The Nature of the Fossil Record
In the Rocks of Eastern Oregon

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A troop of soldiers returning to the Army outpost at Fort Dalles along the Columbia River just over a hundred years ago brought to light the first evidence of prehistoric mammals of the Oregon country. The finds were not spectacular — only several teeth and a few scraps of bones picked up by the cavalry in the colorful badland exposures of the plateau country east of the Cascade Mountains. But this was enough to arouse the keen interest of the local Congregational Church minister at The Dalles, the Reverend Thomas Condon. Of particular interest was a fine fossil jaw with teeth from an extinct rhinoceros. Condon did not know it was a rhinoceros, but he recognized that it did not closely resemble anything living in that part of the country, and he realized that a great discovery might have been made.

Early the next spring Condon obtained permission to travel with a company of soldiers taking supplies to a garrison that had wintered in the field in Harney Valley, southeast Oregon. Much of Oregon east of the Cascade Mountains is relatively arid, with only sparse vegetation composed principally of sagebrush and bunch grasses, so that along the creek and river valleys the volcanic rocks are extensively exposed. Since the old military routes followed such valleys, Condon could readily explore the rock outcrops along the way. That first summer he discovered several fossils in the valley of the Crooked River and considerably more in the extensive exposures along Bridge Creek. Unfortunately, he was prevented from collecting many specimens because of frequent harrassment by marauding Indian bands.

The following summers often found Condon in the field, with a rifle in one hand and a pick in the other, exploring for fossils. Within the first decade of discovery, many historic sites were located, sites extensively collected from in later years.

In 1871 the famous paleontologist O. C. Marsh of Yale University and a party of fifteen students spent the summer in the field, with Condon as guide to the expedition. While there Marsh secured the services of several persons who continued to collect and send specimens to Yale with little interruption until 1877. Expeditions from Pennsylvania, Princeton, California, Oregon, Carnegie Institution, the National Museum (Smithsonian), the United States Geological Survey, and many other institutions have spent a cumulative total of hundreds of individual man-years, through the intervening decades, searching over the outcrops, removing and preparing fossils (chiefly mammals and plants) for shipment, and finally, in the laboratory, cleaning, preparing, and studying the specimens.

The Army, which was responsible in the early years for the initial discovery and for furnishing protection to Condon and others from the Indian bands, was more directly involved later. In 1880 Captain Bendire, with a large party from the Seventh U. S. Cavalry, made collections of plants, mammals, and fish, and turned these over to the Smithsonian Institution in Washington, D. C., for study. When the University of Oregon was founded in 1876, Thomas Condon, the man most directly responsible for the early exploration and for making the finds known in scientific circles throughout the world, was elected to the chair in natural science.[1]

Just what is the nature of the information one can uncover concerning former life? How complete a story is told in the rocks? What can one discover about origins and diversification, about change in the environment and in life? Perhaps the best way to find answers to these questions is to consider first a few facts and principles about the nature of fossils and their occurrence. Then as such facts are applied to an actual field example, such as the record of life entombed in the volcanic deposits of central Oregon, one can perhaps better evaluate their meaning and limitations. The example chosen is significant, both because it is one that demonstrates richness and variety of fossil remains and because it is typical of volcanic rocks, one of the major types of deposits in which land life is preserved. Volcanic deposits are widespread in western North America and are found to a lesser extent in nearly all continents.

Although the processes by which fossils, remnants, or traces of former life, are preserved are not exactly the same, nevertheless they involve many of the same principles used by housewives in the preservation of food for winter. Complete or partial exclusion of air, as in the canning process that restricts oxidation and bacterial decomposition; drying; freezing, as in frozen mammoth, rhinoceros, or buffalo remains in the far north; preservation in a weak, poorly aerated acid solution, as in the peat bogs widespread in northern forests of both America and Europe (comparable to the housewife's use of vinegar, a weak acid, in preservation of pickles); shielding from the chemical and mechanical forces of weathering by a protective location or cover — these are all processes that may contribute to preservation of fossils in different instances.

Relatively rapid entombment in very fine-grained sediments such as clay or in fine volcanic ash have been among the most successful and common means of preserving evidences of former life. Clay is ideal because the particles are so fine that circulation of water and air is greatly retarded. When the particles become compressed and more or less cemented or fused together, the resultant sedimentary rock is shale, which usually splits or cleaves along the bedding plane. Frequently, even when shale appears to be barren of fossils, microscopic examination will reveal plant spores or pollen grains.

Hard or resistant parts of organisms, with sufficient porosity to allow mineral-rich ground water to seep in or through them, are often effectively sealed by the deposition of mineral substances within the interstices or pore spaces. Compounds of carbonate, silica, or iron are commonly deposited in this way. Sometimes the hard parts or skeletal remains, instead of being infiltrated, are partially or completely replaced by mineral matter. The organic remains thus infiltrated or replaced are effectively transformed to the appearance of stone, a process analogous to imbedding materials in plastic today. This process is aptly called *petrification*, a word that literally means "turn to stone." But since fossil remains such as coal or peat may never be mineralized, the degree of mineralization or petrification is in no sense a criterion of whether a plant or animal is a fossil or not.

