KEY PROBLEMS OF QUATERNARY STRATIGRAPHY AND PALEOGEOGRAPHY OF YENISEI RIVER MOUTH REGION

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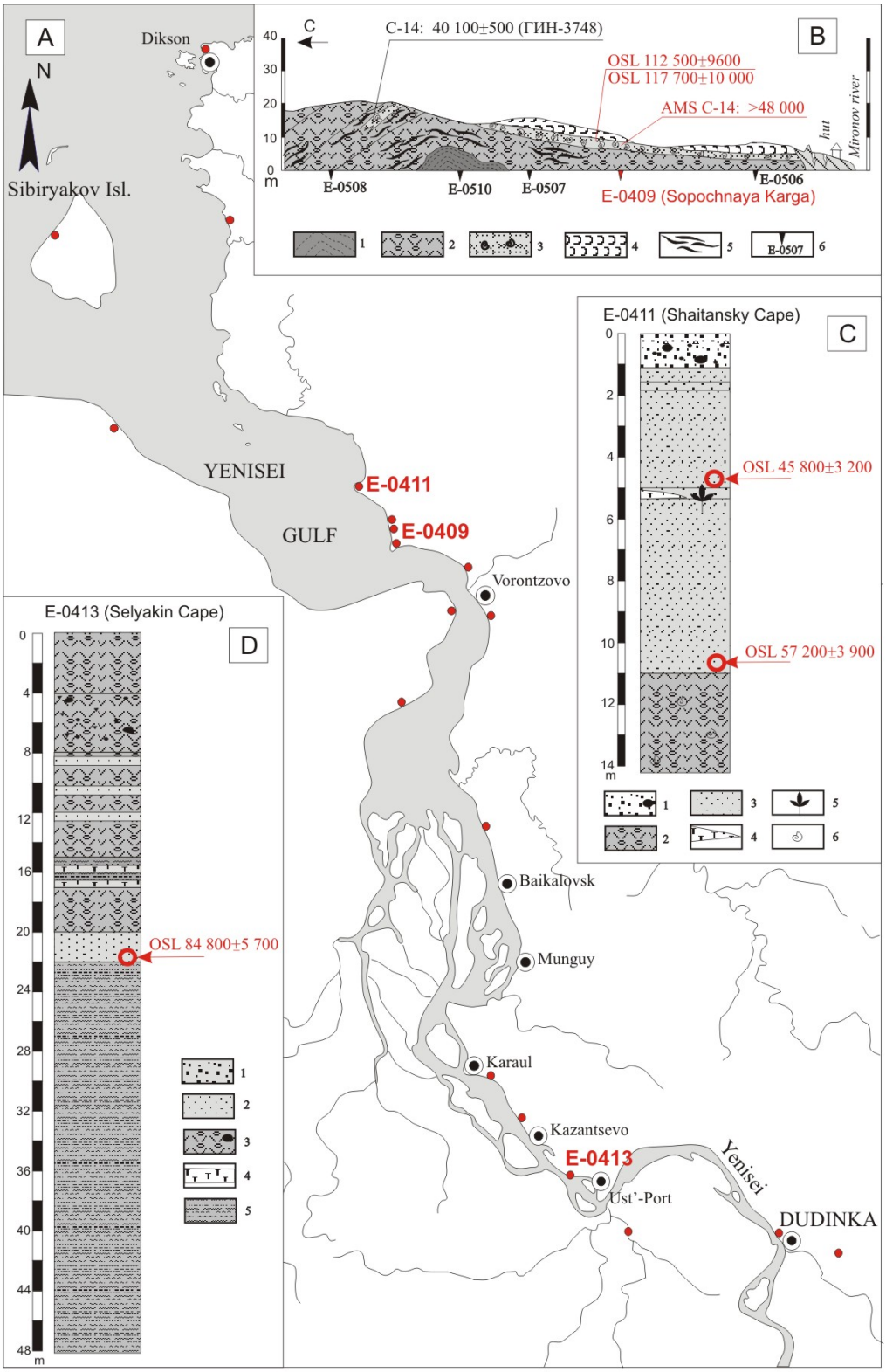
Quaternary deposits of the lower reaches of Yenisei River serve as key sections for Russian sector of the Arctic, and some well-known formations (messovian, sanchugovian, kazanian, zyryanian, and karginian) were described here [*Saks and Antonov, 1945; Saks, 1953*]. Sanchugovskaya suite beds are characterized by dominantly clayey composition, depleted foraminifera complexes, accidental mollusk shells and spore and pollen spectra indicative of cold sedimentation environment. Kazanian beds are commonly clayey sand and sandy clay with abundant Boreal and Boreal-Arctic mollusk fauna and are also rich in microfauna. Karginian Formation, by Saks, includes an alluvium of river terraces, marine postglacial ingression deposits, lacustrine sediments, deluvial beds, and peat. Zyryanian deposits represent sandy and pebble beds as well as sandy clay with cobbles and pebbles. Troitsky [*1966*] based on the mollusk data argued a wide occurrence of karginian beds in the area. Then, in late 1960s, scientists of the Institute of Geology of the Arctic (Leningrad, USSR) suggested a new regional stratigraphy for the loose sedimentary cover of Yenisei River Mouth Region. By their scheme, all stratigraphic units there date back to Pliocene to Pleistocene [*Slobodin and Suzdalsky, 1969; Zagorskaya et al., 1965*] and can be comprehended as results of three marine transgressions: Bolshehetskaya, Kochosskaya & Kazanian. Those sandy and clayey deposits interpreted earlier as zyryanian glacial were reconsidered as pre-Kazanian and included in the Ust'-Port beds [*Slobodin, 1970; Danilov, 1978*]. The Ust'-Port beds was defined by these authors as sand and silt layers bedded above the sanchugovian ones. In contrast to the latter, these are rich in foraminifera complexes.

