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On the morphogenesis and morphodynamics of the shallow zone off the Kuršių Nerija (Curonian Spit)

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Activity of shore processes increased greatly, especially since the 1980s. The most extensive erosion on the Lithuanian coast resulted from storms in the last decade was caused by global climatic changes. Investigations of the coastal zone as a common geosystem become more and more urgent. The shallow zone off the Kuršių Nerija (Curonian Spit) has been analyzed on the basis of geological-geophysical survey performed in 1999. Morphogenesis and morphodynamics of the shallow zone have been examined on the seismoacoustic records, availlable lithological, facial and marine–palynological data and peculiarities of the morphological changes on the shore-face submarine slope. This analysis has resulted in the recent bottom relief map with a contour interval of 1 m (in the paper in 2 m, for technical reasons) and the morphogenetic sketch map.

Morphogenesis, morphodynamics, Curonian Spit, Baltic Sea.

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INTRODUCTION

Kuršių Nerija barrier peninsula (length 98 km, with 38 km situated in Lithuania) is the largest accumulative form on the southeastern Baltic Sea. From morpholithodynamics point of view a sector of accumulation between Kopgalis—Juodkrantė settlements and transitional sector (relatively stable) between Juodkrantė—Nida settlements are prevailing on the northern part of the coastal zone of the Curonian Spit (Janukonis, 1997). Recent face of the shallow zone off the Curonian barrier island was formed under conditions of the Litorina Sea transgressions and Post-Litorina Sea deposition. According to investigation of the ancient shore levels, submarine littoral forms, located at the depths of 38-34 m, belong to the Ancylus Lake regression phases and those at the depths of 30-20 m belong to the Litorina-$_1$ stage. The part of the recent submarine coastal zone is extended from the dynamic shoreline until 20-meter depths, approximately (Fig. 1).

MATERIAL AND METHODS

The paper deals with very detail observations on the existence and extension of the minor relief forms and investigation of their development and morphodynamics. Seismoacoustic, sides scan sonar and bathymetric measurements have been made from the board of R/V "Doctor Lubecki" (Maritime Instytut, Gdansk) since 13th of July to 19th of July 1999. Seismoacoustic profiling has been done along 27 profiles perpendicular and 3 profiles parallel to the coastline with the total length of 311.3 km (Fig. 1). Essentially, the bathymetry measurements and echosounding records, gradients of the submarine slope, morphological expression and morphodynamics of the submarine bars zone face were analyzed in this paper. The ancient coastline forms and recent submarine coastal zone have been examined using inter-calibration with submarine shore formation and short core stratigraphy, known in this area (Kirlys et al., 1971, Kirlys, 1971, 1974; 1974, Gudelis, 1977; 1979, Kabailienė, 1997, Janukonis, 1997, Gelumbauskaitė, 1982, 1991, 2000).

MORPHOLOGICAL FEATURES OF THE SUBMARINE COASTAL ZONE

The echosounding profiles obtained during the survey allowed to observe and examine the morphological features and peculiarities of the morphodynamics of the submarine coastal zone. Going from Kopgalis to Smiltynė the set of profiles reveal that average width of the submarine coastal zone is 3.0 km, and the foot

