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Abstract

As part of a reconnaissance sub-bottom acoustic profiling (SAP) survey, 32 SAP were collected from Lac Flavrian, Quebec, on July 14, 2014. The quality of the returns from Lac Flavrian are generally poor with there being little to no penetration of the sub-bottom along most of the profiles. Despite this, three depositional facies can be identified within the lake basin returns that represent lacustrine, glaciolacustrine and mass movement deposits.

Introduction

Large areas of northwestern Quebec-northeastern Ontario were inundated by a succession of glacial lakes, known as Barlow, Barlow-Ojibway and Ojibway, that evolved within the Timiskaming and Hudson Bay basins between 10 570 and 8470 ± 200 cal BP (Vincent and Hardy 1979; Veillette 1994; Breckenridge et al. 2012). A legacy of these glacial lakes is the regional occurrence of glaciolacustrine deposits that form the Great and Lesser clay belts areas, as has been described in early geological reports (e.g., Coleman 1909, 1922; Wilson 1918; James 1923). Studies in the 1920s by Antevs (1925; 1928) interpreted that the rhythmically laminated couplets composing the deposits are varves which represent annual accretions. He recognized that the varves form a time series that can be correlated throughout the region, based on varve thickness patterns, as subsequent research has verified (Hughes, 1959; 1965; Breckenridge et al., 2012). Many reports mention the presence of beds of "contorted", "deformed", "disturbed" varves within the glaciolacustrine deposits (Wilson 1918; Antevs 1925, 1928; Hughes, 1959; Breckenridge, 2012). Some of these disturbed deposits have been interpreted or inferred to be stratigraphic evidence of paleoearthquakes that occurred during local deglaciation (Adams 1982, 1989; Doughty et al. 2011, 2013).

Recent literature indicates that lake basins are promising areas for investigating paleoseismicity, by identifying stratigraphic levels that contain the deposits of multiple, synchronous, submarine landslides and/or turbidity currents (e.g., Moernaut et al. 2007, 2009; Upton and Osterberg, 2007; Bertrand et al. 2008; Anselmetti et al. 2009; Beck 2009, 2011; Maloney et al. 2013; Morey et al. 2013; Strasser et al. 2013). Mass movement deposits have been recognized within the deposits of lake basins in eastern Canada, including northwestern Quebec-northeastern Ontario, that are attributed to both modern and prehistoric earthquakes (e.g., Shilts, 1984; Shilts and Clague, 1992; Shilts et al., 1992; Ouellet, 1997; Normadeau et al., 2013; Doughty et al., 2010; 2014). Brooks (2015) advocated applying an integrated seismo- and chrono-stratigraphic approach to investigating mass movement deposits as evidence of paleoseismicity preserved in lake basins.

To identify the occurrence of disturbed deposits (i.e., landslide, turbitidy currents and/or soft sediment deformation) preserved in the sub-bottoms of lakes, reconnaissance sub-bottom acoustic profiling (SAP) surveys were collected by the Geological Survey of Canada in July 2014 at eight lakes in the Rouyn-Noranda-Kirkland Lake area, northwestern Quebec-northeastern Ontario (Fig. 1). The results allow an assessment of the extent and character of disturbed deposits in the region and can be used to identify lake basins (or portions thereof) for more detailed SAP surveys to investigate regional paleoseismicity.

This report contains the results of the reconnaissance SAP survey undertaken at Lac Flavrian, Quebec, on July 14, 2015 (Figs. 1 and 2). It summarizes the SAP methodology, includes a map of the profile lines, provides a generalized overview of the deposits contained in the sub-bottom, and a brief notation of the content of the individual profiles. The report contains digital data of the SAP profiles in .keb and .sgy formats, and raster images of the profile returns (bmp). It also contains .kea files that list the date and time of collection, water depth, and geographical coordinates for the profile routes. This report is one of eight that summarize the results of the July 2014 reconnaissance SAP surveys, as listed in Table 1.

