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FOSSILIFEROUS XENOLITHS IN THE MÓBERG FORMATION OF SOUTH ICELAND

BY

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WITH 3 PLATES
AND 8 FIGURES IN THE TEXT

NÁTTÚRUGRIPASAFN ÍSLANDS
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INTRODUCTION

In the winter of 1933 one of my pupils at the College of Reykjavík, Sveinn Pálsson from the farm Skammidalur in the Mýrdalur district in South Iceland, told me that there were shell fossils in the palagonite formation not far from the farm, and shortly afterwards he brought me several shells collected on a ridge named Fjósahryggur. In the spring of 1934, while passing through Mýrdalur with a group of pupils from the Teachers' Training College, I had the opportunity of observing the shell strata, although a careful investigation could not be carried out at the time. Then in the spring of 1936 Professor Niels Nielsen of Copenhagen and I found some shell fossils in the palagonite formation just off the road leading to the east across Höfðabrekkuheiði, a little to the west of the bend in the road going down to the bridge across the river Múlakvísl. The purpose of our journey, however, was not the collection of shell fossils. Yet, during the time we spent looking for fossils, we found some species of *Cardium* and *Mytilus*. In the next few years I was unable to devote much time to the examination of these interesting shell strata, but in July 1952, at last, I went to Mýrdalur for the express purpose of investigating the shell beds. Some time before leaving Reykjavík I had received a letter with a parcel containing a small collection of fossils from the farmer Einar H. Einarsson of Skammadalshóll in Mýrdalur. This farmer had immediately displayed a keen interest in the investigation of the shell beds discovered in his home district. It was soon clear to both of us that it would take some time to collect a sufficient number of specimens, partly because there were relatively few fossils in the shell beds and also because it would prove very difficult to chisel them out of the rock without damaging them. It was therefore agreed that Einarsson should collect as many fossils as possible whenever the work on the farm allowed. In this work he has proved a very discerning and able collector. We have wandered across the field of investigation many times and discussed the problems involved in our investigations. On these occasions his thorough knowledge of the locality has been invaluable. The work of determining and classifying the collection has, on the other hand, fallen upon me, and here acknowledgement is made to everybody who has helped me in my work. I particularly wish to

express my best thanks to Dr. D. F. W. Baden-Powell, University Museum, Oxford, who has examined a part of our collection and generously identified some of the shells.

We now think that our investigations have been carried so far that their results and the conclusions to be drawn from them should be published. In all probability other species of fossils besides those already found are still to be discovered, but we do not believe that they will alter our main conclusions.

THE FIELD OF INVESTIGATION AND ITS SEQUENCE OF STRATA

The field investigated with particular reference to shell fossils extends from Höfðabrekkuheiði in the east to Búrfell in the west. The fossils have mainly been collected in the móberg formation (palagonite formation) on the slope above the Skammidalur farms, while some have also been found in the Núpar in the south of Höfðabrekkuheiði. We have been told that there are shell fossils to be found in the eastern part of the mountain Pétursey where we have not done any work, since the terrain is very difficult and in some places almost inaccessible. On the north side of Pétursey Einar H. Einarsson has discovered rocks resembling the shell formations near Skammidalur.

Above the marshes extending northwards from the Dyrhóla estuary there is a rather steep escarpment whose edge is about 200 metres higher than the base. North of the escarpment there is a stretch of rolling hill country reaching as far as the glacier Mýrdalsjökull. The escarpment takes its name from the farms lying below. Its extreme western part is called Neskambar; here it faces west, while at Neshólar it begins to turn eastwards, and the stretch from Neshólar to Hvammsgil faces south. Close to Neshólar, which are actually hills covered with grass except for some naked rock faces of soft tuff, there is a gully in the escarpment called Nesgil. It is just above this gully that the escarpment reaches its highest point, 270 m above sea level. Along the whole length of Neshraun, a ridge formed of sandy tuff, there is an open fissure with the direction N 16° W. The tuff layers dip on both sides of the fissure away from its edges. East of Nesgil there are precipitous tuff ridges called Skammadalskambar. One of them is Fjósahryggur, already mentioned above. East of Skammadalskambar the slope is not so steep, and here it is covered with grass more than half-way up. The edge of the escarpment above the farm Skammadalshóll is called Sjónaröxl. East of Deildargil are the Giljakambar ridges, and further east there are other ridges called Hvammskambar reaching as far as the gully Hvammsgil.

Most of the fossils mentioned in this paper were found in sediments between Nesgil and the stream Deildará. This stretch is in most places fairly accessible and easy to investigate. Yet the slope extending eastwards from the brooklet between the Skammadalur farms to the southern limits of the gully Deildarárgil is covered with a rather thin layer of earth overgrown with grass. This slope, called Fláar, appears to be some kind of landslide. As already mentioned above, there is an open fissure along the ridge Neshraun. In Mýrdalur there are other fissures with the same direction, and some of these have given the entire region very characteristic features. Among these is the rift valley above the village of Vík between Hatta and Arnarstakkur in the east and the mountain Reynisfjall in the west. It is also our opinion that the gully Deildargil was formerly a fissure, and the valley northwest of Skagnes was probably formed as a fissure with the same direction as those already mentioned. The direction of the fissures is an interesting point, as it does not conform with the normal direction of fissures (SW–NE) dominating in that part of Iceland.

Besides the fissures already mentioned there appear two faults in the escarpment above the Fláar. Between these faults the land appears to have moved downwards. The eastern fault is more clearly discernible than the western one, though the latter is clear enough on closer examination. The dislocations are most noticeable in the very edge of the escarpment. Post-glacial volcanic activities in Mýrdalur have been dealt with in an article by Thorarinsson (1952) who has told me that there was an eruption near Vörður south of Skeiðflöt, i. e. there is an active volcanic fissure with the same direction as the fissure in Neshraun mentioned above.

The part of Skammadalskambar closest to Nesgil on the east side is called Stórhöfuð. It is a neck-shaped formation made of unstratified móberg, its height being about 100 m above sea level. On both sides of Stórhöfuð the móberg formation is stratified, though the stratification is not very clear in places. Next to Stórhöfuð on the west side the móberg beds are vertical, but the dipping of the móberg strata decreases westwards. To the east of Stórhöfuð the móberg beds are dipping N–NE. The dip of the visible bottom layers is about 30 to 40 degrees, but on moving eastwards it tends to decrease, and the top layers are almost horizontal. In the edge of the escarpment east of Skammadalskambar there are thin beds of soft claystone interspersed with small grains of dark pumice. Tuff bombs, about 20—25 cm in diameter, are rather conspicuous in the top layer. The bombs seem to be made of material similar to the móberg surrounding them, but the effect of erosion on them seems to have been slower than on the surrounding rock. Wherever the surface of the móberg formation is not covered with younger strata it is interspersed with small basaltic pebbles which have broken loose from the móberg during the process of denudation. Moreover, the Stórhöfuð móberg formation has a character of its own inasmuch as it contains much larger basaltic

