

XIX.—The Bone-Cave in the Valley of Allt nan Uamh (Burn of the Caves), near Inchnadamff, Assynt, Sutherlandshire. By B. N. Peach, LL.D., F.R.S., and J. Horne, LL.D., F.R.S. With Notes on the Bones found in the Cave, by E. T. Newton, F.R.S. (With Four Plates and Six Text-Figures.)

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A CHARACTERISTIC feature of the plateau of Cambrian Limestone in the neighbourhood of Inchnadamff is the occurrence in it of swallow-holes, caves, and subterranean channels which are intimately associated with the geological history of the region. The valley of Allt nan Uamh (Burn of the Caves), locally known as the Coldstream Burn, furnishes striking examples of these phenomena. One of the caves in this valley yielded an interesting succession of deposits, from which were collected abundant remains of mammals and birds. The discovery of bones of the Northern Lynx, the Arctic Lemming, and the Northern Vole among these relics, and the collateral evidence of the materials forming some of these layers, seem to link the early history of this bone-cave with late glacial time, or at least with a period before the final disappearance of local glaciers in that region.

Several caves in the limestone cliff on the southern slope of the valley of Allt nan Uamh were noted by us in the course of the Geological Survey of the district in 1885, but as our attention was directed mainly to the complicated tectonics of the region, no time was spent on their exploration. Fortunately, during a visit to Inchnadamff in 1889, an opportunity was afforded of a systematic examination of the cave now under description, when we were assisted in the work by the Rev. Mr Short, who had considerable experience in cave exploration in England, and by Mr Clarence Fry.

The collection of bones was submitted to Mr E. T. Newton, F.R.S., for determination, and a brief preliminary report on the deposits and the fauna was communicated to the Geological Section of the British Association in 1892.*

Before describing the sequence of deposits in this bone-cave, a brief account will be given of the physical and geological features of the district, the glaciation, and the underground drainage. For these phenomena have an important bearing on the initiation of the cave, and on the interpretation of the evidence furnished by the earlier deposits.

I. PHYSICAL AND GEOLOGICAL FEATURES OF THE DISTRICT.

The accompanying map (fig. 1) shows the prominent topographical features of the region. In the central tract a marked depression runs from Allt Sgiathaig (Skiag Burn), which flows into Loch Assynt from the north, southwards by Inchnadamff, and along the valley of the Loanan to Ledmore. It is bounded on the east by an undulating plateau which is prominently developed between the Traligill river and Allt nan Uamh. Beyond this plateau there is a conspicuous range of high ground, extending from Glas Bheinn (2541 feet) in a south-easterly direction to Conamheall and Ben More (3273 feet). It is continued southwards in the Breabag range, whose highest points rise above the level of 2000 feet. Allt nan Uamh drains the western slope of Breabag, and joins the river Loanan about a mile and a quarter south from Inchnadamff.

On the west side of the central depression there is a group of isolated hills, Spidean Coinich (2508 feet), Beinn Gharbh (1769 feet), and Canisp (2779 feet), with lofty escarpments facing the west and gentle slopes towards the east. These physical features bear a close relation to the geological structure of the region.

Detailed descriptions of the complicated tectonics of the district surrounding Inchnadamff have been given in the memoir on "The Geological Structure of the North-West Highlands of Scotland."† For our present purpose it will be sufficient to indicate the distribution of the rock formations in relation to the glaciation and the underground drainage.

The depression running along the Skiag Burn and the valley of the Loanan to Loch Awe coincides in a general way with the boundary between the belt of country lying to the east that has been affected by the great series of post-Cambrian movements and the undisturbed area to the west.

* *Brit. Assoc. Rep.* for 1892, p. 720. See also *Trans. Inv. Sci. Soc.*, vol. iv, p. 118.

† *Mem. Geol. Surv.* (1907), pp. 508–525. See also *Geol. Surv.* 1-inch sheets 107 and 101.

The group of isolated hills from Spidean Coinich to Canisp are composed of Cambrian quartzites with intrusive sheets of igneous material, resting partly on Torridon Sandstone, and partly on the ancient platform of Lewisian Gneiss, all in normal sequence.

The range of mountainous ground extending from Glas Bheinn by Conamheall to Ben More is composed of thrust masses of Cambrian quartzite, Lewisian Gneiss, and, to a limited extent, on Ben More of Torridon Sandstone, which have been driven westwards by the Glencoul and Ben More thrusts. The Breabag range consists mainly of displaced Cambrian quartzites (fig. 4, p. 336) with intrusive sheets of igneous material. Further east on Sgonnan Mòr, a core of Lewisian Gneiss is laid bare in association with Torridon Sandstone and Cambrian quartzite, the whole succession on that mountain overlying the Ben More thrust-plane.

The undulating plateau lying between the central depression and the eastern range of mountains consists mainly of Cambrian dolomite and limestone, repeated by numerous thrusts and folds. It stretches from Achumore to Inchnadamff, thence up the Traligill river for a distance of 2 miles, and southwards to Allt nan Uamh and the Ledbeg river. Beyond the granitic intrusion of Cnoc na Sròine it has an extensive development, for it spreads over the peaty flat, about 4 miles in width, south-east of the hamlets of Elphin and Knockan. In the plateau between Inchnadamff and Allt nan Uamh the three lowest groups of the Durness sequence of Cambrian dolomites and limestones (1, Ghrudaidh, 2, Eilean Dubh; 3, Sail Mhòr) are represented; in the peaty moorland south-east of Elphin, only the two lowest have been recorded.

The accompanying section (fig. 2) shows the complicated arrangement of the Cambrian dolomites and limestones between the Traligill river and Allt nan Uamh, where the zones have been heaped up by major and minor thrusts. These piled-up calcareous masses are resting on a sole or thrust-plane that truncates the underlying strata. Of special interest are the two outliers of displaced materials above the Ben More thrust-plane which have been left on the limestone plateau. They form Beinn an Fhuarain and Beinn nan Cnaimhseag to the south and north of Allt nan Uamh. With the exception of a core of Lewisian Gneiss on the west face of Beinn an Fhuarain, these outliers are composed of Torridon Sandstone with a small development of basal quartzite and pipe-rock. They clearly point to the original westward extension of the materials overlying the Ben More thrust-plane, and to their isolation by prolonged denudation from the main mass to the east of Breabag (fig. 2).

