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Petrographic composition and directional properties of tills on the NW surroundings of the Gdańsk Bay, Northern Poland

Piotr Paweł Woźniak,

Piotr Czubla,

Grażyna Wysiecka,

Małgorzata Drapella

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In this paper, the authors focus on some selected lithological properties of tills: petrographic composition of the 5–10 mm fraction, petrographic composition of the coarse fraction (>20 mm, analysed by the indicator erratics method) and the long axis orientation of clasts. As the study area the authors chose a territory located in Northern Poland on the NW surroundings of the Gdańsk Bay – between Puck and Lake Żarnowieckie. It was found that during the Last Glaciation the study region was fed mainly from the territory of Sweden, middle and south-eastern Sweden in particular. There existed, in parallel with the dominant (in the study region) NNW ice-sheet advance direction, also another, local ice-sheet advance route manifested in the east, which deposited a till bed in the neighbourhood of Puck.

Key words: till, petrographic analysis, till fabric, weathering, Vistulian, Pomerania, Poland

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Piotr Paweł Woźniak, **Grażyna Wysiecka**, **Małgorzata Drapella**. Department of Geomorphology and Quaternary Geology, University of Gdańsk, Dmowskiego 16a, 80-264 Gdańsk, Poland. E-mail: geopw@ug.edu.pl; geogw@ug.edu.pl; gosia.drapella@wp.pl; **Piotr Czubla**. Laboratory of Geology, University of Łódź, Narutowicza 88, 90-139 Łódź, Poland. E-mail: piczubla@geo.uni.lodz.pl

INTRODUCTION

One of the primary objectives of investigating the Pleistocene deposits is to determine the stratigraphic position of sediments. Analyses of the petrographic composition of tills seem to be the most common research technique exploited in these studies. Such analyses allow to reveal the region of origin of the erratic material (Czubla, 2001), therefore they indicate also the paths of the ice-sheet streams carrying base-detached debris (Kjaer et al., 2003; Lagerlund et al., 1995; Smed, 1993).

The authors made an attempt to analyse the diversity of the petrographic composition of tills found in the north-eastern part of the Żarnowiec Upland and in the northern edge of the Kashubian Coast. Field investigations were carried out in over 20 different sites, and the results obtained in 15 selected ones are presented and discussed in this paper. Several till samples were taken in each site for the further petrographic examination of the 5–10 mm fraction (following the methodology recommended by the Polish Geological Institute; see, for example, Kenig, 1998). In parallel, the content of carbonates was also checked (Scheibler technique). Besides, the long-axis orientation of clasts in till was analysed (18 sites): in each place, at least 30 clasts were measured (in case of a high diversity 50 pieces) 2–10 cm in length and the elongation ratio of at least 1 : 1.5. Moreover, 12 samples (in total) of the >20 mm fraction were taken from five sites (Fig. 1) for further analysis by the indicator erratics method (Czubla, 2001). There was at least 700 specimens in each of the mentioned >20 mm fraction samples, and quite often even over 1000 specimens. Next, a method proposed originally by Lüttig (1958) and later modified by Smed (1993), Vinx et al. (1997) and Czubla (2001) was applied to find the so-called theoretical home centre of the boulder association (TGZ, *German, Theoretisches Geschiebezentrum*).

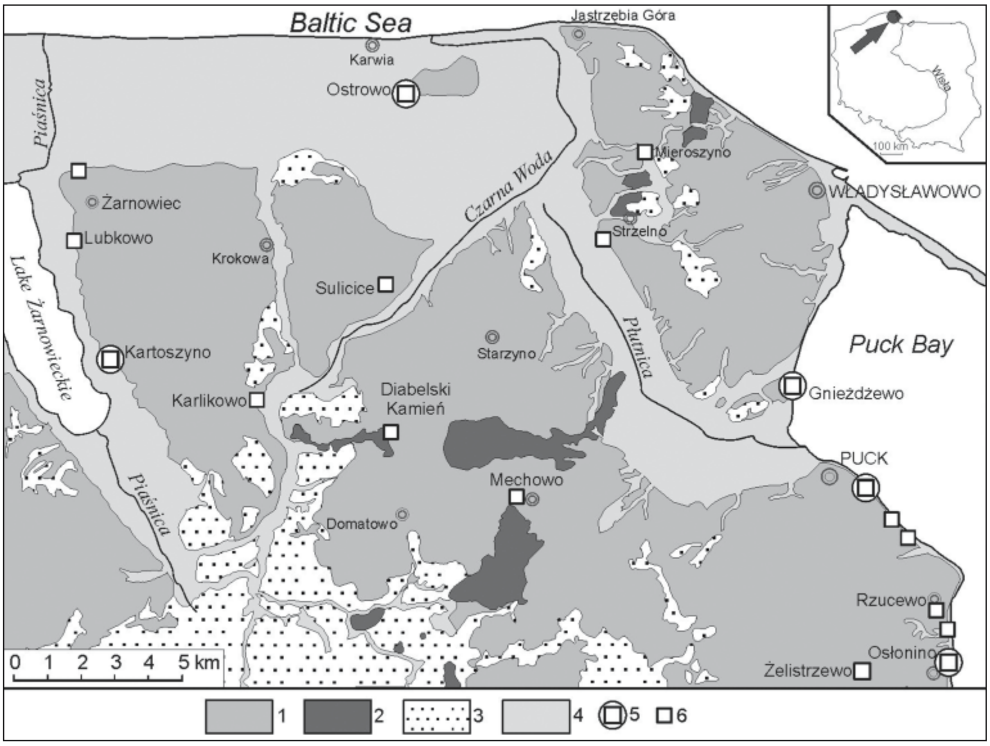

Fig. 1. Simplified geomorphologic sketch of the study territory after Ostaficzuk (1978), Skompski (1989, 2001) with some changes; explanations: *1* – moraine plateau; *2* – end moraines; *3* – outwash plains; *4* – depressions of various origin; *5* – sites with indicator erratics analysis; *6* – other sites discussed in the text

1 pav. Supaprastinta tyrinėto regiono geomorfologinė kartoschema su pakeitimais pagal Ostaficzuk (1978), Skompski (1987)

5–10 MM FRACTION PETROGRAPHY

Petrographic composition analyses of the 5–10 mm fraction in tills in the regions under discussion were carried by many authors (see, for example: Lisicki, 2003; Masłowska et al., 2003; Neumann, Nowacka, 2005; Pikies, Zaleszkiewicz, 2003; Zaleszkiewicz et al. 2000). Their findings, however, are characterized by high differences in the petrographic coefficients of tills, which are assigned to have identical stratigraphic positions (see the list in Prussak, 2000 and a comparison in Neumann, Nowacka, 2005).

