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Falklands Museum

ON THE GEOLOGICAL STRUCTURE AND HISTORY

OF

THE FALKLAND ISLANDS

ACADEMICAL DISSERTATION

BY

THORE G. HALLE

(Reprinted from Bull. Geol. Inst. Univ. Uppsala, Vol. XI.)

UPPSALA 1911
ALMQVIST & WIKSELLS BOKTRYCKERI-A.-B.

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WITH 5 PLATES

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Contents.

Note: The present paper is *N:o 4* in the series of geological publications of the Swedish Expedition to Patagonia and Tierra del Fuego, 1907—1909, under direction of Dr. C. SKOTTSBERG. The previous papers are:

N:o 1. P. D. QUENSEL: On the influence of the ice-age on the continental watershed of Patagonia. Bull. Geol. Inst. Upsala. Vol. 9. 1910.

N:o 2. TH. G. HALLE: On quaternary deposits and changes of level in Patagonia and Tierra del Fuego. Ibidem. Vol. 9. 1910.

N:o 3. P. D. QUENSEL: Geologisch-petrographische Studien in der Patagonischen Cordillera. Ibidem. Vol. 11. 1911.

Introduction.

Since DARWIN'S time, the geology of the Falkland Islands has been almost entirely neglected until the Swedish South Polar Expedition visited the archipelago in 1901—1902. The explorations carried out during this expedition by Prof. J. G. ANDERSSON, proved that the geological structure was not so uniform or uninteresting as had generally been supposed. The important results then obtained gave rise, however, to new questions which could not be solved without fresh explorations being undertaken in the field, and it was, therefore, with great pleasure that I availed myself of an opportunity of spending some time in those far-away islands.

Under the direction of Dr. C. SKOTTSBERG, who had been a member of the Swedish South Polar Expedition, 1901—1903, a little party started from Sweden in September 1907, in order to carry out biological and geological explorations in the Falkland Islands, in Tierra del Fuego and Patagonia. The first few months were spent by Dr. SKOTTSBERG and myself in the Falkland Islands, while Dr. P. D. QUENSEL, the third member of our expedition, went direct to Patagonia. We landed in Port Stanley on the 26th of October 1907, and left the islands on Febr. 12th, 1908. This may appear to be a long time to devote to the geological exploration of such a small district, but it should be remembered that lack of means of communication often forced me to spend a considerable time without any possibility of making geological observations, or to stay in places which were of very little interest from a geological point of view. On account of these circumstances it was only towards the end of our stay in the islands that I found an opportunity of visiting the tract which afterwards proved to be the most interesting. The result of this was, that I was forced to leave many important questions undecided, which arose from the results obtained in that district.

On the other hand, the results obtained would have been still less but for the assistance we were given by the inhabitants of the Falkland Islands — from the authorities in Port Stanley down to the shepherds out in »the camp». His Excellency Governor W. L. ALLARDYCE, who takes great interest in the natural resources of the colony, gave us every help in his power. Mrs. ALLARDYCE has also contributed very much towards a knowledge of the natural history of the Falkland Islands, by creating in Port Stanley a museum of specimens illustrative of the geology, fauna and flora of the colony. It was by means of these collections that I first learned of several finds which afterwards proved to be of great importance for our geological investigations.

For sea-transport for ourselves and our collections, we were entirely dependent on the »Falkland Island Company, Ltd.», whose schooners afford the only possible means of communication round the coast and to the smaller, distant islands. It is a great pleasure to state that the Company assisted us in the most generous manner, as we were granted free passage on the schooners whenever we wished. For assistance in other respects, we are also under great obligations to the gentlemen in the Company's service, especially Mr. W. HARDING, its chief representative in the Falklands, Colonel A. REID and Mr. C. GIRLING. Mr. GIRLING, who, at the period of our visit, was acting as Swedish vice-consul, also took the trouble to send home the collections which we left behind us on our departure for Patagonia. During our expeditions across country we were thrown entirely on the hospitality of the inhabitants, and it is a great pleasure for us to state that we were everywhere received with the greatest kindness. Though our visit coincided with the busy season of the year, the sheep-shearing period, we found no difficulty in getting horses and guides placed at our disposition. For this we are greatly indebted to Messrs. BENNEY on Saunders Island, Mr. BERTRAND of Roy Cove, Dr. BOLUS, Fox Bay, Mr. BONNER on Speedwell Island, Dr. FOLEY of Darwin Harbour, Mr. MATHEWS, Port Howard, Mr. MILLER, Hill Cove, and Mr. PACKE of Port Stanley, and also to many others, too numerous to be mentioned here.

My special thanks are due, however, to Mr. A. L. ALLAN, chief-manager of the farms of the F. I. C. Thanks to his and Mrs. ALLAN'S kindness, I was able to make their charming home at Darwin Harbour my head-quarters the whole of the time I spent in exploring *Lafonia*, the southern half of the east island. Finally, it is a great pleasure to acknowledge all the kind services rendered us by Mr. A. E. FELTON of West Point Island, both during our visit to his interesting island and afterwards. Mr FELTON — who is deeply interested in, and remarkably well acquainted with the natural history of the Falklands — was the first to note and draw attention to the interesting forest-bed on West Point Island, referred to later on.

When, after our return to Sweden, I proceeded to the arrangement of my notes and collections from the Falkland Islands, I had the good fortune to receive help and encouragement from several well-known scientists. Prof. A. G. NATHORST has, as before, given me every possible help in the examination of the palæo-botanical material. Prof. R. ZEILLER of Paris has kindly examined drawings of two critical specimens of *Glossopteris*. The only insect-remain from the Gondwana series has

been examined by Prof. G. HOLM, to whom I am also indebted for the splendid photograph of it published in the present paper. Prof. J. G. ANDERSSON, who was the first to give me the idea of undertaking the journey, has assisted me by his own experiences from the Falkland Islands. Prof. G. LAGERHEIM has kindly examined several specimens of soil in order to determine the presence of microscopical organic remains. Mr. N. ZENZÉN has taken great trouble in the important microscopical studies of different rocks. The marine invertebrates of the Devonian were handed over to the well-known expert in Devonian faunas, Dr. J. M. CLARKE, of Albany, New York. Dr. CLARKE will, later on, publish a description of the fossils. He has, however, kindly placed at my disposal a list, not only of my own fossils, but also of all the material in his possession from the Falkland Islands, as well as a general report on the nature and affinities of the fauna. Dr. W. GOTHAN, Berlin, has had the kindness to examine sections of the wood from the forest-bed of West Point Island. For the photographs of the specimens of rocks published in the present paper I am indebted to my friend S. BOCK. To all these gentlemen I wish to express my warmest thanks.

To my friend and only companion in the Falkland Islands, Dr. C. SKOTTSBERG, I desire to render my sincere thanks for his spirit of good comradeship, which remained unaltered under trying conditions. As leader of the expedition, he did everything in his power to promote the success of the geological work, and to his ability in overcoming the practical difficulties attending it, are due many of the results gained in this department.

Lastly, I have to express my deep gratitude to Prof. HJ. SJÖGREN, who has kindly allowed me to publish my memoir in this Bulletin and to my teacher, Prof. A. G. HÖGBOM, for the interest he has taken, not only in the publication of this paper, but also in my previous studies at the University of Uppsala.

Previous explorations.

We owe our first knowledge of the geology of the Falkland Islands to CHARLES DARWIN (1846[1], 1846[2]), who spent some time on the east island during the expedition of the »Beagle». He found the main formation to consist of a series of sandstone and slate, interrupted by quartzite-ranges running in an E.—W. direction. In the sandstone he collected a number of marine invertebrates which were described later on by MORRIS and SHARPE (1846). All the species described, eight in number, proved to be new, but more or less closely related to forms from the Palæozoic rocks of the northern hemisphere. The fauna having partly a Silurian, partly a Devonian character, the authors did not attempt to determine exactly the age of the formation, but this has now come to be generally regarded as belonging to the lower Devonian.

DARWIN did not visit the west island, but Captain SULIVAN, who was also employed in the survey of the archipelago, made some important observations here. From the west side of Falkland Sound, which divides the two main islands, he recorded a »fine range, 2,000 ft. in height» running N. N. E. — S. S. W., i. e. at right angles to the general strike of the folding zone in the northern part of the island (DARWIN, 1846[1], p. 270). According to a foot-note in DARWIN'S paper (l. c., p. 269), SULIVAN also seems to have found on the west island »subordinate beds of a conglomerate or coarse grauwacke» and »traces of tertiary and boulder formations, corresponding with those of Tierra del Fuego». He also observed on the same island »numerous basaltic dykes». DARWIN gives detailed descriptions of the lithological character of the rocks, of folding and cleavage. He also noticed the remarkable »stone-runs», though his idea of their origin differs much from the modern view.

During the period following DARWIN'S visit, there are no geological explorations of the islands to be noted until 1876, when the expedition on board the »Challenger» spent some time here. Sir WYVILLE THOMSON (1877, p. 245—249) has given a very instructive description of the »stone-rivers». His mode of explaining this strange phenomenon comes very near to the theory now commonly accepted. Marine fossils were collected in the sandstone-formation at Port Louis and Macbride's Head, and described by R. ETHERIDGE (1885, p. 892—894).

A visit which Prof. MOSELY made to the west coast of East Falkland during this expedition, is worthy of note in connection with recent geological explorations in that tract. The then governor, Colonel D'ARCY, had received a report stating the occurrence of coal and graphite at Port Sussex, and, at his request, MOSELY went there to survey the locality. Both the coal and the graphite proved to be nothing but very bituminous black slate and Sir WYVILLE THOMSON (1877, p. 208—209) pointed out that coal of any value could not be expected to occur in the older Devonian rocks of the islands.

Of great interest in connection with the question of changes of level in the Falkland Islands, are the critical observations made by the expedition, on the supposed rising of the land in recent times. At the time, there was a general opinion among the inhabitants, that the land was gradually rising, but no actual proofs had been afforded in support of this view. During the voyage of the »Discovery», Sir JAMES CLARK ROSS had erected, at Berkeley Sound, near the settlement of Port Louis, two tablets in a fixed position relatively to the mean level of the sea, determined as the result of five months' observations. The renewed observations of the »Challenger»-Expedition, extending over a shorter space of time, however, gave the level of the sea as being within an inch of Sir JAMES ROSS' figures, and thus proved that there had been no perceptible change during the space of nearly 40 years (WYVILLE THOMSON, 1885, p. 883—885).

Some specimens of rocks collected during the same expedition have been examined and described by RENARD (1885, 1889). Unfortunately, the information given as to the mode of occurrence of most of these rocks is very unsatisfactory. To some of the specimens reference will be made in the following pages.

During the Swedish South Polar Expedition, 1901—1903, Prof. J. G. ANDERSSON spent some three months in geological explorations of the Falkland Islands, and to him we owe our knowledge of the fact that the geology of the islands is not so simple as the previous researches had given us to understand. When passing round the south coast of West Falkland, he discovered at Cape Meredith the basement of the Devonian formation. Later on, he found an opportunity of visiting this interesting locality from the land side. He was now able to ascertain that the Devonian sandstone rests unconformably on a highly disturbed formation of crystalline rocks, partly gneiss and granite, and partly, probably, a series of metamorphic schists. These lower crystalline rocks have been greatly disintegrated and the upper surface of the formation eroded, before the deposition of the sandstone, which rests upon its basement with an undulating boundary line. The schists were displayed only in the precipitous cliff and were quite inaccessible, but of the other rocks Prof. ANDERSSON secured specimens for closer examination. These specimens were kept on board the »Antarctic» and were afterwards lost with her.

Of very great interest are Prof. ANDERSSON'S studies of the »stone-runs» which had so much puzzled the earlier explorers. After a detailed study of the phenomenon he came to the conclusion that they have been formed by the process known as solifluction (J. G. ANDERSSON, 1906) at the period of maximum glaciation of the surrounding lands. As Prof. ANDERSSON remarks, JAMES GEIKIE has already propounded the same theory (1894, p. 722—723), basing it on DARWIN'S descriptions of the phenomenon, and the conclusion arrived at indepedently by these two geologists may be considered as now being the one generally accepted.

To Prof. ANDERSSON is also due the first account of the changes of level of the islands. This question will be discussed more fully later on.

At Fox Bay, Prof. ANDERSSON collected marine invertebrates identical with those already known from Port Louis. This was the first actual proof that the Devonian formation extends to the west island too. In the southern part of East Falkland marine fossils were nowhere found, but from a few places he brought home some imperfect plant-remains which were afterwards proved to be of very great interest. The best specimens were found on Speedwell Island at the south end of East Falkland. As, at Port Louis, Prof. ANDERSSON had previously discovered, associated with marine invertebrates, another plant-fragment of the same appearance, he judged that the southern part of the island was Devonian too. In accordance with this opinion, Prof. A. G. NATHORST, to whom these fossils were submitted for examination, in his first report on the subject (1904), mentioned them under the name of *Asterocalamites*. Later on, Mr. E. A. N. ARBER, during a visit to Stockholm, pointed out that the plant-remains in question probably belonged to the genus *Phyllotheca* BRGN., of which the oldest representatives appear in the lower Gondwana-series of the southern hemisphere. Prof. NATHORST, after a closer examination (1906), came to the same conclusion, and stated that the specimens very much resemble some of SCHMALHAUSEN'S figures of *Phyllotheca deliquescens* GOEPP. sp., from Siberia. If this opinion were really the right one, then there would occur in the Falkland Islands a formation younger than the Devonian, and belonging probably to the Gondwana-series of the southern Palæozoic continents. The poor quality of the fossils, however, made the determination somewhat doubtful. Prof. KOKEN, in his paper on the Indian Permian and its ice-age (1907, p. 489), seemed, indeed, disinclined to accept these *Phyllotheca*-remains as sufficient evidence of the existence of a true *Glossopteris*-flora in the Falkland Islands. It was, therefore, of some importance that a better material should be secured, and a definite decision of this question formed the most important object of my explorations in the Falkland Islands.

Short accounts of the geological work have already been published in »Ymer», in the »Geographical Journal» and in the »Geological Magazine» (see Bibliography).

The Devonian Formation.

Lithological character.

The Devonian occupies the whole of the Falkland Islands, with the exception of the southern half of East Falkland and two small spots on West Falkland, viz., at Cape Meredith and at Hill Cove. As already described by DARWIN, it consists of a mighty series of sandstone, slate, and quartzite. In large parts of the islands the beds are in a nearly undisturbed position. Within a zone of varying breadth, stretching from Port Stanley westwards to Falkland Sound and continuing on West Falkland in a north-westerly direction, they have, however, been subjected to folding by regional forces.

As a result of Prof. ANDERSSON'S (1907, p. 12) discovery of the basement of the Devonian, we now know the lithological character of the bottom-layers of the latter formation. Resting unconformably on the eroded surface of the disintegrated Archæan rocks, there occurs in the cliffs of Cape Meredith a reddish arkose-like sandstone with a nearly horizontal bedding. Round Stephens Peak, Prof. ANDERSSON (1907, p. 10) found a very coarse sandstone, partly yellow, partly reddish-brown in colour, and containing small quartz-pebbles. The dip of the strata was found to be 10° N. 25° W. To my great regret, I was prevented by lack of time and means of communication from visiting the locality at Cape Meredith. On the south-western islands I found the cliffs of the outer coast to consist of a very coarse sandstone, in the lower parts often containing an abundance of small, rounded quartz-pebbles (fig. 1). The sandstone is, for the most part, very hard, but the coarser varieties easily crumble when exposed to weathering. On account of the S.E.—N.W. strike of the strata in this part, and the occurrence of the Archaean basement at Cape Meredith, the sandstone-series of these islands may be considered as belonging to the lower part of the formation. The dip is generally very faint, towards N. or N.E. I nowhere observed on the south-western islands the softer, fine-grained varieties of sandstone or slate, neither did I notice any fossils there, nor were any known to the inhabitants. The great thickness of this barren sandstone-series is shown for instance, in Mount Weddell, which rises to a height of nearly 380 m., and which, from the base to the summit, consists of a hard, almost quartzitic sandstone with a nearly horizontal bedding of the strata.

In the western islands I noticed in several places a peculiar form of weathering of the coarse sandstone. The sandstone-banks sometimes show a marked vertical jointing, and the rock is, in places, quite broken up into square blocks, remaining *in situ*. Where such blocks are exposed to atmospheric agencies, their easily crumbling edges are worn off, and

Fig. 1. Coastal cliff, New Island. Coarse sandstone belonging to the lower part of the Falkland Devonian. C. Skottsberg phot.

the outer parts peel off in concentric flakes. As the final result, we get rounded boulders of varying size, remaining *in situ* or strewn over the slopes. If it had not been possible to follow the whole process of their formation, these boulders, when occurring in large accumulations, might easily have been mistaken for proofs of a recent submergence of the land. In fact, when I first noticed a wall of such boulders lying loose on the ground on the slope of a hill, I believed them to mark an old shore-line.

Mr. N. ZENZÉN has examined microscopically three different specimens of the older sandstone, from Port Stephens. The most characteristic feature was found to be the very perfect rounding of the grains, strongly suggestive, according to Mr. ZENZÉN of subaërial attrition. This is of some importance, as the origin of the thick lower sandstone-formation is by no means clear. A comparison with desert sands is, however, not supported by any other evidence from the lithological character of the deposits. There are no salt- or gypsum-deposits known from the formation nor have the rocks the red and yellow colours characteristic of desert-sediments. The absence of fossils, the intermixture with rounded pebbles, and the frequent current-bedding, are other characteristics of the sandstones in the basal part of the formation. The most natural thing appears to be to regard this lower sandstone-series as estuarine deposits. The great thickness of these decidedly littoral sediments indicates that the area must have been gradually sinking during their accumulation.

In the middle and northern parts of West Falkland, and in the northern part of the east island, the Devonian rocks occur in two different expressions. Over large areas of low land, and in the valleys of the highlands, the prevailing rocks are soft, fine-grained sandstones and slate, whereas the hills and ridges are invariably formed of hard, coarse often quartzitic sandstone, and quartzite. Of the rocks of the first group the most common is a brownish-yellow to grey sandstone, generally thin-bedded, and often cleaving in large flakes along the bedding planes. In some places, therefore, such as at Fox Bay for instance, this rock is quarried on a small scale and is used for paving. The sandstone sometimes exhibits false-bedding, and other characteristics of a shallow-water deposit. It is often somewhat argillaceous, and passes into slate. Proper slate occurs only in a far lesser degree, the rocks commonly known in the islands as slate being mostly very fine-grained varieties of the sandstone. The fossils, which are only found in these softer rocks, occur mostly in the sandstone.

The coarser and harder rocks which form the mountains are of very varying lithological character, too. Though there are abundant examples of a gradual transition, they remain, on the whole, very different from the rocks described above. In places they are seen to form series of a thickness of at least several hundred metres, without any intercalations of softer beds. There is a continuous series of varieties, from hard, coarse, clastic sandstone to pure quartzite. The latter is especially characteristic of the folded belt. It there shows evident traces of modification by regional forces. But even in the regions of little or no disturbance, the sandstones are often quartzitic. Taking everything into consideration, the hard, coarse sandstones and the quartzite may be taken as a whole, and contrasted with the beds of soft fine-grained sandstones and slate. False-bedding is a common feature of these coarser deposits. There is often a very marked resemblance to the lowest portion of the formation as observed in the south of West Falkland and, from the lithological character, the similar deposits in the north might well be taken to be equivalent with the latter. In the north, the rocks lack the intermixture of rounded quartz-pebbles, so characteristic of the basal portion of the formation, but this could be the result of the deposits having been laid down at a greater distance from the shore. The stratigraphical relations, however, give, as will be seen below, no support to this parallelisation. The rocks of this series are entirely barren of fossils, and all discussion of their precise geological age will have to be based on their relation to the fossiliferous beds.

Marine fossiliferous beds.

In order to illustrate the mode of occurrence of the fossiliferous rocks, a short description may be given here of the localities in which they have been studied.

Port Louis. A detailed description of the lithological character of the Devonian of this locality has been given by Prof. ANDERSSON (1907, p. 8). My fossils were collected partly on the north side of the bay, S.W. from the tidal tablets erected by Sir JAMES ROSS — Prof. ANDERSSON'S fossils, too, are from this place — and partly near Green Patch on the south side. It may be only added that, all round Port Louis and Duperrey Harbour, the general dip of the strata is to the south, i. e., towards the adjacent quartzite-range of Mount Vernet.

Port Salvador. The fossiliferous series round Port Louis continues over the low land to the central part of Port Salvador. On the east side of this large bay, fossils were noticed in several places. Those mentioned in the following list were collected on the southern shore of Middle Creek, where they occur in a thin-bedded fine-grained sandstone, dipping 25° S. As at Port Louis, the dip of the strata round the middle part of Port Salvador is to the south, varying generally from 20°—40°. Farther north I noticed a different strike of the fossiliferous beds. East of North Creek there occur, close to the settlement, sandstone and slate containing a fauna of the same character as that of Middle Creek. The strata dip 30° N. 50° W. N.W. from this place there is a low range of hard sandstone and quartzite without fossils, with the same strike and dip. The harder rocks of this range, which is marked on the Admiralty chart, form the peninsula of Rincon Grande, whereas North Creek is insected in the softer fossiliferous strata.

San Carlos. Near the settlement of North San Carlos there is displayed on the shore of the narrow winding creek, a soft fossiliferous sandstone and slate of the usual type. This locality lies within the zone of great disturbance, and the strata are upraised vertically with a strike N. 65° W.—S. 65° E. Both to the north and the south, the softer fossiliferous strata, which determine the course of the river and the creek, are bordered by quartzite ranges.

Fox Bay. On the N.E. side of this bay, Prof. ANDERSSON made the first discovery of Devonian fossils in West Falkland. The lithological character and position of the rocks have been described by him in some detail. From this place, low land extends across the island to the west coast and also to the north, to the foot of the Hornby Mountains. The whole of this low land appears to be formed of the soft fossiliferous rocks. Near the west coast, E. of *Spring Point,* I collected some of the common Devonian invertebrates.

Port Howard. East of Mount Maria and the Hornby Mountains, there occurs a narrow strip of fossiliferous Devonian rocks. These softer rocks form the bottom of the valley between the high mountain-range in the west and the low coastal ridge in the east. They consist of sandstone of the common kind, sometimes ferruginous, and a dark slate, both very much broken and dislocated. Most of the fossils were collected close to the settlement. The *Rensselaeria falklandensis* CLARKE n. sp. of the following list, was found north of Port Howard, however, on the »track» to Many Branch Creek.

In the northern part of West Falkland, marine fossils have been found on *Saunders Island* and *Pebble Island.* In the eastern part of Saunders Island, the low land consists of sandstone containing a few fossils. The strata dip 10°—15° N. 5°—10° E., in the direction towards Mount Egmont and the higher mountains farther north. On *Pebble Island,* which I had no opportunity of visiting, there were discovered, after I had left the islands, some very interesting fossiliferous strata. The rock seems to be somewhat different from those known in other parts of the islands. To judge from the specimens, it is a very fine-grained black slate, containing calcareous nodules, in which very clearly defined fossils are enclosed. The specimens collected here were sent by Governor and Mrs. ALLARDYCE to Dr. J. M. CLARKE, who has kindly included them in his report on the Devonian fauna.

This report, which is to be followed by a special palæontological paper containing descriptions of the fossils, will be quoted here in extenso.

The Devonian faunas of the Falkland Islands.

By JOHN M. CLARKE.

Such opinion as I have been able to form as to the stratigraphical relations of this fauna is based wholly on the very considerable number of specimens that have now passed through my hands. These embrace not only the material acquired by the Swedish Magellanian Expedition and that brought home by the Swedish South Polar Expedition, but also a series of specimens of superior quality obtained by the intelligent cooperation of Governor and Mrs. ALLARDYCE of Port Stanley. These indicate a highly uniform arenaceous sedimentary facies, barely differentiated in any degree, and in this regard in harmony with the succession of sediments both in the Bokkeveld beds of Cape Colony and the various expressions of the Devonian in southern South America. With the former this agreement is perhaps the more striking, on account of the preeminent sandy character of the beds; for in Argentina the sands are somewhat calcareous and in Bolivia there is evidence of more argillaceous deposits, while in Paraná the Devonian fossiliferous beds are very clayey, though passing into sandstones at the top. There are certain indexes of harmonious succession in these various regions. Thus the lowest fossil-bearing horizon in Bolivia is the »*Scaphocoelia*-sandstone» with true *Rensselaeria*, and it has been suggested by KNOD that the *Rensselaerias* of the Bokkeveld beds lie in a similar position. Such large *Rensselaerias (R. falklandensis)* have been found by Dr. SKOTTSBERG and Mr. HALLE in compact sandstone at Port Howard, W. Falkland.

Again, the succession in the Bokkeveld series shows shales with calc-nodules near the base. These are fossiliferous, and usually one fossil acts as the nucleus of each small concretion. Many of the most clearly defined species of the Bokkeveld are from these lime nodules. Such bodies also occur freely in the Ponta Grossa shales of Paraná, again affording superior fossils, while the best of all the fossils obtained in the Falklands are from such nodules at Pebble Island, W. Falkland, where they occur like plump nuts in a thin shell of lime. The general distribution of these nodules through the austral beds may indicate correlative sedimentary conditions. This fact, however, is of paramount import: that the sedimentary facies is on the whole, throughout the whole austral region, as uniform and undifferentiated as the fauna which it contains.

In speaking particularly of the fauna, emphasis must first be laid on the point just mentioned — that wherever its development, so far as now observed and closely studied, in Bolivia, Argentina (San Juan), Brazil (Paraná), the Falklands and in Cape Colony, it is very slightly differentiated into successive congeries. The fauna of all the regions mentioned is uniform and homogeneous, with some regional differences, but dominated by expressions peculiar to it and found in no other Devonian fauna of the world.[1]

This is distinctly an *austral* Devonian fauna as contrasted with the *boreal* Devonian and has been developed largely by geographic isolation and insulation upon epicontinents distinctly severed from the epicontinents of the north. That the boreal and austral regions approached each other closely in places and were separated by a narrow waterway which may have been at times transgressed (as evinced by the overlapping relations of the Maecurú and Ereré sandstones of the Lower Amazonas and their

[1] Intimations of its presence have been recorded from the Sahara and perhaps also from Tonkin.

quite distinctive faunas), is entirely susceptible of demonstration. The fauna in its entirety must be regarded as of Early Devonian age; indeed, interpreted by northern standards, of Lower Devonian age, and as such represents the entire biologic expression of Devonian time in latitudes south of 10° south, so far as our present knowledge extends.

The Falkland fauna is distinctively expressive of closer intimacy with that of the Bokkeveld series than with the much nearer regions at the west, and careful analysis seems to indicate a probable deep embayment between the Falklands and South America, if not complete temporary insulation of the two regions. Community of species with the west forbids the conception that such insulation was of long duration or its limits impassable.

The species thus far known from the Falkland Islands are here given with their distribution according to localities. After each species name the locality is given, accompanied by initials having the following signification:

P = Swedish South Polar Expedition,
M = Swedish Magellanian Expedition,
A = Collected by Governor and Mrs. ALLARDYCE.

(Identifications in this list are subject to final revision. Species marked with a star (*) occur in the Bokkeveld fauna, Cape Colony; those with a dagger (†) in the South American faunas.)

Fish plate	Halfway Cove, Port Philomel, W. F. (M.) Port Louis, E. F. (P.)
Dalmanites falklandensis nov.	Pebble Island, W. F. (A.) Fox Bay, W. F. (P.)
Cryphaeus Allardyceae nov.	Pebble Island, W. F. (A.)
**Phacops (Metacryphaeus) ocellus* LAKE	Pebble Island, W. F. (A.) Mt. Robinson Range, Chartres River, W. F. (M.)
**Phacops (Anchiopella) cristagalli* (WOODWARD)	Pebble Island, W. F. (A.)
**Phacops (Anchiopella) africanus* (SALTER) LAKE	Pebble Island, W. F. (A.)
**Homalonotus Herscheli* MURCHISON	Pebble Island, W. F. (A.) Port Louis, E. F. (M.) Fox Bay, W. F. (P.) Port Salvador, E. F. (M.)
Proetus sp.	Port Louis, E. F. (M.)
*† *Tentaculites crotalinus* SALTER	Pebble Island, W. F. (A.) Fox Bay, W. F. (P.) Port Louis, E. F. (M.)
*† *Conularia africana* SHARPE	Pebble Island, W. F. (A.)
*† *Orthoceras* cf. *gamkaensis* REED	Pebble Island, W. F. (A.)
**Diaphorostoma Baini* (SHARPE)	Pebble Island, W. F. (A.)
**Bucania* cf. *quadrilobata* (SALTER)	Port Salvador, E. F. (M.) Pebble Island, W. F. (A.)
Tropidocyclus Allardycei nov.	Pebble Island, W. F. (A.)

† *Loxonema?* sp.	Pebble Island, W. F. (A.)
	Port Louis, E. F. (P.)
*† *Nuculites Sharpei* REED	Pebble Island, W. F. (A.)
	Port Salvador, E. F. (M.)
Palaeoneilo (large sp.)	Fox Bay, W. F. (P.)
Toechomya?	Port Howard, W. F. (M.)
† *Cardiomorpha??* *colossea* CLARKE	San Carlos, E. F. (M.)
*† *Spirifer antarcticus* MORRIS & SHARPE	Port Louis, E. F. (M. P. A.)
	Fox Bay, W. F. (M. P.)
	Port Howard, W. F. (M.)
	San Carlos, E. F. (M.)
	Spring Point, W. F. (M.)
	Port Salvador, E. F. (M.)
† *S. Hawkinsi* MORRIS & SHARPE	Port Louis, E. F. (P.)
	Fox Bay, W. F. (M.)
*† *Leptocoelia flabellites* (CONRAD)	Pebble Island, W. F. (A.)
	Port Louis, E. F. (M. P. A.)
	Fox Bay, W. F. (M. P.)
	Port Howard, W. F. (M.)
	San Carlos, E. F. (M.)
	Saunders Island, W. F. (M.)
	Port Salvador, E. F. (M.)
*† *Schuchertella Sulivani* MORRIS & SHARPE	Port Louis, E. F. (M. P.)
	Fox Bay, W. F. (M. P.)
	Port Howard, W. F. (M.)
	Spring Point, W. F. (M.)
	Port Salvador, E. F. (M.)
Leptostrophia concinna (MORRIS & SHARPE)	Port Louis, E. F. (M. P.)
† *L.? mesembria* CLARKE	Port Howard, W. F. (M.)
	Fox Bay, W. F. (P.)
*† *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.)
C. Skottsbergi nov.	Spring Point, W. F. (M.)
	Fox Bay, W. F. (P.)
C. Hallei nov.	Port Salvador, E. F. (M.)
*† *Cryptonella? Baini* (SHARPE)	Fox Bay, W. F. (M. P.)
	Port Louis, E. F. (A.)
Rensselaeria falklandensis nov.	Port Howard, W. F. (M.)
*† *Orbiculoidea Baini* (SHARPE)	Pebble Island, W. F. (A.)
	Port Salvador, E. F. (M.)
	Fox Bay, W. F. (P.)
Pholidops sp.	Fox Bay, W. F. (P.)
Crinoid stems	Port Louis, E. F. (A. P. M.)
	Fox Bay, W. F. (P.)
	Port Salvador, E. F. (M.)
	Saunders Island, W. F. (M.)
† *Clionolithus priscus* (McCOY)	Port Louis, E. F. (A.)
	Fox Bay, W. F. (P.)

Albany, N. Y., Jan. 7th, 1910.»

Plant-bearing beds.

As the Devonian strata of the Falkland Islands belong to the lower part of the formation, there is little hope of ever finding a fossil flora of any importance. Deposits of carbonaceous materials derived, probably, from the vegetation of that period, are only rarely met with, too. The bituminous slate of Port Sussex, known to the inhabitants as »coal» and examined during the »Challenger»-expedition does not belong to the Devonian (see p. 49). On West Point Island Mr. A. E. FELTON has shown me, however, in some places bituminous rocks and also a thin layer of impure graphite. In the western coastal cliffs of that island, he has also discovered a seam of soft impure coal. It occurs as an intercalation in a very hard and coarse, often reddish and ferruginous sandstone, entirely barren of fossils.

The first account of the existence of any fossil plants in the Devonian was given by Prof. J. G. ANDERSSON. At Port Louis he found, associated with the marine invertebrates, a minute *Calamites*-like plant-fragment, but this specimen was afterwards lost at Port Stanley. When visiting Port Louis I attempted in vain to find any more specimens. Later on I discovered in West Falkland plant-bearing layers of Devonian age. The state of preservation of the few fossils obtained here, is such as to make their value a very limited one. As, however, plant-remains are very rare in the lower Devonian and are not at all known from this district, the specimens may be worthy of description, the more so as one or two of them seem to be of some palæobotanical interest.

