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Pollen analysis of sediment cores from lakes in the Rouyn-Noranda region, Quebec

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Grenier, A. and Kliza, D.A., 2005: Pollen analysis of sediment cores from lakes in the Rouyn-Noranda region, Quebec; in *Metals in the Environment Around Smelters at Rouyn-Noranda, Quebec, and Belledune, New Brunswick: Results and Conclusions of the GSC MITE Point Sources Project, (ed.) G.F. Bonham-Carter; Geological Survey of Canada, Bulletin 584, 12 p.*

Abstract: *Ambrosia* pollen was used as a marker for the relative dating of lake-sediment cores from eight lakes in the vicinity of Rouyn-Noranda. The profiles of *Ambrosia* counts versus depth in the cores of these lakes have a characteristic shape, and the first sharp increase from the bottom is taken as a marker horizon. The marker occurs at about 7.5 cm depth at Lake Marlon (4 km east of Rouyn-Noranda) and is found progressively deeper in the cores from lakes farther east, being about 13 cm deep in Lake Vert, 25 km north of Val-d'Or and 100 km east of Rouyn-Noranda. Lead isotope (^{210}Pb) dating of the core from 'Gravel Pit' Lake (9 km east of Rouyn-Noranda) gives an approximate age of the *Ambrosia* marker that is consistent with the age of the development of the Noranda mining community (ca. 1926), and an average sedimentation rate over the whole core of about 0.11 cm/a. The somewhat earlier development of the region farther east, around Val-d'Or and the communities between Val-d'Or and Rouyn-Noranda, may account in part for the deeper position of the *Ambrosia* marker in these cores. However, the sedimentation rate in Lake Vert is between 0.15 and 0.17 cm/a (the boundaries corresponding to the ages of the Val-d'Or and Rouyn-Noranda communities, respectively), and is therefore greater than the sedimentation rate in 'Gravel Pit' Lake.

Résumé : Du pollen d'*Ambrosia* a servi d'indicateur pour la datation relative des carottes de sédiments lacustres extraites de huit lacs, dans la région de Rouyn-Noranda. Les profils de dénombrement du pollen d'*Ambrosia* en fonction de la profondeur dans les carottes ont une forme caractéristique, et la première forte augmentation relevée à partir du fond est considérée comme un horizon repère. Ce repère se trouve à environ 7,5 cm de profondeur sous le lac Marlon, qui est situé à 4 km à l'est de Rouyn-Noranda, et repose à une profondeur progressivement supérieure dans les carottes extraites des lacs plus à l'est, notamment à quelque 13 cm de profondeur sous le lac Vert, à 25 km au nord de Val-d'Or et à 100 km à l'est de Rouyn-Noranda. La datation par isotope du plomb (^{210}Pb) de la carotte prélevée dans le lac «Gravel Pit», à 9 km à l'est de Rouyn-Noranda, attribue au repère associé à l'*Ambrosia* un âge approximatif qui correspond à l'époque de la fondation de la collectivité minière de Noranda (vers 1926) et un taux de sédimentation moyen d'environ 0,11 cm/a pour l'ensemble de la carotte. Le développement plus précoce de la région à l'est, aux alentours de Val-d'Or et des collectivités fondées entre cette ville et Rouyn-Noranda, peut expliquer en partie la plus grande profondeur du repère associé à l'*Ambrosia* dans ces carottes. Toutefois, le taux de sédimentation dans le lac Vert se situe entre 0,15 et 0,17 cm/a (valeurs limites correspondant respectivement aux âges de la fondation de Val-d'Or et de celle de Rouyn-Noranda) et est ainsi supérieur au taux de sédimentation dans le lac «Gravel Pit».

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INTRODUCTION

During the 1920s, the Rouyn-Noranda (Quebec) area underwent great changes associated with prospecting and mining activities. The Horne smelter started operation in 1927, soon after the discovery and opening of the mine. Deforestation was associated with these activities, as land clearing provided space for developing infrastructure, towns, and agriculture. The change from natural forest to agriculture is usually recorded in the pollen spectra of lake sediment by a reduction in the amount of pollen from tree species, and by a sudden rise in the amount of ragweed pollen (*Ambrosia*). The pollen record of lake sediment can therefore be used to identify the depth in the core corresponding to the date of deforestation. Alternatively, radioactive isotopes can be used to date core samples, using for example ^{210}Pb. The pollen method provides an independent check on the isotopic dates, and if there is disagreement, the reasons for the inconsistency need to be explained. An evaluation of ^{210}Pb dates in lake sediments was made by Blais et al. (1995), who compared them to *Ambrosia* pollen and ^{137}Cs dates. Only a few isotopic dates were obtained in the Rouyn-Noranda study, so the results are based mainly on pollen data.

This report presents and discusses analytical and graphical data from pollen analysis of cores collected from eight lakes during Phase I of the GSC MITE Point Sources project (Fig. 1). These lakes were sampled in order to characterize the geographic distribution of metals in lake sediment in the vicinity of a copper smelter, and to examine the temporal distribution of metal with depth in the core (Kliza and Telmer, 2001). The eight lakes comprised a subset of a larger group of about 100 lakes examined during the survey (Bonham-Carter et al., 2001). The lakes (‘Green’ Lake, Lake Vert, Lake Bigat, Lake Claire, Lake Marlon, ‘Gravel Pit’ Lake, Moose Lake, Lake Hector) range from 4 to 100 km from the smelter and have all been directly affected by human activity to some degree (Table 1).

In order to interpret the geochemical profiles seen in lake-sediment cores, age dating of the sediment is important. This provides an estimate of the sedimentation rate as well as a chronology for the sediment sequence. Because of post-depositional changes, such as metal mobility due to diagenesis (*see* discussion in Alpay et al., 2005), caution must be exercised in assuming that metal content of any particular sample in a core is a record of metal deposition coincident with sediment deposition.

Pollen analysis was undertaken partly because of its value as a dating technique and partly because the vegetation history recorded in the sediment can provide evidence about past environmental conditions around the lake that may have a bearing on the interpretation of the geochemical record.

