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*Soil Genesis*

ROBERT CZUBASZEK*

# MINERAL COMPOSITION OF THE MATERIAL BUILDING INPEATLEND DUNES IN THE BIEBRZA RIVER VALLEY AND NAREW RIVER VALLEY**

*Abstract*. The article presents the results of the analysis of mineral composition of the material, which builds soils developed on the inpeatland dunes located in the Biebrza River Valley and the Narew River Valley. The main component of the mineral part of the studied soils is quartz, whose content indicates a relatively low degree of aeolian processes, which is also confirmed by the relatively high content of feldspar. The soils developed on the dunes in the Narew River Valley have smaller amounts of this mineral. It may indicate that they were subject to intense chemical weathering processes. This was confirmed by the results of the analysis of heavy minerals. Weathering indicators, calculated on the basis of their content, were significantly higher in the case of soils which have developed on the inpeatland dunes located in the valley of the Narew River.

Analysis of the mineral composition is necessary in order to conclude about the source, the nature of the environment of sedimentation and the processes occurring during the formation of deposits [20]. Such studies were conducted, among others, by Skiba and Skiba [22] seeking mineralogical indicators of the podzolisation process in shallow soils formed on granitoid covers. The effect of the lessivage process on the transformation and distribution of clay minerals in surface soil levels in Luvisols were shown by Kobierski and Długosz [15]. A good indicator of gleyic processes in soils proved to be lepidocrocite [25], while the presence of preserved structures composed of kaolinite in the clay fraction of soils may indicate a dominance of lithogenetic processes [24].

* R. Czubaszek, DSc.; Department of Environmental Protection and Management, Faculty of Civil and Environmental Engineering, Białystok University of Technology, Wiejska 45A, 15–351 Białystok, Poland.

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Kaczorek and Zagórski [14] used the analysis of the mineral composition in the research on micromorphological characteristics of soils containing bog iron ore. The analysis of the mineral composition may also be a criterion which allows for the separation of sediments of different formations [21], which was confirmed by the study of Kabała *et al.* [13] conducted on multiage terraces in the valley of the river Dobra. This type of analysis can also be used to determine the origin of sediments, including dunes [4, 16, 23].

Minerals are divided into light and heavy ones on the basis of their density and into resistant and non-resistant ones in terms of their sensitivity to mechanical abrasion and chemical weathering. A characteristic feature of the spatial variability of the mineral composition is a statistically significant increase in the content of quartz and minerals resistant to exogenous factors with a decrease in the content of feldspar and non-durable minerals in the heavy fraction of soils. The amount of quartz – the mineral with a high resistance to mechanical abrasion – is selectively enriched with aeolian sediments [11], and the intensity of this process expresses the length of the aeolian processes [20]. Manikowska [18] considered that the main factor causing the loss of feldspar compared to quartz is the cumulative effect of the chemical weathering processes, mechanical abrasion and crushing of the material in aeolian transport. According to Degórski [10], apart from these processes, the initial heterogeneity of the individual minerals' participation in various cycles of sedimentation and soil weathering should be considered. The information on the intensity of the chemical weathering processes is mainly provided by the calculation of the ratios between individual heavy minerals.

Results presented in this paper include part of the research on the particular characteristics of the inpeatland dunes located in the two river valleys: the Biebrza River Valley and the Narew River Valley. Complete characteristics of these objects were presented in previous papers [7–9]. They showed that the specificity of these landforms resulted from an abnormal soil-vegetation system, as well as the uncertain systematic position of the soils developed there. According to previous studies, despite a similar profile structure, the soils developed on the "Biebrza" dunes should be treated as rusty soils, while those developed in the Narew River Valley as podzols, where the disappearance of the elluvial horizon is related to the previous cultivation [6]. The aim of the research presented in this paper was to determine whether the processes identified in the soils developed on the inpeatland dunes were also reflected in the mineral composition of their originated material.