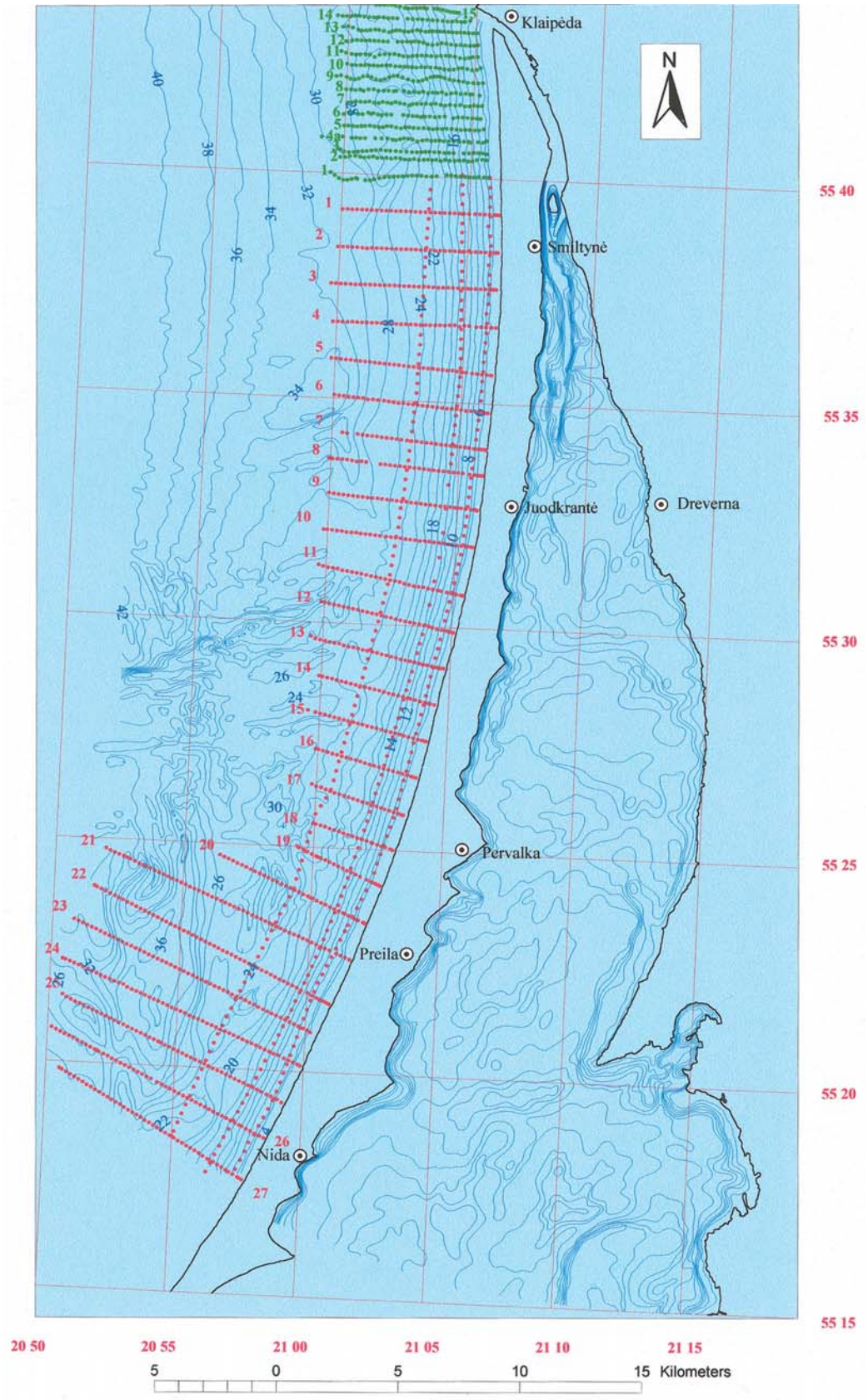

Fig. 1. Location map of the investigated area. Red points mark seismoacoustic lines performed in 1999; green points mark seismoacoustic lines performed in 1994.

of the slope is at –23.5 m depth. Upper shore face, down to the depth of 4.5 m, as submarine bar zone under study varies between 320-370 m and consists from three bars. The sketch of the profile No. 4a (Figs. 1, 2) shows that the crest of the first inner (I) bar is at –1.3 m, the crest of the second (II) bar is at –1.8 m and the crest of the outer (III) bar is at the depth of –2.0 m. The inner trough (between I and II bars) is identified at the depth of –2.4 m, the outer trough between II and III bars is observed at the depth of –4.2 m. Southwards, on the segment II, of the set profiles Nos. 1-9 until settlement of the Juodkrantė, the width of the submarine coastal zone is larger than in the north and ranges in 2.8-3.7 m. The slope has concave form with gradient I=0.00558 of the inclination. The foot of the slope is observed at the depth of –25.0 m. The average width of submarine bar zone is larger too than in the north and varies from 314 to 429 m. The technical possibilities did not allow making survey of the foreshore for all the profiles and some time we could not recognize the first inner bar. On the echosounding records from profiles Nos. 4 and 7 we observed two bars. The crest of the first inner bar is identified at the depth of –2.0 m on the profiles Nos. 4 and 7. The crest of the outer bar being not fully formed on these profiles is observed at –5.1 and –4.0 m. The depth of the inner trough is –3.8 m, and –6.1 and –4.4 m of the outer trough (Fig. 2). Southwards, on the profiles Nos. 10-14 we recognized changes in the submarine coastal zone morphology. The slope became shorter (the foot of the slope identified at –22.0 m) and steeper (profile No. 12, gradient reaches I=0.00856). The width of the submarine bar zone is the same as in the next segment, but the depths of the troughs increased till –4.4 and –7.0 m.

