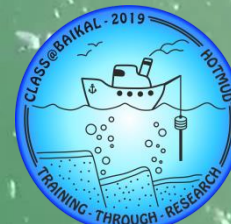1-Lomonosov Moscow State University, Moscow, RF
2-Limnological Institute, Siberian Branch of Russian Academy of Sciences, Irkutsk, RF
3-Centre for Earth Evolution and Dynamics (CEED), University of Oslo, Oslo, Norway

Integrated analysis of geophysical and geochemical data from cold fluid seepage system along the Gydratny Fault (Lake Baikal)

Olesya Vidischeva[1], Marina Solovyeva[1], Evgeniya Egoshina [1], Yana Vasilevskaya [1], Elena Poludetkina [1], Grigorii Akhmanov [1], Oleg Khlystov[2], and Adriano Mazzini[3]

Class@Baikal

INTERNATIONAL CO-OPERATION FOR TRAINING IN MARINE SCIENCES

Training-through-Research:

- 6 international expeditions
- 10 study areas
- 488 cores
- 280 subbotomprofiler lines
- 160 seismic profiles
- 3600 km of seismic record
- More the 50 participants from 20 organizations from 4 countries

**Research topics of Floating University:**

- Natural gas hydrates and focused discharge zones;
- Mud volcanism and clay diapirism;
- Modern deep-water sedimentary systems, canyons and channels systems;
- Neotectonics, bottom morphology, sedimentation;
- Heat flow and thermophysical characteristics of bottom sediments;
- Slope stability / instability.

http://class-baikal.ru/

2

Location

The Gydratny fault is a listric normal fault with predominantly Northern and North-Western Direction. The study area can be divided in two main blocks (hanging wall and footwall, separated by the Gydratny fault).

- The first block (footwall, block 1) is bounded on the North-West by the Obruchev (Olkhon) fault and on the South-East by the Gydratny fault. This large block is essentially undisturbed by faulting and is elevated relative to the block 2.
- The lowered block is characterized by the presence of secondary multiple small faults on the hanging wall.
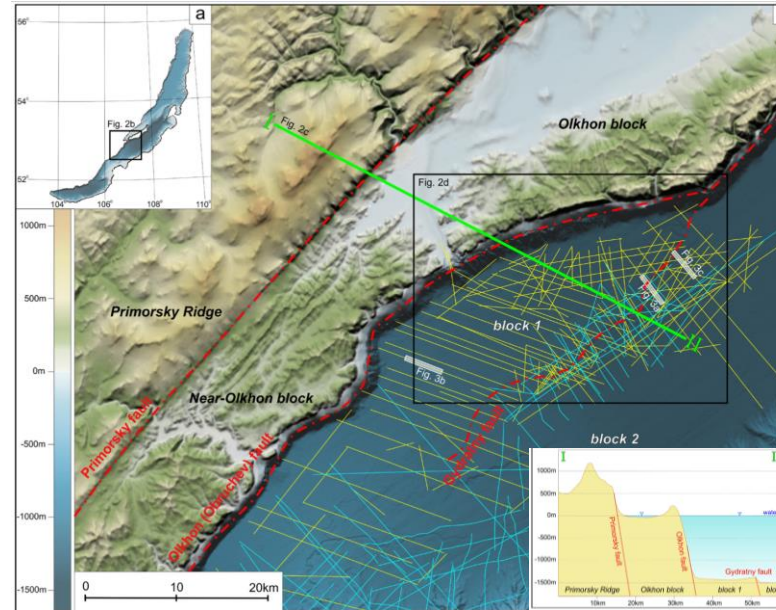
(a) Lake Baikal with the location of the research area (black polygon);
(b) A scheme of seismic data. Green line shows the location of the profile I-II of the bottom relief schematized in panel (c) (Solovyeva et al., 2020).
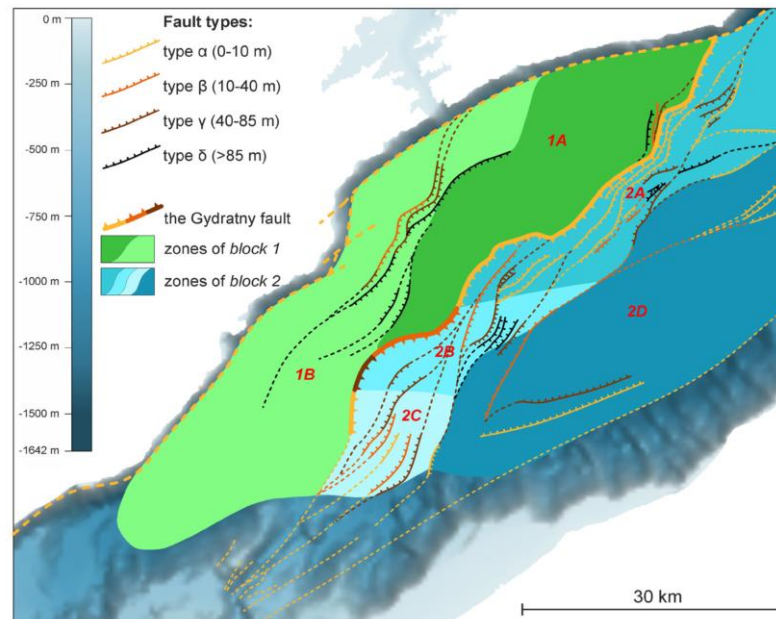
Tectonic scheme of Gydratny Fault zone with classification of structures based on the thickness of overlapping sediments. Solid lines show proved established faults, dotted lines show assumed faults. The names of the zones are indicated in red font (Solovyeva et al., 2020).
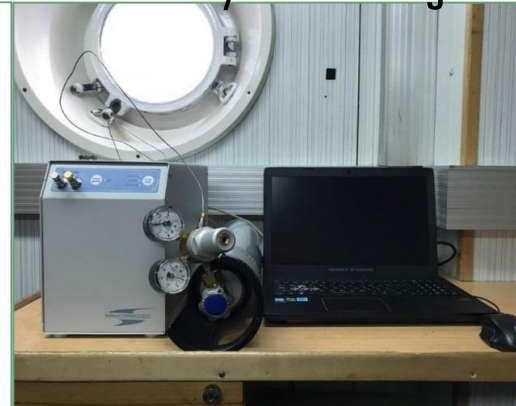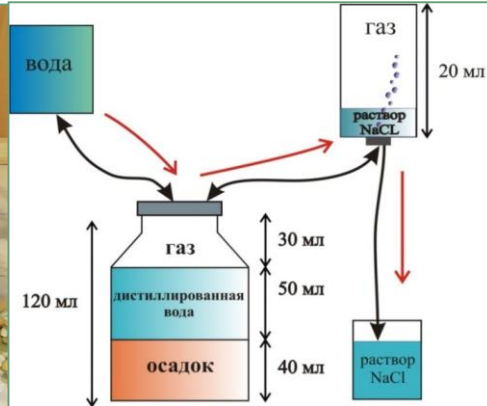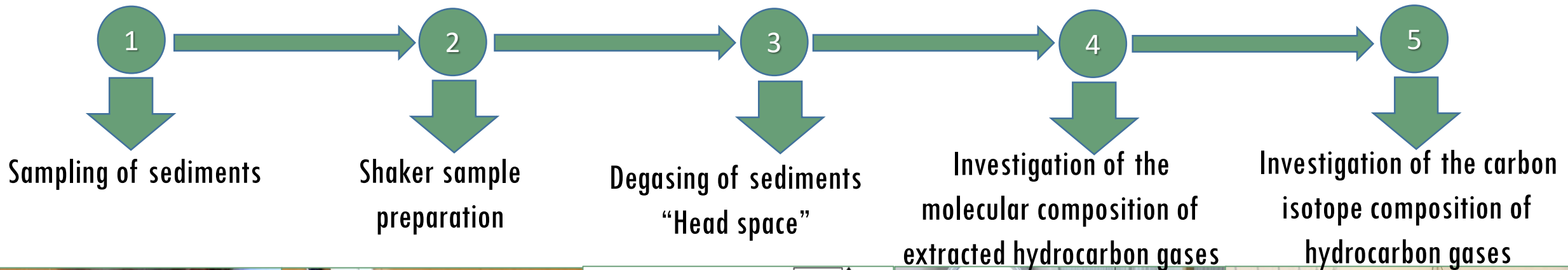
Geographical distribution of the gas hydrate-bearing structures discovered in the South and Central Basins of Lake Baikal