## MATERIALS AND METHODS

Studies on the mineral composition of the soils included 4 soil profiles: two located in the Biebrza River Valley (Orli Grąd and Grądy Leszczynowe); and two located in the Narew River Valley (Maliniak and Łupnik). A total of 16 soil

samples were analyzed. The light fraction was tested in a grain diameter of 0.5–0.8 mm, while the heavy minerals were studied in the fraction with a diameter of 0.06–0.2 mm after their isolation in bromoform. The indicators characterizing the mineral composition were calculated assuming that the weathering-resistant minerals were zircon, cyanite, muscovite, rutile, staurolite, topaz and tourmaline. The group of average resistant minerals included andalusite, apatite, epidote, garnet, titanium and sillimanite, while the non-resistant minerals to chemical weathering were amphibole, biotite, chlorite, glauconite and pyroxene. In this paper, the weathering indicator in Urbaniak-Biernacka [23] modification was used:

$$W_w = (MO/MN)\ MS \quad (1)$$

where: $W_w$ – weathering indicator, MN – minerals non-resistant to chemical weathering [%], MS – minerals with average resistance to chemical weathering [%], MO – minerals resistant to chemical weathering [%].

## RESULTS AND DISCUSSION

The soils developed on the studied inpeatland dunes are mainly build of the light fraction, the content of which reaches 99.8%. Heavy minerals constituted only from 0.2 to 0.6% (Table 1).

The main mineralogical component of the soil substrate is quartz, whose content ranges from 72 to 89%, with a slightly larger share of this mineral in soils developed on the dunes in the Narew River Valley. These values are lower than the results achieved from other dune fields in Poland, where the quartz content reaches 95% [4, 12, 17]. The results obtained for the deposits building inpeatland dunes indicate that a relatively low degree of the aeolian process formed this landform, which is consistent with the results obtained by Banaszuk and Kondratiuk [1] for sediments from the Szelągówka dune field located in the southern part of the Biebrza Basin. Based on the calculated weathering indicators, these authors found that in the case of this object, the low degree of the aeolian process was caused by very a short transport of the local material. The low level of the aeolian process of the dune deposits in the Biebrza River Valley, based on their structural features, was also noted by Mycielska-Dowgiałło [19].

Deposits which build the soils formed on the inpeatland dunes have varied feldspar contents (Table 1). More of this mineral, characterized by low resistance to mechanical abrasion, was found on dunes located in the Biebrza River Valley. According to Manikowska [18], the low content of feldspar in dune sediments, in addition to aeolian erosion, is also affected by chemical weathering processes. Taking into account the above-mentioned low level of aeolian processes, this type of weathering can be a major cause of the lower feldspar content in the "Narew" soils.

TABLE 1. MINERALOGICAL COMPOSITION OF THE STUDIED SOILS (% w/w)

| Object | | Horizon | Depth (cm) | Light fraction | | | | Heavy fraction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | total | among them | | | total | among them | |
| | | | | | quarz | feldspars | rocks fragments | | transparent | non-transparent |
| Biebrza River Valley | Leszczynowe | A | 0–18 | 99.5 | 78.1 | 19.2 | 2.2 | 0.5 | 81.9 | 18.1 |
| | | Bv | 18–37 | 99.5 | 83.1 | 15.1 | 1.3 | 0.5 | 82.5 | 17.5 |
| | | BC | 37–80 | 99.8 | 79.4 | 19.3 | 1.1 | 0.2 | 73.2 | 26.8 |
| | | C | < 80 | 99.8 | 81.5 | 16.4 | 1.9 | 0.2 | 74.5 | 25.5 |
| | Orli Grąd | A | 0–20 | 99.8 | 80.5 | 17.2 | 2.1 | 0.2 | 74.9 | 25.1 |
| | | Bv | 20–46 | 99.6 | 77.1 | 20.2 | 2.3 | 0.4 | 77.6 | 22.4 |
| | | BC | 46–70 | 99.6 | 76.4 | 22.4 | 0.8 | 0.4 | 73.2 | 26.8 |
| | | C | < 70 | 99.5 | 72.0 | 24.7 | 2.8 | 0.5 | 82.1 | 17.9 |
| Narew River Valley | Łupnik | AEs | 0–31 | 99.6 | 88.2 | 6.3 | 5.1 | 0.4 | 73.0 | 27.0 |
| | | Bs | 31–58 | 99.8 | 78.4 | 14.3 | 7.1 | 0.2 | 69.1 | 30.9 |
| | | BC | 58–103 | 99.8 | 80.4 | 15.5 | 3.9 | 0.2 | 74.5 | 25.5 |
| | | C | < 103 | 99.6 | 82.4 | 15.1 | 2.1 | 0.4 | 71.3 | 28.7 |
| | Maliniak | AEs | 0–24 | 99.6 | 89.4 | 7.8 | 2.4 | 0.4 | 76.3 | 23.7 |
| | | Bs | 24–56 | 99.8 | 89.1 | 8.1 | 2.6 | 0.2 | 69.6 | 30.4 |
| | | BC | 56–81 | 99.8 | 89.3 | 8.3 | 2.2 | 0.2 | 79.2 | 20.8 |
| | | C | < 81 | 99.4 | 86.1 | 11.4 | 1.9 | 0.6 | 76.1 | 23.9 |

