THE LOESS-LIKE DEPOSITS IN THE LOWER DANUBE BASIN. GENETIC SIGNIFICANCE

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Abstract. The main goal of this study is the sedimentogenesis of the loess-like deposits in the Lower Danube Basin. A pros and cons genetic analysis of these deposits is carried out in the paper. Resulting from this analysis, the optimal logical solution to explain the distal loess-like sedimentation in the Lower Danube Basin is the joint action of the alluvial and eolian processes. The initial alluvial sedimentation (not solely by overbank flows) could have been continued and extended by the eolian action. The loess-like deposits of the Lower Danube Basin are sedimentary accumulations of primary genesis.

Key words: loess-like, loess, Lower Danube Basin, alluvial, floodplain, eolian.

1. INTRODUCTION

Lack of significant data has always made the sedimentogenetic investigation of the loess deposits in the Lower Danube Basin a challenging task to tackle. The origin of the Lower Danube loess-like deposits is even more challenging.

The main goal of the present paper is to investigate the primary genetic history of the Lower Danube Basin loess-like facies. The study focused on the processes and environments of the loess-like detrital material accumulation.

The area of investigations is the basin of the Lower Danube River (Fig. 1). The Southern Carpathians to the north and the Balkans to the south outline the "*cul-de-sac*" zone of the Lower Danube Basin, sealed to the east by the western shores of the Black Sea (Fig. 1). From a geographic point of view, the Lower Danube Basin is subdivided into three major zones (Fig. 1B): the Romanian Plain, to the north, the Bulgarian Plain, to the south and Dobrogea, to the east.

2. REGIONAL SETTING

2.1. Overview of the loess-like concept

Loess has been defined in different ways by different authors. During the long time debates on this subject, Russel (1944) pointed out that the loess term had been applied in too diverse situations. Consequently, he considered necessary to place the unclear cases into a vague category of "loess-like deposits".

The loess-like term was recommended for the sediments which have loess features, but are not of eolian origin (Pye, 1984). According to this criterion the loess-like term is to be employed whenever there is doubt related to the true loess status of a deposit. Smalley and Leach (1978) pointed out the necessity to differentiate between the loess-like sediments which evolved from loess sediments, and loess-like deposits that had never been true loess. Smalley (2005) considers the term loess-like a deceiving and meaningless notion, the use of which should be avoided.

The terms: primary loess (typical, eolian) and secondary loess (redeposited) have also been used in the literature. Pye (1995) suggested the use of the terms "loess-derived colluvium" and "loess-derived alluvium "for the secondary loess (reworked through various non-eolian processes).

One of the main objectives of the Europe loess map has been to define and record the sediments which occur in association with the loess (typical loess, sandy loess and clayey loess), but show different features. The authors of the Europe loess map used the terms loess-related or loess derivates (Hasse *et al*., 2007) for these sediments. It was

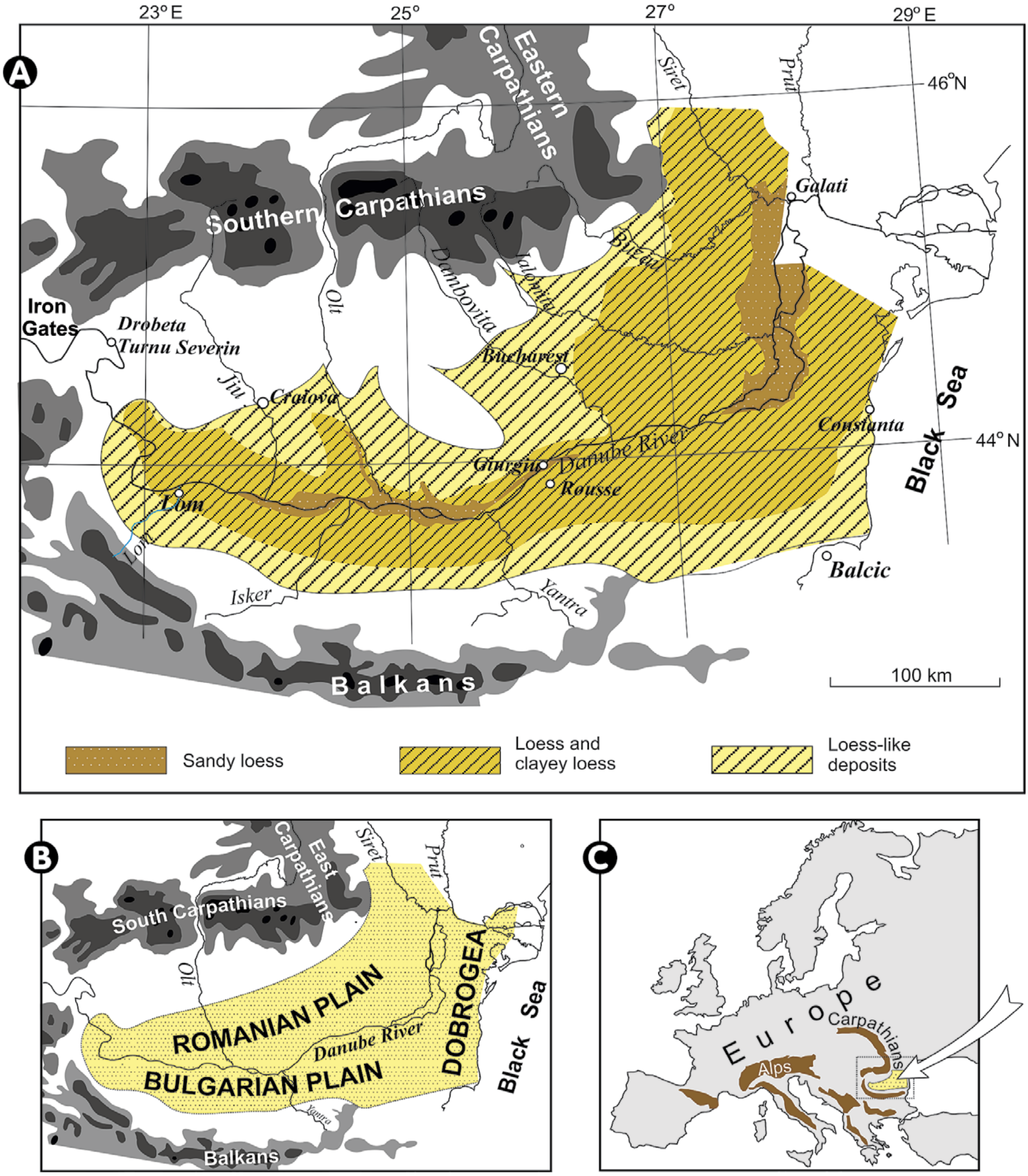

Fig. 1. Lower Danube Basin setting. **A**. Lower Danube Basin loess/loess-like areal extension. After Jipa (2014) with simplified data from Fotakieva and Minkov (1966), Conea (1970a) and Conea (1970b). **B**. The main geographic units of the Lower Danube area. **C**. Study-area location on the map of Europe.

considered that this category includes loess deposits which suffered changes triggered by syngenetic or postgenetic processes. The loess derivates are subdivided in two groups (Haase *et al*., 2007): (1) deposits free of coarse-grained clastics and (2) allochthonous loess sediments with sand and gravel material. Fitzsimmons *et al*. (2012) are calling the first group of sediments "*in situ* loess deposits modified by pedogenic and diagenetic processes", and the second sediment group is named "allochthonous deposits transported by slope processes".

