



Loess–palaeosol sequences in China and Europe: Common values and geoconservation issues



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ABSTRACT

Loess–palaeosol sequences preserve the most significant continental record of climatic and environmental changes during the Quaternary available for scientific study. The Eurasian loess belt in particular could be regarded as one of the most important Quaternary terrestrial records of climatic and environmental changes on a global scale. The Preliminary stratigraphical correlation has determined that loess sections in south-east Europe and China have, perhaps surprisingly, shown many similarities. Unfortunately, these sites, due to their economic (e.g. agriculture and brickyards) and functional (e.g. remote sections as waste disposal sites) values, share the same (both human-induced and natural) threats and are constantly endangered by numerous causes and could be naturally degraded or permanently exploited as a georesource. Conversely, this valuable segment of Earth's geodiversity has gained much attention within the nature conservation community. There are certain individual attempts to protect and promote loess to the general public, which is the case in China (National Geoparks with protected loess, e.g. Luochuan, Huoshi Chai, Kungdongshan, Jingtai, Yellow River), and also in Serbia and Poland. These could serve as good platform for establishing common strategies towards national and international recognition of important loess sections. Thus, the aim of this study is to provide a preliminary and universal strategy concerning conservation, interpretation and promotion (geotourism) of significant Eurasian loess–palaeosol sequences. Once implemented and tested, they could serve for all similar soft-rock exposures and soils.

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1. Introduction

Geodiversity can be defined as the natural range of rocks, minerals, fossils, geomorphological forms and processes, and soil features; it includes their assemblages, relationships, properties and systems (Gray, 2004), or more simply the diversity of geological and geomorphological phenomena in a defined area (Johansson, 2000). The endeavour of trying to conserve geodiversity is defined as geoconservation (Sharples, 2002) and it has been recently discussed in some detail, especially with regard to landscape tourism, by Hose et al. (2011) and Hose (2012) and specifically defined by him as “the act of protecting geosites and geomorphosites from damage, deterioration or loss through the

implementation of protection and management measures” (Hose, 2012, 16). In broader terms it is the actions taken with the intention of conserving and enhancing geological, geomorphological and soil features, processes, sites and specimens (geodiversity), including any associated promotional and awareness raising activities and the recording and rescue of data or specimens from features and sites threatened with loss or damage (Burek and Prosser, 2008; Prosser, 2013).

Nature conservation has become an important contemporary issue for society. Although there are two equally integral parts of the natural environment (Gray, 2005), biotic (living, biodiversity) and abiotic (non-living, geodiversity), there is a general opinion that the latter does not enjoy governmental support and public appreciation at a satisfactory level (Erhartić and Zorn, 2012; Erikstad, 2013; Gray, 1997, 2004, 2008; Pemberton, 2007; Prosser et al., 2011). Because it is almost always, but incorrectly, considered a robust and persistent part of the Earth's crust, geodiversity has been pushed aside with regard to fundamental conservation activities (Gray, 2004; Prosser, 2013).

One of the parts of Earth's geodiversity which has been lately recognised as of considerable importance regarding its (geo)scientific,

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cultural, economic and aesthetic values are loess–palaeosol sequences (Solarska et al., 2013; Vasiljević et al., 2011a, 2011b). This widely spread sediment has proved to be of the utmost significance for scientific, archaeological and agricultural reasons within the Eurasian loess belt. Accordingly, this study provides an insight into some of the key issues regarding loess area treatment from the two case study areas: the Chinese Loess Plateau as the most developed loess region in the world; and the European loess sections (predominantly from the Vojvodina region, North Serbia) with some specific examples of its most important segments.

2. The Eurasian loess belt

Loess and loess-like sediments cover 10% of Earth's land surfaces (Heller and Evans, 1995; Pecs, 1990; Smalley et al., 2011) mostly deposited over extensive areas in mid-latitudes. Typical geographical zones for its deposition, and the areas with the thickest loess–palaeosol sequences, are plains (e.g. Pampean Plain, Russian Plain), plateaus (e.g. Chinese Loess Plateau) and along river basins (e.g. Danube Basin, middle Rhine Basin, Mississippi Basin, middle Yellow River Basin).

The Eurasian loess Belt covers the whole Eurasian continent, from the Atlantic to the Pacific coasts (Fig. 1). Eastern Asia represents the area with the most extensive and continuous loess sediments, mostly deposited in the highland area of north-central China and the Chinese Loess Plateau (Hoang Fagerström et al., 2003a). The formation of these continuous loess–palaeosol sequences by dust deposition began 22 My ago (Guo et al., 2002). According to some authors (e.g. He et al., 2003; Liu, 1985; Zhu, 1989) the material has been transported from the north-western Gobi desert by winds and has accumulated on the Loess Plateau since the beginning of the Quaternary. These processes eventually created the world's largest loess plateau (Derbyshire, 2001) which covers 8° of latitude (35–41°N) and 13° of longitude (102°–114°E); this is an area of more than 530,000 km² (Liu, 1999), at an altitude of some 1000–1600 m above sea level, the surface of which is covered by an average of 100 m thickness of loess–palaeosol sequences (He et al.,

2003). The Plateau belongs to the Shaanxi, Gansu, Qinghai, Ningxia, Qinhai and Neimeng provinces in China (Liu, 1999), but the most complete and thickest loess deposits are found in the provinces of Shanxi, Shaanxi, and Gansu (Stevens et al., 2007, 2008).

