

ESKAR EXCAVATION IN NOVA SCOTIA.—BY WALTER H. PREST,
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Among the interesting but much neglected branches of scientific work awaiting investigation in Nova Scotia is the exploration of eskars. I recently had the pleasure of sectioning an eskar at Middlefield, Queens County, Nova Scotia. I herewith give a general description of this section and the conclusions that seemed to me most reasonable and natural.

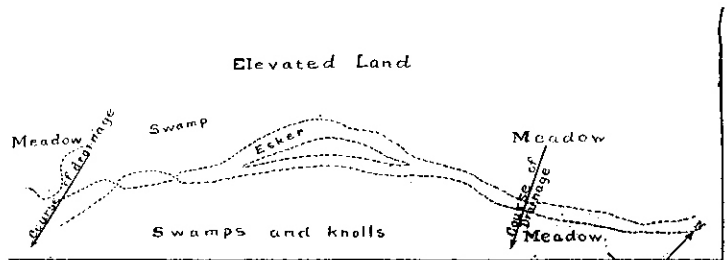
This eskar crosses the road from Annapolis to Liverpool, about thirteen miles from the south coast. It is one of those described in a paper read by me at a meeting of the Nova Scotian Institute of Science in March, 1918.* The following description will give an idea of its structure and the conditions under which it was formed.

*The
Middlefield
eskar*

Its general course is parallel to the south coast and direct across the drainage system of the province. In this peculiarity it is in accord with the great majority of eskars in Nova Scotia. As far as explored by me it begins on a low tableland about five miles west of the Port Medway River, descending the gentle slope for several miles toward that stream. However, as a local peculiarity, it inclines up stream as it approaches the Medway; crossing swamps and crossing successive elevations. It continues on the eastern side of the river with the same variations in height and course. In its approach to a wide meadow it has been spread out as if by the action of the waves of a lake of later age. Here much sand has been spread out in banks and flats. This could not have been so distributed except by the wave action of a shallow and wind-swept sheet of water.

In the neighborhood of the Middlefield road this eskar is from 30 to 80 feet wide and from 5 to 16 feet in height,

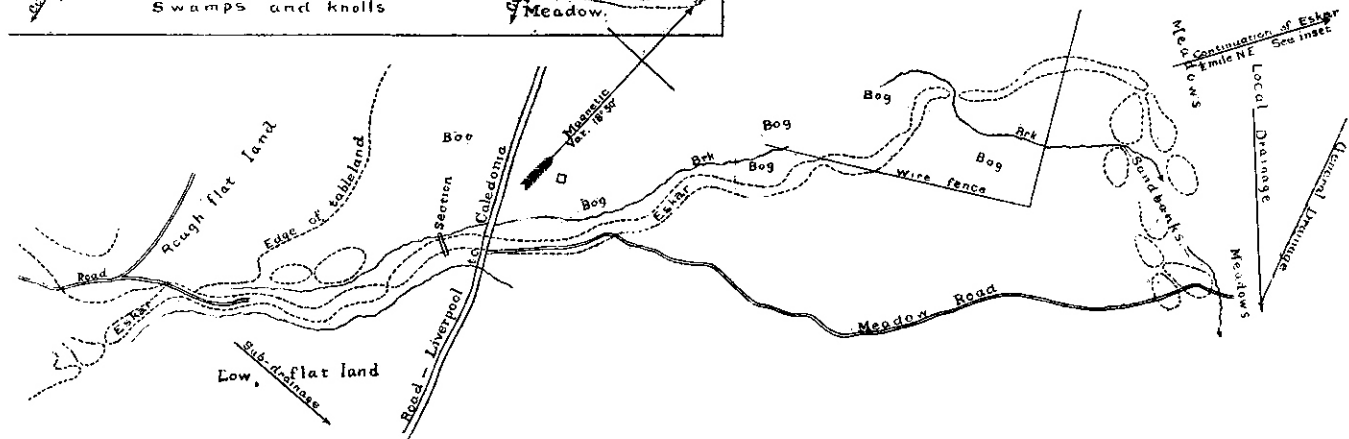
* On the nature and origin of the Eskers of Nova Scotia. Trans. N. S. Inst. Sci., Vol. XIV, Pt. 4. The present paper is supplementary to the former and should be read in connection with it.



ESKAR at MIDDLEFIELD, QUEENS CO., N. S.

Scale 746' = 1".

