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A STRATIGRAPHICAL SURVEY OF THE PLIOCENE DEPOSITS AT TJÖRNES, IN NORTHERN ICELAND

BY

GUÐMUNDUR G. BÁRÐARSON

AKUREYRI, ICELAND

WITH TWO MAPS

KØBENHAVN

HOVEDKOMMISSIONÆR: ANDR. FRED. HØST & SØN, KGL. HOF-BOGHANDEL

BIANCO LUNOS BOGTRYKKERI

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INTRODUCTION

The Pliocene marine deposits of Northern Iceland were first mentioned by EGGERT ÓLAFSSON in his work on the natural conditions of Iceland[1] and later by the same writer in collaboration with BJARNI PÁLSSON in their itinerary.[2] In the latter, mention is made of some mollusc species observed in these strata; the writers also noticed that the fossil mollusc fauna included some species no longer found in a living state in Icelandic waters. A fairly detailed description is given of the state of preservation of the shells, and the calcite casts they enclosed; it was evident that the shell-bearing strata in question must have been deposited directly by the sea at a higher sea level than that of the present day. A brief description is also given of the coal strata here associated with the shell deposits.

Since that time, Tjörnes has been visited by most of the naturalists who have carried out investigations in northern Iceland.

There is a reference to these formations in WINKLER'S geological work on Iceland; the author mentions 24 species of molluscs, and is the first to ascribe these shelly strata to the Pliocene formation, comparing them with the Crag formation in England.[3]

[1] E. OLAFSSON: Enarrationes historicæ de Islandiæ natura et constitutione etc. Copenhagen 1749.

[2] E. OLAFSSON & B. PÁLSSON: Reise igennem Island. Sorøe, 1772.

[3] I. G. G. WINKLER: Island. München 1863.

C. W. Pajkull gives a brief description of these deposits at Tjörnes, and quotes a list of fossil molluscs from the site, compiled by the Danish malacologist O. A. L. Mørch.[1]

Later, Mørch himself published a work on the mollusc fauna of the Tjörnes strata; the most important hitherto extant on this subject.[2] He mentions here 60 species of molluscs, of which 20 are extinct. From the southerly species found in the strata, Mørch concluded that the temperature of the sea at the time of their deposit must have been considerably higher there than at the present day, or at least as high as the present sea temperature on the west coast of Iceland, say at Reykjavik; and he presumes that these shelly deposits answer to the older Red Crag in England and Belgium.

Similar results were arrived at by G. Jeffreys and Searles V. Wood, who investigated remains of shells from Tjörnes collected by J. Starkie Gardner. Jeffreys, however, also maintains that these fossil species include numerous American forms, which he seeks to explain as due to immigration of species in earlier time by the Great Arctic Current from Iceland to America.[3]

The Mineralogical Museum at Copenhagen possesses a manuscript by C. M. Paulsen (dated 1884) on the fossil Crag molluscs of Tjörnes, and by the courtesy of the museum named I have been permitted to copy this MS. The author mentions 117 species from the Tjörnes deposits, in-

[1] C. W. Pajkull: Bidrag til kännedomen om Islands bergsbyggnad. Kungl. svenska Vetenskaps-Akademiens Handlingar VII. No. I. Stockholm 1867.

[2] Mørch: On the Mollusca of the Crag-formation of Iceland. Geol. Magazine. 8. London 1871.

[3] J. Starkie Gardner: The tertiary Basaltic Formation in Iceland, Q. J. G. S. 41. London 1885.

cluding 20 species or more pronounced varieties, established as new by MØRCH. As to the result of his investigations of these fossils from Tjörnes, the author writes as follows:

"In the case of species now living, if we consider their present geographical distribution, we find that:

31 gastropods and 26 conchifers are arctic and largely circumpolar

2 — - 2 — belong exclusively to arctic East America,

3 — have only been found as deep water forms in the Atlantic,

7 — and 8 conchifers have a more southerly distribution (South Scandinavia, England, Western Europe and the Mediterranean) and

1 conchifer, *(Cyprina islandica* var. *pumilio)* has only been found in Odense Fjord and on the coasts of Mecklenburg.

On the coasts of Iceland, as far as their fauna is known, up to the present, there are still living 15 gastropods and 18 conchifers of the fossil species from Hallbjarnastadir."

With regard to the climatic conditions under which the shell deposits must have been formed, he writes: "The fossils hardly warrant the conclusion that the climate of Iceland, at the time of formation of the Hallbjarnastadir deposits, differed in any essential degree from that of the present day, and the formation must therefore be regarded as more recent than even the youngest section of the English Crag formation."

J. F. JOHNSTRUP investigated the Crag strata at Tjörnes in the summer of 1876, and made some collections of fossils. He came to the conclusion that the coal seams

(Surtarbranden) in these deposits were formed of drift-wood.[1]

Dr. Helgi Pjeturss (Pjetursson)[2] has investigated these Pliocene strata at Tjörnes, and gives a fairly detailed description in his thesis for the doctorate and also in a later work on the geology of Iceland.[3] He holds the same view as Johnstrup as to the origin of the coal strata. He found that the shelly sediments were of greater thickness than had hitherto been supposed, and considers that they must be at least 400 metres thick. And, since the shellbearing strata both at Hallbjarnastadir and at Breidavik are covered by basalt or dolerite, he assumed that they must be older than the main bulk of the basalt of which the eastern mountains of Tjörnes are composed, whereas it had formerly been supposed that the Crag strata were more recent than the basalt. He also suggests that the deposit might possibly be divided into several horizons, according to the fauna contained.

F. W. Harmer, in a revision of English Crag molluscs, has also examined collections of shells from Tjörnes, e. g. a fairly extensive collection made by Dr. H. Pjeturss. In his excellent work on the Pliocene Mollusca, Harmer mentions several mollusc species from Tjörnes, with illustrations.[4]

Since commencing my investigations of the fossiliferous shell strata here in Iceland, I have always purposed to

[1] J. F. Johnstrup: Indberetning om . . . Undersøgelses-rejse paa Island i Sommeren 1876. Rigsdagstidende 1876—77, B. Copenhagen 1877.

[2] Helgi Pjeturss: Om Islands Geologi. Copenhagen 1905.

[3] H. Pjeturss: Island. Handbuch der Regionalen Geologie. IV Bd. 1 Abt. Heidelberg 1910.

[4] F. W. Harmer: The Pliocene Mollusca of Great Britain I—IV. London 1914—1919.

make a thorough investigation of these interesting marine formations at Tjörnes. Owing to the paucity of time I was able to spare for my geological investigations, however, I was unable to make long expeditions for the purpose of exploration, and therefore chose the regions near my home for investigation. My projected journey to Tjörnes had thus to be postponed for several years.

Nevertheless, I endeavoured by other means to procure information as to these formations.

In the winter of 1909—10 for instance, I had an opportunity of going through the collections of fossil shells from Tjörnes preserved in the Mineralogical Museum at Copenhagen; the same which had previously been dealt with by Mørch and Paulsen. Since then I have myself obtained some collections of fossils from Tjörnes, procured on the spot by others, and while studying these collections, I have also gone carefully through what has been written on the subject of these deposits by various writers. In 1917, mining operations were commenced in connection with the coal seams found in these Pliocene strata. The official in charge of the work there furnished me with a number of fossils collected from various horizons round the coal strata, with some information as to the position in which they were found. As already mentioned, it was formerly supposed that the brown coal here was formed of driftwood possibly brought hither from other countries. From the composition of some samples examined, and information procured as to position, etc. I felt convinced that these strata could not have been formed by driftwood. Had such been the case, there would have been a predominance of tree trunks (lignite), which, however, was present only in quite small quantities. The greater part consisted of small

remains of plants, which had been compressed and transformed into coal. Moreover, I found, in some lumps of mudstone sent me from these strata, impressions, albeit indistinct, of leaves or portions of leaves, and remains of rootlets running transversely through the horizontal cleavage plane of the lumps. I also discovered, from samples of the superimposed strata, that the lowest shell-bearing strata above the brown coal consisted mainly of sandstone which had the appearance of being a typical littoral formation; farther up, however, these were replaced by more clayey strata which must evidently have been formed in deeper water. This led me to suppose that the coal strata must be a land formation, deposited as peat, either in a swamp or possibly to some extent in fresh water, where the sea water had not reached, after which a subsidence had taken place, and the site had been flooded by the sea. Consequently, the vegetable remains found in the coal-bearing strata must be the residue of vegetation which had flourished on the spot.

These observations greatly encouraged me to set about my contemplated investigation of the strata in question at the earliest opportunity. Nevertheless, I found myself obliged to postpone it for a couple of years. It was not until the summer of 1922 that I was able to proceed to Tjörnes and commence investigations there; I was there again for a fortnight last summer, and continued my studies of the Pliocene deposits.

During these visits to Tjörnes, I was mainly concerned to make a thorough study of the strata sequence in the thick shelly sediments, to form a preliminary view of the stratigraphical conditions and learn to distinguish between the many different strata, both as regards appearance,

composition and the characteristic mollusc species they contained. In all previous collections of fossil molluscs from Tjörnes, the fossils from different horizons had been mixed together indiscriminately. I have now, however, procured separate collections from the numerous shell-bearing strata, and have already fairly rich collections from some 25—30 different horizons. I was thus enabled to lay down some fairly certain characteristics for each horizon, and could then trace the course of the separate strata despite existing faults. I have already measured and drawn a connected section of the marine strata series where it is best exposed along the shore on the western side of the cape which covers a range of abt. 6 km. from Kaldakvísl to Höskuldsvík. I have also drawn a section of the fossiliferous strata on the extreme point of the cape at Breiðavík. The coast range on the western side of Tjörnes, from Höskuldsvík to Breiðavík I have also investigated, making section sketches of some parts. We have here huge layers of stratified sandstones and conglomerates, especially in the vicinity of Breiðavík, but they do not appear to contain shells.

Most of those who have collected fossil shells on the western side of Tjörnes have worked for the most part in the strata round Hallbjarnarstaðaá (Hallbjarnarstaða-kambur and Tungu-kambur) where shells abound, and southward to Hringvershvilft or Reká. Southward again from here as far as Kaldakvísl, no shells have, as far as I am aware, been found up to now, nor in the northernmost portion of the strata series at Stórhöfði and Höskuldsvík. In both places I succeeded in finding fossil-bearing marine strata fairly rich in shells.

My investigations of the Pliocene strata at Tjörnes are still in their initial stage. The shelly sediments range from

the western shore of the cape and Breiðavík up to the interior of the headland itself, possibly right up to the mountains on the east. They are fairly exposed in the deep chines along the rivers Hallbjarnarstaðaá, Skeifá and Reká, which fall away from the east down to the shore. I have still to follow the course of the strata up from the shore. I have followed the rivers mentioned a good way up inland, but had not time to make any thorough study of the sections. There are also a number of faults here which disturb the general effect. The eastern coast of the headland also requires to be investigated. It will take me some time, moreover, to deal with the extensive material of fossil shells already collected. And further, repeated collections must be made in different strata in order to obtain as complete material as possible for determination of the character of the fauna in the various horizons, and thus be better able to trace its alterations from one to another of the strata.

I should myself have preferred to postpone any publication of my work and its results for the present, and wait until I had completed the determination of the mollusc species collected and had an opportunity of studying the strata closely once more. It is quite possible that my views regarding these formations may be altered in various respects by further and more thorough examination. For certain important reasons, however, which I need not enter into here, I have thought it best not to withhold an account of some of my investigations at Tjörnes during the past two summers.

I. The Pliocene Strata on the Western Side of Tjörnes.

a. Introductory Remarks.

1. Extent. The Crag strata are most distinctly exposed on the western side of Tjörnes, in steep slopes some 60—70 metres high, running along the shore for abt. 6 km. from Kaldakvísl in the south and northward to Höskuldsvík below the farm of Isólfsstaðir. They also extend a considerable distance up from the shore towards the east, where they show out in the deep ravines along the streams that pour down from the eastern heights of Tjörnes westward to the shore; at Hallbjarnarstaðaá and Skeifá I have followed the strata 2—3 km to the eastward from the beach. Farther east, the streams have not cut their beds so deep as nearer the shore, so that one sees less of the actual substratum, but it is possible that the Crag strata form the substratum under the loose, more recent formations right up to the hills.

2. Composition of the strata. The entire deposit is formed of sediments, which are as a rule distinctly stratified. The greater part is formed of a clayey sandstone, but in some places we find strata composed mainly of hardened clay or mainly of sand. Only in a few places do we find strata with pebbles embedded in clay or sandstone, and in the few places where they are found, these pebble formations are of but slight thickness. Lava-sheets are here no where found embedded in the deposit throughout its whole extent. The Crag strata themselves in the slope are covered in most places at the top by far more recent (probably late or post-glacial) loose deposits, varying in thickness from some few metres to abt. 10 m. or even a little more. They

are for the most part composed of rolled gravel, sand and clay and in some places present a morainelike appearance.

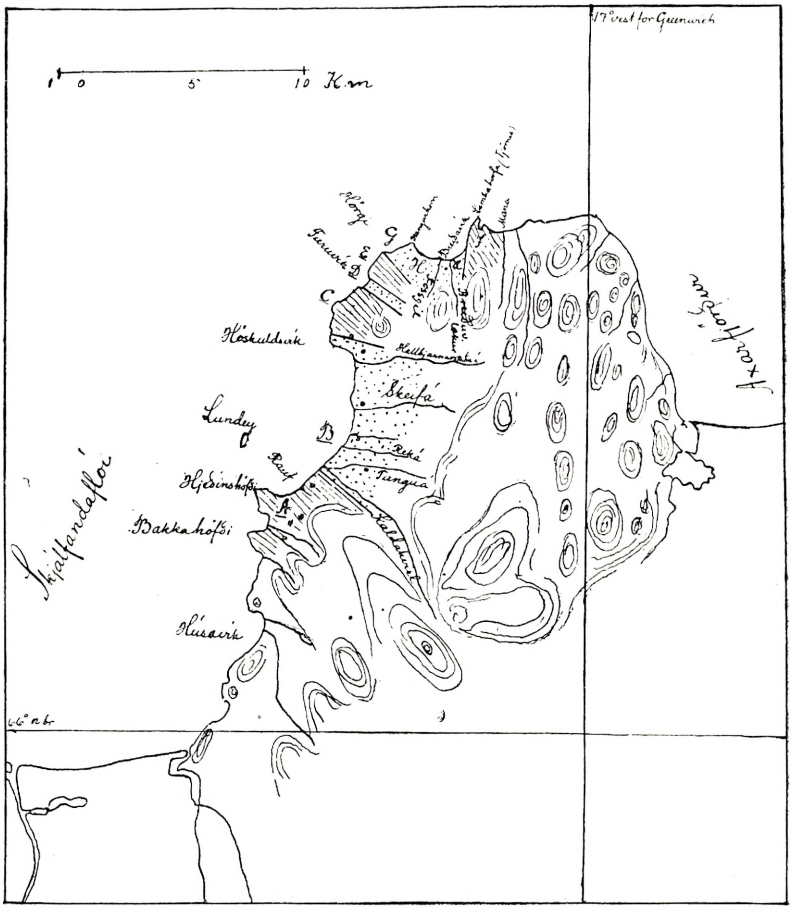

Fig. 1. Sketch map of Tjörnes.
A. Basalt under the Crag strata. *B*. Pliocene deposits between the Kaldakvísl and Höskuldsvík. *C*. Basalt between Höskuldsvík and Furuvík. *D*. Sedimentary deposits at Furuvík. *E*. Basalt between Furuvík and Hörgi. *G*. Basalt overlain by Conglomerate between Hörgi and Stangarhorn. *H*. Marine Sediments at Breiðavík. *I*. Basalt above the Sediments at Breiðavík.

These are for the most part covered with soil and herbage. These more recent formations lie more or less horizontally and therefore lie unconformably on the underlying Crag

strata, which dip considerably. They are, moreover, easily distinguishable from the Crag strata by their abundance of pebbles.

3. Dip. The entire series of strata slopes toward the NW. The slope of the strata as it appears when viewing the position of the small strata in the steep cliffs along the

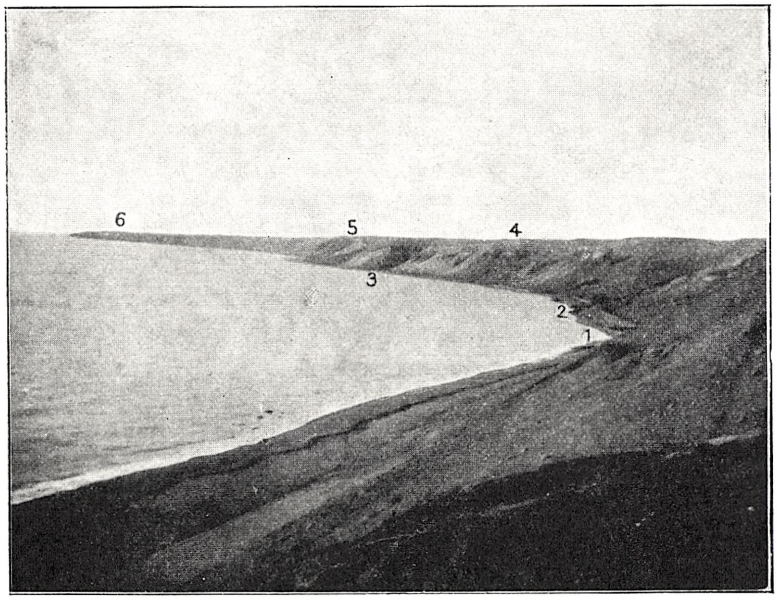

Fig. 2. The Crag cliffs seen from Tungugerðisbakkar. The Reká flows out at *1*, the Hringverslækur at *2* and the Skeifá at *3*. Hringversbakkar *4*, Tungubakkar *5*, Stórhöfði *6*.

shore differs somewhat, and may be more or less pronounced; it always, however, seems to run in the same direction, towards NW. This apparent difference in the inclination of the strata may possibly be ascribed to the fact that the longitudinal direction in different parts of the cliff forms different angles with the directions of the dip of the strata, as the cliff itself follows the indentations of the coastline. In some places, the direction of the cliff almost coincides

with the direction of dip of the strata, and here, the inclination of the stratum margin in the cliff face is of course greater; in other places, the cliff runs nearly transversely to the line of dip, so that the outcrops of the strata lie nearly horizontally along the slopes.

Measurement of the dip of the strata at different places along the cliff gave the following results:

At Nafir		10° NW.
At Hallbjarnarstaðaá	abt.	8° NNW.
From Kambsgjá to Hælskor	abt.	5° N.
At The Coal Mine	abt.	5° N.
From the mine to Skeifá	abt.	4°—5° N.
From Reká to Kaldakvísl	abt.	5°—6° N.

By a streamlet between Reká and Kaldakvísl (Egilsgjóta) I measured the dip in the directions from SE.-NW. where it was abt. 15°, and along Skeifá, which runs from E.-W., I found the slope in several places abt. 10° in a westerly direction.

The dip of the strata thus seems to be from 10°—15° NW, but it is possible that the dip of the strata varies in different parts of the cliff, as the series is broken by several faults, disturbing the original position of the strata.

4. Thickness. The height of the Crag strata from the shore up to the verge of the cliff varies somewhat, from abt. 40 metres up to abt. 70—80 at its highest. The extent of the strata along the shore from Kaldakvísl to Höskuldsvík is abt. 6 km. Reckoning the dip at abt. 5°, this would give a thickness for the whole series of strata of abt. 520 m. But as the strata have dropped in some parts of the southern portion of the cliff, owing to faults, something must be de-

ducted from this. At one point, for instance, at Hringversbakkar, there is a drop of abt. 30 m. Other dislocations are of far less extent. I have also endeavoured to gauge the thickness of the strata by other means. For this purpose, I chose 8 point along the cliff where it was built up from beach to verge exclusively of strata not extending to any of the other seven point. The total thickness of the strata at all these places together I estimated at abt. 430—450 m. True, these measurements were taken by aneroïd, and are therefore not accurate enough. I have not up to now had time to make more accurate measurements of the thickness of the strata along the whole cliff. But from the foregoing I think that one can without fear of exaggeration assume of at least abt. 450 m. for the strata in question.

5. Substrata of the Pliocene deposits. At the stream of Kaldakvísl, it is plainly evident that the Pliocene sediments rest upon basalt. From Kaldakvísl there is a lava-sheet of dark, somewhat altered basalt running in under the fossiliferous clayey sandstone sloping gently northward along the shore, until it dips down under the loose gravel on the shore at Tungugerðistorfa, abt. 250 m. north of the stream (*a* at the bottom of the profile sketch of Tungugerðishöfði). This basalt is also apparent under the Crag sediments up along the Kaldakvísl and Tunguá a little way from the shore, and at the point of junction of these two streams, a fairly clear profile of this basalt is visible, showing also the lowest and earliest strata of the Crag sediments. By the shore close to the south of the Kaldakvísl, the slope is covered for some distance with talus, where the basalt does not appear, but a little farther south along the shore it comes into view again, forming a continuous steep cliff

some 40—50 m. high running southward along Raufarbakkar to the farm of Rauf. Here there are a number of slanting basalt beds, dipping 20°—30° towards the N. along the coast, i. e. dipping considerably more than the Crag strata themselves. The basalt here is highly altered, and as it would seem considerably disturbed, with thin interstrata of tuff- or slag-like material, reddish brown in colour.

The little point known as Hjeðinshöfði juts out a little farther south, and is likewise formed entirely of basalt. In its northernmost part, the basalt sheets slope considerably towards the north, and are similar in appearance to those at Raufarbakkar; farther south, however, the dip of the strata in the basalt is less pronounced. Zeolites (scolecite) are often found in cavities in the basalt. By the river Bakkaá, somewhat farther south, close by the road out to the cape, there is also a quantity of altered basalt containing scolecite crystals, and in Bakkarhöfði, a small point below the farm of Bakki, is also said to be built up of similar basalt. Farther south, along the coast as far as Húsavík, the cliffs are formed of far more recent, probably glacial and post-glacial clay and gravel deposits, in horizontal strata.

