THE AGE OF THE EARTH'S CONSOLIDATION.

HOW SCIENTISTS ESTIMATE PERIODS OF TIME.

BY T. J. J. SEE.

THE assumption of an original uniform temperature for the earth is only a first approximation to the true condition, not justified by a closer examination of the subject. The mathematical theory of the heat distribution in a gaseous globe shows that the temperature increases rapidly toward the center, and hence falls off correspondingly near the surface. Relatively to the average temperature of the whole mass, that of the surface is very low, and that of the center quite high. This is the condition in a gaseous sphere, and it seems certain that it cannot be greatly modified by the surface cooling which leads to incrustation. This latter arises mainly from resisted circulation, and retarded supply of heat from the under layers, as the surface density increases. Prior to the beginning of surface cooling the planet passes through a stage of maximum temperature, and heat is both radiated and conducted through to the outer layers; but eventually the resistance to propagation of heat becomes so great that a fall of temperature is inevitable. In the case of the earth there is excellent reason to conclude that the surface temperature never much exceeded 2,000 deg. Fahr.

The experiments of Profs. Rücker and Roberts-Austen at the Royal College of Science, London, on basalt or dolerite, showed that this rock was completely fused at 1688 deg. Fahr. Basalt is a typical rock of the earth's crust, prevalent in nearly all volcanic districts; and it seems probable that a temperature of 2,000 deg. Fahr. would therefore not only fuse all the principal rocks of the earth's surface, but also reduce many of them to a state of vapor.

The fact that the other planets of our solar system are not at present self-luminous, though the larger masses are known to have high internal temperature, tells against the theory of a very high surface temperature also in the case of the earth. For although we view the other planets at only one stage of their existence, and therefore cannot fully judge of their conditions at other cosmical epochs, yet the absence of self-luminosity when so much heat is known to be stored up within these planets can only indicate that a great lowering of temperature always takes place near the surface, as is also true in a sphere of monatomic gas. Thus, it is not probable that even at the maximum the surface temperature of such masses would be very high. Lord Kelvin has estimated the temperature at 7,000 deg. Fahr., but there are clear indications that this is much too great, and in all probability we shall not be far wrong in using 2,000 deg. as the most acceptable value in all calculations on the secular cooling of the terrestrial globe. The temperature will increase with the depth, but for a shallow layer we may take it to be uniform; the temperature of 2,000 deg. then would not correspond exactly to the surface, but rather to the average of a thin sheet forming the boundary of the molten mass. As the outer layer was no doubt agitated from beneath, it would both lack in uniformity of temperature, and also be constantly changing, so that a mean temperature of 2,000 deg. Fahr. seems to be the closest approximation we can make to the true conditions.

Considering the earth to be a sphere of the same conductivity as ordinary rock, we can mathematically calculate its age since its crust first formed. Lord Kelvin, on an assumption of a crust of 7,000 deg. Fahr., calculated the age of the earth as 101,673,000 years. Following his calculations, but estimating the crust heat at 2,000 deg. Fahr.—which is now agreed on as a more probable figure—we get an age of 8,302,210 years. Accordingly, we conclude from this that the age of our incrustated planet can scarcely exceed ten million years, which accords very well with the duration inferred from the theory of the sun's heat.

The Rev. O. Fisher has developed another method for calculating the age of the earth, based on a consideration of the thickness of the crust and its gradual loss of heat. Considering the thickness of the crust as 17.5 miles, which is very near the thickness indicated by the San Francisco earthquake, the age of the earth appears as 5,262,170 years. Fisher, however, calculates the crust as not exceeding 21.91 miles. Taking this latter figure, the age of the earth is found to be 8,248,380 years.

This agreement with Lord Kelvin's figures is the more interesting since the Rev. O. Fisher cannot reconcile it with what he has hitherto thought the approximate age of the earth, and he endeavors to explain it away. He says:

"This is a far shorter period than geological phenomena appear to require, for although it is not possible for them to assign any definite limit to the world's age, we can form some idea of an inferior limit which it must have exceeded. Sir A. Geikie thinks that the stratified rocks alone, which contain

organic remains, cannot have taken much less than 100 million years for their formation."

He then proceeds to examine the hypothesis of an energetic substratum, and by this process reaches a greater age for the world. But the hypothesis of an inert substratum is obviously the proper one. For the substratum is shown to move only under the throes of an earthquake, and no circulatory movement of lava exists even just beneath the crust. Hence we adhere to the result there obtained, and must consider the significance of the small age of the earth. It will be seen that for a thickness of 22 miles, the age of the earth's consolidation is almost exactly the same as that reached by the use of Lord Kelvin's formula.

The result found by Lord Kelvin's method rests upon the observed rate of increase of temperature downward, namely, 1 deg. Fahr. for 51 feet, which is about the same as the value used by Fourier nearly a century ago, and not improved upon by the deep borings made in recent years. It also rests upon the assumed surface temperature of 2,000 deg. Fahr., which probably is comparatively near the truth. Is it purely an accidental coincidence that with these data one is led by the Fourier-Kelvin formula to an age of 8,302,210 years, while by Fisher's formula, depending on the thickness of the crust essentially verified by earthquake phenomena, one finds the almost identical age of 8,248,380 years? Moderate variations of the data might derange this excellent agreement somewhat, but probably no change of the constants within admissible limits would produce extreme discordance in the resulting ages of the earth. It seems, therefore, difficult to escape the conclusion that these figures really approximate the true age of our incrustated planet. At least the period since the consolidation is of the order of ten million years.

