there was spent 473,583*l.*, on the professional colleges 239,961*l.*, on the training schools 190,920*l.*, on all other special schools 298,474*l.*, on the secondary schools 2,128,612*l.*, and on the primary schools 1,954,236*l.* There was a total income from fees in 1916–17 of universities, professional colleges, and special technical schools of 107,453*l.*, and of secondary schools of 242,620*l.* In 1917 14,799 students matriculated, 4209 qualified for the B.A. examination, 440 for B.Sc., 555 for M.A., and 152 for M.Sc. An elaborate census of education such as this for the United Kingdom would be a welcome contribution to our knowledge of educational affairs.

THE BRITISH ASSOCIATION AT BOURNEMOUTH.

SECTION C.

GEOLOGY.

OPENING ADDRESS (ABRIDGED) BY J. W. EVANS, D.SC., LL.B., F.R.S., PRESIDENT OF THE SECTION.

ONE of the most striking features of our science is the need in which it stands of a large and widely distributed body of workers, and the opportunities it affords to every one of them of making important contributions to scientific knowledge.

Everywhere someone is needed who will devote his spare time to the examination of the quarries and cliffs, where the materials that build up the solid earth are exposed to view, and who will record the changes that occur in them from time to time; for a quarry that is in work, or a cliff that is being undermined by the sea, constantly presents new faces, affording new information, which must be recorded if important links in the chain of evidence are not to be lost. It is equally important that someone should always be on the look-out for new exposures, road or railway cuttings, for instance, or excavations for culverts or foundations, which in too many instances are overgrown or covered up without receiving adequate attention. It is, again, only the man on the spot who can obtain even an approximately complete collection of the fossils of each stratum, and thus enable us to obtain as full a knowledge as is possible of the life that existed in the far-off days in which it was laid down. In his absence, many of the rarer forms which are of unique importance in tracing out the long story of the development of plants and animals, and even of man himself, never reach the hands of the specialist who is capable of interpreting them. It was an amateur geologist, a country solicitor, who saved from the road-mender's hammer the Piltdown skull, that in its main features appears to represent an early human type, from which the present races of man are in all probability descended. Another amateur, who was engaged in the brick-making industry near Peterborough, has provided our museums with their finest collections of Jurassic reptiles. A third, a hard-worked medical man, was the first to reveal the oldest relics of life that had at that time been recognised in the British Isles; and many more examples could be instanced of the services to geological science by those whose principal life-task lay in other directions.

Such workers are, unfortunately, all too few—fewer, I fancy, now than they were before the pursuit of sport, and especially of golf, had taken such a hold upon the middle classes and occupied so considerable a portion of their leisure hours and thoughts One might hope that the extended hours now assured to the working classes for recreation would lead to a general increase of interest in science among them, if it were not that the students of that admirable organisation, the Workers' Educational Association, seem almost invariably to prefer economic or political subjects to the study of Nature. In a large county in which I am interested the number of those in every condition of life who are able and willing to take part in geological research might be told almost on the fingers of one hand, and, so far as I am aware, there has not been a single recruit in recent years from the ranks of the younger men or women.

It might be suggested that the prevailing indifference to the attraction of geological research was due to a conviction that after eighty years of work by the Geological Survey, as well as by university teachers and amateurs, there was little left to be done, and that all the information that could be desired was to be found in the Survey publications. Such a belief can scarcely be very widespread, for, as a matter of fact, comparatively few of the general public realise the value of the work of the Geological Survey, and still fewer make use of its publications. Municipal libraries, other than those of our largest provincial centres, are rarely provided with the official maps and memoirs relating to the surrounding areas, and in the absence of any demand the local booksellers do not stock them. This cannot be attributed to the cost, for, though most of the older maps are hand-coloured and therefore expensive, the later maps—at least, those on the smaller scales[1]—are remarkably cheap, and the memoirs are also issued at low prices. The true explanation appears to be that a geological map conveys very little information to the average man of fair education who has received no geological instruction. This is certainly not the fault of the Survey maps, which compare very favourably with those of other countries, and have been greatly improved in recent years. In particular, the introduction of a longitudinal section on each map and the substitution of the vertical section drawn to scale for the old colour index must greatly assist those into whose hands it comes in obtaining a correct view of the succession of the strata and the structure of the country. Some of the maps are, it is true, so crowded with information—topographical and geological—that it is frequently difficult, even for the trained geologist, to read them without a lens. This is largely due to the fact that they are printed over the ordinary topographical maps in which there is a great amount of detail that is not required in geological maps. In India the Trigonometrical Survey are always ready to supply, as a basis for special maps, copies of their own maps printed off plates from which a portion of the topographical features have been erased.