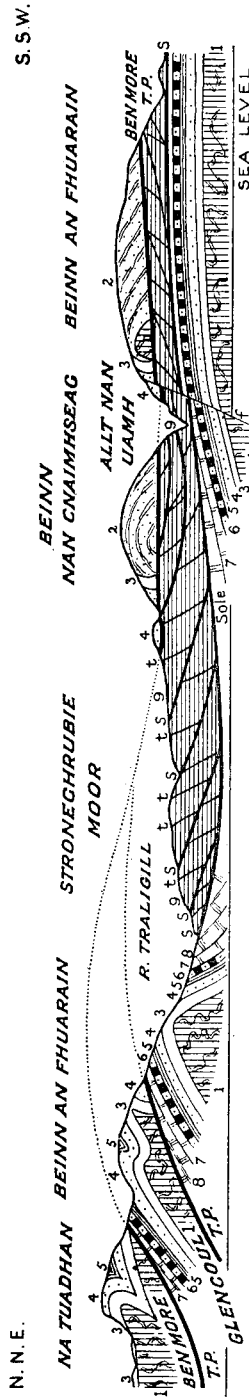


FIG. 2.—Section from Na Tuadhan near Ben More across the River Traligill and Allt nan Uamh to Beinn an Fhuarain.

- 1, Lewisian Gneiss; 2, Torridon Sandstone; 3, basal quartzite (Cambrian); 4, pipe-rock; 5, fucoid-beds; 6, serpulite grit; 7, basal limestone (Ghrudaidh); 8, Eilean Dubh Limestone; 9, piled-up masses of limestone (Imbricate structure), chiefly of Eilean Dubh group; T.P., thrust-planes (Glencoul, Ben More); S, soles or major thrusts; t, minor thrusts; f, subsequent faults.

II. GLACIATION OF THE DISTRICT SURROUNDING INCHNADAMFF AND ALLT NAN UAMH.

In the mountainous district around Inchnadamff there is clear evidence of intense glaciation. The most striking feature of the glacial phenomena is the evidence pointing to the conclusion that during the maximum glaciation the ice-shed did not coincide with the existing watershed.* The striæ at great elevations and the distribution of the boulders prove that the ice-parting lay to the east of the present watershed during the climax of glacial conditions. The ice must have accumulated to a great thickness on the less elevated plateau occupied by the Moine schists east of the Ben More and Breabag range.

During the maximum glaciation the general movement of the ice-sheet at great elevations in this district was in a westerly direction. On Glas Bheinn (see map, fig. 1), at a height above 2000 feet, the striæ point W. 5° N.; on Bealach an Uidhe, between Glas Bheinn and Beinn Uidhe, the direction is W.S.W. at an elevation of about 2000 feet. On the quartzite of Beinn an Fhuarain, east from Inchnadamff, between the 2000- and 2250-foot contour-lines, the trend is north of west. In the high pass north of Conamheall that leads into Coire Mhadaidh, at a level of 2750 feet, the direction is W. 10° S. or W.S.W. Farther south, on the long ridge of Breabag, finely striated surfaces of quartzite have been recorded which point to an ice-movement in a westerly direction.

Confirmatory evidence of this westerly movement is obtained on the mountains north and south of Loch Assynt. On Quinag, at an elevation of 1750 feet, the striæ point W. 5° N., and on Beinn Gharbh, about the 1500-foot contour-line, the direction varies from W. 10° S. to W.S.W. On the eastern slope of Canisp, the striæ point north of west, indicating an ice-movement up the slope in the direction of the plateau of Lewisian Gneiss.

The evidence furnished by the dispersal of the boulders also points to a westerly ice-movement across the mountainous district around Inchnadamff during the maximum glaciation. About 2 miles east from Inchnadamff, on the crest of Beinn an Fhuarain,—a hill composed of Cambrian rocks, we found boulders of thrust Lewisian Gneiss that have been carried westwards from the deep corries north of Ben More Assynt. Farther north, on Mullach an Leathaid Riabhaich, similar blocks of Lewisian Gneiss rest on the quartzite at a height of 2250 feet. On Breabag, on the

* Peach and Horne, "The Ice-shed in the North-West Highlands during the Maximum Glaciation," *Brit. Assoc. Rep.* for 1892, p. 720.

quartzite ridge that runs south from Breabag Tarsuinn, about the 2000-feet level, blocks of thrust gneiss and Moine schist have been recorded. Farther south, along the same ridge, north of Meall Diamhain (see map, fig. 1), small boulders of thrust gneiss and granulitic quartz-schist occur on outcrops of fucoid-beds and quartzites. The boulders of thrust gneiss have been derived from the slice of this material lying to the east above the Ben More thrust-plane. The blocks of granulitic schists have been carried westwards from the Moine schist area, the average height of which is lower than that of the Breabag ridge. It follows that during this westerly movement the Moine schist erratics must have been transported to levels several hundred feet higher than the sources from which they were derived.

Boulder clay is sparsely distributed in the mountainous district around Inchnadamff. It appears in the catchment basins of the Cassley and the Oykell, also in the upper part of the valley of the Ledbeg river. The drift deposits consist chiefly of moraines which have a wide distribution. An examination of the morainic material and of the boulders on the mounds points to a period of confluent glaciers when the Assynt mountains became independent centres of dispersion of the ice. In the valley of the Cassley river, which drains the great corries east of Ben More Assynt and Carn na Conbhairean, boulders of Cambrian quartzite have been traced for about 15 miles down to Invercassley, across the area occupied by the Moine schists. Again, on the Moine schist plateau south-east from Sgonnan Mòr, moraines occur containing blocks of Cambrian quartzite and thrust Lewisian Gneiss which have been borne from that mass of high ground.

When we pass westwards to the central region around Inchnadamff there is evidence to prove that local ice streamed off the eastern slopes of Canisp and Beinn Gharbh, which coalesced with that radiating from the Breabag range. Moraines of retreat are to be found near Stronechrubie and along the valley of the Loanan. Again, part of the confluent glacier ice in the neighbourhood of Inchnadamff moved northwards up the Skiag valley, carrying boulders of the intrusive porphyrite of Beinn Gharbh in its train.

The ground around Inchnadamff is above the level of the raised beaches on the seaboard of the West Highlands. The surface of Loch Assynt is 215 feet above Ordnance Datum line. We are thus deprived of evidence which might enable us to determine the stage when local glaciers ceased to exist in the mountainous region of Assynt.

III. DRAINAGE OF UNDERGROUND WATER AND FORMATION OF CAVES IN THE PLATEAU OF CAMBRIAN LIMESTONE.

The limestone plateau lying between the most westerly thrust-plane or "sole" and the great lines of displacement to the east (Glencoul, Ben More) is admirably adapted for the circulation of underground water, as the limestone is soluble and is traversed by innumerable minor thrusts. These piled-up calcareous masses, as already indicated, lie between impervious strata (Cambrian quartzites and fucoid-beds) to the west and the displaced Lewisian Gneiss, Torridon Sandstone, and Cambrian quartzites forming the eastern range of high ground. The streams descending from the high ground to the west that feed the Skiag Burn and the Loanan river, flow over impervious rocks and suffer no diminution before reaching Loch Assynt. On the other hand, the tributaries draining the western slopes of the Glas Bheinn and Breabag range, on reaching the limestone plateau, either suffer diminution or disappear to issue again at lower levels before sinking to the underlying floor of impervious strata (see map, fig. 1).