The heavy fraction of mineral parts of the studied soils is dominated by garnets and amphiboles (Table 2). Epidotes and tourmalines can be found in larger amounts (several percent). The content of only a few percent was observed for andalusites, apatites, biotites, zircons, cyanites, rutiles and staurolites, while the content of other minerals, such as muscovites, titaniums, sillimanites and topazes, does not exceed 1%.

Taking into consideration the susceptibility of the studied soils to chemical weathering processes (Fig. 1), the average resistant minerals, especially garnets and epidotes, dominate in their mineral parts. Particularly high indicative values of the processes occurred in sediments containing garnets. This is due to the fact that, on the one hand, these sediments show average susceptibility to chemical weathering, and on the other, they belong to the group of minerals with high resistance to mechanical abrasion. Therefore, the content of garnets decreases in

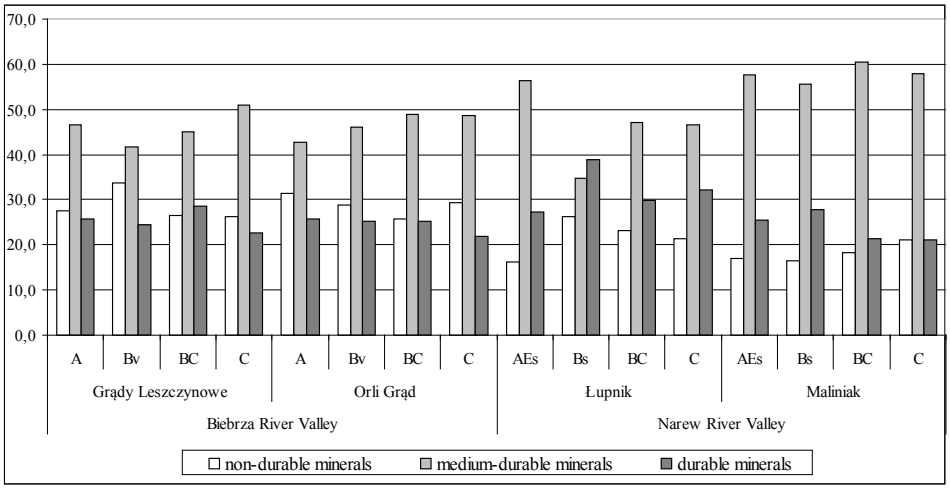


Fig. 1. The content of heavy minerals with various susceptibility to weathering (% v/v).

the soil horizons, while increasing in the repeatedly blown sediments [3]. The content of garnets in the studied soils shows some diversity. In both soils from the dunes in the Biebrza River Valley (Orli Grąd and Grądy Leszczynowe), their content increases in the soil profile, which indicates a low intensity of aeolian processes during the development of the dunes. The situation in the Narew River Valley is slightly different. In the Łupnik profile, the upper part of the profile is clearly enriched with garnets, while in the Maliniak profile, the percentage of this mineral in different genetic horizons is similar (Table 2).

The soils developed on the dunes in the Biebrza River Valley, as well as those from the Narew River Valley have a similar content of the minerals with average resistance to chemical weathering (Table 3). A slightly larger content of these minerals was found in the soil on the Maliniak dune (Narew River Valley). Greater differences between the studied objects can be observed in terms of the content of minerals resistant and non-resistant to chemical weathering processes. The quantitative ratios between the two groups of minerals are primarily varied. In material building soils developed on dunes in the Biebrza River Valley, non-durable minerals slightly outweigh the durable minerals. In the "Narew" soils, the opposite situation is observed, but the dominance of resistant minerals is very clear. This is explained mainly by higher zirconium content in the dunes in the Narew River Valley. This mineral, similar to garnet, is characterized by high resistance to physical agents [2, 5].

