across. There is apparently no stratification, and the mode of occurrence seems to mark this as a small volcanic vent.

10. *North of Mynydd anelwog.*—(Annelog). The low crag near the spring consists of an ash, finer than, but of very similar materials to, the agglomerate just described. Fragments of andesite or basalt are almost identical with the constituents of the preceding specimen, and those of green viridite might be derived from the same source, while occasionally a piece of scoria occurs. The fragments as seen by microscopic examination are small, with slightly irregular outline, and separated by strings of fine dust.

Thus all the patches of "serpentine," except the two mentioned, have now been examined, with the result that not only is there no serpentine present but there is no uniformity in their character, and I shall be able to show that similar rocks occur at many other places in the neighbourhood. Sometimes these "serpentines" are dolerites or compact diabases (andesites or basalts); sometimes they are true volcanic agglomerates. Although, in many cases, they are not interbedded, some probably represent lava flows, or an ash of transported fragments. This result, therefore, further illustrates the characters, which were first described by Professor Bonney from Porth din lleyn. His paper thus gave the key-note to the understanding, not only of that locality, but of others. The question of the geological age of these masses can only be discussed in connection with the surrounding district, since it affords additional examples of similar and allied rocks.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science. Sixty-second Meeting, Edinburgh, August 3rd, 1892. President, Sir Archibald Geikie, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom.

Titles of Papers Read in Section (C), Geology, August 4–10.

Professor C. Lapworth, LL.D., F.R.S., F.G.S., President of Section.

The President's Address.

O. W. Jeffs.—Report of the Committee on Geological Photographs.

J. Lomas.—On the Glacial Distribution of the Riebeckite-Eurite of Ailsa Craig.

Dr. H. W. Crosskey.—Report of the Committee on Erratic Blocks.

J. W. Gray and *P. F. Kendall.*—The Cause of the Ice Age.

W. A. E. Ussher.—The Granites of Devon and Cornwall.

Dr. A. Irving.—The Malvern Crystallines.

J. G. Goodchild.—The St. Bees Sandstone and its Associated Rocks.

H. Woods.—The Igneous Rocks in the Neighbourhood of Builth.

A. G. C. Cameron.—Note on a Green Sand in the Lower Greensand, and on a Green Sandstone in Bedfordshire.

A. G. C. Cameron—The Fuller's Earth Mining Company at Woburn Sands.

C. E. de Rance.—Report of the Committee on the Circulation of Underground Waters.

B. N. Peach.—On a Widespread Radiolarian Chert formation, Arenig Age, in Southern Uplands of Scotland.

J. Horne.—On the Contact alteration of the Radiolarian Chert, along the margin of the Loch Doon Granite.

Dr. H. Hicks.—On the Grampian Series (Pre-Cambrian Rocks) of the Central Highlands.

J. F. Blake.—On the still-possible Cambrian Age of the Torridon Sandstone.

Prof. A. Blytt.—On some Calcareous Tufas in Norway.

Dugald Bell.—Alleged Proof of Submergence in Scotland during the Glacial Epoch. I. Chapelhall, Airdrie.

Dugald Bell.—Alleged Proofs of Submergence in Scotland during the Glacial Epoch. II. Clava and other Northern Localities.

Clement Reid.—Fossil Arctic Plants found near Edinburgh.

H. Coates.—The cuttings of the Crieff and Comrie Railway. Exhibition of Geological Specimens, Maps, and Photographs.

Prof. E. Hull.—The Physical Geology of Sinai and Palestine.

J. F. Blake.—On two tunnel-sections in the Cambrian of Carnarvonshire.

Dr. H. J. Johnston-Lavis.—Report of the Committee on the Volcanic Phenomena of Vesuvius.

Rev. E. Jones.—Report of the Committee on the Elbolton Cave.

B. Harrison.—Report of the Committee on the Excavations at Oldbury Hill.

Prof. T. G. Bonney.—On the Relation of the Bunter Pebbles of the English Midlands to those in the Old Red Sandstone conglomerates of Scotland.

