2. On the Geology of Graham Land

by

J. Gunnar Andersson.

With plates 1—6.

Introduction.

To within the last year or two of the 19th century the Antarctic region has remained for the geologist a *terra incognita.*

Some signs of volcanic activity, some specimens of non-fossiliferous rocks collected on the very few landing-places and a number of pebbles dragged off the coasts, was almost all that the explorers had brought to us from the snow-clad lands of the farthest south.

The section of Antarctica lying south of America was first discovered; and the first discovery of land in this part of the world recorded with certainty, that of the English merchant-captain WILLIAM SMITH, brought also the earliest geological notes from Antartica. On landing upon King George Island, one of the South Shetlands, he found on the beach numerous pebbles of bluish grey slate.[1]

The number of such isolated notes has gradually increased in course of time. So WEBSTER, surgeon of the »Chanticleer» in 1829 noticed »granite or syenite» on one of the islands to the north-west side of the Gerlache Channel;[2] Dumont D'Urville in 1838 found »un calcaire silicieux» and »schistes quartzeux» on Weddell Island in the South Orkney group;[3] in 1843 JAMES ROSS discovered volcanic rocks on Cockburn Island;[4] and some loose stones were collected in 1893 by Captain ROBERTSON on Dundee Island, amongst others red jasper with traces of radiolaria.[5]

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[1] Neue allgem. Geogr. Ephemeriden. Vol. VIII, 1820, P. 117. For some mineralogical notes on the South Shetlands see also the same journal Vol. IX, P. 514 and Vol. X, P. 99—102.

[2] WEBSTER. Narrative of a voyage to the Southern Atlantic Ocean. Vol. I. London 1834. P. 138.

[3] DUMONT D'URVILLE. Voyage au pôle sud. Tome II. Paris 1842. P. 316—317.

[4] ROSS. A voyage of discovery and research in the southern and antarctic regions. Vol. II. London 1847. P. 335. PRIOR. Petrografical notes on the Rock-specimens collected in Antarctic Regions during the voyage of H. M. S. Erebus and Terror. Mineralogical Magazine Vol. XII. 1900. P. 86.

[5] GEIKIE. Notes on some Specimens of Rocks from the Antarctic Regions. Proceed. Royal Soc. Edinburgh. Vol. 22. 1898. P. 66—70.

Already in the first years of geographical research in this region the grand crater island, named Deception Island, caught the attention of the explorers, and signs of activity have been noticed there by several observers, WEBSTER[1] and KENDALL[2] 1829, JOHNSON[3] 1838 and SMILEY[4] 1842. Likewise some notes on volcanic activity upon the small Bridgman Island are given by POWELL, WILKES and D'URVILLE.

During his sealing voyages with the »Jason» 1892—94 Captain LARSEN (afterwards commander of the »Antarctic» during our expedition) landed twice on Seymour Island and made discoveries there, the importance of which can hardly be overestimated: in one place he found fossil molluscs, described by SHARMAN and NEWTON as lower tertiary forms,[5] in another part of the island he discovered trunks of fossilised wood.

Up to the last year af the past century all the literature on the geology of Graham Land consisted only of some scarce and isolated observations which gave no idea of the general geological features of the region. Even the splendid discovery made by Captain LARSEN was more fitted to increase the interest in Antarctic exploration than to throw light on the geological history of Antarctica.

In 1899 the Belgian Expedition under command of A. DE GERLACHE returned from the first wintering of a scientific party in the Antarctic region. Mr. ARCTOWSKI as representant of the geological interests had used every opportunity of collecting rock-specimens, which were examined afterwards by TEALL. From this material we got to know the rough outlines of the petrology of the environments of the Gerlache Channel. From the same tract ARCTOWSKI also brought some very remarkable evidence of an earlier extension of glaciation, larger than the present.

Unfortunately the landwork of the Belgians was very limited, and from a geological point of view they had gone to the wrong side of the continent. For these reasons their geological results are not proportionate to the enthusiasm and energy developed by Mr. ARCTOWSKI. But his little work ought to be prized by all his successors as the first systematic geological survey of a part of the Antarctic lands.

The above cited notes of earlier explorers formed the premises for the geological work of the Swedish Antarctic Expedition, which entered the Graham region in January 1902, and stayed there till November 1903.

[1] WEBSTER. Narrative of a voyage to the Southern Atlantic Ocean. London 1834. Tome I. P. 144—155. Tome II. P. 300—301.

[2] KENDALL. Account of the island of Deception. Journ. Roy. Geogr. Soc. London 1831. P. 62—66.

[3] WILKES. Narrative of the Exploring Expedition. Philadelphia 1844. Vol. I. P. 148—149.

[4] WILKES. Loc. cit. Vol. I. P. 149.

[5] SHARMAN and NEWTON. Note on some fossils from Seymour Island. Trans Roy. Soc. Edinb. Vol. 37. P. 707—709. Notes on some additional fossils collected at Seymour Island. Proceed. Roy. Soc. Edinb. 1897—98. P. 58—61.

NORDENSKJÖLD had chosen his field of work largely with regard to Larsen's finds of fossils on Seymour Island. And soon he found that he was following a good track. Round his winter-station lay absolutely virginal, but easily harvested riches of fossils, and as the researches expanded, the multitude of finds increased.

Also in the mainland region, composed chiefly of plutonic rocks, our expedition made a discovery of the highest importance. While examining the granites and diorites of these tracts NORDENSKJÖLD found them to be most strikingly similar to igneous rocks characteristic for the American cordilleras, eruptives, that he had studied himself both in the far north, in Alaska, and in the Chilean-Fuegian Andes. This confirmation of the consanguinity of American and Antarctic eruptives forms one of the most striking arguments for the »Antarctic Andes», the tectonic connection of Graham Land with South America.

After our return to Sweden NORDENSKJÖLD entrusted me with the preparation and distribution of our palæontological material among specialists and with the publication, as a guide for our palæontologist-collaborators, of a preliminary report of our geological field-work. For the preparation of this paper he has not only given me a free hand but has moreover assisted me in a most obliging manner with every information wanted.

On presenting here to our colleagues the principal results of the geological explorations of our expedition, I am but fulfilling a simple duty if I emphasize the fact that only a very limited part is to be ascribed to my credit.

As can be seen from our narratives I joined the »Antarctic» in the Falkland Islands after the return of the ship from the first summer's voyage southwards, during which the winter-station on Snow-Hill had been established. Thus NORDENSKJÖLD began his geological survey of Graham Land in January 1902, while I did not enter this region until November of the same year, and as for the most interesting part of our field of work, the Snow Hill-Seymour region, I stayed there only the last three weeks before we were relieved. Thus in many of the most important localities I had only to assist NORDENSKJÖLD in a survey that he had begun long before my arrival, in other cases vast areas, as the south-west part of Crown-Prince Gustav Channel and the region SW. of Snow Hill were surveyed by NORDENSKJÖLD alone. Only some few localities are worked out by me alone; on Snow Hill and Seymour Island I only continued work that had already been begun.

The confiding to me for publication of a geological material that may be considered as of extraordinary present interest, is a new manifestation on the part of NORDENSKJÖLD of a friendship that has remained unaltered under varied conditions.

Whenever I come to deal with the geology of the distant southern lands I must call to mind the happy days on Seymour Island in October 1903, a pleasant time after severe hardships, when NORDENSKJÖLD conducted me in his kind way to the spots of his best fossil finds, and the collecting of fossils was hurried on in order to harvest as much as possible ere the expected relief-ship arrived.

This small paper is written primarily as a guide for our palæontologist-collaborators. On the other hand I have received much valuable information from three of them, Prof. W. KILIAN in Grenoble, Prof. A. G. NATHORST in Stockholm and Dr. O. WILCKENS, Freiburg in Br. To these three eminent scientists I herewith offer my best thanks for their important assistance.

Geological regions.

(Correlation of geologic structure and land-forms.)

The area af continental land and islands given on plate 4 is rather extensive. Only on some few landing-places scattered over these vast coastlines has a geologist had the opportunity of using his hammer upon the Antarctic rock, and only some two or three places (Snow Hill-Seymour I, Hope Bay and part of South Orkneys) have been the objects of a systematic geological survey. In fact, most of these islands are unknown from a geological point of view.

Sketching the general geologic outlines as I have essayed on plates 4 and 5, has been possible only by using to a very large extent the method of extrapolation. Experience has taught me that here, in all the places surveyed, a special type of geological structure is always connected with a characteristic and easily recognized land-form. The inland-ice, it is true, has hidden most of the land-surface from the observer, but in the external forms of nunataks and coastal outcrops, even in the shape of the inland-ice itself the principal types of geological structure can be traced with some probability already from a distance.

I will give in the following brief characteristics of the principal geological types distinguished on plates 4 and 5 and of the land-forms connected with them.

Region of folding and of Andine eruptives. This region, embracing the incomparably larger part of all the land area here in question, is composed — as far as is hitherto known — of displaced sediments, in some places evidently folded, but also to a very great extent of a series of plutonic rocks which, according to NORDENSKJÖLD, are closely related to a peculiar type of eruptives characteristic of the American cordilleras throughout their length.

Fig. 1 and plate 1 A illustrate the land-forms predominating in this region. It is a highly mountainous landscape with narrow peaks and ragged crests. The ice-cover is generally incomplete, leaving bare many lofty mountains. Only on the more gentle slopes does it form what can be called »inland-ice». The large valleys are filled with mighty glacier streams, typical »valley glaciers». In some places where the landscape is ice covered all over, the ice-cap in its swarms of crevices and its big hummocks still reveals the ruggedness of the hidden ground.

Region of Ross Island formation. Next to the mountain region follow, on the east coast of the mainland, some broad promontories and large islands (Ross I., Vega I.) of a very characteristic shape. This is a typical plateau-land with the horizontal surface covered by a slightly vaulted inland-ice and the coast-line formed by vertical cliffs, the dark colour of which strongly contrasts with the dazzling whiteness of the frozen sea below and the ice-cap above. (Pl. 1 B and Fig. 5). These splendid natural sections clearly demonstrate the composition of the table-land: a coarse basaltic tuff, only sparely intercalated with lava-flows or traversed by dikes of the same material. The big centre of this region is Ross Island, rising in the interior in a gigantic, flat, conical hill called

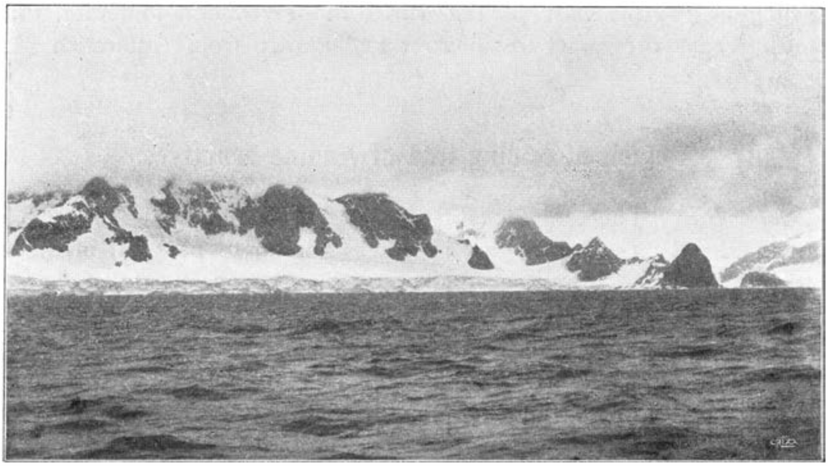

Fig. 1. NW.-coast of the Mainland. C. Anna and environments. Gerlache Channel.

Mount Haddington, the height of which has been estimated at 2,000 m. (?). Possibly the unbroken ice-cap of Mount Haddington hides a large volcano. — Other smaller centres of eruption are Paulet Island and (according to the observations of Dr. Nordenskjöld) Mount Christensen upon Robertson Island.

Region of Snow-Hill — Seymour I. series. (Pl. 2). Seymour Island, a small part of Snow-Hill Island, and a landstrip at Cape Hamilton on Ross Island, are the only land-areas of considerable extent that are free from inland-ice. The absence of ice-cover at these places may be due partly to some slight differences in altitude, exposure and climate to the adjacent and almost completely ice-capped lands and islands, but apparently the principal reason for the exceptional bareness of the places mentioned is the peculiar composition of their ground. In striking contrast to the neighbouring high tuff plateaus, Seymour Island and the two other iceless areas are built up of soft sandstones, which seem to be unfavourable for the development of glaciation.[1]

Owing to the softness of the material all these places are comparatively low (Seymour Island less than 200 meters) and deeply dissected by the action of running water. In fact, these are the only spots in all this part of Antarctica where in summertime snow-melting takes place on a large scale.

Cockburn Island. (Pl. 1 l). This small but remarkable island, situated in the eastern entrance of Admiralty Sound, ought to be mentioned as a special type.

In its contours, with a horizontal plateau and steep sides, it much resembles the smaller islands of the tuff region, and in fact its upper part is built up of the basaltic tuff and of lava beds, but the lower 160 meters of the island consist of soft cretaceous sandstone of the Snow Hill series, and on the tuff plateau there remains a small remnant of a sediment quite unique in this part of the world, the *Pecten*-conglomerate, that is the most recent preglacial fossiliferous bed known from Antarctica.

Region of folding and of Andine eruptives.

Hope Bay. The only locality within this region that has been surveyed in detail is a place where I was forced to pass an involuntary wintering with two others, a small bay on the west side of Antarctic Sound, named *Hope Bay* by Duse, my companion in misfortune. On the basis of my communications the geology of this place has been already in part described by NORDENSKJÖLD in the preceding number of this Bulletin, and it will be useful for the understanding of the following notes to consult the small geologic sketch-map given in that paper.[2] The profiles fig. 2 will also help to illustrate my description.

On the south-eastern side of the bay there is a comparatively low (mostly under 100 m.), hilly, iceless landstrip built up of indistinctly stratified clastic rocks, grey or brown, which may be termed greywacke or

[1] An analogous case can be mentioned from the Arctic regions: King Charles Land east of Spitzbergen, built up largely of soft, easily decayed mesozoic sediments, is almost entirely free from glaciation, while on the other hand Giles Land and the North East Land with a ground of old hard plutonic and metamorphic rocks are covered by inland-ice of purely Antarctic type. The slight difference in latitude between King Charles Land and the last-mentioned islands can by no means justify the obvious contrast in glaciation.

Spitzbergen itself is to a large extent covered with inland-ice and its coast-valleys are filled with big glacier streams. But some valleys, the ground of which is soft, easily desintegrated slate or sandstone, are curiously lacking in glaciers. (See also CHYDENIUS, Svenska expeditionen till Spetsbergen år 1861. Stockholm 1865. P. 372—373.) I will deal more in detail with this problem in a later article.

[2] O. NORDENSKJÖLD. Petrografische Untersuchungen aus dem Westantarktischen Gebiete. Bull. Geol. Inst. Upsala Vol. VI, Part. 2. P. 234—246.

sparagmite. Round our winterhut (Seal Point = Robbenspitze in the German text of the map) a greywacke without any sign of stratification predominates. In this seemingly massive rock there occur, partly as normal intercalations, partly as angular masses, a dark slate, and in alternation with this slate a fine-grained, light-grey sandstone showing current-bedding. Near the hut I noticed in the last-mentioned rock some few very indistinct plant fragments.

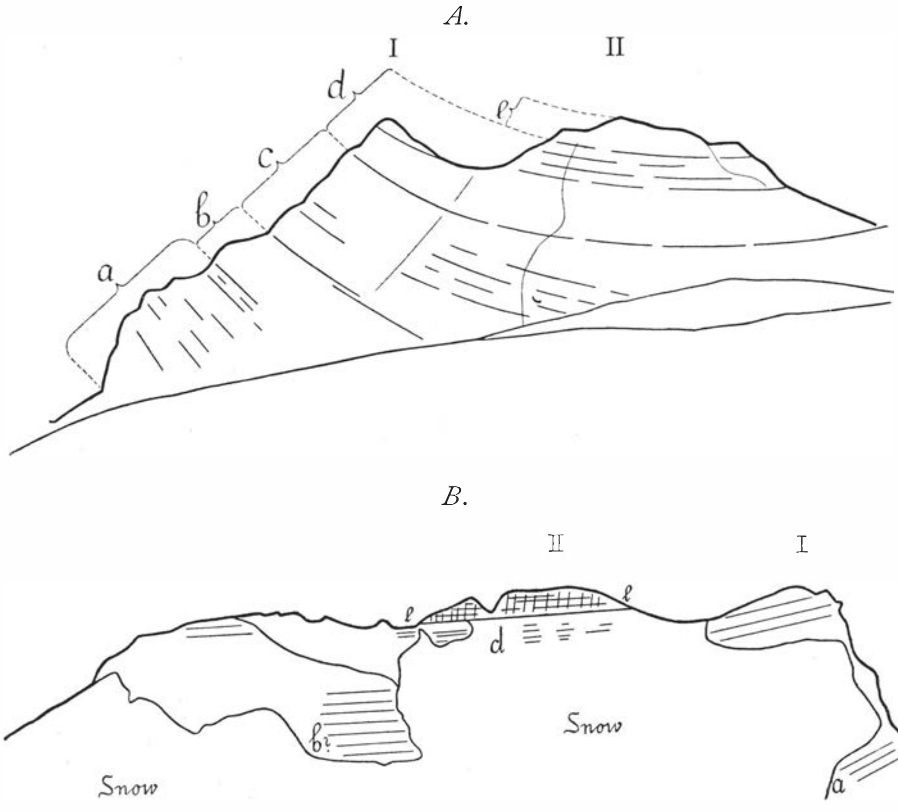

Fig. 2. *Mount Flora, Hope Bay.* A from WSW. B from NE. (B is nearly the same aspect at Pl. 1 A). a. Dark slate with Jurassic flora. b—e. Multicoloured tuff-beds.

The dip of the strata varies in different parts of the low, hilly land. Near Mount Flora the brown sparagmite dips underneath the mountain, and the foundation of Mount Flora itself (underneath *a* in Fig. 2 A) is formed by a rock of the same series.

The basal bed of series *a*, Fig. 2, is a coarse, unstratified conglomerate with pebbles of one meter and more in diameter. To judge from the macroscopical examination, the pebbles seem to be derived exclusively from the underlying greywacke-group, no block of the diorite-gabbro series described in the following has been observed in this conglomerate, a fact that may be of some importance for the discussion of the age of these eruptives.

The upper and head part of group *a* in Mount Flora is a dark, slaty, partly laminated rock abounding in well preserved plant fossils. In close connection with this slate is a dark tuff or tuffoid conglomerate with pieces of carbonized wood.

The material of plant fossils from this slate brought home by us has been examined by Prof. A. G. NATHORST, who has published a preliminary report on this fossil Antarctic flora.[1] The note by Prof. NATHORST is given here in translation:

»The *Equsietaceæ* are represented by a species closely related to *Equisetum (Equsietites) columnare* Brongn., of which also the diaphragmatic discs have been collected.