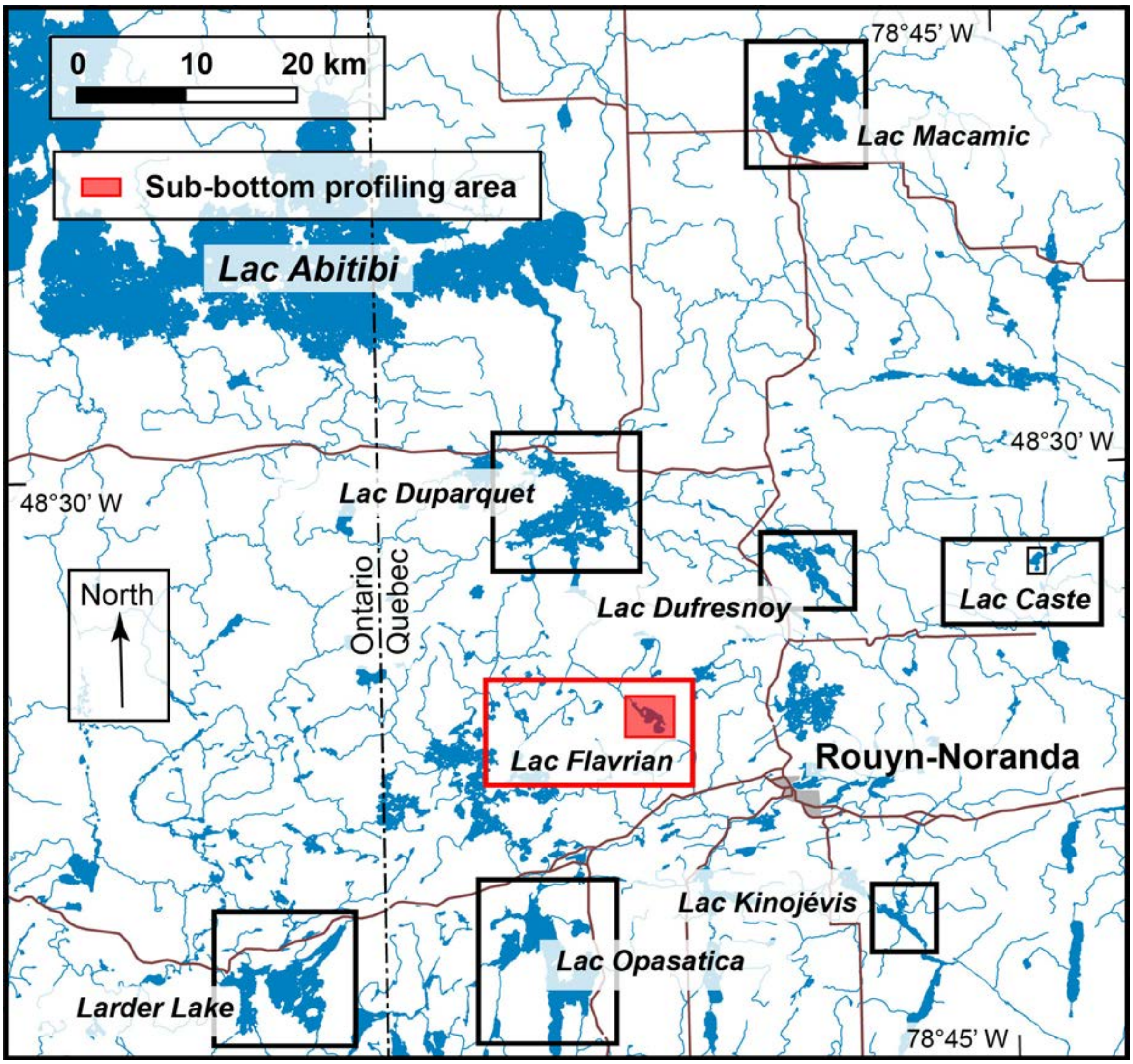

Fig. 1 Map showing the locations of Lac Flavrian and the other seven lake basins in the Rouyn-Noranda area, Quebec, where reconnaissance sub-bottom profiling surveys were conducted in July, 2014.

