Environmental change indicated by grain-size variations and trace elements: An example from the sandy-loess sediments from the Doroshivtsy site (Ukraine)

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Introduction

Loess sequences provide important and in some cases an almost continuous record of Quaternary paleoenvironmental change; some of sequences even provide a record concerning archaeological details. In addition, loess-paleosol sequences provide valuable information concerning environmental change and climate evolution. The loess section of Doroshivtsy became famous due to archeological findings of the Gravettian (Kulakovska et al., 2012) and is situated in the SW part of Ukraine at the right bank of the middle part of the Dniester River (48°35'37.6"N, 025°52'10.7"). The profile is situated in a flat gully and at an undercut slope of the Dniester River close to the village Doroshivtsy in the south-western Ukraine. It represents a ~9 m sequence of sandy loess, intercalated by more humic horizons.

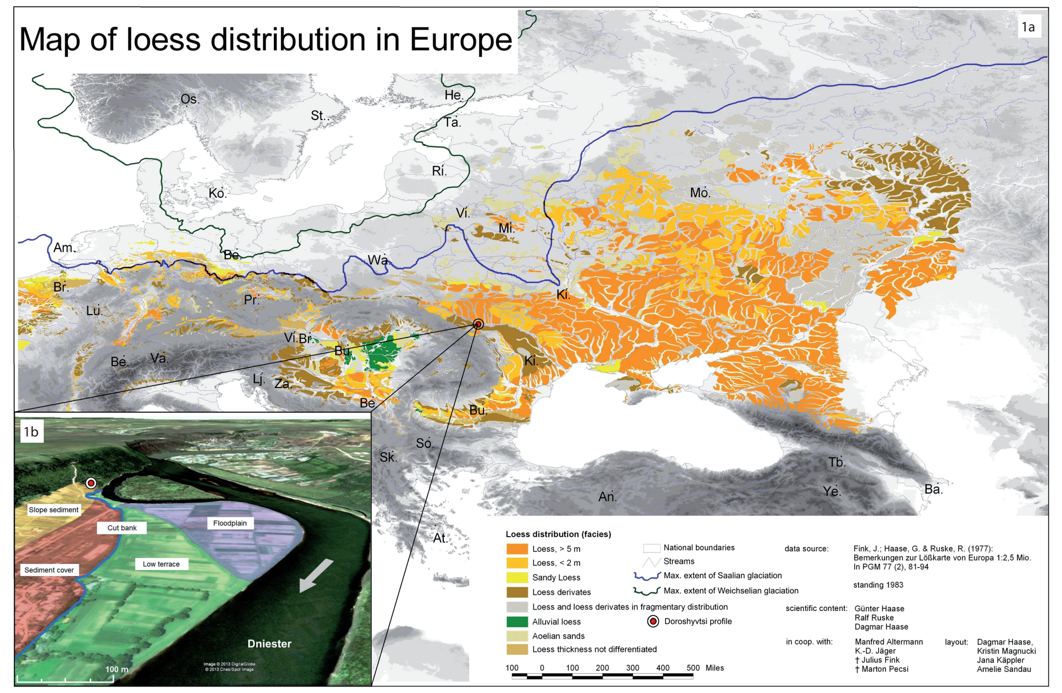

Fig. 1a: Loess distribution in Europe (Haase et al. 2007), Pleistocene ice margins (Weichselian, Saalian) and location of the section Doroshivtsy in the western Ukraine. **Fig 1 b:** Geomorphologic situation of the section on the left bank of the Dniester River.

Regional setting and distribution of loess in the Ukraine and adjacent areas

The geological basement of the southern Ukraine is built from the Polodian Plate and about ~70 % of the Ukraine is covered by Quaternary loess or loss-like deposits (Bockhorst, 2009). In the Doroshivtsy area the Dniester River is incised ~70-100 m in Mesozoic and Cenozoic bedrock and formed a ~1 km wide and flat valley. The modern Dniester River meanders through this valley. The Doroshivtsy section represents a ~9 m sequence of sandy loess, intercalated by more humic horizons. It is situated in a flat gully on an undercut slope on the right side of the Dniester River close to the village Doroshivtsy (Fig. 1). The less steep slope at the valley bottom indicates sediment accumulation of slope material in this position; therefore the section most probably represents a combination of aeolian transported loess and slope-wash material.

