# HOW THE WORLD CHANGES.

*WHEN NEW YORK CITY MAY BE CRUSHED BY A GLACIER.*

**Mr. James Croll's Climate and Time—Effects of Meteorological Changes on the Earth's Crust—Puzzling Questions of Geology—When we May be Desolated by Cold.**

Geology shows that during past ages the earth's crust has undergone successive changes and modifications. The theory that these alterations have been effected by convulsions and cataclysms of nature is now abandoned; and it is held that they were caused by the ordinary meteorological agencies. "The valleys were not produced by violent dislocations, nor the hills by sudden upheavals, but were actually carved out of the solid rock, silently and gradually," by these agencies. "The tools," says Prof. Geikie, "by which this great work has been done, are of the simplest and most everyday order—the air, rain, frosts, springs, brooks, rivers, glaciers, icebergs, and the sea. These tools have been at work from the earliest times of which any geological record has been preserved. Indeed, it is out of the accumulated chips and dust which they have made, afterward hardened into solid rock, that the very framework of our continent has been formed." These climatic agencies, we therefore, the geological agents; and it follows that "in order to a purely scientific geology, the grand problem must be one of geological climate. It is through geological climate that we can hope to arrive ultimately at principles which will afford a rational explanation of the marvellous facts which have been accumulating during the past century."

These effects of meteorological agencies, as exhibited in the earth's crust, demonstrate very extraordinary changes of climate. The discovery of the glacial epoch, and of the fact that a mild temperature extended during the Miocene and other periods to North Greenland, show that at one time a large portion of what is now the temperate clime was buried under ice, while at other times Greenland and the Arctic regions, probably up to the North Pole, were not only free from ice, but were covered with a rich and luxuriant vegetation." It is obvious that to account for these rare changes of climate will be to explain, in a very satisfactory degree at least, some of the most puzzling questions of geology. But to find a reason for these variations which should be in all respects satisfactory, has been esteemed the hardest problem placed before geologists. Many theories have been advanced only to be proved insufficient, such as "a displacement of the earth's axis of rotation in consequence of the uprising of large mountain masses on some part of the earth's surface;" "that the earth during its past geological history may have passed through hotter and colder parts of space;" "a change in the obliquity of the ecliptic;" "that the sun is a variable star, and that the glacial epochs of the geologist may correspond to periods of decrease in the sun's heat;" and the theory of Sir Charles Lyell, in which "those extraordinary changes of climate are attributed to differences in the distribution of land and water."

The inadequacy of Sir Charles's theory, as well as of the others mentioned, is made apparent by Mr. James Croll, in his *Climate and Time*. Applications. This writer makes it sufficiently plain that Sir Charles "does not duly take into account the prodigious influence exerted on climate through the heat conveyed from equatorial to temperate and polar regions by means of ocean currents; and that the effect of placing all the land along the equator would be diametrically the opposite of that which Sir Charles supposes."

For a long time geologists have cherished a growing impression that the glacial epoch and the extraordinary temperature of the climate in Arctic regions during the Miocene and other periods, must have resulted from some astronomical cause. But they have been unable to determine what that cause might be. Laplace showed that the change of obliquity of the ecliptic was comparatively too small to seriously modify climate. The eccentricity of the earth's orbit was the only remaining conceivable cause of the geologically recorded mutations; and more than forty years ago Sir John Herschel and some other astronomers turned their attention to its consideration. But the drift of their conclusions was that change of eccentricity could not greatly affect the earth's climate.

Mr. Croll thinks that these gentlemen disregarded a material consideration.

"The important fact, however, was overlooked that, although the glacial epoch could not result directly from the eccentricity of the earth's orbit, it might indirectly be the result of it. Although increase of eccentricity does not by itself produce a glacial epoch, it may produce it indirectly when it acts as a cause to bring into operation other agencies which of themselves would be inadequate to produce the glacial epoch. Of these agencies the most important are those which have their seat in the ocean. Now, it is well known that the climate of the northern hemisphere is very much influenced by the ocean currents. There are circumstances to which I refer it was impossible that the true cause of the glacial epoch could have been discovered, and, moreover, none of the indirect effects of the eccentricity which, when brought into the glacial epoch, could not in the slightest degree have been known previously to recent discoveries in the science of heat."

