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FOSSILS WILL TELL

by

R. E. Stewart*

The Earth Story

Two thousand million years is a long time in anybody's language; even in that of a geologist.

Yet our earth is believed to be at least 2,000,000,000 years old, perhaps 2,050,000,000, perhaps much older.

During that time the earth's crust has been repeatedly bent, broken, and contorted ... raised high into the air ... plunged deep under the sea ... shaken by great earthquakes and volcanic eruptions ... buried under continental ice sheets ... parched and baked by the desert sun ... lashed by angry seas and stormwinds ... caressed by cool temperate breezes and by gentle zephyrs of the tropics.

And all the while, over most of the earth's surface, and especially upon the bottoms of lakes, seas and oceans, beds of conglomerate, gravel, sand, clay, lime, mud, and deep-sea ooze have been piled one upon another; and in them, as upon the pages of a great book, has been recorded for those who will take the trouble to learn to read it, the story of the ages.

Plants and animals in great abundance and variety populated the earth throughout most of recorded geologic time even as they do today; lived, died, and were buried in the sediments that went to form the rocks in which we now find their fossil remains. Occasionally fossils are also found in igneous rocks. All animals and plants of the present are descendants of this long "Parade of the Living"¹ and consequently the rocks of the earth, together with the land, water and air of the present day, constitute a veritable museum and laboratory of natural science and hold the most complete known record of the development of life upon the earth.

Nature has divided her story into eras, periods, epochs, and lesser units, even as our authors divide theirs into chapters, paragraphs, sentences, and phrases. Her divisions constitute the divisions of geologic time. Each raising or lowering of the land or sea, each change or shift of climate, each period of volcanic activity, when occurring on so grand a scale as the earth has witnessed many times during its history, interrupts or alters the development and distribution of life forms and the deposition of the rock material in which their remains are buried and preserved. When the land is covered by comparatively quiet waters it is built up by the addition or deposition of rock material which is continually being carried into the water by streams and the wind. When the land is raised above the water and exposed to winds and storms, waves, running water and various other forces of nature, much of the deposition ceases, erosion or wearing down of the land begins, and the continuity of sedimentation and of the record of life is broken, although partial records may be preserved in deposits formed over restricted areas by lakes, streams,

* Geologist, Oregon Department of Geology and Mineral Industries.

¹ Bradley, John Hodgdon, Jr., Parade of the Living, Coward-McCann, Inc., New York, 1930.
A nontechnical "story of the geologic history of life on earth."

vulcanism, wind, and other agencies. The widespread deposits which have accumulated during times of general land submergence carry the story of the main chapters of geologic history, while breaks in the sequence of deposition caused by intervening periods of widespread emergence and erosion serve to separate these chapters one from another.

The following table shows the major divisions of geologic time during which the known sedimentary rocks of the earth were deposited, together with the approximate number of years that are believed to have elapsed since the beginning of each division.

Eras	Periods	Epochs	Approximate elapsed time in years
Cenozoic (Recent life)	Quaternary	Holocene or Recent	25,000
		Pleistocene (Glacial)	1,000,000
	Tertiary	Pliocene	15,000,000
		Miocene	35,000,000
		Oligocene	50,000,000
		Eocene	70,000,000
Mesozoic (Mediaeval life)	Cretaceous		120,000,000
			150,000,000
			190,000,000
Paleozoic (Ancient life)		Permian	220,000,000
		Pennsylvanian	254,000,000
		Mississippian	280,000,000
		Devonian	320,000,000
		Silurian	350,000,000
		Ordovician	400,000,000
		Cambrian	500,000,000
Proterozoic (Earlier life)			
Archeozoic (Primeval life)			
Eozoic (Dawn life)			
Unrecorded interval of earth history		At least	1,750,000,000
Origin of the earth		At least	2,000,000,000

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The Specialist and Fossils

Our good fossil-record begins with the Cambrian, but the animals of that period were so highly developed that the existence of animal life upon the earth before that time appears to be a certainty, and objects believed to be fossils have been reported from as far back as the Archeozoic. Fossil shells and shell-like animal remains may be collected from all of the post-Proterozoic sedimentary rock series, which have a reported² maximum known thickness of 306,700 feet, or approximately 58 miles.