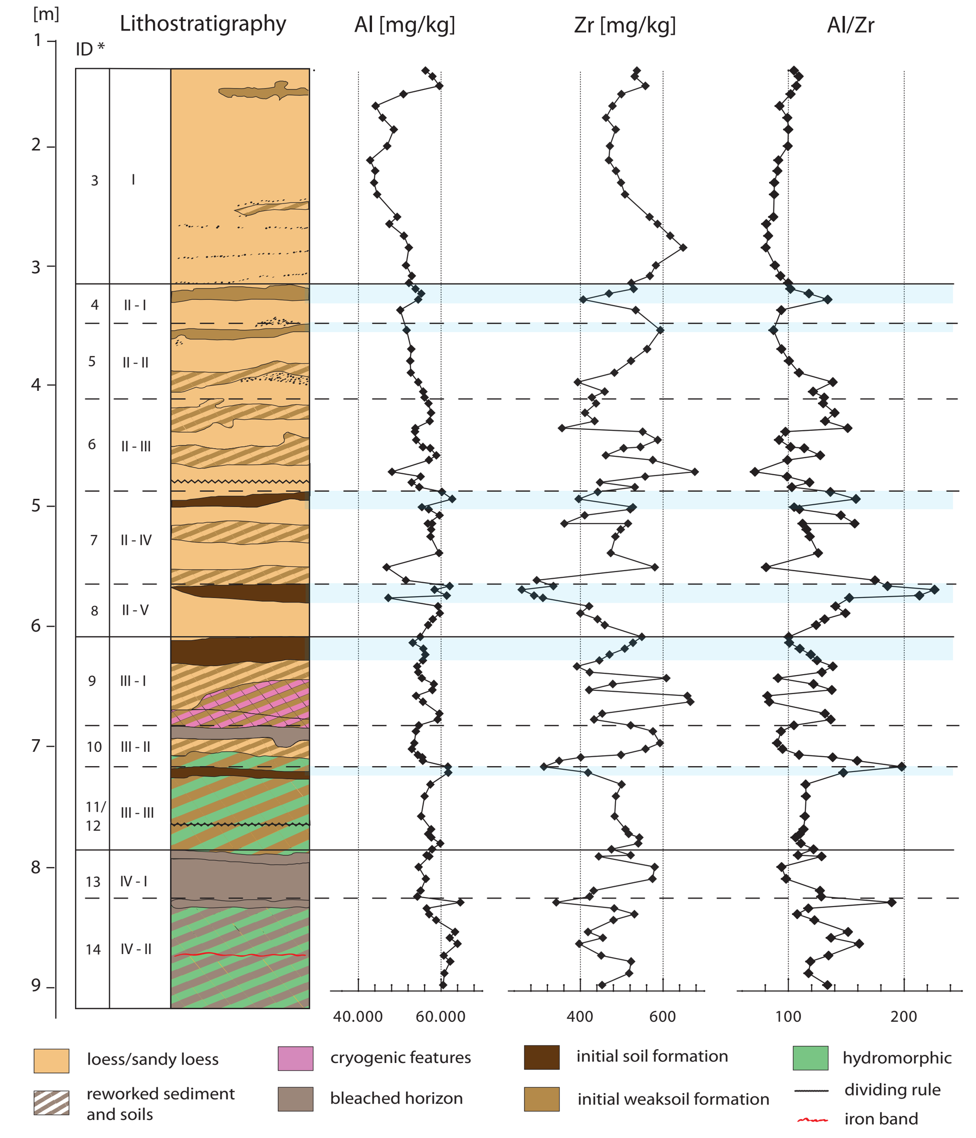

Fig. 2: Lithostratigraphy and selected element concentrations of the section.

