Transcription, June 2016:

Glasgow Herald, Issue 4 (4 January 1896): 6g-6h (A. G. Whyte).

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‘THE AGE OF THE EARTH.’

One of the most important influences on the progress of geology has been the study of problems connected with the length of time occupied by geological epochs. The earliest geologists were guided in their speculations by the authority of traditional belief embodied in the books of the Old Testament. They were forced by their allegiance to the teaching of the Church to accommodate their theories to the accepted account of the spontaneous creation of all organic beings as they at present exist. It was contrary to religious faith to imagine that the earth could be more than a few thousand years old, or that all geological formations could not be related to one universal flood of two months' duration.

The effect of this dominating idea can be realised only by the study of the history of the science. Until the beginning of the present century theories of the earth were of the most fantastic and speculative nature. Imaginary and supernatural agencies, extraordinary and alarming catastrophies, were freely called upon to explain phenomena which could not be rationally elucidated without violating this fixed belief in the literal interruption of Scriptural accounts of the Creation and the Flood. The pages of romance do not contain more whimsical notions than do the writings of the pioneers of geology. Glimmers of truth now and then appeared in these early works, but not until Hutton published his “Theory of the Earth,” one hundred years ago, did these feeble glows rise into a steady light. This admirable book, aided by the publications of Playfair, the talented exponent of Hutton’s views, effectually combated the catastrophic theories of its predecessors and placed the study of geological changes on a scientific basis. Observation took the place of speculation and the authority of act that of tradition, but not without a long and severe struggle. Philosophers, however much impressed by the value of geological facts and deductions, were loath to give up old and cherished ideas. They clung to their traditional faith in spite of the eloquent illustrations of Playfair and the philosophical reasoning of Lyell. The name of the geologist was, in the minds of many people fifty years ago, suggestive of atheistical tendencies, and such a subject as the age of the earth could not at that time be discussed without suspicion of irreverence. At the present day, however, it is one of the open questions of science, and has been freely debated by philosophers of high standing in various branches of study. The geologist, the physicist, and the astronomer have all applied their knowledge and means of investigation to the solution of this difficult problem, and their labours have had considerable effect in advancing the state of knowledge and thought in all their sciences.

Since the question was first raised, most of our foremost geologists have attempted a solution. Sir Charles Lyell was perhaps the first to publish an approximation to the antiquity of the habitable globe. He withdrew his calculation from the later editions of the “Principles of Geology” in which it appeared, but his estimate of 240 million years as the time occupied by geological changes since the formation of the first fossil-containing rocks, is interesting as indicating the periods contemplated by geologists thirty years ago. His investigation, regarded by many contemporary geologists as yielding much too moderate results, was founded on biological grounds. Biology, however, takes its ideas of time from geology; so it will be well to consider the more independent data furnished by purely geological research.

In the minds of geologists who followed the teaching of Hutton and Lyell, the world had in all past time been governed by present natural laws, which varied little in the intensity or character of their effects. Rain fell and rivers flowed, even as they do now; the earth revolved on its axis, and carried continent, island, lake, and ocean from sunrise to sunset even as it now does day by day. The present was to them the key to the past; what happened to-day was the repetition of what happened yesterday and also the forerunner of the events of tomorrow. The principle of uniformity in natural operations has been so ably and widely advocated that is has dominated the geological speculation of the century. One of its chief effects has been to convey the idea that geological time was infinitely great. According to the Uniformitarians, as the supporters of uniformity were called, the great mass of the rocks which constitute the visible framework of the globe was formed by agents still in daily operation. Rain, frost, running water, and sea waves gradually resolve the solid rock into sand and clay, which are washed down by rivers and deposited in the sea, there to be consolidated and raised at a future date to form a new land. The great magnitude of the work which this rock-forming process had performed during past geological epochs was revealed to geologists by their investigations in the "field." At the same time they became impressed by the extreme slowness with which this work was being carried on at the present day. River beds were but slowly worn away, and sea-cliffs long withstood the fury of breaking waves. The accumulation of the detritus of the land was, as a matter of observation, extremely slow. Assuming the uniformity of the action of natural forces throughout past time, geologists were thus lead to consider the time during which our geological formations were deposited as immeasurably [p. 6h] great. This opinion was supported by the majority of leading geologists, without powerful opposition, until Lord Kelvin in 1868 read a paper to the Geological Society of Glasgow on "Geological Time." He approached the question from the physical side, and his method of determination may be briefly indicated.

Observations made in borings and mines show that the temperature of the earth increases at a fairly uniform rate from the surface towards the center. The earth is losing heat by radiation into cold space, and it has been doing so since its formation. These two facts point a time when the earth was hot enough to be entirely molten, and the also afford, upon certain assumptions, supplemented by data furnished by experiments on rocks, a mathematical means of calculating the time which has elapsed since our globe was in that molten state. In this manner Lord Kelvin deduced the age of the habitual earth as about 100 million years. Being convinced of the general truth of his result, and impressed by the difference between it and the vast periods demanded by uniformitarian geologists, he was led to state that geologists' speculation was directly opposed to the principles of natural philosophy. He showed that since the energy of the solar system was being slowly dissipated through various causes, it must have revolved more quickly on its axis; these and many other changes must have influenced the rate of geological work in the past. Thus the eminent physicist was led to assert that "a great reform in geological speculation seemed to have become necessary."

