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Lithology of sediments and stratigraphy of glacial layers of some cliff sections on central and western Polish Coast

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The cliffs studied reveal a high similarity in terms of geological structure and age of sediments. Differences in the geological structure of particular cliffs occur only in the upper part. They are related to the occurrence of reservoir sediments in some profiles.

The thermoluminescence (TL) age of glacial sediments exposed in the lower part of cliffs shows that they are glacial sediments of the Świecie Stadial (54 400–50 800 years BP). In all profiles in which sediments of this type occur, there is a clear "rejuvenation" of their top part (33 200–38 600 years BP).

The age uniformity of glacial sediments is also confirmed by petrographic analysis. The obtained values of petrographic indices explicitly indicate that in all examined profiles the till is the same and that in particular profiles, despite the variability of sediment colour, only one glacial level occurs.

Key words: stratigraphy of glacial sediments, cliff, lithology, TL age, Polish Baltic Coast

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INTRODUCTION

In 2003–2005, a chronostratigraphic and petrographic research of sediments composing the cliffs of the central and western parts of the Polish Coast was performed. Cliffs in Jarosławiec II, Wicie E, Niechorze, Rewal, Trzęsacz, Łukęcin, and Dziwnówek were studied.

The history of cliff investigations in this section of the coast has a long tradition. Research on sediments of the cliff shore of the Rewal Plateau (cliffs in Niechorze and Rewal) was performed as far back as the first half of the 20th century. German scientists (Hartnack, 1926) distinguished two levels of boulder-rich clays. As a result of later research, expanded over the cliffs in Trzęsacz, Łukęcin, and Dziwnówek, carried out by the Poznań centre (Krygowski, 1956; Karczewski, 1961; Kostrzewski, 1967), two till levels, brown and grey ones, were attributed to the Northern Polish Glaciation. A similar opinion was held in the 1980s by Racinowski and Sochan (1981) and Dobracka and Ruszała (1988). These opinions are also referred to by a research of the 1990s (Lagerund et al., 1995; Krzyszkowski et al., 1999). The age differences of brown and grey tills in Niechorze were pointed out by Kopczyńska-Lamparska (1974). A lithological-petrographic research of the Śliwin Cliff (Racinowski et al., 1995; Dwucet et al., 1998) confirmed the opinion of Kopczyńska-Lamparska about the existence of

two levels of boulder-rich clay of different age in the Niechorze-Rewal section.

The sediments exposed in the cliffs in Jarosławiec II and Wicie E had been so far classified as the Gardno phase (Uniejewska, Nosek, 1985).

At the end of the 1980s, the first dating of cliff sediments by the TL method was performed at the Lublin laboratory. The upper, brown till was dated to about 65–90 thousand years BP, whereas the sandy-silty sediments covering it to about 54–65 thousand years BP (Dobracka, Ruszała, 1988). The lower, grey till was dated to 107 thousand years BP (Kaszubowski, 1988).

An analysis of the available archival geological studies and a field survey indicated some inconsistency of the work performed so far and was an incentive for the authors to undertake a new research. The basic problem was determination of the chronostratigraphy of sediments occurring in particular cliffs, and their correlation. For this purpose, all the sediment series were sampled. The collected sediment samples were dated by the TL method. Due to the fact that the TL dating was also performed for tills, i. e. for sediments assumed by some researchers as inappropriate for this type of dating, also a petrographic analysis of all samples was performed. The obtained petrographic indices enabled to construct a lithostratigraphic schema. This schema, in accordance with the authors' assumptions, was a supplement to the chronostratigraphic schema obtained from the TL ages. The location of the examined cliff sections is presented in Fig. 1.

GEOLOGICAL STRUCTURE OF CLIFFS

Jarosławiec–Wicie

In this cliff area, four profiles were made: Jarosławiec I (255.5 thous. km of the Polish seashore, from the Polish–Russian border), Jarosławiec II (256.5 km), Wicie E (261.0 km) and Wicie W (262.1 km).

The lowermost sediment series exposed in the section is the dark-brown clay occurring in Wicie. The thickness of the clay is unknown. The top occurs at 2 m b. s. l. The borehole drilled to a depth of 3.5 m b. s. l. did not reach the base of the clay (Olszak et al., 2006b).

Above the clay, there is a glacial series composed of alternating grey and brown tills; however, the lower part of the glacial series is always made of grey till, while the top of the series is always made of brown till. The boundaries between the tills are vague. There are no clear boundaries either vertically or horizontally (there are cases when brown tills turn on both sides into grey tills). The thickness of glacial sediments is about 6.6–7.5 m. Within the tills, there are sandy layers about 5–10 cm thick. Locally, the top of the brown till is covered by a gravel series (Jarosławiec II).

The glacial sediments are covered by fine-grained aeolian sands. The thickness of these sands ranges from 0.4 to 1.6 m.

Slightly different is the structure of the upper part of the cliff in Jarosławiec I. Here, between the top of the brown till and the base of aeolian sands, there is a series of reservoir sediments. These are rhythmically stratified silty-clayey sediments. These sediments are heavily disturbed (Olszak et al., 2006a). The geological structure of the cliffs in Jarosławiec II and Wicie E is presented in Fig. 2.

