OSL characteristics from central European loess -

Exploratory data analysis using the R package ‘Luminescence’

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Introduction

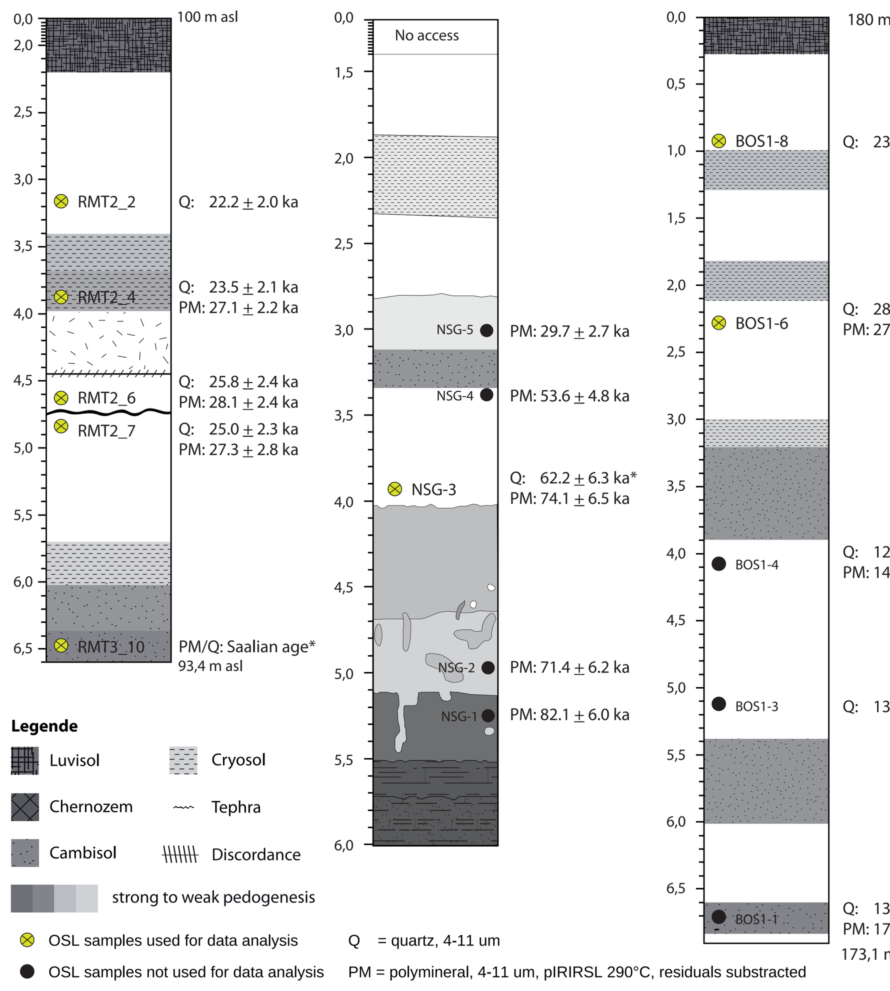
Loess is the most important sediment to reconstruct environmental changes during the glacial-interglacial cycles in central Europe. The major sources are supposed to be (a) braided river systems with seasonal high melt water supply (transported material for deflation from the Alps) and (b) from the exposed shelf during lower sea levels (e.g. Antoine et al., 2009). Local sources could also contribute to the mineral composition as a function of the environmental conditions in the catchment area (e.g. vegetation cover, frost weathering to produce fresh material).

The luminescence behavior of quartz minerals is also related to source material (e.g. Preusser et al., 2008; Gong et al., 2015), transport history and weathering (Pietsch et al., 2008; Jeong et al., 2007). Klasen et al. (2015) have shown, based on component analysis, that a mixture of minerals from different sources can influence the luminescence behaviour of CW-OSL from quartz. This is in angreement with the observation from Jeong et al. (2012) showing that minerals from different locations can have strong differences of their component characteristics.

