OTKA PD-108639 final report

This OTKA/NKFIH postdoc project entitled "*Understanding loess particle mobilization, transport and deposition by wind and loess grain size distributions: implications for Quaternary paleoclimate reconstructions*" started in September 2013 and G. Ujvari has been the Principal Investigator (PI) throughout the 3 and 1/3 project years (from 01-09-2013 to 31-12-2016). **This study aimed at better understanding potential effects of North Atlantic millennial scale climatic events on Carpathian Basin paleoenvironments, especially on dust emissions**, through the multi-proxy investigation of a loess-paleosol record in South-Hungary. **This involved both the development of an extremely precise chronological model and the critical evaluation and better understanding of grain size (and partly magnetic) proxies.** The major findings of this project are detailed below focusing on the most important scientific achievements. Before doing so, I have to briefly touch upon the methodological changes made relative to the original research plan.
Soon after the start of the project I realized that **some methodological changes** will be necessary. Originally, the size distributions of quartz grains were planned to be measured using an image analysis technique. Unfortunately, I could not get access to this instrumentation and came up with the idea to follow another methodology. So, the first task was to obtain a monomineralic quartz separate from bulk loess samples. First, the organic material and carbonates were etched using 30% H_2O_2 and 6M HCl. Subsequently, clay minerals, micas and other layer silicates were removed by fusing the residues with sodium pyrosulfate, and the remaining material (containing feldspars, amorphous silica relics and quartz) was then treated with hydrofluorosilicic acid (Syers et al., 1968) resulting in a pure quartz separate. Finally, the grain size distributions (GSDs) of quartz separates were measured by laser diffraction using a Malvern Mastersizer 3000 laser particle size analyser. **The use of this other procedure for quartz GSDs determinations resulted in a substantial saving**, which was then used for extra radiocarbon analyses. The much larger ^{14}C dataset finally formed the basis of a Bayesian loess chronological model with unprecedented precision making possible robust and high-resolution sedimentation rate/mass accumulation rate (SR/MAR) estimations.

Major scientific achievements

1) As a start of this OTKA project, **a dating framework has been initiated** to establish a preliminary age-depth model for the Dunaszekcső loess-paleosol sequence. This pilot study **aimed at revealing which absolute dating method is the best suited for building a precise loess chronology for the record** as this was meant to be a prerequisite for achieving the most important goal of the project (i.e. timing of abrupt climatic events). Burial ages of quartz and potassium-feldspars grains were determined using OSL, post-IR OSL and post-IR IRSL techniques from seven samples of the sequence, while both charcoal fragments and shells of small (<10 mm) molluscs were AMS radiocarbon dated at five depths. Moreover, the dating potential of secondary carbonates (rhizoliths) was also assessed using radiocarbon and ^{230}Th-U dating. It was found that:
   a) **rhizoliths cannot be Th-U-dated** due to strong detrital contaminations, **and** all these secondary carbonate phases **were formed during the Holocene** as shown by the 14C ages,
   b) the **OSL and post-IR IRSL ages** were mostly overlapping at 2 sigma and the older sediments of the sequence could be dated by the post-IR IRSL method (beyond the useful range of 14C, i.e. 40 ka), but their **large uncertainties** (reaching several thousands of years) prevent us from using these ages to build highly precise loess chronologies,

c) radiocarbon ages were **in good agreement with the post-IR $IRSL_{225}$ ages**, while significantly differed from the rest of luminescence ages (OSL, post-IR OSL and post-IR $IRSL_{290}$) for yet unknown reasons; this should be further investigated in other loess profiles,
d) some of the **mollusc shell-based ^{14}C ages (e.g. *S. oblonga*) were statistically indistinguishable from those of charcoals**, thus the subsequent dating efforts were focused on radiocarbon dating of these two phases.

All these findings were published in:
Újvári, G., Molnár, M., Novothny, Á., Páll-Gergely, B., Kovács, J., Várhegyi, A., 2014. AMS ^{14}C and OSL/IRSL dating of the Dunaszekcső loess sequence (Hungary): chronology for 20 to 150 ka and implications for establishing reliable age-depth models for the last 40 ka. QUATERNARY SCIENCE REVIEWS 106, 140-154.
IF: 4.572

