more powerful for denuding on the west, where more rain falls, and in glacial periods there would no doubt have been more snow. May not the explanation of these facts be, that the western side has gone up higher within some late period: so that although denudation has gone on, perhaps even more rapidly, upon its hills, they nevertheless remain more lofty, because the altitude requiring to be reduced since that time has been more considerable?

VI.—Supplementary Note on Minerals found in Somersetshire.[1]

By Spencer George Perceval.

Agates are found abundantly in Somersetshire. Dr. Buckland mentions their occurrence at Sandford, near Banwell, Worle, and Clevedon. Trans. Geol. Soc., ser. 2, vol. iii., p. 421. See also Sowerby's British Mineralogy, vol. v., 1817, p. 213.

Copper occurs in a conglomerate quarry behind the village of Alcombe, near Minehead.

Fluor spar occurs at Clifton, in the Great Quarry on the Gloucestershire side of the Avon, in the form of small purple cubes, in cavities of the Mountain Limestone, lined with crystals of Calcite and occasionally of Pearl spar: also on the Somersetshire side of the Avon section.

Bitumen also occurs (liquid and consolidated) in adjoining cavities in the Mountain Limestone.

NOTICES OF MEMOIRS.

I.—On the Formation of Mountains.[2]

By Captain Hutton, F.G.S., C.M.Z.S.

"We must never forget that it is principles, and not phenomena—the interpretation, not the mere knowledge of facts—which are the objects of inquiry to the natural philosopher."—Sir J. Herschel.

The formation of mountains does not very well describe the subject on which I propose to lecture to-night, for, strictly speaking, mountains are formed by rain and snow sculpturing and grooving what would otherwise have been table lands, or the highest portions of the undulations of the earth's surface; but on this subject I do not mean to touch. I propose to deal with the undulations themselves, out of which mountains are carved by the rain.

It is well known that the solid surface of the globe is uneven and undulating, that the lower portions are covered by the ocean, while the higher are called the land, and it has also been proved, by observations extending over nearly a century, that these undulations have changed in form and position over and over again, and that changes are still going on. That the solid surface of the earth should heave and quiver, and sway up and down, is one of the most extraordinary phenomena of nature with which science has made us

[1] See list by H. B. Woodward in Geol. Mag., Vol. IX., March, 1872.

[2] Substance of a lecture delivered in the Colonial Museum, Wellington, New Zealand, 13th November, 1872.

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acquainted, and it is one which has never yet received a satisfactory explanation. I hope, however, to be able to show you that it is but the necessary effect of causes which we know from observation to be constantly going on on the surface, combined with the conduction outwards of the interior heat of the earth.

In order to make what I have to say quite clear to you, I must first briefly refer to some general considerations on the interior of the earth. Fortunately, it will not be necessary for me to enter into the hotly disputed question as to whether it is fluid or solid, for this is immaterial to the views that I have to advance; all that is necessary being that the interior is very hot. This is allowed, I believe, by all scientific men, the proof resting principally on the facts that we know from observations, wherever they have been made, that the temperature actually does rise as we descend, at an average rate of about 1° Fahr. for every fifty feet, and that the density of the earth is so small, not much more than twice that of the ordinary rocks of the surface, that there must be some expansive force in the interior sufficiently powerful to balance in a great measure the enormous pressure to which the interior of the earth would be subjected. Assuming then that the interior of the earth is intensely heated, and that the temperature, for a depth say of fifty miles from the surface, increases at the rate of 1° Fahr. for each fifty feet, it necessarily follows that the outer shell, or "crust," as it is commonly called, to a depth of somewhere about thirty-five miles, has a temperature below the melting point of ordinary rocks at the surface, while all below this depth has a temperature above its melting point at the surface. Consequently, we have an outer crust in which the attraction of cohesion among the molecules is greater than the repulsion caused by heat, surrounding a nucleus in which the repulsion caused by heat among the molecules is greater than the attraction of cohesion.

The outer crust must therefore be more or less rigid, while the superheated interior must be in such a state that if the pressure that keeps it in its place is decreased at one point it will expand, and this expansion will permeate through the whole mass until the pressure is again equally distributed throughout. Conversely, if the pressure is increased on any point, this pressure will affect the whole mass and distribute itself evenly through it. Of course I need hardly say that the rigid state of the crust is not separated from the superheated state of the interior by a marked division, but the one passes imperceptibly into the other. Now each portion of this rigid crust must be maintained in its place by three forces, viz.—its weight, the lateral thrust of the arch, and the outward pressure of the superheated interior. While these three forces remain constant, equilibrium will be maintained, and no movements will occur on the surface. But if one or more of these forces change in amount, the equilibrium will be subverted, and movements of the surface will take place. If also the equilibrium be disturbed at one place, it follows, from what I have said about the distribution of pressure in the superheated interior, that the equilibrium will also be disturbed in all surrounding areas. If, for instance, an upheaval of the crust should take place at

