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On the Volume of Terrigenous Sedimentation in the Laptev Sea

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THEME 11: Cenozoic Sedimentary Archives of the Eurasian Marginal Seas: Sampling, Coring and Drilling Programmes

Summary: Volumes of Holocene (10 000 years) terrigenous sediments and annual sediment supply in the Laptev Sea were evaluated from average thickness of the Holocene veneer. Volumes of deposits supplied from various sediment sources and by different processes (abrasion of hinterland and island shores, river discharge, eolian input, drifting ice) were discriminating of deposition in the coastal zone, at river/sea barrier, and in the shelf basin itself. Accumulation by drifting ice and the role of local sea bottom erosion were also considered. Total amount of sediments transported from the Laptev Sea shelf to Amundsen and Nansen Basins of the Arctic Ocean was compared with other Russian Arctic seas.

INTRODUCTION

Estimations of volume of sediments deposited in the basin are based on the map of thicknesses of Holocene veneer compiled in VNIIOkeangeologia; boundaries of the Laptev Sea basin were taken from geographical publications (MARKOV 1980, GORSHKOV 1980). Up to now, several similar evaluations (BAUCH et al. 1999, STEIN & FAHL 1999, BEHRENDS et al. 1999, THIEDE et al. 1999) were attempted for the Arctic Seas including estimations of river discharge (GRAMBERG & POGREBITSKIJ 1984), abrasion of shores (SUZDAL'SKY 1974), thermal abrasion (LOMACHENKOV 1959, GRIGORIEV 1966, POPOV 1967, KLUEV 1970). Information published by ZENKOVICH (1962), BASCOM (1966), LEONT'EV (1980), DJANDJGAVA, KOMAROV & NEIZVESTNOV (1990) and LISITSYN (1991, 1994) was also used as well as data from published marine and naval sources (LAPTEV SEA ATLAS 1972, ATLAS OF THE ARCTIC 1985, TRESHNIKOV & SAL'NIKOV 1985, ZENKOVICH & POPOV 1986). It was admitted that the main part of terrigenous sediments eroded on the land adjacent to the Arctic continental margins had been deposited since the Late Cretaceous epoch in the lower part of progradational continental slope and near continental rise (POGREBITSKIJ 1984). The paper is also based on recently published German data (KASSENS et al. 1994, KASSENS 1997, RACHOR 1997). All estimations carried out in this paper are rather speculative but, nevertheless, tentative evaluations of terrigenous discharge volumes are important for paleoecological and paleoenvironmental purposes as well as for better understanding of modern sedimentary processes in the Laptev Sea.

DISCUSSION

The volume of sediments deposited in the Laptev Sea during the Holocene (Tab. 1) was estimated based on the average thickness of Holocene veneer in various morphological areas of the shelf (Fig. 1). It was admitted that the average density of recent deposits is approximately 2 t m^{-3}. Within the Laptev Sea shelf approximately 2350 x 10^9 t of sediments (235 x 10^6 t per year) were deposited during the Holocene (last 10 000 years). Abrasion of shores of mainland and islands was evaluated taking into account the length of abrasional and accumulative shores, average height of the cliff and rate of its retreat (Tab. 2). It was admitted by SUZDAL'SKY (1974), LEONT'EV (1982) and LISITSYN (1991, 1994) that aproximately only half of the total length of the shoreline is impacted by abrasion. Abrasional products contribute 89 x 10^6 t per year. Products of the coastal abrasion contain (LOMACHENKOV 1959, POPOV 1967, KLUEV 1970, GRAMBERG & POGREBITSKIJ 1974) approximately 21 x 10^6 t year-1 of buried ice (Tab. 3). The main part of the sandy-silty fraction of abrasion products is deposited in the narrow shallow water (less than 30 m depth) zone which constrains about 70 % of the whole material of abrasion. The