The best remedy, however, would be to extend the publication of the maps on a scale of 6 in. to a mile (1 : 10,560). For many years all geological survey work has been, in the first place, carried out on maps of this scale, but they have not been published except in coal-mining areas. There the geological boundaries are printed, but the colouring is added by hand, which makes the maps comparatively expensive. In other localities manuscript copies of the geological lines and colouring on the Ordnance Survey maps can be obtained at the cost of production, which is necessarily considerable. There is, I believe, a wide sphere of usefulness for cheap colour-printed 6-in. geological maps, especially in the case of agricultural and building land, for which the 6-in. Ordnance maps are already in demand. They afford ample room for geological information, and, accompanied by longitudinal sections on the same scale without vertical exaggeration, their significance would

[1] 1 in. to the mile, 1 : 63,360; ¼ in. to the mile, 1 : 253,440, and 1 in. to 25 miles, 1 : 1,584,000.

be more readily apprehended than that of maps on a smaller scale.

It would be of great advantage if there were a uniform usage by which the position in the stratigraphical series of rock outcrops were indicated by colour and their lithological character by stippling (in black or white or colour), following the ordinarily accepted conventions. This course has been pursued by Prof. Watts in the geological map prepared by him to illustrate his "Geography of Shropshire."

Some explanation, apart from the maps themselves, is, however, needed if they are to be rendered, as they should be, intelligible to the general public. The official memoirs which deal with the same areas as the maps do not afford a solution of the difficulty. Excellent as they are from the technical point of view and full of valuable information, they convey little to the man who has not already a considerable acquaintance with the subject. What is needed is a short explanatory pamphlet for each map, presuming no previous geological knowledge, describing briefly and in simple popular language the meaning of the boundary lines and symbols employed, and the nature and composition of the different sedimentary or igneous rocks disclosed at the surface or known to exist below it in the area comprised in the map. A brief account of the fossils and minerals visible without the aid of a microscope should also be included. The probable mode of formation of the rocks and their relation to one another and the subsequent changes they have undergone should be discussed, and at the same time their influence on the agriculture value of the land and its suitability for building sites, as well as on the distribution and level of underground water, pointed out. Some account, too, should be given of the economic mineral products and their applications. These pamphlets should be illustrated by simple geological sections, views of local quarries and cliffs showing the relative positions of the different rocks, figures of the commoner fossils at each horizon, and, where they would be useful, drawings of the forms assumed by the minerals. Each pamphlet would be complete in itself. This would involve a considerable amount of repetition, but it must be remembered that different pamphlets would have, as a rule, different readers.

During the war publications containing desirable information were circulated widely and gratuitously by the authorities to all public bodies concerned, and there seems no reason why the information laboriously gathered by the Geological Survey in the national interests and paid for out of the public funds should not now receive the same treatment. All municipalities, district councils, public libraries, colleges and schools, both secondary and elementary, should receive free copies of the Geological Survey publications dealing with the area where they are situated or with those immediately adjoining it.

Every facility should, of course, be afforded to the public to make use of the Survey publications. They should not only be on sale at the post offices in the areas to which they relate, but it should also be possible to borrow folding mounted copies of the maps as well as bound copies of the explanations and memoirs, on making a deposit equal to their value. When they were no longer required, the amount of the deposit, less a small charge for use, would be repaid on their return to the same or any other post office and the production of the receipt for cancellation. It would thus be possible, when traversing any part of the country, to consult in succession all the Geological Survey publications of the districts passed through. This system would also enable the permanent residents to refer to the more expensive hand-coloured maps, including the 6-in. manuscript maps, at a comparatively small cost.

