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Loess in Italy: Genesis, characteristics and occurrence

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ABSTRACT

There is currently a renewed interest in loess genesis and occurrence in Italy. Well-known loess profiles in northern Italy have been re-examined, and previously unknown loess deposits in central and southern Italy have been reported. This work combines a meta-analysis of published data with new data, presented here for the first time, to provide the state of the art on the spatial distribution, characteristics, genesis, and deposition ages of loess in Italy. A database of 98 soil horizons from 91 soil profiles was created and made available. It stores information on soils formed from loess or containing layers that show admixture of loess. Soil data include the source of information, the topographic, geomorphological and geological setting, kind of parent material and land use, main soil horizon properties as described in the field, soil classification, particle size distribution and chemical data.

Loess is reported from almost all regions of Italy. It is generally pedogenized throughout the entire loess body and forms the parent material of deep and complex soil profiles. The thickness of the loess deposits varies from a few decimeters to a few meters; pedogenesis and local reworking partially change the original loess characteristics. In this study, we propose a set of parameters that help recognizing loess in soils: particle size distribution and sorting, geomorphological setting, pedostratigraphic position, shape of the grains under optical and scanning electron microscope (SEM), and soil-micromorphological characteristics.

The ages of the loess deposits range between 70 ka BP and 18 ka BP. There are also a number of samples that have been dated to the Holocene. The meta-analysis suggests that climate is not the only driver of loess deposition in Italy; geomorphological instability and human disturbance, as well as the influence of Saharan dust, most likely played major roles, too.

This study demonstrates that loess is much more widespread in Italy than previously estimated. Yet, further research on the spatial and temporal distribution of loess deposition across the Mediterranean region is needed to better understand its genesis, sources and trajectories, periods of enhanced loess formation, and the role of loess deposits in ecosystem functioning and resilience.

1. Introduction

Loess deposits are important palaeoenvironmental archives, covering about 10% of Earth's terrestrial surface (Yang et al., 2009). As Quaternary records, loess-palaeosol successions provide relevant information on climate changes and ecosystems' resilience (Muhs, 2006). Soils formed from loess are widely used for agricultural production, e.g. in the northern European and Asian loess belts (Pye, 1984), as loess is the parent material of some of the world's most fertile soils (Brahy et al., 2000). Loess and dust deposits that have been completely incorporated into the soil cover play an important role, too (Lequy et al., 2012), as they provide additional fine particles, calcium carbonate and base cations (Avila et al., 1998). The aeolian input may contribute a considerable proportion of the total amount of nutrients and can enhance soil fertility and carbon sequestration capacity (Lequy et al., 2012). Aeolian deposits on slopes, however, are highly prone to water erosion, and also lead to an enhanced risk of landslides (Mileti et al., 2013).

Loess is defined as sediment that has been mobilized, transported, and re-deposited by wind. It is dominated by silt-sized particles (2–63 μm in diameter; Wright, 2001) and characterized by stabilization

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due to slight synsedimentary dissolution and re-precipitation processes of the contained carbonates (Pécsi and Richter, 1996). Thus, loess is not simply dust that has settled (Sprafke and Obreht, 2016), but its typical characteristics are also a result of various initial syn- or early post-sedimentary alteration processes, which can be summarized as “loessification”.

Loess has been alternatively regarded as a product of sedimentation or pedogenesis (e.g., Smalley et al., 2011 versus Pécsi, 1991). It has been differentiated into primary (wind-deposited) loess and secondary (reworked) loess, which is the product of re-deposition and mixing of primary loess with other materials (Pye, 1984). Identifying and characterizing loess contribution to soils may be a difficult task, since pedogenesis progressively alters the original properties of the loess (Cremaschi, 1987). Such challenge is common in the Mediterranean region, and contributed to the underestimation of loess occurrence in the map of Haase et al. (2007), which did not depict loess deposits in Mediterranean Italy. In contrast, the map of loess deposits by Bertran et al. (2016), derived from the grain-size distributions of European soils, considers loess occurrence in Mediterranean Italy. However, it lacks ground verification and laboratory evidence. Geological maps of Italy report loess deposits only for a few exposures, mainly located in northern Italy, close to the Alpine margin (http://www.isprambiente.gov.it/Media/carg/).

The recognition of the spatial distribution of Holocene and Pleistocene loess deposits is of paramount interest, since it may allow for identifying sources, modes of transport and phases of increased deposition, which can be correlated with climatic changes, tectonic instability, and anthropogenic landscape modifications (Pye, 1984). In addition, recognition that soils with loess contribution are much more widespread in the Mediterranean countries than usually acknowledged can provide new insights into ecosystem functioning and resilience.