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any point, the underlying superheated rocks, being thus relieved from the pressure above them, would expand and rise up, and fill the hollow; but this expansion would spread through the mass, and would therefore lessen the outward pressure of the interior in all the surrounding areas, which would consequently subside, and equilibrium would only be once more restored when the mass of the subsided areas equalled the mass of the elevated areas. Consequently elevation implies subsidence, and *vice versâ*. Where now must we look for the causes that are in operation to disturb this equilibrium? The most obvious is the radiation of heat into space by the earth, and the consequent cooling and contraction of the superheated interior. This is at present almost universally accepted by geologists as the cause of the movements of the surface and the upheaval of mountain chains, but many arguments have been urged against it, and although I am willing to allow that it must have some effect in producing movements, these effects are, I think, completely absorbed by the much larger ones that flow from causes that I shall presently describe; and it is quite impossible that it can be the only cause of movement, partly because some effect must be produced by the other causes that I have yet to describe, and partly because since the Glacial epoch the earth has been warming instead of cooling, and consequently no contraction can have taken place since then, while we know not only that extensive movements have taken place, but that they are still taking place on the surface of the globe.

The other cause of disturbance of the equilibrium, to which I have alluded, is the removal of matter from one portion of the earth by running water and its deposition on another portion. It is now nearly forty years ago since Mr. C. Babbage, in his celebrated paper, read before the Geological Society of London,[1] on the temple of Jupiter Serapis, proposed a theory to account for oscillations of the surface of the earth, which he called the theory of "the change of isothermal surfaces." At about the same time, Sir J. Herschel, in a letter to Sir C. Lyell,[2] proposed to account for the same phenomena by a theory which he called "the alteration of the incidence of pressure." Both these theories are founded on the same fact, viz. the removal of matter from one portion of the earth's surface and its deposition on another; but while Mr. Babbage laid the most stress on the changes of internal temperature that would be thus brought about, Sir J. Herschel laid the most stress on the change of direct pressure, or weight. These theories have never been taken up by geologists, but I hope to be able to show to you that, when combined, they are capable of explaining all, or nearly all, of the observed phenomena. I have already told you that, owing to its internal heat, the mean temperature of the earth increases as we descend into it at the rate of about 1° Fahr. for every fifty feet. If, therefore, the mean temperature of the surface at any place was 50° Fahr. the mean temperature 100 feet below would be 52° Fahr. If now the surface was covered up by a deposit of clay or sand 100 feet thick, and if its surface retained the same mean temperature as the old one, viz. 50°

[1] Quart. Journ. Geo. Soc., iii., p. 186. [2] Proc. Geol. Soc., ii., pp. 548, 596.

Fahr., the mean temperature of the old surface would be raised 2°, or to 52°, while at 100 feet below it would be 54°, and so on, so that the covering of the surface by a deposit 100 feet thick would raise the temperature of the whole underlying rocks 2°. If the deposit was thicker, the temperature would of course be more raised in proportion. Now we know that rocks expand on being heated,[1] and contract on being cooled, and Colonel Totten and Mr. Adie have shown that this expansion for each degree of temperature is from $\frac{1}{250000}$ to $\frac{1}{100000}$ of the whole, according to the nature of the rock. If, however, the deposit was unconsolidated, like clay or sand, and the particles were free to move among themselves, this expansion would have very little effect in raising the surface; but if the deposit was rigid, like limestone, the effect would be totally different, and the irresistible pressure, caused by the expansion of the rock, could only be relieved by the whole stratum bulging upwards and forming an arch, or more properly a dome; and as we know the rate of expansion, we can calculate what the elevation would have to be on a sphere the size of the earth, for various temperatures and for different areas, in order to relieve the pressure. This is exhibited in the following table, which is part of a larger table that I have calculated.[2] In it the upper line is the thickness in feet of the deposit, while the second line is the temperature due to that thickness. The left-hand column is the diameter, or breadth, in miles of the heated area, while the other columns show the elevation in feet that would take place:

Thickness	500 feet.	2,500 feet.	10,000 feet.	25,000 feet.
Temperature	10°	50°	200°	500°
Breadth, 100 miles ...	1,140 feet	3,700 feet.	8,700 feet.	14,600 feet
„ 500 „ ...	1,550 „	7,220 „	24,200 „	49,300 „
„ 1,000 „ ...	1,570 „	7,700 „	28,600 „	65,400 „
„ 2,000 „ ...	1,900 „	7,800 „	30,700 „	74,400 „

From this table it will be seen that formations no thicker nor more extensive than those that we know to have been deposited, are quite capable of being elevated far above the highest known mountains.

