G.N. Kraev

METHANE IN PERMAFROST OF EASTERN ARCTIC

Institute of Physicochemical and Biological Problems in Soil Science, Russian Academy of Sciences

Facts

- IPCC summary for Policymakers: “relative contributions from different source types are not well determined”
- Permafrost response to climate changes is non-uniform, inertial and understudied

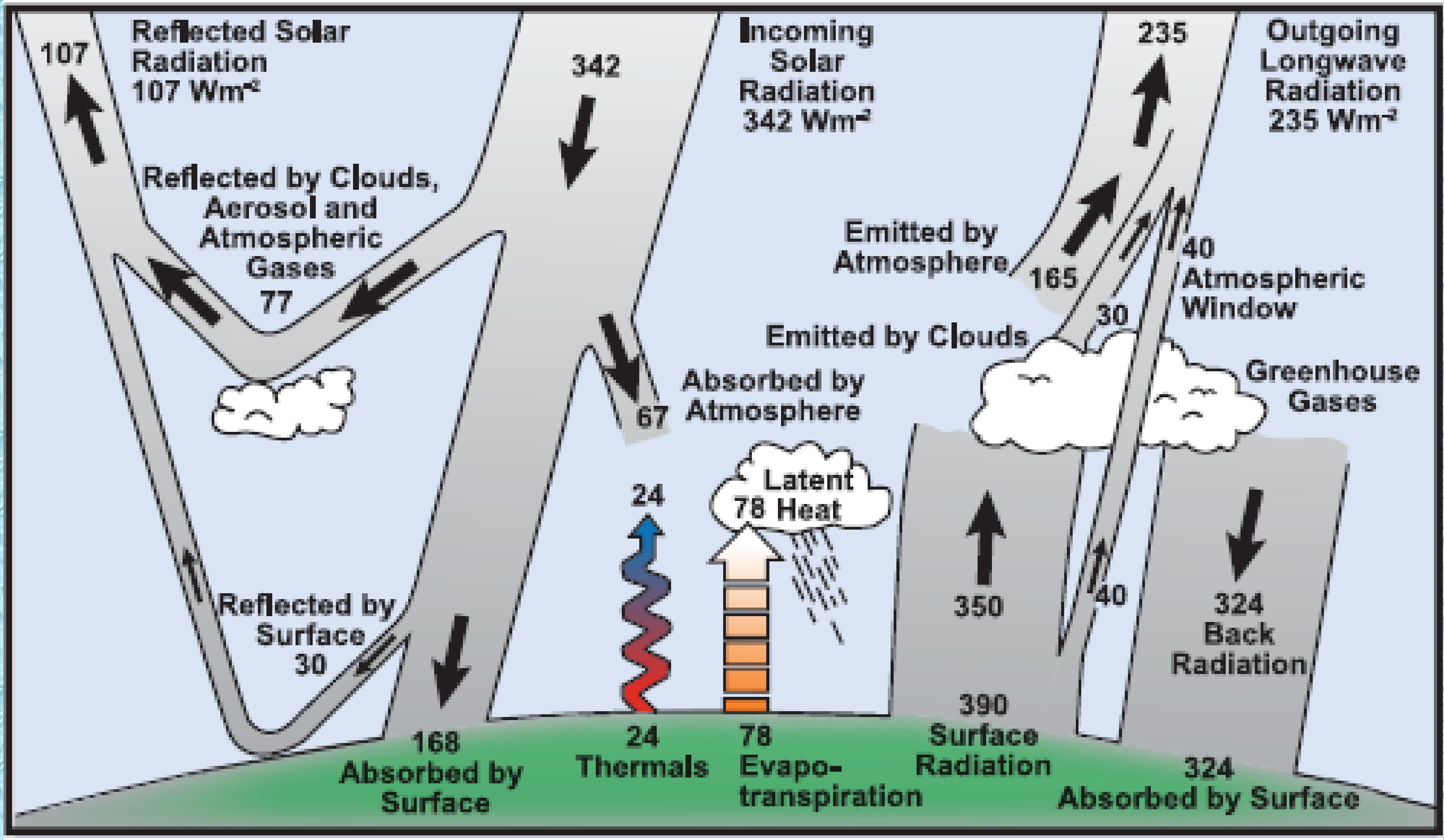
Hypotheses

Disastrous emission of greenhouse gases in case of shallow permafrost degradation by 2100 [Lawrence, Slater 2005], and other models

Permafrost accumulating greenhouse gases when climate cools, and releasing them when degraded at climate warmings [Zimov et al., 2006]

Earth’s annual and global energy balance

(Kiehl & Tremberth, 1997)



The Arctic source of methane

Wetlands are natural sources of methane having the annual efflux to the atmosphere from 28 (Chen, Prinn, 2006) to 43% (Mikaloff Fletcher et al., 2004)

High latitude wetlands provide up to 30% of total wetland flux (IPCC, 2007)

We, methanogenes, produce methane by

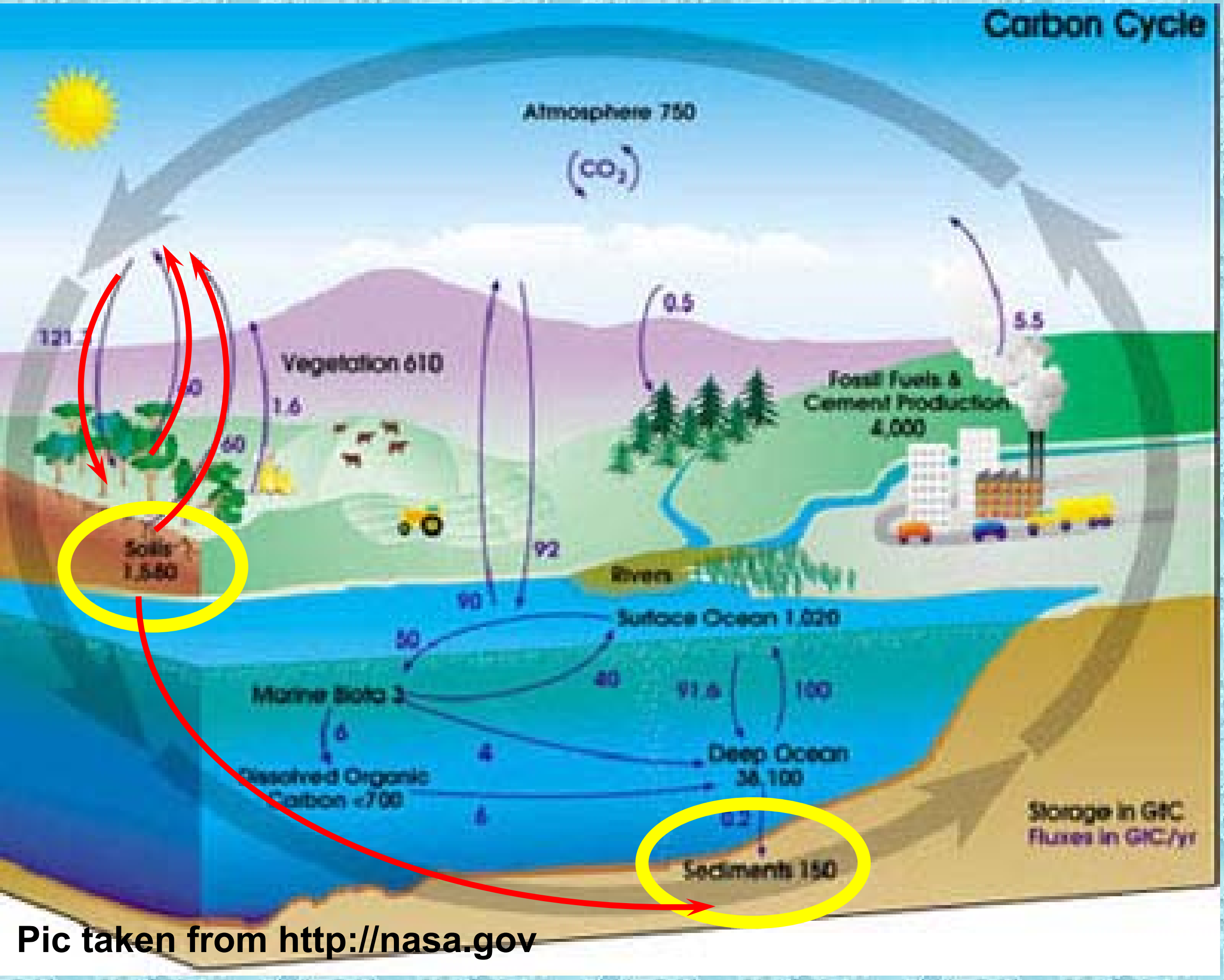
$CO_2+H_2O \rightarrow CH_4$ (carbon dioxide reduction)

