Geological Quarterly, Vol. 39, No. 4, 1995, p. 527–538

Ewa FALKOWSKA

Importance of the recurrence of geological structure of river valleys in the E part of the Polish Lowland to the assesent of influence of anthropogenic pollution

Some similarity in the geological structures of the Narew, Supraśl, and Piwonia River valleys was found when a study was conducted on selected tracts of these rivers. This similarity is due to the occurrence of structures that are characteristics for the same scheme of areal deglaciation: a morainic upland subject to strong glaciotectonic disturbances; fluvioglacial terraces that are adjacent to the upland; and lake basins with distinct evidences of their drainage that have been adopted by the rivers to flow through during the last stage of development of postglacial surface features. Deposits from the Narew valley have also been examined in the laboratory with the aim assessing their sealing capability. In particular, attention was directed to determination of overall adsorption capacity. It was found that a number of beds under study within the Narew valley may constitute an efficient cover that prevents the expansion of pollution. With respect to similarity of morphogenesis within the river valley tracts under consideration a conclusion can be drawn that surficial soils in all three river valleys are of similar physical and chemical properties and therefore, may be prospective for natural protection of groundwaters as is the case of the Narew River deposits in the Suraż area.

INTRODUCTION

River valleys are extremely important areas from an economic point of view; however, the courses of surface runoff from their drainage basins are threatened by pollution. For this reason, particular care should be exerted when assessing the susceptibility of river valleys to the effect of anthropogenic wastes.

The objective of the study presented in this paper is to assess the effect of lithology and origin of different sediment types covering the bottoms of so-called "ancestral" valleys on their ability to stop pollution. The sediments may form a surficial protective cover for groundwaters.

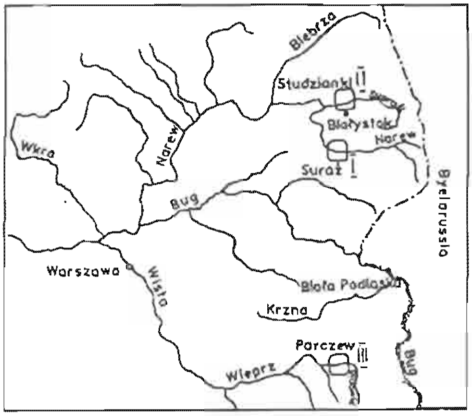

Fig. 1. Location of the study area
I — Suraż — the Narew River, II — Studzianki — the Supraśl River, III — Parczew — the Piwonia River
Lokalizacja terenów badań
I — Suraż — Narew, II — Studzianki — Supraśl, III — Parczew — Piwonia

A few examples from the Narew, Supraśl, and Piwonia River valleys (Fig. 1) are discussed in this paper; all three rivers make use of depressions that originated as glacial melt-out areas.

GEOLOGICAL STRUCTURE AND INITIAL RESULTS OF LABORATORY STUDY

SURAŻ — THE NAREW RIVER

Three primary types of geomorphologic units can be distinguished in the Suraż region. They include a morainic upland, fluvioglacial terraces, and a valley bottom which is considered contemporary to the Narew River. Boundaries of these forms are often masked by deluvial and sometimes colluvial deposits (Fig. 2).

Tentative laboratory examination of deposits occurring in the Narew valley tract under consideration allowed determination of their sealing ability with respect to pollution. There is a strong lithologic differentiation within the deposits that are represented in these geomorphologic units; therefore, the deposits exhibit variable physical and chemical features, among which adsorption capacity takes a special position.

The morainic upland is a zone of a strong disturbance caused by glaciotectonic action affecting all the glacial, fluvioglacial, and ice-dammed lake deposits, most often belonging to earlier glaciation stages. They occur as sands and gravels, clayey sand, and brownish clay. The upland is made up of elevated terrain whose morphology as well as geological structure is the result of areal deglaciation (J. E. Mojski, 1967; E. Falkowski *et al.*, 1988). In the course of its final stage, the valley was filled with large dead-ice blocks that were left in a stretch of exaration depressions. When final melting of glacial ice was over, a lake system developed within these exaration depressions (E. Falkowski, 1970). The push of the dead-ice melting blocks caused extrusion of materials on the upland slopes in the direction of unloaded upland zones. This resulted in the formation of numerous folds (Figs. 3 and 4) and discontinuities of beds such as those irregular structures clearly visible in all gravel pits

