Gas Hydrates of Lake Baikal

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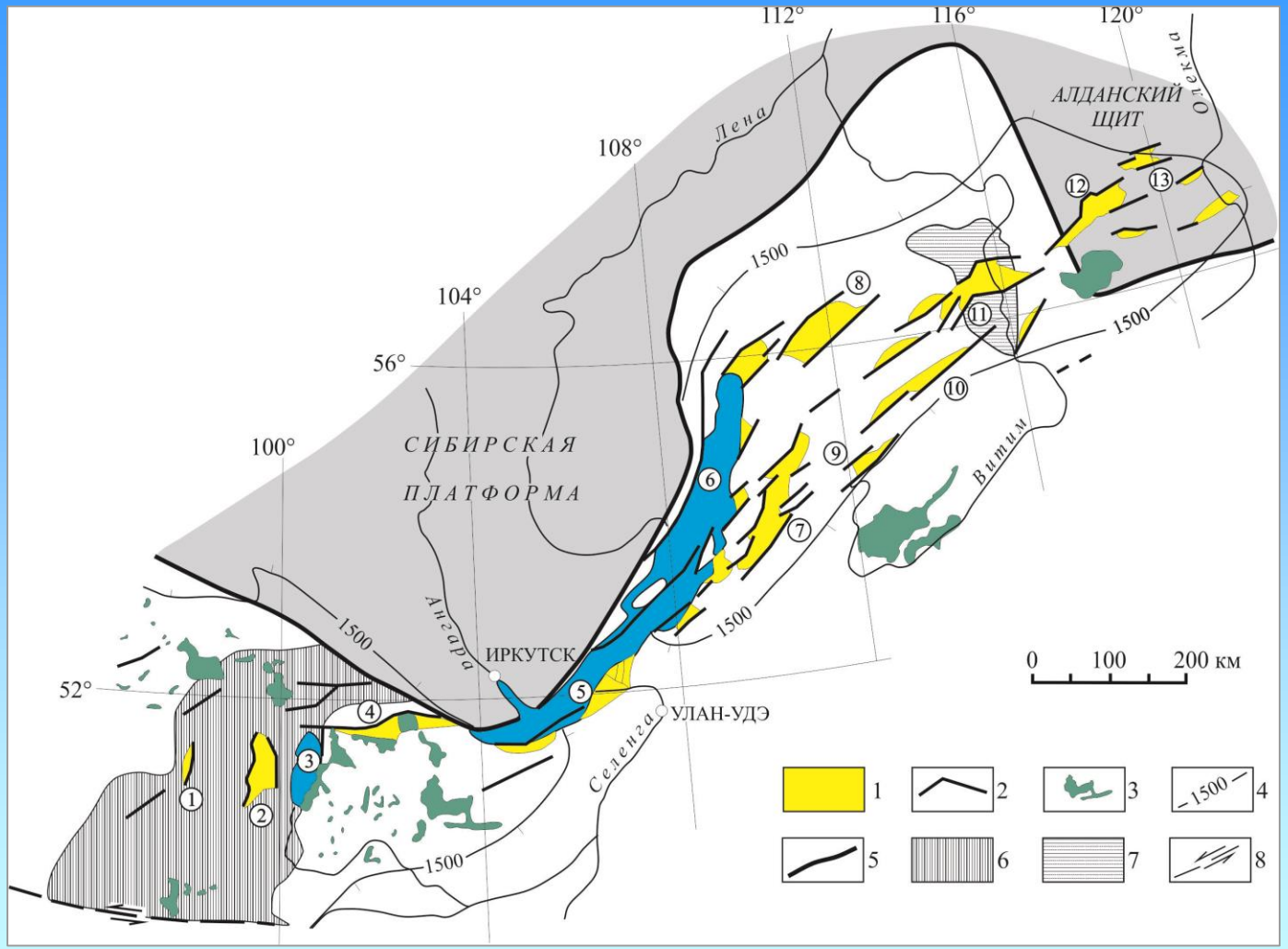
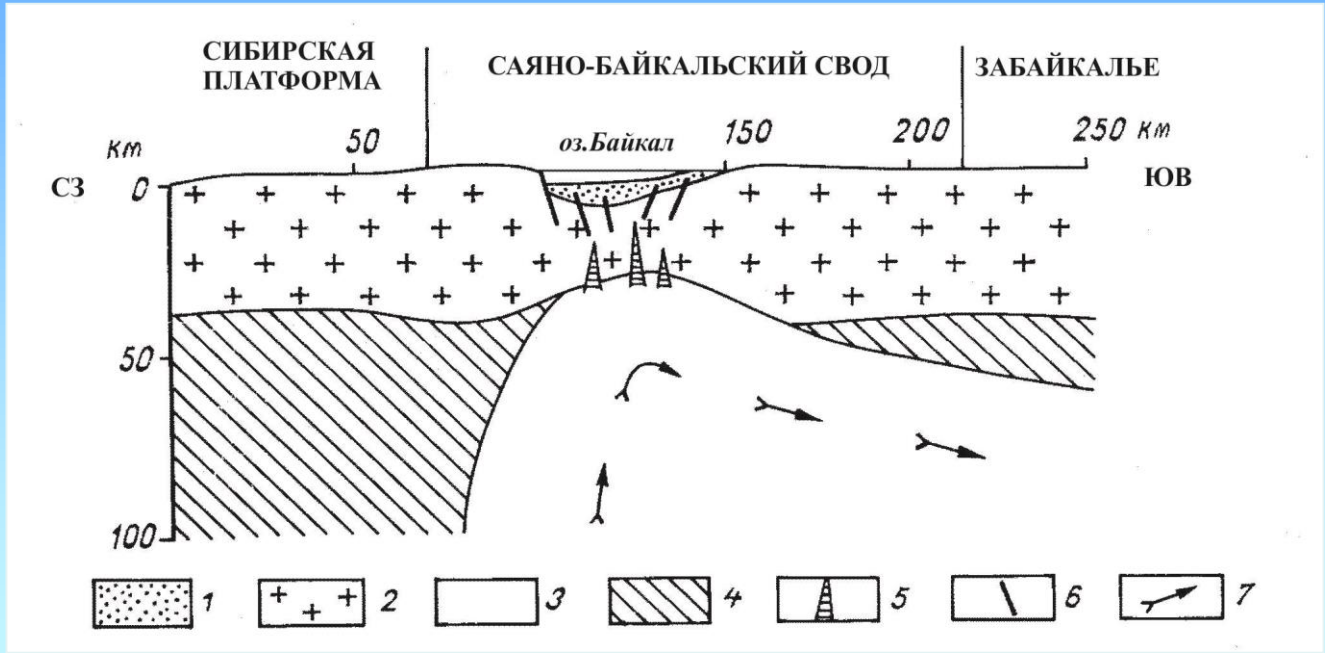
Baikal 2016

Structural position and morphology of the Baikal rift (Logachev, 2003)



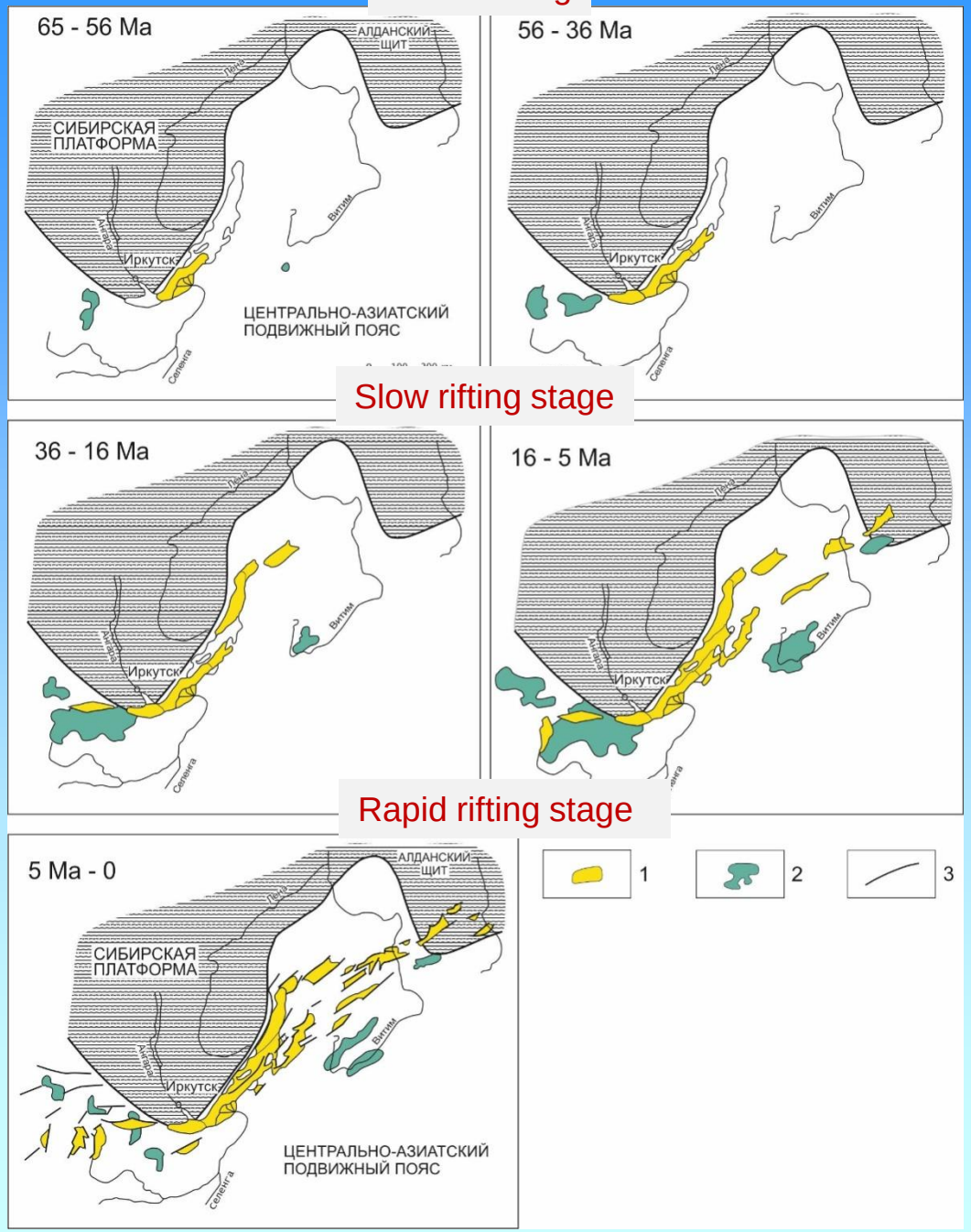
1- rift depressions; numbers in circles: 1 – Busingolsk, 2 – Darkhat, 3 – Khubsugul, 4 – Tunka, 5 – South Baikal, 6 – North Baikal, 7 – Barguzin, 8 – Upper Angara, 9 – Tsipa, 10 – Baunt, 11 – Muya, 12 – Chara, 13 – Tokko; 2 – faults with different kinematics; 3 – volcanic fields; 4 – 1500-meter contour line of the original plantation surface; 5 – the border of the Siberian platform and he Sayan-Baikal mobile belt, 6 – the Tuva-Mongolian microcontinent; 7 – Muya terrane, 8 – eastern part of the Bolnay fault regenerated in the 1905 earthquake.

Formation model of the Baikal rift zone in active rifting (Logatchev, Zorin, 1987)



Structure evolution of the Baikal rift zone (Logachev, 1993, 2002)

Active rifting



Two-term structure of the rift depression section

<u>Early orogenic phase</u>

The lower part of the section contained sandstones, siltstones, mudstones and clays with occasional layers of brown coal, diatomite and marl.

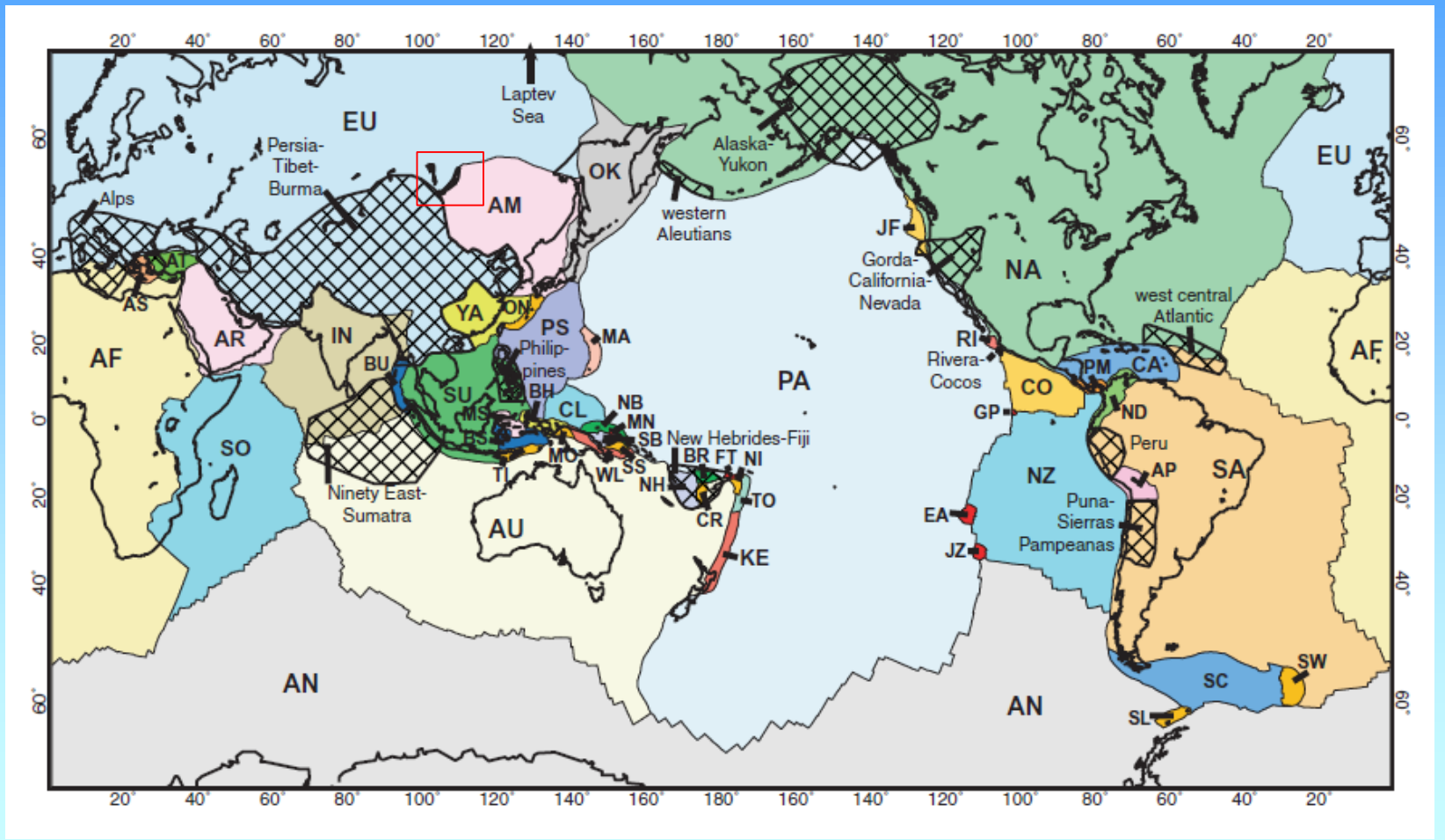
Lifting of the mantle plume and arch formation

<u>Late orogenic phase</u>

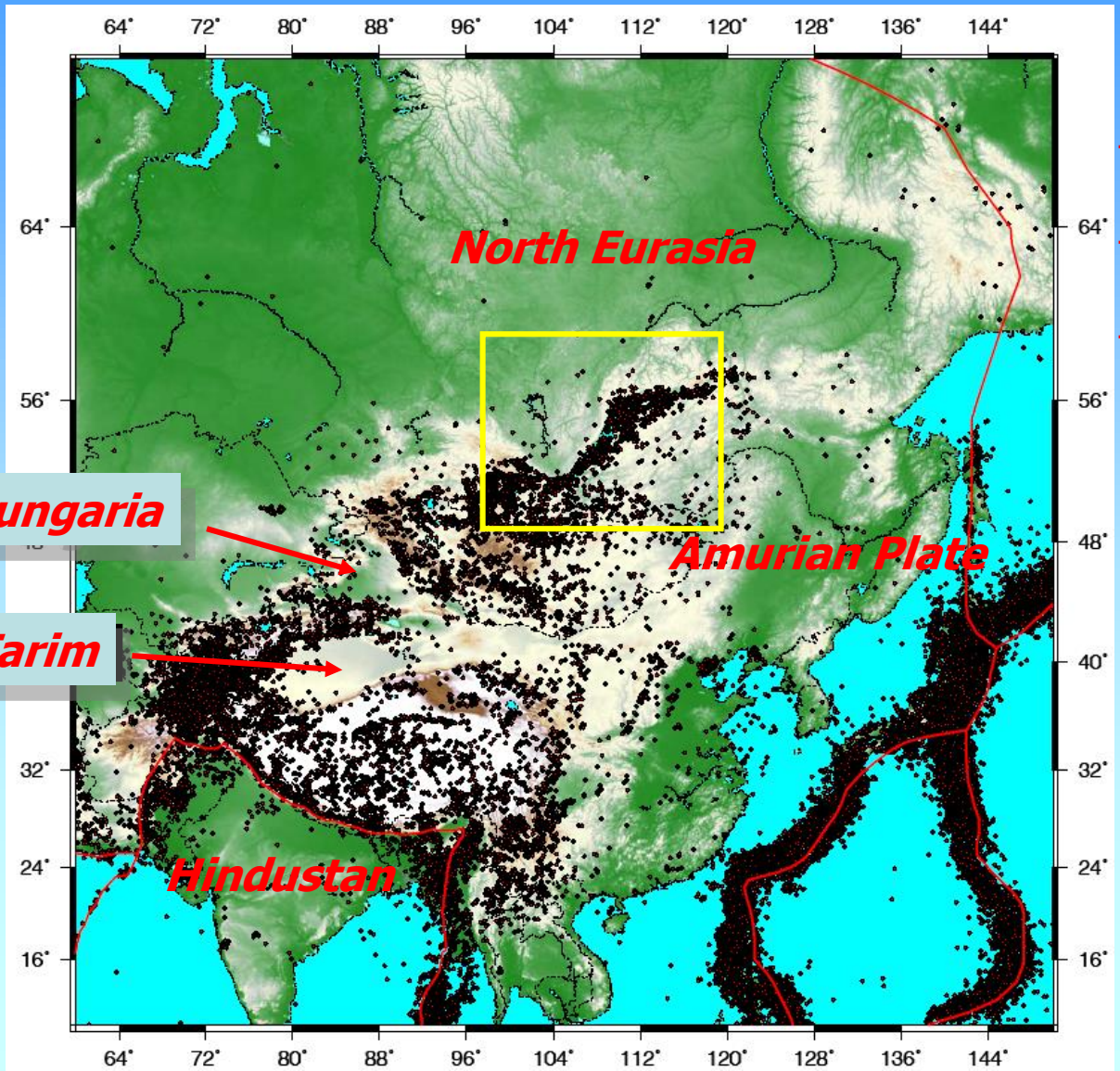
The upper part of the section in margins of the depressions contained sands, gravel, pebbles and conglomerates. The inner parts of the basins contained sands, siltstones and clays with occasional peatbog interlayers.

