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DEPARTMENT OF AGRICULTURE AND TECHNICAL INSTRUCTION FOR IRELAND.

ON ROCK-SPECIMENS DREDGED FROM THE FLOOR OF THE ATLANTIC OFF THE WEST COAST OF IRELAND IN 1901.

BY

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AND

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(Appendix No. IX. to Part II. of the Report on the Sea and Inland Fisheries of Ireland for the Year 1901.)

APPENDIX, No. IX.

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PLATES XX to XXII.

The specimens placed in our hands were obtained from two localities on the Porcupine Bank, some 130 nautical miles west of the Galway coast, and from three others between this Bank and Erris Head in the County of Mayo. The materials, though showing some signs of attrition in former times, cannot be described as pebbles, and are sometimes distinctly angular. The frequent growths of polyzoa, annelids, and corals upon them show that they are at present in a state of rest at the bottom of the sea.

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 (1), 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 only weighed 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 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 (2), 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.

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

(2) "Notes on Rockall Island and Bank," *Trans. Roy. Irish Acad.*, vol. xxxi. (1897), p. 59.

i.

Materials dredged from the Porcupine Bank, depth 90 Fathoms.

Label—Helga LXXVII., 29. vi. '01.

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 XXII.). 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 connection 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 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, associated with sandstone. 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

(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.

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. XX., *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; while pale pseudomorphs with blackened cracks and edges represent the original olivine. The felspar is a labradorite verging on andesine. In its degree of decomposition, this rock resembles the gabbros and dolerites of Carboniferous age in Great Britain, rather than the fresher examples from the Cainozoic region of Carlingford or the Inner Hebrides. It may be noted, moreover, that olivine-basalts occur among the products of the Carboniferous volcano of Limerick. (1)

The specific gravity of this gabbro is 3·00.

A section from one of the fine-grained sandstones shows angular grains of quartz and felspar, 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 ferromagnesian 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. XXI., fig. 1).

ii.

Materials dredged from the region of the Porcupine Bank depth 120 Fathoms.

Label—Helga LXXVIII., 29. vi. '01.

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 may be as much as thirty nautical miles. A striking change in the predominant rock is apparent. The stones are very little rounded, and some of the granites are quite angular. We received the following:—

Biotite-Granite, sometimes coarse-grained, . .	47 stones.
Aphanite, in some cases with veins of aplitic granite,	13 „
Somewhat fine-grained Diorite or Gabbro, . .	2 „
Sandstone, ...	8 „
Quartzite, ...	1 stone.

(1) M'Henry and Watts, "*Guide to the Collections, Geol. Survey of Ireland*" (1895), 94.

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 station "R.T., i., 1D." 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, probably contains 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 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. XX., fig. 2).

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

The sandstones from this dredging show a wide variety, from grey-green types like those described from the Porcupine Bark, 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

(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.

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.

MATERIALS DREDGED FROM A POINT 40 NAUTICAL MILES WEST OF CLEGGAN, CO. GALWAY, DEPTH ABOUT 80 FATHOMS.

Label—Helga LXXXVIII., R.T. iii. 1D., 8. vii. '01.

This dredging was made within the 100-fathom line which marks the edge of the continental plateau, as usually defined. The stones are much more water-worn than those from the region of the Porcupine Bank, and some of them are well-rounded pebbles. Those received by us are as follows:—

Sandstone,	86 stones.
Limestone,	73 „
Biotite-Granite,	29 „
Flint,	4 „
Quartz-rock,	3 „
Diorite,	1 stone.
Decomposed Basalt,	1 „

In addition, we received forty specimens of calcareous organic origin. The only mollusc is *Venus casina*, and the other fragments are colonies of polyzoa.

The largest stone from this dredging is a specimen of granite, measuring 10 cm. by 9 cm. by 5 cm.

Sedimentary rocks are here clearly predominant. The flint 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. The tiny fragment of basalt probably also represents material drifted from the northern area. The diorite is also a minute fragment. The specimens that represent the locality are granite, stained brown, like that from the eastern edge of the Porcupine Bank, and unmetamorphosed sandstone and limestone The limestone is probably the ordinary grey Carboniferous Limestone, which reaches the sea in the synclinal inlet of Clew Bay, and which formerly extended west towards our area along the more southern synclinal of Bengorm and Muilrea. The limestone fragments are bored through and through by molluscs.