The Survey publications should be illustrated in every museum and school in the districts with which they deal by small collections showing the characters of the local rocks, and of the minerals and fossils that occur in them, and care should be taken to see that these collections are maintained in good order and properly labelled.

It would be a good plan for the Survey to appoint a local geologist, an amateur or member of the staff of a university or college, in every area of twenty or thirty square miles to act as their representative and as a centre of local geological interest. He would be expected to given his assistance to other local workers who stood in need of it. He would receive little official remuneration, but inquirers in the neighhood would be referred to him, and where commercial interests were involved he would, subject to the sanction of the central office, be entitled to charge substantial fees for his advice. He would report to the Survey any event of geological importance in the area of which he was in charge—whether it was the discovery of a new fossiliferous locality, the opening of a new quarry,[2] the sinking of a well, or the commencement of boring operations. Many of these matters would be adequately dealt with by local workers, but in other cases it might be desirable for the Survey to send down one of their officers to make a detailed investigation.

One of the most important duties of the Survey, or of its local representative, would be to see that the records of well-sinkings and borings are properly kept, and that where cores are obtained the depth from which each was raised is accurately recorded. At the present time the officers of the Survey make every effort to see that this is done, but they have no legal power to compel those engaged in such operations to give the particulars required. Equally important is a faithful record of the geological information obtained in prospecting or mining operations. This is especially necessary where a mine is abandoned. If care is not then taken to see that all the information available is accurately recorded, it may never be possible later to remedy the failure to do so.

Probably these objects would be much facilitated if engineers in charge of boring or mining operations had sufficient knowledge of geology and interest in its advancement to make them anxious to see that no opportunity was lost of observing and recording geological data. This would be in most cases ensured if every mining student were required to carry out geological research as part of his professional training. It is now recognised that no education in science can be considered to be up to university standard if it is limited to a passive reception of facts and theories without any attempt to extend, in however humble a way, the boundaries of knowledge. In the case of geology such research will naturally in most cases take the form of observations in the field. The important point is that the work must be original, on new lines, or in greater detail than before, and not a mere confirmation of published results. It is only by the consciousness that he is accomplishing something which has not been done before that the student can experience the keen pleasure of the conquest of the unknown and acquire the love of research for its own sake.

There is one respect in which geological workers

[2] It is very desirable that arrangements should be made for the co-operation of the Geological Survey or their local representatives with the Inspectors of Quarries appointed by the Home Office, and that the annual official list of quarries should describe the rocks which are worked, not only by their ordinary economic designations, but also by their recognised geological descriptions.

suffer a heavy pecuniary handicap—the cost of railway fares. This affects both the staff and students of colleges, as well as local workers who are extending their radius of work—an inevitable necessity in the investigation of many problems. It also seriously interferes with the activity of local natural history societies and field clubs, the geological societies and associations of the great provincial towns, and, above all, that focus of amateur geological activity—the Geologists' Association of London. It is difficult to exaggerate the importance of these agencies in the promotion of geological education. Both professional and amateur geologists are deeply indebted to the excursions which are in most cases directed by specially qualified workers, with whom it is a labour of love. At the same time one of their most valuable results is the creation of interest in scientific work in the localities that are visited. Now that the railways are, if report speaks truly, to be nationalised, or at any rate controlled by the State, the claims of scientific work, carried out without reward in the national interest, to special consideration will surely not be ignored. All questions as to the persons to whom such travelling facilities should be extended and the conditions that should be imposed may safely be left to the decision of the Geological Survey, which has always had the most friendly and sympathetic relations with private workers and afforded them every facility and assistance which their comparatively limited staff and heavy duties permitted.

There is at the present time a very urgent need for the provision of further facilities for the analysis of rocks and minerals to assist and complete the researches both of the official surveyors and of private persons engaged in research. The work is of a very special character, and the number of those who have given sufficient attention to it and understand its difficulties and pitfalls is very limited.

