## Geological Climates

I NOW proceed to justify my statement, which has caused Mr. Wallace great surprise, viz. :—

"It is impossible to suggest any rearrangement of land and water which shall sensibly raise the temperature of the west of Europe, or sensibly depress the temperature of the east of North America."

It is proverbially difficult to prove a negative, and the only way to do so in this case is to show that any given redistribution of land and water is incapable of producing the effects ascribed to it.

I have already shown that Mr. Gardner's proposed redistribution by means of a land connection between Greenland and Europe would fail to benefit the west of Europe. In like manner I shall now demonstrate that Mr. Wallace's redistribution of land and water is quite inadequate to raise the temperature of the west of Europe.

Mr. Wallace's proposal is to introduce two new Gulf Streams into the Arctic Ocean, in addition to the present Gulf Stream.

1. The first of these additional Gulf Streams would be the Kuro-siwo, admitted through a widened Behring's Strait, the effect of which, he estimates, would be *to prevent altogether the formation of ice in the Arctic Sea.*

2. The second additional Gulf Stream is provided by allowing the waters of the Bay of Bengal and of the Arabian Sea an outlet to the north through the Caspian depression into the Arctic Ocean. The effect of this second Gulf Stream, he estimates, would be *to raise the temperature of the Polar ocean from 15° F. to 20° F. above the freezing point of water.*

This mode of raising the temperature of the Arctic regions, so as to allow of the growth of their Miocene flora, occurred to me when speculating on the former high temperatures of these latitudes, but I rejected it as inadequate to account for the change of climate required for the following reasons. But before giving these reasons I wish to add that Mr. Wallace has given two precise statements involving quantitative results, without giving the numerical grounds on which he made those statements.

The following are the grounds on which I deny the adequacy of Mr. Wallace's causes of change of climate:—

(*a*) *Air and Water.*—Warm winds and cold winds are in themselves of little consequence in influencing climate, except they blow over a large expanse of warm or cold water; they are in fact only heat and cold carriers for the water. The specific heat of water is more than four times that of air, and water is 815 times heavier, bulk for bulk; therefore one cubic mile of water will contain as much heat as 3260 cubic miles of air at the same

temperature. From this it follows that the temperature of the air at the surface of the sea corresponds with the surface-temperature of the water. This has been fully confirmed by observations made in every latitude, which show that the difference of temperature between the air and sea is never more than one or two degrees Fahrenheit.

(*b*) *Gulf Stream.*—The temperature of the air above the Gulf Stream is :—

| | | | |
|---|---|---|---|
| 62° F. at latitude | 40° | ... | 45° F. at latitude 60° |
| 53 ,, ,, | 50° | ... | 35 ,, ,, 70° |

and the quantities of water contained in the Gulf Stream are :—

| | | | | |
|---|---|---|---|---|
| 36 cubic miles per hour at latitude | | | | 50° |
| 36 | ,, | ,, | ,, | 60° |
| 24 | ,, | ,, | ,, | 70° |

The mean annual temperatures of the several latitudes, in the northern hemisphere, are, taken all round the globe—

| | | | |
|---|---|---|---|
| 29·3° F. at latitude | 60° | ... | 4·5° F. at latitude 80° |
| 14·4 ,, ,, | 70° | ... | 0·0 ,, ,, 90° |

From this it is evident that the Gulf Stream is inadequate to keep the temperature of the Polar cap, from the Pole to 60° lat., above the freezing-point of water; so that if the heat and cold were uniformly distributed, the whole of this great area would be permanently frozen over, the thickness of the ice being greatest at the Pole, and least at lat. 60°.

This ideal ice-cap (on the supposition of uniformly distributed heat and cold) represents accurately the amount of heat that must be introduced into the Arctic regions before their temperature rises to that of the freezing point of water. Its southern limit is lat 58° 51′, where the mean annual temperature all round the globe is 32° F.

The thickness of this ideal ice-cap at the Pole is unknown, but from what we know of the palæocrystic ice of Bank's Land and Grinnel Land must be measured by hundreds of feet; and its mean temperature must be at least 20° F. below the freezing point of water.

Mr. Wallace has put forward the supposition that the introduction of an equal proportion of the Kuro-siwo (to that of the Gulf Stream) would prevent the formation of sea-ice in the Arctic Sea. Before this could happen, the Kuro-siwo must first melt the ice-cap, and then keep it from freezing again.

To show how inadequate this supposition is, I shall calculate what the Gulf Stream has already done, and then show what the Kuro-siwo could do.

Let us suppose that the whole heat of the Gulf Stream, passing northwards through the parallel of 70° N., is employed in melting a supplementary ice-cap extending from the Pole to 70° N. and that this supplementary ice-cap is at the temperature of 32° F. only (*mere ice-sludge*); I find the thickness of ice melted is only 5·874 feet[1] yearly.

