Department of Agriculture and Technical Instruction for Ireland.

MEMOIRS OF THE GEOLOGICAL SURVEY OF IRELAND.

ON ROCK-SPECIMENS

DREDGED FROM THE FLOOR OF THE ATLANTIC OFF THE COAST OF IRELAND,

AND THEIR BEARING ON SUBMARINE GEOLOGY.

BY

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ON ROCK SPECIMENS

Dredged from the Floor of the Atlantic off the Coast of Ireland, and their Bearing on Submarine Geology.

The accompanying Memoir contains an account of rock-specimens dredged from various depths off the Atlantic coasts of Ireland by the Fishery Survey of the Department of Agriculture for Ireland, and examined by the Geological Survey for comparison with the rocks known on the mainland. The results are represented on a coloured map inserted in the Memoir, and are of interest as showing the constitution of the Porcupine Bank, and the prevalence of Cretaceous flint and chalk in 500 fathoms of water off the coast of Kerry. Limestone of Eocene age, unknown in Ireland, is found in the same area. The rock-specimens are so localised as to lead to the conclusion that they represent the actual rock-floor of the sea; and in many cases the structure of the mainland may be thus traced beneath the water. The Cretaceous area, however, must be regarded as a new addition to Irish geology, while the Porcupine Bank represents an igneous mass that probably rose at one time as a rocky island off the western coast.

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PREFACE.

The following Memoir is based on materials supplied from time to time by the Fisheries Branch of the Department of Agriculture and Technical Instruction for Ireland, and is an attempt to carry the work of the Geological Survey over part of the continental plateau now covered by the Atlantic. The evidence of the presence of Cretaceous and Cainozoic limestones off western Ireland appears to be especially convincing. I have to thank my former colleague, Mr. T. Crook, for adding greatly to our knowledge of the deposits, even after his transference to the scientific staff of the Imperial Institute.

GRENVILLE A. J. COLE,
Director.

DUBLIN, *July*, 1909.

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This Memoir is a development and continuation of a paper previously published (1), in which we drew attention to the localisation of certain groups of rock-detritus off the western coast of Ireland, and urged that the materials dredged up represented very fairly the rocks that constitute the sea-floor from point to point. Five deposits were then described, and we have incorporated in these pages such portions of the earlier paper as were needed to give a complete account of these. The dredged material has, in all cases, been supplied to us by the Fisheries Branch of the Department of Agriculture and Technical Instruction for Ireland and was obtained during official surveys.

The interest of such deposits naturally lies in the light that they may throw upon the geological character of a region now covered by the sea. It is necessary to enquire (i.) how far the materials may have been transported by ordinary oceanic currents; (ii.) how far their accumulation may be due to glacial action; and (iii.) how far they are the products of the weathering of rock-masses in their immediate neighbourhood. In the last case, they form our only guides in the geological mapping of the ocean-floor, and may thus assume considerable importance.

Professor David Forbes (2), when describing similar materials from the area between Rockall and Donegal Bay, remarked on their general resemblance to the rocks of north-western Ireland, and was not disposed to invoke glacial action to account for their distribution. He attributed the occurrence of subangular gravel at such depths as 1200 and 1400 fathoms to the "ordinary action of marine currents"; the largest fragment received by him from a depth of 1443 fathoms weighed only 3 grains (0.194 gramme). The materials now placed in our hands from far shallower waters commonly provide fragments 3 cm. in diameter; and the largest mass, brought from the Porcupine Bank, measures 24 by 18 by

(1) Cole and Crook, "On rock-specimens dredged from the floor of the Atlantic off the west coast of Ireland in 1901." Appendix IX. to Part II. of Report on Sea and Inland Fisheries of Ireland for 1901.

(2) "Notes on Specimens of the bottom collected during the first Cruise of the Porcupine in 1869," Proc. Roy. Soc. London, vol. xviii., p. 490.

11 cm., and weighs 9800 grammes. Where there is a community of character in blocks of these dimensions dredged from any one locality, it seems fair to regard them as an indication of some mass now hidden beneath the sea. This view was urged in connection with Rockall Bank (1), as the result of dredgings made in 1896; and it was then pointed out that the fragments may represent boulders originally formed by subaerial action on the surface of land-masses which have since become submerged.

When preparing our previous paper, we were unfortunately not aware that Mr. R. Hansford Worth (2) had recorded similar observations in 1899 in regard to the floor of the western part of the English Channel. Mr. R. H. Worth's work deserves, in a high degree, the attention of geologists. He states the relative proportions in which materials of different types are present in his gravels by their percentages by weight. We prefer, however, for our purposes to retain the merely enumerative system adopted in our earlier paper, and have expressed the composition of the gravels by the percentages of stones of each kind present. In the products of most of the dredgings, there are stones of various sizes in all the rock-groups established by us, and exceptional occurrences can be pointed out in any case of special interest.

In 1903, Mr. O. B. Bøggild published, in the English language, his report on "Samples of the sea-floor along the coast of East Greenland, 74½-70 N.L." (3). He pays considerable attention to the mechanical analysis of his samples, since he deals with the fine muds and sands, as well as with the stones collected. On p. 33 he makes an important comparison between his samples of mixed materials from the sea-floor, which are partly derived from submarine moraines, and the glacial till of Funen, formed in connection with an ice-sheet. The latter is shown to possess a far more homogeneous character. From the lack of uniformity of the materials in adjacent localities, he concludes that ice-drift from the coast has played no conspicuous part in building up the deposits on the east of Greenland (p. 86). On p. 48 and onwards, a number of cases are discussed in which the author feels it necessary to refer the coarser materials to the weathering of the rock-floor in the localities where the dredgings were made. On p. 91 we read: "The existence of rocks at the bottom of the sea can now be proved in many different parts of the territory herein described, but still only in the neighbourhood of the shore. The presence of such rocks indicates that those tracts were, in a comparatively late geological period, higher situated than at present, so that the rocks could be worn away by the atmosphere, or by the erosion of the water."

We are thus glad to observe the agreement of Mr. Bøggild with the general trend of our own conclusions.

(1) Cole, "Notes on Rockall Island and Bank," Trans. R. Irish Acad., vol. xxxi. (1897), p. 59.

(2) "The Bottom-deposits of the English Channel from the Eddystone to Start Point, near the Thirty-fathom line," Trans. Devonshire Assoc. for advancement of Science, &c., vol. xxxi. (1899), pp. 356-375.

(3) Meddelelser on Gronland, vol. xviii., p. 19, and separate publication (Bianco Luno, Copenhagen, 1903).

In May, 1908, Mr. L. R. Crawshay (1) published a paper on "Rock Remains in the Bed of the English Channel," and Mr. R. Hansford Worth (2) gave an admirable account of the stones dredged up by the Marine Biological Association between 1895 and 1906. Mr. Worth calls proper attention to the work of Mr. A. R. Hunt in this field of observation, and to his numerous papers on the submarine geology of the English Channel from 1879 onwards. The appearance of Mr. Worth's paper led to a letter from one of us in the Geological Magazine for August, 1908, in which attention was called to his results, and to the westward extension of Cretaceous and Eocene rocks, as shown by the dredgings off the west of Ireland. Mr. A. R. Hunt commented further on these matters in the same volume of the Geological Magazine, p. 431.

Mr. Hansford Worth's paper includes a consideration of the history of the English Channel and a detailed petrographic description of the rock-specimens dredged up. He has no doubt in tracing the origin of the abundant flints to Cretaceous strata that were deposited in the Channel area (p. 174). These beds were for a time uplifted, and were affected by considerable denudation. Fragments of true chalk, however, have now been added (p. 150) to the rocks known from the English Channel. The specimens are of a hard yellow variety. Still more interesting is the discovery (p. 156) of a block of Eocene limestone, largely composed of Milioline foraminifera. Its site is indicated by the letters E.L., south of Plymouth, on the map issued with the present paper. In the course of an excellent discussion of this material (p. 169), Mr. Worth shows how its occurrence agrees with the general opinion in recent years that the Eocene sea invaded the Paris basin from the west. His conclusions prepare us, then, for the evidence brought forward in the present paper as to an area of Eocene rocks lying in deep water off the west of Kerry. The map given by Professor De Lapparent (3), in 1900, of the European region at the time of the deposition of the Calcaire grossier indicates an inflow from the Atlantic over the Hampshire and Paris Basins, and leaves us quite free to extend the Eocene sea northward up the western shore-line of the Irish area.

The map accompanying the present paper represents the materials dealt with since the commencement of our work in 1901. The percentage constitution of the gravel in each case is shown by various colours arranged in a column. An alternative system of graphic representation by coloured sectors of a circle, the centre of which might lie at the spot where the dredging was made, could not be adopted on a reasonable scale, owing to the closeness of some of the localities.

The Roman numerals at the head of the sections into which this Memoir is divided correspond with those assigned by us to the various dredgings on the map. The Fisheries Branch of the

(1) Journal of the Marine Biological Association of the United Kingdom, New Series, vol. viii. (1908), p. 99.

(2) *Ibid.*, pp. 118 to 188, with numerous plates. Compare Clement Reid, "A probable Eocene outlier off the Cornish coast," Quart. Journ. Geol. Soc. London, vol. lx. (1904), p. 113.

(3) "Traité de Géologie," 4me. édit., p. 1451.

Department of Agriculture and Technical Instruction for Ireland issued in 1905, 1906, 1907, and 1908, Parts I., II., III., and IV. of their "List of Stations," and we are thus enabled to give, between brackets, the official reference numbers and other particulars as supplied in these printed documents. All bearings now given are magnetic. As already stated, we have brought into the present Memoir, with some slight corrections, the descriptions of deposits i., ii., v., vi., and viii., as given in our original paper referred to on p. 1.

I. CENTRE OF PORCUPINE BANK.—Depth 91 fathoms (166 metres). (Helga LXXVII. 124 nautical miles magnetic W. by N. ½ N. of Cleggan Head. Lat. N. 53° 24′ 30″. Long. W. 13° 36′. Fine gravel, coarse sand. 29th June, 1901).

The Porcupine Bank, on which soundings were taken by H.M.S. Porcupine on her first scientific cruise in 1869 (1), lies about 130 nautical miles west of Cleggan in the county of Galway. This spot is convenient as a basis for measurements, since the lines along which other dredgings were made in 1901 radiate from it. The Porcupine Bank is well shown on the Admiralty Chart of the British Islands, the sea-floor rising towards it on the east from a shallow depression between it and Ireland, and falling again far more rapidly on the west down to the 1000-fathom line and truly oceanic waters. The crest of the bank is about 85 fathoms below water, and on the east 185 fathoms are reached in a distance of fifty-three nautical miles, while the same distance on the west brings us to no less than 1600 fathoms (see Plate I.). The Porcupine Bank is thus a part of the European plateau, as would be clearly seen were the 300-fathom line taken to indicate the boundary of the ocean, in place of the 100-fathom line commonly adopted. In this it differs from Rockall Bank, which is divided from the British Isles by a channel of deep water.(2) The possible connexion of the Porcupine Bank with the lost isle of Brasil has been mentioned by Dr. Frazer (3) in his discussion of an ancient map.

The specimens dredged in 1901 from a depth of ninety fathoms are associated with a "sand" composed to a small degree of minute quartz grains and fragments of rocks similar to those of which larger pebbles are forthcoming, and to a far greater degree of shell-fragments; the latter are water-worn, have a dull surface, and average only 2 mm. in diameter. With these are small fresher molluscan shells and spines of echinoderms. The deposit, in view of the "dead" shells so often found in the North Atlantic, is very probably of two ages, and results in great part from the churning up of an ancient shell-bank.

