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Comparative Analysis of Pleistocene Sediments of the Atlantic Ocean

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Abstract—We performed a comparative analysis of quantitative parameters for Pleistocene sediments from the pelagic zone and submarine parts of continental margins of the Atlantic Ocean in seven key areas. In the Neopleistocene compared to the Eopleistocene, the lithogenic fluxes increased both in the pelagic zone and on the continental margins. The residual absolute masses of $CaCO_3$ and biogenic opal decreased in both megafacies zones. The biogenic sedimentation was more important for facies structure of the pelagic zone than for continental margins.

Keywords: Atlantic Ocean, Neopleistocene, Eopleistocene, Pleistocene, bottom sediments, pelagic zone, continental margins

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INTRODUCTION

The relations of sediment fluxes and facies diversity of the oceanic deep-water floor and continental margins have always attracted attention of marine geochemists and lithologists (Murdmaa, 1987). Regional geologists, oil workers, and tectonists are traditionally interested in the geological structure and evolution of continental margins (Burk and Drake, 1974; Konyukhov, 1987, and others). Therefore, works on these problems are of great importance.

This paper finalizes the series of works on the comparative analysis of the quantitative parameters of the Pleistocene sedimentation in the pelagic zones and on the submarine parts of continental margins worldwide (Levitan, 2020; Levitan et al., 2021).

Pleistocene sediments of the pelagic zone in the Atlantic Ocean were described in (Levitan and Gelvi, 2016). Then, we studied Pleistocene sediments in seven key areas of submarine continental margins of this oceanic basin (Fig. 1). For each area, the problems of modern sedimentation were considered and the Neo- and Eopleistocene lithological-facies maps (with isopachs) were compiled. All maps were processed using Ronov's volumetric method (1949) and such quantative parameters as areas, volumes, dry sediment mass, and accumulation rates were compiled in tables. Obtained data are too large to demonstrate in the scope of this paper. Only data on the Scotia Sea have been already published (Levitan et al., 2020).

Below, the main attention is focused on the comparative analysis of obtained quantitative parameters and conclusions drawn from this analysis.

RESULTS

Facies Structure

The Atlantic Ocean consists of two megafacies zones: pelagic zone and submarine continental margins. The pelagic megafacies zone consists of hemipelagic and miopelagic lithological-facies subzones, and each subzone additionally contains azonal submarine rises (ridges, rises, and plateau) of different genesis (Levitan and Gelvi, 2016). As in the modern epoch (Lisitsin, 1978), the distribution of Pleistocene sediments was controlled by a combination of main types of zoning: circum continental, latitudinal (climatic), vertical, and tectonic ones.

The megafacies zone of submarine continental margins of the Atlantic Ocean includes two main types: passive and active island-arc margins. Among the studied key areas, the submarine margins of Africa, West Europe, Iceland, South Greenland, USA and the Gulf of Mexico represents the passive margin. The island-arc margins are located in the Caribbean Sea and Scotia Sea.

The facies structure of the Pleistocene sediments of continental margins, in addition to the geodynamic factors, is also controlled by climatic features, as well as by bottom topography, circulation structure, primary production, and other factors. The role of climate is especially noticeable. In particular, the Pleistocene sedimentary cover in the northern and southern parts of the ocean contains significant amount of marine–glacial sediments; siliceous (essentially diatom) sediments are broadly distributed in the south, while carbonate sediments are practically absent. Carbonate planktic ooze

