Spatially resolved luminescence dating of sediments: First Steps.

Annette Kadereit, Steffen Greilich, Clemens Woda & Günther A. Wagner

Forschungsstelle Archäometrie der Heidelberger Akademie der Wissenschaften am Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

Introduction

Recent advances in optical dating allow the dating of sediments, which have not been completely zeroed prior to deposition. Coarse-grain single-aliquot (SA) dating of insufficiently bleached sediments include amongst others protocols based on the analysis of small aliquots with a reduced number of grains per subsample and single grain (SG) techniques (e.g. Olley et al. 1998, 1999, Clark et al. 1999). However, SG dose-determination requires the knowledge of possible spatial heterogeneiities in dose rate. As a consequence spatially resolved information on both, palaeodose and dose-rate distribution are needed. At the Forschungsstelle Archäometrie, Heidelberg, a new reader for spatially-resolved luminescence detection is beeing developed (Greilich 2004, Greilich et al. 2002) (for details of the LasLum OSL-reader cf. oral presentation of Greilich et al., this conference). First dating-results of the highly resolved optically stimulated luminescence (HR-OSL) dating of stone-surfaces have been presented (Greilich et al., in press). In the future, we would also like to use the potential of the new measuremt instrument for sediment dating and especially for potentially poorly bleached sediments.

Strategies for HR-OSL sediment dating

Basically, we follow two strategies: the analysis of big stones like pebbles or cobbles, which are treated like stone surfaces and coarse-grain, mainly sandy sediments, which are casted in resin, so that they too may be handled like stone surfaces. From the stones or hardened sediments we take small drilling cores (~Ø 5 - 8 mm) (see **fig. 9**). While from the stones only the outer surface may be used for OSL-dating, from the sediment cores several slices (aliquots) may be cut off or better broken off - and used as 'interior surfaces'.

Protocol: IRSL-SAR on yellow feldspar emission

For equivalent dose (D_E) determination we apply a SAR-protocol (Murray & Wintle, 2000). As with the presently available LasLum reader only OSL-readout is possible, irradiation is carried out at an external $^{90}Sr/^{90}Y$ ELSEC ß-source (~3.6 Gy/min) while preheat and cutheat procedures are performed in an external oven for 150 s @ 260 °C. Before OSL-readout the sample is cooled for 300 s @ ~16 °C on a watercooled metal plate. Stimulation of the feldspar component occurs with an IR-laserdiode (837 nm; ~15 mW/cm² at the sample). As in the period of measurements it was not appropriate to change the measurement configuration, only the detection of the yellow feldspar component ~540 nm (Schott glass filter GG475 + BG3, 3 mm each) was possible. The OSL-signal is collected on a nitrogen-cooled CCD camera chip (Princeton Optics). We used a resolution of 50 µm (pixel of 2 x 2 bins) or 100 µm (pixel of 4 x 4 bins) and read out 15 consecutive frames of 60 s each. The background noise per pixel is ~150 - 200 counts/60 s (see black - dark blue colours on **figures 3, 6, 8 + 10**). Data analysis was done with the program *AgesGalore* (Greilich et al., sub.; poster presentation of Afanasjew et al., this conference). The first frame (1-60 s) was used for D_E-determination, while the last frame (841 - 900 s) was used for late light subtraction (Aitken & Xie 1992). Depending on the signal strength and expected equivalent dose of a sample, test doses of ~1.8 Gy, 6 Gy or 18 Gy were administered (mostly <50% of palaeodose).

Unfortunately no tests of anomalous fading could be done before the conference, nor could the internal potassium content of the feldspar grains be determined in time. So far only preliminary low level gamma analyses are available for rough dose rate estimates. However, the principal potential of the spatially resolved technology for sediment dating may still be demonstrated.

Samples and HR-OSL measurements

We selected samples from two study areas, one of which is the Ica-Nazca depression in the northern Atacama desert in southern Peru (**fig. 1**), the other one is the place of finding of the famous lower jaw of the *Homo heidelbergensis* in Mauer near Heidelberg in southwestern Germany (Schoetensack 1908, Wagner & Beinhauer 1997).

