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Research Paper

ESR chronology of alluvial deposits and first human settlements of the Middle Loire Basin (Region Centre, France)

P. Voinchet [a,*], J. Despriée [a], H. Tissoux [a], C. Falguères [a], J.-J. Bahain [a], R. Gageonnet [a], J. Dépont [c], J.-M. Dolo [b]

[a] Département de Préhistoire, Muséum National d'Histoire Naturelle, UMR 7194 du CNRS, Institut de Paléontologie Humaine, 1 rue René Panhard, 75013 Paris, France
[b] CEA, LIST, Gif-sur-Yvette F-91191, France
[c] Société d'Archéologie et d'Histoire du Berry, 18000 Bourges, France

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ABSTRACT

Since 1970, many prehistoric sites have been discovered in the alluvial terraces of several rivers of the Middle Loire River basin (France). During the last decade, the stepped-terraces systems of three of the Loire tributaries, the Creuse, the Cher and the Loir Rivers, were the focus of multidisciplinary studies, involving Quaternary geology, prehistory and geochronology. The geochronological data now available for these systems were mainly obtained by electron spin resonance (ESR) method applied to optically bleached fluvial quartz. These results provide a chronological framework for the evolution of fluvial systems and the human settlements of this area during Lower and Middle Pleistocene. Two phases of human settlement could be distinguished, around 1.1 Ma (Early Palaeolithic – Mode 1) and around 0.7 Ma ago (Acheulean – Mode II).

1. Introduction

Since the 1980s, the improvement of the electron spin resonance (ESR) dating method and its application to date bleached quartz extracted from sediments permitted to provide geochronological data on Pleistocene fluvial deposits and associated archaeological sites. The first application on the Somme River stepped-terraces system clearly indicated the potential of ESR method (Laurent et al., 1998; Bahain et al., 2007). Today, the systematic ESR dating of alluvial systems offers the possibility to build regional chronostratigraphical frameworks for many fluvial systems of Western Europe.

In this paper, we present the ESR dates obtained on fluvial deposits of the main tributaries of the Loire River in the Centre Region, France (Fig. 1). This area was archaeologically surveyed for more than 30 years by J. Despriée, R. Gageonnet and J. Dépont and many prehistoric sites were discovered. The alluvial systems of the Creuse, the Cher and the Loir Rivers, were studied during the last decade using a multidisciplinary approach combining Quaternary geology, prehistory and geochronology. Around 200 fluvial remnants of these systems were sampled for ESR analyses. The results of a first set of hundred samples, after removing incoherent data resulting from sample contamination, are now available. It is now possible to provide a chronological framework for the evolution of the fluvial systems and the human settlements in this area during Lower and Middle Pleistocene.

2. Method

ESR dating of bleached fluvial quartz is based on the response of the ESR aluminium (Al)-centre to solar light and ionizing radiation (Yokoyama et al., 1985; Laurent et al., 1998; Voinchet et al., 2004). The Al-centre can be optically bleached during the fluvial transport. The bleaching is incomplete and a residual, unbleachable signal, must be subtracted from the ESR response prior to any age calculation. The determination of the residual intensity was described in detail in Voinchet et al. (2003).

Analyses were carried out on 100–200 μm size fraction of purified quartz grain. Irradiations were performed using a panoramic ^{60}Co source. Generally, eight aliquots were irradiated with doses ranging between 500 and 30,000 Gy.

* Corresponding author.
E-mail address: pvoinch@mnhn.fr (P. Voinchet).

