Compositional data analysis of sedimentological, mineralogical and geochemical data for the evaluation of Austrian loess and loess loam deposits

Heinz Reitner[1*], Christian Benold[1], Peter Filzmoser[2], Maria Heinrich[3], Gerhard Hobiger[1], Can Mert[2], Julia Rabeder[1], Jürgen M. Reitner[1], Ingeborg Wimmer-Frey[1]

[1] Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria. *heinz.reitner@geologie.ac.at

[2] Research Unit Computational Statistics - Institute of Statistics and Mathematical Methods in Economics, Vienna University of Technology, 1040 Vienna, Austria.

[3] Marxergasse 37/5, 1030 Vienna, Austria.

Introduction

Austrian loess and loess loam deposits represent an important source of raw materials for the heavy clay industry for centuries. Building material quality of loess and loess loam deposits and their suitability for different applications is significantly influenced by their heterogeneous properties. These depend on the geology of the source area, climatic conditions, geomorphological location, stratigraphic position, intensity of weathering and redeposition potential. The description of occurrences, properties and availability of these raw materials is therefore an important prerequisite to meet the industrial quality requirements. At the Geological Survey of Austria a large number of different sub-datasets exist, which comprise grain-size analysis, bulk rock composition, clay mineralogy and geochemistry data of loess and loess loam samples.

Objectives

The project aims to

- establish an interoperable coherent database,
- categorize loess and loess loam occurrences by joint statistical analysis of the data using log-ratio analysis methods and to
- delineate loess and loess loam deposits as an upcoming complement of the Austrian Interactive Raw Materials Information System IRIS-Online (Weber et al., 2019)

  https://www.geologie.ac.at/services/webapplikationen/iris-interaktives-rohstoffinformationssystem/

Materials and methods

In our study we focused on samples within the classic Austrian loess regions in the Northern Alpine foreland areas of Upper and Lower Austria and in the Vienna Basin. We used a digital compiled map of quaternary sediments of Austria (Untersweg et al., 2008, Heinrich et al., 2018) to delineate the occurrences of loess and loess loam (Figure 1).

We mapped the samples to three subregions which are based on occurences of different types of Loess-paleosol sequences (Fink, 1956). Due to increasing amounts of average rainfall from east to west, the subregions were named the dry eastern region (DER), the central transitional region (CTR) and the humid western region (HWR). We categorized our sample locations according to the subregions they fall into (Figure 2).

Within our project, the individual data sets underwent a thorough examination and have been merged into a coherent database to enable the joint regional and statistical analysis of the data. By applying a log-ratio approach the compositional nature of the analysis data has been taken into account. Therefore all analysis data underwent a centered log ratio (CLR) transformation (Aitchison, 1986) before uni-, bi- and multivariate statistical evaluations. Exploratory data analysis of the three groups revealed distinct characteristics (Figure 3). We relate these to differences in weathering conditions in the three subregions, i.e. leading to different amounts of dissolution of carbonates and formation of clayminerals.

By transferring the results of the statistical analysis to a Geographic Information System (GIS) these served as the fundamental basis for our categorization and delineation of the loess and loess loam occurrences.

Finally we evaluated borehole databases provided by the federal governments of Upper Austria (Amt d. OÖ Landesregierung, 2018) and Lower Austria (Amt d. NÖ Landesregierung, 2018) and models of overburden layer thickness of gravel deposits provided by the Geological Survey of Austria. Out of these we gathered information regarding the thickness of loess and loess loam layers.

Results:

Taking into account previously published approaches based on soil profile classifications as well as trends and patterns derived from the analysis data, we finally were able to delineate and characterize different districts of brick raw materials deposits (Figure 4). These will be made publically accessible to the industry and interested parties as an upcoming part of the web-application of the Austrian Interactive Raw Materials Information System IRIS-Online.