Fig. 2: *Irrigation channel at Jaime.*

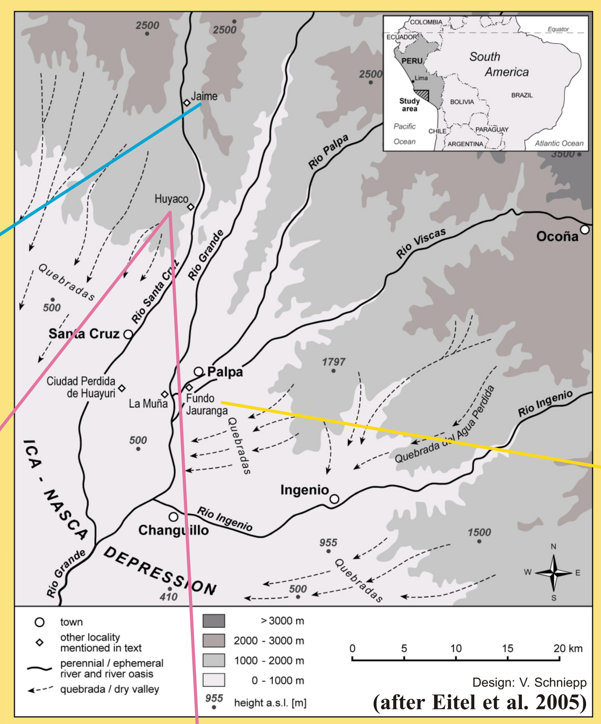

Fig. 1: *Sample locations in southern Peru.*

Fig. 4: *Huyaco deposits in the lower Rio Santa Cruz valley with geoglyph crossing on top.*

Fig. 5: *Sampled Huyaco deposit in the lower Rio Santa Cruz valley.*

Fig. 7: *Alluvial sands from a river terrace of the Rio Palpa and Rio Viscas at Fundo Jauranga.*

Irrigation channel:

Three types of sediments were taken from the Peruvian sites. At the locality of Jaime in the Santa Cruz valley (**fig. 1**) samples were collected from an anthropogenically heaped up sidewall of an irrigation channel (**fig. 2**). The sediment is mainly made up from the fine-grained loess covering the area and contains few pieces of stones from the underlying desert stone pavement. We tried several measurements on the hardened fine-grained material applying a resolution of 2x2 bins (50 µm). But as we could get hardly any signal from the silty fine grains and the small binning additionally worsened the low signal-to-noise-ratio, we changed the strategy and collected the contained stone fragments in a second field campaign. The difference in results for dim fine-grains and bright stone surfaces is demonstrated with two respective dose recovery tests (**figs. 3**).

From eight measured surfaces of stone pieces five were analyzable. Determining the palaeodoses of the brightest areas (= rois of interest / ROIs) with >260 cts/first 60 s (dim sample) up to >6000 cts/first 60 s (very bright sample) from ten ROIs of four samples, we gained D_Es in the range of ~25.8 - 38.4 Gy. Assuming a dose rate of ~3.8 Gy/ka these would represent ages of ~7 - 10 ka. Apparently, the stones were not (sufficiently) bleached during the channel construction but preserved - (much of) what presumably is the palaeodose corresponding to the covering of the desert pavement by loess deposition, which according to conventional IRSL fine-grain dating and ^{14}C-dating in the area started at the onset of the Holocene and lasted until the middle Holocene (Eitel et al. 2005). However, one stone yielded two analyzable ROIs of ~1.4 and 3.7 Gy, respectively, which might represent historical dates of ~0.4 ka and ~ 1 ka probably linked to the construction of the earthwork.

