V.—Glacial Succession in Central Lunenburg.—By W. H. Prest, *Chester Basin, N. S.*

(Read 11th May, 1896.)

While prospecting for gold bearing veins during the past two years, my attention was called to the opportunities thus given to study the glacial geology of the district worked in. The following observations and deductions are chiefly the results of work done in the district between Bridgewater and Mahone Bay, during parts of the years 1895 and 1896. My study of this district is not in any way thorough, but consists merely of occasional observations and their resulting conclusions. Knowing the great difficulty of correlating distinct and distant deposits, I approach the subject with trepidation, but, notwithstanding, trust that the facts given may be of some service to future investigators.

PHYSICAL FEATURES.

The general physical features of this part of Nova Scotia are those of a gradual slope from the central watershed to the Atlantic coast. This watershed, the South Mountain, averages probably 700 feet in height, and is about 45 miles from the Atlantic, which gives the very gentle descent of 1 foot in 340. Its surface is diversified by morrainic accumulations which reach a considerable development near the coast at Lunenburg. The more local features are those of a low table-land, bounded on the south-west by the valley of the Lahave, on the north-east by the Mush-a-mush valley and Mahone Bay, and on the south-east by the Atlantic Ocean. Its northern end is a continuation of the higher land of the interior. In the central parts of this table-land are the shallow subsidiary basins of Rhodenizer's and Cantiloup's Lakes. At Blockhouse, in the eastern part of this area, the surface is undulated by morraines and intervening swamps and valleys. Here in a shallow valley, running about S. 50° E., a large part of my work was done, and observations made. The

height above the sea level is probably about 135 feet. The Lahave occupies a narrow pre-glacial valley, reaching 20 to 30 feet below high tide, and flowing amid picturesque hills about 200 feet high. The Rhodenizer Lake basin drains the highest part of the table-land and flows S. S. W. between morraines and kames until it reaches the estuary of the Lahave. The central part of this basin, at Blysteinner Lake, is 183 feet above mean tide level, while Rhodenizer's Lake is 160 feet. The Cantiloup Lake basin drains the southern part of the tract under discussion, and is occupied and surrounded by morraines which have in some cases diverted the streams from their pre-glacial courses. At Dorey's Brook, in this basin, work was done which disclosed several facts bearing on the glacial succession in this district. I will now give a few sections which represent fairly the majority of those recorded by me. They are numbered to correspond with the glacial or inter-glacial epoch in which they are supposed to have originated. (See page 164.)

DESCRIPTION OF DEPOSITS.

Blockhouse.—The sections set down below are copied from a record kept on the spot, and taken down as the work of trenching and sinking proceeded. As those pits are sunk quite close to each other, the correlation of the deposits in this locality was not a very difficult matter. The sections of course differ as the position and depth of the pits showing them differed, but the corresponding layers in each section will be numbered alike regardless of their distance from top to bottom. The absence or presence of auriferous quartz in the upper layer was owing to its position in regard to the lead. If on the lead, the lower layer contained the gold-bearing quartz ; but if to the south-east, then the upper layer contained it.

Section 1, beginning at the top, 13 feet deep.

5, Clay and rocks, mostly local and much oxidized.

4, Signs of denudation.

3, Dark coloured boulder clay, including granite, quartzite, and other northern drift.

2, *d*, Signs of denudation.

" *c*, Small stones firmly cemented with bog iron.

" *b*, Soft red gravelly clay, slightly stratified.

" *a*, Fine blue clay with local angular drift and auriferous quartz from lead beneath.

Section 2.—Depth 10½ feet.

7, Unstratified brown rocky soil, of local origin, on edge of meadow, probably disarranged by ice.

6, White clay

5, Brown, rusty, gravelly and sandy clay, with broken slate and quartz, all of local origin.

4, Bright red and yellow ocheous clay.

3, Rusty, red and brown stoney clay, with well worn boulders of granite and quartzite, but no local drift. Polished round and oval pebbles, doubtless from a kame of earlier origin, are included in this bed.

2, Blue clay with slate and auriferous quartz from vein beneath.

Section 3.—Depth 8 feet.

