Geological Quarterly, 2007, **51** (2): 179–184

Sedimentary environments of the Late Pleistocene terrestial deposits at Kolodiiv (East Carpathian Foreland, Ukraine) in the light of elementary and aggregate grain-size composition

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Seul C. (2007) — Sedimentary environments of the Late Pleistocene terrestial deposits at Kolodiiv (East Carpathian Foreland, Ukraine) in the light of elementary and aggregate grain-size composition. Geol. Quart., **51** (2): 179–184. Warszawa.

The results of grain-size analysis of silt deposits from the Kolodiiv site are presented. The seven profiles examined are situated on the terrace of the Sivka River, along a *ca*. 1 km stretch of its right bank. They comprise Wartanian alluvial sands and gravels overlain by Eemian deposits and Vistulian loess. The average results of aggregate and elementary analyses of selected stratigraphic units, standard grain-size indices, and some aggregation indices are shown. The results obtained indicate that initial loess material deposited in Kolodiiv was generally not differentiated. Only the youngest palaeosols and the younger loess deposits are enriched in silt, which may suggest lower velocities of wind transporting the material or a change in source material (e.g. from sandy-silty flood sediments to clayey lacustrine sediments). Some changes in source material, transportation force or redeposition of material (e.g. by slope processes) may be deduced from the variable skewness and flatness of the grain-size distribution, both aggregate and dispersion.

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Key words: Kolodiiv, loess section, aggregate grain-size, elementary grain-size.

INTRODUCTION

The source material of loess deposited in the region of Kolodiiv originates mainly from the Carpathian, Podolian and other neighbouring regions. This material was partially segregated *in situ* by weathering processes. Further segregation occurred during transport (mainly aeolian). The material was submitted to hypergenetic processes during deposition and redeposition. Less resistant components could be completely destroyed during weathering and pedogenesis.

Grain-size analyses were made for samples taken at the Kolodiiv site. The seven profiles examined occur along a stretch of the Sivka River terrace almost 1 km long (Fig. 1). The Sivka River is a right tributary of the Dniester River with its estuary about 1 km north of Kolodiiv. The profiles, with thicknesses of up to 20 m, are exposed in the terrace scarp, and consist of deposits from the Wartanian Glacial, Eemian Interglacial and the entire Vistulian Glacial. More than 160 samples were analysed. The average values of aggregate and elementary grain-size, and graining and aggregation indices for each stratigraphic unit were calculated.

The stratigraphy of these sections were described by Łanczont and Boguckyj (2002). Some results of the aggregate and elementary (dispersion) grain-size analyses for the Kolodiiv have been discussed in previous papers (Racinowski *et al*., 2000, 2003; Seul, 2002).

METHODS

Loess sediments are formed of individual mineral grains of different sizes (e.g. quartz, feldspars, muscovite, heavy minerals and very fine clay minerals) and their aggregates.

Aggregates are clusters of different sized grains of quartz, calcite, mica and other minerals. Substances that glue them together (cement) are clay minerals, iron and manganese compounds, calcium carbonate, organic substances and so on. Some of these clusters can be disintegrated with distilled water. Most aggregates are stable and make an integral part of mineral skeleton. However, they are less hard than mineral grains of the same size. The physical and chemical properties of aggregates change under the long-term influence of soil water (e.g.

