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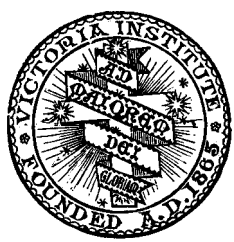

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ORDINARY MEETING, FEBRUARY 21, 1887.

H. CADMAN JONES, ESQ., IN THE CHAIR.

The Minutes of the last Meeting were read and confirmed, and the following Elections were announced :—

MEMBER :—Rev. B. R. Wilson, M.A., Queensland.

ASSOCIATE :—C. M. Davis, Esq., A.M., United States.

HON. CORRESPONDENT :—Rev. A. B. Hutchinson, A.M., Japan.

The following Paper was then read by the Author :—

ON CAVES. By T. MCKENNY HUGHES, M.A., F.S.A., F.G.S., Woodwardian Professor of Geology, Cambridge.

NOW and then it falls to our lot to find an old MS. which throws a flood of light upon some obscure part of history. It had been put aside, buried under a heap of documents of more immediate importance, forgotten till some accident exposed it, some more careful eye caught sight of it, some more experienced judgment recognised its interest.

Such to the geologist is a cave.

He runs his eye over the contents; they may be of little value, or may settle what has long been a matter of speculation or of controversy. They may be a record of the household consumption of some wild beast in his castle; they may tell of the ancient conflict of forces of nature now at rest; or they may derive their chief interest from the character of the material on which the record is preserved.

But the MS. might be passed over, or not read aright, if the discoverer be no palæographer.

So the observer may arrive at very wrong conclusions as to the age and history of a cave, unless he be familiar with the operations of nature which form and fill such caves. This, then, is the point on which I invite discussion this evening: The formation of caves and cave-deposits, with references to some of the more interesting of those which have been explored.

To arrange our subject, I would first notice that there are artificial as well as natural caves, and many natural caves

modified by man. In quite recent times, the soft New Red Sandstone has been scooped out into cells and summer-houses. The chalk has been excavated from very early times in the search for flint, and traces of sojourn in such pits are not wanting. We need not stop seriously to discuss the suggestion that Fingal's Cave was excavated by man. The rock-hewn tombs around Jerusalem, the catacombs of Italy and Egypt are artificial caves.

All along the Vezère and other cliff-margined valleys in the South of France we see the natural caves and rock-shelters, modified sometimes by man, walled up and occupied as store-houses, or even as dwellings. History tells us that those caves were frequently held by troops during the long occupation of that part of France by the English. The Rock of Tayac, like Gibraltar, "a kind of fortress entirely hollowed out of the rock," is frequently mentioned in the history of the wars of the fourteenth and fifteenth centuries.* And the Aquitani, when pressed by Cæsar's troops, retreated to their caves in South-central France. I have heard of a man who lived for some time in a cave in Yorkshire, coming out at night for food,—milk from the neighbours' cows, eggs, or whatever else he could lay hands on. There were many odds and ends in that cave which might have been relics of his sojourn, as well as others of more remote antiquity.†

There are hardly any records of research in caves which are known to have been occupied in recent or historic times. A systematic examination of all the caves in which history tells us the inhabitants of any district once took refuge, and an exact description of all found and observed in them, would be very interesting, and might furnish important evidence bearing upon doubtful questions.

Artificial caves, however, or artificially modified caves, form a very small proportion of those with which we have chiefly to do. The caves in which primæval man lived, and into which in old times hyenas dragged carcasses of the animals they killed or found dead along the river-courses, were all natural caves. So are the celebrated stalactite caves of Germany and America. But we must inquire into the mode of formation of natural caves if we would understand the conditions which surrounded primæval man or speculate on his age.

There are sea-caves formed by the waves that lash the cliffs as if sounding them to find their weaker places. The water

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* *Reliquiæ Aquitanicæ*, p. 4.

† Exploration of Cave Ha, *Journ. Anthropological Inst.* 1874.

itself would soon destroy a jointed rock. As each storm-wave rolls in, it deals a tremendous blow on the fissured mass. Every thin packing of clay between contiguous blocks is soon washed out, and the fissures themselves enlarged. Then there comes into play another action. The space behind the block is filled with water; the thumping wave falls on the narrow opening on one side of it, not on the whole at once; the force is multiplied ten or a hundred times by the hydrostatic paradox, and the block is hammered out. Even in a river this operation is seen going on. Along the valley above Sedgwick's old home in Dent, thin beds of carboniferous limestone with shaley partings form the bed of the stream. The shale perishes, and the great slabs, 5 feet to 10 feet across and nearly 1 foot thick, lie side by side on the bed of the stream. Then in one of the floods so frequent in that district the fissured limestone is filled, and the surplus water rushes in a torrent over the usually almost dry channel. A slab is lifted by the hydrostatic paradox, turned over by the torrent, perhaps swept down, or often left a record of the lifting force which got it out of its bed, but in doing so destroyed the machinery by which it lifted it. So sea-cliffs are more apt to be scooped out into caves and crannies where the rock is jointed or crushed. Any soft, readily-decomposed dyke traversing the harder rock is also more easily removed.

But that is not the only process by which these sea-caves are formed. On the coast of Pembrokeshire, near St. Davids, there is a hole among the crags near high-water mark where, at a certain state of the tide, with each recoiling wave there is a loud sucking noise as the air is being forcibly drawn in through small, wet, weed-covered fissures to take the place of the receding water. It is known as Llesugn from the sound. Were it not for the cracks communicating with the air above we should not be reminded of this force being exercised by every wave in the cave below. Any loose material would be drawn back with the wave, and perhaps carried out of the cave altogether. Many of us are familiar with the phenomena known as "Blow Holes," or "Puffing Holes." The incoming wave fills the tapering cave, and, just as the bore coming up a tidal river rises higher and runs more fiercely when the converging banks force it to pursue its way through a more contracted channel, so when the wave rushes into a narrowing, funnel-shaped cave, with a small aperture communicating with the surface, the water is forced up through the opening, and often a spout of spray is carried high into the air. All these phenomena tell us of the enormous force exerted by the waves

upon the coast, and explain how caves must everywhere be formed where shattered or softer rock is exposed to the lash of the wind-driven sea.

But this is not all. The wave picks up great boulders and hurls them at the rocks that bar its advance. It is quite common, after a storm, to find large stones lodged on a promenade or pier, where they must have been caught up *in* the wave and thrown upon the land. Stones are always carried forward *up an incline* as far as the waves advance; but the cases I refer to now are those in which the stone has been thrown up to the top of a vertical wall. The last place I remember having seen this was in a great storm a few years ago at Hunstanton. The same thing takes place on a grand scale on some of the wild, rocky cliffs of North-Western Scotland, for instance. The Director-General of the Survey has described how in storm, great blocks are hurled up on to the top of the cliff near the Old Man of Hoy.

