practically every species mentioned would be found under the head of each dredging, excluding some few rarer forms.

Grades VI. and VII. are, however, adopted to the exclusion of the silt, except where otherwise stated.

Biloculina ringens.—*Distribution.* Ranges from shore pools to 3,000 fathoms. (Common everywhere, *British Isles.*)

Nowhere numerous, occurs in 96, 97, 83, 85, and ranges from seventh to thirteenth in descending order of frequency. The bottoms on which it mostly occurs are fine gravel; medium gravel, sand, and mud; and coarse gravel, sand, and mud.

Spiroloculina planulata.—*Dist.* Littoral and shallow water sands, but also occurs rarely as deep as 2,000 fathoms. (A common shallow-water form, *B.I.*)

Not infrequent, is common at 83, medium gravel, sand, and mud, and is there third in order of frequency. Occurs fifth in 96, coarse gravel, sand, and mud; fifth in 102, fine sand; seventh in 87, medium shelly gravel; ninth in 94, coarse gravel, sand, and mud.

Spiroloculina limbata.—Dist. Commonest in shallow water, but tolerably frequent to 400 fathoms. (Widely distributed, *B.I.*)

Only a few individuals found.

Miliolina trigonula.—Dist. Prefers temperate zone, never reaches Polar regions, has been found down to 2,300 fathoms; but well marked specimens are rare in deep water. (Generally distributed, *B.I.*)

Not uncommon, but never more than a few individuals present in the quantity of material examined from any dredging. Perhaps more frequent in 97 than elsewhere—here it is fifth on a bottom of fine gravel; occurs also in 87, medium shelly gravel; 103, medium gravel, sand, and mud; and 104, fine sand.

Miliolina seminulum.—Dist. Shallowest shore pool down to 3,000 fathoms, common in every latitude. (Common on every part of the coast, *B.I.*)

One of the three commonest species, its rivals being *Rotalia beccarii* and *Truncatulina lobatula.* At places it is greatly predominant, as for instance at 87, on medium shelly gravel, and 85, on fine gravel. It is also first on 97, fine gravel; is second in 90, 91, 92, 104, 109, all fine sands, in each case being led by *Rotalia beccarii*; is second in 105 and 106, both coarse shelly gravels, in each case again led by *Rotalia beccarii,* the two species together constituting by far the greater number of foraminifera present; is second also in 83, medium gravel, sand, and mud; third in 102, fine sand, and in 96, coarse gravel, sand, and mud; fourth in 103, medium gravel, sand, and much mud, and in 94, coarse gravel, sand, and mud; eighth in 84, coarse gravel, sand, and mud.

Prefers a fine sand, but is well suited by a clean gravel, medium or fine, and does better on shell gravel than most species. Apparently this species does not do so well where the bottom is at all muddy.

Miliolina bicornis.—Dist. Temperate or tropical, shore pools to 40 or 50 fathoms, rare cases as low as 120 fathoms. (Not uncommon in shallow dredgings, *B.I.*)

Nowhere present in considerable numbers, but out of the seventeen stations at which *Miliolina seminulum* has been found, this species has also been taken at twelve. Follows closely the distribution of its more common relative. One specimen from 92 was of the reticulate variety.

Miliolina agglutinans.—*Dist.* Shallow water, and in one instance at 440 fathoms (Atlantic shores of Ireland, and estuary of the Dee, *B.I.*)

An occasional specimen found in Grade VIII., but no sufficient evidence as to nature of bottom preferred.

Haplophragmium canariense.—*Dist.* World-wide, mainly in shallow water, but has been taken in 3,950 fathoms. (Common on muddy bottom all around coast, *B.I.*)

Only found in Grade VIII.; possibly specimens of slightly larger size may occur in Grade VII., and have been overlooked.

