3.4 EXPECTED AVERAGE MAGNITUDE OF GLACIAL EROSION

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ABSTRACT

The amount of glacial erosion that took place over a specific area during a specific glacial event has been estimated for three lithologically distinctive outcrop areas at three localities formerly covered by the Laurentide Ice Sheet. Estimates were made by mapping the glacial dispersal patterns of debris from the source outcrops, calculating the volume of debris dispersed, and dividing the volume by the area of the source outcrops. The average thickness of rock removed from the source areas was about 6 m for volcanogenic rocks in District of Keewatin, <4 m for granitoid rocks in the Appalachian Mountains of Quebec, and about 4.3 m for ultramafic rocks in the latter area.
Expected Average Magnitude of Glacial Erosion

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The purpose of this paper is to summarize techniques and results of estimating average amounts of glacial erosion that might be expected during a major glacial event in geologically complex terrain, such as the Canadian Shield. Such estimates can give some indication of the minimum depths at which nuclear wastes must be buried to avoid exhumation during future glacial events.

Previous estimates of the depths of erosion resulting from at least one glacial event of the Laurentide Ice Sheet vary considerably, ranging from 1000 m+ (White, 1972) to about 10 m (Flint, 1971). Flint (1971, p. 119) probably best summed up the problem of calculating average depths of erosion effected by the Laurentide Ice Sheet when he stated:

"The complex history of the Laurentide Ice Sheet is opposed to any simple view of the distribution of erosion. At one time or another the marginal part of the ice sheet swept over nearly the whole region covered by the ice when at its maximum. Furthermore, there appear to have been various centres of outflow, which shifted their positions from time to time and which should have given rise to complex patterns of erosion and deposition. However, as lithology and topography appear to be the dominant factors in controlling erosion and deposition, such patterns would be indistinct if recognizable at all."

Because it is so difficult to estimate zones of most intense erosion and absolute amounts of erosion on theoretical grounds, the authors have attempted to calculate a figure based on observable results of glacial erosion processes — a figure they have called "specific glacial erosion". Specific glacial erosion is an average depth of erosion that has occurred or can occur over a specific area during a single glacial event. It is calculated by determining the total volume of debris displaced from outcrops that produce
physically, mineralogically, or chemically distinctive detritus when subjected to glacial erosive processes. The total volume of debris produced is divided by the area of the source outcrop to arrive at an average thickness of rock removed, the specific glacial erosion.

So far, specific glacial erosion has been calculated from one lithologically distinctive outcrop area in the District of Keewatin and from two such areas in the Eastern Townships of Quebec. Because of the lithologic characteristics peculiar to each source area, different methodologies were used to arrive at volumes of debris displaced. It is our intention to do several more studies of this type to establish a range of figures for specific glacial erosion for various lithologies in various glaciological and topographic settings. As the number of estimates of specific glacial erosion increase, the relationships of such geologic factors as topography, lithology, and structure to such glaciologically dynamic factors as ice flow velocity, ice thickness, geothermal heat flow, and bed porosity should become increasingly apparent, allowing predictions of expected amounts of glacial erosion to be made with much more confidence than is possible at present.

The general method used to calculate volumes of glacially dispersed debris was the following: (1) a map of the areal pattern of dispersal of the particular "indicator", or component of interest, was based on, in each case, several hundred samples or observations of composition of a single sheet of glacial till; (2) a grid was drawn over the map and the average concentration of the indicator component in each cell of the grid was calculated. In each of the cases studied, this calculation was made in a completely different way; (3) the volume of the indicator component was calculated for each cell of the grid by multiplying the average concentration of the area of the cell by an average thickness of the till assumed in the area of the cell; (4) the volumes of the indicator component from each of the cells were summed and divided by the area of the source outcrops to yield an average amount of erosion — specific glacial erosion.
In all the examples studied, any assumptions that had to be made were made in such a way as to give estimates consistently on the high side. Also, sites were chosen in such a way as to minimize the likelihood that significant amounts of glacial debris could have escaped through meltwater streams. Finally, the problem of preferential partitioning of components into various clast or grain sizes and the varying compositions of different depositional facies of till were considered and accounted for in two of the studies. In the study of ultramafic erosion, the method of analysis used was chosen specifically to circumvent the problems of mineral and clast partitioning.

