



HAL
open science

From natural to cultural mires during the last 15 ka years: An integrated approach comparing 14C ages on basal peat layers with geomorphological, palaeoecological and archaeological data (Eastern Massif Central, France)

André-Marie Dendievel, Isabelle Jouffroy-Bapicot, Jacqueline Argant, Antoine Scholtès, Arnaud Tourman, Jacques-Louis de Beaulieu, Hervé Cubizolle

► **To cite this version:**

André-Marie Dendievel, Isabelle Jouffroy-Bapicot, Jacqueline Argant, Antoine Scholtès, Arnaud Tourman, et al.. From natural to cultural mires during the last 15 ka years: An integrated approach comparing 14C ages on basal peat layers with geomorphological, palaeoecological and archaeological data (Eastern Massif Central, France). *Quaternary Science Reviews*, 2020, 233, pp.106219. 10.1016/j.quascirev.2020.106219 . hal-02531966

HAL Id: hal-02531966

<https://amu.hal.science/hal-02531966>

Submitted on 4 Apr 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

From natural to cultural mires during the last 15 ka years: An integrated approach comparing ¹⁴C ages on basal peat layers with geomorphological, palaeoecological and archaeological data (Eastern Massif Central, France)

André-Marie Dendievel ^{a,*}, Isabelle Jouffroy-Bapicot ^b, Jacqueline Argant ^c, Antoine Scholtès ^d, Arnaud Tourman ^{d,e}, Jacques-Louis de Beaulieu ^f, Hervé Cubizolle ^d

^a Univ. Lyon, ENTPE, UMR CNRS 5023 LEHNA-IPE, 3 Rue Maurice Audin, F-69518, Vaulx-en-Velin Cedex, France

^b Université de Bourgogne-Franche-Comté, UMR CNRS 6249 Chrono-Environnement, 16 Route de Gray, F-25030, Besançon Cedex, France

^c Aix-Marseille Université, UMR CNRS 7269 LAMPEA, 5 Rue Du Château de l'Horloge, F-13094, Aix-en-Provence, France

^d Univ. Lyon, Université Jean Monnet, UMR CNRS 5600 EVS-ISTHME, 6 Rue Basse des Rives, F-42023, Saint-Etienne Cedex, France

^e Géo Sol'eau Environnement, 21 Rue Brossard, F-42000, Saint-Etienne, France

^f Aix-Marseille Université, UMR CNRS 7263 IMBE, Campus Étoile, Faculté des Sciences St-Jérôme, Case 421, Avenue Escadrille Normandie Niémen, F-13397, Marseille Cedex 20, France

ARTICLE INFO

Article history:

Received 23 November 2019

Received in revised form

12 February 2020

Accepted 12 February 2020

Available online 27 February 2020

Keywords:

Spatio-temporal distribution of mires

Peat initiation

Climate changes

Human impact

Radiocarbon dataset

Vegetation dynamic synthesis

ABSTRACT

This paper studies mire initiation modalities from the Late-Glacial to the Holocene by comparing radiocarbon ages on basal peat layers (112 sites from the Eastern French Massif Central – EFMC) with long-term land cover changes. We developed a semi-quantitative method based on the degree of openness and on Anthropogenic Impact Factors (AIF scores) from palaeoecological data (mire and lake records). Archaeological information was also considered to evaluate human impact. We compared regional mire development trends with datasets from Northern Europe, Siberia, Alaska and Canada, and with global CH₄ emission. Heterogenous cases of mire initiation were highlighted during the last 15 ka years in the EMFC. From 15 to 11.7 ka cal. BP, some mires and histic horizons occurred, although further research is needed to better understand these peat accumulation phases. Related to the Early Holocene warming, a mire generation established by terrestrialization, in the southern EFMC where geomorphology favoured fens. Bogs also formed by paludification in the whole area between 10 and 7 ka cal. BP. Then, various cases of mire initiation were found from 4.4 to 2.4 ka cal. BP. The high number of mires established since 2.4 ka cal. BP could be related to major anthropogenic changes, indirectly favouring fens (in former ponds for instance) or small bogs (at the back of roads, walls or in abandoned drainage systems). This last generation was typical of Western European mountains and implied that moderate human impact may also produce socio-ecosystems with high ecological value.