There are a number of environments where traces or remnants of certain living forms seem destined to be preserved. For example, in coral reefs such as the Great Barrier Reef, which extends for more than a thousand miles along the northeastern coast of Australia, are found a great variety of animals and plants. These include various types of corals, moss animals, encrusting algae, tube worms, shelled animals, and a few other forms which become firmly cemented to the substrate — the skeleton of the reef — and build it up layer by layer as they grow and add to the older skeletal framework of the reef. Like a tree that grows by adding layer on layer to its girth, a coral reef grows upward from its base to near the surface of the sea and then spreads out around countless tropical islands and seamounts. Besides the attached forms of life, a wealth of colorful, free-living plants and animals, such as fish, crabs, marine worms, seashells, starfish, jellyfish, and many other forms of life, abound in any tropical reef. The variety of form and color, the symmetry, and the exquisite beauty surpass description.

But note that only a fraction remains. In a fossil coral reef one might find, among the hard parts that are preserved, identifiable remnants of perhaps fifty to seventy-five of the more than three thousand species that may have inhabited the reef.[2] The great host of soft-bodied forms, and even many animals having hard parts readily preserved under other circumstances, seldom leave a trace. Most forms are consumed by predators or scavengers, large or small, and the hard parts are broken to bits by the action of the waves. Yet the few remaining species speak eloquently of a distinctive environment.

Certain other environments seem destined to oblivion. Traces of the life of high mountains or freshwater streams may persist for a few years or even centuries in a bog, in an alpine meadow, or in a terrace gravel, but in general the record is exceedingly poor. Mountains generally are source areas for sediments, not areas where quick and permanent burial is possible. Wind, rain, snow, or floods may destroy, but they seldom bury for more than a few years at most the traces of such life as may have abounded.

Even extensive lowland areas may be ineffective in preserving a record of much of the most characteristic life. Before the settlement of the American West by ranchmen, vast herds of bison and countless smaller herds of pronghorn antelope, together with a host of less conspicuous mammals, large and small, roamed over the prairies and high plains. Remains from the many generations of these magnificent animals that lived during recent centuries are seldom encountered today. Occasionally a few skeletons are turned up in a bog, an old salt lick, gravel or sand deposits of a recent river terrace, or perhaps in a cave or rock shelter together with artifacts of ancient man. For the most part, preservation has not been in deposits that might be expected to be permanent. Although the bison has a heavy, comparatively resistant skeleton and horns, probably not more than one in a million was ever preserved, and only a small fraction of these are ever found.

In North America the only comparatively extensive deposits being formed today that might be expected to preserve representative samples of land life fairly permanently are the deltas of great sediment-laden rivers, the undrained Great Basin of the West, and the undrained lakes and bogs of the northern regions. Deposits from most other areas may be expected to be relatively transitory, stripped off again after a few years or centuries as the face of the land is worn down. Of the rivers, the Colorado and the Mississippi transport by far the greatest sediment load, the latter moving approximately two million tons of suspended particles to the Gulf daily during most of the year, and up to twice that quantity during times of flooding.[3]

Much of the life of vast areas of the earth today is essentially unrecorded in the sedimentary record. But circumstances now are not necessarily typical of all former times. If one judges from the somewhat more abundant remains of land life in many sediments from past times, one may conclude that in many respects the present is not an adequate key to the past. Nevertheless, at no time is the preservation of various habitats and forms of life at all equal — some are preserved, some perish without a trace.

Even in marine environments, opportunities for fossilization are unequal. Many years ago in an anniversary address to the Geological Society of London, Sir Charles Lyell (1851) commented on the results of a series of 140 dredgings of near-surface sediments from the sea bottom off the coast of England. Although a wealth of life abounded in the seas there, it is surprising how small a portion of it was ever trapped in sediments. Indeed, the dredgings would be expected to bring up some incomplete decomposed remains that would never become permanently preserved in the sedimentary record. Lyell stated:[4]

> I allude to the observations laid before the British Association, at Edinburg, in 1850, by Messrs. Forbes and MacAndrew, who in the summer of that year explored the bed of the British seas from the Isle of Portland to the Land's End, and thence again to Shetland. They have recorded and tabulated the numbers of the various organic bodies, obtained by them in 140 distinct dredgings, made at different distances from the shore, varying from a quarter of a mile to forty miles. The list of marine invertebrate animals, both radiata, mollusca, and articulata, is by no means inconsiderable, but very few traces of any vertebrate animal were found. When these occurred (in five or six cases only), they were limited to fish, consisting of a few ear-bones, as in the Crag, and of small vertebrae. No cetaceans [whales, etc.] were met with, no relics of terrestrial mammals, although at some points they approached near to the shore so as to dredge up a few fragments of wood. In two or three instances only were any articles of human manufacture, such as a glass bottle, fished up. If reliance could be placed on negative evidence, we might deduce from such facts, that no cetacea existed in the sea, and no reptiles, birds, or quadrupeds on the neighbouring land.

