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Elevated temperature IRSL dating of loess sections in the East Eifel region of Germany

Esther D. Schmidt [a,b], Sumiko Tsukamoto [a,*], Manfred Frechen [a], Andrew S. Murray [b]

[a] Leibniz Institute for Applied Geophysics (LIAG), Section 3: Geochronology and Isotope Hydrology, Stilleweg 2, D-30655 Hannover, Germany
[b] Nordic Laboratory for Luminescence Dating, Department of Geoscience, Aarhus University, DTU Risø Campus, DK-4000 Roskilde, Denmark

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ABSTRACT

It has been shown that the infrared stimulated luminescence signals measured at elevated temperature after an IR stimulation at 50 °C (post-IR IRSL) are significantly more stable than the conventional IRSL at 50 °C (IR_{50}). In this study a post-IR IRSL protocol using a second IR stimulation temperature of 290 °C ($pIRIR_{290}$) was applied to 17 polymineral fine grain (4–11 μm) samples from various loess sections in the Eifel region (Wannenköpfe, Dachsbusch, Kärlich and Ariendorf) with independent age control to test the reliability of ages using the $pIRIR_{290}$ signal. The laboratory-measured fading rates are below 1%/decade on average for the $pIRIR_{290}$. Both IR_{50} and $pIRIR_{290}$ signals of 9 samples were found to be in field saturation. The average ratio of the sensitivity-corrected natural signal to the laboratory saturation level for the $pIRIR_{290}$ is 0.98 ± 0.02 ($n = 9$), showing that field saturation is equal to laboratory saturation for the $pIRIR_{290}$ signal from polymineral fine grains from the Eifel region. Minimum equivalent dose estimates were calculated from the characteristic saturation dose of the dose response curves, giving minimum ages estimates of ~230–420 ka, and suggesting that the $pIRIR_{290}$ signal can be used to date loess to ~300 ka. The $pIRIR_{290}$ ages estimates of the samples from the Wannenköpfe and Dachsbusch sites are in good agreement with independent age control showing that the IRSL dating using $pIRIR_{290}$ signal without fading correction is apparently reliable. Our data suggest that the loess units E, F, G and the lower part of H at the Kärlich site were accumulated >270 ka and that the palaeosol of the Kärlich Interglacial I most likely developed during marine isotope stage (MIS 9) or earlier. The pedocomplex on the top of Loess bed II at the Ariendorf section can be correlated with MIS 7.

1. Introduction

Loess records are sensitive archives of climate and environment change and provide important information on local and regional environmental processes and conditions for the Middle and Late Pleistocene period in Europe. Many extensive well exposed sections in loess deposits are known from the Middle Rhine area located in the Rhenish Massif in Germany (Fig. 1). These loess/palaeosol sequences often overlie fluvial terraces or fill craters in the East Eifel Volcanic Field. In this area, loess is often intercalated by air-fall tephra layers originating from the Eifel volcanism. According to Boenigk and Frechen (2001a,b), the volcanism of the East Eifel Volcanic Field in Germany was reactivated between 500 and 600 ka. Numerous volcanic depressions and crater are located in the Eifel area and form excellent sediment traps, and the changes in climate and environment of the past have been recorded in the loess/palaeosol successions.

The loess-palaeosol sequences of (late) Middle Pleistocene scoria cones in the East Eifel Volcanic Field are generally well preserved (Boenigk and Frechen, 2001a,b). We have investigated four sites in the region: (i) Wannenköpfe, (ii) Dachsbusch, (iii) Kärlich, and (iv) Ariendorf (Fig. 1). The four loess sections provide excellent sediment archives of Middle Pleistocene climate and environmental change. All four of these sections have been intensively investigated in previous studies (e.g. Brunnacker et al., 1969, 1975; Bibus, 1980; Boenigk and Frechen, 1998, 2001a,b; Frechen and Justus, 1998; Litt et al., 2008) but reliable numerical age estimates for the loess and palaeosol are still lacking at most sites, especially for the Middle Pleistocene deposits. This makes both, interpretation of the terrestrial climate archives and correlation with other important European loess records, difficult: there is an urgent need for a reliable chronology. Luminescence dating is the obvious choice.

* Corresponding author.
E-mail addresses: Sumiko.Tsukamoto@liag-hannover.de, sumiko0824@gmail.com (S. Tsukamoto).

