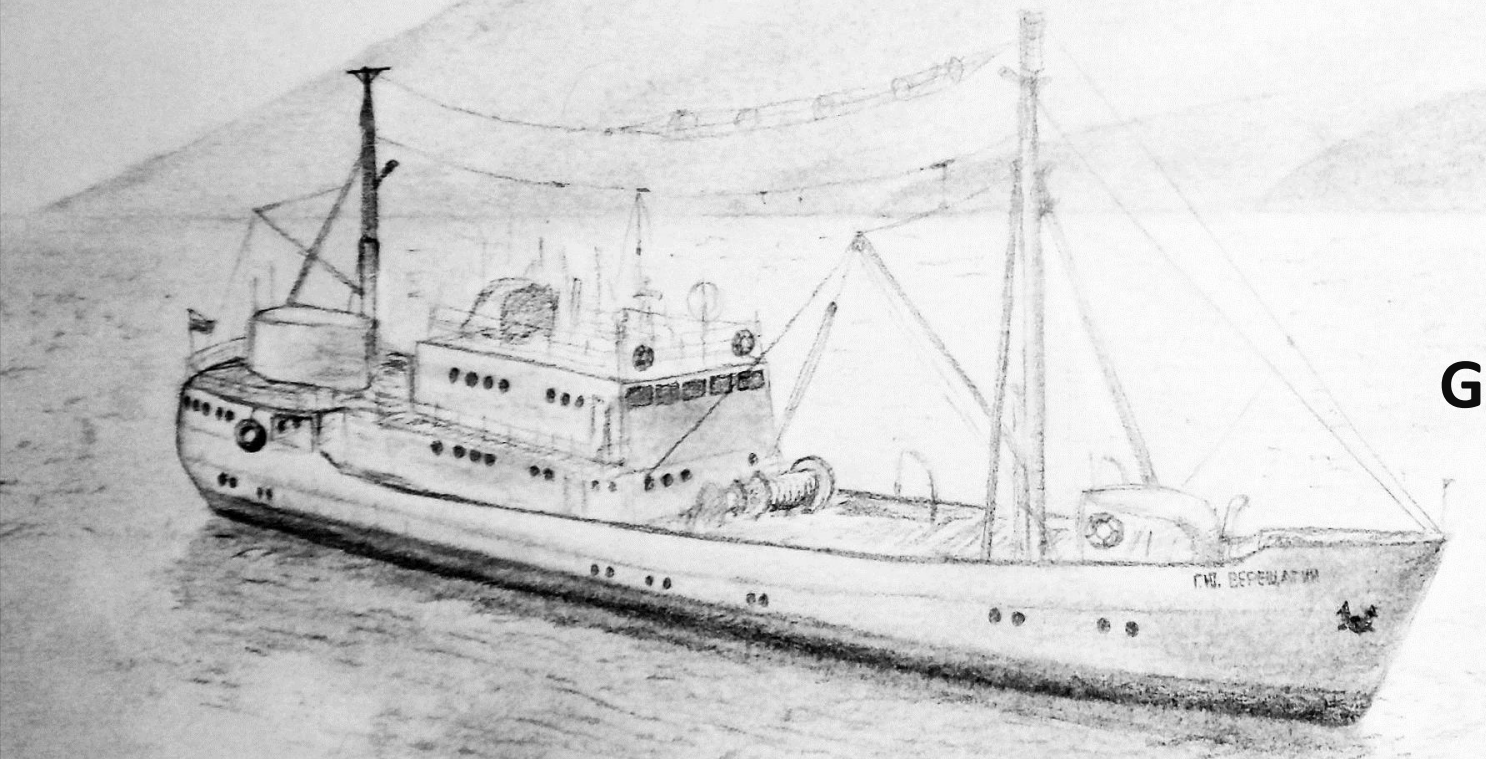
The Khuray deep-water fan:
a beautifully complex lacustrine depositional system of Lake Baikal



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About the Class@Baikal Project

About the Floating University:

- The Floating University is a long-lasting international research and training programme, which was initiated by the Moscow State University and executed with UNESCO support since 1991.
- The «Training-through-Research» experience served as a solid foundation of the Class@Baikal Project, which has started successfully in 2014 on the Baikal Lake. Since then, 6 expeditions were organized onboard RV «G.Yu. Vereshchagin».
- Collected material is being processed by students which participated in the expedition under a supervision of researchers and professors who collaborate in the framework of the Program. Educational portion of the program is closely integrated with real research work.

Traditional research topics of Floating University:

- Natural gas hydrates and focused hydrocarbon gas seepages;
- Mud volcanism and clay diapirism;
- Modern deep-water depositional systems, deep-sea fans, canyons and channel complexes;
- Neotectonics, seafloor morphology, sedimentation;
- Heat flow and thermophysical characteristics of bottom sediments;
- Slope stability/instability

Chair holder: Dr. Grigorii G. Akhmanov
http://floatinguniversity.ru/
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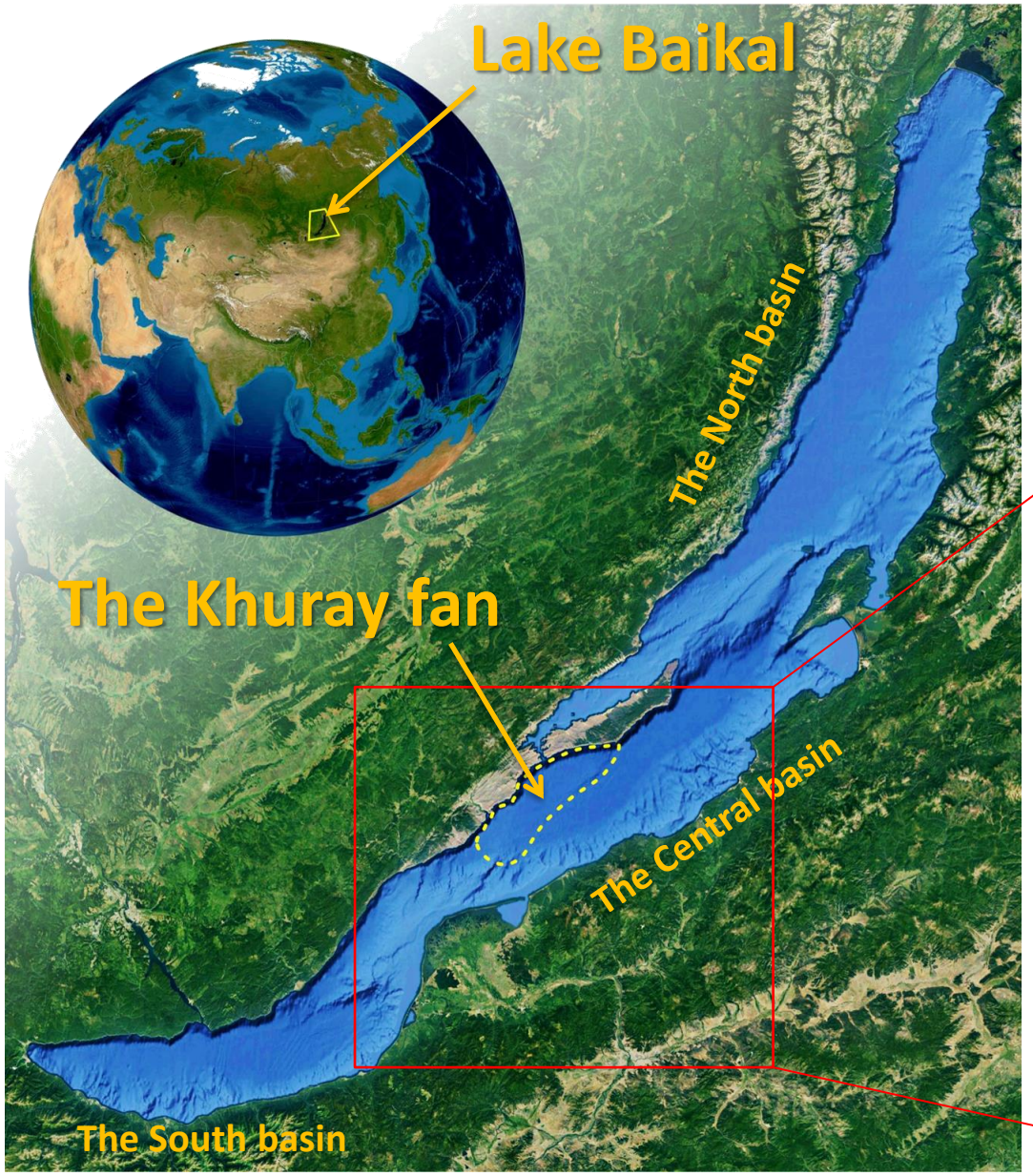
Location of studied area



The study area is located in the south-west deep-water part of the Central basin of Lake Baikal on the water depth varying from 800 to 1580 meters.

Objectives of investigation

The Khuray depositional system has a unique structure. Its major peculiarity is a presence of the canyon (Khuray canyon) in the distal part of the system.

