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Late–Glacial—Holocene history in Curonian Lagoon (Lithuanian sector)

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Abstract The palaeogeographical conditions and depositional–erosional activity of the fresh water basins during Allerød-Boreal periods have been investigated using created GIS database of the stratigraphical units. Palaeorelief of the till loam, IL-BIL and A_{1-2} Baltic Sea stages is reconstructed and exposed on 3D schemes, with relationship between the roughness and dimension of the morpho-lithogenetic processes during Late-Glacial and Holocene revealed.

Keywords *Baltic Sea, Curonian Lagoon, palaeogeography, Late-Glacial, Holocene.*

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INTRODUCTION

The Kuršių Marios (Curonian) estuary, as a lagoon on the eastern part of the Baltic Sea, is an important basin for investigation of evolution of shelves and coastal zone in Late–Glacial—Holocene.

According to previous data (Gelumbauskaitė, Grigelis 1995, 2001; Gelumbauskaitė 2002) it could be stated that the actual elongated plain of the Kuršių Marios bottom, gently inclined from north to south, contains Jurassic/Cretaceous basement at 50-78 m b.s.l., incised by the palaeochannel at the depths of 82-95 m b.s.l., on the central part. The reconstruction of the Late–Glacial—Holocene palaeomorphology and history of the Curonian Lagoon shows the interdependence between the roughness of the till loam surface and Holocene depositional sequence. The palaeorelief of the surface of the till loam reflects predomination of glacial erosion on the western part with minimum depths 30-34 m b.s.l. and glacigenic sediments, reformed by fluvial erosion, during postglacial eustatic lowstand on the eastern part with maximum depths of 3-6-16 m b.s.l. The cover of the Late–Glacial—Holocene deposits are very uneven and ranges from 5 m in the SE part to 30 m in the central part. Late–Glacial—Holocene history of the Curonian Lagoon can be separated into two parts: fresh water phase (Local Ice Lakes–Baltic Ice Lake–Ancylus Lake stages) and brackish water phase (Litorina–Post-Litorina stages) with formation of sandy barrier (Curonian Spit). The present paper is aimed mainly at geological evolution of fresh water phase of the Baltic Sea in Curonian Lagoon.

MATERIAL AND METHODS

This paper contains the continuous studies of the depositional–erosional history and geodynamic conditions of the central and northern parts of the lagoon are based on the interpretation of the echosounding, high resolution seismic profiling, boreholes and short cores (Gelumbauskaitė 2002; Gelumbauskaitė, Gaidelytė 2003, 2004). During previous period of investigations the EUROSEISMIC metadata base and boreholes metadata base have been created for the Curonian Lagoon. More than 400 km echosounding, seismic profiles and 90 boreholes drilled on the Curonian Lagoon, Curonian Spit and eastern mainland during 1963-2002 geological mapping and marine scientific programs have been examined (Fig. 1). Analysis of well exposed seismic units and correlation with boreholes and short cores, where litho–biostratigraphy and radiocarbon–optically stimulated luminescence dating were made,

allowed creating the GIS database of the stratigraphical units for Late–Glacial—Holocene at more than 130 sites. Using software packages EXEL and ArC/View 3.0 version the drafts for the palaeorelief schemes handmade compilation were prepared on a scale of 1:50,000. Later the drafts, with depicted isolines, were vectorised and cartographic images created. For interpolation the scheme of the heterogeneous till loam surface, Grūda stadial (Upper Nemunas–Late Weichselian)—Medininkai–Warthe glacial (Bitinas, 1997) and palaeorelief schemes on the boundary between stratigraphical units Allerød—Younger Drias (Local Ice Lakes and Baltic Ice Lake, IL–BIL 13,500-10,300 ^{14}C BP) / Boreal (Ancylus Lake transgression-regression phases, A_{1-2}, 9,300-8,000 ^{14}C BP), and Atlantic (Litorina Sea transgression phases L_1 7,800 ^{14}C BP) have been made (Figs. 2, 3, 4).