It may have occurred to you that a bed of limestone would not be capable of supporting itself as an arch, and, therefore, that instead of being elevated it would break up into fragments; this is very true, if the arch was entirely unsupported, but as soon as the expansion overcame the rigidity of the crust, and movement commenced, the underlying superheated rocks, being relieved from pressure, would rise up and still press upwards on the rising arch, so that the pressure expended in elevation would be that capable of overcoming the rigidity only of the crust, and not its weight. You may also have noticed that unless the rate of deposition was greater than the

[1] Clay contracts on being heated, but this does not affect the theory.

[2] This table is calculated on the suppositions that the earth is a sphere, with a radius of 3956 miles, and that rocks expand ·000005 for 1° Fahr.

rate of the conduction of heat outwards, no deposit would rise above the surface of the sea, for as soon as deposition ceased the increase of temperature would cease also; and conversely, the greater the difference between the rates the greater would be the rise, for the longer would be the time before the deposit attained its normal temperature.

The data to estimate these rates are not very exact, more especially the rate of deposition, but the following is the best information that I can collect:—

Monsieur Joseph Fourier has calculated that the earth decreases in temperature by radiation 1° Fahr. in 3,000,000 years,[1] and from this we can deduce that the conduction outwards must be about one-tenth of an inch a year. Sir W. Thomson's calculations, founded on experiments made at Edinburgh, Greenwich, and Upsala, give an outward conduction two and three quarter times as fast; but these experiments were made on dry rocks, and he allows that if the rocks were saturated with water, as all newly-formed deposits would be, his estimate would have to be reduced by one-half; which would then give an outward conduction of one-eighth of an inch per year. Peclet's experiments show also that the conductivity of limestone is only two-fifths of the average taken by Sir W. Thomson, or one-tenth of an inch per year. Consequently, we cannot be far wrong if we take the average conductivity outwards at one-ninth of an inch per year.

Professor Dana has estimated that limestone grows at the rate of one-eighth of an inch per year, and sandstone five to ten times as fast, or from five-eighths to one and a quarter inch per year; while the average increase in thickness of the clays of deltas appears to be about one-fifth of an inch per year; so that if we suppose a formation to be about one-third limestone, we get an average rate of deposition for the whole formation of one-third of an inch per year, or three times as fast as the conduction of heat outwards.

If at the present time the internal heat travels outwards at the rate of one-ninth of an inch per year, it would take 54,000 years to heat a deposit 500 feet in thickness; but a deposit 500 feet in thickness implies a rise of temperature in the underlying rocks of 10°, which implies an elevation of 1,140 feet if the heated area was 100 miles in diameter, or 1,900 feet if it was 2,000 miles in diameter, consequently in the first case the land would have risen 1,140 feet, and in the last 1,900 feet in 54,000 years, or at the rate of from two to three and a half feet per century, which is just the rate that Sir C. Lyell considers as most probable from observation.

But in former times when the internal temperature increased three times as fast as it does now, or 1° for seventeen feet, the conduction outward would be equal to the deposition, and consequently no land could rise above the water, and this may have been the cause of the "insular condition" which seems to have prevailed over the world during Palæozoic times. According to the theory of the secular cooling of the earth, advocated by Sir W. Thomson, these conditions must have occurred about eleven and a half millions of years after the formation of the crust, or about eighty-eight and a

[1] Theorie de la Chaleur, Paris, 1822.

half millions of years ago. From that time to the present, elevation must have gone on in an increasing scale; but, although increasing in height, it must have also been decreasing in rapidity, and a time must inevitably arrive when elevation will be so slow that it will do no more than equal denudation, and when again, therefore, no more land can rise much above the surface of the sea. Now, it has been estimated that a foot of soil is removed by denudation in from 500 to 12,000 years, according as the land is mountainous or level, and if we take the lowest estimate as that which will be nearest to the conditions at the time I am talking about, we find that the interior heat would have to increase at the rate only of 1° in 10,000 feet to bring about the result.[1] This, by Sir W. Thomson's theory, will not be for thirteen billions of years; so that the earth is but in its infancy between birth and the repose of old age, and we have plenty of time to look forward to for improvement and development.

But leaving these speculations, it is, I think, time that I gave you an illustration of the theory. I select the Wealden District in the South of England. This district extending through Kent, Sussex, and Hampshire, is formed by an anticlinal curve of the Cretaceous and wealden strata. The thickness of the beds is 3,400 feet, and the highest part of the arch would have attained, if the upper portion had not been denuded off, a height of about 3,600 feet above the sea. The base of the arch below London is about 500 feet below the sea, so that the total rise of the arch must have been about 4,100 feet, while the breadth of the anticlinal from London to some point in the English Channel is about 100 miles; these, therefore, are our data. Now a thickness of 3,400 feet implies an elevation of temperature of 68°, and this over a breadth of 100 miles would give an elevation of 4,650 feet, that is to say 150 feet more than the actual rise. But as the land rose above the sea denudation would commence to work upon it, so that the temperature would not be able to rise the whole 68°, and this will account for the 150 feet which the anticlinal arch failed to attain.