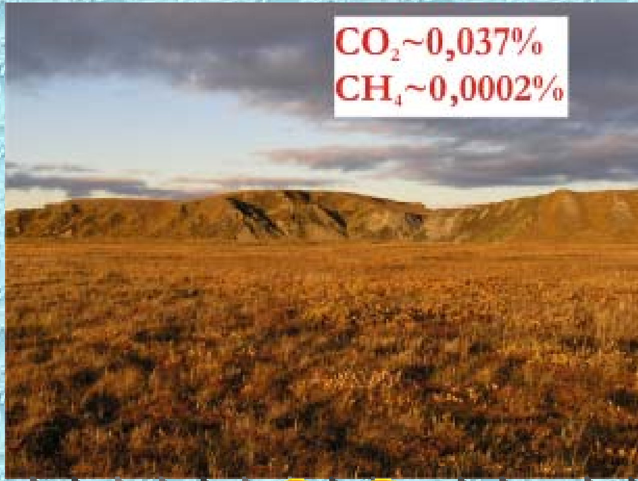
$CH3COO^- \rightarrow CH_4+CO_2$ (acetate fermentation)

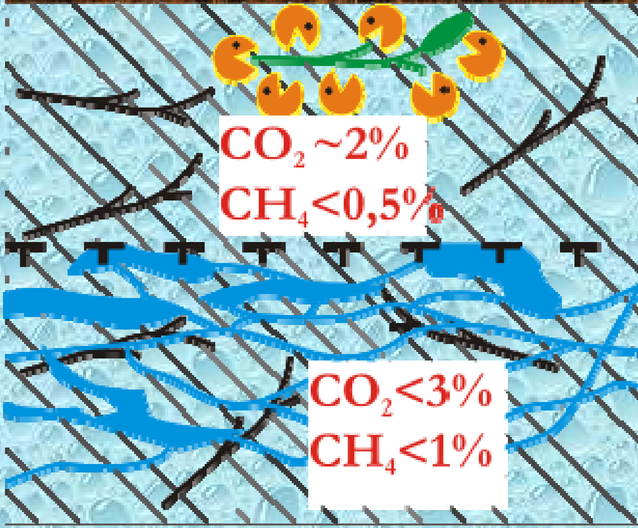
in anoxic environments with low redox potential lower than -0,2 V

We like waterlogged soils on permafrost and are adopted well to cold

Gas trapping by permafrost







We suppose the accumulation pattern of gases is homogenous within a landscape under similar environment and burial conditions

Purpose

Adequate assessment of CO_2 and CH_4 currently buried in permafrost, that could be easily involved in Carbon cycle if permafrost degrade

Use of methane as a source of paleoinformation especially in regions where long records of methane trapped in ice unavailable.

Tasks

- To understand CH_4 patterns in permafrost
- To assess the volumes of embedding deposits

Site Description

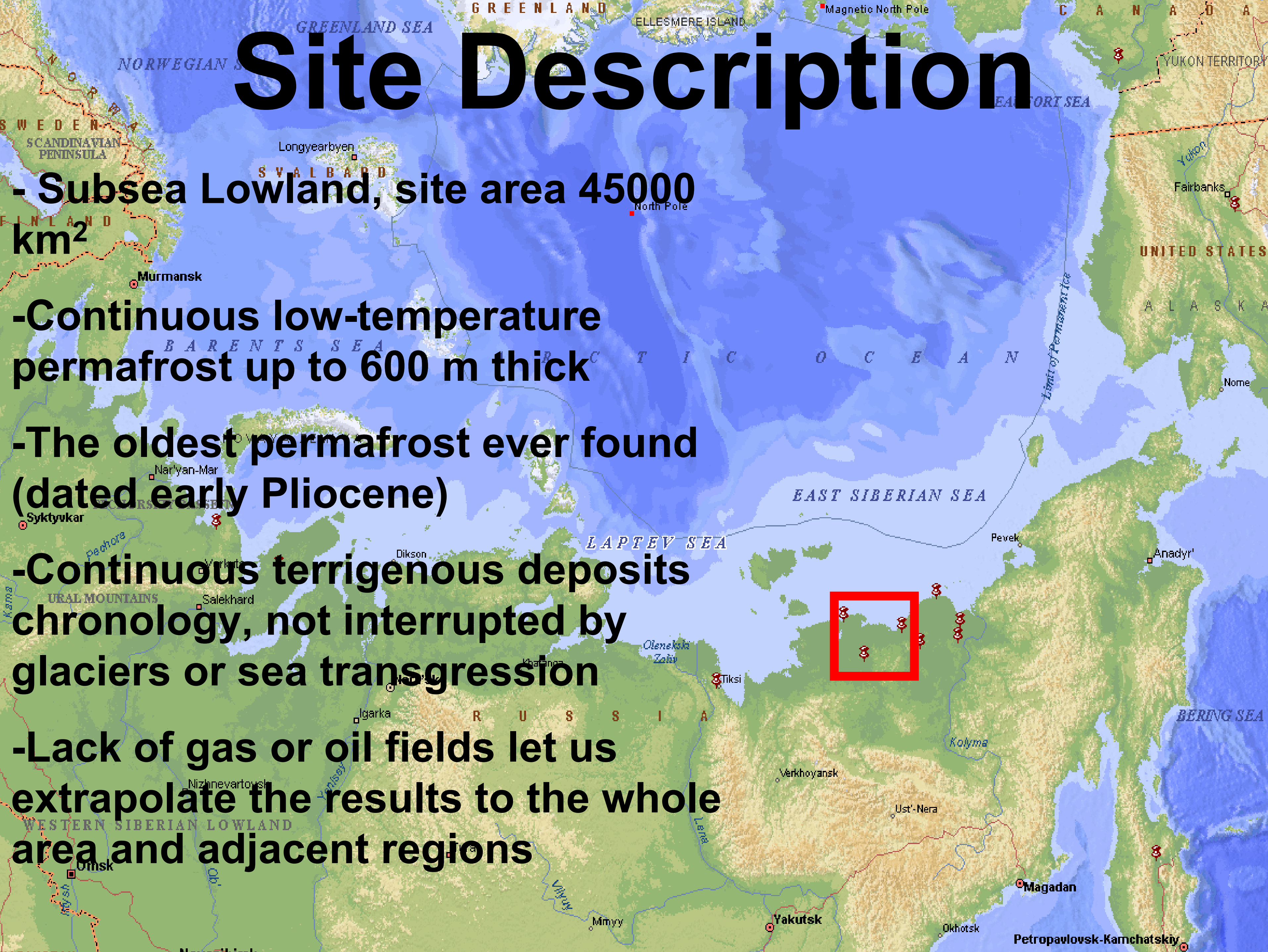
- Subsea Lowland, site area 45000 km^2

- Continuous low-temperature permafrost up to 600 m thick

- The oldest permafrost ever found (dated early Pliocene)

- Continuous terrigenous deposits chronology, not interrupted by glaciers or sea transgression

- Lack of gas or oil fields let us extrapolate the results to the whole area and adjacent regions