However, this standpoint implying the Neogene age for the most part of the sequence was then criticized in the literature [*Arkhipov et al., 1980*]. The concept of a widely-spread karginian unit was later revived based on the radiocarbon dating of voluminous organics [*Kind, 1974; Danilov and Parunin, 1982*]. Kaplyanskaya and Tarnogradsky [*1975*] were inclined to consider the sanchugovain cobble sandy clay as a glacial product.

New EPR [*Arkhipov, 1997*], OSL and AMS [*Astakhov and Mangerud, 2005*] dates were yielded recently for Yenisei River Mouth Region. These dates support older (kazanian) age of the deposits recognized earlier as the Karginian Formation in the stratotypic sections at Cape Karginsky and in the Malaya Kheta river valley.

The research of stratigraphy and paleogeography of Yenisei River Mouth Region is now carried out by VNIIOkeangeologia, St. Petersburg, Russia, in collaboration with the Institute of the Earth's Cryosphere and Moscow State University (the latter, in 2004-2009). First results of these studies were presented in Annual Reports of field campaigns of VNIIOkeangeologia (2004-2007), as well as at the conferences [*Romanenko et al., 2005; Streletskaya et al., 2005*] and in research papers [*Streletskaya et al., 2007; 2009*].



А - Scheme of Quaternary sections of Lower Yenisei Area.
Red dots shows studied sections.
Б – Sopochnaya Karga section (East bank of Yenisei Gulf) near SopKarga Polar station : 1 – Late Cretaceous rocks; 2 – clayey silts; 3 – sands with shells; 4 – modern solifluction; 5 – deformations; 6 – numbers of sections.
В – Shaytansky Cape section: 1 – sand with pebbles; 2 – clay; 3 – sand; 4 – peat; 5 – plant fragments; 6 – shells.
Г – Selyakin Cape section: 1 – sand with gravel; 2 – fine-size sand; 3 – clay; 4 – peat; 5 – laminated silts.

More than 40 natural outcrops of loose sediments were described along the Yenisei valley, its tributaries, and at the Yenisei Estuary shore. Grain size, spore and pollen contents, foraminifera, ostracoda and diatoms were studied. Sampled marine and freshwater mollusks were identified. A wide range of environments including marine, glacial-marine, lagoon, fluvial, limnic and limnic to bog, have been reconstructed.

A series of OSL, AMS C^{14}, and U-Th dates have been obtained for these deposits. Radiocarbon dating was performed for the freshwater mollusk shells (*Pisidium amnicum* Mull., *Lymnea peregra* Müller, *Anisus spirorbis* L.) from a thin layer of sandy clay rich in wood remnants. This layer divides upper stratified ice and the ice complex deposits with polygonal vein-filling ice in a round-shaped thermokarst pit near the Sopochnaya Karga polar station. The date we obtained, 10.282±67 ka (AA-75298), evidences for the Early Holocene age of the host clayey sand.

