Petrifications and Their Teachings.

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MOST people have some general ideas as to what scientific men mean when they speak of "fossils" or "petrifactions," but the notions attached to these terms are not always very clear and precise, and considerable uncertainty prevails as to the mode in which these bodies are found, the methods which are employed in studying them, and the principal deductions which may fairly be drawn from their nature in different cases. In the following article, therefore, we propose to briefly consider the points above alluded to, and to deal shortly with the questions as to where fossils are found, what they are, how they are studied by scientific observers, and what are the more important lessons which they teach us. As to the first question-namely, where do we find fossils ? -it is sufficient to say that all the objects which we call by this name are found buried in the earth. The name "fossil" itself is in allusion to this fact (from the Latin fossus, dug up). All fossils, then, are found in the earth, some simply buried in the comparatively soft sands, clays, and gravels which cover such large portions of the dry land, while others occur locked up in the stony embrace of the hard and compact rocks, which form the solid framework of the earth's crust, and from which they can only be exhumed by the use of the hammer and the chisel. In the next place, What are the objects to which we apply the term of "fossils" In all cases, when we come to examine into the matter we find that fossils are the remains of animals or plants which formerly lived upon the globe, and which have been buried in the earth by natural causes; or they consist of objects from which we can certainly infer the former existence of such animals or plants. Most commonly we have in fossils actual portions of one of these buried animals and plants-a shell, or a bone, a stem, a leaf, or the like-and for this reason the name of "petrifaction" is not a good substitute for that of " fossil," since the former implies that the object so called has been really "turned into stone." This is not by any means necessarily the case. On the contrary, fossils are often little, if at all, changed from the original constitution which they possessed as parts of some once living animal or plant; and even ,when they look quite stony, this is generally only due to the fact that all the interstices and cavities of the original body have been filled with earthy or mineral matter derived from the surrounding rock. When we find in the earth an actual bone or shell, or a piece of wood, or a leaf, we can, of course, at once assert positively that there once existed actual animals or plants to which these belonged; though it may not be out of place just to notice that people did not always reason in this way. At one time it was thought that the objects which we call "fossils,'" however closely they resembled parts of actually living animals and plants, had really nothing to do with the former existence of living beings, but that they had been formed in the rock, by what one might call a kind of fermentation, in virtue of which the particles of the rock arranged themselves so as to give rise to bodies resembling shells, bones, and other organic forms. It is hardly necessary to say that no one nowadays would credit the inert particles of any rock-mass with any such inexplicable formative power. We have, however, to remember that fossils are not necessarily actual parts of animals or plants which were once in existence upon the earth, though this is very commonly their nature. Any object or any marking in the rocks, from which we are enabled to judge of the former existence of an animal or a plant, is properly called a fossil. Thus, an animal walking across the wet sand of the sea-shore, or over the soft mud of an estuary, leaves a series of foot-prints, from which we can not only infer the former existence of the animal itself, but from which we can often actually judge as to the character and structure of the animal which made the prints, though we may never have seen its bones. Such foot-prints, then (Fig. 1), though they have never themselves formed parts of the body of any animal, are still rightly called "fossils." Similarly, a plant buried in the soft mud or sand at the bottom of the sea or of a lake, may itself decay and disappear, but may, at the same time, leave an indelible impression of its stem or its leaves upon the soft material in which it is imbedded. Should this sand or mud become hardened into rock, this impression may be so perfectly preserved that we can tell accurately the kind of plant by which it was produced; and this, too, we should with propriety call a "fossil." Again, if we imagine such an object as the shell of a periwinkle or a cockle to be buried in the mud of the sea-bottom, it is clear that the soft surrounding material would fill the whole or the greater part of the interior of the shell; and if we further imagine the mud to be slowly hardened into rock, it is clear that we should find in the inside of the shell a sort of stony kernel, which would faithfully represent the shape and markings of the cavity in the interior. If we broke open the rock, we should either find the actual shell, with this kernel or "cast" in its inside; or the shell might actually have been dissolved away, and might have disappeared, leaving for our inspection the cast alone (Fig. 2). In such a case, we should still call the "cast " a "fossil," and though it had never itself formed part of any animal, we might still be able to tell with certainty the kind of shell within which it had been formed. We have, in the next place, to consider the methods in which fossils are studied by scientific observers; and in this connection the first point to notice is that the modes of study available in