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On the Shoreline Dynamics of Russian East Arctic Seas During the Cenozoic[1]

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ABSTRACT

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It is possible to recognise four major Cenozoic regressive-transgressive cycles along the coast of eastern Arctic Russia. Direct morphological and sedimentological evidence of old shorelines is abundant both as raised and submerged forms. Relic barrier and lagoon facies have been located on the shallow shelf, forming complex on- and offlap facies assemblages. In places evidence has been disturbed by recent tectonic activity. Changes in sea-level are also reflected in aggradation-degradation stratigraphic sequences in coastal valleys and terraces. It is postulated that the most recent sea-level cycle is as yet unfinished, and will culminate in a transgression 2,000 yrs from now.

ADDITIONAL INDEX WORDS: *Barrier facies, coastal valley, lagoon facies, old shorelines, regressive-transgressive cycle, sea-level cycle, terrace.*

INTRODUCTION

The timing of transgressive rhythms over the coastal-shelf area of north-eastern Russia has been outlined in various publications (Table 1), although studies of these works reveals a lack of interpretational consistency between stratigraphic relations and of marine dating sediments. Most likely, such inconsistencies arise because of different levels of information from different areas and inapplicability of small area data to different regions. This, naturally, covers difficulties in classification and palaeogeographic correlation. However, an important advance in studying these subjects has been made recently by PUMINOV (1981 a, b).

Much information is available from geological investigations of the superficial Cenozoic deposits from the coastal lowlands and the coastal mountain valleys of the north-east USSR, plus some data from boreholes drilled through the pack-ice along the east Arctic coast. This information indicates the need to reconsider the stratigraphic relationships and dating of marine sediments in particular sequences, as well as regional correlations of marine strata. The data obtained from recent investigations, plus reassessment of earlier work, make it apparent that a new picture of the Cenozoic history of the USSR Arctic Seas should be drawn.

In order to ascertain the number and timing of transgressive cycles it is necessary to consider evidence of cyclic development of the coastal river systems, in particular their buried channels.

According to recent work, three erosional cycles can be recognized in the formation of the drainage system within the USSR East-Arctic shelf region. These are timed to the late Paleocene-early-middle Oligocene, early-middle Pliocene, and Pleistocene (PUMINOV, 1981 b). On the basis of these data, it may be inferred that the rise of sea-level over the modern land area could have occured during the intervening periods; i.e. the Miocene, late Pliocene, and Holocene. However, it should be noted that sequences in the Anadyrskaya, Chauskaya and other lowlands, as well as the bottom sediments in the inlets (Kolyunchinskaya, Chaunskaya, etc.) reveal deposits characterized by marine organisms or

[1]*[Editorial Note: We are pleased to publish the English version of papers presented at the 1982* **INQUA** *Symposium (Shorelines Commission) held in Moscow. Russian versions were previously published in collection by "Nauka" and Moscow State University publishers but this is the fifth installment in a series of reports that will appear in subsequent issues of the journal.] Received 15 January 1984.*

Table 1. Age-Distributions of Marine Transgressions in Recent Lowlands of Eastern Arctic USSR, According to Different Investigators.

Author, Year	Age Indices											
	P_1	P_2	P_3	N_1	N_2	Q_I	Q_{II}	Q_{III}^1	Q_{III}^2	Q_{III}^3	Q_{III}^4	QIV
Baranova, Biske, 1964				—	—			—				
Petrov, 1966				—	—					—		—
Degtyarenko, 1971				—	—					—		
Zagorskaya *et al*, 1972					—	—	—	—			—	—
Ivanov, 1973	**	**	**		—	—	—			—		
Puminov, 1975			**	—	—	—		—	—			
Biske, 1975, 1978				—	—		—	—		—		—
Lastochkin, Fyodorov, 1978					—						—	—
Gladenkov, 1978				—	—							
Puminov, 1975, 1981a, b	***	***	—	—	—							—

Legend: —— Marine Environments, * Paralic Environment.

Marine lithologies, which together with paleobotanical data suggest that during the Paleocene-Eocene marine conditions (in part, paralic) dominated in certain areas. Thus in the eastern USSR Arctic, the pattern of the unconsolidated Cenozoic series in the coastal lowlands, coastal mountain valleys and contiguous areas reveals four sedimentary cycles. Each cycle comprises (1) lowland continental deposits contemporaneous to the upland denudational stage. (These in most cases were reworked or completely destroyed by the transgressive sea); and (2) marine deposits, associated with the base-level, highstand abrasion and accumulation phases.