It becomes clear that the possession of a skeleton, other hard parts, or resistant cuticles, which are readily preserved, is not necessarily enough to ensure preservation and subsequent discovery as fossils of even a few members of a population. Preservation and subsequent recovery of even traces, for most kinds of animals and plants, are the exception rather than the rule. "Dust thou art, and unto dust shalt thou return" (Genesis 3:19) is the fate not only of men but also of nearly all of the countless billions of other living things with which men share the land area of the planet. In most habitats the overwhelming majority of animals, great and small, and plants of every description, once they die, are quickly destroyed or reduced to a state beyond recognition. Organisms of decay, scavengers, agents of chemical decomposition, and mechanical wear ordinarily make quick work of even comparatively resistant parts. "As a flower of the field, so he flourisheth. For the wind passeth over it, and it is gone; and the place thereof shall know it no more" (Psalm 103:15-16).

Even when fossils consist of well preserved parts, there may still be problems in interpretation. We tend to forget that at best fossils are usually only traces of past life. Sometimes these traces are very difficult to relate clearly to living forms or to one another. We shall consider two incidents.

For more than a century now, twigs and needles of trees that seem to belong to species identical with or very close to *Sequoia,* the living genus of redwoods of the coast ranges of northern California and southern Oregon, have been known from localities scattered through much of the northern hemisphere in Europe, Asia, North America, and even many points in the Arctic as distant as Spitzbergen, well north of the Arctic Circle. Such leaves are also abundant in two of the formations from central Oregon that we shall consider.

It was in 1941, when communication between America and the Orient was nearly at a standstill, that S. Miki, a Japanese student of fossil plants, made the surprising discovery that fossil redwoods of Japan that had been assigned to the North American type *(Sequoia)* actually exhibited rather basic differences both in leaf arrangement and in certain features of the cones and twigs. He established for them a distinct new genus, *Metasequoia.* He also suggested that they might be deciduous, that is, lose their leaves in the winter instead of being evergreen, as are the familiar redwoods of western North America. Before American students of fossil plants had had opportunity to read Miki's paper, there came the amazing discovery by Chinese botanists of a hitherto unknown large conifer in the forests of the Szechuan Province in central China, a tree that was recognized as possessing the distinctive features of the fossil *Metasequoia* remains described by Miki. Full confirmation of Miki's brilliant discovery was provided. The fossil tree had come to life. It is now known that most of the fossils once assigned to the redwood *Sequoia* from both temperate and Arctic regions, including many of the specimens from central Oregon, actually belong to the newly discovered "dawn redwood," *Metasequoia.*[5]

No type of fossil is more intriguing to man than fossils of men or of animals structurally close to man. But such fossils are exceedingly scarce; hence they seldom fail to attract considerable attention when they are found.

The second incident, now an almost apocryphal story in the annals of American paleontology, concerns reports of just such a discovery.

On March 14, 1922, the famous paleontologist Henry Fairfield Osborn received a small package from Nebraska which contained a single considerably worn molar tooth. The paleontologist Harold Cook who had collected the tooth in the Pliocene Snake Creek beds felt that it resembled more closely the anthropoid-human type of molars than that of any other known mammal. Osborn responded immediately, "It looks one hundred percent anthropoid." After comparing the specimen with "all the books, the casts, and all the drawings" and consulting with three other specialists, two of whom were eminent specialists on fossil Primates, Professor Osborn wrote: "It is hard to believe that a single small water-worn tooth, 10.5 mm. by 11 mm. in crown diameter, can signalize the arrival of the anthropoid Primates in North America in Pliocene time. We have been eagerly anticipating some discovery of this kind, but were not prepared for such convincing evidence of the close faunal relationship between eastern Asia and western North America as is revealed by this diminutive specimen." Osborn designated the tooth as a type of a new genus *Hesperopithecus* (western ape) which, indeed, seemed to have closer resemblances with "Pithecanthropus," the Java man, and with modern man than with apes!

But, alas, later comparative studies by other paleontologists have demonstrated that the tooth undoubtedly belongs to a fossil peccary, a little animal which resembles a pig! Experiences like this tend to keep most scientists humble and cautious. This incident is not quoted in criticism of those who made the mistake, because, as every paleontologist knows, anyone is likely to miss occasionally. And for every mistake there are numerous discoveries, many of which are validated by later finds. But it does demonstrate the thin ice one is on when working with fragmentary specimens.[6]

Thus we see that at best the record of past life is biased by many factors beyond our control. The chances for fossilization are enormously unequal for different forms of life: unequal population density; unequal preservability of resistant versus delicate forms of life; unequal preservation of various habitats; unequal chances for exposure, detection, and discovery of the fossil remains; unequal opportunity for preservation at different time levels in earth history (occasional catastrophes are about the only possibility for burial of certain types); unequal quality of preservation, so that reliable information is not always obtainable from the remains — all contribute to an inadequate and in many ways biased record of past life.[7] Yet in spite of all such limiting factors, in many deposits a wealth of information may be uncovered.