Considerable changes of the morphological features have been fixed on the profiles Nos. 15-22, between the latitudes of the Agila Cape and settlement Preila. The width of the submarine bar zone going from north to south ranges from 429 m (profile No. 16) to 714 m (profile No. 22, see Fig. 2), and the width of slopes varies from 1.2 to 2.0 km with gradients I=0.00806. The variability of the submarine bars is also fixed. On the profile No. 18 an outer bar, not fully formed, has been observed at –5.4 m, and the inner bar going shoreward was at the depth of –2.6 m. Between these bars a very deep and large outer trough is identified at the depth of –7.7 m. The inner trough, going shorewards, has been found at the depth of –5.2 m. Extreme significances of the morphological features were recognized on the profile No. 22. The trough with the depth of –9.5 m was found on the slope top, outside the outer bar. The crest has been fixed at –5.8 m. Going

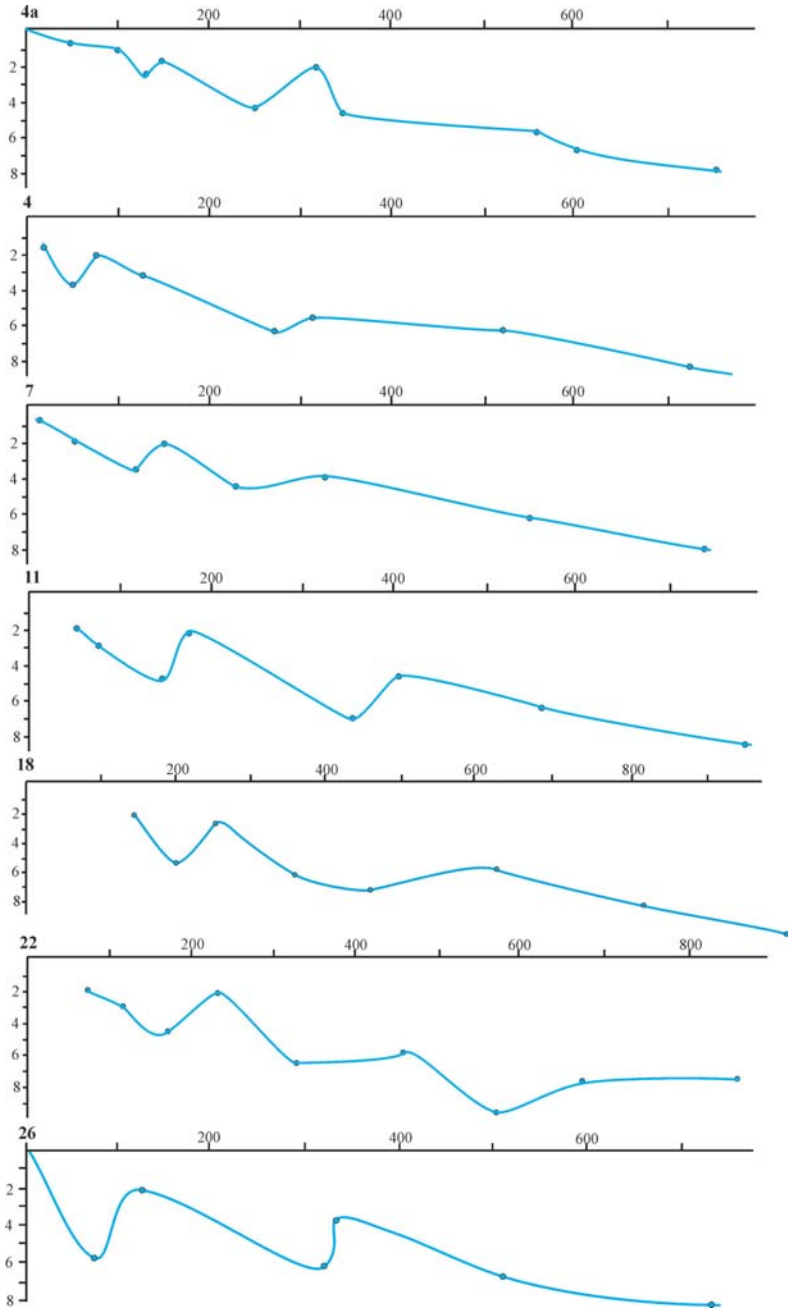

Fig. 2. Profiles of the Kuršių Nerija submarine bar zones performed in August 1999. Distance towards offshore (m). 4a – profile number (see Fig. 1).

shorewards, two inner troughs with depths ranging from –6.6 to –4.5 m have been identified, and the inner bar –2.0 high m is also recognized (Fig. 2).

On the southern segment of the submarine coastal zone a 371-m wide submarine bar zone and a 2.29-km wide submarine slope are identified. The foot of the slope is observed at the depth of –20 m. Between Preila–Nida settlements large-scale erosion has been observed on the submarine bar zone. On the profile No. 26 two bars at the depths of –2.1 m (inner) and –3.7 m (outer), and deep troughs at the depths of –6.1 m (inner) and - 6.5 m (outer), have been recognized.

MORPHODYNAMICS OF THE SUBMARINE COASTAL ZONE