The large blocks placed in our hands consist of a partly ophitic gabbro of medium grain; they are rounded on all angles and edges, but retain traces of the original joint-planes that

(1) Proc. Roy. Soc. London, vol. xviii. (1869-70), plate 4.

(2) See T. Rupert-Jones, "On Rockall," Trans. Roy. Irish Acad., vol. xxxi. (1897) p. 97.

(3) "On Hy Brasil," Journ. R. Geol. Soc. Ireland, vol. v. (1879), p. 128.

bounded them. Their weights in kilogrammes are as follows:—9·8, 7·1, 4·7, 2·3, 2·3, 1·9. With them we received the following smaller stones:—

Gabbro, sometimes decomposed, . .	1935 stones.
Sandstone, ...	511 ,,
Fine-grained Biotite-Granite, . .	1 stone.
,, red Gneiss, . . .	1 ,,

From the considerations already put forward, we conclude that the Porcupine Bank within the 100-fathom line, at the point where this dredging was made, consists of a mass of gabbro, furnishing 80% of the deposit, associated with sandstone, which furnishes 20%. The latter is mostly grey and fine-grained, and no veins of the gabbro have been seen in the sandstone pebbles. Nor are the latter, in the ordinary sense, metamorphosed. Their superior powers of resistance may, of course, have allowed them to survive as the only representatives of a mingled sedimentary series, the relation of which to the predominant mass of gabbro remains unknown.

In microscopic section (Pl. II., fig. 1), the gabbro of the Porcupine Bank exhibits in part an ophitic structure. The pyroxene is a yellowish brown, and, in a thick section, one or two grains show the characteristic pleochroism of a rhombic species, associated with the ordinary augite. It is accompanied by some brown biotite. Pale pseudomorphs with blackened cracks and edges represent the original olivine. The felspar is a labradorite verging on andesine.

The specific gravity of this gabbro is 3·00.

A section from one of the fine-grained sandstones shows angular grains of quartz and fespar, some of the latter being repeatedly twinned; in addition, we find fairly abundant detrital epidote, some light and dark mica, and one or two pale purple grains which are probably amethyst. The rock, like many "grauwackes" and diabases, is coloured by little films of chlorite, which have developed between the constituents, at the expense of other ferro-magnesian minerals. Their source in this case is almost certainly the detrital biotite.

This sandstone resembles the hard rocks, often erroneously styled "grits," that are common in Irish Silurian strata. There is no probability of its having been derived from the decay of the adjacent gabbro, and there is, on the other hand, strong likelihood of its having been formed from the fine-grained gneisses with biotite and epidote that are common in the metamorphic series of north-west Ireland. One such metamorphic rock is figured by us in the present paper (Pl. III., fig. 1).

II. Eastern Edge of Porcupine Bank.—Depth 120 fms. (219 m.). (Helga LXXVIII. 109 nautical miles magnetic W. by N. ½ N. of Cleggan Head. Lat. N. 53° 23′. Long. W. 13° 13′. Coarse sand, shells. 29th June, 1906).

This dredging was made outside the eastern edge of the bank, as limited by the 100-fathom line drawn upon the Admiralty

Chart of the British Islands. Its distance from the preceding dredging is fifteen nautical miles. A striking change in the predominant rock is apparent. The seventy-one stones received are very little rounded, and some of the granites are quite angular. The percentage composition of the deposit is as follows:—

Biotite-Granite, sometimes coarse-grained, . .	66
Aphanite, in some cases with veins of aplitic granite (18), with somewhat fine-grained Diorite or Gabbro (3), ...	21
Sandstone and Quartzite, ...	13
	100

The largest of all these stones is a piece of granite weighing only 156 grammes, and measuring some 6 cm. by 5 cm. by 3 cm.

Here, then, granite clearly predominates, and the association of it with aphanite penetrated by granite veins is significant. The granite stones have a yellow-brown exterior, the colour being especially noticeable on the felspars. This is due to a staining spreading from the outside after the formation of the detrital fragments, as is especially well seen in specimens from dredging No. viii. The colouring is stronger than that which arises during the subaerial weathering of granite, and gives the fragments a superficial resemblance to the brown syenites of Miask in the Urals.

Under the microscope, the granite proves to be rich in microcline; apatite is freely included in the felspar, but also occurs markedly in association with the streaky patches of biotite. Epidote is abundant in these patches, and the arrangement of the ferromagnesian constituent in the mass recalls those rocks of composite origin that are common in north-west Ireland (1). The original granite magma in such a case may have had the composition of aplite, *i.e.*, the "alaskite" magma of Mr. Spurr (2).

In northern Ireland, this magma again and again intrudes into earlier schists and aphanites, belonging to the "Dalradian" series. Off the Porcupine Bank, this series is probably represented by the aphanites and diorites dredged up; but a gneissic type of the granite, which we have studied under the microscope, seems to contain much material derived from mica-schists. It is practically a fine-grained biotite-gneiss, with eyes of microperthitic felspar about 7 mm. long. Both epidote and sphene are, as seems usual in composite masses, associated with the long streaks of biotite.

In section, the specimens of aphanite dredged up at this point show both hornblendic and micaceous hornblendic types, similar to the "epidiorites" of so many metamorphic areas. Sphene occurs at the junction with the aplite veins, and apatite

(1) G. Cole, "Metamorphic Rocks in E. Tyrone and S. Donegal," Trans. R. Irish Acad., vol. xxxi. (1900), pp. 443 and 447.

(2) 20th Ann. Rep. U. S. Geol. Survey, pt. vii. (1900), p. 189.

is sometimes abundant. The aplite becomes, as usual, enriched with ferromagnesian material in its passage through the more basic rock. The fact that five out of the thirteen stones classed as aphanite show veins of aplite conspicuous to the naked eye indicates that the site of this dredging is near the margin of the granite mass from which the more abundant type of stone has been derived. (Pl. II., fig. 2).

The two stones of slightly coarser type, classed as diorite, contain epidote, which almost entirely replaces the felspars in the specimen selected for microscopic examination.

The sandstones from this dredging show a wide variety, from grey-green types like those described from the Porcupine Bank, to red rocks resembling typical Old Red Sandstone. They imply a considerable extension of sediments in this locality, and bear no signs of penetration or metamorphism by the granite magma.

Judging from our knowledge of the rocks of similar aspect on the west coast of Ireland, we may with much probability picture this side of the Porcupine Bank as consisting of "Dalradian" rocks penetrated by the usual granites, which may be those so generally associated with the Caledonian folding. Devonian and Carboniferous sediments probably overlie these masses here, as on the mainland; and exposures of unaltered Silurian strata may, of course, also occur, lying between them and the "Dalradians."

III. North central part of Porcupine Bank.—Depth 91·5 fms. (167 m.). (S.R. 147. 120 nautical miles magnetic W.N.W. of Slyne Head. Lat. N. 53° 27′. Long. W. 13° 37′. Gravel, sand, shells. 24th August, 1904).

XVII. Porcupine Bank, near No. iii.—Depth 109·5 fms. (200 m.). (S.R. 148. 125 nautical miles magnetic W.N.W. of Slyne Head. Lat. N. 53° 33′. Long. W. 13° 39′. Coarse sand, stones. 24th August, 1904).

Dredgings Nos. iii. and xvii. may well be considered together, so as to obtain a more complete and general view of the characters of the gabbro of the Porcupine Bank. Dredging No. iii. shows a great preponderance of this gabbro, which is clearly the important constituent of the bank. From 2133 stones received, we obtain the following percentages:—

Gabbro	77
Sandstone	22
Fine-grained Granite	1
	100

The granite fragments are all small, while some of the masses of gabbro are large, and are well rolled by water-action.

Mr. G. S. Blake has made for us the following analysis of the typical rock from dredging No. iii.:—

OLIVINE-GABBRO, PORCUPINE BANK, OFF WEST OF IRELAND. Lat. N. 53° 27′. Long. W. 13° 37′.

Silica	48·41
Alumina	16·15
Ferric oxide	1·39
Ferrous oxide	8·61
Magnesia	7·12
Lime	11·83
Soda	2·34
Potash	0·60
Water (above 100° C.)	0·95
Water (below 100° C.)	0·27
Carbon dioxide	0·91
Titanium dioxide	1·19
Phosphorous pentoxide	0·22
Sulphur	0·12
Manganous oxide	0·18
Sulphur trioxide	trace
	100·29

Barium was looked for, but was not observed.

Dredging No. xvii. was taken at five nautical miles from the site of No. iii. and farther down the north-west slope of the bank. It gave 78 blocks of gabbro; 11 of these were distinctly large and subangular, weighing from 1·7 kilogrammes up to 5 kg. The smallest stone of the remaining 67 weighed 50 grammes; 63 subangular blocks of sandstone occurred, weighing from 50 grammes up to 4·2 kg. Four granite specimens and one dubious "greenstone" also deserve mention. The percentages are thus:—

Gabbro	54·0
Sandstone	43·0
Granite	2·5
	99·5

But a more important contribution to knowledge is made by this dredging than was made by the others on or near the Porcupine Bank. Two of the pebbles show that the gabbro was penetrated by veins of granite. Similar veins occur in the aphanite found in No. ii., as has been previously noted and figured (Pl. II., fig. 2); but we then compared the two types of rock with those common among the metamorphic series of western Ireland. The granite of No. ii. is not necessarily of the same age as that forming veins in specimens from No. xvii.; but we may now be satisfied that a granite cuts the gabbro of the Porcupine Bank.

The separate sample of fine gravel sent us from No. xvii., described as "sand from tow-net on dredge," merely emphasises the preponderance of gabbro over sandstone in this area. A

few grains of limestone, and one of gneiss, occur; but fine material of this kind may have been drifted from some distance when the bank formed part of a subsiding coast.

The olivine-gabbro of the Porcupine Bank has been naturally considered by us as possibly of Palæozoic age, since the familiar Cainozoic basalts and dolerites of the volcanic region of northern Ireland and the Inner Hebrides were not traceable on the slopes of the bank. At the same time, this olivine-gabbro forms an exception among the other dredged materials, all of which show clear relationship with the rocks of western Ireland. The specimens received by us since the publication of our earlier paper are less decomposed than those from Nos. i. and ii., in which we determined the felspar to be "labradorite verging on andesine." A portion of the olivine-gabbro from No. xvii. was crushed until all the particles passed a sieve having 90 meshes to the linear inch. The magnetite was separated from the crushings by means of a small horseshoe-magnet, the poles of which were covered with a movable paper cap. The ferromagnesian constituents were then separated by an electro-magnet, in a field of moderate strength. Both separations were made under water, as it is not possible to make good magnetic separations when dealing with a dry powder; and it is not permissible to wash away the powder from the coarser portion, since the felspar becomes accumulated in excess in the more finely powdered portion. The separated portions were weighed with the following results:—

(*a*) Attracted by horseshoe magnet ...	2·9%	approximately.
(*b*) Attracted by electro-magnet ...	43·0%	,,
(*c*) Unattracted residue	54·0%	,,

(*a*) Consists of magnetite which is titaniferous.

(*b*) Consists chiefly of augite; it also contains hypersthene, dark brown biotite, green hornblende, and olivine.

(*c*) The non-magnetic residue is almost entirely plagioclase.

