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LUMINESCENCE DATING WORK FROM THE HEIDELBERG GROUP: A KEY TECHNOLOGY IN GEOARCHAEOLOGY

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ABSTRACT

Geoarchaeology is a growing discipline in archaeological science. It aims at the natural environment as context of past human societies and at the interaction between both, the environment and man as part of a joint ecosystem. This topic is also of considerable concern of present societies. Like other historic sciences, geoarchaeology requires accurate chronologies. Since one deals in geoarchaeology predominantly with sediments and rocks, luminescence methods play a key role. This is demonstrated in two case studies from Phlious in southern Greece and Nasca in southern Peru. The results show clearly climatically triggered social developments and feedbacks to the environment.

KEYWORDS: luminescence dating, geoarchaeology, Phlious basin, colluvium, Palpa-Nasca region, geoglyph

INTRODUCTION

Geoarchaeology deals with the application of geoscientific methods and concepts in order to understand the development of ancient landscapes as operating space of past societies. It studies inparticular the effects that the natural environment had on the development of past human cultures. During the Holocene, which comprises the last 11.5 millennia, there have been relatively long periods of environmental stability enabling the rise of high civilizations. But the Holocene has also seen severe climatic changes and other geologic hazards like catastrophic volcanic eruptions and earthquakes, so one might ask whether they have contributed to the collapse or rise of ancient cultures. Another geoarchaeological research aim is to investigate to which extent ancient humans changed their environment - a topic which is of great relevance to present societies.

It is obvious that for such kind of studies the knowledge of a solid time-frame is essential in order to recognize causes and effects as well as the rate of processes. Apart from archaeological approaches commonly the radiocarbon dating is used if organic materials are available, but in view of the predominance of clastic sediments with their inorganic minerals, such as feldspar, quartz and calcite, the luminescence techniques are indispensable. Their latest methodological developments allow novel insights in the interaction between past cultures and their physical environment, which is demonstrated in two case studies.

PREHISTORIC SOIL EROSION IN THE BASIN OF PHLIOUS

The first one is the basin of Phlious, located ca. 30 km southwest of Corinth, NE-Peloponnesus, in southern Greece. It is known for its rich archaeological remains, mainly from the classical period, but also for prehistoric ones, in particular the Mycenean tombs of Aidonia. The basin floor is at an altitude of ca. 280 m above sea level (a.s.l.) and surrounded by mountains reaching up to 1600 m a.s.l.. The lower part of the basin slopes are covered by colluvial and the floor by alluvial sediments, which both are important archives for reconstructing former landscapes.

When the protecting forests were cleared by the early farmers, the freshly exposed surface became vulnerable for soil erosion. The soil material was washed downwards by rain-drops splashing it away from the point of impact as well as surface runoff and deposited at the foot-slope. This process continued as long as the agricultural activities went on. In this way a culluvium can be considered as the correlate sediment of agricultural land-use further uphill. Colluvium contains characteristically ceramic sherds and small pieces of charcoal pointing to man causing the soil erosion. Some of the soil material mobilized on the slopes may be entrained to a discharging river and redeposited as alluvium in the river plain. By dating these sediments one can gain insights into changes of human land use and/or of climatic conditions at the time of their deposition. It has been shown that the dating of charcoal by C14 and ceramics by archaeological means is often only of little worth since these materials are usually redeposited and give only a *terminus post quern,* whereas optically stimulated luminescence (OSL) dates the deposition of the colluvium directly, provided there was sufficient bleaching of the feldspar and quartz grains during their down-slope transport (Lang and Honscheidt 1999, Fuchs and Wagner 2005). The colluvium and alluvium samples were collected from trenches, drill-holes and natural outcrops in the Phlious basin. Altogether about 120 f them were OSL-dated. Luminescence measurements were applied to the coarse grain quartz fraction.

The ages show that colluvia were deposited already since Early Neolithic in the 7th millennium BC in a depth of 8 m below the current ground. The presence of ceramics in that depth confirms the anthropogenic influence. In 0.5 m depth the colluvium dates from the Medieval period. The depth distribution of the ages allow to calculate sedimentation rates, which indicate cultural periods when land use was intensified (Fig. 1). Apparently the sedimentation rate was very low during pre-Neolithic time. It increased strongly with the beginning of the Neolithic, i.e. with the arrival of the first farmers. During the Chalkolithic and the Early Bronze Age it is again low, whereas during the Middle and Late Bronze Age it is high again. This wave-like structure of the sedimentation rate continues through the Early Iron Age (low), into the Classical to Roman periods (high) and the Medieval period (low) (Casselmann et al. 2004, Fuchs et al. 2004).