Area		Area (km^2)	Average thickness of deposits m	Volume (km^3)	Weight (10^9 t)
HIGHS	1	2000	1.00	2	4
	2	1000	1.00	1	2
	3	4530	1.50	7	14
	4	7200	1.00	7	14
	5	36890	1.75	65	129
	6	13820	3.75	52	104
	7	10100	0.15	2	4
	8	4140	1.00	4	8
	9	34920	1.75	61	122
	10	3720	0.15	1	1
	11	3870	2.50	10	19
	12	5340	1.00	5	11
LOWS	13	76340	1.00	76	153
	14	193430	1.50	290	580
	15	139390	1.75	244	488
	16	86550	3.00	260	519
	17	69520	1.25	87	174
Total		692760	1.50	1174	2346

Tab. 1: Amount of Holocene deposits in the Laptev Sea (for location of areas see Fig. 1)

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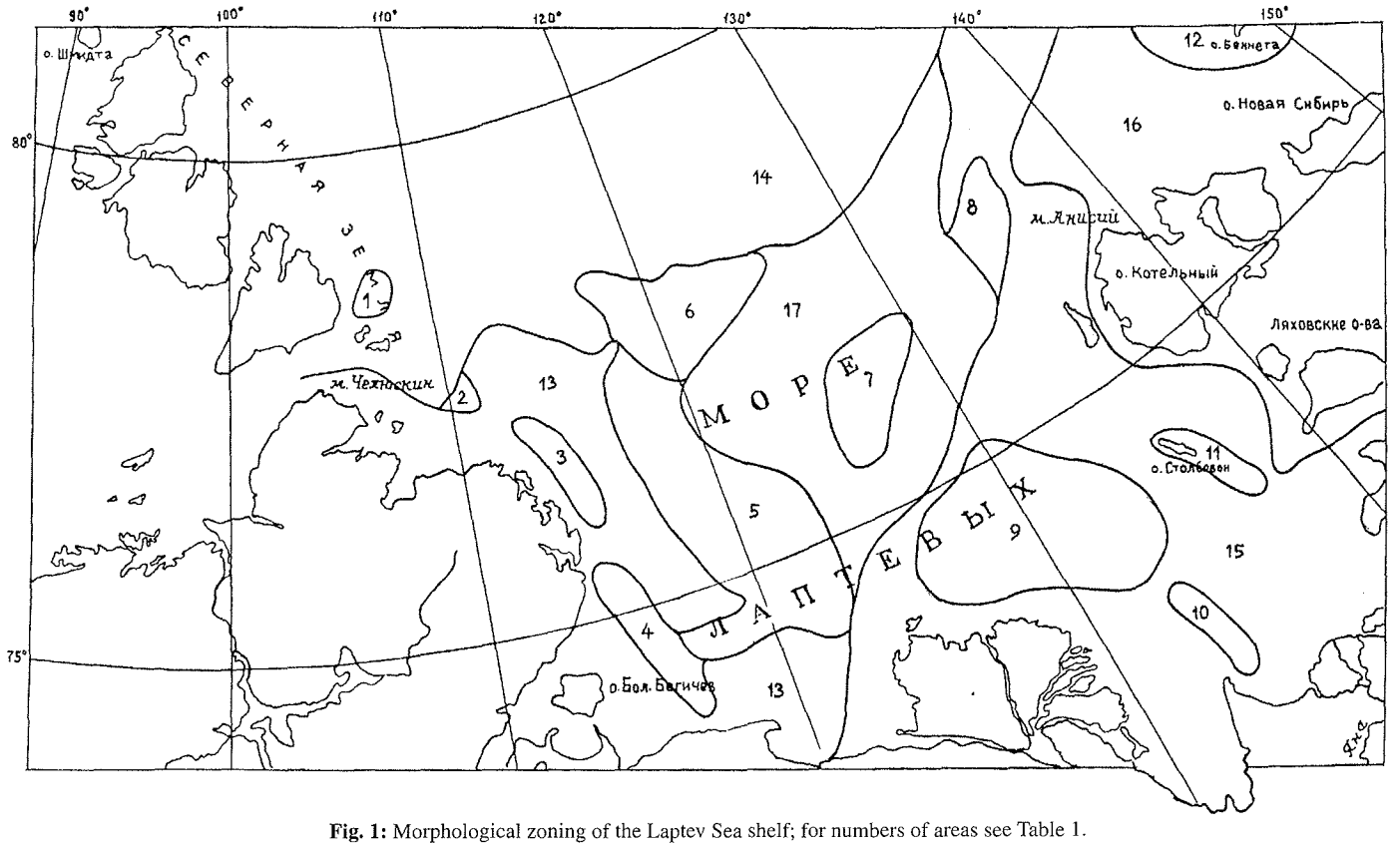

