Ice-borne Sediments in Minas Basin, N. S.—By J. Austen Bancroft, *Acadia College, Wolfville.*

(Read before King's Co. Branch of N. S. I. S., 21st April, 1903.)

The power of running water to carry along mud, sand, gravel and fragments of rock to a considerable distance, is greatly increased in those countries where during some part of the year the frost is of sufficient intensity to form ice of considerable thickness.

During a winter of average severity, a person standing upon the government pier at Wolfville, King's County, N. S., watching an ebb tide, is impressed with the immense amount of ice carried down the Cornwallis River into Minas Basin. Within the ice, which is very muddy in general color, pebbles and fragments of rock may be seen entangled. This ice-borne detritus may be referred to at least three different sources :—

(i.) Ice forms along the banks of the rivers which flow into Minas Basin. During a slight thaw, small streamlets bear gravel and sand down upon its surface. Upon colder days, if there is not much snow on the ground, the wind sifts down its contribution of fine material upon the ice. With a following slightly higher tide, a layer of ice is formed upon the old surface, and a thin stratum of detritus is locked up and ready for later transportation. By the buoyant power of the water, assisted by sudden changes of temperature of the atmosphere, these projecting masses are broken off and are drifted away by the current. Each miniature iceberg thus formed, tears away some debris from the bank of the river.

(ii.) In some places, the shore-line of Minas Basin is marked by cliffs, which are exposed to wave action and the scour of tidal currents. For example, at Starr's Point and at Long Island, the land platform terminates in cliffs of a dull red sandstone of Triassic age. Its chief constituents are rounded grains of white to colorless quartz, decolorized and almost lustreless flakes of muscovite and biotite, and a few particles of decomposed feldspar, and the whole cemented together by calcite. The calcite fills the interstices of the rock, and forms a thin film about each individual grain of sand. The frozen interstitial water acts as a powerful force in the disintegration of this sandstone, cracking the calcite, and thus loosening the more durable grains of quartz and mica. Another instance may well be cited. Between Avonport and Hantsport, for the greater part of the distance, is a continuous cliff of purplish to black, finely laminated shale, with interspersed layers of sandstone and clay ironstone. In some places, the shale is capped by a thin layer of boulder clay. Water freezes between the laminæ of the shale, and breaks it up into thin scale-like fragments. Large cakes of ice are left by the receding tide beneath these cliffs, and on a sunny day, there is a continual shower of this frost-loosened detritus upon their surfaces. Sometimes landslides, on a small scale, of the overlying boulder clay pour down upon the ice a load of debris.

(iii.) The ebb tide leaves many cakes of ice stranded on the area which is left bare between high and low water. During the interval of time between ebb and flood tide, they are frozen to the surface of the ground; but only to be floated again at high water. They then lift a thin layer of detritus from the land area to which they have been frozen. One ice crust was noticed floating about with a layer of sod, which, doubtless, had been in this manner removed from the surface of the marsh. Upon being floated, a layer of ice forms upon the lower surface of the ice and the debris is thus enclosed. If this action goes on for several days, it gives the ice a well stratified appearance.

During the second week in February, 1903, while studying at Acadia College, the writer, under the guidance of Professor Ernest Haycock, performed a series of experiments, in order to ascertain the amount of sediment carried by the ice in Minas Basin at that time. The winter was not very severe, and the ice did not attain to the thickness which had characterized it during some previous years.

At the mouth of Mud Creek, the thickness of between fifty and sixty cakes of ice which had been left there by the outgoing tide was carefully measured. It was impossible to include in these measurements some of the thicker cakes of ice which were floating down the Cornwallis River. The average thickness, by this method, was found to be one and a half feet. This estimate was a very conservative one, since the thicker cakes of ice which are stranded, some even ten and twelve feet in thickness, seem to lodge upon the stretch of marsh laid bare upon the opposite side of the Cornwallis River. But in calculating the average, the cake of greatest thickness measured was seven feet thick, another was five feet thick, and the rest ranged from this down to three inches.