SEDIMENTARY CYCLES

The first three sedimentary cycles are briefly described below, whereas the fourth, a probably uncompleted cycle, is discussed in more detail.

First Cycle

The earliest Cenozoic sedimentary cycle — Paleocene-Eocene — lasted about 30 M years and was initiated apparently under quiescent tectonic conditions, characterized by extensive lowering of terrestrial relief and paralic sedimentation over a vast area (Figure 1). For example, in the Chaunskaya Lowlands and the Chaunskaya Inlet, the early Cenozoic alluvium occurs at depths of −55 to −65 m below present sea-level, lacustrine-alluvial deposits at −60 to −90 m, paralic facies at −90 to 140 m and marine clays at −90 to −140 m. In the Kamak Bay (Kolyunchinsakay Inlet) Cenozoic clays occur at depths of 45-70 m below present sea-level. In the Anadyrskaya lowlands and Anadyrskaya Bay paralic deposits may exceed 400 m in thickness yet in the western areas, for example, in the Dmitrii Laptev Strait, they do not exceed 100 m.

Second Cycle

The early-middle Oligocene period was characterized by tectonic rejuvenation, manifest in the eastern region by high uplifts. This resulted in the creation of a clearly-delineated incised river valleys and in the transition from marine to lacustrine-alluvial sedimentation (see Figure 1). For example, the altitude of the thalweg of the Oligocene downcut in the Kymyneyveem river valley is 150 m below present sea-level. In the area of the Anadyrskaya basin evidence of changes from marine (paralic) to limnic environments is found at depths of 500-900 m below some sea-level deposits reaching 300 m and more in thickness.

The transgression of the sea during the late Oligocene-Miocene (Figure 2) resulted in the accumulation of sediments, varying in thickness between 30 to 300-700 m., corresponding to the extent of regional downwarping. In the Anadyrskaya basin, where downwarping was greatest, the marine facies of the transgressive cycle occupy variable vertical ranges, eroded surfaces occurring at depths between 20-400 m below present sea-level, with bases between 160-900 m.

Coastal facies of this second cycle occur around the B. and M. Lyakhovsky Islands at an altitude of 0-20 m; in the Chaunskaya lowlands at +10 to −60 m, in the Pegtimel river delta at −40 to −80 m; in the Vlakaraiskaya Lowlands at +15 to −0 m; in the Vankaremskaya Lowlands at +10 to +90 m and on the coast of Anadyrsky Bay, in the Pestsovaya river basin at up to +120 m.

