haps take a large stone in each hand, and I have certainly found this useful in traversing rapid glacier streams when mid-thigh deep.

Frenchay, near Bristol, August 18 F. F. TUCKETT

Fascination

Is it a fact that snakes can fascinate birds? With reference to the fascination of man, the ingenious explanation offered in NATURE, vol. xxii. p. 338, seems to me unsatisfactory, in that it supposes the individual fascinated to be self-conscious in a degree necessary for the consideration which of two courses to adopt to escape danger. This supposition implies an amount of self-consciousness which surely is absent in such cases as narrated? I have frequently experienced this fascination when standing on the railway platform as the engine was steaming in, and with myself at those times it was to be accounted for by the *absorption of attention by the external object, little being left for self*. That cries for assistance showed consciousness of danger, as in cases mentioned by Mr. Curran in NATURE, vol. xxii. p. 318, might be explained by the fact that these would follow on a much less attention to self than would be required for movement to carry the body out of danger. Indeed they would be the outcome of *feeling* rather than of *thought*. This view seems to be borne out by the very description of those fascinated, *e.g.*, "have had their senses so engaged by a shell in its descent," "whose every gyration in the air he could count" (NATURE, vol. xxii. p. 318), and it is expressed definitely by Mr. Spencer ("Principles of Psychology," vol. ii. p. 438):—

"When the external object or act is an astounding one, the observer partially loses consciousness of himself. He is, as we say, *lost* in wonder, or has *forgotten* himself; and we describe him as afterwards *returning* to himself, *recollecting* himself. In this state, the related impressions received from the external object, joined with representations of the objective changes about to follow, monopolise consciousness, and keep out all those feelings and ideas which constitute self consciousness. Hence what is called 'fascination;' and hence the stupefaction on witnessing a tremendous catastrophe. Persons so 'possessed' are sometimes killed from the inability to recover self-consciousness in time to avoid danger." RICHARD HODGSON

Cambridge, August 17

"Hyper-Space"

IF some one learned in many dimensions would throw some light on *rudimentary contour lines in hyper-space*, it would doubtless interest many readers of NATURE, and inconceivably yours, $\sqrt{-1}$

August 9

THE BRITISH ASSOCIATION

THE fiftieth Annual Meeting of the British Association was opened yesterday evening at Swansea, when Prof. Allman resigned the presidential chair to Prof. Ramsay, who gave his inaugural address.

At midday on Monday the reception rooms at the Agricultural Hall, St. Helen's Road, were formally opened for the transaction of the business of the Association, under the direction of Mr. Gordon, the permanent under-secretary of the general staff, and the local honorary secretaries, Dr. Wm. Morgan and Mr. James Strick, and their efficient local staff. The hall, our Swansea correspondent informs us, is admirably situated on the borderline that separates the business part of the town from the west end residential suburbs, and the conveniences of the place are augmented by a good line of tramway and a temporary cab-stand in front, and telegraph, telephone, and post-office within the building. The arrangements had been brought to a very creditable state of completion by Monday, and the visitors have been pouring into the town steadily since Saturday. The suburban watering-place of Oystermouth, or The Mumbles, and many others of the favourite summer resorts of Gower are full to overflowing, but in the more immediate outskirts of the town, on the gently-sloping hill-sides that offer such excellent fresh air and such extended prospects of landscape and sea-view, there is ample accommodation for all comers, thanks to the really warm local hospitality and to the careful arrangements of the Local Committee.

A fair number of papers are down for reading in the various sections, the usually popular section of geography, however, exhibiting a sad dearth of contributions; we trust things may look brighter here before the end of the meeting.

INAUGURAL ADDRESS OF ANDREW CROMBIE RAMSAY, LL.D., F.R.S., V.P.G.S., DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM, AND OF THE MUSEUM OF PRACTICAL GEOLOGY, PRESIDENT

On the Recurrence of Certain Phenomena in Geological Time

IN this address I propose to consider the recurrence of the same kind of incidents throughout all geological time, as exhibited in the various formations and groups of formations that now form the known parts of the external crust of the earth. This kind of investigation has for many years forced itself on my attention, and the method I adopt has not heretofore been attempted in all its branches. In older times, Hutton and Playfair, in a broad and general manner, clearly pointed the way to the doctrine of uniformity of action and results, throughout all known geological epochs down to the present day; but after a time, like the prophets of old, they obtained but slight attention, and were almost forgotten, and the wilder cosmical theories of Werner more generally ruled the opinions of the geologists of the time. Later still, Lyell followed in the steps of Playfair, with all the advantages that the discoveries of William Smith afforded, and aided by the labours of that band of distinguished geologists, Sedgwick, Buckland, Mantell, De la Beche, Murchison, and others, all of whom some of us knew. Notwithstanding this new light, even now there still lingers the relics of the belief (which some of these geologists also maintained), that the physical phenomena which produced the older strata were not only different in kind, but also in degree from those which now rule the external world. Oceans, the waters of which attained a high temperature, attended the formation of the *primitive* crystalline rocks. Volcanic eruptions, with which those of modern times are comparatively insignificant, the sudden upheaval of great mountain chains, the far more rapid decomposition and degradation of rocks, and, as a consequence, the more rapid deposition of strata formed from their waste—all these were assumed as certainties, and still linger in some parts of the world among living geologists of deservedly high reputation. The chief object of this address is, therefore, to attempt to show, that whatever may have been the state of the world long before geological history began, as now written in the rocks, all known formations are comparatively so recent in geological time, that there is no reason to believe that they were produced under physical circumstances differing either in kind or degree from those with which we are now more or less familiar.

It is unnecessary for my present purpose to enter into details connected with the recurrence of marine formations, since all geologists know that the greater part of the stratified rocks were deposited in the sea, as proved by the molluscs and other fossils which they contain, and the order of their deposition and the occasional stratigraphical breaks in succession are also familiar subjects. What I have partly to deal with now, are exceptions to true marine stratified formations, and after some other important questions have been considered, I shall proceed to discuss the origin of various non-marine deposits from nearly the earliest known time down to what by comparison may almost be termed the present day.

Metamorphism.—All, or nearly all, stratified formations have been in a sense metamorphosed, since, excepting certain limestones, the fact of loose incoherent sediments having been by pressure and other agencies turned into solid rocks constitutes a kind of metamorphism. This, however, is only a first step toward the kind of metamorphism the frequent recurrence of which in geological time I have now to insist upon, and which implies that consolidated strata have undergone subsequent changes of a kind much more remarkable.

Common stratified rocks chiefly consist of marls, shales, slates, sandstones, conglomerates, and limestones, generally distinct and definite; but not infrequently a stratum, or strata, may partake of the characters in varied proportions of two or more of the above-named species. It is from such strata that metamorphic rocks have been produced, exclusive of the metamorphism of igneous rocks, on which I will not enter. These may be looked for in every manual of geology, and usually they may be found in them.

As a general rule, metamorphic rocks are apt to be much contorted, not only on a large scale, but also that the individual layers of mica quartz and felspar in gneiss are bent and folded in a great number of minute convolutions, so small that they may be counted by the hundred in a foot or two of rock. Such metamorphic rocks are often associated with masses of granite both in bosses and in interstratified beds or layers, and where the metamorphism becomes extreme it is often impossible to draw a boundary line between the gneiss and the granite; while, on the other hand, it is often impossible to draw any true boundary between gneiss (or other metamorphic rocks) and the ordinary strata that have undergone metamorphism. Under these circumstances it is not surprising that when chemically analysed there is often little difference in the constituents of the unmetamorphosed and the metamorphosed rock. This is a point of some importance in relation to the origin and non-primitive character of gneiss and other varieties of foliated strata, and also of some quartzites and crystalline limestones.

I am aware that in North America formations consisting of metamorphic rocks have been stated to exist of older date than the Laurentian gneiss, and under any circumstances it is obvious that vast tracts of pre-Laurentian land must have existed in all regions, by the degradation of which, sediments were derived wherewith to provide materials for the deposition of the originally unaltered Laurentian strata. In England, Wales, and Scotland attempts have also been made to prove the presence of more ancient formations, but I do not consider the data provided sufficient to warrant any such conclusion. In the Highlands of Scotland, and in some of the Western Isles, there are gneissic rocks of pre-Cambrian age, which, since they were first described by Sir Roderick Murchison in the North-west Highlands, have been, I think justly, considered to belong to the Laurentian series, unconformably underlying Cambrian and Lower Silurian rocks, and as yet there are no sufficient grounds for dissenting from his conclusion that they form the oldest known rocks in the British Islands.

It is unnecessary here to discuss the theory of the causes that produced the metamorphism of stratified rocks, and it may be sufficient to say, that under the influence of deep underground heat, aided by moisture, sandstones have been converted into quartzites, limestones have become crystalline, and in shaly, slaty, and schistose rocks, under like circumstances, there is little or no development of new material, but rather, in the main, a re-arrangement of constituents according to their chemical affinities in rudely crystalline layers, which have very often been more or less developed in pre-existing planes of bedding. The materials of the whole are approximately the same as those of the unaltered rock, but have been re-arranged in layers, for example, of quartz, felspar, and mica, or of hornblende, &c., while other minerals, such as schorl and garnets, are of not infrequent occurrence.

It has for years been an established fact that nearly the whole of the mountain masses of the Highlands of Scotland (exclusive of the Laurentian, Cambrian, and Old Red Sandstone formations) mostly consist of gneissic rocks of many varieties, and of quartzites and a few bands of crystalline limestone, which, from the north shore to the edge of the Old Red Sandstone, are repeated again and again in stratigraphical convolutions great and small. Many large bosses, veins, and dykes of granite are associated with these rocks, and, as already stated, it sometimes happens that it is hard to draw a geological line between granite and gneiss and *vice versâ*. These rocks, once called Primary or Primitive, were first proved by Sir Roderick Murchison to be of Lower Silurian age, thus revolutionising the geology of nearly one-half of Scotland. To the same age belongs by far the greater part of the broad hilly region of the south of Scotland that lies between St. Abb's Head on the east and the coast of Ayrshire and Wigtonshire on the west. In the south-west part of this district, several great masses of granite rise amid the Lower Silurian rocks, which in their neighbourhood pass into mica-schist, and even into fine-grained gneiss.

In Cornwall the occurrence of Silurian rocks is now well known. They are of metamorphic character, and partly associated with granite; and at Start Point, in South Devonshire, the Silurian strata have been metamorphosed into quartzites.

In parts of the Cambrian areas, Silurian rocks in contact with granite have been changed into crystalline hornblendic gneiss, and in Anglesey there are large tracts of presumed Cambrian strata, great part of which have been metamorphosed into chlorite and mica-schist and gneiss, and the same is partly the case with the Lower Silurian rocks of the centre of the island, where it is almost impossible to disentangle them from the associated granite.

In Ireland similar metamorphic rocks are common, and, on the authority of Prof. Hull, who knows them well, the following statements are founded:—"Metamorphism in Ireland has been geographical and not stratigraphical, and seems to have ceased before the Upper Silurian period.

"The epoch of greatest metamorphism appears to have been that which intervened between the close of the Lower Silurian period and the commencement of the Upper Silurian, taking the formations in ascending order.

"It is as yet undecided whether Laurentian rocks occur in Ireland. There are rocks in north-west Mayo very like those in Sutherlandshire, but if they are of Laurentian age they come directly under the metamorphosed Lower Silurian rocks, and it may be very difficult to separate them.

"Cambrian purple and green grits are not metamorphosed in the counties of Wicklow and Dublin, but the same beds at the southern extremity of county Wexford, near Carnsore Point, have been metamorphosed into mica-schist and gneiss.

"In the east of Ireland the Lower Silurian grits and slates have not been metamorphosed, except where in proximity to granite, into which they insensibly pass in the counties of Wicklow, Dublin, Westmeath, Cavan, Longford, and Down; but in the west and north-west of Ireland they have been metamorphosed into several varieties of schists, hornblende-rock, *and gneiss, or foliated granite*."

It would be easy to multiply cases of the metamorphism of Silurian rocks on the continent of Europe, as, for example, in Scandinavia and in the Ural Mountains, where, according to Murchison, "by following its masses upon their strike, we are assured that the same zone which in one tract has a mechanical aspect and is fossiliferous, graduates in another parallel of latitude into a metamorphic crystalline condition, whereby not only the organic remains, but even the original impress of sedimentary origin are to a great degree obliterated." The same kind of phenomena are common in Canada and the United States; and Medlicott and Blanford, in "The Geology of India," have described the thorough metamorphism of Lower Silurian strata into gneiss and syenitic and hornblende schists.

In Britain none of the Upper Silurian rocks have undergone any serious change beyond that of ordinary consolidation, but in the Eastern Alps at Gratz, Sir Roderick Murchison has described both Upper Silurian and Devonian strata interstratified with separate courses of metamorphic chloritic schist.

Enough has now been said to prove the frequent occurrence of metamorphic action among Cambrian and Lower and Upper Silurian strata.

If we now turn to the Devonian and Old Red Sandstone strata of England and Scotland, we find that metamorphic action has also been at work, but in a much smaller degree. In Cornwall and Devon five great bosses of granite stand out amid the stratified Silurian, Devonian, and Carboniferous formations. Adjoining or near these bosses the late Sir Henry De la Beche remarks, that "in numerous localities we find the coarser slates converted into rocks resembling mica-slate and gneiss, a fact particularly well exhibited in the neighbourhood of Meavy, on the south-east of Tavistock," and "near Camelford we observed a fine arenaceous and micaceous grauwacke turned into a rock resembling mica-slate near the granite." Other cases are given by the same author of slaty strata turned into mica-schist and gneiss in rocks now generally considered to be of Devonian age.