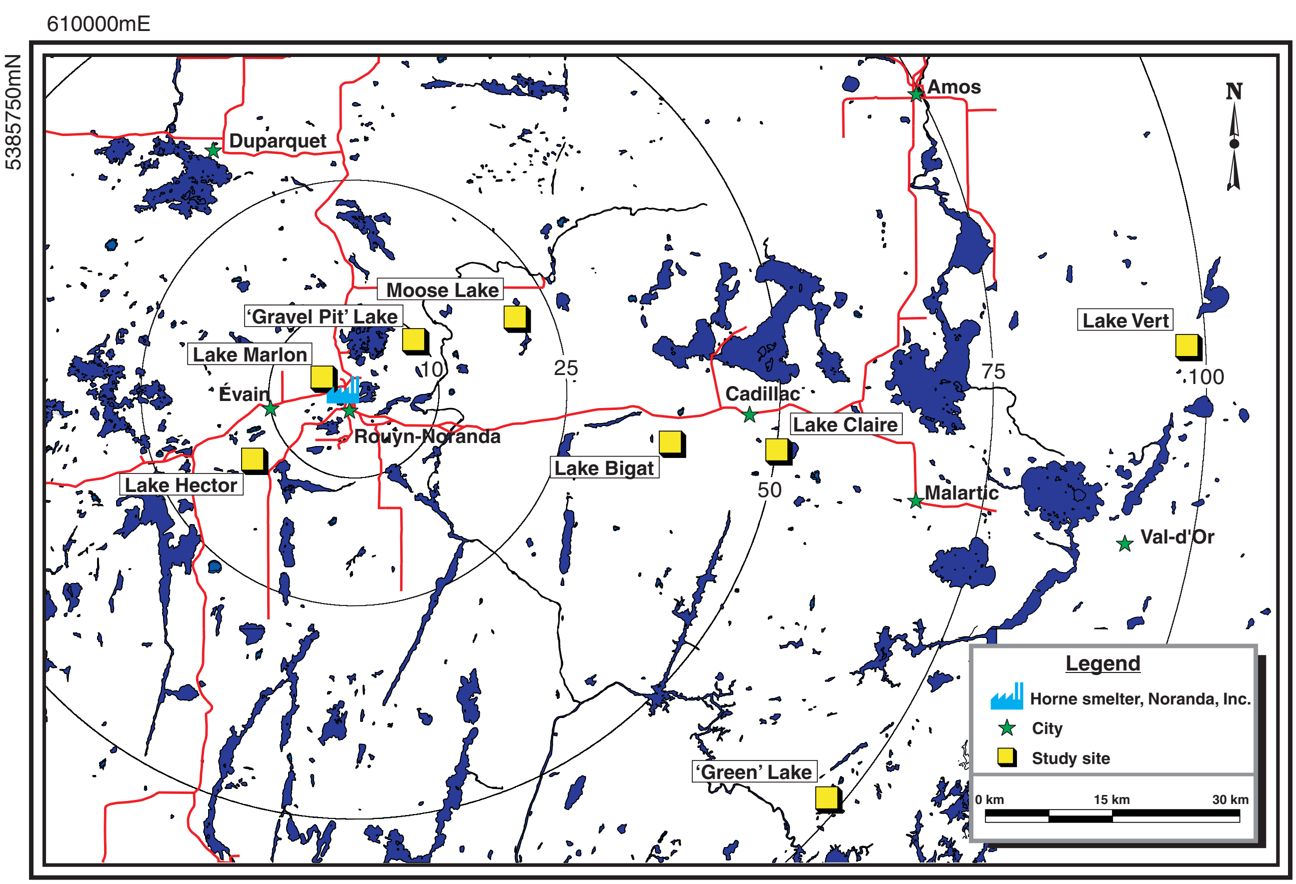

Figure 1. *Location map showing the Horne smelter at Rouyn-Noranda and the lakes. Circles are at 10, 25, 50, 75, and 100 km from the smelter.*

Table 1. Lake characteristics. Lakes are arranged from west to east. Depth to *Ambrosia* marker is shown on profiles in Figure 4.

Lake	Latitude (°N)	Longitude (°W)	Distance from smelter (km)	Depth (m)	Lake area (km^2)	Drainage basin area (km^2)	Depth to *Ambrosia* marker (cm)
Lake Hector	48.1786	79.1728	14	8.1	0.16	0.89	3.5
Lake Marlon	48.2648	79.0638	4	2.3	0.29	1.15	7.5
Gravel Pit Lake	48.3060	78.9171	9	4.1	0.07	1.05	9
Moose Lake	48.3293	78.7591	21	3.4	0.04	0.85	10
Lake Bigat	48.1967	78.5123	38	5.8	0.30	3.02	9
Lake Claire	48.1891	78.3450	50	11.3	0.07	1.47	11
Green Lake	47.8216	78.2648	74	19.4	0.24	1.00	13
Lake Vert	48.2989	77.6950	100	14.0	-	-	13

METHODS

Standard laboratory techniques used in the Diatom Laboratory at the Geological Survey of Canada in Ottawa were applied to the analysis of pollen in the lake sediments. Pollen grains were concentrated using the method of Faegri and Iversen (1989), using the following steps. (1) Three tablets of *Lycopodium* spores were added to the sediment samples, which were then placed in a 15 mL centrifuge tube. (2) Hydrochloric acid (HCl) (10%) was added to remove calcium carbonate and dissolve the *Lycopodium* tablets. (3) Next, 10% KOH was added to remove humic acids. (4) Siliceous matter was dissolved with 48% HF. (5) Finally, an acetolysis mixture ($C_4H_6O_3$ and concentrated H_2SO_4 in the volume ratio 9:1) was added to remove cellulose. Samples were stored in silicone oil and mounted on slides for examination using a Leitz DMRB light microscope at 400x magnification. Four lakes were analyzed for a full pollen spectrum, and an additional four lakes were analyzed solely for *Ambrosia* pollen. Each core was examined approximately every second centimetre (i.e. 0–2 cm).

Lead isotope (^{210}Pb) dates were determined for a small number of samples from 'Green' and 'Gravel Pit' lakes by Flett Research Ltd., Winnipeg, Manitoba, using standard methods. Intervals of 2 cm were examined down core and results were compared with the pollen-derived marker dates for these lakes.

Several assumptions are involved in dating lake sediments by ^{210}Pb (Blais et al., 1995). A key assumption is that postdepositional mobility of Pb is negligible. Two alternative models are commonly applied to lead dating of sediment profiles: the Constant Supply model and the Constant Initial Concentration model. In either case, various factors can influence the supply of ^{210}Pb, such as atmospheric flux, residence time in catchment soils or lake water, particle settling velocity, fraction of ^{210}Pb bound to particulates, and the extent of sediment redistribution (focusing) in the lake. In the Constant Supply model, the supply of atmospheric ^{210}Pb to sediments is constant, whereas in the Constant Initial Concentration model, the supply of ^{210}Pb is proportional to the sedimentation rate. Of the dates compared by Blais et al (1995), the Constant Initial Concentration model dates were almost always significantly younger than the Constant Supply model dates, and they postulate that this was due to dilution of lead brought on by changes in sedimentation rate due to clear cutting, forest fires, or construction. They concluded that the Constant Supply model is more appropriate than the Constant Initial Concentration model because it shows better agreement with markers of known history. The Flett Research Ltd. laboratory used the Constant Supply model, but their results were modified to allow for changes in sedimentation rate with time. For information about the method, *see* http://www.flettresearch.ca/Webdoc4.htm.

RESULTS

Pollen spectra

The Lake Bigat pollen spectrum is composed mainly of tree species (~90%) with a minimum of about 85% at 8.5 cm depth (Fig. 2, top). The shrub pollen content is relatively constant over the whole sequence at about 7%. The herb pollen content represents less than 5% of the entire pollen count, with a slight increase in samples from the upper section, starting at 10.5 cm depth.

The most abundant species are *Picea* (spruce), *Pinus* (pine), and *Betula* (birch), which range respectively from 30 to 35%, 23 to 32%, and 18 to 27%. *Picea* is generally constant throughout the profile, whereas *Pinus* and *Betula* show some fluctuation. *Salix* (willow) species is almost absent between the bottom of the core and 10.5 cm depth, but appears above this level at about 1%. *Ambrosia* (common ragweed) is constant from the base to 10.5 cm depth (<1%) and increases at this point to reach a maximum of 2.5% near the surface. In the same way, *Artemisia* is generally constant from the base to 10.5 cm depth, at which point it increases markedly to 2% or more.

The pollen from the 'Gravel Pit' Lake core (Fig. 2, bottom) shows some differences compared to the pollen from Lake Bigat. Overall, tree pollen is a little less abundant in the 'Gravel Pit' Lake core and decreases markedly above about 10.5 cm depth, perhaps indicating the onset of land clearing. Pollen from shrubs and herbs increases in the upper section with the change starting at about 10.5 cm depth.