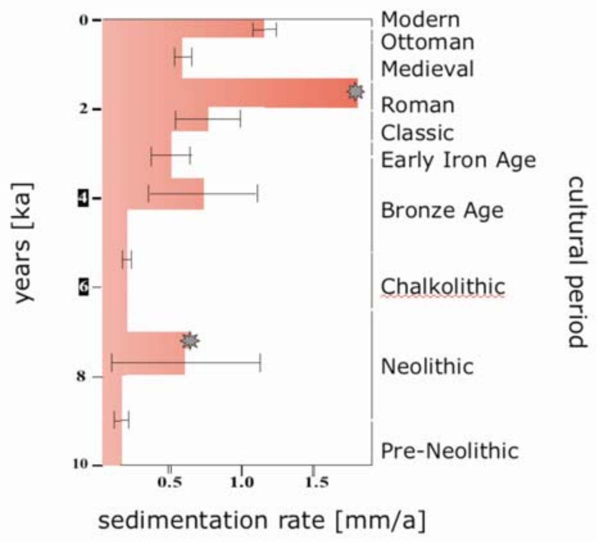

Fig. 1: Sedimentation rates of colluvia at various depths (and archaeological periods) in a 10 m deep trench at the northern foot-slope of the Phlious basin, Peloponnesus. The rates vary from period to period. Similar patterns were found in nearby trenches. The asterix symbols indicate, that these rates are minimum values for methodological reasons (after Fuchs et al. 2004).

Such ups and downs of colluvial formation - and thus of soil erosion - over the last 7.5 millennia have also been observed at several sites in southwestern Germany (Lang et al. 1999, Kadereit et al. 2009). In both cases these alternations seem to correlate with patterns of the cultural development, in which societies with larger population alternate with such of lower ones. There are essentially two possibilities to explain this phenomenon: (1) The land-use stayed more or less at same intensity through all the time, but the intensity of soil erosion was controlled by climatic changes, in particular precipitation. Our attempts, to find such correlation in both mentioned regions failed so far, including the so-called Dark Ages (with cool climate, mass migration and low soil erosion) around 1000 BC in eastern Mediterranean and around 400 AD in Middle Europe. (2) Another explanation is the cycle of man-geosystem-interaction (Bork et al. 1998). In this model firstly the geoecosystem is in equilibrium with vegetation protecting the soil; then deforestation and agricultural land use leads to increasing population and soil erosion, followed by degradation of soil quality and depopulation, which finally leads to declining land use, reforestation and restabilisation of the geoecosystem. The length of such cycles is estimated in the order of at least several hundred years. But one should keep in mind that also novel agricultural techniques, such as the introduction of the plow in the Early Bronze Age, might have had a sudden influence on soil erosion.

ENVIRONMENTAL CHANGE AND CULTURAL DEVELOPMENT IN THE NASCA REGION

Although the coastal area between the Pacific and the Andes in southern Peru consists of a hyperarid desert belt, it bears rich traces of high civilizations. Especially near Nasca and Palpa the desert surface is covered by innumerable geoglyphs, renowned as world cultural heritage. This region was in the past densely populated, particularly during the Nasca culture which is known for its polychrome ceramics. One has always wondered how such high culture could have risen and been sustained in such physically hostile environment. Thus, a multidiscipinary project was performed in this area in order to investigate the climate change and its effects on the history of the Prehispanic cultures (Reindel and Wagner 2009). For establishing the prehistoric time-frame, luminescence dating was essential due to the omnipresence of rocks and clastic sediments and stone monuments. Organic material suited for C14 was restricted to the river oases crossing the desert belt from the Andes towards the Pacific. The task for luminescence dating within the project was twofold: the age determination of the hitherto undated geoglyphs and of the various fluvial and aeolic sediments.

For the dating of the geoglyphs a novel technique of spatially high resolution OSL-measurements (HR-OSL) of rock surfaces was developed (Greilich et al. 2002). It determines the moment, when a stone surface was for the last time exposed to daylight. When the geoglyphs were constructed by moving away stones by detaching stones from the desert pavement and depositing them at the geoglyph rim, the stones became exposed to daylight (Fig. 2). For sampling the rocks were removed at night out of the ground and cores were drilled from the lower, light-shed surface. For quasi-nondestructive sampling the rocks were put back to their former position and no visible traces were left. The HR-OSL was measured on quartz and feldspar grains in their original petrographic context. The HR-OSL ages of granitoid stones sampled on different types of geoglyphs range between 900 and 2200 years and are in good agreement with archaeological and geomorphic reasoning. The results for one of the dated geoglyphs are shown in Fig. 3. Few samples still exhibited geological ages, i.e., the formation of the pediment on which the stones are lying. Possibly they were not moved during daylight. Also later reworking by nature or man is evident from more or less recent age values (Greilich and Wagner 2009).