Preliminary Estimates of Specific Glacial Erosion

In Keewatin, distinctive late Precambrian red volcanogenic and sedimentary indicator erratics were traced from their sources near Baker Lake to the coast of Hudson Bay, some 300 km distant. Mathematical extrapolation of their exponential dispersal profile (Shilts, 1976) indicated that they would still be detectable some 600-650 km from their source as, indeed, they were on Coats Island, near the mouth of Hudson Bay, where they comprise 1±0.5% of the till. Calculations of volume of red debris dispersed were based on frequencies derived from its percentage, by weight, in the 2-6 mm fraction of over 800 samples of till. Total volumes were obtained from calculations made on three separate grids. Based on the results from the three grids, specific glacial erosion figures of 6.3, 7.5, and 11.3 m were calculated. Because we treated the variables in such a way as to give high figures, we estimate that the average depth of erosion is most likely in the 5-6 m range.

The asbestos-bearing ultramafic rocks of the Thetford Mines area of Quebec contain a consistent concentration of 0.2% (2000 µg/g) nickel. We reasoned that a till composed entirely of ultramafic debris should have a bulk composition of 2000 µg/g nickel, and one with 50% ultramafic detritus
should have 1000 μg/g nickel, etc. Using this geochemical reasoning, rock and mineral partitioning becomes unimportant if bulk compositions are available. Using nickel concentrations derived from till fractions equivalent to bulk samples, and a grid system similar to that described for Keewatin, we have estimated that about 4.3 m of specific glacial erosion occurred on the mineralogically soft (serpentinized peridotite), structurally massive ultramafic outcrops.

Granite boulders, quarried and transported englacially from four granite batholiths in the Appalachian mountains adjacent to the Thetford Mines area, form a dense, bouldery mantle on the underlying basal till of the region. The basal facies has generally less than half the granite frequency of the surface mantle. Using a dispersal grid similar to those described above, we calculated the volume of dispersed granite represented by the surface mantle by multiplying the average granite frequency for each cell by the volume of boulders in each cell, a figure that was determined by calculating the average density of boulder cover on undisturbed fields. The surface mantle represents an average of 0.77 m of specific glacial erosion from each of the four granite plutons studied, and even if this figure is multiplied by five to account for the granite in underlying till and in unmapped parts of the dispersal train in the United States, a maximum figure of specific glacial erosion of less than four metres is obtained. We estimate that the true magnitude is on the order of two metres.

Thus, values of average depths of glacial erosion during one glacial event (duration of the dynamic conditions necessary for erosion at each site is not known) for three types of rock, both near and far removed from the glacial centres of outflow responsible for their erosion, yield values of less than about 10 metres, with the most likely estimates falling
in the range of two to six metres. It should be borne in mind that in each case studied, considerably more or less erosion could have taken place at various locations in each source area, depending on topography and presence of zones of structural weakness.
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GEOTECHNICAL RESEARCH: PROCEEDINGS OF THE
SEVENTH NUCLEAR FUEL WASTE MANAGEMENT INFORMATION MEETING
1980 May 5-6, Ottawa, Ontario

ABSTRACT

The Seventh Nuclear Fuel Waste Management Information Meeting was held in Ottawa, 1980 May 5-6. Participants at the meeting gave thirty-four presentations on geophysics, geology, hydrogeology and other aspects of the geotechnical research program.

Atomic Energy of Canada Limited
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1982 January
RECHERCHE GEOTECHNIQUE: DEBATS DE LA Septième Réunion d'INFORMATION SUR LA GESTION DES DÉCHETS DE COMBUSTIBLE NUCLEAIRE DES 5 ET 6 MAI 1980 A OTTAWA, ONTARIO

RESUME

La Septième Réunion d'Information sur la Gestion des Déchets de Combustible Nucléaire a eu lieu à Ottawa les 5 et 6 mai 1980. Les participants y ont présenté trente-quatre communications sur la géophysique, la géologie, l'hydrogéologie et d'autres parties du programme de recherche géotechnique.

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1982 janvier