The *Hydropterids* are represented by a species of *Sagenopteris* closely related to or possibly identical with *S. Phillipsi* Brongn. The *ferns* are very abundant and belong to a multitude of genera: of the genus *Cladophlebis* the type *C. denticulata-nebbensis-whitbyensis* is represented by several species, which are rather difficult to determine; *Cladophlebis* (*Dicksonia*) *lobifolia* Phill. (sp.) seems to be identical with a species of this flora; of *Todites Williamsoni* Brongn. (sp.) both sterile and fertile fronds have been found. The genus *Scleropteris* is rich in species, and also *Stachypteris* seems to be represented. Amongst other ferns ought to be mentioned *Thinnfeldia indica* Feistm. (*salicifolia* Oldh. sp.) and a form of *Pachypteris*. The *Sphenopterideans* are represented by the types of *Sph. hymenophylloides* and *Sph. Williamsoni*, and amongst the ferns of this group ought to be mentioned a species, rather rare, it is true, but interesting because of the likeness of its small fronds to those of *Trichomanes speciosum* Willd. of the recent flora. In addition to these forms there are several others, but those mentioned above are the most important.

Amongst the *Cycadophytes*, the genus *Otozamites* is represented by several species, the leaves of which are in general rather small, as is the case with most species of this genus in the upper Gondwana flora of India (Jabalpur, Kach). *Williamsonia pecten* Phill. (sp.) occurs here, and also a small fruit, the size of which is the same as that of *W. Forchhammeri* Nath. from Bornholm. Moreover there occur large leaves resembling those of *Nilssonia tenuinervis* Nath., but it should be stated that this type is hardly distinguishable from certain species of *Oleandridium*, when, as is here the case, the nervation is somewhat obliterated. Of the genus *Pterophyllum* we have to note a splendid specimen of the type of *Pt. Morrisianum* Oldh. of India; some fragments indicate one or two other species of this genus.

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[1] NATHORST. Sur la flore fossile des régions antarctiques. Comptes rendus. June 6, 1904.

Amongst the fragments of *conifers* the most interesting consist of isolated cone-scales of *Araucarites cutchensis* Feistm., thus belonging to another type than the *Araucarias* of the recent South-American flora. Foliferous branches of different types of conifers are common: some are similar to »*Taxites*» *tenerrimus* Feistm. and »*Cheirolepis*» *gracilis* of the same author, a third type approaches the *Brachyphyllum mamillare* Feistm. (non Lindley), others again remind one of *Palissya* and *Elatides*.

Considered as a whole, this Jurassic flora resembles on the one hand the European Jurassic flora, on the other the upper Gondwana flora of India (Jabalpur, Kach). From a climatological point of view there can be traced no difference between the floras mentioned, and in this respect the collection from the Antarctic region might have been gathered on the coast of Yorkshire, as the absence of big-sized *Otozamites* may be considered as accidental. In its abundance of species the flora from Hope Bay far surpasses all jurassic floras hitherto known from South America.»

Of very great importance in the report of Prof. NATHORST is the fact that there is in this flora also a representative of the waterferns (*Sagenopteris*) proving that the fossiliferous slate was probably deposited in a freshwater basin. The only animal fossils occurring together with the plants are some very badly preserved bivalves, which have not yet been examined by a specialist, but seem to be a freshwater form. The lacustrine deposit as well as the occurrence of large undamaged specimens of delicate plants indicate that the flora has been preserved near its habitat.

The upper part of Mount Flora consists of multicoloured, mostly light-grey to white volcanic tuffs (*b*—*e*, Fig. 2) the thickness of which may be estimated at considerably more than 200 meters. Seen from some distance all these tuffs appear distinctly bedded, as shown by fig. 2 and some of them also in hand specimens look neatly stratified. The lowest part of the series, *b* of the figure, is light-grey in colour, *c* is darker, *d* shows a distinct alternation of dark and lightcoloured beds, *e* is a dark rock forming the very crest of the mountain and exhibiting, especially on the northern side (fig. 2 B), a very marked vertical jointing.

Macroscopically all these rocks look very strange and problematic; the microscopical examination made by NORDENSKJÖLD has proved that some of them at least are tuffs derived from acid volcanic rocks. Fossils were never noticed in these tuffs.

The southernmost and supramarine part of the Hope Bay valley is filled by a beautiful glacier, as clearly shown in the map given in Nordenskjöld's paper. On the western side of the glacier rises a steep mountain wall that feeds two surface moraines confluent in the lower part of the glacier. These moraines consist chiefly of a light grey, granitoid acid eruptive that forms the main constitutent of the mountain above.

To judge by the microscopical examination made by NORDENSKJÖLD this rock offers much interest. It is a quartz-diorite characterized by the beautiful zonal structure and marked idiomorphismus of the plagioclase, a rock in every respect similar to the quartz-diorite of the American cordilleras.

In the above-mentioned mountain wall there occur also dikes of augite-porphyrite, the biggest of the dikes having a breadth of three meters.

Out of the southeastern part of the valley glacier rises a solitary high nunatak. The surface moraine emanating from here consists partly of the quartz-diorite. An important constitutent of the moraine is also gabbro, showing in many blocks transitions to the quartz-diorite. Apparently the last mentioned rock together with the gabbro and all the transitional stages between these two extremes, are only more or less acid diffentiations from a common magma. Because of the relationship to magmatic rocks of the American cordilleras this diorite-gabbro series is named in this paper Andine eruptives.

Also some blocks of the augite-porphyrite were noticed in this eastern moraine, indicating that even in the nunatak which feeds this moraine dikes of the porphyrite traverse the diorite-gabbro series.

As shown by the description given above there is a great variety of rocks round Hope Bay: Andine eruptives in the southern and southwestern nunataks, and along the southeast coast and in Mount Flora a series of sediments, greywacke at the base, a dark slate with Jurassic plant-fossils in the middle, and some hundred meters of volcanic tuffs at the top. From the gentle syncline which this series forms in Mount Flora we learn that the region has undergone mountain-folding in postjurassic times.

The age of the diorite-gabbro series is not fixed. As fragments and pebbles of this series are never noticed in the sparagmites and conglomerates we may be right in supposing that the eruptives are postjurassic, and in fact it is very tempting to consider them as simultaneous with the mountain-folding. But as the igneous rocks have been nowhere observed to intrude in the sediment series the question of their age must be left unsettled.

NW-coast of Graham Land from Mount Bransfield to Cape Murray (Pl. 5). This coast, partly unknown up to the time of our expedition was surveyed by the »Antarctic» Nov. 26—Dec. 5 1902. At every landing I collected specimens of all rocks that were exposed in icefree islets and shore-nunataks. Sediments were in this region noticed only in two or three places, but the variety of eruptives was quite surprising. Almost every outcrop was lithologically different from surrounding places, even in the case where the distance between them was only some few hundred meters. It seemed to me rather aimless to try on the spot to make provisional determinations of this multitude of igneous rocks, as I could collect splendid specimens of them for definite microscopical examination. All my field-notes and sketches refer to these specimens. As the whole of this material went down with the »Antarctic» my notes are now almost useless, and the scattered indications I can give here on the geology of this region will be of very little scientific value.

On plate 5 I have marked with the letter S the only two places upon this coast where I noticed sedimentary rocks.

The one is a group of small islets SSW of C. Roquemaurel, built up of foliated quartzite-like beds dipping 30° NW. Cape Roquemaurel itself consists of eruptive material probably belonging to the Andine diorite-gabbro series.

The other locality for sedimentary rocks is a place named C. Kjellman (not noted on the map) and situated halfway between C. Roquemaurel and C. Gunnar. The alternating dark and lightcoloured beds of this spot run vertically from SW—NE, that is, parallel to the coast.

No indications of fossils were noticed in these two places.

In three localities, C. Neumayer on Trinity Island, Challenger Island on the east side of C. Murray and C. Neyt on Liège Island I found a rock that I have jotted down in my note-book as »grey granite» and »lightcoloured diorite» and which is very probably the acid link of the Andine diorite-gabbro series.

At the northern slope of Mount Bransfield we made a very hurried landing. During my flying visit I fancy I noticed some quartz-diorite and a quartzite-like stratified rock very near to each other as constitutents of the solid ground.

Besides these localities there remain many of our landing-places as to the lithological character of which I cannot give any indications.

Still, one of them must be briefly mentioned, viz. a point on the mainland coast between Cape Karl Andreas and C. Gunnar. Here a shore-nunatak exhibits a coarse conglomerate with boulders of up to 2 meters in diameter. (Pl. 3). In general the mass is quite unstratified and really much like a bottom-moraine, though the rock is evidently old and seems to have taken part in the mountain-folding. Only in one spot, where the conglomerate is less coarse, does it show slight indications of bedding. The material of the pebbles is very varied, beautiful porphyries being very common amongst many other kinds of rock.

Gerlache Channel. This region, forming the continuation to the southwest of the coastline visited by us, was surveyed by the Belgian Antarctic Expedition in 1898, and Mr. Arctowski of this expedition has published some preliminary notes on their geological finds.[1]

Only in one place, Wilhelmina Bay, did he find sedimentary rocks, schists, in which no fossils were noticed.

At three landing-places, Flandres Bay, Bank Island and Wilhelmina Bay, granite formed the ground; Cape Anna was found to consist of serpentine, and in two landings in Errera Channel porphyrite was met with.

[1] Arctowski. Géographie physique de la région antarctique. Bull. Soc. belge de Géographie 1900.

The continuation of the geological description given by Mr. ARCTOWSKI is of such interest that it must be cited here verbally:

»Toute la partie extérieure au contraire, c'est-à-dire l'archipel de Palmer, les îles de la baie de Hugues et l'extrémité Nord des terres de Graham, où nous avons également fait un débarquement — (non loin du cap Renard), est formée principalement de diorite, présentant des compositions variées, de sortes qu'en certains endroits, ce sont des diorites quartziques. Au X:e débarquement, nous avons trouvé du gabbro, formant l'un des nunataks. M. Teall, à l'obligeance duquel je dois ces premières indentifications petrographiques des roches trouvées en place, m'écrit que nous avons decouvert une bonne série de roches plutoniques, rangées au point de vue de leur composition depuis les peridotites (presentées par la serpentine) jusqu'aux plus acides aplites, et comprenant des gabbros, des diorites et des granites.»

These notes by Mr. ARCTOWSKI form a striking parallel to the conditions found by me farther to the northeast. In both regions sediments are very scarce and the ground consists chiefly of plutonic rocks. Moreover it is highly probable that the aplite-granite-diorite-gabbro-peridotite series mentioned by Mr. TEALL will be found to be identical with the quartz-diorite-gabbro series of Hope Bay, only that the amplitude of acidity is somewhat larger in the more extensive material examined by Mr. TEALL. Thus the Andine eruptives seem to be the principal constitutent of the west coast of Graham Land at least from Antarctic Sound to the southwest end of Gerlache Channel.

Joinville Island. We did not land upon this island, but to judge from the mountain forms visible from Hope Bay I fancy that at least the part of the island nearest to Antarctic Sound ought to be included in the region of mountain-folding and of Andine eruptives.

Borchgrevink Nunatak. At the farthest south (about 66° S. L.) of his long sledge-journey NORDENSKJÖLD reached a nunatak, named by him as above, that he found to consist of quartzporphyry. This is actually the only point on the whole east coast of the mainland south of Duse Bay the lithological character of which is known.

Besides the above mentioned observations on solid rock, some further evidence on the geological structure of the mainland can be gained from loose blocks that have been found on the eastern islands, partly in tertiary conglomerates of Seymour and Cockburn Islands, partly in a morainelike mass underneath the tuff-formation at Cape Hamilton on Ross Island and partly spread over the recent land surface. Evidently these pebbles have been transported in Tertiary and Quarternary times from the mountain region to their present places.

Dr. NORDENSKJÖLD has collected a considerable material of these blocks and given a preliminary report on them.[1] He has found most abundantly granites, quartzdiorites, porphyries and porphyrites, some of them showing structural relationship to rocks that he collected during his earlier expedition to Patagonia.

Phyllites of varied type are common amongst the pebbles, but gneiss is comparatively scarce; however, one of the most remarkable of all blocks, a giant, 6—7 meters in diameter and lying on the highest plateau of Seymour Island, consists of this last-mentioned kind of rock.

South Shetland Islands. This far extended island range running parallel to the main land (Pl. 4) is almost unknown from a geological point of view.

When in 1820 WILLIAM SMITH, who is considered the first discoverer of true Antarctic land, paid a visit to the northeastern part of King George Island he found a bluish grey slate to be the prevalent rock amongst the pebbles on the beach.[2]

The first landing from the »Antarctic» was made in Harmony Cove upon Nelson Island, and some stone specimens from here are fortunately saved and show that the rock here is a greenish porphyrite.

The following summer (Nov. 1902) we landed on a small rock W. of Snow Island and on the east point of Livingston Island. In both places I found a darkcoloured eruptive but, the specimens being lost, I cannot say anything as to its nature.

It is only the parallelism of the island range to the mainland and the resemblance of the ragged mountains in both regions that has led me to include the South Shetlands in the region here in question.

South Orkney Islands. The first note on the geology of this island group we owe to DUMONT D'URVILLE, who in 1838 landed upon the small Weddell Island and reported from there »un calcaire silicieux» and »schistes quartzeux» »dont l'inclinaison des couches était d'environ 80° du NNO au SSE.»[3]

The Scottish Antarctic Expedition under the leadership af W. C. BRUCE, which wintered in 1903 at Laurie Island collected very important geological material, that has been described by J. H. H. PIRIE, geologist of the expedition.[4]

On Coronation Island was found a coarse conglomerate »dipping at about 30° in a north-easterly direction».

The principal rock of Laurie Island and the small Saddle Island is

[1] This Bulletin. Vol VI, Part 2, P. 240—241.

[2] Cf. P. 19.

[3] DUMONT D'URVILLE. Loc. cit. Tome II. P. 316—317.

[4] PIRIE. On the Graptolite-bearing Rocks of the South Orkneys. Proc. Royal Soc. Edinburgh. Vol. XXV. Part. VI. 1905. P. 463—470.

greywacke, but on the first-mentioned island also shaly rocks occur. »In one situation only were regular beds of shale found, alternating with layers of greywacke. Commonly the shale occurs simply as patches in the greywacke, seemingly irregularly mixed up with it, or with ill-defined borders shading off into the greywacke.

Near the eastern end of Laurie Island, on a small islet called Graptolite Island, some fossils were found in the shale. One is a graptolite, *Pleurograptus?*. the other fragments are considered to be parts of a Phyllocarid crustacean, probably nearly allied to *Discinocaris*. According to the evidence afforded by these fossils the age of the shale is youngest lower, or oldest upper Silurian.

»The most common strike of the rocks is north-westerly, varying from NNW to WNW, the dip being in most cases at a high angle north-easterly or south-westerly. One definite anticlinal axis was observed running in a NNW and SSE direction.»

»We have here to deal with a series of plications whose axes run in a general NW and SE direction—probably rather nearer NNW and SSE».

In fact there is very little in the above description that speaks for the connection of the South Orkneys with the region of mountain-folding of Graham Land.

The direction of the folds NW—SE does not point to such an affinity. The South Orkneys, as far as hitherto known, consist merely of folded sedimentary beds; in the mainland, on the other hand, the sediments seem to form only small and scattered patches in a vast area of igneous rocks. And finally the fossiliferous beds of the South Orkneys are much older (Silurian) than the only strata of fixed age (Jura) in the folded region of the mainland.

But still I think that not one of these facts positively contradicts a connection that, from a more general point of view, seems highly probable.

To their position and outlines the South Orkneys can be very well supposed to form the continuation eastwards of the South Shetland island range, and already in the eastern part of the South Shetland group we may be able to trace a bending of the axis of the island range to ESE as in the South Orkneys. In fact, Elephant and Clarence islands with adjacent small islets form a group of striking likeness to the South Orkneys. (Pl. 4). Unfortunately the geology of the Elephant-Clarence group is completely unknown, but I fancy that, once surveyed, these islands will be found to form a connecting link between the westerly South Shetland Islands and the South Orkneys.

The great difference in age between the shales of Graptolite Island and the beds of Hope Bay is no argument against such a connection. It may be considered merely as an indication that this folding range, as many others, includes strata of very different age, and its offers wide possibilities to future research for fossiliferous beds both in the island range and on the mainland.

Snow Hill-Seymour Island series.

Topography of Snow Hill and Seymour Islands.

Snow Hill Island is for the most part covered with inland ice, which according to NORDENSKJÖLD shows a hilly surface with deep depressions that evidently follow the valleys of the hidden ground. The highest point measured on the inland ice is 300 meters above the sea-level.

Through the ice-sheet range three groups of nunataks, and in the NE. the island forms a narrow projection of about six kilometers in length, that is completely free from ice-cover.

This icefree peninsula is highest along the northwest coast, which forms steep, lofty cliffs. Eastwards and towards Seymour Island Sound the land slopes gradually and here the coastal cliffs are rather low.

In the form of a hard ridge there runs through the peninsula a basalt-dike that rises over the surrounding soft sediments and forms, near locality 3 (Pl. 6), »The basalt-top», the highest summit of the iceless peninsula.

In many places near the coast, thus south of the winter station and on the eastern side of the peninsula, streamlets of melted snow have cut deep valleys in the soft Cretaceous beds.

Seymour Island. Across this island runs a transverse valley from Penguin Bay to an unnamed bay on the opposite coast E. of Cape Bodman. The bottom of this valley is not much above the level of the sea; a slight submergence of the region would here divide Seymour Island into a large southwestern and a much smaller northeastern part. Thus this transverse valley may be considered as homologous to the shallow sound between Snow Hill and Seymour Island.

The part of Seymour Island southwest of the valley referred to above is mostly low and deeply dissected by running water. In some places the appearance of the land is rather peculiar, with many small hills between the erosive lines.

A basalt-dike (possibly the continuation of the Snow Hill dike) runs through this part of the island, forming at least one pronounced top, lying not far from locality 9.

Low perpendicular sea-cliffs border the land in all places where the valleys of the small rivers do not slope gradually to the sea.

The smaller northeastern part of Seymour Island presents a somewhat different appearance. Most of it forms a high plateau (180 m., the highest part of Seymour Island), the surface of which is completely even without any sign of river-cutting. East of this plateau up to the northeastern part of the island runs a strip of deeply dissected land.

The two parts of Seymour Island exhibit a somewhat different geological structure: the larger southwestern part is built up of Senonian (older Seymour I.) beds which are only slightly younger than the Snow Hill beds; the northeastern part of Seymour Island, on the other hand, consists of the »Younger Seymour I.-beds» (upper Oligocene or lower Miocene).[1]

Thus from a stratigraphical point of view we have to divide the Snow Hill-Seymour region into two very unequal parts, the one consisting of Snow Hill and the larger part of Seymour Island (Upper Cretaceous), the other being what remains of Seymour Island (Tertiary).

Cretaceous strata.[2]

(Snow Hill beds and older Seymour I. beds.)

Snow Hill Island is built up chiefly of fine-grained, soft sandstone beds that in many places have the consistence of loose sand. In these soft and easily desintegrated beds lie in some places (loc. 2 and 3) concretions of harder sandstone more or less rich in glauconite. Fresh cuts in these concretions are grey to brownish grey in colour, but weathered surfaces are deep reddish brown to liver-coloured, with a very peculiar polished appearance. The smaller of these nodules are evidently formed round some organic body, since a fossil shell or an ammonite is found in almost every one of them. The bigger lumps of this hard sandstone are often quite crowded with fossils of various kind, ammonites, shells, corals and fish scales.

