XXVII.—Stratigraphical Observations in the Stor Fjord Region of Spitsbergen. By G. W. Tyrrell, A.R.C.Sc., D.Sc., F.G.S., Lecturer in Geology, University of Glasgow. With an Appendix on the Mesozoic Fossils from Spitsbergen collected by Dr G. W. Tyrrell. By J. Weir, Ph.D., D.Sc., F.G.S. (With One Plate and Five Text-figures.)

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Introduction.

The Stor Fjord is the great bight which is situated on the eastern side of the mainland of Spitsbergen, and separates it from the large Barents and Edge Islands which lie farther east (see map, fig. 1). It is widest towards the south, the distance between the South Cape of Spitsbergen and Negro Point on Edge Island being 107 miles. At its northern end the Stor Fjord narrows considerably and terminates in Heley (or Helis) Sound, which connects it with the Barents Sea by way of Olga Strait.

The shores of the Stor Fjord are composed almost entirely of flat-lying Mesozoic strata carved into tabular mountains and plateaus separated by widely-opened valleys which, on the mainland side, carry many large glaciers. Only one glacier, however, the Duckwitz Glacier (called the Gregory Glacier in 11 *), flows into the sea on the eastern side of the Stor Fjord from Barents Island.

The observations on which the present paper is based were made on two journeys, each of a week's duration, in the summers of 1919 and 1920. The writer was fortunate on both voyages in having the company of Mr J. Mathieson, F.R.G.S., and Mr J. M. Wordie, M.A., to whom he is much indebted for assistance in various ways. On the 1919 trip we also had the company of the late Dr W. S. Bruce, who was then in failing health, but was able from his vast experience of Spitsbergen conditions to direct the party to several localities favourable for landing and for geological observations.

The Stor Fjord is usually open to unimpeded navigation only for two of the summer months owing to the prevalence of drift ice from the east; but the short periods after occasional gales from the north or north-east, which effectually sweep the ice from the fjord for a week or two, are most favourable for exploration. The climate is distinctly more extreme and much colder than that of the western coast of Spitsbergen. The coastal ice or ice foot consequently persists longer, and sometimes offers a serious obstacle to landing. Observations made under these conditions are naturally often rather hurried and cannot be as full and continuous as one could wish. The discontinuity and the gaps in the reconnaissance work described later are thereby explained. Nevertheless, many new data are recorded in this paper, and several new stratigraphical points have emerged from their discussion (see page 683 and the Appendix by Dr J. Weir). It is hoped that the publication of these observations will aid and supplement the more extensive work which has been carried out, and which is still pending, by Norwegian, British, German, and Russian investigators.

Details of Sections.

Mt. Keilhau.—Mt. Keilhau lies at the entrance of Stor Fjord north-east of the southernmost point of Spitsbergen. It consists of a hogback slope mantled in talus to the east, broken off on the south-western side by a great vertical escarpment which runs down to the shore

* The numbers refer to the References to Literature, p. 689.

from a height of nearly 2000 feet. From the shore the cliff at first trends to the N.N.W. and then N.W., but about a mile S. of the summit it suddenly changes direction to the N.N.E., thus producing a vertical projecting bastion north of which there is a deep gully reaching nearly to the summit of the mountain. The escarpment reaches the shore on the eastern side of Keilhau Bay, and makes a rocky projection which is continued seaward in a line of skerries.

A traverse from the shore to the top of the mountain gave the section which forms the upper half of the table below. The continuation of this section in the lower slopes of Mt. Keilhau and in the so-called Fossil Ridges to the west has been investigated by W. Werenskiold (in H. Frebold, 23, p. 11, pl. i, figs. 1 and 3). The details are given in the lower half of the table.

The whole of the Mt. Keilhau and Fossil Ridges section is therefore comprised in the following table, with horizon determinations by H. Frebold (23, p. 26). The succession ranges from the uppermost Trias to possibly the Aptian stage of the Lower Cretaceous. The latter is based on the discovery by W. Werenskiold of a loose slab from Mt. Keilhau (23, p. 24), which contains lamellibranchs and the impressions of ammonites resembling, although not closely determinable, *Crioceras*-like forms such as have been found in the *Ditrupa* beds of Spitsbergen. The strata of the upper part of Mt. Keilhau undoubtedly belong to a "Continental Series," which has been placed by Obruchev (15) within the Upper Jurassic of Eastern Spitsbergen (Upper Portlandian), and by H. Frebold (18, p. 29) within the Lower Cretaceous (Barremian, Hauterivian, and Upper Valanginian) of Western Spitsbergen.

Thickness in Feet.	Lithology and Fossils.	Horizon.
385	Black shales with thin beds of hard quartzitic sandstone, and a few clay ironstones.	Possibly Aptian (see text, above).
360	Thin-bedded yellow blocky sandstones. Individual strata show carbonised plant remains, ripple-marks, mud-cracks, and flakes of contemporaneous shale.	
75	Quartzite with thin intercalations of shale.	
	Plant-bearing black shales.	Continental Series (Lower Cretaceous).
285	Sandy shales with streaks and lenticles of coal.	
140	Quartzite.	
75	Micaceous black shale.	
85	Hard coarse yellow quartzite.	
300	Hard grey quartzite.	
>1300	Clay shales and marly shales. (This is the great scree-covered lower slope of Mt. Keilhau below the first thick quartzite.)	Probably Middle and Lower Valanginian (Volga Stage).
16	Black shales.	
16	Beds with clay-ironstone concretions. Fossils: *Aucella* and the ammonites *Rasenia* and *Cardioceras*. Bed B of Werenskiold.	Lower Kimmeridgian.
33	Black shales.	
1	Shales with ammonites (*Cardioceras* and *Rasenia*). Bed A of Werenskiold.	
115	Black shales.	
10	Shales.	
50	Black shales.	
115	Black shales with lenses of clay ironstone towards the top.	Probably Oxfordian.
33	Hard reddish shales.	
33	Black shales with eight thin beds or series of clay-ironstone lenses.	
50	Black shales.	Lower Callovian with *Macrocephalites* (*Kepplerites*) on Kistefjellet.
6	Hard fissile sandstone.	
65	Black shales.	
7–10	Red-weathering conglomerate.	Base of Jurassic.
	. . . .	Slight discordance on Kistefjellet.
	Sandstone.	Trias.

The portion of the stratigraphical table above the median horizontal line is that compiled by the writer, below the line by W. WERENSKIOLD (23, p. 11). The total thickness of the Jurassic and Cretaceous strata in the Mt. Keilhau region thus appears to be about 3550 feet, as compared with the maximum thickness of 4875 feet obtained by OBRUCHEV (15) in the region between Whales Bay and Agardh Bay.

Whales Bay.—Whales Bay is the deep indentation on the west coast of the Stor Fjord 43 miles S.S.W. of Agardh Bay (see map, fig. 1). This part of the Stor Fjord coast is geologically almost unknown. Apart from the now inaccessible literature of the Russian Arc of Meridian Expedition of 1899–1901, the only recent work is that of S. OBRUCHEV (15), who in 1925 spent a few days in the investigation of the stratigraphy of the coastal region between Whales Bay and Agardh Bay. The range of his work in the Whales Bay region was between Mt. Schoenrock on the south of the bay to Mt. Nicolas Joukovsky on the north (see map, fig. 1).

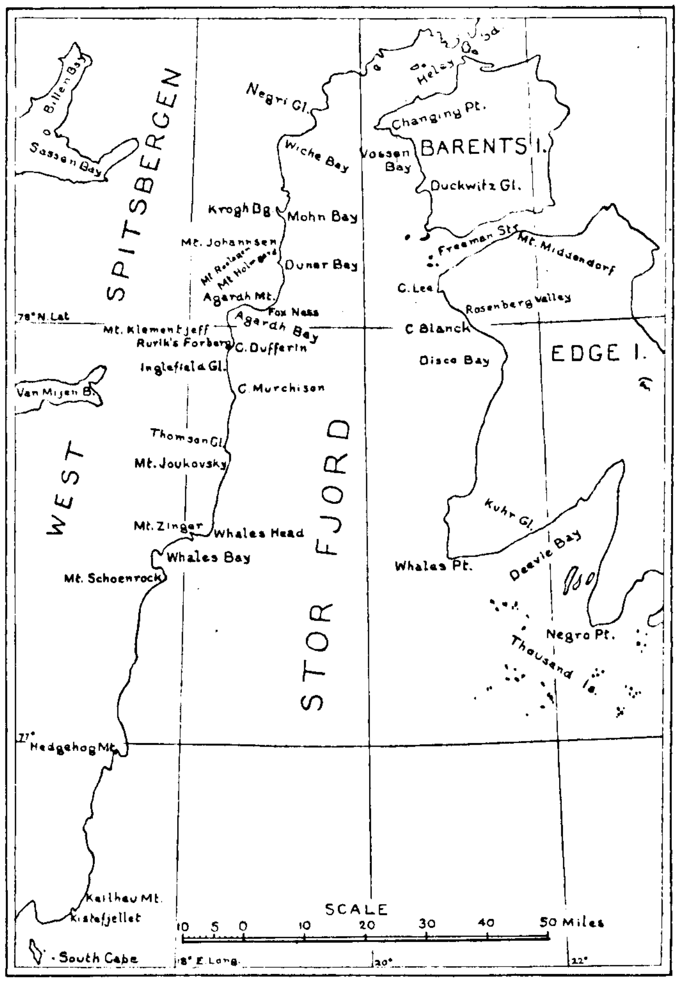

FIG. 1.—Locality map of Stor Fjord region, Spitsbergen. Based on the map in H. KNOTHE (24), with additions.

The writer's section was made in the ascent of a mountain with a rounded summit, on the north side of the bay. This may or may not be the Mt. Zinger of OBRUCHEV's section (15, fig. 3, p. 67). In his notes the writer called it "Whales Head Mt." The section compiled is given in the right-hand column of the table of strata (see below). A continental coal-bearing series occurs at the base of the mountain and on the adjacent coast, consisting of black and grey shales and sandstones, which are sometimes calcareous, and carry numerous lines and beds of ironstone lenticles. The upper thousand feet, however, consists of a marine series with horizons containing ammonites, lamellibranchs, and worm remains (*Ditrupa*). Some intermingling of marine and continental strata occurs at the junction, as is shown by the appearance of fossil tree trunks in dark shales at 1250 feet above sea-level, with marine lamellibranchs in an ironstone 10 feet below (fossil loc. 229).

