Methane in sediments of the Chukchi Sea: spatial distribution, origin, and flux estimation

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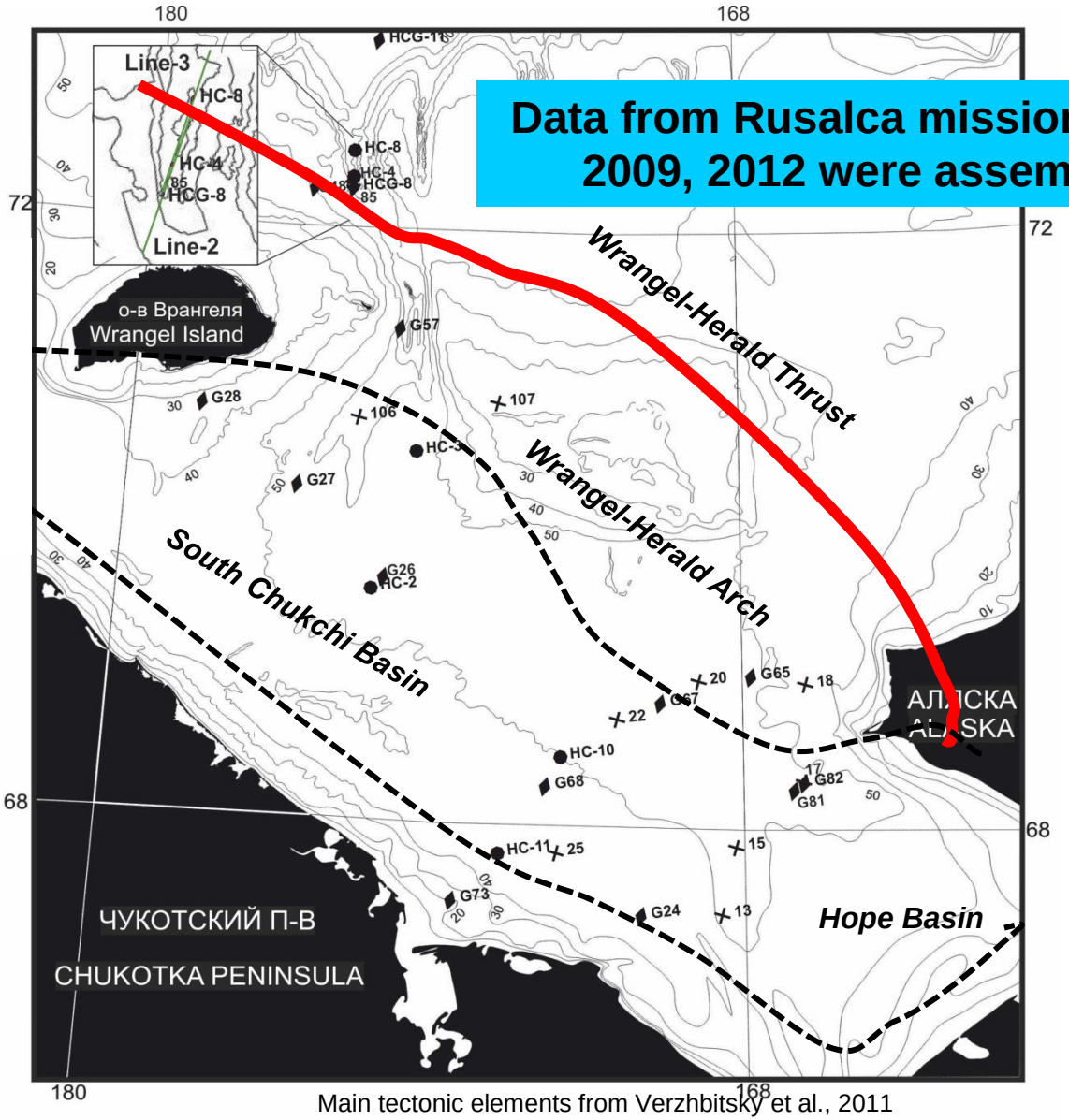
DATA: methane in sediment