The force of the Atlantic waves at the Skerryvore Rocks, as estimated by the marine dynamometer, an instrument designed by Thos. Stevenson for this purpose, was found to be as much as 6,083 lb. to the square foot.*

From the height to which the spray was thrown, he inferred a pressure of about 3 tons to the square foot; and further recorded that a block of stone, estimated at 48 tons in weight, "was seen to move under the influence of each wave."†

"On the Bound Skerry of Whalsey, which is only exposed to the waves of the North Sea or German Ocean, he had found . . . . masses of rock weighing 9½ tons and under, heaped together by the action of the waves at the level of no less than 62 feet above the sea; and others ranging from 6 to 13½ tons were found to have been quarried out of their positions *in situ*, at levels of from 70 to 74 feet above the sea. Another block of $7\frac{7}{10}$ tons, at the level of 20 feet above the sea, had been quarried out and transported to a distance of 73 feet . . . . over opposing abrupt faces as much as 7 feet in height." ‡

It is clear that such waves and such boulders would make short work of broken rock or a rotten dyke, and any old cave or fissure opened out by the sea would not be likely to have much of the original deposits left in it. The first storm would clear out all earth and bones, and leave in its place only the well-worn pebbles of a rocky shore,—the battered shot of nature's great marine artillery. A sudden upheaval would leave the cave either quite clear, if it was on a clean,

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* Stevenson, Thos. *Edin. New Phil. Jour.* xlviii. 1850, p. 41.
† Ditto, *Proc. R. Soc. Edin.* vol. ii. 1844-50, p. 13.
‡ Ditto, *Proc. R. Soc. Edin.* vol. iv. 1862, p. 200.

rocky shore, or filled with heaped-up pebbles, if it opened on to a shingle beach. By its form and by its contents we could generally make a shrewd guess whether it was a sea-cave or not. We should ask whether the parts where the cave expands are those on which the sea would act with greatest force and efficiency, or whether the shape could be better explained by reference to torrents coming in the other way. We should examine the contents to see whether in their character or arrangement they indicated the action of the in-rushing water, or whether they are such as could never have survived the scour of tidal and wind-driven waves. When we have to inquire into the origin of caves in inland cliffs and on mountain-sides, now far above the sea, where many of the traces above-described may have been long removed by denudation, there are further tests to be applied. There we should have regard to their manner of occurrence and their place in the physical geography of the neighbourhood. A sea-cave does not necessarily, or even commonly occur in the line of drainage from the uplands, but in the higher cliffs and headlands between the valleys that run down to the sea. Whereas the caves due to subterranean watercourses lie in the lines of drainage; and the caves due to sub-aërial waste coincide in distribution with the outcrop of the beds that readily lend themselves to that kind of weathering.

Moreover, allowing for the possibility of unequal elevation of different parts of a coast-line, we can still generally find sufficient evidence to show whether the rock in which the cave occurs forms part of an old sea-cliff or of an escarpment.*

We must remember also that during the formation of a sea-cave the base of the cliff is being swept by the sea. Sometimes an inland stream washes the base of a rock in which a watercourse cave has its outfall, but generally in the case of inland-formed caves a vast mass of talus is being formed along the base of the cliff in which the cave occurs. The scour of floods may keep the mouth open, but as the water is being drained off to other and lower levels, this sweeping of the cave mouth ceases, and the cave deposits show interbedded fallen rock and transported earth and stones, and often the remains of animals.

As a general statement we may say that a typical sea-cave runs into a cliff which rises vertically from the level of the

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* Cf. Whitaker, *Q.J.G.S.* vol. xxiii. c. 186, p. 265. *Geol. Mag.* vol. iv. 1867, pp. 457, 443.

floor of the cave, or is even undercut a little, because the talus has always been removed from the base, so that the fragments broke away all over the face of the cliff from top to bottom, and the base sometimes was even undermined by the waves.

In the case of an inland cliff, on the contrary, the fallen rock is not removed, so that only the upper part of the cliff above the sloping mass of talus is exposed to the action of the weather. The exposed part is reduced in height as the talus grows, so that the cliff keeps on receding above only, as the talus keeps covering up more and more of the lower part.

The form that a chalk cliff would eventually have behind the talus has been calculated by the Rev. O. Fisher.*

Of course, the sea-cliff, when removed inland by elevation, gets, after a time, eaten back by sub-aërial weathering, and covered over by talus like any ordinary escarpment.

Gaping fissures of such a character that they could in any case be looked upon as caves are very rare, but the fault-breccia that commonly fills such cracks is easily removed, and the various denuding agencies are apt to follow fissures, and thus caves be formed along them. The unequal flow of lava curling and coiling over the half-cooled mass of earlier flows sometimes leaves openings like caves.

It is said that some of the caves in volcanic districts are opened out by the various acidic vapours which act on the micaceous and other schistose rocks which have been already fissured by the earthquakes so frequent in those countries; as, for instance, in the case of some of the caves of Corinth and the Cyclades.†

These are, however, few and unimportant, seldom occurring where a cave would be much frequented by man or the lower animals.

The commonest caves, and those which generally have proved of greatest interest, are the old subterranean watercourses so frequent in limestone rocks. The way in which these caves are formed is well known, but many of the phenomena connected with them appear to be less clearly understood, and so we hear of various startling theories propounded which, on inquiry, turn out to be based on a wrong interpretation of the mode of formation of the deposits found

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* *Geol. Mag.*, vol. iii. 1866, p. 354. See also Davison, *Geol. Mag.*, vol. 1886, p. 65.

† Virlet, *Bull. Soc. Géol. de France*, t. ii. p. 329.

in such caves. It is to these questions I especially invite attention to-night, and in the selection of examples in illustration I shall be chiefly guided by the desire to make clear the distinction between the age of the caves and of the cave deposits, and the mode of formation of the cave earth and laminated clays, stalagmitic floors, and broken-up travertine breccias, stream-gravel, and angular talus.

First, I would just remind you that these caves are formed in a rock which can not only be mechanically broken up and carried off, but can also be dissolved in water and carried away in solution wherever water can pass. Even pure water can take up two grains per gallon of carbonate of lime, of which these rocks are largely composed. But pure water is very rarely found in nature. The rain generally takes up some carbonic acid from the air, and when it falls on the ground gets a great deal more from the decomposing vegetation; and water with carbonic acid in it acts rapidly upon the limestone rock, carrying off part of it as a bicarbonate of lime, while the earthy part is washed away in mechanical suspension till it settles down in some pool of still water as mud, often forming a considerable part of the cave-earth which fills all the interstices of the broken rock. As may be seen by the analyses of hard waters, it is not uncommon to get 25 grains per gallon of carbonate of lime in the water of limestone districts, and this means the never-ceasing operation of the agencies which tend to form caves.

So, of course, the most favourable conditions for the formation of such caves are,—First, a limestone into which the water can trickle down along joints and fissures, and find its way out at some lower level. Secondly, an area over which the rain can gather into streamlets and collect from vegetation the acids which will help it to dissolve the rock. The crack into which the water first finds its way may be very small; the water soon opens it out, acting first chemically, then mechanically, on the surrounding rock. When the sand and broken rock get a free passage, mountain torrents, full of débris torn from the hill-side or washed out of ancient boulder-clays, are precipitated into the chasms, which take the place of the half-opened joint, and the work goes on apace.

It is quite clear that in such circumstances it must often happen that, as the clay or shale on the hill-side is being denuded away, the water must find its way into the jointed limestone further and further back continually, and, in the deep recesses of the mountain, new channels must often carry off the water that once ran higher up. Thus, the higher outfalls are left dry, and then they are in a state for man and

beast to inhabit. Sometimes, however, when all the hill is full after some great thunderstorm, water spurts out of every joint and spouts in torrents from each cave, and until the cave is quite beyond the chance of such catastrophes, we cannot hope to find a clear, continuous record of its old inhabitants.

To give an example of a cave now being formed in one part and periodically modified in another, I will carry you to the flanks of Ingleborough, where the conditions are peculiarly well suited for the formation of caves and for the examination of all the accompanying phenomena. Many of you are familiar with the form of the grand bluff known as Ingleborough,—the most conspicuous feature as you look north from Lancashire towards the borders of Yorkshire and Westmoreland. Its flat cap of millstone grit; its steep slopes of rapidly-crumbling Yoredale shale, here and there braced up by *throughs* of sandstone, or grit, or limestone; its great table of mountain limestone, on which these all stand; and its base of Cambrian and Silurian, altogether combine to furnish some of the most charming bits of scenery and most interesting bits of geology in the kingdom. On the S.E. slopes of Ingleborough is a great hollow space where the water runs off the impervious Yoredale shale and the patchy drift down to the basement table of mountain limestone. The drainage area is about a square mile, and the stream is usually small and generally lost at once in the first open joints of the limestone that it gets to. But a flush of rain-water soon fills these crevices to overflowing, and the surplus water rushes on 100 yards or so to a great chasm, known as Gaping Gill Hole, into which it plunges with a roar. The air dragged down, tangled in the water, ascends in a current, carrying mist and spray far above the chasm's brink. I have watched this wonderful abyss many a day of storm and sunshine. No one has ever been to the bottom of it; but I can tell you something more about it that bears directly on the subject we are considering.

