Loess and soils in the eastern Ebro Basin

Jaume Boixader a, b, Rosa M. Poch b, *, Sally E. Lowick c, J. Carles Balasch b

Department d’Agricultura, Ramaderia, Pesca, Alimentació i Medi Natural, Generalitat de Catalunya, Catalonia, Spain
b Departament de Medi Ambient i Ciències del Sòl, Universitat de Lleida, Lleida, Catalonia, Spain
c Institut für Geologie, Universität Bern, Switzerland

article info

Article history:
Available online 13 September 2014

Keywords:
Loess
Ebro Valley
Last Glacial Maximum
Pedogenic gypsum
Pedogenic carbonates

abstract

Wind-blown sandy and silty deposits were formed during the late Quaternary in the NE Iberian Peninsula. They are the most significant in the West Mediterranean region, together with those described in the Tagus River basin (Iberian South Subplateau), forming small scattered patches across parts of the SE Ebro Depression and SW Catalan Mediterranean Range. Two major depositional environments are distinguished. The first (largest) outcrop covers the lower Ebro reaches on the SE border of the Ebro Depression, the Prelitoral Coastal Range and the Môra d’Ebre Basin. A second outcrop, to the north, consists of a few patches scattered over a wide amphitheatre surrounding the western tributaries of the Segre River, from the wind-exposed Segrià platforms to the Almenara Range in its northernmost part. They consist of highly sorted fine sands and silts, 1–12 m thick (though most typically 3–4 m thick), and coarser than typical loess. They are highly uniform, lack any sedimentary structures and are pale ochre. The deposits are calcareous (30–45% CaCO_3), basic to alkaline and with some soluble salts.

Five selected sequences of primary loess (namely Mas de l’Alerany, Tivissa, Guiamets, Batea and Almenara) were studied to ascertain deposit characteristics and soil development. All sections show a consistent vertical granulometric variability that may be attributed to wind intensity changes, and hinders the recognition of spatial particle size distribution. Pedogenesis is mostly related to calcium carbonate redistribution, which accumulates as nodules, large rhizocreations or biogenic calcite. Secondary gypsum (Batea and Almenara sequences) is probably related to primary gypsum blown from the source areas that was redistributed by leaching and precipitation at the bottom of the profiles. In a few places (Mas de l’Alerany outcrop) a fersialitic, rubefacted-recalciified soil indicates the presence of an older generation of loess. While the dominant WNW winds and particle coarseness suggest that the loess originates from nearby alluvial fans and fluvioglacial plains, the presence of gypsum and Mg anomalies may be evidence of more distant sources of the Central Ebro Depression and Ondara-Corb alluvial fans.

Optical Stimulated Luminiscence (OSL) ages for the more recent deposits (Guiamets, Batea, Almenara) are between 18 and 34 ka, while the old Mas de l’Alerany sequence is more than 115 ka. These ages indicate loess deposition during the last cold phases of the Quaternary and with pedogenesis occurring during warm interglacial periods.

1. Introduction and objectives

The term loess (from the German löss) was first applied by von Leonhard in 1823 to describe friable silty deposits found in the Rhine valley and was then promoted by Lyell (1834–1846) during a visit to the Mississippi loess valley. Despite its early description, the aeolian origin of these materials was not accepted until the late nineteenth century, when the huge extent of these deposits was recognised in many parts of the world, i.e. Central Europe, Russia and China. It is now estimated that about 10% of the Earth’s surface is covered by loess (Pye, 1995).

From the early twentieth century a distinction was made between primary eolian and secondary loess (loess-like), which results from the removal and redeposition of primary loess. Towards the middle of the last century, the need for weathering and pedogenic processes to acquire the typical characteristics of loess deposits, as opposed to simple windblown dust was postulated, requiring a certain time for accumulation (Obruchev, 1945; Pecsi, 1990).