Near the northern limit of the limestone plateau north of Achumore, no streams descend from the western slope of Glas Bheinn between Loch Gainmhich and Allt a Chalda Mòr. The plateau, which is here comparatively narrow, is dotted with swallow-holes. The water that falls on its surface disappears below ground and probably supplies Allt a Chalda Beag, which issues near the outcrop of the Glencoul thrust-plane, and, flowing across the limestone belt, enters Loch Assynt near Castle Bay.

The Big Chalda stream (Allt a Chalda Mòr) draining Glas Bheinn and Beinn Uidhe, on reaching the outcrop of the Glencoul thrust-plane at the eastern margin of the limestone belt, loses part of its waters along this plane. Between the Big Chalda and Allt Poll an Droighinn, a tributary of the Traligill river, swallow-holes and open chasms occur along the outcrop of the Glencoul thrust-plane where the water descending the quartzite slopes to the east disappears.

The phenomena connected with the drainage of underground water in the limestone plateau are best displayed in the area drained by the Traligill river and its tributaries and Allt nan Uamh. About a mile and a half up the Traligill from Inchnadamff Hotel the stream suddenly plunges into a cavern along the outcrop of an important thrust-plane or "sole." This line of disruption forms a prominent feature in the landscape (Pl. I), the surface of the plane of movement giving rise to a well-marked slope on the northern side of the channel. The accompanying section (fig. 3) shows the relations of the strata where this "sole" appears at the surface in the Traligill.

On the north side of the Traligill between the river and the outcrop of the Glencoul thrust-plane the Cambrian strata form an arch, on whose southern limb there is a normal ascending sequence from the basal quartzites (3 in fig. 3) to the limestones of the Eilean Dubh group (8 in fig. 3) exposed on the northern bank of the river channel. Here they are truncated by a thrust which has caused the basal limestones (7 in fig. 3) to override the members of the younger group (8 in fig. 3).

After flowing underground for about a quarter of a mile, the Traligill reappears but with diminished volume (Pl. I). About two hundred yards

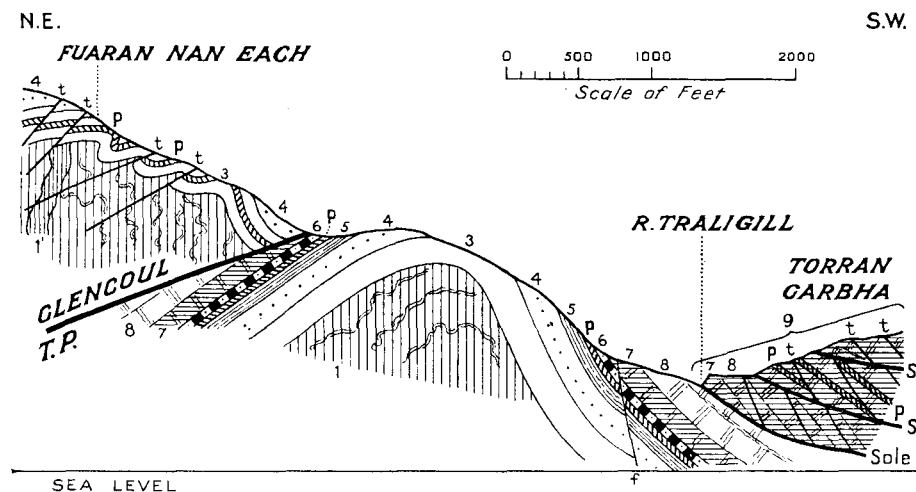


FIG. 3.—Section from Fuaran nan Each across the Traligill River to Torran Garbha.

- 1, Lewisian Gneiss; 3, basal quartzite (Cambrian); 4, pipe-rock; 5, fucoid-beds; 6, serpulite grit; 7, basal limestone (Ghrudaidh); 8, Eilean Dubh Limestone; 9, piled-up masses of limestone (Imbricate structure), chiefly of Eilean Dubh group; P, porphyrite sills; T.P., Glencoul thrust-plane; S, soles or major thrusts; t, minor thrusts.

farther down the stream a sudden increase in the volume of water is perceptible, the probable cause of which will now be indicated.

About half a mile up the valley from the point where the Traligill enters its subterranean channel, and about two hundred yards south from the river, caves occur which are locally named Uamh an Tartair (Cave of Roaring, literally Great Noise) and Uamh an Uisge (Cave of Water). They lie along the outcrop of the Traligill thrust-plane just described, which is prolonged south-eastwards in the direction of Cnoc nan Uamh. Descending one of these caves, the observer encounters an underground river which is seen to leap over a waterfall and pass down a steep slope into a wide cavern. It is probably fed by several streams, which, during heavy rains, flow down the western slope of Breabag and plunge into large swallow-holes on reaching the limestone plateau (fig. 4). It is highly probable also

that this underground river, which is not visibly connected with any surface stream, may be the source of the accession to the Traligill river below its point of issue from the subterranean channel.

Loch Maol a' Choire, a small sheet of water, situated on the limestone plateau about three-quarters of a mile south from the Traligill river (see map, fig. 1, p. 329), is now almost a closed basin. The rocks are concealed by the surrounding peat, but from the available evidence it would appear that the loch is probably floored with fucoid-beds and serpulite-grit, and perhaps partly with glacial material. A dry channel connecting this loch with the Traligill is traceable on the surface of the ground, evidently representing an old stream course carved by the water issuing from the lake. In the lower part of this channel occurs a cave (Uamh Cailliche Pearag) which forms a tunnel with an aperture up stream. It is clear that the water at one time entered this chimney, flowed out of the tunnel, and pursued its course above ground till it joined the Traligill.

Throughout the limestone plateau the most striking example of the disappearance and reappearance of a stream is furnished by the Allt nan Uamh or Coldstream Burn. It rises near the crest of the Breabag range above the 2000-foot contour-line (fig. 1, p. 329), descends the quartzite slopes, and, soon after reaching the limestone belt, plunges beneath the surface, and runs underground for a distance of about a mile. It reappears as a powerful spring (Fuaran Allt nan Uamh, spring of the Burn of the Caves), about half a mile above the junction of the Coldstream Burn with the Loanan river. In periods of excessive rainfall or rapid melting of snow in the upper part of the catchment basin, when the volume of water is too large for the subterranean channel, the swollen stream reverts to its old water-course. But under normal conditions the channel remains dry for about a mile above the Fuaran Allt nan Uamh.