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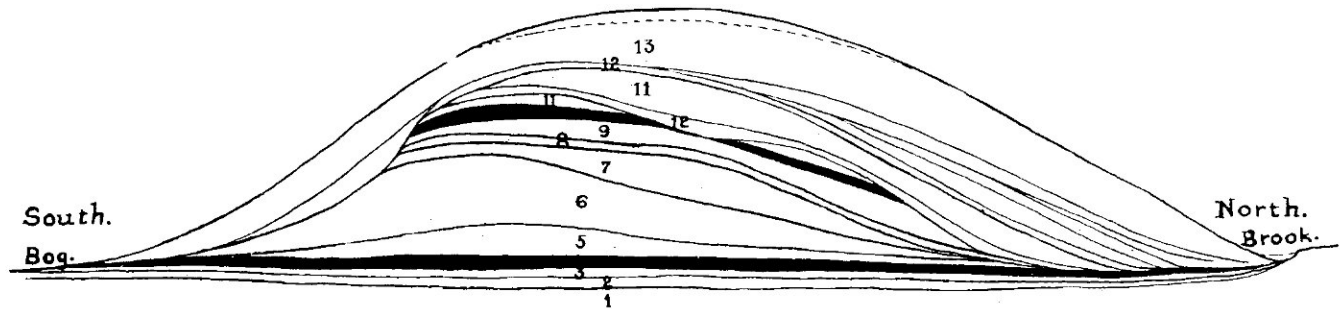


being a very noticeable feature in the landscape. The surrounding country, especially to the north, is only moderately covered by glacial debris.

The eskar material is evidently reworked drift. Like other eskars, its varied character and peculiar form are its most striking features. They have been the cause of much speculation as to origin and mode of deposition. This eskar shows evidence of extreme changes in the conditions governing its deposition. Rapid evasion and quiet sedimentation are evident within a few feet or even inches of each other. A glance at the cross section will show the relation of these beds to each other.

Beginning at the bottom of our excavation we find what appears to be a somewhat modified boulder clay. The depth of this could not be determined without a pump, as the soil contained a large amount of water. Above this a layer of fine clay, passing into a red bed of much worn rocks, No. 3, cemented by iron oxide. These indications of a rapid current and mineral precipitation are followed by an intensely black deposit of rocks, gravel and sand, No. 4. This has apparently been blackened by a precipitation of manganese oxide in addition to iron. This passes gradually into another layer of red iron cemented rocks, No. 5. These last three beds seem to have been the product of one period of rapid water transportation. This question of mineral precipitation needs a more thoro and detailed investigation than I had time to carry out; but the *modus operandi* is probably the same as that which fills our brooks with bog iron and manganese.

On this iron cemented bed of coarse material is laid a thick bed of well assorted gravel, graded to a wonderful degree of perfection. One would think that human intelligence had been used in the process. It is the thickest bed in the section. Its sides, especially on the south, was eroded before the next bed, No. 7, was laid down, This consists of rounded rocks, gravel and sand, evidently deposited by a very rapid, but at times a variable current. It also suffered erosion, before the next bed, No. 8, was laid down.



Section across an eskar at Middlefield, Queens County, N.S.
 Width 80 ft, Height 16 ft, Course S 36° W, Scale 12' = 1".

- 13.- Disturbed gravel, rocks, and sand.
- 12.- Stratified rocks and gravel, fine and coarse.
- 11.- Rounded rocks, with very little gravel.
- 10.- Fine laminated clay.
- 9.- Fine sand.
- 8.- Coarse sand.
- 7.- Rocks, gravel, and sand.
- 6.- Fine gravel, well assorted.
- 5.- Rounded rocks and gravel cemented with bog iron.
- 4.- Same, with trace of bog manganese.
- 3.- Same as Bed No 5.
- 2.- Fragmentary seams of clay with boulders.
- 1.- Partly modified drift.

W. H. Prest.

Beds No. 8, 9 and 10 were deposited under a variable but gradually lessening turbulence of waterflow. First, gravel and coarse sand, then fine sand. Then came a rather sudden change to extremely quiet conditions when a very finely laminated clay was laid down. This clay could be deposited only when a former outlet was dammed by debris and the resultant current capable of moving only the very finest material. This tranquil condition ended in a period of slight erosion.

On the fine clay was laid the fine sands of bed No. 11, followed again by erosion which cut deeply into the southern side of the eskar. The cause of this erosion is referred to later.