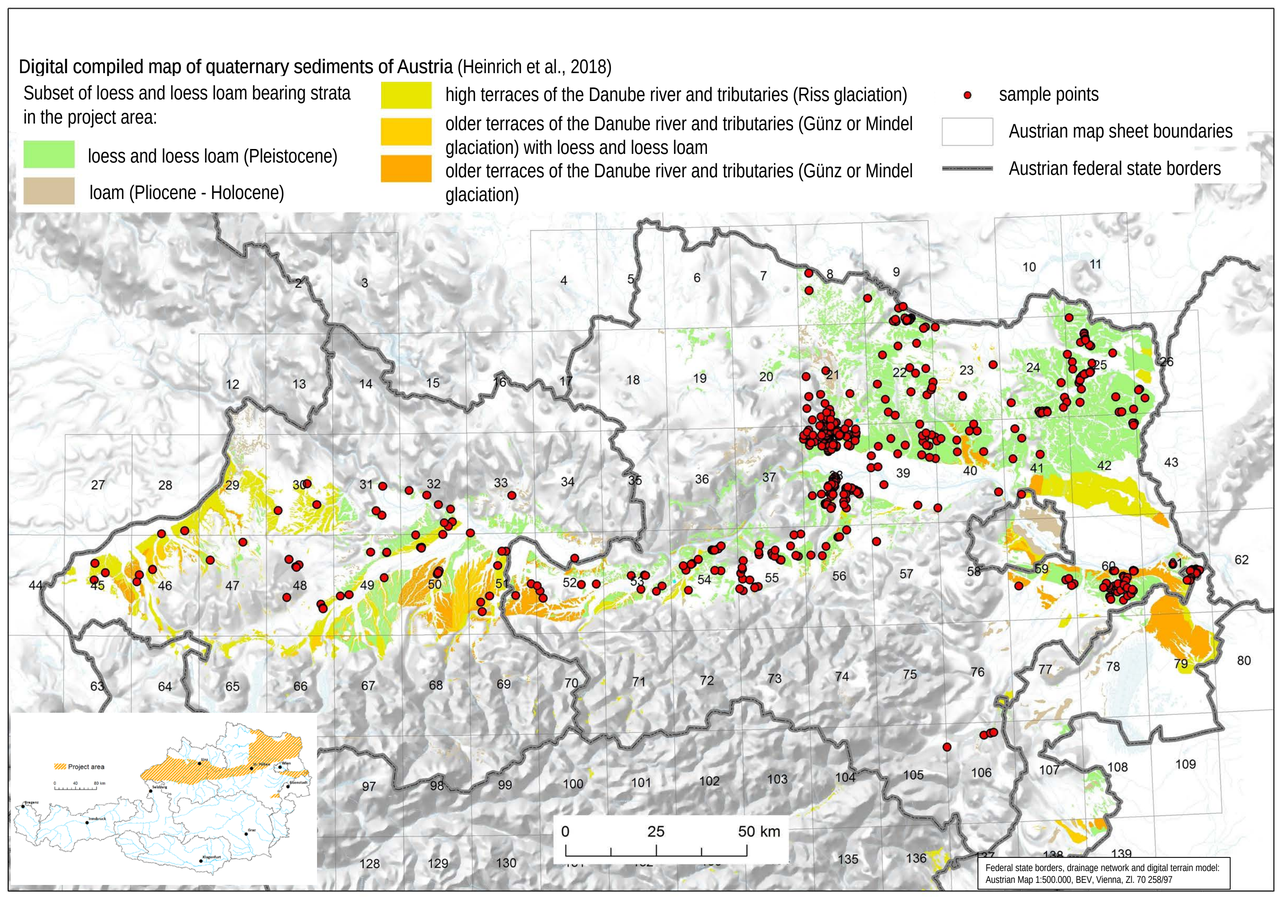

Fig. 1: Location of loess and loess loam samples in the classic Austrian loess regions in the Northern Alpine foreland areas of Upper and Lower Austria and in the Vienna Basin (insert map depicts project area in Austria).

