OSL-dated loess-deposits from the eastern Atacama desert-margin (14-15°S), Peru: Evidence of Holocene humid periods and enhanced South American summer monsoon.

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Introduction

The Atacama desert and the central Andean region have long been recognized as a key region for past climatic changes that are driven by alterations of the southern oscillation (e.g. Baker et al. 2001, Geyh et al. 1999, Veit 1996) and interrelations

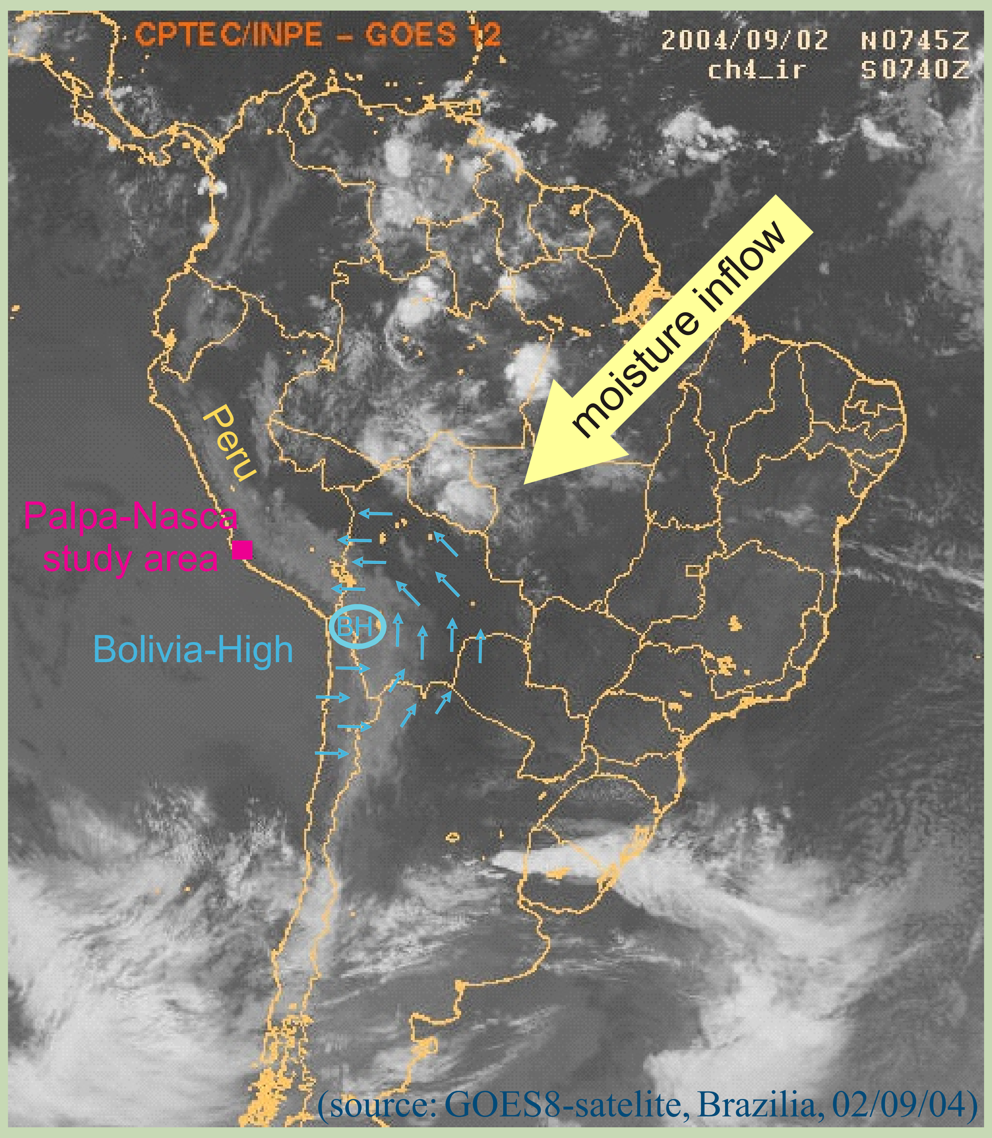

Fig. 1: La Nina-like ENSO high index/cold phases of strengthened South American Summer Monsoon (SASM) imply an enhanced moisture advection from the Atlantic ocean, increased convection and rain-water recycling in the Amazon basin area, the evolution of a strong and southerly displaced Bolivian High, the advective assistance of higher-tropospheric zonal easterly winds, and thus more moisture transport from the continental source area to the area of the eastern Atacama desert margin (e.g. Garreaud et al. 2003, Zhou & Lau 1998). Principally, the modern day scenario of mechanisms must have also worked in the past (Vuille 1999).