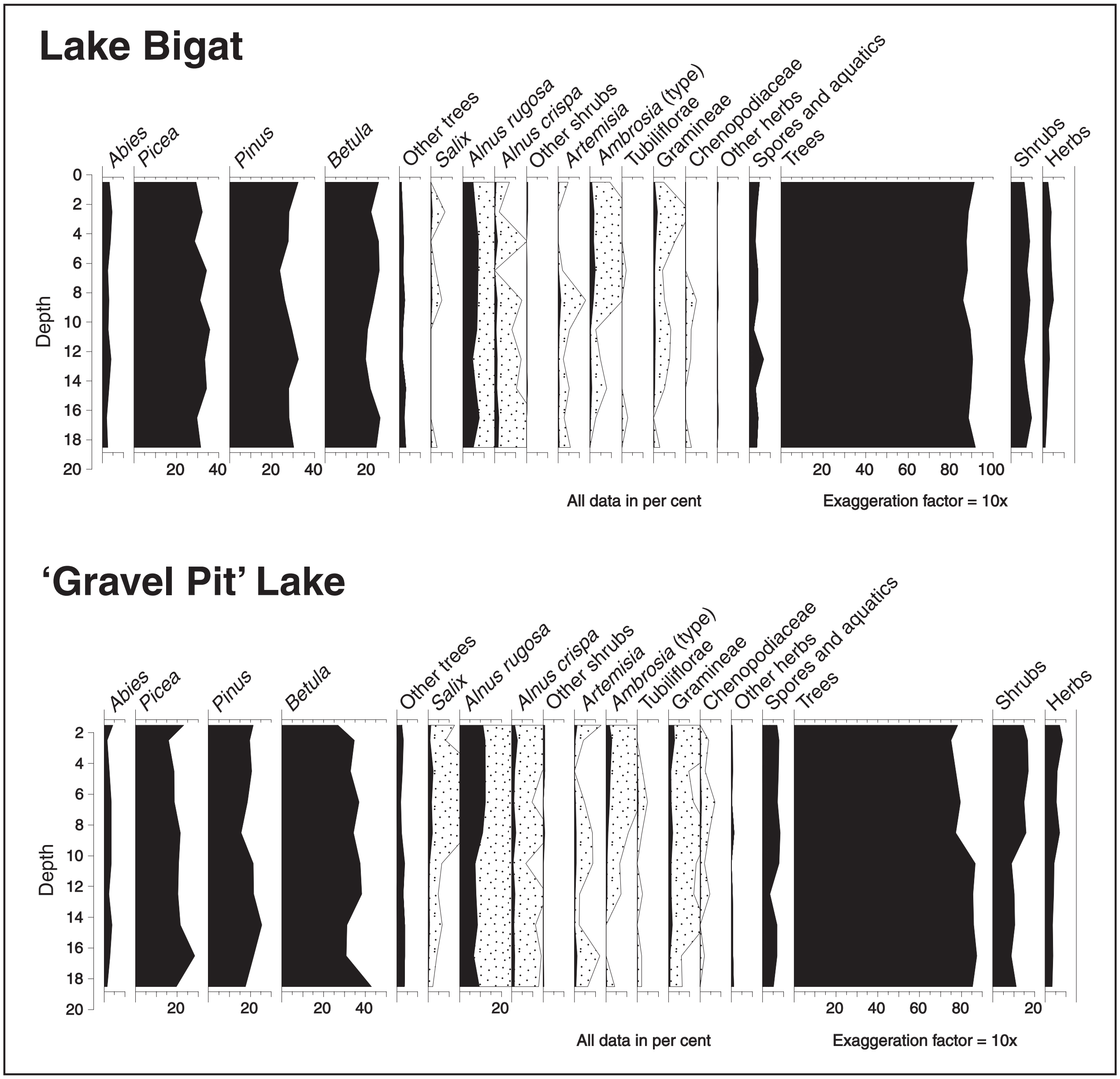

***Figure 2**. Pollen stratigraphy of Lake Bigat and 'Gravel Pit' Lake.*

Betula pollen is more abundant than *Picea* or *Pinus* pollen in the 'Gravel Pit' Lake core. *Salix* and *Alnus rugosa* show a marked increase in the upper section starting at the 10.5 cm mark.

The pollen from 'Green' Lake (Fig. 3, top) shows that trees dominated throughout the profile (over 90% of the total count). No consistent changes were noted in the profile, except that some fluctuations occurred in the 10 to 14 cm depth interval.

Pinus is the dominant species of the pollen spectra, accounting for approximately 55% of the pollen. *Ambrosia* is the main herb species. It is nearly absent in the basal section of the profile, but starts to increase at about 15.5 cm and continues to increase in the middle part of the profile before decreasing again at the surface.

The Lake Hector pollen profile (Fig. 3, bottom) shows that tree species (95%) predominate, with a small change toward herbs and shrubs in the uppermost samples.

As for the other lakes, the three major tree species are *Picea*, *Pinus*, and *Betula*, which are about evenly balanced. Individual herb species are nearly absent from the pollen spectrum with percentages lower than 1%.

