Glacial Lake Gayhurst: Insights into the Midwisconsinan History of the Southeastern Sector of the Laurentide Ice Sheet

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Summary

Complex sequences of ice marginal and frontal deposits have been mapped and documented in the Saint-François and Chaudière river valleys, north of the international border. In most cases, these sediments and landforms, as well as other geomorphological features, are significant indicators of the extent of former ice-dammed lakes primarily because their elevation is intimately linked to well-documented outlets. Their stratigraphic architecture is, however, complex, and their subsurface extent poorly documented. The Quaternary geology of South Eastern Québec is unique in several aspects. The Pleistocene stratigraphy is characterized by a three-till sequence, each till being underlain and overlain by glaciolacustrine sediments deposited in ice-dammed lakes during advance or retreat phases. Occurrences of sub-till glacial lake sediments in the region are commonly regrouped under the Gayhurst Formation, which stratigraphic position between the Chaudière and Lennoxville glacial deposits suggests a mid-wisconsinan age (MIS 3?). Interpretations of Gayhurst Formation derived mainly from many stratigraphic sections that provide elevation estimates of some possible outlets that controlled the lake evolution. Sediments deposited by retreating glaciers are generally thick and irregularly bedded in couplets of variable thickness. In contrast, fine-grained sediments deposited in lakes dammed by advancing glaciers consist of thin and evenly laminated sediments. These glacial lake deposits are widely exposed in stratigraphic sections and have been documented in numerous boreholes. The objectives of this study are 1) to define the physical lateral extension of the Gayhurst Formation; 2) to bring additional precisions on the paleogeographic reconstructions through the evaluation of different meltwater routing scenarios in New-Brunswick, Maine and Vermont, and; 3) to determine the age of this glaciolacustrine sequence using IRSL dating. Here will present recent field and stratigraphic data that were acquired in the course of a groundwater/Quaternary geology mapping project in the Chaudière and Saint-François valleys.

Introduction

The study area covers two major watersheds in southeastern Québec; the Chaudière River watershed with a surface area of 6 682 km^2 and the St-François River watershed with a surface area of 10 228 km^2. This region is located to the north of Vermont, of New Hampshire and to the northwest border of Maine. Most streams are tributary to either the St-François and Chaudière rivers, which flow northwest across the strike of the Appalachians to the St-Lawrence River. The study area lies mostly within the Appalachian geologic Province. This study contributes to the Pleistocene stratigraphic framework of Québec by the application of new geomodeling tools and geochronological methods. Field and laboratory investigations were initiated in 2007 through a major hydrogeological program initiated by the *Ministère du Développement Durable de l'Environnement et des Parcs du Québec* for the entire Chaudière and Saint-François Valleys drainage basins.

The Quaternary stratigraphic framework in the Appalachians of southern Quebec

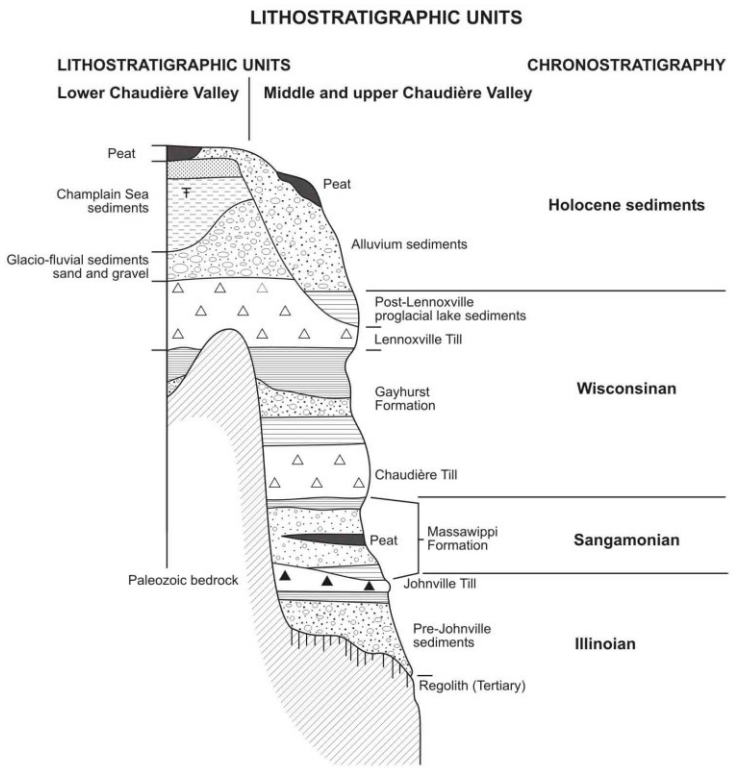

Figure 1: Quaternary lithstratigraphic framework for the Chaudière River Basin Basin, (modified from McDonald and Shilts, 1971; and Shilts, 1981). The elevated portion of the bedrock is a schematic representation of the Notre-Dame Mountain Anticlinorium as it marks the approximate limit between the St-Lawrence Lowlands to the West and the Appalachians to the East. A simplified stratigraphic scheme is shown for the Lower Chaudière Valley.