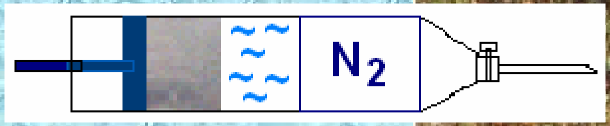


Methods

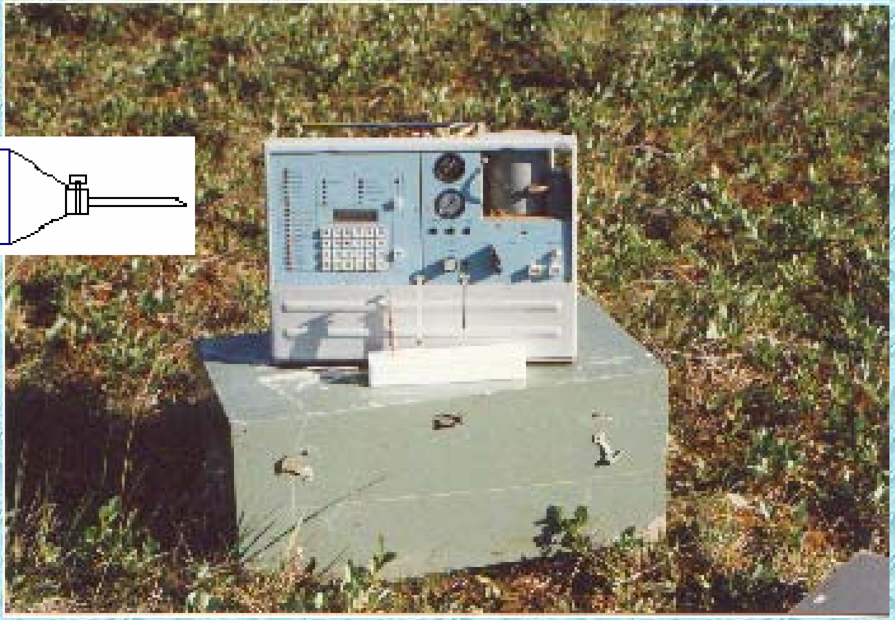
Sampling permafrost cores and outcrops

(~200 samples from 4 key sites, 15 boreholes)

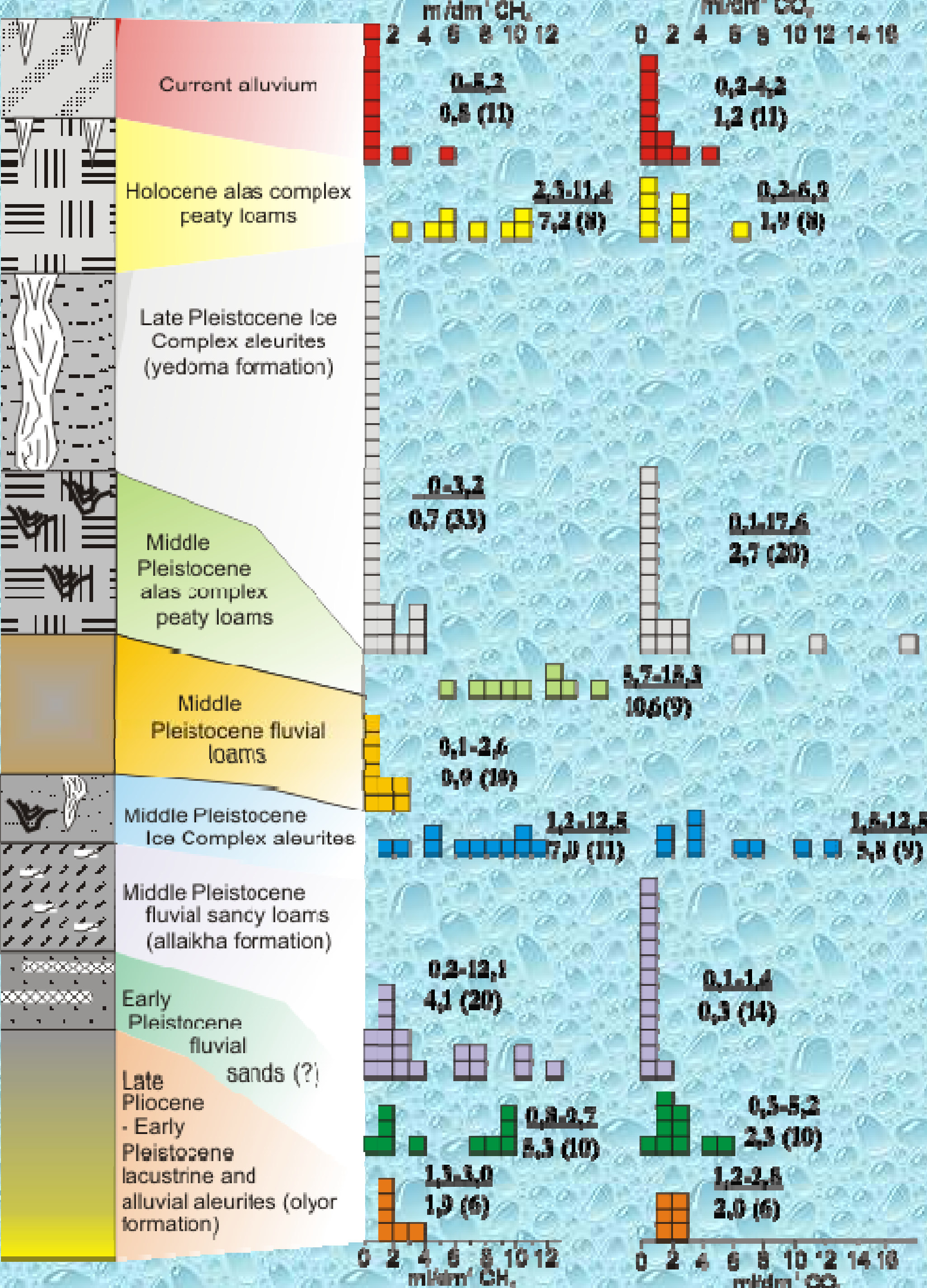
Degassing 50 g samples in NaCl solution, headspace filled with N_2 until melt and destructed.



Gas chromatography KhPM-4 (Khromatograf, Russia) Porapack-Q, 25C, catarometer for CO_2; 50C, flame ionizing detector for CH_4



