13. *The* Tertiary Basaltic Formation *in* Iceland. By J. Starkie Gardner, Esq., F.L.S., F.G.S. (Read December 3, 1884.)

A grant from the Government Fund enabled me to visit Iceland in 1881, with a view of studying its interbasaltic flora. I explored a considerable part of the island and visited every locality that I could reach where lignite had been met with. I did not take notes of some of the localities where my visits were hurried; but the conclusion I invariably arrived at was, that the sedimentary deposits in which vegetable remains are found, are situated among the glassy rhyolitic flows above the columnar series of basalt. The rhyolites are usually pale in colour, and with banded structure, but are sometimes black pitchstone or obsidian. They cap the loftiest mountains of the district west of Akreyri, and extend at least to Baula, a mountain in the same latitude as Snaefell, and possibly beyond this. They also occur on the east coast, though I did not reach any of them in that part of Iceland, which I only visited from the Danish mail-boat, which calls in many of the fiords. I did not pay particular attention to their thickness, but at Sandafell I measured 30 feet of white, pink, ivory-coloured, and black glassy lavas. The thickness is, I believe, sometimes greater than this, and they are interrupted and overlain by smaller flows of basalt. The horizon is, however, certainly continuous, and marks a very definite stage or phase in the great series of Tertiary eruptions which extended from Ireland to Iceland in Eocene times.

I cannot yet present data to show how much younger this part of the Icelandic series may be than the columnar division of the formation in Ireland. Being near the southern limit of the flows, the series may have ceased to be formed at a far earlier period in Ireland than further north; and this I believe to be the case, as there are no fragments of glassy lavas in the Boulder-clays of Ireland. Denudation may, however, have swept very much of the basalt away. There is no base to the formation exposed in either Iceland or the Faröes, and we are therefore ignorant of its total thickness; but some of the mountains reach an altitude of 6000 feet, and are still within its limits. Iceland, like Ireland and Scotland, has also suffered very great denudation. The mountains of the north and east coasts average some 2000 feet in height, and are entirely eroded out of horizontal sheets of basalt. The valleys radiate towards the sea, and many form fiords of considerable size. On the east coast especially, the only remains of the highest layers of basalt are pinnacles or columns along the mountain tops. The mountains are wall-like and continuous, with few lateral openings of no great breadth, and flat-topped in most regions. Their sides are precipitous, except where masked by talus. Glaciation is very conspicuous, and every valley is occupied by a rushing torrent fed by the melting snows of the interior, so that travellers cannot proceed on foot for any distance, except towards the interior. The rarity of dykes is one of the most noticeable features of the basalts; on one occasion I only observed one in a

journey of 30 miles along one of these mountain walls. The oldest basalts are not columnar, and are very compact. The whole series, up to the rhyolites at least, was spread out in vast and almost horizontal sheets, and I saw no indications that any were submarine, except some of the newer beds towards Reykjavik, which occasionally contain sea-shells among the indurated tuffs. They are utterly different in appearance from the recent lava-flows, which always follow the directions of valleys or water-courses, and it seems impossible that they could ever have been erupted from craters, no matter of what magnitude. The recent volcanic eruptions are as utterly independent of the Tertiary system of erupted rocks as an outburst in Ireland, at the present moment, would be independent of the basalts there. They are all Postglacial and fresh-looking, while the Tertiary rocks have been, without exception, eroded on a stupendous scale and subjected to ice-action.

As would be expected, from the fact of their being on such a different horizon, the fossil plants of the Icelandic Tertiaries differ very essentially from those of Ireland and Scotland. The Irish plant-beds are all below the horizon of the columnar basalts, and from their similarity to the flora of the Heersian stage of Gelinden, in Belgium, they cannot be assigned to a later date than the older Eocene. The Mull flora, on the contrary, is situated above some of the columnar basalts, and has already lost the Heersian characteristics, but is still probably of Lower Eocene age. The Icelandic plant-beds are very much newer, and might, from their general character, be assigned to even so late a stage as the Miocene. Some 40 species are recorded, but there are only a few that seem to rest on a sure basis, among them being *Abies*, *Alnus*, and *Acer*. I was not fortunate enough to bring back any extensive collections, but I have had an opportunity of examining, at Copenhagen, those that exist.