Plume spreading and stretching acceleration

Scheme of the Earth's lithospheric plates and blocks (Bird, 2004)

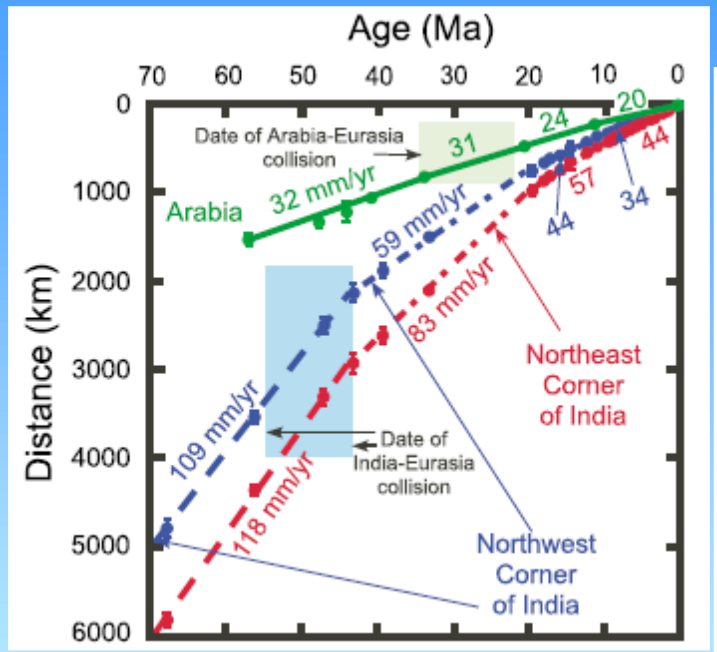


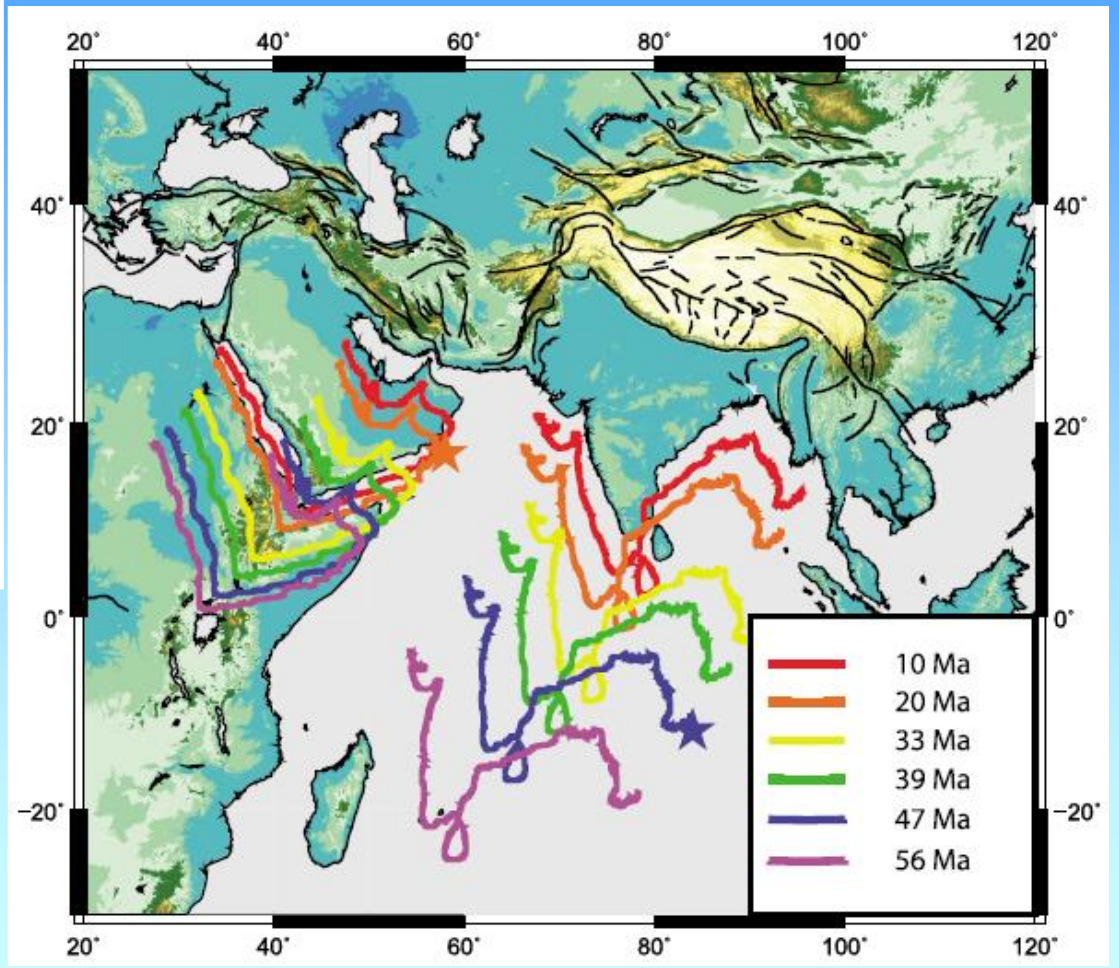
Position of the Baikal rift zone
(dots indicate the epicenters of the 1994-2000 earthquakes, M>4)



- Localization near the stable North Eurasia
- High tectonic and seismic activity
- Source of tectonic forces?

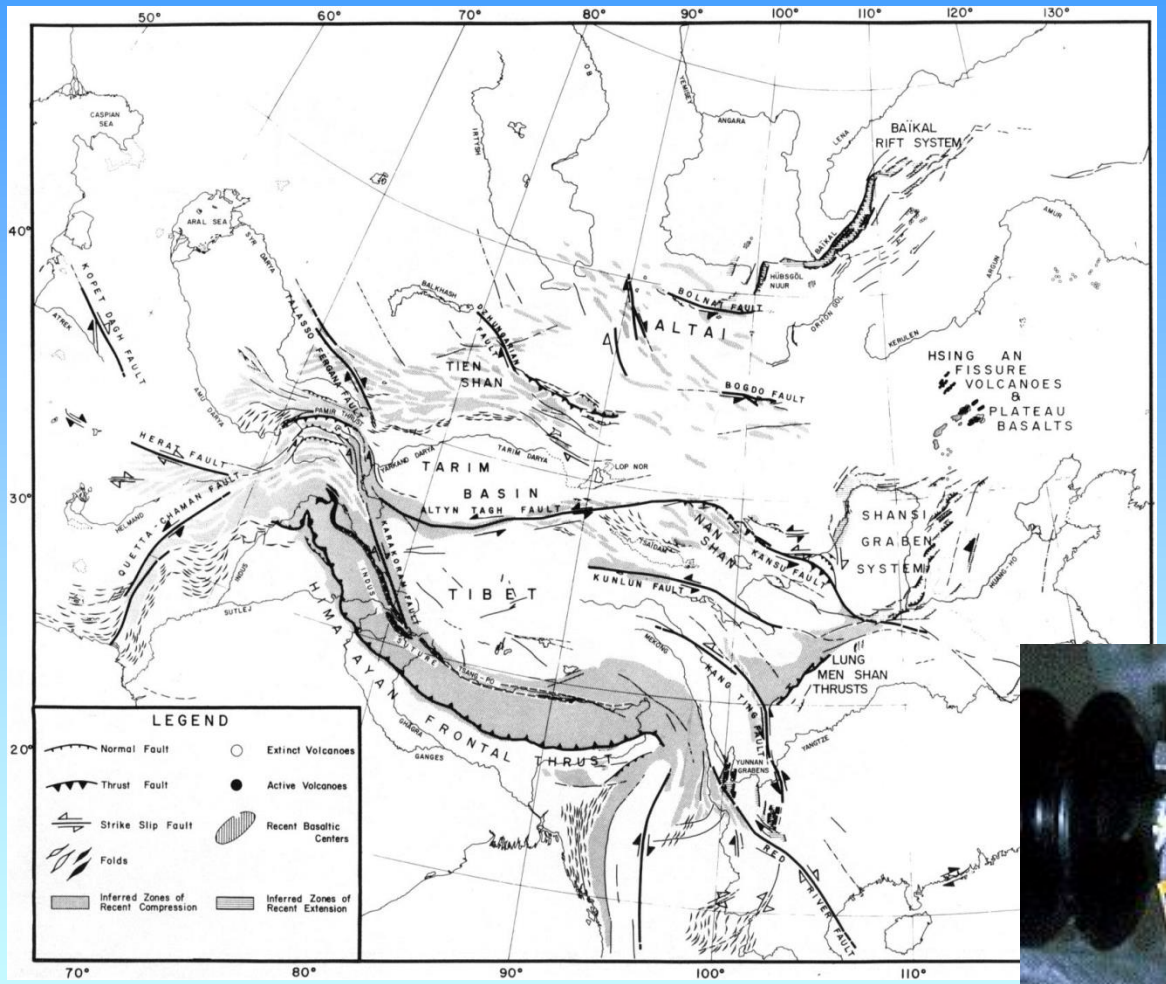
Convergence history of the Hindustan, Arabia and Eurasia blocks (by Hatzfeld & Molnar, 2009)





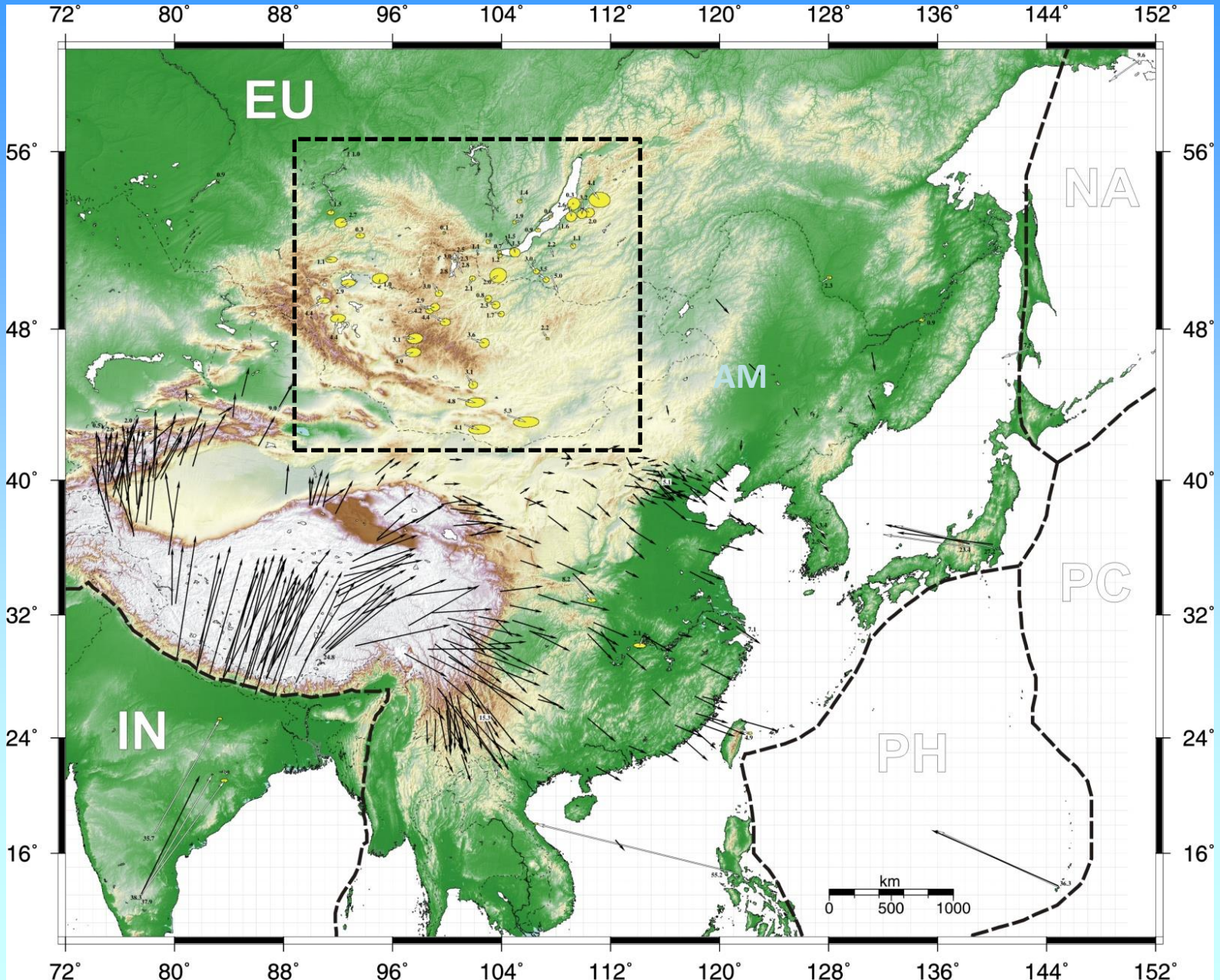
Alternative data:
The collision onset ~34 Ma (Aitchison et al., 2007; Bera et al., 2008; Henderson et al., 2011).

Formation models of the tectonic structures in the zone of the continental collision of Hindustan and Eurasia (Molnar & Tapponnier, 1975)

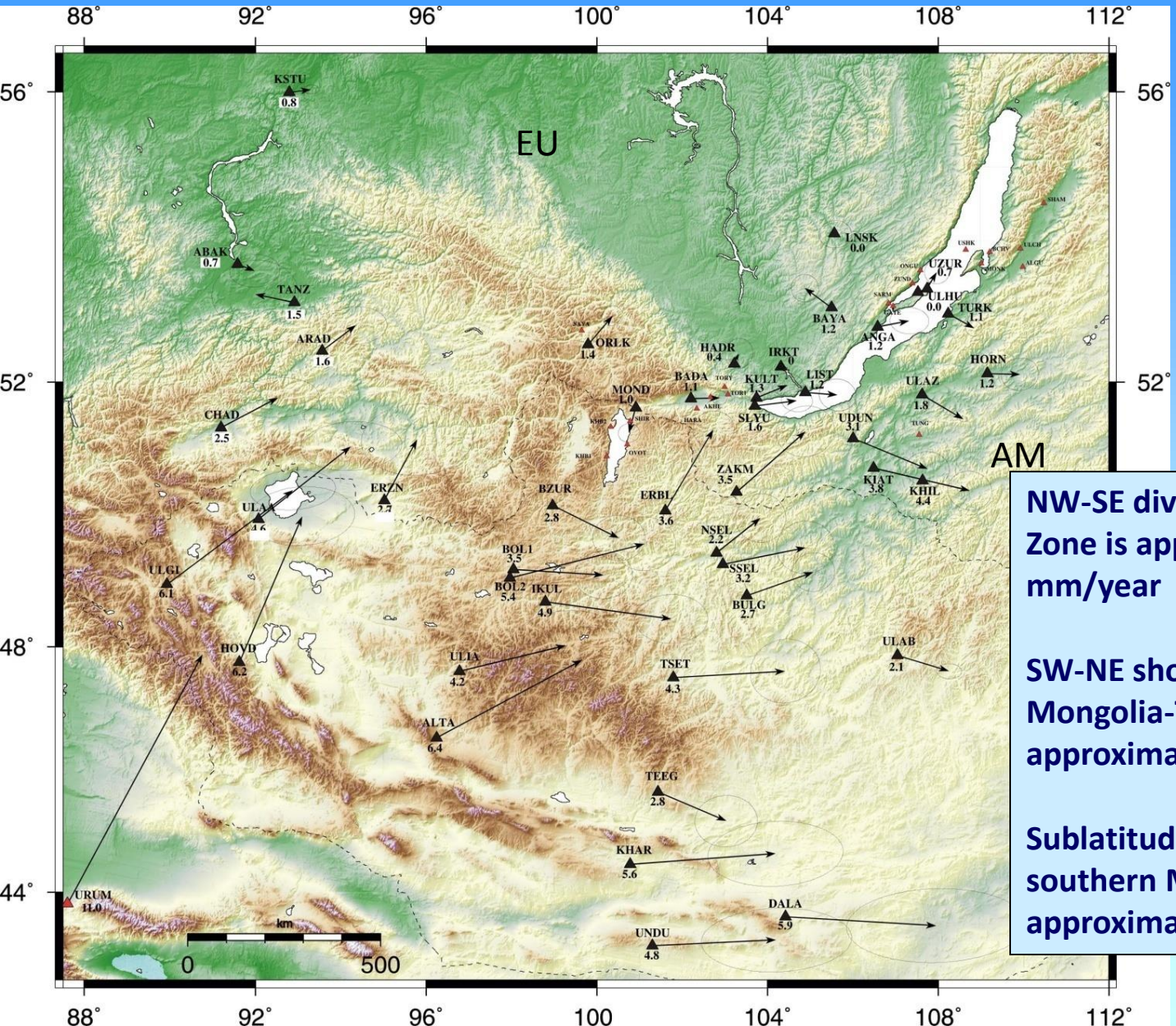


Physical modelling of lateral extrusion on the plasticine model (Tapponnier et al., 1982)

Horizontal displacement velocity field of Central and Eastern Asia based on the GPS-measured data (with respect to North Eurasia) (Wang et al, 2001)



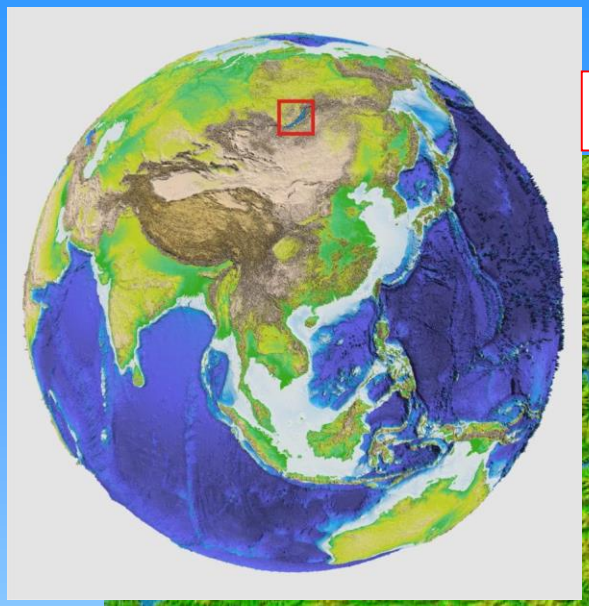
Horizontal displacement velocity field of Mongolia-Siberia mobile area based on the 1994-2007 measured GPS-data with respect to the IRKT (Irkutsk) site (according to V.A. Sankov)



NW-SE divergence in the Baikal Rift Zone is approximately 3-4 mm/year

SW-NE shortening in western Mongolia-Tuva-the Eastern Sayan is approximately 2-4 mm/year

Sublatitudal shift of central and southern Mongolia is approximately 4-5 mm/year



Lake Baikal is located in Central Asia

Thickness of sediments, km

Max depth, m

4,5 km

940m

Age >25 My

1642m

7,5 km

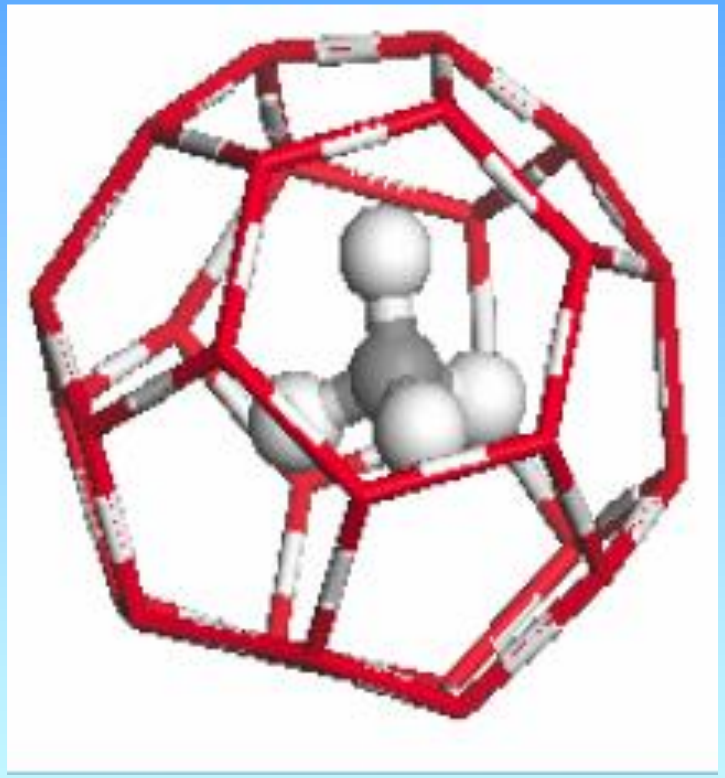
> 9 km

1420m

5,5 km

The age and thickness of the Baikal deposits favour formation and accumulation of gas and liquid hydrocarbons. The depth of the lake (with respective high pressure) and the low near-bottom water temperature (ca. 3.5 degrees) results in the presence of gas hydrates.