In Europe, loess and loess-like sediments cover almost 1/5 of its total land surface (Haase et al., 2007, Fig. 2) and are thus a major sediment type as a soil parent material. Dust accumulation emanated from the maritime areas of north-western Europe, over central Europe, and as far eastwards as the Ukraine and the Russian plains (Fig. 2). Much of the loess cover in eastern and central Europe has been re-deposited by the Danube River and its tributaries. Other major areas of loess are associated with other large rivers such as the Po in Italy, the Rhine in Western Germany, and the Rhone in France (Smalley, 1995). A magnified sequence of the European loess map (as shown in Fig. 2) clearly indicates that the greatest thickness of loess deposits occurs in the area of the lower Pannonian Basin (marked in orange colour (loess > 5 m) and dark yellow) that belongs to the Vojvodina Province of northern Serbia. Accordingly, loess–palaeosol sequences situated in the Vojvodina region represent the most detailed archive of climatic and environmental fluctuations during the Middle and Late Pleistocene on the European continent (Marković et al., 2005, 2009, 2011).

3. Loess as geoheritage–geoconservation importance

As protecting the whole geodiversity would be too extreme or “geocentric” (Gray, 2004), let alone unaffordable, there needs to be a clear understanding of geoconservation terminology and principles. Therefore, all parts of geodiversity that are of great importance for humankind and thus are specifically identified as having conservation significance are determined as Earth's geological heritage or geoheritage (Sharples, 2002). This importance is recognised by numerous authors as geodiversity values and is mainly used to assess the parts of geodiversity directed towards geoheritage (Komac et al., 2011; Vujičić et al., 2011). The most relevant and applicable division of geodiversity values was given by Gray (2004, 2008); he identified over 30 different values of

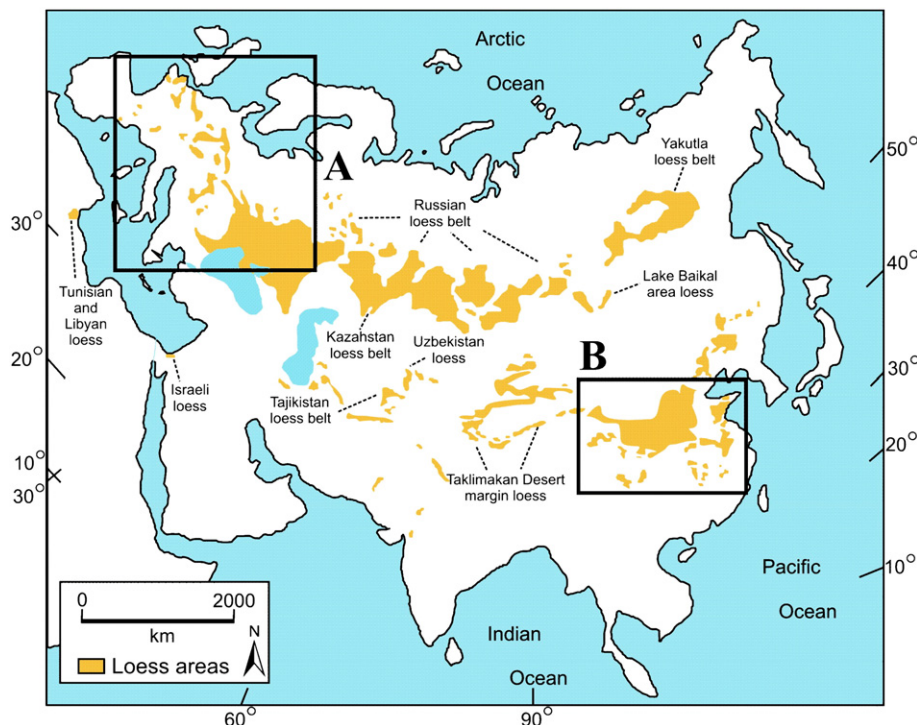


Fig. 1. Distribution of loess in Eurasia with the localities and areas of thickest loess deposition according to Muhs (2007, modified) with locations indicated the European Loess Belt (A) and the Chinese Loess Plateau (B).