Notwithstanding this comparative failure, I do not feel discouraged, but firmly believe that very great results in this direction might attend another visit, especially to the north-west peninsula, to which I have not yet been. Had I been provided with a tent and stores, I might have made longer stays on the spots where plants are likely to occur. Sir Joseph Banks, in his 'Letters on Iceland,' 1780, p. 11, speaks of petrified leaves at Reikum, some of which, in black shale, were brought home. Two localities on the north-west peninsula are mentioned in the 'Flora foss. Arctica,' vol. i. In Olafsen's * exhaustive account there is a precise description of the Surturbrands of Bardestrand, associated with which is a bed of greyish slate divided into laminæ from 3 lines to ½ an inch thick, and containing leaves, among which oak, birch, and willow were easily distinguished. Besides these there were leaves as large as the palm of the hand, which had preserved their minutest venation. The leaves, he says, could with care be removed entire, though as thin as paper. Nine other localities for lignite in this region are mentioned, several of which must be worth investigating.

[I called attention in 'Nature,' August 2, 1883, to two instances

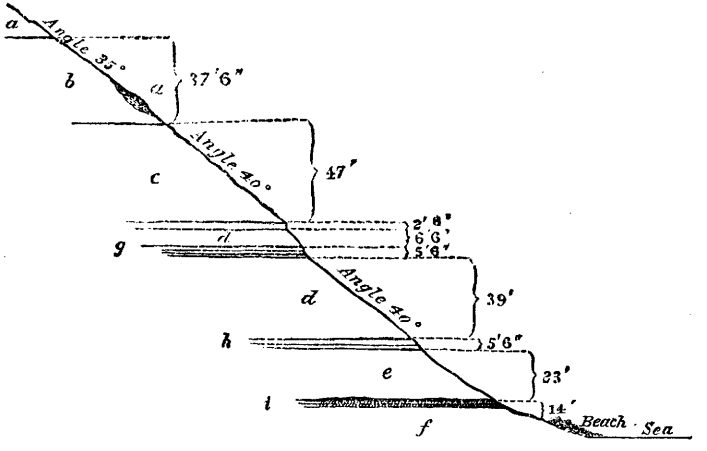
* Vol. ii. p. 393.

where great masses of relatively recent lava debouching from mountain valleys on to plains had produced a very sensible subsidence, leading to the formation of extensive lakes. In the case of Thingválla the plain has sunk at least 100 feet, leaving perpendicular cliffs of lava on the slopes at its northern end, from which the central mass has been torn. These may possibly throw some light on the formation of Lough Neagh.]

Húsavík Marine and Freshwater Beds.

By far the most important of the sedimentary deposits connected with the basalts occurs on the coast 7 miles N.E. of Húsavík, in N. lat. 66° 10′. They rest upon basalt or a basaltic breccia. In approaching them from Húsavík, the first exposure occurs in a grassy *cirque*, named Hringvershujlft, or the "little round valley." The escarpment is about 260 feet high, but slopes at an angle of 45°, and its base is somewhere about 100 feet above the sea-level. The fossiliferous beds rest upon a mass of greenish grey clayey material, succeeded by 20 feet of pale, more or less laminated sandstone with plant-remains. These proved unfortunately to be all of a rush-like nature, much macerated and utterly valueless. Three feet of lignite followed, and then 10 feet more sandstone with similar plants, and then four beds of lignite in succession, each 1 foot thick and

Fig. 1.—*Cliff-section on coast 9 miles N.E. of Húsavík.*

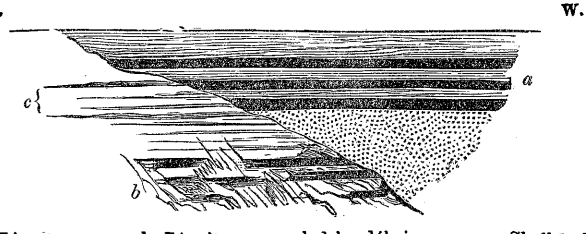


a. Glacial deposits.
b. Greenish-grey tuff.
c. Sandy clay with broken shells.
d. Sandy clay, unfossiliferous.
e. Sandy clay with fossils.
f. Sandy clay without fossils, with a band of laminated sandstone with green grains.
g. Four bands with *Cyprina*, the bottom layer with *Actæon Noæ*, and *Cardium echinatum*.
h. Bands of broken shells, with *Cyprina*, *Actæon*, and *Cardium*.
i. Continuous band of comminuted shells of variable thickness, average 2 feet.