3D tools were used for interpretation of palaeogeographical data in the Curonian Lagoon. Linear elements of the palaeosurfaces were used for GIS interpolation. Each digital elevation model requires a spatial database wherein points of the palaeorelief are assigned coordinates *XY* on the plane, and the vertical coordinate *Z* (Badura, Przybylski 2005). In order to construct digital maps the *XYZ* data were transformed into a so-called grid, i.e. 3D network what recognised by the computer as a model of the palaeosurface. The models were made using Surfer8 program, produced by Golden Software.

The modeling of present position of the sediments accumulated in different phases of the Baltic Sea is important component for the reconstruction of digital elevation models (DEM_t), describing the terrain elevation of the area in the past. For the full reconstruction of the elevation at the study area relative sea level curves are needed (Harff et al. 2001; Meyer 2003).

The database was formed including geographical data (*X*, *Y* coordinates of cores and "artificial" points) and geophysical–geological data (altitudes of the palaeosurfaces of the till loam, the Baltic Ice Lake, and the Ancylus Lake stages). The "artificial" points were transformed from isolines of the palaeorelief schemes, depicted at 5 m intervals, using ARC/View 3.2a program. For interpolation of the grid the *minimal curvature* method with 30 m horizontal spatial resolution (*XY*) and 5 m vertical resolution (*Z*) was applied. 3D schemes were projected in metric coordinates of the Transverse Mercator projection, where central meridian is 21° (spheroid GRS-80).