Niechorze–Rewal–Trzęsacz

Within the cliffs in Niechorze, Rewal and Trzęsacz, a total of four profiles were examined. The first two are located in Niechorze (Niechorze II – 369.4th km of the sea shore, Niechorze III – 368.8 km). The remaining two profiles are located in Rewal (370.2 km) and Trzęsacz (373.15 km).

The geological structure of the cliffs in this section of the coast is very similar to the structure of the cliffs in Jarosławiec II and Wicie E. This concerns especially the cliffs in Niechorze and Trzęsacz (Olszak, Seul 2004, 2005).

In the Niechorze III profile, at the sea level, dark grey glacial till is exposed. The top of this till gently declines westwards. On the top of the till, there are fluvioglacial sediments. The base of this series is formed by coarse-grain sands turning into fine-grain sands towards the top. Above the fluvioglacial sedi-

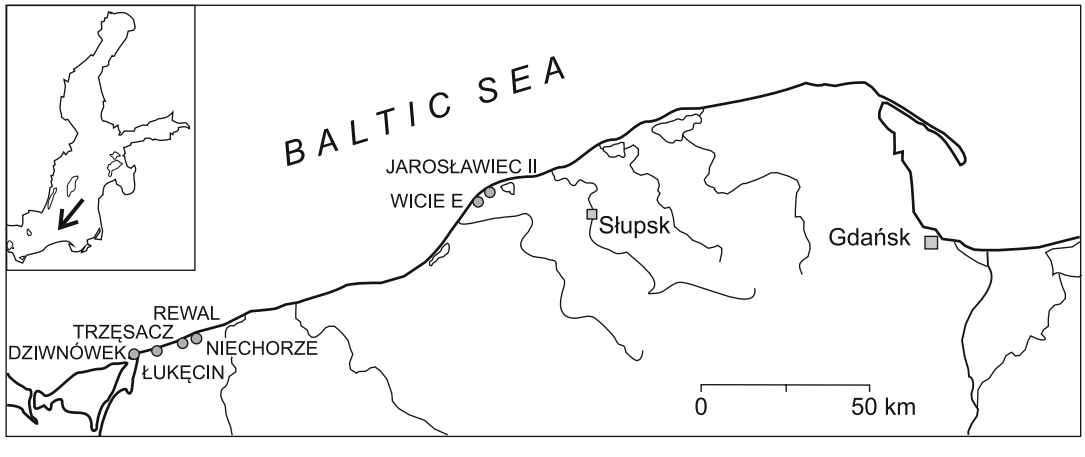

Fig. 1. Location of examined cliff sections

1 pav. Tirtų skardžių geografinė padėtis

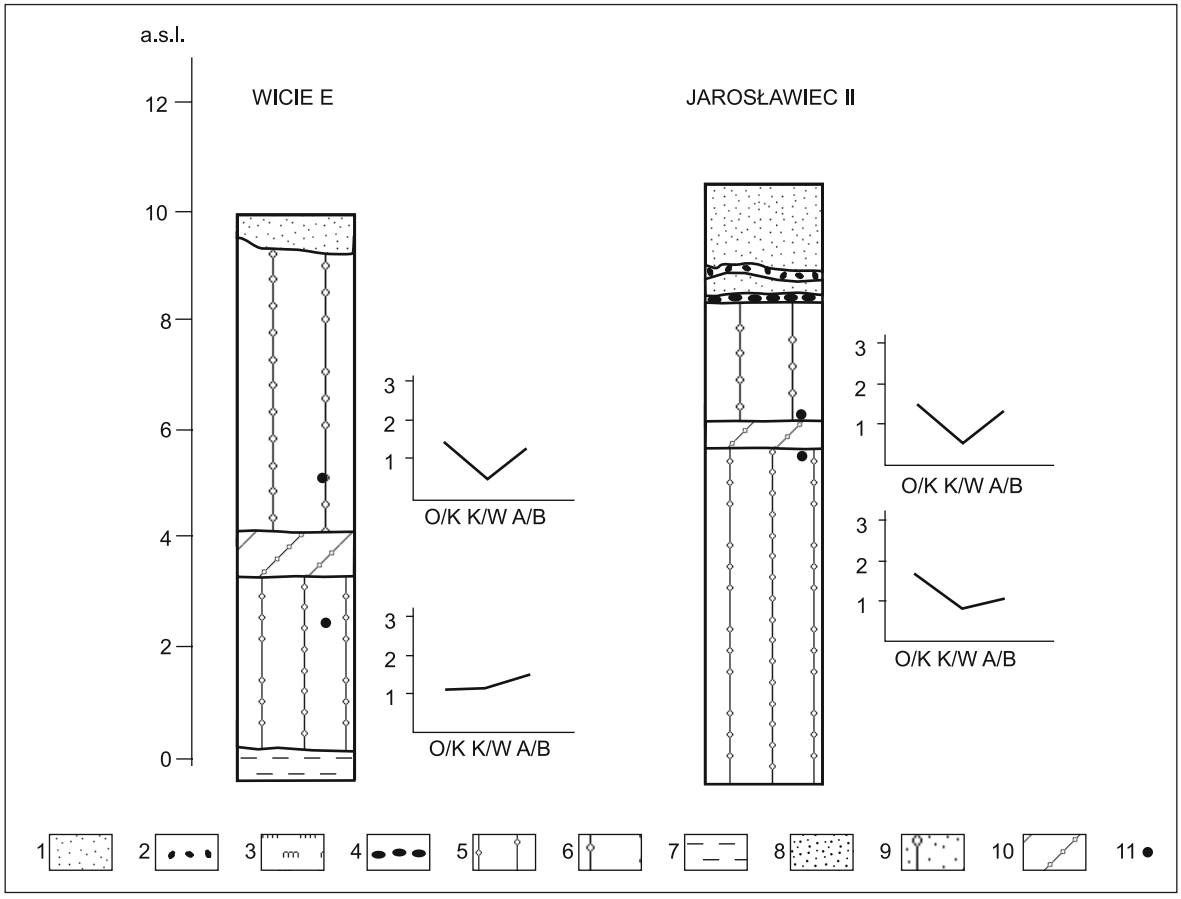

Fig. 2. Geological structure and age of sediments of cliffs in Jarosławiec II – Wicie E section

1 – fine-grained sand, *2* – gravel, *3* – silt, *4* – pavement, *5* – grey till, *6* – brown till, *7* – clay, *8* – coarse-grained sand, *9* – sandy till, *10* – brownish-grey till, *11* – sampling sites; O / K – ratio of sedimentary rocks to crystalline rocks and quartz originating from their decomposition; K / W – ratio of crystalline rocks to limestones; A / B – ratio of rocks not resistant to weathering to rocks resistant to weathering

2 pav. Skardžių Jaroslavecas II – Vicije E geologinis pjūvis ir uolienų amžius

1 – smulkus smėlis, *2* – žvyras, *3* – aleuritas, *4* – cokolis, *5* – pilka morena, *6* – ruda morena, *7* – molis, *8* – rupus smėlis, *9* – smėlinga morena, *10* – rudai-pilka morena, *11* – pavyzdžiai; OK – nuosėdinių uolienų santykis su kristalinėmis uolienomis ar kvarco grūdeliais; K / W – kristalinių uolienų santykis su klintimis