separated from each other, the first from the second by 4 feet and the others by intervals of 3 feet each, of a more compact marl of an almost stony character. The whole is capped by 30 feet of sandstone without plants. About a mile further east the lignites thin and are only four in number and of less uniform thickness. The base is still formed of greenish, indurated, sometimes ferruginous, sandy clay, about 200 feet thick, passing towards the west into a basaltic breccia at its lower part. The lowest bed of lignite is 18 inches thick, and the other three 1 foot each, separated respectively by 16, 12, and 6 feet, and the uppermost surmounted by 14 feet of matrix, terminating with a conglomerate of rounded pebbles. Half a mile beyond this, to the east, the whole of the lignites dip below the sea-level. A mile further along the coast, at the angle of a chine, is the section shown in fig. 1.

The fossiliferous beds rise inland, and cannot be traced more than a few hundred yards up the chine. They are much faulted,—one fault up the chine had a downthrow of 60 feet,—most of the faults being in a N.N.E. direction or nearly parallel with the shore, producing sometimes an apparent overlying of the shell-beds by the lignites (fig. 2).

Fig. 2.—*Fault causing Shell-beds to be apparently overlain by Lignites, near Húsavík, Iceland.*



a. Lignites. *b*. Lignites concealed by débris. *c*. Shell-beds.

Much of the matrix, especially towards the base, is exceedingly like our London clay. The shells occur in bands, and particular species are confined to particular horizons. Across the chine the beds almost immediately dip out of sight (fig 3), and are succeeded by higher and unfossiliferous beds, more compact and indurated, and paler in colour. These are also much faulted.

I ceased to take notes beyond the Cape, but I subsequently rode along the coast to the extreme point of Tjörnes, where I understood lignites had been met with; but for ten miles the unfossiliferous bed seemed to continue without any change.

I endeavoured to determine some of the species by comparison at the Jermyn Street Museum, and submitted the list of names which resulted, and the specimens, to Mr. Searles V. Wood and to Dr. J. Gwyn Jeffreys, who very kindly furnished me with the details embodied in the accompanying table.

Dr. Mörch, in the work referred to above, gives a list of 58

List of Fossil Shells *collected by* Mr. J. Starkie Gardner *in* Iceland. By J. Gwyn Jeffreys, LL.D., F.R.S.

Table *of* Distribution *and* Remarks *by* Searles V. Wood, Esq., F.G.S.

English Crag.	North American.	European Seas.	Arctic.	Name of Species.	Synonyms and remarks.	Coralline Crag.	Oldest part of Red Crag.	Middle or main part of ditto.	Newest part of ditto.	Living or not, and where.
				CONCHIFERA.						
—	...	—	...	Cardium echinatum, *Linné*		—	—	×	×	B
—	—	...	—	—— islandicum, *L.*						
—	—	...	—	—— groenlandicum, *Chemnitz*		—	—	×	×	G
—	—	—	...	Cyprina islandica, *L.*		×	?	×	×	B
—	—	...	—	Astarte crenata, *Gray*	A. crebricostata, *Forbes*	—	—	—	×	B
—	—	—	—	—— compressa, *Montagu*	Var. striata	—	?	×	×	B
—	—	—	—	Tellina balthica, *L.*		—	—	—	×	B
—	—	...	—	—— calcaria, *Ch.*	And var. obliqua	×	×	×	×	E
—	...	—	—	Mactra solida, *L.*		—	—	×	×	B
—	—	...	...	Mesodesma deauratum, *Turton*		—	—	×	×	A
—	—	...	—	Glycimeris siliqua, *Spengler*	? G. angusta, *Nyst*, fide *Searles Wood*	×	—	×	—	E
—	—	—	—	Mya arenaria, *L.*		...	×	×	×	B
—	—	—	—	Saxicava norvegica, *Sp.*						
				GASTROPODA.						
—	—	—	—	Littorina littorea, *L.*		—	—	×	×	B
—	—	...	...	Natica heros, *Say*	N. catenoïdes, *Searles Wood*	—	×	×	—	E
—	—	...	—	—— affinis, *Gmelin*	Var. occlusa.					
—	—	—	—	—— aperta, *Lovén*	Bulbus flavus, *Gould.*					
—	—	...	...	Buccinum groenlandicum, *Ch.*		—	×	—	—	G
	—	...	...	Murex cinereus, *Say.*						
	—	...	—	Fusus despectus, *L.*						
	—	...	...	—— curtus, *Jeffreys*	F. Stimpsoni, *Mörch*; F. Olavii, *Beck*	...	?	?		
	—	...	...	Nassa trivittata, *Say*	? N. propinqua, *Sby.*; *Searles Wood*	—	×	×	—	A?
—	...	...	...	—— monensis, *Forbes*		—	—	×	—	E
—	—	—	—	Pleurotoma turricula. *Montagu*	Var. Fusus harpularius, *Couthouy*	—	×	×	×	B
—	—	...	—	—— pyramidalis, *Ström*	F. pleurotomarius, *Couth.*	—	—	×	×	A
—	—	...	—	—— bicarinata, *Couth.*		—	—	×	—	A
—	...	? —	...	Actæon noæ, *J. Sowerby*	? Tornatella pusilla, *Forb.*	—	×	×	—	E
20	23	10	18	27						