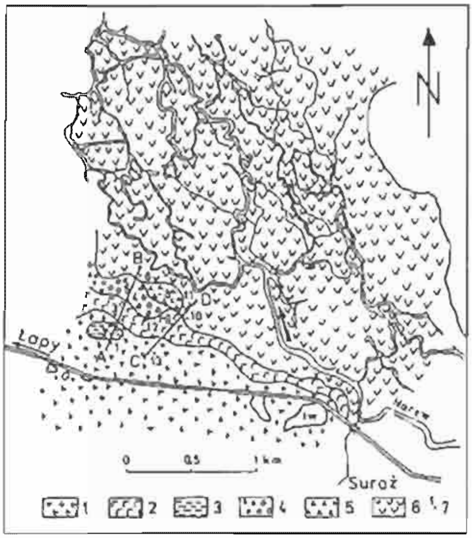

Fig. 2. Morphogenetic sketch of the Narew valley in the Suraż area

1 — morainic upland; 2 — deluvium (that masks the boundaries of the geomorphologic units); 3 — lacustrine deposits within the morainic upland; 4 — kame terrace; 5 — outcrop of boulder clay material in the river valley; 6 — valley bottom; 7 — boreholes; A–B, C–D — geological cross-sections; żw — gravel pit

Szkic morfogenetyczny doliny Narwi w okolicach Suraża

1 — wysoczyzna morenowa; 2 — deluwia maskujące granice jednostek geomorfologicznych; 3 — osady jeziorne na wysoczyźnie morenowej; 4 — taras kemowy; 5 — wychodnia materiału zwałowego, gliniastego w dolinie rzeki; 6 — dno doliny; 7 — otwory wiertnicze; A–B, C–D — linie przekrojów geologicznych; żw — żwirownie

in the area, in which beds of lithologically variable material intersect each other. The existence of a number of complex and sometimes isolated forms of stratal arrangement can contribute much to limitation of pollution migration by creating low permeability barriers that cause elongation of a filtration path.

In addition, extrusion of materials of different plasticity resulted in formation of an upland slope morphology that is diversified by hills and depressions with the evidence of limnic sedimentation. The depressions take the form of closed basins or flat terrace-like areas (Figs. 2 and 3), filled with organic-rich mud, organic-rich clay, and organic-rich sandy clay. They could only be deposited when the lake level was relatively higher. This phenomenon could have a larger extent in the Narew valley — K. Laskowski (1970, p. 30) described an organic sediment appearing "...4 m above the recent bottom of the valley..." near Uhowo, and M. Domagała (1967) found an organic sediment in the Tykocin area.

A high content of clay fraction (up to 56%) and a very poor permeability, accordingly, are the main features of soils making up the upland. From a practical point of view, these soils can be reckoned among impermeable. They show high and medium values of adsorption capacity with respect to cations (CEC: 19–31 meq/100 g of soil). Illite is the main component of the clay fraction. A surficial soil zone is enriched in organic matter (approx. 3%). With respect to this situation, the morainic upland can be, to some extent, considered as a "zone of natural protection" for groundwaters.

The fluvioglacial terraces occur as "lathes" of kame terraces covering the slope of the upland; they are confined to the edge zones of the melt-out areas. Fine- and medium-grained sands, variable in colour (from yellowish to brownish) with hardpan layers dominate the lithology of the terraces. Also, some beds enriched with clay fraction were found here.

B. Kozerski and Z. Pazdro (1990) were of the opinion that the quartz sands making up the structure are of medium permeability. Their hydraulic conductivity is of the order of 10^{-5} m/s. Illite is dominant in secondary beds.

