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Research paper

New luminescence dating results based on polymineral fine grains from the Middle and Upper Palaeolithic site of La Ferrassie (Dordogne, SW France)

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In this study we compare different infrared stimulated luminescence (IRSL) signals for dating archaeological deposits. The IRSL and the more recently developed post-IR IRSL (pIR-IR) methods were investigated using polymineral fine grains extracted from the Middle and Upper Palaeolithic western excavation area in the site of La Ferrassie (Dordogne, SW France). The IRSL data measured at 50 °C (IR_{50}) are compared to those obtained with the elevated pIR-IR signals measured for two stimulation temperatures, 225 °C ($pIR\text{-}IR_{225}$) and 290 °C ($pIR\text{-}IR_{290}$). The signals are documented in terms of bleaching and fading rates. In addition, comparisons of the IR_{50} ages corrected either with the H + L method (Huntley and Lamothe, 2001) or with the dose rate correction method (DRC, Lamothe *et al.*, 2003) are presented. Results show that the polymineral fine grains give a reasonable estimate of the burial age of the samples. The IR_{50} and $pIR\text{-}IR_{225}$ provide the most reliable ages when they are corrected using the DRC method (because of saturation effects). The polymineral ages are then compared with the previously obtained ages on K-feldspar coarse grains, quartz OSL (Guerin *et al.*, 2015) and radiocarbon ages with the aim of accessing information on the depositional processes. It appears that further comparison of polymineral fine grains to coarse grains is beneficial to evaluate bleaching. Moreover, the polymineral results either confirm or refine the chronology of the La Ferrassie sequence proposed by Guérin *et al.* (2015), that is, the Mousterian layers range from marine isotope stage (MIS) 5 to the middle of MIS 3. In particular, i) the base of Layer 3 is pushed back to the end of MIS 4 or beginning MIS 3 and ii) the chronological attribution of Layers 4 and 5 is confirmed as MIS 3. Finally, the chronology of the Aurignacian layer (Layer 7) is strengthened by all the feldspars results.

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1. Introduction

Since their inception thirty years ago, the optical luminescence dating techniques have grown in use due to the ubiquity of the materials usable as dosimeters and the various potential applications of these techniques in geology, geomorphology, and archaeology. In particular, quartz mineral has been shown to be a robust and accurate dosimeter (Murray and Olley, 2002; Rittenour, 2008), which is usually dated using the optically stimulated luminescence method (OSL; Wintle and Murray, 2006). As a compliment to quartz, feldspars have steadily grown in popularity due to certain advantages over quartz: the infrared stimulated luminescence (IRSL) signal from K-feldspar (Hütt et al., 1988) is significantly brighter than the signal of quartz and it saturates at higher doses, thus offering the possibility to extend the dating limit to more than 500 ka (Lamothe, 2016). However, routine use of feldspars is hampered by the anomalous fading effect (Wintle, 1973; Spooner, 1994) which is explained as resulting from quantum mechanical tunneling of electrons (Visocekas, 1985) escaping from the main dosimetric trap to neighbouring defects. This phenomenon, which is sample dependent (Lamothe et al., 2012; Trauerstein et al., 2012), leads to an age underestimation if it is not corrected for or circumvented (Aitken, 1985). To tackle this problem, two approaches are used: i) measure the laboratory fading rate and correct for it or ii) try to minimize this phenomenon. For the first approach, Auclair et al. (2003) have proposed a technique to properly measure the fading rate, while Huntley and Lamothe (2001) or Lamothe et al. (2003) have devised two different correction techniques. Other correction methods have been proposed more recently (e.g. Kars et al., 2008) without invalidating the former. The second approach makes use of a signal that is less or not affected by anomalous fading (e.g. Sanderson and Clark, 1994; Tsukamoto et al., 2006; Li and Li, 2011). In particular, a novel technique has been recently introduced for dating feldspars, which consists in a two-step stimulation protocol (Thomsen et al., 2008; Buylaert et al., 2009). Firstly, a stimulation with infrared photons at low temperature, typically 50 °C (IR_{50}), aims to drain the traps more prone to anomalous fading and in a second step, an IR-stimulation at elevated temperature releases a more stable signal. This second signal, named post-IR IRSL (pIR-IR), yields a lower fading rate, hence a smaller uncertainty due to the anomalous fading correction. This technique has been successfully used to determine burial ages of Eemian samples from various depositional environments (fluvial, aeolian, coastal), using sand-sized feldspars and/or polymineral fine grains (e.g. Stevens et al., 2011; Thiel et al., 2011a; Wacha and Frechen, 2011; Murray et al., 2014; Zhang et al., 2015).