Distribution of CH4 (left) and CO2 (right) through the section

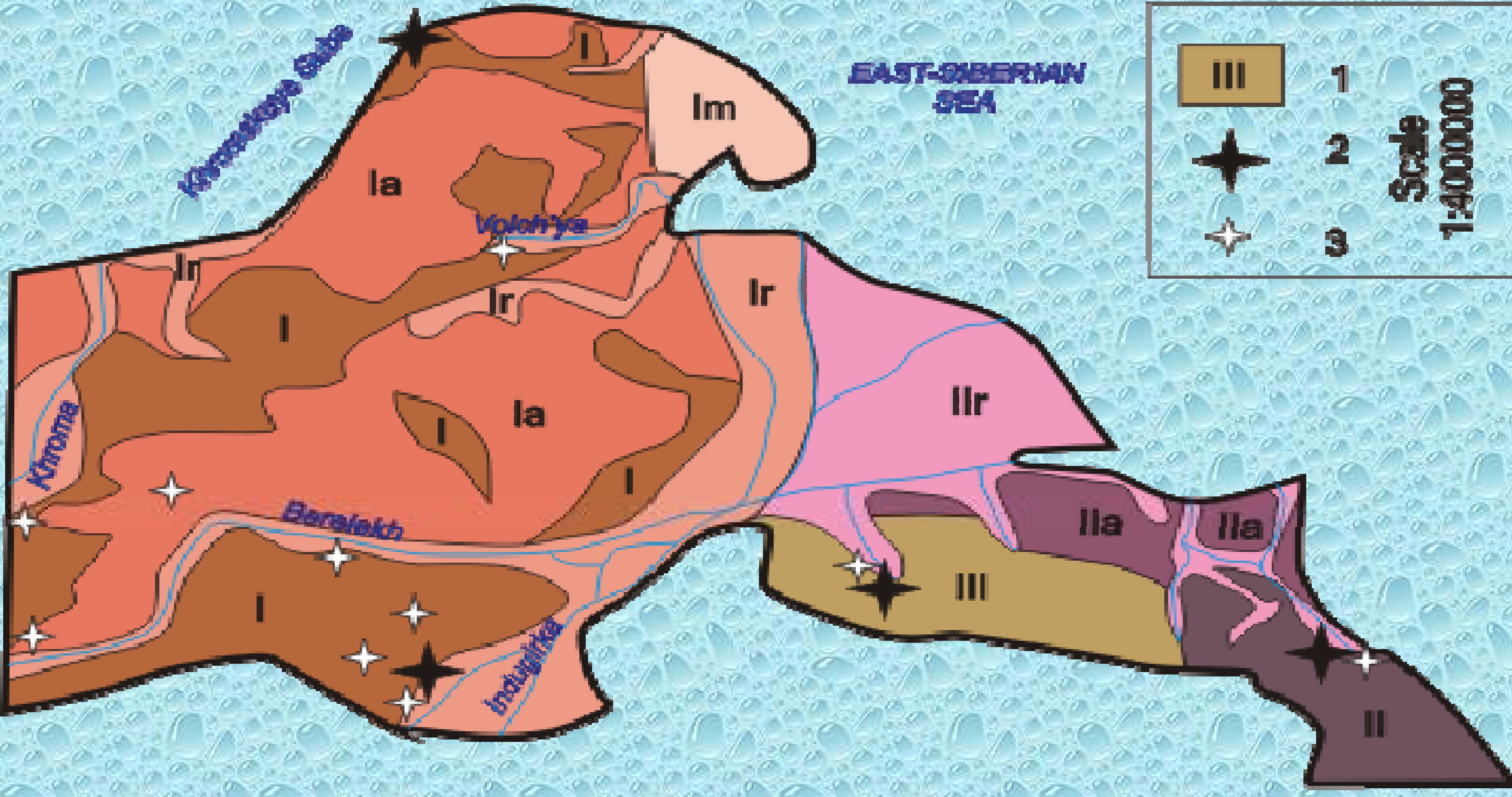


Lack of CO_2 and CH_4 in fluvial deposits of Glacial Stages

Main storages of CO_2 and CH_4 concentrated in Alas complex peaty deposits of Interstadials

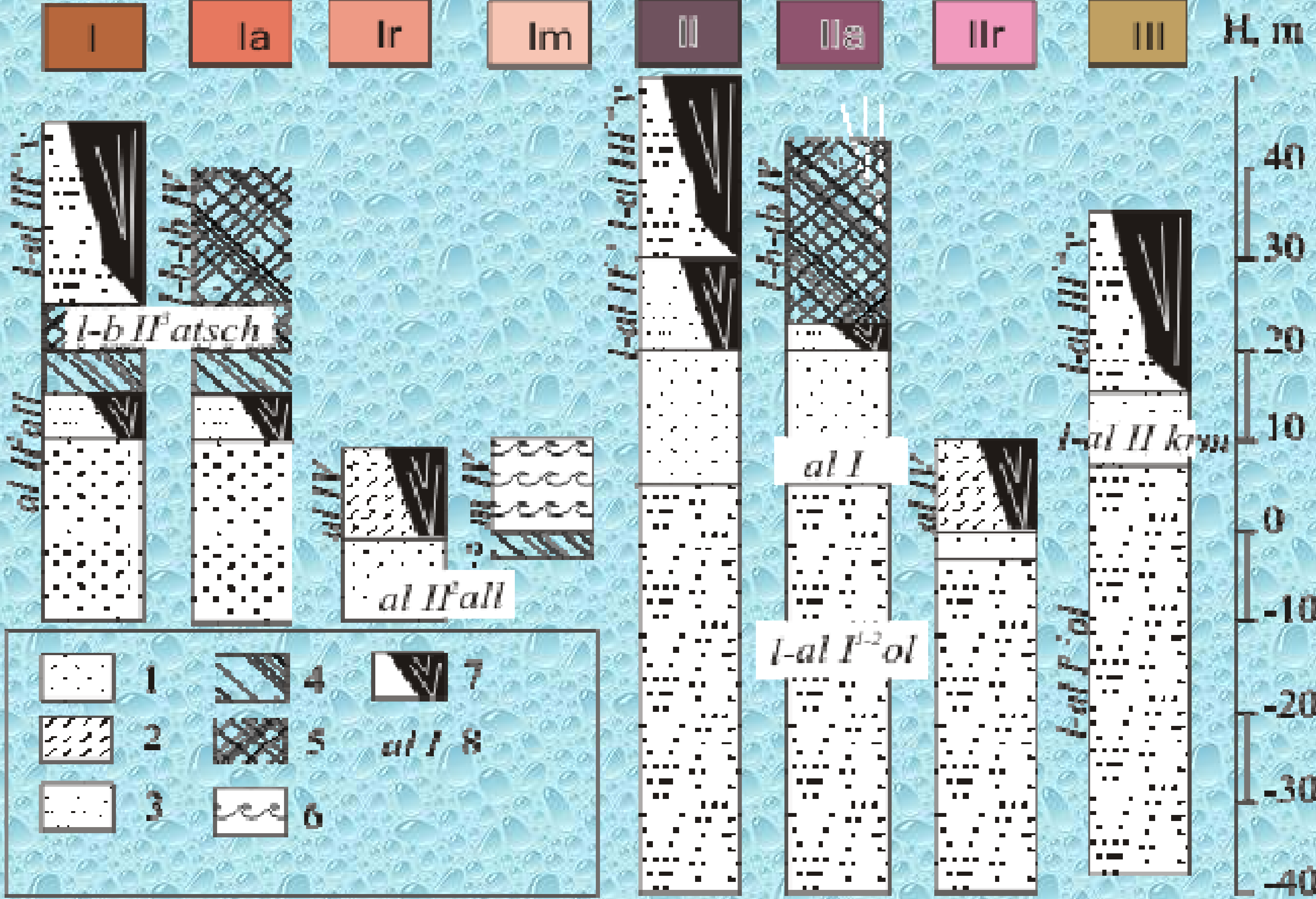
Mean concentration of greenhouse gases in permafrost is 0,1 g/m^3 C-CH_4, and 0,03 g/m^3 C-CO_2

Quaternary Stratigraphy in Lower Indigirka Region



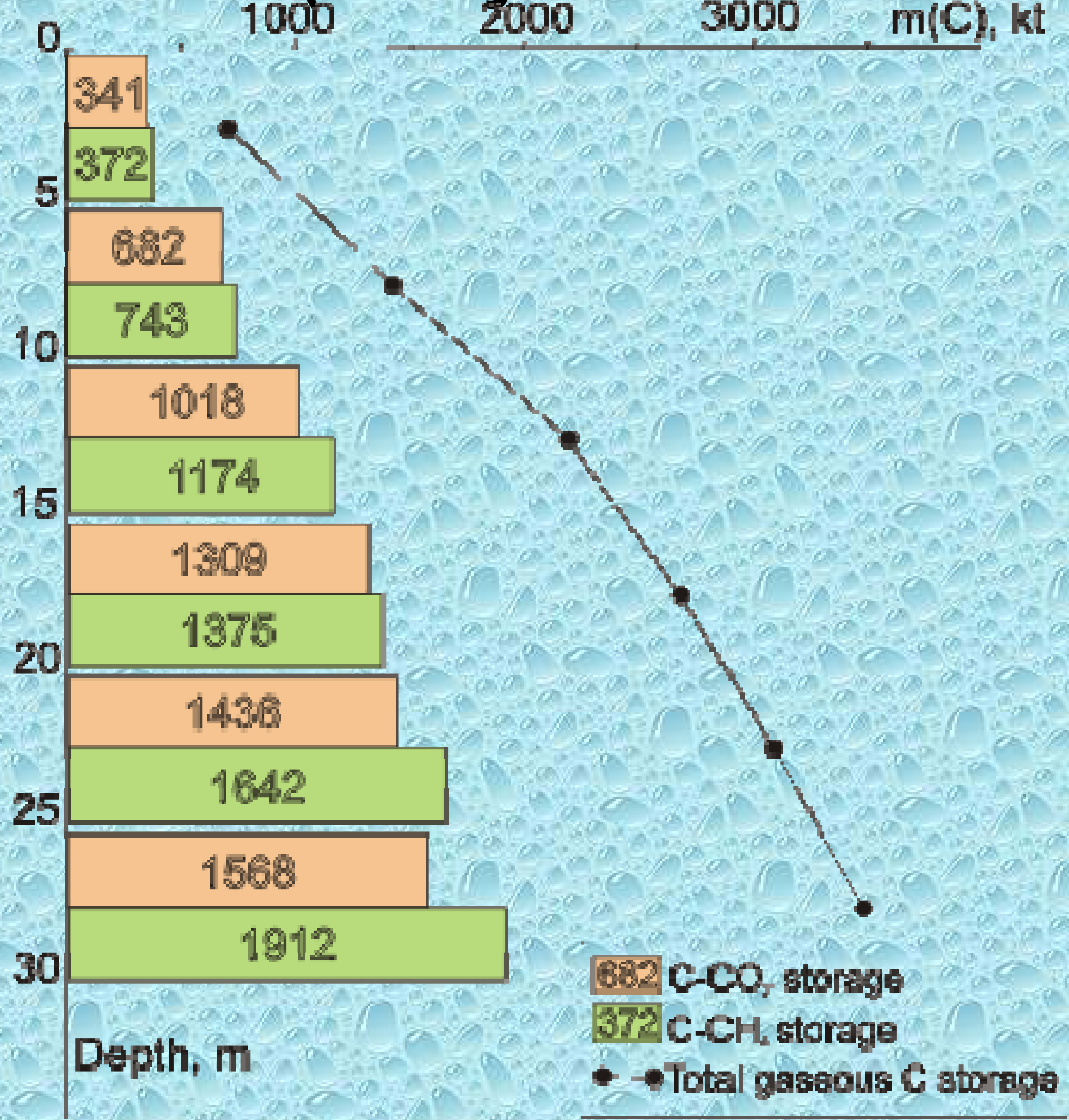
1 - section type
2 - study sites
3 - key sections (outcrops) of Quaternary Deposits