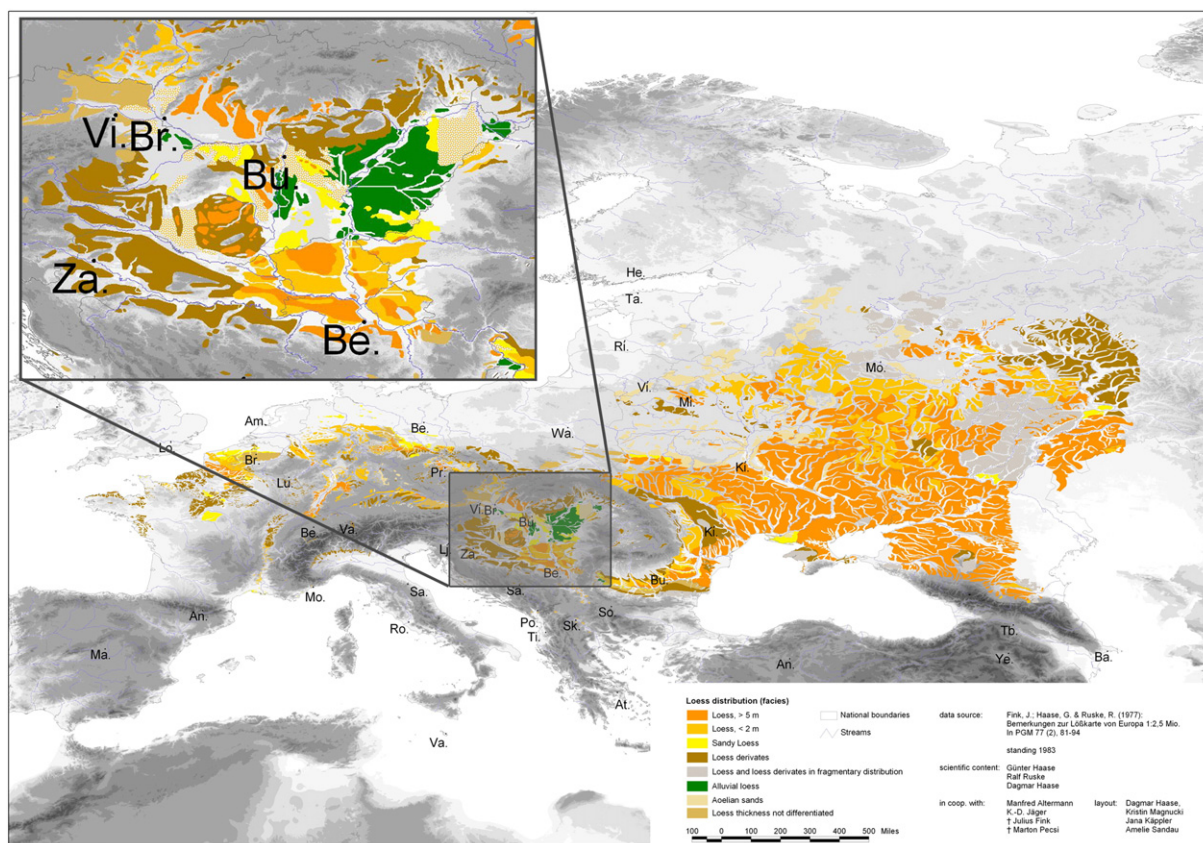


Fig. 2. Loess deposition in Europe according to Haase et al. (2007) with attention to thickness of Pannonian loess sections.

geodiversity which were later applied to loess in the Vojvodina region (northern Serbia) by Vasiljević et al. (2011a). These values (over 20 of them) were sorted within several categories and for the purpose of this study they will be studied and applied to the case study area with

considerable modifications. In addition, Fig. 3 provides a diagrammatic overview of the interaction of the loess formation with specific scientific, social, cultural, natural and evolutionary developments of the Earth that would be referred in this section.

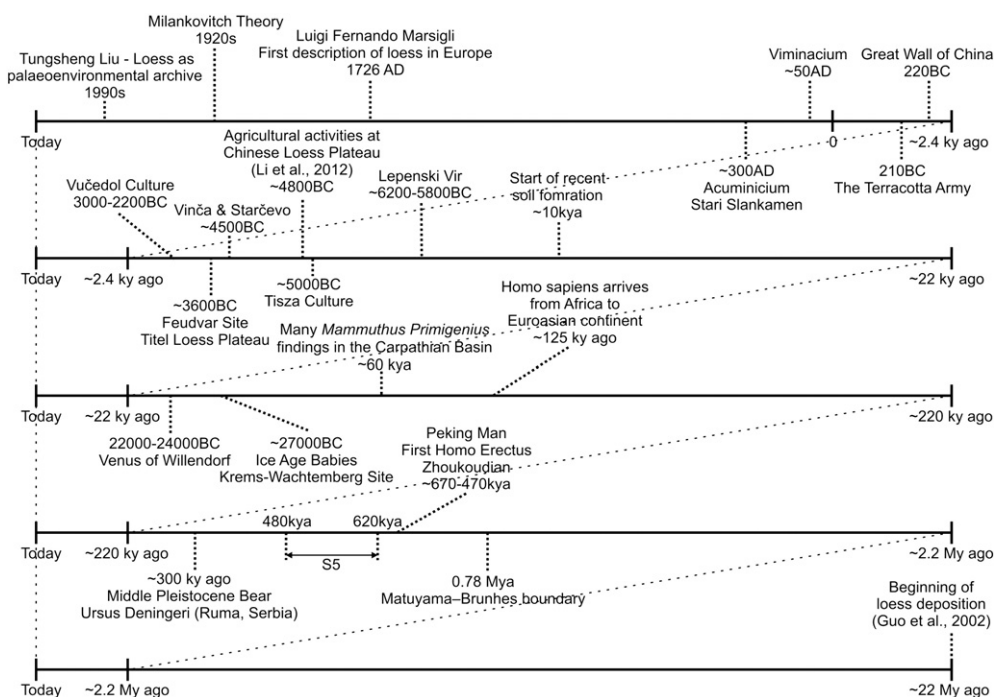


Fig. 3. Interaction and comparison of human civilisation with the development of loess sediments.

3.1. Scientific and educational values of loess

Loess has gained great importance in the reconstruction of past climates ever since the pioneer works of Kukla (1977) and Heller and Liu (1982). It was then proved by them that loess was formed during glacial periods, when climates were cold and dry, interlayered with soil bodies, representing the shift from cold and dry to warm and wet climatic conditions (e.g. Kukla, 1977; Pecs, 1990). Thus, loess–palaeosol sequences are indeed interesting geological formations which encase the Earth's climate history over many glacial and interglacial cycles, or even geological ages and represent an important terrestrial palaeoclimatic and palaeoenvironmental archive.

Chinese loess is considered by many authors (e.g. Ding et al., 2002a, 2002b, 2005) as the Earth's most complete and thickest. According to numerous authors (e.g., Bush et al., 2004; Lu et al., 1999; Rutter, 1992; Sun et al., 1999; Vandenberghe et al., 1997), terrestrial records from the Chinese Loess Plateau have yielded a wealth of proxy data from which it is possible to reconstruct climatic conditions throughout the Quaternary. Furthermore, as reported by Zhenga et al. (2003), the deposition and formation of Chinese loess–palaeosol sequences was under the great influence of winter and summer monsoons that deflated dust from the deserts of the Asian interior to construct the Plateau and then during interglacial periods supported soil development. Additionally, in China, where loess is called 'huangtu' (yellow earth), the association of loess with wind-blown dust was already known two millennia ago (Liu et al., 1985). This indicates that loess sequences also preserve an evolutionary history for the East Asian monsoon regime. Finally, in comparison with any other types of palaeoclimatic records available (e.g. marine sediments, ice core, etc.), only the Chinese loess–palaeosol sequences of the last 2.6 My were recorded continuously; this makes it a fundamental archive for understanding the climatic history of the Earth (e.g. Liu, 1985; Liu and Ding, 1998; Liu et al., 2005).