We now turn again to the story inscribed in the rocks of the Oregon country. In few areas of North America, or indeed the world, has the succession of fortuitous circumstances necessary for the preservation and later recovery of a variety of land life of a significant segment of earth history been so favorable as in the Columbia River Plateau of the Pacific Northwest, particularly that region known as the John Day country of central Oregon.[8] One has only to travel along the numerous canyons and river valleys, such as the Columbia, the Yakima, the Snake, the Deschutes, or the John Day, that dissect the plateau country to discover how remarkably widespread and thick are the dark basaltic lava flows. These lava flows are the most characteristic feature throughout the plateau's more than 200,000 square miles of geographic extent. Williams has estimated the total volume of lava as not less than 100,000 cubic miles.[9] But there is more than lava. Beneath and above and punctuating the flows are colorful deposits known as volcanic tuff and breccia.

Now when lava flows out through volcanic vents or fissures, immense heat like that of a furnace usually incinerates completely any trace of life in its path, although molds of tree stumps or even animals may be preserved in rare instances. By contrast, explosive volcanic eruptions that blast into the air large quantities of more or less finely divided rock particles, called volcanic ash, or larger fragments, are less destructive. Often by the time the finely divided particles settle like a layer of snow onto the ground, they are cool enough to provide a thick protective blanket that entombs and preserves a portion of the life destroyed by the holocaust. Commonly, explosively volcanic eruptions are followed by torrential rains that saturate the ash to the consistency of soft mush, so that ash and larger rock fragments from around volcanic vents or high areas flow out as a widespread, fairly even layer. The mineral-rich ash and larger fragments become compacted and cemented to form hard rock known as volcanic tuff (small particles) or volcanic breccia (larger particles).

One of the most striking contrasts between the picture of years past, which unfolds in the Oregon country, and the picture we see today is in the magnitude of the geological events transpiring in the region. Today a lava flow or volcanic explosion that ejects a fraction of a cubic mile of lava or ash makes news even if it is on the other side of the world. When on the order of five cubic miles is explosively ejected and a tidal wave that destroys 30,000 or 40,000 villagers is generated, as when the East Indian island of Krakatoa exploded in 1883, it is an event that goes down in the annals of history.[10] We can scarcely comprehend the magnitude of activity required to build up deposits of lava and ash averaging perhaps one-half mile in depth over hundreds of thousands of square miles. In this case the present is surely not an adequate index to this "age of fire," as it has sometimes been called.

In the river valleys of central Oregon five distinctive volcanic formations that lie superimposed one above another may be recognized. Two are below the most extensive lava flows and two are above. In certain other parts of the plateau in Oregon and Washington, approximately comparable formations are also exposed. TABLE 1 lists these formations from top to bottom, the reverse order in which the rocks have been deposited.

TABLE 1†

Formation	*Description*	*Feet*§	*Fossils*
Rattlesnake‡	Volcanic tuff; a welded or fused acidic tuff; thin flows of lava, gravel, sand, and silt.	800	Vertebrates and plants
Mascall	Volcanic ash and tuff, which weathers to a whitish buff or brown badland relief; gravel, sand, and silt lenses.	1,000	Vertebrates and plants
Columbia River Basalt	Many flows of dark basaltic lavas, with only very minor ash or soil partings locally.	2,000	Very rare
John Day	Upper part: buff-colored tuffs. Middle part: greenish-colored tuffs. Lower part: reddish-colored tuffs.	1,000	Vertebrates and plants
Clarno	Variable beds, including tuffs, irregular volcanic conglomerates (agglomerates), lava flows, gravel, sand, and clay.	3,000	Vertebrates and plants
Marine sedimentary rocks	Underlying the volcanic series, as may be seen where erosion has cut completely through the volcanic sequence of strata, an underlying series of nonvolcanic rocks is exposed. These are primarily composed of water-laid sediments, most of which contain fossil sea animals.		Marine invertebrates

† Data from Stock (1946) and Baldwin (1964).[11]

§ Approximate thickness in feet measured at right angles to the bedding plane (central Oregon); hence not indicative of present relief.

‡ Deschutes formation to the west.

This is the series of colorful volcanic rock formations of central Oregon that Thomas Condon explored for fossils in the 1860's, and even today it is still yielding fossil land animals and plants. Perhaps it would be best to look first at the record of fossil plants, since on land the plants are a better index of the environment than warm-blooded animals are. The story of exploration could fill a volume, but space allows only a few brief excerpts from the writings of Ralph W. Chaney (of the University of California at Berkeley), a long-time student of the ancient forests of Oregon.[12]