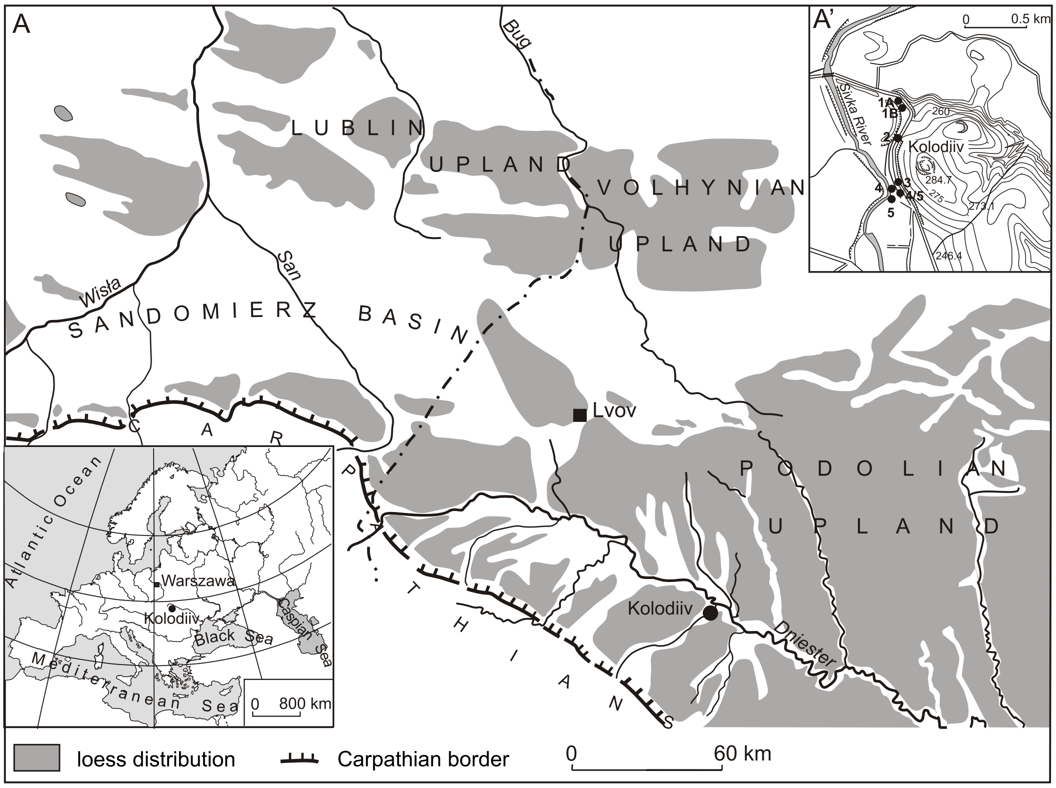

Fig. 1. A — location of profiles investigated at Kolodiiv; A' — sketch map of loess regional distribution (after Łanczont and Boguckyj, 2007)

Prikłoński, 1955; Grabowska-Olszewska *et al.*, 1977; Grabowska-Olszewska, 1990).

Some aggregates are initial, and syngenetic with formed loess. Part of these are destroyed whereas other, new, aggregates are created as a result of hypergenetic processes, especially soil processes. These issues were discussed in works by Jersak (1973) and Dwucet (1993), who investigated aggregates from the chemical point of view and by using microscope methods.

Grain-size analyses of loess samples from the Kolodiiv site were made using the areometric method (after Casagrande — according to the standard PN–88/B–04481). First, the suspension was dispersed in distilled water with the use of magnetic mixer. After filling measurement cylinders with this suspension, a manual mixer was applied several times, and density measurements were made. Such analysis has been named aggregate (microaggregate) analysis. Then after adding a peptising agent (a mixture of six-methane-phosphate of sodium and anhydrous sodium carbonate according to the standard PN–76/9180–06), and mixing several times, density measurements of suspension were made after one day. This analysis has been named dispersion (elementary) analysis. Then the suspension was put through a sieve with mesh dimensions of 0.04 mm, then dried and sieved through sieves with mesh dimensions at 1φ intervals (1.0, 0.5, 0.25, 0.125 and 0.063 mm) and additionally through a 0.05 mm sieve. During evaluation of grain-size analysis results of loess sediments, ranges of substitute diameters for silt fraction were also used, at 1φ intervals (0.0313, 0.0156, 0.0078, 0.0039 and 0.002 mm), and smaller than 0.002 mm, which reflects the content of the clay fraction.

Standard grain-size indices after Folk and Ward (1957), and some aggregation indices were calculated from the grain-size distributions obtained both for aggregate and elementary analyses. The results are shown in Table 1.

