Quaternary International 399 (2016) 198–207

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Loess: Rock, sediment or soil — What is missing for its definition?

Tobias Sprafke [a,*], Igor Obreht [b]

[a] Institute of Geography and Geology, University of Würzburg, Am Hubland, 97074 Würzburg, Germany
[b] Department of Geography, RWTH Aachen University, Templergraben 55, 52056 Aachen, Germany

ARTICLE INFO

Article history:
Available online 29 April 2015

Keywords:
Loess
Loessification
Dust
Biological loess crusts
Loess derivate
Loess-like sediment

ABSTRACT

Loess is commonly defined as an accumulation of windblown silt. However, the complex mechanisms that are responsible for most of the structural characteristics of loess require a more precise explanation. The common definition of loess ignores a set of processes that start during and after the subaerial deposition of silt. The term loessification has been used by a number of authors to refer to the quasi-pedogenic/quasi-diagenetic processes that result in the typical aggregation of loess; however these mechanisms are rarely described in detail. Depending on the researcher's background, loess is classified as sediment, soil or rock.

This review gives an overview on loess definitions through time and evaluates the main concepts related to loess formation. Several gaps of knowledge are identified that require a number of specific studies related to different aspects of loess formation in various environments. We propose to 1) differentiate primary loessification which initializes the formation of loess structure from secondary loessification which takes place subsequently and 2) define loess-like sediments as deposits that experienced loessification but were not transported aeolian. Mainly aeolian processes and loessification are of equal importance to define loess.

1. Introduction

Loess is commonly defined as an accumulation of windblown silt, covering more than 10% of the earth's surface, mainly in the earth's temperate zone (Pye, 1995; Pécsi and Richter, 1996; Muhs and Bettis, 2003). Loessification is a term that groups the quasi-pedogenic or quasi-diagenetic processes that transfer a loose silt-dominated substrate to a loess-like deposit, with its specific characteristics (Pécsi and Richter, 1996; Smalley and Marković, 2014). However, the general understanding of these processes is very limited, hampering a classification of loess as sediment, soil or rock (Smalley et al., 2011). To date, there is still no commonly accepted definition of loess (Muhs and Bettis, 2003), despite its significance.

Since its first description published 190 years ago (Leonhard, 1824), the research on the formation of loess — or substrates that were termed that way — led to numerous attempts to define it genetically (Smalley et al., 2001). The one characteristic found in all definitions is the predominance of silt, especially in its coarse fraction (Pécsi, 1990; Pye, 1995; Muhs et al., 2014). Smalley (1971) and Smalley et al. (2001) conclude that a major conflict regarding loess definition is related to competing fundamental perspectives of two major disciplines: Sedimentologists stress the processes of material production, transport, and accumulation by wind; pedologists focus on post-depositional processes that form many significant characteristics of loess, but that also take place in substrates that are not completely of aeolian origin (Smalley, 1971).

Any yellowish, carbonate bearing, quartz rich, silt dominated substrate (minor contents of [fine]sand and clay) from an outcrop in Central Europe (e.g. the type locality Haarlass near Heidelberg, Fig. 1A), formed by aeolian deposition and aggregated by loessification during glacial times would be widely accepted as (typical) loess. However, many deposits share only a part of these characteristics and defining them as loess may be questionable.

Some authors assume that aeolian deposition of mineral dust is the key process to define loess as a sedimentary body and neglect the significance of other concepts (Pye, 1995; Muhs and Bettis, 2003; Muhs et al., 2014). However, significant characteristics of many loess deposits are related to post-depositional processes (Pécsi, 1990, 1995; Smalley and Marković, 2014), such as cementation and aggregation, in geological and pedological terms, respectively. Diagenetic and pedogenetic alterations are mentioned

* Corresponding author.
E-mail address: tobias.sprafke@uni-wuerzburg.de (T. Sprafke).

http://dx.doi.org/10.1016/j.quaint.2015.03.033
1040-6182/

Fig. 1. Loess(-like) deposits. A: Haarlass, Heidelberg (Central Europe). Type section of loess (Leonhard, 1824). Photo by C. Hornung (Heidelberg). B: Batajnica, Serbia (SE-Europe). One of few plateau-like loess deposits in Europe with quasi-continuous loess-palaesol sequences. C: Landscape in the surrounding of Luochuan, Chinese loess plateau. Largest loess deposit in the world with longest LPS and specific loess morphology. Photo by Z. Svirčev (Novi Sad), D: Caspian Lowlands, Iran, close to border to Turkmenistan: Small mesas (10–20 cm height) in the semi-desert composed mainly of silty to fine sandy sediments. Mean annual precipitation: ~ 100–200 mm. The darker mesas are connected to cyanobacterial mats which partly prevent the silty parent material from erosion.

repeatedly to refer to loess as (soft/sedimentary) rock or (synsedimentary/synlithogenic) soil. Frequently, the term loessification is used as a synonym for the post-depositional processes that are relevant to form loess (Pécsi, 1990, 1995), although it is still not clear which are the geological and ecological factors leading to the specific loess-like structures of many quaternary silt-dominated sediments.

Despite the contemporary trend to reduce loess to a deposit of windblown dust (Muhs et al., 2014), due to recent findings on possible syn-to post-depositional processes (Svirčev et al., 2013) and remaining questions on what loess is (Makeev, 2009), this review focuses on identifying the reasons why it is difficult to come to a commonly accepted definition of loess. First the significance of loess and related deposits is summarized to highlight the reasons behind the different perspectives. Second, an overview of loess definitions through time serves to illustrate how different perspectives developed. The main processes attributed to loess and related deposits are then reviewed and gaps of knowledge for a commonly accepted definition of loess identified.

2. Significance of loess and related deposits

Loess and related deposits are one of the most widespread Quaternary sedimentary formations, most abundant in semi-arid regions of inner Eurasia (Smalley et al., 2011). In the humid temperate area, loess deposits formed during the cold stages of the Pleistocene. Alternations of loess and palaeosols are usually interpreted to reflect the broad global climatic oscillations during the Quaternary (Muhs and Bettis, 2003). Though, there are several examples for interglacial loess formation indicated by studies of Holocene deposits (Lehmkuhl et al., 2014; Muhs et al., 2014), which are often related to (semi-)arid areas (Crouvi et al., 2010). Further confirmations of recent loess come from Alaska (Muhs et al., 2003) and the Chinese Loess Plateau (Pécsi and Richter, 1996). In the Danube basin, where loess-palaeosol sequences (LPS; Fig. 1B) rather clearly illustrate environmental changes during the last ten glacial–interglacial cycles (Fitzsimmons et al., 2012), recent research has shown that loess formation may not have ceased at the end of the Pleistocene, but continued during Early Holocene times (Marković et al., 2014). But loess is not only a Quaternary phenomenon; in China loess formation may have started as early as the Miocene (Guo et al., 2002). There are also late Palaeozoic loess deposits of equatorial Pangaea (Soreghan et al., 2008) and Precambrian loessites in northern Norway (Edwards, 1979) – however altered by significant diagenesis.

Loess sediments, mainly composed of windblown particles, are key palaeoclimatic archives, recording past global atmospheric mineral dust dynamics and palaeoenvironmental changes (Kohfeld