B-4.1.2 Methane Emission Rate from Permafrost Area

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Abstract

The permafrost in Siberia contains much more ice than that in Alaska and Canada. The methane contained was formed in past after the last glacial period by microbiological process and enclosed in permafrost so called ice complex as bubbles. It is now thawing gradually and the methane contained in it is released to the atmosphere directly. From the methane contained, the thawing rate and the length of cliff where the ice complex is exposed directly to the atmosphere, the release rate of methane is estimated to be 2 - 10 Tg yr^{-1}.

The methane emission from tundra area, Tiksi at the mouth of Lena River, observed was dependent on both the soil temperature and the thawing depth of permafrost. The maximum of emission observed was 80 mg m^{-2} day^{-1}, and it is very dependent on the atmospheric temperature. Thus the global warming in future is expected to enhance the methane emission and cause a positive feedback.

The methane emission from lakes above permafrost, so called alas, have been measured near Yakutsk. The emission from the rim of the lake occupies the main part and was 140 mg m-2 day-1 for a large lake, about 500m in diameter to 160 mg m-2 day-1 for a small lake, about 100m in diameter.

The vertical profiles of dissolved methane in wetland have been obtained to understand the formation process of methane. The fermentation experiments suggest the importance of precursor formation process.

Key Wards Methane, Methane Flux, Natural Wetland, Siberia

1.Introduction

Permafrost and the vegetation above are fragile and the positive feedback through the enhanced methane emission is expected. There are several feedback scenarios, (1) how the permafrost melts and the methane contained in it is released to the atmosphere, (2) how the lakes are formed by distortion to the ice rich permafrost and the methane is emitted, (3) how the methane emission is enhanced in Tundra area in warmer climate, and (4) the microbiological process including the formation of precursor, CH_3COO^- and H_2?

2. Estimation of methane release from the thawing ice complex

Ice complex, or edoma, is peculiar to the permafrost in Siberia. Ice complex is composed of ice wedge in many cases. It was formed after the last glacial period; water is collected when the water rich soil is frozen, and this ice grows by the process to form a vertical crack when the ice rich soil is cooled more in winter, followed by the fulfillment by water on surface in spring. Thus formed ice wedge contains a lot of methane as methane formed by microbiological process is contained in the surface water. The percentage of bubbles in ice is sometimes 10% of volume, and the maximum percentage of methane was found to be 0.1% (See Fig.1). The origin of methane is biogenic as $\delta^{13}C$ is -70‰. The ice-complex now is not stable and the thawing rate is about 4 to 6 m yr^{-1} at the cliff of Arctic Ocean. The thawing permafrost at a cliff is released directly without passing through a melted soil, an active layer, where the large part of methane is oxidized.

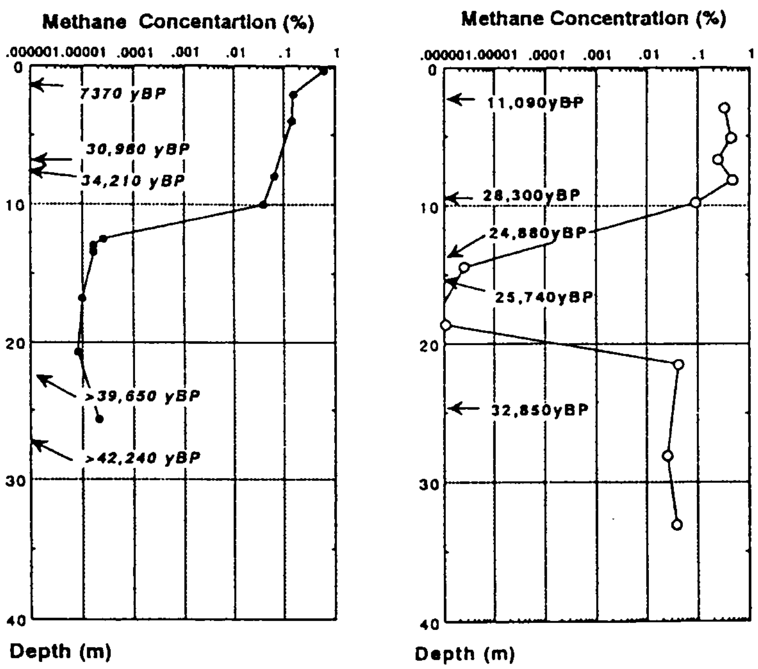


Fig.1. Methane concentration in ice wedge sampled at Bykovsky Peninsula and Lyakhovsky Island. The dating is by ^{14}C analysis of organic particles in ice.