The above-mentioned basalt must be far older than the Crag sediments, and as the basalt beds here dip far more than the strata of the subsequent Pliocene deposits, a disturbance must have taken place since the formation of the basalt, giving it a considerable incline towards the north or north-west before the Crag strata had commenced to form, showing that some considerable time must have intervened between the formation of the basalt and the first deposits of the Pliocene. A comparison of he sections near Kaldakvísl also seems to suggest that the

surface of the basalt must have been somewhat uneven and deeply furrowed when the sediments were deposited, which may perhaps be taken as an indication that the basalt itself had been subjected to erosion for some considerable time during the period prior to the formation of the Crag strata.

6. Conglomerate deposits under the fossil-bearing Crag sediments. Above the basaltic substratum at Tungugerðishöfði, north of Kaldakvísl, there is a deposit of conglomerate or large rounded stones up to abt. 1 m. in diameter, (3 in the sketch of Tungugerðishöfði, fig. 3). The cementing material is a coarse clayey sandstone, but this hard matrix has in course of time become disintegrated and weathered away and the smoothed stone blocks were loosened and precipitated to the shore, which is also entirely covered with such boulders as far north as the conglomerate deposit can be traced along the cliff.

On the south side of Kaldakvísl, on the slope close down by the stream itself, abt. 50 metres from the shore, there are also smoothed stones embedded in the mudstone. Just opposite, on the other side of the Kaldakvísl, where the Tunguá flows into it, the fundamental basalt is seen to be directly overlain by a conglomerate stratum some 2—3 metres thick, containing well rounded stones up to 1 metre in diameter. The cementing material here is a grey, very hard, clayey sandstone; above this comes coal-bearing sandstone belonging to the fossiliferous Crag formation (see the description of the section, p. 20).

Where the basalt at Raufarbakkar ends at the talus by the shore, close south of the Kaldakvísl, (see the plate), the basalt merges into a peculiar conglomerate-like formation composed of very large blocks; the cementing material

is very hard and transformed, but it is not impossible that it may be a pseudo-conglomerate produced by alteration of the underlying basalt.

At Hjedinshöfði there is also smoothed gravel and conglomerate above the basalt, similar in appearance to that

Fig. 3. Conglomerate deposit at Tungugerðishöfði. At the bottom, beach covered with rounded stones (*1*), on the right the solid basalt (*2*) and above this the conglomerate.

at Kaldakvísl, many of the stones are well smoothed and quite round, the largest measuring up to 1 m. in diameter. Here also the conglomerate is in some places covered by a stratum of basalt.

At the southern end of Raufarbakkar, close to the shore near the farm of Rauf, there is also a boulder deposit, with very large stones, partly rounded and up to abt. 1 m. across; the cementing material seems to be a very hard and close-grained clayey sandstone.

These last-mentioned conglomerate deposits bear so close a resemblance to the conglomerate strata under the Crag strata at Kaldakvísl that it seems natural to suppose they must have been formed simultaneously.

I found no glacial striation anywhere on the surface of these blocks, they were often spherical, others had rounded corners and polished sides. As this deposit covers a considerable area above the basalt, it is hardly likely that the material could have been deposited by a stream. And as these pebble strata at Kaldakvísl are so closely associated with the subsequent marine strata, it seems natural to suppose that they are a marine littoral deposit, formed during the time when the sea began to overflow the shore, prior to the formation of the Crag strata themselves. These large spherical stones must then have been subjected to wave action on a coast where the breakers were very powerful. But the fine sandy mudstone with remains of plants, which overlies the pebble deposit (see under A, next section) and seems to be closely associated therewith, forms a contrast to this as it must probably have been deposited in more sheltered places, e. g. in quiet creeks or possibly lagoons of brackish water, and the succeeding thick fossiliferous Pliocene deposit on the western side of Tjörnes seems also to have been deposited where the waves were not very powerful, as they are almost entirely composed of clay and sand deposits, with no stones or gravel embedded therein. This calls for some further explanation, but I will not go further into the question here, as I have not yet had time to study the conditions of contact between the conglomerate strata and the succeeding fossiliferous strata as closely as I should wish.

b. Strata Sequence in the fossiliferous Deposits between Kaldakvísl and Höskuldsvík.

A. Strata with plant remains at Kaldakvísl.[1]

As already mentioned, the shelly sediments here rest on basalt, which crops out south of the Kaldakvísl and also extends in under the strata to the north of it, as shown in the accompanying section sketch. Then, above the basalt, comes the conglomerate deposit with the large rounded stones. Closely associated with these conglomerates are deposits of clay with vegetable remains, showing out most clearly by the rivers Kaldakvísl and Tunguá, especially at the confluence of the two streams, a little distance from the shore.

Here, close down by the river bed (Tunguá) we have

a. Dark basalt, 3—4 m. of the same appearance as the lowest at Tungugerðishöfði.

b. The above mentioned conglomerate strata, 2—3 m., the largest smoothed blocks abt. 1. m. diameter.

c (uppermost). Reddish brown or dark grey mudstone (abt. 3 m.) with remains of plants, forming continuous strata rather high up on the mudstone.

Abt. 100 m. farther up the Tunguá I came upon strata of coal-bearing shale abt. 25 cm. thick, embedded between grey and brown clay deposits abt. 2 m. above the river.

Mudstone with plant remains I have also observed on the south side of the Kaldakvísl, close down by the water, 20—30 m. from the bridge that leads over the stream. The shell stratum here by the road south of the river seems

[1] In the accompanying section sketch, the various strata are marked with the same letter or figure as appears in the text here following before the description of the stratum in question. Nos. 1—25 are shell-bearing layers or horizons, and A—J coal-bearing or possibly other extramarine formations.

also closely associated with this plant clay, as impressions both of twigs and leaves have been found in the mudstone close down to the shelly stratum.

1. The Mytilus deposit at Kaldakvísl.

On the southern side of Kaldakvísl, where the road leads down to the bridge across the river, I found the most southerly shelly stratum belonging to the Crag strata (1) which must doubtless be the oldest. The shells here lie abt. 10 m. above the shore and are embedded in dark grey or brown clay sandstone. Under the shell stratum were deposits of yellowish brown clay with carbonised twigs and impressions of leaves. I found here the following species:

Mytilus edulis L. Very frequent, mostly with united, closed valves.

Tapes sp. Chiefly "nuclei" or impressions left by shells.

Balanus sp. Often attached to shells. The shells themselves were for the most part largely decomposed or had entirely disappeared, giving place to ferruginous compounds. Often only the mudstone nuclei of the shells remained; some few of the nuclei were also formed of calcite.

This shelly stratum is here seen to be of only very slight extent, and cannot be traced further, as the slope here on both sides is covered with loose fallen masses. Between the Tunguá and the Kaldakvísl, at their confluence, there are, however, similar deposits with *Mytilus edulis*. In the same stratum were also scattered about some petrified fragments and splinters of wood and twigs.

2. The Tapes horizon at Tungugerðishöfði.

At Tungugerðishöfði, on the north side of Kaldakvísl, there is a distinct section of the sediments. We find here:

a. The basalt dipping northward down to the shore.

b. Conglomerate deposit with partly smoothed large blocks up to 1 m. diameter.

c. Brownish argillaceous sandstone up to abt. 20 m. above the shore.

d. Dark brown mudstone, mixed with sand, up to 30 m. above the shore. I found here some petrified twigs and indistinct impressions of small vegetable remains.

e. Brownish yellow clay deposits up to the edge of the terrace 55 m. above the sea-level.

At about 40 m. above sea-level, there are fairly continuous shelly strata here, (2) with a slight dip (abt. 5°) to the northward, like the other strata in this section. Here I found, inter alia, the following species:

Tapes sp. Very frequent and almost the only form found in this stratum. Specimens with united closed valves filled with sandstone are very common. The largest specimens are 47 mm. long. Some of these Tapes specimens I feel fairly certain can be ascribed to *Tapes aureus* Gmel. but some of them possibly are *Tapes virgineus* L. or another species.

Cardium echinatum L. Some few defective loose valves. The shells are found here in a similar state of preservation to that of the specimens from the south side of the Kaldakvísl.

To the north of this section, the cliff is covered with herbage for abt. 100 m. (Tungugerðistorfa) where one cannot trace the strata. At I, however, the strata jut out, and here, at the top of the slope, there is brownish sandy mudstone, and at the bottom of the same large rounded stones similar in appearance to those above the basalt in the last-mentioned section. Presumably, these strata with rounded stones belong together, although the stones here reach higher

above the shore, the difference of level being possibly due to dislocation. At II, on the south side of a gully, Egilsgjóta, we have once more the large rounded stones farthest down on the shore (a) here doubtless a continuation of the similar strata above the basalt in Tungugerðishöfði. Above this is dark sandstone in which I could find no trace of fossils (b). Somewhat higher up, I found, at abt. 20 m. above sea-level, a distinctly stratified dark grey sandstone with intercalated strata of decomposed plant remains (c); these strata inclined abt. 14° down towards the coast. At abt. 30 m. above the shore there was a thin stratum of very small pebbles (d) which appeared to run somewhat deeper farther south.

3. The Mytilus-Tapes horizon at Tungugerðisbakkar.

At Tungugerðisbakkar, on the northern side of Egilsgjóta, there is a distinct section of the strata for some distance. At the bottom of the slope are the same strata as on the south side of the gully, save for the underlying conglomerate stratum (a). At abt. 20 m. above sea-level, we have also here the continuation of the gravel stratum with the small pebbles from the last section (d) which here continues along the slope until it disappears under loose deposits near the shore.

Then follow brown sandstone deposits mixed with clay, and abt. 10 m. above the last-mentioned gravel stratum come continuous shelly strata marked 3 on the section sketch.

The following species were found here:

Mytilus edulis L. Very frequent, here occurring with united closed valves.

Cyprina islandica L. Fairly frequent, up to 80 mm. long.

Tapes sp. Frequent, some with closed valves, the largest 49 mm.

Balanus sp. Some few specimens.

The shells themselves were as a rule much decomposed, and often only the nuclei of mudstone (more rarely of calcite) which had filled the shells were left. This shelly stratum continues a good way north along the section. sloping down to the shore.

B. The Coal Stratum at Tungugerðisbakkar.

In these deposits at Egilsgjóta, abt. 10 m. above the Mytilus-Tapes horizon, there is a coal-bearing deposit of abt. 1 m. thick, and partly mixed with sand and clay deposits blackened by admixture of vegetable remains. This coal stratum seems to be composed of small plant remains which have become transformed to some extent. I found no remains of tree trunks (lignite) here, but had not time to make a very close examination. This coal stratum crops out on the terrace slope some distance northward, as shown in the sketch.

4. The Tapes horizon at Tungugerðisbakkar.

Next to the above-mentioned coal-bearing stratum come yellowish brown mudstone deposits which continue up to the edge of the terrace. Here again there is a shelly stratum 5—6 metres above the coal stratum (4). It was not particularly rich in shells, and did not seem to form entirely continuous strata; the molluscs, however, were to be found in the same particular horizon in the deposit.

I found here:

Tapes sp. The shells themselves had disappeared, but

had left nuclei of specimens with closed valves, the largest specimens 47 mm. long.

The shelly stratum here in Tungugerðisbakka is so like the strata south of Kaldakvísl (1) and at Tungugerðishöfði (2), with a mollusc fauna so nearly identical, that it might well be imagined to be a continuation of these. The intervening coal-bearing stratum, however, seems to me to argue against this.

The strata sequence was similar to the north along the cliff. But in the northern parts, the cliff itself was somewhat lower; possibly some of the upper strata may have been carried away by erosion. There is a higher hill behind, covered with herbage, so that the tuff strata themselves are not accessible (III). At the edge of the cliff by IV I found, in the brownish yellow clay, concretions with impressions of twigs with bark and small fragments of wood; and in the concretions a little farther down I noticed some impressions of molluscs.

The northernmost end of this cliff (V) along the shore, where it meets the little stream Reká, is formed for a distance of abt. 200 m. of very irregular and confused strata; the whole system here looks like the ruins of fallen sediments from the Crag strata behind, round the Reká.

5. Cardium-Tapes sediments in the Reká and adjacent strata.

The stream Reká has dug out a fairly deep ravine in the Crag stratum a little way up from the shore. Here new shelly strata appear, which are not seen in the southern part of the cliff. In the slope on the north side of the stream there is a fairly distinct section of the strata. But a dislocation fissure runs transversely across the stream here through

the deposits, a little way below a small waterfall, in the direction from NNE.—SSW. West of this, the strata have dropped a couple of metres, and nearer the shore, they are much disturbed and sunk further down. I found here

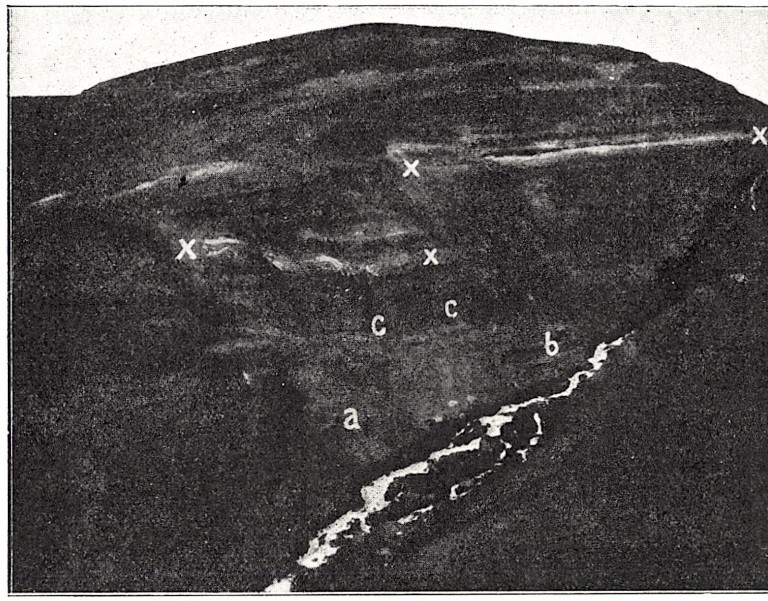

Fig. 4. The river Reká and slope on the north side of same. Upper left corner looking out towards Rekárkinn. Coal-bearing strata (C) at *x*. Faults in the strata distinctly visible, as the light coloured strata (*x*) belong together. *a* Cyprina horizon, *b* Abra horizon, *c* Cardium-Tapes horizon.

a shell stratum deep down in the deposit near the river, doubtless the oldest on the spot. They are marked on the sketch fig. 4 as follows:

a. Here I found the following species:

Cyprina islandica L. Frequent.

Cardium echinatum L. Some few valves.

Mactra sp. Frequent.

Natica sp.

This stratum is the same one which appears in fallen

slabs of tuff nearest the shore in the most northerly disturbed portion of Tungugerðisbakkar (V).

In the undisturbed strata below the waterfall there are the following:

b. Sandstone, 6—8 metres. In the uppermost part of this were thin strata with *Abra* (*prismatica*, Mont.?), the shells compressed, and the specimens much decomposed, for the most part with connected, closed valves, with nuclei of clayey sandstone.

c. Clayey sandstone with shells, 4—5 m. The characteristic species in this strata were as follows:

Cardium sp. Very frequent, with united closed valves. In most of the specimens, the shells had been corroded or dissolved away, but nuclei of sandy mudstone were found in considerable quantity. This *Cardium* species is very much like *Cardium ciliatum* Fabr. and may perhaps be ascribed to this. It differs, however, slightly from the form at present living on these coasts, so that I am not certain it is the same species.

Tapes aureus Gmel. Very frequent, in same state of preservation as the foregoing species. Abt. 40 mm. long.

The Cardium-Tapes deposit continues southward along the slope on the other side of the river behind the disturbed portion near the shore. Fragments from this stratum are also included among the fallen debris on the shore (V); I found, for instance, at the top of this portion of the cliff, both *Tapes aureus* and *Cardium*, as also farther north close to the river. In the slope along the beach leading from Reká down to Hringvershvilft (VI) the Crag strata are also to be seen, but the sequence here is somewhat disturbed, and the strata have dropped along faults which seem to run transversely across the Reká in the direction of

N. or NNE., out to Hringvershvilft. In solid strata on the slope I found a continuation of the Cardium-Tapes horizon (c) and at a somewhat lower level a shelly deposit apparently corresponding to the Abra horizon at Reká (b). I found here:

Mytilus edulis L. Small young specimens.
Cyprina islandica L. A fragment.
Abra (*prismatica* Mont.?) Frequent.
Natica sp.

C. Coal-bearing Strata at Reká.

Above the Cardium-Tapes deposits in the ravine at Reká coal-bearing strata crop out. In this series there are, at the bottom:

a 1) Dark grey sandstone without shells, 2—3 m.

b 1) Coal stratum of 10—15 cm. thickness. It contains much clay and is formed from highly transformed vegetable remains, though some very fine fibres can be discerned on the cleavage surfaces. I found no tree trunks or large twigs in this.

c 1) 1—2 m. sandy mudstone, yellowish brown or reddish brown with iron compounds.

d 1) Brown coal stratum 3—4 cm.

e 1) 1—2 m. sandy mud- or sandstone with small irregular fissures round which the sandstone has been coloured yellow or reddish brown with rust. No shells.

These coal-bearing strata continue south over the Reká, and can here be followed southward along the slope, over the Cardium-Tapes strata; they are also found in the fallen debris nearer the shore (V).

It must be presumed that the coal-bearing strata in the Tungugerðisbakkar (B) and by the Reká (C) were formed on dry land or possibly in a fresh water lake cut off from the sea. In the sandstony strata immediately above and below these formations there are also no marine shells. As the intervening shelly marine strata in which the bivalves seem to occur "in situ" (with united closed valves) were formed, the sea must have overflooded the coast, presumably owing to a subsidence of the land here during the period between the formation of these coal deposits.

The *Tapes* species and *Mytilus edulis* do not need great depth of water, and may therefore have been deposited in a very shallow part, or possibly very close to the shore. The richer strata at Reká, (with *Cardium*, *Cyprina*, *Abra* etc.) were presumably deposited at a somewhat greater depth, at the time when the subsidence or overflooding of the tract was at its maximum.

6. The Mactra horizon at Rekárkinn.

From the coal deposits on the north side of the Reká runs a slope some 25—30 metres high, formed of yellowish brown or dark grey clay and sandstone deposits up to the edge of the cliff (abt. 60 m. above sea-level). This I have named Rekárkinn on the sketches. A continuation of these strata is also found in a hill on the south side of the river (VII). Towards the north, however, the strata are bounded by loose deposits and an overgrown tract, leading from here to the grassy hollow named Hringvershvilft. In this deposit, abt. 45 cm. above sea-level, there is a rather thin shelly stratum of sandy mudstone. This contains:

Mactra sp., the predominant species in this stratum;

the shells are destroyed and only nuclei of mudstone left, the largest abt. 50 mm. long.

Margarita sp.? 1 Specimen taken here.

Above this shell horizon comes dark grey sandstone, (abt. 10 m) containing thin strata of mudstone and a number of hard nodules of the same; above this is yellowish brown sandstone (abt. 10 m.) with lumps of sandstone up to 15 cm. diam.; these appeared to be concretions, but I found no organic remains.

7. The Balanus-Nucula horizon at Hringverslækur and Hringvershvilft.

Hringvershvilft is a depression or a grassy hollow in the Crag strata nearest the shore, formed presumably to some extent by a fall in the level caused by faults. Round this depression towards the north and east the Crag strata form high steep slopes, where the structure of the strata is clearly discernible; their respective positions, however, have been greatly dislocated by numerous faults. The underlying strata in the cliff are here most distinctly visible at the Hringverslækur near the shore. I noted here the following strata:

a (lowest). Yellowish brown mudstone (abt. 2 m.) exposed close down by the sand on the shore at the southern side of the stream. This contained a number of shells, including:

Nucula sp. with crenelated inner-margin.

Under this stratum I found a thin black layer of coal-bearing shale mixed with fine sand.

b. Dark clayey sandstone (below a small waterfall in the river bed itself) abt. 1 m. thick. Various fossil shells were found here:

Mytilus modiolus L. with united closed valves.

Nucula sp. Fairly frequent, often with united closed valves, the same as in stratum a.

Mactra sp.

Balanus sp.

This stratum merges gradually into those following:

c. Very hard and close grained sandstone (abt. 1 m.) with a large *Balanus* sp. in considerable quantity. This is the same *Balanus* sp. as in the underlying stratum, and is much larger than the one found in the Mytilus deposit at Kaldakvísl, and differing greatly in appearance, somewhat resembling *Balanus porcatus.*

A similar shell deposit is found somewhat higher up the slope south of Hringvershvilft; I found here at least one stratum with Balanus, similar in appearance to that at Hringverslækur. In the deposit below this I found skeleton remains of a small species of whale (Delphinus) round it were remains of shells and some isolated specimens of lignite (driftwood?) which was also found in several other places in this deposit. Among the remains of shells on this slope I found *Pecten* (*islandicus*, Müll.?) a partly corroded valve in a concretion. Also *Abra alba*, Wood.

These strata continue south along the slopes round Hringvershvilft rising to the southward until they are interrupted by a sunken part (VIII) of the more recent strata (the Cyrtodaria stratum etc.) but they reappear again to the south of this, in the slope farthest south at Hringvershvilft (VIII x), I found here the characteristic Balanus stratum and also the same *Nucula* sp. as at Hringverslækur.

D. Coal-bearing formations at Hringverslækur.

Above the Balanus horizon at Hringverslækur come the following strata.

a (lowest). Grey mudstone, 1—2 m., no shells.

b. Abt. 40 cm. clayey bituminous shale with insignificant remains of fine vegetable fibre and some small fragments of lignite. Embedded in this were thin strata of bituminous mudstone.