A sketch of elementary cell of Gas Hydrate (GH)



1m^3 GH =160m^3 methane

Phase boundary diagram of gas hydrate stability

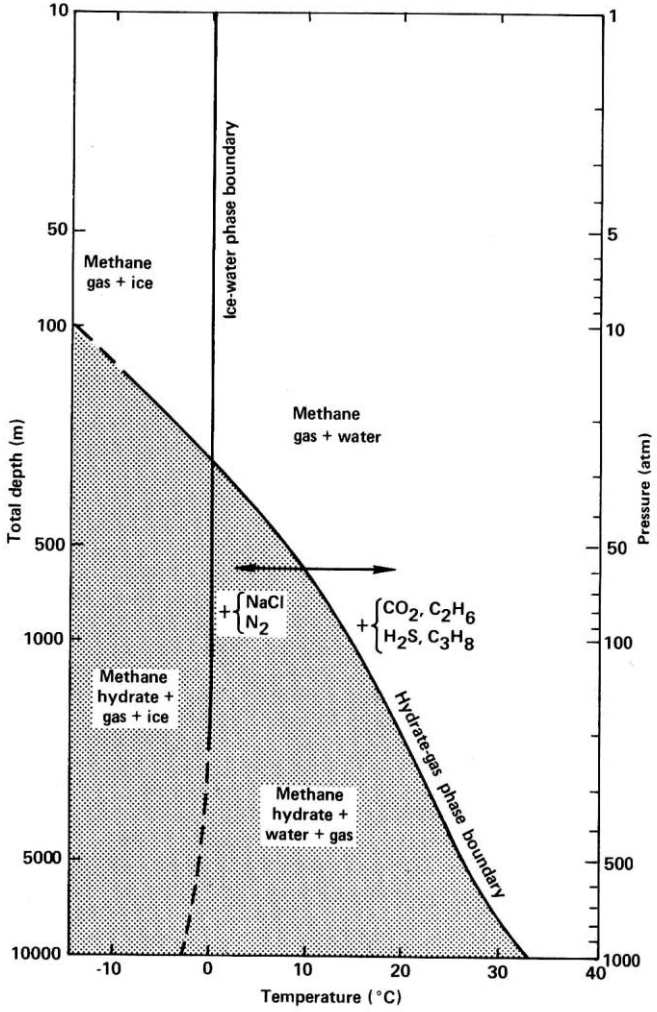
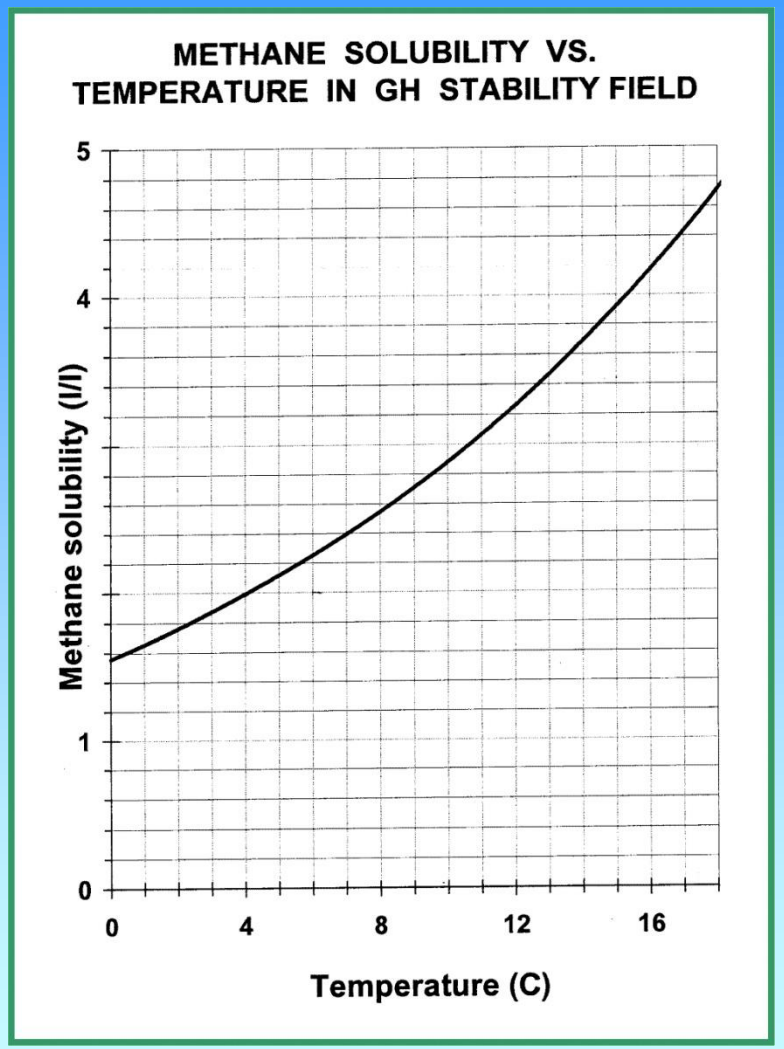
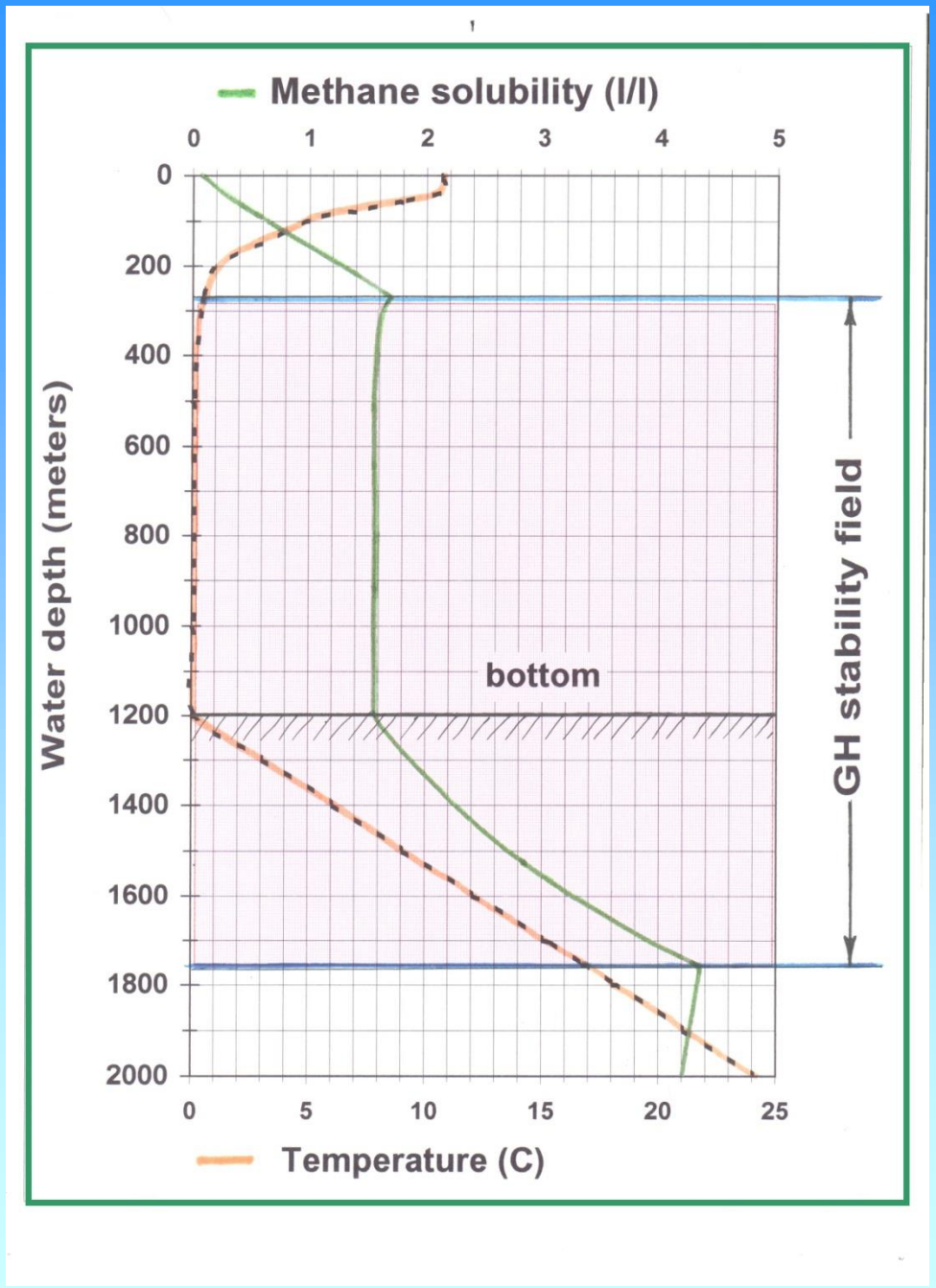


Figure 2. Phase boundary diagram showing free methane gas and methane hydrate (pattern) for a pure water and pure methane system. (Addition of NaCl to water and of N_2 shifts the curve to the left. Additions of CO_2, H_2S, C_2, and C_3 to C_1 shift the boundary to the right. Arrows indicate the direction but not the magnitude of the shifts. Depth scale is an approximation based on the assumption that lithostatic and hydrostatic pressure gradients are both 0.1 atmosphere per meter. Redrawn after Katz et al. [1959] and modified from Kvenvolden and McMenamin [1980].)


METHANE SOLUBILITY VS.
TEMPERATURE IN GH STABILITY FIELD
Methane solubility (l/l)
0
1
4
5
0
4
8
12
16
Temperature (C)


Methane solubility (l/l)
0
1
2
3
4
5
Water depth (meters)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
bottom
GH stability field
0
5
10
15
20
25
Temperature (C)

Idealized section that show zone of gas hydrate stability for outer continental margins

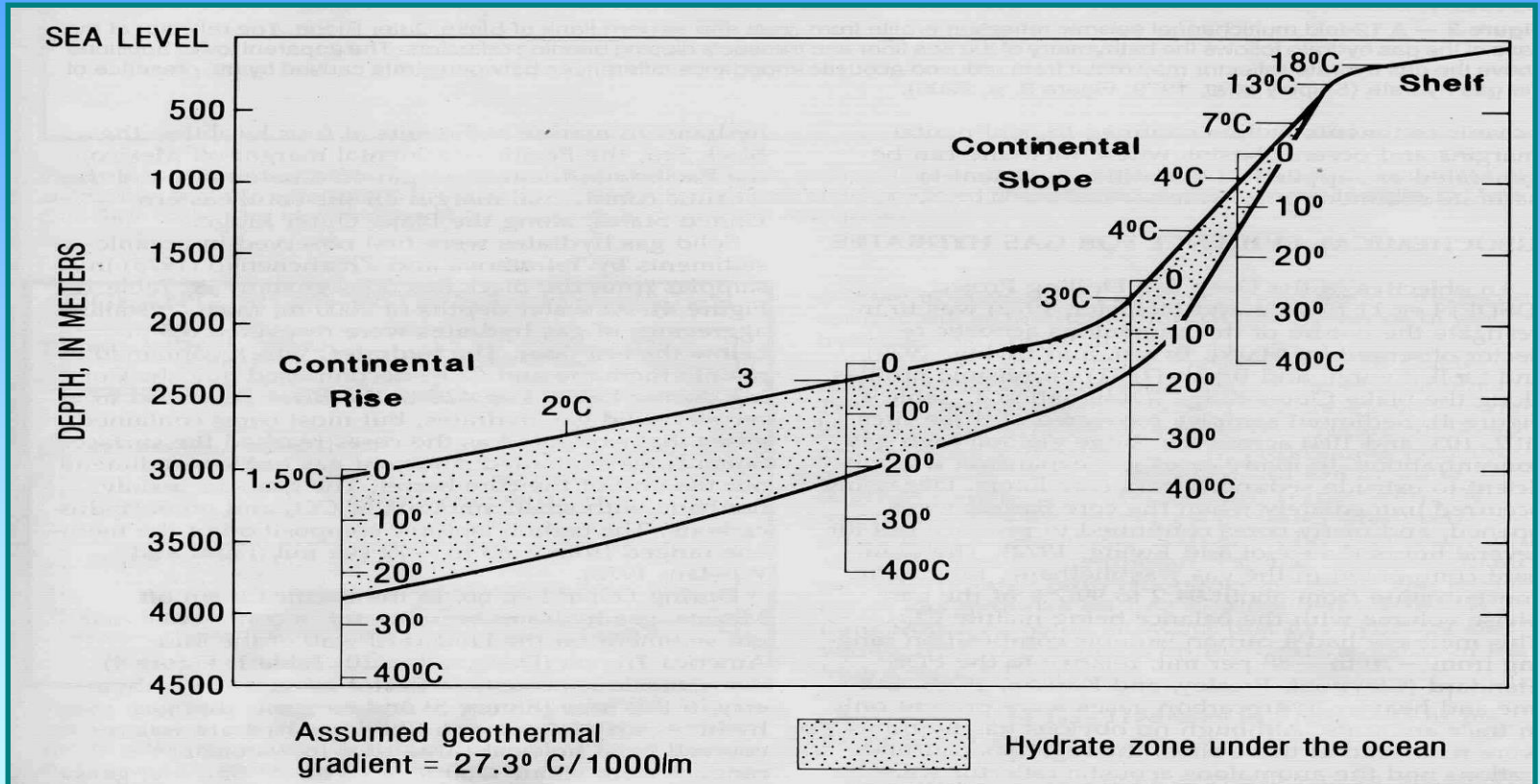


Figure 2 — Idealized section that shows the zone of gas hydrate stability for outer continental margins. Stippled area is potential region of gas hydrate formation where pressure and temperature conditions are correct for hydrate stability (Figure 1) assuming an adequate methane supply. The following assumptions apply: 1) geothermal gradient of 27.3°C/km; 2) lithostatic and hydrostatic pressure gradients of 0.1 atm/m; and, 3) bottom-water temperature range from 1.5° to 18°C depending on water depth. Redrawn from R. D. McIver, written communication, 1979.