Results obtained us confirm the already known common weathering of the youngest tills, which occurs in the study area (Woźniak, 2006). It manifests itself mainly by decalcification of tills, which results in a significant decrease of carbonate rocks in the gravel fraction, or in extreme cases even in their absolute deficiency. An intensive weathering zone spreads usually down to 2–3 m under surface, which, together with the low thickness of youngest tills found in the region, quite often means that this zone extends up to the entire till horizon. The above-mentioned high variation of the petrographic coefficient values found in the literature can be attributed, among other things, to the lack of adequate attention to sediment weathering. The petrograhic contents of the 5–10 mm fraction, examined us, in case of youngest, not weathered tills can be characterized by the following values of the petrographic coefficients: O / K = 1.3–1.7, K / W = 0.7–0.8, A / B = 1–1.3, the carbonate rate being about 9%. In some places, we observed a considerable vertical variation in the petrographical composition of examined tills, which was not an effect of till weathering and which was reproduced in different parts of an outcrop. In such cases, we sought for the origin of the observed phenomenon in changes of the source areas, occurring during a particular ice-sheet advance (compare Figs. 2a and 2b).

INDICATOR ERRATICS AND CLAST ORIENTATION

Based on the results of the indicator erratics method, we found that the study region was mainly fed from the territory of Sweden – middle and south-eastern Sweden mostly. There is a lack of Finnish rocks in the examined samples (except erratics from the Aland Islands). The western location of the source area (Fig. 3) is confirmed also by a small occurrence of dolomites, whose outcrop centre marked on the circle maps (Figs. 2, 5 and 6), appears to be pretty far away towards the east (in West Estonia). One should keep in mind, however, that these rocks (dolomites) can be found also further to the south, among Silurian and Devonian deposits (Smed, 1994). Analysis of the position of the Żarnowiec Upland and the Kashubian Coast against the territory of Sweden and the bottom of the Baltic Sea from where the majority of

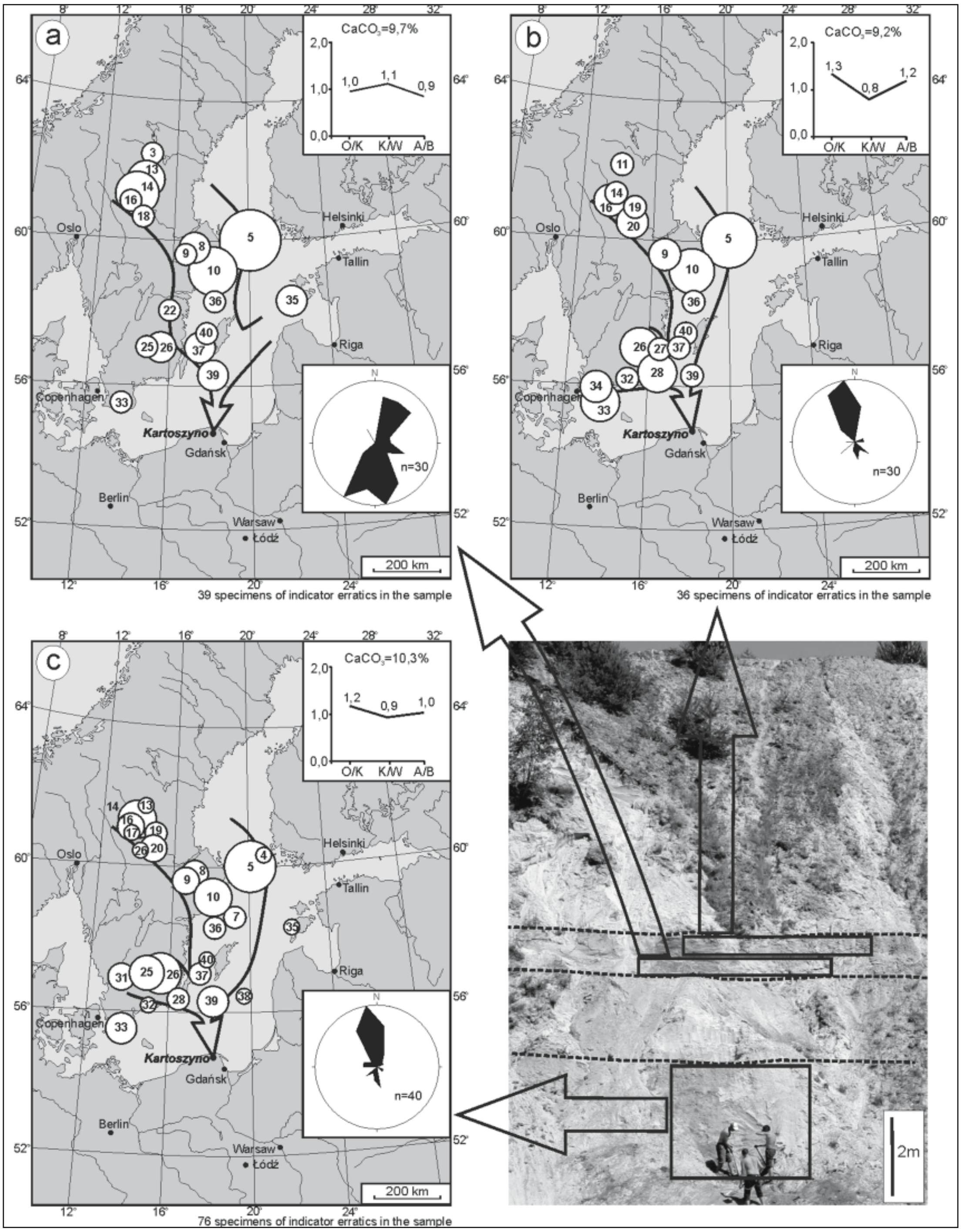

Fig. 2. Site Kartoszyno – results of selected analyses: *a* – in the base part of the upper till, *b* – in the roof part of the upper till, *c* – in the lower till