To the geologist and biologist falls a major portion of the task of reading and interpreting this record of the earth's history.

The scope of geology has become so broad and its applications so varied that every geologist must, almost of necessity, become a specialist along some line before he has been long out of college. Some will go into teaching, some into industrial work; others will join various governmental surveys and still others will make expeditions to distant, little known regions of the earth - all in the interest of geology and its application to the knowledge, wealth and welfare of mankind.

Among all of these will be specialists galore. There will be economic geologists, mining geologists, mineralogists, petrologists, petroleum geologists, field geologists, subsurface geologists, engineering geologists, military geologists, geophysicists, geochemists, oceanographers, volcanologists, historical geologists, structural geologists, stratigraphers, paleontologists, and many others.

The work of some of these has a more obvious and immediate practical application than that of others, but the work of each is actually very closely tied in with and very important to that of all the rest. The contribution of the "pure" scientist, that frequently scorned and often unheralded Daniel Boone of science who probes the distant frontiers and horizons of theoretical possibility, is, in the long run, probably most important of all.

It would be difficult to pick from the various fields of geology any one that is more fundamental, more indispensable than any of the others. In all probability, however, stratigraphy and structural geology would be placed at or near the top of the list by any experienced geologist.

Stratigraphy is the study of rock strata, the conditions of their deposition, their composition, character, distribution, geologic sequence and relative age. It deals largely, although not entirely, with those features and characteristics which date back to the time of deposition.

Structural geology deals with the attitudes of rock strata, with those features and relationships which have developed for the most part since deposition as a result of folding, breaking, and faulting. Folding and faulting may result in the accumulation of oil, gas, and water and in exposing or bringing to within workable distances of the surface all manner of ores and other mineral resources. Breaking and faulting form zones favorable for subsequent mineralization. From both economic and a purely scientific standpoint, therefore, it is very important to map the stratigraphic and structural geology of areas which may have mineral possibilities and to map it carefully and well.

One of the most important tools in stratigraphic and structural geology, and, therefore, in geologic mapping is paleontology, the science of the life of past geologic time.

The Ore.-Bin³ recently carried an excellent review of man's interest in fossils from the time of his earliest fantastic misconceptions of their true origin, nature and significance to that of his final realization that they represent animals and plants that once lived upon the earth, his knowledge of their significance in the chronology of life development and earth history, and his application of this knowledge to practical problems in biology and geology. In summary the author states that:

²Wilmarth, M. Grace, The geologic time classification of the U.S. Geological Survey compared with other classifications: U.S. Geol. Survey Bull 769, pp. 6-7, 1925.

³Packard, E. L., Why Study Fossils, The Ore.-Bin, vol. 7, no. 8, pp. 47-48, August 1945.

"The study of fossils ... has through thousands of years, given man glimpses of the life of the past; furnished proof of the fact of organic evolution; given an outline of the history of life on earth through some 1800 millions of years, and unexpectedly developed into a tool in the hands of stratigraphic and economic geologists which permits precise identification of strata often containing a wealth of oil or other geologic resources."

Fossils constitute the chief evidence in problems of correlation and are among the best indicators of geologic age.

Geologic Age and Time

Strictly speaking, the geologic age of rocks should probably be considered in terms of the number of years that have elapsed since their deposition. Actually, however, geologists usually think of geologic age in terms of stratigraphic position and date the age of strata more with regard to their place in the record of a series of geologic events than to any consideration of actual elapsed time in years. For example, the Coaledo formation is said to be "upper Eocene" in age, not "55,000,000 years old," and the Astoria formation is similarly dated as "middle Miocene."