Bottom Simulated Reflector on seismic profile

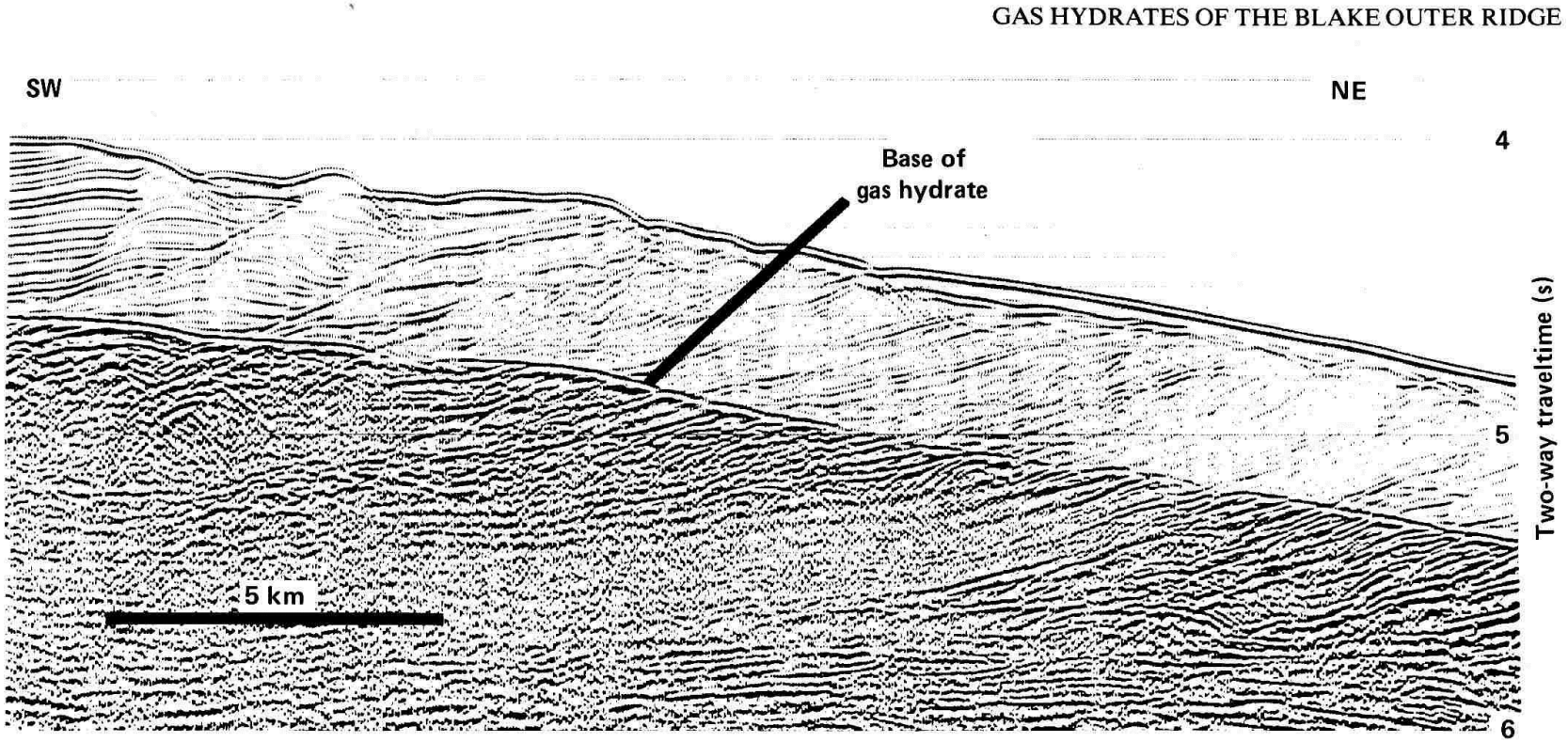
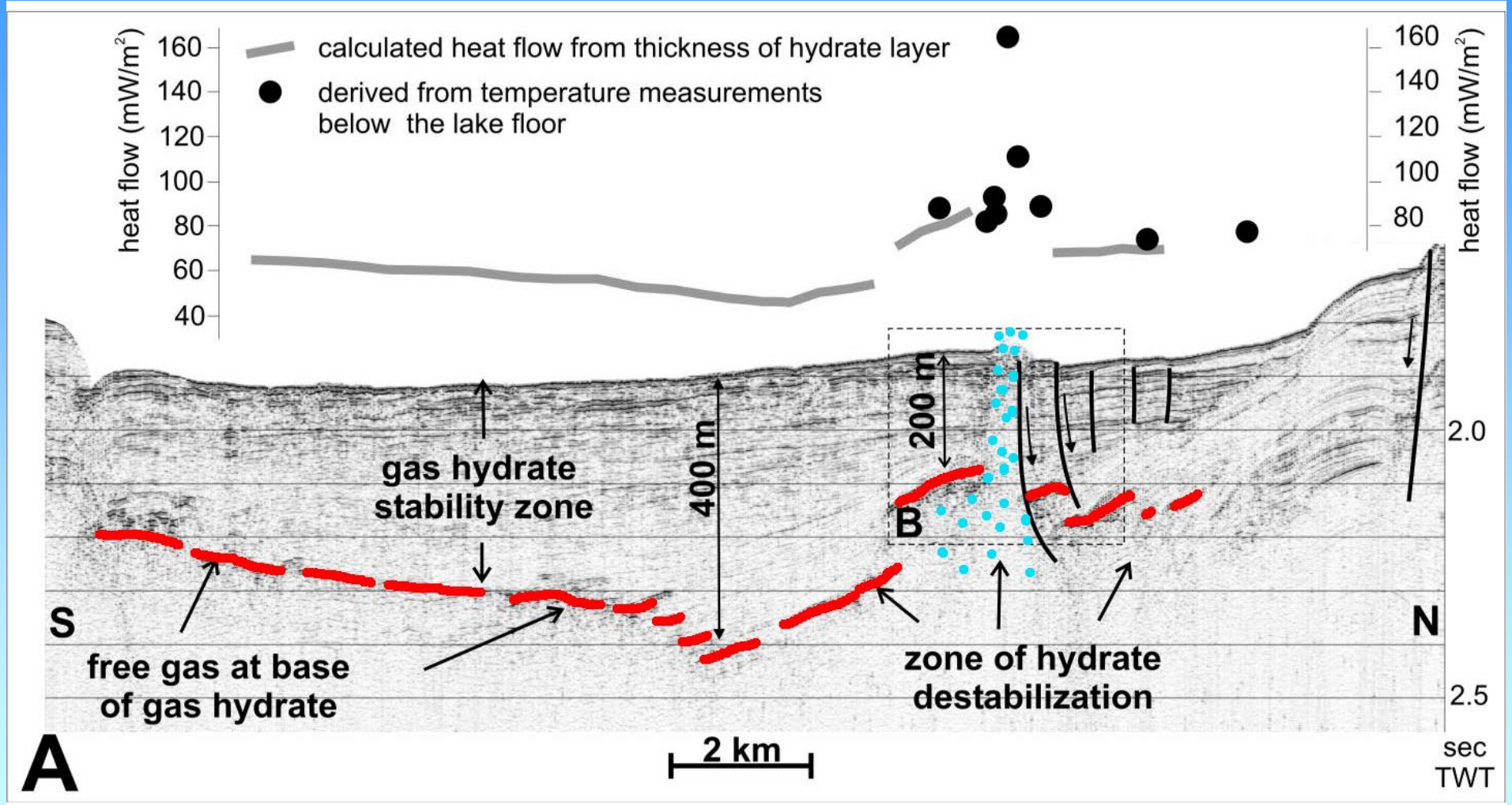
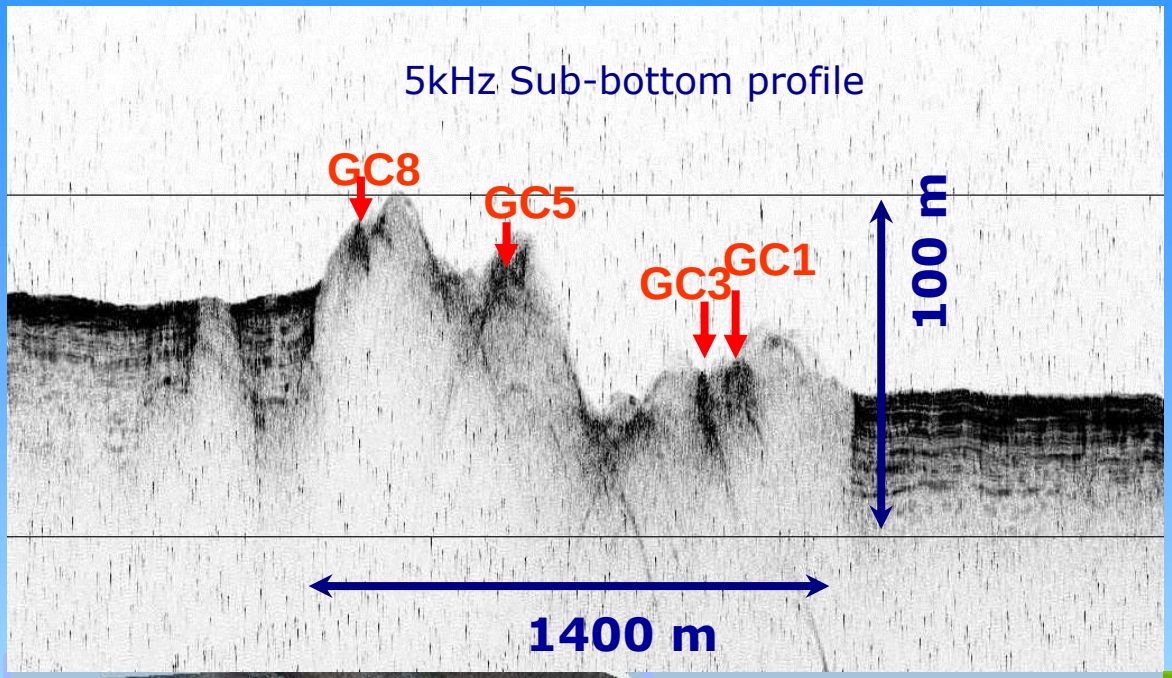


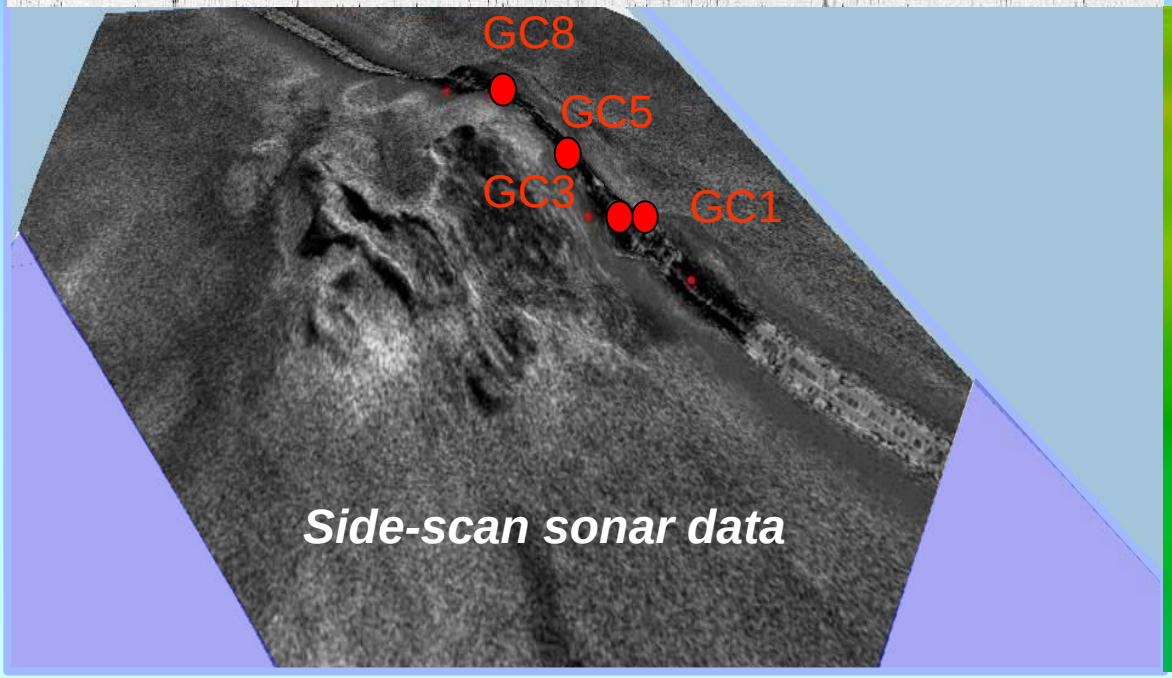
Figure 3. A 12-fold multichannel seismic reflection profile from the crest and eastern flank of the Blake Outer Ridge. (The reflector probably marks the base of the gas hydrate and follows the bathymetry of the seafloor and transects dipping bedding reflectors [Shipley et al., 1979, fig. 3, p. 2206].)

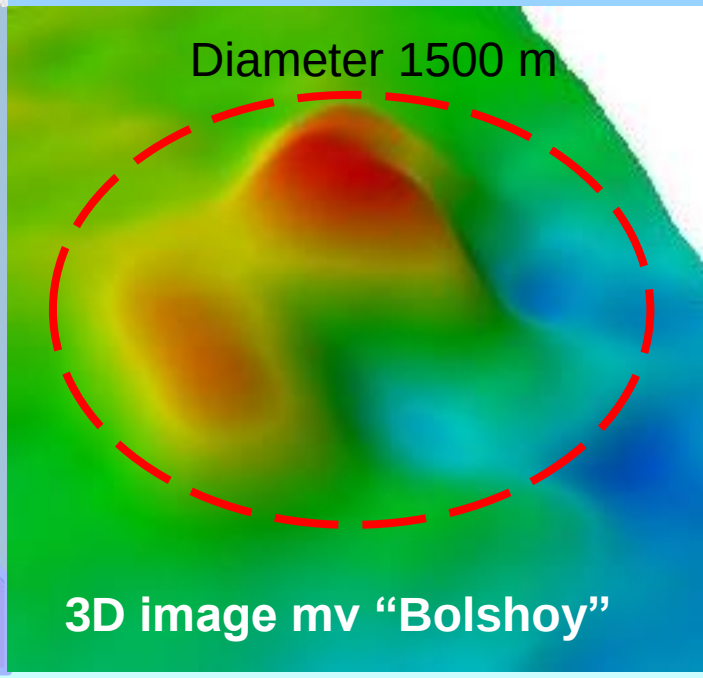


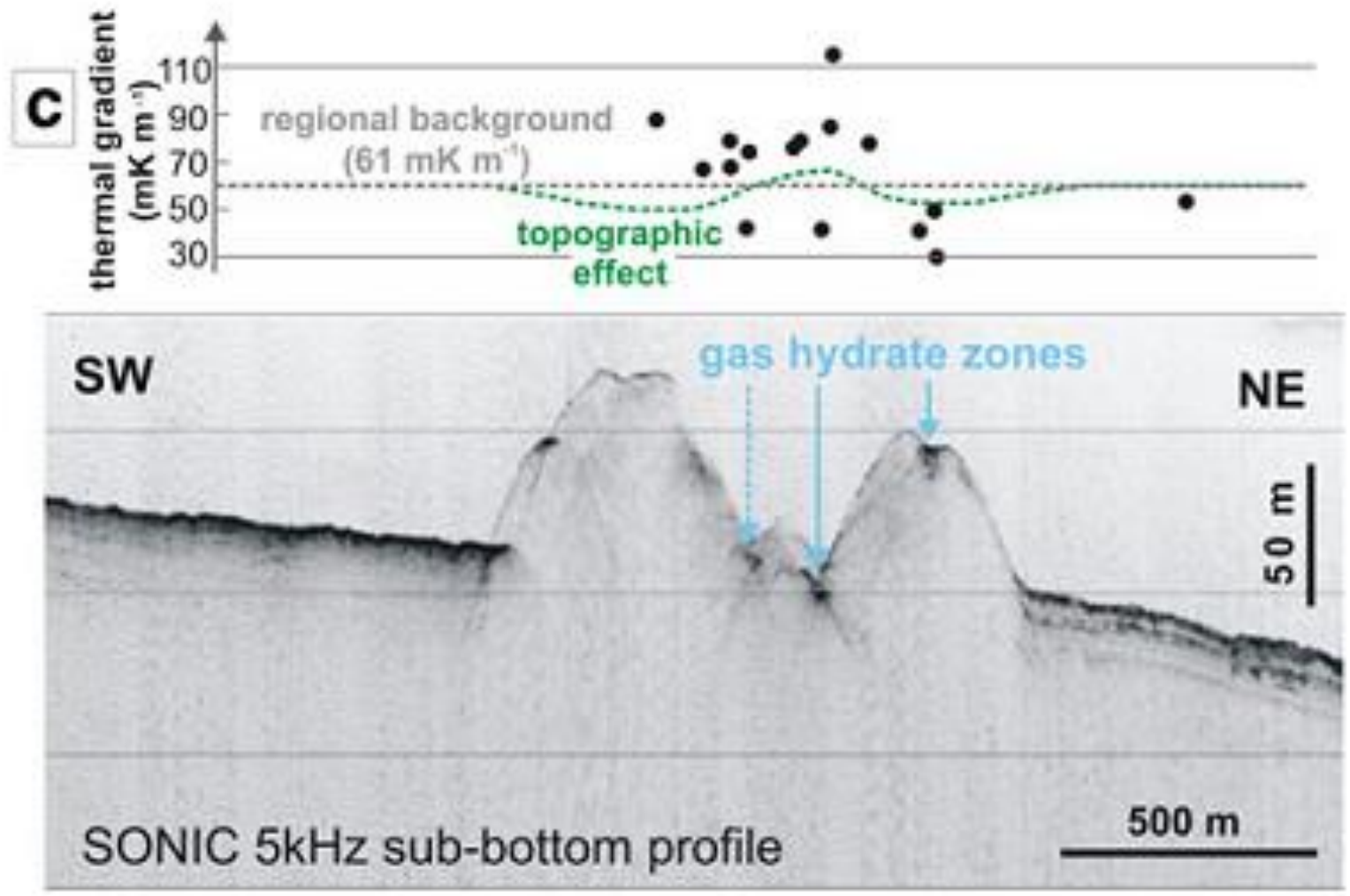
P. Van Rensbergen* et. al. 2002 Geology; v. 30; no. 7; p. 631-634;



Geophysical data indicate the presence of hydrates by dark patches. Hydrates have only been retrieved at these patches.

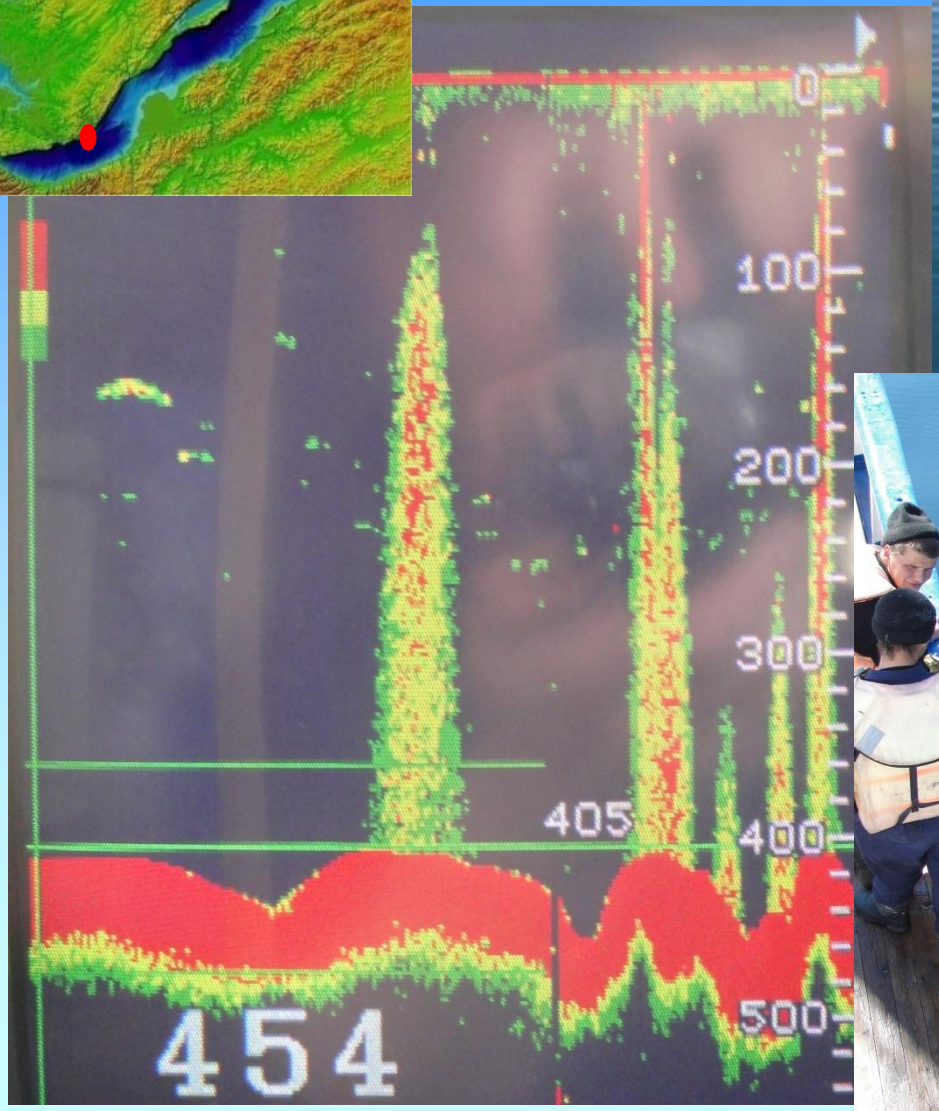


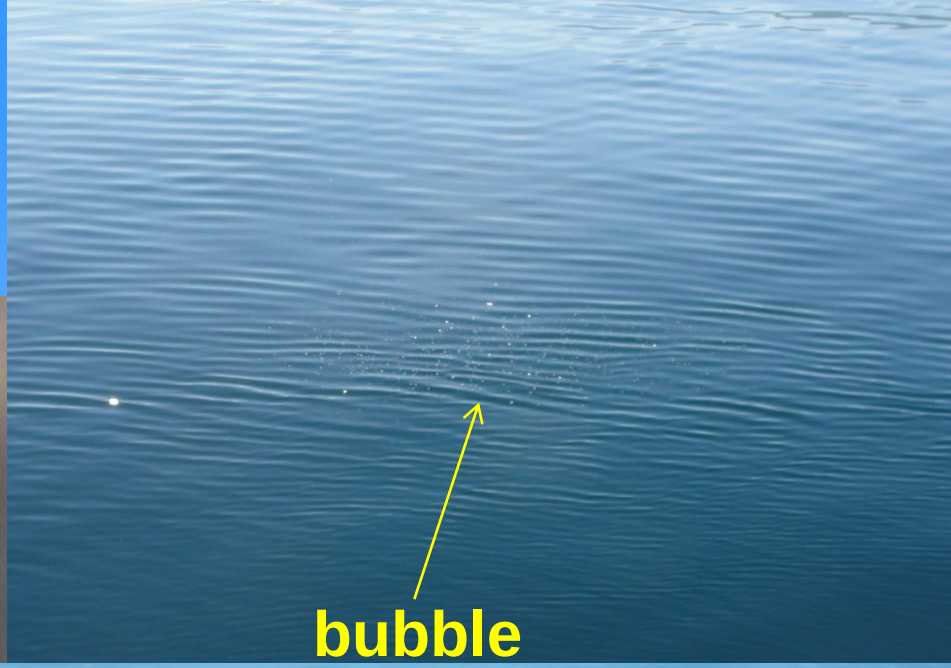




Poort et al., Geo-Mar Lett (2012) 32:407-417

«Goloustnoe» (G-2)





bubble

A gas hydrate in the form of frozen sand and silt layers was discovered at the depth of 121m and 161 m in the sediment core.

