The Age of the Earth:

HOW IT CHANGED FROM THOUSANDS TO BILLIONS OF YEARS

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In the beginning God created the heaven and the earth. These opening words of Scripture have lost none of their beauty or majesty in the few thousand years since they were recorded. Man's concept of his planet and of its place in the universe has changed progressively and radically; but to each generation, with its limited view of nature, the scriptural account of the earth's origin has been widely accepted and harmonized with man's explanation of it.

In the mid-seventeenth century, when Archbishop James Ussher published his conclusion that the world was created in 4004 B.C., there was little difficulty in harmonizing this date with the facts of nature then known. During the seventeenth and eighteenth centuries, most scientists attempted to relate the evidence found in fossils and sedimentary rocks to the Genesis Deluge. Although many fanciful and absurd theories were proposed, there was relatively little conflict between theologians and scientists during this period.[1] In fact, most writers on the subject had been educated originally in theology!

An age of approximately 6,000 years for the earth and its inhabitants was almost universally accepted. Today most geology textbooks give a figure nearly a million times larger. The story of how this change came about is a fascinating chapter in the history of the conflict between science and religion. The debate goes back to the fifteenth and sixteenth centuries when Copernicus and Galileo suggested a theory for the structure of the universe that was not compatible with the theological teachings of their contemporaries — teachings that were based on a wrong interpretation of several passages of Scripture. Though more restricted, the argument continues even now; and much of it centers on the issue of Creation and the age of the earth.

It seems to me instructive to deal with the matter in its historical perspective to

determine, if possible, how we have arrived at the present state of the conflict between what many scientists say are "irrefutable facts" concerning the antiquity of the earth and what a number of theologians point to as "divinely inspired statements" that limit the earth's age to thousands of years.

The difference between a thousand and a billion is impressive. If you were one of a group of a thousand people among whom a thousand dollars were equally divided, you would be richer by one dollar. But if a billion dollars were equally divided among the thousand, you would become a millionaire (before taxes)! To change the earth's age from thousands to billions is no trivial change. This shift of opinion did not occur suddenly. Nor was it generally accepted without controversy — either in the scientific community or elsewhere.

NO SIGN OF A BEGINNING — NO PROSPECT OF AN END

Toward the end of the eighteenth century, James Hutton, a Scottish geologist, proposed a theory of the earth that introduced the concept of uniformitarianism — a concept based on the assumption that existing geological processes had operated uniformly since the earth's origin. Earlier theories had accounted for the observed geological changes in the outcrops of the earth's crust as the result of one or more catastrophes. Hence, if the geological processes were regarded as having operated uniformly since the beginning, vast periods of time would be needed to accomplish the changes previously thought to have taken place in 6,000 years. Hutton never attempted to assign absolute ages to the rocks.

> These phenomena, then, are all so many marks of the lapse of time, among which the principles of geology enable us to distinguish a certain order, so that we know some of them to be more, and others to be less distant, but without being able to ascertain, with any exactness, the proportion of the immense intervals which separate them.[2]

Hutton was the first to point out the significance of unconformities — where one series of strata rests on the upturned edges of another and thus is not continuous with it. He interpreted these upturned beds as originally having been deposited horizontally, then subsequently upheaved, folded, tilted, and partly eroded. After this sequence of events, the upper series of the strata was deposited on this eroded surface. To Hutton, vast periods of time were essential for the sequence of events to produce these unconformities.

One of Hutton's most significant contributions was the recognition that some rocks were not produced by the action of water. From field evidence he perceived that basalts (which he called whinstones) and granites had once been molten but subsequently had crystallized.

The reasoning that "subterraneous heat" must be involved — labeled the plu-

tonic theory — was violently opposed by those who held the neptunian theory advanced by A. G. Werner, a German mineralogist of great influence. The neptunists believed that virtually the entire crust of the earth had precipitated, or settled, out of a vast primeval ocean that once enveloped the earth. Furthermore, the neptunists claimed that their theory fitted the scriptural record of Creation and the Deluge far better than did the plutonic theory. The controversy between the plutonists and the neptunists was intense and bitter. The neptunists labeled the plutonic theory atheistic, primarily because of the vast time periods necessary to cool and crystallize molten rock and to produce the sequence of changes observed in the many unconformities of the geologic record.