Numerous structures of focused hydrocarbon gas discharge and near-surface gas hydrates accumulations are associated with this tectonic scarp. For this reason in 2018 was proposed to name this structure Gydratny fault, i.e. Gydratny as «gas hydrates bearing».
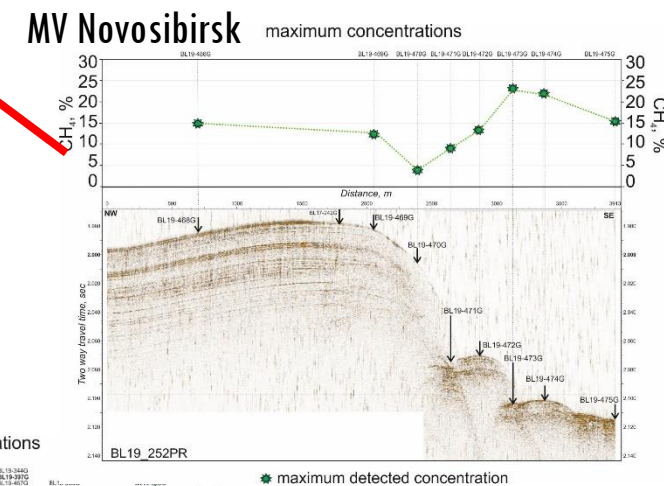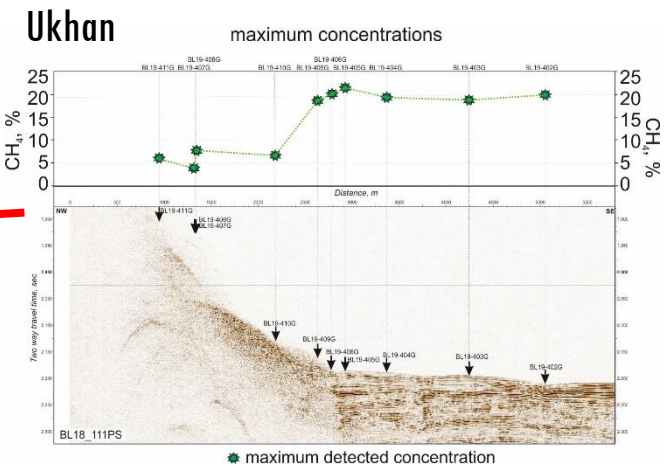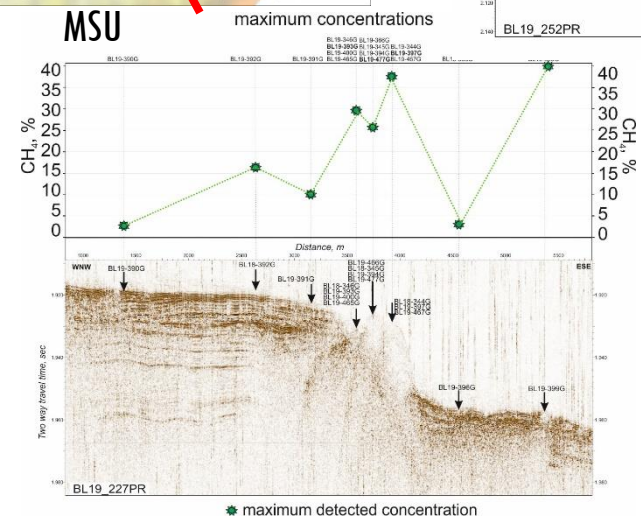