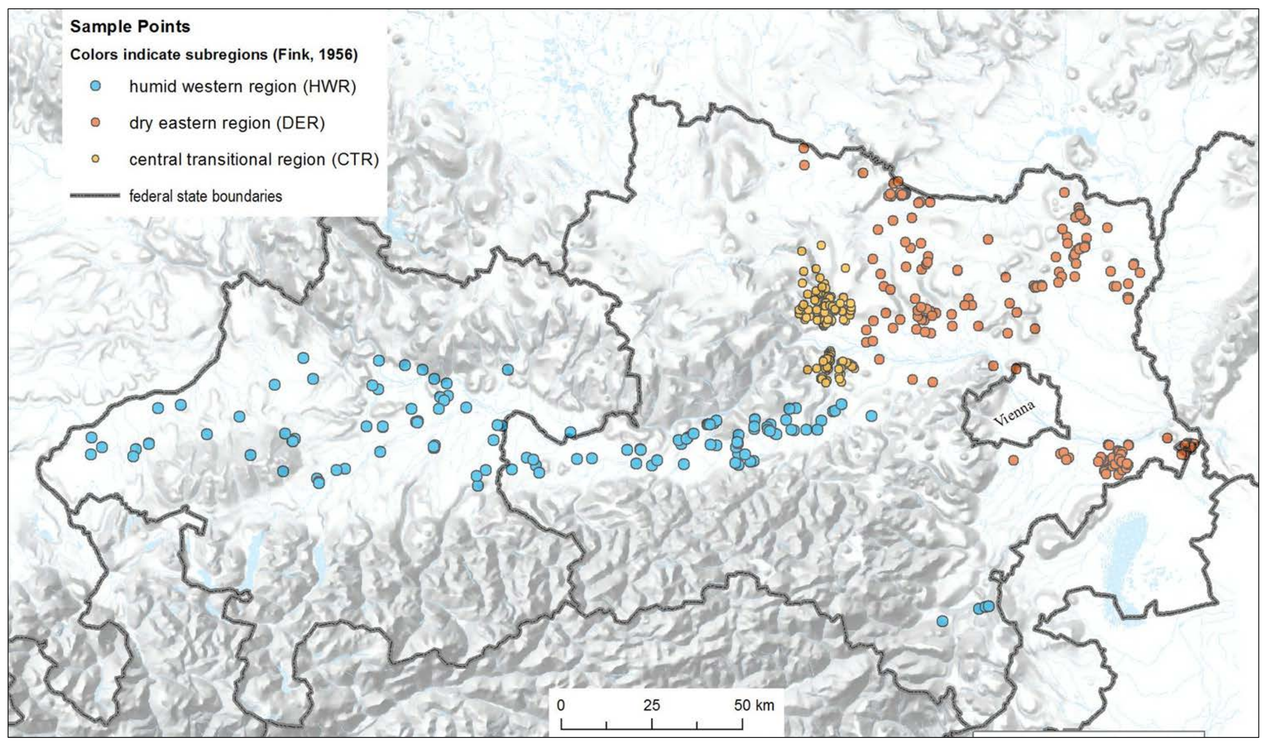

Fig. 2: Mapping of loess and loess loam samples according to three subregions: dry eastern region (DER), central transitional region (CTR) and humid western region (HWR) (Fink, 1956).

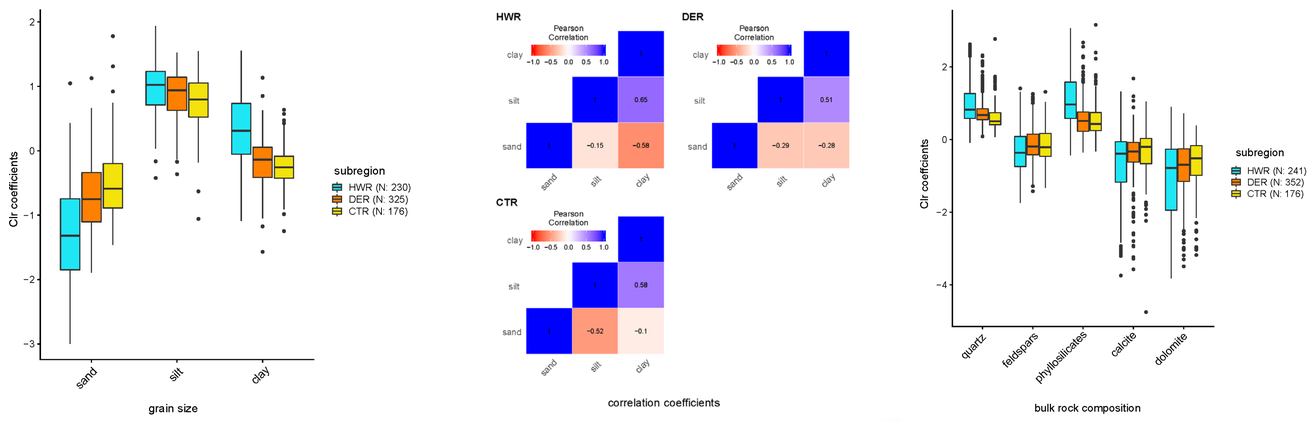

Fig. 3: Exploratory data analysis of centered log ratio (CLR) transformed datasets, grouped according to subregions: boxplots (left) and heatmaps of correlation coefficients (center) of grain size data, boxplots of bulk rock composition data (right).