You see from this that Mr. Croll believes the eccentricity of the earth's orbit to be the primary cause of those great changes of climate that are known to have taken place in our globe. But to make this appear, it is especially necessary for him to show that the system of ocean currents is produced by the general system of winds, in order to connect the chain of intermediate physical agencies; and, consequently, for him to refute the arguments of those who have assigned any other plausible cause for these currents. He reduces the theories on this subject to two divisions, the first of which attributes the motion of the water to the impulse of the wind, and is the one that he sustains; the second attributes the motion of the water to the force of gravity brought into action by difference of density. He divides the supporters of this second theory into two classes, and regards Maury as the representative of the first, which professes to find a sufficient cause for the Gulf Stream and other ocean currents in a difference of specific gravity; and Dr. Carpenter as the representative of the second, which "affirms that there is a general movement of the upper portion of the ocean from the equator to the poles, and a counter movement of the under portion from the poles to the equator. This movement is attributed to difference of specific gravity between equatorial and polar water, resulting from difference of temperature."

Very calmly, candidly, minutely, and thoroughly Mr. Croll examines both branches of the gravitation theory, applies to alleged and admitted facts the test of well-established mechanical principles, and shows that the supposed cause is utterly inadequate to the known effect. In regard to Lieut. Maury's discussion of the subject he goes further, and proves by citations from that writer's most famous work that its author attempts to demonstrate the existence of two causes which neutralize each other:

"Here we have two theories put forth regarding the cause of ocean currents, the one in direct opposition to the other. According to the one theory, ocean currents exist because the waters of the equatorial regions are less dense than the waters of the polar regions, and according to the other theory ocean currents exist because the waters of equatorial regions, in consequence of their greater saltness, are more dense than the waters of the polar regions. If the one cause be assigned as a reason why ocean currents exist, then the other cause is equally assigned as a reason why they should not exist. According to both theories the difference of density between the two masses of water is the cause that gives rise to currents, but while the one theory maintains that the equatorial waters are lighter than the polar, the other theory maintains that they are heavier. If the theory of the one be true, then that of the other must be false, and it is logically impossible that both of them can. It is true that it is not two currents, the one contrary to the other, with which we have to contend in this inquiry, but it is one current producing effects in one direction and another producing current in the contrary direction. In the discussion regarding the origin of the winds, the one mainstay is opposed to the other."

The importance of finding the true cause of ocean currents, as a step toward solving the problem and giving an adequate and intelligible reason for the extraordinary changes of climate that have occurred since geological history began to be formed, is shown by the exhibition of some facts in regard to the influence which these currents now exercise on the temperature of different zones. These facts have been furnished by recent discoveries in relation to the science of heat, and the information obtained through explorations of the sea. The Gulf Stream conveys as much heat as is received from the sun by 1,500,955 square miles at the equator; and as much as all the heat received from the sun by 2,062,993 square miles of the temperate region. If due allowance be made for the loss in polar regions, in consequence of the obliqueness of the sun's rays, the heat conveyed by the Gulf Stream will probably be equal to about one-half the amount received by the entire Arctic region of 8,130,000 square miles.

The total area of the Atlantic from the latitude of the South of Florida, 266 miles north of the Tropic of Cancer, to the Arctic Circle, is 10,000,000 square miles; it is about 85,000,000 square miles. In this case the quantity of heat carried by the Gulf Stream into Atlantic through the Straits of Florida is to that received by this entire area from the sun as 1 to 4.12, or to round numbers as 1 to 4. It therefore follows that at least one-fourth of the heat received by the Atlantic is due to the Gulf Stream. Would those who call in question the efficiency of the Gulf Stream be willing to admit that a decrease of one-fourth in the total amount of heat received from the sun, yet the entire area of the Atlantic from within 200 miles of the tropical zone to the Arctic regions, would not sensibly affect the climate of Northern Europe? If they would not willingly admit this, why, then, contend that the Gulf Stream does not affect climate? for the stoppage of the Gulf Stream would diminish the Atlantic of 27,429,750,000,000,000 pounds of energy in the form of heat per day, a quantity equal to one-fourth of all the heat received from the sun by that area.