The Devonian rocks and Old Red Sandstone are of the same geological age, though they were deposited under different conditions, the first being of marine, and the latter of fresh-water origin. The Old Red Sandstone of Wales, England, and Scotland has not, as far as I know, suffered any metamorphism, excepting in one case in the north-east of Ayrshire, near the sources of the Avon Water, where a large boss of granite rises through the sandstone, which all round has been rendered crystalline with well-developed crystals of felspar.

On the continent of Europe a broad area of Devonian strata lies on both banks of the Rhine and the Moselle. Forty years ago Sedgwick and Murchison described the crystalline quartzites, chlorite, and micaceous slates of the Hundsruck and the Taunus, and from personal observation I know that the rocks in the country on either side of the Moselle are, in places, of a foliated or semi-foliated metamorphic character. In the Alps also, as already noticed, metamorphic Devonian strata occur interstratified with beds of metamorphic schists, and, Sir Roderick adds, "we have ample data to affirm that large portions of the Eastern Alps . . . are occupied by rocks of true palæozoic age, which in many parts have passed into a crystalline state."

I know of no case in Britain where the Carboniferous strata have been thoroughly metamorphosed, excepting that in South Wales beds of coal, in the West of Caermarthenshire and in South Pembrokeshire, gradually pass from so-called bituminous coal into anthracite. The same is the case in the United States, in both instances the Carboniferous strata being exceedingly disturbed and contorted. In the Alps, however, Sir Roderick Murchison seems to have believed that Carboniferous rocks may have been metamorphosed: a circumstance since undoubtedly proved by the occurrence of a coal-measure calamite, well preserved, but otherwise partaking of the thoroughly crystalline character of the gneiss in which it is imbedded, and which was shown to me by the late Prof. Gastaldi, at Turin.

I am well acquainted with all the Permian strata of the British Islands and of various parts of Continental Europe, and nowhere, that I have seen, have they suffered from metamorphic action, and strata of this age are, I believe, as yet unknown in the Alps. This closes the list of metamorphism of Palæozoic strata.

I will not attempt (they are so numerous) to mention all the regions of the world in which Mesozoic or Secondary formations have undergone metamorphic action. In Britain and the non-mountainous parts of France they are generally quite unaltered, but *in the Alps* it is different. There, as every one knows who is familiar with that region, the crystalline rocks in the middle of the chain have the same general strike as the various flanking stratified formations. As expressed by Murchison, "as we follow the chain from north-east to south-west we pass from the clearest types of sedimentary rocks, and, at length, in the Savoy Alps, are immersed in the highly-altered mountains of Secondary limestone," while "the metamorphism of the rocks is greatest as we approach the centre of the chain," and indeed any one familiar with the Alps of Switzerland and Savoy knows that a process of metamorphism has been undergone *by all the Jurassic rocks* (Lias and Oolites) of the great mountain chain. Whether or not any strata of Neocomian and Cretaceous age have been well metamorphosed in this region I am unable to say; but it seems to be certain that the Eocene or Lower Tertiary Alpine formation, known as the Flysch, contains beds of black schists which pass into Lydian stone, and also that in the Grisons it has been converted into gneiss and mica-schist, a fact mentioned by Studer and Murchison. I also have seen in the country north of the Oldenhorn nummulitic rocks so far foliated that they formed an imperfect gneiss.

In Tierra del Fuego, as described by Darwin, clay slates of early cretaceous date pass into gneiss and mica-slate with garnets, and in Chonos Islands, and all along the great Cordillera of the Andes of Chili, rocks of Cretaceous or Cretaceo-oolitic age have been metamorphosed into foliated mica-slate and gneiss, accompanied by the presence of granite, syenite, and greenstone.

This ends my list, for I have never seen or heard of metamorphic rocks of later date than those that belong to the Eocene series. Enough however has been said to prove that from the Laurentian epoch onward the phenomenon of extreme metamorphism of strata has been of frequent recurrence all through Palæozoic and Mesozoic times, and extends even to a part of the Eocene series equivalent to the soft unaltered strata of the formations of the London and Paris basins, which, excepting for their fossil contents, and sometimes highly-inclined positions, look as if they had only been recently deposited.

Volcanoes.—The oldest volcanic products of which I have personal knowledge are of Lower Silurian age. These in Wales consist of two distinct series, the oldest of which, chiefly formed of felspathic lavas and volcanic ashes, lie in and near the base of the Llandeilo beds, and the second, after a long interval of repose, were ejected and intermingled with the strata forming the middle part of the Bala beds. The Lower Silurian rocks of Montgomeryshire, Shropshire, Radnorshire, Pembrokeshire, Cumberland, and Westmoreland are to a great extent also the result of volcanic eruptions, and the same kind of volcanic rocks occur in the Lower Silurian strata of Ireland. I know of no true volcanic rocks in the Upper Silurian series.

In the Old Red Sandstone of Scotland lavas and volcanic ashes are of frequent occurrence, interstratified with the ordinary lacustrine sedimentary strata. Volcanic rocks are also intercalated among the Devonian strata of Devonshire. I know of none in America or on the continent of Europe.

In Scotland volcanic products are common throughout nearly the whole of the Carboniferous sub-formations, and they are found also associated with Permian strata.

I now come to the Mesozoic or Secondary epochs. Of Jurassic age (Lias and Oolites), it is stated by Lyell with some doubt, that true volcanic products occur in the Morea and also in the Apennines, and it seems probable, as stated by Medlicott and Blanford, that the Rajmahal traps may also be of Jurassic age.

In the Cordillera of South America, Darwin has described a great series of volcanic rocks intercalated among the Cretaceo-oolitic strata that forms so much of the chain; and the same author, in his "Geological Observations in South America," states that the Cordillera has been, probably with some quiescent periods, a source of volcanic matter from an epoch anterior to our Cretaceo-oolitic formation to the present day. In the Deccan volcanic traps rest on Cretaceous beds, and are overlaid by Nummulitic strata, and, according to Medlicott and Blanford, these were poured out in the interval between Middle Cretaceous and Lower Eocene times.

In Europe the only instance I know of a volcano of Eocene age is that of Monte Bolca near Verona, where the volcanic products are associated with the fissile limestone of that area.

The well-preserved relics of Miocene volcanoes are prevalent over many parts of Europe, such as Auvergne and The Velay, where the volcanic action began in Lower Miocene times, and was continued into the Pliocene epoch. The volcanoes of the Eifel are also of the same general age, together with the ancient Miocene volcanoes of Hungary.

The volcanic rocks of the Azores, Canaries, and Madeira are of Miocene age, while in Tuscany there are extinct volcanoes that began in late Miocene, and lasted into times contemporaneous with the English Coralline Crag. In the north of Spain, also, at Olot in Catalonia, there are perfect craters and cones remaining of volcanoes that began to act in newer Pliocene times and continued in action to a later geological date. To these I must add the great *coulées* of Miocene lava, so well known in the Inner Hebrides, on the mainland near Oban, &c., in Antrim in the north of Ireland, in the Faroe Islands, Greenland, and Franz-Joseph Land. It is needless, and would be tiresome, further to multiply instances, for enough has been said to show that in nearly all geological ages volcanoes have played an important part, now in one region, now in another, from very early Palæozoic times down to the present day; and, as far as my knowledge extends, at no period of geological history is there any sign of their having played a more important part than they do in the epoch in which we live.

Mountain Chains.—The mountain-chains of the world are of different geological ages, some of them of great antiquity, and some of them comparatively modern.

It is well known that in North America the Lower Silurian rocks lie unconformably on the Laurentian strata, and also that the latter had undergone a thorough metamorphism and been thrown into great anticlinal and synclinal folds, accompanied by intense minor convolutions, before the deposition of the oldest Silurian formation, that of the Potsdam Sandstone. Disturbances of the nature alluded to imply beyond a doubt that the Laurentian rocks formed a high mountain-chain of pre-Silurian date, which has since constantly been worn away and degraded by sub-aërial denudation.

In Shropshire, and in parts of North Wales, and in Cumberland and Westmoreland, the Lower Silurian rocks by upheaval formed hilly land before the beginning of the Upper Silurian epoch; and it is probable that the Lower Silurian gneiss of Scotland formed mountains at the same time, probably very much higher than now. However that may be, it is certain that these mountains formed high land before and during the deposition of the Old Red Sandstone, and the upheaval of the great Scandinavian chain (of which the Highlands may be said to form an outlying portion) also preceded the deposition of the Old Red Strata. In both of these mountain regions the rocks have since undergone considerable movements, which in the main seem to have been movements of elevation, accompanied undoubtedly by that constant atmospheric degradation to which all high land is especially subject.

The next great European chain in point of age is that of the Ural, which according to Murchison is of pre-Permian age, a fact proved by the Permian conglomerates which were formed from the waste of the older strata. On these they lie quite unconformably and nearly undisturbed on the western flank of the mountains.

In North America the great chain of the Alleghany Mountains underwent several disturbances, the last (a great one) having taken place after the deposition of the Carboniferous rocks, and before that of the New Red Sandstone. The vast mountainous region included under the name of the Rocky Mountains, after several successive disturbances of upheaval, did not attain its present development till after the Miocene or Middle Tertiary epoch.

In South America, notwithstanding many oscillations of level recorded by Darwin, the main great disturbance of the strata that form the chain of the Andes took place apparently *in post-cretaceous times*.

The Alps, the rudiments of which began in more ancient times, received their greatest disturbance and upheaval in post-Eocene days, and were again raised at least 5,000 feet (I believe much more) at the close of the Miocene epoch. The Apennines, the Pyrenees, the Carpathians, and the great mountain region on the east of the Adriatic and southward into Greece, are of the same general age, and this is also the case in regard to the Atlas in North Africa, and the Caucasus on the borders of Europe and Asia. In the north of India the history of the Great Himalayan range closely coincides with that of the Alps, for while the most powerful known disturbance and elevation of the range took place after the close of the Eocene epoch, a subsequent elevation occurred in post-Miocene times closely resembling and at least equal to that sustained by the Alps at the same period.

It would probably not be difficult by help of extra research to add other cases to this notice of recurrences of the upheaval and origin of special mountain chains, some of which I have spoken of from personal knowledge; but enough has been given to show the bearing of this question on the argument I have in view, namely, that of repetition of the same kind of events throughout all known geological time.

Salt and Salt Lakes.—I now come to the discussion of the circumstances that produced numerous recurrences of the development of beds of various salts (chiefly common rock-salt) in many formations, which it will be seen are to a great extent connected with continental or inland conditions. In comparatively rainless countries salts are often deposited on the surface of the ground by the effect of solar evaporation of moisture from the soil. Water dissolves certain salts in combination with the ingredients of the underlying rocks and soils, and brings it to the surface, and when solar evaporation ensues the salt or salts are deposited on the ground. This is well known to be the case in and near the region of the Great Salt Lake in North America, and in South America in some of the nearly rainless districts of the Cordillera, extensive surface-deposits of salts of various kinds are common. The surface of the ground around the Dead Sea is also in extra dry seasons covered with salt, the result of evaporation, and in the upper provinces of India (mentioned by Medlicott and Blanford) "many tracts of land in the Indo-Gangetic alluvial plain are rendered worthless for cultivation by an efflorescence of salt known in the North-West Provinces as *Reh*," while every geographer knows that in Central Asia, from the western shore of the Caspian Sea to the Kinshan Mountains of Mongolia, with rare exceptions nearly every lake is salt in an area at least 3,500 miles in length. This circumstance is due to the fact that all so-called fresh-water springs, and therefore all rivers, contain small quantities of salts in solution only appreciable to the chemist, and by the constant evaporation of pure water from the lakes, in the course of time, it necessarily happens that these salts get concentrated in the water by the effect of solar heat, and, if not already begun, precipitation of solid salts must ensue.

The earliest deposits of rock-salt that I know about have been described by Mr. A. B. Wynne of the Geological Survey of India, in his memoir "On the Geology of the Salt Range in the Punjab."[1] The beds of salt are of great thickness, and along with gypsum and dolomitic layers occur in marl of a *red colour* like our Keuper Marl. This colour I have for many years considered to be, in certain cases, apt to indicate deposition of sediments in inland lakes, salt or fresh, as the case may be, and with respect to these strata in the Punjab Salt Range, authors seem to be in doubt whether they were formed in inland lakes or in lagoons near the seaboard, which at intervals were liable to be flooded by the sea, and in which in the hot seasons salts were deposited by evaporation caused by solar heat. For my argument, it matters but little which of these was the true physical condition of the land of the time, though I incline to think the inland lake theory most probable. The age of the strata associated with this salt is not yet certainly ascertained. In "The Geology of India" Medlicott and Blanford incline to consider them of Lower Silurian age, and Mr. Wynne, in his "Geology of the Salt Range," places the salt and gypsum beds doubtfully on the same geological horizon.

The next salt-bearing formation that I shall notice is the Salina or Onondaga Salt Group of North America, which forms part of the Upper Silurian rocks, and lies immediately above the Niagara Limestone. It is rich in gypsum and in salt-brine, often of a very concentrated character, "which can only be derived from original depositions of salt," and it is also supposed by Dr. T. Sterry Hunt to contain solid rock-salt 115 feet in thickness at the depth of 2,085 feet, near Saginaw Bay in Michigan.