Frequently, the loess-like name has been applied to deposits not known from a genetic point of view. Grabowski (1999) points out that loess-like sediments interpretation is difficult, because the slope, eolian and soil-forming effects are overlapping. Hasse *et al*. (2007) also mentioned that the genetic meaning of the loess-related sediments is partly unknown.

2.2. Overview of the loess and loess-like investigation in the Lower Danube Basin

The loess scientific research in Bulgaria and Romania (covering the entire Lower Danube Basin territory) has a long history. The early studies date back from the second half of the XIX[th] century. In Romania, the systematic study began in the Romanian Plain, where Murgoci (1907) presented, partly based on borehole data, the earliest view on the distribution, origin and age of the Romanian loess. After the Second World War, the loess-paleosoil sequences in the Romanian Plain and Dobrogea were studied by soil scientists (A. Conea, M. Popovăț, N. Bucur, N. Barbu and others), mostly interested in the upper loess succession, and by hydrogeologists (E. Liteanu, C. Ghenea, T. Bandrabur and others). In the Romanian literature, the first known detailed study was presented by Coteț (1957), related to the western part of the Romanian Plain (Fig. 2). During this investigation stage, the knowledge on lithology/texture and stratigraphy of the loess deposits came to maturity, a fact materialized by the first modern loess maps.

Following a long period of intense loess investigation, in Bulgaria, synthesis papers were published by Gunchev (1935), Yaranov (1956), Minkov (1968), and others.

Loess mapping, started to show definite results in the 7[th] decade of the XX[th] century (Fotakieva and Minkov, 1966; Conea *et al*., 1963; Conea, 1970a,b), but detailed mapping continued during the next decades (Codarcea and Bandrabur, 1977; Ghenea *et al*., 1980).

After a long time interval of classical loess stratigraphy studies in the Lower Danube Basin, since the end of the XX[th] century the use of modern dating methods enhanced the loess knowledge (see a review by Rădan, 2012). Presently the L1 to L8 loess beds are correlated with *MIS 4* to *MIS 20*, spanning a time period of 800 ka (Middle Pleistocene - Upper Pleistocene age, and Lower Pleistocene age related to the L7-L8 beds).

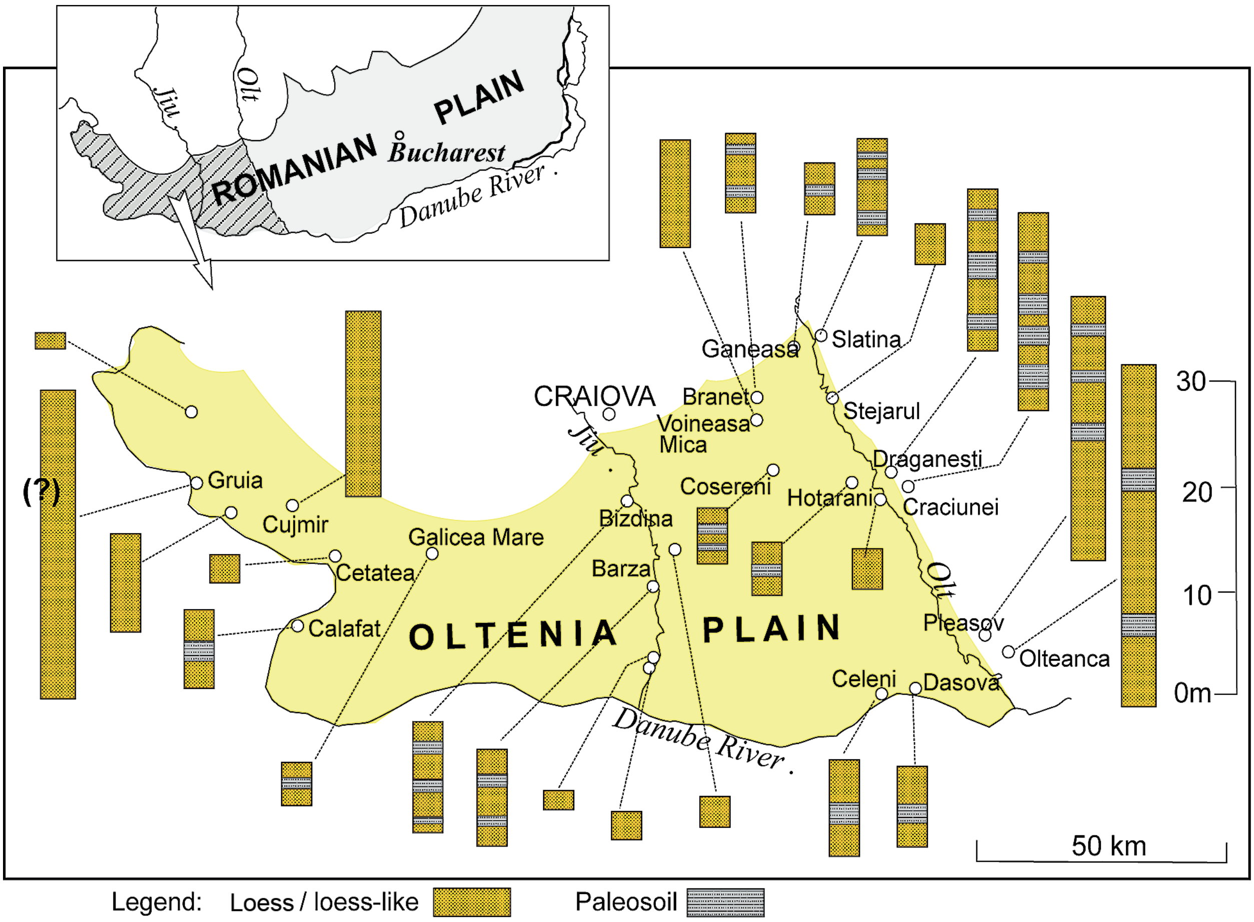

Fig. 2. The first published detailed survey of the loess/loess - paleosoil successions, in the western part of the Romanian Plain. Data from Coteț (1957). The author-mentioned most of the investigated deposits are of loess-like type.

