Molecular characterization of soil organic matter along a soil chronosequence in Midtre Lovénbreen foreland in Svalbard

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Abstract

Glacier forelands give an opportunity to study the successional processes in the terrestrial ecosystem along the chronosequence at a time, since the ice covers of glacier have receded over the past century. The newly exposed soil gives chances for plants and microorganisms to be established, and these organisms contribute to build up the soil organic matter (SOM) pool in this region. To investigate molecular compositions of SOM along a soil chronosequence, we took the surface soil samples at 0–5 cm depth in the glacier foreland of Midtre Lovénbreen, Svalbard in 2014. Seven sampling sites inside the moraine represented soil ages as 3, 8, 36, 57, 65, 70, and 77 years (sites 1 – 7, respectively). Two sites outside the moraine (sites 8, 9) were also selected as a reference. Before soil sampling, vegetation composition and coverage were surveyed. Since SOM is a mixture of materials showing various turnover time, and the content of SOM was very low in the glacier foreland, density-size based SOM fractionation was used. Firstly, sodium polytungstate solution (1.55 g cm^{-3}) was used to separate soil into the free light fraction (FLF) which floats on the solution and the heavy fraction (HF) which sinks. Secondly, the HF was further separated as the sand-size fraction and silt and clay-size fraction based on size. Molecular composition of FLF which mostly consisting of recently added organic matter was analyzed by pyrolysis-Gas Chromatography/Mass Spectrometry (py-GC/MS) and TMAH(tetramethyl-ammonium hydroxide)-py-GC/MS at two pyrolysis temperatures (350 and 600 °C). The sand-sized and silt and clay sized fractions were treated with hydrofluoric acid to increase carbon concentration by removing mineral particles and analyzed by py-GC/MS at two temperatures (350 and 600 °C). We are currently analyzing molecular characteristics of SOM from these samples. The results of this study could provide better understanding of molecular composition of SOM, successional processes, and the relationships between SOM composition and vegetation in a newly exposed glacier foreland.

Introduction

- It is predicted that the Arctic region will experience the most severe and rapid effects of global warming. Analysis of temperature series (1912-2010) on Svalbard has shown positive linear trends for annual values as well as spring, summer, and autumn series.
- Global warming has resulted in rapid melting of ice and glacier retreats, and the Svalbard glaciers are following the same pattern. The newly exposed glacier forefield gives chances for plants and microorganisms to be established and these organisms would contribute to build up new SOM pool in this region.
- Since SOM acts as the major sink and source of soil carbon, it is important to investigate its structure and function to understand the carbon cycle in the terrestrial ecosystem.
- Glacier forefields present us a good chance to study processes of SOM formation. The purpose of this study is to investigate molecular compositions of SOM along a soil chronosequence.

Study area

Fig. 1. Glacier foreland of Midtre Lovénbreen, Brøgger Peninsula, Svalbard (79°N, 12°W).

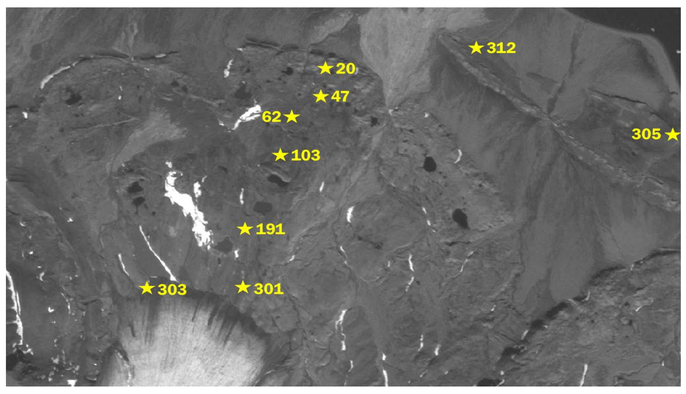

Fig. 2. Sampling location along the transect in Midtre Lovénbreen (7 sites inside moraine, and 2 sites outside moraine). Surface soil samples (0-5 cm depth) were taken from each site.

