Art. XVII.—*A Lower Huronian Ice Age;* by A. P. Coleman.

Of late years the evidence for ice ages far older than the familiar Pleistocene Glacial Period has been growing rapidly, and at least one Paleozoic ice age, that of the Permian or Permo-Carboniferous of India, Australia and South Africa, must be looked on as fully established. All the geologists who visited South Africa with the British Association in 1905 were convinced of the glacial origin of the Dwyka "tillite," or bowlder clay, and of the striated rock surfaces beneath, found from point to point for 600 miles. The evidence for the equivalent glacial beds of Australia and India appears to be equally clear, as shown by Professor David of Sydney University at the late meeting of the Geological Congress in Mexico.

This well established ice age of Paleozoic times makes it far more probable that glacial periods are a normal, if infrequent, feature of the world's past history; and adds weight to the evidence so far recorded of very ancient ice ages, such as those of the Cambrian.

It will be recalled that what is probably an early Cambrian glacial deposit was described by Reusch in the Gaisa beds of northern Norway in 1891;* and reëxamined by Strahan in 1897. The region in which these comparatively small outcrops of bowlder clay were found is, however, in latitude 70°, so that Arctic conditions of a local kind might not be surprising.

More recently Bailey Willis has described before the Geological Society of America an early Cambrian or possibly Precambrian Glacial formation on the Yang-tse river in China, in latitude 30°. The specimens of striated stones which he displayed were characteristic, and the matrix suggested an ancient bowlder clay.†

In 1905 A. W. Rogers of the Cape Colony Survey described a glacial conglomerate in the Table Mountain series. This had been discovered four years before, but was now worked out more in detail and found to extend at least 23 miles. It contains stones of typically glacial appearance. The age of these rocks seems not quite certain, since no fossils have been found in the Table Mountain series, but they are very early

* Norges geologiska Undersögelse; Det nordlige Norges Geologi, pp. 26–34, 1891. Geol. Soc. London, vol. liii, pp. 137–146, 1897. Mr. Strahan's paper is accompanied by plates showing the bowlder clay and the striated rock surface beneath it.

† Year Book No. 3, Carnegie Inst., p. 282; see also Chamberlin and Salisbury's Geology, II vol., pp. 273–4, where photo reproductions of glaciated pebbles are given.

Devonian if not older.* In 1906 Rogers described a still more ancient glacial formation in the Griquatown series of Hay, where striated bowlders occur in a very hard matrix, from which they slowly weather out. Two of these stones kindly sent me by Mr. Rogers are, as I can testify, thoroughly glacial in appearance. The Griquatown series is certainly older than the Cape rocks, apparently Cambrian or Precambrian.† If Precambrian, the series must come near the upper limit, since there are apparently three other series beneath it, the Campbell Rand, the Kheiss, and the Namaqualand schists. It occupies perhaps about the position of the Keweenawan in America.

Since this paper was prepared a very interesting article by E. H. L. Schwarz on "The Three Paleozoic Ice Ages of South Africa" has appeared.‡ Schwarz was associated with Rogers in at least part of the work and is convinced of the glacial character of the lower deposits. This account of them agrees with Rogers' papers cited above, but gives more details.

In an excellent paper before the recent Geological Congress Prof. David described ancient glacial deposits, probably of Cambrian age, in Australia and India, and showed some very glacial-looking material from Australia, but I have seen no printed copy of his paper.

From the foregoing references it will be seen that Cambrian or possibly late Precambrian glacial deposits have been found in various places in both hemispheres in latitudes from 70° to 30°. If they all belong to one period the refrigeration must have been widespread, and one can hardly account for them all as due to local mountain glaciers.

