GEOLOGY

AS

A BRANCH OF EDUCATION.

BY

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INTRODUCTORY NOTICE.

The following pages were delivered as an Inaugural Lecture at the College of Civil Engineers, at Putney, where a system of general scientific education has recently been organised. They have equal reference to the similar system pursued at King's College, London, in the 'Department of general instruction in the Applied Sciences.'

It is the wish of the Author to direct attention to the method of instruction adopted in these two Institutions; and he believes that, by showing the advantage of Natural History as a branch of Education, he is carrying out, to the best of his ability, the great principle involved in both of them; and that, at the same time, he is effectually advancing the cause of Education in this country.

The instruction communicated, both at King's College and the College at Putney, includes every subject most useful for those who intend afterwards to employ themselves actively in the business pursuits of life. Without too exclusive reference to the details of Engineering, Architecture, or Agriculture, but with reference to each in such a measure as is thought most likely to be generally useful, the student, in these Institutions, is conducted by those methods of Elementary Education which experience has stamped as most sound and effectual, through a course of instruction which communicates facts and information, without being permitted to dwell upon the acquisition of these facts as the ultimate object of education. The sciences are applied, but they are first taught; and this *teaching*, the leading on of the intellect to instruct itself, and to take an interest in the acquirement of knowledge because of the satisfaction arising from the reception of truth, is much more dwelt upon and valued than the mere communication of abstract facts.

King's College, London,
27th January, 1845.

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In introducing the subject of Geology as a branch of education desirable, because useful, for practical men, I wish to explain my own idea of the value of Natural History generally in adapting the mind for the reception of a kind of evidence with which we must often be satisfied; but in exercising which, if we do not fully understand its true value, and the method of using it, we may be involved in many doubts and difficulties; while, on the other hand, if we comprehend its nature, we shall often find it very important in assisting us to arrive at sound conclusions on practical subjects.

It will be at once perceived, by these introductory remarks, that I do not propose to treat the subject of Geology as a mere amusement, nor even as consisting of a detail of facts to be narrated and terms to be explained. Geology, in its present state, involves far more than this kind of instruction, and it must be earnestly pursued, and looked upon as an important study, by every one who would succeed, or, at least, who would distinguish himself in the professions of Civil Engineering and Architecture, or in those employments which have reference to Mining and even Agriculture. In all these pursuits it will be found that a knowledge of the materials of which the earth's crust is made up, of the order of arrangement of those materials, of their contents in the shape of organic remains, (indicating the relative age of the formations) of the disturbances which have altered the originally horizontal position of rocks deposited as sediment from water, and of the other investigations bearing on, or forming Geology, must be carefully acquired, and will be constantly brought into use. I think it will also appear that a familiar acquaintance with these facts, the foundations of Geology and the first results of geological investigation, is needed in the most ordinary affairs of life ; and I trust to prove to your satisfaction that the science which it is my province to teach, is not only deeply interesting, but eminently useful and practical.

You are all, no doubt, aware that education is an earnest and a serious matter. It has its fundamental principles, its general and special applicability, and its different methods, adapted for fully developing the powers of different individuals and classes, and enabling each to produce the greatest and the best effect. Its great value and importance is manifest in the melancholy instances that occur of opportunities lost and progress checked for the want of it. But there is such a thing as general education as distinguished from that which is special ; and although it is a chief object in this place to enforce the latter, I am willing to hope that you are not unwilling to return to first principles, and look to the former also. I propose, therefore, now to offer a few remarks on the Elements of Education, more particularly with reference to Natural History, and I shall dwell on the nature of the various methods that may be adopted, all of them, however, being ultimately derived from the same general principles, and leading to the same general results.

I understand by Education a preparation of the intellectual powers, enabling man to do the work he has to do with the greatest ease to himself, and in the most effectual manner for the benefit of his fellow-creatures—I do *not* understand that it includes necessarily, or even properly, a heaping together of information, when it is crowded, if I may so say, into the intellectual capacity, without order and without consideration; and I would remind you, also, that no one can be useful to the best of his ability and properly perform his allotted part in life, without some self-education,—without, that is, careful consideration and thought,—and a conscientious exercise of all the faculties with which, as a man, he is endowed. Capacity is, indeed, a small part of the intellectual ability; and without a power and a habit of arranging knowledge, so that it may be readily referred to on proper occasions, knowledge itself, so far from being useful, is positively an incumbrance.

There are, therefore, two great objects to be attained by education. The first is the formation of habits of thought; and the second the accumulation of a due number of useful facts, storing, not overloading, the intellect, and always practical, or readily brought to bear upon the subject in hand whenever they can possibly be useful; but this latter object is by no means the most important of the two, nor ought the former on any account to be sacrificed to render this more complete. Education is, I repeat, a preparation of the mind for receiving information, and does not necessarily require that much direct information should form a part of it.