1. Introduction

Within a global context of mire loss all over the world, the need to understand the way of development of these ecosystems has

become a key issue for nature preservation. Indeed, mainly due to anthropogenic actions affecting water tables (drainage, intensive livestock grazing, conifer plantations, peat extraction, etc.), Earth would have lost almost 16% of peat surfaces, of which about 50% in Europe since the end of the 19th century AD (Joosten et al., 2017; Joosten and Clarke, 2002). This is also a major concern in the Eastern French Massif Central (EFMC), where 20% of the primary peat surfaces have disappeared, and 54% are severely degraded (Cubizolle, 2019; Manneville et al., 2006). Mires could offer sustainable resources and “ecosystem services” when well managed for biodiversity, water resource, and have a carbon sink role (Laine

* Corresponding author.

E-mail addresses: andre-marie.dendievel@entpe.fr (A.-M. Dendievel), Isabelle.Jouffroy@univ-fcomte.fr (I. Jouffroy-Bapicot), j.argant@wanadoo.fr (J. Argant), antoine.scholtes@laposte.net (A. Scholtès), arnaud.tourman@geo-soleau.fr (A. Tourman), jacques-louis.debeaulieu@orange.fr (J.-L. Beaulieu), herve.cubizolle@univ-st-etienne.fr (H. Cubizolle).

et al., 1996; Renou-Wilson et al., 2019). On mires, water saturation generates anaerobic conditions which reduced the degradation of organic matter and contribute to preserve organic matter remains over time (pollen, spores, plant macrofossils, beetles, etc.). The organic-rich stratigraphies from mires constitute a heritage value and those “natural archives” could record evidence of environmental and landscape changes from the past to present (Barber, 1993; Bell and Walker, 2014; Martini et al., 2006).

In middle-mountain areas, favourable humid and fresh conditions are needed to initiate peat accumulation (rainfall >900 mm year⁻¹, and mean annual temperatures <9 °C, according to Cubizolle and Thébaud, 2014), although peat initiation could be triggered by local changes in hydrological conditions. For instance, natural geological barriers (lava flows, landslides, dune formation) can impeded drainage, lead to a water balance tipping point, and thus mires can be formed (Andriessse, 1988; Meurisse-Fort, 2008). In addition, human actions could be directly or indirectly involved, sometimes since the Prehistory, specifically where activities were concentrated and included fires, dam or road building (Bussi eres et al., 1996; Caseldine and Hatton, 1993; Cubizolle et al., 2012; Moore, 1988). Worldwide, climatic and human-induced peat initiations are suitable thanks to large radiocarbon datasets based on the dating of mire basal layers, i.e. when peat initiation began (e.g. Gallego-Sala et al., 2015; Gorham et al., 2007; Korhola et al., 2010; MacDonald et al., 2006; Pontevedra-Pombal et al., 2017; Ruppel et al., 2013). In the Northern Hemisphere, two major peat inception steps are known from 10 to 8 ka cal. BP, and during the last 4.2 ka cal. BP, however diverse hypotheses are assumed to explain these phenomena (i.e. moisture and temperature changes due to climate or human forcing) and sometimes overlap each other (Cubizolle et al., 2012; Hughes and Barber, 2003; Jones and Yu, 2010; Korhola et al., 2010; MacDonald et al., 2006; Ruppel et al., 2013). To go further on these questions, one key challenge is to improve radiocarbon dating approaches by the integration of land cover changes, land use, and archaeological data, to discuss ecosystem trajectories in the course of human or climate forcing from local to larger scales (Stephens and ArchaeoGLOBE Project authors, 2019; Whitehouse et al., 2018).

In this paper, we propose to study a corpus of 112 mires on the Eastern French Massif Central (EFMC) where basal layers were dated by radiocarbon (Fig. 1; see also. Dendievel et al., 2020). To supplement previous studies performed on some parts of the Eastern French Massif Central (Cubizolle et al., 2013, 2012; Cubizolle and Argant, 2006), our research aims at developing a spatio-temporal analysis of mire initiation dynamics on a north-south geographical transect covering more than 350 km, from the Morvan (Burgundy) to the M ezenc Massif (Ard eche Uplands). The most original aspect of this work is devoted to the statistical integration of land cover and land use data thanks to a semi-subjective method using ranked scores (from 0 to 8 points) based on the degree of openness and on the occurrence of direct or indirect anthropogenic indicators (Jouffroy-Bapicot et al., 2013). We also integrated archaeological data syntheses in order to discuss evidence of anthropogenic forcing on peat initiation, linked to water or landscape management for instance. This integrated approach is performed for the first time at the scale of the whole EFMC in order to interpret and discuss past and recent human influence on regional mire ecosystems.

