ARTICLE IN PRESS

Quaternary International xxx (2017) 1–16

Contents lists available at ScienceDirect

Quaternary International

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

Green amphibole distribution as a stratigraphic tool in loess sequences from Belgium: A review

Stéphane Pirson [a, b, *], Jean-Marc Baele [c], Sanda Balescu [d], Paul Haesaerts [b], Etienne Juvigné [e], Erik Meijs [f], Paul Spagna [b]

[a] Direction de l'Archéologie, Service Public de Wallonie, 5100 Namur, Belgium
[b] Directorate Earth and History of Life, Royal Belgian Institute of Natural Sciences, 1000 Brussels, Belgium
[c] Department of Geology and Applied Geology, University of Mons, 7000 Mons, Belgium
[d] Laboratoire Halma Ipel (UMR 8164), University Lille 1, 59655 Villeneuve d'Ascq Cedex, France
[e] Department of Geography, University of Liège, Sart-Tilman, B-12A, 4000 Liège, Belgium
[f] ArcheoGeolab, Pal Maleterstraat 42, 3573 PH Utrecht, The Netherlands

ARTICLE INFO

Article history:
Received 9 December 2016
Received in revised form
28 April 2017
Accepted 14 June 2017
Available online xxx

Keywords:
Loess
Heavy minerals
Microprobe analyses
Late and middle pleistocene
Stratigraphic correlations
Cave entrances

ABSTRACT

The use of heavy minerals as a stratigraphic tool in the study of loess sequences from NW Europe originated some 70 years ago. One major problem in using the available data sets is the heterogeneous stratigraphic context of the samples, given the complex historic evolution of the stratigraphic framework of loess sequences. This paper aims at presenting a review of the use of heavy minerals for stratigraphic studies in loess sequences from Belgium, focusing on the important role of green amphiboles. We provide the first synthesis of the available data for Belgium in a common and accurate lithostratigraphic framework, i.e. the loess lithostratigraphic units recently reviewed by the National Commission for Stratigraphy. A total of 121 samples studied by 4 different researchers and collected from 13 different loess sections are considered. We also document the detailed mineralogical composition of these green amphiboles based on new microprobe analyses. Our results show that the green amphibole content of regional loess deposits presents a remarkable consistency in their stratigraphic distribution. Five groups are defined here, covering the entire Pleistocene loess sequence, from MIS 11 to Weichselian. While GA distribution used alone is not a discriminatory criterion, it becomes most of the time discriminatory when combined with the palaeoenvironmental signature of the sequence deduced from pedostratigraphy.

1. Introduction

North-western Europe, including Belgium, southern Netherlands, western Germany and northern France, has played a major role in the genesis and further developments of Late Pleistocene loess research. Along with the naming of loess by Von Leonard in early 1820s and the determination of the aeolian origin of loess by von Richthofen in the 1870s (Smalley et al., 2001; Zöller and Semmel, 2001), stratigraphic research was developed by pioneers such as Dumont, Ladrière, Rutot or Commont (see Gullentops, 1954; Paepe and Sommé, 1970; Sommé and Tuffreau, 1978 and references therein).

Since early works, the main tools used for correlating loess sequences are pedological (either cryogenic or not) and sedimentary markers. However, the existence of similar type of pedofacies occupying distinct stratigraphic position (convergence) is problematic, such as for tundra gleys or luvisols. The same goes for some specific lithofacies. This situation partly explains why the stratigraphic framework of loess sequences from Belgium underwent several major changes over the past 60 years, (Gullentops, 1954; Paepe and Vanhoorne, 1967, 1976; Haesaerts et al., 1981; Juvigné et al., 1996; Meijs, 2002; Haesaerts, 2004; Pirson et al., 2009; Haesaerts et al., 2011a, 2016). The use of other tools, as advocated in the International Stratigraphic Guide (Salvador, 1994), is therefore necessary to test the validity of marker horizons generally used to correlate sequences, in order to avoid the weakness of counting backward methods in sequences where gaps are frequent.

