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Genetic interpretation of micromorphological features of gully loess-soil deposits (case study: Kolonia Celejów, E Poland)

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Abstract: Five complex soil profiles in gully system on Nałeczów Plateau (E Poland) were examined. They represent the loess sediments modified by soil processes and postpedogenic transformations. Two examined profiles represent natural and mature Luvisols with diagnostic illuvial horizon (Bt argillic) developed on the edge of plateau geomorphologic level and in the relict valley bottom. The other soil profiles reflects postpedogenic soil degradation, redeposition and secondary accumulation (deluvia, colluvia and/or proluvia). Record of these processes are the micromorphological features created by lithological processes (=primary loess and secondary pedoliths) or by pedogenesis (mainly bioturbation, illuviation, de- and recalcification). The important group of microfeatures are pedorelicts which clearly confirm genetic dependences of pedoliths (deluvia and proluvia) and soils developed *in situ* and located in higher hypsometric levels in the catchment.

Keywords: gully erosion, loess, pedogenesis, soil degradation, micromorphology

Introduction

Micromorphological method is mainly used in pedology to describe the soil processes and specify the typology of soils (e.g. Bullock et al. 1985; Stoops 2003). Therefore, its main role is evidence the individual and specific microforms created by definite soil process or the group of microfeatures which reflect the multi-stage evolution of soil cover. For this reason, micromorphology has found wide application in studies of polygenetic sediments and soils, in particular the Quaternary loess-paleosol sequences (e.g. Kemp 1999, 2001, Mroczek 2008).

Usually, very complex nature – like described above – have gully sediments filling the bottoms, slopes and fossil piping channels or forming the accumulation layers next to the erosion edges. Their primary location is commonly associated with degraded and redeposited layers originally situated in higher geomorphologic areas in the catchment. Finally, their homogeneity impedes the indication of primary sources of gully sediments, especially in clastic materials filling the bottoms as so-called *proluvia*. However, the use of micromorphology in research of redeposited sediments enable to indicate the alimentation sources through the identification of specific older and relict microfeatures created by litho- and pedogenic processes. These microforms allowed to detail the genesis and specify the ways and character of transport (e.g. Mroczek 2008).

Materials and methods

The selection of the study areas was based on previous field works and on earlier studies in the western part of northwest part of Lublin Upland (e.g. Rodzik & Zgłobicki 2000; Rodzik et al. 2009). The area is located in Nałęczów Plateau, adjacent to the Vistula River valley (Fig. 1). The main surface rocks are loess and loess-like sediments (max. thickness 30 m), where the relative relief reaches up to 90 m and the average density of the gully network – ca. 2.5 km km^{-2}.

Micromorphological analyses were conducted in four loess-soil profiles located within the gullies dissecting the system of dry valleys in the Kolonia Celejów on the Nałęczów Plateau (Rodzik et al. 2009). The examined exposures differ mostly in their geomorphological situation, degree of soil develop-