between palaeoclimatic variations and the rise and fall of southern American cultures have become a focus of geoarchaeological studies (e.g. Abbott et al. 1997, Binford et al. 1997, Eitel et al. 2005, Grosjean et al. 1997a, Ortloff & Kolata 1993). However, while there is general agreement that dramatic changes of humidity have occurred repeatedly during the late Pleistocene, the chronology of moist and dry intervals is still in dispute (e.g. Geyh et al. 1999 versus Sylvestre et al. 1999 or Quade et al. 2001 versus Grosjean 2001). Problems encountered concern (unknown) reaction and relaxation times of the studied palaeoproxies as e.g. lake and ground-water level changes with respect to the driving climatic signal (estimated adjustment times of at least 0.5-1.5 ka according to Rech et al. (2003)), confusion about the geomorphogenetic nature of the sedimentary archives leading to contradicting palaeoclimatic interpretations of more humid or more arid conditions (Grosjean et al. 1997 and Grosjean 2001 vs Quade et al. 2001 and Rech et al. 2003 at the important site of Puripica) and uncertainties of dating methods or their application to problematic material. Several chronologies have been gained from ^{14}C-dated lake sediments usually void of terrestrial plant remains, although modern reservoir effects of the shallow Altiplano lakes and salars are known to be up to 8000 years (Geyh et al. 1999, Grosjean 1994, Grosjean et al. 1997b, Grosjean et al. 2001, Sylvestre et al. 1999, Valero-Garcés et al. 1996). ^{234}U/^{230}Th ages are not unproblematic, as thorium-contamination can not be excluded (Sylvestre et al. 1999). Thus, with respect to palaeoclimatic interpretation it seems advisable to distinguish between "primary", i.e. quickly-adjusting climate-proxies and slower responding "secondary" climate-proxies, which are rather palaeoenvironmental (e.g. palaeohydrological) proxies. Further, it seems desirable to have additional age control by independent dating techniques.

Loess deposits at the eastern Atacama desert-margin

The occurrence of loess deposits in the Palpa-Nasca area, S-Peru, was first published by Eitel et al. (2005). This type of sediment may be interpreted as a proxy towards more humid conditions at the eastern desert margin at times when a grass- or herbaceous vegetation cover fixed the dust blown from a then reduced desert area. The west- and eastward shifting of the desert margin is controlled by an increased or respectively reduced summer monsoon influence from the east (fig. 1). The (dis-)appearance of a grass or herbacious vegetation cover responds quite promptly to a respective climate signal, and so does the resulting loess accumulation. We therefore consider loess as a "primary" climate proxy.

