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Application of a petrographic method to identification of the till floes

One presented the results of the petrographic and mineralogical studies of tills from the environs of Sompolno (Kujawy). On the basis of the petrographic composition of gravels, composition of heavy minerals as well as grain size and calcium carbonate content one distinguished in tills six lithostratigraphic units. Interpretation of the calculated petrographic coefficients led to the identification of the floes of the older tills, occurring within the younger tills. An attempt was made to explain the mechanism of incorporation.

INTRODUCTION

The studied area occurs to the north and north-east from Sompolno in the ranges of Kujawy Lakeland (Fig. 1). The pre-Quaternary substratum consists of Mesozoic (mainly Cretaceous) and Tertiary sediments, mostly Oligocene sands and Miocene clays, as well as Pliocene clays (E. Ciuk, 1979; E. Ciuk, A. Mańkowska, 1981).

The petrographic and mineralogical studies were performed for profiles of four boreholes: Dębołęka-11 (D-11), Mąkoszyn Grochowiska-10 (MG-10), Mąkoszyn Grochowiska-20 (MG-20) and Mąkoszyn Grochowiska-25 (MG-25).

The profiles were obtained from the boreholes, that the Department of the Brown Coal Deposits of the Polish Geological Institute commissioned to perform in 1985/1986 (the profiles MG-10, MG-20 and MG-25) and in 1989 (the profile D-11) for prospecting purposes, and afterwards they were used in 1994 for preparation of the *Detailed geological map of Poland* in the scale 1:50 000, the Sompolno sheet.

In the paper one presents the results of the petrographic and mineralogical studies of tills, occurring in the above-named boreholes (*cf.* R. Zabielski, 1995). The studies were performed in the Laboratory of Lithology of the Department of Quaternary Geology of the Polish Geological Institute in Warsaw. For the tills one determined petrographic composi-

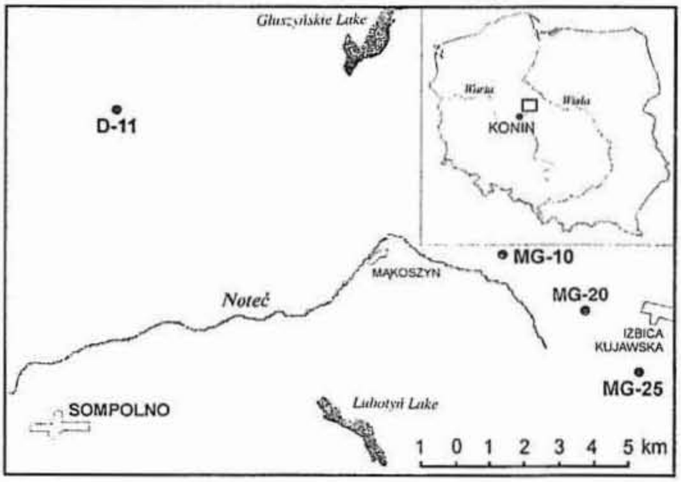


Fig. 1. Location of the area of investigations
Położenie obszaru badań

tion of gravels (5.0–10.0 mm fraction), heavy minerals (0.1–0.25 mm fraction), content of calcium carbonate (< 0.1 mm fraction) and grain size.

The two first features are characterised in details, and the other ones are outlined. The results of the analysis of the petrographic composition of gravels were especially useful, as well as the petrographic coefficients, calculated on the basis of the petrographic composition, namely O/K, K/W, A/B, where: O — total of the Scandinavian sedimentary rocks (Wp + Dp + Łp + Pp); K — total of the Scandinavian crystalline rocks and quartz (Kr + Qp); W — total of the Scandinavian limestones and dolomites (Wp + Dp); A — total of the Scandinavian rocks not resistant to weathering (Wp + Dp + Łp); B — total of the Scandinavian rocks resistant to weathering (Kr + Pp + Qp).

LITHOLOGIC CHARACTERISTICS AND CHRONOSTRATIGRAPHY

On the basis of the performed studies, one divided the tills occurring in the profiles into six separate lithostratigraphic units (I–VI, Fig. 2), differing first of all in petrographic composition of gravels, heavy mineral composition and to lesser extent grain size. The tills are characterised in the sequence from the bottom toward the top. Petrographic composition of the gravels and the respective values of the petrographic coefficients, and the heavy mineral composition one presented in graphs (Figs. 3–8) as means for a peculiar till (excluding the floes, whose values of the petrographic coefficients are given separately). The plots present the vertical variations of the calcium carbonate content as well.

One should accentuate, that during the distinguishing of tills one accepted the opinion, that tills connected with the consecutive glacial periods may be characterised by petrographic coefficients depending on the petrographic composition of gravels (J. Rzechowski,

