Biostratigraphy of Late Holocene bottom sediments from the Northern part of Chukchi Sea

Short communication

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ABSTRACT. The research goal is the investigation of environmental processes of recent sedimentation in the Arctic Ocean area. A short core (length – 37 cm) was taken from the Northern part of the Chukchi Sea. Analytical methods included macroscopic sedimentological description by smear-slides, dating by γ-measurements of ^{137}Cs and ^{210}Pb, diatom and palynological analyses. Sedimentation rates at the research site have been determined to be 1 mm y^{-1}. Thus, the age of the cored sediments spans approximately 400 years, which includes the period of the Little Ice Age. Abundant cold-water diatom species and spores of terrestrial plants within the lower part of the sediment core are characteristic for cold climate conditions, which dominated the Little Ice Age. The occurrence of Jurassic, Cretaceous, and Neogene species of spores and pollen in the Holocene deposits are the evidence of coastal abrasion and the subsequent transfer of the material to the coring site by currents. Southern, subtropical, and tropical species of diatoms within the upper, more recent part of the core reveal the transfer of material by currents from the Pacific Ocean to the Arctic Ocean through the Bering Strait. The results of biostratigraphic analyses indicate environmental changes during the last 400 years, revealed in bottom sediments of the Northern part of the Chukchi Sea.

Keywords: Chukchi Sea, bottom sediments, Little Ice Age, recent sedimentation, pollen, diatoms

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1. Introduction

Recent climate warming (Brohan et al., 2006; Wilson et al., 2007) leads to changes in the natural environment, both on continents and in oceans. The research has been conducted in the Chukchi Sea, a marginal sea of the Arctic Ocean, located between Chukotka and Alaska. Here, the increase of the mean annual air temperature over the past decades has caused a distinct areal reduction of ice cover (Stone, 1997; Crane, 2005). Such climatic and environmental changes are reflected in the formation and composition of the bottom sediments of the Chukchi Sea (Astakhov et al., 2018; Vologina et al., 2018; Astakhov et al., 2019; Vologina et al., 2019).

Compared to other marginal seas of the Arctic Ocean, the Chukchi Sea is characterized by its higher biological productivity, caused by the inflow of warmer Pacific waters through the Bering Strait [Ogorodnikov and Rusanov, 1978; Grebmeier et al., 2006; Astakhov et al., 2015]. Consequently, biostratigraphic methods are particularly important for studying bottom sediment of this area and are widely used (Saidova, 1994; de Vernal et al., 2005; Obrezkova et al., 2023).

This paper presents biostratigraphic results of palynological and diatom analyses of upper layers of bottom sediments sampled in the Northern region of the Chukchi Sea and leads to a better understanding of environmental processes of recent sedimentation in this region of the Arctic Ocean.

2. Material and Methods

Sediments were taken during an international expedition with the research vessel «Professor Khromov» in 2012. Core b16 with a length of 37 cm was recovered from a «boxcorer» at a site in the northern part

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of the Chukchi Sea with coordinates 72°32'37.8" / N 175°59'42" W, at a water depth of 100 m (Fig. 1). After splitting the core in half a macroscopic description of the split core was carried out, followed by the analysis of smear-slides with a light microscope SK14 (magnification x 100). Smear-slide description included the qualitative determination of the particle size and the occurrence of lithological and biological components. The sediments of the core were dated by γ-measurements of the activities of ^{137}Cs and ^{210}Pb, described by (Vologina et al., 2018; Vologina et al., 2019). Diatom and palynological analyses were carried out at sampling intervals of 1 cm to 2 cm. Diatom analysis was performed according to (Zhuze et al., 1969; Diatoms of the USSR, 1974) and preliminary results were published by Vologina et al. (2018). Technical processing of samples for palynological analysis was carried out according to a well-known method (Berglund and Ralska-Jasiewiczowa, 1986).