In this study, the total methane release from the ice complex in Siberia was estimated from the following values:

(1) Methane contained in ice complex bubble; both in ice wedge and sediment
Volume percentage is between 1 and 3 %

(2) Percentage of bubble volume
10% in volume

(3) Thickness of ice complex which contains bubbles
Between 10 to 20m

(4) The thawing rate of bare cliff

Between 4 to 6 m yr^{-1}

(5) The length of bare cliff along the sea sore and river

Between 3000 to 8000km in Siberia

Then the total release of methane is estimated to be between 2 to 4 Tg yr^{-1}.

(This section is by Dr.Fukuda, Hokkaido Univ.)

3. Methane emission from Tundra wetland

Methane emission has been measured at Mustakh Island near Tiksi at the mouth of Lena River. This is a flat island of the size of 7 km x 0.5 km with thick permafrost. The water level is near the surface and peat and *Carex* are the main vegetation. The methane emission rate

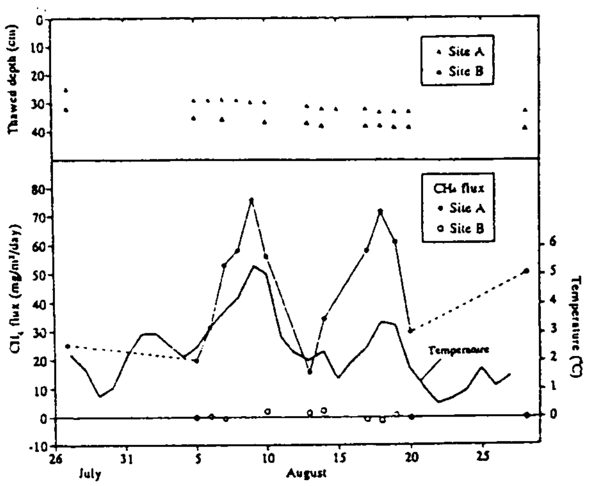


Fig.2. Methane emission rate(●) and averaged soil temperature(solid line) and the thawing depth(▲).

is shown in Fig.2 together with daily averaged surface soil temperature (lower figures) and the thawing depth (upper figure). It is clearly observed that the methane emission is large when the soil temperature is high, but the emission rate is almost the same between August 9 and 18 although the soil temperature on 18 is lower by 2 degrees. The air temperature is decreasing after the peak at the middle of August but the thawing depth is getting deeper until the end of August. There are two possible reasons to explain the reason why the methane emission is not parallel to the soil temperature; one is the thickness of active layer contributes to the total surface flux, and the other is it takes time for the process to convert the biomass to the precursor of methane synthesis, CH_3COO^- and H_2. The chemical analysis of dissolved organic compounds and hydrogen to distinguish between these hypothesis. The relation between the methane flux and the integrated temperature in ℃ above 0 degree shows a good linear relationship, R^2=0.7 (Fig.3).

(This section is by Dr.Nakano, Tokyo Metropolitan Univ.)

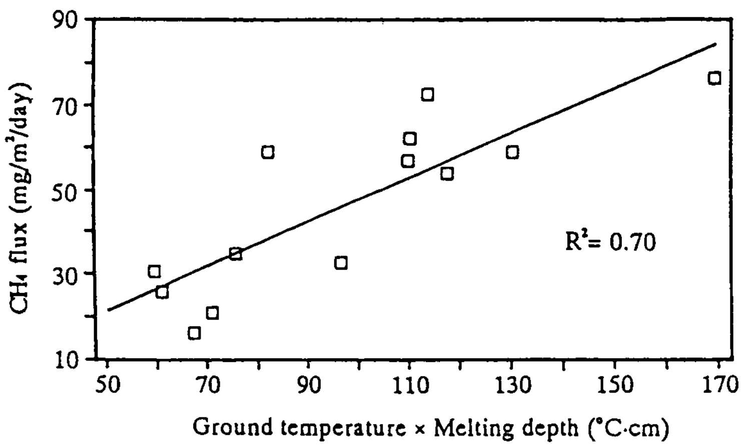


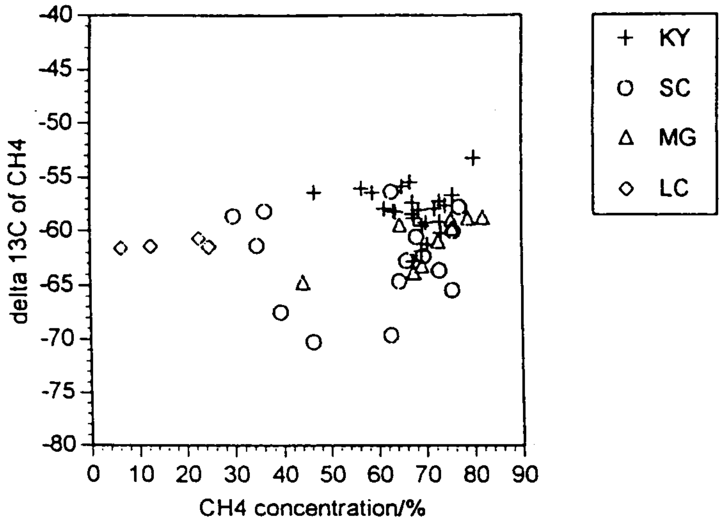
Fig.3. Relation between methane flux and the integrated temperature above 0 degree.