If therefore the Gulf Stream were cut off by a barrier at 70° N. lat. an additional growth of ice at 32° F. less than 6 feet thick might grow upon the area from the Pole to 70° N. lat.

Of course the Gulf Stream expends its heat in melting local ice in the Spitzbergen and Barentz Seas, and perhaps still further east in summer along the Siberian coast, and not in melting the supplemeatal ice-cap I have imagined; nevertheless the whole work done by it does not exceed the melting of the ice-cap from the Pole to 70° lat., and of a uniform thickness of 5·874 feet. In other words, the work done by the Gulf Stream north of 70° lat. is equivalent to the melting of 4382 cubic miles of ice at 32° F., which represents a definite quantity of heat. It is however much easier to conceive the ice-cap from the Pole to 70° lat., of 5·874 feet thick, than 4382 cubic miles of ice.

As the ice melted between the Pole and 70° lat. has a temperature of 6° F., instead of 32° F., it is easy to see that the thickness of ice-cap melted by the Gulf Stream is 4·813 feet instead of 5·874 feet.

(*c*) *The Kuro-siwo admitted through Behring's Strait.*—Mr. Wallace quotes me as stating that the volume of the Kuro-siwo is 2½ times the volume of the Gulf Stream: I believe it to be so, but in the present discussion shall consider it to be only twice as great; for at least one-fifth of it obtains partial entrance into Behring's Strait, and behaves like the Gulf Stream; as appears from the lesser rigour of the climate of the Parry Islands, from the open water discovered by Collinson along the northern coast of America, and from the return cold current of the coast of China.

From the calculations I have just given it appears that the Kuro-siwo current admitted through a widened Behring's Strait would be competent to melt a thickness of ice-cap extending from the Pole to 70° lat., amounting to 9·626 feet.

I shall leave your readers to judge whether this amount of ice-melting justifies Mr. Wallace in asking "Suppose that only an equal proportion (to that of the Gulf Stream) of the Kuro-siwo entered the Arctic Ocean, is it not probable that no sea-ice at all would form there?"

To me this question appears like a proposal to Hercules to clean out the Augæan stables with a teaspoon.

(*d*) Let us now add on the *Mozambique Current*, converted into a *Caspian depression Gulf Stream.* Of this current I cannot allow Mr. Wallace to appropriate more than half, unless he shows cause for a land barrier preventing the other half from continuing its present course into the southern hemisphere, there to aid in mitigating the climates of the Temperate and Antarctic zones.

The *Caspian Gulf Stream* will then cut off another slice of 3·609 feet in thickness from the ice-cap extending to 70° lat. Is this amount of ice-melting sufficient to perform the feat assigned to it by Mr. Wallace of "raising the former [the Polar sea] to perhaps 15° or 20° F. above the freezing point"?

(*e*) If there be any truth at all in the power of Gulf Streams to modify the climates of the Temperate and Polar zones, the southern hemisphere should be warmer than the northern hemisphere, as it receives three Gulf Streams instead of 1½ Gulf Streams (without discussing their relative volumes).

This is the actual fact, as is easily proved, notwithstanding the iterated parrot-like statements to the contrary copied from text-book to text-book.

I have shown that, taking the annual mean temperature at all longitudes, the cold of the northern hemisphere is represented by an ideal ice-cap which is thickest at the north pole and terminates in the latitude 58° 51′ N., where the mean annual temperature is 32° F.

In the southern hemisphere, the latitude at which the mean annual temperature for all longitudes is 32° F., is found at 62° 41′ S. This limit of the ideal southern ice-cap (measuring the Antarctic amount of cold) lies nearer to the South Pole by 3° 50′, or 230 geographical miles, than the corresponding limit of the northern ice-cap from the North Pole.

These limits of ideal ice-cap at the North and South Poles are independent of the wholly different question as to which of the Poles has the largest volume of ice surrounding it, into which I shall not enter at present.

(*f*) From what I have proved above it is evident that the two return compensating currents from the Arctic seas will still consist of ice-cold water, one of which, on the coast of Asia, of double the volume of the Labrador current, will reduce the climate of China and Northern Japan to a condition compared with which the present climate of Hudson's Bay would be a Garden of Eden; and the other would bring the Ural range and Eastern Europe into the present condition of Labrador. I think it is evident, under these latter conditions, that Bournemouth would suffer, and not gain, by Mr. Wallace's arrangements of land and water. The services rendered to the Arctic lands by the two new Gulf Streams would, in my opinion, be dearly purchased by the damage done by their compensating currents in the sub-tropical latitudes of Eastern Asia and Eastern Europe.

SAML. HAUGHTON

Trinity College, Dublin, December 31, 1880

[1] I assume the following data :—Area from Pole to 70° lat. = 4,476,200 sq. gr. m.; latent heat of ice-cold water = 144° F.; Gulf Stream = 24 cub. miles per hour; temperature = 35° F.