In Europe, compared with all other loess–palaeosol sequences that were generally formed during the late Pleistocene and are characterised by smaller total thicknesses (e.g. Antoine et al., 2001; Rousseau et al., 2001; Shi et al., 2003; Vandenberghe et al., 1998), the loess–palaeosol sequences in the Vojvodina region have the greatest total thickness because they were formed during the last million years (Marković et al., 2009, 2011). The multidisciplinary research approach that consists of detailed investigations of lithostratigraphy and pedostratigraphy, magnetic and palaeomagnetic properties, grain size variations, geochemical analysis, amino acid racemisation measurements in fossil mollusc shells as well as luminescence dating, also indicates that the loess deposits in the Vojvodina region are amongst the oldest and most complete loess–palaeosol sequences in Europe (Marković et al., 2009, 2011; Schmidt et al., 2010; Stevens et al., 2011).

Apart from proving the high level of scientific importance, this and similar research and its published discoveries have created new dimensions of loess appreciation—their educational (Dong et al., 2009) and geotouristic value (Vasiljević et al., 2011a, 2011b). Loess research has a remarkable history, dating in Europe from the 1720s when the first description of loess was given by the Italian officer Luigi Ferdinando Marsigli (see Fig. 3) in his work as a military engineer for the Habsburg Monarchy. More than two centuries later, loess was shown to be a reliable archive of palaeoclimatic and palaeoenvironmental conditions during the Quaternary and is nowadays a significant part of every geoscience higher education curriculum. Loess is thus an important resource for education and training through in situ practical studies of geology and Earth sciences (Vasiljević et al., 2011a).

3.2. Cultural and social values of loess

Cultural and social values of geodiversity are presented as "...values placed by society on some aspect of the physical environment by reason of its social or community significance" (Gray, 2004, 70). As loess areas are

considered as the key regions of the origins of civilization in both China and Europe they are the areas rich in valuable historical, archaeological, anthropological and palaeontological sites.

The appearance of Man and the development of ancient Chinese culture are associated with the loess. There appears to be a relationship between the loess deposits and the origin of early Chinese culture (Smalley, 1968) and its origin (Dong et al., 2012). Thus, to many anthropologists in the 1920s, Asia seemed the most likely place for "the cradle of mankind" (Kjergaard, 2012, 97) with even more poetic determination as "the palaeontological Garden of Eden" from the authors of that period (Andrews, 1932, 453); regarding that proposal, a high concentration of Neolithic sites was contemporaneously found in the fertile valleys of Wei, Xiliao, Guanzhong and the Yellow River Basins and surrounding Loess Plateau. Wagner et al. (2013) conducted mapping of the spatial and temporal distribution of northern China archaeological sites of the Neolithic and Bronze Age that recognised a total of 36,422 archaeological sites representing 12 regions and 11 administrative units. Two provinces with distinctive loess deposits, Shandong and Shaanxi, revealed the highest number of sites, 7134 and 6267 respectively, covering the time interval between 5000 BC and 500 BC. The main reason for these numbers is the great fertility and topography of loess areas (e.g. Catt, 2001; Smalley et al., 2009; Zgłobicki and Baran-Zgłobicka, 2012) for agricultural production, even in its most primitive forms.

Within the same area, Huang et al. (2002) identified Neolithic village sites in the Guanzhong Basin. This locality constitutes the southern Loess Plateau and represents one of the cultural centres of Chinese history where, since the Bronze Age, 11 dynasties have built their capital cities surrounding the present Xi'an City in the basin. Consequently, several thousands of Neolithic village sites have been found within this basin mostly settled due to the loess soils underpinning arable farming since 8000 years BP (Huang et al., 2002). This area is also the location of one of the most important archaeological findings of the 20th century, the terracotta warriors and horses of the Qin Dynasty (221–206 BC) (Hu et al., 2009). Other research comes from Dong et al. (2013) who in the period 2008–2011 investigated 42 prehistoric sites in the upper Yellow River valley (Qinghai Province) that are covered with natural sediments (such as loess and palaeosols).

From an even earlier archaeological period (the Palaeolithic) came the most impressive discovery of the famous Peking Man in the 1940s (now lost) and subsequently from the late 1950s onwards, who occupied a cave near Zhoukoudian (near Beijing) (Zhou et al., 2000). Although the cave was not formed of loess, the sediment dating was correlated to S4–S7 of the loess depositional cycles in China and the climatic cycles of deep-sea cores (Huang, 1993, 1995; Huang et al., 1991). This establishes the presence of Peking Man intermittently in the Zhoukoudian area from around 670 ka BP to 470 ka BP (Zhou et al., 2000).

On the other side of the Eurasian continent, the banks of the Danube and its tributaries, together with the fertile plains of central Europe mostly covered by loess deposits, were throughout history ideal places for prehistoric humans' settlements. However, as reported by Romanowska (2012) loess is responsible for most of Europe east of the Rhone being called "the terra nova for Lower Palaeolithic archaeology". As the high rates of loess deposition have been recorded during the Middle Pleistocene (Dodonov et al., 2006) most of the central and eastern European sites are deeply "hidden" under thick (up to 50 m) loess sediments. This resulted in the low density of Lower Palaeolithic sites with the few (a mere 20) sites found so far (Romanowska, 2012) mostly as a result of industrial activities that went down to depths of several (or more) metres under the recent soil cover (Romanowska, 2012; Vasiljević et al., 2011a).