In the Lower Devonian strata of Russia near Lake Ilmen, Sir R. Murchison describes salt springs at Starai Russa. Sinkings, "made in the hope of penetrating to the source of these salt springs," reached a depth of 600 feet without the discovery of rock salt, "and we are left in doubt whether the real source of the salt is in the lowest beds of the Devonian rocks or even in the Silurian system."

In the United States brine springs also occur in Ohio, Pennsylvania, and Virginia, in Devonian rocks.

In Michigan salts are found from the Carboniferous down to the Devonian series; and in other parts of the United States, Western Pennsylvania, Virginia, Ohio, Illinois, and Kentucky, from the lower Coal-measures salts are derived which must have been deposited in inland areas, since even in the depths of inland seas that communicate with the great ocean, such as the Mediterranean and the Red Sea, no great beds of salt can be deposited. Before such strata of salt can be formed, supersaturation must have taken place.

In the North of England, at and near Middlesborough, two deep bore-holes were made some years ago in the hope of reaching the Coal-measures of the Durham coal-field. One of them at Salthome was sunk to a depth of 1,355 feet. First they passed through 74 feet of superficial clay and gravel, next through about 1,175 feet of red sandstones and marls, with beds of rock-salt and gypsum. The whole of these strata (excepting the clay and gravel) evidently belong to the Keuper marls and sandstones of the upper part of our New Red series. Beneath these they passed through 67 feet of dolomitic limestone, which in this neighbourhood forms the upper part of the Permian series, and beneath the limestone the strata consist of 27 feet of gypsum and rock-salt and marls, one of the beds of rock-salt having a thickness of 14 feet. This bed of Permian salt is of some importance, since I have been convinced for long that the British Permian strata were deposited, not in the sea, but in salt lakes comparable in some respects to the great salt lake of Utah, and in its restricted fauna to the far greater salt lake of the Caspian Sea. The gypsum, the dolomite or magnesian limestone, the red marls covered with rain-pittings, the sun-cracks, and the impressions of footprints of reptiles made in the soft sandy marls when the water was temporarily lowered by the solar evaporation of successive summers, all point to the fact that our Permian strata were not deposited in the sea, but in a salt lake or lakes once for a time connected with the sea. The same may be said of other Permian areas in the central parts of the Continent of Europe, such as Stassfurt and Anhalt, Halle and Altern in Thuringia, and Sperenberg, near Berlin, and also in India.[1]

Neither do I think that the Permian strata of Russia, as described by Sir Roderick Murchison, were necessarily, as he implies, deposited in a wide ocean. According to his view all marine life universally declined to a minimum after the close of the Carboniferous period, that decline beginning with the Permian and ending with the Triassic epoch. Those who believe in the doctrine of evolution will find it hard to accept the idea which this implies, namely, that all the prolific forms of the Jurassic series sprang from the scanty faunas of the Permian

[1] Many earlier notices and descriptions of the Salt Range might be quoted, but Mr. Wynne's is enough for my purpose.

[1] See "Physical Geology and Geography of Great Britain," 5th edition, where the question is treated in more detail.

and Triassic epochs. On the contrary, it seems to me more rational to attribute the poverty of the faunas of these epochs to accidental abnormal conditions in certain areas, that for a time partially disappeared during the deposition of the continental Muschelkalk which is absent in the British Triassic series.

In the whole of the Russian Permian strata only fifty-three species were known at the time of the publication of "Russia and the Ural Mountains," and I have not heard that this scanty list has been subsequently increased. I am therefore inclined to believe that the red marls, grits, sandstones, conglomerates, and great masses of gypsum and rock-salt were all formed in a flat inland area which was occasionally liable to be invaded by the sea during intermittent intervals of minor depression, sometimes in one area, sometimes in another, and the fauna small in size and poor in numbers is one of the results, while the deposition of beds of salt and gypsum is another. If so, then in the area now called Russia, in sheets of inland Permian water, deposits were formed strictly analogous to those of Central Europe and of Britain, but on a larger scale.

Other deposits of salt deep beneath overlying younger strata are stated to occur at Bromberg in Prussia, and many more might be named as lying in the same formation in Northern Germany.

If we now turn to the Triassic series it is known that it consists of only two chief members in Britain, the Bunter Sandstones and the Keuper or New Red Marls, the Muschelkalk of the Continent being absent in our islands. No salt is found in the Bunter Sandstones of England, but it occurs in these strata at Schöningen in Brunswick, and also near Hanover. In the lower part of the Keuper series deposits of rock-salt are common in England and Ireland. At Almersleben, near Calbe, rock-salt is found in the Muschelkalk, and also at Erfurt and Slottenheim in Thuringia and at Wilhelmsglück in Würtemburg. In other Triassic areas it is known at Hönigsen, Hanover, in middle Keuper beds. In the red shales at Sperenberg and Lieth on the Lower Elbe, salt was found at the depth of 3,000 feet, and at Stassfurth the salt is said to be "several hundred yards thick."

In Central Spain rock-salt is known, and at Tarragona, Taen, and also at Santander in the north of Spain, all in Triassic strata. Other localities may be named in the Upper Trias, such as the Salzkammergut, Aussee, Hallstatt, Ischl, Hallein in Salzburg, Halle in the Tyrol, and Berchesgaden in Bavaria.

In the Salt Range of mountains in Northern India saliferous strata are referred with some doubt by Medlicott and Blanford to the Triassic strata.

In the Jurassic series (Lias and Oolites) salt and gypsum are not uncommon. One well-known instance occurs at Berg in the valley of the Rhone in Switzerland, where salt is derived from the Lias. Salt and gypsum are also found in Jurassic rocks at Burgos in Spain. At Gap in France there is gypsum, and salt is found in the Austrian Alps in Oolitic limestone.

In the Cretaceous rocks salt occurs, according to Lartet, at Jebel Usdom by the Dead Sea, and other authorities state that it occurs in the Pyrenees and at Biskra in Africa, where "mountains of salt" are mentioned as of Cretaceous age. The two last-named localities are possibly uncertain; but whether or not this is the case, it is not the less certain that salt has been deposited in Cretaceous rocks, and, judging by analogy, probably in inland areas of that epoch.

In the Eocene or Older Tertiary formations, rock-salt is found at Cardona in Spain, and at Kohat in the Punjab it occurs at the base of Nummulitic beds. It is also known at Mandi in India in strata supposed to be of Nummulitic Eocene age.

The record does not end here, for a zone of rock-salt lies in Sicily at the top of the Salina clays in Lower Miocene beds, and in Miocene strata gypsum is found at several places in Spain, while salt also occurs in beds that are doubtfully of Miocene age (but may be later) at Wielitzka in Poland, Kalusz in Galicia, Bukowina, and also in Transylvania.

In Pliocene or Later Tertiary formations, thick beds of gypsum are known in Zante, and strata of salt occur in Roumania and Galicia, while in Pliocene rocks, according to Dana, or in Post-Tertiary beds, according to others, a thick bed of pure salt was penetrated to a depth of 38 feet at Petit Anse in Louisiana. This ends my list, though I have no doubt that, by further research, many more localities might be given. Enough, however, has been done to show that rock-salt (and other salts) are of frequent *recurrence* throughout all geological time, and as in my opinion it is impossible that common salt can be deposited in the open ocean, it follows that this and other salts must have been precipitated from solutions, which, by the effect of solar evaporation, became at length supersaturated, like those of the Dead Sea, the great salt lake of Utah, and in other places which it is superfluous to name.

Fresh-water. Lakes and Estuaries.—I now come to the subject of recurrences of fresh-water conditions both in lakes and estuaries. In the introduction to the "Geology of India," by Messrs. Medlicott and Blanford, mention is made of the Blaini and Krol rocks as probably occupying "hollows formed by denudation in the old gneissic rocks," and the inference is drawn that "if this be a correct view, it is probable that the cis-Himalayan Palæozoic rocks are in great part of fresh-water origin, and that the present crystalline axis of the Western Himalayas approximately coincides with the shore of the ancient Palæozoic continent, of which the Indian peninsula formed a portion." The Krol rocks are classed broadly with "Permian and Carboniferous" deposits, but the Blaini beds are doubtfully considered to belong to Upper Silurian strata. If this point be by and by established, this is the earliest known occurrence of fresh-water strata in any of the more ancient Palæozoic formations.

It is a fact worthy of notice that the colour of the strata formed in old lakes (whether fresh or salt) of Palæozoic and Mesozoic age is apt to be red: a circumstance due to the fact that each little grain of sand or mud is usually coated with a very thin pellicle of peroxide of iron. Whether or not the red and purple Cambrian rocks[1] may not be *partly* of fresh-water origin, is a question that I think no one but myself has raised.[2]

There is however, in my opinion, no doubt with regard to the fresh-water origin of the Old Red Sandstone, as distinct from the contemporaneous marine deposits of the Devonian strata. This idea was first started by that distinguished geologist, Dr. Fleming, of Edinburgh, followed by Mr. Godwin-Austen, who, from the absence of marine shells and the nature of the fossil fishes in these strata, inferred that they were deposited, not in the sea, as had always been asserted, but in a great fresh-water lake or in a series of lakes. In this opinion I have for many years agreed, for the nearest analogies of the fish are, according to Huxley, the Polypterus of African rivers, the Ceratodus of Australia, and in less degree the Lepidosteus of North America. The truth of the supposition that the Old Red Sandstone was deposited in fresh water, is further borne out by the occurrence of a fresh-water shell, *Anodonta jukesii*, and of ferns in the Upper Old Red Sandstone in Ireland; and the same shell is found at Dura Den in Scotland, while in Caithness, along with numerous fishes, there occurs the small bivalve crustacean *Estheria murchisoniæ*.

I think it more than probable that the red series of rocks that form the Catskill Mountains of North America (and with which I am personally acquainted) were formed in the same manner as the Old Red Sandstones of Britain; for, excepting in one or two minor interstratifications, they contain no relics of marine life, while "the fossil fishes of the Catskill beds, according to Dr. Newberry, appear to represent closely those of the British Old Red Sandstone" (Dana).

The Devonian rocks of Russia, according to the late Sir Roderick Murchison, consist of two distinct types, viz., Devonian strata identical in general character with those in Devonshire and in various parts of the continent of Europe. These are exclusively of a marine character, while the remainder corresponds to the Old Red Sandstone of Wales, England, and Scotland.

At Tchudora, about 105 miles south-east of St. Petersburg, the lowest members of the series consist of flag-like, compact limestones accumulated in a tranquil sea, and containing fucoids and encrinites, together with shells of Devonian age, such as Spirifers, Terebratulæ, Orthis, Leptænas, Avicula, Modiola, Natica, Bellerophon, &c., while the upper division graduates into the Carboniferous series as it often does in Britain, and, like the Old Red Sandstone of Scotland, contains only fish-remains, and in both countries they are of the same species. "Proceeding from the Valdai Hills on the north," the geologist "quits *a Devonian Zone with a true 'Old Red' type* dipping under the

[1] By Cambrian, I mean only the *red and purple* rocks of Wales, England, Scotland, and Ireland, older than the Menevian beds, or any later division of the Silurian strata that may chance to rest upon them.

[2] "On the Red Rocks of England of older date than the Trias." *Jour. Geol. Soc.*, 1871, vol. xxviii.

Carboniferous rocks of Moscow, and having passed through the latter he finds himself suddenly in a yellow-coloured region, entirely dissimilar in structure to what he had seen in any of the northern governments, which, of a different type as regards fossils, is the true stratigraphical *equivalent of the Old Red system*." This seems to me, as regards the Russian strata, to mean that just as the Devonian strata of Devonshire are the true equivalents of the Old Red Sandstone of Wales and Scotland, they were deposited under very different conditions, the first in the sea and the others in inland fresh-water lakes. At the time Sir Roderick Murchison's work was completed, the almost universal opinion was that the Old Red Sandstone was a marine formation. In the year 1830 the Rev. Dr. Fleming of Edinburgh read a paper before the Wernerian Society in which he boldly stated that the "*Old Red Sandstone* is a *fresh-water formation*" of older date than the Carboniferous Limestone. This statement, however, seems to have made no impression on geologists till it was revived by Godwin-Austen in a memoir "On the Extension of the Coal-measures," &c., in the *Journal* of the Geological Society, 1856. Even this made no converts to what was then considered a heretical opinion. I have long held Dr. Fleming's view, and unfortunately published it in the third edition of "The Physical Geology and Geography of Great Britain," without at the time being aware that I had been forestalled by Dr. Fleming and Mr. Godwin-Austen.

To give anything like a detailed account of all the fresh-water formations deposited in estuaries and lakes from the close of the Old Red Sandstone times down to late Tertiary epochs is only fitted for a manual of geology, and would too much expand this address; and I will therefore give little more than a catalogue of these deposits in ascending order.

In the Coal-measure parts of the Carboniferous series a great proportion of the shales and sandstones are of fresh-water origin. This is proved all over the British Islands by the shells they contain, while here and there marine interstratifications occur, generally of no great thickness. There is no doubt among geologists that these Coal-measure strata were chiefly deposited under estuarine conditions, and sometimes in lagoons or in lakes, while numerous beds of coal formed by the life and death of land plants, each underlaid by the soil on which the plants grew, evince the constant recurrence of terrestrial conditions. The same kind of phenomena are characteristic of the Coal-measures all through North America, and in every country on the continent of Europe, from France and Spain on the west to Russia in the east, and the same is the case in China and in other areas.