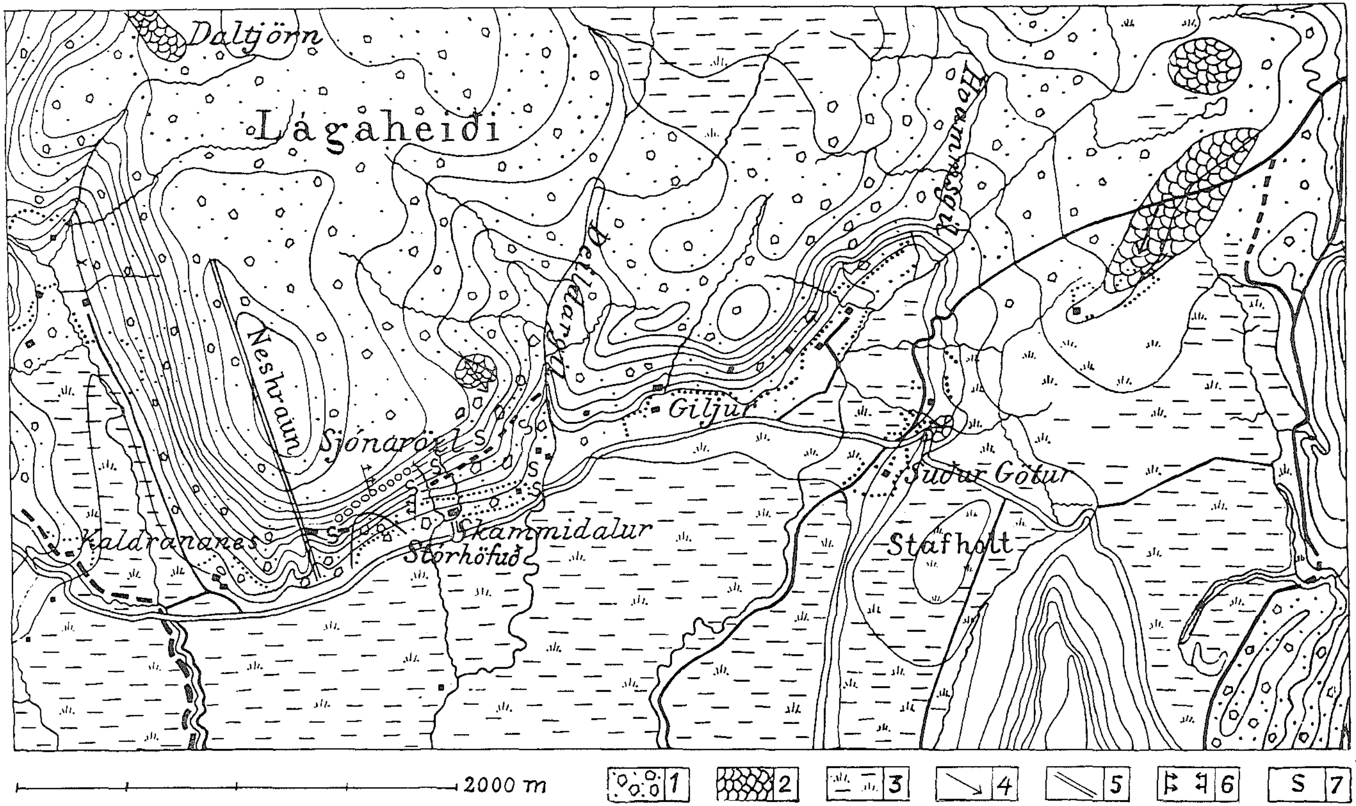
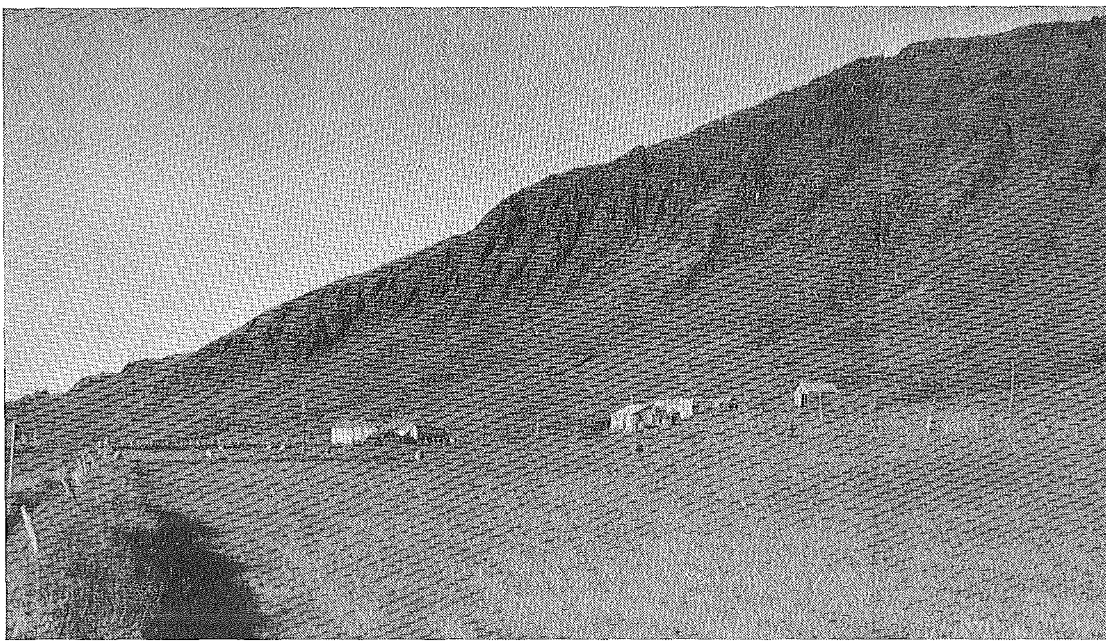


Fig. 1. 1. Móberg, 2. Dolerite, 3. Cultivated land and meadow, 4. Striae, 5. Open fissure, 6. Faults, 7. Shell fossils.



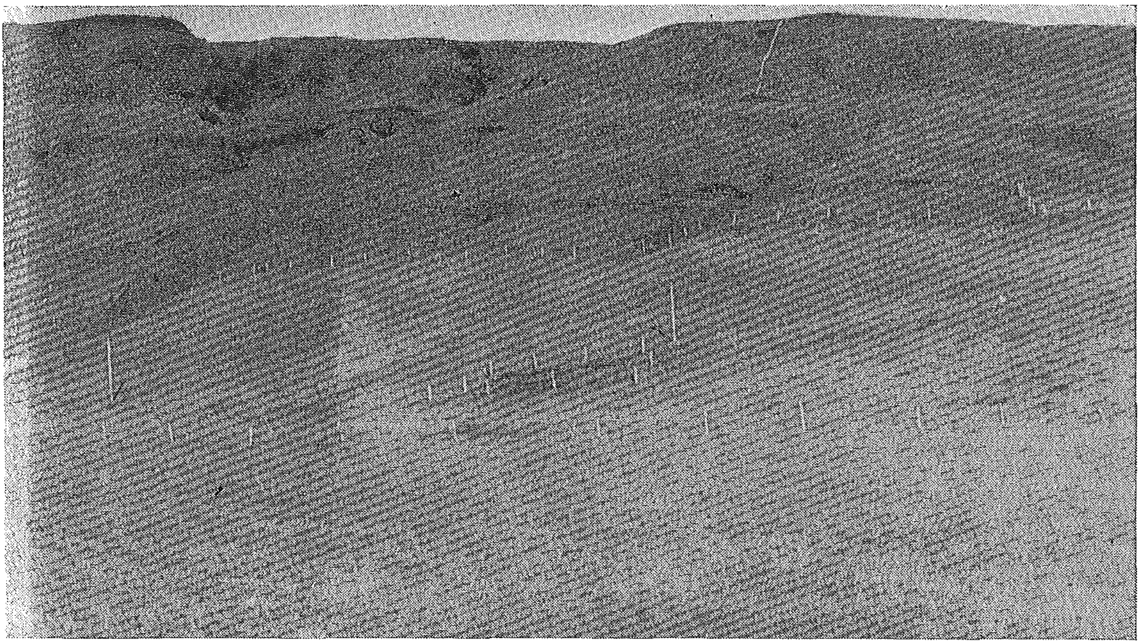
Neskambar Skammadalskambar

Fig. 2. Panoramic

blocks than the stratified móberg on both sides. These blocks in the Stórhöfuð are up to one metre in diameter, and a few of them are even larger. They are most conspicuous towards the bottom of the section, but further up they are fewer and also smaller in size. In the stratified móberg formations on both sides of Stórhöfuð there are immense numbers of angular, fine-grained basaltic fragments about 5 cm in diameter, though the size of some of them is between 5 and 10 cm.

In spite of a most persistent search we have not succeeded in finding any shell fossils in the móberg of Stórhöfuð, i. e. it appears to be entirely unfossiliferous. This clearly sets it apart from the surrounding móberg strata on both sides where all the fossils described below have been found in stratified sedimentary rocks, or xenoliths, named "shell boulders" here. The shell boulders are no doubt extraneous matter and will be closely described below.

The móberg rock of Skammadalskambar seems to be very similar in texture throughout. It is fawn-coloured and for the most part made up of compact basaltic glass interspersed with zeolites, calcite crystals, crypto-crystalline basaltic particles and pumice grains. Part of the basaltic glass is clear and transparent,



ield of investigation.

but most of it is palagonitized, the glass particles often having yellowish chloride edges. Bearing in mind the conclusions of those who have investigated the Icelandic móberg most carefully we believe that the móberg of Skammadalskambar is formed of pyroclastics, probably after a subglacial eruption or in circumstances where water has affected the solidification of the basaltic magma. (Peacock 1926, Nielsen and Noe-Nygaard 1936.)

The móberg — both the fine-grained material and the larger particles — is magnetic. This proves that the temperature of the móberg magma has been several hundred degrees when it solidified. The shell boulders, however, are only magnetic on the outside, which has grown hot when the boulders were carried upwards in the hot móberg magma, but the heat has not been intense enough to affect their inside or nucleus.

It has been mentioned above that on top of the móberg in Sjónaröxl there are beds of doleritic lava along a limited area. A similar type of rock is to be seen at several places on top of móberg formations to the north of the Mýrdalur region. There is dolerite, for example, in the steep rocks north of Dalsvatn (a lake), on

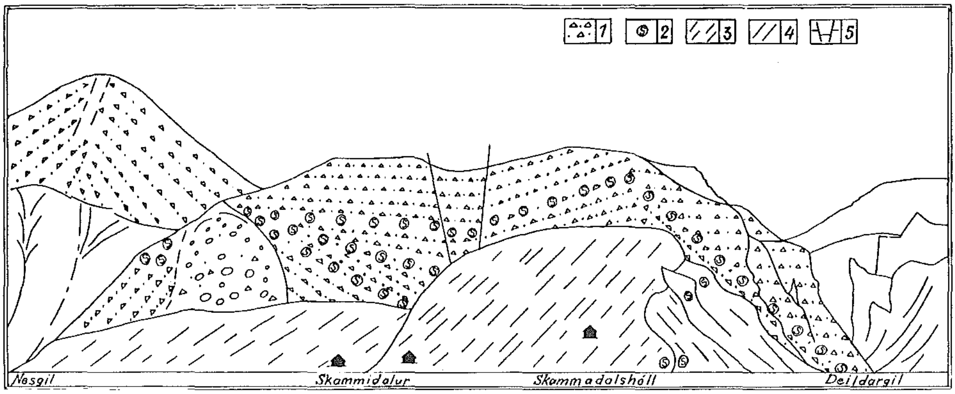


Fig. 3. Sketch showing cross section of area investigated.
1. Móberg, 2. Shell fossils, 3. Landslide, 4. Open fissure, 5. Faults.

the moor north of the abandoned farm Rof, and also in a hill called Fall north of Rof. At the junction where the road winds between the farms Norðurgötur and Suðurgötur dolerite occurs underneath a muddy moraine. Finally, the móberg of Dyrhólaey is covered with dolerite on the east side. There is no doubt that at many places in Mýrdalur besides those already mentioned doleritic lava is to be found on top of the móberg formations.