Methods:

Particle size was measured with a Laser Diffraction Particle Size Analyzer (Beckman Coulter LS 13 320 PIDS) by calculating the mean diameters of the particles within a size range of 0.04 - 2000 µm with an error of 2 %. To remove the organic matter, the samples were treated with 0.70 ml 30 % H2O2 at 70 °C for several hours. To keep particles dispersed, the samples were treated with 1.25 ml Na4P2O7 for 12 hours. To determine the grain-size distribution the Mie theory is used (Fluid RI: 1.33; Sample RI: 1.55; Imaginary RI: 0,1). To determine the element concentrations of the fine-grained fractions, the <63-µm fraction was sieved and dried at 105 °C for 12 h. An 8 g-quantity of the sieved material was mixed with 2 g Fluxana Cereox, homogenized and pressed to a pellet with a pressure of 20 t for 120 s. All samples were measured twice with the XRF device (Spectro Xepos). Mean values were calculated from the two measurements.

To characterize the sediment layers we used an individual SiS-ratio (3.5 to 8.1 µm / 69.6 to 161.1 µm) (Fig. 4) which we calculate on the basis of the genetic grain size dependence of same chemical elements. To narrow down the silt range we correlated the GS-results with Al and Rb values. The upper coarse silt / fine sand range we narrow down with respect to the Zr values (Fig. 2). For comparison we calculate the U-ratio of 44 to 16 µm versus 5.5 to 16 µm (Vandenberghe et al., 1985).

Results

Based on the field description (Fig. 3) and the grain size distribution the profile can be divided into four main genetic units representing changes during the deposition (Fig. 2). Part I (1-3.2 m) of the profile is characterized by aeolian loess and sand deposition intercalated with a few gravel lines. Part II (3.2-6.1 m) of the profile is influenced by aeolian, denudative and weak soil forming processes. Part III (6.1-7.8 m) of the section represents a combination of aeolian loess, re-deposited slope material. Part IV (7.8-9.1 m) is mainly composed of clayey and silty layers of tundra gley. The whole parts III and IV are affected by hydromorphic conditions. As most of the sediment is rather homogeneous sandy silt the U-ratio did not show any distinct variations. However, calculations with different grain-size ratios show that the fine silt to fine sand ratio (SiS-ratio) of 3.5 to 8.1 µm and 69.6 to 161.1 µm provide clear peaks. These variations of the SiS-ratio represent environmental changes which are also observed by structures and weak soil formations in the section during field work and fit also to the different archeological layers. In addition, geochemical analysis show comparable results to the SiS-ratio and provide further evidence for the differentiation of the stratigraphic units. Summarizing we can detect 3 different main units and 11 sub-units which are related to paleoclimatic and environmental conditions.

Radiocarbon dating and pIR IRSL ages based on feldspar ages are conclusive within the expected age range of the Gravettian period (22-28 ka). The loess section is composed mainly of sandy silt and covers the time span from about 26 to 16 ka. This is one of the very few sections in Europe which provides a high resolution sedimentary record including prehistoric finds of the cooling maximum of the last glacial cycle.

