Stratigraphic description of Lac le Caron peatland with a ground penetrating radar; estimation of the amount of organic carbon

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Introduction

The anaerobic conditions prevaling in peatlands induce slower decomposition rates by microbial activity than biomass production, hence forming an organic carbon (C) sink (Vitt *et al.*, 2000). This process allows peatlands to sequester half of the total atmospheric C (Cubasch *et al*, 2001, IPCC). Peatlands cover 4 millions km^2 on the Earth surface, representing 3% of the total land area. The accumulated peat mass is estimated at 5-6000 Gt (Lappalainen, 1996), which corresponds approximately to 455 Pg of organic C (Gorham, 1991). This amount represents 1/3 of the organic C stocked in soils of the planet (Francez, 2000). According to Payette and Rochefort (2001), 11.5% of the Québec territories are occupied by peatland ecosystems. In the context of the global warming, it is essential to determine the total amount of sequestrated carbon with the highest degree of accuracy (Gorham, 1991; Kettles and Tarnocai, 1999; Francez, 2000; IPCC, 2007). The use of integrated analyses (e.g. loss-on-ignition (LOI), Troels-Smith, plant macrofossils, or radiocarbon (14C) datation) allows to identify the succession of the stratigraphic units forming the peatland sediments. Each of the organic stratigraphic layer possesses a unique relative C content that contributes to the total amount of C stored in peatlands. Previous work have been done to estimate the total amount of C using average values for peat thickness, C content as well as bulk density (e.g. Gorham, 1991; Vitt *et al.*, 2000; Sheng *et al.*, 2004). Because the northern Québec peatlands are located in remote regions, obtaining data to generate a database that is effective to optimize the calculations of C is expensive and time consuming. The use of Ground Penetrating Radar (GPR) represents a good alternative to collect continuous profiles and cost-effective data (Baraniak, 1983; Warner *et al.*, 1990; Hänninen, 1992; Sheng *et al.*, 2004). GPR is a geophysical imaging technique based on the reflection of high frequency electromagnetic pulses (Neal, 2004). The reflections occur at the location of changes in the electrical properties of the soil (dielectric permittivity (ε), electrical conductivity (σ) and magnetic permeability (μ)).

The estimation of the total amount of organic carbon (C) in the peatlands of the Eastmain region is based on the following objectives:
- calculation of the volume of peat in order to determine the C mass;
- identification of the different peat horizons (differential C values);
- correlation of the stratigraphy obtained with GPR with manually collected cores.

Study area

Lac le Caron is an ombrotrophic peatland located near the Eastmain river watershed. The mineral basin underlying the peat mass was formed by sands from deltaic origin, deposited during the withdrawal of the sea. The deepest part of the basin (5,31m) revealed an age of 7580- 7440 cal. BP, using ^{14}C radiocarbon dating method. The total surface area of the peatland is 2.44km^2.

Methods and results

Figure 2. Location of the different transects.

During summer 2008, we worked with a *Pulse EKKO 100* to collect over 6 km of GPR profiles (figure 2). We used a 200 MHz antennas, a 25cm data collection step, a 300 nanoseconds (ns) time window and a 50cm antennas separation. Some of these parameters were determined on a " testing or reference zone", represented by a trench of 10,25m long that was dug where several parameters tests were realized. The trench was also used to identify the main stratigraphic units (peat description at every 25cm), and to correlate them with the GPR data. In the trench, a metal rod was inserted at the contact of the stratigraphic units. A reflection hyperbola appears on the GPR profile at the location of the rod, allowing the identification of the stratigraphic reflector (figure 3). At each end of the trench, a peat core was collected for subsequent analyses (e.g. Troels-Smith description and loss-on-ignition) providing results on peat composition and carbon content (figure. 4 A-B). In the trench, a sample was collected for each main peat unit (4) in order to subsequently determine the approximate relative permittivity (ε_R) by time-domain reflectometry (in a probe or in a cell) (figure 6). Paleoecological reconstruction is also realized from 5 distinct peat cores in the Lac le Caron peatland (figure 2). The results from these reconstructions will be integrated with the interpretation of the GPR data. The choice of the GPR profile locations was determined from those of the coring sites, in order to allow complementary interpretation of the data from the two projects. Using a *DGPS 5800/5700* by *Trimble*, coordinates values (X, Y, Z) of each single GPR data were also collected. These data are used for topographic corrections of the GPR profiles as well as to locate the transects in a geographic information system (GIS).