Explanations: maps present parent areas of indicator erratics, the circle's area corresponds with the percentage of erratics in an analysed stone sample; arrows show the assumable glacial transport path of erratics to the analysed site; the lower overlapped boxes – the long axis orientation of clasts; the upper overlapped box – main petrographic coefficients based on the composition of the 5–10 mm fraction and carbonate content; numbers on the maps: 1 – Ångermanland granite-gneiss, 2 – Revsund and Björna granites, 3 – Rätan granite, 4 – Åland and/or Nystad pyterlite, 5 – Åland granite, Haga granite, Åland rapakivi, Åland aplite granite, Åland granite porphyry, 6 – red Baltic quartz porphyry, 7 – brown Baltic quartz porphyry, 8 – Uppsala, Vänge and Arnö granites, 9 – Sala granite, 10 – Stockholm granite, 11 – Glöte porphyry, 12 – Särna porphyry and tinguaite, 13 – Grönklitt and grey Dalarna porphyries, Åsby diabase, 14 – Åsen, Bredvad and Kåtlla porphyries, Garberg granite, 15 – Blyberg porphyry, Klittberg ignimbrite and porphyry, Rännås, Blyberg, Orrlok and other Dalarna ignimbrites and porphyries, 16 – Öje diabase and melaphyre, Dala sandstone, Digerberg sandstone and conglomerate, 17 – Heden porphyry, 18 – Venjan porphyry, 19 – Järna granite, 20 – Siljan granite, Siljan rapakivi, Märsta porphyry, 21 – brown and red Graversfors granites, Östgöta granites, 22 – Kinda granite, 23 – Flivik and Virbo granites, Påskallavik and Sjögelö porphyries, 24 – Mariannelund granite, Emarp, Nymåla, Fagerhult and Lönneberga porphyries, 25 – grey and red Växjö granites, 26 – red Småland granites, Vislanda granite, Småland porphyries, 27 – Vånevik granite, 28 – Kalmarsund and Tessini sandstones, 29 – Filipstad granite, 30 – Kristinehamn granite, Filipstad granite (southern variant), 31 – granat amphibolithe, 32 – Karlshamn and Spinkamåla (Halen) granites, 33 – kullaite, Scolithos and Hardeberga sandstones, 34 – Skåne basalt, 35 – dolomites, 36 – red Cambrian sandstones, 37 – red Ordovician limestones, 38 – Old-Red sandstone, 39 – Beyrichia limestone, 40 – Palaeoporella limestone

2 pav. Selektyvios analizės Kartoszyno vietovėje rezultatai: *a* – viršutinės morenos pagrindas, *b* – viršutinės morenos viršus, *c* – apatinė morena the recognized indicator rocks come, enables to determine the direction of the ice-sheet advance to be in accordance with the measured clast long axis orientation (sector between NNW and NW, Fig. 4). In some sites, we found deviations from the mentioned ice-sheet advance direction, the biggest ones being discovered in Ostrowo; in each case, however, they oscillated within the north-western sector. This phenomenon can be explained by adjustments of the ice movement directions, within the base of the ice-sheet, to the shape of a local relief in the advance area (Benn, Evans, 1998).

Location changeability of the source areas can be tracked, for example, in tills from Osłonino (Fig. 5). It is characterized by a definite TGZ shift of the roof part of the upper till towards the east as compared to the base part and the lower till (Fig. 3). The mentioned shift manifests itself in particular in a lower proportion (in the collected samples) of rocks from Dalarna, Uppland and the Stockholm region in favour of rocks from the Aland Islands. This fact cannot be explained by the weathering phenomena alone (there is as much as 48.4% of carbonate rocks in the base part of the upper till, and this rate decreases to just 11.7% in the roof part), because in the weathered deposits the volcanic rocks from Dalarna are typically preserved remarkably well, while in the discussed case, the actual content of this particular

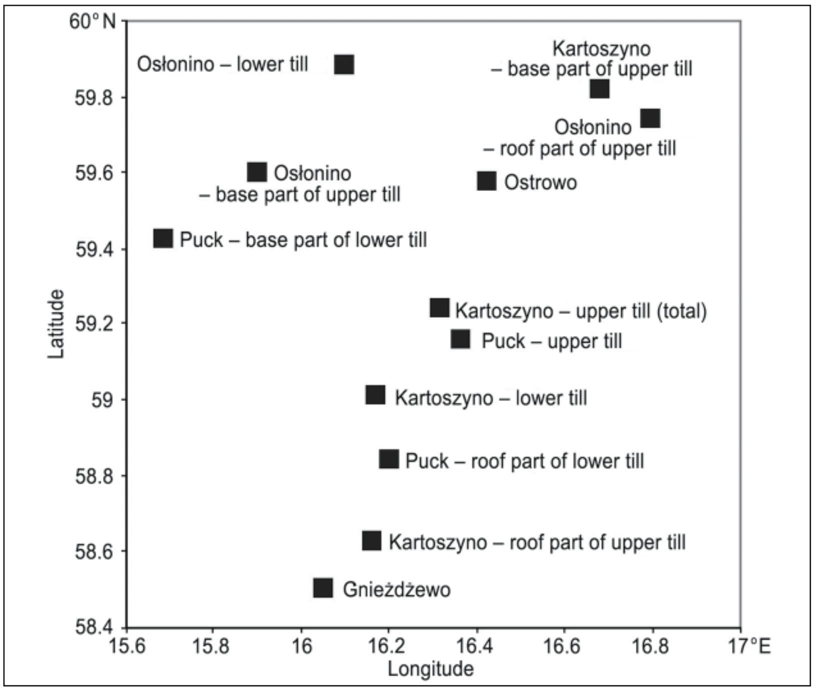

Fig. 3. TGZ diagram; method proposed originally by Lüttig (1958) and later modified by Smed (1993), Vinx et al. (1997) and Czubla (2001) was applied