The system is developed in very narrow rift basin. The evolution of the system is highly affected by active neo-tectonics.

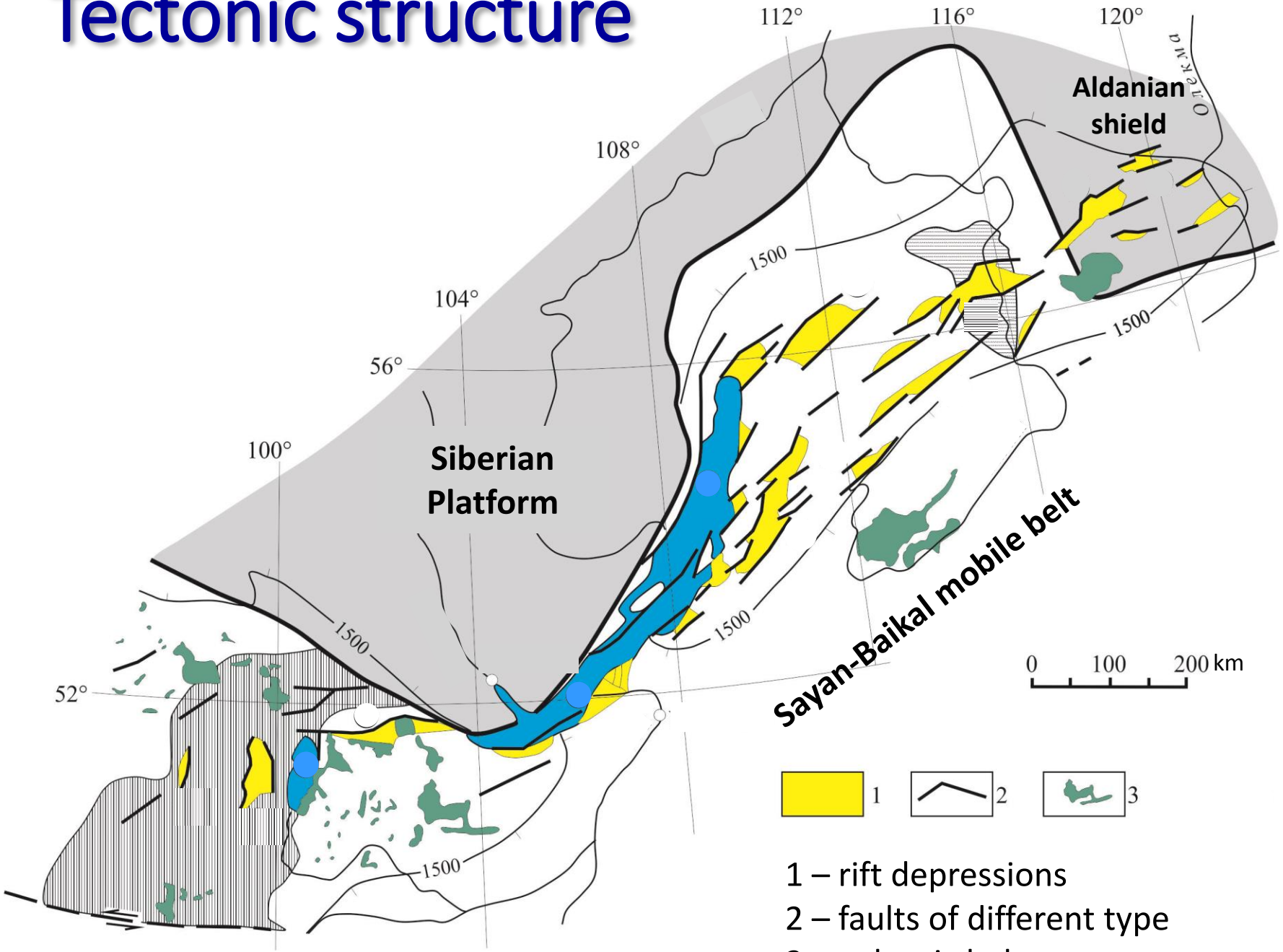
The Khuray depositional system is a remarkable example of modern “non-classical” deep-water fan. Detailed geological and geophysical studies of modern depositional systems can be a key to correct interpretation of paleo-analogues.

Objectives:

Study of the structure and evolution of the deep-water depositional system Khuray:

- Creation of scheme of valley-channel complex
- Determination of the source of clastic material
- Estimate of the duration of the system development

Tectonic structure



Lake Baikal is the World's oldest and deepest lake, which has been formed within a recently active rift zone at the edge of Siberian platform. Active tectonics influences all subaqueous geological processes in the Lake area with sedimentation, in particular.

Investigation methods and equipment

Geophysical surveying

Continuous profiling

- Source: towed **sub-bottom profiler** (2015)
  - Frequency: 6 kHz
  - Propagation distance: up to 50 m

6 lines
105 km

- Source: on-board **sub-bottom chirp profiler** (2015, 2016, 2019)
  - Frequency: LFM signal 1-10 kHz
  - Propagation distance: up to 40 m

82 lines
590 km

- Source: multi-electrode **spark source** «sparker» (2017, 2018)
  - Frequency: 350 kHz
  - Propagation distance: up to 400 m

61 lines
1020 km

Side-scan sonar (2015)

- Frequency: 30 kHz

6 profiles
120 km²

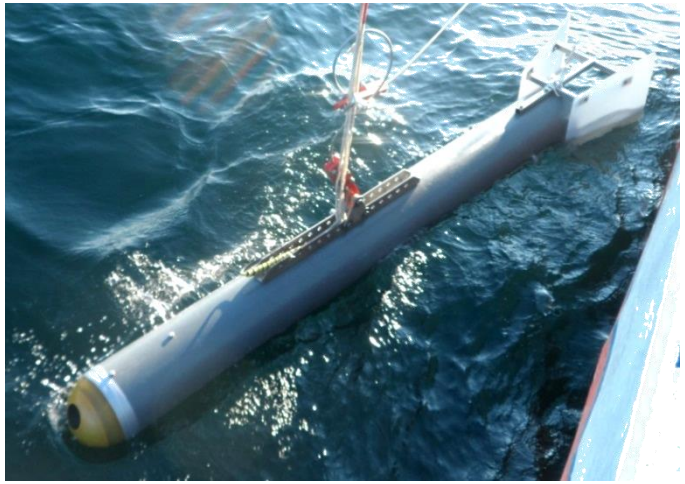
Bathymetry data

- LIN SB RAS and RCMG **bathymetry data** after RAS 17.8 Program (2009) and FWO Flanders (1.5.198.09) Project
- De Batist M., Canals M., Sherstyankin P., Alekseev S. & the INTAS Project 99-1669 Team, 2002. A new **bathymetric map** of Lake Baikal.

RV «G.Ju. Verechagin»

Chip profiler «KNUDSEN Chirp 3260»

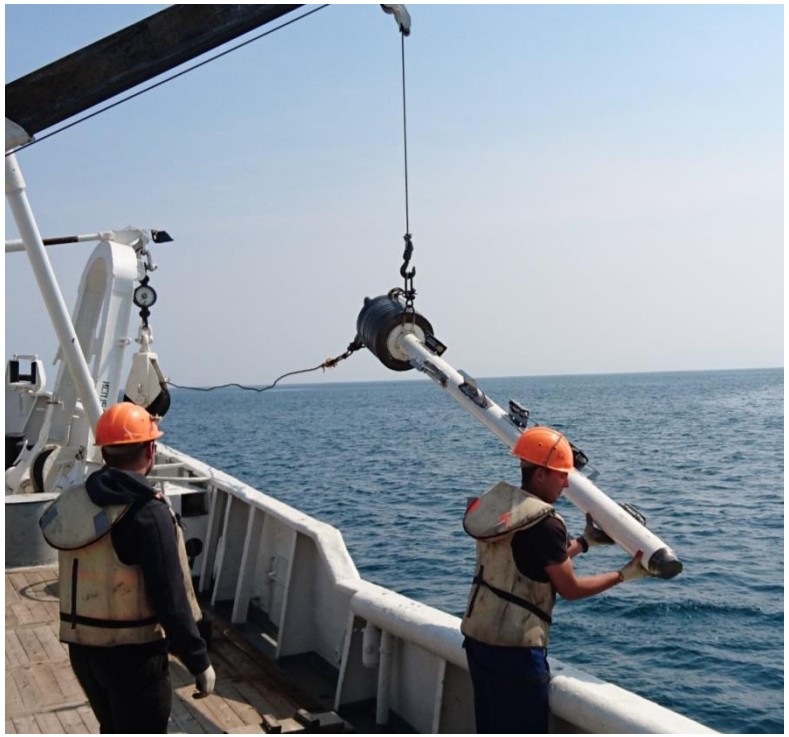
Sub-bottom profiler and side-scan sonar «Sonic-3D»