Then succeeded alternating conditions, during which were deposited the gravel and sands of bed No. 12 and the coarser material of bed No. 13. Thence, to the top of the eskar, the deposits showed the results of alternating rapid and moderate currents. All these upper beds showed the confusing postglacial effects of frost and the growth of vegetation.

Now let us summarize the possible history of this deposit. At the beginning we have a provincial if not a continental glacier. All large glaciers show crevasses, and our Nova Scotian glacier could hardly have been an exception. The cause of the formation of ice crevasses is evidently a tension or strain which reaches its breaking point where the slope of descent changes to one more or less steep. This is the case both in Greenland and on the Antarctic continent. It must have been so at Middlefield, where we have to the south a gentle tho fairly even slope and to the north a flat lake region. And yet this eskar does not lie exactly on the edge of the lake region, but a short distance to the south. At the edge of the lake region we have a few short ridges, evidently the beginning of another system of crevasses, which in time might have become the seat of a prominent eskar.

We have here support for the belief that crevasses, after their successive formation across a continental ice sheet, were carried forward in the general advance until climatic changes called a halt. The surface water, pouring into the debris gathered each summer, sufficed to keep the crevice open until

*Variable
conditions*

Erosion

*Summary
of history*

*The
Crevasse
theory*

the melting ice added to the accumulation and formed a permanent eskar. I think all will agree that where the slope is so slight as in Maine and Nova Scotia, no advance was possible after the mass and moving power of the ice had dwindled to a certain point. When this stage was reached its dissolution began. Only then began that re-erosion and redeposition of stratified eskar material that is so noticeable a feature of these deposits.

It has been objected by some, that hills and other local irregularities would mark the icefields with a system of radiating cracks. I admit this where the ice was thin or the elevations were increased to mountains. But I cannot think that a 300 or 400 foot hill would be noticeable under an ice sheet 5,000 to 10,000 feet thick. And besides, the well-known plasticity of ice enables it to accommodate itself to extreme irregularities of surface. This fact is attested to by the testimony of many explorers and investigators. For this reason small and local cracks not enlarged by running water would certainly close, freeze up and disappear in winter. But the immense cracks formed along the slopes of a continental glacier are too wide and deep to be thus easily disposed of. That they were not thus disposed of is evident to all who have read the account given of them by Arctic and Antarctic explorers. Only in great icefields could such deep and lasting crevasses be formed. Even there the smaller cracks would close or refill with ice before they could gather enough material to keep them open until a higher temperature and a flow of water made them permanent. The size of the larger cracks must have made them permanent from the first.

I have made the claim that the edges of the cracks thus formed may be used as an eroding tool. But it has been objected that on account of the plasticity of ice all cracks may close before being used in the work of erosion or as a place for the deposition of debris. That all cracks do not do so we have these facts to the contrary, viz.: Shackleton, Nansen, and

others, tell us that on sunny days the surface water from the melting ice disappeared in wide deep cracks in the centre of vast icefields. That these crevasses never became full is ample evidence that the water passed away in the depths of these channels. Even the supposed subglacial streams must be fed thru crevasses from the surface, else where would the water come from?—and if not permanently open, where would the water go? This melting of the surface ice is a common summer occurrence, and can be the only possible source of water in the great ice sheets of the glacial age. I doubt if any crevasses could close permanently in a latitude where summer melting was possible. This, added to the eroding power of the debris incorporated in the base of the ice sheet, must in ages prove ample for all the results noted.

*Only
source
of water*

We know that frozen or cemented basal drift is and has been ridden over by advancing ice sheets. Such instances have been noted in Dawson's Acadian Geology and numerous other works. We know that frozen or cemented till is often loosened by the percolation of water. Also it must be acknowledged that the impact of surface water, descending as Polar explorers saw it, for perhaps 1,000 feet, must without doubt be a very effective eroding agent. It may also be doubted whether the lower ice edge in a glacial crevasse is capable of eroding the underlying drift. We know that the frontal edge does so. Knowing this, we cannot doubt at least the moderate erosive power of an ice edge many miles to the rear, where the ice sheet is probably many times thicker and the weight immensely greater than at the front.

*Erosion by
falling water*

Thus even before the cessation of glacial movement the churning effects of summer torrents from the glacial surface would wear and polish the debris for the grading and stratification of a later age. It may be reasonably concluded that this torrential action recurred each summer for many ages before all forward movement of the ice sheet stopped. We are also compelled to admit that under these known conditions the debris in these crevasses must be subject to much greater

*Churning
effects*

wear than the compact and frozen till in the inequalities beneath the ice sheet. Its orderly stratification was therefore possible only in the closing stages of the ice age, when moderate tho often interrupted currents transferred the debris along the crevasse from higher to lower grounds. Slight movements along the line of glacial action after stratification had begun would account for the curved and distorted layers noted by some observers.

