

purposes. Under field conditions the corer would be lifted from the hole after drilling each 18-inch increment, and after removal of the core a 36-inch extension rod would be added before drilling the next two increments. It is estimated that with one man operating the drill and a second logging the cores and selecting palynological and radio-carbon samples a two-man team could core a frozen bog 8 ft. deep in 30 to 45 minutes.

Probably several different power units would prove satisfactory in operating the SIPRE ice-corer, so that choice may be based on availability and individual preferences. In choosing between the two units tested, weight and ease of operation are the important considerations. With the Haynes Earth Drill only the driving head at the end of a flexible shaft drive is mounted on the corer and operation is more convenient than with the McCulloch motor, which is mounted directly on top of the coring column. However, the comparatively light weight of the McCulloch motor would be a decided advantage in airborne operations.

Details of power units tested

McCulloch chain-saw motor. Model 35 C/W, 3.5 H.P., 2-cycle, with 20:1 worm drive attachment, fitted with special handles according to specifications of Pacific Naval Laboratory, Esquimault (DRB/P-4749, September 27, 1960), and an adapter to connect drive shaft to SIPRE corer extension rods. Weight with fuel tank empty 26 lbs. Manufactured by McCulloch Company of Canada, Rexdale, Ont.; modifications by Coast Power Machines, Ltd., Victoria, B.C.

Haynes Earth Drill. Model 450, Briggs and Stratton 4.5 H.P., 4-cycle gasoline motor, Model 141332, with adapter for SIPRE corer extension rods. Weight with fuel tank empty 85 lbs. Manufactured by Haynes Manufacturing Company, Livingstone, Texas.

OWEN L. HUGHES*
J. TERASMAE*

LANDFORM STUDIES IN THE MIDDLE HAMILTON RIVER AREA, LABRADOR

Introduction

During the summers of 1961 and 1962 landform studies were carried out in the area around the Grand Falls of the Hamilton River, Labrador. The chief aim was to determine, as far as possible, the sequence of events that led to the development of the system of canyons occupied by the middle part of the Hamilton River and many of its tributaries.

During the summer of 1961 field work was carried out by the writer alone, using simple methods. In 1962, with the aid of a field assistant, N. Oesterreich, and using more elaborate techniques, it was almost possible to complete the field work. Most time was spent in the relatively accessible areas around Twin Falls and Grand Falls, but visits were also made by float plane to two areas 18 and 40 miles due east of Grand Falls, and a traverse was made by canoe along the Hamilton River from below Grand Falls to Goose Bay. Austin Montague of Northwest River was canoe man.

Methods

Ground checking of airphoto interpretation of landforms and surface geology, and general investigation on the ground was the basic technique employed. Generally this showed that wherever there is a local relief of more than about 100 feet, the minor landforms can usually be resolved into a sequence of erosional or depositional forms or a combination of both, produced under conditions of lowering of the level of the ice surface, lowering of the watertable within the ice, and an increasing ratio of water to ice.

Soil samples were collected where appropriate, chiefly for analysis of particle size. Those from the banks of the lower Hamilton River are to be examined for microfossils.

Striations and associated marks on bedrock indicating direction of ice movement were found only occasionally. The majority indicated the previously recorded movement in the area, which was from the northwest.

*Geological Survey of Canada, Ottawa, Ont.

About 40 miles east of Grand Falls is an area of drift showing linear features in a NE-SW direction. Several crag-and-tail forms in the area leave no doubt that the lineations were formed by an ice movement from the southwest. Evidence that this movement preceded that from the northwest was found on Bell Mountain, 20 miles east of Grand Falls. Here were found both grooves aligned southwest and striations aligned northwest, intersecting in such a way that it was clear that the movement from the northwest was later.

Till-fabric analysis. The orientation of stones contained in till was analysed wherever it was felt that this might yield information on the mode of deposition of the till. Most of the resulting 31 diagrams show a maximum orientation northwest-southeast, i.e., in the direction of the latest regional ice movement. This suggests that most of the tills analysed were laid down from the ice without much disturbance by slumping or squeezing, which was not always the mode expected. A few analyses were made in three dimensions. Two of these were of a deposit within Bowdoin Canyon, the gorge of the Hamilton River below Grand Falls. They suggest that this deposit is till and is not the result of landslides or solifluction. Therefore at least part of the Bowdoin Canyon must have existed while till was being deposited and it cannot be entirely post-glacial, as might have been presumed from its youthful form. Landform evidence suggests strongly that only the uppermost mile of the 5-mile-long canyon has been formed since deglaciation by retreat of the falls.