OBRUCHEV's section of the same mountain block, although not necessarily the same mountain, is given in the left-hand column of the stratigraphical table, taken from his profile section (15, fig. 3, p. 67) under the heading of Mt. Zinger. Correlation between the two sections has been effected by making the top of a marked "Red Horizon" at 760 feet above sea-level coincide with the top of an horizon of dark shales with numerous ironstones in OBRUCHEV's section. The latter agrees well in essentials with that made by the writer. OBRUCHEV finds a continental coal-bearing series at the base, followed by beds with "*Ditrupa*" which the writer failed to find at the corresponding horizons in his section.

On the other hand, the writer collected from two good *Ditrupa* horizons near the top of the mountain which OBRUCHEV failed to record. It is also possible that the two *Ditrupa* beds in the respective sections are identical, and that my suggested correlation between the "Red Horizons" is erroneous.

The fossils collected on Whales Head Mt. have been identified by Dr J. WEIR (p. 695). The assemblage at 1240 feet (loc. 229) indicates an horizon well down in the Lower Aptian, and that at 1540 feet (loc. 230) corresponds definitely with the Lower Aptian fauna recorded by SOKOLOV and BODYLEVSKY from Kolfjellet, Bell Sound. A Hoptilid ammonite collected between 1540 feet and 1715 feet, probably not *in situ*, is regarded by Dr L. F. SPATH as probably Albian, and it is likely, therefore, that Albian strata cap the mountain.

Professor J. WALTON has kindly examined the fossil wood collected at 1250 feet (loc. 234). He writes: "The preservation is not quite good enough for accurate determination of genus or species. It agrees in some characters with the genus *Xenoxylon* Gothan, but the critical features of the medullary ray cells are not preserved." *Xenoxylon* has been recorded from the Festung section at Green Harbour (6, p. 366) in beds belonging to the *Dentalium* (=*Ditrupa*) Series, and thus from an horizon approximately the same as that on Whales Head Mt.

Table of Strata on North Side of Whales Bay.

<table>
<tr><th rowspan="2"></th><th colspan="2">MT. ZINGER (OBRUCHEV).</th><th colspan="3">WHALES HEAD MT. (TYRRELL).</th></tr>
<tr><th>Lithology and Fossils.</th><th>Thickness in Feet.</th><th colspan="2">Lithology and Fossils.</th><th>Thickness in Feet.</th></tr>
<tr><td rowspan="2">Upper Neocomian to Middle Valanginian.</td><td>Grey thick-bedded quartz sandstone.</td><td>13</td><td rowspan="5">Slabby sandstone.
Shelly ironstone with *Ditrupa* (loc. 233).
Prominent scarp of slabby sandstone.
Calcareous mudstone with *Ditrupa* (loc. 232).
Ammonites in sandy shale.
Ironstone rich in *Lamellibranchs* (loc. 230).
Green slabby sandstone.</td><td rowspan="5">Massive beds of dark sandy shales, with other rocks as detailed.</td><td rowspan="5">805</td></tr>
<tr><td>Dark shales and finegrained thin-bedded sandstones; thick bands of ferruginous sandy limestone and siderite.
Lamellibranchs and *Ammonites*.</td><td>153</td></tr>
<tr><td rowspan="3">Lower Valanginian.</td><td>Alternations of grey shales and fine-grained sandstones, with harder grey sandstones at intervals.</td><td>136</td></tr>
<tr><td>Intercalations of shale in light grey sandstones.
Lamellibranchs and *Ammonites*.
Sandstones free from shale towards base.</td><td>104</td></tr>
<tr><td>*Lamellibranchs* and *Ammonites* in upper beds.
Alternating shales and sandstones.</td><td>348</td></tr>
<tr><td>Upper Aquilonian?</td><td>Black and dark grey shales.</td><td>68</td><td rowspan="2">Fossil tree trunk (loc. 234)
Lamellibranchs in ironstone (loc. 229).</td><td rowspan="2">Dark shales with occasional thin bands of ironstone.</td><td rowspan="2">140</td></tr>
<tr><td></td><td>Black and grey sandy shales with ironstones containing a rich *Lamellibranch fauna*.</td><td>49</td></tr>
</table>

Table of Strata on North Side of Whales Bay—continued.

	Mt. Zinger (Obruchev).		Whales Head Mt. (Tyrrell).	
	Lithology and Fossils.	Thick-ness in Feet.	Lithology and Fossils.	Thick-ness in Feet.
Middle Aquilonian.	Dark grey calcareous shales with mica; every 6–10 feet thin lenticular beds of grey calcareous sandy shale with worm remains (*Ditrupa*).	380	Escarpment of plant-bearing shaly sandstone. Dark shales with occasional thin beds of hard yellow ferriferous shale.	150
			Dark shales with lines of ironstone lenticles.	230
	Black and dark grey shales with ironstones every 6–10 feet; often beds of yellow ferriferous sandstone. Worm remains (*Ditrupa*).	172	Purple and grey shales with numerous lines of ironstone nodules. "Red Horizon."	200
	Shales predominate in upper part. Dark grey, platy, fine-bedded sandstones with occasional interbeds of shale. Sparse *Unio* and rare *Pecten*.	244	Alternating grey sandstones, black shales, and sandy shales.	130
			Scree.	
Continental Series.	Six-foot bed of sandstone in upper part. Grey shales, partly sandy.	146	Dark calcareous shales.	358
	Thin-bedded sandstones alternating with sandy shales. *Plant remains* and coal seams about middle of bed, and at base.	202	Escarpment of dark sandy limestone.	12
	Thick-bedded quartz-sandstone, coaly.	32	Limy sandstones and nodular limestones. Black and micaceous shales with coaly streaks and lumps, and plant remains.	30 +
(Lower Aquilonian. to Upper Portlandian.)	Dark grey clayey sandstone with shales; black micaceous sandstone at base.	56		
	White and light grey thick-bedded quartz sandstone; conglomerates at base. Rest on eroded surface of Portlandian.	65		
Middle Portlandian.				

Obruchev relegates the succession in the mountain block north of Whales Bay to horizons between the Middle Portlandian (Upper Jurassic) and Upper Neocomian (Lower Cretaceous), and places the "Continental Series" well below the Valanginian. This, however, is seriously discrepant with results obtained in the west of Spitsbergen, and latterly in Agardh Bay, where a well-known Continental Series occurs above the Lower Valanginian. It is fairly certain that the Continental Series which caps Mt. Agardh (20, p. 279) is the same as that which occurs at the base of the Whales Bay mountain block. There is consequently conflicting palæontological evidence the bearing of which is discussed by Dr J. Weir in the palæontological Appendix (p. 695).

Along the coast to the north of Whales Head Mt. Mr J. M. Wordie found that a coarse white quartzite appeared and continued some miles to the northward. This bed was about 6 feet thick, and was approximately 640 feet below the base of the "Red Horizon" (stratigraphical table, p. 679). A yellow sandstone which formed tors on the beach and stacks out to sea occurred 80 feet below the white quartzite. These strata are doubtless to be correlated with the sandstones at the base of the Continental Series in Obruchev's section (table, p. 679), and with the sandstone horizon which occurs at 1185 feet above sea-level in Rurik's Forberg 30 miles farther north (p. 680).

Cape Dufferin.—Cape Dufferin is the promontory on the northern side of the Inglefield Glacier, and may also be regarded as the southern horn of Agardh Bay (map, fig. 1). Behind it rises the tabular mountain known as Rurik's Forberg.* The section in this mountain is given in the following table. The great vertical scarp of sandstone at 1185 feet is undoubtedly the base of the Continental Series which occurs at the foot of the Whales Bay mountain block. This horizon is correlated with the Fastnings (or Festung) Sandstone of the western sections at Green Harbour (Frebold, 18), and with the Fastnings Sandstone of Hagerman's sections in the region between Agardh Bay and Van Mijens Bay (14, p. 203). Hagerman states that the Fastnings Sandstone forms the summit of Mt. Klementjeff, 6 miles N.N.W. of Rurik's Forberg (14, p. 200). Mr J. M. Wordie found fossilized tree trunks in strata at 1500 feet above sea-level in the mountain immediately north of Rurik's Forberg, and just south of the Balt Glacier. These have been described by Professor J. Walton (16).

Section of Rurik's Forberg, Cape Dufferin, Agardh Bay.

Lithology.		Thickness in Feet.	
Summit of mountain, 1830 feet above sea-level. White-weathering, dark red ironstone at 1625 feet.	Thin-bedded sandstones, alternating with red ferriferous shales, 1615–1830 feet.	215	Continental Series, 645 feet.
Thin-bedded yellow sandstone, 15 inches thick at 1540 feet. Rusty-weathering grey sandstone, 1 foot thick at 1500 feet. Cannel coal, 4 inches thick at 1465 feet. Plant bearing clay-ironstone at 1440 feet, 1 foot exposed. Thin-bedded carbonaceous sandstone, 10 feet exposed, at 1390 feet.	Alternating thin-bedded grey and yellow shales, sandstones, and plant-bearing ironstones, 1295–1615 feet.	320	
Vertical scarp of yellow and white sandstones, coarse, gritty, conglomeratic in places, and full of carbonized plant remains.	Fastnings Sandstone, 1185–1295 feet.	110	
Grey and black pyritous shales, with thin beds of clay-ironstone nodules. Fossils—ammonites, lamellibranchs, crinoids, fish-scales, and plant remains. 100–1185 feet. Kimmeridgian ammonite found below 1000 feet.		1085	Aucella Shale.
Dolerite sill, 0–100 feet.		100+	

* See maps in G. de Geer (10) and in Hagerman (14).

No fossils were found in the upper part of the mountain save poorly-preserved plant remains, which Dr H. HAMSHAW THOMAS has provisionally determined as cf. *Eretmophyllum* sp. and cf. *Phœnicopsis* sp. The total thickness of the strata between the base of the Fastnings Sandstone and the top of the mountain is 645 feet; and as the thickness of the Continental Series is 745 feet according to OBRUCHEV, this series must continue to the top of Rurik's Forberg. The details of the section are given in the table on p. 680.

Some miles farther north Professor K. GRIPP made a reconnaissance on the mountain north of the Rurik Valley (19, p. 238). This must be Mt. Klementjeff (2428 feet) of G. DE GEER's map (10), which is known to be capped by the Fastnings Sandstone. At a height of 200 m. (656 feet) he found a scarp of hard sandstone upon which rested a closely-packed conglomerate of sandy phosphorite, pebbles of Permo-Carboniferous cherts, etc., containing fossils which prove it to represent the basal conglomerate of the Jurassic. From the fossils of the conglomerate and associated beds FREBOLD regards it as of Upper Lias age (20, p. 256). The conglomerate was overlain by yellow clay-ironstone, which formed a terrace feature on the hillside. Following this terrace eastward Professor GRIPP found a faulted overfold disturbance by which the beds were let down approximately 1200 feet. This disturbance, trending northward, is continuous with a similar disturbance which was found by GRIPP on the northern side of the Agardh Valley. The strata to the east of the fold line were found to incline gradually to the east until the top of the Trias disappeared below sea-level a few hundred metres east of the Rurik Valley.