Explanatory pamphlet



1 - sands, 2 - sandy silts, 3 - silts, 4 - loamy silts, 5 - peaty silts and peats; 6 - saline silts; 7 - ice wedges; 8 - stratigraphic indices

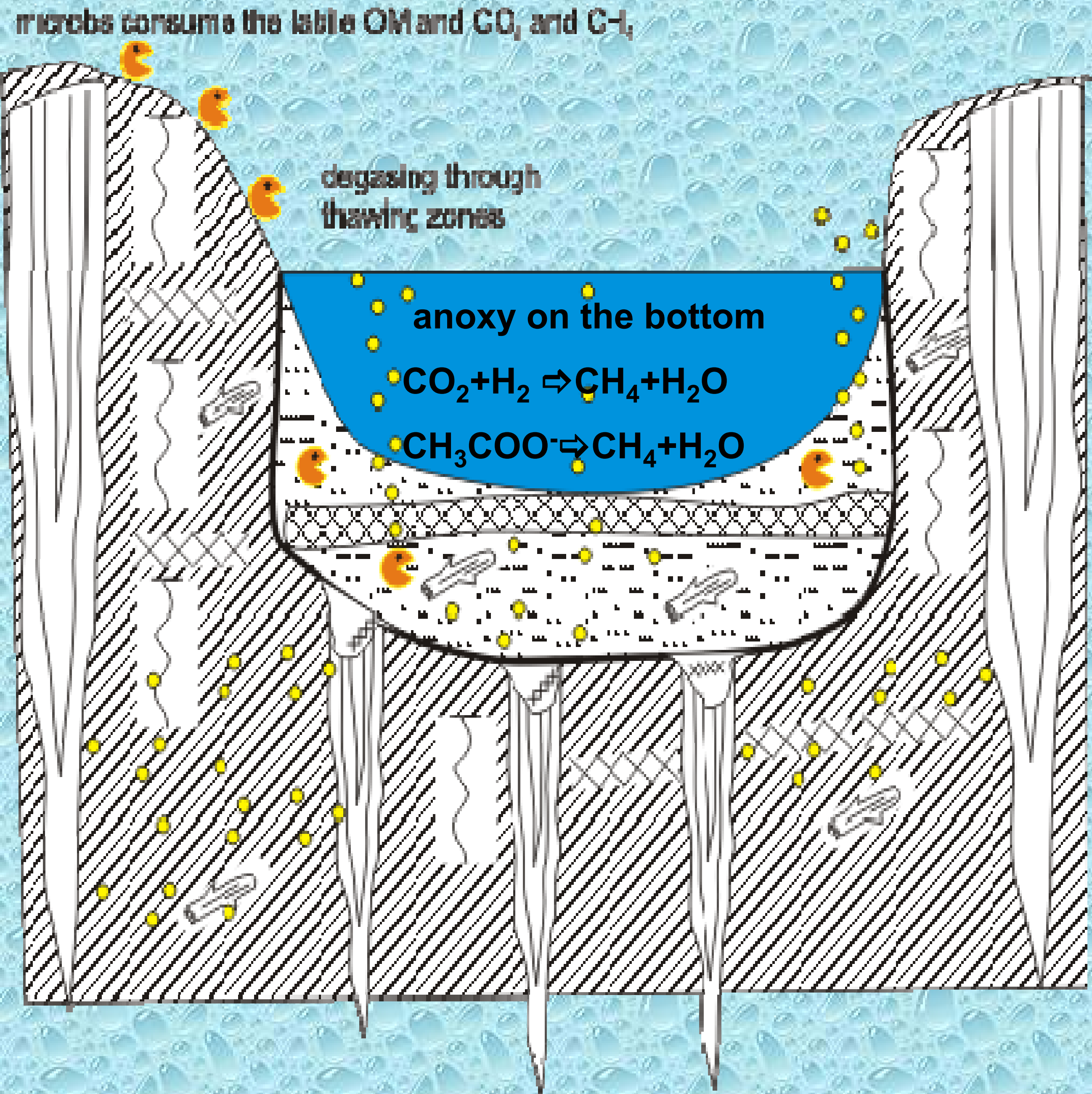
Cumulative C-(CO_2+CH_4) storages in permafrost (study area = 45000 km^2)



Degassing mechanisms

- **Coastal retreat**
- **Thermokarst**
- **Surface emission**

Thermokarst bursts due to warming



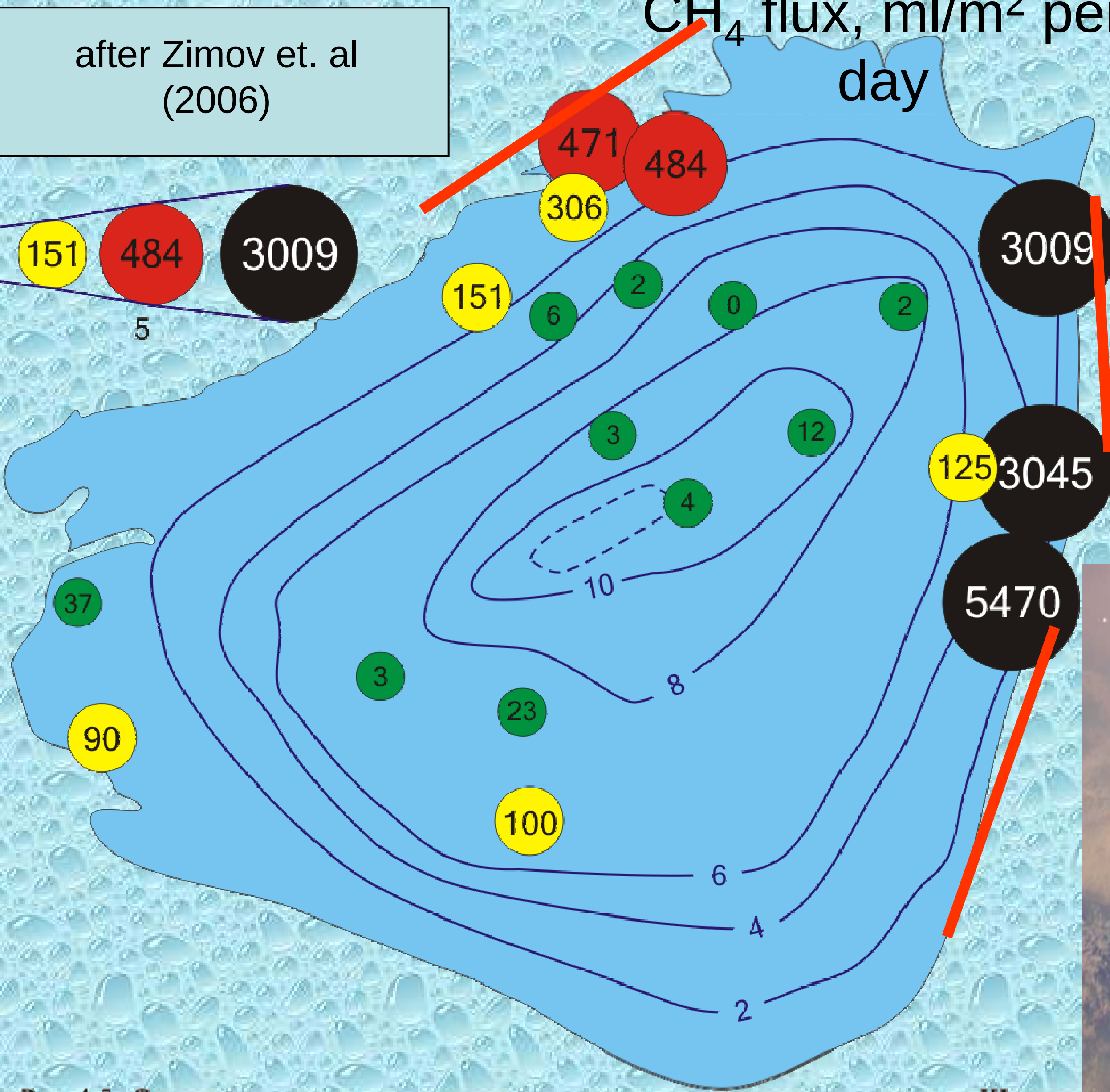
58% of the Late Pleistocenic Lake Alluvial Plain have turned to thermokarst plains. Up to 15 m deep basins formed due to ice-rich sediments melting.

