THE A B C OF FOSSILS.

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We shall start out with a definition which would do if we were writing a scientific treatise but we shall make every effort to break away from the technical method in what follows. As the definition will show, however, even the technical may be perfectly simple, and might often be more so than it is.

Fossils are direct evidences of life preserved by natural burial in the rocks of the earth's crust.

Fossils therefore represent life and occur in rock, but they need not be the actual remains of plants or animals, and the rock need not be the hard substance which we usually think of when we hear that term. In fact many beds of sand, mud, clay, and marl come within our definition, and all hard rock, with the exception of those that are igneous or volcanic, was once soft. It has been hardened by pressure, heat, and cementation (cement-ation) during the ages that have passed since it was first laid down.

Although a layer of lava (molten rock) flowing into water has been known to trap clams that were crawling over the chilled surface of a previous layer of the same kind of rock, and fossil clam-bakes of this kind have been found on Vancouver Island, for example, fossils are almost always confined to sedimentary rock. By this we mean rock which has been formed from wind-blown dust or sand; from the mud, sand, or gravel in river beds or valleys; from the sediment which falls to the bottom of ponds, lakes, or oceans; from the material piled up or carried by ice rivers, or glaciers; and from deposits for which animals and plants are responsible, for example coral reefs and coal beds. It will easily be seen that sand or mud settling in water would arrange itself in comparatively flat layers, but all sedimentary rocks, whether thrown together by the wind, by a river, by the waves, or by a glacier are piled up in similar layers; they are stratified to use the proper term, and this stratification is often surprisingly regular.

The amount of mud and sand which is being carried by rivers into the ocean, where it must of course all settle, has been computed for the Mississippi, but instead of giving you the number of billion cubic feet a year or the number of hundred million tons a year let us suppose that someone should put in the plant needed to strain this mud and fine sand out of the water before it reaches New Orleans and should send it past that city in canal barges. If these barges were 100 feet long the people in New Orleans would see a barge full of sand pass every 10 seconds or less, and since it would take the river 30 seconds to float a 100 foot barge past a given point the barges would have to pass in bunches of three and there could be no space between the back of one set of three barges and the front of the next. If the man we have imagined were to take care of all of the sand and mud for a year he would have to work day and night, Sundays and holidays, winter and summer, and never allow an inch of space between each set of three barges. If these were to dump their loads in the Gulf of Mexico the sand would settle in piles but the river spreads it out very widely and sends enough material each and every year to spread a one inch carpet over more than 3000 square miles of the gulf's bottom.

This gradual piling-up process, one which takes place on land as well as in the water, affords a continual opportunity for the natural burial of the remains of the animals or plants that die and drop to the bottom. Those remains that do not decay and are preserved, however this may be done, are called fossils. So also are the casts or molds of animals that do decay, their footprints, etc. Whatever the form of the evidence that the animal or plant once lived, it simply must be direct, and whatever the manner in which the burial took place, it must have been by natural means. For example, hard coal, though we know it to be formed of plant remains, is not a fossil, the evidence is indirect; and a dog does not make a fossil, or even start one on the way, when he buries a bone. The latter may be a perfectly natural thing for the dog to do but it does not come within our definition of the term natural, a fact which will be perfectly clear before we are through.

An animal tries to cross a slough and gets mired, or sinks in quicksand, another breaks through the hardened surface of a tar pool and disappears, a jelly-fish is stranded on a tidal flat and the next tide covers it with a layer of sand or mud, an animal walks across some drying mud and the next rain washes sand into its footprints, an insect gets caught in a drop of resin, a mammoth is frozen in the ice in a polar climate, an animal dies on the desert and its whitened bones are covered by the next sand storm, a leaf sinks to the bottom of a pool and is covered with mud, a snail or a clam dies and the shell lies on the bottom of the ocean until it is covered, a coral or a sponge growing on the bottom is smothered by a shifting of the current which covers it with sand.