2. Regional settings

2.1. Environmental synthesis

The Eastern French Massif Central (EFMC) is part of a geographical region, which is more than 350 km long and ca. 70 km

width (Fig. 1). Our research focuses on the mires located, from north to south, (i) on the Morvan Massif, (ii) on the Bois Noirs and Madeleine Mountains, (iii) on the Livradois-Forez Mountains, (iv) on the Pilat Massif, (v) on the M ezenc-Meygal Massif, and (vi) on the Dev es Plateau (Figs. 1 and 2). On the EFMC, the elevation generally increases from north to south: lower altitudes are found on the Morvan Massif (500–900 m a.s.l.), while higher altitudes occur on the Livradois-Forez Mountains (650–1634 m a.s.l.) and, even more, at south, on the M ezenc-Meygal Massif (800–1753 m a.s.l.). Zone (vi), i.e. the Dev es area, which is located on the south-western part of the studied area, is a high plateau comprised between 800 and 1421 m a.s.l. (Fig. 1). As regards climate settings, this area is characterized by an oceanic to mountainous climate with strong seasonal temperature variations, which are climaxing at south (Mean Monthly Temp. M ezenc = 5 ± 9 °C versus Mean Monthly Temp. Morvan = 9 ± 8 °C). Rainfall increases at higher latitudes, but since latitudes and relief are negatively correlated in the EFMC (Figs. 1 and 2), annual rainfall ranges from 900 to 1500 mm year⁻¹ in the whole area (Antonetti et al., 2006). These environmental settings constitute an essential basis for the establishment of mires by paludification (Fig. 2), in particular for ombrotrophic mires (Fig. 2-c), mostly formed between 900 and 1450 m a.s.l. in the EFMC (Cubizolle and Th ebaud, 2014).

From a geological point of view, the EFMC is characterized by a high diversity of Middle Devonian to Late Carboniferous volcano-sedimentary and granite formations (Faure et al., 2009). These formations are found in the Morvan Massif (ca. 370–330 Ma – million years ago), in the Bois Noirs and Madeleine Mountains (330–320 Ma), while the “Velay Dome” (ca. 300 Ma) is the main basement of the Livradois-Forez, Dev es and M ezenc-Meygal areas. Crustal melting and rifting created a NW-SE fault network and led to the bedrock uplift, which is found from 500 to 1634 m (i.e. Pierre-sur-Haute peak, Forez), nowadays. Multiple volcanic episodes occurred during Miocene and Pliocene epochs (Mergoill and Boivin, 1993; Nehlig et al., 2003): in the Forez (20–13 Ma), Meygal (14–9 Ma), M ezenc (11–5.7 Ma) and Dev es zones (3.5–1 Ma). Basalt, phonolite and trachyte lavas cover the granite basement at some places and culminates at Mount M ezenc (1753 m a.s.l.; Fig. 1). A last volcanic period created numerous maar craters (hydro-magmatic stage) and strombolian cones (0.75–0.02 Ma) in both Dev es and M ezenc-Meygal Plateaux (Defive et al., 2011; Nomade et al., 2014; Sascio, 2015). Finally, small glaciers and late Pleistocene periglacial processes (mostly during the Last Glacial Maximum) have left typical moraines and blockstreams in the highest mountains (Forez and M ezenc Massif).

This geological background and the subsequent geomorphological evolutions were significant for the development of spring and slope mires (topogenous and soligenous ones) by paludification because they controlled the volume of water tables, the presence of springs along faults or between rocks, the slopes, and thus the runoff speediness (Fig. 2-a-b). In addition to climate, these contexts were also very important for the establishment of raised bogs, found from the Morvan to the Pilat Massif (Fig. 2-c; Th ebaud et al., 2003). Such mires are mainly built by *Sphagnum* accumulations but also include basal wooden contexts with birches (*Betula* sp.), alders (*Alnus glutinosa* L. Gaertn.) or willows (*Salix* sp.). Current surfaces are dominated by heathlands of *Calluna vulgaris* (L.) Hull or by Poaceae, incl. *Molinia caerulea* (L.) Moench, mainly linked to fire regime and agro-pastoral activities. Fluvial mires are scarce because river valleys are generally narrow and steep in the EFMC. Pleistocene eruptions and glaciations were also decisive for peat inception in the southern areas (i.e. Dev es and M ezenc-Meygal Plateaux) where limnogenous mires can easily develop by the terrestrialization of maar crater lakes (Ribains Marsh, Narces of Chaudeyrolles, etc.) and on former periglacial lakes established on blockstream