Fairly common in 96, coarse gravel, sand, and mud; not uncommon in 103, medium gravel, sand, and mud; occurs in 83, 84, gravels with sand and mud, and also in 109, a fine sand. Some of the silts have not been examined. The species, however, appears to prefer gravel with mud rather than fine sand, and is certainly more numerous on those grounds where the silt is a more prominent constituent of the bottom-deposit.

Textularia sagittula.—*Dist.* Cosmopolitan, shallow water, but has been found down to 2,675 fathoms. (A common littoral and shallow-water form, *B.I.*)

Textularia agglutinans.—*Dist.* Whole world, with little reference to depth—5 fathoms to 3,125 fathoms. (Generally distributed, *B.I.*)

Textularia gramen.—*Dist.* Almost all latitudes, commoner on shallow bottom than at great depths. (Mounts Bay, Cornwall, etc., *B.I.*)

The last-named three species may very well be taken together, as their distribution on the grounds in question is very similar.

It should, however, be remarked that by far the greater number of the individuals taken belong to species *gramen*; *agglutinans* is comparatively infrequent, and *sagittula* only occasionally occurs.

Textularia gramen was taken in sixteen out of a total of seventeen dredgings. It was the second species numerically in 84, coarse gravel, sand, and mud, and in 96, coarse gravel, sand, and mud. It was third in 85 and 97, fine gravels; in 103, medium gravel, sand, and mud; in 105, coarse, shelly gravel; in 87, medium, shelly gravel; and in 109, fine sand. It was fourth in 89B, fine sand; fifth in 90, fine sand; sixth in 83, medium gravel, sand, and mud; in 94, coarse gravel, sand, and mud; and in 106, coarse, shelly gravel. It was third and fourth in 91 and 92, both fine sands, but not very frequent in either.

Within the area examined the nature of the bottom seems to have little influence on the distribution of this species.

Bulimina pupoides.—Dist. Shallow water to 1,000 fathoms. Indian Ocean, Cape of Good Hope, South Pacific, etc. (Common all around coast, *B.I.*)

Nowhere very numerous in Grades VI. and VII. Taken in 106, coarse, shelly gravel; 92, fine sand; 103, medium gravel, sand, and mud; 102, fine sand; 94, coarse gravel, sand, and mud; 84, coarse gravel, sand, and mud; 97, fine gravel; and 83, medium gravel, sand, and mud.

Apparently prefers the coarser sands and gravels, independently of the relative amount of silt present.

Bolivina punctata.—Dist. Cosmopolitan, 2 fathoms to 2,750 fathoms. (Generally distributed, *B.I.*)

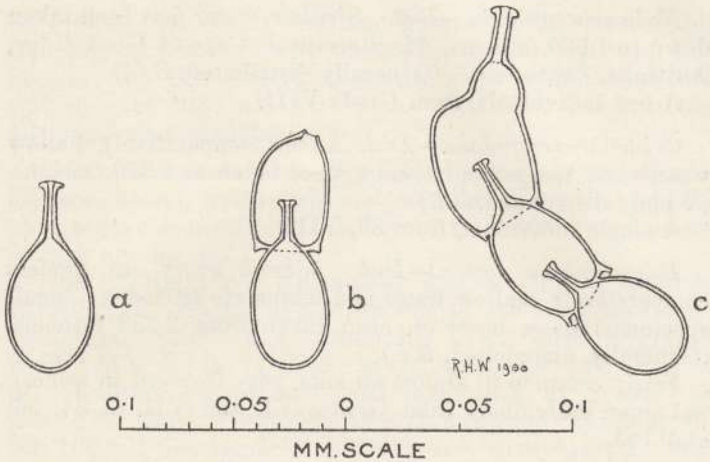
Bolivina dilatata.—Dist. Limited to North Atlantic, down to 1,180 fathoms. (Torquay, Mounts Bay, etc., *B.I.*)

Bolivina punctata is rarely found in Grades VI. and VII., and *Bolivina dilatata* somewhat sparingly. Both are more numerous in the silts (Grade VIII.), and there *punctata* is perhaps slightly the more frequent. Both are found on every class of bottom-deposit, from coarse gravel, with sand and mud, to a merely mud bottom, as in parts of Plymouth Sound. Better adapted to live on a very muddy bottom than most other species mentioned in this paper.