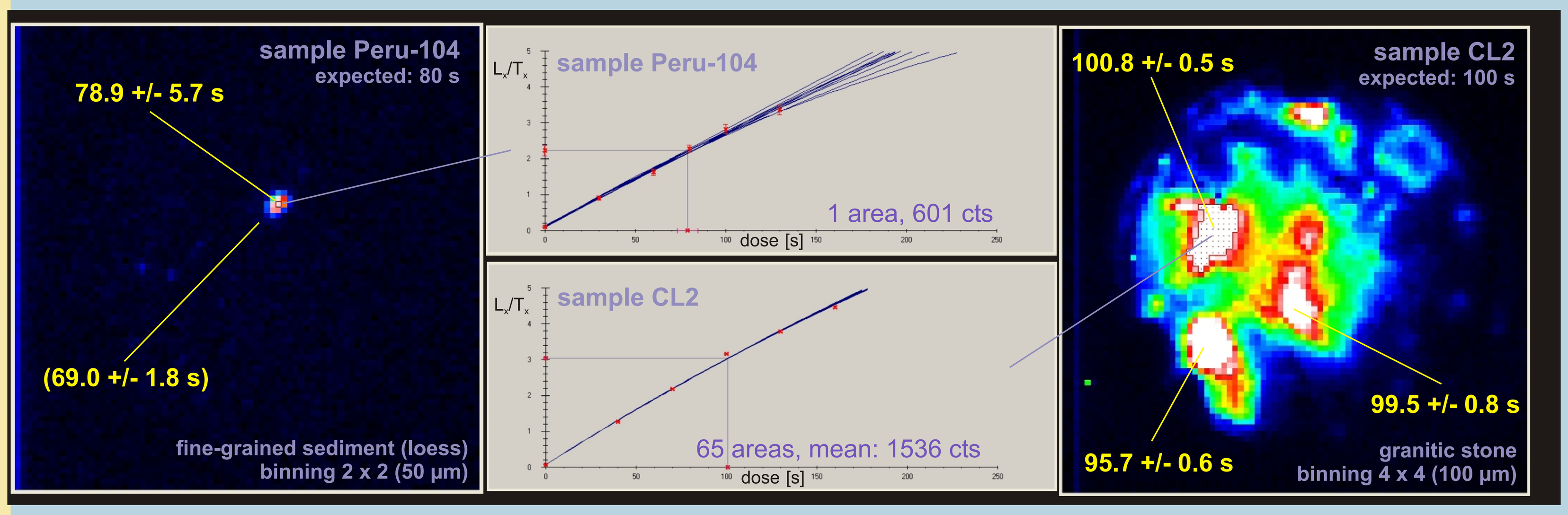

Fig. 3: *Dose recovery tests for loessic sediment (left, Jaime, Peru-104) and stone surface (right, Cerro Llipata, CL2). Fine-grains and high-resolution measurements (2x2 bins, 50 µm) do not lead to satisfactory results. While only few pixels are analyzable and only the brightest pixel delivers the expected dose, the surrounding area of 8 pixels underestimates the laboratory dose. Dose recoveries of larger feldspars with less measurement resolution (4x4 bins, 100 µm) provide good results.*

Huyaco:

Alluvial fans and debris flows (huyacos) made up from coarse sediments like pebbles and boulders often fill the mouths of the dry valleys (quebradas) at the Andean foot. They are attributed to major El Nino events. The hypothesis that they may have had catastrophic effects on precolumbian people and may have even promoted the fall of the Nasca culture (200 BC - 600 AD) (Grodzicki 1994) must be rejected, as undestructed Nasca period geoglyphs stratigraphically overlay the huyaco deposits (Eitel et al. 2005; **fig. 4**). We sampled a boulder from a huyaco deposit in the lower Rio Santa Cruz valley (**fig. 5**). In the laboratory three cored subsamples were measured on the LasLum reader. One example is given in **fig. 6**. From the brightest spots we gained D_Es between 34.3 and 45.8 Gy. Since measurements of internal potassium contents of the individual grains are still needed, we do not know whether the variation is due to differences in microdosimetry or may be attributed to differential bleaching. Assuming a dose rate of ca. 3.5 Gy/ka we get OSL-ages of ~10 - 13 ka. This could mean that huyaco deposition preceded loess accumulation and may have occured in the wet Tauca period.