This is first depth hydrate samples in Baikal

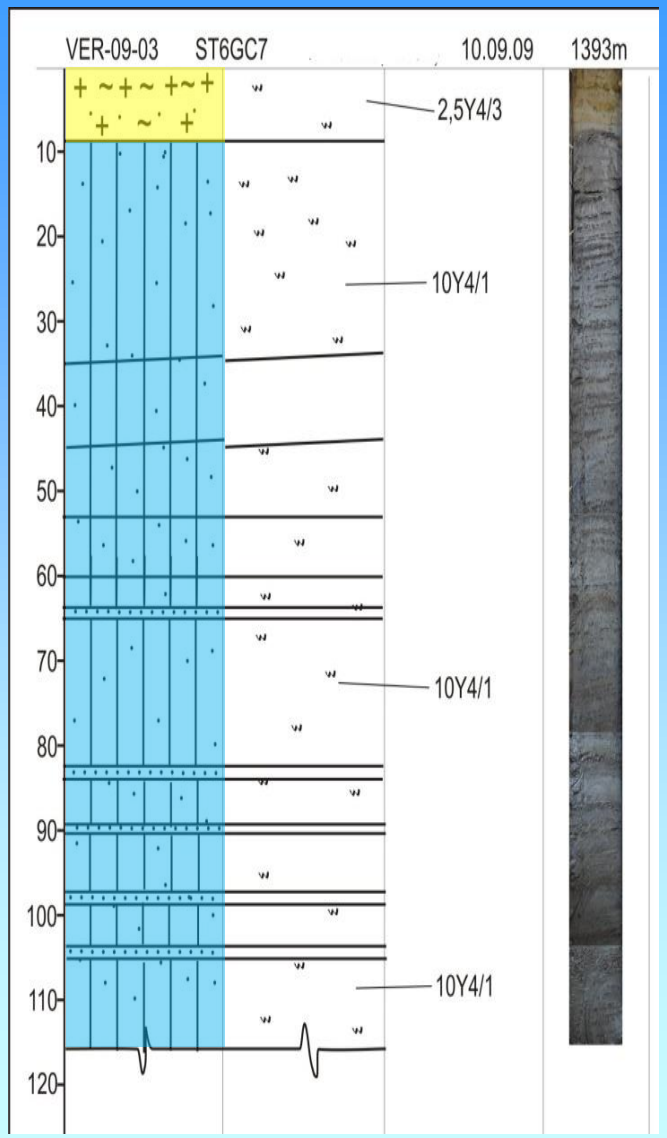
BDP-97

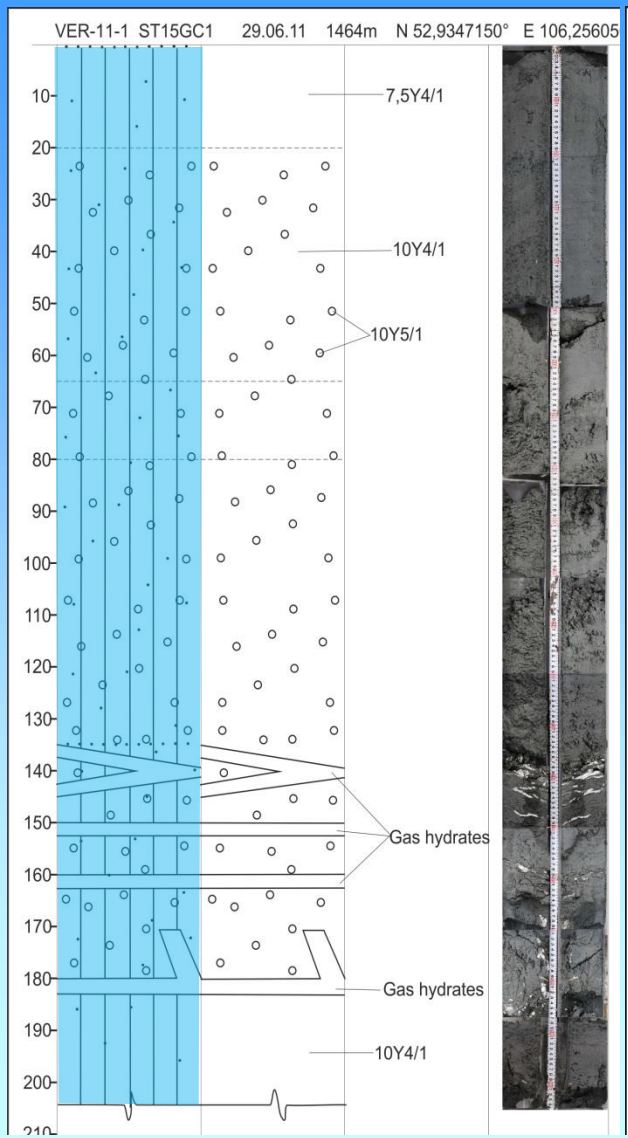
mud volcano

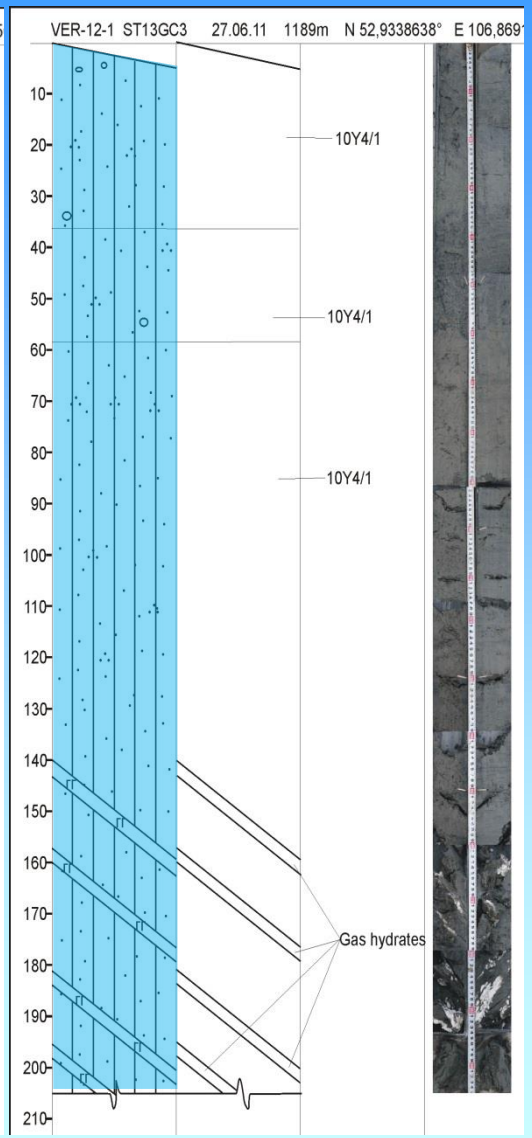
seepage

Baikal typical cross-section

Gas hydrate typical cross-section



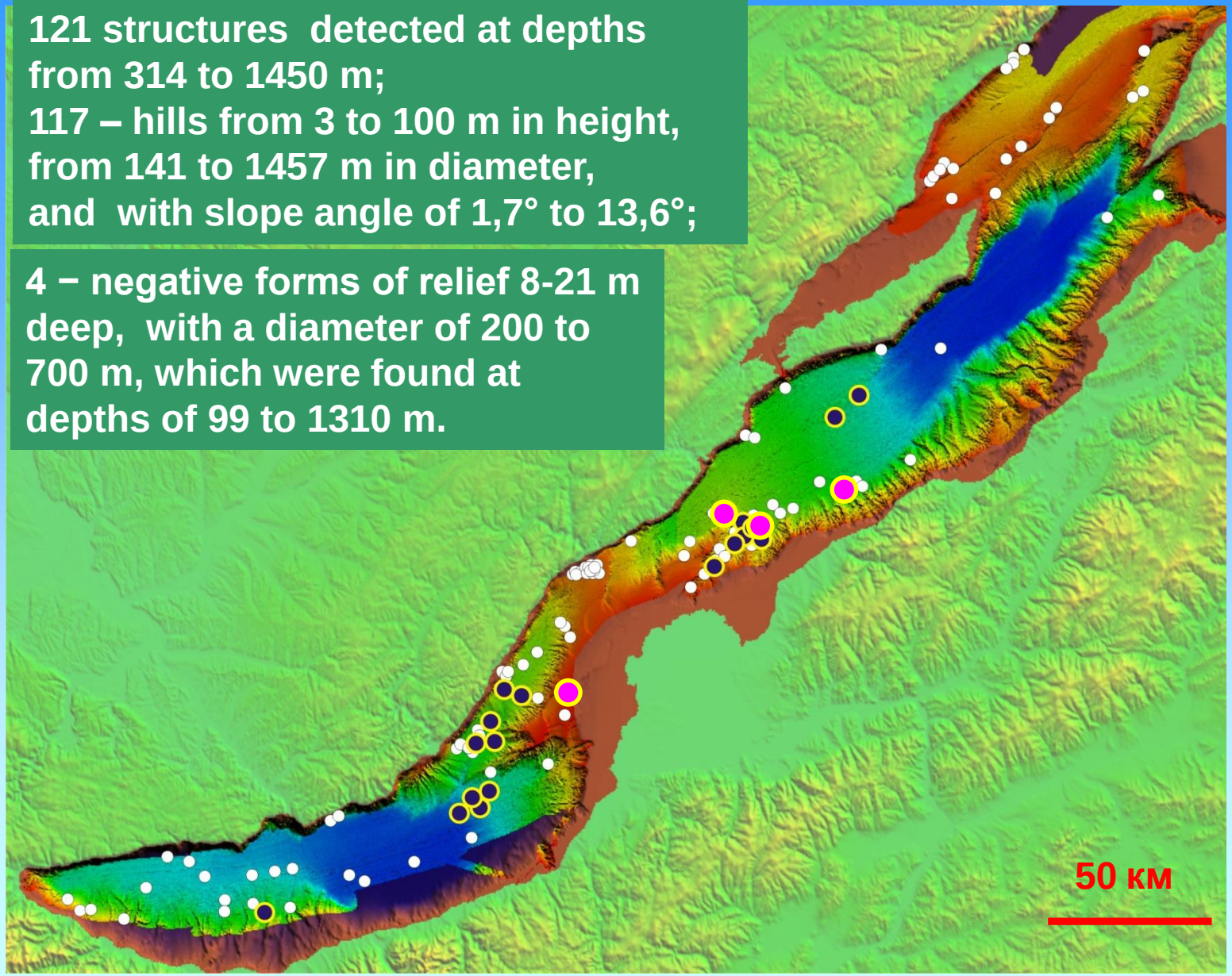


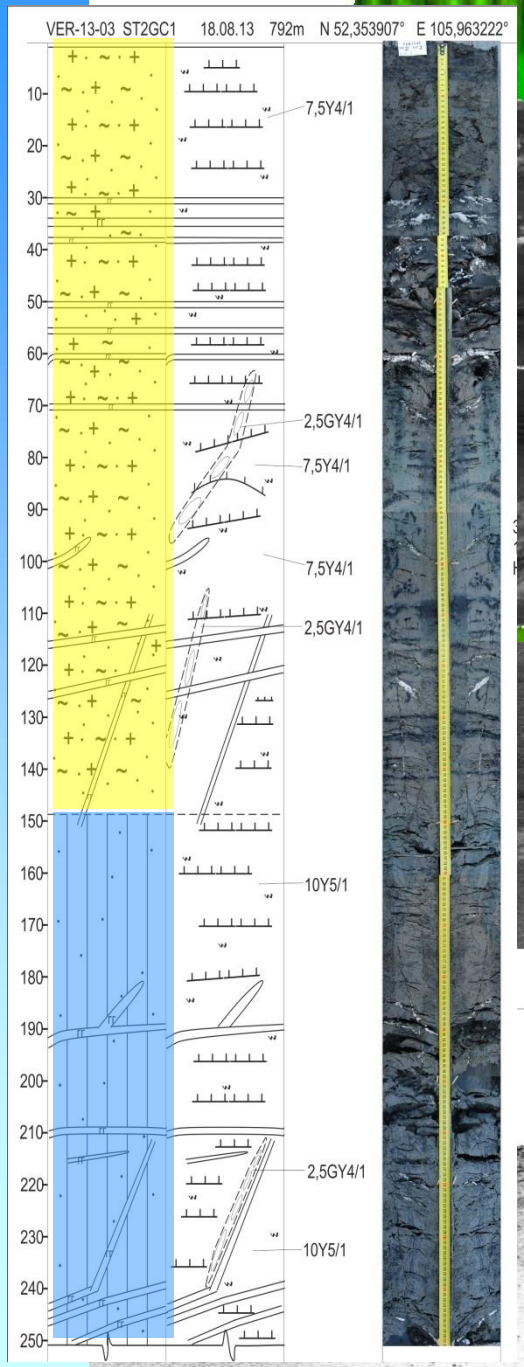


diatom ooze | pelite | silt and sand | clay | mud breccia

121 structures detected at depths from 314 to 1450 m;
117 – hills from 3 to 100 m in height, from 141 to 1457 m in diameter, and with slope angle of 1,7° to 13,6°;

4 − negative forms of relief 8-21 m deep, with a diameter of 200 to 700 m, which were found at depths of 99 to 1310 m.