So far, I have been using as working theories only the observations of the most reliable explorers—facts which none of us would have the temerity to doubt. Readers of the works of Arctic and Antarctic explorers will acknowledge the actual operation at the present time in the polar regions of what I propose to call the Crevasse theory of eskar formation. Only this small doubt remains; We cannot see the Polar eskars as we see our own. But doubt in this case would be the same as if we emptied a scuttle of coal into a deep dark hole, and then doubted its presence there because we could not see it.

To return to the treatment of more local details we may note some peculiarities of the Middlefield eskar. One is the absence of large boulders; in fact the entire absence of anything but the most well-worn and rounded rocks of any kind. Even river and lacustrine boulders do not show a more intense torrential action. Nothing less than the most violent and long-continued agitation, as under a torrent of water falling from an immense height, could show such results.

In regard to the absence of large boulders, those being firmly bedded in the ice sheet could not have been easily overridden and swept into the maelstrom of aqueous action unless in the course of the crevasse. Large boulders would more probably be carried forward in the general ice movement.

Another peculiarity is the abrupt enlargement of the upper end of the Middlefield eskar on the eastern side of a flat tableland. This enlargement is a perfectly natural result of the enlargement of the highest part of the crevasse by the

fall of surface water at the first possible point of entrance where the ice was thinnest.

And now let us review as far as possible from the limited local evidence at hand the successive processes that brot about the present form of the Middlefield eskar.

Review of Evidence At the bottom of the Middlefield crevasse, after the final pause of the ice sheet, began a slight erosion. This depression was afterwards filled in with modified drift. Its then stationary character is shown by the fine sediment that followed this erosion which was deposited among the exposed rocks of the boulder clay.

Insufficiency of old theories This deposit is shown as No. 2 on the sectional plan. The conditions accompanying the deposition of this fine clay prevents the acceptance of any of the theories of origin usually applied.

A glacial lake on the slope of this watershed is an impossibility. A super-glacial stream would have no source of debris supply. A subglacial stream on the top of a watershed could not wear and polish the eskar material at its very beginning as this was polished. None of these theories can explain all the peculiarities of eskars.

A crevasse dammed by debris is the only explanation that will account for quiet water on the slope of a watershed, and its retention at such a high level. We find evidence here for the belief that each stage of erosion provided material for the damming of the crevasse and the beginning of a quiet water stage in which was deposited the finer material of the next beds.

Beds No. 3, 4 and 5 show turbulent water conditions in a bed of smoothly worn boulders. The most striking peculiarity of these beds is that they show the precipitation of mineral matter instead of clay.

A striking feature Beds No. 6, 7, 8, 9 and 10 make a series which show an increasing current to No. 7, and then a decreasing tho irregular current which ended in the extremely quiet water deposit at No. 10. The important

information conveyed by this clay bed will be referred to later on. Then came a slight change in conditions and a stronger current covered the clay with sand. (Bed No. 11). Then came a period of erosion which cut away both sides of all the beds from No. 6 to No. 10. This was caused either by the removal of a debris dam or by an increase of temperature and a more rapid melting of the ice and a consequent increase in the flow of water.

*High level
erosion and
deposition*

One result of this erosion was that the southern side of the eskar is the most steeply eroded, while the northern slope is broader and less steep. These facts tell a tale of great import. Nearly all of us have noticed in ice-filled road drains, how a crack becomes a watercourse which fills with earth as the crack grows larger. If the crack ran north and south nothing worthy of note happened. But if it ran east and west the north side received more sunlight than the south side. And as the north side melted faster, the debris spread out on that side while lying higher and closer to the south or shady wall.

*An
important
evidence*

The Middlefield eskar tells us the same tale. A tale of a time when high ice walls enclosed and overhung the debris there and the slanting southern sunlight shone only on the northern wall. The south wall, always in the shadow, could melt but slowly, and the debris lying against it was eroded but little, long retaining its steep face. The north wall of the crevasse receding faster, gave more room for the eroded material, hence the gentle slope. Nature's records here seem to be clear and easily read. The relative slopes of the sides of an east and west eskar are important evidences of origin, and I much desire such information from other investigators.