All of these may, and have for that matter, become fossils; it is only necessary that the mud or the tar or the sand or the resin or the ice shall be preserved (obviously it can not be washed away or destroyed without destroying the fossil), and that the footprint or the shell or the bone or the leaf, or its impression, shall be preserved as well. This is made easy by the hardening of the mud or sand into rock, a process which is sure to follow if the material is given enough time. If the jelly-fish can hold its shape until the layer of mud has hardened, smaller particles will gradually filter into the cavity which it leaves, and these may be different enough from those around it so that when the rock is split apart on this particular layer the shape of the jelly-fish can be seen. The cavity may even become filled with calcite or a similar mineral. The two layers of mud that pressed the upper and under sides of the leaf may show its form and outline even though the leaf decay. On the other hand the shell or the bone, or even the entire body, as in the case of the mammoth, may be preserved as it is, without change. Sometimes, however, only the tube or burrow in which the animal lived is preserved.

Still another way in which fossils may be preserved is best described by supposing that you were to change a picture, a mosaic, which owed its features to the skilfull arrangement of differently colored berries by substituting for each berry a pebble of the same shape, size, and color. You would have changed nothing about the picture but its lasting qualities, you would have made it safe from decay. It is this process in nature but on a very much smaller scale which has given us such fossils as petrified wood. The exchange of particles is here so fine that the smallest details of structure are preserved and may be studied under the microscope.

Now many of the softer rock deposits are exposed at the surface of the earth and man has cultivated the layer of soil immediately above, but they were laid down, formed, ages ago and during the lifetime of the animals and plants whose remains can now be found in them. As we have said these are the real fossils. If a farmer living on such a soil should dig down three or four feet and bury a dog that dog would not become a fossil even though the bones did not decay and were to be dug up thousands of years later together with the remains of the real fossils. It did not get where it is in the ordinary course of events, man put it there. If the real fossils were dog bones it might be difficult to separate the fossil dog bones from the farmer-buried dog bones. But it would be almost impossible to mix a group of animals that had lived on the earth for any great length of time prior to another with that other, so that the fossil expert, for whom the term paleontologist is in common use, could not detect the mixing. If one bone or shell did not give the fact away another would, and even the two sets of dog bones would probably differ from each other, for animals and plants have always changed from age to age. It is this progressive change in time which we call evolution.

If the person who dug up the fossil bones and the farmer-buried dog bones had looked closely he would have seen that the earth around the farmer's dog had been disturbed, that the lines of bedding (stratification) in the nearby rock stopped some distance from the dog and that the earth near it was jumbled together; also that this was not true with regard to the bedding near the fossils. It is this care in collecting and attention to detail which is natural to paleontologists, and which others must make use of when they collect fossils if these are to have any value. Many of the doubtful points in the earth's history, such as whether the human bones which have been found in certain places in our West, or in Argentina, are those of primitive man or those of recent natives were made doubtful by carelessness or lack of observation on the part of the person who first made the discovery.

Nature has been very careful about recording what she has done, however careless she may be in destroying that record, and fossils may be likened to the hieroglyphics which the Egyptians used to carve, in more ways than one. They, the fossils, are Nature's handwriting, her method of labelling the rocks of the earth's crust, and while fossil hieroglyphics are sometimes hard to read, and while they, like those of Egypt, mean little or nothing to the ordinary person, their story is easily read by the man who knows.

Perhaps we can better illustrate the use of fossils by comparing them to the documents placed in the foundation stones of buildings. It is customary to seal up in such stones objects like the daily papers of the date upon which the stone is laid, coins, etc., anything which will indicate to the one who opens the vault, whether this be done in a hundred or a million years, and when every other evidence as to the age of the building may have been lost, the exact period of the earth's history during which the building was erected. Nature has sealed up in rocks of all ages but the oldest, in all but a few varieties, and in nearly all places, articles (fossils) which convey an accurate idea of the relative time at which the different rocky tombs were built, and we are daily becoming more expert in reading the story they tell.