Spatial changes in mean grain diameter (*Mz*), can indicate either transport direction of aeolian silts (material fines down the transport path) or wind force (with higher wind velocity, coarser material is transported, giving values of *Mz*). Changes in wind velocity during deposition can be inferred on the basis of sorting (σ_1). Low values of the sorting index can indicate constant wind velocity during deposition. High values of sorting index suggest changeable wind speeds during sediment deposition. The skewness of grain-size distributions (Sk_1) gives information about deflation processes. Values lower than the average calculated for a given profile suggest a predominance of deflation, while higher values characterise free deposition of silts. The values representing normal distributions indicate equilibrium between deposition and redeposition. The kurtosis index (K_G) reflects the character of the depositional process. Curves flatter than normal distributions indicate mass deposition of mineral material, while steeper curves suggest a dominance of deflation (Racinowski *et al.*, 2001; Seul *et al.*, 2001).

The direction of material transport and the intensity of deposition (or redeposition) may be deduced from grain-size composition. Aggregate grain-size indices depend on the properties of material transported by aeolian processes, which usually consists of cemented silt grains (Jersak, 1973), and also on the conditions of diagenesis.

Aggregation indices inform about structure stability (Vogeler index), about aggregate stability (Denisov index) or

Table 1

The Kolodiiv site, averaged values for selected stratigraphic units

Symbol	Stratigraphic units after Łanczont and Boguckyj (2002)	Fraction content [%]			Grain-size indices after Folk and Ward (1957)			
		sand	silt	clay	*Mz*	σ_1	Sk_1	K_G
			A D	A D	A D	A D	A D	A D
S0	Holocene soil S0	17.8	81.6 65.4	1.4 17.6	5.20 6.16	1.23 2.08	0.31 0.35	1.34 0.93
L1	Krasyliv and Rivne units L1-l1	22.7	76.8 63.3	1.1 14.1	5.17 6.16	1.34 2.08	0.15 0.35	1.29 1.05
	Upper Pleniglacial loess L1-l1	31.1	67.4 57.7	1.4 11.2	4.94 5.53	1.48 2.10	0.15 0.29	1.24 1.10
	Dubno 1 set of palaeosols L1-s1	25.1	72.9 65.4	2.1 9.4	5.16 5.64	1.48 1.98	0.24 0.30	1.24 1.06
	Middle Pleniglacial loess L1-l2	35.5	63.2 55.6	1.2 8.9	4.83 5.32	1.43 1.99	0.17 0.33	1.21 1.05
	Dubno 2 set of palaeosols L1-s2	51.1	47.6 40.0	1.4 8.8	4.43 4.88	1.52 2.12	0.22 0.43	1.13 1.14
	Lower Pleniglacial loess L1-l3	49.2	49.7 42.6	1.1 8.3	4.38 4.78	1.38 1.95	0.19 0.37	1.21 1.36
S1	Kolodiiv 1 palaeosol S1-s1	51.6	47.6 41.8	1.1 6.6	4.32 4.79	1.41 2.03	0.15 0.39	1.20 1.12
	Loess between Kolodiiv 1 and 2 palaeosols S1-l1	42.8	56.5 50.5	1.2 6.7	4.43 4.96	1.34 2.00	0.15 0.41	1.36 1.19
	Kolodiiv 2 palaeosol S1-s2	42.7	56.0 45.5	1.5 11.8	4.53 5.25	1.44 2.23	0.15 0.38	1.26 1.01
	Loess between Kolodiiv 2 and 3 palaeosols S1-l2	38.5	59.7 46.7	1.8 14.8	4.64 5.44	1.57 2.35	0.17 0.32	1.29 0.89
	Kolodiiv 3 palaeosol S1-s3	23.2	74.6 56.2	2.4 20.6	5.14 6.29	1.36 2.14	0.35 0.17	1.19 0.83
	Eemian pedocomplex SS1 (I+II)	33.5	64.0 50.0	2.6 16.6	4.86 5.67	1.50 2.17	0.22 0.26	1.13 0.97
Alluvial deposits (equivalent of L2)	Wartanian alluvial muds	35.0	64.3 53.5	0.7 11.5	4.60 5.31	1.26 2.14	0.07 0.39	1.24 1.24
	Wartanian alluvial sand deposits	53.0	46.9 42.0	0.7 5.0	4.13 4.29	1.34 1.74	0.26 0.42	0.89 1.18
Average values	Kolodiiv profiles — without alluvial deposits	35.6	63.0 52.4	1.5 11.9	4.76 5.43	1.41 2.10	0.19 0.33	1.24 1.07