A. Harker.—On Porphyritic Quartz in Basic Igneous Rocks.

Alexander Somervail.—On the Relations of the Rocks of the Lizard district.

B. N. Peach and *J. Horne.*—On the Ice-shed in the North-West Highlands during the Maximum Glaciation.

B. N. Peach and *J. Horne.*—On a Bone Cave in the Limestone of Assynt.

Prof. W. J. Sollas.—Report on the Committee on Investigating the Structure of a Coral Reef.

Miss M. Ogilvie.—Landslips in the St. Cassian Strata of the South Tyrol.

J. G. Goodchild.—On a Granite junction in Mull.

J. G. Goodchild.—The St. Bees' Sandstone and its associated Rocks.

J. J. H. Teall.—The Sequence of Gneissose Rocks.

Prof. W. J. Sollas.—Supposed Radiolarian Remains from the Slates of Howth.

Prof. J. W. Sollas.—Supposed Radiolarian Remains from the Culdaff Limestone.

E. T. Newton.—On Some Dicynodont and other Reptilian remains from the Elgin Sandstone.

Dr. R. H. Traquair.—On the Distribution of Fossil Fishes in the Edinburgh District.

M. Laurie.—The Eurypterid Fauna of the Silurian Rocks.
Prof. T. R. Jones.—Report of the Committee on Fossil Phyllopoda.
R. B. Newton.—On the occurrence of *Chonetes Pratti* (Davidson) in the Carboniferous Rocks of Western Australia.
A. Smith Woodward.—Report of the Committee on the Registration of Type Specimens.
G. R. Vine.—Report of the Committee on the Cretaceous Polyzoa.
C. Davison.—Report of the Committee on Earth Tremors.
A. Harker.—On Porphyritic Quartz in Basic Igneous Rocks.
Dr. H. J. Johnston-Lavis.—The Occurrence of Pisolitic Tuff in the Pentlands.
W. W. Watts.—Notes on some Limerick Traps.

TITLES OF PAPERS BEARING UPON GEOLOGY READ IN OTHER SECTIONS:—

Section A.—Mathematical and Physical Science.

Report of the Committee on Meteoric Dust.
Report of the Committee on the Seismological Phenomena of Japan.
Report of the Committee on Underground Temperature.

Section D.—Biology.

H. O. Forbes.—Remarks on a Series of Extinct Birds of New Zealand, recently discovered.
W. Carruthers, F.R.S.—On the structure of the stem of a typical *Sigillaria.*
T. Hick.—On *Calamostachys Binneyana.*
A. C. Seward.—Notes on specimens of *Myeloxylon* from the Millstone Grit and Coal-measures.

Section H.—Anthropology.

H. O. Forbes.—On the Contemporaneity of Man and the Moa.
Report of the Prehistoric Inhabitants Committee.

II.—BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, EDINBURGH, 1892.

Address to the Geological Section by PROFESSOR C. LAPWORTH, LL.D., F.R.S., F.G.S., President of the Section.

IT has, I believe, been the rule for the man who has been honoured by election to the Chair of President of this Geological Section of the British Association to address its members upon the recent advances made in that branch of geology in which he has himself been most immediately interested. It is not my intention upon the present occasion to depart from this time-honoured custom; for it has both the merit of simplicity and the advantage of utility to recommend it. In this way each branch of our science, as it becomes in turn represented, not only submits to the workers in other departments a report of its own progress, but presents by implication a broad sketch of the entire geological landscape, seen through the coloured glasses, it may be, of divisional prejudice, but at any rate instructive and corrective to the workers in other departments, as being taken from what is to them a novel and an unfamiliar point of view.

Now every tyro in geology is well aware of the fact that the very backbone of geological science is constituted by what is known as stratigraphical geology, or the study of the geological formations. These formations, stratified and unstratified, build up all that part of the visible earth-crust which is accessible to the investigator. Their outcropping edges constitute the solid framework, the surface of which forms the physical geography of the lands of the present day, and their internal characters and inter-relationships afford us our only clues to the physical geographies of bygone ages. Within them lies enshrined all that we may ever hope to discover of the history and the development of the habitable world of the past.

