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V. HEAT.

The sources and effects of heat come here under consideration. The effects are those connected with the making and modifying of the earth's rocks, strata, and life, exclusive of the more comprehensive changes resulting from the earth's gradual refrigeration. They include (*a*) expansion and contraction; (*b*) fusion, solidification, and attending igneous phenomena; (*c*) metamorphism and vein-making, besides chemical compositions, decompositions, and other effects. After some observations on (I.) the Sources of Heat, these subjects are considered under the following heads: (II.) Expansion and Contraction; (III.) Igneous Action and Results; (IV.) Metamorphism; (V.) Veins.

The effects here referred to are mostly due to heat above the ordinary temperature. But some geological changes of the widest influence have been carried forward by simple changes in climate. Hence all sources of change in temperature, however slight, have a geological interest.

I. SOURCES OF HEAT AND THEIR DIRECT CLIMATAL EFFECTS.

The Sun as a Source of Heat.

It has been stated that the heat which the earth receives from the sun's rays gives it a temperature 300° F. above that which it would have in cold sunless space. The annual amount is constant through all orbital changes, but its distribution through the year varies with these changes.

1. *Changes connected with the seasons.*—The sun, owing to the obliquity between the earth's equatorial plane (at right angles to the axis of rotation) and the plane of the ecliptic (or that of its orbit) gives more light and heat for about six months, between the vernal and autumnal equinoxes, to the northern hemisphere than to the southern, making thereby a northern summer with a southern winter; and the reverse for the other six months. The difference in the heat received is in the ratio of 5 per cent for the summer interval between the equinoxes to 3 for the winter interval.

Further, the time of the equinoxes, or that of the sun's crossing of the equator, northward and southward, is slowly changing backward in the series of months, and in less than six centuries the vernal equinox, now on March 21, will be in the month of February; thus the summer months after a while will become those of the winter. The rate of the *precession* of the equinoxes is about 50·1 seconds a year, or a degree in about 71·6 years, which corresponds nearly to a month in 2158 years, and a complete revolution in 25,868 years.

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