The teaching of useful facts is, however, by no means to be thought lightly of, and is perfectly compatible with the main object of Practical and Scientific Education, which consists in such a preparation for active life in certain professions as includes the knowledge of peculiar classes of facts most useful in those professions.

The study of grammar as illustrated and rendered interesting by the acquirement of other languages than our own, and more especially the Latin and Greek tongues, has been found, by very long experience, to be admirably adapted to prepare the intellectual powers for almost every subsequent effort that may be required, provided, of course, it is pursued with reason and in moderation. The pursuit of mathematics is another and not less important branch of education; for by it the reasoning powers are fully exercised, and the mind at first, as in childhood, receiving without suspicion every conclusion presented by analogy, is taught by this pursuit to require distinct proof of every proposition stated—certain terms having been originally defined, and certain preliminaries granted, beyond which no assumptions are allowed, no analogies admitted. Now the study of grammar, although it leads the mind to dwell upon analogies and often requires that we should be satisfied with conclusions in which actual mathematical proof is not to be obtained, does not in itself involve any method of pursuing investigation, or any argumentative principles. The intellect, therefore, taught to receive mathematical conclusions as the only ones absolutely certain, is not unlikely to question the truth of results when this proof is not attainable; and such evidence as is usually met with in the practical affairs of life is scarcely looked upon in its true light, or weighed with a due regard to its importance. The practical result of this is, that in too many cases unsound conclusions are admitted from carelessness and from a want of appreciation of the true nature of the evidence; and a habit becomes formed of acting without due consideration, and is accompanied at the same time by a sceptical turn of mind exceedingly injurious to intellectual health, and greatly mischievous in its results on society at large.

There is, I firmly believe, a groundwork of educational science, if I may use the expression, in Natural History, which might well be taken advantage of, in preparing young men for mixing with the world; and I think, to make use of the words of a philosophical writer of our day, that "Natural History ought to form part of education, in order to correct certain prejudices which arise from cultivating the intellect by means of mathematics alone."*

One of the main advantages to be derived from the study of Natural History, is the introduction of a habit of looking on analogy in its true light, as an important guide in discovering truth: and this is the more valuable, as analogy is, in fact, one of the chief methods which the mind employs in arriving at conclusions from conflicting evidence. In the pursuit of all kinds of Natural History, we are obliged always to compare before we decide; and the extent to which this comparison ought to go is so great, that very few naturalists indeed have been able fully to grasp all the complicated relations presented by Nature, although there can be no question that it is chiefly this power of comprehending numerous classes of facts that most distinguishes the greatest of all naturalists from their fellow-workmen. It was in this way that ARISTOTLE in ancient times, and CUVIER in our own day, attained so lofty a position among philosophers; and no one will

* Whewell, "Philosophy of the Inductive Sciences," vol. i. xliii.

doubt that it is this power that must be exercised, if any one would yet undertake to arrange, according to their natural affinities, any tribe of organised beings.

As a subject of education, I believe Geology is the best adapted of all the Natural History sciences, and requires most immediately the exercise of those intellectual powers which it is desirable to cultivate by such pursuits. This is the case for many reasons. In the first place, Geology is the link by which the sciences of observation, properly called Natural History, connect themselves with Astronomy, and become capable of the application of the principles of pure mathematics. Its leading conception also seems to be that of historical cause:* in the consideration of its details, every other department of Natural History must necessarily enter: it admits of both those methods of investigation, an habitual practice of which is most conducive to the advance of the student; and while it opens a new and more extended field to the mathematician, it brings back to simple analytical principles the discursive habits acquired by the observer of Nature's works in the field, and leads him to stricter investigations and habits of closer thought.

But it may be necessary to show how this is the case, and what is the nature of Geological science, and its relations with general science—and this I proceed to do.

Geology, as I have already observed, is not merely an important department of Natural History, but is that particular department by means of which Natural History is connected with mathematical science. Its object is to observe and describe the structure of the external crust of our globe, and from the consideration of phenomena thus presented to view, to trace the successive changes that

* Whewell, *ante cit.*, xxxiii.

have taken place upon the earth, and the various laws or modes of action employed in effecting these changes.