ments, there is another level of grey till. In its base part, there are numerous interbeddings of fine-grain sands. This till is covered by a series of fine-grain sands. Above the sands, there lies brown-grey boulder-rich clay. This clay in the base has a grey-brown colour which changes upwards into brown-grey without a clear borderline. Above the clay, there is a series of silty sands. These sands turn upwards into coarse-grain sands with an admixture of gravel. The upper part of the cliff wall is made of brown boulder-rich clay. Towards the top, the clay changes its colour into yellow-brown. In some places, above the clay, there is only recent podzolic soil. In other places, the clay is covered by a thin series of aeolian sands, underlying the soil.

The cliff in the Niechorze II profile is made almost exclusively of boulder-rich clays. In the lower part of the cliff wall, there is grey till changing in the top into brown-grey till without a clear borderline. There are neither sediments separating a particular till series nor a cutting surface or erosion pavement. The thickness of the transition zone is about 0.20–0.30 m. The top of this till series is situated at an altitude of about 3.00 m a. s. l. The upper part of the cliff wall is made of yellow-brown till. In the top, the till has a brown colour. In this part, there are also large pebbles of crystalline and limestone rocks. The cliff crown is made of aeolian sands on which the present podzolic soil developed.

The geological structure of the cliff in Rewal is definitely more diverse. At the base of the cliff, there are light grey laminated fine-grain sands. They have a greenish shade due to the presence of glauconite. These sands are covered by a thin layer of dark-brownish till which in the eastern part of the profile descends below the sea level. This till changes upwards without a clear borderline into brownish-grey till containing a considerable quantity of weathered gravels. In the brownish-grey till, there are also clay and fine-grain sand lenses. The sediments in the lenses are heavily disturbed. The top of this till series declines gently eastwards. It is situated at an altitude of about 7–8 metres a. s. l. In the top of the brownish-grey till, there is a level of erosion pavement, separating this till from the ablation series situated above. The ablation series is made of sandy brown-yellow till and decalcified coarse-grained sands covering it, which contain a significant admixture of gravels. The