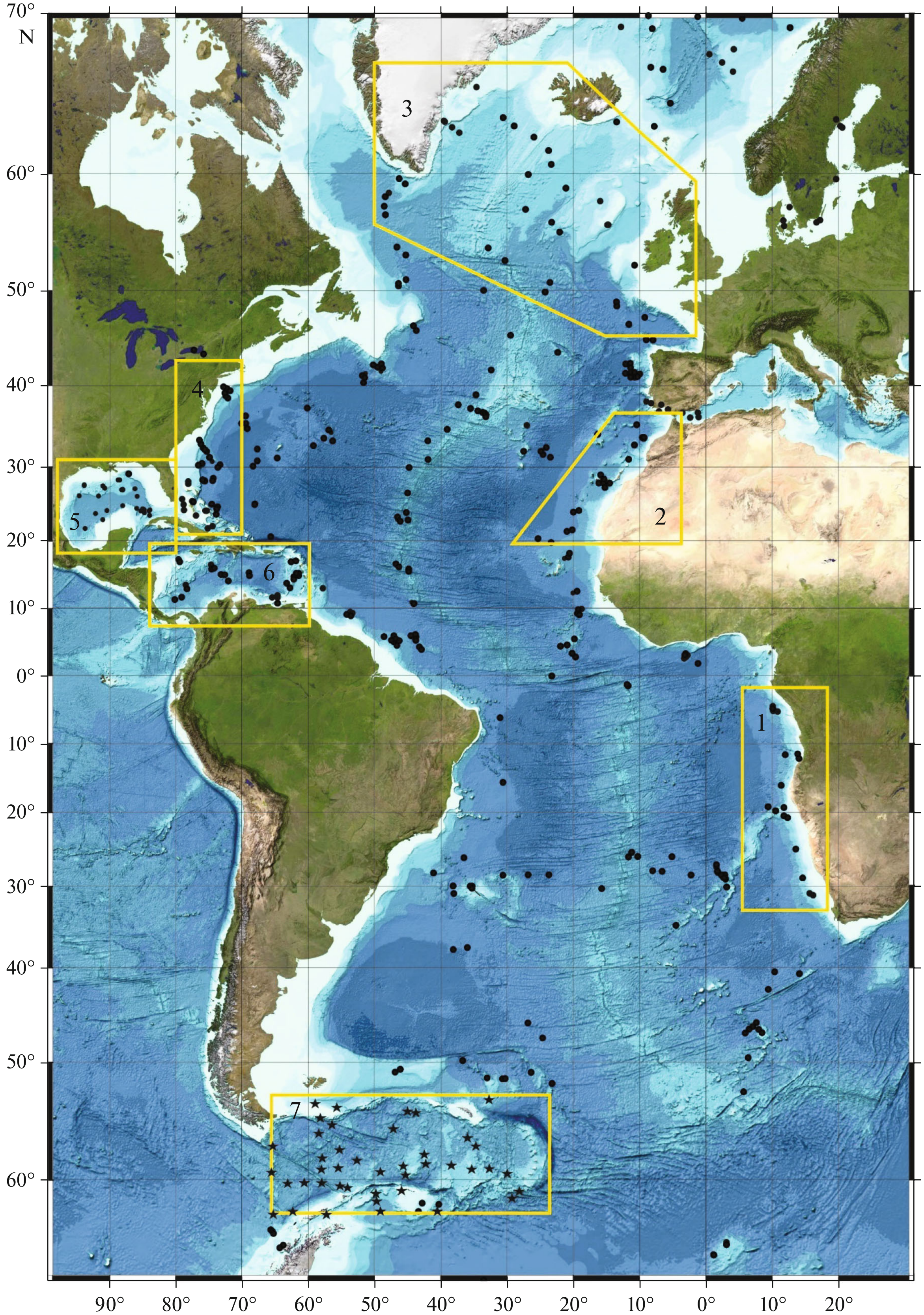

Fig. 1. Location of deep-water holes (filled circles) in the Atlantic Ocean. Asterisks correspond to the long sediment cores in the Scotia Sea. Numerals mark the studied areas of submarine continental margins: (1) Southwestern Africa; (2) Northwestern Africa; (3) West Europe; Iceland, and south Greenland; (4) USA; (5) Gulf of Mexico; (6) Caribbean Sea; (7) Scotia Sea.

Table 1. Areas (S, thou. km^2), average thickness (H, m), and volume (V, thou. km^3) of Pleistocene sediments in the Atlantic Ocean

Stratigraphic units	Parameters	Pelagic area	Southwestern Africa	Northwestern Africa	North Atlantic	USA	Gulf of Mexico	Caribbean Sea	Scotia Sea	All continental margins
Neopleistocene	S	70579	227	653	1697	691	1179	2472	1834	8753
	H	24	66	32	51	98	204	45	7	64
	V	1703	15	21	87	68	240	112	13	556
Eopleistocene	S	71417	227	653	1928	679	1194	2575	1831	9087
	H	32	66	58	31	65	95	21	2	36
	V	2271	15	38	61	44	114	53	3	328
Pleistocene	S	70998	653	653	1813	685	1187	2524	1833	8920
	H	56	132	90	82	163	299	66	9	99
	V	3974	30	59	148	112	354	165	16	884

and benthic buildups, in contrast, are widespread at the moderate and low latitudes.

Further, the paper will be mainly focused on the comparative analysis of quantitative parameters of sedimentation in both megafacies zones, on the one hand, and on revealing the trends of Pleistocene sedimentation, on the other hand.

Areas, Thickness, and Volumes of Pleistocene Sediments

Table 1 summarizes the results for the pelagic zone of the Atlantic Ocean and for its continental margins. It is seen in Table 1 that not all areas of continental margins have been studies. For instance, the South American margin was recovered by only few deep-water holes at depths up to 3000 m. The areas of continental margins in the Labrador Sea and on the Newfoundland latitude, as well as on the Antarctic passive margin were not taken into account. Based on available data on areas of Neopleistocene sediments of continental margins (Table 1), the total area of Neopleistocene sediments on the Atlantic continental margins is 8753 thou. km^2. The studied areas of the Atlantic submarine margins occupy 71.7% of total area of all types of continental margins.

