

Particle Size Distribution in Loess Deposits – New Insight into Inter-Hemispheric Linkages of Past Atmospheric Circulation and Aeolian Dust Dynamics Recorded in Danube and Central Asian Loess

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*Eurasien
Löss
Äolischer Staub
Atmosphärische Zirkulation*

Contents

Zusammenfassung	199
Abstract	199
1. Introduction	200
2. First Results	200
References	200

Partikelgrößenverteilung in Lössablagerungen – Neue Einblicke in Atmosphärenzirkulation und Staubtransport der Vergangenheit in Lössen aus dem Donauraum und aus Zentralasien

Zusammenfassung

Löss (äolischer Staub) definiert sich vor allem durch seine eng begrenzte Partikelgrößenverteilung innerhalb der Siltfraktion. Durch die Anwendung hochauflösender Partikelgrößenanalytik und Verbesserungen bei der Probennahme und -behandlung konnte gezeigt werden, dass die bisher als unimodales Maximum angesehene Siltfraktion äolischer Sedimente tatsächlich eine charakteristische bimodale Verteilung (twin peak) aufweist. Untersuchungen an hochaufgelöst beprobten Lösssequenzen in Eurasien (Serbien, Rumänien, Usbekistan und Kasachstan) haben weiterhin gezeigt, dass die bimodale Siltverteilung wahrscheinlich ein generelles Phänomen für äolisch abgelagerte Lössse darstellt und eine paläoklimatische Signatur von langfristigen Dynamiken im interhemisphärischen Staubtransport Eurasiens abbildet.

Abstract

Loess (essentially airborne silt) has been characterised by its narrow size distribution in the silt range, say 10–50 µm with a mode at about 30 µm (SMALLEY, 1995). The silt distribution has always been seen as a uni-modal material but now it appears, after advances in measurement technologies as well as in sample collection and preparation, to be bimodal. The bimodal silt distribution (twin peak or Eden effect) seems to be a major and significant phenomenon of loess sediments in general and we will discuss the relation of internal material controls in the quartz minerals and external climatic driving factors that are recorded in the aeolian dust record of several loess sequences across Eurasia (Middle Europe, SE Europe, Middle Asia, Central Asia and the Chinese Loess Plateau), where a continuous and highly resolved grain size sampling has taken place. If it can be established that loess is essentially bimodal and that this bimodality allows palaeoclimatic data to be obtained, the use of loess in Quaternary studies will be enormous.

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1. Introduction

Advances in measurement technologies as well as in sample collection and sample preparation have shown that the particle size distribution of the silt fraction of loess is much more complex than has been hitherto suspected. By definition loess is characterised by its particle size distribution with a polymodal distribution and a strong dominance of the middle and coarse silt fraction. We found that the silt mode appears to be in fact two silt modes/maxima, as there are two closely adjacent peaks in the particle size curve (twin peaks). One at approximately 20 μm and the other at approximately 40 μm , separated by a noticeable gap centered at 30 μm .

2. First Results

A first observation of the twin peak effect has been recorded by EDEN in a study of the loess in Essex (EDEN, 1980). EDEN gave a clear indication of the twin peak phenomenon but his findings excited no comment. A complex study on the loess of SE Kazakhstan studied the very clear and persistent splitting of the major peak on the loess size analysis diagram in more detail, and similar tests were carried out on loess from classic European loess regions in the Vojvodina, the Dobrogea, as well as on loess from the Chinese Loess plateau, all displaying the same two peaks effect (MACHALETT et al., 2008).

The effect has now been observed again, in artificial loess produced in a laboratory. A Bromhead ring-shear testing machine was used as a simple model glacier to provide shear deformation for samples of quartz sand, and this proved to be a very effective silt producing device (O'HARA-DHAND et al., submitted). Analysis of the silt-sized product shows a clear two peaks result. An explanation for this could lie in the crystal structure and complex deformation mechanisms of low quartz, the main constituent for loess particles, and that each mechanism has a characteristically sized product. This accounts for the 20 μm and 40 μm size modes. A contribution to the deformation systems may be made by internal defects which are found in natural quartz crystals; and it does appear that they may have a contribution to make to silt forming mechanisms.

The variations of the bimodal silt (twin peak) distribution recorded in loess sequences are not random. Both maxima vary significantly in height and area when comparing samples from different stratigraphic units of long loess se-

quences and reflect a signal that clearly correlates with the stratigraphic position within the studied loess record. The coarser silt peak is pronounced within loess layers, while the finer silt peak B is stronger in stratigraphic layers that correspond with temperate climate conditions. In order to depict the variations within the bimodal silt distribution we developed the twin peak ratio, establishing a quantitative comparison between the two silt peaks.

Analyses of the twin peak ratio in Eurasian loess sequences (e.g. Stari Slankamen and Mosorin, Serbia; Mircea Voda, Romania; Almaty-Remisowka, Kazakhstan) show recurrent long-term trends within the dust record, suggesting that a continuous force triggered the aeolian dust sedimentation on a glacial-interglacial scale. The recurrent long-term trends in the dust transport record represent lasting changes from glacials to interglacials and vice versa, affected by decreasing or increasing aeolian dust transport activities. In consideration of the modern synoptical atmospheric circulation patterns and aeolian dust transport in the region (taking place mainly through cyclones forming along the polar front), we hypothesize that the observed trends are a consequence of the long-term migration (and seasonal duration and permanency) of the Eurasian polar-front during the Pleistocene. As the polar front activity is intimately connected with the development and position of the high level planetary frontal zone the data give insight to long-term aeolian dust dynamics and climate variability of interior Eurasia that are linked with inter-hemispheric climates.

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