Exploratory data analysis using the R package ‘Luminescence’ can be a powerful tool to look at a mass of data which extracted from luminescence measurements. We present a closer look into the components of quartz from different localities and timeslices to look what observations can be made against the background of sedimentological and stratigraphical informations.

Selected loess sections

Romont (Belgien) | **Frankenbacher Schotter** | **Achenheim (Alsace)**



Sample properties

sample	OIS	properties
RMT2_2	OIS 2	primary loess, no congelifraction, no pedogenesis, no postsedimentary relocation
RMT2_4	OIS 2	Cryosol, developed in primary loess, strong congelifraction, hydromorphology, solifluction
RMT2_6	OIS 2	niveo-aeolian loess, relocated, possibly tephra incorporated due to periglacial processes
RMT2_7	OIS 2	niveo-aeolian loess, relocated, possibly tephra incorporated due to periglacial processes
RMT3_10	$\geq$ OIS 6	arctic brown soil, Mn and Fe precipitation, compact
RMT1_15**	OIS 3	laminated colluvium above a interstadial soil, build up of loess and soil sediment, relocated
RMT1_13**	OIS 5a,b	chernozem, tephra incorporated, strong bioturbation
NSG-3	OIS 4	primary loess, no pedogenesis, no visibile periglacial processes, no relocation
BOS1-8	OIS 2	primary loess, no pedogenesis, no visibile periglacial processes, no relocation
BOS1-6	OIS 2	relocated loess, weak hydromorphology, weak cryoturbation

Remarks:
*: Just one aliquot from a dose test measurement
**: Sample not shown in the profile sketches.