The locality is Halfway Cove, an arm of Port Philomel. Round the little bay, the strata consist of a soft, yellowish sandstone with intercalations of grey clay. The rock is very much disintegrated, and the bedding-planes are covered with mica-scales. The poor quality of the fossils is partly due to this fact. The strata dip 10° N. 30° W., and are traversed by a narrow diabas-dyke running parallel to the strike. The fossils were found on the shore at the south side of the bay, mostly in a layer of soft, impure shale and clay, a few decimetres in thickness. Farther north, too, at the S.W. end of North West Bay, I noticed the same plant-bearing rocks. Passing southwards from this locality, older layers are met with, as a faint northerly dip seems to prevail for some distance to the south. About 10 km. south of Halfway Cove, east of Spring Point, is the above-mentioned locality for marine invertebrates. If there is no intervening fault-line between the two places, the plant-bearing rocks should, consequently, occupy a higher horizon than those with marine fossils.

Plant-remains.

In the following pages will be described some of the plant-remains. As two of the forms seem to be different from anything hitherto known, they should, perhaps, for the sake of reference, be provided with names, but, supported as I am by so scanty a material, I have hesitated to increase the number of problematic Devonian genera. The numbers of the figures will serve sufficiently well, I think, till better specimens be obtained, or the identity with some other plant-remains be established.

Lepidodendroid fragments.

Pl. 1, figs. 1—3.

Among the badly-preserved stem-fragments from Halfway Cove, there occur a few which are certainly of Lepidodendroid nature. The best specimens are shown in pl. 1, figs. 1—3. The largest one (fig. 1), is an impression, 4 cm. long and 1,5 cm. broad. Where it is sufficiently well preserved, the surface shows longitudinally elongated rhombic areoles, appearing as faint depressions. The areoles are disposed spirally, but the arrangement in longitudinal rows is more conspicuous, as they touch each other with their upper and lower ends. Laterally, the areoles are separated from each other by slightly elevated bands which bring the vertical rows into still better relief. The outlines of the areoles are not very distinct, and their shape varies somewhat, from rhombic to elongated polygonal. The areoles show no trace of any median line, nor of the leaf-scar, but near the upper end there is seen, in some better preserved places, a fairly distinct pit-like hollow (fig. 2). This scar evidently marks the position of the leaf-trace. The specimen most probably represents an impression of a decorticated surface, corresponding to the stage of preservation known as *Bergeria*.

A specific determination of this fragment is, of course, impossible, but it may be compared with some other more or less imperfectly known Lepidodendroid remains. The closest resemblance appears to be to *L. Gaspianum* DAWS., in which, to judge from DAWSON'S figures (1862, figs. 26—28, 58; 1871, figs. 82—84), the areoles form distinct vertical rows, as in the Falkland specimen. In the same species there is sometimes, too, a scar near the upper end of the areoles (DAWSON, 1882, p. 105).

In general structure, the Falklandspecimen may also be compared with *L. nothum* UNG. and *L. australe* MCCOY, both of which represent the *Begeria*-stage of preservation. These species — which may be identical — have, however, areoles many times larger, relatively to the thickness of the branches, than those of our specimen (see, for instance, FEISTMANTEL, 1878, pls. 1 and 13; SEWARD, 1910, p. 179, fig. 187).

Fig. 3 shows another indeterminable stem-fragment of Lepidodendroid nature. The specimen consists of an impression and the corresponding cast, and evidently represents a more advanced stage of decortication, approaching to some forms of *Knorria*. There are no distinct areoles, but low elevations on the cast, and corresponding depressions on the impression. The upper part of the elevations and depressions is much more marked than the lower, which passes insensibly into the intervening flat surface. This fragment may very well belong to the same species as the one described above.

Indeterminable stem-fragments.

Pl. 1, figs. 4—9.

In the shale of Halfway Cove occur several specimens of slender branches, which undoubtedly belong to one and the same kind of plant. They do not show much resemblance to any known fossil, but, having regard to the scantiness of the material, it hardly appears permissible to create a new name.

The best specimens are shown in pl. 1, figs. 4—9. They consist of dichotomously divided axes, measuring 1—2 mm. in breadth on the impressions. The surface is even, or is faintly striated longitudinally. The specimen in fig. 6 shows some small scars in the shape of rounded pits on the impression. They occur only rarely and, as it seems, without any fixed mode of arrangement. They may be leaf-scars, but this cannot be determined. No leaves or other lateral appendages are seen in connection with the stems. Judging from this specimen, which, in places, shows carbonized remains of the organic substance, the branches seem to have been solid and of a woody consistency. Figs. 4, 5, 7 and 8 show completely flattened, thin branches. The specimen shown in fig. 8, is of special interest. It agrees perfectly with the other fragments in the dichotomous branching of the stem and in general habit. The right-hand branch terminates, however, in a globular organ. As the stem also thickens towards the top, the whole branch becomes clavate. The terminal, globular protuberance has a diameter of 3 mm. on the impression, i. e., 2—3 times that of the lower part of the branch. It passes insensibly into the thickened upper part of the axis, and represents no independent organ merely attached to the top of the stem, As is indicated in fig. 9, the periphery of the impression is better marked and is rendered darker in colour by organic matter, which conveys the impression of a hollow body. In figs. 4 and 6, there are also seen faint indications of similar terminal protuberances.

I know of no species of fossil plants, Devonian or younger, to which these fragments could be referred. Dichotomously branched axes, in their general aspects closely resembling the Falkland specimens, have been described from the lower Palæozoic rocks in different parts of the world. The nearest analogy is to be found in *Hostimella hostimensis*, POTONIÉ and BERNARD (1904, p. 14, figs. 11—51), which species is partly identical with *Hostinella hostinensis* BARRANDE (STUR, 1881, p. 23, pls. 3, 4). Figs. 42—46, especially, in the former paper, have a striking resemblance to the Falkland specimens. The figures show no analogies to the terminal body, however. On the contrary, some of the Bohemian specimens possess fine, pointed, sometimes circinate ultimate segments, and there is some evidence that at least a part of what is called *Hostinella*, represents fragments of some fern-rachis. Apparently, this cannot be the case with the Falkland specimens. What their real nature is, it is impossible to say. The woody texture of the stem seems to indicate that they cannot very well belong to an alga, but probably to some primitive vascular plant. The small scars on the specimen shown in fig. 6, possibly indicate that the fossils may represent leaf-bearing shoots. The terminal globular body may be imagined as having something to do with the reproduction, though its morphological nature is altogether obscure.

Unknown plant-fragment.

Pl. 1, figs. 10, 11.

Fig. 10, pl. 1, shows a small plant-fragment, of obscure systematic affinities. As it has, however, a peculiar habit, it deserves a description.

The specimen consists of the impression of an axis, bearing, on one side, lateral appendages. The axis, which is slightly curved, has a length of 27 mm. and is 1 mm. broad. The lateral appendages arise from the concave side. At first sight they seem to be of foliar nature, but when closely examined they are found to be rather thick and clavate. They are about 3 mm. long, and consist of two well-defined parts, a rather thick stalk with, at the top, a rounded body, circular or oval on the impression. This terminal body is always clearly defined towards the stalk, and evidently represents a morphologically distinct organ. This is clearly seen in the enlarged drawing, fig 11.

One is naturally tempted to assume that the rounded terminal body may represent some sort of fructification, perhaps a sporangium. The organic substance is preserved as a thick carbonaceous sheet, quite different from the thin coal-crust covering the rest of the specimen, and shows that the bodies were rather thick, probably globular. A few of these were examined microscopically, after the usual chemical treatment, but without result. The membrane did not present any structure, and no spores were found. While being treated with a stronger solution of ammonia, the whole was dissolved.

It is impossible to form any opinion as to the affinities of this fossil. The first idea that presents itself is to regard it as a unilaterally developed segment of a fern-frond. The round bodies at the top of the lateral appendages would then represent either sporangia or cup-like indusia, surrounding sori. The stalk would be a segment of higher order, and it may be remarked that it has, though not very sharply marked off from the main axis, a somewhat different surface sculpture, more like that of a foliar organ. In the general organization, the fossil might possibly be compared with a fertile segment of *Archæopteris*, but I know of no form of that genus presenting any closer resemblance to the Falkland specimen. Among fossil remains of obscure affinities, a few specimens referred by J. REID and P. MACNAIR (1899, p. 372 pl. 21, fig. 2) to *Zosterophyllum myrtonianum* PENH. sp.,[1] seem to afford the nearest analogy to the Falkland fossil. The name *Zosterophyllum* was given originally to grass-like leaves, and there is no evidence of any connection between these and the supposed fructifications. The latter, therefore, cannot be referred to that genus, and still less can this be the case with the Falkland specimen. Having regard to the fragmentary nature of the material, I think it better to refrain from creating any new generic name until more reliable information be obtained. Perhaps, even, the fossil will prove not to belong to a vascular plant at all.

Stratigraphical conditions and correlation of the Devonian.

As seen from Dr CLARKE'S report, the Devonian fauna of the Falkland Islands is very uniform in character. The beds of the different localities contain, on the whole, the same fauna, and may be regarded as roughly equivalent. In all the localities the fossils are found only in a few well-defined strata, some decimetres in thickness at most, and occurring at a little distance vertically above each other. This fact gives rise to the question whether the fossiliferous strata occur as intercalations throughout the whole series of generally barren Devonian sediments, or represent a definite fossiliferous horizon of the formation. In the former case, the whole formation would be determined, as to its age, by the palæontological zone represented by the fossils, while, in the latter event, part of it might be considerably older or younger. It has been remarked above, that the fossils are confined to the fine-grained sandstone and the slate. These finer and softer rocks which, however, are only occasionally fossiliferous, occupy large areas in different parts of the islands, and are found to form continuous series, with a thickness of some hundreds of metres at least. The uniformity of the fauna is also an argument in favour of regarding these finer sediments as a stratigraphical unit. If the fossils had anywhere been shown to occur in this series on different horizons, at a great vertical distance from each other, this would have given a minimum figure for the vertical range of the fauna. This is not the case, however, but, on the other hand, it has not been shown that the fossils are confined to a certain, limited horizon. For the pre-

[1] Unfortunately, I have not had an opportunity of seeing PENHALLOW'S original paper which was published in the »Canadian Record of Science», 1892, pt. 1.

sent, therefore, the fauna may be regarded as roughly expressive of the age of the series of softer finer grained sediments as a whole.

If the fossiliferous series is thus regarded as a unit, its relation to the coarser barren sediments has still to be settled. As described above, the lowermost part of the formation — known to be so from the occurrence of the Archæan basement at Cape Meredith — is displayed in the extreme south and, probably, the south-west of West Falkland. The hard, coarse-grained, often quartzitic sandstones of this region show no intercalations of fossiliferous softer rocks. These are not met with, when passing to the north, until the region of low land is reached between Fox Bay and Spring Point. These fossiliferous rocks — sandstone and slate — are much finer grained than the deposits in the south. There is nothing incongruous in the idea, that the finer condition of the material might indicate merely a regional difference, and be due to deposition at a greater distance from the shore, supposing this to have been situated somewhere south of the island. It seems more likely, however, that the fossiliferous rocks occupy a higher horizon in the series, and overlie the coarse sandstones in the south and south-west. There is, in the southern part of West Falkland, a general dip to the north or north-east. This dip is very faint, but is quite sufficient to bring the strata of coarser sediments in the south below the level of the fossiliferous beds in the line Fox Bay — Spring Point. The fact that the basement of the formation does not crop out in any place north of Cape Meredith, in spite of the steep dip of the strata in several places, also shows that it is covered there by a mighty series of sediments.

The hard sandstones and quartzites of the high land in the northern parts of the islands often show, as mentioned above, a remarkable resemblance to those of the basal portion af the Devonian, displayed in the south and south-west of the western island. The two series are separated by the band of fine-grained fossiliferous rocks between Fox Bay and Spring Point. Their relation to each other can, accordingly, be settled only by ascertaining the position of the northern quartzitic rocks relative to the fossiliferous beds. There is often a continuous transition between these two series, the sandstones becoming less interstratified with slate and growing gradually harder and coarser towards the quartzite or quartzitic sandstone. This transition had already been observed by DARWIN, who, likewise, regarded the two series as representing different horizons. In order to show his view of the relation between the two series, the following remark may be quoted (DARWIN, 1846[1], p. 269):

»I nowhere actually saw the superposition of the clay-slate on the quartz, but in several places on the sea-shore I traced the most gradual transitions between these two widely different formations. — — — From the manner in which the clay-slate and sandstone often come up on each side to the base of the quartz-ranges, I have no doubt that this rock is a lower and more arenaceous formation metamorphosed.»

DARWIN'S opinion as to the superposition of the softer rocks on the quartzite does not, however, seem to hold good as a general rule. I have observed, in several places, the two different series in close connection, and, in some cases, there is no doubt that their relation to each other is not what it was believed to be by DARWIN.

Round Halfway Cove at Port Philomel, W. F., the rocks are, as described above, a soft sandstone and shale, containing Devonian plant-remains. The same kinds of soft rocks form the whole of the low land south of Port Philomel, and continue in a southerly direction to Spring Point at least, where I have found Devonian invertebrates. In the whole of this region the dip is a very faint one to N.W.—N.E. The surrounding mountains consist of hard quartzitic sandstone. The ideal section (fig. 2) shows the relative position of the two series. At North West Bay the rock is the same plant-bearing sandstone as round Halfway Cove, dipping 15° N. 10° W. Passing towards N.N.W. the same rock and the same dip are met with in the low land at the foot of the plateau in the north. In ascending the south-east slope of this plateau, the rock passes gradually into the hard quartzitic sandstone which forms, with the same dip of the strata, the high land of the peninsula between Port Philomel and King George Bay.

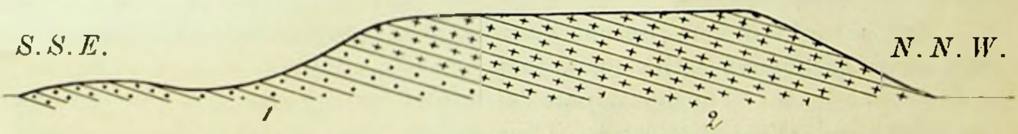

Fig. 2. Ideal section of the peninsula between Port Philomel and King George Bay. — *1.* Soft plant-bearing sandstone and clay; — *2.* Hard quartzitic sandstone. Horizontal scale 1 : 60,000. Vertical scale 1 : 8,000.

The low land between Fox Bay and Spring Point and from thence to the north, consists of soft fossiliferous sandstone, in which marine fossils have been found at the two localities mentioned. The strata dip slightly, and generally to the north. Over the low land rise Mount Sulivan, Mount Philomel, and other plateau-like hills, evidently isolated outliers left by the denudation. These mountains are seen, even at some distance, to consist of the common hard quartzitic sandstone, and this rock evidently rests on the soft sandstone of the surrounding low land.

A similar relation between the different rocks seems to exist on Saunders Island. In the eastern part of that island there occurs, near the settlement, a soft sandstone, containing some few marine fossils. These beds dip slightly (10°—15° near the settlement) towards N. 5°—10° E. Advancing in this direction, the rock passes underneath the hard quartzitic sandstone of Mount Egmont and the higher mountains farther north.

Passing to the eastern island, the stratigraphic relations at Port

Salvador afford another example. The fossiliferous strata of North Creek dip 30° N. 50° W., and are apparently covered by the quartzitic sandstone of the low ridge of Rincon Grande, as described on p. 14.

The only place where I have found fossiliferous layers within the mountain range of E. Falkland is at North San Carlos. Owing to the very disturbed position of the rocks, the stratigraphical conditions are not so clear here. The fossil-bearing sandstone-beds are upraised vertically, striking S. 65° E.—N. 65° W. On both sides, the quartzite dips at a very oblique angle from the fossiliferous beds. These seem to form here an anticlinal (see section, fig. 15), and to be covered by the quartzite.

Several other examples of the same relationship between the quartzite and the softer rocks could be given. The facts now mentioned will, however, be sufficient to show that, as a rule, the relationship between these rocks is not the one supposed by DARWIN. On the contrary, the fossiliferous strata, in every place where it has been possible to make out the stratigraphical conditions, are overlain by the quartzite, or the hard, coarse sandstone, its equivalent outside the mountain range. It is possible that a part of the coarse barren sandstones in the northern half of the islands may correspond to the lower series of similar rocks, known from the south of West Falkland. As the fossiliferous series has, however, in no case been found to rest upon such rocks, this question must remain an open one.

In the light of our present knowledge, a subdivision of the Devonian into three successive series may, therefore, be adopted, as a working hypothesis at least. The basal part is formed by the coarse sandstones in the south of West Falkland. Then follow the softer and finer grained fossiliferous sediments which, in their turn, are covered by another series of coarse hard sandstones and quartzites. It is not possible to give any exact figures respecting the thickness of the different series, but, in each instance, it certainly amounts to at least several hundred metres. As already mentioned, the precise mode of formation of the coarse hard sandstones at the bottom of the formation is not known, and the same may be said of the higher horizon of similar rocks. But, apart from this, the sequence of strata illustrates the typical course of a transgression. Its maximum is marked by the fine-grained fossiliferous rocks in the middle of the Devonian series. These rocks, too, have, however, the character of shallow-water deposits, formed not far from the shore. As the nature of these sediments remains about the same all through, the subsidence must have continued during their accumulation. The coarse sandstones that follow mark the commencing regression. In consequence of the continuation of this movement, the region became land again, and has probably remained so till recent times, as only continental deposits are known from the following periods. The Devonian transgression was evidently a very short episode in the history of this old land mass.

All over the southern hemisphere there has been traced a marine transgression, coincident in time with the one which befell the Falkland Islands. Its age has been determined as Lower Devonian, and its fauna has been found to be very uniform in all the different regions, but different from the contemporaneous faunas of Europe and showing only a little closer relationship to that of North America. It is now known from South Africa, Australia, Bolivia, Brazil, the Argentine Republic, and the Falkland Islands. The recent extensive studies of the South American faunas by Dr. J. M. CLARKE have revealed the very interesting fact, that the Falkland fauna is distinctly more closely allied to that of South Africa than to that of the far nearer Devonian areas in South America. A comparison of the nature of sediments and the sequence of strata in the Falkland Islands and South Africa is, therefore, readily suggested, and it has already been noted by Dr. CLARKE (see above, p. 16), that both districts are characterized by a predominance of arenaceous material. In the »*Geology of Cape Colony*» by A. W. ROGERS and A. L. DU TOIT (1909) there is a general review of the Devonian of the latter district. On the folded and eroded Pre-Cape rocks follows, as the lowermost member of the Cape system, the Table Mountain series of quartzites and sandstones without fossils. Above these come the Bokkeveld beds, sandstones and shales, containing marine invertebrates. This series is overlain by the sandstones, quartzites, and shales of the Witteberg group, which have yielded only some poor plant-remains.

Now, the lowermost group of the Falkland Devonian appears to present all the characteristic features of the Table Mountain series. In both cases there are light-coloured, coarse-grained arenaceous sediments which frequently exhibit false-bedding, and also often contain small rounded quartz-pebbles scattered throughout the matrix. Concerning their origin, the same points have been argued for the Table Mountain sandstones, as now, above, for the corresponding Falkland rocks (see ROGERS and DU TOIT, 1909). The position — that of the lowermost part of the formation, below the fossiliferous series — is, in both cases, the same. To the Bokkeveld group of shales and sandstones that follows, corresponds the fossiliferous middle division in the Falkland Islands. The fact that the Bokkeveld beds contain the fauna which presents the closest analogy to that of the Falkland Devonian, gives a definite support to the parallelization. In South Africa too, some badly preserved Lepidodendroid plant-remains have been found in the upper part of the middle series. The upper series of sandstones and quartzites in the Falkland Islands corresponds to the uppermost part of the Bokkeveld and, perhaps, to part of the Witteberg group, too. The rocks of the Witteberg group are, too, to a great extent, coarse sandstones and quartzites, and, as in the Falkland Islands, often resemble those of the lowermost group of the formation. No fossil plants corresponding to those known from the Witteberg series have yet been found in the Falkland Islands, and there is no evidence that the whole of that series is represented by equivalent sedimentary beds in the latter region.

The points of resemblance between the South African and the Falkland Devonian are certainly striking, and, at any rate, it is sure that the district which presents the closest analogy to the Falkland Devonian, both in fauna and in sequence of strata, is found in South Africa.

The Permo-Carboniferous Formation.

Discovery and extension.

As mentioned above (p. 10), the first intimation of the existence in the Falkland Islands of a formation younger than the Devonian was communicated in a paper by Prof. NATHORST in 1906 (p. 72). On the ground of the resemblance shown by some of the plant-remains, collected by Prof. J. G. ANDERSSON on Speedwell Island, to forms of *Phyllotheca*, more especially to *Phyllotheca deliquescens* GOEPP. sp., these plant-remains were regarded as indicating the occurrence in the Falkland Islands of Permo-Carboniferous beds with the flora of the Gondwanas. The specimens were, however, so fragmentary as to render the determination somewhat uncertain and, as Prof. NATHORST points out, *Phyllotheca* is not exclusively characteristic of the Gondwanas but is known to have persisted into the Jurassic.

In accordance with Prof. NATHORST'S view, Prof. ANDERSSON (1907, p. 14) distinguishes the plant-bearing beds from the Devonian. He also remarks, that these beds will possibly be found to constitute the whole southern part of East Falkland, south of Brenton Loch and Choiseul Sound.

During the course of the first few days after my arrival at Darwin Harbour, which is situated at the head of Choiseul Sound, I discovered in the low coastal cliff between the settlement and Goose Green some few specimens of *Glossopteris*. Later on, I found in several other localities in East Falkland, both *Glossopteris* and other representatives of the flora of the southern Palæozoic continents, thereby proving that a large part of this island does not belong to the Devonian, but to a later formation comparable with some part of the Gondwanas. I should like to suggest the name *Lafonian* as a local designation for these beds, as contrasted with the prevailing Devonian of the islands.[1]

The extension of the *Glossopteris*-bearing series is roughly coincident with that of the low land south of the Wickham Heights. The small islands

[1] *Lafonia* is the name given in the Falkland Islands to the southern peninsula of the eastern island.

round the coast of the southern part of East Falkland most certainly consist of the same formation too. A fossil flora of Gondwana-type has been found as far south as the southern point of Speedwell Island. In the west, the limit between the two formations runs along the west coast of Falkland Sound. Even the small islands, such as, for instance, the Swan Islands, situated just outside that coast, may, from their topography and position, safely be assigned to the Lafonian. In the north, the *Glossopteris*-series comes in direct contact with the Devonian of the northern part of the island. From Falkland Sound to Mount Usborne the limit of the first named series runs close along the foot of the mountain-range, as rocks of the

Fig. 3. The Wickham Heights with Mt. Usborne, seen from Darwin Harbour. In the fore-ground the low land formed by the Lafonian. C. Skottsberg phot.

Lafonian series occur north of Port Sussex, whereas the mountains consist of Devonian quartzite. The contrast between the low land of Lafonia and the Devonian mountains is seen in the photograph fig. 3. Further east, the limit is, topographically, not so well marked. From Choiseul Sound the land rises gradually towards the mountains in the north. Mount Pleasant is built up of Devonian quartzite, but only a little distance farther south, the basal layers of the Lafonian are met with.

Glacial boulder-beds.

The Lafonian has, on the whole, a nearly undisturbed position. With the exception of the southernmost part, there is, however, a faint dip to the south, often imperceptible to the eye. The inclination increases towards the folding range in the north. The bottom-layers, consequently, are found exposed near the northern limit of the formation. Unfortunately, outcrops of solid rock are not very frequent in these parts, as the ground is mostly covered by peat. So much as is displayed, however, proved to be of considerable interest.

North of Port Sussex I found at the bottom of the Lafonian series, a mudstone containing angular fragments of other rocks. I have used the term, mudstone, because the matrix is a very fine-grained argillaceous substance, but the rock appears generally more or less gritty, from the abundant intermixture with small quartz-grains. Its colour varies

Figs. 4 and 5. Specimens of the tillite, N. of Port Sussex. Nat. size. S. Bock phot.

somewhat, apparently in accordance with the relative amount of quartz-grains. Generally it is grey, changing from a dark-bluish colour to a yellowish grey. On the weathered surface it becomes of a lighter yellowish- brown. The matrix is entirely devoid of stratification, and the larger fragments are scattered irregularly through the matrix and show no indication of having been sorted in water. The rock is not very firmly consolidated and, on cleaving it, the pebbles separate easily from the matrix. The angular fragments included in the rock are only of small size, hardly exceeding a few centimetres in diameter. For the most part, they consist of hard sandstones, but pebbles of granite are fairly common too. To the naked eye, the sandstones are of very much the same aspect as some kinds of the common Devonian rocks. The granite is grey, coarse-grained, and generally somewhat disintegrated. As granite is not found *in situ* in the islands, with the exception of the small outcrop at Cape Meredith, about 130 km. distant, the occurrence of granite-pebbles was a matter of some surprise to me at the time.

As the pebble-bearing rock is entirely devoid of stratification, it was not possible to determine the inclination of the bed. The locality was situated near the foot of the mountains, which here strike N.W-S.E. Passing in a southerly direction from the locality, a fine-grained sandstone is met with. The contact between the sandstone and the pebble-bearing mudstone is, however, not displayed. A short distance south of the former locality, I found isolated angular pieces of granite in the sandstone, and here the strata appeared to dip 40° S.W. Still further south, the dip is somewhat fainter but in the same direction. Most probably, the pebble bearing mudstone underlies conformably the sandstone displayed farther south. The few outcrops in which I observed the former rock had an extension of less than 100 metres in a line perpendicular to the strike of the strata north and south of the place, but its thickness may be considerably greater than would appear from this observation. The rock shows no marked cleavage, or any other traces of the action of regional forces.

It may be mentioned that this peculiar pebble-bearing rock appears to have been observed a long time ago. Among the specimens of rocks collected at Port Sussex during the »Challenger»-Expedition and described by RENARD, there is one which seems to be identical with the rock described above (RENARD, 1889, p. 102).

As, notwithstanding the absence of large blocks, the general aspect of the pebble-bearing rock reminded me strongly of an indurated moraine or *tillite*, the term proposed by PENCK (1908, p. 234), I was much interested in searching for similar rocks in other places, and some time afterwards I found, at the shepherd's house, called Cerritos, near the foot of Mount Usborne, a boulder-bearing rock of essentially the same lithological character as that north of Port Sussex. There is, however, some difference to be noted between the rocks of the two localities. At Cerritos there is a greater variation in the structure of the matrix. In places the ground-mass is rather gritty, more like the specimens from Port Sussex; in general, the intermixture with quartz-grains is not so prominent, but the rock is more like a pure mudstone. In accordance with this fact, the colour changes from a light grey in the coarser varieties to a dark-bluish hue in the denser ones. The consistence varies somewhat, too, but generally, the rock is much more solid than at Port Sussex. The darker varieties are very hard, and present to the eye an almost crystalline appearance. The rock breaks into sharp-edged flakes and, in consequence of the firm consolidation, the fracture often passes right through the boulders embedded. As at Port Sussex, there is no trace of stratification of the matrix, and the boulders are irregularly distributed in it.

The rock shows a marked, but irregular vertical cleavage running in a W.N.W.-E.S.E. direction, and also thrust-planes on a small scale, parallel to the cleavage. With the hand-lens there is sometimes seen a parallel structure in the matrix. It is parallel to the cleavage-lines and is evidently due to pressure, like the cleavage itself. The boulders when of an elongated shape, show no definite system of arrangement in respect to the small thrust-planes or cleavage-lines.

Fig. 6. Tillite from Cerritos. Nat. size. S. Bock phot.

The boulders attain a greater size than at Port Sussex, but they do not exceed a few decimetres in diameter. They consist, as far as my observations go, of granite and (often quartzitic) sandstones occurring in about equal proportions. A striking feature is the common occurrence of parallel joints traversing the inclusions. They occur both in the sandstones and the granite, and are apparently independent of the original structure of these rocks. They appear mostly to be independent of the matrix, too; only in one case have I seen a fracture continuing into the matrix. The small thrust-planes which traverse the rock, are not continuous through the boulders either. The joints appear to be perpendicular to the cleavage-planes of the matrix, but there is no certainty that this is a constant relation. Loose boulders, which have weathered-out from the rock, are often found split up into sections along these joint-lines. The boulder shown in fig. 7, shows two systems of joints crossing each other at right angles.

The boulders are subangular, with slightly rounded edges. In appearance they are equally different from the rounded pebbles of a typical conglomerate, and from the sharply angular pieces of a fault-breccia. The surface of the granite boulders is generally uneven, evidently on account of the great effect that weathering has had on this rock. Some of the granite boulders and, practically, all the blocks consisting of quartzite or sandstone show, however, a smooth polished surface which at once attracts the attention. Very often the surface has been ground to flat, polished faces, giving a roughly facetted appearance to the boulders. Striae were only observed in one case. As, however, the rock breaks equally well through the inclusions and round them, I could only examine the surface of a limited number of boulders, mostly such as had weathered-out from the rock. In such exposed surfaces the striation may, however, soon be obliterated. In fig. 7 is seen a typical glaciated boulder of quartzitic sandstone from this locality. The striae are perfectly distinct, and cross each other at varying angles. They occur only on one side of the boulder; the surfaces of the other sides are flat and even, and show no striae or traces of grinding but represent, no doubt, joint-planes. The specimen is evidently a fragment of a large, jointed boulder, and it is not known whether the other sides, too, of the original boulder have been striated. In any case, it is not a «Reibstein», but a typical glaciated boulder, such as are found in connection with Quaternary and modern glaciations. No real facetted pebbles, with all the striae on each face running in one direction, were met with at this locality.

As the rock shows no stratification, it is not possible to determine the inclination of the bed. The rock remains quite uniform, within a zone of a breadth of several hundred metres, in a direction perpendicular to the strike. As there are traces of local faults, however, repetitions of the bed may very well occur. The rock is seen only in isolated outcrops, so it is also possible that it belongs to different boulder-bearing beds, separated by intercalations of stratified rocks. At any rate, the thickness of the boulder-bearing rock probably amounts to some hundreds of metres.

The boulder-bearing rock at Cerritos occupies the same position relative to the Devonian and the Lafonia-series, as the similar deposit at Port Sussex. Probably, the same kind of rock forms a continuous zone, along the foot of the mountains between these localities, It was to be expected, from the analogous tectonic conditions, that the zone continued also further eastwards. When riding from Darwin Harbour to Port Stanley I also struck the same rock at the shepherd's house near Mount Pleasant, and Dr. SKOTTSBERG found it about 5 km. S.E. from the top of that mountain. In both places it is exactly like the rock at Cerritos. From these two localities I have no observations concerning the stratigraphical conditions, apart from the general conclusion that here, too, the rock occupies the same position in respect to the other deposits of the Lafonia-

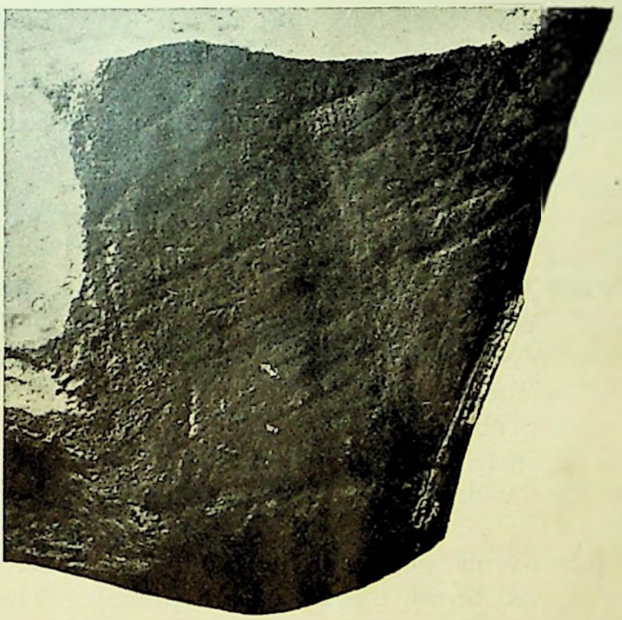

Fig. 7. Polished and striated boulder of quartzitic sandstone from the tillite of Cerritos. Nat. size. S. Bock phot.

series. There is, at any rate, no doubt that, in general, the boulder-beds form the basal part of that series.

Mr. N. ZENZÉN, who has examined microscopically my specimens of the East Falkland tillites, has kindly placed the following report at my disposal.

»Thin slices of the tillites from Port Sussex, Cerritos and Mount Pleasant show that fragments of the following rocks are present:

1. *Biotite-granite*, very well preserved.

Mineral composition: Biotite, partly chloritized; albite; soda-orthoclase; orthoclase (?); quartz; apatite; zircon. (Cerritos.)

2. *Biotite-granite,* somewhat pressed.

Min. comp.: Chloritized biotite; albite; microcline; quartz; zircon. (Cerritos.)

3. *Biotite-granite,* very strongly cataclastic.

Min. Comp.: Quite decomposed and crushed biotite; acid plagioclase; microcline (sometimes perthitic); quartz; dark ore; apatite; zircon. (Cerritos.)