Also the Cretaceous beds on Seymour Island consist of fine-grained soft sandstone and sand. Nodules of the characteristic liver-coloured type, so common on Snow Hill, are never (or only very rarely) met with on Seymour Island.

The chief constitutent of the Cretaceous fauna (considered as a whole) is *ammonites*, abounding both in specimens and species. Next to them in

[1] Pl. 6 is erroneous as to the limit between the two formations. As stated more fully in the description to the plates, the line of demarcation ought to be drawn close to the west of locality 10. Even with this correction the geological boundary line does not strictly coincide with the transverse valley, as locality 10 (Tertiary strata) lies close to the southwest of the valley.

[2] A note on Cretaceous fossils from Snow Hill Island was published during our stay in the South:

STUART WELLER. The Stokes collection of Antarctic fossils. Journal of Geology. Vol. XI. N:o 4. 1903. P. 413—419.

Stokes is an American artist who joined the "Antarctic" on its first voyage to the Graham region, but left the expedition in Port Stanley in March 1902.

He collected some fossil specimens on Snow Hill Island during two days in Febr. 1902 when the wintering party was landed. Though he had agreed not to communicate anything of the scientific results of the expedition, we found on our return that a description of his small fossil collection had been published.

Evidently he did not give the eminent palæontologist who wrote the description much information about the conditions under which the fossils were collected, as our expedition is called in Mr. Weller's paper "Belgian Antarctic Expedition".

importance come the *bivalves* and *gastropoda; fish-remains* and *corals* are also tolerably common, while *echinids* and *decapoda* are but rarely found. Some scarce pieces of wood were found in the Snow Hill beds.

Already during the field-work we noticed a near relationship between the Cretaceous strata of the two islands, but at the same time such marked differences that a division into the two local groups Snow Hill beds and Older Seymour I. beds may prove to be necessary.

A slight petrological difference has already been noticed. When collecting ammonites we found that several of the most abundant types were limited to one of the islands and that was also the case with some of the other shells. A large *Aporrhais*, very common on Snow Hill, is never found together with the Seymour Island ammonites, and the *oysters*, rather common on the last-mentioned island, seem to be absent or rare in the true Snow Hill beds. *Tubulostium callosum* Stol. is one of the most common Snow Hill fossils. A few specimens of *Tubulostium* were collected on Seymour Island, but they are bigger and may belong to another species or variety.

The only group of Cretaceous fossils hitherto examined by specialists is that of the cephalopoda. Prof. KILIAN has kindly sent me preliminary lists of the species, and these are given here below to illustrate the difference and relationship between the two faunas:

Snow Hill.	*Seymour Island.*
Holcodiscus Madrasinus Stol.	*Holcodiscus Madrasinus* Stol.
» *Kalika* Stol. sp. (very abundant).	» *cf. Kalika* Stol. sp.
» *Æmilianus* Stol. sp.	» *Æmilianus* Stol sp.
» *cf. cliveanus* Stol. sp. (abundant).	
» *cf. Theobaldianus* Stol. sp.	
» *n. sp. aff. Theobaldianus* (abundant).	
» *cf. Karapadensis* Stol. sp. (abundant).	
» *cf. buddhaicus* Kossm.	
» *Bhavani* Stol. sp.	» *Bhavani* Stol. sp.
» *cf. Moraviatoorensis* Stol. sp. (rare).	
» *cf. recurrens* Kossm.	» *recurrens* Kossm.
» *n. sp. A.* (abundant).	
» *n. sp. B.*	
» *n. sp.*	
Pachydiscus cf. rotalinus Stol. sp.	*Pachydiscus.*
	» *(Holcodiscus) gemmatus* Huppé sp.
	» *cf. Gollevillensis* d'Orb. sp.
	» group of *neubergiens* Quenst.
	» *n. sp.*
Desmoceras (Puzosia) diphylloides Forbes sp.	
» (») *cf. sugata* Forbes sp.	
» (») group of *latidorsata.*	
» *aff. Denisoni* Stol. sp.	

Snow Hill.	*Seymour Island.*
Tetragonites sp.	
Hamites cf. cylindraceus d'Orb. sp.	
Gaudryceras politissimum Kossm.	*Gaudryceras.*
» *varagurense* Kossm. (common).	
» *cf. Marut* Stol.	
» *sp.*	
	» *cf. striatum* Jimbo sp.
	» *Kayei* Stol. sp.
	» group of *Sacya* Stol. sp.
Lytoceras imperiale Yabe.	
Phylloceras Surya Forbes sp.	*Phylloceras sp.*
» *ramosum* Meek.	
Sonneratia sp.	*Sonneratia sp.*
Nautilus cf. Bouchardianus d'Orb.	*Nautilus sp.*
Belemnites sp.	

These parallel lists indicate a marked difference between the two faunas. Several species are common to them both, but the predominant forms are different. The chief part of the Snow Hill species belong to the genus *Holcodiscus* and several of the most abundant of these forms are not found on Seymour Island. On this island, however, species of *Pachydiscus* and *Gaudryceras* form essential constitutents of the fauna and they are all different from the Snow Hill representatives of the genera mentioned.

As to the affinity of these Antarctic ammonites to other Cretaceous faunas, Prof. KILIAN has made the following remarks:

»La plupart de ces formes sont des espèces caractéristiques ou se rapprochent d'Ammonites caractéristiques des assises de Trichinopoly (couches supérieures) d'Aryaloor et de Valudayoor dans l'Inde, c'est à dire du Sénonien; quelques espèces seulement (*Gaudryceras cf. Marut* Stol. sp., *Holcodiscus cf. cliveanus* Stol. sp. *H. Moraviatoorensis* Stol. sp. et *Pachydiscus rotalinus* Stol. sp.) du reste rares et isolées, indiqueraient un niveau inférieur, celui des couches supérieues d'Ootator dans l'Inde, équivalentes du Turonien, mais il faut remarquer que les formes les plus caractéristiques de ce niveau (*Schlœnbachia*, *Acanthoceras* etc.) font défaut. Le type faunique rappelle à un haut degré celui des dépôts néocrétacés de l'Inde si remarquablement decrits par M. Kossmat après des traveaux de Stoliczka, ainsi qu'à un degré un peu moindre, mais cependant notable, celui du Crétacé supérieur (Nanaimo Group) de l'île de Vancouver, du Japon (abondance des *Gaudryceras* et des *Pachydiscus*), de la Patagonie, du Natal etc.

La présence de *Pachydiscus gemmatus* Huppé sp., de *Lytoceras Kayei* Stol. sp. et de *Pylloceras ramosum* Meek., ainsi que celle d'un grand *Pachydiscus* voisin de *P. Quiriquinæ* Steinm. et de *P. colligatus* v. Binck. à l'île Seymour, évoque un rapprochement avec les couches de Quiriquina que nous ont fait connaître M. Steinmann et ses collaborateurs sur une île de la côte pacifique de l'Amérique du Sud.»

After these general remarks on the Cretaceous formation considered as a whole I will try to characterize the different localities as far as this is possible before the palæontological material has been worked out.

As the strata of the Snow Hill-Seymour group seem to dip by slow degrees towards E. to ESE. we may expect to find the oldest beds in the most southwestern locality.

This is also the case. Near the middle of Snow Hill Island lies a nunatak-group (loc. 6) from which NORDENSKJÖLD brought some fossiliferous slabs which, both in their petrological character and in the general appearance of the fauna, remind one of loc. 3 of the ice-free peninsula. In one of these pieces was found a small twig of a conifer, determined by Prof. NATHORST as *cfr. Sequoia fastigiata* Sternb. sp., the only to any extent determinable plant fossil in all the Cretaceous series.[1] Together with this remnant of a conifer lay some specimens of a coral, a small mussel, fish-scales and some ammonites, which have been examined by Prof. KILIAN, who has found them to be »a *Puzosia cf. sugata* Forbes sp. (transitionary to *P. latidorsata* d'Orb. sp.) and a small *Desmoceras* (*Puzosia*) of the group of *P. planulata* Sow. sp.»

Prof. KILIAN writes: »This locality seems to be somewhat older than the other and to correspond to the Ootator group of India, viz. lower Cenomanian.

Next in age to loc. 6 seems to come loc. 2 of the ice-free peninsula. The fauna of this last-mentioned locality contains, according to Prof. KILIAN, some species that remind one of the Ootator beds, but they are mixed with forms characteristic of the Aryaloor and Trichinipoly faunas.

The age of loc. 3 and 5 is not yet definitely settled, but to judge from the preliminary determinations made by Prof. KILIAN it may be supposed to be approximately that of loc. 2.

Locality 4 at the southeastern corner of the ice-less peninsula has been erroneously marked on Pl. 6 as belonging to the »Snow Hill beds». This place was discovered by the physician of the wintering party, Dr. EKELÖF, and NORDENSKJÖLD in his notes has named it »Ekelöf's Locality». Here was found in a soft clayey matrix a fauna consisting of mostly small-sized, well preserved fossils, shells, corals, echinoid spines, etc.

A very similar fauna was collected on Seymour Island, loc. 8. Apparently some species at least are common to both localities and the general appearance of both fauna and rock is the same in the two places. This identity of the faunas of loc. 4 and 8 has been confirmed by Prof. KILIAN. The ammonite-remains from loc. 4 belong, according to him, to *Pseudophyllites Indra* Stol. sp. and *Pachydiscus sp.* »La localité 4 de Snow Hill paraît, comme celle de l'île Seymour (loc. 8), appartenir à un horizon superieur du Sénonien».

[1] According to a communication kindly made by Prof. NATHORST, the true *Sequoia fastigiata* Sternb. sp. belongs to the Cenomanian of Europe and to the Cenomanian and Senonian beds of Greenland.

After all, there can be no doubt that loc. 4 belongs to the »Older Seymour Island beds» and it is only through inadvertency that this place has been marked on the map, as all the rest of Snow Hill, with the colour of »Snow Hill beds».

Of locality 1, S. of the winter-station, we are somewhat doubtful as to its age. In a bank of fine-grained sandstone with carbonate of lime forming the cementing matrix, there occurs in great abundance a mussel that has been determined by Dr. WILCKENS to be *Lucina Townsendi* White (mentioned from Snow Hill already by Weller L. c. P. 415).

This form, according to the determinations made by Dr. WILCKENS, has been collected also on loc. 4 and on Seymour Island not far from 8. This seems to indicate that loc. 1 is nearer in age to the Older Seymour I. beds than to the close lying localities 2, 3 and 5, where *Lucina Townsendi* was never noticed and where the rock is quite different from that of loc. 1. With this premise one could feel tempted to suppose the musselbank of loc. 1, owing to a fault, to have been lowered to the level of the beds of the adjacent loc. 2.

But the age of loc. 1 is very uncertain. The ammonites enumerated by Prof. KILIAN from this locality are all found also in loc. 2, but never seen in the older Seymour I. beds. Thus the question of the age of loc. 1 must be left unsettled, at least until the fossil material has been fully worked out.

The ammonite fauna of the »Older Seymour I. beds» has been characterized above according to the determinations made by Prof. KILIAN, who has compared this fauna with that of the Quiriquina beds in Southern Chile.

The mussels of the ammonite-bearing Seymour I. beds have not yet been determined, but Dr. WILCKENS has sent me a communication about one of these species that points to the same conclusion as the notes on the ammonites: »a *Lahillia* most like *L. veneriformis* Hupé sp. from the Quiriquina beds».

In locality 9, situated round the upper part of a river-valley running to the NW. coast of Seymour Island, was collected in nodules of dark grey limestone a fauna consisting chiefly of several species of bivalves. The total absence of ammonites in this fauna led us, during our survey work, to consider it as belonging to the upper series of Seymour I. deposits (Younger Seymour I. beds) and so it was also marked in the map Pl. 6.

But Dr. WILCKENS, after having examined the mussels of loc. 9, told me that the fauna is decidedly Cretaceous, as several of its species are identical with mussels from the Patagonian *Lahillia Luisa*-fauna described by himself. The preliminary list drawn up by Dr. WILCKENS of the mussels of loc. 9 is given here:

»*Lahillia Luisa* Wilck.
Lahillia n. sp.
Astarte venatorum Wilck.
Nucula suboblonga Wilck.
Pyropsis gracilis Wilck.
Malletia sp.
Aporrhais sp.

The Patagonian beds with *Lahillia Luisa* are considered by WILCKENS to be Senonian, but their relation in age to the Chilean Quiriquina beds he has left undecided.[1]

On Seymour Island we have besides the *Lahillia Luisa*-beds (Loc. 9) another Senonian series with ammonites (SW. part of the island), that has been compared with the Quiriquina beds. Because of the general dip of the strata in the Snow Hill—Seymour region, with the oldest beds in the SW. (loc. 6, Cenomanian) and the youngest in the NE. (loc. 11 Tertiary), one could feel tempted to suppose loc. 9 to be younger than the ammonite-bearing strata in the SW. part of Seymour Island. But it must be accentuated that such a supposition is by no means supported by actual observations. In fact, not one of the localities in this region has been proved by means of supraposition to be younger than another. The conditions are here very unfavourable to such an investigation: the flatness of the land, the gentle dip of the strata and the sameness of the sediments, all combine to make a stratigraphical survey very difficult.

In an easterly direction from loc. 9 there lies at the coast a prominent point (south from the small isolated strip of the basalt-dike, pl. 6).[2]

On the hills behind this point were found, in soft sandstone, trunks of fossilized wood. As no other fossils were noticed together with the wood, the age of these beds cannot be fixed. But it must be mentioned that

[1] WILCKENS. Die Lamellibranchiaten, Gastropoden etc. der oberen Kreide Südpatagoniens. Sonderabdruck aus den Berichten der Naturf. Ges. zu Freiburg i B. Band XV. 1905. P. 63—64.

In another paper published at about the same time, WILCKENS has proved the synchronism of the *Lahillia Luisa*-beds of Southern Patagonia with the Rosa- and Salamanca-beds of northern and central Patagonia and classed them together under the name "San Jorge formation".

"Ob nun die San Jorge-Stufe ins Senon gehört oder noch in die dänische Stufe reicht ist für das Wesen ihres Vorkommens eine völlig müssige Frage".

Die Meeresablagerungen der Kreide- und Tertiärformation in Patagonien. Neues Jahrb. für Mineralogie etc. Beilageband XXI. 1905. P. 145—146.

[2] As a guide for future explorers we may note that the name Penguin Bay, given by NORDENSKJÖLD, is not very appropriate. No penguins breed in the bay; the only penguin rookery on Seymour Island is at the point mentioned above. On the same point lies a depot of provisions established by NORDENSKJÖLD and enlarged by the Argentine Relief Expedition.

between the basalt-dike and locality 10 were found some specimens of a large *Pinna* identical with or similar to a species very common in the Snow Hill beds. This find may prove that the Cretaceous formation extends close up to loc. 10, and thus it may be considered possible, but by no means certain, that the wood is of Cretaceous age.

According to the descriptions given above, the Cretaceous deposits of the Snow Hill—Seymour region may be grouped as follows, though it must once more be pointed out that the relationship of age between the different localities is in some cases very uncertain:

Probable succession of the Cretaceous beds of the Snow Hill—Seymour region.

Local denominations.	Localities of Pl. 6.	Epochs.	Corresponding deposits in other regions.
Older Seymour Island beds.	Loc. 9. Beds with *Lahillia Luisa.* SW. part of Seymour I. (with Loc. 8) and Loc. 4 Snow Hill.	Senonian.	Patagonian beds with *Lahillia Luisa.* Quiriquina beds of S. Chile. Aryaloor, Valudayoor and Upper Trichinopoly beds of India.
Snow Hill beds.	Loc. 2 (3 and 5?)		
		Turonian possibly hidden underneath the inland ice.	
	Loc. 6.	Cenomanian.	Ootator beds of India.

Outside the Snow Hill and Seymour Islands Cretaceous beds have been observed in several places on Cockburn Island and Ross Island cropping out underneath the basalt-tuff formation.

Cockburn Island, On this small island Cretaceous strata have been observed cropping out here and there through the talus that covers the steep sides (pl. 1 C).

In most places only *Callostium* and some fragments of ammonites were found. The ammonites have been determined by Prof. Kilian as *Holcodiscus cf. Theobaldianus* Stol. sp. and *H. n. sp. A.*, proving that these Cockburn beds belong to the Snow Hill series.

The localities 12 and 13 (Pl. 6) are of special interest.

At 12 (fig. 3) the Cretaceous beds are exposed to a thickness of about 150 meters. These strata are not rich in fossils. In the lower part of the section (b of the fig.) I found three specimens of *Pinna*, a small, smooth *Pecten*, a decapod and an ammonite. At a height of 150 m., only 10 m. underneath the basalt-tuff, some specimens of *Callostium* were collected.

At loc. 13 a thin basalt-dike traverses the sedimentary beds. Close to this dike in soft sandy beds of common Snow Hill type was found a

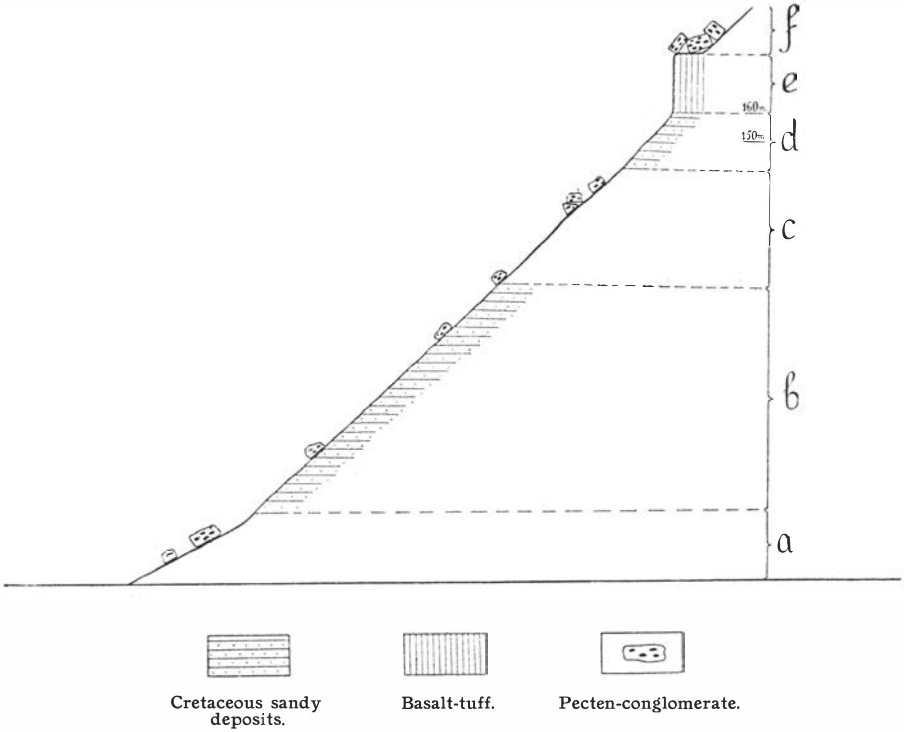

Fig. 3. Detail section. E. side of Cockburn I. Loc. 12.

layer, about one meter in thickness, rich in glauconite and quite crowded with fossils, mostly small forms: a globulous bryozoan, two species of brachiopoda, small gastropoda etc. This fauna of pygmean forms is quite different from the typical fauna of the Cretaceous beds of this region, and as no common Snow Hill fossil was found in the sandy beds in which the glauconitic layer lies intercalated, it is somewhat doubtful whether this layer with its surroundings belongs to the Cretaceous series. But as the sandy beds of this place seem to be connected on both sides with indubitable Cretaceous strata, I think this singular bed too is most probably only an intercalation, with anomalous petrological and faunistic facies, in the normal Snow Hill sediments of Cockburn Island.