dealing with living animals are only partially applicable to the science of fossils, or Paleontology, as it is technically called (from the Greek palaios, ancient; onta, beings; logos, discourse). In studying living beings, the naturalist has the immense advantage if being able to examine all the parts of the animal, whether these be soft or hard. Not only can he investigate the form and structure of any skeleton which the animal may possess, but the muscles, nerves, internal organs, and soft tissues generally are open to his inspection. Hence naturalists usually decide upon the characters and position of any given animal according to the peculiarities presented by its soft parts, and they attach comparatively little importance to the nature of any hard structures, such as shells or bones, which may be present. The student of fossils, however, is in a totally different position. When animals or plants J1re buried in the earth, all their soft parts decay and disappear. Almost the only exceptions to this - and they are exceptions which prove the rule- are cases in which animals have been preserved in the frozen ground of the far North, as in an ice-house. Thus the bodies of individuals of the Northern Elephant or Mammoth, now extinct, have been found in the frozen soil of Siberia, with their flesh and hair still attached to them, and, indeed, little altered since the death of the animal. Cases such as these are, however, of the most exceptional character, and the same may be said of the few remaining instances in which the soft parts of animals are known to have been preserved in a fossil condition. Two things follow from this. In the first place, we can never expect to find in the rocks any remains of animals which are entirely soft, and which do not possess any hard structures or skeleton at all. Hence, a vast number of animals, such as earthworms, leeches, sea-anemones, jelly-fishes, sea-slugs, and many others, are either unknown as fossils, or are only recognisable by means of markings which their soft bodies may have left after their death upon the mud of the sea-bottom, or the sand of the sea-shore. At the same time, we are not justified, because we do not find these and similar animals as fossils, in concluding that they did not exist in past time- the probabilities of the case being all the other way. In the second place, as regards those animals which are found in the fossil state, with wholly insignificant exceptions, the student is unable to investigate anything but the hard parts or skeleton, since all the soft parts have disappeared in the process of fossilisation. Hence, the student of fossils has to proceed in his work by methods less perfect than those open to the naturalist. The latter decides upon the nature and position of any given animal, as we have seen, mainly from the anatomical characters of the muscles, nerves, internal organs, and soft parts generally;. but the former has to arrive at a similar decision without any other materials on which to found a judgment save such as may be afforded by the hard parts or skeleton, which can alone be preserved in the rocks. Nor does the above adequately express the difficulties against which the worker with fossils has to contend. Not only has he nothing more than the skeleton of the animal to go by, but very often he does not even get that skeleton in a perfect condition. It is true, of course, that we often meet with the skeletons of small animals, such as the shells of shell-fish and the like, in an unmutilated state. Even in these cases, however, the fact that the shell - has been buried in the rock, and is tilled with mineral matter, often prevents our studying it fully, since we can examine, perhaps, only its exterior surface, or we may only be able to see a part -of it; so that its most important characters- may be lost to us. In the case of the skeletons of the larger animals, on the other hand, it is rare indeed to meet with perfect specimens in a fossil condition. The visitor to the splendid geological galleries of the British Museum is apt to form a somewhat different opinion; but the above is the real truth. Generally, the student of fossils has little more presented for his inspection than a few detached scales, a portion of a skeleton, a number of bones dislocated from their natural positions and confusedly jumbled together, or, it may be, a single bone or tooth. Even when he may possess a very large series of bones, there is the strongest probability that these were found in the rock altogether disconnected and detached from one another; and even if they should belong to the same kind of animal, they will probably belong to many individuals of the same, so that there still remains the task of piecing together these scattered and fragmentary remnants, and of showing whether or not they have any real connection with one another. In accordance, then, with what principles and laws can the student work out the problem we have just indicated-a problem which at first sight might appear to be one beyond human powers. The answer to this question is to be found in the fact that the various parts which compose any living body, whether animal. or vegetable, invariably bear a certain relation to one another, and are mutually inter-connected in some definite and for the most part discoverable manner. Each organ and each structure in a given animal stands in some relation to all the other parts and organs of the same animal, the peculiarities of the one corresponding with definite pecluiarities in all the others. The law of this relationship-its why and wherefore-we do not know, but the fact remains as a piece of empirical knowledge, which we can use without knowing its fundamental import. It follows from this that certain structures and certain organs are always found together, and are never found apart. The one implies the other; and, if we know