3. Results

The sediments of core b16 are represented by clayey silt with an insignificant admixture of sand (Fig.2). The relatively homogeneous lithological composition indicates stable depositional conditions during their formation. Dating results reveal a sedimentation rate of approximately 1 mm y^{-1}, implying a time range of 400 years for core b16. It includes the period of the Little Ice Age (LIA) from 1600 AD–1850 AD to the present (Vologina et al., 2018). Thus, the studied deposits belong to the Late Holocene.

3.1. Palynological analysis results

The total amount of pollen and spores in the sediments of core b16 ranges from 221 to 637 specimens (Fig. 2). Based on their composition, two different sections can be distinguished in the core.

Section 1: 17–37 cm. *Picea obovata* and *Sphagnum* sp. are dominant in this interval, which is characterized by a high content of spores (46–54 %), especially represented by *Sphagnum* sp. (30–38 %). Tree pollen (19–28 %), containing mainly *Picea obovata* (13–21 %), *Pinus* sec. *Cembra* (2–4 %) and *Pinus sylvestris* (2–4 %). Shrubs (12–21 %) are less frequent in the spectrum and mainly represented by *Betula* type *Nanae* (6–13 %) and *Duschekia* sp. (4–10 %). Grass pollen (7–15 %) are less frequent and contain mainly by Ericales (1–7 %), *Artemisia* sp. (up to 3 %), Cyperaceae (up to 2 %) and various herbs (2–5 %).

Section 2: 0–17 cm. This section is dominated by *Picea obovata*, *Betula* type *Nanae*, *Duschekia* sp. and *Sphagnum* sp. The content of spores (43–51 %) decreases and is represented by *Sphagnum* sp. (29–37 %), Polypodiaceae (4–9 %), Lycopodiaceae (2–5 %). The amount of tree pollen changes slightly (12–28 %), characterized by *Picea obovata* (8–20 %), *Pinus* sec. *Cembra* (1–4 %), *Pinus sylvestris* (1–4 %), *Betula* type *Albae* (up to 2 %). Section 2 contains more shrub pollen (16–29 %), namely *Betula* type *Nanae* (8–14 %), *Duschekia* sp. and *Salix* sp. (6–16 %). Grass pollen account for 9–12 %, including Ericales (1–5 %), Cyperaceae (up to 4 %), *Artemisia* sp. (up to 4 %), Poaceae (up to 2 %) and various herbs (2–4 %).

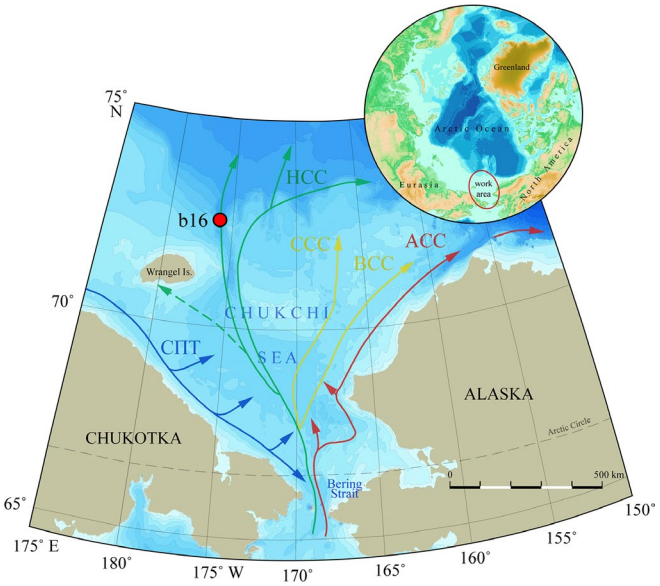

Fig.1. Map of Chukchi Sea with the positions of core b16. The arrows mark main ocean currents within Chukchi Sea according to (Stein et al., 2017): SCC – Siberian Coastal Current, HC – Herald Canyon Current, CC – Central Channel Current, BC – Barrow Canyon Current, ACC – Alaska Coastal Current.