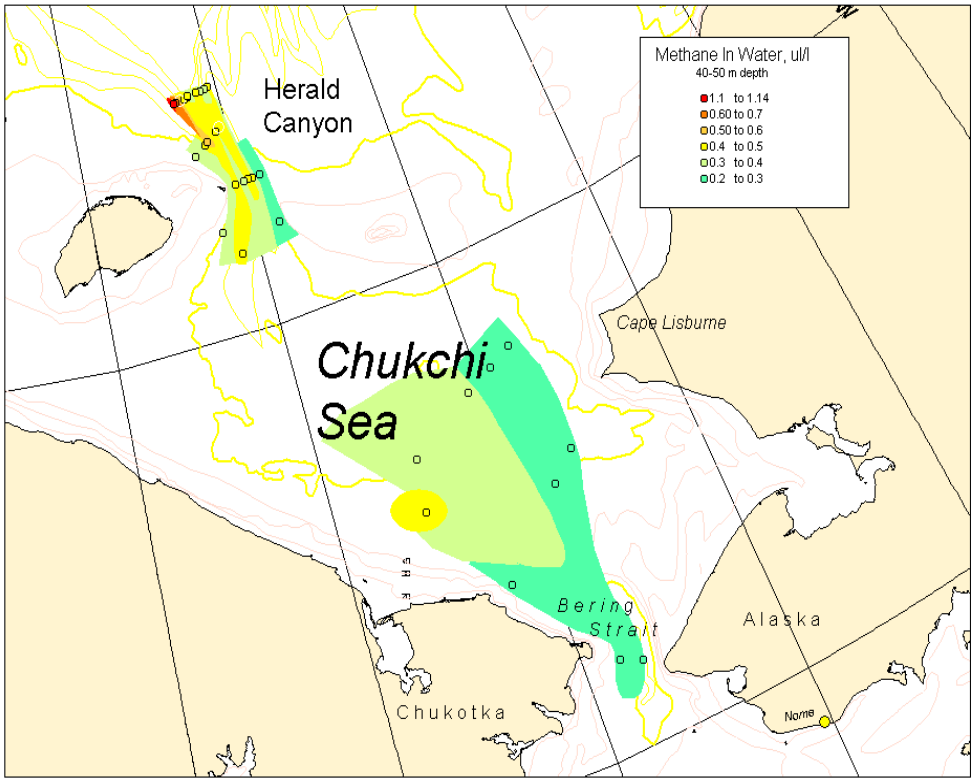


Main tectonic elements from Verzhbitsky et al., 2011

Станции грунтового пробоотбора (Core sampling stations):

✕ 2004 ♦ 2009 ● 2012 сейсмические профили (seismic profiles)

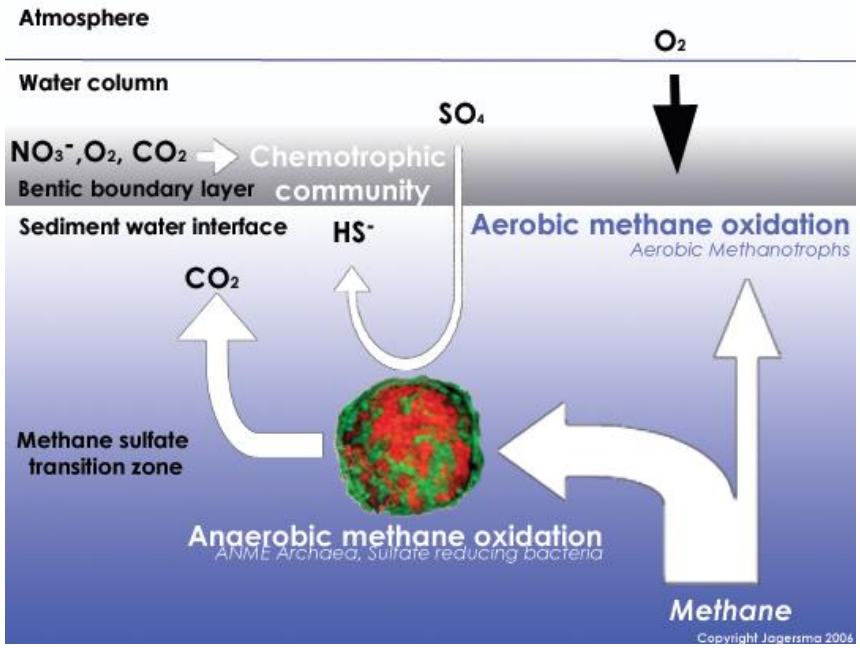
DATA: Methane in the water RUSALCA 2004 data + 2009 and 2012