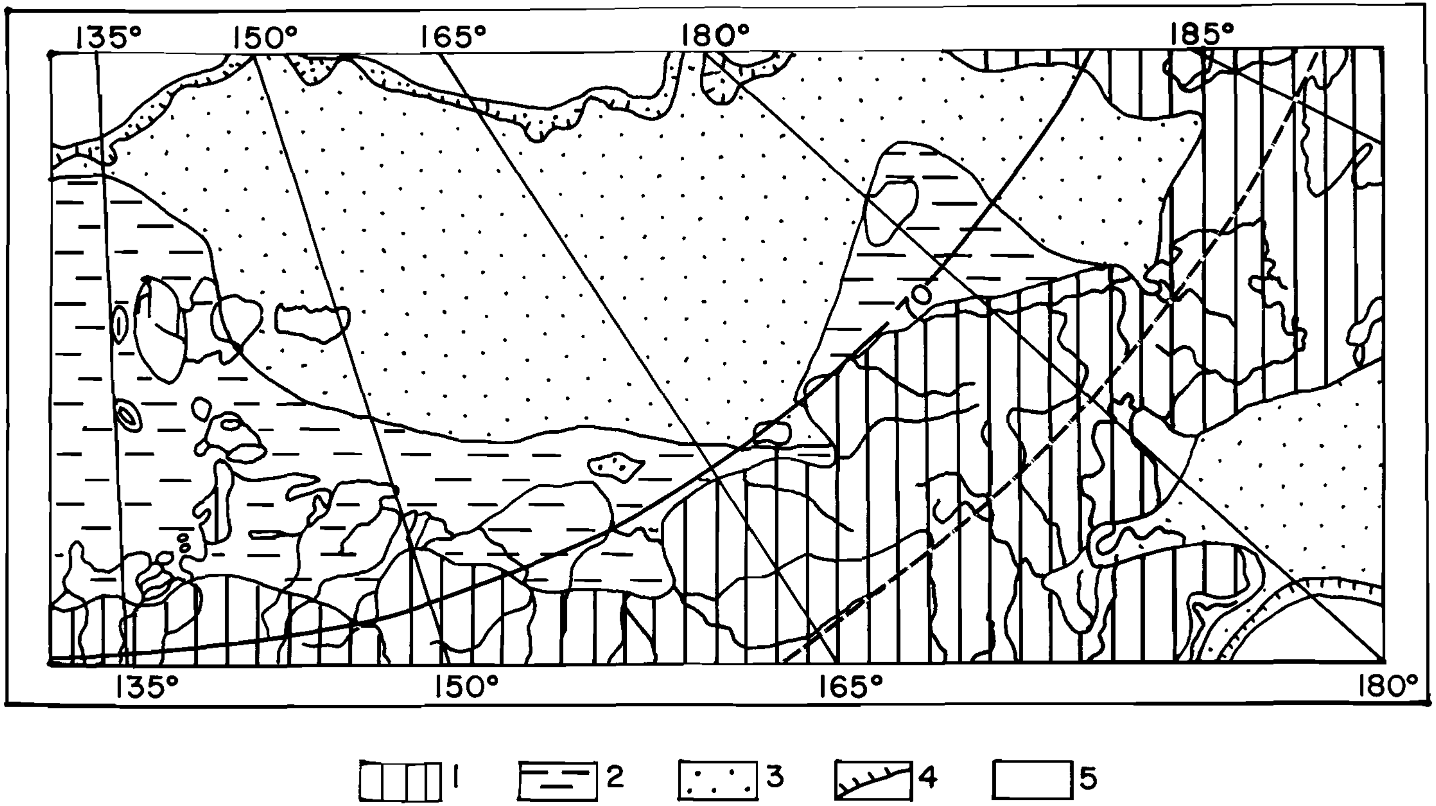

Figure 1. Schematic paleogeographical map of the Eocene and early-middle Oligocene Periods (scale 1:15,000,000). (1) Land area during the Eocene; (2) Lagoonal plains of Eocene paralic sedimentation; (3) The Eocene sea; early-middle Oligocene plain; (4) The edge of the continental slope; (5) Continuous existence of the sea through the Eocene and early-middle Oligocene.