Agardh Bay and Region to the North and West.—On 6th August 1919 the writer landed on the northern shore of Agardh Bay near Fox Ness, but owing to lack of time was only able to ascend Mt. Agardh to a height of 415 feet. At the landing-place there was a section in horizontal, thin-bedded, yellow, pyritous sandstones, with occasional layers full of plant fragments. These sandstones form a platform at about 80 feet above sea-level, which the writer took for a ledge of marine erosion; Professor GRIPP (19, pp. 241–42), however, regards it as an erosion terrace due to more rapid weathering of the soft Jurassic shales which overlie it. As GRIPP found the basal phosphoritic conglomerate of the Jurassic in fragments lying upon this erosion terrace, the sandstone must belong to the Upper Trias. GRIPP found sandstones with clay-galls and plant-remains below the basal Jurassic conglomerate on the northern side of the Rurik Valley, south of Agardh Bay (19, p. 238). The writer found water-worn fragments of hard, dark-grey quartzite, chocolate-coloured sandstone, chert, etc., which doubtless came from the basal Jurassic conglomerate.

At the inner (northern) edge of the sandstone platform there are loose, crumbling, red and yellow sandstones interbedded with paper shales, the whole dipping east at a very small angle. A scree of disintegrated paper shale occurs up to 270 feet above sea-level, where there is a thin bed of red-crusted ironstone. Then come more black shales with intercalated grey, calcareous, thin-bedded shale, forming a slight feature on the hillside. At 310 feet the shale contains numerous lamellibranchs (*Aucella bronni*, etc.), and at 400 feet again numerous lamellibranchs (*Aucella* sp.), together with ammonites which Dr L. F. SPATH has kindly identified as *Amœboceras nathorsti* Lundgren and *Rasenia* sp., and regards as of Lower Kimmeridgian age. Numerous indeterminable fragments of Belemnites also occur at this horizon. At 415 feet occurs a bed of hard calcareous shale.

A section of Mt. Agardh made by Professor GRIPP, and interpreted on the basis of its fossils by H. FREBOLD, is given in fig. 2, I (20, pp. 270–80, pl. i, fig. 3). The section given by OBRUCHEV (15, p. 67) is shown in a parallel column (fig. 2, II). While these sections are concordant as regards their lower halves, FREBOLD found Valanginian fossils below the down to form the northern part of the plateau summit. This section has also been observed by Professor GRIPP (19, p. 242).

Mt. Johannsen, Mohn Bay.—On the south side of Mohn Bay a small glacier, the Usher Glacier, runs parallel with the northern scarp of Mt. Johannsen. The writer visited this locality on the 6th August 1919, and again on 13th August 1920, and tabulated two sections of the northern scarp, one within a mile of the shore, the other about 3 miles west of the coast. The first of these sections shows the basal conglomerate of the Jurassic with pebbles of black chert, fine-grained conglomerate and phosphatic concretions * at a level of about 640 feet. This identification is rendered quite certain by the discovery of black paper shales with Lower Kimmeridgian ammonites 200 feet above this horizon (loc. 210). The Kimmeridgian shales do not occur in the western section as a rise in the strata takes them above the level of the top of the plateau; but in the stratigraphical table (p. 684) correlation is effected between beds of rusty-weathering coarse sandstones at 995 feet and 625 feet respectively in the two sections.

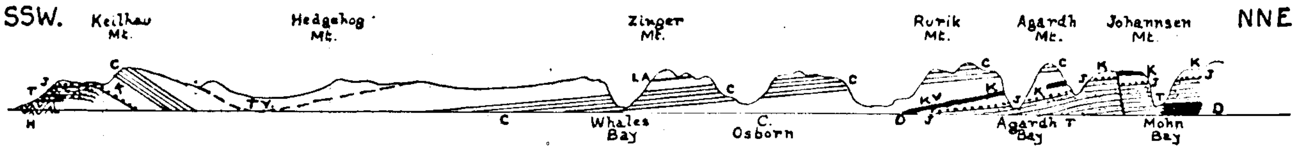

FIG. 3.—General section of coast from South Cape to Mohn Bay along western side of Stor Fjord. Vertical scale greatly exaggerated. The plateau and mountain tops rise to about 2000 feet above sea-level. H, Hecla Hoek Series; T, Trias; J, Jurassic basal conglomerate; K, Lower Kimmeridgian; KV, Lower Volgian; C, Continental Series; TY, Tertiary; LA, Lower Aptian; D, dolerite sill.

In the table (p. 684) the figures on the left hand of each column represent the heights of the bases of the strata groups above sea-level. The horizontal line marks the junction of the Jurassic above with the Triassic below.

Krogh Berg, the mountain flanking the Usher Glacier on the north, consists (GRIPP, 19, p. 242; FREBOLD-GRIPP, 20, p 257) of sandstones and shales of the Upper Trias, containing clay-ironstones, and dolomitic layers rich in lamellibranchs. Near the summit, towards the western side of the mountain, Professor GRIPP found the fossiliferous Jurassic basal conglomerate, which is overlain by yellow sandstone. He surmised that the Jurassic basal conglomerate should be found in the strata which dip to the east on the northern flank of Mt. Johannsen where, in fact, it was found, but not recognised as such, by the writer in August 1919.

Summary of Stratigraphical Results on Western Coast of Stor Fjord.—New detailed sections have been compiled at Mt. Keilhau, Whales Bay, Cape Dufferin, Agardh Bay, and Mt. Johannsen. Observations at these points have been summarized by means of a general section along the coast from South Cape to Mohn Bay (fig. 3). This section clearly exhibits the main structural feature as an asymmetrical syncline, the centre of which is occupied by the Tertiary strata at Davis Harbour. The axis of this syncline appears to run in a north-westerly direction, and probably coincides with the synclinal axis which emerges on the southern coast of Ice Fjord near Advent Bay. The short southern limb of the syncline dips much more steeply than the longer northern limb. A further section (fig. 4) from Whales Bay to Mohn Bay illustrates the detailed succession and structure of the northern limb.

Amongst the new stratigraphical data recorded in this part of the paper are the discovery of the phosphoritic Jurassic basal conglomerate on the south side of Mohn Bay, of Lower Kimmeridgian and probably Upper Oxfordian at Agardh Bay and Mohn Bay, and of Lower

* I am indebted to my colleague, Miss A. T. NEILSON, M.A., for chemical confirmation of the presence of phosphorus in this conglomerate.

Continental Series which caps Mt. Agardh, whilst OBRUCHEV relegates this horizon to the Middle Portlandian. There is consequently a serious discrepancy in observation, the cause of which is still unsolved. My section, so far as it goes, agrees with both the above. FREBOLD, however (20, p. 275), regards *Amœboceras nathorsti*, or, as he calls it, *Cardioceras nathorsti*, as indicative of the Oxfordian in Spitsbergen. This fossil was not found by the Gripp Expedition on Mt. Agardh, but the presence of Oxfordian was rendered almost certain, in FREBOLD's opinion, by the occurrence of paper shales, which contain *C. nathorsti* in the Festungs profile at Green Harbour, on Mt. Agardh, in the correct stratigraphical position. My discovery of *C. nathorsti* at 400 feet above sea-level would therefore be regarded by FREBOLD as fully confirmatory of the presence of Oxfordian (or Lower Kimmeridgian) on Mt. Agardh.

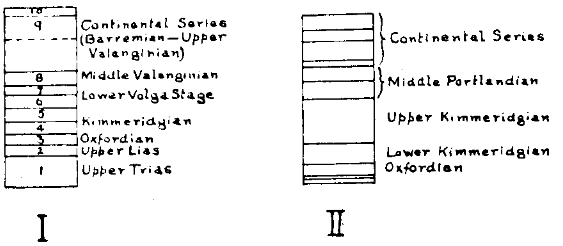

FIG. 2.—Comparison of sections of Mt. Agardh by GRIPP and FREBOLD (20, pl. i, fig. 3) and OBRUCHEV (15, p. 67). See text, p. 681. The numbers on the left-hand column are those attached to the formations by GRIPP.

Professor GRIPP found a striking downfold to the east in the nameless mountain which occurs between Mt. Roslagen and the Eistra Valley, on the northern side of the great Agardh Valley, some miles east of Mt. Agardh (19, p. 238). Middle Triassic rocks dip gently to the west on the western side of this disturbance. To the east the Upper Triassic strata are brought down to a lower level, and an eastern dip finally brings the Jurassic down to near sea-level. The above fold is the northward continuation of the faulted overfold which was found on the south side of the Agardh Tundra in Mt. Klementjeff (p. 681).

Mr A. STEVENS, M.A., B.Sc., who crossed from Sassen Bay to Agardh Bay in August 1919 with two colleagues, and made some geological notes, collected ammonites on Mt. Holmgard (west of Mt. Agardh) at 870 feet and 1000 feet above sea-level. These have been identified by Dr L. F. SPATH as Perisphinctids ("*Virgatites*") sp. indet., indicating probably a Kimmeridgian horizon. The Kimmeridigan occurs at a lower level on Mt. Agardh (fig. 2), and the above discovery is thus in harmony with the observed rise of the strata west of Mt. Agardh. Mr STEVENS also found that Mt. Agardh was capped by a massive sandstone, beneath which lay a thick series of black carbonaceous shales with thin bands of ironstone. A notable change of colour in the strata from dark to light is observed in Professor GRIPP's photograph of Mt. Agardh (20, pl. i, fig. 3) at the level marked by a broken line in section 1, fig. 2, of this paper. This level probably marks the top of the black shales noted by Mr Stevens.

In the hills which border the coast east of Mt. Agardh the sandstone scarp of the Continental Series is seen about two-thirds of the way up to the summits, showing that the easterly dip continues to the coast. Rounded blocks of yellow sandstone are strewn on the hillsides. Near Duner Bay the strata begin to rise towards the north, thus bringing in lower beds. On the north side of Duner Bay Professor GRIPP found that the slopes of the plateau were in sandstones of the Upper Trias, whilst at the top the phosphorite-bearing basal Jurassic conglomerate was found, overlain by dark ironstone-rich Jurassic shales. The tabular mountain which intervenes between Duner Bay and Mohn Bay is known as Mt. Johannsen. A section along the coastal slopes of this mountain as seen from the sea is given in fig. 4. It shows the Upper Trias sandstones to the south underlain by black shales, and interrupted midway by a fault which brings down Jurassic rocks to a lower level. A dolerite sill which is consistently found with the Jurassic shales from Cape Dufferin northwards is brought

Tabular Summary of Triassic and Jurassic Strata on Northern Flank of Mt. Johannsen, Mohn Bay.