These formations are to the stratigraphical geologist what species are to the biologist, or what the heavenly bodies are to the astronomer. It was the discovery of these formations which first elevated geology to the rank of a science. In the working out of their characters, their relationships, their development, and their origin, geology finds its means, its aims, and its justification. Whatever fresh material our science may yield to man's full conception of nature, organic and inorganic, must of necessity be grouped around these special and peculiar objects of its contemplation.

When the great Werner first taught that our earth-crust was made up of superimposed rock-sheets or formations arranged in determinable order, the value of his conclusions from an economic point of view soon led to their enthusiastic and careful study; but his crude theory of their successive precipitation from a universal chaotic ocean disarmed the suspicions of the many until the facts themselves had gained such a wide acceptance that denial was no longer possible. But when the greater Scotchman, Hutton, asserted that each of these rock-formations was in reality nothing more nor less than the recemented ruins of an earlier world, the prejudices of mankind at large were loosed at a single stroke. Like Galileo's assertion of the movement of the globe, this demanded such an apparently undignified and improbable mode of creation that there is no wonder that, even down to the present day, there still exist some to whom this is a hard saying, to be taken, if taken at all, in homœopathic doses and with undisguised reluctance.

Hutton as regards his philosophy was, as we know, far in advance of his time. With all the boldness of conviction he unflinchingly followed out these ideas to their legitimate results. He claimed that as the stratified formations were composed of similar materials—sands, clays, limestones, and muds—to those now being laid down in the seas around our present coasts, they must, like them, have been the products of ordinary natural agencies of rain, rivers, and sea waters, internal heat and external cold, acting precisely as they act now. And, further, as these formations lie one below the other, in apparently endless downward succession, and all formed more or less of these fragmentary materials, so the present order of natural phenomena must have existed for untold ages. Indeed, to the commencement of this order he frankly admits 'I see no trace of a beginning or sign of an end.'

The history of the slow acceptance of Hutton's doctrines, even among geologists, is, of course, perfectly familiar to us all. William Smith reduced the disputed formations to order, and showed that not only was each composed of the ruins of a vanished land, but that each contained in its fossils the proof that it was deposited in a vanished sea inhabited by a special life creation. Cuvier followed, and placed it beyond question that the fossilised relics of these departed beings were such as made it absolutely unquestionable that these creatures might well have inhabited the earth at the present day. Lyell completed the cycle by demonstrating stage by stage the efficiency of present natural agencies to do all the work required for the degradation and rebuilding of the formations. Since his day the students of stratigraphical geology have universally acknowledged that in the study of present geographical causes lies the key to the geological formations and the inorganic world of the past.

In this way the road was paved for Darwin and the doctrine of descent. The aid which had been so ungrudgingly afforded by biology to geology was repaid by one of the noblest presents ever made by one science to another. For the purposes of geology, the science of biology had practically completed a double demonstration: first, that the extinct life discernible in the geological formations was linked inseparably with the organic life of the present; and, second, that every fossil recognised by the geologist was the relic of a creature that might well have existed upon the surface of the earth at the present time. Geology repaid its obligation to biology by the still greater twofold demonstration: first, that in the economy of nature the most insignificant causes are competent to the grandest effects, if only a sufficiency of time be granted them; and, second, that in the geological formations we have the evidences of the actual existence of those mighty eons in which such work might be done.

The doctrine of organic evolution would always have remained a metaphysical dream had geology not given the time in which the evolution could be accomplished. The ability of present causes to bring about slow and cumulative changes in the species is, to all intents and purposes, a biological application of Hutton's ideas with respect to the original geological formations. Darwin was a biological evolutionist, because he was first a uniformitarian geologist. Biology is pre-eminent to-day among the natural sciences, because its younger sister, Geology, gave it the means.