My first view of the Bridge Creek hills was in 1920. Together with Chester Stock, then an instructor in geology at the University of California, and a graduate student, Richard J. Russell, I had traveled by autostage to Mitchell, where we found that the next stage northward would not depart until the following day. Leaving Stock to bring our bulkier equipment, Russell and I started out on foot over the winding road down Bridge Creek. After an eight-mile walk, we came to a house in a grove of cottonwoods, described in Merriam's paper as Allen's ranch. A young couple named Wade was operating this ranch, and with a little persuasion agreed to provide meals and lodging. Nowadays, one would hesitate to arrive unannounced and ask for such accommodations; but in the days before good roads it was a custom of the country to take care of travelers. Earlier that summer, I had enjoyed the hospitality of William R. Mascall, James Cant, and Jerome Moore in the valley of the John Day River to the east; I had even been left in temporary charge of the Moore ranch, to milk the cows, feed the chickens, and do other chores while the family went to pick huckleberries in the Blue Mountains. After getting established at the Wade ranch, Russell and I started for the fossil locality on a side road which came down out of Bear Creek. My notes for this afternoon read: "Two and a half miles southwest of Wade's (Allen's) ranch where the road to Fitzgerald's passes a small white hill, there are two rounded hills about thirty feet high, one on either side of the road. These are covered with white bits of shale containing leaves." Here was the Bridge Creek locality which Condon had visited more than half a century before....

At the Bridge Creek locality, a single slab of rock, weighing only a few pounds, may show the imprints of dozens of leaves on its surface; when split along its many bedding planes with a broad chisel, scores of additional specimens may be uncovered (Chaney, 1925). In 1923, I quarried 98 cubic feet of leaf-bearing shale from three pits on the low hill to the right of the road (Chaney, 1924) ; I split the slabs of ashy shale into thin layers which yielded a total of 20,611 specimens, or an average of more than two hundred to a cubic foot.

The Bridge Creek locality, which is in the lower reddish tuffs of the John Day formation, still yields rich returns today for those who have the patience to quarry the rock and split the ashy shales apart.

Several striking facts emerge as one compares the fossil plants from the successive volcanic formations in Oregon. First, a marked climatic change seems to be indicated. The climate of eastern Oregon today is semiarid, cool temperate, with dry summers. Fossil plants in the upper, more recent levels are mostly from plants that still live in Oregon today (aspen, cherry, box elder, cottonwood), but in somewhat less arid parts of the state, suggestive of similar climate with, however, slightly greater rainfall. By contrast, species preserved in the lowest formation of the volcanic sequence (Clarno) most closely resemble species one would find in subtropical or tropical forest having adequate moisture throughout the year. Breadfruit, cinnamon, laurels, palm, an avocado, and tropical types of ferns are among the species represented. The rich fossil floras of the intermediate levels (John Day and Mascall formations) include many types that today are characteristic of warm, temperate climates with adequate rainfall in the summer. The closest living counterparts for the majority of species preserved in these levels now flourish in the mixed forests of eastern United States and Central China (Szechuan Province). The plant species seem to suggest that during the time in which the volcanic rocks were being deposited, the climate was undergoing a marked change from humid, subtropical, with moist summers, to cool, temperate, with dry summers.[13] Much corollary evidence from other parts of the world, based on both plant and animal fossils, suggests that the change was widespread geographically. Characteristic animals of coral reefs that today are restricted to tropical seas may be found as fossils in latitudes as far north as the Oregon and Washington coasts in rock strata that seem to correspond to the lower lying volcanic formation of Oregon, the Clarno formation.

A second feature of the record is the remarkable stability, that is, the evident lack of change of the plant species represented. The majority of leaves that appear as fossils seem to be closely similar to or identical with the leaves of various species of forest trees still living today. It is true that not all of the levels of rock strata in which flowering plants are known to be abundantly recorded are represented in Oregon. Nevertheless, the lack of change is striking. Furthermore, in other areas where deposits classified as Paleocene or Cretaceous (commonly held to be more ancient) are found, most of the plants still are scarcely distinguishable from living genera. In the fossil record there is absolutely no clear evidence that the flowering plants, or indeed the other major plant types, have originated from one or more common ancestral types.

In the first undisputed appearance of flowering plants in the fossil record, numerous and diverse complex modern families are represented, apparently including many living genera such as the maples, service berry, dogwoods, figs, magnolias, sycamores, poplars, oaks, sassafras, and grapes. One student of fossil plants has summed up the problem still confronting students of plant evolution in the following cogent way: "In particular, these include the 'abominable mystery' surrounding their early evolution, notably their center of origin, their ancestry, and their 'sudden appearance' in the Middle Cretaceous as a fully evolved, wholly modern phylum."[14]

In an article in the British scientific journal *Nature,* the botanist T. G. Tutin[15] affirms the same truth in typical forthright British fashion: "In the ninety-two years since the publication of the 'Origin of Species' a great deal of argument but remarkably little fact has been produced about the relationships of the angiosperms [flowering plants]. . . . Meanwhile, neither paleobotany, morphology, anatomy or cytology has thrown any light on the origin of the angiosperms or of any major group within the angiosperms which an unbiased observer can regard as unequivocal. Indeed, one may go further and say that no more is known now about the origin of any major group of plants than was known in 1859." In fact, relationships of the various plant groups are so obscure that there is considerable lack of unanimity over which features should be considered primitive and which should be considered advanced or derived.[16]