Notes on Dr. J. Gwyn Jeffreys's List.

The term "Arctic" in the fourth column of this list includes not only those parts of the Atlantic and Pacific Oceans which belong to America and Asia, but also those parts of the European seas which lie within the Arctic circle.

The list shows that of the 27 species collected by Mr. Gardner, 20 are found in the English Crags, 23 live in the North-American seas, 10 only in the European seas as above restricted, and 18 in the Arctic seas of both hemispheres. It also shows that nearly the same number of species occur in the Crag and North-American seas; 16 species are common to both those categories; 5 appear to be American, and 3 Arctic, none of which are Crag. The connexion between the Crag and North-American Mollusca is therefore more intimate than between the Crag and European Mollusca, not taking the Arctic Mollusca into account. Two species, and those questionably, are supposed to be extinct. I should regard this Iceland deposit rather as Post-tertiary or Quaternary than as Pliocene.

All the non-existing species are inhabitants of comparatively shallow water; some are littoral.

The peculiarly North-American species (*Mesodesma deauratum*, *Natica heros*, *Murex cinereus*, *Fusus curtus*, and *Nassa trivittata*) have not been recorded as living on the Icelandic coasts. Iceland is geographically separated from North America by Greenland, where the marine Mollusca are more European than American *. But the course of the Great Arctic current is from Iceland to Newfoundland and the western coasts of North America; and this may account for the former occurrence of North-American species in Iceland, as evidence of their origin or source of distribution at that epoch when the shells were overwhelmed by a volcanic flow of lava. All the Mollusca which now live in the Icelandic sea are either Arctic or North European, and have apparently been derived from Spitzbergen or Finmark by means of the same current which is continued from Iceland to Newfoundland.

J. Gwyn Jeffreys.

4th Dec., 1884.

* See my paper on the 'Valorous' Expedition in the 'Proceedings' of the Royal Society for 1875.

Notes on Mr. S. V. Wood's Table.

B. Signifies living in British seas and elsewhere.
A. On North-American coast only.
G. Greenland and Arctic seas only.
E. Not known as living.

The large carinated shell referred to (p. 96) is probably *Trophon antiquus*, var. *carinatus*. Mr. S. V. Wood remarks that only the sinistral form of *T. antiquus* occurs in the oldest part of the Red Crag, and this not carinated. Both the sinistral and dextral forms of var. *carinatus* occur in the middle part of the Red Crag. It is the carinated form which is Arctic, not British.

To these we may add the following species, overlooked by Dr. Gwyn Jeffreys, identified by Mr. Searles V. Wood, and also occurring in the paper by Dr. Mörch on the Iceland Crag at p. 321 of vol. viii. of the Geol. Mag. (1871):—

Buccinum Dalei, only a fragment or two of which are known from the Coralline Crag, though it is very abundant in the older and middle part of the Red Crag.

Pleurotoma hispidula, a rather doubtful Coralline-Crag species, now living in the Mediterranean.

Mactra arcuata, known throughout the Crags and extinct.

Tellina obliqua, rare in coralline and older parts of the Red Crag, but abundant in the rest of the Red Crag and in the oldest Glacial beds. Treated as a variety by Dr. Gwyn Jeffreys.