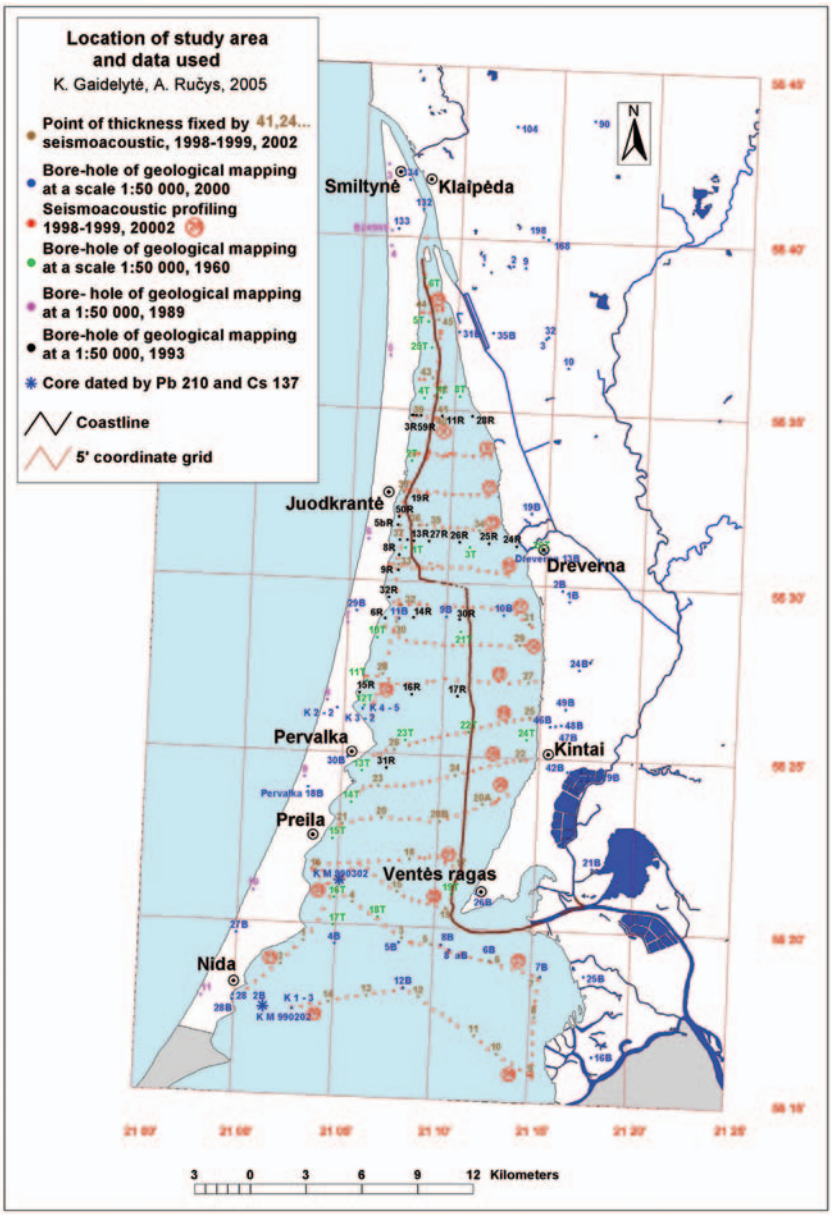

Fig. 1. Location of study area and data used.

RESULTS AND DISCUSSION

Palaeorelief of the till loam (stadials of Grūda–Late Weichselian and Medininkai–Warthe)

The reconstructed palaeorelief of the till loam clearly explain denudational–abrasional character of this palaeosurface on the all bottom area (Fig. 2). Only in the south of the study area, close to the eastern mainland, the end moraine ridge up to 3.0–0.0 m b.s.l. has been recognized.

The western part of the Curonian Lagoon is shaped by three small pools. The pool–like lobe is extended on the south with depths –36–20 m b.s.l. The eastern part of this pool, located in front of the Nemunas delta region, is separated from the

western part by a moraine ridge. This moraine ridge is expressed not only on the palaeorelief of the till loam surface, but also in recent topography, and is prominent on the present relief as Kalvos and Akmenos banks. Its continuation stretches to mainland occupying coastal region along the Curonian Lagoon. This ridge, named as Pajūris end moraine ridge, determined as Pajūrio oscillation (Baltija Stage, Upper Nemunas–Late Weichselian glaciation) and presented by upper till horizon belonging to the Baltija Stage, was recognised only onshore (boreholes 26B, 42B, 1B, 31B, 35B). Basal till of this ridge nearshore, on the south of Curonian Lagoon, is regarded as a till of Grūda stage (8B, 8, 8a boreholes).

Ancient shorelines of the BIL with maximum height of 6 m a.s.l. imprinted on the slopes of this ridge, during the Baltic Sea transgression phases, have been observed and examined at the traverse Dreverna–Kintai settlements (19B, 13B, 2B, 46B, 47B, 8B, 42B, 25B, 16B).

Following to the north, close to Curonian Spit, Preilos and Panerijos lows are situated on the present topography. According to the data obtained from the boreholes 5S, 6S, 9S, 3T, 2T and seismic records done in locations 1, 2, 8, 11, two pool–like grooves (with minimum depths 34-30 m b.s.l.), separated by basal till plain, with a maximum depths 18-24 m b.s.l., are exposed on the palaeorelief of till loam, in the same places.

Over most of the till loam palaeosurface in the central and eastern parts of the Curonian Lagoon region is distinguished as the basal till plain, deposited during Medininkai–Warthe regional stage (based on the boreholes 27B, 4B, 7B, 5B, 27B, 11B, 4416B, 4415B data and seismic records at the locations 44, 43, 22, 20, 17, 18, 12, 1330, 28, 38, 37, 1, 2, 3, 4, 5, 6, 7). The morphology of the basal till plain is slightly undulated, and from south and north limited by Preila and Panerija grooves. In the northern corner of the Curonian Lagoon topography rather like gently inclined slope adjoins the Pajūris end moraine ridge.

Palaeorelief of the Local Ice Lakes and the Baltic Ice Lake stages (IL–BIL)

The retreat of the ice sheet front from moraine ridges of the Pajūris Phasial began about 13,500 ^{14}C BP on the Lithuanian coast. First, the dammed Local Ice Lakes were formed. Later, the lakes developed into the Baltic Ice Lake stage (Gudelis 1979; Kabailienė 1999).