Deep taliks form under thermokarst lakes.

Thawed Labile Carbon assimilates by microbial communities

Thermokarst lake ebullition

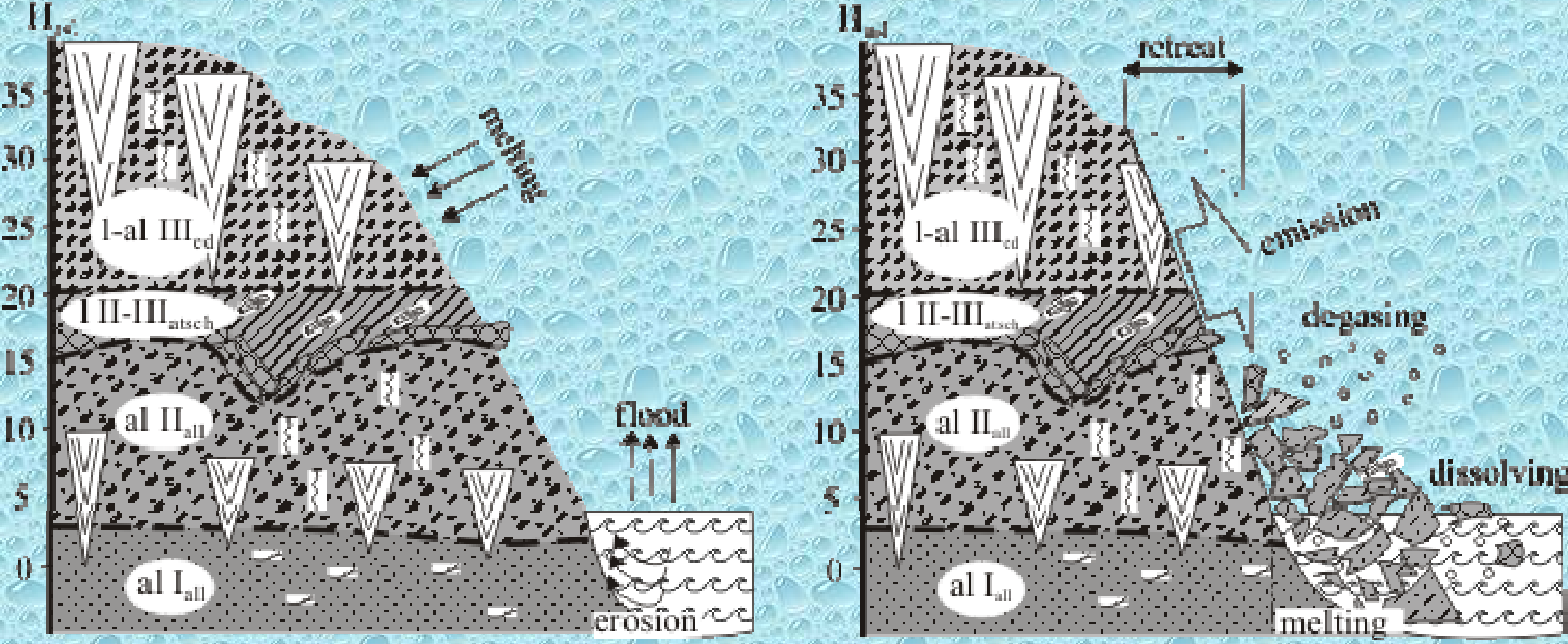
mean summertime CH_4 flux, ml/m^2 per day



Assuming the lakes area the mean of 242 t(C)/yr km^2 of CH_4 is emitted from the lakes at 45000 km^2 study area

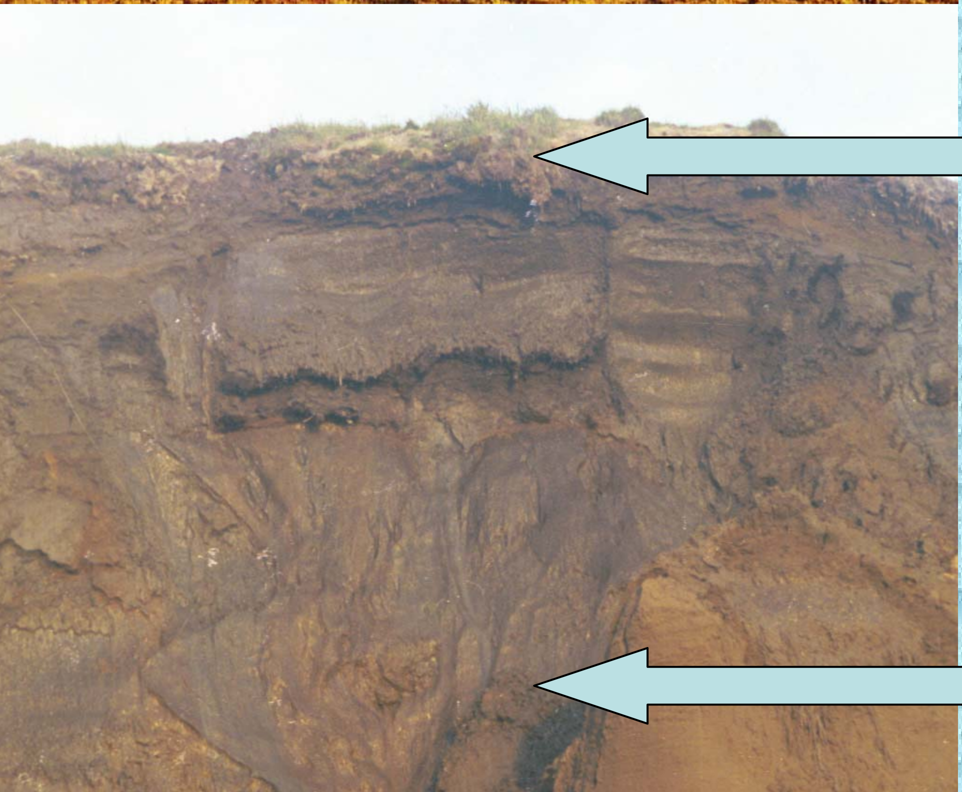

Photo by K.M. Walter

Coastal retreat



- **1.5-5 m/yr [Kholodov et al., 2003], mean 3 m (15 yrs monitoring (1984-99) of a section)**
- **Gaseous C input is 2 t/yr for the study area (200 km of 15 m steeps)**

Annual Flux 222 Kt C-CO_2/km^2 (Fedorov-Davydov, 2002); 4,8 Kt C-CH_4/km^2 (Samarkin et al., 1994)



Maximal C-(CH4+CO2) in the active layer (<1 m) 1,8 Kt/km^2; 0,5 Kt/km^2 C-CH_4 (Samarkin et al., 1994)

30 m permafrost storages 78 t/km^2 C-(CH_4+CO_2)

