The sources and transport pathways of loess in Eastern Europe and Russia: insights from detrital zircons

Thomas Stevens, **Alexandra Engström Johansson**, **Chiara Költringer**, **Yunus Baykal**, **Grzegorz Adamiec**, **Piotr Moska**, **Gábor Újvári**, **Redzhep Kurbanov**, **Zdzisław Jary**

ABSTRACT

Loess deposits contain exceptional information on the activity of past windblown dust sources. Constraining these dust sources is an essential step in understanding the complex feedbacks between dust and climate change in the past, and allows for better interpretation of loess climate and environment proxies such as grain-size and mass accumulation rate. However, deciphering source information rests upon the ability to discriminate the different sediment sources to loess, based on some intrinsic property of the material or constituent minerals (provenance indicator). Many such provenance indicators exist but in most loess areas the results from these methods often yield conflicting or ambiguous results. In recent years, considerable breakthroughs in understanding the provenance of Chinese loess deposits have been achieved through the use of single-grain provenance indicators, particularly through the use of detrital zircon U-Pb age dating. However, in European loess, comparatively little single-grain provenance work has been conducted to date, and the specific sources of loess in different parts of European loess belt are often poorly known. Here we report on new research that seeks to address this through detailed single-grain provenance analysis of loess deposits in Eastern Europe and Russia. Using initial new detrital zircon U-Pb age data from southern Poland, the Lower Volga River area of Russia and southern Hungary we show how the technique can be used to pinpoint specific dust sources of loess deposits in Europe, and examine their temporal changes. We also discuss the limitations of this approach and ambiguities over interpretation, as well as considerations regarding the number of grains analysed and statistical treatment. In general, the results demonstrate the importance of multiple dust sources and multi-step fluvial transport of silt material in European-Russian loess formation, but also highlight the possibility of highly dominant, localised mountain sources for some loess deposits. Finally, a perspective on future challenges in deciphering loess source in Europe is given, and suggestions presented for emphasis on multi provenance proxy studies.

The European Loess Belt -

- a high-resolution archive of rapid environmental change

A new reference radiocarbon chronology for Last Glacial interstadials derived from earthworm calcite granules of the Nussloch loess sequence (Germany)

Olivier Moine, Pierre Antoine, Christine Hatté, Amaëlle Landais, Jérôme Mathieu, Jérôme Mathieu, Charlotte Prud'homme, Denis-Didier Rousseau

ABSTRACT

The climate of the last glacial period is characterized by the occurrence of numerous centennial-to-millennial interstadials. Marine and lacustrine pollen records as well as isotopic speleothem records already benefit from precise chronologies based on radiocarbon and Uranium/Thorium dating methods, which were still lacking for loess sequences.

In Last Glacial loess sequences of the European Plain, typical loess units alternate with hydromorphic (tundra gleys) or pedogenic (arctic/boreal brown soils) horizons. Grain size analyses and molluscan communities respectively highlight decreased wind dynamics and higher humidity and temperatures during the formation of these horizons. Comparisons between loess grain size records and Greenland dust records led to correlate these two types of soil horizons with Greenland interstadials owing to their lower dust content compared to stadials. Nevertheless, luminescence-based chronologies were still not precise/accurate enough to define an undisputable correlation scheme.

Owing to the scarcity of organic remains (wood, charcoals and bones) in west-European loess, we developed an appropriate protocol to obtain radiocarbon ages from earthworm calcite granules. These granules, as well as terrestrial mollusc shells, are indeed present in large amounts in both types of soil horizons. This protocol has been tested on 46 samples taken from all soil horizons of the loess sequences of Nussloch (Rhine Valley, Germany), which present one of the most comprehensive records of the last glacial period in Western Europe.

The resulting chronology confirms the link between each tundra gley and arctic/boreal brown soil formed between 47 and 20 ka ago with a unique Greenland interstadial (Figure). Furthermore, we also dated minor cryogenic horizons formed between 27 and 20 ka characterized by changes in grain size and in the molluscan fauna composition comparable to those of the main soils. Despite the absence of synchronous oxygen isotopic excursions, they surprisingly correlate with dust concentration minimums in Greenland ice cores, and with changes in several other marine and continental proxy records. These results reflect the high sensibility of loess environment to climate changes and a more complex climate variability at mid-latitude than in Greenland during the Last Glacial Maximum (Moine et al., 2017).

This new dating protocol thus led us expect precise correlations between distant loess sequences and, combined with other proxies, the mapping of palaeoenvironmental conditions associated with each interstadial phase across Europe for the Middle and Upper Weichselian.