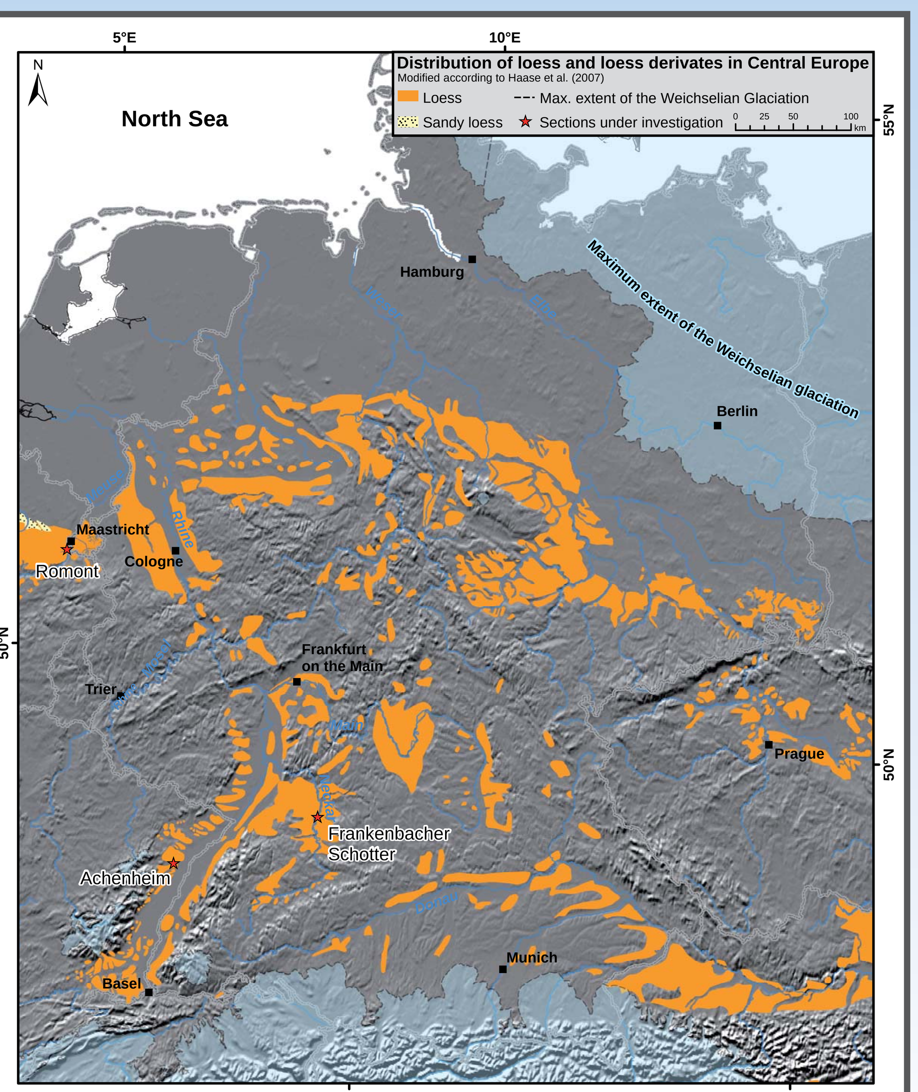


Fig. 1: Distribution of aeolian sediments in central Europe (modified according to Haase et al. (2007), Zagwijn & van Staalduinen 1975 und Haesaerts et al. 2011).

Exploratory data analysis of cw curve fitting

Relative contribution for the first channel and photo-ionisation cross sections of the fast, medium and slow components

	Achenheim		FS	Romont						
	BOS1–6	BOS1–8	NSG–3	RMT1–13	RMT1–15	RMT2–2	RMT2–4	RMT2–6	RMT2–7	RMT3–10
Age:	28.5 ka	23.9 ka	62.2 ka	---	---	22.2 ka	23.5 ka	25.8 ka	25.0 ka	Saalian
ED:	78 Gy	65 Gy	194 Gy	190 Gy	142 Gy	67 Gy	70 Gy	81 Gy	78 Gy	470 Gy
TD:	28 Gy	23 Gy	108 Gy	112 Gy	72 Gy	34 Gy	34 Gy	40 Gy	40 Gy	112 Gy
T:	260°C	260°C	280°C	280°C	260°C	260°C	260°C	280°C	280°C	280°C
n:	15	13	4	1	17	10	15	10	15	1