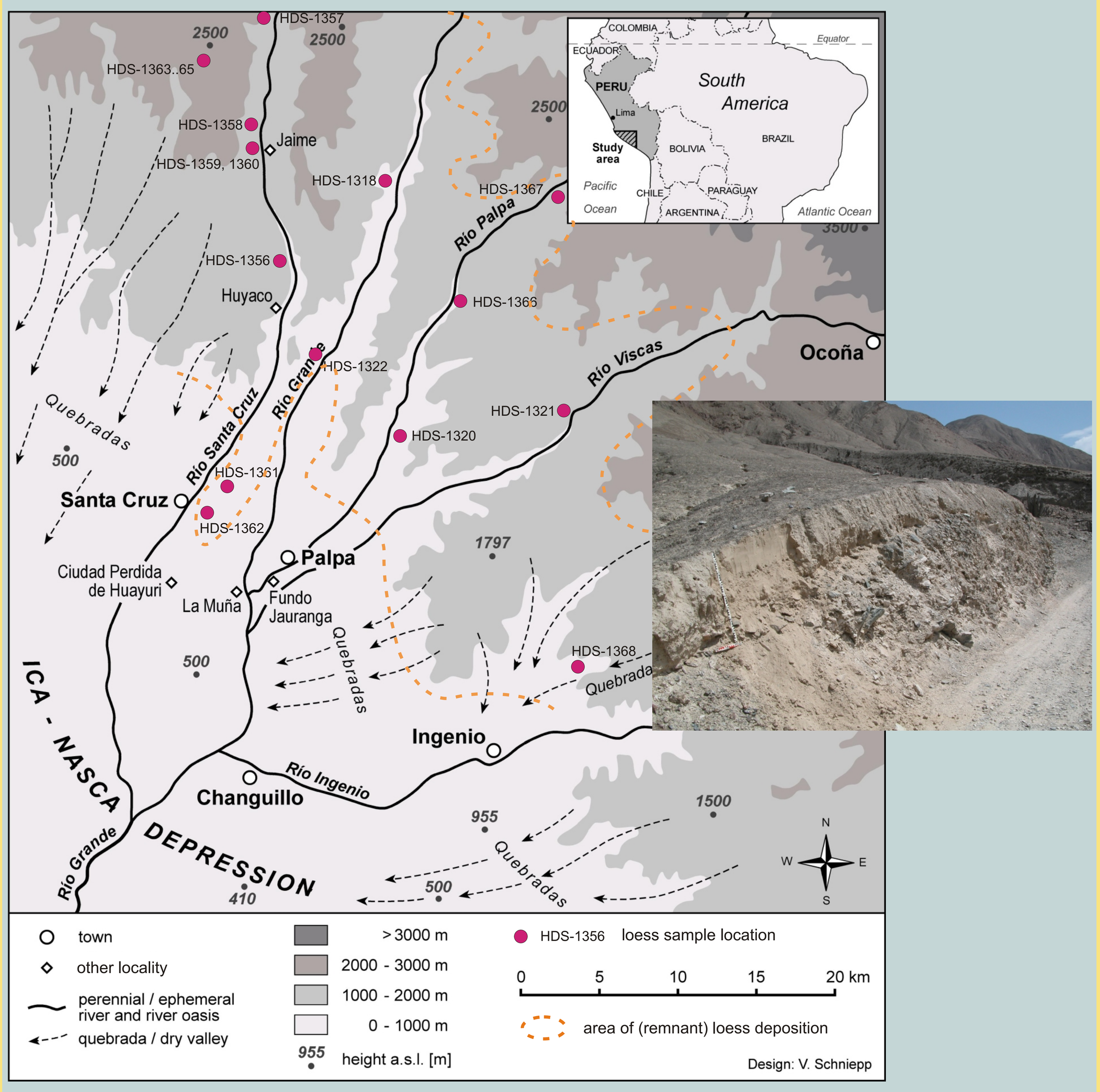

Fig. 2 (map, left): The Nasca-Palpa study area at the western Andean footslope resp. eastern Atacama desert margin, with area of loess occurences and locations of IRSL-dated loess samples.
Fig. 3 (photo, right): Loess exposure on the road to Tibillo (Rio Santa Cruz valley, OSL-sampling locality HDS-1357) at ~1200 m a.s.l. Thicknesses of the cover beds vary between 40 cm and 50 cm.

Luminescence dating

In a geomorphological context optical stimulated luminescence (OSL) dating is a technique to determine the time when a mineral grain was last exposed to daylight during a former cycle of erosion, before it became effectively shielded from further light impact in a sediment sink. In order to analyse the silty loess deposits (for sample locations see fig. 2), we applied an infrared-stimulated luminescence (IRSL) multiple-aliquot additive (MAA) protocol to the polymineral fine-grain fraction (4-11 µm) detecting the blue (410 nm) feldspar emission. The protocol follows Lang et al. (2003), who found excellent agreement between IRSL- and independent ^{14}C-ages for late Pleistocene loess deposits from S-Germany.

Preliminary loess chronology

So far 16 samples from 14 localities have been analysed. At two localities the thickness of the cover bed allowed to take two samples (samples HDS-1359/60 and HDS-1363/64). In both cases the upper sample yielded ages ~4.2 ka, while the samples from the base gave dates ~9.8 ka. In fig. 3 the IRSL-ages are presented as a cumulated probabilty distribution. It seems that during the Holocene humid periods of loess accumulation around 9.9 ka, 7.3 ka, 4.2 ka and 2.7 ka have altered with drought periods of no loess sedimentation around 8.6 ka, 5.3 ka and 3.2 ka. These findings are consistent with observations of shifts of the eastern desert margin further south in Chile (22-23 °S), where changes of SASM have been derived from ^{14}C-dated midden analyzed for their content of pollen from grass and herbacious species (Latorre et al. 2003). Interestingly, in the middle to younger Holocene intervals of apparently increased SASM influence (La Nina-like situation) alternate with periods of El Nino borne debris flow (huayaco)