VER-13-03 ST2GC1 18.08.13 792m N 52,353907° E 105,963222°
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
7,5Y4/1
2,5GY4/1
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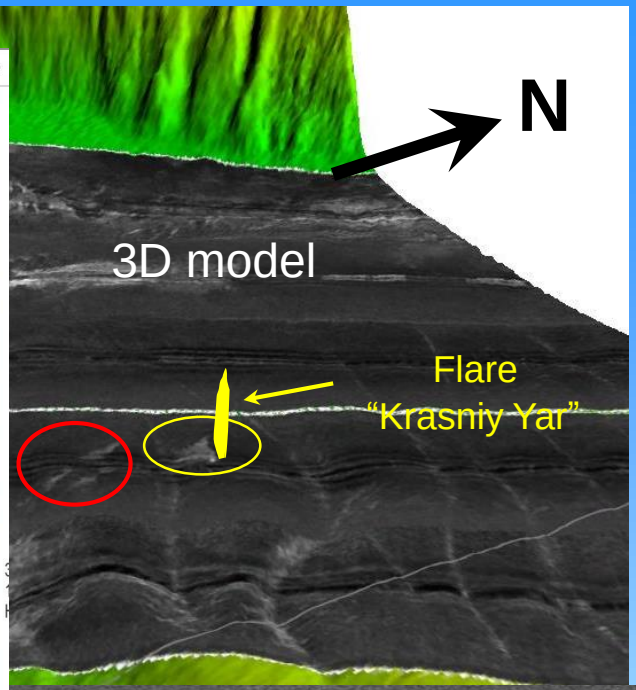
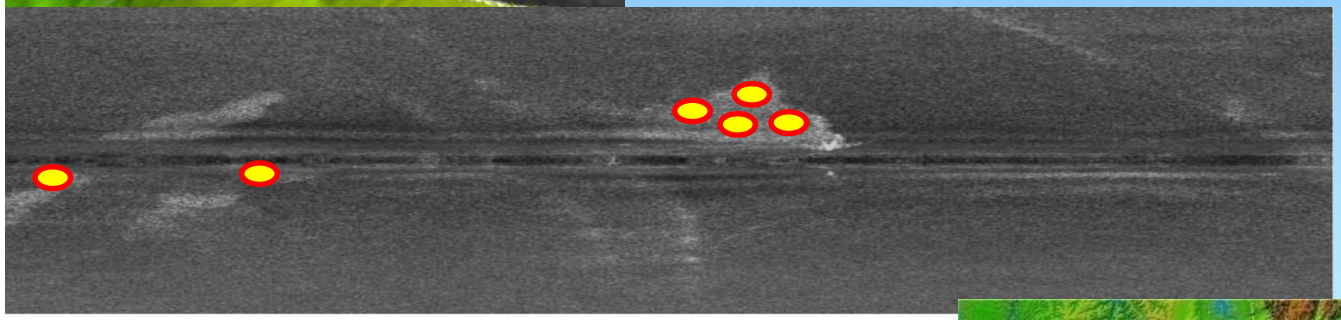
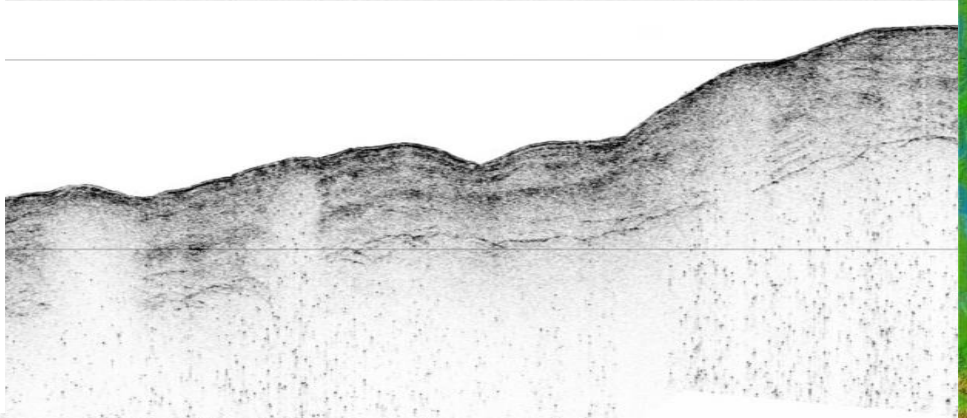
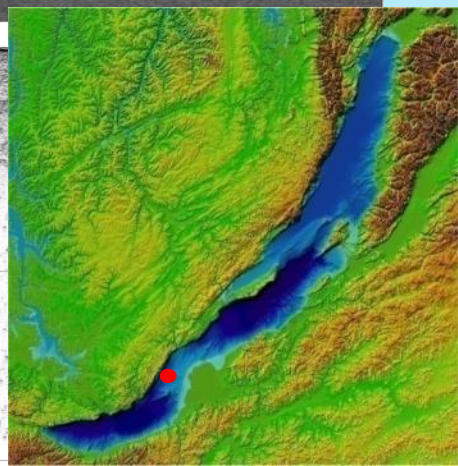
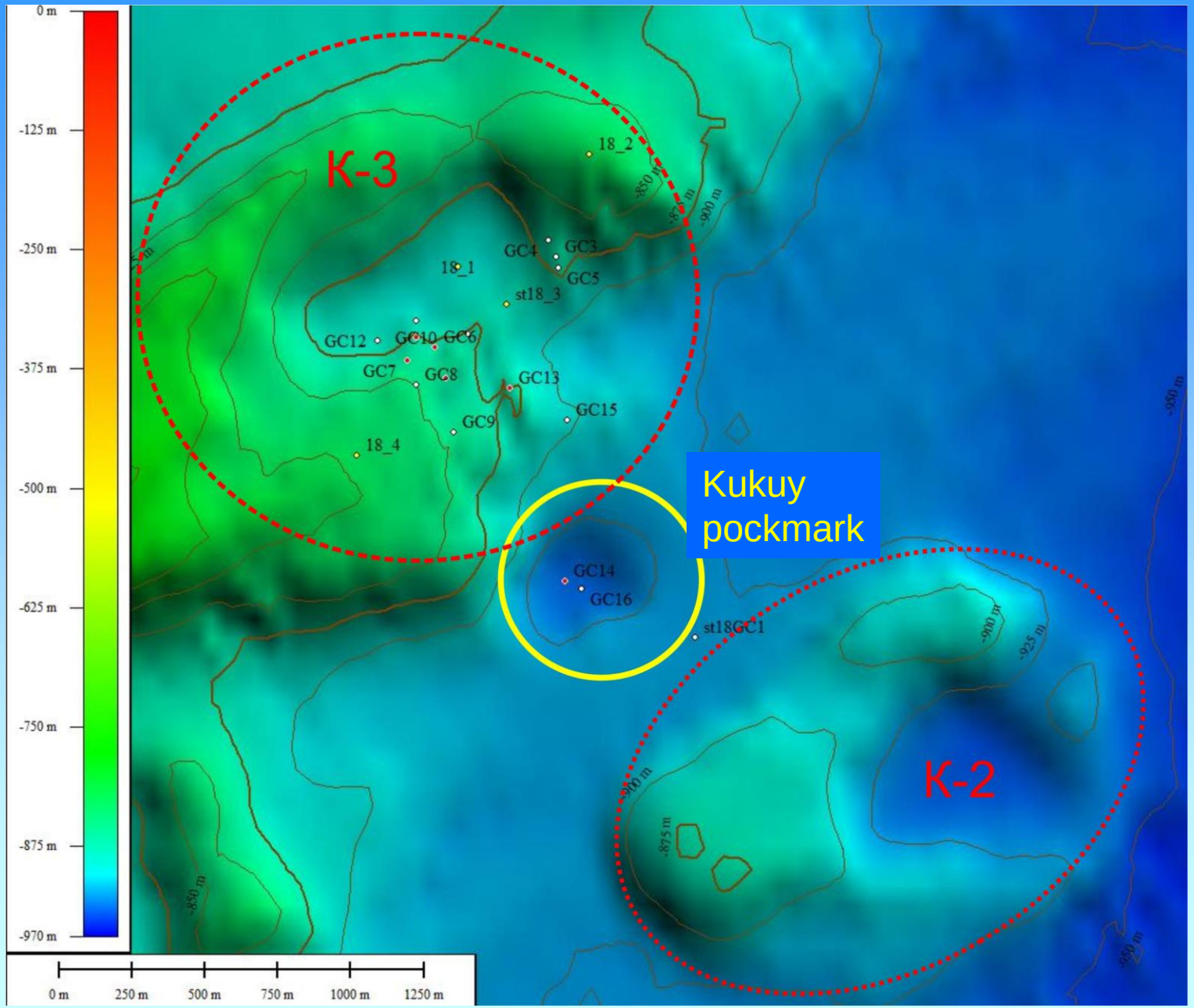
2,5GY4/1
10Y5/1
2,5GY4/1
10Y5/1


N
3D model
Flare
“Krasniy Yar”








0 m
-125 m
-250 m
-375 m
-500 m
-625 m
-750 m
-875 m
-970 m
0 m
250 m
500 m
750 m
1000 m
1250 m
K-3
K-2
Kukuy pockmark
18_2
18_1
st18_3
GC4
GC3
GC5
GC12
GC10
GC6
GC7
GC8
GC13
GC15
GC9
18_4
GC14
GC16
st18GC1
-850 m
-875 m
-900 m
-925 m
-950 m

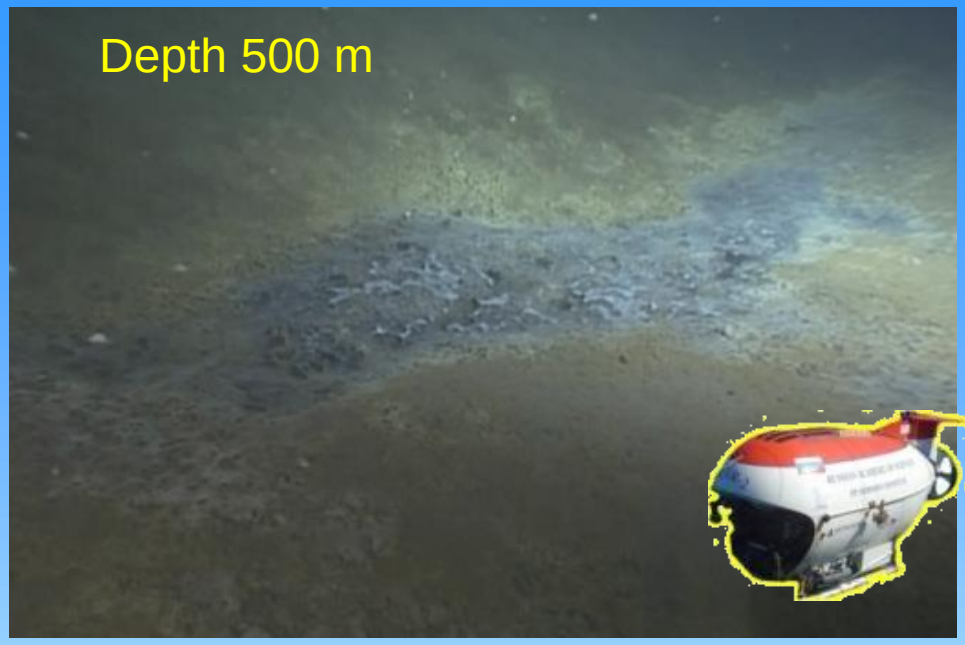
Depth water 1400 m

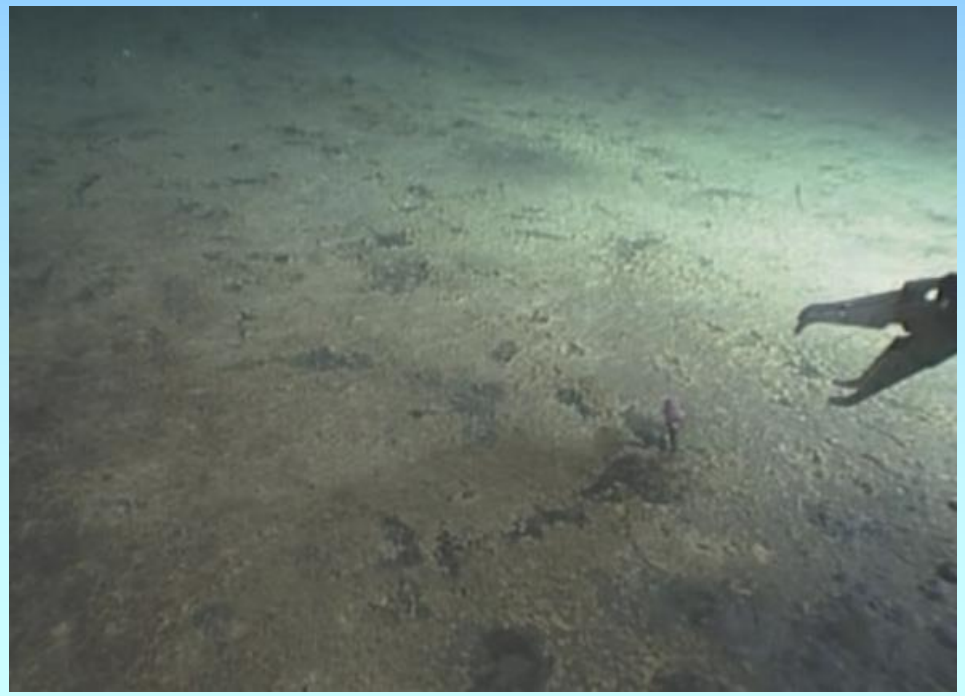
GAS HYDRATE

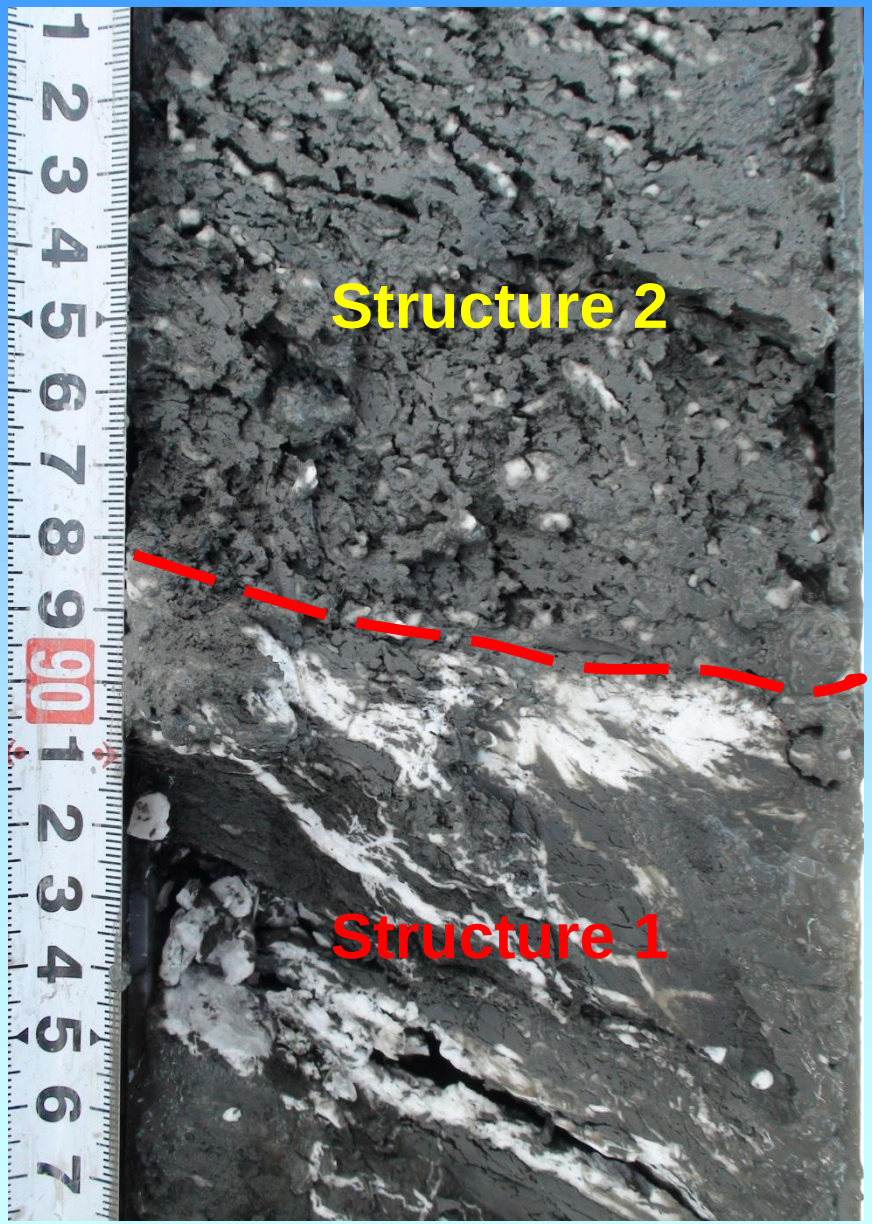
In 2009 with submersible «MIR», near the «flare» «Saint-Petersburg» we found hills almost completely made out of gas hydrates. The hills were up to several meters high.

Outcrops of the massive GH in a small cleft on the top of GH hill. Bacterial mats in the form of mucous filaments in foreground of GH are visible

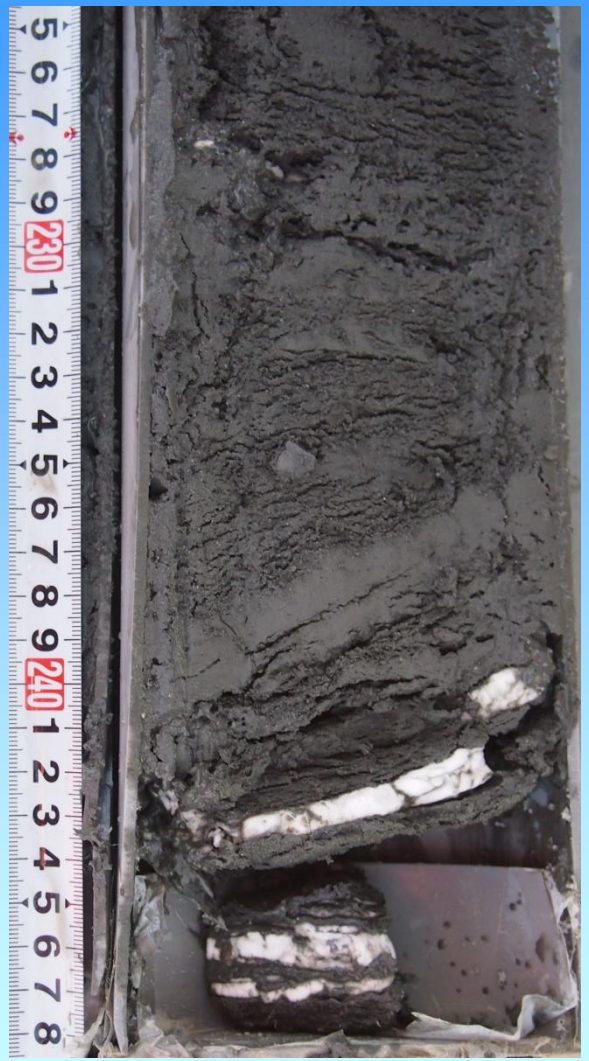
“PosolBank”







