Cultural Aspects in Geology.¹

By Prof. W. A. PARKS, University of Toronto.

THE science of geology is wide in scope and general in application; it deals with matter and with life, with time and with space; it touches the philosophical and borders on the romantic; majesty and beauty are its essentials, and imagination is necessary for its pursuit. The cultural value of such a science is not to be despised. It is my purpose to direct attention to well-known features of our science. I shall attempt to introduce no new facts, and I beg that you will consider my remarks merely as an attempt to lay emphasis on a selected few of the many great lessons of geology.

THE LAW OF TENDENCY TO THE COMPLEX.

To account for the existence of the human race and to determine the purpose, if there be a purpose, for its existence is probably the greatest and most fundamental problem with which humanity is confronted. An answer is not yet forthcoming, but it is interesting (and cultural) to inquire if the science of geology can throw any light on a problem so stupendous.

In the first place, it is to be noted that the earth is very old; its age is to be reckoned, not in millions, but in hundreds of millions of years. In the second place, living creatures have inhabited the globe, not from the beginning, but from the earliest period of which we have a definite record. Does not the inconceivably long duration of the earth itself and of life constitute a guarantee of a similar extension into the future? This assumption may not be in accord with rigid logic, but it falls within the scope of high probability. Further, geological history shows conclusively that some force or tendency has acted on the life principle to the production of higher and higher forms culminating in man. Is there any reason to assume that this long-enduring gradient should change its direction? I confidently believe that geological history teaches us that the earth, and life, and the upward tendency of life will all three reach out into the illimitable future.

The tendency towards the more complex (higher) seems to be a feature, not only of the organic, but also of the inorganic world. In the lower orders of life the tendency to the complex has acted throughout all the ages without the conscious volition of the individual. With the advent of the higher nervous complex that we call "reason" a new factor entered the field, a factor so important that many geologists now favour the establishment of a separate era, the "psychozoic," for the age of man. Undoubtedly the rise of mentality in the Pleistocene must be regarded as a geological event of profound importance. From the evolutionary point of view it may mark an event of comparable significance, in that it may be interpreted as a great saltation of the mental attributes without a corresponding physical development. The general tendency to the complex is not interrupted, but its manifestation is less material and more spiritual. It is a reasonable assumption that future evolution will be mental rather than physical, and that the long-continued upward gradient of complexity will not turn in its course.

I venture to state that the greatest lesson in geology

is the tendency to the complex; if there be a purpose behind all things, the working-out of that purpose is herein revealed. It follows, therefore, that man can best fit into the scheme of things by facilitating the operation of a principle which has endured through all time and is to be regarded in the light of a revelation. The *duty* of man, if these premises be correct, is so to direct his efforts that his mental capacity may be strengthened and that a slightly better equipment may be transmitted to his offspring.

I would emphasise, also, the fact that all races of creatures and all individuals of a race do not evolve to higher forms. Similarly, it is not to be expected that all men are destined to give rise to higher types under the action of a beneficent, all-pervading principle.

The development of mentality in the human race has introduced new factors; perhaps it would be better to say it has strongly accentuated certain old factors. By reason of his superior mental equipment, man has acquired a degree of dominance never attained by any earlier race. Surely, his reason should temper his power, and he should realise the enormous responsibility that has fallen into his hands.

EVOLUTION.

Geological investigation has established, beyond all doubt, the basic facts that life has changed during the course of the ages, that this change has been uniform in direction over the whole globe, and that the general tendency has been towards greater complexity both in physical structure and in mental equipment. It has been established, further, that in certain instances, sequences are found indicating the gradual passage of one species into another. This observation is not necessarily a proof of descent, but it is a strong argument in its favour.