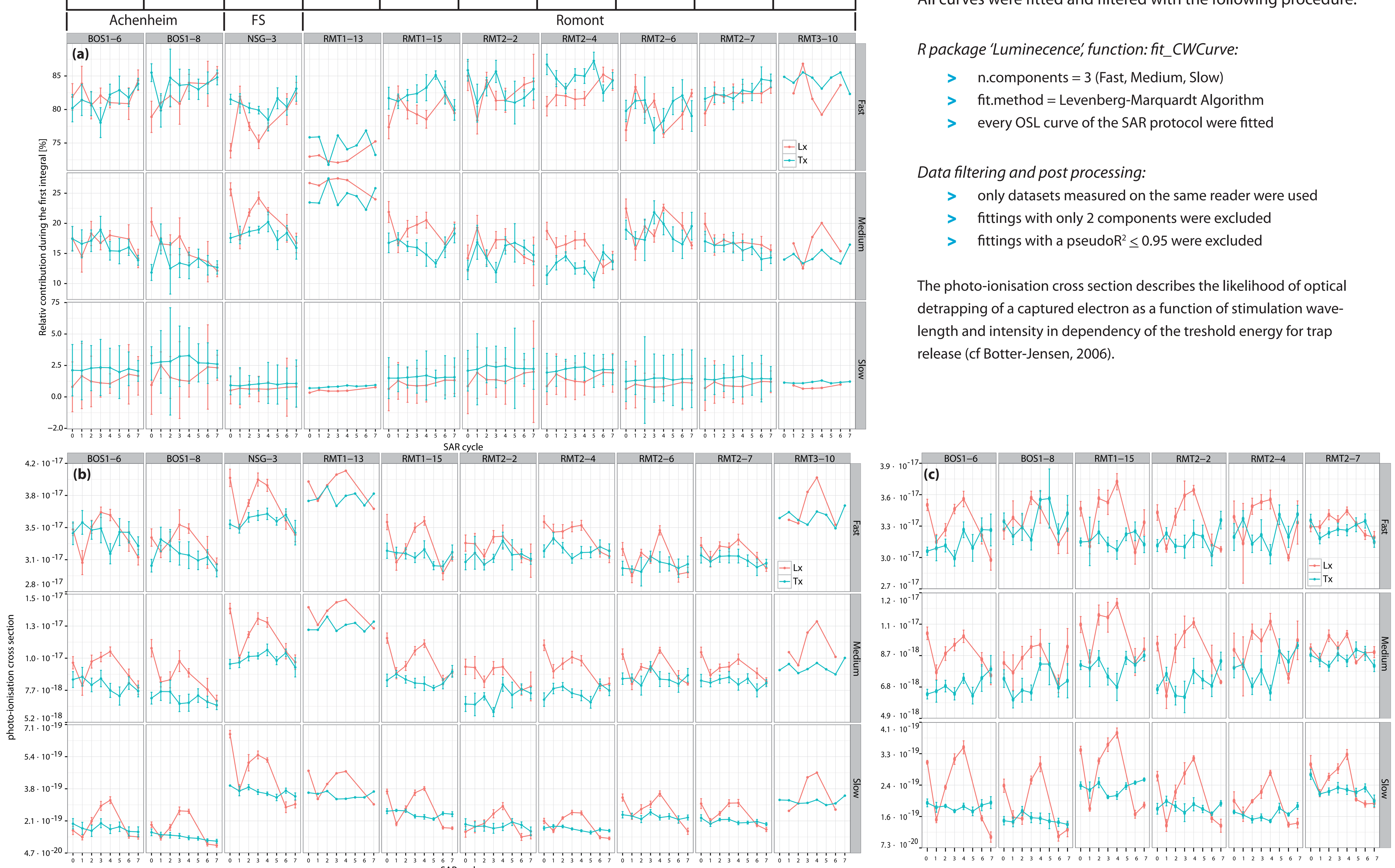


Fig.2: All points are the median of a distribution of n values. The error bars are the standard deviation. The red values shows values Lx, the blue values Tx curves. The x axis shows the cycles of the SAR protocol. ‘0’ = LN, ... R7/T7. (a) The relative contribution of each component to the inisital 0.16 seconds of the CW decay curve. (b) The photo-ionisation chross section for the fast, medium and slow component of equivalent dose and (c) dose recovery measurements. Note that the scale of th ED and DRT cross sections are not equal.

Materials and Methods

Samples

- all samples are fine grain, 4-11 um from loess
- 1,324 decay curves from equivalent dose measurements
- 723 decay curves from dose recovery tests

All curves were fitted and filtered with the following procedure:

R package ‘Luminescence’, function: fit_CWCurve:

- n.components = 3 (Fast, Medium, Slow)
- fit.method = Levenberg-Marquardt Algorithm
- every OSL curve of the SAR protocol were fitted

Data filtering and post processing:

- only datasets measured on the same reader were used
- fittings with only 2 components were excluded
- fittings with a pseudo$R^2 \leq 0.95$ were excluded

The photo-ionisation cross section describes the likelihood of optical detrapping of a captured electron as a function of stimulation wavelength and intensity in dependency of the treshold energy for trap release (cf Botter-Jensen, 2006).

Observations

Relative contribution of components

- the relative contribution is not controlled by the irradiation dose
- despite of sample **RMT1-13** and **NSG-3**, all components vary within the same range but with different patterns
- the individuell trends within the components do not follow characteristic patterns
- **RMT1-13** shows a strong difference in the composition for the fast and medium component compared to other samples
- **NSG-3** has a relativ weak fast and a strong medium component in the natural signal
- **RMT2-2** and **2-4** are of the same age, but shows a difference in fast and medium component for the natural signal
- **RMT2-6** show a broader scattering and a shift to a more medium component dominated composition. The sample was taken directly above a tephra , which shows slight cyroturbation. It could be incorporated in **RMT2-6**.