Not far from loc. 13 the sandy beds present, on a large scale, a strongly developed current-bedding.

Cape Hamilton. I have not visited this place, and the following notes are due to a communication kindly sent to me by Prof. NORDENSKJÖLD.

Round Cape Gage the tuff formation seems to descend to the sea-surface, and this is the case also on the south coast of Ross Island from Lockyer Island all the way to C. Broms on the west coast.

But at Cape Hamilton the tuff formation is not found until we reach a height of 220—230 m. above the sea, resting on a mighty sedimentary series.

The greater part of this series may be supposed to belong to the Cretaceous formation, as *Callostium* was collected nearly up to the base of the basalt-tuff.

These Cretaceous beds are extremely poor in fossils; besides the shell just mentioned only one other gastropod and some joints of crinoids were noticed. Litologically the series is very uniform: soft sandstone without harder layers but with numerous nodules, which in this place are always devoid of fossils.

Next above the Cretaceous beds follows a moraine-like mass, some meters in thickness: in a clayey matrix lie numerous angular fragments of crystalline rocks foreign to the locality (granite etc.; no volcanic rocks or porphyries were noticed amongst these fragments of plutonic eruptives and crystalline schists). Also pieces of »claystone» were noticed. The largest of these lumps of foreign rocks did not exceed half a meter in diameter; most of them were much smaller.

Between this moraine-like mass and the superposed tuff lies a bed of »clayish sandstone», two meters in thickness, with numerous small fragments of basalt, and exhibiting evident current-bedding. Apparently this sediment must be considered as connected with the basalt-tuff resting on it.

The horizontal extent of these beds could not be determined, as they were very little exposed.

Sidney Herbert Sound. The northernmost locality of Cretaceous strata is a place named »The Naze» in Sidney Herbert Sound. Here a low and narrow promontory juts out from Ross Island, exhibiting some few meters thickness of Cretaceous beds, covered on the Naze by postglacial clay (fig. 4). At the base of the promontory the land rises to a hill of basalt-tuff overlying the Cretaceous beds. In these strata were found numerous specimens of *Callostium*, 2 small *Ostrea*-like mussels, a gastropod and an ammonite which, according to Prof. KILIAN, is undeterminable but possibly a *Holcodiscus* of the group of *H. Bhavani* Stol.

Also on the west side of Ross Island (Crown Prince Gustaf Channel) sedimentary beds cropping out underneath the basalttuff have been noted. These tracts were visited only by NORDENSKJÖLD, and he has given me the following notes:

At Obelisk Point was found a coarse yellow sandstone with carbonized plant remains. It seems as if this sandstone formed a subsided body bounded by faults from the surrounding cliffs of basalt-tuff, but more probably the sandstone forms the bedding of the tuff.

N. of Obelisk Point up to Cape Lagrelius a sedimentary series was seen here and there at the base of the tuff formation. At the last-named cape it was found to consist partly of beds which may be considered as only fine-grained tuffs, partly of a coarse conglomerate of considerable thickness with pebbles of various types of crystalline rocks (also porphyries, but, as far as was noticed, no basalt).

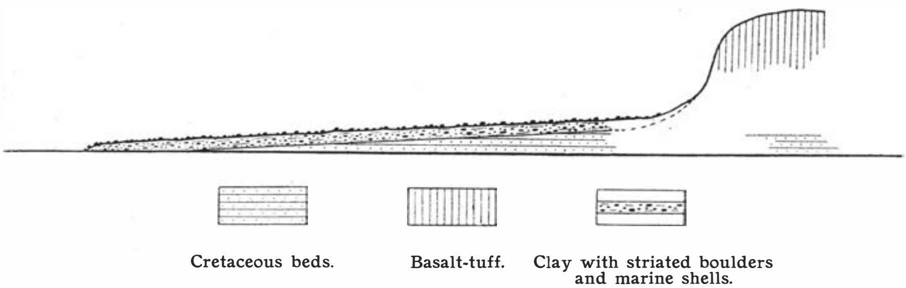

Fig. 4. Sidney Herbert Sound. "The Naze".

Also on the very northernmost point of Ross Island, Cape Lachman, were seen at some distance, at the base of the tuff cliff, gently projecting slopes, such as indicate — to judge by our experience at other places — sediments underlying the tuff formation. As we did not visit this cape, no opinion can be expressed as to the nature of the supposed sediments.

Tertiary beds of Seymour Island.

As has been proved above (p. 40) we have been able to trace with some degree of certainty the Cretaceous formation on Seymour Island to close up to the SW. side of loc. 10. But in this locality itself a younger horizon has replaced the Cretaceous series, though we could not find the exact boundary between the two formations.

The prevalent rock of loc. 10 is a sandstone cemented by carbonate of lime and partly developed as a tuff with fragments of augite-porphyrite. In this sandstone NORDENSKJÖLD discovered (already in Dec. 1902) determinable plant-fossils. These have been examined by Prof. NATHORST, who has published the following preliminary report:

»Les *Fougères* y sont assez communes et appartiennent à plusieurs espèces différentes, mais les débris sont de petites dimensions et difficiles à déterminer. Une Conifère a feuilles distiques rappelle assez, à première vue, l'aspect d'un *Sequoia*, mais un examen attentif semble indiquer qu'il s'agit d'un autre genre. Une seule feuille isolée semble appartenir à une *Araucaria*, assez voisin de *l'Ar. brasiliensis*. Les feuilles de *Dicotylédones* sont généralement petites et presentent le même facies que celles de certaines flores tertiaires de l'Europe méridionale. Comme fait intéressant il y a lieu de signaler quelques feuilles de *Fagus*».[1]

As these plants occur in a marine deposit and as they form, moreover, only small and broken fragments, it cannot be considered as certain that they grew in the immediate vicinity of the place where they were deposited.

As to the age of this flora Prof. NATHORST, after his preliminary examination, has not ventured to enter into any details, but has only stated that it is decidedly *Tertiary*.

In the plant-bearing sandstone was found also a bed crowded with mussels. But unfortunately these are badly preserved, and the small material brought home by us suggests no hints as to the age of the deposit.

Locality 10 is situated on the south-west side of the transverse valley that connects the two opposite bays of Seymour Island. The northeastern part of the island from the transverse valley to the northernmost point consists of soft sandstone much resembling the Cretaceous beds, but differing from them in the occurrence of conglomeratic intercalations with numerous small pebbles of crystalline, mostly granitic rocks foreign to the region. Besides these allothigene pebbles there occur also numerous small pieces of dark sandstone.

The fauna of these beds consists chiefly of mussels and gastropods, which have been handed over for examination to Dr. WILCKENS, who has sent me the following preliminary list:

Lahillia angulata Ph. sp.
Cucullæa alta Sow.
Modiola Ameghinoi Ih.
Ostrea.
Cominella obesa Ph. sp.
Turritella cf. exigua Ortm.
Bullia cf. globulosa.[2]
Natica.
Struthiolaria.

The majority of these forms are characteristic also for the »Patagonian formation» or the »Patagonian molasse» as it has been named by STEINMANN and WILCKENS, and according to the latter there can be no doubt that the two deposits are contemporaneous. The Patagonian molasse is thought by WILCKENS to belong to Upper Oligocene or Lower Miocene.[3]

[1] NATHORST. Sur la flore fossile des régions antarctiques. Comptes rendus. June 1904.

[2] Found, according to Dr. WILCKENS, by NORDENSKJÖLD in the "Patagonian Molasse" at Cabo Sunday in Tierra del Fuego".

[3] WILCKENS. Die Meeresablagerungen der Kreide- und Tertiärformation in Patagonien. Neues Jahrb. f. Min. Beilageband 21. 1905. P. 164.

Besides the shells which form the majority of the fauna there occur in the Younger Seymour I. beds a *Lingula* and — abundantly — another, articulate brachiopod, a crinoid, etc.

At one place within the region of this series numerous bones of birds and two vertebræ of a big mammal were found scattered on the ground together with quantities of pebbles of crystalline rocks. Apparently both the pebbles and the bones were a residuum of the destruction of conglomeratic beds in the series forming the ground, and that the bones belonged to the Tertiary beds was confirmed by the fact that Dr. WIMAN, when examining them, found in a small lump of rock adhering to one of the bones several specimens of *Lingula*, which occurs together with the marine shells in the surrounding beds. The bird bones were all found by WIMAN to belong to penguins, five new genera being described by him, viz: *Anthropornis Nordenskjöldi*, *Pachypteryx grandis*, *Eospheniscus Gunnari*, *Delphinornis Larsenii* and *Ichtyopteryx gracilis*.

The mammal vertebræ were identified as belonging to a *Zeuglodon*.[1]

Ross Island Formation.

(Basaltic tuffs and lavas.)

When on December 7, 1902, the »Antarctic» entered the sound between Joinville Island and the mainland that now bears the name of the our good old ship, I noticed in the southern entrance of the sound a group of plateau-shaped islands, the dark coastal cliffs of which offered already at a distance a marked horizontal bedding that suggested sediments possibly rich in fossils. During the course of the day we found a way through the ice in the sound and late in the evening I was able to land on the easternmost point of one of these islands, now named Uruguay Island. When I got close, my hope of finding fossiliferous beds was sadly dissappointed. The high precipitous wall forming this point was built up merely of a dark coloured volcanic tuff formed of basalt-blocks flung together chaotically. Here and there this rock was intercalated by beds of a light reddish-brown and apparently consisting of fine-grained tuff material.

Three weeks later I entered with two companions the till then unknown archipelago inside the northern part of the Erebus and Terror Gulf. After having crossed the mainland from Hope Bay to Duse Bay we found ourselves again surrounded by plateau-shaped capes and islands that reminded us of the Argentine Islands.

[1] WIMAN. Vorläufige Mitteilung über die alttertiären Vertebraten der Seymourinsel. This Bulletin. Vol. VI. Part. 2. 1905. P. 247—252.
WIMAN. Über die alttertiären Vertebraten der Seymourinsel. Wiss. Ergebnisse der Schwedischen Südpolar-Expedition. Bd III. Lief. 1. 1905.

The island on the west side of the entrance of Duse Bay especially caught my attention. In it were exposed a series of dark and light yellowish brown beds, the whole showing a very pronounced bedding and forming a gentle syncline. For a second time I was disappointed in my expectations of finding a fossiliferous series. In the talus at the base of the cliff of the island I found only the same tuff formation that I had met before on Uruguay Island.

The above statement will give some general idea of the basalt tuff formation that has got its name from the big Ross Island, which seems to be built up almost exclusively of this rock.

The tuff consists of basalt fragments (the size of which varies from minute grains to gigantic blocks, many meters in diameter) cemented by a

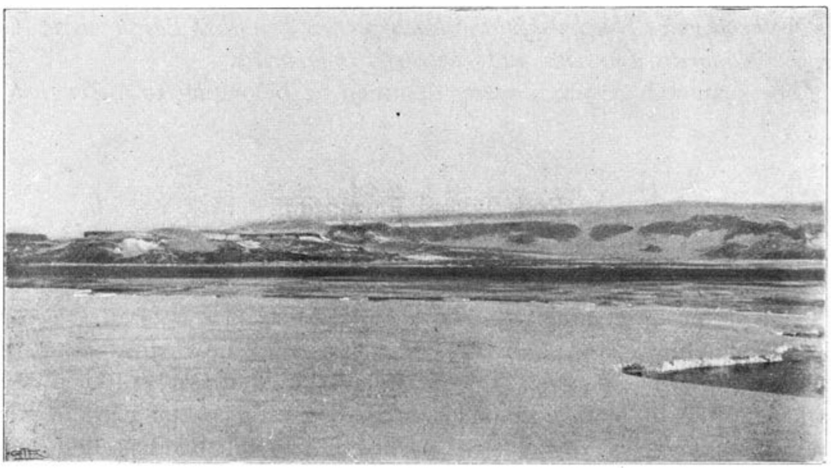

Fig. 5. Part of the SE. coast of Ross Island. The dark coastal cliffs are formed of the basalt tuff.

yellowish or brown palagonitic mass. Often the basalt pieces are veritable bombs with a vitreous crust.[1] A bed of basalt has also been observed, at least in one place, intercalated in the tuff, but certainly such beds form only a very subordinate part of the formation. Dikes traversing the tuff have also been noticed in the small Devil Island on the north side of Vega Island, but this must also be considered as exceptional. On the east coast of Duse Bay and round Vega Island I have followed the coastal cliffs mile after mile without seeing anything but various types of the tuff.

In many places (thus the east coast of Duse Bay and the whole of Vega Island) the sections exhibit a marked unconformability within the tuff formation. In the lower and larger part of the cliffs the strata are inclined, but these inclined beds are cut off and superposed by a horizontal series of less thickness, but consisting of the same material.

[1] Nordenskjöld. L. c. P. 244.

At first I felt inclined to explain these facts by assuming that the inclined beds had suffered a slight folding, that had ended and that had been followed by a period of denudation before the upper horizontal part of the tuff formation was formed.

But on the north side of Vega Island, W. of C. Well-met, we found splendid coastal sections which offered a more natural explanation of the undulations of the older tuff series.

Fig. 6 reproduces such a section. The unconformability between the older and the younger beds is here splendidly developed. But also within the older series there is another marked unconformity, or a current-bedding developed on a large scale.

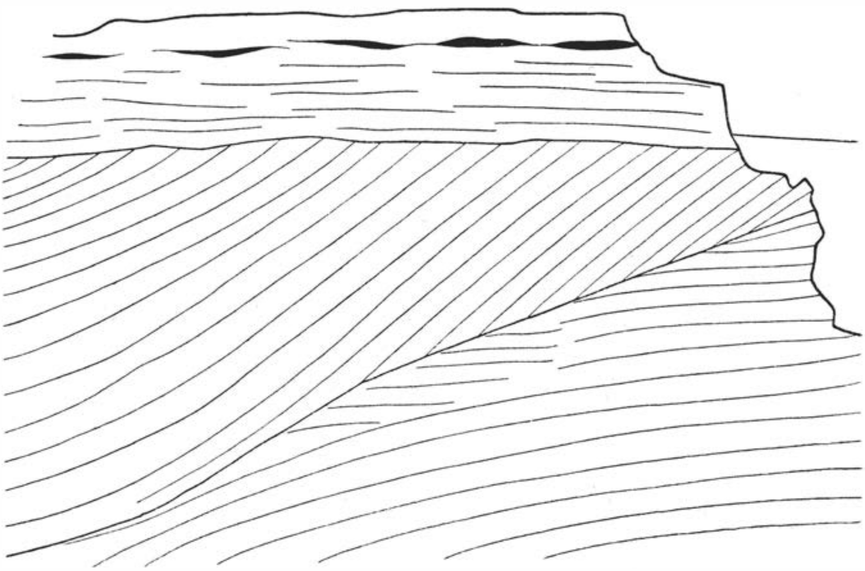

Fig. 6. N. side of Vega Island, W. of Cape Well-met. Coastal cliff (calculated to be considerably more than 100 m. high) built up of coarse basalt-tuff. The dark strips in the upper, horizontal series are in nature light-brown in colour and probably consist of fine-grained palagonite-tuff.

After the examination of a section like this — and several others proving the same were noticed on Vega Island — no doubt can remain, I think, that the inclination of the beds of the older series is *primary:* during violent explosions the coarse tuff was flung together in inclined beds; periods of erosion alternated with the eruptions, and as the force and direction of the explosions changed, the dip of the strata became varied. I also think there can be no doubt that these strata were formed subaërially, as such deep discordances cannot possibly have been formed submarinely, but only on a land surface.

After the violent and somewhat chaotic deposition of this older series followed a time of denudation, that resulted in a horizontal cut through the older undulating beds. On this surface formed by denudation was afterwards deposited the upper part of the tuff formation.

Of the centres which gave origin to this vast and mighty formation, we know very little. As already mentioned, dikes, indicating the passage of the magma to the surface, are noticed only in some rare instances.

Paulet Island, on the NE. side of the Gulf, consists exclusively of olivin-basalt and is considered by NORDENSKJÖLD to be a veritable crater island. So is also the case with Mount Christensen, situated on the north side of Robertson Island far down in the south; but both these volcanoes lie outside the main region of the Ross I. formation.

Very likely also the top of Cockburn Island marks a centre of eruption.

Through the ice-free peninsula of Snow Hill Island and through the larger southwestern part of Seymour Island runs a basalt dike, rarely more than 10 meters broad, consisting of typical olivin-basalt. NORDENSKJÖLD has noticed that close to this dike the sediments are in some places strongly metamorphised.

NORDENSKJÖLD, in his paper on the petrology of the region, has pointed out the very interesting fact that in different parts of the tuff formation the basalt is found to enclose fragments of foreign rocks that are apparently plutonic eruptives. Such enclosures have been found by me in the tuff at the eastern side of the mouth of Duse Bay.

The tuff formation is found to rest, at Cape Hamilton, on Cockburn Island and in Sidney Herbert Sound, on Cretaceous beds. As will be proved in the next chapter the tuff itself on Cockburn Island is superposed by the *Pecten*-conglomerate, the age of which is probably Pliocene. These facts limit the age of the tuff formation.

The boundary between the folded region and the tuff formation runs on the maps in a very regular curve, which might easily suggest the idea that a fault forms the boundary line and that the Erebus and Terror Gulf, including the tuff islands, is a sunken area.

But it must be mentioned that the boundary is only roughly drawn on the maps, and it seems highly probable that in reality its course is much more complicated.

I had no opportunity of seeing the basement of the tuff formation in the northernmost part of its region, but the zoologist of our expedition, Mr. K. A. ANDERSSON, has communicated to me an observation bearing on this question made by him in Nov. 1903 on a boat-voyage with Captain LARSEN from Paulet Island to Hope Bay. On Irizar Island he saw the tuff formation resting on a granite-like basement, that may possibly be the diorite series of the region of folding. As the rock-specimens collected by him were lost, the information is somewhat uncertain, but his account is nevertheless very noteworthy.

For the rest I think it very probable that the tuff formation occurs sporadically also within the region of folding, as in one place at least, on the north side of Pendleton Island, I saw from a distance a section exhibiting in its stratification a striking likeness to the coastal cliffs of the tuff islands.

On plate 4 I have marked with the colour of the tuff formation two active volcanoes in Bransfield Strait, Deception Island and Bridgman Island. As my petrological material from Deception Island was lost with the »Antarctic» I am not able to give any fresh information about the petrological character of this island. The following brief description of the two volcanoes is based chiefly on the notes given by travellers in the first part of last century.

Deception Island is a large crater island, 15—19 km. in diameter. The crater itself forms a basin, 9—10 km. in width and connected with the ocean by a very narrow entrance, only about 200 meters wide. Small craters are described as situated on the inner slope of the big volcano.