IV. RELATION OF THE CREAG NAN UAMH BONE-CAVE TO THE GLACIAL DEPOSITS IN THE VALLEY OF ALLT NAN UAMH.

About a mile and a quarter up Allt nan Uamh from its point of junction with the Loanan river, a prominent crag of Eilean Dubh limestone (named on the 6-inch map Creag nan Uamh, Crag of the Caves) appears on the south side of the valley at a height of about 150 to 200 feet above the dry channel of the stream. The bone-cave is the most easterly of three caves at the base of this crag (Pl. II, fig. 1). The steep slope between the caves and the stream course is composed of highly denuded glacial drift, partly covered with scree material (Pl. II, fig. 1). On both sides of the valley at this point there is a considerable develop-

ment of drift (Pl. III, figs. 1 and 2). On the northern slope it forms a well-marked terrace (fig. 5), whose surface is about the level of the bone-cave. A corresponding terrace is observable about 1200 yards farther down the valley. No satisfactory sections of this deposit are exposed, but from the absence of morainic contour we infer that it represents the ground-moraine produced during the maximum glaciation, or at a later stage during the period of confluent glaciers.

It seems reasonable to conclude that the valley of Allt nan Uamh was originally filled with this impervious glacial drift up to the level of the caves (see dotted line *a*, fig. 5), so that the water entering the limestone was obliged to escape at the edge of the terrace where it bounded the limestone crag.

A later stage in the history of the valley is indicated by the dotted line *b* (fig. 5), when the stream had removed part of the drift terrace, so that the water issued from the Otters' Cave. Here the limestone appears at the surface through a thin covering of drift, about half-way down the slope (Pl. II, fig. 1, O.C.). Since that period the stream has excavated its channel to its present level (*c*, fig. 5), without reaching the solid rock for some distance above and below the line of section. About half a mile farther down, however, the rocky floor is exposed where the stream issues from its subterranean channel (Fuaran Allt nan Uamh). Between the caves and the point where the Coldstream Burn reappears the bottom of the valley displays a succession of alluvial terraces marking stages in the removal of the glacial drift.

V. SEQUENCE OF DEPOSITS IN THE CREAG NAN UAMH BONE-CAVE.

The exploration of the most easterly cave in Creag nan Uamh yielded a definite succession of deposits, given below in descending order:—

1. Peaty matter from a few inches to 1 foot in thickness.
2. Lenticular layer of calcareous marl about 1 foot thick.
3. Red clay or cave-earth from 1 to 3 feet in thickness, which furnished abundant remains of mammals and birds with indications of occupation by man.
4. Fine grey clay, about 6 inches thick, containing quartzite blocks.
5. A bed composed of limestone fragments yielding bones of mammals and birds.
6. A layer of gravel consisting of stones mostly foreign to the cave.

A careful consideration of the evidence has led us to the following conclusions regarding the significance of these deposits, which are discussed in sequence, beginning with the oldest (fig. 6).

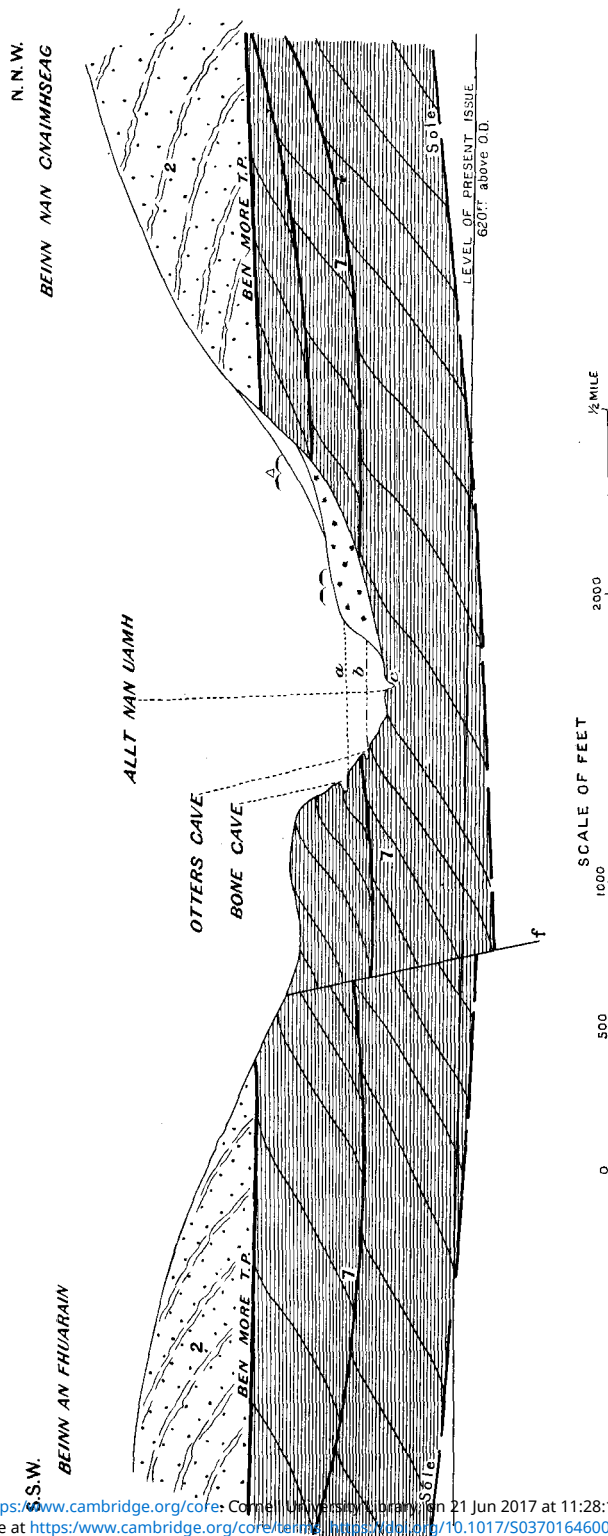


FIG. 5.—Section across the valley of Allt nan Uamh from Beinn an Fhuarain (Hill of the Spring) to Beinn nan Chaimhseag (Hill of the Bearberry), showing the position of the Bone-Cave and the Otters' Cave.

2, Thrust Torridon Sandstone; 7, piled-up masses of Eilean Dubh Limestone; T.P., Ben More thrust-plane; —, drift terrace; Δ, scree debris; α, dotted line indicates probable extension of drift when water issued from Otters' Cave; c, present dry channel of Allt nan Uamh.