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.

iv.

MATERIALS DREDGED FROM A POINT 30 NAUTICAL MILES WEST OF CLEGGAN, DEPTH 73½ FATHOMS.

Label—Helga CXVII., 23. viii. '01.

This dredging is on the straight line between Cleggan and the last one, but is ten nautical miles nearer to the coast. The sea-floor

was covered with a gravel of small stones, in a ground of fragments of molluscan shells, echinoid tests, and polyzoan colonies. The larger stones picked out from among these give us:—

Limestone,	50 stones.
Sandstone,	17 „
Biotite-Granite,	12 „
Diorite,	2 „ (small).
Basalt (sp. gravity = 3·01),	1 stone.
Chert,	2 stones (small).

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.

The characters of these materials, then, so closely correspond with those from the preceding station as to render separate description unnecessary. The proportion between the granite stones and the total sedimentary material is almost exactly the same in both cases.

V.

MATERIALS DREDGED FROM A POINT 40 NAUTICAL MILES N. 22° W. OF CLEGGAN, CO. GALWAY, DEPTH ABOUT 86 FATHOMS.

Label—Helga LXXXV., R.T. i. 1D., 5. vii. '01.

This dredging was made some sixteen nautical miles west of the Mullet promontory on the coast of County Mayo. 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.

Yellowish 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. We received:—

Fine-grained Gneiss, with Quartz-Schist and Quartzite,	373 stones.
Sandstone, mostly fine-grained,	285 „
Biotite-Granite, Quartz-Diorite, and Diorite,	68 „
Limestone, sometimes with chert,	39 „
Flint of Cretaceous type,	7 „
Rhyolite,	1 stone.

As in the dredging in 120 fathoms 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. XXI., 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. XXI., 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 occur in these between the quartz and microcline. 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 crystals of the latter 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 granite 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 con-

(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.

solidation. The evidence as a whole, however, 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 the two preceding ones, *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.

The one pebble of stony rhyolite seems an obvious stranger. It is well rounded, and is like some of the pebbles that have been borne from the Cainozoic 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 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.

VI.

Conclusion.

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 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, of which we shall hope to find other outcrops as time goes on; but this igneous mass may possibly be of Palæozoic age. The view of Suess, that the Atlantic basin is here determined by faults cutting across the previous folded structures of the country, is in no way opposed by the observations, so far as they have gone. 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),

(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.

by the relics traceable between Ireland and the Færöe Islands. There is much reason to suppose that this faulting is, at the earliest, of Pliocene age; and recently Dr. Nansen (1) has concluded, from a consideration of sunken shell-banks between Iceland and Jan Mayen, that the sea-bottom "during the time of the greatest ice-sheet of Europe, must have been uplifted at least 2,600 metres higher than it is at present." (2). 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 recently described by Messrs. Herdman, Dawson, and Clement Reid, (3) 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.

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

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

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

DESCRIPTION OF PLATES.

PLATE XX. Fig. 1. Microscopic section of olivine-gabbro, Porcupine Bank. Altered olivine is seen near the centre. × 11.

Fig. 2. Microscopic section of granular aphanite (epidiorite) invaded by granite veins, east side of Porcupine Bank. Specimen showing junction of the two rocks. × 11.

PLATE XXI. Fig. 1. Microscopic section of gneiss rich in patches of associated epidote and biotite, 40 nautical miles N. 22° W. of Cleggan, Co. Galway. × 11.

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

PLATE XXII. 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.

A. T. & Co. (Ltd.)
200. Wt. P. 544. 1. 1904.

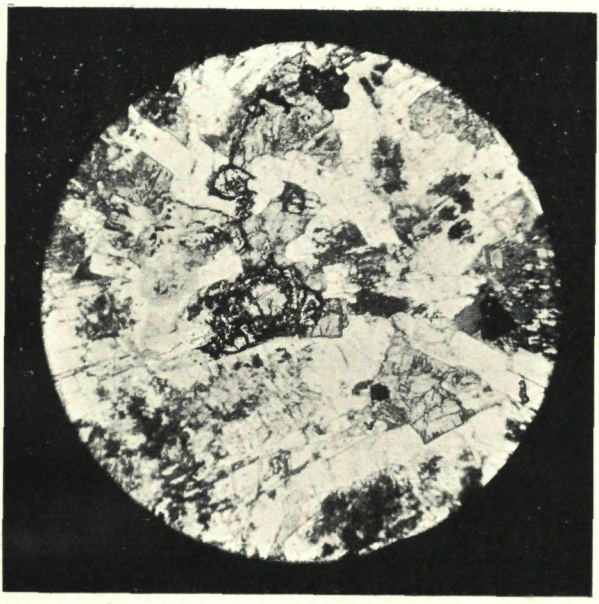


FIG. 1.