Methods

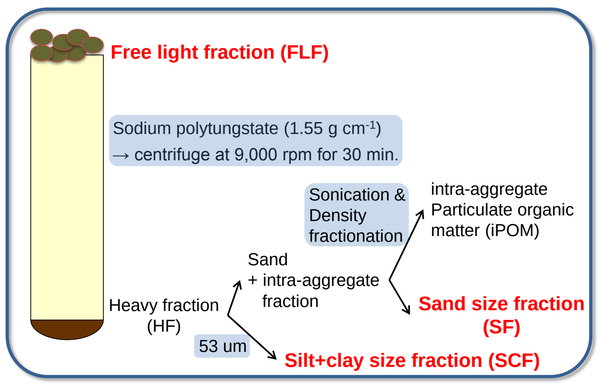

Fig. 3. SOM fractionation. Each fraction (red color) is used for analyzing multi-shot py-GC/MS. Some FLF samples is methylated using TMAH, and then analyzed.

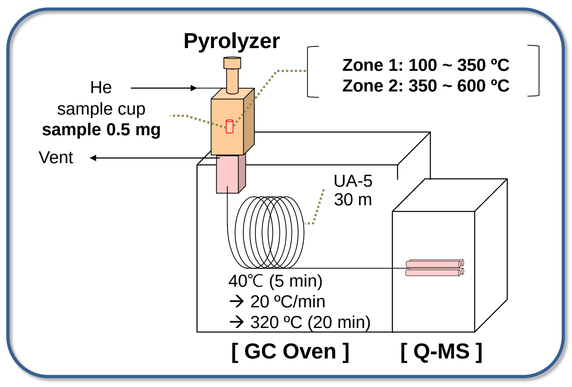

Fig. 4. Multi-shot pyrolysis GC/MS. First shot temperature is 350 ºC, and second is 600 ºC.

Derivatization

For improving detection of lignin, cutin, and suberin derived compounds, FLF samples were methylated using TMAH. Injected 10 uL TMAH (25% aqueous solution) to around 5 mg samples of 8 sites, and were incubated for 24 hours. We could not analyze sample of Site 1 (ML303) due to low yields of FLF.

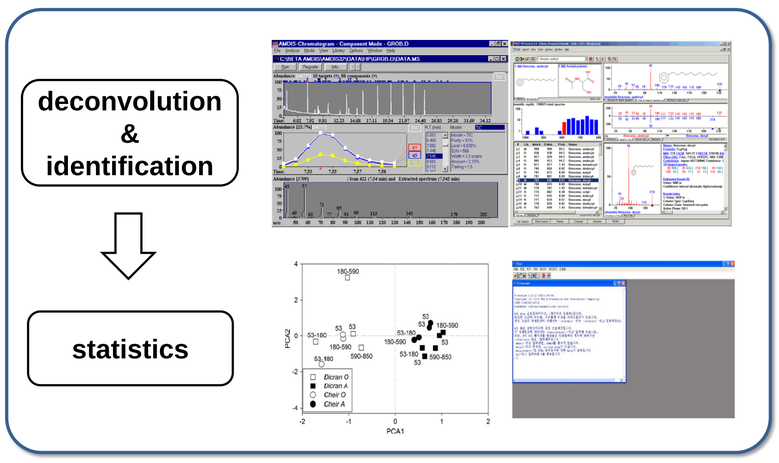

Fig. 5. Scheme of data analysis. 1) deconvolution and identification of peaks using AMDIS and NIST library, and 2) multivariative analysis principal component analysis (PCA) using R statistics.