The facts of Geology are derived from, and partly consist of, observations made concerning the nature of the earth's crust in all parts of the known world; and they may be comprised under three distinct heads. These are, 1st, the fact of stratification, in other words, the fact that the earth's surface, examined to as great a depth as we are able to penetrate, exhibits not a miscellaneous assemblage of rocks and stones, promiscuously huddled together; but a very regular series of beds or strata, each stratum being itself regular and evenly-disposed, and differing from those above and beneath it. 2nd, The fact of the existence in these beds of the remains of animals and vegetables characteristic of them, and differing for the most part from the species at present inhabiting the earth and seas; and 3rdly, the fact that these different fossiliferous strata are frequently altered from the originally horizontal position in which they must have been deposited; and rocks are occasionally present, which seem to have been subsequently intruded, and their intrusion to have been accompanied by mechanical violence. The three great classes of facts thus grouped and considered in their bearing upon one another, and upon Natural History, form the groundwork of all geological speculation; and the statement of the details with reference to each of them forms together what is called Descriptive Geology.

It must be obvious, upon the slightest consideration, that no one can possibly be qualified to theorise, or to discuss the value of general views deduced from observations on any subject, who is not fully aware of the nature and extent, the comprehensiveness and the detail of the facts that have been accumulated with reference to the subject from which deductions are to be drawn; and the mischievous tendency of arguments and objections raised by persons, who are not acquainted with the facts, will be at once recognised. Even at the present day, although we know much that is certain, and large classes of phenomena have been fully and fairly recorded, so much remains to be done, that generalizations which include more than a limited number of groups of facts, are extremely dangerous; and no universal law has yet been enunciated to include all the recorded phenomena. But, years ago, when the attempts to explain the *modus operandi* of the Deity in the creation of the world, were more numerous and common than happily they are now, the ignorance on the subject was much greater; and perhaps men are now more modest, because their increased information enables them to perceive also their numerous deficiencies.

I say this in the commencement, and I say it while endeavouring to show that there is much that is valuable, and much that is certain in the study of Geology; for I am convinced that no benefit can be derived, and no sound conclusion reached, until the student thoroughly understands what is really the object of the science he studies, and what also is beyond the immediate reach of attainment in it.

Looked on as a branch of education, the study of Geology may be considered as teaching a strict method of induction in philosophy, a knowledge of the inductive facts having been obtained not only by actual observation, but also in some measure by that kind of experiment in which Nature herself performs the chief part. In this respect, it may be said, Geology does no more than enlarge the sphere of Natural History observations, by extending them indefinitely to all past ages; but in fact this extension gives them a new and important feature, and enables us to make use of the term History, and apply it to natural objects, in its widest, most general, and most philosophical sense, instead of limiting its signification to a mere account of present existencies. Looked upon in connection with Geology, Natural History ceases to be a mere description of species and of existing analogies. It attains continuity and perpetuity. It seeks for causes acting through successive periods, combating change, and producing change. It looks for harmony, not merely with reference to that which is, but to that which has been, a harmony uniting many elements which now seem discordant, by links which perhaps no longer exist, but which are not the less real; a harmony produced by the constant and uniform action of the same principles, the same laws, and the same wise government, which has first given the laws and has constantly preserved them in their integrity.

If, then, any branch of Natural History is valuable as an educational science, I think it not too much to maintain that that branch must be Geology; for while it includes all the others, it extends them through the past to the earliest period of the earth's existence, thus involving, as I before observed, historical succession.

But perhaps, it may be objected, that, while professing to treat the subject of Geology, with reference to its practical usefulness, I allow myself to be carried away by the theory of education, which I put forth. My answer to such objection is, that, in endeavouring to impart a knowledge of principles, I am in reality preparing you for the only means of making useful and practical applications. Mere facts alone cannot be applied, until their mutual bearing is understood; and for this purpose, it seems to me, the true principles of Natural History should form a branch of education.

I have already defined what I mean by Geology, and in what way I consider, that for this purpose of Education, it possesses great advantages. But if this is the case generally, it must be so in a far more special degree to those who wish for a Professional Education, and who will soon go forth into the world as practical men—and yet it is to such more especially that I say, make yourselves familiarly acquainted with the *principles* of a science, if you are in any way likely to be called upon to apply it practically.

But let me explain this a little more clearly. You are taught the elements of mathematics in order that you may be familiar with the nature of mathematical demonstration; and if you are ever to make your mathematics and your knowledge of its rules useful, I need not say how absolutely essential it is that you should clearly understand the strict meaning of those definitions upon which every proposition must rest, and without a perfect acquaintance with which no advance can be made. In mathematics, the meaning of words is first clearly defined, and the words having thus a technical and definite sense, can themselves be used in defining the conditions of a problem. Now, this may be looked upon as a principle in which mathematical reasoning differs from much of the reasoning with which we are obliged to be satisfied in other sciences. In the Natural History Sciences, for instance, no such definition of words can be given. Our first knowledge of the ideas that belong to such sciences, must be derived from the external senses; they are, in the strictest sense of the word, *material;* and thus, knowledge and the method of communicating it, when such natural material objects are the subject of description, must be from *analogy*, and not from *definition.* The one process, the Mathematical, is purely abstract and mental; it has relation to the powers and faculties of the mind, and could exist and be carried on without reference to the body. The other, the Physical, that which relates to external nature, is practical, tangible, and, in contradistinction to that which is ideal, may be said to be real. You are taught first in your Mathematical studies to combine ideas introduced and limited by strict definition, and you work out from this combination new results. You are now about to enter upon another study, in which you will obtain your notions from a comparison of external objects, and from the method which is called *analogy*. You will no longer receive those strict definitions upon which you may fall back and repose at any point of your progress. You will have presented to you *types*, or resemblances, which are more or less complete, more or less characteristic, more or less striking, but always real, and admitting of every variety of application, and every imaginable gradation.