The regional stratigraphic framework records three advances of the Laurentide Ice Sheet across the southeastern Appalachians of Quebec and into northern New England (McDonald, 1967; Shilts, 1970; McDonald and Shilts, 1971). These glacial episodes are represented, from oldest to youngest, by the Johnville, Chaudière, and Lennoxville tills (Fig. 1). The description of the regional lithostratigraphy is modified herein from the synthesis of Lamothe et al. (1992). This Quaternary stratigraphic framework has been developed through several decades of extensive field work, including geophysics and geochemistry programs as well as systematic drilling and trenching by the researchers of the Geological Survey of Canada.

The end of the Chaudière glaciation was marked by a short-lived retreat of Appalachian and Laurentide ice towards the Appalachian front. Glacier ice in the St-Lawrence Valley impounded glaciolacustrine waters in the northwardflowing Chaudière and St- Francois valleys, resulting in deposition of locally thick glaciolacustrine and deltaic sediments of the Gayhurst Formation.

The Gayhurst Formation

This formation comprises lacustrine sediments deposited in a large lake that existed in the Appalachians and recording the nonglacial interval between the Chaudière and Lennoxville glacial phases. The Chaudière glacier front retreated (to the limit between the St-Lawrence lowlands and the Appalachians province) across the area from south or southeast to north or northwest. The low-level stage of the lake was at an elevation of about 370 ± 5 m a.s.l (Fig. 2). The outlets associated with this event are through the fluvial valleys of Famine and Daaquam rivers and/or by a drainage through Island Pound (Vermont /New Hampshire).

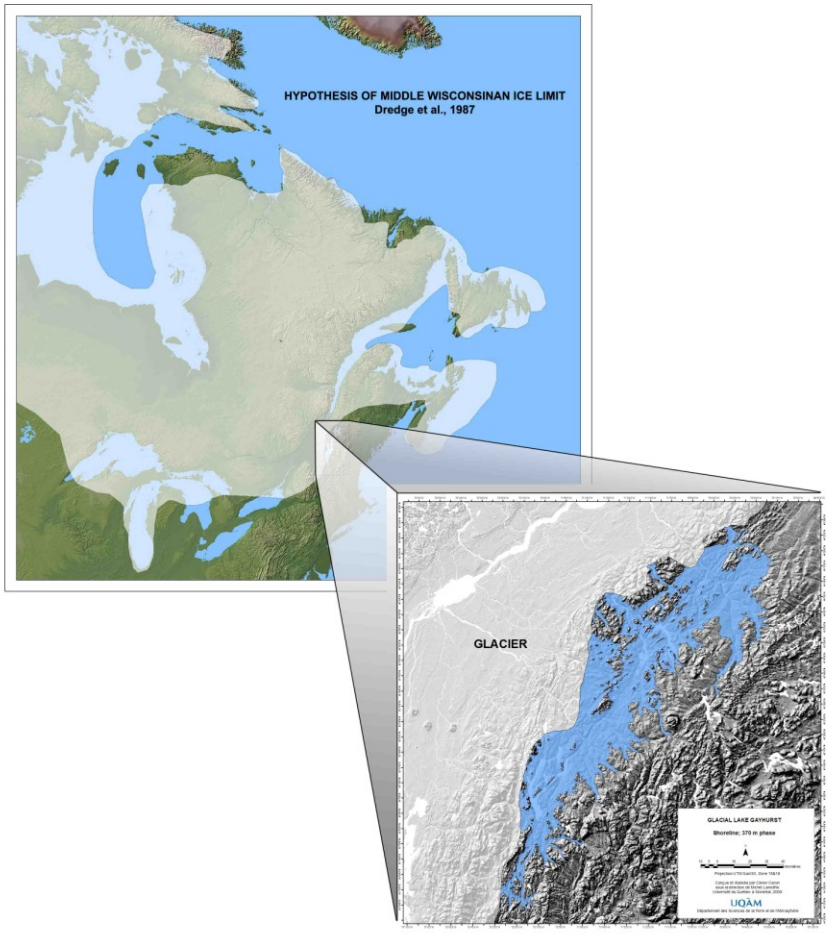

Figure 2: The maximum extent of MidWisconsinan Glacial Lake Gayhurst. As the normal drainage is from the International Border towards the St. Lawrence River, any ice expansion across the St- Lawrence Valley, and into the Appalachians would have created ice-dammed lakes, during each glacial advance and northward retreat.