Rocks exposed in separated localities are said to correlate if they are of equivalent geologic age. The geologist's work in correlating them consists in determining this age equivalence. Correlation may, therefore, be defined as the determination of equivalence in geologic age and stratigraphic position of stratigraphic units in separated areas.

As we have already seen, the time during which the fossiliferous rocks of the earth were deposited is measured, not in just thousands, tens of thousands or even hundreds of thousands of years, but in hundreds of millions and perhaps in billions of years. During that time earth's first and simplest living things made their appearance, and from them through the processes of organic evolution have developed the whole past and present plant and animal kingdoms of our planet.

Effects of Environment

The changes involved in these evolutionary processes were made largely in response to changes in the environments in which the organisms were privileged or forced to live, as, for instance, changes in temperature, humidity, light, food supply, enemies, relative elevations of land and sea, and, in the case of water-living forms, such additional factors as depth, salinity, and turbulence of the water.

In general these environmental changes took place gradually and at rates which permitted most of the plants and animals either to adapt themselves to the new conditions or migrate to areas where their normal environment still prevailed. Sometimes, however, new conditions developed so rapidly that many species and groups in the areas so affected were unable either to survive or escape the changes, and consequently dropped out of the picture altogether. Unless their lines were perpetuated in other areas of favorable environment, the exit of these forms was final and they became extinct.

So long, however, as they persisted elsewhere without appreciable evolutionary change, they might reappear with recurrences of favorable environment. Such migratory reappearances usually threw them into different floral and faunal associations than before, thus giving rise to distinctive fossil assemblages which we now find even more valuable than index fossils in many problems of correlation.

It follows, therefore, that most sedimentary rocks contain fossils and fossil assemblages which differ from those in older and younger rocks but resemble those in rocks of equivalent age, and that consequently the geologic age and correlation of rock strata may be determined from the fossils they contain.

Not all rocks contain fossils, but in many cases the age of unfossiliferous rocks may be determined from their stratigraphic and structural relationships to fossil-bearing beds. In general they may be assumed to be older than overlying beds and

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younger than underlying beds, although older beds may overlie younger as a result of overturn, faulting, or intrusion. Igneous rocks are younger than rocks through which they have passed in working their way toward the earth's surface.

Fossils also indicate the conditions of deposition of the rocks in which they occur. Since organic development was primarily a response to environment, the fossil remains of the plants and animals of the past reflect the conditions which brought them into being and thereby give authentic evidence of the conditions under which the sediments of their time were deposited.

The Role of Paleontology in Oil Exploration

Paleontology plays an important role in many branches of economic geology. A good example is its application to the discovery and production of petroleum.

The four primary requirements for an oil field are (1) a source, (2) a reservoir, (3) a trap, and (4) a discoverer.

The discoverer is usually an experienced operator with initiative, "know-how," ample finances, good equipment, experienced personnel, persistence and courage. Occasionally a discovery is made by the fellow who comes in (frequently "on a shoestring") equipped with little except the courage to rush in and a desire to gamble (usually with other people's money) on something involving greater risk than the puppies and the ponies.

Experienced, legitimate operators nearly always, and other operators sometimes⁴ base their exploratory drilling upon careful, detailed geological and, often, geophysical studies.

The problems that face a geologist upon going into a new area are legion, but, regardless of all others, if he is in search of petroleum he will be constantly on the lookout for (1) organic shales which may have served as source beds for oil and gas; (2) permeable, porous beds which may serve as reservoir rocks; and (3) traps in which the oil and gas may be accumulated and held under high pressures.⁵

Organic shales commonly contain the remains of many minute plants and animals from which petroleum is believed to have been derived. Most of our west coast oil appears to have come from diatoms - plants so small that thousands of them may be found in less than a cubic inch of shale.

Reservoir rocks must be sufficiently porous to provide storage space for oil and gas, and sufficiently permeable to permit relatively free migration. They must also be accessible to oil and gas from the source beds, as by direct contact between the source and reservoir beds, or by movement of the oil and gas through intervening beds or along faults or other fractured zones.