The difference between the argument from analogy, and that derived in the course of mathematical demonstration, is thus seen to be fundamental; and thence arises the necessity that you should be made acquainted with the *principle* of Natural Science, that prevailing idea of typical resemblance and analogy, which so thoroughly and invariably characterises it.

Without some such explanation it might seem strange that, in a lecture, the first of a course devoted to the subject of Geology, I should first of all, and as one of the most necessary introductions to the subject, endeavour to communicate to you a notion of the true nature of species; but you will now understand that in doing so, I am preparing the way for the acquirement of that idea which is the basis of Natural History, and therefore of all Geology.

We may define *species* to mean a collection of individuals which resemble one another in some essential peculiarity of structure, more than they resemble the individuals of any other group,* and when once a definite and satisfactory conception of this meaning (a very general, although, perhaps, a sufficient one) is attained, a great deal is done towards acquiring a knowledge of typical resemblance.

The meaning of analogy, and the sense in which a knowledge of the nature of species is useful in Natural History, is, perhaps, best exemplified by referring to the laws of mutual relation that have been discovered to exist between structure and habit, and their application to the determination of extinct species. Now it is clear that, unless there is such a thing as species, unless, that is, there are essential peculiarities—be they what they may—beyond which individuals do not vary, and varieties do not extend, there could be no certainty in any argument from analogy. When, however, we find that every animal, concerning whose habits we have certain knowledge, exhibits in every, even the most minute, part of its structure something which, to the careful observer, has distinct reference to those habits; and when, on the other hand, the comparative anatomist is enabled to determine accurately the nature of many of the habits from the examination of a single bone, a tooth, or a small fragment of a tooth; then we see that order and system reign in Nature; and

* This definition is not strictly that which is admitted in Natural History, for this latter is the result of observation and experiment; and however probable, fails in absolute certainty. The admitted definition of species seems to be that of a group of which individuals or pairs of individuals produce their like in successive generations, while with regard to animals and vegetables of different species, although under certain artificial circumstances they may originate individuals uniting to a certain extent the peculiarities of the two species, yet this cannot be perpetuated, and is certainly limited to a very narrow range.

that it is, therefore, contrary to probability that there should exist any such element of confusion as would be necessarily involved by the interchange of specific character and the formation of new varieties by a mixture of species.

It is greatly to be lamented that, in consequence of a very imperfect Natural History Education, many persons calling themselves, and considered as naturalists, are not aware of the importance of knowing the true nature and extent of differences that are properly specific; and such persons, probably, may be inclined to underrate the importance of this part of our subject. I cannot but look upon it, however, as a matter of the first and most vital consequence that the student of Natural History should be familiar with this elementary knowledge; but I allude to it now only as an illustration in its reference to the law of mutual relation of general and specific structure in organised beings; a law derived solely from a careful study of analogies, and the result of the establishment of which has been to afford a means by which each species may be identified by almost any fragment that may be found. The application of this law also is so generally felt to be well founded, that any one at the present day merely seeing the track of a cleft foot might safely conclude that it had been left by a ruminating quadruped, this foot-mark alone being sufficient to give to the observer a knowledge of the structure of the teeth, the jaws, the vertebræ, the bones of the extremities, and the pelvis of the animal that had passed, although, it must be remembered, that whatever may be the nature and the object of this mutual relation, we owe a knowledge of its existence to observation, and not to abstract reasoning.

Analogy, therefore, the foundation of such important generalisations in Natural History generally and in Geology, is essentially founded upon the observation of facts, and is among the most valuable of all methods of induction. You will find, hereafter, how completely the whole subject of Descriptive Geology is a succession of valuable practical examples of reasoning according to this method, and you will see how that which at first only suggested itself to the mind as possible, gradually becomes probable by additional evidence, and at length attains so high a degree of probability as to claim to be received as unconditionally true. Step by step you will be called upon to advance in this course, conviction will be forced upon you when you find that every observation, and every additional fact, tell the same tale, and harmonise with the same result; and at length, when you have gone through the subject, and made yourselves acquainted with the investigations of so many observant and intelligent men, you will be in a condition to advance yet further, to examine and draw conclusions for yourselves, and to apply practically the knowledge you have obtained.