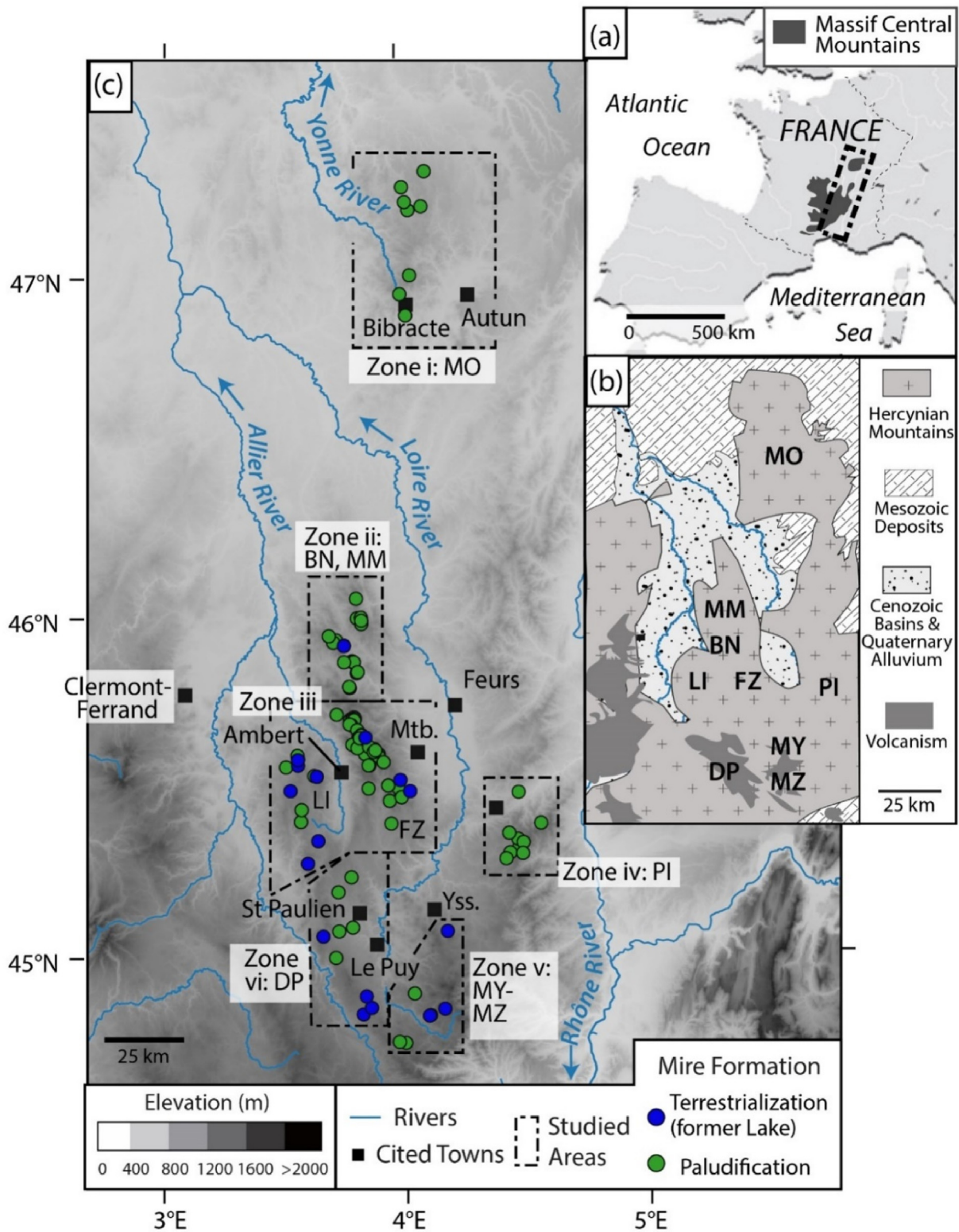


Fig. 1. Map of the mires established during the last 15 ka cal. BP on the Eastern French Massif Central (EFMC). a) Location of the Massif Central Mountains in Western Europe. The EFMC is represented by a square. b) Regional geology. c) Topographical situation of the studied sites of the EFMC. Zones i to vi refer to the natural regions cited in the text: Zone i = Morvan Massif (MO), Zone ii = Bois Noirs (BN) and Madeleine Mountains (MM), Zone iii = Livradois (LI) and Forez (FZ) Mountains, Zone iv = Pilat Massif (PI), Zone v = Meygal (MY) and Mézenc (MZ) Massif, Zone vi = Devès Plateau (DP). Abridged names of cited towns: Mtbr. = Montbrison; Yss. = Yssingeaux.