The analytical work of the Survey is organised on a very modest scale in comparison with the *personnel* and equipment of the laboratory of the United States Geological Survey, though the quality of the work has been, as a rule, in recent years quite as high. There are two analytical chemists attached to the Geological Survey, and some of the other members of the staff are capable of doing good analytical work. The demand, however, for analyses for economic purposes is so great that it is impossible to carry out all the analyses that would be desirable in connection with the purely scientific work of the Survey itself. There is, consequently, no possibility of their being able to assist private investigators.

In the absence of facilities for obtaining rock analyses, petrological work in this country is at present seriously handicapped. A striking illustration of the inadequate provision for analyses is revealed in the fact that for the whole of the early Permian granitic intrusions in the south-west of England, covering nearly two thousand square miles, and including numerous different types and varieties, there are only four analyses in existence, and of these two are out of date and imperfect. This is all the more remarkable in view of the fact that these rocks are closely connected with the pneumatolytic action that has given us almost all the economic minerals of the south-west of England.

Another direction in which the work of the Survey could with advantage be extended is in the execution of deep borings[3] on carefully thought out schemes by which a maximum of information could be obtained. Both in Holland and Germany borings have been carried out to discover the nature of the older rocks beneath the Secondary and Tertiary strata, and Prof. Watts in his presidential address to the Geological Society in 1912, dwelt on the importance of exploring systematically the region beneath the wide spread of the younger rocks that covers such a great extent of the east and south of England. Prof. Boulton, my predecessor in this chair, has endorsed this appeal, but nothing has been done or is apparently likely to be done in this direction. It seems extraordinary that no co-ordinated effort should have been made to ascertain the character and potentiality of this almost unknown land that lies close beneath our feet and is the continuation of the older rocks of the west and north to which we owe so much of our mineral wealth. It is true that borings have been put down by private enterprise, but, being directed only by the hope of private gain and by rival interests, they have been carried out on no settled plan, and the results, and sometimes the very existence, of the borings have been kept secret. The natural consequences of this procedure have been the maximum of expense and the minimum of useful information.

Unfortunately, in recent years percussion or rope-boring, which breaks up the rock into fine powder, has more and more, on account of its cheapness, replaced the use of a circular rotating drill, which yields a substantial cylindrical core that affords far more information as to the nature of the rocks and the geological structure of the district. If private boring is still to be carried on, the adoption of the latter procedure should be insisted on, even if the difference of cost has to be defrayed by the Government. It is quite true that a considerable amount of useful information can be collected by means of a careful microscopic examination of the minute fragments which alone are available for study, so that the nature of the rocks traversed can be recognised; but the texture of the rock is destroyed, as well as any evidence which might have been available of its larger structures and stratigraphical relations, and almost all traces of fossils. It is, too, impossible to tell with certainty the exact depth at which any particular material was originally located, for fragments broken off from the sides of the bore may easily find their way to the bottom.

A good illustration, and one of many that might be cited, of the misdirected energy that is sometimes expended in prospecting operations was afforded a few years ago by a company that put down a boring for oil through more than a thousand feet of granite without being aware of the nature of the rock that was being traversed. In this case a percussion drill was employed, but a few minutes' examination of the material should have enabled the engineer in charge, supposing he had even an elementary knowledge of geology, to save hundreds of pounds of needless expenditure. The sum total of the funds which have been uselessly expended in this country alone in hopeless explorations for minerals, in complete disregard of the most obvious geological evidence, would have been sufficient to defray many times over the cost of a complete scientific underground survey.

If research is to be carried out economically and effectively, it must be organised systematically and directed primarily with the aim of advancing knowledge. If this aim be well and faithfully kept in view, material benefits will accrue which would never have been thought to be sufficiently probable to warrant the expenditure of money on prospecting.