Khlystov et al., 2018

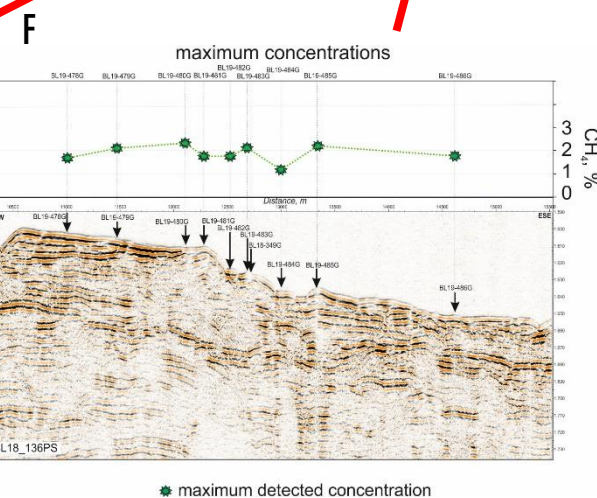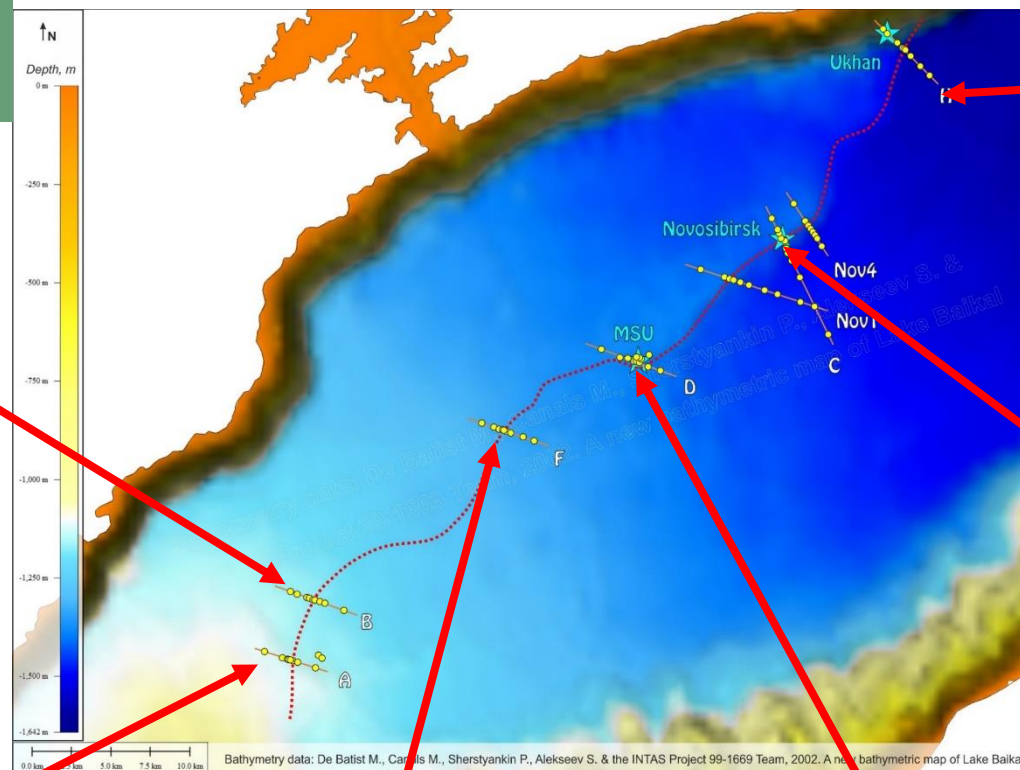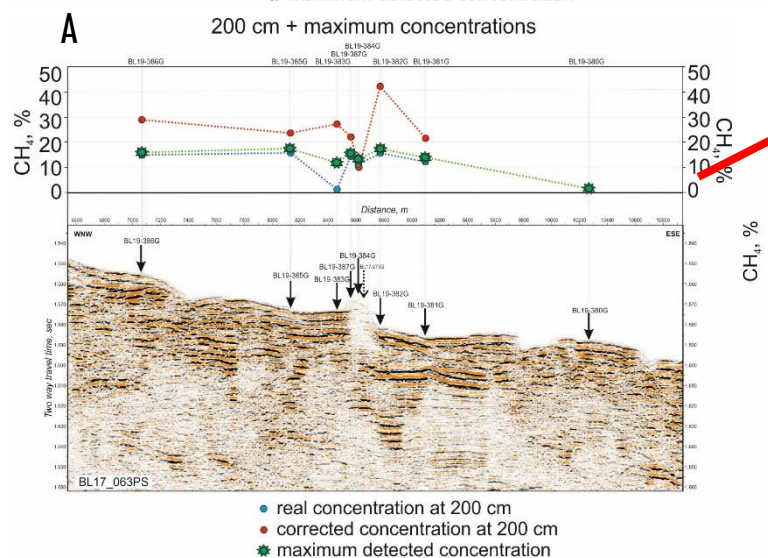Line with focused discharge zones (above the Gydratny Fault)

Research methods

During the Cass@Baikal expedition in 2019, 6 geochemical profiles were carried out crossing the Gydratny Fault. At each profile, 10 bottom sampling stations were selected. Sampling for gas geochemistry was performed from each core. Gas-geochemical studies included:

1 → 2 → 3 → 4 → 5

1 Sampling of sediments

2 Shaker sample preparation

3 Degasing of sediments "Head space"

4 Investigation of the molecular composition of extracted hydrocarbon gases

5 Investigation of the carbon isotope composition of hydrocarbon gases

SKO/SKL (LABTEH)   Hromatek Kristall 2000   Delta V dvantage

Geochemical profiles

6
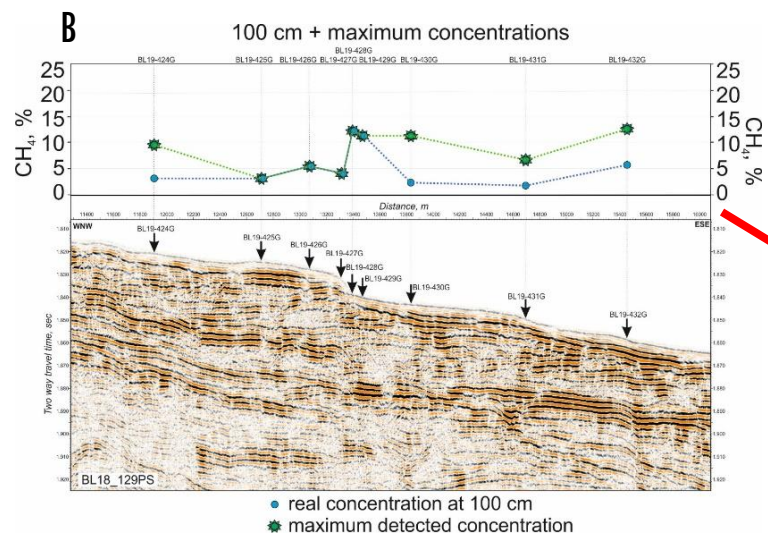
Methane concentration
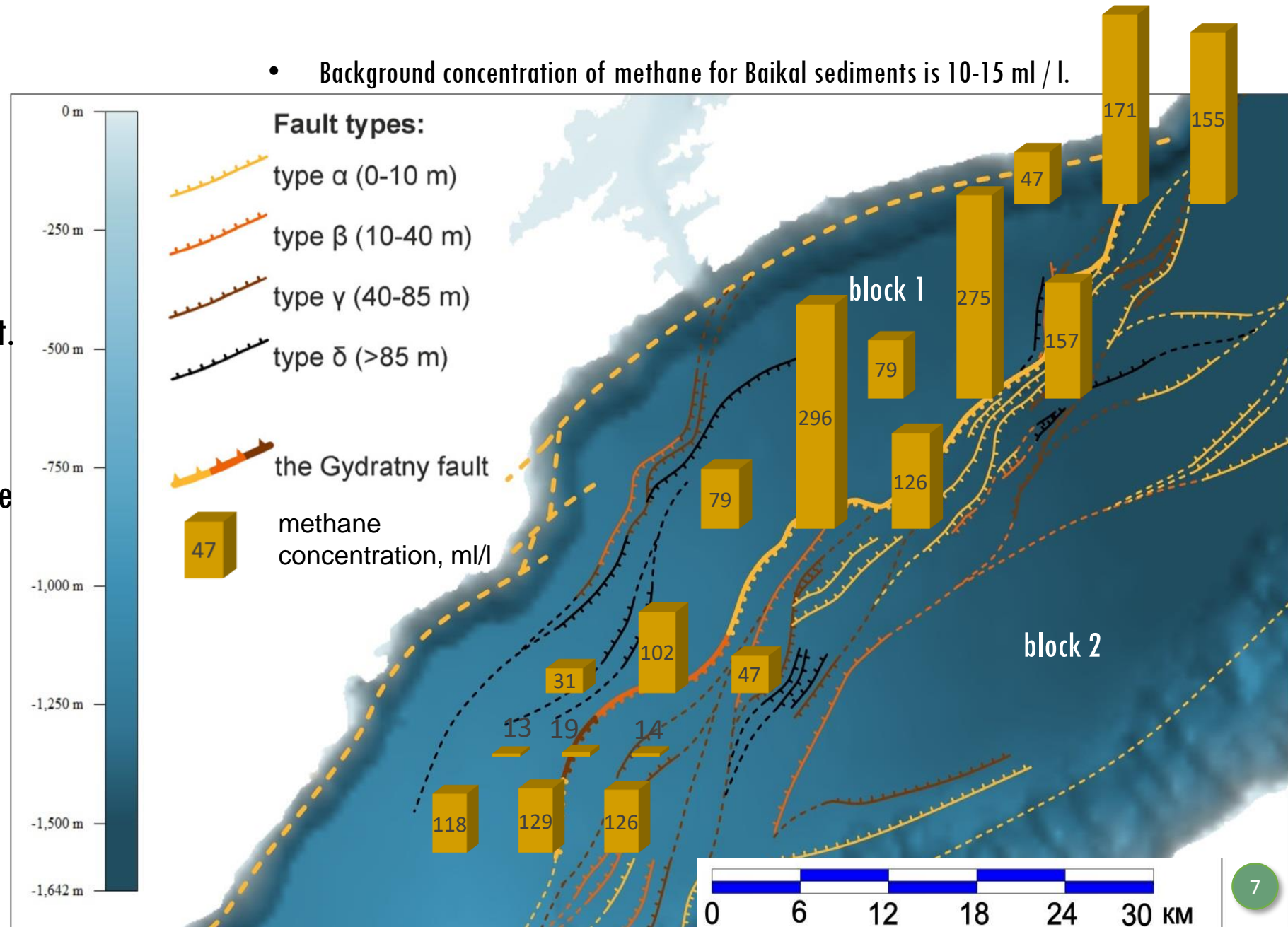
- Highest gas concentration observed directly above the fault.

- Methane concentrations are higher in the northern part of the fault.

- Methane concentrations in block 2 are higher than in block 1.

- Background concentration of methane for Baikal sediments is 10-15 ml / l.