4. *Gneiss.*

Min. comp.: Muscovite; biotite, decomposed; acid plagioclase, pretty much weathered; microcline, somewhat perthitic; quartz. (Cerritos.)

5. *Garnet-gneiss,* much pressed.

Min. comp.: Biotite, much chloritized; colourless garnet, partly chloritized; albite; microcline; dark ore; zircon. (Port Sussex.)

6. *Gneissic rock,* garnet- and epidote-bearing.

Min. comp.: Biotite; brownish garnet; epidote; acid plagioclase; microcline, partly perthitic; quartz; titaniferous magnetite; zircon. (Cerritos.)

7. *Diabase (?),* very much weathered.

Min. comp.: Plagioclase, decomposed; chloritic substances. (Mount Pleasant, Cerritos.)

8—10. Various, very fine-grained *sandstone*-varieties, which show no distinct traces of pressure.

Min. constituents: Grains of quartz; feldspar; muscovite; decomposition-products of biotite; apatite; zircon. In one of the fragments there is present a rather abundant clayey matrix, in the two other cases the grains lie close together. (Cerritos, Port Sussex.)

11. *Sandstone* with siliceous cement and very well rounded grains. Somewhat pressed.

Narrow quartz-veins penetrate the fragment. Some few grains of microcline, zircon, and brown tourmaline are present. The rock strongly resembles the lower Devonian sandstones of Port Stephens in West Falkland. The only difference is, that the quartz-grains of the sandstone-fragment in the tillite carry a much greater abundance of fluid inclusions. (Cerritos.)

12. *Sandstone,* traversed by a narrow quartz-vein.

The quartz of the vein especially, gives very strong strain-shadows. The grains of quartz and (subordinate) microcline of the sandstone are subangular to angular. (Cerritos.)

13. *Quartzite.*

Very fine-grained, quite recrystallized, with a brownish-yellow, pleochroitic mica, partly arranged in short curved streaks. Some few grains of apatite and dark iron-ore are present. (Cerritos.)

14. *Sandstone,* very much pressed, feldspar-bearing.

The larger grains lie in an abundant ground-mass composed of small quartz-grains and approximately parallel flakes of sericite. (Port Sussex.)

Under the microscope there is seen no assorting at all of the material of the tillites. The rock-fragments grade from rather large to comparatively small ones (about 1 mm. in diameter). They lie in an abundant fine-grained mass consisting of an approximately uniform mixture of mineral fragments of all possible sizes less than circa 1 mm. in diameter. The presence of a rather dark, brownish matter, probably ferruginous, prevents the closer examination of the finest-grained, more argillaceous parts of the tillites. The recognizable mineral fragments are all of the same kind, and present the same characters as the minerals composing the rock-fragments just described. I have stated the presence of: quartz, generally showing the characteristics of the quartz of granitic or gneissic rocks, plagioclases, potash-feldspars, garnet, epidote, apatite, and mica. Quartz- and feldspar-fragments are the most common; the other recognizable mineral fragments form only a very insignificant proportion. It should be remarked, especially, that recognizable flakes of mica are very rare.

The mineral fragments are generally angular, not unfrequently sharply angular, and show no traces of having been water-worn. Only occasionally do we meet with a more rounded quartz-grain, which possibly could have been derived from a sandstone with rounded quartz-grains.

In the slides there are often seen rudely parallel lines. They are darker than the surrounding mass, and wind along and between the mineral fragments. They must represent, I think, the lines of intersection with the cleavage-planes of the imperfectly fissile tillites. After the formation of the tillites, these must have been indurated, as there has been no special difficulty in obtaining fairly good thin-slides. Partly because of the dark, brownish matter which more or less completely conceals the finest grained parts of the tillites, there was in most cases no possibility of obtaining any information as to the nature of the indurating cement by means of microscopical examination alone. But in a couple of slides I have noticed the presence of new-formed quartz, and it may be supposed, I think, that the cement is siliceous, too, in general at least. I have not been able to prove any recrystallizing in the finer grained parts of the tillites. Many of the quartz- and rock-fragments do not show any undulose extinction, or any distinct traces of any pressure at all, but I cannot deny the possibility that the pressure to which the tillites have been subjected may have produced part, at least, of that undulose extinction which is presented by many of the quartz-fragments in the finer grained parts of the tillites, as well as by the quartzes of many of the rock fragments. I wish to remark, especially, that I cannot find any necessity for supposing that the fragment of sandstone, No. 11, Cerritos, has been subjected to any pressure before the formation of the tillite. But I feel quite sure that this pressure cannot account for the quartzite, No. 13, Cerritos, nor the very pronounced cataclastic effects exhibited by one of the granite-fragments (No. 3, Cerritos), nor the pressure phenomena in one of the gneiss-fragments (No. 5, Port Sussex) and in the sandstone, No. 12, Cerritos, nor the metamorphism of the sandstone, No. 14, Port Sussex. As for this last-mentioned sandstone-fragment, I should wish to add, that the parallel structure which has been impressed upon it, and which shows itself in the arrangement of the new-formed muscovite-flakes, forms, in the slide, an angle of about 90° with the dark lines interpreted as representing the very imperfect cleavage of the tillites. This would appear to render it impossible to suppose the metamorphism of this sandstone-fragment to have taken place after the formation of the tillite.»

Outside the area occupied by the Lafonia-series there seems to be, in one place, an outlier of the boulder-bearing deposit. On the northern coast of West-Falkland there occurs at the settlement of Hill Cove a rock very similar to that of Port Sussex. It occupies the low land just by the shore at Byron Sound. The thickness of the deposit is, in the exposed sections, not more than 20 m. at most. The deposit represents a small subsided area, limited by faults, as will be more fully described later on. The matrix is yellowish-grey in colour, sometimes a little darker, shading-off into blue. It is coarser than the rock of Port Sussex, but here, too, the gritty aspect is due to intermixture with quartz-grains of varying size, cemented by a fine argillaceous substance. The rock is of very loose consistence, and the boulders separate easily from the matrix. The deposit shows a rough horizontal bedding, but this is, perhaps, not an original feature. In small specimens no stratification is seen, and the boulders are scattered irregularly throughout the matrix. The number of boulders varies very much. The photograph, fig. 8, is of a place where boulders are comparatively scarce; as a rule they are more numerous, though never so abundant as to form a real conglomerate. Some of the boulders appear to consist of the common Devonian sandstones which form the larger part of the islands. This suggested from the first the idea, that the deposit did not belong to the Devonian, but was of a more recent date. Although, on the occasion of my visit to Hill Cove, I did not know of the occurrence of Lower Gondwana in the Falkland Islands, and still less of the presence of glacial beds, I was struck by the moraine-like appearance of the deposit. This idea was further corroborated by the occurrence of erratic material among the boulders. Perhaps the larger part of the boulders consists of coarse-grained, greatly disintegrated granite and gneiss. There were also found a red quartz-porphyry, and a metamorphosed sandstone different from the common Devonian rock. The granite boulders are often of great size, half-a-metre in diameter, or more. They have long been a puzzle to the inhabitants, who knew of no occurrence of solid granite in the islands. Though it is only a conjecture, I think that, very likely, this

Fig. 8. Section through the tillite of Hill Cove. C. Skottsberg, phot.

deposit is identical with the boulder-formation noticed in West Falkland by SULIVAN, and compared by him to the more recent »boulder-formation» (moraines inclusive) of Tierra del Fuego (DARWIN, 1846[1], p. 269, note).

The larger boulders are often somewhat rounded; the smaller ones are subangular, and very like those from Cerritos. In one case I found a typical facetted pebble, shown in fig. 9. The most prominent face shows marked parallel grooves and striae. There are, in addition, a few fainter striae running in different directions. The few parallel striae observed on the other facet run at an acute angle to the more prominent system.

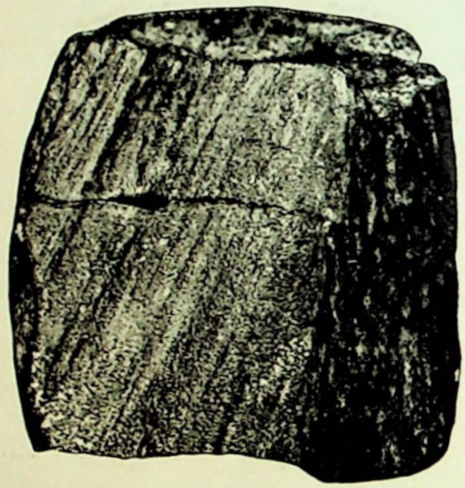

Fig. 9. Facetted pebble. Hill Cove.
Nat. size. S. Bock phot.

The tillite of Hill Cove has been examined by Mr. N. ZENZÉN, who gives the following description of it:

»Fragments of the following rocks were found:

1. *Gneiss*, schistose.

Mineral composition: Muscovite, biotite, oligoclase-albite, quartz, and zircon.

2. *Biotite-granite*.

Min. comp.: Biotite, basic oligoclase, orthoclase, quartz, apatite. Myrmekite is present. The quartz grains are quite crowded with extremely thin acicular inclusions of rutile.

3. *Quartz-porphyry*, red.

Some few phenocrysts of quartz, and numerous ones of oligoclase-albite. The ground-mass is chiefly built up of micropegmatitic pseudo-spherulites. Small heaps of dark-green biotite, partly chloritized, occur, probably representing pseudomorphs after some Fe-Mg-silicate.

4. *Sandstone,*
not much pressed, rich in feldspar-grains (plagioclase). The matrix is very abundant, argillaceous, and contains numerous, small, new-formed flakes of biotite. Mica also occurs amongst the grains which are angular to subangular.

5. *Sandstone,*
rich in feldspar-grains. Muscovite and biotite also occur. The grains are angular to subangular. The matrix is very abundant, argillaceous.

The tillite of Hill Cove does not seem to have been indurated in any great degree. It is almost impossible to get a slide from its fine-grained parts. The one which has been made presents only some quartz-fragments and small patches of the finest-grained parts. But from what I have seen I can state that there seems to be no difference between this tillite and those of East Falkland but the much lesser degree of induration, and the somewhat different nature of the rock-fragments. I should wish to emphasize the numerous, small, new-formed biotites in the matrix of the sandstone-fragment, No. 4. I think they must have existed when the tillite was formed, and as far as I have been able to find out, it seems to be probable that this sandstone has been subjected to contact-metamorphism.»

Apart from the faint traces of bedding displayed at the Hill Cove locality, the boulder-bearing deposits described above are so uniform as to leave no doubt as to the similarity of their origin. The evidence of a glacial origin of these rocks appears to be quite conclusive. The lithological character of the matrix is decidedly that of a typical, indurated moraine, or *tillite*. The intermixture of angular quartz-grains of varying size in the fine argillaceous substance, which give a gritty aspect to the otherwise dense matrix, speaks against any sorting of the material by water-action. This structure is very different from that of a common sedimentary rock, but is typical of a glacial boulder-clay. The rough bedding of the rock at Hill Cove might, possibly, be taken for an indication that the material of this deposit was discharged in water. The boulder-bearing beds of East Falkland show no trace of stratification, but are, in all respects, typical tillites; and the Hill Cove deposit may quite well be of the same nature. As far as the lithological character of the matrix is concerned, the Falkland boulder-formation is decidedly suggestive of moraine-deposits, formed by land-ice. The distribution of the boulders in the matrix is also in favour of this view. Inclusions of every size are scattered about confusedly, and the boulders are not confined to certain horizons.

The erratic nature of the boulders is another circumstance in favour of a glacial origin. In great measure they consist of rocks which seem to be identical with such of the underlying Devonian formation. The great number of granite boulders found in every locality, and the few boulders of other foreign rocks from Hill Cove must, however, have travelled over considerable distances. It is only along the northern limits of the formation that the Lafonian of East Falkland is seen to rest upon the Devonian. There is, however, every reason to suppose that the Devonian basement continues underneath the former formation much farther south. In the region where the Devonian is not now capped by the Lafonian, the denudation has evidently continued even after the deposition of the latter formation, as this has been completely worn away. Lower strata, too, have been exposed in this part by the mountain-folding. Notwithstanding these facts, the basement of the Devonian has not been laid bare in any part, except at Cape Meredith in the extreme south of West Falkland. It is, therefore, probable that no rocks older than the Devonian would have been exposed within a great distance at the time when the boulder-bearing deposits were laid down. Unfortunately, there are great difficulties in the way of determining the origin of the boulders, and, consequently, the direction of ice-movement. The Falkland Islands form only an insignificant remainder of the great land-mass existing here in the late Palæozoic, and we do not know what rocks then formed the land-surface in the adjacent regions. As to the granite-boulders, the thought readily suggests itself, that they may be derived from the formation of pre-Devonian crystalline rocks, which now rises above the level of the sea at Cape Meredith. Unfortunately, we possess no specimens of these rocks that we can compare with the boulders, and we can only suggest that, very possibly, the granite discovered here by Prof. ANDERSSON, will prove to be identical with that of the boulders. The fact that the crystalline basement now rises towards the south gives one the idea, however, that the underlying rocks which have probably supplied the erratic material, may have been exposed in this direction. We may, then, imagine a highland of pre-Devonian crystalline rocks south of the present southern coast of the islands, as the gathering-ground for the Permian ice-masses. It is to be hoped that new material will be procured from the granite and crystalline schists of Cape Meredith, in order to make it possible to institute a comparison between the erratic boulders and these rocks. This is the only possible way in which the important question of the direction of ice-movement can be solved.

The glacial nature of the boulder-bearing deposits is further confirmed by the distinctly glaciated surface of some of the inclusions. As mentioned above (p. 40) there was found at Hill Cove a facetted pebble, showing striation, and agreeing in every respect with similar structures from the Permian boulder-beds in other parts of Gondwana-land. Such facetted and striated pebbles have been the subject of much discussion, and their glacial origin has been questioned, because the Quaternary or recent glaciations were not known to have produced effects of the kind in question. The exact mode of formation of the facetted pebbles cannot be regarded as definitely solved. KOKEN and NOETLING (1903, p. 101) have presented, however, what appears to be a plausible explanation, based on some observations in the Indian Salt Range. According to these observations, the one-sidedly flat-ground boulders (»Reibsteine») were fixed in hard-frozen soil, and their upper surfaces ground down by the moraine advancing over it. A renewal of the same process with a different position of the boulder would result in the producing of facetted pebbles which evidently represent only a special variety of the «Reibsteine». PHILIPPI (1908, p. 353) has, later on, advanced a somewhat different theory. As late as in 1900, PENCK (p. 267) stated that similar facetted pebbles were not known from the Diluvial moraines, or the deposits formed by modern glaciers. Since the attention of European glacialists has been called to this subject, typical facetted pebbles have been described from Quaternary moraines, and PHILIPPI (1904, p. 737) has found such in Antarctic icebergs. The glacial origin of the facetted pebbles in the Gondwana tillites appears, then, to be beyond doubt. At any rate, this is a question concerning the Permian glaciation in general. The occurrence of facetted pebbles in the Falkland boulder-beds is another evidence of the homology of the latter with the unquestioned moraines in other parts of Gondwana-land.

It is well known, that striation of boulders may, in some cases, be the result of mass-movement. PENCK (1900, p. 268), especially, has directed our attention to such «pseudo-glacial» striation and has emphasized the necessity of considering this possibility when discussing the evidence for a Permian ice-age. Since that time, the different kinds of striation have been critically studied in several places. HOWCHIN, especially, has had occasion to examine the structures, in the case of the Lower Cambrian glaciation of South Australia, as the boulder-beds have there been clearly modified by mechanical strain. The original striation of the boulders has, in many caes, been obliterated by friction and «pseudo-glacial» striae, superinduced. The pressure striae are easily distinguished from the true glacial striation. They are equal in size and depth, are parallel, or radiate from a prominent part of the boulder. One of the blocks, obtained at Cerritos, shows such pressure-striation, very much like that on a boulder figured by HOWCHIN (1908, fig. 6, p. 246). This structure is totally different from the striation seen on the boulder in fig. 7, which is certainly of glacial origin. At Cerritos there is evidence of both pressure and vertical movements in the tillite, and such processes may well be responsible for the faintly marked «pseudo-glacial» striation mentioned above. But these movements have been working mainly along the numerous small thrust-planes traversing the matrix. There is no evidence of a mass-movement throughout the whole deposit which could have been able to grind flat faces on numerous boulders, polish nearly all, and induce striation of the kind exhibited by the specimen in fig. 7. And at Hill Cove, where a facetted and striated pebble has also been found, the boulder-bearing bed is quite horizontal and shows no effect produced by mechanical strain.

As may be gathered from what has been said above, there is a most perfect agreement, between the Falkland boulder-bearing beds, and the Permian tillites in other regions. The agreement with the corresponding deposits in South Africa appears to be the most striking feature. Indeed, the descriptions given by ROGERS and DU TOIT (1909) in their «Geology of Cape Colony» of certain parts of the Dwyka tillites could, with very slight modifications, be quoted for the Lafonian boulder-beds. There is, in both cases, the same difference between the loose consistence of the rock when in an undisturbed position, and its harder, more solid character in the regions which have been subjected to folding. The very hardest varieties of the tillite at Cerritos have an almost crystalline aspect, and I was at first in doubt whether the rock was not of volcanic origin. A closer examination and, above all, the microscopical investigations made by ZENZÉN definitely excluded this possibility. It is of interest to note, however, that the Dwyka boulder-bed of South Africa was, when first discovered, regarded as a volcanic rock and for some time was referred to as «trap conglomerate» and «claystone-porphyry», or even as «a species of trachyte». The Talchir tillites, too, have been regarded as volcanic.

The peculiar, close jointing of the boulders at Cerritos is also a feature met with in other localities where similar deposits have been influenced by mass-movement. This structure is probably in no way connected with the glacial origin of the rock, but is a secondary feature. It has, however, been recorded also from the horizontally-bedded northern Dwyka of Cape Colony, the joint-planes there being generally horizontal but, occasionally, also vertical (see ROGERS and DU TOIT, 1909, p. 182). In the southern, folded Dwyka of the same district, the joints are stated to be parallel to the strike but not to the bedding-planes. As described above, I have found the fractures to be in most cases at right angles — or nearly so — to the cleavage-lines, though it is not sure that this will prove to be a constant feature. I find that HOWCHIN describes the same kind of jointing from the Lower Cambrian boulder-beds of South Australia, and states that the fractures are vertical to the cleavage. KOKEN (1907, p. 450) seems inclined to regard the jointing as an original structure caused by pressure during the formation of the moraines. The fact that the fractures are strictly parallel to each other in one and the same boulder, even in such as are no typical «Reibsteine», speaks decidedly against this view. There also appears to be sufficient evidence, both from the Falkland Islands and other Palæozoic boulder beds, of a certain relation of the jointing to the cleavage in the matrix. In one case I have also seen a joint-plane of a boulder continue into the matrix.

A striated floor has not yet been found underneath the Lafonian boulder-beds. As, in these parts, the ground is mostly covered by thick peat, the contact between the two formations will certainly be found displayed only to a very limited extent. In some favourable localities, however, — such as, for instance, where the limit strikes the coast-line, or in the higher region north of Choiseul Sound — the direct contact will perhaps be discovered. I do not doubt but that the surface of the Devonian will then be found to exhibit the characteristic features of a glaciated floor, such as «roches moutonnées», grooved and striated surfaces, etc.

Fluvio-(?) and limno-glacial beds.

The stratified deposits covering the Lafonian boulder-beds are, in general, characterized by the occurrence of plant-remains. In the lower beds, fossils are very rare, however, and in some parts are not found at all. There is also a certain difference in lithological character between the lower and the higher parts of the stratified series. It seems, indeed, as if the influence of glacial conditions could be traced for some distance up into the stratified deposits, and was responsible for some peculiar features of their lowermost portion.

The general dip of the strata is, in the whole region of the Lafonian, to the south or to the south-west in the north-western part. Passing in a southerly direction, younger and younger layers are, accordingly, met with. In some parts, especially at Darwin Harbour, there is, however, an abnormal strike and dip, which may cause older layers to crop out more to the south than would be expected. Undeterminable plant-remains, and a piece of petrified wood have been found as far north as between Port Sussex and Cantera. The unusually steep southerly inclination of the strata round Port Sussex probably causes a higher portion of the series to be preserved here than is the case more to the east. In spite of diligent search, however, determinable fossils have not been found north of Darwin Harbour. The region between the tillite beds in the north and Brenton Loch and Darwin in the south may, therefore, be assigned to the lower part of the Lafonian.

On the whole, this lower division, as well as the formation generally, consists of arenaceous or argillaceous sediments, only differing somewhat as to colour and the relative coarseness of the material. The absence of calcareous sediments is a still more striking feature of the Permo-Carboniferous series than it is of the Devonian.

To the basal part of the stratified series belongs, evidently, the sandstone north of Port Sussex mentioned above (p. 32). It is grey or yellowish in colour, and contains small scattered pieces of granite as an evidence of the continuance of glacial conditions. It occurs just south of, and evidently overlies, the boulder-bed. The dip is about 40° S.W. and, passing in this direction, the succeeding higher beds are seen to be of the same lithological character, but without embedded erratics. Still further south, it is succeeded by the dark slate at Port Sussex.

Further east, erratic inclusions have not been found in the stratified deposits, but it seems probable that here, too, glacial conditions have prevailed during the formation of the lower portion of the said beds. In many places between Cerritos and Darwin Harbour, there are good sections of parts of this lower division, but, on account of the abundant growth of the peat, it is impossible to connect the different observations, or to arrive at a detailed stratigraphical subdivision. The common rocks are sandstone and claystone, the latter passing into a more or less thinly

Fig. 10. Sandstone with intercalated band of claystone. Darwin Harbour. Nat. size. S. Bock phot.

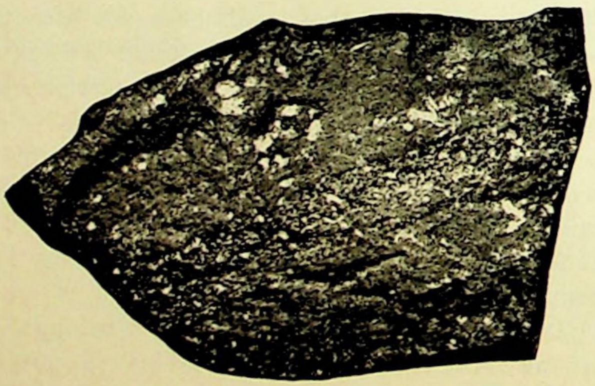

Fig. 11. Slate with a band of sandstone. Darwin Harbour. Nat. size. S. Bock phot.

laminated slate. The sandstone is fine-grained, and, generally, thin-bedded like the fossiliferous Devonian sandstone. Anything approaching the harder and coarser rocks of that formation has not been noted in the Lafonian. In colour, the sandstone is yellow, grey, or brown, sometimes shading-off into green. The finer grained, slaty deposits also show a great variety of colours, from light-grey to nearly black, and often shading-off into green, too. There is every transition, from slates to compact clay-stones.

The rocks of the lower series occur in characteristic development north of and around Darwin Harbour. They here closely approach the fossiliferous rocks a little farther south, which evidently belong to a higher horizon. Direct superposition was not seen, however, and the stratigraphy here is not very clear on account of a varying strike and dip. A most prominent feature is the repeated alternation of beds of coarse sandstone and dense clay-stone or slate. As a rule, one kind of rock predominates, while the other occurs as thin intercalations, often only a centimetre or less in thickness. Figs. 10 and 11 show two typical specimens from a place just south of the settlement. The intercalated bands can only be followed a short distance, as they thin out and disappear on account of the current-bedding of the deposits. This is another, and most characteristic feature of the lower Lafonian. It is found also higher up in the series, but not nearly so well developed.

Fig. 12. Laminated claystone. Darwin Harbour. Nat. size.
S. Bock phot.

Another example of rapid changes in the sedimentation can be noted in a certain kind of claystone, which occurs in typical development near the settlement of Darwin Harbour. It is worked at this place in a small quarry near the beach, and is used for building purposes. The rock, which is nearly horizontally bedded, shows a marked lamination caused by the alternation of differently coloured zones. The alternation of the zones is a fairly regular one, one yellowish brown and one dark-grey zone, forming together one layer, or marking one cycle of sedimentation. The thickness of each stratum of two zones varies considerably, generally between some few millimetres and one centimetre. On a microscopical examination of a section of this rock it is seen that the brown or yellow zone is formed of much coarser material, angular or but little rounded quartz-grains being abundantly mixed in the denser matrix. The dark-grey zone, which often has a shade of green, consists of purer, fine argillaceous material. The whole appearance of this rock is strongly suggestive of the well-known seasonally laminated clays from the areas of Diluvial glaciation. In these clays, each stratum is generally understood to represent the sedimentation of one year. The coarser grained brown or yellow zone, formed during the melting of the ice in spring and summer, passes gradually into the dark-grey zone corresponding to a slower sedimentation, and this borders, with a sharply-defined limit, on the lower zone of the following year. In the claystone of Darwin Harbour the limits between the zones are not so regularly marked, and it is not always possible to distinguish between a gradual change from brown to grey, and the rapid one from grey to brown. Yet, the resemblance to the real seasonal clays is great, and it seems probable that this Permo-Carboniferous clay owes its peculiar lamination to a succession of annual layers. At any rate, a certain periodicity in the sedimentation is undubitable.

In the section at the quarry, the laminated claystone has a thickness of only a couple of metres. Its relation to the current-bedded sandstones and claystones south of the locality, is not directly seen. Probably it overlies the latter beds as, close by, the dip was found to be 10° N. 60° W. This is the only place where I have seen a rock of this kind. The slaty deposits at Camilla Creek, farther north, sometimes exhibit a sort of lamination, which is not nearly so regular, however.

Taken as a whole, the stratified deposits of the lower Lafonian are characterized by a rapid and repeated alternation of different sediments, a great local variation, and frequent current-bedding, As, too, in contrast with the higher part of the formation, determinable fossils are absent, these rocks may, with some accuracy, be regarded as fluvio- or limno-glacial sediments. The occurrence of small, undeterminable vegetable remains in several places shows that, during the deposition of the series, the vegetation was not far distant. The current-bedding characterizing several of these sediments, indicates the presence of running water. Gravelly deposits, or shingle-beds, so common in the Diluvial fluvio-glacial, have not been noted, however, and, possibly, the coarser current-bedded sandstones should also be regarded as delta-deposits, and the whole series as limno-glacial, formed in the large basin in which the higher part, too, of the formation was laid down. The lamination of the claystone at Darwin Harbour seems to indicate that the water was not salt, and this is more than probable from the total absence of any traces of marine life in the entire formation.

Plant-bearing beds.

In lithological character, the upper, plant-bearing division of the Lafonian also shows a great local variation. Sandstone, claystone, and slate are the dominant rocks, and often occur in alternating beds. The sandstone is generally thin-bedded and fine-grained, and sometimes shows current-bedding. The usual colour is yellow, but brown and grey varieties also occur. The sandstones are not to be distinguished from the Devonian rocks. The slate and the claystone are mostly dark-grey, often with a conspicuous shading-off into green. The rock last-named is very characteristic on account of its occurrence in thick compact banks, without any visible stratification, but traversed by joint-lines. Calcareous sediments are entirely absent.

The variation in lithological character is the same throughout the whole division, and also in the different parts of the area occupied by it. There is, too, no unconformity of general importance, the irregularities in the stratification which are now and then to be seen, being only strictly local. There is, therefore, no ground for a subdivision into successive series. The only trace of any difference in this respect may, possibly, be found in a not very marked prevalence of more fine-grained sediments in the south. This fact might be accounted for by assuming a greater distance from the shore, which would then have been situated somewhere north of the northern limit of the formation. As, however, there is generally a faint dip to the south or south-east, it is more probable that the prevalence of finer sediments in the south is due to the occurrence of a higher horizon there. The palæontological data seem, indeed, to offer some slight evidence in the same direction.

When passing from north to south, the first place where vegetable remains are met with, is at Port Sussex (see above, p. 45). With the exception of a piece of badly-preserved fossilized wood of the *Dadoxylon*-type, there occur, however, only undeterminable fragments. Immediately north of the creek, the rock is a dark slate, traversed by joint-lines and with a sharp dip (generally about 60°) to the S.W. The rock is often quite black, in consequence of carbonaceous impregnation, and also contains lenticular lumps of soft, impure lignite. It was this »coal» that was examined by MOSELY during the »Challenger»-Expedition. Port Sussex evidently marks a fault-line. On the S.W. side, the rock is a yellow sandstone, in which the plant-fragments were found. The dip here is fainter, but in the same direction.

On the peninsula south of Choiseul Sound and Brenton Loch, determinable plant-remains were collected in several places. There is not much difference to be noted between the various localities. The same variation of sandstone, slate, and claystone is seen in all of them. The fossils occur in all the different kinds of rocks, but are better preserved in the fine-grained varieties, especially in a very hard, siliceous slate. The more important localities will be enumerated here.

Between Darwin Harbour and Bodie Inlet. The alternating beds of sandstone and claystone dip faintly to the S.W. Fossils were found scattered in the different rocks the whole way along the shore, from a place between Darwin and Goose Green to Bodie Inlet.

Bodie Creek Head. Plant-remains occur here in a very hard grey-green slate with the usual southerly dip. Associated with the plant-remains was also found an impression of an insect-wing, described below by Prof. G. HOLM.

Dos Lomas. The plant-bearing rock is a yellow to grey-green, very hard claystone. The strike here, as in several places along the western shore of Falkland Sound, is N. 30° E.—S. 30° W., the dip 12° N. 60° W.

East of Low Bay. The strata, which here dip only faintly to the south, are composed of sandstone and a dense, hard, slaty claystone. They have yielded several specimens of plants.

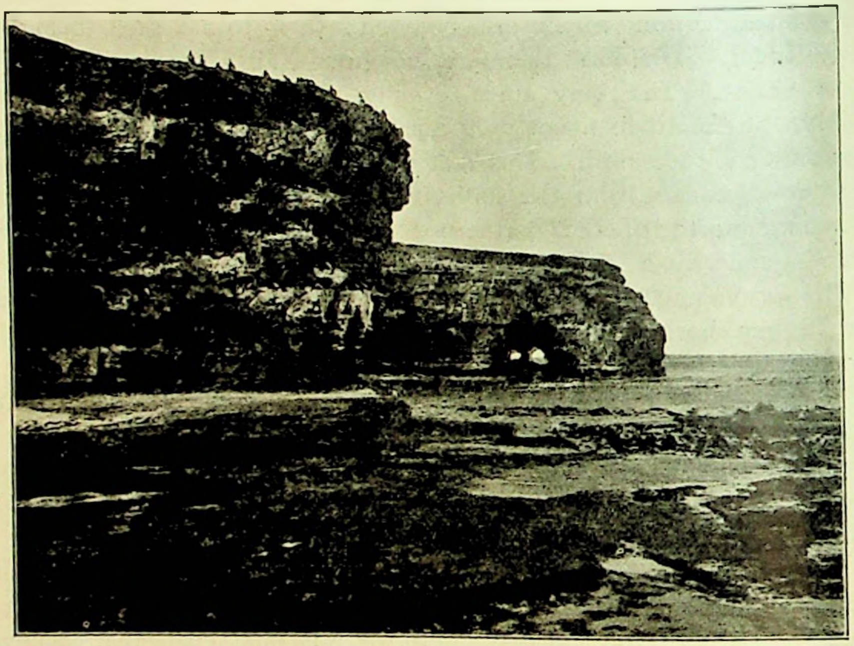

Fig. 13. Coastal cliff formed by Lafonian sandstone. Low Bay, E. Falkland. C. Skottsberg phot.

North Arm. At the creek, north of and opposite the settlement, occur numerous, but generally badly-preserved plant-remains. The prevailing rock is a dense, hard, grey or green claystone, dipping 5° S.S.E.

On *Speedwell Island,* fossil plants were collected on the east coast, north and south of the settlement, and at the southern point of the island. Most of the fossils were found in a dense, grey-green claystone. The bedding is nearly horizontal.

On the coast opposite the island, plant-remains also occur in similar rocks.

Fossilized wood was not seen at any of the localities yielding impressions. Several specimens, however, have been found at the following places: East of Tranquilidad, near Arrow Harbour, and at two places on opposite sides of Bodie Inlet. The wood was, in every instance, found lying loose on the ground, and the prevailing rock is everywhere a coarse sandstone.

Plant-remains.

In the following pages the fossil plants of the Lafonian will be briefly described. As regards nomenclature, ARBER'S monograph (1905) has been followed as a rule. In the limitation of species, too, the principles of that well-known work have been adopted. Synonyms have not been given, as the species are all well-known, and any information required in this respect can be found in ARBER'S catalogue.

Phyllotheca australis BRGN.

Pl. 1, figs. 12—20.