Fraction content according to aggregate (A) and dispersion (D) analyses; *Mz* — mean grain diameter, σ_1 — sorting index, Sk_1 — skewness index, K_G — kurtosis index

structural bonds (Gorkova index), and are also helpful in the distinction of soils. The comparison of standard indices of dispersion and aggregate grain-size with aggregation indices can be helpful in distinguishing, for example, layers affected with weak pedogenesis with sections.

GENERAL GRAIN-SIZE EVALUATION OF LOESS DEPOSITS FROM KOLODIIV

It may be concluded on the basis of aggregate grain-size analysis that the majority of loess deposits can be classified as silts (younger Vistulian deposits) and sandy silts (older Vistulian and Wartanian deposits). The average content of sand fraction in the stratigraphic units distinguished is 35% and varies from 15% for contemporary Holocene soil to over 50% for an older unit representing the interstadial Dubno 2 soil with the underlying loess (L1-l3) and the interstadial Kolodiiv 1 soil (S1-s1). The coarse silt fraction (0.063–0.02 mm) is predominant in the aggregate grain-size. The average content of silt in these profiles varies from 50.7 to 75.0%, and the content of the clay fraction varies from 1.3 to 2.8% (Fig. 2). Loess deposits transformed by pedogenesis, namely palaeosols, are characterised by a slightly higher content of clay fraction than loess layers not so transformed. For aggregate analysis, the mean grain diameter (*Mz*) is 4.76φ, and the sorting is weak (σ_1) and aver-

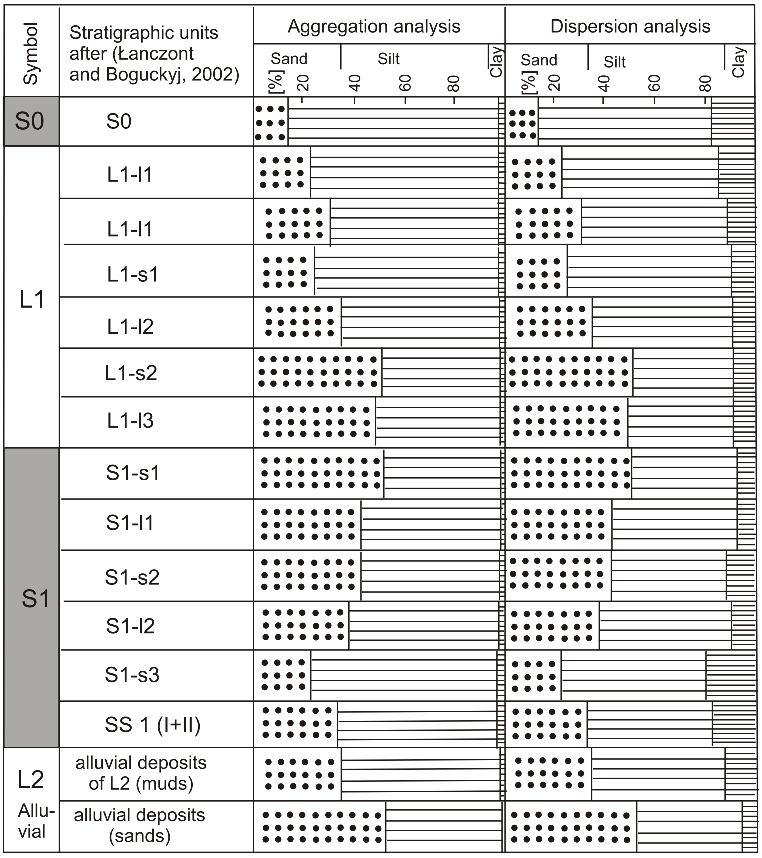

Fig. 2. The Kolodiiv site; percentages of particular fractions obtained by aggregate and dispersion methods

