Quaternary International 374 (2015) 189–197

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Application of OSL dating and ^{137}Cs measurements to reconstruct the history of water erosion: A case study of a Holocene colluvium in Świerklany, south Poland

Grzegorz J. Poręba [a, *], Zbigniew Śnieszko [b], Piotr Moska [a]

[a] Institute of Physics CSE, Department of Radioisotopes, Silesian University of Technology, Akademicka 2A str., 44-100 Gliwice, Poland
[b] Kazimierz Wielki University, J.K. Chodkiewicza 30 str., 85-064 Bydgoszcz, Poland

ARTICLE INFO

Article history:
Available online 6 May 2015

Keywords:
Colluvium sediments
OSL dating
Cs-137
South Poland

ABSTRACT

Slopes used agriculturally at medium latitudes in European loess areas are modelled mainly by washing processes. The thickness of colluvium depends on the intensity of washing processes and the length of time of agricultural use, and it ranges from tens of centimetres to several meters in extreme cases. In southern Poland, anthropogenic deforestation of some slopes, and consequently washing processes, begun as early as 5 ka. However, in many places these processes began much later. As a result, colluvium accumulated at the foot of the slopes corresponds to different stages of the prehistoric and historical anthropopressure. Those specific stages of anthropogenic prehistoric erosion can be distinguished by dating methods. Dating may be used to establish the beginning of the prehistoric agricultural activity in a particular area and to determine the extent of areas used for agriculture in the past.

To study Holocene colluvium, the Świerklany site was selected mainly due to an archeological-rescue excavation associated with the construction of the highway in the vicinity of Świerklany village. For laboratory study, four sample profiles were collected from key points of the study area. Two of them were located at the foot of slopes, one at the eroded part of the slope and one in a former pond area on the extension of the one of the tested slopes. Beside this, 10 cores were collected to measure ^{137}Cs activity concentration as a modern erosion tracer. In the laboratory, analyses of ^{137}Cs activity concentration, grain size distribution and luminescence characteristics were done. The quartz extracted from the collected colluvial sediment was suitable for age determination based on the OSL SAR protocol. The OSL results for the lower part of the profiles indicate that fossil soils developed about 10 ka. Younger results from overlying materials were used to infer a range of erosion and transport processes since deforestation associated with the establishment of Świerklany village, in the thirteenth century. The most modern phase of landscape activation are described by the ^{137}Cs measurements, because ^{137}Cs is present on the slope deposits to plough depth. The soil layer which contains ^{137}Cs was dated by the OSL method for a period of 25–75 years, and the results obtained with both methods are in good agreement Results of investigations of the colluvium in Świerklany area clearly document good bleaching of OSL signal for sediments derived from washing (slope sediment).

1. Introduction

Slopes used agriculturally at medium latitudes in European loess areas, equally in the past as at present, are modelled mainly by washing processes (Śnieszko, 1991). These processes are responsible for the accumulation of the colluvium material at the foot of a slope. The thickness of colluvium depends on the intensity of washing processes and the length of time of agricultural use and it ranges from tens of centimetres to several meters in extreme cases. Locally, colluvia are separated by fossil soils (Śnieszko, 1995). In southern Poland, anthropogenic deforestation of some slopes, and consequently washing processes, began as early as about 5 ka. However, in many places these processes began much later (Starkel, 2005). As a result, colluvium accumulated at the foot of the slopes corresponds to different stages of the prehistoric and historical anthropopressure (Kruk et al., 1996). Those specific stages of

* Corresponding author.
E-mail address: Grzegorz.Poreba@polsl.pl (G.J. Poręba).

http://dx.doi.org/10.1016/j.quaint.2015.04.004
1040-6182/

anthropogenic prehistoric erosion can be distinguished by dating methods. Dating may be used to establish the beginning of the prehistoric agricultural activity in a particular area and to determine the extent of areas used for agriculture in the past. The radiocarbon method can be used for the dating of colluvium only in exceptional cases (Bluszcz et al., 2007). On the other hand, luminescence dating (OSL) appears to be much more useful, allowing satisfactory results even for colluvium younger than 60 years. An alternative age indicator for the youngest sediments is the ^{137}Cs method which additionally provides an independent age control for OSL dating (Ritchie and McHenry, 1990; Poreba, 2006). Ages of colluvium related to Neolithic or younger prehistoric settlements located on the Polish territory were studied in the past by Bluszcz et al. (2007) and Poręba et al. (2011, 2013). In those studies, examples of luminescence dating of colluvium are shown; at the same time those works commented on methodical limitations of OSL dating of this kind of sediment. The assumption that the transport of quartz grains is the main factor responsible for bleaching processes of the OSL signal in relation to other sediments in case of anthropogenic colluvium seems problematic (Fuchs and Lang, 2009).