Within areas of accumulation, however, there must be no avenue of escape from the reservoir beds if wells drilled into them are to be commercially productive. These areas constitute the traps and oil pools which are the final objective of the field geologist.

These traps may be either structural, stratigraphic, or both.⁶ Their multiplicity of types is too great to fall within the scope of this paper, but they may be found both described and illustrated in almost any good textbook on petroleum geology.

⁴Meinzer, O. E., (in charge of Div. of Ground Water, U.S. Geol. Survey), "Introductory Note" to Ellis, A. J., The Divining Rod, A History of Water Witching, U.S. Geol. Survey, Water-Supply Paper No. 416, pp. 5-6, 1917. Considers and discredits the forked twig, or so-called divining rod, and other more complicated spurious instruments (frequently referred to as "witch sticks," "doodlebugs," etc.) used for locating water, oil, or other minerals.

⁵Illing, Vincent C., Role of Stratigraphy in Oil Discovery, Bull. Amer. Assoc. Petrol. Geol., Vol. 29, No. 7, pp. 872-884, July 1945. Treats the subject under three sub-titles: (1) Stratigraphy and Source Rocks, (2) Stratigraphy and Reservoir Rocks, (3) Stratigraphy and Oil Preservation.

⁶Wilhelm, O., Classification of Petroleum Reservoirs, Bull. Amer. Assoc. Petrol. Geol., Vol. 29, No. 11, pp. 1537-1580, November 1945. An excellent detailed study and classification of petroleum reservoirs.

Structural traps are due chiefly to folding and faulting; stratigraphic traps to pinching out of the reservoir beds or to variations of permeability within them. Structural traps are the ones most commonly reflected at the surface. In the search for stratigraphic traps and for structural traps that lack surface expression we are largely dependent upon subsurface geology and geophysics.

Faulting may literally make or break a trap; make it by sealing off the upper truncated ends of broken and tilted reservoir beds against rocks which are impervious to oil and gas, or break it by providing a fractured zone along which oil and gas may escape or water may enter the reservoir sands.

In nearly all cases the field geologist will need fossil evidence in connection with his stratigraphic and structural studies from the very beginning. He will want to be able to recognize and correlate all rock formations within his area. As the work progresses he will need to correlate more closely in order to detect faults and other structural irregularities which may have a bearing upon oil accumulation.

His first knowledge of possible source and reservoir rocks will be based upon surface evidence, but any hole drilled to test them for oil and gas will be so located as to penetrate them at depths of several hundred or several thousand feet. Consequently he will need to know the stratigraphic interval between the surface rocks at the drill site and the sand he wishes to test in order to be able to estimate the depth at which the sand should be encountered. This calls for detailed analysis of fossil ranges.

As soon as possible after going into the field, therefore, the experienced geologist familiarizes himself with the fossils of his area. Many require detailed study for which he has neither time nor facilities in the field, and consequently they are sent to laboratories especially staffed and equipped for such work. This is particularly true of the microfossils whose ranges are worked out in great detail from samples taken at close intervals throughout all exposed sections of the sedimentary rocks of the area.

During the drilling that follows these field and laboratory studies, paleontology work is continued in even greater detail than before. The problem shifts from surface to subsurface geology, and buried details of stratigraphy and structure that control the accumulation of oil and gas are worked out largely through the study of well cuttings and cores. Micropaleontology, the study of microscopic fossils, is one of the most important branches of subsurface geology.

Statistics⁷ show that in California:

"Fourteen of the 32 (oil and gas) fields discovered during 1944 were located through subsurface studies. Another 4 discoveries resulted from a combination of subsurface and surface geology and 7 more discoveries from a combination of subsurface geology and geophysical work. Subsurface geology, therefore, played a major role in the discovery of new fields."