Since fossil experts in all countries are continually at work on these problems, and since an expert in Japan, for example, should know exactly what a

Canadian expert is writing about, we have agreed that all fossils shall have Latin names and that these names shall be used at all times whether the work is written in Japanese or English, or any other language. Since the presence of the same name for two or more things would introduce even worse confusion between the workers in the different countries we have also agreed to give different names to different animals and but one name to similar animals wherever they may be found. This is the only method by which we can speak of or compare accurately and intelligently the fossils occurring in different countries, but since we already know and have described and illustrated several hundred thousand different kinds of fossils some of the names are a little complicated. This explains the unusualness of names such as those in the papers by Whittaker in the April number of the Naturalist and by Lambe and McLearn in the May number. Instead of John Jones, William Jones, and Mary Jones we speak of Jones John, Jones William, and Jones Mary, or to use real fossil names, *Obolus parvus*, *Obolus major*, and *Obolus typus*, putting the important or group name first as do the Chinese. Li Hung Chang is Mr. Li, for example, a change we have to make whenever we get out a directory, a telephone book, or an index, but which the Chinese and the fossil experts do not.

Now let's go back to the farmer's dog. You will remember that we decided that it did not come within the definition and therefore was not a fossil, but supposing the farmer had dug up some fossil bones from another farm, fossils that lived earlier and were therefore really older instead of younger, as the dog was, and buried them in the same way. These would of course be fossils; they were and the fact of their having been moved did not change their nature, but once again, it would take a very expert farmer (a very expert paleontologist in fact) to fool any paleontologist this way. Curiously enough, however, Nature herself has done many things, things which must be included under the head of natural burial, much more confusing than anything we have supposed the farmer to do. Old sea bottoms with their included fossils have been hardened into rock, elevated above the sea, cracked, and the cracks widened by the wear of running water or frost just as such cracks, or joints, are being widened today, and animals living millions of years later have dropped into these cracks and been covered up and preserved. What real difference is there between the farmer-buried dog three or four feet down in a grave beside fossils thousands or millions of years *earlier* than itself and fossils 15 or 20 feet down in a crack beside fossils that much earlier than themselves? None, except that the one is natural, the other artificial, but when we are dealing with fossils this difference is essential. Again, other sea bottoms, hardened into rock and elevated above the sea, are being gradually worn away by agencies which are unable to dissolve the harder included fossils and these weathered-out specimens are being picked up by storms and washed into the ocean to lie on the bottom with animals which have just died. The next layer of mud will cover both, the recent animal and the million year old fossil, and when the new sand has hardened into rock the two forms will be found in the same grave. What real difference is there between the farmer-buried fossils in a grave beside fossils thousands or millions of years *later* than themselves and the nature-buried fossils lying beside fossils fully as much later than themselves? None, except, as in the former case, that one just happened, it was the natural thing, the other was man made and accompanied by an act of will.

If you wonder why paleontologists do not include under the term fossils *any* direct evidence of life preserved in the earth's crust we shall have to say that the evidence of man's interference may be lost and can be hidden, and that his ability to transport animals or plants long distances without leaving any trace as to their source, his conscious interference with the natural course of events, irrespective of the motive, introduces complications which warrant us in putting the limit we have assigned and insisting on natural burial. As a matter of fact we usually confine the term fossils to the evidences of life which have been preserved to us from the prehistoric period, popularly speaking, but the study of fossils and the study of biology merge so closely together that they can not be separated. So do the study of fossil or "prehistoric" man (paleontology) and the study of early or historic man (archaeology).

If you think our illustrations have been too complicated we can only say that Nature has been known to still further confuse the whole problem by turning a whole series of such rocks completely upside down and by scraping half or three-fourths of them away and otherwise disturbing them during the process which has elevated them above the sea. Furthermore we have taken up only a few of the problems which are involved. The animals and plants that peopled the earth at any one time millions of years ago, for example, differed from place to place and from country to country fully as widely as do the animals and plants of today.

