the north of England appear in this district to be replaced by valley deposits of various kinds.

The present features of East Norfolk have been, I think, in the main produced by the deepening of irregularities left on the disappearance of the great ice-sheet. The mound of Contorted beds pushed up by the ice still remains and forms the high land near Cromer. Valleys have been cut out of it, and the tops of the contortions planed off, but it still forms an important feature in the physical geography of Norfolk.

I have been quite unable to find any trace of the inter-glacial valley erosion mentioned by Messrs. Wood and Harmer. Where the Middle Glacial descends into the valleys, it is the result of contortion, and not of erosion, and it is difficult to understand how a Post-Glacial valley could coincide with an Inter-Glacial one, cut through soft beds, and which had been filled up and must be again excavated. If a valley happens to cut through a number of contortions, synclinal will occasionally bring the gravel to the bottom; but where an anticlinal is cut, the gravel is not to be found, and it is then said that it has been all scoured out of the valley.

III.—MR. HILL ON THE CAUSE OF THE GLACIAL EPOCH.

By JAMES CROLL, LL.D., F.R.S.

I HAVE just read Mr. Hill's criticism on my views as to the cause of the Glacial Epoch, and have to thank him for the fair and courteous way in which he has treated the subject. I fear Mr. Hill has come to his conclusions somewhat too hastily. He appears to me to have totally misapprehended the real effect of fogs and a snow-covered surface on climate, and also the influence of eccentricity on the trade-winds. But I must defer for the present entering into any discussion on the matter. My object just now is simply to direct attention to an erroneous assumption which appears to lie at the base of nearly all the objections which have been urged against the theory that the Glacial Epoch resulted from an increase of eccentricity.

It is assumed that when the eccentricity was at a high value, and the summer in perihelion, more snow must have been melted than at present. It is assumed that the quantity of snow melted must be proportional to the heat received from the sun. Suppose that on a certain area a given amount of snow falls annually. The amount of heat received from the sun per annum is computed, and after the usual deduction for that cut off by the atmosphere has been made, if it be found that the quantity remaining is far more than sufficient to melt the snow, it is then assumed that the snow must be melted, and that an accumulation of snow and ice year by year in this area is impossible. To one approaching this perplexing subject for the first time such an assumption looks very plausible, but nevertheless it is one totally opposed to known facts. Take, for example, Greenland. We know that that area receives from the sun per annum

more than fifty times the amount of heat required to melt all the snow and ice formed on it, and yet that country is buried under ice. The annual precipitation on Greenland in the form of snow and rain, according to Dr. Rink, amounts to only 12 inches, and two inches of this he considers is never melted, but is carried away in the form of icebergs. The quantity of heat received at the equator from sun-rise to sunset, if none were cut off by the atmosphere, would melt $3\frac{1}{2}$ inches of ice, or 100 feet a year. The quantity received between latitude 60° and 80° , which is that of Greenland, is, according to Meech, one-half that received at the equator. The heat received by Greenland from the sun, if none were cut off by the atmosphere, would therefore melt 50 feet of ice per annum, or 50 times the amount of snow which falls on that continent. What then cuts off the 98 per cent. of the sun's heat? Is it clouds and fog? If so, why do not these, according to Mr. Hill's theory, supply sufficient heat to melt the small quantity of snow which falls on Greenland? And if the heat is not cut off, and far more than sufficient to melt the ice reaches the ground, why is not the ice melted?

Take another example. South Georgia in the latitude of England is covered with snow and ice down almost to the sea-shore during the whole summer, and yet the amount of heat which that island receives is sufficient to melt 62 feet of ice. Why then are not the snow and ice melted? Suppose the snowfall there were ten times greater than that of Greenland, which it evidently is not, yet this would not amount to one-sixth part of what the sun's heat could melt. What then cuts off the 80 per cent. of the sun's heat? It cannot, according to Mr. Hill, be either clouds or fogs, and if the heat is not cut off, the question returns, why are not the snow and ice melted? There is still another thing to be explained. The snow falls in that region in the very middle of summer, but snow would not fall unless the temperature was near the freezing-point. Why then have we such a low midsummer temperature, notwithstanding the fact that the sun is in perihelion at that season?

There is another class of facts utterly at variance with Mr. Hill's fundamental proposition. The lofty peaks of the Himalayas, the Andes, and other mountain ranges are covered with perpetual snow. There comparatively few of the sun's rays are cut off, and yet the snow is perennial. Few, I suppose, would admit that at these great elevations more than 50 per cent. of the sun's heat could be cut off. But if 50 per cent. reached the snow, this would be sufficient to melt 50 feet of ice, and this no doubt is more than ten times the quantity which actually requires to be melted. Why then does not the heat melt the snow?

I have little doubt that if Mr. Hill will ponder over the subject, so as to find out a satisfactory answer to the foregoing queries, he will satisfy himself that the causes to which I attribute the Glacial Epoch are not so impotent as he has been led to suppose.