The ratio of calculated pelagic to continental margin sediment areas in the Neopleistocene was 8.06. These ratios for the Eopleistocene and Pleistocene are 7.86 and 7.96, respectively. Remind that the total area of pelagic sediments also involves the Norwegian–Greenland basin. This fact explains the high values of the above presented ratios.

The total volumes of the Neopleistocene sediments at the continental margins (Table 1) equal 556 thou. km^3, and those of the Eopleistocene and Pleistocene sediments are 328 and 884 thou. km^3, respectively. The volume ratios of pelagic to continental margin sediments are, respectively, 3.06, 6.92, and 4.50 (Table 1). The volume ratios of Neopleistocene to Eopleistocene sediments are 0.75 in the pelagic zone and 1.70 on the continental margins.

The average thicknesses shown in Table 1 (volume to area ratio) indicate that the considered values in the pelagic zone equal 24 and 32 m for the Neopleistocene and Eopleistocene, respectively. Hence, the total thickness of the Pleistocene sediments is 56 m. In the areas of the studied continental margins, the average thicknesses equal, respectively, 64, 36, and 99 m, while their variations account for, respectively, from 7 to 204 m, from 2 to 114 m, and from 9 to 299 m. The lowest values were determined for the Scotia Sea, and the highest, for the Gulf of Mexico.

Dry Sediment Mass and Accumulation Rate

It is impossible to recalculate data on volumes of natural sediments presented in Table 1 for a dry sediment mass, because the physical properties of sediments of different composition significantly differ. Therefore, data presented in Table 2 were obtained using previous data on masses of definite lithological varieties for the studied areas of the Atlantic Ocean.

Thus, the dry sediment masses of the pelagic zone of the Atlantic Ocean for the Neopleistocene, Eopleistocene, and entire Pleistocene account for 1291, 1505, and 2796 × 10^{18} g, respectively. The total values for all studied continental margins are, respectively, 539, 325, and 864 × 10^{18} g. Hence, excluding the above-mentioned areas of continental margins, for which data on sediment volumes and masses are absent, the pelagic zone of the Atlantic Ocean in the Neopleistocene, Eopleistocene, and Pleistocene in general accumulated much more dry sediment than all the studied continental margins. The corresponding mass ratios are 2.40, 4.6, and 3.2. Hence, taking the area of all continental margins approximately one third more than the studied area and assuming the same mass distribution pattern, the horizons on the deep-water floor

Table 2. Dry sediment mass (M, 10^{18} g) and mass accumulation rates (I, 10^{18} g/Ma) of Pleistocene sediments in the Atlantic Ocean

Stratigraphic units	Parameters	Pelagic zone	Continental margin of Southwestern Africa	Continental margin of Northwestern Africa	Continental margin of Europe, Iceland, and South Greenland	Continental margin of USA	Gulf of Mexico	Caribbean Sea	Scotia Sea	All continental margins
Neopleistocene	M	1291.0	11.4	18.1	86.1	60.2	256.0	98.9	8.2	538.9
	I	1634.2	14.4	22.9	109.0	76.2	324.1	125.2	10.4	682.2
Eopleistocene	M	1504.8	9.4	35.7	55.6	45.1	125.7	51.4	1.7	324.6
	I	1504.8	9.4	35.7	55.6	45.1	125.7	51.4	1.7	324.6
Pleistocene	M	2795.8	20.8	53.8	141.7	105.3	381.7	150.3	9.9	863.5
	I	1561.9	11.6	53.8	79.2	105.3	213.2	84.0	5.5	488.4

contain more dry sediment mass than simultaneous horizons of continental margins. Thereby, the Eopleistocene is characterized by the especially high mass gradient.

The study of proportions of sediment mass between Neo- and Eopleistocene shows that the pelagic zone in the Atlantic Ocean accumulated 1.17 times more dry sediment masses in the Eopleistocene compared to the Neopleistocene. The higher sediment mass in the Eopleistocene compared to the Neopleistocene was also documented for the submarine continental margin of Northwestern Africa. In all other studied areas of submarine margins (as well as in total for the studied areas), the amount of sediments in the Neopleistocene was more than that of the Eopleistocene.

For each of the considered region, the values of dry sediment mass accumulated per time unit (accumulation rate) were even higher than mass alone. Their proportions between the pelagic zone and all continental margins unambiguously indicate as follows: (1) the sharp prevalence of pelagic zone for all simultaneous horizons; (2) the higher accumulation rates in the Neopleistocene compared to the Eopleistocene for the entire Atlantic Ocean. However, the I Neopleistocene/I Eopleistocene ratio for separate continental margins significantly differs. Based on this ratio, two groups of the margins are distinguished: (1) > 1 and (2) < 1. The first group includes submarine continental margins of Southwestern Africa, Europe, Iceland and South Greenland, USA, Gulf of Mexico, Caribbean Sea and Scotia Sea. The second group includes only the Northwestern African margin.