The dolerite is everywhere scratched by glaciers. At Sjónaröxl the direction

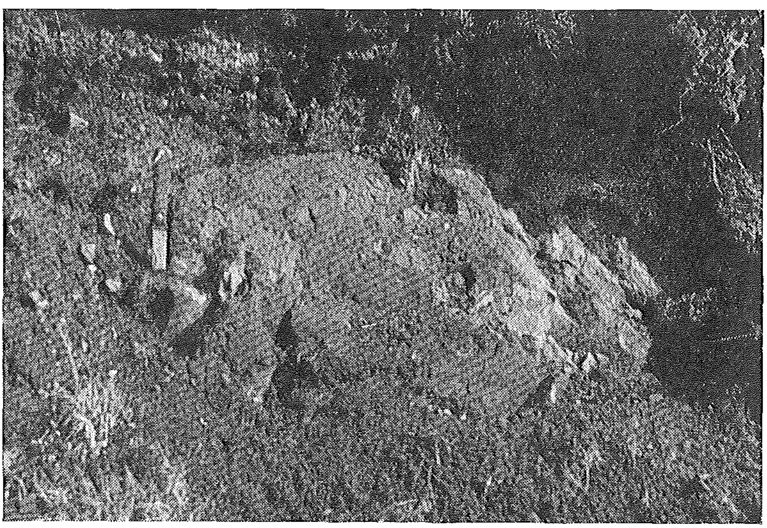


Fig. 4. Fossiliferous xenolith in the móberg at Sjónaröxl.
The knife is 20 cm long.

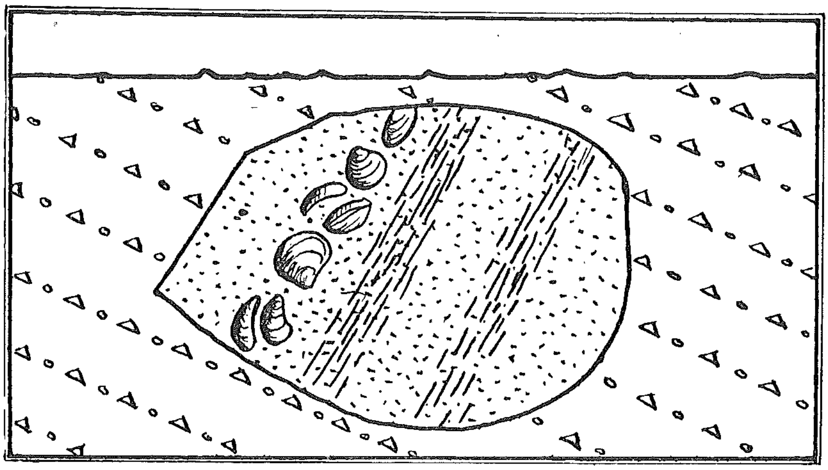


Fig. 5. The sandy layers of the xenolith are unconformable to those of the surrounding móberg.

of the striae is S 20° E. North of Rof the direction is S 22° W, and at Dyrhólaey the striae point straight south. It is quite certain that these doleritic lava beds are only small remnants of larger and more continuous doleritic lava beds that have been eroded by glaciers and winds. Distinctly wind-worn rocks (from easterly winds) can be seen on the surface of the dolerite at Dyrhólaey.

It is not known whether these doleritic lava flows owe their origin to one or more volcanic centres, but it seems more than likely that there has been more than one centre of origin. This is proved by the fact that the doleritic remnants are spread over a wide area. The exact location of the volcanic centres is not known, but several things indicate that the lava flows have come from the north. Thus, for instance, the lava beds slope southwards. A closer investigation of the dolerite would probably reveal its place of origin. At Dyrhólaey there appears to be a doleritic lava edge across the lower part of the headland, while the higher part never seems to have been covered with doleritic lavas.

From a geomorphological point of view the region of Mýrdalur must be considered to be younger than the above-mentioned doleritic area. The residuals of this area are, in our opinion, the stretches of land called Stafholt, Langholt and the whole southward-leaning terrace on which the Foss farms are standing. The headland of Dyrhólaey is also a part of this ancient plain.

The ridge Steigarháls cannot at present be determined with full certainty, but there are indications that it is a younger formation. The surface of the doleritic plain is lower than the móberg mountains Reynisfjall, Hatta and Arnarstakkur, and the same can be said of the móberg foundations of the glaciers to the

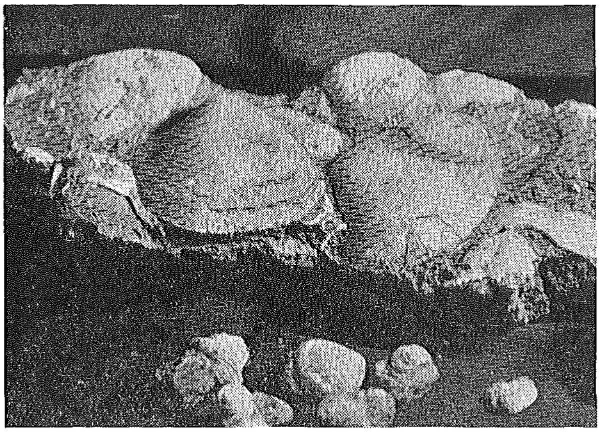


Fig. 6. Some of the xenoliths contain shells lying were closely together.

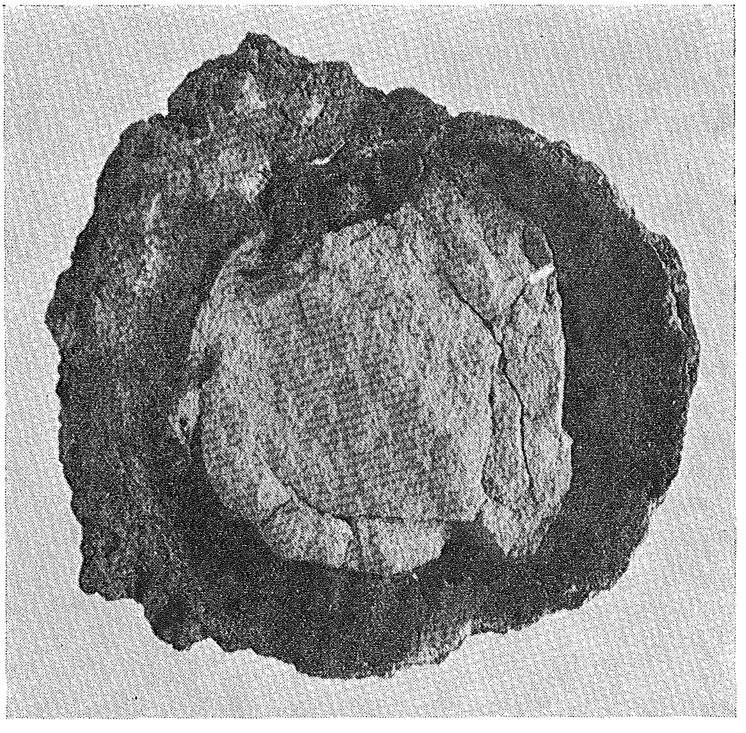


Fig. 7. Volcanic bomb with basaltic crust and shell fragments in the tuff core.

north. The age of the three móberg mountains just mentioned cannot be traced further back than to the last glaciation, that is, to an age of glaciers that eroded and scratched the doleritic lavas and removed the volcanic centres from which the lava flows had come.

We once more revert to the shell boulders already mentioned. These are somewhat different in size and structure, but they might eventually be classified as follows: (a) Boulders, either globular or oval in shape, the largest about 55×75 cm; surface grey-brown, inside dark-blue. These boulders are made of fine-grained and sandy conglomerates which are distinctly stratified. Across the boulders there run thin layers of water-worn basaltic pebbles which are round in shape and about 1—3 cm in diameter, fossiliferous, containing both shells and leaf impressions. (b) Boulders irregular in shape and greyish in colour, made of coarse-grained sandstone interspersed with small basaltic fragments. These boulders are stratified, the largest one being about 1 m in diameter. Only three such irregular boulders have been discovered, all of them west of Stórhöfuð. The boulders are fossiliferous. (c) Volcanic bombs (Fig. 7), with a basaltic crust around them. Their tuff nucleus contains fragments of shells. These bombs are as a rule smaller than the boulders mentioned above.

DESCRIPTION OF THE FOSSILS

A. PLANT FOSSILS

A few impressions of small dicotyledonous leaf fragments have been found among the shells in the sedimentary xenoliths at Skammidalur. The leaves are not so completely represented as to make a definite determination possible. Impressions of leaves and shells are found in pebbles about 1—2 cm in diameter, which proves that the leaves have settled at the bottom of the sea. The clearest impressions seems to belong to the *Vaccinium* group (Fig. 8 a), and there is another one resembling *Salix* (Fig. 8 b). The other leaf impressions are not sufficiently clear for a definite botanical classification.