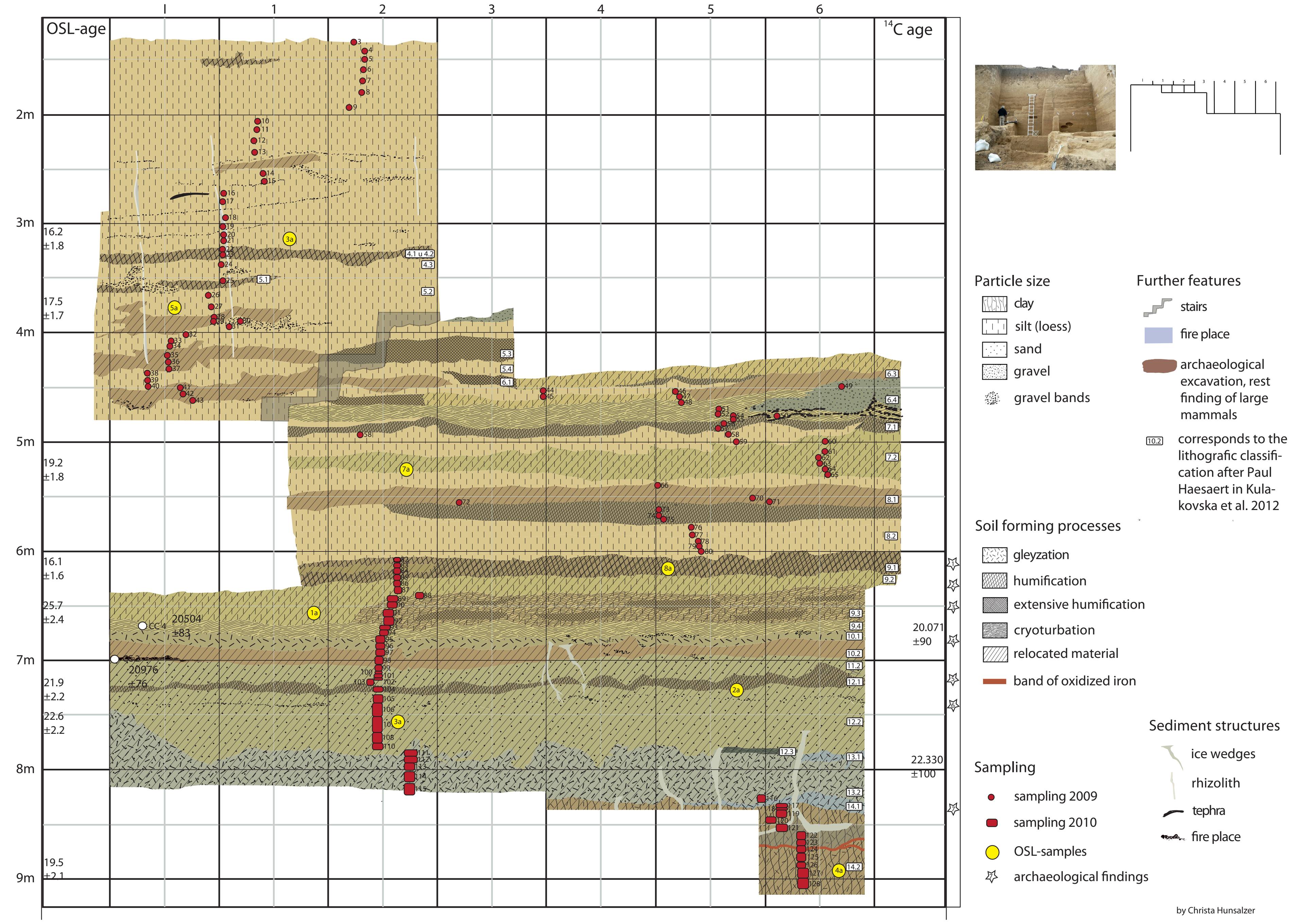

Fig. 3: Detailed sketch of the section.