Fault types:

type α (0-10 m)

type β (10-40 m)

type γ (40-85 m)

type δ (>85 m)

the Gydratny fault

methane concentration, ml/l

block 1

block 2

0 m
-250 m
-500 m
-750 m
-1,000 m
-1,250 m
-1,500 m
-1,642 m

171
155
47
275
157
79
296
126
79
47
102
31
47
13 19 14
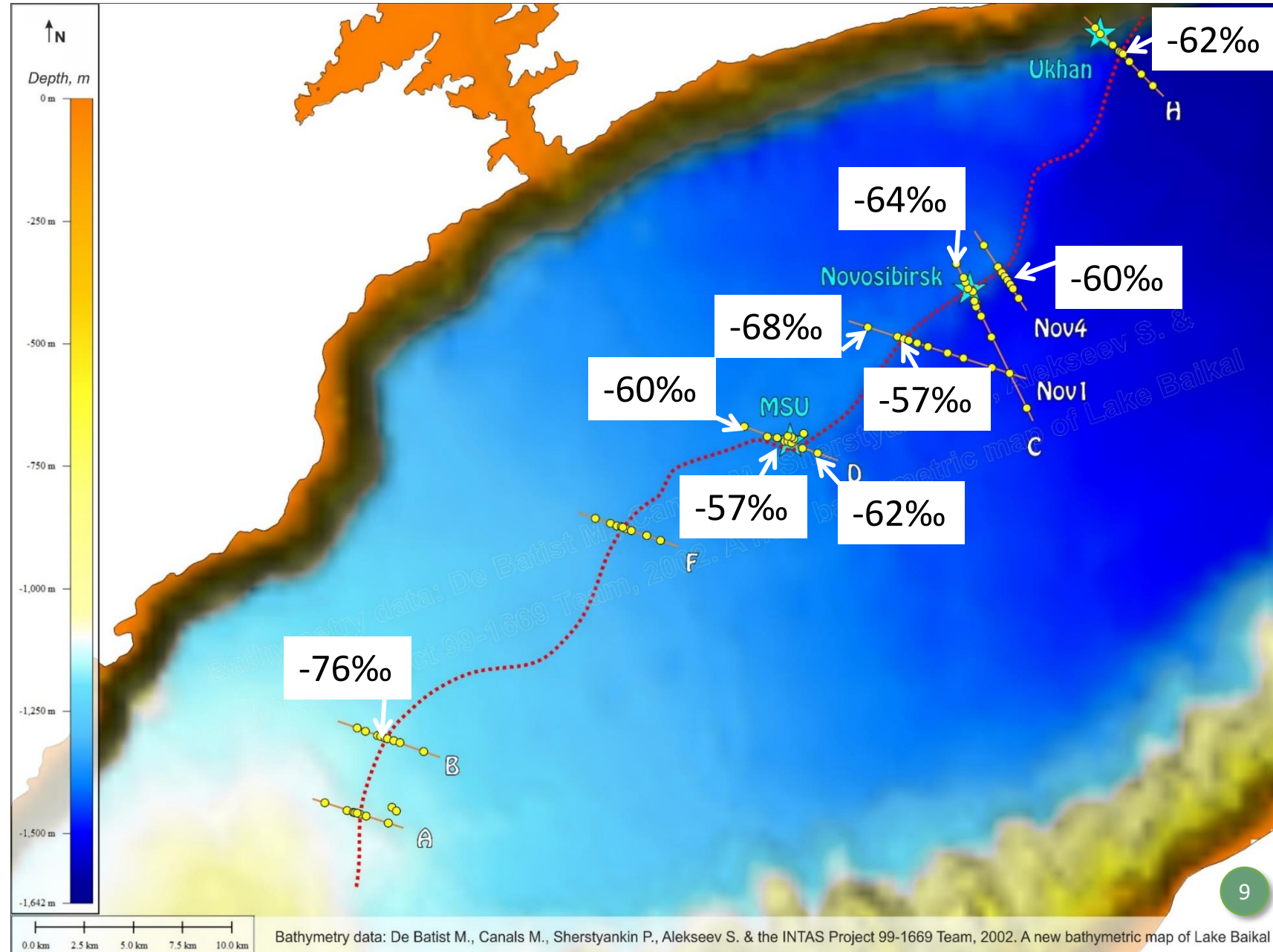118 129 126

0 6 12 18 24 30 КМ

7

Sum C2+

- The sum of C2+ components varies from 0 to 0,46.

- The sum of methane homologues is the highest when intersecting the main fault and increases northwards.