It is, however, not only in the areas occupied by Secondary or Tertiary rocks that systematic boring is urgently needed. There are many other localities where important information as to the structure of

[3] I have not space to deal here with the shallow borings in soft strata which have been so successfully conducted on the Flanders front during the war by Capt. W. B. R. King, of the Geological Survey.

the rocks could probably be obtained in this manner. Opinion is very much divided as to the relation of the Devonian to the older rocks in South Devon and Cornwall, but there is little doubt that a series of judiciously placed borings would solve the problem without difficulty. In North Devon and West Somerset the question as to whether the Foreland Grits are a repetition by faulting of the Hangman Grits could also be settled at once by borings in the Foreland Grits and in the Lynton beds.

It is not, however, on *terra firma* alone that such investigations may be usefully carried out. The floors of the shallow seas that separate these islands from one another and from the continent of Europe are still almost unknown from the geological point of view, although their investigation would present no serious difficulties. Joly has described an electrically driven apparatus which, when lowered so as to rest on a hard sea-floor, will cut out and detach a cylindrical core of rock, and retain it until raised to the surface. Afterwards he invented a still more ingenious device, in which the force of the sea-water entering an empty vessel is substituted for electrical power, but, unfortunately, neither the one nor the other has actually been tried or even constructed.

Meantime, however, vertical sections up to 80 cm. of the mud of the deep seas have actually been obtained in iron tubes attached to sounding apparatus employed in the course of the voyage of the *Gaussberg*. These reveal a succession of deposits of which the lower usually indicate colder water conditions than the upper.

In many places rock fragments are dredged up by fishing-boats. These should, of course, be used with caution in drawing conclusions as to the distribution of rocks *in situ* on the sea-bottom, as such fragments may have been transported when embedded in ice-sheets or in icebergs or other forms of floating ice, or entangled in the roots of floating trees; but where the rock fragments can be shown to have a definite distribution, as in those described by Grenville Cole and Thomas Crook from the Atlantic to the west of Ireland, and by R. H. Worth from the western portion of the English Channel, they may be regarded as affording trustworthy information as to the geology of the area.

There seems every reason to believe that advances in submarine geology will not be only of scientific interest, but will bring material benefits with them. It seems quite possible that off the shores of Northumberland and Durham there are, in addition to extensions of the neighbouring coalfield, Permian rocks containing deposits of common salt, sulphate of calcium (gypsum and anhydrite), and, above all, potash salts comparable to those at Stassfurt, which have proved such a source of wealth to Germany.

No less important than the work of the Geological Survey is that of our great national museums. I have already alluded to the need for local collections to illustrate the geology of the areas in which they are situated. The museums of our larger cities and our universities will naturally contain collections of a more general character, but it is to our national museums that we must chiefly look for the provision of specimens to which those engaged in research can refer for comparison, and it is imperative that they should be maintained in the highest state of efficiency if the best results are to be obtained from scientific investigations in this country. The ability and industry of the staff of the mineral and geological departments of the Natural History Museum are everywhere recognised, as well as their readiness to assist all those who go to them for information, but in point of numbers they are undeniably insufficient to perform their primary task of examining, describing, arranging, and cataloguing their ever-increasing collections so as to enable scientific workers to refer to them under the most favourable conditions.[4] Even if the staff were doubled, its time would be fully occupied in carrying out these duties, quite apart from any special researches to which its members would naturally wish to devote themselves. The additional expense incurred by the urgently needed increase of the museum establishment would be more than repaid to the country in the increased facilities afforded for research.

There is room, too, for a considerable extension in the scope of the activity and usefulness of our museums in other directions, and more especially in the provision of typical lithological collections illustrating the geology of different parts of the British Empire and of foreign countries.

So far as the United Kingdom is concerned, this requirement has been admirably fulfilled in the museums attached to the Survey headquarters in London, Edinburgh, and Dublin, and there is a smaller collection of the same nature, excellent in its way, at the Natural History Museum. But to obtain a broad outlook it is essential that the attention of geological workers should not be confined to one country, however diversified its rocks may be, and it is impossible to assimilate effectively publications dealing with the geology of other parts of the world without being able to refer to collections of the rocks, minerals, and fossils described.

Such collections should include not only rock specimens in the ordinary sense of the term, but also examples of metalliferous veins and other mineral deposits which present important distinctive features.