3 pav. TGZ diagrama. Metodą pasiūlė Lütting (1958), vėliau modifikavo Smed (1993), Vinx ir kt. (1997) ir panaudojo Czubla (2001)

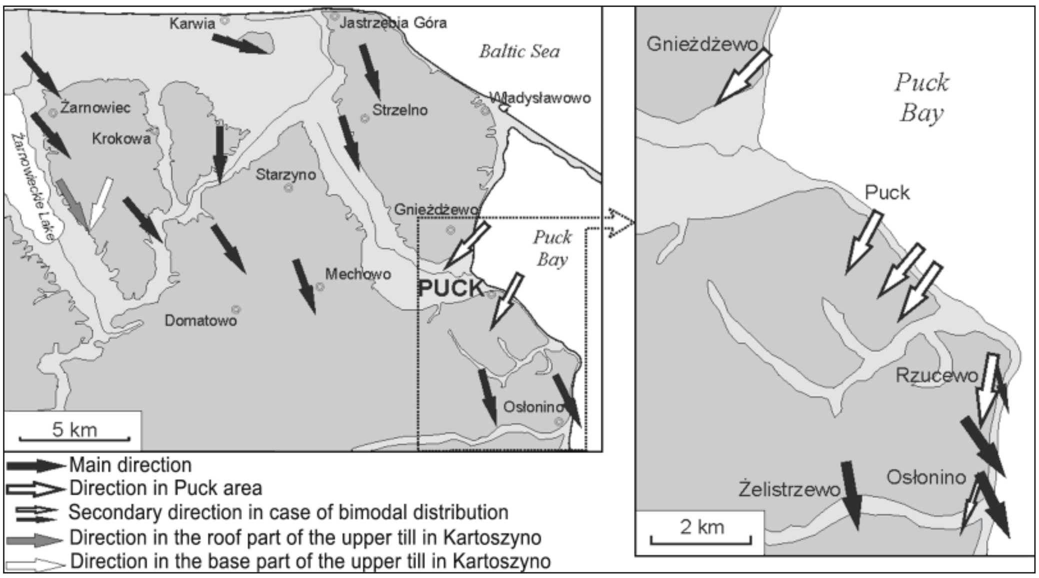

Fig. 4. Prevailing long axis orientation of the clasts in selected sites

4 pav. Klastų ilgųjų ašių vyraujančios orientacijos kai kuriuose pjūviuose

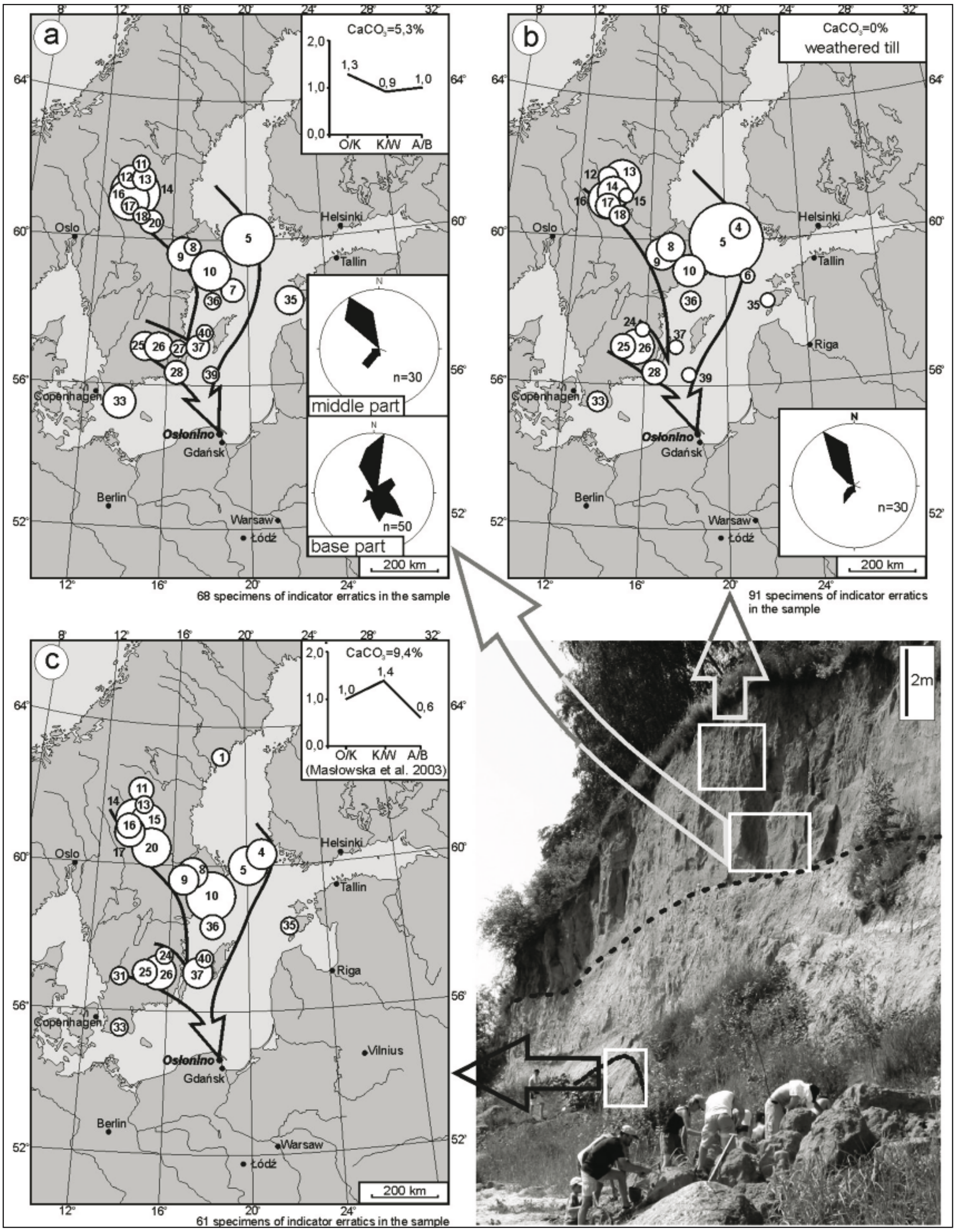

Fig. 5. Site Osłonino – results of selected analyses: *a* – in the base part of the upper till, *b* – in the weathered part of the upper till, *c* – in the lower till; for explanations, see Fig. 2

5 pav. Oslonino pjūvio selektyvios analizės rezultatai: *a* – viršutinės morenos pagrindas, *b* – viršutinės morenos išdūlėjusi dalis, *c* – apatinė morena

rock in the roof, partly weathered, part of upper tills was not too high. Both factors, i. e. weathering and shifts to the other source areas, could contribute here to the observed decreased proportion of the biotite-reach Uppland and Stockholm granites. Almost identical orientations of clasts in both parts of the till bed confirm a stable local ice flow direction, but they do not allow to reveal the earlier path of the ice stream (from the source area). Unfortunately, petrographic analyses of the 5–10 mm fraction did not help too much, as here the weathering phenomenon of the roof part of the upper till led to a significant variation of the obtained results. Weathering phenomena unquestionably cannot explain the low proportion of limestone (only 27%) in the lower, not weathered till horizon in Osłonino. This fact can only be attributed to the evident more western location of the source area of the lower till.

UNCHARACTERISTIC DIRECTIONAL PROPERTIES IN THE NEIGHBOURHOOD OF PUCK

In the eastern part of the study region, in cliffs located in Gnieżdżewo and Puck areas, an uncharacteristic (for this district) orientation of clasts was discovered: the dominant direction clearly deviated to the east (Fig. 4). The TGZ coordinates, close to those under discussion, had been already obtained also for two different till beds in Kartoszyno (the lower and the roof part of upper till) (Fig. 3). The stratigraphic position of the upper, not weathered till in Kartoszyno, characterized by vertical petrographic composition changeability (probably due to changes in the source areas occurring during a particular ice-sheet advance, see Fig. 2), has not been unambiguously determined so far. Preliminary thermoluminescence (TL) dating investigations of sand above the considered till provided the value of 26.6 ± 2.9 ka BP (UG 6070, second attempt UG 6069 gave an open result), while the values of 124.8 ± 13.0 ka BP (UG 6067) and 123.1 ± 12.5 ka BP (UG 6068) were obtained for sands located below the till. These initial TL dating outcomes seem to suggest that the