The final luminescence signal of quartz grains in a colluvium is affected by:

- the amount of aggregates in mineral material transported on slope during washing,
- the presence of resistant mineral coatings on quartz grains,
- the type and duration of agricultural practices before washing and after colluvium accumulation,
- the intensity and type of washing,
- the intensity of pedoturbation before transport and after accumulation.

Unfortunately, it is impossible to quantitatively determine the individual influence of the factors listed above on the results of luminescence dating of a colluvium. Before transport on the slope, the quartz grains have an initial luminescence signal accumulated since the previous accumulation process. In areas covered by vegetation, this signal could be changed by mixing processes (i.e. pedoturbation) during soil formation. A part of older quartz grains moves to the surface where they can be bleached and at the same time a part of younger material moves into deeper layers of the soil. The longer and more intensive pedoturbation processes caused the more changes of the initial luminescence signal. The washing processes during formation of a soil profile on a loess slope are inhibited by natural vegetation. When vegetation is destroyed and epipedons are loosened during agricultural practices, luminescence signal can change as a result of mechanical mixing of the soil. With increasing timespan between the soil erosion and these agricultural practices, the probability of luminescence signal change also increases. Heavy washing on the slope is associated with tempestuous precipitation. Heavy–drop rainfall reaching the soil surface previously disturbed by agricultural practices causes breakage of grain aggregates and isolation of single grains of quartz, leading to an increased likelihood of being exposed to sunlight during transport. Soil grains can reach the foot of the slope immediately, or they may be retained in the upper parts of the slope and transported to the foot of the slope during the next precipitation event (redeposition). Grains of soil can be transported down the slope as a result of sheet or rill washing. During the rill transport of quartz grains on the hill slope, the grains can be mixed which will cause different levels of the initial luminescence signal. Colluvium with a large amount of material originating from rill erosion has a luminescence signal different from that of the colluvium with material dominated by sheet erosion input. Between heavy-drop precipitation events at the top of the colluvium, pedogenesis occurs and sometimes this type of sediment can be mixed by agrotechnical practices (Starkel, 1997).

The results of OSL dating of colluvium may be different from the real age due to problems with bleaching of quartz grains during redeposition. The magnitude of those differences has been investigated in this work. Furthermore, ^{137}Cs measurement, grain size distribution and archaeological surveys for loess colluvium have been employed in order to help the reconstruction of the chronology of erosion history in the study area.

2. Study area

A loess area near Świerklany village was selected for this study. This area is characterized by attitude ranges from 265 to 285 m a.s.l and is located on the Rybnicki Plateau which is a part of Silesia Upland (50°01′30″ N, 18°35′59″ E). In this region, mean annual precipitation is 750 mm with maximum precipitation occurring during summer months, and the annual average temperature is 7.8 °C (Kruczała, 2000). Świerklany is located 25 km south of Katowice in southwest Poland on the Pleistocene decarbonised aeolian sediment (Fig. 1) (Dwucet, 1986). According to the stratigraphy prepared by Maruszczak (1991, 2001) for Polish loess, this sediment could be described as LMG (upper younger loess).

The loess-like sediment on the Rybnicki tableland is without carbonates. This means that this sediment was accumulated quite slowly in the humid climate (Jersak, 1973).

The typical thickness of loess deposits on the Rybnicki Plateau rarely exceeds a few meters, and at their borders silty sands and sandy silt frequently are found. The study area lies on the Pleistocene silty sands a few dozen meters from the border of the loess deposits. This part of Silesia Upland has always been characterized by excellent conditions for agricultural development, but the soil cover developed on the loess sediment is susceptible to erosion (Kruk et al., 1996). The earliest historic evidence of existence of the Świerklany village originates from the thirteenth century. Our investigation was carried out on land intensively farmed since the Medieval Ages due to high soil fertility (Chwałek and Majewski, 2007, 2008).

3. Field work

Prior to the luminescence and isotope analysis, archaeological surveys were conducted before motorway construction. Detailed archaeological excavations were carried out on an area of 17,925 m^2. Those surface excavations took place along slopes with different exposures; they allowed determination of the spatial extent of the colluvium cover and its structure. Places with the greatest thickness of colluvium were selected for OSL dating. In the vicinity of the studied slopes, documentation of artefacts, drawings and photographic documentation of selected parts of excavations were conducted. Among the 781 artefacts found during the archaeological study, the majority are connected with the historical period. Most of the artefacts were connected with the late Medieval and later period. This is also confirmed in the historical sources.

Older single artefacts were not associated with any permanent settlement. There is no evidence that during the Holocene processes other than washing occurred in the study area (Chwałek and Majewski, 2008).

Four locations were selected for a detailed luminescence study (Fig. 1). In Świerklany I, samples were taken from the horizon of enrichment of fossil soil – $B_{f/col}$ (SW 1_6, Fig. 4) and fossil humus horizon – A_f (SW 1_5, Fig. 4). Samples were taken from differently coloured layers of colluviums overlying fossil soil (SW 1_4, SW 1_3, SW 1_2) and from the plough depth (topsoil) (SW 1_1). In both the