Multi-electrode spark source «sparker» and single-channel streamer

Investigation methods and equipment

Geological investigations



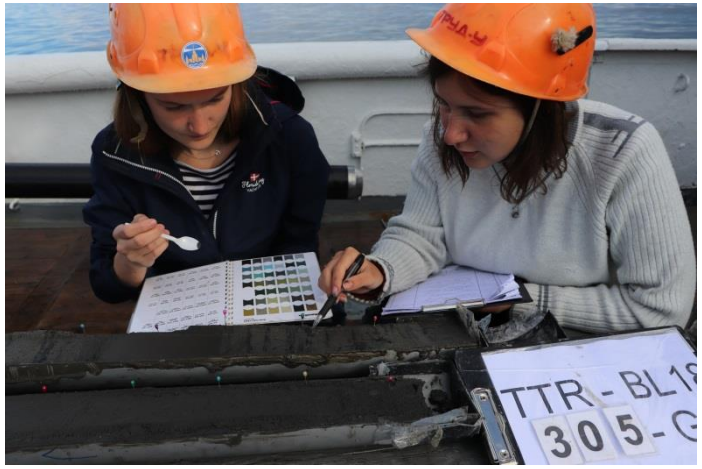
Bottom sampling (2014 – 2019)

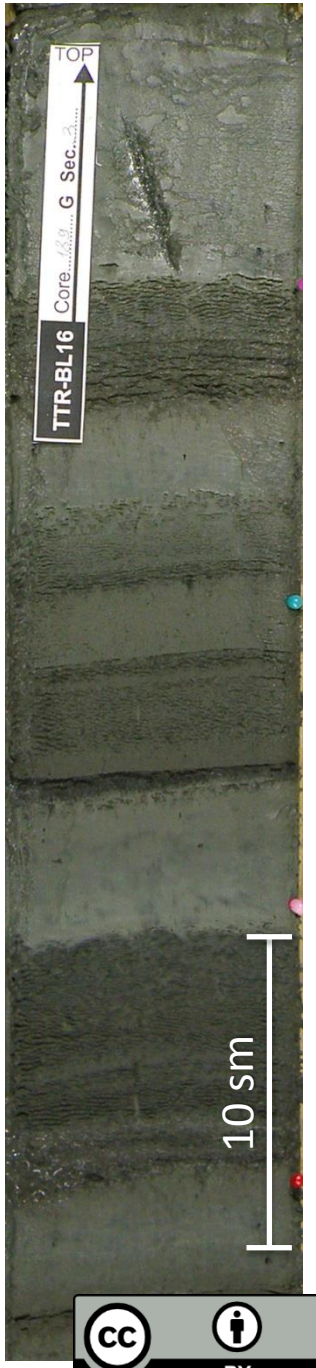
- Gravity cores
  - Length: 3,5 and 5,5 m
  - Weight: 500 and 800 кг
  - Diameter of plastic liner: 100 mm

132 sites
250 m of cores

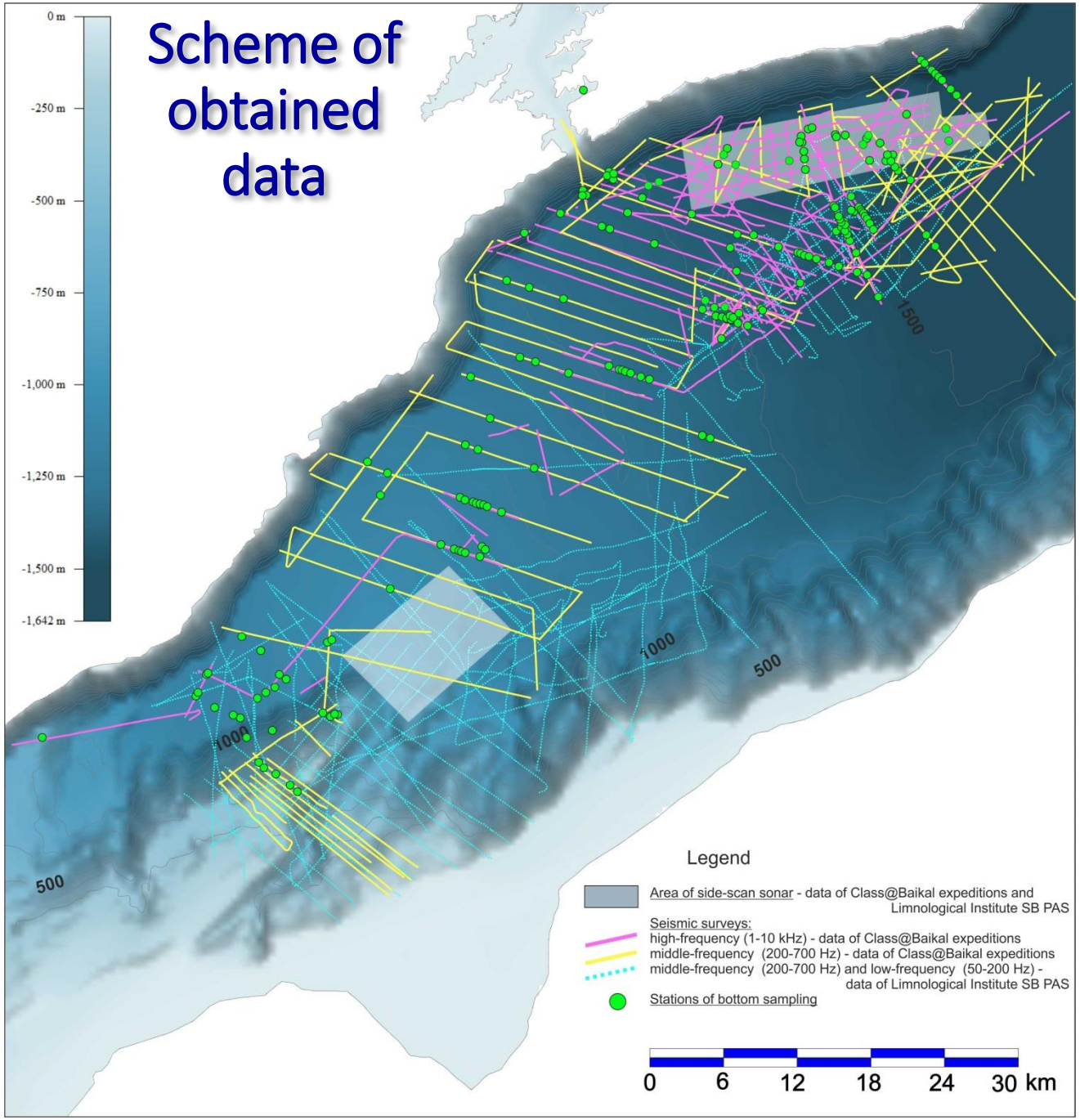
Laboratory analysis (2014 – 2019)

- Lithological description
- Geochemistry assaying
- X-ray computer tomography analysis (CT)
- Granulometric analysis
- Analysis of mineral composition