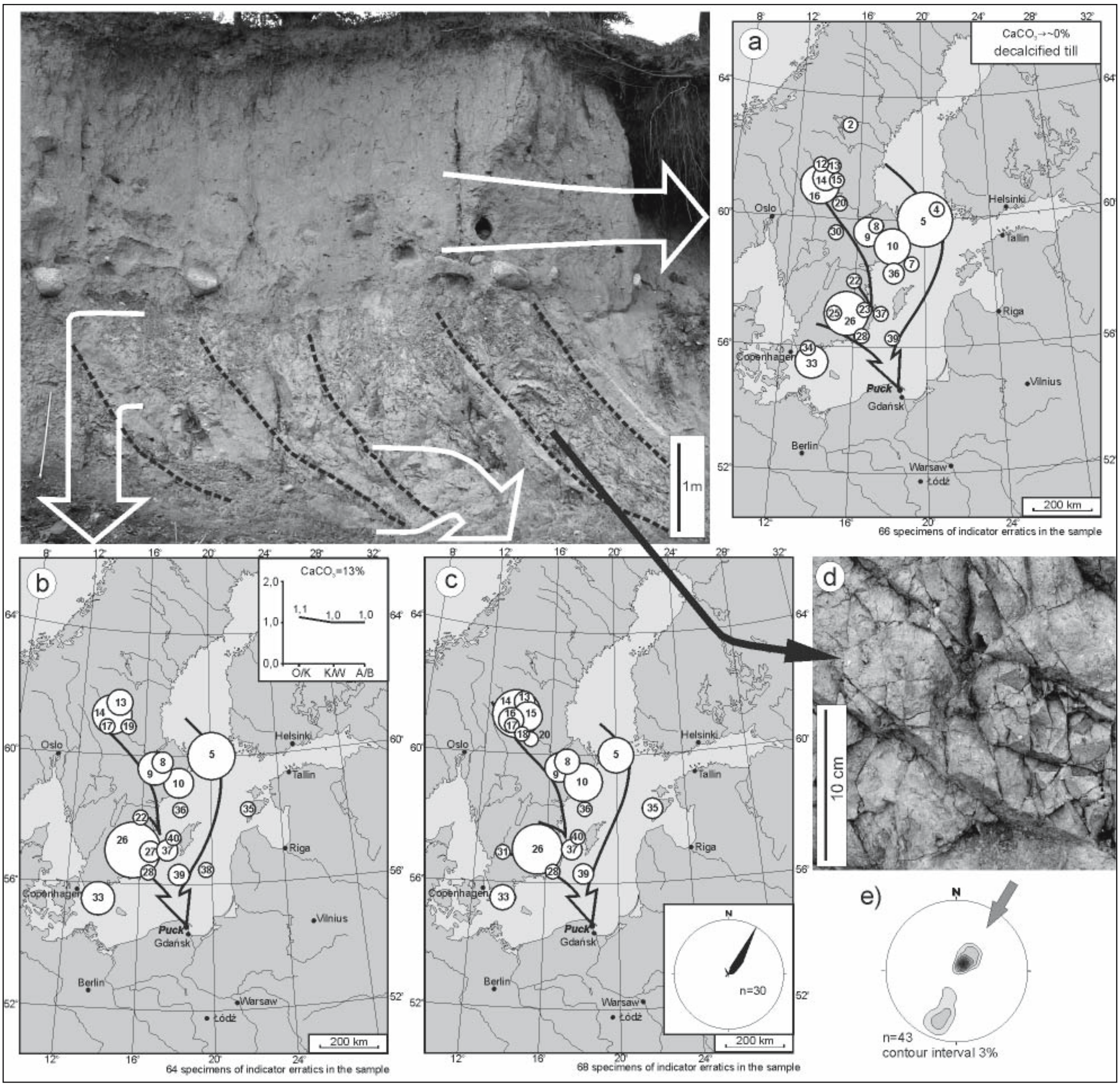

Fig. 6. Site Puck – results of selected analyses: *a* – in the upper till, *b* – in the middle part of the profile (the roof part of the lower till), *c* – in the base part of the lower till, *d* – joint system in the lower till, *e* – projection of the poles to Riedl joint planes in the lower till (projection on the lower hemisphere, suggested ice flow direction marked by the arrow); for other explanations, see Fig. 2

6 pav. Pucko pjūvio selektyvios analizės rezultatai: *a* – viršutinė morena, *b* – profilio vidurinė dalis (apatinės morenos viršus), *c* – apatinės morenos pagrindas, *d* – plyšių sistema apatinėje morenoje, *e* – polių projekcijos apatinės morenos Riedlio plyšių paviršiuose upper till in Kartoszyno can originate in the middle part of the Vistulian Glaciation (Świecie Stadial) and the lower till in a glaciation older than the Vistulian. It should be stressed, however, that these are only the preliminary results and that the site in Kartoszyno still needs a further, detailed chronostratigraphic investigation.

Analysis of the Puck profile suggests that its base part may be a fragment of an older bed: it is separated from the upper till by a boulder pavement, and its structure shows an evident deformation (thrust structure, upturned till scales with intercalation of sandy bodies a characteristic joint system). Similar macroscopic properties (dark-grey to olive-grey colour, joint system, a considerable percentage of the clay fraction, apparent deformation) and location of the TGZ of the base part of the lower till in Puck and the lower till bed in Osłonino seem to indicate their similar stratigraphic position. The analysis of the complicated joint system in Puck (Fig. 6d) enabled us to distinguish the Riedl joint system. Its identified orientation (Fig. 6e) appears to be in good agreement with the long axis orientation of the measured clasts in the upper till and boulder striation (Parchem, Wysota, 2008) and is similar to the directional properties of deformations under the base of the youngest till, occurring in a more distant (southern) part of the Puck cliff. All that, together with the mentioned clast orientation in the Puck area (Fig. 4), suggest the ice stream advance from the NNE.

Till above the boulder pavement, apparent in the upper part of the Puck cliff, is strongly weathered, and weathering modified its petrographic composition (reduction of limestones, lack of dolomites, disintegration of igneous and metamorphic rocks rich in biotite). Nevertheless, the analysis of this till by the indicator erratics method appeared still useful, contrary to petrographic examination of the 5–10 mm fraction.