For several years it has seemed to me very probable that there was a still more ancient ice age, at the beginning of the Lower Huronian in the Archean as defined in Canada or the Archeozoic or lowest Algonkian as defined by various American geologists. The so-called Huronian "slate conglomerate" of Ontario has attracted attention ever since Logan and Murray mapped and described it in the typical region north of Lake Huron nearly fifty years ago. Good descriptions of it are given by Logan in the 1863 report of the Canadian Geological Survey; where he refers to the different kinds of rock enclosed as pebbles or bowlders, granite, felsite, certain greenstones and jasper, for example; and describes the matrix as sometimes slaty, sometimes more quartzitic or like diorite or greenstone. At present the matrix would generally be called

* Trans. S. African Phil. Soc., vol. xvi, part 1, May, 1905.

† Trans. Geol. Soc. S. Africa, vol. ix, 1906; The Campbell Rand and Griquatown series in Hay, pp. 8 and 9.

‡ Jour. Geol., vol. xiv, No. 8, pp. 683–691.

graywacke or slate, though sometimes it is schistose or looks like an eruptive rock.

The pebbles or bowlders are in many cases subangular or sharply angular and are found miles away from any known source; and as they may be of any size up to blocks weighing tons, and are frequently very sparsely scattered through an unstratified matrix, a stone or two in several yards, one cannot help suspecting that the transporting agency was ice rather than water. There are parts of the formation where the pebbles or stones are well rounded and crowded in certain bands. In such cases they are probably true water-formed conglomerates; but the prevalent type of the rock with scattered subangular stones or bowlders should not be called a conglomerate, any more than a Pleistocene bowlder clay would receive that name. The appearance of these so-called slate or graywacke conglomerates is closely like that of the Dwyka bowlder clays, for which Penck suggests the term "tillite."

Good examples of these bowlder-bearing rocks are found in the original Huronian region on Echo lake, near Desbarats and on the Palladeau Islands. At the last locality smooth water-worn surfaces give excellent sections of the rock, the scattered red granitic bowlders standing out sharply from the dark greenish gray matrix. The granite bowlders similarly enclosed near Desbarats are twenty miles from the nearest known outcrop of that rock.

Logan describes a similar "slate conglomerate" from Lake Temiscaming, and also a schist conglomerate from Doré river on Lake Superior as belonging to the same formation; and in some cases his measurements made them hundreds or even thousands of feet thick.*

Later explorations in northern Ontario, described in reports of the Bureau of Mines of the province, have brought to light many other areas of the so-called conglomerate, some very characteristic ones occurring near Sudbury and east of Lake Wahnapitae; while schistose varieties, which have undergone more severe squeezing and metamorphism, occur near Shoal Lake, Manitou Lake and on the Lake-of-the-Woods. In fact, rocks of the kind are found from point to point across all northern Ontario, a distance of nearly 800 miles, and from the north shore of Lake Huron in latitude 46° to Lake Nipigon in latitude 50°.

The more schistose of these conglomerates have their pebbles flattened and rolled out into lenses not at all suggesting glacial action; but the fact that all of them, whether schistose or unmodified, occupy, so far as known, the same position, immediately over the Keewatin, and contain pebbles and

*G. S. C., 1863, p. 56.

bowlders of the same rocks, granite, banded jasper, etc., makes it very probable that they belong to the same age and have had a similar origin.

It is evident that for useful study the least metamorphosed examples of the bowlder-bearing rock should be selected, such as those of the typical Huronian region or those between Sudbury and Lake Temiscaming.

In the western region I have never succeeded in loosening stones from their matrix so as to observe whether the surfaces were striated. Until recently the same difficulty was met in the eastern conglomerates; but the new silver mining district at Cobalt has at last furnished a few pebbles and larger stones which have preserved their original surfaces.

The outcrops at Cobalt are well exposed and show the usual variations of the so-called basal Huronian conglomerate. There are some indefinite bands crowded with small stones, often well rounded, while other parts of the outcrops have very few bowlders or smaller stones, and these are often angular. The matrix varies from slaty material, sometimes with a hint of stratification, to graywacke composed of coarse and fine rock fragments, mostly quite unrounded. A few geologists have supposed, as was formerly suggested for the Dwyka of South Africa, that the matrix is a basic eruptive rock; but its fragmental character is clearly seen in the field and in thin sections.