Recent outlines of the Lower Danube loess basin research history are available in papers by Evlogiev (2007), Rădan (2012), and Rădan *et al*. (2013).

The preparation of INQUA Europe loess maps had important effects on the loess study in the Lower Danube Basin. The use of a common European loess definition has promoted a unitary scientific approach for the different groups of loess researchers, in Bulgaria and Romania.

In the Lower Danube Basin, the loess-like subject was initially tackled in connection with the presence of coarse-grained interbeds in the deposits at the periphery of the loess basin. Subsequently, the loess mapping outlined the extension of the finer-grained, silty-clayey loess-like deposits. The European loess map project was also benefic for the loess-like deposits investigation. The necessity to separate loess *versus* loess-like on the map has promoted the study of the loess-like facies in the Lower Danube River area.

3. METHODOLOGY

The investigation reported in this paper is an attempt to the genetic interpretation of the information regarding the general and basic Lower Danube Basin loess features (facies, geological dating, stratigraphy, areal distribution). Accordingly, the data used in the present study are gathered from published papers.

The internal sedimentary structures are important for the analysis of the sedimentogenetic features, but such structures are absent or not visible in the Lower Danube Basin loess-like deposits (Fig. 3). This is why the present study focused on features expressed by the areal variation of some sedimentary parameters, examined at the scale of the entire Lower Danube loess basin. In this context the synthesis maps of the Lower Danube loess texture and thickness (Jipa, 2014) provided important data for the present study.

Only the major loess-like facies was taken into account in the present investigation. Consequently, the sedimentogenetic examination focused on the loess-like facies separated on the Lower Danube Basin loess maps.

4. DATA PRESENTATION

Loess-like sediments in the Lower Danube Basin

Following the commonly accepted definition, in the Lower Danube Basin the loess-like name was given to deposits showing some loess characteristics only. In the Bulgarian Plain and the Romanian Plain areas the largest part of the loess-like facies consists of sediments finer-grained than loess, but displaying loess aspects. This type of deposits was mentioned some time ago in the Romanian Plain. Coteţ (1957) pointed out the net domination of the loess-like deposits in the western part of the Romanian Plain (Fig. 2). Before the Romanian Plain loess mapping had been completed, Emil Liteanu and his co-workers (Lite-

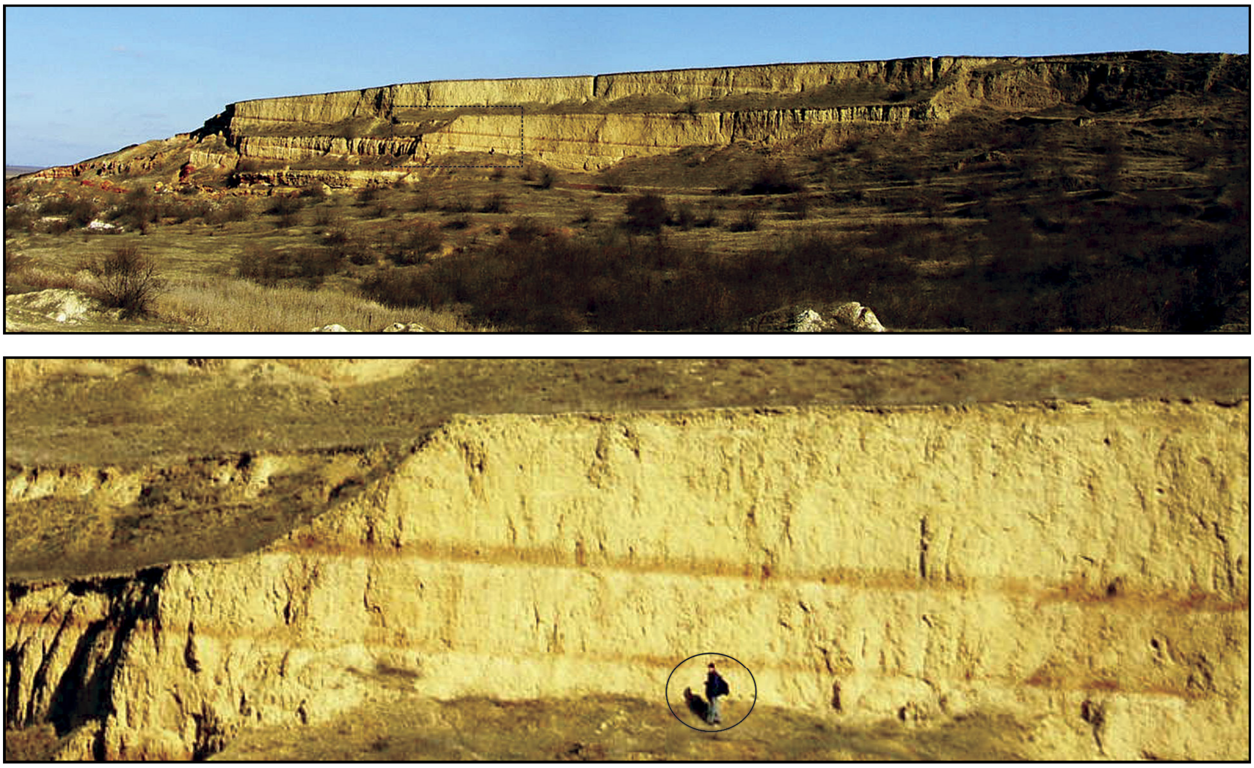

Fig. 3. Loess deposits cropping out in the Gherghina Quarry (Mircea Vodă locality), Constanţa County, Romania. *Photo: Silviu Rădan*. The alternation loess/paleosoil is visible. The detail picture shows the high internal homogeneity of the loess deposits.

anu and Ghenea, 1966 and references therein) even proposed that, in the Romanian Plain area, only the loess-like name should be applied, and recommended to discard use of the loess term.

Descriptive characteristics. According to Conea *et al*. (1963), the loess-like deposits in the Romanian Plain are unconsolidated rocks with a variety of colors (yellow, reddish, gray) and reduced porosity, less homogeneous than the loess deposits (occasionally showing bedding), with variable plasticity and cohesion (depending on their grain-size), and with variably distributed carbonates.

The interbedding of the loess and paleosoil units is characteristic to the Lower Danube Basin area. The number of loess-paleosoil couplets is variable, from the absence of the paleosoil interbeds to seven or eight couplets (Rădan *et al*., 2013). From the Figure 2 (presenting an area where Coteț, 1957, maintains that mostly loess-like deposits occur), it is visible that the interbedding is also well developed in the loess-like facies.