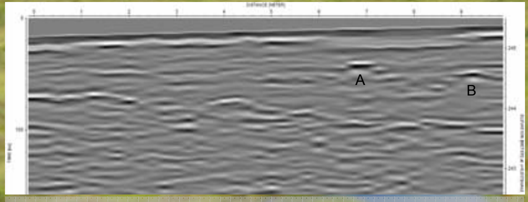

Figure 3. A- A metal rod introduced at 244,76m at the decomposed/roots peat contact; B- A metal rod introduced at 244,68m at the fresh/fibric peat contact.

On a 25m section, the watertable depth was measured with a piezometer tube at each 50cm. The results were plotted on a graph and compared with the GPR data collected on the same section (figure 5). At the core sampling location, a water sample was also collected at every 50cm in the peat sediment, using a piezometer tube. The electrical conductivity (σ) of the water was measured with a *pH meter Orion 250A+ (thermo electron corporation)* (table1).

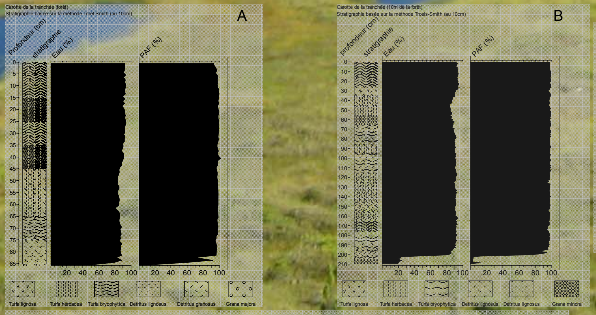

Figure 4.A and B. Stratigraphic and loss-on-ignition data of the peat cores collected at the trench site.

Processing of the GPR data was performed using 2D REFLEXW software. We picked time-zero (move start-time), applied an automatic gain control (AGC gain) of 40 ns length, reduced the lowest frequency content with a substract-mean filter (Dewow), applied FK migration (Stolt) and corrected the topography. The average velocity of the peat was determined by comparing the peat thickness measured with a corer that the thickness measured by GPR (v=0,037 m/ns).

Nom de l'échantillon	Profondeur	pH	Specific σ	Straight σ
LLC-C 50cm	50	4.67	29.3	23
LLC-C 100cm	100	4.75	33.6	25.7
LLC-C 150cm	150	4.37	36.4	27.7
LLC-C 200cm	200	4.26	35.2	26.9
LLC-C 250cm	250	4.37	32.8	25.8
LLC-C 300cm	300	4.55	31.9	25.3
LLC-C 350cm	350	5.27	46.5	37.9
LLC-C 400cm	400	4.54	44.6	36.6
LLC-C 450cm	450	4.72	37.2	30.5
LLC-C 500cm	500	5.26	46.8	39.1
LLC-L1 50cm	50	4.37	40	35.8
LLC-L1 100cm	100	4.25	36.4	32.7
LLC-L1 150cm	150	4.36	35	31.3
LLC-L1 200cm	200	4.32	36.9	32.5
LLC-L1 238cm	238	4.54	41.6	37.1
LLC-L2 50cm	50	4.16	56.4	49.8
*LLC-L2 110cm	110	4.85	36.2	32
LLC-L3 50cm	50	4.75	48.6	42.8
LLC-L3 100cm	100	4.33	37.1	32.8
LLC-L3 150cm	150	4.86	27.6	24.2
*LLC-L3 200cm	200	6.82	86.4	77.2
LLC-L3 250cm	250	5.71	78.5	69.6
LLC-L4 50cm	50	4.67	35.7	31.5
LLC-L4 100cm	100	4.42	35.4	31.2
LLC-L4 150cm	150	4.33	31.1	27.5
LLC-L4 195cm	195	4.66	22.2	19.6
Mare	0	4.09	38.4	31.5

Table 1. Electrical conductivity and pH results.

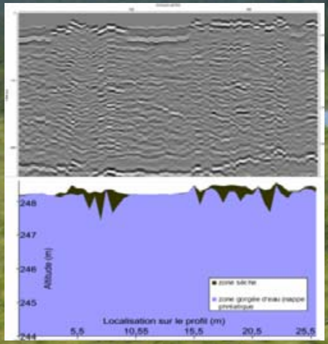

Figure 5. Water table depth; A- GPR data, B- manual measurements.

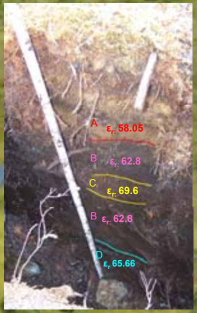

Figure 6.The permittivity results.