On both sides of the vigorous debate were distinguished and able adherents. As often happens, much new information was obtained from the intensive study of the earth's crust conducted in the hope of proving one theory or the other. The controversy eventually ended with the general acceptance of the theories of the plutonists (or vulcanists, as they were sometimes called). Although the plutonic theory had been labeled atheistic by its opponents, it is interesting that the leading proponents strongly defended it as harmonizing with Scripture, as illustrated by a defense quoted from John Playfair.

> On what is now said is grounded another objection to Dr Hutton's theory, namely, that the high antiquity ascribed by it to the earth, is inconsistent with that system of chronology which rests on the authority of the Sacred Writings. This objection would no doubt be of weight, if the high antiquity in question were not restricted merely to the globe of the earth, but were also extended to the human race. That the origin of mankind does not go back beyond six or seven thousand years, is a position so involved in the narrative of the Mosaic books, that any thing inconsistent with it, would no doubt stand in opposition to the testimony of those ancient records. On this subject, however, geology is silent; and the history of arts and sciences, when traced as high as any authentic monuments extend, refers the beginnings of civilization to a date not very different from that which has just been mentioned. . . .
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> On the other hand, the authority of the Sacred Books seems to be but little interested in what regards the mere antiquity of the earth itself; nor does it appear that their language is to be understood literally concerning the *age* of that body, any more than concerning its *figure* or its *motion*. The theory of Dr Hutton stands here precisely on the same footing with the system of Copernicus; for there is no reason to suppose, that it was the purpose of revelation to furnish a standard of geological, any more than of astronomical science. It is admitted, on all hands, that the Scriptures are not intended to resolve physical questions, or to explain matters in no way related to the morality of human actions; and if, in consequence of this principle, a considerable latitude of interpretation were not allowed, we should continue at this moment to believe, that the earth is flat; that the sun moves round the earth; and that the circumference of a circle is no more than three times its diameter.[3]

Rationalization? Probably in part. Nevertheless, the foregoing was an attempt to find harmony between God's words and his works.

During the controversy between Hutton's and Werner's followers, Georges Cuvier, a French biologist, studied the fossil-bearing strata around Paris.[4] Cuvier,

the father of comparative anatomy and vertebrate paleontology, compared fossil shells and the skeletal remains of vertebrate fossils with those of living animals and concluded that many of the fossil forms represented species and genera distinct from any living animals. Furthermore, these fossil forms were found in a sequence of strata in which many fossils were restricted to particular sedimentary layers. By carefully comparing the associated fossils with their living counterparts, he was able to distinguish some beds as marine, others as fresh water, and still others as terrestrial.

A religious man and a creationist, Cuvier attempted to harmonize his findings with Scripture by proposing a series of creations and catastrophes — the most recent one being that recorded in Genesis, which he believed took place 5,000-6,000 years ago. He held that each catastrophe was followed by a special creation of new species that coincided with the sequence of fossils found in successive sedimentary strata.

In Great Britain, William "Strata" Smith, like Cuvier, also found a remarkable regularity in the fossil sequence that occurs in sedimentary strata.[5] His geological map of Great Britain, published in 1815, earned him the title "father of English geology." The map was the result of twenty-four years' work in tracing the order of the strata with their associated fossils from one outcrop to another. Smith was the first to use fossils ("index fossils") in correlating strata over large distances.

THE PRESENT IS THE KEY TO THE PAST

After the publication of Cuvier's and Smith's findings, it remained for British geologist Sir Charles Lyell to bring the various theories into focus. Lyell's *Principles of Geology,* an immediate success when it was published in 1830, went through twelve editions before he died in 1875. The book relied on Hutton's uniformitarian approach and presented a rather convincing argument that the strata and the fossils were arranged in a definite sequence for which vast amounts of time must have been necessary. To Lyell the concept of time was crucial in the development of the science of geology. He believed that it was impossible for the pioneers in geology to make any progress "so long as they were under a delusion as to the age of the earth."[6]

Lyell traveled extensively and documented geological changes that had taken place during past ages. The variations in sea level that were superimposed on manmade structures, the erosion of historically dated volcanic areas, the growth of the Nile Delta, and the recession of Niagara Falls were some of the many phenomena for which Lyell tried to obtain actual rates of change. His estimate of 35,000 years for the excavation of the Niagara chasm[7] was considerably longer than the currently accepted time based on radiocarbon dating. An important

point as to this time estimate is made in a nineteenth-century geology textbook by Joseph Le Conte of the University of California.