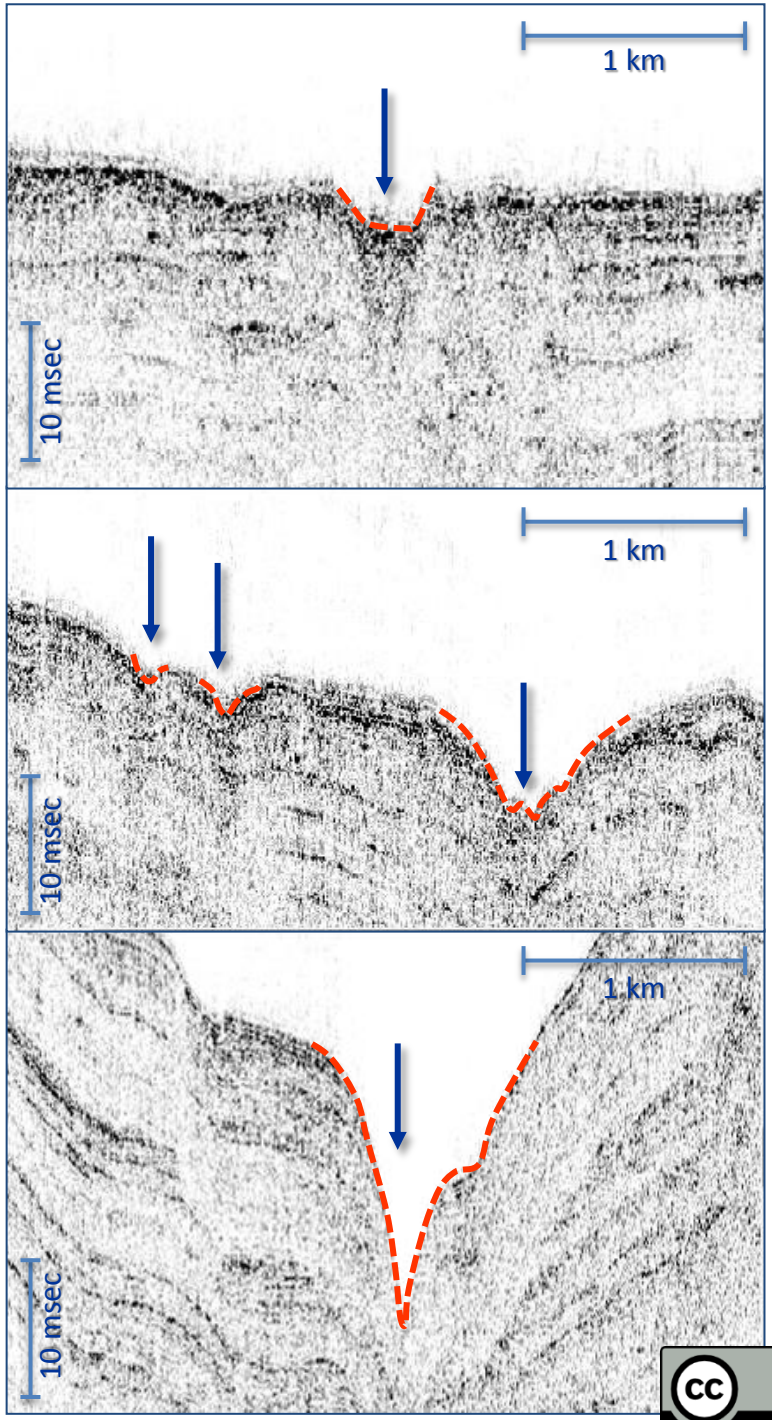




Scheme of obtained data



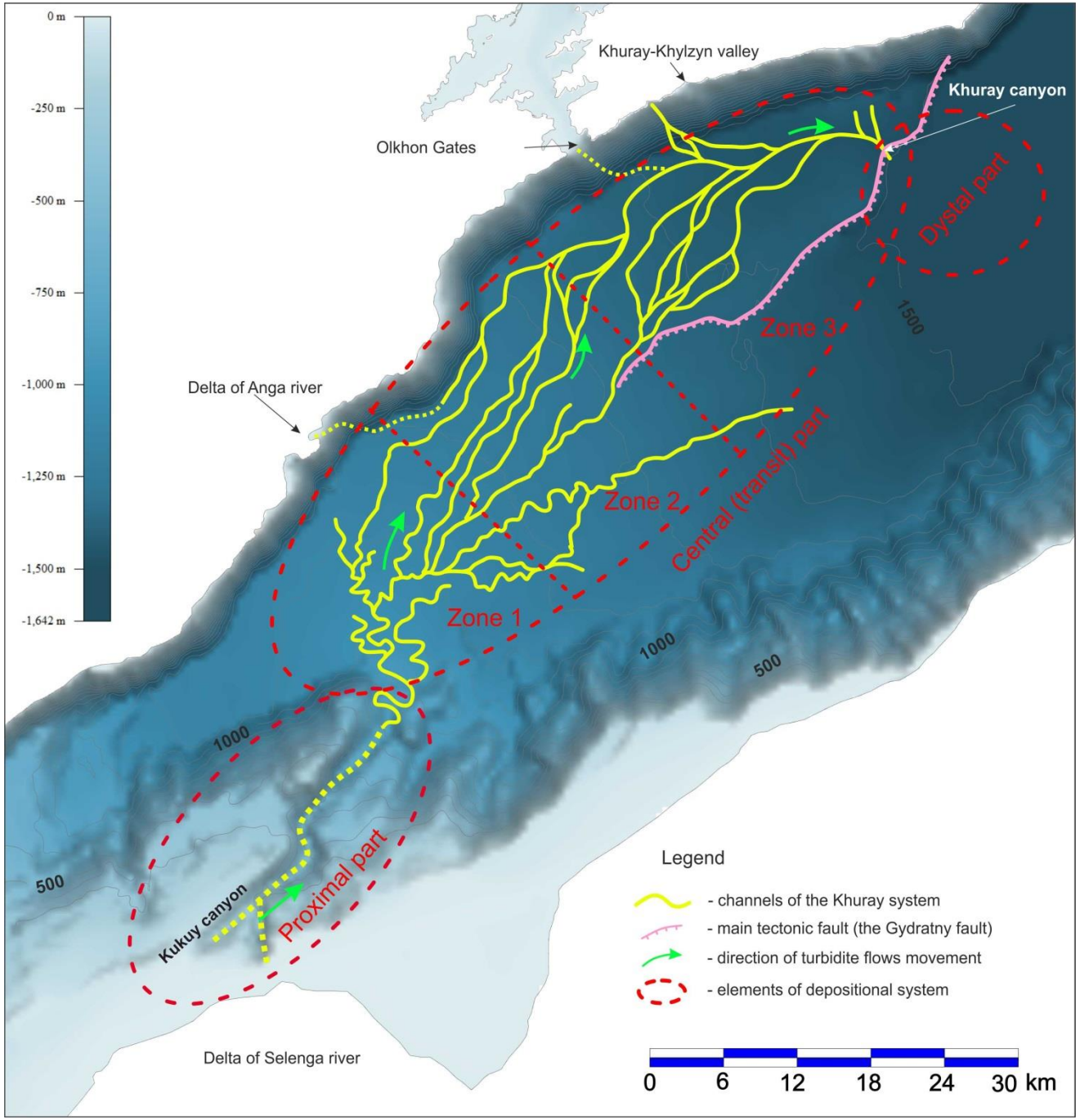
Examples of channels on chirp profiler data



«Braided» channels

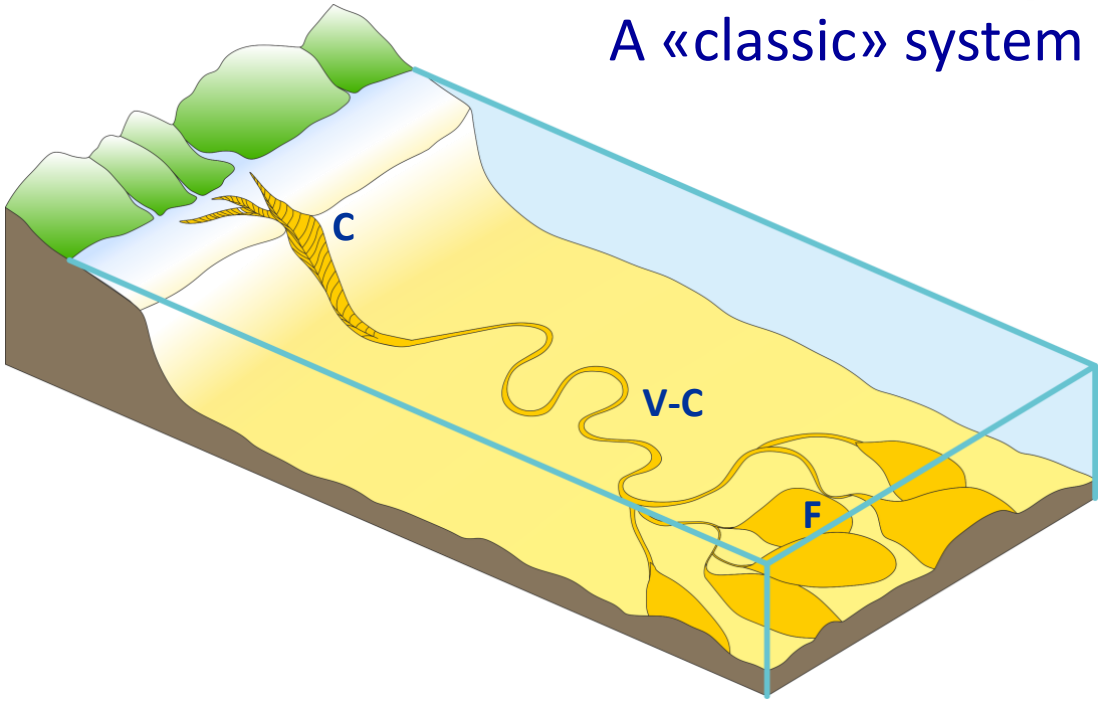
Braided channels of the deep-water depositional system Khuray

Braided river (e.g. Joekulgilkvísl)