Lagena lævis.—Dist. Commonest and most widely distributed of all lagena, extends from the Arctic to the Antarctic, from shore pools to 2,438 fathoms. Geologically, first occurs in the Upper Silurian. (Common, *B.I.*)

Common in all silts, too small to occur in Grades VI. or VII. A typical lagena, but some specimens from these dredgings have adopted a nodosarian habit, a few occur with second chambers and one with three. So far as the author's knowledge extends these are the first recorded instances.[1]

[1] Since writing the above I find that Goës states that certain starved short-necked individuals have been found with *two* chambers. The specimens now figured are not short-necked.



a. Lagena lævis—normal.
b. " two chambers; from VIII., 103.
c. " three chambers, the last a complex; from VIII., 83. All ×300.

Lagena sulcata.—Dist. One of the most abundant and generally distributed of the genus, littoral to 2,750 fathoms. Geologically, first known in the Upper Silurian. (Common, *B.I.*)

Found in 97, 89, and 109. Small specimens also found in the silts, one of the less common forms on this ground.

Lagena striata.—Dist. Occurs in every sea in shallow water, and at times down to 600 fathoms and more. (Common, *B.I.*)

Frequent in all silts, a few large individuals found in Grades VI. and VII.

Lagena orbignyana.—Dist. World-wide, shallowest seas to 3,000 fathoms. (Common, *B.I.*)

Occurs in nearly if not quite all silts. Larger specimens found in Grade VII. of 83, 84, 87, 90, 97, 102, 103.

Lagena lagenoides.—Dist. Most familiar as a Mid-Atlantic species, down to 2,740 fathoms. (Sparsely distributed all around the coast, *B.I.*)

One specimen only, from 103, VIII.

Lagena apiculata. One individual from 94.

Nodosaria communis.—Dist. World-wide, littoral zone down to 3,000 fathoms. (Generally distributed, *B.I.*)

One specimen, from 96, VIII.

Nodosaria scalaris.—Dist. Shallow water, has been taken down to 1,630 fathoms; Mediterranean, Cape of Good Hope, Australia, Japan, etc. (Generally distributed, *B.I.*)

A few individuals, from Grade VIII.

Cristellaria crepidula.—Dist. Affects comparatively shallow waters and temperate latitudes, once taken at 2,350 fathoms. (Widely distributed, *B.I.*)

A single individual, from 83, VIII.

Polymorphina lactea.—Dist. Almost every sea, prefers comparatively shallow water and temperate latitudes. Small specimens have, however, been taken from 2,350 fathoms. (Generally distributed, *B.I.*)

Fairly common in almost all silts, very frequent in some.

Larger individuals from Grades VI. and VII. of 84, 96, and 103.

Globigerina bulloides.—Dist. Cosmopolitan, almost everywhere that any other species is found. (Comparatively rare on the East Coast, common at some distance from land on the Atlantic seaboard, *B.I.*)

Found in all dredgings; most numerous in silts, but occasional large specimens in Grade VII. Totally independent of local conditions.

Spirillina vivipara.—Dist. Almost every part of the world, but prefers muddy bottoms of less than 150 fathoms. Has been taken down to 620 fathoms. (Generally distributed. Specimens, however, not very common, *B.I.*)

Found in 83, 87, 96, 97, 103, and 109, on bottoms ranging from fine sand to coarse gravel with sand and 17 % of silt. Not uncommon, and is found, here at least, on bottoms which certainly cannot be described as muddy.

Discorbina rosacea.—Dist. Almost every sea, at home on shallow bottoms, rare below 250 fathoms, but has been met with down to 1,000 fathoms. (Widely distributed, *B.I.*)

Occurs in sixteen out of the total of seventeen dredgings. Is usually fifth or sixth numerically. Common in most places, but not very numerous anywhere. It is impossible to suggest the local conditions most favourable to this species.