that the one structure is present, we can assert with an approach to certainty that the other was present also. We have to make the reservation that this association of different structures with one another is only known to us as a matter of experience, and that, in our ignorance of its real reason, we are not justified in asserting positively that it has invariably held good through- out past time. Possibly, we may-indeed, we some- times do-find structures which we now only know as associated with other particular structures, to be occasionally accompanied by organs of quite a different nature. Still, our experience is now a wide one, and it is upon this empirical law of the general or constant association of different organs and structures with one another that the reasoning of the student of fossils must be based. He has only a small portion of each animal open to his examination, and from the characters' of this he must infer what were the characters of the parts which he cannot examine directly. If our knowledge were sufficiently complete; if we could satisfactorily ex- plain such apparent departures from this law as we already know; and, still more, if we had any real knowledge of why certain structures are associated with each other: then we should doubtless be able to reconstruct a now lost and extinct animal from a mere fragment of its skeleton, and to demonstrate with certainty what must have been the form of the missing parts (Fig. 3.) As it is, though allowances must be made for the imperfection of our knowledge, it is wonderful with what precision the skilled worker in this field of science can reason from what we know to what we do not know, and can build up and restore an entire animal from detached fragments of its bony framework. The working of this law of the "correlation of organs," as it is technically called, will be readily understood if we select one or two examples of its practical application. Suppose, for instance, that we had dug out of the earth such a fragment of a fossil bone as we have represented in Fig. 3; how should we proceed to determine the structure and relationships of the animal to which it belonged in the first place, then, our knowledge of the anatomical structure of living animals-without which it would be utterly futile to attempt to solve even the simplest problem of this nature-would at once tell us that the bone in question is the broken half of the lower jaw of a quadruped or "mammal." This, of itself, would convey a good deal of information, for we should be at once able to infer with certainty that the animal which originally owned this bone was one which suckled its young; that its skin was more or less extensively covered with hair; that it had at least two legs, and probably four; that its skull was jointed on to its back-bone by a double joint; that it breathed air directly; and that it had hot blood. All known living animals which have a lower jaw at all like the one here under consideration, also possess the other peculiarities just mentioned; and we are justified in assuming, in the absence of direct proof to the contrary, that the same was the case with animals which formerly inhabited the earth, but which have now disappeared. We should, in the next place, notice that this broken half of the lower jaw still contains, firmly inserted in their sockets, one of the front teeth, an eye-tooth, and three of the back teeth. We should further observe that all those parts of these teeth which are visible above the bony substance of the investing jaw, save the limited portion once covered by the gum, are invested by a continuous layer of bright, shining enamel. Lastly, we should find that the eye-tooth is remarkable for its great size, and its pointed and conical shape, and that the back teeth are equally remarkable for possessing pointed crowns, with sharp-edged and scissor-like edges. Now, the next step in the investigation at present before us, is to compare this lower jaw with the same portion of the skeleton of the known living quadrupeds; and this comparison is rendered easier because we know that no animals, save such as are carnivorous, or live upon the flesh of other animals, possess similar large and pointed eye-teeth, and similar serrated and sharp-edged back teeth. This form of the teeth, namely, is obviously an adaptation to the habit of killing animal prey for food, the pointed eye-teeth being used to kill the prey, and the sharp-edged back teeth being employed in cutting up the flesh into morsels sufficiently small to be swallowed. Acting upon these considerations, we should at once seek to compare our fossil jaw with the jaws of the ordinary "beasts of prey" (Carnivora) such as dogs, bears, wolves, cats, tigers, lions, and the like; and we should find that the unknown bone which we had exhumed is clearly part of the skeleton of an animal of this class. No other living quadrupeds possess teeth similar in their character to those of the fossil now in question. This conclusion, however, canies with it a number of inferences of more or less importance. We know from this that the possessor of this jaw lived upon animal food; that its lower jaw was so jointed to the skull as to allow principally of back-ward and forward movements; that it had four well-developed legs, and that its toes were terminated by sharp and crooked claws. Pursuing our researches in greater detail still, we should next compare our fossil jaw with the jaws of various kinds of living beasts of prey, and we should discover that we are dealing with a jaw hardly, if at all, distinguishable from that of the living lion. We have figured here the complete skull of the living lion, and it will at once be seen what portion of the lower jaw is preserved in the fossil, and how close is the likeness between the living and the fossil form. Our jaw, in fact, belongs to the great lion, which once