Plant-remains belonging to *Phyllotheca* have been collected in several places in Lafonia. Most of the specimens are from Speedwell Island, from which locality the genus was first recorded by Prof. NATHORST (1906), on an examination of the material collected by Prof. ANDERSSON. Some of the new specimens agree closely with Prof. ANDERSSON'S, but some of different aspect were also found. With the better material now available a more exact determination may be attempted. As is usually the case with fossil Equisetales, the remains are very fragmentary, however, and the different parts occur detached from each other. Under such circumstances, specific determination must always be a matter of much uncertainty, and this the more so, as there is much doubt regarding the delimitation and the systematic value of the different species hitherto recorded from the Gondwanas. It is, however, fairly sure that the greater part of the specimens belong to *Phyllotheca australis* BRGN.

Equisetaceous stem-fragments are among the most common fossils in the Lafonian. As a rule, they are casts or impressions of decorticated stems, the outer layers having been removed before the fossilization. In such cases there is no possibility of even a generic determination. Sometimes the original surface of the stem is preserved, but the leaves are worn off. Several specimens of that kind may, with some accuracy, be referred to *Phyllotheca australis*. Figs. 12—14, pl. 1, show two such impressions. The largest fragment has a length of 9 cm. and a breadth of 1 cm. The internodes measure about 1 cm. in length. There is no trace of the leaves, the sheaths having been detached immediately at the node. The number of leaves may still be made out, however, as the commissural furrows which separate the segments of the sheath continue below the node. On the impression they appear as ridges with a faint median groove. They are fairly distinct at the node, but taper quickly downwards and generally disappear above the next node. In some cases they can, however, be traced as faint lines the whole way down to the next lower node. Sometimes these lines meet the commissural furrows of the lower node, in other cases they alternate, equally distinctly, with these furrows. On the surface of the stem is thus repeated the feature known from the interior casts of *Phyllotheca*, viz., that the bundles may be continuous at the node, or alternate as in *Equisetum*. This is, however, by no means characteristic of *Phyllotheca* alone, but the same feature has been recognized in other Mesozoic Equisetales (HALLE, 1908[1], p. 25). With the exception of the fine lines forming the downward continuation of the commissural furrows, the internodes show a perfectly smooth surface. In the middle of each segment there is seen, in some cases, just below the node, a faint line which apparently marks the continuation of the leaf-trace passing out into the sheath. The number of segments is about 12—14 on the impression, and consequently 24—28 on the whole stem. As the sheaths with their free segments are not preserved, the distinctive character of the genus is not present in these specimens. They could, in fact, be referred equally well to *Equisetites*, and would certainly have been so, had they been found in the Mesozoic of the northern hemisphere. The Falkland specimens agree well, however, with figures given of stems of *Phyllotheca*, especially with the one in ARBER'S monograph (1905, pl. 2, fig. 6).

The association of stem-fragments of this kind with leaf-sheaths of *Phyllotheca*-type, both in the Falkland Islands and in other parts of Gondwana-land, also affords a strong argument for their being referred to *Phyllotheca*. In such cases where leaf-sheaths of *Phyllotheca* have been found in connection with the stem, this has a similar appearance to the Falkland specimens. On the other hand, true *Equisetites* with the leaves coherent in sheaths for the greater part of their length have not yet been recorded from Gondwana land. *Equisetites Morenianus* KURTZ (1894, p. 129, pl. 3, fig. 1) is at least doubtful, and might equally well be attributed to *Phyllotheca*, as has indeed been remarked by ARBER (1905, p. 33), though this author hesitatingly applies the generic name *Equisetites*. KURTZ himself remarks that the species very probably belongs to the genus *Schizoneura* (l. c., p. 136). If *Phyllotheca* be substituted for this name, I think it would come nearer the truth. There is nothing in KURTZ'S figure that does not agree perfectly with illustrations published of smaller branches of *Phyllotheca*, especially with the figures given by SCHMALHAUSEN (1879, pl. 10, figs. 6, 6 a) of *P. deliquescens*. All these facts taken into consideration, it seems fairly certain that the Falkland stems described above belong to *Phyllotheca* and not to *Equisetites*.

In the specimen shown in fig. 14, there are seen at the upper node some small round markings. They are situated at the upper ends of the commissural furrows, between the segments of the sheath. From their mode af arrangement, these markings may, with some certainty, be regarded as scars of slender branches placed in verticils round the node. Branches of this kind are not known before as occurring in *P. australis*, but the specimen very much resembles the typical one seen in fig. 12, and cannot well be distinguished from it. *P. australis* was defined by BRONGNIART (1828, p. 151) and McCOY (1847, p. 156) as possessing simple stems, differing in this respect, according to the latter author, from his new species *P. ramosa* (l. c., p. 156, pl. 11, figs. 2, 3). ARBER has lately (1902, p. 14) included the latter species together with *P. Hookeri* McCOY (in part) under *P. australis*. In none of these forms, however, is there known a form of branching like that of the present specimen.

The leaf-sheaths of the larger stems occur only isolated in the rock, whereas those of the smaller branches remain attached to the nodes. The specimens figured in pl. 1, figs. 15, 16, probably represent basal portions of detached leaf-sheaths, deprived of their free teeth. The one shown in fig. 16, agrees perfectly, as regards the number and breadth of the segments, with the basal continuations of the leaf-sheaths seen on the stems (as, for instance, in fig. 12, pl. 1). Other sheaths are larger, with broader segments, but as there is a gradual transition between the different forms, they probably belong to the same species. The sheath figured in fig. 17, is more open and cup-like, and seems to be still attached to the stem. There are also some remains of the free teeth. The length of the sheaths varies considerably. Probably there is, in this respect, some difference between the larger stems and the slender branches. It is also possible, that the sheath splits up more deeply in older specimens.

Detached sheaths with the free segments preserved, also occur in the rock. Two specimens are shown in figs. 18, 19, pl. 1. In the small specimen, fig. 18, the coherent part of the sheath is also indicated. The free teeth are short, only 3—5 mm., and considerably more than 10 in number. In some of them a median vein is distinctly seen.

In pl. 1, fig. 20, is represented a fairly large stem-fragment with the leaves still connected. It is somewhat different from the other specimens, but it probably also belongs to *P. australis*. The stem is about 1 cm. broad on the impression; the length of the internodes is 10—15 cm. The internodes are broadly sulcate, and the ribs opposite or alternate at the nodes, as in the specimen (fig. 12) described above. The coherent parts of the sheaths are not preserved, but at the sides of the impression free segments are seen attached, exactly at the nodes. The length of these free segments is about one half of that of the internodes. They are directed obliquely upwards, and are slightly incurved. It appears as if the sheath had, in this case, split up right down to the base. The present fragment differs from most specimens of *P. australis* in the comparatively broad ribs of the stem. In this respect it agrees very well with a specimen figured by FEISTMANTEL (1878, pl. 15, fig. 1; 1890, pl. 14, fig. 1). The latter specimen, however, has broader and more coherent segments, very similar, except in size, to the sheath in pl. 1, fig. 18 of the present paper.

Specimens which can be referred to *P. australis* are found at nearly all the localities yielding fossil plants. It has not been collected at the northernmost localities, Darwin Harbour and Dos Lomas, and it seems to be more common in the extreme south.

The species is known with certainty only from Australia and Tasmania. It ought to be remarked, however, that *P. indica* BUNBURY from the Raniganj Group of India may quite well be identical with the Australian species, although a different opinion also exists.

Phyllotheca cfr. **deliquescens** GOEPP. sp.

Pl. 1, figs. 21—26.

In describing the first fossils from the Gondwanas of the Falkland Islands, Prof. NATHORST noted the close resemblance shown by some of these Equisetaceous remains to *Phyllotheca deliquescens* GOEPP. sp. This was especially the case with the specimens shown in figs. 1, 2, and 6 of his paper (1906, pl. 7). The occurrence of the species in the Falkland Islands is, to some extent, confirmed by some fragments in my collection which agree, at any rate, far better with illustrations given of *P. deliquescens* than with any other species of that genus found in the Gondwanas.

Fig. 21, pl. 1, shows a detached sheath with apparently about 10—12 segments. The free part of each segment is about 15 mm. long, is linear and very narrow; the apex is acutely pointed. The coherent part is very short and the sheath has evidently belonged to a fairly slender branch. The possibility is not quite excluded that this sheath may have been borne by a plant of the same kind as those referred here to *P. australis,* but, on the whole, the resemblance to *P. deliquescens* is the greater. Some of SCHMALHAUSEN'S specimens (1879, pl. 10), especially, are very similar.

A still greater resemblance to the latter species is presented by some slender branches with the sheaths still in position. Some of these specimens are shown in natural size in pl. 1, figs. 22—24. The sheaths are narrow and funnel-shaped, their lower parts being closely applied to the stem. The free segments measure up to 15 mm. in length; they are narrow and linear in shape, and acutely pointed, as in the specimen shown in fig. 21. In all the specimens the free segments are directed obliquely upwards, and their tips are slightly incurved. Fig. 25 represents a fragment of a sheath, enlarged four times. These specimens show a striking resemblance to those figured by SCHMALHAUSEN (1879), especially to his fig. 2 c, pl. 1; figs. 6, 7, pl. 10. The small branch figured by NATHORST (1906, pl. 7, fig. 6) is evidently of the same kind, too. The only difference between the Falkland specimens and those from Siberia appears to be that, in the former, the internodes are shorter, as compared with the length of the free segments. Slender branches like those described here are not known to occur in *P. australis.* As stated above, one of the Falkland specimens apparently belonging to that species, shows, however, scars of branches, placed in whorls at the nodes, and such branches may possibly have been similar to those here referred to *P. deliquescens*.

The larger stems of *P. deliquescens* are generally understood to be more broadly sulcate than those of *P. australis*, and *P. indica*. Much weight cannot be attached to this difference, as the latter two species may also have possessed stouter stems, only that these have not been found in connection with the leaf-bearing shoots. There is, indeed, no evidence that such stout, broadly sulcate casts as are now commonly referred to *P. deliquescens* belong to this species, any more than they do to *P. australis* or *P. indica*. Broadly-ribbed stems, agreeing perfectly with those figured by different authors as *P. deliquescens*, are of common occurrence in the Falklands. One such specimen is figured in pl. 1, fig. 26.

The specimens here referred to *P. deliquescens* are from the same localities as those described under *P. australis*. The specimen shown in fig. 26, however, is from Dos Lomas.

P. deliquescens is known with certainty only from Siberia. The age of the beds in which it occurs there, has been a matter of some dispute. SCHMALHAUSEN and POTONIÉ have advocated a Jurassic age, whereas ZEILLER has shown the close connection of the flora to that of the Permian of Europe and North America. The specimens from the Gondwanas of New South Wales, India, and South Africa, referred to this species (ARBER, 1905, p. 22), consist only of casts or impressions of stems, without sheaths. In my opinion, such material does not permit of even a generic, far less of a specific determination. The species has been recorded by BODENBENDER (1902, p. 238, 248) from the Argentine Republic, but this statement is not accompanied by any description or illustrations. It must, at present, be regarded as doubtful whether SCHMALHAUSEN'S species has hitherto been found in the southern Permo-Carboniferous at all. In consequence, I have not definitely included the Falkland specimens in *P. deliquescens*, although it must be stated that they agree more closely with the Siberian fossils than do any of the stems recorded from the Gondwanas.

Glossopteris Browniana BRGN. (pro parte).

Pl. 1, fig. 27—29 a.

Glossopteris Browniana has been found in the Falkland Islands, but only some few specimens have been collected and no entire leaves are represented. The largest fragment is shown in pl. 1, fig. 29. It measures little more than 5 cm. in length and represents the basal portion of a frond. It is about 2 cm. broad at the broken distal end. Neither in this fragment, nor in any other, is the exact shape of the frond to be seen, but, as far as can be made out, it agrees fairly well with that of *G. Browniana*.

The venation is clearly seen in several specimens. In all the fronds referred to this species, the lateral veins arch rather abruptly near the midrib, and continue in a direction forming a fairly open angle with the margin. The meshes are broad, polygonal or trapezoidal, and somewhat irregular in shape. There is very little difference in shape and size between the meshes bordering on the midrib and those near the margin. The venation is shown in figs. 27 a, 28 a, 29 a. As compared with the typical specimens figured by ZEILLER (1896, p. 363, figs. 8—10) the venation of the Falkland fronds is rather more open, with broader meshes. In the specimen shown in fig. 27, pl. 1, some of the meshes are almost as broad, comparatively, as in *G. retifera* FEISTM. The agreement with *G. Browniana*, is, however, the more conspicuous. The difference between these specimens and those of *G. indica* is very marked and, as far as the Falkland specimens are concerned, the distinction between the two species is clearly defined.

Most of the fronds referred here to *G. Browniana* are from the locality south of Dos Lomas at Falkland Sound. The specimen shown in fig. 28, however, is from south of Goose Green. A badly preserved frond from Speedwell Island probably belongs to the same species, too.

G. Browniana is one of the most widely distributed species of the *Glossopteris*-flora. It is known both from India and Australia, but, unlike *G. indica*, it is most commonly distributed in the latter continent. It is also known from many places in South Africa, and from Portuguese East Africa. It has further been recorded by D. WHITE (1908, p. 499, pl. 6, figs. 3, 4, 6) from the Gondwanas of Brazil, and by KURTZ (BODENBENDER, 1902, p. 212, 254) from the Argentine Republic.

In contrast to *G. indica*, this species appears to have died out with the close of the Permian. It had been recorded by ZEILLER from the Triassic of Tonquin in 1882, but in 1903 (p. 88), the same author was able to state that the plant in question is really *G. indica*.

Glossopteris indica SCHIMPER.

Pl. 2, figs. 1—6 a.

The greater number of the specimens of *Glossopteris* from the Falkland Islands belong to *G. indica* SCHIMPER. In general, the specific determination meets with no difficulty. The material illustrates, however, the great variability of the species, and a few specimens seem, in some respects, to approach other related species.

The largest specimen from the Falkland Islands is that shown in pl. 2, fig. 1. It measures about 21 cm. in length, and is nearly 4 cm. broad in the widest part. The lamina is somewhat narrower than is generally the case in this species, but is otherwise of typical shape. The gradual contraction towards the base is seen in the figure. The apex is nearly complete, and is seen to be acute as in the Indian specimens. The apex of another frond also belonging to this species is seen in pl. 2, fig. 3.

The venation, too, varies considerably. Pl. 2, fig. 2 a shows the typical venation of the Falkland specimens. The lateral veins are more or less parallel, are oblique, and arch gradually towards the margin. The venation agrees, on the whole, with that of the type-specimen as re-drawn by ZEILLER (1896, p. 367, figs. 11, 12), and of a great number of specimens figured by the same author (1896, 1902). In general, forms with dense venation and parallel. comparatively rarely anastomosing secondary veins, seem to be predominant among the Falkland-material of this species.

Figs. 6, 6 a, pl. 2, represent a specimen of *G. indica* which seems to deserve a separate description. The frond is more than 4 cm. broad and appears to have been comparatively short. The chief characteristic is, that, except near the midrib, the secondary veins are very little arched or are almost straight. Close to the midrib the venation is not seen quite clearly, only the stouter veins being preserved. Prof. ZEILLER, to whom I have submitted the drawings of the specimen, has pointed out that the apparent open angle formed by the basal portions of the lateral veins with the midrib, is suggestive of *G. damudica* FEISTM. As stated above, the preservation is not very good, but a careful re-examination has convinced me that the veins are generally more arched at the base than at the spot shown in the figure, and join the midrib more tangentially. The specimen should, therefore, most probably be included in *G. indica* but, at the same time, it must be admitted that it differs considerably from other specimens of that species found in the Falkland Islands.

G. indica is the most common fossil in the Gondwana-beds of the Falkland Islands. I have collected it in the following localities: Darwin Harbour, Goose Green, Bodie Creek Head, Dos Lomas, Low Bay, Speedwell Island; in fact at nearly every place where any determinable plant-impressions have been found.

As to the distribution of the species in other parts of Gondwana-land, it is of interest to note that it is most commonly distributed in India (Talchir and Damuda groups) and also in South Africa, but that it is comparatively rare in Australia, where it is replaced by *G. Browniana.* D. WHITE (1908, p. 503, pl. 6, figs. 5, 7, 8) has recorded it from Brazil, and BODENBENDER (1895, 1896) from the Argentine.

In Russia it has penetrated in Permian time into the region of northern vegetation (AMALITZKY, 1897, 1901). In Tonquin it has been found to survive into the Triassic.

In pl. 2, figs. 4, 4a is shown a specimen which may best be referred to *G. indica*. It consists of an impression of the lower portion of a frond, represented by both counterparts. The fragment is 5 cm. long, with a breadth, at the broken upper end, of about 2,5 cm. As far as the shape of the frond can be made out, there is a close agreement with *G. indica*. The venation presents some peculiarities, however, which make its attribution to that species a somewhat doubtful step. The midrib is unusually stout, and is distinctly longitudinally striated. The lateral veins form an acute angle with the midrib and are slightly arched. Close to the midrib the areoles are fairly large and open; at a greater distance from it, they rapidly become narrower, and the marginal part of the lamina is characterized by very dense sub-parallel secondary veins, forming only few anastomoses. The very dense sub-parallel venation in the greater part of the lamina is noteworthy, as it distinguishes the specimen from *G. Browniana*, to which it otherwise presents some resemblance.

This contrast between the open venation bordering on the midrib, and the very dense one of the greater portion of the lamina, recalls the structure of *Glossopteris stricta* BUNB., as figured by BUNBURY (1861, pl. 9, fig. 5) and FEISTMANTEL (1881, pl. 37 A, figs. 1—2; pl. 38 A, fig. 3; 1882, pl. 21, fig. 11). In *G. stricta*, however, the contrast is still more pronounced. In the latter species, the course of the secondary veins, too, is different, as these first emerge at an acute angle, then bend abruptly and continue in an almost straight line in a direction nearly perpendicular to the margin. The present specimen can, therefore, not very well be referred to *G. stricta*, but should rather be included in *G. indica*. I find that FEISTMANTEL has figured from the Kamthi Group of the Indian Gondwanas some fronds with a very similar venation, under the name of *G. indica* (1881, pl. 27 A, figs. 3, 5). These fronds are referred to under the same name both by ARBER (1905, p. 64), and, partly, by ZEILLER (1902, p. 8). The same course is followed here, but it should be stated that the present frond is very different from other specimens of *G. indica* from the Falklands.

The specimen is from Low Bay, where it occurs associated with *G. indica* and *Phylloteca* sp.

Glossopteris angustifolia BRGN.

Pl. 3, figs. 1—4.

In my collection there are several specimens which agree perfectly with the illustrations given of *G. angustifolia* BRGN. There is some dispute as to whether this kind of frond is worthy of specific rank or not. It is retained here as a separate species in accordance with the views of ZEILLER (1896, p. 369; 1902, p. 16), and ARBER (1905, p. 72).

The specimens are not complete, but there is enough left of the frond to give an idea of its shape and size. Pl. 3, fig. 3 shows the lower portion of a frond. The base tapers gradually, and the frond has evidently been linear. The breadth is 10 mm. Unfortunately, none of the Falkland specimens has the apex preserved. In pl. 3, fig. 1 is shown an unusually large frond. It measures 17 cm. in length, and yet the upper end shows no sign of tapering to form an apex. The greatest breadth is about 2 cm. The proportion between length and breadth is, thus, the same as in typical *G. angustifolia* (5—15 cm. × 1—2 cm., according to ARBER, 1905). SEWARD has described from Natal, under the name of *G. Browniana* var. *angustifolia* (1904, p. 99, pl. 4, fig. 3), a narrow frond that much exceeds the present fragment in size.

The venation is somewhat variable but is always comparatively dense. The lateral veins are only slightly arched, and form acute angles with the midrib. The midrib is distinct and persistent throughout the part of the lamina preserved. So far, there is a close agreement with BRONGNIART'S type-specimen, as re-figured by ZEILLER (1896, p. 370, figs. 14, 15). In the Falkland specimens, the lateral veins are unusually dense and parallel. A typical instance of this is seen in the drawing, pl. 3, fig. 2, from the specimen, fig. 1. In this case, the very densely crowded veins are strictly parallel quite up to the margin of the frond. Anastomoses are very rare, and some veins seem to form no cross-connections at all. In this respect, the Falkland specimens form a transition to the interesting variety described by SEWARD (1908, p. 114, pl. 9, fig. 2), under the name *Glossopteris angustifolia* BRGN. var. *tæniopteroides*, though, in this latter plant, the variation in a Tæniopteroid direction has gone much farther. It is worthy of note, that the Falkland-specimens of *Glossopteris indica* show a similar tendency to parallelism of the lateral veins and reduction of anastomoses. The fact that the same variation from the average specific type occurs in both cases, may seem to favour the idea of the identity of these two species. ARBER (1905, p. 74), has pointed out the coincidence in distribution, and of this the Falkland Islands afford a new example. There is no doubt but that both species are very closely related, and it is not impossible that the two types of fronds may have been borne by the same plant. The shape of the frond is, however, fairly constant and there is generally no difficulty in deciding whether a specimen belongs to *G. indica* or to *G. angustifolia*. In regard to this fact, it is the more practical way to retain both species separated.

Glossopteris angustifolia was found at the southernmost point of Speedwell Island and at Bodie Creek Head, in both places associated with *G. indica*.

G. angustifolia has been recorded from several other parts of Gondwana-land. According to ARBER (1905, p. 75) it has been found in the Damuda division of India, in South Africa (both in the Ecca and the Beaufort beds), and in Portuguese East Africa. In northern Russia it penetrates into the region of the northern type of vegetation (AMALITZKY, 1897, 1901). Together with some other species it still survived in the Triassic of Tonquin.

In addition to the specimens figured, there was found another frond which may be compared with *G. angustifolia*. The fragment measures 45 × 8 mm.

It probably represents a young frond. The shape of the leaf agrees with that of *G. angustifolia*, but the apex appears to have been more obtuse, and the venation is not quite so close and parallel as in the other Falkland specimens of that species. It may be a narrow frond of *G. Browniana* (*G. linearis* McCoy, 1847, p. 151, pl. 9, figs. 5, 5 a), but in regard to the venation the resemblance to *G. angustifolia* is, perhaps, the more apparent. The specimen was found at Low Bay.

Glossopteris damudica Feistm.

Pl. 3, figs. 5, 6, 7.

The specimen shown in pl. 3, fig. 5, has been here referred to this species, in accordance with the opinion of Prof. Zeiller, who has kindly examined my drawings of it.

The preserved part of the frond is about 9 cm. long, with a breadth of about 3,5 cm. Neither the base nor the apex is preserved, so that the exact shape of the lamina cannot be ascertained. It is seen, however, that, in the middle portion, the margins are parallel for a considerable distance. The general shape, therefore, appears to approach nearly that of a *Tæniopteris*. As regards venation there is also a superficial resemblance to that genus. The midrib is stout and persistent through the preserved portion of the lamina. The secondary veins form nearly a right angle with the midrib; they are very dense and parallel, and run in a straight line to the margin. A closer examination shows that they form frequent anastomoses, the areoles, being, except close to the midrib, long and narrow.

The venation is essentially that of *G. damudica* Feistm. Most specimens described under this name have a somewhat different shape, the lamina being comparatively broader, mostly obovate. A specimen figured by Feistmantel (1881, pl. 31 A, fig. 1), from the Barákar Group of India has, however, — though much larger — the same narrow shape and parallel margins as the Falkland frond. A still closer agreement is shown by the latter to some figures given by Zeiller (1902, pl. 4, figs. 5, 6), of specimens from the Raniganj Group and the South Rewah Basin. As regards the venation, the present specimen has the chief characteristics of *G. damudica*, i. e., the perfectly straight course of the secondary veins, and the open angle which they form with the midrib. Typical specimens of *G. damudica* generally show, bordering on the midrib, short and open areoles, distinct from the narrow, trapezoidal meshes in the greater part of the lamina. In the portion shown in pl. 3, fig. 6, such areoles are not seen, As Prof. Zeiller has kindly pointed out in a letter, the areoles are, in some cases, known to be absent (Feistmantel, 1881, pl. 25 A, fig. 4; Zeiller, 1902, pl. 4, figs. 5, 5 A; and also in a specimen in the museum of the École Supérieur des Mines, Paris.) A renewed examination of the Falkland specimen has, moreover, revealed in the basal part of the frond some small, open areoles bordering on the midrib. These are seen in fig. 7, which also shows how the lateral veins set on to these areoles in the manner characteristic of the species. There appears, then, to be no doubt as regards the reference of the specimen to *G. damudica.* It need only be remarked that, in the Falkland frond, the venation is somewhat denser than in the specimens hitherto described. But this is certainly not a character necessitating a specific separation.

The specimen was found at Dos Lomas, together with *G. Browniana, G. indica*, *Gangamopteris cyclopteroides* etc.

G. damudica is best known from India, where it occurs both in the Talchir and the Damuda divisions. It has also been recorded from South Africa (FEISTMANTEL, 1889, p. 46, pl. 4, figs. 7, 7 a). If it is identical with *G. ampla* DANA, as is thought by ARBER (1905, p. 78), the same species would also occur in Australia. Most of the specimens described under the latter name are, however, very different from the Indian fronds.

Gangamopteris cyclopteroides FEISTM. var. major (FEISTM.).

Pl. 3, figs. 8, 9.

This well-known Gondwana species is represented in the Falkland collection by two specimens only.

The best fragment is figured in pl. 3, fig. 8. It shows a portion about 8 cm. in length of an obovate frond. Only a part of the left side of the lamina is preserved, and the margin is, for the most part, not quite clearly seen. It is, however, evident that the frond has been very protracted and narrow at the base. On the impression, the frond appears curved to the left, but this is probably accidental and due to the preservation.

That the fragment belongs to a *Gangamopteris* is evident from the venation. There is no midrib, but the basal part of the frond is provided with several unusually strong, sub-parallel, median veins. These median veins only occasionally bifurcate or anastomose with each other (see fig. 9). The narrow, petiolar basal part of the frond is entirely occupied by the median sub-parallel veins which do not here give off any lateral branches. Higher up, the median veins pass insensibly into the freely dividing and anastomosing lateral venation. The lateral veins form a very acute angle with the median line of the frond, but arch outwards and reach the margin at a much more open angle.

There is, in essential features, a fairly great agreement with *G. cyclopteroides*. Characteristic of the Falkland specimens is the distinct median zone of rarely anastomosing longitudinal veins, and also the contraction of the frond into an elongated petiolar basal part. In this respect the shape of the frond is decidedly that of *G. major* FEISTM. which is regarded by ARBER (1905, p. 113), evidently quite correctly, as merely a variety of *G. cyclopteroides*.

The acute inclination of the lateral veins somewhat recalls one of the characteristics of *G. Kashmirensis* SEWARD (1905, p. 3, pl. 8, figs. 1—6; pl. 9, fig. 1). The shape of the frond is, however, different from that of the latter species.

Both specimens were found in one locality south of Dos Lomas on the west coast of Lafonia.

G. cyclopteroides is essentially characteristic of the lower part of the Gondwanas. In India it is confined to the Talchir and Damuda divisions. It has further been found in Australia, South Africa, Brazil and the Argentine. It is one of the types known to have penetrated into the province of the northern flora, since it was found by AMALITZKY (1901) in the Permian of northern Russia.

Scale-frond of **Glossopteris** sp. (?).

Pl. 3, fig. 10.

I have figured, in pl. 3, fig. 10, a frond of rather obscure affinities. It consists of a narrow, petiolar basal portion, and a cordate lamina. The latter is somewhat broader than long, and has a rounded apex. The margin is entire. Unfortunately, the venation is not clearly shown. The veins are seen to spread from the base of the lamina and to divide dichotomously. I am not quite sure of the occurrence of anastomoses, but on careful examination there appeared to be some faint cross-connections.

As regards the shape, the nearest analogy to this fossil seems to be found in the specimens figured by SCHMALHAUSEN from Siberia under the name of *Ginkgo integerrima* (1879, p. 85; pl. 16, figs. 12—15), and at first I regarded the Falkland specimen as related to that plant. If, however, the venation, as seems probable, is reticulate, a comparison with *Ginkgo* cannot be appropriate. The fossil may represent an unusual form of *Gangamopteris*, or perhaps, rather, a scale-frond of a *Glossopteris*. The scale-fronds of *Glossopteris* are known to vary greatly in shape. ZEILLER (1902, pl. 3, figs. 4—13) has figured several specimens considered as belonging to *G. indica* and of these, the one, especially, fig. 11, shows some resemblance to the Falkland frond. It is, however, more acute, and the base is not so cordate but is more gradually protracted.

The specimen is from Dos Lomas.

Coniferous branches.

Pl. 3, figs. 11—15.

I have reproduced in pl. 3, figs. 11—15 some small, indistinct impressions, apparently of Coniferous affinities. They represent slender twigs, occasionally branched, as in the specimen shown in fig. 11. The leaves are arranged spirally round the shoot. The largest entire leaves measure only about 5 mm. in length, but there are also broken fragments of larger ones. Their shape is linear or lanceolate, generally somewhat falciform. Some of the leaves show a median line, which seems to represent a midrib. It may, however, quite as well be the median edge of a keeled leaf (see fig. 14, pl. 3).

The systematic position of these remains is naturally doubtful. Of fossils known from Gondwana-land, *Voltzia heterophylla* shows some resemblance to the present fragments. Provided the longitudinal line of some of the leaves does not actually represent a midrib, there is no character by which they can be distinguished from small twigs of that species. On the other hand, the determination must remain open to doubt, as long as the other type of leaves characteristic of *Voltzia heterophylla* has not also been found. It should be mentioned, however, that there occur in the same rock, pieces of what appears to be detached linear leaves, which may possibly represent the other type of foliage.

Voltzia heterophylla has its main distribution in the Triassic of the northern hemisphere. FEISTMANTEL has recorded it from the Gondwanas of India, where it occurs in the Karharbari and Raniganj groups. D. WHITE (1908, p. 569, pl. 8, figs. 11—13 b) has recently described some coniferous remains from Southern Brazil similar to the Falkland specimens, under the name *Voltzia* (?) sp. In these specimens the leaves are, however, broader and, according to WHITE'S figures, are also provided with a distinct and persistent midrib.

The *Voltzia*-like specimens from the Falklands were found only on Speedwell Island, north of the settlement at Halfway Cove.

Desmiophyllum sp.

Pl. 3, figs. 16, 17.

Figs. 16, 17, pl. 3, show two specimens of some detached leaves of obscure systematic position, found in the southernmost part of East Falkland. The leaves are linear in shape and of varying size. The specimen shown in fig. 17, is more than 10 cm. long, without being complete. The broadest fragment measures 1,2 cm. across. The leaves contract very gradually towards the base, as is seen in fig. 17, None of the specimens shows the apex preserved. Most of the leaves are slightly curved, as, for example, the one in fig. 16. Generally, there is no distinct venation, but only an irregular, longitudinal striation. In the specimen shown in fig. 16, the veins are fairly distinct, however, at least in the basal part of the leaf, their number being 12—14 near the base. The veins are strictly parallel and equally prominent. Only in one place is one of the veins seen to divide.

That the specimens are of foliar nature is evident. On the other hand, it is impossible to decide whether they represent simple leaves, or leaflets of a pinnate frond. In the latter case they would probably belong to some Cycadophyte; in the former they might possibly be of Cordaitean affinities. Their resemblance to certain forms of Cordaitean leaves from the northern hemisphere is indeed undeniable. In any case, these leaves appear to be different from any remains hitherto recorded from the Palæozoic rocks of Gondwana-land.

COUNT SOLMS LAUBACH has proposed to use the name *Desmiophyllum* as a provisional designation for such band-like, parallel-veined leaves or pinnules, and this course has been adopted here.

The specimens are from the coast of East Falkland opposite Speedwell Island.

Dadoxylon Lafoniense, n. sp.

Pl. 4, figs. 1—7.

From Dr. FOLEY in Darwin Harbour I have received a specimen of silicified wood which appears to be of some interest. It represents the basal part of a branch and has attached to it some remnants of the outer layers of the axis by which it was borne.

The branch measures 3,5—4 cm. in diameter and the preserved part is a couple of centimetres long. The wood is markedly excentrically developed, being thicker on the side facing from the main axis. The pith is partly well preserved and is comparatively large, being about 1 cm. in diameter. In transverse section it is round, but the margin shows some 10—12 irregular, faintly prominent angles (pl. 4, figs. 1, 2). In the section the pith is partly disintegrated, but in the living state it was evidently solid. In a radial section it is seen to be continuous and not discoid as in Cordaites. On the same section there are seen two, occasionally interrupted, longitudinal zones of disintegration, one on each side, distant 2 or 3 mm. from the margin of the pith. These zones, which are not well defined, are probably only of accidental nature. On the higher level on which the transverse section was made they have disappeared. The cells of the pith, as seen in transverse section, are rounded or polygonal. Near the margin their diameter is about 25—35 μ.; towards the centre they increase in size and may measure as much as 150 μ. in diameter. The cells bordering on the wood appear, in a longitudinal section, arranged in vertical rows. In radial section, they are quadratic or rectangular, only rarely a little higher than broad. Nearer the centre of the pith, the cells are always broader than high, often 2—3 times so, and more irregular in shape.