Expression of the Baltic Ice Lake stage palaeorelief varies and is strongly influenced by the morphology of the till loam palaeosurface (Fig. 3). It is gently inclined from east to west and stretched from south to north. Reconstructed topography of the palaeoplain is displaced at the altitudes from 4 m a.s.l. on the eastern borderland to 25 m b.s.l. on the western, on the Curonian Spit. The palaeoplain is shaped by two inlets, at the traverses Dreverna–Juodkrantė and Perv-

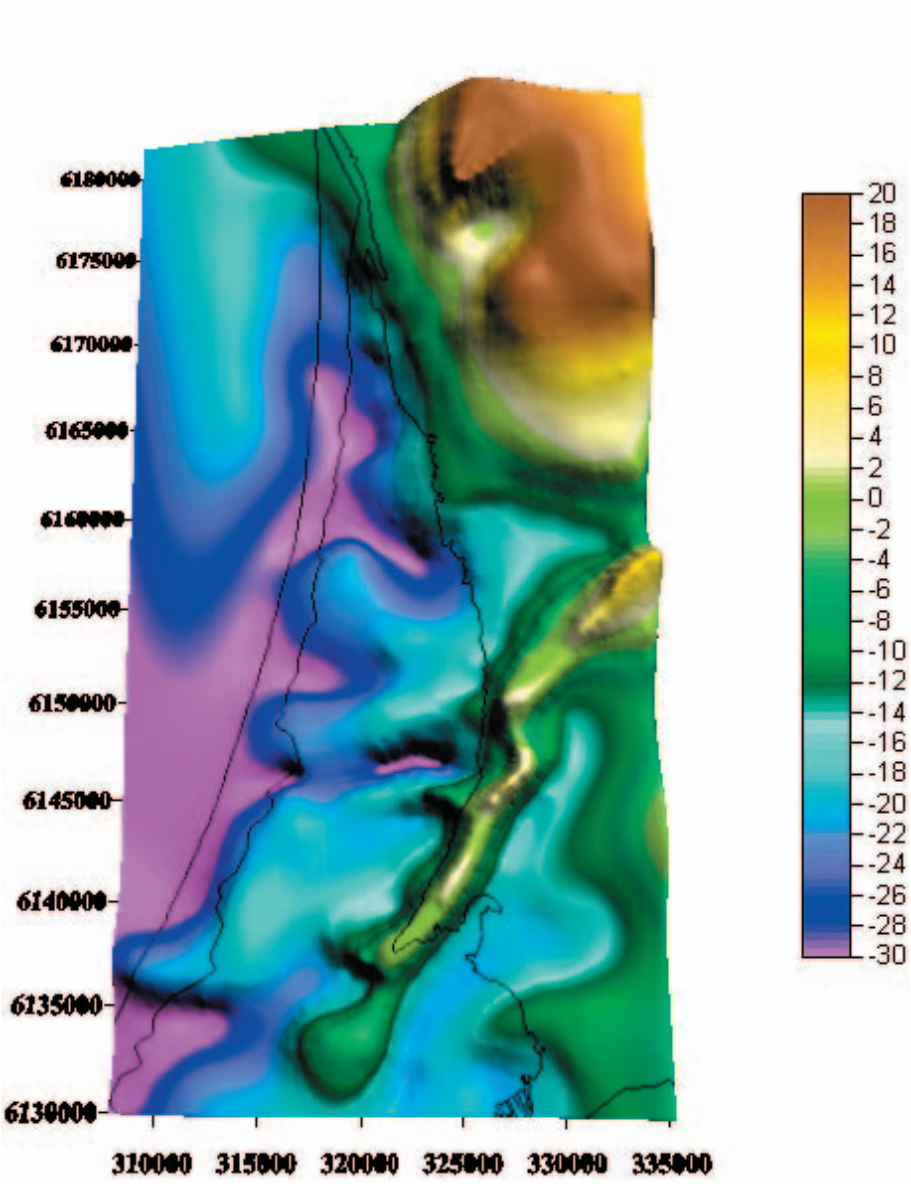

Fig. 2. A colour shaded palaeorelief scheme of the till loam (stadials of Grūda–Late Weichselian and Medininkai–Warthe).