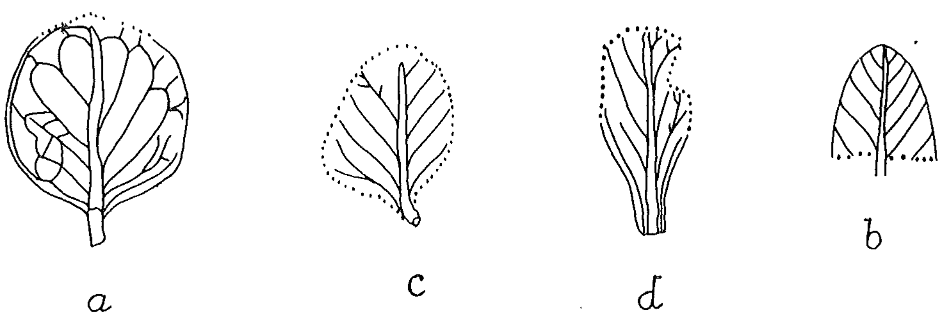


Fig. 8. a: Leaf resembling that of *Vaccinium* group. b: Closest resemblance to leaf of *Salix*. c, d: Dicotyledonous leaf fragments, not identified.

B. ANIMAL FOSSILS

VERMES

Serpentula sp. Plate I, Fig. 1.

Our collection contains a calcareous tube attached to the inner side of *Cyprina islandica*. The tube has been assigned to the family *Serpulides* within the order of *Polychaetae*. The apical part of the tube is narrow and nearly straight, but the tube gradually increases in thickness forming whorls that lie almost in the same plane. The surface of the tube is, as far as can be seen, fairly smooth, and it is adorned with one or more rows of small protuberances. The outer section of the tube is egg-shaped and provided with a small crest. The inner section seems to be round. The walls of the tube are made of long prismatic crystals which are obliquely arranged, and every one of the crystals points forward and outward.

There is no doubt that the fossil belongs to the *Serpulides,* but as it does not completely agree with any living *Serpula* the generic name *Serpentula* has been chosen (Nielsen, K. Brünnich 1931). And since there is no fossil of the *Serpulides* here for comparison the generic name cannot be given.

Arenicola cf. *marina L.* Plate I, Figs. 2, 3.

The rocks of the shell boulders are abundantly marked by holes in which there lived worms or other organisms. Many of these holes are U-shaped and they are usually filled with casts. The marks are presumably made by sandworms.

BRACHIOPODA

Rhynconella (Hemithyris) cf. *psittacea* Gmelin. Plate I, Fig. 4.

In the Skammidalur collection there are several brachiopods which, with one exception, represent the same species within the genus *Rhynconella.* As all of the shells are in a rather bad condition it is difficult to assign them to a fixed species. In many respects they resemble the *psittacea,* while differing in other respects. Among existing species the fossils are no doubt most closely related to *Hemithyris psittacea.* These happen to be the same kinds of *Brachiopoda* as I have mentioned before in connection with the Tjörnes beds (Áskelsson 1941), and in all likelihood this is the same species as the one assigned to Hallbjarnarstaðakambur by Schlesch (1924) and named *Rhynconella psittacea* by him.

Hemithyris psittacea has twice been recorded as living in Icelandic waters (off the Mýrdalur coast at a depth of 135 m, and to the west of the promontory Látrabjarg at 252 m). The species is boreo-arctic and circumpolar. Its bathymetrical range is from about 2 to 1300 metres. Empty shells have sometimes been washed ashore by the surf. (Wesenberg-Lund 1938.)

Cf. *Rhynconelloidea sp.* Plate I, Fig. 5.

One *brachiopod* from the Skammidalur formation resembles a young specimen of the *Rhynconelloidea.* However, as the dorsal shell is missing no further determination can be made.

MOLLUSCA

LAMELLIBRANCHIA

Nucula tenuis Montagu.

Quite a few specimens of *Nucula tenuis,* all of which have lost the periostracum, have been found in the shell boulders of Fjósahryggur and Sjónaröxl. They are small and thin and conform well with modern specimens of this species except that they have fewer teeth. The existing shells have 28 teeth: 18 anterior and 10 posterior. In the fossil shells I have never counted more than 22: 15—16 anterior and 5—6 posterior. In this respect the shells resemble the *Nucula* shells of the British Red Crag more than any living *Nucula tenuis.* (Wood 1950.) The largest specimen is 10 mm in length.

I have found this species in the Tjörnes beds. It exists all around Iceland, and off the west coast of Europe it is to be found all the way from the Polar Sea to the Mediterranean. In North-America it ranges from Labrador down to Maryland on the east coast, and from Alaska to California on the west coast. (Abbot 1955.)

Lima sp.

Only one impression of a fossil resembling sp. of *Lima* has been found. The impression is to be seen on a claystone filling inside a *Cyprina islandica.* The genus has not yet been discovered in the Tjörnes beds. It is well known from the Pliocene and Pleistocene of Europe. (Heering 1950.) Living species of *Lima* are known from deep waters around Iceland. (Óskarsson 1952.)

Mytilus edulis Linné.

Fossils of blue mussels may be said to be quite common in the Skammidalur formation. While varying in size they are very characteristic of the *Mytilus edulis* type. In the Pliocene and lower Pleistocene of the countries lying nearest to Iceland this is a rather variable species, divided into several varieties on the basis of dissimilar living conditions. The similarity of all the fossils from the Skammidalur collection is a clear indication that the shell boulders inside which they were found are all from the same strata.

The Tjörnes beds contain *Mytilus edulis* throughout the whole formation (Bárðarson 1925). It is common in the British Red Crag and in corresponding beds on the Continent. It is also found among the warm-water species of the Búlandshöfði, but it has not be discovered in the Brimlárhöfði, as is only to be expected, since the Brimlárhöfði fauna corresponds only to the cold-water fauna of the Búlandshöfði. *Mytilus edulis* is quite common in the post-glacial sediments of Iceland. Nowadays the blue mussel is one of our commonest shells.

Astarte cf. *sulcata* Da Costa.

Only one fossil from our collection can be assigned to the genus *Astarte*. There is some uncertainty as to the species but it conforms most closely with the *sulcata* Da Costa. Further determination can only be made if new fossils are found.

Cyprina islandica Linné. Plate I, Figs. 6, 6 a.

There is an abundance of *Cyprina islandica* in the Skammidalur shell boulders, most of them very similar in appearance to the living species, while others seem to be atypical as their outline is more elongated antero-posteriorly, i. e. they are less circular than the typical form. On these atypical specimens, too, the margin behind the umbo is straighter than on the typical form. These shells seem also to be less inflated than is usually the case with this species, although the degree of inflation is probably within the range of variation of that characteristic. (See Plate I, Fig. 6 a.)

A distinct difference in size is obvious, there being two separate size classes, as seen from the following measurements (in mm):

Length	*Height*	*Length*	*Height*
85	75	14	12
77	64	13	11
70	59		

The largest specimens are the most common ones, though there is indeed no scarcity of smaller shells. From the L : H ratio it can be seen that the smaller shells approach the circular form more than the larger ones.

Schlesch (1924) records the species *pumilis* Wood from the Tjörnes formation. It is very difficult to decide, on the evidence available, whether the shells classified here as *Cyprina islandica* embrace more than one species.

Cf. *Cyprina rustica* J. Sowerby. Plate I, Fig. 7. Plate II, Figs. 8, 9.

This species is less abundant in the Skammidalur formation than *Cyprina islandica*. The shells are more tumid than *C. isl.* and the umbo is more turned inwards. These shells are rather variable in outline, some being almost circular while others are elongated. The latter seem to conform well with the type *De-*

franchii which has been recorded from the Tjörnes sediments by Schlesch (1924).

Cardium edule Linné. Plate II, Fig. 10.

Very few specimens, all of them small, have been found in the Skammidalur formation, and it proved very difficult to pry them out of the rock face in undamaged form. It is only in recent years that living specimens of *Cardium edule* have been found in the sea around Iceland. True, an empty valve was said to have been found on a beach in E-Iceland around the turn of the century; and also that another one was found in 1901 in the Westman Islands. It was not until 1948, however, that it was found and clearly identified at Gufunes in SW-Iceland. Since that time it has appeared along a coastline reaching from Reykjanes in SW-Iceland to Rauðasandur in W-Iceland. *Cardium edule* is not mentioned by Bárðarson (1925) from the Tjörnes sediments but Schlesch (1924) records the form *edulinum* Sowerby. *Cardium edule* has not been found in the Pleistocene deposits at Snæfellsnes or at Breiðavík at Tjörnes, nor in the post-Pleistocene beds of Iceland. It seems, therefore, that this species is now returning to the waters of Iceland for the first time since it disappeared after the formation of the Skammidalur shell boulders.

Cardium edule is known from the Pliocene and Pleistocene of both Great Britain and the Continent of Europe (Heering 1950).

Cardium echinatum Linné.

Only a few damaged specimens of *Cardium echinatum* have been found at Skammidalur and Höfðabrekkuheiði. Today it lives off the south coast of Iceland and in the Faxa Bay. It is known from the Tjörnes deposits and also from the British Red Crag.

Venus gallina Linné. Plate II, Fig. 11.