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Direct dating of faulting in the absence of overlying sediments

Sumiko Tsukamoto, Benny Guralnik, Kiyokazu Oohashi, Makoto Otsubo

ABSTRACT

Past activity of active faults is typically estimated from deformed Quaternary sediments, containing a combination of measurable displacement markers and dateable material. In crystalline bedrock areas undergoing rapid erosion, faults can be observed geologically or geomorphologically without overlaying dateable Quaternary units. For such faults, there is currently a lack of broadly applicable methodology to evaluate their activity indices, which in turn poses a threat to infrastructure and densely populated areas. In this study, we introduce a novel concept to evaluate fault activity from trapped charge in quartz – specifically, the optically stimulated luminescence (OSL) and electron spin resonance (ESR) signals. The level of saturation of these signals, alone or in combination, has the potential to quantify the activity of faults where slip rates are presently poorly constrained or unknown.

We show preliminary results for an outcrop of the Atotsugawa Fault (active fault in the central Japan). The fault core consists of fault gouge and breccia including granite clasts. Four test samples were taken, including a location previously dated by quartz OSL (Ganzawa et al., 2013) to 200 ± 200 years, (broadly consistent with the last large earthquake at 1858). The equivalent dose (De) and dose response curves were obtained using pulsed OSL to minimise signal contamination by feldspar OSL. Relatively uniform De values and n/N were calculated for all samples, and ranged between 42 ± 11 ka and 56 ± 19 ka, except for one younger sample with a higher environmental dose (19 ± 5 ka). Although all the apparent ages appear ca. two orders of magnitude older than those of Ganzawa et al. (2013), the relatively uniform values (mean age: 47 ± 4 ka; mean fraction of saturation: 0.33 ± 0.02) can be considered as representative of the activity of the Atotsugawa Fault during a similar timescale. These apparent ages, together with a trap depth of 1.66 ± 0.03 eV and a frequency factor of 1 x 1013 s-1 (Murray and Wintle, 1999), and an estimated recurrence interval of Atotsugawa Fault of 2.5 ka (Research Group of Atotsugawa Fault, 1989), were used to predict the fault shear heating that has repeatedly occurred during past large earthquakes. Our modelling suggests that flash heating of the fault gouge during each large earthquake is broadly equivalent to 250°C for 10 s. Inverting our exercise, we suggest that if one can estimate the degree of recurrent flash heating independently (e.g. via shearing experiments), it is in turn possible to calculate a recurrence interval for a given fault.

Amino acid racemisation dating of mammalian enamel: a UK proboscidean geochronology

Marc Dickinson, Adrian Lister, Kirsty Penkman

ABSTRACT

Construction of chronological frameworks capable of robustly estimating the age of mammalian remains are imperative to understanding a range of palaeontological enquiries. Direct dating of mammalian remains is extremely difficult beyond the limits of radiocarbon dating (~50 ka). Analysis of the predictable breakdown of proteins and amino acids in wide variety of calcium carbonate (CaCO3) based biominerals has been a powerful tool for Pleistocene age estimation (back to ~2.5 Ma), but to date, its application to mammalian remains has been challenging. By targeting a proteinaceous fraction found within the crystalline structure of biominerals (the intra-crystalline fraction), the difficulties associated with contamination, leaching and environmental influences are circumvented. We have assessed the suitability of tooth enamel for intra-crystalline protein decomposition (IcPD) dating by testing both the protein breakdown and the intrinsic properties of the inorganic crystal structure of enamel through simulated degradation experiments. We have found that a fraction of amino acids can be successfully isolated from enamel that are expected to remain stable over long time scales.

A geochronology based on the extent of amino acid racemisation in proboscidean enamel has been constructed from known age material, with an age range that shows the technique successfully dates material from the UK up to Late Pliocene in age. It is therefore now possible to provide direct age estimation for unknown age proboscidean material from the same temperature region (likely to be Northern Europe) through comparative assessment based on our existing framework. Enamel AAR has the potential to be expanded to a range of mammalian species and can be developed for additional geographic regions. The focus of this framework has been on Quaternary age samples, but due to the slower breakdown of the enamel proteins, the dating range of this method may extend much further back in time.

Tree ring dating using oxygen isotopes: a master chronology for central England

N.J. Loader, D. McCarroll, D. Miles, G.H.F. Young, D. Davies, C Ramsey

ABSTRACT

Traditional dendrochronology, based on matching patterns of ring width variability, works best when trees are growing under significant environmental (climatic) stress. In the UK, and elsewhere in the temperate mid-latitudes, trees generally experience less stress, so dating is more difficult and often fails. Oxygen isotopes in tree rings passively record changes in the isotopic ratios of summer precipitation, so they carry a strong common signal, which offers potential for cross-dating.

A master chronology covering the period 1200-2000CE was constructed using the oxygen isotope ratios of the latewood cellulose of oak samples from central England and the method evaluated by dating timbers of known age and historic timbers that could not be dated by conventional dendrochronology. The agreement between samples and the master chronology is exceptionally strong, allowing the dating of timbers with far fewer rings than is normally the case for conventional dendrochronology.

The isotope dating method has the potential to revolutionise dendrochronology, allowing the dating of short and invariant ring sequences from young, fast-grown trees which are commonplace throughout the historic building record and which were, until now, considered almost impossible to date.