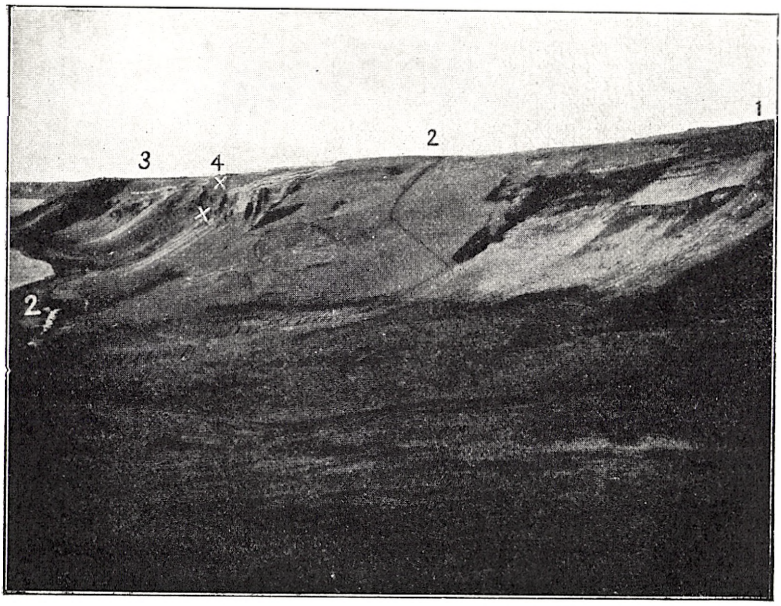

Fig. 5. Northern part of Hringvershvilft and Hringversbakkar, seen from southern part of Hringvershvilft. *1.* Subsided part of Hringvershvilft, *2.* Hringverslækur. *3.* The ravine at Skeifá. *4.* Hringversbakkar, the lighter strata seen at the top follow the coal seams (F). The fault at Kálfadalslækur seen from the relative positions at *x*.

c. Grey slate 1—2 m., no shells.

d. From here up to abt. 20 m. above the shore there is a grey sandy mudstone. In the upper half of these were nodules of very hard mudstones (concretions?) arranged in several parallel strata or bands in the deposit. Very sparse remains of marine shells were found here, including remains of *Mactra* sp.

e. Pale grey slate with compressed branches (lignite) and possibly roots of small shrub growths.

Higher up were some much disturbed deposits of yellowish brown and reddish brown mudstone with thin coal-bearing strata and scanty remains of shells which might possibly be ascribed to the lowest portion of the succeeding Cyrtodaria strata.

Coal-bearing deposits of similar composition to those here at Hringverslækur are found in the slopes at Hringvershvilft and southward as far as the above mentioned depression of the more recent strata (VIII), and in the slope south of this (VIII x) there are also similar coal-bearing strata. They are easily distinguishable from the succeeding strata by their lighter yellowish brown or reddish brown colour. Under the Cyrtodaria stratum on the north side of Skeifá there are also coal-bearing strata in a yellowish brown sandstone which may possibly be a continuation of these strata.

A small portion of the cliff between Hringvershvilft and Rekárkinn is overgrown and covered with loose deposits, so that it is impossible to see the connection between the lower strata at Hringvershvilft and the upper ones at Rekárkinn, but it seems fairly certain that nothing of importance in the strata sequence can be hidden here.

8. The Cyrtodaria stratum.

Next in the series is a shelly deposit of at least 15 m. in thickness, which I have named as above, from the fact that *Cyrtodaria siliqua* is the most characteristic species in this stratum; it is far more predominant here and occurs in larger specimens than in any other stratum of the cliff. This stratum first appears distinctly in the depressed middle

part of the cliff at Hringvershvilft (VIII), and immediately north of the fault which bounds it at a higher level, where it seems to run right up to the edge of the cliff itself (XI and X). From here, it runs northward over Hringverslækur in a gradual slope out to Hringversbakkar, where it forms the substratum of the cliff. A fault running through the cliff on the north side of Kálfadalslækur raises its surface some 20—30 metres, and it can be followed northward from here to Skeifá. On the north side of this, it is cut through by several smaller breaks, and a little farther north it dips under the talus at some 10—15 metres above the shore.

The Cyrtodaria stratum is formed for the most part of dark grey sandstone. The lower portion of this, which crops out on the north side of Skeifá and lowest in the cliff on the north side of the big fault at Kálfadalslækur, is lighter in colour, and here, more clayey strata are found embedded in the sandstone, with small concretions arranged in several parallel bands in the deposit. Here, where it merges into the underlying coal-bearing deposit, it takes on a yellowish or reddish colour (iron compounds). Similar formations are found in the lowest part of the Cyrtodaria stratum at Hringvershvilft, and south of Hringverslækur there are concretions with remains of shells inside (*Cyrtodaria*, *Mactra* etc). In some few places I found flattened pieces of lignite and petrified wood in this stratum[1]. Fossil shells, especially *Cyrtodaria* and *Mactra* sp. were found scattered at various levels in this stratum, and even near its substratum. But in the upper part, where it joins the succeeding strata, there was a continuous shelly

[1] In loose gravel at Skeifá near the shore I found a small cylindrical piece of petrified wood bored by *Teredo*. Whether it came from the Cyrtodaria stratum or was carried down by the stream from higher strata I do not know.

stratum very rich in shells; this shell horizon shows out most distinctly on both sides of the deep ravine at the waterfall of Skeifá. *Corbulomya complanata* was very prominent here. In the Cyrtodaria strata I found, *inter alia* the following species:

Cardium echinatum, L. Comparatively rare (Length 52 mm.).

Cyprina islandica, L.

Mactra 2 sp. Fairly frequent.

Zirphæa crispata, L. Only found in the Corbulomya horizon at the upper part of the stratum.

Cyrtodaria siliqua (Spengler). Very frequent, in large and thick-shelled specimens (75—80 mm. long) generally with united and often with closed valves.

Corbulomya complanata (Sow.). The most frequently occurring species in the upper shell horizon, thick-shelled specimens (Length 35 mm.).

Natica 2 sp. Fairly frequent.

E. The non-fossiliferous Sandstone Stratum at Hringversbakkar and Tungubakkar.

The Cyrtodaria stratum is covered by a layer of dark sandstone abt. 10—12 m. thick. It is found farthest south in the depressed portion of Hringvershvilft (VIII), and is seen in the cliff along Hringversbakkar and Tungubakkar. North of Skeifá, it appears now and again under the coal-bearing strata, but here it is to some extent covered with talus. At the coal mine it comes out close to the shore, and probably then dips below the sea-level. This stratum has no shells, and is in some places less distinctly stratified; I found no plant remains here either. In some parts, this stratum has become transformed in its uppermost parts near the coal strata, and assumed a yellowish-brown colour.

F. The Coal Strata at Hringversbakkar and Tungubakkar.

This coal-bearing stratum, where mining operations were carried on during the late war, is so much thicker, and so different from the other coal-bearing strata farthest south in the cliffs that it is easily distinguishable from them. It appears farthest south in the depressed portion at the middle of Hringvershvilft; from here out to Hringverslækur the underlying strata have been lifted right up to the edge of the cliff and the coal strata eroded away.

They reappear at the top of the cliff close to the north of this streamlet and then slope northward to the dislocation fissure north of Kálfadalslækur, where they are once more raised to the upper edge of the cliff. On the south side of Skeifárfoss they crop out distinctly at 45—50 m. above the shore. They are visible at several places in the slope along Tungubakkar, where they incline slightly towards the north, and at the coal mine, they drop again nearly to the shore, where they disappear under loose deposits.

I have not yet had time to study the coal strata closely or measure the thickness of the strata accurately at different places. The thickness of this deposit seems to vary somewhat, as a rule abt. 2 m., in some places up to 4 or a little over. The number of coal strata in the deposit is as a rule 3, but in some places there are 4.

In the coal mine and in the slope north of Skeifá at 25—30 metres' height, the measurements gave the following result:

At the top is the littoral Mytilus deposit. Then follow:

	At the mine cm.	At Skeifá cm.
a. coal stratum, slaty	40	15—20
b. sandy mudstone	30	35

		At the mine cm.	At Skeifá cm.
c.	coal stratum, slaty	10	10
d.	sandy mudstone	16	65
e.	coal slate mixed with clay and fine sand	70	30—40

f. yellowish brown clayey sandstone, possibly the upper part of the underlying sandstone (E); it is not impossible, however, that coal-bearing strata may be found somewhat deeper down, as this stratum was partially covered in both places.

At Hringversbakkar, the coal strata are also mostly 3 in number. But at Skeifá, a little way up from the waterfall, I found 4.

The coal strata themselves are for the most part formed of small plant remains; the cleavage surfaces show partially transformed, fine plant fibres and what look like grass stems. There are, however, thin, flattened branches, but they seem to be comparatively few in number, though there are some few places where lignite has been found, formed of large, compressed tree trunks. In the mudstone under the coal strata also, one may often find both impressions and carbonised remains of plant roots, twining vertically down through the same. At Tungubakkar I also found leaf impressions, including one whole impression which looked like that of a *Salix* leaf, but unfortunately they were not in such a state of preservation as to permit of determination. I found no remains of marine shells anywhere in these strata.

We may conclude from the above that these coal strata cannot have been formed of driftwood, as hitherto supposed, but from plants grown on the spot. Presumably, the coal

strata originated as peat in a bog, or possibly in a fresh water lake, where the sea water did not enter.

The coal strata here are of little use as fuel; owing to a strong admixture of clay, they leave a great deal of ash, and

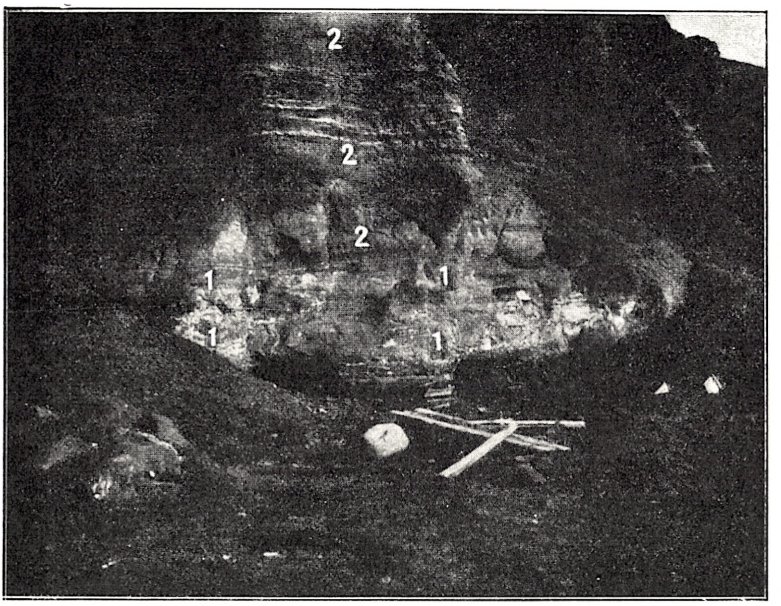

Fig. 6. Strata immediately above the brown coal strata (F) at the coal mine. Two shafts seen at the bottom. *1* The littoral Mytilus deposit (9) 2 the Cyprina-Mactra series (10) lowest stratum.

also contain a quantity of sulphurous compounds, emitting a strong smell when burnt. It might, however, be worth while for people from the adjacent farms to get coal here for fuel.

9. The littoral Mytilus deposit at Tungubakkar and Hringversbakkar.

Immediately above the uppermost coal stratum in the coal mine there is a stratum of rather coarse-grained sandstone, 2—3 m. thick. In this occur, scattered about, some

very small rounded stones, and abt. 2—$2^1/_2$ m. up in the same a quantity of pebbles somewhat larger arranged in more or less continuous layers in the sandstone. In this stratum there are a number of marine shells, but they are somewhat decomposed. *Mytilus edulis* L. is the most characteristic species here, and occurs often with united closed valves filled with sandstone.

Mytilus deposits similar in appearance to this are found all through above the coal strata along the whole of Tungubakkar, from the mine southward to Skeifá where the strata in situ appear. On the south side of Skeifá it appears somewhat farther south at the top of the cliff above the coal strata. South of the fault at Kálfadalslækur it again appears above the coal strata at a lower level; it is also seen above the coal strata up at the edge of the cliff in the depression at Hringvershvilft (VIII).

Among the molluscs I collected at different localities in this strata may be noted the following:

Pecten islandicus Müll. Only a single valve, defective, found at the coal mine.

Mytilus edulis L. Very frequent and often with united closed valves, the largest specimens abt. 75 mm. long.

Mytilus modiolus L. Part of a single valve.

Cardium echinatum L. Rare.

Cardium (*ciliatum* Fabr.?) Rare.

Cyprina islandica L. Some few valves found in this stratum.

Mactra sp. Some few valves brought home from this stratum.

Natica sp. Rare.

Balanus sp.

The relations of beds seem to suggest that the peat strata of which the coal strata were formed were flooded by the sea owing to a subsidence, so that the littoral formations could be deposited above them, either on the shore or in very shallow water. The fine material of which this shelly stratum is formed suggests that the inundation took place in a sheltered creek or fjord well protected from the waves. The littoral gravel higher up in the stratum suggests perhaps that the strength of the waves afterwards increased. It is probable that *Mytilus edulis* lived on the spot, as it is found so often with united closed valves. The other bivalves seem to occur more often as separate valves.

The subsequent strata which I shall now describe show that the submergence of the land, which can be traced in this deposit, gradually increased.

10. Cyprina-Mactra series at Tungubakkar.

This deposit is a continuation of the Mytilus stratum running upwards, and shows out most distinctly in the steep clay and sandstone rocks above the mine, where it is, I should say, at least 20 metres thick. It is formed chiefly of sandstone, with an admixture of clay. Shells are found here in considerable quantity, for the most part assembled in several more or less continuous bands in the sandstone; the shells are often broken and the fragments smoothed at the edges and rounded. The bivalves seem to occur most frequently with separated valves. There is also an alternation in the stratification, strata of coarse-grained sandstone and finer sand with an admixture of clay in turns. In the rocks above the mine there are, immediately above the Mytilus deposit:

a. abt. 4 m. grey sandstone with 2 thin shelly clayey strata.
b. „ 4 m. sandstone containing 4 thin shelly bands mainly *Cyprina* and *Mactra*.
c. „ 6 m. sandstone with scattered shells of *Cyrtodaria*, *Corbulomya* etc.
d. Two thin strata with specimens of *Mactra*, *Cyprina* etc.; in the lower portion, the shells are whole, but broken in the upper.
e. Two bands with *Mactra* and *Cardium*.
f. In the uppermost part of the rock I saw also two shelly strata, but could not get at them.

I found here the following species:

Cardium echinatum L. Comparatively rare.

Cyprina islandica L. Very frequent.

Mactra sp. Rather frequent.

Cyrtodaria siliqua Spengler, taken in the upper shell horizons.

Corbulomya sp. Fairly frequent in some of the higher horizons.

Natica sp.

North of the mine, the continuation of these strata is covered by loose deposits, but to the south, they can be traced along the Tungubakkar as far as Skeifá. Above the Mytilus strata at Hringversbakkar they are also visible for a short distance at the top of the cliff, where the series is also lowered, south of the dislocation at Kálfadalslækur.

These strata were presumably deposited at a somewhat greater depth than the Mytilus deposit, but the great number of smoothed shell fragments seems to suggest that the waves were more powerful at the time of their formation here. — In the shelly strata higher up, however, whole

shells occur more frequently. It would seem as if this deposit had been formed in shallow water, and partly of shells washed up together.

11. The Mactra-Pectunculus series at Svarthamar.

North of the coal mine there are several shelly horizons in the slope round the so-called Svarthamar, which I have here taken together, under the above name. They appear most distinctly at Litli-Svarthamar and farther south in a rock wall of mudstone high up the slope from Svarthamar, as also at Svarthamar near the coast. To the south and north these strata are covered by talus and I could not therefore distinguish the contact between them and the Cyprina-Mactra deposit above the coal mine, or draw any sharp boundary line between them. As regards the composition and relative position of the strata, there is considerable difference between these two deposits. The slope of the strata in the cliff seems to suggest that these shell strata round Svarthamar should come immediately after the Cyprina strata above the mine; it is possible, however, that the lowest Svarthamar strata also occur uppermost in the strata above the mine.

I marked here the following shell horizons:

a. Shell stratum uppermost at Stóri-Svarthamar (2—3 m. above sea) where I found *Emarginula crassa*, Sow., *Mactra* sp., *Nucula* sp. etc. Below this stratum at Svarthamar are also several less prominent shell horizons.

b. A shell stratum with many species is exposed most distinctly at the bottom of the cliff wall, on the slope up from Svarthamar (abt. 40 m. above sea). Besides bivalves such as *Mactra*, *Cyprina*, *Cardium* and *Pectunculus*, there are also several species of gastropods (*Littorina*, *Natica*, *Nassa* etc.).

c. Two separated strata with *Mactra*, *Cyprina* and *Pectunculus* with whole, often closed valves; found both at Litli-Svarthamar and in the rocks on the slope up from Svarthamar.

d. A stratum 2—3 m. thick with *Mactra* and *Cyprina*,

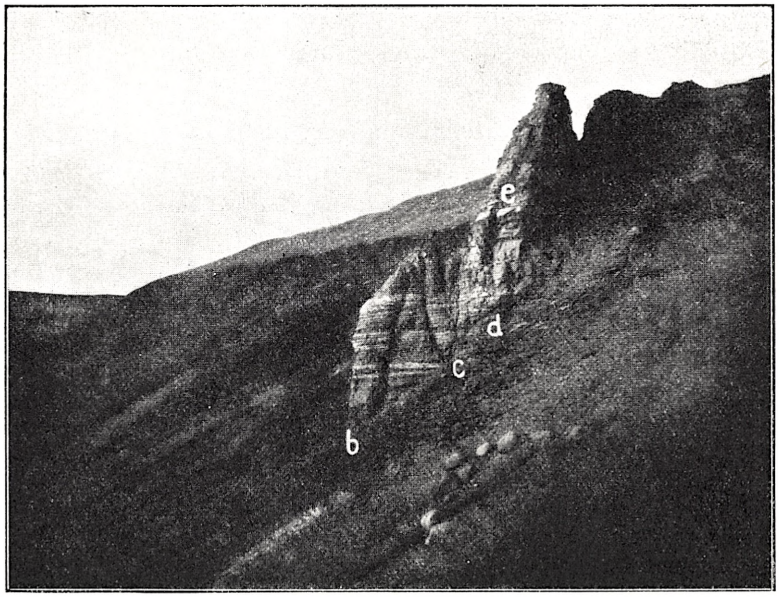

Fig. 7. Litli-Svarthamar. Seen from Stóri-Svarthamar. The light stripes are shell strata. Letters *b*—*e* refer to accompanying section description. The lighter deposits higher up the cliff on the other side of Litli-Svarthamar are the younger gravel deposits covering the Crag strata (see p. 10).

which appear in numerous thin layers in the deposit. The valves mostly separate and often broken.

e. 2—3 thin strata with fragments of *Cyprina* and *Mactra* (50—60 m. above sea-level). These two last-named strata show out distinctly in the southernmost part of the cliff wall from Svarthamar up. In these deposits I collected abt. 25 species of molluscs, chiefly from horizon *b*. Of these I mention the following:

Pecten (*islandicus* Müll.?). Two fragments taken from

the talus below the rocks on the slope south of Svarthamar.

Mytilus sp. A fragment (*b*).

Nucula sp. Some valves (*a*).

Pectunculus glycimeris L. Some whole valves taken at Litli Svarthamar (*c*) and fragments in stratum *b*. Not found outside this series (11).

Cardium echinatum L. Fairly frequent in horizon *b*.

Cyprina islandica L. Very frequent, especially in horizons *c*—*e*.

Cyprina rustica Sow. seems to be less frequent than the foregoing.

Mactra 2 sp. doubtless both *M. procrassa* S. Wood, which is the most frequent species in Horizon *b*, and *M. arcuata* Sow. These Mactra species seem to be the most prominent forms in this series.

Cyrtodaria siliqua Spengl. Rare. Some specimens from Horizon *b*.

Zirphœa sp. Some fragments (*b*).

Emarginula crassa, Sow. Some few specimens (*a* and *b*).

Natica sp. frequent in horizon *b*.

Trochus sp. 1 spec. (*b*).

Littorina sp. Frequent.

Bela sp. 1 spec.

Nassa lamellilabra Nyst. Frequent (*b*).

Nassa sp. Some specimens (*b*).

Urosalpinx cinereus Say. 8 specimens (*b*).

Liomesus sp.

Sipho sp.

The shelly strata at Svarthamar are for the most part of rather coarse-grained sandstone (*a*) and must therefore have been deposited at slight depth. The strata in horizon

b are formed of mudstone and here also the fauna is richest in number of species, possibly owing to the fact that the strata in question were formed in deeper water. The higher strata in the series are composed of more sandy material. The succeeding stratum (12) seems also to be a typical coast formation. This may possibly be due to oscillation in the sea-level while the strata were in course of formation.

12. The Corbulomya Winkleri horizon at the bottom of Tungukambur.

At the bottom of Tungukambur on the south side of Hallbjarnarstaðaá a shell stratum appears close down by the river. It is formed of dark grey, coarse-grained sandstone, and contains a quantity of shell fragments and shells in a decomposed state. The most prominent species here is a small mollusc which I have determined as *Corbulomya Winkleri*, Mörch. This shell stratum seems to have been formed of shells washed together on the beach or at slight depth. I also found here a small piece of carbonised wood (driftwood?).

I found here the following mollusc species:

Cardium sp. Impression of a shell fragment.

Cyprina islandica, L. Some fragments.

Cyprina rustica, Sow. Some separate valves.

Mactra sp. Only a single defective valve.

Cyrtodaria siliqua Spengler. Some defective valves.

Corbulomya Winkleri, Mörch. Very frequent (Length abt. 30 mm.).

Natica sp. Several specimens taken in this stratum, but in a poor state of preservation, and some compressed.

This stratum can be seen at several places in the bottom of the ravine at Hallbjarnarstaðaá. But in the slope southward along the shore it is covered with loose deposits. At

the top of the slope up from Svarthamar (abt. 60 metres above sea-level) I found *Corbulomya Winkleri* very frequent in a sandstone stratum. Possibly a continuation of this horizon.

13. The Cyprina islandica horizon at Tungukambur.

This shell horizon lies abt. 8—10 m. above the river, and is formed of two shell strata where *Cyprina islandica* seems to be almost the only form. In the lower stratum it occurs most frequently in whole specimens with closed valves and filled with sandstone, more rarely with calcite crystals. In the upper shell stratum loose shells and fragments are more often found.