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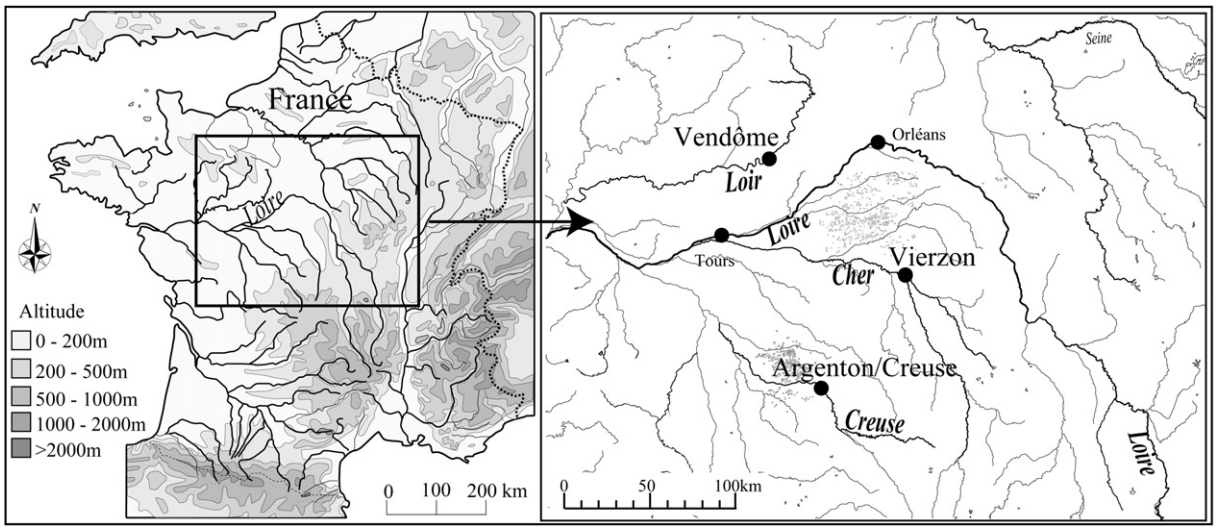

Fig. 1. Location of the studied river systems in Middle Loire Basin (Region Centre, France).

ESR measurements were performed at 107 K with a Bruker EMX spectrometer using the experimental conditions proposed by Voinchet et al. (2004). The signal intensity is measured between the top of the first peak at $g = 2.018$ and the bottom of the 16th peak at $g = 2.002$ of the Al hyperfine structure (Toyoda and Falguères, 2003). The equivalent doses were determined by fitting of the experimental data, including the bleached, natural and irradiated points, to zero, using a single exponential function with a least-square method (Yokoyama et al., 1985).

The dose rate was calculated from the activities of the radionuclides obtained by gamma-ray spectrometry measurements. Alpha and beta attenuations were estimated from the tables of Mejdahl (1979) and Bell (1980). We used a k-value of 0.2 (Yokoyama et al., 1985; Laurent et al., 1998) and the dose-rate conversions of Adamiec and Aitken (1998). The cosmic dose rate was calculated from the equations of Prescott and Hutton (1994).

3. Creuse River System

Since 1982, field work along the Middle Creuse River Valley, in Argenton-sur-Creuse area (Indre, France) has identified numerous distinctive fossil fluvial formations. Our researches have shown the impact of the recent tectonics and of the nature of the bedrock on the Pleistocene fluvial record (Voinchet et al., 2007). According to the nature of the bedrock and rarity of observable alluvial remnants, which prohibit precise longitudinal correlations, the area was divided into three distinct sectors (Despriée et al., 2004). For each sector, ESR results show a good reproducibility and generally a good coherence with the altimetry.

From the first set of ESR results (Table S1), a schematic history of the fluvial system can be proposed for the Middle Creuse River Valley (Fig. 2). The highest terrace, which seems to indicate the beginning of the valley incision, is dated to around 1.8 Ma. The main part of the stepped system was developed during the last million years and each alluvial formation represents a full glacial/interglacial cycle. This global scheme is therefore consistent with that of the Somme (Antoine et al., 2007; Bahain et al., 2007), 450 km to the north.