The island is to a great extent covered by ice. An alternation of layers of volcanic ashes and ice has been mentioned by some old visitors and was noticed also by me. It does not seem necessary to refer this phenomenon to repeated eruptions but only to the violent gales that spread masses of old ash over the snowfields.

WEBSTER and KENDALL, who visited the island on board the »Chanticleer» in 1829, have given us the most reliable information about the recent signs of volcanic activity:[1] numerous hot springs were noticed, the temperature of which was found to be 88° C. Streams of sulphuretted hydrogen and steam were emitted from the ground, the fumaroles being especially numerous on the shores of the basin, particularly between high and low water-mark.

Lieutenant JOHNSON of Wilkes' squadron, who in 1838 paid a visit to Deception Island, speaks of »boiling springs» and small craters, three or four feet in diameter, from which »a heated vapour is constantly issuing accompanied by much noise».[2]

WILKES in his narrative also speaks of a Captain SMILEY, who touched at Deception Island in 1842 and reported that »the whole south side of Deception Island appeared as if on fire». »He counted thirteen volcanoes in action.» There seems to have been some exaggeration in this old skipper's account.

When we passed the island in Nov. 1902 the entrance to the crater was unfortunately filled by ice, so we could not reach the interior of the island.

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[1] For references see P. 20.

[2] WILKES. Narrative of the Exploring Expedition. Vol I. P. 149.

The small Bridgman Island that rises high and steep — as an isolated rock — out of the sea, has been mentioned by sailors who have passed near to it as exhibiting certain indications of solfatara action.

POWELL in 1821 speaks of a thick smoke emerging from a crater on the west side of the island.[1]

WEDDELL, who in the same year passed »within 200 yards» of the island, »observed smoke issuing through the fissures of the rock, and apparently with much force».[2]

D'URVILLE,[3] who passed the island in 1838, and WILKES,[4] in 1839, both distinctly perceived the smoke issuing from its sides. Under the lee of the island WILKES noticed »a strong sulphurous smell».

BALCH has made us acquainted with two captains, LYNCH and ELDRED, who are said to have landed in 1880 upon Bridgman Island. Here they killed a fur seal that »had the fur all burnt off on one side; they thought that, as Bridgman Island was then smoking, perhaps this seal had come in contact with some hot lava or volcanic fires.»[5]

This tale of the burnt seal sounds much like a yarn, so perhaps also the information given by these skippers on volcanic activity on Bridgman I. is not very reliable.

Apparently Bridgman I. rises abruptly from a considerable depth, as not far from it we sounded 1511 m., the greatest depth of Bransfield Strait.

The Pecten-conglomerate of Cockburn Island.

Cockburn Island rises like a big beacon in the eastern entrance of Admiralty Sound. (Pl. 1 C.)

Its profile is very characteristic: a horizontal plateau, the sides of which form in the upper part a precipitous cliff and underneath this a high and steep talus slope. On the northernmost part of the plateau rises a conical top (fig. 7, p. 52).

The steep cliff consists of basalt tuff, the waste slope underneath the cliff hides Cretaceous strata underlying the tuff. The top of the island is built up merely of the tuff formation, that here to a considerable extent consists of lava-beds intercalated in the tuff.

These are the principal geological features of Cockburn Island. But still there remains to be mentioned a deposit that plays, it is true, only a

[1] Neue allgemeine geographische Ephemeriden 1825. P. 172.
[2] WEDDELL. A voyage towards the South Pole. London 1827. P. 133.
[3] D'URVILLE. Voyage au pôle sud. Tome II. P. 142—143.
[4] WILKES. Narrative. Vol. I. P. 140.
[5] BALCH. Antarctica Addenda. Journal of the Franklin Institute 1904. P. 83—84.

very insignificant part in the composition of Cockburn Island, but that will be found to be of much importance for the understanding of the geology of the whole region.

At loc. 12, a place that has been discussed above (p. 41) with reference to the Cretaceous beds, I noticed on the lowest part of the slope a big block that instantly caught my attention, for numerous white patches on its surface flashed in the light at already quite a distance. At first I took it for a big tuff block with crusts of some white mineral in it. But on approaching I found to my great surprise that the light patches were specimens of a big, splendid *Pecten* and that the rock was a conglomerate with numerous blocks of the basalt tuff in it.

As shown in fig. 3, p. 41, blocks of this conglomerate lay scattered on the slope all the way up to the tuff-cliff, 160 m. above the sea. This precipitous cliff I could not climb, and hence I could not find the original home of the conglomerate, but I saw some blocks of it on the top of the cliff resting in a half-overhanging position, proving that the conglomerate-bed lies upon the tuff.

The same day (Oct. 22, 1903) that I found these blocks of the *Pecten*-conglomerate, my companion on the trip to Cockburn Island, Dr. BODMAN, climbed the island on its west side. From the conical top he brought several specimens of tuff and basalt, but found no trace of the conglomerate. However, while crossing a part of the plateau he found some blocks of foreign crystalline rocks and two worn fragments of *Pecten*.

I had no opportunity of climbing on to the plateau to look for the conglomerate bed. Evidently it covers only a very small part of the plateau, as blocks of the conglomerate are met with nowhere in the slopes of the island, except at loc. 12.

In fig. 7 I have given my conception of the structure of Cockburn Island. Probably this profile is not absolutely correct, in that the tuff may descend nearer to the sea in the north (underneath the top), but as I have no detailed observations on the unconformability between the Cretaceous beds and the tuff formation I have drawn the figure in rough outline.

Most of the pebbles in the conglomerate consist of basalt and basalt-tuff, many of them being of considerable dimensions; one basalt block being not less than 1,8 m. in diameter. Possibly the top of Cockburn Island of today formed an island in that sea on the shore of which was formed the *Pecten*-conglomerate.

Besides the numerous blocks of basalt and tuff there were found in the conglomerate also some pebbles, small-sized and few in number, consisting of foreign crystalline rocks, gneiss and granite. A pebble of the last mentioned type has been examined microscopically by NORDENSKJÖLD, who has found it to be a biotite-granite, very probably of Andine type.

The most prominent fossil of the conglomerate is, as remarked before, a large and beautifully preserved *Pecten*. Of a large *Panopæa*- like form and of a limpet-shaped shell were found only bad casts. A *Terebratuloid brachiopod* is rather common. A *Balanus* and some species of *bryozoa* were collected, often attached to outsides of the *Pecten*-valves and to the pebbles of the conglomerate. From the sandy mass forming the cementing matrix of the conglomerate many *foraminifera* and some *ostracoda* were picked out.

From the mode of occurrence of the conglomerate it was at once evident that it must be a very young Tertiary or very old Quarternary deposit.

Amongst the Tertiary and Quarternary deposits of Patagonia there is one which caught my attention, offering very remarkable affinities to

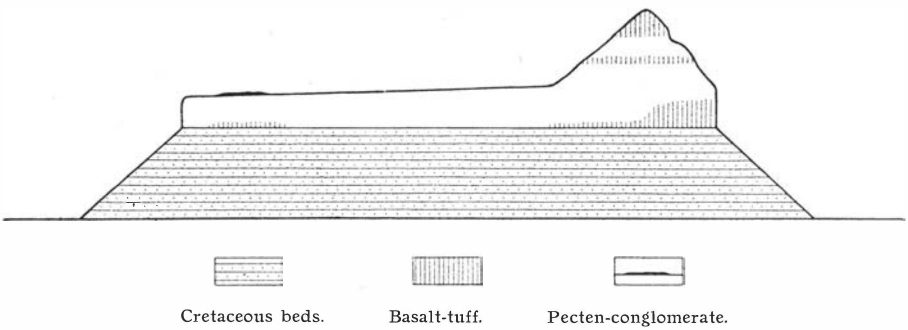


Fig. 7. Ideal section of Cockburn Island.

the *Pecten*-conglomerate of Cockburn Island, i. e. the Paraná beds (Cape Fairweather beds of S. Patagonia).[1]

The mode of occurrence of the two sediments is very much the same: the *Pecten*-conglomerate rests on a subaërial deposit (the basalt-tuff) that must be supposed to be younger than the marine Miocene of Seymour Island, while the Cape Fairweather beds have been deposited on the eroded surface of the Santa Cruzian beds, a subaërial lacustrine deposit that is underlaid by marine Miocene beds.

All authors seem to agree in considering the Paraná-Cape Fairweather formation to be Pliocene.

[1] HATCHER. The Cape Fairweather Beds. American Journ. of Science 1897. P. 246—248.

BORCHERT. Die Molluskenfauna und das Alter der Paraná-Stufe. Neues Jahrb. f. Min. Beilage-Band 14. 1901. P. 171—236.

ORTMANN. Tertiary invertebrates. Reports of the Princeton University Expeditions to Patagonia. Vol. IX. Part 2. P. 307—310.

WILCKENS. Die Meeresablagerungen der Kreide- und Tertiärformation in Patagonien. Neues Jahrb. f. Min. Beilage-Band. 21. 1905. P. 180—185.

The large and beautiful *Pecten*, that is the chief fossils of the conglomerate on Cockburn Island, is very closely related to a Cape Fairweather species, *Pecten actinodes* Sow. In size, general form and shape of the ears there is no difference, except that the right valve may be less flat than that of *P. actinodes*. The arrangement of the ribs shows more difference: the principal ribs are only about twenty, the intermediate ones are never more than three, that in the middle being generally stronger than the two others. Moreover, there is much variation in the appearance of the ribs and on some shells there is no marked distinction between principal and intermediate ribs, all being of about the same strength. I think that the Cockburn *Pecten* will be found to be a species distinct from, but very nearly related to *P. actinodes* Sow.

It is not definitely proved that the *Pecten*-conglomerate of Cockburn Island is contemporaneous with the Cape Fairweather beds, but I think, when all the circumstances are taken into consideration, that this will be found highly probable. The coming examination of the fauna by Dr. HENNIG in Lund will clear up the relationship of the two faunas. But perhaps, after all, the question of the age of the Antarctic conglomerate will remain to some extent unsettled, as it has not been possible to decide whether the Paraná beds in the north of the Argentine Republic are contemporaneous with the Cape Fairweather beds.

Both ORTMANN and WILCKENS feel inclined to consider the differences between the just mentioned formations as due to a difference not in age but in latitude. »We must take into account the much more southern location of the Cape Fairweather beds than any of the other beds, and if they all really belong to the Pliocene, we should expect considerable climatic differences in their fauna.» (Ortmann L. c. P. 308).

As a possible indication of climatic differentiation we may mention that whilst several species of *Ostrea* form a considerable part of the faunas of the South American beds mentioned above, no sign of this cold-fearing genus has been noticed in the Antarctic conglomerate.

Maximum glaciation of Graham Land.[1]

Almost all land in this region is ice-covered. In most places only the very steep mountain slopes and some small islets off the coast are free from ice. Only in the Seymour Island region do we find some considerable land-areas free from ice, a fact that may be explained by assuming

[1] In a separate paper the author will give a more detailed report on this subject.

that on Seymour Island etc. the rock forming the ground is unfavourable to the development of glaciation.

But even in the places where the ice-cover is most complete, the deposition and movement of the ice is apparently very slow. Only real valley glaciers, formed by confluence of ice from different sides, flow with sufficient force to plunge into the sea so far that the front is lifted up from the ground, broken off, and floats away in the shape of icebergs.

But the ice-caps that more uniformly cover island and parts of the land have apparently only a very scanty supply of ice from the interior to the coast. Along Snow Island in the South Shetland group, in Gerlache Channel and on the north side of D'Urville and Joinville Islands we followed such ice-capped coasts mile after mile, and at low water we noticed almost everywhere a narrow strip of dark rock underneath the cliff of the ice. Thus the renewal of the ice is so slow that the action of the waves and the rising and falling of the tide alone suffice to tear away all the ice that reaches the shore-line.

NORDENSKJÖLD has proved that there is in these regions no lasting deposition of snow on the surface of the inland ice in winter-time, as the dry winter-snow is swept away soon after its precipitation and carried out into the ocean by the rarely quiescent southwesterly gales. Only in summer-time, when the falling snow is often wet and the storms are less violent, are new beds added to the surface of the inland ice.[1]

Thus the present glaciation of these tracts is — even if far from »dead» — still very slow and powerless. Certainly no icebergs of the tabular antarctic type are formed at the coasts of northern Graham land, north of a line drawn through Admiralty Sound across the land to the southern entrance of Gerlache Channel. North of this line only smaller icebergs of irregular form are generated, principally by the valley-glaciers. All the large tabular icebergs that we saw in the waters round the northern part of the Graham region must have come from more southerly coasts that we could not reach.

But in a bygone time the glaciation of these tracts was much more extensive than today.

ARCTOWSKI is the first to have found evidence of an earlier larger extension of the glaciation in the Graham region. He has described from the southwest part of Gerlache Channel »roches moutonnées», moraines and erratics, proving according to his statement the existence of »un immence glacier qui se serait écoulé dans le détroit de la Belgia (Gerlache Channel) vers l'ouest, c'est-à-dire vers l'océan Pacifique».[2]

In the NE. part of the same channel I found, on visiting the region on board the »Antarctic», still more significant traces of the old glaciation.

One of the Islands in Brialmont Bay, named by us Moose Island,

[1] NORDENSKJÖLD. Note sur la glaciation antarctique. La Géografie 1904.

[2] ARCTOWSKI. Sur l'ancienne extension des glaciers dans la région des terres découvertes par l'expédition antarctique belge. Comptes rendus. Paris. August 27 1900.

showed evident signs of ice-action right up to its top, more than 200 meters above the sea. The SW. side of the island forms a slope with typical »roches moutonnées», the surfaces of which are polished and striated in a SW.—NE. direction. The opposite (NE.) side of the island is a typical »lee-side», a steep cliff without any sign of ice-action. Right to the top were found erratics, boulders consisting of rocks quite foreign to the island.

There can be no doubt that this island was once covered by a glacier moving from SW. to NE. A single glance at our maps (pl. 4 and 5) will suffice to show that such a direction of the movement of the ice was here possible only in case the ice-stream filled Gerlache Channel in all its breadth and was forced to the NE. by the pressure against the island range that forms the NW. side of the channel.

Not far from Moose Island we sounded in the channel 620 m. depth. If we add to this 200 m., being the minimum height of the island, we get an approximate idea of the thickness of this gigantic ice-stream that once filled Gerlache Channel.

Also in Hope Bay I found very clear evidence of the earlier maximum glaciation.

In the innermost part of the small bay there plunges into the sea a valley-glacier, the recent front of which rises only about 20 m. above the sea-level. But two kilometers outside the end of the glacier there lies on the east coast of the bay a rocky hill 100 m. in height, that was once covered by the valley-glacier, as demonstrated by polished rock-surfaces with striæ running parallel to the valley and by boulders originating from nunataks which rise at the sides of the valley-glacier.

Also on the extreme points of the now ice-free land to the east side of the bay, I found erratics from the inner part of the valley.

These facts demonstrate an earlier extent of the glaciation, that must be considered as very remarkable when we take into consideration the fact that only some five kilometers behind the present front of the valley-glacier we reach the ice-shed, that also at the time of the maximum glaciation must have limited the confluence of ice to this valley-glacier.

On the southernmost point surveyed by our expedition, the Borchgrevink nunatak in 66° S. L., NORDENSKJÖLD found, by means of erratic boulders, that the inland-ice once rose 300 meters higher on the sides of the nunatak than it does today.

On Seymour Island the traces of earlier glaciation are very doubtful. The loose sandy sediments are not able to preserve any surfaces with signs of ice action. Moraine beds were not noticed here, and the possible loose lying erratics are mixed with masses of pebbles that derive from the destruction of Tertiary conglomerates. But the pebbles of crystalline rocks in these conglomerates are, as far as we noticed, only very small (few cm. in length). As many of the boulders on the plateau (180 m. above sea-level) on the northern part of Seymour Island are large and some of them exhibit striation, we must infer that they have been transported by ice (inland-ice or icebergs).[1]

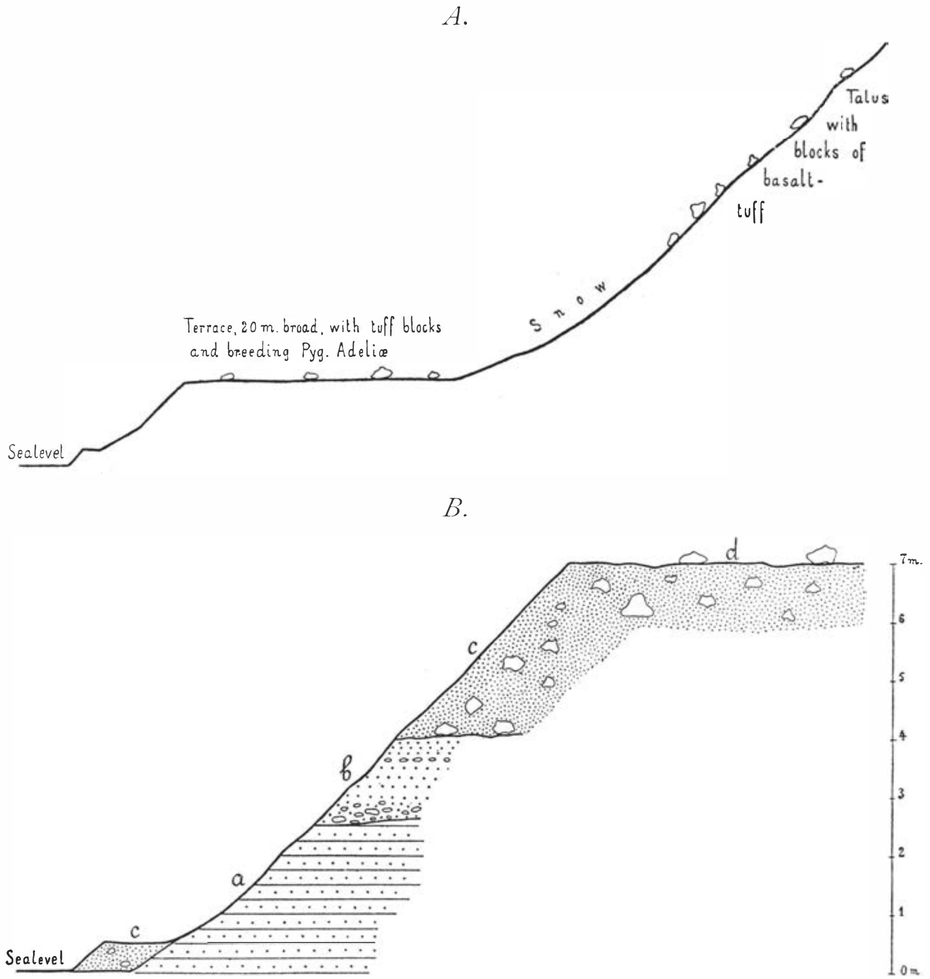


Fig 8. Shore terrace and lowest part of talus slope. N. point of Cockburn Island. B being a detail of the lowest part of A. *a* = Cretaceous beds. *b* = beds of shingles and sand *c* = guano. *d* = terrace-plan with talus blocks and breeding penguins.

The occurrence of these large boulders and striated blocks on the plateau of Seymour Island cannot be explained except by one of these two presumptions:

[1] In order to give some idea of the dimensions of the largest of these blocks on the plateau, it may be mentioned that a boulder of gneiss-granite was found to measure 4 m. in length and 2 m. in height. Another, the biggest of all, a gneiss-boulder, measured 6 to 7 m. in length. This boulder exhibited on some surfaces striation that may be supposed to have been produced by ice. Some smaller striated blocks were undoubtely ice-worn.