Were all ocean currents stopped, the mean annual temperature of the equator would be 135 degrees Fahrenheit above zero, and that of the poles 85 degrees below zero; that is to say, the equator would be 55 degrees warmer than it is now, and the poles 81 degrees colder. It seems obvious enough that this condition of climate would be induced, approximately, by the substitution of land for water in the equatorial clime, since it is hard to avoid the conclusion "that ocean currents are the great agents employed in distributing over the globe the excess of heat received by the sea in intertropical regions;"

"Let us try to raise the temperature of the whole earth, water should be placed along the equator, and land, as it is supposed by Maury, carried to the north and south, and replaced at the equator, the possibility of conveying the sun's heat from the equatorial regions by means of ocean currents is prevented. The transference of heat could then be effected only by means of the upper currents of the trades; for the heat conveyed by ocean currents along the sea bottom, if any, can be no sensible help in the transference of heat from the equator, for convecting heat. They might remove the heat from the equator, but they could not, as we have already seen, carry it to the temperate and polar regions; for the heat carried by the lower currents would be required to remove from the equator the quantity of heat which would be dissipated into stellar space; the ocean would convey the heat to the south, where, instead of being of any benefit, it would be a hindrance. But, in the upper currents, the heat would be in the proper direction, and, as we have seen, would be required for convecting it. They might remove the heat from the equator, but they could not, as we have already seen, carry it to the temperate and polar regions; for the heat carried by the lower currents would be required to remove from the equator the quantity of heat which would be dissipated into stellar space; the ocean would convey the heat to the south, where, instead of being of any benefit, it would be a hindrance. But, in the upper currents, the heat would be in the proper direction, and, as we have seen, would be required for convecting it.

"Suppose also that the warm currents, having been withdrawn from the northern hemisphere, would flow into the South with a velocity equal to the velocity of the southern hemisphere? Such a transference of heat would raise the temperature of the latter hemisphere, and would lower that of the former. It would consequently raise the mean temperature of the antarctic regions much above what it now is, and, in the manner which those regions are at present situated would, in a great degree, at least, disappear. The northern hemisphere, thus deprived of the heat from the equator, would be under a condition of climate similar to what we know it was during the glacial epoch, while the other hemisphere, receiving the heat from the equator, would be under a condition of climate similar to what we know it was in the northern hemisphere during a part of the Upper Miocene period, when North Greenland enjoyed a climate as mild as that of England at the present day.

Admitting that the truth of what has been said can be established by incontestible proofs, it must follow that any cause which should produce a deflection of these ocean currents from the northern into the southern hemisphere, would be the primary motive of glaciation in that half of the globe from which the currents should be turned. Mr. Croll very strongly maintains that such a cause is the eccentricity of the earth's orbit, which, by calling intermediate agencies into action, brings about the most extraordinary changes of climate. When the eccentricity is at its greatest limit, the earth in aphelion is 16,212,700 miles farther from the sun than it is in perihelion. The direct heat of the sun is inversely as the square of the distance; therefore the amount of heat received by the earth when in these two positions will be as 19 to 23.