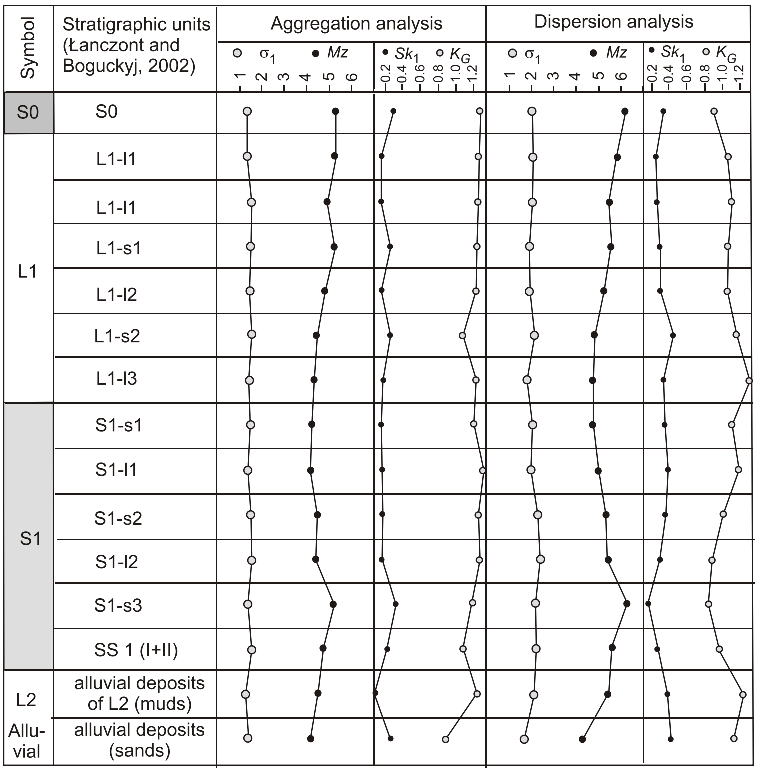

Fig. 3. The Kolodiiv site; grain-size indices after Folk and Ward (1957) for aggregate and dispersion analyses

ages 1.41. Grain-size distributions are close to normal with positive skewness (Sk_1 averages +0.19), and more steep than normal with a sharp maximum (K_G averages 1.24; Fig. 3).

The same sediments subjected to dispersion (elementary) analysis were classified as silts, silty loams, and loams. The silt fraction is also predominant (it varies from 40 to 65% on the average) but mostly is within the range of 0.0312–0.008 mm. The average content of clay fraction is over four times higher than that determined by aggregate analysis. Part of this fraction may be related to the disintegration of aggregates of the silt fraction (Fig. 2).

The mean grain diameter is about 5.4φ, and sorting (σ_1) is very weak (it averages 2.1). Grain-size distributions are close to normal (K_G averages 1.1) with a distinct maximum. They are characterised by a positive skewness (Sk_1 averages +0.30). Palaeosols are characterised by slightly higher values of mean grain diameter (*Mz*), lower values of sorting index (σ_1), and variable values of Sk_1 and K_G, both for aggregate and dispersion analyses.

The range of grain-size indices is shown in Figure 3. The silt and clay fractions as determined by dispersion analysis (elementary) in comparison with aggregate (micro-aggregate) analysis of loess deposits may be noted.

The average aggregation indices calculated for selected stratigraphic units weakly characterize the deposits at Kolodiiv (Fig. 4). Observation of the diagram of aggregation indices, shows that only differences between the deposits representing the Eemian–Early Vistulian soil succession (Horohiv) and the Middle and Upper Vistulian loess may be noted.