6. The gravel on the floor of the cave is composed of well-rounded stones, comprising quartzites, porphyrites, serpulite-grit, fucoid-beds, and limestones. Most of the materials are foreign to the cave. They might have been obtained by streams traversing the quartzite slopes of Breabag and the drift-covered limestone plateau. The arrangement of the layers and the interlocking of the pebbles indicate that the gravel was deposited by a stream issuing from the cave. It is evident, therefore, that the stream transporting these stones from the upper part of the catchment basin of Allt nan Uamh must have flowed underground on reaching the limestone plateau, and that part of the current at least must have found a channel through the bone-cave. It is quite possible that this gravelly bed may

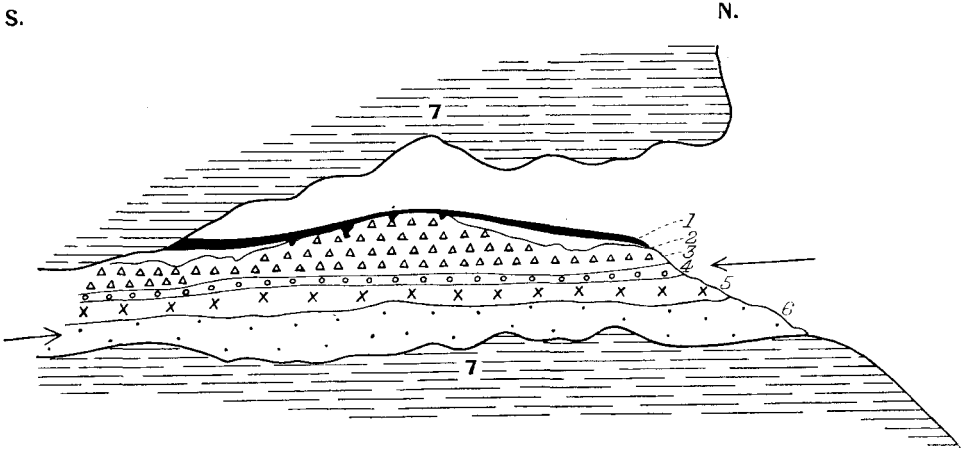


FIG. 6.—Diagrammatic section showing sequence of deposits in Creag nan Uamh Bone-Cave.

1, peaty layer; 2, marl; 3, cave-earth; 4, grey clay; 5, bed of limestone fragments; 6, gravel.

have accumulated on the floor of the cave while glaciers still existed in the high ground to the east.

5. The bed of fine splinters of limestone overlying the gravel indicates that the cave had already become a dry one, and that the water had begun to circulate at a lower level. The limestone fragments appear to be largely due to frost action on the roof and sides of the cavern. The almost entire absence of red clay or *terra rossa* would seem to indicate that there was very little drip from the roof during the accumulation of this bed.

From this layer were exhumed the remains of the Arctic Lemming, Field Vole (*Microtus agrestis*), Rat Vole (*Microtus ratticeps*), Bear, and birds. The great number of pinion bones and anchylosed dorsal vertebral bones of birds shows that the deposit must have been formed very slowly. The pinion bones of ptarmigan occur in lenticular layers containing the remains of hundreds of individuals.

4. The compact grey clay with small quartzite boulders, forming bed 4, resembles to some extent the morainic material in the adjoining valley. No fragment of limestone from the roof or walls of the cavern was observed in this deposit. These facts suggest that the layer was due to morainic material, derived from the quartzite slopes of Breabag, which had been carried on the surface of a glacier and shot into the cave from the lobe of ice that passed down the valley of the Coldstream Burn. If the material had been derived from the high terrace of drift left in the valley (see fig. 5), a greater variety of stones would have been found in the clay. No organic remains were noted in this deposit.

3. Bed 3 is perhaps the most interesting member of the succession. It consists of red clay or *terra rossa*—a true cave-earth—with occasional splinters of limestone, and, at the east end of the cave, some stalagmite. Its thickness is variable and its surface uneven (see fig. 6), showing that the falls from the roof were very irregular. The mammals obtained from this deposit include Northern Lynx, Reindeer, Red-deer, and Otter, as well as a very large number of Frog bones; and there is just a possibility that the Arctic Lemming and Rat Vole occur also in this bed, but definite evidence is wanting. It is worthy of note that the antlers of Reindeer represent very young individuals, while those of the Red-deer are very massive.

No less interesting is the evidence pointing to the conclusion that during the accumulation of this bed the cave was tenanted by man. In various layers, fireplaces and firestones, split and burnt bones were observed but no artefacts were detected. It was noted that some of the Reindeer antlers had been sawn off. The Fox, Otter, and Badger, whose remains are associated with those of other mammals in the cave-earth, need not have been contemporary with the period of occupation by man, for these animals may have burrowed into the deposit in historic times.

The surface of the bare portions of bed 3 was pitted with numerous small conical holes formed by drips from the roof of the cave. These yielded abundant remains of the common Frog and Toad, and the Natter-jack Toad. Some of the larger pits were filled with the long bones of these creatures, packed closely together, thus indicating a protracted period for their accumulation. Near the eastern wall of the cave the *terra rossa* and the limestone splinters were locally cemented by a small amount of stalagmite not only at the surface but at different depths farther down.

The cave-earth probably marks a change to wet and milder conditions than those which prevailed during the deposition of bed 5, composed, as already indicated, of limestone fragments and yielding bones of mammals and birds.

2. The layer of whitish marl occurred chiefly on the western side of the floor of the cave (see fig. 6). The remains obtained from it consist almost wholly of the shells of small Pupa-like land snails, pointing to a long period when, with the exception of a few splinters, only the limestone-loving land shells dropped from the walls and roof of the cave.

1. The thin peaty layer at the top is composed almost wholly of excrement of sheep. In recent years it has been the custom during severe snow-storms to drive the sheep into this part of the valley to enable them to find shelter in the caves of Creag nan Uamh.

Among the mammals obtained from this bone-cave the Arctic Lemming is of special interest because the remains of this animal were found by the late Mr James Bennie in the arctic plant bed of the ancient lake at Corstorphine, near Edinburgh. At the latter locality the palæontological evidence indicates that the deposit is probably of late glacial age.

In his published description of this old lake deposit Mr Bennie did not record his discovery of the jaw-bone of the Lemming which had been determined by Mr E. T. Newton, F.R.S. Special thanks are due to Mr William Evans, F.R.S.E.,* for calling attention to this discovery and obtaining permission from the Geological Survey to have the jaw-bone re-examined by Mr Newton. He reported: "I do not think there can be any doubt as to the larger jaw belonging to a Lemming, and it is closely allied to the Arctic Lemming, which is now called *Dicrostonyx torquatus*; but being imperfect one cannot speak with certainty as to the species."

The arctic plant bed at Corstorphine occurs in the lower part of a succession of lacustrine deposits filling a silted-up lake. The seeds and leaves collected by Mr Bennie were determined by the late Mr Clement Reid, F.R.S., who stated that the vegetation consists mainly of dwarf willow and birch with a few herbaceous plants belonging to species still living within the Arctic Circle.† Amongst the arctic species are dwarf birch (*Betula nana*), willows (*Salix polaris*, *S. herbacea*, *S. reticulata*), the white dryas (*Dryas octopetala*), and *Oxyria digyna*. From the evidence of the plants Mr Reid inferred that the deposit is probably of late glacial age.‡ This conclusion is confirmed by the occurrence in the plant bed of remains of *Lepidurus* (*Apus*) *glacialis*, a phyllopod now found living only in the freshwater lakes of Greenland and Spitsbergen. The discovery of the remains of the Arctic Lemming in the same deposit is another link in the chain of evidence indicating the climatic conditions which then prevailed in Scotland.

