ART. LX.—*Are there Glacial Records in the Newark System?* by ISRAEL C. RUSSELL.

SEVERAL expressions of opinion have been published by geologists in this country, respecting the existence of glaciers along the Atlantic border during the deposition of the rocks of the Newark system. It has been recently stated by Prof. J. D. Dana,† that this period “ended in a semi-glacial era, as is

* Appendix, No. 11, U. S. Coast Survey. Report of 1869, also Petermann's Geogr. Mittheilungen, vol. xvi, pp. 393-398.

† Quartz sand and pebbles, and greensand (perhaps hornblende) seem to be the only minerals which preserve their integrity in moderate depths at the bottom of the ocean; feldspar and mica are rarely found, and the so-called “mud” consists very often of the finest sand with some mica flakes, and with a just sufficient admixture of clay to produce cohesion.

‡ This Journal, III, xl, 1890, p. 436.

admitted by all who have studied the beds." As there is possibly not the unanimity of opinion among those who have studied the Newark system, that is suggested in the line quoted; it may be well to glance at the evidence on which those who consider that the period referred to contains glacial deposits or ended in a semi-glacial era, base their conclusions.

In describing certain coarse deposits on the eastern border of the Deep River area of Newark rocks in North Carolina, W. C. Kerr* suggested that they indicate a sub-Newark glaciation: but these beds are considered as post-Newark by W. M. Fontaine.† A similar remark was made by N. S. Shaler and W. M. Davis,‡ in reference to the origin of the coarse conglomerate of the Newark system in the Connecticut valley. It has also been stated by J. D. Dana§ that the Connecticut valley had its violent floods during the Newark period, which may have been enlarged by the waters and ice of a semi-glacial era. But the most extended discussion of the possible glacial origin of certain coarse deposits in the Newark system has been made by W. M. Fontaine.† The arguments he advances are based on the following considerations:

First. The presence of coarse conglomerate and breccias. *Second.* Absence of fossil mollusks, radiates, etc. *Third.* Unexplained phenomena in the drainage and relief of the Appalachians, which are supposed to have been initiated by glaciers. *Fourth.* Extinction of the fauna and great change in the flora of the Atlantic border in the interval between the Newark and Cretaceous periods.

The evidence of glaciation according to Dana|| "consists in thick deposits of stones and bowlders in which occur masses two to four feet in diameter, and therefore such as only ice could have handled and transported. They are situated along the west side of the area in Virginia, Maryland and New Jersey (where the dip of the Jura-Trias [Newark] beds is westward) and on the eastern in Connecticut and Massachusetts (where the dip is eastward).¶ Fontaine has found in Virginia and Maryland that they are the *later beds* of the formation." Exposures of Newark rocks north of Amherst, Mass., containing bowlders three to four feet in diameter are referred to, and Edward Hitchcock's conclusion that they are "the upper beds" of the series, cited. Coarse deposits near East Haven, Conn., are also mentioned.

* Rep. Geol. North Carolina, vol. i, 1875, p. 146.

† This Journal, III, xvii, 1879, p. 34.

‡ Illustrations of the Earth's surface, Glaciers. Boston. 1881. pp. 95, 96.

§ This Journal, III, xvii, 1879, p. 330.

|| This Journal, III, xl, 1890, p. 436.

¶ Note in this Journal, III, xli, 1891.

Before examining the evidence, let us endeavor to determine what facts should be looked for, in case glaciers did invade the area in which Newark rocks were being deposited.

Preservation of Glacial Records.

All records of glaciation not buried beneath subsequent deposits, would certainly be destroyed by subaërial decay and erosion, during such a lapse of time as has intervened between the Newark period and the present day. Exception to this conclusion may, perhaps, be found in the changes which glaciers make in the drainage and topography of a region, but this matter is as yet little understood. Among the direct evidences of glaciation which might be preserved for indefinite ages, under suitable conditions, the following may be enumerated :

First. Smoothed and striated rock surfaces, if buried beneath fine sediments, might be preserved in their original condition ; or casts of them might be taken, in the same manner that casts of footprints, showing the most delicate markings, have been preserved in great abundance in the Newark rocks themselves.