(*c*) contains some apatite, a little pyrite and zircon, a few splinters of quartz, and a number of reddish brown fragments, resembling limonite. The pyrite and zircon were isolated by means of methylene iodide. The zircon thus obtained was found to consist of complete crystals of the ordinary type, such as are more commonly observed in acid rocks—colourless prisms, capped with pyramids and containing the characteristic inclusions. The largest crystal observed measured about 0·5 mm. by 0·1 mm. by 0·1 mm. Although very small in amount (certainly much less than 0·01% of the rock), the zircon is strikingly noticeable when some fifteen or twenty grammes of the rock are crushed and the heavy non-magnetic portion, obtained in the way described above, is examined under the microscope. A portion of the felspars was separated into five parts according

to specific gravity by means of bromoform, and gave the following results:—

	Specific Gravity,			Average extinction on cleavage-plates, with respect to the predominant edge.	Per cent.
(1)	2·65	to	2·70	15°	1·0
(2)	2·70	,,	2·72	21°	25·6
(3)	2·72	,,	2·75	29°	41·6
(4)	2·75	,,	2·84	31°	29·8
(5)	2·84	,,	3·05	(mostly opaque)	1·8

These results indicate a perfect gradation between oligoclase-andesine and anorthite, with excessive development in the neighbourhood of bytownite. Partial decomposition and consequent saussuritisation explain the high specific gravities at the basic end of the series. The fragments of (1) are little, if at all, decomposed. Milky white decomposition-products are pronounced in (2) and (3), but more so in (4), while the fragments of (5) are almost completely opaque. In no case, however, can the decomposition-products be resolved under the microscope.

A few splinters of quartz occur in (1).

The more we consider the characters of this olivine-gabbro, the more we are now inclined to regard it as allied to the Cainozoic masses of Carlingford Mountain, in the county of Louth, and of the Inner Hebrides. The olivine-gabbro of Carlingford, consisting of anorthite, partly ophitic augite, and olivine, was first accurately described by A. von Lasaulx [1] in 1878; and he suggested a comparison between it and certain dolerites of Killala Bay, in Co. Mayo. Anorthite had previously been determined in the Carlingford rock by Rev. S. Haughton [2]. Mr. A. Harker's [3] description of the Cainozoic gabbros of Skye shows a predominance of labradorite over bytownite and anorthite; but there seems nothing in the analyses quoted by him that would remove the rock of the Porcupine Bank from alliance with that of Skye. The Porcupine Bank gabbro contains ferrous rather than ferric compounds, and inclines to be rich in alkalies as compared with the average amount yielded by the corresponding rocks in Skye. It is, moreover, poorer in alumina, the figures for which are somewhat high in the analyses from Skye.

It is pleasant for us to record that Mr. G. H. Kinahan, in a letter to one of us in November, 1906, suggested independently that the Porcupine Bank represents the remains "of a Tertiary volcanic vent." Professor Sollas and Mr. McHenry [4] have, moreover, indicated one such vent as far south and west as Bunowen Castle, south-west of Clifden, in Co. Galway.

(1) Journ. R. Geol. Soc. Ireland, vol. v. (1878-80), p. 36.

(2) "Experimental researches on the Granites of Ireland," Quart. Journ. Geol. Soc. London, vol. xii. (1856), p. 196.

(3) "The Tertiary Igneous Rocks of Skye," Mem. Geol. Survey United Kingdom (1904), pp. 103-10.

(4) "On a volcanic neck of Tertiary age, in the county of Galway." Trans. R. Irish Acad., vol. xxx. (1895), p. 732.

IV. On the 100-fathom line west of the Galway coast. Depth 95 fms. (174 m.). (A. IV*a*. R. T. III. 1. 40 nautical miles magnetic W.N.W. of Cleggan Head. Sand, gravel. 18th August, 1902).

V. Close to No. iv.—Depth 78 fms. (143 m.). (Helga LXXXVIII*a*. R. T. III. 1. 40 nautical miles magnetic W.N.W. of Cleggan Head. Sand, gravel, stones. 8th July, 1901).

The results of these two dredgings are similar, and in both the stones are rather small and waterworn, and about 1 to 3 cm. in diameter.

No. v. was described in section iii. of our previous paper, and may be now compared with No. iv.

	IV.	V.
Total number of stones supplied ...	732	197
	PERCENTAGES.	
Sandstone	41	43
Limestone and Flint (Carboniferous type)	46 (5% flint)	36 (no flint)
Biotite-granite	11	15
Flint (Cretaceous type) ...	—	2
	98	96

In No. iv. there were in addition Shale (3 stones), Clay-ironstone (2 stones), Diorite (2 stones), Mica-schist (1 stone), Vein-quartz (1 stone).

In No. v. there were Vein-quartz (3 stones), Decomposed Basalt (1 stone), Diorite (1 stone), and numerous specimens of *Venus casina* and colonies of polyzoa.

The only remarkable difference is in the flint present, no Cretaceous flint occurring among the large number of stones dredged from the deeper site.

The flint in No. v. is of the Cretaceous type, pebbles of which are found on the shore of Inishbofin, near Cleggan, and in many other places on the west coast. Specimens have recently been found by Mr. H. J. Seymour in the glacial drift of Co. Limerick (1). The tiny fragment of basalt probably represents material drifted from the northern area. The diorite is also a minute fragment. The specimens that represent the locality, both in iv. and v., are granite, stained brown, like that from the eastern edge of the Porcupine Bank, and unmetamorphosed sandstone and limestone. The Cretaceous flint in No. v., moreover, is probably of local origin, in view of the results of other dredgings. The limestone is probably the ordinary grey Carboniferous Limestone, which reaches the sea in the synclinal inlet of Clew Bay, and which, with its underlying sandstone, formerly extended west towards our area across the old peneplain marked by the summits of the Bengorm and Muilrea mountains. The limestone fragments are bored through and through by molluscs.

(1) "Geol. of country around Limerick," Geol. Survey of Ireland (1906), p. 64.

The sandstone for the most part resembles the Lower Carboniferous sandstones of the mainland. A compact greenish specimen was selected for microscopic examination, on account of its different aspect. It consists largely of small angular fragments of altered andesitic lavas, with equally angular quartz-grains. This fact makes the reference of this fine-grained greenish type to Silurian strata all the more probable.

Nos. iv. and v. suggest the existence of a region between the Porcupine Bank and the Irish coast, where the rocks now found in the lowland east of Connemara are repeated in a submerged lowland on the west. This point is further emphasised by a study of No. vi.

VI. WITHIN THE 100-FATHOM LINE WEST OF THE GALWAY COAST. Depth 74·5 fms. (136m.). (Helga CXVI. 30 nautical miles magnetic W.N.W. of Cleggan Head. Sand, shells, gravel, stones. 23rd August, 1901).

This dredging is on the straight line between Cleggan and No. v., but lies ten nautical miles nearer the coast. The material was described in section iv. of our previous paper. The larger stones are not much more than 3 cm. across, and lie in a gravel of organic fragments and small stones not separately determined. The material present may now be stated in percentages of the total of the 84 larger stones examined, which were picked out from the ground-work of small stones and fragments of molluscan shells, echinoid tests, and polyzoan colonies.

	PERCENTAGES.
Limestone	60
Sandstone	22
Biotite-granite	14
	96

The stones are distinctly water-worn, like those from the dredging ten miles farther west, and the limestone pebbles are bored by molluscs. The average size of the stones is only about 3 cm. by 3 cm. by 3 cm.; one of the limestone fragments is, however, exceptionally large for this area, measuring 10 cm. by 7 cm. by 2 cm.

Here again we have sedimentary rocks, as in Nos. iv. and v., accounting for 80% of the material. The synclinal of Carboniferous Limestone that enters the sea at Clew Bay probably continues away to the south-west, and the Hercynian folding, in all probability, brings up Old Red Sandstone, as well as basal Carboniferous Sandstone, from beneath it, abutting on westerly prolongations of the granite of Connemara. A dredging between No. vi. and Cleggan Head may be expected to yield a preponderance of granitic and metamorphic material. The area of sedimentary rocks indicated by Nos. iv., v., and vi. extends northward and westward, as is shown by the succeeding dredgings.

(G. A. J. C. AND T. C.)

VII. OUTSIDE THE 100-FATHOM LINE, WEST OF THE MAYO COAST. Depth 105 fms. (192 m.). (T. 25. 20 nautical miles magnetic N.W. of Achill Head. Rock, sand. 10th August, 1904).

Numerous dead shells, Pecten, Venus, Cardium, &c., occur here. The 101 stones supplied are about 2 to 3 cm. in diameter, and are often almost angular. The composition of this gravel may be thus summarised:—

	PERCENTAGES.
Quartzite and Sandstone	46
Limestone	27
Granite and Gneiss	22
Flint (Cretaceous type)	4
Clay-ironstone	2
	101

The granite and gneiss, and probably some of the quartzite, indicate the proximity or the submarine extension of the ancient mass of Mayo. This feature is still more pronounced in No. viii.

(G. A. J. C.)

VIII. INSIDE THE 100-FATHOM LINE, WEST OF THE MAYO COAST. Depth 87 fms. (159m.). (Helga LXXXV*a*. R. T. I. i. 40 nautical miles magnetic N. of Cleggan Head. Sand, stones. 5th July, 1901).

This dredging was described in section v. of our previous paper. The following large subangular blocks were obtained:—

Fine-grained Biotite-Gneiss, five blocks, weighing respectively 4·1, 3·7, 1·0, 0·6, and 0·4 kilogrammes.

Yellow current-bedded sandstone, one block, weighing 2·4 kg.

The smaller stones show a preponderance of metamorphosed material; moreover, the total bulk of the representatives of ordinary sediments is far less in proportion than the figures below given would imply; that is to say, the fragments of sandstone, limestone, &c., are on the average smaller than those of schist and gneiss. True pebbles are somewhat rare.

While granite largely prevails among the crystalline material to the south, off the county of Mayo and northward it is frequently gneissic, and it is accompanied by the diorites, quartzites, and mica-schists so well known in the "Dalradian" areas of western Ireland. These rocks are, of necessity, grouped together in No. viii. and in several other cases, the letter G being consequently omitted from the pink rectangle that indicates the percentage of the granite and its associates on the map. As a matter of fact, out of 441 stones (57 per cent. of the total) thus thrown together in No. viii., 373 are "fine-grained gneiss, quartz-schist, and quartzite." Mica-schist is not present in this dredging; 7 flints of Cretaceous type (about one per cent.) occur among the 773 stones examined.

It is interesting to note that Mr. J. R. Kilroe, in his recent paper on "The Silurian and metamorphic rocks of Mayo and

North Galway," (1) holds that quartzite is far more largely developed throughout Northern Mayo than has been represented on the Survey maps. At the same time, the absence of mica-schist from this dredging gives it a local character, and suggests that the material was not derived by drifting from any distant source.

	PERCENTAGES.
Granite, Diorite, fine-grained Gneiss, Quartz-Schist, and Quartzite, ...	57
Sandstone, mostly fine-grained, ...	37
Limestone, sometimes with flint, . . .	5
Flint of Cretaceous type, ...	1
	100

As in dredging No. ii., near the Porcupine Bank, some specimens styled by us granite graduate into the type styled fine-grained gneiss. Some stones of the latter type, again, clearly represent intrusions of the granite magma into an aphanitic series. A gneiss specially selected for examination proves to be virtually a granite rich in strings of biotite and pale well developed epidote. These two minerals are in close association (Pl. III., fig. 1.) A more typical and flaggy specimen, finer in grain, which fairly represents some hundreds of the metamorphic rocks dredged up at this point, shows a pale mica interfoliated with quartz and untwinned granular felspar (Pl. III., fig. 2). The felspar has a lower refractive index than quartz, and is probably orthoclase. Yellow epidote is abundant in the micaceous bands, and granular apatite occurs. The quartz frequently shows strain-shadows. This rock, which occurs also in large blocks, is very probably the fundamental one of the district, associated with a few amphibolites and aphanites. Judging by occurrences on the mainland, and by one or two obviously composite specimens dredged up, as already mentioned, we may conclude that the modifications of the granite of this area towards hornblendic types result from its interaction with the basic members of this earlier series.