CONCLUSIONS

Aggregate grain-size reflects properties of material transformed during transport, deposition and redeposition. Based on the results of aggregate analysis, the material in the profiles investigated is mostly classified as silts and sandy silts.

Dispersion (elementary) grain-size characterises the initial material from which the examined deposits originated. The majority of these are classified as silts and silty loams. Part of the material (e.g. gleyed horizons) is defined as silty loams or even clays.

The aggregate and elementary analyses indicate that the initial loess material deposited in Kolodiiv was generally uniform. Only the youngest palaeosols and younger loess complex are enriched in silt, which may suggest lower velocities of wind transporting the material or a change in source material (e.g. from sandy-silty flood sediments to clayey lacustrine sediments).

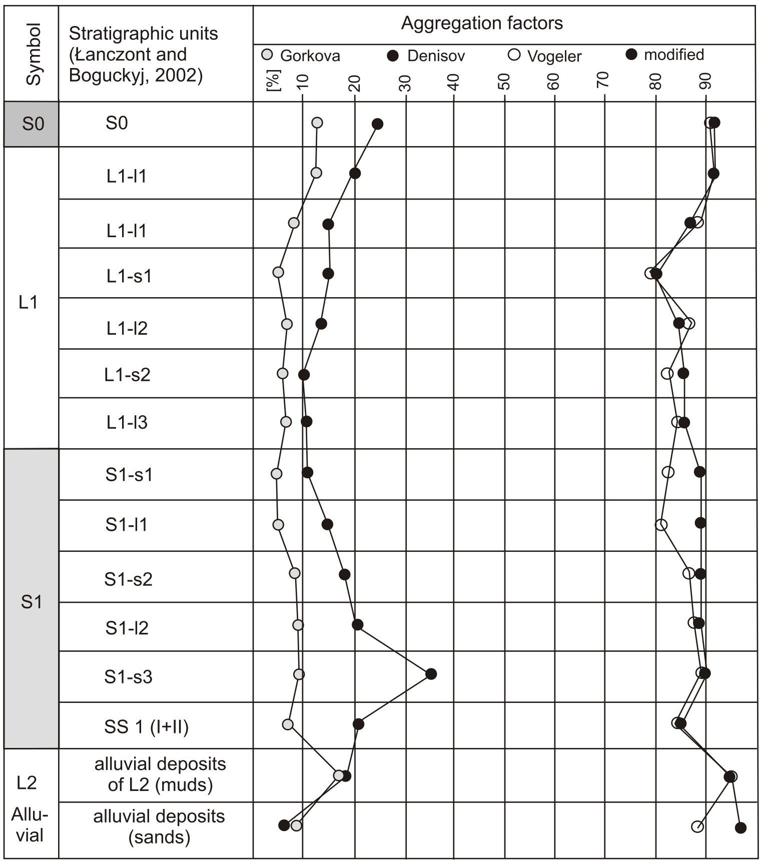

Fig. 4. The Kolodiiv site; some aggregation indices for particular stratigraphic units

Some changes in source material, wind speed or amount redeposition (e.g. by slope processes) may be deduced from the variable skewness and flatness of the grain-size distribution, both aggregate and dispersion. Differences in grain-size composition observed in the profiles examined is less evident when comparing the average values calculated for particular stratigraphic units. However, some differences in grain size are present between palaeosols with different degrees of transformation and typical loess material. A little finer material occurs in those deposits that were transformed by pedogenesis. The loess layers that did not undergo significant pedogenesis are characterized by a more homogeneous grain-size composition.

During the entire Vistulian period with its changeable climatic conditions, mineral material underwent redeposition and transformation many times. Using grain-size composition, it will be possible to deduce local and general directions of silt transport only after completing the research on the lithology and stratigraphy of the Vistulian deposits in the Halyč Prydnistrov'ja region.

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