Fifteen till-fabric analyses were made in an area of 10 square miles around Twin Falls, where there are many deep man-made sections associated with a power project. In this area the lithology and roundness of the stones, and the proportion of striated stones were analysed as well as their orientation. The stone collections have not yet been fully worked out, but a few comments can already be made on the results.

Since the distinctive metasedimentary rocks of the Labrador Trough outcrop

about 60 miles to the west and northwest of Twin Falls, but not to the southwest, it was hoped that the proportion of Trough rocks among stones in the till might distinguish tills from the southwest from tills originating in the northwest, even in the deep canyons where the results of orientation analysis would be difficult to interpret. It was found however that the average percentage of Trough rocks was less than 5 per cent, so that even in a sample of 200 stones variations in the percentage of Trough rocks would not be very significant. Even so, it may be significant that one 60-foot section in a partly re-excavated buried canyon shows a steady decrease in the proportion of Trough rocks with depth, with none at all in the lowest of the five samples. This suggests that the lowest till was not derived from the northwest.

Immediately southeast of Twin Falls is an outcrop of distinctive garnetiferous gabbroic gneiss. This is found only in the tills very close to the outcrop, implying there has been no important recent ice movement from the southeast.

Considerable variations in the roundness of stones contained in the tills were found, which help to distinguish one till sheet from another, e.g., the ablation till from the basal melting till.

The proportion of striated stones is extremely small. Apparently only the Trough rocks were sufficiently soft and fine-grained to record recognizable striations.

Pollen analysis. Eleven profiles through peat bogs were obtained, using a Hiller peat-corer. The profiles form a sequence from Esker, 110 miles west-northwest of Grand Falls, to a point 40 miles east-southeast of Grand Falls. The pollen in these is being analysed by the writer under the direction of Dr. J. Terasmae of the Geological Survey of Canada.

Results from the first four bogs, which are near, or west of Grand Falls, suggest that they began forming in the same pollen zone as the bog examined by Grayson¹ at Ross Bay (Mile 224), 90 miles west-southwest of Grand Falls,

or in a slightly later zone.

One of these bogs is situated about 0.5 mile downstream from Grand Falls, in a former channel of the Hamilton River on the southern rim of the present canyon, a channel that must have been abandoned as soon as the canyon had been cut back to this point by retreat of the falls. The lowest pollen zone present in this bog appears to be the same as the lowest zone present in nearby bogs situated in kettle holes, where there is no reason to expect bog development would have been delayed once the ice had gone. This suggests that at least half of the 1-mile post-glacial retreat of the Grand Falls took place during the century or two following deglaciation. This would be a period when the river was still carrying huge volumes of meltwater.

During the search for bogs suitable for coring one *palsa* bog was discovered in a rather unlikely position on a terrace of coarse material on the north slope of the Hamilton River valley, about 15 miles east-southeast of Grand Falls.

Radiocarbon dating. From nine of the bogs cored a larger sample of the lowest predominantly organic layer was collected for possible radiocarbon dating. Three of these samples have now been dated. They were from bogs 0.5 mile north of Grand Falls, 0.25 mile south of Grand Falls, and 14 miles due east of Grand Falls. The dates were, respectively, 5255 ± 200 , 5450 ± 220 , and 5575 ± 250 years before present. Allowing time for the deposition of the small thickness of silt below the dated peat samples, and for the formation of the first peat, the best estimate of the date of deglaciation of the area around Grand Falls appears to be 5750 ± 350 years before present. It is hoped that full details of these dates will be published in the *Radiocarbon Supplement* of the *American Journal of Science*.

Bedrock was not studied systematically, but one interesting find was made. The form of the several deep canyons in the Twin Falls area certainly suggests that they are controlled by major structural weaknesses, probably

faults. The centres of their beds however are concealed in most places either by rivers or by drift, so that direct signs of faulting hitherto observed at the surface have consisted only of closely spaced joints, hematite staining, and a few slickensides. In 1962 evidence of a single major fault was found in the form of an extensive fault breccia with considerable voids, contorted strata, and local metamorphism.