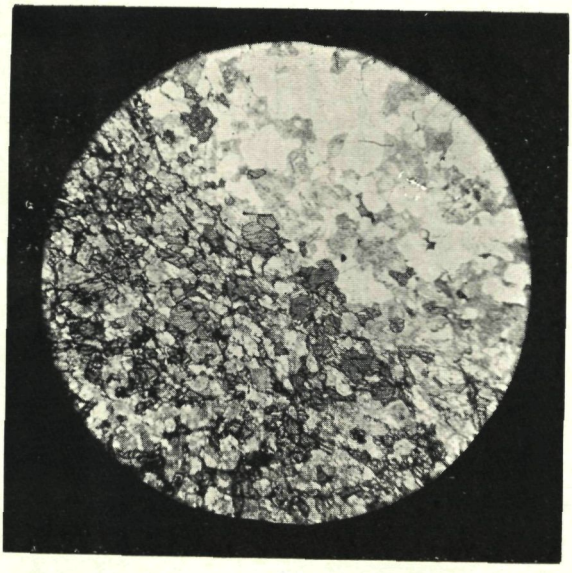


FIG. 2.

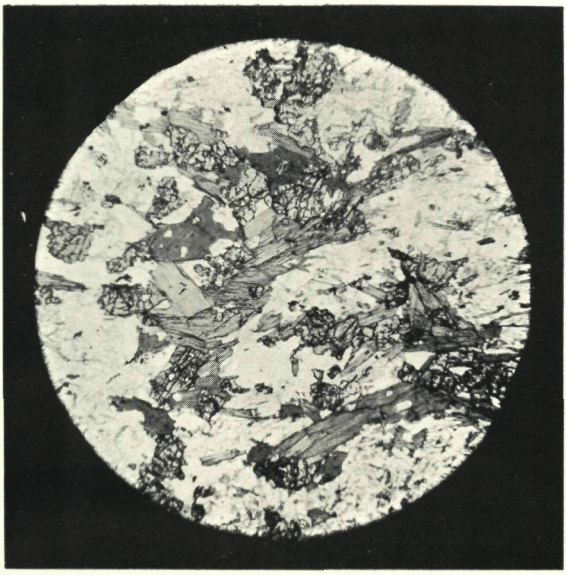


FIG. 1.

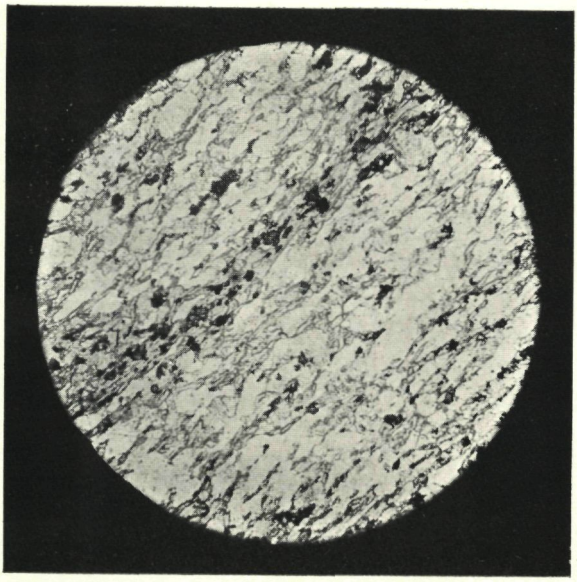
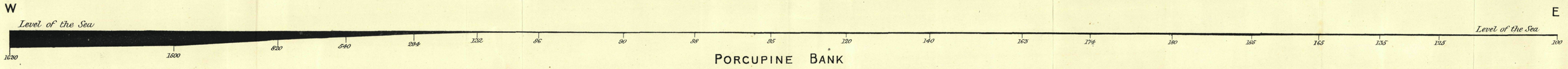


FIG. 2.



PORCUPINE BANK

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.