However, the Upper Palaeolithic brought many archaeological sites within the Gravettian culture, a prevalent culture existing before the last glacial epoch, closely related to loess sections of central and eastern Europe (Nýltová Fišáková, 2011). For example, the loess section Krems-Wachtberg (Lower Austria) is well known for its

Upper Palaeolithic find layer that contains a double and a single infant burial (Händel et al., 2009; Lomax et al., in press) and a single grave with a three-month old individual, which are embedded in a very well-preserved living floor with a hearth (Thomas and Ziehaus, in press).

Many so called 'Venus figurines' are found throughout the Upper Palaeolithic in central Europe (Willendorf II, Moravany, Petřkovice) of which the Willendorf Venus (Fig. 4) is a famous example (Verpoorte, 2009; Nývltová Fišáková, 2011). In addition, a key loess profile for the reconstruction of the terrestrial palaeo-environment of central Europe at the time of the Last Glacial and Interglacial near Nussloch (southwestern Germany) is also a Venus figurine site (Kadereit et al., 2013). Many other representative Middle and Upper Palaeolithic sites are found in the East Carpathian Foreland (Łanczont and Madeyska, 2005; Madeyska, 2002), Předmostí, Dolní Věstonice and Pavlov in Czech Republic (Lisá et al., 2013), Russia (Kostienki) and the Ukraine (Molodova), etc.

Several important Mesolithic and Neolithic archaeological sites (Padina, Lepenski Vir, Vlasac, Vinča-Belo brdo, Starčevo, and Hajdučka Vodenica) are located in the Danube Gorges that confine some 150 km of the Danube River (Nehlich et al., 2010). The Neolithic period brought some of the most recognizable prehistoric layers from this period in the Danube valley–Baden, Kostolac and Vučedol (Trbojević Vukičević et al., 2006). Additionally, other loess landscapes of the Pannonian Plain were also the cradle of the first civilisation, of which the most impressive is the Tisza Culture dating from the fifth century BC (Gulyás and Sümegi, 2011).

Loess has also preserved many palaeontological sites in eastern, central and southern Europe. There are numerous examples from the Vojvodinian sections, such as the Middle Pleistocene Bear (*Ursus Deningeri*) found in the Ruma loess section (Marković et al., 2006) and several mammoth skeletons found on different localities in Serbia: Crvenka, Ruma, and Petrovaradin (Vasiljević et al., 2011a). However, the most representative is the skeleton of Middle Pleistocene 'steppe' mammoth—*Mammuthus trogontherii* found at the Drmno open lignite mine near Kostolac town (north-east Serbia) in 2009 (Figs. 5 and 7C). Due to the loess–palaeosol sequences surrounding the remains, this skeleton was remarkable for its completeness and excellent state of

preservation. Moreover, its completeness is unique for this species, with no similar examples found in the Mediterranean basin, which is fundamental for further (geological, archaeological, osteological, etc) research on the Quaternary mammal fauna of this and the even wider region (Lister et al., 2012).

In addition to several other mammoth skeletons recently found in the same area there also lies the most important and the largest Roman settlement and military encampment of Upper Moesia; 'Viminacium' covering an area of 220 ha in the inner city, extending to over 450 ha in the wider city region (Golubović and Korać, 2010). Along with this archaeological and cultural asset, there are many other examples of their close relationships to loess sections as strategic and architectural points in Serbia (Vasiljević et al., 2011a), Poland (Solaraska et al., 2013), and northern China (Derbyshire, 2001; Derbyshire et al., 1997).

3.3. Other values of loess in brief

The geodiversity value most recognised and appreciated by the general public is the visual or aesthetical one (Hose, 2010). Thus this quality is the starting point for geodiversity appreciation in the beginning (Gray, 2004, 2005; Pemberton, 2001) as "it refers quite simply to the visual appeal provided by the physical environment" (Gray, 2004, 81).

Although considered as "soft rock" georesource or even soil sediments (Derbyshire, 2001), loess areas provide unique, attractive and appealing landscape, especially in China (Fig. 6). Deep loess gorges, wavy plateaus, steep and high loess profiles, pseudokarst landforms such as loess caves, loess sinkholes, dry valleys, gullies or pyramids, all provide exceptional natural atmosphere for human senses especially in remote destinations. These places attracted past and continue to attract modern landscape tourists (today defined by Hose, 2008a, 2010 as geotourists), nature-lovers, recreationalists and even inspire artists (Gray, 2004, 2005; Hose, 2008a; Vasiljević et al., 2011a). Evidently, or unfortunately, all these values of loess could cause too extensive use and exploitation and thus be degrading factor which will be further elaborated in the next section.

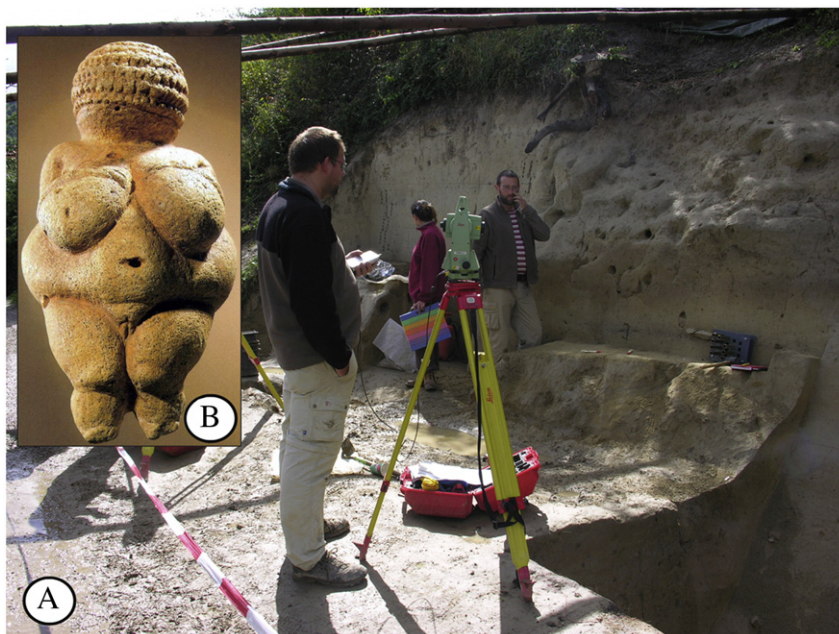


Fig. 4. Archaeological and loess site near Willendorf (A) and a statue of the Venus of Willendorf (B). Photo: S.B. Marković.