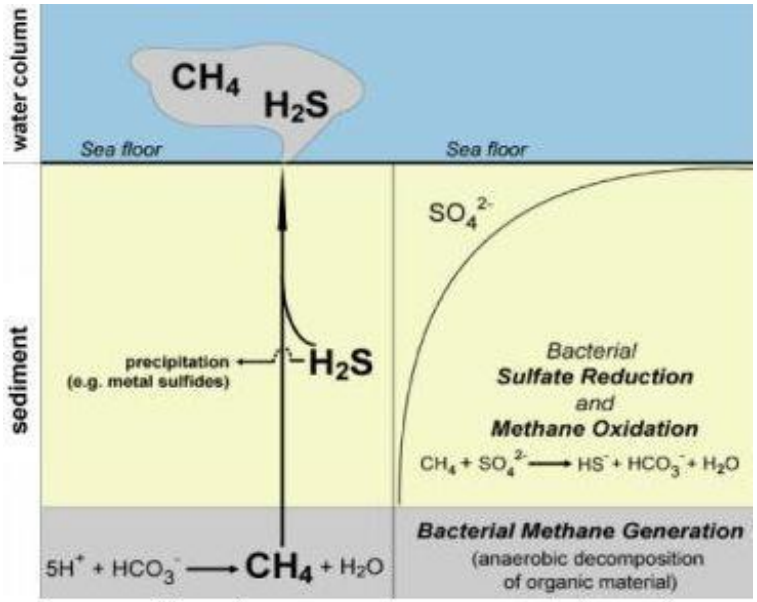


Outcome for the publication

- Map of methane content in the water
- Comparison with that of sediment
- CH4 flux from sediment to the water
- Intensity of AOM in water (A. Savvichev)