T. prætenuis. Very abundant in both middle and newest part of Red Crag, but rare in the oldest Glacial beds. In the newest part of the Red Crag both these Tellens are associated with the living Arctic species, *T. calcaria*, which occurs in all Glacial beds. Both *T. obliqua* and *T. prætenuis* are unknown from any but the oldest Glacial beds, and of the east of England only. They are now extinct.

There are also a few species remaining undetermined. Mr. S. V. Wood, from the evidence before him, regarded the bed as not later than the Middle Red Crag, and he remarked on the close affinity between their Mollusca.

species, at least 16 of which are of very doubtful value. I was unable to extract a large fusiform shell, which was much cracked, and in an almost inaccessible position; but I made a drawing with measurements, before attempting to remove it, and saved the greater part of it. This can be reproduced when necessary.

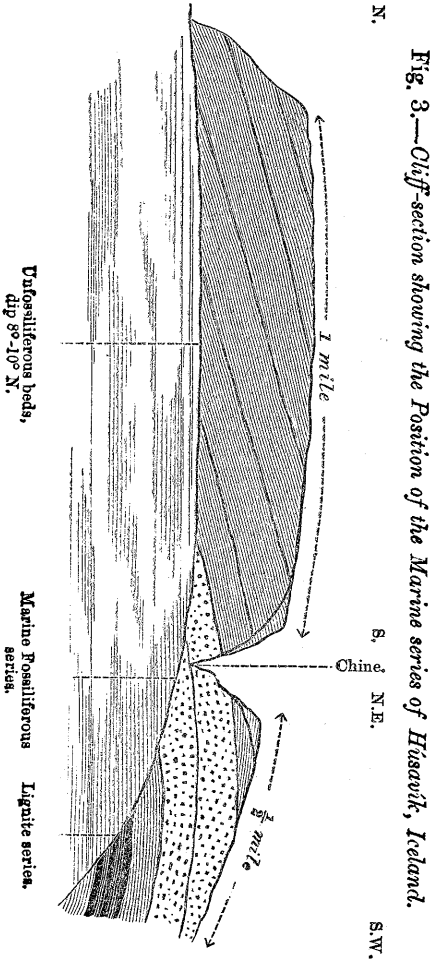


Fig. 3.—*Cliff-section showing the Position of the Marine series of Húsavik, Iceland.*

Dr. Gwyn Jeffreys has some valuable remarks to make upon these fossils; but as I believe that further specimens have been submitted to his inspection from abroad, I trust he will be induced to communicate a paper on the subject, which I forbear in any way to forestall. I think, however, I should, for various reasons, be inclined to assign a greater age to the deposit, from its general

appearance on the spot, than Dr. Gwyn Jeffreys may do, or even than Mr. Searles Wood. The occurrence of the fauna of the Red Crag, with Mediterranean species, so many degrees north, would dispose me to consider them as belonging to a somewhat warmer climate and therefore presumably to a rather earlier period than I should do if meeting with the same assemblage further south.

This part of the country is a table-land, with mountains some distance inland, from which lava streams have issued in relatively recent times. Nearer Húsavík the cliffs are of basalt and volcanic breccias, and to the east the plateau is composed of horizontal basalts with a thick alluvial capping of loam, ready to produce a bed of laterite if ever again overflowed by lava streams.

It is impossible, from the coast-section, to form any just idea of the relationship of this sedimentary formation to the Tertiary basalts; and the determination of its precise age cannot, unfortunately, at present throw any light upon their history, though presenting a problem of great independent interest.

Coal is said to occur near the base of the mountains on the opposite side of the bay, facing Húsavík; and as these do not present a basaltic contour, they might be worth investigation.

Tjarnir ("short lakes").

About 25 miles due south of Akreyri is a valley the sides of which, about 2000 feet high, are composed of basalt, scarcely intersected by any dykes. The coal reported to be found here proved to be obsidian. The rhyolitic lavas overlying the basalts form a very important series at this point.

Sandafell (not the Sandfell marked on maps).

This mountain is situated about 25 miles S. of the Skagafjörd, and 6 miles above Abaer, the nearest farmhouse, on the river Banda. The basalt is covered by a clay bed with rootlets a foot thick, succeeded by brown coal passing into lignite, another foot, and then 150 feet of volcanic breccia, with large blocks of basalt imbedded towards the base. There are then 30 feet of pale tuffs, and a band of pitchstone decomposed into vertical needles overlain by pink and ivory-coloured banded rhyolites, and finally basalt. This section is at the angle of the two valleys formed by the rivers Tinnaa and Banda; and, looking up the former, the pitchstone band is conspicuous between the lighter masses for at least a mile, being on the right hand at an elevation of about 600 feet, and at least 800 or 900 on the left. Up the Banda the lignite thickens to 3 feet.