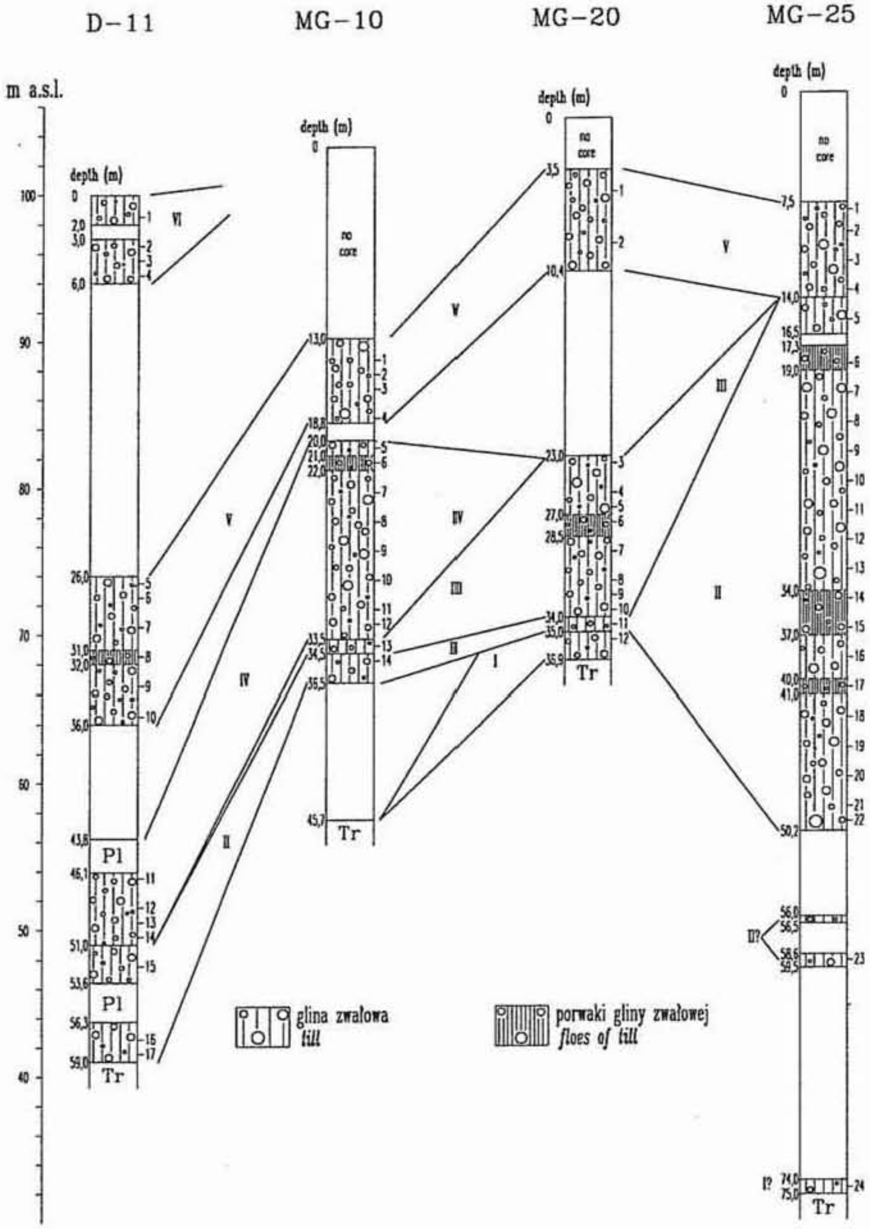


Fig. 2. Geological profiles of the investigated boreholes

I–VI — lithostratigraphical units; Pl — floes of Pliocene; Tr — Tertiary; numbers at the right side of the profiles — sample numbers

Profile geologiczne badanych otworów wiertniczych

I–VI — jednostki litostratygraficzne; Pl — kry plioceńskie, Tr — trzeciorzęd; liczby z prawej strony profilów — numery próbek

1971, 1974, 1976, 1977, 1980, 1982; K. Choma-Moryl *et al.*, 1991; W. Stankowski, D. Krzyszkowski, 1991; B. Gronkowska, 1993; K. Kenig, 1993). The differences in petrographic composition probably resulted from coming of the rock material from various alimentation areas in Scandinavia, what one may connect with migration of the glaciation centres and change of the location of the ice divide. This change was ascertained by textural studies of tills as well as on the basis of the distribution of several tens of kinds of the Scandinavian erratics on the European continent (J. Dudziak, 1961; J. Nunberg, 1971; J. Ehlers, H. J. Stephan, 1983).

Till I occurs in the profile MG-20, where it achieves thickness of c. 2 m (Fig. 2). It is gray sandy till with gravel, overlying Tertiary sediments. One distinguished it in a uniform till complex only in the profile of the borehole MG-20 due to a different petrographic composition of gravels, when compared with the remaining part of the complex. This till may be a floe in the bottom of till II (Fig. 3). Probably the till, occurring in the lowermost part of the profile MG-25 directly on the Miocene beds (Fig. 2), is the age equivalent of the discussed till I, however, due to low content of gravels, it was not investigated.

The values of the petrographic coefficients of the till I (Fig. 3) are comparable with the coefficients of the lithotype P1 distinguished by J. Rzechowski (1971, 1974, 1977) in the group of tills of the South-Polish Glaciations in the area of central Poland. Regarding this fact and the lowermost stratigraphical position of the till (it occurs under the till II of the accepted connection with the San Glaciation), apparently one may relate this till to the Nida Glaciation (*Instrukcja...*, 1991).

Till II occurs in all the investigated profiles (Fig. 2). The till is clayey-sandy (locally only sandy one, as in the profile MG-25), gray, with occasional pebbles of the Scandinavian rocks. Prevailing of crystalline rocks over Scandinavian limestones and the high value K/W with respect to other coefficients (this causes that the plot has a shape of the upside-down-oriented letter V, Fig. 4) are the characteristic features of this till.

Frequency of the local rocks is small. Only in the profile D-11 the high content of the local limestones was found, what influenced the percentage content of the remaining components, though the proportions of the main groups, i.e. crystalline rocks and Scandinavian limestones are similar to those in the other profiles. Domination of the local limestones in the profile D-11 might be of a local importance (*cf.* J. Rzechowski, 1980), because this profile occurs in a significant distance from the other ones (Fig. 1).

The till with a high value of the coefficient K/W occurs commonly in the area of Western Poland and it is connected with the South-Polish Glaciation. J. E. Mojski (1985) relates the till with this kind of the coefficient value with the second stadial of the South-Polish Glaciation (in the tripartite division) and J. Rzechowski (1971, 1974, 1977) with the second and the third lithotype of the South-Polish tills.