In that country, so favourable for the formation of all the various kinds of swallow-hole, cave, and keld, I once had the good fortune to witness one of those grand storms which in a few minutes change the face of nature, and in a few hours leave a mark that ages may not efface.

I had climbed some way up Ingleborough. It was a glorious July morning. Myriads of insects were busy with their own various pursuits. The haymakers were hard at work; more hurried, perhaps, as the weatherwise saw thickenings towards the south, and felt the sultry heat that warned them

there might be a storm. I turned now and then as I got higher, and saw the mist gather on the southern horizon. Soon it took shape and formed in the eddies as the rapidly-rising wind crept on. Two principal masses of cloud came crowding up, converging on Ingleborough, from Lancaster and Clitheroe. I had once before seen that kind of sky in South Wales, and, a few hours after, thirty-eight bridges were carried away in our county. So warned, I hurried homewards, and it was well I did. The clouds appeared to me to be rolling on in vertical planes. I ran, and only just got in to my inn before the worst was on us. Drenched haymakers, who had lingered too long in some insufficient temporary shelter, kept coming into the village. The storm burst with all its fury on the south-eastern flank of Ingleborough.

The stream that drains that area runs through the village of Clapham. The valley is dammed close above the village, to form a small tarn. This soon felt the flood, but, of course, the equalising effect of a lake upon the stream below it prevented our realising the tremendous rainfall for a time; because, before the stream could be raised six feet as it flowed out of this lake, the whole area of the lake had to be raised to that extent. But very soon this was done and the arch was filled, and a great spout of turbid water was projected forward on to the rocks at the base of the dam above the church. I went up the valley round the lake towards the celebrated Ingleborough Cave. It was a striking scene. Water spurted out of every crack and joint in the rocks, but the united subterranean watercourses could not carry it all, and the overflow from the drift-covered country above the usual outfalls rushed down the valley, carrying mud and boulders with it in its headlong course. The stream below the cave runs over bare limestone for a considerable distance, and the noise made by the boulders, as they were rolled along the rocky floor, was so great that my companions thought the thunder-storm was beginning again, and hurried home. I went on to the great cave. Here I saw a wonderful sight. The lower cave was full, and the water was spouting out of the upper cave, which is usually dry, as you pour water out of the mouth of a kettle; and well it might, for, if the swallow-hole that feeds it was full to overflowing, it had had the pressure of more than eleven atmospheres upon it.

This was one of the most instructive geological phenomena it has ever fallen to my lot to witness. Here I saw what was, to all intents and purposes, a local cataclysm. Gentle slopes of pasture, where usually no stream ran, were suddenly gashed by a torrent, and the débris swept far away across the

lowlands. Underground passages, high above the present water-channels, were swept clean by the body of water forced through them under enormous pressure. Caves that had been sealed up for years with barriers of stalagmite, which one would have thought might have defied the rush of any flood, were burst open. Most of this débris—all, in fact, that was moved by the first rush of water—was carried down the valley. Some remained around the mouth, and some in embayed corners in the caves. Here we saw fragments of stalagmitic floors, mixed up with débris washed in from the swallow-holes above. Some might have seen here evidence that, after the cave had been formed and occupied and gently filled by earth, and coated and partitioned by stalactite and stalagmite, there came an age of flood,—perhaps of submergence,—when the old deposits were re-sorted, the old floors broken up, and that the cave then entered upon another phase of its history. How different the facts! I saw this revolution taking place. It was all over in three short hours. It was another illustration of the great law of Uniformitarianism, which I have heard the Duke of Argyll well state thus: *Local catastrophic action is not inconsistent with continuity of causation.*

We must bear these things in mind when we are examining cave-deposits.

The peat torn away from the mountain-side above was so beaten up in this great natural churn that the water of the tarn did not get clear for months. The sediment did not settle for three weeks in a long glass which I filled during the flood. There must have been a layer of fine carbonaceous clay formed over the bottom of the tarn and in many a deep cave-pool after that storm. When the rain ceased, the water soon ran off the mountain-side, and I went up to examine Gaping Gill, the great swallow-hole that feeds the cave. I found a passage opened out among some blocks on one side of the stream a little above the chasm. I thought I might perhaps find a zigzag descent, which would lead me down into Gaping Gill Hole. So I crept in.

I soon got beyond the light, and therefore took the precaution of throwing stones in front of me before I advanced. I found the slope increased rapidly, and then all of a sudden the stones dropped into a deep hole, down which they whirred, knocking the sides here and there till they dropped, with a booming noise, into deep water below. I wriggled out, and returned another day, with friends and candles and string, for I could not drop the stones straight so as to clear the sides, and so estimate the depth by the time they took in

falling. Sometimes the weight I attached to the string was too small, so that the increased weight of the string itself, when wetted by the splash of underground waters, prevented my being able to judge whether my plummet had touched the surface of the water below or not. Sometimes the jagged rocks cut my string, and I lost hundreds of feet in this way. At last, however, I got the right sort of string and a convenient weight, and I found that the water here plunged into a vertical hole 360 feet from the grass-covered turf above.

This was not, however, the principal chasm, and I saw a curious sight on the southern, or lowest, face of the great chasm beyond: it was battered and bruised as if it had been bombarded for hours, and so it had. In that flood hundreds of boulders, carried forward by the rush of water, were hurled against the opposite face of rock, and then, dropping into the great chasm, were hurried away through the subterranean watercourses and caves down to the valley far below, where they still rolled on with a noise like thunder over the smooth, rocky bed of the stream, till arrested when the velocity of the water was checked in the wider spaces, or finally stopped in the little tarn below.

Here was the whole story of the formation and infilling of limestone caves, and the sudden breaking up of all the older deposits and the return of tranquil deposition, to be read in Nature's clearest writing.

First we saw the results of the chemical action of the acidulated water running off the peaty moor, and opening out the crevices in the jointed limestone.

Then there was the mechanical action observed on a grand scale in storm,—the boulders and pebbles pounding away the solid rock. And next there were the sand and mud left as the water subsided, and the old state of things returned.

Another curious fact I noticed, which shows how the fragmentary rock is rubbed down into mud by the action of running water. There was a fetid smell arising from this flood water, such as the people about there said they had not perceived before. I followed up the stream, and noticed a great quantity of black sand throwu down here and there along its course. This was derived from the bituminous limestones of the lower part of the Yoredale rocks and the upper part of the mountain limestone, and I at once suspected the cause of the smell. When I rubbed a handful of this sand together there was the same fetid smell at once produced. The air tangled in the seething flood was carried down the valley, and, when released, gave off the gases caught up from the pounded rock.

As we cannot follow these watercourses down from above through all their subterranean wanderings, let us go down into the valley below where the water comes down, and see if we can work our way back into the hill towards the foot of the great chasm, and see what is going on there. It is here we find what is more properly a cave being formed. The water drops from one level to another, then runs along between the beds, and drops again. By putting your ear to the fissured rock in one place, you can hear, from the deep recesses of the earth, the sound of a waterfall that man has never seen. Not far off, a beautiful clear river flows out of the lower cave. This is 600 feet below the swallow-hole, where the water enters on the hill above. When the rain floods the stream above, this, too, runs turbid. Some 20 feet above it is the entrance to the other cave, the celebrated Ingleborough Cave, a more ancient outfall for the water, which now runs at the lower level.