Principal schemes

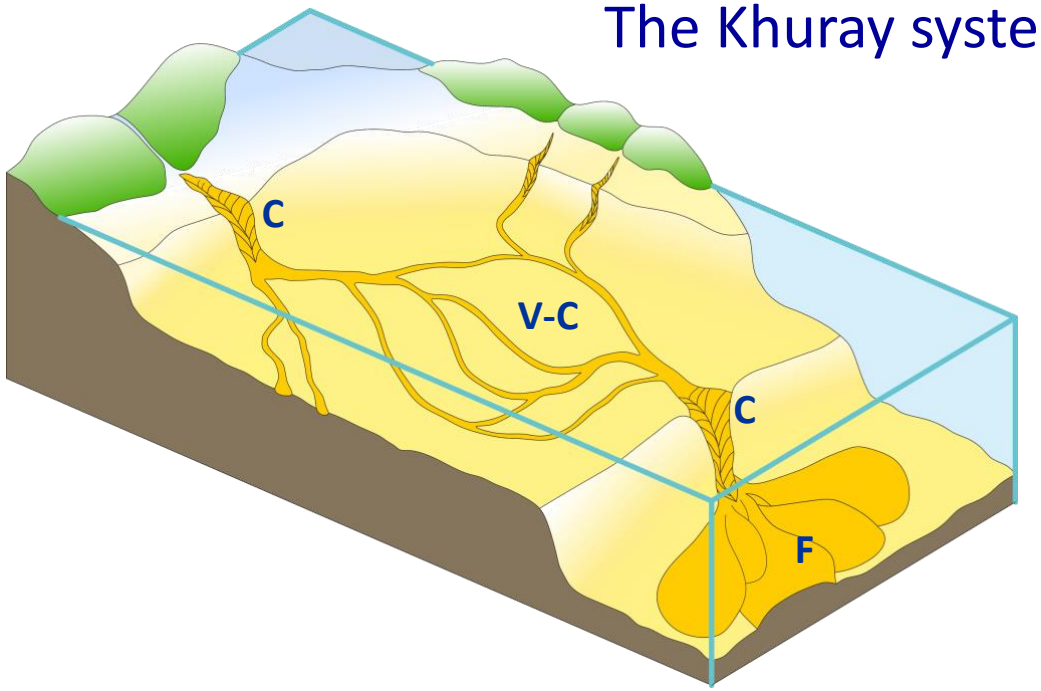
A «classic» system



- Canyon is located only in proximal part
- Valley-channel complex is long and narrow
- Channels are very meandering

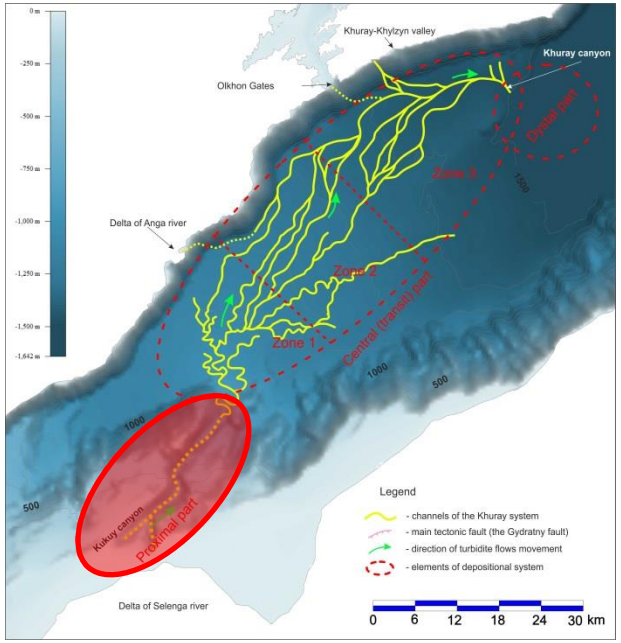
C – Canyon
V-C – Valley-channel complex
F – Lobes of fans

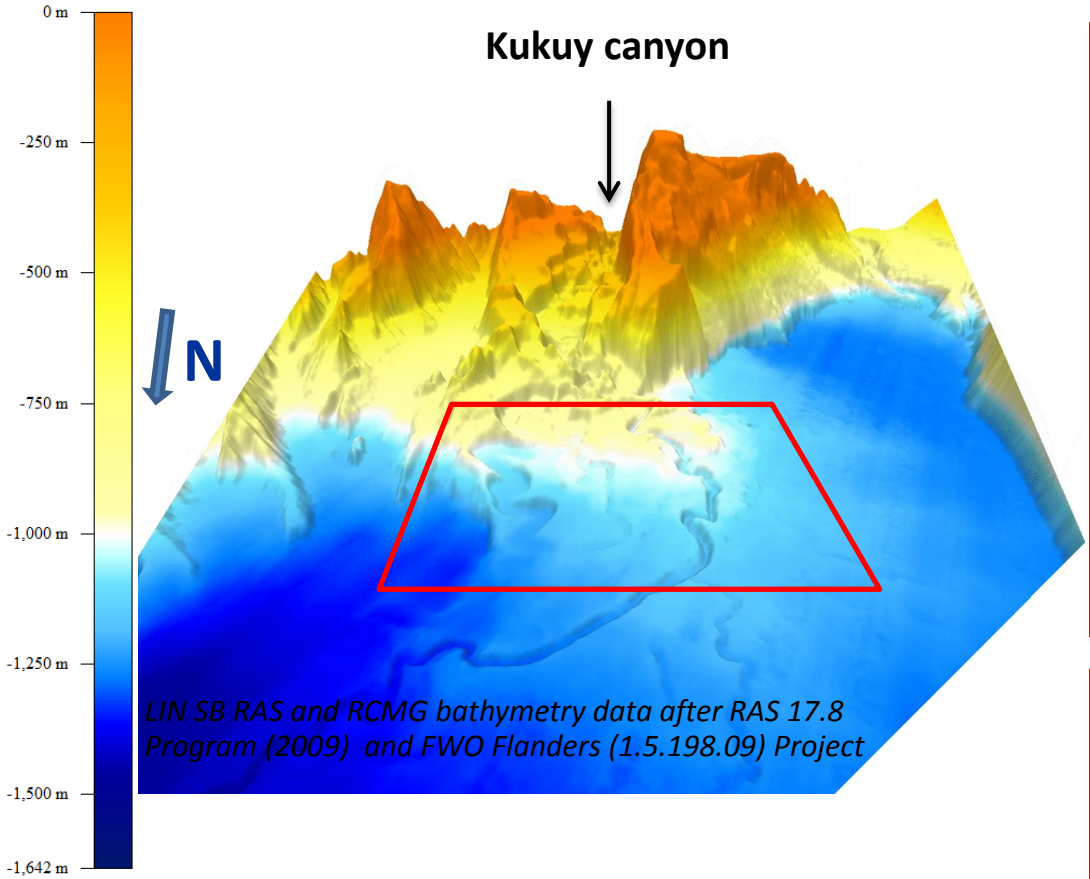
The Khuray system

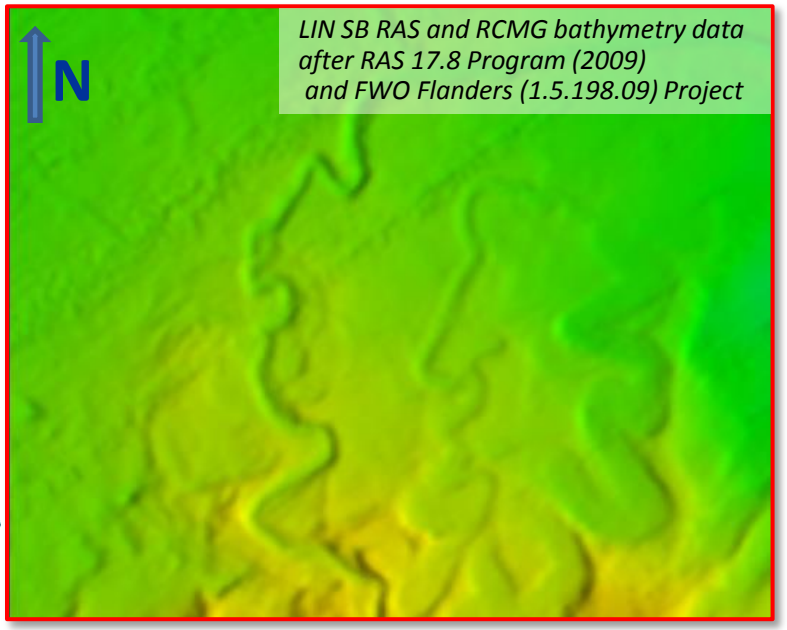


- Canyon is located not only in a proximal part of the system, but also in a distal part
- Valley-channel complex is wide
- Channels are slightly meandering
- Channels are joined again in one in the distal part
- Valley-channel system locates on the tectonic bench with an active fault

Proximal part

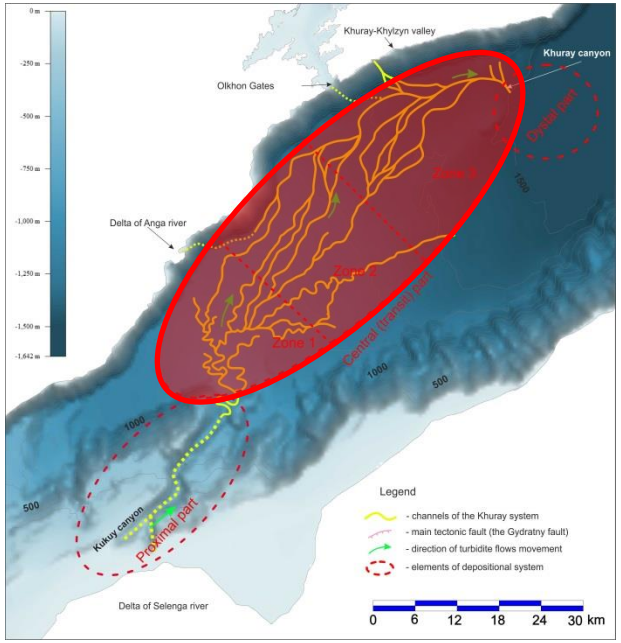






The system is fed by the Kukuy canyon, which is incised into the north part of the Selenga deltafront. In its upper reaches, immediately beyond the mouth of the Kukuy canyon, the Khuray system is represented by a set of meandering channels forming typical deep-water channel-levee complexes, which are well-expressed in bottom topography.