The floes of older sediments one observed in the till II. In the profile D-11 they are compact silts and overlying gray and gray-green clays with yellow and olive mottles, and with slips, almost calcareous-free, occurring at the depth of 56.3–53.6 m. At the border of the clays with the overlying till one observed disturbances in form of small involutions. On the basis of the macroscopic features of the sediments, their general type and the disturbances at the clay/till border one may ascertain, that these sediments are a floe of Pliocene beds, because till under- and overlying the clays and silts, has the same petrographic features (Fig. 4). A similar floe of the Pliocene clay occurs at the depth of 46.1–43.8 m (profile

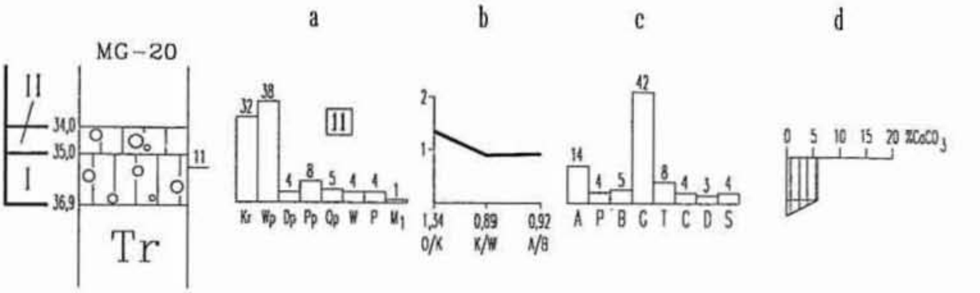


Fig. 3. Petrographic and mineralogical characteristics of the till I

a — petrographical composition of gravels: Kr — crystalline rocks, Wp —Scandinavian limestones, Dp — Scandinavian dolomites, Pp — Scandinavian sandstones, Qp — Scandinavian quartz, W — local limestones, P — local sandstones, M_1 — Palaeocene mudstones, I — others; numbers in the quarters — sample numbers; b — petrographical coefficients: O/K, K/W, A/B (for explanations see the text); c — heavy minerals: A — amphibole, P — pyroxene, B — biotite, G — garnet, T — tourmaline, C — zircon, D — disthene, S — staurolite; d — content of calcium carbonate; other explanations see Fig. 2

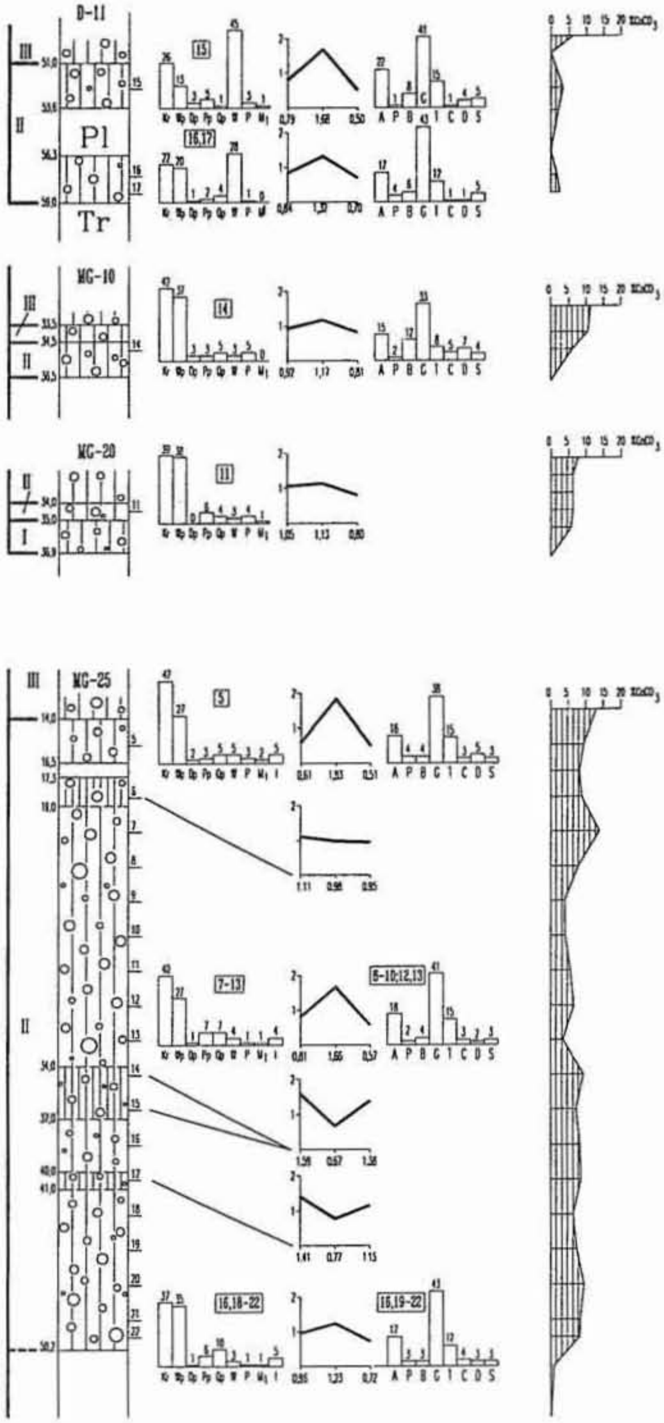
Petrograficzna i mineralogiczna charakterystyka gliny zwałowej I

a — skład petrograficzny żwirów: Kr — skały krystaliczne, Wp — wapienie skandynawskie, Dp — dolomity skandynawskie, Pp — piaskowce skandynawskie, Qp — kwarc skandynawski, W — wapienie lokalne, P — piaskowce lokalne, M_1 — mułowce paleoceńskie, I — inne; liczby w kwadratach — numery próbek; b — współczynniki petrograficzne: O/K, K/W, A/B (objaśnienia w tekście); c — minerały ciężkie: A — amfibol, P — piroksen, B — biotyt, G — granat, T — turmalin C — cyrkon, D — dysten, S — staurolit; d — zawartość węglanu wapnia; pozostałe objaśnienia jak na fig. 2

D-11), above the till IV (Figs. 2, 6). Floes occur as well in the profile MG-25, but they are fragments of older tills (probably of the Nida Glaciation). One distinguished them on the basis of their petrographic composition, which differed from the composition, generally observed in the till II. The distinguished floes occur at the depths of c. 41–40 and 37–34 m as well as 19–17.3 m. Palaeozoic limestones (42–50%) prevail on crystalline rocks (27–28%) in the petrographic composition of the gravels (in the floes), with a scarce dolomite share (2–5%) and a little higher content of the Scandinavian sandstones (4–5%) and quartz (7–9%). This caused different proportions of the petrographic coefficients than for the till II (Fig. 4). Among the local rocks, limestones (5–6%) and sandstones (3–4%) prevail. Till balls and wood fragments are completely absent here, whereas in the till II they occupy 3–6% of the total gravel frequency and are present there in majority of the samples.