These practical applications belong, no less than the descriptions, to that elementary part of the study of Geology which I consider so useful for the purposes of education; but they require to be considered carefully, to be indicated rather than dwelt upon, and employed as instances rather than considered as an end.

Without this there would be great danger of the true object of education being mistaken, and my Lectures might become mere routine information, having no reference to my own special object and your requirements.

The applications that bear most distinctly and immediately on practical conclusions, are more numerous and direct with respect to Geology than other of the Natural History Sciences. Thus in mining, the selection of a mining ground in an untried district, the determination of the spot where boring for coal or other embedded minerals shall take place, the method of proceeding when a fault or a system of disturbances is unexpectedly met with, are all dependent on the structure of the earth, and are, therefore, in so far, directly geological questions. In engineering, again, the selection of a spot for sinking an Artesian well, the determination as to which is most expedient of two conflicting lines of railway, the actual construction of a railway with regard to cuttings and tunnels, and many other matters of like kind, are also immediate applications of geological principles; and so, likewise, must be considered the selection of a safe foundation, or a good material for building, as geological results not less important to the architect, and the proper management of the soil and subsoil to the agriculturist. In all these cases, however, it is by a knowledge of the principles upon which the science is founded, and not merely upon a slight and popular acquaintance with its general results, that Geology is a useful guide, and an important aid in arriving at practical conclusions.

It cannot possibly be impressed too forcibly upon you that a mere superficial knowledge of facts is absolutely useless, and may even be mischievous, and that this is nowhere more true than with reference to Geology and its application to practice. Every day renders it more important that practical men should be acquainted with Geology; for this science is constantly exhibiting new analogies, new relations of cause and effect are traced, and modifications of laws are discovered, all bearing more or less directly on questions affecting the stability and permanence of engineering and architectural works, whether undertaken on the surface or in the bowels of the earth. But the very vigour of life which causes these discoveries to multiply so rapidly, renders it the more necessary to be cautious and philosophical in arriving at conclusions: and it is therefore a familiarity with the fundamental principles, not an empirical knowledge of results, that can alone be permanently useful.

The general usefulness of a science seems to depend on two conditions; first, on the degree of definiteness of which it is capable; and next, on the nature of its applications. In both these respects Geology ranks very high, and in the latter, more especially, it is hardly surpassed by any science. The importance of distinctness in fundamental principles also will be evident when we consider how much we depend in forming our opinions on the degree of certainty that can be reposed upon the system to which we refer. Now, in Geology, all the main facts are clear and undeniable, and may be made evident to the eye and understanding of every one who will honestly and patiently search for them.

These facts are indeed startling, and seem perhaps to oppose themselves in some measure to preconceived notions; but they are not, for that reason the less certain; nor because they are unexpected, may we venture to set them aside unconsidered. The applications of Geology are, in like manner, numerous, direct, and highly important, bearing immediately on pursuits in which large sums of money are employed, and many thousands of human beings exposed daily to frightful risks, and scarcely less immediately on other occupations, as for example, those of Engineering, Architecture, and Agriculture, certainly most important to the well being and progress of society. In point, therefore, of general usefulness and importance in its bearing on practical pursuits, it will, I trust, be clear that our science is well worthy of investigation.

I have now shown what I consider to be the nature and meaning of Geology, its value as a subject of general education, and also the nature of its position with regard to the pure sciences. Before concluding this Lecture, I would also point out to you its relations to the Natural History Sciences a little more in detail than I have hitherto done.

These relations may be considered with reference to the two great classes of the Natural History Sciences, the one treating of inorganic, and the other of organic bodies. With the former, Geology has, as may be supposed, many interesting links by means of Mineralogy and Chemistry; and with regard to the latter, that department of Geology called Palæontology—the Natural History of the extinct races—is so intimately dependent at every turn on Zoology and Botany, and has so many common interests with them, that it cannot be separated from them even in thought.

The real nature of Geology has been comparatively a short time understood, even by those who called themselves Geologists, for, till very lately, the science was considered a branch of Mineralogy, and that even when Mineralogy itself could scarcely be looked on as more than a kind of imperfect Terminology, founded on observations still more imperfect, and having little claim to be considered as a branch of Natural History. The relations of Mineralogy to Geology are, although not unimportant, few and easily learnt.