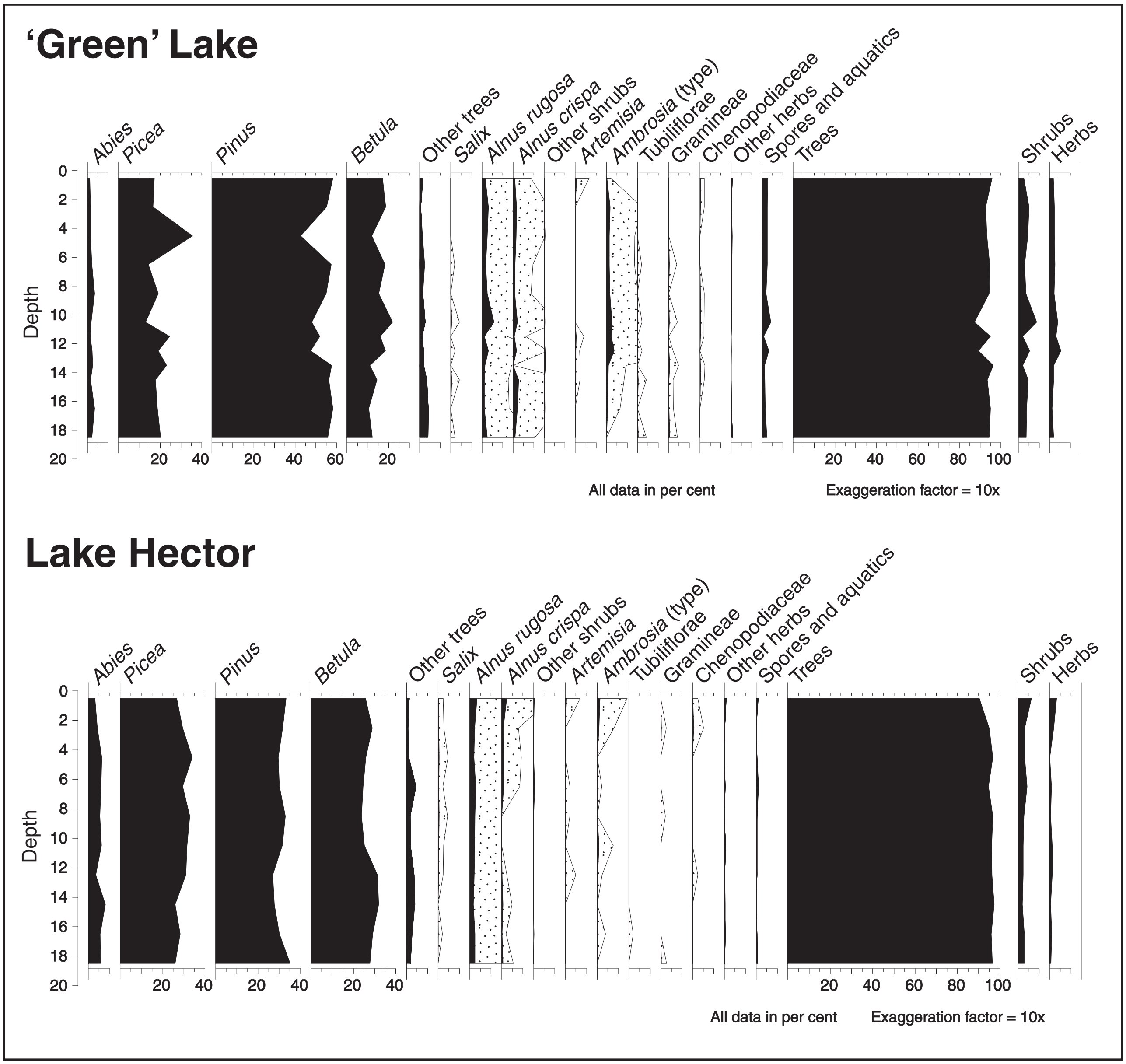

Figure 3. Pollen stratigraphy of 'Green' Lake and Lake Hector.

Ambrosia counts

Figure 4 illustrates the concentration of *Ambrosia* pollen as grains/cm³, plotted against depth in the core. Note that the horizontal scale (grain count) changes from lake to lake. In general, grain counts range from close to zero to as high as 18 000 grains/cm³ (Lake Bigat); most lakes have maximum values in the 5000 to 10 000 grains/cm³ range. All lake cores have very low counts at the base; the counts increase in samples from farther up the profile, but the pattern of increase differs from lake to lake. The sequence of the plots in Figure 4 is from west to east. Lake Hector is west of the smelter, whereas Lake Marlon is north-northwest, just 4 km from Rouyn-Noranda. The remaining lakes are at progressively greater distances approximately east of the smelter, except for 'Green' Lake that is southeast. Distances from the smelter are shown in Table 1. The following descriptions are organized with the lakes starting in the west and progressing eastward.

Compared to the other study lakes, the *Ambrosia* profile for the Lake Hector core is unique. The count remains low (<1000 grains/cm³) below 4.5 cm depth, then rises steeply toward the surface.

The *Ambrosia* count for the Lake Marlon core starts to increase at about 8 cm from the surface and reaches a maximum of 5900 grains/cm³ at 2.5 cm depth.

The *Ambrosia* count for the 'Gravel Pit' Lake core increases steadily from about 13 cm depth, reaching a maximum of 9000 grains/cm³ at 4.5 cm.

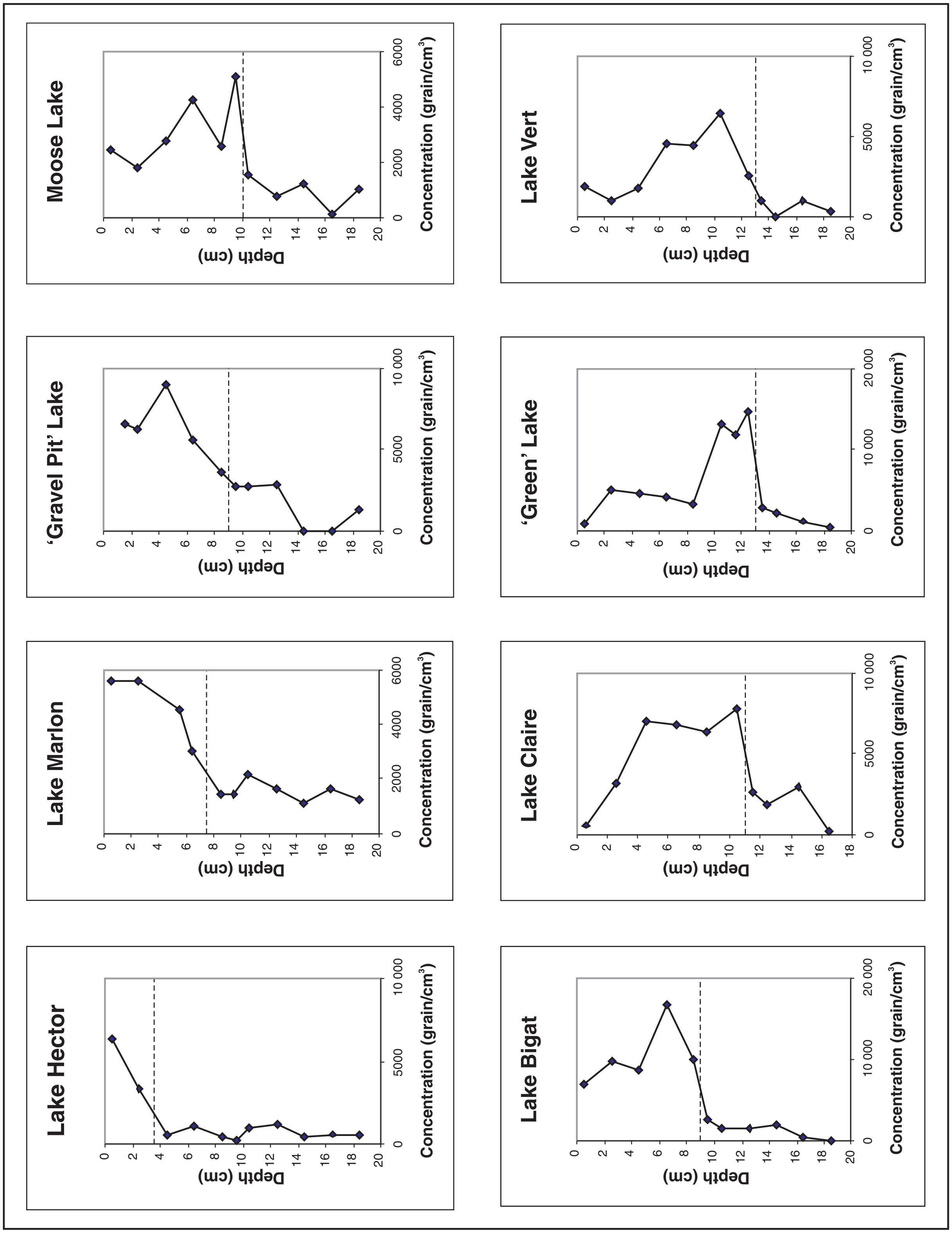

Figure 4. Ambrosia *pollen profiles. Lakes are arranged from west to east (see Fig. 1), starting with Lake Hector and ending with Lake Vert. The first major increase in* Ambrosia *pollen content is treated as the marker, shown as dotted line.*

The *Ambrosia* count for the Moose Lake core is low (<1500 grains/cm³) at the base of the profile to 10.5 cm depth; it rises to a maximum of 5200 grains/cm³ at 9.5 cm, then decreases gradually toward the surface.