The lithological and palæontological collections which I am now advocating should be arranged so that each group of specimens illustrates an area possessing distinctive geological features. Little has hitherto been done in this direction. The mineral department of the Natural History Museum possesses a large and extensive collection of foreign and Colonial lithological specimens arranged according to localities, which is too little known, but it is naturally very unequal and incomplete, some countries being comparatively well represented and others scarcely at all. The geological department of the museum is well provided with palæontological specimens, but these are arranged according to their biological affinities, and they might well be supplemented by a series of typical collections illustrating the fauna and flora of the more distinctive horizons in different areas. This is all the more important, as the mode of preservation may be very different in different places. The provision of such facilities for the study of the geology of other lands is especially desirable in London in view of the number of students of mining and economic geology who receive their training in this country and ultimately go out into the world to find themselves face to face with problems in which a true understanding of the local geology is absolutely essential.

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It is more difficult to arrive at the true interpretation of the phenomena presented by the endogenetic rocks[5] which have come into existence by the action of the forces of the earth's interior, for the conditions of temperature and pressure under which they were formed, whether they are igneous rocks in the narrower sense, or mineral veins, or metamorphic in

4 Even the number of skilled mechanics is quite insufficient, though their work is urgently needed. In the Geological Department provision is made for two only, and at present but one is actually at work.

5 T. Crook, *Min. Mag.*, vol. xvii., p. 87, 1914.

origin, were widely different from those with which we are familiar. In such circumstances the ultimate physical principles are the same, but the so-called constants have to be determined afresh, and a new chemistry must be worked out. It is necessary, therefore, so far as possible, to reproduce the conditions that prevailed—a task which has been courageously undertaken and, to a considerable extent, accomplished by the geophysical laboratory of the Carnegie Institution of Washington.

By artificial means temperatures and pressures have been already produced far higher than those that were in all probability concerned in the evolution of any of the rocks that have been revealed to us at the surface by earth-movements and denudation, for it is unlikely that in any case they were formed at a greater depth than five or six miles, corresponding with a uniform (or, as it is sometimes termed, hydrostatic) pressure of 2000 or 2400 atmospheres, or at a greater temperature than 1500° C. Indeed, it is probable that the vast majority of igneous and metamorphic rocks, as well as mineral veins, came into existence at considerably less depths, and at more moderate temperatures. It is true that most of the rock-forming minerals crystallise from their own melts at temperatures between 1100° C. and 1550° C., but they separate out from the complex magmas from which our igneous rocks were formed at lower temperatures.

It has been found possible at the geophysical laboratory to maintain a temperature of 1000° C. or more under a uniform pressure of 2000 atmospheres for so long a time as may be desired, and, what is equally important, the temperature and pressure attained can be determined with satisfactory accuracy, the temperature within 2° C., and the pressure within 5 atmospheres.

It has been ascertained that such uniform pressure as would ordinarily be present at the depths mentioned does not directly affect the physical properties of minerals to anything like the same extent as the difference between the temperature prevailing at the earth's surface and even the lowest temperature at which igneous rocks can have been formed. It has, however, a most important indirect action in maintaining the concentration in the magma of a considerable proportion of water and other volatile constituents[6] which have a far-reaching influence in lowering the temperature at which the rock-forming minerals crystallise out—in other words, the temperature at which the rock consolidates—and in diminishing the molecular and molar viscosity of the magma, thus facilitating the growth of larger crystals and the formation of a rock of coarser grain. They must also be of profound significance in determining the minerals that separate out, the order of their formation, and the processes of differentiation in magmas.

It is, therefore, obvious that any conclusions derived from the early experiments which were carried out with dry melts at normal pressures must be received with very considerable caution. Nor does much advance appear to have been made, even at the geophysical laboratory, in experiments with melts containing large amounts of volatile fluxes, and yet, if we are to reproduce even approximately natural conditions, it is absolutely necessary to work with magmas containing a proportion of these constituents, and especially water, equal in weight to at least one-third or one-half of the silica present. This will obviously present considerable difficulties, but there is no reason to doubt that it will be found possible to surmount them.