The oldest archaeological evidence in the Creuse valley is the 'Pont-de-Lavaud' prehistoric settlement (Eguzon-Chantôme, Indre; Despriée et al., 2006), where several archaeological pavements and numerous artefacts of archaic lithic industry (Mode 1 – Early Paleolithic) were recovered. The mean age of the corresponding alluvial formation, derived from 10 ESR dates, is around 1.1 Ma. Hence, the "Pont-de-Lavaud" site is contemporary with the early human settlements already observed elsewhere in Eurasia (Martínez-Navarro et al., 1997; Arzarello et al., 2007) as well as evidence of a human presence in France during the Lower Pleistocene, in spite of the beginning of periglacial climatic oscillations (Despriée et al., 2006).

4. Cher River System

Since 2003, field surveys in the Middle Cher River Valley have allowed the establishment of the sequence of the Pleistocene alluvial formations (Fig. 3; Despriée et al., 2007). In this valley, geological observations are complicated by the fact that the differences between the relative altitudes of the highest terraces are very small. In addition, middle sheets are rarely preserved and the lower formations spread out the 2 km wide alluvial plain.

Two distinct sectors, called "Berry" and "Sologne", were defined, respectively, upstream and downstream of Vierzon (Cher, France). In the "Berry" Sector, the deposits are often preserved in karstic

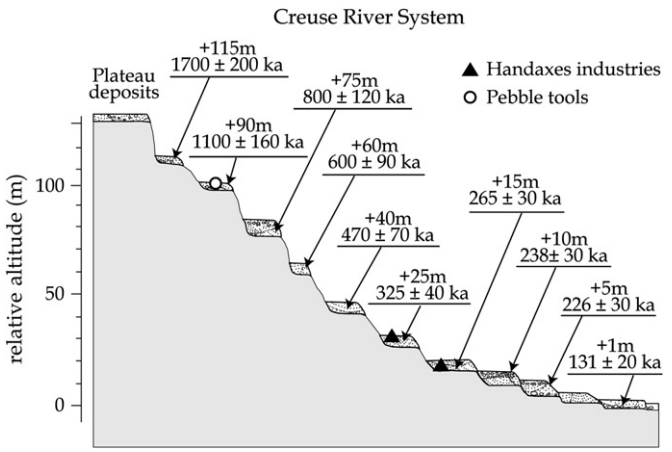

Fig. 2. Schematic stepped-terraces system of the Creuse River and mean ESR results. The altitudes of the terraces are given with respect to the base of the present-day floodplain.

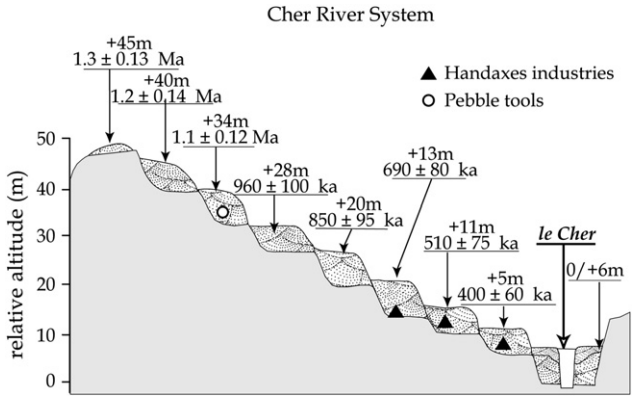

Fig. 3. Schematic stepped-terraces system of the Cher River and mean ESR results. The altitudes of the terraces are given with respect to the base of the present-day floodplain.

systems or on tilted down blocks. In the "Sologne" Sector, the valley incision is reduced because of the subsidence of the Sologne Basin, and only five alluvial formations have been observed.

The ESR results (Table S2) indicate that the Cher Valley began its incision during the Lower Pleistocene, in spite of a low incision rate of the other main tributary valleys of the Middle Loire Basin. However, the interpretation of the results is complicated by subsidence and/or karstic collapses, which have locally caused a stacking of the alluvial formations (Voinchet et al., 2007).