METHANE FLUX ESTIMATION

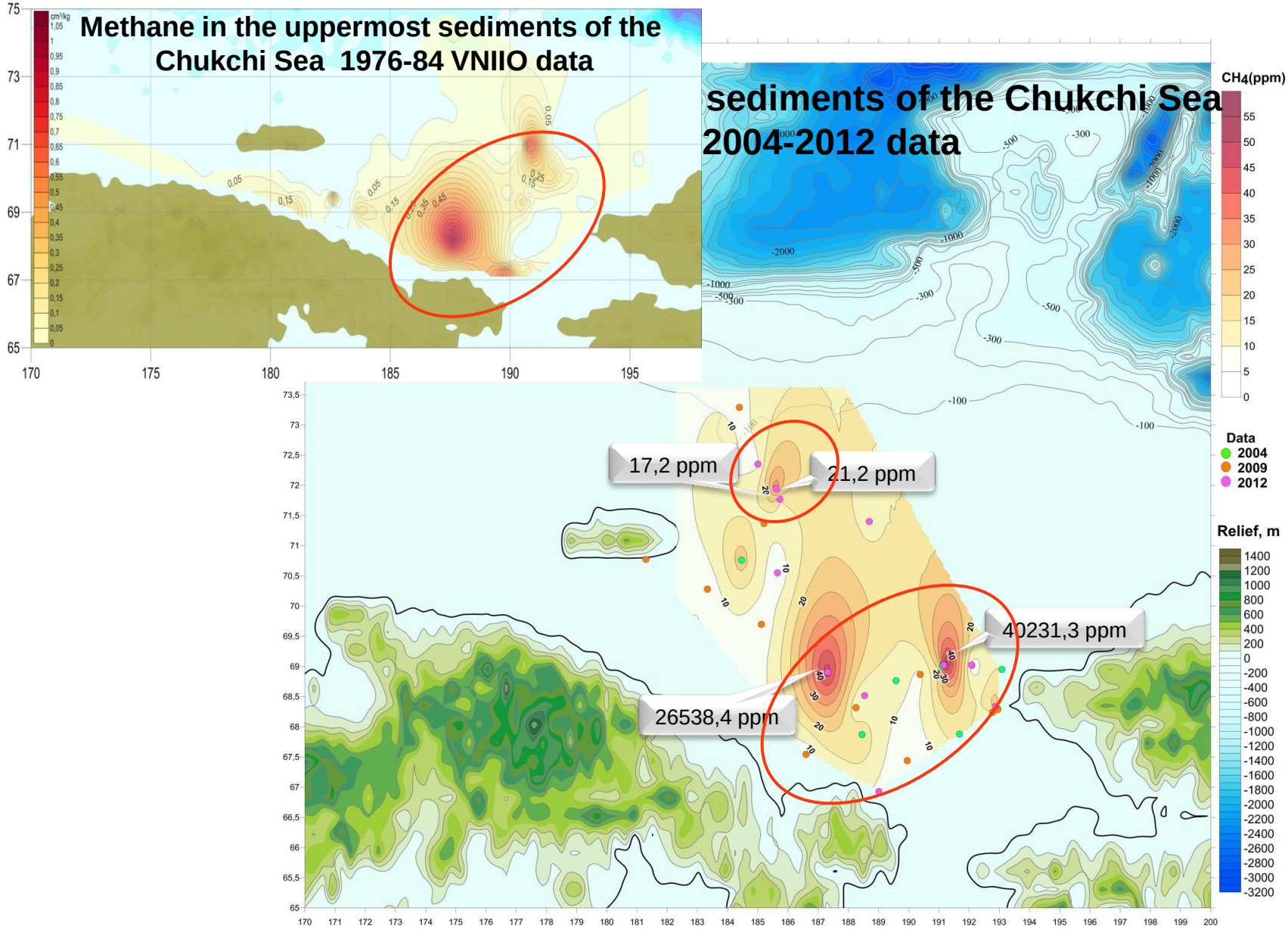




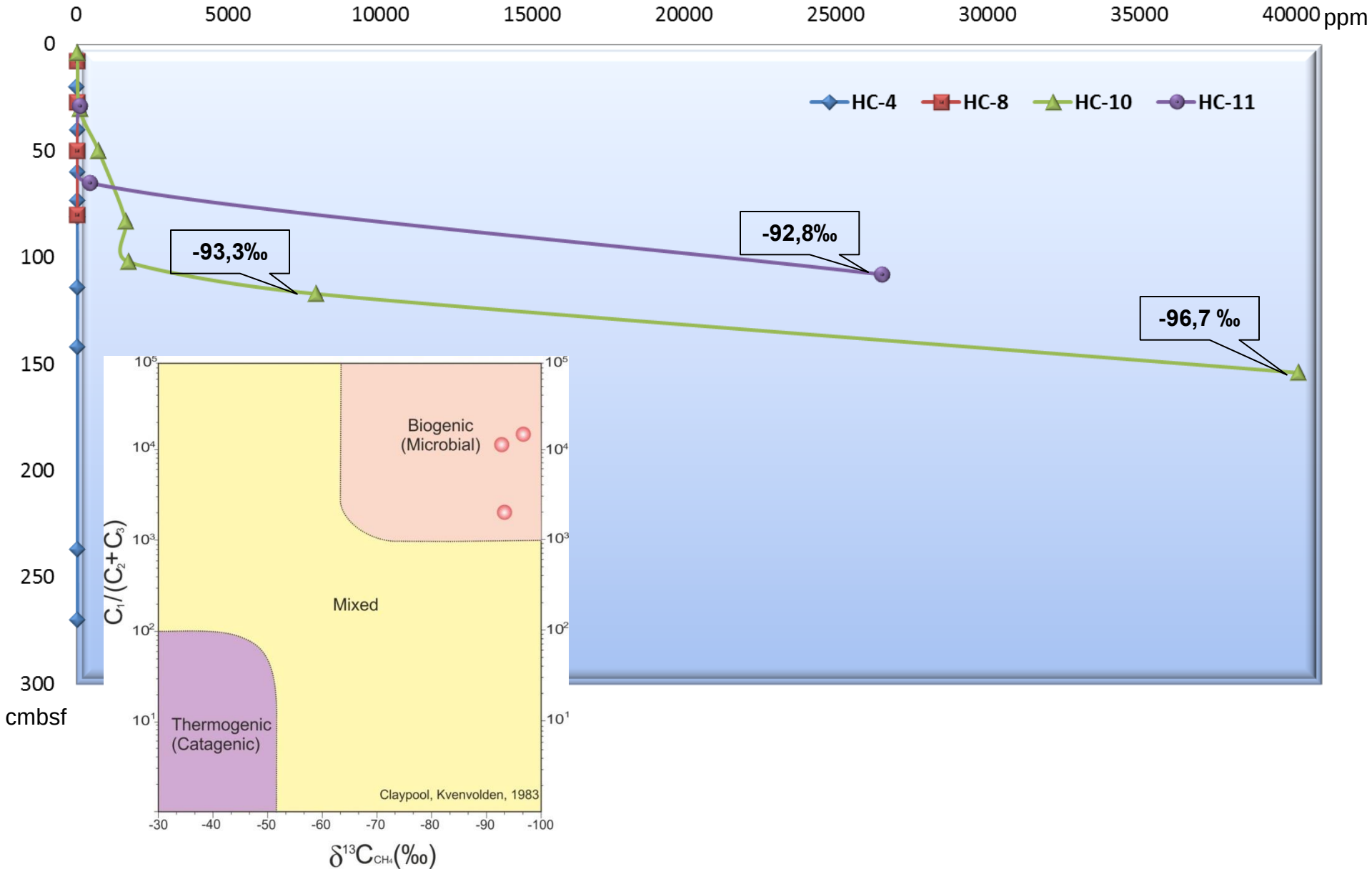
Scheme of methane production and degradation