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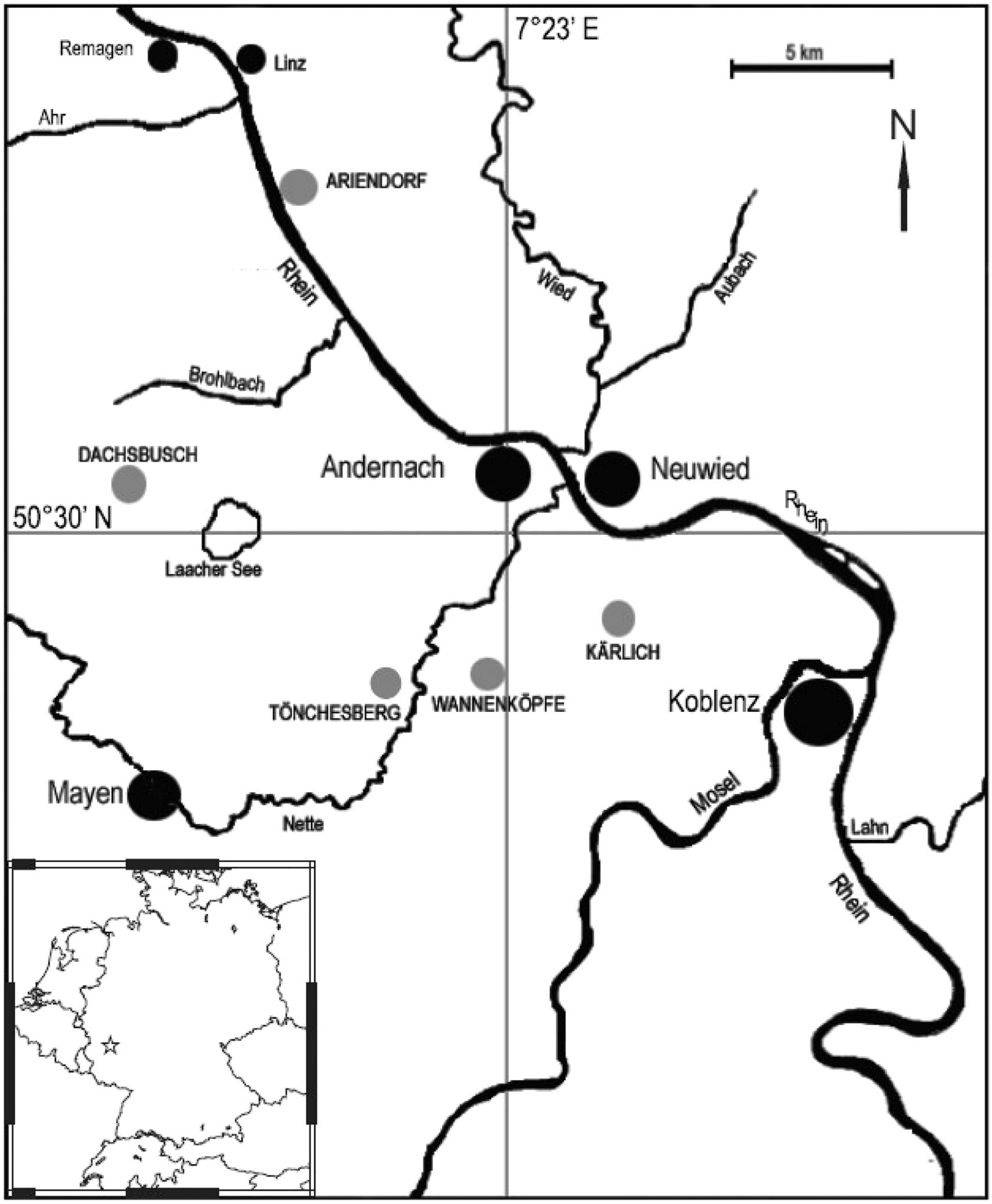

Fig. 1. Map of the East Eifel area showing the positions of Wannenköpfe, Dachsbuch, Kärlich, Ariendorf and Tönchesberg sections.

Thermoluminescence (TL) and infrared stimulated luminescence (IRSL) age estimates have been presented by several authors for the loess deposits of the Wannenköpfe, Kärlich and Ariendorf sections (Wintle, 1985; Zöller et al., 1988; Balescu, 1988 (in Turner, 1997); Frechen, 1990, 1992; Frechen and Justus, 1998). Unfortunately, Frechen (1992) pointed out that significant age underestimation has to be taken into account when giving TL age estimates beyond 90 ka, and the existing luminescence ages cannot be regarded as reliable age estimates for the penultimate glacial loess. Recently, new methods to extend the age range of luminescence dating have been proposed. Thomsen et al. (2008) proposed a new dose measurement for feldspars based on single aliquot regenerative dose (SAR) protocol, with detection in the blue (320–460 nm). This protocol involves elevated temperature stimulation with IR for 100 s at 225 °C, following stimulation with IR for 100 s at 50 °C (IR_{50}), a so-called post-IR IRSL (pIRIR) measurement sequence. Buylaert et al. (2009) showed that the observed fading rates for the pIRIR signal in their K-feldspar samples are significantly lower than from the conventional IR_{50} and that the signal is bleachable in nature. More recently, Thiel et al. (2011a) adopted a preheat of 320 °C for 60 s for their pIRIR protocol to date polymineral fine-grains, to allow pIRIR stimulation at higher temperatures. They justified this increased preheat temperature using the conclusions from Murray et al. (2009) who argued that the main IRSL trap for K-feldspar lies above 320 °C; this suggests that a preheat of at least up to this temperature can be used. Thiel et al. (2011a) chose to use IR stimulation at 290 °C for 200 s ($pIRIR_{290}$) after bleaching the aliquots with IR at 50 °C for 200 s. They reported the natural $pIRIR_{290}$