Life appeared on the globe in pre-Cambrian time; of its inception we shall probably never be able to obtain direct evidence. In course of time, however, recognisable protoplasmic units appeared—unicellular creatures neither plant nor animal. The second great event of life history occurred somewhat later in the pre-Cambrian—the separation of the parent stem into ancestral plants and ancestral animals. Here I would like to emphasise the fact that the difference between plants and animals lies, not only in the different nature of the metabolism, but also in the possession by the latter of a sensibility or mental equipment so vastly superior, that we are accustomed to think of it as absent in the vegetable world. In order to simplify our inquiry, let us confine the question to the animal stem, and let us imagine the primitive creature to be a generalised protozoan, as sooner or later it was. Within the pre-Cambrian occurred a third great organic event of tremendous significance—the Protozoa gave rise to the Metazoa. Having accomplished this feat, the ancestral Protozoa continued to reproduce their own kind. Despite differentiation, the making of genera and species, of offshoots that lived and offshoots that failed, the Protozoa during more than 500,000,000 years have never given rise to anything but unicellular offspring. The conclusion is obvious, that in the pre-Cambrian occurred

¹ From the presidential address delivered at Southampton on August 27 before Section C (Geology) of the British Association.

a marvellous event due to certain conditions which have never since been duplicated.

Similarly the primitive coelenterate, presumably a sponge, gave rise to ancestral Cnidaria still within the pre-Cambrian. Never since has the sponge given rise to anything but the sponge, but the phylum has continued to exist and to differentiate within seemingly fixed bounds. Before the close of the pre-Cambrian all the phyla of Invertebrata arose successively in this manner. Possibly we may include the vertebrates, although they have not yet been found so far back in time. These are well-known principles, but reiterated here because I think that they are not always given their true value.

I would emphasise—the origin of phyla as great events in geological history, the crowding of these events into the pre-Cambrian, the continuation of ancestral stocks, and their failure ever again to give rise to new phyla. It would appear, further, that higher phyla have not developed through highly specialised genera of lower phyla. For the invertebrates this is evident in the appearances of all the phyla in the pre-Cambrian; for the vertebrates, in the first place nothing is known with certainty, and in the second place the various phyla appeared long before high specialisation was attained by the ancestral stock. Amphibia arose from primitive Devonian ganoids, not from highly specialised teleosts; reptiles were derived from early Permian stegocephalians, not from highly specialised Anura or Urodela. The eutherian mammals appeared with startling suddenness in the basal Eocene, and before the close of the period had developed into all the great classes.

Evolution in the phyletic sense is not a gradual process, not uniformitarian, but marked by great events in time. Specialisation and consequent fixation of characters are adverse to phyletic differentiation.

It is apparent that phyla can arise only through genera and species. How far the phyletic principles may apply in the lower taxonomic ranks is an interesting question, the consideration of which would unduly extend this address. I would venture to state, however, that close adaptation (high specialisation) is likewise inimical to the production of new genera and species. Further, I believe that close adaptation is the main cause of extinction.

Let us assume the existence of an organism *perfectly* adapted to its environment. Is it not a safe conclusion that *any* change in environment must result in the death of such organism? That there is now or that there ever has been a perfectly adapted animal is extremely doubtful, but all animals must be more or less adapted or they could not exist. It may be stated that *the margin between perfect and necessary adaptation* is the zone in which organic evolution is possible; further, that the nearer an animal approaches perfect adaptation, the more liable it is to extinction on the advent of changed conditions. This conclusion is in accord with the generally recognised fact that in many instances highly specialised animals have suffered sudden extinction; it is also in accord with the general observation that the geological record is one of extinction and replacement in so far as species and even higher taxonomic divisions are concerned.

The great weight of geological evidence points to the

supplanting of one species by another, not to the transformation of species into their successors. A single transformation sequence may be regarded as sufficient to establish the principle, but an adequate explanation must be given of the failure of vertical serialiations in the great majority of cases. This explanation is not yet forthcoming, and its lack stands as the chief item in the *contra* account of the balance sheet of evolution.

It is to the unfavourable changes that we must look for an explanation of the more deeply seated organic evolution, and by unfavourable I mean adverse to the present condition of the animal in that it is forced to further adaptation. A change of this kind is not of necessity *adverse to life*; it may even be stimulating. The animals towards the margins of a colony, by reason of their less perfect adaptation, may in a few instances survive an unfavourable change. The first impulse of these survivors will be to escape by flight, and thereby diminish the fatal suddenness of the change and thus achieve adaptation.