I will give you another and more general illustration. During the Eocene period a large ocean, at least 5,000 miles long by 1,800 broad, extended over the south of Europe and the north of Africa, and was continued eastward through Asia Minor, Persia, and Northern India to China. In this ocean, what is known as the Nummulitic Limestone was formed to a thickness of 15,000 feet. Consequently if, as I have said, large limestone deposits produce elevation, it is here that we ought to find the evidence of it; and this we plainly do in the Atlas, Pyrenees, Alps, Apennines, Carpathians, Himalayas, and the mountain chains of Persia; we find, in fact, that the area of the Nummulitic Limestone embraces the most mountainous country in the world, and geology shows us that these mountains are all about the same age, and all have been elevated since the period of the Nummulitic Formation. A thickness of 15,000 feet of limestone over an area 1,800 miles in breadth is also more than sufficient to elevate into the air the most towering peaks of the Himalaya.

[1] I need hardly say that these numbers are introduced as an illustration merely, and make no pretension to accuracy.

I might also adduce the Appalachian mountains in America as a beautiful illustration of the theory, every elevation that has taken place distinctly following the deposition of limestone, and occurring only where the limestone was deposited, except, perhaps, the last elevation after the Carboniferous period, which at present I cannot account for—for, according to American geologists, the Carboniferous Limestone never overlaid these mountains. But, besides the deposition of matter, any other cause that changed the temperature of the surface, would also produce alterations of level—a rise in the temperature being followed by elevation, and a fall by subsidence owing to the cooling and contracting rocks forming part of the surface of a sphere. In this way, the Gulf Stream, by raising the temperature of Norway and Sweden, is causing them to rise; while the cold Arctic current, sweeping down through Baffins Bay and striking against Greenland, is causing that country to sink.

Turning now to the second cause of the subversion of equilibrium, viz. change in the incidence of pressure, we find our data not so satisfactory, for we have no means of estimating the rigidity of the crust, and therefore of the weight it would bear before beginning to move, but nearly all geologists agree that most thick formations of sandstones and clays have been deposited upon a sinking area, and that in a large number of cases the subsidence has been approximately equal in rapidity to deposition. Now the chances are, of course, enormously against subsidence being equal to deposition, unless one is caused by the other, and when many cases of the kind are brought forward, our former suspicion becomes almost a certainty. This, of course, only applies to clays and sandstones, for I have already shown that limestones, as soon as they begin to expand, by heat, rise up and relieve the pressure; but with unconsolidated beds, like clay or sand, the horizontal thrust could never get powerful enough to overcome the rigidity of the crust, and consequently they could never rise.

As large deposits of limestone, therefore, elevate areas, so large deposits of argillaceous strata depress them. But while argillaceous strata are being formed they will not only be compressed by the sinking of the spherical surface on which they rest, but they will also at the same time be expanded by heat, and these two, together, will throw the beds into folds or contortions.

If we suppose that the subsidence is equal to the thickness of the formation, which is the most reasonable supposition that we can make, we can calculate the amount of compression due to sinking, and to expansion from heat, due to different thicknesses. Some of these are given in the following table, the upper line of which represents the thickness of the formation in feet, and the lower the proportionate compression:—

Thickness	5,000 feet	10,000 feet	20,000 feet	25,000 feet
Compression ...	$\frac{1}{1000}$	$\frac{1}{500}$	$\frac{1}{300}$	$\frac{1}{200}$

A first inspection of this table will give the impression that these compressions are not nearly enough to account for the contortions we see in mountain districts, but I believe that our ideas of contortions are very incorrect, owing to the necessarily exaggerated sections that accompany geological descriptions. The only sufficiently accurate section that I have been able to see is Professor Ramsay's beautiful section through Snowdon, in North Wales, and after carefully measuring it, and allowing for the faults and intrusive rocks, I find that the compression in this mountainous district is one-sixteenth. We must also remember that the contortions that we now see are the sum of all the compressions that have taken place at various times, for the rocks after being bent do not straighten out again on being stretched, but elongate by faulting. A considerable amount of the contortions of the lower beds of a formation will also be a necessary consequence of elevation by expansion, for during elevation the lower beds will not be able to expand so much as the upper ones of the arch, although much more heated.