Sometimes, it is hard to differentiate between the loess and loess-like deposits. Conea (1970a) found out that in some zones of the Romanian Plain the upper loess bed reveals a loess-like appearance. A similar case is reported from Dobrogea (Conea, 1970b) where the loess deposits are different from the loess-like ones only by a higher percentage of coarser-grained particles (sand and coarse silt).

Textural characteristics. The loess-like texture shows important variation. Conea *et al*. (1963) pointed out that the Romanian Plain loess-like facies includes various texture sediments (Fig. 4), from silty-sandy deposits to silt and clay deposits; sometimes, with coarse sand particles or small pebbles. The main loess-like textural types are represented by the two varieties differentiated on the loess map, namely: (1) fine, silty-clayey deposits and (2) deposits with coarse-grained detrital material (Conea *et al*., 1963; Conea, 1970a).

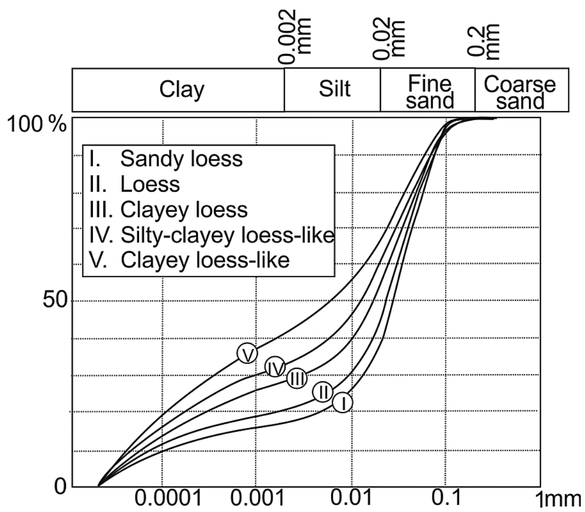

Fig. 4. Grain-size cumulative curves of the loess and loess-like deposits from the eastern part of the Romanian Plain. Atterberg grain-size scale. From Conea *et al*. (1963).

According to Conea *et al*. (1963), the clay fraction of the loess-like deposits from the Romanian Plain area is 30 - 35% in the silty-clayey varieties, and over 40% in the more clayey loess-like deposits (Fig. 4). A similar conclusion was reached by Liteanu and Ghenea (1966). These authors describe the loess-like deposits from the western part of the Romanian Plain as dominantly reddish-brown sediments with 25 - 35% clay fraction (Atterberg scale), 20 - 50% silt, 10 - 30% fine-grained sand, and 0 - 3% coarse sand. The loess-like deposits from the southern part of the Bulgarian Plain have 37% clay fraction in the uppermost bed (L1) and 30% in the second bed (L2) of the loess-like/paleosoil succession (Evlogiev, 2007).

In restricted areas from the northern Romanian Plain, Conea (1970a) mapped deposits with a more advanced clayey character, the clay fraction ranging between 45% and 60%.

The second loess-like type from the Lower Danube Basin is singled out by the presence of coarser-grained sand particles. A first variety of this loess-like type shows only a small increase of the amount of coarser-grained particles in the grain-size constitution of the rock. This loess-like variety occurs at both the northern and the southern boundaries of the Lower Danube loess basin. Evlogiev (2007) acknowledges the increase of the sand fraction with 2 - 4% in the loess-like deposits from the southernmost part of the Bulgarian Plain. Conea (1970a) also indicates the existence of a higher percentage of coarse-grained particles in the loess-like deposits from the area close to the Southern Carpathian piedmont.

Another type of loess-like deposit with coarse-grained material was reported by Liteanu and Ghenea (1966). Small lens-like bodies of fine-grained gravel and relatively thick sand beds are intercalated at different levels into silty-clayey loess-like deposits from the northeastern part of the Romanian Plain. This type of loess-like deposits (called deluvial and mixed) was separated on the Conea (1970a) map (Fig. 5).

Loess to loess-like areal relationships in the Lower Danube Basin. Well-developed and constant textural and sediment thickness changes occur in the Lower Danube loess basin (Fig. 6). These variation trends have been revealed by the loess maps drawn by Fotakieva and Minkov (1966) and Fotakieva and Minkov (in Haase *et al*., 2007) in the Bulgarian Plain (south of the Danube channel) and by Conea (1970a), Conea (1970b), Codarcea and Bandrabur (1977), and Ghenea *et al.* (1980), in the Romanian Plain and Dobrogea (north and east of the Danube channel).

The coarsest-grained and thickest loess deposits are located along the Lower Danube channel, forming longitudinal, narrow, apparently discontinuous strips (Fig. 6).

Sideway from the Danube channel, the grain-size and thickness decrease. The coarse-grained loess is replaced with normal loess, and the loess turns into silty-clayey, loess-like deposits. Simultaneously, these deposits become thinner and thinner away from the Danube channel (Fig. 6).