TABLE 2. THE CONTENT OF TRANSPARENT HEAVY MINERALS (% V/V)

| Object | | Horizon | Minerals non-resistant to chemical weathering | | | | | Minerals average resistant to chemical weathering | | | | | | Minerals resistant to chemical weathering | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | amphiboles | biotites | chloritess | glauconites | pyrocsenes | andalusites | apatites | epidotes | garnets | titaniums | sillimanites | zircons | cyanites | muscovites | rutiles | staurolites | topaz | tourmalines |
| Biebrza River Valley | Grądy Leszczynowe | A | 23.4 | 0.8 | 0.3 | 0.0 | 3.1 | 2.1 | 1.8 | 13.8 | 27.3 | 0.5 | 1.0 | 3.6 | 1.3 | 0.0 | 2.1 | 6.5 | 0.5 | 11.7 |
| | | Bv | 28.2 | 1.1 | 0.6 | 0.0 | 3.7 | 2.0 | 1.4 | 12.7 | 24.9 | 0.3 | 0.6 | 3.4 | 2.5 | 0.0 | 2.0 | 5.6 | 0.3 | 10.7 |
| | | BC | 19.6 | 1.3 | 0.5 | 0.3 | 4.7 | 2.1 | 1.6 | 11.3 | 28.8 | 0.5 | 0.8 | 5.5 | 3.1 | 0.3 | 2.6 | 7.3 | 0.5 | 9.2 |
| | | C | 19.0 | 1.7 | 0.7 | 0.2 | 4.6 | 1.0 | 0.5 | 11.2 | 37.8 | 0.2 | 0.2 | 4.9 | 3.2 | 0.0 | 2.4 | 5.4 | 0.0 | 6.8 |
| | Orli Grąd | A | 22.7 | 2.6 | 1.5 | 0.3 | 4.4 | 1.7 | 1.2 | 10.2 | 29.2 | 0.3 | 0.3 | 3.8 | 2.6 | 0.0 | 3.5 | 7.0 | 0.0 | 8.7 |
| | | Bv | 19.1 | 3.5 | 1.4 | 0.0 | 4.9 | 1.7 | 1.2 | 10.7 | 31.8 | 0.0 | 0.6 | 3.2 | 2.9 | 0.0 | 1.4 | 9.5 | 0.6 | 7.5 |
| | | BC | 17.6 | 2.9 | 1.5 | 0.0 | 3.8 | 1.8 | 1.2 | 11.7 | 33.7 | 0.0 | 0.6 | 4.4 | 3.2 | 0.3 | 1.5 | 7.6 | 0.3 | 7.9 |
| | | C | 17.5 | 4.7 | 2.6 | 0.3 | 4.4 | 1.2 | 0.3 | 8.7 | 37.9 | 0.0 | 0.6 | 1.7 | 2.9 | 0.0 | 0.9 | 7.6 | 0.3 | 8.5 |
| Narew River Valley | Łupnik | AEs | 12.0 | 0.7 | 0.4 | 0.0 | 3.3 | 0.9 | 0.2 | 7.0 | 47.9 | 0.0 | 0.4 | 8.7 | 1.3 | 0.2 | 2.8 | 5.0 | 0.2 | 8.9 |
| | | Bs | 20.0 | 1.4 | 0.7 | 0.0 | 4.2 | 2.4 | 1.2 | 14.1 | 16.5 | 0.2 | 0.5 | 12.2 | 3.5 | 0.0 | 5.4 | 7.5 | 0.2 | 9.9 |
| | | BC | 17.1 | 1.3 | 0.5 | 0.0 | 4.2 | 1.8 | 0.5 | 12.6 | 31.6 | 0.0 | 0.5 | 7.1 | 2.6 | 0.0 | 3.9 | 6.8 | 0.0 | 9.2 |
| | | C | 15.1 | 0.8 | 0.5 | 0.0 | 5.0 | 2.0 | 1.0 | 8.8 | 33.9 | 0.3 | 0.5 | 10.1 | 3.8 | 0.3 | 4.0 | 5.3 | 0.0 | 8.8 |
| | Maliniak | AEs | 10.4 | 1.8 | 1.2 | 0.0 | 3.6 | 2.7 | 1.2 | 8.9 | 44.4 | 0.0 | 0.6 | 6.5 | 3.3 | 0.0 | 1.8 | 7.7 | 0.3 | 5.9 |
| | | Bs | 10.9 | 1.6 | 0.6 | 0.0 | 3.4 | 2.2 | 1.6 | 10.3 | 40.6 | 0.3 | 0.6 | 7.2 | 4.7 | 0.0 | 2.2 | 6.9 | 0.0 | 6.9 |
| | | BC | 11.7 | 2.5 | 0.6 | 0.3 | 3.1 | 1.2 | 0.9 | 10.2 | 47.8 | 0.0 | 0.3 | 2.8 | 2.8 | 0.0 | 0.9 | 7.4 | 0.3 | 7.1 |
| | | C | 13.2 | 2.8 | 1.6 | 0.0 | 3.4 | 1.3 | 0.9 | 10.0 | 45.5 | 0.0 | 0.3 | 2.5 | 2.5 | 0.0 | 0.9 | 7.5 | 0.3 | 7.2 |

