PROFESSOR GEIKIE ON THE GLACIAL PERIOD.

ON Nov. 12 the Edinburgh Geological Society held its anniversary meeting, at which Professor Geikie delivered his presidential address, the subject being, "Supposed Causes of the Glacial Period." The lecturer began by remarking that, although the subject of his address had frequently been canvassed, the last word had not yet been said. The question of the cause or causes of the Ice Age was indeed a hard one, and he was not going to advance any novel speculation or hypothesis on the subject. His object was rather to examine certain views, which, after having been abandoned as untenable, had again been put forward to account for the phenomena of the glacial period. Before attempting to criticise these views it was obviously necessary to ascertain, in the first place, what conclusions had been arrived at with regard to the climatic conditions of glacial or Pleistocene and post-glacial times. We must first have an adequate conception of those conditions before we could estimate the value of any theory of their origin. The climatic conditions of the Pleistocene were then considered. It was shown that at the climax of the so-called glacial period the line of perennial snow in Europe was depressed for not less than 3,500 feet on an average. To bring about such a depression the mean annual temperature must have been lowered 10° or thereabout.

Full consideration of all the glacial phenomena led to the following conclusions: (1) That the cold of the glacial period was a general phenomenon due to some widely-acting cause — a cause sufficient to influence contemporaneously the climate of Europe and North America. (2) That glaciation in our continent increased in intensity from east to west, and from south to north. (3) That where now we have the greatest rainfall, in glacial times the greatest snowfall took place. (4) That in the extreme south of Europe, and in North Africa and South-western Asia, increased rain-precipitation accompanied lowering of temperature — from which it might be inferred that precipitation in glacial times was greater, generally, than it is now.

The remarkable climatic changes of the glacial or Pleistocene period were next considered. It had been proved that the period was interrupted certainly once — perhaps, as many geologists maintained, at least twice — by what were known as inter-glacial conditions. The evidence of this was treated in considerable detail, and the character of the inter-glacial climate was described as being markedly temperate and genial. There could be no doubt whatever that the Pleistocene period was characterized by great oscillations of climate — extremely cold and very genial conditions alternating. The evidence of the post glacial beds showed likewise that these had been accumulated under similar, but much less marked, alternations of cold and temperate climates. Lastly, attention was directed to the fact that both in Pleistocene and post-glacial times changes in the relative level of land and sea had taken place.

Any suggested explanation which did not fully account for these various climatic and geographical conditions could not be satisfactory. The view which had met with considerable acceptance, especially by American geologists, was that which attributed the phenomena of glacial times to great movements of the earth's crust. Professor Geikie then proceeded to examine that "earth-movement hypothesis" in detail. He pointed out that in the first place there was not the least evidence of great continental elevations in the northern hemisphere, such as the hypothesis postulated. Next, he showed that even if the desiderated earth-movements were admitted, they would not account for the phenomena. Each of the several applications of this earth-movement hypothesis was criticised in succession, with the result that they were all found inadequate. Neither great elevation of the northern lands alone, nor such elevation accompanied by submergence of the Isthmus of Panama and the deflection of the Gulf Stream, would account for the peculiar conditions of the Ice Age. These changes, no doubt, would profoundly affect the maritime regions of North America and Europe, but they would not reproduce the conditions that obtained at the climax of the Ice Age. Another objection to the earth-movement hypothesis was this, that it did not account for inter-glacial conditions. The advocates of that hypothesis imagined that those conditions would supervene when the highly-elevated northern regions were depressed to their present level, and when the Isthmus of Panama reappeared. But these were precisely the conditions that obtained at the present time, and yet in spite of them the climate was neither so equable nor so genial as that which obtained in inter-glacial times and during the mild stage of the succeeding post-glacial period. The earth-movement hypothesis must be rejected, not only because it was highly improbable that such wonderfully rhythmic elevations and depressions of high northern lands and of the Isthmus of Panama could have taken place, but chiefly because it did not explain the conditions of the glacial period, while it practically ignored those of inter-glacial times.