1: Seymour Island was once covered by inland ice that carried foreign boulders to the spot in question.

or 2: Seymour Island was in one part of the glacial period submerged about 200 m. below its present position, and during this time icebergs discharge big boulders on the submerged plateau.

To decide between these two suppositions is at present hardly possible.

The emergence of the land in postglacial times.

In Hope bay numerous well rounded pebbles were noticed spread over the slope some few meters above the present sea-level in places that are not now reached by the action of the waves. But when we get higher than these first few meters above the sea the signs of an earlier higher level of the water gradually disappear, and I think it can hardly be doubted that it is the frost-weathering that has split the pebbles, which have lain for a long time exposed, and thus obliterated the highest traces of sea action.

In these regions there is also another process at work, that has certainly contributed to efface the old beaches: viz. the slow movement of the detritus masses down the slopes during snow melting.[1]

For these reasons there is very little chance of finding here any raised beaches but such as are of very recent origin.

At the N. point of Cockburn Island I found a section that exhibits very clearly a small upheaval of the land. Fig. 8 A. presents a good part of the slope on a small scale; B. is a detail of the lowest part of A.

Just above the sea-level we find here a low (0,5 m.) and narrow terrace (*c*), from which the slope rises at an angle of about 45° to 7 m. above sea-level. At this height we find another terrace, 20 m. broad (*d*). Over this terrace are spread numerous blocks of basalt tuff, which have rolled down from the talus slope above that rises to the tuff-cliff.

On the terrace, between the tuff-blocks, breeds a small colony of Adélie penguins, which line their simple nests with small pebbles (2—5 cm. in diameter) that they pick up on present beach. The ground on which these penguins live is very peculiar: a mass composed of tuff blocks, penguin bones and the shingles used for the nests, the whole cemented by the birds excrements.

This guano mass rests on a bed *b* of sand and well rounded shingles (some pebbles being 3 dcm. in diameter). This littoral deposit rests upon the common Cretaceous beds of Cockburn Island (*a*). The narrow and low terrace close to the sea is also formed of guano, and on its top some few pairs of penguins had built their nests.

[1] In another paper I have discussed this process more in detail: Solifluction, a component of subaërial denudation. Journal of Geology 1906. N:n 2. P. 91—112.

Evidently the bed *b* was formed when the sea reached somewhat higher up the sides of Cockburn Island than today, but the upheaval of land indicated by this singular section does not exeed some few meters.

In Sidney Herbert Sound, on the point called »The Naze», I found another deposit that gives evidence of a somewhat greater emergence of the land. (Fig. 4, P, 43.)

The low point is formed chiefly of Cretaceous beds, but these are for the most part hidden by a bed of clay some 2—3 meters in thickness.

This clay at first reminds one of boulder-clay, as it contains numerous small and big rounded blocks (mostly basalt and basalt-tuff, also granitic rocks) some of which were found to be striated. But on the other hand the clay is distinctly stratified and rich in marine shells. Amongst these I fancy I have seen a big *Voluta*-like gastropod, but unfortunately I could not save any specimen of this remarkable shell. The only fossil remains that I was able to bring home from this deposit are some fragments of a large bivalve and two perfect valves of a smaller species. These mussels have been examined by Mr. R. HÄGG, who has kindly informed me that the large fragments belong to *Anatina elliptica* King and the smaller valves to *Thracia meridionalis* Smith.

Mr. Hägg has also sent me a note on the distribution of these two mussels in the recent sea: *Anatina elliptica* has been collected at Kerguelen Island (15—28 fathoms depth), at the South Shetland Islands and at Victoria Land (10 fath.), *Thracia meridionalis* at Kerguelen I. (20—60 fath.), Marion Island (50—75 fath.) and Prince Edward Island (100—150 fath.)

To judge solely from these notes, 20 fathoms would be the least depth in which this clay can have been deposited, and with this premise we come to the conclusion that the clay has undergone an upheaval of at least 40 meters, as it is now about 4 meters above the sea-level. But the premise is very uncertain, as possibly with more extended researches *Thracia meridionalis* will be found to live also in lesser depths than 20 meters.

Also another objection could be raised against the above conclusion viz. that the shells were not deposited where they lived, as the clay may be a boulder-clay. Still, I think this must be regarded as very improbable, because of the regular stratification of the deposit. The numerous blocks in the clay may be considered as discharged from floating ice.

The notes on the distribution of the two molluscs are interesting also from a climatological point of view. The one, *Anatina elliptica*, is a widely distributed species found in one Subantarctic (Kerguelen I.) and two Antarctic localities (South Shetland and Victoria Land), the other is—as far as is hitherto known—a strictly Subantarctic species (Kerguelen I., Marion I., Pr. Edw. I.). To these facts may be added that I have a dim recollection of having noticed in the clay a large *Voluta*-like gastropod, that instantly reminded me of a species that we dragged at the Falkland Islands. Never — as far as I know — has such a large-sized gastropod been taken alive in the Antarctic Ocean proper.

The observations just mentioned may possibly indicate that during the time when this clay was deposited the climatic conditions of the Graham region were not as severe as today. But it must not be forgotten that the frequent occurrence of striated blocks in the clay proves an action of ice that, to some extent, contradicts such presumption.

At any rate, this locality is worthy of the special attention of future explorers.

Geographical development of the Graham region.

The oldest rocks hitherto known within the mainland region are the plant-bearing Jurassic beds of Hope Bay.

The syncline formed by these strata proves that a folding has passed over these tracts in Postjurassic times.

The Jurassic beds of Hope Bay form one of the small patches of sedimentary rocks which are scattered on the mainland and the adjacent islands in a vast area of eruptives (in this paper named the Andine granite-gabbro series).

The age of these eruptives cannot be settled by means of our observations. It is probable, though not actually proved, that they are younger than the Jurassic beds of Hope Bay, as no fragments of these granites etc. are found in the conglomerates and tuffs of Jurassic series.

But on the other hand no intrusions or metamorphic effects of the diorites are noticed in the Jurassic strata, though they lie very close to one another.

As to the upper limit of age of the granite-diorite-gabbro series our evidence is also very scarce: In the Pliocene *Pecten*-conglomerate of Cockburn Island was found a granite-pebble that, according to NORDENSKJÖLD, very probably belongs to this series. In the Miocene pebble-beds of Seymour Island numerous crystalline rocks occur, but in the small material brought home by us no undoubted Andine type has been found.

Thus our direct observations have yielded only very vague information as to the age of the Antarctic eruptives of Andine type. But with the premise that the actual consanguinity with the corresponding South American rocks also indicates simultaneity, we can find in the mode of occurrence of these last-named rocks evidence on the question of the age of the Antarctic eruptives.

From the Patagonian cordilleras HAUTHAL has described a granite which, to judge from his description, very probably belongs to what is here called the Andine type. In Cerro Payne and Mount Fitz Roy this granite forms laccoliths covered by Cretaceous beds which are traversed by granite-dikes and show very marked signs of metamorphism. E. of Cerro Payne sheets of diorite occur in Middle and Upper Cretaceous beds. HAUTHAL declares these Andine eruptives to be of Young Cretaceous or Old Tertiary age.[1]

HAUTHAL considers the extension of these eruptives and the formation of the laccoliths to have been very essential for the formation of the cordillera. This view may be applied to the Graham region to explain the prevalence of the eruptives. Possibly here in some places the disturbance of the small patches of sedimentary rocks is only an effect of the profuse extrusions of magma.

The most ancient beds outside the mountain region are the Cretaceous strata of Snow Hill, etc. The oldest of these strata noted by our expedition are those of the nunatak loc. 6, but the real basal bed of the Cretaceous series is not known to us.

The thickness of the Cretaceous series may be roughly estimated to be at least 500 m. Through the whole of its extent this series is a shallow water deposit, as a marked current-bedding has been noticed as welt in its lowes (Cockburn I.), as in its upper part (S. coast of Seymour I.). When these facts are taken into consideration we must conclude that a subsidence of the sea-bottom with some hundred meters took place during the deposit of the Cretaceous series.

According to the palæontological examinations executed by Dr. WILCKENS there must be a great hiatus in time between the Cretaceous beds of loc. 9 and the Tertiary strata of loc. 11. But in the field no unconformity could be traced between the two formations. Somewhere about the W. of loc. 10 must be the boundary, but during the survey on Seymour I. we considered all the strata of the island to be a continuous deposition with different faunas in the lower and upper part, but with the same sandy type of rock all through, the only petrological difference being the occurrence of thin pebble-strips in the Younger Seymour I. beds.

Also from Patagonia HAUTHAL has recorded a concordant supraposition of Tertiary beds upon the Cretaceous.[2]

The oldest Tertiary bed, that of loc. 10, is plant-bearing with the plant-remains very fragmentary and broken, as if they had been rolled upon a beach. Such is also the case with the shells occurring together with the plants and the rock itself is rich in tuffogene material and bears a littoral appearance. In the upper parts of the Tertiary series shingle-beds and penguin bones occur, proving that the littoral character of the deposit is continuous. As the thickness of the Miocene series is at least 200 meters, a subsidence of the bottom of the sea must have taken place also during its deposition.

[1] HAUTHAL. Ueber patagonisches Tertiär. Zeitschr. der Deutsch. geol. Ges. 1898. P. 438—439.

HAUTHAL. Mitteilungen über den heutigen Stand der geol. Erforschung Argentiniens Compte rendu du IX. congrès géol. intern. Wien 1904. P. 653—654.

[2] HAUTHAL. Ueber patagonisches Tertiär. P. 436.

A very remarkable feature is the common occurrence of small shingles of crystalline rocks (granite, granophyre) in the Miocene beds. It clearly demonstrates that already in Miocene times areas of crystalline rocks penetrated through the mighty Cretaceous beds. Probably these crystalline areas were about the same as the present mountain region, that may be supposed to have existed already in Miocene times. But unfortunately we paid all too little attention to collecting specimens of these Miocene pebbles, so that for the present we must leave many interesting questions unsolved.

The relationship of age of the basalt tuff formation to the Miocene beds is also a doubtful problem.

In three places (Cape Hamilton, Cockburn I. and Sidney Herbert Sound) the tuff rests directly upon Cretaceous beds. But in one of these localities at least (Cockburn I.), and possibly also in the others, it is not the youngest Cretaceous strata, but the older part of the series, the Snow Hill beds, that forms the sub-stratum of the tuff. Thus the younger Cretaceous beds (Older Seymour I. beds) must have been destroyed in these places before the tuff was deposited. It is then by no means improbable that also the Miocene series was included in this process of destruction.

The large basalt-dike of Snow Hill-Seymour Islands traverses only Cretaceous beds on these islands, but it leaves Seymour Island before entering the Miocene area, and it is very possible that the dike continues also in the Miocene beds on the bottom of the sea on the east side of Seymour Island.

The tuffogene material in the plant-bearing bed at the base of the Miocene series is of a quite different appearance to the basalt tuff, and consists of fragments of augite-porphyritic effusives and of volcanic glass. In the Miocene shingle-beds no pebbles of basalt or basalt-tuff were noticed, but this negative evidence is — because of the scantiness of our observations — not very important.

The total absence of the tuff formation between the Cretaceous and the Miocene beds of Seymour I. is an argument in favour of the conception of the tuff formation as being younger than the Miocene beds. But when all the above mentioned facts are taken into consideration it must be admitted that the problem must be left unsolved if it depends on evidence from the Antarctic regions. Still, also in this case, we can find a very illustrative parallel in the conditions in Patagonia. There, in Sierra de las Baguales, Tertiary beds (Patagonian molasse WILCKENS) are traversed by numerous basalt dikes and superposed by a coarse basalt-tuff.[1]

As stated above (P. 47), the tuff formation is very likely formed on

[1] HAUTHAL. Ueber patagonisches Tertiär. P. 439.

WILCKENS. Die Meeresablagerungen der Kreide- und Tertiärformation in Patagonien Neues Jahrb. f. Mineralogie etc. Beilageband. XXI. 1905. P. 191.

a land-surface. But in Pliocene times the sea invaded parts of the area of the tuff formation and deposited on it the *Pecten*-conglomerate.

If we try to put into a consecutive narrative the scattered notes given above, the geographical development of our region may be described as follows:

In Jurassic times there was land here, and the land was covered with a rich vegetation growing rankly in a mild and uniform climate. At the place where today the small Hope Bay lies, there existed a freshwater basin in which fragments of this vegatation were deposited. The flora of this Antarctic land offered close affinities to the contemporaneous floras of India and of Europe.

About the conditions of these tracts in older Cretaceous times we have found no evidence, but from Cenomanian and Senonian epochs we know of a mighty series of fossiliferous beds. In those times the eastern part, at least of the Graham region, was occupied by a shallow sea. The gradual subsidence of its bottom was balanced by sedimentation, so that the depth and the character of the sediment remained almost unaltered throughout the formation of the Upper Cretaceous series. Some few plant remains are scattered in these beds, but the chief part of their fossils forms a marine fauna rich in ammonites of Indopacific type. In the youngest link of the Cretaceous series no ammonites occur, but here is found a fauna of bivalves and gastropoda, the nearest allies of which have been described from Patagonia.

After the deposition of these beds with *Lahillia Luisa* there is in the succession of sediments a hiatus up to the Younger Oligocene or Older Miocene.

During this time the region was probably lifted over the surface of the sea, and very likely the formation of the mountain range falls within this period.

Along a curved line running in these tracts from SW. to NE. powerful masses of dioritic magma protruded, giving, through the differentiation connected with its solidification, origin to a series of nearly allied eruptives, granite-diorite-gabbro. The process of these eruptions as well as their effect upon preexisting sediments is very imperfectly known.

Evidently the formation of the mountain range has determined the principal outlines of the land in the northern and western parts of our region. Gerlache Channel is a typical longitudinal valley and the South Shetland Islands form a very clearly marked range parallel to that of the mainland. Also the large Bransfield Strait is a tectonic basin. The greatest depth observed by us was 1511 m., but — as I will demonstrate in detail in another paper — it is shut off from the open ocean by shelves rising to less than 500 m. below the sea-level.

In Younger Oligocene or Older Miocene times the sea invaded the low non-folded land SE. of the mountain range. The subsidence and sedimentation seem to have been strictly balanced during the deposition of the Miocene series, as it is littoral all the way up. The fauna of these beds is closely related to that of the marine Miocene of Patagonia.

In Younger Miocene times, after an upheaval of the land, the Tertiary and Younger Cretaceous beds were to a very great extent destroyed, and the Older Senonian beds laid bare. Upon this surface formed by denudation a mighty formation of basalt tuff was deposited by means of violent subaërial eruptions.

But once more, very probably in Pliocene times, the land submerged, and on the denuded surface of the basalt tuff was deposited the *Pecten*-conglomerate.

It cannot be doubted that the basalt tuff once formed a much more continous area than today and that the large eastern channels, Crown Prince Gustav Channel, Admiralty Sound, Sidney Herbert Sound and Frithiof Sound are younger than the tuff (and probably also than the *Pecten*-conglomerate).

The large Crown Prince Gustav Channel, running nearly parallel to the mountain range, might be supposed to be a tectonic valley, a sunken area, limited by faults. But the complicated outline of the west side of Ross Island and the northern coast of the channel round Duse Bay is not in favour of such an explanation, and for such narrow and complicated channels as Admiralty Sound, and above all Sidney Herbert Sound, the theory of tectonic valleys is hardly applicable.

We are forced to suppose that these valleys were, at least to a large extent, cut out in the vast tuff area by means of landsculpturing forces during a period when the land lay much higher than today. This must have happened in very late Tertiary or early Quarternary times, and it is very probable that the inland ice during the maximum glaciation continued the dissecting work carried out before by running water and other subaërial agents.

This conception of the region having been much elevated in preglacial and probably also early glacial times coincides in a remarkable way with an actual observation made on the NW. coast of Graham Land: the traces of a large ice-stream that once filled Gerlache Channel, the depth of which is more than 600 m. below sea-level. Possibly the existence of this powerful ice-stream will be better explained if we assume a greater elevation of the land during its time.

The only fact we know about the earlier glaciation is that in some places (Gerlache Channel, Hope Bay, Borchgrevink Nunatak) it was much more. extensive than today. But how far it expanded in the tuff region and over Seymour I. we cannot determine. The oscillations of sea-level during the glacial period is also an unsolved problem. In this respect the conditions on Seymour Island are very doubtful (P. 57).

From the Postglacial epoch we know with certainty of nothing but a slight emergence of the land.

Homology between Graham Land and S. America.

In one of the earlier accounts of the South Shetlands there is a very remarkable note on a supposed connection between these islands and South America:

»They (the S. Shetland Is.) seem to be a continuation of the Cordillera of the Andes, and Archipelago of Tierra del Fuego; being, for the most part, precisely of the same formation with the latter -- their strata even inclining the same way» (Introductory note by JOHN BARROW to an article on the Island of Deception).[1]

This idea of homology between the two regions mentioned was readopted many years later (1888) by a German geographer, Dr. H. REITER, and developed by him in accordance with the then much more advanced state of geomorphological science.[2]

Stimulated by the splendid interpretations of the structures of the continents given by SUESS in the first volume of »Das Antlitz der Erde», REITER tried to prove that there is in the Antarctic region a continent forming a true reflection of S. America: the South Shetlands, Graham Land and Alexander Land, forming a parallel to Tierra del Fuego and the adjacent part of the west coast, Victoria Land corresponding to the Gulf of Arica and the coast of Peru, Wilckes Land to the north coast of S. America, etc.

From the Graham region to Victoria Land there is supposed to run a mountain range quite homologous to the Andes of S. America.

This daring theory is of much interest in dealing with the part of Antarctica nearest to S. America; as regards the more distant parts of Antarctica it may be questionable.

REITER thinks there may possibly be a connection between the Graham region and S. America via the South Sandwich Islands and S. Georgia, but to this point he pays no special attention. A connection of these last named islands to S. America had been supposed already by BELLINGSHAUSEN.[3]

In 1895 ARCTOWSKI, apparently without knowing of the explanations given by BARROW and REITER, sets forth as a new hypothesis what had been more or less clearly expressed by the two former authors. ARCTOWSKI summarizes his conception of the problem in the following words:

[1] Journal of the Roy. Geogr. Soc. Vol. I. 1831. P. 62.

[2] REITER. Die Südpolarfrage und ihre Bedeutung für die genetische Gliederung der Erdoberfläche. Zeitschr. f. wissensch. Geopraphie. Bd VI. 1888. P. 1—30.

[3] FRICKER. Antarktis. P. 108.

»Les Terres de Graham se rattachent à la Patagonie par une chaîne sous-marine qui forme un grand arc de cercle entre le cap Horn et les îles Schetland, et la chaîne tertiaire des Andes réapparaît de nouveau dans les Terres de Graham.»