Feet.	Section 1 Mile from Coast.	Feet.	Section 3 Miles from Coast.
880	Base of dolerite sill.		
	Black paper shales with Lower Kimmeridgian ammonites.		
795	Black carbonaceous shale.		
680	Scree of black shale.		
640	Scree with orange-weathering sandy limestone, becoming sandstone below, and with conglomerate at base (basal conglomerate of Jurassic).		
	JURASSIC		
	TRIASSIC		
630	Purple and grey shales.	995	Rusty-weathering grey carbonaceous sandstone on hilltop projecting through ice.
625	Coarse rusty sandstone, bed 5 feet thick (correlated with 995 feet in opposite section).		
585	Grey and green carbonaceous sandstones.		Ice.
545	Blue shales with red ironstone bands.		
530	Grey and green sandstone.	865	Base of ice carapace.
480	Blue and grey shales, with ironstone bands containing small lamellibranchs (loc. 208).	845	Grey sandy shale, with bed of red ironstone.
		805	Red and bluish shales with ironstone bands and nodules.
430	Grey, green, and blue shales with intercalations of thin-bedded rippled sandstones.		
	Grey sandstone.		
410	Laminated sandy shales.		
405	Grey-green thin-bedded sandstones, 5 feet thick.		
		765	Calcareous and ferruginous band.
320	Thin-bedded sandstones.	695	Grey, blue, and green sandy shales alternating with blue shales.
		685	Bluish sandy limestone, with broken lamellibranch shells.
		650	Blue sandy shale.
			Light green sandy shale.
	Scree.	635	Green and blue sandy marl.
		610	Thin-bedded argillaceous limestone.
		562	Blue shales with thin calcareous beds, and a bed of coarse green felspathic sandstone at 580 feet.
		560	Limestone 2 feet thick, with 6-inch shelly band.
		555	Thin-bedded sandstone, rippled and mud-cracked.
		530	Blue mudstone, with limy interbeds.
		525	Blue sandy limestone, 2 feet thick.
			Grey sandy shales.
		515	Rusty clay-ironstone, 1 foot thick.
		510	Grey sandy shale.
		495	Blue pyritous shale.
		450	Rusty-weathering bluish limestone, 5 feet thick, interbedded with greenish sandstone.
		420	Thin-bedded and false-bedded greenish rusty-spotted sandstone, with argillaceous interbeds.
			Scree for 235 feet.
		185	Grey carbonaceous platy sandstone and blue shale with a plant-bearing ironstone.
		120	Hard blue and grey calcareous shales, with micaceous and arenaceous interbeds containing plant remains.

Volgian at Cape Dufferin. The existence of the Continental Series at Mt. Keilhau and at Cape Dufferin, and of Aptian and Albian strata at Whales Bay, have been established. The observations on the Lower Cretaceous strata at the last-named locality afford some support to FREBOLD's determination of the age of the Continental Series as Lower Cretaceous, in opposition to OBRUCHEV's view that it is of Upper Jurassic age (see the discussion of this question by Dr J. WEIR, p. 695).

Barents Island.—I have not been able to discover any stratigraphical sections from Barents Island in the literature. Hence the following observations are all new.

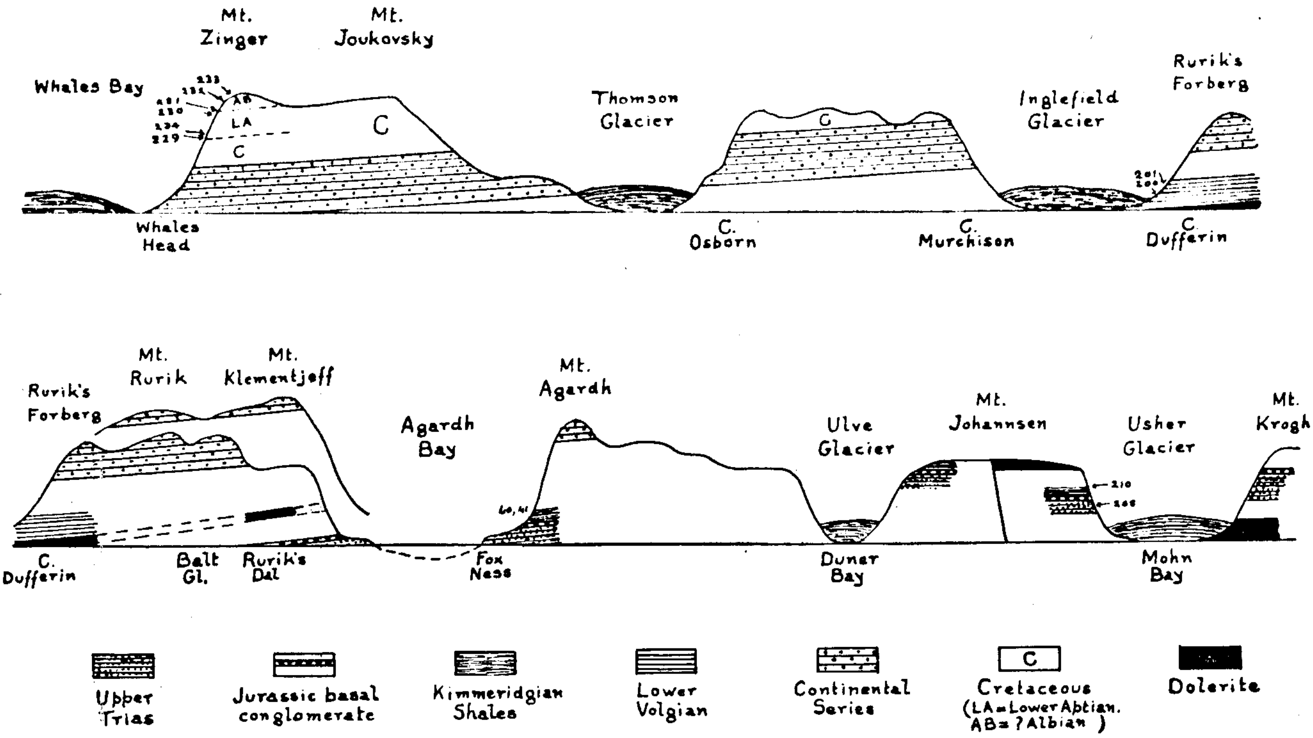

FIG. 4.—Detailed section of western coast of Stor Fjord from Whales Bay to Mohn Bay. Vertical scale greatly exaggerated. Heights of plateau and mountain tops in general about 2000 feet. The numbers attached to the profile indicate the fossil localities referred to in the text.

Strata of the Upper Trias occur at Changing (Forväxling) Point at the north-western corner of Barents Island. The beds consist of alternating arenaceous and argillaceous sediments, the arenaceous types including micaceous and arkosic varieties, the argillaceous blue, black, and brown bituminous shales, with limy and sandy intercalations and nodular red ironstones full of lamellibranchs and small ammonites (locs. 53, 60; see p. 691). The fossils obtained were *Nathorstites* sp. and *Halobia zitteli,* with Ostracoda in some layers.* These are regarded by Dr L. F. SPATH and Dr J. WEIR as a Lower Neo-Trias or Carnian assemblage.

The structure of the peninsula, as seen in a traverse from S.W. to N.E., is a flat anticline broken by several small faults. An enormous dolerite dike bounds the peninsula on the south,† and another but much smaller dike cuts the strata near the coast about two miles north of the large dike.

A few miles to the south of Changing Point, towards the northern side of Vossen Bay, the following section was measured:—

* My colleague, Miss M. LATHAM, M.A., kindly examined the Ostracoda, but found them too poorly preserved for exact identification.

† G. W. TYRRELL and K. S. SANDFORD, "Geology and Petrology of the Dolerites of Spitsbergen," *Proc. Roy. Soc. Edin.*, vol. liii, 1933.

Table of Strata in Coastal Cliff, North Side of Vossen Bay.

Feet.		
695	Sandy limestone, with interbeds of shale above.	
	Shales in scree.	
680	Sandstone, 2 feet exposed.	
	Shales in scree.	
640	Calcareous sandstone, a few feet exposed.	
	Grey and blue shales in scree.	
575	Calcareous sandstone, a few feet exposed.	
445	Grey and blue sandy shale with thin sandstone beds at intervals. Fissile sandstone with fossil shells at 520 feet (WORDIE)	130 feet.
435	Thin-bedded green sandstone	10 „
415	Blue sandy shale	20 „
385	Thin-bedded rusty-weathering grey-green sandstone with shaly intercalations in the lower half. Ferruginous nodules and plant remains in upper half (WORDIE)	30 „
340	Grey and blue shales with thin oil-shales and a 2-inch-thick cannel coal. Poorly exposed	45 „
185	Thin-bedded laminated micaceous sandstone, with much contemporaneous contortion, false-bedding, ripple-marks, shale-flakes, and indeterminable plant remains. Shale beds become abundant towards the top. This is the thick prominent escarpment in the section	155 „
125	Blue shale, with some bituminous bands	60 „
110	Grey feldspathic thin-bedded sandstone, with some intercalations of shale	15 „
65	Grey shale, with thin sandstone intercalations towards top	45 „
50	Thin-bedded sandstone, with intercalations of shale	15 „
	Scree with blocks of fragmental shelly limestone.	

(The figures on the left-hand side of the table represent the heights of the *bases* of the respective groups of strata above sea-level. Those on the right-hand side record the thicknesses.)

Although no identifiable fossils were collected from this locality there can be little doubt but that the strata must be assigned to the same Upper Triassic horizon as those of Changing Point. A fault with a downthrow of 95 feet to the south occurs in the section, according to observations by Mr J. M. WORDIE.*

A further section was measured in the coastal scarp immediately north of the Duckwitz Glacier, with the results given in the table below:—

Table of Strata in Coastal Scarp on North Side of Duckwitz Glacier.

Feet.		
1195	Fissile sandstone. Top of scarp.	
1160	Grey-green sandy shale, with intercalations of fissile sandstone	35 feet.
1025	Scree with fragmentary exposures of: Fissile sandstone, Calcareous sandstone with fragmentary shells, Blue shale, Crumbling rusty-weathering sandstone; named in order downwards.	
1010	Thin-bedded sandy limestone, false-bedded, weathers into large spherical and discoidal concretionary forms	15 „
890	Scree, with blue shale.	
865	Fissile, rusty-weathering grey sandstone, with carbonaceous layers; false bedded	25 „
835	Blue shale, with thin central intercalation of fissile sandstone	30 „
820	Fissile sandstone, as above	15 „
800	Scree, with blue shale.	
765	Fissile sandstone, as above	35 „

* See profile section in TYRRELL and SANDFORD, *op. cit., supra.*

Table of Strata in Coastal Scarp on North Side of Duckwitz Glacier—continued.