The enclosed stones include large and small blocks of granite, many felsitic and porphyritic rocks, greenstones, and a few bits of banded silica derived from the iron formation of the underlying Keewatin.

Professor Miller, who has mapped the region for the Bureau of Mines of Ontario, guardedly suggests the resemblance of this rock to bowlder clay.* He calls attention to the fact that "the granite bowlders are often two or three feet or more in diameter and distant a couple of miles from exposures of the rock"; but on the whole seems opposed to a glacial origin.

By the exercise of care and patience it has been possible to break from their matrix wholly or partially about twenty of these stones, mostly only an inch or two in diameter, but half a dozen from three to six inches across. As coarse-grained rocks like granite seldom show distinct striations in modern bowlder clays, felsites and fine-grained greenstones were selected to work upon. Of the twenty stones four or five are more or less striated, but only one is heavily and decisively scored. Unfortunately the matrix could not be completely

* Bur. Mines, 1905, p. 41.

removed from this one, but the exposed surfaces show the striations well on one face and distinctly on two others.

Several of the smaller pebbles have the peculiar somewhat uneven but well polished faces with rougher corners so often seen in the smaller stones of bowlder clay.

Though the number of stones available is small, the proportion showing more or less striation is as large as in recent bowlder clay and all the usual features of ice-carved stones are found in them. It may be added that they were taken from undisturbed parts of the formation with no faulting to cause slickensides, and that the stones themselves had not been squeezed nor broken in the matrix.

No striated surfaces were found where the conglomerate rested on the underlying Keewatin; but the only contact of the two rocks examined was unfavorable for displaying such a surface. Mining operations show that the rocks beneath the Huronian have on the whole an uneven, somewhat undulating surface of low hills and valleys, the conglomerate often more or less filling in these valleys.

In the silver region the Lower Huronian has a maximum thickness of about 500 feet so far as known. There are also, as shown by Prof. Miller, conglomerates in the next overlying formation, the Middle Huronian.

The evidence for a Lower Huronian Ice Age may be summed up as follows:

A peculiar rock consisting of graywacke or finer materials showing little or no stratification but containing pebbles or stones, sometimes crowded, but more often scattered a few feet apart, is found from point to point over an area 800 miles long by 250 miles broad. The stones are of all sizes up to diameters of several feet and of all shapes from rounded to angular, many being subangular with rounded corners. The stones are of several different kinds, some fragments of the immediately underlying rock, others having a distant source.

In the Cobalt mining region a few polished and striated stones have been broken out of the matrix. They are closely like stones from the Pleistocene bowlder clay of the same region except that they lack the Niagara limestones of the recent drift.

Hand specimens of matrix and enclosed pebbles are precisely like the Dwyka tillite or conglomerate of South Africa, which is undoubtedly of glacial origin.

Against the glacial theory is the fact that no *roches moutonnées* have yet been found on the underlying Keewatin rocks. All the positive evidence is favorable to the theory of glacial action as the cause of these curious bowlder-strewn rocks.

If the evidence given above is accepted, the occurrence of glaciation is probable over an area too large to be the work of merely local mountain glaciers, and one must assume the presence of ice sheets comparable to those which formed the Dwyka.

The Lower Huronian is the second formation in the geological succession in North America, only the Keewatin coming before it; so that the probable action of ice on a large scale is pushed back almost to the beginning of known geological time. This implies that the climates of the earlier parts of the world's history were no warmer than those of later times, and that in Lower Huronian times the earth's interior heat was not sufficient to prevent the formation of a great ice sheet in latitude 46°.

The bearing of these points on early geological history and on theories of the earth's origin is self evident.

It should be kept in mind, however, that the evidence, though favorable and in some directions strong, is scarcely wide enough to give certainty in a matter of so much theoretical importance.