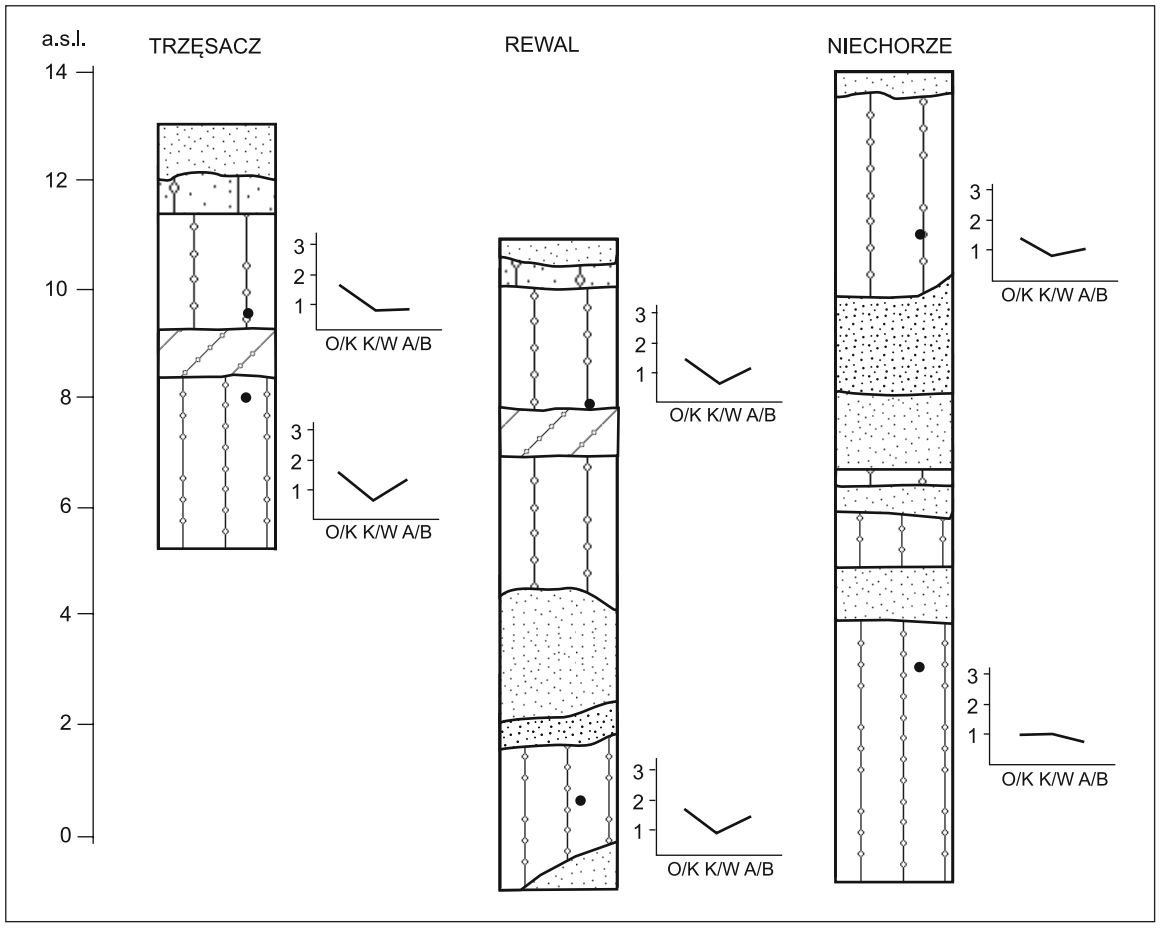

Fig. 3. Geological structure and age of sediments of cliffs in section Niechorze, Rewal and Trzęsacz

3 pav. Niečorės, Revalio ir Tresačio skardžių pjūviai ir uolienų amžius

cliff crown is made of aeolian sands in whose base there is a discontinuous level of older soil (Allerød?).

Within the cliff in Trzęsacz, the research covered only the upper part of the wall. The lowest exposed sediment is grey sandy till. In this till, there are isolated quite large pebbles. The top of the till is situated horizontally at an altitude of 8.60 m a. s. l. This till was exposed to a depth of 7 m (counting from the level of the cliff crown). Unfortunately, its base could not be uncovered.

Directly on the grey till there lies brown-grey till. Its thickness is 1.30 to 1.40 m. Between the grey and the brown-grey till there is no clear borderline. There is only a transition zone of several centimetres, within which a clear change in the colour of the till occurs.

The subsequent level is light-brown till. The contact of this till with the brown-grey till situated underneath, like with the one between the grey and brown-grey ones, is unclear. This till contains isolated gravel grains.

The highest till level is here represented by brown till. The top of this till is heavily transformed by soil-forming processes. Like in the previous case, here the borderline between the light brown and brown till is vague. The transition zone between these tills is about 20–30 cm thick.

The crown of the cliff in Trzęsacz is made of fine-grain aeolian sands of light yellow colour. The thickness of the aeolian series is about 0.60 m. The geological structure of the cliffs in the Niechorze–Rewal–Trzęsacz section is presented in Fig. 3.

Łukęcin–Dziwnówek

The geological structure of the cliff in Łukęcin (381.5th km of the Polish seashore) up to an altitude of 4.5–5.0 m a. s. l. is almost identical to the Trzęsacz profile (Olszak, Seul, 2005). The cliff base, up to an altitude of 2.0 m a. s. l., is made of sandy grey boulder-rich clay. The base of the clay lies below the sea level.

Directly on the grey till there lies brown-grey till. The thickness of the till, like in Trzęsacz, is about 1.30 m. This till contains large isolated pebbles. The transition from grey to brown-grey till is gradual. There is no clear lithological borderline. The top of the till is situated horizontally at an altitude of 3.30 m a. s. l.