Fossil Study, a Universal Aid

Petroleum geology is by no means the only field to which paleontology is extremely important. Any project involving field work and mapping in marine sedimentary rocks will of necessity draw heavily upon paleontology for some of its most critical data.

Fossils are closely tied in with every important relationship of sedimentary rocks, for they are scattered through all of the earth's sedimentary series and some of its igneous rocks as a part of the rocks themselves. They are coal. They are diatomite. They are building stone. They are the remains of organisms from which petroleum and natural gas have been formed. They constitute the chief evidence in problems of correlation and are among the best indicators of geologic age. They indicate the conditions under which the sediments of their time were deposited. They have lived during periods of earth history when horses had five toes, fishes wore coats of armor, and enormous beasts and reptiles roamed the lands and swam the seas.

⁷Moody, Graham B., Developments in California in 1944, Bull. Amer. Assoc. Petrol. Geol., Vol. 29, No. 6, p. 652, June 1945.

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What stories these fossils could tell if they could only talk!

Better let us say, what stories they could tell if we but understood their language, because to the person who has learned to understand them, fossils - no daisies they - will tell their secrets any day.

OREGON BAUXITE DESCRIBED

Large reserves of ferruginous bauxite, an ore which may constitute an important source of alumina to supply Northwest aluminum plants, are described in a bulletin just issued by the Oregon Department of Geology and Mineral Industries. The deposits are widespread in northwestern Oregon but are found mainly in Washington, Columbia, and Marion Counties.

Discovery of high-iron bauxite in Washington County about 35 miles northwest of Portland was first announced by the department in 1944 and a short report on the discovery was issued in August of that year. Since that time additional field work has extended the known occurrences into other counties and revealed an entirely new bauxite area near Salem.

Considerable interest in the aluminum-bearing deposits has been shown by some of the large industrial companies, and Alcoa Mining Company, a subsidiary of the Aluminum Company of America, is at present engaged in a large-scale drilling and exploration project on these deposits in Washington and Columbia Counties.

F. W. Libbey, W. D. Lowry, and R. S. Mason of the department staff are the authors of the 97-page publication, which discusses the geology and economics of the deposits, and describes the 94 localities where the bauxite has been found. Not all of these localities are of commercial grade or size, however. Descriptions of two exploration projects by the department which indicated over 5,000,000 long tons of ore are given. Numerous analyses of the ore, together with maps and illustrations, are included in the publication which is available at the office of the department, 702 Woodlark Building, Portland, and the field offices at Baker and Grants Pass. Price postpaid \$1.00.

NEW MAP OF THE GEOLOGY OF NORTHWEST OREGON

The first report on the U.S. Geological Survey's recent investigations of the stratigraphy, structure, and oil and gas possibilities of the Coast Ranges in northwest Oregon has been released. The report is accompanied by a geologic map of an area including about 4,250 square miles west of the Willamette River and north of latitude 45°15'.

The map, which is on a scale of about 1 inch = 2.3 miles, shows the distribution of the major geologic units, ranging in age from Eocene to Recent, by patterns overprinted in green on a topographic base map printed in black. It is accompanied by two structure sections showing the relations of the strata, and by six stratigraphic sections showing the nature of the various rock units.

As an aid to oil geologists and others interested in the geology of the region, the fossil localities are indicated by symbols on the map, and lists of the fossils found at each locality are printed on the same sheet. A brief accompanying text summarizes the stratigraphy and structure of the area.

The map, measuring 44 by 64 inches, and entitled "Geology of northwest Oregon west of Willamette River and north of latitude 45°15'," has been issued as Preliminary Map 42 of the Oil and Gas Investigations series. Copies may be purchased on or after December 11, 1945 from the Director of the U.S. Geological Survey, Washington 25, D.C., at 70 cents each,

and will also be available for "over-the-counter" sale at the U. S. Geological Survey offices at Room 234 Federal Building, Tulsa, Okla.; Room 533 U. S. Post Office and Court-house Building, Los Angeles, Calif.; and at Room 314 Boston Building, 828 17th Street, Denver, Colo.