Mineralogy has for its object to determine the nature and properties, and, if possible, the mode of formation of those substances of which the earth is made up, and which are called minerals. The recognition of these different minerals, the arrangement of them in a certain order, and the statement of their properties, constitute the whole of this pursuit, unless it is looked upon as a department of

Crystallography, in which case, indeed, it may be advanced to the dignity of a science, but only by the mathematical investigation of crystalline structure, and the aid of a powerful and accurate mathematical analysis. Mineralogy, in fact, without Crystallography, has neither a sound foundation, nor any unity of character. It may be amusing, and in some respects even useful as a pursuit; but it can rise no higher, and it possesses value in Geology only when employed to communicate useful technical knowledge, bearing on the practical applications of Geology to mining and metallurgy. But I will not here enter on a discussion as to the relative importance of different branches of Natural History; and I only wish to point out to you that Mineralogy is a pursuit, to a certain extent different from, and independent of, Geology, and that it extends only to a consideration of the mechanical and chemical constitution of those substances, the arrangement and grouping of which, and their association in particular localities under certain circumstances, forms of itself only one class of geological phenomena. It is, however, an adjunct, and not unfrequently a useful one, in enabling the student to recognise and class the various materials of the earth's crust; and notwithstanding that it holds an inferior rank when compared with other studies bearing on Geology, a knowledge of the mineral constituents of rocks is yet of great practical interest, especially when united with Chemistry, and when, by the aid of this union, it is attempted to trace the workings of Nature in her vast subterranean laboratory.

Thus far, then, Mineralogy (more particularly in its relation to Chemistry) is a necessary and most useful handmaid to Geology. Of simple minerals, of the chemical elements, of the laws of atomic proportion, of the complicated problems relating to the different forms assumed by minerals under certain circumstances, the student of Geology, as such, takes little heed. His researches have little or no reference to such combinations, for his main object is to investigate the nature and origin of vast masses which are usually amorphous, and in which perfect crystals are sparingly distributed. But whenever crystalline action has taken place on a large scale—and it must not be forgotten that every day adds some new fact in illustration of the extent to which such action has really extended—then the phenomena become strictly geological, and of the most interesting nature; and thus an intimate union exists between these branches of Natural Science, the chemist investigating the laws of the atomic constitution of bodies, the crystallographer determining the law of the arrangement of parts by the aid of mathematical analysis, brought to bear upon the results of actual experiment and observation; while the geologist receives these contributions to the general stock of information, and applies them to increase his knowledge of the general constitution of the globe, and the mutual arrangement of its different parts. When this is done, he is in a condition to prepare a series of other and higher problems, on the solution of which depends the determination of laws, by whose agency changes have been effected, terminating in the present condition of the earth's crust.

But it is chiefly the relations of Geology with Natural History in the more common acceptation of the term, with Zoology and Botany, that have attracted attention, and excited the lively interest of all observers of nature; and these relations have been found so important, that they have resulted in the formation of a distinct branch of Geology, under the name of *Palæontology*.

The nature of Palæontology is partly explained by the word. It is an account of those organised beings, whether animal or vegetable, whose existence as species dates farther back than the introduction of man upon the earth. It assumes, therefore, the very important fact that true specific distinctions can be determined, and their meaning understood, although the animals and vegetables themselves no longer exist in a living state, or, in other words, it makes use of the argument from analogy—so necessary to be comprehended before any advance can be made in Natural History investigations — and applies it to investigate the remains of organic beings found embedded in the different strata of which the earth's crust is made up.

Thus it is that the fact of the existence of such remains, and the deductions which a knowledge of recent animals enables the comparative anatomist and the naturalist to derive from that fact, are the foundations of Palæontology and the materials of which its superstructure of important mains generalizations is built up.

It is well known, and has long been known, that many stratified rocks contain the remains of animals which inhabited the sea at the period when the rocks were deposited, and occasionally, also, fragments of such land and freshwater animals and vegetables as were transported by rivers to the ocean, or deposited in lakes. These remains have been called *fossils*.

But a little observation was soon sufficient to show that the fossils of different strata vary considerably in many important characters; and even looking only at their general appearance, they evidently indicate a wider departure from the forms of existing animals and vegetables, in proportion as those fossils are examined which are taken from the rocks lower down in the series. Two important generalizations are hence derived:—first, that a very large proportion of the strata must have been formed by a slow and gradual process at the bottom of water, and must, therefore, have required a very long period of time for their production; and, secondly, that as groups of fossils quite distinct from one another are obtained from different strata, and each group is, to a certain extent, characteristic of its own bed, and contains some species not found in any other, *fossils may be assumed as characteristic of formations*, and may be made use of to identify them when other means are inapplicable.

But my business, at present, is rather with the effect which the study of fossils has upon Zoology and Botany than its bearing on Geology. This important view of Palæontology was clearly understood and well illustrated by Cuvier, and to him alone are naturalists indebted for the first establishment of those principles of analogy upon which were based his admirable and useful classification of animals, and his deductions, still more remarkable, concerning the structure, form, and habits of species long since extinct.