We have, indeed, been compelled to group together the granites and diorites at this point, though the two ends of the series are perfectly distinct. The felspars show the usual orange-brown stain, and the chief external variation among the specimens seems to lie in the amount of hornblende. The specific gravities of thirteen specimens indicate fairly the range of composition:—2·59, 2·63, 2·64, 2·66, 2·68, 2·68, 2·69, 2·69, 2·71, 2·79, 2·84, 2·90, 3·00.

At one end we have Biotite-Microcline-Granites, which may contain no hornblende, even when the specific gravity reaches 2·66. Micropegmatitic intergrowths between the quartz and microcline occur in these. A specimen with a specific gravity of 2·71 shows both biotite and hornblende; sphene and magnetite occur in little clusters. The felspar is partly orthoclase and partly plagioclase; the extinctions of the crystals of the latter

(1) Proc. R. Irish Acad. vol. xxvi. sect. B. (1907), p. 139, &c., and Plate IX.

which are available in our section indicate at least andesine, and Szabó's flame-tests refer the species to labradorite. Zoned specimens show that the composition is not always uniform throughout the crystal. The close resemblance of this rock to the typical Tonalite of Monte Adamello (1) is of interest.

The other end of the series may be represented by a specimen with a specific gravity of 2·90. Here hornblende and felspar are seen distinctly interfoliated, as in many "epidiorites" produced under metamorphic action. The quartz that is seen under the microscope seems to be of secondary origin, but cannot be traced to any granitic intrusion. There is no doubt that this rock, with its abundant hornblende and saussuritic felspars, results from the alteration of a gabbro like that of Oritor in east Tyrone (2).

The enrichment of ordinary granites with hornblende at the expense of gabbros and diorites has been discussed by Lévy, Sollas, and others (3); and, in view of the instances established in the north of Ireland, the variations in the granite and quartz-diorite series represented in the present dredging are very probably due to the interaction of a granite magma with the basic series of the same area.

Signs of strain occur in the crystals in some of the granites of this dredging, as if earth-pressures had acted on them since consolidation. The evidence as a whole is in favour of classing them with the granites that penetrate the metamorphic and "Dalradian" series in the counties of Sligo, Donegal, Londonderry, and Tyrone.

It is of interest to note that a line joining the site of this dredging and a point intermediate between dredgings v. and vi., *i.e.*, those west of Cleggan, where similar granites evidently occur, runs in a characteristic "Caledonian" direction, and supports the view that we are here examining merely a submerged portion of north-west Ireland.

The sandstones and limestones of this dredging call for little comment. The Old Red Sandstone type is almost absent; and the occurrence of black chert within some of the limestone fragments goes far in this area to prove their Carboniferous origin.

One pebble of stony rhyolite occurs, and seems an obvious stranger. It is well rounded, and is like some of the pebbles that have been borne from the Cainozic dykes of County Down into the eastern Irish drift. Under the microscope, however, it proves to verge on quartz-andesite, and has much in common with the lavas associated with the Old Red Sandstone in Scotland, and, to a limited extent, in northern Ireland.

In addition to the above, the following large stones were dredged up by the Fishery Survey, in all probability from this locality; we are informed, however, that their exact source is now doubtful:—Aphanite, weight 3·7 kg.; limestone, three

(1) See Zirkel, "Lehrbuch der Petrographie," Bd. ii. (1894), p. 505.

(2) G. Cole, "Geology of Slieve Gallion, Co. Londonderry," Sci. Trans. R. Dublin Soc., vol. vi. (1898), p. 237.

(3) See *ibid.*, pp. 226, 227, and references in "Metamorphic Rocks in E. Tyrone," Trans. R. I. Acad., vol. xxxi., pp. 438 and 439.

blocks, weighing respectively 1·5, 1·4, and 0·17 kg.; sandstone, three blocks weighing respectively 1·1, 0·55, and 0·25 kg.; and granite, 0·22 kg. One of the limestones is cherty, and the sandstones may also be of Carboniferous age.

(G. A. J. C. and T. C.)

IX. NEAR THE 400-FATHOM LINE, WEST OF THE MAYO COAST. Depth 388 fms. (710m.). (S.R. 151. 50 nautical miles magnetic W.N.W. of Eagle Island. Lat. N. 54° 17′; Long. W. 11° 33′. Stones, rock. 27th August, 1904).

A large number of stones was furnished by this dredging, varying in size from 12 cm. in diameter down to a fine gravel. The large stones are hardly at all rounded. Mingling a fifth part by weight of the fine gravel with 85 larger stones, 1076 stones of various sizes were obtained, which give the following percentages:—

Sandstone and Quartzite (76·0) and friable Shale (5·0)	81·0
Granite (6·0), Mica-Schist, Gneiss, and Amphibolite	10·0
Flint (Cretaceous type)	7·0
Limestone	1·5
	99·5

In addition, there were, in this portion of the material, 9 stones of Olivine-basalt of the usual northern type. The Cretaceous flints (75 stones, limited to the material of finer grain), are unmistakable, though most of them have become soft through partial solution, like those in some of the old flint-gravels on the Surrey hills. The distribution of these flints is not altogether explicable by drifting from the north, since they amount to 4 per cent. in No. vii., are very rare in No. viii., rise to 7 per cent. in the present dredging, and are rare again farther north in No. xi. On the whole, they appear more abundant in a zone outside the 100-fathom line.

The "rock" recorded by the Fishery Survey at this point consists of a fairly consolidated modern limestone, largely composed of polyzoa and foraminifera. The deposits described by the "Challenger" survey in depths of 200 to 380 fathoms off Bermuda [1] are of interest for comparison, though their state of consolidation is not recorded. Mr. J. Lomas [2] has pointed out the part that may be played by polyzoa in the building up of rocks by the catching of sand-grains and foraminifera in their zoœcia as they lie on the sea-floor. Herr Linck's recent work [3] on the separation of calcium carbonate by inorganic action from sea-water shows us how such limestones may receive

[1] Rep. H.M.S. Challenger, "Deep Sea Deposits" (1891), p. 48 and Pl. XIII.

[2] "On sea-bottoms and calcretes." Report on Pearl Oyster Fisheries of Gulf of Manaar, Ceylon, Part I., p. 159. Published by the Royal Society, 1903.

[3] "Die Bildung der Oolithe und Rogengesteine," Neues Jahrbuch für Min, &c., XVI, Beilage-Band (1903), p. 513.

a cement of aragonite, where organic decay is prevalent, and where ammonium carbonate acts in consequence on the calcium sulphate of sea-water. This cement passes into calcite in older examples, like the material of oolitic grains.

The application of Meigen's test, involving the use of cobalt nitrate, gives, however, no indication of aragonite in the case of this deposit off the Irish coast. Aragonite crystals were treated, as a control, side by side with cleaned fragments from a thin slice of the marine limestone. A calcite cement in a modern rock, according to Linck's researches, indicates a local saturation of the sea-water with calcium bicarbonate brought down from the land. Such a condition occurs near shore, and principally in bays and harbours. The limestone now forming in the estuary of the Liffey in Dublin Bay is probably of this description. The suggestion obviously arises that the limestone from dredging No. ix. was formed in shallower waters, and has reached its present position near the 400-fathom line as a consequence of the subsidences of which we have such frequent evidence in the west. It may be thought that we are not justified in basing so large a conclusion on a mineralogical detail. It appears, however, that this compact polyzoan limestone has now ceased to form, since numerous serpulæ have attached themselves to its surfaces, and solution-hollows and organic borings occur freely in it.

XIV. OUTSIDE THE 500-FATHOM LINE, WEST OF THE MAYO COAST. Depth 550 fms. (1005 m.). (S.R. 277. 50 nautical miles magnetic W.N.W. of Eagle Island. Lat. N. 54° 17′ 30″. Long. W. 11° 34′. Gravel, shells. 15th November, 1905).

This dredging was made close to the position of No. ix., but in much deeper water. The slope from the continental edge is here dropping quickly westward, and the gravel collected is much what might be expected from the washing down of the finer material out of the deposit revealed in No. ix. Since all the stones are small, about 2 cm. in diameter, the attempt to keep the quartzites separate from the fine-grained gneisses fails, and all we can say is that there seems a larger proportion of granitoid and metamorphic material than in No. ix. The constitution of the gravel from No. xiv., neglecting the very fine material, may be stated as follows, from an examination of 165 stones:—

	PERCENTAGES.
Sandstone and some Quartzite (40·0) and Shale (8·0)	48·0
Granite, Gneiss, Mica-Schist, and some Quartzite	32·0
Flint (Cretaceous type) and hard Chalk ...	14·5
Limestone	3·0
	97·5

The following were represented by one pebble each:—Decomposing Basalt, Epidiorite, Carboniferous flint, and a volcanic cinder. Recent barnacles are common from this deposit.

The practical absence of Carboniferous flint from Nos. ix. and xiv., and the scarcity of limestone fragments, show that the Carboniferous Limestone is not well represented at this part of the sea-floor. The amount of limestone present in any dredging is, of course, always proportionately too low, owing to the large amount of solution that goes on, especially at the greater depths. The quantity of Cretaceous flint, together with a few fragments of true chalk, is noteworthy. (See No. xix., p. 22).

X. OUTSIDE THE 300-FATHOM LINE, WEST OF DONEGAL BAY. Depth 335 fms. (650 m.). (S.R. 142. 31 nautical miles magnetic N.N.W. of Eagle Island. Lat. N. 54° 35′. Long. W. 10° 54′. Coarse sand, stones. 11th August, 1904).

This dredging provided only 53 stones, forming a coarse gravel, with sub-angular to rounded blocks often 5 cm. in diameter.

	PERCENTAGES.
Sandstone (22 stones) and Quartzite (5 stones)	53
Limestone (one as a clay-residue; 16%), and Flint (Carboniferous type; 6%) ...	22
Granite and Gneiss, with one Mica-Slate	12
Flint (Cretaceous type)	10
	97

The abundance of Cretaceous flint, almost equalling that shown by No. xiv., is here suggestive, while the Carboniferous rocks re-appear, and hold their own in the next dredging, No. xi., and conspicuously so in Nos. xiii. and xv., farther to the north.

XI. WITHIN THE 100-FATHOM LINE, WEST OF DONEGAL BAY. Depth 73 fms. (134 m.). (S.R. 93. 20 nautical miles magnetic N. by W. of Eagle Island. Rock, coarse gravel. 10th February, 1904).

The stones here form a fairly coarse gravel, many being over 5 cm. in diameter. Out of 506 stones examined, sandstone is by far the most prevalent material; and the largest stones are sandstone, one measuring 15 cm. long. Grey limestone, containing Carboniferous fossils, and the chert associated with it, come second; while the "Dalradian" series of granites, gneisses, and schists form only about an eighth of the deposit. One of the blocks of fluidal granite is, however, 10 cm. long. Shells occur, mainly the characteristic *Venus casina*, in various stages of decay. A Pectunculus present has become very thin and friable through solution-hollows.

	PERCENTAGES.
Sandstone (49) and Quartzite (2) ...	51
Limestone (25) and Flint Carboniferous type; 9)	34
Granite, Gneiss, and Schist	13
Vein-quartz	1
	99

In addition, there were two Cretaceous flints, two fragments of Shale, and one of brown Dolomite. The "rock" referred to above in the nautical description of the bottom probably resembles that already described form No. ix., since one fragment of "calcicrete," or cemented calcareous gravel, was received by us.

Four other samples dredged from the same ground on 15th November, 1904 (S.R. 177) have been compared with the above, but do not seem to require separate description.

XII. (See after No. xvi.).

XIII. OUTSIDE THE 300-FATHOM LINE, WEST OF DAWROS HEAD, CO. DONEGAL. Depth 366 fms. (669 m.). S.R. 194. Latitude N. 54° 49′. Long. W. 10° 30′. Rock. 10th February, 1905).