Fig. 2: Rim of trapezoid geoglyph PAP379 near Palpa in southern Peru. The trapeze has been constructed by transporting the rocks of the desert pavement towards the rim (arrow), from where the samples for OSL dating were collected (photo: Wagner).

For the landscape reconstruction different types of sediment archives were dated with OSL (Kadereit et al. 2009). (1) *Debris flows* made up from coarse sediments such as pebbles and boulders often fill the mouths of the dry valleys at the Andean foot-zone. The deposits are attributed to heavy rainfall. The HR-OSL technique was applied to a dioritc boulder; the ages range between 11.3 and 14 ka, but are equal within error ranges. (2) The desert is widely covered by *loess*, which was deposited during more humid times, when the coastal desert was regularly influenced by moisture influx from the east.

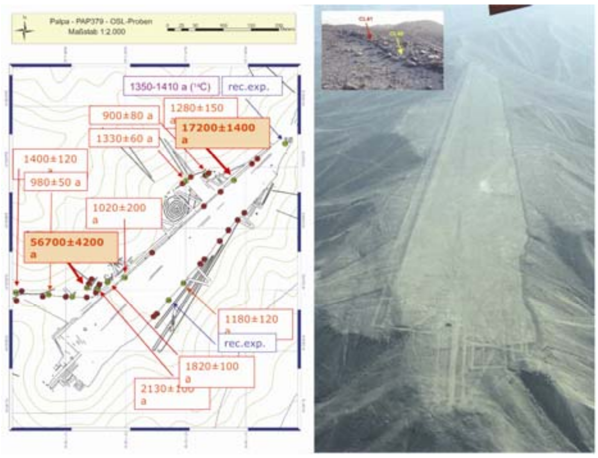

Fig. 3: Luminescence (HR-OSL) ages (in years) of stones (on their lower, light-protected face) from the geoglyph PAP379. They determine the last exposure of the stones to daylight, and thus the various phases of building the geoglyph (supported by a single C14-age on maize). There are few stones showing geomorphological ages or recent exposure (after Greilich and Wagner 2009).

A then denser vegetation cover combed the dust from the winds. The polymineral fine grains of the loess samples were dated by infrared stimulated luminescence (IRSL). It appears that during the Holocene humid periods of loess accumulation around 9.9, 7.3, 4.2, and perhaps 2.7 ka (only one sample) alternated with drought periods of no loess sedimentation around 8.6, 5.3, and 3.2 ka ago. (3) *Fluvial deposits* along the allochthonous rivers that originate from the high Andes provide fertile river oases amid the desert region. At several locations, samples were taken from river-terrace deposits for coarse-grain quartz OSL dating. The results reveal insufficient bleaching, so that only maximum ages can be calculated. Yet, supported by the results of accompanying C14-dating, the dates indicate a period of major fluvial activity during the Little Ice Age (1400-1700 AD), which is also supported by OSL and 14C dates of debris-flow deposits at the mouth of a currently dry valley.

Combined with the geomorphic data the OSL as well as C14 ages allow the reconstruction of the geomorphic and climatic history, which then can be correlated to the Prehispanic cultural development in the Nasca-Palpa region (Unkel et al. 2007). The loess deposits indicate that in the Holocene the present desert region was grassland until the third millennium BC, followed by gradual aridisation. During the first millennium BC the Paracas civilization developed and was replaced after 200 BC by the Nasca civilization. After 200 AD the aridisation accelerated and the Nasca settlements shifted eastwards up the valleys of the Andean footzone. Shortly after 600 AD the Nasca civilization collapsed. After 1100 AD the aridization trend reversed so that Late Intermediate Period (LIP) people re-occupied the extending grassland area till the 16th century AD. The Little Ice Age was again very dry so that LIP settlements were abandoned and desert conditions reappeared lasting until today (Unkel et al. 2007, Eitel and Machtle 2009).

CONCLUSION

The luminescence dating techniques have now advanced to a high methodological level. Thus they can be applied to a large variety of clastic rocks, which are commonly met in geoarchaeological contexts. This enables them to contribute essentially to the solution of important archaeological problems concerning the operating space of ancient civilizations. Several geoarchaeological studies (e.g. Eitel 2007) have demonstrated that climatic changes severely affected humans. In some cases they caused cultural collaps, in others successful response strategies led to even further cultural progress.

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