Fig. 5. The skeleton of *Mammuthus trogontherii* found at the Drmno loess section.
Photo: Dj. A. Vasiljević.

4. General threats to loess sections

Whilst loess–palaeosol sequences, as previously demonstrated within this study, are a significant part of Earth's geodiversity, these values are unfortunately not recognised by the general population and local communities; this leads to the incorrect management and ignorant use of these natural resources. Apart from human interference, certain natural processes also have degrading influences on loess sections. The various possible threats, recognised specifically for loess according to Gray's (2004) list of general threats to geodiversity, are given in Table 1.

The general division of threats was made by recognising natural and human-induced ones. The first division presents all natural processes that could physically degrade loess–palaeosol sequences.

4.1. Natural threats—erosion

Land cover is one of the most changeable environmental components in temporally and spatially (Geria et al., 2010; Kobayaishi and

Koike, 2010; Zgłobicki and Baran-Zgłobicka, 2012) which indicates that loess is highly subject to erosion owing to sparse vegetation cover (Hoang Fagerström et al., 2003a) and the heavy concentrations of rainfall in mid-latitudes. This is especially the case in China during summer (Liu, 1999) and consequently the Chinese Loess Plateau is one of the most serious soil erosion areas in the world (He et al., 2003). Derbyshire (2001) reports that when the summer monsoon penetrates deeply into the interior of the continent of Asia the loess regions are affected by aggressive and long-lasting rain intervals. These events initiate several erosion-related phenomena, such as loess landslides (water saturation of loess mantle causing the loess to disintegrate instantaneously under its own weight) and changes in the loess fabric (Derbyshire et al., 1995). However, according to the same author (2001) this occurrence is less evident in northern China because the dry climate maintains under-saturated conditions and the consequent stability of loess are relatively sustained over this vast area.

A somewhat similar case can be seen in Europe where the loess landscape is not on such a vast scale but still exposed to the weathering



Fig. 6. Loess Landscape in Luochuan, China.
Photo: S.B. Marković.

Table 1

The list of threats to geodiversity according to Gray (2004) applied to loess sections by Vasiljević (2011a) with further modifications.

Threat origin	Threat inducement	Description/example
Natural	Erosion Tectonics	
Human-induced	Functionality/economical	Agriculture & urbanisation Extraction Other (military/cemeteries)
	Legislative framework	Legislation Policies Ownership
	Ignorance	Waste disposal Uncontrolled vegetation Recreation/tourism effects

of its thinner deposits. However, the specific loess landforms such as loess “caves”, wells, cliffs, depressions, gullies and natural bridges all have limited periods of existence due to their vulnerability to erosion (e.g. Lukić et al., 2009; Zeeden et al., 2007). These relief forms as well as their scientific and educational importance could also have immense aesthetic appeal, particularly those in the Vojvodina region (Lukić et al., 2009; Vasiljević et al., 2011a, 2011b). They preserve information on the processes of loess soil erosion that could help in future attempts to limit the loss of such material through conservation programs (Lukić et al., 2012).

4.2. Human-induced threats

Patently, loess sections worldwide have been facing increasingly serious soil erosion of various degrees caused by both natural and human factors as well as its consequent environmental deterioration (Wei et al., 2006) through sedimentation, pollution and increased flooding (Morgan, 2005). But, unlike natural processes which are inevitable, and obviously natural, human-induced threats could and should be controlled, sustained and in some cases prevented (Table 1). Geodiversity has been exploited by humans since the early beginnings of civilisation; thus many functional values of geodiversity could have devastating effects on their existence. Accelerated soil erosion and increased loss of the land surface are in many cases the results of various inappropriate human activities reflected through infrastructure construction, mining and agriculture (Hoang Fagerström et al., 2003b; Wei et al., 2006). Amongst all the human factors, agriculture has adapted to and impacted the environment more than any other activity (Li et al., 2012a).

4.2.1. Agriculture

Loess sediments form parent material for very agriculturally productive soils such as chernozems (Smalley et al., 2009), which puts them amongst the most fertile in the world (Catt, 2001). Thus, loess areas, thanks to this occurrence, are important areas of agricultural production (Zgłobicki and Baran-Zgłobicka, 2012). Furthermore, agricultural activities as one of the most important developments in human history emerged in the early Holocene from hunter–gatherer societies and progressed rapidly thereafter (e.g. Li et al., 2012a; Sidle et al., 2004). The same authors demonstrated this with the example of the Xishanping site in the western Loess Plateau where plant remains from archaeological sites, especially sites of agricultural activity during the Neolithic, dating from 4800 BC (Li et al., 2012a) were found.

Today, the Chinese Loess Plateau is an area of more than 530,000 km² (Zhu, 1986) and is home to a population of more than 80,000,000 people (He et al., 2003). Considering the fact that approximately 56% of the total inhabitants of China (or 737 million people) live in rural areas (Li et al., 2012b); this population pressure forces people to farm, often unwisely, more marginal land which leads to improper land use particularly when using sloping loess land for the cultivation of food crops to meet

the need of the residents (Liu, 1999; Sidle et al., 2004) as shown in Fig. 7D.