Available data allowed us to calculate the mass accumulation rate (MAR) separately for the pelagic zone and the studied submarine continental margins. The calculation results for the Neopleistocene, Eopleistocene, and entire Pleistocene, respectively, are as follows: 2.315, 2.120, and 2.107 g/cm^2 ka for the pelagic zone; and 7.793, 3.572, and 5.408 g/cm^2 ka for the continental margins. Thus, the average value of Pleistocene sediment flux on the submarine margins is approximately 2.5 times higher than the average sediment flux in the pelagic zone.

The lithological composition of Pleistocene sediments of submarine continental margins in the Atlantic Ocean differs from that of the pelagic zone. Therefore, information on the lithology of the studied deposits is required for the interpretation of above presented data. The next section presents corresponding data on the main sediment groups: lithogenic, carbonate, and siliceous ones.

Dry Sediment Masses of the Main Sediment Groups and Sediment-Forming Components

The lithogenic group of sediments includes the prevailing terrigenous sediments, volcanogenic–terrigenous sediments, miopelagic clays, and scarce volcanic ashes. The carbonate sediments include not only carbonate planktic ooze and carbonate–detrital deposits, but also clayey–carbonate ooze and carbonate turbidites. The siliceous sediments are represented by the diatom ooze and diatom clays.

Calculation results of dry sediment mass of sediments are presented in Table 3. Its study shows that the lithological composition in the pelagic zone differs from that of continental margins.

Generalization of obtained results shows that the proportions of lithogenic, carbonate, and siliceous sediments in the pelagic zone in the Neopleistocene, Eopleistocene, and Pleistocene in general were 58 : 36 : 6, 29 : 66 : 5, and 43 : 52 : 5, respectively. The considered proportions for submarine continental margins in the studied region are 72 : 27 : 1, 56 : 41 : 3, and 66 : 32 : 2, respectively. Thus, in general, the region of submarine continental margins is dominated by lithogenic sediments, while the carbonate and siliceous sediments are the second and third in abundance. The contribution of the latter is negligible. In the pelagic zone, the predominant carbonate sediments were radically changed by the prevalence of

Table 3. Dry sediment mass (M, 10^{18} g) of the main groups of Pleistocene sediments in the Atlantic Ocean

Stratigraphic units	Sediments	Pelagic region	Continental margin of Southwestern Africa	Continental margin of Northwestern Africa	Continental margin of Europe, Iceland, and Southern Greenland	Continental margin of the USA	The Gulf of Mexico	Caribbean Sea	Scotia Sea	All continental margin
Neopleistocene	Lith.	739.7	5.4	0	65.1	28.7	224.5	55.7	7.6	389.0
	Carb.	464.1	4.9	16.9	17.3	31.5	31.5	43.2	0.2	145.5
	Silic.	71.0	1.1	1.2	0	0	0	0	0.4	2.7
Eopleistocene	Lith.	391.6	4.2	0	38.1	21.6	90.9	20.4	1.6	176.8
	Carb.	900.6	2.1	25.5	15.3	23.5	34.8	30.9	0.03	132.1
	Silic.	81.0	3.1	6.5	0	0	0	0	0.04	9.6
Pleistocene	Lith.	1131.3	9.6	0	103.2	50.3	315.4	76.1	9.2	565.8
	Carb.	1364.7	7.0	42.4	32.6	55.0	66.3	74.1	0.2	277.6
	Silic.	152.0	4.2	7.7	0	0	0	0	0.4	12.3

lithogenic sediments at the Eo- and Neopleistocene boundary. Thereby, the relative role of siliceous sediments remained the same, very insignificant. On average, the Pleistocene was characterized by the relatively higher role of carbonates in the pelagic zone, and the prevalence of lithogenic sediments on the continental margins. The relative role of siliceous sediments likely remained unchanged.

The above mentioned proportions of the main groups of bottom sediments indicate that the pelagic zone in the Neopleistocene compared to the Eopleistocene demonstrated a decrease of carbonates and an increase of lithogenic sediments. Continental margins were characterized by the significant increase of the relative content of lithogenic sediments and a decrease of carbonates.

At the same time, the careful study of Table 3 indicates strong differences between key areas of continental margins. For instance, the lithogenic deposits clearly dominate among sediments of North Atlantic, Gulf of Mexico, and Scotia Sea. The content of carbonate sediments is relatively high at the Northwestern Africa and southeastern United States margins, as well as in the Caribbean Sea.