In Scotland, according to Prof. Judd, fresh-water conditions occur more or less all through the Jurassic series, from the Lias to the Upper Oolites. In England fresh-water strata, with thin beds of coal, are found in the Inferior Oolite of Yorkshire, and in the middle of England and elsewhere in the Great Oolite. The Purbeck and Wealden strata, which in a sense fill the interval between the Jurassic and Cretaceous series, are almost entirely formed of fresh-water strata, with occasional thin marine interstratifications. By some the Wealden beds are considered to have been formed in and near the estuary of a great river, while others, with as good a show of reason, believe them to have been deposited in a large lake subject to the occasional influx of the sea.

In the eastern part of South Russia the Lias consists chiefly of fresh-water strata, as stated by Neumayr.

The Godwana rocks of Central India range from Upper Palæozoic times well into the Jurassic strata, and there all these formations are of fresh-water origin. Fresh-water beds with shells are also interstratified with the Deccan traps of Cretaceous and Tertiary (Eocene) age, while 2,000 feet of fresh-water sands overlie them.

In South-Western Sweden, as stated by Mr. Bauerman, "the three coal-fields of Hoganas, Stabbarp, and Rodingé lie in the uppermost Triassic or Rhætic series." In Africa the Karoo beds, which it is surmised may be of the age of the New Red Sandstone, contain beds of coal. In North America certain fresh-water strata, with beds of lignite, apparently belong to the Cretaceous and Eocene epochs, and in the north of Spain and south of France there are fresh-water lacustrine formations in the highest Cretaceous strata.

In England the Lower and Upper Eocene strata are chiefly of fresh-water origin, and the same is the case in France and other parts of the Continent. Certain fresh-water formations in Central Spain extend from the Eocene to the Upper Miocene strata.

There is only one small patch of Miocene beds in England, at Bovey Tracey, near Dartmoor, formed of fresh-water deposits with interstratified beds of lignite or Miocene coal. On the continent of Europe Miocene strata occupy immense independent areas, extending from France and Spain to the Black Sea. In places too numerous to name they contain beds of "brown coal," as lignite is sometimes called. These coal-beds are often of great thickness and solidity. In one of the pits which I descended near Teplitz, in Bohemia, the coal, which lies in a true basin, is 40 feet thick, and underneath it there is a bed of clay, with rootlets, quite comparable to the underclay which is found beneath almost every bed of coal in the British and other coal-fields of the Carboniferous epoch. The Miocene rocks of Switzerland are familiar to all geologists who have traversed the country between the Jura and the Alps. Sometimes they are soft and incoherent, sometimes formed of sandstones, and sometimes of conglomerates, as on the Righi. They chiefly consist of fresh-water lacustrine strata, with some minor marine interstratifications which mark the influx of the sea during occasional partial submergences of portions of the area. These fresh-water strata, of great extent and thickness, contain beds of lignite, and are remarkable for the relics of numerous trees and other plants which have been described by Prof. Heer of Zurich with his accustomed skill. The Miocene fresh-water strata of the Sewalik Hills in India are well known to most students of geology, and I have already stated that they bear the same relation to the more ancient Himalayan Mountains that the Miocene strata of Switzerland and the North of Italy do to the pre-existing range of the Alps. In fact it may be safely inferred that something far more than the rudiments of our present continents existed long before Miocene times, and this accounts for the large areas on those continents which are frequently occupied by Miocene fresh-water strata. With the marine formations of Miocene age this address is in no way concerned, nor is it essential to my argument to deal with those later Tertiary phenomena, which in their upper stages so easily merge into the existing state of the world.

Glacial Phenomena.—I now come to the last special subject for discussion in this address, viz., the Recurrence of Glacial Epochs, a subject still considered by many to be heretical, and which was generally looked upon as an absurd crotchet when, in 1855, I first described to the Geological Society boulder-beds containing ice-scratched stones and erratic blocks in the Permian strata of England. The same idea I afterwards applied to some of the Old Red Sandstone conglomerates, and of late years it has become so familiar, that the effects of glaciers have at length been noted by geologists from older Palæozoic epochs down to the present day.

In the middle of last July I received a letter from Prof. Geikie, in which he informed me that he had discovered mammilated *moutonnée* surfaces of Laurentian rocks, passing underneath the Cambrian sandstones of the north-west of Scotland at intervals, all the way from Cape Wrath to Loch Torridon, for a distance of about 90 miles. The mammilated rocks are, says Prof. Geikie, "*as well rounded off as any recent roche moutonnée*," and "in one place these bosses are covered by a huge angular breccia of this old gneiss (Laurentian) with blocks sometimes 5 or 6 feet long." This breccia, where it occurs, forms the base of the Cambrian strata of Sutherland, Ross, and Cromarty, and while the higher strata are always well stratified, where they approach the underlying Laurentian gneiss "they become pebbly, passing into coarse unstratified agglomerates or boulder-beds." In the Gairloch district "it is utterly unstratified, the angular fragments standing on end and at all angles," just as they do in many modern moraine mounds wherever large glaciers are found. The general subject of Palæozoic glaciers has long been familiar to me, and this account of more ancient glaciers of Cambrian age is peculiarly acceptable.

The next sign of ice in Britain is found in the Lower Silurian rocks of Wigtonshire and Ayrshire. In the year 1865 Mr. John Carrick Moore took me to see the Lower Silurian graptolitic rocks at Corswall Point in Wigtonshire, in which great blocks of gneiss, granite, &c., are imbedded, and in the same year many similar erratic blocks were pointed out to me by Mr. James Geikie in the Silurian strata of Carrick in Ayrshire. One of the blocks at Corswall, as measured by myself, is nine feet in length, and the rest are of all sizes, from an inch or two up to several feet in diameter. There is no gneiss or granite in this region nearer than those of Kirkcudbrightshire and Arran, *and these are of later geological date than the strata amid which the* *erratic blocks are imbedded.* It is therefore not improbable that they may have been derived from some high land formed of Laurentian rocks of which the outer Hebrides and parts of the mainland of Scotland form surviving portions. If so, then I can conceive of no agent capable of transporting large boulders and dropping them into the Lower Silurian mud of the seas of the time save that of icebergs or other floating ice, and the same view with regard to the neighbouring boulder-beds of Ayrshire is held by Mr. James Geikie. If however any one will point out any other natural cause still in action by which such results are at present brought about, I should be very glad to hear of it.

I must now turn to India for further evidence of the action of Palæozoic ice. In the Himalayas of Pangi, south-east of Kashmir, according to Medlicott and Blanford, "old slates, supposed to be Silurian, contain boulders in great numbers," which they believe to be of glacial origin. Another case is mentioned as occurring in "transition beds of unknown relations," but in another passage they are stated to be "very ancient, but no idea can be formed of their geological position." The *underlying rocks are marked by distinct glacial striations.*

The next case of glacial boulder-beds with which I am acquainted is found in Scotland, and in some places in the north of England, where they contain what seem to be indistinctly ice-scratched stones. I first observed these rocks on the Lammermuir Hills, south of Dunbar, lying unconformably on Lower Silurian strata, and soon inferred them to be of glacial origin, a circumstance that was subsequently confirmed by my colleagues Prof. and Mr. James Geikie, and is now familiar to other officers of the Geological Survey of Scotland.

I know of no boulder formations in the Carboniferous series, but they are well known as occurring on a large scale in the Permian brecciated conglomerates, where they consist "of pebbles and large blocks of stone, generally angular, imbedded in a marly paste . . . the fragments have mostly travelled from a distance, apparently from the borders of Wales, and some of them are three feet in diameter." Some of the stones are as well scratched as those found in modern moraines or in the ordinary boulder-clay of what is commonly called the Glacial epoch. In 1855 the old idea was still not unprevalent that during the Permian epoch, and for long after, the globe had not yet cooled sufficiently to allow of the climates of the external world being universally affected by the constant radiation of heat from its interior. For a long time, however, this idea has almost entirely vanished, and now, in Britain at all events, it is little if at all attended to, and other glacial episodes in the history of the world have continued to be brought forward and are no longer looked upon as mere ill-judged conjectures.

The same kind of brecciated boulder-beds that are found in our Permian strata occur in the Rotheliegende of Germany, which I have visited in several places, and I believe them to have had a like glacial origin.

Mr. G. W. Stow, of the Orange Free State, has of late years given most elaborate accounts of similar Permian boulder-beds in South Africa. There great masses of moraine matter not only contain ice-scratched stones, but on the banks of rivers where the Permian rock has been removed by aqueous denudation the underlying rocks, well rounded and mammillated, *are covered by deeply incised glacier grooves* pointing in a direction which at length leads the observer to the Pre-Permian mountains from whence the stones were derived that formed these ancient moraines.[1]

Messrs. Blanford and Medlicott have also given in "The Geology of India" an account of boulder-beds in what they believe to be Permian strata, and which they compare with those described by me in England many years before. There the Godwana group of the Talchir strata contains numerous boulders, many of them six feet in diameter, and in one instance *some of the blocks were found to be polished and striated, and the underlying Vindhyan rocks were similarly marked.*" The authors also correlate these glacial phenomena with those found in similar deposits in South Africa, discovered and described by Mr. Stow.

In the Olive group of the Salt range, described by the same authors, there is a curious resemblance between a certain conglomerate "and that of the Talchir group of the Godwana system." This "Olive conglomerate" belongs to the Cretaceous series, and contains ice-transported erratic boulders derived from unknown rocks, one of which of red granite "is polished and striated on three faces in so characteristic a manner that very little doubt can exist of its having been transported by ice." One block of red granite at the Mayo Salt Mines of Khewra "is 7 feet high and 19 feet in circumference." In the "Transition beds" of the same authors, which are supposed to be of Upper Cretaceous age, there also are boulder beds with erratic blocks of great size.

I know of no evidence of glacial phenomena in Eocene strata excepting the occurrence of huge masses of included gneiss in the strata known as Flysch in Switzerland. On this question, however, Swiss geologists are by no means agreed, and I attach little or no importance to it as affording evidence of glacier ice.

Neither do I know of any Miocene glacier-deposits excepting those in the north of Italy, near Turin, described by the late eminent geologist, Gastoldi, and which I saw under his guidance. These contain many large erratic boulders derived from the distant Alps, which, in my opinion, were then at least as lofty or even higher than they are now, especially if we consider the immense amount of denudation which they underwent during Miocene, later Tertiary, and post-Tertiary times.

At a still later date there took place in the north of Europe and America what is usually misnamed "*The* Glacial Epoch," when a vast glacial mass covered all Scandinavia and distributed its boulders across the north of Germany, as far south as the country around Leipzig, when Ireland also was shrouded in glacier ice, and when a great glacier covered the larger part of Britain and stretched southward, perhaps nearly as far as the Thames on the one side, and certainly covered the whole of Anglesey, and probably the whole, or nearly the whole, of South Wales. This was after the advent of man.

Lastly, there is still a minor Glacial epoch in progress on the large and almost unknown Antarctic continent, from the high land of which in latitudes which partly lie as far north as 60° and 62°, a vast sheet of glacier-ice of great thickness extends far out to sea and sends fleets of icebergs to the north, there to melt in warmer latitudes. If in accordance with the theory of Mr. Croll, founded on astronomical data, a similar climate were transferred to the northern hemisphere, the whole of Scandinavia and the Baltic would apparently be covered with glacier-ice, and the same would probably be the case with the Faroe Islands and great part of Siberia, while even the mountain tracts of Britain might again maintain their minor systems of glaciers.

Conclusions.—In opening this address I began with the subject of the oldest metamorphic rocks that I have seen—the Laurentian strata. It is evident to every person who thinks on the subject that their deposition took place *far from the beginning of recognised geological time.* For there must have been older rocks by the degradation of which they were formed. And if, as some American geologists affirm, there are on that continent metamorphic rocks of more ancient dates than the Laurentian strata, there must have been rocks more ancient still to afford materials for the deposition of these pre-Laurentian strata.

Starting with the Laurentian rocks, I have shown that the phenomena of *metamorphism* of strata have been continued from that date all through the later formations, or groups of formations, down to and including part of the Eocene strata in some parts of the world.

In like manner I have shown that ordinary volcanic rocks have been ejected in Silurian, Devonian, Carboniferous, Jurassic, Cretaceo Oolitic, Cretaceous, Eocene, Miocene, and Pliocene times, and from all that I have seen or read of these ancient volcanoes I have no reason to believe that volcanic forces played a more important part in any period of geological time than they do in this our modern epoch.

So also mountain chains existed before the deposition of the Silurian rocks, others of later date before the Old Red Sandstone strata were formed, and the chain of the Ural before the deposition of the Permian beds. The last great upheaval of the Alleghany Mountains took place between the close of the formation of the Carboniferous strata of that region and the deposition of the New Red Sandstone.

According to Darwin, after various oscillations of level, the Cordillera underwent its chief upheaval after the Cretaceous epoch, and all geologists know that the Alps, the Pyrenees, the Carpathians, the Himalayas, and other mountain-chains (which I have named) underwent what seems to have been their chief great upheaval after the deposition of the Eocene strata, while

[1] Mr. Stow's last memoir on this subject is still in manuscript. It is so exceedingly long, and the sections that accompany it are of such unusual size, that the Geological Society could not afford their publication. It was thought that the Government of the Orange Free State might undertake this duty, but the late troubles in South Africa have probably hindered this work—it is to be hoped only for a time.

some of them were again lifted up several thousands of feet after the close of the Miocene epoch.

The deposition of salts from aqueous solutions in inland lakes and lagoons appears to have taken place through all time—through Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Eocene, Miocene, and Pliocene epochs—and it is going on now.