Central part



Features of channels

Zone 1:

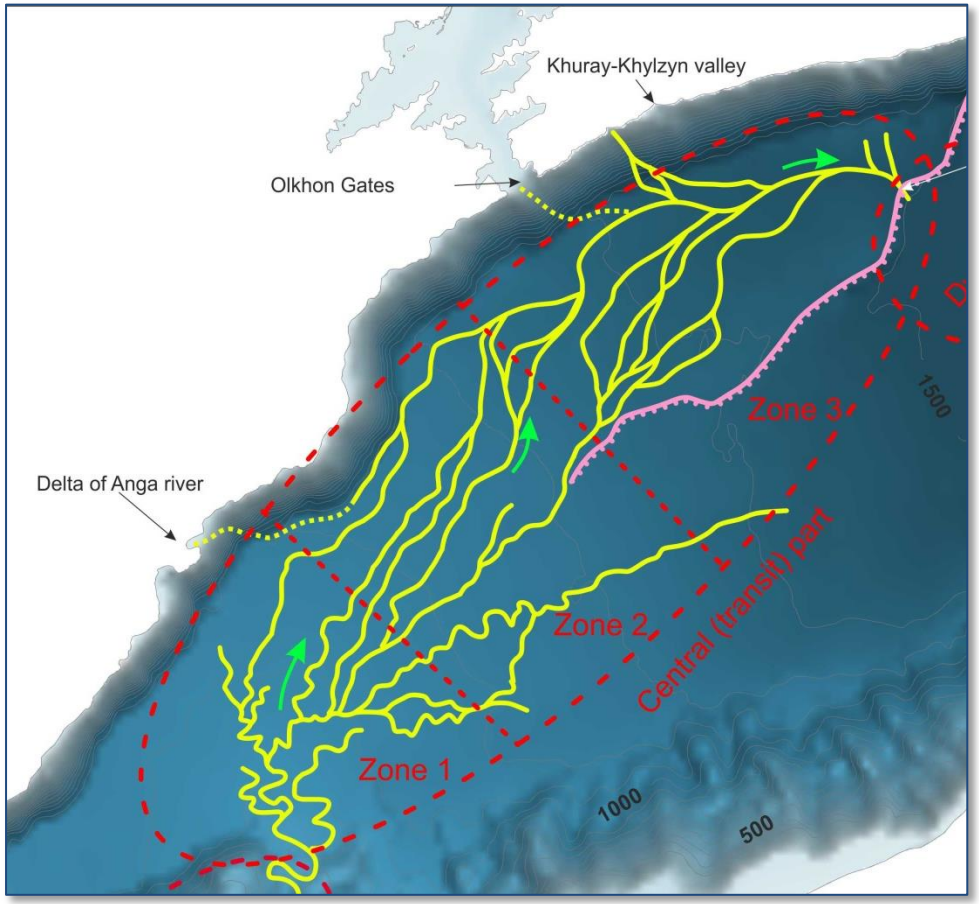
- Well-expressed in bottom topography
- Forms fan-shaped branches
- Channels are very meandering

Zone 2:

- Very difficult detected
- Sub-parallel
- Channels are less meandering

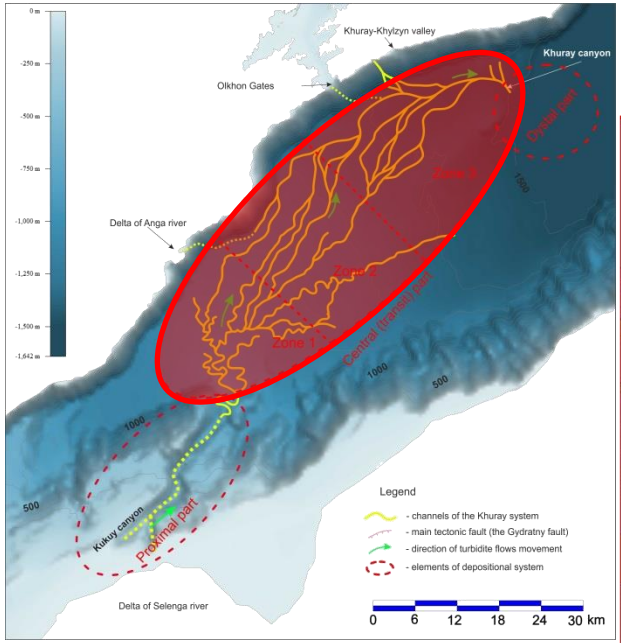
Zone 3:

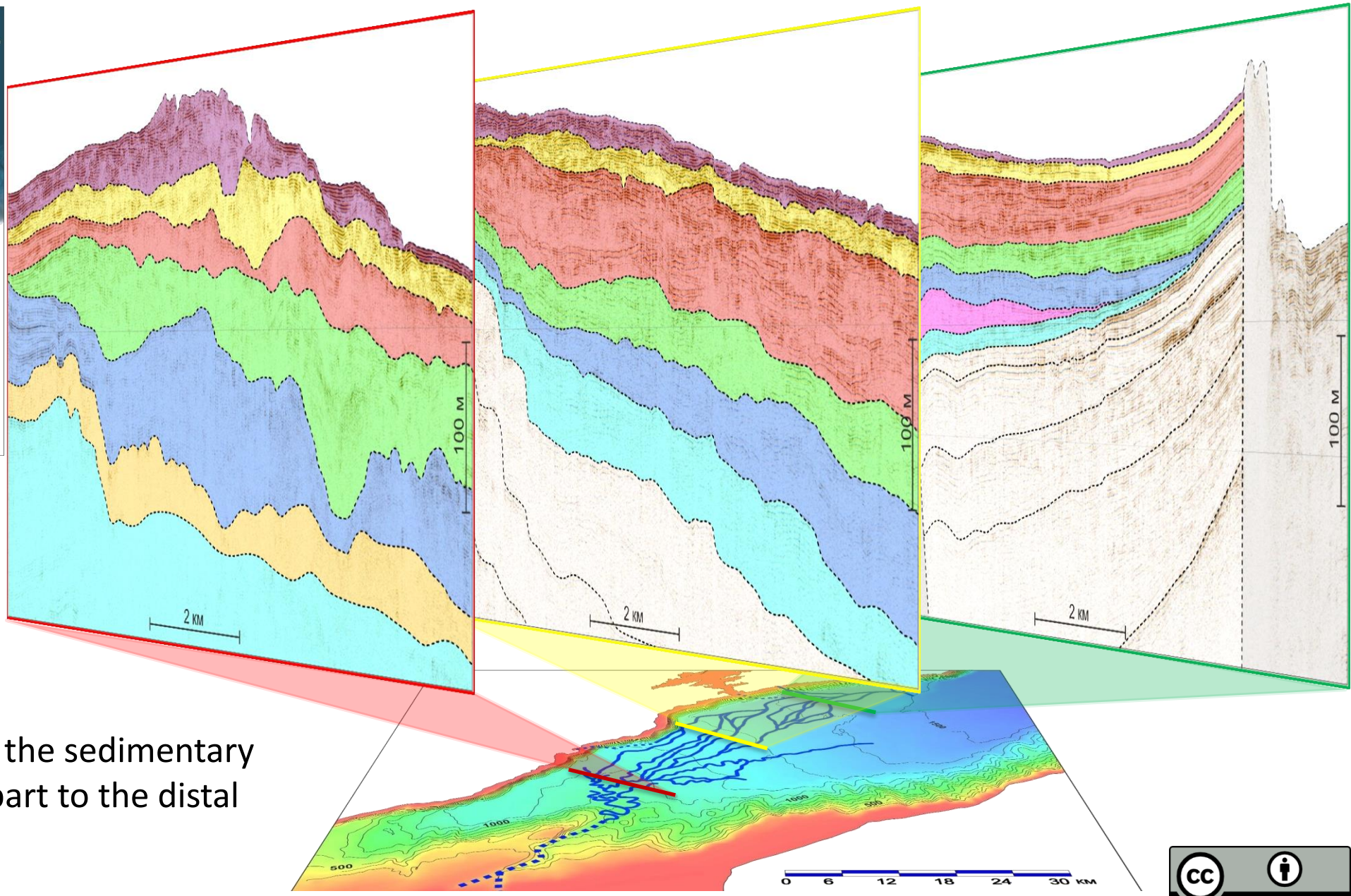
- Well-expressed in bottom topography
- Distinct detected
- Merge each others



The central part of the system develops over a large uplifted fault block, which is separated from of the rest of the Central basin by a well-expressed tectonic escarpment up to 80 m high. Within the block the system of the meandering channels is gradually replaced by a system of less distinct channels, which form a large braided channel complex less commonly observed in deep-water fan systems. At the distal part of the system, the channels become better expressed in bottom relief again and begin merging with each other forming, eventually, a single main channel.