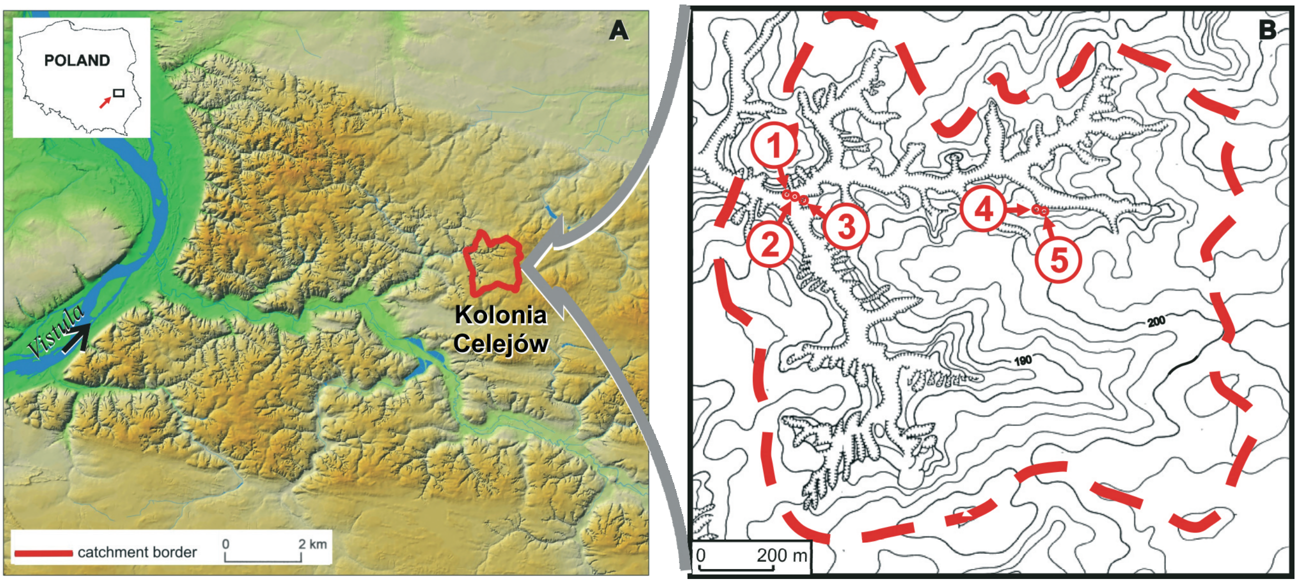

Fig. 1. Location of the Kolonia Celejów on western part of Nałęczów Plateau (A) and soil profiles in the gully, mentioned in the study (B)

ment, and kind of possible postpedogenetic transformations (Fig. 2). Soil horizons were described using the terms outlined by Reuter (2000). Soil profiles description is as follows:

- profile 1: Buried Luvisol with the profile 1Adel-2fA-2fAEet-2fBt-2fC-2fCca, developed in the top of loess remnant (deluvial loess) in the escarpment of gully dissecting the valley bottom;
- profile 2: Initial deluvial soil with the profile Adel1-Cdel1-Cdel2, developed on the gully bottom and accessible in a dissection of proluvial deposit cover;
- profile 3: Tripartite deluvial-colluvial sequence with the profile 1Adel-2Bt-3C, accessible in the gully escarpment, in the inactive suffusion kettle dissecting the valley slope;
- profile 4: Truncated and buried Luvisol with the profile 1Adel-2fBt1-2fBt2-2fC-2fCca, accessible in the gully escarpment, in the reactivated suffusion kettle dissecting the valley slope;