The studied objects are also diverse in terms of the weathering indicator calculated on the basis of the mineral composition [19]. In the case of the "Narew" soils, the material in the upper parts of the soil profiles is characterized by the indicator which is over two times higher than that for the material in the soils from the Biebrza River Valley (Table 3).

TABLE 3. PERCENTAGE OF MINERALS OF VARYING RESISTANCE TO WEATHERING AND WEATHERING INDICATORS OF SOIL MATERIAL

| Object | | Horizon | Depth (cm) | MN | MS | MO | (MO/MN)·MS |
|---|---|---|---|---|---|---|---|
| Biebrza River Valley | Grądy Leszczynowe | A | 0–18 | 27.6 | 46.6 | 25.8 | 43.6 |
| | | Bv | 18–37 | 33.6 | 41.8 | 24.6 | 30.6 |
| | | BC | 37–80 | 26.4 | 45.1 | 28.5 | 48.7 |
| | | C | 80–100 | 26.3 | 51.0 | 22.7 | 44.0 |
| | Orli Grąd | A | 0–20 | 31.5 | 42.8 | 25.7 | 34.9 |
| | | Bv | 20–46 | 28.9 | 46.0 | 25.1 | 40.0 |
| | | BC | 46–70 | 25.8 | 49.0 | 25.2 | 47.9 |
| | | C | 70–100 | 29.4 | 48.7 | 21.9 | 36.3 |
| Narew River Valley | Łupnik | AEs | 0–31 | 16.3 | 56.4 | 27.3 | 94.5 |
| | | Bs | 31–58 | 26.4 | 34.8 | 38.8 | 51.1 |
| | | BC | 58–103 | 23.2 | 47.1 | 29.7 | 60.3 |
| | | C | 103–150 | 21.3 | 46.5 | 32.2 | 70.3 |
| | Maliniak | AEs | 0–24 | 16.9 | 57.7 | 25.4 | 86.7 |
| | | Bs | 24–56 | 16.6 | 55.6 | 27.8 | 93.1 |
| | | BC | 56–81 | 18.2 | 60.5 | 21.3 | 70.8 |
| | | C | 81–110 | 21.0 | 58.0 | 21.0 | 58.0 |

MN – minerals non-resistant to chemical weathering, MS – minerals average resistant to chemical weathering, MO – minerals resistant to chemical weathering, (MO/MN)·MS – weathering indicator (in Urbaniak-Biernackia [23] modification).

The mineral composition of sands composing the inpeatland dunes differs from the composition of the materials on the Szelągówka dune field in the Biebrza River Valley. This applies especially to the contents of individual heavy minerals. Similar to the inpeatland dunes, the heavy fraction of the mineral soil substrate of the Szelągówka dune field is dominated by garnets and amphiboles [1]. However, they differ in terms of their quantitative relationships. Sands building the inpeatland dunes contain more garnets and fewer amphiboles. The differences in the contents of these two minerals also cause variations in the total content of groups of minerals with different susceptibility to weathering. The rusty soils on the Szelągówka dune field contain far more non-resistant minerals, as compared to the resistant ones (Table 4). A similar situation is also observed in the inpeatland dunes in the Biebrza River Valley, but here the advantage of the non-durable minerals over durable ones is small (Fig. 1).