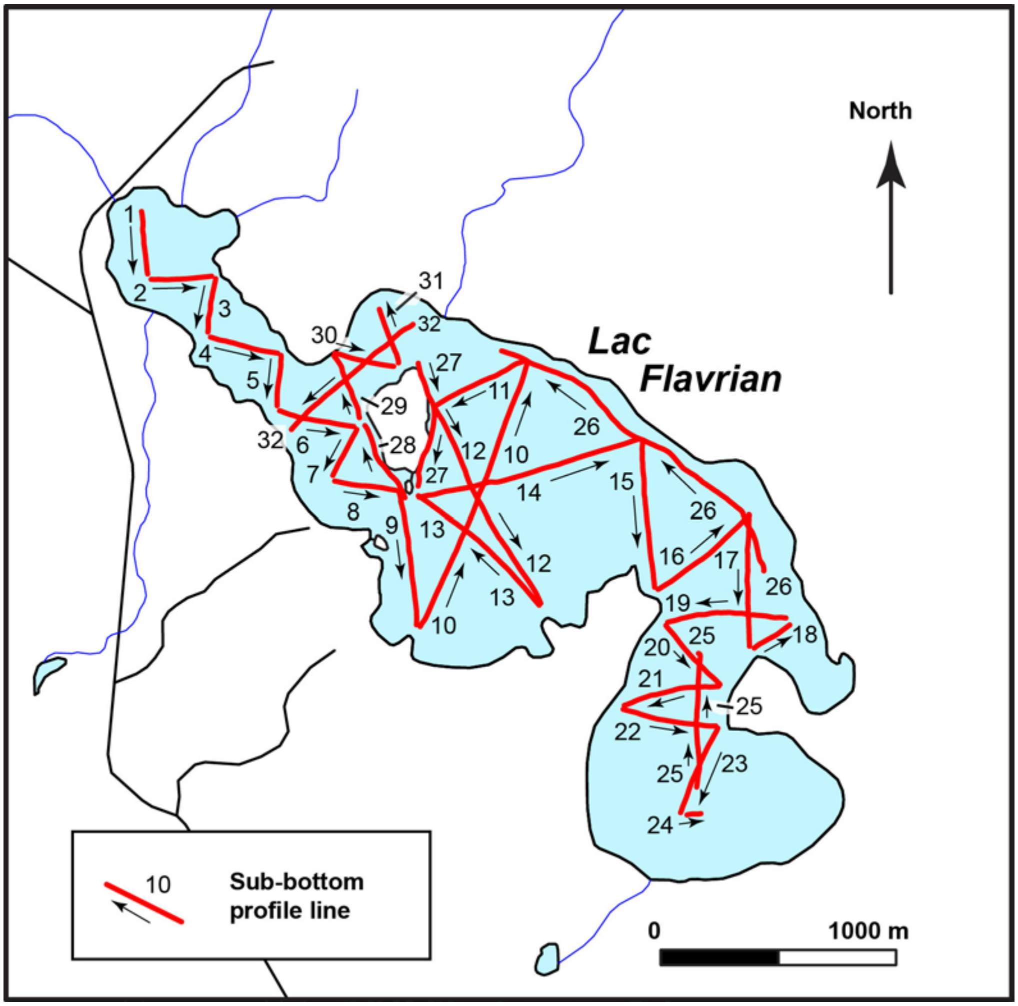

Fig. 2 Map of Lac Flavrian showing the locations and numbering of the 32 sub-bottom profile lines.

Table 1 List of Open Files containing reconnaissance sub-bottom profiling of eight lakes in the Rouyn-Noranda-Kirkland Lake area, northwestern Quebec-northeastern Ontario.

