

forest vegetation. In others, the ordinary exogenous trees predominate, almost to the exclusion of others. In some Arctic and Alpine regions mosses and lichens prevail. In the coal period, we have found none of the higher Exogens, and only a few obscure indications of the presence of Endogens; but Gymnosperms abound, and are highly characteristic. On the other hand, we have no mosses or lichens, and very few algæ, but a great number of ferns and Lycopodiaceæ or club-mosses. Thus the coal formation period is, botanically, a meeting-place of the lower Phænogams and the higher Cryptogams, and presents many forms which, when imperfectly known, have puzzled botanists in regard to their position in one or other series. In the present world, the flora next akin to that of the coal period, is that of moist and warm islands in the southern hemisphere. It is not properly a tropical flora, nor is it the flora of a cold region, but rather indicative of a moist and equable climate. Still we must bear in mind that we may often be mistaken in reasoning as to the temperature required by extinct species of plants differing from those now in existence. Farther, we must not assume that the climatal conditions of the northern hemisphere were in the coal period at all similar to those which now prevail. As Sir Charles Lyell has shown, a less amount of land in the higher latitudes would greatly modify climates, and there is every reason to believe that in the coal period there was less land than now. Farther, it has been shown by Tyndall and Hunt that a very small additional amount of carbonic acid in the atmosphere would, by obstructing the radiation of heat from the earth, produce almost the effect of a glass-roof or conservatory, extending over the whole world. Again, there is much in the structure of the leaves of the coal plants, as well as in the vast amount of carbon which they accumulated in the form of coal, and the characteristics of the animal life of the period, to indicate, on independent grounds, that the carboniferous atmosphere differed from that of the present world in this way, or in the presence of more carbonic acid,—a substance now existing in the very minute proportion of less than one-thousandth of the whole, a quantity adapted to the present requirements of vegetable and animal life, but probably not to those of the coal period."

"HOW COAL GREW.

"With regard to this important subject, I would rather invite attention to the details to be presented in subsequent pages, than

make any preliminary general statements. It is, however, necessary to notice here the several views which have prevailed as to the probable accumulation of coal, by driftage or growth *in situ*, in water or on land. I have already, in previous publications,* stated very fully the conclusions at which I have arrived on some portions of this subject, and I would now sum up the more important general truths as follows:—(1.) The occurrence of *Stigmaria* under nearly every bed of coal, proves beyond question that the material was accumulated by growth *in situ*; while the character of the sediments intervening between the beds of coal proves with equal certainty the abundant transport of mud and sand by water. In other words, conditions similar to those of the swampy deltas of great rivers are implied. (2.) The true coal consists principally of the flattened bark of Sigillarioid and other trees, intermixed with leaves of ferns and *Cordaites*, and other herbaceous debris, and with fragments of decayed wood, constituting 'mineral charcoal'; all these materials having manifestly alike grown and accumulated where we find them. (3.) The microscopical structure and chemical composition of the beds of cannel-coal and earthy bitumen, and of the more highly bituminous and carbonaceous shales, show them to have been of the nature of the fine vegetable mud which accumulates in the ponds and shallow lakes of modern swamps. When such fine vegetable sediment is mixed, as is often the case, with lime it becomes similar to the bituminous limestone and calcareo-bituminous shales of the coal measures. (4.) A few of the under-clays which support beds of coal are of the nature of the vegetable mud above referred to; but the greater part are argillo-arenaceous in composition, with little vegetable matter, and bleached by the drainage from them of water containing the products of vegetable decay. They are, in short, loamy or clay soils, and must have been sufficiently above water to admit of drainage. The absence of sulphurets, and the occurrence of carbonate of iron in connexion with them, prove that, when they existed as soils, rain-water, and not sea-water, percolated them. (5.) The coal and the fossil forests present many evidences of subaerial conditions. Most of the erect and prostrate trees had become hollow shells of bark before they were finally imbedded, and their wood had broken into cubical

* "On the Structures of Coal," Quart. Jour. Geol. Soc., vol. XV.; also vol. XXII. p. 95. "Air-breathers of the Coal Period," Montreal, 1863. p. 18.