This serious charge was answered by Professor Huxley in his presidential address to the Geological Society of London one year later. Uniformitarianism, the author endeavoured to show, was becoming a thing of the past, and many geologists freely admitted the greater intensity of natural forces in former ages. He also demonstrated that on purely geological grounds no longer a period than about 100 million years ago need by considered necessary for the accomplishment of terrestrial revolutions. Hi line of argument was that adopted by Haughton, Geikie, and other geologists, and supported by Lyell, as affording the best available means of estimating geological time. The land, as we have already seen, is being slowly worn down, and its detritus deposited by rivers in the sea. The rate at which this action is

proceeding may be ascertained with some approach to accuracy by a series of measurements of the amounts of sediment carried down by rivers in different parts of the globe. This is one factor in the calculation. The other is the thickness of the deposits which constitute the formations of past geological epochs. From careful measurements of the above quantities—the rate at which rock-matter accumulates and the thickness of rock-matter accumulates—Sir Archibald Geikie concluded that about 100 million years was something near the age of the earth.

Thus for the time being geology and physics were reconciled upon this important question, and the discussion remained comparatively in the background till at the beginning of the present year Professor Perry brought it once more to the front by endeavouring to prove that one of Lord Kelvin's assumptions was unwarrantable. It is needless to explain here how Professor Perry's objection was refuted by experiments previously made by many physicists and latterly confirmed in Glasgow University. The discussion had the important effect of drawing Lord Kelvin's attention to an article on the subject in the *American Journal of Science* by Clarence King. This writer had investigated the thermal properties of rocks under conditions which had not hitherto been considered, and on the strength of new data thus acquired he calculated, by Lord Kelvin's methods, that the age of the earth was approximately 24 million years. This estimate was upheld by Lord Kelvin, and once more geologists and physicists seemed unable to agree.

But the former had overlooked a most important element in their calculation. Alfred Russel Wallace in his excellent work "Island Life," was the first, I believe, to point out the source of error in the geologist's reasoning. The detritus of the land, he showed, was almost wholly deposited within 30 miles of the shore; beyond that the ocean bed was completely free from land-derived material. From measurements of the length of the coast line over the globe and the area of the land, he proved that the latter area—that over which denudation was proceeding—was about nineteen times greater than the area over which the sediments were laid down. Therefore, he reasoned, the rate of increase of thickness of sediments must be 19 times greater than the rate of decrease of the height of the land area. With this correction he estimated the age of the earth as about 28 million years, a period which, he added, was more probably over than under the true one.

Although this result differs by four millions of years from that arrived at by the physicist, it may be regarded, in a question of this nature, to be consistent with it. The data upon which both are based are very uncertain, and the solutions derived therefrom, by processes however accurate, must be correspondingly uncertain. The numbers of millions of years here stated as expressing the antiquity of the globe must therefore be looked upon as mere attempts to represent the order of magnitude of the length of a period we can little hope to exactly ascertain.

One more method of determination remains, and it is one to which the physicists have appealed in support of their results. It is founded upon the time during which the sun, considered as a cooling body, has been in approximately the condition in which we now end it. Since geological changes depend on the light and heat of the sun, the time during which these changes were proceeding must be limited by the time during which the sun has been radiating heat and light after the manner of the present day. Ball, Newcomb, Lord Kelvin, and others agree in emphatically stating that the sun cannot have thus illumined the earth for more than 20 million years. Therefore they conclude the age of the earth cannot be more than such some period, and they hold that the coincidence between the results obtained by the two methods, physical and astronomical, is a strong argument for their validity.

All of the methods discussed above are, however, based upon the assumptions of an arbitrary and questionable nature. Every one of the principal factors is liable to considerable alteration as experience and knowledge increase. The difference between Lord Kelvin's estimate of 1868 and that of the present year shows the effect of a change in only one of the data for calculation. Such vast strides are being made in the various sciences involved in the discussion that the computations of the antiquity of the globe must be accepted with much greater reservation than is sometimes indicated by their authors. The assuredness with which statements and deductions are advanced is liable to inspire to false coincidence in the mind of the reader.

As the question stands in the present, most geologists regard the restricted periods enforced by physicists as much too short. Sir Archibald Geikie, in reviewing the subject at the beginning of this year, says that "there seems at present every prospect that the physicists will concede not merely the 100 million years with which the geologists would be quite content, but a very much greater extent of time." There is, therefore, little likelihood that a satisfactory settlement will be arrived at for a long time, but the discussion must not for this reason be regarded as a waste of time and energy. It has brought to light many interesting facts both in physics and geology. Speculation in the latter science has been so much influenced that a writer in the *American Journal of Science* in 1893 concluded a resumé of the various estimates of the age of the earth with the remark:—"No more important conclusion in the natural sciences, directly or indirectly modifying our conceptions in a thousand ways, has been reached this century." The views of geologists have been broadened and deepened, and are now resolving themselves into rational foundation of theory and deduction. Geological speculation is no longer directly opposed to the principles of natural philosophy. This change is in part due to the rapid growth of purely geological knowledge, but also in great measure to the free investigation of the age of the earth by physicists, among whom Lord Kelvin has from the first maintained a leading position.

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