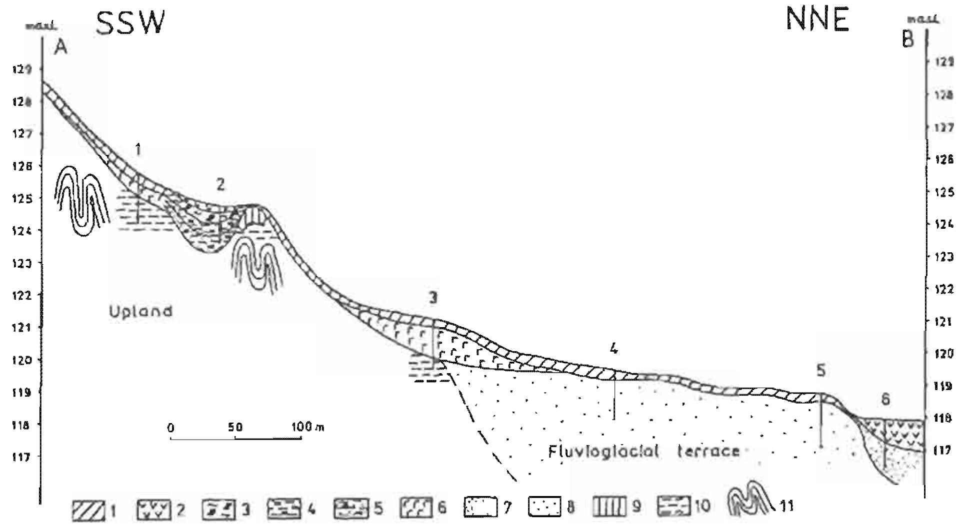

Fig. 3. Geological cross-section A–B through the slope of the Narew River valley in the Suraż area

1 — surficial soil; 2 — peat-earth; 3 — organic lacustrine mud, black; 4 — organic clay, grey; 5 — organic sandy clay, grey; 6 — deluvium; 7 — lacustrine sands, white; 8 — kame-terrace sands, of variable gradation, yellow; 9 — glacial till, brown; 10 — clay of the morainic upland, brown; 11 — glaciotectonic disturbances evidenced in the outcrops within the upland area; *1–6* — boreholes

Przekrój geologiczny A–B przez stok doliny w rejonie Suraża

1 — gleba; 2 — mursz; 3 — namuł organiczny jeziorny, czarny; 4 — ił organiczny szary; 5 — ił piaszczysty organiczny, szary; 6 — deluwia; 7 — piaski jeziorne białe; 8 — piaski różnoziarniste tarasu kemowego żółte; 9 — glina zwałowa brązowa; 10 — ił wysoczyzny morenowej, brązowy; 11 — zaburzenia glacitektoniczne obserwowane w odkrywkach na wysoczyźnie; *1–6* — otwory wiertnicze

Overall adsorption capacity of deposits in the kame terraces (medium-grained sands, predominantly) is in the range of 13–14 meq/100 g of soil. The presence of hardpan zones (or horizons that are cemented with Al, Fe, and Mn oxides as well as SiO_2) is an essential element in the geological structure of this geomorphologic unit, since they constitute an important barrier that counteracts the migration of pollution. Their importance consists in decreasing the vertical ability of solutions to flow down through the soils; in addition, they exhibit an increased chemical activity with respect to these substances. It should be noticed here that all laboratory examinations dealt with disturbed samples; this resulted in worse results than in reality. Therefore, the appearance of illuvial zones in the form of hardpan horizons should be considered extremely positive.

The slope of the upland and the fluvioglacial terraces are both covered by deluvium with slightly clayey sand, clayey sand, and fine-grained sand on a local scale. Solifluction of muddy deposits was also found (Fig. 4); they are composed of brownish clay, light brownish clayey sand, and light brownish clayey sand interfingering with sand. Their most common position is overlying the deposits of the kame terraces.

The slope deposits are composed of granular soils (fine- and medium-grained sands) as well as cohesive soils with the clay fraction in the range of 2–17% (slightly clayey sand, clayey sand and clayey and sandy silt). Illite is a dominant mineral in the clay fraction.

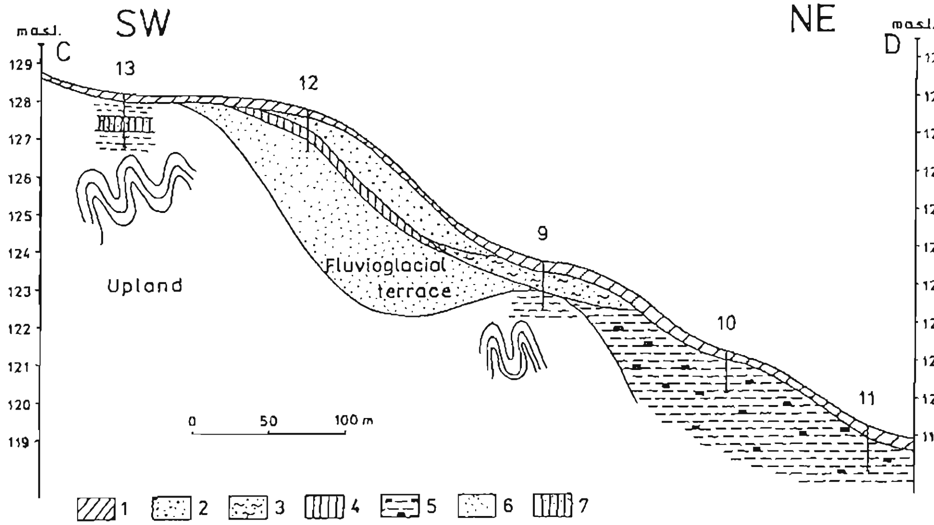

Fig. 4. Geological cross-section C–D through the slope of the Narew River valley in the Suraż area