This cave was explored many years ago by Mr. James Farrer. I have followed it for about a quarter of a mile, and, with some others, been let down to a lower level at the end. We squeezed our way along till we came to a long, deep cave, full of water, which seemed to flow gently towards the mouth of the lower cave. In the great flood of 1872, all the subterranean caves and fissures were filled, and the water spouted out of the upper cave, carrying along with it great masses of rock, which helped to break up the stalagmitic floors and barriers. This flood was so exceptional that most of the débris was carried clean away; but we saw, when we examined the ground round the mouth of the cave, and the well-known passages inside, what had been going on; how stalagmitic floors had been undermined, broken up, and re-deposited, and how the torrent débris was sometimes left in the embayed corners of a limestone cave. But this was a cave not far above the existing watercourse. When a cave has been formed in the side of a rapidly-deepened gorge, where, however high the flood may rise, the water can never sweep it out with a rush, gentler processes of denudation and deposition still go on. The débris that falls about the mouth ponds back the rain, and gathers in the fissured rock, and turns in the rivulet that would have trickled down the hill. The damp clay clings to the rock and frets away its surface, and things washed in work their way down along the face of the opening, gradually-weathered limestone, and lie in clay washed down with them.

It is easy to distinguish the chemically-fretted rock from that which has been worn, smoothed, and rounded by the

mechanical action of the sand and pebble-laden water; as you can distinguish the pholas-bored rock from that in which the holes are due to weathering. On the chemically-weathered surface the less soluble grains and bands stand out. This is a useful test.

When any partly-closed cave is invaded by periodic rushes of rain-water, the débris is carried down from above through fissures, or washed in from the mouth, and so we find re-sorted drift and the material of the rainwash from the surface-soil outside the cave occurring also in layers in the cave; and if the cave happens to be occupied by wild animals when not flooded, we find their bones and the remains of their food scattered over the floor or buried in the rainwash.

But when the turbid water fills a pool in the cave or a pond outside it, and the mud is allowed to settle down quietly, the coarser falls first and the finest last. Then the water evaporates or soaks through the sides, or perhaps remains clear and tranquil till the next rain carries in a flood of muddy water. The deposit so formed will have a tendency to split along the layers of coarser sand or loam which first settled down after flood; that is, it would be a laminated clay. As long as the pool was about the same depth, and the amount of mud carried in suspension in the water was the same, the thickness of the laminæ would be practically the same, representing just the mud in one pondful of turbid water, whatever the interval between the refilling of the pond might be. The turbid water may come from the bottom of a glacier, or from melting snow, or from a heavy rainfall; but it certainly has no necessary connexion with glacial action. We see laminated clay so formed commonly in the corner of any old quarry, in ditches, or in caves.

In Chapel le Dale, a valley on the west side of Ingleborough, there is a beautiful chasm which has been so opened out by the action of the torrent that you can get down to the bottom, where the water plunges on to a bed of broken rock and pebbles, through which it passes, as through a sieve or very coarse filter, into the water-courses that carry it off down Chapel le Dale. This great chasm is probably a fair representative of all the large swallow-holes. Hull Pot and Hunt Pot, on the flanks of Whernside, are of the same kind. Probably there is in Gaping Gill somewhere a place where the water in ordinary weather filters through coarse gravel, for I have sent down many boards with a notice on each that I would reward any person who brought it back to me, but I have never heard of one of my notices being found. Yet at times great boulders do get through, so it may be that the

paint of my notices was destroyed in the subterranean waterfalls and rapids.

These chasms or funnel-shaped holes are the feeders of the caves. They are only vertical caves formed in the horizontal surface of the rock. They are known as Swallow-holes, Pot-holes, Sink-holes, and in Italy as Dolinas. They have various local names, expressing the idea that they are not part of the more regular and common operations of nature: the Devil's Chaldron, as in French, Chaldrons du Diable, Marmites des Géants, Bêtoires, or, more simply named, they are the Katabothra of the Greeks.

They begin sometimes under the covering of drift, and, when the opening grows too large, or the covering soil is sodden and will not hold its own weight together, the surface breaks in. Mr. Haythornthwaite, of Kirkby Lonsdale, told me that on a farm of his above Wethercote Cave, after wet weather, he once saw one fall in.

How swallow-holes are formed in chalk has been described by Prestwich.*

The age of the cave-deposits is quite a separate question from that of the caves themselves. The formation of the caves was a time of destruction; but the infilling of the caves belonged to a time of accumulation—when there was no great scour through the caves, but the rain carried in earth and stones, if there was loose drift above, or only muddy water if the cave was nearly closed, or perhaps nothing was deposited but the fine unctuous clayey residuum of the chemically-decomposed limestone itself. Angular fragments disengaged by frost or heat formed a barricade about the mouth. Bones were washed in or carried there by beasts of prey—and man. Buckland† referred most of the caves that he explored to hyena-dens. Constant Prevost‡ thought the bones that occurred so thickly in the cave-earth in Franconia were all washed in by torrents. This explanation will hold only in exceptional cases. The bones may have been washed from one part to another of a cave, and a few do get washed in from above. I have seen three sheep being carried down towards a swallow-hole, and have found two drowned rabbits and some dead trout on the gravel at the bottom of Hunt Pot, on the flanks of Whernside. But we never see the ground so covered with bones of various animals that a flood

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* *Q. J. G. S.* vol. x. 1854, p. 222.
† *Reliquiæ Diluvianæ.*
‡ *Mem. Soc. d'Hist. Nat. Paris*, t. iv.

would wash them into caves and form an ossiferous deposit like that in the caves of Franconia.

There can be, however, no general explanation for all bone-bearing caves. We must examine all the evidence in each case, and then form our opinion as to how a particular bone-bed was formed. Buckland's view seems to me to be in most cases the correct one.

So are caves formed and modified, and filled and swept clean and filled again, and we must bear all these facts in mind when we attempt to read the story of a cave from the deposits which we find in it.

Broken-up stalagmitic floors are not evidence of the action of the sea, but, on the contrary, must generally be referred to land floods.

Laminated clays are not evidence of glacial action, but only of alternations of muddy and clear water, such as follow rainy and fair weather.

Some of the most interesting caves, in respect of their contents and the light they throw on the history of primæval man, are only rock-shelters—abris—such as are seen in the Dordogne district.* They are sometimes longitudinal sections of parts of subterranean watercourses, but are more commonly due to the weathering away of soft rock between two harder beds. It does not always require a stream or direct rainfall to wet the surface of a rock sufficiently to let the frost act upon it. The travelling moisture of the air, condensed in and on the cold rock, is enough, and is probably the chief agent in case of a rock undercut so far that the rain cannot touch it, just as Rendu† explains the film of ice upon the snow at high elevation not by the melting and refreezing of the snow, but by the condensation of the little moisture left in the air which comes in contact with the snow in those high regions.

The carbonate of lime of the limestone is removed by the water and carbonic acid; but whither does it go, and what becomes of the earthy residuum which forms so large a part of some limestones? These can also be traced, and furnish us with evidence of another kind that this subterranean chemical denudation is going on. When the acidulated water falls upon chalk, for instance, and, instead of being collected into rivulets, acts over the whole surface, we find a great mass of red clay, full of flints which have been weathered out. A great part of this red clay is the insoluble portion of the chalk. All limestones have a good deal of iron

* Lartet, Christy, and Jones, *Reliquiæ Aquitanicæ*, 1876.
† Rendu, *Théorie des Glaciers*.

in them. When the limestone is weathered away and the iron is oxydised, it colours the earthy residuum red. So cave deposits are often red. When the same process has been carried on at a considerable depth, as, for instance, over the surface of the chalk where covered by the lower Tertiary deposits, the residuum is unoxidised and green.* The carbonate of lime has been carried away in solution, making the spring and river water hard, lining all kettles and boilers with fur. At the mouth of a cave or a spring-head in a limestone district, where the water first gives off part of its carbonic acid, down goes the carbonate of lime which the water can no longer carry, and coats the moss and grass, and anything on which it can collect; and thus we see in petrifying springs only a proof that the chemical waste, which, under certain conditions, forms caves, is going on continually.