Thickness of Gayhurst Formation sediments reaches up to > 100 m, in places. This glaciolacustrine unit is present in most valley bottoms. Southeastward readvance of the Laurentide glacier from its maximum retreat position at the Appalachian front, was continuous across Quebec and New England. This readvance is called the Lennoxville glaciation and represents the major late Wisconsin glacial event in the region. Thinly bedded varves record the initiation of this ice readvance into the Appalachians highlands, covering the low level outlets and causing the lake level to rise at about 430 m. Sediments deposited by this glacial lake generate hydrogeological incidence specially for the pelagic facies which are burieds aquitards for several tributaries rivers of the Chaudière and St-François rivers.

Paleogeographical reconstructions in the Appalachians of SE Quebec are strongly dependent of the glacial and nonglacial events occurring the Central St-Lawrence Lowland. The main problem is to determine if the St-Lawrence lowlands was open during the maximum retreat of the Chaudière glacier.

Approach and methods

Reconstructing the paleoenvironment of Glacial Lake Gayhurst represents an important challenge, mostly because the shorelines and the geomorphology associated with this glacial lake have been stripped away during the advancing phase of the Lennoxville glacier. The Gayhurst Formation can be better understood using the concepts of sequence stratigraphy. In particular sediment accommodation space is seen as a critical element in stratigraphical analysis. The use of geomodeling is a very powerful tool to reconstruct the subsurface architecture and to quantify sediments volume. Thus, this study proposes the development of a methodology for three-dimensional numeric geomodelization of surficial deposits for two major river drainage basins, totalling more than 20 000 km^2. This kind of model is based on the integration of surficial sediments map and boreholes logs with the use of GIS and 3D geomodeling system. This geomodeling study is an original approach for defining the physical lateral extension of the Gayhurst Formation. From this, paleogeographic reconstructions emerge that can be tested against potential glacial meltwater routing in New-Brunswick, Maine and Vermont.

Geologic and hydrogeologic data were integrated in a database structure already described by Boisvert and Michaud (1998). All records in the database are spatially referenced by UTM coordinates and most by elevation. The database is composed of achival boreholes from the provincial database (Hydrogeologic Information System (SIH)), federal database (GSC) and from private firms. Data for a total of 40 000 boreholes and 30 000 outcrops were compiled for the study area. Extensive field work was carried out between 2007 and 2009, including surficial mapping and detailed geologic section analyses. Over 30 maps of the Quaternary geology were validated and completed at a scale of 1: 50 000. A new methodology for three-dimensional numeric geomodelization of surficial deposits is proposed in this study. This kind of model is based on the integration of the surficial map and boreholes logs with the use of GIS and 3D geomodeling system. This geomodeling defines the thickness and stratigraphic distribution of Quaternary deposits and it is based on strict coherence between surface distribution deduced from geologic maps and borehole stratigraphy Data processing will be achieved using gOcad. This software permits an integration of varied data and has a very powerful calculation capacity.

An IRSL dating program was initiated to obtain absolute ages for the Gayhurst Formation. We are currently investigating the IRSL chronology of a buried delta associated with this glacial lake event in the Chaudière Valley. This delta was built by an ancestral Chaudière River into glacial Lake Gayhurst, which submerged the Chaudière and adjacent valleys in the time interval extending from the retreat of the Chaudière glacier and its readvance as the Lennoxville glacier. These deltas consist primarily of sands that grade upwards into cross-bedded gravels, with cut-and-fill structures indicating deposition at or near the lake's surface at 396m a.s.l. Current directions in the gravels are generally northward, parallel to the present drainage, and the entire sandy unit is about 22 m thick. The preliminary depositional age for the Gayhurst sample is 56 ± 7 ka. This would suggest that (Chaudière/Laurentide) ice still-stand corresponding to the 370m level occurred in the earliest part of MIS 3. This preliminary age, together with other feldspar AF-corrected ages for underlying Massawippi (nonglacial) sediments, is now the basis for a revisited chronostratigraphic framework for Southeastern Québec.

Conclusions

Classical geological mapping and modern 3D hydrostratigraphic analysis generate a definite lithosome geometry for the Gayhurst Formation. The application of a relatively new dating method (IRSL) provides a precise time-frame for the deposition of this event. The Gayhurst project allows a unique snapshot for the midWisconsinan paleogeography of the Laurentide Ice Sheet.

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