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Dynamics and sources of last glacial aeolian deposition in southwest France derived from dune patterns, grain-size gradients and geochemistry, and reconstruction of efficient wind directions

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ABSTRACT

Dune pattern, grain-size gradients and geochemistry were used to investigate the sources and dynamics of aeolian deposition during the last glacial in southwest France. The coversands form widespread fields of low-amplitude ridges (zibars), whereas Younger Dryas parabolic dunes mainly concentrate in corridors and along rivers. Spatial modelling of grain-size gradients combined with geochemical analysis points to a genetic relationship between coversands and loess, the latter resulting primarily from dust produced by aeolian abrasion of the coversands. The alluvium of the Garonne river provided also significant amounts of dust at a more local scale. The geochemical composition of loess shows much lower scattering than that of coversands, due to stronger homogenisation during transport in the atmosphere. Overall, sandy loess and loess deposits decrease in thickness away from the coversands. Dune orientation and grain-size gradients suggest that the efficient winds blew respectively from the W to the NW during the glacial, and the W-SW during the Younger Dryas. A comparison between the wind directions derived from the proxy data and those provided by palaeoclimatic simulations suggests a change of the main transport season. Ground surface conditions and their evolution throughout the year, i.e. the length of the season with snow and frozen or moist topsoil, and the seasonal distribution of wind speeds able to cause deflation are thought to have been the main factors that controlled the transport season in the study area.

1. Introduction

In the Aquitaine basin (Southwest France), Pleistocene coversands spread over a surface of approximately 12,000 km^2, and are bordered on their eastern and southern margins by a large loess belt. The stratigraphy of aeolian deposits has been the focus of recent studies and a large set of ^{14}C, ESR and OSL ages is available both for coversands and loess (Bertran et al., 2009, 2011; Hernandez et al., 2012; Sitzia et al., 2015). Mapping of aeolian deposits has also been the subject of many attempts. The conventional field approach allowed precise delineation of the coversands since the 60's (Enjalbert, 1960; Legigan, 1979), but the loess deposits were always omitted in the maps, and are still lacking on the current 1/50,000 geological map of France (*infoterre.brgm.fr*). Bertran et al. (2011) showed the potential of coupling field mapping and the use of soil databases designed for agricultural purposes, in which physico-chemical analyses of topsoil samples are listed. A first map of loess and transitional facies was produced using the

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online BDAT database (www.gissol.fr) where the sand, silt and clay content of topsoil samples are averaged at the scale of administrative units of an area of tens of square kilometers. Since then, the Land Use and Cover Area frame Statistical survey (LUCAS) database on topsoil properties in Europe has been made available and was used for further mapping of aeolian deposits (Bertran et al., 2016). The points which satisfy the grain-size criteria of coversands and loess were extracted from the rasters of predicted soil texture established by kriging of the LUCAS data by Ballabio et al. (2016). These rasters have a resolution of 500 m. A comparison with previous maps showed a good fit in most of the tested areas in Europe (Bertran et al., 2016). Improvement of the French database (Donesol, http://acklins.orleans.inra.fr/outil/donesol) and access to raw data makes it now possible to investigate more in detail the aeolian deposits at a regional scale, since more refined information on grain-size composition and on loess thickness is available.

Pioneer mineralogical studies have been performed by Klingebiel (1966) and Legigan (1979). They have suggested that the sources of the coversands were mostly Mio-Pliocene alluvial and deltaic sands that crop out on the continental plateau. However, these studies remain crude, and the possible contribution of wind-blown particles derived from the alluvium fed by the surrounding ranges (Massif Central, Pyrenees) was hardly detectable using heavy mineral analyses alone. The provenance of the particles and the transport paths remain, therefore, to be documented in detail. Grain-size gradients (Lautridou, 1985; Ruegg, 1983; Liu, 1988), loess thickness (Frazee et al., 1970; Mason, 2001), and the mineralogical and chemical composition of the deposits (Muhs et al., 2008; Stevens et al., 2010; Rousseau et al., 2014) have proved to be efficient tools for reconstructing the transport paths at a regional scale and for identifying the main factors involved in deposition. Together with dune orientation, these data give insight into past atmospheric circulation and have been widely used for reconstructing wind directions during the Last Glacial in Europe (Poser, 1950; Maarleveld, 1960; Léger, 1990; Isarin et al., 1997; Zeeberg, 1998; Van Huissteden et al., 2001; Renssen et al., 2007).

The aim of this paper is to combined geomorphological, sedimentological and geochemical approaches to better understand the origin and dynamics of the aeolian deposition in southwest France. Then, the reconstructed wind regimes during the Last Glacial in the study area are compared with previous climatic simulations (Sima et al., 2009, 2013), in an attempt to identify the period of the year favourable to dust activity for different climate patterns.