> All attempts to estimate *accurately* the time consumed in excavating Niagara gorge must be unreliable. . . . Mr. Lyell thinks, from personal observation, that the average rate could not have been more than one foot per annum, and probably much less. At this rate it would require about 36,000 years. But, whether more or less than this amount, this period must not be confounded with the age of the earth. The work of excavating the Niagara chasm belongs to the present epoch, and *the time is absolutely insignificant in comparison with the inconceivable ages* [italics supplied] of which we will speak in the subsequent parts of this work.[8]

Lyell was one of the first to recognize that fossils in the lower beds of a sequence of sedimentary strata had fewer living representatives than did fossils in the upper beds. In fact, he used this principle to classify the tertiary deposits of Europe into the New Pliocene, Older Pliocene, Miocene, and Eocene groups.[9] From studying the uppermost layers — the New Pliocene (now called Pleistocene) deposits — he determined that from 90 to 95 percent of the fossil species were also found as living species. In the Older Pliocene strata only 35 to 50 percent were still represented among living species, in the Miocene deposits 17 percent, and in the Eocene beds only 3.5 percent. As stratigraphic studies continued, these percentages changed somewhat, but the concept that the "degree of strangeness" increases toward the base of a sedimentary sequence is still considered valid in geology and paleontology.

Nowhere is this principle better illustrated than in the deep-sea cores being collected in the JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) deep-sea drilling project. Fossil planktonic foraminifera and other microfossils show similar relationships to living species. Invariably the deeper one goes in a sediment core, the higher is the percentage of extinct microfossil species found. The stratigraphic ranges of many extinct species form the basis for correlating the sediments sampled in the large number of recovered deep-sea cores. The recognition of former worldwide magnetic reversals is now supplementing the use of fossils in correlating one core with another.

EXPRESS IT IN NUMBERS

"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it." This quotation from Lord Kelvin (William Thomson 1824-1907) illustrates the problem geologists faced in the latter half of the nineteenth century, when Kelvin began to apply the principles of physics to solve the riddle of the earth's age.[10] Geologists generally had been wary of expressing geologic time in numbers of years. Most were content to regard geologic time as very long, vast, incomprehensible, or even unlimited.

Some, however, tried to "express it in numbers" by measuring the thickness of

sedimentary strata and relating this measurement to a supposed rate of sedimentation. Limestone was thought to accumulate at much slower rates than detrital sediment, such as sandstone or shale. Estimates of sedimentation rates were obtained by observing the great rivers of the world and measuring their sediment load. The measurements yielded crude estimates that varied from 10 million years to 6 billion years![11] By assuming different rates of erosion and sedimentation in the past, one could end up with almost any desired age for the stratified rocks. Measuring the rate of salt accumulation in the oceans was another crude attempt to assign numbers for the years thought to be necessary for certain geological processes.[12]

Kelvin's final calculations in 1897 placed the age of the earth between 20 and 40 million years,[13] which was far less than earlier estimates that had been based on assumed sedimentation and erosion rates. Kelvin's method assumed an original molten earth that cooled according to known physical laws until the temperature gradient observed in its crust equaled that predicted by the mathematical model. It was clear that there was a serious discrepancy between the rates he estimated and the earlier rates. Most geologists felt that something was wrong with Kelvin's assumptions. For instance:

> That there must be some flaw in the physical argument I can, for my own part, hardly doubt, though I do not pretend to be able to say where it is to be found. Some assumption, it seems to me, has been made, or some consideration has been left out of sight, which will eventually be seen to vitiate the conclusions, and which when duly taken into account will allow time enough for any reasonable interpretation of the geological record.[14]

> The exact formulas of a mathematical science often conceal the uncertain foundations of assumptions on which the reasoning rests and may give a false appearance of precise demonstration to highly erroneous results.[15]

Some geologists sought to accommodate Kelvin's age limitation by assuming what seemed very rapid erosion and sedimentation rates. Many ignored Kelvin and continued to use revised data on stratigraphic thicknesses and sedimentation rates to determine geologic time. Their estimates were generally ten to thirty times higher than Kelvin's figures.