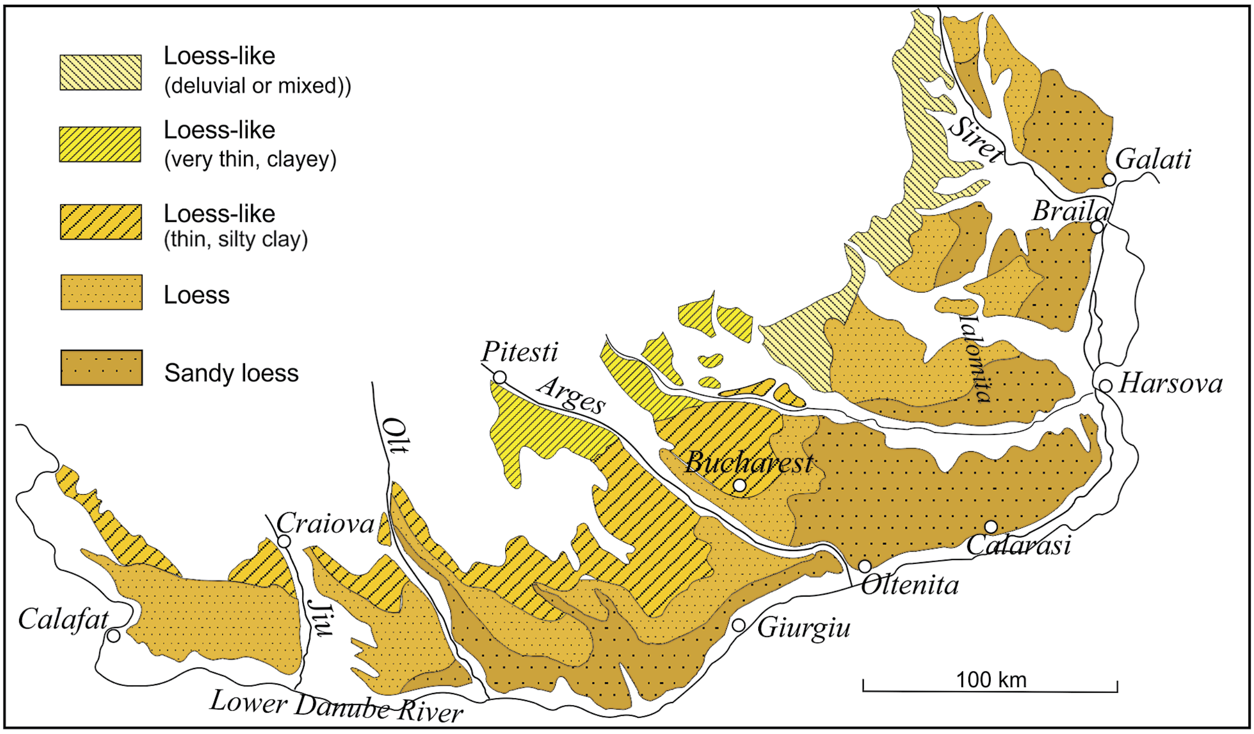

Fig. 5. Loess and loess-like deposits in the Romanian Plain area, lithology and general thickness. Redrawn from Conea (1970a)

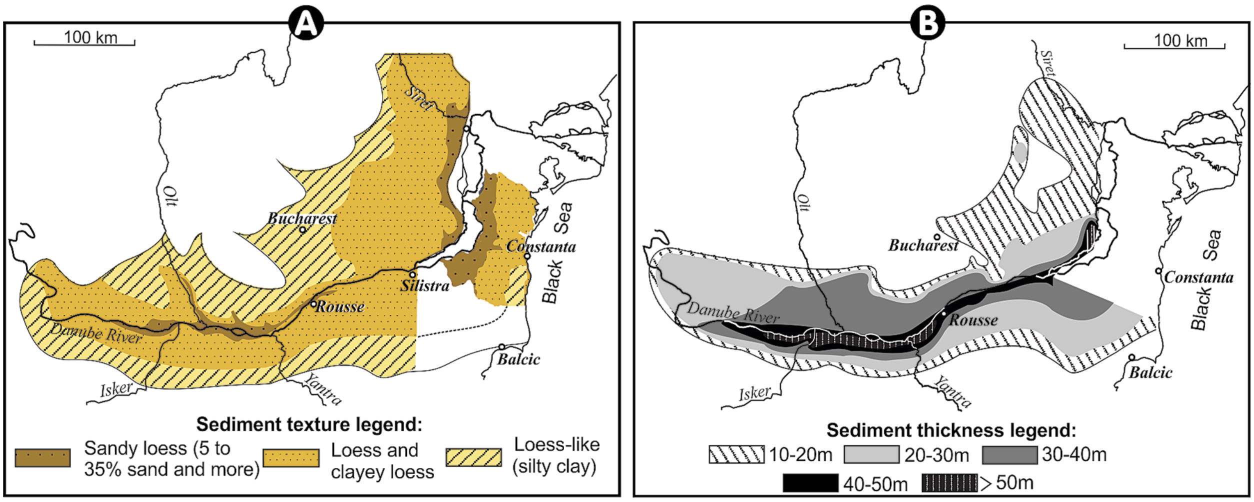

Fig. 6. Integrated areal distribution of the loess and loess-like texture (**A**) and sediment thickness (**B**) in the Lower Danube Plain. Simplified and modified from Fotakieva and Minkov (1966), Conea (1970 a, b), Codarcea and Bandrabur (1977), Ghenea *et al.* (1980) and Fotakieva and Mincov (in Haase *et al.*, 2007). Modified from Jipa (2014). The two sketch-maps reveal the coarse-grained and the thickest loess deposits occur along the Lower Danube course. Away from the channel the loess sediments are getting finer-grained and thinner toward the periphery of the Lower Danube Basin.

The loess-like deposits, making up the finest-grained and thinnest facies of the Lower Danube loess basin, are located at the periphery of the basin.

Loess-like deposits location on the loess-map. Loess-like (loessial clay) deposits have been mapped by Fotakieva and Minkov (1966) in the Bulgarian Plain. Besides loess-like deposits, in this area, occur sandy loess, typical loess and clayey loess deposits. These facies appear as parallel bands (also parallel to the Lower Danube course), forming a succession which becomes finer-grained away from the Danube channel. The loess-like deposits mapped in the area at the south of the Danube River crop out as a continuous sediment band of fairly constant wideness, located in the southern extremity of the Bulgarian Plain.

In the Romanian Plain area, the loess-like deposits are well developed, occurring as a predominant facies in the western and central Romanian Plain, while the loess is dominant in the eastern part (Conea,1970a) (Fig. 5). In contrast to the loess-like deposits from the Bulgarian Plain, the loess-like deposits at the north of the Lower Danube River appear on the map as a highly irregularly shaped area (Fig. 5). In the central part of the Romanian Plain, the loess-like deposits extend southward to the proximity of the Danube channel.

In Dobrogea, where Conea (1970b) focused on the upper loess bed, the loess-like deposits were mapped from the eastern part of the area, toward the Black Sea, while the loess deposits appear toward the Danube channel.

Loess/loess-like correlation in the Lower Danube Basin. The synchronism of the sedimentary units separated on the loess maps of the Bulgarian and Romanian Plains areas (especially, between loess and loess-like entities) is significant for the investigation carried out in the present paper. However, the lateral correlation of the loess/loess-like sedimentary units is little known in the Lower Danube Plain area.

Some data from the Bulgarian Plain area (Evlogiev, 2007) revealed the lateral extension of the loess beds is differential. This is probably a reason for the lack of the bed-to-bed loess correlation in the Lower Danube Basin.

As concerns the large-scale correlation, the Lower Danube loess maps indicate there is a lateral transition between the coarse-grained loess, true loess, and loess-like units. This suggests the sediments of the three main texture types intercorrelate.

The correlation between loess and loess-like map units was confirmed by Ana Conea investigations of the Romanian Plain and Dobrogea head deposits. During the Romanian Plain head deposits mapping (Conea, 1970a), loess deposits were separated close to the Danube River and loess-like deposits farther away from the Danube River. Focusing strictly on the uppermost bed of the loess Dobrogea succession, Conea (1970b) separated lateral variations from sandy loess (close to the Danube River) to typical loess and, farther on, to fine-grained loess (loess-like). The occurrence of the loess and loess-like lateral variations in a quite restricted stratigraphic interval (including only the uppermost bed) strongly indicates that loess and loess-like mapped units are coeval.