There are five specimens of this species in the collection, all of them practically undamaged. The largest shells are 22 mm in length and 19 mm in height. They are thick and have a great number of concentric ridges. The ventral margin is crenulated. Nowadays the *Venus gallina* is not found in the sea around Iceland. Schlesch mentions *Venus strictula* from the Tjörnes beds. This is probably the same species. I have not seen the *Venus gallina* mentioned in the British Red Crag, but it is known from the Pliocene deposits of other European countries.

Distribution today: Great Britain, the west coast of Europe from Finland down to the Mediterranean (Jensen and Spärck 1934).

Spisula cf. *elliptica* Brown. Plate II, Figs. 12, 13.

There are only a few specimens in the collection, most of them similar to the *Spisula* species found off the south coast of Iceland today, i. e. *Spisula solida* var. *elliptica* Brown. The main difference is that the umbo of the fossil is smaller and the length greater in relation to the height. L = 19 mm, H = 13 mm.

In the Tjörnes beds the family *Mactridae* is represented by the genus *Mactra*, but I do not know whether any species of *Spisula* occur there. *Spisula elliptica* is found in the British Red Crag and in the lower Pleistocene of the Netherlands (Heering 1950). Today it is to be found living near the shores of Britain, the Faroe Islands, Denmark, and several other countries (Jensen and Spärck 1934).

Abra cf. *alba* Wood.

The collection contains only two specimens. The shells are small and thin; length 15 mm, height 9 mm. At present there are two species of *Abra* in the sea around Iceland: *Abra prismatica* Montagu and *Abra nitida* Müller, both found off the S- and W-coasts. It ought to be mentioned that there are some points of resemblance between the fossil and the species *prismatica*. Yet I find the resemblance even greater with the European species *alba*.

Abra alba is found in the Tjörnes beds and in the British Red Crag (Bárðarson 1925, Heering 1950).

Scrobicularia plana da Costa.

There are a few specimens in the collection. They are rather thin, and the umbo, situated in the middle, is small and pointed. The hinges are small but can be clearly seen on the fossil. The shells are ornamented with delicate concentric furrows.

Scrobicularia plana does not live in Icelandic waters today, nor has it been mentioned in the Tjörnes beds or any of the later deposits of Iceland. It is known from the British Red Crag and is found today along the west coast of Europe, from S.Norway down to the Mediterranean (Jensen and Spärck 1934).

Tellina obliqua J. Sowerby. Plate III, Figs. 14, 15, 16.

Shells of this species were only found in one of the Skammidalur boulders. However, they occur in great abundance. I have examined between ten and twenty specimens some of which are bound together by ligaments. There is a considerable variability as to shape: some of the shells approach the circular form, while others are a little elongated. The shape appears clearly from the measurements given below:

Height 25 mm	Length 27 mm
— 28 —	— 30 —
— 27 —	— 30 —
— 28 —	— 32 —
— 32 —	— 29 —

The outside of the shells is covered with irregular concentric lines of growth, and the posteriorly situated fold is quite distinct.

This extinct species is well known from the Tjörnes beds. Bárðarson (1925) assigns it to the *Cardium groenlandicum* zone (from horizons Nos. 14, 15, 17, 18, 19, 21, 22 and 23). In horizon No. 14 of the Tjörnes beds this shell occurs together with another extinct animal, *Acteon noae*, which will be discussed below. *Tellina obliqua* has not been found in the Pleistocene shell beds of Snæfellsnes and Breiðavík at Tjörnes. In Great Britain it is less frequent in the Coralline Crag than in the Red Crag, where it may be found in most localities (Wood 1856). Later, in the Glacial Series, it disappears (March Gravels zone).

Macoma calcarea Chemnitz. Plate III, Figs. 17, 18.

This species occurs in almost all the Skammidalur shell boulders. The shells are of considerable variety as to outline, the smaller ones having a straight and fairly steep posterior margin which forms a sharp angle with the ventral margin. The posterior side of the larger shells is more curved, the shape as a rule being oval-elongated.

In the Tjörnes beds this species is found in the uppermost zone, the *Cardium groenlandicum* zone and in horizons Nos. 16, 18, 19, 21 and 23. In the Crag beds of England it occurs in the Red Crag, while it is absent from the Coralline Crag (Wood 1857).

Macoma calcarea is very common in Icelandic waters.

Cyrtodaria (?) *angusta* Nyst. & Westendorph. Plate III, Fig. 19. Plate II, Fig. 19 a.

Shells of the genus *Cyrtodaria* occur in several of the shell boulders of Skammidalur. In the collection there are nine specimens, some of them belonging together. The least damaged specimen is 40 mm long and 20 mm high. The beak is small, no teeth are visible, and there is a clear impression made by the hinge.

There are no species of the *Cyrtodaria* living nowadays in the sea around Iceland. Bárðarson in his work on the Tjörnes deposits (1925) mentions *Cyrtodaria siliqua* Spengler which is very common in many horizons of the Tjörnes deposits. Soot-Ryan (1932) believes that the *Cyrtodaria* species, both in the Tjörnes deposits and the Crag deposits of England, was in reality the *C. kurriana* Dunker. As the *C. kurriana* is supposed to have undoubted northern relationships MacNell (1957) concludes that Soot-Ryan's explanation is very surprising (vid. also Ockelmann 1958 : 144). Our material is too fragmentary for a definite generic determination, but the fossils seem to be in closest conformity with the Crag species *angusta* which is very closely related to the living American species *C. siliqua* Spengler.

GASTROPODA

Acteon noae J. Sowerby. Plate III, Figs. 20, 21.

This gastropod has been found in two shell boulders at Fjósakambar. The specimens are in every respect similar to the *Acteon noae* shells of Tjörnes apart from the fact that the former are smaller in size. As far as size is concerned the Fjósakambar specimens are in much better conformity with the Crag specimens of England (Schlesch 1924).

Acteon noae occurs mainly in the Red Crag of England and the Scaldenian of Belgium. It is considered fairly common in the earliest part (Waltonian) of the Red Crag, but it disappears in the Norwich Crag (Harmer 1923). In the Tjörnes deposits it has been found in the uppermost zone, the *Cardium groenlandicum* zone, but mainly in horizons No. 14 and 21. It is much more abundant in horizon No. 14 than in any other shell stratum of the Tjörnes cliffs.

Acteon tornatilis Linné

Some of the smaller *Acteon* shells from Fjósakambur seem to be in better conformity with the recent species *Aceton tornatilis* than any other shells. *Acteon tornatilis* has not yet been found in the Tjörnes deposits, but it is well known in the Pliocene and Pleistocene of England and the European Continent. Today it lives near the south and west coast of Iceland (Thorson 1941).

Adeorbis cf. *pulchralis* S. V. Wood. Plate II, Figs. 22, 23.

This small and pretty gastropod has not been found before in Icelandic deposits. The specimens show a significant variability but will not be determined here with full certainty, while reference is made to the photo plates (Plate II, Figs. 22 & 23). The species is known from the Pliocene and Crag deposits of England (Coralline Crag-Waltonian). As far as we know, it is now extinct.

Nassa ? prismatica Brocchi. Plate II, Fig. 24.

There are four specimens in the collection, all of them small in size, the largest one being 14 mm in length. The peculiar *Nassa* features are easily seen on the surface, so there should be no doubt as to the genus. Dr. D. Baden-Powell has been kind enough to determine the species. In the Tjörnes deposits the genus is known from the two uppermost zones, i. e. from the *Cardium groenlandicum* and *Mactra* zones. *Nassa prismatica* is known from British Crag deposits, notably the Red Crag.

Hydrobia ulvae Pennant. Plate II, Fig. 25.

There is only one specimen in the collection. It is a small gastropod, about 5 mm in length. The specimen is undamaged and the determination should therefore be reliable. *Hydrobia ulvae* does not live in Icelandic waters any more and has not been found in Icelandic deposits before. Today it is common around the coast of England and W-Norway up to Lofoten.

Hydrobia ulvae is known from the Red Crag beds of England (Wood 1872) and from later deposits. Brøgger (1900/01) assigns it to the post-glacial of Norway.

?Purpura lapillus Linné.

One of the specimens of the collection has been assigned to this species, although there is some doubt about the determination. Bárðarson has not found it in the cliffs on the west side of Tjörnes. Schlesch mentions *Purpura tetragona* from the Tjörnes beds. The species is known in Iceland from the interglacial, both from Breiðavík at Tjörnes and Búlandshöfði in W-Iceland. It is also common in several of the post-glacial deposits of Iceland. *Purpura lapillus* has been found in the youngest British Crag deposits (Harmer 1914).

In the sea around Iceland *Purpura lapillus* has been observed off the south and west coast up to Straumnes in W.Iceland. In recent years, however, living specimens have been found in N.Iceland (Áskelsson 1935).

Natica clausa Broderick & Sowerby.

There is one specimen of the genus *Natica* in the collection. It has been classified as the species *clausa*. Besides, several of the shells in the collection have been bored through by the *Natica*. *Natica* species have been found in all three zones on the west side of Tjörnes. The genus *Natica* is very common in the British Crag deposits, esp. the Waltonian.

Turritella tricarinata Brocchi.

There are a few specimens of this species in the collection which Baden-Powell has determined generically. It has not been found in the Tjörnes beds. The genus *Turritella* is known from the inter-glacial of Búlandshöfði *(Turritella erosa* Couthany). This recent species is also known from the glacial deposits of several countries.

Turritella tricarinata is extinct, but the species is common in the Coralline Crag of Britain, being also well known in the Waltonian (Harmer 1918).

CRUSTACEA

Balanus sp.