Fig. 1: Morphological zoning of the Laptev Sea shelf; for numbers of areas see Table 1.

clayey fraction contributes about 30 % of abrasion sediments; at least half of it usually is also deposited in the coastal zone (LISITSYN 1994).

The content of carbonate, biogenic material and organic matter in onshore sediments is not significant. Carbonates are abundant only in Paleozoic rocks which occur in small areas near the shoreline of Taimyr Peninsula (POGREBITSKIJ 1984) where these rocks are the source of more than 50 % of terrigenous sediments disintegrated in the coastal zone. Abrasional deposits usually contain 1.5 % of organic matter, sometimes more (GRAMBERG & POGREBITSKIJ 1984). About 7 % of abrasion products is transported by drifting ice and another 7 % by fast ice.

	type of shore	shore-line length (km)	aver-age shore height (m)	aver-age shore retreat (m y^{-1})	weight of abraded deposits (10^6t y^{-1})
MAINLAND	Glacial/tectonic	1100	100	0.02	2.00
	Abrasion/ accumulation	40	10	1.50	0.50
	Accumulation	280	5	0.50	0.50
	Deltaic	1300	4	0.50	3.00
	Accumulation, bays	750	15	1.50	17.00
	Abrasion, bays	560	10	2.00	11.00
	Colluvial	180	20	3.00	11.00
ISLANDS	Ice bearing, tectonic	400	50	0.02	0.25
	Glacial/tectonic	300	50	0.02	0.25
	Accumulation	280	100	0.50	1.50
	Abrasion/ accumulation, bays	320	10	1.50	5.00
	Colluvial	620	20	3.00	37.00
	TOTAL	6130			89.00

Tab. 2: Input of terrigenous products of abrasion per year into the Laptev Sea.

Generally about quarter of the total terrigenous products of abrasion is supplied by buried ice of the shores. The main part of these sediments is deposited in the coastal zone and only about 10 % is transported into the outer shelf basin. Differentiation of material of abrasion in the Laptev Sea is shown in Table 3 in comparison with other Russian Arctic seas.

River discharge supplies (Tab. 4) approximately 24 x 10^6 t $year^{-1}$ of suspended matter into the Laptev Sea. 90 % of this material is deposited near river/sea barrier, 7 % is transported by fast and drifting ice, 2 % is deposited in coastal zone and only 1 % is deposited in the outer shelf basin. Dissolved matter of river discharge (73 x 10^6 t $year^{-1}$) is distributed like those: 80 % - near river/sea barrier, 7 % - in the drifting ice, 1 % - in coastal zone and 12 % - in the outer shelf basin (Tab. 4). These data were published by LISITSYN (1991, 1994).

Drifting ice sedimentation (79 x 10^6 t $year^{-1}$) was evaluated taking into account the whole volume of the ice in the basin and an average content of deposits in the ice (approximately 50 000 tons of sediments in 1 km^3 of ice). Obviously the main part of these deposits (77 %) is transported into the North Atlantic (TIMOFEEV 1963) across the Arctic Ocean (approximately 61 x 10^6 t $year^{-1}$). Depositional input of aerosols was

Seas	sources			abrasional input, 10^6 t y^{-1}							
	total	rocks	sedi-ments	buried ice of shores	shallow waters				outer Shelf		
					fractions		carbonate		Drifting ice	Organic matter	Sus-pended matter
					>0.01 mm	<0.01 mm	terri-genous	bio-genic			
Barents	81	9	72	11	49	10	2	<1	5	1	3
Kara	97	5	92	24	51	11	1	<1	5	1	3
Laptev	89	3	86	21	47	10	1	<1	5	1	3
E-Siberian	197	2	196	49	104	22	1	1	10	2	8
Chuckchi	72	1	71	18	38	8	<1	<1	4	1	3