2. Geological setting

Since the beginning of the Middle Pleistocene, the centre of the Aquitaine basin was quite similar to its current configuration and corresponded to a sand plain almost lacking relief and gently sloping toward the Atlantic Ocean. Such a context, unparalleled along the French coast, favoured the accumulation and preservation of aeolian deposits throughout the glacial phases of the Pleistocene (Bertran et al., 2011; Sitzia et al., 2015).

At the basin scale, the following geomorphological units have been distinguished (Fig. 1B): (1) ventifact pavements, present mainly in the northern part of the basin at the surface of the plateau alluvium on both sides of the Garonne River (Plateau Girondin and Blayais); (2) the coversands ("Sable des Landes Formation" *sensu* Sitzia et al., 2015), limited by the Garonne river to the east and the north, the Adour river to the south, and the Atlantic Ocean to the west; (3) a large loess belt mainly developed to the east and the south of the coversands.

Recent works allowed reappraisal of the regional chronostratigraphy of sand and loess deposits (Bertran et al., 2009, 2011; Sitzia et al., 2015). Three main phases of coversand

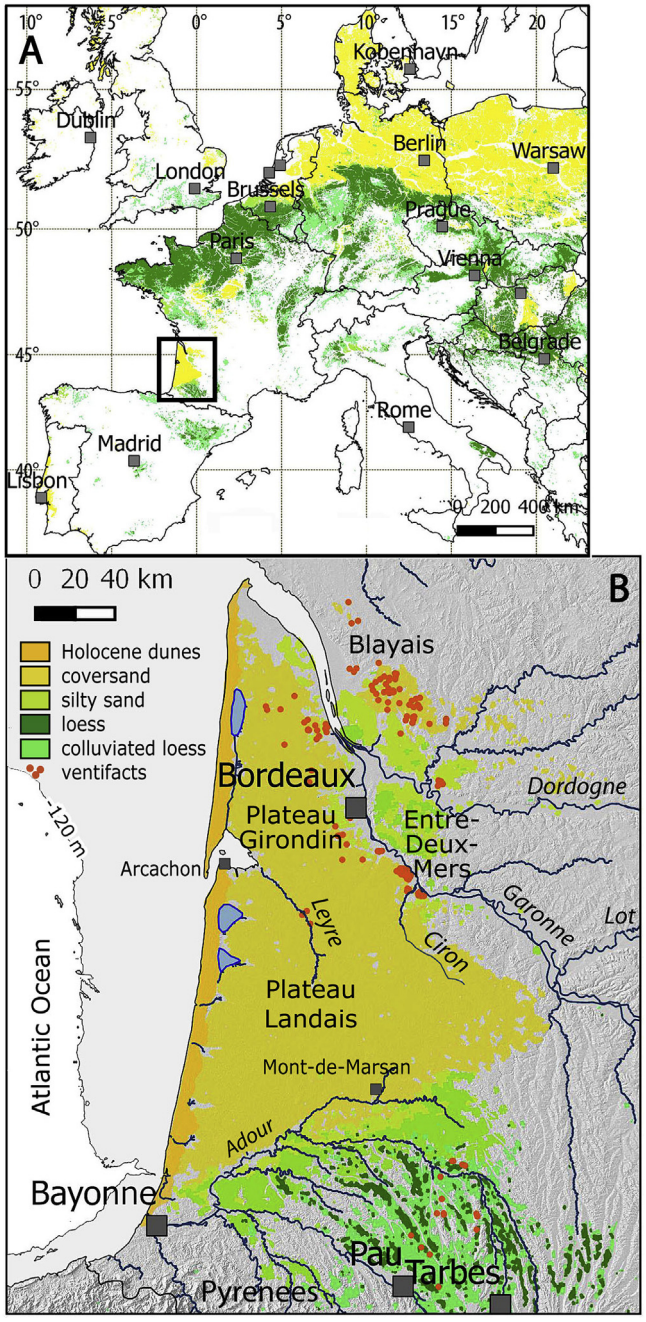

Fig. 1. European aeolian deposits. A – General map from Bertran et al. (2016) and location of the study area; B – Close-up view of southwest France. The distribution of ventifacts is from Bertran et al. (2011).

accumulation were identified throughout the Last Glacial (Sitzia et al., 2015): (1) Marine Isotopic Stage (MIS) 4–3 (64–32 ka), characterized by predominant wet sandsheet accumulation; (2) MIS 2 and the beginning of MIS 1 (Greenland Interstadial 1e) (25–14 ka), associated with the development of dry sandsheets and coincident with the maximum expansion of the Landes desert; (3) Younger Dryas (YD, Greenland Stadial 1), marked by the development of parabolic dune fields. Parabolic and dome dunes dating back to the 14th-19th centuries have also been documented and probably reflect local dune reactivation due to increased human impact on the vegetal cover during the Little Ice Age (Bertran et al., 2011).