Even nowadays, agriculture, with its utilisation of irrigation and fertility maintenance techniques, has caused severe environmental consequences, particularly extensive soil erosion (Hoang Fagerström et al., 2003b; Sidle et al., 2004). This issue, for instance, was analysed by Hoang Fagerström et al. (2003b) for the land use in the Danangou catchment (Ansai County, Shaanxi province) where extensive loess agricultural terracing has been practised in order to provide enough food for the villagers. These authors indicate severe environmental consequences with particular attention to soil erosion as the community does not practise alternative conservative land use due to the poor living standard. In Europe, especially the central parts (Pannonian Basin), the loess has been the basis of fertile soils formation such as chernozems which caused high percentage of agricultural crops. In the Vojvodina region almost 60% of area is covered by loess and loess-like sediments (Marković et al., 2008) and without any sustainable planning and management this industry presents the foremost danger for loess.

4.2.2. Urbanisation

The Loess Plateau in China has a long history of human encroachment that has undoubtedly influenced gully development. Prior to the Sui Dynasty (581–618 AD), the Loess Plateau apparently had few gullies and was largely covered by forests and lush grasslands (Shi and Shao, 2000; Sidle et al., 2004). Thus the loess of Shensi, China, soft and easily excavated, has given rise to peculiar artificial loess-cave dwellings (Fig. 7B). Nowhere else in the world is loess more typically or extensively developed; and probably nowhere else, except possibly in similar sections of the adjoining province of Kansu, are these novel underground dwellings so numerous or widely distributed (Fuller and Clapp, 1924). The current extensive process of urbanisation in China could imply drastic changes of the agricultural management which will have significant consequences to Central Chinese Loess Plateau landscape dynamics. This issue would lead to cave-dwelling migrations from these areas to more urban ones which could put the local tradition and way of life under pressure.

Loess in Europe has not been used in such measure for dwelling (some examples are found in Croatia and Serbia, e.g. Vasiljević et al., 2011a; Stober et al., 2012) but in most cases attractive locations (near river banks) are nowadays extensively used for weekend houses and settlements building, specially at sections along Danube and Tisza rivers (Fig. 7A).

4.2.3. Extraction and other physical degradation

The most significant European loess profiles are (or were formerly) exposed at brickyard outcrops such as Nussloch, Kesselt, Dolni Vestonice, Červený Kopec, Krems, Paks, Basaharc, Sütto, Kostolac (Fig. 7C), Madaras, Katymár and Mircea Voda. One of the key loess sites for investigating climate variations of the Middle and Late Pleistocene of central Europe, Červený Kopec near Brno in the Czech Republic, which was used as a base for correlation with marine sediments (e.g. Kukla, 1975, 1977), was destroyed by its long-lasting exploitation for construction material. Consequently, only a few palaeo-pedocomplexes of the ‘classical’ loess profiles in Europe remain (Vasiljević et al., 2011a). Recent example comes from north-eastern Serbia, where since the 1870s extensive exploitation of coal and other surface resources, including loess, has been conducted. As stated in the previous section, this site is a well known Roman settlement and more recently the location of discovery of several mammoth skeletons in 2009 (Lister et al., 2012) and 2012. Although the majority of the discoveries would not have been accomplished without exploitation activities, much of these the geological, archaeological and palaeontological interest was either partially damaged or completely obliterated.

Physical degradation of geodiversity, in this case loess, is also caused by the ignorant behaviour of temporary and permanent users, such as local communities, tourists, recreationalists and other

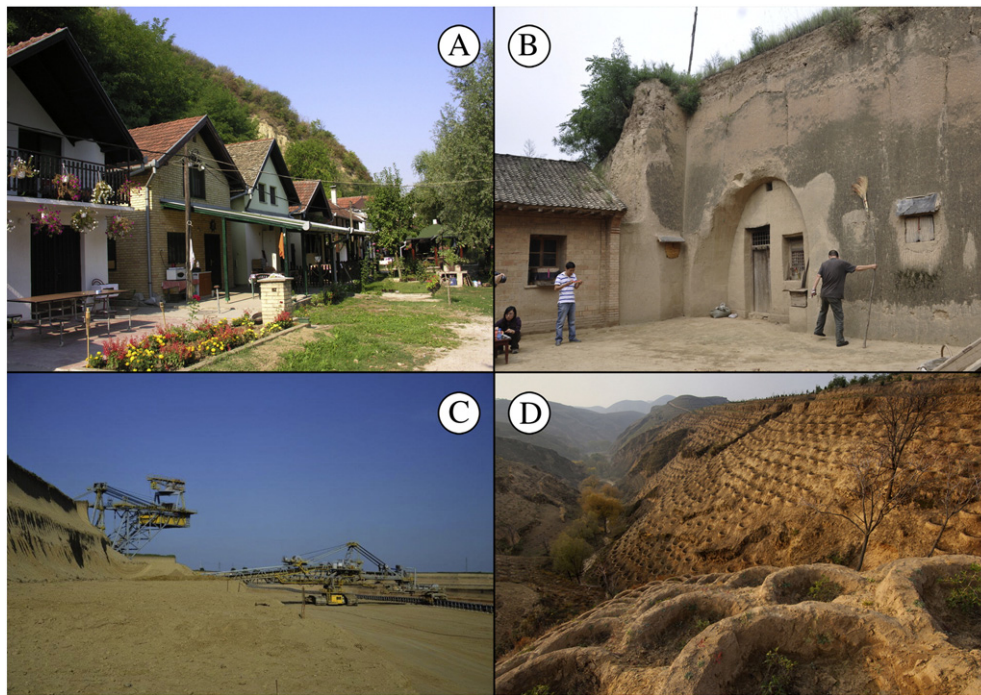


Fig. 7. Different kinds of loess exploitation: Illegal settlement just below Titel loess plateau, Serbia (A); Loess dwellings in Luochuan, China (B); Extensive loess exploitation in Kostolac, Serbia (C); Loess terracing for agriculture in China (D).

visitors whose unconscionable actions (e.g. waste disposal, uncontrolled vegetation, recreation/tourism effects) could also severely damage the natural environment; this latter consideration might well provide an argument for at least limited geoconservation measures at some threatened loess sites.