The submarine coastal zone in respect of morphodynamics is divided in: (a) the outward slope of the submarine bars, where the littoral drift is caused by waves processes, (b) long shore trough of the outer bars, where character of the littoral drift is caused by long shore currents, (c) one or two inners bars and troughs in between, where prevails character of the littoral drift cross direction on to the shoreline. Many studies in 1960-1970s covered morpholithodynamics of the near shore zone (Kirlys, 1971, 1974, 1974; Kirlys et al., 1971,) revealed that submarine coastal zone off of the Spit of Kuršių Nerija, as accumulation form is stable in space and time. Width of the submarine bars (surf) zone under study ranged between 600-700 m. High of the crest of the inner bars was 0.5-1.0 m (I) and 1.2-1.5 m (II), and high of the outer bar crest was of 2.5-3.0 m (III). On the basis of this investigation is concluded that activity of the long shore drift, call out erosion in the outer trough and activity of the transversal littoral drift can have an effect on width and variability of the submarine bars zone.

Analyses of the survey made in 1999 shows that the width of the submarine bars varies from 314 to 714 m .The narrowest zone of submarine bars is observed on the second segment (profile No. 8) and the largest one is on the IV segment (profile No. 22). According to our data crest height of inner bars varies from –1.3 to –2.1 m and the height of outer bar crest ranges from -3.7 to –5.4 m. The depth of the inner troughs varies from -2.4 to – 6.1 m, and the depth of the outer trough ranges from –4.0 to –7.2 m (Fig. 2). Correlation with profiling data in 1966-1972 (Fig. 3) allows constitute the variability of the submarine forms. Deep down the bottom of the troughs, especially on the segments IV and V, it is shown that the process of erosion can predominate.

MORPHOGENESIS OF THE SUBMARINE PLAIN DISPLAYED AT THE DEPTHS OF 20-40 M

The ancient submarine shore formation at the depth of 20-60 m of the southeast Baltic Sea was studied in 1970-1980s (Gudelis et al., 1977; Kabailienė, 1997; Gelumbauskaitė, 1982, 1991, 2000). The data gathered and examined in this paper disclose many new elements in the morphological features of the Ancylus Lake and Litorina Sea stages submarine shore formation displayed on the shallow zone off the Kuršių Nerija Spit at the depths from 20 to 40 m (Fig. 4).