Planorbulina mediterranensis.—Dist. Almost every sea within temperate and tropic zones; commonest at less than 50 fathoms. It has been taken down to 1,125 fathoms. (Generally distributed, *B.I.*)

Found in 83, 84, 89, 91, 94, 104, and 106, on every variety of bottom that occurs on these grounds. The presence of hydroids may have some influence on the abundance of this species; but this is very uncertain, since hydroids are not numerous at 106; whereas *Planorbulina* is common in the silt from that dredging.

Truncatulina lobatula.—Dist. Common at every latitude. Prefers littoral, laminarian, and coralline zones, but is still conspicuous at nearly 3,000 fathoms. (One of the commonest British species, *B.I.*)

One of the three commonest species on the grounds investigated. Taken in sixteen out of the total seventeen dredgings. Stands first numerically in 83, medium gravel, sand, and mud; in 84, coarse gravel, sand, and mud; and in 103, medium gravel, sand, and mud, with 17 % silt. Is second in point of numbers at 102, fine sand; third in 89, 92, 104, all fine sands, and 106, coarse shelly gravel. Not numerous in either 90 or 105, and apparently absent; probably poorly represented in 85.

This species was noted adherent to hydroids, with an apparent preference for *Sertularella gayi* as a host.

Wherever the hydroids are plentiful, *Truncatulina* is well represented; its numbers fall as the hydroids decrease, until, as at 84, where the latter are scarce, the foraminiferan is practically absent. This is its habit on these grounds; but from its general distribution in depth it is evident that *Truncatulina lobatula* cannot by any means be always dependent on these hosts. Nor is it suggested that even in this locality all the individuals were originally adherent to hydroids.

Rotalia beccarii.—Dist. Essentially a shallow-water species, most abundant in littoral and laminarian zones of temperate seas. Occupies the margins of all great oceans except the Arctic and Antarctic. Although really at home in shallow water, has been taken at a depth of 2,950 fathoms. (Generally distributed, *B.I.*)

Another of the three commonest species on these grounds.

Occurs in every dredging. Stands first in 89, 90, 91, 92, 94, 96, 104, 106, or in nine hauls; stands second in 85, 87, 105; third in 84, 89, 92; fourth in 91, 109. Undoubtedly the commonest species of all on these grounds. Attains its greatest numbers on some of the fine sands, but flourishes almost independently of nature of bottom.

Polystomella striato-punctata.—Dist. World-wide, normal habitat in less than 100 fathoms but not infrequent down to

600, rare specimens from two stations at 2,000 fathoms. (Generally distributed, *B.I.*)

Nowhere numerous, small specimens occur in the silt of 103 and 109, etc.

Species occur in addition to the thirty odd mentioned above, and further dredgings now in hand give yet others. So far, however, as any practical knowledge as to habitat can be gained, the above list exhausts the information available at the present moment.

The author leaves the subject, as he has left others, to be continued if time and opportunity serve.

For a knowledge of the accompanying fauna, Mr. E. J. Allen's paper, *Journal Marine Biological Association*, New Series, vol. v. No. 4, June, 1899, should be consulted. The following table gives the locality of each haul, nature of bottom, and the number of Mr. Allen's "ground" in which the haul lies.

TABLE III.