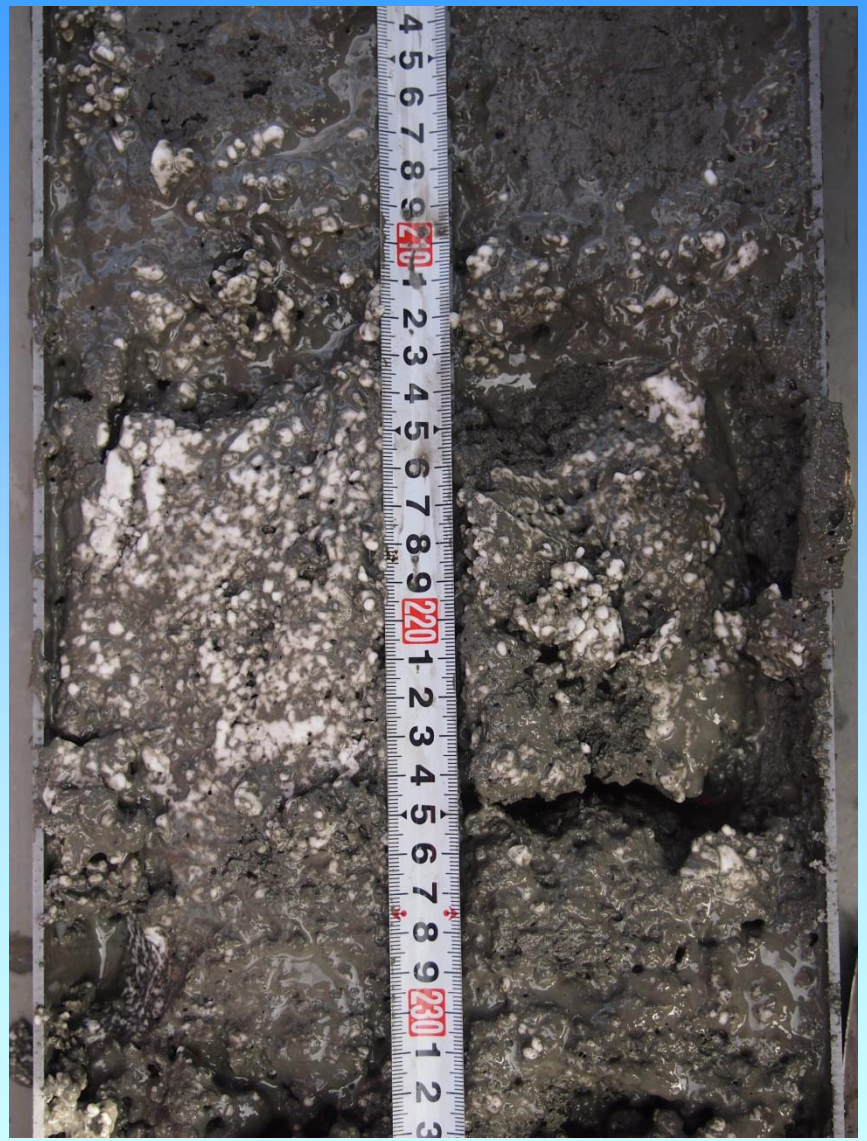

ЦЕНА
GC-5



Lens-like

Veined

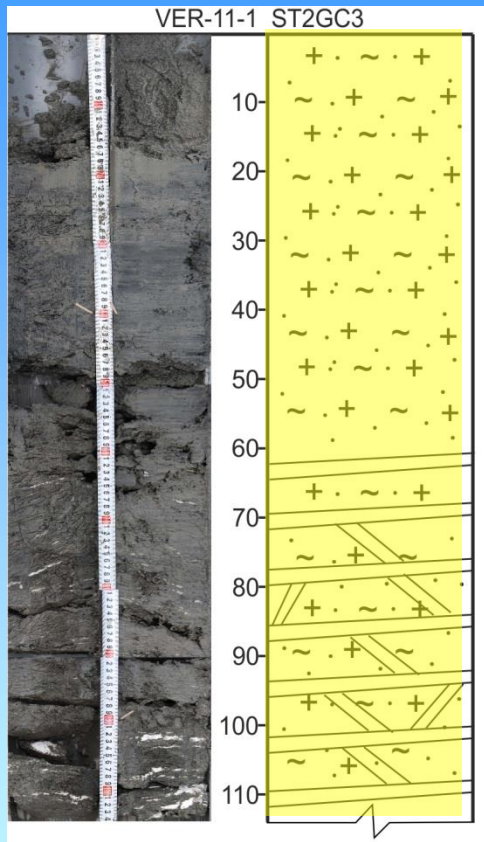
Tilted layers

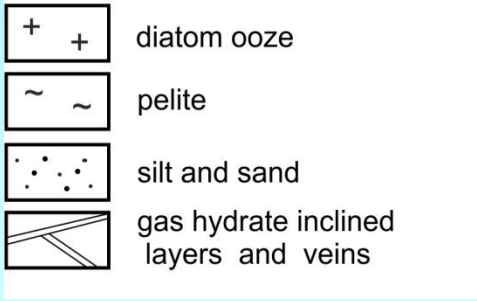


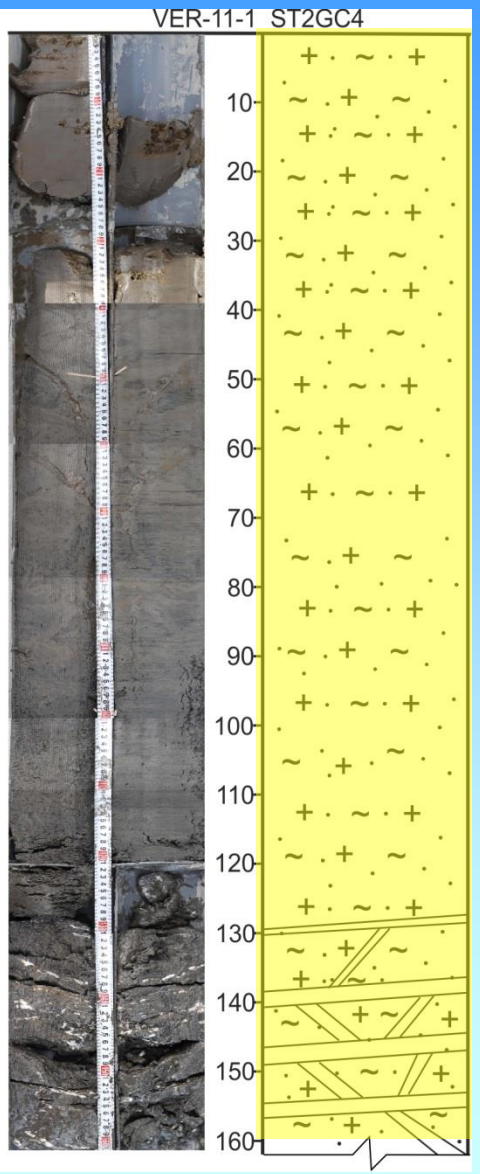
Granules

Gas hydrates samples in diatom layer

seep «Goloustnoe» (G-2), “K-12” mv “K-0”, “K-11”

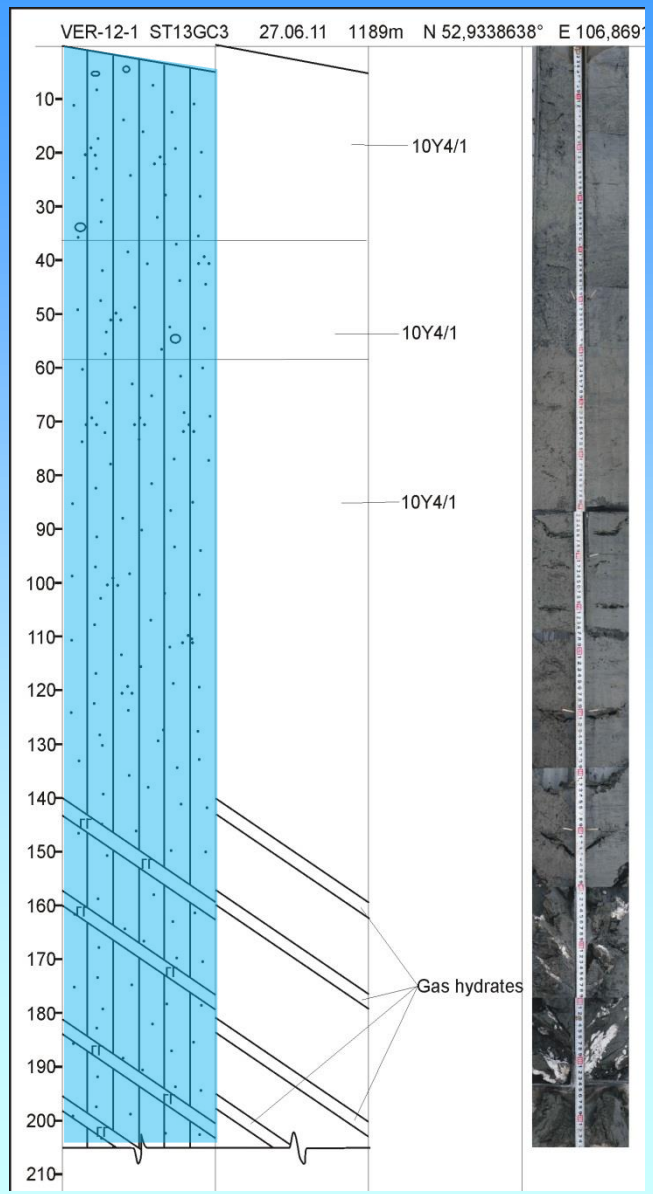




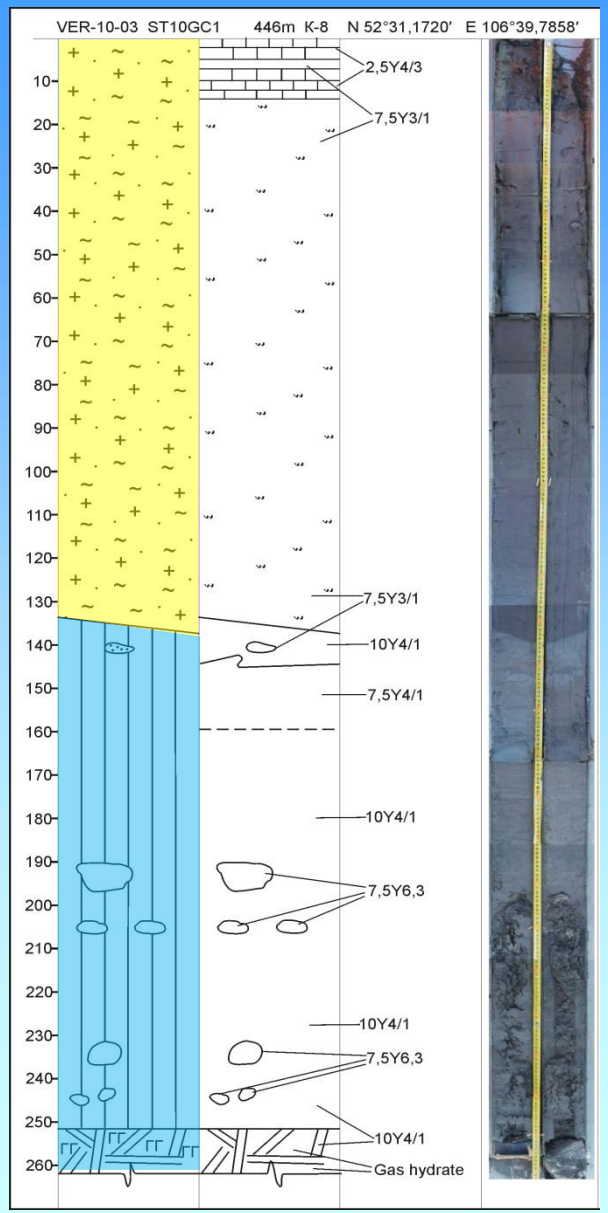


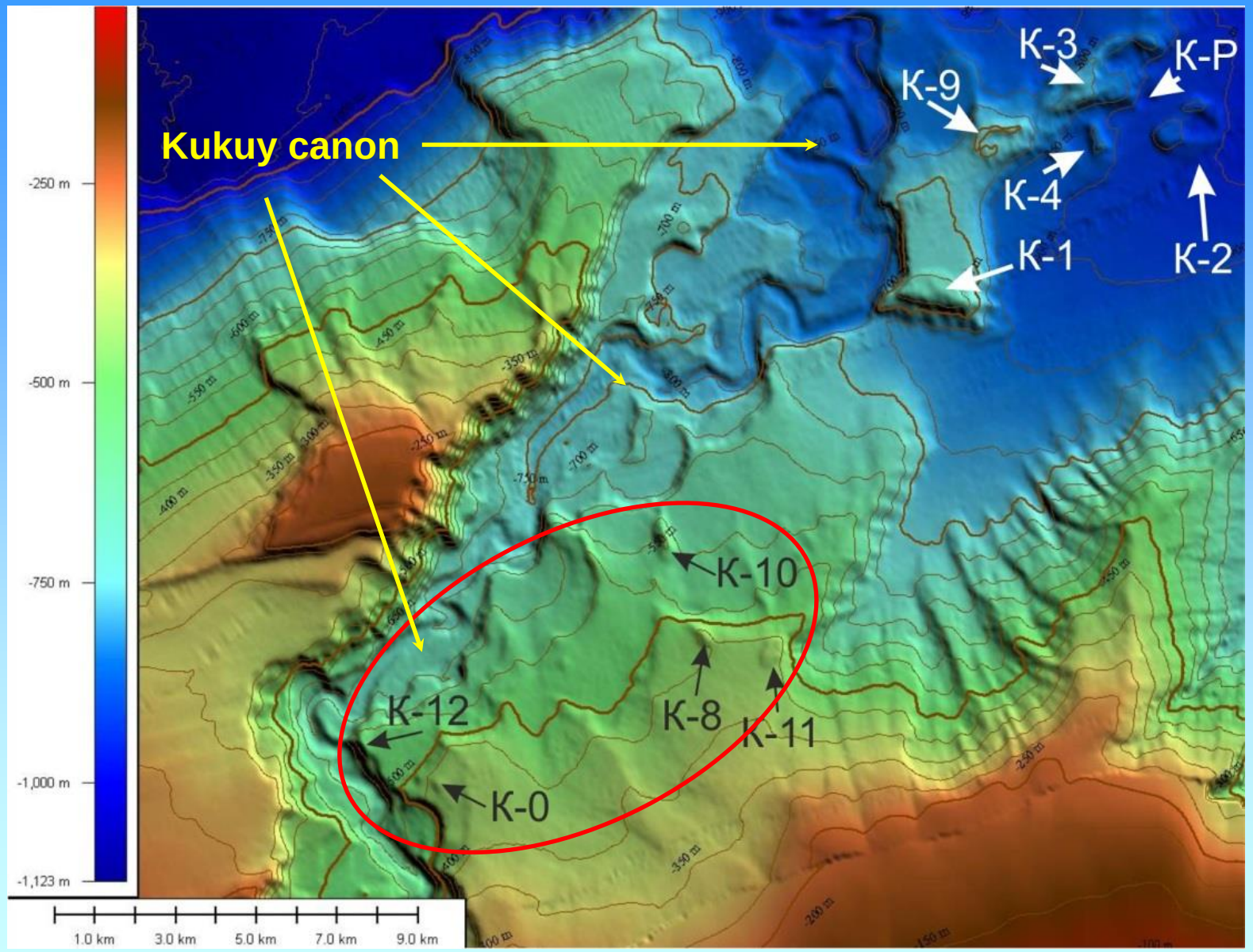
Gas hydrates samples in clay layer

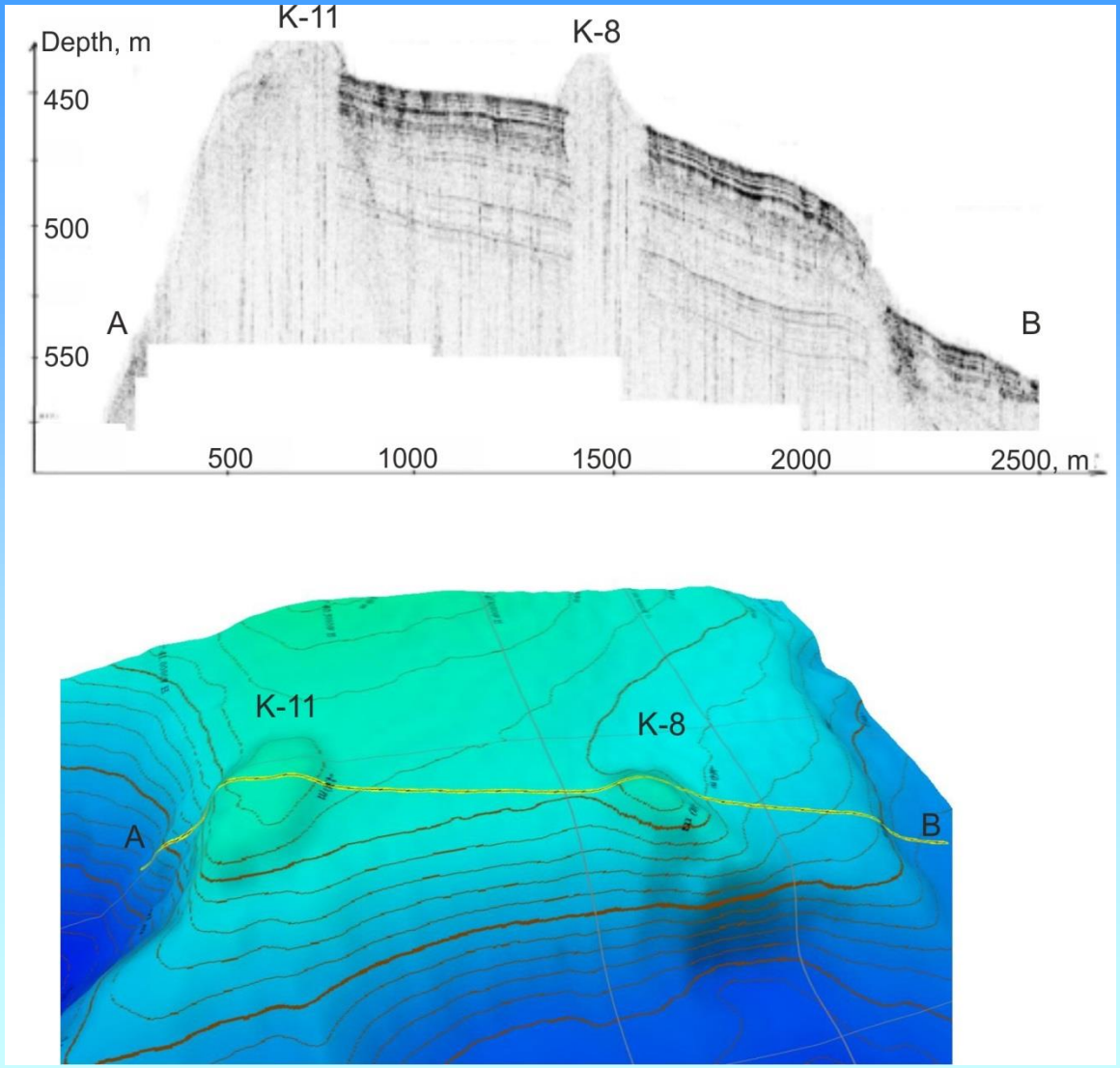
seep “13”, “K-4”



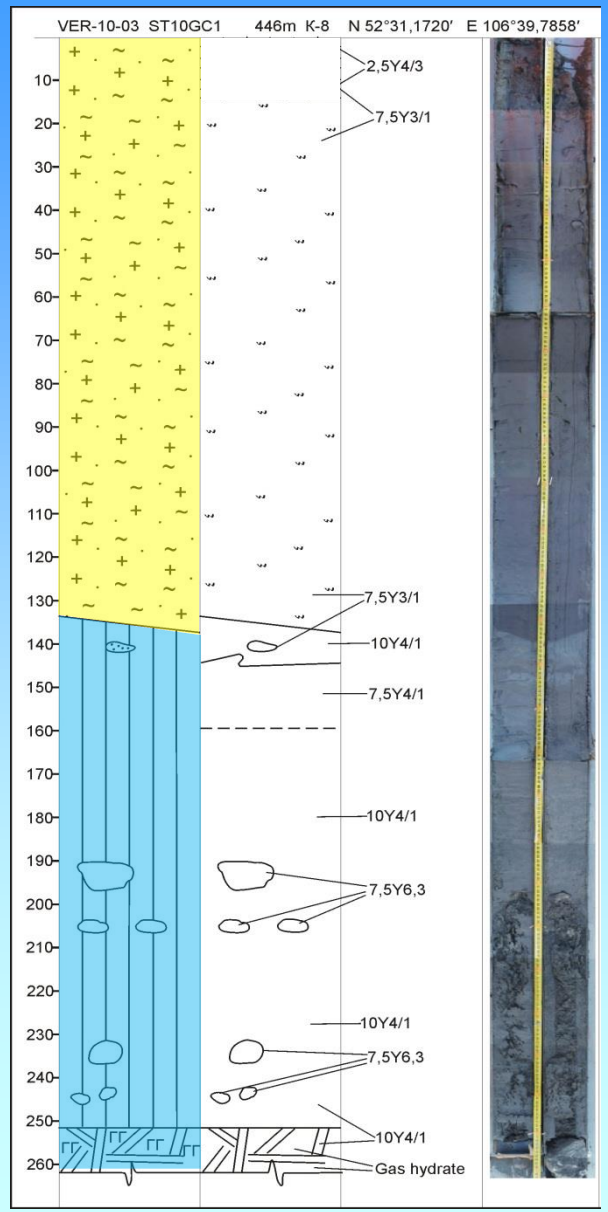
mv “K-8”, “K-10”