Feet.		
680	Scree, with blue shale.	
620	Fissile sandstone as above, with shale intercalations towards base	60 feet
515	Blue shale, mostly in scree, ironstone horizons with lamellibranchs near base (loc. 214)	105 ,,
495	Fissile sandstone as above, with ripple-marks and shale-flakes	20 ,,
450	Scree, with blue shale.	
445	Brown bituminous limestone, with small nodules of ironstone	5 ,,
330	Brown and blue bituminous shale, resistant, forms blocky escarpments. Occasional paper-shales, and sandy or calcareous beds. Fossils—fish-scales, lamellibranchs, and plants	115 ,,
	Scree and raised beach material.	
120	Top of dolerite sill.	

(The figures on the left-hand side of the table represent the heights of the *bases* of the respective groups of strata above sea-level. Those on the right-hand side record the thicknesses.)

The strata consist chiefly of alternations of blue shales and fissile sandstones, with a thick horizon of bituminous shale at 330 feet above sea-level. The whole series, including the dolerite sill, dips towards the E.N.E. at angles from 5 to 10 degrees. Hence, probably, lower horizons are exposed in this section than at Vossen Bay farther north. It may be that the calcareous sandstone with fragmentary shells near 1100 feet in this section is to be correlated with the fragmental shelly limestone found in the scree below 50 feet in the Vossen Bay section. There are, however, other horizons of shelly limestone, often somewhat arenaceous, as, for example, that which occurs below a thick shale with sphærosiderite horizons at Cape Lee, Edge Island (see p. 688). The only identifiable fossil found in the Duckwitz Glacier section is *Halobia zitteli*, and Dr WEIR has therefore assigned it to the Lower Neo-Trias (Carnian). To the south of the Duckwitz Glacier the main horizon of bituminous shale can be seen faulted and intersected by a thin dolerite sill.*

Edge Island.—Two landings were made at Cape Lee at the north-western corner of Edge Island, and three sections were compiled, the results of which are shown in fig. 5. The strata consist mainly of shales, with occasional thin beds of limestone and calcareous shale, alternating with thinner strata of slabby sandstones which are often calcareous. A constant horizon of shelly limestone at heights of 345, 420, and 425 feet respectively in the three sections contains lamellibranchs which are mostly broken into small pieces, but amongst which Dr WEIR has identified *Gervilleia* sp. juv. Zones of fossiliferous sphærosiderite nodules occur in the shales about 100 feet above this horizon from which Dr SPATH and Dr WEIR have identified ammonites and lamellibranchs of Lower Neo-Trias or Carnian age (p. 691).

Some of the shale bands are tough and bituminous, and weather in blocky fashion, giving rise to fairly prominent escarpments which can be easily followed along the hillsides. Thus, the thick shale with sphærosiderite nodules between 350 and 600 feet above sea-level (see sections B and C, fig. 5) can be traced along the northern coast of Edge Island towards the east. In this direction the strata at first rise gently, and a new escarpment of shale gradually comes into view near sea-level. This is undoubtedly the thick shale below the dolerite in section A, fig. 5, which is usually obscured by scree. A broad open valley running to the south occurs just west of Mt. Middendorf on the north coast, and near it the strata begin to dip towards the east, thus producing a flat anticlinal structure. A corresponding flexure in the same beds is seen in the coastal scarps of Barents Island on the opposite (northern) side of Freeman Strait.

Followed to the south along the west coast of Edge Island the prominent escarpment of

* See profile sections in TYRRELL and SANDFORD, *op. cit.*, *supra*.

shale mentioned above continues as far as Cape Blanck, and appears to be absolutely horizontal. Near Cape Blanck the dark shale is succeeded above by a considerable thickness of light-coloured beds with numerous hard bars. These probably represent the successive beds of limestone and sandy limestone which appear in the same relative position in section B (fig. 5)

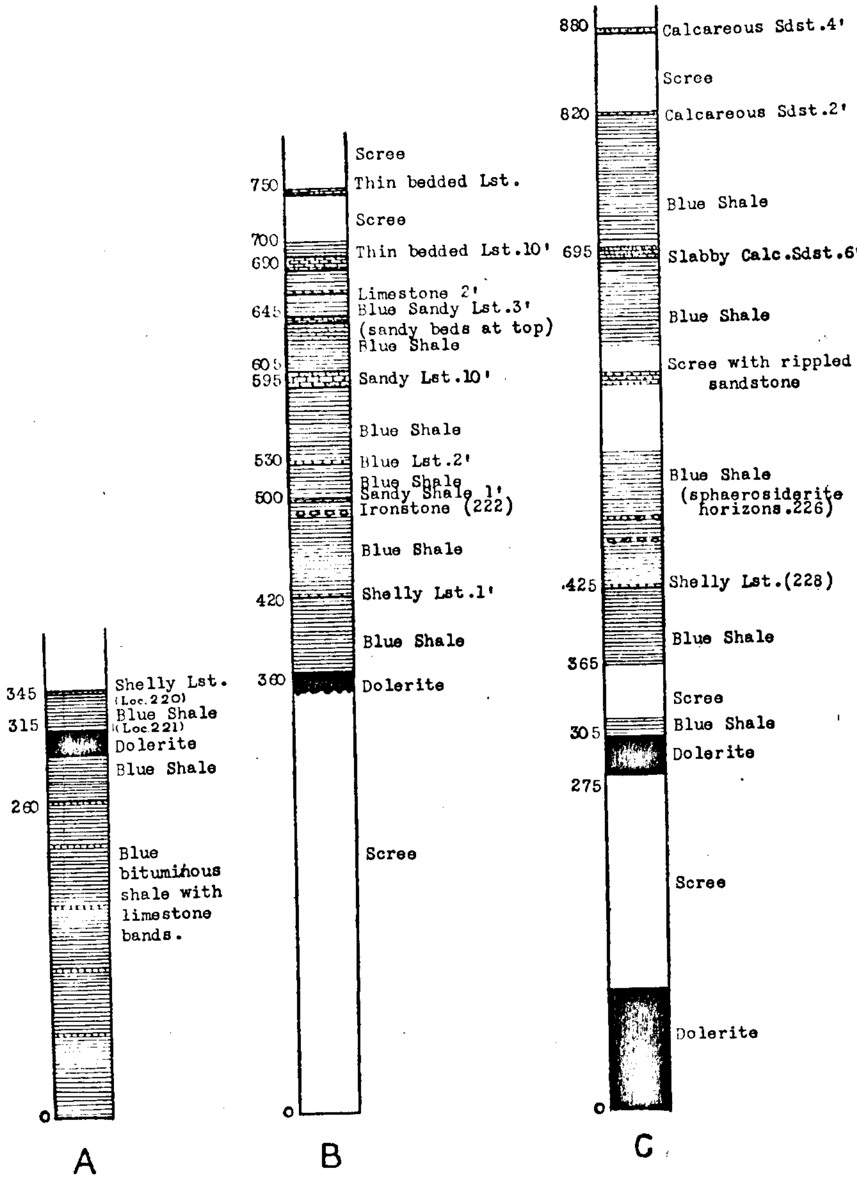

FIG. 5.—Comparative sections of Triassic strata near Cape Lee, Edge Island. A, section at gorge and waterfall half a mile E. of small bay; B, section on western side of small bay N.E. of Cape Lee; C, section from shore to Russian cairn, Cape Lee. Figures on left-hand of sections indicate heights above sea-level. Fossil localities indicated by numbers on right-hand sides of sections.

above 595 feet. Farther south the main dark shale horizon is seen to continue at approximately the same level (between 350 and 600 feet) all round Disco Bay. On the south side of the bay a thick prominent scarp of yellowish colour (? sandstone) comes in about 500 feet above the shale horizon.

The only geological observations on Edge Island subsequent to mine were made by N. L. FALCON during the late H. G. WATKIN's expedition of 1927 (17). Mr FALCON distinguished three series of rocks in ascending order: (*a*) oil-shale series with occasional limestone bands; (*b*) blue and purple shales with bands of ferruginous limestone and ironstone nodules;

and (*c*) a sandstone and shale series consisting of fissile sandstones alternating with sandy shales. It will be seen that this subdivision corresponds exactly with the detailed sections from Cape Lee (fig. 5). Mr FALCON found reptilian remains in the oil-shale series near the Kuhr Glacier (Deevie Bay) and at Cape Lee. I also found a single badly-worn reptilian vertebra in the blue bituminous shales of the section N.W. of Cape Lee (fig. 5, A). Beds of Rhætic age are stated to occur high up in the succession at Cape Lee, and Jurassic fossils have been found in the sandstones and shales of the highest series at Whales Point and Negro Point (6*a*).

ACKNOWLEDGMENTS.

Thanks are due to Dr L. F. SPATH and Dr J. WEIR for their palæontological determinations, and to Dr J. WEIR in particular for the Appendix dealing with the fossils and their stratigraphical implications. Professor J. WALTON and Dr H. HAMSHAW THOMAS have kindly given their opinions on the palæobotanical material. The author is also indebted to Mr J. M. WORDIE and Mr A. STEVENS for their kind permission to include some observations made by them in this paper, and to his colleagues Miss A. T. NEILSON and Miss M. LATHAM for assistance on special points. Acknowledgments are due to the Carnegie Trust for the Universities of Scotland for a grant towards the cost of the illustrations of this paper.

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APPENDIX.

MESOZOIC FOSSILS FROM SPITSBERGEN COLLECTED BY DR G. W. TYRRELL.

By J. WEIR, Ph.D., D.Sc., F.G.S.

Dr TYRRELL'S collection comprises Upper Triassic, Jurassic, and Lower Cretaceous fossils from the east coast of Spitsbergen. It is unnecessary to give a detailed bibliography or historical account of previous palæontological research on the Spitsbergen Mesozoic. That has been done exhaustively in the recent works of FREBOLD (23) and SOKOLOV and BODYLEVSKY (23*a*). Reference may be made, however, to publications of FREBOLD (20), OBRUCHEV (15) and GIRMOUNSKY (15*a*), that deal particularly with the Jurassic and Cretaceous of the East Coast.

In the following pages species are recorded under the locality numbers used by Dr TYRRELL in the preceding stratigraphical paper. The chronological value of the assemblages is discussed under the locality headings, and brief notes on the material, with figures of certain fossils, illustrate the nature of the evidence.