A list of the species is as follows:

Cardium echinatum, L. Rare.

Cyprina islandica, L. The most prominent species (length 75—80 mm.).

Cyrtodaria siliqua, Spengler. 1 defective valve.

Natica sp.

These Cyprina strata continue southward over the slope along the shore, but are covered over in several places by loose fallen material. In the loose gravel up at the edge of the cliff, above Litli-Svarthamar I found quite a number of fragments of *Cyprina islandica*. Possibly it is a continuation of these strata. A little distance from the shore this Cyprina stratum is found in the river bed, under water, at Hallbjarnarstaðaá and rises thence to a higher level up the gully.

14. The Actæon horizon at Tungukambur.

Above the Cyprina horizon comes a stratum 6—8 metres thick consisting of sandstone mixed with clay. There is no

continuous stratum of shells in this, but light coloured strips are seen here and there, composed of shell residue. Above this comes a deposit very rich in shells, which I have called the Actæon horizon, as *Actæon Noæ* is more or less frequent here, and far more frequent than in any other shell stratum on the cliff. The main shell stratum here is abt. 1 m., but shells are also found both above and below it, so that the whole shell deposit may be reckoned as 3—4 m. I took abt. 20 species here. Among the most frequent is *Cardium groenlandicum*, which I have not previously found in the older strata. It seems here to replace the *Mactra* species, which I do not find in my collections from this or more recent strata in the cliffs.

I found here the following species:

Modiolaria nigra, Gray. Some few valves (Length 38 mm.).

Leda sp.

Cardium groenlandicum, Chemn. frequent (Length 63 mm.).

Cardium sp.

Cyprina islandica, L. Fairly frequent.

Cyprina rustica, Sow. Less frequent.

Astarte 2 sp.

Macoma obliqua, Sow. Frequent.

Solen ensis, L. Fairly frequent, abt. 1 metre above the main shell stratum.

Mya truncata, L. f. *ovata* Jensen. Frequent.

Panopea norvegica, Spengler. Rare.

Cyrtodaria siliqua, Spengler. Frequent, especially young spec.

Natica 3 spec. Frequent.

Acrybia flava, Gould.

Bela sp. 1 spec.

Nassa sp. 1 spec.

Buccinum undatum, L., frequent.

Buccinum groenlandicum, Chemn.

Sipho (*Olavii*, Mörch?) Rare.

Actæon Noæ, Sow. Fairly frequent.

The bivalves are comparatively rarely found here with united closed valves.

The Actæon stratum is found in the slope southward along the shore, but is here partially covered with loose gravel. On the north side of Hallbjarnarstaðaá (Hallbjarnarstaðakambur) it occurs at a couple of metres above the river, where the Cyprina stratum lies under water. In the ravine along the river it can be followed for a considerable distance from the coast.

15. The Sipho horizon at Tungukambur and Hallbjarnarstaðakambur.

At abt. 12 metres above the Actæon horizon there is again a stratum rich in shells which I have named as above, as several *Sipho* species are very prominent in this, and far more frequent than in any other horizon in the cliff. In the clayey sandstone between the Sipho and Actæon horizons there are some scattered shells, and close under the Sipho horizon 3—4 thin strata with *Cyprina* shells. The Sipho stratum crops out distinctly in Hallbjarnastaðakambur abt. 20 m. above the shore, and is continued in along the steep slopes of the ravine following the river (Hallbjarnarstaðaá). It runs up to the edge of the cliff a good way north of Litli-Svarthamar.

Of all the marine strata found north of the coal mine, this must be the one formed at the greatest depth, as the material in which the shells are embedded is mainly hardened clay less mixed with sand than other strata of this

series. The frequency of the *Sipho* species in the stratum also seems to point in the same direction.

In addition to the *Sipho* species, *Mya truncata* f. *ovata* is also very frequent and occurs in large specimens; likewise

Fig. 8. Tungukambur, the slope down to Hallbjarnarstaðaá. Seen from the path above Hallbjarnarstaðakambur. *a*. Cyprina islandica horizon (13). *b*. Actæon horizon (14). *c*. Sipho horizon (15). *d*. The youngest gravel deposits covering the Crag strata. The discordance between these deposits and the underlying Pliocene strata is distinctly visible.

Cardium groenlandicum, *Cyprina rustica* etc. I collected here some 25 mollusc species among which the following may be mentioned:

Modiolaria nigra, Gray. 1 spec.
Cardium echinatum, L. 1 valve.
Cardium groenlandicum, Chemn. Frequent.
Cyprina rustica, Sow. Frequent.

Cyprina islandica, L. seems to be less frequent than the foregoing species.

Macoma obliqua, Sow. Frequent.

Macoma sp.

Mya truncata, L. forma *ovata*, Jensen. Very frequent, large elongated specimens with closed valves (80—90 mm).

Panopea norvegica, Spengler. 1 valve.

Cyrtodaria siliqua, Spengler. Fairly frequent, especially young specimens.

Natica 2 or 3 sp. Very frequent.

Bela 2 sp. Some few specimens.

Searlesia Lundgreni, Mörch. 2 specimens.

Buccinum undatum, L. Frequent.

Buccinum groenlandicum, Chemn. Frequent.

Neptunea despecta, L. Some few specimens.

Sipho Olavii, Mörch. One of the most conspicuous forms in this stratum.

Sipho tortuosus, Reeve.

Sipho sp.

Liomesus canaliculatus, Dall. 2 specimens.[1]

16. The Mya-Macoma horizon at Tungukambur and Hallbjarnarstaðakambur.

At the top of Tungukambur, close below the recent gravel deposits, at the top of the cliff, there is a continuous shelly stratum abt. 10 m. above the Sipho horizon, and 40—45 m. above the sea-level. The same stratum also appears distinctly at Hallbjarnarstaðakambur at 30—35 m. above the beach. In this stratum, *Mya truncata* f. *ovata* is very frequent, though mostly in young specimens, also

[1] According to information received from Kári Sigurjónsson at Hallbjarnarstaðir, *Actæon Noæ* is to be found in this stratum, but is extremely rare.

Macoma sp. possibly *M. calcaria*, Chemn. but the shells in the piece of mudstone brought home were so broken that they could not be determined with certainty.

In this stratum at Tungukambur I found some bones of a seal which Vice-Inspector H. WINGE considered must have belonged to *Phoca groenlandica* or a closely related species.

A couple of metres above and below this stratum *Mya* and *Macoma* also occur in non-continuous thin strata. The continuation of this stratum is found in the steep slope on the south side of Hallbjarnarstaðakambur leading down to the river. Here, in a small sandy portion of this stratum, many small gastropods (*Bela* and *Nassa*) were found.

I found in the above mentioned strata the following species:

Mytilus phaseolinus, Fabr. 1 valve.

Nucula sp. 1 valve.

Cardium (*ciliatum*, Fabr.?). 1 small valve.

Cardium groenlandicum Chemn. Less frequent.

Cyprina rustica, Sow. Less frequent.

Astarte sulcata, da Costa. 2 valves.

Macoma (*calcaria*, Chemn.?). Very frequent. Shells decomposed and broken.

Thracia (*truncata*, Brown?). Some small specimens (length 12 mm.) taken in this stratum at Tungukambur and a couple of metres higher up in the deposit.

Mya truncata, L., f. *ovata*, Jensen. Very frequent.

Natica sp. 7 young specimens.

Gibbula sp. 1 specimen.

Admete viridula, Fabr. var. *costellifera*, Sow., frequent in the sandy part of the stratum, in the slope on the south side of Hallbjarnarstaðakambur.

Bela sp. At the same place.

Nassa lamellilabra, Nyst. Same place, frequent.
Buccinum undatum, L. Some young specimens.
Buccinum groenlandicum, Chemn., 2 specimens.
Buccinum sp.
Sipho Olavii, Mörch, 2 specimens.

17. The Macoma obliqua-Cyprina rustica horizon at the top of Hallbjarnarstaðakambur.

This shell stratum lies abt. 12 metres higher by the road up the Hallbjarnarstaðakambur, than the last-mentioned. The most frequently occurring species here seem to be *Macoma obliqua* and *Cyprina rustica*. This is the only place where I have found *Sipho islandicus*. I found here the following species:

Modiolaria nigra, Gray. Impression of one shell.
Cardium groenlandicum, Chemn. 2 valves.
Cyprina rustica, Sow. Very frequent. (L. abt. 50 mm.).
Macoma obliqua, Sow. Very frequent.
Solen sp. Some defective valves.
Thracia (*truncata*, Brown?). Some young specimens in the deposit a couple of metres below the main shell stratum.
Mya truncata, L. f. *ovata*, Jensen. Frequent.
Panopea norvegica, Spengler. 1 shell.
Cyrtodaria siliqua, Spengler. 1 shell. (L. 46 mm.).
Natica sp. Fairly frequent.
Bela sp. 3 specimens.
Buccinum sp. 5 specimens.
Neptunea despecta L.
Sipho islandicus, Chemn. 1 spec. (L. 77 mm.).
Sipho sp. 2 specimens.

This shell stratum shows out fairly distinctly at the top of the slope facing southward towards the river.

18. The Cyprina rustica-Cyrtodaria horizon at the bottom of Kambsgjá.

Kambsgjá is a small ravine in the cliff, dug out by the action of water, abt. 200 m. north of Hallbjarnarstaðakambur. The solid strata here are covered with loose fallen masses, 25—30 m. above the shore. At abt. 30 m. height, there is a shelly horizon, fairly rich in shells; *Cyprina rustica* and *Cyrtodaria* are the most prominent species.

I found here the following:

Cyprina rustica, Sow. Frequent.
Astarte (*borealis*, Chemn.?). 1 valve.
Astarte sulcata, da Costa. Some valves.
Astarte (*Banksii*, Leach?). 2 valves.
Astarte incerta, Wood. 2 valves.
Macoma obliqua, Wood. Some defective valves.
Macoma calcaria, Chemn. Some valves.
Mya truncata, L. f. *ovata*, Jensen, fragments.
Panopea norvegica, Spengler, 1 valve (L. 53 mm.).
Cyrtodaria siliqua, Spengler. Frequent.
Gibbula tumida, Mont. Some few specimens.
Natica sp. Frequent.
Trochus sp. 2 specimens.
Admete viridula, Fabr. var. *Couthouyi*, Jay. Frequent.
Nassa sp. Some specimens.
Bela 2 spec. Frequent.
Buccinum (*undatum*, L.?). 3 specimens.
Buccinum groenlandicum, Chemn. 2 specimens.
Neptunea despecta, L. 3 specimens.
Sipho sp. 1 defective specimen.

Southward along the slope between Kambsgjá and Hallbjarnarstaðakambur this stratum is discernible between the loose masses of fallen material, and in the slope north of

the path leading up Hallbjarnarstaðakambur the southernmost remains of it are found 10—12 m. above the last-mentioned stratum, at abt. 55 m. above the shore.

This and the following stratum at Kambsgjá are considerably mixed with sand, and must be said to be composed of a clayey sandstone, whereas the strata at Hallbjarnarstaðakambur should rather be called sandy mudstone, as they contain large quantities of clay.

19. The Gastropod horizon at Kambsgjá.

At Kambsgjá there is another stratum very rich in shells at abt. 35 m. above the shore; *Cyprina rustica* is very frequent here as also *Mya truncata*, f. *ovata*, but *Cyrtodaria* is hardly so frequent here as in the stratum last mentioned. A specially characteristic feature of this horizon is the occurrence en masse of different gastropod species, e. g. *Buccinum*, *Natica*, *Neptunea*, *Lunatia*, *Admete* etc. At abt. 1 metre above this stratum there is a fine loose sandstone where *Mya truncata*, f. *ovata* was found in large specimens with united closed valves; also *Cyprina rustica* and *Mytilus phaseolinus*.

I found in this horizon some 35 species of molluscs, of which the following may be noted:

Mytilus phaseolinus, Phil. Some valves from the sandstone above the shell stratum itself.

Leda pernula, Müll., 1 valve.

Cardium groenlandicum, Chemn. Fairly frequent.

Cyprina rustica, Sow. Very frequent.

Venericardia borealis, Conrad. 5 shells.

Astarte sulcata, da Costa. 1 shell.

Astarte (*Banksii*, Leach?). Some valves.

Macoma obliqua, Sow.

Macoma calcaria, Chemn.

Solen sp. Some defective valves in the sandstone above the shell stratum.

Mya truncata, L. f. *ovata*, Jensen. Very frequent in the sandstone above the shell stratum (L. abt. 70 mm.).

Panopea norvegica, Spengler. 1 valve, defective.

Cyrtodaria siliqua, Spengler. Fairly frequent.

Nacella pellucida, L. 3 specimens.

Acrybia flava, Gould. 2 specimens.

Natica sp. Frequent.

Admete viridula, Fabr., var. *Couthouyi*, Jay, frequent.

Bela 3 sp. Frequent.

Nassa lamellilabra, Nyst. 4 specimens.

Nassa sp. 3 specimens.

Buccinum undatum, L. Frequent.

Neptunea despecta, L. var. Fairly frequent.

Anomalosipho Verkrüzeni, Kobelt. var. *plicifera*, Brögger, 4 specimens (46 mm.).

Sipho sp. 2 specimens.

Cylichna cylindracea, Penn. 1 specimen.

This stratum occurs on both sides of the ravine, but cannot be traced farther as the slopes on both sides are now covered with talus.

20. The Cyprina horizon at Kambsgjá.

This shelly horizon lies abt. 10 m. higher than the last mentioned, or abt. 45 m. above the shore. *Cyprina islandica* is most prominent here and *Cyprina rustica* is also frequent. They form together continuous shell strata and occur chiefly with united closed valves, filled with yellowish calcite crystals.

I have here found in all the following species:

Cyprina islandica, L. Very frequent.

Cyprina rustica, Sow. Very frequent.

Cyrtodaria siliqua, Spengler. 1 valve, defective.

Astarte (*crenata*, Gray, var. ?). 1 shell.

Natica sp. 2 specimens.

Sipho sp. 1 specimen, defective.

Somewhat farther south, this stratum joins on to the most recent pebble deposit at the surface of the cliff. North of Kambsgjá it is covered with loose gravel.

21. The Bela horizon at the top of Kambsgjá.

This shell stratum lies at the top of Kambsgjá, 5—6 m. higher than the Cyprina horizon, and abt. 65 m. above the shore. Very characteristic is the great quantity of *Bela* species here found; among the bivalves, *Cardium groenlandicum* and *Cyprina rustica* rank first, and occur commonly with whole, closed valves. On the south side of the ravine, this stratum soon comes to an end in loose masses of gravel belonging to the covering layer at the top of the cliff. North of Kambsgjá it is probably hidden under loose deposits close below a rock shelf of hard sandstone at the top of the cliff. Farther north, the continuation of this brownish rock shelf lies somewhat higher, probably owing to a fault. Here, lower down, in a small jutting point of dark grey material called Gráaklöpp, there are strata of shells at abt. 40 m. above the shore, which I consider as identical with the Bela stratum at the top of Kambsgjá as the *Bela* species are very frequent in both places. In collections from these two places I have the following species:

Modiolaria nigra, Gray. 2 valves taken in both places.

Cardium groenlandicum, Chemn. Found in both places, very frequent in this stratum at Kambsgjá (L. 50—55 mm.).

Cyprina rustica Sow. Very frequent in this stratum at Kambsgjá (L. abt. 70 mm.).

Venericardia borealis, Conrad. Fairly frequent at Gráaklöpp.

Macoma obliqua, Sow. Both places.

Macoma calcaria, Chemn. Frequent at Kambsgjá.

Mya truncata, L. f. *ovata*, Jensen. Both places.

Cyrtodaria siliqua, Spengler. Both places, but rare.

Gibbula tumida, Mont. 1 spec. at Kambsgjá.

Trochus sp. 1 specimen at Kambsgjá.

Margarita sp. 1 specimen at Kambsgjá.

Calyptraea chinensis, L. 2 specimens at Gráaklöpp (determined by Dr. A. Bell).

Natica sp. Very frequent in both places.

Lunatia sp. Frequent at Kambsgjá.

Admete viridula, Fabr. var. *Couthouyi*, Jay. Frequent in both places.

Bela 3 sp. Very frequent in both places.

Nassa sp. Some specimens from both places.

Buccinum groenlandicum, Chemn. 2 spec. from Kambsgjá.

Buccinum sp. Fairly frequent at Kambsgjá.

Neptunea despecta, L. 1 specimen at Kambsgjá.

Liomesus canaliculatus, Dall. 1 specimen at Kambsgjá.

Sipho sp. 4 specimens, defective, from Kambsgjá.

Searlesia costifer, Wood. 1 specimen from Kambsgjá (35 mm.).

Actæon Noæ, Sow. 2 specimens from Gráaklöpp.

Actæon is extremely rare in this stratum. The finding of *Calyptraea chinensis* should also be noted, this species not having been found in any other of the earlier strata.

22. The shelly sandstone shelf.

The shelf of brownish sandstone above the Bela horizon, to which I have referred above, I have taken as a distinct stratum because it juts out distinctly here in the slope in the form of projecting rocks slanting northwards out along the cliff. It appears at a height of abt. 20—30 m. above

sea-level at Bæjarlækur and reaches the shore near Tóugjá. The stratification is not very marked, the whole being formed of a very hard, fine-grained sandstone, more durable than the sediments above and below. It is grey in colour, but turns brown on the weathered surfaces.

Scattered remains of shells are found in this stratum, especially *Macoma*. In the portion above Gráaklöpp I have taken:

Macoma obliqua, Sow. Very frequent.
Panopea norvegica, Spengler.
Cyrtodaria siliqua, Spengler.
Gibbula tumida Mont.
Natica sp.
Bela sp.

23. The Astarte Strata.

These strata crop out farthest south at the top of the cliff south of the so-called Hælskor, and run out obliquely along the cliff; on the north side of Bæjarlækur they lie abt. 40 m. above the shore, at Tóugjá abt. 20 m. above the shore and abt. 200 m. north of here they run right down to the beach. They are easily distinguished from the other adjacent strata even at some distance by a thin layer of pebbles and littoral gravel embedded in the shelly deposit. At Tóugjá this deposit is composed of the following strata:

f	(uppermost). Brown sandstone without shells abt.	3 m.
e.	Closely cemented *Cyprina* fragments	0.40 m.
d.	Sandstone mixed with clay, scattered shells, grey in colour	4.0 m.
c.	Small pebbles and gravel	0.20 m.
b.	Light coloured sandy mudstone fairly rich in shells	2.0 m.
a.	Dark grey sandy mudstone with scattered remains of shells, thickness down to the talus	4.0 m.

At Bæjarlækur no Cyprina stratum was found as at e, or if so, it was much thinner; otherwise the sequence here appeared to be the same. The deposit under the pebble stratum (c) was richest here in fossil shells.

I have the following species from here:

Pecten (*islandicus*, Müll.?). Only a small fragment.

Mytilus sp. A small defective specimen.

Cardium groenlandicum, Chemn. Fairly frequent.

Cyprina rustica, Sow. Frequent.

Cyprina islandica, L. Less frequent.

Venericardia borealis, Conrad. Frequent (20 mm. high).

Astarte sulcata, da Costa. Fairly frequent.

Astarte (*crenata*, Gray, var. ?). Some specimens.

Macoma obliqua, Sow. Fairly frequent.

Macoma calcaria, Chemn. Some specimens.

Panopea norvegica, Spengler. 4 valves.

Cyrtodaria siliqua, Spengler. Fairly frequent.

Corbulomya Winkleri, Mörch. Frequent.

Zirphæa crispata, L. Some fragments.

Nacella pellucida, L. 1 specimen.

Lepeta caeca, Müll. 2 specimens.

Gibbula sp. 2 specimens.

Calyptraea chinensis, L. 1 specimen (Diam. 25 mm.).

Natica sp. Frequent.

Admete viridula, Fabr. var. *Couthouyi*, Jay. 5 specimens.

Bela 2 spec. Fairly frequent.

Nassa lamellilabra, Nyst. Some few specimens.

Neptunea despecta, L. var. 3 specimens.

Sipho tortuosus, Reeve. 1 specimen.

I also found bones of whales in this stratum, both at Hælskor and between Bæjarlækur and Tóugjá.

This stratum seems to be a typical littoral formation

(c—d), as suggested by the pebbles and the fact that shell fragments are also often rounded; it must be taken as the last stage of a subsidence of the land here, commencing with the formation of the littoral Mytilus deposit over the

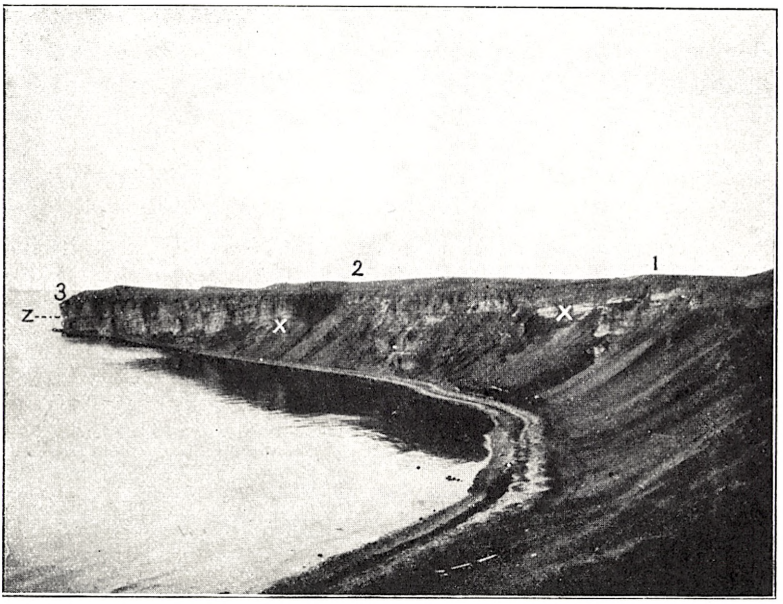

Fig. 9. View of the Pliocene deposits in the cliff out towards Svarthöfdi. Seen from the path above Hallbjarnarstaðakambur. *1* Bæjarlækur, *2* Tóugjá, *3* Nafir, the light strata at Bæjarlækur and Tóugjá (×) are the Astarte strata (23), the dark stratum next above these is the non-fossiliferous clayey sandstone (G). The light stripe at *z* in Nafir is the mudstone with plant remains (I). The thick dark stratum below these is the sandstone with tree trunks (H) but at the top of the cliff is the shell-bearing sandstone with tree trunks (24).

coal stratum and reaching its maximum in the formation of the Sipho horizon at Tungukambur, ending with the formation of this stratum.