On the brown-grey till, there lies brown till with a large content of gravel. The border between the two tills is unclear. The top of the brown till in the eastern part of the profile is situated horizontally at an altitude of about 5.0 m

a. s. l. In the western part of the profile it descends to an altitude of 4.0 m a. s. l. This results in considerable differences in the thickness of the till. In the eastern part the thickness is 1.60–1.70 m, whereas in the western part it decreases to about 0.70 m.

The structure of the upper part of the cliff in Łukęcin differs from that of the cliff in Trzęsacz. The brown till is here covered by a series of diagonally stratified fine- and medium-grain sands. These sands are of fluvioglacial origin.

Above the fluvioglacial sediments, there is light-brown flow till. This till forms a wedge eastwards. Its maximum thickness in the western part of the profile is about 1.5 m. The top of the till is situated horizontally at an altitude of 6.3 m a. s. l.

The light brown till is covered by a series of fine-grain ice-dammed sands of a light grey colour. These sands are horizontally stratified. Their top is situated horizontally at an altitude of 6.2 m a. s. l. In the eastern part of the profile they occur directly on fluvioglacial sediments.

The crown of the cliff in Łukęcin, like in Trzęsacz, is made of fine-grain light yellow aeolian sands covered by podzolic soil.

The structure of the cliff in Dziwnówek (384.9th km) is similar to the structure of the cliffs in the previous profiles. The differences occur mainly in the thickness of particular layers.

The base of the cliff wall is made of grey boulder-rich clay. In the top part, the clay contains a considerable admixture of a sandy fraction. The base of the clay is situated below sea level. Within the top part of the clay there is a xenolith of sand-silt sediments.

At an altitude of about 2 m a. s. l., the grey till changes smoothly into brown-grey till containing isolated boulders and a considerable admixture of gravel fraction. The thickness of this till is about 1.8–1.9 m.

The brown-grey till is covered by a layer of brown till about 1.80 m thick. In the base and central part, it contains gravel material, while in the top, the proportion of the sandy fraction clearly increases.

The upper part of the wall of the cliff in Dziwnówek is made of fine-grain laminated aeolian sands. Their thickness is about 1.8 m. The geological structure of the cliffs in Łukęcin and Dziwnówek is presented in Fig. 4.

AGE OF SEDIMENTS

Thermoluminescence (TL) dating was performed for all sediments composing the examined cliffs. What can raise doubts is the usability of glacial tills for such a type of dating. Many years' experience with dating such a type of sediments indicates that it is possible to date them. The problem is obviously the zeroing of tills. The results of laboratory analyses indicate, however, that the dating factors in this case are the pressure and friction exerted by the advancing continental glacier (Olszak, 1999).

Results of the dating of sediments of the cliff in Jarosławiec indicate that there is a clear age diversity of sediments there (Fig. 2). The grey till exposed in the base of the cliff wall was dated to 58.6 ± 8.8 thousand and 60.0 ± 9.0 thousand years BP. For the top part of the till series, made of brown till, the following dates were obtained: 38.6 ± 5.8 thousand and 33.2 ± 5.0 thousand years BP. These dates suggest that this is till from the Świecie Stadial. The dates for the brown till do not fit this interpretation. They are clearly too "young". From the point of view of thermoluminiscence dating, it should be assumed that both tills occurring here (grey and brown) are nonetheless of the same age. The "rejuvenation" of the dates of the brown till is rather a result of postsedimentation processes, e. g., weathering.

In Jarosławiec II (Fig. 2), the dating covered also the fluvioglacial and aeolian sands covering the till. For fluvioglacial sediments, two TL dates were obtained: 17.0 ± 2.6 and 16.2 ± 2.4 thousand years BP. For aeolian sands and silt-clay sediments occurring below them, six TL dates ranging from 11.0 to 11.5 thousand years BP were obtained.

An almost identical age sequence was obtained for sediments building the cliff in Wicie. For the grey till building the lower part of the cliff wall and for the lower part of the brown (brown-grey) till, the obtained TL dates ranged from 60.8 ± 9.1 to 54.4 ± 8.0 thousand years BP (Fig. 2). There are altogether seven dates. Such a narrow time range and a relatively big number of dates allow these tills to be attributed to the Świecie Stadial of the Wisła Glaciation. The TL age of the upper part of the brown till situated higher ranges from 33.9 ± 5.1 to 37.6 ± 5.6 thousand years BP. Thus, this is a situation identical to that in Jarosławiec (Fig. 2).