Patterned ground. In 1961 it was noted that well-developed stone nets had formed on the bed of the former Atikonak River, which had been diverted by a dam only about 5 years previously. Photographs were taken of the existing polygons and of places where it was thought others might be forming. These points were visited and photographed again in 1962. No obvious changes had taken place. This suggests that polygons reach full development within 1 or 2 years and then stop developing. This must be so unless the polygons already existed below the water before the river was diverted. One observation on the present beach of the Hamilton River suggests that polygons may persist a little below high water level. Therefore an examination was made of the former bed of the Unknown River at Twin Falls, newly exposed in the spring of 1962 by the diversion of the river. No patterned ground was found. A series of photographs was taken at points showing areas of the river bed made up of what was thought to be frost-susceptible material. It is hoped to compare these with the ground after one winter, to see whether polygons are forming.

Conclusions

The following conclusions are necessarily incomplete and provisional.

The landforms of the area have been shaped by two ice movements, one from the southwest, and a later from the northwest.

The greater part of the canyons of the area existed before the ice disappeared. Grand Falls, for example, has probably receded only about 1 mile since the ice roof over it broke up about 5700 years ago, and most of this

recession took place immediately after deglaciation. It is uncertain to what extent the canyons were formed by subglacial meltwater erosion during the last glaciation.

Wherever there is a local relief of more than 100 feet the minor landforms can usually be resolved into a sequence of erosional or depositional forms or both, produced while the level of the ice surface and the water table within the ice were falling, and the ratio of water to ice was increasing. In very flat areas the till was laid down from stagnant or moving ice without widespread slumping or squeezing, and the forms produced by meltwater are relatively distinct.

Acknowledgements

The research reported in this paper has been financially supported by the Defence Research Board of Canada under Grant-in-aid No. 3201-07, the National Research Council of Canada, the British Newfoundland Corporation, and the Geographical Branch of the Department of Mines and Technical Surveys, Ottawa. The writer has received advice about the preparation of the paper from Dr. F. K. Hare and Prof. J. B. Bird, both of the Geography Department, McGill University, from Mr. A. C. Graves of Shawinigan Engineering Co., and from Dr. J. Terasmae, Geological Survey of Canada.

A. MORRISON*

¹ Grayson, J. F. 1956. The post-glacial history of vegetation and climate in the Labrador-Quebec region as determined by palynology. Ph.D. thesis, Univ. of Mich.

*Geography Department, McGill University, Montreal.

OBSERVATIONS OF MUSK OXEN ON BANKS ISLAND, NORTHWEST TERRITORIES, CANADA

Little is known of the status of musk oxen (*Ovibos moschatus*) on Banks Island. Tener¹ has summarized the available information and estimated the population at approximately 100. Observations made in the summer of 1963 suggest that the animals are more abundant than previously supposed.

Between June 11 and August 12 eight flights were made between Sachs Harbour and a campsite on the Bernard River. The part of the island traversed during these flights is shaded in Fig. 1. On August 2 a reconnaissance flight was made over the northern part of the island (Fig. 1).

Approximately 60 musk oxen were seen. One was observed travelling west at the campsite on the Bernard River on July 17. Another was seen from the plane near Sachs Harbour on August 1. All others were seen on the reconnaissance of August 2. In the area between the campsite and Cape McClure (locality A, Fig. 1) two individuals and one group of 13 were observed. In the northeastern part of the island (locality B, Fig. 1) four groups were recorded, consisting of 5, 12 (including 2 young), 16, and about 10 animals, respectively. None were observed in the frequently travelled sector between Sachs Harbour and the Bernard River.

The largest number of musk oxen reported from the island in recent years was 30¹. Our observations of almost 60 animals on a single flight would suggest that the present population of musk oxen on Banks Island may be considerably larger than Tener's estimate in 1958. Furthermore, the observations suggest that the musk oxen tend to concentrate in the northern third of the island, at least during the summer months. This is also supported by personal reports from natives at Sachs Harbour, who see fewer animals in summer than in winter.

Support of the field work was provided by the Arctic Institute of North America under contract with the Office of Naval Research. We wish to thank Max C. Brewer, Director of the Arctic Research Laboratory, for logistic support.

WILLIAM J. MAHER*

RICHARD T. HOLMES†

¹Tener, John S. 1958. J. Mammal. 39:404.

*Dept. of Zoology, University of Saskatchewan, Saskatoon, Sask., Canada.

†Museum of Vertebrate Zoology, University of California, Berkeley, Calif., U.S.A.