Photo-ionisation cross section of the equivalent dose measurement

- for most of the samples, the cross sections follow the irradiation dose (SAR cycle), despite of **RMT2-4** and possibly **2-2** and **2-7**
- difference between samples becomes more ‘obvious’ by the testdose
- **RMT3-10** can be differntiate especially by the fast component
- the variation of the Tx measurements are very low

Photo-ionisation cross section of the doe recovery measurements

- all samples follow the SAR cycle for every component within the Lx measurements, despite of **RMT2-7**
- in contrast to the ED measurement, sample **RMT2-4** and **2-2** follow the SAR cycle and behave equally

First conclusions

Most of the samples do not show significant differences which can be associated with a different provenance during specific times slices. Only 3 samples seems to have a clearly delimitable behavior (**NSG-3, RMT1-13, RMT3-10**).Unfortunatly., up to now these calculations are based only on 1 to 4 aliquots. The results should be treat with caution. Nevertheless, ecpecially for **RMT1-13** strong pedogenetic processes as well as the presence of tephra could be the source of the different behavior instead of another major source of the minerals.
In contrast, **RMT2-2** and **2-4** show a different behaviour, especially for the natural signal but also with a lower magnitude for the Ln and Tx values. Both samples were deposited chronological within the same unit with a slight time difference. However, the sedimentological history is different. **RMT2-2** is a primary loess without any overprinting by postsedimentary processes.

Discussion

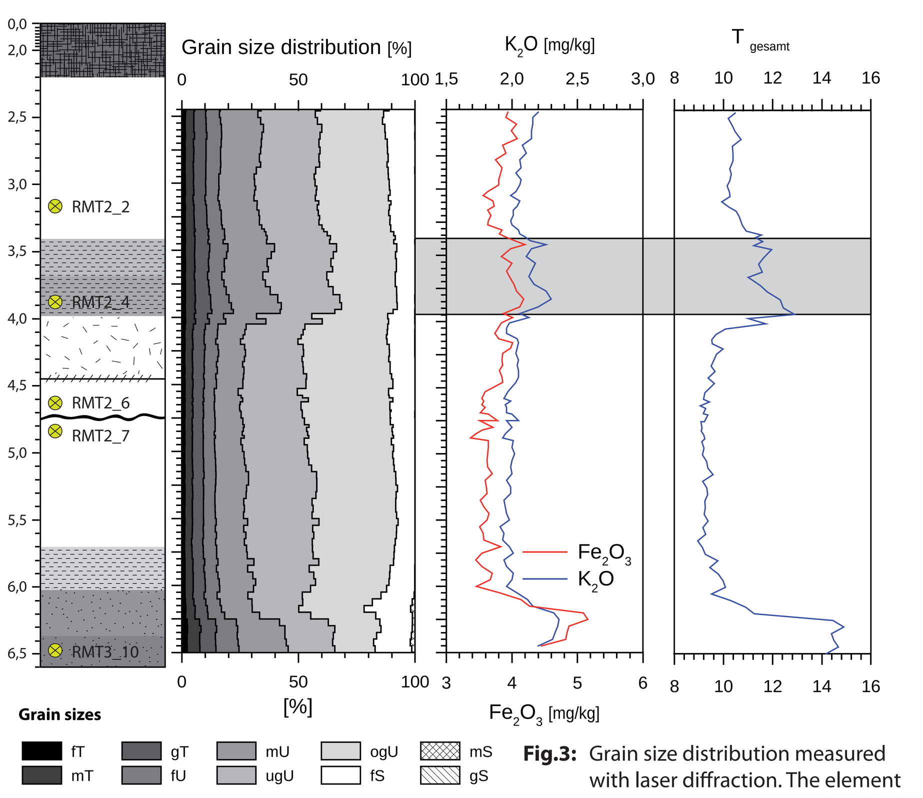


Fig.3: Grain size distribution measured with laser diffraction. The element contents were measurend with XRF.

