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FINAL REPORT

ON

GEOLOGICAL INVESTIGATIONS

IN THE

FALKLAND ISLANDS.

BY

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1.—INTRODUCTION.

Until now there has never been any official geological examination of the Falkland Islands. Charles Darwin, in the "Beagle," visited the Islands in 1833 and again in 1834, and in 1846 published an account of their geology in the Quarterly Journal of the Geological Society.[1] The fossils collected by him were described by Morris and Sharpe.[2] In 1876 the "Challenger" Expedition spent some time at the Falkland Islands and marine fossils were collected in the north-eastern part of East Falkland at Port Louis and Macbride's Head. These fossils were described by R. Etheridge, Junior, in 1885.[3] Mosely, of the "Challenger" Expedition, rode out to Port Sussex, on the west coast of East Falkland, to examine an alleged occurrence of coal and graphite, supposed, at the time, to occur in the Devonian rocks of the Islands but now known to be in the Permo-Carboniferous series. Renard, in 1885 and 1889, described rock specimens from the Islands collected during the "Challenger" Expedition,[4] but the exact sources of the material described are not at all clear. Subsequently the Islands appear to have been entirely neglected by geological investigators until, during the Swedish South Polar Expedition of 1901-03, Professor J. Gunnar Andersson[5] found opportunity for some three months' work in the Falklands. In 1906 Mr. E. T. Newton described fossils from the Islands brought home by the Scottish National Antarctic Expedition.[6] As the outcome of the interesting discoveries made by Andersson, the Swedish Magellanian Expedition of 1907-09 was led to include the Falkland Islands in its itinerary, and Drs. Thore G. Halle and Carl Skottsberg carried out geological and botanical investigations there between October, 1907 and February, 1908. To Dr. Halle we owe the most comprehensive account of the geology of the Falkland Islands hitherto published.[7] The marine fossils obtained by Andersson and Halle, augmented by a further collection secured by Governor and Mrs. Allardyce, were submitted for examination to Dr. John M. Clarke, of the New York State Museum, and have been fully described and figured by him.[8]

One of the most significant new facts brought to light by Halle's work was the wide extent, in the Falkland Islands, of the Permo-Carboniferous or Gondwana rocks—formations which are known to contain, in other parts of the world, valuable deposits of coal. At about the same time as Halle's work was published, the Imperial Institute reported upon an interesting

1 1846. Darwin, C. "Geology of the Falkland Islands." Q.J.G.S., Vol. 2, pp. 267–274.

2 1846. Morris, J., and Sharpe, D. "Palæozoic Brachiopods from the Falkland Islands." Q.J.G.S., Vol. 2, pp. 274–278, pls. 10, 11.

3 1885. Etheridge, R. (Junior). (On Devonian fossils). In the Report on the Scientific Results of the Voyage of H.M.S. "Challenger." Narrative, Vol. 1, pt. 2, p. 892.

4 1885. Renard, A. "Notice sur quelques roches des 'fleuves de pierres' aux iles Falkland." Bull. Acad. Roy. Sci. Bruxelles, Ser. 3, T. 10.

1889. Renard, A. "Report on the rock specimens collected on oceanic islands during the voyage of H.M.S. "Challenger." Report on the Scientific Results, etc., Physics and Chemistry. Vol. 2.

5 1902. Andersson, J. G. "Antarctic expeditionens arbeten på Falklands öarna och Eldslandet, 1902." Ymer (22). Stockholm.

1903. Andersson, J. G. "The scientific work of the Swedish Antarctic Expedition at the Falkland Islands and in Tierra del Fuego." Geographical Journal, London, Vol. 21.

1906. Andersson, J. G. "Solifluction, a component of subaerial denudation." Journal of Geology, Vol. 14.

1907. Andersson, J. G. "Contributions to the geology of the Falkland Islands." Wiss. Ergebn. der Schwedischen Südpolar-Exped., 1901–03. Bd. 3, Lief. 2. Stockholm.

6 1906. Newton, E. T. "Notes on fossils from the Falkland Islands brought home by the Scottish National Antarctic Expedition in 1904." Proc. Roy. Phys. Soc. Edin., Vol. 16, pt. 6. pp. 248–257, pl. 10.

7 1912. Halle, T. G. "On the Geological Structure and History of the Falkland Islands." Bull. Geol. Inst. Uppsala, Vol. 11, pp. 115–229, pls. 6–10.

8 1913. Clarke, J. M. "Fosseis Devonianos do Parana." Monographias do Serviço Geologico e Mineralogico do Brasil.

specimen of a bitumen or cannel with a very high oil-content, which had been received from the Falklands. The letter accompanying the sample stated that there appeared to be several outcrops of this material in various parts of the Falkland Islands. A further sample was sent to Australia and was recognised as being practically identical with the oil-bearing rock of Hartley, New South Wales, the latter rock occurring in strata of Permo-Carboniferous (Gondwana) age. It therefore appeared possible that investigation of the Permo-Carboniferous rocks of the Falkland Islands by a geologist might lead to the discovery of valuable deposits of coal or oil-bearing rock. Other mineral samples, suggesting the possible occurrence in the Islands of valuable ores of iron and copper having also been forwarded to the Imperial Institute for analysis, it was deemed advisable to have the Islands surveyed by a geologist.

I arrived in the Falkland Islands to carry out this work on 25th December, 1920. I undertook a comprehensive survey for coal, oil and other minerals, made a collection of palæontological and petrological specimens and obtained data for the construction of the geological map of the Islands. I left the Colony on 2nd April, 1922.

The work of the survey was faced by many difficulties. Climatic conditions constituted the first hindrance. I find that the average number of days per year on which rain fell during the four years 1917-1920 inclusive was 240, that is, roughly, two out of every three. Much of my field-work was rendered unpleasant by rain. Another very real drawback to survey work in the field, and along the coasts, was the frequency, suddenness and violence of the winds. Sudden violent winds (termed locally " woollies ") were a real menace when proceeding by sea in a small vessel—usually a sailing cutter.

By far the greatest hindrance to the survey was the difficulty of getting about. The Islands are served by one small steamer which conveys stores and mails to the various coastal settlements and collects the bales of wool. During my stay, even this broke down and had to be sent to Buenos Ayres for repairs—its work being performed, in the interim, by a sailing schooner. The steamer would leave Port Stanley, at fairly frequent intervals, on a set itinerary, the length of a trip occupying anything from one to five weeks. In seeking a passage by sea to a particular settlement, one had to take one's chance as to whether the steamer was including that place in her next trip, and even then one might circumnavigate the Islands before arriving at one's destination. I have known cases where people have waited several months for a particular passage. Moreover, travelling by this steamer, in anything but the best of weather, is a real hardship, dreaded indeed, by most of the inhabitants. The vessel might, at a pinch, accommodate some seventeen passengers with some approach to reasonable comfort, but I have known all-night passages, in bad weather, with as many as eighty passengers on board, including many women, and everybody ill except the very hardiest seafarers.

In the case of the smaller outlying islands, some of these possess small sailing cutters, although these latter are, in several instances, in an advanced state of rottenness. It is hardly an exaggeration to state that one risk's one's life when encountering a " woolly " during a trip on some of these craft.

When one desires to visit one of these outlying islands which possesses a cutter, the procedure adopted is primitive. One proceeds to the point on the mainland nearest the island and sets fire to many square yards of the ubiqitous " diddle-dee." (A variety of crowberry, everywhere abundant, which burns fiercely, with much heat and great smoke). On perceiving the smoke of the answering fire from the island, one repairs to the nearest shepherd's house to await the arrival of the cutter—perhaps for a week.

It was at first suggested that I should be supplied with a small motor-boat for use in examining the rock-sections exposed in the numerous creeks, but it soon became apparent that, for many reasons, such a scheme would not be practicable, and the idea was abandoned.

Towards the latter end of my stay in the Colony, a small drifter, for special Government work, arrived at Port Stanley, but of this I was never able to avail myself.

In the earlier stages of my work I made many trips in the steamer, with the object of familiarizing myself with the general character of the coasts of the Islands, examining the rocks in the vicinity of the settlements, and gaining a working notion of the geological structure of the Colony. Later, I occupied myself in examining the interior, getting from place to place on horseback.

Travelling overland, within the Colony, is done entirely on horseback, and possesses its own peculiar terrors for the uninitiated. Every settlement maintains its troop of horses, and each isolated "camp" shepherd has his own troop. The horses are never shod. They are left to roam and fend for themselves, and are never fed by their owners. When horses are required for riding, the troop is first rounded up and certain horses selected. This operation may take several hours, since the troop may be feeding miles away, perhaps half a working day being thus occupied. It may be that the horse selected for one's use has not been ridden for a considerable time, and one usually approaches one's mount with an interest acute to the point of trepidation.

The Falkland Islands is no country for a stranger to ride in without a guide. There are very definite routes from point to point and the best of reasons for their definiteness. Often the course pursued from point to point seems very roundabout, but enquiry elicits the information that a more direct route would encounter some obstacle, such as an uncharted peak, a large uncharted pond too deep to ford, a stretch of more than usually boggy country, or a fence at a point where no gate was provided. The inhabitants commonly speak of the "track" to any particular place, but the uninitiated stranger can, in general, perceive no visible track. The term "track" connotes the course habitually taken between point and point—a devious progression governed by the nature of the country to be crossed and the position of fence-gates. The latter, in general, have been provided at points which suit the convenience of the particular sheep-farm to which the fence belongs—and to the casual wayfarer seem often to have been positioned with singular perversity.

In conducting my survey work in the interior of the country I was absolutely and entirely dependent upon the kindly and sympathetic help of the inhabitants—the station-managers and the "camp" shepherds. Anything approaching a detailed examination of the interior would have been quite impossible but for the help thus afforded.

Station-managers and "camp" shepherds alike willingly and gratuitously housed me and fed me for as long as I chose to stay with them, provided horses to meet my needs and either constituted themselves my guides or found others to act in that capacity. In the earlier stage of my work inland I at one time contemplated maintaining a number of horses and travelling in the interior with an assistant, a tent and a supply of provisions. It was soon perceived, however, that not only was this course for many reasons very difficult and expensive to adopt, but unnecessary. It was found possible so to arrange my programme of work that a day's surveying commenced at the "camp" house from which I departed in the morning and finished at the house at which I put up for the night, although this procedure frequently entailed many hours in the saddle in addition to the field-work, and much devious wandering between houses.

It was frequently no easy matter (especially in the height of the sheep-farmers' season) for a station-manager to provide me with a horse and guide at short notice. The sheep-farms are managed with a strict eye to economy and there is no superfluity of either horses or men. Yet, almost invariably, both horse and guide were ready for me as soon as I required them. It is with great pleasure that I express here my warmest thanks for, and sense of appreciation of, the spirit of sympathetic helpfulness in which I was almost everywhere received. I shall always retain, too, very pleasant memories of the kindly hospitality everywhere accorded me. Any attempt to record here the names of those to whom I am thus indebted would involve mention of almost every station-manager in the Falklands and the majority of the "camp" shepherds. Outside Port Stanley, there must be only a few houses in the Falkland Islands which I have not visited.

When on tour in the "camp" one carried one's personal effects (reduced to the narrowest minimum) in a pair of Spanish saddlebags known as "maletas." There was no convenience for carrying numerous and weighty geological specimens, and as day succeeded day, the problem of how to dispose of one's specimens became pressing. Here the camp shepherds most obligingly assisted me. On my departure from a shepherd's house I would leave a load of specimens which the shepherd would convey to the farm head-quarters at the settlement, there to await the next call of the steamer. In this way I was able to gather together a collection much more considerable than would have been the case had I been obliged to rely upon my own resources.

I carried a plate camera with me and took numerous photographs, but, as can readily be imagined, riding over such rough country frequently meant disaster to my pictures. Plates innumerable were smashed, and several times the camera itself, the latter being repaired only with difficulty, owing to one's limited resources.

Before leaving England arrangements had been made for the consignments of geological specimens, which I forwarded periodically, to be housed in the Geological Department of the Imperial College of Science and Technology, South Kensington. On my return I carried out my examination of the specimens thus collected, in the geological laboratories of the College, and my best thanks are due to Professor W. W. Watts, F.R.S., and his staff, for the excellent facilities afforded me.

The work of the survey was accomplished in twelve tours.

As a result of the survey I was able to draw up the following table for the rock-succession in the Falkland Islands:—

Rock-Succession in the Falkland Islands.

				Thickness (feet).	
			Post-Permo Carboniferous Igneous Intrusions (dykes only).		
Rhætic (?) Triassic, Permian, and Upper (?) Carboniferous (in lower part of sequence).	Upper Lafonian Series, 9,250.	West Lafonian Beds.	Alternating sandstones and shaly beds, with plants of the Glossopteris Flora allied to Upper Triassic or Rhætic species of other areas.	7,000	11,700
		Bay of Harbours Beds.	Alternating claystones, shaly beds and sandstones, with the Glossopteris Flora, containing plants of Permian age.	2,250	
		Choiseul Sound and Brenton Loch Beds.	Shaly beds, striped by alternations of thin lighter and darker bands. (Seasonally? banded "varve" rocks.) Glacial material deposited in fresh water.		
	Lower Lafonian Series, 2,450.	Lafonian Sandstone.	Fairly fine-grained sandstone, sometimes with embedded erratics in lower part.	300	
		Black Rock Slates.	Thin-bedded cherty beds and slates overlying the tillite.	2,150	
		Lafonian Tillite.	Glacial Boulder-Beds.		
		Bluff Cove (Fitzroy Basin) Beds.	Shales and sandstones, occurring only locally.		

UNCONFORMITY.

Carboniferous or Devonian.	Port Stanley Beds.	Quartzites and quartzitic sandstones with intercalated shales. Forms the heights of the northern part of the Colony.	2,500 ?	10,000 ?
(?) Devonian.	Port Philomel Beds.	Sandstones, shales and flagstones, with Lepidodendroid plant-remains.		
Lower Devonian.	Fox Bay Beds.	Sandstones, shales, flaggy and slaty rocks, abundantly fossiliferous at certain horizons. Typically developed at Fox Bay, West Falkland, but frequently exposed elsewhere on the lower ground beneath the quartzitic heights.	2,500 ?	
	Port Stephens Beds.	Sandstones, quartzites and quartz-conglomerates. Apparently unfossiliferous. Occurring in southern half of West Falkland.	5,000 ?	

UNCONFORMITY.

Archæan.	Cape Meredith Series.	Igneous and Metamorphic Rocks. Seen only at Cape Meredith, West Falkland. Only small thickness seen.

The work of the survey confirmed the conclusion, formed by Dr. Halle, that the rock-succession in the Falkland Islands is essentially similar to that of the Cape Colony. The grouping of the strata given here differs in no important respect from that suggested by Halle, who was the first definitely to indicate the rock-sequence and correlations with other areas. Both in the stratigraphical features of the rock-succession and in the structure of the country the Falkland Islands exhibits a very close similarity to the area in the southern part of the Cape Province lying north of the Kleine Zwartebergen between Karroo Poort and Willowmore. The oldest rocks of the Falklands, seen at Cape Meredith, West Falkland, are probably the equivalent of some portion of the Pre-Cape Rocks of the Cape Province. The lower sandstones, quartz-conglomerates and quartzites of the southern part of West Falkland appear to be equivalent to, or homotaxial with, the Table Mountain Series of the Devonian of Cape Colony. The overlying, softer, fossiliferous sandstones and shales represent the equivalents of the Bokkeveld Beds. The upper quartzites, sandstones and shales which succeed these beds are equivalent to, or homotaxial with, the Witteberg Beds. Moreover, the thicknesses of these several rock-groups appear to correspond in the two areas. Then follows the rock-sequence of the Karroo or Gondwana formation, and these beds, in their turn, show great similarity to the corresponding beds of the Southern Karroo. The basal member, the Lafonian Tillite, is the equivalent of the Dwyka Tillite of the Southern Karroo, and is of about equal thickness. The Falklands' Karroo Beds above the tillite make up a considerable thickness of strata, apparently approaching 10,000 feet, being composed entirely of sandy and shaly beds apparently equivalent to the Ecca, Beaufort, and part of the Stormberg Series of the Southern Karroo. In these respects the beds are very like those of the area of the Southern Karroo referred to above, and in notable contrast with the corresponding Karroo Beds of the Transvaal, in which area the whole Karroo System is represented, but in a much attenuated form, by only about 500 feet of strata.

From the economic point of view this close resemblance of the rocks of the Falkland Islands to those of a particular part of the Cape Colony is unfortunate. The coal deposits of South Africa occur only in the Karroo System, and the Cape Province is not so well favoured in the matter of coal-seams as the Transvaal and Natal. In the Transvaal some 500 feet of Karroo Beds include strata of Middle Ecca age which carry numerous thick coal-seams. The coal-seams of Natal also occur in the Middle Ecca Beds. In the Cape Province, however, the great thickness of Lower Karroo strata (including Ecca Beds) contains no coal-seams, the latter occurring only in the Upper Karroo Beds and the workable ones being confined to the Molteno Beds. But even these are thin, impersistent and poor in quality. In the case of the Falkland Islands the state of affairs is even more unfortunate, for if beds of Upper Karroo age occur, they occupy only a very insignificant strip of country in the extreme west of Lafonia, bordering Falkland Sound. With regard to the older Devono-Carboniferous formation, the Table Mountain Series in the Cape Province is known to contain quartz-reefs carrying gold in association with ores of zinc and lead, and the Table Mountain Sandstone furnishes a useful building stone. No such mineral occurrences have been detected in the corresponding rocks of the Falkland Islands, although suitable building stone could be procured from this formation were it required. The Bokkeveld Beds of the Cape Province do not furnish any stone or minerals of much economic value, and the succeeding Witteberg Beds have no economic importance. The same remarks apply to the equivalent beds in the Falkland Islands.

A more detailed consideration of the unfortunate lack of notable mineral resources in the Falkland Islands will be found later in this Report.

2.—THE LOWER CRYSTALLINE ROCKS (ARCHÆAN) OF CAPE MEREDITH, WEST FALKLAND.

The oldest rocks seen in the Falkland Islands occur in the cliffs of Cape Meredith, West Falkland, and there is no other exposure of similar rocks (in place) anywhere in the Islands, unless it be on some outlying island such as

Beauchêne Island, which I had no opportunity of visiting. These rocks were discovered in 1902 by Professor J. Gunnar Andersson of the Swedish South Polar Expedition, but his specimens were lost with the ship of the Expedition, the "Antarctic." Dr. Halle had no opportunity, during his stay in the Colony in 1907-08, of visiting Cape Meredith. I took an early opportunity of visiting this important and interesting exposure, and spent several days in an examination of it. By a fortunate circumstance there is, not far from the cliffs, a shanty which I was able to occupy during my study of the section and this greatly facilitated the work.

Andersson described the cliff at the western end of the section as inaccessible, but I approached it from the landward side, and, with the aid of the services of a most useful guide, found a way down and secured specimens and photographs. I examined the section from west to east, but had to ascend to the cliff-top before reaching the southernmost point of the cape, as the exposure becomes, after a time, quite inaccessible.

At the southernmost point of the cape the descent to the sea is quite easy, and I was able to resume my examination and to follow the rocks for some way round the bay between the two points of the cape. On the eastern side of this bay, however, the cliffs rise vertically for nearly 300 feet, with the older rocks inaccessible at the bottom.