Different investigators will naturally form different estimates of the age of the earth as found by the several different methods of approximation; but it is difficult to see how the larger values formerly current can be justified by physical research based on the propagation of heat involved in the secular cooling of the globe. The writer has not the geological learning requisite for the use of the methods based on sedimentary rocks and their deposits of organic remains, but it seems very doubtful if these methods can lay claim to even approximate accuracy; and to most minds the conclusions drawn from the physical methods will naturally carry much greater weight.

Some considerations, however, based on the probable average rate of the elevation of the Andes, taken at only one-tenth of an inch a year, or ten inches in a century, seem to show that the age of these mighty mountains need not much exceed three million years. In the case of the mountains west of the Rockies a numerical estimate is not quite so easy, but it is doubtful if anything authorizes an estimate exceeding five million years. In this immense period the whole country west of Laramie may have been raised from the sea; in fact, this is indicated by the abundant fossils of saurians in the beds of Wyoming, as well as by the numerous parallel ranges of mountains in Nevada and California, showing the successive recessions of the sea. One is led, therefore, to think that, after all, our consolidated globe may not have an age exceeding eight or ten million years. In comparison with the brevity of human history, such periods are almost infinite; and so little is known of the rates of variation of organic species under the unknown conditions of the past, that we may well hesitate before assuming longer periods for the life of our incrustated planet.

In contemplating this result we are again confronted with the question of the cosmical significance of radium. Several years ago, when the enthusiasm over the radium discoveries was at its height, there were those who admitted a terrestrial history of a thousand million years. But mysterious as radium still remains, it is doubtful if such a view is generally held to-day. It is a remarkable fact that the more we study radium, the less we seem to really understand the part it plays in cosmical processes. So far, at least, there is no proof that it exerts any sensible influence, except possibly in chemical transformations.—Abstracted from Popular Astronomy.

THE BEAUFORT SEA.

THE vast archipelago reaching from the vicinity of Greenland westward to the boundary line which touches the continent 400 miles east of the eastern boundary of Alaska incloses an area which was explored by Capt. Einar Mikklesen and Mr. Ernest Leffingwell, some one or two years ago. An account of the expedition has been published in the Bulletin of the American Geographical Society. The northern edge of this

group slopes away from Grant Land in latitude 83 to Prince Patrick Island, a short distance above the 77th parallel, and the region of which we speak, concerning which little or nothing was formerly definitely known, lies between the archipelago and the land extending northward to Bering Strait. It is called Beaufort Sea by geographers, owing to their belief that there is a practically unbroken stretch of ocean from Alaska to the pole. The plans of the expedition unfortunately miscarried, and it was impossible to set up winter quarters on the western edge of the archipelago in Bank's Land. If this depot had been established, a sledge journey would have been made afterward in a westerly direction from Prince Patrick Island, during which soundings through the ice could have been made, showing whether or not water existed underneath. Owing to the necessity of abandoning the vessel at Flaxman Island near the Alaskan coast, the sledges of the party were driven nearly 100 miles from the continent, during which journey the inquiry regarding the depth of the sea was carried on. It was found that for two-thirds of the distance the water was shallow. It then suddenly deepened, and with more than two thousand feet of line out the bottom could not be reached. This led to the inference that the "continental shelf" extends not more than sixty miles from the coast. It is held by many geographers that it is hopeless to look for large islands in the Arctic Ocean after the continental shelf has been passed; they would feel that the existence of water was determined if the position of the boundary of the continental shelf could be accurately determined. There is, of course, a slight chance that Capt. Mikklesen followed a "submarine valley" and had not left the true continental shelf. Much of the ice traversed was of a variety seldom formed except in a landlocked sea, while certain peculiarities in the set of the currents indicated the probability of the existence of a barrier to the eastern of the path to be followed. This makes the finding or the discovery of a large island in Beaufort Sea, while not absolutely removed, a very remote possibility.

KILLING OFF OUR BIGGEST BIRD OF PREY.

TO-DAY the California condor—the largest bird of prey inhabiting the United States—is represented by a miserable remnant lingering in southwest California; its distributional area, once extending as far north as the Fraser River in British Columbia, is now a mere dot on the map.

In the old days it abounded every spring on the Columbia River, feeding on the salmon cast up on the shore. It hung round the Indian villages for the sake of the offal thrown away, and, together with ravens and turkey buzzards, visited the water-falls and cascades of the salmon rivers. The fish, being obliged to take leaps at these places in their progress along the stream, often landed themselves high and dry among the bushes, and thus provided a meal for the expectant condors. The present species also fed on carrion, and was very voracious. When on the ground this condor walked with a strut, like a turkey, but was obliged first to run or hop several yards before launching itself into the air. Once on the wing its flight was slow, steady and graceful, its noble proportions dwarfing the turkey buzzards in the same valley to mere swallows.

"Their quills are used by the hunters for tobacco-pipes," observed Mr. David Douglas many years ago. "Recently the Mexican and Indian gold-seekers have well-nigh exterminated the California condor for their magnificent hollow quills, which afford rough-and-ready purses for carrying gold-dust!"—The Zoologist.

THE WORLD'S PRODUCTION OF COAL.

THE world's production of coal in 1906 amounted to about 1,106,478,707 short tons, of which the United States produced 414,157,278 tons.

Since 1868 the percentage of the world's total coal produced by the United States has increased from 14.32 to 37, and this country now stands far in the lead of the world's coal producers. In 1906 the United States produced 43.7 per cent more coal than Great Britain and 85 per cent more than Germany. Exclusive of Great Britain the United States in 1906 produced more coal than all the other countries of the world combined.

It is interesting to note that 96 per cent of the world's coal production is mined north of the equator. Australia is the only continent lying entirely to the south of the line. More than half the area of Africa lies to the north, and Europe and Asia are entirely north of the line.