ART. L.—*On Eccentricity and Perihelion Longitude of the Earth's Orbit as a cause of change of Climate.* From the Presidential Address before the Geological Society of Dublin, by Rev. SAMUEL HAUGHTON, in February, 1882.

ANOTHER astronomical cause of change in geological climate was proposed by Adhemar, and afterward worked out more fully by Croll, J. Murphy and Wallace.

This is the secular variation in climate depending on the eccentricity and perihelion longitude of the earth's orbit.

The change depending on the position of the perihelion is completed in about 21,000 years; while that depending on the eccentricity requires much more time to pass through its course. In fact, astronomers have proved that the eccentricity of the earth's orbit may have been $\frac{1}{12}$th instead of $\frac{1}{60}$th, as at present; but are unable to say how long ago the maximum eccentricity occurred.

Adhemar, Croll and J. Murphy deduce from this astronomical cause the alternate glaciation of the northern and southern hemispheres every 21,000 years, which glaciation is more or less severe in proportion as the eccentricity during the perihelion period is greater or less. Mr. Croll, however, places the glaciation of a hemisphere in the time when its winter solstice is in aphelion; whereas Mr. J. Murphy places the glaciation of a hemisphere in the time when its winter solstice is in perihelion.

I have given a mathematical demonstration of the form of this secular inequality in climate,* which may be thus expressed without the use of mathematical symbols:—

The mean annual temperature of any place varies as the eccentricity of the earth's orbit, and as the range of temperature from summer to winter jointly.†

Of these two factors of climate, viz: eccentricity and range of temperature, the first is astronomical and the second terrestrial, depending on distribution of land and water, on ocean currents and prevailing winds.

If we suppose the terrestrial factor to be the same, while the eccentricity attains its maximum, the greatest possible change in mean annual temperature for any place on the earth's surface turns out to be less than 5° F.; and in order to produce a sensible effect upon climate, we must suppose that the annual range (terrestrial factor) must vary also by variation in the dis-

* Proceedings of the Royal Society, 19th February. 1881.

† $\Theta_0 \propto \varepsilon\rho$, where Θ_0 = mean annual temperature; ε = eccentricity of earth's orbit; ρ = annual range of temperature at place.

tribution of land and water. This is of course possible; but such a variation must follow its own development, and be quite independent of eccentricity or perihelion.

I shall allow, however, the advocates of this theory permission to make the terrestrial factor what they please (within the limits which the observed facts of climate permit), and then inquire whether the theory can account for geological climates.

1. I take as my first example the present climate of *Discovery Harbor*, Grinnell Land, close to the Miocene Plant-beds:—

July temperature, +37°·2 F.; mean annual temperature, −1°·7 F.; January temperature, −40°·6 F.; annual range, 77°·8 F.

I have elsewhere* shown that the July temperature of Discovery Harbor, during Miocene times, was probably higher than 63°·7 F.; that is to say, 26°·5 F. higher than its present amount. This would require, at the time of maximum eccentricity, an annual range of temperature greater than 120°·7 F.†

The foregoing amounts to a demonstration, that a change in the eccentricity of the earth's orbit from $\frac{1}{60}$th to $\frac{1}{12}$th would not produce in Grinnell Land the summer temperature necessary to ripen its Miocene fruits, unless it were accompanied by such a redistribution of land and water as would raise the annual range of temperature from 77°·8 F. to 120°·7 F.; that is to say, increase the already great range by more than half its present amount.

I have no hesitation in saying that (with the present quantity of sun-heat) this amounts to an impossibility.

The greatest range of annual heat now found in N. America occurs at *Melville Island*, where we have—

July temperature, +42°·35 F.; January temperature, −36°·40 F.; range, 78°·75 F.

The greatest known annual range of temperature occurs (as we might expect) in the northeastern part of Europasia. Observations taken at *Jakutsk* for seventeen years give the following results—

July temperature, +62°·15 F.; January temperature, −43°·82 F.; range, 105°·97 F.

This shows that even a redistribution of land and water, replacing N. America by a continent like Europasia, would still leave the annual range of temperature 16°·73 F. short of

* Lectures on Physical Geography, p. 321.

† For $\frac{\varepsilon\rho}{2}+\frac{\rho}{2} > 63°{\cdot}7 + 1°{\cdot}7 > 65°{\cdot}4$ F.; therefore, when $\varepsilon=\frac{1}{12}$, ρ must be greater than 120°·7 F., and if $\varepsilon=\frac{1}{60}$, ρ must be greater than 128°·7 F.

what the Miocene vegetation of Grinnell Land requires. This is a *Reductio ad absurdum* of the changes of geological climate produced by the secular inequality of the eccentricity and perihelion longitude of the earth's orbit.

Similar arguments may be applied to the other well-known Miocene Plant-beds of the high northern Atlantic latitudes.

2. For a second example, in Miocene times, *Spitzbergen* must have had a July temperature greater than 64°·4 F.* Its present climate is—

July temperature, +37°·2 F.; annual temperature, +16°·5 F.; January temperature, −4°·2 F.; range, 41°·4 F.

It is easy to see that the annual range of temperature in Miocene times in Spitzbergen must have exceeded 88°·4 F.† at the time of maximum eccentricity, in order to account for the fruits ripened there in summer.

This, although not an impossible case, like the former case of Grinnell Land, is yet quite incredible; for we have to imagine a redistribution of land and water such as would more than double the annual range of temperature in Spitzbergen, or raise it from 41°·4 F. to 88° 4 F.

3. The Miocene Plant-beds of *Disco*, on the west coast of Greenland, furnish a third proof that change of eccentricity of the earth's orbit is not sufficient to account for former geological climates. The present climate of Disco is—

July temperature, +44°·1 F.; January temperature, −4°·9 F.; annual temperature, +19°·6 F.; range, 49°·0 F.

The probable Miocene July temperature of Disco was greater than 72°·3 F.‡ From this it follows, that the annual range of temperature at Disco in Miocene times must have exceeded 97°·2 F., when the eccentricity of the earth's orbit was a maximum.§

* Lectures on Physical Geography, p. 332.

† For $\frac{\rho}{2}(1+\varepsilon) > 64°{\cdot}4 - 16°{\cdot}5 > 47°{\cdot}9$ F. This gives, when $\varepsilon = \frac{1}{12}$, $\rho = 88°{\cdot}4$ F.

‡ Lectures on Physical Geography, p. 340.

§ For $\frac{\rho}{2}(1+\varepsilon) > 72°{\cdot}3 - 19°{\cdot}6 > 52°{\cdot}7$ F.; $\rho(1+\varepsilon) > 105°{\cdot}4$ F.; and, when $\varepsilon = \frac{1}{12}$, $\rho > 97°{\cdot}3$ F.