The Lake Bigat curve has a pattern approximately similar to that of Moose Lake.

The pattern for the Lake Claire core indicates that the *Ambrosia* count starts to increase at a depth perhaps as low as 12 cm and decreases to close to zero at the surface.

In the 'Green' Lake core, the *Ambrosia* count begins to increase at about 13 cm depth, maintains a short-lived peak, and decreases to a low count about 8 cm depth.

In the Lake Vert core, the *Ambrosia* pollen counts starts to increase at about 13 cm depth, peaks at 10 cm depth, then decreases more gradually toward the surface.

Lead isotope dates

Results for the ^{210}Pb signatures show varied sedimentation accumulation (dry weight) rates within the sediment profiles (*see* Table A-1, A-2, Fig. A-1, A-2). For 'Gravel Pit' Lake (9 km from the smelter), results showed that the rates of sediment accumulation (dry weight) changed with time. The top 3.5 cm of the core indicate a rate of 0.004 g/cm²/a. The middle sections of the sediment profile (3.5–7.5 cm) indicate a rate of 0.0365 g/cm²/a and the bottom of the core (7.5–11.5 cm) indicates a rate of 0.0079 g/cm²/a. These rates are speculative because of the small number of data points. Assuming that accumulation rates are constant over time within each of these three sections, the ages at the bottom of the extrapolated sections were calculated. This places the ca. 1925 (i.e. about 73 years before the core was taken in 1998) marker at approximately 8 to 9 cm down core (Table 2). This is not inconsistent with the position of the *Ambrosia* marker (Fig. 4), although the uncertainty in both the position of the *Ambrosia* marker and the Pb date make precise estimates impossible.

Data for 'Green' Lake (74 km from the smelter and south of the other sampled lakes; *see* Table A-2, Fig. A-2) provide peculiar results (R. Flett, pers. comm., 2003) and, as a result, they are not included in the interpretation. Hall et al. (2005) also found unusual geochemical values in the 'Green' Lake core. These unusual patterns may be the result of anthropogenic disturbance.

INTERPRETATION AND DISCUSSION

Pollen spectra

The pollen spectra of 'Gravel Pit' Lake suggest that a major event occurred at about 9.5 cm depth. The concentration of tree pollen from around the lake is clearly reduced, whereas that of shrub and herb pollen (including *Ambrosia*) increases. This event most likely corresponds to the time when excavation of the nearby gravel pit began. The loss in relative abundance of trees indicates that a large open canopy was created, where opportunistic herbs and shrubs could spread. Lake Bigat also recorded a similar signal at a depth of 9 cm in the sediment, where herb pollen replaced tree pollen. The location of this lake between several centres of historic mining and prospecting activities suggests that *Ambrosia* levels increased in response to land clearing and agricultural development.

The response from Lake Hector is quite different from that of the two previous lakes. Unlike the other lake basins, Lake Hector is located on top of Mount Kékéko (approximately 13 km southwest of Rouyn-Noranda, in a direction against the prevailing wind). The concentration of herb pollen from the valley is notably low in this core, presumably because pollen was not transported by wind from the cleared area to the northeast. Moreover, the immediate environment was preserved from human activities until the early 1970s, at which time a private club was located in the vicinity of the lake. This event probably accounts for the increase in *Ambrosia* pollen at a shallow depth.

'Green' Lake has a distinct *Pinus* pollen concentration. Concentrations are approximately double those in the other lake basins. The abundance of pine trees suggests that the underlying soils may be coarser grained than in other basins, which increases the drainage capability of the soil (Vincent, 1973). Other tree species such as spruce tend to grow in moister soils. 'Green' Lake, in fact, lies on a deposit of glacial moraine extending north-south. This is apparent in an airphoto taken in the fall of 1946 (Fig. 5). This airphoto also indicates that logging activities (clear cutting) west of the lake had once extended into the drainage basin. Today, this area has been reforested and some of the logging roads remain. This localized event was perhaps recorded in the lake-sediment profile and may be the reason for the increase in herb pollen at 13.0 cm depth.

Ambrosia

Generally, *Ambrosia* is not abundant in the Abitibi–Témiscamingue area (Frère Marie-Victorin, 1964). The abundance of this species within the pollen spectrum is low for this region of west Quebec. As mentioned earlier, this species is a good indicator of the development of agricultural or deforestation activities within a region (McAndrew, 1988).

The sediment profiles of seven of the eight lakes show a substantial increase in *Ambrosia* pollen; the exception is Lake Hector, which shows a slight increase in the top 4 cm. The three other lakes around Rouyn-Noranda (Marlon, 'Gravel Pit', and Moose) show an increase in *Ambrosia* at between 7.5 and 10.0 cm depth. These time markers most likely reflect the activities associated with mining and smelting operations in Rouyn-Noranda. The lakes closer to the town of Cadillac (Bigat and Claire), approximately 50 km from the smelter, show a rise in *Ambrosia* that occurs deeper in the core (9.0 and 11.0 cm depth), whereas the most distal lakes (Vert and 'Green') show the deepest marker at 13.5 cm depth. The *Ambrosia* changes reflect major human activities within the study area. Probably not all lakes were directly affected by the smelting and mining activities, although

Table 2. Lead isotope (^{210}Pb) results for 'Gravel Pit' Lake. Sampling was done in August 1998. Dates were calculated by the Flett Research Ltd. laboratory according to a modified Constant Supply model, with three different sedimentation rates.

Section no.	Extrapolated depth (cm)	Extrapolated cumulative mass in section (g/cm^2)	Years in extrapolated section (a)	Age at bottom of extrapolated section (a)
1	0–1.5	0.006	0.006/0.004=1.5	1.5
2	1.5–3.5	0.170	0.170/0.004=42.5	43
3	3.5–5.5	0.221	0.221/0.0365=6.0	49
4	5.5–7.5	0.347	0.347/0.0365=9.5	58.5
5	7.5–9.5	0.371	0.371/0.0079=47.0	105.5
6	9.5–11.5	0.458	0.458/0.0079=58.0	163.5