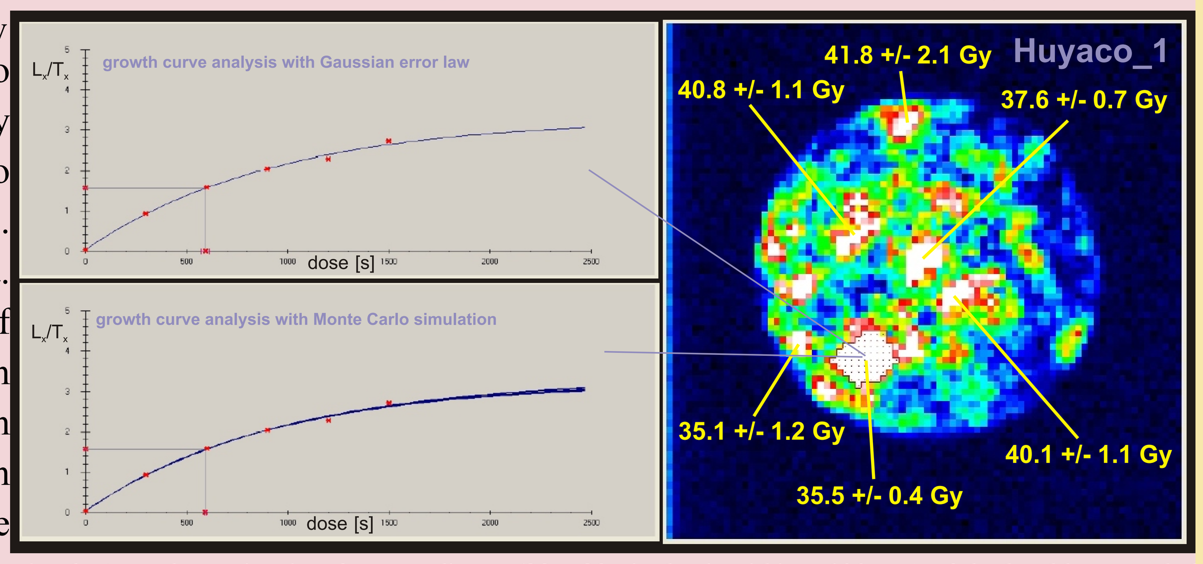

Fig. 6: *Dose determination for one aliquot (82 x 82 pixels, 4 x 4 bins, 100 µm) of the boulder sampled from the huyaco deposit in the lower Santa Cruz valley. (ROIs with >400 cts/first 60 s per pixel)*

Alluvial sand Peru:

Sandy alluvial deposits were sampled from an opencut into river terrace sediments of the Rio Palpa / Rio Viscas at the Fundo Jauranga (**fig. 1**). In its lower part the profile contains artefacts dating to the Nazca period (pers. comm. Dr. Markus Reindel). Two samples from the upper part of the profile wall (**fig. 7**) were casted into resin. We measured one slice of one core from sample HDS-1472 (**fig. 8**). From two ROIs (>250 cts/first 60 s per pixel) we determined D_Es of 2.8 and 4.8 Gy. As from preliminary low level gamma measurements dose rates of ~3.5 Gy/ka are expected, corresponding OSL-ages could lie about 0.8 and 1.4 ka.

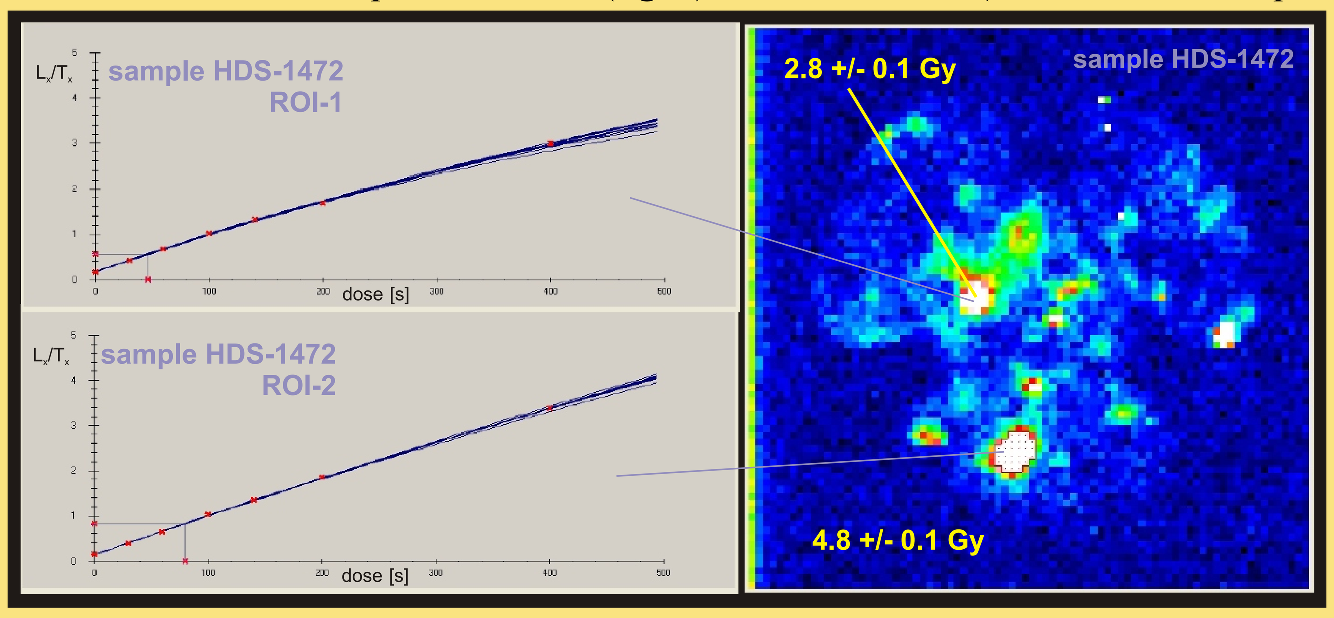

Fig. 8: *Dose determination for two ROIs (>250 counts/first 60 s) of sample HDS-1472 cored from an embedded alluvial sand in the Nasca basin.*