There are still unanswered questions in the record of fossil plants, both for those who believe in an initial special creation of separate basic types and for those who believe that the origin of basic groups is the result of natural processes. The virtual absence of the flowering plants (the dominant type of plants in the world today, including most of the familiar plants we see around us) in layers below those mentioned above (the Cretaceous system) is a problem from either point of view. From the evolutionary point of view, where are the ancestors that should indeed include connecting links between the principal groups? From the viewpoint of special creation, where are the ancestors that should have been living when the lower lying deposits with fossil land life were laid down? At the present time neither question is answered by the fossil record. This leads to the next basic point illustrated by the record of fossil plants in the Oregon country.

The record from several of the Oregon formations is commonly described as "rich," but still it is tantalizingly incomplete. A tropical or subtropical forest is indicated by palms, laurels, figs, cinnamons, and other trees with large, thick entire leaves, such as are common in these environments. Furthermore, the animals that are known from the Clarno formation include extinct rhinoceroses, a small four-toed horse with low-crowned teeth adapted for browsing on leaves, a tapir, an oreodont, an archaic carnivore, and crocodile types that would probably be at home in a subtropical forest environment. These forms of life speak of a specific habitat, a habitat that from similar environments today we infer may have supported eight or ten thousand species of animals and plants.

There must have been scores of amphibians, hundreds of species of birds, thousands of insects, and many hundreds of kinds of plants; yet fewer than a hundred kinds of animals and plants of all types have been described as fossils. Numerous major groups common in any tropical forest today, some of which are known as fossils elsewhere, are completely missing — and this in spite of the fact that the Clarno formation is almost unique in the wide range of kinds of fossils represented in a single formation. Near Hancock Park, one level exhibits beautifully preserved leaves; not far away are the

Clarno "nut beds" famous for the abundance of fossil seeds, including walnuts, figs, etc.; not more than a half mile away are outcrops of tuff that have preserved at one level a number of tree stumps, upright and apparently in position of growth; within a few hundred feet is an important mammal quarry that is still yielding bones; about two miles away in the Clarno formation is a silicified, swampy deposit with ferns, etc.

Few circumstances are more favorable for the preservation of land life than the rapid deposition of mineral-rich volcanic ash and breccia; yet even under such ideal circumstances the record is not more than a skeleton as compared to a fully formed body. Much can be learned. But built-in factors of bias should caution us against unconsciously assuming that the record is adequate or complete, and against arriving at hasty conclusions on the basis of negative data, such as the absence of fossils of certain types.

The animal life recorded in the volcanic formations of the Oregon country reveals another fascinating story — but again, in actuality, only fragments are now discernible. Above, we have briefly commented on the life of Clarno, the lowest or deepest of the five formations being compared. The overlying badlands of the colorful John Day formation, particularly the middle and upper portions, which possess dominantly greenish and buff-colored rocks respectively, have preserved the greatest variety of mammals known from any of the volcanic formations of the plateau country. The John Day formation is that series of volcanic tuff deposits that lies just beneath the most extensive dark lava flows known as the Columbia River Basalts. Evidence from microscopic analysis of the particles forming the tuff indicates that some beds composed of particles that retain their sharp angles and edges were apparently deposited (by air drop from volcanic explosions) essentially where they are now found, or at least close by. Others in which the particles have been rounded and altered seem to have been considerably reworked by wind and water subsequent to the eruptions. Included in the essentially unreworked category are those that preserve the very abundant leaves of the Bridge Creek area where Chaney identified 20,611 leaves from 98 cubic feet of tuff.

More than one hundred species of mammals have been recovered and described from the middle and upper John Day beds. There are horses, tapirs, rhinoceroses, giant pigs, peccaries, oreodonts, camels, large-clawed ungulates, wolves and other members of the dog family, sabertoothed cats and true cats, weasels, opossums, rabbits, squirrels, beavers, mountain beavers, pocket gophers, and many other less familiar forms.

In contrast to the plants, which in the majority of instances closely resemble living species, most of the mammals exhibit certain distinct differences from the most similar living species. Several species of horses are known which range in height from scarcely over two feet to the size of Shetland ponies. All had spreading feet with three toes, each provided with a hoof well adapted for relatively soft terrain. Their low-crowned teeth were well adapted for feeding on leaves, or browsing as it is called. Multiple toes with hoofs, small size, and teeth adapted for browsing are features that would remind one of modern tapirs, which are very much at home in tropical forests. These small horses are widespread in fossil deposits of both the Old and the New Worlds.