At the western end of the section the older rocks first emerge from the sea, from beneath the Devonian sandstones, with a north-westerly dip, and proceeding eastwards occupy more and more of the cliff-section, the junction-line between the two formations being irregularly undulating. On either side of, and at, the most southerly point of the cape, the entire cliff is composed of the older rocks. Still farther eastward the Devonian sandstones again begin to make their appearance and the older rocks gradually disappear from view beneath the sea.

The evidence of the pre-Devonian age of the rocks is perfectly clear, in view of the marked unconformity which separates the two formations. The older rocks comprise both igneous and metamorphic rocks, the latter apparently including metamorphosed sediments.

At the western end of the section, where the older rocks first emerge from the sea, there is a great mass of dark-coloured schist, with a north-westerly dip, the appearance of which strongly suggests a metamorphosed sandstone. Intruded into this, but not into the Devonian sandstones above, in the form of laccolitic masses, dykes, veins, strings and patches, is another mass of pale-pinkish, coarse-grained pegmatite. The crystalline schist has been much folded and contorted by the intrusions. Cutting both these masses, but not the overlying Devonian sandstones, occur numerous dykes, dark-brown in colour. The schist disappears eastward, before the most southerly point of the cape is reached. Here, in addition to the pegmatite, other rocks occur, such as gneiss and a yellowish granite. There is also a seam of a very characteristic pink quartzite.

The old rocks of Cape Meredith are abundantly represented as boulders in the Lafonian Tillite everywhere in the Falklands.

The junction of the Archæan with the overlying Devonian sandstones is well seen in the photograph. (*See* Fig. 3.) Microscope sections, and photo-micrographs of some of these rocks have been prepared, and notes concerning them are given here :—

1. *Blue-black schist, Archæan, Cape Meredith, West Falkland.*—A dark-coloured rock obviously associated with and penetrated by the Archæan, igneous rocks of Cape Meredith. It has been much folded by the igneous intrusions, and is overlain, with a marked unconformity, by the nearly horizontal sandstones of the Devonian. It is an excellent example of a schist, and strongly suggests, by its appearance in the cliffs of Cape Meredith, a metamorphosed sandstone. Under the microscope the rock is seen to consist almost entirely of quartz and green hornblende, the schistose texture being pronounced. Other minerals are conspicuously rare. (*See* Fig 6.)

2. *Coarse, very typical pegmatite, Archæan, Cape Meredith, West Falkland.*—The main mass of the Archæan at Cape Meredith is composed of this rock. Consists essentially of pink felspar and quartz. Under the microscope the felspar is seen to be microcline. Assessory

minerals are conspicuously rare, but one slide of this rock showed an interesting occurrence of Xenotime, the rare phosphate of the yttria metals. Occurs as boulders in the Lafonian Tillite. (*See* Fig. 7.)

3. *Yellowish granite, Archæan, Cape Meredith, West Falkland.*—A holocrystalline rock, medium to rather coarse in grain. Consists mainly of yellowish felspar and quartz. Under the microscope the presence of biotite, decomposing to chlorite, is detected. The felspar is microcline, which, as usual, has been the last product of consolidation of the rock. Accessory minerals conspicuously rare. Occurs abundantly as boulders in the Lafonian Tillite. (*See* Figs. 9 and 10.)

4. *Pink quartzite, Archæan, Cape Meredith, West Falkland.*—The relation of this rock to the other Cape Meredith Archæan rocks is not clear. I saw the rock only as a line of boulders projecting, for a few yards, through the humus of a decayed balsam-bog, a little inland from the most southerly point of the cape. It occurs below the level of the base of the Devonian and must therefore be associated with the older series, but I was unable to detect it anywhere in the cliff-section although it may be exposed in the inaccessible portion. Very abundant as boulders in the Lafonian Tillite. Under the microscope the rock is seen to be a silicified sandstone or quartzite formed by the secondary deposition of interstitial quartz. The secondary silica deposited around the original grains (the outlines of which are very clearly defined) is seen to be in optical continuity with the original grains. The rock shows little evidence of either contact or dynamo-metamorphism, although some of the quartz-grains show undulatory extinction indicative of pressure. (*See* Fig. 16.)

5. *Dark-brown dyke rock, invading Archæan schist and pegmatite, Archæan, Cape Meredith, West Falkland.*—Iron-pyrites occurs abundantly, in patches, in this rock. A sample was submitted to the Imperial Institute, for assay for gold, but neither gold nor silver was found to be present. An intrusive igenous rock of basic composition, very much decomposed. Ground-mass consisting of highly decomposed red felspar and laths of hornblende, with a fair quantity of chloritic material. Idiomorphic hornblende and red felspar occur, together with augite, olivine and iron-pyrites. (*See* Fig. 18.)

The detailed examination of this rock at the Imperial Institute showed that it is an augite-hornblende-lamprophyre of the vogesite class.

The field-relations, megascopic and microscopic characters of these rocks all point to their correlation with some part of the Pre-Cape Group of the Cape Province, possibly with part of the Nama System. The granite of the Paarl and Stellenbosch districts of the Cape Province contains a fair amount of microcline, and that of the extreme southern end of Van Rhyn's Dorp in Namaqualand is a biotite granite with microcline felspar which passes into a gneiss.

3.—THE DEVONO-CARBONIFEROUS ROCKS.

In Cape Colony the rocks of this age comprise (1) the Table Mountain Series at the base; (2) the Bokkeveld Series as the middle member, and (3) the Witteberg Beds as the uppermost member. As indicated above, a similar three-fold grouping of the corresponding Falklands' rocks is possible, and a very close similarity of the rocks of the two areas is discernible.

Beyond noting the fact that the thickness of strata in each of the three groups must be great, I was unable, through lack of suitable sections, to make any calculations of the actual thickness of any one of the groups. I find, however, that if the same thicknesses be assumed for these rock-groups as those which they are known to possess in Cape Colony, there is a notable agreement between the dip of the strata as observed in the field and the position of the outcrops of the beds.

The lowest group of the series, consisting of sandstones, quartz-conglomerates and quartzites occurs only on West Falkland, south of Port Edgar and Port Richards, and on Weddell, Beaver and New Islands. They are well seen around Port Stephens. As in the Table Mountain Series of the Cape Province the rocks of this group are remarkably constant in lithological character

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throughout their entire thickness, which must be about 5,000 feet. The false-bedded sandstones and quartzites present features remarkably similar to those of the Table Mountain Sandstone. In the Peninsula and Stellenbosch areas of the Cape Province the base of the Table Mountain Series is usually a red micaceous gritty shale, and on the north face of Table Mountain this is often the first rock met with at the junction with the granite or Malmesbury beds. In the cliffs of Cape Meredith, West Falkland, the junction of the sandstones with the granite is similarly marked by a thin band of red micaceous shale.

Again, the Cape Province beds have been found to contain, at one horizon, a definite tillite, indicative of Devonian glacial conditions. It seems likely that a similar tillite occurs at South Harbour, West Falkland (south-western part of West Falkland, north of Port Stephens). I was never able to visit this locality but was kindly supplied with a collection of the local rocks. Most of the rocks in the collection were the typical quartzitic sandstones of the lower series, but there were some specimens of shale, and several fragments of a characteristic and unmistakable tillite, very like the Lafonian tillite of the Permo-Carboniferous series.

With regard to the sandstones and quartzitic rocks of which these lower beds are so largely composed, the description given by Rogers and Du Toit (Geology of Cape Colony) of the Cape Province equivalents applies with precision to the Falklands' rocks. As in the Cape Province, an interesting conversion of the sandstone rock into quartzite under the influence of weathering, is frequently observable. The sandstone is false-bedded and very much jointed. Under the influence of the frequent rains and the high winds the rock weathers rapidly, giving rise to ground very rough and difficult to traverse, and producing much sand, the presence of which is very detrimental to the sheep-pasture. The weathered rocks often assume extraordinary shapes. (*See* photograph Fig. 11.)

As in the Cape Province a very frequent feature in these sandstones is the occurrence of rounded pebbles of white quartz. In some instances the pebbles become so abundant that the rock is a regular quartz-conglomerate. No traces of fossils have so far been found in this lower series of rocks in the Falklands and in the case of the Cape Province equivalents the only fossils known are lamellibranch shells, not well-enough preserved for determination.

In one important respect, however, these beds in the Falklands differ notably from their Cape Province representatives. In the latter area these rocks have been very much folded, giving rise to numerous, characteristic quartzitic fold-ridges. In the Falkland Islands the area occupied by the outcrop of these rocks has been conspicuously unaffected by folding-movement and constitutes the least disturbed region in the Islands. From Cape Meredith to Port Richards the beds dip gently to the northwards, generally in a direction somewhat east of north. On Weddell, Beaver and New Islands the same rocks are seen, either nearly or quite horizontal. Over the area occupied by the outcrop of these rocks, harder bands form ridges and patches of higher ground, but the strata are always gently-dipping.

The whole of the remainder of the outcrop of Devono-Carboniferous rocks in the Falkland Islands is occupied by strata equivalent in age to the Bokkeveld and Witteberg Beds of the Cape Province. I nowhere saw the junction between the lower series and the fossiliferous sandstones and shales, but it must occur somewhere in the neighbourhood of Port Richards and Port Edgar. At many localities to the northward the characteristic suite of marine invertebrates has been obtained from the fossiliferous series, and I was informed, just before I left the Colony, that the usual kinds of fossils had also been found at Port Edgar.

In contrast with the underlying older rocks, the middle and upper series of the Devono-Carboniferous have been intensely folded. The amplitude of the folding is sometimes on a grand scale, exceeding the combined thickness of the two sets of beds involved. The fossiliferous series is much less resistant to weathering than the overlying quartzitic series, with the consequence that the lower ground is, in general, occupied by the outcrop of the fossiliferous rocks and the higher ground by the quartzitic sandstone. In the time at my disposal I was unable to map in detail the boundaries between the fossiliferous series and the quartzitic series, but the areas occupied by their respective outcrops can be indicated.

In West Falkland, the east coast region, from Manybranch Harbour to Fox Bay, has been affected by a magnificent anticlinal ridge-fold on a grand scale. This fold possesses a very steep, almost vertical, easterly limb, the remnant of which constitutes the very conspicuous coastal ridge of quartzitic sandstone extending from White Rock Bay southwards to Port Edgar. The westerly limb of the fold is seen in the steeply-inclined spurs on the easterly flank of the quartzitic range of the Hornby Mountains. The arch of the fold has been completely denuded away and actually hollowed out in the fossiliferous series underlying the quartzitic rocks, so that a longitudinal valley extends from Port Howard towards Fox Bay, and all along it the crushed and highly-inclined rocks of the fossiliferous series are exposed, striking parallel to the coastal quartzitic ridge and the coastline.

To the north of Port Howard the whole of the low-lying country bounded by the coastal ridge on the east, Mount Edgeworth on the west, Mount Maria on the south, and the Six Hills on the north, is occupied by the outcrop of the fossiliferous beds. Many of the characteristic fossils have been obtained at the creeks of Manybranch Harbour.

West of the Hornby Mountains the fossiliferous series crops out in the centre of West Falkland and has yielded fossils in the banks of the Chartres River, at Chartres Settlement, and at inland exposures.

The series is also exposed between Mount Sulivan and Port Philomel.

Farther north, the low-lying land connecting the two main masses of Saunders Island is composed of the fossiliferous series, and there is a similar area bordering the coast on the southern side of Pebble Island. Golding Island and probably other of the small islands in its neighbourhood are also composed of the fossiliferous rocks.

In all probability, too, there is an area of these rocks bordering the coast of the mainland between River Harbour and Shallow Bay. The remainder of the Devono-Carboniferous outcrop in West Falkland is occupied by the outcrop of the upper quartzitic series, of which all the peaks and high ground north of Port Edgar are composed.

In East Falkland the broad belt of mountainous country extending, on the east, from Port Fitzroy to Berkeley Sound and, on the west, from north of Port Sussex to Port San Carlos, in which the Wickham Heights is the most southerly of the continuous ranges, is composed of the upper quartzitic sandstone series, although there may be included undetected outcrops of the fossiliferous series which is folded up with the overlying beds. In fact, one such outcrop has been detected, at North San Carlos, within the mountain-belt. Here, at the settlement, I collected the usual marine invertebrates of the fossiliferous beds in vertical strata.

The fossiliferous series outcrops on the low ground all round Port Salvador and Port Louis, and the beds show many evidences of disturbance. It must also occur farther north, for the Challenger Expedition obtained fossils at Macbride's Head.

There appears to be no clear line of demarcation between the strata with marine fossils and the overlying quartzitic sandstones, but above the fossiliferous series occur soft yellow sandstones, thin-bedded micaceous sandstones and greyish-brown sandy shales, in which indistinct traces of plants can sometimes be discerned. Strata of this character occur around the entrance to Port Philomel and also around the head of Port North. At a still higher horizon, apparently within the upper quartzitic series, fragments of Lepidodendroid plants have been obtained at Port Purvis.

In the case of the Bokkeveld Series of the Cape Province it has been found possible to subdivide the beds into four groups predominantly of shales, alternating with and separated by three groups predominantly of sandstones. The marine fossils are more abundant in the lower groups and disappear entirely in the uppermost 400 feet of strata, in which only poor plant-impressions have been observed. Yet although the fossils are mostly in the lower layers, those that occur near the top are no less characteristic of the assemblage as a whole. The best-preserved specimens of the fauna are those which occur in calcareous nodules in the lowest group of strata.

I have not been able to group in any such way the corresponding sandstones and shales of the Falkland Islands. The marine fossils occur throughout the series, and become conspicuously abundant at certain horizons, or rather in certain localities, which, probably, means the same thing. In the upper portions of the series where the marine fossils disappear, indistinct plant-impressions have occasionally been found. Calcareous nodules, in which well-preserved fossils occur, are found abundantly in shale-beds on the shore, on the southern side of Pebble Island, west of the settlement. The beds on this island dip 14 degrees to the N.E. The hills are composed of the upper quartzitic sandstone series, with the same dip. Since the highest point on the island is 915 feet above sea-level it follows that either the nodaliferous beds of Pebble Island occur at a higher horizon than those of the Cape Province or that the fossiliferous series as a whole is thinner. The former explanation is probably the correct one. In the course of fossil-collecting in these beds in the Falkland Islands I noted some points of interest. Some fossils, such as Spirifer antarcticus Morris & Sharpe, Leptocoelia flabellites Conrad, Schuchertella Sulivani Sharpe, and Chonetes falklandicus Morris & Sharpe are ubiquitous, invariably occuring at every fossiliferous horizon. Others, such as the trilobites, are distinctly more common at some horizons than others; and other specimens again apparently show a strong tendency to confine themselves to certain horizons. For example—in spite of assiduous search I secured but one specimen of Rensselæria although Halle obtained R. falklandica Clarke in numbers in sandstone at Manybranch Harbour, West Falkland. The specimen obtained by myself came from Fox Bay, West Falkland. Leptostrophia ?? mesembria Clarke was found by Andersson and myself at Fox Bay only, and by Halle at Port Howard only. The large Chonetes C. Skottsbergi Clarke and C. Hallei Clarke I found around Port Salvador, namely, at Middle Creek and Teal Inlet, where they occurred in great profusion, to the exclusion of other fossils. I did not find C. Skottsbergi elsewhere, although Andersson obtained it at Fox Bay and Halle at Spring Point, West Falkland. In the case of C. Hallei only a single specimen has hitherto been recorded, obtained by Halle at Port Salvador, East Falkland. Apart from the numerous specimens of this fossil found at Middle Creek and Teal Inlet, Port Salvador, I secured but one other example elsewhere, namely from a calcareous nodule at Pebble Island.

Although, as compared with the amount of study which has been given to the faunas of other formations of the geological column, the Devonian rocks have been neglected, yet, by a fortunate circumstance, the marine fauna of the fossiliferous sandstones and shales of the Falkland Islands has already been dealt with in close detail. This work has been performed by Dr. John M. Clarke, Director of the New York State Museum, one of the foremost authorities in the world on Devonian faunas. Dr. Clarke has examined the material gathered together in three collections of fossils from the Falkland Islands' rocks, namely, the specimens secured by Professor J. G. Andersson during the Swedish South Polar Expedition, those obtained by Dr. T. G. Halle during the Swedish Magellanian Expedition and a third collection made by Governor and Mrs. Allardyce. Dr. Clarke dealt with this material in full detail in a memoir of the Brazilian Geological Survey. (" Fosseis Devonianos do Parana," Monographias do Serviço Geologico e Mineralogico do Brasil, 1913.) He published a full description, list and illustrations of the fossil specimens from the Falkland Islands, and it therefore only remains to supplement that list in the light of the further material obtained by myself. The list thus supplemented is given below. Specimens obtained by Prof. Andersson during the Swedish South Polar Expedition are marked (P); those obtained by Dr. Halle during the Swedish Magellanian Expedition are marked (M); those of the Allardyce collection are indicated by (A); and specimens obtained during my geological survey of the Islands are marked (B):—

Species occurring in the Bokkeveld Beds of the Cape Province are marked with a star, thus *.

Species occurring in the corresponding beds of South America are marked with a dagger, thus †.

Records which are new for the Falkland Islands are marked (N).

Devonian, Falkland Islands. Faunal List.

Fish Plate	Dunnose Head, Halfway Cove, Port Philomel, W.F. (M).
Dalmanites falklandicus Clarke	Pebble Island, W.F. (A), (B).
	Fox Bay, W.F. (P).
(N) †Dalmanites accola Clarke ...	Pebble Island, W.F. (B).
*Dalmanites (Mesembria) acacia Schwarz	Pebble Island, W.F. (A), (B).
(N) * †Cryphæus australis Clarke	San Carlos North, E.F. (B).
	Pebble Island, W.F. (B).
Cryphæus Allardyceæ Clarke	Pebble Island, W.F. (A).
	N.W. of Port Howard, W.F. (B).
	Fox Bay, W.F. (B).
* †Calmonia ocellus Lake ...	Pebble Island, W.F. (A), (B).
	Mt. Robinson range, Chartres River, W.F. (M).
(N) †Calmonia signifer Clarke ...	Pebble Island, W.F. (B).
Calmonia sp.	Fox Bay, W.F. (B).
*Dalmanites africanus Salter. Lake (?)	Pebble Island, W.F. (A).
*Homalonotus Herscheli Murchison	Pebble Island, W.F. (A), (B).
	Port Louis, E.F. (M).
	Fox Bay, W.F. (P), (B).
	Port Salvador, E.F. (M).
	Chartres River. (B).
	Port Howard, W.F. (B).
Prœtus sp.	Port Louis, E.F. (M).
* †Tentaculites crotalinus Salter	Pebble Island, W.F. (A).
	Fox Bay, W.F. (P).
	Port Louis, E.F. (M).
	Teal Inlet, Port Salvador, E.F. (B).
	Manybranch Harbour, W.F. (B).
* †Conularia africana Sharpe ..	Pebble Island, W.F. (A).
* †Orthoceras cf. gamkænsis Reed	Pebble Island, W.F. (A), (B).
	Fox Bay, W.F. (B).
*Diaphorostoma Allardycei Clarke	Pebble Island, W.F. (A), (B).
	Teal Inlet, Port Salvador, E.F. (B).
*Bellerophon quadrilobata Salter	Port Salvador, E.F. (M).
	Pebble Island, W.F. (A), (B).
(N) †Ptomatis Moreirai Clarke ...	Pebble Island, W.F. (B).
Tropidocyclus antarcticus Clarke	Pebble Island, W.F. (A).
Loxonema ? sp.	Pebble Island, W.F. (A).
	Port Louis, E.F. (P).
* †Nuculites Sharpei Reed ...	Port Salvador, E.F. (M).
	Fox Bay, W.F. (B).
	Pebble Island, W.F. (B).
†Nuculites Reedi Clarke ...	Pebble Island, W.F. (A), (B).
	Fox Bay, W.F. (B).
(N) †Nuculites cf. Branneri Clarke	Pebble Island, W.F. (B).
(N) †Leptodomus cf. Ulrichi Clarke	Manybranch Harbour, W.F. (B).
(N) Janeia sp.	Port Howard, W.F. (B).
	Chartres River, W.F. (B).

