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APPENDIX.

CAUSES OF CLIMATAL CHANGES.

The discussion upon Professor Geikie's valued paper having tended to show how diverse are the views held upon this subject, it may be permitted to quote certain remarks made "On the Causes of Climatal Changes," by Sir J. William Dawson, C.M.G., F.R.S., in his last new work.*

The subject . . . is one which has been in dispute ever since I began to read anything on geology, nearly sixty years ago. It ought to have been settled, but up to to-day one finds in geological works and papers—especially those relating to the Glacial age—the most divergent views.

Mr. Searles V. Wood, in an able summary of the possible causes of the succession of cold and warm climates in the northern hemisphere, enumerates no fewer than seven theories which have met with more or less acceptance, and he might have added an eighth. These are:—

1. The gradual cooling of the earth from a condition of original incandescence.
2. Changes in the obliquity of the ecliptic.
3. Changes in the position of the earth's axis of rotation.
4. The effect of the precession of the equinoxes, along with changes of the eccentricity of the earth's orbit.
5. Variations in the amount of heat given off by the sun.
6. Differences in the temperature of portions of space passed through by the earth.
7. Differences in the distribution of land and water in connection with the flow of oceanic currents.
8. Variations in the properties of the atmosphere with reference to its capacity for allowing the radiation of heat.

* *Some Salient Points in the Science of the Earth.* Hodder and Stoughton. 1893. This valuable work is "intended as a closing deliverance on some of the most important questions of Geology, on the part of a veteran worker."

Something may be said in favour of all these alleged causes; but as efficient in any important degree in producing the cold and warm climates of the Tertiary period, the greater number of them may be dismissed as incapable of effecting such results, or as altogether uncertain with reference to the fact of their own occurrence.

1. That the earth and the sun have diminished in heat during geological time seems probable; but physical and geological facts alike render it certain that this influence could have produced no appreciable effect, even in the times of the earliest animals and plants, and certainly not in the case of Tertiary floras and faunas.
2. The obliquity of the ecliptic is not believed by astronomers to have changed to any great degree, and its effect would be merely a somewhat different distribution of heat in different periods of the year.
3. Independently of astronomical objections, there is good geological evidence that the poles of the earth must have been nearly in their present places from the dawn of life until now. From the Laurentian upward, those organic limestones which mark the areas where warm and shallow equatorial water was spreading over submerged continents, are so disposed as to prove the permanence of the poles. In like manner all the great foldings of the crust of the earth have followed lines which are parts of great circles tangent to the existing polar circles. So, also, from the Cambrian age the great drift of sediment from the north has followed the line of the existing Arctic currents from the north-east to the south-west, throwing itself, for example, along the line of the Appalachian uplifts in Eastern America, and against the ridge of the Cordilleras in the west.
4. The effects of change of eccentricity and precession have been so ably urged by Croll, and recently by Ball, and have so strongly influenced the minds of those who are not working geologists, that they deserve a more detailed notice.
5. The heat of the sun is known to be variable, and the eleven years' period of sun spots has recently attracted much attention as producing appreciable effects on the seasons. There may possibly be longer cycles of solar energy; or the sun may be liable, like some variable stars, to paroxysms of increased energy. Such changes are possible, but we have no evidence of their occurrence, and they could not account for periods of refrigeration of limited duration like the Glacial age.
6. It has been supposed that the earth may have at different

times traversed more or less heated zones of space, giving alternations of warm and cold temperature. No such differences in space are, however, known, nor does there seem any good ground for imagining their existence.

7. The differences in the form and elevation of our continents, and in the consequent distribution of surfaces of different absorbent and radiating power, and of the oceanic currents, are known causes of climatal change, and have been referred to in these papers as competent to account for many, at least, of the phenomena.
8. Reference has already been made, in connection with the distribution of plants, to the possibility that the primeval atmosphere was richer in carbon than that of more modern times, and that this might operate to produce diminution of radiation, and consequent uniformity of temperature ; but this cause could not have been efficient in the later geological periods.

Sir William Dawson having further reviewed the fourth and seventh theories enumerated by Mr. Wood, urges the sufficiency of the old Lyellian theory of geographical changes, with such modifications as recent discoveries have rendered necessary to account for facts.—ED.