Examples: RMT2-2 and RMT2-4
Does frost weathering influence the luminescence behavior?

Fig.3 shows the grain size distribution (GSD) of the section Romont. **RMT2-4** lay within a cryosol of the Last Glacial Maximum. Frost weathering broke up sandy size particles and leaded to a shift of the GSD to fine silt and clay. The correspondance with the elemental contents of Fe_2O_3 and K_2O affirmed the responsibilty of frost weathering for this shift rather than other pedogenetic processes. Addtionally, after etching sample **RMT2-4** for quartz dating, nearly twice as much material remain compared to **RMT2-2**. The relative proportion of quartz within the sample changed.

It is very likly that the breakup of the chrystal lattice due to freezing and expansion of H^+ should influence the relative contribution of traps within the quartz mineral and therefore the luminescence behavior it self.

Perspective
ESR measurements or isothermal decay experiments could give some insights, if the relative contribution from specific traps changed due to such weathering processes.

Conclusion

1. Exploratory data analysis using R can deliver a fast overview of the general luminescence behavior (e.g. component composition) for dose recovery, preheat-plateau tests and equivalent dose measurements.
2. The presented data suggests that no changes in the major sources of loess occured based on the components. Small contributions from local sources cannot be excluded.
3. The magnitude of changes during SAR cycles for one samples and between samples cannot be associated with specific patterns. It is unclear if the variation are caused by lumienscence kinetics or if they are just the scattering of data due to natural variations and the fitting procedure.
3. The incorporation of tephra layers (RMT1-13, possibly RMT2-6) and pedogenetic processes (RMT-13, RMT1-15 mixture of soil sediments and loess) can be the source of the different behavior. The influence of frost weathering (RMT2-4) on the luminescence cannot be proven for sure.

Outlook

- Exploratory data analysis of the raw data of quartz meausrements is a powerful tool to investigate the characteristics of single sample or huge datasets.
- The comparison of datasets is easily processable and can deliver additional information about samples.
- In combination with other analysis like NR(t) plots, the informations about samples properties can be expanded bexond dating purposes.
- The approach could be tested for smaller area with a heterogenous geology, like fluvial catchments, to identify the process systems in time.

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References

Gong, Z., Sun, J., Lü, T., 2015. Investigating the components of the optically stimulated luminescence signals of quartz grains from sand dunes in China. Quaternary Geochronology 29, 48–57. doi:10.1016/j.quageo.2015.06.004
Jeong, G.Y., Cheong, C.-S., Choi, J.-H., 2007. The effect of weathering on optically stimulated luminescence dating. Quaternary Geochronology, LED 200511th International Conference on Luminescence and Electron Spin Resonance Dating 2, 117–122. doi:10.1016/j.quageo.2006.05.023
Klasen, N., Fischer, P., Lehmkuhl, F., Hilgers, A., 2015. Luminescence dating of loess deposits from the Remagen-Schwalbenberg site, Western Germany. Geochronometria 42. doi:10.1515/geochr-2015-0008
Pietsch, T.J., Olley, J.M., Nanson, G.C., 2008. Fluvial transport as a natural luminescence sensitiser of quartz. Quaternary Geochronology 3, 365–376. doi:10.1016/j.quageo.2007.12.005
Preusser, F., Chithambo, M.L., Götte, T., Martini, M., Ramseyer, K., Sendezera, E.J., Susino, G.J., Wintle, A.G., 2009. Quartz as a natural luminescence dosimeter. Earth-Science Reviews 97, 184–214. doi:10.1016/j.earscirev.2009.09.006

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