The quantity of travertine thrown down in some districts is enormous. A great part of Rome is built of this, the Lapis tiburtinus, so named from Tivoli.

In caves, as the water gets towards the outlet, the carbonate of lime is precipitated round the edge of a pendent drop or on the margin of some tranquil pool, or, instead of the water eating away the walls of the cave, it coats it over with stalactite, and so protects it from further waste. In doing so it frequently closes up altogether the fissures through which the water once ran. So it grows here, stops growing there; is laid on thickly in one place favourable for its rapid precipitation,—as, for instance, where the water is splashed over the surrounding stones and aërated at a waterfall,—while it takes ages to form a thin film in another adjoining chamber. When the great storm of 1872 broke up the floors at the mouth of Ingleborough Cave, I saw modern ginger-beer bottles which had been buried a foot deep in the stalagmite. On the other hand, Pengelly records that names cut on the walls of Kent's Cavern as far back as the beginning of the seventeenth century† are only just varnished over, as it were, with a thin stalagmitic coating. From the nature of the case this travertinous deposit must be of extremely irregular accumulation, and it is of no value as a measure of the age of the deposits which it covers. On the spray-moistened blades of grass or moss evaporation is rapid, and the travertine soon forms a thick

* *Q. J. G. S.* 1866, p. 402.

† Pengelly, *Brit. Assoc. Reports.* Kent's Cavern Committee, 10th and 11th Report, 1874, 1875.

porous mass; and inside the caves there is a difference in the quantity of water that trickles over different parts, a difference in the amount of carbonate of lime in solution in the water, and a difference in the rate of evaporation and giving-off of the acid gas.

Most of the leading facts with regard to caves and cave-deposits were noticed by Dr. Buckland, and clearly told in his interesting book, the *Reliquiæ Diluvianæ*. We must remember, of course, that he wrote that work to support a theory, and so, when he gets to the description of the gravels, &c., associated with the cave-deposits, either in or near the caverns, he sees in them the evidence of a short and transient, but universal, flood. But he quite realised the long sojourn of the beasts of prey in the caves, and the many generations of animals that furnished them with food. He says that he had estimated that in some of the German caverns the bones found indicated ten times the number of individuals that could in the flesh have been crammed into the cave. He spared no pains in gathering information as to the habits of the modern representatives of the hyæna and other animals whose remains occur in the deposits; and his graphic description leaves little to be added. It is interesting to read his ingenious inquiries into the cause of the polished and worn bones which are found in these old hyæna-dens, which he refers to the trampling of the animals on the fragments as they lay partly imbedded in the muddy floor; pointing out, by way of illustration, how some objects of reverence, in stone or metal, have been rubbed down by the touch of devotees. He probably had in his mind the toe of the bronze statue of St. Peter in Rome, which has been polished and worn by the lips of the faithful.

Buckland's view, that the deposits of the celebrated Kirkdale Cave, and other similar caves which he refers to, would be connected with a great submergence, which he identified with Noah's Flood, was not, however, so wild as we are sometimes inclined to think, in our eagerness to assert the independence of such inquiries from all preconceived ideas or theological tenets. There certainly is evidence in many places along our coasts of small depressions since the occupation of those districts by man, and it is extremely probable that the land had not, at any rate, recovered its present elevation in this country after the greater submergence that followed on the Glacial age, before man appeared on the scene.

There is a great deal of evidence of torrent-action in these caves. There are marine shells washed into them and buried in the same earth as Palæolithic man and the extinct

mammals. Buckland's view was, as I believe, far more nearly in accordance with facts than the views of those who have argued for the pre-Glacial age of some of these caverns, which contain only the later group of early Pleistocene mammals. It agrees with the view that there has been a great submergence since the occupation of some of the known Pleistocene caves, but is less wild than the theory that the deposits of that submergence are Glacial because they contain a large percentage of material derived from older Glacial deposits. I have already combated the view that the contents of the Victoria Cave * were pre-Glacial, and I have recently† examined the evidence upon which the theory that the contents of the caves of Ffynon Beuno were pre-Glacial because they were anterior to the submergence which followed the Glacial age. This view was far more untenable than that of Dr. Buckland, for its advocates held that if the sea of the last submergence washed the mouth of these caves after they had received the deposits containing the Palæolithic remains now found in them, that in itself would constitute a proof that those remains were pre-Glacial.

It is a very curious thing that, although we find such abundant evidence of Palæolithic man in caves as well as in river deposits, there should be so few remains of his bones. Perhaps it was because such little care was taken of the dead that all traces of them were soon destroyed by beasts of prey. However, the fact remains; and, therefore, it is of great importance to inquire into any alleged occurrence of human bones of Palæolithic date. One such announcement was made some years ago, when it was reported that a whole human skeleton had been found with the remains of the mammoth and other extinct animals in a cave on the coast near Mentone. The skeleton was brought to Paris, where I saw it. In a photograph which was shown to me soon after the discovery there were two Neolithic implements lying beside the body, but these were not exhibited with it in Paris. The body was lying on its side in a red earth, with few fragments of any kind in it. There was a quantity of oxide of iron about the head, which might have been the remains either of ornaments in pyrites or of a pigment formed of reddle.

Some years afterwards I had an opportuity of examining the place where it was said to have been found, and of con-

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* *Trans. Vict. Inst.* March, 1879, vol. xiii. p. 316.
† *Q. J. G. S.* (Nov. 17, 1886), vol. xliii. 1887, p. 73.

versing about it with M. Bomfils, who was there at the time it was discovered. The cave is one of several which occur east of Mentone in the Limestone Rocks, known as Baousse Rousse, the Red Rocks. The cave was partly filled with cave earth and angular fragments of limestone fallen from the roof and sides. In this the skeleton was found, as far as I could gather, *interred*. I learned that the implements which I noticed in the photograph had not been found with it, but had been put in to make a better picture. It appeared that, though found with the bones of the extinct mammalia, it was not Palæolithic, but buried among them, and so it may have been of any subsequent date. The evidence, however, which appeared to assign its more probable age to it,—namely, Neolithic,—was unfortunately of no value, as the implements were not found with the skeleton, but only placed by it to make a more interesting photograph.

Some caves, like that of Adelsberg, about twenty-six miles east of Trieste, open out into grand halls draped with stalagmite and sparkling with crystalline incrustations. One of the chambers measures 665 × 640 × 100 feet, and in another, on every Whit-Monday, a great ball is given. The work of excavation is still going on here, for a river empties itself into the cavernous rock below the entrance to these grottoes, and is heard roaring in the deep recesses far within the cave.

In other cases, instead of such vast halls, we find a more immense extent of galleries, as in the Mammoth Cave of Kentucky. Both suggest a great lapse of time. In this it is estimated that there are about 150 miles of underground passages. All the drainage of that area drops into great swallow-holes which join the general network of subterranean channels. In them a uniform earth temperature of 54 deg. Fahr. is maintained. No frost and thaw aid the denudation there. As long as the area drained has been unchanged and the amount of acid in the water has not varied, the rate of waste has probably been the same; and though we cannot offer any numerical estimate of the time it has taken to remove so much rock in this way, we cannot help feeling that it must have been very long.

If we turn to the fauna of this cave, we get a peep at Nature carrying on some of her most mysterious work. Here we find animals modified to accord with their surroundings, organs unused being atrophied and lost. Where there was no light, they could not see. So many of the insects, crustaceans, and fish are blind. The wild spring and headlong flight of the grasshopper would be dangerous in those dark recesses. The poor insect would dash against the rock or

drop into some treacherous pool. So nature deprived it of wings, and, instead, lengthened its antennæ, so that it could feel in time to save itself when, with less impetuous leaps, it came against an obstacle.