The new species would arise rather suddenly with but few individuals of the transition stages. Arrived at a favourable habitat, migration would cease, multiplication would ensue, and closer and closer adaptation would be achieved. Eventually an approximation to perfect adaptation would render the new species liable to extinction on the recurrence of unfavourable conditions.

This explanation of the common failure of vertical serialiations emphasises migration as a factor in evolution and leads to the conclusion that transitional stages are few in number, scattered over wide geographical extents, and disposed in stratigraphically oblique lines. Barrell's "diastems," to be referred to later, support this explanation of abrupt changes in the faunas.

THE AGE OF THE EARTH.

The mysteries of time and of space have long been subjects of profound contemplation and scientific inquiry; they are intimately connected with the destiny of man and bring him into touch with the infinite. High is the cultural value of the mere contemplation of infinity, and of supreme importance is any light that may be thrown on a problem long regarded as beyond human comprehension. In recent years the theory of relativity has opened to the mathematically trained mind a possible avenue to a solution, but to most geologists this avenue is a closed road.

The determination of the actual age of the earth has long engaged the attention of philosophers and scientists, and various widely divergent estimates have been made by approaching the subject from different points of view.

Kelvin, Tait, King, and other great physicists but a few years ago allowed the geologist a maximum of 40,000,000 years for the age of the earth. Recent studies on radioactive minerals have induced the same school to raise the figure to 1,710,000,000 years, a *volte face* that emphasises the danger incurred by "the dictatorial hierarchy of exact scientists" in raising a mathematical structure on an insecure foundation.

The chief methods of determining the age of the earth other than those based on radioactivity, are: the rate of decline of solar energy, the gradient of earth temperature, the quantity of salt in the seas, the rate of organic

differentiation, and the rate of denudation of lands and of accumulation in the seas in relation to the known thickness of strata made throughout the geological ages.

The determination of age by means of radioactivity depends on the fact that uranium and thorium break down into lead and helium, and that the rate of this disintegration is known. The time required for half a given amount of these elements to break down is known as the half-value period. This period, according to Gleditsch, can be calculated to within 2 per cent.; for radium it is 1660 years and for uranium 6×10^9 years. An atom of uranium breaks down into one atom of lead and eight atoms of helium; if the content in these elements can be measured and compared with the quantity of unaltered uranium in an equal volume of the mineral, it is evident that the age of the mineral can be deduced.

Lyell long ago demanded 240,000,000 years for organic differentiation, and Darwin thought 200,000,000 too short for the purpose. On stratigraphic evidence, Barrell considered 250,000,000 a reasonable estimate for the duration of geological time since the pre-Cambrian.

The history of the subject shows that high figures were originally proposed by geologists and that, later, they tried to lower their estimates under the influence of the shorter time allowed by the physicists. More recently, the greater figures endorsed by the physicists permit the geologist ample time for his processes; both lines of inquiry are now pointing to the same result—higher and higher estimates of the immense antiquity of the globe.

Intimately connected with the estimation of time are the rates of erosion of old rocks and of deposition of new. Herein lies the most dependable geological means of determining the duration of the periods; nevertheless, there are serious difficulties to overcome, among which may be mentioned: variations in the rate of decay under different conditions, variation in the rate of deposition, and the occurrence of unrecorded intervals either evident or obscure.

The rate of erosion has received much attention, but as this factor is obviously dependent on the shape and condition of the land surface, its average for all time is difficult to estimate. Barrell considers that denudation by solution lowers the land surface one foot in 30,000 years, and that mechanical degradation accomplishes this result in 13,800 years. The two forces acting together require 9000 years to effect one foot of erosion.