2) Encouraged by the preliminary 14C-dating results I have decided to pursue this research direction to establish a loess chronology for <40 ka, unprecedented in loess research so far. Accordingly, **further tests were performed on both charcoals (two-step combustion protocols) and shells of numerous mollusc species** to clarify if there is a strong potential in mollusk shell 14C-dating for loess or not. It was found that,
   a) **charcoal ^{14}C ages are protocol-dependent**, with ages obtained from the high temperature (800 ºC) fraction of the two-step combustion (TSC) protocol being always the oldest and likely most reliable,
   b) one-step combustion (OSC) at 1000 ºC produces comparable ages with those obtained from the low temperature (400 ºC) fraction of the TSC protocol,
   c) **discrepancies between the TSC_{400} and TSC_{800} ages become larger for older, and less well-preserved charcoal fragments**,
   d) testing of shell ages against those of charcoals reveals that **Succineidae sp., *Chondrula tridens*, *Trochulus hispidus* and members of the family Clausiliidae yield ^{14}C ages that are statistically indistinguishable from charcoals** recovered from the same stratigraphic interval, or with the TSC_{800} charcoal age (Fig. 1),

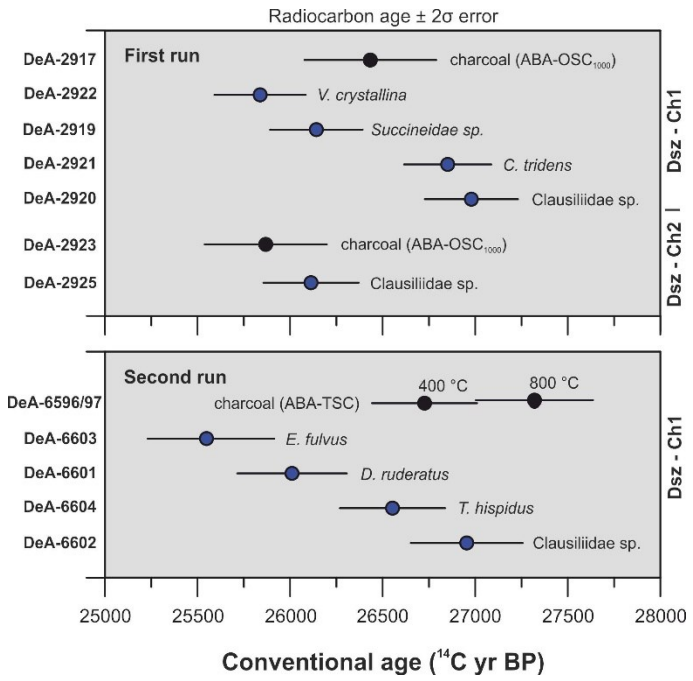

Figure 1. Comparison of conventional AMS radiocarbon ages of charcoal fragments and mollusc shells from samples Dsz-Ch1 and 2 (depths 8.20, and 8.25 m).

e) conservative estimates of **95% uncertainties of a Bayesian age-depth model for the Dunaszekcső sequence are in the range of 500-800 yr** (Fig. 2), and these are mostly well below those of luminescence chronologies.

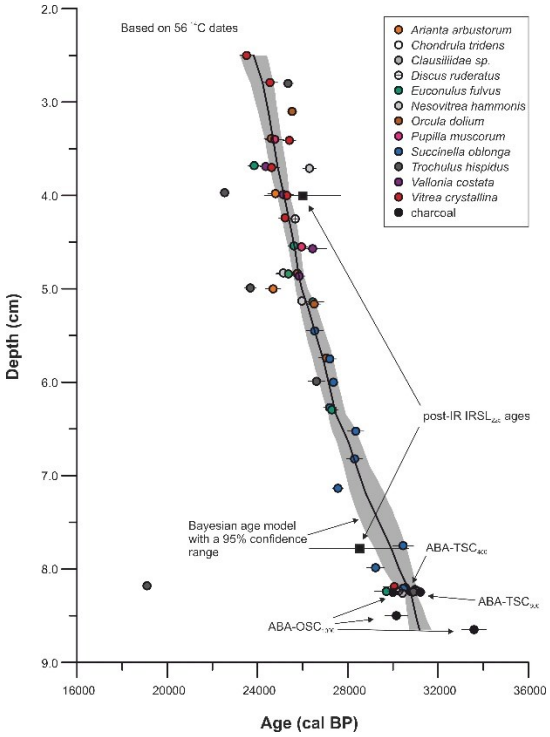

Figure 2. Bayesian age-depth model for the 8.65-2.50 m section of the Dunaszekcső loess record and calibrated mollusc shell and charcoal ^{14}C ages (mean age ± 2s). Two post-IR $IRSL_{225}$ ages are also shown for comparison (errors are 2s).