But the inevitable consequence of the work of Darwin and his colleagues was that the centre of gravity, so to speak, of popular regard and public controversy was suddenly shifted from stratigraphical geology to biology. Since that day stratigraphical geology, to its great comfort and advantage, has gone quietly on its way unchallenged, and all its more recent results have, at least by the majority of the wonder-loving public, been practically ignored.

Indeed, to the outside observer it would seem as if stratigraphical geology for the last thirty years had been practically at a standstill. The startling discoveries and speculations of the brilliant stratigraphists of the end of the last century and first half of the present forced the geology of their day into the very front rank of the natural sciences, and made it perhaps the most conspicuous of them all in the eyes of the world at large. Since that time, however, their successors have been mainly occupied in completing the work of the great pioneers. The stratigraphical geologists themselves have been almost wholly occupied in laying down upon our maps the superficial outlines of the great formations, and working out their inter-relationships and subdivisions. At the present day the young stratigraphical student soon learns that all the limits of our great formations have been laid down with accuracy and clearness, and finds but little to add to the accepted nomenclature of the time.

Our palæontologists also have equally busied themselves in working out the rich store of the organic remains of the geological formations, and the youthful investigator soon discovers that almost every fossil he is able to detect in the field has already been named, figured, and described, and its place in the geological record more or less accurately fixed.

In France, in Germany, in Norway, Sweden, and elsewhere, in Canada and in the United States, work as thorough and as satisfactory has been accomplished, and the local development of the great stratified formations and their fossils laid down with detail and clearness.

Many a young unfledged but aspiring geologist alive to these facts, and contrasting the well-mapped ground of the present time with the virgin lands of the days of the great pioneers, finds it hard to stifle a feeling of keen regret that there are nowadays no new geological worlds to conquer, no new systems to discover and name, and no strange and unexpected faunas to unearth and bring forth to the astonished light of day. The youth of stratigraphical geology, with all its wonder and freshness, seems to have departed, and all that remains is to accept, to commemorate, and to round off the glorious victories of the dead heroes of our science.

But to the patient stratigraphical veteran, who has kept his eyes open to discoveries new and old, this lull in the war of geological controversy presents itself rather as a grateful breathing time; the more grateful as he sees looming rapidly up in front the vague outlines of those oncoming problems which it will be the duty and the joy of the rising race of young geologists to grapple with and to conquer as their fathers met and vanquished the problems of the past. He knows perfectly well that Geology is yet in her merest youth, and that to justify even her very existence there can be no rest until the whole earth-crust and all its phenomena, past, present, and to come, have been subjected to the domain of human thought and comprehension. There can be no more finality in Geology than in any other science; the discovery of to-day is merely the stepping-stone to the discovery of to-morrow; the living theory of to-morrow is nourished by the relics of its parent theory of to-day.

Now if we ask what are these formations which constitute the objects of study of the stratigraphical geologist, I am afraid that, as in the case of the species of the biologist, no two authorities would agree in framing precisely the same definition. The original use of the term formation was of necessity lithological, and even now the name is most naturally applied to any great sheet of rock which forms a component member of the earth-crust; whether the term be used specifically for a thin homogeneous sheet of rock like the Stonesfield slate, ranging over a few square miles; or generically for a compound sheet of rock, like the Old Red Sandstone, many thousands of feet in thickness, but whose collective lithological characteristics give it an individuality recognizable over the breadth of an entire continent.

When Werner originally discovered that the 'formations' of Saxony followed each other in a certain recognizable order, a second characteristic of a formation became superposed upon the original lithological conception—namely, that of determinate 'relative position.' And when William Smith proved that each of the formations of the English Midlands was distinguished by an assemblage of organic remains peculiar to itself, there became added yet a third criterion —that of the possession of 'characteristic fossils.'

But these later superposed conceptions of time—succession and life-type—are far better expressed by dividing the geological formations into zoological *zones*, on the one hand, and grouping them together, on the other hand, into chronological *systems*. For in the experience of every geologist he finds his mind instinctively harking back to the bare lithological application of the word 'formation,' and I do not see that any real advantage is gained by departing from the primitive use of the term.