In the transverse section there are seen in the pith, close to its margin, some circular or elliptical lacunæ (figs. 1—3), about 8 in number and measuring nearly 0.5 mm. in diameter. In some cases they are placed in the prominent angles of the pith; in others there is no such relation. They are always sharply defined, and the margin sometimes shows a yellow coating. The medullary cells bordering on the lacunæ are of normal shape, only a little extended tangentially. These round lacunæ probably represent sections of some kind of secretory canals, such as are known in different kinds of fossil gymnospermous woods. Structures very similar in shape and position occur, for instance, in *Poroxylon Edwardsi* (BERTRAND & RENAULT, 1886, refigured in SCOTT'S Studies in Fossil Botany, pt. 2, p. 505) and are interpreted as mucilage-canals. Unfortunately the canals are not shown in the longitudinal sections in my possession.

As mentioned above, the margin of the pith forms a number of small projections entering into the woody zone. The wedges of wood contained between each two of these corners also present an irregular limit to the pith, as the inner part of the wood is divided into segments projecting with a convex outline into the pith. In the inner part of these segments the tracheides are much narrower than in the typical secondary wood, and more rounded in transverse section. Towards the inner edge the radial arrangement of the elements also becomes much less pronounced, and in some cases these are quite irregularly grouped. Generally there is a gradual transition, but sometimes the inner, narrow elements form a group fairly distinct from the radial series of the outer wood. There is, however, always an immediate contact with no intercalation of parenchyma between the two kinds of wood. No doubt these inner, irregularly-grouped tracheides represent the xylem of the primary bundles, and the angles of the pith projecting between them, the primary medullary rays. The latter taper quickly outwards and pass over into typical uniseriate medullary rays of the secondary wood. As the primary elements are only in some cases to be distinguished from the secondary wood, and this forms no definite bundles, the number of primary strands cannot be made out. It seems, however, to have been comparatively large. There are no definite protoxylem-groups preserved, but, in somes cases, the elements are seen to diminish in diameter towards the interior. As far as present evidence goes, therefore, the structure appears to have been endarch.

Unfortunately, the preservation of the finer structures of the wood is very unsatisfactory in this specimen. This appears to be due to decomposition through bacterial activity. At any rate, the tissues of the stem are filled up by numberless minute obovate bodies suggestive of bacteria. These often occur in dense rounded masses in the medullary cells. Whatever the cause may be, the tracheides are so disintegrated as to show almost nothing of the structure of the walls. I thought I recognized in a few cases some trace of a spiral structure in the narrow tracheides bordering on the pith, but I am not quite sure. In the outer parts of the wood, the radial walls sometimes show pits of the *Dadoxylon*-type, usually biseriate. The tracheides are narrow, square or polygonal in transverse section, with thick walls. They measure about 20—35 μ in diameter.

The medullary rays are always uniseriate. They are very low, numbering only 1—6, very rarely 9, cells in height; 2—4 is the commonest number. In a tangential section the cells are about 14—18 μ in breadth.

The secondary wood shows a very marked zonal structure. Examined microscopically, this is seen to be due to the development of real annual rings. The innermost ring measures about 6—7 mm. in breadth, the outer ones about 3—5 mm. In accordance with the excentric development of the wood, the breadth of each ring varies somewhat.

In addition to the specimen described above, I have found another piece of silicified wood, evidently of the same kind. In this second specimen, the pith is not preserved, but the wood shows the finer structures much better than does the first specimen. The agreement between the two specimens, in such features as can be compared, is perfect, and leaves no doubt as to their identity, as far as identity goes in fossil wood. The figures 5—7, pl. 4 are from this second specimen. The annual rings are quite as well developed as in the first specimen and measure 3—7 mm. in diameter.

The main interest of this species is in the fact that the pith is preserved in the first specimen. Fossil woods of the *Dadoxylon*-type seem to be of fairly common occurrence in certain parts of Gondwana-land, though but little attention has been paid to them as yet. Of *Dadoxyla* described from the Gondwana-series, only *Dadoxylon Pedroi* ZEILLER (1895, p. 619, pl. 9, fig. 4) from southern Brazil shows the structure of the central part of the stem. From this species the Falkland stem differs in several points but the general structure is seen to be somewhat similar. Both species have a large pith, but in *Dadoxylon Pedroi* it is even larger, measuring 37—38 mm. as compared with 10 mm. in the Falkland specimen. In both species the pith is solid and not discoid as in *Cordaixylon*. It is of interest to note this, as a great number of Palæozoic *Dadoxyla* from the northern hemisphere have been identified as belonging to the Cordaiteae, and the same might be suspected to be the case with similar woods from the Gondwanas. The structure of the pith in the two species, which alone give any information on this point, does not support the idea of a Cordaitean nature of the *Dadoxyla* of Gondwana-land. The size of the pith is noteworthy, however, and the absence of a discoid structure does not actually forbid an affinity with the Cordaiteae. The existence of types, belonging, or at least allied, to that group in the Palæozoic rocks of Gondwana-land, seems probable from the occurrence of leaves like those of *Noeggerathiopsis* and of seeds of the *Cardiocarpus*-type.

In the structure of the pith there is a well-marked difference between *D. Pedroi* and the present stem. In the former species there occur in the pith secretory canals, each one representing only one vertical row of cells, and grouped together in a number of from 2 to 15 or 20. The secretory canals occurring in *D. Lafoniense* are of quite a different kind, being much larger, and each one corresponding to a greater number of medullary cells. They are strikingly similar, as seen in transverse section, to those known in *Poroxylon Edwardsi.* Structures of this kind are not characteristic of *Dadoxylon* but, together with the great size of the pith, mark some tendency in a Cycadean direction. As, in other respects, there is a perfect agreement with *Dadoxylon*, which genus is, moreover, only of a provisional nature, the right plan is, most evidently, to use this generic name.

The zone of secondary growth differs from that of *Dadoxylon Pedroi* mainly in the structure of the medullary rays. These are very high in the latter species, there sometimes being as many as 50 superimposed cells; in the Falkland stem the number is generally 1—6. In other respects, too, there is a great difference between these two species. The unusually low medullary rays form the most prominent characteristic of the secondary wood of *Dadoxylon Lafoniense*. In fact, this feature distinguishes it from most Palæozoic *Dadoxyla*. As regards the structure of the secondary wood, however, some few species of *Dadoxylon* from the Gondwanas of Australia agree fairly well with the latter. SHIRLEY (1898, p. 14, 15, pl. 25, 26) has described from Queensland, among other woods, two species, viz., *Araucarioxylon (Dadoxylon) Binneyi* SHIRLEY, and *A. Brisbanense* SHIRLEY with medullary rays of only 2—9 and 2—10 cells in height respectively. SHIRLEY'S brief descriptions and very indistinct illustrations do not give any clear idea of the species. The medullary rays appear, however, to be, on an average, higher than in *Dadoxylon Lafoniense*. A closer agreement seems to exist with *Araucarioxylon (Dadoxylon) Felixianum* SCHENK (1890, p. 870) from New South Wales. This is described as possessing annual rings of growth and medullary rays of 1—5 (occasionally — 15) superimposed cells. There is no statement as to the horizon from which the species is derived. As far as the structure of the secondary wood is concerned, the Falkland stem may possibly be identical with SCHENK'S species. It is, however, impossible to form a definite opinion, as only a very brief description and no illustrations of the latter are given. Further, the medullary rays are in no case found to number in *Dadoxylon Lafoniense* as much as 15 cells in height. As, too, the structure of the pith and the primary xylem is not known in anyone of the specimens which show a similar character of the secondary wood, the right course is certainly to create a new species. The chief characteristic of this, then, would be in the structure of the pith.

The specimen showing the structure of the pith is from Arrow Harbour, south of the inner part of Choiseul Sound. The other specimen was collected near Tranquilidad.

Dadoxylon cf. angustum Felix.

Pl. 4, figs. 8, 9.

Among the specimens, which show only the structure of the secondary wood there is one fairly well characterized type, which seems to deserve a short description. The specific identity is a matter of much uncertainty, as it always is in similar cases. I have referred the wood provisionally to *Dadoxylon angustum* Felix (1894, p. 48). In a transverse section, the tracheides are square or polygonal, measuring about 28—45 μ in radial diameter. The walls are much thinner than are those of the former species. There are no distinct rings of growth in the wood, but to the naked eye it shows very marked and regular concentric circles. Under the microscope these are seen to represent merely zones of badly-preserved and compressed tracheides. Such false annual rings occur also in the former species and in other fossil woods. They often show a tendency to coincide with the inner limit of the spring wood. It is possible, therefore, that true annual rings have existed, but that they are now obliterated by the concentric zones of compressed elements. This possibility is confirmed, to a certain extent, by the fact that, in some cases, there it a difference in the diameter of the tracheides on both sides of the zones, the wider elements occurring on the outer side.

The tracheides show on their radial walls two to three rows of pits. These are of the common *Dadoxylon*-type, bordered, mostly contiguous, and then with polygonal outlines. In favourable cases the central pore may be seen. It is elliptical, with the larger diameter almost horizontal. At the contact between the tracheides and the medullary rays there are some smaller, simple pits, rounded or elliptical, and then almost horizontal. Their number is 2—5 in each field.

The medullary rays are numerous and very long. In radial section the cells are rectangular or trapezoidal, about 6—9 times longer than high. The height of the rays varies greatly, from 1 to as many as 25 superimposed cells. They are normally uniseriate; only occasionally do there occur two cells in breadth.

A characteristic feature is, that the cells of the medullary rays are very narrow, as seen in a tangential section, measuring only 10—15 μ.

Pith and cortex are not preserved.

The chief characteristic of this wood lies in the thin-walled tracheides and the very narrow medullary rays. These are only about $^1/_2$—$^1/_6$ of the breadth of the tracheides, as seen in tangential section. Among fossil woods from the Gondwanas, *D. angustum* Felix is distinguished by the same characteristics. The description is not accompanied by any illustrations, but Prof. Felix has kindly lent me the sections for the purpose of comparative study. The chief difference is, that in the Australian species, the tracheides are narrower, but the agreement is, indeed, so great that the Falkland specimens may provisionally be referred to *D. angustum*. It is true that the age of this species is not known. On account of the presence of annual rings, GOTHAN (1905, p. 91) has, indeed, doubted that it is derived from the Carboniferous rocks. The occurrence of annual rings in the woods of the Lower Gondwanas is, however, now well established, and this argument consequently no longer holds good. There is, therefore, nothing to prevent the assumption that the FELIX specimen comes from the Permo-Carboniferous beds, which are known to be widely distributed in New South Wales.

General character and relationship of the flora.

From the above description of the fossil plants of the Lafonian, the following species are seen to be represented:

Phyllotheca australis BRGN.
» cf. *deliquescens* GOEPP. sp.
Glossopteris Browniana BRGN.
» *indica* SCHIMP.
» *angustifolia* BRGN.
» *damudica* FEISTM.
Gangamopteris cyclopteroides FEISTM. var. *major* (FEISTM.).
Coniferous branches.
Desmiophyllum sp.
Dadoxylon Lafoniense n. sp.
» cf. *angustum* FELIX.

The first knowledge gained from a comparison of the different localities is the pronounced uniformity of the flora. Although the whole number of species has not been found at any one locality, the general character of the flora is unmistakably the same. It must be noted, however, that *Gangamopteris cyclopteroides* var. *major*, and also *G. damudica*, occur only at Dos Lomas in the north. *Glossopteris Browniana* has also been found only in the northern half of Lafonia. *Phyllotheca australis* is especially common in the south, and has not been found north of Bodie Creek. It appears that the difference in the distribution of these plants may accord with a slightly different age of the deposits, and this is already probable from the general inclination of the strata.

The flora of the Lafonian is entirely a typical Lower Gondwana flora. During the late Palæozoic, this flora was spread with a remarkable uniformity all over the southern continents and the Indian Peninsula. The geological age of the *Glossopteris*- or Lower Gondwana-flora has been the subject of much dispute. As it is totally different from the Palæozoic floras of the northern hemisphere and, at the same time, shows a certain correspondence with the vegetation of the older Mesozoic, it was at first regarded as being of Secondary age. This opinion was held by FEIST-

MANTEL especially. It is now commonly agreed, however, that the lower part of the Gondwanas belongs to the later Palæozoic, although the precise age of the different divisions is still a matter of dispute. The boulder-beds are considered by some authors as Upper Carboniferous, but by others (as for instance FRECH and KOKEN) as Permian. The question, where, in the Gondwanas, the limit should be drawn between the Palæozoic and the Mesozoic has also been a matter of much uncertainty, and the most varying views are held. SEWARD places the Panchet even in the Palæozoic, whereas the other extreme is represented by FRECH, who draws the limit between the Karharbari and the Damudas. Generally, however, the latter division is, in accordance with ARBER and others, reckoned to the Palæozoic. KOKEN draws the limit between the ~~Karharbari~~ Raniganj and the Barakar.

For the Falkland Gondwana the lower limit is fixed only by the age of the glacial boulder beds, which evidently correspond to the Talchir of India and the Dwyka of South Africa. The Lafonian, accordingly, extends some distance back into the Palæozoic; how far, will depend on the age assigned to the base of the Gondwanas generally. The lowermost parts of the Gondwanas are especially characterized by *Gangamopteris*, and we find that the only locality where this plant has been found in the Lafonian is in the north, and appearently belongs to the lower part of the plant-bearing formation. The uppermost horizon of the Gondwanas preserved in the Falkland Islands may, from the general inclination of the strata, be taken to occur in the south of the island. As mentioned above, *Phyllotheca* is especially characteristic of this part. In other regions of Gondwana-land this genus first attains its maximum development in the Damudas, though it occurs in Australia as early as in the Lower Coal measures. It is probable, therefore, that the Falkland Gondwana may extend as high up as into part of the Damuda. The flora of even the highest part of the Lafonian shows no affinity with that of the Panchet, but is entirely Palæozoic as far as the few fossils known are concerned.

In comparing the Lafonian flora with that of the other Gondwana districts, it is necessary to state that the Gondwana vegetation shows very little regional variation. It was, indeed, just as equally distributed over the southern continents as the contemporaneous, but totally different, northern flora in the other hemisphere. The difference to be noted between the floras of the different Gondwana-areas is mainly connected with the intermixture of foreign elements. In India and Australia the Gondwana flora occurs in its typical development. In South Africa, in Brazil, and in the Argentine Republic there is plain evidence of the co-existence, together with the pure Gondwana-flora, of several members of the northern flora, mainly arborescent Lycopods. In the Falkland Islands all determinable impressions belong to typical species of the Gondwana-flora, known from all, or some, of the other Gondwana-areas. The parallel-veined leaves of *Desmiophyllum*-type alone, cannot be identified with any Gondwana-plant. They may be compared with leaves of a *Cordaites*, but it is not possible to make any certain determination. The petrified stem, described above as *Dadoxylon Lafoniense*, shows, like the Brazilian *D. Pedroi* ZEILLER, a certain resemblance to Cordaitean stems. In the typical Gondwana-flora, too, there is, however, in *Noeggerathiopsis*, a type which has been referred to the Cordaitales. At any rate, the Lafonian flora presents no species that we are sure are invaders from the northern flora. This is to be expected, too, as the mixed floras appear to be confined to the border-zone between the two phytogeographical provinces, and the Falkland Islands were well within the region of the Gondwana-lands.

Insect-remains.

(BY G. HOLM.)

»As seen in the photograph (fig. 14), the insect-wing from Bodie Creek Head is complete both as regards contoure and neuration, all the

Fig. 14. Insect-wing from Bodie Creek Head, three times enlarged. G. Holm phot.

principal veins, at least, being traceable. A number of cross-veins, too, appear in the outer halves of the interspaces. The membrane has been thin, and the longitudinal folds stand out very distinctly, as is seen in the photograph. A peculiar feature is, that the innermost part of the wing which is preserved right down to the point of attachment to the thorax, is very narrow and linear, and looks like a stalk.

In consequence of the present scanty knowledge of the oldest insect-remains, the wing cannot be referred to any known genus. It belongs, however, to the *Palæodictyoptera*, according to HANDLIRSCH'S classification. On account of the cross-veins it might possibly be placed in the (probably artificial) family *Lithomantidæ* of HANDLIRSCH. This wing is specially interesting, not only on account of its age and its excellent preservation but, above all, because it represents the only insect-remains which, with certainty, are found in the Gondwana System. It is true that HANDLIRSCH has described an insect from Kashmir under the name *Gondwanoblatta reticulata*, but he remarks at the same time that the age of that fossil is not determined with absolute certainty.»

Eruptive dykes.

It has been stated above that during the expedition of the «Beagle» «basaltic» dykes were noted in West Falkland by SULIVAN. Later on, the «Challenger»-Expedition brought home some specimens of volcanic rocks from the islands. Of these specimens, which have been described by RENARD (1875, 1889), some may originate from eruptive dykes, but most of them appear to have been collected as boulders, and there is no information as to the mode of occurrence of the rocks. The first description of eruptive dykes is given by Prof. J. G. ANDERSSON (1907, p. 11) who discovered, at Fox Bay, two small diabase dykes traversing the Devonian sandstone. The rocks of these dykes were examined by Prof. O. NORDENSKJÖLD (ibidem) and described as being in the one case an olivine-diabase, in the other a diabase-porphyrite without sure traces of olivine.

I have noted eruptive dykes in some places in West Falkland, viz. at Halfway Cove, Spring Point and N. of Fox Bay, and in East Falkland N.E. of the entrance of Brenton Loch.

Halfway Cove (at Port Philomel). The dyke runs parallel to the strike of the sandstone, close to the place where the Devonian plant-remains were collected. The rock, much weathered, is only traceable as a string of comparatively fresh, round kernels in a yellowish earthy mass, almost like the surrounding sandstone. On account of its decomposed state, the dip and breadth of the dyke cannot be made out with certainty. It has a steep dip, however, and seems to be hardly more than one metre broad. It was traced for a length of some hundred metres.

Fox Bay. The two dykes described by Prof. J. G. ANDERSSON occur close to the bay. It is noteworthy that the direction of these dykes, E.—W., is parallel to the strike and to the coast which is, no doubt, determined by a fault-line (see below). Some distance farther north, on the «track» to Port Howard, I noted a dyke running about N.N.E.—S.S.W. It could be traced only as a low wall of diabase-boulders half covered by the vegetation. The specimens of this rock were unfortunately lost. This dyke is parallel to the coast of Falkland Sound N.E. of Fox Bay.

Spring Point. At the east side of the creek E. of Spring Point I found a diabase-dyke which runs from thence towards S. 15° W. for a distance of about one kilometre at least. It is almost covered by the peat, and projects only as a wall of loose boulders. It may be a few metres in breadth.

Brenton Loch. Near the entrance of this bay there is, on the N.E. side, a marked diabase dyke running N. 40° O.—S. 40° W. and traversing the Lafonian sandstone. From the shore it can be traced inland some 50 metres, then it becomes covered up by the soil-cap. The breadth is about 13 m. The sandstone dips 10° N. 65° W. and is traversed by cleavage-lines, parallel to the dyke and with a nearly vertical dip. The rock of the dyke appeared to be uniform throughout; the sandstone has a dark colour at the contact.

Port Sussex. On the northern shore of this bay, near the inner end, there were found a great number of diabase-boulders. Probably there is a dyke here, but it was not seen and is perhaps covered by the sea. The bay is, at least along its northern shore, limited by faults which have produced brecciated structures of the rocks.

Mr. N. ZENZÉN has kindly placed at my disposal the following short summary of the results of the microscopical examination of the Falkland diabases, inclusive of the specimens collected at Fox Bay by Prof. J. G. ANDERSSON.

»The specimens of diabases submitted to me for examination are all fine-grained, and in undecomposed state, dark-coloured.

The microscopical examination shows the primary constituents to consist of plagioclase, monoclinic pyroxenes, titaniferous magnetite, pyrite, apatite and, in some or single cases, olivine, orthorhombic pyroxene and biotite. As decomposition products occur chloritic and serpentinous substances, besides some carbonate.

All the rocks carry rather basic plagioclases, generally zonary built, with twins according to the albite, Carlsbad and sometimes the pericline law. In the central parts of the crystals, the plagioclase mostly has been found to be bytownite, with the composition Ab_{25} An_{75}. In the outer parts it rises to andesine at least.

The presence of orthorhombic pyroxene has been proved in one place only, at Spring Point, where it is represented by a bronzite. The monoclinic pyroxenes always have a comparatively light colour, varying from nearly colourless to a brownish or greenish brown colour. At Spring Point, Brenton Loch, and Port Sussex, part of the monoclinic pyroxenes seem to belong to the enstatite-augites of WAHL (Magnesiumdiopside of ROSENBUSCH). The diabases of Brenton Loch and Port Sussex show pseudomorphs, sometimes idiomorphic, probably after some pyroxene, perhaps an orthorhombic one.

Olivine occurs only at Fox Bay, where it forms numerous, more or less idiomorphic individuals in the rock of the dyke No. 1 of J. G. AN-

DERSSON. I have found some distinctly recognizable pseudomorphs of it also in the specimens of dyke No. 2. In the less decayed portions of dyke No. 1, the olivine is only slightly altered, as has already been described by NORDENSKJÖLD.

Recognizable biotite, in very small quantities, was found in the specimens from Port Sussex and Brenton Loch. Numerous grains of iron-ore occur in all slices. For the most part it is certainly titaniferous magnetite, sometimes with a narrow rim of leucoxene. Grains of pyrite, too, are not seldom seen. Apatite seems to be very rare.

At Fox Bay the olivine and part of the plagioclases occur as phenocrysts. The diabases of Brenton Loch (and Port Sussex) also present a porphyritic appearance which is caused by some of the pseudomorphs before mentioned which are rather large and idiomorphic. At Halfway Cove the intergrowth between pyroxene and plagioclase is distinctly ophitic, in all other cases the pyroxene forms comparatively small isometric individuals or elongated, rather idiomorphic prisms. The feldspar phenocrysts of the diabases of Fox Bay are more or less tabular, but with this exception the habit of the plagioclases is always rather prismatic. The rock of Halfway Cove is amygdaloid, the cavities being filled up with chloritic substances and carbonate. Any isotropic base is not present, but part of the decomposition products of the rock may have originated out of a glassy groundmass. All the other rocks seem to be holocrystalline. They always carry small patches of interstitial matter which is not isotropic and probably chiefly consists of feldspar substance carrying microlites of other minerals. In one case I could state that these patches of interstitial matter consist of an intergrowth of skeleton forms of plagioclase.

As will be evident from the above description, there are some variations in the mineral composition and, in lesser degree, in the structure of the diabases of the different localities. These differences are not greater, however, than could be met with in any complex of contemporaneous dykes — in my opinion at least. The rocks from East Falkland do not occupy any separate position. They are probably closely related to the diabase of Spring Point, if not nearly identical with it.»

Tectonic features.

In large parts of the Falkland Islands, the strata of both the Devonian and the Lafonian remain in horizontal position. In other parts they have been subjected to deformation by regional forces. Both folding from lateral pressure and subsidence along fault-lines have co-operated to establish the present tectonic outlines of the islands. Although the leading features are fairly clear, there exists still much uncertainty, both as regards the nature of the different displacements and the epochs when they took place.

It is known from Prof. J. G. ANDERSSON'S discovery (see above, p. 9) that the Devonian at Cape Meredith rests with horizontal bottom layers on the older crystalline formation. This latter has been very much disturbed before the deposition of the Devonian. The age of the lower formation is not known with certainty, but it is probably Archæan, and the deformation is, in that case, most certainly Archæan, too. At any rate, a long time must have elapsed between this, the oldest disturbance noted in the Falkland Islands, and the commencement of sedimentation in the early Devonian.

The most conspicuous result of the later, post-Devonian deformation has been the formation of the mountain-ranges in the northern parts of the islands. This mountainous district has already been described by DARWIN (1846[1], 1846[2]) while, later on, Prof. J. G. ANDERSSON has studied some tectonic details. In East Falkland the folding-zone runs due E.—W. from the eastern coast to Mount Usborne. There it bends towards the N.W., and continues in this direction till it reaches the coast at Falkland Sound. In West Falkland, as will be seen later on, the strike in the northern part also runs S.E.—N.W. or E.S.E.—W.N.W.

In the east, the mountainous country measures about 20 km. across, from Port Fitz Roy to Berkeley Sound. It corresponds to the belt of stronger folding, and consists of numerous parallel quartzite ridges, separated by longitudinal valleys cut down in the softer rocks. In the whole district the regional forces have essentially manifested themselves in folding of the strata, which are often laid in fine, regular folds. Overthrusts on a large scale have not been noted, and the fault-lines, too, appear to be of little importance. No volcanic rocks have been found within the folded belt. The most conspicuous of the E.—W. ranges is the one called the Wickham Heights. It seems to coincide with the zone of maximum intensity in the folding. The strata here are mostly upraised vertically, and the rocks are strongly metamorphosed.

In the east, the southern limit of the folded belt is determined by the coastline. Its northern margin is not well marked but, on the height of the southern shore of Berkeley Sound, the dip gradually becomes less steep, and the rocks less metamorphosed. More to the west, the folding-zone is broader, as its southern border is not encroached upon by the sea. How far it extends here to the south is not exactly known, but Mount Pleasant certainly belongs to it. I have not been able to study in this part the manner in which the folded belt passes into the undisturbed area further south.

The change in the direction of the mountain-ridges west of Mount Usborne, seems to involve some difference in structure, too. In the section, fig. 15, I have endeavoured to show the structure of the mountain-range, as seen in passing during the course of a ride between Port Sussex and North San Carlos. The northern part of the section, from North San Carlos to South San Carlos is — as it should be — at right angles to the strike. The southern part forms an angle of about 45° with the strike, but, as the section is only schematic, the exaggeration of the horizontal distance is not of much consequence. In both parts of the section the natural dip is shown. At North San Carlos, where the fossiliferous Devonian sandstone seems to form an anticline and to be overlain by the quartzite (see above, p. 26) the strata are almost vertical. In passing to the south, the

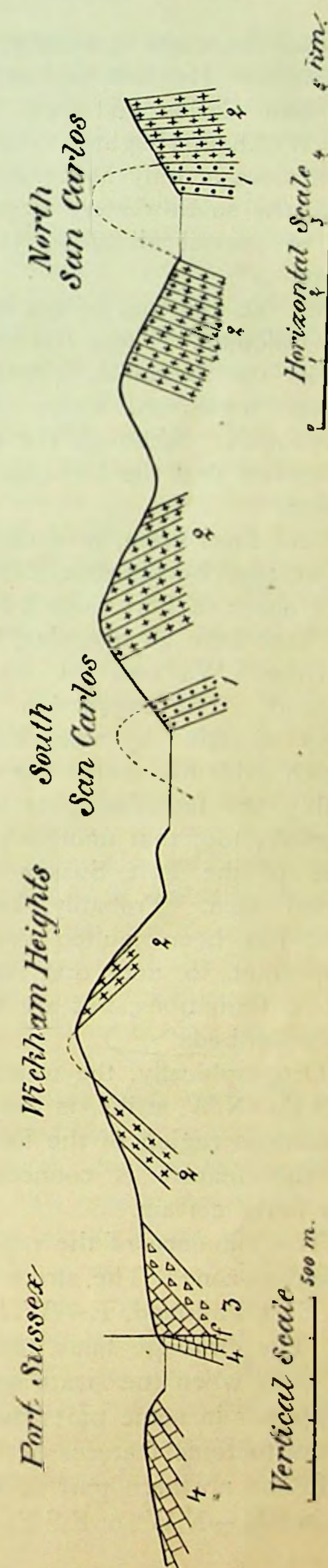

Fig. 15. Schematic section of the mountain range between North San Carlos and Port Sussex. 2. — Devonian quartzite. 1. — Devonian sandstone and slate. 3. — Lafonian tillite. 4. — Lafonian sandstone and slate. f — Fault-line.

inclination decreases gradually, and the lateral pressure appears to have been fainter. The last, and at the same time, the highest ridge, between South San Carlos and Port Sussex — which forms the continuation of the Wickham Heights — seems to form a simple anticline with a dip to both sides of only about 45°. I also noticed the same dip of 40°—45° S.W. in the south-western slope of Brodie Peak, and the same inclination seems to prevail all along the border of the mountain-range to Mount Usborne.

Just at the foot of the mountains, we meet with the bottom layers of the Lafonian. These dip in the same direction and at about the same angle as the Devonian quartzite in the mountain-slopes. This quartzite has been mentioned above as probably forming the uppermost part of the Devonian. Although the contact was not found displayed, it seems fairly certain that the Lafonian here rests conformably upon the Devonian quartzite.

Fault-lines seem, however, also to play a part in the structure of the south-western border-zone of the western mountain range. The north-eastern shore of Port Sussex is evidently determined by a fault-line. The strata have here an irregular, but always very steep, dip, generally about 60° to the S.W., and the rock, a dark slate, is very much broken and brecciated. The depression of Port Sussex is continued in a south-easterly direction by a marked longitudinal valley, the north-eastern side of which evidently marks the continuation of the fault-line in this direction. Probably the fault-line goes as far as to the foot of Mount Usborne. It is possible, too, that another parallel fault-line occurs, forming the southern margin of the Port Sussex depression, and that, accordingly, this is a subsided area. Probably, however, the whole area southwest of Port Sussex has been faulted down relatively to the mountain-range, and it is important to note that the fault-lines do not follow the limit between the two formations, but are well within the Lafonian area, south-west of the boulder-beds.

Orographically, the western part of East Falkland, that is, the region of a S.E.—N.W. strike, is characterized by the rapid transition between the mountainous region of the folding zone and the low land south-west of it. That this feature is connected with a subsidence of the latter district seems fairly certain.

The influence of the regional forces is traceable even far outside the real folding-zone. The strike of the strata, when they show any inclination, is, in East Falkland, E.—W. in the eastern, and S.E.—N.W. in the western part. The cleavage lines, too, generally run in the same directions, sometimes even when the strata appear perfectly horizontal. Different tectonic lines appear in some parts, however, and will be mentioned in connection with the tectonic features of West Falkland.

In the northern part of West Falkland, the dominating tectonic lines strike in S.E.—N.W., or E.S.E.—W.N.W. This direction is more pronounced in the west, where both coast-lines and mountains strike regularly N. 55° W.—S. 55° E. The western headlands are continued in a north-westerly direction by rows of islands reaching far out to sea. The remotest are the Jason Islands, which form the extreme north-western corner of the archipelago. Thus the dominant tectonic lines of West Falkland strike in the same direction as in the western part of East Falkland. But, in comparing the two islands generally, a certain difference will be noted in orography and in tectonic features. In West Falkland the folding has been much less intense, whereas subsidence along fault-lines largely determines the main orographic features and the coast-lines. The fact that the highest mountains in West Falkland do not coincide with the region of maximum folding is an expression of that general rule. In the western part of East Falkland, the folding has not affected the southern ranges which form the continuation of the Wickham Heights, so much as it has done the region further north, round North San Carlos. A line in the continuation of this belt of maximum folding nearly coincides with the northern coast of West Falkland. The tectonic features of this coast are not known, but it appears rather doubtful whether a real folding range occurs here. The nearest observations, on Saunders island, at Rapid Point, and at the Warrah River, give a very slight inclination af the strata, the dip not exceeding 15°. S.W. of this belt of little disturbance the intensity of folding increases, as it would seem, gradually, the steepest inclination (60° N.E.) being observed in the quartzite-range N.E. of Byron Sound. This range is continued to the N.N.W. by a series of islands. The largest is Carcass Island, where I noticed, in passing on board a schooner, a steep dip of the quartzite-like rocks. This zone, now described, from Carcass Island to N.E. of Byron Sound, and continuing toward sthe E.S.E. in the same direction, represents, with a possible exception of the unknown N.E. coast, the maximum of N.W.—S.E. folding in West Falkland. Yet the evidences of lateral pressure are very faint, the strata being only moderately inclined and never vertically upraised, while the rocks show hardly any trace of regional metamorphism.

S.W. of the same zone lie the highest mountains of the Falkland Islands. They form part of a broken highland-belt stretching from the vicinity of Port Howard to West Point Island. In striking contrast to the mountainous district of East Falkland, this region shows very little trace of regional disturbance, and only a faint dip of strata, much fainter than in the adjacent district in the N.E. All along the S.W. coast of Byron Sound, from West Point Pass to Hill Cove, the hard barren sandstones dip 20°—30° N. 35° E. The dip seems to decrease for some distance inland. In the mountains south of Hill Cove this is clearly seen. In the northern slope of Mount Adam, the highest point in the Falkland Islands (700 m.), the dip is 15° N. 35° E., and, on the summit, the hard quartzitic sandstone dips only 5°—10° in the same direction. Passing in the direction of the strike towards E.S.E., pretty nearly the same dip is noted the whole way to Mount Maria.

South-west of the mountain-range from West Point to Port Howard the inclination of the strata decreases steadily, but the same strike prevails in the southern half of West Falkland. The dip is generally 5°—10°, mostly to the N. or N.E. The structure of this part has been more fully described above, in connection with the stratigraphical conditions of the Devonian.