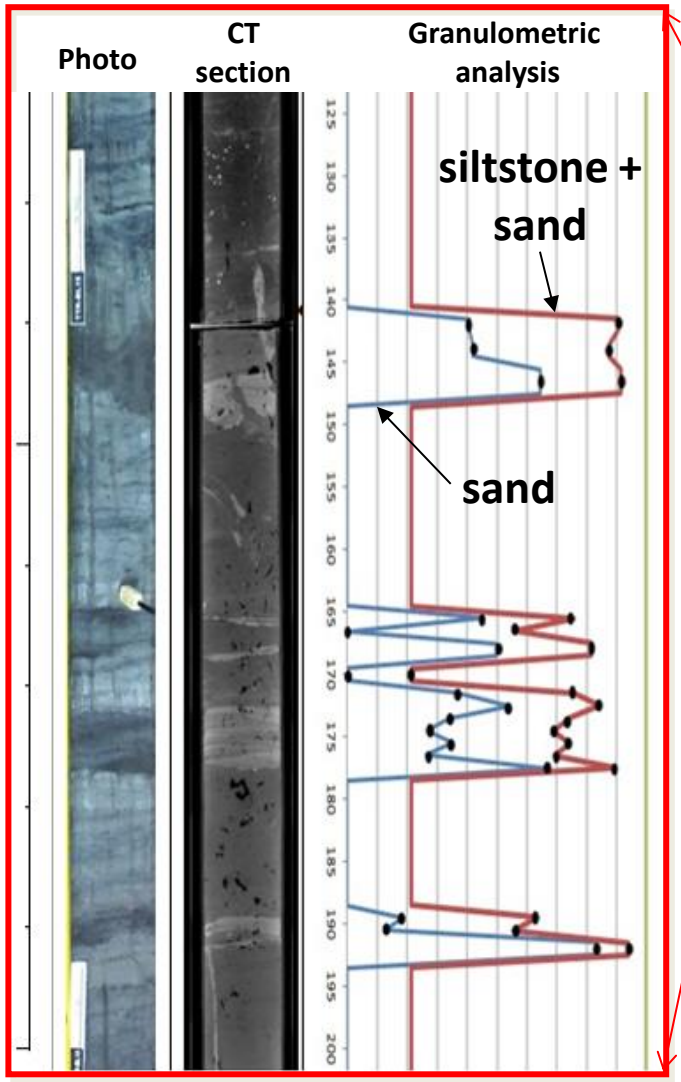
Central part





Changes in the structure of the sedimentary section from the proximal part to the distal part of the Khuray system

Central part



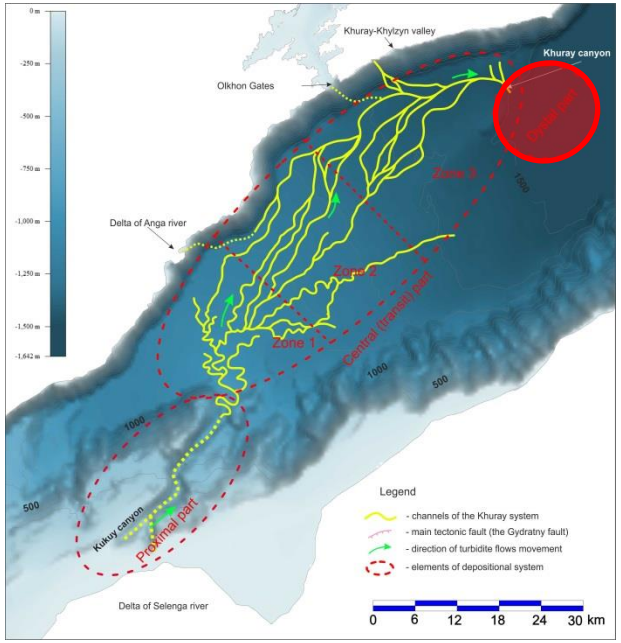
Some attempts have been made to correlate turbidite layers between cores from neighboring stations of bottom sampling

Holocene diatomaceous ooze

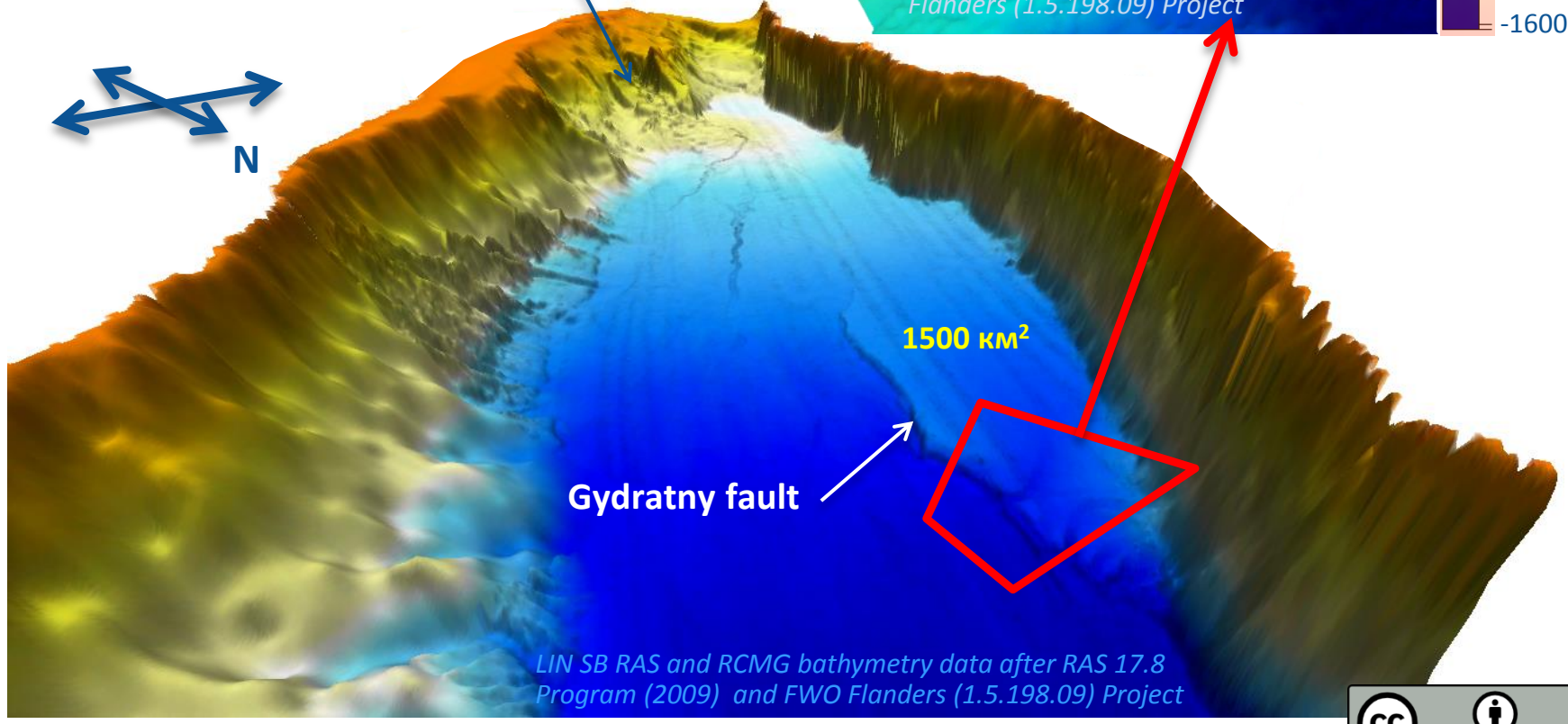
Late Pleistocene clay

Sandy turbidites

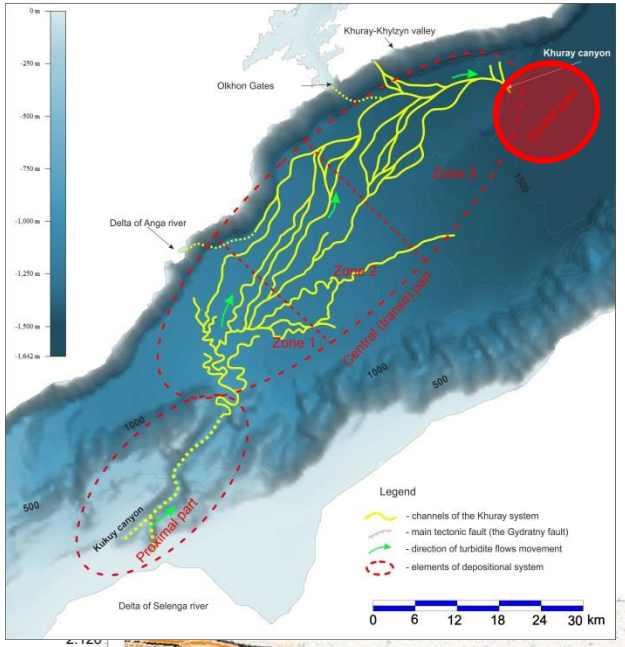
Distal part



Once the small channels converge into the single one, it reaches a tectonic escarpment and forms a distinct erosional incision named the Khuray canyon.