G. Dark grey Clay Mudstone without Fossils.

Immediately above the littoral Astarte deposit comes a stratum of dark grey, clayey sandstone, very fine in the grain, showing no distinct horizontal stratification. Its southernmost outcrop is at the upper edge of the cliff between Hælskor and Bæjarlækur and slopes outwards, like other strata here, (10° to WNW.), reaching down to the beach at Nafir in Stórhöfði. Its thickness seems to vary somewhat. At Tóugjá it was abt. 5 m. thick. In other places it may be a little more or a little less. I did not succeed in finding any trace of organic remains in this stratum. As it does not contain marine shells, and also rests upon a beach formation, which must have been formed during an upheaval of the coast, it seems to me reasonable to suppose that it is an extramarine formation, possibly deposited in calm fresh water or in brackish water; as to this, however, I do not venture to say more at present.

H. Sandstone with Tree Trunks.

This stratum commences at the top of the cliff between Bæjarlækur and Tóugjá, continuing thence on the Stórhöfði, where it dips below the beach, north of the little headland of Nafir. I was not able to measure the thickness exactly, but estimate it from 10—15 m. or perhaps a little more where it is thickest. It is brown in colour, and formed of rather fine-grained sandstone showing discordant stratification, the minor strata varying somewhat in the direction of their slope. There is no trace of marine shells, but scattered tree trunks are found here and there. These are light yellow in colour and, according to investigations kindly made by Prof. O. Böggild, "petrified in a phosphorite substance, and in cavities in the pieces there are at times

deposited long yellowish crystals of calcite but there are also colourless apophyllite crystals resembling octahedra and very small crystals of other zeolites". Mag. sc. F. J. Mathiesen, who had some pieces for investigation, found that they were from conifers. These tree trunks on the whole retain their original round form and have only been found in a prone position in the stratum. A point which argues against their having come from a distance as driftwood is the fact that several of the trunks have roots and branches attached. One such trunk I found at Nafir, down at the shore, where this stratum adjoins the underlying mudstone. At a first glance it seemed to me that the roots were in their original position, sticking down into the mudstone, but on closer observation, I came to the conclusion that they were not. All the ramifications of the tree were enveloped in the sandstone, which here filled up a small depression in the clayey sandstone. From the observations hitherto made as to these finds it seems to me evident that the trunks in question cannot be driftwood; it seems more likely that they are remains of trees grown in this country and washed down by a stream and buried in a sandbank deposited by it in the alluvial plain or in a shallow lagoon cut off from the sea.

Small pieces or flakes of mudstone are also frequently found enclosed in the sandstone of this stratum; they are easily distinguishable from the sandstone itself, being formed of finer materials, with distinct concordant stratification and brownish yellow in colour. These flakes, which are rarely more than 25—30 cm. in length, are sharply separated from the sandstone and retain their sharp edges and corners showing that they cannot have been exposed to the action of sea waves. The most likely explanation

seems to be that they are fragments of clay deposits broken off by a river in its course and carried down to their present site.

I. Mudstone with Plant Remains.

This horizon is easily recognisable, even at a distance, from the other deposits at Stórhöfði round Nafir, by the light coloured bands at top and bottom. It runs down to the beach abt. 200—250 m. north of Nafir and rises thence to the southward along the vertical wall of the cliff reaching up to its top at a little north of Tóugjá. Where this deposit touches the shore at Stórhöfði I found the following strata.

c. uppermost abt. 1 m. pale grey or yellowish stratified sandstone merging gradually into the stratum above and possibly rather a portion of this. Here especially at the top, I found flattened twigs and pieces of petrified wood and other transformed remains and impressions of various plant-remains surrounded by iron compounds.

b. 1—1 1/2 m. dark grey, non-stratified mudstone with no vegetable or organic remains.

a (lowest). 1—1 3/4 m. pale yellow stratified mudstone with vegetable remains. Flattened and transformed remains of plants were found here, especially at top and bottom. I also found here a small rootlet of a tree running from the upper limit of the layer vertically down through it.

These observations suggest that the stratum was partially formed of soil covered with vegetation. These strata change some way south along the cliff, the intervening dark mudstone apparently thinning out and disappearing, and the lighter strata (a and c) uniting in one.

24. Shell-bearing sandstone with tree trunks.

This stratum first appears a little way north of Tóugjá, at the upper edge of the cliff above the plant horizon at Stórhöfði; its lower margin touches the shore abt. 200 m. south of Stapi. From here it continues to Höskuldsvík, where it disappears under a covering of grass, and its upper edge has now run down close to the shore. I have no accurate measurements of its thickness, but estimate it at abt. 15 m. This stratum somewhat resembles the tree-trunk sandstone (H) being formed largely of dark brown sandstone but without the peculiar discordance in the stratification of the sand which is so typical of the treetrunk sandstone; also, the sandstone strata and the more clayey strata seem to alternate to some extent. Petrified tree trunks are also found here and there in a state of preservation similar to that described under H; here, however, it seems to be exceptional for branches and roots to be found attached to the stems, though I did find some in this condition. All the trunks were found in a prone position, the diameter being as a rule only 10—15 cm. exceptionally abt. 20 cm.

Marine shells appear scattered here and there throughout this stratum, at any rate in its upper part, and at the top, near the boundary between this and the next, remains of shells are found embedded in coarse sandstone; the shells however, were so crushed and decomposed that they could hardly be determined, though I did recognise *Cardium groenlandicum* and a *Littorina* sp. This stratum must then, at any rate in part, be a marine deposit, and its upper portion seems to be a typical littoral formation.

J. Coal-bearing mudstone at Höskuldsvík.

Above the coarse-grained shelly sandstone at the top of the last mentioned stratum we find, at Höskuldsvík, a stratum 6—7 m. thick, of dark grey stratified mudstone without shells. At the upper part of this are two thin (2—

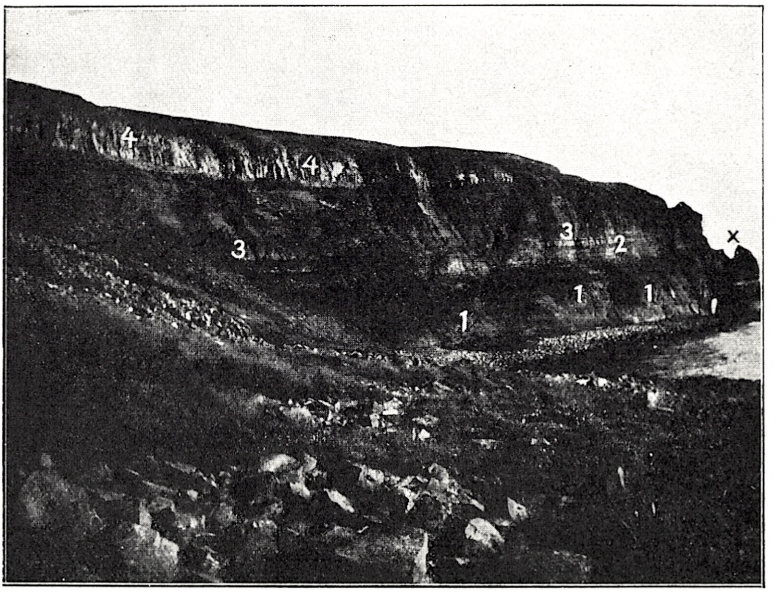

Fig. 10. The Pliocene strata at Höskuldsvík seen from the north looking southwards to Stapi (×). *1*, the shell-bearing sandstone with tree trunk (23). *2*, the coal-bearing mudstone (J). *3*, the Littorina horizon (25) *4*, basalt.

3 cm.) seams of coal with some sand and about the middle of this a stratum 5—6 cm. thick of slightly carboniferous shale. The presence of these carboniferous strata and the fact that no marine shells are found here shows that this mudstone stratum is not a marine formation but rather a fresh water deposit. This stratum continues from Höskuldsvík southward as far as Stórhöfði, and ends at the top of the cliff near Nafir.

25. The Littorina horizon at Höskuldsvík.

Next in order comes a rather coarse sandstone with shells, abt. 3 m. thick. The characteristic species is a *Littorina* sp. which I have not hitherto found elsewhere in the Pliocene deposits. The shells seem to be largely washed up together by the waves, the bivalves as a rule appearing as separate valves. They are much decomposed, and therefore hard to procure in whole specimens for determination. I found in all the following:

Pecten (*islandicus* Müll?). 1 small fragment.

Mytilus edulis, L. Frequent.

Cardium groenlandicum, Chemn. Fairly frequent.

Mya sp. Much resembling *Mya arenaria* L,, but cannot be determined with certainty as the specimens are so badly damaged.

Saxicava sp.?

Cyrtodaria siliqua, Spengler. Some fragments.

Littorina sp. Frequent. Possibly a variety of *L. rudis*, Maton.

Natica sp.

Buccinum undatum, L. Fairly frequent.

Neptunea despecta, L. Some few specimens, very large.

Sipho sp.

This shell deposit, which is doubtles a littoral formation, occurs at 12—15 m. above the shore, where it begins farthest north on a grassy slope at Höskuldsvík, rising at Stórhöfði right up to the edge of the cliff.

This shell stratum is the uppermost and most recent in the Pliocene deposits on the western side of Tjörnes. At Höskuldsvík it continues upwards in the form of a stratum of dark brown stratified sandstone 10—15 m. thick, with

no organic remains; it has, however, about the middle, small smoothed pebles arranged in a thin stratum in the sandstone.

Volcanic forces have finally sealed this interesting series above described with a stratum of basalt covering the sediment deposits at Höskuldsvík. This basalt is more or less distinctly columnar and rather light grey in colour, thus presenting at some distance the appearance of doleritic lava. It begins at the top of the cliff a little south of Stapi, and runs northward from there concordantly with the underlying sediments at Höskuldsvík, dipping down to the shore a little way north of Höskuldsvík and followed by several strata of basalt running out along the coast.

c. Distribution of the Mollusc Species in the Strata between Höskuldsvík and Kaldakvísl.

The table herewith (p. 70) shows the mollusc species mentioned in the foregoing survey of the strata sequence in the Tjörnes cliff. As already mentioned, the material of fossil shells collected from these strata is still by no means fully dealt with, and my collections from the various shell horizons include many species, besides those above mentioned, which I have not yet been able to determine and have therefore not noted here. The generic names *Mactra*, *Bela*, *Natica* etc. also comprise several distinct species. This survey of the distribution of the mollusc species in the strata is therefore extremely inadequate, and will also doubtless be considerably altered by continued and more thorough collections on the spot. But it may serve for the present as a rough general guide to the character of the fauna in the various deposits of the series.

According to this survey, it seems that we can divide the marine strata noted into the following three zones according to the mollusc species they contain.

1. The Tapes Zone is the oldest and comprises the shell strata 1—5, which are exposed in the cliff from Kaldakvísl northward as far as Reká. *Tapes aureus* (and possibly other *Tapes* species) have hitherto only been found in these strata. All these shell strata appear to be formed at a slight depth, or possibly close in to shore. In the sandy clay deposits, and at times together with them, vegetable remains are frequently found, and the clay deposits are often reddish brown with iron.

2. The Mactra Zone comprises the shell strata 6—12. In all these strata there are the large *Mactra* species (*Mactra procrassa, M. arcuata* and others) which are very prominent in some of them e. g. Nos 10 and 11. *Mactra* are also found in the uppermost shell horizons in the Tapes section (stratum 5). In my collection from stratum 12, I found only 1 Mactra shell but in the material from the more recent strata farther north along the cliff it is not represented at all. It is nevertheless not impossible that these *Mactra* species might be found there, but in such case they must doubtless be far more rare than in strata 6—11. In the Mactra Zone there are two coal-bearing strata (D and F). The shell strata immediately above and below these are typical littoral formations. The oldest shell strata in this section (6 and 7) contain comparatively few mollusc species, and were pretty evidently formed at a very slight depth; the clayey sandstone in the cliff here (especially near the coal-bearing strata) is often yellowish or reddish brown with iron compounds and similar in appearance to that in the Tapes section. The Cyrtodaria stratum (8) is not

particularly rich in species, and appears to have been formed at comparatively slight depth. But the depth seems to have increased during formation of the shell deposit above the coal stratum F, and in certain horizons in the Mactra-Pectunculus Series (11 b) the mollusc fauna is fairly rich in species, which may possibly be taken as indicating that this stratum was deposited in deeper water than other shell strata in the Mactra section. Among species hitherto only found in the Mactra section may be mentioned the following:

Mytilus modiolus.

Nucula sp. (with crenelated inner margin).

Abra alba.

Pectunculus glycimeris.

Emarginula crassa.

Urosalpinx cinereus.

3. The Cardium groenlandicum Zone comprises the shell strata 13—25. In stratum 13 it is true, I did not find this species, but in all the younger shell strata of the cliff (14—25) it is fairly frequent. I have noted this species in my journals as occurring in the Mactra section north of the coal mine (above coal stratum F). But it is not found in the collections from these strata. I am therefore inclined to suppose that it is not found in these strata or farther south along the cliff. What I have here entered as *Cardium groenlandicum* may have been one of the foregoing *Mactra* species as these, in a state of erosion, much resemble *C. groenlandicum*. This question, however, must be left for future investigation.

The youngest shell strata in this section (24 and 25) are probably littoral deposits. But in the continuous marine series Nos. 13—23 there are shell horizons which must

Table showing distribution of molluscs in the Pliocene strata be-

Mollusc species here arranged according to depth at which found in the series	The Basalt at Höskuldsvík	Cardium groenlandicum Zone: The Littorina Horizon at Höskuldsvík	Coal-bearing mudstone at Höskuldsvík	Shell-bearing sandstone with tree trunks	Mudstone with plant remains	Sandstone with tree trunks	Dark grey clay-mudstone without fossils	The Astarte strata	Shelly sandstone shelf	The Bele horizon at Kambsgjá	The Cyprina horizon at Kambsgjá	The Gastropod horizon at Kambsgjá	The Cyprina rustica—Cyrtodaria horizon at Kambsgjá	The Macoma obliqua—Cyprina rustica horizon at Kambsgjá	The Mya—Macoma horizon at Tungukambur etc.
		25	J	24	I	H	G	23	22	21	20	19	18	17	16
I. Mollusc species hitherto found only in the Cardium groenlandicum zone.															
Mya sp.		×													
Saxicava sp.?		×													
Littorina (rudis, Maton?)		×													
Lepeta cæca, Müll.								×							
Lunatia sp.										×					
Calyptræa chinensis, L.								×		×					
Searlesia costellifera, Wood										×					
Leda pernula, Müll.												×			
Venericardia borealis, Chemn.								×		×		×			
Nacella pellucida, L.								×				×			
Neptunea despecta, L. var.												×			
Anomalosipho Verkrüzeni, Kob. var. plicifera, Brögger												×			
Cylichna cylindracea, Penn.												×			
Astarte incerta, Wood													×		
Astarte (borealis, Chemn.?)													×		
Gibbula tumida, Mont.									×	×			×		
Gibbula sp.								×							×
Sipho islandicus, Chemn.														×	
Mytilus phaseolinus, Fabr.												×			×
Astarte sulcata, da Costa								×				×	×		×
Macoma calcaria, Chemn.								×		×		×	×		×
Thracia truncata, Brown														×	×
Admete viridula, Fabr.															
v. costellifera, Sow.															×
v. Couthouyi								×		×		×	×		

Observe! { = Fresh water deposits, = non-fossiliferous strata.

tween Kaldakvísl and Höskuldsvík on the western side of Tjörnes.

			Mactra Zone										Tapes Zone									
The Sipho horizon at Tungukambur etc.	The Actæon horizon at Tungukambur	The Cyprina islandica horizon at Tungukambur	The Corbulomya Winkleri horizon at Tungukambur	The Mactra - Pectunculus series at Svarthamar	The Cyprina—Mactra series at Tungubakkar	The littoral Mytilus deposit at Tungubakkar etc.	The coal strata at Hringversbakkar and Tungubakkar	The non-fossiliferous sandstone strata at Hringversbakkar etc.	The Cyrtodaria stratum	Coal-bearing formations at Hringverslækur	The Balanus—Nucula horizon at Hringverslækur etc.	The Mactra horizon at Rekárkinn	Coal-bearing strata at Reká	Cardium-Tapes deposit at Reká etc.	The Tapes horizon at Tungugerðisbakkar	The coal stratum at Tungugerðisbakkar	The Mytilus—Tapes horizon at Tungugerðisbakkar	The Tapes horizon at Tungugerðishöfði	The Mytilus deposit at Kaldakvísl	Strata with plant remains at Kaldakvísl	Pebble deposits at Kaldakvísl	Basalt at Kaldakvísl and south of there
15	14	13	12	11	10	9	F	E	8	D	7	6	C	5	4	B	3	2	1	A		

Table showing distribution of molluscs in the Pliocene strata be-

Mollusc species here arranged according to depth at which found in the series	The Basalt at Höskuldsvík	Cardium groenlandicum Zone													
		The Littorina Horizon at Höskuldsvík	Coal-bearing mudstone at Höskuldsvík	Shell bearing sandstone with tree trunks	Mudstone with plant remains	Sandstone with tree trunks	Dark grey clay-mudstone without fossils	The Astarte strata	Shelly sandstone shelf	The Bela horizon at Kambsgjá	The Cyprina horizon at Kambsgjá	The Gastropod horizon at Kambsgjá	The Cyprina rustica—Cyrtodaria horizon at Kambsgjá	The Macoma obliqua—Cyprina rustica horizon at Kambsgjá	The Mya—Macoma horizon at Tungukambur etc.
	25	J	24	I	H	G	23	22	21	20	19	18	17	16	
Buccinum sp.									×				×	×	
Macoma sp.															
Neptunea despecta, L.	×						×		×		×	×	×		
Sipho tortuosus, Reeve							×								
Liomesus canaliculatus, Dall.									×						
Searlesia Lundgreni, Mörch															
Modiolaria nigra, Gray									×				×		
Leda sp.															
Cardium groenlandicum, Chemn.	×		×				×		×		×		×	×	
Macoma obliqua, Sow.							×	×	×		×	×	×		
Solen ensis, L.															
Solen sp.											×		×		
Mya truncata, f. ovata, Jensen									×		×	×	×	×	
Panopea norvegica, Spengler							×	×			×	×	×		
Acrybia flava, Gould											×				
Buccinum undatum, L.											×	× ?		×	
Buccinum groenlandicum, Chemn.									×			×		×	
Sipho Olavii, Mörch														×	
Actæon Noæ, Sow.									×						
II. Species found both in the Cardium groenlandicum and Mactra Zones.															
Cardium sp.															
Corbulomya Winkleri, Mörch							×								
Mytilus sp.							×								
Cyprina rustica, Sow.							×		×	×	×	×	×	×	
Trochus sp.									×			×			

tween Kaldakvísl and Höskuldsvík on the western side of Tjörnes.