6, Fine dark coloured clay.

5, Well oxidized local drift, consisting of gravel, clay, quartzite and slate.

4, Finely stratified sandy seam.

3, Gravel, clay, and worn boulders, some of them granite, with tough clay near bottom.

Section 4.—Depth 8 feet.

5, Brown, loose, rusty slate, gravel, and auriferous quartz, all of local origin.

4, Four inch seam of angular slate, cemented with bog iron

3, Boulder clay of a more northern origin.

Section 5.—Depth 14 feet.

5, Brown, rusty, and partly cemented drift, of local origin, containing auriferous quartz.

4, Signs of denudation.

3, Clay, with massive boulders of quartzite slate, trap and granite, all well worn. This bed contains polished pebbles of

granite and quartz, no doubt derived by denudation from a kame of earlier age.

2, Blue clay, with broken fragments of local rocks.

Section 6.—Depth 15 feet.

5, Brown, rusty and partly cemented slate and gravel, with auriferous quartz, all of local origin.

4, Signs of denudation.

3, Boulder clay with large boulders of trap, granite, quartzite, and slate, and fine tough clay at the bottom. Contains rounded and smoothly polished crystalline rocks which seem to have been eroded from an earlier deposit.

Dorey's Brook.—Section, 6 feet deep.

5, Local drift, with auriferous quartz, from a vein near by.

4, *d*, Fine tough white clay, without quartz.

" *c*, Fine tough brown clay, without quartz.

" *b*, Fine tough brown clay, with quartz, from above-mentioned vein.

" *a*, Modified boulder clay, with quartz.

3, Boulder clay, granite rare, quartz absent. The above section is about 140 feet above tide level.

Rhodenizer's Lake.—Kame with section at an angle of 45°, about 60 feet deep, and about 180 feet above mean tide level.

3 (?), Surface soil apparently till, 4 feet.

2 *e*, Stratified beds of sand, gravel, clay, and small rounded rocks, 17 feet, 8 inches.

" *d*, Conglomerate of large rounded rocks, many of them granite and trap, 2 feet.

" *c*, Stratified beds, as at 2, *e*, 12 feet, 4 inches.

" *b*, Unstratified or disintegrated bed of sand clay and waterworn rocks, 4 feet.

" *a*, Stratified layers as at 2, *e*, 15 to 20 feet.

1, Drift conglomerate of worn and angular fragments of slate, quartzite, granite, and trap, thoroughly cemented by bog iron.

It shows no sign of stratification, and contains large numbers of striated boulders.

A few boulders with the striations almost effaced are found in 2, *a*, and striated boulders are also found in the surface soil, 3. Oxidization is most complete in the lowest bed, 1, which is of great thickness, while the upper bed is the least oxidized of all. This is only part of a larger kame which has suffered extensive denudation on the western side.

At Bridgewater it is impossible to get a good section, but near the railway station and at Sebastopol the beds show the following arrangement:

7, Recent alluvium, with tree trunks and stumps, and ancient Indian implements, overspread by forest growth.

6, Modified drift and river gravels.

2 to 5, Succession uncertain. Deposit consist of boulder clay, kames, and river terraces; the kames being very highly oxidized and consisting of the same material as the underlying oxidized drift.

1, The so-called Bridgewater conglomerate,—a pasty iron cemented mass of rounded and angular boulders of quartzite, slate, granite, trapand diorite. This is the most highly oxidized deposit in this part of the province, and contains striated rocks. It is slightly modified in its upper portions, but is underlaid by completely oxidized local drift, consisting of angular fragments of slate in a matrix of clay and sand.

CORRELATION OF DEPOSITS.

First Glacial Epoch.

The Bridgewater drift conglomerate is evidently the most ancient glacial deposit in this part of Nova Scotia. The evidence for this is as follows:—

1st. It is always seen in direct contact with the bed rock and cemented thereto, so as to become in its lower portions almost immovable without the aid of dynamite.

2nd. In spite of its extreme hardness, it has been denuded to a greater extent than any other such wide-spread deposit in the region under consideration. The only places where it can now be seen being along the valley of the Lahave, and along the watershed to the east.