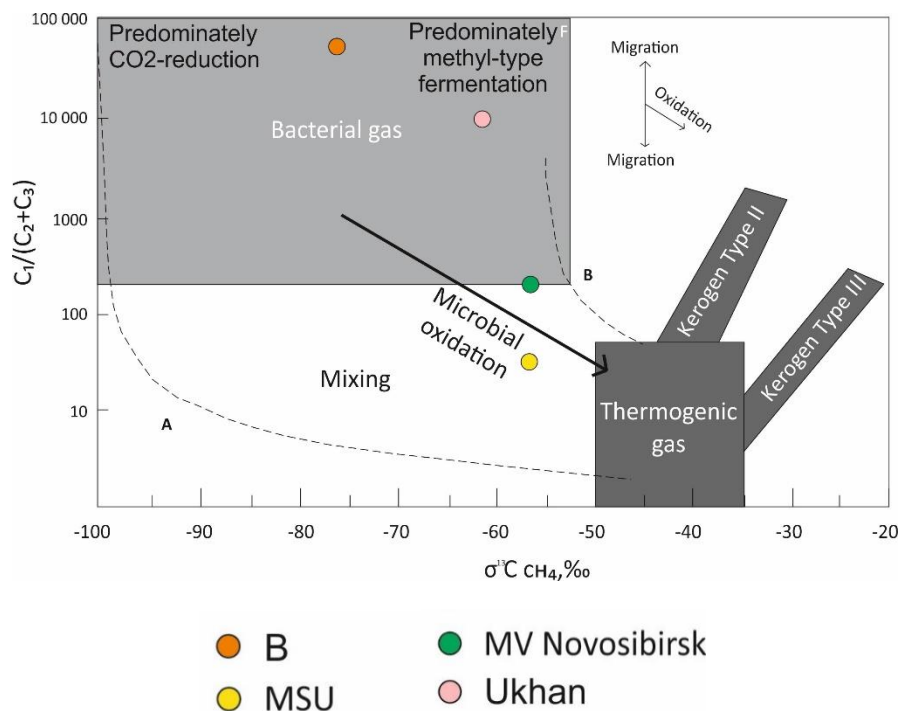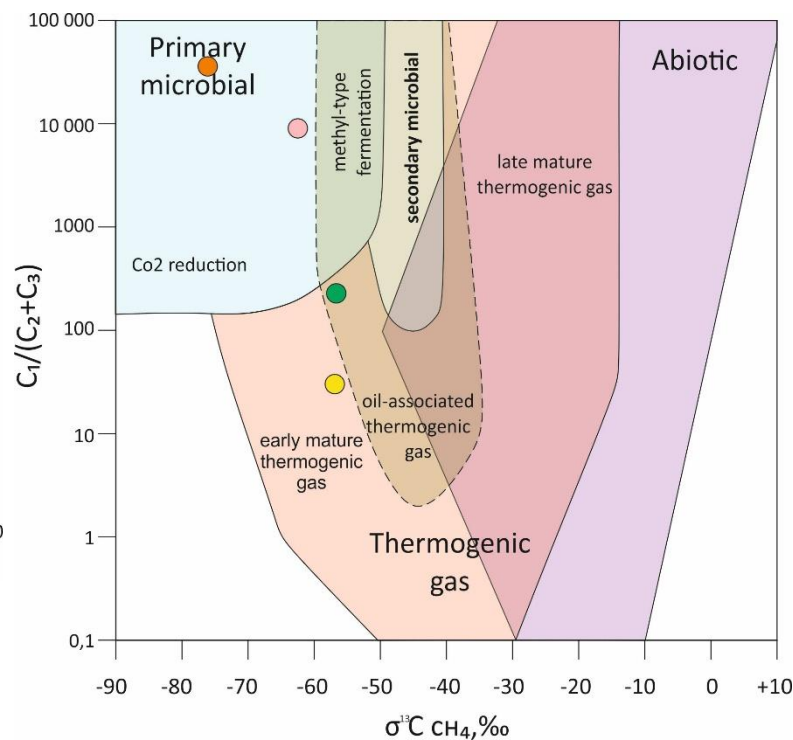- The highest values are observed at Novosibirsk mud volcano.
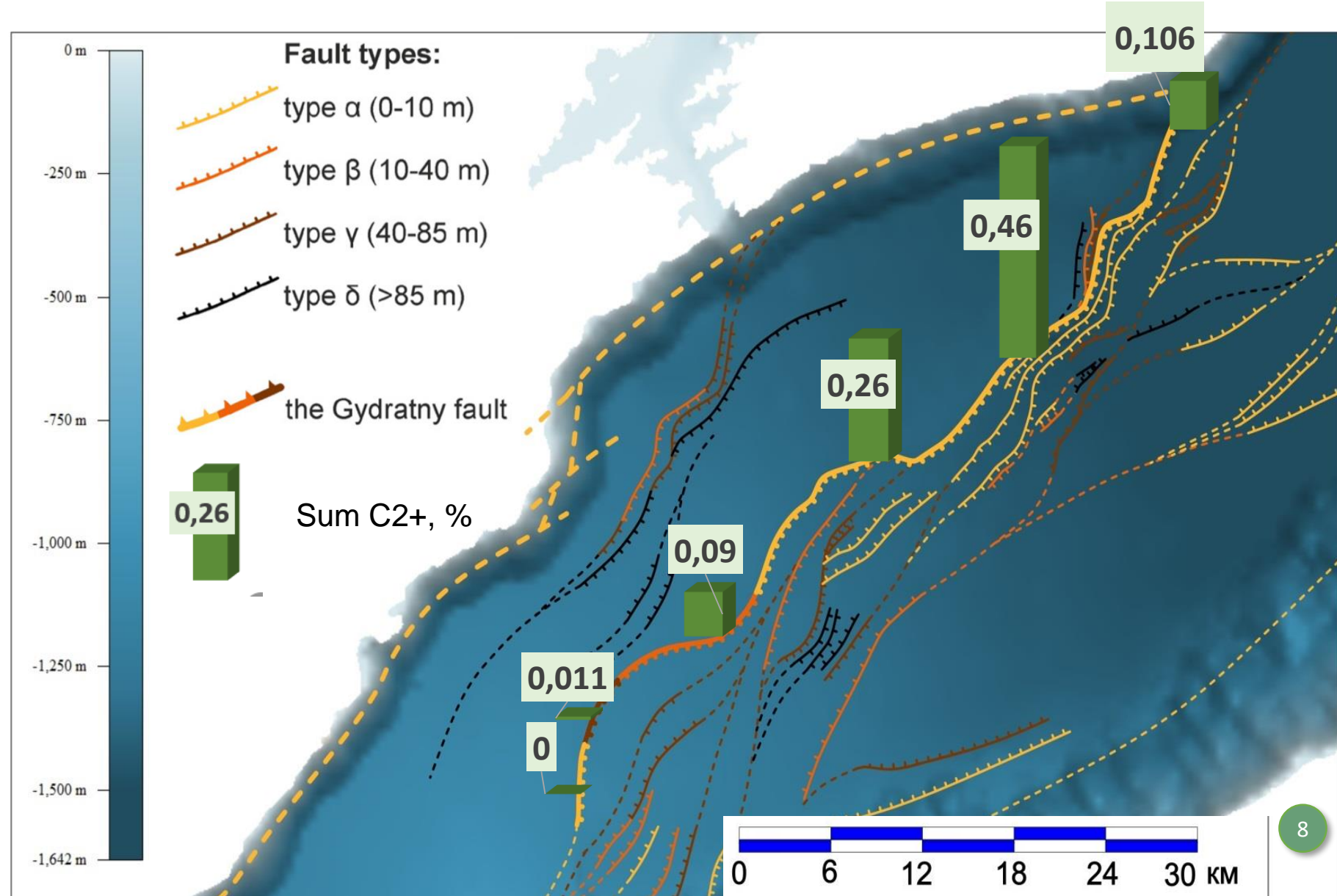
$\delta^{13}C$ of methane

- The methane carbon isotopic composition ranges from -72 to -57‰ VPDB.