(N) †Prothyris (Paraprothyris) Knodi Clarke	Pebble Island, W.F. (B).
Palæoneilo (large sp.) ...	Fox Bay, W.F. (P).
Tœchomya ?	Port Howard, W.F. (M).
†Cardiomorpha ?? colossea Clarke	San Carlos North, E.F. (M).
* †Spirifer antarcticus Morris & Sharpe	Port Louis, E.F. (M), (P), (A). Fox Bay, W.F. (M), (P), (B). Port Howard, W.F. (M), (B). San Carlos North, E.F. (M), (B). Spring Point, W.F. (M). Port Salvador, E.F. (M). Teal Inlet. (B). Pebble Island, W.F. (B). Manybranch Harbour, W.F. (B). Chartres River, W.F. (B).
*Spirifer Hawkinsi Morris & Sharpe	Port Louis, E.F. (P). Fox Bay, W.F. (M). Port Howard, W.F. (B). N.W. of Port Howard, W.F. (B). Chartres River, W.F. (B).
* †Leptocœlia flabellites Conrad	Pebble Island, W.F. (A), (B). Port Louis, E.F. (M), (P), (A). Fox Bay, W.F. (M), (P), (B). Port Howard, W.F. (M), (B). San Carlos North, E.F. (M), (B). Saunders Island, W.F. (M). Port Salvador, E.F. (M). Teal Inlet. (B). Chartres Settlement, W.F. (B). Manybranch Harbour, W.F. (B).
(N) Derbyina sp.	Chartres Settlement, W.F. (B). Teal Inlet, Port Salvador, E.F. (B).
(N) Cœlospira ? sp.	Teal Inlet, Port Salvador, E.F. (B).
* †Schuchertella Sulivani Morris & Sharpe	Port Louis, E.F. (M), (P). Fox Bay, W.F. (M), (P), (B). Port Howard, W.F. (M). Spring Point, W.F. (M). Port Salvador, E.F. (M). Teal Inlet. (B). Manybranch Harbour, W.F. (B). Pebble Island, W.F. (B). Chartres Settlement, W.F. (B).
(N) †Schuchertella Agassizi Hartt & Rathbun	Fox Bay, W.F. (B). Pebble Island, W.F. (B). N.W. of Port Howard, W.F. (B).
†Leptostrophia concinna Morris & Sharpe	Port Louis, E.F. (M), (P).
†Leptostrophia ?? mesembria Clarke	Port Howard, W.F. (M). Fox Bay, W.F. (P), (B).
* †Chonetes falklandicus Morris & Sharpe	Port Louis, E.F. (A), (M), (P). Fox Bay, W.F. (M), (P). Spring Point, W.F. (M). Port Salvador, E.F. (M). Port Howard, W.F. (B). Chartres Settlement, W.F. (B). Teal Inlet, Port Salvador, E.F. (B). Manybranch Harbour, W.F. (B). Pebble Island, W.F. (B).
Chonetes Skottsbergi Clarke ..	Middle Creek & Teal Inlet, Port Salvador, E.F. (M), (P). Spring Point, W.F. (M). Fox Bay, W.F. (P).

Chonetes Hallei Clarke ...	Middle Creek, Port Salvador, E.F. (M), (B). Teal Inlet, Port Salvador, E.F. (B). Pebble Island, W.F. (B).
* †Cryptonella ? Baini Sharpe ..	Fox Bay, W.F. (M), (P), (B). Port Louis, E.F. (A). Teal Inlet, Port Salvador, E.F. (B).
Rensselæria falklandica Clarke	Manybranch Harbour, W.F. (M).
Rensselaeria sp.	Fox Bay, W.F. (B).
* †Orbiculoidea Baini Sharpe ...	Pebble Island, W.F. (A), (B). Port Salvador, E.F. (M). Fox Bay, W.F. (P), (B).
(N) †Orbiculoidea cf. Bodenbenderi Clarke	Pebble Island, W.F. (B). Fox Bay, W.F. (B).
(N) Orbiculoidea sp. (large) ...	N. of Port Howard, W.F. (B).
Crinoid stems	Port Louis, E.F. (A), (P), (M). Fox Bay, W.F. (P). Port Salvador, E.F. (M). Teal Inlet. (B). Saunders Island, W.F. (M). Chartres Settlement, W.F. (B). Port Howard, W.F. (B).
*Clionolithus priscus McCoy ..	Port Louis, E.F. (A). Fox Bay, W.F. (P).

As has been already sufficiently indicated, in sedimentary facies, the marine fossiliferous rocks of the Falkland Islands bear a very remarkable resemblance to the corresponding series of South Africa and, as can be seen from the foregoing list, the resemblance in fauna is also very pronounced. According to the faunal list published by Dr. Clarke, the Falkland Islands appeared to be more closely allied to the Cape Province area than to that of South America. The augmented list set out above emphasizes the faunal affinity of the Falklands with South America as well as South Africa, and suggests that when the palæontology of these regions shall come to be more fully known, the homogeneity of the austral Devonian fauna will be established.

In view of the ample descriptions and illustrations of the fossil species published by Dr. Clarke, it will not be necessary in this place to enter upon a detailed discussion of specimens or to reproduce figures.

As in the Cape Province, there is no clear line of demarcation between the marine fossiliferous beds and the plant-bearing sandstones and shales above. The plant-remains of the higher beds are rare and in a poor state of preservation. On the northern side of Port Purvis, West Falkland, I found a few traces sufficiently well preserved to enable me to note the presence of a Lepidodendroid plant in these beds.

These plant-remains have been examined by Professor A. C. Seward, F.R.S., of Cambridge, and the following information is given in his report concerning them. A few carbonaceous impressions of Lepidodendroid stems, too imperfect for specific determination, and showing no surface-features, were obtained in sandstone rocks from Port Philomel (Halfway Cove), West Falkland. The fragments are superficially at least very similar to some specimens of Arthrostigma from Norway and of Protolepidodendron from Bohemia, as also to the later Cyclostigmas. Not improbably the fossils are fragments of some Lepidodendroid plant similar to examples discovered by Halle in the Falkland Islands. A few traces of Lepidodendroid plants were collected in sandstone on the north side of Port Purvis (Purvis Rincon), West Falkland, probably at a higher horizon in the pre-Gondwana Series. Halle obtained plant-remains from Halfway Cove agreeing closely with these specimens. Stems such as these have been described from several parts of Gondwanaland, both from Permo-Carboniferous and from older rocks. Some of the specimens of Bothrodendron irregulare Schwarz (which would be more appropriately included in the genus Cyclostigma) from the Witteberg

Beds of South Africa, bear, on the whole, the closest resemblance to the plant-remains from Port Purvis. The geological age of the Witteberg Series can hardly be determined with precision on the meagre palæobotanical evidence available. Summing up the slender evidence, Professor Seward is disposed to consider that the balance of probability is in favour of assigning the scanty relics of the oldest vegetation of the Falkland Islands to a Devonian flora, probably a Middle rather than an Upper Devonian flora.

The beds tend to become coarser, more reddish and quartzitic in the upper part, but thin shale-beds are frequent throughout their thickness. Beyond the scanty plant-remains no other fossils were found in these beds, neither did I detect the presence of Spirophyton, which occurs in the corresponding beds of the Cape Province.

The upper quartzitic sandstone of these beds is the most conspicuous rock in the Falkland Islands. It is well seen around Port Stanley in the gaunt, barren ridges whose presence does much to chill the optimism of the stranger arriving at these inhospitable-looking shores. All the main ranges are composed of it, these latter being in the form of what appear at first sight to be simple ridge-folds separated by equally simple troughs, although a closer inspection shows that the character of the folding is complicated in consequence of the occurrence of a good deal of isoclinal overfolding.

4.—GONDWANA ROCKS.

The geological survey definitely established the fact, first announced by Halle, that rocks younger in age than the uppermost quartzitic sandstones of the Devono-Carboniferous Series occupy the whole of the southern part of East Falkland. They also form a long coastal strip on the east coast of West Falkland, and a number of separate, isolated outliers in the northern part of West Falkland. The survey proved that these younger rocks comprise a thickness of strata exceeding 11,000 feet—a total greater than might have been expected from the general appearance of the country occupied by their outcrop. The lowest beds of this younger series consist of undoubted glacial boulder-beds, comparable in every way with the corresponding beds of the same age in South Africa, Australia and India. These lowest beds are about as thick as their representatives in South Africa. They are succeeded by a sandstone formation of no great thickness, which is followed by a series of beds composed of alternations of sandy and clayey rocks. This third and uppermost set of beds consists of more than 9,000 feet of strata in which it is apparently impossible to effect any subdivisional grouping on lithological grounds. This monotonous series occupies the whole of Lafonia (the southern part of East Falkland) but is entirely absent from West Falkland, save for insignificant traces on the extreme edge of the east coast of that island. The Permo-Carboniferous Beds of West Falkland otherwise comprise only the lower glacial boulder-beds (tillite), with (sometimes) the succeeding sandstone formation.

Owing to the isoclinal folding to which the lower members of this younger series of rocks have been subjected, it is difficult to gain any accurate idea of the thickness of the beds. Three sets of observations of the dip of the lower glacial boulder-beds (as inferred from that of the beds above and below, the boulder-beds having no clearly-marked bedding-planes) and the breadth of their outcrop on the east coast of West Falkland gave respectively 2,300, 2,500 and 2,800 feet as the apparent thickness of this deposit, but even in this area there is evidence of subsidiary isoclinal folding. Another determination of the thickness of the glacial boulder-beds, made at Port Sussex, East Falkland, gave 2,300 feet. I find that 2,300 feet is the figure given for the thickness of the Dwyka Series in Cape Colony. Taking the whole of my observations as a basis, I put the thickness of these beds, including the slaty beds immediately overlying them, and the locally-occurring shaly beds below, at 2,150 feet.

There is no definite series of shaly beds at the base of the glacial boulder-beds as there is in South Africa. In a few places I saw the actual junction of the boulder-bearing formation with the older quartzitic sandstones and there were no intervening shaly beds. In other places, however, I saw, rarely, shaly beds in the lower part of the glacial formation, so that, apparently, impersistent lenticular shaly beds occur. The top of the boulder-bearing formation is, however, marked by a thin but definite bed of cherty shale or slate which I was able to trace for a considerable distance across East Falkland, from Island Harbour, beyond Black Rock, to Shepherd's Brook, Port Sussex.

The succeeding sandstone formation (Lafonian Sandstone) does not appear to possess any great thickness and presents no features of special interest. I detected no fossils in it. I put its thickness at 300 feet.

An old boundary wall, built, I believe, by the Gauchos, consisting of stacked turf-sods overgrown by whinbush, runs from Brenton Loch, at the place called the Boca, to Darwin Settlement. The whole of East Falkland south of this boundary wall is known as Lafonia. The whole area of Lafonia, including the islands around it, is composed of the thick series of alternating sandstones and shaly rocks. This series contains fossil plants belonging to the Glossopteris Flora, and I was able to secure specimens of these plants at various localities.

To the glacial boulder-beds at the base of the Permo-Carboniferous Series in the Falklands the name " Lafonian Tillite " was given by Halle. In East Falkland the tillite forms a continuous belt of country stretching east and west on the southern side of the Wickham Heights, from the head of Port Harriet to the coast north and west of Port Sussex. In the eastern portion of the tillite belt, from Port Harriet to Mount Pleasant, the folding to which the district has been subjected has caused the tillite outcrop to be interrupted by parallel ridges of the underlying quartzitic sandstone, these ridges being easterly spurs from the main mass of the Wickham Heights. Port Fitzroy is bounded, north and south, by two such ridges, the intervening trough being occupied by the tillite, through the outcrop of which the Fitzroy River has cut its valley. Fitzroy Basin (Bluff Cove), North Basin and Port Harriet have similarly resulted from erosion of the tillite lying in a long east and west trough between parallel folds of the underlying quartzitic rocks. In this eastern area the southerly limit of the tillite occurs at Island Harbour and Pleasant Road. From Mount Pleasant to Port Sussex the tillite outcrop forms one continuous belt of country uninterrupted by any breaking through of the underlying rocks, although the effects of the folding are to be seen in the repeated and monotonous recurrence of low ridges of the tillite, usually exhibiting, on their crests, small exposures of the very characteristic rock, always affected by a strong vertical cleavage with a general east and west strike. The tillite reaches its steepest inclination, and shows its narrowest outcrop, on the east coast of West Falkland, and as this region is approached, the dip of the formation steadily increases, so that its outcrop gradually decreases in width. In the west of East Falkland the whole outcrop of the tillite occurs within the narrow area, about three-quarters of a mile wide, between the northern shore of Port Sussex and the foot of the quartzitic hills, whereas in the east the outcrop (though interrupted by the breaking-through of three ridges of the rocks beneath) extends from Port Harriet to Pleasant Road.

In the features which it presents, the Lafonian Tillite is in every way comparable with the Dwyka Tillite of South Africa. It is a rock typically bluish or greenish in colour, compact and fine-grained. (*See* Fig. 5.) In the Falklands it shows local variations due to the amount of induration to which it has been subjected and the extent to which it has been weathered. In some places, as at Cerritos, in East Falkland, it is an intensely hard, blue-black rock which rings under the hammer. In other places, as at Port Purvis and Hill Cove, West Falkland, it is mostly seen as a badly-weathered, brown, clayey mass crowded with erratic boulders. Wherever it occurs, however, it is at once recognised by certain very characteristic features. Its inclusions range in size from small angular particles to worn boulders some feet in diameter. The included rock-boulders show great variety in composition. Granite, gneiss and quartz-porphyry are common, and the rocks occurring in the Archæan series of Cape Meredith are generally to be noted in any exposure of the tillite, together with many types not seen in that area. Sandstones, quartzites, black slates, diabases and sometimes masses of conglomerate composed of rounded pebbles of quartzitic sandstone set in a ferruginous matrix, occur as boulders. Many of the boulders show one or more striated flattened faces giving a roughly facetted form to the pebbles, produced as the result of ice-action. The quartzitic rocks upon which the tillite rests also show in some places (*e.g.*, Port Purvis and west of Hill Cove) the characteristic smooth and striated surface associated with glaciation. The striations run north and south and I infer that the general movement of the ice was northward. The tillite shows no planes of bedding, so that its dip can only be inferred from that of the underlying quartzite and overlying Lafonian Sandstone. It almost invariably shows a strong vertical cleavage, produced, after its deposition, as the result of the movements which folded the country. This cleavage runs parallel to the strike of the beds. A curious effect produced by it is that of regular and close jointing in the included boulders, so that often these latter fall to pieces at a tap of the hammer. The joint-planes in the boulders do not continue into the matrix. An interesting feature at Hill Cove, West Falkland, is the occurrence, in the tillite, of a lenticular seam of quartzitic sandstone which, where it adjoins the tillite, contains erratic boulders such as occur in the latter. It is the presence of this seam which gives rise to the promontory north-east of the settlement, at the eastern point of which the Hill Cove jetty is built.

The southerly limit of the tillite outcrop in East Falkland is marked by one of the many low but continuous ridges which run across the country in a direction which veers from E.—W. in the eastern part of the island to N.W.—S.E. in the western part. The ridge referred to is composed of black to greyish-black cherty slate, and the name "Black Rock," given to one of the shepherds' houses which stands on this ridge between Mount Pleasant and Darwin, evidently refers to the rock of which the ridge is composed.

The Lafonian Sandstone, which succeeds the tillite, is a fairly fine-grained, uniform, soft, rather thin-bedded brown sandstone. It is much concealed beneath the "camp" vegetation, exposures being singularly rare and unsatisfactory. It has, like the tillite, been very much crushed and broken by lateral pressure from north and south, which has caused isoclinal folding. This fact, together with the unsatisfactory nature of its exposure, makes it very difficult to form any accurate idea of its thickness which I put at about 300 feet.

In its lower part it occasionally contains included fragments and small boulders of igneous and other erratics, such as are found in abundance in the underlying tillite. At Port Sussex, and at the head of Swan Inlet, the base of the Lafonian Sandstone shows finer-grained, silty rocks, with a somewhat pale bluish or greenish tinge. These beds are obviously passage-beds from the upper cherty slate of the tillite. In its upper part the Lafonian Sandstone shows a very interesting passage from typical sandstones into striped silty rocks ("varve" rocks), which show a banded appearance on fracture-edges due to the alternation of darker and lighter coloured zones. Halle compared these rocks with the seasonally laminated clays produced in other areas during much later glacial epochs. He regarded them as having been deposited in a large fresh-water basin. The typical sandstones and "varve" rocks alternate repeatedly. The transformation from sandstone to striped siltstone is completed within the thickness of a few feet of strata and the lowest horizon at which the change takes place affords a useful geological boundary which I mapped as representing the upper limit of the true Lafonian Sandstone.

The occurrence of the striped or banded siltstone is responsible, in a very remarkable degree, for the existence of Choiseul Sound and Brenton Loch. This rock weathers very badly and in the capricious climate of the Falkland Islands disintegrates with great rapidity. It splits readily along the numerous and closely-packed bedding-planes and also, after a little exposure, along the parallel planes separating the darker and lighter coloured layers. The thin laminæ readily break up under weathering and soon crumble to a dirty greyish silt or coarse clay. The great inlets of Choiseul Sound and Brenton Loch occur at the outcrop of this feebly-resisting stratum, and the sea has made such inroads upon it that now only a fringe of it remains, bordering the northern and southern shores of these arms of the sea. Were it not for thrust-faulting in the neighbourhood of Darwin Settlement, which has displaced the siltstone and substituted therefor more resistant rocks, Lafonia would be an island to-day.

The small islands in Choiseul Sound are composed of much-fractured sandstone, usually with a beach fringe of striped siltstone. They appear to be remnants of more resistant sandstone seams between the softer rocks, although isoclinal folding may have played a part in their formation.

On the southern side of Brenton Loch and Choiseul Sound the land maintains its undulating aspect of ridges and troughs for some distance southward, leading one to suspect the continuance of isoclinal folding, but I did not obtain sufficient field-evidence to determine the southerly limit of the fold-belt with precision. The lower part of Bodie Inlet and the northern half of Lively Island lie within the fold-belt, and it is probable that no overfolding occurs south of a line passing through or near the head of Bodie Inlet, midway between Choiseul Sound and Low Bay, and across the middle of Lively Island.