Fragments of *balani* occur quite uniformly in the shell boulders.

ECHINODERMATA

Small fragments of shells traceable to echinoderms have been found in the boulders.

SOME GENERAL REMARKS ON THE FOSSILS

The Skammidalur beds contain both fossilized plants and animals. The animal fossils consist of 26 genera and 30 species, divided as follows: 2 brachiopods, 2 worms, 9 gastropods, 15 bivalves (lamellibranchia), 1 crustacean, and 1 echinoderm which can scarcely be more fully determined. Below some of the species will be discussed and conclusions drawn from them, primarily as regards the conditions under which they lived and their geological age.

As already stated, the sediments containing the shell fossils are derived, i. e. they are not now *in situ.* They have not, however, been carried a long distance, for then the xenoliths would not be so large or so variously shaped. The evidence available supports the conclusion that all the animals lived at the same place and originate from the same shell strata. Moreover they seem to have formed one animal society. It is worth pointing out, however, that one of the bivalves might be somewhat younger than the others, namely *Venus gallina,* which occurs later than the other species, at least in British deposits. But since *Venus gallina* occurs in the same shell boulder as *Cyrtodaria angusta,* for instance, it can hardly be disputed that both species have lived here at the same time. This will be dealt with more fully below.

Among the 30 species found 8 are extinct. These are: *Serpentula sp., Cyprina rustica, Cyrtodaria angusta, Tellina obliqua, Acteon noae, Adeorbis pulchralis, Nassa prismatica* and *Turritella tricarinata,* i. e. about 27 per cent of the entire fauna of the shell deposits. With the exception of the two last-mentioned species, of which only one specimen of each was found, all the other extinct species must be considered to be very common. Some of them, like *Tellina obliqua* and *Cyrtodaria angusta,* are among the most common species found in the shell deposits. This relative proportion of extinct species — and even more so the number of individual specimens within each species — excludes all possibility of comparison with the holocene shell beds. For this reason, and also because no arctic species are found among the Skammidalur fossils, there is no possibility of making a comparison with the Breiðavík deposits at Tjörnes or with the Búlandshöfði deposits.

Among recent species in the Skammidalur fauna twelve live in the sea around Iceland today. These are:

Rhynconella (Hemithyris) psittacea,
Nucula cf. *tenuis,*
Mytilus edulis,
Astarte sulcata,
Cyprina islandica,
Cardium edule,
Cardium echinatum,
Spisula cf. *elliptica,*
Macoma calcarea,
Acteon tornatilis,
Purpura lapillus,
Arenicola cf. *marina.*

The *Brachiopod* species is included in this list although it is not quite certain whether the fossil is really the Icelandic *Hemithyris psittacea* living near the south-west coast of Iceland today. It is, at any rate, closely related to the fossil. Two of these species, *Nucula tenuis* and *Macoma calcarea,* are arctic, but the southern limit of their range lies at a considerable distance south of Iceland. The former is found near the coast of Europe down to Gibraltar, and even in the Mediterranean. The southern limit of the latter is in the Bay of Biscay.

Both the *Cardium* species are of boreal origin. *Cardium edule* seems to be a newcomer to the shell fauna of Iceland. There are no reliable data concerning its arrival in Icelandic waters until the year 1948. According to information furnished by Mr. Ingimar Óskarsson this species has been found along the coast from Reykjanes in S.W.Iceland to Rauðisandur in W.Iceland. *Cardium echinatum* lives off the south coast and in Faxa Bay. Other recent species from the Skammidalur fauna, such as *Mytilus edulis, Astarte sulcata, Cyprina islandica, Spisula elliptica* and *Acteon tornatilis,* are boreal. Some of them, like *Spisula elliptica* and *Acteon tornatilis,* life off the SW-coast of Iceland.

There are four recent species in the Skammidalur fauna that are not found in Icelandic waters today, i. e. *Venus gallina, Abra* cf. *alba, Scrobicularia plana* and *Hydrobia ulvae.* These four make up 23.5 per cent of all the modern species found at Skammidalur. One of them, *Abra alba,* is lusitanian, but the others are boreal with their southern limits in the warm sea off the European west coast. From the above it appears to be possible to conclude that the Skammidalur fauna lived in waters somewhat warmer than the sea around Iceland today.

G. G. Bárðarson divided the shell beds of Western Tjörnes into three zones, as known. In the lowest zone containing the guide fossil *Tapes aureus,* called the *Tapes* zone by Bárðarson, there are five shell horizons numbered 1—5. In the next zone, characterized by species of the genus *Mactra,* there are 7 shell beds numbered 6—12. Among guide fossils in this zone may be mentioned *Mactra procrassa* and *Abra alba.* In the uppermost zone, often named the *Cardium groenlandicum* zone, there are 14 shell horizons numbered 13—26. Here one horizon (marked 18 A) has been added to those counted by Bárðarson (Áskelsson 1941).

When the shell beds of Skammidalur and Tjörnes are compared it should be borne in mind that while those of Tjörnes have been thoroughly investigated stratigraphically, their fauna has not yet by any means been fully examined. Yet, if a comparison is nevertheless made between these two oldest known fossil faunas of Iceland, it appears (a) that among 30 species from Skammidalur 14 are also found at Tjörnes, and 4 of these *(Nassa prismatica, Cyrtodaria angusta, Tellina obliqua* and *Cyprina rustica)* are extinct, and (b) that the *Tapes* species found solely in the lowest zone of the Tjörnes beds are not at all to be found at Skammidalur. On the other hand, the Skammidalur fauna contains those three species which alone occur in all three zones at Tjörnes, i. e.

Mytilus edulis,
Cyprina islandica, and
Cardium echinatum.

The two first-mentioned species are in fact among the most common fossils at Skammidalur.

Among the Skammidalur shells there is one species, *Abra alba,* which has been found only in the *Mactra* zone at Tjörnes. Among species occurring both in the *Mactra* and *Cardium groenlandicum* zones of Tjörnes six have been found at Skammidalur. These are:

Rhynconella psittacea,
Nucula tenuis,
Cyprina rustica,
Cardium edule,
Cyrtodaria angusta, and
Nassa cf. *prismatica.*

These six species make up about 43 per cent of the total number of Skammidalur fossils also occurring in the Tjörnes deposits.

Four species in the Skammidalur fauna, i. e. *Astarte sulcata, Tellina obliqua,* *Macoma calcarea* and *Acteon noae,* occur exclusively in the uppermost zone, *Cardium groenlandicum,* at Tjörnes.

From what has been said above it ought to be obvious that there are so many similarities between the Skammidalur and Tjörnes faunas that a correlation between these two formations is fully justified. From a general comparison of the formations the parallels are closest between the Skammidalur deposits and the *Mactra–Cardium groenlandicum* zones of Tjörnes. Any comparison with the *Tapes* zone is wholly excluded.

Investigations of the vertical distribution of the various species ought to bring out to which of the two Tjörnes zones the Skammidalur formation can be most closely correlated.

In the examination of individual species one is soon struck by the now extinct *Acteon noae,* which occurs widely but has a short vertical distribution. For this reason it is a convenient guide fossil when the ages of strata are being correlated. At Tjörnes this species occurs in two horizons, Nos. 14 and 21, which are both in the *Cardium groenlandicum* zone. This gastropod clearly suggests, therefore, that the Skammidalur formation is of the same age as the uppermost Tjörnes zone. The same conclusion is reached when the *Tellina obliqua* is examined. True, the vertical distribution of this clam is somewhat greater than that of the gastropod. Yet it may be looked upon as a sort of guide fossil in Icelandic shell deposits. At Tjörnes it occurs only in the *Cardium groenlandicum* zone, and at Skammidalur it is, as already stated, one of the most abundant species in certain shell boulders. Our conclusion reached in connection with *Acteon noae* is therefore strengthened, viz. that the Skammidalur formation is of the same age as the *Cardium groenlandicum* zone at Tjörnes. In the third place, further support for this theory might be found in the fact that certain species from the *Mactra* zone, for instance *Pectunculus glycimeris,* have not been found in the Skammidalur shell formation in spite of a most persistent search. Everything, therefore, appears to support the conclusion that the Skammidalur shell formation and the *Cardium groenlandicum* zone of Tjörnes are of the same age.

Although the Skammidalur shell beds can thus be placed in the stratigraphy of Iceland, their geological age remains to be fixed. What is the age of this formation? In his treatise on Tjörnes Bárðarson states emphatically that although the likeness of the Tjörness and the British Crag is quite obvious, no exhaustive comparison between these formations can be made until the Tjörnes fauna has been more closely investigated. Now, however, a comparison between the Skammidalur shell beds and foreign shell beds might quite possibly form a more reliable basis to work on, as the investigation of the Skammidalur fauna as a whole is more thorough than that of the fauna of Tjörnes.