In the heavy mineral assemblage the association: garnet-amphibole-tourmaline is apparent, though the percentage contents of the minerals in various profiles may be different. One does not observe any decrease of calcium carbonate content within the limits of the distinguished floes; this content equals 7–9% and is the same as in the till II.

Till III occurs first of all in the profile MG-20, where it achieves the thickness of c. 12 m, and in the profile MG-10 in the lower part of the glacial complex at the depth of 34.5–33.5 m. It is gray clayey till with occasionally present pebbles of the Scandinavian rocks. The till was distinguished on the basis of the values of the petrographic coefficients, among which the O/K and A/B are extremely divergent, and the K/W achieves an intermediate


D-11
Pl
Tr
MG-10
MG-20
MG-25

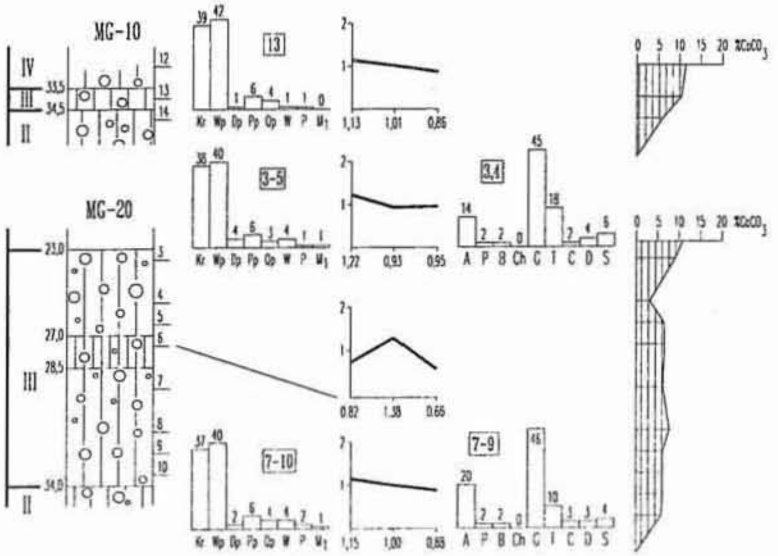


Fig. 5. Petrographic and mineralogical characteristics of the till III
For explanations see Figs. 2 and 3
Petrograficzna i mineralogiczna charakterystyka gliny zwałowej III
Objaśnienia jak na fig. 2 i 3

value or a value close to the A/B. The till typically has an uniform petrographic and mineralogical composition.

At the depth of 28.5–27.0 m (profile MG-20) there has observed different petrographic composition of gravels, in which crystalline rocks (44%) distinctly dominated on Palaeozoic limestones (32%), what influenced the proportions of the petrographic coefficients: O/K = 0.82, K/W = 1.38 and A/B = 0.66. These proportions are characteristic for the earlier described till II. In the assemblage of heavy minerals, the decrease of amphibole content (6%), and domination of garnets (45%) and tourmalines (16%) are apparent. However, the content of $CaCO_3$ (6.2%) did not decrease, what one would expect due to the occurrence of a weathering horizon, and what could be the reason of the high share of the crystalline rocks. Supposedly, it is a floe of older till, all the more so as the till under and above the floe showed very similar petrographic composition and similar heavy mineral and calcium carbonate contents.

Till of such characteristic distribution of the values of the petrographic coefficients, i.e. their decrease from the O/K through the K/W to the A/B is similar to the youngest lithotype of the South-Polish till, distinguished by J. Rzechowski (1971, 1974, 1977). Both the till III

Fig. 4. Petrographic and mineralogical characteristics of the till II
For explanations see Figs. 2 and 3
Petrograficzna i mineralogiczna charakterystyka gliny zwałowej II
Objaśnienia jak na fig. 2 i 3

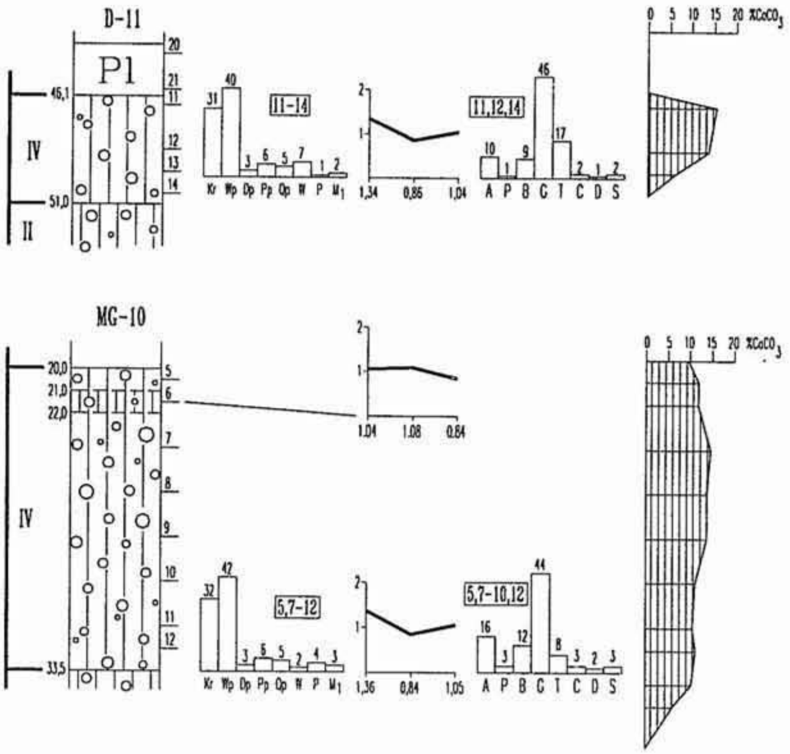


Fig. 6. Petrographic and mineralogical characteristics of the till IV
For explanations see Figs. 2 and 3
Petrograficzna i mineralogiczna charakterystyka gliny zwałowej IV
Objaśnienia jak na fig. 2 i 3

and the earlier described till II in the sense of the names used for the *Detailed geological map of Poland* in the scale 1:50 000 one may probably attribute to the San Glaciation (*Instrukcja...*, 1991).