1 — surficial soil; 2 — deluvial sand of variable gradation; solifluction: 3 — slightly clayey sand, brown, 4 — clayey and sandy silt, brown; 5 — organic lacustrine clay, greenish-grey; 6 — kame terrace sands of variable gradation; 7 — glacial till — clayey sand, brown; *9–13* — boreholes; other explanations see Fig. 3

Przekrój geologiczny C–D przez stok doliny Narwi w rejonie Suraża

1 — gleba; 2 — piasek różnoziarnisty deluwialny; spływ błotny: 3 — piasek gliniasty brązowy, 4 — glina brązowa; 5 — ił organiczny jeziorny zielono-szary; 6 — piasek różnoziarnisty tarasu kemowego; 7 — glina zwałowa piaszczysta, brązowa; *9–13* — otwory wiertnicze; pozostałe objaśnienia jak na fig. 3

With respect to hydraulic conductivity, the deposits under consideration can be reckoned among soils of medium and weak permeability; they even may be considered semipermeable (B. Kozerski, Z. Pazdro, 1990). Consequently, migration of pollution through these deposits is limited. An overall adsorption capacity is in the range of 13 to 30 meq/100 g of soil. Some portion of the deposits is enriched with the organic matter (up to 2% and even more), which forms irregular interlayers. Due to this arrangement, the sealing ability of deposits develops vertically.

In principle, lacustrine deposits make up the valley bottom. They are represented by organic mud, organic clay, and peats with intercalated sands taking the shape of embankments. Extent of the valley, braided river channel (Fig. 2), and organic character (to some extent) of the deposit are evidence that since its origin was the lake basin first, it was adopted to be a river valley as the youngest post-glacial form of the land surface here.

A high content of organic matter, up to 23%, is the characteristic feature of the lacustrine deposits occurring in the valley bottom. For the most part they are semipermeable or practically impermeable. Only organic fine-grained sand exhibit medium permeability. Illite takes a dominant position in the clay fraction (up to 57%). Overall adsorption capacity is from 15 to 46 meq/100 g of soil. Based on such features, a conclusion can be drawn that behaviour of soils in the valley bottom is not neutral in relation to pollution of different types and can restrict migration of pollution to a large extent. Participation of sandy alluvium

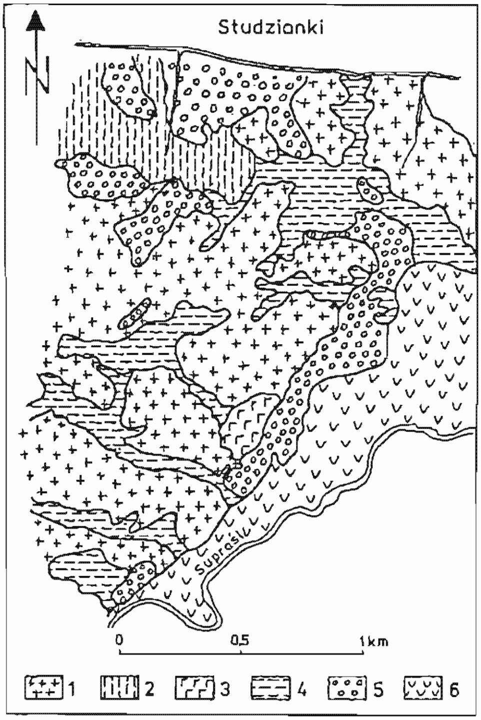

Fig. 5. Morphogenetic sketch of the Supraśl valley in the Studzianki area

1 — the morainic upland; 2 — ice-dammed basins within the upland area; 3 — deluvium; 4 — tributary valleys (of intermittent tributaries to the Supraśl River); 5 — kame terraces and kames; 6 — valley bottom

Szkic morfogenetyczny doliny Supraśli w okolicach Studzianek

1 — wysoczyzna morenowa; 2 — zastoiska na wysoczyźnie; 3 — deluwia; 4 — dolinki boczne (okresowych dopływów Supraśli); 5 — tarasy kemowe i kemy; 6 — dno doliny

is unimportant (low percentage only) and therefore, it was never subject to special study before.