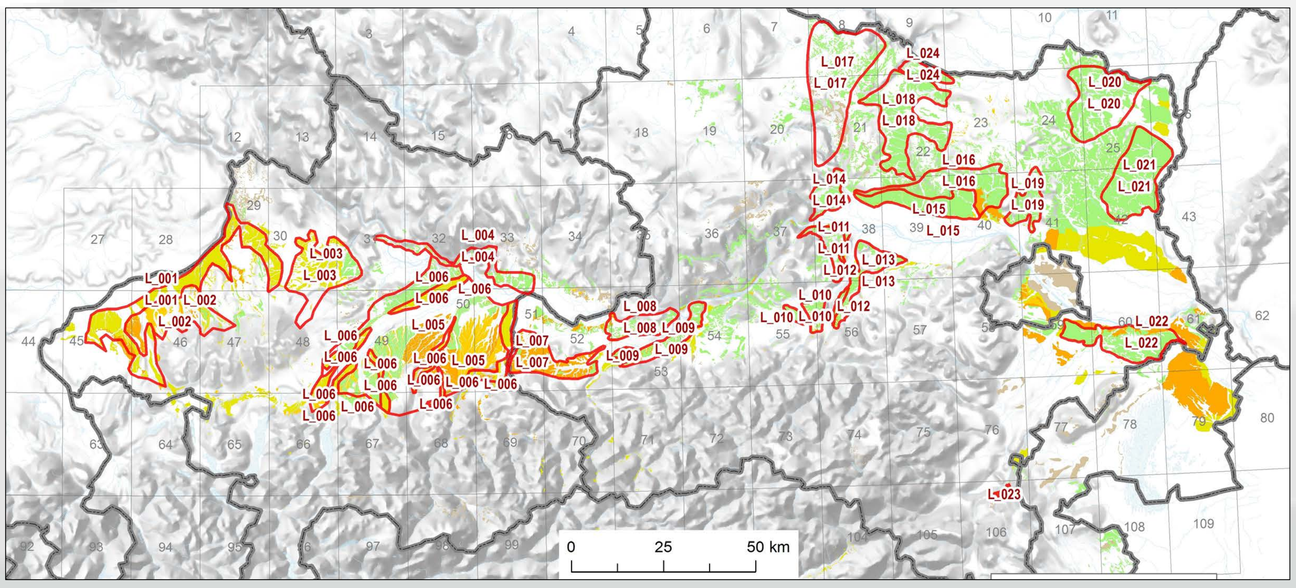

Fig. 4: Delineation of loess and loess loam districts (boundaries in red colour) in the classic Austrian loess regions in the Northern Alpine foreland areas of Upper and Lower Austria and in the Vienna Basin.

References:

Aitchison, J. (1986). The Statistical Analysis of Compositional Data. Monographs on Statistics and Applied Probability.- 416 p., Chapman & Hall Ltd., London (UK). (Reprinted in 2003 with additional material by The Blackburn Press)

Amt d. NÖ Landesregierung (2018): Bohrungsdatenbank HADES.- borehole database of the federal government, St. Pölten (AT).

Amt d. Oö Landesregierung (2018): Bohrpunkte GeoloGIS.- borehole database of the federal government, Linz (AT).

Fink, J. (1956): Zur Korrelation der Terrassen und Lösse in Österreich.- Eiszeitalter und Gegenwart, **7**, pp. 49-77, 9 Fig., Ohringen (DE).

Heinrich, M., Untersweg, T. & Lipiarski, P. (Eds.) (2018): Digitale Arbeitskarte zur Verbreitung von Lockergesteinen in Österreich 1:50.000 unter Verwendung publizierter und unpublizierter geologischer Karten.- Unpubl. digital dataset, VLG-Proj. Bundesweite Vorsorge Lockergesteine, Geological Survey of Austria, Vienna (AT).

Untersweg, T., Lipiarski, P. & Heinrich, M. (2008): Die digitale Karte quartärer Sedimente in Österreich: Ein „Spin-off" rohstoffgeologischer Bearbeitung.- Abh. Geol. B.-A., **62**, pp. 117–122, Geological Survey of Austria, Vienna (AT).

Weber, L., Schedl, A. & Lipiarski, P. (2019): IRIS Online (Interaktives Rohstoff Informations System), ein Beispiel für ein weltweit einzigartiges digitales Rohstoff-Informationssystem = IRIS Online (Interactive Raw Materials Information System), an Example for a Worldwide Unique Raw Materials Information System.- Berg- und Hüttenmännische Mh**., 164/2**, pp. 56-66, Springer, Vienna (AT).

This project was funded by the Austrian Minerals Resources Research Partnership of the Federal Ministry of Education, Science and Research

Federal Ministry Republic of Austria Education, Science and Research