4.2.4. Legislative issues

Except for the previously considered physical threats that directly endanger geodiversity, there is a group of threats mostly related to certain legislative and bureaucratic issues. Legislation is a method that is widely used within nature conservation bodies to give formal protection to specific areas, also implied for geological and geomorphological sites. The most notable international formal protection is provided by UNSECO Geoparks and the World Heritage List.

In China there are 20 geoparks within the UNESCO designated Global Geoparks network and 138 National Geoparks designated by the Ministry of Land and Resources as of 2007, but only a few have protected loess, e.g. Luochuan, Huoshi Chai, Kungdongshan, Jingtai, and the Yellow River. These organisations by themselves do not provide any protection (Hose, 2007, 2008b; Vasiljević et al., 2011a) which leaves them only with limited governmental funding. Unfortunately, these areas are consequently far from major funding priorities, not just governmental but also those of voluntary conservational agencies. This is why the condition and infrastructure of these protected areas are generally not so well developed as say those for major archaeological and other cultural heritage sites. In Europe, no loess sections are covered by any measure of international formal protection, although there were some theoretical proposals for the Vojvodina province in northern Serbia (Marković et al., 2005; Vasiljević et al., 2009, 2011a, 2011b).

Another problematic issue is the ownership of loess sites as it is not uncommon that some natural (especially geological) sites are owned by organisations or individuals with little or no interest in their protection and conservation; indeed, measures to attain such an ideal scientific and geotouristic situation might well interfere with their commercially profitable exploitation. For example, some of the most important loess sections are owned by small private brickyards

(e.g. Ruma, Irig, Crvenka, Orlovat, Novo Miloševo only in Vojvodina), which do not intend, for quite understandable commercial reasons, to manage their sites for the benefit of geoconservation. A similar situation pertains in the brickyards at Crvenka, Petrovaradin and Kikinda also in Serbia (Hose and Vasiljević, 2012; Vasiljević et al., 2011a). This presents great problems for further research, has implications for geoconservation, and could irreversibly exploit loess sediments to their ultimate in-situ destruction. The example of Germany and the Nussloch limestone quarry, which is the site of one of the most important loess sections in the world (Antoine et al., 2001) shows how re-cultivation of these sites could enhance their visible geodiversity. The measures determined by the re-cultivation plan from 2001 indicated preservation of this loess section amongst the many other geosites later included in the Global Geopark Bergstrasse–Odenwald.

5. Further steps and proposed implications—concluding comments

The study has shown that loess–palaeosol sequences in Europe and China exhibit certain similarities concerning their human appreciated values, especially scientific and cultural. Loess worldwide presents a significant part of the Earth's geodiversity with numerous sites that need to be statutorily established as geoheritage and thus legally protected on both national and international levels.

However, many other values (e.g. functional and economic) have devastating effects on loess geosites. This study's analysis has demonstrated that loess in the case study areas is put under serious and constant pressure as a consequence of people's, often worsened by their ignorance, activities. The main threats to loess by people are from extensive agriculture, soil extraction for brick and ceramic production, and urbanisation. Therefore, it is essential to establish a strategy that delivers the most effective geoconservation measures for loess.

The first step should definitely be the establishment of an inventory of the most significant loess profiles and sections. As it is impossible and impracticable to protect and/or conserve all loess–palaeosol sequences it is fundamental to find the most representative ones that could serve various scientific, educational, cultural, (geo)touristic and other activities' needs.

All inventoried sites should then be recognised by national conservation and governmental bodies, preferably together with some international recognition or accreditation through UNESCO. Indeed, the best scenario would be dual national (geoheritage) and international (geopark, World Heritage Site) recognitions. For much easier implementation of much bigger projects such as these ones, it is important to establish specific policies that could be used to achieve geoconservation objectives in many ways. As smaller steps, policies are easier to put into practice and do not demand necessarily high resource investments. In some cases, legislation enables the policy details to be developed later. Excellent British examples of detailed 'regional' geoconservation management plans are provided by the various Local Geodiversity Action Plans (LGAPs) which are commissioned research to examine the feasibility of adapting its action planning approach to geosites (Burek, 2012). The plans, work and results arising from these documents could be further expanded and improved to meet the conditions of most complex international conservational bodies.

One of the projects that could be named as a pioneer practical step towards the implementation of loess geoconservation was made by the Municipality of Indija (Vojvodina, Serbia) which initiated a project entitled 'Loessland' with the aim to protect and promote the loess profile "Čot" in Stari Slankamen. This venture includes a modern visitor and research centre, at the loess cliff in Stari Slankamen, fully equipped for activities directed to educating the visitors and intensifying cooperation between scientific and cultural institutions (Vasiljević et al., 2011a). Unfortunately, whilst the project has been under development since 2008 only the initial scoping work has been completed and there are presently insufficient funds to start actual construction of the architecturally remarkable building. However, a small start has been made with tourist signage and an information panel.

A lack of experience in geoconservation, especially in some European countries, and even China, that do not practise this method, could lead to similar actions or even no actions at all. Thus, any form of international group for loess (geo)conservation and the promotion of its values to the general public could be of great assistance. Within the group, experts worldwide could share their ideas and collaborate on various researches, area management, organisation, and planning that could finally lead to the creation of a universal model of 'soft rock' geoconservation.

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