Going southwards from Kopgalis on the segment I, at the foot of the recent submarine slope, we observed three subsurface terraces at the depths of 19-22, 23-25, 25.7 –28 m, on the segment II – two subsurface terraces at the depths of 25.0-27.8, 28.8-29.0 m, on the segments III, IV and V – two subsurface terraces at the depths of 19.2-21.6, 22.8-25.0 m. The terrace surfaces at 22.8–25 m cut trough an elongated fragment of channel and some small lows at the depths of 26.0–28.0 m, which could be connected.

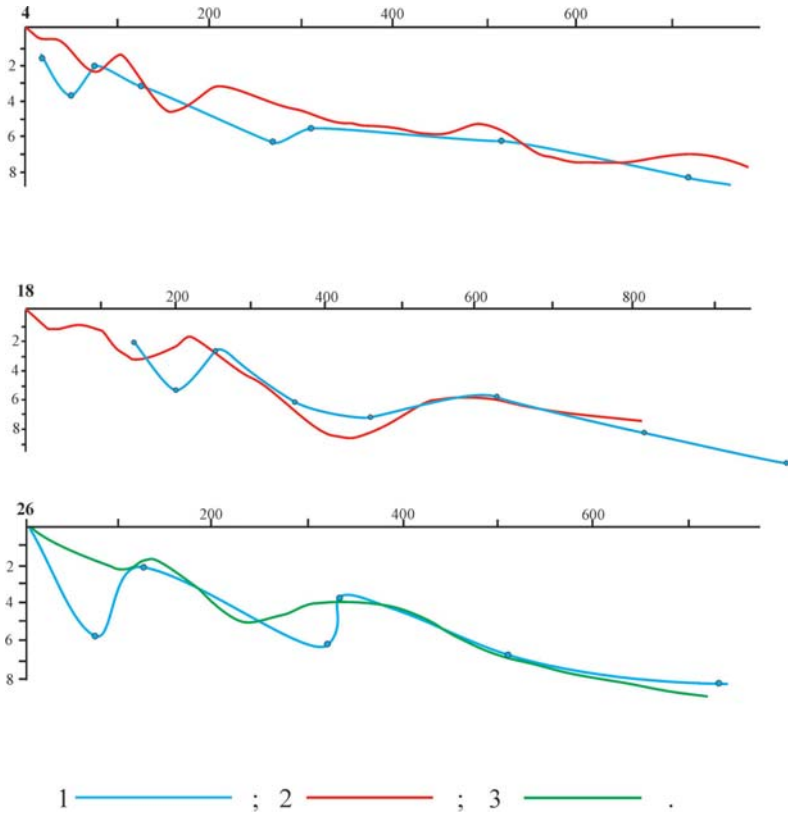

Fig. 3. Correlation of the Kuršių Nerija submarine bar zones. 1 - profiles performed in 1999.08; 2 - typical profiles performed in 1965-1970; 3 - profiles performed in 1968.08.