The subsidence of an area caused by the weight of newly-deposited matter will compress the underlying superheated rocks, and, as explained at the commencement of the lecture, this will cause an increase of upward pressure in the surrounding areas. This increase of upward pressure will cause elevation in the surrounding districts, the rocks will be subjected to tension, and fissures will be formed. Up these fissures the superheated rocks of the interior will rise, and if they reach the surface will form volcanoes and overflow as lava streams. In this way mountains of quite a different character to those we have lately considered will be formed.

I have now explained to you the theory of Messrs. Herschel and Babbage in its simplest form, but in nature we should rarely find this simplicity. These two great powers—expansion by heat, and increase of weight—would sometimes combine and sometimes interfere with each other. Complications would also arise from the different degrees of fusibility, conductivity, porosity, and expansion of rocks, while the changes in physical geography caused by the changes in the position of the land would constantly alter the mean temperature of the surface, so that very complex phenomena might result from these simple causes.

To sum up. Mountain chains are of two kinds. The first, of which the Alps may be taken as a type, are composed of folded and contorted strata, generally associated with metamorphic and granitic rocks. These have been formed by heavy argillaceous deposits, causing subsidence and contortion, which have been subsequently elevated by the superposition of calcareous beds. The second kind, of which the Andes may be taken as the type, are composed of nearly horizontal strata, generally associated with volcanic rocks.[1] These have been formed by the upward pressure of the underlying rocks caused by the subsidence of adjoining areas, and owe their height

[1] See also Darwin "On Volcanic Phenomena in South America."—Trans. Geol. Soc., 2nd series, p. 601.

partly to this upward pressure, but often in great part to the overflowing of the superheated rocks on the surface.

There is, however, one other point that has still to be taken into account. If we calculate the mass of the ocean we shall find that it is sufficient, if the surface of the earth were level, to cover it entirely to a depth of at least two miles. Now, if it is true that the earth has been formed by the slow condensation of gaseous matter, we can see no possible reason why any of the gaseous materials should be confined in the interior solidifying portions, and by their attempts to escape cause eructations, or bubbles that could raise any part of the solid mass more than two miles high. In other words, I do not see how there could be any boiling or swelling up sufficient to form land above the surface of the ocean. If then there was no land in this primeval ocean for denudation to act upon, what was it that first disturbed the equilibrium of the crust and so led the way to those stupendous changes that we know have since taken place? But one answer can I think be given to this question, viz. *the origin of life.* Chemists are agreed that carbonate of lime was in solution in this primeval ocean, and when life, or rather life capable of secreting carbonate of lime, appeared, it would abstract this substance out of the ocean and deposit it on particular areas, and thus, by disturbing the equilibrium, would prepare the world to be the habitation for those countless myriads of organized beings which now swarm over it.

I will hazard one more supposition. Over this primeval ocean the winds must have swept with great regularity, and currents must have followed in their wake. Now these currents would naturally take two directions, one N.E. and S.W., and the other at right angles to it. If, therefore, we suppose life to have originated at any one point, it would gradually spread in a N.E. and S.W., or N.W. and S.E. direction, and the first calcareous deposits, and consequently the first land, would take these directions also. This would give the direction of other deposits, and although much obliterated by the complications that have since taken place, we can possibly, even now, trace in the directions of our mountain chains some remnant of this primeval arrangement. But this is sheer speculation.

Such is an outline of what I propose to call the Herschel-Babbage theory, after the two distinguished philosophers who originated it; it has the advantage over all other theories of the same nature of being capable of being proved or disproved by observations in the field. When firmly established, as I believe it will be, it will throw a new light on geology, for it gives significance to the thickness and composition of every rock, and to its geographical position; it gives significance to every bend and fold in the strata, to every fault and volcanic dyke; and it will also be found to furnish us with a key that will decipher many of the hitherto obscure passages in geological history.

II.—The Antiquity of Man in Britain.[1]

By James Geikie, F.R.S.E., F.G.S.,

District Surveyor H.M. Geological Survey of Scotland.