The Early Palaeolithic artefacts recovered in the alluvial deposits during the excavations of Lunery site (Cher) were dated to about 1.1 Ma and confirm the Lower Pleistocene age of the human settlement of the Middle Loire Basin (Despriée et al., 2007). The ESR ages obtained for the middle formations indicate that Acheulean handaxe industries were present and developed in this area around 700 ka (Brinay "la Noira" locality), i.e. 200 ka earlier than previous estimations (Despriée et al., 2007).

5. Loir River System

Since 2001, researches undertaken in the Loir River basin around Vendôme (Loir-et-Cher, France) have allowed to identify ten stepped Pleistocene fluvial formations (Fig. 4) (Despriée et al., 2003). Their periglacial nature and sedimentary facies are strictly related to the lithology of the bedrock. The stepped system is not homogeneous and two sectors were distinguished.

The ESR results (Table S3) show that the three highest alluvial sheets date from the Lower Pleistocene and indicate a significant uplift of about 60 m at the boundary between Lower and Middle Pleistocene. The middle terraces may belong to the marine isotopic stages 14 and 11, between 500 and 400 ka. The lower terraces, dated to between 300 and 200 ka, are largely spreading in vast basins related to the most important faults (Despriée et al., 2003).

Some archaic pebble industries were found in the highest alluvial sheet, dated from the Lower Pleistocene, as in the Creuse and Cher valleys. Besides, the Acheulean industries appear around 500 ka and the Levallois technology, between 300 and 200 ka.

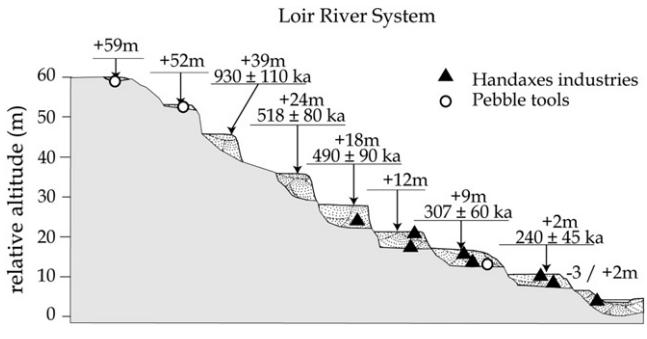

Fig. 4. Schematic stepped-terraces system of the Loir River and mean ESR results. The altitudes of the terraces are given with respect to the base of the present-day floodplain.