In making such a comparison, three species are mainly of interest, namely: *Acteon noae, Tellina obliqua* and *Macoma calcarea.*

Acteon noae is first mentioned as occurring in the Waltonian Crag beds of SE-England. In the Norwich Crag beds it is found to be extinct. *Tellina obliqua* occurs first in the Coralline Crag, i. e. in the uppermost Pliocene deposits, where it is considered rather uncommon. It is said to be abundant in the Walton Crag beds, on the other hand, but in the glacial series it disappears entirely. It is well known that the chalky *Macoma* does not occur in the Pliocene shell beds of England. It has not been found in the Coralline Crag; it is not frequently met with in the Walton Crag, but after that it is very common. It may be said, therefore, that those three species place the Skammidalur shell formation between the extreme limits of the Walton and Norwich Crag beds, and it could thus be correlated with the beds of the Calabrian age of the Mediterranean. This ought to be a reliable time determination provided that these three species have, geologically speaking, occurred simultaneously in Iceland and Britain, which they indeed appear to have done. It follows that the Pliocene-Pleistocene boundary at Tjörnes must be moved downwards. Thus the uppermost zone at Tjörnes, at any rate, must be of old Quaternary age, and in all likelihood it will become the paleontological point of view when the Tjörnes beds have been investigated as closely as they deserve that only the *Tapes* zone belongs to the Pliocene.

CONCLUSIONS

The conclusions of these investigations might be summarized as follows:

The shell boulders of the Skammidalur formation have been carried up with hot magma under the influence of glaciers.

Although the rock structure of the shell boulders is rather variable, perhaps suggesting different places of origin, the fauna has all the characteristics of one animal society. *Venus gallina,* which at some places occurs later than some other species of the Skammidalur fauna, must belong to this fauna because it occurs in the same boulders as for instance *Cyrtodaria angusta.*

The shells have lived in shallow waters, or very near the coast where a river or several brooks have carried twigs and leaves down to the sea.

The Skammidalur fauna has lived in waters somewhat warmer than the sea around the south coast of Iceland today.

In Iceland the Skammidalur fauna corresponds to the uppermost zone, *Cardium groenlandicum,* of Tjörnes. The age is old Pleistocene, the shell beds being correlative with the Norwich — Red Crag beds of Britain and the Calabrian age of the Continent of Europe. (Baden-Powell 1956.)

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EXPLANATIONS OF THE FIGURES

(PLATES 1—3)

PLATE I.

Fig. 1. *Serpentula sp.* Calcareous tube attached to the inner side of *Cyprina islandica.*

Figs. 2, 3. *Arenicola* cf. *marina* L. Casts from U-shaped holes in the sediments.

Fig. 4. *Rhynconella (Hemithyris) psittacea* Gmelin.

Fig. 5. Cf. *Rhynconelloidea,* a young specimen.

Figs. 6, 6a. *Cyprina islandica* L., Dim.: L. 85 mm, H. 75 mm, L. 73 mm, H. 60 mm respectively.

Fig. 7. Cf. *Cyprina rustica* J. Sowerby.


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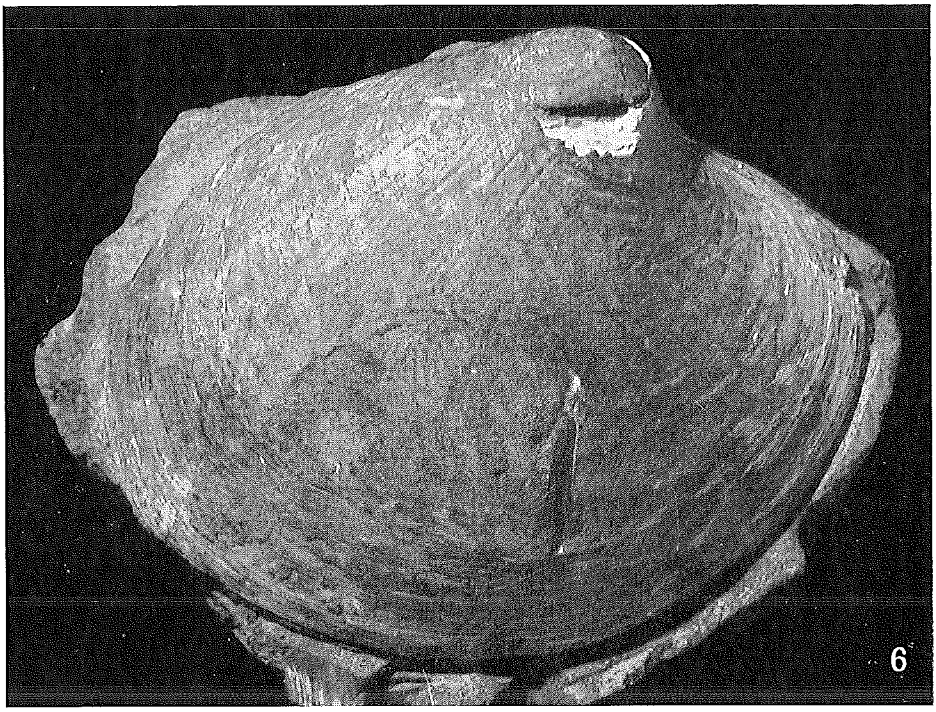
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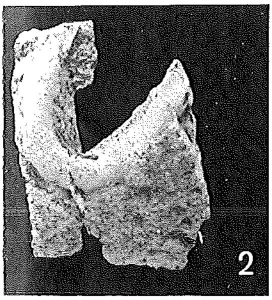
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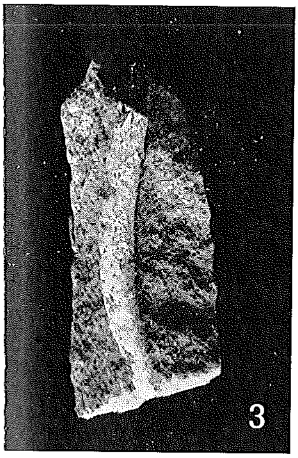
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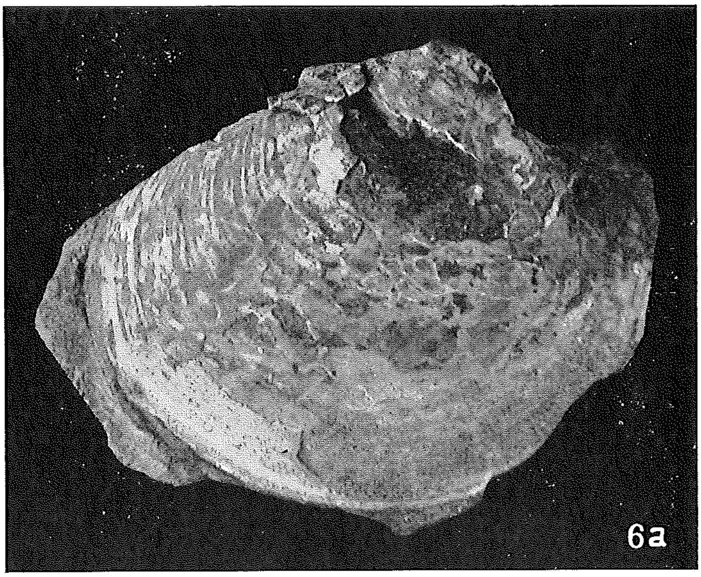
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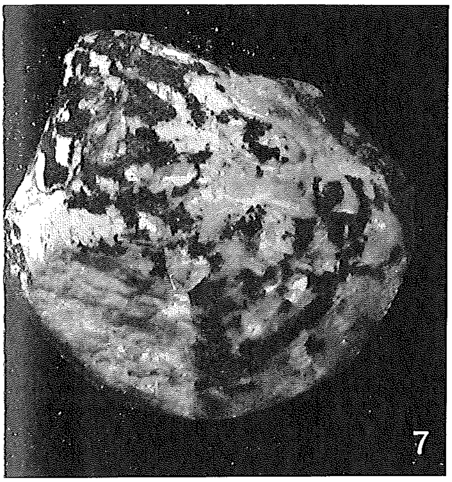
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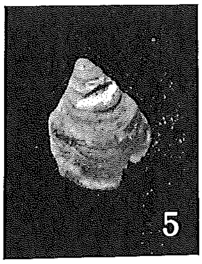
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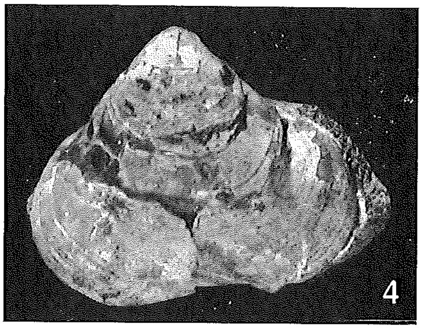
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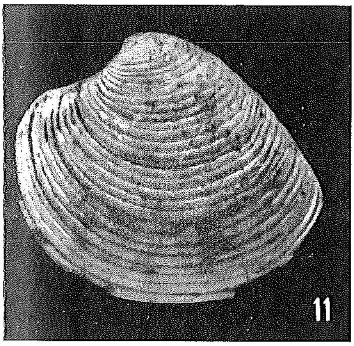
PLATE II.

Figs. 8, 9. *Cyprina rustica* J. Sowerby var. *defranchii* van Beneden.
Fig. 10. *Cardium edule* L.
Fig. 11. *Venus gallina* L., Dim.: L. 21 mm, H. 18 mm.
Figs. 12, 13. *Spisula* cf. *elliptica* Brown, Dim.: L. 19 mm, H. 13 mm.
Fig. 19a. *Cyrtodaria ?angusta* Nyst. & Westendorph, Dim.: L. ca. 40 mm, H. 20 mm.
Figs. 22, 23. *Adeorbis* cf. *pulchralis* S. V. Wood.
Fig. 24. *Nassa* cf. *prismatica* Brocchi, Dim.: L. 14 mm.
Fig. 25. *Hydrobia ulvae* Pennant, Dim.: L. 5 mm.