* Corresponding author. Universitat de Lleida, Medi Ambient i Ciències del Sòl, Av Rovira Roure 191, 25198 Lleida, Catalonia, Spain.
E-mail address: rosa.poch@macs.udl.cat (R.M. Poch).

http://dx.doi.org/10.1016/j.quaint.2014.07.046
1040-6182/© 2014 Elsevier Ltd and INQUA. All rights reserved.
Smalley and Vita-Finzi (1968) described loess as clastic deposits, predominantly quartz of 20–50 μm diameter (mode of 30 μm), that were transported and deposited by wind. However, loess displays a greater complexity and a larger variation in characteristics, such as thickness of the deposits, particle size (varying modal intervals from 8 to 16 μm in the China Plateau, to 50–65 μm in Nebraska (USA)), colour, mineralogy, geochemical composition, geotechnical characteristics and morphology. Although the origin of the silt was initially attributed to areas with glacial sediments (glacial loess), it was later acknowledged that in some regions the dust was sourced from desert areas (Yaalon and Ganor, 1973), and was therefore referred to as peri-desertic loess (Smalley and Vita-Finzi, 1968; Yaalon, 1987). Some authors (Wright, 2001) have stressed the significance of environmental, tectonic and geomorphological factors at all stages in the formation of loess sequences, as opposed to focussing only on their origin. Other authors (Iriondo and Krohling, 2007) refer to other geomorphic processes, parent materials (as pyroclastic or gypsum rocks) and environments involved in the generation of loess, in order to emphasize the complexity of formation processes and sources.

Pécsi (1990) listed the characteristics required for a deposit to be considered typically loessic, although not all described loess meets all these characteristics (Pye, 1995). The vast majority of loess deposits display evidence of some degree of modification or reworking with post-depositional bioturbation, weathering and pedogenesis, but these changes are not considered essential for qualification as a loess deposit.

Mediterranean loess deposits were only recognised late in the twentieth century (Brunnacker, 1969; Yaalon, 1969; Bornand et al., 1977; Brunnacker, 1980; Coudé-Gaussen et al., 1982, 1983; Cremaschi et al., 1990; Haase et al., 2007). The preparatory work for the 1957 INQUA excursion involved an update on the knowledge and extent of loess in Spain, although some participants had already acknowledged their presence (eg. Solé Sabarís et al., 1957). At that time, sixty deposits of aeolian origin had already been recognised in the Manresa area of Catalonia (ICME, 1956). Since then, Spanish authors have overlooked the presence of such deposits and only foreign authors have mentioned them: in Andalusia (Brunnacker and Lozek, 1969; Günster et al., 2001), and the Levant region (Dumas, 1977). However, extensive accumulations of loess in the Middle of the River Tagus Valley (Garcia-Giménez and González, 2010; García-Giménez et al., 2012) and the Castilian branch of the Iberian and South Submeseta (González et al., 2000) have recently been reported. Some small areas have been dated to the Middle Pleistocene, although the most extensive areas date from the Upper Pleistocene with an age of 42.7 ka BP, and a group of small areas date from the Pleistocene-Holocene (11.1–12.1 ka BP) (García-Giménez and González, 2010).

With respect to the Ebro Basin, several authors (Torras and Riba, 1968; Fink, 1969; Faraco, 1975; Mensua and Ibáñez, 1975; Van Zuidam, 1976; Gutiérrez-Elorza et al., 2002; Iriondo and Krohling, 2004) referred to “gypsum silts”, giving them an aeolian origin in some cases. In the lower Ebro Valley geologists have recognized for a long time the presence of silty deposits, while carefully avoiding the use of the term loess (ICME, 1981). In spite of this, several authors have reported soils developed on loess in NE Spain (Bech and Solé, 1977; Maldonado et al., 1979; Gallart, 1981; Josa, 1983; Solé-Benet et al., 1988; Müller et al., 1990; Lewis et al., 2009), although little relevant information regarding its origin and characteristics has been provided. Courty and Vallverdú (2001) mention aeolian deposits with a typical loess size in Abris Romaní (Capellades).