Tusked pigs known as elotheres were truly giant in size, the largest mammals known from the John Day beds. One skull in the University of California collection is two and one-half feet long, and numerous isolated bones indicate that some specimens were considerably larger and must have stood at least six or seven feet high. The late J. C. Merriam, who spent many years studying fossil mammals from the Oregon country and other

The John Day formation, with dark Columbia River basalt flows, near Turtle Cove.

localities in the Pacific states, suggests that "probably few animals have ever existed that were better able to protect themselves than the huge Miocene boars; yet they have long since disappeared from the earth leaving no direct descendants."[17] He describes the discovery and removal of a huge specimen from the John Day beds near Picture Gorge:

> When the large *Elotherium* skull now in the museum of the University of California was found, only a portion of a single dingy front tooth was in sight; and not until several days of hard labor had been expended in cutting away the surrounding rock with pick and chisel was it at all certain that the whole cranium was present. The skull was situated in an almost inaccessible place near the top of a steep bluff about two hundred feet high, and in order to get standing-room from which to work, it was necessary to cut foot-holes. To make matters worse, the cranium ran straight back into the cliff, necessitating so much excavation that a number of loose blocks above were almost certain to fall and damage it. To avoid all possibility of accident, steps were cut to a pinnacle about twenty feet above the specimen and from that point the face of the cliff was systematically torn down till a working space was uncovered. The whole operation of excavating occupied for two weeks as many persons as could conveniently work at the same time, and resulted in the discovery of the most important parts of the animal's skeleton. The lower jaw was found intact some distance away from the cranium, one of the fore limbs and a few scattered bones were beneath the head, and close behind it were all of the neck vertebrae.[18]

By far the most abundant remains in the John Day beds are from animals that in size and body proportions, and possibly also habits, seem to resemble the peccaries and swine of today. They are in an extinct group called "oreodonts" or "ruminant hogs," which up to the present time is known only from deposits in the New World. There are, in fact, several mammal families whose fossil and living members are restricted to the New World. Those represented in the deposits of the Oregon country include: the pocket gopher family (Geomyidae), the kangaroo rats and their allies (Heteromyidae), the pronghorns (Antilocapridae), and the large ground sloths of the extinct New World family (Megalonychidae).

The nature of occurrence of fossils in the John Day formation often seems to indicate partial or complete dismemberment before burial. Entire skeletons are rare, individual bones or parts of skeletons are relatively common. Some bones give evidence of having been gnawed by rodents before burial. The volcanic tuff in which they are entombed may at times have been considerably reworked by water and wind before the remains were finally buried.

The reference to "abundant" mammal fossils in the John Day and some other formations is likely to be misleading to a reader who has not collected fossils. "Abundant" fossils of marine life may mean that the limestone rock is packed with or largely composed of seashells, corals, etc. "Abundant" plant fossils may imply that a shale or ash layer has leaves or leaf fragments almost wherever the rock is split, at least in certain zones. In contrast, mammals are considered relatively abundant when possibly three or four or perhaps a half dozen skulls can be located in a week or two of careful search over the outcrops. Unless, as occasionally occurs, a pocket or nest has been located where a number of mammals are found near together, it never pays to dig at random in search of fossil mammals. To do so would be tantamount to shooting at random in the forest in the hope of killing a deer.

Overlying the colorful John Day tuffs are many layers of dark basaltic lavas, a most unusual place to find even traces of life. And the lava beds are indeed virtually barren. Nevertheless, there are at least two levels in Washington, near Blue Lake along the banks of the Grand Coulee, where molds of upright stumps and prostrate logs may be observed between the lava flows. In still another level, completely contrary to what anyone would predict, there is a well-formed mold of a small rhinoceros, apparently a member of the widespread but now extinct genus, *Diceratherium*.[19] Several bones were found within when the empty mold was first discovered. It has been conjectured that the rhinoceros was in a freshwater body, which accounted for rapid enough cooling to prevent immediate cremation of the remains.

Along the Columbia River not far from Arlington the same formation has a distinct soil zone with numerous fossil roots between two of the lava flows. This is well exposed in a recent roadcut for Interstate Highway 80. In places the soil appears little altered, whereas in others it has been apparently baked to a brick red from the heat of the lava flow. Such fossil soils have been reported at several levels.

The assemblages of animal life recorded in the more superficial Mascall formation that overlies the Columbia River lavas, and in the Rattlesnake formation above the Mascall, are not as great in variety as is preserved in the John Day formation below. Yet they exhibit distinctive features that contribute to the total picture. Although faunas include many of the general groups, nearly all of the genera and species are different in each formation. In general, the mammal remains of the upper formations seem to resemble living types more closely than those from the lower formations. Oreodonts so prominent in the John Day beds below are present, but much less common and less varied. Camels, horses, rhinoceroses, deer, rodents, and carnivores are found. Giant pigs are not recorded, but large members of the elephant tribe, a type of mastodon, enter the picture. The camels are larger than those in the John Day beds. Remains of *Merychippus,* a pony-sized horse with three toes and with the high-crowned teeth that possessed complex enamel patterns well adapted for grazing, are relatively common in the Mascall deposits.

In the volcanic deposits of the Rattlesnake formation are preserved a range of mammal types one might expect to encounter in a primeval savannah country. The presence not only of large camels but also of numerous horses and antelopes, both of which are well adapted for grazing and which are not very different from living forms, suggests open grassland country. Mastodons, rhinoceroses, peccaries, and indeed a large variety of fossil tree leaves point to the existence of woodlands as well.