Profiled lake basin	GSC OF number
Lac Caste	7991
Lac Dufresnoy	7990
Lac Duparquet	7989
Lac Flavrian	This report
Lac Kinojévis	7987
Lac Macamic	7985
Lac Opasatica	7984
Larder Lake	7986

Lac Flavrian

Lac Flavrian is located ~15 km west-northwest of Rouyn-Noranda, Quebec. The lake is elongated and irregularly-shaped; the long-axis is oriented approximately northwest-southeast. It is ~4 km long, up to 1.4 km wide and 3.3 km^2 in area (Fig. 2). A large bedrock island is located in approximately the middle of the lake. A small delta is prograding into the southern side of the middle area of the lake. The outlet is located at the northwest end of the lake. Access to the lake was obtained using a public boat launch at the northwest end of the lake, located beside the outlet creek.

Methodology

The SAP survey on Lac Flavrian was undertaken on July 14, 2014, using a Knudsen 320M™ profiler coupled to low (28 kHz) and high (200 kHz) frequency transducers. The pole-mounted transducers were attached on the side of a 4.9 m (16 ft) aluminum boat powered by a 30 hp motor. Traversing speed during profiling ranged between 5 to 7 $km.hr^{-1}$. Profiling routes were mapped using streamed differentially-corrected GPS coordinates collected with a Novotel Smart-V1 antenna-receiver and recorded in combination with the digital SAP data. The active depth window of the profiler was set to 0-20 m. The profiling routes are depicted in Fig. 2.

Profiler and GPS data for each profile were recorded digitally on a notebook computer as .keb and .kea files. A .keb file is a Knudsen proprietary format that can be opened with Knudsen PostSurvey™ v1.61[1] software, which is included with the download of this Open File. In the .keb format, the profile returns include a depth scale and vertical line stamps which display time and geographical coordinates (degree-decimal minutes). The vertical line stamps are made at the start/end of the profiles as well as at 20 sec intervals during profiling (Fig. 3).

To further facilitate profile viewing, the .keb file of the 28 kHz channel returns for each profile has been converted to a .sgy format file as well as a .bmp raster image. The .kea file contains the date and time of data collection, water depth, and geographical coordinates of the profile routes.

[1] PostSurvey v1.61 is proprietary property of Knudsen Engineering Ltd.™ and is intended for authorized use only. Any use, other than the specific purpose of playback/displaying Knudsen data is prohibited. PostSurvey v1.61 has been included in the download of OF-7988 with the permission of Knudsen Engineering Ltd.™. The software has been provided for the convenience of the OF-7988 user. A user of this software does so entirely at their own risk.

The .kea files are an ASCII format and can be opened through a spreadsheet software, such as Microsoft Excel®. Depths on the profiles in the .keb and .kea files are based on a sound velocity in water of 1500 $m.s^{-1}$.

The .keb, .sgy, .bmp and .kea files for each profile are contained in designated profile folders. The folders form a digital Appendix that accompanies the download of this report.