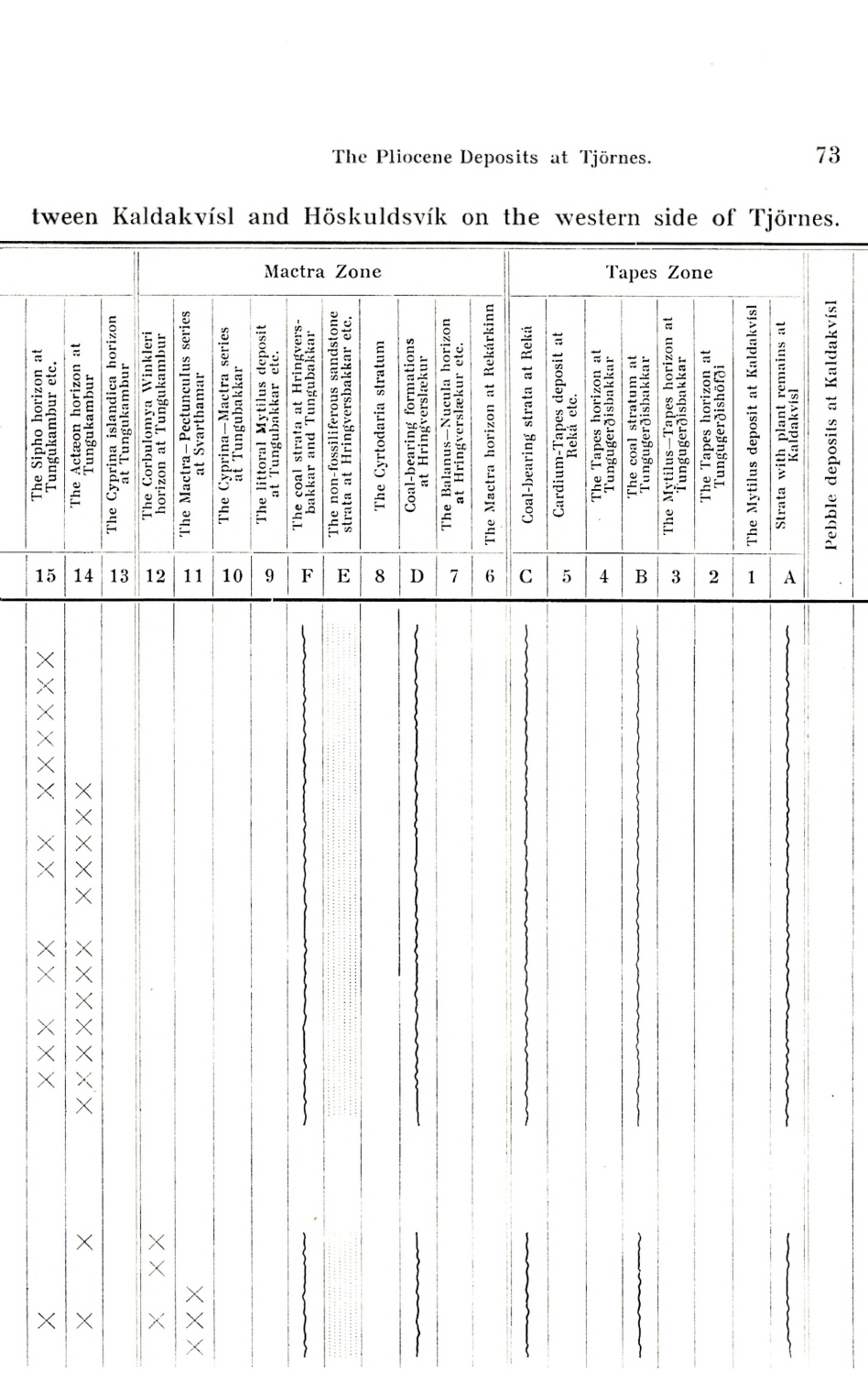

Table showing distribution of molluscs in the Pliocene strata be-

Mollusc species here arranged according to depth at which found in the series	The Basalt at Höskuldsvík	Cardium groenlandicum Zone													
		The Littorina Horizon at Höskuldsvík	Coal-bearing mudstone at Höskuldsvík	Shell-bearing sandstone with tree trunks	Mudstone with plant remains	Sandstone with tree trunks	Dark grey clay-mudstone without fossils	The Astarte strata	Shelly sandstone shelf	The Bela horizon at Kambsgjá	The Cyprina horizon at Kambsgjá	The Gastropod horizon at Kambsgjá	The Cyprina rustica–Cyrtodaria horizon at Kambsgjá	The Macoma obliqua–Cyprina rustica horizon at Kambsgjá	The Mya–Macoma horizon at Tungukambur etc.
		25	J	24	I	H	G	23	22	21	20	19	18	17	16
Bela sp.								×	×	×		×	×	×	×
Nassa lamellilabra, Nyst.								×				×			×
Nassa sp.										×		×	×		
Sipho sp.		×								×	×	×	×	×	
Cardium (ciliatum, Fabr.?)															×
Cyrtodaria siliqua, Spengler		×						×	×	×	×	×	×	×	
Zirphæa crispata, L.								×							
Pecten (islandicus, Müll.?)								×							
Nucula sp.															(×)
Margarita sp.										×					
III. Species hitherto found only in the Mactra Zone.															
Pectunculus glycimeris, L.															
Zirphæa sp.															
Emarginula crassa, Sow.															
Littorina sp.		×													
Liomesus sp.															
Urosalpinx cinerea, Say.															
Corbulomya sp.															
Corbulomya complanata, (Sow.)															
Mytilus modiolus, L.															
Abra alba, Wood.															
IV. Species found both in the Mactra and Tapes Zones.															
Mactra sp.															

tween Kaldakvísl and Höskuldsvík on the western side of Tjörnes.

			Mactra Zone										Tapes Zone								
The Sipho horizon at Tungukambur etc.	The Actæon horizon at Tungukambur	The Cyprina islandica horizon at Tungukambur	The Corbulomya Winkleri horizon at Tungukambur	The Mactra - Pectunculus series at Svarthamar	The Cyprina—Mactra series at Tungubakkar	The littoral Mytilus deposit at Tungubakkar etc.	The coal strata at Hringversbakkar and Tungubakkar	The non-fossiliferous sandstone strata at Hringversbakkar etc.	The Cyrtodaria stratum	Coal-bearing formations at Hringverskekur	The Balanus Nucula horizon at Hringverskekur etc.	The Mactra horizon at Rekárkinn	Coal-bearing strata at Reká	Cardium-Tapes deposit at Reká etc.	The Tapes horizon at Tungugerðisbakkar	The coal stratum at Tungugerðisbakkar	The Mytilus—Tapes horizon at Tungugerðisbakkar	The Tapes horizon at Tungugerðishöfði	The Mytilus deposit at Kaldakvísl	Strata with plant remains at Kaldakvísl	Pebble deposits at Kaldakvísl	Basalt at Kaldakvísl and south of there
15	14	13	12	11	10	9	F	E	8	D	7	6	C	5	4	B	3	2	1	A		
×	×			×																		
				×																		
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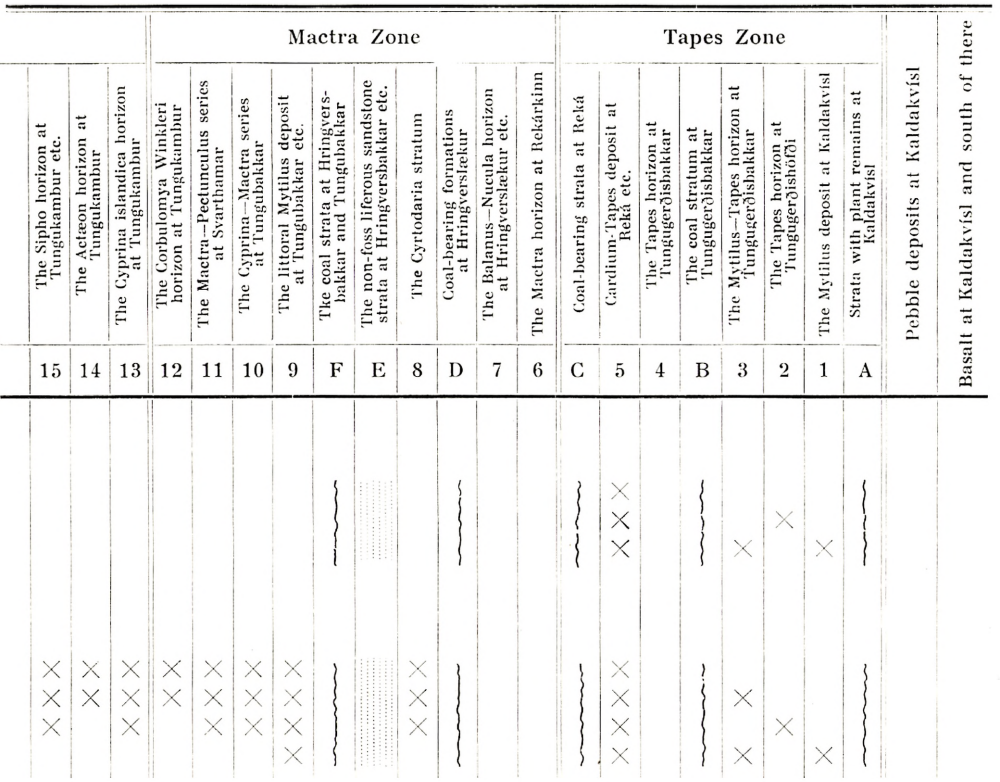
Table showing distribution of molluscs in the Pliocene strata be-

Mollusc species here arranged according to depth at which found in the series	The Basalt at Höskuldsvik	Cardium groenlandicum Zone													
		The Littorina Horizon at Höskuldsvik	Coal-bearing mudstone at Höskuldsvik	Shell-bearing sandstone with tree trunks	Mudstone with plant remains	Sandstone with tree trunks	Dark grey clay-mudstone without fossils	The Astarte strata	Shelly sandstone shelf	The Bela horizon at Kambsgjá	The Cyprina horizon at Kambsgjá	The Gastropod horizon at Kambsgjá	The Cyprina rustica—Cyrtodaria horizon at Kambsgjá	The Macoma obliqua—Cyprina rustica horizon at Kambsgjá	The Mya—Macoma horizon at Tungukambur etc.
		25	J	24	I	H	G	23	22	21	20	19	18	17	16
V. Mollusc species hitherto found only in the Tapes Zone.															
Abra (prismatica, Mont.?)			⌇		⌇	⌇	⌇								
Tapes aureus, Gmel.			⌇		⌇	⌇	⌇								
Tapes sp.			⌇		⌇	⌇	⌇								
VI. Molluscs found in all three zones.															
Natica sp.		×	⌇		⌇	⌇	⌇	×	×	×	×		×	×	×
Cyprina islandica, L.			⌇		⌇	⌇	⌇	×			×				
Cardium echinatum			⌇		⌇	⌇	⌇								
Mytilus edulis, L.		×	⌇		⌇	⌇	⌇								

have been deposited at greater depth than other shell strata in the cliff, and this may, inter alia, have been the cause why this zone is richer in species than the Mactra and Tapes zones. The main bulk of the new species in this zone are of arctic origin though there are some more southerly forms (boreal and Lusitanian) which are not found in the collections from the Mactra and Tapes Zone, e. g. *Calyptræa chinensis, Mytilus phaseolinus, Nacella pellucida.*

tween Kaldakvísl and Höskuldsvík on the western side of Tjörnes.



d. On the Climatic conditions at the time of formation of the Pliocene strata.

It was my intention in this paper to give only a brief survey of the strata sequence in the Pliocene deposits at Tjörnes: it would be premature here to go further into a discussion of the climatic conditions, depth etc. at the time of formation of the strata. This must wait until the strata have been better investigated and the fossils dealt with as far as possible. I will therefore merely touch on the question at present.

1. The Tapes Zone. *Tapes aureus*, Gmel. is the most characteristic species in the Tapes zone, and fairly large specimens are found there (40—47 mm. long). This species is an European Lusitanian form, which on the coasts of Norway does not reach as far north as Lofoten. Its distribution ranges from the west coast of Norway to the Christiania Fiord at depths from 0—20 m (G. O. Sars 1878). In Danish waters, it has not been found in a living state inside the Skaw (Petersen 1888) but it is frequently met with off the English coast, and penetrates as far south as the Mediterranean. The occurrence of this species suggests that: The marine strata of the Tapes deposit must have been formed under conditions of temperature similar to those now prevalent in the south of Norway, or on the west coast of Norway.

2. The Mactra Zone. This zone, which comprises 6 shelly strata or series of considerable thickness (at least 150 m.) with coal-bearing terrestrial formations embedded therein, must have been so long in forming that the climate could alter considerably during the period involved. Among the southern forms found in this zone may be mentioned:

Abra alba, Wood. Found in stratum 7, under the coal-bearing stratum D; specimens 20—25 mm long. This is an European Lusitanian form, not found in Norway north of Lofoten, where, according to G. O. Sars (1878) it attains a size of 11 mm. and lives at a depth of 10—80 m. From here its distribution extends southward along the shores of Europe and right down to the Mediterranean. In English waters it lives on muddy bottom, even up to low water mark (Jeffreys) which appears to agree well with the position in which it was found in the above-mentioned strata,

where it occurred together with fragments of driftwood in mudstone.

Nucula sp. with crenulated inner margin, was found in stratum 7, and in the *Mactra-Pectunculus* series (11). This form does not belong to *N. tumidula* Malm which is the only *Nucula* species with crenulated inner margin found north of Lofoten. Among North-European species, it most resembles *Nucula nitida* Sow. which has its northern limit on the west coast of Norway though it does not quite agree with the specimens of that species which I have had for comparison.

Pectunculus glycimeris L. This Lusitanian species was only found in the Mactra-Pectunculus series (11) where it appears to be rare. In Norway it has only been found (according to G. O. Sars) on the west coast, and is not met with farther south in Norway, or in Danish waters. Round the British Isles it is frequent at depths from 14—200 m., and ranges from there to the Mediterranean and the Canaries.

Emarginula crassa, Sow., was also found here in series 11. The northernmost record of this species in Norway is Lofoten.

The presence of the above mentioned species, especially *Pectunculus glycimeris*, in the marine strata of the *Mactra* Zone distinctly suggests that: The climatic conditions at the time of formation of these strata had attained a level at least as favourable as on the warmest range of the Norwegian coast (West coast of Norway) or possibly approximating to the climatic conditions of the British Isles nowadays.

Pecten islandicus Müll. I found this species in this zone in the littoral deposit above the coal mine (stratum 9) and some few fragments and defective valves possibly belonging

to this species also in stratum 7 and stratum 11.[1] This bivalve is an arctic species, which in Norway belongs chiefly to the arctic zone from Lofoten to Finmark but is also found in a living state, though far more rarely, considerably farther south, e. g. at Bergen and Bohuslän? (G. O. Sars 1878, N. Odner 1915). It may thus well have lived together with the above-mentioned Lusitanian species. Empty valves of this species are also found frequently off the British isles (Jeffreys). In the youngest Tapes stratum at Reká (stratum 5) and in the Mytilus deposit above the coal stratum (stratum 9) there is a frequently occurring *Cardium* species, much resembling *C. ciliatum* Fabr. but as it differs somewhat from the present form of *C. ciliatum* living on this coast I am not sure it is the same species. In Norway, *Cardium ciliatum* does not live together with the above mentioned boreal and Lusitanian species, its southern limit of distribution in Norway lying in eastern Finmark.

Among living American species found in the Mactra zone I may mention the following:

Mactra procrassa, Wood (= *M. solidissima*, Dillwyn, *M. ponderosa* Phil.) is doubtless fairly frequent in the Mactra zone, especially in stratum 11. The northern limit of its distribution on the east coast of America lies in the Gulf of St. Lawrence at Labrador, though it is less frequent there (Whiteaves 1901). Farther south, however, it is very frequent, and goes right down to the Gulf of Mexico.

Cyrtodaria siliqua Spengler is very frequent in stratum 8 in the Mactra zone. It is a circumpolar species, and on the

[1] I found many large valves of this species in a stratum in the so-called Tungugrænur at Reká, some considerable distance from the coast, but as I have not yet had time to investigate the strata series up along the river, I do not know to which stratum along the coast this Pecten deposit is to be referred.

east coast of America it penetrates as far south as the coasts of Nova Scotia (Halifax) and lives together with *Mactra solidissima* in the Gulf of St. Lawrence. In the Mactra deposit north of the mine, where *Pectunculus* was found (stratum 11), this species seems to be very rare. I have only a few fragments from here. It is likewise not found in the material I have from Hringvershvilft (stratum 7) where *Abra alba* was found.

Urosalpinx cinerea Say. Found in the Mactra-Pectunculus series (11). Living at the present day on the coasts of New England. The northernmost find is in the southern part of the Gulf of St. Lawrence (Prince Edward Island; Whiteaves 1901).

3. The Cardium groenlandicum Zone. Among southern mollusc forms found in this zone I may mention the following:

Mytilus phaseolinus (shell strata 16 and 19).

Cardium echinatum (shell stratum 15).

Solen ensis (shell stratum 4).

Nacella pellucida (shell strata 19 and 23).

Gibbula tumida (shell strata 18, 21 and 22).

All these species, with the exception of *Solen ensis*, are still found living on the south and west coasts of Iceland, but do not reach the north coast of the country. In Norway they extend as far as to East- and West-Finmark, and *Solen ensis* goes as far north as Tromsö and Öxfiord in West Finmark (G. O. Sars). These species must thus have lived in a warmer sea than is at present found in North Iceland. The temperature of the sea here at that time must have been at least as high as on the west coast of Iceland, or at present on the coasts of Finmark in Norway.

A point of great importance is the occurrence of *Calyptræa chinensis* L. in this zone. This is an eastern Atlantic, southern Lusitanian species which has not, as far as I am aware, been found in the present day farther north than the coasts of England, but extends southward as far as the Mediterranean, Madeira and the Canaries (Jeffreys). It has only been taken in strata 21 and 23, and occurs in well preserved whole specimens, the size exceeding that noted by Jeffreys for the species in English waters. Having regard to the present distribution of the species, it seems natural to suppose, if we can attach any weight to these finds of this one species, that the climate at one time, when these strata were in formation, had attained a condition as favourable as that of England or the British Isles. The shell strata in which *Calyptræa* is found are among the youngest in the series, which must have been formed during a progressive raising of the land after the great subsidence marked in the Pliocene strata here, had reached its maximum. During this submergence period it would seem, from what we now know of the strata, that several southern (Lusitanian) forms found in the older strata disappeared, and many new species of arctic origin immigrated in their stead; the arctic element in the mollusc fauna seems to become more and more prominent, and the fauna gradually assumes a more modern character (*Cardium groenlandicum*, *Astarte*, *Bela*, *Buccinum*, *Sipho*, *Neptunea* etc.). True, boreal forms such as *Nacella pellucida*, *Mytilus phaseolinus* and *Gibbula* seem to become more frequent in the younger strata of the series (19—23) than in the older ones (13—18), which is possibly an indication of increasing temperature of the sea during the reelevation of the land which followed the maximum of the subsidence. But the

arctic species *Cardium groenlandicum* is very frequent in the same strata where *Calyptræa chinensis* is found, though the former has its southern European limit far to the north of *Calyptræa's* northern boundary as it does not go west of the North Cape in Norway. *Solen ensis* again has not, so far as I am aware, been found living together with *Cardium groenlandicum* on the coasts of northern Europe, but in the Tjörnes cliff, fossils of both are found in the same shell horizon (No. 14).

These observations, then, do not seem to agree with our knowledge of the distribution of these species at the present day on the shores of western Europe. But it will perhaps be best to postpone discussion of the questions involved until the interesting deposits here have been better investigated.

The north American species *Venericardia borealis* (Conrad) is first found in this zone, in the shell horizon no. 19, increasing in frequency thereafter, and seems to reach its maximum in the Astarte strata (23). In North America, it lives together with *Cardium groenlandicum*, on the east coast of America its distribution ranges from Hudson Strait to Connecticut in the south, and on the Pacific side to California (Catalina Island; Whiteaves 1901).

Liomesus canaliculatus (Dall). I found some few specimens of this in horizons 14 and 21. This species has only been found in a living state in the Bering Sea (Dall) where *Cardium groenlandicum* also lives[1].

[1] There are several mollusc species quoted both by Mörch and Paulsen (l. c.) from the Pliocene strata at Tjörnes which I have not mentioned in this paper; most of them are possibly among those specimens which I have collected from these strata but have not yet determined as to species. I have not mentioned these species cited by the writers in question in the text here, as I do not know in what part of the strata series they were found.

II. Sequence of Strata on the Western Side of Tjörnes, from Höskuldsvík to Breiðavík.

a. The Basalt between Höskuldsvík and Furuvík.

From Höskuldsvík northward to Furuvík the coast is bounded by steep basalt cliffs built up of 3—4 basalt beds having about the same dip as the basalt above the Pliocene sediments at Höskuldsvík (abt. 10° to the NW. or NNW.). This basalt stratum at Höskuldsvík is the oldest of these basalt beds, running in under the others a little way north of Höskuldsvík. Near Höskuldsvík, there is in one place, embedded between the basalt sheets, a stratum of clayey sandstone, 3—4 m. thick, with small smoothed pebbles scattered here and there. The uppermost basalt sheet in this series is laminated and with large flattened cavities.

b. Marine (?) Sediments at Furuvík.

At Furuvík, a little creek about midway between Höskuldsvík and Breiðavík, this schistose basalt stratum seems to be overlain by conglomerates, mudstone and sandstone, forming cliffs 35—40 metres high along the shore. We have here, on the eastern side of the creek:

1 (lowest). The basalt.

2. Above this, conglomerates, containing smooth rounded stones, the largest 15—20 cm. in diameter. These stones appear to have been worn by the action of water or rolled in the sea.

3. Light brown stratified mudstone with some few rounded stones.

4. Conglomerate with thin strata of mudstone embedded.

5. Dark thin basalt sheet, which farther north merges into several thin basalt beds with white amygdaloids.

6. Conglomerate (abt. 1—2 m. thick).

7 (uppermost). Greyish basalt more or less distinctly columnar. These sediments look very much like marine deposits, but I did not succeed in finding any marine shells or other animal remains there. The strata incline towards the NW.

c. The Basalt between Furuvík and Hörgi.

The basalt which here appears above the sediments at Furuvík continues northward and forms steep cliffs along the shore out to a little jutting point below the farm of Sandhólar, known as Hörgi. The uppermost basalt stratum in this basaltic series which shows out distinctly in the cliff face on the western side of Hörgi is a typical "apalhraun" as it is called in Icelandic; that is, its surface was originally very uneven, rugged and of slag-like appearance. Above this come the conglomerate deposits. Evidently the surface of the lava had not become levelled before the succeeding sediments had commenced to deposit, far less polished by any glacier. Its rugged surface still crops out distinctly in the cliff, and breccia has formed in the hollows, in slag-like, sharp-edged pieces, broken off from the surface of the lava. The cementing material is as a rule coarse sand with an inconsiderable admixture of clay, often with more or less distinct stratification. This breccia covers the lava completely and merges gradually into the conglomerate above. I found no stones with glacial striation in the conglomerate, or any sign whatever of glacial origin; it certainly does not resemble a moraine deposit as this is in some places more or less stratified. The stones it con-

tains are also as a rule smoothed and spherical and of the same appearance as in littoral gravel deposits; the cementing material is sand with a small admixture of clay.

d. Basalt with Conglomerate above, between Hörgi and Stangarhorn.

The northernmost point on the west side of Breiðavík is called Stangarhorn. The range of coast between here and Hörgi is bounded by a steep cliff. The substratum here is basalt, which runs fairly high up the cliff, and above this are thick deposits of conglomerate, continuing northward from Hörgi. The basalt lava with its uneven surface seems to form the substratum somewhat farther north (1), then comes a thin greyish stratum of doleritic (?) lava. These two strata are divided near Hörgi by a stratum of sandstone and rolled gravel abt. 1 m. thick. Farther north, a reddish brown scoria stratum forms the boundary between them. Above this doleritic lava (2) come conglomerates. The sequence seems to be much the same far to the north, but in some places, (e. g. at the so-called Fuglavík) the dolerite stratum (2) thins out and disappears, while the basalt lava (1?) increases in thickness. Near Stangarhorn, there must in one place have been a deep gully with steep sides in the underlying basalt at the time when the conglomerate began to form, as it is now filled by this. At Stangarhorn there are the following:

1. Lowest, on the shore, conglomerate with small spherical stones, in one place with finely stratified mudstone. (Fig. 11, d).

2. Dark basalt (8—9 m.) with a trace of schistosity (?) at the bottom, higher up with indistinct columnar formation. (Fig. 11, e & f).