5. DISCUSSION OF DATA

5.1. Genetic significance of the loess-like sediments in the Lower Danube Basin. The pros and cons of the fluvial/eolian hypotheses

5.1.1. Hypothesis 1: the Lower Danube loess-like detritus was accumulated in a floodplain environment by overbank flows

Arguments in favor of Hypothesis 1:

The decreasing trend of the loess and loess-like grain-size and thickness. The integration of the Lower Danube loess maps (Jipa, 2014) revealed the bilateral trend of the loess deposits texture and thickness variation. These changes evolve from the Danube fluvial channel toward the loess basin periphery. This kind of setting is characteristic to the floodplain evolution. Numerous studies of floodplain aggradation demonstrate a decrease in deposition rate, thickness and mean grain size of overbank deposits away from the active channel (*e.g*., Marriott, 1992; Guccione, 1993; Walling *et al*., 1998; Middelkoop and Asselman, 1998).

The obvious textural and thickness bilateral variation, away from the fluvial channel (Fig. 6) is a solid argument pleading for (1) Danube provenance of the most loess detrital material, and for (2) loess detritus accumulation in a floodplain environment. These conclusions also apply to the Lower Danube loess-like deposits, the finest-grained and thinner sediments of the loess basin.

The overbank-flow transport and sedimentation is the most considered process of the floodplain build up. The floodplain grain-size changes due to the overbank flow are well described by Guccione (1993). The overbank flows, carrying sandy-silty-clayey detritus transferred from the active alluvial channel, discharge the sandy and coarse clay load close to the channel. As the overbank flow moves ahead, away from the channel toward the basin periphery, the suspended silt fraction becomes finer and finer-grained. The suspended clay variation cannot be evaluated due to the pedogenesis process.

Arguments against Hypothesis 1:

The large extension of the Lower Danube floodplain. When considering the almost all the Lower Danube loess basin as the transport and sedimentation environment of the detrital material transferred from the Danube channel, the picture of an exceptionally wide paleo-floodplain is outlined. The modern floodplain of large rivers, like the Mississippi and the Amazon is several tens of kilometers wide. Guccione (1993; Table 1) mentioned the wideness of the Mississippi floodplain of 59 km. The wideness of the Solimões-Amazon River floodplain figured by Mertes (1994; Fig. 1) amounts to 75 km. The size of the paleo-floodplain outlined by the conceptual model of the Lower Danube loess basin (Jipa, 2014) is significantly larger (Fig. 6). In the western part of the Lower Danube Basin, the loess and loess-like floodplain deposits extend by around 50 km to the north and to the south of the Danube channel. In contrast, in the eastern part of the basin, the floodplain loess and loess-like area exceeds 100 km on each side of the Danube channel (more than 200 km for the whole plain).

In view of this size, the question is asked if the overbank flows were able to extend 50 - 100 km away from the Danube channel. The results of some of the floodplain studies (*e.g.*, Wolman and Leopold, 1957) suggest low values for the ability of the overbank flows to transport sediment. This is why the sandy load is dropped quickly and at a short distance from the active channel. Presently, there is no information on the maximal extension of the fine silty and clayey overbank flows.

The transport and sedimentation processes in the floodplain environment. More than half a century ago, Wolman and Leopold (1957) concluded that for the sedimentogenesis of some fine-grained alluvial deposits, the part played by the floods originated from the alluvial channel is not clear. Subsequent studies revealed the importance of the complex crevasse splays or lacustrine deltas in floodplains with variable topography (Smith *et al*., 1989; Tye and Coleman, 1989; Tornqvist and Bridge, 2002; Weerts and Bierkens, 1993; Smith and Perez-Arlucea, 1994; Aslan and Autin, 1999).

The enhanced relief at the floodplain periphery. The fine-grained silt deposits of the Lower Danube loess basin spread out on a long distance, to the subaerial terrain at the margin of the floodplain. The relief of the floodplain bottom is, probably, a little higher at the periphery of the basin. Considering the lower sedimentation rate and the smaller sediment thickness, the floodplain extension in this area, through overbank flows or other alluvial mechanisms, could be discontinued.

The loess/loess-like internal sedimentary structure. One of the characteristics of the loess deposits is the visual lack of internal sedimentary structure. This aspect is also present at the loess-like deposits from the Lower Danube Basin. In the case of the silty-clayey (loess-like) deposits, accumulated during a single flood episode, the advanced grain-size sorting, which selected only very fine particle, explains the (apparent?) lack of internal lamination. If multiple flood events have been active, the normal case in a floodplain environment, there are more chances for visible grain-size variations to occur.

The absence of aquatic fauna. Evlogiev (2007) pointed out the lack of aquatic fauna in the loess deposits. The same feature is characteristic for the loess northward from the Danube River, but *Bradybaema fruticum* fauna was found in the Romanian Plain (Liteanu, 1953; Bandrabur, 1961) and *Chondrula tridens* fauna in Dobrogea (Conea, 1970b). The investigations carried out by Snegin (2005, 2014) indicated that the floodplain forest is one of the preferred habitats of these terrestrial gastropods.

5.1.2. Hypothesis 2: the Lower Danube loess-like detritus was accumulated by eolian processes

Arguments in favor of Hypothesis 2:

The large extension of the Lower Danube floodplain. The eolian agent is able to transport silt-size particles on large distances. This eolian capacity could explain the large floodplain areal of the Lower Danube Basin.

The enhanced relief at the floodplain periphery. The eolian processes have higher capacities than the overbank flows, to transport and deposit silt material on the higher relief bottom at the flood plain periphery. Evlogiev (2007) mentioned that younger and younger loess beds cover the six alluvial terraces from the Bulgarian Plain. Eight loess beds cover the T6 terrace, only five beds on T5, while the T1 terrace is covered by only one loess bed.

The loess/loess-like internal sedimentary structure. As the eolian transport process leads to very good grain-size sorting, the homogeneity (lack of visible lamination) is a characteristic feature of the loess deposits.

The morphological elements of eolian origin (gredas and erosion valleys). In the loess area from the northern Bulgarian Plain, Rozycki (1967) mentioned the occurrence of elongated ridges, known as gredas. In the author's opinion, these morphology features are accumulative loess forms.

The erosion valleys, interpreted by Evlogiev (2007) as appearing during the sedimentation of the loess detrital material under the paleo-winds action, are located in the northeastern Bulgarian Plain.