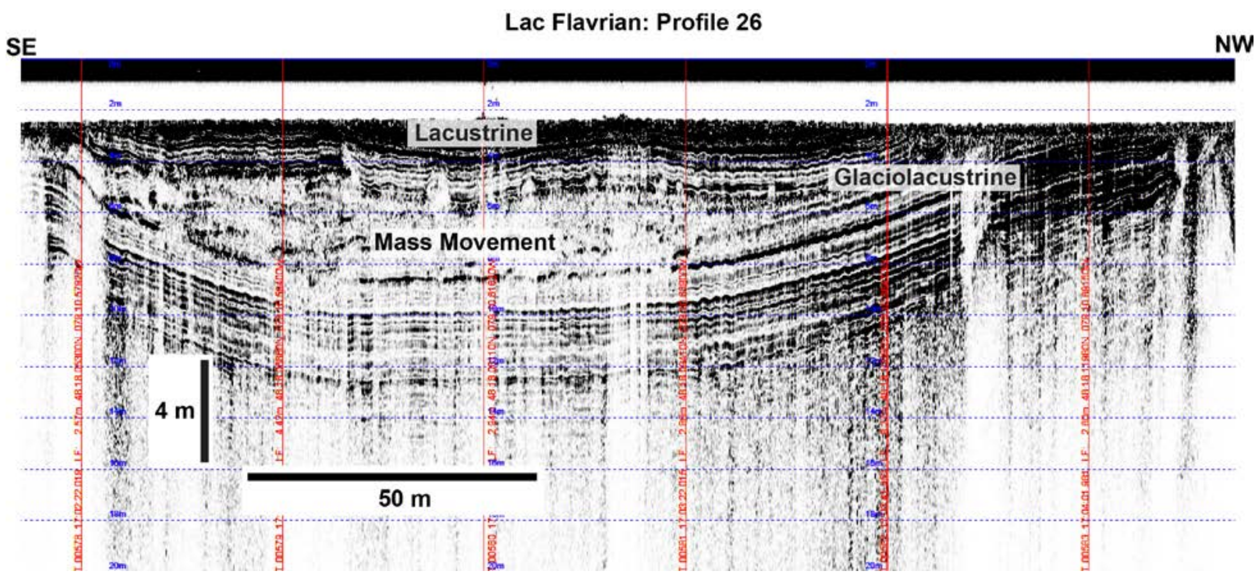

Fig. 3 Example of a sub-bottom acoustic profile from Lac Flavrian, showing lacustrine, glaciolacustrine and mass movement facies. These returns are from a portion of profile 26 where there was good penetration of the sub-bottom. See Fig. 2 for the location of the profile. Although inferred to be representative of deposits within the lake, there was little to nopenetration of the sub-bottom alobng most of the 32 profiles. The horizontal dashed lines show depth at 2 m intervals and the vertical lines are time-geographical coordinates stamps.

Results

Thirty-two profiles were collected from Lac Flavrian, as shown on Fig. 2 and summarized briefly in Table 2. The profiling follows a general zig-zagging pattern along the lake and around the island.

The quality of the returns from Lac Flavrian was generally poor because of little to no penetration of the sub-bottom along most of the profiles (see Table 2).

From the limited areas of the sub-bottom that were penetrated, three depositional facies are present in Lac Flavrian, as exemplified in Fig. 3 and summarized as follows:

Lacustrine facies – consists of transparent to weakly bedded deposits (Fig. 3); bed spacing is variable. The basal boundary is conformable and commonly well defined by a strong impedance layer. Deposits of this facies are interpreted to have aggraded in the post-glacial basin of Lac Flavrian.

Glaciolacustrine facies – consists of multiple, decimetre-scale, parallel reflectors that are draped on the underling topography (Fig. 3). Deposits exhibiting this facies are common to many lakes on the Canadian Shield and reflect sedimentation within a glaciolacustrine depositional environment. The deposits of this facies in Lac Flavrian deposits are inferred to have aggraded within glacial Lake Ojibway.

Mass movement facies – consist of transparent, diffuse or irregular returns (Fig. 3), possibly including blocks (clasts) of intact glaciolacustrine deposits the bedding of which may be rotated with respect to the glaciolacustrine facies. The upper surface of the facies may be smooth or irregular. Bed thickness is variable from decimetres to several metres in scale and may pinchout laterally. Basal contact can be conformable or erosive along a given profile.

Deposits of the mass movement facies in Lac Flavrian are best captured in profiles 2, 3, 4, 5 and 10. The deposits are overlain by glaciolacustrine deposits, indicating that the movement(s) occurred within glacial Lake Ojibway.

Summary and conclusions

Thirty-two SAP were collected from Lac Flavrian , Quebec, on July 14, 2014.

The quality of the returns from Lac Flavrian was generally poor with there being little to no penetration along most of the profiles.

Despite the limited penetration of the sub-bottom, three facies are identified within the SAP returns that represent lacustrine, glaciolacustrine and mass movement deposits.