Second. Bowlders, smoothed, faceted and striated by glaciers (similar markings are also produced by river ice), might retain their records for indefinite periods, especially if they were imbedded in fine sediments or cemented by calcareous or other infiltrations.*

Third. When glaciers enter an estuary or a lake, moraines are deposited in unassorted or but imperfectly arranged, heaps about their extremities. The distance from the shore to which these deposits may be carried depends on the size of the glaciers and on the depth of the water they enter. A shallow estuary or lake could offer but feeble resistance to the advance of glaciers and might have moraines deposited widely over its bottom. On the other hand, glaciers entering a basin in which the water is as deep as the ice streams are thick, would have their advance checked abruptly and the moraines deposited would be confined to the borders of the basin ; but scattered bowlders might be carried to great distances on floating ice. Should glaciers plow their way into shallow basins in which fine sediments were being deposited, it is evident that the beds beneath them might be greatly disturbed, while contortions would appear in adjacent strata owing to the unequal distribution of the load imposed on them.

* Since writing these pages, a paper has appeared by Dr. Hans Reusch, on "Glacial striæ and boulder-clay in Norwegian Lapponie from a period much older than the last ice-age." *Norges geol. undersøgelse aarbog for 1891*, in which descriptions are given of striated rock surfaces protected by morainal material containing striated and faceted bowlders. These records are thought to be of Cambro-Silurian age.

Fourth. The effect of a glacial period on animal and plant life has received much attention, but what records of the presence of glaciers at any special time might be expected in contemporaneous fossils, is still indefinite. A glacial period is usually considered as a cold period (the presence of local glaciers in mountainous regions, however, does not imply an Arctic climate). If a cold period followed a warm period, it is to be expected that migrations of fauna and flora would follow. Alternations of warm and cold periods would probably be accompanied by the extinction of many types. That changes of this character did take place during the Pleistocene glacial epoch, is apparently well established.

On the other hand, we know that luxuriant floras exist on the margins and even on the surface, of living glaciers of vast extent, which are not essentially different from plants of the same species growing at a distance from all perennial ice. In the present state of knowledge, it does not seem possible for paleobotanists to designate any group or assemblage of fossil plants which might not have flourished in proximity to glaciers.

While glaciers may be surrounded by a mild atmosphere, congenial to plant life, the waters into which they discharge either directly or after melting, are cold and could not be inhabited by animals characteristic of temperate or tropical climates.

It is to be expected, therefore, that sediments laid down in water into which glaciers are discharging could only contain the records of faunas, exclusive of land animals, characteristic of cold climates.

Weight of the Evidence.

Having in mind what records might reasonably be expected to occur in the rocks of the Newark system, providing glaciers had assisted in their deposition, let us see what the facts are:

First. No smoothed or striated rock surfaces either in the Newark system itself or on the floor on which it rests, have ever been found.

Second. No glaciated boulders have been observed in the system.

Third. No scattered boulders or large rock fragments indicating iceberg drift, have been found in the off-shore deposits.

Fourth. No Newark fossils indicating a cold climate, even in a remote way, have been discovered.

The paucity of molluscan life has been advanced as indicating Arctic conditions. It is well known, however, that mollusks and many other forms of life, inhabit the seas of northern regions close to where glaciers discharge. Shells occur also in

Pleistocene glacial clays. The evidence that glaciers are not necessarily accompanied by an extermination of mollusks in adjacent waters, is abundant. Besides, the hypothesis that mollusks are absent from the Newark sediments on account of glacial conditions, does not stand alone; other explanations of the same phenomena with many facts to support them have been advanced.

I have previously suggested that the great numbers of reptiles, some of them of gigantic size, the bones and foot prints of which occur in the Newark rocks, could not have lived in an estuary or lake into which glaciers were discharging and on which icebergs floated. Cold-blooded animals at the present time among which we must look for the nearest living allies of the "foot-print animals," are confined to warm regions; and there is no reason to suppose that this law of nature was reversed during the Newark period. The swarms of reptiles, both great and small, that lived at that time must have required an abundant food supply; this implies that the shores they haunted were more like those of Florida than those of Greenland at the present time.

The fossil plants of the Newark are Araucarians, ferns, equisetæ and cycads. If these have any bearing on the question of climate they indicate sub-tropical and not Arctic conditions; although there is no reason why they might not have grown in proximity to glaciers.