It is pertinent to mention that the average values shown in Tables 1–3 for continental margins are mainly defined by regions with the maximum values of a definite parameter. For instance, these are masses of lithogenic matter in the Gulf of Mexico for Table 3.

The allowance for the above mentioned unstudied areas of continental margins can slightly modify the presented proportions of the main sediment groups. Nevertheless, the proportions of main lithologies seem to be correct.

For the genetic interpretation of sediments and understanding their chemical composition, it is more correct to operate with masses of main sediment-forming components (lithogenic matter, $CaCO_3$ and biogenic opal) rather than with masses of main sediment groups. For calculations, the average $CaCO_3$ content in carbonate sediments was taken to be 85% (correspondingly, the content of lithogenic component is 15%), opal in siliceous ooze accounts for 60% (i.e., the content of lithogenic matter equals 40%). The low-carbonate sediments contain, on average, 50% $CaCO_3$ and 50% lithogenic component, while weakly siliceous sediments contain 40% opal and 60% lithogenic matter. Obtained results are shown in Table 4.

As follows from analysis of the table, the masses of all components on the continental margins in the Neopleistocene, Eopleistocene, and Eopleistocene in general were lower than in the pelagic zones (only within the studied areas!). Thereby, during Pleistocene, the masses of lithogenic matter both in the pelagic zones and on continental margins increased, while the masses of biogenic component, in contrast, decreased.

Mass Accumulation Rate (MAR) of Sediment Groups and Sediment-Forming Components

The calculated mass accumulation rates of main sediment groups (separately for pelagic zone and submarine continental margins) for the Neopleistocene, Eopleistocene, and entire Pleistocene are shown in Table 5. Its examination indicates that both megafacies zones in the Neopleistocene have preserved similar sedimentation pattern with the clear predominance of lithogenic fluxes on the floor, at much lower fluxes of carbonate sediments, and minor fluxes of siliceous sediments. Thereby, the MAR of lithogenic and carbonate sediments on the continental margins were 4.3 and 2.5 times higher than those of pelagic zones, while that of siliceous sediments was 0.3 times lower. In the

Table 4. Masses (M, 10^{18} g) of major sediment-forming components of Pleistocene sediments in the megafacies zones of the Atlantic Ocean

Stratigraphic unit	Components	Pelagic region	All continental margins	$\frac{M \text{ Cont. Margin.}}{M \text{ Pelagic zone}}$
Neopleistocene	Lithogenic matter	894.2	446.6	0.5
	$CaCO_3$	267.6	93.8	0.4
	Biogenic opal	97.9	1.1	0.01
Eopleistocene	Lithogenic matter	710.7	276.7	0.4
	$CaCO_3$	977.6	99.8	0.1
	Biogenic opal	112.1	3.5	0.03
Pleistocene	Lithogenic matter	1604.9	723.3	0.5
	$CaCO_3$	1245.2	193.6	0.2
	Biogenic opal	210.0	4.6	0.02

Table 5. Mass accumulation rates (MAR, g/cm^2 ka) of sediment groups and main sediment-forming components of Pleistocene sediments in the megafacies regions of the Atlantic Ocean

Stratigraphic units	Sediments, components	Pelagic region	All continental margins	$\frac{M \text{ Cont. Margin.}}{M \text{ Pelagic zone}}$
Neopleistocene	Lithogenic sediments	1.327	5.650	4.3
	Carbonate sediments	0.832	2.104	2.5
	Siliceous sediments	0.127	0.039	0.3
	Lithogenic matter	1.604	6.459	4.0
	$CaCO_3$	0.480	1.356	2.8
	Biogenic opal	0.176	0.016	0.1
Eopleistocene	Lithogenic matter	0.548	1.970	3.6
	Carbonate sediments	1.261	1.454	1.2
	Siliceous sediments	0.113	0.106	0.9
	Lithogenic matter	0.995	3.045	3.1
	$CaCO_3$	1.369	1.098	0.8
	Biogenic opal	0.157	0.039	0.2
Pleistocene	Lithogenic matter	0.890	3.568	4.0
	Carbonate sediments	1.074	1.739	1.6
	Siliceous sediments	0.120	0.077	0.6
	Lithogenic matter	1.263	4.530	3.6
	$CaCO_3$	0.980	1.213	1.2
	Biogenic opal	0.165	0.029	0.2

Eopleistocene, the sedimentation structure significantly changed: it remained practically the same for continental margins, while the mass accumulation rates of carbonate sediments in the pelagic zone became higher than in the Neopleistocene, exceeding those of lithogenic sediments (Fig. 2). Thereby, the ratios of mass accumulation rates on margins to those of the pelagic zones was approximately the same as in the Neopleistocene.