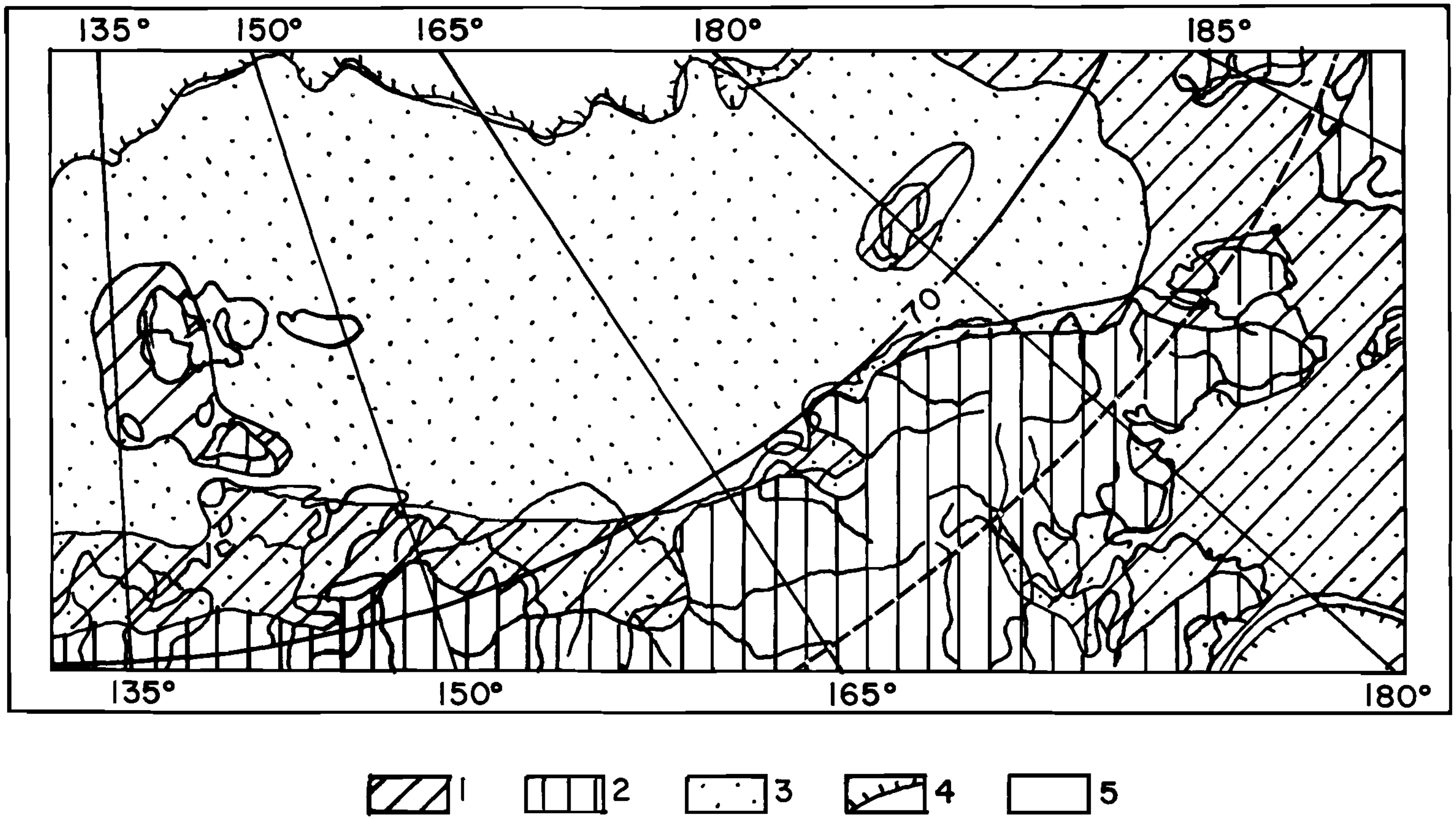

Figure 2. Schematic paleographical map of the late Oligocene, Miocene and early-middle Pliocene Periods (scale 1:15,000,000). (1) Land area during the late Oligocene; (2) Land area during the Miocene; (3) Late Oligocene-Miocene Sea; early-middle Pliocene plain; (4) Edge of continental slope; (5) Continuous existence of the sea through late Oligocene-early-middle Pliocene.