A much more formidable obstacle in realising the conditions under which rocks are formed is the small scale on which our operations can be carried on. There are important problems connected with the differentiation of magmas, whether in a completely fluid or partly crystallised state, under the action of gravitation, for the solution of which it would seem for this reason impossible to reproduce the conditions under which Nature works. Instead of a reservoir many hundreds of feet in depth, we must content ourselves in our laboratory experiments with a vertical range of only a few inches. There are, however, other phenomena that require investigation and that involve a great difference of level in their operation, but do not take place at such elevated temperatures. Such are some of the processes of ore deposition or transference, especially secondary enrichment. Here, with the friendly assistance of mining engineers, but at the cost of considerable expenditure, it might even be possible to experiment with columns several thousand feet in vertical height.

In any attempt to reproduce the processes of metamorphism other than those of a purely thermal or pneumatolytic character, or to imitate the conditions that give rise to primary foliation, we must consider the effects of non-uniform or "directed" pressure involving stresses that operate in definite directions and result in deformation of the material on which they act. Unlike uniform pressure, which usually raises the crystallisation point, directed pressure may lower it considerably and thus give rise to local fusion and subsequent recrystallisation of the rock. At the same time it profoundly modifies the structure, resulting in folds and fractures of every degree of magnitude. One of the most pressing problems of geology at the present moment is to determine the effects of directed pressure in its operation at different temperatures, and in the presence of different amounts of uniform pressure, a factor which has probably an important influence on the result, which must also depend on the proportion and nature of the volatile constituents which are present, as well as on the time during which the stresses are in operation.

The time elements in the constructive or transforming operations of Nature cannot, of course, be adequately reproduced within the short space of individual human activity, or, it may be, that of our race; but I am inclined to think that, even in the case of metamorphic action, the importance of extremely prolonged action has been exaggerated.

In attempting to imitate the natural processes involved in the formation and alteration of rocks and mineral veins, we require some means of ascertaining when we have approximately reproduced the conditions which actually prevailed. It is not sufficient to bring about artificially the formation of a mineral occurring in the rocks or mineral deposits under investigation, for the same mineral can be reproduced in many ways. It is, however, probable that a mineral produced under different conditions is never identical in all its characters. Its habit, or the extent to which its possible faces are developed (a function of the surface tension), the characters of the faces which are present, its twinning, its internal structure, inclusions, and impurities, all vary in different occurrences, and the more closely these can be reproduced the greater the assurance we obtain that an artificial mineral has been formed under the same conditions as the natural product.

For this purpose it is, above all, necessary that there should be in the first place a systematic comparative study of these characters and of the association in which they are found. The results thus obtained should be of the greatest value in indicating the directions along which experimental work would

[6] John Johnston, Journ. Franklin Inst., January, 1917, pp. 14–19.

be most probably successful. They should be supplemented by laboratory studies of the relations of such subsidiary crystallographic characters to the environment in the case of crystals which can be formed under normal conditions of temperature and pressure, and therefore under the immediate observation of the experimenter. Some work has, in fact, already been done on the effects on these characters of the presence of other substances in the same solution.

In the study of the secondary alterations of metalliferous deposits, especially those which consist of the enrichment of mineral veins by the action of circulating solutions, either of atmospheric or intratelluric origin, the study of pseudo-morphs gives, of course, valuable assistance in determining the nature of the chemical and physical changes that have taken place.

The problem of the structure and nature of the earth's interior, inaccessible to us even by boring, would seem at first sight to be well-nigh insoluble, except so far as we can deduce from the dips and relations of the rocks at the surface their downward extension to considerable depths. We can, however, gain important information about the physical condition of the deeper portions from the reaction of the earth to the external forces to which it is subjected, and still more from a study of the "preliminary" earthquake tremors that traverse it, the time occupied in their passage, and the difference in intensity of those that follow different paths. These methods are, however, not applicable to the earth's crust. Its physical characters appear to be distinct from those of the interior, but very little is as yet definitely known about them, except, of course, in the neighbourhood of the surface, and for this reason they are usually ignored in calculating the paths of tremors traversing the earth. It seems to be separated from the deeper portions of the earth by a surface of discontinuity at which earthquake vibrations travelling upwards towards the surface may be reflected. Calculations based on the total time taken by these reflected waves to reach the surface after a second passage through the earth's interior appear to indicate that this surface of discontinuity, whatever its nature may be, is at a depth of about twenty miles, though there can be little doubt that this depth varies considerably from point to point.