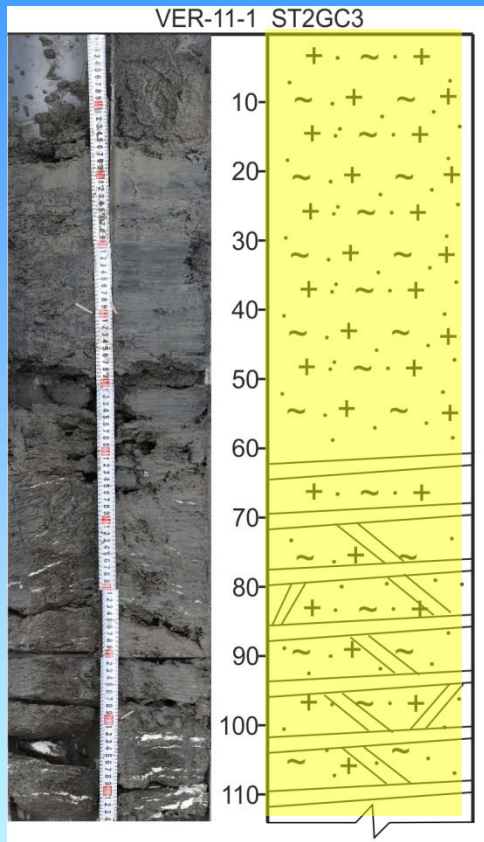

Kukuy canon
K-3
K-P
K-9
K-4
K-1
K-2
K-10
K-12
K-8
K-11
K-0
-250 m
-500 m
-750 m
-1,000 m
-1,123 m
1.0 km
3.0 km
5.0 km
7.0 km
9.0 km

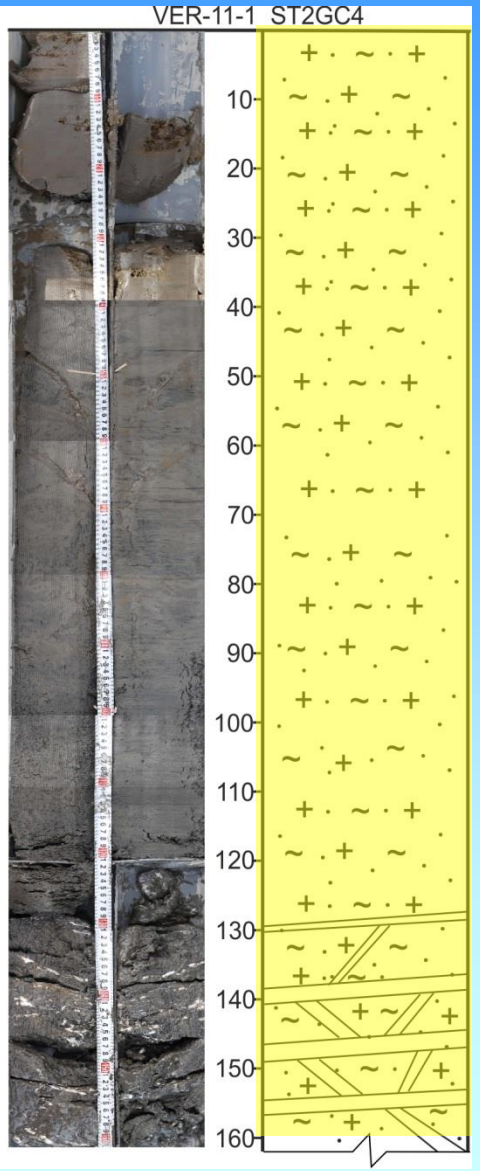

Depth, m
450
500
550
K-11
K-8
A
B
500
1000
1500
2000
2500, m
K-11
K-8
A
B

mv K-8



mv K-11



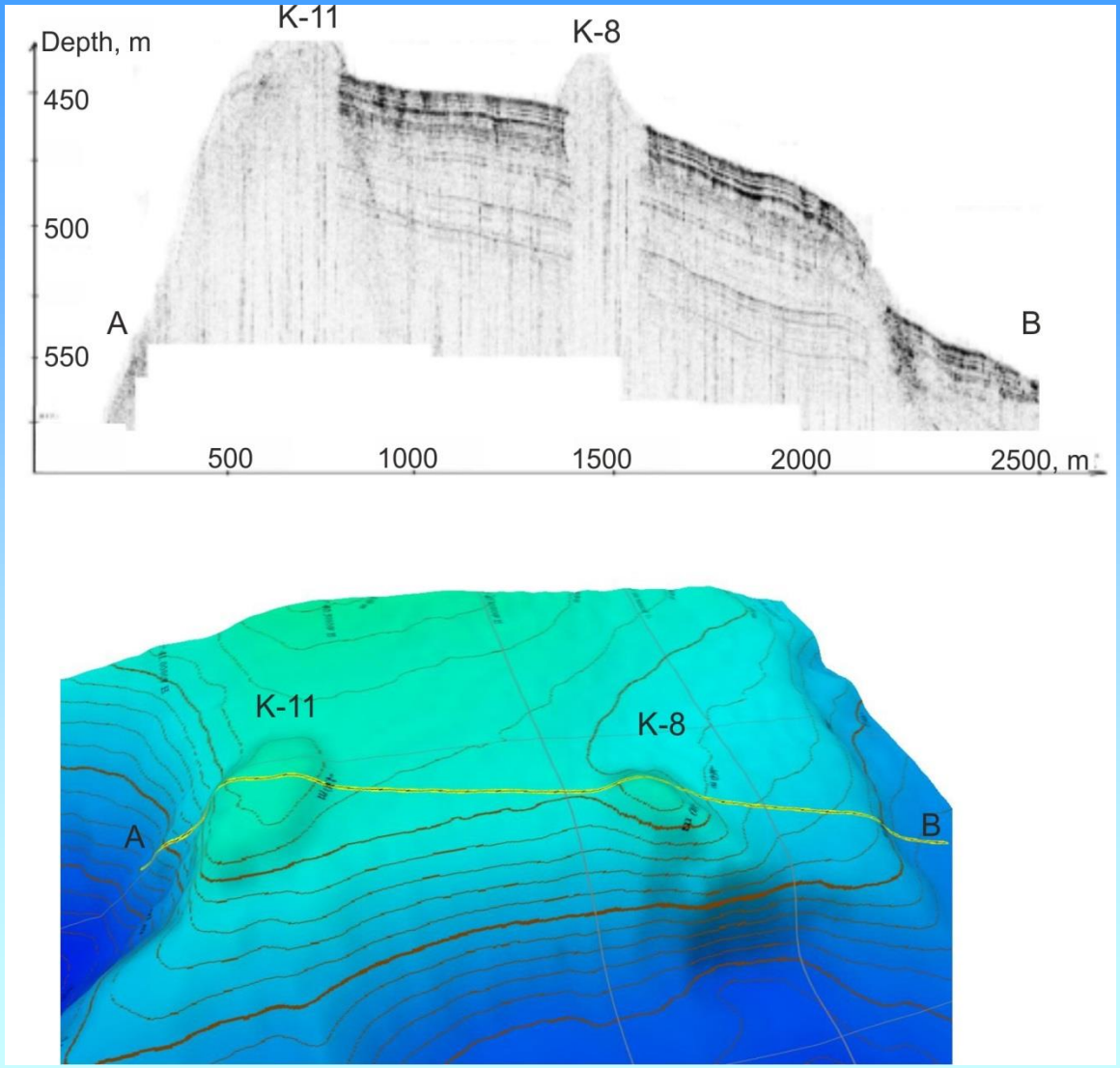


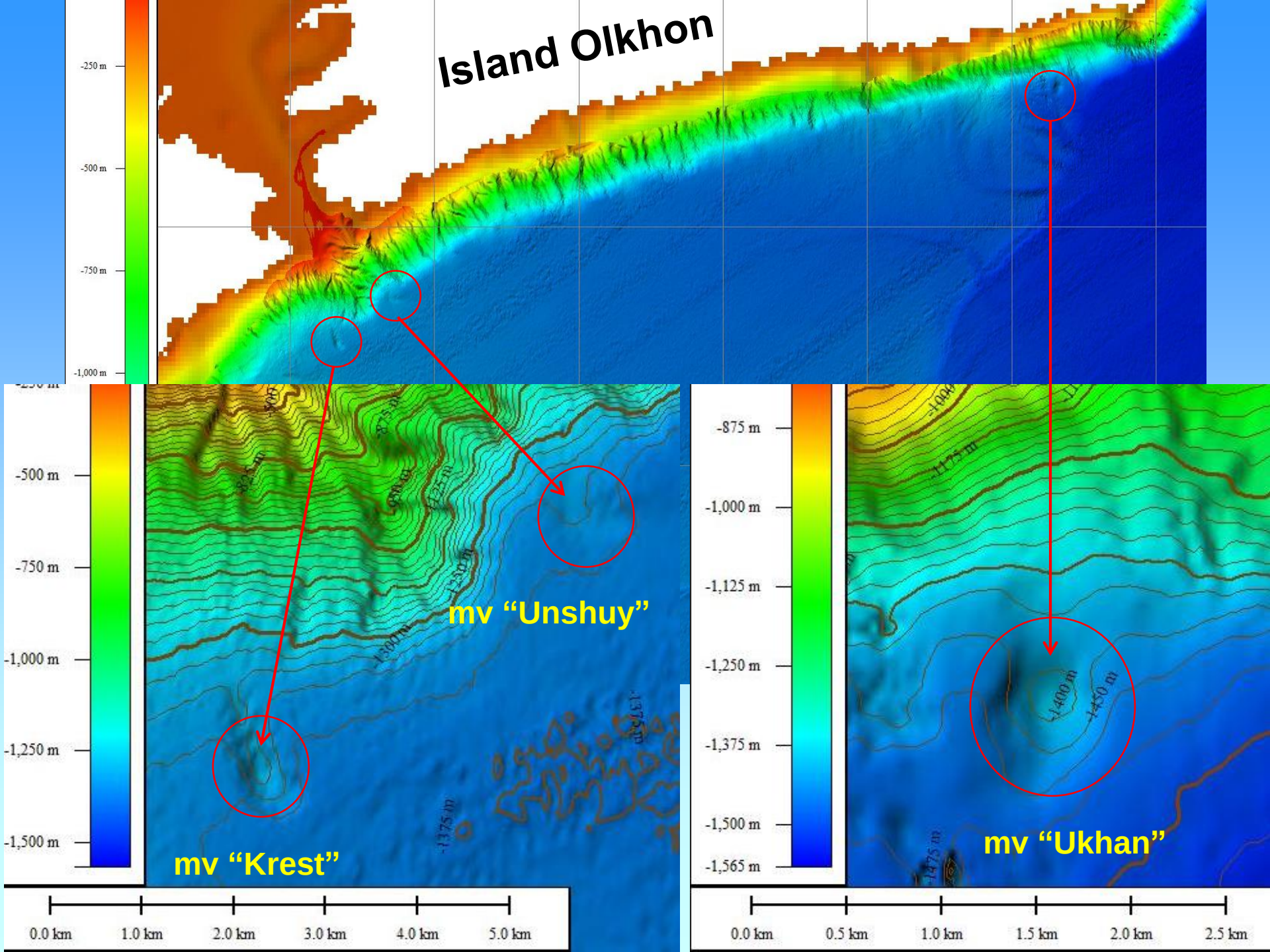
diatom ooze

pelite

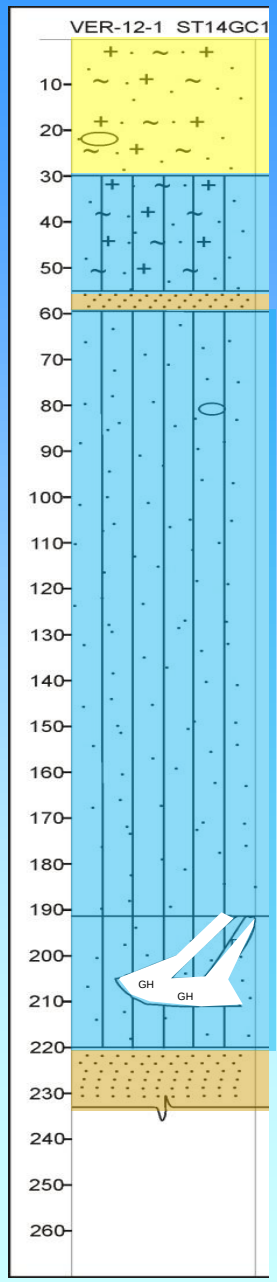
silt and sand

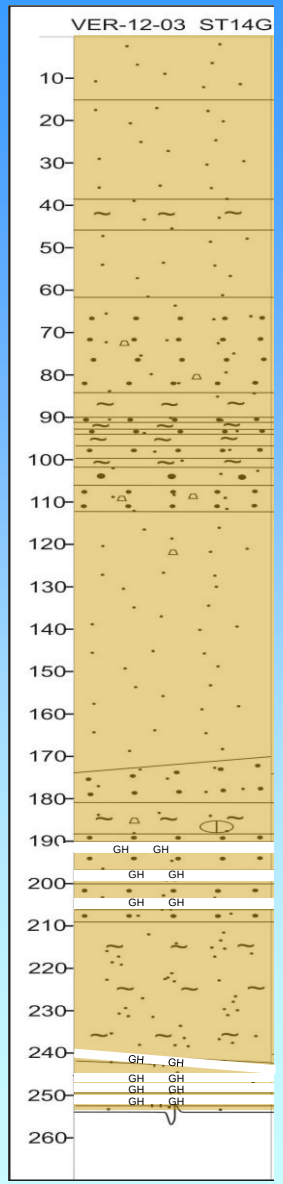
gas hydrate inclined layers and veins

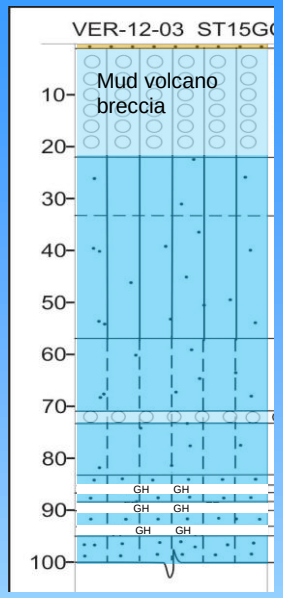

Depth, m
450
500
550
K-11
K-8
A
B
500
1000
1500
2000
2500, m
K-11
K-8
A
B

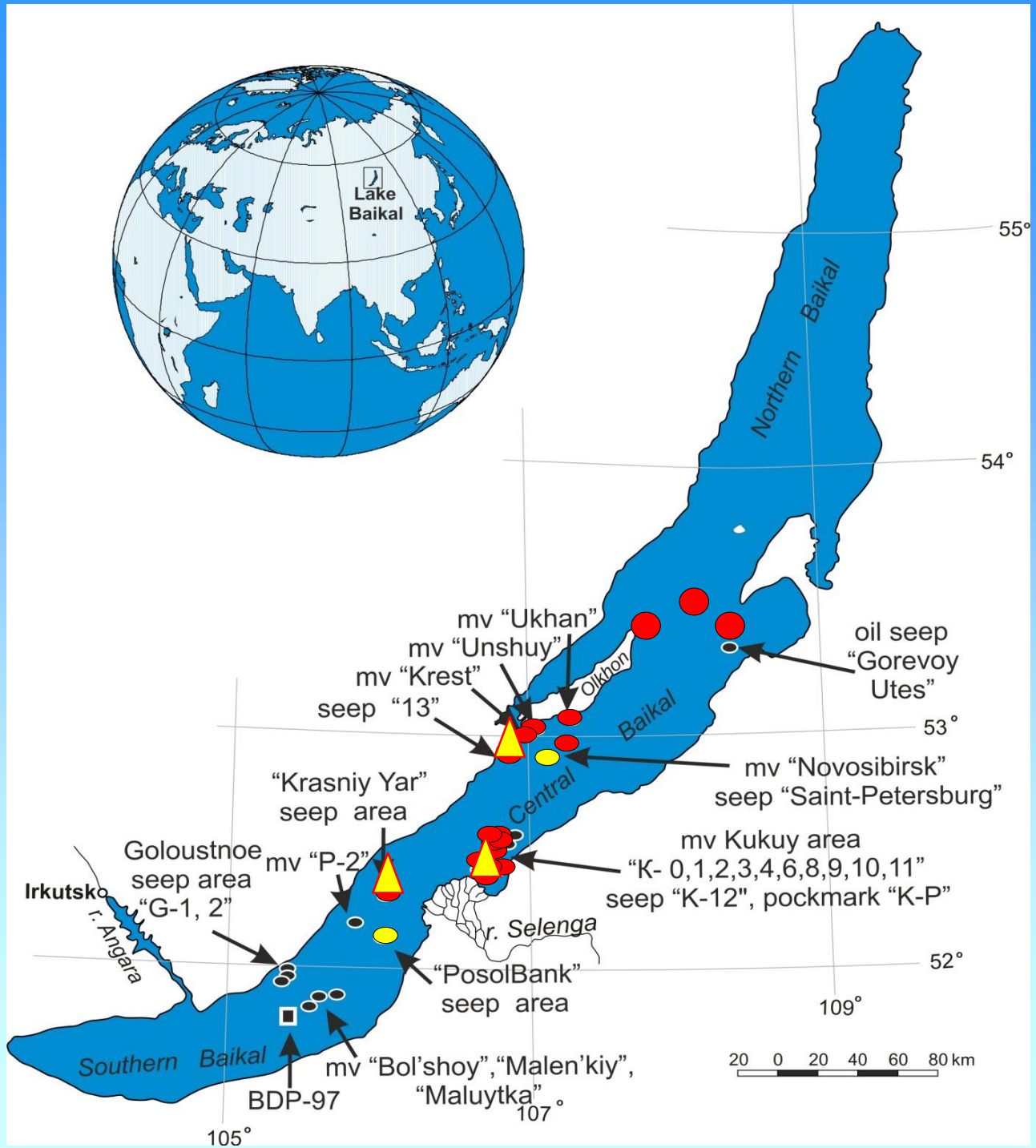

Island Olkhon
-250 m
-500 m
-750 m
-1,000 m
mv “Unshuy”
mv “Krest”
mv “Ukhan”
-875 m
-1,000 m
-1,125 m
-1,250 m
-1,375 m
-1,500 m
-1,565 m
0.0 km
1.0 km
2.0 km
3.0 km
4.0 km
5.0 km
0.0 km
0.5 km
1.0 km
1.5 km
2.0 km
2.5 km

mv “Krest” mv “Unshuy” mv “Ukhan”









12 sites have been found during the past three years thanks to the data of 2009 multibeam survey ● and 3 – of echosounder ▲, 2 - of deep-seamanned submersibles MIR ⬭.

Thank you for your attention

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