Barrell's estimate of 250,000,000 years since the beginning of the Palæozoic was arrived at by a study of details of deposition under the hypothesis of rhythms in geological time. According to this author, time is to be measured by rhythms or pulsations, the greater rhythms having shorter rhythms imposed upon them. The longer are to be measured in terms of the smaller, and the smaller in terms of years. A single rhythm is an erosion cycle and small partial rhythms are superimposed on it. Present erosion and sedimentation owing to the Pliocene-Pleistocene uplift is unduly high, with the result that estimates of time based on the present rate of erosion are much too short. Barrell would further increase the time by restricting the area of deposition to the zone immediately below the local base level, and making the accumulation dependent on

upward oscillations of the base level or downward oscillations of the bottom.

In connexion with the rate of sedimentation and its bearing on the age of the earth, it is apparent that the intimate structure of the stratified rocks must be looked to for data bearing on the problem. To this end the character and mode of formation of these rocks are now receiving an increasing degree of attention. A better understanding of sedimentation is being obtained by direct observation on the formation of modern sediments, determination of the precipitating value of algae and bacteria, studies on coral reefs, deep-sea investigations, studies on colloidal solutions, investigations of chemical deposits, and a better appreciation of the value of facies and vegetal terrestrial deposits. Direct investigation of the rocks themselves is leading to an increased use of the petrographic microscope and of analytical methods. Secondary features of stratified rocks are receiving greater attention, horizontal transitional stages are better understood, and the relationship of strata to sea invasions has led to a fuller appreciation of the value of palæogeography.

THE ORIGIN AND INTERIOR OF THE EARTH.

The question of the earth's origin is evidently closely related to the problem of its age. Although geologists are inclined to disclaim this aspect of the subject, I feel that it cannot be disregarded under the title of this address. The interior of the earth is beyond direct observation; the deepest mines and bore-holes scarcely penetrate the outermost skin. Certain fundamental facts, however, may be taken as established. The interior is hot, rigid, and heavy (sp. gr. 5.6 as compared with 2.7 for the known exterior); the accessible exterior is composed of elements common to the universe. Beyond this all is vague and speculative.

It is worthy of particular emphasis, however, that while the earth as a whole acts as an almost perfectly rigid body, the external envelope with which we are familiar is by no means rigid. Adjustments have taken place throughout all geological time, and I need not quote evidence that they are still taking place. The acquisition of perfect rigidity by the globe is to be regarded as a tremendous calamity. This condition attained, the universal deluge is within sight geologically speaking, and the end of the present order of things must inevitably ensue. Earthquakes, therefore, are not to be regarded as unmixed calamities; they are evidence that the fatal total rigidity has not yet been attained.

It might be asked if there is any evidence in geological history of an approach to a condition of total rigidity or of a tendency in this direction. There can be little doubt that pre-Cambrian events were on a scale seldom, if ever, attained in later time. Cambrian and Ordovician transgressions of the sea were also on a grand scale, but later movements, on the whole, seem to have been smaller and more local in their expression, although there were notable exceptions as the Tethys sea in Europe, the great invasion of the Coloradoan geosyncline in Upper Cretaceous time in North America, the tremendous volcanic activity of the Miocene, and the grand epoch of mountain-building in the Pliocene and Pleistocene.

The general conclusions seem to be that the earth is not showing a trend towards rigidity, but that earth movements and vulcanism are becoming less profound in scope and less widespread geographically, the average of activity being maintained by more frequent recurrence.

EARTH MOVEMENTS AND ADJUSTMENT.

The causes of earth crumpling and the dynamic laws which govern the phenomena are subjects well within my theme, but their consideration would lead me to undue length. Earth movements, of necessity, are bound up with theoretical considerations of the earth's interior. Whether earth crumpling is due to loss of terrestrial heat and consequent contraction of the nucleus, or whether the modern concept of isostasy offers a better explanation, there must be a downward limit to terrestrial disturbances. This limit has been placed at 113.7 kilometres and termed the "depth of compensation."

It is obvious that a consideration of this subject would lead to a discussion of land forms and their influence on human activities—definition of nationality, physiographic control, distribution of faunas, and countless other effects, all of which extend beyond the realm of technical geology and form part of a general education if they are not "cultural" in the narrower sense. There is, however, one great lesson to be derived from the study of earth movements that bears on the general scheme of things and is worthy of especial mention—the marvellous continuity of conditions.