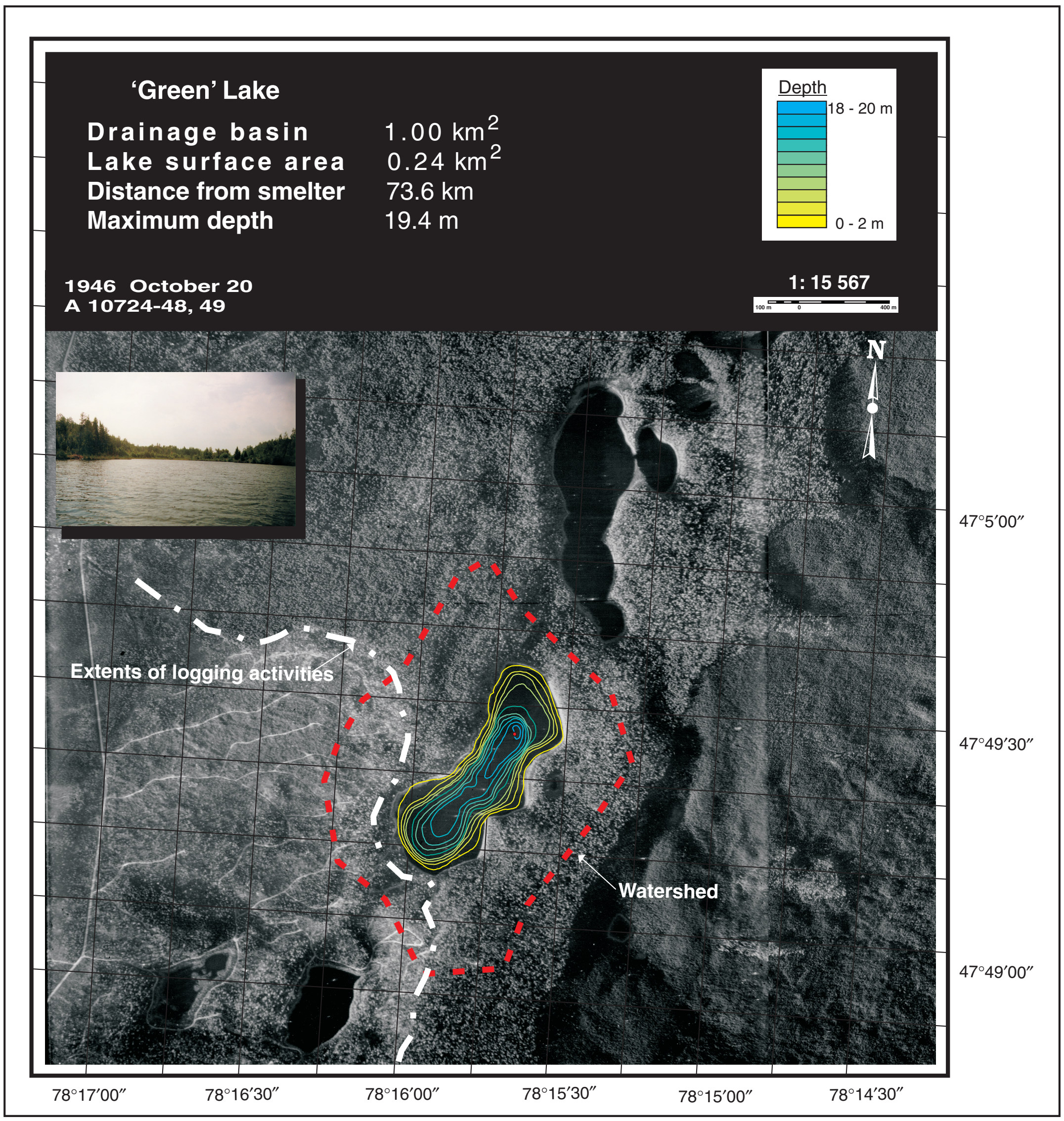

Figure 5. *Airphoto for 'Green' Lake (NAPL A10724-48, 49).*

associated activities such as logging and excavation would have been responsible for changes in the local mix of vegetation.

The trend from east to west is evident in the *Ambrosia* data, with the increase in *Ambrosia* pollen concentrations occurring at progressively higher levels in the sediment cores, as is shown in Table 1 and Figure 4 (note that the order of the lakes is by longitude). The *Ambrosia* marker is nearer the surface of the core in the lakes around Rouyn-Noranda than in the lakes to the east. There is also a parallel trend in lake depth, with lakes being deeper in the east than in the west, but the significance of this is uncertain and may not be relevant. Two hypotheses could explain the trend in the progressive change in the *Ambrosia* marker. 1) The *Ambrosia* marker is a single time line and the change is the result of a higher sedimentation rate in the east than in the west. 2) The *Ambrosia* marker shifts because land clearing and related activities occurred earlier in the east than in the west. Historical records show that the first mining activities in the area of Val-d'Or occurred in 1911 (Chabot et al., 1995), about 15 years before the development of the Noranda area. The *Ambrosia* marker in Lake Vert (the most easterly lake) is at 13 cm, whereas it is at 7.5 cm in Lake Marlon (the lake farthest west, except for the unusual Lake Hector). It seems unlikely that this difference (13:7.5, almost a factor of 2) can be completely explained by a 15-year difference in the time of land clearing because development began 74 years ago in Noranda and 87 years ago in Val-d'Or, and the ratio 87:74 represents a factor of less than 1.2, much less than the difference in marker levels. A possible explanation for an increased sedimentation rate in the deeper eastern lakes is sediment focusing — a mechanism that involves moving sediment preferentially into the deeper parts of the lake, so that the sedimentation rate is not constant everywhere. Perhaps sediment focusing was more prevalent in the eastern (deeper) lakes than the western lakes, and the change in the *Ambrosia* marker was affected by both a moving time line and a changing sedimentation rate. This could be tested by doing an *Ambrosia* count in one or more shallow lakes around Val-d'Or, or by getting absolute ages to pinpoint the dates of the *Ambrosia* markers for lakes in the east and in the west.

Comparison of Ambrosia markers and ^{210}Pb dates

For 'Gravel Pit' Lake, the *Ambrosia* marker is placed in the 7.5 to 9.5 cm interval; if the Pb age is 58.5 years at 7.5 cm and 105.5 years at 9.5 cm (Table 2), then linear interpolation would put the age of the Noranda clearing (1926) at a depth of about 8.1 cm. Despite the uncertainties involved, the *Ambrosia* marker is therefore consistent with the Pb date, assuming that the increase in *Ambrosia* happened at about the time of the Noranda development.

Unfortunately, there are too many unexplained features of the ^{210}Pb data from the 'Green' Lake core for a reliable absolute age determination of the *Ambrosia* marker. The unusual geochemical profile results found by Hall et al. (2005) on the 'Green' Lake core also are indicative of some unknown disturbance that affected this lake.

SUMMARY AND CONCLUSION

In the Rouyn-Noranda area, colonization historically began in about 1917 and really gained in importance in 1926 with the construction of the Horne smelter (Roberts, 1956). This event was associated with an increase in *Ambrosia* pollen. With the exception of Lake Hector, all the lakes studied clearly show an increase in *Ambrosia* and herb populations that can be ascribed to land clearing associated with mining, agriculture, road construction, and related development. A ^{210}Pb date for the *Ambrosia* marker in the 'Gravel Pit' Lake core (9 km east of Rouyn-Noranda) is consistent with the age of Noranda development. A trend indicating that the lakes in the eastern part of the study area have an *Ambrosia* marker deeper in the core than the lakes in the western part may reflect a shift in the time of land clearing (e.g. Val-d'Or was developed earlier than Rouyn-Noranda) and a change in sedimentation rate due sediment focusing. The average sedimentation rate in 'Gravel Pit' Lake is about 8.1 cm in 76 years or 0.11 cm/a, using the 1926 date for Noranda and a combination of the *Ambrosia* marker and Pb date. Sedimentation rates in the eastern lakes, Lake Vert for example, are uncertain because the *Ambrosia* marker has not been dated. If we assume that the youngest age of the *Ambrosia* marker in Lake Vert (i.e. the Noranda clearing event) is 76 years, the corresponding sedimentation rate is 13 cm in 76 years or 0.17 cm/a. On the other hand, if the age is that of Val-d'Or development, then the rate is 13 cm in 87 years or 0.15 cm/a, still substantially greater than the rate for 'Gravel Pit' Lake.