Surficial soil forms a continuous cover that supplementarily protects groundwater from pollution. Its thickness is small (0.3 m only); however, the combined effect of organic matter, weak permeability, the CEC value up to 30 meq/100 g of soil, and continuity in appearance may be significantly efficient in intercepting pollution. Special care in future studies should be directed toward the surficial soil; attention should also be directed toward the Narew River alluvium.

STUDZIANKI — THE SUPRAŚL RIVER

A constricted gorge zone between the two lake basins was found in the Studzianki village area; both lake basins have been adopted to be a river valley (E. Falkowska, T. Falkowski, 1994). Similar to the area discussed so far, this region also has a morainic upland (Fig. 5) adjacent to the Supraśl River valley, with a very complicated geological structure and morphology. The area was affected by intensive glaciotectonic and glaci-isostatic processes, similar to those acting in the Suraż area, that resulted in formation of a number of extruded forms and disturbances. They are evidenced in many outcrops (Fig. 6). The material which makes up these complex, contact forms of dead-ice is differentiated and consists of gravel, sand, and silt through clayey and sandy silt, and clay.

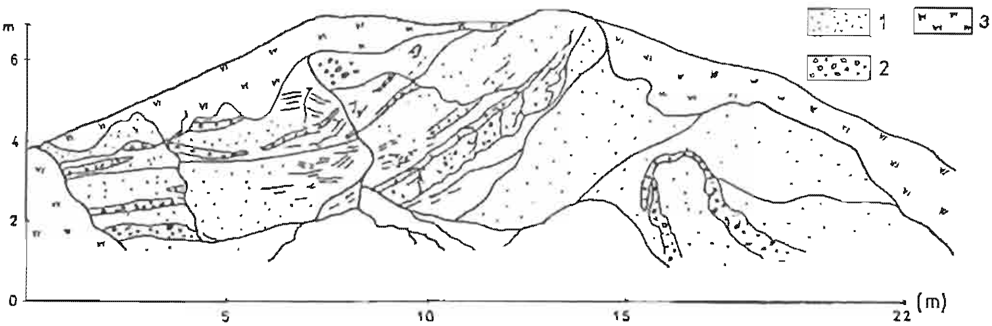

Fig. 6. An example of glaciotectonic disturbances in the glacial upland deposits in the Studzianki area (E. Falkowska, T. Falkowski, 1994)

1 — sands, 2 — gravels, 3 — surficial soil

Przykład zaburzeń glacitektonicznych w osadach wysoczyzny lodowcowej w okolicach Studzianek (E. Falkowska, T. Falkowski, 1994)

1 — piaski, 2 — żwiry, 3 — gleba

Attention should be directed toward a number of forms filled with clay and silt (Fig. 5) that are not large in size and occur among the hills. These are ice-dammed basins originated as the result of melting-out of dead-ice blocks that calved from the glacier. A broad and flat bottom is a feature typical of these forms. Today, they are fragments of "...intermittent water course valleys — tributaries to the Supraśl River ..." (E. Falkowska, T. Falkowski, 1994, p. 48). Stagnant forms were developed as the proglacial terraces of cohesive soils were built-up within the contact zone between the extruded hills and the dead-ice blocks when an undrained lacustrine-postglacial system was still in its early stage.

A "lath" of fluvioglacial terraces was found within the upland slope. Lithologically, the terraces are composed of fine-, medium-, and coarse-grained sands that are in places enriched with gravel fraction. In many locations the fluvioglacial beds are covered with deluvial deposits of variable grain-size composition depending on their origin.

Fluvioglacial deposits occurring within the valley bottom are built-up of sands and gravels; they are overlain by peaty muds and peats. Strong glaciotectonic disturbances were also found in the channel zone (E. Falkowska, T. Falkowski, 1994). Recent alluvium of the Supraśl River represents a small portion of deposits occurring here.