Although the profiles demonstrate the presence of mass movement deposits, Lac Flavrian is deemed a poor basin for follow-up detailed profiling and core collection to further investigate the mass movement deposit(s) because of the overall poor quality of the sub-bottom.

Acknowledgements

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Table 2 Summary listing of the Lac Flavrian sub-bottom profile lines

Profile Number	Direction	Length (m)	Comments
1	S	264	- No penetration along entire profile - Weedy
2	E	254	- No penetration along entire profile - Weedy
3	SSW	227	- No penetration along entire profile - Weedy
4	ESE	290	- No penetration along entire profile - Weedy
5	S	213	- No penetration along entire profile
6	ESE	319	- Faint and shallow penetration at very end of profile, no penetration elsewhere - Weedy - Returns show lacustrine and glaciolacustrine deposits
7	SW	218	- Faint and shallow penetration along first half of profile, but no penetration along second half - Returns show lacustrine and glaciolacustrine deposits
8	E	260	- Good penetration along last third of profile, but no penetration elsewhere - Returns show lacustrine, glaciolacustrine and mass movement deposits
9	S	560	- Good penetration along beginning of profile, but no penetration elsewhere - Returns show lacustrine, glaciolacustrine and mass movement deposits
10	NNE	1191	- Good penetration in middle of profile, shallow penetration at end of profile, but no penetration elsewhere - Returns show lacustrine, glaciolacustrine and mass movement deposits
11	WSW	419	- Good penetration along beginning of profile, but no penetration elsewhere - Returns show lacustrine, glaciolacustrine and mass movement deposits
12	SSE	927	- Good penetration along first third of profile, but no penetration elsewhere - Returns show lacustrine, glaciolacustrine and mass movement deposits
13	NW	686	- Good penetration at very end of profile, but no penetration elsewhere - Returns show lacustrine and glaciolacustrine deposits
14	ENE	957	- Good to faint penetration along first quarter of profile, but no penetration elsewhere, except for faint penetration at the end of the profile - Returns show lacustrine, glaciolacustrine and mass movement deposits
15	S	618	- No penetration along entire profile
16	NE	494	- Sporadic penetration at the end of the profile, but no penetration elsewhere - Returns show lacustrine, glaciolacustrine and possible mass movement deposits
17	S	552	- Good penetration along first third of the profile, faint and shallow penetration along the last third of the profile but no penetration in-between - Returns show lacustrine, glaciolacustrine and mass movement deposits

18	ENE	178	- Faint penetration along first half of profile, but no penetration elsewhere - Returns show lacustrine, glaciolacustrine and mass movement deposits
19	W	504	- Faint to good penetration along initial half of profile, but no penetration elsewhere - Returns show lacustrine, glaciolacustrine and mass movement deposits
20	SE	337	- Faint penetration near beginning and end of a short profile - Returns show lacustrine, glaciolacustrine and mass movement deposits
21	W	408	- No penetration along entire profile - Shallow
22	E	397	- No penetration along entire profile
23	SSW	388	- No penetration along entire profile - Shallow and weedy
24	E	59	- No penetration along entire profile
25	N	567	- Shallow penetration and faint returns at the end of the profile, but no penetration elsewhere - Weedy - Returns show possible glaciolacustrine deposits
26	NW	1505	- Good penetration along most of profile except for middle area - Returns show lacustrine, glaciolacustrine and mass movement deposits
27	S	539	- No penetration along first third of profile, but good penetration elsewhere - Returns show lacustrine, glaciolacustrine and mass movement deposits
28	NNW	352	- Good penetration, but faint returns along entire profile - Returns show lacustrine, glaciolacustrine and mass movement deposits
29	NNW	284	- Faint returns at start of profile and good returns elsewhere - Returns show lacustrine and glaciolacustrine deposits
30	ESE	254	- No penetration along entire profile
31	NNW	239	- No penetration along entire profile
32	SW	678	- Good penetration locally in middle of profile, but no penetration elsewhere - Returns show lacustrine and glaciolacustrine deposits

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