Professor Geikie next considered the proofs of former submergence which are so abundantly met with in temperate and northern latitudes, and discussed the various views which have been advanced to account for the facts. He concluded his address by considering an objection which had been urged against the physical theory of the glacial period as advocated by the late James Croll. This objection was based on certain estimates of the rate of erosion of river-valleys, the accumulation of alluvial deposits, and so forth, from which it was sought to show that only some 7,000 or 10,000 years had elapsed since the close of the glacial period. The consideration that, if this contention were true, it would bring the close of the Ice Age down to the dawn of civilization in Egypt was rather startling, to say the least. The fact was, however, that all such estimates, however carefully made, were unreliable. Dr. Croll's theory might some day be supplanted by one more satisfactory, but it would not be overturned by niggling and inconclusive measurements of that kind. That theory holds the field in giving the simplest and most consistent interpretation of the climatic vicissitudes of the Pleistocene and post-glacial periods, while it is the only one that throws any light on the very remarkable conditions that obtained during inter-glacial times.

LETTERS TO THE EDITOR.

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The Loup Rivers in Nebraska.

PERMIT me to submit through your columns to Professor Hicks the following questions and comments on his acceptable account of the Loup and Platte Rivers in *Science* for Jan. 29 last.

The topographic maps of the region in question are too incomplete for one to learn much from them concerning the present condition of the river valleys; but from general descriptions of that part of the country and from the brief mention by Professor Hicks of the "channels excavated from fifty to two hundred feet

in soft tertiary marls" it may be inferred that the streams are little advanced in their present cycle of development. Professor Hicks postulates that at the beginning of the current cycle of river history, the several branches of the Loup River all pursued independent courses to the Platte. The origin of those early courses is not stated; whether they were consequent on the slanting surface of the tertiary marls, or whether they represented the finally adopted positions of old rivers of a previous cycle of growth.

Old rivers, revived by the uplift of the plains into a new cycle of growth are common enough in the western country, and perhaps the Platte and Loup may be of that kind; but, if so, it does not seem possible to explain the present course of the main Loup River as resulting from a recent capture of its several north-west branches. River captures occur during the early maturity of a river system. If the Platte and the Loup are revived from the old stage of a previous cycle, the captures should have taken place in the earlier part of that cycle; and when the river courses had thus become well adjusted, they would be maintained even after uplift and entrance into another cycle, unless distinctly new conditions were thereby introduced. The possibility of this will be considered in a later paragraph.

If the rivers are not now in a second cycle of development, but are in their first cycle, having first taken their course when their region rose from the waters in which its strata were deposited, and having since then done nothing more than cut their shallow trenches in the general unbroken surface of the country, then we must ask whether their initial courses must have been in the arrangement postulated by Professor Hicks, or whether they may not from the beginning have had courses essentially on their present lines of flow. This latter alternative appears to be indicated at the end of Professor Hicks's article, if I read it aright. Assuming that the last great tertiary lake not only submerged the area of the Loup River, but spread its lacustrine sediments over the surface so as to obliterate any channels of earlier date, then on the disappearance of the lake, the rivers would be newly developed on the faint slopes of its deposits. The Platte, bringing down silt in large amount, may have been at that time a constructive river, busied in building up a broad delta-like flood-plain, further and further out on the lacustrine deposits as they were revealed. If so, it would turn its lateral tributaries down-stream, and the existing arrangement would be produced without the aid of headwater erosion and capture. Hence, until the process of flood-plain deflection is excluded, it does not seem necessary to include the process of headwater erosion and capture.

But even if it be supposed that the courses of the rivers at the beginning of the present cycle were arranged as postulated by Professor Hicks, and that all of them from the Beaver to the South Loup entered directly into the Platte, it seems impossible to explain their present arrangement by the headwater erosion and piracy of the Loup. The conditions for so systematic a process do not occur in the region under consideration, as will appear from the following analysis.

In the first place, it is important to remember that it is not the river but the little trickling headwater streams on the slopes of the divides that do the capturing in cases of the kind here discussed. The capture of one river by another, or lateral abstraction, as described by Gilbert in his most original examination of this problem in his report on the Henry Mountains is a comparatively rare occurrence, and is not applicable here.