The stones from this dredging are all small and fairly comparable with one another, being subangular, and about 2 to 3 cm. in diameter. Sandstone is conspicuous, as in No. xi., and in several other dredgings from this region. The limestone may, of course, be diminished in all such cases by solution; but it can never have been so abundant hereabouts as it is off the Connemara coast. In the present dredging, however, the grey limestone and its chert together balance the sandstone; and the deposit is, like those of the group north of No. viii., poor in "Dalradian" material. 215 stones were examined.

	PERCENTAGES.
Sandstone (43·0) and Shale (Carboniferous type; 2·0)	45·0
Limestone (33·5), and Flint (Carboniferous type; 10·5)	44·0
Granite and Gneiss, with one Mica-schist	9·0
Flint (Cretaceous type)	2·0
	100·0

Modern echinodermal remains are frequent in this deposit.

XIV. (See after No. ix.).

XV. CLOSE TO THE 200-FATHOM LINE, WEST OF TEELIN HEAD, CO. DONEGAL. Depth 208 fms. (380 m.). (S.R. 174. 30 nautical miles magnetic N. by W. of Eagle Island Lat. N. 54° 43′. Long. W. 10° 35′. Sand, gravel. 14th November, 1904).

This dredging yielded a coarse gravel, with some stones 4 cm. in diameter. The forms are subangular and almost angular. The common yellow marine alteration-film makes it difficult to distinguish the granites from the sandstones in this series. 130 stones were examined, and the results compare closely with those given by Nos. xi. and xiii. in the same area. The site of No. xiii. lies only about five nautical miles to the north.

	PERCENTAGES.
Sandstone (46), and Shale (5·4) ...	51·4
Limestone (27·7) and Flint (Carboniferous type; 1·5)	29·2
Granite, Gneiss, and Quartzite ...	15·4
Chalk and Flint (Cretaceous type) ...	3·0
	99·0

One of the fragments of chalk shows remains of the sponge Plocoscyphia. There is evidence from this dredging of the local formation of a modern limestone, composed of the hard parts of polyzoa (compare No. ix.).

We now for a time leave the western region, in which there is so little sign of northern glacial drift, or of material imported from a distance, for one which has no doubt experienced a copious deposition of foreign stones. We have been given two samples, four nautical miles apart, from the sea between Islay and the Antrim coast, the floor of which was undoubtedly traversed by ice from Scotland in comparatively recent geological times. In neither case, however, are the stones sufficiently numerous to furnish material for conclusions of importance, and other samples from this area must be hoped for, as well as from the presumably volcanic floor between the Isle of Mull and Inishowen.

XVI. North of Rathlin Island, off the Antrim coast (Rathlin Deep). Depth 103 fms. (189 m.). (S.R. 118. Lat. N. 55° 20′. Long. W. 6° 8′. Rock, shells. 13th May, 1904). Numerous shells, mainly *Venus casina,* and arms of starfishes, were mingled with the 49 stones received. The stones formed a coarse gravel.

	PERCENTAGES.
Sandstone (48), and Shale (4)	52
Compact igneous rocks, "felstone" type	16
Basalt	12
Gneiss, Schist, and Quartzite	10
Carboniferous Limestone	4
	94

One Chalk-flint and one Diorite also occurred. As already remarked, the great variety of rocks in the Antrim area to the south, and the probability of admixture through ice-drift from the metamorphic promontories and islands to the north, makes it difficult to draw any local conclusions from this limited quantity of material.

XVII. (See after No. iii.).

XII. North of Rathlin Island, off the Antrim coast (Rathlin Deep). Depth 125 fms. (229 m.). (S.R. 200. Lat. N. 50° 20′. Long. W. 6° 12′. Stones. 14th February, 1905).

Ten fair-sized subangular stones were received, from 4 cm. to 13 cm. in diameter. Five of these were dolerites, one was olivine-basalt, two were micaceous sandstones, and two clay-ironstones. The dredging was too limited to be represented by percentages on the map.

All of these stones suggest a local origin, and may have been deposited by a late ice-drift from the south, such as is known to have traversed the Londonderry area. A well laminated black shale was dredged up from the same locality, bored into by Pholadidea. The wrinklings produced on the shale at the entries to the crypts of this mollusc resemble interestingly those found in the borings of the Cambrian annelid Histioderma. The compactness of the shale suggested that it might have come from some extension of Liassic strata; but the results of washing it and sifting its material leave no doubt that it represents a deposit of the recent sea. It includes modern shell-fragments, and particularly *Nodosaria raphanus* Linné. The large amount of iron-pyrites, deposited in the form of minute nodules, makes it probable that the conditions when the black mud was deposited were less favourable to animal life than they now are; and this is supported by the fact that modern shell-fish are now boring into a deposit which has clearly ceased to accumulate. In N. Androussow's researches on the floor of the Black Sea (1), it is shown that sulphuretted hydrogen practically poisons the water in that basin against ordinary animal life from about 100 fms. downwards, being freely liberated by the action of bacteria on decaying animal matter, and on the sulphates in solution. Pyritous mud is the natural accompaniment of such action.

Certain recently made dredgings off the coast of Kerry, which form a series by themselves, seem of special service in what may be called submarine stratigraphy, and supply much needed information as to the material resting on the sea-floor off the rocky and indented coast of south-west Ireland.

XVIII. About 400 fathoms off the coast of Kerry. Depth 385 to 440 fms. (704 to 805 m.). (S.R. 365. Lat. 51° 25′ N. Beam-trawl shot in Long. 11° 29′ W., 385 fms., and hauled in Long. 11° 36′ W., 440 fms. Sand, stones. 10th to 11th August, 1906).

The chief feature of No. xviii. was the bringing up, from so considerable a depth, of three large stones. One block, measuring about 30 by 28 by 16 centimetres, is a diallage-dolerite of fairly fresh aspect. Another one, very angular, measuring about 18 by 14 by 9 cm., is a granite with light and dark mica, and is also very little altered. The third and largest, measuring about 45 by 30 by 20 centimetres, is a granulitic gneiss, with a well

(1) "La Mer Noire." Guides des excursions du viie. Congrès géol. internat., St. Petersbourg, 1897. Fascicule xxix., p. 7.

marked flow-structure; 64 much taller stones came up, mostly only 2 cm. in diameter. These yield the following percentages:

Sandstone (including one quartzite 40·0) and Shale (1·5)	41·5
Gneiss and Biotite-Granite (22·0), Mica-Schist (3·0), and Vein-quartz from Mica-schist (3·0)	28·0
Flint (Cretaceous type)	19·0
Scoriaceous or amygdaloidal Basalt (6·0) and Dolerite (1·5)	7·5
Felsitic lavas	3·0
Anthracite (probably from a steamer) ...	1·5
	100·5

Some of the small stones retain striæ, as if they had been imprisoned in glacier-ice, and it is quite possible that we are here dealing with distributed moraine-material, like that recorded by Bøggild off the Greenland coast. But the Cretaceous flints are a local feature, and are also surprisingly abundant in dredgings Nos. xix., xx., xxi., and xxii.

XIX. Outside the 300-fathom line, off the coast of Kerry. Depth 342 fms. (626m.). (S.R. 399. Lat. 51° 28′ N. Long. 11° 33′ 30″ W. 5th February, 1907).

From about 2000 stones collected at this point, 400 were selected at random for examination. These stones are mostly rounded, and are of various sizes, but the majority are about 1·5 cm. in diameter. The material is, therefore, a gravel of only medium grain.

	PERCENTAGES.
Sandstone (45·75) and Shale, which sometimes passes into Phyllite (8·25)	54·00
Granite and Gneiss (15·75), Vein-quartz (4·00), Mica-schist (2·75), and Quartzite (2·25)	24·75
Flint (Cretaceous type; 10·25) and Chalk (2·25)... ...	12·50
Amygdaloidal Basalt (3·25) and Dolerite (1·00) ...	4·25
Limestone (2·50) and Flint (Carboniferous type; 2·00) ...	4·50
	100·00

Foraminifera are frequent in the hollows of the stones, and gastropod-shells and echinoderm-spines occur. Several lumps formed by the growth of calcareous algæ (nullipores) around tubes of serpulæ have also been observed. The sandstone often occurs in blocks larger than the average, one measuring 23 by 14 by 5 cm. Ten per cent. of the sandstone specimens have a calcareous cement. Some of the gneiss shows a composite origin, granite having intruded into biotite-schist.

The Cretaceous flint is often quite sharp on the edges, and is thus unlike that of the glacial drift on the east of Ireland. Some of the flattish flakes measure 6 by 4 cm. The presence of

genuine chalk (nine examples among 400 stones) also points to the weathering of a Cretaceous mass at no great distance from this locality. This chalk has been examined in section under the microscope. Like some of the Antrim samples, and those from dredging No. xiv., it is of a hard and somewhat grey-brown type, and may possibly have been affected in this Kerry area by basalt, of which there is good evidence in this dredging. Hard chalk, however, occurs at various horizons in Cretaceous regions, and beds of it in the Paris Basin have been regarded by M. Cayeux (1) as representing stages when deposition was arrested. Such chalk is found freely, as is well known, in north-east England, away from volcanic influences; and Mr. R. H. Worth's (2) specimens from the English Channel are all of a hard yellow or cream-coloured variety. Ordinary soft white chalk occurs, side by side with hard varieties, in dredgings xx. and xxii. The whole assemblage of stones, if we omit the sandstone, is not at all what one would expect as the result of glacial deposition from the nearest existing land. One of the sandstone pebbles shows striation, and it might be urged that all the Cretaceous material comes from the breaking up of a large block of chalk carried by ice-drift from the north. Such blocks may be seen, distributing angular flakes of flint as they decay, in the boulder-clays and gravels of Ballycastle in Co. Antrim. But the abundance of Cretaceous flint in the adjacent dredging, No. xviii., where it reaches 19 per cent., and the still more striking evidence of Nos. xx., xxi. and xxii., furnish a strong argument for the recognition of deposits of this age far west of their present limits in eastern Devonshire. The results from this dredging and Nos. xx. and xxii. were referred to in a paper on "Probable Cretaceous and Cainozoic outliers off the coast of Kerry," read before the British Association in Dublin in 1908, of which an abstract was published in the *Irish Naturalist*, Vol. XVII. (1908), p. 232. (The title of the paper as there given is misprinted).

XX. Close to the 500-fathom line, off the coast of Kerry. Depth 468 fms. (856m.). (S.R. 480. Lat. 51° 23′ N. Long. 11° 38′ W. Stones. 28th August, 1907).

The spot is about W.S.W. of Valentia Island. From a large series of subangular or rounded stones collected at this point, 400 were selected at random, and the following percentages were obtained:—

Sandstone (33·75) and Shale (9·0)	42·75
Flint (Cretaceous type) and Chalk and White Limestone	27·25
Mica-schist, Quartzite, and Vein-quartz (14·25), and Gneiss and Granite (8·25)	22·50
Carboniferous Limestone and Flint (Carboniferous type)	4·50
Olivine-basalt and Dolerite	2·75
	99·75

(1) "Contrib. à l'étude des Terrains Sédimentaires" (1897), p. 487.
(2) *Op cit.*, p. 150.

This deposit included numerous recent corals and plates of Lepas. Molluscan remains were scarce; one fragment of Terebratula was also found. This material of recent organic origin was picked out and separated, as in other cases.

The sandstone, shale, and Carboniferous limestone may easily represent a continuation of the Old Red Sandstone and Carboniferous masses that lie to the east. The metamorphic rocks remind us that the "Inch conglomerate" on the south side of the Dingle promontory contains pebbles of such rocks, which point to the presence of underlying Dalradian ridges. One well rounded pebble of andesitic tuff occurs. This was probably drifted hither, and it is important to note that one of the quartzite pebbles shows glacial striæ. The wonder is that it stands alone in this respect among the large number of specimens that were examined from this dredging.