A 'zone,' which may be regarded as the *unit* of *zoological succession*, is marked by the presence of a special fossil, and may include one or many subordinate formations. A *system*, which is, broadly speaking, the *unit of geological time* or *succession*, includes many 'zones,' and often, but not always, many 'formations.' A *formation*, which is the *unit of geological stratigraphy*, is a rock sheet composed of many strata possessing common lithological characters. The formation may be simple, like the chalk, or compound, like the New Red Sandstone, but, simple or compound, local or regional, it must be always recognizable, geographically and geologically, as a lithological individual.

As regards the natural grouping of these lithological individuals as such, fair progress has been made of late years, and our information is growing apace. We know that there are at any rate three main groups: 1st. The stratified formations due to the action of moving water above the earth-crust. 2nd. The igneous formations which are derived from below the earth-crust. 3rd. The metamorphic formations which have undergone change within the earth-crust itself. We know also that of these three the only group which has hitherto proved itself available for the purpose of reading the past history of the globe is that of the stratified formations.

Studying these stratified formations therefore in greater detail, we find that they fall naturally in their turn into two sets, viz.: a mechanical set of pebble beds, sandstones and clays formed of rock fragments washed off the land into the waters, and an organic set of limestones, chalk, etc., formed of the shells and exuviæ of marine organisms.

But when we attempt a further division of these two sets our classification soon begins to lose its definiteness. We infer that some formations, such as the Old Red and the Triassic, were the comparatively rapid deposits of lakes and inland seas; that others, like the Coal-measures, London-clay, etc., were the less rapid deposits of lagoons, river valleys, deltas, and the like; that others, like our finely laminated shales and clays of the Silurian and Jurassic, were the slower deposits of the broader seas; and finally, that others, like our Chalk and Greensand, were possibly the extremely slow deposits of the oceanic deeps.

Nevertheless, after looking at the formations collectively, there remains no doubt whatever in the mind of the geologist that their mechanical members are the results of the aqueous degradation of vanished lands, and that their organic members are the accumulated relics of the stony secretions of what once were living beings. Neither is there any possibility of escape from the conclusion that they have all been deposited by water in the superficial hollows of the sea-bottoms and ocean floors of the earth-crust of their time.

In the life of every individual stratified formation of the mechanical type we can always distinguish three stages: first, the stage of erosion and transportation, in which the rock fragments were worn off the rocks of the higher ground and washed down by rain and rivers to the sea; second, a stage of deposition and consolidation below the surface of the quiet waters; and third, a final stage in which the completed rock-formation was bent and upheaved, in part at least, into solid land. In the formations of the organic type three corresponding stages are equally discernable: first, the period of mineral secretion by organized beings; second, the period of deposition and consolidation; and third, the final period of local elevation in mass. But one and all, mechanical and organic alike, they bear in their composition, in their arrangement, and in their fossils, abundant and irresistible evidence that they *were* the products and that now they are the memorials of the physical geography of their time.

Guided by the principles of Hutton and Lyell, geologists have worked out with great care and completeness the effects of those agencies which rule in the first of these three life-stages in the history of a mechanical formation. No present geological processes are more familiar to the young geologist than those of denudation, erosion, and transportation. They form together the subject-matter of that most wonderful fascinating chapter in geology which from its modest opening among the quiet Norfolk Sandhills sweeps upwards and onwards without a break to its magnificent close on the brink of the gorge of the Colorado. But our knowledge of the detailed processes of deposition and consolidation which rule in the second stage is still exceedingly imperfect, although a flood of light has been thrown upon the subject by the brilliant results of the *Challenger* Expedition. And we are compelled to admit that our knowledge of the operations of those agencies which rule in the processes of upheaval and depression is as yet almost nil; and what little we have already learnt of the effects of these agencies is the prey of hosts of conflicting theories that merely serve to annoy and bewilder the working student of the science.