Owing to the alternation of sandstones with striped siltstones throughout a considerable thickness of strata, and the fact that northern Lafonia has been affected by isoclinal folding, the belt of East Falkland around Choiseul Sound and Brenton Loch shows alternating, parallel outcrops of the two rock types, both on the north and the south of these two inlets. Some distance to the southward, however, the "varve" rocks disappear and the sandstones alternate with more normal shaly rocks.

The whole of the remainder of Lafonia, as well as the islands around it, is an area occupied by a thick series of alternating sandstones and shaly rocks. In spite of their thickness I could discover no lithological differentiation at any horizon sufficiently marked to afford a boundary for geological mapping. Satisfactory sections of these rocks are of rare occurrence, an exposed thickness of from 20 to 30 feet in any one section being very seldom exceeded, except in the case of the westerly dipping beds seen at the creeks along the western shore of Lafonia, between Dos Lomas and Danson Harbour.

The alternating beds of sandstone and claystone are of small individual thickness, both, in general, being seen in the usual insignificant section of a few feet. The sandstone beds in the series show little variation from bottom to top, the common rock being a brown to grey fairly soft sandstone of medium grain, physically indistinguishable from the Lafonian Sandstone of the main mass. A very fine-grained and intensely hard greenish sandstone also occurs however, in the lower part of the series, and around Darwin and Walker Creek yielded specimens of the Glossopteris Flora. The argillaceous beds show rather more variation, ranging in colour from brown, yellow or grey, to green, and in constitution from almost a fine-grained sandstone to compact mudstones, laminated shaly rocks and sometimes typical slates. The finer-grained laminated varieties contain the best specimens of the Glossopteris Flora.

Over a wide area in Lafonia these rocks are either gently dipping or quite horizontal.

Much of the interior of Lafonia consists of gently-undulating, frequently boggy land, covered with rough, coarse grass, over which one rides mile after mile without seeing even the most insignificant exposure to afford a clue to the nature of the rocks beneath. Occasionally a little ravine, either dry or occupied by a small "arroyo," will show a small section in the Upper Lafonian Beds, but the only adequate sections are those exposed in the sides of the creeks on the western side of Lafonia, from Dos Lomas to Danson Harbour. Here the beds are seen dipping in an unexpected direction, namely, to the W.N.W., at an angle which varies slightly but is about 12 degrees on the average. The Lafonian portion of Falkland Sound therefore constitutes a very fine example of a syncline. The Lower Lafonian Beds of the coastal strip on the opposite side of the Sound dip very steeply to the E.S.E. (*See* Section.)

Inland from the west coast of Lafonia the rocks are concealed beneath grass and peat-covered "camp," but here and there I observed a rare and insignificant section, and was surprised to note the continuance of the west-north-westerly dip of about 12 degrees for several miles inland. Somewhere between the west coast and the Bay of Harbours this dip must flatten out, however, for around the latter place there is a faint trend of the strata to the S.S.E. The country in a line between Danson Harbour and Darwin Harbour consists of nothing but soft peat-flats and ponds. There are no rocks to be seen over this tract, but this must be about where the dip flattens out before becoming reversed in direction. It would appear, therefore, that this upper series of alternating sandstones and shaly rocks must possess a thickness of at least 8,000 feet.

On Speedwell, George and Barren Islands the strata are horizontal, save from slight local disturbances. Around Adventure Sound the rocks are practically horizontal, and on Bleaker Island absolutely so. Around Bull Cove and Fanny Cove there is a very faint dip to the N. In these circumstances it would appear that the very highest Lafonian Beds occur on the islands in Falkland Sound.

I had thought it possible that Speedwell Island or George Island might show Lower Lafonian rocks, perhaps the tillite, but the strata there are well up in the Lafonian succession. This shows that the south-westerly limit of the Permo-Carboniferous Beds lies well to the west of those islands.

The Upper Lafonian Beds yielded fossil plants belonging to the Glossopteris Flora at several horizons in different localities in East Falkland (Lafonia). These fossils have been examined by Professor Seward, and I give here a summary of his report upon them. The detailed report is published in the Quarterly Journal of the Geological Society of London (Vol. LXXIX., 1922, pp. 313-333), to which reference may be made for fuller particulars. Among the specimens from North Arm (Bay of Harbours) were a number which bore a superficial resemblance to bulbous stems. These Professor Seward regards as rock-structures, although specimens of similar type were described some years ago as fossil seeds. Dealing with the numerous specimens of Equisetaceous stems in the collection, Professor Seward states that in the absence of fairly well-preserved leaves, it is impossible to distinguish with confidence between stems of Phyllotheca, Schizoneura, Neocalamites and Equisetites, but he believes that several of the specimens bore leaves of the Phyllotheca type, although no complete leaf-sheaths were to be seen. On the other hand he has no doubt that some of the specimens of Equisetaceous stems cannot be included in the genus Phyllotheca. Professor Seward identifies Phyllotheca australis from George Island and other localities. With regard to the numerous specimens of Glossopteris leaves, he states that a thoroughly satisfactory determination and specific separation is a hopeless task. Most of the specimens belong to Glossopteris indica Schimper, whilst a fairly large number agree more closely with the nearly allied type G. Browniana Brongniart. These two species cannot always be distinguished with confidence and the determinations must be, to some extent at least, provisional. Halle recorded Glossopteris angustifolia Brongniart from the southernmost point of Speedwell Island and Bodie Creek Head, and Glossopteris damudica Feistmantel from Dos Lomas. Professor Seward states that in the collection are several narrow Glossopteris leaves identical in form with G. angustifolia Brongniart as figured by Halle from the Falkland Islands, and by other authors from different localities. These narrow leaves were collected at the southernmost point of Speedwell Island, but as none of them show a type of venation identical with that figured by Dr. Halle as characteristic of G. angustifolia, and as there occur specimens illustrating a complete transition between spatulate and more linear examples, Professor Seward does not adopt Brongniart's specific name. Also in the collection are some specimens from Dos Lomas which, although they approach G. damudica in the character of their venation, cannot be clearly distinguished in this respect as specifically distinct from G. indica.

There is one interesting specimen of Glossopteris indica Schimper in the collection which Professor Seward compares with G. indica Schimper, var. Wilsoni, discovered in Antarctica by Dr. Wilson, 300 miles from the South Pole.

It is interesting to note that Professor Seward finds no example of Gangamopteris in the collection, although a type which he refers to as Glossopteris indica Schimper, cf. G. decipiens Feistmantel is described as intermediate in venation between Glossopteris and Gangamopteris. He states that it is tempting to interpret the variation from the more typical G. indica type in the direction of Gangamopteris as evidence of greater antiquity, and is inclined to assign to the beds at North Arm containing this intermediate type of leaf, a position below that of the beds containing the more typical examples of G. indica.

Some of the specimens in the collection, from George Island and the Bay of Harbours, are stated to be clearly identical with that figured by Halle, from Dos Lomas, as Gangamopteris cyclopteroides var. major Feistmantel, but

Professor Seward prefers to group them under Glossopteris Browniana Brongniart and to consider that Gangamopteris has not yet been discovered in the Falkland Islands. Leaves showing the characters of Glossopteris Browniana Brongniart have been recognised in the collection in specimens from several localities.

Some interesting specimens in the collection from Cygnet Harbour and Egg Harbour are compared with Neocalamites Carrerei Zeiller, and a very close resemblance noted between them and a Rhætic species from Tongking, a species from the Molteno beds (Upper Karroo, probably Upper Triassic in age) of South Africa, another from strata in China considered to be of Rhætic age, and a fourth from the Permian rocks of the Petchora district. On this evidence Professor Seward is disposed to assign the beds at Cygnet Harbour and Egg Harbour to a slightly higher position in the Gondwana System than the other plant-bearing strata.

Silicified wood, from Walker Creek and Fanny Cove, which is described under the heading of Dadoxylon Bakeri, sp. nov., while not in itself furnishing a trustworthy criterion of geological age, as stems of the same general type range from Devonian to Upper Triassic horizons, is nevertheless regarded as bearing the closest resemblance to stems from the Barakar (Damuda) Beds of India and the Ecca Series of South Africa.

Professor Seward concludes that, excluding the possible representatives of Neocalamites, the flora as a whole is indicative of a position in the Lower Gondwana System, but not in the lowest part thereof. This opinion is based partly upon the absence of undoubted Gangamopteris leaves, and in part on the resemblance of the Falkland plants to those recorded from India, South Africa, and other parts of Gondwanaland. He is inclined to regard the Falkland flora as homotaxial with the Damuda and Beaufort floras of Gondwanaland, the Permian of Angaraland, and Permian rocks in the Northern Hemisphere, while the beds at North Arm may be somewhat older and those at Cygnet Harbour and Egg Harbour somewhat younger.

I am in agreement with Professor Seward as to the beds at Cygnet Harbour and Egg Harbour representing a higher horizon than those at North Arm. The fossiliferous beds at Dos Lomas, Egg Harbour and Cygnet Harbour occur on the same line of strike, all at sea-level, in an area where there is a very constant dip of the rocks at about 12 degrees W.N.W. Consequently these three localities exhibit practically the same geological horizon. This dip is maintained inland, to the eastward, for a considerable distance before the rocks flatten out prior to taking on (which they do only locally) a very gentle dip in the reverse direction. Hence the North Arm beds would represent a lower geological horizon The fossil Neocalamites Carrerei Zeiller occurs in the Molteno Beds of Cape Colony, which are of Upper Triassic or Rhætic age. These Molteno Beds present a peculiar feature in the occurrence in them of smooth rounded or oval pebbles which range in size from a few inches across up to boulders a couple of feet in diameter. They are specially abundant along a certain horizon and form a bed of conglomerate a few feet in thickness. The pebbles are almost entirely of quartzite. The section at Dos Lomas creek showed the same feature, this being the only locality in which I observed it. Here many rounded boulders, up to and exceeding a foot in diameter, of intensely hard siliceous sandstone or quartzite, were found imbedded in greenish-grey claystones. The section also showed thin sandstone beds intercalated with the claystones. The horizon of these beds must be practically the same as that seen at Egg Harbour and Cygnet Harbour. But, in company with other fossils, Glossopteris Browniana Brongniart was found to occur at Dos Lomas. Now this species is one which is not known to survive the Permian. Consequently if the beds at Dos Lomas, Egg Harbour and Cygnet Harbour are of Upper Karroo age they are probably but very little above the base of that series. The highest Karroo Beds seen in the Falklands occur on the islands in, and along the east coastal fringe of, Falkland Sound, and about 7,000 feet of sandstones and shales, quite similar lithologically to the beds which yielded Neocalamites Carrerei Zeiller overlie the latter. It is unfortunate that I did not discover any plant-remains in these highest beds as it appears likely that they constitute a good development of the Mesozoic Karroo Beds. It is to be observed, however, that the exposed area occupied by these Upper Karroo Beds is of very limited extent, consisting merely of an extremely narrow coastal fringe along the western border of Lafonia and the small uninhabited islands in Falkland Sound.

In West Falkland the Upper Lafonian Beds do not occur, save for an extremely narrow strip along the shore from Port Howard to southward of Hill Gap. Here they are seen to be very highly inclined, dipping 75 degrees to the E.S.E. At all other exposures of Permo-Carboniferous beds in West Falkland, only the tillite occurs, except on the southern side of Port Purvis, where the tillite is succeeded by the lower portion of the Lafonian Sandstone.

Illustrations of the fossil plants collected by myself from the rocks of Gondwana age in the Falkland Islands are published in Professor Seward's paper in the Quarterly Journal of the Geological Society of London. One example only—a characteristic frond of Glossopteris indica Schimper cf. G. decipiens Feistmantel, from North Arm, Bay of Harbours—is reproduced here. (*See* Fig. 8.)

5. REMARKS ON THE CORRELATION OF THE (STRATIFIED) GONDWANA ROCKS OF THE PRINCIPAL AREAS.

The deposits of terrestrial and freshwater type, often of great thickness, occurring in many widely-separated areas in the Southern Hemisphere, and elsewhere, which were formed in late Palæozoic and early Mesozoic times, and which show abundant evidence of glacial conditions associated with the rise, development and spread of the important Glossopteris flora, offer for solution some of the most interesting and difficult problems of present-day geology. A great initial difficulty is the problem of establishing a satisfactory age-correlation between the series of these rocks as developed in different areas. The setting-in of glacial conditions is almost always marked, where these strata have been formed, by boulder-bearing deposits (tillite) of variable, but often great, thickness. If it were the case that these latter deposits were everywhere contemporaneous they would afford a fundamental datum and the matter of the age-correlation of the succeeding beds would be a simple one. It appears to be capable of demonstration, however, at least in certain regions, that the tillite of any one area is not strictly of the same age throughout that area, and consequently the difference in age presumably increases considerably from area to area, when these are widely remote. Other evidence, from various sources, is available, and the whole has been, and is being, called upon to assist in solving the problem. Each class of contributory evidence offers its own difficulties, however, so that for the age-correlation of these strata, which occur to-day in widely-separated areas, the geologist relies upon the sum-total of the evidence available from all these sources, no one of which would of itself be entirely adequate to settle the matter. For example, vulcanism was rife during the formation of these rocks. In the south-east Australian region igneous outbursts and intrusions occurred during the deposition of the Lower Marine Series, during that of the Greta Coal Measures, and towards the close of the deposition of the Upper Marine Series. In the Falkland Islands dolerite dykes pierce the whole series of terrestrial strata. In Argentina hypabyssal and volcanic rocks are associated with the red sandstones of the Sierras Pampeanas, sheets of porphyrite occur east of the Jachal River, in the Cerro Bola sheets of diabase, augite-porphyrite and melaphyre occur at two horizons, and in the Trapiche area andesites and augite-porphyrites occur at two horizons. In South Brazil the Serra Geral eruptives, 600 metres thick, consisting of amygdaloidal diabase and basaltic rocks, are associated with the São Bento Series of the Santa Catharina System. East of the Paraná River immense dykes and intercalations of augite-porphyrite occur. Basaltic rocks occur in the Amazonas and in São Paulo. Similar rocks occur in the south-east of Matto Grosso. In Cape Colony the Drakensburg Volcanics, 4,000 feet thick, occur associated with the Stormberg Series. In Peninsular India volcanic rocks are interbedded with the Rajmahal Series. Yet, in spite of this evidence of notably widespread igneous activity during the formation of the late Palæozoic and early Mesozoic terrestrial strata, the igneous rocks of themselves afford no conclusive age-criteria, and it is only from the combined evidence available from all sources that we infer that the igneous activity attained its maximum about the close of the Triassic period, or during Rhaetic times.

Again, the Beaufort Series of Cape Colony is predominantly characterised by the occurrence of a fauna of fossil vertebrates, and some of the forms occur in the Panchet Series of Peninsular India. Labyrinthodont remains have also been found in the Hawkesbury Series of New South Wales, and reptilian remains allied to some of those from the Upper Beaufort Beds occur in the Rio do Rasto red beds of the São Bento Series of the Santa Catharina System of Southern Brazil. Nevertheless, while the occurrence of such a fauna is suggestive evidence in favour of a correlation of the beds in which it occurs in the several areas, the meagre information available from the areas other than South Africa and India, and the uncertainty as to the time-allowance to be made for migration and dispersal of forms, renders this evidence too slender to be of itself a decisive factor in the age-correlation of the strata.

With regard to the very valuable evidence afforded by the fossil plants of the Glossopteris flora, probably the chief difficulty is that whilst many members of this flora show a wide range in space, their time-range is also great, so that the occurrence of these forms in the rocks does not afford criteria of the necessary order of exactitude for precise age-correlation. In these circumstances characteristic associations of groups of plants assumes a high degree of importance. At the stage to which the investigation of the whole problem has now proceeded, it appears exceedingly probable that the Glossopteris flora originated in a comparatively isolated southern botanical province, which was subsequently invaded by forms from the north. Consequently it becomes of importance to note the presence or absence of northern forms when studying the flora of any area of development of these late Palæozoic and early Mesozoic terrestrial rocks. According to the latest information available from the South American area, as put forward by Keidel, this invasion by northern forms occurred at an early stage of development of the Gondwana rocks, for a mixture of the true Glossopteris flora with northern types of Lepidodendron and Nœggerathiopsis is known from the Precordillera and the Sierra de los Llanos, where the strata are apparently of Talchir and Karharbari age.

Very important evidence is afforded by the occurrence of marino-glacial strata, wherein the material of the Permo-Carboniferous tillites, accumulated beneath, in, and on the glaciers and ice-sheets of the period, and transported by them, was carried somewhat beyond the confines of the ancient Gondwanaland and deposited in the sea bordering its coasts. Or, it may be that, in consequence of movements of submergence of the land, the encroaching sea carried its fauna to be deposited amid the glacial débris. This association of marine fossils with glacial deposits has been observed in the east, west and north of Australia, in Tasmania, on the northern border of India, on the western margin of South Africa, in south-east Brazil and in the Precordillera of western Argentina. If the age of the marine fossils could be definitely established as either Carboniferous or Permian this would fix the age of the associated glacial deposits, but there does not appear to be as yet any agreement amongst geologists on this point. Of late there appears to have been a tendency to assign the lowest glacial strata of the great terrestrial and freshwater series to a Carboniferous rather than a Permian horizon, but in a very recent and important communication, Keidel ("Sobre la Distribución de los Depósitos Glaciares del Pérmico conocidos en la Argentina y su significación para la estratigrafía de la serie de Gondwana y la Palæogeografía del hemisferio austral." Boletín de la Academia Nacional de Ciencias, Cordoba, Tomo 25, 1922, pp. 239-368) has presented strong evidence and arguments in favour of the view that there was a widespread marine transgression at the beginning of Permian times, and that the lowest beds of the glacial series are of Permian age. He states that in certain areas of the Precordillera of western Argentina, rocks of Lower Gondwana age are transgressive over older strata, including Carboniferous sediments, and that boulders of Carboniferous rocks can be seen in the tillite of the glacial series. Hence it does not yet appear to be possible to establish an altogether satisfactory scheme for the correlation of the rocks of Gondwana age which have been studied in widely separated areas of the world. The grouping adopted in the table given here is based upon the latest information known to me concerning these rocks. In grouping the Karroo Beds of Cape Colony I have followed Du Toit in regarding the Dwyka tillite and Upper Dwyka shales as Upper Carboniferous, the Ecca Series and Lower Beaufort Beds as Permian, the Upper Beaufort Beds as Lower Triassic, the Molteno and Red Beds of the Stormberg Series as Upper Triassic or Rhætic, and the Cave Sandstone and Volcanic Beds of the Stormberg Series also as possibly Rhætic. For the South Brazil and Argentina rocks I have followed the recent grouping given by Keidel. For the New South Wales rocks I have followed the latest views of Sir T. W. Edgeworth David, who regards the Lower Marine Series as partly Carboniferous and partly Permian in age. With regard to the grouping of the Falklands' Gondwana rocks I have been guided by Professor Seward's study of their fossil plants and his conclusions therefrom. Two considerations, however, have led me provisionally to regard the Lafonian Tillite as of Upper Carboniferous age. Although Professor Seward has stated that the flora of the Falklands' Gondwana rocks as a whole is indicative of a position in the Lower Gondwana System, but not in the lowest part thereof, and has suggested the correlation of the rocks with the Damuda and Beaufort, it is to be remembered that about 2,500 feet of lower strata of Gondwana age, most of which is tillite, occur beneath the series of the Falklands' Lafonian from which the fossil plants were obtained. Now the South African geologists consider, in view of the gradual diminution in thickness of the Dwyka Series towards the north, and the increasing gap in the succession below it, that a considerable thickness of the southern tillite must have been deposited before the northern tillite began to be laid down. In the light of the attractive hypothesis that the portions of Gondwanaland represented to-day by the Falkland Islands, south-eastern Brazil, and eastern and north-western Argentina, lay, in Permo-Carboniferous times, much nearer to South Africa, this view assumes a wider significance. Proceeding northwards from the Falklands' area a great and orderly decrease in thickness of the tillite is to be noted, accompanied by an increasing hiatus between it and the rocks upon which it rests. As has been stated, in the Falklands, the Lafonian tillite, with a thickness of 2,000 or more feet, rests upon rocks equivalent in age to the Witteberg Series of Cape Colony. In the Sierra de la Ventana, in eastern Argentina, the tillite has a thickness of not less than 60 metres, and probably much more. It contains boulders of limestone including fossils of Devonian age, suggesting that the fossiliferous Devonian rocks were exposed in the vicinity during its formation. In Santa Catharina the Orleans Conglomerate (tillite), together with the sandstones and shales which underlie it, attain a thickness of about 100 feet and rest upon Archæan granite. In the north-east of Paraná the thickness of the tillite sometimes reaches 10 metres, and the deposit rests upon the Tibagy Sandstones, which are crowded with the characteristic Lower Devonian fauna of the Bokkeveld Beds of Cape Colony. In the state of São Paulo the tillite is from 10 to 13 feet thick and rests upon Archæan gneiss. Consequently, if, as Keidel states, the tillite of Argentina and southern Brazil is of Permian age, there appear to be good grounds for supposing that part, at least, of the Lafonian tillite of the Falkland Islands is of somewhat greater age than this, and since the Dwyka of South Africa is regarded as of Upper Carboniferous age, it seems reasonable to correlate the Lafonian tillite of the Falklands with this deposit.