The great interest of No. xx., however, obviously lies in the 82 Cretaceous flints and the 27 pieces of white limestone and chalk found in the series of 400 stones. One of the flints measures 10 by 8 by 6 cm. Most of them are angular, or only rounded on corners or edges, like those in the gravels formed *in situ* on the English downs. The Cretaceous chalk is often of the characteristic soft white variety, and contains casts of the sponge Ventriculites; a detached cast of a Ventriculite was also found. Two of the chalk-lumps are glauconitic (Pl. IV., fig. 1). The largest lump of chalk measures 8 by 5 by 4 cm., and the material is unmistakable, despite the corrosion that it has naturally undergone. Dredging No. xxii., however, will lead us much further towards a knowledge of the remarkable deposits of Cretaceous material, which form in this area an immensely larger portion of the submarine gravels than they do at any points studied in the northern region.

"White Limestone" has been spoken of above, since one specimen among the 400 stones of all kinds that were examined differed obviously from the chalk, and showed an unusually cavernous texture. In section it reveals numerous milioline foraminifera, and is clearly of Cainozoic type. On picking out the white limestones from another series of some eight hundred stones from this dredging, three more Cainozoic specimens were found, and sections were also made from these.

In the first of these examples, crystallisation of the calcite ground and of the shell-materials has obscured the organisms; but echinoid fragments and polyzoan colonies are visible, in addition to the foraminifera. Small angular quartz-grains occur. In a second specimen the quartz is larger and more abundant, and is clearly derived from granitic rocks. A grain of glauconite and a pebble of sandstone are also present in the section. Polyzoa form a large part of the rock, which contains, however, a fair number of foraminifera and one or two echinoid fragments. The third specimen is almost a calcareous sandstone, quartz-grains forming half the mass. The organic fragments are obscured by crystallisation and by a deposit of calcite needles from the interstitial ground. The conditions under which these sandy limestones were formed is fairly paralleled by some of the

samples of modern foraminiferal ooze, with numerous quartz-grains, echinoid spines, and occasional fragments of brachiopod and other shells, which are dredged up from the neighbourhood at the present day. The sandy ooze accompanying the stones described from dredging No. xxii. may be cited as an example; but it is obviously a product of water deeper than that in which the milioline limestones were deposited.

Mr. R. Hansford Worth's careful description of a block of Eocene milioline limestone, a foot long, (1) from 39 miles S. 11° W. of the Eddystone, in the English Channel, strongly supports the view that these Irish specimens are also of Eocene age. From the description of dredging No. xxii., it will be seen that the Cainozoic beds extend some twenty miles farther to the north of the site of No. xx.

XXI. NEAR THE 500-FATHOM LINE, OFF THE COAST OF KERRY. Depth 468-560 fms. (856-1024m.). (S.R. 479. Lat. 51° 21′ N. Long. 11° 4′ W. 28th August, 1907).

This dredging is very near No. xx. Only 67 stones were received.

	PERCENTAGES.
Sandstone (54) and Shale (3)	57
Flint (Cretaceous type)	20
Quartzite (9) and Granite (4)	13
Carboniferous Limestone	10
	100

Here again the proportion of flint is remarkable. One of the sandstone pebbles has an abundant calcareous cement, and may be from a mass of recent origin, like those formed in our glacial drifts.

XXII. OUTSIDE THE 500-FATHOM LINE, OFF THE COAST OF KERRY. Depth 600-660 fms. (1097-1207m.). (S.R. 486. Lat. 51° 37′ 30″ N. Long. 12° 0′ W. Trawl and dredge. 3rd September, 1907).

The spot is to the north of No. xx., and further out to sea. It is about W. by S. of Valentia Island.

From a very large number of stones collected, none being of any exceptional size, 700 were chosen at random, and gave the following results. The fine material of recent origin between the stones is a foraminiferal sand, rich in Orbulina. (See Appendix II., p. 30).

	PERCENTAGES.
Sandstone (40) and Shale and Slate (17)	57·00
Flint (Cretaceous type) and Chalk and White Limestone	22·00
Mica-schist and Quartzite (9·50), Granite and Gneiss (7·00)	16·50
Carboniferous Limestone	3·00
Dolerite and Basalt	1·25
	99·75

(1) *Op. cit.*, Journ. Marine Biological Association of the United Kingdom, vol. viii, (1908), pp. 156 and 169.

Even the sandstones, though mostly of the usual type, yield six samples of far more modern aspect. They are not like the "calcicrete" mentioned from No. xxi., though some calcareous cement is present in one or two specimens. There seems strong probability that they are of Cretaceous age, like the Albian and Cenomanian sandstones of western England, which there rest directly on Palæozoic rocks. It is noteworthy that no specimens of this type have been found among the thousands of pebbles of sandstone examined from the dredgings farther north.

The slate is green and purple, closely resembling the Carboniferous slate of south-west Ireland. One more shaly stone is distinctly marked with glacial striæ. The basalts are often amygdaloidal, with beautifully developed zeolitic needles in their steam-hollows. They have a thoroughly Cainozoic aspect, when compared with the known igneous series of Ireland.

The flints, of which 129 examples occurred among the 700 stones examined, are at times fairly rolled, with characteristic brown surfaces; but some are very angular, as if from masses shattered by frost. It is quite possible that part of the material represents water-worn gravel, formed on an old land-surface where Cretaceous rocks occurred, and that another part of it represents similar detrital flint shattered by frost during the severities of glacial times.

Twenty-four specimens of chalk occurred, including both soft white and hard grey-brown varieties. Two of the specimens examined are glauconitic. Like most of the submarine limestones, the majority of these stones are deeply excavated by solution-hollows. One of the pebbles of white limestone shows, with the aid of the lens, abundant milioline foraminifera. In section (Pl. IV., fig. 2) it has a distinctly Cainozoic aspect, and may be compared with those previously mentioned from dredging No. xx. It is quite possible that other specimens may occur among the stones here classed as chalk, though the great prevalence of flint and the general appearance of the stones make it probable that most of these white limestones are of truly Cretaceous age.

(G. A. J. C.)

Conclusions.

The results of this examination of dredged materials is far more satisfactory than we should have anticipated, and indicates that a fair conception of the geology of the submarine western plateau, and even of the ocean floor, may be acquired through the surveys of successive years. Off the west of Mayo and Galway, we seem to be outside the region of Cainozoic volcanic activity, and to find little but submerged masses of the rocks familiar in western Ireland. The exception is the olivine-gabbro of the Porcupine Bank, which very probably represents a subterranean intrusion of the magma that appears at the surface in the form of basalt farther north. The distinctly volcanic types of basalt off the coast of Kerry, and possibly the alteration of some of the Cretaceous chalk in the same area, point to the occurrence

of Cainozoic eruptions, which may be posterior to those of Antrim. The abundant relics of Cretaceous deposits in the south, and the equally good evidence of Cainozoic limestone, indicate an interesting extension of the types of strata known to us in the Paris Basin. This evidence repeats farther to the west that already announced by Mr. R. H. Worth from the English Channel; and we now know from the Irish specimens that we can set no westward limit to the Upper Cretaceous sea.

The view of Suess, that the existing Atlantic basin is determined on the west of Ireland by faults cutting across the previous folded structures of the country, is in no way opposed by our observations. The evidence gathered from sunken banks of molluscan shells in the region to the north shows how comparatively recent much of the Atlantic submergence may have been. The breaking up of the old basaltic plateau into blocks limited by faults is recorded on the surviving surface of Antrim and Londonderry, and is evidenced, as Sir A. Geikie has urged (1), by the relics traceable between Ireland and the Färoe Islands. There is much reason to suppose that this faulting is, at the earliest, of pliocene age; and Dr. Nansen (2) has concluded, from a consideration of sunken shell-banks between Iceland and Jan Mayen, that the sea-bottom "during the time of greatest ice-sheet of Europe, must have been uplifted at least 2600 metres higher than it is at present" (3). Dr. Brögger is similarly persuaded that in the last interglacial epoch the continental platform stood 100 to 300 metres higher than it does at present. Such conclusions regarding the area to the north cannot fail to affect our views of the settlement of the whole East Atlantic border.

In conclusion, the deposits placed in our hands by the Fishery Survey from the Atlantic coast of Ireland afford an interesting contrast with those described by Messrs. Herdman, Dawson, and Clement Reid, (4) from the drift-encumbered sea-floor between Ireland and England. In the latter case, no evidence appears to have been forthcoming as to the nature of the rocks underlying the deposits. The glacial drift still clings to the coast on both sides of the Irish Sea, and its presence suggests that the stones dredged up in that sea had already become well mingled during the Glacial epoch, before they were distributed across the floor of the intervening basin.

(G. A. J. C. and T. C.)

(1) "The Tertiary Basalt-plateaux of North-Western Europe, Quart. Journ. Geol. Soc. London, vol. lii. (1896), pp. 399-405. Also "Ancient Volcanoes of Great Britain" (1897), vol. ii., p. 447. See also "Rockall Island," Trans. R. Irish Acad., vol. xxxi., p. 59, and Wallich, "North-Atlantic Sea-Bed" (1862), p. 63.

(2) In Brögger, "Om de senglaciale og postglaciale nivåforandringer i Kristianiafeltet," *Norges geologiske undersögelse*, No. 31 (1901), pp. 94-96.

(3) Brögger's summary in English, *ibid.*, p. 683.

(4) "Fishes and Fisheries of the Irish Sea," Lancashire Sea-Fisheries Memoir, No. II. (1902), pp. 10-19.

APPENDIX I.

Stones from the Klondyke Bank.

Mr. E. W. L. Holt has also supplied specimens received from the Hydrographer of the Admiralty. These were gathered by the tallow of the sounding lead of H.M.S. "Argo," in August, 1908, at several stations about the Klondyke Bank, an important fishing-ground off N.W. Ireland. The depths were from 75 to 234 fms. The area covered is an interesting one, lying at about 56° N. latitude and between 7° 42′ 30″ and 9° 25′ W. longitude. The stones are naturally small, and are mostly sandstones of ancient types, with vein-quartz and granitoid rocks, such as are common in the Dalradian series of western Scotland and north-west Ireland. Only one sample of basalt appears; but the collection is not sufficiently extensive to justify a percentage enumeration, or the formation of any conclusion as to the mode of origin of the deposits.

(G. A. J. C.)

APPENDIX II.

Foraminiferal deposits from off the south-west of Ireland.

The materials dredged during 1907 include several specimens of foraminiferal deposits from the sea-floor to the west and south-west of the counties of Kerry and Cork. The specimens were dredged from various parts of the continental slope at depths ranging from about 500 to nearly 800 fathoms, along a line running roughly north-west and south-east between a point about 80 nautical miles west of Dunmore Head (Co. Kerry), and a point about 100 miles south-west of Mizen Head (Co. Cork).

The detrital ingredients of these specimens are, on the whole, fine-grained, and are such as might be expected to have been drifted from the coast or from shallower waters by the action of currents. The descriptions of these and similar deposits is desirable, since it furnishes data for the comparison of older sedimentary rocks with those now in course of formation.

The results established by the "Challenger" Report on deep sea deposits relate more particularly to those in the deeper parts of the ocean. Much work of geological value remains to be done on detrital sediments, especially with regard to those occupying the ocean bed in the shallower waters surrounding continents, *i.e.*, in those very areas where terrigenous sedimentation goes on most rapidly. A detailed study of a large number of such sediments now forming in an area adjacent to a continental margin the geology of which is well known would provide data of great interest and value concerning the manner

in which detrital materials are dispersed in ocean waters, and might be expected to throw some light on the conditions under which older sediments have been laid down.