In regard to the marked modifications in the flora and the extermination of the fauna of the Newark period, before the deposition of the next succeeding formation, referred to by Fontaine, we know that such changes have occurred at the close of each important division of geological history and may be accounted for in most cases by the imperfections in the records. Breaks in the life records invariably accompany breaks in stratigraphy. The assumption that these changes at the close of the Newark period were due to glaciation, is making an exception to a general rule, without facts to support it.

The Coarse Deposits.

It has been stated by Hitchcock and Fontaine, that the coarse deposits of the Newark system belong at the top. These statements lead Dana, as already cited, to the conclusion that the Newark period ended in a semi-glacial era. If the coarse deposit were confined to the top of the series, which as I shall show below, they are not, it would scarcely follow that they marked the close of the period, for the reason that deep erosion has unquestionably taken place.

But the coarse deposits are not confined to the top of the series. Wherever the base of the system is exposed it is almost

always found to be a coarse conglomerate or breccia. This deposit has been brought to the surface in several instances by faults and its character is well known. Coarse conglomerates occur especially on the east border of the Connecticut Valley area and on the west border of the New York-Virginia area and the detached areas in Virginia and North Carolina which fall in line with it. The beds are not continuous, but occur as local deposits. Where the coarse material is thickest, it grades into fine material both along the strike, that is along the shores against which it was deposited, and in a direction at right angles to the shore. Toward the center of the area of deposition, the coarse beds become fine and overlap or interdigitate, with fine off-shore sediments. As the upheaval of the system has not been uniform, erosion has cut far deeper in certain localities than at others. Thus, in northern New Jersey the Newark rocks are known to be not less than three or four thousand feet thick, while in the prolongation of the same area in Maryland, the thickness is certainly much less. The present base-level of erosion has cut deeper into the system at the south than at the north; yet all along the ancient shore, joining the two extremes, coarse deposits occur from time to time. The evidence points definitely to the conclusion that coarse deposits occur at all horizons from the bottom of the system up to the highest beds that now remain. If these beds are glacial deposits, then glaciers must have existed throughout the deposition of the system.

The coarse deposits along portions of the borders of the various Newark areas are always of local origin. They are not heterogeneous accumulations gathered from a broad area, as might be expected if they are of glacial origin, but have been derived from terranes in the immediate vicinity of where they now occur. The material forming the large boulders in particular, may invariably be found *in situ*, near at hand.

No contortion of the fine sediments adjacent to or interstratified with the coarse deposits have been observed, such as would result from the extension of glaciers into the basins in which the fine sediments had been accumulated, or from the superposition or moraines upon them. On the contrary, the phenomena noted at many localities are fully explained on the assumption that the strata both coarse and fine, were deposited contemporaneously as water-laid beds.

The fine deposits intimately associated and even interstratified with the coarse deposits, are frequently ripple-marked, sun-cracked, and contain rain-drop impressions and the footprints of animals, at many horizons; thus showing conclusively, that the water bodies in which the strata were spread out were shallow. There is, therefore, no reason why glaciers

entering the basin should have halted at the immediate shore, and deposited their loads. Besides, the coarse deposits are not of the heterogeneous character typical of morainal accumulations, but are stratified and cross-bedded. It has been stated by those who claim that the deposits in question are of glacial origin, that they contain boulders three to four feet in diameter, and therefore such as only ice could have handled and transported. My own observations have shown that boulders either rounded or sub-angular, of the size indicated are not rare. Huge angular masses of rock like those to be seen on nearly every Alpine glacier, however, never occur. Those of my readers who have followed the Appalachian rivers south of the southern margin of the drift, will remember many instances where streams are encumbered with boulders of even larger size than those mentioned above. These are being swept along by every flood, and did the streams empty into lakes, would be deposited in shore conglomerates. It may be remarked also, that river ice might have assisted in the movement of the Newark boulders, without supposing the existence of glaciers.

After reviewing the voluminous literature relating to the Newark system and personally examining nearly every area occupied by it, I fail to find any evidence to support the hypothesis that glaciers assisted in its deposition. That there may have been glaciers on the Appalachians previous to or during the Newark period, is within the bounds of possibility, but as yet there is no evidence in this connection on which to base an opinion; we can only say that if they were present during the period under discussion, they did not reach the estuaries in which sediments were being deposited.

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