Correlation of the (Stratified) Gondwana Rocks of the Principal Areas.

	India (Peninsular).	South Africa (Cape Colony).	South Brazil.	Argentina (Western).	Falkland Islands.	Australia (New South Wales).
Jurassic	Rajmahal [Upper Gondwana]			Liassic plant-bearing beds of the Cordillera and Patagonia		
						Clarence
Triassic	Mahadeva [Upper Gondwana]	Stormberg [Upper Karroo]	São Bento [Santa Catharina System]	Marine Transgression		
				Rhætic [Riojan]	Upper Lafonian Series (upper part)	Wianamatta
	Panchet [Lower Gondwana]	Upper Beaufort [Middle Karroo]		Red Sandstones of Sierras Pampeanas [Riojan]		Hawkesbury
Permian	Raniganj [Damuda] [Lower Gondwana]	Middle Beaufort [Middle Karroo]	Rio Rasto [Santa Catharina System]		Upper Lafonian Series (lower part)	Upper or Newcastle Coal Measures
	Barakar [Damuda] [Lower Gondwana]	Lower Beaufort [Middle Karroo]	Passa Dois [Santa Catharina System]	Catuna [Riojan]		Dempsey Series
						Middle or Tomago Coal Measures
	Karharbari [Lower Gondwana]	Ecca [Lower Karroo]	Tubarão [Santa Catharina System]	Jejenes [Riojan]		Upper Marine Series
	Talchir [Lower Gondwana]		Itararé (marino-glacial in part) [Santa Catharina System]	Zonda and Tontal (marino-glacial) [Riojan]	Lafonian Sandstone	Lower or Greta Coal Measures
Upper Carboniferous		Dwyka [Lower Karroo]			Lafonian Tillite	Lower Marine Transition Beds (partly marine)

Note. ~~~~~~ signifies unconformity.

6. THE LATER INTRUSIVE ROCKS.

Both the Devono-Carboniferous and the Gondwana rocks in the Falkland Islands are pierced by igneous dykes. Both Andersson and Halle noted the presence of these intrusions and have given a description of the rocks. The date of these intrusions is clearly later than that of the deposition of the youngest Gondwana rocks now seen in the Islands. It is likely that they were a concomitant of the strong folding which affected this area at some period considerably subsequent to the Permo-Carboniferous glacial epoch. From the evidence afforded by the remarkably similar series of igneous rocks in Cape Colony it has been suggested that the latter rocks were intruded during the late Triassic or Jurassic Period and there is nothing in the evidence from the Falkland Islands to discountenance this idea.

The intrusions are all in the form of dykes and are much more numerous in West than East Falkland. On the former island I observed and mapped parts of the courses of a good number of dykes, noted a number of others whilst riding on occasions when I was unable to obtain bearings which would give their positions on the chart, and was also informed of others which I had no opportunity of seeing. These dykes are almost always seen as grass-covered ridges with boulder-strewn crests, traversing the "camp," sometimes quite low but rising on occasion to as much as 60 or 80 feet above the general level of the surrounding country. As a rule they are of remarkably constant width and often run in straight lines, or with only gentle sinuosities, for several miles. Some of them are of large size, being fully 100 yards wide. It is obvious, from the clearly-marked alignment of some of these dykes, that the several outcropping portions represent successive exposures of one and the same intrusion. It is clear, for instance, that a great dyke runs from near Fox Bay, west of the Hornby Mountains, to Port Purvis, a distance of between 30 and 40 miles, breaking surface at intervals. It is likely that this dyke gives off another arm, south of Mount Moody, which traverses the "centre camp" and crosses Golding Island to Pebble Island. Another long intrusion traverses the camp between Fox Bay and Port Edgar, makes in the direction of Mount Sulivan, afterwards crosses the Chartres River close to the settlement and runs parallel to the Teal River for some distance.

In East Falkland the dykes are not nearly so numerous and appear to be confined to the western side of the Island. They are seen between the head of Port Sussex and Brenton Loch, and an interesting example, which invades some of the highest Gondwana rocks in the Falklands, occurs between Egg Harbour and Cygnet Harbour.

The igneous rock of which the dykes are composed is remarkably uniform in appearance and all the intrusions evidently belong to the same period of igneous activity. The dykes show a well-marked radial disposition suggesting that the intrusions emanated from a common centre situated at the southern end of Falkland Sound, south of Fox Bay. In the neighbourhood of Falkland Sound, however, the trend of the dykes is clearly influenced by, and associated with, the strike of the rocks into which they are intruded, and this strike is equally clearly the result of the post-Permo-Carboniferous folding of the country.

The rock of which the dykes are composed is extremely hard, dark-coloured and heavy. It is blue-black when freshly broken, but weathers reddish or yellowish brown. It is evidently remarkably like the dyke-rocks of the same age which occur in Cape Colony. The chemical composition of the latter rocks has been given as follows:— Silica, 52·7; alumina, 11·4; ferric oxide, 9·0; ferrous oxide, 3·7; lime, 11·6; magnesia, 7·4; potash, 0·7; soda, 2·3; water, 1·4; total, 100·2. The average specific gravity of these Cape Colony dyke-rocks is very nearly 3·0. In view of the very close similarity of the Falkland dyke-rocks to the corresponding rocks of Cape Colony, chemical analyses of these rocks were not made. The specific gravity of a typical specimen of the dyke-rock from Fox Bay, West Falkland, was found to be 2·92.

An examination of microscope sections of a number of these rocks showed their close similarity to the corresponding rocks of Cape Colony. Rocks of this type are now called dolerites in this country. A variation in texture is discernible under the microscope. Some of the more holocrystalline types could be described as coarse diorites whilst the finer-grained examples, with lath-shaped felspars, are typical dolerites. The photomicrographs show the general character of the rocks and indicate the variation in texture. (*See* Figs, 1, 2, 4.)

The constituent minerals of these rocks are plagioclase felspar, often showing good lamellar twinning, augite, sometimes seen decomposing to a fibrous green mineral, olivine, more abundant in some examples than others, sometimes showing serpentinous alteration-products, and titaniferous iron-ore. Hornblende occurs, in varying quantity, and appears to be original. Quartz is absent and biotite remarkably rare.

The effects produced by the intrusion of these dykes into slightly carbonaceous shaly rocks will be referred to later.

7. REMARKS ON VARIOUS QUESTIONS.

(*a*) The Falkland Islands in relation to other areas.

In considering the structural features of an isolated archipelago like the Falkland Islands it is natural for the geologist to seek a reason for the existence of the area as land. This is not difficult in the present case. These islands owe their existence to folding movements. A set of somewhat meandering folds traverses the northern part of the islands in a general direction somewhat north of west and south of east, and are responsible for the formation of low mountain-ranges having this trend, the Wickham Heights being the most conspicuous example. Folding of other orientation occurs also, namely, along axes of N.N.E.—S.S.W. trend. The most important fold of this series skirts the east coast of West Falkland, for a considerable distance, on the inland side, in the neighbourhood of Falkland Sound. From White Rock Bay, in the north-east of West Falkland, to east of Fox Bay this fold is seen as a fine denuded anticlinal arch, its easterly limb being formed by the coastal ridge and its westerly limb by the Hornby Mountains. Falkland Sound is a fine syncline lying on the eastern flank of this fold. (*See* Section.)

Much of the land bordering the folded area of the islands is quite low, and a lowering of the general land-level by only a few fathoms would greatly alter the outline and diminish the area of the Islands. A lowering of the land, of less than 25 fathoms, would cause the complete disappearance of the whole of Lafonia and would completely submerge every vestige of Gondwana rocks in the Falklands, leaving exposed only the crests of the dominant ridges, more than ever accentuated by the elimination of the bordering fringes.

The folding of the Falkland Islands occurred at some time subsequent to the deposition of the youngest rocks now seen in the area, possibly about the close of Triassic times, although it may have been pre-Rhætic. No evidence has been detected to show whether there is any difference in age between the two sets of folding-movements, but a very noteworthy feature is the marked sympathy between the trend of the dolerite dykes and the N.N.E.—S.S.W. folding. The dykes often run parallel to the strike of these folds for miles and their intrusion was probably contemporaneous with, or immediately subsequent to this folding. In all probability the period of the igneous intrusions in the Falklands was that of the very similar intrusions in Cape Colony, which are themselves regarded as being of the same age as the Drakensburg Volcanic Beds. The latter are correlated with the Serra Geral eruptives of the São Bento Series of South Brazil, the volcanic rocks associated with the red sandstones of the Sierras Pampeanas of Argentina and the Triassic eruptives of Patagonia. The period of volcanic activity is now regarded as being at about the close of the Triassic, or during Rhætic times.

The folding of the Falkland Islands probably synchronised with that of the southern part of Cape Colony, and it seems noteworthy that in both areas folding took place in two strongly contrasted directions. The evidence of folding of the same age in north-western and eastern Argentina has been discussed by Keidel in a recent paper. He terms these movements "Gondwanides" and regards their age as Permian. The Patagonian area has also been studied very recently by Windhausen, who considers it possible to trace evidence indicative of folding-movements of Permian age throughout a belt of country of marked sinuosity extending from the Gulf of St. Matias to the south-eastern extremity of Tierra del Fuego. Windhausen groups these movements with the "Gondwanides" of Keidel, and considers that their operation resulted in the development of the "Cordillera Prepatagonica," an anticlinal axis which, in Mesozoic and Tertiary times, was subjected to posthumous movements which, in their turn, influenced the lithology and disposition of the later sediments.

Keidel states that where, in Patagonia, rocks come to the surface which, by their age and other circumstances can be regarded as belonging to the Gondwana Series, they are those of the continent of Gondwanaland itself such as it would have developed in Triassic times. Examples of these outcrops are offered by the porphyries and tuffs of the Bay of Camarones and the porphyries at the mouth of the River Deseado and other places. In the neighbourhood of St. Julian these rocks are associated with carbonaceous shales containing an Estheria, probably of Upper Triassic or Rhætic age. In such rocks Keidel found Estherias closely resembling E. Draperi Jon. of the Stormberg Series of Cape Colony. In the Rio Negro territory of Patagonia the Upper Triassic or Rhætic igneous rocks directly overlie the ancient granite and old, dislocated sediments in which no trace of Permian rocks has so far been observed.

Windhausen's attempt to trace the course of the movements which he, in common with Keidel, regards as Permian in age, is based upon the argument that any orogenic movement necessarily forms zones of weakness and of fracture, and in such zones, which are distinguished by a minor resistance, it is customary for effusive rocks which follow on the phase subsequent to the orogenic movement to reach the surface. Hence he considers the Triassic igneous rocks of Patagonia as directly linked with orogenic movement in Permian times and as being the effusive rocks which characterised the phase subsequent to the orogenic movement. He supposes the Triassic igneous rocks to lie on the belt of this folding and endeavours to explain certain peculiar features in the lithology and arrangement of the later Mesozoic and Tertiary rocks of eastern Patagonia as being due to posthumous disturbances along the fold-belt.

Taking all the evidence into consideration it would appear that we may group the set of movements (Gondwanides) which folded the frontier-country of the Brasilia of Keidel on its southern and western sides with the Patagonian folds discussed by Windhausen, the folds of the Falkland Islands and those of the southern part of Cape Colony. Keidel and Windhausen have taken the age of this folding to be Permian, but on the balance of evidence it appears more likely that its age is late Triassic.

Keidel and Windhausen regard the great granitic mass of Chubut, between the Rio Negro and the Rio Chubut, in Patagonia, together with an apparently similar mass farther south in Santa Cruz, between the Rio Deseado and the Rio Chico, and the granitic basement rocks of the Falkland Islands as integral portions of the crystalline nucleus of the continental complex of Patagonian Gondwanaland. Keidel unites this region, through Antarctica, with Australia, to form an area of Gondwanaland encircling the South Pole, and unites further, as a distinct entity, his area of Brasilia, through Africa, with eastern India, to form a more northerly portion of Gondwanaland, constituting the equatorial belt of Suess.

In considering briefly the structural relations between the Falkland Islands and other areas, attention will be confined to the South American and South African regions, as any further extension of the enquiry would lead beyond the scope of the present report.

Looking upon the Falkland Islands as a portion of Patagonian Gondwanaland in Permo-Carboniferous times, they appear as an area lying near the northern shore-line of a land-mass composed of an Archæan crystalline nucleus flanked on its northern side by Devonian or Devono-Carboniferous sediments. There is no evidence to show how far this land-mass extended towards the south, but it probably stretched for a great distance and was possibly connected with Antarctica. This view is suggested by the great thickness of the tillite in the Falkland Islands. All the evidence is in accordance with the view that the movement of the ice was towards the north. The easterly extension of the land-mass is unknown, but to the west and north-west it appears to have extended to the Santa Cruz and Rio Negro areas of Patagonia. After the deposition of the tillite in the Falklands area the formation of fresh-water sandy and shaly beds appears to have gone on steadily until towards the end of the Triassic period, but in the Patagonian region only old dislocated sediments of unknown age are known to occur between the ancient granitic rocks and eruptives and sediments of Upper Triassic or Rhætic age. A stretch of sea separated Patagonian Gondwanaland from the land-mass of Brasilia to the north. This area must have embraced south-east Brazil, Uruguay, Paraguay, northern Argentina and Bolivia. Like the more southerly land-mass it was a complex consisting of an ancient crystalline nucleus bordered by Palæozoic sediments, though in this case the latter ranged in age from Cambrian to Carboniferous. The Pampean sierras of western Argentina appear to have been a centre of dispersal of the ice, which seems to have moved radially outwards from this area. To the eastward, however, the sea extended into Paraná, for marine fossils have been found in this area associated with the tillite. The direction of the ice-movement here is an open question, for the numerous boulders of granite and gneiss occurring in the tillite may have come either from the belt of Archæan along the Atlantic coast or from the similar Archæan masses farther west. In the southern sierras of Buenos Aires the tillite forms a belt of considerable extent, the sea apparently lay to the southward, and the ice-movement was presumably seawards. In the South African area the Gondwana land-mass lay to the north, the tillite thickens southwards, the ice-movement was in a general southerly direction, and the sea lay to the south.

When we consider the state of affairs in Permo-Carboniferous times in the Patagonia—Falklands, Brasilia and South African areas in the light of the recent speculations of Wegener concerning the drifting of continental masses, the data appear to be in concord and capable of a simple interpretation. According to Wegener, the continental masses are patches of lighter rock (Sial), floating and moving in a layer of denser rock (Sima), of unknown thickness. On his theory, known as the displacement theory, North and South America were, in Mesozoic times, continuous with Europe and Africa. They then broke away and moved westwards in Tertiary times, the Andes being forced up by pressure on the forward edge of the drifting continent.

Applying the displacement theory to the present data, we suppose that in Permo-Carboniferous times Brasilia lay adjacent to western Africa, the southern part of Cape Colony was continued westwards as the southern sierras of Buenos Aires, and the Patagonia—Falklands land-mass lay to the south, being separated by a stretch of sea from Brasilia—Africa Gondwanaland. The movement of the ice was towards this sea. Late in Triassic times the pressure which was eventually to disrupt Gondwanaland produced notable effects. The frontier-countries of the Gondwana land-masses, surrounded by resistant crystalline nuclei, yielded to strong lateral pressure from north and south, being crushed between an equatorial belt on the north (which was subsiding and extending itself laterally in consequence of the reduction of the equatorial bulge engendered by the slackening of the earth's speed of rotation), and a resistant Antarctic continent. The Gondwanides, skirting the west and south of Brasilia, were developed. The folds of southern Cape Colony appeared. The northern half of the Falkland Islands was corrugated by east and west folds. Under the pressure the South American area commenced to drift westward. The Atlantic rift was initiated, or if already in existence, was broadened. Differential shearing ensued, the uppermost and lightest layers of the Sial, consisting of the later Palæozoic and Gondwana deposits, developing a more rapid drift than the crystalline nuclei which they flank. The N.N.E.-S.S.W. folding of the Falkland Islands developed as the upper layers were sheared across an impeding edge of the crystalline rocks beneath. The folds in the Patagonian Gondwana strata were diverted as they encountered projecting masses of the ancient rocks. A temporary release of the pressure was marked by a great and general appearance of eruptive rocks, and the resultant lowering of level led to a widespread unconformable overlap of Upper Triassic or Rhætic rocks. In the Falklands area this was not very marked. Although numerous dolerite dykes were intruded into the Devonian and Gondwana rocks, there was no great development of eruptives, and the deposition of strata of Triassic age appears to have followed that of older Gondwana rocks in a normal manner. In Patagonia, however, Estheria-bearing Upper Triassic or Rhætic strata, together with effusives, appear to rest upon the ancient granitic rocks. Again, in the Sierras Pampeanas of north-west Argentina the red sandstones of the Triassic rest unconformably on Lower Gondwana rocks, and in the southern extremity of the sierras of Umango, Famatina and Velasco transgress on to the ancient gneiss and granite. In the sierras of Cordoba and San Luis the basal layers of the Gondwanas have not been discovered, and it is very probable that they do not exist there, either through non-deposition or denudation prior to the formation of the upper stages. Gondwana strata are unknown in the region of the provinces of Tucuman and Catamarca. In Uruguay the Passa Dois Series of the Permian is represented in the east and north-east, but in the west and south these beds are overlapped by the upper layers of Triassic age, which eventually come to rest on the old crystalline basement rocks. In southern Brazil the movement of submergence carried the elevated gneiss and granite areas which rise so sharply along the coast between Rio de Janeiro and Florianopolis to a lower level and completed the severance of Brasilia from Africa. The Triassic São Bento Series transgressed the limits of the underlying rocks, both eastward and westward, and in northern São Paulo they are seen resting directly upon the old crystalline gneisses and quartzites.