In obvious contrast to the general strike in S.E.—N.W. there appears on the map of West Falkland also another orographic line, striking in

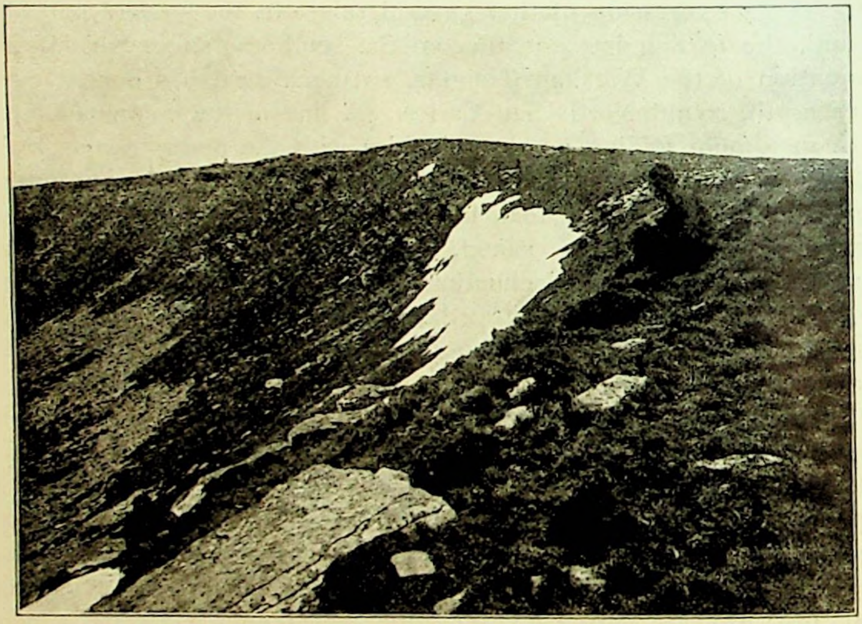

Fig. 16. The summit of Mt. Adam (700 m.), with nearly horizontal beds of quartzitic sandstone. C. Skottsberg phot.

N. 30°–40° E.—S. 30°—40° W. The coast-line to Falkland Sound is evidently determined by this other direction. SULIVAN mentions (DARWIN, 1846, p. 270) «a fine range, 2,000 ft. in height», near and parallel to the west coast of Falkland Sound. This range is evidently identical with the Hornby Mountains, which stretch from Mount Maria in the north to Mount Moody in the south. Before entering on the nature of the Hornby Mountains it may be as well to consider the structure of the coast.

The east coast of West Falkland, from the south corner of Port Edgar in the south, to the north end of Port Howard, and possibly even to the north entrance of Falkland Sound, is bordered by a low but very conspicuous ridge. I have not visited the coast north of Port Howard, but there is marked on the Admiralty Chart a ridge separating Many

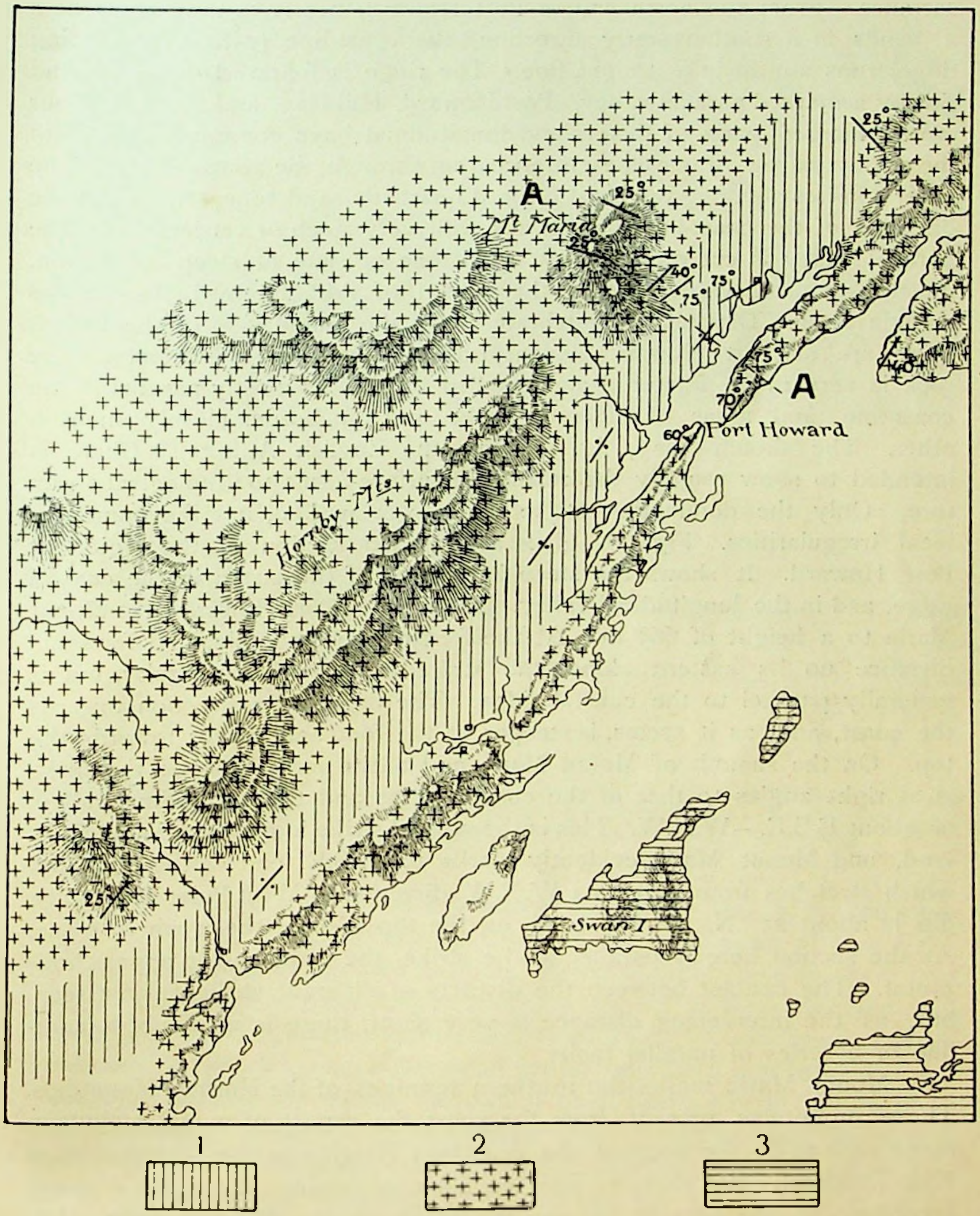

Fig. 17. Sketch-map of the east coast of West Falkland at Port Howard
After the English Admiralty Chart.
1 — Fine-grained, fossiliferous Devonian sandstone and slate. 2 — Coarse, hard Devonian sandstone. 3 — Lafonian.

Branch Harbour from Falkland Sound and broken only by the narrow entrance. From the north end of Port Howard, nearly to the point where it bends in a south-westerly direction, the coast-line (with its bordering ridge) runs almost in a straight line. The ridge is followed on the inland side by a marked parallel valley. Port Howard, Hill Gap, and Shag Harbour are submerged parts of this valley, longitudinal bays communicating with the sea by narrow, transverse entrances cut through the coastal ridge. The latter consists all along the coast of hard quartzitic sandstone, striking in the direction of the coast-line and always with very steep or vertical dip. The parallel valley is cut down in soft sandstone or slate of steep inclination, mostly upraised vertically. In the region of Port Howard these rocks contain marine Devonian invertebrates. On the inland side of the valley, there are at Port Howard evident traces of vertical movements. The rock is very much fractured and crushed by faults, mostly parallel to the coast-line, and areas of different strike and dip border closely on each other. The sketch—map, fig. 17, after the English Admiralty Chart, is intended to show roughly the relation of surface-forms to lithological structure. Only the dominating strike and dip is marked, not the numerous local irregularities. Fig. 18 gives a simplified section of the region at Port Howard. It shows the steep inclination of the strata in the coastal ridge, and in the longitudinal valley. Just west of Port Howard rises Mount Maria to a height of 665 m. At the foot of the mountain, and for some distance up its eastern slope, the strike is somewhat irregular, but is generally parallel to the coastal ridge. The dip is in a direction towards the coast, and, as it seems, is steeper at the foot and fainter towards the top. On the summit of Mount Maria and on its northern slope, the strike is at right angles to that of the coastal ridge and the longitudinal valley, or about E.S.E.—W.N.W. This is the normal strike in northern West Falkland, and Mount Maria evidently marks the S.S.E. end of the highland, which stretches from here in a W.N.W. direction to West Point Pass. The dip is about 25° N. 20° E., both on the top and on the northern slope. As the section here is parallel to the strike, the strata on it appear horizontal. The contact between the districts of different strike was not seen, but, as the intervening distance is very short, there is no doubt a fault-line or a series of parallel faults.

Mount Maria marks the northern terminus of the Hornby Mountains. These mountains present from the coast the aspect of a real mountain-range such as do, for instance, the Wickham Heights in the folded zone of East Falkland. But there is little evidence of folding, the strata dipping, according to the present knowledge, mostly in one direction only. The Hornby Mountains end abruptly to the south, and in the direction of their strike we find, E. and N.E. of Fox Bay, low land with the usual strike of the strata in E.S.E.—W.N.W. Not much is known of the structure of the Hornby Mountains. They appear to consist of hard, quartzitic sandstone like the coastal ridge and the interior highland. It seems permissible to suppose, that they may agree in structure with Mount Maria. But the N.N.E.—S.S.W. direction appears to manifest itself farther inland here than in the north, as I noted at the south-west side of Mount Moody a dip of 25° W.N.W. which continued as far as the eye could reach towards the N.N.E.

The occurrence of the N.N.E.—S.S.W. strike along the western coast of Falkland Sound is a most prominent feature in the tectonic conditions of West Falkland. The unusually steep inclination of the strata as compared with the narrow extent of the disturbed area, and the absence of reliable evidences of folding is not suggestive of a real folding-zone like that of the East Falkland mountain ranges. On the other hand, it is evident that faults have played an important part in the establishment of the present features. The coast-line, from Port Howard to Fox Bay at least, certainly

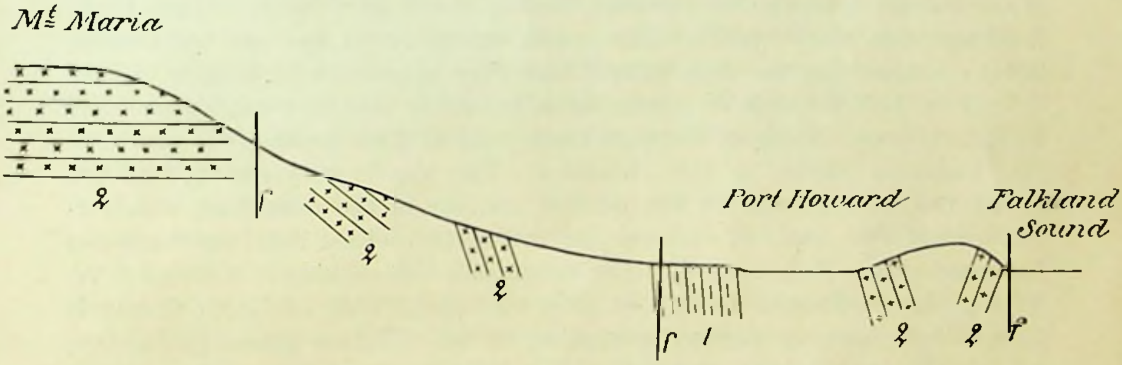

Fig. 18. Schematic section of the East coast of West Falkland at Port Howard (Line A—A., fig. 17). *1*— Slate and sandstone with Devonian invertebrates. *2*— Devonian quartzitic sandstone. *f*— Fault-line. Vertical scale much exaggerated.

represents a fault-line. Whereas in the coastal ridge the Devonian sandstones dip nearly vertically, the Lafonian on the west coast of East Falkland has an almost undisturbed position. Evidently the whole southern part of East Falkland has been faulted down in respect to West Falkland, and the Lafonian thus protected from being worn away. Considering that the basement of the horizontal Devonian crops out above sea level at Cape Meredith, and that the equally horizontal plant-bearing beds on Speedwell Island probably belong to the uppermost part of the Lafonian, the vertical displacement must be taken to amount to more than one thousand metres. All facts considered, it seems more probable that the N.N.E.—S.S.W. strike along the east coast of West Falkland is due mainly to subsidence along fault-lines. The coastal ridge would then represent the edge of a subsided mass in vertical position, and the parallel valley be cut down in the fossiliferous slate and sandstone which normally underlie the hard, barren sandstone. Where the N.N.E.—S.S.W. line crosses the W.N.W.—E.S.E. strike of more inclined strata, as at the foot of Mount Maria near Port Howard, the solid rock is broken up into parts of varying and irregular strike and dip.

From the point, N.E. of Fox Bay, where the coast-line bends in a south-westerly direction, to south of Port Edgar, the conditions appear to be very much the same, too, as those further north. The coast is evidently determined by a fault and is bordered by a low ridge of hard sandstone. Inside this ridge there is low land consisting of softer rocks, containing at Fox Bay the same marine invertebrates as at Port Howard. The bays widen inside the barrier in very much the same manner. The inclination of the strata is, however, not so great in this region, and the disturbance does not make itself visible so far inland. On the east side of the inner part of Fox Bay, just about where the cross on the map marks the locality for marine fossils, there is a very gentle dip towards the S.W. The dip increases towards the entrance, and in the coastal ridge at East Head it amounts to about 35° S. The conditions at Port Edgar are not known, but to judge from the Admiralty Chart they appear to be similar.

The N.N.E.—S.S.W. direction is traceable in a few places on East Falkland, too. North of Brenton Loch, and at Dos Lomas, the strata of the Lafonian strike in this direction. The dip is very gentle, and the strike has no influence on the general contour of the coast-line, which is exclusively the result of erosion. In the north of East Falkland there can be noted on the Admiralty Chart an orographic line running N.N.E.—S.S.W. The peninsula Rincon Grande at Port Salvador, N.W. of North Creek, is formed by quartzitic sandstone striking in the direction named (see above, p. 14). It is continued towards the N.N.E. by a quartzitic ridge, shown on the chart. The straight, narrow entrance of Port Salvador, as well as North Creek which is cut down in softer rocks, are also evidently determined by the same tectonic line.

The cleavage-lines in the north-western part of Lafonia are sometimes found to run parallel to the big fault-line at Falkland Sound, as, for instance, near the entrance of Brenton Loch. In the region of N.N.E. —S.S.W. strike, east of the northern part of Port Salvador, the cleavage is, on the other hand, parallel to the folding-zone in the south.

It appears from the instances quoted above, that the coast-lines are occasionally determined by fault-lines. The exact course of the coast-line is naturally the result of epigene forces. It has been stated by J. G. ANDERSSON (1907, p. 29 et seq.) that the narrow branching bays, which are so characteristic of the islands, are submerged river-valleys. But as for the large open bays, the same author has also remarked that they «may be due partly to subsidence along fault-lines». Such origin is, indeed, clear, as regards some of the bays on the west coast of West Falkland. Byron Sound is evidently of tectonic origin. At Hill Cove, the horizontal tillite of the Gondwana series occurs at sea-level, whereas the high land immediately south of it consists of Devonian sandstone, dipping 20° N.N.E. The two formations are here clearly separated by a fault-line of a considerable throw. The continuation of the same fault line in a W.N.W. direction coincides with the unusually straight coast of Byron Sound, and it is more than probable that the whole depression of Byron Sound is due to subsidence along that line. The structure of the N.N.E. coast of the bay is not known, but there is probably another fault-line here.

King George Bay, or at least its outer part, is another subsided area. On Rabbit Island the dip is in the greater part of the island 15° N. or N.N.W. On the S.W. coast, however, it is 25° S. 30° W. The limit between the areas of different strike is marked by a fissure, and the rock on both sides shows evident traces of friction. The same line can be followed towards S.S.E. along a chain of small rocks and the outer coast of Hummock Island. The sea here is very deep close to the coast, as is shown by the course of the 25 fathom-line on the map, pl. 5. Queen Charlotte Bay may, too, be considered as a tectonic depression limited at least to the N.W. by a fault-line. Direct evidence of the occurrence of a fault-line has not been obtained here, but the straight coast-line and the great depth of the sea close to it give support to the supposition that such a fault-line exists.

The Falkland Islands are, in their present state, only a small remnant of the large continental areas existing here in the late Palæozoic. As they must be regarded as a «horst», it is only natural that their outlines should be roughly determined by faults. It is of interest, however, to note that the fault-lines in some parts still appear in the topography, and coincide with the actual coast-lines. There is not much information to be gained concerning the epochs when the different displacements took place. It is clear, however, that the more important fault-lines, such as the Byron Sound, the Falkland Sound, and the Port Sussex lines, are younger than, at least, the lower Lafonian.

The age of the E.—W. folding in the Falkland Islands is a matter of great interest, but, at the present time, of some uncertainty, too. The folding-zone in East Falkland falls within the Devonian area, the Lafonian remaining, on the whole, in a nearly horizontal position. At first sight, therefore, the folding appears to be older than the latter formation. But, as J. G. ANDERSSON has already remarked, there are some facts in favour of the opposite opinion. The increase in the dip of the strata towards the mountain-range in the north has been noted above (p. 31). North of Port Sussex it reaches 45° S.W. at the foot of the mountains. This southerly dip is, in itself, not sufficient evidence that the folding has affected the Lafonian, as it could be due to flexures caused by the subsidence of Lafonia. But it appears that the formation last mentioned overlies the Devonian conformably (see above, p. 78). The effects of pressure, seen in the tillite of Cerritos, speak for the action of regional forces, too. All things taken into consideration, it seems more probable that the folding is younger than the lower Lafonian at least, and that the larger part of that formation remains in undisturbed position, only because it is situated outside the folded belt. The only fact which appears, so far, to be in opposition to this opinion, is that, according to Mr. ZENZÉN, many of the inclusions of sedimentary rocks in the East Falkland tillites show more effects of pressure than does the matrix of these rocks (p. 37). Although some of these inclusions of pressed rocks may well be derived from the underlying Devonian, direct evidence is lacking, and as they may have been transported a long way, they do not afford any proof that the Devonian has been folded before the deposition of the bottom-layers of the Lafonian. At any rate, the age of the folding cannot be definitely fixed without new explorations in the field.

Attention has already been called to the apparent close relation in several instances between folding and subsidence in consequence of faults. It is most tempting, in such cases, to regard both phenomena as roughly contemporaneous, and the faults as being an effect of the same regional disturbance which produced the folding. On the other hand, the subsidence of masses has probably influenced the process of folding. The faulting down of Lafonia south of Port Sussex may be the principal cause of the rapid dying out towards the south of the folding in western East Falkland. The great fault-line which determines the western coast of Falkland Sound is evidently closely connected with the disturbance in the zone of N.N.E.—S.S.W. strike along the Hornby Mountains.

The diabase dyke traversing the Lafonian sandstone at the entrance of Brenton Loch (p. 74) is naturally younger than the formation of at least the lower portion of that series. It may be suggested as, at any rate, very likely, that the eruption took place contemporaneously with the subsidence of the district. The dyke runs parallel to the great fault-line of the west coast Falkland Sound. According to Mr. ZENZÉN'S investigations (p. 74) the different diabase dykes in West Falkland show a certain resemblance in lithological character to each other and also to the Brenton Loch dyke, the rocks of the latter locality being even intermediate between those of some of the West Falkland dykes. At any rate, there is nothing contrary to the possibility of their belonging to one period of eruption. All these eruptive dykes are restricted to the undisturbed region, no traces of volcanic action having been found within the folded belt. Although there is no direct evidence, it appears to be a reasonable suggestion that the eruptions may be connected with, and an effect of, the general Permian or post-Permian deformation.

It has been pointed out above in several instances, that the Falkland Islands show a striking agreement with South Africa as regards the organic remains and the stratigraphical features of both the Devonian and the Gondwanas. Although the two districts are widely separated geographically, and have a quite different position in regard to the leading tectonic lines of the earth, this resemblance compels one to a comparison of the tectonic structure, and of the relation of the two formations. In Cape Colony, the conditions in this respect vary somewhat in different parts. The greatest resemblance to the Falkland Islands is found in the south. Along the northern border of the Zwartebergen, the Dwyka tillites rest conformably upon the Witteberg series. The age of that series is not known with certainty but here, too, there appears to be a hiatus between the two formations, only not so great as in the Falkland Islands, the Witteberg beds probably reaching a higher horizon than the Falkland Devonian. At any rate, the Karroo-formation has been folded together with the Devonian. Within the mountain-ranges there occur only isolated outliers of the former formation, but it comes up with inclined strata along the northern border-zone, in very much the same manner as the Lafonian south of Wickham Heights. It is not exactly known when the folding commenced in South Africa, but it is proved that, at least in the south, the main part of the disturbance took place after the Ecca-period. (ROGERS, 1909, p. 441). It is also known that the folding had ceased long before the Lower Cretaceous beds of the Uitenhage formation were laid down. The folding was accompanied by intrusions of dolerites in the lower Karroo beds and, as in the Falkland Islands, these eruptions have avoided the folded belt. Among these South African eruptives there are also rocks of the same composition as the Falkland diabases. There is, of course, no evidence of direct connection between the tectonic lines of the Falkland Islands and those of South Africa. As the regional disturbance in the latter district cannot be brought into connection with any of the leading tectonic lines of the earth, it is, however, worthy of note that the conditions in the Falkland Islands show a certain analogy which, naturally, should not be over-estimated, however.

Apart from this analogy with the far away mountain ranges of Cape Colony, there is only one of the leading tectonic lines to be considered in connection with the Falkland Islands. It is the Cordillera de los Andes. The Falkland Islands show, at the same time, the sequence of strata characteristic of Gondwana land. It is, therefore, in the border-zone between this old land-mass and the Andes that a region of similar structure could be expected. (In the last volume of the *Antlitz der Erde* (p. 557), SUESS has already called attention to this question, in consequence of the discovery of the Gondwana in the Falkland Islands.) Such a border-zone is known to exist in the Argentine *Præcordilleras* and the *Sierras Pampeanas*. The structure of these mountain ranges is known in its main features through the explorations of BRACKEBUSCH, of STELZNER, BODENBENDER (1896, 1897, 1902) and STAPPENBECK. In the *Sierras Pampeanas*, the Permo-Carboniferous rests unconformably on metamorphic rocks of the Archæan or the oldest Palæozoic, the Devonian not being represented. The *Præcordilleras* show a continuous series of Permo-Carboniferous and Triassic beds of the Gondwana-type resting conformably upon the Devonian, which shows a close relationship to that of the

Falkland Islands. As, in the Falkland Islands too, the Gondwana appears to rest conformably upon the Devonian and to be folded together with it, the analogy must not be overlooked. In the border-zone of the Argentine Cordillera the disturbance has, however, continued until recent times. Not only does the Triassic lie conformably upon the Permian, but the Tertiary and Diluvial, or still younger beds, have been very much disturbed. In the Falkland Islands there is no trace of such recent movements. The upper limit of the deformation, however, cannot be determined on account of the absence of any post-Permian strata older than the Quaternary.

The geographical position of the Falkland Islands points, decidedly, to a similar relation between their tectonic lines and those of the Andes as that existing in the case of the *Præcordilleras*. The Andes, in the extreme south of the South American continent, bend to the east, and the idea has long ago been expressed that the Andine structure continues in a curve over the South Sandwich Islands to Graham Land. This hypothesis has been confirmed in a very positive manner by the explorations carried out during the Swedish South Polar Expedition, 1901—1903, mainly by Prof. J. G. ANDERSSON (1906). The dominating E.—W. strike of the mountain ranges in East Falkland is parallel to this hypothetic easterly continuation of the Fuegian Cordillera. The bend in a N.W.—S.E. direction in the west of the island might, then, correspond to the curve of the Andes in southernmost Patagonia and Tierra del Fuego. In relation to the Andes, the main mountain ranges of the Falkland Islands thus seem to occupy the same parallel position as the Argentine *Præcordilleras*. There is, however, another difference in addition to the one remarked upon above. The folding in the Falkland Islands disappears rapidly towards the south, i. e. towards the central Cordillera. In the southern part of the islands both the Gondwana and the Devonian remain in horizontal position, the latter resting upon the metamorphosed præ-Devonian basement at Cape Meredith. There is, accordingly, a broad, undisturbed zone intervening here between the Palæozoic mountain range and the central Cordillera. In spite of the above mentioned differences which prohibit the comparison from being pursued up into details, the *Præcordilleras* seem, as far as the present evidence goes, to represent the nearest analogy to the Falkland Islands to be found anywhere. At present the latter are, therefore, best considered as a part of the border-zone of Gondwana-land which has been involved in the Andine folding-belt.

Remarks on Permian geography and glaciation.

The occurrence of a mighty series of rocks belonging to the Gondwana System necessitates the existence of considerable land-masses in the region of the Falkland Islands during the late Palæozoic. That the Lafonian extended far beyond the small district it now occupies is shown by the existence of the outlier at Hill Cove, and there is no doubt that the present archipelago is only a very small remnant of a larger Permian land-area. The Lafonian is wholly a continental series without any trace of marine fossils, and the basin alone in which the strata were formed must have been much larger than the present islands, as its borders are nowhere seen. And then there will also have been a wide area of exposed land from which the whole amount of sedimentary material was supplied. But the evidence fails us when we attempt to form an opinion of the extension of the land and its connection with other Permian land masses. Only vague conjectures can be ventured on the basis of what is known generally of Permian geography. The latest attempt to sketch the disposition of land and water during the Permian is the map accompanying KOKEN'S (1907) paper on the Indian Permian and the Permian ice age. On this map, the Falkland Islands are represented as the southernmost corner of a continent which comprehends the southern part of South America with a presumptive bridge in the region of Paraná and São Pablo over to the Brazilian-African-Indian land-mass. If the Gondwana-flora of the Falkland Islands may be taken as the basis of any speculations on land-connections, it seems more probable, however, that the islands were connected with more central parts of Gondwana-land. It is a pure Gondwana-flora and, as such, it will require, if any weight be laid on the evidence of plant-geography, the possibility of free interchange of species with some of the other regions possessing a similar flora. Now the Brazilian Gondwana is characterized by a mixed flora of elements both — and mainly — from the southern continents and from the region of the northern flora. If the Falkland Islands had any connection with another land possessing a similar pure Gondwana-flora it could hardly be only over a region with a different, mixed flora evidently belonging to the border-zone between the two great phytogeographical provinces. That there were in the region of the Falkland Islands, larger land-areas than are intimated on KOKEN'S map, is, I think, very probable, but in what direction they extended we do not know. The flora is not of much value as evidence in this respect. The typical vegetation of Gondwana-land was very uniform, and there is scarcely any noticeable difference between the different continental areas. A much greater number of species, at least, would be required for a comparison, than are as yet known from the Falkland Islands. There is, however, the possibility, that the land-masses of the late Palæozoic extended much further south than is believed by KOKEN. On his map there is a large Antarctic ocean running all round the earth to the south of the Gondwana continents. It is on the existence of this ocean that his explanation of the Permian ice age from geographical causes is largely based. The circumpolar arrangement of the Gondwana provinces has, however, provoked the idea of a large Antarctic continent as the centre of the phytogeographical province of the *Glossopteris*-flora. PENCK (1900) has pointed out the necessity of taking this possibility into consideration, notwithstanding the difficulties presented by the idea. D. WHITE (1907), in discussing the causes of the Permian glaciation, is inclined to accept the theory of a large Antarctic continent «of which South America, Australia and South Africa were possibly but lobes» CHAMBERLIN and SALISBURY (1906, p. 675) also assume, in their elaborate discussion of the Permian glaciation, that South America was connected with the Antarctic land-mass, and that, again, with Australia in India. Without expressing a definite opinion on this matter, it should be admitted that the occurrence of a mighty series of continental sediments, of thick beds of moraine-deposits, and of a pure Gondwana-flora as far south as in the Falkland Islands, gives a stronger evidence for the existence of continental conditions in southern latitudes than there was before. The recently better established analogy between South America and the Antarctic leads, as SUESS (1909, p. 559) has pointed out, to the idea of an old land-mass in the region of Coat's Land, corresponding to the «Vorland» of Brazil. A connection between the Falkland Islands and this hypothetic continent would appear very probable. Should future explorations in the Antarctic reveal the existence of a Permian land-mass there, the idea of a wide, continuous Antarctic ocean south of the now known Gondwana areas would lose much in probability.

In regard to a possible direct connection of the Falkland Islands with South Africa, the striking resemblance in different respects between these two regions — in spite of the intermixture of the South African *Glossopteris*-flora with northern elements — is worthy of note. It is of some importance, however, that the rich land fauna of the Karroo-beds does not seem to have reached the Falkland Islands. Future explorations may possibly reveal vertebrate remains in the Lafonian but this is not very probable, as fossil bones, did they exist, could scarcely have failed to attract the observation of the inhabitants. At present, the insect-wing mentioned above (p. 71) is the only trace of animal life met with in that series. The important discovery recently made of marine fossils above the Dwyka tillite in German South-West Africa (SCHROEDER, 1908) proves that, in the early Permian, South Africa was bordered to the west by the sea. This fact speaks against a direct connection of the Falkland Islands with South Africa, and gives a strong support to KOKEN'S objections against the idea of large land areas west of South Africa.

If future explorations should give any evidence of the existence of larger Permian continents in southern latitudes, these might, in some cases, serve as connecting links between the different Gondwana areas. It would, then, be possible to considerably reduce the large land-masses now generally postulated in the belt of the trade-winds. The latter hypothetic continents now form a conspicuous difficulty when dealing with the Permain glaciation, as they would certainly be subjected to a dry or even desert-like climate, rather than form regions of rich precipitation. And all the theories which endeavour to explain the Permian glaciation, postulate a very abundant precipitation to counterbalance the difficulty of assuming an abnormally low temperature in low latitudes.

The lack of decisive evidence concerning the late Palæozoic land-connections is a great drawback when discussing the Permian ice age. The fact that glacial conditions existed in the Falkland Islands, too, far away from the hitherto-known areas of Permian glaciation, is a matter of some importance. But it does not give much information bearing on the nature and causes of the Permian glaciation generally. Such evidence as it affords is mainly of a negative character.

As long as glaciated areas were known only from India, Australia, and South Africa, their arrangement round the Indian Ocean was the most striking feature of their distribution. It has led to the theory of a change in the position of the South Pole into the middle of the Indian Ocean. This would bring the glaciated areas into a distance from the then pole, less than that of the borders of the northern Quaternary glaciation from the present North Pole. The difficulties that this explanation meets with are well known. As, however, other attempts towards an understanding of the abnormal Permian glaciation have likewise failed, a displacement of the pole has now and again been advocated. PENCK (1900) has pointed out, that, as long as no glaciation is known from South America, the excentric position of the glaciated areas relatively to the South Pole is apparent. He remarks at the same time, that the problem would appear in a new light if traces of glaciation were found in South America, as the zonal arrangement of the regions of glaciation would be more conspicuous.

There has been some uncertainty as regards traces of glacial action in the South American Gondwanas. From the Argentine it is known that conglomerates occur at the base of the Gondwana system. But traces of ice-action have not been found, and the conglomerates are not considered as glacial (BODENBENDER, 1897, p. 234). From Brazil there are some records of conglomerates supposed to be of glacial origin. The most important are those of I. C. WHITE who, as a leader of the Brazilian Coal Commission, has done much to increase our knowledge of the Gondwana series of that country. WHITE (1908, pp. 11, 51) considers the Orleans conglomerate at the base of the Rio Turbarão-series as glacial. It seems, indeed, to contain erratic material, and may be of glacial nature, but the evidence of a moraine-like structure, and of polished and striated boulders, is still wanting. The glacial nature of these conglomerates has also been doubted. (KOKEN, 1908, p. 461). The same remark applies also to the boulder-beds described as early as in 1888 by DERBY. The evidence of a Permian glaciation in the Falkland Islands appears, however, to be conclusive and it is certainly not consistent with the theory of a displacement of the pole. KOKEN (1907) who, himself, is decidedly in opposition to that theory, has marked on his map the position of the pole most favourable for the theory. It will be seen from a comparison with this map that the glaciated area in the Falkland Islands is only about 10° distant from the supposed Permian equator. Apart from all difficulties attached to it, the theory does not, then, in any way simplify the problem, and will have to be definitely abandoned.