DISCOVERY OF RADIOACTIVITY

Much of Kelvin's work (theory, assumptions, and results) seemed unassailable until a few years after the discovery of radioactivity. Scientists began to realize that radioactivity itself was generating heat in the earth's crust, and calculations showed the concentration of radioactive elements to be sufficient to account for the entire heat flux from the earth. Replacing the assumption of a cooling earth with this new concept of a radioactive heat-generating earth made Kelvin's calculations (which had been based on a cooling earth) meaningless.

Progress in the understanding of radioactivity was rapid. By 1905 Ernest Rutherford, a British physicist, applied radioactivity to the determination of geological time.

> The helium observed in the radioactive minerals is almost certainly due to its production from the radium and other radioactive substances contained therein. If the rate of production of helium from known weights of the different radioelements were experimentally known, it should thus be possible to determine the interval required for the production of the amount of helium observed in radioactive minerals, or, in other words, to determine the age of the mineral.[16]

In spite of the problem of helium loss from radioactive minerals, Rutherford presented data showing probable ages for some mineral samples of around 500 million years. Because lead is also a product of the radioactive breakdown of radium and uranium, he predicted its use for dating — which would be more satisfactory, since lead, unlike helium, should not escape the mineral structure so easily.

In a 1917 comprehensive review paper, Joseph Barrell — using radioactive dating and geological methods — published a geologic time-scale that agrees remarkably with time-scales now being published in the literature.[17]

In the nearly seventy years since Rutherford's application of radioactivity to geology, a number of elements with radioactive isotopes have been used for age-dating purposes: potassium 40/argon 40, rubidium 87/strontium 87, spontaneous fission of uranium 238 (fission-track dating), pleochroic halos, uranium 238/lead 206, uranium 235/lead 207, thorium 232/lead 208, and others. While discrepancies are common, the methods that assign ages of a few billion years to the oldest rocks of the earth's crust are in general agreement.[18]

The currently accepted value for the age of 4.5 billion years is derived from the composition of lead isotopes in various samples of lead from the earth and from meteorites.[19] Of course, assumptions are involved in radioactive age-dating methods. These assumptions may seem reasonable to some and unreasonable to others, but geoscientists generally accept radioactive age-dating methods because the results are consistent.

DISCUSSION

Different individuals are impressed in various degrees by different kinds of evidence. The data from radioactive age-dating studies impress many people because the data appear to give a series of precise numbers for the geological age of numerous samples.[20] Persons who are troubled about an age for the earth that exceeds 6,000 years feel that the difficulties would vanish if radioactive age-dating could be explained away. Not so!

I have attempted to present — not defend — what geologists since the middle

of the eighteenth century have concluded about the earth's age. As the science of geology developed and as data on the rocks and fossils of the earth's crust accumulated, theories were formed and vigorous debates took place.

But when radioactive age-dating techniques were introduced, there was little or no basic change in geological thinking. In other words, the conclusions of geologists as to the vast time periods of geology *had already been formed* during the nineteenth century *before* radioactivity was even discovered! True, radioactive age-dating provided numbers, but many geologists had been assigning similar numbers long before the discovery of uranium and radium. It may be added that these conclusions had largely been formed even before the concept of organic evolution was accepted.

Scientific theories are seldom entirely correct or entirely false; generally they are only approximations to the truth. A valid theory not only stands the test of time but usually is modified as subsequent discoveries are made. Because scientific method in reality is a method of trial and error, an incorrect theory will be discarded eventually as more and more conflicting data accumulate. Thus, if current geological theory is in error, eventually it will be corrected.

The questions asked should be concerned not only with the assumptions and results of radioactive age-dating methods but with such basic geological concepts as stratigraphic sequence and correlation and the rates of geological processes. No single individual nor even a single generation can collect sufficient data necessary to answer all the questions of geology. With humility we each must admit that there are far more data available than we can comprehend. But this fact should not discourage us from the attempt.

All possibilities should be considered, including the possibility that many details of current geological theories are indeed on the right track and are approximations to the truth. Many persons who believe such to be the case believe also in the inspired scriptural accounts of Creation and the Flood. For these persons there is little or no conflict between science and the Bible when scriptural accounts are interpreted in their historical context.