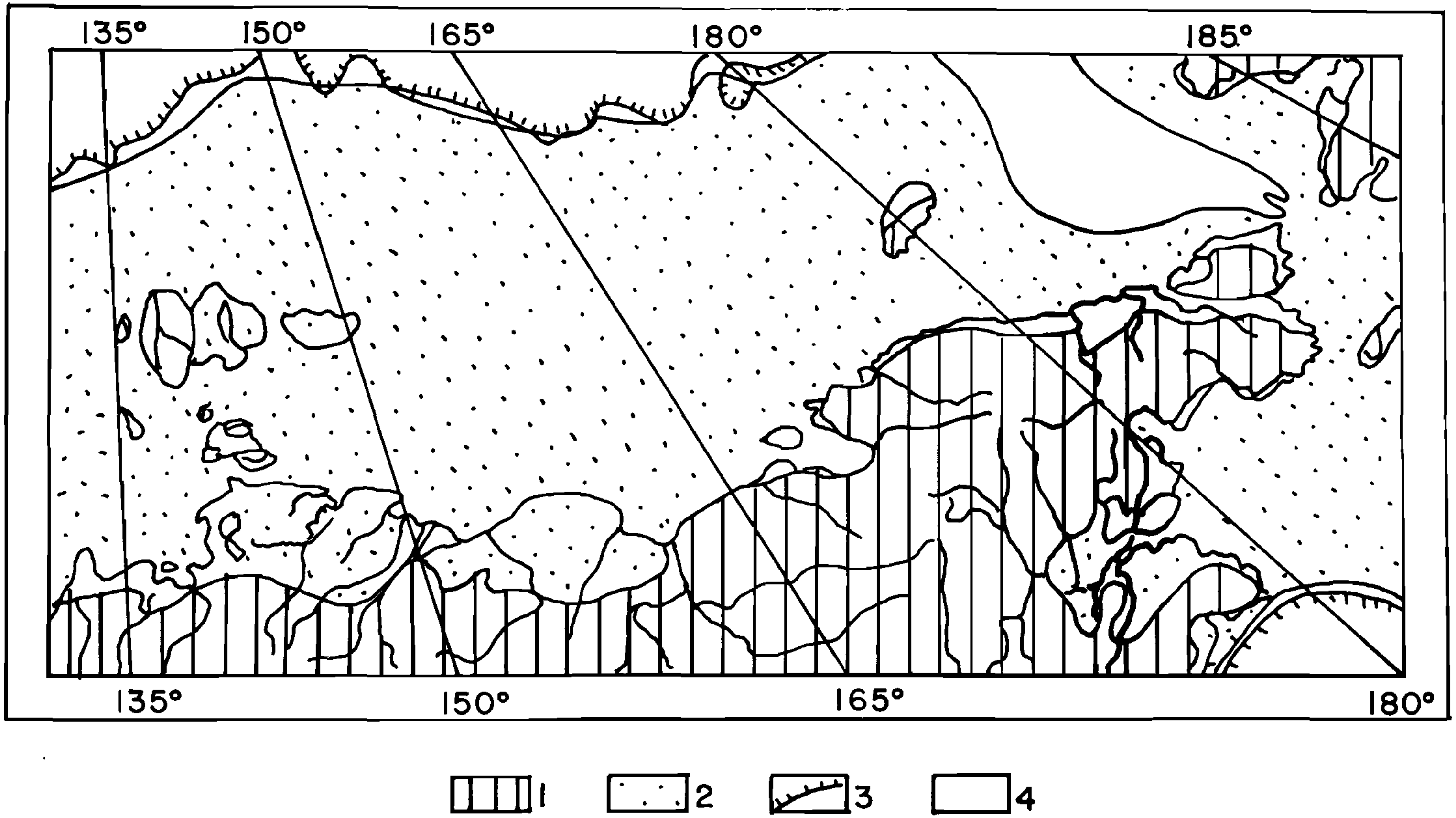

Figure 3. Schematic paleogeographical map of the late Pliocene and Pleistocene Periods (scale 1:15,000,000). (1) Land area during the late Pliocene; (2) Late Pliocene sea plain at the end of late Pleistocene; (3) Edge of continental slope; (4) Continous existence of the sea through the late Pliocene and Quaternary Periods.

Third Cycle

The third sedimentary cycle of the early-middle Pliocene was characterized chiefly by upwarping, resulting in the creation of extensive marine base-level terraces in the area of the former Miocene sea-floor (see Figure 2). These terraces probably extended to the edge of the modern shelf. This depositional cycle was reflected in the renewed down-cutting of the rivers, so that thalweg depths are −5 to 20 m below present sea-level to the north of Bolshoi Lyakhovsky Island, −15 m in the Kolyma region, −20 to −35 m in the Peftimel river delta, +10 to −50 m in the Chaunskaya Lowlands, −5 to −15 m in the Valkaraiskaya lowlands, −5 to 10 m in Vankaremskaya and Kolyuchinskaya lowalands, −60 m in the Koyntkhunskaya lowlands and −250 to −480 m in the Anadyrskaya lowlands.

The rise of the sea, at the end of the Late Pliocene (Figure 3), has left traces of abandoned shorelines in the western part of the the region at altitudes between +40 to +80 m; in the Kilyma region at +50 to +70 m; in the Chaunskaya lowlands at +50 to +60 m; in the Vankaremskaya lowlands, on the eastern coast of the Krest Bay, in excess of +200 m and in the Koynatkhunskaya lowlands and on the coast of the Anadyrsky Bay at +40 to +100 m.

Fourth Cycle

The fourth sedimentary cycle is the Pleistocene which was initiated under conditions of variable upwarping, allowing the regression of the late Pliocene sea and forming a series of terraces, ranging in heights from 10 to 160 m. The lower parts of the sections in these terraces commonly show sublittoral facies (cross-bedded sands and gravels), overlain by open sea sediments (silts, loamy sands and clays) often over 20 m in thickness. Regressive facies are represented by rhythmic alternations of marine sediments, coastal-marine facies, all subsequently overlain by lacustrine and lacustrine-alluvial deposits. The total thickness of the regressive facies does not exceed 5 to 10 m. At times, the open sea regressive facies may be missing from the sequence, with the remaining regressive facies resting directly on Marine sediments of late Pliocene age.