* *Proc. Roy. Phys. Soc.* (1906), vol. xvi, part 8; also *The Scot. Naturalist*, No. 17, May 1913, p. 97.

† *Brit. Assoc. Rep.*, 1892, p. 716.

‡ *Origin of the British Flora*, 1899, p. 62.

The Corstorphine lake occupied a hollow in the boulder clay. The ice had finally retreated from the lowlands of Scotland, but glaciers still lingered in some of the Highland valleys. The deposits of the 100-feet beach, which have yielded at certain localities shells of an arctic type and bones of the small arctic seal, were then being laid down. Indeed, all the available evidence seems to point to the conclusion that the Corstorphine Lemming is of late glacial age.

The deposits of the Creag nan Uamh bone-cave are certainly later than the accumulation of the ground-moraine in the valley of Allt nam Uamh. They seem to us of special interest and importance from the light which they throw on the mammalian and avian life that flourished in the North-West Highlands since the climax of the Ice Age and during Neolithic time.

Our special thanks are due to Mr Spencer L. Arnot for the photographs of the bone-cave and the drift deposits in the valley of Allt nan Uamh which are reproduced in Pls. II and III, to Dr W. Inglis Clark for the photograph of the thrust-plane in the Traligill river from which Pl. I has been made, and to the Carnegie Trustees for a grant in aid of the illustrations. Mr John Mathieson, H.M. Ordnance Survey, has kindly revised the spelling of the Gaelic place-names appearing in the text.

VI. NOTES ON BONES FOUND IN THE CREAG NAN UAMH CAVE,
INCHNADAMFF, ASSYNT, SUTHERLAND. By E. T. NEWTON, F.R.S.

A small collection of bones from Creag nan Uamh cave, Inchnadamff, was submitted to me for examination by my colleagues Drs Peach and Horne in the year 1890; but only a brief reference to the fauna of the cave was made by them in their short preliminary report [*Brit. Assoc. Rep.* for 1892, p. 720]. During the last few months this series of remains has been re-examined and some 36 distinct vertebrate forms recognised: 15 mammals, 17 birds, 3 amphibians, and 1 fish.

The presence among these remains of Reindeer, Bear, Northern Lynx, Arctic Lemming, and *Microtus ratticeps* show that the deposits of this cave are not of very recent origin, but that a considerable lapse of time must have taken place since they were accumulated; indeed, it seems highly probable that some of these deposits (Bed 5) are of late Pleistocene age, although no characteristic extinct species has been observed. All the above-named mammals are living forms. The Reindeer and Bear are known to have been living in this country in historic times, and it is possible that the other three, although giving a boreal aspect to the fauna of the cave, may have continued to live in Sutherland until a much more recent date than is usually supposed. On the other hand, neither of these three species has hitherto been found in modern deposits in this country, and, in so far as the southern parts of Britain are concerned, may be taken as characteristic Pleistocene forms; but the case is not quite the same for the north of Scotland.

The Lynx is represented among these remains by a femur and a metatarsal bone, both of which agree with corresponding bones of a Northern Lynx in the British Museum except in being a little smaller, but in this respect they are like the bones of this species from Teesdale described by W. Davis (*Geol. Mag.*, 1880, p. 346). We have no evidence that the Lynx was living in Britain in historic times, although it may have lingered in the wilder parts of northern England and Scotland without being recorded. All the remains of Lynx yet discovered in Britain are from caves or rock fissures, and in no case have they been associated with extinct Pleistocene species.

A single small canine tooth of a Bear from Bed 5 is scarcely sufficient for the definite determination of the species, yet it seems most probable that it represents the Brown Bear (*Ursus arctos*) which was living in Britain in early historic times (A.D. 500–1000).

The Otter is represented by a few bones from Bed 3, and the Badger by a skull and several bones from the same horizon, but there is always the possibility of the latter animal having burrowed into the deposit at a later date. The Stoat and Weasel have been found in Bed 5, parts of skulls and limb-bones of both species having been met with. A single caudal vertebra of a Fox alone represents that animal.

Portions of Red-deer and Reindeer antlers occur in this cave, and similar remains have been recorded from many deposits of prehistoric and modern date in various parts of Scotland, where Reindeer were still living in the twelfth century.

There are a few limb-bones of a large Hare; and as no such fossil remains appear hitherto to have been recorded from Scotland, it is of peculiar interest to ascertain, if possible, to what species and variety these belong. The specimens available for comparison are a femur and a humerus, both nearly perfect, and an upper incisor tooth. There are also portions of a tibia, an ulna and some foot-bones, but these do not give much help. The femur and humerus both present characters of their proximal ends which at once show their affinity to the Variable Hare (*L. variabilis*) rather than to the Common or Brown Hare (*Lepus europæus*); and the incisor tooth has cement in its anterior groove, thus pointing to a similar affinity. It is not easy, however, to decide to which variety of *L. variabilis* these remains should be referred, and this determination rests chiefly upon measurements. One naturally, in the first place, compared them with the modern Scottish Blue-hare (now called *Lepus variabilis scoticus*), but the bones of my own example of this species were so much smaller and more slender than the Assynt bones that it seemed unlikely they could be the same. Length of Assynt femur, 132 mm.; Scotch Hare, 115 mm. Length of Assynt humerus, 111 mm.; Scotch Hare, 92 mm. On further comparison with measurements of specimens in the College of Surgeons Museum, given by Mr Martin A. C. Hinton in his masterly paper on Fossil Hares (*Sci. Proc. R. Dublin Soc.*, vol. xii, N.S., p. 225, 1909) and with specimens of Russian Variable Hares in my own collection, I find that there is a considerable overlap in the sizes of these varieties. The largest Scotch Hare is very nearly as large as the Assynt fossil; but on the other hand some of the Russian *L. variabilis* are smaller. As a matter of fact, the Assynt humerus is longer and the femur more robust than are these bones in the largest of my Russian specimens, and approach the dimensions of the Kentish fossils given by Mr Hinton. There remains, therefore, a doubt regarding the variety represented by these Assynt remains, and this will, I think, be best shown by recording them as *Lepus variabilis scoticus*?

Dicrostonyx, the Arctic Lemming, is undoubtedly represented by a few jaws and teeth found in Bed 5 and perhaps also in Bed 3; there are likewise some limb-bones which in all probability belong to the same form. Until the last few years British fossil Lemmings, of the *D. torquatus* type, have generally been referred to that species; but more recently Mr Martin A. C. Hinton and others have shown that there are dental and cranial differences among these fossils which necessitate a further subdivision, and Mr Hinton has described one of these under the name of *D. henseli*, and, for another, revives the name of *D. guillemi* of Sanford. Of these species the former is allied to the recent *D. hudsonius*, while the latter more nearly resembles the recent *D. torquatus*.