alka–Kintai settlements. A large inlet as a gap separates Pajūris end moraine ridge at the traverse of Dreverna settlement–Dreverna River valley with minimum depth of 13.1 m b.s.l. (seismic record locations 34-36 and boreholes 13B, 19B, 24R, 20T). The second gap–like channel (with minimum depth of 5.6 m b.s.l.) dissects the same moraine ridge at the traverse of Kintai settlement (seismic record locations 1, 2, 8, 24, 22, 25 and boreholes 22T, 24T, 46B, 48B, 47B, 42B, 19B). Last mentioned channel is distinguished in the seismic units at the top of the till loam and on the boundary of BIL/A. Using correlation with borehole stratigraphy it has been recognised as a channel, that could be constituted like Minija palaeo-valley. Following to the south, in the central part of the Vidmarių Low, on the topography of BIL, the Pajūris moraine ridge repeats topography of the till loam expression. Its northern slope step is reflected at the depths of 9-15 m b.s.l. and southern at the depths of 5-13 m b.s.l.

The ancient shoreline of the BIL transgression phases have been examined and fixed on the western slope of the Pajūris end moraine ridge at 5-7 m a.s.l. The transgression peak constituted at 11,700±180 ^{14}C BP, at the beginning of the Allerød (Bitinas et al., 2002). IL–BIL deposits are found almost in entire Curonian Lagoon basin and on the mainland of the Nemunas River delta area. According to the data obtained from 11S, 10S, 16T, 17T, 18T, 4B boreholes and cores, this binominal depositional complex is composed of grey brownish clay with silt interlaying on the bottom sections, as well as mostly of sand and silt in the upper part of the sections prevailing in the lows of the western part. In the rest part of the lagoon more chaotic and more similar shore facies of the IL–BIL complex, composed by silt, sand and gravel (boreholes 29B, 11B, 10B, 9B, 13T, 23T, 22T, 1T, 3T, 11B, 10B, 9B, 31B, 7S, 6S, 5S, 4S and seismic units locations 18-43) have been observed. Thickness of the sediment complex varies from 8 m in the south-western part to 12 m in the central part of the study area.

Going northwards thickness of the BIL is reduced to 4 m. The character of the infilling of the boreholes allows to identify depositional break at the boundary of the BIL/A_1 on the central and northern parts of the Curonian Lagoon. The internal acoustic stratification of the seismic units on the limit between BIL/A_1 confirms its erosional character.