An important question in the discussion of the Permian glaciation, is, whether there was, at this time, a zonal distribution of climate. This matter has been taken up for discussion by MANSON (1891, 1907[1], 1907[2]) and although his ideas have not gained many adherents they may be worthy of some consideration. According to his theory, the planetary heat of the earth was at this time still the controlling factor in surface temperatures, the solar influence being checked by a thick cloudy atmosphere. Apart from objections of physical nature, MANSON'S theory appears at first sight to be in agreement with some phytopalæontological facts. The Palæozoic vegetation of the northern hemisphere was, indeed, spread out with a remarkable uniformity from the equator to far north of the polar circle. A consequence of MANSON'S theory would be the absence of changes of seasons, such as result now from the annual moving of the zones. Now it is well known that fossilized woods of the Palæozoic generally do not possess any annual rings indicating a change of seasons. This fact may be accounted for by assuming a sufficiently high temperature even during the vinter, but it might also depend on a uniformity of the climate during the whole year. In the northern hemisphere, annual rings appear first in the Mesozoic and, to judge from GOTHAN'S important papers (1907, 1910) on fossil woods of the Arctic region, earlier in the high latitudes than in central Europe.[1] In connection with the Permian

[1] Attention may be called here, by the way, to a question which has, in my opinion, a claim to be considered when dealing with the Arctic floras as indicators of climatic

glaciation in the southern hemisphere, fossilized wood has been found possessing unmistakable annual rings. For the Falkland Islands this fact has been stated above (p. 66) in the case of *Dadoxylon Lafoniense*. Annual rings have previously been described in Australian Gondwana *Dadoxyla* (SCHENK, 1890, p. 870; SHIRLEY, 1898; ARBER, 1905, p. 190), but this fact seems not to have received due attention at the hands of geologists. A regular succession of annual rings may be taken to indicate a periodical change of warm and cold seasons. This is the more justifiable in the matter of gymnosperms (GOTHAN, 1908). The annual rings in the Gondwana *Dadoxyla* speak, therefore, for the existence of cold winters for some time after the disappearance of the ice-masses. In any case, the annual rings point to a periodicity in the climate, not consistent with MANSON'S theory.

If the banded claystone described above is really comparable with the seasonally laminated clays of the Diluvium, as indeed seems probable, it would afford another and equally important evidence of periodicity and solar control of the Permian climate.

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conditions. GOTHAN'S ideas have regard to fossilized wood from Spitsbergen and Kung Karls Land, situated in Lat. 75°—80° N. With the present position of the pole, the Arctic night prevails here for a number of months. The darkness of the long night will have made the assimilation of carbon dioxide an impossibility, and will consequently have checked the forming of new tissues. This standstill, independent of changes in temperature, may well have produced similar effects to those of a winter-rest caused by a minimum of temperature. The influence which the long Arctic day and night exerted on the life-process of a vegetation, favoured by a warm climate, must indeed have been very peculiar. Little attention has been paid to this question as yet. This is only natural, as the phenomenon has no parallel at the present day, and as there exists very little positive material available for tracing its effects on the plant-life. Prof. NATHORST, however, when describing the peculiar structure of *Pseudocycas*, has touched upon the question. As far as concerns the annual rings of the fossil wood from Kung Karls Land, the eventual influence of the polar-night should certainly at least be taken into consideration.

The forest-bed of West Point Island.

The continental conditions which set in with the close of the Devonian transgression seem to have prevailed in the Falkland Islands until recent time. At least, no marine deposits younger than the Devonian are known from the islands. The accumulation of continental sediments going on during the time of the *Glossopteris*-flora, ceased, too, with the close of the Permian. From that time on, there are no deposits giving any information as to the history of the islands until the beginning of the Quaternary period. This was marked in Tierra del Fuego, South Georgia and other adjacent regions by the great glaciation traced in different parts of the southern temperate zone. The Falkland Islands were certainly not glaciated in Quaternary time, but the Ice Age seems to have been represented here by a great development of the process of *solifluction* (see J. G. ANDERSSON, 1903, 1907) caused by the severity of climatic conditions. At least this theory affords the best explanation of the phenomenon of the stone-runs characteristic of the islands. We do not know much about the kind of climatic conditions that preceded this period of low temperature. Some light is shed on this question, however, by an interesting deposit which has lately been discovered in the islands.

Shortly after my arrival in the Falklands I was shown by Mrs. ALLARDYCE some pieces of large tree-trunks sent in to the Falkland Islands Museum from West Point Island. The wood had been discovered by Mr. A. E. FELTON on West Point Island in November 1899. As the Falkland Islands are to-day entirely destitute of wild-growing trees — even the few planted ones doing very poorly — the discovery gave rise to many questions as to the origin of the wood. Mr. FELTON, who took much interest in the find, dug several sections through the bed containing the wood, and procured a great number of large trunks. From his own observations he came to the opinion that the trunks were not merely recent drift wood from the coast of Tierra del Fuego, but the remains of a forest, growing in the vicinity in bygone times.

When the Scottish Antarctic expedition under Dr. BRUCE visited the Falklands, Mr. FELTON presented to the expedition a specimen of the wood which was, later on, placed in the museum of Edinburgh. According to a letter to Mr. FELTON from Mr. BROWN, it was, however, declared by all geologists, who had seen it, to be drift-wood. This was also the view generally held by the inhabitants of the islands, but Mr. FELTON did not give up his opinion that the wood bed was a local deposit.

In December 1907 I found an opportunity of spending some days on West Point Island, and I naturally made use of this stay to study the forest-bed. The first glance quite sufficed to convince me — though I had before supposed the wood to be drift-wood — that the bed was not a sea-shore deposit.

During my stay on the island I made a small sketch-map of the locality and its immediate neigbourhood. This sketch-map is shown in

Fig. 19, View of the settlement (Clifton Station) of West Point Island, West Falklands. A. E. Felton phot.

fig. 20. In order to give an idea of the extension and mode of occurrence of the forest-bed, I have marked on the map some of the places where the wood has been met with by Mr. FELTON or myself. The locality is situated at the small bay forming the harbour of the settlement, on the inner side of the island. The bay is surrounded by high hills which come down to the sea in steep slopes. The general aspect of the locality is seen in the photograph, fig. 19. The forest-bed extends almost all round the inner side of the little bay. The distance between the extreme limits of the area in which the wood has been noted, is about 550 m. The first find was made by Mr. FELTON on the beach, but shortly afterwards he found that the bed extended inland under a cover of loose deposits. The bed is encountered mostly in a narrow strip along the shore. This is due to the fact, that here it comes very near to the sur-

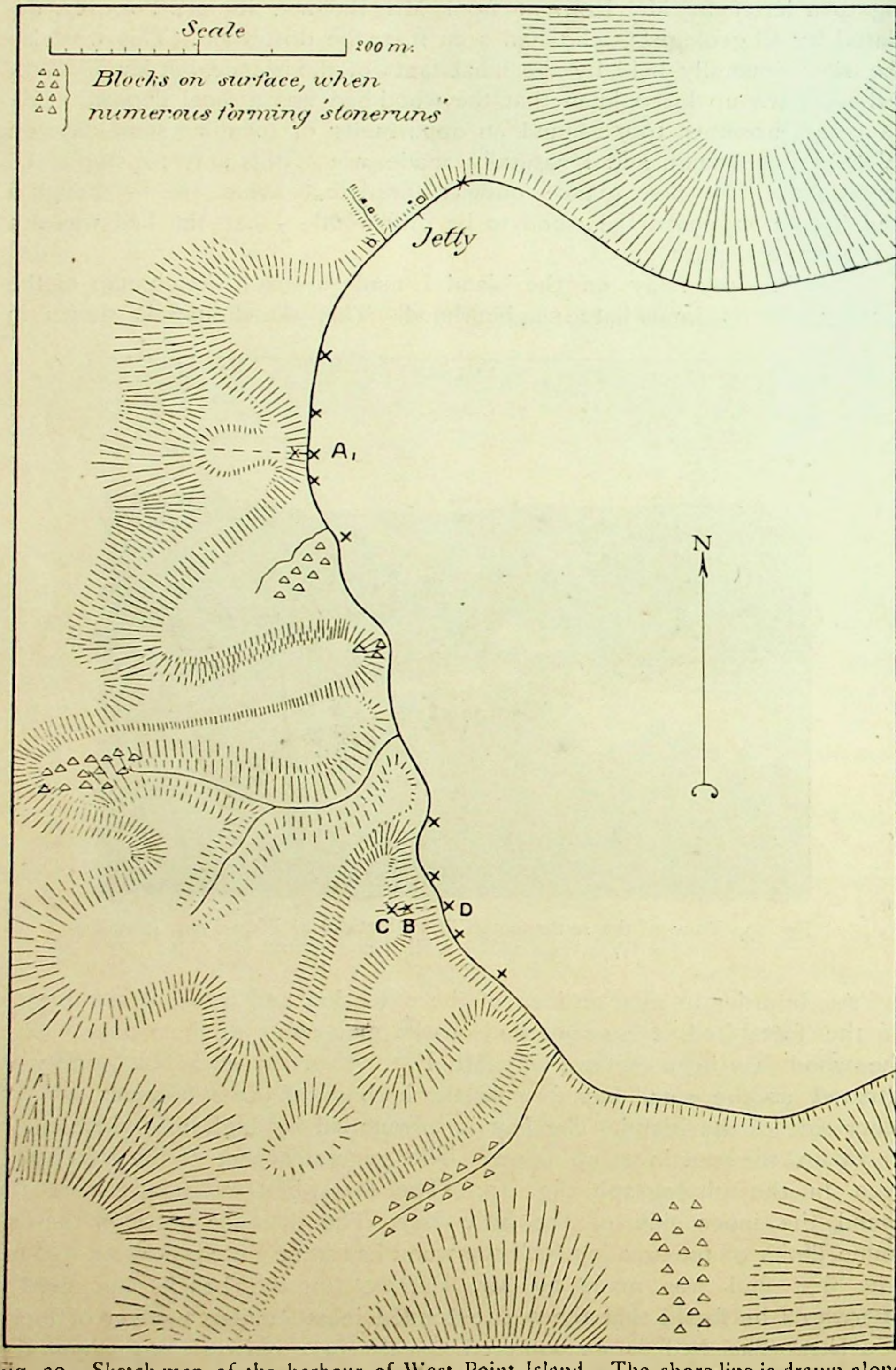

Fig. 20 Sketch-map of the harbour of West Point Island. The shore-line is drawn along the high-water mark. × — Places where the forest-bed was found on digging or boring.

face, as the superincumbent bed of soil has been to some degree removed by the action of the sea. By means of borings I have traced its existence as far out as to the low-water mark, and Mr. FELTON, too, has obtained wood in several places when digging at low water within the tidal zone. How far the bed extends inland is not definitely known. The thickness of the superincumbent soil seems to increase when passing from the shore, as the inclination of the slope of the land-surface is steeper than that of the forest bed. The greatest distance from the shore on which I have found the bed is about 30 m. at C on the map, where it was met with at a depth of 2,75 m. below the surface, 8 m. above high-water mark. Mr. FELTON informs me, however, that he has found the wood still far-

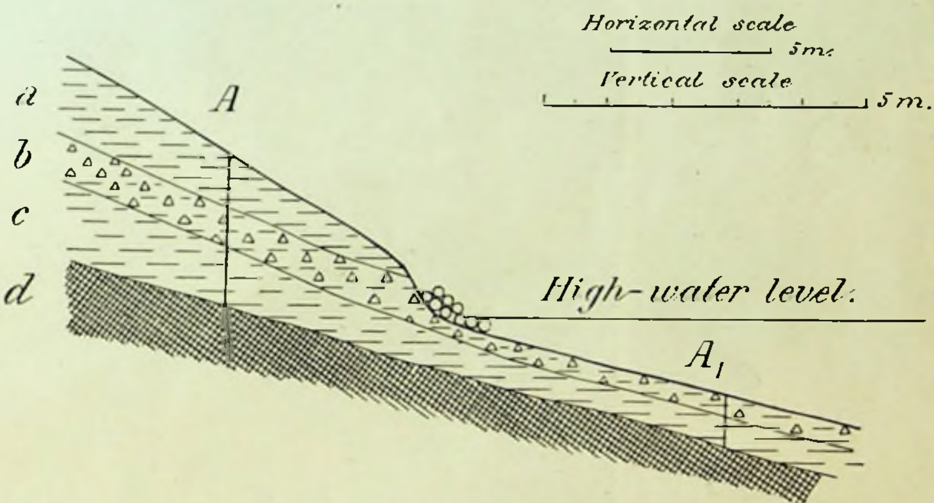

Fig. 21. Section at **A** on the sketch-map.

ther inland. I tried to bore down to the bed in several other places higher up in the slope, but without success, as the bore was checked by the stones which were present in abundance in the soil.

Section A.

In two places I dug sections down to the forest-bed. The section figs. 21 and 22, was made at **A** on the sketch-map. Mr. FELTON hat dug a pit here some years ago, but it had been filled up later on and had to be reopened. The following section was obtained:

a) Yellowish clay .... 0,90 m.
b) Bed of big angular blocks and scattered pebbles cemented by clay .... 0,60 m.
c) Clay, containing lenses and strips of black soil. In the lower part numerous trunks of trees .... 0,90 m.
d) Black vegetable soil with densely packed trunks .... 1,00 m. +

Fig. 22. Section at A on the sketch-map. C. Skottsberg phot.

Layer *a*. The clay is yellow in colour, and comparatively pure as compared with the next lower layer, but always somewhat intermixed with sand and small stones. It shows no traces of stratification. Clay of the same kind is often found on the surface in this region, where the vegetation is scanty.

Layer *b*. This is a bed of angular blocks of varying size, often a few dm. in diameter. These blocks are scattered irregularly and show no traces of water-action. There also occur, subordinately, small, rounded pebbles. The whole is cemented by a yellowish clay, like that of *a*, and shows no traces of stratification. The blocks and pebbles are sometimes densely packed; sometimes the matrix is more abundant.

Layer *c*. This layer consists of a very tough, yellowish clay, enclosing only very few and small stones. It contains lenses and strips of black colour. This is due to intermixture with humus formed by decomposition of vegetable matter. These black intercalations are more predominant towards the bottom. In the lower part there also occur pieces of wood and large trunks. Some projecting pieces are seen in the photograph. The layer passes insensibly into the next lower one.

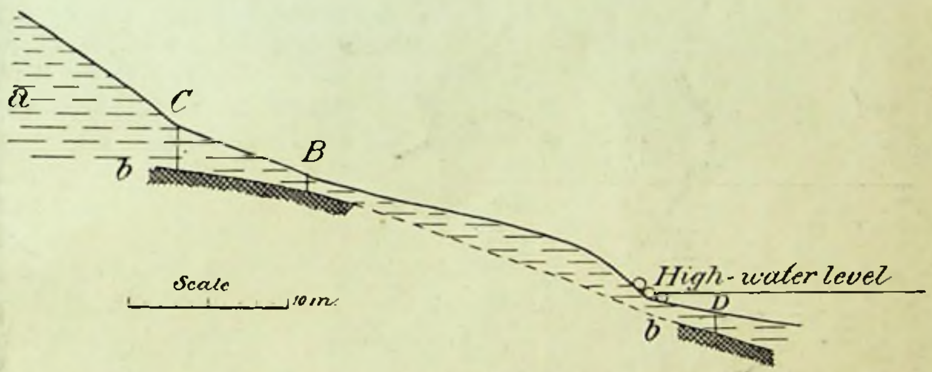

Fig. 23. Section **C-B-D** on the sketch-map.

Layer *d*. This layer consists of a dark vegetable soil, mixed in varying degree with sand. It contains tree-trunks and smaller pieces of wood in great abundance. In consequence of the entrance of water it was impossible to reach the bottom of this layer. The bore, too, was useless on account of the abundance of thick, hard trunks. Mr. FELTON informs me that, on a previous occasion, he has dug down more than 1 m. through this bed without reaching the bottom. All the way down it presented exactly the same aspect.

Section B.

This locality is situated about 325 m. S. of **A.** It is higher up the slope, the height of the surface being about 8 m. above high-water mark. I had a section made here to a depth of 1,85 m. through the following layers (figs. 23 and 24):

a) Yellowish clay .... 0,75 m.
b) Black forest-bed .... 1,1 m. +

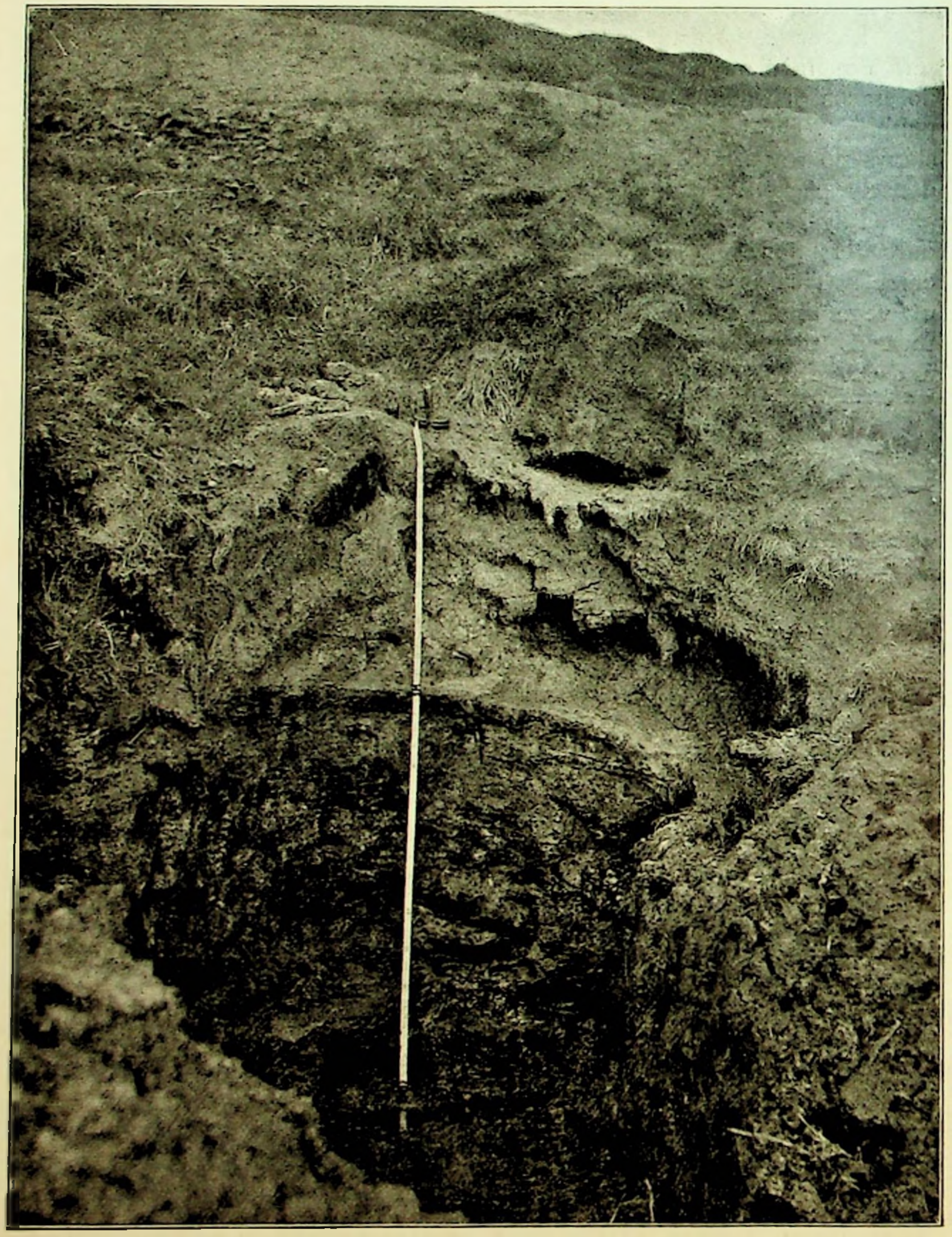

Fig. 24. Section at B on the sketch-map. C. Skottsberg phot.

Layer *a*. The clay is light-coloured, generally yellowish. It shows no trace of stratification, and it contains small angular pieces of sandstone. The bed has probably had a much greater thickness, as the section is situated in a depression at the side of which the clay projects as a cliff. Here the clay has probably a thickness of at least 2 m. The clay in places contains darker spots, apparently resulting from the decay of pieces of wood, but it presents a very sharp limit to the next lower layer.

Layer *b*. This bed is nearly black in colour, consisting of a mixture of humus and fine sand or clay. The whole bed contains a large number of pieces and big trunks of wood. The abundance of the trunks rendered the digging very difficult, and it was not possible to reach the bottom of the bed. Its thickness exceeds 1,1 m., however.

At C on the sketch-map, about 8 m. from the former locality, on the slope right above it, I bored down through the clay and found the forest-bed at a depth of 2,75 m. below the surface. Immediately above the place where the boring was made, the land rises steeply, and the clay here has evidently a greater thickness. The surface of the forest-bed at C lies only a few dm. higher than at **B.** In a right line with these two places, Mr. FELTON has found the forest-bed within the tidal region only a little below the surface of the ground. It is evident, therefore, as is seen from the section, fig. 23, that the bed has not everywhere the same inclination, and also that it does not follow the present land-surface.

The forest-bed is very uniform in the different localities. It consists of a humus-like soil mixed with mineral matters and wood. The tree-trunks sometimes attain a remarkable size. Mr. FELTON has found a piece of more than 6 ft. in diameter. Another trunk was still provided with a root, 6 ft. long. Smaller trunks and branches occur also, and I have found even slender twigs of 5 mm. or less in diameter. The wood is brown in colour, a little darker than the trunks in the peat-bogs of Northern Europe. Sometimes the wood has been replaced by marcasite which, when exposed to the air, is altered into a powder of iron sulphate. Occasionally the mineral forms perfect pseudomorphs of whole branches, but it also occurs as irregular lumps mixed with the vegetable soil. The forest-bed resembles in every respect the vegetable soil formed by decaying vegetation on a land-surface. The bed has evidently not been formed in water, still less as a litoral deposit of the sea, but by growth *in situ* on the surface.

The soil covering the forest-bed, shows, too, no signs of having been deposited in water. The only trace of water-action is represented by the few rounded pebbles in the layer *b* at **A.** They play only a subordinate rôle, and may quite well occur in secondary position. Otherwise, the boulders and pebbles are rough and angular. The finer material is sometimes nearly pure sand and clay, as in **B,** but the commonest kind of soil consists of a stony clay or sand, sometimes charged with larger blocks. This kind of soil is exactly like the waste-cap which generally covers the ground in the mountainous districts of the Falkland Islands.

As no trees grow to-day in the Falklands, nor have been found in the extensively worked peat-bogs, it is only natural that the wood in the forest-bed should have been considered as drift-wood. From the above description of the mode of occurrence, it is clear that this opinion can hardly be correct, as the whole deposit shows apparent traces of having been formed on land. And the wood itself does not appear to have been drifting in water at all, far less for a time sufficient for its transport from the coast of South America to the Falkland Islands. The trunks are not rounded or worn, and are often provided with protruding roots and branches, and sometimes have the bark preserved. The slender twigs, too, occasionally found in the bed, are not at all suggestive of drift-wood. If additional evidence were needed, it might also be remarked that, among the great number of fragments, there has not been found even one piece of beech-wood. The present forests in Tierra del Fuego and southern Patagonia consist almost exclusively of beeches (species of *Nothofagus*), and so does the recent drift-wood found on the coasts of the Falkland Islands. At this particular spot very little drift-wood is found to-day, as the locality is situated at a small, sheltered bay. All these facts, however, are of secondary importance. The nature of the forest-bed is, in itself, sufficient evidence that it is not a marine or a sea-shore deposit.

Fig. 25. Tree-trunk from the forest-bed. Much reduced. A. Lindley phot.

In regard to the age of the deposit, very little information is gained from the wood itself, a specific determination being hardly possible. The fresh, unaltered appearance of the wood, and the nature of the deposit, tend to show that it cannot be very old, probably not older than Quaternary. It is, therefore, at least very probable that the wood belongs to some living species. These, then, should be looked for in the present vegetation of southern South America. All the pieces of wood, which I have examined, are of coniferous trees. In the present vegetation of southern South America there occur only few gymnosperms. It appeared, therefore, to be of some interest to compare the wood with some of these living species, on the understanding that even a perfect agreement does not prove a specific identity. On examining the material I found two distinct types of wood, and sections of these were submitted to the well-known specialist in wood-anatomy and fossil wood, Dr. W. GOTHAN of Berlin. Dr. GOTHAN has kindly sent me the following report:

«Ich bemerke zunächst, dass die folgenden Bestimmungen nur unter der Voraussetzung gemacht sind, dass — wie bei quartären Pflanzen anzunehmen — sie zu den von Ihnen genannten *Podocarpus, Saxegothæa, Fitzroya, Libocedrus* gehören. Die genaue Bestimmung ist bei Holzresten von *Cupressinoxylon*-Bau immer schwierig, meist unmöglich.

N:o 1. Wohl sicher *Podocarpus chilina.* Begründung: *Saxegothæa* ist es nicht, weil die Verdickungen der horizontalen Markstrahlwände fehlen; *Fitzroya* nicht, weil die Verdickungen der vertikalen Markstrahlzellwände fehlen; *Libocedrus* nicht, weil diese, wie die Cupressineen zumeist, «cupressoide» Markstrahltüpfel hat. Von Podocarpen scheidet aus: *Podocarpus andina* und *nubigena:* erstere wegen der grossen Markstrahltüpfel; letztere hat als Markstrahltüpfel im Frühholz mehrere kleinere Eiporen ähnlich *Glyptostrobus,* aber lockerer. Bleibt bloss ausser *Podocarpus chilina* noch *Dacrydium Fonki,* zu welcher das Holz gehören könnte. Nach meinen Präparaten scheint es eher *Podocarpus chilina* zu sein; allerdings habe ich von *Dacrydium Fonki* nur ganz junges engzelliges Holz — wie überhaupt das rezente Holzvergleichsmaterial sehr schwer zu beschaffen ist. Diese und das vorliegende Holz haben als Markstrahltüpfel auch im Frühholz den Typus, den ich 1905, p. 47, fig. 8 a, abgebildet habe, mit dem stark vertikal geneigten linealen Porus. Markstrahltüpfel ausserdem meist nur 1—2 pro Kreuzungsfeld, also locker, ebenfalls charakteristisch für Prodocarpeen im Gegensatz zu Cupressineen etc. (Von den amerikanischen Podocarpeen kenne ich holzanatomisch ausser den oben genannten *P. salicifolia,* Venezuela, die sehr ähnlich *P. chilina* ist, ferner *P. Sellowi,* die zur Gruppe δ (1905, p. 101) gehört, nicht dagegen *P. coriacea,* Jamaika, und *P. Lamberti,* Bras.; doch kommen diese ja als in den Tropen befindlich, hier auch nach Ihrer Meinung nicht in Frage.)

N:o 2. Dürfte *Libocedrus chilensis* sein (Gattung sicher). Sicher nicht kommen in Betracht: *Fitzroya* und *Saxegothæa* (s. unter 1), Podocarpeen auch nicht, da die Markstrahltüpfel ausgesprochen «cupressoid» (1905, p. 48) sind, mit im Frühholz fast horizontal stehendem Porus. Die Struktur ist durch starke Spiralstreifung oft etwas verwischt, doch noch genügend erhalten. Es bleibt also bloss *Libocedrus;* nach meinen Præparaten ist die Übereinstimmung absolut, doch muss ich leider hinzufügen, dass ich *L. tetragona* holzanatomisch noch nicht untersuchen konnte und nicht sagen kann, ob diese etwa wie *L. decurrens* stark verdickte Markstrahlzellvertikalwände hat oder nicht, u. a. Die Gattung ist aber unter den vorn genannten Voraussetzungen sicher.»

It is seen from the foregoing report that the two kinds of wood from the forest-bed agree closely with such gymnosperms as are now living in the temperate zones of South America. This does not prove, as already remarked, a specific identity, but it is worthy of note, because a comparison with living species from southern South America appears in some degree justifiable. The wood, as stated above, can not be very old, probably not older than the oldest Quaternary. At that time conditions very similar to those of the present day already prevailed in these regions, and the present phytogeographical provinces were certainly long ago established. It is enough, in this connection, to recall the well-known fact that even the flora of the Oligocene or Miocene Patagonian Beds in Tierra del Fuego and southern Patagonia show a remarkable agreement with the present vegetation of temperate South America. And the forest-bed of West Point Island is, no doubt, of a much more modern date.

That the forest-bed represents the remains of a vegetation growing on the spot in bygone times, appears to be beyond doubt. However little can be said about the nature of that vegetation, it is sure that it points to climatic conditions quite different from those of the Falkland Islands to-day. Coniferous trees of a size like that of the fossil trunks are not met with now in South America until much farther north. And the living species agreeing anatomically with the wood of the forest-bed, do not go south of Lat. 43°—44° S.[1] Altogether, the vegetation seems to have been a luxuriant one and growing under favourable conditions, whereas the Falkland Islands to-day have little more to show than shrubs. As appears from the occurrence of luxuriant forests in Tierra del Fuego, in a still more southerly latitude, it is not so much the low temperature as the want of water (physiologically, as the resultant of precipitation, wind and soil) that prohibits the growth of trees in the Falklands. If the trees of the forest-bed had been of a kind growing now in Tierra del Fuego it would only have been necessary to assume a change in these factors. But the tree-trunks of the forest-bed belong to at least two different conifers, whereas there occurs in Tierra del Fuego and southernmost Patagonia only one coniferous tree, *Libocedrus tetragona*. This appears not to be identical with any one of the two fossil forms; at any rate it does not attain the size of the larger trunks in the forest bed. It seems, therefore, probable that the temperature was higher than at present, about the same as in the regions where conifers of a corresponding size, *Podocarpus chilina* and *Libocedrus chilensis* especially, grow to-day.

We may, then, imagine that at one time forests, nearly corresponding to those of the rainy west coast of Patagonia lying between Lat. 40° and 44° S., covered the hillsides of West-Point Island. It is difficult to tell exactly in what manner the deposit has been formed. In the above-mentioned forest-region of Patagonia, where the ground becomes saturated with water from the heavy rain-fall, landslips are of common occurrence. In this manner real forest-beds are sometimes formed, covered with thick banks of clay. The large tree-trunks of such buried forests protruding from the *barrancas* of the river-valleys, are a feature familiar to every one who has travelled in those parts. The West Point forest-bed has prob-

[1] According to Dr. C. Skottsberg.

ably originated in a similar manner. The clay immediately covering the bed in loc. **B** is probably of similar and contemporaneous origin. Specimens of this clay have been examined microscopically by Prof. LAGERHEIM, who has kindly communicated the result. The clay was found to contain an abundance of pollen-grains of conifers, represented by two or three different kinds; further, spores of two pteridophytes and a pollen-grain of a dicotyledonous plant. The gymnospermous pollen-grains are all of the type provided with air sacks, and may well belong to species of *Podocarpus*. It is well known that spores and pollen-grains, more especially such as have air chambers, may be carried a long distance by the winds. But it seems highly improbable that the present pollen-grains can have been carried in the rainy atmosphere the whole way from Western Patagonia, which is the nearest region from which they could be derived. Their great abundance in the clay must, indeed, be considered as excluding that possibility. It appears far more probable that they, together with the spores and the dicototyledonous pollen-grain, are remains of the vegetation that formed the forest bed. No algæ or other sea or fresh water organisms were found in the clay, and this may, with some accuracy, be regarded as a subaërial deposit.

The local origin of the forest-bed once admitted, it is possible to arrive at a minimum value for its geological age. It is fairly well established through the investigations of Prof. J. G. ANDERSSON, that the Glacial Epoch was marked in the Falkland Islands by an unusual development of *solifluction*, caused by the severity of the climatic conditions. This phenomenon has evidently extended its unfavourable influence all over the islands, as the characteristic stony clay of the fossil detritus-flows forms the soil-cap almost everywhere. The stone-runs are known, from Prof. ANDERSSON'S studies, to be the washed-out remains of such ancient «mud-streams» unusually rich in big boulders. In the valleys round the locality of the forest-bed, small but typical stone-runs are seen, and still smaller accumulations of boulders are found on the surface, actually on the top of the bed. The layer *b* at loc. **A** is a detritus-clay, charged with stones and big boulders, and suggesting a fossil detritus-flow. In general, the loose material covering the forest bed — with exception of the pure clay at loc. **B** — is not to be distinguished from the common soil-cap formed by fossil «flowing soil». In some parts of the Falkland Islands solifluction is still at work on a small scale, but this is not the case at the present locality, the there ground being well covered with vegetation.

In another way, too, we arrive at the conclusion that the forest-bed must be of præ-glacial age. The peat-bogs which cover large areas of the Falklands, date back to the period of solifluction, i. e. the Glacial Epoch. In these peat-bogs there have never been found any tree-trunks or any other wood remains than the shrubs still growing in the islands. The negative evidence is, in this case, unusually strong, as the peat is extensively worked for fuel, and tree-trunks, if existing, could not have failed to attract the attention of the inhabitants.

How far back the forest-bed dates in præ-glacial time we do not know. As has been remarked above, the wood has a very unaltered appearance and would seem to indicate, like the general nature of the deposit, a young, probably a Quaternary age. The forest-bed might then be roughly compared — as regards its geological age — with the Cromer forest-bed in England. At any rate, it is evident that the mild climate which it indicates, has prevailed in the Falkland Islands at a comparatively recent period.

