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The significance of morphogenetic analysis in the assessment of soil–water conditions in Quaternary sediments

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A B S T R A C T

The landform pattern of the Polish Lowlands, which originated during and after the Warta Glaciation, is closely connected with areal deglaciation and directions of geomorphological landform evolution. Landscape-shaping processes were significant for the creation of sediment configuration and sediment characteristics of particular landforms and thus for properties of sediments. Determination of the relationships between the origin of a landform and its physical/geochemical properties can facilitate the evaluation of geological conditions carried out for land use planning that should take into account the sensitivity of the geological environment (soil, groundwater) to the migration of contaminants. The aim of this research was to find *geomorphological means of identifying* physicochemical and hydrogeological properties of Quaternary sediments that enable fast and precise assessment of long-term and recent soil–water conditions. The investigations were conducted in two areas of the Polish Lowlands that were formed during the Warta Glaciation. During geological mapping of distinguished landforms, 169 samples of sediments were collected for laboratory testing. The samples were analyzed for particle size, calcium carbonate, organic matter content, pH, permeability coefficient, CEC, and adsorption of Cd and Pb. The results show that these distinguished glacial landforms are characterized by the recurrence of superficial lithological profiles with typical physicochemical parameters. Thus, the morphogenesis of postglacial areas of central Poland formed during the Warta Glaciation has influenced the ability of surface deposits to retain contamination. A total of seven insulation classes of landforms in terms of differentiated insulating abilities of deposits, as well as the ranges of values for each insulating parameter, have been identified.

1. Introduction

Economic development should be based on the principle of sustainable development to occur in harmony with the environment and to minimally affect its individual elements. Thus, its adverse effects on the geological environment (e.g., groundwater chemistry) should be minimized. Therefore, spatial planning must take into account the sensitivity of soils to the migration of contaminants. Knowledge of this feature allows us to reliably assess the impact of economic objects on the environment and to optimize their location. To recognize the area properly in terms of the sensitivity (i.e., the capacity to insulate the groundwater from contamination), carrying out detailed studies is necessary involving the determination of lithological composition and physicochemical properties (including sorption and filtration) of deposits in the vadose zone. Characterizing the hydrogeological and geomorphological conditions of study areas is also necessary. Only such a comprehensive analysis allows the identification of the succession of geologic layers composed of soils with specific insulating parameters and allows one to determine the spatial diversity of pollution risks by identifying areas of natural geological insulation barriers. For this reason, morphogenetic analysis that is based on a credible interpretative key established for the given region (of a specified geological history) should be the basis for such activities.

In recent years, progressively more attention has been paid to the relationship of the geochemical and physicochemical properties of sediments with the morphogenesis of landscapes (Falkowska, 2009b; Griffioen et al., 2012). However, this relationship is most often emphasized in analyses of river valleys (Evans and Davies, 1994; Helios-Rybicka, 1996; Rhoads and Cahill, 1999; Ciszewski and Malik, 2004; Miller and Orbock Miller, 2007). Relatively little work, however, concerns the analysis of these properties in postglacial areas (e.g., Maxe and Johansson, 1998; Rawlins et al., 2003; Sharma and Phanikumar, 2006; Appleton and Adlam, 2012). To date, (i) a relationship between the spatial variation of insulating properties of surface deposits and the zonal lithologic pattern of a small crevasse-filled feature (an esker) in Haninge, Sweden (Maxe and Johansson, 1998), has been found; (ii) the importance of parent material to the geochemical properties of surface sediments (topsoils) in eastern England, and thus for geological structures, has been determined—the origin of these structures determines the mineral composition of sediments (Rawlins et al., 2003); (iii) it has been discovered that better accuracy is obtained by taking geological structures into account during the

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process of creating the contamination map than by basing the analysis only on the interpolation of the contents of these elements (Northampton urban area in the English Midlands; Appleton and Adlam, 2012); and (iv) the importance of the pattern and lithology of layers composing the vadose zone to the groundwater quality in the Castleford industrial zone, England (Sharma and Phanikumar, 2006), has been found. Little research on the relationship between the geochemical characteristics of insulating sediments and the geomorphological development of glacial areas was done.

The relationship between the geochemical properties of surface sediments and the lithostratigraphic variability also facilitates conducting regional studies (Van Gaans et al., 2011). This relationship was used, among others, in constructing maps of insulating properties in the Haninge municipality near Stockholm, Sweden (Maxe and Johansson, 1998) and in creating a classification of susceptibility to contamination for Quaternary sediments of different origins near Birzai, Trakai, and Kretinga, Lithuania (Holman et al., 2000). Regionalization of the insulating properties is also shown in the soil and groundwater vulnerability maps issued within the Geoscientific maps project by the Geological Survey of Finland (Nikkarinen et al., 1996).