- Methane is 13C-enriched above the gas focused zones: the structure MSU and MV Novosibirsk (-57‰ VPDB).

- The southern segments of the fault shows 13C-depleted methane (isotopically lower): -76 ‰ VPDB.

Bathymetry data: De Batist M., Canals M., Sherstyankin P., Alekseev S. & the INTAS Project 99-1669 Team, 2002. A new bathymetric map of Lake Baikal

Genetic type of gas

Bernard diagram to outline gas types (after Whiticar, 1994)

Legend: B, MSU, MV Novosibirsk, Ukhan

Genetic diagram of d13C-C1 versus C1/(C2 + C3) (Milkov, Etiope, 2018)
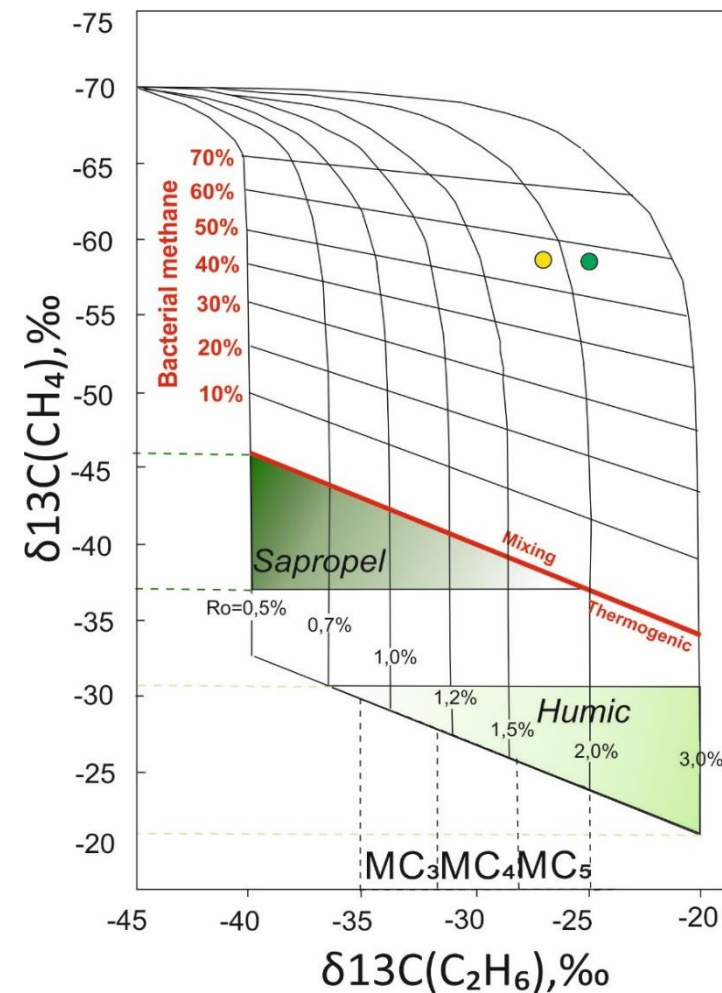
(D.Jarvie et al., 2007)

Gas from MSU structure and MV Novosibirsk has a mix origin.

The ethane carbon isotopic composition varies from -23 to -27 ‰ VPDB, suggesting that these are thermogenic gases that migrate from deep layers of the basin sedimentary infill.
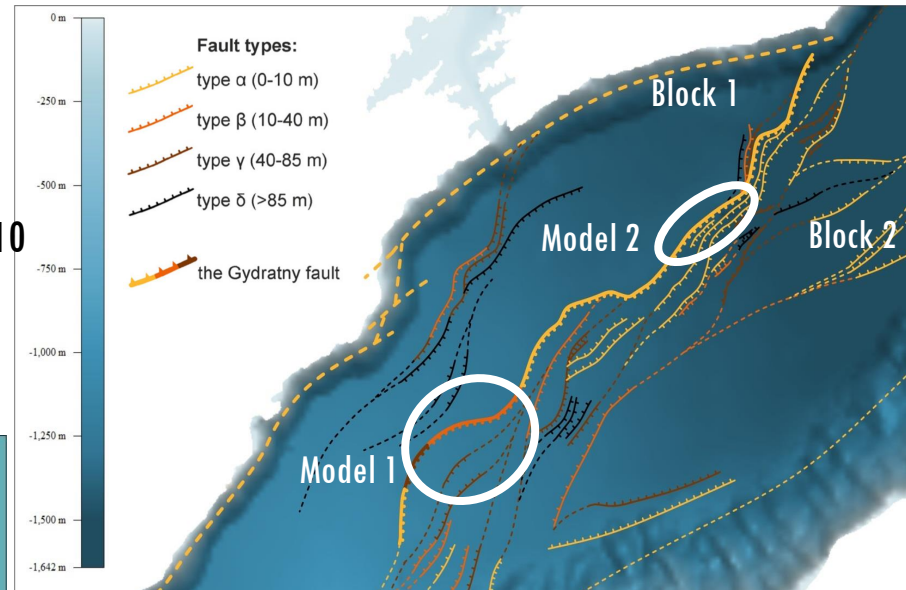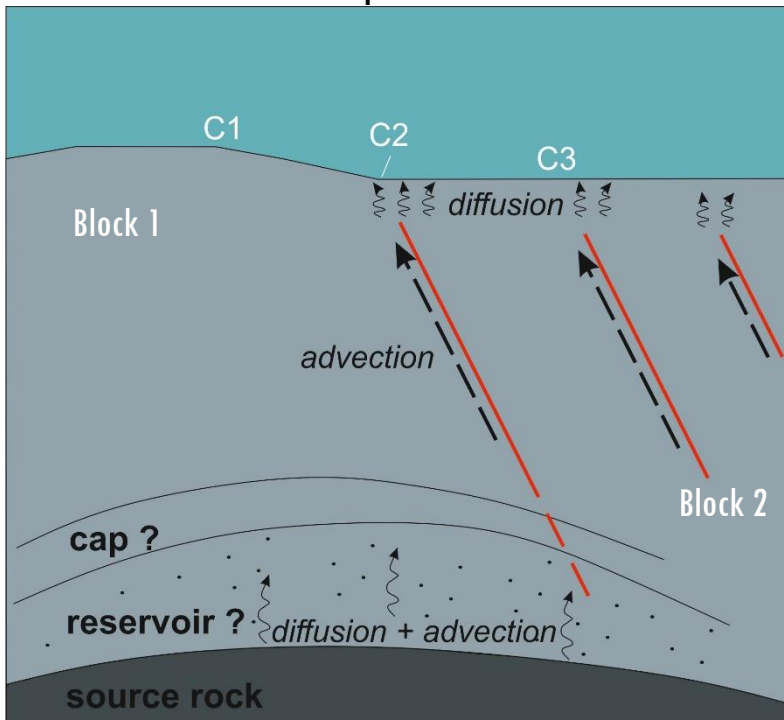
Organic matter is humic and high mature. The gas contains a significant amount of biogenic methane (more than 50%).