In examining the few specimens of dredged material here dealt with, the aim has been to give a definite indication of their physical condition and the mineral composition of their detrital ingredients.

A weighed quantity of the dry material was taken in each case, and treated with cold dilute acid to dissolve the calcareous matter. The residue was then allowed to settle, and was washed free from acid by decantation, the decanted water being set aside for the recovery of the clayey matter which remained in suspension. The residue was then boiled with water and stirred, to break up as far as possible the flocculated clay particles. The clay and fine silt portion of the residue was then decanted off, so as to secure for the grains of fine silt a limiting maximum size approximately equivalent to a hydraulic value of one millimetre per second. In this way the specimen was divided into three parts:—

(1) Calcareous matter.
(2) Sand and coarse silt.
(3) Fine silt and clay.

Parts (2) and (3) were collected, dried, and weighed, (1) being estimated by difference.

The results thus obtained cannot claim a high degree of quantitative accuracy, since the dilute acid takes up a certain amount of soluble non-calcareous matter, while for various reasons it is difficult to decant a sediment to a fixed hydraulic limit with strict accuracy. Nevertheless, the results obtained by this method of separation give a safe indication of the general physical condition of a specimen. The statement of percentages for the three ingredients referred to above gives a much more definite idea of the character of a specimen than would a loosely-used term such as "foraminiferal mud." Having made the separation, the operator has incidentally obtained, in a fairly clean state, that portion of the specimen which is required for a mineralogical study of the detrital ingredients, viz., the sand and coarse silt.

It is convenient to treat the sand and coarse silt with a heavy liquid, preferably bromoform (sp. gr. 2·84), in order to float off the lighter minerals—quartz, felspar, glauconite, etc. The glauconite can be separated from the quartz and felspar by the magnetic method. Grains which have a specific gravity exceeding that of bromoform are present only in comparatively small amounts. If the quantity be very small, it is well to mount this material all on one slide after having extracted the magnetite. If sufficient of the heavier ingredients can be obtained, it is advantageous to separate the weakly magnetic portion from the non-magnetic portion, weighing them and mounting the various parts separately.

Description of Specimens.

XXII. Depth 600-660 fms. (S.R. 486. Lat. 51° 37′ 30″ to 51° 36′ 30″ N. Long. 11° 58′ to 12° 0′ W. Townet on trawl; foraminiferous mud, large stones removed. 3rd Sept., 1907).

This is the foraminiferal sand referred to in the description of dredging No. xxii. in the foregoing pages (p. 25). The specimen is a light-coloured loose sand of medium grain, containing numerous unbroken foraminifera. Its physical composition is as follows:—

Calcareous matter	...	...	25 per cent.
Sand and coarse silt	...	...	70 per cent.
Fine silt and clay	...	...	5 per cent.

The calcareous matter consists almost entirely of the foraminifera *Orbulina universa* and Globigerina in roughly equal proportions, and mostly in an unbroken state. The comparatively large spheres of Orbulina make its presence obvious; they all pass through a sieve having holes 1 mm. in diameter, but large numbers remain on the 0·5 mm. sieve, and of these many of the spheres reach a diameter of 0·8 mm.

The sand and coarse silt on treatment with bromoform gave the following amounts of lighter and heavier ingredients:—

Portion lighter than bromoform	...	99·2 per cent.
,, heavier ,, ,,	...	0·8 per cent.

Of the lighter portion (quartz, etc.), only about 6·5 per cent. of the grains exceeded 0·5 mm. in diameter. The largest grain observed was an angular fragment of quartz having an average diameter of about 2 mm. Another angular fragment, consisting partly of quartz and partly felspar (apparently a granite or gneiss fragment), had an average diameter of about 1·77 mm. A disc-like fragment of fine grained sandstone 1 mm. thick and 2 mm. in diameter was observed, and also a fragment of microcline and one of red slate, each about 1 mm. in diameter; but the grains exceeding 1 mm. in diameter were very few. It will be noticed that the stones, previously dealt with by one of us, were separated before the material came into our hands.

The grains of the lighter portion consist mostly of quartz with a free admixture of felspar (partially decomposed), and altered glauconite casts in spherical and other shapes, brown or grey in colour. Fragments of slate and what appears to be fragments of fine-grained argillaceous sandstone are also present, but are not numerous. A considerable proportion of the quartz grains show a fine-textured mosaic between crossed nicols, indicating that they are of metamorphic origin. Flint grains, showing the characteristic compact structure between crossed nicols, are present in considerable numbers. A remarkable feature exhibited by this sand is the abundance of rounded grains. It is improbable that the almost perfectly smooth and rounded exterior of many of the grains can be due to water action alone, and one feels compelled to attribute their condition to the fact that they have been wind-blown. The

occurrence of such rounded grains in modern ocean-deposits was frequently noticed among those described in the "Challenger" Reports; but in those cases the size of the grains and the situation of the deposits made it possible to account for their presence by the action of atmospheric currents. In the present instance, both the size of the grains and the situation of the deposits are quite inconsistent with such a mode of origin. Only one explanation seems possible. Such grains occur commonly in Cretaceous rocks, and have been frequently observed both in the Greensand and Chalk of England. Their occurrence in the Cretaceous rocks may be explained in two ways: (1) by derivation from the Trias, (2) by the prevalence of desert conditions on the land areas from which the terrigenous material of the Cretaceous sediments was derived. The occurrence of coarse Cretaceous detritus on the sea floor in the area under consideration has been already proved (p. 23, etc.), and it is not improbable that bluffs of Cretaceous sediments, submerged in recent geological times, occur buried beneath these waters off the Kerry coast. It seems difficult, indeed, to explain the occurrence of the rounded grains referred to, apart from the disintegration of such Cretaceous rocks. The frequent presence of silicified foraminifera and chalcedonised sponge spicules in other specimens of these dredgings (see below) leads to a similar conclusion.

The portion of the sand and coarse silt heavier than bromoform was treated magnetically, with the following result:—

		PER CENT.
Strongly magnetic	Magnetite	22
Weakly magnetic	*augite*, *hornblende*, *garnet*, *hypersthene*, *brownish opaque grains*, epidote, olivine, tourmaline, staurolite, ilmenite, biotite, chlorite, glaucophane	71
Relatively-non-magnetic	*whitish opaque grains*, *zircon*, *kyanite*, rutile, muscovite, andalusite, sillimanite	7
		100

The more abundant minerals in the weakly magnetic and relatively non-magnetic groups are printed in italics; the others are present only in comparatively small amounts. The constituents referred to as opaque grains are probably various in origin, though many of them consist of saussuritised felspar.

The hornblende is partly green and partly brown, the latter variety being intensely pleochroic. Some of the grains included under hornblende show bluish tints, indicating that they are probably sodic varieties. Tabular crystals of glaucophane are present, showing the combination of prism and orthopinacoid. An examination of these shows that they are flattened on the orthopinacoid. The extinction is practically straight. The pleochroic tints shown are sky blue with the short diagonal of the polariser along the prism edge, and violet when the short diagonal is across that edge. Observation in convergent light showed a slightly oblique emergence of a negative acute bisectrix, and a measurement of birefringence along this direction gave the value 0·003. The excess of this number over the value usually given for $\gamma - \beta$ in glaucophane, and the slightly oblique emergence of the acute bisectrix, were probably due to the fact that the orthopinacoid was not lying quite horizontally in the field. The optical sign with regard to the prism edge is positive. This evidence, as a whole, proves conclusively that the mineral is glaucophane.

Kyanite is well represented; andalusite is less frequent; and only a few prisms of sillimanite are to be observed. The andalusite is in a fresh condition, in the form of cleavage prisms, showing its characteristic pleochroism—rose-tinted when the short diagonal of the polariser is along the direction of the prism edge, and colourless or greyish green when the short diagonal is across that direction. Its optical sign with regard to the prism edge is negative, and the degree of birefringence normal to the prism face is about equal to that of the maximum for quartz in grains of the same size. The extinction is straight.

The association of the kyanite, andalusite and sillimanite with one another and with garnet, staurolite and glaucophane makes quite an interesting feature, and indicates that this assemblage of minerals has probably been derived directly from the disintegration of metamorphic rocks. The occurrence of any two or three of these minerals would perhaps be consistent with the view that they might be derived from sandstones, etc., but it is highly improbable that they could all be associated except as the direct product of the disintegration of schists or gneisses. The intervention of an ordinary clastic stage would probably be accompanied by a degree of dispersion which would render such an association impossible.

For the same reason the association of augite, brown hornblende, olivine, hypersthene, and saussuritised felspar, together with the absence of merocrystalline fragments, strongly suggests that this assemblage has originated directly from the disintegration of an olivine-gabbro or a dolerite.

XXIII.—Depth 491-520 fms. (S.R. 491. Lat. 51° 57′ 30″ N. Long. 12° 10′ 30″ to 12° 15′ 30½″ W. Baby dredge. Sand with foraminifera and some sponge spicules. 7th Sept., 1907.)

XXIV.—Depth 533-570 fms. (S.R. 493. Lat. 51° 57′ 30″ to 51° 59′ N. Long. 12° 22′ to 12° 27′ W. Baby dredge. 8th Sept., 1907).

XXV. Depth 766-788 fms. (S.R. 499. Lat. 50° 57′ to 50° 53′ 30″ N. Long. 11° 31′ to 11° 28′ W. Baby dredge. Fine Sand. 11th Sept., 1907).

XXVI. Depth 661-672 fms. (S.R. 506. Lat. 50° 36′ to 50° 32′ N. Long. 11° 18′ to 11° 19′ 30″ W. 12th Sept., 1907).

The four specimens the labels of which are given above have so many features in common that they may be treated together. They may all be described as grey calcareous ooze or foraminiferal mud, the fine silt and clay portion being much in excess of the sand and coarse silt in all cases. There are little or no unbroken remains of foraminifera. The specimens are now partly in the condition of grey chalk-like powder, and partly in the condition of compact lumps which can only be broken with difficulty between the fingers. When placed in water after drying, these chalk-like lumps disintegrate after the manner of an ordinary dry clay, showing that they owe their lumpiness and compact condition to the cementing action of the clayey constituents. The physical composition of the specimens is shown by the following table of percentages:—

	XXIII.	XXIV.	XXV.	XXVI.
Calcareous matter .	44	49·5	57	55
Sand and coarse silt .	26	19·0	13·5	16
Fine silt and clay .	30	31·5	29·5	29

Deducting the calcareous matter, and calculating the relative proportions of sand and coarse silt to fine silt and clay in the detrital portion alone, we get the following percentages:—

	XXIII.	XXIV.	XXV.	XXVI.
Sand and coarse silt .	46·5	37·5	31·5	35·5
Fine silt and clay .	53·5	62·5	68·5	64·5

In all cases the approximate average diameter of the largest grain was about 1 mm. In all four specimens the proportion of the sand and coarse silt grains exceeding 0·5 mm. in diameter was practically negligible, the amount being slightly variable, but in all cases less than one per cent. of the sand and coarse silt.

The lighter portion of the sand and coarse silt contains the following ingredients:—

Quartz grains, many of which in all the specimens show between crossed nicols the fine-textured mosaic suggestive of quartz of metamorphic origin.

Felspars, including orthoclase, microcline, and ordinary plagioclases. In many cases these felspar grains are much decomposed.

Glauconite, in small amount as green and brown grains.

Compact argillaceous sandstone.

Platy slate fragments.

Silicified foraminifera.

Chalcedonised sponge spicules.