Up to 1.8 % of redeposited forms of the Neogene age (N) occur throughout the core (*Tsuga* sp., Juglandaceae, *Carya* sp., *Myrica* sp., *Alnus* sp., *Quercus* sp., *Betula* sp. *Corylus* sp., *Ulmus* sp., *Tilia* sp., *Osmunda* sp.) and up to 1 % of forms of the Jurassic (J) and Cretaceous (K) periods (*Cyathidites*-type, *Pinus protocembra, Gleicheniidites* sp., *Ginkgo* sp., *Cicatricosisporites* sp.) (Fig. 2).

3.2. Results of diatom analysis

The distribution of the most typical diatoms in the sediments of core b16 is presented in Table. 54 taxa of diatoms have been identified. The composition is dominated by planktonic species (61.1 %). The content of neritic species is 30 %, oceanic species – 26 % and sub-littoral species – 18.5 %.

Arctoboreal and subboreal diatoms amount 62.8 % of the total diatom content. Nevertheless, a distinct occurrence can be observed of southern boreal, subtropical and tropical species, as well as redeposited ancient diatoms.

Approximately half of all diatom valves belong to the genus *Chaetoceros* Ehr. (up to 50 %) and the species *Chaetoceros* sp.(up to 28 %). *Coscinodiscus marginatus* Ehr. represents 0.5–8.3 %, *Ch. mitra* (Bailey) Cleve – 1.1–6.2 %. The increased content of diatom species is observed in the lower part of the core (Section 1, Table), where arctoboreal, cold-loving species of the genus *Thalassiosira* dominate: *Th. antarctica, Th. hyalina*, as well as *Bacterosira fragilis*, *Coscinodiscus marginatus, Actinocyclus* sp., *Paralia sulcata* (Ehr.) Cl., *Rhizosolenia hebetata* (Bail.) Gran. and numerous representatives of the genus *Chaetoceros*.