PARCZEW — THE PIWONIA RIVER

The valley bottom of the Piwonia River is filled with typical lacustrine sediments such as peats and organic mud (Fig. 7). Alluvium is of Recent age and fills in the recent river channel insignificantly. Also, lacustrine deposits connected with sedimentation in a shallow water environment were found covering the beds in the "lath" of kame terraces. They created a terrace system (Fig. 8), the origin of which is closely connected with drainage of lakes left as the result of melting-out of dead-ice blocks.

The hills within the morainic upland and those surrounding the lake basins are made up of variable sediments: medium- and coarse-grained sands and gravels through clayey sand

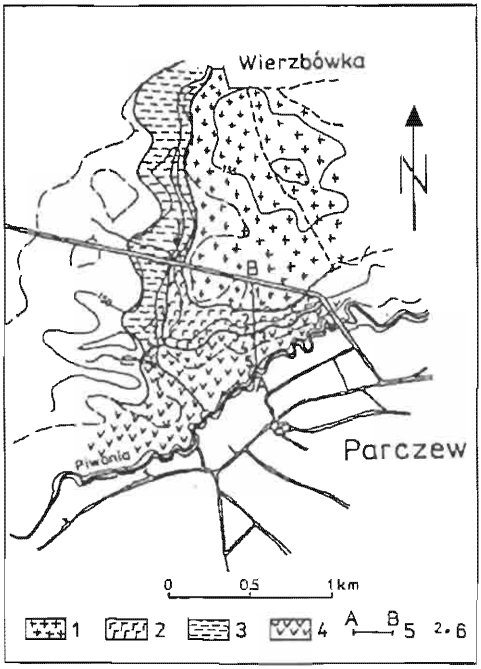

Fig. 7. Morphogenetic sketch of the Piwonia River in the Parczew area

1 — morainic upland; 2 — deluvium; 3 — tributary valley (of the intermittent tributary to the Piwonia River); 4 — valley bottom; 5 — geological cross-sections; 6 — borehole

Szkic morfogenetyczny doliny Piwonii w okolicach Parczewa

1 — wysoczyzna morenowa; 2 — deluwia; 3 — dolinka boczna (okresowego dopływu Piwonii); 4 — dno doliny; 5 — linia przekroju geologicznego; 6 — otwór wiertniczy

and clayey and sandy silt. They appear to be strongly affected by glaciotectonic disturbances. A system of flat terrace-like areas developed among elevations; they form so-called "tributary" valleys (similar to those occurring in the Studzianki area described above) and are filled in with fine-grained sediments.

Deluvium occurring in the Parczew region is a very characteristic deposit. It appears as a relatively thick cover (up to approx. 2 m) taking the shape of terraces (Fig. 8). A high degree of intermingling is observed within the deluvium material. Included in this material are small, though numerous, beds enriched in organic matter.

RECAPITULATION

Despite different extent of stadials and glacial stages, there is a good similarity of the geological structure of the three pan-like tracts of the river valleys under consideration. This is due to their origin which was restricted to the same mechanism of areal deglaciation (E. Falkowski *et al.*, 1988) that followed a repeatable sequence of events. In all three regions structures developed that are characteristic for the following order of morphogenesis: the morainic upland originated as extruded contact forms of dead-ice blocks, with very common strong glaciotectonic disturbances; the fluvioglacial terraces that are adjacent to the upland; and a series of lake basins with distinct evidences of drainage. Noteworthy is the fact that there are organic sediments occurring high above the valley bottom, which suggests that