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APPENDIX

^{210}Pb Results on Green Lake and Gravel Pit Lake Cores (extract from R. Flett, unpub. rept., 2000, p. 1–2)

Gravel Pit Lake

The core yielded easily measurable activity and showed a reasonably exponential decrease in ^{210}Pb with depth, see Table A-1 and Figure A-1. The rate of sediment accumulation changed with time: Section 1 (0-1.5 cm) and Section 2 (1.5-3.5 cm) indicate a rate of about 0.004 g/cm2/yr. Section 3 (3.5-5.5 cm) and Section 4 (5.5-7.5 cm) indicate a rate of about 0.0365 g/cm2/yr. Sections 5 (7.5-9.5 cm) and Section 6 (9.5-11.5 cm) indicate a rate of about 0.0079 g/cm2/yr. The rates are speculative because only two data points make up each estimate.

The constant slope chronology and the chronology based on the CRS model agree reasonably well. The two methods should give the same results provided the rate of ^{210}Pb supply has been constant and all the ^{210}Pb has remained in the core.

Green Lake

The core yielded easily measurable activity and showed a reasonably exponential decrease in ^{210}Pb with depth. The rate of sediment accumulation changes suddenly with time, see Table A-2 and Figure A-2.

Sections 1-7 (0-13.5 cm) indicate a sediment accumulation rate of about 0.0308 g/cm²/yr. A plot of unsupported ^{210}Pb activity versus accumulated sediment gives a straight line slope with an R^2 of 0.99 in this section. It appears that the sedimentation rate was approximately constant when these top 13 cm were deposited.

Sections 8-14 (13.5-35 cm) indicate a rate of about 0.0075 g/cm²/yr. There is some variation in rate over time (R^2=0.93), and therefore the rate is more speculative.

The overall shape of the ^{210}Pb curve (Fig. A-2, see also Table A-2) indicates that some important data points may be missing. Section 7 should have significantly lower ^{210}Pb activity than section 8, because of the dilution effect of the high accumulation rate in Section 7. Also the CRS model gives very different age estimates than the slope method. The CRS results (Table A-2) cannot be trusted because the CRS model requires that all the initially deposited isotope must be accounted for in the core. This appears not to be the case. It is possible that 1) a large part of the ^{210}Pb inventory was missed by analysing only every second slice, or 2) that part of the sediment column that was once above Section 8 was removed by erosion, or 3) that recent sediment accumulating in the upper 7 sections (0-13.5 cm) is from a different, more ^{210}Pb-rich, source.

Because of the uncertain interpretation of the Green Lake data, the age corresponding to the *Ambrosia* marker has not been estimated.

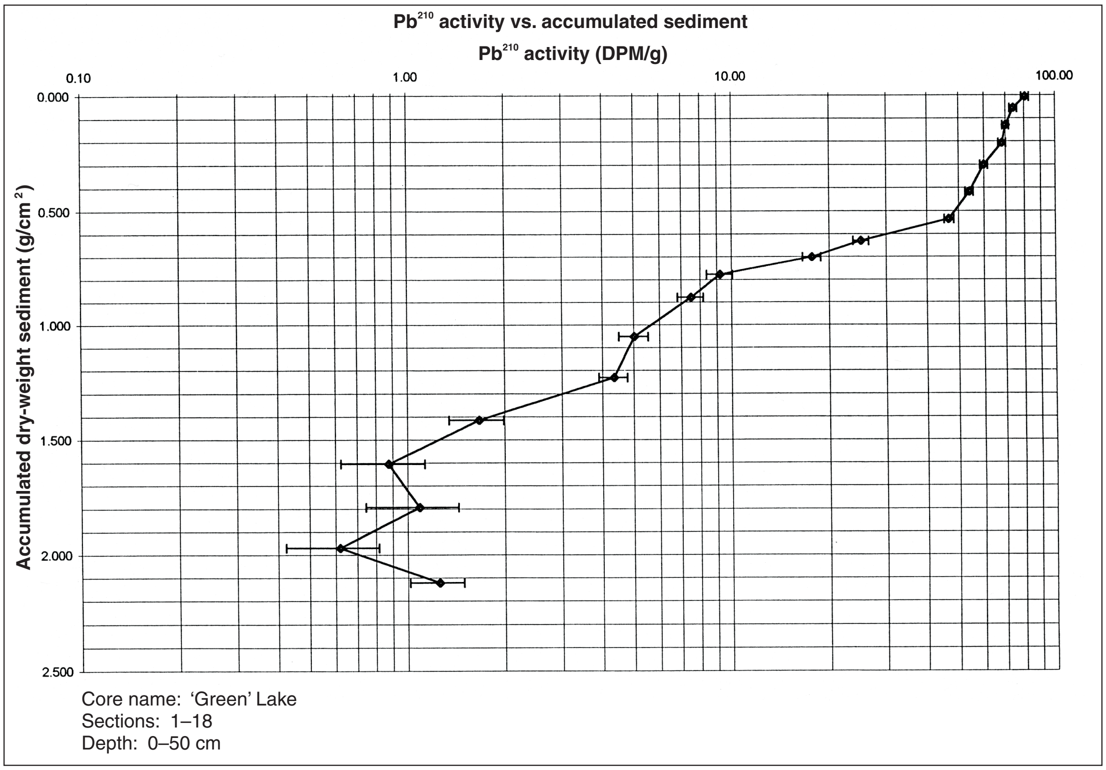

Figure A-1. *Lead isotope (^{210}Pb) activity versus accumulated sediment for 'Gravel Pit' Lake (*after *R. Flett, unpub. rept., 2000).*

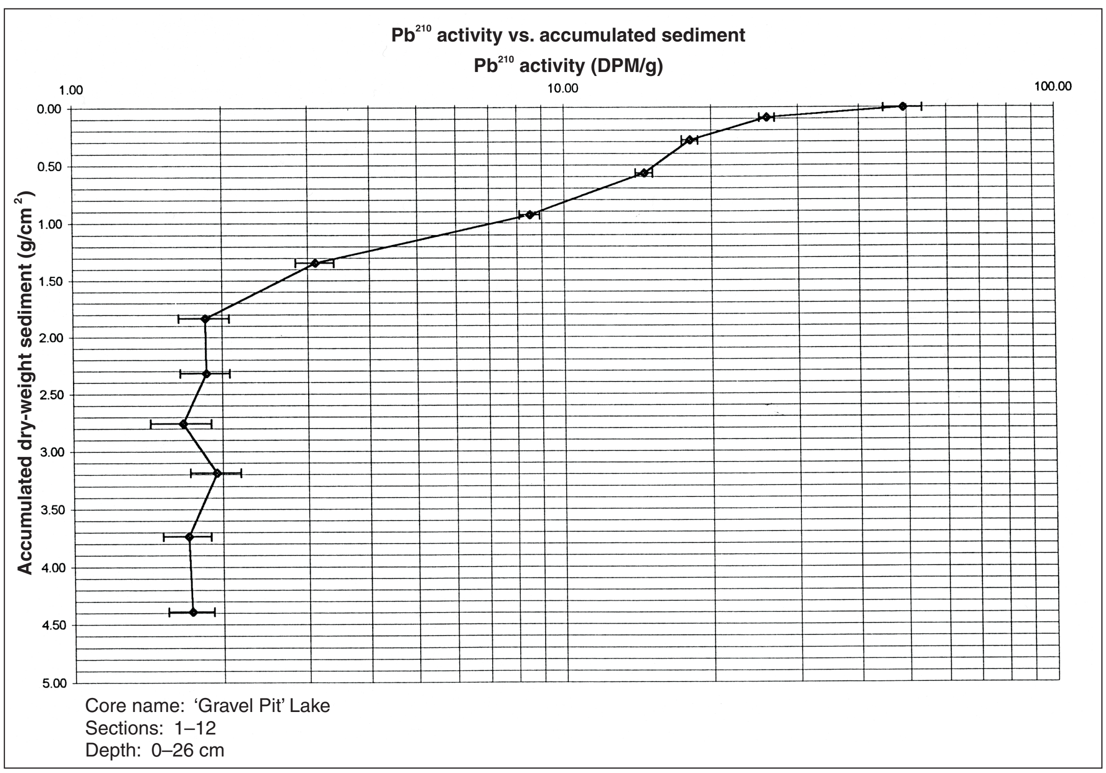

Figure A-2. *Lead isotope (^{210}Pb) activity versus accumulated sediment for 'Green' Lake (*after *R. Flett, unpub. rept., 2000).*

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Table A-1. Lead isotope results for 'Gravel Pit' Lake (*after* R. Flett, unpub. rept., 2000).