Arguments against Hypothesis 2:

The paleo-winds pattern of the Lower Danube loess basin. The reconstruction of the dominant paleo-winds in the area of the Lower Danube is a long term topic (Rozycki, 1967; Maruszczak, 1967; Evlogiev, 2007; Buggle *et al*., 2008). Some of the paleo-wind pattern studies are based on the orientation of the morphological features regarded as eolian deflation products (gredas - Rozycki, 1967; erosion valleys - Evlogiev, 2007), from the northern Bulgarian Plain. For the southwestern and the northeastern Romanian Plain, Buggle *et al*. (2008) relied on the dispersal directions of the sand dunes (which are younger than loess deposits – Liteanu and Ghenea, 1966).

With some variations of the directions, two major Lower Danube paleo-winds systems come out of the results of the studies mentioned above (Fig. 7): (1) a NW to SE (or NNW to SSE) system, in the western Lower Danube Basin, and (2) a N to S eolian system (with variations to SSW and SSE), in the eastern extremity of the basin. There is a distinct disagreement between the reconstructed paleo-wind directions and the bilateral trend of the textural and thickness changes of the Lower Danube loess and loess-like deposits. The paleo-winds picture cannot explain the bilateral texture and thickness decline away from the Danube channel.

A paleo-wind system directed toward the east, parallel to a segment of the Lower Danube, was pointed out by Rozycki (1967) and Maruszczak (1967). This wind trend is in agreement with the grain-size diminishment along the Danube described by Evlogiev (2007). This conformity is regarded by Evlogiev (2007) as an evidence of the eolian transport. However, the same effect could be produced through progressive alluvial sorting.

Taking into consideration only the Bulgarian Plain loess cover, Jaranov (1956), Minkov (1968) and Evlogiev (2007) considered the southward texture and thickness decrease was generated through eolian transport. Maruszczak (1967, p.187) pointed out that "if the winds were perpendicular to the river, as assumed by Jaranov (1956), the loess cover would be asymmetric with relation to the river, extending chiefly on one side of it".

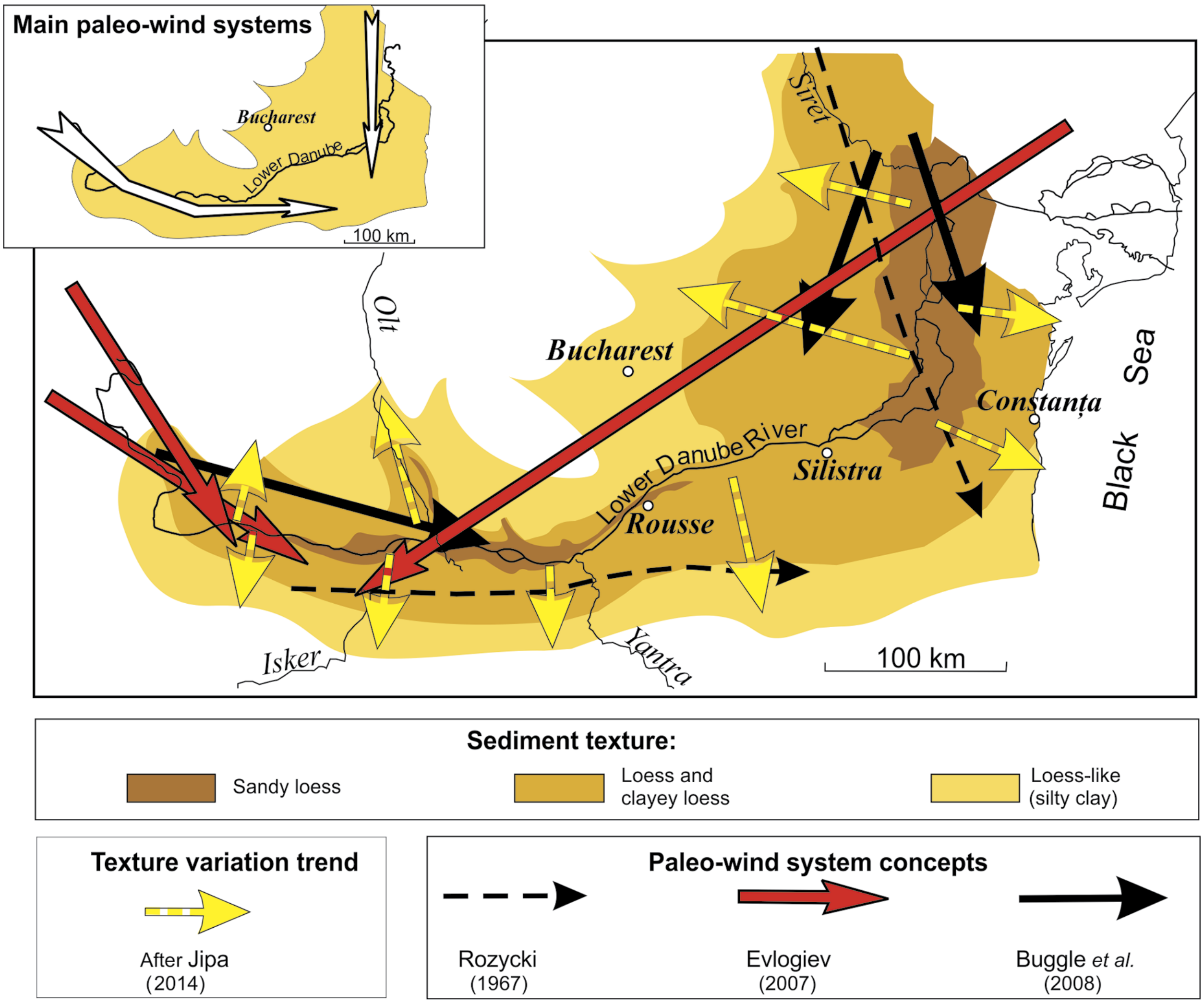

Fig. 7. The paleo-wind systems considered to have been active during the accumulation of the Lower Danube loess/loess-like detrital material. Data from Rozycki (1967), Evlogiev (2007) and Buggle *et al*. (2008). The trends of the bilateral loess/loess-like texture and thickness changes (data from Jipa, 2014) are presented for comparison with the paleo-wind pattern. The textural sketch of the Lower Danube loess basin simplified and modified after Jipa (2014).

The loess/loess-like internal sedimentary structure. The failure to observe internal lamination applies not only to the loess deposits, but also to the fine-grained floodplain sediments (Gucione, 1993). A similar grain-size sorting effect is reached by the eolian transport, as well as by the overbank flow, and this is the reason for the (apparent?) internal homogeneity.

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The pros and cons analysis of the hypothesis regarding the alluvial or/and eolian genesis of the loess-like sediment accumulations shows that both concepts have aspects difficult to explain.

The present author believes that the assessment of floodplain sedimentation in the Lower Danube loess basin is well supported by the bilateral grain-size and thickness diminishment, away from the Danube channel toward the basin periphery.