»Au sud du cap Horn la pente est abrupte, tandis qu'à l'est de la terre de Feu se trouve une plate-forme sous-marine qui sert de soubassement aux îles Falkland, à l'île Georgia, et qui se recourbe vers le sud. Il serait donc des plus intéressant de connaître exactement le relief de cette plate-forme, sur sa bordure ouest, et de savoir si elle se rattache aux Terres de Graham.»[1]

In two later articles, published after his return from the Antarctic regions, ARCTOWSKI has touched again on this question.[2]

In his useful review of our information relative to the Antarctic regions up to 1898, FRICKER has discussed this problem more in detail than any of his predecessors.[3] FRICKER traces the connection between the two continents from Staaten Island, the easternmost part of Tierra del Fuego, across the Burdwood Bank, Shag Rocks, South Georgia, South Sandwich Islands and South Orkney Islands. This range of islands is compared by him with the Antillean island range: S. Georgia taking in this southern group the place of Puerto Rico or Haiti; and the South Sandwich Islands, being partly at least of volcanic nature, form a most striking parallel to the Lesser Antilles.

The geological survey of Graham Land, carried out by our expedition, has strongly supported this theory of homology between the Antarctic region in question and S. America.

In a preliminary paper on the petrology of Graham Land NORDENSKJÖLD has sketched a parallel between the two continents,[4] and some notes on the same subject are given by WILCKENS in a small paper, in which he sets forth his determinations of the bivalves and gastropoda collected by us.[5]

The affinities of the two continents can be classified in three groups of facts, all of which are only different expressions of the identity in geological structure:

1. *The outlines and orography of southernmost S. America and of*

[1] ARCTOWSKI. Observations sur l'intérêt que présente l'exploration géologique des terres australes. Bull. Soc. géol. de France. 1895. P. 589—591.

[2] ARCTOWSKI. Géographie physique de la région antarctique. Bull. de la Soc. belge de Géographie 1900. N:o 1.

ARCTOWSK. Projet d'une exploration systematique des régions polaires. Bruxelles 1905. P. 12.

[3] FRICKER. Antarktis. P. 108—110.

[4] NORDENSKJÖLD. Petrographische Untersuchungen aus dem westantarktischen Gebiete. This Bulletin. Vol. VI. Part 2. P. 234—246.

[5] WILCKENS. Zur Geologie der Südpolarländer. Centralblatt für Mineralogie etc. 1906. P. 173—180.

Graham Land are so similar that the one continent can be said to be the reflected image of the other.

In both cases we have to deal with the narrowing extremities of large land-masses facing each other, and both curved the same way, in an easterly direction.

The high mountains filling the western and southern parts of the lands round the Straits of Magellan correspond to the mountain ranges forming the northern and western parts of Graham Land, and in both regions we find a low table-land E. of the mountain range, in S. America Patagonia and the flat northern part of Tierra del Fuego, in the South the tuff area and the Snow Hill-Seymour region. In Graham Land this eastern region is comparatively narrow, but the difference is only apparent. Much of it is certainly hidden underneath the far extended low ice-terrace discovered by NORDENSKJÖLD, and the sea outside this coast is comparatively shallow. If the ice-cover were cleared away, and the land emerged some hundred meters, Graham Land would be much more strikingly similar to S. America.

Characteristic of the mountain region of southernmost S. America are the long and narrow longitudinal channels such as Beagle Channel, Admiralty Sound with its continuation, Lago Fagnano, and the western part of the Straits of Magellan. We find precisely the same type of longitudinal valleys in the South, in Gerlache Channel. Bransfield Strait is also a basin bordered by parallel mountain ranges, but it is much broader than any one of the named American channels and this big basin that has no equivalent in the north is the only essential disturbance in the symmetry of the two regions.

On the E. side of the South American cordillera there lie in the table-land several broad waters: E. part of the Straits of Magellan with Bahia Inútil, Otway Water, Skyring Water, Last Hope Inlet and a series of large lakes, Lago Argentino etc. Also to this feature we find an equivalent in the South, viz. the wide channels cut in the tuff region, Crown Prince Gustav Channel with Duse Bay, and Admiralty Sound.

2. *The geological structure of the two regions is strictly symmetrical.*

The symmetry in position of the two mountain ranges, of Tierra del Fuego and of Graham Land, is evident.

The consanguinity of the dioritic eruptives of the two ranges is very remarkable. Rocks of this type were collected in Gerlache Channel already by the Belgian Expedition. But NORDENSKÖLD is the first to have recognized their near affinities to the eruptives with which he was so familiar from America.

These rocks form a series from granites to gabbros. The quartz-diorite forming the prevalent type is characterized by occurrence of orthoclase and plagioclase in more or less equal quantities and by marked idiomorphismus and beautiful zonal structure of the latter mineral.

These characteristic rocks have been found by Nordenskjöld in

Alaska; they are known from Vancouver Island, from Yellowstone Park and from Sierra Nevada in California; recently they have been described by HÖGBOM from the Lesser Antilles, and they have been mentioned from many parts of the S. American Andes as far as the southernmost part of the continent.[1]

The recognition made by NORDENSKJÖLD of these Andine eruptives as a most frequent rock in the Antarctic mountain range is the strongest support to the theory of a connection between S. America and Graham Land; it is a very happy application of petrology to the service of geomorphology, and it must be regarded as one of the most important results of the Swedish Antarctic Expedition.

E. of the mountain ranges there expands in both continents an unfolded table-land, built up of gently dipping, often almost horizontal sedimentary strata of the Cretaceous and Tertiary ages. In Graham Land mighty beds of basalt-tuff to a very large extent cover the marine beds, and also in Patagonia numerous small volcanic cones, and vast plateaus of basalt occur in the same position. Also basalt-tuff has been noticed from Patagonia.

Finally it must be mentioned that as a parallel to the numerous active volcanoes on the American cordillera, we find in Deception I. and Bridgman I. two volcanoes of feeble activity situated on a longitudinal line within the mountain region of Graham Land.

3. *The sequence of Upper Cretaceous and Tertiary marine beds is the same in Patagonia and in Graham Land; submergence and upheaval of land have befallen the two continents simultaneously.*

The basement of the Cretaceous beds of Graham Land is perfectly unknown, as well as the lowest part of the Cretaceous series itself. The oldest bed, that of loc. 6, is supposed to be Cenomanian, Turonian beds are not found, but the Senonian epoch is represented by a mighty series, rich in ammonites in the lower part; in the uppermost beds containing the *Lahillia Luisa*-fauna.

Also in Patagonia the lower part of the Upper Cretaceous and its basement is very imperfectly known, so in this respect we can make no comparisons between the two continents.

But from S. Patagonia HAUTHAL has described a series of beds, which offer very remarkable parallels to the Cretaceous of the Snow Hill-Seymour region. Oldest are the beds with *Inoceramus Steinmanni* Wilck. considered by WILCKENS as probably Cenomanian or Turonian. Upon these beds follow others rich in ammonites, the description of which by PAULCKE is not yet published. In the uppermost part of the series the ammonites become very rare, and here we meet — just as on Seymour

[1] NORDENSKJÖLD. Die krystallinischen Gesteine der Magellansländer. Wissenschaftliche Ergebnisse der Schwedischen Expedition nach den Magellansländern Bd. I. Heft. 2. P. 181—214.

HÖGBOM. Zur Petrographie der kleinen Antillen. This Bulletin. Vol. VI. Part. 2. P. 214—232.

Island — the fauna with *Lahillia Luisa.* Upon the *Luisa*-beds there lie in two localities strata rich in oysters, which are considered by WILCKENS to be very near in age to the beds with *L. Luisa.* These beds and other Senonian strata are grouped together by WILCKENS under the name of San Jorge-series, which is proved by him to be very widely distributed in Patagonia.

Upon the marine Senonian (possibly also Danian) San Jorge-series there follow beds of supramarine origin rich in remains of big mammals, the *Pyrotherium-Notostylops*-beds. Because of their position between the Senonian San Jorge-beds and the Lower Miocene Patagonian molasse these continental beds are considered to represent Eocene and Oligocene.

On Seymour Island beds corresponding to the Patagonian molasse seem to rest directly upon Cretaceous strata and it is only thanks to the palæontological determinations made by Dr. WILCKENS that we know there is a great hiatus between the two formations.

After the vast extent of land in the Palæogene period the ocean invaded, in Young Oligocene or Old Miocene times, large areas of Patagonia as well as of Graham Land, and the marine Miocene deposits of the two regions are very similar not only in their fauna but also in the character of the sediment.

The Patagonian molasse is superposed by subaërial or limnic beds with a very rich and remarkable mammal fauna, the Santa Cruz-formation. In some places this supramarine formation is in its turn covered by marine Pliocene beds.

In the same position we meet in Graham Land the mighty basalt tuff formation, that is also a subaërial deposit, proving that Graham Land as well as Patagonia rose in Middle Miocene times out of the shallow sea in which the molasse had been deposited.

Also in Patagonia we find vast basalt sheets and basalt tuff, here actually resting upon the molasse. As stated by HATCHER a large part at least of the Patagonian basalt is of about the same age as the Santa Cruz beds. The basalt in some places penetrates the beds in question, but on the other hand the basalt is supposed to have been »the source from which was derived much of the material of the latter deposits (the Santa Cruz beds), since the latter are very largely composed of volcanic conglomerates and ashes».

»I can only account for this on the theory, that these craters were in existence and active prior to and during the deposition of the Santa Cruz beds.»

»It is also evident that many of these craters continued active long after the deposition of the Santa Cruz beds, for many of the lava flows may still be seen, in places, descending from the plains down over the slopes into the valleys of the water courses, showing that the latter had been eroded prior to the flow of streams exhibiting such conformation».[1]

[1] HATCHER. Geology of Southern Patagonia. Am. Journal of Sience. 1897. P. 350.

Also some parts of the basalt formation in Graham Land may be relatively recent as some craters remain tolerably well preserved. But much of the basalt tuff must be of Miocene age as it is superposed by the *Pecten*-conglomerate, in which basalt pebbles are very abundant.

From the province of Entrerios in the north to Puerto Gallegos in the south there occur in the Argentine Republic along the Atlantic coast marine beds resting upon the older Tertiary and containing a fauna with a considerable amount of recent forms. These beds are named Paraná-formation in the north and Cape Fairweather beds in the south and are considered to date from the Pliocene age. But the synchrony of all these deposits is not definitely settled. Still more uncertain at present is the connection of the Antarctic *Pecten*-conglomerate to the Pliocene S. American beds, though, on the other hand, the likeness of the faunas and the accordance of the mode of occurrence strongly supports the idea that also in Pliocene times a transgression has befallen the two continents simultaneously and uniformly.

It is evident that our knowledge, not only of Graham Land but also of Patagonia, is at present all too imperfect to permit us to fix the oscillations of the coast-line in Younger Cretaceous and Tertiary times as strictly simultaneous in both regions. It is quite possible that future, more detailed researches will prove that for instance the uppermost stratum of San Jorge series does not exactly coincide with the youngest Cretaceous bed of Seymour Island, that the extent in time of the deposition of the Younger Seymour I. beds does not exactly correspond with that of the Patagonian molasse, that the *Pecten*-conglomerate is not strictly synchronous with the Paraná-formation etc. But the general sequence of oscillations is clearly proved to have been the same in both continents. Periods of vast extension of land have been followed in quite identical alternation by times of invasion of the ocean.

Unfortunately we do not know anything with certainty about the true nature of these oscillations. If they depended upon a rising and falling of the level of the ocean, they may have spread far beyond the regions here in question, as seems to have been the case with the transgressions and retreat of the ocean in Younger Cretaceous times.

But on the probable assumption that most of the oscillations mark movements in the earth's crust, they may be considered as a strong support to the hypothesis of consanguinity between the two continents.

In the table given on page 70 I have tried to draw a parallel between Tierra del Fuego and Graham Land including Quarternary times.

The Fuegian deposit that I have compared with the raised post-glacial clay in Sidney Herbert Sound is a clayey deposit with marine diatoms found by NORDENSKJÖLD 10 m. above the sea-level at Páramo in northern Tierra del Fuego and named by him Magellan clay.[1]

Of course there is no reason to suppose that these two clays belong to exactly the same part of the Post-glacial epoch. I have only intended to point out in the table that we have in both regions as well post-glacial clays as shingle-beds raised above the surface of the sea by means of a late upheaval of the land.

The homology of southern S. America and Graham Land in orography, geological structure and development is now a well-established fact.

But another closely allied problem remains unsolved, viz. the supposed connection between the two continents via South Georgia. This question, extending over areas far beyond the region forming the scope of this paper, I will leave untouched at present, but will discuss it, as far as is possible in the present state of our knowledge, in a later article on the bathymetrical conditions of the parts of the ocean E. of Tierra del Fuego and of Graham Land.

Development of southernmost S. America and Graham Land.

Epochs	**S. America** (mostly after Wilckens)	**Graham Land**	Facies of oscillations
Quarternary	Raised beaches	Raised beaches	Regression
	Magellan clay	Clay with *Thracia meridionalis*	Transgression
	Maximum glaciation	Maximum glaciation	Regression
Pliocene	Formation of lakes and channels E of the cordillera.	Formation of eastern channels	
	Paraná-formation	*Pecten*-conglomerate	Transgression
Upper and middle Miocene	Basalt beds and craters	Basalt tuff formation	Regression
	Santa Cruz beds		
Lower Miocene	Patagonian molasse	Younger Seymour I. beds	Transgression
Oligocene and Eocene	*Pyrotherium-Notostylops* beds	Hiatus	Regression
	Mountain-folding	Mountain-folding	
Senonian	San Jorge series	Older Seymour I. beds	Transgression
		Snow-Hill beds	

[1] NORDENSKJÖLD. Über die posttertiären Ablagerungen der Magellansländer. Wiss Ergebn. der Schwed. Expedition nach den Magellansländern. I, 1. P. 58.

Notes on the maps.

Pl. 5 and especially Pl. 4 are only intended to give a general idea of distribution of the different formations.

The observation spots are very scarce in many parts of the region; this is especially the case on the mainland. For these tracts the geologied structure has been inferred from the land forms as seen from a distance.

On plate 5 some doubtful places, as, for instance Joinville Island, are left uncoloured; on the smaller-scaled pl. 4 I have marked them with the colour that seems me most probable. Still Dundee Island, the geological composition of which is very questionable has been left untouched.

As to Pl. 6 it must not be forgotten that on Seymour Island the boundary line between Older and Younger Seymour I. beds is placed erroneously.

As the rich fauna of loc. 9 does not contain any ammonites we supposed it, at the time of our visit, to belong to the Tertiary series and drew the boundary line to the west of this locality.

But Dr. Wilckens has found the fauna of loc. 9 to be identical with the Senonian *Lahillia Luisa*-fauna of Patagonia.

According to this determination the limit between the two formations ought to be drawn close to the west of loc. 10, which is decidedly Tertiary.

It must also be mentioned that loc. 4 of Snow Hill I. is erroneously marked with the same colour as the rest of Snow Hill I. In fast it belongs to »Older Seymour I. beds, its fauna being nearly allied to that of loc. 8.

Addendum.

When the first chapters of this paper were already in the press I came across a preliminary note on eruptive rocks collected by the French Antarctic Expedition under the command of Dr. Charcot.[1]

These rocks, which were collected round the SW. entrance of Gerlache Channel form two series, one consisting of granitoid eruptives, the other of »roches microlitiques d'origine incontestablement volcanique et à facies recent».

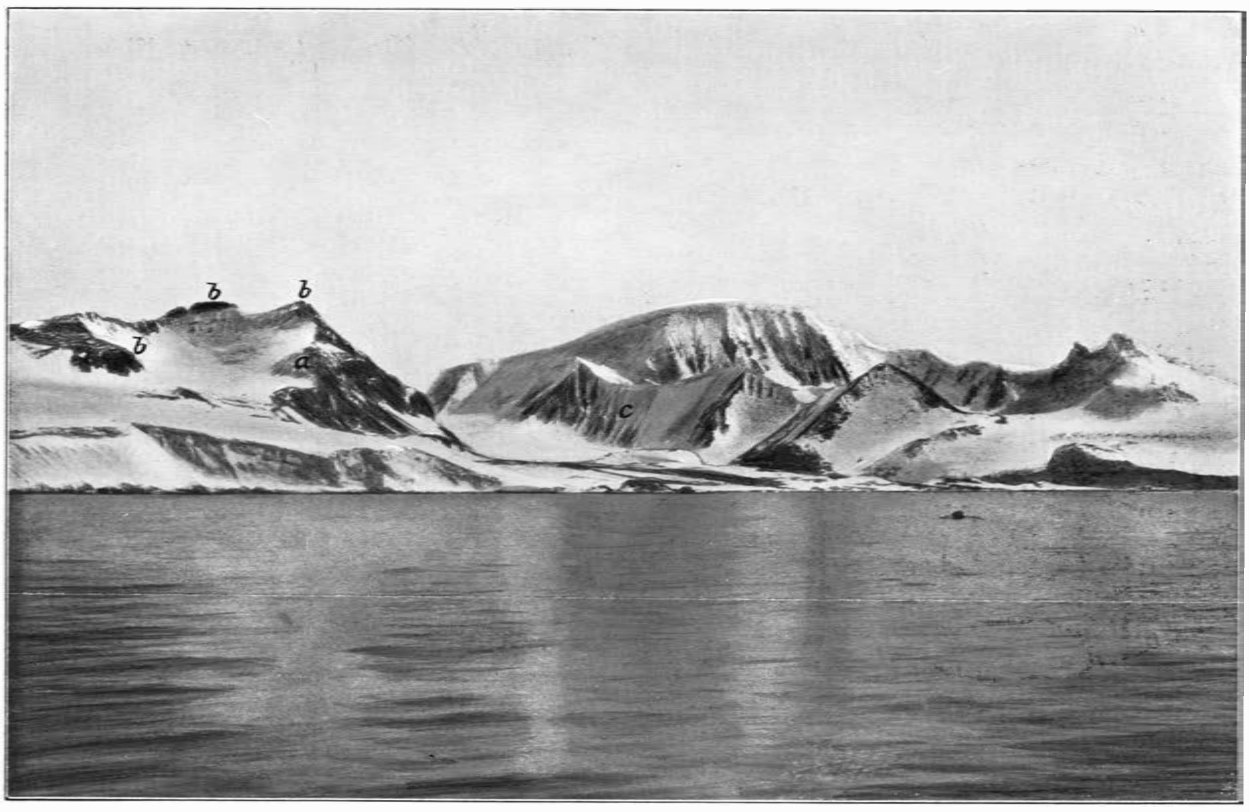
Only the granitoid rocks are described. Amphibole-granite, quartz-diorite and gabbro are the principal types.

»Toutes ces roches paraissent constituer une série pétrographique continue.» Evidently this is the Andine series of eruptives (See the descriptions given by Teall and Nordenskjöld, P. 27—30).

[1] Gourdon. Les roches éruptives grenues de la Terre de Graham recueilies par l'expédition antarctique du Dr. Charcot.

Comptes rendus. Paris. 11 Déc. 1905.