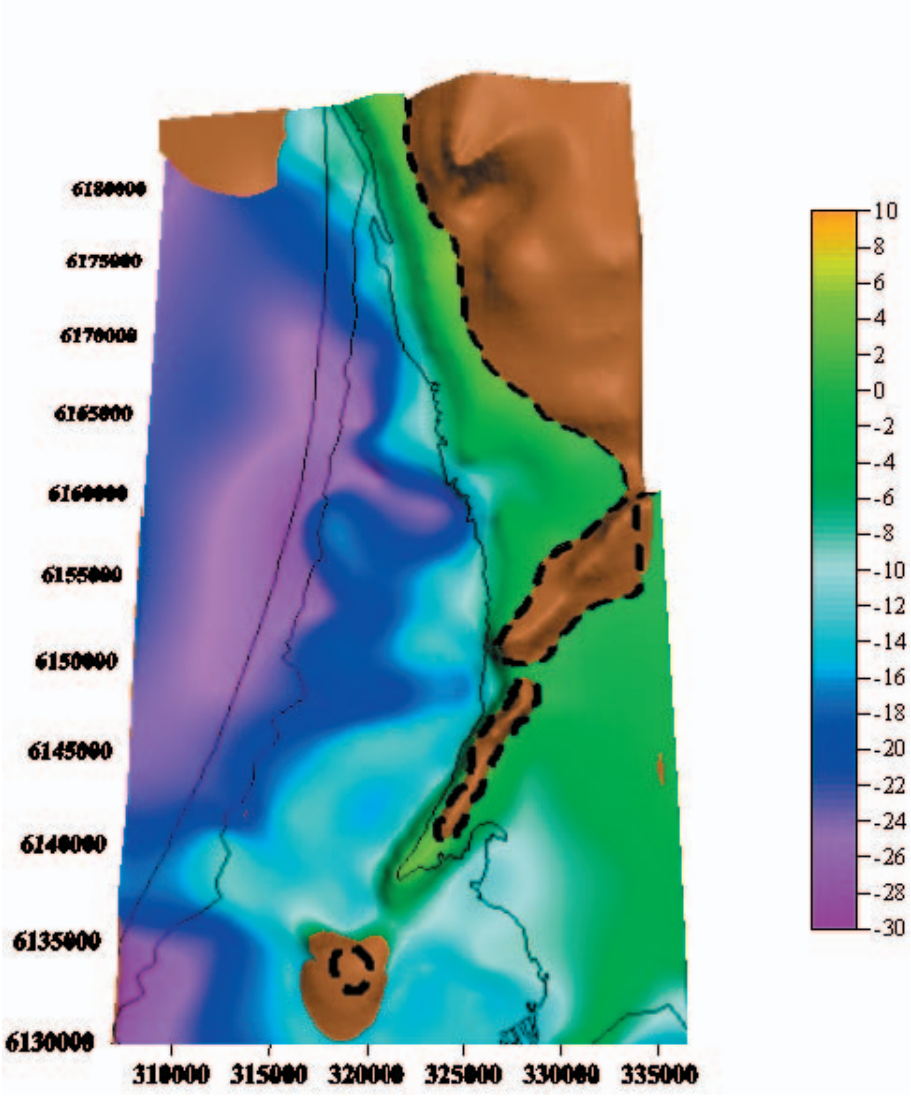

Fig. 3. A colour shaded palaeorelief scheme of the top of the Local Ice Lakes and Baltic Ice Lake stages.

Palaeorelief of the Ancylus Lake stage (A_{1-2})

As a result of the isostatic land uplift in Central Sweden, the Baltic Sea basin was isolated from the Ocean. The Baltic became a large inland lake, the Ancylus Lake. It happened at Boreal time about 9,300-8,000 ^{14}C BP. (E. Andrén 1999).

Several authors investigated and discussed the shorelines and displacement of the shore formations on the Lithuanian coast of the A_1 phases at 6-4 m (8,700-8,500 ^{14}C BP) and A_2 at 38-45 m b.s.l. (8,300 ^{14}C BP) (Gudelis 1979; Kabailienė 1967, 1996; Kunskas 1996; Bitinas et al. 2002; Gelumbauskaitė 2002; Gelumbauskaitė, Gaidelytė 2003).

The morphology of the palaeosurface of the Ancylus transgression-regression phases is most likely smoothed plain, dissected by three inlets at the traverse Kintai–Preila, Dreverna–Juodkrantė and Alksnynė. The palaeorelief is expressed from 5.5 m b.s.l. depth nearby the eastern lagoon coast and to 15.0 m b.s.l. nearby the western part (Curonian Spit) (Fig. 4).

More complicated morphology is depicted on the northern and eastern parts of the lagoon, where it is reflected by variable, truncated character of the infilling at the A_2/L_1 boundary. The ancient shoreline of the Ancylus Lake maximum transgression has been recognised on the seismic records at the depth of 5.5 m b.s.l. of the eastern borderland and in front of the Nemunas River delta. According to data of boreholes 45R, 27R, 26R, 25R, 1T, 4T, 25T, 5T, 3T, 30T, 19B, 13B and seismic units in locations 34-37, silty sandy sediments of the Pra-Minija–Dreverna River were revealed at the traverse of Juodkrantė–Dreverna settlements. The thickness of the A_{1-2} grew up here until 8-9 m; whenever in Curonian Lagoon reached 4 m in average (24R, 25R, 11R, and 9R).

The sediments are presented by silt and sand on the shallows of the Curonian Lagoon. When Ancylus Lake retreated on the second half of the Boreal, the process of peat accumulation has started in the pools. During the prolonged regression water level dropped some meters, and the sand, later silt and clay was accumulated (Kabailienė 1999).

CONCLUSIONS

The morphology of the palaeosurfaces on the boundary between till loam and BIL/A/L Baltic Sea stages is reconstructed and exposed on the 3D schemes. The interdependence between Late–Glacial surfaces roughness and dimension of the depositional–erosional activity during Allerød–Boreal time on the northern part of the Curonian Lagoon is revealed.