Well-preserved leaves have been obtained from the yellow tuff, and are now in the University Museum at Copenhagen. Though I searched diligently, I was not fortunate enough to discover any bed with fossils worth bringing away. At the corner of the Tinnaa are magnificent groups of columnar basalts, bent in many directions, and twice fanning out like the clam-shell cave at Staffa. Some fallen segments measured 3 and 4 feet in diameter. The pale-

coloured rhyolites reappear in all the mountains at a high level as far as Akreyri.

Hof.

A few miles south of Godalir, at the angle formed by the first tributary to that river on its left bank, the section has been cut through by the stream, and forms a perpendicular bank 12 feet high, in which are over twenty layers of lignite separated by gritty marls and ferruginous bands, crowded with vegetable matter, with a soft sandstone at base, similar in appearance to that of Húsavík. At 12 feet a bed of lignite composed of compressed tree-trunks occurs, and then another, 3 feet thick. The bank then slopes at an angle of 30° for a distance of 60 feet, still abounding in lignitic matter, when it is concealed by the greatly overhanging remnant of an old moraine. On the opposite, or south bank, the same beds are capped by columnar basalt. The plants again proved to be nothing but rush-like monocotyledonous débris, with seeds, and probably remains of *Chara*. The dip shown in both exposures (S.E. and N.) is 9°, and the formation is probably extensive. The diameter of the largest compressed trunk I extracted was 20 inches; but this did not seem to be the full width. There were many large trunks in the bed of the stream, the branching of which suggested willows of large dimensions.

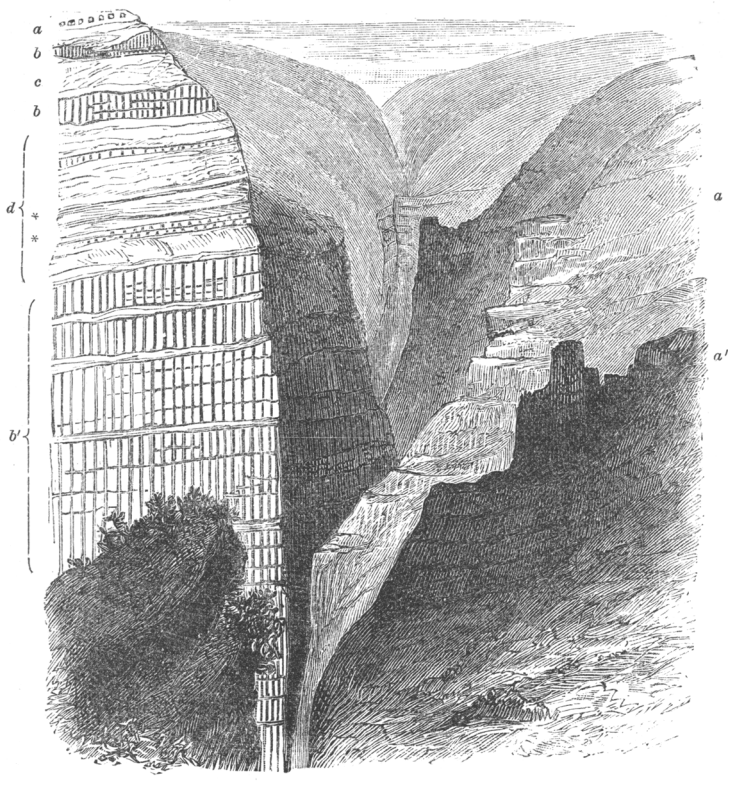
In this neighbourhood, about 7 miles from Hofsgil, a magnificent section of over 1000 feet in depth can be studied (fig. 4). It forms the side of one of the wildest conceivable gorges or cañons. The precipitous and even perpendicular sides are composed of more or less columnar basalts, separated by partings of almost vermilion-red earth, which has stained them a reddish purple. Where the sides are not perpendicular, fragments of the old moraines, cold slaty grey in colour, cling to them, weathered into fantastic shapes and looking like ruined masonry. The torrent is just visible as pure white foam at the bottom. The section here reproduced is of general interest as showing the composition of the ordinary North Icelandic mountain from top to bottom. Its upper part, as viewed from across the gorge, forms a slope of from 50° to 60°, and overhangs a tremendous precipice, so that it would not be accessible without great danger. It is evidently similar to Sandafell, not many miles distant; and that the black band is really lignite is apparent from my subsequently picking up pieces in the bed of the river.