*The only
solution*

I must say here that while evidences of such erosion are noticeable on the lower layers they are not so prominent as on the beds numbered from 6 to 11.

This erosion was the beginning of new conditions brought on by increasing waterflow. The result probably of increasing temperature. Strong currents covered the lower beds with unconformable layers of generally coarse but variable character. Large rocks alternate with small rocks, gravel and sand. The upper

*Agreement
with climatic
improvement*

layers are confused by the growth of vegetation and the effects of frost.

We have in this eskar evidences of two periods of erosion, two periods of deposition, and a period of mineral precipitation.

Summary of local evidence These represent apparently, no sudden changes of climate or increase or decrease of rainfall, but only the conditions seen in the average rapid stream. There the erosion and transport of material forms or removes pools and rapids as a river erodes its bed.

In drawing conclusions from these observations we must remember that this section was made on but one portion of a long eskar, which differed in height, breadth, and environment in its different parts. It is only by averaging the results from many sections that correct conclusions can be arrived at.

Evidence limited I think however that the following may be accepted as a working hypothesis. The eskar material, while being gathered, was thrust forward in the general glacial movement. All this time the enclosed debris, according to evidence of polar expeditions, was subject to the most tumultuous agitation by the streams of water poured into the crevasse by the melting summer sun. This was the first stage of eskar formation.

A working hypothesis Then came a pause and the process of stratification. The melting ice gave up its enclosed material, adding to that already gathered. And this material was continually worn, rolled, and gradually shifted from higher to lower levels as long as water remained in the crevasse. This condition, of course, ended on the higher sooner than on the lower ground. But all these conditions were localized and probably repeated many times in the same place as the ice sheet proceeded toward its dissolution.

That water transport of heavy material has thus been effective is seen in the immense eskars that traverse river valleys. Such a ridge is seen at Nine Mile River, Hants County, Nova Scotia. Here is seen an enormous eskar 50 feet high and often 300 feet wide. It traverses the valley, usually parallel to the river but sometimes crossing it. There is evidence to

Other Evidence in Nova Scotia

show that the river once ran at this high level. To do so it must have occupied a glacial crevasse until the ice melted enough to allow it to occupy its original bed. We may reasonably conclude that during this time all the material that would otherwise have been transported in lower channels filled the crevasse.

The same enormous valley eskars are seen in the basin of the Ashuanippi and other rivers of Labrador. *Enormous eskars of Labrador* Details concerning these eskars have been published by the Canadian Geological Survey.

A friend has drawn my attention to the frontal theory of eskar formation advanced by W.B. Wright, of the Geological Survey of Iceland. In this the essential condition is the presence of stagnant water along a retreating ice front. *The Frontal theory* In reply I must say that such a condition could not apply on this gradually sloping watershed where the wide river valley offers no obstructions capable of forming anything larger than pools and ponds. These long ridges of variously bedded deposits of varied character means locally confined and swirling currents and changing conditions of very local extent. Only on the low lands where lakes are possible is the debris from the eskar spread out in wide banks of regular stratified material.

Trowbridge, writing on the eskars of the west, notes that eskars are more common on rough than on level country. *Evidence from the West* For instance, hundreds are seen in Maine and Sweden, while on the Upper Mississippi they are very rare. This is valuable evidence, and indicates the need of inequalities of surface for the production of the tension needed for the formation of crevasses.

Finally, I will put this problem to opposers of the crevasse theory of eskar formation: How could the quiet water necessary for fine clay deposition on the top of an eskar, and on the slope of a watershed, ever have been retained except by enclosing walls that have since disappeared? *An unsolved problem*

In my former paper on Eskars read before this Institute in 1918, I maintained the crevasse theory of the origin of eskars. *Former paper on eskars* I still see no reason to alter my conclusions.

Before closing I must note a detailed examination of a road cutting thru an eskar near Pictou town made by Dr. A. H. MacKay, Superintendent of Education for Nova Scotia.* These details were handed to the Canadian Geological Survey by Hugh Fletcher, and if not destroyed must be available yet. I regret not being able to compare them with my own observations.

In concluding this description I must thank those whose generosity has made possible the cutting of the first section thru an eskar in Nova Scotia for purely scientific purposes.

* Dr. MacKay maintains that the Pictou Town eskar is best accounted for on the Crèvevasse Theory—that none of the other theories can account for all the conditions observed.—*The Editor.*