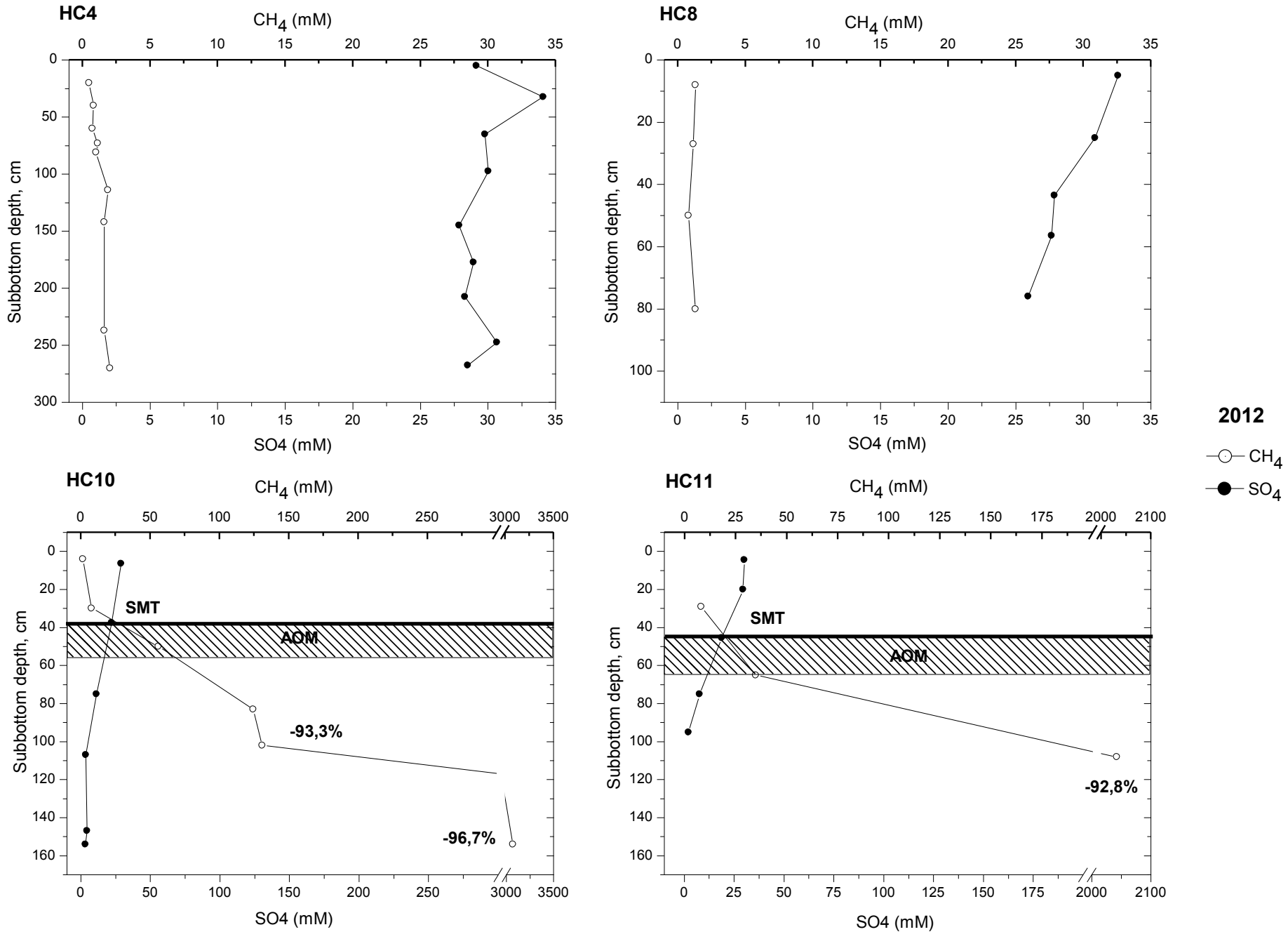
We focus on the vertical CH_4 flux observed by the linear slopes of vertical SO_4^{2-} profiles (Borowski et al., 1999; Coffin et al., 2008)