In like manner fresh-water and estuarine conditions are found now in one region, now in another, throughout all the formations or groups of formations, possibly from Silurian times onward; and glacial phenomena, so far from being confined to what was and is generally still termed *the* Glacial epoch, are now boldly declared, by independent witnesses of known high reputation, to begin with the Cambrian epoch, and to have occurred somewhere, at intervals, in various formations, from almost the earliest Palæozoic times down to our last post-Pliocene "Glacial epoch."

If the nebular hypothesis of astronomers be true (and I know of no reason why it should be doubted), the earth was at one time in a purely gaseous state, and afterwards in a fluid condition, attended by intense heat. By and by consolidation, due to partial cooling, took place on the surface, and as radiation of heat went on, the outer shell thickened. Radiation still going on, the interior fluid matter decreased in bulk, and, by force of gravitation, the outer shell being drawn towards the interior, gave way, and, in parts, got crinkled up, and this, according to cosmogonists, was the origin of the earliest mountain-chains. I make no objection to the hypothesis, which, to say the least, seems to be the best that can be offered, and looks highly probable. But, assuming that it is true, these hypothetical events took place so long before authentic geological history began, as written in the rocks, that the earliest of the physical events to which I have drawn your attention in this address was, to all human apprehension of time, so enormously removed from these early assumed cosmical phenomena, *that they appear to me to have been of comparatively quite modern occurrence, and to indicate that, from the Laurentian epoch down to the present day, all the physical events in the history of the earth have varied neither in kind nor in intensity from those of which we now have experience.* Perhaps many of our British geologists hold similar opinions, but, if it be so, it may not be altogether useless to have considered the various subjects separately on which I depend to prove the point I had in view.

SECTION C

GEOLOGY

Opening Address by H. C. Sorby, LL.D., F.R.S., &c., President of the Section

In selecting a subject for an address to be given in accordance with the custom of my predecessors, I was anxious that it should be in some way or other connected with the locality in which we have met. If I had been adequately acquainted with the district, I should have thought it incumbent on me to give such an outline of the general geology of the surrounding country as would have been useful to those attending this meeting. I am, however, practically a stranger to South Wales, and must therefore leave that task to others. On reflecting on the various subjects to which I might have called your attention, it appears to me that I could select one which would be eminently appropriate in a town and district where iron and copper are smelted on so large a scale, and, as I think, also equally appropriate from a geological point of view. This subject is the comparative structure of artificial slags and erupted rocks. In making this choice I was also influenced by the fact that in my two anniversary addresses as President of the Geological Society, I have recently treated on the structure and origin of modern and ancient stratified rocks, and I felt that, if in the present address I were to treat on certain peculiarities in the structure of igneous rocks, I should have described the leading conclusions to which I have been led by studying the microscopical structure of nearly all classes of rocks. It would, however, be impossible in the time now at disposal to treat on all the various branches of the subject. Much might be said on both the purely chemical and purely mineralogical aspects of the question; but though these must not be ignored, I propose to draw your attention mainly to another special and remarkable class of facts, which, so far as I am aware, have attracted little or no attention, and yet, as I think, would be very instructive if we could fully understand their meaning. Here, however, as in so many cases, the observed facts are clear enough, but their full significance is somewhat obscure, owing to the want of adequate experimental data, or of sufficient knowledge of general physical laws.

A considerable amount of attention has already been paid to the mineral constitution of slags, and to such peculiarities of structure as can be learned independently of thin microscopical sections. A very complete and instructive work, specially devoted to the subject, was published by von Leonhard about twenty-two years ago, just at the time when the microscope was first efficiently applied to the study of rocks. Since then, Vogelsang and others have described the microscopical structure of some slags in connection with their study of obsidian and other allied volcanic rocks. At the date of the publication of von Leonhard's work the questions in discussion differed materially from those which should now claim attention. There was still more or less dispute respecting the nature and origin of certain rocks which have now been proved to be truly volcanic by most unequivocal evidence. I am not at all surprised at this, since, as I shall show, there is such a very great difference in their characteristic structure and that of the artificial products of igneous fusion, that but for the small portions of glass inclosed in the constituent crystals, described by me many years ago under the name of "glass-cavities," there would often be no positive proof of their igneous origin. There was also considerable doubt as to the manner in which certain minerals in volcanic rocks had been generated. The observed facts were sufficient to prove conclusively that some had been formed by sublimation, others by igneous fusion, and others deposited from more or less highly-heated water, but it was difficult or impossible to decide whether in particular cases certain minerals had been formed exclusively by one or other process, or sometimes by one and sometimes by the other, or by the combined action of water and a very high temperature. I must confess that, even now that so much may be learned by studying with high magnifying powers the internal structure of crystals, I should hesitate very much in deciding what were the exact conditions under which certain minerals have been formed. This hesitation is probably as much due to inadequate examination, and to the want of a complete study of typical specimens, both in the field and by means of the microscope, as to the unavoidable difficulties of the subject. Such doubt, however, applies more to the origin of minerals occurring in cavities than to those constituting a part of true rock masses, to which latter I shall almost exclusively refer on the present occasion. In the formation of these it appears to me that sublimation has occurred to a very limited extent. In many cases true igneous fusion has played such a leading part that the rocks may be fairly called *igneous*, but, in other cases water in some form or other has, I think, had so much influence, that we should hesitate to call them *igneous*, and the term *erupted* would be open to far less objection, since it would adequately express the manner of their occurrence, and not commit us to anything open to serious doubt.

In studying erupted rocks of different characters we see that at one extreme they are as truly igneous as any furnace-product, and at the other extremity hardly, if at all, distinguishable from certain deposits met with in mineral veins, which furnish abundant evidence of the preponderating, if not exclusive influence of water, and have very little or nothing in common with products certainly known to have been formed by the action of heat, and of heat alone. Between these extremes there is every connecting link, and in certain cases it is almost, if not quite, impossible to say whether the characteristic structure is due more to the action of heat than of water. The great question is whether the presence of a small quantity of water in the liquid or gaseous state is the true cause of very well-marked differences in structure, or whether greater pressure and the necessarily slower rate of cooling were not the more active causes, and the presence of water in one state or another was merely the result of the same cause. This is a question which ought to be solved by experiment, but I fear it would be almost impossible to perform the necessary operations in a satisfactory manner.

What I now propose to do is to describe a particular class of facts which have lately attracted my attention, and to show that the crystalline minerals in products known to have been formed by the action of heat alone have a certain very well-marked and characteristic structure, which is gradually modified as we pass through modern and more ancient volcanic to plutonic rocks, in such a manner as to show at once that they are intimately related and yet differ in such characteristic particulars that I think other agencies than mere heat must have had great influence in producing the final results.

In dealing with this subject I propose in the first place to describe the characteristic structure of products formed artificially under perfectly well-known conditions, and then to pass gradually to that of rocks whose origin must be inferred, and cannot be said to have been completely proved.

Crystalline Blowpipe Beads.—Some years ago I devoted a considerable amount of time to the preparation and study of crystalline blowpipe beads, my aim being to discover simple and satisfactory means for identifying small quantities of different earths and metallic oxides, when mixed with others, and I never supposed that such small objects would throw any light on the structure and origin of vast masses of natural rock. The manner in which I prepared them was as follows.—A small bead of borax was so saturated with the substance under examination at a high temperature that it became opaque either on cooling or when slowly re-heated. It was again fused so as to be quite transparent, and then very slowly cooled over the flame. If properly managed, the excess of material held in solution at a high temperature slowly crystallised out, the form and character of the crystals depending on the nature of the substance and on the presence of other substances added to the bead as test reagents. By this means I proved that in a few exceptional cases small simple solid crystals are formed. More frequently they are compound, or occur as minute needles, but the most characteristic peculiarity is the development of complex skeleton crystals of extreme beauty, built up of minute attached prisms, so as to give rise to what would be a well-developed crystal with definite external planes, if the interspaces were all filled up.

In many cases the fibres of these skeletons are parallel to three different axes perpendicular to one another, and it might be supposed that the entire skeleton was due to the growth of small needle-shaped crystals, all uniformly elongated in the line of one crystalline axis, so that the resulting mass would be optically and crystographically complex; but in some cases the different systems of fibres or needles are inclined obliquely, and then the optical characters enable us to prove that the separate prisms are not similar to one another, but developed along different crystalline planes, so as to build up one definite crystal, mechanically complex, but optically and crystographically simple, or merely twinned. In a few special cases there is a well-pronounced departure from this rule, and truly compound groups of prisms are formed. In the centre there is a definite simple prism, but instead of this growing continuously in the same manner, so as to produce a larger prism, its ends, as it were, break up into several smaller prisms slightly inclined to the axis of the first, and these secondary prisms in like manner break up into still smaller, so as ultimately to give rise to a curious complex, brush-like growth, showing in all positions a sort of fan-shaped structure, mechanically, optically, and crystographically complex.

I have done my best to describe these various kinds of crystals seen in blowpipe beads as clearly as can be done without occupying too much time, but feel that it is impossible to make the subject as simple as it really is without numerous illustrations. However, for the purpose now in view, it will I trust suffice to have established the fact that we may divide the crystals in blowpipe beads into the following groups, which, on the whole, are sufficiently distinct, though they necessarily pass one into the other:—

1. Simple crystals.
2. Minute detached needles.
3. Fan-shaped compound groups.
4. Feathery skeleton crystals.

It must not be supposed that crystals of one or other of these groups occur promiscuously and without some definite relation to the special conditions of the case. Very much depends upon their chemical composition. Some substances yield almost exclusively those of one group, and other substances those of another, whilst in some cases a difference in the rate of cooling and other circumstances give rise to variations within certain limits; and, if it were possible to still further vary some of the conditions, these limits would probably be increased. Thus, for example, the earliest deposition of crystalline matter from the glassy solvent is sometimes in the form of simple solid prisms or needles, but later on in the process it is in the form of compound feathery tufts; and, if it were possible to cool the beads much more slowly whilst they are very hot, I am inclined to believe that some substances might be found that in the early stage of the process would yield larger and more solid crystals than those commonly met with. This supposition at all events agrees with what takes place when such salts as potassium chloride are crystallised from solution in water. Some of my blowpipe beads prove most conclusively that several perfectly distinct crystalline substances may be contemporaneously deposited from a highly-heated vitreous solvent, which is an important fact in connection with the structure of igneous rocks, since some authors have asserted that more than one mineral species cannot be formed by the slow cooling of a truly melted rock. The great advantage of studying artificial blowpipe beads is that we can so easily obtain a variety of results under conditions which are perfectly well known and more or less completely under control.

Artificial Slags.—I now proceed to consider the structure of slags, and feel tempted to enter into the consideration of the various minerals found in them, which are more or less perfectly identical with those characteristic of erupted rocks, but some of the most interesting, like the felspars, occur in a well-marked form only in special cases, where iron ores are smelted with fluxes, seldom if ever employed in our own country, so that my acquaintance with them is extremely small. My attention has been mainly directed to the more common products of our blast furnaces. On examining these, after having become perfectly familiar with the structure of blowpipe beads, I could see at once that they are very analogous, if not identical, in their structure. In both we have a glassy solvent, from which crystals have been deposited; only in one case this solvent was red hot melted borax, and in the other glassy, melted stone. Thus, for example, some compounds, like what I believe is Humboldtilite, crystallise out in well-marked solid crystals, like those seen occasionally in blowpipe beads, whereas others crystallise out in complex feathery skeletons, just like those so common in, and characteristic of, the beads. In both we also often see small detached needles scattered about in the glassy base. These skeleton crystals and minute needles have been described by various writers under the names *crystallites*, *belonites*, and *trichites*. Though we have not the great variety of different forms met with in the beads, and cannot so readily vary the conditions under which they are produced, yet we can at all events see clearly that their structural character depends both on their chemical constitution and on the physical conditions under which they have crystallised. None of my microspical preparations of English slags appear to contain any species of felspar, but several contain what I believe is some variety of augite, both in the form of more or less solid prisms, and of feathery skeletons of great beauty and of much interest in connection with the next class of products to which I shall call your attention, viz., rocks artificially melted and slowly cooled.

Rocks Artificially Melted.—I have had the opportunity of preparing excellent thin microscopical sections of some of the results of the classic experiments of Sir James Hall. I have also carefully studied the product obtained by fusing and slowly cooling much larger masses of the basalt of Rowley, and have compared its structure with that of the original rocks. Both are entirely crystalline, and, as far as I can ascertain, both are mainly composed of the same minerals. Those to which I would especially call attention are a triclinic felspar and the augite. The general character of the crystals is, however, strikingly different. In the artificial product a considerable part of the augite occurs as flat, feathery plates, like those in furnace slags, which are quite absent from the natural rock, and only part occurs as simple solid crystals, analogous to those in the rock, but much smaller and less developed. The felspar is chiefly in the form of elongated, flat, twinned prisms, which, like the prisms in some blowpipe beads, commence in a more simple form and end in complex fan-shaped brushes, whereas in the natural rock they are all larger than in the artificial, and exclusively of simple characters. On the whole then, though the artificially melted and slowly cooled basalt is entirely crystalline, and has a mineral composition closely like that of the natural rock, its mechanical structure is very different, being identical with that of blowpipe beads and slags.