Results

Table 1. Site description and Soil organic carbon contents of 9 sampling sites

	site number	sampling site	retreat year	age	SOC (%) total	FLF	iPOM	SF	SCF
inside moraine	Site 1	ML303	2011	3	0.1	36.0		0.1	0.2
	Site 2	ML301	2006	8	0.3	17.4	33.3	0.1	0.3
	Site 3	ML191	1978	36	0.2	29.3	32.9	0.1	0.2
	Site 4	ML103	1957	57	1.1	28.1	37.1	*0.3*	0.7
	Site 5	ML62	1949	65	0.1	31.3	13.0	*0.1*	0.7
	Site 6	ML47	1944	70	1.0	26.5	32.5	*0.6*	1.1
	Site 7	ML20	1937	77	0.6	31.0	37.6	0.3	1.3
outside moraine	Site 8	ML305			3.0	32.6	37.5	0.9	2.8
	Site 9	ML312			7.0	28.9	38.3	3.7	5.1

❖ comparison with molecular characteristics of each fraction and site

- The sites which are closest to the glacier terminus, few compounds were detected from py-GC/MS analysis. The soil organic carbon content of these sites were also very low. This could suggest that SOM had very labile SOM which could have converted into CO_2 under 350 ºC.
- From the py-GC/MS analysis on 27 samples (3 fractions from 9 sites), 73 compounds were detected in zone 1 (100 - 350 ºC), and 85 compounds in zone 2 (350 - 600 ºC).

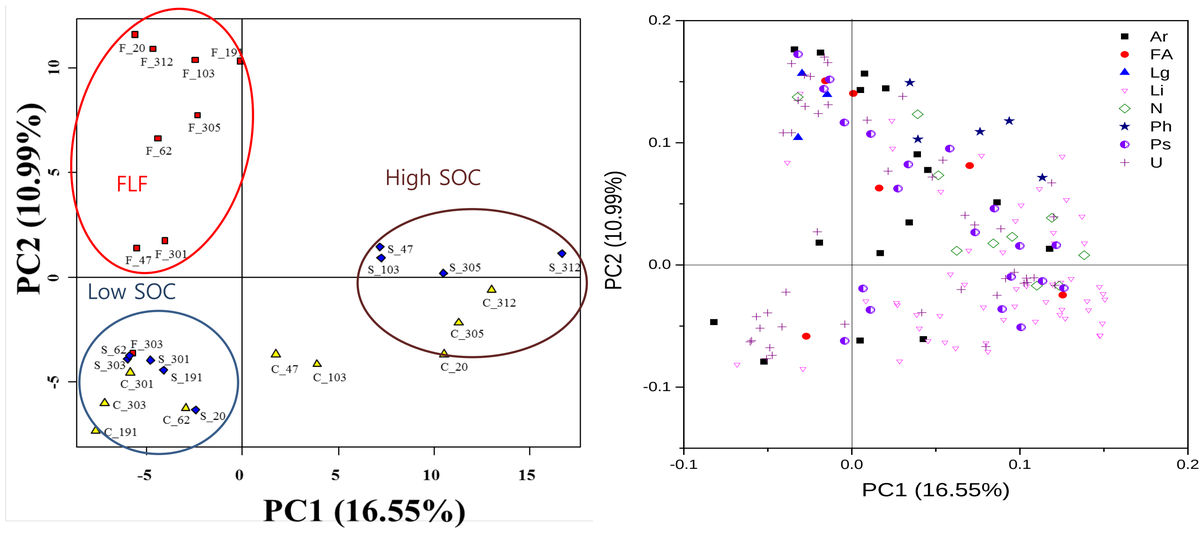

Fig. 6. Results of PCA using molecular characteristics of 27 samples from py-GC/MS analysis. a) score plot, b) loading plot.

- **Divided into 3 group; FLF, SF & SCF from sites with a low SOC content, SF & SCF from sites with a high SOC content**
- **Lignin and some aromatic compounds showed a relatively higher proportion in FLF. These substances were considered to be derived from plants.**
- **A proportion of hydrocarbon was high in SF & SCF from sites with high SOC content, and unknown compounds in those with low SOC.**
- **We could not see any clear trend of molecular characteristics of SOM along the chronosequence in this region.**

❖ py-GC/MS and TMAH-py-GC/MS analysis of FLF

- After methylation, more substances were detected from both zone 1 and 2. Many methylated substances were detected in zone 1, but there was a minor difference in pyrolysis products between from py-GC/MS and from TMAH-py-GC/MS in zone2.