One more important conclusion can be drawn from Table 5. Dividing MAR of Neopleistocene sediments by that of the Eopleistocene sediments yields 2.42, 0.66, and 1.12 for the lithogenic, carbonate, and siliceous sediments, respectively. This series for continental margins is 2.87, 1.45, and 0.37. Thus, the lithogenic fluxes accumulated on the floor increased practically equally in the both megafacies zones (slightly more on the margins) in the Neopleistocene com-

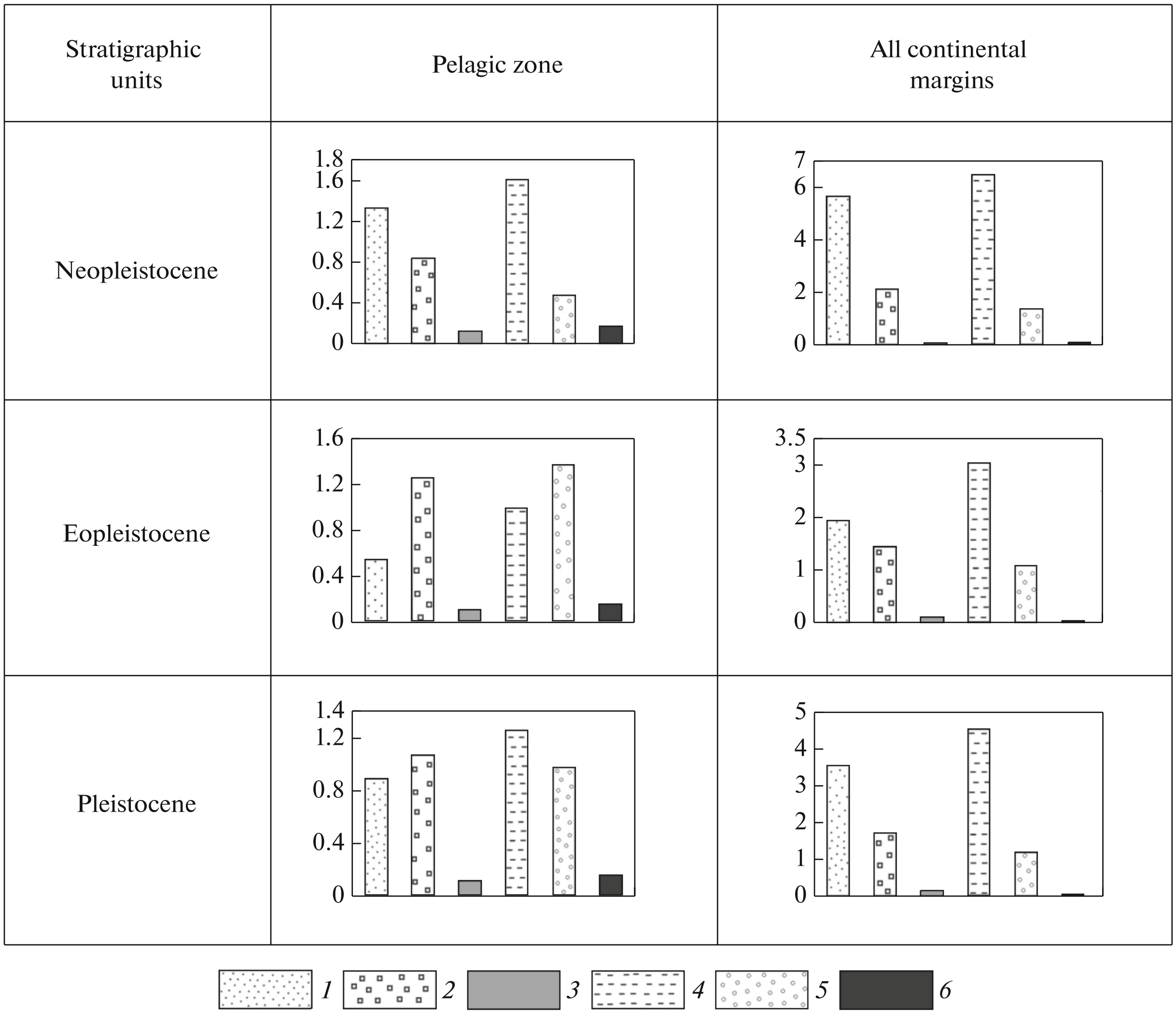

Fig. 2. Mass accumulation rates (g/cm^2 ka) of sediment groups and main sediment-forming components of Pleistocene sediments. Symbols: (*1*) lithogenic sediments; (*2*) carbonate sediments; (*3*) siliceous sediments; (*4*) lithogenic matter; (*5*) $CaCO_3$; (*6*) biogenic opal.

pared to the Eopleistocene. The mass accumulation rates of carbonate sediments in the pelagic zone became slightly lower in the Neopleistocene compared to the Eopleistocene, while those of siliceous sediments, became slightly higher. In contrast, the mass accumulation rates of carbonate sediments on the continental margins in the Neopleistocene increased compared to the Eopleistocene, while those of siliceous fluxes, decreased.