In the South African area there is a general thinning-out of each of the subdivisions of the Karroo System (with the exception of the Middle Ecca Beds) from the Stormberg region north-east to the Transvaal border. Over the entire Transvaal the thickness of the Karroo Beds is only one-fifth to one-tenth of that in the Cape Province, and this is due in great part to a double overlap and to stratigraphical breaks. Though the Upper Karroo (Upper Triassic and Rhætic) is certainly developed, it is questionable if the Middle Karroo (Permian and Lower Triassic) is present. The folding in the southern parts was produced by a thrust from the south against the block of old rocks, the beds being thrown into a series of parallel folds, and the anticlines being sometimes overturned towards the north and the overthrust faults dipping to the south. Great strike-faults, running east and west on the south side of the most crumpled ranges have downthrows reaching at least 10,000 feet. One such great fault is known to be of Triassic or early Jurassic age.

Since there are no rocks younger than Triassic in the Falkland Islands, we have now pursued the geological history of the area, in its relation to contiguous areas, as far as may be.

The general conclusion to which one is led, as a result of the application of the speculations of Wegener to this particular problem is that the relinquishment of the concept of the general permanence of oceanic and continental areas will leave geologists free to utilise another which bids fair to go far in the attempt to solve many pressing problems in present-day geology.

A point of general interest which emerges is that, if we may now accept the drifting of continental masses as a concept which it is permissible to apply to the solution of geological problems, we may interpret a strongly-folded belt of country as the frontier-country or forward edge of a mass which was drifting at the time of the development of the folds. From this point of view it would appear that southern South America must have been drifting to the westward long before Tertiary times, as suggested by Wegener. The work of Keidel has shown that even as far back as during Permian times a great overthrusting towards the east occurred in the Argentine precordillera, which area was then the frontier-country of the Gondwanaland of Brasilia. Again, in inter-Cretaceous times the "Patagonides" were developed—a set of folds enwrapping the western sides of the great ancient granitic mass of Chubut, in Patagonia—the forward edge of the drifting Patagonian Gondwanaland. If we are to regard the great Tertiary folding of the Andes as evidence of a westerly drift, it is equally legitimate to consider the similar earlier folding as indicative of a westerly drift in earlier times.

A damaging criticism of the views of Wegener which has been put forward by Dr. Harold Jeffreys is that the physical causes that Wegener offers for the migrations of continents are entirely inadequate. Dr. Jeffreys has suggested that there is a quite adequate physical cause for such continental migration, if recourse is had to it, in the slowing-down of the earth's rate of rotation. This retardation would lead to a diminution of the earth's equatorial bulge, with a consequent equatorial contraction which would result in a force perfectly capable of splitting up continents.

I have utilised this idea in the present attempt to interpret the structural features of the Falkland Islands in relation to other areas, taking the view that this equatorial contraction would result in a tendency on the part of the equatorial continental masses to thrust themselves southward in the southern hemisphere and northward in the northern hemisphere. If in the southern hemisphere there existed, as I have supposed, a great Antarctic continental mass, the result would be a strong lateral pressure from north and south effecting compression in the intermediate latitudes and tending to initiate continental rifts and drifting to east and west.

A great geological stumbling-block is to account satisfactorily for the widespread evidences of severe glaciation in Permo-Carboniferous times, particularly in the southern hemisphere. It appears to have been Wegener's great hope that the concept of continental drift would finally clear away this long-standing difficulty. He has not, however, been able to show that the far-flung fragments of Gondwanaland have drifted from a latitude in which it is easy to recognise the possibility of their having undergone severe glaciation, and in his dilemma has not hesitated to have recourse to the drastic expedient of uprooting the South Pole and suggesting that it occupied a position in the vicinity of South Africa. Not only will many geologists view this seemingly unwarranted step with grave misgiving—it is one which will surely deter the half-convinced from a final acceptance of Wegener's ideas. Why must the pole be made to move towards the continents when the latter are free to drift in its direction? One cannot but feel that the conceptions of Wegener, valuable as they are, have effected but a partial solution of one of the most interesting and difficult problems of present-day geology—and it would appear that in all the discussion which has centred round the brilliant ideas assembled and clearly set forth for the first time by Wegener, one potent possibility has been overlooked—that of the effects of a former increased inclination of the earth's axis of rotation.

(*b*) Remarks on the "Stone-runs" of the Falkland Islands.

The "stone-runs" or "rivers of stone" of the Falkland Islands have been, in the past, the subject of some discussion. The problem of their origin has been dealt with, amongst others, by Sir C. Wyville Thomson, of the Challenger Expedition, and more recently by Professor J. G. Andersson. Wyville Thomson regarded the phenomenon as a product of present conditions but Andersson, whilst admitting that the process of stone-run formation can still be seen in operation in the Falklands at the present day, denies that it is still working with full effectiveness. He considers the phenomenon to be the result of "solifluction" and regards the material of the stone-runs as the cargo carried by "flowing soil" or "mud-glaciers"—semi-fluid masses moving downhill, and produced in summer-time during snow-melting. He considers the period of greatest activity of the process to be now past and to have been that of the Pleistocene ice-age.

After having seen a great deal of the Falkland stone-runs I find myself very largely in agreement with Professor Andersson, although I think that whilst flowing mud doubtless assisted considerably in the transport of the stones, it is questionable whether it was the most important agency in the formation of the stone-runs.

The stones are from the crests of the ridges composed of the quartzitic sandstone of the Devono-Carboniferous rocks. They are often of great size and are piled upon each other in the valley-bottoms in a tumbled manner, with great crevices between them and in many cases not a trace of soil either upon or between them. In other cases the stone-runs are seen to be almost entirely overgrown, and some are concealed beneath a covering of peat. The formation of the stone-runs now to be seen in the Falklands is not the aggregate result of a slow process which is still continuing. The stone-runs were all produced at one and the same time—a time now past, though not long past, in the geological sense—and one of no great geological duration. The stones are not far-travelled. They are composed of the same rock as that of the hill-tops of their immediate neighbourhood and are still angular. They must have proceeded to their present positions of rest with considerable velocity—in fact, they must have been tumbled thereto. One of the most striking facts about these stone-runs is the often extremely gentle gradient of the valley-bottoms in which they rest. No streams flowing down such slopes could, in the ordinary way, acquire velocity sufficient to have transported such great blocks to their present positions of rest. In seeking a time, not geologically remote, when existed conditions favourable to the accumulation of such masses of boulders in the valley-bottoms, the Pleistocene ice-age at once occurs to the mind of the geologist. In the absence of evidence to the contrary one assumes that the Falkland Islands must have existed then much as they do to-day—as a small, isolated group of islands. With the advent of glacial conditions the snow-line descended to sea-level and only the quartzite crests of the highest areas remained as "nunatakka" protruding through the universal ice-sheet. But the isolation of the area, its small size, and the nature of the surface undergoing glaciation led to the production of glacial phenomena of specialised type. No far-travelled rocks entered the area. The uniform character of the quartzitic sandstone rock undergoing glaciation led to similar uniformity in the character of the débris deposited. No great glaciers were formed. No tills, moraines, boulder-clays, glacial gravels, and so forth, were produced. No striated pavements or scored boulders were left as the evidence of moving ice. The "rivers of stone" simply represent the material accumulated in the valley-bottoms from the screes which formed as the result of frost-action upon the exposed "nunatakka." Blocks of stone, split off from the exposed ridges, slithered downwards over the icy surface and accumulated below. With the periodical melting of the snow and ice, the valley-bottoms were scored and deepened by the rushing torrents, and the blocks subsided, higgledy-piggledy, to their present resting-places, the later stages in their transportation, just prior to their final arrestment, being no doubt largely the work of mud-streams.

(*c*) Remarks on recent changes of level in the Falkland Islands.

There is no doubt whatever that in a great many places in the Falkland Islands there has been an elevation of the land in recent times. It would be a simple matter to accumulate, in a short time, an abundance of evidence to prove this. I have seen raised beaches, varying in height from place to place from a few feet to perhaps 50 feet above present sea-level. In some places perhaps several hundred yards inland I have seen old sea-cliffs with beach-débris at their bases. Islands, once separated, are to be seen to-day united by necks of land composed of beach material. Striking instances are to be noted where the heads of creeks are now cut off from the sea by barriers of stones, with the water on the inland side standing several feet above present sea-level. There are innumerable cases of shallow depressions, not far from the sea, which were once obviously the sites of ponds but which are now quite dry. It is fairly common, too, to encounter heavy beach-litter, such as parts of whale-skeletons, well inland and some height above present sea-level. The inhabitants can quote many evidences to show that the land has risen recently and appears to be still rising. On the other hand I found no evidence whatever of either a Quaternary submergence prior to this movement of elevation, or any subsequent submergence, such as Professor Andersson has referred to. I found myself unable to recognise in any of the numerous creeks of the Islands, any clearly-marked features which pointed to their being submerged river-valleys. In the great majority of cases these creeks are clearly synclinal folds or eroded anticlinal folds, the structure of which continues seaward, and in other cases there is little doubt but that the depressed areas now occupied by arms of the sea represent lines of weakness set up by faulting.

(*d*) Remarks on the alleged Forest-bed of West Point Island.

With regard to the alleged forest-bed of West Point Island, West Falkland, it was a matter of regret to me that I was never afforded the opportunity of making an examination of the site. I regard it as a significant fact, however, that I was unable to note, in any other part of the Falkland Islands, any further evidences of buried forests. On one occasion when the local steamer called, for a few minutes, at West Point Island, the site of one of the excavations at which buried tree-trunks had been found was pointed out to me, and I noted that it was very near the present beach. It is a notable fact, too, in view of the evidence proving a general rising of the land in recent times, that of fourteen sites, marked on Halle's map of West Point Island Harbour, at which the buried wood was found, eleven occur at or below present high-water mark. Most geologists who have seen the wood declare it to be drift-wood, and, having seen specimens myself, I incline to the same opinion. I have seen similar tree-trunks stranded on the beaches around Bull Cove, East Falkland. Even if the tree-trunks had been or were to be found well inland, and as much as 50 feet above present sea-level, I should still be inclined to regard the material as drift-wood deposited on a beach subsequently raised and buried beneath hill-wash and peaty growths. That coniferous trees agreeing anatomically with the wood of the alleged forest-bed are not met with to-day in South America south of Lat. 43° proves nothing. It would be a much more significant fact if some of the trees had been discovered standing vertical, in the position of growth.

8. ECONOMIC CONSIDERATIONS.

RESULTS OF A COMPREHENSIVE SURVEY FOR COAL, OIL, AND OTHER MINERALS.

(*a*) The Search for Coal.

As pointed out in the Introduction, two circumstances combined to produce a somewhat hopeful outlook in regard to the possible occurrence of coal in the Falklands. Since before the time of the "Challenger" Expedition the older Devonian and Carboniferous rocks of the Colony had not been regarded with any hope in this connection, and the demonstration of the barrenness of the corresponding series of rocks in Cape Colony seemed to give the death-blow to coal prospects in the Falklands. But with the discovery of Permo-Carboniferous rocks hopes were revived and the despatch from the Colony of samples of a cannel or bitumen became a matter of considerable interest. It was known that the Permo-Carboniferous rocks which succeed the Devonian and older Carboniferous in South Africa contain valuable coal-seams—the important Witbank Coalfield of the Transvaal, for instance, occurs in these Permo-Carboniferous rocks. Moreover, the equivalent rocks of other areas in Africa, and of India, Australia and Brazil also contain valuable coal deposits.

It had been stated in a despatch from the Falkland Islands that there appeared to be several outcrops of the bituminous material in different parts of the Islands. I found, on arrival in the Colony, that this statement had been made in consequence of single specimens of the substance having been sent in to Port Stanley from a few widely-scattered localities. The specimens known being so few in number it was not a difficult matter, during my tours, to enquire into the circumstances attending the finding of each. It soon became apparent that all the specimens were found singly, and each on a beach. The distribution of the specimens bore no relation whatever to the outcrop of the Gondwana rocks. More than half the specimens came from Devono-Carboniferous beaches, and more came from West than from East Falkland, although the area occupied in the west island by Gondwana rocks is very insignificant. In the course of my survey work I obtained other specimens myself and of these just as many were found on Devono-Carboniferous as on Gondwana beaches. As the result of my survey I satisfied myself that there is no exposed outcrop on land of this substance in either the Devono-Carboniferous or Gondwana rocks of the Falklands. Prior to my survey of the Colony a search for this same substance had been made by Mr. D. Ferguson, who, in a letter to Governor Allardyce, stated that "it does not occur exposed in the Falklands, a point on which I satisfied myself after an extended tour of the Islands."

I found the specific gravity of the material to be intermediate between that of fresh-water and sea-water. The substance floated in sea-water but sank in fresh-water. Most of the specimens exhibited both worn areas and fresh fractures. I formed the opinion that the material must have drifted to the shores of the Islands.

The dip of the Gondwana rocks in the Falklands is such that the whole of the lower portion of the series outcrops on land, although the rocks are poorly exposed in consequence of the universal overgrowth of vegetation. Nevertheless, had seams of this bituminous material occurred in these lower rocks it is likely that some of them would have been exposed somewhere along the outcrop. In the case of the upper portion of the Falkland Gondwana rocks the state of affairs is different. In consequence of the synclinal structure of Falkland Sound (*see* Section), the outcrop of a considerable thickness of these upper beds is entirely concealed beneath the waters of the Sound and it is very doubtful whether the portion of the sequence thus concealed appears elsewhere in Lafonia. Hence if the concealed beds contained seams of this bituminous material, these seams would crop out on the bottom of Falkland Sound and it is conceivable that portions might become detached, float to the surface and thus be washed on to the shores of the Islands. Another possibility is that beds high up in the Falkland Gondwana sequence occur beneath the sea to the south-east of Lafonia and may perhaps carry seams of this material, from which the fragments have been washed ashore. I consider it somewhat unlikely, however, that the material is detached from submerged reefs and washed in by currents. If such reefs existed and were undergoing erosion I consider that much more of the material would be found on the beaches.

A notable point is that a sample of the substance was sent to the National Museum, Melbourne, and was recognised by F. Chapman as "practically identical" with the oil-bearing rock of Hartley, New South Wales. The microscopic structure of the two rocks was the same, and the specific gravity of each was slightly more than one. I have been informed that at one time this material was exported from Australia for the distillation of burning-oil and for gas-making purposes, and an old inhabitant of the Falklands assured me that he could remember sailing-ships carrying cargoes of "cannel coal," putting into Stanley Harbour. It is not impossible that the original source of the few stray fragments of cannel found on the Falkland beaches may have been Australia.

Since writing the above I have come across what I regard as information conclusively settling this question. In his report to the Brazilian Coal Commission, 1908, Dr. David White described Reinschia australis Bert. and Ren., braziliensis n. var. in a specimen of boghead coal, labelled as coming from Puhuy, Bahia ?, Brazil. His report contains the following interesting footnote:—"As these pages were being printed, and too late to make the necessary alterations in the text, I have received authentic information from Brazil to the effect that for a number of years past, fragments of boghead coal, similar to the one here discussed, have been found at various points along a very considerable section of the Brazilian coast and under circumstances that have led the Brazilian geologists who have examined them to attribute them to passing vessels. A large block found near Santos figured in the Chicago Exposition of 1893, and accompanying the note sent was a fragment found on the coast of Santa Catharina. The latter specimen is so like, in its physical characters, the ones here described as to leave practically no room for doubt regarding the identity of the material as to source. On the other hand the identity above noted of its microscopic composition with that of the kerosene shale of New South Wales makes it almost absolutely certain that the above-mentioned interpretation of the Brazilian geologists is the correct one. As is well known the Australian material has been extensively shipped to Europe and probably for the most part the vessels conveying it have passed along the Brazilian coast where one or more of them may have suffered shipwreck. In view of the wide distribution of this material on the coast of Brazil and of the interest that it has from time to time awakened it is perhaps not to be regretted that, under a misapprehension, it has been included in the study of Brazilian vegetable remains." In the course of his previous description of the material Dr. White had already written, "Its aspect, as well as its microscopical composition, is so similar to that of the kerosene shale boghead from New South Wales that, were it not for the source of the specimen and the record of the original label, I should hardly venture to describe it as pertaining to Brazilian palæontology." Dr. White compared the material with the kerosene shale (boghead) from the Blue Mountains, in New South

Wales, and distinguished the traces in it of the alleged gelatinous alga *Reinschia australis* as the variety "braziliensis" on account of the proportionately greater abundance of large thalli.

With regard to the possibility of the occurrence in the Falklands of seams of ordinary bituminous coal, it soon became apparent that the rocks of the older Devono-Carboniferous series were no more productive than those of the corresponding series in Cape Colony which they so much resemble. Attention was therefore turned to a systematic examination of the Gondwana series, but the result was disappointing. As the survey proceeded it became apparent that the sequence of Gondwana rocks in the Falklands bears a close resemblance to that of the corresponding rocks in Cape Colony—a series which, unfortunately, whilst showing a thickness of strata amounting to 18,000 feet or more, contains coal-seams only in its upper portion, with those of workable quality (although even they are thin, impersistent and poor in quality), being confined to an horizon (Molteno Beds) apparently only represented in the Falklands by the rocks composing the small islands in Falkland Sound, and an insignificant coastal strip on the western side of Lafonia. Had the rock-succession resembled that of the Transvaal or Natal instead of that of Cape Colony there would probably have been a very different report to make.

It may be mentioned that a misinterpretation of geological structure made by Halle has, in a measure, buoyed up hopes which were only subsequently to be dashed. Halle stated that a great fault, of more than 1,000 metres throw, extended along a great part of the east coast of West Falkland, and that the Gondwana rocks on the eastern side of this fault had been thrown down relatively to the older Devono-Carboniferous rocks on the western side. Had this been the true state of affairs a further thickness of some 3,000 feet or more of Gondwana rocks, belonging to an horizon higher than any represented in the Falklands, might have been expected to occur in Lafonia, and the possibility of the occurrence of coal-seams thereby increased, in rather more than like proportion. The work of the survey showed, however, that no such faulting as that alluded to by Halle occurs, and the hope of the occurrence of coal was accordingly diminished.

The so-called "coal" and "graphite" which occurs within a very small area at the head of Port Sussex, East Falkland, is found at the base of the Lafonian Sandstone. Here the sandstone becomes finer-grained, more silty or shaly, and somewhat carbonaceous. An igneous dyke has been intruded into the strata at this spot and the carbonaceous material occurs within the aureole of metamorphism. The material has been examined and described as of no commercial value by the officers of H.M. Geological Survey.