The book of nature and the written word shed light upon each other.[21]

Since both have the same Author, a correct understanding of both will prove them to be in harmony.[22]

Within the geological sciences there are indications that some long-held ideas are being modified and even discarded. The concept that the *rates* of geologic change have always been uniform is no longer considered valid. "Substantive uniformitarianism as a descriptive theory has not withstood the test of new data and can no longer be maintained in any strict manner."[23]

In answer to the question of why whole groups of animals have simultaneously died out, geologists and paleontologists now consider that a series of catastrophes is more likely the cause than are the slow, incessant geologic changes postulated by uniformitarianism.[24] To explain the often excellent preservation of fossils in the light of sedimentation rates of approximately one foot per several thousand years has always been a problem. At these slow rates, hundreds or even thousands of years would be needed to bury the fossils, and they would not be well preserved under these circumstances. Geologists are considering that rapid burial is necessary to explain the fine preservation often found. This does not mean, however, that geologists are considering a single catastrophe, such as the Flood, as an adequate explanation of the fossil record. Instead, numerous catastrophes are considered the more likely cause of much of the sedimentary record of the earth's crust.

Recently I made a three-hundred-mile geological field trip by raft on the Colorado River from Lee's Ferry to Lake Mead. Only a little more than a hundred years had elapsed since John Wesley Powell's first expedition, and early photographs from his second expedition were available for numerous areas along the river. In many cases it was possible to stand in the exact spot where Powell had taken pictures nearly a hundred years before. Sometimes almost every rock and boulder in the old photograph could still be indentified, apparently little change having occurred in the intervening century. In other cases no rocks or boulders in the old photographs could be identified; the change was almost complete.

What made the difference? Sudden catastrophes! Some side canyons had experienced periods of extreme flooding that completely altered the surface features, whereas other nearby canyons had not. At Crystal Creek (mile 99) a 1966 flash flood carried debris down from the North Rim and, within the space of a few *hours,* completely altered the surface features at the point where the creek enters the Colorado River. In fact, that single event created what is now one of the most exciting and vigorous rapids along the entire river. The differences observed along the Colorado River over the last hundred years cannot be explained by slow, uniform changes. Rather, the explanation seems to be a series of sudden changes that have taken place, with most of the actual change occurring in the space of a few hours.

Geologists are using this kind of explanation for a variety of geologic phenomena. Volcanic action is sudden, and the changes are often dramatic. Floods and hurricanes can accomplish more in a few hours to change the surface features of parts of the earth than hundreds of years of normal climatic activity could. Earthquakes and landslides often cause rapid geologic changes. Whether the concept of sudden changes will alter the overall need for time in the geologic record re-

mains to be seen. But it seems certain that as new data are obtained from the earth, a closer approximation to the truth will be possible.

SUMMARY

The purpose of this presentation has been to show that the current belief in enormous spans of time for the geological history of the earth *did not* result from the application of radioactive age-dating methods. This concept of vast time periods resulted largely from studies on rates of sedimentation and erosion and, contrary to some opinions, did not involve the theory of organic evolution.

The science of geology has its own methods and techniques. If one would learn from the earth the secrets of its past, one must learn to speak the language. The advice of Peter Severinus, the sixteenth-century Dane, to his students is still applicable today after 400 years:

> Go, my Sons, buy stout shoes, climb the mountains, search the valleys, the deserts, the sea shores, and the deep recesses of the earth. Look for the various kinds of minerals, note their characters and mark their origin. . . . Observe and experiment without ceasing, for in this way and in no other will you arrive at a knowledge of the nature and properties of things.[25]

No matter how man's theories about the age of the earth may change, never will it be old fashioned or outdated for the committed Christian to declare with the psalmist, "The heavens declare the glory of God; and the firmament showeth his handiwork," or to believe with the writer of Genesis, "In the beginning God created the heaven and the earth."

REFERENCES AND NOTES

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Diverse theories held that fossils were "discarded patterns left over from the creation" or "sports of nature" from the spontaneous generation of the earth. In the eighteenth century, fossils were considered as relics of Noah's flood; and before Cuvier's careful work on comparative anatomy, many skeletal remains of the larger vertebrate animals were thought to be human remains of the antediluvians.

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In his study of the fossils of the Paris Basin, Cuvier was joined by his associate, Alexandre Brongniart, who had a good knowledge of rocks and minerals. Some of the contributions often credited only to Cuvier should be credited jointly to Cuvier and Brongniart.

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