The large lateral extent of the Lower Danube loess basin, and consequently, the outsize overbank flow required to cover such distances, is a weak point of the alluvial hypothesis. It is doubtful that the transport and sedimentation of the silty-clayey loess-like detritus could be ascribed only to the floodplain flow process. Other floodplain sedimentary processes (complex crevasse splays, lacustrine deltas, and others) might have concurred, but little is presently known about their mechanisms.

The eolian mechanism offers a good sedimentary mechanics explanation for the large dispersal of the silty-clayey (loess-like) detritus. Nevertheless, the eolian agent action alone cannot explain the two opposite transport trends of the detrital material, from the river channel to the margins of the Lower Danube loess basin.

The optimal logical solution to explain the large and distal loess-like sedimentation in the Lower Danube Basin is the joint action of the alluvial and eolian processes. The initial alluvial sedimentation (mainly, but not exclusively, by overbank flows) could have been continued and extended by the eolian action.

It is to be underlined that the loess-like deposits of the Lower Danube Basin are sedimentary accumulations of primary genesis. They appear as the product of the progressive sorting and distal sedimentation of the detrital material, transferred from the Lower Danube channel and dispersed sideway by alluvial and eolian agents.

5.2. The loess-like sediments associated with coarse-grained detritus

Two types of loess-like sediments are separated on the loess maps and in the literature of the Lower Danube loess basin: silty-clayey sediments (loessial clay by Fotakieva and Minkov, 1966; silty-clay loam by Conea, 1970a) and loess-like sediments associated with coarser-grained clastics (Liteanu and Ghenea, 1966; Conea, 1970a; Evlogiev, 2007). The silty-clayey type is the dominant type of loess-like sediments in the Lower Danube Basin, and the genetic analysis (chapter 5.1) refers to this facies. The second type of loess-like deposits from the Lower Danube Basin is marked by the association with coarse-grained clastic material. The Lower Danube Basin loess researchers identify these loess-like deposits as deluvial (Fotakieva and Minkov, 1966; Conea, 1970a), deluvial - proluvial (Liteanu and Ghenea, 1966) or alluvial (Evlogiev, 2007). The location of these deposits at the transition between the plain and the submountain, hilly zone, is the argument supporting their opinions.

In our interpretation, the deluvial or deluvial - proluvial names should be given to the coarse-grained material associated with the loess-like deposits. This material represents detrital fluxes originated from the area surrounding the loess basin, which entered into the marginal zone of the loess and loess-like Danube Basin. They appear now as coarse-grained interbeds in the loess-like sediments.

Evlogiev (2007) reveals that the loess-like sediments at the southern boundary of the Bulgarian Danube Plain display a slightly higher amount (2-4%) of sand-size particles. This could represent deluvial clastic material which entered the loess-like sedimentation area by diffusion, or other similar processes.

5.3. Previous opinions on the alluvial sedimentation in the Lower Danube Loess Basin

Quite a few Bulgarian and Romanian scientists expressed opinions on the role played by the fluvial factors in the accumulation of the Lower Danube loess. The best articulated and realistic concept on this subject belongs to Ian J. Smalley and his coauthors.

Smalley and Leach (1978) reviewed the data concerning the origin and distribution of loess in the area crossed by the Danube River. This paper prompted major rethinking of the investigations seeking information on the accumulation of the loess detrital material. Smalley and Leach (1978) considered the loess detritus, transported by the Danube River, was accumulated in the Danube flood plain, and finally, reworked by eolian processes.

In the same context, the concept of the two main types of loess (Smalley and Derbyshire, 1990) evolved: the mountain loess (the detritus of which comes from mountain source-areas) and the ice-sheet loess. Definite proofs supporting the differentiation of the two loess types were provided by the Buggle *et al*. (2008) investigation of the Danubian and Ukrainian loess deposits. Based on a geochemical assessment, Buggle *et al*. (2008) reached the conclusion that the Vojvodina and Dobrogea loess consists of Danube alluvial material, unlike the Ukrainian loess detritus which is glaciofluvial, of the Fennoscandinavian ice sheet nature. Commenting these data, Smalley *et al*. (2009) underlined that the loess from Voyvodina and Dobrogea belongs to the mountain loess type, while the Ukrainian loess is of the glacial/ice-sheet type; two major types which incorporate the most part of the world loess deposits.

Smalley *et al*. (2009) emphasized that the river transport is essential, and have a key contribution to the location of the loess detrital material accumulation area.

6. CONCLUSIONS

On the loess maps of the Lower Danube Basin, two types of loess-like sediments are separated: silty-clayey sediments, and silty-clayey sediments associated with coarser-grained clastics.

The regular (and most frequent) loess-like deposits of the Lower Danube Basin are silty-clayey in texture and display no particular association with coarser-grained particles or sediments. On the Lower Danube loess maps, three main textural facies are separated: coarse-grained loess, regular loess and loess-like. There is lateral transition between these types of deposits, sideways in respect to the Danube channel. In this setting, the loess-like facies include the finest grain-sized and the thinnest sediments of the Lower Danube Basin, located at the periphery of the basin.

A pros and cons analysis of the Lower Danube loess-like sedimentogenesis was made. The study pointed out that both the alluvial and the eolian hypotheses show significant weak points.

The floodplain sedimentation hypothesis is well supported by the bilateral grain-size and thickness diminishment, away from the Danube channel toward the Lower Danube loess basin periphery. Yet, the wideness of the Lower Danube loess basin might be too large to be covered by the floodplain processes (overbank flow or others).

The Lower Danube loess paleo-winds pattern cannot explain the bilateral texture and thickness variation trends, from the river channel to the margins of the basin. The joint action of the alluvial and eolian processes is the optimal logical solution to explain the large and distal loess-like sedimentation in the Lower Danube Basin. The initial alluvial sedimentation (not exclusively by overbank flows) could have been continued and extended by the eolian action.

The Lower Danube Basin loess-like sediments associated with coarser-grained clastics have been identified as deluvial in the existing papers. Our study shows that only the coarse-grained clastic material associated with the loess-like deposits is of deluvial/deluvial-proluvial origin. The coarser material represents detrital influxes originated from the area surrounding the loess basin, which entered into the peripheral zone of the loess and loess-like basin.

The loess-like deposits of the Lower Danube Basin are primary sedimentary accumulations. They are the product of the grain-size selective transport and distal deposition of the silty-clayey detrital material, transferred from the Lower Danube channel and dispersed sideways by alluvial/eolian agents.

Much additional data from the Lower Danube loess basin are necessary for a more advanced knowledge of the loess and loess-like sedimentary accumulation. The genetic analysis carried out in this paper is a first attempt of this kind. We consider it an invitation for further investigations and better supported interpretations.

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