The analysis of the history of fresh water basins in the Curonian Lagoon shows that not only glaciolacustrine and lacustrine processes in Allerød–Boreal time have formed sediment complexes. Three palaeochannels, found at the traverse of Kintai–Preila, Dreverna–Juodkrantė and Alksnynė, demonstrate that fluvial processes were significant for development of the Curonian Lagoon during IL/BIL/A_2 regression phases. Investigations of sedimentary complexes confirmed that deposition in the western part of the study area was uninterrupted, while in the central and eastern parts it was more variable and truncated.

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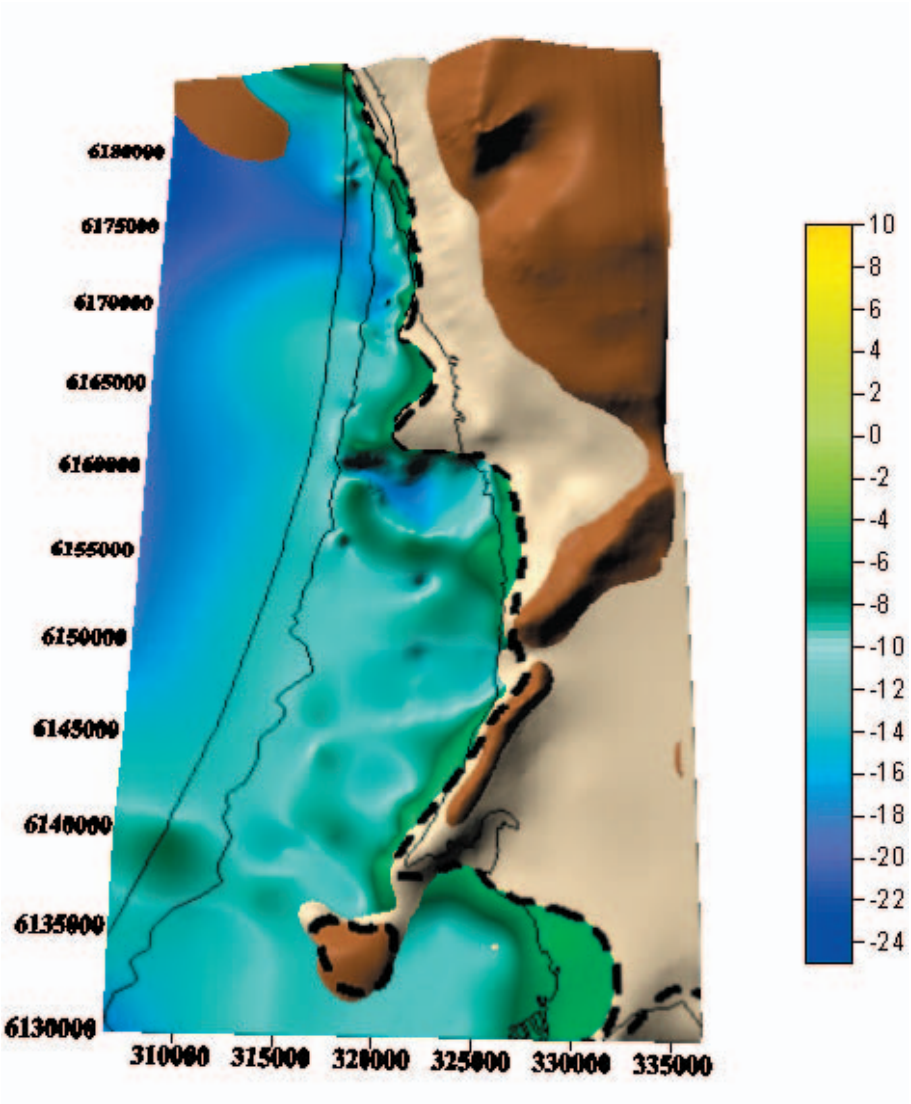

Fig. 4. A colour shaded palaeorelief scheme of the top of the Ancylus$_{1-2}$ Lake stage.

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