In the second place, capture by little headwaters is most common in regions of tilted rocks of varied hardness, and on the headwaters of "subsequent" streams; that is, streams whose headwater-growth is dependent on the opportunity given by the weathering of some especially weak stratum, along whose strike the stream extends. No such special opportunity has been offered to the Loup River in this region of horizontal beds.

In the third place, as one headwater stream grows, all other adjacent headwaters of the same kind grow at about the same pace. Hence, if the Loup River has so greatly extended itself by headwater erosion, all the other headwater streams should have grown also, and the country thereabouts would be much more dissected by channels than it now is.

Finally, the location of Prairie Creek seems to contradict the supposition that the branches of Loup River ever joined the Platte directly; for, if they had, then Prairie Creek must be, like the supposed extension of the Loup, an example of headwater erosion; and this is not to be thought of in a stream so systematically located between two parallel and larger rivers in a district of horizontal beds.

Taken all together, it does not seem necessary to give any especial emphasis to headwater erosion and capture in this river system. The natural result of excessive deposition along the Platte, as described by Professor Hicks, is alone sufficient to account for the present arrangement of the streams. The growth of the Platte flood-plain may have dammed back some of its tributaries, as certain branches of the Red River in Louisiana are dammed back and converted into shallow lakes; and the present main Loup River would then be developed by lateral overflow along the margin of the flood-plain; but this is quite another process from headwater erosion and capture.

These suggestions are only tentative; for not having seen the region and having no full account of its geological history or of its topography, I can only submit them for criticism.

W. M. DAVIS.

Harvard College, Feb. 10.

Origin of the Frigid Period in the Northern Hemisphere.

IN my letter, published in your issue of Oct. 16, I stated that the independent circulation of the southern ocean waters was the main cause of ice-sheets forming on the lands situated in the high latitudes of the southern hemisphere; and that such currents were caused by the strong westerly winds, which blew the surface waters of the southern ocean constantly around the globe, and thus prevented the tropical surface currents from largely entering its waters. Consequently, through this cause and the constant gathering of ice in the antarctic regions the temperature of the southern latitudes was slowly lowering; and that the growing coldness would continue until the southern ice-sheets filled the Cape Horn channel and prevented the further independent movement of the southern ocean waters. This being accomplished, the westerly winds would blow the surface waters of the sea away from the eastern side of the ice-formed isthmus and the southern lands of South America, and so cause a low sea-level, that would attract the surface waters of the tropical seas far into the southern latitudes, and thus in time furnish heat sufficient to melt the ice from the southern lands I also stated that an ice period could not be perfected in the northern hemisphere without the assistance of cold derived from a frigid period in the southern hemisphere. The independent circulation of the arctic waters is not complete, owing to land obstructions; but it is able to largely prevent the tropical Gulf Stream waters from entering the higher northern latitudes. The prevailing westerly winds blow the surface waters of the Atlantic away from the eastern shore of North America from Georgia to Labrador; consequently the low sea-level thus caused attracts the high-level tropical waters of the Gulf of Mexico through the Florida channel well into the northern latitudes; and during the same time the westerly winds which blow the surface waters of the Atlantic away from the American coast are also causing a high sea-level on the seas abreast north-western Europe, which creates a return current through the Arctic Ocean, passing through the several straits leading into Baffins Bay, and also down the eastern coast of Greenland. Thus the ocean waters of the high northern latitudes maintain a partly independent circulation, which serves to crowd the Gulf Stream away from the higher latitudes, and thus lower the temperature of the arctic regions. Through this exclusion of tropical waters, glaciers have formed on Greenland and other arctic shores; and these glaciers are probably slowly increasing, as every iceberg launched from the frigid lands and floated to the Gulf Stream lowers somewhat the temperature of the north Atlantic, and so causes conditions more favorable for larger accumulations of ice. Still it is probable that a northern ice period could not be perfected by this process alone should the tropical and southern oceans maintain their present temperature. But with the assistance of a frigid period in the