However, data on mass accumulation rates of main sediment-forming components are more suitable for comparative analysis (Table 5). As a result, the analysis of these data confirmed our previous conclusions drawn from obtained mass accumulation rates both for the pelagic zones and on continental margins. Thereby, the MAR of lithogenic matter on the continental margins were 3–4 times higher than those of the pelagic zone. The intensity of $CaCO_3$ sedimentation on the margins also increased relative to the pelagic zone in the Neopleistocene, and decreased in the Eopleistocene. The mass accumulation rates of biogenic opal during the entire Pleistocene was higher in the pelagic zone than on submarine continental margins (Fig. 2).

One more conclusion can be obtained from analysis of Table 5. Dividing MAR of the Neopleistocene main sediment-forming components by that of the Eopleistocene yields values of 1.61, 0.35, and 1.12, respectively, for the lithogenic matter, $CaCO_3$, and biogenic opal, in the pelagic zone. These values for the megafacies zone of continental margins are 2.12, 1.24, and 0.41. Thus, in the Neopleistocene compared to the Eopleistocene, the lithogenic flux increased in both megafacies zones, but more significantly on the continental margins than in the pelagic zone. The $CaCO_3$ fluxes increased on the continental margins and decreased in the pelagic zone. The biogenic opal fluxes on the continental margins decreased.

DISCUSSION

This paper considers data on the Atlantic Ocean floor areas covered by Pleistocene sediments, which account for 86.4% of its total area (*Atlas…,* 1980). Both megafacies zones in the Neopleistocene are characterized by the same facies structure with the predominance of lithogenic deposits, essentially lower content of carbonate sediments, and very insignificant fraction of siliceous sediments. In the Eopleistocene, approximately the same sedimentation structure was typical of the continental margins, whereas pelagic zone demonstrated the predominance of carbonate sediments over lithogenic sediments.

Lithogenic matter is mainly precipitated on the continental margins in proximity to source area. According to our data, the thickest depocenters in the Neopleistocene were developed in the deltaic area of the Mississippi–Missouri system and in the Mississippi fan. Judging from literature, sequences of approximately the same thickness were accumulated in the Amazon fan; significant amounts of lithogenic material were accumulated in the Niger fan (Lisitsin, 1988).

Significant role in the accumulation of lithogenic material in the Atlantic region was played by the continental glaciation in the Northern and Southern hemispheres. Thereby, the scales of accumulation of marine–glacial sediments in the Neopleistocene significantly increased compared to the Eopleistocene (Levitan and Gelvi, 2016).

Significant influx of volcanic and volcanoterrigenous material was recorded near the areas of active Pleistocene volcanism: Iceland and Lesser Antilles. Judging from literature data, the same processes were described in the vicinity of the Canary Islands and other regions of active volcanism in the within-plate regions (Levitan and Gelvi, 2016).

Masses of miopelagic clays in the Eopleistocene were much higher than in the Neopleistocene owing to the lesser dilution by terrigenous and carbonate material (Levitan and Gelvi, 2016).

Note also much greater role of terrigenous and volcanogenic turbidites in the Neopleistocene compared than Eopleistocene. This phenomenon is caused by the elevated lithogenic flux from surrounding continents and islands. The reasons for such changes are complex and diverse. The orogenic neotectonic movements played a leading role in the Pacific and Indian oceans, while their role in the Atlantic Ocean was much lower (except for some areas, in particular, Amazon fan and the northern part of the submarine Reykjanes Ridge). Significant role was also played by the glacioeustatic fluctuations of the sea level against the background of its general lowering during Pleistocene. This is especially clearly traced in the Pleistocene sequences of the Gulf of Mexico, Northern Atlantic, and on the submarine margin of the United States.

Clearly greater increase of lithogenic fluxes on continental margins compared to the pelagic zone in the Neopleistocene indicates that the continental margins accumulated much more amount of this sedimentary material than pelagic zones.

Dissolved matters supplying in the ocean (including such nutrients as phosphates, nitrates, dissolved organics, and others) are usually transferred by currents and homogenized. In the Atlantic Ocean, unlike Pacific Ocean (Levitan, 2020), the nutrients in the Pleistocene were mainly restricted to the pelagic zone.