The ammonite determinations were made by Dr L. F. SPATH, to whom Dr TYRRELL and the writer desire to express their cordial thanks.

Triassic.

With the exception of loc. 208 on Mt. Johannsen all the Triassic localities occur either on Barents Island or on Edge Island, and the fossils indicate a Lower Neotriassic (Carnian) age.

Barents Island.

Loc. 53. Second gully on shore, 1 mile N.E. of Changing Point:
Nathorstites sp. juv.; *Halobia zitteli* Lindstr.

Loc. 60. Hillside, 295 feet above sea-level, 2 miles N.N.E. of Changing Point:
Nathorstites sp. juv.; *Halobia zitteli* Lindstr.

Loc. 214. N. side of Duckwitz Glacier, 515 feet above sea-level:
Halobia zitteli Lindstr.

Edge Island.

Loc. 220. Shelly limestone, bituminous shale series, at 345 feet above sea-level, gorge in small bay N.E. of Cape Lee:
Indeterminable lamellibranchs.

Loc. 221. At 315 feet above sea-level (below loc. 220), bituminous shale series, etc.:
Cladiscites ? sp.; *Nathorstites* spp. cf. *concentricus* (Öberg); *Halobia zitteli* Lindstr.

Loc. 222. Sphærosiderite horizon, about 500 feet above sea-level, about ½ mile west of above:
Halobia zitteli Lindstr.

Loc. 226. Sphærosiderite horizon, about 500 feet above sea-level, Cape Lee:
Nathorstites concentricus (Öberg) (Pl., fig. 17) and several *Nathorstites* sp. juv.; *Halobia zitteli* Lindstr. (Pl., fig. 11); *Daonella* cf. *dubia* (Gabb); *Pseudomonotis* (*Eumorphotis*) *tschernychewi* Wittenburg.

Loc. 228. Bituminous shale, about 60 feet below base of sphærosiderite horizon, Cape Lee:
? *Gervilleia* sp. juv.

Mt. Johannsen.

Loc. 208. N. face of Mt. Johannsen, about 500 feet above sea-level and 160 feet below the basal Jurassic conglomerate:
Estheria minuta (Alberti) (Pl., fig. 2).

Notes on certain Triassic Fossils.

Pseudomonotis (*Eumorphotis*) *tschernychewi* Wittenburg.

(Pl., figs. 3 and 8.)

Pseudomonotis (*Eumorphotis*) *tschernychewi* Wittenburg. "Triasfoss. v. Spitzbergen," *Trav. Mus. géol. Pierre-le-Grand. Acad. Sci. St. Pétersbourg*, tome iv, 1910, p. 34, pl. i, fig. 1.

This species is represented by two specimens from loc. 226. One specimen (fig. 8) is an impression in ironstone of the umbonal region of a left valve, with pyritised remains of the test adhering. The ornament consists of radial ribs disposed according to magnitude in the regular arrangement indicated by Wittenburg. In Wittenburg's specimen (a left valve) the external ornament is eroded in the umbonal region, and he naturally assumed that all the strongest ribs in the marginal parts of the valve were of the first order. The arrangement of the ribs in Dr Tyrrell's first specimen suggests that in the umbonal region Wittenburg's twenty ribs of the first order can be further subdivided into two orders: the complete rib formula therefore reads 1443442443441.

The second specimen (fig. 3) is a left valve in black papery shale. The external surface is applied to the matrix, and the exposed internal surface shows the same ornament as the eroded umbonal region in Wittenburg's figure—*i.e.* closely-set dichotomous radial ribs of one order, reticulated by closely-set growth lines.

Daonella cf. *dubia* (Gabb).

(Pl., fig. 22.)

The fragmentary impression (reversing ribs and interspaces) of a *Daonella* from papery shales at loc. 226 may be compared either with *Daonella dubia* (Gabb) * or *D. lindströmi* Mojs.† A final determination is not possible as the entire ventral margin is absent. I have preferred to record it as *D.* cf. *dubia*, because the primary furrows are not so strong as in *D. lindströmi*, more closely resembling in depth those of Gabb's form.

Daonella dubia and *D. lindströmi* are generally regarded as Anisian. The association of the present specimen with *Halobia zitteli* and Carnian ammonites suggests that those species may have a longer range than hitherto attributed to them, or that they may be represented at horizons higher than Anisian by mutants that, within a radius of about 18 mm. from the umbo are indistinguishable from the Anisian form.

JURASSIC.

The Jurassic fossils all come from the west coast of Stor Fjord. Two distinct faunas are present —a Lower Kimmeridgian from the N. side of Agardh Bay, and a Lower Volgian from Cape Dufferin and Rurik's Forberg. Upper Oxfordian may also be present on the N. side of Agardh Bay and the N. face of Mt. Johannsen.

The fossils from these horizons with exact details of location and comments on the assemblages are indicated below.

UPPER OXFORDIAN OR LOWER KIMMERIDGIAN.

Loc. 40. From shale 310 feet above sea-level, hillside above Fox Ness, N. side of Agardh Bay:
Aucella cf. *bronni* (Rouill.) Lah.

This is probably the horizon with *Cardioceras* and *Aucella* of the *bronni* group recorded by FREBOLD (20, pp. 266, 275) from Fossilniveau 1 of GRIPP's section on Mt. Agardh. The fossils of the GRIPP and TYRRELL collections do not furnish conclusive evidence of the age of this horizon —the oldest of the fossiliferous horizons above the basal Phosphorite Conglomerate on Mt. Agardh. In Dr TYRRELL's section it occurs 90 feet below the undoubted Lower Kimmeridgian of loc. 41. FREBOLD's palæontological argument in favour of regarding GRIPP's Fossilniveau 1 as "Upper Oxfordian" rather than Lower Kimmeridgian is based on the occurrence of *Aucellæ* of the *bronni* group, which are associated in the Festung section with *Amœboceras nathorsti*, a species that is regarded by FREBOLD as an index of Upper Oxfordian. It ranges to a higher horizon, however, as undoubted *A. nathorsti* (determined by Dr L. F. SPATH) has been collected by Professor BAILEY and the writer ‡ from Midgarty, on the East Sutherland coast, in association with *Rasenia mutabilis*. The "*Cardioceras alternans*," recorded by SALFELD § from Wester Garty, East Sutherland, belongs to the *nathorsti-robustus* group and is associated in the Marcus Gunn collection from that locality with various *Aulacostephanus* of the *eudoxus* (i.e. *pseudomutabilis*) zone. Similarly *Aucella bronni* ranges high in the Kimmeridgian.‖ Unequivocal direct fossil evidence of the Upper Oxfordian age of Dr TYRRELL's loc. 40 and GRIPP's Fossilniveau 1 is therefore not yet available, although "Upper Oxfordian" is consistent with the stratigraphical relations to the Lower Kimmeridgian of loc. 41 in Dr TYRRELL's section.

Loc. 40 lies 230 feet above the Jurassic basal Phosphorite Conglomerate, and the intervening

* *Palæontology of California*, vol. i, 1864, p. 30, pl. v, fig. 28; see also SMITH, *U.S. Geol. Surv.*, Prof. Paper, vol. lxxxiii, 1914, p. 143, pl. xiv, fig. 5; pl. xlix, figs. 10–11; pl. l, figs. 1–3.

† See SMITH, *loc. cit.*, p. 144, pl. xlix, figs. 1–3.

‡ BAILEY, E. B., and WEIR, J., "Submarine Faulting in Kimmeridgian Times: East Sutherland," *Trans. Roy. Soc. Edin.*, vol. lvii, 1932, pp. 461, 463.

§ "Die Gliederung der Oberen Jura in Nordwesteuropa," *N. Jahrb. Min.*, Beil.-Bd. xxxvii, 1914, p. 195.

‖ (23*a*, pp. 34 and 35.) BAILEY and WEIR, *loc. cit.*, Appendix II.

strata, largely covered by scree of paper shale on Dr TYRRELL's section, yielded no fossils. Callovian has not so far been identified on the east coast, but it occurs at Kistefjellet in the extreme south; in the west at the Festung and Botneheia; and in the Arctic region generally. The Callovian transgression was therefore widespread, and we may expect to find marine deposits of this stage on the east coast of Spitsbergen.

From the Phosphorite Conglomerate, on the south side of Agardh Bay and elsewhere, GRIPP collected an Upper Liassic ammonite fauna of somewhat mixed character. According to GRIPP's observations (20, p. 257), the conglomerate is about 3 metres thick. At Kistefjellet, in the extreme south, it is separated from the Trias by a weak discordance, and Callovian ammonites occur about 20 metres higher in the section. At Botneheia, in the west, Callovian occurs directly on top.

FREBOLD (20, pp. 270–75) regards the apparently heterogeneous ammonite fauna as a homogeneous assemblage from a single horizon. His exhaustive argument in favour of this interpretation is most useful, but we may suggest that fuller palæontological knowledge and detailed study of the sedimentation phenomena would yield an alternative explanation. The Upper Liassic transgression in Spitsbergen was probably very shallow and currents would prevent the deposition of regularly bedded fine materials. If these conditions lasted during several hemeræ they would result in concentration of the coarser material and shells of several zones. The phosphorite content suggests long-continued working of the material in the sea-floor. Slight uplift succeeding the shallow water conditions of the Upper Liassic would result in local emergence, as at Botneheia, where subsequent transgression allowed the deposition of Callovian directly on top of the Conglomerate; elsewhere uplift may have been less pronounced and emergence more transient, allowing deposition of a varying thickness of unfossiliferous (?) Bajocian and Bathonian between the Conglomerate and the fossiliferous marine Callovian. The similar and approximately contemporaneous assemblages of Upper Liassic ammonites from apparently a single horizon—*e.g.* at Aveyron—quoted by FREBOLD in support of his interpretation of the Spitsbergen Conglomerate-fauna may themselves be condensed faunas, the product of current concentration in comparatively shallow water.

Loc. 210. Black shale horizon between 800 and 880 feet, N. face of Mt. Johannsen:
Amœboceras nathorsti (Lundgr.) (Pl., fig. 7).

This horizon lies between 160 and 240 feet above the Phosphorite Conglomerate and may be equivalent to Dr TYRRELL's loc. 40 and GRIPP's Fossilniveau 1.

LOWER KIMMERIDGIAN.

Loc. 41. From shale 400 feet above sea-level, hillside above Fox Ness, N. side of Agardh Bay:
Indeterminable belemnites; *Rasenia* sp.; *Amœboceras* cf. *kitchini* (Salf.; Sokolov and Bodylevsky, pl. vii, fig. 1) (Pl., fig. 15); *Aucella bronni* (Rouill.) Lah., and var. *lata* Lah.

LOWER VOLGIAN.