3. Greyish dolerite (?) falling into handsome regular columns which can be split into laminæ transversely (8—10 m.). A small islet, »Kerling«, north of Stangarhorn abt. 200 m. from the coast, is formed of the same stratum. (Fig. 11, g).

4. Uppermost, conglomerate. (Fig. 11, c).

The basalt in the cliffs between Höskuldsvík and Stangarhorn differs in several respects from that under the shelly strata on the western side of Tjörnes, which shows out in Raufarbakkar and Hjeðinshöfði. North of Höskuldsvík, the basalt strata are altogether lighter in colour, less inclining, and more regular in their sequence, whereas the basalt strata south of the Kaldakvísl are much disturbed, and the basalt itself partially altered. There is therefore hardly any reason to suppose that the basalt substratum of the Pliocene strata which dips below the sea a little north of Kaldakvísl should have been raised above the sea again here between Höskuldsvík and Breiðavík. — It is, of course, not impossible that minor dislocations should have taken place in the basaltic series on this range of coast, though I have not noticed any such, during my brief investigation there last summer. But the whole appearance of this series between Höskuldsvík and Stangarhorn seems to be that of a continuous formation, younger than the fossiliferous Pliocene deposits on the western side of Tjörnes, but older than the sediments at Breiðavík, since they are covered by conglomerate strata which appear to be the oldest strata in the sediments at Breiðavík.

The two doleritic strata in the anterior part of the Stan-

garhorn seem, however, to be an exception from this, as they also rest on conglomerate. I shall go further into this in the next section.

III. The Pliocene Deposits at Breiðavík.

Breiðavík is a small creek cutting into Tjörnes from the north between Stangarhorn on the west and Valadalstorfa (Tjörnes Point) on the east. The creek is walled in by steep cliffs 40—50 m high, but on the eastern side, at Valadalstorfa, the cliff is lower, abt. 20 m. at its lowest. The cliffs are for the most part built up of conglomerate, sandstone and mudstone; solid basalt rocks are only found under the conglomerate at Stangarhorn, and on the eastern side of the creek, the sediments are overlain by a basalt stratum dipping to the NW. I have made a section sketch of the strata in the cliffs on the east and south sides of the bay, and reproduce this herewith, as a description of the strata sequence would hardly be intelligible without it. I have also made sketches of various parts of the cliff south and east of Stangarhorn at the west side of the creek, endeavouring to unite these in a continuous section sketch to show the connection of the sequence.

1. The basalt or dolerite at Stangarhorn.

In the last chapter I described the sequence on the west side of Stangarhorn nearest the point itself. For further convenience this is also reproduced in the accompanying section sketch (Fig. 11) which I jotted down in my notebook during the brief examination. Here, on the right of the picture, is a continuation of the strata which commenced at Hörgi. At the bottom, the basalt is of considerable

thickness (*a*) and appears to end at a^1, above this is a thin basalt stratum (*b*) which here thins out and disappears, uppermost is conglomerate (*c*). At *x* there is a ravine with steep sides running down into the basalt stratum (*a*) and filled with conglomerate. At *y* there seems to be a change in the sequence. At Stangarhorn (on the left in the sketch) the conglomerate (*d*) is at the bottom of the cliff, which is not the case farther south along the shore, below Hörgi.

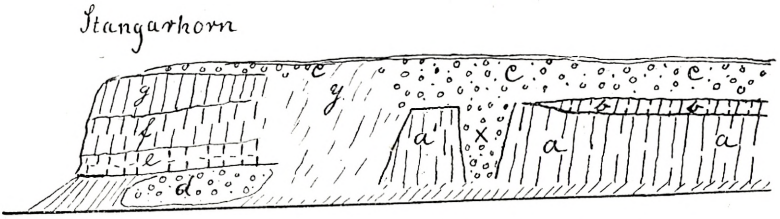


Fig. 11. Section Sketch from western side of Stangarhorn.

Above this we have then: *e*, dark chistose basalt, *f*, dark basalt not chistose, *g*, greyish doleritic (?) lava 8—10 m thick, regularly columnar, *c*, conglomerate (uppermost).

These solid lava strata (*e*—*g*) also crop out in the west side of Stangarhorn and here thrust a wedge into the conglomerate deposit, under- and overlaid by the latter; they thin out rapidly here and disappear, it would seem, a little distance from the point itself.

It is possible that this discrepancy in the sequence on the western side of Stangarhorn is due to dislocation somewhere about *y*, but as the basalt on the front of Stangarhorn also seems considerably different from the basalt south of *y*, it may possibly be much more recent, and perhaps have originated from another site of eruption than the basalt under the conglomerate farther south (*a* and *b*) which must be older than the entire conglomerate deposit and appears to have been subjected to erosion (by the sea?)

before the conglomerate began to form. This seems to be indicated by the unevenness of the surface of the basalt where it ends in the cliff at a^1 and x. — The lava sheets, however, at the front of the Stangarhorn must have been formed while the conglomerate was in course of formation, as the conglomerate lies both above and below it.

2. The conglomerate deposits on the south-west side of Breiðavík.

The cliff from Stangarhorn nearly up to Fossgil is largely formed of conglomerate which appears to be a direct continuation of the conglomerate stratum at the bottom of the Stangarhorn, and the conglomerate at the top, which covers the cliff west of Stangarhorn right up to Hörgi in the south. These conglomerate deposits between the Stangarhorn and Fossgil are of highly varying composition, and the stratification also varies considerably. At some places near Stangarhorn especially, smoothed rolled stones and gravel with a scanty admixture of sand and clay predominate in large parts of the cliff; in other places, finer materials (gravel and sandstone more or less mixed with clay) predominate, sometimes extending deep down in the cliff, while the stony conglomerate deposits in other parts reach far up and form projecting points in the slope owing to their greater power of resistance. — It would seem as if one and the same stratum may be richer in stones at one place than at another. On the whole, however, the upper strata in the cliff here seem to be formed of finer material which is also more predominant farther to the east (section *e* and *f*). In the conglomerate portions themselves, a more or less distinct stratification is discernible,

but the strata are in several places much folded. At the pebble points *a*, *b* and *c* the sequence was as follows:

1. (at bottom) Conglomerate with sandstone as cementing material.

2. Conglomerate, cementing material mudstone mixed with sand.

3. Conglomerate, cementing material sandstone.

4. Distinctly stratified sandstone alternating with thin strata of more clayey material. In these I found a quantity of carbonised plant stems and fragments of twigs, the largest, abt. 1 cm. diameter, still retaining their original rounded form. They seem to occur only in some few restricted horizons. The stratification here was more or less regular, the strata lying horizontally, in contrast to the strata deeper down in the deposit, which were much folded (strata 1—3).

At Stekkjarnef (*d*) there are also similar folded pebble strata, the interstices between the stones being filled with rather coarse sandstone. At one point here, (*x*) near the talus at the bottom, I noticed a folded stratum of more clayey material, containing small twigs of similar appearance to those already described above (in strata 4 at the points *a*, *b* and *c*), as also small fragments of carbonised wood, the largest abt. 3—4 cm. long.

Where the cliff was formed of finer material, the stratification was also more or less regular and more pronounced, In one such section of the cliff near *e* I found:

1. Abt. 10 m. above the shore a thin mudstone stratum with scanty remains of thin carbonised twigs.

2. Abt. 15 m. above the shore a thin continuous stratum of small smoothly rounded stones.

3. Alternating strata of fine gravel, sand and sandy

mudstone up to abt. 30 m. above the shore. Fairly high up in these deposits were some few larger stones, including one abt. ½ m. diameter.

4. Stratified sandstone up to the edge of the terrace (abt. 50 m. above sea-level).

The southernmost part (*f*) of this deposit is also mainly formed of finer material.

The smoothed stones in this conglomerate deposit are mostly basalt, but there are often pebbles of brown or yellowish brown tuff stone, some of them showing distinct stratification (fresh water or sea sediments?) much resembling the Pliocene sediment on the western side of Tjörnes. I did not succeed, however, in finding any remains of fossil shells therein.

It has been suggested that this conglomerate deposit at Breiðavík was of glacial origin, and possibly a moraine deposit. To my mind, there are the following arguments against this view: 1) That more or less distinct stratification is present in this deposit, with an assortment of the material according to its coarser or finer grain. 2) That the conglomerate contains almost exclusively well smoothed, often spherical stones with polished surface, not shaped like ordinary icepolished boulders. Nor did I succeed in finding any stones with glacial striation. 3) That the cementing material in the conglomerate is altogether predominantly composed of sandstone, often rather coarse; clay and mudstone were only present in relatively insignificant quantities.

The larger blocks of stone found scattered about in the more argillaceous strata in the parts of the cliff at *e* can however possibly have been shifted with floating ice floes and dropped down to the spot where they now lie, unless

indeed, they were washed down by the action of the waves on a steep shore.

Altogether, these conglomerates seem to me to be a marine littoral deposit, partly formed in shallow water on a somewhat exposed coast, where the breakers were unimpeded in their action. But there are no certain proofs of this, as marine shells have not yet been found in these strata.

It might also possibly be to some extent a delta deposit formed by a large river, which, in altering its channel, has scattered the gravel and sand carried down over a considerable area.

3. Mudstone with large boulders west of Fossgil.

In the part of the cliff at *f* the sandy gravel deposits end in a mudstone stratum a couple of metres thick, containing a quantity of stones of varying size up to abt. 1 m. diameter. These stones are not so well smoothed as in the conglomerate deposits, but the edges are often worn and the corners more or less rounded off. This stratum goes down to the shore, or is covered by detritus a little way north of Fossgil and rises to the west up the slope to the edge of the cliff, or merges into the sand and gravel deposits at the top of the cliff above the conglomerate (2). In the ravine along Fossgil, this strata is also found in several places, e. g. close to the main road leading to the farm of Breiðavík.

This deposit, which was found to contain no fossils, in any part resembles a moraine deposit or boulder-clay to some extent, both from the appearance of the stones and from the fact that they seems to be irregularly tumbled together in the stratum. But as I did not succeed in finding

any stones with glacial striation in the deposit, and as there seems to be some indication of stratification in the same, I consider it extremely doubtful whether it is of glacial origin. Possibly the point may be decided by closer investigation of the deposit at several different places.

4. Slaty clayey, sandstone at Fossgil.

A streamlet known as Fossgil, flowing from the south, forms a small waterfall where it pours down to the shore on the south side of Breiðavík. At the bottom of the cliff face behind the waterfall there is a stratified, partially slaty sandy clay deposit of a light greyish brown colour, and in the minor stratifications themselves the colour changes a good deal, in lighter or darker shades. The stratum here was abt. 2—3 m. thick, it could be traced westward along the slope above the stony stratum 3. In the ravine along Fossgil it also crops out in several places, as for instance at the above-mentioned spot on the road to Breiðavík where it is 3—6 m. thick. I found no fossils in this stratum.

5. The dark sandstone at Fossgil.

The rock wall behind the waterfall is composed of several oblique strata of fine-grained clayey sandstone, highly indurated, of a dark grey colour. At the transitions between strata the sandstone is less indurated and lighter in colour. These sandstone strata dip 10—12° towards the east, and dip down under the sand on the shore abt. 200 m. east of the waterfall, but rise again to the edge of the cliff to the west of it. These strata are also found in the ravine up along the stream, and reach some distance in from the shore, where this deposit seems to diminish in thickness as we get farther from the shore. The deposit consists of

very fine material, neither gravel nor small stones were found there, and I did not succeed in finding any fossil remains of animals or plants. Diatom investigations might perhaps determine whether this is a fresh water formation or of marine origin. These three last-mentioned strata seem to dip rather more towards the east (or NE.) than the strata of the conglomerate deposit.

6. The conglomerate at Fossgil.

Above the dark sandstone (5) at Fossgil there is conglomerate with fairly distinct stratification, sloping sharply towards the east down to the shore. It is also found at the top of the cliff on the western side of Fossgil. The stones in the conglomerate are comparatively small and fairly rounded; the cementing material is sandy mudstone. Nearest Fossgil on the eastern side of the waterfall, the strata dip abt. 20° towards the east, but farther eastward their incline gradually diminishes. Among the smoothed basalt stones in the conglomerate I also found some few smoothed pebbles of mudstone containing remains of fossil shells (*Corbulomya* sp.) which must have originated in a Pliocene deposit, similar to that found on the western side of Tjörnes. Possibly this conglomerate is a delta deposit or littoral formation; in such case, the older shelly Pliocene strata must have been raised so high that they were exposed to erosion or disintegration either by running water or by the sea, during the time the conglomerate was in process of formation. This deposit can also be traced southward along the ravine along Fossgil.

7. Pebble deposit with large boulders between Fossgil and Breiðavíkurlækur.

This deposit shows out in the cliff abt. 200 m. west of the hill called Breiðavíkurlækur. It is built up of closely packed pebbles and boulders up to $^1/_2$ m. diameter, and is separated from the last-mentioned stratum (6) by a deposit formed of finer material (sand and small gravel). The stones in this stratum are far larger than in the conglomerate at Fossgil and not so finely smoothed; some of them resemble in shape the ordinary striated stones, and at a close view, this deposit looks like an irregularly packed moraine deposit; viewed from a little distance, however, it will be seen that there is some stratification, the strata sloping abt. 15° towards the east. I could find no marks of striation on the surface of the stones. — This deposit can, in my opinion, hardly be regarded as a moraine, at any rate, not directly deposited by a glacier. It is not impossible, however, that the boulders here which look like moraine boulders may have been acted on by a glacier situated not far away and washed forward by a stream, though there are as yet no certain proofs of this.

8. The Mudstone round Breiðavíkurlækur.

At the point where the streamlet called Breiðavíkurlækur falls down to the shore, the lower part of the cliff on both sides of the stream is formed of stratified, somewhat sandy mudstone, rather light brown in colour. It slopes towards east or NE. (abt. 7°) and dips right down under the shore some 120 m. farther north, but continues westward to the last-mentioned pebble deposit between Breiðavíkurlækur and Fossgil (7) and seems to overlie it. This mudstone as far as I could ascertain, contains no shells. Possibly

the strata marked 8?, 8 x and 8 y, farther east along the cliff, are a continuation of this deposit.

9. Dark sandstone stratum east of Breiðavíkurlækur.

This peculiar dark stratum juts out midway along the slope along Breiðavíkurlækur and continues thence eastward along the coast, running down to the shore 120—180 m. east of Breiðavíkurlækur. This stratum, which is abt. 160 cm. thick, is much more indurated than the mudstone both above and below, and is eroded more slowly, so that it juts out somewhat from the cliff. Where it runs down to the shore, it falls into two strata with an intervening layer of light mudstone abt. 60 m. thick. In the upper dark stratum here I found (at x) some very scanty remains of fossil shells.

Some 450 m. farther east along the shore there is a similar stratum (marked 9?) in the cliff abt. 20 m. above the shore continuing thence almost horizontally out to the upper part of the so-called Svarthamar, after which it seems to thin out and disappear. The substratum here, as at Breiðavíkurlækur, is stratified sandstone containing no fossils (8?). If 9 and 9? are really one and the same stratum, then a dislocation must have taken place at a fault about c, whereby the more westerly strata were lowered, the depression thus formed being filled up with younger, shelly marine strata (10).

10. The Macoma mudstone at Breiðavík.

Above the stratum of dark sandstone (9) at Breiðavíkurlækur comes a greyish stratified mudstone continuing eastward and forming the substratum of the cliff along the

shore from the point where stratum 9 ends to the presumed fault farther east, at *c*. There is possibly a thin continuation of this to the east above 9? but I could not make certain of this. According to my measurements, the minor strata in this deposit seem to incline less (abt. 5°) to the east or NE. than in the underlying strata nearest Breiðavíkurlækur.

Scattered about in this stratum lie marine shells, but they are few in number and found only here and there. The most frequently occurring species seems to be *Macoma calcaria*, Chemn.; I also found two small specimens of *Mya truncata*, L. at one place in this stratum. This stratum is pierced at two points by thin dykes of sandstone running obliquely through the strata. The one on the west (*a*) really consists of two separated dykes abt. 50 cm. apart, one 10 cm. the other 9 cm. thick. The dyke *b* lies abt. 340 m. farther north along the coast.

The upper limit of the Macoma deposit I did not investigate, but presume that it merges gradually into the succeeding shelly stratum (the Cyprina deposit, 12).

11. The Conglomerate deposit at Svarthamar.

Svarthamar is a conglomerate rock rising some 20 m. from the shore in the cliff abt. midway between Breiðavíkurlækur and Höfðaskarð. It is formed of well rounded, often spherical small stones or gravel, embedded in a scanty cementing material of sand mixed with clay. The rock shows a trace of somewhat undulating, sloping stratification, especially in its western half. The strata incline abt. 20^0 towards the NE. Among the smoothed basalt stones one frequently finds small spherical stones of a brownish tuff; I found no shell remains, however, in these stones, though

the tuff itself much resembles some of the shelly mudstone deposits on the western side of Tjörnes, nor were fossil shells to be found anywhere else in this conglomerate. Here and there, however, were small fragments of carbonised

Fig. 12. The cliff at Breiðavík near Svarthamar seen from the shore looking south. *1*, Svarthamar (11 on the section sketch). 2, the Cyprina deposit (12).

wood (Surtarbrandur). For the rest, this deposit most resembles some of the rocks in the conglomerate deposit farther west at Breiðavík (2) but the pebbles here were smaller on the whole.

In the slope abt. 100 m. north of Svarthamar there is a small rock (11 d) of the same material abt. 10 m. above the shore.

12. The Cyprina deposit at Breiðavík.

At the top of the cliff above Svarthamar there is a very rich shelly stratum of sandy mudstone which I have here

called the Cyprina deposit, as *Cyprina islandica* is the most prominent species there. This Cyprina deposit is found at the top of the cliff somewhat to the south and west, but I had not time last summer to examine the uppermost strata of the cliff here, and could not therefore determine with certainty the boundaries of its extent in that direction. I have marked in the section sketch with 12 (?) what I take to be its probable extent westward along the cliff. This deposit can also be traced northward along the cliff nearly out to Stapavík, where it runs down to the shore. The clayey sandstone, with similar fauna (*Cyprina* etc.) also shows out at *e* between the conglomerate 13 and 12 x, and *Cyprina* is also found in both these conglomerate strata. *Cyprina islandica* was found, too, under the conglomerate in similar strata at *f*, *g*, *h* and *i*. This deposit varies somewhat in its composition, the sandstone being more or less argillaceous in different places, and at the point of tran sition to the succeeding pebble deposit there are intercalated strata of fine gravel and sand.

I found fossil marine shells at various places in this stratum, and in particular, obtained many well preserved specimens in fallen blocks from the cliff above Svarthamar. Of these I mention the following:

Anomia sp. Defective shell from Svarthamar.

Pecten islandicus, Müll. Some fragments (Svarthamar).

Mytilus edulis, L. Fairly frequent (Svarthamar).

Mytilus modiolus, L. Some few defective valves (Svarthamar).

Cardium (*ciliatum* Fabr.?). Fragments.

Cardium groenlandicum, Chemn. Several specimens from Svarthamar.

Cyprina islandica, L. Frequent (at Svarthamar and at *e*, *f*, *g* and *h*, the largest specimens abt. 80 mm. long).

Astarte borealis, Chemn. 1 valve at Svarthamar, abt. 40 mm. long.

Macoma calcaria, Chemn. Frequent (length 40 mm.).

Mya truncata, L. Frequent.

Cyrtodaria siliqua, Spengler. Fairly frequent.

Nacella pellucida, L. 2 specimens from Svarthamar.

Margarita sp. 1 specimen from Svarthamar.

Natica sp. Fairly frequent, defective specimens.

Purpura lapillus, L. 1 specimen from the deposit near the shore below Torfhóll (*i*).

Buccinum (*undatum*, L.?). Some specimens from Svarthamar.

The shells are on the whole well preserved and generally entire but those of the bivalves are mostly in separate valves.

In a little ravine known as Threngingar along a small streamlet flowing from the south in Breiðavíkurlækur, there is a shelly clayey sandstone a good way from the shore 70—80 above sea-level. The mollusc fauna here seems to be very nearly the same as in the Cyprina sandstone at Breiðavík, and I therefore imagine it must be a continuation of the same stratum. I found here the following species:

Mytilus edulis, L.

Cyprina islandica, L. Frequent, some with united closed valves.

Astarte sp. Some fragments.

Macoma calcaria, Chemn. Frequent.

Mya truncata, L. Some umbonal parts.

Cyrtodaria siliqua, Spengler.

13. The shell-bearing pebble deposit in the cliff between Svarthamar and Stapavík.

In the slope north of Svarthamar the strata are somewhat confused in their relative positions and difficult to follow. There are here the following:

11 d. At abt. 10 m. above the shore a small conglomerate rock of the same type as Svarthamar.

8 y. Above this, a sandy stratified mudstone without fossils, 6—7 metres thick, possibly a continuation of stratum 8 x above the northern part of Svarthamar, and stratum 8 (and 8?) farther south in the cliff.

12 x. Conglomerate 4—5 m. thick containing a quantity of fossil shells (including *Cyprina islandica*). The stones here are well smoothed and somewhat larger than in 11 d. This stratum only shows out for a little way along the cliff and thins down very soon towards the south; in the cliff above Svarthamar it seems to have disappeared altogether. Northward also it seems to disappear or merge gradually into the succeeding stratum (12). This pebble stratum seems to be situated at the bottom of the Cyprina deposit.

12. The Cyprina deposit, which forms a continuation of the last-mentioned pebble deposit (12 x) up to the edge of the cliff (40—45 m. above the shore) is rich in shells here (*Cyprina*, *Mytilus*, *Cyrtodaria* etc.) and contains a quantity of small rounded pebbles.