Future work

- Common-middle point (CMP) analyses (to determine the velocity) ;
- Correlation of the stratigraphic reconstructions provided from all sources of data;
- Interpretation of the GPR profiles, linked with other data sources;
- Creation of a database to include in a GIS;
- Interpolation of the data in order to cover the entire peatland surface;
- Estimation of the organic carbon contained in the Lac le Caron peatland.

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References

- Baraniak, David W. , and Donohue & Associates. 1983. «Exploration for surface peat deposits using ground penetrating radar». In (C.H. Fuchsman and S.A. Spigarelli eds) *Symposium on peat utilization* (October 10-13 1983).
- Cubasch, U., G. A. Meehl, G. J. Boer, R. J. Stouffer and M. Dix. 2001. «Projections of future climate change ». In Climate Change 2001: The Scientific Basis., J. T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P. J. Van der Linden, X. Dai, K. Maskell and C. A. Johnson (Eds.). Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, p.526-582.
- Francez, André-Jean 2000. «La dynamique du carbone dans les tourbières à Sphagnum, de la sphaigne à l'effet de serre». *Année Biologique*. vol. 39, p. 205-270.
- Gorham, Eville 1991. «Northern peatlands:role in the carbon cycle and probable responses to climatic warning». *Ecological Applications*. vol. 2, p. 182-195.
- Hänninen, Pauli. 1992. «Application of ground penetrating radar and radio wave moisture probe techniques to peatland investigation». *Geological survey of Finland*. Bulletin 361, p. 1- 71.
- Kettles, Inez M., et Charles Tarnocai. 1999. «Development of a model for estimating the sensitivity of canadian peatlands to climate warming». *Géographie physique et Quaternaire*. vol. 53, no.3, p. 323-338.
- Lappalainen, E. 1996. «General review on world peatland and peat resources». In: E. Lappalainen (Eds) Global peat ressources, UNESCO, International Peat Society, Geological Survey of Finland, p. 53- 56.
- Neal, Adrian. 2004. «Ground-penetrating radar and its use in sedimentology: principles, problems and progress». *Earth-Sciences Reviews*, no 66, p. 261-330.
- Payette, Serge, and Line Rochefort (Eds). 2001. *Écologie des tourbières du Québec-Labrador*. Saint-Nicolas: Les Presses de l'Université Laval, 644 p.
- Sheng, Yongwei, Laurence C. Smith, Glen M. MacDonald, Konstantine V. Kremenetski, Karen E. Frey, Andrei A. Velichko, Mary Lee, David W. Beilman et Peter Dubinin. 2004. «A high-resolution GIS-based inventory of the Siberian peat carbon pool». *Global Biogeochemical Cycles*. vol. 18, p. 1-14.
- Vitt, Dale H., Linda A. Halsey, Ilka E. Bauer et Celina Campbell. 2000. «Spatial and temporal trends in carbon storage of peatlands of continental western Canada through the Holocene». *Canadian Journal of Earth Science*. vol. 37, p. 683-693.
- Warner, Barry G. , David C. Nobes et Brian D. Theimer. 1990. «An application of ground penetrating radar to peat stratigraphy of Ellice Swamp, southwestern Ontario». *Canadian Journal of Earth Science*. vol. 27, p. 932-938.

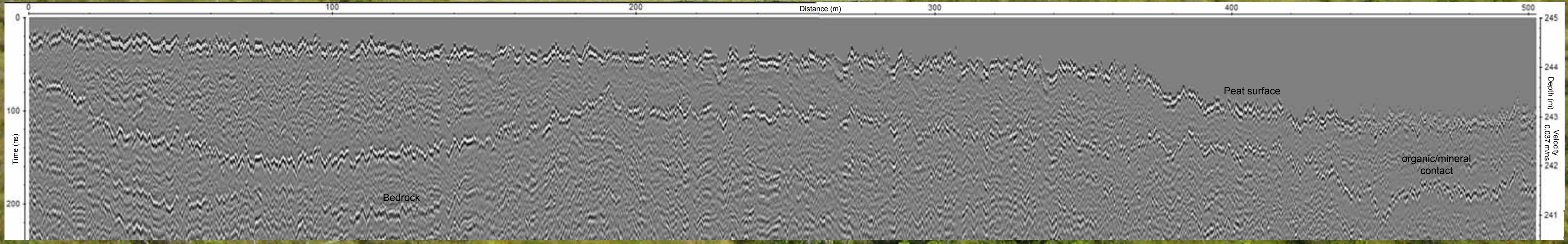

Figure 1. This figure shows a 500 m profile, transect # 6 (see figure 2). The organic/mineral contact is identified over the entire profile. Unconsolidated sediments over the bedrock can be locally observed as well as the stratigraphic reflectors in the peat accumulated.