METHANE SPATIAL DISTRIBUTION

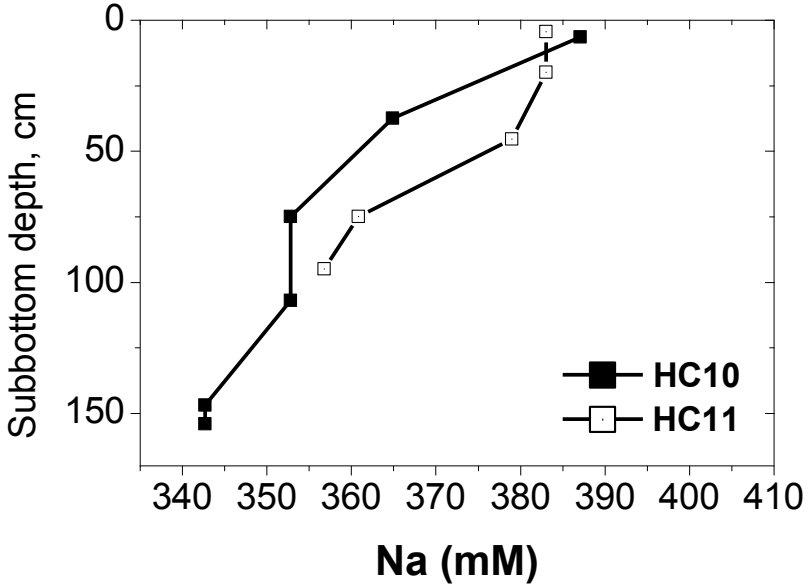


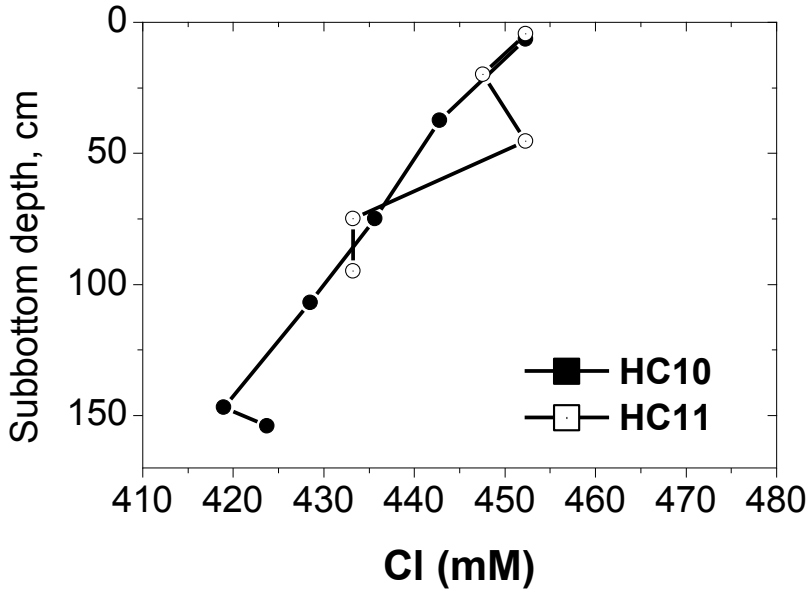
METHANE DEPTH PROFILES AND ITS ISOTOPIC COMPOSITION




HC4
CH4 (mM)
Subbottom depth, cm
SO4 (mM)
HC8
CH4 (mM)
Subbottom depth, cm
SO4 (mM)
2012
CH4
SO4
HC10
CH4 (mM)
SMT
AOM
-93,3%
-96,7%
Subbottom depth, cm
SO4 (mM)
HC11
CH4 (mM)
SMT
AOM
-92,8%
Subbottom depth, cm
SO4 (mM)

Fluid filtration rate calculation





Conditions of steady-state flow

$$\phi D \frac{dc_{top}}{dx} + u \times c_{top} = 0$$

u – filtration rate; ϕ – porosity (0.7)