All these findings were published in:
Újvári, G., Molnár, M., Páll-Gergely, B., 2016. Charcoal and mollusc shell 14C-dating of the Dunaszekcső loess record, Hungary. QUATERNARY GEOCHRONOLOGY 35, 43-53.
IF (2015-ben): 3.142

Dating of the Dunaszekcső sequence has been further continued from the saving on quartz grain size measurements, and the upper part of the record has been re-sampled in 5 cm resolution for further ^{14}C measurements. At the moment **115 radiocarbon ages are available for age-depth modeling**, but I am **still waiting for ca 10 more dates**. Using this precise chronological model an extremely high-resolution SR/MAR dataset can be obtained, and **the age model will soon allow for interpreting the proxy datasets and compare them to Greenland dust records at an unprecedented resolution**. A paper is going to be published on the subject in the first half of 2017, while an abstract with preliminary results was published in 2016 at the EGU on the subject:

Újvári, G., Stevens, T., Varga, Gy., Kovács, J., Molnár, M., 2016. Coeval dust accumulation minima in Greenland and East Central Europe over 31-23 ka. GEOPHYSICAL RESEARCH ABSTRACTS 18, Paper EGU2016-2794.

3) As mentioned above, grain size (GS) proxy evaluations were considered critical in this project and also in a broader sense. In this work we collected bulk loess and quartz GSD data at 5 cm resolution from the Dunaszekcső sequence, together with magnetic susceptibility (MS) data (same resolution) acquired at two frequencies (0.47 and 4.7 kHz). Frequency-dependent MS is a proxy of the concentration of superparamagnetic (SP) grains in loess-paleosol records and using the MS data the effects of pedogenesis on grain size proxies could be separated from other factors, thereby enabling a better GS evaluation. I have spent two years with preparations that proved to be necessary for putting together the review part of a paper dealing with the GS evaluations.
Clearly, **loess particle size distributions** and derived statistical measures **are widely used proxies in Quaternary paleoenvironmental studies**. **However**, the interpretation of these proxies often only considers dust transport processes. To move beyond such **overly simplistic proxy interpretations**, and toward proxy interpretations that consider the range of environmental processes that determine loess GSD variations the physics of dust particle mobilization and deposition must be reviewed. Furthermore, using high-resolution bulk loess and quartz GS datasets from the Dunaszekcső sequence, we showed that, because **GSDs are affected by multiple, often stochastic processes**, changes in these distributions over time allow multiple interpretations for the driving processes. Consequently, **simplistic interpretations of proxy variations in terms of only one factor (e.g. wind speed) are likely to be inaccurate**.

Since the whole story cannot be explained in a concise form, I encourage the evaluator to read the paper published on the subject:

Újvári, G., Kok, J.F., Varga, Gy., Kovács, J., 2016. The physics of wind-blown loess: Implications for grain size proxy interpretations in Quaternary paleoclimate studies. EARTH-SCIENCE REVIEWS 154, 247-278.
IF (2015-ben): 6.991

4) Although there are **some additional datasets/results** partly related to this OTKA/NKFIH project, their findings are not detailed here. These publications (with reference to this PD project) includes:

   Újvári, G., Stevens, T., Svensson, A., Klötzli, U.S., Manning, C., Németh, T., Kovács, J., Sweeney, M.R., Gocke, M., Wiesenberg, G.L.B., Markovic, S.B., Zech, M., 2015. Two possible source regions for central Greenland last glacial dust. GEOPHYSICAL RESEARCH LETTERS 42, 10399-10408.
   IF: 4.212

   Marković, S.B., Stevens, T., Kukla, G.J., Hambach, U., Fitzsimmons, K.E., Gibbard, P., Buggle, B., Zech, M., Guo, Z., Hao, Q., Wu, H., O'Hara Dhand, K., Smalley, I.J., Újvári, G., Sümegi, P., Timar-Gabor, A., Veres, D., Sirocko, F., Vasiljević, D.A., Jary, Z., Svensson, A., Jović, V., Lehmkuhl, F., Kovács, J., Svirčev, Z., 2015. Danube loess stratigraphy - Towards a pan-European loess stratigraphic model. EARTH-SCIENCE REVIEWS 148, 228-258.
   IF: 6.991

Summary

In this OTKA/NKFIH project I showed among others that: 1) precise loess chronologies can be established using mollusc and charcoal-based ^{14}C ages, 2) the loess GS proxies should be used with extreme cautions in Quaternary paleoenvironmental studies, and 3) there is a strong correlation between SR/MAR minima and Greenland Insterstadials (not yet published), implying that Carpathian Basin paleoenvironments sensitively responded to North Atlantic millennial timescale climatic events over 20-40 ka.

Sopron, 05.01.2017.

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References

Syers, J.K., Chapman, S.L., Jackson, M.L., 1968. Quartz isolation from rocks, sediments and soils for determination of oxygen isotopes composition. Geochim. Cosmochim. Acta 32, 1022–1025.