Alluvial sand Germany:

The expected age for the alluvial sand, in which the the lower jaw of the *Homo heidelbergensis* was found (**fig. 9**), lies beyond 500 ka (Zöller et al. 1997), which cannot reliably be determined using feldspar grains due to longterm fading. However, HR-OSL analyses may provide useful information on luminescence characteristics like e.g. the shape of the growth-curves of individual feldspar grains at high doses or longterm fading. The bright spots (ROIs with >500 cts/first 60 s per pixel) analyzed in this study provide D_Es of ~170 - 300 Gy (**fig. 10**), which would yield ages of ~120 - 200 ka, if a dose rate of ~1.5 Gy / ka is assumed. Once UV-transmittent lenses are available at the Forschungsstelle Archäometrie future studies will focus on green light stimulated HR- OSL on quartz in order to find 'hot grains' that do not saturate even at high doses.

Fig. 9: *Alluvial sand from Mauer embedded in resin (with 3 drilling holes).*

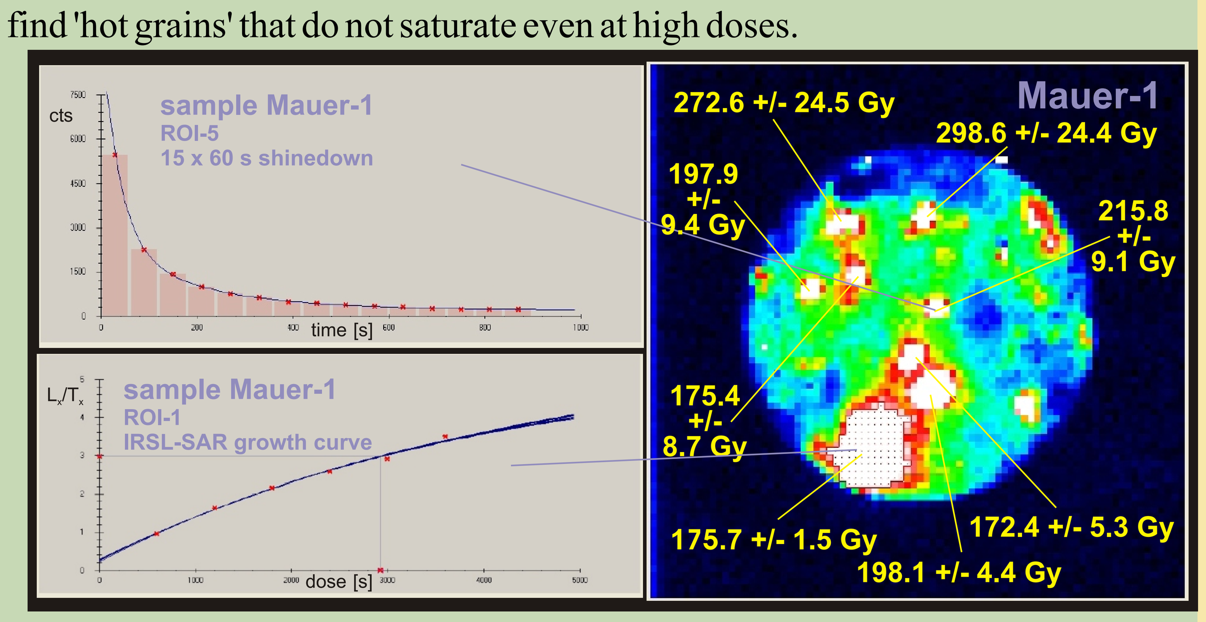

Fig. 10: *Dose determination for ROIs (>500 counts/first 60 s) of a sample from alluvial sands of Mauer.*

email-adresses:

Annette Kadereit: a.kadereit@mpi-hd.mpg.de
Steffen Greilich: steffen.greilich@mpi-hd.mpg.de
Clemens Woda: clemens.woda@mpi-hd.mpg.de
Günther A. Wagner: g.wagner@mpi-hd.mpg.de

Funding from Bundesministerium für Bildung und Forschung **is gratefully acknowledged.**