If one looks at the total picture of faunal succession in the strata of the Columbia Plateau, there arises the question of how much time may be required for the completion of study of what confronts us here. One must consider the interbedded volcanic deposits, the establishment of the diverse mammalian faunas and their peculiar ecologic and climatic needs, their disappearance, and the length of time necessary for a new fauna that had its life and soil destroyed by volcanic activity to come in and occupy the area.

As one reviews the record of fossil mammals preserved in the sequence of volcanic deposits of central Oregon, at least two further points deserve comment. First, the general impression one gains from a survey of the fauna seems to reinforce the evidence provided by the fossil plants, namely, that the trend of climatic and environmental change was from moist, subtropical forests, with adequate rainfall in all seasons, toward cooler, drier climates, with progressively more open country.

Second, although the animals differ considerably from level to level, with a higher degree of strangeness in the lower deposits, one does not see transitional or intermediate forms that bridge the gaps between one family or order of mammals and another. The horses, for example, include nearly the full range of adaptation one sees within this family (Equidae), and yet these horses are not clearly connected, in the fossil record either here in Oregon or elsewhere, to any other mammal family.

This absence of connecting links between the basic types, the families and orders of mammals, and other forms of animal life as well, seems to be a nearly universal feature of the fossil record.[20] It is indeed one of the greatest theoretical obstacles for those who believe that the various basic types of life have not always been distinct but have risen from common ancestors. Although such students usually attribute the absence to the spotty and inadequate nature of the fossil record, nevertheless, a major problem remains. As the paleontologist Norman Newell points out, "Many of the discontinuities tend to be more and more emphasized with increased collecting."[21]

In the foregoing account I have attempted to give several glimpses into the wealth of information that has been combed from the rocks of the volcanic deposits of the Columbia River Plateau, particularly that section well exposed along the river valleys in central Oregon. Only certain facets could be touched on, but I have introduced data to illustrate the nature of information one can gain from the fossil record, even though the meaning of these data is often obscure.

In retrospect, as one endeavors to assess the mute testimony of the rocks deposited during this period of volcanic catastrophes, this "age of fire" as it is sometimes called, the thoughtful student can hardly escape drawing certain conclusions. Perhaps the most fundamental conclusion is this. Although a wealth of knowledge about plants and animals of times past may be learned, even under the most favorable succession of circumstances for the preservation of successive samples of a variety of land life, the record is still so incomplete that many basic questions cannot be answered with certainty from the available data. Those who come to the fossil record in search of proof regarding either creation, by some means or another, or evolution of basic forms of life will be disappointed. Such proof does not exist in the fossil record. Available evidence is equivocal and subject to various interpretations. One may justifiably feel that the evidence in the fossil record favors one or the other of several viewpoints. However, each viewpoint should not be equated with proof, as is so often done.

It is appropriate to ask: "Granted that from the fossil record alone proof regarding origins is not possible, still how does the weight of evidence look to you?"

The more I probe into the secrets of nature the more I am impressed that the adjustments on this planet for life are too numerous to be accounted for by chance. Some will say life had no alternative but to adapt to the circumstances that exist, but I feel that this statement misses the point. Existence of a source of energy and organization; of a chemistry of matter that allows for complex structures, processes, and interchanges necessary for any imaginable system of life; of essential elements and compounds such as carbon and water, each with countless, unique, and remarkable properties absolutely essential to life as we know it, and to life processes, seem to me to point to a designer, a source of plan and organization and power.

The location of the planet Earth in the temperate zone of the solar system and the adjustments by which the narrow range of temperature friendly to life are maintained; the continued existence of suitable habitats for land, water, and air life in the planet and of a suitable atmosphere seem to me to be strong evidence that the planet is not the product of chance. Order and organization of the universe point to a dependable administration. Remarkably intricate and complex structures both at the molecular and organismal level, and the numerous interdependent complex physiological processes that must exist in even the simplest conceivable independent forms of life, and to a far greater extent in higher forms, seem to point to a designer of incomparably superior ability. The existence of beings capable of appreciation of truth, of beauty in a myriad of forms, of higher values such as love and devotion, and of spiritual perception again suggest to me a creator with far greater capacities than those possessed by the created beings. If it takes personal intelligence to understand an edifice, it must take far greater intelligence to plan the edifice. It may be possible to have a picture without an artist or a cathedral without an architect, but I am unable to conceive of such a situation. Words are feeble instruments to express ideas so vast.

What does all of this have to do with the fossil record and origins? Simply this: when I study the record of the rocks I find there an order of nature in both the inanimate and the living world similar to that which exists on the earth today. Someone has said, "We are reading the first verse of the first chapter of a book whose pages are infinite." Yet in this verse is revealed to me the undisputed work of a creator, a revelation no less magnificent than that which is given in the early verses of the sacred Scriptures.

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