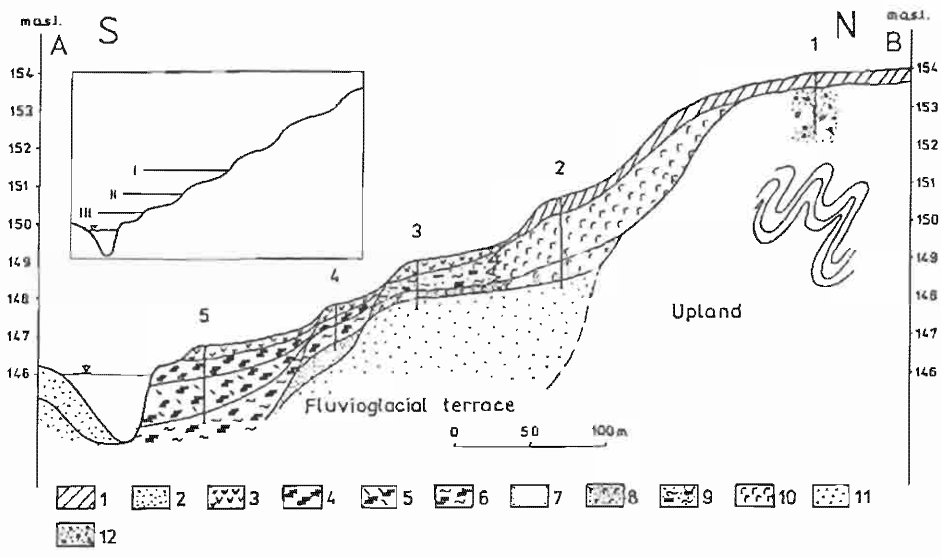

Fig. 8. Geological cross-section A–B through the slope of the Piwonia River valley

1 — surficial soil; 2 — alluvial sand of variable gradation; 3 — peat-earth; 4 — well-decomposed peat; 5 — weak- and medium-decomposed peat with organic debris; 6 — organic lacustrine mud; 7 — fine-grained sand, white, of the early phase of the lacustrine sedimentation; 8 — older deluvial laminated sands of variable gradation; 9 — organic sandy silt; 10 — younger deluvial fine-grained sands, yellowish-grey; 11 — kame-terrace medium-grained sands, yellow; 12 — sands of variable gradation mixed with gravel, variable in colour, as the deposits within the morainic upland; *1–5* — boreholes; I, II, III — extents of lake surface; other explanations see Fig. 2

Przekrój geologiczny A–B przez stok doliny Piwonii

1 — gleba; 2 — piaski różnoziarniste aluwialne; 3 — mursz; 4 — torf dobrze rozłożony; 5 — torf słabo i średnio rozłożony z detrytusem organicznym; 6 — namuł organiczny jeziorny; 7 — piasek drobny jasnoszary wczesnej fazy sedymentacji jeziornej; 8 — piaski różnoziarniste laminowane deluwialne starsze; 9 — pył piaszczysty organiczny; 10 — piasek drobny żółtoszary deluwialny młodszy; 11 — piasek średnioziarnisty żółty tarasu kemowego; 12 — piaski różnoziarniste ze żwirem różnej barwy — osady wysoczyzny morenowej; *1–5* — otwory wiertnicze; I, II, III, — zasięgi zwierciadeł wody w jeziorze; pozostałe objaśnienia jak na fig. 2

the lakes originally had a large extent. Bottoms of pans filled with stagnant-water sediments were adopted as flow-through lakes, and such a situation exludes erosional character of the exemples of river valleys described herein. Only in the final phase of post-glacial land surface development were the lake pans utilized by recent rivers to flow through and build up alluvium amongst the peats and organic muds. In no case was evidence of meander-like shifting of a river bed observed from aerial photographs. The slope deposits, whose lithology is closely connected with the morphogenesis of the valleys are site-specific and very common within all the three valleys of the Narew, Supraśl, and Piwonia Rivers. Their lithology is closely connected with the morphogenesis of the valleys.

CONCLUSIONS

1. Results of laboratory examination provide evidence that the sediments of the Narew River valley can be an efficient protective cover counteracting expansion of pollution. There is close similarity between morphogenesis of the two valley tracts under consideration to morphogenesis of the Narew River valley in the Suraż area; based on this similarity, it can be concluded that surficial soils are also of similar physical and chemical properties and therefore, similarly prospective for the protection of groundwaters in a natural way.

2. The occurrence of glaciotectonic disturbances decreases migration of pollution, since due to such processes a number of irregular and isolated bed arrangements appeared; such arrangements create barriers of very low permeability that elongate a filtration path.

3. Of particular importance for groundwater protection is the large extent within the valleys of lacustrine sediments enriched in organic matter of very high chemical activity with respect to different pollution types.

4. Recurrence of the same type of origin and geological structure of the valley tracts in the areas of Studzianki, Parczew, and Suraż suggests that there is need for further study of this phenomenon; substantial economic value of the phenomenon is not excluded.

5. Based on the recurrence of features appearing within exemple cases of the three river valley tracts from different regions in NE Poland, it can be further concluded that the same type of geological structure may be common in the Polish Lowland too; therefore, applied geology should focus on this issue.