lived in England, as well as in most parts of Europe, and which is known as the "cave-lion." This final conclusion enables us to infer still more minute particulars as to the structure and mode of life of the animal which owned this jaw. We are now able to assert with certainty that its claws could be retracted within sheaths of the skin by the action of elastic ligaments; that it walked upon the tips of its toes; that its tongue was roughened by little horny prickles, which enabled it to readily scrape off the flesh from the bones of its prey; and that the pupils of its eyes assumed the form of a vertical slit during the day-time. Even, therefore, if we had never found any other bones of the cave-lion than the lower jaw here figured, we should still be able to decide as to the kind of animal which originally possessed this jaw, and we should even be able to reconstruct the entire skeleton for ourselves. Of course, it is not in every case that the problem set before the paleontologist is as easy a one as this. The fossil may be much less perfect, or rather much more imperfect, than the jaw which we have selected; and .the type to which it belongs may be a much less marked, and a much less easily recognisable one. Moreover, some fossils show an association of characters which are now only found apart, so that we should not always be able to reason with absolute certainty, from the known recent forms, as to the structure and habits of the fossil animal. Still, the instance we have chosen is a good one, as illustrating the method in which paleontologists carryon their work, this method in all cases consisting in a comparison of the imperfect fossil specimens with the comparatively perfect specimens of living animals of the same or of related types. Nor does it matter what may be the nature of the fossil; the method of procedure is the same. If we have to do with a piece of the skeleton of a fossil sponge, a coral, a sea-urchin, a crab, a limpet, a cockle, a cuttle-fish, a fish, a reptile, or a bird, we should proceed in just the same way. We should first use our knowledge of living forms to enable us to decide broadly to which of the great divisions of the animal kingdom the fossil under examination belonged, and then, in the next place, we should compare it with the skeleton of its nearest existing relations, gradually narrowing the circle of possible affinities, and trying, if possible, to place it in or near some group with which it could be directly compared. As our aim here has simply been to illustrate a general principle, one example is as good as a score, and we shall, therefore, merely content ourselves, in conclusion, with pointing out some of the most important bearings of the science of fossils, as thus elucidated, upon various other departments of human knowledge. In the first place, we find that while we cannot study fossils except by first acquainting ourselves with the structure and characters of living beings, our knowledge of the former has in turn vastly helped us in our investigation of the animals and plants now in existence upon the globe. Many cases, for example, are known, in which living animals are separated from one another by wide gaps, and in which we can place a long row of fossil forms to fill up the apparent interval. Again, there are many points connected with the present distribution of animals and plants upon the globe, which are only intelligible when we come to study the distribution and range of allied forms in past time. In another respect, fossils afford us most important information as to the way in which the rocks forming the crust of the earth have been originally formed. Thus, if we find any bed of rock to be filled with the remains of corals, sea-urchins, or other animals which we know at present as only inhabiting salt water, then we can infer with certainty that this rock, even though it may now be situated at the summit of our highest mountains, must have been formed originally at the bottom of the sea. In the same way, if the rock should contain the skeletons of such shell-fish as we know now to inhabit rivers or lakes, then we are justified in concluding that it was formed in fresh water. If we meet with the bones of land-animals mixed up with marine shells, then we may suppose that the rock was originally deposited as a bed of sand or mud in the sea, but in the immediate neighbourhood of a coast-line, or at some point where a river debol1chedinto the ocean. If the rock, on the other hand, be charged with the remains of terrestrial plants, we infer that it was either itself an ancient soil, or that it was formed in the sea or in a lake in close vicinity to the land. Finally, the study of fossils leads us to very important conclusions as to the distribution of dry land and sea in past periods, and as to the climate of different parts of the earth's surface during successive epochs. Should we meet with the trunks or leaves of palms, or the remains of ancient coral-reefs, we are warranted in supposing that we have here clear indications of a climate of almost tropical warmth. On the contrary, if we find the bones of the reindeer or the musk-ox, we are equally entitled to regard these as signs of a cold or nearly Arctic climate. In this manner, and in many other ways, the student of fossils finds himself called upon to consider, and in many cases to decide upon, a vast number of problems relating to the former history of the earth, the climatic vicissitudes which it has undergone, the changes which have taken place in the disposition of the dry land and sea, and the nature and mode of life of the successive races of animals and plants which have peopled the surface of our planet. In a word, the science of paleontology constitutes one of the most important of the elements of the general history of the earth, since the time when first it became the theatre of life.