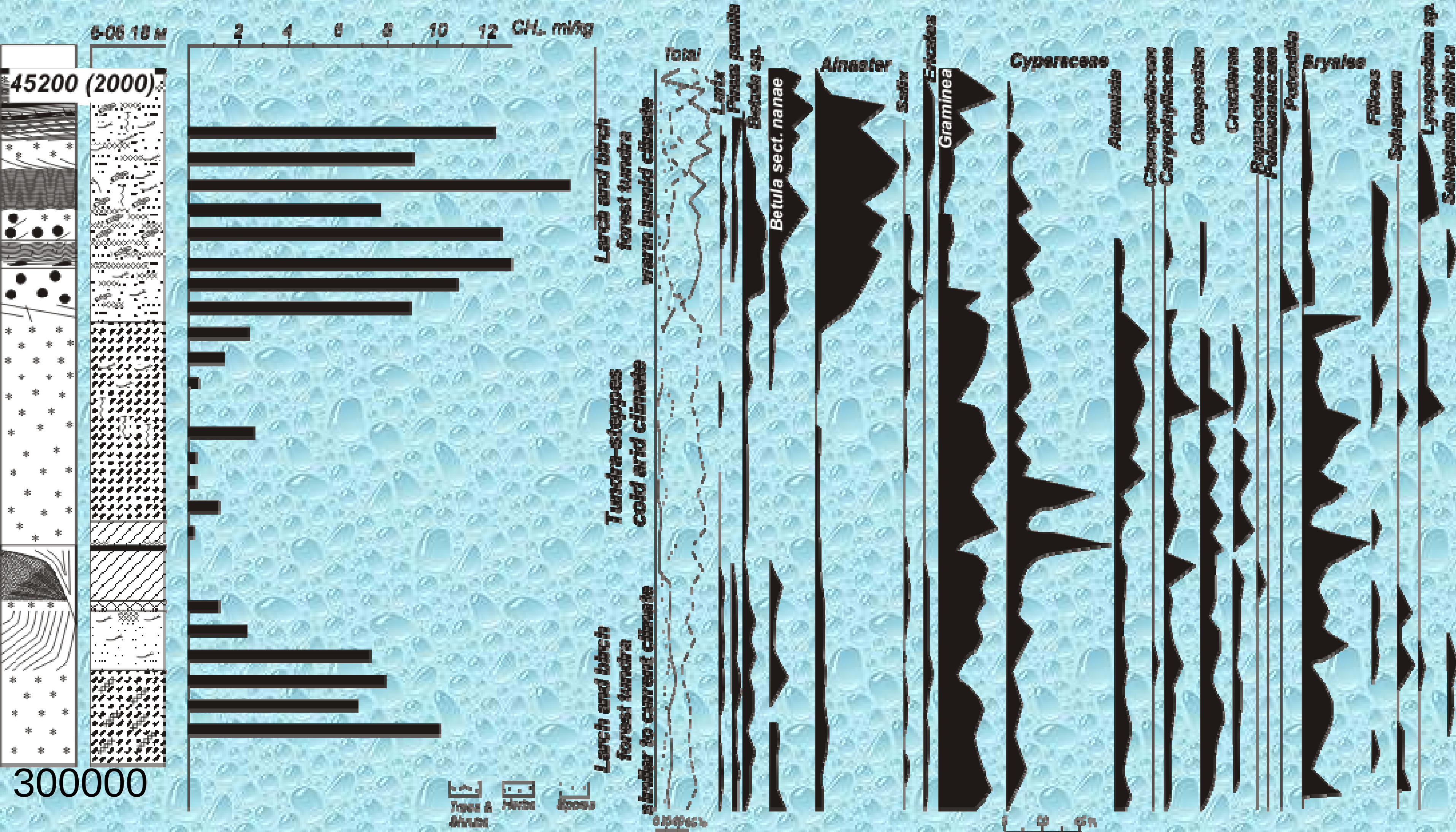
Conclusions

- Greenhouse gases concentration in permafrost rise in cool periods and fall in warm
- Storages of greenhouse gases in permafrost are low comparative to wetland soils
- The fate of the greenhouse gases could be different, with thermokarst having the greatest flux

Assesments for the Continuous Permafrost Area (10,9 Mkm^2)

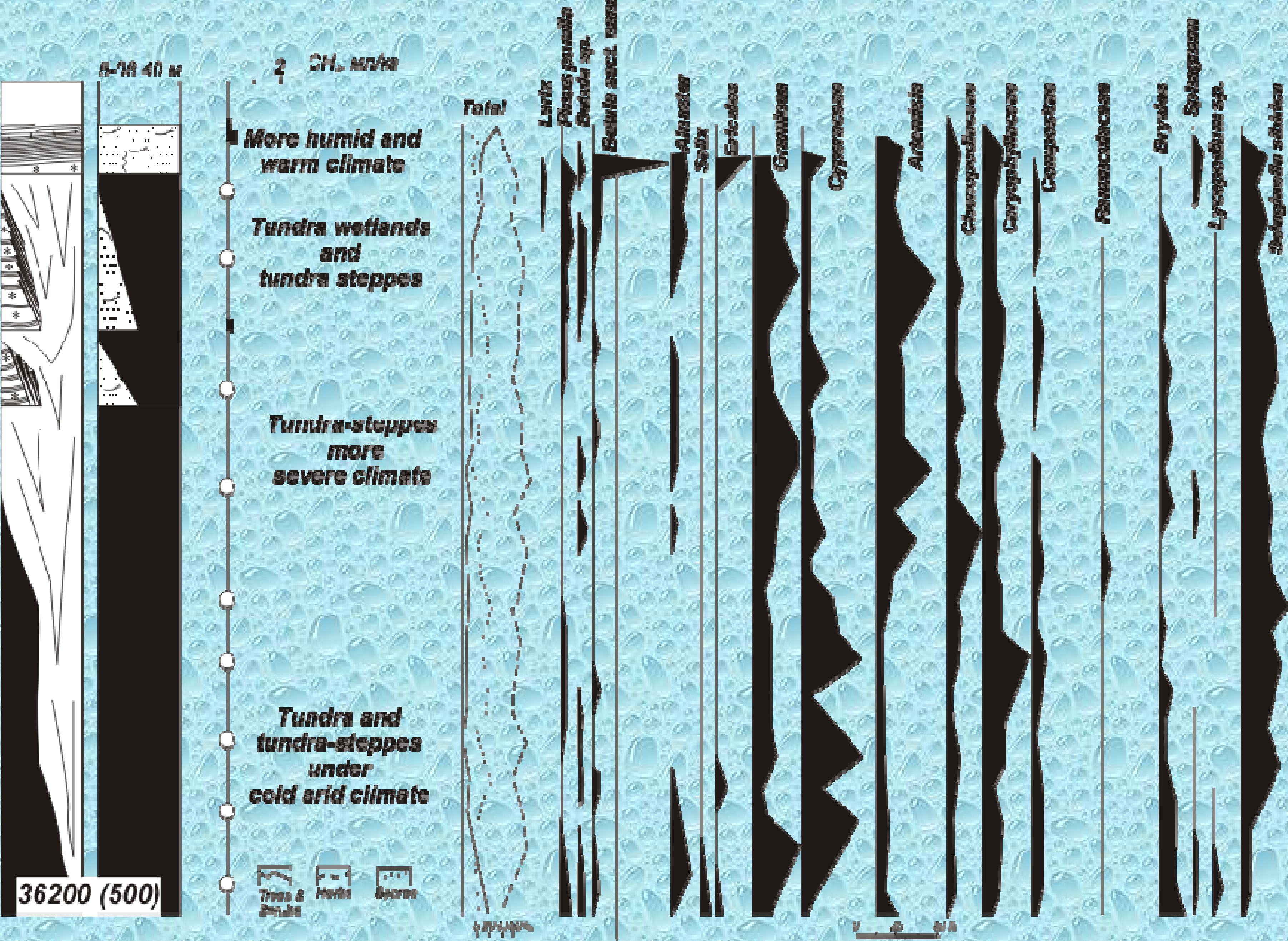
- Storages in upper 30 m permafrost ~850 Mt of C-CO_2+CH_4
- 3 m coastal retreat of 5000 km of steeps result in 0,6 Kt(C)/yr release of CO_2 and CH_4
- Lake emission 58,5 Kt/yr
- Soil “Respiration” 2,5 Gt/yr