Mr. Geikie, after some introductory remarks, in which he dwelt pointedly upon the great advance made within recent years in our knowledge of prehistoric times, went on to say that what he proposed to do on that occasion was to bring before his audience in a general way the evidence which had weighed with archæologists and geologists in assigning to man a much greater antiquity than had at one time been allowed. Thereafter he should attempt to sketch in outline certain investigations of his own, which enabled him, as he thought, to give a greater precision to our views of that antiquity, and this to such a degree that, with the help of the astronomer and the physicist, he believed we should eventually arrive at some approximate estimate of the number of years which had elapsed since the earliest savage tribes of whom we had any trace first occupied the caves of England. Mr. Geikie next proceeded to describe how archæologists had arranged under three groups all the monuments and memorials of man that belonged to prehistoric times. The oldest relics were rude implements of stone; next in point of antiquity came articles of bronze, and these were succeeded by relics made of iron. Hence arose the terms Stone Age, Bronze Age, and Iron Age. He cautioned his hearers, however, against supposing that any hard and fast line separated these three ages. Each undoubtedly flowed into the one by which it was succeeded. With the ages of bronze and iron the geologist had but little to do, they lay chiefly within the domain of archæology. It was quite another matter, however, with the stone age, the history of which could be worked out only by the geological method. The Stone Age was subdivided into two periods, termed respectively the neolithic or new stone period, and the palæolithic or old stone period. To the neolithic period belonged those implements and weapons which are often more or less polished and finely finished, and which, in variety of form and frequent elegance of design, evince no small skill on the part of the old workmen. These relics, he remarked, occurred throughout the whole length and breadth of the land, from the south of England to the north of Scotland, and they abounded in Ireland. As a rule they were met with at or near the surface of the ground, and were often associated with the remains of such animals as sheep, horse, dog, pig, and certain species of oxen. The weapons and tools of the palæolithic period were of altogether ruder form and finish. They were merely chipped into the requisite shape of adze, hatchet, scraper, or whatever the implement might chance to be. Although some dexterity was shown in the fashioning of these rude implements, yet they certainly betokened much less skill than the relics of the neolithic period. He remarked that an experienced

[1] Being the substance of a Lecture delivered on 30th January, 1873, before the Birkenhead Literary and Scientific Society, Claughton Road, Birkenhead.

archæologist had no difficulty in recognizing and distinguishing palæolithic implements at once from relics of the neolithic age. They found no tools or implements of intermediate forms that might indicate a gradual improvement and progress from the rude palæolithic types to the polished and elegant implements used by neolithic man. The one set of tools was sharply marked off from the other. The conclusion could not be resisted that the people who used the palæolithic implements were much less advanced, and decidedly inferior in mechanical skill and contrivance to the race or races by whom the polished implements were fashioned. A distinct passage could be traced from the new stone period into the bronze age; but between the disappearance of palæolithic man and the advent of neolithic man there occurred a blank which the ingenuity of archæologists had hitherto failed to bridge over. The lecturer then proceeded to describe the positions in which palæolithic implements were found, viz. in caves and in ancient river gravels. As a good example of the former he instanced Kent's Cavern in Devonshire, and gave some details as to the mode in which the implements were associated with the remains of extinct mammalia upon the floor of that cave, all buried under a thick cake of stalagmite. The special proofs of the great antiquity of this cavern-deposit were pointed out, the lecturer remarking that now no one who was competent to judge doubted that the animal remains and the human relics both belonged to one and the same period or periods. The mammalia he classed under two divisions—first, species which lived, and many of which are still living, under arctic conditions; and second, species which are either now denizens of temperate and warm regions, or have in those zones their nearest representatives. The first group embraced such animals as the reindeer, glutton, musk-sheep, etc. The second group contained the horse, wolf, wild-cat, extinct cave-bear, Irish deer, and so forth—all being species characteristic of temperate climates; while as representatives of warm climates we had two species of rhinoceros, the elephant, the hippopotamus, the lion, the hyæna, and others. Mr. Geikie insisted that this commingling of arctic and southern species pointed to former changes of climate, and not, as some had supposed, to a period of strongly contrasted summers and winters, during which great migrations took place. Such a climate could not possibly obtain in Europe under the geographical and physical conditions which are known to have existed during pleistocene times. He then recapitulated the geological evidence furnished by cave deposits, and showed that nowhere did the palæolithic deposits pass up gradually into neolithic accumulations. On the contrary, there was a sharp and abrupt break between the older and the later deposits. The evidence relating to the ancient river gravels was next taken up. The position of these deposits was described, and the mode of their formation indicated by means of diagrams. The occurrence in these ancient river beds of palæolithic implements, and the remains of extinct and no longer indigenous mammalia, furnished evidence in regard to changes of climate of precisely the same nature as that supplied by the cave-earths and breccias. It was also clearly proved by the river gravels that palæolithic man entered Britain ages before the valleys in the south of England were hollowed out to their present depth—that during his long occupation the rivers succeeded in cutting out the valleys to their present depth and breadth—and that not until this was effected did palæolithic man disappear and neolithic man take his place. No neolithic remains occurred in the ancient river gravels. The evidence of these gravels thus bore out that which was furnished by the caves and by a comparison of the two sets of stone implements themselves, and all combined to show that a decided and well-marked break separated the palæolithic from the neolithic period. What, then, was the nature of this break? What caused palæolithic man and the old pachyderms to disappear at once and altogether before neolithic man and an almost totally different group of animals entered the country? To answer this question it was necessary to consider the deposits belonging to that wonderful period which was known as the Ice Age, or Glacial Epoch. By means of maps and diagrams the lecturer then pointed out the salient features of the evidence under this head. He described a number of sections representing glacial deposits in Scotland, Switzerland, and North America, and explained how these showed that the Glacial epoch was not one long uninterrupted age of ice, but rather a succession of cold and mild periods. There was distinct evidence to prove that the great ice-sheet which buried Scotland to a depth of not less than three thousand feet, and which filled up all our shallow seas and even overflowed the outer Hebrides, sometimes melted away from our seas and low grounds and retired to the deep glens of the highlands, and then rivers flowed in our valleys and many lakes appeared, and the country was clothed and peopled with plants and animals. Similar phenomena were found to characterize the glacial deposits of Switzerland and America. The Scottish interglacial deposits had yielded remains of the mammoth, the Irish deer, the horse, the great ox, and smaller animals such as frogs and water-rats, and fragments of various kinds of trees, besides organisms peculiar to fresh-water. The Swiss accumulations contained beds of lignite with which were associated the great ox, the rhinoceros, the elephant, and other animals.