No sciences are more intimately dependent on the mutual advance of each, and none are more benefited by every discovery that takes place in any department of Natural History, than are Zoology and Geology as connected by Palæontology. If new information is gained in any department of the one, it is rare and singular if such new matter cannot be immediately brought to bear upon the other; and I might readily quote instances of this mutual advance, which has become more uniform and invariable with every addition made to the number of facts recorded in both.

The study of Palæontology, however, bears, in some respects, the same reference to Zoology and Botany that the generalizations of Geology, abstracted from the consideration of fossils, have to Mineralogy and Crystallography. So far as regards existing species of living beings, there can only be an analogy of comparison, and none of succession. The zoologist is able, indeed, to compare, with great minuteness, the species living in distant countries under similar external conditions, and he becomes aware of the important fact that something more than accidental circumstances influence the distribution of species. But the palæontologist goes much farther than this. He sees that not merely are species different in different countries at the same period, but that in the same district also there has been succession and change, that each species has its maximum of development in time as well as in space; each has had a beginning, and from a small commencement has become gradually of more importance, increasing in numbers and in its influence on other species; and in most of the instances with which he has to deal, each has had its period of decay; so that species, like individuals, are born, flourish, and die, exhibiting thus an analogy, which even the most lively imagination could hardly have surmised from a mere examination of existing nature.

Palæontology, then, as it is a history for an indefinite period of organised beings, of which the description of a single group of representatives *in time*, is called Zoology and Botany, so does it admit of a more philosophical treatment than these sciences, and so much the more does it become adapted to fill the imagination and guide the intellect of man. Inasmuch as man differs from the lower animals by being endowed with the faculty of availing himself of the experience of those who have preceded him on the earth, in the same proportion and manner does

Palæontology surpass Zoology, and so does Geology surpass Natural History generally. And this is no vain boast or unmeaning comparison. Natural History, in the usual acceptation of the term, is the description of natural objects as they are. Geology is the true Natural History, for it is the history of the progress of Nature's works. But because it is impossible to describe continuous events arising out of one another, and each in succession having reference to all that had gone before, without being familiar with the present condition of things, so would it be utterly unreasonable to judge of or study Geology without including Zoology and Botany.

The elements of geological knowledge consist of the observations of the naturalist: the habits acquired by the study of living nature, must be transferred to that more arduous, but scarcely more doubtful task, the investigation of the remains of past generations; and it was only by careful and laborious researches, made with reference to existing species, and proving that in them no one part can undergo a change without a corresponding change taking place in all the others, that Cuvier was able to determine, from the Paris Basin fossils, as many as ninety species of animals, not one of which is now represented by any living creature. But when he had so studied, and had proved to demonstration the law of the mutual relation of general and special structure in organised beings, then was his result found useful and immediately applicable; so that, of the multitude of fragments which afterwards came under his observation, he was enabled by the knowledge he had acquired, to refer them all, each to its proper species, when it belonged to a species then determined, to its genus, when its species was unknown, and to its order when referable to a new genus, assigning, in all cases, the proper characters which distinguished the new discovery from the genera and species most nearly allied.

Besides these relations of Geology with the organic and inorganic bodies of which the earth's crust is made up, there are others, the consideration of which ought not to be passed over. The most important of these has reference to physical geography, and the general conditions of land on the earth's surface. In this is included the configuration of land, the appearance of hill country and plains, the intersection of mountain ranges by valleys and gorges, and the extent to which all these phenomena have been influenced by the geological structure of a district.

It is impossible for any one to cast his eye on a map coloured geologically, or consider the direction of mountain ranges, the course of the drainage of a district, the extent of its plains, or the direction of the lines of elevated table land, without a clear conviction of the bearing of geological investigations upon such phenomena. In England, for instance, the higher hills, and the only districts that can be called mountainous, run along the west of our island, and are principally evident in Cornwall, Wales, and Cumberland; while, towards the east, there is a gradual, though broken approximation to the plain and level ground. And how this is connected with geological structure, it is not difficult to perceive. The general direction of all the stratified rocks in England, is the same as the direction of the higher ground; and it would be easy to show that the apparent exceptions only render the evidence of a relation existing between the geological and geographical structure still more perfect.

Nor is this the case only in our own country; whenever similar investigations have been made, and the geological structure determined, a corresponding result has been arrived at, and the physical features of a district have always been found to depend immediately on the arrangement and relations of the rocks, whether stratified or unstratified, which it is the object of the geologist to examine. In a new country the first geological notions may be deduced from physical Geography, and valuable suggestions are derived from a careful study of these phenomena of the frame-work of the earth. It will be manifest, however, that if the form and general appearance of mountain and hilly districts can communicate a notion of their geological structure, the engineer must value and ought to possess this knowledge, since it might often influence greatly his plans and calculations.