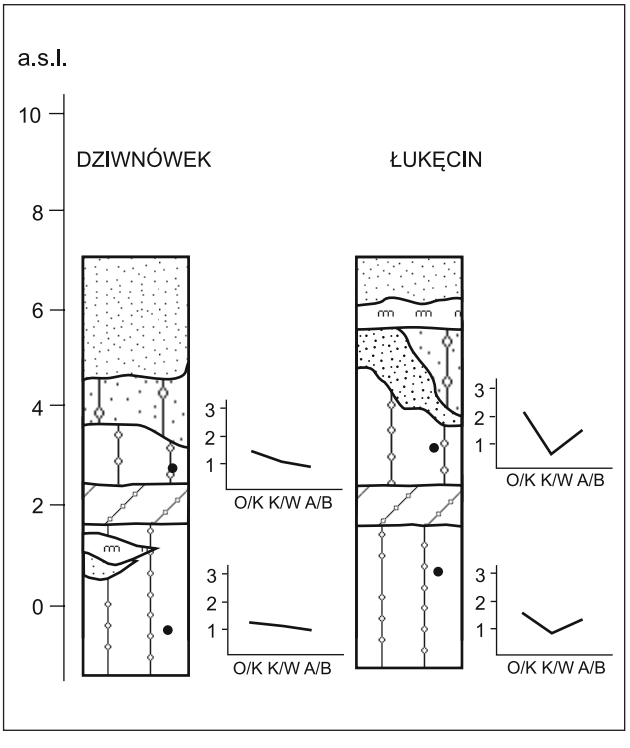

Fig. 4. Geological structure and age of sediments of cliffs in Łukęcin ir Dziwnówek

4 pav. Lukecino ir Dzivnovieko skardžių pjūviai ir uolienų amžius

In the case of the cliff in Niechorze, especially valuable for TL dating proved to be the Niechorze III profile (Fig. 3). While, as already mentioned, the Niechorze II profile contains only tills, in this profile there are sediments of various origin (glacial and fluvioglacial). This offers a possibility to verify the obtained TL dates.

In both profiles, the lower part of the cliff wall is made of grey till. A total of five TL dates were obtained for this till. Four of them range from 57.5 ± 8.6 to 59.9 ± 9.0 thousand years BP. Only the fifth date in the Niechorze III profile does not fall in the range (50.1 ± 7.5 years BP). This clear lowering of TL age could be related to the fact that in this till level there are small interbeddings of coal.

For the upper level of the grey till in the Niechorze III profile, only one TL date was obtained: 59.1 ± 8.9 thousand years BP. Thus, this date is consistent with the TL dates presented above for the lower level of grey till. Additionally, the dates for the grey till are confirmed by the TL date (58.8 ± 8.8 thousand years BP) obtained for fine-grain fluvioglacial sands which separate the till levels.

The brown-grey till situated above was dated twice. In both profiles, an identical TL date was obtained for this till: 55.8 ± 8.8 thousand years BP. The fluvioglacial fine-grain sands situated below and above the till were dated three times in the Niechorze III profile. The obtained TL dates range from 52.6 ± 7.9 to 57.1 ± 8.6 thousand years BP. Thus, they should be assumed to be of the same age as the grey and brown-grey till.

For the brown till situated highest, the TL dates varied from 36.4 ± 5.5 to 37.8 ± 5.7 thousand years BP. This is an identical situation as in the case of the cliff in Jarosławiec II.

The oldest sediments exposed in the base of the cliff wall in the Rewal profile are fine-grain sands containing glauconite (Fig. 3). For these sediments, only one TL age was obtained (111.3 ± 16.7 thousand years BP). Due to the fact that this is only one date and that glauconite is present in these sands, this date should be treated with considerable caution.

The dates obtained for the complex of grey and brownish-grey tills situated above range from 67.5 ± 9.2 to 60.8 ± 9.1 thousand years BP. A slightly younger date, 57.7 ± 8.5 thousand years BP, was obtained for the clays forming the lens. This slightly lower date results mainly from a considerable organic material content in clays.

In contrast to the previous sites, the dates obtained for the yellow-brown till occurring in the upper part of the cliff wall are only slightly lower than the dates obtained for the grey till: 59.5 ± 8.9 and 52.3 ± 8.0 thousand years BP. These dates are indirectly confirmed by the date of the base part of the ablation sands covering the till: 54.5 ± 7.1 thousand years BP. The dates obtained for the top part of these sands are already much younger: 39.7 ± 6.2, 26.2 ± 3.9 and 20.8 ± 3.0 thousand years BP. This rejuvenation of the top part of the ablation sands is related to the partial, secondary "zeroing" of the material. The record of this partial "zeroing" is clearly visible in the shape of the TL curves. This probably occurred as a result of a partial eolisation of the top of the ablation sands.

In the Trzęsacz profile, only tills were dated. For the lower grey till, only one date was obtained: 59.0 ± 8.9 thousand years BP. This date confirms the age of the grey till obtained in the remaining profiles. For the light brown till occurring above, two TL dates were obtained: 55.3 ± 8.3 and 55.4 ± 8.3 thousand years BP. They are almost identical to the dates obtained for this type of till in the Rewal profile. Noteworthy is the third date, 37.1 ± 5.6 thousand years BP, obtained for the top, heavily sandy, part of the till. This date coincides with the dates in other profiles obtained also for a sandy top of brown till (Fig. 3).