There must be numerous surfaces of discontinuity in the earth's crust in addition to that forming its lower limit. Such would be the boundaries between great tracts of granite or granitoid gneiss and the basic rocks that in all probability everywhere underlie them; the surface dividing gneisses and crystalline schists from unmetamorphosed sediments overlying them unconformably; that between hard Palæozoic rocks and softer strata of later age; and the surfaces of massive limestones or sills.

It deserves consideration as to how far it may be possible to add to our knowledge of the earth's crust by experimental work with a view of the determination of surfaces of discontinuity by their action in reflecting vibrations from artificial explosions, a procedure similar to that by means of which the presence of vessels at a distance can be detected by the reflection of submarine sound-waves. The ordinary seismographs are not suited for this purpose; the scale of their record, both of amplitude and of time, is too small for the minute and rapid vibrations which would be expected to reach an instrument situated several miles from an explosion, or to distinguish between direct vibrations and those that may arrive a second or two later after reflection at a surface of discontinuity. As the cylinder on which the record is made would be only in motion while the experiment was in progress, there would be no difficulty in arranging for a much more rapid movement. At the same time it would be desirable to dispense with any arrangement for damping the swing of the pendulum, which would be unnecessary with small and rapid vibrations, and would tend to suppress them. It is possible that it might be better to employ a seismograph which records, like that devised by Galitzin shortly before his death, variations of pressure expressing terrestrial acceleration, instead of one which records directly the movements of the ground. It would, however, probably be found desirable to substitute for the piezo-electric record of pressure employed by Galitzin a record founded on the effect of pressure in varying the resistance in an electric circuit. This is, in fact, the principle of the microphone and most modern telephone receivers, but quantitatively they are very untrustworthy. This would not matter so much for the present purpose, where the time of transmission is the most important feature in the evidence.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Mr. B. M. Jones, Emmanuel College, has been elected to the Francis Mond professorship of Aeronautical Engineering at the University, founded by Mr. Emile Mond in memory of his son, who was killed in the war. This is the first professorship in aeronautics which has been filled in this country. Mr. Jones entered Emmanuel College as an Exhibitioner in 1906. He afterwards became a scholar, and obtained First Class Honours in the Mechanical Sciences Tripos of 1909. From 1910 to 1912 he was employed on aeronautical research at the National Physical Laboratory, and held a research scholarship from the Imperial College, London. In the capacity of an assistant he continued in this work until May, 1913, when he left the National Physical Laboratory to take up the design of rigid airship construction and other aeronautical work for the firm of Sir G. W. Armstrong, Whitworth, and Co. In September, 1914, Mr. Jones joined the Royal Aircraft Establishment, and remained there, carrying out aeronautical research and experimental work until May, 1916. He was then transferred to the Armament Experimental Station, Orford Ness, with the rank of captain, R.F.C., eventually rising to the position of Assistant Controller of Experiment and Research with the rank of lieut.-colonel. His chief activities were directed towards aerial gunnery and aerial bombing, and in order to gain first-hand experience of fighting conditions he qualified as a pilot and served with No. 48 Squadron, R.F.C., in France during the early months of 1916. On being demobilised in March last, Mr. Jones was elected a junior fellow of Emmanuel College, with the post of director of engineering studies at the college.

SHEFFIELD.—The council has received with much regret the resignation of Prof. J. O. Arnold, dean of the faculty of metallurgy and professor of metallurgy in the University since 1889. Steps will shortly be taken to appoint a successor.

DR. J. G. STEWART has been appointed lecturer in engineering at University College, London.

A CHAIR of laryngology has recently been established in the University of Paris, the first occupant of which is to be Dr. Sebileau.

THE sum of 400,000*l.* has been bequeathed to the University of Sydney by Sir Samuel McCaughey.