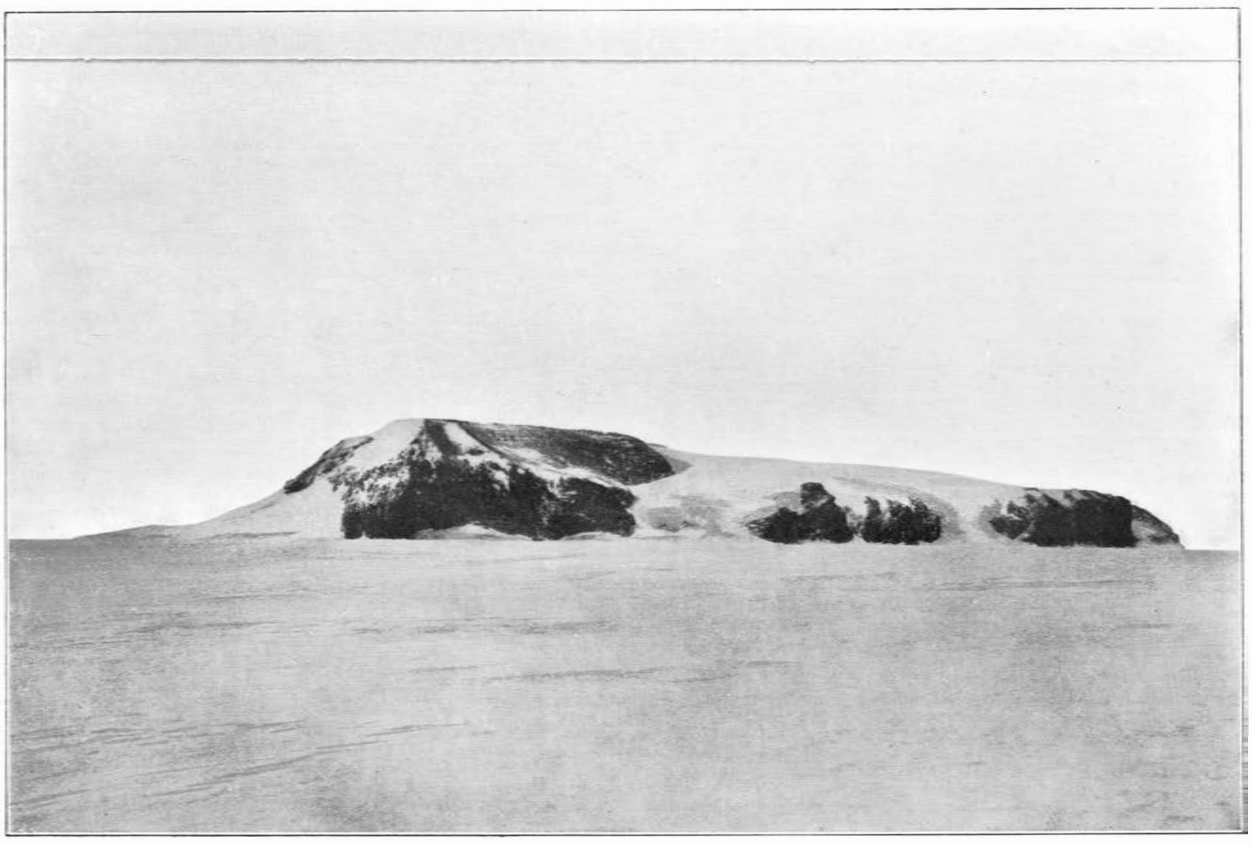
A.



Hope Bay.

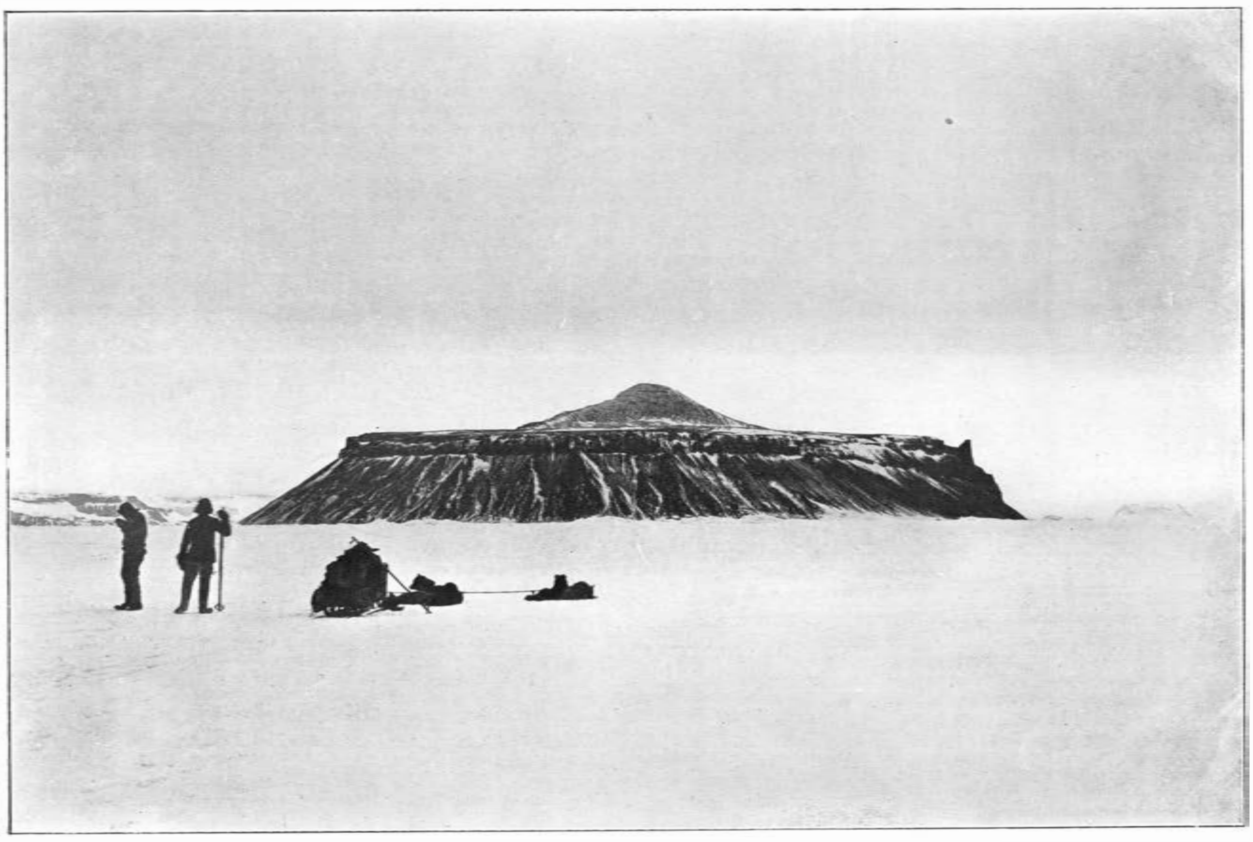
a = dark slate with Jurassic flora. b = multicoloured tuff-beds.
c = quartz-diorite.

B.



Lockyer Island.
Basalt tuff.

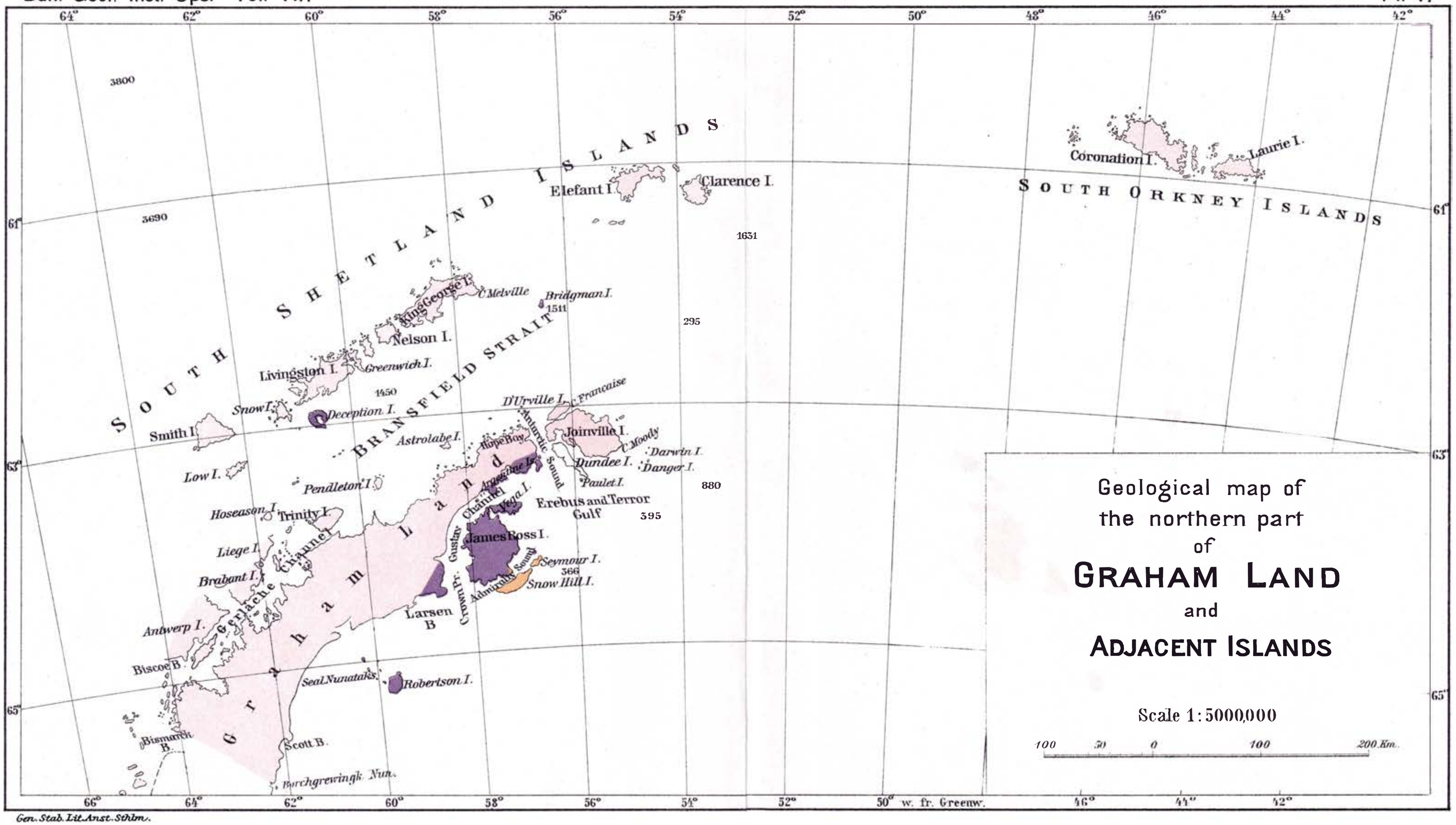
C.



Cockburn Island. (From ESE).
Top and vertical cliff consist of basaltic tuff and lava.
The talus slopes hide Cretaceous beds.

Ice-less peninsula of Snow Hill I. in the foreground;
in the background Seymour I. (to the right)
and Cockburn I. (to the left).

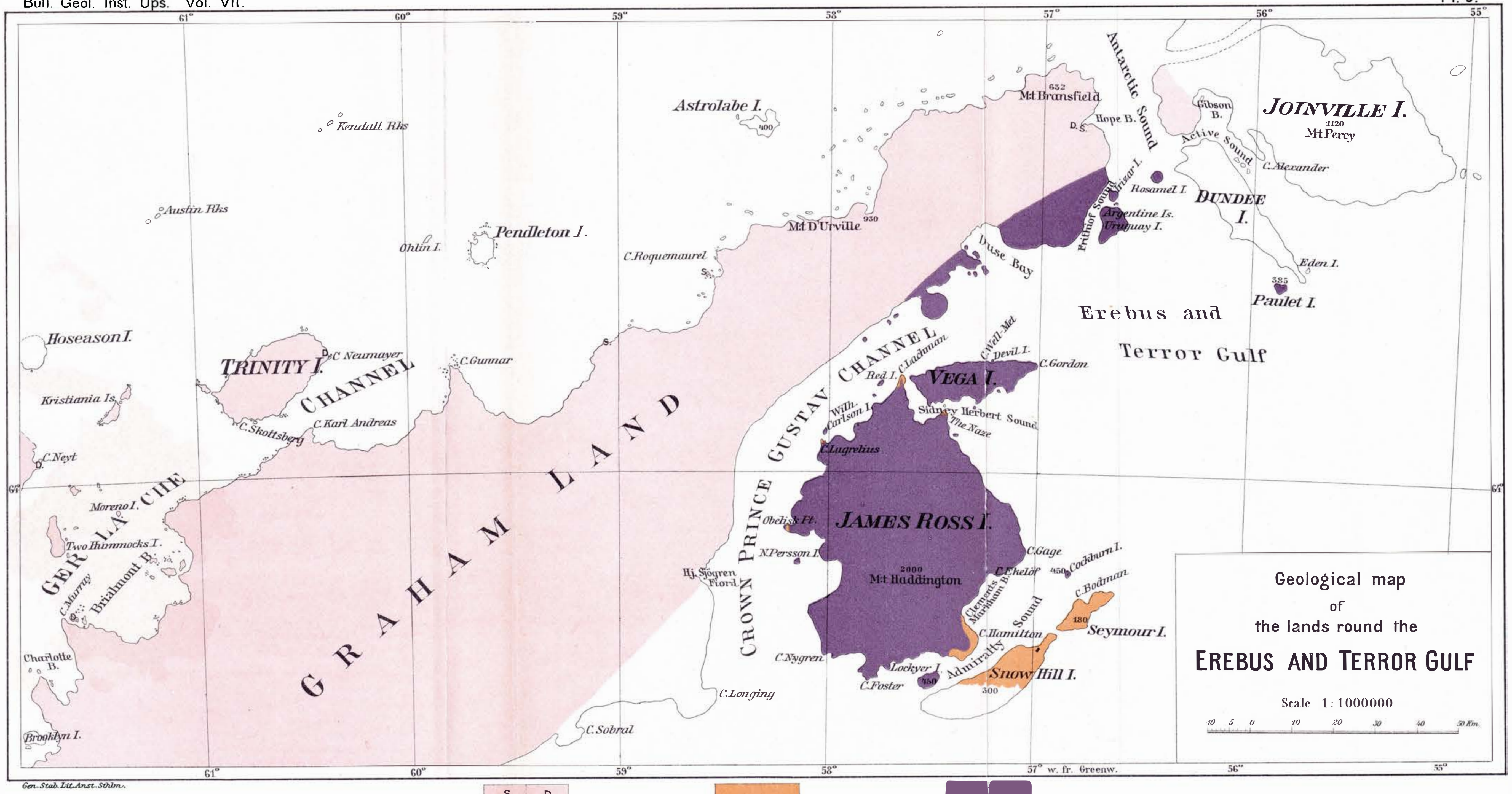
Moraine-like conglomerate or breccia. Gerlache Channel.
Coast-nunatak between
C. Karl Andreas and C. Gunnar.



Region of folding and of Andine eruptives.

Snow-Hill-Seymour I.-series.

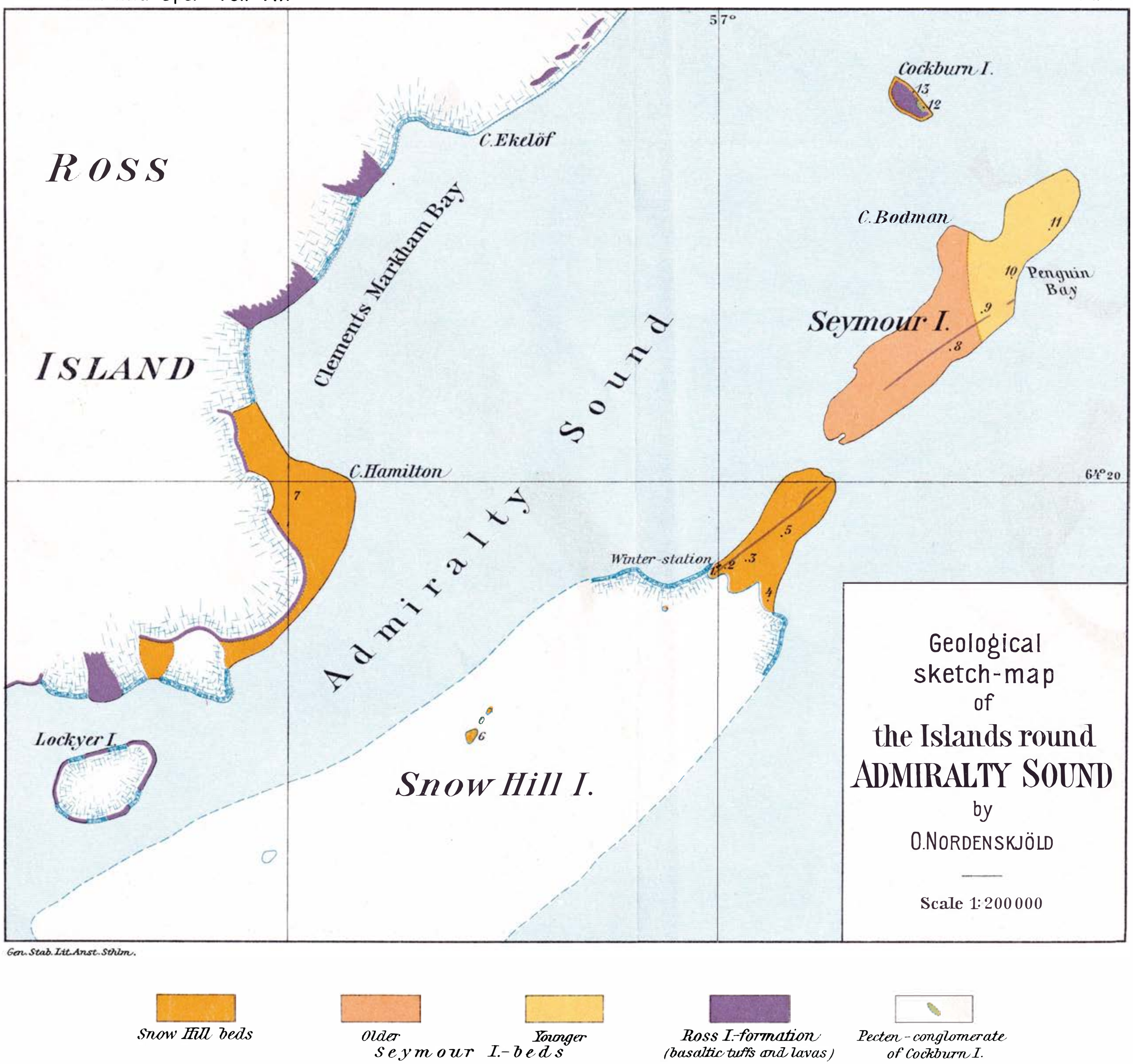
Ross I. formation. (basaltic tuffs and lavas.)



S. D.
Region of folding and of Andine eruptives.
(S = Sediments. D = Quartz diorites.)

Snow Hill-Seymour I.-series.

Ross I. formation.
(basaltic tuffs and lavas.)



Geological
sketch-map
of
the Islands round
ADMIRALTY SOUND
by
O. NORDENSKJÖLD
Scale 1: 200000
57°
64°20
Cockburn I.
C. Ekelöf
Ross
Island
Clements Markham Bay
C. Bodman
Penguin Bay
Seymour I.
Admiralty Sound
C. Hamilton
Winter-station
Lockyer I.
Snow Hill I.
Gen. Stab. Lit. Anst. Sthlm.
Snow Hill beds
Older
Younger
Seymour I.-beds
Ross I.-formation
(basaltic tuffs and lavas)
Pecten-conglomerate
of Cockburn I.