4. Methane emission from Alas

In East Siberia, there are a lot of shallow lakes called Alas. They are formed by the thaw of ice rich permafrost by some distortion such as forest fire and timber harvest. The methane emission from these lakes have been measured by chamber method along a transect from the lake to the glass land. The methane flux form the lake water surface obtained by a floating chamber was in the range between 83 and 830 mg CH_4 m-2 day-1. The values from the rim wet area were in the range between 108 and 518 mg CH_4 m-2 day-1, and those from dry grassland between 10 and 109 mg CH_4 m-2 day-1. The integrated value from the geographic data was 161 mg CH_4 m-2 day-1 for a mall lakes less than 100 m in diameter, and 138 mg CH_4 m-2 day-1 for a large lakes about 500m in diameter, typically. The reason of larger averaged flux from small lakes is due to the relatively large wetland area compared with the area of water surface, the emission form former is much larger than the latter. The relation with acidity of water was not clearly observed.

The stable carbon isotopes of methane in gas babbles sampled by string the sediment of lakes has been measured by GC/ isotope MS. The samples from a deep lakes, more than 1 m in depth) contains 66% of methane in the bubble, and the rest was nitrogen gas mainly. The methane concentration from shallow lakes were very different between 20 and 80%, and the oxygen concentration was about 3%. The percentage of carbondioxide was around 2-10%, and it does not depend on the sampling points and lakes.

The stable isotope ratio in bubble was -61‰ on average, between -53 to -71‰, and it is independent on the methane concentration. In contrast the stable carbon isotope in carbondioxide has a very clear dependence on the methane concentration. (See Fig.4) The isotope ratio in high methane concentration sample, more than 70%, was as high as -3‰. The zero crossing extrapolating to methane zero value is between -17 and -19‰, which is larger than the isotope ratio of present biomass. Similar methane concentration dependence is observed in the sample of Kushiro Wetland, Hokkaido in Japan, but the zero crossing value is -2.5, which is close to the present biomass. This heavy methane may be ascribed to the process of H_2 + CO_2, where the isotope ratio of CO_2 is different from the original organic compounds.



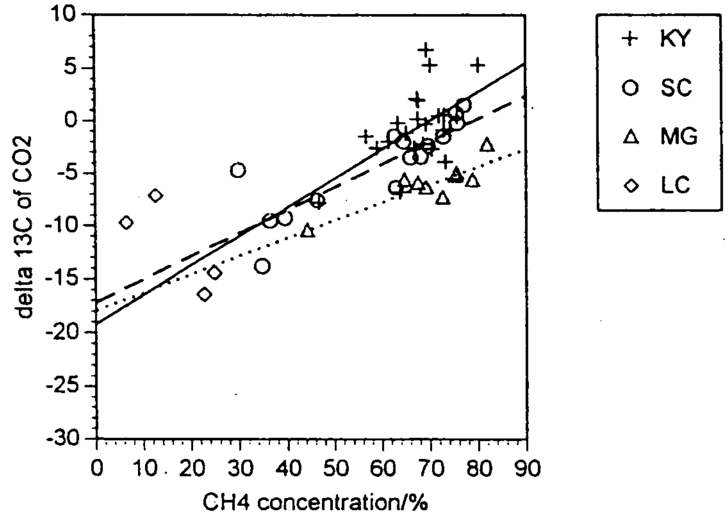


Fig.4. Stable isotope ratio in CH_4 and CO_2 v.s. CH_4 concentration in the bubble sample from Alas near Yakutsk, East Siberia.

5. Conclusion

The global methane emission from thawing ice-complex at the cliff facing to Arctic Ocean in Siberia has been evaluated to be 2-10 Tg yr^{-1}.

The methane emission from arctic tundra is dependent on both the soil temperature and the thawing depth, or the history of soil temperature. Full season measurement including the spring spike emission which has been accumulated after the surface is frozen is necessary to evaluate the global emission.

The emission from the permafrost thawing lakes, Alas, has been measured and the global estimation is now possible from the satellite image data.

These processes are enhanced by the global warming and the basic data to evaluate the methane emission in warmer climate have been obtained. Positive feedback is expected.