JUSTICE FOR GOLD MINERS

Identical bills S. 1497 and H.R. 4393 have been introduced in the Senate and House of Representatives by Senator Murray and by Representative Engle. The provisions are reproduced below:

A BILL

For the relief of the owners of certain gold mines which were closed or the operations of which were curtailed by War Production Board Limitation Order L-208.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, THAT ANY OWNER OF A GOLD MINE WHO INCURRED A FINANCIAL LOSS DUE TO THE CLOSING OR CURTAILMENT OF OPERATIONS OF SUCH MINE AS A RESULT OF THE RESTRICTIONS IMPOSED BY WAR PRODUCTION BOARD LIMITATION ORDER L-208 DURING THE EFFECTIVE LIFE THEREOF MAY, WITHIN SIX MONTHS AFTER THE EFFECTIVE DATE OF THIS ACT, FILE A CLAIM OR CLAIMS FOR THE AMOUNT OF SUCH LOSS, INCLUDING THE COSTS OF PLACING SUCH MINE IN A CONDITION EQUIVALENT TO THAT WHICH IT WAS IN AT THE TIME SUCH MINE WAS CLOSED OR ITS OPERATIONS CURTAILED AS A RESULT OF SUCH ORDER, BUT NOT INCLUDING PAYMENT FOR LOST PRODUCTION.

Sec. 2. (a) THE SECRETARY OF THE TREASURY IS AUTHORIZED AND DIRECTED TO APPOINT AN EXAMINER, WHO SHALL BE PAID A COMPENSATION AT THE RATE OF \$7,500 PER ANNUM, AND SHALL BE FURNISHED WITH AN ADEQUATE STAFF TO CONSIDER SUCH CLAIMS. IT SHALL BE THE DUTY OF SUCH EXAMINER TO CONSIDER ALL CLAIMS FILED UNDER THIS ACT AND TO CERTIFY FOR PAYMENT BY THE SECRETARY OF THE TREASURY SUCH CLAIMS AS HE SHALL FIND QUALIFIED FOR PAYMENT UNDER THE TERMS OF THIS ACT, IN SUCH AMOUNTS AS HE SHALL FIND ARE DUE. IT SHALL FURTHER BE THE DUTY OF THE EXAMINER TO SETTLE ALL CLAIMS WITHIN ONE YEAR AFTER THE DATE OF FILING THEREOF, EXCEPT WHERE PREVENTED BY UNUSUAL CIRCUMSTANCES.

(b) THE PERTINENT RECORDS OF OTHER AGENCIES OF THE FEDERAL GOVERNMENT SHALL BE MADE AVAILABLE TO THE EXAMINER UPON REQUEST.

Sec. 3. THE SECRETARY OF THE TREASURY IS AUTHORIZED AND DIRECTED TO PAY, OUT OF SUCH SUMS AS MAY BE APPROPRIATED UNDER THE TERMS OF THIS ACT, SUCH CLAIMS AS ARE CERTIFIED TO HIM UNDER THE TERMS OF THIS ACT.

Sec. 4. APPEAL MAY BE TAKEN FROM ANY DECISION OF THE EXAMINER BY A SUIT BROUGHT IN THE UNITED STATES DISTRICT COURT FOR THE DISTRICT WHEREIN THE PETITIONER IS DOMICILED OR WHEREIN HIS MINING OPERATIONS WERE CONDUCTED.

Sec. 5. THERE ARE HEREBY AUTHORIZED TO BE APPROPRIATED SUCH SUMS AS ARE NECESSARY TO CARRY OUT THE PROVISIONS OF THIS ACT.

Sec. 6. THIS ACT SHALL TAKE EFFECT ON THE FIRST DAY OF THE FIRST CALENDAR MONTH FOLLOWING THE DATE OF ITS ENACTMENT.

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