(*b*) The Search for Oil.

From the outset the prospects of finding liquid petroleum in the Falklands were not encouraging. The older series of Devono-Carboniferous rocks had been explored in Cape Colony and had never yielded oil of any kind. Much capital and labour had also been spent in exploring parts of the Gondwana sequence of the Cape—notably the Upper Dwyka Beds—again without success. The officers of the South African Geological Survey had examined areas of the Southern Karroo in the hope of finding oil-bearing strata, and had reported adversely. The notable similarity existing between the rocks of Cape Colony and those of the Falklands had already been pointed out.

It was therefore with no high hopes that this part of the programme of work was embarked upon, and the results of the survey were not surprising. Within the whole area of the Falklands I did not see a single piece of evidence at the surface indicative of the existence of oil in the strata below. I observed no seepages, neither did I anywhere notice bituminous material filling cracks and fissures. The failure to find, in any quantity, bituminous material such as one had been led to hope occurred, was a further disappointment. In rare instances thin seams and other occurrences of somewhat carbonaceous material occur. These have developed from shale-bands, sufficiently carbonaceous to be black in colour, which, happening to occur in a zone of pressure where the rocks have been folded and crushed, have had imparted to them, in consequence of slickensiding, a shining coal-like appearance. Some material from one of the most promising-looking of these deposits was sent to the Imperial Institute for analysis as a possible oil-shale, but the report upon it was altogether discouraging. In other cases, as at Port Sussex, the heat and pressure occasioned by the intrusion into the strata of an igneous dyke has resulted in the formation of a somewhat graphitic material. At Port Howard the same effect has been produced in shaly rocks, quite locally, by pressure alone.

When I began to accumulate data bearing upon the structure of the area I realised that even had the rocks under examination been at one time oil-bearing, many opportunities for the escape of the oil must long ago have been afforded. In the case of the Gondwana rocks, for example, even supposing these to have been at one time oil-bearing, the folding and denudation which they have undergone would have rendered the escape of much of the oil an easy matter. The development of the strong syncline of Falkland Sound would have caused the oil to migrate from the trough of the syncline to the upturned slopes. The western slope is exceedingly steep (*see* Section) and as it extends along a great part of the east coast of West Falkland would have afforded a very ready line of escape for oil. The eastern limb of the syncline is more gently sloping and in the western part of Lafonia it flattens out along a N.N.E.—S.S.W. axis. To the east of this axis the strata take on a very gentle dip to the S.E. before flattening out again still farther east. The very gentle anticlinal structure of western Lafonia would be ideal for oil-prospecting, were the rocks known to be oil-bearing and adequately protected by some impervious cap-rock. The rocks at present exposed in Lafonia have probably never been covered by any much higher strata and they are perhaps not of the type best suited to serve as a sealage for petroleum. Since the folding of the rocks probably dates back to pre-Jurassic times, it would appear that ample opportunity must have been afforded for the escape of much of any oil which the strata may at one time have contained.

Nevertheless, the problem of the possibility of the occurrence of liquid petroleum in the Falkland Islands is one which can never be definitely settled until exploratory boring is undertaken. Until then there will always be a speculative value to be put upon this area. It does not follow that because one failed to detect surface-indications of its presence there is no oil in the Colony. It would not be difficult to locate suitable rock-structures for exploring operations, and I give it as my opinion that two borings, at carefully-chosen sites, one to explore the Gondwana and the other the Devono-Carboniferous rocks, would definitely settle the question. In the case of the latter boring a depth of between 3,000 and 4,000 feet should be sufficient, if a site is chosen where only a small thickness of glacial boulder-beds (tillite) covers the quartzitic sandstone, and the latter has an anticlinal disposition. A good site for such an exploration would be a little inland to the west of Shallow Cove, Port Fitzroy, East Falkland, on the southern slope of the quartzite ridge. The Falkland Islands Company's Fitzroy settlement lies just south of this ridge, and a site on the tillite north-west of the settlement should be quite suitable.

With regard to an adequate exploration of the Gondwana rocks a deeper boring would be necessary, certainly not less than 4,000 feet, and deeper if possible. An almost ideal site for such an exploration would be in west Lafonia, about midway between the sites marked on the Admiralty Chart as Orqueta and Mariquita.

(*c*) The Search for other Minerals.

The Falkland Islands appear to be discouragingly deficient in minerals of economic importance. Little better success attended the search for minerals other than coal and oil. At various times mineral specimens have been received at the Imperial Institute from the Falkland Islands, and it has been hoped that useful mineral deposits might occur. It would appear that, in the past, mineral specimens have been sent from the Falkland Islands to the Imperial Institute for examination, not because the minerals occur in abundance and may possibly be of value commercially, but because they have been regarded as rare specimens likely to interest scientific authorities at home.

Iron-ore, either as limonite or siderite (chalybite) occurs in the Colony. A sample of the carbonate ore of iron, received at the Imperial Institute in 1907, was found to contain 58·95 per cent. of oxide of iron—an amount sufficiently high to make this a valuable ore for the manufacture of iron if it should occur in commercial quantities. Unfortunately it does not. It is very sporadic in its occurrence, being found only in small, local patches, not more than a foot or so in diameter and a few inches in thickness. It would take a long time to collect any quantity of it, and the question of its transport over the "camp" would be a difficult one.

There are no kaolin deposits of any importance. I undertook to submit a further sample of Falkland Islands' kaolin to the Imperial Institute but in spite of considerable searching, could never succeed in discovering a deposit sufficiently noteworthy, either as regards extent or quality of the material. Very occasionally small, lenticular seams are seen but they are never more than a few inches in thickness and a few feet in length. The material is always very gritty from its inclusion of quartz-grains, and of no commercial value. When present it always occurs on low ground at the foot of quartzite ridges, and has resulted from the decomposition of the somewhat felspathic quartzitic rock.

I see no hope of the occurrence of gold in the Colony. The only hopeful area was that at the Archæan exposure of Cape Meredith, in the old igneous and metamorphic rocks, but the yellow mineral which has perhaps been mistaken for gold in this area has, on the result of analysis of a rock-sample submitted by myself, proved to be iron-pyrites.

There are no notable deposits of graphite.

Many of the sand-deposits on the beaches, however, attracted my attention. This beach-sand is often very white and of conspicuous uniformity of grain. It occurred to me that this sand might possibly be of value for the manufacture of glass, although the remoteness of the area renders this doubtful. I decided, however, to collect samples for subsequent examination. I give below the results of testing some of these sands :—

A good glass-sand should consist practically entirely of quartz-grains. The material should be as white as possible in colour, that is to say, the grains should not be stained with any coating of iron-oxide. The percentage of iron in the sand should not exceed a trace, for the best quality optical glass and cut glass. Up to ·1 per cent. of iron-oxide is permissible if the sand is to be used for the manufacture of plate and window-glass, chemical apparatus, globes, etc. Where the iron-content approaches 1 per cent. the sand can only be used for the cheapest class of bottles. The ideal glass-sand is closely approached by the sand from Fontainebleau, near Paris. The percentage of iron-oxide in this sand has been shown by chemical analyses to be about ·006 per cent. It is important that the sand should be well graded, that is, that the grains should show a well-marked tendency to approximate to an average size, which should be neither too fine nor too coarse, although a certain amount of latitude is permissible.

Little accurate scientific work upon the mechanical constitution of sands has as yet been done, although some important pioneer work has been performed by Professor P. G. H. Boswell, of Liverpool University. Some three years ago I spent some months in investigating the mechanical constitution of certain British sands, and devised two factors, an Equivalent Grade factor and a Grading Factor, which should, in due course, prove useful criteria in the case of sands for economic purposes. The Equivalent Grade factor expresses the average coarseness of the material in millimetres, and the Grading Factor the measure of the tendency of the material as a whole to approximate to the Equivalent Grade. A perfectly graded sand, that is, one in which all the grains are of the same size, would have a Grading Factor of 1. Such sands do not occur in nature and the Grading Factor is always a decimal fraction of unity. For a good glass-sand, however, the Grading Factor should not fall below about ·700.

These methods have not yet, so far as I am aware, been applied in the commercial world, to sands useful for economic purposes. I give a graph which compares the mechanical constitution of some Falkland Islands' sands with Fontainebleau sand and some British sands which are successfully employed in glass-manufacture. It will be seen that, so far as mechanical constitution is concerned, the Falkland Islands' sands are quite satisfactory for use in glass-manufacture, some of the samples tested yielding Grading

Factors actually higher than than that of the famous Fontainebleau sand. However, when the iron-content of the material is investigated the superiority of the Fontainebleau sand is demonstrated. Even to the eye the latter sand shows a closer approach to a white colour than do the cleanest samples from the Falklands. A selected Falklands' sand (Hooker's Bay, Port Stanley) was submitted to a partial chemical analysis by Mr. A. Wolf, of the Imperial College of Science and Technology. It gave the following result :—

Iron (as Fe_2O_3)	... ...	0·42 per cent.
Aluminium (as Al_2O_3)	... ...	3·75 per cent.

From this it will be seen that the iron-content is too high for this sand to be of value for optical and cut glass or for plate and window-glass. The presence of the aluminium is, however, a point in its favour. An excellent thermometer-glass, which stands repeated melting, blowing and fusing without change, is made in the Thuringian Forest district and the excellence of the glass is believed to be due to the fact that the special sand employed contains 3·66 per cent. of alumina.

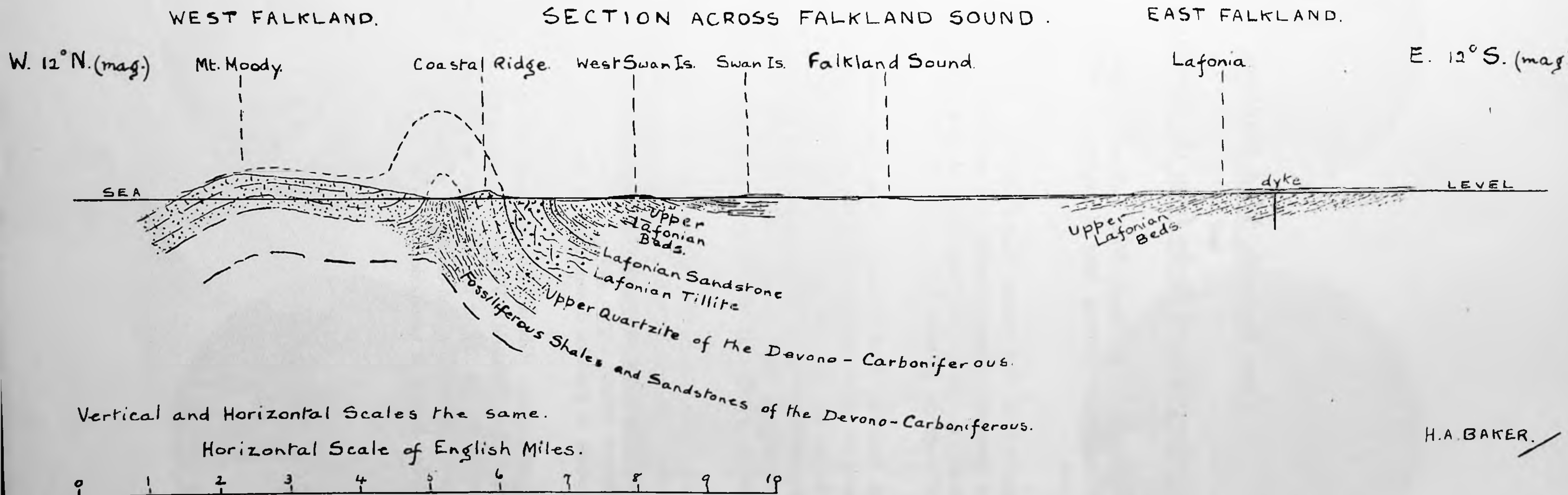
HERBERT A. BAKER,

Government Geologist, Falkland Islands.

X

X

Y



WEST FALKLAND.
SECTION ACROSS FALKLAND SOUND.
EAST FALKLAND.
W. 12° N. (mag.)
Mt. Moody.
Coastal Ridge.
West Swan Is.
Swan Is.
Falkland Sound.
Lafonia.
E. 12° S. (mag.)
SEA
LEVEL
dyke
Upper Lafonian Beds.
Upper Lafonian Beds
Lafonian Sandstone
Lafonian Tillite
Upper Quartzite of the Devono-Carboniferous.
Fossiliferous Shales and Sandstones of the Devono-Carboniferous.
Vertical and Horizontal Scales the same.
Horizontal Scale of English Miles.
0 1 2 3 4 5 6 7 8 9 10
H. A. BAKER.

Cape Meredith, West Falkland,

and

Photomicrographs of Rocks from the Falkland Islands.

FIG. 1. Dolerite dyke, New Island, West Falkland. Viewed in ordinary light. x 25 diameters. Showing laths of plagioclase felspar, augite, and much olivine.

FIG. 2. Dolerite dyke. Port Sussex, East Falkland. Viewed in ordinary light. x 25 diameters. Texture coarser and more holocrystalline than in the example of Fig. 1. Showing laths of plagioclase felspar, augite and some magnetite granules.

FIG. 3. Cape Meredith, West Falkland. View from western side, looking S.E. towards the southernmost point of the cape. Showing the unconformable junction of the Archaean igneous rocks below (the rock showing in picture is pegmatite) with the Devonian sandstones above. The Archaean hornblende-schist is some distance behind (N.W. of) the camera, and the granite on ahead, near, and at, the southernmost point of the cape.

FIG. 4. Dolerite dyke, Poncho Valley, near Double Creek, Port Richards, West Falkland. Viewed in ordinary light. x 25 diameters. Texture still coarser than in the examples of Figs. 1 and 2. Showing stout laths of plagioclase felspar, augite, and good olivine. Some iron-oxide, probably magnetite, in granules disseminated in the ground-mass.

FIG. 5. Lafonian Tillite (Glacial Boulder-Beds of the Permo-Carboniferous), Cerritos, East Falkland. Viewed in ordinary light. x 20 diameters. An indurated boulder-clay or till, composed of irregular fragments of quartz, frequently stained by iron-oxide, in a fine-grained, dark ground-mass consisting largely of iron-oxide.

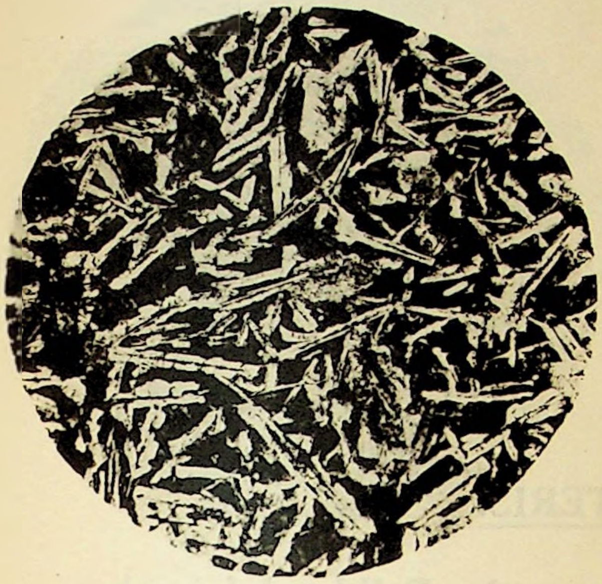


Fig. 1.

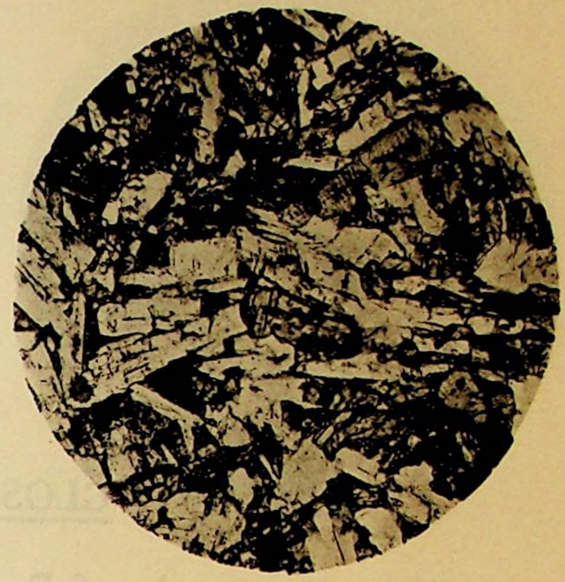


Fig. 2.

Fig. 3.

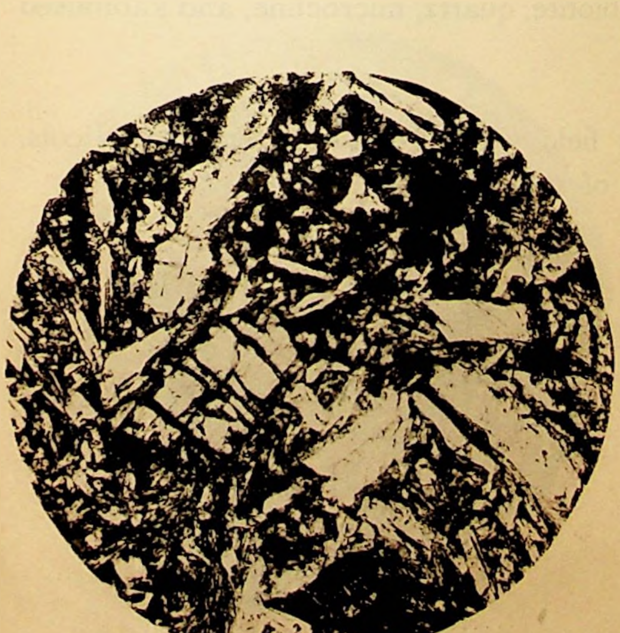


Fig. 4.

Fig. 5.

GLOSSOPTERIS.

Photomicrographs of Rocks from the Falkland Islands.

FIG. 6. Archaean, Cape Meredith, West Falkland. Viewed in ordinary light. x 20 diameters. Typical hornblende schist, consisting of hornblende and quartz, with well-marked schistose texture.

FIG. 7. Archaean, Cape Meredith, West Falkland. Viewed between crossed Nicols. x 20 diameters. Pegmatite. Consisting of microcline felspar (showing the cross-hatching characteristic of this mineral when viewed between crossed Nicols, due to the intersection of two sets of twin-planes almost at rightangles) and quartz.

NOTE.—Later re-examination of the sections of this pegmatite has revealed an interesting occurrence of Xenotime (chemical composition YPO_4, phosphate of the yttrium metals). A similar occurrence in granite-pegmatites of phosphates of the yttrium metals is known in other areas, notably Southern Norway.

FIG. 8. Glossopteris indica Schimper cf. G. decipiens Feistmantel. x 1·27. From North Arm, Bay of Harbours, Lafonia, East Falkland.

FIG. 9. Archaean, Cape Meredith, West Falkland. Viewed in ordinary light. x 25 diameters. Granite. Showing biotite, quartz, microcline, and kaolinised orthoclase.

FIG. 10. Same rock as in Fig. 9. Same field viewed between crossed Nicols. To show cross-hatched appearance of the microcline.

Fig. 6.