3rd. Since its deposition over highland and lowland alike, and in the pre-glacial valley of the Lahave, that river has been re-excavated and the conglomerate left only in a few isolated patches along its banks. And this has taken place before the depositions of lowest kames and boulder clay.

4th. It debris has been formed into kames which are in turn older than the boulder clay that covers them.

5th. It is more intensely oxidized than any other deposit in the southwestern counties; so much so, that some parts of it constitute almost pure bog iron ore. In no more striking manner can its immense relative antiquity be illustrated than by comparing its highly oxidized condition with that of the overlying till. While the later boulder clay is oxidized only a few feet in depth, this earlier deposit is oxidized and cemented throughout a depth of at least 20 feet. Even beneath the Rhodenizer Lake kame it is just as highly oxidized as elsewhere, although over 30 feet, and formerly 60 feet, of stratified beds covered it.

Extent.—It seems to have formerly masked a large part of the province, since it is found at widely separated points, as Bridgewater; Greenfield, Queens County; Maitland, Lunenburg County; and the Grove, Richmond, which is within the limits of the City of Halifax. The depth to which it covered the country was no doubt considerable, as it is found in the Lahave valley from the sea level to 200 feet above it.

Origin.—That this deposit is not pre-glacial or inter-glacial, its unstratified condition decides. That it is glacial the presence of striated boulders testifies with no little weight. That it is of northern origin is proved by the contents, which consist of slate from near by, quartzite from the north-west, granite from the

central watershed, diorite from the south side of the Annapolis valley, and trap from near the Bay of Fundy.

First Interglacial Epoch.

To this epoch evidently belongs the Rhodenizer Lake kame, and the lower part of section 1 at Blockhouse. The evidences of their position and antiquity are :—

1st. At Blockhouse, section 1, we have 2, *a*, blue clay, with local drift ; *b*, stratified soft red gravelly clay ; *c*, bog iron ore, underlying the lower boulder clay.

2nd. At Rhodenizer's Lake the kame seems to be overlaid by boulder clay, and underlaid by the Bridgewater conglomerate.

3rd. This kame is more highly oxidized at a depth of 30 feet than the boulder clay at a depth of 5 feet. At Blockhouse also, the bog iron of section 1 is over one foot, showing an interglacial period of considerable length.

4th. The Rhodenizer Lake kame seems to have suffered great denudation on its western side. What remains seems to be but a fraction of its former size.

5th. Rounded, oval, and smoothly polished pebbles of quartz and crystalline rocks have been found in the lower boulder clay at Blockhouse, and which, no doubt, were eroded from an earlier water-worn deposit, such as the Rhodenizer Lake kame. The difference between the semi-angular boulders of the lower till, and the polished pebbles scattered among them, was at once noticeable and bespoke for the latter a far greater age.

Since the re-excavation of the pre-glacial valley of the Lahave, I cannot conceive how the conditions could have been favourable for the formation of the Rhodenizer Lake kame on the watershed to the east.

That the Lahave was re-excavated before the deposition of the lower boulder clay, is shown by the presence of that deposit in the valley at tide level two miles below Bridgewater. The formation of the kame and the re-excavation of the valley must have been contemporaneous, as the deepening of the latter and

its tributaries, and the consequent draining of the watershed at Rhodenizer's Lake, would have prevented the formation of the kame. If, as is maintained, this was near the southern limit of glacial extension, then the deep valleys to the east and west of this tableland would influence the course and lessen the eroding power of the thinned-out extremity of the last glacier. The complete removal of a kame on a watershed would then be extremely doubtful. Again, the formation of interglacial kames was but the natural result of influences then in operation. The retention of interglacial, as well as pre-glacial deposits, while being over-ridden by glaciers, was also but a common occurrence.* River terraces must also have been formed from the debris resulting from the re-excavation of the Lahave in this epoch. But whether their remains are represented by the deposits on the river east and south of Bridgewater, I had no time to attempt to decide.

Second Glacial Epoch.