Distinguishing No. of haul.	No. of ground.	Locality.	Nature of bottom.
83	XII.	Eddystone, S. by E. ¼ E., 3 miles	Medium gravel, sand, and mud
84	XI.	Eddystone, S.E. by S., 2¼ miles	Coarse gravel, sand, and mud
85	XIV.	Eddystone, S.E. by S., 1 mile	Fine gravel
87	XVI.	Eddystone, S.E. by S., ¾ mile	Medium shelly gravel
89B	VIII.	Eddystone, S.E. by S., 2 miles	Fine sand
90	V.	Breakwater light, N.W. ¼ N., 6 miles	Fine sand
91	III.	Eddystone, W. by S., 3½ miles	Fine sand
92	I.	Eddystone, W. by S., 5 miles	Fine sand
94	IX.	Eddystone, E. ½ S., 3 miles	Coarse gravel, sand, and mud
96	X.	Eddystone, E., 2 miles	Coarse gravel, sand, and mud
97	XV.	Eddystone, W., 2 miles	Fine gravel
102	VI.	Eddystone, N., 2½ miles	Fine sand
103	XIII.	Eddystone, N.W., 1 mile	Medium gravel, sand, and mud (17 % silt)
104	II.	South of Mewstone Buoy, 10 miles	Fine sand
105	XVII.	Bolt Head, N.N.E., 1 mile	Coarse shelly gravel
106	XVII.	Bolt Head, N., 2 miles	Coarse shelly gravel
109	VII.	Eddystone, E.N.E., 2 miles	Fine sand

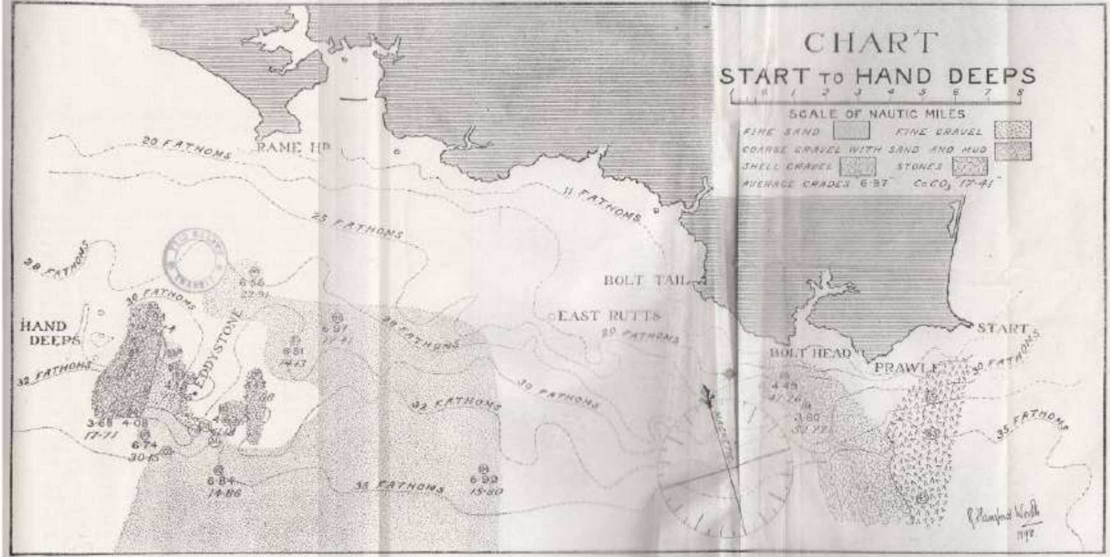


CHART
START TO HAND DEEPS
1 2 3 4 5 6 7 8
SCALE OF NAUTIC MILES
FINE SAND
FINE GRAVEL
COARSE GRAVEL WITH SAND AND MUD
SHELL GRAVEL
STONES
AVERAGE GRADES 6·97 CaCO3 17·41
RAME HD
20 FATHOMS
11 FATHOMS
25 FATHOMS
38 FATHOMS
30 FATHOMS
BOLT TAIL
EAST RUTTS
HAND DEEPS
EDDYSTONE
32 FATHOMS
BOLT HEAD
PRAWLE
START
35 FATHOMS
6·56
22·91
6·97
17·41
6·81
14·13
3·68
17·71
4·08
6·74
30·15
6·84
14·86
6·99
15·80
4·49
3·60
MAGNETIC

Face p. 502