But not one of the formative triad of detrition, deposition, and re-elevation can exist without the others. No detrition is possible without the previous upheaval of the rock-sheet, from which material can be removed; no deposition is possible without the previous depression of the rock-sheet, which forms the basin in which the fragmentary material can be laid down.

Our knowledge, therefore, of the origin and meaning of any geological formation whatever can at most be only fragmentary until this third chapter in the life-history of the geological formation has been attacked in earnest.

Now all the rich store of knowledge we possess respecting the first stage in the life of a geological formation has been derived from a comparison of certain phenomena which the stratigraphical geologist finds in the rock formations of the past, with correspondent phenomena which the physical geographer discovers on the surface of the earth at the present. And all that we know of the second stage again has been obtained in precisely the same way. Surely analogy and common sense both teach us that all which is likely to be of permanent value to us as regards the final stage of elevation and depression must be sought for in the same direction.

Within the last twenty years or so many interesting and vital discoveries have been made in the stratigraphy of the rock formations, which bear largely upon this obscure chapter of elevation and depression. And I propose on this occasion that we try to summarise a few of these new facts, and then, reading them in conjunction with what we actually know of the physical geography of the present day, try to ascertain how such mutual agreement as we can discover may serve to aid the stratigraphical geologist in his interpretation of the true meaning of the geological formations themselves. We may not hope for many years to come to read the whole of this geological chapter, but we may perhaps modestly essay an interpretation of one or two of the opening verses.

In the physical geography of the present day we find the exterior of our terraqueous globe divided between the two elements land and water. We know that the solid geological formations exist everywhere beneath the visible surface of the lands, but of their existence under the present ocean floor we have as yet no absolute certainty. We know both the form of the surface and the composition of the surface of the continental parts of the lithosphere; we only know as yet even in outline the form of its oceanic portions. The surface of each of our great continental masses of land resembles that of a long and broad arch-like form, of which we see the simplest type in the New World. The surface of this American arch is sagged downwards in the middle into a central depression which lies between two long marginal plateaux, and these plateaux are finally crowned by the wrinkled crests which form our modern mountain systems. The surface of each of our ocean floors exactly resembles that of a continent turned upside down. Taking the Atlantic as our simplest type, we may say that the surface of each ocean basin resembles that of a mighty trough or syncline, buckled up more or less centrally into a medial ridge, which is bounded by two long and deep marginal hollows, in the cores of which still deeper grooves sink to the profoundest depths. This complementary relationship descends even to the minor features of the two.

Where the great continental sag sinks below the ocean level we have our gulfs and our Mediterranean, seen in our type continent as the Mexican Gulf and Hudson Bay. Where the central oceanic buckle attains the water-line we have our oceanic islands, seen in our type ocean as St. Helena and the Azores. Although these apparent crust-waves are neither equal in size nor symmetrical in form, this complementary relationship between them is always discernible. The broad Pacific depression seems to answer to the broad elevation of the Old World —the narrow trough of the Atlantic to the narrow continent of America.

Every primary wave of the earth's surface is broken up into minor waves, in each of which the ridge and its complementary trough are always recognisable. The compound ridge of the Alps answers to the compound Mediterranean trough; the continuous western mountain chain of the Americas to the continuous hollow of the Eastern Pacific which bounds them; the sweep of the crest of the Himalaya to the curve of the Indo-Gangetic depression. Even where the surface waves of the lithosphere lie more or less buried beneath the waters of the ocean and the seas, the same rule always obtains. The island chains of the Antilles answer to the several Caribbean abysses, those of the Ægean Archipelago answer to the Levantine deeps.