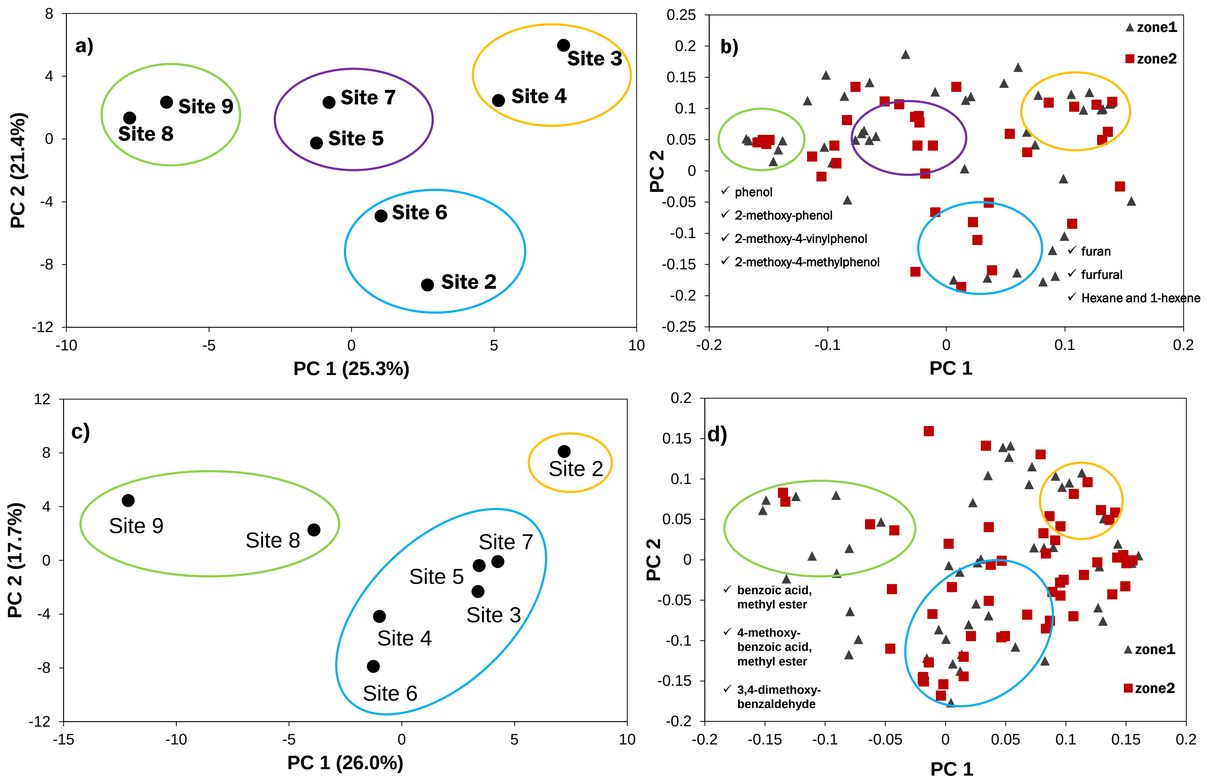

Fig. 7. Results of PCA using molecular characteristics of FLF from py-GC/MS analysis. a) a score plot and b) a loading plot. Results of PCA using molecular characteristics of FLF structure from TMAH py-GC/MS analysis. c) a score plot and d) a loading plot.

- **There was relatively a high proportion of lignin derived compounds from the two sites outside moraine in both analyses.**
- **In Site 2, which was the closest to the glacier, the structure of FLF was similar to site 6 in py-GC/MS analysis. There was relatively a high proportion of small sized compounds such as furan, furfural, and hexane. In TMAH-py-GC/MS analysis, Site 2 showed different SOM structure compared to other sites inside moraine.**

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