Much attention was given to the selection of those ice cakes which were carrying the average amount of sediment, and for this purpose many more cakes of ice were broken open and carefully inspected. Then thirty-four pounds of the ice containing an average quantity of detritus was melted and filtered upon large filter papers in the laboratory. The sand and mud collected on the filter paper was dried in an oven at a temperature of 90° C. The weight of the sediment found in this quantity of ice was found to be 1.1 pound. Upon examining portions of this material under the microscope, at least three distinct varieties of diatoms were noticed. From an admiralty chart, the length of the coast line of Minas Basin, was found to be about 120 miles, without taking into account the many small indentations and irregularities of the shore. The width of the tidal flats exposed at low water, from the same chart, was estimated to be about three-fourths of a mile. If these calculations are at all in error, it is due to the estimates taken not being large enough. The amount of ice in the Basin, at the time the experiment was performed, was such that when it was low water the tidal flats laid bare were covered with irregular ice masses, and much ice still remained floating.

The results of the complete experiment here appears in summary form, together with the conclusions derived from them :—

One square mile $= 5280 \times 5280 = 27{,}878{,}400$ sq. ft.

Average thickness of 59 cakes of ice $= 1\frac{1}{2}$ ft.

$\therefore$ Number of cubic feet of ice covering one square mile

$$= 27{,}878{,}400 \times 1\tfrac{1}{2} = 41{,}817{,}600 \text{ cubic ft.}$$

The weight of one cubic foot of ice of salt water on an average = 55lbs.

Now in 34 lbs. of ice, the weight of sediment found = 1.1 lb.

$\therefore$ In 55 " " " " " $= \dfrac{55 \times 1.1}{34}$

$= 1.779$ lb.

Hence the weight of sediment in ice covering an area of one square mile $= 41{,}817{,}760 \times 1.78 = 74{,}435{,}328$ lbs.

Length of coastline, Minas Basin (approximately) = 120 miles.

Average width of tidal flats $= \frac{3}{4}$ of a mile.

$\therefore$ Amount of surface (at the least) covered by ice

$$= 120 \times \tfrac{3}{4} = 90 \text{ sq. miles.}$$

$\therefore$ Weight of sediment borne by the ice covering this area

$$= 74{,}435{,}328 \times 90 = 6{,}699{,}179{,}520 \text{ lbs} = 3{,}349{,}590 \text{ tons.}$$

This result shows the transported material to be much more than might have been expected by the casual observer. But, after having performed the experiment, one has the feeling that the result obtained is far from being an exaggeration of what actually takes place. Where the stretch laid bare at low water is greater than at Wolfville, as in Cobequid Bay, the ice attains a much greater thickness. As might be expected, the amount of sediment carried by the ice varies with the severity of the winter. During what may be called a broken winter, several sets of ice may be formed,—a prolonged thaw nearly clearing the Basin of ice, only to be followed by a cold snap with a new ice crust.

The amount of sediment carried by this floating ice is greatly emphasized to one if he watches the melting of some of the ice clumps stranded upon the marsh by an exceptionally high tide. In one case, the layer of sediment left after the melting of such a stranded cake was six inches thick, and in the midst of the detritus was a boulder of trap rock which weighed over twenty pounds. Early in the spring, the marsh has the appearnce of being covered with ant hills, this effect being produced by the melting of these isolated ice cakes, and the deposition of their burden of debris. These scattered heaps of sediment do not seem to be easily levelled down by succeeding high tides. If by the continued formation of laminæ, deposited by the following high tides, they should be buried, it would seem as if they should be of some geological significance in the structure of the rock formed, at a later date, of these stratified marsh sediments. Possibly they would cause slight irregularities in the bedding, or give the rock a patched appearance. But this is largely conjecture.

This material deposited on the marshes in this way is caused by the standing of only a few stray ice cakes. A good deal of the floating ice is carried out into the Bay of Fundy. Much of it melts while floating in the waters of Minas Basin. Some of it melts while resting on the area left bare between high and low water. But wherever the melting takes place, it necessarily is accompanied by the deposition of the burden of detritus. The ice which floats about in Minas Basin during the winter, is thus seen to be a very important agent in the transference of mud and silt, abstracted from the land, to the sea bottom.