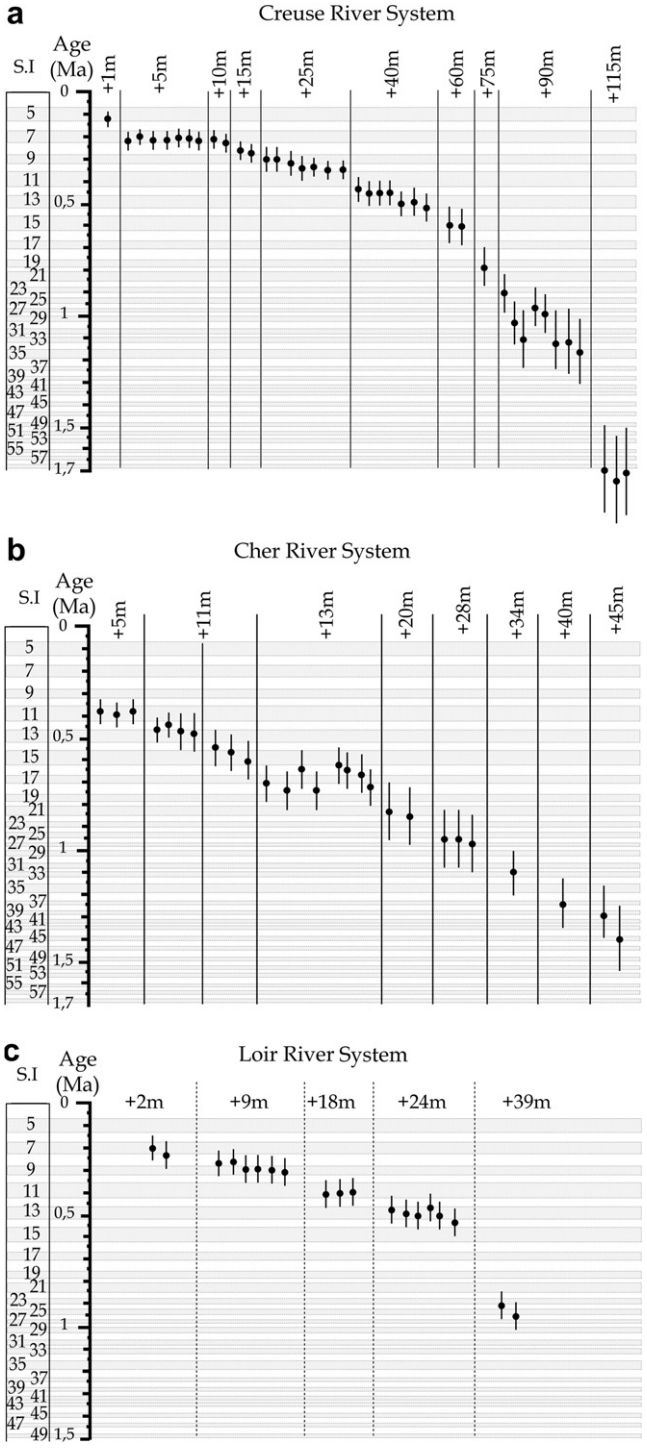

Fig. 5. ESR dates obtained from the Creuse (a), Cher (b) and Loir (c) River Systems versus marine isotope stages (Shackleton, 1995).

6. Conclusions

The geochronological results obtained for the Quaternary alluvial deposits of three tributaries of the Loire River (Creuse, Cher and Loir) illustrate clearly the great potential of ESR method for dating such deposits. The use of the aluminium centre allows the dating of Lower and Middle Pleistocene deposits accurately and reproducibly. The ESR results can then contribute to the construction of the regional chronological framework for Quaternary times, allowing a comparison in Western Europe and of the first settlements in Eurasia.

The ages obtained for the sediments of each valley (Fig. 5) confirm that the human settlement of the Middle Loire Basin has begun during Lower Pleistocene. In this sector, six Early Palaeolithic sites were dated to between 1 and 1.2 million years. The corresponding lithic industries (Mode 1, Pebble tools) were manufactured with local raw materials (quartz, flint, limestone, …), i.e., the rocks available in the fluvial deposits. Later, at the beginning of the Middle Pleistocene, the Acheulean industries appear in the Middle Loire Basin. The handaxes industries are systematically abundant in the middle terraces of the three studied valleys, between 700 and 200 ka. The gap between the two sets of localities would reinforce the hypothesis of two waves of settlements, before and after the Brunhes–Matuyama boundary (Despriée et al., 2006). These archaeological assumptions should be verified in the future, through the analyses of the second set of one hundred sediments collected in these three systems and through the study of other fluvial systems of the Middle Loire Basin, for example the Indre River, Sarthe River and Middle Loire River systems.

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Appendix. Supplementary data

Table S1. ESR dates obtained on fluvial sediments of the Creuse River System. The following analytical data are shown: maximal bleaching percentage (Bl), equivalent dose (D_E), sediment water content, dose rate and age.

Table S2. ESR dates obtained on fluvial sediments of the Cher River System. The following analytical data are shown: maximal bleaching percentage (Bl), equivalent dose (D_E), sediment water content, dose rate and age.

Table S3. ESR dates obtained on fluvial sediments of the Loir River System. The following analytical data are shown: maximal bleaching percentage (Bl), equivalent dose (D_E), sediment water content, dose rate and age.

Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.quageo.2009.03.005.

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