This gorge was evidently at one time filled in solid with Boulder-clay or moraine, and enormous masses of rolled stones are spread over the valley below. The stones have been arranged into sharply defined terraces. A river entering from a valley to the east had accumulated an enormous mass of shingle, before the main river cut its way through and cut down at least half the area to a level of 30 or 40 feet lower; after which the rivers united and further reduced it as much again, affording an instructive example of terrace-formation.

A better clue to the formation of parallel roads is furnished by a

small valley, marked Sandklettaváth, about lat. 64° 21′, between Reykholt and Thingválla. It is marked as a lake without any outlet; but in August there was only a little water at one end, the stream

Fig. 4.—*Cliff and Ravine about 7 miles from Hofsgil, height about* 1000 *feet.*



a. Boulder-clay. *a′*. Boulder-clay weathered into architectural forms.
b. Basalt. *b′*. Basalt with partings of bright red and brown earth.
c. Rhyolite. *d*. Sedimentary rocks, about 130 feet, chiefly yellow and drab sandstones, with two intercalated bands of lignite, marked **.

connecting it with Ukaváth being also dry. The plain is level, destitute of vegetation, about three miles long and one broad, closed in on three sides by mountains and on the fourth by a lava-stream. Its shores are regularly terraced all round, the terraces being only 2 or 3 feet high. It is evidently a shallow lake for a great part of the year, and the terraces have some connexion with the recurring formation and disappearance of a dam of snow or ice at its eastern extremity.

Hredevátn.

This is a small lake in western Iceland, lat. 64° 41′. A bed of coal occurs in a romantic ravine about 800 feet above the lake, and towards its northern end. The coal is but 18 inches thick, and is immediately under a bed of basalt, with yellow tuffs underneath it. It reappears in a gully 100 yards to the N. W., with a dip of about 15° to the S. W. The section is entirely overgrown and covered by earth, and would require much time to uncover; but I exposed a bed of brown papyraceous shale, and underneath it a short brittle sandy clay, with rootlets and vegetable remains. Above the shale there was yellow tuff; but several hours' search brought forth nothing in the shape of well-preserved leaves, though they are stated to have been found in the tuff at this spot. Another lignite or coal bed is said to occur four hours' ride to the west.

The coal is used for fuel, but is as costly to obtain, owing to its inaccessible position, as sea-borne Scotch coal.

Stafholt.

This locality is a small promontory six or seven miles south of Hredevátn, on the banks of the river, and nearly at the sea-level. The point forms a low cliff, and does not extend beyond 50 yards. The matrix is a coarse yellow brecciated tuff, in which trees of considerable length and girth are imbedded separately, and principally on one horizon, only a few feet above the water. Smaller pieces of wood lie above. These trunks are partly in the condition of lignite, and partly imperfectly silicified, with their structure beautifully preserved. The deposit is much cut up by dykes.

Discussion.

Dr. Gwyn Jeffreys said his attention was called to the Icelandic beds with fossil shells by Prof. Steenstrup at Copenhagen in 1869, and further material had been collected by the late Dr. Mörch, to whose memory as a conchologist the speaker offered his tribute of admiration. It was remarkable that among the shells there were very few Arctic species. It reminded him of the Moel-Tryfaen assemblage of shells, among which temperate forms occurred in great abundance.

Prof. Judd stated that the series of rhyolites brought from the north of Iceland by the author consisted of stony rhyolites, exhibiting banded spherulitic and perlitic structure, passing into pitchstone and obsidian. Some of the rocks are vesicular and even pumiceous, and they are associated with obsidian- and pumice-tuffs.

Mr. Etheridge bore testimony to the great perseverance shown by the author in working out the Icelandic and Irish beds. He thought the collection of shells from Húsavík was of the most interesting character.

The Author said that many of the shells occur in beds of about a foot thick. The shelly beds are covered by great thicknesses of stratified but unfossiliferous ashes.