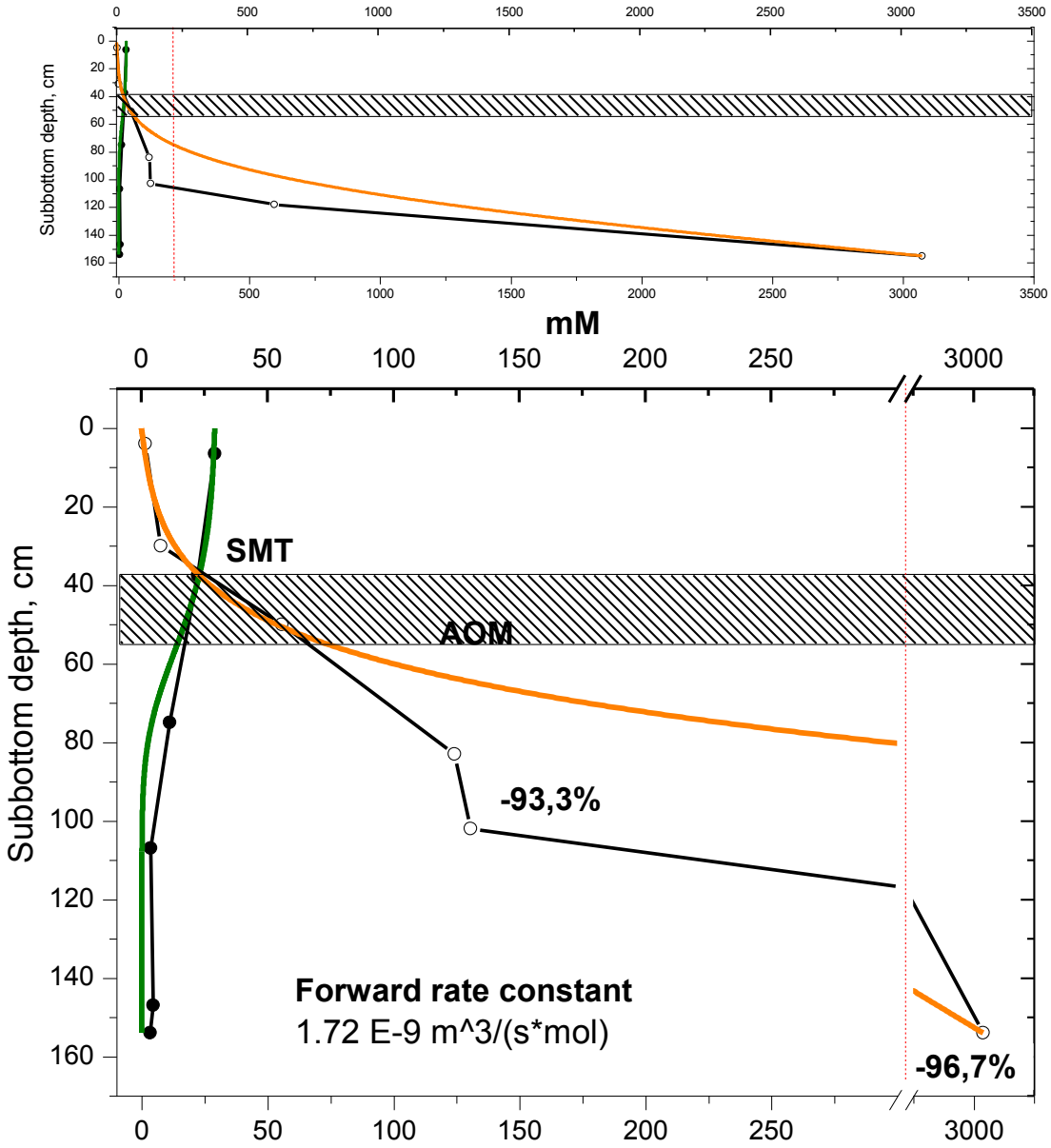
D – NaCl diffusion coefficient (0.76e-9 m^2/s)