Till IV one distinguished in the profile D-11 at the depth of 51.0–46.1 m directly on the till II and in the profile MG-10 at the depth of 33.5–20.0 m, where it occurs on the till III. It is a light gray till of the silty-sandy variety in the profile D-11 and the sandy one in the profile MG-10. Taking into account the proportions between the petrographic coefficients, one ascertained, that in the discussed till, unlike in the earlier described ones, the coefficient O/K achieved the maximum value and the coefficient A/B ranged about 1. They are plotted in the shape of the letter V (Fig. 6), thus the proportions among them are different than in the tills II and III. K. Kenig (1993) obtained similar values of the petrographic coefficients for the tills of the Ślesin environments (occurring to the west from the studied area) and included them to the tills of the South-Polish Glaciations. J. E. Mojski (1985), quoting other authors, presents comparable values of the petrographic coefficients as typical of the Wilga

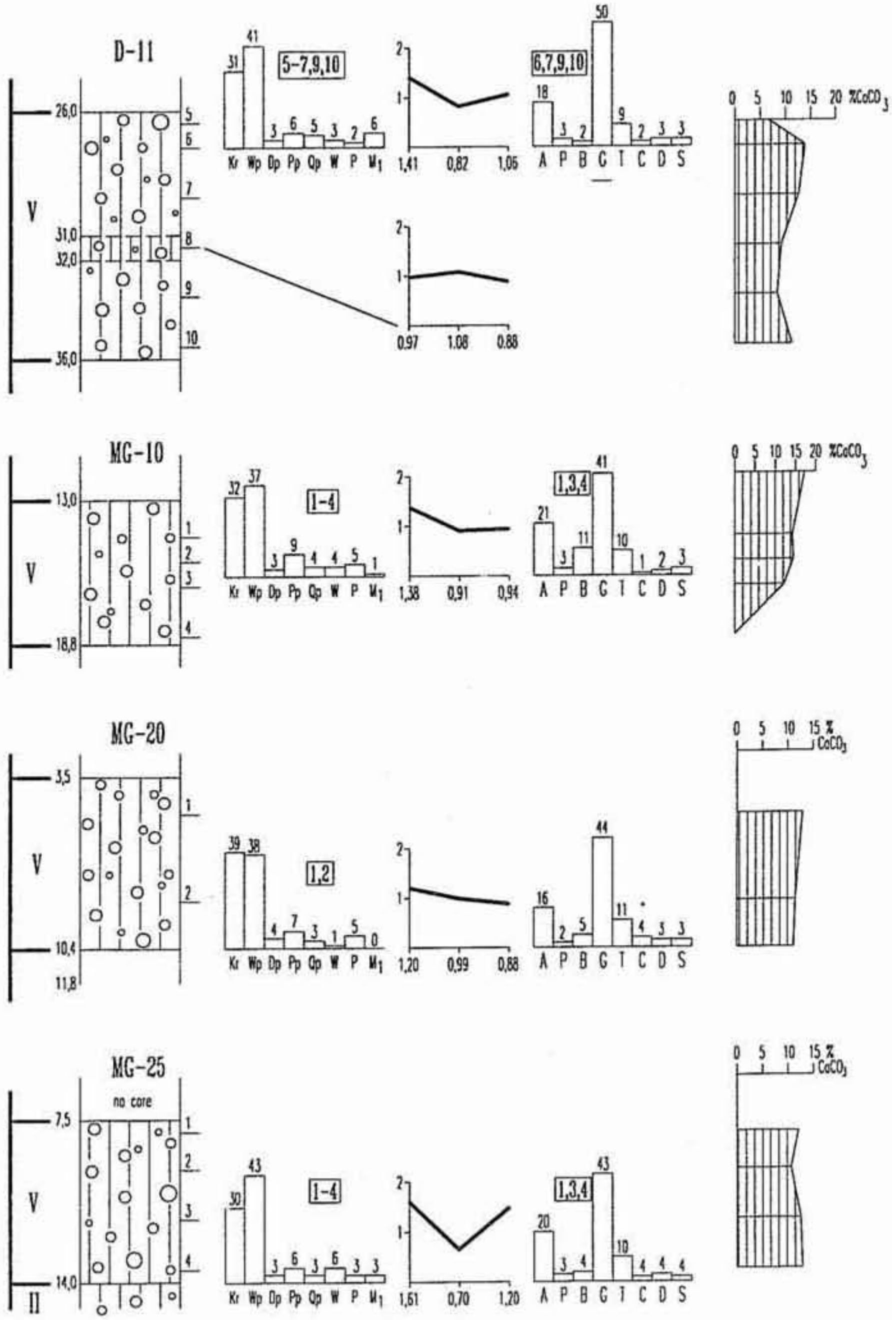


Fig. 7. Petrographic and mineralogical characteristics of the till V
For explanations see Figs. 2 and 3

Petrograficzna i mineralogiczna charakterystyka gliny zwałowej V
Objaśnienia jak na fig. 2 i 3

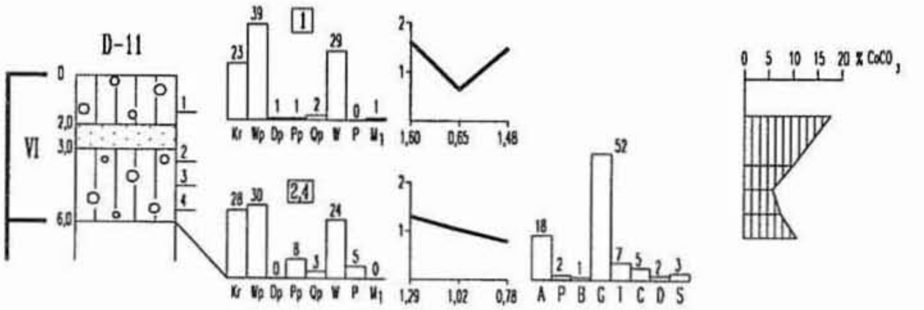


Fig. 8. Petrographic and mineralogical characteristics of the till VI
For explanations see Figs. 2 and 3
Petrograficzna i mineralogiczna charakterystyka gliny zwałowej VI
Objaśnienia jak na fig. 2 i 3

Glaciation. An attention should be paid to relatively high biotite content (9–12%) in tills I–IV, which decreases to few percentage in younger tills.