Tab. 3: Differentiation of eroded material in the Arctic Russian Seas

estimated based on the average square of the Laptev Sea covered by ice (610 000 km²) and average aerosols flow (8 mg/sm3, LISITSYN 1994). Dissolved matter forms salt lenses in the ice and actually does not participate in modern sedimentation. Generally melted ice is responsible for the input of 18 x 106 t year-1 of deposits to the bottom.

All sediments supplied into the Laptev Sea from various sources (abrasion, river discharge and drifting ice) reach 177 x 10^6 t year-1 and are distributed in different areas of the shelf (Tab. 4): 34 % is deposited in the coastal zone, 45 % is deposited at the river/sea barrier and drifting ice accumulates 10 % of terrigenous sediments. Only 11 % of these deposits is transported into the outer shelf basin. The main part of terrigenous sediments supplied to the basin, however, was produced by submarine erosion of local highs on the sea bottom (215 x 106 tons per year).

The difference between terrigenous input (392 x 106 t year^{-1}) and weight of deposited sediments (235 x 10^6 t year,-1 see Tab. 1) is equal 157 x 10^6 t year-1. It means that this amount of deposits is transported to the deep Arctic Basin (partly towards the North Atlantic). So the Laptev Sea shelf contributes approximately 15 % of terrigenous input from Russian Arctic seas to the deep Arctic basin.

Generally the Laptev Sea is characterized by terrigenous input controlled by various sources: local submarine erosion of bottom highs (55 %), river discharge (21 %), abrasion of shores (16 %) and drifting ice (7 %).

The difference between the whole volume of this discharge and sediments accumulated on the shelf corresponds to the total amount of deposits transported across the shelf to the deep sea basin (156 x 10^6 t year-1). Pilot estimations of the role of Arctic Seas in the sedimentary pattern of the Arctic Ocean show that the Laptev Sea and its coasts contribute 16 % of the whole volume of terrigenous discharge to deep sea basin.

CONCLUSIONS

Nowadays there is still a strong lack of accurate data dealing

Areas of the sea	Terrigenous input, 10^6 t y^{-1}						
	river discharge		Abrasion of shores	drifting ice sedimentation		local sub-marine erosion	Total
	sus-pended	dis-solved		aero-soles	bottom		
River/sea barrier	22	58					80
Coastal zone	<1	1	59				60
Drifting ice	2	10	5				17
Outer shelf basin	<1	4	4	11	1	215	235
Total in outer shelf basin without local submarine erosion	<1	4	4	11	1	-	20
Total without local submarine erosion	24	73	68	11	1	-	177
TOTAL	24	73	68	11	1	215	392

Tab. 4: Differentiation of terrigenous material in the Laptev Sea

with measurements of concrete dynamic features of modern sedimentation in the Russian Arctic seas. Very recently Holocene sedimentation rate data based on AMS14C datings and its paleoenvironmental significance were published by BAUCH et al. (1999) and STEIN & FAHL (1999). All estimations in this paper are rather speculative. Concrete values of sedimentation characteristics (i.e. average weight of 1 m^3 of terrigenous deposits, volume of sediments deposited in river mouths, size of fast and drifting ice, etc.), however, will be studied in the nearest future and estimations would be changed respectively. Nevertheless, speculative evaluation of average volume of annual terrigenous input, abrasional products, river discharge and local submarine erosion as well as differentiation of terrigenous material in various shelf areas could be useful for general investigation of the character of modern and recent sedimentation.

Analysis of the distribution of annual terrigenous supply shows that the Laptev Sea shelf constrains a complicated geosystem where variable differentiation of depositional material occurs within different shelf zones. One of the main processes of terrigenous input is local erosion of the sea bottom.

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