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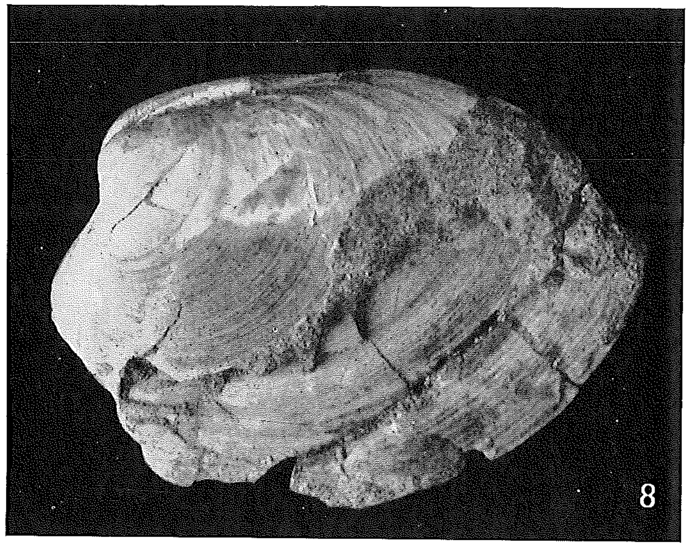

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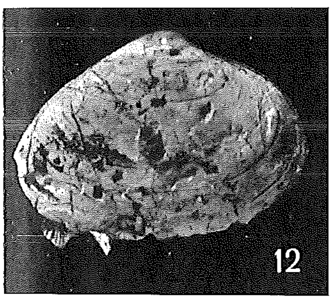

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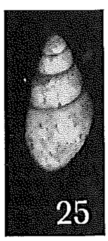

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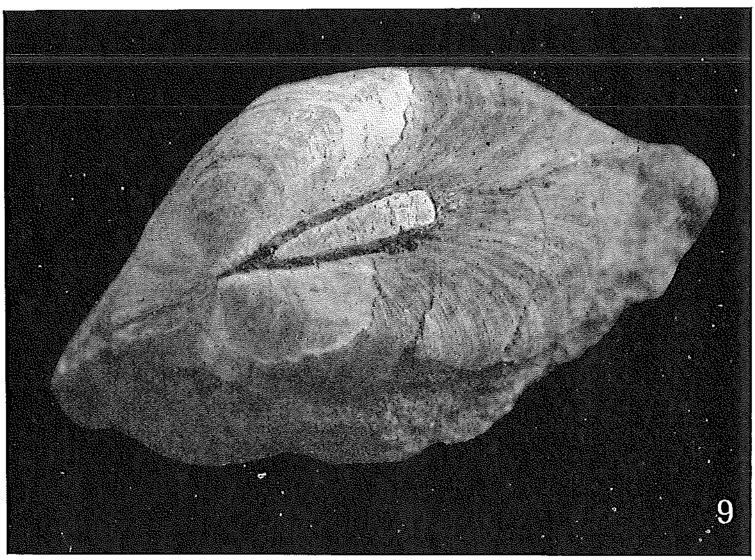

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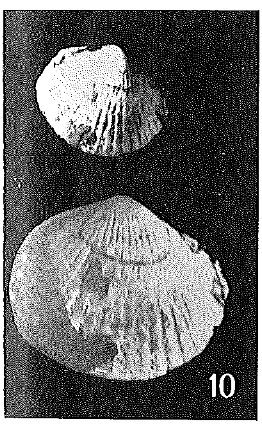

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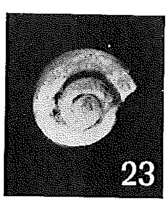

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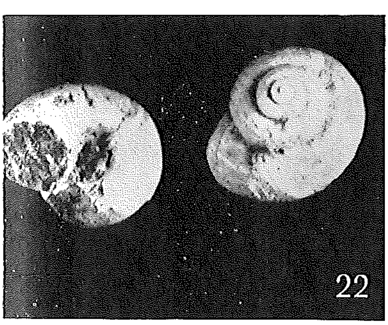

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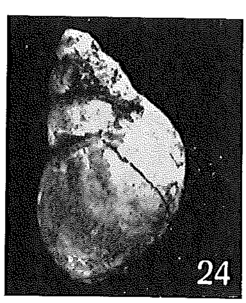

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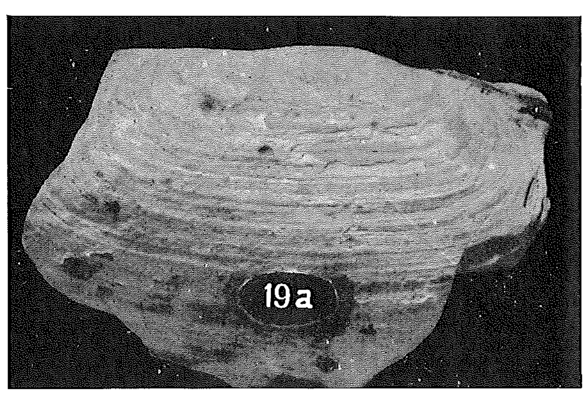

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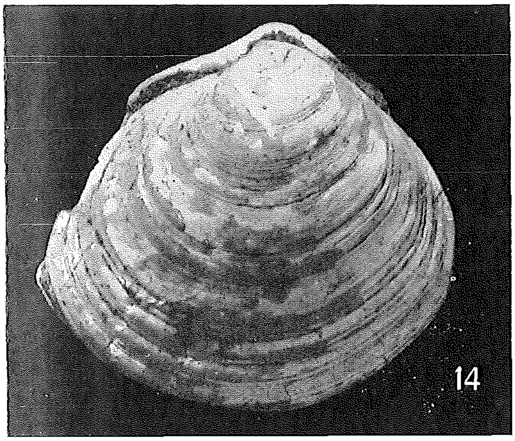
PLATE III.

Figs. 14, 15, 16.	*Tellina obliqua* J. Sowerby.
Figs. 17, 18.	*Macoma calcarea* Chemnitz.
Fig. 19.	*Cyrtodaria angusta* Nyst. & Westendorph.
Figs. 20, 21.	*Acteon noae* J. Sowerby.

PLATE III.



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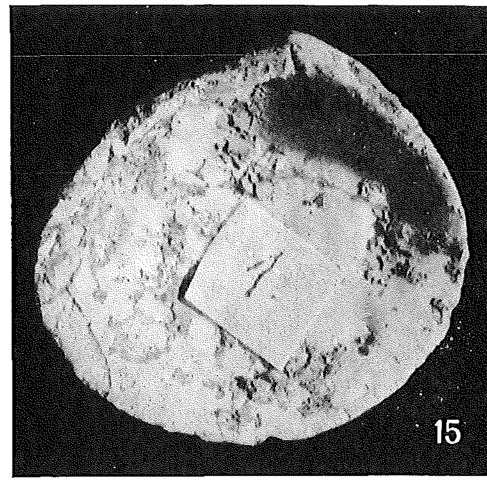

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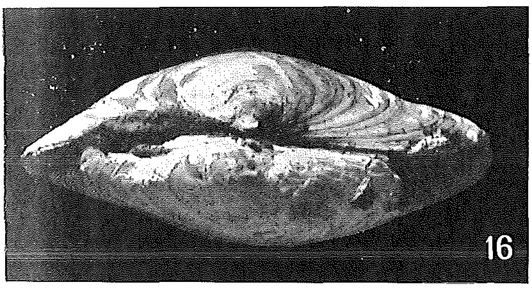

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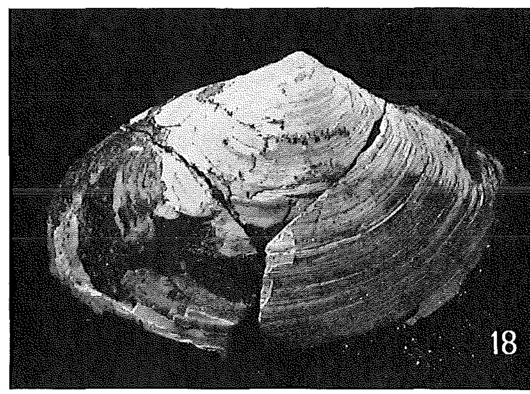

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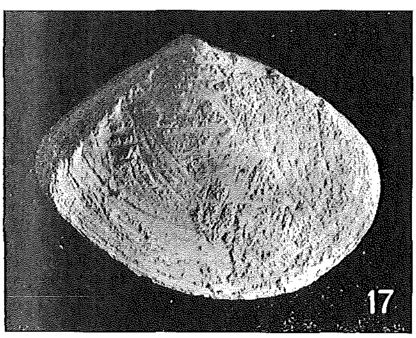

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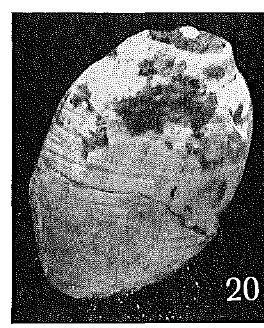

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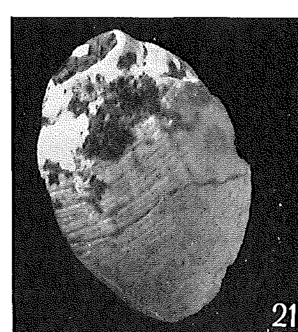

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