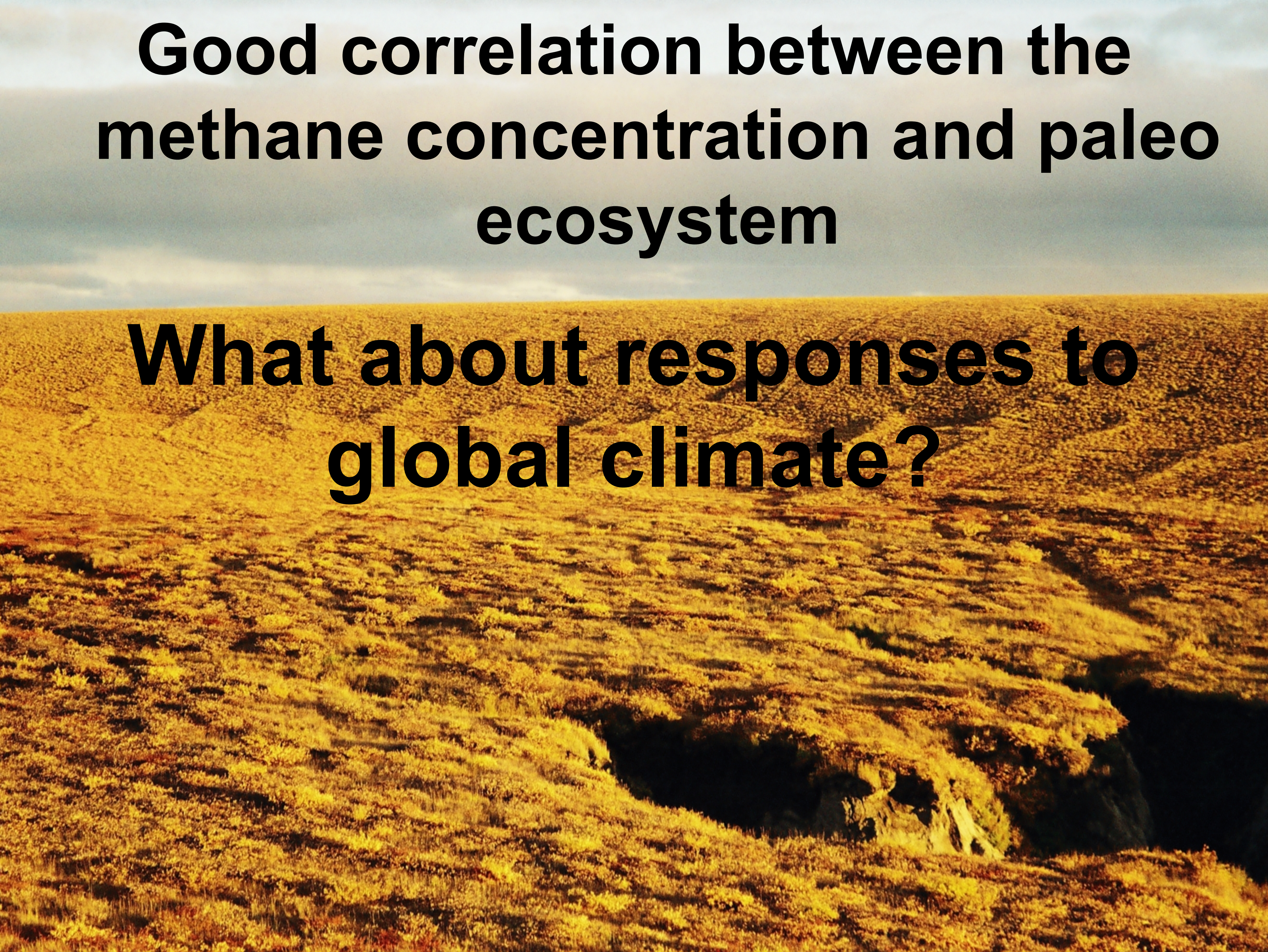
Synchronization with spore-pollen spectra



The standard deviation is shown in parentheses for ^{14}C-dates, other dating have been made palaeontologically by *Dycrostonix* teeth stratigraphy [Sher, 1984]. Spore-pollen spectra have been compiled by Kaplina et al. (1980).

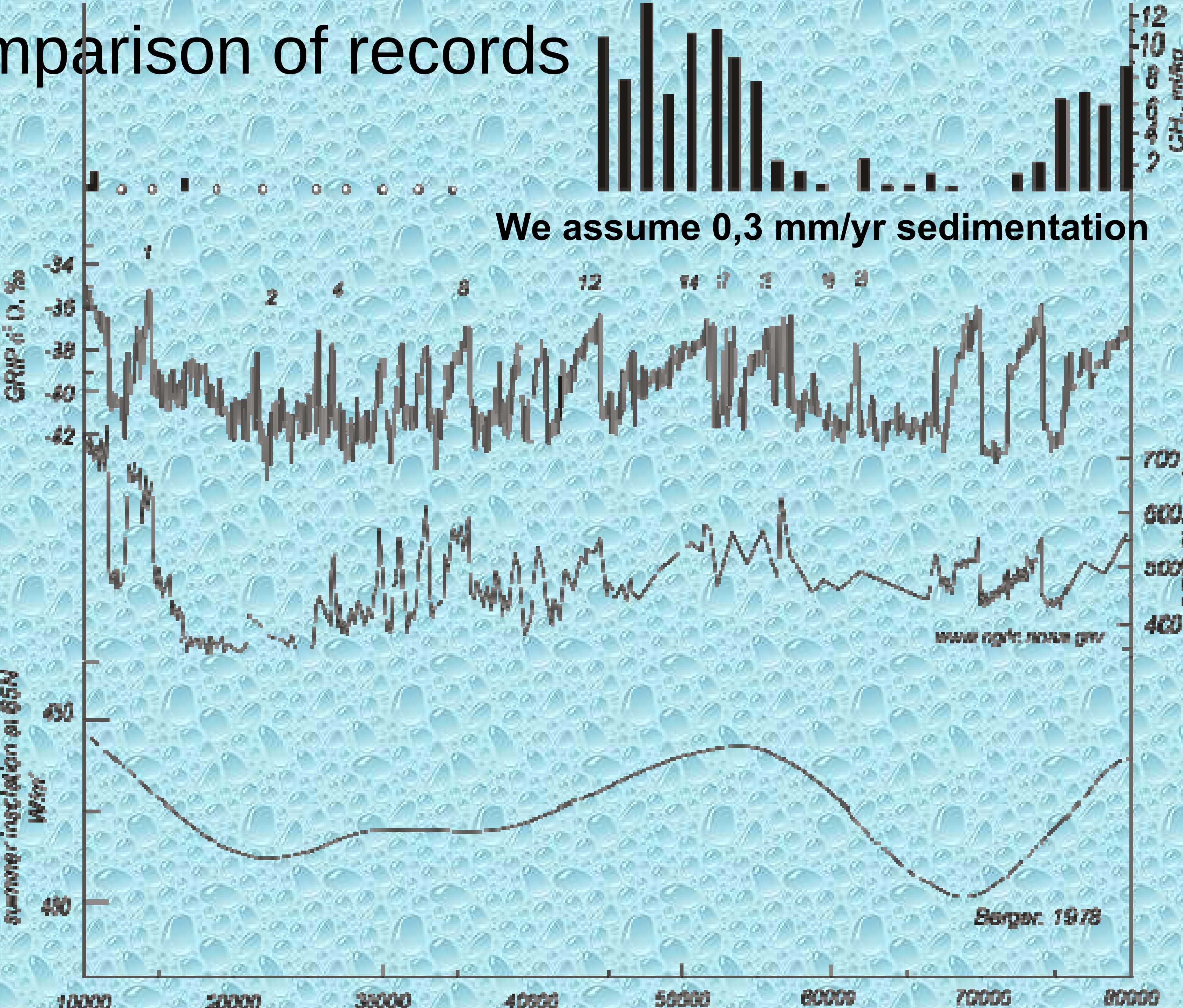
Synchronization with spore-pollen spectra




Good correlation between the methane concentration and paleo ecosystem
What about responses to global climate?

Comparison of records

We assume 0,3 mm/yr sedimentation



Conclusions

Methane concentrations in permafrost have reached maximums during interstadials and Holocene, when bursts of thermokarst occurred.

- Minimal concentrations are found in Glacial Time fluvial and lake deposits of Ice Complex
- Methane distribution in permafrost reflects the paleo ecosystem
- The changes in environment however could occurred due to climate or facial changes

Prospects

- Collaboration with Greenland ice core team to synchronize permafrost and ice-core methane records and use methane chronology for regional-scale paleotemperature reconstruction (especially for those, where ice caps did not existed during Quaternary)
- Collaboration with european scientists in the frame of FP-7 (?) for the process-based study of global warming introducing several new components unmentioned in models existing.
- Permafrost studies as special habitat for microorganisms and conservative source of biogenic resources worldwide.