One could have wished for better material to indicate the species inhabiting the Assynt district in Pleistocene times; but fortunately there are two characteristic upper molars preserved (m^1 and m^2), and these show the greater development of their posterior angles as in *D. torquatus* (see figure by Barrett Hamilton, *Hist. Brit. Mams.*, part xiv, p. 388, 1913) and not the reduced condition seen in the recent *D. hudsonius* and in the fossil *D. henseli*. Although the characters of the Assynt fossils may not be so marked as in the figure just referred to, they agree very closely with recent specimens in the British Museum. There are four more or less imperfect lower jaws, and only one of these retains the last molar tooth (m_3), which is said to be characteristic but less distinctly so than the upper molars. This hindermost lower molar in our fossil has its anterior angles as fully developed as in some of the recent *D. torquatus*, and the same may be said of the second lower molar (m_2). It is clear, therefore, that this Assynt Lemming belongs to the *D. torquatus* type as distinguished from *D. hudsonius*. With regard to the size of these Assynt specimens, the series of molar teeth in two of them measures 7.5 mm. (alveolar length), and in a third, probably young jaw, 6.5 mm. Among the specimens of *D. torquatus* type now in the British Museum there is much difference of size, the alveolar length of the lower molar series varying from 6.0 mm. to 7.7 mm. These differences may be due to age, and perhaps to local varieties not yet distinguished, but they fall into two groups—those with the molar series measuring from 6.0 mm. to 6.6 mm. in length, and a larger form, two specimens, measuring respectively 7.3 mm. and 7.7 mm. There is a remarkable agreement, therefore, between the measurements of these recent and our fossil specimens. The first of the larger recent forms is from N.W. Siberia and the second from Wellington Channel (75° N. 93° W.), that is, far to the N.E. of North America. Most of the smaller recent forms are

from Discovery Bay (82° N. 65° W.). From this it will be seen that both large and small forms occur in the extreme N.E. of North America, although their habitat may be 500 miles apart; and the smaller form lives on the most northerly land yet discovered. From what has been said above, there appears to be no valid reason for separating the Assynt Lemmings specifically from the recent forms, which at present are included under the name of *D. torquatus*. But what about fossil forms?

The only fossil Lemming of *D. torquatus* type which, so far as I know, has been recognised and named, is *D. gulielmi*, and this agrees with *D. torquatus* in the pattern of its teeth, but is said to be distinguished "by its considerably larger size, shorter and broader incisive foramina, broader nasals, and heavier teeth." As we have no skulls from Assynt for comparison, and as the patterns of the teeth are alike, the larger size and heavier teeth are the only characters left for comparison, and in these particulars the Assynt specimens do not agree with *D. gulielmi*, the alveolar length of the three molars being 8.3 mm. Until better specimens are forthcoming, the Assynt Lemming will be referred to *Dicrostonyx torquatus*.

An incomplete skull of a small Water Vole is most probably referable to the black Scottish variety now called *Arvicola amphibius reta*, Miller; but its horizon and that of a lower front tooth of a Bank Vole (*Evotomys glareolus*) are uncertain. Jaws of the Field Vole (*Microtus agrestis*) and also of *Microtus ratticeps* have been found in Bed 5.

Avian remains are numerous and represent several genera and species. The bones of Ptarmigan (*Lagopus mutus*) are by far the most numerous, and the greater number of these are metacarpal and metatarsal bones; among which were a few of larger size which seem to belong to Red-grouse (*Lagopus scoticus*); and it thus appears that at the time these cave deposits were accumulating, Ptarmigan were much more abundant than Red-grouse in the north of Scotland. Several genera of Ducks have been identified, while the Little Auk (*Mergulus alle*) and the Puffin (*Fratercula arctica*) are each represented by a single bone.

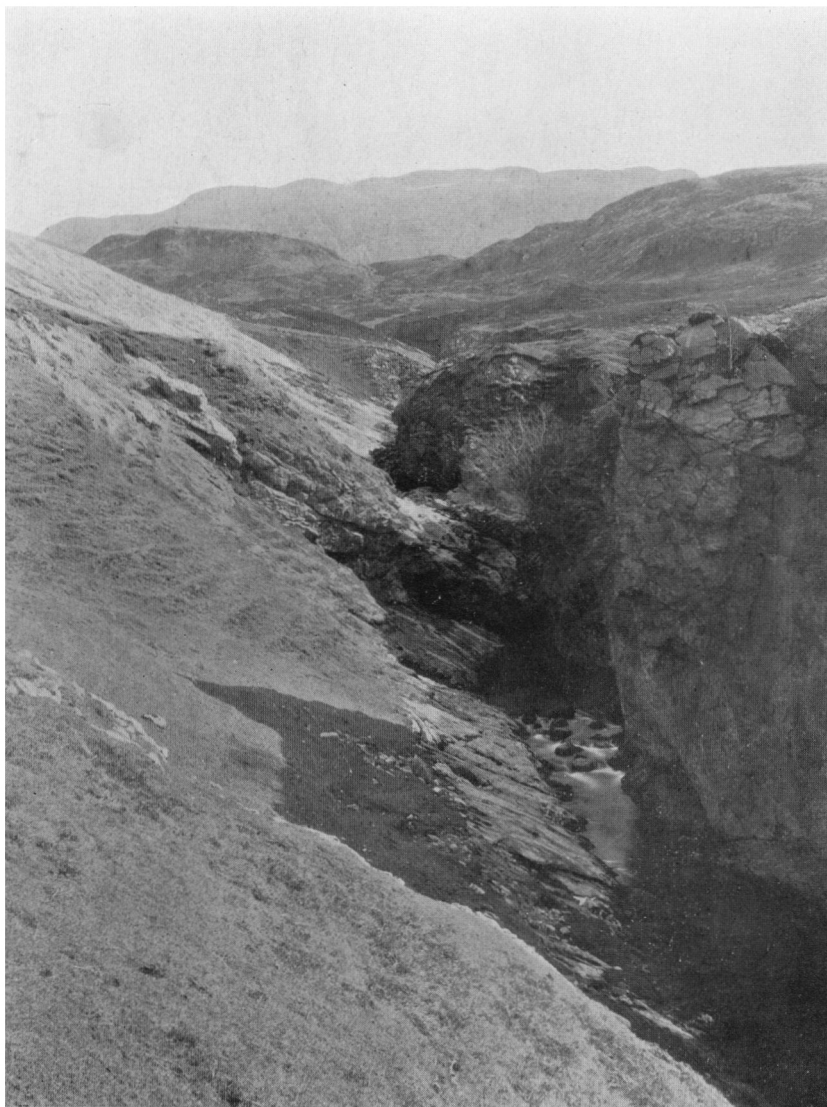
Remains of the Common Frog (*Rana temporaria*) were found in large numbers in "pockets" in Bed 3, and with them a few bones of the Common Toad (*Bufo vulgaris*). A small humerus and one or two other bones agree so closely with corresponding parts of the Natter-jack Toad (*Bufo calamita*) that I have, although with hesitation, included that species in the list.