To this period probably belongs the lower till of Blockhouse and Dorey's Brook, and the morraines surrounding them. It is seen filling the re-excavated valley of the Lahave at tide level, without having been there modified to any noteworthy extent. At Blockhouse it underlies the auriferous drift, and at Dorey's Brook it is seen beneath the interglacial clays and upper or auriferous beds, which last are of local origin. This lower till contains trap, granite, diorite, slate and quartzite. These rocks are sometimes much worn, but are generally semi-angular and easily distinguished from the rounded and polished pebbles included among them, and which were evidently eroded from some earlier deposit. It is but slightly oxidized where it is covered by the upper auriferous drift, showing that no very long time elapsed between the deposition of those two deposits. The course travelled by the drift, from the lode at Blockhouse was about S. 22° E. This may be a local deflection, as the

* Chalmer's Report on the Surface Geology of Eastern New Brunswick, 1895, page 47 ; M. also, Acadian Geology, 2nd ed., page 68.

general course of the striæ on the highlands around, is about S. 45° E., while the course of the valley in which the lode lies is about S. 50° E.

At Dorey's Brook, a thin bed of partly oxidized boulder clay containing granite and other northern drift, laid on the bed rock; while in the layers above, granite was absent. A large morraine, 2½ miles southeast of Dorey's Brook, contains much northern drift, with quartz, easily recognized as coming from a vein a little east of the brook. Their travelled course was about S. 40° E. The lower till, where covered by an upper layer of later origin, is but slightly oxidized, and in some places not at all; but this is probably owing to subsequent denudation, I have not been able to divide the till of the northern part of this district into an earlier and later deposit. The inference from this seems to be, that the next interglacial recession did not reach to the northern part of the area under discussion. A single deposit would there include what is represented further south by the deposits of two apparently distinct glacial epochs separated by a short interglacial period.

Second Interglacial Epoch.

This should be classed as a slight re-cession of the glaciers, rather than an interglacial epoch. The evidence at hand seems to indicate that while there was a re-cession of the ice at Blockhouse, it did not retire as far north as the granite, or even as far as the next quartzite belt, two or three miles distant. However, in its effect upon the purpose of my work, viz., the discovery of a gold bearing vein, it was adequate to an ordinary interglacial epoch, as it divided the drift into two portions, differing in character, condition of contents, and in the course traversed by it. The deposits belonging to this epoch consist, at Blockhouse, of red and yellow ochreous clay, (see section 2); finely stratified sand, (section 3); thin bed of bog iron, (section 4).

At Dorey's Brook are various coloured clays underlaid and overlaid by unstratified drift (see section). The overlying drift in all these sections is of local, and the underlying drift chiefly

of northern, origin. This shows that the ice sheet did not recede far enough to gather before it in its second advance any northern drift, while the slight oxidizing of the lower beds reveals a length of time which is very limited when compared with that of the first great interglacial epoch. This epoch is often represented by a slight denudation of the oxidized part of the underlying boulder clay.

Third Glacial Epoch.

This, the last invasion of this district by the ice sheet, has left as its legacy the local auriferous drift of Blockhouse and Dorey's Brook. In both these places it was probably gathered from exposed hummocks and loose debris in the immediate neighbourhood. It consists largely of angular slate boulders and oxidized clay and gravel, with here and there a few boulders eroded from the lower till. The most noteworthy point in this deposit, aside from the fact that it contains the gold-bearing drift of Blockhouse, is that the direction of its movement is different from that of the lower boulder clay. While the course of the latter has been about S. 22° E, that of the former has been from S. 50° to 55° E. Thus, while the underlying drift has been subject to continental or at least provincial influences, the upper drift is local both in composition and course of movement. At Dorey's Brook, also, the course travelled by the upper drift is influenced by the local surface contour. Its course is about S. 65° E., while that of the quartz in the interglacial clays is N. 80° to 90° E., and the underlying boulder clay probably S. 40° E. The tracing of the course travelled by the different layers of drift, is often a painstaking and difficult study, where no striations are left as a guide. But once its origin and the course it has travelled are known, it becomes our most reliable guide in the search for gold-bearing veins, and as such will repay the most patient investigation.

Post Glacial Epoch.