The study is so complicated that few geologists care to postpone the beginning of their period of full activity as working geologists by the number of years of preparation required for even an elementary understanding of the story told by the fossils occur-

ring in the rocks which they will study. Those geologists who do wait to become paleontologists stand in the same relation to the geologist that the student of ancient history who can read its picturesque language does to the student of ancient history who can not.

Paleontologists are forced by the broadness of the subject, however, to specialize and usually confine themselves to certain groups of animals or certain groups of rocks, the usual unit of animals being some such group as snails, crabs and crablike animals, corals, or sponges, or even lesser groups. The usual unit in rocks is one covering a period of several million years, a unit which is perhaps best described as a tenth, roughly speaking, of the time since life began to leave its traces in the rock.

If the story of the changes which have taken place in the life on our earth is complicated, so is the story of the changes through which our earth has passed, and the one could not be read without the other. But having observed the order in which the rocks were laid down in favorably located places we are able to study life as it has existed from age to age, and we arrive at evolution, or the idea of a progressive change in life forms as we go from the earlier to the later. Knowing the history of these life changes on our earth and being able to recognize their different stages in the fossils which fill so many of our rocks we are able to trace rock horizons from place to place in unfavorable places, across lakes or seas and underground.

Most of our mineral deposits: coal, iron, oil, salt, etc., etc., occur in such rock horizons, layers whose position in the general order is known, layers which either have fossils peculiar to themselves or lie between layers which do. For example, and space will permit us to give only one: Sands in a certain section of California are found to contain oil. Similar sands show at the surface in many other places, are mapped by the geologists, and wells are bored wherever the sands occur in the hope of striking other oil wells. The sands are thick and boring is expensive, roughly $10,000 for every well sunk, yet the return on the few which reach oil is sufficient to induce private capital to go ahead. A paleontologist is sent out to the field by the official survey and finds that the supposed sand horizon is not one but two, that these are separate and distinct, each with its own particular group of fossils, that they are thousands of feet apart vertically, one being much older than the other, and that only one of them carries oil. He visits the various sand showings, or outcrops as they are called, and maps the distribution of the oil-bearing sand. He is thus able to cut down the absolutely useless drilling, or "wildcatting" as it is called, by one half. If the sand is the oil-carrying one conditions of internal or external structure will affect the location of oil pools but drilling has a chance of success; if it is not the time and money used in drilling are absolutely wasted. A man on a nominal salary, as a part of his regular work, saves the expense of drilling hundreds of useless wells, any one of which would have cost four or five times his salary for a year. The error which private industry is somewhat prone to fall into is the hiring of poorly trained geologists, or men who merely call themselves such, a poor policy in spite of the fact that almost any geologist or pseudo-geologist is better than none. The paleontologist mentioned, for example, and his case is not unusually exceptional, was worth ten times his government salary to any one of the oil companies in California and of course his real value to the country at large, or to the government which employed him, could be measured by the same amount.

For the reader who should question the dispatch of a government geologist for the saving of large sums of money for private industry we shall have to say that the present development of our mineral resources depends in large part upon the far-sightedness and public-spiritedness of private industry; that every dollar which they take out of the ground adds to the sum total of the wealth which we all share, to however small a degree; and that every dollar which they are kept from wasting is left in that same sum total. If they pay it out uselessly it might better be thrown away, because the drilling of the useless well wastes also the time of labor which might have been engaged in productive work. This is elementary economics, not paleontology, but fossils have a dollars and cents value which is sometimes lost sight of. To place it before you in a general statement: Geologists and paleontologists take from mining, second only to agriculture as the leading industry of North America, a large part of its luck or chance, and give it an element of certainty which is of inestimable value to it and to the country at large.