TABELA 4. PERCENTAGE OF MINERALS OF VARYING RESISTANCE TO WEATHERING AND THE WEATHERING RATES OF SOIL MATERIAL ON THE SZELĄGÓWKA DUNE FIELD (BASED ON BANASZUK AND KONDRATIUK [1])

| Object | Horizon | MN | MS | MO | (MO/MN) MS |
|---|---|---|---|---|---|
| 1 | A | 12.8 | 41.9 | 45.2 | 148.0 |
| | Es | 11.9 | 43.4 | 44.7 | 163.0 |
| | Bs | 29.9 | 33.8 | 36.3 | 41.0 |
| | BC | 40.1 | 38.6 | 21.7 | 20.9 |
| | C | 71.0 | 18.6 | 10.5 | 2.8 |
| | G | 37.9 | 39.7 | 22.3 | 23.4 |
| 2 | AE | 42.9 | 38.0 | 19.3 | 17.1 |
| | Bv | 42.8 | 38.5 | 18.9 | 17.0 |
| | BC | 42.9 | 36.7 | 20.5 | 17.5 |
| | C | 46.4 | 38.1 | 15.7 | 12.9 |
| 3 | AE | 40.8 | 40.2 | 18.7 | 18.4 |
| | Bv | 47.9 | 36.2 | 15.8 | 11.9 |
| | BC | 36.6 | 42.5 | 20.9 | 24.3 |
| | C | 41.8 | 36.9 | 21.4 | 18.9 |

MN – minerals non-resistant to chemical weathering, MS – minerals average resistant to chemical weathering, MO – minerals resistant to chemical weathering, (MO/MN)·MS – weathering indicator (in Urbaniak-Biernacka [23] modification).

The differences in the ratios between different groups of minerals also affect the weathering indicators that are much higher in the case of the material which builds the soils on the inpeatland dunes. This concerns in particular the "Narew" soils, in which the degree of weathering of the material is also much higher than in the dunes from other parts of Poland. Both Bednarek [4], who studied soils in Tuchola Forest, and Janowska [12], who analyzed the soils in the Kampinoski National Park, received in the vast majority, significantly lower rates of weathering of the material.

## CONCLUSIONS

1. Parent material of the soils developed on the inpeatland dunes has a relatively low degree of aeolian processes, wherein a greater intensity of these processes was found for the "Narew" deposits. This is indicated by a higher content of minerals which are resistant to mechanical abrasion, such as quartz, garnets and zircons.

2. Low levels of aeolian processes of all materials and a smaller amount of feldspar in the soil material forming the dunes in the Narew River Valley, in comparison to the deposits from the Biebrza River Valley, indicates intense chemical weathering processes in the "Narew" soils.

3. The dominance of the content of minerals resistant to chemical weathering processes over the non-resistant ones in the sediments forming the dunes in the Narew River Valley and calculated on the basis of their content weathering indicators shows that weathering process observed in these dunes are more intensive than in the single dunes or dune fields in the Biebrza River Valley, as well as in the dune fields in other Polish regions.

4. Identified on the basis of the analysis of the mineral composition, the differences between the materials building the inpeatland dunes in the Biebrza River Valley and Narew River Valley indicate their distinct specificity manifested by the unusual soil-vegetation system and the diverse soil-forming processes occurring in the soils developed on these dunes.

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## SKŁAD MINERALNY UTWORÓW GLEBOWYCH BUDUJĄCYCH WYDMY ŚRÓDTORFOWE W KOTLINIE BIEBRZAŃSKIEJ I DOLINIE NARWI

Artykuł przedstawia wyniki analiz składu mineralnego utworów, z których wykształciły się gleby na wydmach śródtorfowych położonych na obszarze Kotliny Biebrzańskiej i doliny Narwi. Głównym składnikiem mineralnej części gleb jest kwarc, którego zawartość wskazuje na stosunkowo niski stopień eolizacji badanych osadów, co potwierdza również stosunkowo wysoka zawartość skaleni. Mniej tego minerału zawierają gleby z doliny Narwi, co może wskazywać, że podlegały one intensywnym procesom wietrzenia chemicznego. Potwierdziły to także wyniki analizy minerałów ciężkich. Obliczone na podstawie ich zawartości wskaźniki wietrzenia materiału były znacznie wyższe w przypadku utworów, z których wykształciły się gleby na wydmach śródtorfowych w dolinie Narwi.