Volcanic Rocks.—Passing now to true natural igneous rocks, we find some, like obsidian, which closely correspond with blowpipe beads, slags, and artificially melted rocks, in having a glassy base through which small crystalline needles are scattered;

but the more completely crystalline volcanic rocks have, on the whole, a structure very characteristically unlike that of the artificial products. I have most carefully examined all my sections of modern and ancient volcanic rocks, but cannot find any in which the augite or magnetite is crystallised in feathery skeletons. In the case of only one single natural rock from a dyke near Beaumaris have I found the triclinic felspar arranged in just the same fan-shaped, brush-like groups, as those in similar rocks artificially melted and slowly cooled. The large solid crystals in specimens from other localities sometimes show that towards the end of their growth small flat prisms have developed on their surface, analogous to those first deposited in the case of the artificial products. In slags composed almost exclusively of what I believe is Humboldtilite, the crystals are indeed uniformly as simple and solid as those in natural rocks, but the examination of different blowpipe beads shows that no fair comparison can be made between altogether different substances. We must compare together the minerals common to the natural and the artificial products, and we then see that, on the whole, the two classes are only just distinctly connected by certain exceptional crystals and by structural characters which, as it were, overlap enough to show that there is a passage from one type to the other. In the artificial products are a few small solid crystals of both augite and a triclinic felspar, which closely correspond to the exceptionally small crystals in the natural rocks, but the development of the great mass of the crystals is in a different direction in the two cases. In the artificial products it is in the direction of complex skeletons, which are not seen in the natural rock, but in the natural rock it is in the direction of large simple solid crystals, which are not met with in the artificial products. There is a far closer analogy in the case of partially vitreous rocks, which, independent of the true glassy base common to them and the artificial products, often contain analogous crystalline needles. Even then, however, we see that in the artificial products the crystals tend to develop into complex skeletons, but in the natural rocks into simple solid crystals.

It must not be supposed that these facts in any way lead me to think that thoroughly crystalline modern and ancient volcanic rocks were never truly fused. The simple, large, and characteristic crystals of such minerals as augite, felspar, leucite, and olivine often contain so many thoroughly well-marked glass inclosures as to prove most conclusively that when the crystals were formed they were surrounded by, and deposited from, a melted glassy base, which was caught up by them whilst it was still melted. This included glass has often remained unchanged, even when the main mass became completely crystalline, or has been greatly altered by the subsequent action of water. I contend that these glass inclosures prove that many of our British erupted rocks were of as truly igneous origin as any lava flowing from a modern volcano. The difference between the structure of such natural rocks and that of artificial slags must not in my opinion be attributed to the absence of true igneous fusion, but to some difference in the surrounding conditions, which was sufficient to greatly modify the final result when the fused mass became crystalline on cooling. The observed facts are clear enough, and several plausible explanations might easily be suggested, but I do not feel at all convinced that any single one would be correct. That which first suggests itself is a much slower cooling of the natural rocks than is possible in the case of the artificial products, and I must confess that this explanation seems so plausible that I should not hesitate to adopt it if certain facts could be accounted for in a satisfactory manner. Nothing could be more simple than to suppose that skeleton crystals are formed when deposition takes place in a hurried manner, and they so overgrow the supply that they develop themselves along certain lines of growth before there has been time to solidly build up what has been roughly sketched in outline. I cannot but think that this must be a true, and to some extent active, cause, even if it be inadequate to explain all the facts. What makes me hesitate to adopt it by itself is the structure of some doleritic rocks when in close contact with the strata amongst which they have been erupted. In all my specimens the effects of much more rapid cooling are perfectly well marked. The base of the rock when in close contact is sometimes so extremely fine-grained that it is scarcely crystallised, and is certainly far less crystalline and finer-grained than the artificial products to which I have called attention, and yet there is no passage towards those structures which are most characteristic of slags, or at least no such passage as I should have expected if these structures depended exclusively on more rapid cooling. We might well ascribe something to the effect of mass, but one of my specimens of basalt melted and slowly cooled in a small crucible is quite as crystalline as another specimen taken from a far larger mass, though I must confess that what difference there is in this latter is in the direction of the structure characteristic of natural rocks. The presence or absence of water appears to me a very probable explanation of some differences. When there is evidence of its presence in a liquid state during the consolidation of the rock, we can scarcely hesitate to conclude that it must have had some active influence; but in the case of true volcanic rocks the presence of liquid water is scarcely probable. That much water is present in some form or other is clearly proved by the great amount of steam given off from erupted lavas. I can scarcely believe that it exists in a liquid state except at great depths, but it may possibly be present in a combined form or as a dissolved vapour under much less pressure, and the question is, whether this water may not have considerable influence on the growth of crystals formed prior to eruption, before it was given off as steam. I do not know one single fact which can be looked upon as fairly opposed to this supposition, and it is even to some extent supported by experiment. M. Daubrée informs me that the crystals of augite formed by him at a high temperature by the action of water have the solid character of those in volcanic rocks, and not the skeleton structure of those met with in slags. The conditions under which they were formed were however not sufficiently like those probably present during the formation of erupted lavas to justify our looking upon the explanation I have suggested as anything more than sufficiently plausible, in the absence of more complete experimental proofs.

Granitic Rocks.—I now proceed to consider rocks of another extreme type, which for distinction we may call the granitic. On the whole they have little or nothing in common with slags or with artificial products similar to slags, being composed exclusively of solid crystals, analogous in character only to slag-crystals of very different mineral nature. As an illustration I would refer to the structure of the products formed by fusing and slowly cooling upwards of a ton of the syenite of Grooby, near Leicester. Different parts of the resulting mass differ very materially, but still there is an intimate relation between them, and a gradual passage from one to the other. The most characteristic feature of those parts which are completely crystalline is the presence of beautiful feathery skeleton crystals of magnetite, and of long flat prisms of a triclinic felspar, ending in complex, fan-shaped brushes. There are no solid crystals of felspar, hornblende, and quartz, of which the natural rock is mainly composed, to the entire exclusion of any resembling those in the melted rock. As looked upon from the point of view taken in this address, the natural and artificial products have no structural character in common, so that I think we must look for other conditions than pure igneous fusion to explain the greatly modified results. We have not to look far for evidence of a well-marked difference in surrounding circumstances. The quartz in the natural rock contains vast numbers of fluid cavities, thus proving that water was present, either in the liquid state or as a vapour so highly compressed that it afterwards condensed into an almost equal bulk of liquid. In some specimens of granite there is indeed clear proof that the water was present as a liquid, supersaturated with alkaline chlorides, like that inclosed in the cavities of some minerals met with in blocks ejected from Vesuvius, which also have to some extent what may be called a granitic structure.

In the case of one very exceptional and interesting granite, there is apparently good proof that the felspar crystallised out at a temperature above the critical point of water—that is to say, at a temperature higher than that at which water can exist as a liquid under any pressure—and it caught up highly compressed steam, comparatively, if not entirely, free from soluble salts; whereas the quartz crystallised when the temperature was so far lowered as to be below the critical point, and the water had passed into a liquid, supersaturated with alkaline chlorides, which have crystallised out as small cubes in the fluid-cavities, just as in the case of minerals in some of the blocks ejected from Vesuvius.

Confining our attention, then, to extreme cases, we thus see that rocks of the granitic type differ in a most characteristic manner from the products of artificial igneous fusion, both in the structure of the crystals and in containing liquid water inclosed at the time of their formation. The question then arises whether these differences were due to the presence of the liquid water, or whether its presence and the characteristic structure were not both the effects of the great pressure of superincumbent rocks. I do not see how this can be decided in a perfectly satisfactory manner, but must confess that I am inclined to believe that, whilst great pressure was necessarily the reason why the water did not escape as vapour, the presence of liquid water during final consolidation must have had a very considerable influence in modifying the structure of the rock, and had a great share in developing what we may call the granitic type.

It would be very instructive to follow out the gradual passage from one extreme type to another far more completely than is possible on the present occasion. The most interesting examples of rocks intermediate between the granitic and volcanic types that I have been able to examine in adequate detail are the various Cornish elvans and other quartz felsites, which furnish all but a complete passage from pitch-stone to granite. Some specimens prove that quartz may crystallise out from and inclose a perfectly glassy base, without a trace of liquid water, and at the same time other specimens prove equally well that, as we approach the granitic type, the quartz was not deposited from a glassy solvent, but inclosed more or less water. In the few intermediate cases there appears to be evidence of the conjoint presence of uncombined water and melted stony matter. On the whole, if we take into consideration only the external form of the larger crystals, rocks of the granitic type are very much as though the crystals met with in truly volcanic rocks had been strained out from the glassy or fine-grained base, and the intermediate spaces filled with quartz. The internal structure of the crystals is however very different, the cavities in one class containing glass, and in the other water. This most essential and characteristic difference proves that rocks of the true granitic type cannot have been formed simply by the more complete crystallisation of the general base of the rock. If the crystals in granite were analogous to those developed in volcanic rocks, and the only essential difference were that the residue crystallised out more slowly and completely, so as to give rise to a more coarsely crystallised base, the crystals first formed ought not, as I think, to differ so essentially as that in one case they should inclose only glass, and in the other only water. Taking all into consideration, we can therefore scarcely suppose that the crystals in granitic rocks were deposited from a truly melted dry glassy solvent, like those in volcanic rocks or in slags.

General Results.—I have, I trust, now said enough to show that the objects here described may be conveniently separated into three well-marked groups, viz. artificial slags, volcanic rocks, and granitic rocks. My own specimens all show perfectly well-marked and characteristic structures, though they are connected in some cases by intermediate varieties. Possibly such connecting links might be more pronounced in other specimens that have not come under my notice. I must, however, base my conclusions on what I have been able to study in an adequate manner, by examining my own preparations, and leave it for others to correct any error into which I may have been led from lack of more numerous specimens. In any case the facts seem abundantly sufficient to prove that there must be some active cause for such a common, if not general difference in the structural character of these three different types. The supposition is so simple and attractive that I feel very much tempted to suggest that this difference is due to the presence or absence of water as a gas or as a liquid. In the case of slags it is *not* present in any form. Considering how large an amount of steam is given off from erupted lavas, and that, as a rule, no fluid-cavities occur in the constituent minerals, it appears to me very plausible to suppose that those structures which are specially characteristic of volcanic rocks are in great measure, if not entirely, due to the presence of *associated* or *dissolved vapour*. The fluid-cavities prove that water was sometimes, if not always, present as a *liquid* during the consolidation of granitic rocks, and we can scarcely hesitate to conclude that it must have had very considerable influence on the rock during consolidation. Still, though these three extreme types appear to be thus characterised by the absence of water or by its presence in a state of vapour or liquid, I think we are scarcely in a position to say that this difference in the conditions is more than a plausible explanation of the differences in their structure. At the same time I do not know any facts that are opposed to this conclusion, and we should perhaps not greatly err in thus correlating the structures, even though the water was not the essential and active cause of the differences.

Confining our attention to the more important crystalline constituents which are common to the different types, we may say that the chief structural characters of the crystals are as follows:—

a. Skeleton crystals.
b. Fan-shaped groups.
c. Glass cavities.
d. Simple crystals.
e. Fluid cavities.

These different structural characters are found combined in different ways in the different natural and artificial products, and for simplicity I will refer to them by means of the affixed letters.

The type of the artificial products of fusion may generally be expressed by $a + b$ or $b + c$; that is to say, it is characterised by skeleton crystals and fan shaped groups, or by fan haped groups and glass-cavities. In like manner, the volcanic type may be expressed occasionally by $b + c$, but generally by $c + d$, and the granitic by $d + e$. These relations will be more apparent if given in the form of a table as follows:—

Slag type	$a + b$ / $b + c$
Volcanic type	$b + c$ / $c + d$
Granitic type	$d + e$

Hence it will be seen that there is a gradual passage from one type to the other by the disappearance of one character and the appearance of another, certain characters in the meanwhile remaining common, so that there is no sudden break, but an overlapping of structural characteristics. It is, I think, satisfactory to find that, when erupted rocks are examined from such a new and independent point of view, the general conclusions to which I have been led are so completely in accord with those arrived at by other methods of study.

Conclusion.—And now I feel that it is time to conclude. I have necessarily been compelled to give only a general account of the subject, and perhaps for want of adequate description many facts may appear more complex than they really are. Some are indeed of anything but simple character, and their full explanation is perhaps beyond our present power. The greater part are, however, much more simple and easy to observe than to describe; and, even if I have failed to make everything as plain as I could wish, I hope that I have succeeded in making the principal points sufficiently clear to show that the structure of slags and analogous artificial products throws much light on the structure and origin of the various groups of erupted rocks. I feel that very much still remains to be learned, and, as I think, could be learned by the further extension of this method of inquiry. What strikes me most is the great necessity for the more complete appreciation of experimental methods of research; but to carry out the experiments necessary to clear up the essential difficulties of the subject would, I fear, be a most difficult undertaking. In the meantime all that we can do is to compare the structure of known artificial products with that of natural rocks, and to draw the best conclusions we can from the facts, as viewed in the light of our present knowledge of chemistry and physics. My own impression is that there is still much to be learned respecting the exact conditions under which some of our commonest rocks were formed.

SECTION D

BIOLOGY

OPENING ADDRESS BY DR. A. C. L. G. GÜNTHER, M.A., PH.D., F.R.S., PRESIDENT OF THE SECTION

SIXTEEN years ago, at the meeting of the British Association at Bath, the duty which I am endeavouring to discharge to-day was intrusted to my predecessor and old friend, the late Dr. John Edward Gray. In the address which he then delivered before this section he spoke on "Museums, their Use and Improvement;" and he, who had devoted a whole lifetime to the formation and management of one of the greatest zoological collections in the world, was well qualified to give an opinion and advice on this subject. Indeed, when I read now what he then insisted on as a necessary change in the system of museums, I feel compelled to pay a passing tribute to his memory.