Do these changes also point to a great lapse of time? or may we believe that among the lower forms of life, and those in which the generations follow one another most rapidly, these changes also may be much more rapid? There is nothing in the nature of the case to show that evolution must be slow. If forms of life are modified by their environment, the rate of change in the organic being *may* yet be slow; but, as far as we can see, it often is very rapid. What an opportunity for studying such questions. An animal, the type of liveliness—the sunny grasshopper, the flying ruby emerald or topaz—is plunged at once and for ever into the darkness of earth's innermost recesses. No need of wings, where it dare not fly; no use for eyes, where it cannot see; no advantage in gorgeous hue, where there is no light to be reflected. What will become of it? Nature cuts off its wings; nature blinds its eyes; nature washes out its brilliant colours; but, in compensation, gives it means to guard against its new dangers by lengthening out its antennæ, to let it feel its way about.

If this process is still going on, what will it come to? Does it go on indefinitely throughout all nature, or are there limits of evolution for all, or its own limit for each form? On the one hand, from analogy we learn that we must not assume, because development goes on constantly within our short experience, that it must go on in the same way indefinitely. Were a being from a treeless planet to visit our earth and report upon what he observed of the growth of an oak, he might record that the tree developed in the same way each year—bud, leaf, flower, fruit; and that twig, branch, and bowl grew in proportion; and the roots shot out downwards and sideways, seeking, with what looked almost like intelligence, the best-suited soil. He saw no reason why it might not go on for ever while our earth could bear it. How different the fact. The oak tree has its term of life. So may species, for aught we can at present certainly say, have their term of life. But what determines it? Again, I appeal to analogy not as an argument so much as in illustration. Fairy-rings on the grass are the annular spaces on which a certain fungus grows. This fungus scatters its spores all round, but they will grow only on the virgin soil outside, and, as they will not grow where they have grown before, inside the ring the species becomes extinct.

But plants help one another. A forest creeps along the hillside and the vale, destroys the life that will not grow below it, but itself exhausts the soil, and in time perishes, having, however, renovated the soil for other plants which were kept out so long. In the four and six course farming man recognises this. Many diseases are but growths which creep across the world, feeding upon the constitutions that favour them, and then die out. Could we but destroy the seed that lingers somewhere to spread again over an earth peopled by new generations.

Shall we say, then, this is the difference? The individual has a term of life measured by the vitality inherent in himself, which cannot be wholly renovated.

The species has no limit to its life, save that imposed by its surroundings, which, however, it renders unsuitable by using up that on which its life depends. This, however, can be renewed. But will the same life be there to take advantage of the renovation? That is the question in each case.

The dying-out and migration of species thus becomes only the outward growth of the *fairy-ring*.

The incoming of new species only the appearance of the wingless, colourless grasshopper in the Mammoth Cave.

The CHAIRMAN (H. Cadman Jones, Esq.).—I presume I need hardly put it to the Meeting that we should return our thanks to Professor Hughes for his very interesting paper, which it has been a great pleasure to listen to. After some communications have been read, it will be open to those whose studies have lain especially in the direction of the subject taken up to commence the discussion.

Captain FRANCIS PETRIE, F.G.S. (the Honorary Secretary). Among the letters received from those unable to be present this evening are the following. The first and second are from the Duke of Argyll and Professor Hulke, F.R.S., mentioning that they have read Professor Hughes's paper with much interest, and adding that they have no criticisms to pass upon it. The third is from Sir J. William Dawson, K.C.M.G., F.R.S. :—

"McGill College, Montreal,
"*March* 16, 1887.

"I beg to thank you for your kind communication of an early copy of the interesting paper by my friend, Professor McKenny Hughes, on Caves. I am glad that Professor McKenny Hughes is applying his well-known acuteness and discrimination to those modern deposits which have given rise to so much somewhat crude discussion and speculation. His paper on the Drifts of the Vale of Clwyd * I regard as one of the most valuable we have recently

* *Quarterly Journal of the Geological Society*, February, 1887.

had, and especially so as placing the drifts of Wales more closely in relation with those so widely distributed in Canada, than heretofore. In the present paper he has very clearly illustrated, in the case of Ingleborough Cave, the fact that true uniformitarianism in geology includes local and occasional catastrophic action. This I regard as of the most vital importance to geological reasoning, and especially in the explanation of cavern deposits and river gravels, which, more than most other formations, are liable to be affected by violent and paroxysmal local *debacles*, as well as by apparently capricious accidental changes. The utmost caution and the most careful and minute observation are necessary in dealing with these deposits, and in estimating their ages and their relation to the human period.

"With kind regards,

"I remain, yours truly,

"J. WILLIAM DAWSON."

"Captain Francis Petrie."

The Rev. J. Magens Mello, M.A., F.G.S., writes:—

"I am very sorry that I am unable to be present at the reading of Professor McKenny Hughes's paper this evening. To the greater part of it I have nothing that I could add save in the way of corroboration from personal observations of similar instances. But I have the very strongest doubts whether there can be any trace whatever left in our caves of the Noachian Deluge, even granting that catastrophe involved our islands, which I am hardly prepared to admit. My own experience of British caves, both from observation and from reading, tends to show that the contents of, at any rate, most of them have been the gradual accumulation of a long series of years, during which they were occupied partly by beasts, partly by men, and that there is no evidence whatever to be found in them of so sudden a cataclysm as the Great Flood, the historical character of which is, however, abundantly confirmed by overwhelming proofs of various kinds."

The Rev. Dr. Walker, F.L.S., says:—

"Dun Mallard, Cricklewood,
"*February* 19.

"On p. 96, Professor McKenny Hughes speaks of the appearance of 'the wingless, colourless grasshopper in the mammoth cave.' I should be glad to be informed whether or not the *same* species, winged and coloured, is found outside the caves in broad daylight? If not, the inference would seem to be that the grasshopper in question had originally been created sightless, to fit it for its natural surroundings, and not have gradually become so through the unused organ being atrophied and lost. As it is inconceivable that any particular species would survive in the dark cave, and have disappeared long years since in the open air, where all the conditions for supporting and prolonging existence are so much more favourable. Lastly, short antennæ and the possession of wings are not the characteristics of *all* grasshoppers living in the light, as I can prove by species captured by myself and in my own collection."

Also a letter, just received, from Sir Charles Warren, regretting that he is unable to be present, as he had intended.

Sir WARINGTON W. SMYTH, F.R.S.—In response, sir, to your invitation, I have much pleasure in saying that I am sure the paper we have just listened to must have been a great treat to the whole of us. My friend, Mr. McKenny Hughes, the Woodwardian Professor of Geology at Cambridge, has had an unusual amount of experience in hunting up and examining caves, and I may state that, having during a series of years had opportunities of exploring several of those he has mentioned, I feel particularly indebted to him for the graphic account he has given us of a district and cave I have not seen. I shall not attempt to follow him into the difficult region into which he has been carried by the wingless grasshoppers of which he has spoken,—a part of the question which we may look upon as separated from the earlier portion of the paper. I desire only to express to him the reasons why I feel especially gratified with some of the points he has put before us in describing the modes by which caves have been formed and the manner in which they have been filled by various kinds of material. I recollect that in my earlier days of geological study I was surprised to find that a former generation of geologists—I speak especially of Professors Buckland and Sedgwick and their continental contemporaries—set very great store by the examination of caverns, and entered not only into a series of explorations, but of philosophic considerations, of a most interesting character, on this subject. Indeed, I do not know that anything more interesting can be pointed out than the work by Professor Buckland, of which Professor Hughes has reminded us,—*Reliquiæ Diluvianæ*,—although it is, doubtless, true that the theory on which he relied so much at the time he wrote that book is now very much discredited. The descriptions he gave with such admirable freshness of the different caves he visited and the facts he submitted cannot be studied by us without great advantage. I had the happiness, when a young man, of making a tour into that part of Franconia in which Dr. Buckland particularly delighted, and of seeing some caves in the neighbourhood of Muggendorf, which he made a special locality; and the impression formed in my mind coincided with his view as to the filling of the caverns in that part of the world by a succession of cave bears with the bones of animals which they had dragged in, so that in process of time they became a rich harvest to the geologist, who, on taking up the stalagmite which covered the cavern floors, found the bones of those animals embedded in it. I remember being greatly struck with a cave high up the side of the Muggendorf Valley, where it was clear that the hollow had been formed by the action of water containing carbonic acid, and that some of the bones discovered there must have come in by accident from openings above. In fact, the bones of two human beings were found in that cave underneath the chasm through which they had evidently fallen. The same thing has been impressed on me most forcibly in the district of Cross Fell, Cumberland, where, having, some few years ago, had occasion to be frequently crossing