Loc. 200. Shale-ironstone horizon, Cape Dufferin:
Lucina fischeri d'Orb.; *Oxytoma* sp. juv.

Loc. 201. Shale-ironstone horizon, lower slopes of Rurik's Forberg, below 1000 feet:
Perisphinctid sp. ind.; *Cyprina* (?) *inconspicua* Lindstr.; *Aucella pallasi* Keys. (Pl., fig. 23).

The fauna of these two localities is equivalent to the lamellibranch fauna recorded by SOKOLOV and BODYLEVSKY (23*a*, pp. 112, 113) from Niveau 17 and Niveau 18 of the Festung, and assigned to the Lower Volgian stage on account of association with *Perisphinctes* cf. *scythicus* Vischn. According to Dr TYRRELL's section these localities should occur about 1000 feet above the basal conglomerate (here below sea-level) and about 880 feet above the Lower Kimmeridgian horizon with *Rasenia* and *Aucella bronni*.

Lower Cretaceous.

The Cretaceous fossils in Dr Tyrrell's collection all come from the mountain on the north side of Whales Bay, west coast of Stor Fjord. A thickness of about 720 feet of sediments separates the oldest of Dr Tyrrell's Lower Cretaceous horizons from the youngest. The oldest horizons, at 1240 feet above sea-level (loc. 229) and 1540 feet (loc. 230), yield lamellibranch assemblages that indicate L. Aptian; still higher, above 1540 feet, a Hoplitid (probably not collected *in situ*) may indicate the presence of Albian. The two *Ditrupa* bands at 1700 and 1890 feet (locs. 232 and 233) may be provisionally assigned to this stage; *Ditrupa* occurs at various horizons in the Spitsbergen Aptian and Albian (see Frebold, 23; Sokolov and Bodylevsky, 23*a*).

All Dr Tyrrell's Cretaceous fossils come from above the Continental Series, the lowest Cretaceous horizon (loc. 229, Lower Aptian) lying from 450–500 feet above the highest beds of the Continental Series, according to Dr Tyrrell's section. Obruchev has placed the Continental Series of East Spitsbergen in the Upper Portlandian and Lower Aquilonian. According to Frebold and Sokolov and Bodylevsky this assignment contradicts the unequivocal palæontological evidence obtained on the west coast; there the overlying and underlying marine sediments determine the age of the Continental Series as Upper Valanginian-Barremian. Obruchev's age determination of the Continental Series involves a remarkable crossing of time and facies-planes between West and East Spitsbergen that is difficult to account for in the facies history of the Upper Jurassic and Cretaceous in Spitsbergen. Dr Tyrrell's collection does not establish the age of the Continental Series within narrow limits. In his section it is some 700 feet thick and is bracketed with about 500 feet of overlying and 600 feet of underlying beds, between the Lower Volgian of Rurik's Forberg and the Lower Aptian of Whales Bay.

The section on Rurik's Forberg between Dr Tyrrell's Lower Volgian horizon and the base of the Continental Series was largely obscured by scree, but in view of the absence of Upper Volgian in Spitsbergen it probably consists largely of marine Valanginian; if so, the Continental series on the east coast is Lower Cretaceous, and not uppermost Jurassic as stated by Obruchev.

Details of the Lower Cretaceous localities and fossils are given below.

Lower Aptian.

Loc. 229. Ironstone horizon, 1260 feet, mountain N. side of Whales Bay:
Inoceramus aff. *labiatiformis* Stolley; *Aucellina* aff. *caucasica* v. Buch.

The *Inoceramus* may be the form recorded by Frebold (23, p. 46) as *Inoceramus* cf. *labiatiformis* Stolley, in association with *Aucellina* sp. aff. *caucasica, Nucula* sp. and gastropods, from the Aptian of Green Harbour.

The *Inoceramus* aff. *labiatiformis* Stolley of Sokolov and Bodylevsky (23*a*, pp. 48, 131) is probably the same form. These authors record its occurrence "am Strande bei Kolfjellet" in association with *Nuculana angulatostriata*, which they regard as an index of Lower Aptian.

There is good evidence, therefore, for the Aptian age of the oldest of Dr Tyrrell's Cretaceous horizons, and in view of the occurrence of the Lower Aptian *Nuculana angulatostriata* at loc. 230, 188 feet higher in section, the horizon is probably low in the Lower Aptian.

Loc. 230. Ironstone horizon, 1540 feet, mountain, N. side of Whales Bay:
Nuculana angulatostriata (Sok. and Bodyl.); *Entolium orbicularis* (Sow.) (Pl., fig. 12); *Aucellina aptiensis* Pompj.

This assemblage definitely corresponds to the Lower Aptian fauna of the Wittenburg Collection from Kolfjellet, Bellsund, recorded by Sokolov and Bodylevsky.

Loc. 231. Sandstone horizon, between 1540 feet and 1600 feet, mountain, N. side of Whales Bay:
"*Hoplites*" (probably new) (Pl., fig. 5).

Dr Spath compares this specimen to the "*Hoplites*" recorded by himself from probable Albian (*Geol. Mag.*, 1921, p. 356). Dr Tyrrell says his specimen may not have been *in situ*, but may have fallen from a higher level to the position in which it was collected.

NOTES ON CERTAIN JURASSIC SPECIES.

Aucella bronni (Rouillier) Lah.

? *Plagiostoma concentricum* J. de C. Sow. *Min. Conch.*, vol. vi, 1827, pl. 559, fig. 1.
Aucella bronni Sokolov and Bodylevsky, *loc. cit.*, 1931, p. 34, pl. i, fig. 3; pl. v, figs. 5 and 6 (with synonymy).

Numerous examples of this form were collected at locs. 40 and 41. Typical examples are represented as well as var. *lata* Lah. (Pl., fig. 9). The latter is regarded by POMPECKJ and PAVLOV as synonymous with *A. solodurensis* de Loriol.

In the writer's opinion *A. bronni* is a synonym of *Plagiostoma concentricum* J. de C. Sow. The question is discussed in an appendix to a recent paper by Professor E. B. BAILEY and the writer,* and the argument need not be repeated here. If the view expressed there is correct, SOWERBY's name has precedence and the species must be called *Aucella concentrica* (J. de C. Sow.); a new name is therefore required for *Aucella concentrica* (Fischer), which post-dated *Plagiostoma concentricum* (J. de C. Sow.). I take this opportunity of figuring a specimen of *Plagiostoma concentricum* (Pl., fig. 16), or "*Lima*" *concentrica*, as it is usually called in British geological literature, collected by Professor E. B. BAILEY and the writer in the East Sutherland Kimmeridgian for comparison with figures of *Aucella bronni* in the works of LAHUSEN, SOKOLOV, PAVLOV, and others.

Cyprina (?) *inconspicua* Lindstr.

(Pl., fig. 13.)

Cyprina inconspicua Lindström. "Om trias- och jura-försteningar från Spetsbergen," *K. Svensk. Vet.-Akad. Handl.*, vi, 1865, p. 11, pl. iii, figs. 7, 8.
Cyprina inconspicua Sokolov and Bodylevsky, *loc. cit.*, 1931, p. 75.

This species is represented in Dr TYRRELL's collection by one large valve (length 25 mm. approx., height 18 mm.) and the open valves of one small individual (length 12 mm., height 9 mm.) in ironstone from loc. 201.

FREBOLD (*loc. cit.*, 1930, p. 58, pl. xx, fig. 6) records a *Cyprina* cf. *inconspicua* from beds of probably Albian age. There is no question of the present occurrence being Albian. It belongs to the Lower Volgian horizon at loc. 201, about 600 feet below the base of the Continental Series.

Lucina fischeri d'Orb.

(Pl., fig. 19.)

Lucina fischeriana d'Orbigny. In MURCHISON, DE VERNEUIL, and KEYSERLING, *The Geology of Russia*, vol. ii, p. 458, pl. xxxviii, figs. 31, 32.
Lucina fischeri Sokolov and Bodylevsky, *loc. cit.*, 1931, p. 74.

Impressions of valves with adhering remnants of the test, from loc. 200, probably represent the form recorded by SOKOLOV and BODYLEVSKY from the Lower Volgian of the west coast, and assigned by them to *Lucina fischeri*; unfortunately, SOKOLOV and BODYLEVSKY give no figure.

The dimensions of a typical specimen are: length 21 mm., height 17 mm., length of anal portion 10 mm. In their much-compressed form, oval-subquadrate outline, and inconspicuous beaks situated rather nearer to the anal than to the anterior margin, Dr TYRRELL's specimens agree very well with D'ORBIGNY's figures and description.

D'ORBIGNY stated that *L. fischeri* was collected by VERNEUIL and KEYSERLING from the Oxfordian stage. The assemblage to which Dr TYRRELL's specimens belong corresponds to a similar lamellibranch assemblage from Niveaux 17 and 18 of the Festung, assigned by SOKOLOV and BODYLEVSKY to Lower Volgian on account of association with *Perispinctes* cf. *scythicus* Vischn.

* *Op. cit.*, 1932, Appendix II.

Loc. 232. *Ditrupa* band, 1700 feet, mountain, N. side of Whales Bay:
Ditrupa cf. *decorata* Stolley.

Loc. 233. *Ditrupa* band in shelly ironstone, 1980 feet, mountain, N. side of Whales Bay:
Ditrupa (? *Dentalium*) sp.

The fossils from these two localities (232, 233) afford no direct evidence of the stage to which the deposits belong, but in view of the position relative to locs. 230 (Lower Aptian) and 231 (with Hoplitid —not *in situ* ?—of probable Albian age), it seem possible that the stage may be Albian.

Notes on the Cretaceous Fossils.

Ditrupa cf. *decorata* Stolley.

(Pl., fig. 21.)

The specimens in the *Ditrupa* bed of loc. 232 are strongly curved, about 25 mm. long, and are 3 mm. in diameter of cross-section at this length. The external surface is not exposed in any example, and the ornament is not reproduced in impression; the internal surface of specimens sectioned by the fracture surface reveals to the lens circular striæ that are too fine to reproduce on the internal cast of the tube. This striate ornament is interrupted at irregular intervals by narrow, shallow furrows.

Ditrupa (*Dentalium* ?) sp.

The *Ditrupa* band at loc. 233 is crowded with the crushed fragments of a *Ditrupa* (or *Dentalium* ?). The tube is narrow and rather thick (thickness of shell, ·5 mm. at a diameter of 2 mm. in cross-section). There is no ornament of any kind on shell or cast.

Aucellina aptiensis Pompj.

(Pl., fig. 18.)