Till IV has a relatively uniform petrographic composition, if compared with other horizons, where this composition is more variable. Only in the top part of the till at the depth of 21–22 m (profile MG-10) it is a little different. The content of the crystalline rocks and Scandinavian limestones is the same here (c. 34%), what influences the values of the petrographic coefficients, equal as follows: O/K = 1.04, K/W = 1.08 and A/B = 0.84. Such proportions of the coefficients are characteristic for the till III and it is not excluded, that within the ranges of the till IV a floe of the till III may occur. Calcium carbonate content in the discussed till with respect to the other tills is high and ranges in most samples from 11 to 15%.

Till V one distinguished in all the investigated profiles. It is a gray till of the sandy-silty variety in the profiles D-11 and MG-10, and silty-clayey in the profiles MG-20 and MG-25. Average composition and the values of the petrographic coefficients one presented in Fig. 7. Despite the differences in the petrographic and mineralogical compositions in individual profiles, these tills were correlated among other things for this reason, that they occur as the only ones among the sandy sediments (except of the profile MG-25, where this till lies directly on the till II). J. Czerwonka, B. Witek (1977) obtained comparable values of the petrographic coefficients for the tills from south-west Poland and K. Kenig (1993) — for tills found to the west of the studied area, correlating them with the Warta Glaciation.

Different petrographic composition of gravels observed in the profile D-11 at the depth of 30–31 m one should probably connect with the floe of till III.

Till VI was distinguished only in the profile D-11, because in the other profiles the upper parts of the drilling cores did not preserve. This till lies on light gray hiatal sands, in turn underlain by the older till V (*cf.* R. Zabielski, 1995). The till VI is gray, sandy, with a distinct bipartition of its bed. In its lower part (depth 6.0–3.0 m) it has gray colour and displays weathering features, thus this part was not taken into account in further considerations. In the upper part (depth 2.0–0.3 m) its colour is yellow-gray with rare pebbles of the Scandinavian rocks. Each of the parts probably accumulated at different stage, separated by a period of weathering, that was recorded in the lower part of the described till.

The high values of the coefficients O/K and A/B in the upper part of the till (Fig. 8) and their significant difference with respect to the K/W values indicate a till, different that the earlier described ones. Such proportions of the petrographic coefficients, that caused the plot shape of the letter V with steep branches, typical of the Wisła Glaciation (J. Rzechowski, 1980). K. Kenig (1993) obtained similar values of the petrographic coefficients for tills occurring to the north of Konin, and she related those tills to the same glaciation.

MECHANISM OF THE FLOES INCORPORATION

The floes, occurring in the investigated tills one distinguished essentially on the basis of the different petrographic and mineralogical composition, when compared with the surrounding till. Certain researchers exclude such values of the coefficients from the calculations of the mean as the extremum ones. The present author, however, interpreted such values as an evidence of the occurring floes of the older tills. It is interesting, that the petrographic composition of the floes most frequently is close to that one observed in the older distinguished tills, where from they might have been taken by the transgressing younger inland ice. The occurrence of floes and glacial floes carried by inland ice has been described many times in literature (J. Weertman, 1961; R. F. Flint, 1971; G. S. Boulton, 1972; H. Ruszczyńska-Szenajch, 1976; M. Pasierbski, 1984), however, the mechanism of their incorporation is discussed rather rarely.

According to G. S. Boulton (1972), the processes of glacial erosion are influenced by thermic structure of the inland ice. Within the inland ice limits one may distinguish a zone, where the rock material from the base of ice is imbibed due to regelation.

H. Ruszczyńska-Szenajch (1976) described the mechanism of the incorporation of the material from the base of the inland ice and formation of the floes, which occurred within tills or in their neighbourhood. She distinguished the floes of the glaciotectonic genesis (depressions and squeezing moraines) and the floes formed due to glacial sedimentation. According to the latter author, the material of certain glacial floes could enter the just-melted-out and not consolidated bottom moraine as an element of an unsedate density-driven system. The floes may form as well due to mechanical action (décollement) of the inland ice having an uneven bottom surface with abundant frozen-in moraine. The glacial floes may be transported not only within the ice but also within the just-formed till.

From the J. Weertmans model (1961), concerning the mechanism of the incorporation of the large fragments of the base (Fig. 9), there appears, that the front of the inland ice thrusting over its forefield under certain conditions freezes to the forefield sediments. This causes the increase of the thickness of the inland ice front and increase of the strain necessary to continue the ice movement. The freezing of the sediments to the inland ice bottom causes the shift of the isotherm 0°C deeper in the base. Along this isotherm a detache surface appears similarly to the origin of the sliding plane (Fig. 10). In result of that, the volume of the sediment (or floe), detached along the weakened contact with the base, and frozen to the ice bottom, starts to move together with the inland ice, and subsequently the floe can be incorporated along the sliding planes into the ice body, frequently without any change of the primary structure of the sediment (M. Pasierbski, 1984).