* Corresponding author. Direction de l'Archéologie, Service Public de Wallonie, 5100 Namur, Belgium.
E-mail address: stephane.pirson@spw.wallonie.be (S. Pirson).

http://dx.doi.org/10.1016/j.quaint.2017.06.026
1040-6182/

A very efficient tool for correlating sequences is tephrostratigraphy, as volcanic ashfalls give accurate chronostratigraphic markers (Juvigné, 1993; Pyle et al., 2006; Pirson and Juvigné, 2011; Lowe, 2011; Blockley et al., 2014). However, no tephras have been so far recognized in Belgium for Middle Pleistocene while only three tephras are known in the Late Pleistocene loess belt: Laacher See, Eltville and Rocourt Tephras (Juvigné, 1993; Pouclet et al., 2008; Pouclet and Juvigné, 2009; Pirson and Juvigné, 2011).

Another classical tool frequently used to correlate loess sequences is dating. Very few radiocarbon dates are available in Belgium (Paepe and Vanhoorne, 1967; Haesaerts and de Heinzelin, 1979; Haesaerts et al., 1981; Van den haute et al., 1998; Haesaerts, 2000) as reliable material for dating is scarce, and they are only dealing with the last 45 ka BP. Luminescence dates, either TL and IRSL, or more recently OSL, were also applied to some loess sections in Belgium (Wintle, 1987; Juvigné and Wintle, 1988; Van den haute et al., 1998, 2003; Frechen et al., 2001; Zens et al., 2017). The TL method has also been used as a relative dating technique termed "TL stratigraphy" for chronological discrimination and stratigraphical correlation of Weichselian and Saalian loess (MIS 2, 4, 6, 8) in NW Europe (Balescu, 1986a, 1988; Balescu et al., 1986a, 1986b, 1986c, 1988). The TL signals of both quartz and alkali feldspars grains (40–50 μm) from loessic sediments provided useful geochronometers. The MFE ratio measured on feldspars, defined as feldspar relative ages (e.g. Balescu et al., 1986c, 1988), provide relative chronologies. Such TL relative ages estimated on feldspars notably allowed to distinguish pre-Weichselian from Weichselian loess, and enabled chronological discrimination between early and late Saalian loess (MIS 8 and 6). Moreover this method demonstrated the existence of 3 successive loessic generations within the late Saalian period (MIS 6).

A third tool, on which we will focus here, is the study of heavy minerals. The first research dedicated to mineralogical composition of loess in Belgium dates back to early XXth century (Cornet, 1901; see also review in Juvigné et al., 1999). Heavy mineral assemblages in loess published by various authors present significant differences, notably due to distinct laboratory methods as pointed out by Juvigné (1978, 1979). All in all, the most frequent transparent heavy minerals in the fraction 63-30 μm are obviously zircon, tourmaline, rutile, epidote, green amphibole and garnet (Gullentops, 1954; Juvigné, 1978; Juvigné et al., 1999). The use of heavy minerals was immediately recognized as a powerful tool for sourcing loess deposits, which soon appeared to have an allochthonous origin likely related to the erosion of crystalline rocks (Cornet, 1901). Studies from the last 40 years showed that allochthonous loess from NW Europe is mainly derived from sediments blown out from two sources: 1) the periglacial braided alluvial plains of the Rhine, Thames, Meuse, Somme and Seine rivers, including their prolongation in the dried out shelves of the Channel and the North Sea as well as the Channel River, and 2) the glaciofluvial outwash plains extending in front of the Scandinavian ice sheet (Juvigné, 1976, 1978; Lautridou, 1985; Balescu, 1988; Juvigné et al., 1999; Antoine et al., 2003a, 2009; Lehmkuhl et al., 2016).