Aucellina aptiensis Pompeckj. "Über Aucellen und Aucellenähnliche Formen," *Neues Jahrb. f. Min.*, Beil.-Bd. xiv, pp. 352–355, pl. xvi, figs. 1–3. (For synonymy see Sokolov and Bodylevsky, *loc. cit.*, 1931, p. 46).

Several specimens in ironstone from loc. 230. Dimensions of the most complete specimen: length 23 mm., height 19 mm. Dr Tyrrell's specimens belong to the typical form and not to the variety figured by Sokolov and Bodylevsky, in which the height exceeds the length. The radial ornament is well marked.

Aucellina aff. *caucasica* (v. Buch).

(Pl., figs. 4, 6, and 10.)

Aucellina sp. aff. *caucasica* Frebold, *loc. cit.*, 1930, p. 46, pl. xviii, figs. 1–4.

Several specimens of both valves in ironstone from loc. 229 have the outline and closely-set lines of radial ornament that characterise the group of *Aucellina caucasica* (v. Buch) and *A. gryphæoides* (J. de C. Sow.). They probably represent the *Aucellina* sp. aff. *caucasica* recorded by Frebold from the Aptian of Green Harbour.

Inoceramus aff. *labiatiformis* Stoll.

(Pl., fig. 1.)

Inoceramus cf. *labiatiformis* Frebold, *loc. cit.*, 1930, p. 46.
Inoceramus aff. *labiatiformis* Sokolov and Bodylevsky, *loc. cit.*, 1931, p. 48.

Fragmentary cast of right valve showing numerous closely-set growth lines. In this respect it apparently resembles the *Inoceramus* aff. *labiatiformis* described by Sokolov and Bodylevsky; unfortunately these authors give no figure, so it is impossible to say whether the identity of ornament is absolute. Owing to its fragmentary condition it is impossible to give dimensions for comparison with those quoted by Sokolov and Bodylevsky, but Dr Tyrrell's specimen is definitely broader than STOLLEY's types, and in this additional feature corresponds with the form described by SOKOLOV and BODYLEVSKY. Dr TYRRELL's specimen may belong to the same form as the *Inoceramus* cf. *labiatiformis* recorded by FREBOLD, but the latter gives neither figure nor description, and no comparison is possible.

Nuculana angulatostriata (Sokolov and Bodylevsky).

(Pl., fig. 14.)

Leda angulatostriata Sokolov and Bodylevsky, *loc. cit.*, 1931, pl. xii, figs. 4–6.

Several specimens on a slab of ironstone from loc. 230, with *Aucellina aptiensis* and *Entolium orbicularis*. Dimensions of the largest specimen: length 29 mm., height 16 mm. These dimensions are almost twice the largest recorded by SOKOLOV and BODYLEVSKY.

Two valves with their external surfaces applied to the matrix are figured. Part of one of the valves is broken away, showing in impression the characteristic ornament of two systems of concentric lines that cross and anastomose, especially near the ventral border.

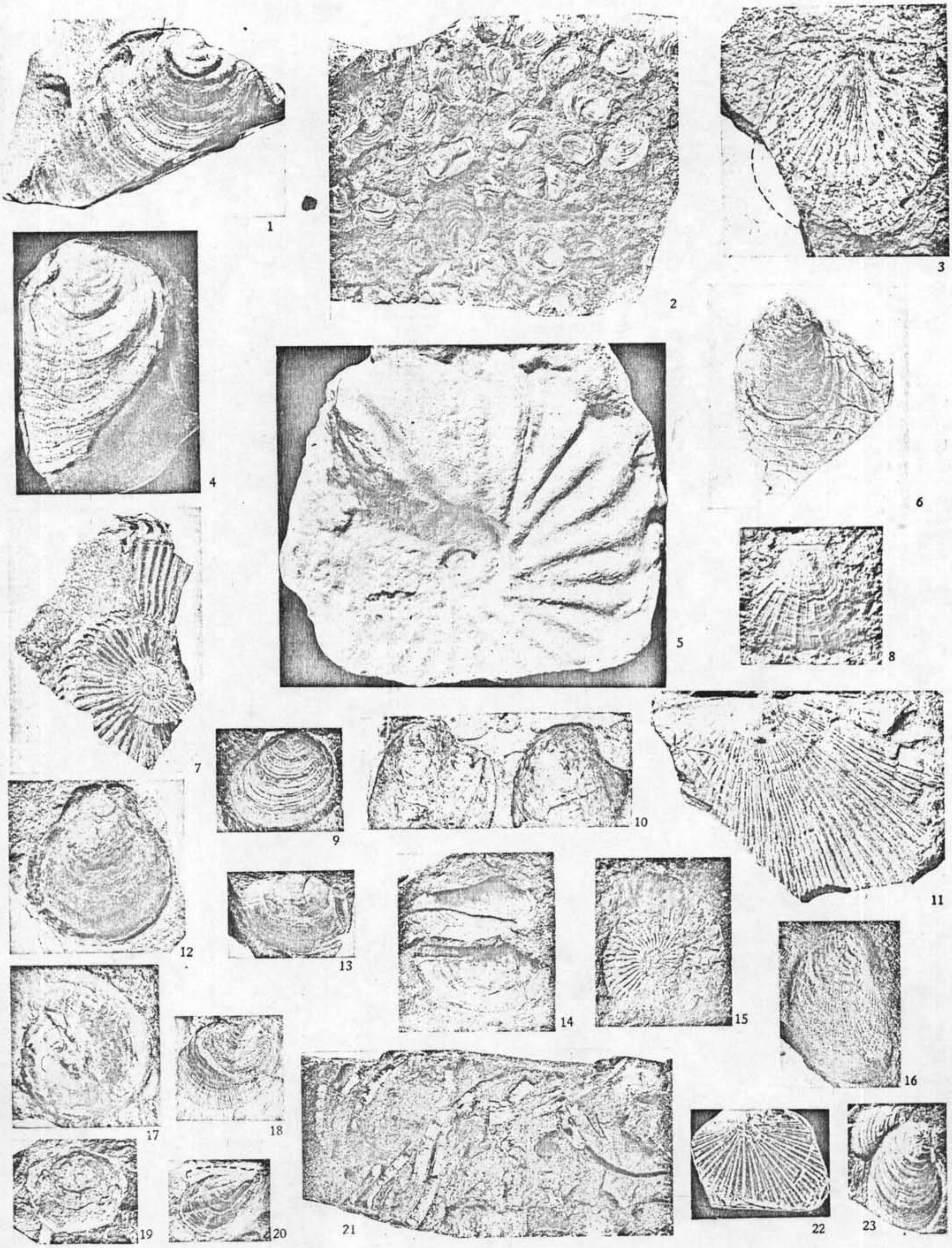
SOKOLOV and BODYLEVSKY think that this form is probably synonymous with the species recorded by POMPECKJ under the *nomen nudum Leda* (*Yoldia*?) *tenuiruncinata*. According to STOLLEY, *Leda tenuiruncinata* is a characteristic fossil of the *Ditrupa* band.

DESCRIPTION OF PLATE.

(Specimens are in the Hunterian Museum, University of Glasgow.)

Fig. 1. *Inoceramus* aff. *labiatiformis* Stolley. $\times \frac{9}{10}$. Loc. 229. Lower Aptian.
Fig. 2. *Estheria minuta* Alberti. $\times \frac{9}{5}$. Loc. 208. Trias.
Fig. 3. *Pseudomonotis* (*Eumorphotis*) *tschernychewi* Witt., juv. $\times \frac{9}{5}$. Inner surface of left valve. Loc. 226. Carnian.
Fig. 4. *Aucellina* aff. *caucasica* (v. Buch). $\times \frac{9}{10}$. Plaster cast of right valve. Loc. 229. Lower Aptian.
Fig. 5. "*Hoplites*." $\times \frac{9}{10}$. Plaster cast. Loc. 231. Albian?
Fig. 6. *Aucellina* aff. *caucasica* (v. Buch). $\times \frac{9}{10}$. Left valve. Loc. 229. Lower Aptian.
Fig. 7. *Amœboceras nathorsti* (Lundgr.). $\times \frac{9}{10}$. Loc. 210. Lower Kimmeridgian or "Upper Oxfordian."
Fig. 8. *Pseudomonotis* (*Eumorphotis*) *tschernychewi* Witt. Plaster cast; umbonal region of a left valve. $\times \frac{9}{5}$. Loc. 226. Carnian.
Fig. 9. *Aucella bronni* var. *lata* Lah. $\times \frac{9}{10}$. Loc. 41. Lower Kimmeridgian.
Fig. 10. *Aucellina* aff. *caucasica* (v. Buch). $\times \frac{9}{10}$. Loc. 229. Lower Aptian.
Fig. 11. *Halobia zitteli* Lindstr. $\times \frac{9}{10}$. Loc. 226. Carnian.
Fig. 12. *Entolium orbicularis* (Sow.). $\times \frac{9}{10}$. Loc. 230. Lower Aptian.
Fig. 13. *Cyprina* (?) *inconspicua* Lindstr. $\times \frac{9}{10}$. Loc. 201. Lower Volgian.
Fig. 14. *Nuculana angulatostriata* (Sok. and Bodyl.). $\times \frac{9}{10}$. Loc. 230. Lower Aptian.
Fig. 15. *Amœboceras* cf. *kitchini* (Salf.; Sok. and Bodyl., pl. vii, fig. 1). $\times \frac{9}{10}$. Loc. 41. Lower Kimmeridgian.
Fig. 16. "*Plagiostoma*" *concentricum* J. de C. Sow. (= *Aucella bronni* Lah.). $\times \frac{9}{10}$. *Mutabilis*-zone, about 100 yards east of the mouth of Midgarty Burn, East Sutherland.
Fig. 17. *Nathorstites concentricus* (Öberg). $\times \frac{9}{10}$. Loc. 226. Carnian.
Fig. 18. *Aucellina aptiensis* Pomp. $\times \frac{9}{10}$. Loc. 230. Lower Aptian.
Fig. 19. *Lucina fischeri* d'Orb. $\times \frac{9}{10}$. Loc. 200. Lower Volgian.
Fig. 20. ? *Gervillia* sp. $\times \frac{9}{10}$. Loc. 228. Carnian?
Fig. 21. *Ditrupa* cf. *decorata* Stolley. $\times \frac{9}{10}$. Loc. 232. Aptian or Albian.
Fig. 22. *Daonella* cf. *dubia* (Gabb). $\times \frac{9}{10}$. Plaster cast of an impression in paper shale. Loc. 226. Carnian.
Fig. 23. *Aucella pallasi* Keys. $\times \frac{9}{10}$. Loc. 201. Lower Volgian.

DR J. WEIR: "MESOZOIC FOSSILS FROM SPITSBERGEN COLLECTED BY DR G. W. TYRRELL."



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