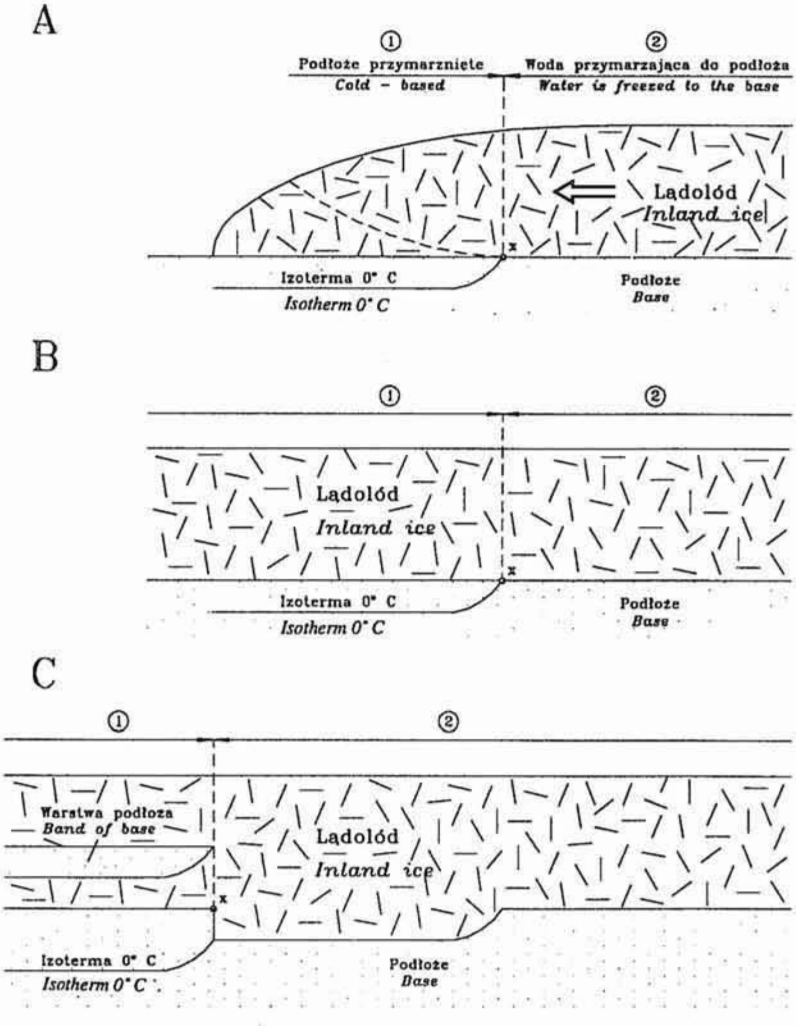


Fig. 9. Incorporation of base deposits by inland ice, after J. Weertman (1961), slightly modified
A–C — consecutive phases
Inkorporacja osadów podłoża przez lądolód według J. Weertmana (1961), nieco zmienione
A–C — kolejne fazy

In the studied case, the occurrence of the older tills within the younger ones should be connected with exaration, that resulted in taking the base fragments and their transportation either in the inland ice bottom, or along the in-glacial sliding planes. Formation of the sliding planes (strike-slip dislocations), which are of the fault nature, resulted from the exceeding of the ice resistance to shearing. The sliding planes form in the areas of the compensation strain (Fig. 10), which occur most frequently:

— when a passive flow of the inland ice occurs, caused by the base morphology,

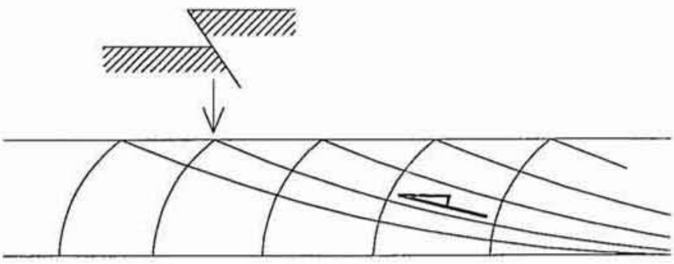


Fig. 10. Model of sliding plane in compression zone of inland ice after J. F. Nay (1952)
Model płaszczyzn ślizgowych w strefie pasywnej lądolodu według J. F. Naya (1952)

— close to the ice front, where the ice movement is slower than in the upper part of the inland ice due to ice thinning,

— when friction of the inland ice on the base increases or the ice freezes to the base.

The moraine material occurring in the bottom of the inland ice is cut by sliding planes, stimulating formation of fissures that may collect and transport the material from the base (Fig. 11).

As it appears from the J. Weertmans studies (1961), the value of the adhesion force, that appears at the contact of ice with its base in extremal cases may exceed ten times the resistance to shearing of ice. Thus, this relation indicates, that the shear surface develops at

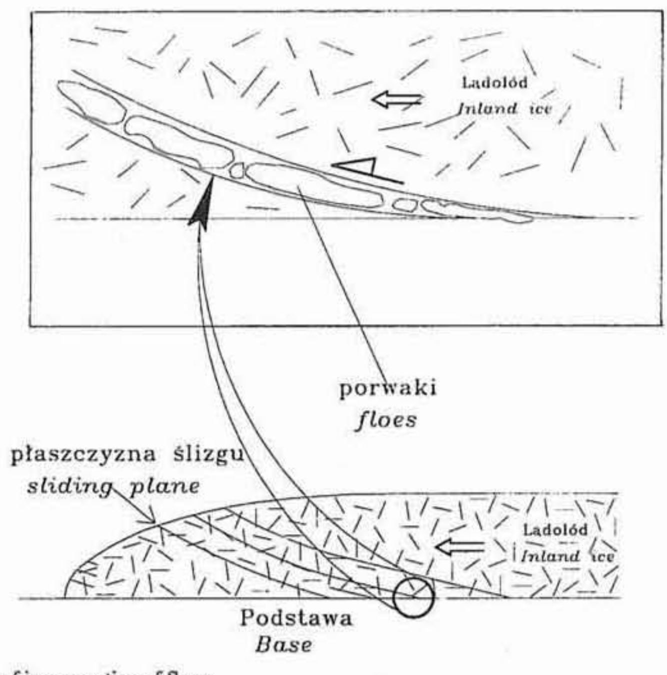


Fig. 11. Pattern of incorporation of floes
Schemat inkorporacji porwaków

the places of the least resistance, not at the contact of the ice frozen to its base. Incorporation of the soft bottom sediments as well as the dead ice with moraine (from the preceding transgression) was ascertained during transgression of the glacier Variegated in the years 1982–1983 (M. Sharp *fide* J. Jania, 1993).