Without at all dwelling on the value of these practical applications, which will afterwards occupy our attention in detail, I trust I have now shown that Geology, at any rate, is worth learning, even if it were only for such immediate results; but I would far more anxiously and earnestly impress upon you, that, as a branch of education, the study of Geology and of Natural History is desirable and useful, and because it is the foundation of the most useful result of Natural History studies in Education, I will venture yet once again, to impress upon you the value of the argument and method of analogy. In speaking of it, Bishop Butler has said, "This method of concluding and determining is practical; and what, if we will act at all, we cannot but act upon in the common pursuits of life, being evidently conclusive in various degrees, proportionable to the degree and exactness of the whole likeness."* Deeply impressed myself with its importance, I would have you study Geology more especially with reference to this view, considering the facts presented to your no-

* "Butler's Analogy," Introduction.

tice, as subjects of thought, suggesting hypotheses the value of which you must determine by comparing and judging, and exercising your minds in the investigation and explanation of phenomena.

In conclusion, let me remind you very briefly, of the true nature and extent of the science on which we are about to enter, and of its value in such investigations as those you are likely to be engaged in hereafter.

The point to be chiefly borne in mind in studying Geology, is that it is *real*—a statement of facts, not of opinions. The importance of this can hardly be overrated; for, instead of expressing as a mere probability that the earth was formed according to certain views we may have of the matter, and that if this view should prove correct, the phenomena, whatever they may be, possess a certain significance, Geology simply states as a matter of fact, that there are such and such appearances, account for them how we will, or whether we account for them at all or not. Say what we will, and think as we will, the surface of the earth *is* formed for the most part of beds lying one over another, amounting to a very great number; these beds contain fossils in a certain condition, and they exhibit certain marks of disturbance. These are facts, not speculations—Geology has to describe these facts, and to make use of them; and this is perfectly independent of any attempt to account for them. It is, indeed, true, that half a century ago, these facts were not known, or if known, were not recognised; but the wild speculations of those days of ignorance were not more thoroughly irrational than would be at this day the questioning the existence of observed phenomena, or attempting to account for them by any methods but those we should apply in investigations of other kinds, where no conclusion was to be dreaded, and where common sense and reason were our only guides.

But, besides the general structure of the earth's crust, Geology, we find, also introduces us to a knowledge of certain remains of organic beings, embedded in the different strata at the time of their formation. The study of these introduces another, and a large class of facts, bearing upon general Zoology and Botany; but strengthening, in a singular manner, the conclusions to which we otherwise arrive in the study of pure Geology, or the arrangement and superposition of strata. This subject also involves difficulties, and requires careful investigation; but, like the former, it is real, and not in any sense an opinion or a speculation.

The rocks and their contents, which appear to have been regularly deposited, are now irregular, and exhibit marks of disturbance. The study of these disturbances is one which properly, and even necessarily belongs to our subject; but it is perhaps the most difficult of all the departments of Descriptive Geology, requiring great experience and the exercise of a cautious and philosophic spirit.

The practical applications of Geology form another and somewhat different class of investigations. They, so far as they result immediately from geological principles, offer the strongest testimony to the truth of geological conclusions. Practical men assume the correctness of these conclusions, and act upon them; and in proportion as they are tried by this test, and found to succeed, the confidence felt by the miner, the engineer, and the architect, will be diffused generally in society, and Geology become a part of the necessary information required from those entering on such professions. With regard to this, I would only remind you, that, to arrive at any of these practical results, and to draw conclusions safely, clear and definite notions of the fundamental principles, and the methods of Geology, must be attained; for without these, however you may be able to exhibit superficial knowledge, you cannot possibly be trusted to make an observation, or draw a conclusion.

It is sometimes, and indeed not unfrequently said, that there is hardly enough yet known in Geology to justify these assumptions of its importance; and that its systems and arrangements, and conclusions, are constantly changing, so that what is learnt to-day will have to be unlearnt to-morrow. This, however, is the statement of persons who do not know the subject. It is not true, either in fact or in inference. The foundations of Geology are sound and firm, and cannot be disturbed—they are based on a rock, and they may safely defy the storm of ignorance and prejudice. As fact after fact is made known and added to the great store of accumulated knowledge, each now finds its appointed place; the corner stones are set in, the walls are rising rapidly around us, and the temple of our science already shows its broad front, its noble proportions, and something even of its finished beauty. It is true, indeed, that the structure is yet incomplete: here a tower is wanting to strengthen and unite into a solid mass one portion of the edifice—there we may conclude, that another portion has still to be commenced; but what is done is done well. It is work that will endure, for it is based on unchangeable truth.

THE END.

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