The oldest sediment exposed in the cliffs in the Łukęcin–Dziwnówek section is the grey boulder-rich clay (Fig. 4). It builds, like in other profiles, the base of the cliff. In total, three samples from this till were dated. The obtained TL dates range from 57.9 ± 8.7 to 58.7 ± 8.8 thousand years BP. These dates reveal a high concordance. Additionally, one sample of silt sediments from the xenolith in the Dziwnówek profile was dated. The date (59.0 ± 8.9 thousand years BP) is concordant with the dates obtained for the grey till.

From the brown-grey till overlying the grey till, four samples were dated. The TL ages ranged from 52.3 ± 7.8 to 58.0 ± 8.7 thousand years BP. As one can see, they are very close to TL dates obtained for the underlying till.

Similar TL dates were obtained from the brown till situated higher in the Łukęcin profile. The TL age of this till is 56.3 ± 8.4 to 56.7 ± 8.5 thousand years BP as defined for two samples.

Considerably younger TL dates were obtained for the highest level of the brown till in the Dziwnówek profile: 36.7 ± 5.5 to 36.8 ± 5.5 thousand years BP. These dates correspond to the dates obtained for the top sandy parts of brown tills.

The youngest TL age obtained for sediments composing the examined cliffs is 13.1 ± 2.0 thousand years BP. They were obtained from the light brown till from the Łukęcin profile. This date, due to the flow character of the sediment, is unreliable. Like in the case of the ablation sands in the Rewal profile, a secondary "zeroing" of the material took place here. In such a case, this date determines the time when the flow occurred.

PETROGRAPHIC COMPOSITION

Petrographic composition was defined for samples collected from postglacial tills. The petrographic composition of the gravel fraction found in them was determined for the fraction of 16–8 mm, 8–4 mm, and 4–2 mm. The range 4–2 mm was treated as complementary, as not always there was a statistical representation of gravels in the range 8–4 mm. When determining the petrographic composition, crumbs of crystalline rocks, quartz, Palaeozoic limestone and dolo-

mites, Palaeozoic sandstone and slates were distinguished. A group of local rocks was also distinguished; it contains Mesozoic limestone, sandstone and siltstone, flint stones, etc. (e. g., crumbs of brown coal, pyrite, and ferruginous concretions). The petrographic examination was performed for the same samples that were subject to TL dating.

The obtained results enabled calculation of petrographic coefficients:

- O / K – ratio of sedimentary rocks (Palaeozoic limestones, Palaeozoic dolomites, Palaeozoic slates and sandstones) to crystalline rocks and quartz originating from their decomposition;
- K / W – the ratio of crystalline rocks to limestones (Palaeozoic limestones and Palaeozoic dolomites);
- A / B – the ratio of rocks not resistant to weathering (Palaeozoic limestones, Palaeozoic dolomites and Palaeozoic slates) to rocks resistant to weathering (crystalline together with quartz originating from their decomposition and sandstones).

In the examined cliff sections, at the sea level, grey morainic till of various thickness is exposed. This till complex is characterised by a content of clay fraction of a dozen percent. The grey tills are overlain by brown tills only locally separated by sandy material.

In the cliffs of the central part of the Polish Coast (Jarosławiec II and Wicie E sites), in grey tills, limestone rocks (42%) prevail over crystalline rocks (32%). In Wicie, in grey till the proportion of crystalline rocks ranges from 34 to 37%, and limestones constitute from 34 to 46%. The proportion of sandstones and dolomites in the grey tills of Central Pomerania is about 10–12%, and in the local material from 5 to 7%. In the brown tills, apart from their decalcified top part, the situation is similar. Noteworthy is the fact that the brown till in Jarosławiec is decalcified to a depth of 4 m

Table. **Petrographic indices O / K, K / W, A / B for the 8–4 mm fraction of cliff sediments on the Western and Central Polish Baltic Coast**
Lentelė. **4–8 mm frakcijos pavyzdžių, paimtų iš Baltijos jūros Lenkijos vakarinės ir vidurinės pakrantės, petrografiniai rodikliai O / K, K / W, A / B**

	Depth, m below surface			
Dziwnówek – 384.9 km				
Indices (fractions in mm) 8–4	Brown till 3–4 m		Grey till 5–6 m	
O / K	1.3	1.9	1.1	1.4
K / W	1.0	0.7	1.0	0.8
A / B	0.8	1.1	0.9	1.1
Łukęcin – 381.5 km				
Indices (fractions in mm) 8–4	Brown till 2–4 m		Grey till 6–7 m	
O / K	2.0	1.9	1.4	1.4
K / W	0.6	0.7	0.8	0.9
A / B	1.4	1.2	1.1	0.9
Trzęsacz – 373.15 km				
Indices (fractions in mm) 8–4	Brown till 2–4 m		Grey till 4–6 m	
O / K	1.4	1.9	1.7	0.9
K / W	0.9	0.7	0.7	1.5
A / B	0.9	1.1	1.3	0.6
Rewal – 370.2 km				
Indices (fractions in mm) 8–4	Brown till 2–4 m		Grey till 5–10 m	
O / K	1.5	1.6	1.5	1.3
K / W	0.8	0.7	0.8	0.9
A / B	1.2	1.2	1.2	0.6
Niechorze – 368.8 km				
Indices (fractions in mm) 8–4	Brown till 2–4 m		Grey till 7–10 m	
O / K	1.3	1.4	1.0	1.4
K / W	0.9	0.8	1.0	0.8
A / B	1.0	1.4	0.8	1.0
Wicie E – 261.5 km				
Indices (fractions in mm) 8–4	Brown till 4–6 m		Grey till 7–8 m	
O / K	1.4	1.1	1.1	1.4
K / W	0.6	0.9	1.1	0.9
A / B	1.3	1.1	1.7	0.9
Jarosławiec II – 254.5 km				
Indices (fractions in mm) 8–4	Brown till 4–5 m		Grey till 5–5.5 m	
O / K	1.7		1.6	
K / W	0.7		0.8	
A / B	1.3		1.0	