Cremaschi (1987) published the first comprehensive review of loess deposits in Italy. His documentation focused on loess exposures along the Po Plain and the southern Alpine foreland. Some occurrences were also reported from the Adriatic basin, namely the islands of Croatia and the Conero promontory in the Marche region. It was also Cremaschi (1987) who reported for the first time that loess deposits in Italy are mostly pedogenized, and that sequences including unweathered loess are limited to a few sites. This new notion laid the foundation for successive studies, integrating sedimentological and pedological approaches (Cremaschi, 2004; Cremaschi and Van Vliet-Lanoë, 1990; Cremaschi et al., 1990; Busacca and Cremaschi, 1998). The sources of the loess were attributed to periglacial environments and braided riverbeds. In terms of timing, loess accumulation was related to the Pleistocene glaciations. The maps published first by Cremaschi (1987) and successively refined thereafter (Cremaschi, 2004), provided the first representation of the geographical distribution of loess deposits in Italy, and the first acknowledgement of their, so far overlooked, importance.

Later, Giraudi and co-authors carried out several studies on the high plateaus and karst depressions of the central and southern Apennines (Frezzotti and Giraudi, 1990; Giraudi et al., 2013; Giraudi, 2015). They reported the occurrence of thick and extensive aeolian deposits, which they interpreted as Saharan dust, though they also considered possible contributions from local sources. The deposition of these sediments was attributed to the Late Glacial and Holocene periods.

Priori et al. (2008) and Costantini et al. (2009) also reported the presence of loess in soils on hills of central Italy. In these cases, the origin of the loess was attributed to local sources. The times of its deposition included the late Upper Pleistocene as well as the middle Holocene.

A set of recently published papers documented previously unknown occurrences of loess in different parts of Italy, especially in its northern regions, namely in Trentino (Borsato, 2009), Veneto (Peresani and Nicosia, 2015), Liguria (Rellini et al., 2009) and Piedmont (Frigerio et al., 2017), including both typical and reworked loess, deposited on various substrates in different geomorphological settings. Known loess exposures along the Po Plain were reinvestigated by applying modern techniques (Amit and Zerboni, 2013). Mileti et al. (2013) discussed the presence of aeolian sediments in soils of the northern, central and southern Apennines and compared them to volcanic ejecta. Sandy and sandy-silty aeolian deposits located near the Ionian coast were reported by several authors (Wagner et al., 2007; Sauer et al., 2010; Andreucci et al., 2012). The growing interest in loess in the Mediterranean region led to the establishment of the INQUA Project “AEOMED” in 2012–2015 (Sauer et al., 2015), and its follow-up INQUA Focus Group GEODUST (2016–2019).

The aims of the present study were:

(1) to establish an open database for gathering and disseminating information on soils developed from loess and soils with loess additions in Italy, in a format that could be used also in other countries,
(2) to carry out a meta-analysis of the spatial distribution of loess and loess additions to soils in Italy, based on published and new soil data,
(3) to extract from this meta-analysis a preliminary overview of the spatial distribution and characteristics of loess in Italy, related to glacial and non-glacial environments in different regions and geomorphological settings, and
(4) to develop some preliminary hypotheses on the timing and probable processes involved in the genesis of loess in the various regions of Italy.

2. Materials and methods

2.1. Study area and general approach

The study area comprises the whole of Italy, stretching between 36° and 47° north, from the central Mediterranean basin to the temperate zone of the northern hemisphere (Fig. 1). Because of its geographic position, Italy represents a bridge between the loess belt of central Europe and the desert loess originating from the Sahara.

The interplay of the relief of the country with the wind regimes determines the sources, trajectories and areas of deposition of aeolian sediments. A major part of Italy is hilly or mountainous; the Alps represent the highest elevations of geographic Europe (Monte Bianco 4810 m) and act as a barrier with respect to the cold winds from the Arctic regions. The other important mountain chain of Italy, i.e. the Apennines, runs northwest to southeast, thus representing an obstacle for west winds coming from the Atlantic Ocean, but also for winds from northeastern directions. Occasionally, strong warm and humid winds blow from the south (the so-called “scirocco”), carrying dust from the Sahara Desert northwards to the Alps and beyond (Costantini et al., 2013).

We compiled all published work on loess in Italy that we became aware of during an extensive literature research and subjected the obtained data, together with new data of several own studies, to a meta-analysis. This meta-analysis concentrated specifically on soils formed from loess, while soils formed from other aeolian sediments, e.g., volcanic ejecta or coastal dunes, were excluded. Thus, the focus of this study was on loess deposits whose aeolian nature was clearly recognized and documented, although local slope processes and anthropogenic impact might have reworked some of them, and possibly mixed them to some extent, e.g. with colluvial materials or autochthonous soil material.

The loess was then classified as follows:

1) typical loess (TL), i.e. loess showing characteristics typical for loess according to Pécsi and Richter (1996), mainly consisting of silt with minor other contributions, not reworked after its aeolian deposition,
2) reworked loess (RL), i.e. loess that has been mixed with other sediments and/or has been transported by agents other than wind