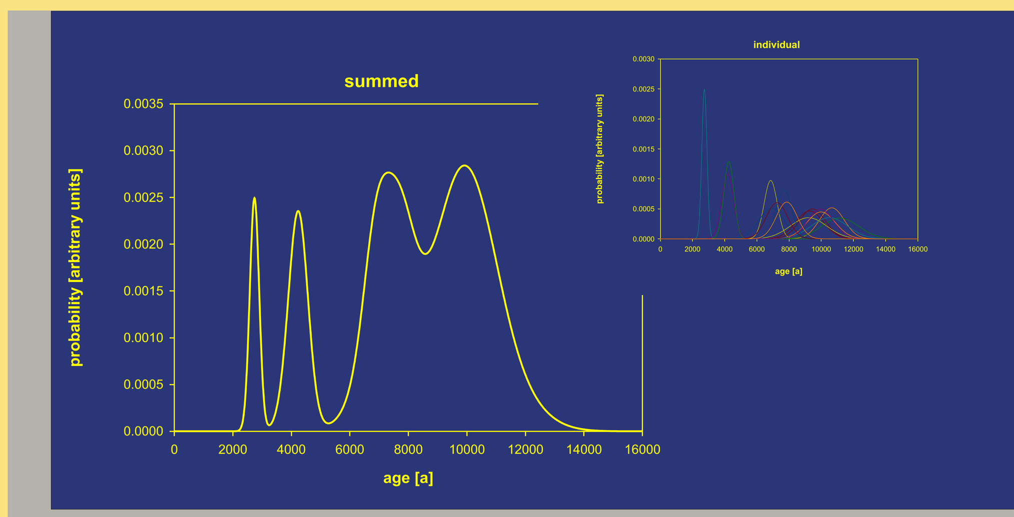

Fig. 4: IRSL fine-grain ages of 16 loess samples. The data are illustrated as probability distributions. The area under the Gaussian curve is the same for each sample, while the width corresponds to the 1-Sigma error (inset, top right). The individual curves have been summed up to yield cumulated probabilty distributions.

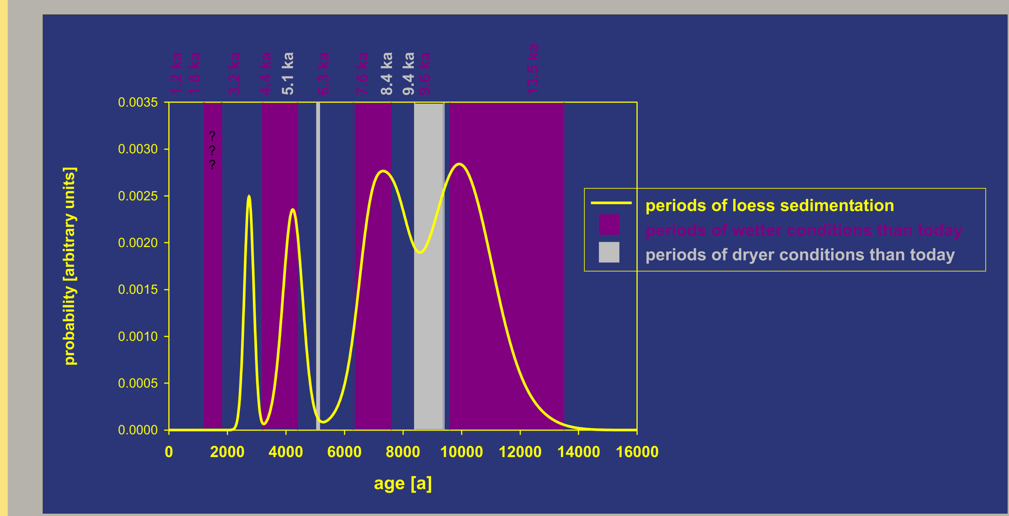

Fig. 5: The preliminary loess chronology corresponds well with obersavtions of moisture changes at the eastern margin of the arid prepuna in northern Chile (22-23 ° S) (Latorre et al. 2003).

deposits in S-Peru. Debris flow dating occurred using ^{14}C-dating on terrestrial material (mostly intercalated between huayaco units). The youngest historical huayacos date after 3.5 ka at Qda. Los Burros, after ~3.8 ka at Punta el Abogado and between ~3.0 ka and ~4.2 ka at Qda. Jara, which might correspond to the dry period ~3.2 ka, while next older deposits date between ~6.3 and 5.0 ka at Qda. Los Burros and ~5.1 ka at Qda. Tacahuay, which corresponds to the dry period ~5.3 ka. The next older deposits date at ~8.7 ka at Qda. Tacahuay and between ~8.5 and ~9.4 ka at Qda. Los Burros, resp., which could correspond to the dryer period ~8.6 ka (all huayaco data calibrated ^{14}C ages from Fontugne et al. 1999, Keefer et al. 1998, Keefer & Mosley 2004 and Ortlieb & Vargas 2003).

Conclusion

Desert margin loess is an excellent archive for climate reconstructions in the South-American western Andean foreland, which accomplishes the suite of available, but not always unambiguously interpretable palaeoproxies. The application of OSL-techniques to the loess deposits provides a dating method which has not been intensively used for sediments of the area so far but which we regard as useful considering that many chronologies are based on not reliably datable lake and wetland deposits. The preliminary OSL-based loess chronology established so far is in agreement with other reliably dated "primary" climate proxies from the area.

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