The pelagic zones and continental margins of the Pacific and Indian oceans in the Pleistocene demonstrated an increase of masses and accumulation rates of carbonate sediments. In contrast, the Atlantic Ocean demonstrated a definite anomaly. This trend is also noted for the continental margins, while pelagic zone shows much greater masses and accumulation rates of carbonates in the Eopleistocene compared to the Neopleistocene. This phenomenon is explained by the elevated dissolution of carbonates at great depths in the Atlantic Ocean beginning from 1.1 Ma (Sexton and Barker, 2012). Our calculations suggest that up to 480.2×10^{18} g carbonate sediments were dissolved for the last 1.1 Ma in the Atlantic Ocean. Thus, in the Neopleistocene the amount of carbonates dissolved in the pelagic zone was approximately the same as remained in sediments. It was previously indicated (Sexton and Barker, 2012) that this interesting phenomenon was caused by the unprecedented increase of influx of Antarctic bottom and deep waters dissolving carbonates during the Middle Pleistocene transition. It should be noted that this phenomenon is correlated with a simultaneous increase of drift volumes in the North Atlantic, which is caused by the increase of contour currents. In general, the Atlantic submarine continental margins located at depths up to 3000 m and in the deeper waters of the Caribbean Sea, where Antarctic waters are not supplied, retained a "common oceanic" trend of increasing carbonate masses and mass accumulation rates during Pleistocene.

Pleistocene sediments of the Atlantic Ocean are more carbonate than Pacific and Indian sediments. However, this phenomenon on the continental margins and pelagic zones is caused by different reasons. In general, continents surrounding these oceans have different geological structure (Khain, 2001). It is well-known to hydrochemists that the Atlantic waters have more "carbonate" composition while the Pacific Ocean, more "siliceous" composition. The continental margins of the Atlantic Ocean are characterized by the lower contribution of diluting terrigenous sediments in this phenomenon compared to other oceans. In the pelagic zone, this phenomenon is mainly controlled by the greater area of diverse submarine ridges and rises relative to the deep-water basins than in the Pacific and Indian oceans (Harris et al., 2014).

The important features of silica accumulation are as follows: (1) the localization of most part of biogenic opal and its high accumulation rates in the southern pelagic zone of the ocean (in diatom ooze and clays) instead of continental margins; (2) approximately equal accumulation rates of biogenic opal in the pelagic sediments of the Eo- and Neopleistocene (with insignificant predominance in the Neopleistocene); (3) confinement of silica accumulation on the continental margins to upwelling zone along West Africa (first of all, within the Bengal upwelling); (4) obvious predominance of silica accumulation in the upwelling zones in the Eopleistocene compared to the Neopleistocene. The latter phenomenon is caused by the peculiar upwelling history related to the ascent of intermediate subpolar waters in the Northern and Southern hemispheres, rather than by the evolution of the aeolian activity on the neighboring deserts.

CONCLUSIONS

Our study allowed us to obtain data on the lithological composition of the Neo- and Eopleistocene sediments on area amounting for slightly less than 90% of total area of the Atlantic Ocean.

Two megafacies zones were distinguished: pelagic zone and submarine continental margins. These zones were compared using several quantitative parameters. The average thicknesses of Pleistocene sediments in the pelagic zone and on the continental margins are 56 and 99 m, respectively (Table 1). In the Pleistocene, the dry sediment mass of main sediment groups in the pelagic zone was 3.2 times higher than that of continental margins (Table 2), while masses of lithogenic matter, $CaCO_3$, and biogenic opal, respectively, were 2.2, 6.4, and 45.7 times higher (Table 4). At the same time, the ratios of mass accumulation rates of the main sediment-forming components in the pelagic zone to those of continental margins in the Pleistocene strongly varied, amounting 0.3, 0.8, and 5.7 for lithogenic matter, $CaCO_3$, and biogenic opal, respectively (Table 5).

The comparison of data on the Neopleistocene and Eopleistocene revealed that during Pleistocene the dry sediment mass increased by 1.6 times on the continental margins, and decreased by 0.9 times in the pelagic zone. The corresponding ratios of dry sediment mass of lithogenic matter, $CaCO_3$, and opal main sediment-forming components accounted for 1.3, 0.3, and 0.9 for pelagic zone and 1.6, 0.9, and 0.3 for submarine margins, respectively.

This paper analyzed the lithological changes in the Atlantic Ocean during part of the Quaternary period, from 1.8 to 0.01 Ma. The variation trends were studied for large time intervals: Neopleistocene and Eopleistocene. In the paleoclimatology, these intervals are characterized by a global cooling trend, which occurred simultaneously with the global sealevel fall, as well as by an increase of glacier volume and primary production. This was accompanied by the multi-period climatic variations: glacial–interglacial, orbital, suborbital, and others. Actually, these changes affected also the composition of bottom sediments of the Atlantic Ocean. They overprinted the above-mentioned sedimentation trends during the Pleistocene.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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