Changes of level in the islands.

Records of recent changes in the level of the land have long been current in the Falkland Islands, it being said that the sea was gradually retreating from the coasts. The observations of the «Challenger»-Expedition (see above, p. 9) proved that this opinion, unsupported as it was by any definite data, was only called forth by the gradual growth of the land by accumulation of sediments, such as may occur in favourable places at any stationary coast-line.

The explorations carried out by Prof. J. G. ANDERSSON have revealed, however, that the level of the islands has experienced considerable changes in a more remote yet, in a geological sense, modern period. He recognized in the numerous narrow and branching bays, submerged river valleys, which proved beyond doubt that large areas now covered by the sea were once land, and affected by erosion. The erosion of these valleys has been shown by Prof. ANDERSSON to have occurred before the Glacial Period, as the stone-runs are seen to cover the slopes and bottoms of the valleys, and consequently are younger than these. Prof. ANDERSSON has studied, with the assistance of the English Admiralty Chart the depths of these submerged valleys, and proved that, at the time of their formation, nearly the whole of the archipelago formed one continuous land-mass, about 46 or possibly 73 m. higher than at present.

I have not made any special studies of this interesting question, such requiring detailed soundings round the coasts, and I can only corroborate the correctness of Prof. ANDERSSON'S statements, which embrace, indeed, all that can be said based on the present material of soundings. I reproduce, however, two photographs representing typical Falkland creeks. The one shown in fig. 26, Victoria Creek, a branch of Choiseul Sound, is an unusually fine example of a submerged river-valley. It shows a striking feature of the typical creeks, viz. the fresh and unaltered appearance of the banks. In the present instance these look as if a river were actually flowing between them, and the strong tidal current may, indeed, play the part of a river in eroding the banks, as has been suggested by Prof. ANDERSSON, concerning the creeks generally.

At a still later epoch, subsequent to that of the stone-runs, the Falkland Islands were, according to Prof. ANDERSSON (1907, p. 33), subjected to a submergence bringing considerable areas of the present land-surface below the level of the sea. This opinion was based on some apparent traces of old shore-lines on higher levels, such as terraces and shingle-beds. Of the terraces, one was found on the south side of Mount Low, on the peninsula between Berkeley Sound and Port William. It was found to be 89 m. above sea-level, cutting straight across a stone-river, but not quite distinctly developed. Two terraces were observed near Fox Bay, the higher and distincter one at 117 m. Another terrace was recorded from the southern slope of Mount Sulivan. Concerning all these terraces, Prof.

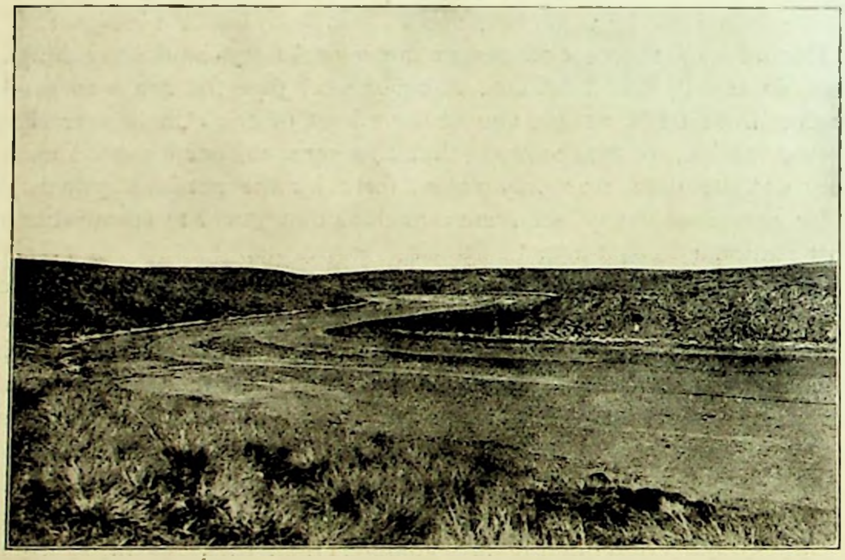

Fig. 26. Victoria Creek, East Falkland. C. Skottsberg phot.

ANDERSSON says that they are, to some extent, doubtful, some of them also showing a gentle slope which rather suggests terraces formed by outcrops of solid rock. No shingle-beds were found in connection with these terraces. Later on, Prof. ANDERSSON discovered, however, on the steep slope of Cape Meredith, shingle-beds representing unmistakable raised beaches. These shingle-beds reach a height of 69 m. above sea-level, and this figure is considered, accordingly, as expressing the minimum of submergence. That this submergence must have occurred in post-glacial times, cannot be doubted, even if no weight is placed on the fact that the supposed shore-line cuts across the stone-run on Mount Low.

Unfortunately, I can contribute no definite data towards a better knowledge of a Quaternary submergence. During our travels overland and round the coasts I naturally looked with great interest for raised beach-terraces or other marks of old shore-lines, but the result was altogether negative. Sometimes, as along the southern border of the Wickham Heights I thought I perceived at some distance raised shore-lines on the slopes of the hills, but, on closer examination, they proved to be merely horizontal outcrops of the solid rock, or the flat surfaces of peat-bogs dammed up behind some ridges. At any rate, I did not find one unquestionable beach-terrace, in spite of the abundance of favourable localities presented nearly everywhere in the islands. It should be remembered, however, that the abundant growth of peat, even on the slopes, is apt to obliterate, to a certain extent, old terraces which may have existed. The recent waste-flow observed in many places has also the same effect.

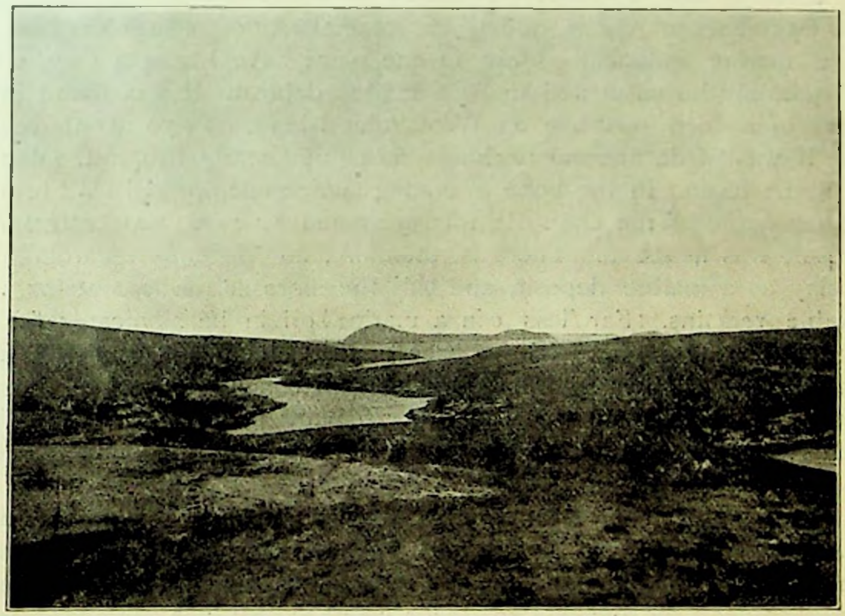

Fig. 27. Creek at Roy Cove, West Falkland. C. Skottsberg phot.

Perhaps more surprising is the fact that I found no shingle-beds anywhere. Only in one place, on New Island, S.W. from the settlement, did I find, 58 m. above sea-level, accumulations of rounded boulders which could possibly be taken to represent an old shore-line. A closer examination revealed, however, that these rounded boulders were only the result of a peculiar kind of weathering as described above, on page 12.

Deposits of sand and clay which could be considered, with any probability, as evidence of a submergence were also looked for in vain. The complete absence — as far as my observations go — of such deposits is, indeed, quite a striking feature of the islands. Where the solid rock does not crop out, it is covered only by a waste-cap, formed by the detritus-flows from the period of extensive solifluction, and by vegetable soil. Yet, the conditions would have been, in most parts, very favourable to the accumulation of marine sediments during a period of submergence, as the numerous winding creeks and river-valleys afford any number of protected spots where the deposits, once laid down, would have been protected from destruction on the upheaval of the land. This is especially the case in Lafonia, the southern half of East Falkland. This peninsula consists of nearly level, low land which would have been altogether submerged, and would have risen above the sea-level almost simultaneously, leaving little opportunity for a removal of the sediments by the action of the waves.

Where any clay has been found at all in the bottom of the peat-bogs, it forms only a thin cover, capping the waste-bed. It contains mostly small fragments of rocks, and looks, generally, more like a detritus-clay than a marine sediment. Only in one place have I seen a clay, which could possibly be suspected to be a marine deposit. It was found in the bottom of a deep peat-bog on West Point Island, 60—70 m. above sea-level. It was of an unusual thickness, measuring nearly 1 m. in the deepest part of the basin. In the hope of finding marine microorganisms I brought home a sample of the clay. It was examined by Prof. LAGERHEIM, but the result was negative. There is, therefore, no reason for regarding even this clay as a marine deposit, and this the more so, as it contains some vegetable remains. Far less can a marine origin be advocated for any other of the clay-deposits I have seen in the Falklands, and microscopical examination of a few, somewhat promising specimens has given no positive result. The fact that no shells or other remains of marine life have, with certainty, been found on higher levels, has already been pointed out by Prof. ANDERSSON.

I am forced, then, to admit that I have not been able to obtain any *unquestionable* facts that would add to our knowledge of a Quaternary submergence in the Falkland Islands. As far as my own observations go, I should, indeed, be inclined to doubt whether any such submergence has really taken place. There are, however, the raised beach-marks discovered by Prof. ANDERSSON at Cape Meredith. Prof. ANDERSSON has informed me that the shingle-beds, the material of which consists mainly of granite, are, in all respects, typical beach-walls, and that no mistake is possible. It rests with future explorations to gain a better knowledge of this Quaternary submergence, and to discover why traces of its existence are so rarely met with.

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Explanation of plates 1—4.

(All figures in natural size, if not otherwise stated.)

Pl. 1.

Lepidodendroid fragments.

Fig. 1. Impression of decorticated stem.
» 2. Portion of the same specimen, $\frac{3}{1}$.
» 3. Impression of a fragment of a more decorticated stem.

Fig. 4—9. Unknown stem-fragments. Fig. 9, top of the specimen, fig. 8, $\frac{3}{1}$.

Fig. 10, 11. Undeterminable plant-fragment. Fig. 11, portion of the same specimen as fig. 10, $\frac{4}{1}$.

Phyllotheca australis Brgn.

Fig. 12. Impression of a stem without leaves, but showing bases of segments and commissural furrows.
» 13. Portion of the same specimen, $\frac{3}{1}$.
» 14. Fragment of a stem showing branch-scars.
» 15, 16. Detached leaf-sheaths, the free portions of the segments not preserved.
» 17. Leaf-sheath, showing remains of the free portions of the segments.
» 18, 19. Leaf-sheaths with the free portions of the segments. The specimen shown in fig. 19, possibly belongs to another species.
» 20. Broad-ribbed stem, with leaves.

Phyllotheca cf. **deliquescens** Goepp. sp.

Fig. 21. Detached leaf-sheath with remains of 11 free segments.
» 22—25. Fragments of leaf-bearing branches; fig. 25, $\frac{4}{1}$.
» 26. (?) Broad-ribbed stem.

Glossopteris Browniana Brgn. (pro parte).

Fig. 27—29. Fragmentary fronds; figs. 27 a—29 a, portions of the same fronds, showing venation, $\frac{3}{1}$.

Pl. 2.

Glossopteris indica SCHIMP.

Fig. 1, 2. Typical fronds; fig. 2 a, portion of the frond in fig. 2, $\frac{3}{1}$.
» 3. Fragment showing the pointed apex of the frond.
» 4. Frond with unusually wide meshes near the midrib; fig. 4 a, portion of the same frond, $\frac{3}{1}$.
» 5. Scale-frond?
» 6. Frond with unusually straight secondary veins, somewhat resembling *G. damudica*; fig. 6 a, portion of the same frond, $\frac{3}{1}$.

Pl. 3.

Glossopteris angustifolia BRGN.

Fig. 1—4. Typical fronds; fig. 2, portion of the specimen in fig. 1, showing venation, $\frac{2}{1}$.

Glossopteris damudica FEISTM.

Fig. 5—7. Fig. 5, typical frond; figs. 6, 7, portions of the same specimen, $\frac{3}{1}$.

Gangamopteris cyclopteroides FEISTM. var. **major** (FEISTM.).

Fig. 8, 9. Fig. 8, fragmentary frond, showing the protracted basal portion; fig. 9, portion of the same specimen, $\frac{3}{1}$.

Fig. 10. Scale-frond of *Glossopteris* sp.?

Coniferous branches (Conf. *Voltzia heterophylla* BRGN.).

Fig. 11—15. Badly preserved branches; figs. 12, 14, portions of the specimens shown in figs. 11, 13 respect., $\frac{3}{1}$.

Desmiophyllum sp.

Fig. 16, 17. Detached leaves(?); fig. 16 showing the parallel venation.
» 18. Problematicum.

Pl. 4.

Dadoxylon Lafoniense n. sp.

Fig. 1. Transverse section of branch.
» 2. Portion of the same section, showing the pith with mucilage-canals, $\frac{4}{1}$.
» 3. D:o. Showing inner border of wood and a mucilage-canal, $\frac{13}{1}$.

Fig. 4. D:o. Showing inner border of wood, $\frac{40}{1}$.
» 5. Tangential section, $\frac{36}{1}$.
» 6. Radial section, $\frac{60}{1}$.
» 7. Transverse section of secondary wood, showing limit between two annual rings, $\frac{40}{1}$.

Dadoxylon cf. angustum Felix.

Fig. 8. Tangential section of secondary wood, $\frac{40}{1}$.
» 9. Radial » » » » $\frac{70}{1}$.

All the specimens figured are in the Palæobotanical Department of the State Museum of Natural History, Stockholm.

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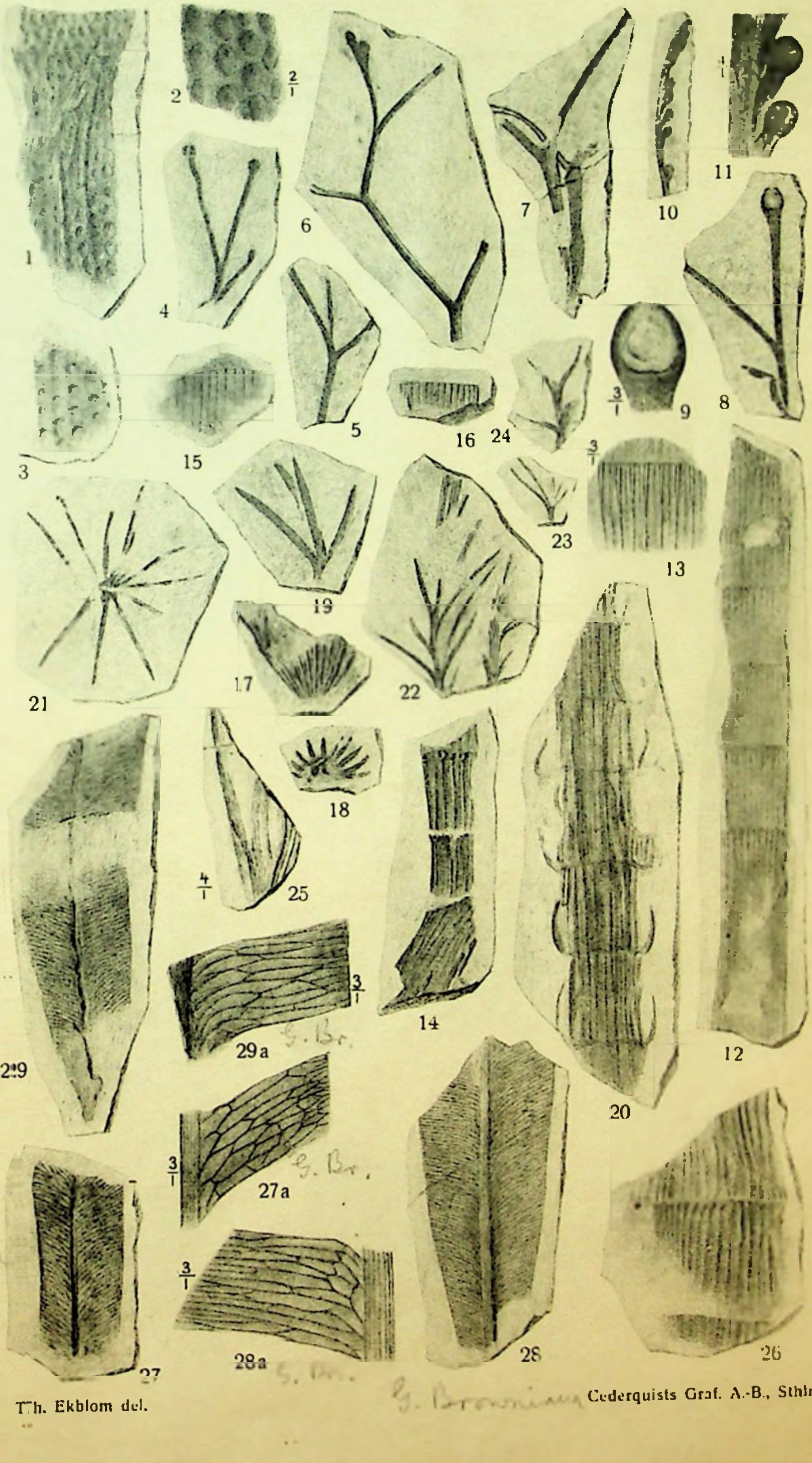
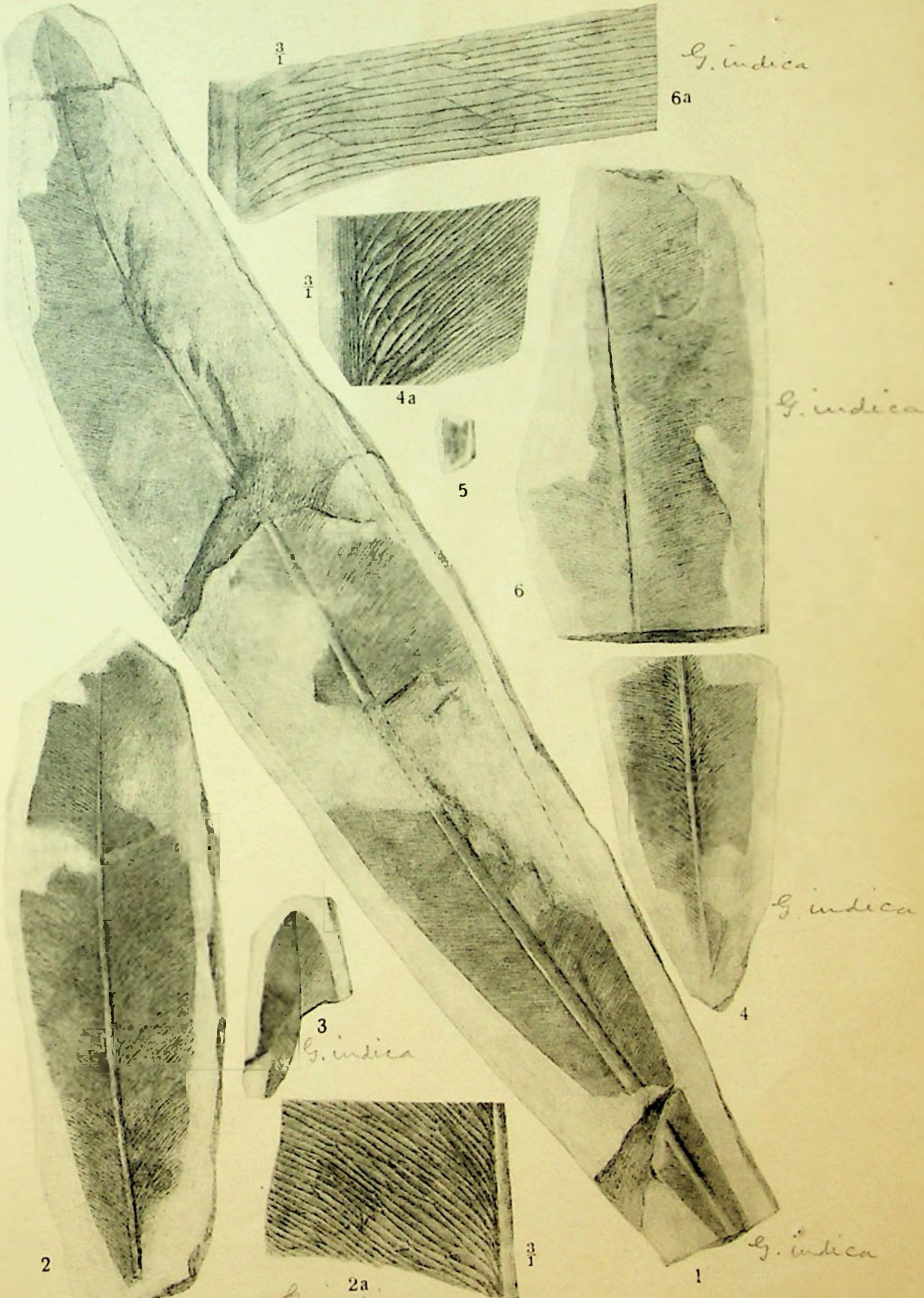


Th. Ekblom del.

G. Browniana

Cederquists Graf. A.-B., Sthlm.



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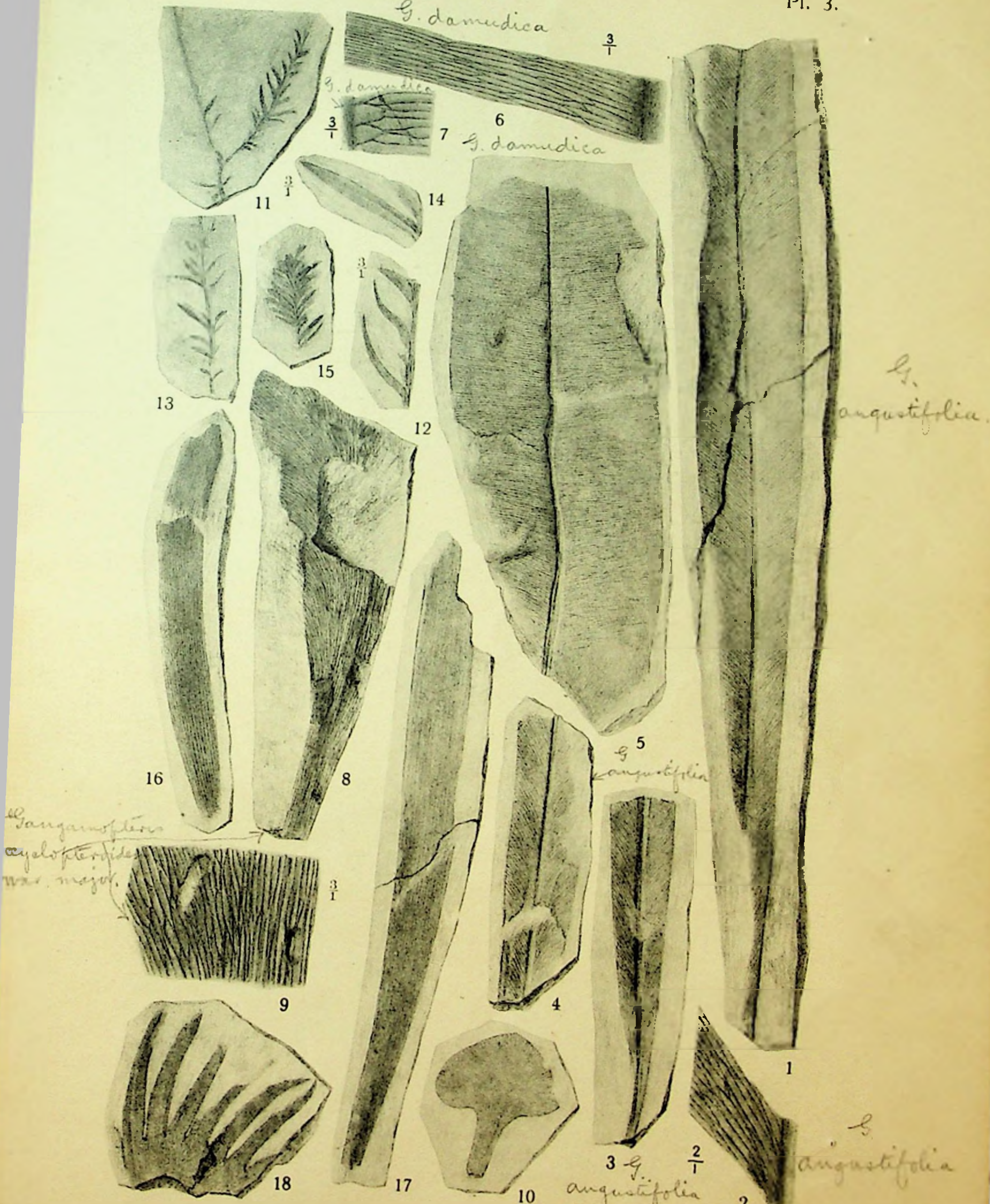

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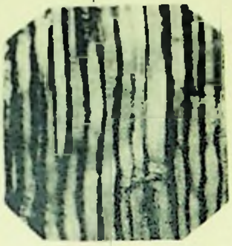

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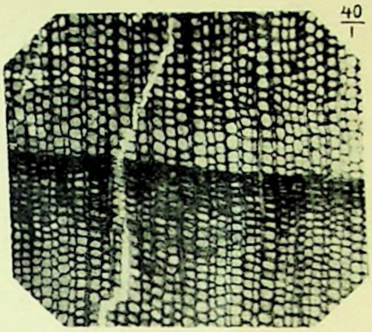

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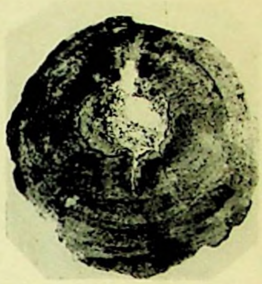

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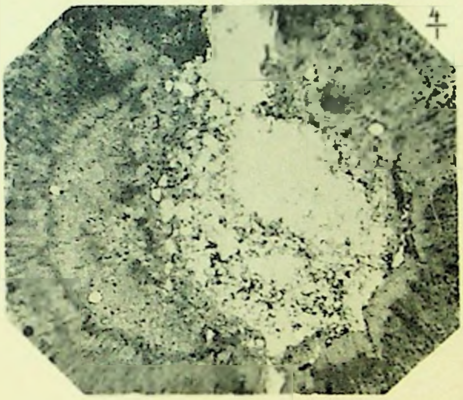

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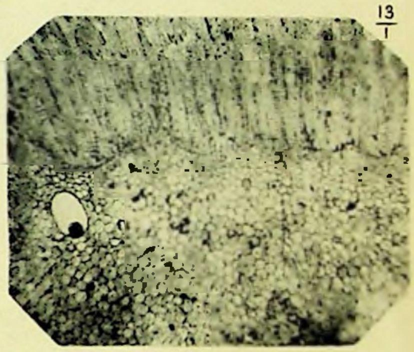

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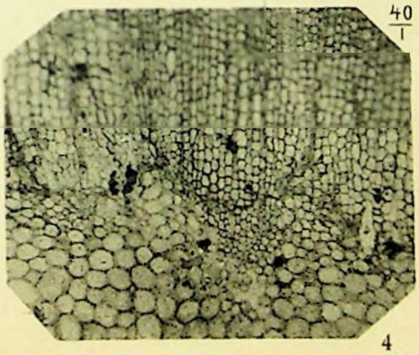

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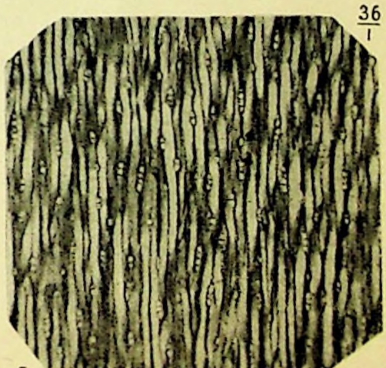

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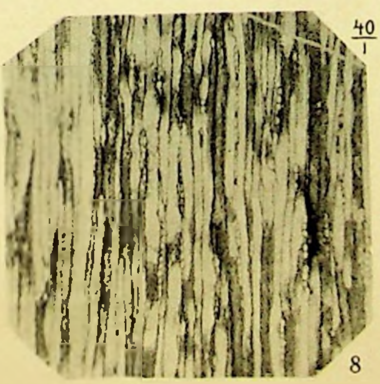

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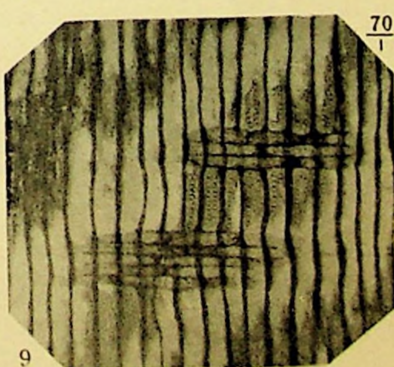

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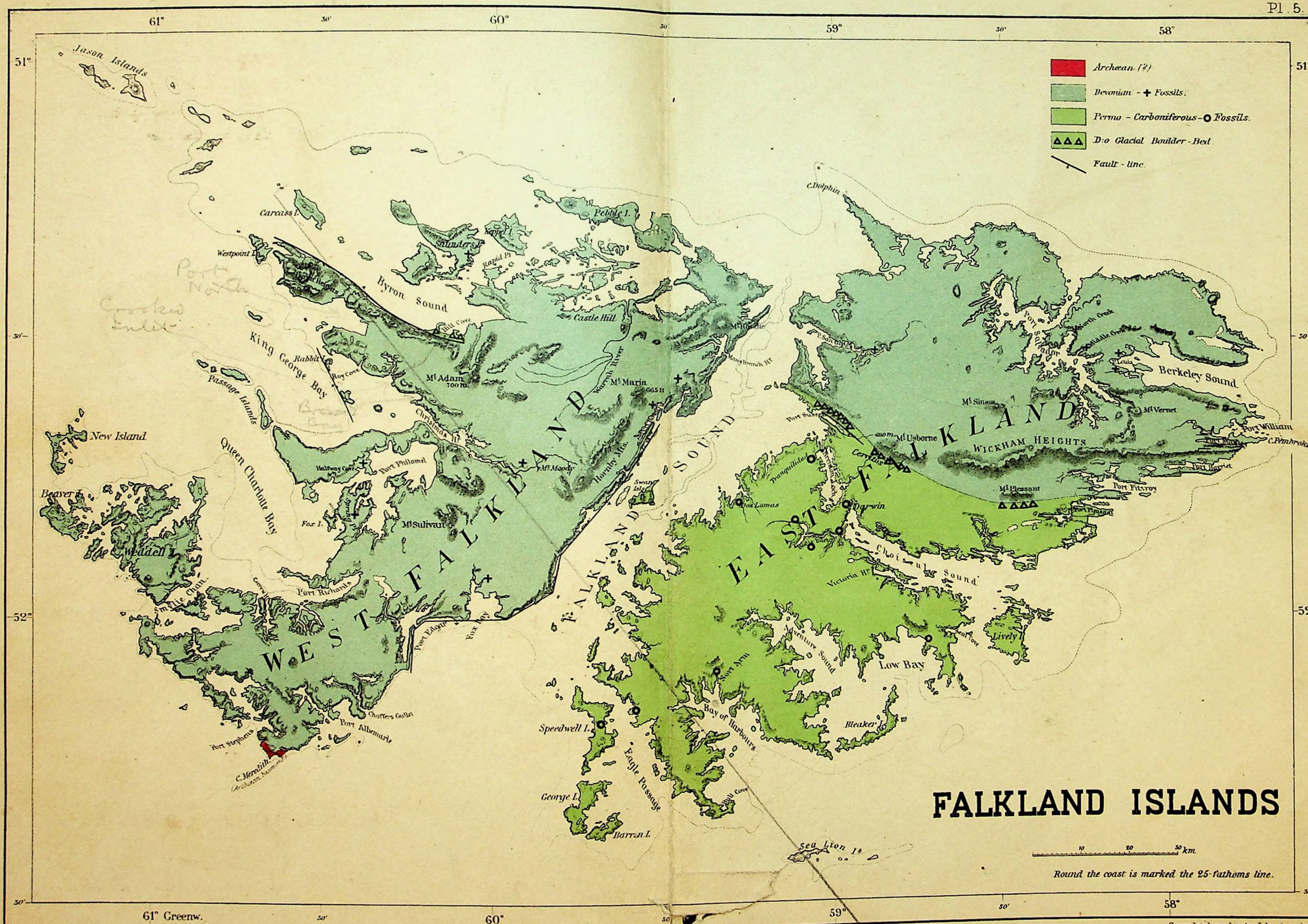

Drawn by C. J. O. Kjellström.

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