Fish vertebræ and portions of skulls occurred in some numbers in Bed 5, and belong to either salmon or trout.

*List of Vertebrata from Creag nan Uamh Cave.**

	Bed 5.	Bed 3.	Bed 3 or 5.
MAMMALS.			
Lynx, <i>Felis lynx</i> , Linn. . . . .	...	S	S
Stoat, <i>Mustela erminea</i> , Linn.	S	...	S
Weasel, „ <i>vulgaris</i> , Linn.	S	...	S
Fox, <i>Vulpes alopec</i> , Linn. . . . .	...	...	S
Otter, <i>Lutra vulgaris</i> , Erxleb. . . . .	...	S	SL
Badger, <i>Meles taxus</i> , Schreber . . . . .	...	...	SL
Bear, <i>Ursus arctos</i> , Linn.	S	...	...
Red-deer, <i>Cervus elaphus</i> , Linn. . . . .	...	S	S
Reindeer, „ <i>tarandus</i> , Linn. . . . .	...	S	S
Hare, <i>Lepus variabilis scoticus</i> ?	S	...	SL
Lemming, <i>Dicrostonyx torquatus</i> , Pallas	S	...	S
Water Vole, <i>Arvicola amphibius reta</i> ?, Miller . . . . .	...	...	L
Field Vole, <i>Microtus agrestis</i> , Linn.	S	...	SL
Rat Vole, „ <i>ratticeps</i> , Key and Bl.	S	...	SL
Bank Vole, <i>Eutamias glareolus</i> , Schreber . . . . .	...	...	L
BIRDS.			
Chaffinch ?, <i>Fringilla</i>	S	...	...
Barnacle Goose, <i>Bernicla leucopsis</i> , Bechst. . . . .	...	...	L
Swan, <i>Cygnus olor</i> ?, Gmel. . . . .	...	...	L
Mallard ?, <i>Anas boschas</i> ?, Linn. . . . .	...	...	L
Teal, <i>Querquedula crecca</i> , Linn.	S	...	...
Wigeon, <i>Mareca penelope</i> , Linn.	S	...	...
Tufted Duck, <i>Fuligula cristata</i> , Leach	S	...	...
Long-tailed Duck, <i>Harelda glacialis</i> , Linn.	S	...	SL
Eider Duck, <i>Somateria mollissima</i> , Linn.	L	...	L
Common Scoter, <i>Oedemia nigra</i> , Linn.	S	...	S
Velvet Scoter, <i>Oedemia fusca</i> , Linn. . . . .	...	...	L
Ptarmigan, <i>Lagopus mutus</i> , Montin.	SL	...	SL
Red-grouse, <i>Lagopus scoticus</i> , Lath.	SL	...	...
Golden Plover, <i>Charadrius phalaris</i> , Linn. . . . .	...	...	L
Grey Plover, <i>Squatarola helvetica</i> , Linn.	S	...	...
Little Auk, <i>Mergulus alle</i> , Linn.	S	...	...
Puffin, <i>Fratercula arctica</i> , Linn. . . . .	...	...	L
AMPHIBIA.			
Frog, <i>Rana temporaria</i> , Linn.	S	S	S
Toad, <i>Bufo vulgaris</i> , Laur. . . . .	...	S	...
Natter-jack ?, <i>Bufo calamita</i> ?, Laur. . . . .	...	S	...
FISH.			
Salmon or Trout	S	...	...

* The letter S indicates that the specimen is located in the Geological Survey Collection Edinburgh ; the letter L, in the Geological Survey Collection, London.



View of Traligill River issuing from underground channel along bared outcrop of thrust-plane.
Limestone plateau in middle distance. Quartzite mountain of Breabag in background.



FIG. 1.—Creag nan Uamh, limestone escarpment with three caves on same level (B. Bone-cave; C. C. Caves). Glacial drift and scree material on lower slope (O. C. Otters' Cave). Dry channel of Allt nan Uamh in foreground.

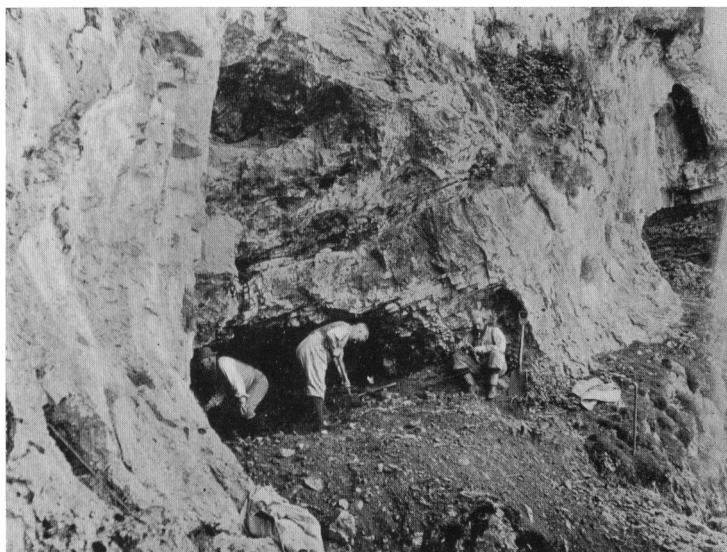


FIG. 2.—View of Bone-cave after excavation.



FIG. 1.—Valley of Allt nan Uamh, with denuded terrace of glacial drift in foreground. Limestone cliff with caves in middle distance.



FIG. 2.—Allt nan Uamh looking east, with denuded terrace of ground-moraine in foreground. Limestone cliff with caves in middle distance. Quartzite mountain of Breabag in background.



Description of this Plate is given on page 849.

EXPLANATION OF PLATE IV.

(Figs. 1-5*a* natural size.)

- Fig. 1. *Lynx*, right femur, front view.
Fig. 2. „ „ metatarsal, front view.
Fig. 3. *Ursus* sp., canine tooth.
Fig. 4. *Lepus variabilis scoticus*? femur, back view.
Fig 5. „ „ „ humerus, front view.
Fig. 5*a*. „ „ „ humerus, proximal end.
Fig. 6. *Microtus ratticeps*, right ramus, lower jaw. $\times 2$.
Fig. 7. „ „ right lower front molar tooth m_1 , surface view. $\times 10$.
Fig. 8. *Dicrostonyx torquatus* right ramus, lower jaw. $\times 2$.
Fig. 9. „ „ right upper m^1 . $\times 10$.
Fig. 10. „ „ right upper m^2 . $\times 10$.
Fig. 11. „ „ left lower m_1 . $\times 10$.
Fig. 12. „ „ left lower m_2 . $\times 10$.
Fig. 13. „ „ right lower m_3 . $\times 10$.

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