In Osłonino, where three measurement series were performed (Fig. 5 a, b), clast orientation is similar to the one in the youngest tills in the majority of sites between the Puck Bay and the Lake Żarnowiec, whereas in Gnieżdżewo, Puck and just a few kilometres to the south of Puck, the leading direction deviates considerably to the east. Yet one should keep in mind that the clasts orientation in the base part of the youngest till bed in Osłonino has a bimodal distribution. A significant group of clasts lies along the NNW–SSE direction, while another group indicates the direction of NNE–SSW (thus close to the one observed in Puck and Gnieżdżewo). A bimodal clast orientation was also observed in the base part of till in the nearby Rzucewo site (Fig. 4). Therefore, it can be believed that, in parallel with the dominant (in this region) NNW ice-sheet advance direction, there might exist also another, local ice-sheet advance direction manifested in the east, which deposited a till bed in the area of Puck and Gnieżdżewo. And, just a few kilometres to the south of Puck, this local advance direction was again dominated by the main ice stream. The hypothesis of a purely local character of the untypical ice-sheet advance direction (from NNE) is supported by the small proportion rocks from the eastern part of Fennoscandia in the whole association of the indicator erratics in samples from Gnieżdżewo and Puck.

CONCLUSIONS

The authors come to the conclusion that the analysis of the coarse fraction petrographic composition by the indicator erratics method provides most comprehensive information on the glacial transport paths and stratigraphic position of the tills studied. The long axis orientation studies of the clasts contained in till appear to be a good supplement to the former techniques, but they deliver the knowledge of the ice-sheet advance direction only across a given area (some local alterations may exist). Petrographic analyses of tills by the indicator erratics method proved to be useful also in case of weathered sediments in which the petrographic examination of the 5–10 mm fraction showed ineffective. However, the results obtained for the study region still do not provide a high level of confidence because of the lack of an appropriate reference profile with an entirely resolved stratigraphic position. Determination of the stratigraphic position of the till studied is particularly complicated when a vertical variation of its petrographic composition is evident, which can be attributed to two concurrent factors: changes in the source areas occurring during a particular ice-sheet advance and some post-depositional weathering processes progressing from the roof part of the bed. Thus, to dispel the existing doubts and ambiguities, further investigations of the area are required, in particular, research based on dating techniques.