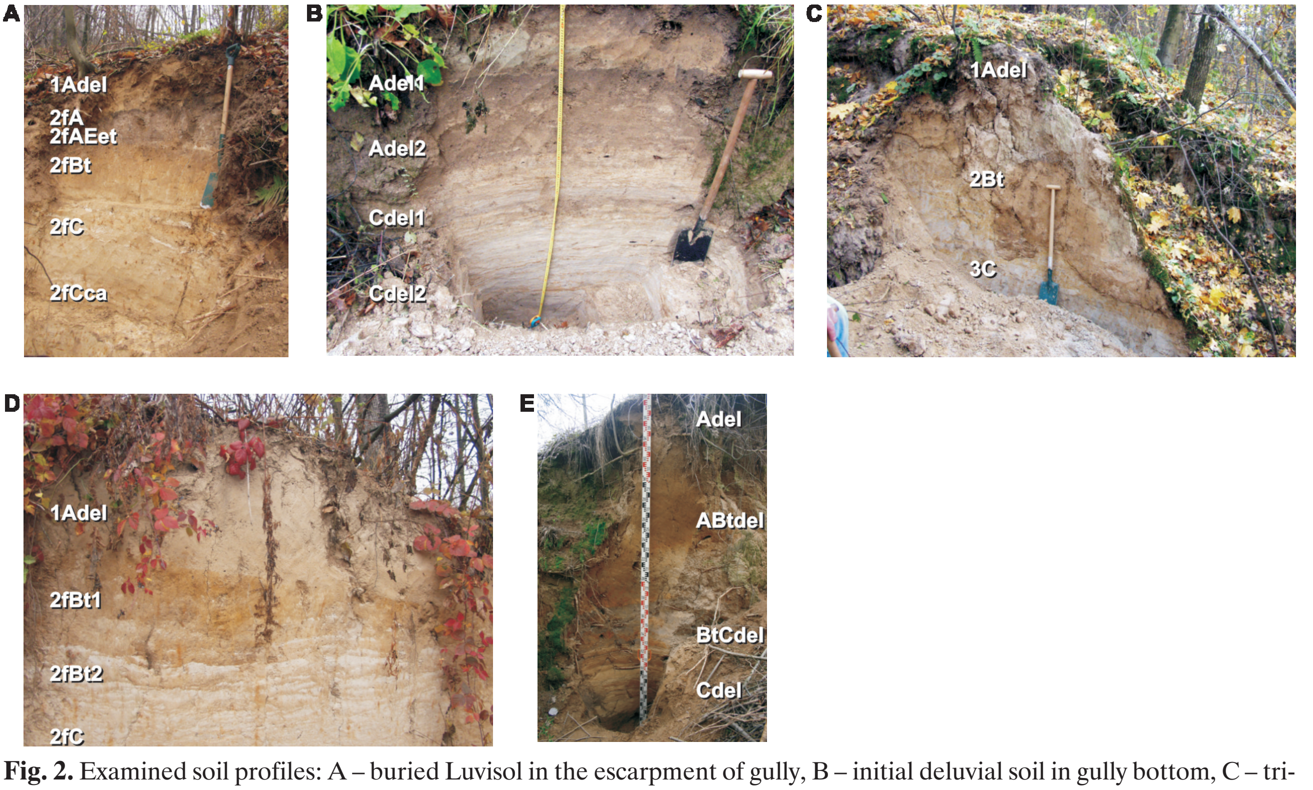

Fig. 2. Examined soil profiles: A – buried Luvisol in the escarpment of gully, B – initial deluvial soil in gully bottom, C – tripartite deluvial-colluvial sequence in the gully escarpment, D – truncated and buried Luvisol in the reactivated suffusion kettle, E – sequence of soil deluvia in the reactivated suffusion kettle

– profile 5: Sequence of soil deluvia with the profile Adel-ABtdel-BtCdel-Cdel filling the reactivated suffusion kettle (opposite the profile 4).

The undisturbed samples were collected using standard (80×60×40 mm) Kubiena tins for safe transport back to laboratory for impregnation with crystic resin. The technique adopted the approach of Lee & Kemp (1992) and Mroczek (2008) to produce approximately 30-micron thick thin sections (7×5 cm^2). More than 30 thin sections were analysed under plane and polarized light. Samples were described using the terms outlined by Bullock et al. (1985) and Stoops (2003).

Results and conclusions

Micromorphological analyses (see Table 1) enable us to draw the following genetic conclusions:

1. The mature soils (profiles 1 and 4) belonging to Brownearths type contain preserved and rather well developed Bt horizon with features of argic diagnostic endopedon. Illuvial clay coatings and infillings in channels and pore space are its representative and diagnostic microfeatures;
2. The products of redeposition of soil horizons occur as the infilling of suffusion kettle (profile 5) and as deluvia (so-called agricultural diamictons, profiles 3, 4 and 5). This fact is mainly evidenced by pedorelict features of these deposits (according to Fedoroff & Goldberg 1982 and *vide* classification proposed by Mroczek 2008). From among all distinguished micromorphological features, the following belong to pedorelicts: illuvial papules and angular Fe and Fe-Mn nodules, and similarly looking amorphous pieces of charcoal, Their primary soil origin is confirmed by optical features and size resembling the forms occurring *in situ*, as well as pebble-like shape indicating rounding of primary microforms during their redeposition (rather short transport);
3. The Bt horizon of mature soil (profile 3) was redeposited *en bloc* without additional deformation. Micromorpho-logical record confirms its illuvial origin and lack of connection with the overlying epipedon 1Adel (diamicton) and underlying endopedon 3C (primary loess). This horizon can be recognized as typical colluvia composed exclusively of material from the Bt-argic soil horizon.

Proluvia covering the modern bottom of gully (profile 2) are the products of redeposition of primary loess and soils developed on it, which were transported at longer distance and more mixed (homogenized) than the materials mentioned above. This fact is unambiguously indicated by pedorelict features, which are considerably more rarely found and individual microforms have smaller diameters, as well as by the occurrence of lithogenic carbonate microforms (microsparite and sparite crystals.

The conducted analyses enable us to evidence the record of natural postglacial pedogenesis in the form of Luvisol profiles with the diagnostic Bt-argic soil horizon in plateau-slope and valley bottom positions. Their age is older than that of gully system. The complex of micromorphological features distinguished in the C horizon (parent material) of these soils has remarkably lithogenic nature so they developed on primary loess.

Pedorelict features of the redeposited sediments indicate their alimentation sources. Moreover, they evidence a gradual obliteration of pedogenic features with the transport length. These features enable us to reconstruct the sequence of events: sedimentation → pedogenesis → degradation → transport → deposition, with partially still preserved their soil nature.

