

## NOTE VII., p. 228.

I have given in the text the usual explanation of the phenomena of the glacial epoch. The theory of northern elevation, however, as the sole or principal cause of continental glaciers, has never been regarded, by many geologists, as completely satisfactory. Within a few years renewed attempts have been made to connect these phenomena with astronomical changes of a secular character.

At sundry epochs in the history of the world, agencies seem to have arisen which brought into existence and transported over considerable distances vast quantities of rounded pebbles and finer detrital materials. In some cases—as in the Niagara, Permian, and Upper Miocene periods—smoothed and striated rock-surfaces have been discovered, similar to those which are generally attributed to glacier action. In the intervening periods evidences of tropical temperature present themselves. The suggestion has therefore been made that more than once in the history of the world—perhaps at somewhat regular intervals widely removed—the northern portions of the continents have been visited by a reign of frost.

To account for these apparently secular phenomena, new investigations have been made upon the effects of the secular variations in the longitude of the equinox, the eccentricity of the earth's orbit, and the obliquity of the ecliptic. This is not the place to enter into an exposition of the discussions which have arisen. I may, however, simply explain the nature of the relation which subsists between terrestrial climates and the cosmical changes alluded to.

1. As to the variation in the eccentricity of the earth's orbit, it is evident that when the northern hemisphere has its winter in perihelion during the time of greatest eccentricity, the amount of glaciation must be considerably less than when the same hemisphere has its winter in aphelion during the time of greatest eccentricity.

2. As to the variation in the obliquity of the earth's axis, it appears that when the obliquity is greatest, the winter temperature of the polar regions can not be much severer than when the obliquity is least—since when the sun is below the horizon it is immaterial whether it be two degrees or ten below—while the summer temperature of the polar regions will be increased by the whole increase in the verticality of the sun's rays. The effect, therefore, of an increase in the obliquity of the earth's axis will be to diminish the average glaciation of the polar regions.

3. Suppose now the minimum glaciation of the polar regions, so far as due to obliquity, to occur at the time when the northern hemisphere experiences minimum rigors of climate through the effect of increased eccentricity; the conjunction of these two minima of cold in the north polar regions would, it is thought, remove the ice cap, and effect conditions of climate such as prevailed when Greenland, in the Miocene period, supported trees of tropical nature and luxuriance.