References

1. Benn D. I., Evans D. J. A. 1998. *Glacier & Glaciation*. London: Arnold. 734 p.
2. Czubla P. 2001. Eratyki fennoskandzkie w utworach czwartorzędowych Polski środkowej i ich znaczenie stratygraficzne. *Acta Geographica Lodziensia* 80: 174.
3. Kenig K. 1998. Petrograficzne podstawy stratygrafii glin morenowych Polski północno-wschodniej. *Biuletyn PIG* 380: 90.
4. Kjaer K. H., Houmark-Nielsen M., Richardt N. 2003. Ice-flow patterns and dispersal of erratics at the southwestern margin of the last Scandinavian Ice Sheet: signature of palaeo-ice streams. *Boreas* 32: 130–148.
5. Lagerlund E., Malmberg Persson K., Krzyszkowski D., Johansson P., Dobracka E., Dobracki R., Panzig W. 1995. Unexpected ice flow directions during the Late Weichselian deglaciation of the South Baltic area indicated by a new lithostratigraphy in NW Poland and NE Germany. *Quaternary International* 28: 127–144.
6. Lisicki S. 2003. Litotypy i litostratygrafia glin lodowcowych plejstocenu dorzecza Wisły. *Prace Państwowego Instytutu Geologicznego* 177: 105.
7. Lüttig G. 1958. Methodische Fragen der Geschiebeforschung. *Geologisches Jahrbuch* 75: 361–418.

8. Masłowska M., Olszak I. J., Jurys L., Michałowska M. 2003. Budowa geologiczna, stratygrafia i paleogeografia osadów południowej części klifu osłonińskiego. *Geologia i geomorfologia pobrzeża i południowego Bałtyku* 5: 111–120.
9. Neumann M., Nowacka N. 2005. Zróżnicowanie petrograficzne glin morenowych na Pobrzeżu Kaszubskim. In: R. K Borówka (ed.). *Plejstoceńskie i holoceńskie przemiany środowiska przyrodniczego Polski. Wybrane aspekty*. Szczecin: Oficyna In Plus. 48–52.
10. Ostaficzuk S. 1978. *Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1 : 50000, arkusz Sławoszyno*. Warszawa: Wydawnictwo Geologiczne. 77 p.
11. Parchem M., Wysota W. 2008. Stop 10: Sedimentology of the Puck cliff deposits. In: S. Lisicki (ed.). *Quaternary of the Gulf of Gdańsk and Lower Vistula regions in Northern Poland: sedimentary environments, stratigraphy, and palaeoegeography*. Warszawa: PGI. 95–196.
12. Pikies R., Zaleszkiewicz L. 2003. *Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1 : 50000, arkusz Rumia*. Warszawa: Wydawnictwo Geologiczne. 42 p.
13. Prussak W. 2000. Wstępny profil litologiczno-stratygraficzny plejstocenu Pobrzeża i Pojezierza Kaszubskiego według opracowanych arkuszy SMGP w skali 1 : 50 000. In: S. Uścinowicz, J. Zachowicz (eds.). *Stratygrafia czwartorzędu i zanik lądolodu na Pojezierzu Kaszubskim*. Gdańsk: Państwowy Instytut Geologiczny, Oddział Geologii Morza. 70–74.
14. Skompski S. 1989. Morfogeneza i wiek Pobrzeża Kaszubskiego. *Studia i Materiały Oceanologiczne* 56. *Geologia Morza* 4: 171–178.
15. Skompski S. 2001. *Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1 : 50000, arkusz Puck i Puck N*. Warszawa: Wydawnictwa Geologiczne. 34 p.
16. Smed P. 1993. Indicator studies: a critical review and a new data–presentation method. *Bulletin of the Geological Society of Denmark* 40: 332–340.
17. Smed P. 1994. *Steine aus dem Norden*. Berlin–Stuttgart: Gebrüder Borntraeger. 194 p.
18. Woźniak P. P. 2006. Interpretational problems induced by regional changeability of petrographic till composition. *Archiv für Geschiebekunde* 5(1–5): 237–250.
19. Vinx R., Grube A., Grube F. 1997. Vergleichende Lithologie, Geschiebeführung und Geochemie eines Prä-Elster-I-Tills von Lieth bei Elmshorn. *Leipziger Geowissenschaften* 5: 83–103.
20. Zaleszkiewicz L., Masłowska M., Olszak I. J., Koszka-Maroń D., Michałowska M. 2000. Stanowisko 7. Klif w Jastrzębiej Górze. In: S. Uścinowicz, J. Zachowicz (eds.). *Stratygrafia czwartorzędu i zanik lądolodu na Pojezierzu Kaszubskim*. Gdańsk: Państwowy Instytut Geologiczny, Oddział Geologii Morza. 117–119.

Piotr Paweł Woźniak, Piotr Czubla, Grażyna Wysiecka, Małgorzata Drapella

LEDYNINIO MOLIO IŠ GDANSKO ĮLANKOS ŠIAURĖS VAKARŲ PAKRANTĖS (ŠIAURĖS LENKIJA) PETROGRAFINĖS SUDĖTIES IR NUOTRUPINĖS MEDŽIAGOS ORIENTACIJOS TYRIMAS