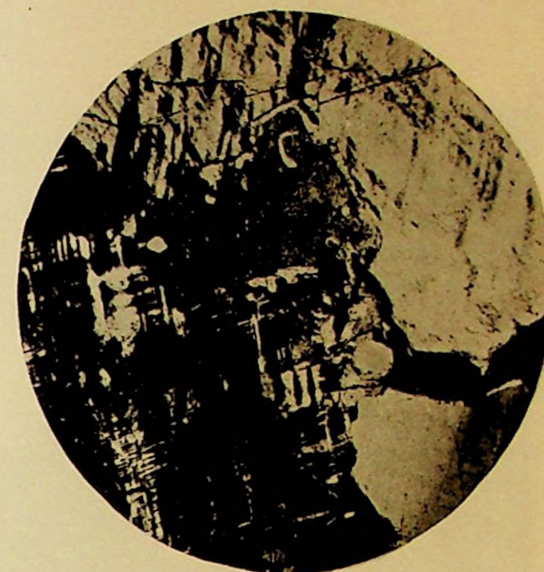


Fig. 7.

Fig. 8.

Fig. 9.

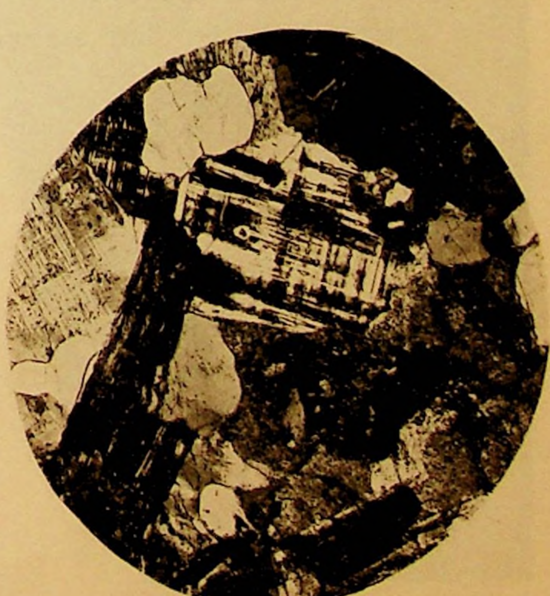


Fig. 10.

Devono-Carboniferous and Gondwana Rocks, Falkland Islands.

FIG. 11. Part of the so-called "Indian Village," Port Stephens, West Falkland. Showing the erosive action of wind-blown sand upon the lower quartzitic sandstones of the Devonian.

FIG. 12. Western side of entrance to Bluff Cove (Fitzroy Basin), Port Fitzroy, East Falkland. Showing strong folding of the upper quartzitic sandstone of the Devono-Carboniferous rocks.

FIG. 13. View of a coastal section on the eastern side of Bleaker Island, East Falkland. Showing horizontal disposition of the Upper Lafonian Beds (Gondwana).

FIG. 14. Coastal section in Lafonian Tillite (Glacial Boulder-Beds of the Permo-Carboniferous). West of Hill Cove, West Falkland. Note absence of bedding in the deposit. The tillite contains many erratic boulders, although this feature is not well shown by the photograph. Boulders derived from the tillite are strewn abundantly on the beach.

Fig. 11.

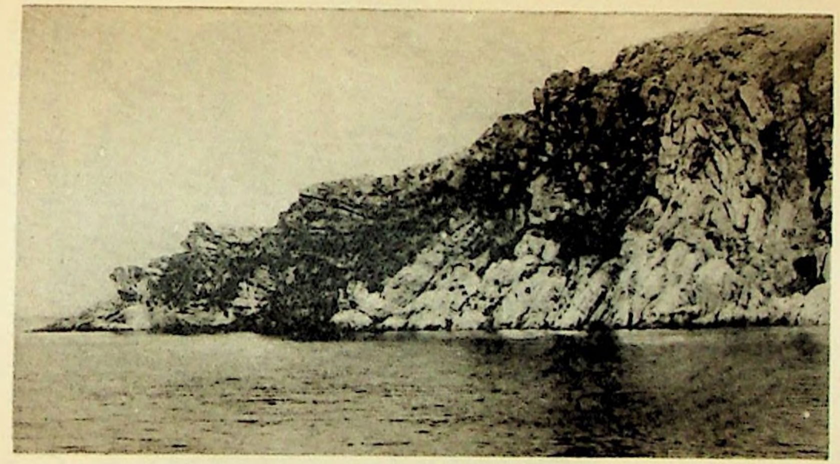


Fig. 12.

Fig. 13.

Fig. 14.

Photomicrographs of Rocks from the Falkland Islands.

FIG. 15. Igneous boulder from the Lafonian Tillite (Glacial Boulder-Beds of the Permo-Carboniferous), Port Purvis, West Falkland. To show the identity of this rock with that of Figs. 9 and 10, viz., the Archaean granite from Cape Meredith, West Falkland. Viewed between crossed Nicols. x 25 diameters. Microcline, with characteristic cross-hatched appearance, well seen. Kaolinised felspar (orthoclase) and quartz also shown. Biotite is present in the slide but is not seen in the field selected.

FIG. 16. Archaean, Cape Meredith, West Falkland. Viewed in ordinary light. x 20 diameters. Pink quartzite. Showing very well rounded quartz-grains in a ground-mass of siliceous cement. The quartz-grains are coated with haematite, which is the cause of the pink colour of the rock. Magnetite occurs also.

FIG. 17. Boulder of pink quartzite from the Lafonian Tillite (Glacial Boulder-Beds of the Permo-Carboniferous) Hill Cove, West Falkland. To show the identity of this rock with that of Fig. 16, viz., pink quartzite of the Archaean, Cape Meredith, West Falkland. Viewed in ordinary light. x 20 diameters. Showing the same well rounded quartz-grains (coated with haematite) set in a siliceous cement. Magnetite present. Field shows rather more iron-oxide than does that of Fig. 16.

FIG. 18. Archaean, Cape Meredith, West Falkland. A chocolate-coloured dyke cutting the Archaean hornblende-schist and pegmatite. Viewed in ordinary light. x 20 diameters. Hornblende-lamprophyre of the camptonite or vogesite type. Rock much decomposed. Highly decomposed felspar and laths of hornblende in ground-mass, with chloritic material. Porphyritic crystals of hornblende well seen. Magnetite and olivine present. Augite and iron-pyrites occur in the slide but not in the field photographed.

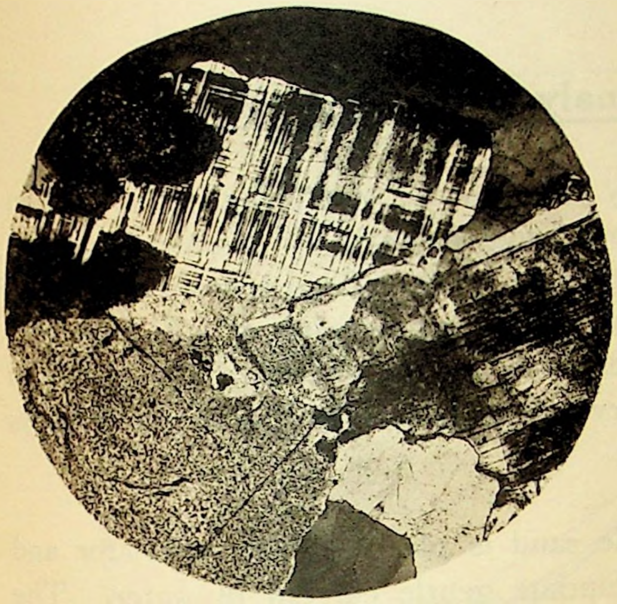


Fig. 15.

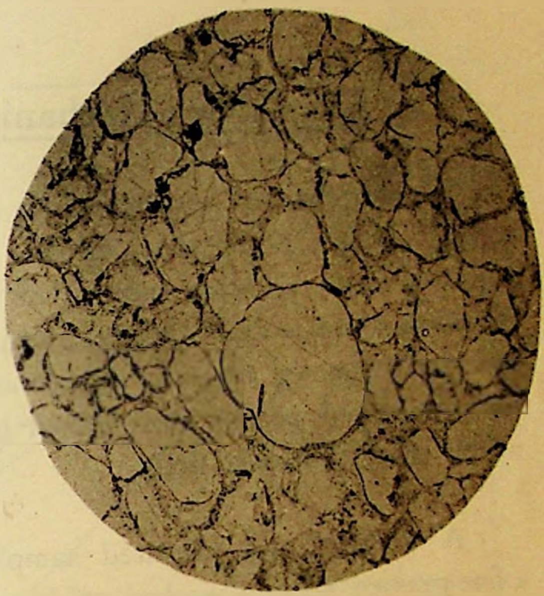


Fig. 16.

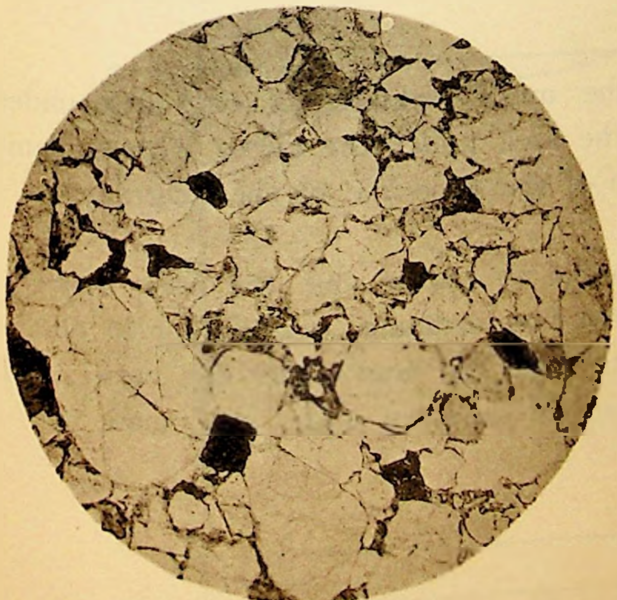


Fig. 17.

Fig. 18.

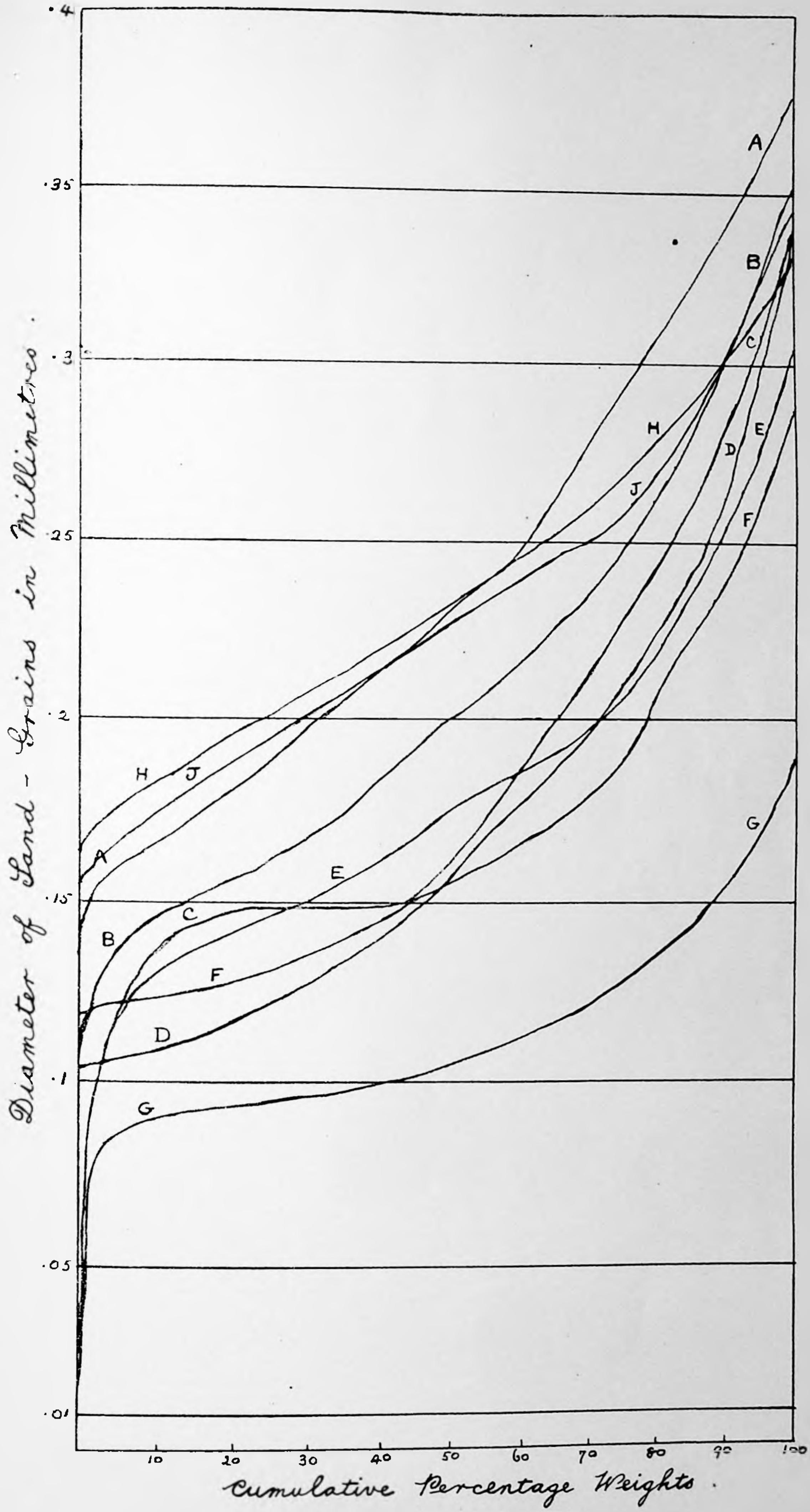
Elutriation (Mechanical Analysis) Curves of Sands.

The mechanical analysis of a sand by the process of elutriation consists in sorting and separating the sand into numerous small portions by means of suitably-adjusted, upward-flowing currents of water in glass tubes. Experimental work has established the current-speed requisite to wash off sand-grains of less than any specified diameter, and the upper and lower limits of diameter of the grains in each separated portion are known by observing the speeds of the water-currents which effect the separations.

A weighed and prepared sample of the sand is placed in the elutriator and a fine-grained portion washed off by an appropriate gentle current of water. The weight of the portion thus removed is determined and its percentage-weight calculated. This percentage-weight is marked off on the graph along the abscissa which represents the upper limit of diameter at which the separation has been effected. A further portion of the sample, consisting of somewhat coarser grains, is then washed off by appropriately increasing the speed of the current. The percentage-weight of the portion removed is acertained as before, and the result is added to that previously obtained (thus giving the total percentage-weight washed off). The result is again marked off on the graph along the appropriate abscissa. By continuing the process the whole of the sample is at length dealt with and a series of points on the graph are obtained which, when joined up, give the elutriation-curve of the sand.

The Equivalent Grade (of Baker) is the mean ordinate of the area under the curve. This is found by taking out the area under the curve with a planimeter and dividing the result by the length of the base-line of the diagram.

The Grading Factor (of Baker) is obtained by taking out the area between the Equivalent Grade line, the curve, and the first ordinate, doubling it to obtain the total variation-area, subtracting the result from the area under the curve, and expressing the remainder as a decimal fraction of the area under the curve.



ELUTRIATION CURVES.

Falkland Islands' Beach Sands compared with Good Glass Sands.

A.	Hooker's Bay, Port Stanley, E.F.	Equiv. Gr. ·243, Gr. Fact. ·777
B.	Fontainebleau, France	Equiv. Gr. ·210, Gr. Fact. ·831
C.	Stone, nr. Aylesbury, England	Equiv. Gr. ·187, Gr. Fact. ·730
D.	Elephant Bay, Pebble Is., W.F.	Equiv. Gr. ·173, Gr. Fact. ·712
E.	Aylesford, Kent, England	Equiv. Gr. ·181, Gr. Fact. ·786
F.	Burythorpe, Yorks, England	Equiv. Gr. ·168, Gr. Fact. ·786
G.	Denford, Northants, England...	Equiv. Gr. ·113, Gr. Fact. ·800
H.	Kidney Island, East Falkland	Equiv. Gr. ·237, Gr. Fact. ·849
J.	Carcass Point, Fox Bay, W.F.	Equiv. Gr. ·232, Gr. Fact. ·841


THE
FALKLAND ISLANDS.
GEOLOGICALLY SURVEYED
by
H. A. BAKER, D.Sc., D.I.C., F.G.S., F.R.G.S.,
1921-22.
WEST
FALKLAND
EAST
FALKLAND
Jason Is.
Carcass Is.
Saunders Is.
Keppel Is.
Golding Is.
Pebble Is.
Pebble Sound
Tamar Pass
West Point Is.
Byron Sound
Hill Cove
White Rock
Port Purvis
The Six Hills
White Rock Bay
Port San Carlos
Manybranch Harbour
C. Dolphin
Macbride Hd.
Port Salvador
Rincon Grande
Port Louis
Johnson Hr.
Berkeley Sound
Teal Inlet
Mt Simon
Mt Vernet
Mt Low
Pt William
Port Stanley
Port Harriet
Mt Kent
Mt Wickham
Wickham Heights
Mt Usborne
Bodie Pk.
Port Sussex
Brenton Loch
Mt Pleasant
Port Fitzroy
Port Pleasant
Swan Inlet
Black Rock
Hill Head
Island Hr.
Camilla Ck.
High Hill Ho.
Darwin
Bodie Inlet
Dos Lomas
Egg Hr
Cygnet Hr.
Choiseul Sound
Walker Creek
Wharton Hr
Findlay Hr.
Lively Is.
Low Bay
Moffitt Hr.
North Arm
N.W. Arm
Danson Hr.
Lion Cr.
Bay of Harbours
Fanny Cove
Bull Cove
Bleaker Is.
Adventure Sd.
Speedwell Island
George Island
Barren Is.
Sea Lion Is.
Falkland Sound
Port Howard
Hornby Mts
Mt Maria
Mt Robinson
Mt Edgeworth
Mt Adam
Mt Fegen
King George Bay
Christmas Hr.
Chartres
Chartres R.
Mt Chartres
Mt Philomel
Mt Doyle
Mt Moody
Mt Sulivan
Port Philomel
Halfway Cove
Spring Pt.
Black Hills
Swan Is.
West Swan Is.
Shag Cove
Fox Bay
New Is.
Beaver Is.
Weddell Is.
Mt Weddell
Queen Charlotte Bay
Port Richards
South Hr.
Port Stephens
Mt Young
Port Edgar
Port Albemarle
C. Meredith
Statute Miles
0 9 18 27 36
61°
60°
59°
58°
INDEX
Rhaetic(?) Triassic Permian and (?) Upper Carboniferous
Upper Lafonian Series
Lower Lafonian Series
Upper Lafonian Beds (upper part)
Upper Lafonian Beds (lower part)
Lafonian Sandstone
Lafonian Tillite
Devono-Carboniferous
Middle group with marine fossils, where noted — Fox Bay Beds
Archaean
Igneous dyke
Fault
12° Dip
Settlement of more than one house: Note. A few not marked
Solitary shepherd's house. Note. Some not shown
Peak