Our research has been conducted in an area NE of the Iberian Peninsula, east of the Segre River and south of the Sío River (Fig. 1) and lower Ebro Valley, to Benifallet canyon. For simplicity we call this area the Eastern Ebro Valley. While the existence of other loess or loess-like deposits east of this canyon are known (Maldonado et al., 1969; DAR, 2010), our study is restricted to this area where more information was available.

The soils of NE Iberian Peninsula have been surveyed since 1984 at the 1:25,000 scale (Danés et al., 1991). During the surveys, soils on widespread sandy loam materials were identified in the lower Ebro Valley (DARP, 1987; Boixadera et al., 1989); they did not fit the existing descriptions of Quaternary deposits of the area, and could not be explained by fluvial, alluvial, colluvial or gravitational processes. The properties (grain size, sorting, colour, micromorphy, geotechnical behaviour) and the geomorphological exposure of these deposits corresponded to loess or loess-like materials (Balasch et al., 2010, 2011).

The aim of this research is to present the extent, characteristics and significance of these deposits in the SE Ebro Depression and SW Catalan Coastal Range, to determine their loessic nature, to describe the extent of pedogenesis on them, and to propose source areas and ages for the aeolian material. This information contributes to the understanding of the paleoenvironmental and climatic conditions of the NE part of the Iberian Peninsula during the Quaternary and the role of loess in the present day soil cover.

2. Physical setting

The Ebro Basin is a sedimentary basin that developed and filled during the Paleogene and early Neogene, after which it was drained and carved by the Ebro River (Fig. 1a). It is bounded to the north by the Pyrenees, by the Iberian southwest ridge, and to the southeast by the Catalan Coastal Range. The Pyrenees reach almost 3500 m, are composed mainly of granitic and metamorphic rocks, that were largely covered by ice during different phases of the Quaternary. The last presence of ice in the Pyrenees valleys was about 15 000 years ago (Calvet et al., 2011), with only cirque glaciers present during the Little Ice Age.

The oldest Paleogene sediments in the Ebro Depression outcrop in its eastern and northern margins, consisting of marine detritic and carbonate rocks. After a regression, most of the sedimentary fill of the basin was formed of continental detritic sequences (conglomerates, sandstones and lutites) as well as evaporitic rocks. The center of the Ebro Basin is covered by outcrops of lutites, sandstones, limestones and gypsum, as well as Quaternary unconsolidated deposits associated to the drainage system (terraces and aluvial fans) and lacustrine deposits in endorheic playa-lake areas (e.g. Las Saladas de Monegros). The origin of the extensive Quaternary powdery gypsum surface deposits in this semi-arid region is not due to wind or desert processes, but was identified as the result of a soil forming process (Herrero, 1991; Herrero et al., 1992; Artieda, 2013). Some of the lutites of the eastern Ebro Depression fringe also contain diagenetic fibrous gypsum.

Other Quaternary detrital deposits include those covering the Pla d’Urgell east of Lleida; alluvial fans of the Corb and Ondara Rivers flowing from east to west, that spread over the plain, with no connection with the Segre River (Fig. 1b). Soils with high amounts of gypsum have been described on these Quaternary calcareous materials (Poch, 1992; Herrero et al., 1993). The Serra d’Almenara, extending W–E, is located north of these alluvial fans, and can be considered the southernmost folded structure of the pre-Pyrenean ranges, caused by the Alpine orogeny.

Before arriving at the Mediterranean Sea, the Ebro River (Lower Ebro Valley) crosses the SW section of the Prelitoral Coastal Range (Catalan Coastal Range), also due to Alpine folding. There, the geomorphological unit of the Móra basin, within the Prelitoral system is found (Fig. 1b). To the east, the Móra basin limits are