13. Close to the north of a small ravine (*e*) here formed in the edge of the cliff, we find again, exposed at the top of the cliff, a pebble deposit of considerable thickness containing a quantity af shells and shell fragments of the same species as in stratum 12 (*Cyprina* etc.). This I have called the shell-bearing pebble deposit (13 in the

section sketch). Gravel and sand deposits here run in continuation of the stratum itself obliquely out along the cliff and end in a larger pebble rock (*f*) somewhat farther down in the slope. The Cyprina deposit crops out again here under the conglomerate, and merges gradually into the same; the boundary line shows alternate strata of clay sand and gravel with remains of fossil shells (*Cyprina* etc.); in the conglomerate itself there are also some scattered remains of *Cyprina*. Abt. 500 m. farther north (*g*) the same pebble deposit juts out, from the talus in the slope here also resting on the Cyprina deposit; but from here it is covered with fallen debris right out to Höfðaskarð, where it comes to light once more (*h*, *i*) and can now be traced again out along the cliff as far as Stapavík, where it slopes down to the shore and dips below the level of the sea.

The stones in this pebble deposit are for the most part well rounded and often spherical; as far as I could see, they were not the least like striated stones. The cementing material was mostly rather rich in sand. As already observed, some shell remains were found here and there. But they were very scanty, and occurred mostly near the lower limit of the stratum, where it meets the Cyprina deposit. From the foregoing, it seems evident that this must be a marine deposit formed in rather shallow water or on the shore itself. — The gradual transition from the underlying very shelly clay and sand deposit (the Cyprina deposit) to this stratum of gravel and pebbles above seems also to suggest a progressive raising of the land while the strata were being formed, and in respect of their fauna, these two strata (12 and 13) seem very closely allied.

14. The Cardium-Mya deposit at Breiðavík.

Above the shell-bearing pebble deposits in the cliffs on the eastern side of Breiðavík there are first of all slaty sandstone deposits a couple of metres thick, containing a

Fig. 13. Part of the cliff on the eastern side of Breiðavík between Svarthamar and Höfðaskarð. *1*, Cardium-Mya deposit (14). 2, Basalt (15); the strata immediately beneath are covered with fallen debris.

quantity of fine gravel, this again passing over into a mudstone or clayey sandstone, highly indurated, dark grey in colour, finely grained and with a slight admixture of sand. It is abt. 6 m. thick, with not very distinct stratification. This stratum begins in the cliff abt. 200 m. north of Svarthamar, and continues northward until it dips down under the beach at Stapavík. It is fairly rich in fossil shells at most places. I found here the following species:

Pecten islandicus, Müll. Not very frequent. Brought home some defective valves.

Mytilus edulis, L.? Some fragments found in this stratum may possibly belong to this species.

Nucula tenuis Mont. 1 valve from Höfðaskarð.

Leda pernula, Müll. One valve, from the same place.

Cardium ciliatum, Fabr. Fairly frequent. Remains of several valves taken at the same place.

Cardium groenlandicum, Chemn. Frequent, often found with united closed valves (L. 65 mm).

Macoma calcaria, Chemn. Very frequent with united closed valves, largest specimens 44 mm.

Mya truncata, L. Very frequent, found in very large specimens (abt. 80 mm.) often »in situ« with united closed valves.

Cyrtodaria siliqua, Spengler. Some few shell fragments.

Natica (*clausa*, Brod. & Sow?.). Several defective specimens.

Buccinum (undatum L?). Some few defective specimens.

The shells were often found whole and well preserved in this deposit but owing to the hardness of the clayey sandstone and the difficulty of cleavage it was not easy to get the shells out whole.

15. Basalt at top of the cliff on the eastern side of Breiðavík.

Just about where the Cardium-Mya deposit begins in the cliff east of Svarthamar, it is covered by a dark thin stratum of basalt forming the uppermost solid stratum in the cliff here. It increases in thickness towards the north; it has been eroded away at Höfðaskarð, but reappears at Torfhóll and continues thence without interruption northward along the cliff to the northermost point of the ness. At Stapavík it is abt. 10—12 m. thick; north of this its

under surface goes right down to the sea, and from here onwards the cliff to the northward as far as Tjörnes Point is entirely covered by this basalt stratum, which is in some places abt. 20 m. thick. This stratum slopes towards the

Fig. 14. The cliff at Torfhóll and Höfðaskarð in Breiðavík. *1*, The Cyprina deposit (12). *2*, Shell-bearing pebble deposit (13). *3*, The Cardium-Mya deposit (14). *4*, Basalt (15).

NE. It covers the whole of the ness and forms also a steep cliff on its eastern side, but for a short distance here, near the small creek of Sandvík, the Cardium-Mya deposit crops out again below, close down by the shore. — Farther east, the coast is low and covered with shingles and recent marine deposits, where the solid substratum does not crop out. In the cliff south of Höfðaskarð, the basalt at the bottom merges into a breccia-like stratum of slag, where lumps of lava and slag have become kneaded together with a yellow tuff-like matrix. Above the basalt there are only thin strata

of young deposits of gravel, sand, clay and soil. — The basalt continues from Breiðavík towards the south-east as far as the higher hills some little distance from the shore. I had not time, however, to study the strata conditions farther south or east from Breiðavík.

16. Remarks on the Breiðavík deposit.

I have already pointed out that the sediments at Breiðavík must be the youngest sections in the series at Tjörnes described in the present paper. That certain strata at Breiðavík (stratum 6) contain rolled shelly tuff-stones which must be supposed to originate from older Pliocene strata, possibly the same which are found on the western side of Tjörnes between Kaldakvísl and Höskuldsvík, also proves that the Breiðavík deposits must be much younger than these strata on the western side of Tjörnes.

A long period of time must have intervened between the formation of the shell-bearing Pliocene strata on the western side of Tjörnes and the first deposition of the shelly sediments at Breiðavík, as the intervening strata which crop out on the coast from Höskuldsvík to Hörgi and Stangarhorn (the two basalt deposits and the sediments at Furuvík) are of considerable thickness, and must have taken some time to form. The lowest, non-fossiliferous strata at Breiðavík (strata 2—8) which crop out in the cliff between Stangarhorn and Breiðavíkurlækur are also of considerable thickness (100 m. at least), and certainly must have taken a long time to form. During the period in question also, much erosion must doubtless have taken place in the adjacent regions, which is evident from the material of which these sediments are formed, the older marine strata being thus exposed to the disintegrating action of erosion.

Furthermore, the strata of Breiðavík are not concordant with the older strata on the western side of Tjörnes. The strata at Breiðavík dip roughly NE, whereas those on the western side of the ness dip NW, which may presumably be taken as the sign of a considerable difference in age.

There is also considerable difference between the mollusc fauna of the fossiliferous strata at Breiðavík (strata 12—14) and that which we find on the western side of the ness. The southern European forms as well as most of the American species have here disappeared, nor have I found any extinct mollusc forms in these fossiliferous strata at Breiðavík. The fauna here seems altogether more like the fauna at present living on the Coast of Iceland than in any other of the shelly strata at Tjörnes, nearly all the principal mollusc species in the Breiðavík strata being still found in a living state in Iceland waters.

That the shell strata at Breiðavík must nevertheless be ascribed to the Pliocene deposits seems to the evident from the fact that *Cyrtodaria siliqua* Spengler, a very prominent species in the marine strata on the western side of Tjörnes, is still fairly frequent at Breiðavík. This species does not now live in Iceland waters, nor has it been found here fossil in post-tertiary strata. Dr. Helgi Pjeturss has also found a *Littorina* sp. in the strata at Breiðavík (l. c.), and Prof. A. S. Jensen considers it cannot be referred to any of the species of *Littorina* now living in Iceland[1]. The highly indurated mudstone and sandstone in which the shells from Breiðavík are found embedded also greatly resembles the fossiliferous strata in the cliffs along the west coast of Tjörnes.

[1] In my collection from Breiðavík there are no specimens of this *Littorina* but I had very little time to make collections in the shelly strata during my visit there last summer as most of it was taken up with examination of the strata sequence in the cliffs.

The mollusc fauna in the shelly deposits at Breiðavík is of boreo-arctic character; I have not found any typical high arctic species there up to now. About one-third of the species I have collected from there are boreal and do not live in the high arctic seas (*Mytilus edulis*, L., *Mytilus modiolus*, L., *Cyprina islandica*, L., *Nacella pellucida*, L. and *Purpura lapillus*, L.). All these boreal species still live at the coasts of Iceland. Two of them, *Purpura lapillus*, L. and *Nacella pellucida*, L., have not been found living at the present day on the north or east coasts of Iceland but are frequent on the south and west, where the action of the Gulf Stream is most pronounced. All the other mollusc species I have taken here, (with the exception of *Cyrtodaria siliqua*, Spengler) also live at the present day on the west coast of Iceland. Consequently, we must take it that the shell strata at Breiðavík must have been formed under climatic conditions similar to those now prevailing on the west coast of Iceland.

These boreal species were found mainly in the Cyprina deposit (12); in the youngest shelly stratum (14) I found none of these boreal species except *Mytilus edulis*, L., which seems to suggest that this stratum was deposited in a colder sea than the Cyprina stratum, and that the temperature was decreasing when the shelly series at Breiðavík was being formed. Consequently, the boreal elements in the marine fauna would be disappearing, possibly owing to the approach of the glacial period. This supposition, however, must be advanced with all reserve, as the fauna of the strata in question has still to be thoroughly investigated.

The fossil mollusc fauna at Breiðavík resembles mostly that of the youngest shelly deposits on the western side of Tjörnes, the *Cardium groenlandicum* zone. In Breiðavík, *Car-*

dium groenlandicum is very frequent, as also in the zone mentioned, and nearly all the other species which I found at Breiðavík were also found in the Cardium groenlandicum zone. — An exception is the *Purpura lapillus*, L. which I found in the Cyprina deposit at Breiðavík, but which has not hitherto been found on the western side of the ness. On the other hand, Breiðavík lacks, as already mentioned, many mollusc species found in the Cardium groenlandicum zone, as for instance:

Extinct species: *Cyprina rustica*, Sow., *Astarte incerta*, Wood, *Corbulomya*, *Nassa lamellilabra* Nyst, *Searlesia costellifera* Wood, *Searlesia Lundgreni*, Mörch, *Actæon Noæ*, Sow.

Living European species: *Solen*, *Gibbula*, *Calyptræa chinensis* L.

Living American species: *Venericardia borealis*, Conrad, *Liomesus canaliculatus*, Dall.

The alteration in the composition of the fauna from the Cardium groenlandicum zone to the Breiðavík deposit shows a distinct and decisive approach to the present mollusc fauna of Iceland and indicates at the same time a decrease in the temperature of the sea with less favourable condtions of life for the southern mollusc forms, at the time when the shell deposits at Breiðavík were in process of formation.

Dr. Helgi Pjeturss, (l. c. 46—47) mentions that the cliffs at Breiðavík contain glacial formations or deposits with striated stones. The fauna in the shell strata at Breiðavík, as far as it is hitherto known, affords no support for the supposition that a high arctic Pleistocene climate should have been prevalent here at the time these strata were formed, since the fauna, as I have already pointed out, is of boreo-arctic character, like that now living on the west coast of

Iceland. Nor do the deposits immediately adjacent to the shell strata look like glacial formations. The suggestion as to glacier action in the strata of the cliff at Breiðavík is presumably due to the presence of boulders in the gravel and clay deposits at Fossgil (strata 3 and 7 on the section sketch) which lie deeper in the series than the shell strata. Both these strata present some resemblance to glacial formations, and contain stones and large boulders, somewhat similar in shape to ordinary striated stones, but as I did not succeed in finding any glacial striation on the surface of the stones, and as these deposits further showed more or less distinct stratification, I cannot for the present accept the view that they should be moraines directly formed by glaciers. If these strata are of glacial origin — which I consider by no means proved — it is more likely that they are fluvioglacial formations, formed by material washed down by a glacier torrent. In such case, the glacier must have spread out over the adjacent mountains when these strata were being formed.

This also agrees well enough with the conditions in south Iceland at the present day where the glacier torrent shifts sand, gravel and large stones from the glaciers down to the sea, which here contains a fauna including many southern (both boreal and Lusitanian) mollusc species and is of even more southerly character than in west Iceland.

CONCLUDING REMARKS.

The thickness of the fossiliferous Pliocene strata on the western side of Tjörnes, between the Kaldakvísl and Höskuldsvík I have estimated at abt. 450 m. (p. 11). To this must be added the last-noted sediments at Breiðavík

and the marine sediments at Furuvík (Fig. 1, D); also the basalt which is found both above and below these sediments at Furuvik (Fig. 1, C and E). Unfortunately, I was not able to make accurate measurements of the thickness of these strata, but from some aneroid measurements which I made there in some few places last summer, when following the strata northwards along the coast, I should think that the series of strata between Höskuldsvík and Hörgi amount to abt. 100 m. (each of the sediments at Furuvík abt. 40 m.). The sediment deposits at Breiðavík I take to be at least 150 metres thick.

The Thickness of the entire Pliocene deposit at Tjörnes should thus be at least abt. 700 metres.

As the Pliocene mollusc fauna of Iceland has not yet been further investigated, it is impossible at present to give any exhaustive comparison between this and the English Crag fauna.

There can hardly be any doubt but that the Icelandic Pliocene fauna is altogether very closely allied to the English Crag fauna, as by far the greater part of the mollusc-species found in the Tjörnes strata also occur in the Crag strata in England. That several living American species of molluscs are possibly more common in the Icelandic Pliocene deposit than in the English is not surprising when we imagine that the arctic ingredient in the fossil Crag fauna had its origin farther north, possibly in what is now the Arctic Ocean, and was in course of migration southward in the Pliocene period, which, in a climatological respect must be designated as a transition period between the Miocene and the Ice Age (Pleistocene), during which the climate gradually deteriorated in the north from temperate to high arctic. Iceland and America may then have lain

nearer the centre of distribution of the Crag fauna, in which case it would be natural that several mollusc species especially of arctic origin, should attain a higher degree of frequency in Iceland and North America than farther south, say, on the English coasts. The climatic conditions in the sea off the shores of North America are, I think, also subject to far more variation from one season of the year to another, than off the coasts of Europe, where the Gulf Stream softens to some extent the extremes of summer and winter. It might therefore be possible that various marine molluscs could live on through the ages on the coasts of North America but have died out in Iceland and England, and be now only found here fossil in the Pliocene strata.

If we consider the information as to climatic conditions which the Pliocene strata at Tjörnes appear to furnish, and the alteration in climate which seems to have taken place while these shell-bearing strata were in process of formation, then these deposits at Tjörnes seem in some degree comparable to the English crag formation.

The most thermophile species in the Tjörnes deposit which are chiefly associated with the older shell-bearing zones, suggest similar climatic conditions to those of South and West Norway, or possibly of the British Isles.

The older zones in the English Crag (Coralline Crag and Red Crag), also contain southern mollusc species, which in the present day are first found living in the Mediterranean or along the western coasts of Portugal and France. Considering how much farther north the Icelandic Pliocene strata lie than the English, it seems possible that these Pliocene deposits in Northern Iceland and England may have been formed somewhere about the same time.

In the younger Pliocene strata, a similar change in the char-

acter of the fauna is discernible in both places. The southern mollusc species gradually give place to an immigrant northern or arctic fauna, closely related to the mollusc fauna now living on the shores of the North Atlantic. In the Icelandic Crag, however, no such mollusc forms have yet been found as would suggest a colder climate than that of the present day on the coasts of Iceland where the Pliocene strata are found. — It is impossible at present to estimate the age of the strata from the proportion between living and extinct species in the Icelandic Crag, as the fossil fauna here is too little known as yet.

I hope, however, later to be able to go further into these questions, in connection with the description of the fossil Crag fauna from Tjörnes.

I take this opportunity of expressing my very sincere thanks to Prófessor O. B. Bøggild and Docent J. P. J. Ravn of the University of Copenhagen for their kindness and courtesy in enabling me to study collections at the Mineralogical Museum in Copenhagen, and even lending me specimens of several mollusc species to take to Iceland for purposes of comparison on the spot. Also for the help and encouragement which they have accorded me on various occasions, which have greatly furthered the progress of my investigations at Tjörnes.

Dr. N. O. Odhner of Stockholm, and A. Bell, Esq. of Ipswich, have assisted me in the determination of the Crag molluscs, and Dr. H. Spärck has lent me some recent mollusc species from the Copenhagen Zoological Museum for comparison; to these gentlemen also I which to express

my best thanks. — I am also indebted to Mr. Kári Sigurjónsson, of Hallbjarnarstaðir, for the generous hospitality accorded me during my visits to Tjörnes the last two summers. He took a keen interest in my researches, and endeavoured in every way to aid me in the work, even assisting in the collection of specimens. I have also since then received from him several handsome specimens of molluscs procured by himself in various shell-bearing horizons of the Pliocene strata. He is a keen collector and a most conscientious and reliable observer.

Postscript.

While this treatise was in the press I received a paper on the mollusc fauna in the Pliocene deposits at Tjörnes by Mr. H. Schlesch in Copenhagen (Zur Kenntnis der pliocänen Cragformation von Hallbjarnarstadur etc. — Abhandl. des Archiv für Molluskenkunde Band I. H. 3. — Frankfurt a. M. 1924). There are many points in this treatise on which I should like to offer some remarks, but as there is no room here for such remarks, I think I had better return to them later. Here I only wish to make the following observations:

1) It is clear to me, from the list of the species, that the author has confounded species from different shell-bearing horizons in the formation, so that his information about the stratigraphical distribution of the species in the fossiliferous deposits is not to be relied upon.

2) In the author's collections from Tjörnes, on which his treatise is founded, the identification of the species are not sufficiently reliable. I have examined his collections from Tjörnes, presented by him to the Natural History Museums in Reykjavík, Stockholm, Copenhagen and London, and found out that several species in these collections are not correctly named.

Errata.

page 24^{12} *for* Coal-bearing *read* coal-bearing.
— 31^{13} *for* Hringvershvilft *read* Hringverslækur.
— 60^{5} *for* Svarthöfdi *read* Stórhöfdi.
— 80^{20} Following C. M. Paulsen's manuscript (l. c.) I have here taken *Mactra procrassa*, Wood, as identical with the North-American species *M. solidissima*, Dillwyn. But after having had the opportunity of comparing these two species with each other in the British Museum, I must consider them as specifically distinct. Consequently, what has been written here about the distribution of *Mactra procrassa*, Wood, on the coasts of North-America is to be omitted.

Explanation of Plate I.

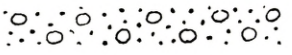
A—J ..... Land or fresh-water deposits.
1—25 ..... Marine shell-bearing. deposits.


Basalt.


More or less continuous layers of marine fossil shells.


Coal strata (lignite), more or less continuous.


Pebbles.


Postpliocene sand, clay and gravel deposits at the top of the cliff.


Talus.


Covered by herbage.


Petrified tree trunks, with roots and branches attached.

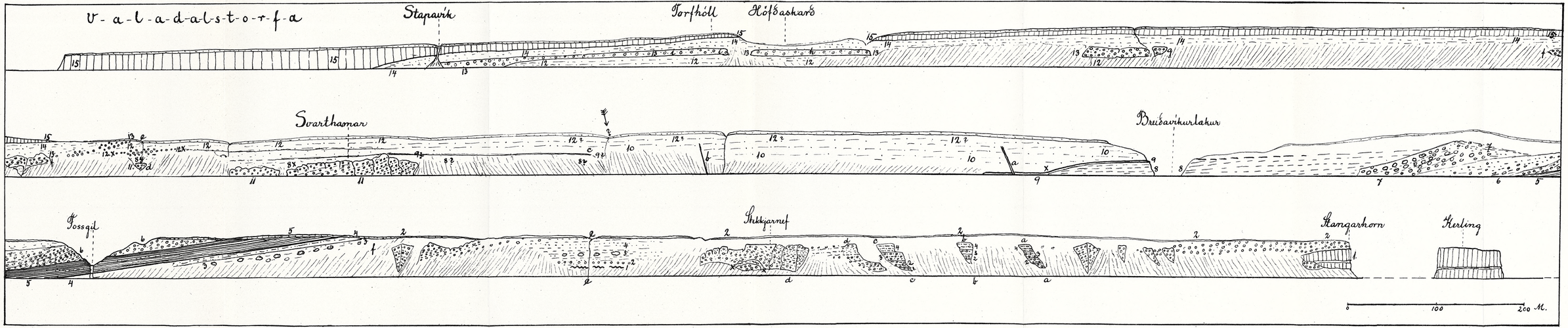

Faults.

CONTENTS

Færdig fra Trykkeriet den 7. April 1925.

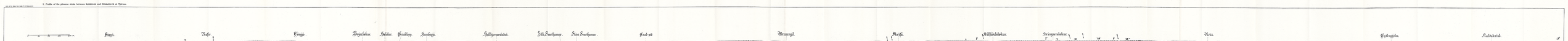
D. K. D. Vid. Selsk. Biol. Medd. IV, 5 [Bárðarson]

II. Profile sketch of the pliocene strata in Breiðavík at Tjörnes.



TUTEIN & KOCH.

1. Profile of the glacene strata between Kaldakvísl and Hítárdalsvík at Tjörnes.



BIOLOGISKE MEDDELELSER

UDGIVNE AF

DET KGL. DANSKE VIDENSKABERNES SELSKAB

1. BIND (Kr. 13,85):

Kr. Ø.

1. Kroman, K.: Laws of muscular action. 1917 0,95
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5. Walbum, L. E.: Undersøgelse over Petroleumsæthers og nogle rene Kulbrinters Indvirkning paa Tyfus-Coligruppens Bakterier. With a Résumé in English. 1918 1,05
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10. Raunkiær, C.: Forskellige Vegetationstypers forskellige Indflydelse paa Jordbundens Surhedsgrad (Brintionkoncentration). 1922 2,40

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1. Jensen, P. Boysen: Studien über den genetischen Zusammenhang zwischen der normalen und intramolekularen Atmung der Pflanzen. 1923 1,10
2. Müller, P. E.: Bidrag til de jydske Hedesletters Naturhistorie. Karup Hedeslette og beslægtede Dannelser. En pedologisk Undersøgelse. Med 1 Kort. Avec un résumé en français. 1924 8,25
3. Lindhard, J.: On the Function of the Motor End-Plates in Skeletal Muscles. 1924 1,00
4. Boas, J. E. V.: Die werwandtschaftliche Stellung der Gattung Lithodes. (Med 4 Tavler). 1924 2,35
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