The portion of the sand and coarse silt heavier than bromoform is very small, and not more than about 0·1 per cent. The following minerals are present in all cases, the amounts being variable:—

magnetite,	zircon,	muscovite,
hornblende,	rutile,	ilmenite,
augite,	tourmaline,	sillimanite,
garnet,	biotite,	staurolite.
epidote,	chlorite,	

In addition to the foregoing minerals, the following were also observed:—

In No. XXIV., apatite, blue corundum and kyanite.
In No. XXV., apatite, andalusite and olivine.
In No. XXVI., andalusite, corundum, hypersthene, glaucophane and hæmatite.

(T. C.)

DESCRIPTION OF PLATES.

PLATE I. Section across the Porcupine Bank from the 100-fathom line to oceanic waters. Vertical and horizontal scale the same, so as to show the true form of the sea-floor.

PLATE II. Fig. 1. Microscopic section of olivine-gabbro, Porcupine Bank (Dredging No. i.). Altered olivine is seen near the centre. × 11.

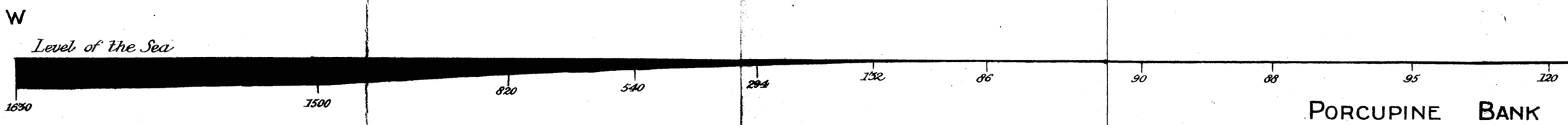
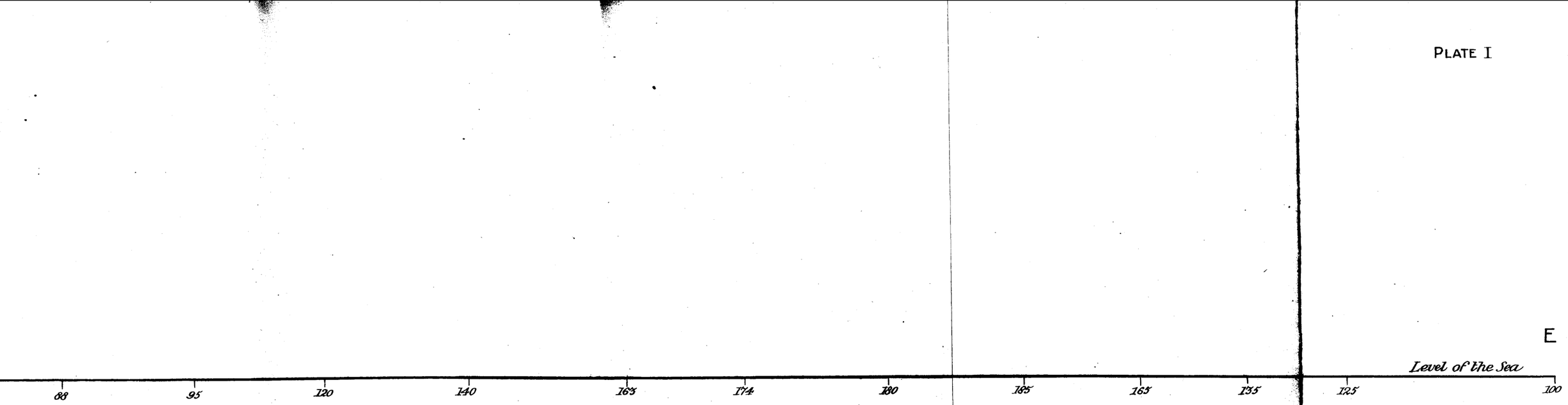

W
Level of the Sea
1630
1500
820
540
294
152
86
90
88
95
120
PORCUPINE BANK

PLATE I



Section across the Porcupine Bank.
Scale 1 inch = 5 nautical miles.
The same Scale is used for the vertical measurements.
Depths in fathoms indicated by numbers beneath the Section.

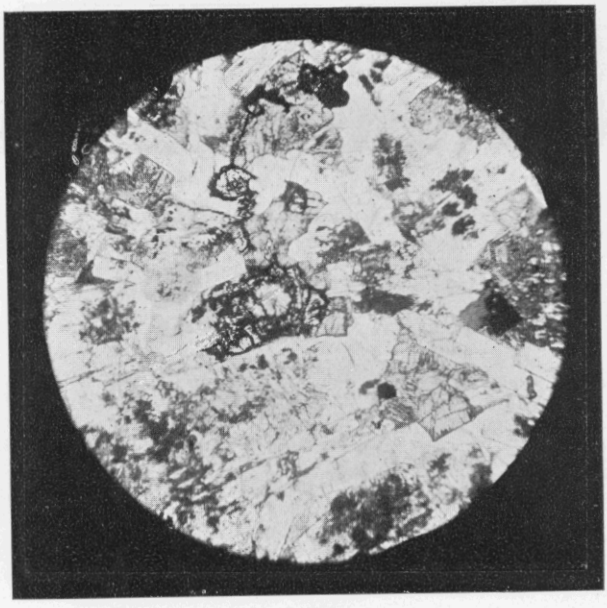


Fig. 1.

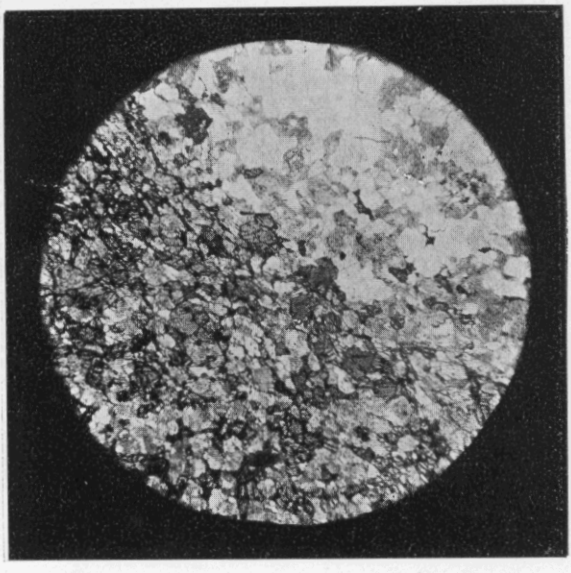


Fig. 2.

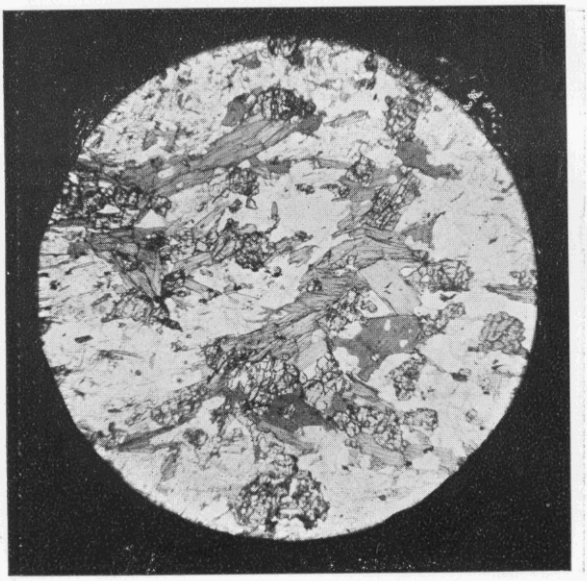


Fig. 1.

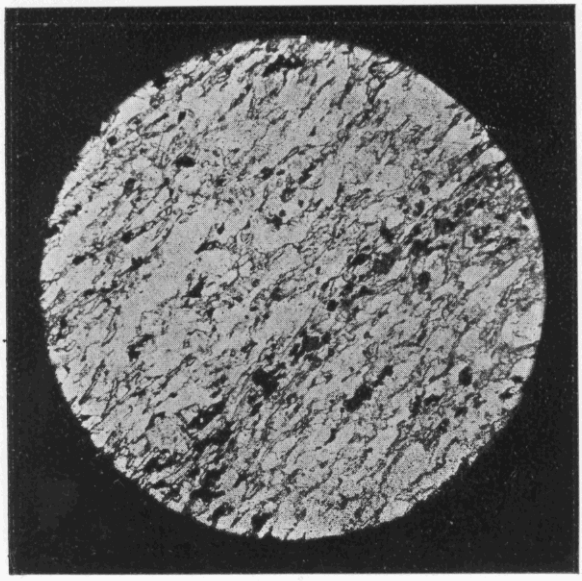
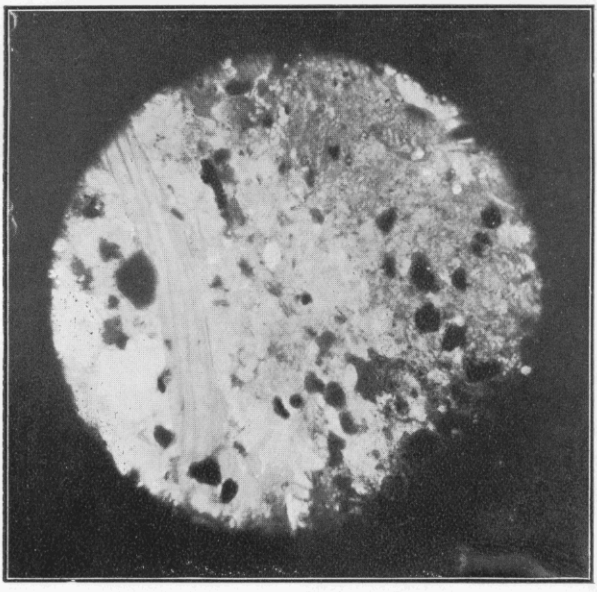


Fig. 2.



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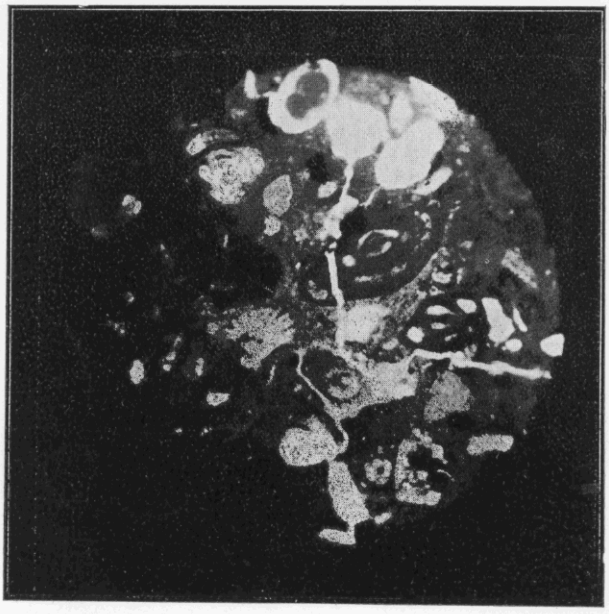

Fig. 2.

Fig. 2. Microscopic section of granular aphanite (epidiorite) invaded by granite veins, east side of Porcupine Bank. Specimen showing junction of the two rocks (Dredging No. ii.). × 11.

PLATE III. Fig. 1. Microscopic section of gneiss rich in patches of associated epidote and biotite, 40 nautical miles magnetic N. of Cleggan, Co. Galway (Dredging No. viii.). × 11.

Fig. 2. Microscopic section of fine-grained gneiss from same locality, with pale mica and epidote in foliation-layers. × 11.

PLATE IV. Fig. 1. Microscopic section of glauconitic chalk, showing foraminifera, polyzoa, &c., from 468 fms. off the coast of Kerry (Dredging No. xx.). × 22.

Fig. 2. Microscopic section of milioline limestone, from about 650 fms. off the coast of Kerry (Dredging No. xxii.) × 22.

(61). Wt.—6045—S.27. 500. 1/'10. C.&Co. G.4.

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MAP
UNABLE
TO
SCAN