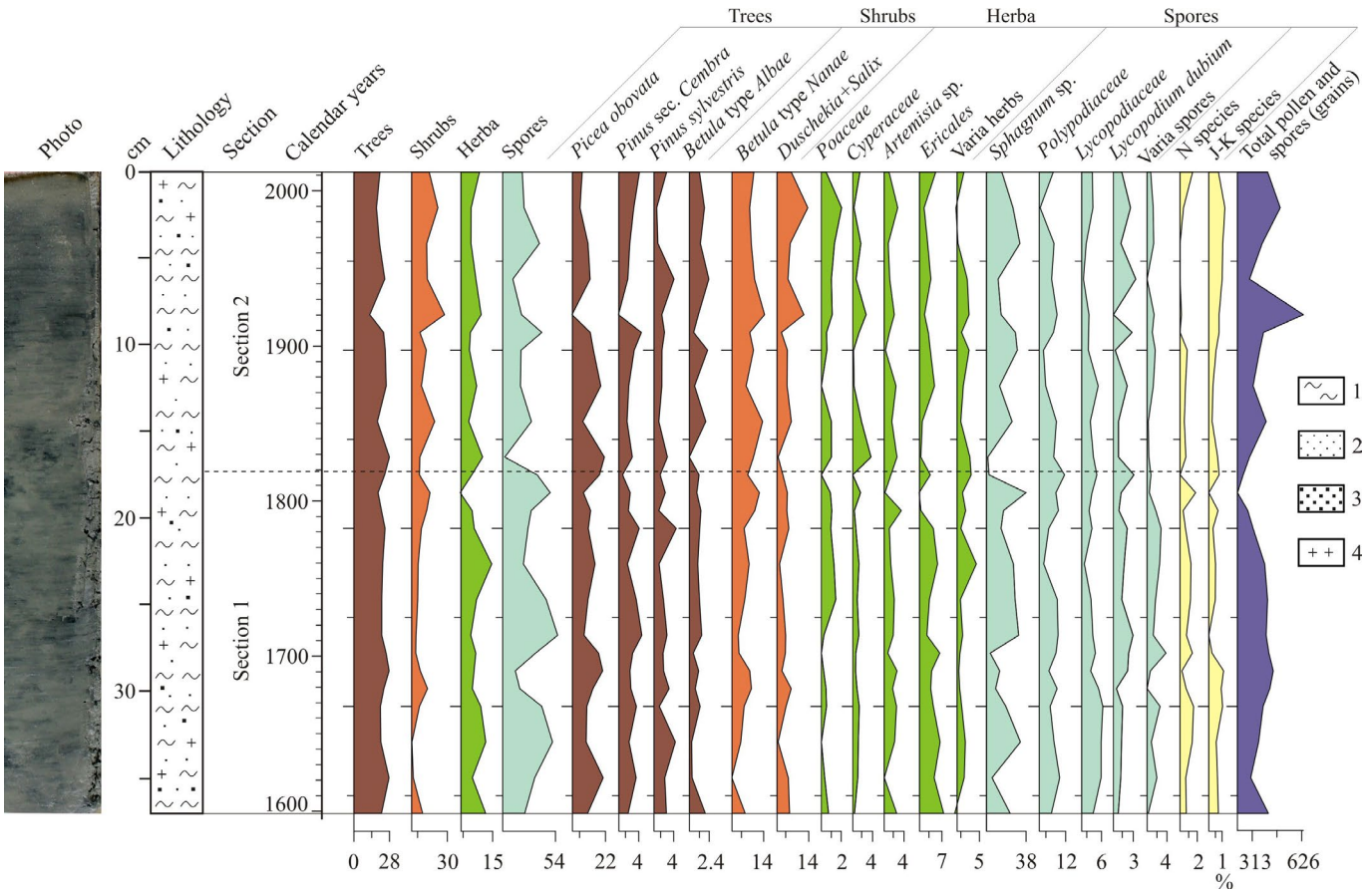

Fig.2. Core b16: photo, lithology and diagram of pollen and spores. Legend of lithology: 1 – clay, 2 – silt, 3 – sand, 4 – diatoms. Note for the diagram: N – Neogene, J-K – Jurrassic-Cretaceous.

4. Discussion

The Holocene sediments of the Chukchi Sea consist mainly of material formed by bottom erosion and coastal abrasion (Yashin, 2000). Material from river runoff accounts for not more than 7 %. In the sediments from the northern part of the Chukchi Sea the terrigenous fractions predominate over the biogenic components.

The palynological spectra of sediments from core b16 generally reflect forest-tundra and tundra vegetation, which is widespread along the coasts of the Chukchi Sea including a distinct predominance of pollen of shrubs, herbs and spores. In the lower part of the core, corresponding to the period of LIA, an increase in the content of spores is associated to colder climatic conditions. Re-deposited species of the Jurassic, Cretaceous, and Neogene are observed throughout the entire sediment core (Fig. 2). They derived from coastal abrasion and subsequent transfer by currents. The results are distorted by the significant content of coniferous pollen (especially spruce). Their most likely source is assumed to be by currents from the Bering Sea.

Most of the diatom species observed in the sediments of core b16 (almost 2/3 of the total composition) are characteristic of cold-water conditions at high latitudes. The presence of south boreal, subtropical, and tropical valves is most likely caused by their entry through the Bering Strait (Astakhov et al., 2015; Vologina et al., 2018), facilitated mainly by currents (Grebmeier et al., 2006). The identification of changes in composition and quantity of pollen, spores and diatoms in the sediments allows a distinction of two stages of sedimentation. Obviously, lower temperatures during cooler environmental conditions throughout LIA prevailed during the time of sedimentation within the lower half of the core. This caused lower biological productivity and lead to the increase of the cold-water species of genus *Thalassiosira* (Table) (Vologina et al., 2018).

The obtained data correlate well with variations in the chemical composition of bottom sediments sampled in the northern part of the Chukchi Sea (Astakhov et al., 2019). The results of palynological and diatom analyzes complement the geochemical data for core b16 and are consistent with the reconstruction of ice conditions in the Arctic over the past 300–400 years (Astakhov et al., 2019).