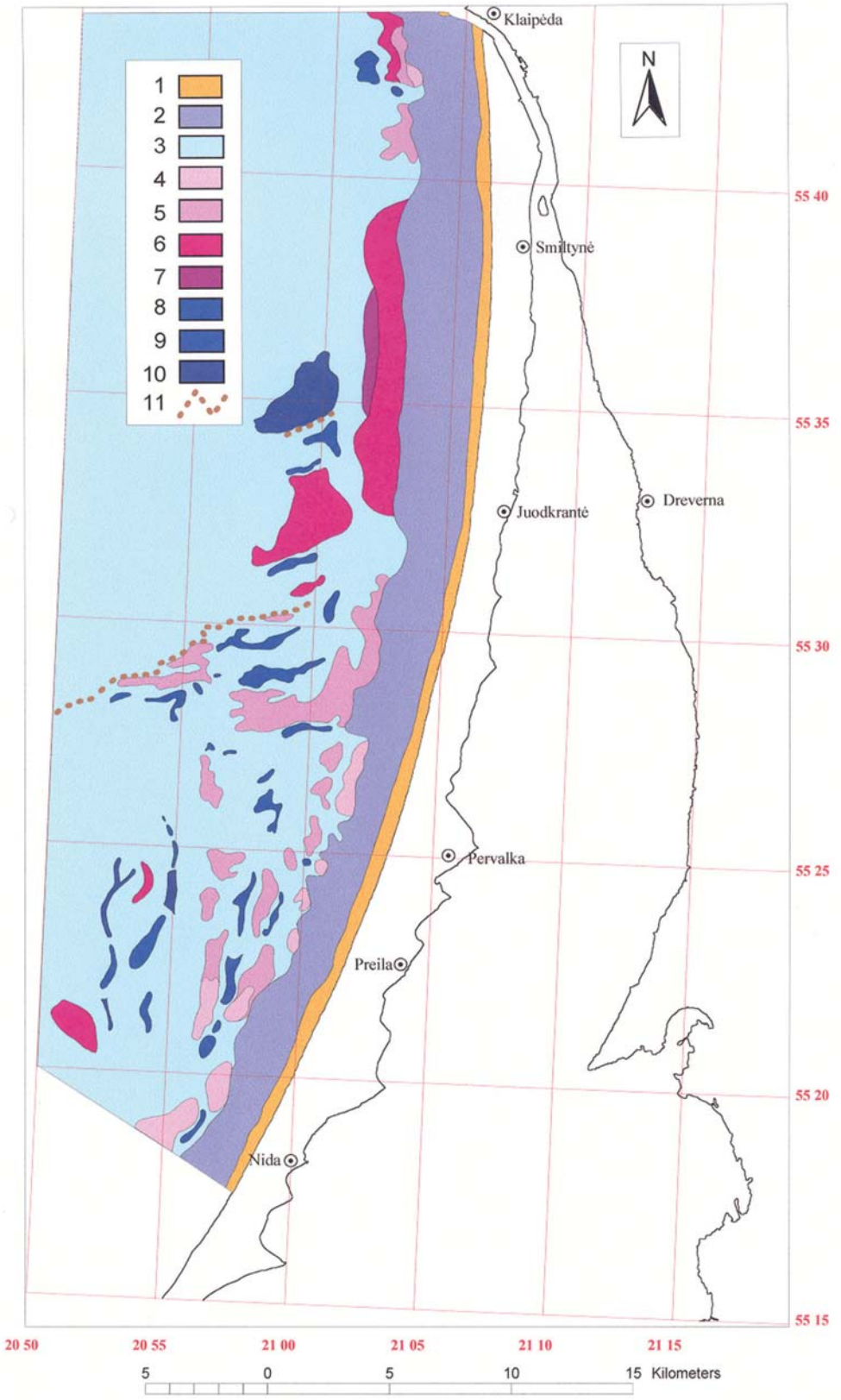

Fig. 4. Morphogenetic sketch map. 1 – submarine zone of bars; 2 – submarine slope; 3 – submarine plain displayed at the depth of 20-40 m; 4 – I terrace subsurface at the depth of 19-22 m; 5 – II terrace subsurface at the depth of 23-25 m; 6 – III terrace subsurface at the depth of 25.7-28 m; 7 – IV terrace subsurface at the depth 28.8-29 m; 8 – lows at the depth of 26-30 m; 9 – lows at the depth 34-36 m; 10 – channels; 11 – scarps at the depth 38-30-28-26.

According compiled spectrograms and its correlation with lithological and marine–palynological data (Gelumbauskaitė, 1982), these ancient shoreline forms we can recognize as forms of the first transgression phases of the Litorina Sea.

Going seawards, recent small lows and fragments of the channel shape submarine plain at the depths of 30-38 m are mutually separated by the elevations at the depths of 34.0-36.0 m. On the segment III, between latitude of the Agila Cape and latitude of the Pervalka settlement we identified well-exposed scarps at 38-28 m depths. All these relief forms according to existing litho- biostratigraphy data can be interpreted as ancient shoreline forms formed during fluctuations of the Ancylus Lake regression phases.

CONCLUSIONS

Analyses of the morphological features of the shallow zone off the Kuršių Nerija Spit allowed to make a very detailed reconstruction of the relief of the shallow zone, and to describe its genesis and morphodynamics. On the basis of our studies it is concluded that the erosion processes become more active on the transitional sector of the coastal zone off the Curonian Spit. Examination of the morphogenesis of the ancient shoreline formation of the Ancylus Lake, and Litorina Sea stages, revealed many unknown forms and elements of the ancient relief.

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