Using heavy minerals for stratigraphic studies in loessic sediments originated in The Netherlands (Van Doormael, 1945). Its first application in Belgium followed a few years later (Gullentops, 1954). These earliest investigations demonstrated the high potential of this approach, already emphasising the role of a green amphibole: green hornblende. They led to the distinction between the "Upper loess" (probably Weischselian) and the "Lower loess" (probably pre-Weichselian) notably based on their high or low green hornblende abundance, respectively.

During the following decades, several scientists carried on with this topic in NW Europe, either in Belgium, NW France, The Netherlands or Germany (e.g., Lautridou, 1968; Pissart et al., 1970; Juvigné, 1978, 1979, 1985; Thieme et al., 1981; Balescu and Haesaerts, 1984; Mees and Meijs, 1984; Meijs, 1985; Balescu, 1986a, b, 1988; Janus, 1988; Semitita, 1997; Henze, 1998; Juvigné et al., 1999; Meijs, 2002; Römer et al., 2016). From a simple scheme, distinguishing the "Upper loess" from the "Lower loess", the complexity increased, especially for Middle Pleistocene.

This paper aims at presenting a review of the use of heavy minerals for stratigraphic studies in loess sequences from Belgium, focusing on the important role of green amphiboles. The main goal is to provide the first synthesis of the data available so far for Middle Belgium in the framework of the recently reviewed loess lithostratigraphic sequence (Haesaerts et al., 2011a), in order to give for the first time a common detailed lithostratigraphic framework to the available dataset. An additional objective is to document the detailed mineralogical composition of these green amphiboles based on new microprobe analyses.

2. Green amphiboles as a stratigraphic tool: history of researches

In most of the papers, the green amphiboles (GA) were described as green hornblende using the optical microscope. In chapter 3, we will criticize this specific point. In the present chapter, the use of the term "green hornblende" refers to the terminology employed by the cited authors.

2.1. "Lower loess" vs. "upper loess"

The importance of GA in loess sequences has been recognized since the earliest stratigraphic studies using heavy minerals. Van Doormael (1945) showed that the "Lower loess" (probably pre-Weichselian) contains less GA and garnet and more zircon and rutile than the "Upper loess" (probably Weichselian) in Dutch Limburg (Table 1). In Belgium, Gullentops (1954) demonstrated a similar trend at Rocourt (Fig. 1) and suggested to use the ratio "green hornblende/epidote" as a stratigraphic marker. At Rocourt, this ratio is close to 1/1 in the Late Pleistocene loess and about 1/3 in older loess. In NW France, Lautridou (1968) also found a greater concentration of GA in Late Pleistocene than in Middle Pleistocene loess, later ascribed by Paepe and Sommé (1970) to the Weichselian and Saalian, respectively.

Significant progress was made in the 1970s thanks to the work of Juvigné (1976, 1978). He systematically studied the distribution of different transparent heavy minerals from seven distinct loess sequences in Hainaut and Hesbaye. He also took into account contamination of the loess with heavy minerals from the geological background through mineralogical and grain-size analysis. His results suggested that the ratio (green hornblende + garnet)/(zircon + rutile) (= Mineralogical index: MI) was the most discriminating. Juvigné (1978) showed that the Weichselian loess, with MI values between 0.56 and 4.1, can be easily distinguished from pre-Weichselian loess, which exhibits MI values lower than 0.6.

At this stage of research, the low MI values recorded in the lower part of the Weichselian sequence were interpreted as a result from the mixing with older loess, poor in green hornblende and garnet (Gullentops, 1954, p. 161; Juvigné, 1978, p. 80).

2.2. Late Saalian loess rich in green amphibole

In the following years, this distinction between Weichselian loess rich in GA and pre-Weichselian loess poor in GA was also documented by other researchers in Belgium (Mees and Meijs, 1984), The Netherlands (Meijs, 1985), France (Lautridou, 1985) and Germany (Thieme et al., 1981; Henze, 1998).