On the northern coast of the Chukotsk Peninsula four sets of wide abrasional and aggradational benches can be distinguished, occurring at heights between 200-120, 120-80, 80-40 and 40-10 m above present sea-level. These landforms mark four major phases of the early Pleistocene regression of the late Pliocene sea, namely the Ekug, Kymyney, Eelyan, and Nutauge (PUMINOV, *et al.* 1972). These benches can be correlated with a similar series elsewhere on the North-East USSR Arctic coast at heights between 10 to 70 m (BISKE, 1978; PETROV, 1966; PROKHOROVA and IVANOV, 1973).

The final stages in the development of most terrace and bench forms are characterized by the sequential construction of coastal barriers, following creation of large, stranded marine shoals. The cores of these sand banks were supported on basement ledges and support large backbarrier freshwater lagoons subsequently infilled with lagoonal, lacustrine and eventually alluvial and deltaic facies. The latter have accumulated under subaerial conditions, and have often been subjected to cyrogenic processes. On some parts of the Chukotsk Peninsula coast (e.g. the lower Amguema river, on the shores of Kolyuchinskaya and Mechigmenskaya Inlets), continuity in this deposition sequence was interrupted during the formation of the 80-40 m bench, when the valley glaciers advanced seaward and in some places extended beyond the coast.

A later, but attenuated, marine regression (see Figure 3), in the Chukotsk, led to the abandonment of marine terraces, which from their levels may be grouped into several sets at heights of 12-18, 22-28, 32-38, 42-50 and 55-60 m above present sea-level (DEGTYARENKO, 1971; BABAEV and ZHINDAREV, 1979; HOPKINS, 1976). Effects of later degradational processes on the benches are reflected not only in the river valleys but also in the pattern of the modern sea floor facies where occurrence of lenticular sands containing pebbles and gravels, represent old river channels or old alluvial outwash fans. These are know to lie at depths of 15, 27, 33-40 m below sea level. Further proof of the existence of a subaerial stage in the development of these benches is provided by the occurrence of peats and lagoonal sediments, at depths between 11-14, 20-40 m, overlain by Holocene marine deposits. The data on Anadyrsky Bay serve to indicate that at depths greater than 60 m, the Holocene sediments are underlain by deposits containing diatoms.

During the final stages of the late-Pleistocene transgression, the above-mentioned terraces, river valleys and boggy interfluve deposits were inundated by the sea. Evidence of several stages of shoreline migration from present shelf margin towards the land are reflected in abrasion terraces, low relief coastal barrier sequences and infilled lagoons, forming a continuous staircase of now submerged landforms at depths of 55, 38, 30, 20 and 10 m.

The upper horizons of these bottom sediments show an upward ascending sequence from coastal-marine facies through littoral facies and finally to open water facies. Peats and lagoon sediments are buried beneath these silts and clays of marine origin. In local areas, for example around Cape Dezhnev and Cape Bering, abrasion terraces and cliffs have been recognized, so that sediments of the fourth transgression overlie Pliocene deposits comformably, at depths ranging from 12 to 22 m.

The shorelines of the maximum late Pleistocene-Holocene transgressions lie at absolute heights of −3 to −7 m to below present sea-level, while abandoned shorelines of the earlier sea-level rise at heights of 2-3 m above present datum. Recent Neotectonic uplift of the coast has resulted in the local emergence of sand shoals, the withdrawal of water from certain lagoons, and, due to the simultaneous action of longshore drift, the formation of graded coasts. In recent times much of the depositional coast has been eroded, resulting in the shoreward relocation of many forms. This may be seen around Russkaya Koshka, on the spit complex in the Anadyrsky Bay and in the Kolyuchinskaya Inlet.

CONCLUSION

Thus the depositional pattern of the eastern Arctic USSR is dominated by four sedimentary cycles. Three cycles ended in transgressions, with the adjacent land areas being inundated by the sea. There is reason to believe that the fourth cycle will not end in a transgression with the future shoreline forming near the abandoned shorelines of the three earlier transgressions.

Finally, attention is called to the difference in the duration of these sedimentary cycles: I — about 30 M a; II −20-24 M a; III — 10 M a; IV — incomplete 2-3 M a. If we assume that the regressive and transgressive phases occurring within each cycle are of equal length, then the period remaining for the manifestation of the IV cycle may be about equal to the duration of the Pleistocene era.

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Editorial Note:

Traditional Soviet bibliographic style includes only the journal volume and issue number. We have made no effort to complete citations as they refer to works in the Russian language.