North of Sopochnaya Karga a number of sections have been described with kazanian sand or clayey sand rich in marine mollusks *Hiatella arctica* L., *Astarte sulcata* (da Costa), *Angulus* sp. nov., *Astarte montague* (Dillw.), *Acanthocardia ciliate* (Fabr.), *Chlamys islandicus* (Müll.), *Mytilus edulis* Linn., *Clinocardium ciliatum* (Fabr.), *Nuculana minuta* (Müll.), *Yoldiella* cf. *intermedia* (Sars), *Tachyrchynchus* sp nov., *Buccinum bayani* Jouss., *B. undatum* (Linn.), *Mya* cf. *arenaria* (Linn.), *Neptunea communis* (Midd.), *Hemithyris* sp., *Criptonatica clausa* (Brod. & Sow.), *Solariella obscura* (Couth.), *Admete viridula* (Fabr.), *Oenopota pyramidalis* Storm, *O. nobilis* (Müll.), *Euspira pallida* (Brod. & Sow.), *E. Catena* (da Costa), *Boreotrophon truncates* (Storm), *Balanus* sp. (analyzed by A. Krylov). The material for dating was sampled from the upper part of kazanian deposits. AMS radiocarbon dating of an *Angulus* sp. nov. shell yielded a radiocarbon age of more than >48 000 years (AA-76991). An OSL dating was performed for the host sand. The dates are 112,5±9,6 ka (RLQG 1769-107) and 117.7±10.0 ka (RLQG 1770-107). Earlier Kaplyanskaya and Tarnogradsky obtained a radiocarbon date for a voluminous sample of kazanian sand from somewhere directly northward of the described area, which was 40,1±0,5 ka (GIN-3748).

Two dates were obtained from the sand topping the sequence at Cape Shaitansky (72ºN, 90.1 m a.s.l.), 45.8±3.2 ka (RLQG 1796-048) and 57.2±3.9 ka (RLQG 1797-048). The sand is foraminifera-free but contains some wood, weeds, sponges, diatoms and megaspores. Spore and pollen spectra evidence for warm environment with predominantly taiga vegetation. Trees make up the most part of these spectra. Based on the texture and structure of the sand one can suggest a fluvial deposition. The sand overlies a thick pack of dark-brownish-gray compact sandy clay readily breakable into small angular clasts. This pack includes fragments of bivalve mollusks, accidental shells of foraminifera, and abundant associations of largely freshwater diatoms.

Another OSL date comes from the sand covering varved silt at Cape Selyakin, 84.0±5.7 ka (RLQG 1795-048). This silt body was first referred to Sanchugovian Formation [*Saks & Antonov, 1945; Saks, 1953; Troitsky, 1966*] but later was redefined by Troitsky [*1979*] as a separate local chronostratigraphic unit. The overlying sand, which we dated by the OSL method, Troitsky considered Sanchugovian. Still, if the date is correct, the sand has to be referred to zyryanian glacial deposits. Nevertheless, this is in disagreement with the spore and pollen spectra proving a warmer environment than both below and above and suggesting therefore rather a northern subzone of taiga than an ice desert. Rich diatom complexes from these deposits should be interpreted as formed at a marshy lower floodplain. The below varved Selyakin silt may have kazanian age, similar to the section at Malaya Kheta, where finely laminated silt at the base of the section has an OSL age of 80-121 ka [*Astakhov and Mangerud, 2005*].

As was shown above, the new data considerably constrain the stratigraphy of the Yenisei River Mouth Region. Kazanian deposits appear to occur widely than karginian ones.

Thus, in Taimyr Peninsula, the dating confirms the karginian age only for the deposits bedded below 20 m a.s.l., while based on the Taimyr Lake level changes the karginian ingression of sea had to be up to 40 m above the modern sea level [*Bolshiyanov, 2006*]. It seems plausible that deposits of various age and facies built up the principal landforms in that area, from sanchugovian to kazanian and, possibly, to yet younger ones.

Besides, our data do not confirm a wide coverage of zyryanian glaciers believed to spread from a glaciation center in Kara Sea. The Early and Late Zyryanian basin sediments including varved silt with "warm" spectra and rich freshwater diatom complexes in the sections of Cape Selyakin and Cape Shaitansky suggests an environment rather close to nowadays than a serious chilling favoring a glaciation.

Also, the new data do not support an allochtonous position of kazanian sand with abundant Boreal mollusk fauna [*Kaplyanskaya and Tarnogradsky, 1975*]. Indeed, if these sediments were transported by a glacier from the Kara Sea floor to its modern shoreline, the OSL dates would show not a kazanian but zyryanian age. In addition, in many localities, the mollusk shells, however fragile, remain in living position and largely intact.

One of the hardest challenges in the study area remains the correlation of individual sections. Ubiquitous occurrence of permafrost including thick buried ice layers and polygonal vein-filling ice favors partial seasonal melting and vigorous solifluction, thermal denudation and thermal abrasion. The upper parts of the sections could have been well displaced, melted and refrozen. Add poor exposure of sediments, ongoing tectonic dislocation pronounced in slumping on the flanks of uplifts, and quick alternation of facies of similar age within short distances.

To further investigate and gain new insights into the interrelation of Quaternary units of Yenisei River Mouth Region, a Georadar profiling similar to seismoacoustic profiling on shelf is strongly desired, coupled with wider involvement of all available modern techniques for studying the outcrops.

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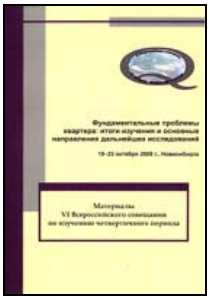

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