Draw a section of the surface of the lithosphere along a great circle in any direction, the rule remains the same: crest and trough, height and hollow, succeed each other in endless sequence, of every gradation of size, of every degree of complexity. Sometimes the ridges are continental, like those of the Americas; sometimes orographic, like those of the Himalaya; sometimes they are local, like those of the English Weald. But so long as we do not descend to minor details we find that every line drawn across the earth's surface at the present day rises and falls like the imaginary line drawn across the surface of the waves of the ocean. No rise of that line occurs without its complementary depression; the two always go together, and must of necessity be considered together. Each pair constitutes one of those geographical units of form of which every continuous direct line carried over the surface of the lithosphere of our globe is made up. This unit is always made up of an arch-like rise and a trough-like depression which shade into each other along a middle line of contrary curvature. It resembles the letter S, or Hogarth's line of beauty, and is clearly identical in form with the typical wave of the physicist. Here, then, we reach a very simple and natural conclusion, viz., the surface of the earth-crust of the present day resembles that of a series of crust-waves of different lengths and different amplitudes, more or less irregular and complex, it is true, but everywhere alternately rising and falling in symmetrical pairs like the waves of the sea.

Now this rolling wave-like earth-surface is formed of the outcropping edges of the rock formations which are the special objects of study of the stratigraphical geologist. If, therefore, the physiognomy of the face of our globe is any real index of the character of the personality of the earth-crust beneath it, these collective geographical features should be precisely those which answer to the collective structural characters of the geological formations.

In the earlier days of geology one of the first points recognised by our stratigraphists was the fact that the formations were successive lithological sheets, whose truncated outcropping edges formed the present surface of the land, and that these sheets lay inclined at an angle one over the other, as William Smith quaintly expressed it, like a tilted 'pile of slices of bread and butter.' But as discovery progressed the explanation of the arrangement soon became evident. The formations revealed themselves as a series of what had originally been deposited as horizontal sheets, lying in regular order one over the other, but which had been subsequently bent up into alternating arches and troughs (i.e. the anticlines and synclines of the geologist), while their visible parts, which now constitute the surface of our habitable lands, were simply those parts of the formation which are cut at present by the irregular plane of the present earth's surface. All those parts of the great arches and troughs formerly occurring above that plane have been removed by denudation; all those parts below that plane lie buried still out of sight within the solid earth-crust, although in every geological section of sufficient extent it was seen that the anticline or arch never occurred without the syncline or trough—in other words, that there was never a rise without a corresponding fall of the stratum. Yet it is only of late years that the stratigraphical geologist has come clearly to recognize the fact that the anticline and syncline must be considered together, and must be united as a single crust-wave, for the arch is never present without its complementary trough, and the two together constitute the tectonic or orographic unit. *The Fold*, the study of which, so brilliantly inaugurated by Heim in his 'Mechanismus der Gebirgsbildung,' is destined, I believe, in time, to give us the clue to the laws which rule in the local elevation and depression of the earth-crust, and furnish us with the means of discovery of the occult causes which lie at the source of those superficial irregularities which give to the face of our globe its variety, its beauty, and its habitability.

We have said already that this wave or fold of the geologist resembles that of the wave of the physicist.

Now we may regard such a wave as formed of two parts, the arch-like part above and the trough-like part below. The length of the wave is naturally the length of that line joining the outer extremities of the arch and trough, and passing through the centre node or point of origin of the wave itself, which bisects the line of contrary curvatures. The amplitude of the wave is the height of the arch added to the depth of the trough. Now the arch part of such a wave, if perfectly symmetrical, may clearly be regarded as belonging either to a wave travelling to the right, in which case the complementary trough is the one in that direction, or it may be regarded as belonging to a wave travelling to the left, in which case its trough must be the one in that direction. But as in the case of the sea wave, the advancing slope of the wave is always the steeper, and the real centre of the wave must lie half-way down this steeper slope; so there is no difficulty in recognizing the centre of a geological fold and its real direction of movement.

The fold of the geologist differs from the ordinary wave of the physicist, essentially in the fact that even in its most elementary conception, as that of a plate bent by a pressure applied from opposite sides, it necessarily includes the element of thickness. And this being the case, the rock sheet which is being folded and curved has different layers of its thickness affected differently; in the arch of the fold the upper layers of the rock sheet are extended, while its lower layers are compressed. On the contrary, in the trough of the fold the upper layers are compressed and the lower layers are extended. But in both arch and trough alike there exists a central layer, which, beyond taking up the common wave-like form, remains practically unaffected.