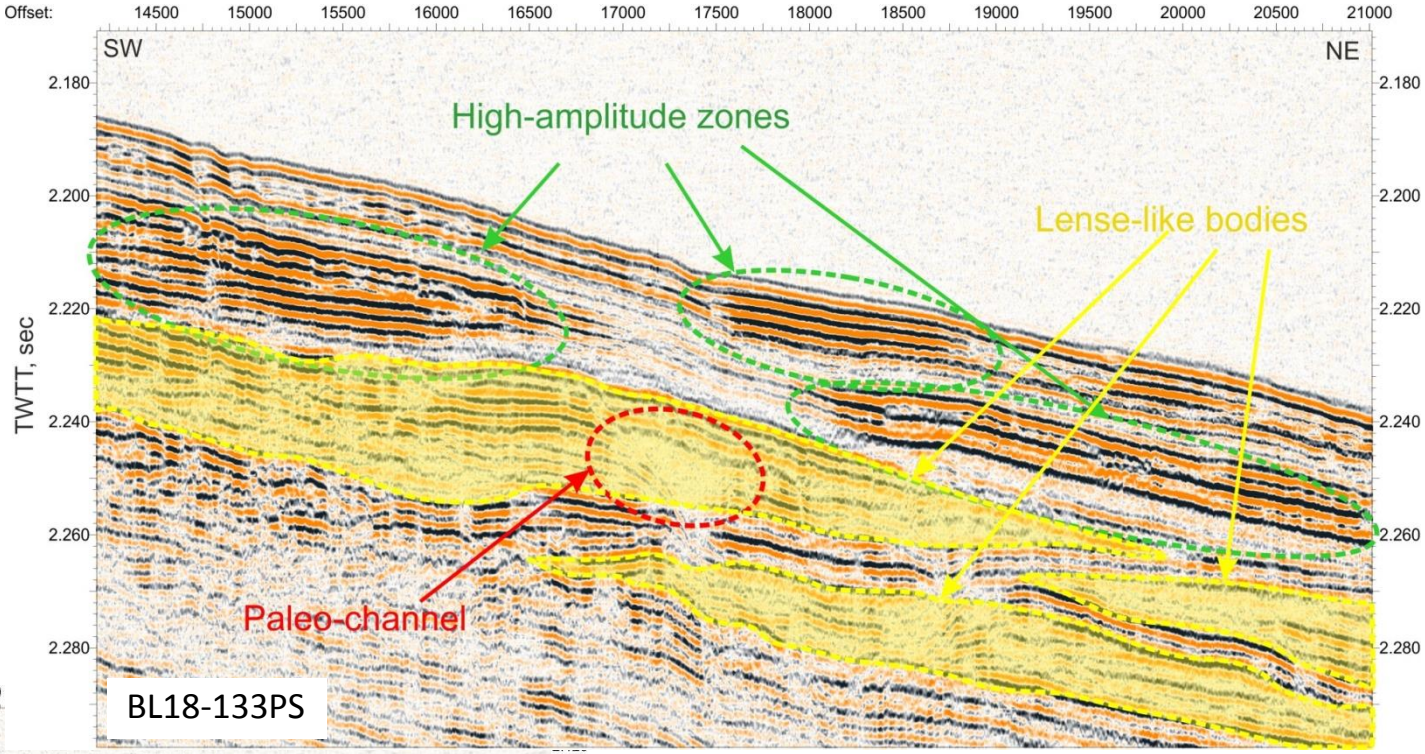
Distal part

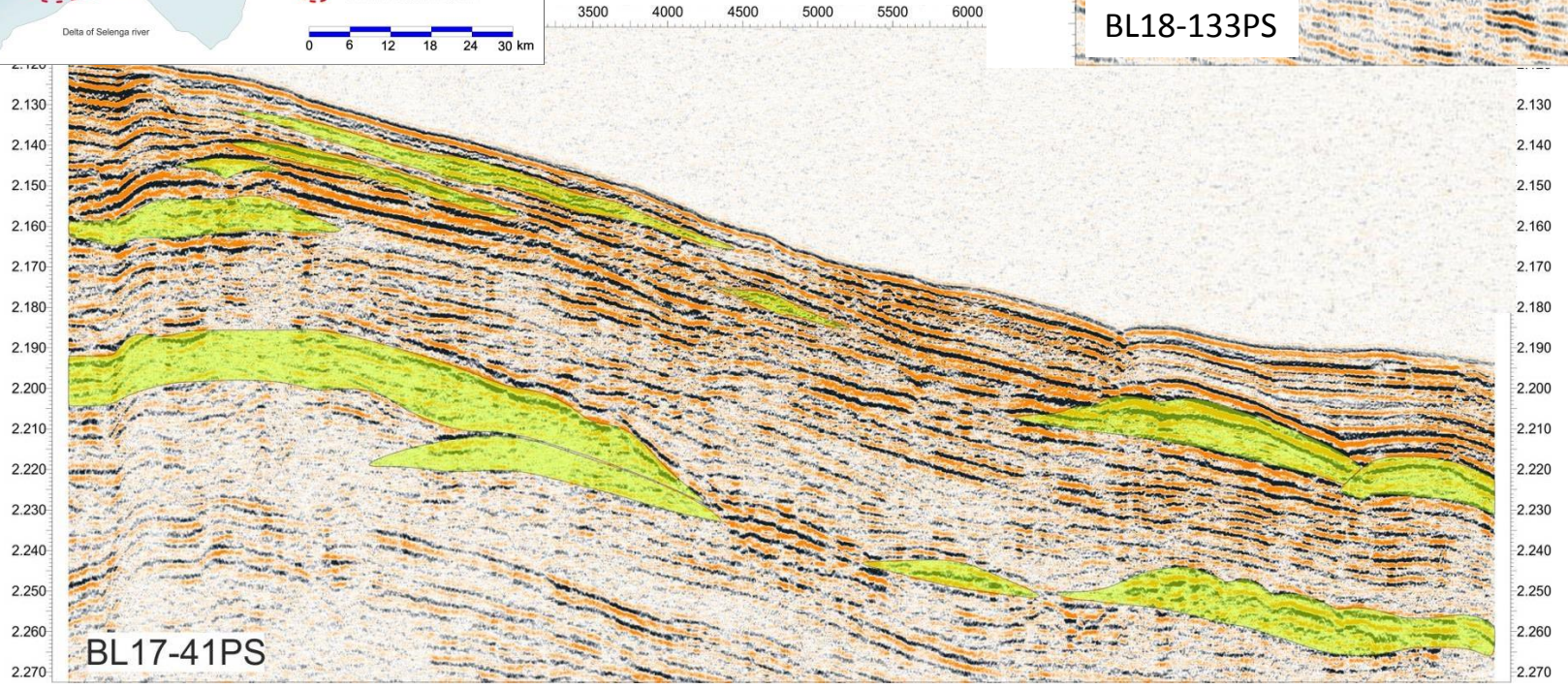


Average sedimentation rates (turbidites) during the late Pleistocene were 75 cm/k.y.

[Evangelinos et al., 2017]

Using this rates the age of the Khuray system is about 70 000 years





Several depositional lobes forming the lower reaches of the Khuray fan are found beyond the mouth of this secondary canyon, which is associated with a base of an active tectonic fault.

There are a lot of large buried paleo-lobes, which were detected on seismic lines

Conclusions

- The Khuray deep-water depositional system has a very complex structure. Khuray-Khylzyn valley is one of several sources of terrigenous material. Selenga river is one of the major sources of clastic material.

- The channels are characterized by numerous branches and merges, different degree of meandering and incision in different parts of the system. The revealed features of mass-movement and actively changing morphology of the whole system are probably determined by active neotectonic processes.

- Differences in the characteristics of turbidite layers as well as the parameters of buried paleo-channels and paleo-lobes, indicate a change in the activity of the system over time and its development, at least, during the last 70 000 years. BUT the current activity of the Khuray system is not proved.

- The results of the cores study demonstrate a periodic activity of channels.

- **Active tectonic processes are believed to be the key factors responsible for the development of such complex architecture of the Khuray lacustrine deep-water depositional system comprising typical slope meandering channels, braided channel complex and several cascading canyons.**

Acknowledgements

The Class@Baikal project and its «Training-through-research» expeditions are unthinkable without help and support of many people and organizations. The authors are grateful to all of them and also thank captains M.V. Chernykh and R.A. Bityutskiy and the crew of RV «G.Yu. Vereshchagin» for their high professionalism and friendly atmosphere during the expeditions.

Thank you for your attention!

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