the mountains, it happened that, being short of time, I was sometimes so pressed that, after I had left the railway at Penrith, in making my way over a place 1,000 feet high to my shooting-box on the middle of the moor, I was overtaken by darkness before I could reach home. I had observed how amenable the district was to swallow-holes. Very often, where there was only a thin covering of sandy rock, there was, at short distances from one another, a succession of caverns hollowed out of the limestone stratum, and these becoming enlarged had given way at the top and fallen in so as to leave a crater-like opening. One night, when it was pitch dark, I came suddenly upon one of these craters, and tumbling head over heels picked myself up at the bottom. I then found that I was very near a little hole through which water was trickling, and when I got to the shooting-box I found, on putting my hands in my pockets, that they were full of moss; so that I felt sure I had had a complete capsize. It struck me that, supposing I had broken my legs and had been left there to starve to death, my bones would probably have been carried by the water through one of the openings in the rock into a limestoue cavern beneath. Thus it seemed to me that at times small bones may have been introduced into caverns through these openings above, and at others, bones of the larger animals may have got in through the chasms we find in the rocks. There is the Plymouth limestone again, which often, through quarrying operations, has been the means of presenting to us the bones of lions and tigers and a number of other animals which at the present day are strangers to anything like our latitudes; but I will not detain you by going into this branch of the subject. I may say, however, that what has been put before us in reference to the Ingleborough and other caves teaches us a very important lesson. I was rather astonished by what the author of the paper told us as to the stalagmitic floors being forced up by the action of a very heavy flood of rain water, and I cannot help seeing therein one of those difficulties that are exceedingly apt to puzzle tyros in geological inquiry. I have always felt that the examination of these caves ought to be conducted with the very greatest care and caution, and that the question of their formation and contents was a matter requiring to be dealt with by the most experienced geologists; because, when we come to the breaking up of stalagmite floors and the bones embedded in them, it stands to reason that conclusions of the most dangerous kind may easily be arrived at far too hastily. Whether one refers to caves that are to be found on the sea-shore or to caverns met with in the inland limestone districts, there are on all sides a great many subjects to be considered in forming our conclusions. I cannot help referring to one peculiarity in regard to caves, which, perhaps, Professor Hughes has not seen, but which I have noticed in a district to the east of Ingleborough, namely, at Swaledale, in the locality of Grinton Moor, where one finds on going through the caves the joints in some of the beds are enlarged in a curious fashion. The caves there, where the miners find the most valuable lead ores, are longitudinal, and present appearances so numerous, and so

obviously showing the results of the very long continued action of subterranean streams, that one is puzzled as to what has occurred there, and at a loss to connect what is seen with those great bodies of water which may through the weathering of the limestone, have washed everything out. There no boulders are to be seen—nothing but the most beautifully fine dolomitic sand and crystallised lead ores, sometimes showing in large masses, like sides of bacon. In the Forest of Dean there are similar openings, where a valuable iron ore is found, the other materials in these caves also being almost entirely dolomitic. I should like to hear from Professor Hughes whether he has observed anything of the kind at Ingleborough. Here let me say that I think one of the most important lessons we have to learn is, the great caution that ought always to be observed in seeing that our observations are made with scientifically systematic precision; and, in the next place, in only accepting statements that are made as to these matters when they are founded on exact work of this kind, undertaken by experienced persons, well qualified to judge of the mode in which cave-openings have been formed as well as of the mode in which they have been filled.

Mr. J. STALKARTT.—I should like, in saying a few words on this subject, to know whether the history of the tigers and hyænas, whose remains are found in the caverns spoken of, is different from that of the tigers and hyænas now existing in different parts of the world? Ordinarily, when a tiger or hyæna kills any animal he does not drag it into a cave, but eats it where it has been seized; it is only when it has young to feed that it drags the carcass to its den. A lion does not carry its prey up a mountain side; it lies in wait near the track of the animal it kills, and there takes its fill. The hyæna might drag its prey down a hill, but would hardly drag it uphill. We know that in India these animals kill and eat their prey on the spot, only sometimes carrying their prey a short distance. They may quarrel over the remains, and drag pieces hither and thither; but, for the most part, they eat where they kill; that which they leave is chiefly the head. Suppose a bullock that has died a natural death is found: the jackals quarrel over it; a leg is drawn here, and another there, but the greater portion of the carcass is left, and the head, which they cannot gnaw, invariably remains. Therefore, I am not inclined to believe that these caves were the resort of hyænas in the manner alleged. I think we ought to inquire into the fact whether the hyænas referred to by geologists had habits differing from those of similar animals at the present day.

Mr. S. R. PATTISON, F.G.S.—I take it that the hyænas spoken of as found in caves were not only inhabitants of those recesses, but made incursions in search of prey. In Somersetshire the existence of the lion is too well attested to admit of any doubt, and the fair inference from the bones found in the caves is that they were dragged there. It is, however, by no means certain that all the hyæna and other bones found in caverns were those of animals dragged in: doubtless many of them are those of

animals that died a natural death where they are found. I am sure we ought to be thankful that Professor Hughes, during his Ingleborough explorations, was able to escape being made a martyr to science; for I can understand, having travelled those moors myself, how easily an accident of a serious nature might have occurred. As to the paper this evening, it fully bears out Professor Hughes's promise to tell us all about the operations of nature in forming and filling these rocky caves; and not only has he kept his word in this respect, but he has given us a graphic and picturesque account of the exceptional meteorological circumstances which sometimes act as factors in these transactions. With regard to the glacial period, it may be gathered that there was first of all a glacial period; then a pluvial period which has been slightly referred to as that of a Deluge; then the period in which there was the final subsidence of the land and the accumulation of modern gravels which we now behold. The controversy arises as to whether the animals whose bones are found in the caves lived before the glacial period or afterwards. What I have to say on this point is that the glacial period is really a sort of sliding scale. Its effects may have been felt at one spot and not at another at the same time, so that there must have been constant wasting at one time and place and constant accumulation at another; the result being that life may have made its appearance, and then its evidences may have been mechanically covered up by the changes. The subject is one of extreme difficulty, and I should say it is impossible, as far as dogmatic assertion goes, to say much more than this. I quite agree with Sir Warington Smyth that these matters should be dealt with by geologists with the utmost caution, especially with regard to the conditions of life during the glacial period. With regard to the animals found in the Kentucky Cave, Professor Hughes thinks that certain of the features to which he refers in the case of those creatures have been modified by their surroundings; but the fact is that there is no trace of modification, for, as far as our knowledge goes, the features there remarked have always been the same,—the long antennæ and absence of wings in the insects he alludes to having been constant. Consequently, I cannot see the force of producing these as proofs of evolution. Then, as to the mushrooms in the fairy rings, which, it is said, are prevented from growing inside through the material being exhausted, so that there the species become extinct; I submit that the species does not become extinct. The individual dies, but not the species; and, although it may be speculated on as a theory, we have no instance of a species dying out in that way. I will not now enter iuto any argument upon the point, but simply claim to enter a *caveat* against it.