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Table 1. Micromorphological record of soil profiles in Kolonia Celejów catchment; the frequency of features is recorded in number of dots: one (■) mark single, and four ■■■■) common presence; the diameters are in microns; microstructures: m – massive, ch – channel, f – fissure; carbonates: M – micrite, Ms – microsparite, S – sparite

Soil horizons	Microstructers	Calcitic microfeatures							Clay & dust microfeatures					Fe microforms					Fe-Mn microforms					Organic mater				Excrements	
				coatings			infillings		clay mcroforms					nodules					nodules					cells		charcoals			
		calcitic b-fabric	crystals	hypocoatings	inside channels	inside fissures	inside channels	inside fissures	continuous coatings	continuous infillings	deformed	papules	dusty-clay microfeatures	with sharp boundries	iffuse	with ring	ferrous background	ypocoatings	ith sharp boundries	diffuse	with hypocoating	aggregates	pseudomorph with hypocoating	with structure	amorphic	with structure	amorphic	single	loose infillings
Profile 1: Buried Luvisol																													
1Adel	m-ch											■ 500		■■■ 400			■							■■■ 1000	■■ 1000		■■■ 800	■ 1000	
2fA	ch-m																	■■ 400						■■ 1000			■ 1000		■■■ 1000
2fAEet	ch									■ 800					■■ 400		■■■■	■■ 400			■■■■ 500						nnn 1000		
2fBt	ch-f								■■■ 300	■■ 1000	■■ 1000				■■ 500		■■■			■■■ 500	■■ 500								
2fC	ch-m		■ Ms	■ M	■ M										■■■ 400		■■■			■■ 500	■■ 400	■■■ 500							
2fCca	ch-m	■■■■	■■■■ S	■■■■ M	■■■■ M	■ M	■■■■ M	■ M							■■■ 400		■■■	■ 200		■■■ 500	■■ 600	■ 700							
Profile 2: Initial deluvial soil																													
Adel1	m-f	■■■	■■■ M, Ms, S	■■ M		■■ M		■■ M				■■ 200	■■■ 500	■■ 300			■■	■■ 300	■■ 100						■ 300		■■ 100	■ 300	■■■ 500
Cdel1	m-ch	■■■■	■■■ M, Ms, S					■■■ M				■ 100		■■ 300			■■		■ 100	■■ 100		■■■ 300			■■ 300	■■ 200	■■ 100		
Cdel2	m	■■■■	■■■ M, Ms, S									■■ 100		■ 300			■■■■		■■ 200						■■ 200				

Profile 3: Tripartite deluvial-colluvial sequence																													
1Adel	m-ch	■■■■	■■ Ms, S											■■ 500					■■■ 600					■■■ 800	■■ 800		■■■ 1000		■■■ 1000
2Bt	ch-f									■■■■ 700	■■■■ 1000	■■ 500																	
3C	ch-m	■■■■	■■■■ S	■■■■ M	■■■■ M		■■■■ M			■ 1000	■ 800												■■ 600						
Profile 4: Truncated and buried Luvisol																													
1Adel	ch-f	■■										■■ 400		■■■ 500			■■		■■■■ 500					■■ 1000			■■■■ 1000		■■■ 1500
2fBt1	ch-f								■■■■ 1000	■■■■ 1100					■■■ 700														
2fBt2	ch-f								■■■■ 1000	■■■■ 800					■■■ 600														
2fC	ch-m		■ Ms												■■ 400														
2fCca	m-ch	■■■■	■■■ Ms, S	■■■■ M	■■■■ M		■■■■ M								■■ 600		■■	■■ 500											
Profile 5: Sequence of soil deluvia																													
Adel	m-ch	■■■	■■■ Ms, S	■■■■ M	■■■■ M		■■■■ M					■■ 500		■■ 500			■■■	■■ 500	■■■ 400					■■■ 1000			■■ 1000		■ 1000
ABtdel	m-ch	■■■	■■■ Ms, S									■ 500		■■■ 500			■■		■■ 500					■■ 1000			■■■■ 1000		
BtCdel	m-ch	■■	■ Ms, S		■■ M,Ms,S							■■■■ 800		■■■■ 600					■■ 600						■■■ 1000		■ 1000		
Cdel	m-ch	■■■■	■■■ S		■■■ S		■■■ S					■ 400		■■■■ 500			■■	■■■ 500	■■ 500								■■■ 800		

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