The reduction in the amount of heat received from the sun owing to its increased distance would lower the annual temperature to an enormous extent. In the present case the effect of the eccentricity of the orbit is greatly modified by the fact that the greater part of the land of the globe happens to be in that hemisphere which is exposed to a long extent of snowy winter when the sun is at a great distance, and the very small portion which falls as show should be melted by a short summer and a mild winter. The trades on that hemisphere will be necessarily exceedingly powerful, while on the other hemisphere, where there is comparatively little snow to melt, and where it would be melted by the comparatively short summer, the trades would be comparatively feeble. According to Sir Charles Lyell, the northern trade winds of this hemisphere will be found to be the strongest, and the southern trade winds of the southern hemisphere. The seasons are not between the tropics so much as in the temperate zones, and consequently there is no great difference between the trades of the two hemispheres at the equinoxes. But when the sun is in aphelion, the length of the winters will be to that of the summer as 7 to 5; that is, the winters will then last only 1½ days longer than the summer, but the trades will also be much longer. At present the winter trades are to the summer trades as 4 to 3; but when the sun is in aphelion, the winter trades will be to the summer trades as 7 to 5. Now, if the winter trades be equal, the longer the snow accumulating period, the greater the accumulation.

Thus, when the short summer should begin, the ground would be covered with this extra accumulation of snow; and in turn this snow would lower the summer temperature, and to a great extent prevent melting. In three ways masses of snow and ice tend to lower summer temperature: First—By direct radiation, which tends to lower the temperature of all surrounding bodies to thirty two degrees. Second—By reflection of the sun's rays back into space. Those rays which are not reflected, but absorbed, do not raise the temperature. They disappear in the work of melting the ice, every pound of which is fused at an expense of heat enough to raise a pound of water to 142 degrees. Third—By chilling the air and condensing vapor into thick fog. The thick fogs and cloudy sky would prevent the sun's rays from reaching the earth, and the snow, in consequence, would remain during the summer.

Other causes being equal, the quantity of solar heat received in Greenland during summer is considerably greater than in England. Consequently, were it not for snow and ice, it would enjoy as warm a climate during summer as that enjoyed by England. But the snow and ice extend to the latitude of England, and our summers of cold country would be as cool as those of Greenland. Our summers would then be as cold as our winters are now, and our winters would be middle of summer would be as common as rain.

While this lowering of temperature is induced on the hemisphere which has its winters in aphelion at the time when the earth's orbit is at its superior limit of eccentricity, an effect exactly the opposite of this will be produced on the other hemisphere which has its winters in perihelion. There the shortness of the winters and the higher temperature caused by the nearness of the sun will unite to prevent the accumulation of snow. Thus while one hemisphere is cooled the other is heated.

Now, let it be admitted that the ocean currents are caused by the system of winds, since they are shown to be a sufficient cause for such an effect, and since other supposed causes can be proved insufficient; since also many known facts go to sust in this theory; how then will these currents be affected by these conditions of climate?

Owing to the great difference between the temperature of the glacial and other periods, there is a reversal of air from the poles to the equator. It is to this that the trade winds owe their existence. Now, as the strength of these winds is a great rule, it depends upon the difference of temperature that may exist between the equator and higher latitudes, it follows that the trades on the cold hemisphere will be stronger than those on the warm hemisphere. Suppose, then, that the glacial period comes on, and that the northern hemisphere are covered to a large extent with snow and ice, the air is kept almost in the freezing point of water all the summer and winter. The trades on that hemisphere will be necessarily exceedingly powerful, while on the other hemisphere, where there is comparatively little snow to melt, and where it would be melted by the comparatively short summer, the trades would be comparatively feeble. According to Sir Charles Lyell, the northern trade winds of this hemisphere will be found to be the strongest, and the southern trade winds of the southern hemisphere. The seasons are not between the tropics so much as in the temperate zones, and consequently there is no great difference between the trades of the two hemispheres at the equinoxes. But when the sun is in aphelion, the length of the winters will be to that of the summer as 7 to 5; that is, the winters will then last only ½ days longer than the summer, but the trades will also be much longer. At present the winter trades are to the summer trades as 4 to 3; but when the sun is in aphelion, the winter trades will be to the summer trades as 7 to 5. Now, if the winter trades be equal, the longer the snow accumulating period, the greater the accumulation.

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