Mr. D. Howard, V.P.C.S.—It seems to me that the paper to which we have just listened is one of exceptional value, not merely on account of the inherent interest of the subject, but from the very useful and sound method of study it puts before us. It was, I think, a most fortunate accident that led

Professor Hughes to Ingleborough at the time of the great storm, the effects of which he has described, because a more accurate and valuable account of that catastrophic incident could not have been furnished. The subject is one of very great importance in many ways. The more we are struck with the continuity of causation, the more must we guard against circumstances which carry the idea too far, especially in regard to questions connected with chemistry, which afford abundant examples of the danger of carrying this theory beyond its legitimate scope. We have many examples of stalagmites forming with perfect regularity, and we assume that the process has been going on from endless time. I have twice seen the Ingleborough Cave. The first occasion was during a very wet summer, when a vast deal of water came down, not in torrents, but with a very rapid formation of stalagmite. The autumn following was very dry, and the stalagmitic formation not so rapid, and I could not help thinking how utterly impossible it must be to form anything like an accurate judgment of the speed of formation when the process was shown to be going on at two different rates. It is not merely the action of carbonic acid in the destruction of the rock that strikes one, but the wonderful way in which the solvent process goes on hollowing out the lime and disintegrating the stone, until some flood occurs and washes away vast quantities of the broken up débris. This is specially the case in the carbonated rocks, where you get a more rapid solution than in other cases; because the rock is honeycombed and cut to pieces in a wonderful manner, so that it goes to pieces with a comparatively small rush of water. Throughout the whole of this question you must bear in mind that a very slight alteration in the balance, whether of the carbonic acid produced by the surface vegetation, or in the proportion of water to carbonic acid, may make a very wide difference in the result. The presence of a little more or less silica in the water may make a vast difference in the mode in which the travertine is deposited. Any one who has had experience in connexion with steam boilers knows full well that you may have it deposited in an exceedingly hard scale if there be a sufficient amount of silica to cement it together; or, if this is not the case, it may exist as an exceedingly soft powder, which blows away directly the blow-off cock of the boiler is opened; in the same way it is not merely the percentage of carbonate of lime that is dissolved and set free by the evaporation of the carbonic acid, but whether there is sufficient cementing action going on to form a solid mass to resist the inflow of the water. One cannot help being struck with the amount of careful knowledge displayed by the author of this paper. He goes back to the most minute forms of things. This is what Lord Bacon did many years ago; but the lesson is one that has not been fully learned yet, although it is refreshing to find that it has been acquired and put in practice by Professor Hughes.

Sir WARINGTON W. SMYTH—(taking up from the table a pipe encrusted with stalagmitic deposit) asked how long it had taken to produce that result.

Professor HUGHES said he was unable to say.

Sir WARINGTON W. SMYTH.—I have seen a pipe as large as this filled up in two years.

Professor HUGHES then replied, saying :—A question has been raised by Sir Warington Smyth as to how the bones got into the caverns. That, question is one that ought to be asked with regard to each cave separately. There is, first, the suggestion that the bones may have been washed in from above. I have discussed this point (p. 90). Or the bones may have been carried in by animals that inhabited the caves; and then we have to consider whether these caves were ever hyæna dens, whether the beasts of the present day behave in the same way as those whose remains are found in the caves appear to have done. Dr. Buckland found that they do. He examined carefully the bones of the animals gnawed by hyænas, and found the marks of teeth on the bones so dealt with, and that those bones which had marrow in them or some little flesh adhering to them have had splinters torn away, or are altogether broken up. Thus, it is clear, from the accumulation of evidence, that hyænas were there, and had dragged in the remains of many of the larger animals which are found lying about. In some cases we find, instead of a mass of broken bones, the bones lie whole upon the floor of the cave. This seems to have been the case where the remains of bears are found ; it is different when we have a hyæna den. It is evident that, in determining these questions, a great many things have to be taken into account. As to the way in which the carcasses are dealt with, we must remember that, when the larger animals have done with them, the smaller ones come in,—the foxes, the rats, and the mice,—all of them pulling the bones about. We trace them by the marks of their little teeth. Thus, you may find the bones drawn up into crevices into which they could not have been carried by the larger animals. Once, at Cambridge, I was shown a set of bones that ought not to have been in the gravels, from which they were said to have been obtained. I went and asked the workmen where they got them. They showed me the place, and told me they were in a sort of hole stretching from one point to another across the corner of the pit. I cleared out and examined the hole, and noticed in it a series of claw-marks, showing that the place had been used by badgers and foxes. Thus we had another example of the way by which the bones were conveyed into places where the larger animals could not have taken them nor water have washed them. Or, again, the bones may be those of animals which died in the cave —bears, for instance. In one case the bats were described as furnishing, in the shape of their own bones, a large portion of the deposit. Thus, it will be seen, we have to go from one thing to another to arrive at the true explanation. Those animals came there, lived there, and died there, and the remains of bats covered the whole of the bottom of the cave. Owls and other birds of prey also bring in remains of animals, as I pointed out in the case of Cave Ha. The same kind of thing has been noticed in America, where in the upper layers of cave-deposits are, in a number of cases, found

the pellets of owls, and lower down the bones of small animals, packing all the interstices. Therefore, it is necessary that in every case we should consider how the bones found in a particular cave got there.

Mr. J. STALKARTT.—They do not eat in caves. We find in India that the tiger will not go into a cave where he has a wilderness or jungle at hand. This is so in the case of the tigers close by the Himalayas; but another tiger, which is rather smaller, and is found on the other side of the Ganges, does go into caves, and has there been shot in the most plucky manner by British officers. If you get evidence from those caves of such a deposit of bones as has been described, then, doubtless, the inference which has been drawn will hold good. It may be that the hyænas spoken of may have gnawed the bones before they got into the caves. When a lion or a tiger has killed an ox or other large animal, and sucked the blood or eaten part of the flesh, the jackals go to the carcass and finish the work, or the vultures assemble and tear it to pieces.

Professor HUGHES.—We have not found traces of the tigers behaving otherwise than according to their ordinary habits at the present time. We do, however, find remains of hyænas in the caves, and, as we are informed, the hyænas of to-day do leave their marks on the bones of the animals they eat, and other traces, just such as are found in the caves, and that, I think, is sufficient. With regard to the glacial epoch, I have confined myself to what has happened in one particular valley, and asked what is the order of events found there, for the glacial conditions found in another hemisphere can make no difference as far as this particular matter is concerned. The record of intermediate forms is exceedingly rare. If we could find in any of these caves a set of deposits representing every stage in the growth of cavern-deposits, we should possibly get all the various developments of the intermediate forms of life; but, not having these, we say that the remains we find are those of creatures which do suit their surroundings, and differ from the nearest allied forms by modifications such as might be carried out according to the laws of evolution as worked out and observed within the limits of our lives. It is one of those cases in which you have an hypothesis founded in the first place on one bit of evidence, and then supported by the comparison of that with another bit of evidence, until you get more and more data added to what was at first insufficient and the foundation of a tentative hypothesis only, and in the end you come to the conclusion that nothing but that hypothesis will fit in with all the observations made. With regard to what has been said about the fairy rings, what I meant was that the plant became locally extinct within the circle, and, if its possible area of growth were limited, and it were pushed to the margin, it might, in the same way, become totally extinct. As to species having died out, I need only mention the sea-cow, the dodo, and the auk.

Mr. PATTISON.—I did not mean it in that way.

Professor HUGHES.—Then, we are agreed. All we have to do is to show

that species do appear under such conditions, that we may say they have been modified to suit certain laws, and that they die away when the surroundings are unsuitable. As to the rate of modification, I will only mention the change in the character of shells produced by the introduction of unfavourable conditions, such as fresh or salt water, and refer to the vast mass of evidence given by Darwin, in his work on Plants and Animals under Domestication.

The Meeting was then adjourned.