Zoology, geology, botany were to him not distinct and independent studies; the views advanced by Lamarck, by Treviranus, viz., that our knowledge of these sciences would remain fragmentary and one-sided as long as they were not studied in their mutual relations, found in him one of the earliest advocates in this country. Against all opposition he tried to unite the zoological and palæontological collections in the British Museum, giving up this attempt only after having convinced himself of the impracticability of the scheme; and he readily joined the band of men who demanded that a museum should be not merely a repository for the benefit of the professed student and specialist, but serve in an equal measure for the recreation of the mass of the people and for their instruction in the principles of biology. This was the spirit in which he worked; and in the last years of his life he had the satisfaction of being able to say that there was no other collection in existence more accessible and more extensively used than the one under his charge.

I am encouraged to return to-day to the same subject because I have daily the opportunity of observing that the public more and more comprehend the use of museums, and that they appreciate any real improvement, however slight. Paragraphs, leaders, articles published in the public journals and periodicals, references made in speeches or addresses, questions put in the Houses of Parliament whenever an opportunity offers—all testify that the progress of museums is watched with interest. Not long ago a Royal Commission entered deeply and minutely into the subject, and elicited a mass of evidence and information invaluable in itself, though you may differ from some of the conclusions and views expressed in their final Report. Biological science has made rapid strides: not only do we begin to understand better the relations of the varieties of living forms to each other, but the number of the varieties themselves that have been made known has also been increased beyond all expectation, and the old repositories have everywhere been found too narrow to house the discoveries of the last forty years. Therefore you find that the United States, Austria, Prussia and Saxony, Denmark and Holland, France and Great Britain, have erected, or are building anew, their national museums, not to mention the numerous smaller museums, which are more or less exclusively devoted to some branch of biological science.

The purposes for which museums are formed are threefold:—(1) To diffuse instruction among, and offer rational amusement to, the mass of the people; (2) to aid in the elementary study of biology; and (3) to supply the professed student of biology or the specialist with as complete materials for his scientific researches as can be obtained, and to preserve for future generations the materials on which those researches have been based.

Although every museum has, as it were, a physiognomy of its own, differing from the others in the degree in which it fulfils one, or two, or all three of those objects, we may divide museums into three classes, viz.:—

(1) National, (2) Provincial, and (3) strictly Educational museums—a mode of division which may give to those of this assembly who are not biologists an idea of what we mean by the term "species." The three kinds pass into each other, and there may be hybrids between them.

The museum of the third class, the strictly *Educational institution*, we find established chiefly in connection with universities, colleges, medical and science schools. Its principal object is to supply the materials for teaching and studying the elements and general outlines of biology; it supplements, and is the most necessary help for, oral and practical instruction, which always ought to be combined with this kind of museum. The conservation of objects is subservient to their immediate utility and unrestricted accessibility to the student. The collection is best limited to a selection of representatives of the various groups or "types," arranged in strictly systematic order, and associated with preparations of such parts of their organisation as are most characteristic of the group. Collections of this kind I have seen arranged with the greatest ingenuity, furnishing the student with a series of demonstrations which correspond to the plan followed in some elementary text-book. This, however, is not sufficient for practical instruction; besides the exhibited permanent series, a stock of well-preserved specimens should be kept for the express purpose of allowing the student to practise dissection and the method of independent examination. And in this latter I am inclined to include the method of determining to what order, family, genus, or species any given object should be referred. By such practice alone can the student learn to understand the relative value of taxonomic characters and acquire the elementary knowledge indispensable for him in the future.

Finally, in the educational museum should be formed a series of all the animals and plants, which are of economic value or otherwise of importance to man.

The proposal to unite living and extinct forms in one series, which has been urged by eminent men with such excellent reasons, might be tried in the educational museum with great advantage to the student, as the principal objections that are brought forward against this plan being carried out in larger collections, do not apply here.

A museum which offers to the teacher and student the materials mentioned, fulfils its object; its formation does not require either a long time or heavy expense; but the majority of these institutions outgrow in time their original limits in one or the other direction; and if such additions do not interfere with the general arrangement of the museum, they neither destroy its character, nor do they add to its value as a strictly educational institution.

The principal aim of a *Provincial* Museum ought, in my opinion, to be popular instruction. I do not mean that it should be merely a place for mild amusement and recreation, but that it should rank equal with all similar institutions destined to spread knowledge and cultivate taste among the people. To attain this aim it should contain an arranged series of well-preserved specimens representing as many of the remarkable types of living forms as are obtainable; a series of useful as well as noxious plants and animals; of economic products derived from the animal and vegetable kingdoms; and last (but not least), a complete and accurately-named series of the flora and fauna of the neighbourhood. The majority of provincial museums with which I am acquainted are far from coming up to this ideal. One of the first principles by which the curator of such a museum should be guided is to admit into his collection no specimen unless it be well mounted and a fair representation of its species. He has not the excuse of his colleague in charge of a large museum, who has to retain those monsters which are literally his *bêtes-noires*, viz., specimens to which a history is attached, and the removal of which would sooner or later be resented by some of his fellow-labourers. The only too frequent presence of such badly-mounted specimens in provincial museums is not always the fault of the curator. The slender means with which he is provided are generally insufficient to encourage taxidermists to bestow the necessary amount of skill and time on their work. Besides, taxidermy is an art which depends as much on natural gift as drawing or modelling, and as long as we are obliged to be satisfied with receiving into our collections mediocre specimens, mediocre stuffers will take up taxidermy as a trade without there being one who is naturally qualified for it.

The direct benefit of a complete collection of the flora and fauna of the district in which the provincial museum is situated, is obvious and cannot be exaggerated. The pursuit of collecting and studying natural history objects gives to the persons who are inclined to devote their leisure hours to it, a beneficial training for whatever their real calling in life may be: they acquire a sense of order and method; they develop their gift of observation; they are stimulated to healthy exercise. Nothing encourages them in this pursuit more than a well-named and easily accessible collection in their own native town, upon which they can fall back as a pattern and an aid for their own. This local collection ought to be always arranged and named according to the plan and nomenclature adopted in one of those numerous monographs of the British fauna and flora in which this country excels; and I consider its formation in every provincial museum to be of higher importance than a collection of foreign objects.

The majority of provincial museums contain not only biological collections, but, very properly, also collections of art and literature; it is no part of my task to speak of the latter, but before I proceed to the next part of my address, I must say that nothing could more strikingly prove the growing desire of the people for instruction than the erection of the numerous free libraries and museums now spread over the country. The more, the healthier their rivalry, the safer their growth will be, especially if they avoid depending on aid from the State or placing themselves in the hands of a responsible minister—if they remain what they are—municipal institutions—the children and pride of their own province.

However great, however large a country or a nation may be, it can have in reality only one *National* Museum, truly deserving of the name. Yours is the British Museum; those of Scotland and Ireland can never reach the same degree of completeness, though there is no one who wishes more heartily than I do that they may approach it as closely as conditions permit. The most prominent events in the recent history of the British Museum (to which I must confine the remainder of my remarks) are well known to the majority of those present;—that the question either of enlarging the present building at Bloomsbury, or of erecting another at South Kensington for the collections of natural history, was fully discussed for years in its various aspects; that, finally, a Select Committee of the House of Commons reported in favour of the expediency of the former plan; that the Standing Committee of the Trustees, than whom there is no one better qualified to give an opinion, took the same view; and that, nevertheless, the Government of the time decided upon severing the collections and locating the natural history in a separate building as the more economical plan.

The building was finished this year at a cost of 400,000*l.*, exclusive of the amount paid for the ground on which it is erected. It is built in the Romanesque or round-arched Gothic style, terra-cotta being almost exclusively employed in its construction. It consists of a basement, ground-floor, and two storeys, and is divided into a central portion, and a right and left wing. Its principal (southern) façade is 675 feet long. As you enter the portal, you come into a cathedral-like hall called the "Index Museum," 120 feet long, 97 feet wide, and 68 feet high; behind this there is a large side-lighted room for the British fauna. On each side of the hall there is a side-lighted gallery each 278 feet long by 50 feet in width; seven other galleries of various widths, and therefore adapted for various exhibitions, join at right angles the long gallery of the ground floor. The first and second storeys are occupied by galleries similar to the main galleries of the ground-floor.

The collections are distributed in this building thus:—The western wing is occupied by Zoology, the eastern by the three other departments, viz., the ground-floor by Geology, the first-floor gallery by Mineralogy, and the second-floor gallery by Botany. The central portion is, as mentioned above, divided into the room for British Zoology and into the "Index Museum," that is "an apartment devoted to specimens selected to show the type-characters of the principal groups of organised beings." The basement consists of a number of spacious, well-lit rooms, well adapted for carrying on the different kinds of work in connection with such large collections.

There is no doubt that the building fulfils the principal condition for which it was erected, viz., space for the collections. The zoological collections gain more than twice as much space as they had in the old building, the geological and minerological about thrice, and the botanical more four times. This increase of space will enable the keeper of the last-named department to bring the collections correlated with each other into close proximity, and to prepare a much greater number of objects for exhibition than was possible hitherto. The mineralogical department, already so admirably arranged in the old building, has now been supplied with the space requisite for a collection of rocks, with a laboratory and goniometrical room. Geology is now in a position to exhibit a great part of the invertebrata, which hitherto had to be deposited in private studies, besides devoting one or two of the new galleries to a stratigraphical series. On the zoological side we have been great gainers (not with regard to the proportion of space), but inasmuch as we were more impeded by the crowded state of our collections than any of the other departments. We are enabled to avoid the exhibition of heterogeneous objects in the same room or gallery; mammals, birds, reptiles, fishes, mollusks, insects, echinoderms, corals, and sponges have each a smaller or larger gallery to themselves. With the exception of the specimens preserved in spirits, the study-series can be located in contiguity with, or at least close vicinity to, the exhibition-series. There is ample and convenient accommodation for the students, who may work in a spacious room centrally situated, and arranged for their exclusive use at four other different localities immediately adjoining the several branches of the collection.

I believe that some of the members of the British Association will feel somewhat disappointed that the zoological and botanical collections on the one hand, and the palæontological on the other, continue to be kept distinct. Who will, who can doubt that the two branches of biological science would be immensely benefited by being studied in their natural mutual relations? and that palæontology more especially would have made surer progress if its study had been conducted with more direct application to the series of living forms? But to study the series of extinct and living forms in their natural connection, is one thing, and to incorporate in a museum the collection of fossils with that of recent forms, is another. The latter proposal, so excellent in theory, would offer in its practical execution so many and insuperable difficulties, that we may well hesitate before we recommend the experiment to be tried in so large a collection as the British Museum. I have mentioned above that in a small collection such an arrangement may be feasible to a certain degree; but in a large collection you cannot place skins, bones, spirit preparations, and stones in the same room, or perhaps in the same case, exposing them to the same conditions of light and temperature, without injuring either the one or the other. Each kind of those objects requires for its preservation special considerations and special manipulations; and by representing them in each of the several departments you would have to double your staff of skilled manipulators with their apparatus, which means multiplying your expenses. Departmental administration generally, and especially the system of acquisition by purchase or exchange, would become extremely complicated, and could not be carried on without a considerably greater expenditure in time and money. Thus, even if the old departmental division were abandoned for one corresponding to the principal classes of the animal kingdom, each of the new departments would still continue to keep, for considerations of conservation, those different kinds of objects, at least locally, separate. The necessity of this has been so much felt in the British Museum, that the Trustees resolved to store the spirit specimens at South Kensington, in a building specially adapted for the purpose, and separated from the main building, as the accumulation of many thousand gallons of spirits is a source of danger which not many years ago threatened the destruction of a portion of the present building in Bloomsbury.

I could never see that by the juxtaposition of extinct and living animals the student would obtain particular facilities for study, or that the general public would derive greater benefit than they may obtain, if so inclined, from one of the numerous popular books. They would not be much the wiser if the *Archæopteryx* were placed in a passage leading from the reptile- to the bird-gallery. And it certainly cannot be said that the separation of living and extinct organisms, so universally adopted in the old museums, has been a hindrance to the progress of our knowledge of the development of the organic world; this knowledge originated and advanced in spite of museums' arrangements. What lies at the bottom of the desire for such a change amounts, in reality, to this, that museums should be the practical exponents of the principle that zoologists and botanists should not be satisfied with the study of the recent fauna and flora, and that palæontologists should not begin their studies or carry on their researches without due and full reference to living forms. To this principle every biologist will most heartily subscribe; but the local separation of the various collections in the British Museum will not offer any obstacles whatever to its being carried out. The student can take the specimens, if not too bulky, from one department to the other; he may examine them in the gallery without interference on the part of the public; or he may have all brought to a private study, and, in fact, be in the same position with regard to the use of the collections as those who have charge of them. A plan which has been already initiated in the old building will probably be further developed in the new, viz., to distribute in the palæontological series such examples of important living types as will aid the visitor in comprehending the nature and affinities of the creatures, of which he sees only the fragmentary remains.