below the ground level, and in the brown till occurring under it limestone prevails over crystalline components. In the profile in Wicie, brown tills have a similar content of limestone and sandstone as the grey tills located below.

Grey tills occurring in cliffs of the Western Polish Baltic Coast are very petrographically similar to the grey tills of cliffs of the central part of the Polish Baltic Coast. In them, limestone slightly prevails (about 40%) over crumbs of crystalline rocks (32–35%). Sandstones and dolomites constitute about 10% and local material below 8%. Characteristic is the occurrence of pre-Quaternary xenoliths in the grey tills (e. g., Turon clays in Rewal). These tills contain also crumbs of Miocene brown coal.

The complex of grey-brown and brown morainic tills overlying the grey tills contains slightly less of clay fraction. In some places, the grey or brown-grey tills are separated by sandy material. However, in many sites there is no clear borderline between these tills. Brown tills contain isolated lenses of sandy material. In the complex of brown tills, there is also a small domination of limestone over crystalline rocks. Sandstones and dolomites constitute about 9% and local material slightly over 10%.

In all the examined profiles, the grey and brown tills are similar from the pertrographic viewpoint. The investigation revealed the occurrence of carbon detritus in grey tills, which can cause their colouring, as well as of calcite and dolomite visible in diffractometric examinations. These examinations revealed a lack of carbon detritus and calcite in brown tills. What should be emphasised is the occurrence of glauconite and a small prevalence of Palaeozoic limestones in the grey tills in comparison with the brown ones. Another noteworthy fact is the level of the brown and brown-yellow tills occurring in patches in some sites of the Rewal Plateau cliffs. These are tills formed in the melting phase (melt-out tills). They are more sandy than the remaining ones. Probably due to weathering processes they were considerably decalcified. The petrographic indices of grey and brown tills are listed in Table.

CONCLUSIONS

The geological structure of the examined cliff sections of the Polish coast of the Baltic reveals a high similarity. In all the profiles, the base part of the cliff wall is made of grey moraine till. This till changes upwards without a clear borderline into grey-brown till, then into brown-grey and brown till. The latter builds the surface of the ground behind the cliffs. Only locally is it covered by Holocene aeolian sands.

Thermoluminescence dating has shown the equal age of all the tills occurring in the examined profiles. The obtained TL dates range from 54 400 to 50 800 years BP. In all the profiles, there is also a clear "rejuvenation" of the top part of the brown till (33 200–38 600 years BP). This rejuvenation is related to the weathering of the top part of this till. The dating results indicate that the till comes from the Świecie Stadial of the Wisła (Vistula) Glaciation.

There is no clear differentiation, in petrographic terms, of boulder-rich clays of the western and central parts of the Polish Baltic Coast with respect to both brown and grey tills, which indicates a similar source of origin of the material found in these tills and the formation of these sediments in one glacial cycle. The diversity of the colour of the glacial sediments, varying from grey through grey-brown to brown, results only from the content of Tertiary material (brown coal) in their base part.

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VIDURINĖS IR VAKARINĖS LENKIJOS PAMARIO SKARDŽIŲ LEDYNINIŲ NUOGULŲ LITOLOGIJA IR STRATIGRAFIJA

S a n t r a u k a

Tirti Baltijos jūros pakrantės pjūviai tiek geologine sandara, tiek ir uolienų amžiumi yra labai panašūs. Ryškesnė kaita tarp vėlyvojo pleistoceno uolienų nustatyta tik pačioje viršutinėje pjūvio dalyje, ir tai susiję su baseininių nuosėdų susikaupimu kai kuriose vietose.

Ledyninių nuogulų, atsidengiančių pajūrio skardžiuose, termoliuminescencinis (TL) amžius rodo jų klostymąsi paskutiniojo apledėjimo metu – Sveci stadijoje (54 400–50 800 BP). Viršutinė pjūvio dalis yra atjaunėjusi – uolienų amžius – 33 200–38 600 BP.

Ledyninių nuogulų, kurios atsidengia pajūrio skardžiuose, TL amžius yra gana vienodas ir patvirtina petrografinius uolienų panašumus. Taigi, nepaisant spalvinių skirtumų, ledyninės nuogulos priklauso vienai stadijai.

Raktažodžiai: ledyninės nuogulos, litologija, termoliuminescencinis amžius (TL), Lenkijos Baltijos pakrantė