Translated by Zdzisław Siwek

Instytut Hydrogeologii i Geologii Inżynierskiej
Uniwersytetu Warszawskiego
Warszawa, al. Żwirki i Wigury 93
Received: 12.06.1995

REFERENCES

DOMAGAŁA M. (1967) — Holoceńska ewolucja środowiska geologicznego, w dolinie Narwi koło Tykocina dla potrzeb inżyniersko-geologicznej charakterystyki terenu. Arch. Inst. Hydrogeol. i Geol. Inż. Wydz. Geol. UW. Warszawa

FALKOWSKA E., FALKOWSKI T. (1994) — Differences of lithology and sorption properties of surface deposits and their significance in protecting of extend contamination on the glacial relief area in example of Supraśl river valley (in Polish with English summary). Zesz. Nauk. AR, Wrocław, 246, p. 47–55.

FALKOWSKI E. (1970) — History and prognosis for the development of bed configurations of selected sections of Polish Lowland rivers (in Polish with English summary). Biul. Geol. Wydz. Geol. UW, **12**, p. 5–122.

FALKOWSKI E., FALKOWSKI T., GRANACKI W., KARABON J., KRAUŻLIS K. (1988) — Morphogenesis of a fluvial pattern in Biała Podlaska District in connection with a probable course of deglaciation (in Polish with English summary). Prz. Geol., 36, p. 619–630, no. 11.

KOZERSKI B., PAZDRO Z. (1990) — Hydrogeologia ogólna. Wyd. Geol. Warszawa.

LASKOWSKI K. (1970) — Charakterystyka inżyniersko-geologiczna okolic Łap w nawiązaniu do genezy form. Arch. Inst. Hydrogeol. i Geol. Inż. Wydz. Geol. UW. Warszawa.

MOJSKI J. E. (1967) — Conditions of deglaciation in the area surrounding Białystok during the Middle-Polish Glaciation (in Polish with English summary). Czas. Geogr., 38, p. 275–290, no. 3.

Ewa FALKOWSKA

ZNACZENIE POWTARZALNOŚCI BUDOWY GEOLOGICZNEJ DOLIN RZECZNYCH WSCHODNIEJ CZĘŚCI NIŻU POLSKIEGO DLA OCENY WPŁYWU ZANIECZYSZCZEŃ ANTROPOGENICZNYCH

Streszczenie

Przedstawiono badania wybranych przykładowo tzw. „odziedziczonych" odcinków dolin rzecznych. Prowadzono je dla określenia wpływu litologii i genezy występujących tam typów osadów na ich zdolności do zatrzymywania zanieczyszczeń.

Stwierdzono powtarzalność budowy geologicznej trzech wytypowanych obszarów, które obejmowały dolinę Supraśli w rejonie Studzianek, dolinę Piwonii w okolicach Parczewa oraz dolinę Narwi w okolicach Suraża. Wyniki pozwoliły stwierdzić, że opisane kotlinowate odcinki dolin charakteryzują się bardzo podobną budową geologiczną, związaną z tym samym typem deglacjacji arealnej. We wszystkich omówionych rejonach powstały typowe dla tego modelu morfogenezy struktury:

— wysoczyzny morenowe jako wypiętrzone formy kontaktowe martwych lodów z bardzo powszechnymi, silnymi zaburzeniami glacitektonicznymi;

— tarasy fluwioglacjalne;

— misy jeziorne z wyraźnymi śladami drenażu, wykorzystane w końcowym etapie rozwoju postglacjalnej rzeźby terenu przez rzeki jako trasy przepływu;

— pokrywy deluwialne.

Należy podkreślić, że osady organiczne, występujące wysoko ponad dnem, świadczą o dużym pierwotnym zasięgu jezior. Dna dolin wypełnione osadami wód stojących tworzyły przepływowe jeziora, co wyklucza erozyjny charakter opisanych przykładowo dolin rzecznych.

Osady z okolic Suraża zostały wstępnie przebadane laboratoryjnie w celu określenia ich właściwości izolacyjnych. Szczególną uwagę zwrócono na wyznaczenie ogólnej pojemności sorpcyjnej. Stwierdzono, że szereg utworów występujących na omawianym odcinku doliny Narwi może stanowić skuteczny płaszcz ochronny zapobiegający rozprzestrzenianiu się zanieczyszczeń.

Dzięki podobieństwu morfogenezy omawianych odcinków dolin należy spodziewać się, że ich grunty pokrywowe będą wykazywać zbliżone cechy fizykochemiczne i dlatego, podobnie do osadów z rejonu Suraża, będą perspektywiczne przy naturalnej ochronie wód.