5. Conclusion

Detailed biostratigraphic analyses of a sediment core from the northern part of the Chukchi Sea allow the reconstruction of environmental conditions during the last 400 years in this part of the Arctic Ocean. The lower section of the core was formed during the cooling period of the Little Ice Age. It is characterized by the deposition of the cold-water diatoms and the increased content of spores of terrestrial plants. The upper core-section represents the time after the end of LIA, when warmer climate conditions prevailed and led

Table. Content of the most frequent species of diatoms in the core b16 (in % of the total number)

Section	Depth, cm	*Achnanthes brevipes*	*Bacterosira fragilis*	*Coscinodiscus marginatus*	*Chaetoceros* sp.	*Ch. mitra*	*Chaetoceros* (spores)	*Nitzschia* sp.	*Rhizosolenia* sp.	*Thalassiosira antarctica*	*Th. hyalina*	*Th. nordenskioeldii*	*Thalassionema nitzsehioides*
2	0–1	3.7	2.6	1.1	12.4	5.7	59.9	4.0	0.15	0.5	0.3	4.0	0.9
	3–4	1.3	1.0	4.1	3.4	1.1	41.7	4.3	1.5	3.2	0.9	1.7	3.0
	5–6	1.8	3.5	2.2	2.4	3.9	47.5	5.1	0.6	2.7	1.1	3.1	3.1
	7–8	1.5	2.3	1.7	5.4	6.2	49.4	3.2	0.8	1.9	0.9	0.6	2.6
	9–10	3.2	1.8	0.9	12.4	5.8	35.1	4.5	0.5	3.6	0.9	0.8	2.2
	11–12	1.1	1.9	2.1	15.5	4.1	41.9	3.2	8.0	3.4	–	1.9	3.4
	13–14	0.7	3.3	1.6	14.9	3.3	44.2	3.6	0.5	3.1	–	2.5	1.1
	15–16	1.4	2.3	0.9	9.2	5.5	49.3	4.3	0.9	1.3	–	2.3	1.1
1	17–18	1.2	2.7	8.3	16.6	4.2	32.3	3.7	2.3	2.1	1.1	0.2	2.7
	19–20	0.7	2.1	1.5	19.3	6.1	42.1	5.3	2.1	0.8	0.2	1.2	2.8
	21–22	1.3	4.2	1.1	22.5	5.3	32.1	3.3	1.7	2.0	0.4	1.6	3.6
	23–24	1.0	2.1	0.7	28.4	4.0	35.6	4.5	1.6	2.0	0.9	1.8	1.4
	25–26	1.5	2.0	1.3	25.1	5.2	29.4	3.3	3.1	4.1	2.5	–	1.3
	27–28	1.3	2.1	1.0	28.0	4.0	27.3	4.1	3.4	3.0	1.3	0.3	2.7
	29–30	0.9	1.3	0.5	14.9	4.3	40.3	2.9	1.6	4.5	0.9	0.2	0.2
	31–32	0.6	1.1	0.5	14.7	2.6	45.1	4.1	2.7	2.6	0.1	1.0	1.5
	33–34	0.3	1.6	0.6	9.8	4.6	45.4	4.0	2.4	3.0	1.0	0.6	2.2
	35–36	0.8	1.6	2.3	10.5	8.4	29.0	3.9	2.6	3.9	1.5	0.3	1.6
	36–37	0.8	1.2	1.1	12.5	2.8	50.1	3.7	1.8	1.2	1.5	0.8	1.2

to a distinct reduction of the cold-water diatoms and spores of terrestrial plants. The appearance of southern boreal, subtropical and tropical diatom species in the sediments of the northern part of the Chukchi Sea is caused by the transfer of Pacific waters through the Bering Strait to the Arctic Ocean. Transport of coniferous pollen and spores to the sediments of the Chukchi Sea occurs mainly by ocean currents and by wind drift from land areas. Coastal abrasion and the subsequent transfer by currents are responsible for Jurassic, Cretaceous and Neogene species of spores and pollen redeposited in the Holocene deposits.

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Conflict of interest

The authors declare no competing interest.

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