With regard to the further arrangement of the collections in the new building, it has been long understood that the exhibition of all the species, or even the majority of them, is a mistake, and that, therefore, two series of specimens should be formed, viz.:—one for the purposes of advanced scientific study—the study-series; and the other comprising specimens illustrative of the leading points both of popular and scientific interest; this latter—the exhibition series—being intended to supply the requirements of the beginner in the study of natural history and of the public. As the zoological collections are better adapted for exhibition than the others, the following remarks refer principally to them. The bulk of our present exhibition-series is the growth of many years; and to convert it into one which fulfils its proper purpose is a gradual and slow process, nor can it be expected to reveal its character until it has been removed into the new locality. The exhibition will be probably found more liberal than may be deemed necessary by some of my fellow-labourers; but if a visitor should, on leaving the galleries, "take nothing with him but sore feet, a bad headache, and a general idea that the animal kingdom is a mighty maze without plan," I should be inclined to believe that this state of bodily and mental prostration is the visitor's, and not the curator's fault. The very fact that the exhibition series is intended for a great variety of people, renders it necessary to make a liberal selection of specimens; and I simply follow the principle of placing in it all those objects which, in my opinion, the public can understand and appreciate, and which, therefore, must contribute towards instruction. The public would receive but an inadequate return for keeping up a national museum if they were shown, for instance, a dozen so-called "types" of the family of parrots or humming-birds; they require a good many more to see what nature can produce in splendour and variation of colour, in grotesqueness of form; or to learn that whilst one of these groups of birds is spread over all the countries of the tropical zone, the other is limited to a portion of a single continent. To render such an exhibition thoroughly useful, two additional helps are required, viz., a complete system of explanatory labels, and a popularly-written and well-illustrated handbook, which should not only serve as a guide to the more important and interesting specimens, but give a systematic outline of the all-wise plan which we endeavour to trace in God's creation.

There is one part of the museum which I intend to treat in a different manner from the rest; and that is the collection of British animals. For the same reasons for which I have in a former part of this address insisted on district faunas being fully represented in provincial museums, I consider a complete exhibition of the British fauna to be one of the most important objects of the National Museum. Its formation is, strange as it may appear to many of you, still a desideratum, and a task which will occupy many years. It will not be easy (especially when you are in danger of infringing an Act of Parliament) to form a complete series of British birds, showing their change of plumage, their young, their eggs, their mode of nidification; it is a long work to collect the larvæ and chrysalides of insects, and to mount the caterpillars with their food-plants; and we shall require the co-operation of many a member of the British Association when we extend the collection to the marine animals and their metamorphoses. But all the trouble, time, and labour spent will be amply repaid by the direct benefits which all classes will derive from such a complete British collection.

My time is becoming short, and yet I find that I am far from having completed the task I had set to myself. Therefore let me briefly refer only to a few points which, of late, have much agitated those who feel a direct or indirect interest in the progress of the National Museum. In the first place, we must feel deeply concerned in everything relating to the conservation of the collections. If the objects could speak to you, as they do to those familiar with their history, many of them would tell you of the long hours of patient inquiry spent upon them; many might point with pride at the long pages written about them—alas! not always with the even temper which renders the study of natural science a delight and a blessing; others would remind you of having been objects of your wonder when you saw them depicted in scientific books, or in some household work; whilst not a few could tell you pitiful tales of the enthusiastic collector who, braving the dangers of a foreign climate, sacrificed health or life to his favourite pursuit. Collections thus obtained, thus cherished, representing the labours of thousands of men, and intended to instruct hundreds of thousands, are worth preserving, displaying, and cultivating. No cost has been spared in housing them: let no cost be spared in providing proper fittings to receive them, a sufficient staff to look after them, and the necessary books to study them.

What we chiefly require in a well-constructed exhibition-case is that it should be as perfectly dust-proof as possible, that it should lock well and easily, and yet that it should be of a light structure. Every one who has gone through a gallery of our old-fashioned museums must have noticed how much those broad longitudinal and transverse bars of the wooden frame of the front of a case interfere with the inspection of the objects behind them, hiding a head here, a tail there, or cutting an animal into two more or less unequal portions. Ill-constructed cases have brought zoological collections as much into bad repute as bad stuffers; and if it be thought that a pound could be saved in the construction of a case, that pound will probably entail a permanent expense of a pound a year. Now all the requisites of a good exhibition-case can be obtained by using metal wherever it can be substituted for wood; and although its use is more expensive than that of wood, you will join with me in the hope that no mistaken desire of economy will prevail now, as the time has arrived to furnish our priceless collections with adequate fittings.

Probably all of those present are aware that the formation of a natural history library has been urged almost from the very first day on which the removal of the Natural History Collections to South Kensington was proposed. But the cost and extent of such a library have been very variously estimated. And I am sorry to say that it is, I believe, owing to expressions of opinion on the part of those who ought to know better, that the cost of this library was considerably underrated when the removal to South Kensington was determined upon. We cannot blame the Government that they hesitated for years before they acceded to the pressing representations of the Trustees of the British Museum to begin with its formation, when they were told by naturalists that the cost of such a library would be something between 10,000*l*. and 20,000*l*. I could hardly believe my eyes when I read, only a few weeks ago, in the leader of a weekly periodical specially devoted to science, "that had the Trustees put aside 1,000*l*. a year for this purpose, when it was first determined to remove the Natural History Collections ten years ago, there would have been by this time in existence a library fully adequate to the purpose." The writer must have either a very poor idea of the objects and work of a national museum, or an imperfect knowledge of the extent of the literature of natural history. 10,000*l*. might suffice to purchase a good ornithological library, and 1,000*l*. would purchase the annual additions to all the various branches of natural history; but the former sum would be much too small if the purchase of those works only were intended which are required for the technical work of naming animals, plants, fossils, and minerals. A better calculation was made by the Select Committee of the House of Commons on the British Museum in 1860, who stated that the formation of a natural history library would "cost about 30,000*l*. at the present time" (1860). Considering that twenty years have elapsed since, and that this part of the literature has shown year by year a steady increase, we must put our estimate considerably higher than the writer of that article.

With the aid of some of my friends who know, from their daily occupation, the market value of natural history works, I made a calculation some years ago, and we came to the conclusion that a complete natural history library will cost 70,000*l*., and, unpalatable as this statement may be to those who have advocated the removal of the natural history collections, and therefore must be held responsible for this concomitant expense, it will be found to be true. It will be satisfactory to you to learn that the Government have at last sanctioned the expenditure of half that amount.

Now, in my opinion, such a library formed in connection with the National Museum should not be reserved for the use of the officials, but I would recommend that it should be accessible to the general class of students in the same manner as any other part of the collections. It is for this reason that I wish to see it rendered as perfect as possible with respect to the older publications (many of which are getting scarcer year by year) as well as to the most recent. Whether or not a similarly perfect collection of natural history books exists in some other place in London, is another question with which I am not concerned. It is evident that a general national library ought to contain a perfect set of books on natural history, irrespective of other claims; but to have natural history collections in one place, and the books relating to them in another miles away, will produce as much inconvenience as is experienced by the person who puts the powder into the one barrel of his gun and the shot into the other.

If the British Museum (for the collections will remain united under this old time-honoured name, though locally separated) continues to receive that support from the Government to which it is justly entitled, I have no doubt that it will not only fulfil all the aims of a national collection, but that it will be also able to give to the kindred provincial institutions the aid which has recently been claimed on their behalf. Under an Act of Parliament which was passed in the previous session, and which empowers the Trustees to part with duplicate specimens, several of those museums have already received collections of zoological objects. But I consider it my duty to caution those who are in charge of those museums to be careful as to the manner in which they avail themselves of this opportunity. Well-preserved duplicates of the rarer and more valuable vertebrate animals are very scarce in the British Museum; the funds for purchase being much too small to permit of the acquisition of duplicates. What we possess of this kind of duplicates are generally deteriorated specimens, and therefore ought not to be received by provincial museums. On the other hand, our invertebrate series, especially of mollusks and insects, will always offer a certain number of well-preserved duplicate specimens, and a sufficient inducement for provincial museums to select their desiderata.

It has been suggested that as the British Museum has correspondents and collectors in almost every part of the globe, and has therefore greater facilities for obtaining specimens than any other institution, it should systematically acquire duplicates, and form a central repository, from which provincial museums could draw their supplies. If the necessary funds to carry out this scheme were granted, I cannot see any objection to it on the part of the British Museum which, on the contrary, would probably derive some benefit. But there is one, and in my opinion a very serious, objection, viz., that this scheme would open the door to the employment of curators of inferior qualifications; it would relieve the curator of a provincial museum of an important part of his duty, viz., to study for himself the requirements of his museum, the means of meeting them, and to become well acquainted with the objects themselves. A curator who has to be satisfied with the mechanical work of displaying and preserving objects acquired, prepared, and named for him by others takes less interest in the progress of his museum than he whose duty it would be to *form* a collection; he is not the person in whose charge the museum will flourish.

In speaking of the claims of Provincial Museums on the National Museum, the kindred Colonial institutions should not be forgotten. We owe to them much of our knowledge of the natural history of the Colonies; they are the repositories of the collections of the temporary and permanent surveys which have been instituted in connection with them; and they have concentrated and preserved the results of manifold individual efforts, which otherwise most likely would have been lost to science. The British Museum has derived great benefit from the friendly relations which we have kept up with them; and, therefore, they are deserving of all the aid which we can possibly give them, and which may lessen the peculiar difficulties under which they labour in consequence of their distance from Europe.

I am painfully aware that, in the remarks which I have had the honour of making before you, I have tried the patience of some, and not satisfied the expectations of others. But so much I may claim: that the views which I have expressed before you as my own are the results of many years' experience, and, therefore, should be worthy of your consideration; and that I am guided by no other desire than that of seeing the museums in this country taking their proper place in regard to biology, and as one of the most important aids in the instruction of the people.

NOTES

IN mediæval ages Rheims was a seat of learning, and in 1547 the Cardinal of Lorraine established there a university, which flourished until it was suppressed at the French Revolution. But although the present Republican Government has instituted in this ancient city a school of medicine, the liberal arts are little cultivated by the inhabitants, who are mostly engaged in commercial and manufacturing occupations. Rheims possesses the greatest wine trade in the world and the richest woollen manufactories in France. So, although the French Association has met with a very handsome reception, the local budget of scientific contributions was very meagre indeed, except in the sections of anthropology and archæology, which were a local success. M. Cotteau gave an address describing the geological character of the Rheims district, and illustrated by the local exhibition which had been arranged in one of the halls of the Lycée by M. Perron. M. Lemoine, Professor in the School of Medicine of Rheims, exhibited a rich collection of objects of palæontological interest which had been formed by him from the surrounding district. This was exceptionally rich in objects of the cretaceous period, mostly of polished stone, and wonderfully preserved in the caves so numerous in the cretaceous formation, and which are now utilised to protect against variations of temperature an immense quantity of bottled wine destined to be sent to all parts of the world. An excursion, specially interesting for archæologists, was organised to Epernay, where M. Baye, a rich proprietor, had collected in his château a number of curiosities belonging to the Carlovingian periods. Two other special excursions were organised, the first to the ruins of old Courcy Castle and St. Gobain, the largest glass foundry in France, where a large lump was cast in presence of the visitors, and the second to St. Menehould, which was supposed in former times to be the key of French independence. The most attractive excursion was undoubtedly to the caves where champagne is manufactured by the old process, which was scientifically described by M. François, a chemist of Châlons-sur Marne. A demonstration of the principles of the operation was given in the caves of Pommery, where Madame Pommery kindly permitted the visitors to make a practical test of the quality of her celebrated produce. Synoptical tables had been prepared exhibiting the progress of the manufacture. The superiority of the champagne manufactured in Rheims and vicinity is attributed not only to the long experience of the workmen and the excellence of the receipts used, but to the perfect equality of temperature maintained in the old galleries where it is stored. Some of these are several acres in area, and are quite full of bottles. After the final meeting a general excursion was made to the celebrated grotto of Han in Belgium. The two lectures by M. Perier on "Transformism," and M. Garel on "Radiant Matter," were delivered, at the solicitation of the local committee for their information; the lecturers confined themselves to the clear enunciation of known facts, and to experiments already well known to the scientific world. M. Javal gave a public lecture on the Hygiene of the Eye, and M. Richet on the Symptoms of Somnambulism. About 500 members were present at the meeting this year, exclusive of local members. Among foreign visitors were Professors Sylvester and Hennessy. At the final session M. Janssen was elected president for 1882, when the meeting will be held at La Rochelle, and M. Emile Trelat will be general secretary; they will act as vice-president and vice-secretary respectively for the session of 1881, which will be held at Algiers in the first week after Easter. The president of the Algiers session will be M. Chauveau, Professor at the Veterinary School of Lyons, and the secretary will be M. Maunoir, general secretary of the French Geographical Society. A very large attendance is anticipated, as a diminution of 50 per cent. on the fares is expected, and the visit will take place at an exceptionally advantageous season. A general committee has been formed, having at its head M. Tomel, senator of Oran, and director of the newly-created School of Sciences. The Governor-General will be honorary president, and M. MacCarthy, president of the Algiers Society of Natural Sciences, has been nominated by the General Committee of Rheims president of the Section of Geography. The Rheims authorities and citizens have done everything within their power to welcome their guests, and the meeting has been on the whole successful.

FROM an additional Circular sent us from the American Association we see that nearly all the railway lines connected with Boston, the place of meeting, offer great facilities for the conveyance of members. Some of the companies indeed give those attending the meeting free tickets, while the others issue tickets at one-half the usual rates. Is it too much to expect similar advantages from English companies? Has the attempt ever been made?

A VERY interesting annual meeting of the Entomological Club of the American Association was to be held at Boston on Tuesday. Among other subjects to be brought forward, Mr. A. R. Grote was to speak of generic characters in the Noctuidæ; Mr. E. P. Austin hoped to exhibit some interesting series from his extensive collection of North American Coleoptera; Mr. Wm. Saunders to discuss Insectivorous Birds, their merits and demerits; Rev. H. C. McCook to read a paper on the Honey Ants of the Garden of the Gods, Colorado; Mr. S. H.