The diameter of the earth is about 8000 miles and the maximum of relief of the lithosphere about eleven miles, approximately 0.14 per cent. Oceanic waters have filled the depressions and continental masses have risen above the water-level—a condition that has maintained throughout all time in the opinion of most geologists. The present area of the land is 27.7 per cent. of the whole terrestrial surface, and the average height above sea-level of the continental masses is only 2120 feet according to de Lapparent. It is apparent that the actual volume of that part of the lithosphere which projects above sea-level is extremely small when compared with the volume of the whole globe.

It is well known that the power of erosion is sufficiently great to have reduced this relatively small mass to sea-level time and time again throughout the long course of the geological ages. Nevertheless, it is confidently believed that this result has never been entirely achieved. Rejuvenation has kept pace with erosion throughout the hundreds of millions of years that the earth has endured. In my opinion this marvellous nicety of adjustment between two great sets of opposing forces is one of the major lessons of geology. Is it a mere coincidence or is it evidence of design?

CLIMATE.

Climatic change must be regarded as an ever-present factor. It is highly probable that variation in climate will greatly affect the activities of the human race within a measurable number of years, and it is not impossible that the sites of our present centres of civilisation will be buried under glaciers and that a new civilisation will occupy, under a genial climate, the present inhospitable regions around the poles.

Despite the changes in any given locality, the continued existence of life is sufficient evidence that the whole globe has not experienced, from the earliest geological time, any very great universal change in climate. Gruner has proved to the satisfaction of most geologists the existence of algæ in the Keewatin of Minnesota. The great masses of limestone with disseminated graphite of the Grenville are at least suggestive of life, and Moore has brought forward convincing evidence of algæ in the Animikie of Belcher Islands in Hudson Bay. Both the Archæozoic and the Proterozoic, therefore, were warm enough to permit organisms to exist despite the intervening event of an ice age in the Huronian.

Wonderful have been the changes in climate and far-reaching their effects, but truly marvellous has been the continuity of a range of temperature permitting the existence of life from the very dawn of earth history to the present moment. Nothing short of a cosmical catastrophe can alter a condition that has maintained for nearly two thousand millions of years. Surely if culture is the cultivation of the spirit, the contemplation of geological climate should lift the mind above the mere material into the realm of the philosophical and the spiritual. If the continuity of the observed range of temperature is due to a single factor—solar energy—the endurance of that energy is a marvellous thing. If the observed climatic continuity is a composite result due to various sources of energy, it is still more marvellous.

THE STUDY OF GEOLOGY.

Whatever satisfaction is to be derived from the acquisition of knowledge, there is always a discouraging factor in the realisation of our limitations. Owing to the complex nature of the subject and the vast number of facts involved, the study of geology is peculiarly effective in this respect, and cannot but tend to a humble attitude of mind. Another potent influence to this end is the realisation of the mistakes that have been made, even in the basic principles of the science. From the fantastic theories of the cosmogonists arose eventually the doctrine of catastrophism; this conception yielded to uniformitarianism, and to uniformitarianism was added the doctrine of evolution. Le Conte described Darwin as a uniformitarian evolutionist. To-day uniformitarianism is being questioned seriously from both the inorganic and the organic points of view. We are swinging back to a conception of a milder catastrophism variously expressed as rhythm, diastrophism, and so on. The necessity of drawing conclusions from doubtful or insufficient evidence is an ever-present antidote for dogmatism. Many of our conclusions are merely inferences subject to revision in the light of further evidence.

To humbleness and caution I would add a conviction of theism as a result of the study of geology. I fear to venture on dangerous ground, but I must be allowed the opinion that materialism offers no adequate explanation of the wonders of geology. With revealed religion I am not here concerned, but I believe that the inconceivably long gradient that has led ever upward to the mentality of man has not been traced without design, and I see no reason why that gradient should terminate. I look, rather, to its upward continuation to even greater heights beyond.