The La Ferrassie rock-shelter, in SW France, provides a deep and complex depositional sequence resulting from different sedimentary processes. The northern part of the site has been extensively excavated and studied since the 19th century, delivering Middle to Upper Palaeolithic occupation evidences and the western sector has been the focus of more recent studies during the past 6 years. In this sector the sediments are fluvial-deposited sands and gravels overlain by slope deposits (Turq et al., 2012). This context makes the La Ferrassie site an interesting case study where the effect of different depositional processes on the age determination using different minerals and signals can be achieved. Our investigations are focused on the application of three luminescence protocols on polymineral fine grains fraction using the IR_{50} and pIR-IR signals at different temperatures, 225 °C ($pIR\text{-}IR_{225}$, e.g. Buylaert et al., 2009; Alappat et al., 2010; Lowick et al., 2012) and 290 °C ($pIR\text{-}IR_{290}$, e.g. Thiel et al., 2011a, 2011b, 2012; Stevens et al., 2011; Murray et al., 2014). Their bleaching efficiency and severity of fading rate will be compared. The IR_{50} ages corrected from fading either with the H + L correction method (Huntley and Lamothe, 2001) or with the DRC correction method (Lamothe et al., 2003) will be discussed. Finally, luminescence ages will be presented along with ages previously obtained with the same techniques on the K-rich sand-sized feldspar, OSL on quartz and with the radiocarbon dating technique applied to bone collagen (Guérin et al., 2015). The comparison between these different datasets will provide information on the depositional processes for improving the chronological framework of this important archaeological site.

2. La Ferrassie rock-shelter

2.1. Site description

The site of La Ferrassie is a rock-shelter, corresponding to a former cave partly collapsed, located against an Upper Cretaceous limestone cliff along a narrow valley which is a tributary of the Vézère River, France (Fig. 1). It was discovered at the end of the 19th century. D. Peryony and L. Capitan began excavations in 1907 in the northwest part of the shelter and continued with a series of trenches moving eastward until 1922 (with an interruption from 1914 to 1917). H. Delporte carried out excavations from 1968 to 1973, focusing especially in cleaning a large perpendicular section along the north and east sections of the shelter. This allowed a study of the more than 6 m of deposits in this portion of the site. This important stratigraphy documents palaeoenvironments at the beginning of the last Pleniglacial in southwestern France along with a sequence of successive human occupations from the Middle Palaeolithic period but also the beginning of the Upper Palaeolithic (Turq et al., 2008, 2012). The site is also famous for the discovery of remains of seven Neanderthal individuals, including adults, children, infants, and two foetuses (Capitan and Peyrony, 1909, 1911, 1912, 1921). The skeleton of La Ferrassie 1 is one of the most complete Neanderthals yet discovered.

The western sector of the site (Fig. 2a), between the area excavated by Peyrony and Capitan and the modern road, was left undisturbed until 2010 when a new multidisciplinary team led by A. Turq began the excavations. The deposits, which represent a 3 m-thick sedimentary sequence in the studied area (Fig. 2b), show a succession of alluvial sediments at the base overlain by several layers of colluvium (Turq et al., 2012). Eight major lithostratigraphic units are associated with Middle Palaeolithic lithic assemblages (Layers 1 to 5) overlain by a Châtelperronian assemblage (Layer 6) and Upper Palaeolithic occupations (Layers 7 and 8). Layer 1 and 2 yielded assemblages that include discoïdal and Levallois

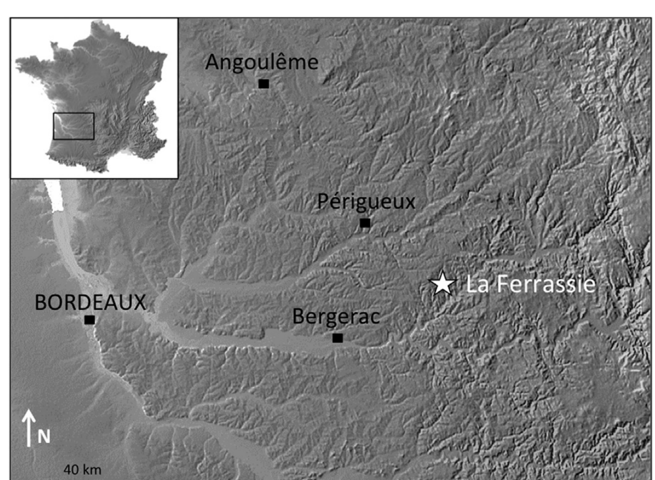

Fig. 1. The position of La Ferrassie on the geological map (from Karnay, 1999).