The deposits of this epoch consist of modified drift and river terraces. At this time the land appears to have been more elevated than at present, during which the beds of many of our

rivers were deepened. This I attempted to show in a paper read before the Institute on February 8th, 1892. These old river beds now form the channels of many of our harbours. Their formation has been ascribed to the tides, but apparently nothing less than the disjointing action of frost, aided by the attrition of rocks and gravel urged on by a rapid torrent, could cut away those deep and precipituous channels. The modifying influences of this epoch have had a very important effect on the distribution of the drift in some of our gold districts. At Blockhouse, however, it did not disturb the upper deposits to any appreciable extent, so we gave it but little attention.

As the deposits of the recent era merge into those of the historical period, I shall not deal with them. Several facts which have lately come to my knowledge possess a peculiar interest, inasmuch as they throw some light on that dim period that connects the historical with the geological history of Nova Scotia. They deserve a critical examination and a more extended notice than I am able to give them.

GENERAL CONCLUSIONS.

As this paper is already probably too long, I shall conclude it with the following remarks. That there has been a time when a continental glacier ploughed its way across the Bay of Fundy and the Province of Nova Scotia, seems to be beyond doubt, notwithstanding recent assertions to the contrary.* The alternative of a local or provincial ice sheet, is not in accordance with well-known facts except in the latest stages of the ice age. How otherwise could boulders of trap from the Bay of Fundy surmount the central watershed, and be distributed over the whole southern slope from Halifax to Yarmouth? They are not a chance occurrence, but are found in abundance in nearly every morraine and kame. How could a comparatively thin ice sheet flow along such a gentle descent as 1 foot in 340, unless it had the powerful influence of a continental glacier to

* See Chalmers Report on the Surface Geology of Eastern New Brunswick, 1895, pages 95 and 108.

back it? If we choose the latter as the cause of many of our phenomena, we have the following succession of events. They are numbered to accord with the supposed corresponding deposits in the sections before given :—

1. General glacial epoch: Nova Scotia covered by a continental glacier which masked the country with an enormous thickness of glacial debris of northern origin.

2. Interglacial epoch of considerable length, during which the pre-glacial valley of the Lahave was re-excavated to its former depth, immense kames formed, and the remaining drift oxidized more completely than any recent deposit. As a proof of the enormous length of this interglacial epoch, nothing is more convincing than the complete oxidization of these underlying deposits compared to the relatively slight change of a like nature wrought in ordinary boulder clay of a more recent date. The development of the *Pithecanthropus erectus*, with its 1000 cubic centimetre skull, is no surprise when such lengthened periods are dealt with (pardon this digression.)

3. A glacial epoch of shorter duration and less intense action. This was probably divided into two lesser epochs near the southern limit of its extension by a slight recession, and thus gave rise to the upper and lower deposits of Blockhouse. There was probably a repetition of such recessions and advances, until the general ice sheet dwindled to a local ice field and finally disappeared.

4. A local recession at Blockhouse, as mentioned above, during which a few beds of clay, sand, and bog iron were deposited.

5. A slight re-advance of glaciers on courses governed by the local surface contour. In its bearing on the deposition of the auriferous drift at Blockhouse, this re-advance was adequate to a separate glacial epoch, and from a miner's stand-point will have to be treated as such.

6. Final retreat of glaciers, formation of river terraces and general elevation of the country, during which our now submarine river channels were excavated.

7. Recent subsidence of our southern coast, as our buried forests and peat bogs indicate.

As is well-known, the study of glacial geology is of vast importance to the future of gold mining in Nova Scotia, and the discovery of important lodes are even now depending on a true explanation of the mysteries which surround the deposition and distribution of those deposits. What makes the matter very intricate, is that each district has been subject to local as well as general influences, thus necessitating a thorough local investigation before any trustworthy conclusion can be arrived at. Neglect of such a thorough investigation has been the chief cause of the many failures in the search for gold-bearing veins in Nova Scotia. But the days are fast going by when the working miner looked with supreme contempt on the study of geology as the hobby of a few students and men of leisure. It has been said that the science of the past will be the common-sense of the future, and the writer can make no apology for this article other than that he is contributing his feeble efforts to bring about this much-desired end.