In America ancient forests were found lying between glacial deposits, the trees being still indigenous to that country, and remains of the old pachyderms had been met with in a similar position. In Scandinavia there was evidence to show that the glacial epoch was interrupted by at least two mild interglacial periods. The evidence derived from all these regions also clearly proved that since the last cold period of the glacial epoch there had been no warm or genial conditions, but only a gradual amelioration of climate down to the present time. The lecturer then went on to point out what bearing these facts had upon the question of man's antiquity in Britain. The evidence furnished by the palæolithic deposits showed that during their accumulation man experienced two kinds of climate, one of which was cold and almost arctic in character, the other mild and genial. Now, as no mild or genial climate had supervened in

Britain since the close of the Glacial epoch, it was clear that the hippopotami and elephants and other southern mammalia associated with palæolithic implements could not belong to Postglacial times: they must be either of Interglacial or Preglacial age. This conclusion received very strong support from the peculiar manner in which the implement-bearing gravels were distributed. These were confined solely to the south of England. None occurred in the north of England, in Scotland, in Ireland, in Scandinavia, or in Switzerland. In Scotland and in Switzerland we did get remains of the animals which were contemporaneous with the men of the old stone period, but these remains were all of Interglacial age. The same was the case in North America. If we took a map of the northern hemisphere, and coloured upon it all the ground covered with the deposits that were laid down during the last cold period of the Glacial epoch, we should find that none of the old pachyderms (hippopotami, elephants, etc.) and no flint implements were ever met with at the surface within that area. We should, indeed, get the old mammalia, but only in Preglacial and Interglacial deposits. But immediately beyond the limits of the coloured area we should observe that in Europe all the valleys (as in the south of England and in France) were more or less filled with vast deposits of river gravels, which contain abundant remains of the old pachyderms, and immense numbers of flint instruments. And it was well known that in America the great bone deposits, so abundant in the Mississippi valley and elsewhere, ceased to appear whenever the limits of the northern drift were approached from the south. These facts, he thought, could only be explained in one way—namely, by admitting that palæolithic man and his congeners belonged to interglacial times and in all probability to Preglacial times also. The absence of palæolithic deposits from the regions referred to was thus explained in a simple and reasonable way. The great confluent glaciers had ploughed out these deposits, and what portion the glaciers had spared had been subsequently covered up by marine accumulations during the last great submergence. But in those regions which the glaciers had not reached, and which were never submerged, the palæolithic gravels still existed in great force. Mr. Geikie then gave some account of Mr. Croll's theory, which explains the cause of great cosmical changes of climate, and showed how admirably Mr. Croll's conclusions tallied with the general results obtained from a study of the glacial deposits. The date given by Mr. Croll for the beginning of the glacial epoch was about 240,000 years ago; and this epoch, with all its alternations of cold and warm periods, lasted for about 1,600 centuries. Many most competent judges inclined to believe that man was of Preglacial age, which would give him an antiquity in Britain of more than 200,000 years. It was certain, at all events, that the animals with which palæolithic man was associated did live in Preglacial and during Interglacial times. This, of course, did not prove that man was of preglacial age; but since his implements were found at the very bottom of our cave deposits and old river gravels, it was highly probable that he entered our country as early at least as the elephant and hippopotamus; and the southern mammalia, as he had shown, could not have lived in Britain in Postglacial times. Seeing, therefore, that man was undoubtedly contemporaneous with these animals, we could not resist the conclusion that he dated back to interglacial ages. It could not, indeed, be demonstrated that he occupied our caves during the earlier warm periods of the glacial epoch, but the evidence was decisive as to his presence in Britain during the last mild Interglacial age. And such being the case, he must have been the witness of several grand geological revolutions. During the last interglacial period he entered Britain at a time when our country was joined to Europe; at a time when our winters were still severe enough to freeze over the rivers in the south of England; at a time when glaciers nestled in our mountain valleys. He lived here long enough to witness a complete change of climate—to see the arctic mammalia vanish from England and the hippopotamus and its congeners take their place. At a later date, and while a mild climate still continued, he beheld the sea slowly gain upon the land, until, little by little, the whole country was submerged as far south as the valley of the Thames—a submergence which reached in Wales and Scotland to the extent of 2,000 feet or thereby. At the same time a great depression drowned all the low grounds of Northern Europe. When this depression had reached or nearly reached a climax, the last glacial period began. Intense arctic cold converted the few islets which then represented Britain into a frozen archipelago. From the ice-foot that clogged the shores fleets of rafts set sail, and as they journeyed on dropt angular blocks over the bottom of the sea. And where was palæolithic man at this time? Perhaps in the south of Europe, but surely not in England. Mr. Geikie then described the later changes, and showed how upon the re-elevation of the land Britain was again joined to the continent. It was during this last continental condition of our island that neolithic man and the animals with which he was associated made their appearance. Palæolithic man and the southern mammalia had, as far as Britain was concerned, vanished for ever. This was the explanation he gave of the great break that separated the new stone age from the old stone age. The one age was marked off from the other by a vast lapse of time—by a time sufficient for the submergence and re-elevation of a large part of Northern Europe, and a great change of climate.—*Liverpool Daily Albion*, February 1st, 1873.