Santrauka

Straipsnio autoriai pabandė panagrinėti moreninio molio, atidengto Pajūrio šiaurinėje dalyje tarp Žarnoveckio ežero ir Pucko įlankos, petrografinės sudėties kaitą. Iš 15-os vietų buvo paimti ledyninio molio ėminiai 5–10 mm grūdelių frakcijos petrografiniams tyrimams. Dvidešimtyje vietų buvo išmatuota nuotrupinės medžiagos orientacija ledyniniame molyje. Penkiose vietose atrinkta 12 ėminių nuotrupų, didesnių nei 20 cm, siekiant išaiškinti pagrindines uolienas, nurodančias medžiagos šaltinį (1 pav.). Buvo manoma, kad iš literatūrinių šaltinių žinoma didelė vienos stratigrafinės priklausomybės molio petrografinių koeficientų sklaida (5–10 mm frakcijoje) gali būti susijusi su dūlėjimo poveikiu. Tačiau kai kuriose vietose buvo pastebėta 5–10 mm frakcijos vertikali petrografinės sudėties kaita, kuri neturėjo ryšio su ledyninio molio išdūlėjimo laipsniu ir pasikartojo įvairiose atodangos vietose (2 pav.). Šių pakitimų priežastimi galėjo būti progresuojantį ledyną maitinančios provincijos kaita. Šią mintį patvirtino riedulių statistinės analizės rezultatai. Pagrindinis kristalinių uolienų nuotrupų šaltinis į ledyną pateko iš vidurio ir pietryčių Švedijos rajonų (2, 3, 5 ir 6 pav.). Tirtuose ėminiuose nėra Suomijos uolienų (išskyrus Alandų salas) ir palyginti nedaug Rytų Europos platformos dolomitų. Eratinių nuotrupų analizė Fenoskandijos fone leidžia nustatyti ledyno slinkimo kryptį, kuri sutampa su nuotrupų orientacija morenose (NNW ir NW sektoriai, 4 pav.). Kai kur šiaurės vakariniame sektoriuje orientacija nukrypusi nuo šios krypties ir tai paaiškinama vietovės reljefo nulemta ledo slinkimo krypties kaita ledyno apatinėje dalyje. Tirinėtos srities rytinėje dalyje, klifuose prie Punsko ir Gneždževo (1 pav.) pastebėta nebūdinga šiam rajonui riedulių orientacija, didžioji dalis ryškiai nukrypusi į rytus (4 ir 6 pav.). Pucke klifo apatinėje dalyje tikriausiai slūgso senesnio sluoksnio molio fragmentas. Nuo viršutinės dalies jį skiria riedulių horizontas ir pastebima deformacija. Sudėtingos plyšių sistemos analizė padėjo nustatyti Redlio plyšius, kurių kryptys taip pat patvirtina užslinkimą iš NNE (6 pav.). Nebūdinga kryptis pastebima dar keletą kilometrų piečiau Pucko, o Oslonino apylinkėse ji yra iš NNW (4, 5 ir 6 pav.). Eratinių riedulių sudėtis Pucko apylinkėse ir gretimų vietų molio yra panaši, todėl negalima sakyti, kad nebūdinga užslinkimo kryptis rodo esant kitą moreninį horizontą. Greičiausiai tai yra ledyninio srauto tekėjimo vietinė modifikacija, kuri užsibaigia per keletą kilometrų piečiau Pucko (4 pav.). Ledo slinkimo vietinį pobūdį (iš NNE) taip pat liudija Fenoskandijos rytinės dalies medžiagos nebuvimas riedulių grupėje.

Пётр Павел Возьняк, Пётр Чубля, Гражына Высецка, Малгожата Драпелла

ИЗУЧЕНИЕ ПЕТРОГРАФИЧЕСКОГО СОСТАВА И ОРИЕНТИРОВКИ ОБЛОМОЧНОГО МАТЕРИАЛА В ЛЕДНИКОВЫХ ГЛИНАХ СЕВЕРО-ЗАПАДНОГО ПОБЕРЕЖЬЯ ГДАНЬСКОГО ЗАЛИВА, СЕВЕРНАЯ ПОЛЬША

Резюме

Авторами статьи предпринята попытка проследить изменчивость петрографического состава моренных глин, обнажающихся в северной части Приморья, между Жарновецким озером и Пуцким заливом. В 15 точках были взяты пробы ледниковых глин для петрографических исследований зерен размером 5–10 мм. Примерно в 20 точках была измерена ориентировка обломочного материала в ледниковой глине, а в 5 точках получено 12 проб обломков размером более 20 мм в целях выявления доминирующих обломков, указывающих на источник материала (рис. 1). Предполагалось, что известный по литературным источникам большой разброс петрографических коэффициентов (во фракции 5–10 мм) для глин одинаковой стратиграфической позиции может быть связан с влиянием выветривания. Однако в некоторых точках была отмечена значительная вертикальная изменчивость петрографического состава фракции 5–10 мм, не связанная со степенью выветривания ледниковой глины, повторяющаяся в разных частях обнажения (рис. 2). Причиной этих изменений могла стать смена питающей провинции наступавшего ледника. Эту гипотезу подтвердили результаты статистического анализа доминирующих обломков. Основное поступление скального материала в ледник шло с территории центральной и юго-восточной Швеции (рис. 2, 3, 5 и 6). В составе исследованных проб отсутствуют финские породы (кроме обломков с Аландских островов) и присутствует относительно немного доломитов Восточно-Европейской платформы. Анализ состава эрратических обломков на фоне геологического строения Фенноскандии позволяет определить направление наступления ледника. Оно соответствует ориентировке обломков (сектор между NNW и NW, рис. 4). В некоторых точках подтвердилось отклонение ориентировки обломков от этого направления, колеблющееся в границах северо-западного сектора. Это явление предположительно объясняется изменением направления движения льда в нижней части ледника под влиянием локальных элементов рельефа местности. В восточной части исследованной области, в клифах около Пуцка и села Гнежджево (рис. 1), была зафиксирована нетипичная для этого района ориентировка валунов: доминирующее направление в них отклоняется явно к востоку (рис. 4 и 6). В нижней части клифа в Пуцке, вероятно, выступает фрагмент старшего пласта глины. От верхней части он отделён валунным горизонтом и носит отчётливый отпечаток деформации. Анализ имеющейся в ней сложной системы трещин позволил выделить трещины Редля, ориентировки которых также свидетельствуют о на ползании со стороны NNE (рис. 6). Это нетипичное направление наблюдается также всего в нескольких километрах на юг от Пуцка, а в окрестностях села Ослонино сменяется на NNW (рис. 4, 5 и 6). Состав доминирующих эрратических валунов в глинах из Пуцка и из окрестных точек отбора однотипен. Поэтому нельзя утверждать, что нетипичное направление на ползания указывает на наличие другого моренного горизонта. Скорее следует предположить, что это лишь местная модификация движения ледового потока, распространение которой кончается в нескольких километрах на юг от Пуцка (рис. 4). О местном характере нетипичного направления наноса льда (с NNE) свидетельствует почти полное отсутствие в группе доминирующих валунов пород, происходящих из восточной части Фенноскандии.