The present study aimed to (i) find regularities in lithological and structural development of glacial landforms on the areas formed during the Warta Glaciation, (ii) investigate the relationship between the ability to retain contaminants by various types of deposits in some areas of the Polish Lowlands that were shaped during the Warta Glaciation and their morphogenesis and distribution in the geological space, (iii) relate the insulating properties of soils with the system of geomorphological features (i.e., find a geomorphological key to identify areas with different insulation properties), and (iv) create a classification of landforms in terms of the ability of their deposits to retain contaminants—the classification may be the basis for constructing maps of insulating properties of sediments.

2. Study areas

The studies were conducted in two regions of central Poland. Their landscape was shaped as a result of deglaciation of ice sheets of two stadials of the Wartanian (Wartha/Warta) Glaciation (corresponding to the Saale Glaciation in western Europe). These were (Fig. 1):

- The Bielsk Plain near Orla—formed during the Wkra Stadial (Mojski, 1972; Lindner and Marks, 1999; Brud and Kupryjanowicz, 2002); and
- The Nidzica Upland near Grzebsk—formed during the (upper) Mława Stadial (Michalska, 1967; Różycki, 1972).

The Polish Lowlands exhibit latitudinal diversification that corresponds to the limits of subsequent Scandinavian glaciations. Therefore, we assumed that the chosen areas may be regarded as typical for the assessment of soil water environmental sensitivity to anthropogenic pollution in regions formed during the Warta Glaciation. Zonation of the postglacial landscape development in Poland was emphasized by many researchers (e.g., Galon, 1972; Różycki, 1972; Lindner, 1988; Mojski, 2005).

Both analyzed areas are characterized by varied relief, although the degrees of their variabilities are slightly different. Distinct relief variations, as well as a greater extent and abundance of features, are clearly observed in the Nidzica Upland (Fig. 2). Similarities include the presence of features that suggest areal deglaciation. These include melt-out depressions, melt-out depressions within the upland, kame terraces, and eskers. However, the Nidzica Upland area is also composed of eskers and dead-ice moraines, as well as by features marking regressive stillstands of the ice sheet, i.e., terminal moraines (Michalska, 1967; Mojski, 1972; Bałuk, 1979; Falkowski et al., 1988; Musiał, 1992; Uniejewska, 2001; Brud and Kupryjanowicz, 2002).

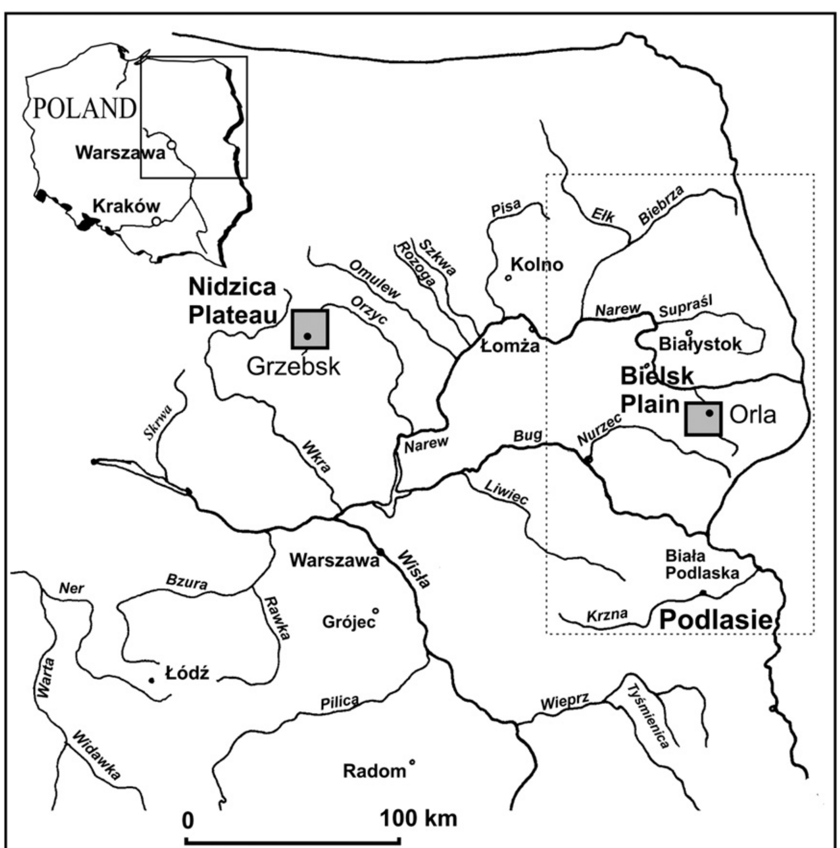

Fig. 1. Location of the study areas.