III.—Short Notices.

1.—Academy of Natural Sciences, Philadelphia.

At a meeting of the Academy of Natural Sciences, Philadelphia, Prof. Cope exhibited the cranium of the horned Proboscidian of Wyom ng *Loxolophodon cornutus*, and made some remarks on its affinities. The short-footed Ungulates or *Proboscidia* are represented by two very different families in the Eocene formations of North

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America, the *Eobasiliidæ* and *Bathmodontidæ*. The first embraces four known genera, as follows:—

1. Nasal bones with flat horizontal horn-cores overhanging their apex. Cervical vertebræ short; malar bone much reduced in front. *Loxolophodon*, Cope.

2. Nasal bones with small tuberosities.
Cervical vertebræ short. *Eobasileus*, Cope.
Cervical vertebræ longer; the malar bone reaching maxillary face. *Uintatherium*, Leidy.

3. Nasal bones with produced, cylindric horn-cores.
Cervicals? *Megaceratops*, Leidy.

Of the above genera there are five well-determined species, viz.: *L. cornutus*, Cope; *E. pressicornis*, Cope; *U. robustum*, Leidy; *U. lacustre*, Marsh; and *M. coloradoensis*, Leidy. *E. furcatus*, Cope, and *U. mirabile*, Marsh, would, perhaps, have to be added.

There are two genera of *Bathmodontidæ*, as follows:—
One posterior molar with two transverse crests. *Bathmodon*, Cope.
Three posterior cross-crested molars. *Metalophodon*, Cope.

Of this family 4 species are known, viz. *Bathmodon radians*, Cope; *B. semicinctus*, Cope; *B. brevipes*, Cope; *Metalophodon armatus*, Cope;

Philadelphia, February 28th, 1873.

2.—Memoirs of the Geological Survey of India.

In the Memoirs of the Geological Survey of India, vol. viii., pt. 2, Mr. Hughes has again contributed to the literature on the Coal-fields of India. Extending his labours to the West of the Damúdá Valley, he has mapped and reported upon two separate areas of Coal-bearing rocks, which have received the official titles of the Itkhúri, and Daltonganj Coal-fields. The importance of the Itkhúri basin is small, and there appears little chance of its ever becoming more than a local source of supply for the coarser necessities of engineering requirements.

The Daltonganj basin, on the other hand, seems destined—owing to its proximity to the Son (Sone) and to the canal works in connexion with that river—to occupy a much more active sphere in the economic history of India.

Politically this field—notwithstanding the inferior quality of its coals—may in the future be of high value: for during the great mutiny of 1857 it supplied some coal to the steamers engaged in transporting our troops from Bengal to the more disturbed districts of the North West; and should a like disaster again occur, its resources may be once more called into requisition for the purposes of quelling insurrection. We trust that these Memoirs are only the prelude to some general work on the Coal-fields of India. Already that country has, through the labours of Dr. Oldham and his able staff of Assistants, been rescued to some extent from the obscurity in which it was shrouded; and we trust that these separate contributions to the Memoirs of the Survey will before long be embodied in such form as best appeals to those interested in the industrial welfare of our Colonies.