But the geological fold has in addition to length and thickness the further element of breadth, and this fact greatly complicates the phenomena.

But many of the movements which take place in a rock sheet which is being folded, or in other words those produced by the bending of a compound sheet composed of many leaves, can be fairly well studied in a very simple experiment. Take an ordinary large note-book, say an inch in thickness, with flexible covers, rule carefully a series of parallel lines across the edges of the leaves at the top of the book, about $\frac{1}{8}$ of an inch apart, and exactly at right angles to the plane of the cover. Then, holding the front edges loosely, press the book slowly from back and front into an S-like form until it can be pressed no further. As the wave grows it will be noticed that the cross lines which have been drawn on the upper edge of the book remain fairly parallel throughout the whole of the folding process, except in the central third of the book, where they arrange themselves into a beautiful sheaf-like form, showing how much the leaves of the book have sheared or slidden over each other in this central portion. It will also be seen when the S is complete that the book has been forced into a third of its former breadth. It is clear that the wave the book now forms must be regarded as made up of three sections: viz. a section forming the outside of the trough on the one side, and a section forming the outside of the arch on the other, and a central or common section, which may be regarded either as uniting or dividing the other two.

As this experiment gives us a fair representation of what takes place in a geological fold, we see at a glance that the geologist is forced to divide his fold into three parts—an arch limb, a trough limb, and a middle limb—which latter we may call the *copula* or the *septum*, according as we regard it as connecting or dividing the other two. Our note-book experiment, therefore, shows us also that in the trough limb and the arch limb the leaves or layers undergo scarcely any change of relative position beyond taking on the growing curvature of the wave. But the layers in the central part, or *septum*, undergo sliding and shearing. It will be found also, by gripping the unbound parts of the book firmly and practicing the folding in different ways, that this *septum* is also a region of warping and twisting. This simple experiment should be practised again and again until these points are apparent, and the various stages of the folding process become clear; the surface of the book being forced first into a gentle arch-like rise with a corresponding trough-like fall, then stage by stage the arch should be pushed over on to the trough until the surfaces of the two are in contact and the book can be folded no further.

(*To be continued.*)

REVIEWS.

I.—Argiles de Speeton et leurs Équivalents. By A. Pavlow and G. W. Lamplugh. Extracted from the "Bulletin de la Société Impér. des Naturalistes de Moscou," Nos. 3 and 4, 1891. With eleven plates (Moscow, 1892).

THAT the study of life-zones furnishes the key to the elucidation of the relationship of fossiliferous rocks, however widely separated geographically, has long been recognised by palæontologists, and this lesson is enforced anew in the admirable monograph before us.

The authors divide their work into three parts; the first (pp. 1–33) contains a description of the beds at Speeton (Speeton Clay) and their equivalents in Lincolnshire, by Mr. Lamplugh; the second (pp. 34–155) gives a description, written by M. Pavlow, of those forms of Mesozoic Cephalopods—Belemnites and Ammonites—which are of the greatest importance for purposes of comparative stratigraphy. These fossils are compared with the fossils of other countries, chiefly with Russian forms, of which some are figured as well as described. This part of the work is preceded by a table (pp. 36–37) indicating the sub-divisions of the Jurassic and Lower Cretaceous beds of the neighbourhood of Moscow, and of the lower Volga region (Bas Wolga). Furthermore, M. Pavlow deals with the relationship between the Speeton and Lincolnshire beds and those of other countries (pp. 156–201).

The material upon which the memoir under review was based consisted in the main of Mr. Lamplugh's collection of fossils made at Speeton and in Lincolnshire, supplemented by many specimens lent to the authors by the officials connected with some of the leading Continental and British Museums.

In order to make clear the remarks which follow we here reproduce part of a stratigraphical table furnished by M. Pavlow, showing the different "zones" into which the Speeton and Russian beds have been divided.