Section number	Sample ID	Upper section depth (cm)	Lower section depth	Extrapolated upper section depth (cm)	Extrapolated lower section depth (cm)	Dry wt. Wet cc. (g/cm^3)	Mass in extrapolated section (g/cm^2)	Cumulative mass to bottom of current section (g/cm^2)	Plot-point of cumulative mass in current section (g/cm^2)	Pb^{209} counts less detector background	Pb^{210} counts less detector background	Weight of sample counted (g)	Count time (sec)	Pb^{210} Supported activity (DPM/g)	Error Pb^{210} - 1 S.D. (DPM/g)	Pb^{210} unsupported activity (DPM/g)	Age at bottom of extrapolated section in years (CRS model estimate)	Depth of bottom edge of current section (cm)
1		0	1	0.0	1.5	0.012	0.018	0.018	0.006	2077	1351	0.145	30000	80.64	2.19	79.67	1.1	1.5
2		2	3	1.5	3.5	0.037	0.073	0.091	0.054	2061	1335	0.157	30000	74.17	2.03	73.19	5.7	3.5
3		4	5	3.5	5.5	0.040	0.079	0.170	0.130	2177	1989	0.234	30000	70.19	1.57	69.21	11.2	5.5
4		6	7	5.5	7.5	0.036	0.072	0.242	0.206	2180	1469	0.177	30000	68.44	1.79	67.46	17.0	7.5
5		8	9	7.5	9.5	0.059	0.118	0.360	0.301	1607	1318	0.245	30000	60.12	1.66	59.14	27.7	9.5
6		10	11	9.5	11.5	0.057	0.114	0.474	0.417	1612	1195	0.246	30000	54.12	1.57	53.14	41.3	11.5
7		12	13	11.5	13.5	0.061	0.122	0.596	0.535	1394	847	0.233	30000	46.83	1.61	45.86	62.6	13.5
8		14	15	13.5	15.5	0.033	0.066	0.662	0.629	1609	329	0.146	30000	25.15	1.39	24.18	72.6	15.5
9		16	17	15.5	17.5	0.039	0.078	0.740	0.701	1687	236	0.142	30000	17.69	1.15	16.72	84.0	17.5
10		18	19	17.5	19.5	0.038	0.075	0.815	0.777	1607	119	0.144	30000	9.23	0.85	8.26	91.3	19.5
11		20	22	19.5	23.0	0.043	0.151	0.965	0.879	1556	125	0.192	30000	7.51	0.67	6.54	108.0	23.0
12		24	26	23.0	27.0	0.043	0.174	1.139	1.052	1746	94	0.192	30000	5.03	0.52	4.05	129.3	27.0
13		28	30	27.0	31.0	0.046	0.184	1.323	1.231	1644	97	0.243	30000	4.35	0.44	3.38	186.5	31.0
14		32	34	31.0	35.0	0.046	0.183	1.506	1.415	1430	27	0.203	30000	1.67	0.32	0.69		35.0
15		36	38	35.0	39.0	0.049	0.197	1.703	1.605	1163	12	0.211	30000	0.88	0.25	-0.10		39.0
16		40	42	39.0	43.0	0.045	0.181	1.885	1.794	1134	10	0.145	30000	1.09	0.34	0.11		43.0
17		44	46	43.0	47.0	0.043	0.172	2.057	1.971	1522	10	0.190	30000	0.62	0.20	-0.36		47.0
18		48	50	47.0	50.0	0.032	0.096	2.153	2.121	2027	28	0.198	30000	1.25	0.24	0.28		50.0
Blank										1144	5							
2		2	3							2061	1335	0.157	30000	74.17	2.03	73.19		
2 Dup		2	3							1603	937	0.146	30000	71.97	2.35	71		

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Table A-2. Lead isotope results for 'Green' Lake (*after* R. Flett, unpub. rept., 2000).

Section number	Sample ID	Upper section depth (cm)	Lower section depth	Extrapolated upper section depth (cm)	Extrapolated lower section depth (cm)	Dry wt. Wet cc. (g/cm^3)	Mass in extrapolated section (g/cm^2)	Cumulative mass to bottom of current section (g/cm^2)	Plot-point of cumulative mass in current section (g/cm^2)	Pb^{209} counts less detector background	Pb^{210} counts less detector background	Weight of sample counted (g)	Count time (sec)	Pb^{210} supported activity (DPM/g)	Error Pb^{210} - 1 S.D. (DPM/g)	Pb-210 unsupported activity (DPM/g)	Age at bottom of extrapolated section in years (CRS model estimate)	Depth of bottom edge of current section (cm)
1		0	1	0.0	1.5	0.004	0.006	0.006	0.002	1403	123	0.032	30000	49.28	4.44	47.49	0.6	1.5
2		2	3	1.5	3.5	0.085	0.170	0.176	0.091	2079	790	0.263	30000	25.99	0.92	24.20	10.7	3.5
3		4	5	3.5	5.5	0.111	0.221	0.397	0.286	2113	707	0.332	30000	18.13	0.68	16.34	23.3	5.5
4		6	7	5.5	7.5	0.173	0.347	0.744	0.570	1729	593	0.422	30000	14.62	0.60	12.83	51.9	7.5
5		8	9	7.5	9.5	0.186	0.371	1.115	0.929	1789	416	0.491	30000	8.51	0.42	6.72	104.4	9.5
6		10	11	9.5	11.5	0.229	0.458	1.572	1.344	1511	127	0.485	30000	3.11	0.28	1.32		11.5
7		12	13	11.5	13.5	0.262	0.523	2.096	1.834	1430	73	0.495	30000	1.85	0.22	0.06		13.5
8		14	15	13.5	15.5	0.224	0.447	2.543	2.319	1508	75	0.481	30000	1.86	0.21	0.07		15.5
9		16	17	15.5	17.5	0.214	0.428	2.971	2.757	1141	51	0.482	30000	1.67	0.23	-0.12		17.5
10		18	19	17.5	19.5	0.213	0.426	3.397	3.184	1382	73	0.487	30000	1.95	0.23	0.16		19.5
11		20	22	19.5	23.0	0.227	0.794	4.191	3.737	1708	81	0.500	30000	1.70	0.19	-0.09		23.0
12		24	26	23.0	26.0	0.100	0.299	4.490	4.390	1828	90	0.512	30000	1.73	0.18	-0.06		26.0
13																		
14																		
15																		
16																		
17																		
18																		
Blank										1144	5							
2		2	3							2079	790	0.263	30000	25.99	0.92			
2 Dup		2	3							1578	575	0.280	30000	23.41	0.98			

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