c_{top} – NaCl concentration at the upper profile

HC-10 $\boldsymbol{u = 1.05\ cm/y}$

HC-11 $\boldsymbol{u = 1.01\ cm/y}$

Results of modeling

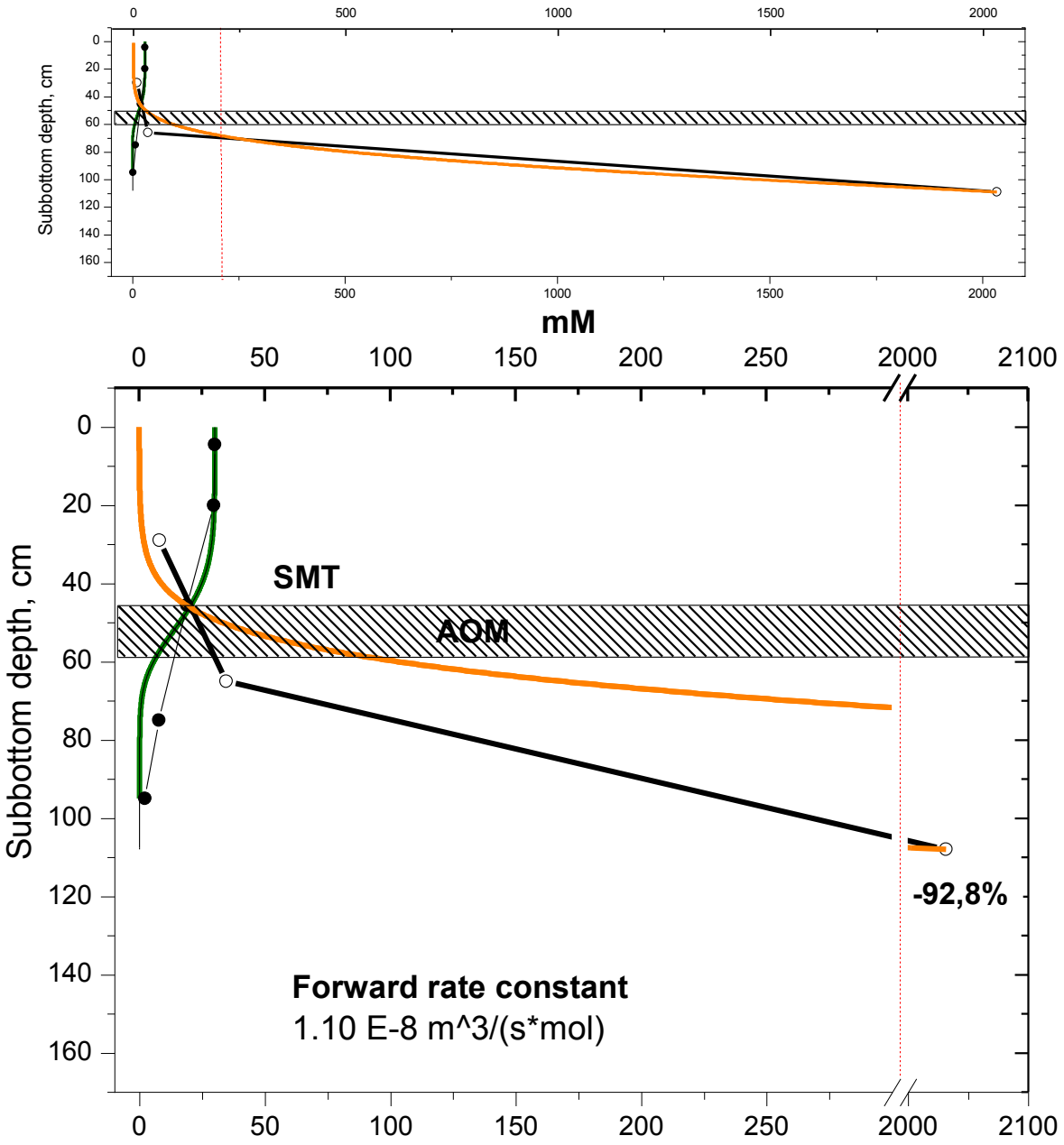


HC10

- Methane in situ (mM)
- Sulfate in situ (mM)
- Methane (mM), modeling data
- Sulfate (mM), modeling data

Rate of fluid filtration		Time to reach SMTZ
1.05 cm/y	**-**	**5 months**

Results of modeling



HC11

Methane in situ (mM)

Sulfate in situ (mM)

Methane (mM), modeling data

Sulfate (mM), modeling data

Rate of fluid filtration	**Time** to reach SMTZ
1.01 cm/y	**- 1.5 months**

Sulfate diffusion rates were calculated from the linear fit to the concentration gradient according to Fick's first law (Berner, 1964, 1978):

$$J = -\varphi \cdot Ds \frac{dC(SO4)}{dz}$$

where *J* represents the $SO4^{-2}$ flux (mmol cm^{-2} s^{-1}), φ is the sediment porosity, *Ds* is the sediment diffusion coefficient, $C(SO_4)$ is the range in $SO4^{-2}$ concentration and z is the range in depth for the linear section of the $SO4^{-2}$ porewater profile. Ds is the diffusion coefficient for $SO4^{-2}$:

$$Ds = \frac{D0}{1 + n * 1(-\varphi)}$$

where *D0* is assumed to be 8.7×10^{-5} cm^2 s^{-1} (Iversen and Jørgensen, 1993), n = 3 was assumed for the clay silt sediments in this region, and φ is the sediment porosity determined from core sub-samples.

Station	SO_4^{-2} diffusion flux (Js, mmol cm^{-2} s^{-1})	CH_4 diffusion flux (Jm, mmol cm^{-2} s^{-1})
HC-10	-4,35833E-06	0,872393E-03
HC-11	-7,30695E-06	1,088886E-03

CONCLUSIONS

- This study provides a thorough assessment of spatial variation in CH_4 concentrations in sediments within two areas of the Chukchi Sea: Herald Canyon area and the South Chukchi Basin

- The evidences on microbial origin of the methane in the South Chukchi Basin were obtained for first time

- Strong spatial variation in CH_4 diffusion though out the shallow sediments measured in this study

- Results reveal moderate to low vertical methane flux relative to other regions in the Arctic Ocean, including those with high atmospheric CH_4 flux (Shakhova et al., 2005). Next step – estimation for the water column

- The scale and shape of measured headspace CH_4 and pore water SO_4^{2-} profiles varied between two studied locations, suggesting a large degree of spatial variability in methane fluxes within the Chukchi sea

NEXT STEPS

- **Geochemical background of methane concentration for sediment of the Chukchi Sea**
- **Map of methane content in the water**
- **Comparison with that of sediment**
- **Further modeling and methane flux estimations**
- **CH4 flux from sediment to the water**
- **Intensity of AOM in water (A. Savvichev)**