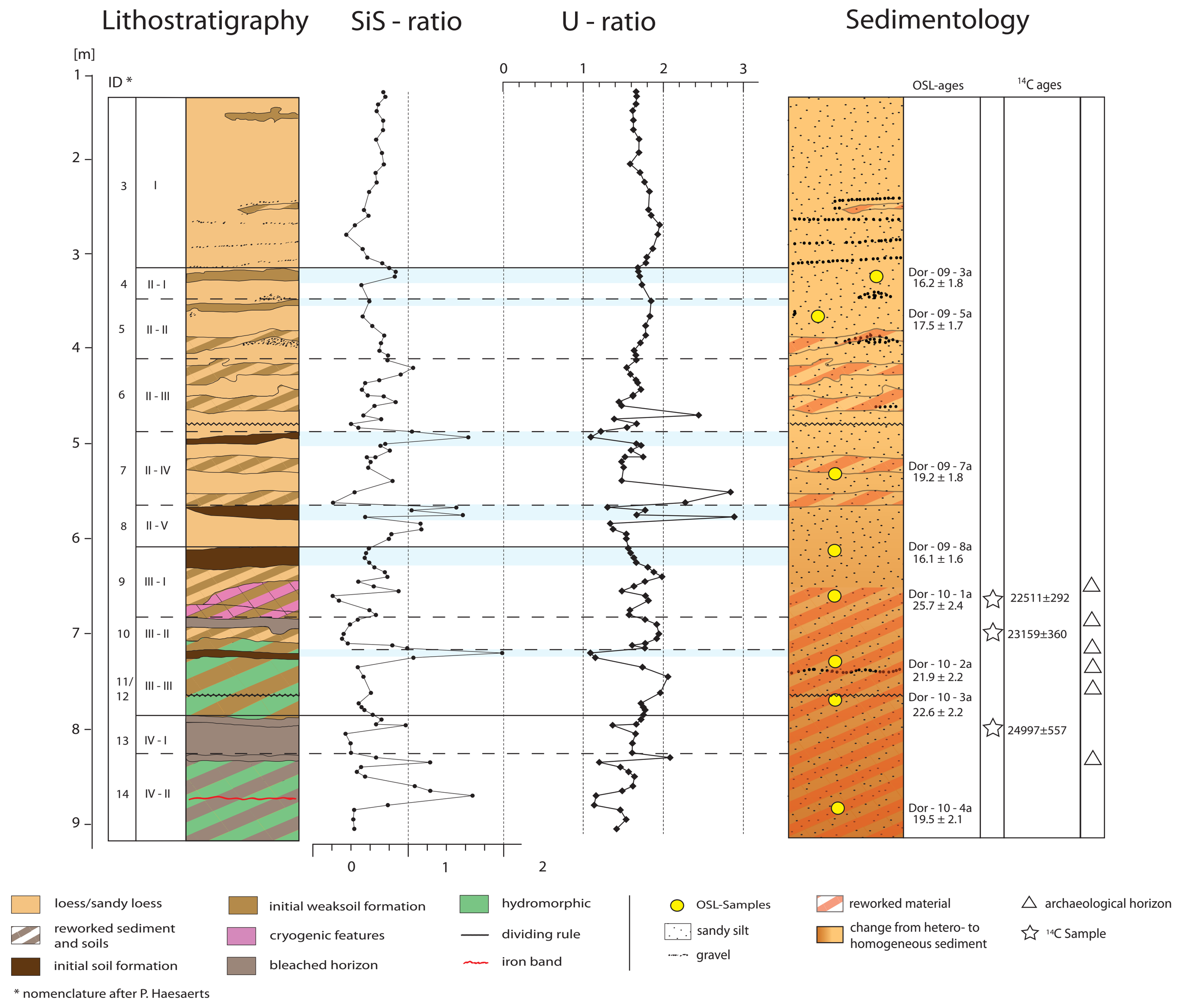

Fig. 4: Lithostratigraphy and sedimentology of the section. The individualized SiS-ratio takes into account the silt and the fine sand fraction and shows more distinct variations than the U-ratio in this multiprocessual archive.

Summary

The Doroshivtsy sandy loess section is dedicated to the Gravettian period (Kulakovska et al., 2012) which is dated to about 22-28 ka in the Ukraine. The sediment from the lower unit of the Doroshivtsy loess section is reworked and therefore, the relative age overestimation of OSL feldspar data is due to partial bleaching. This is supported by coincident feldspar and radiocarbon ages. Despite the relative overestimation, quartz and feldspar ages are conclusive within the expected age range of the Gravettian period (22-28 ka) in the Ukraine which shows that the proportion of partial bleaching of the pIRIR signal is less explicit (Klassen et al.; submitted).

Different grain size ratios often allow similar interpretations. The advantage of the individualized SiS-ratio compared to the U-ratio is their independency of firm boundaries. The environmentally sensitive ranges of the GS-spectrums are compared as a ratio.

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