Gas migration models

Model 1

The fault does not reach the surface.

- Concentrated hydrocarbon fluids disperse in the overlying sediment.
- Methane concentration in sediments exceeds 2-10 times background values.
- Sum C2+ = 0-0,09 %.
- Methane is 13C-depleted.

Fault types:
- type α (0-10 m)
- type β (10-40 m)
- type γ (40-85 m)
- type δ (>85 m)
- the Gydratny fault

Block 1
Block 2
Model 2
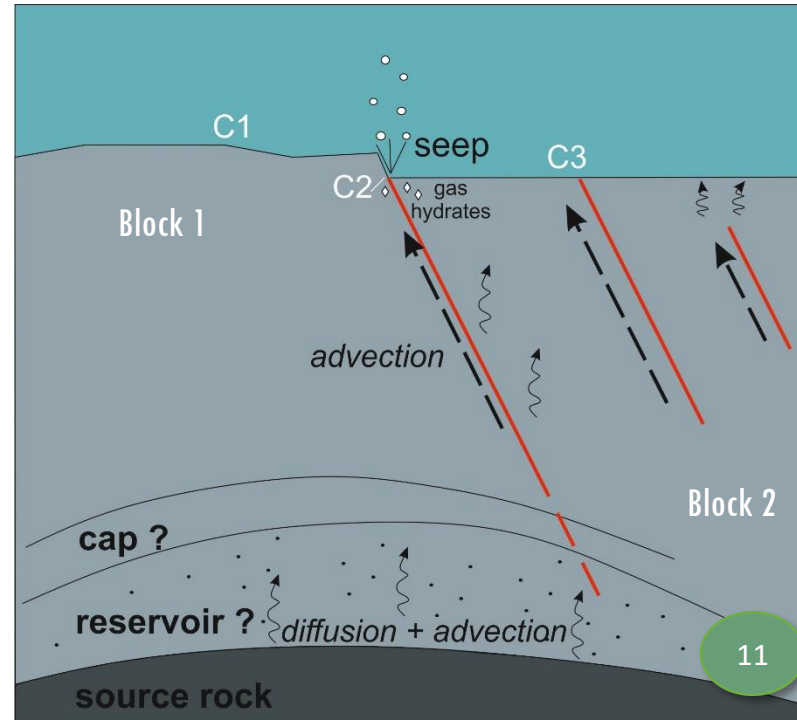Model 1

Concentration of methane

$$C1 < C2 > C3$$

The Gydratny master fault is accompanied by numerous subsidiary faults developed within hanging wall while footwall is less faulted. The associated faults are believed to enhance the main fluid migration system and this interpretation is supported by observations of normally higher methane concentrations in bottom sediments of the hanging block.

Model 2

The fault system is a well expressed normal fault.

- Concentrated gas fluids reach the lake floor, forming a zone of focused gas discharge and near-surface gas hydrates.
- The methane concentration in sediments exceeds 20-30 times background values.
- Sum C2+ = 0,11-0,26 %.
- Methane is 13C-enriched.

Block 1
Block 2
C1
C2
C3
diffusion
advection
cap ?
reservoir ? diffusion + advection
source rock

Block 1
Block 2
C1
C2
C3
seep
gas hydrates
advection
cap ?
reservoir ? diffusion + advection
source rock

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Conclusions

- The molecular and carbon isotopic composition of HC gases suggests that thermogenic gases migrates through a fault from deep layers of sedimentary infill of the basin.

- The concentration of methane and its homologues varies along the fault. Seismic data show a well-established segmented nature of the Gydratny Fault system, which is believed to control the observed variations of fluid discharge rates.

- The methane concentration in block 2 is higher than in block 1. The Gydratny master fault is accompanied by numerous subsidiary faults developed within hanging wall while the footwall is less faulted. The associated faults are believed to enhance the main fluid migration system.

- The mechanism of molecular and isotopic fractionation is well represented within the Gydratny fault, allowing the study these phenomena occurring at close distances. This confirms the uniqueness of Lake Baikal as a natural laboratory.

Thank you for the attention!