After the inland ice extinction the till forms, typical of a given glaciation, with floes of an older sediment (e.g. Poznań clay or an older till) embedded in it. Consequences of such process may be recorded by the petrographic composition of gravels of the tills, what means changes of this composition and different petrographic coefficients.

Evidently, the material transported along the sliding planes not always must occur as a block of an undisturbed structure, especially that in these planes there act shearing forces and the material taken from the base may mix with the moraine material, occurring in the bottom of the inland ice. Due to such process a partial change of the petrographic composition of the gravels may occur (especially at the contact of the floe with the surrounding till), and the petrographic coefficients would have thus intermediate values between the ones of the wall till and the ones of the detached material.

FINAL REMARKS

The above presented considerations, concerning the mechanism of incorporation and transportation of the floes of the older tills in the younger ones have an interpretational character. The profiles of the boreholes were the studied material, thus the observation of the described phenomenon was limited to the location of the profile. Similar values of the petrographic coefficients, occurring in certain depth intervals within the vertically continuous complexes of tills, yielded the dividing of the tills into separate lithostratigraphic units, each one of the specific petrographic and mineralogical composition. According to the commonly accepted opinion, the units may be related to succeeding glaciations, whose centres changed their positions, resulting in alimentation of the rock material from various areas of Scandinavia. Changes of the petrographic composition of gravels, observed at certain depths within the ranges of the distinguished units, one interpreted as the floes of the older tills, occurring at the secondary deposit in the younger tills.

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ZASTOSOWANIE METODY PETROGRAFICZNEJ DO WYODRĘBNIENIA PORWAKÓW GLIN ZWAŁOWYCH

Streszczenie

Badaniami objęto gliny zwałowe występujące w profilach 4 otworów wiertniczych zlokalizowanych na N i NE od Sompolna (Pojezierze Kujawskie) (fig. 1). W glinach tych określono: skład petrograficzny żwirów (frakcja 5,0–10,0 mm), skład minerałów ciężkich (frakcja 0,1–0,25 mm), zawartość węglanu wapnia (frakcja < 0,1 mm) i uziarnienie. W artykule położono nacisk przede wszystkim na wyniki badań dwóch pierwszych cech, a pozostałe omówiono ogólnie. Szczególne znaczenie przy interpretacji miały wartości współczynników petrograficznych O/K, K/W i A/B, obliczone na podstawie składu petrograficznego żwirów, gdzie: O — suma skandynawskich skał osadowych (Wp + Dp + Łp + Pp); K — suma skał krystalicznych i kwarcu skandynawskiego (Kr + Qp); W — suma wapieni i dolomitów skandynawskich (Wp + Dp); A — suma skandynawskich skał nieodpornych na wietrzenie (Wp + Dp + Łp); B — suma skandynawskich skał odpornych na wietrzenie (Kr + Pp + Qp). Dały one podstawę do podziału glin i wyodrębnienia w nich porwaków osadów starszych (fig. 2–8).

Zbliżone wartości współczynników petrograficznych, uzyskane w pewnych interwałach głębokościowych w obrębie ciągłych pionowych kompleksów glin zwałowych, pozwoliły podzielić gliny na 6 odrębnych jednostek litostratygraficznych charakteryzujących się określonym składem petrograficznym i mineralnym (J. Rzechowski, 1971, 1974, 1976, 1977, 1980, 1982; K. Choma-Moryl i in., 1991; W. Stankowski, D. Krzyszkowski, 1991; B. Gronkowska, 1993; K. Kenig, 1993). Zgodnie z powszechnie panującym poglądem mogą one być związane z kolejnymi zlodowaceniami, których centrum zmieniało swe położenie, co z kolei wpływało na pobieranie materiału skalnego z różnych obszarów Skandynawii (J. Dudziak, 1961; J. Nunberg, 1971; J. Ehlers, H. J. Stephan, 1983). Wydzielone jednostki litostratygraficzne można przyporządkować odpowiednim jednostkom chronostratygraficznym (J. Rzechowski, 1971, 1974, 1976, 1977, 1980; J. Czerwonka, B. Witek, 1977; J. E. Mojski, 1985; *Instrukcja*...,1991; K. Kenig, 1993).

Zmienności składu petrograficznego żwirów, zaobserwowane na pewnych głębokościach w obrębie wydzielonych jednostek litostratygraficznych, zinterpretowano jako porwaki starszych glin zwałowych występujące na wtórnym złożu w obrębie glin młodszych (fig. 4–8). Na uwagę zasługuje fakt, że skład petrograficzny żwirów wydzielonych porwaków w większości przypadków jest bardzo zbliżony do składu zaobserwowanego w glinach starszych, z których prawdopodobnie mogły być one pobierane przez transgredujący młodszy lądolód.

Powstanie porwaków należy wiązać z egzaracją i inkorporacją osadów podłoża (fig. 9). W wyniku egzaracji osady podłoża były odkłuwane przez transgredujący lądolód. Odłączone fragmenty podłoża dostawały się w obręb lądolodu i jego moreny (fig. 10, 11) wzdłuż płaszczyzn ślizgowych (J. F. Nay, 1952; J. Weertman, 1961; R. F. Flint, 1971; G. S. Boulton, 1972; H. Ruszczyńska-Szenajch, 1976; M. Pasierbski, 1984).

Po stopieniu lądolodu powstała glina zwałowa właściwa danemu zlodowaceniu z porwakami starszego osadu (np. starszej gliny zwałowej, iłu plioceńskiego jak w przypadku otworu wiertniczego D-11) w jej obrębie. Konsekwencje tak zachodzącego procesu mogą być zapisane w składzie petrograficznym żwirów glin zwałowych, co wyraża zmienność tego składu w profilu i odmienne współczynniki petrograficzne.