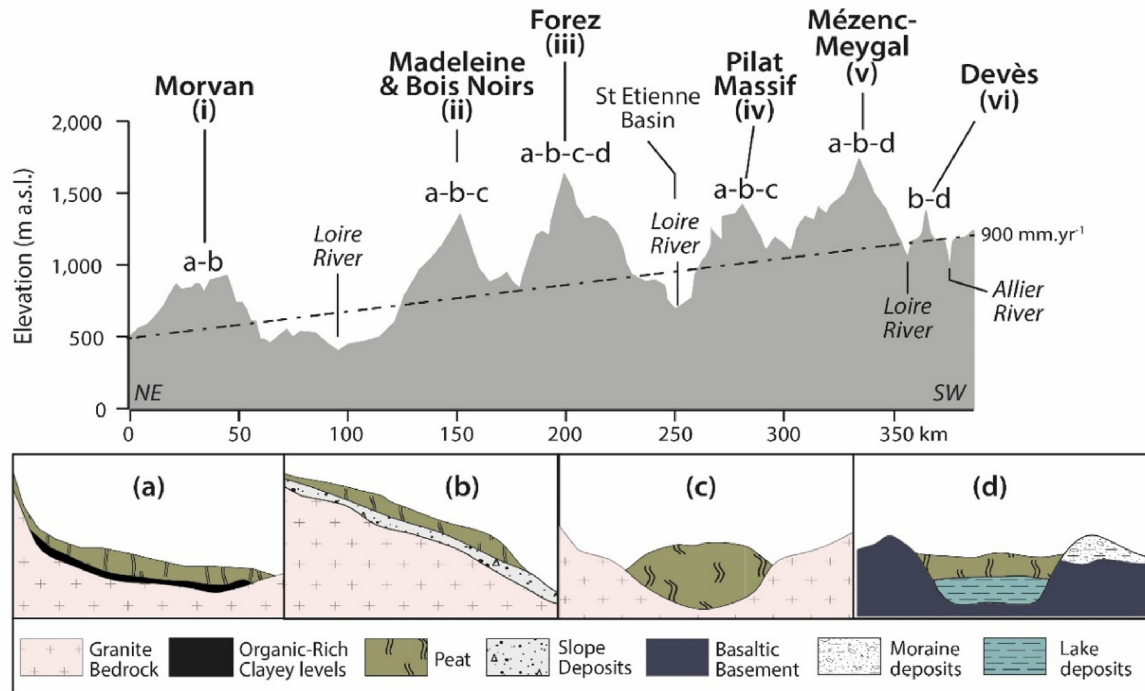


Fig. 2. Distribution of mire types according to the elevation on a north-east (NE)/south-west (SW) transect (EFMC, France). Letters i to vi refer to the natural regions cited in this paper (see also Fig. 1). The dashed line symbolises a mean rainfall of 900 mm/year. Mire types follow the topology established by Cubizolle et al. (2004) and Cubizolle and Thébaud (2014). a) Topogenous mires, b) soligenous mires, c) ombrogenous mires, d) limnogenous mires in a volcanic or periglacial context.

areas or behind moraine-dams (e.g. La Narce du Béage, and Gourdes-Aillères fens). Furthermore, on these sites, pioneering mire phases, sometimes known as “transiting mires”, also offer a very high biodiversity including underwater, floating, emergent and typical mire plants (for a case study, see Dendievel et al., 2019).

2.2. Archaeological background

Giving an overview of past occupations and site densities over time is not easy especially because regions and periods are not documented with the same accuracy in the EFMC. Here, we compiled information from recent syntheses (Cubizolle et al., 2012; Dendievel, 2017; Dendievel et al., 2019; Jouffroy-Bapicot et al., 2013; Scholtès, PhD in preparation).

Neolithic presence is mainly supported by isolated findings of silex blades, arrow heads, ground-stone axes and megaliths, although well documented sites are scarce (Rialland and Letterlé, 2013; Surmély et al., 2001). Early Neolithic occupations have been demonstrated by archaeology and palaeoecology in the southern zone, i.e. Mézenc Massif, around 7.5–6.8 ka cal. BP (Daugas and Raynal, 1989; Dendievel et al., 2019). In the northern zone, human impacts occurred most certainly during the Early Neolithic, but dwellings are mainly known since the Middle Neolithic (6.8–5.8 ka cal. BP), especially on the Mont-Beuvray (Jouffroy-Bapicot et al., 2013; Martineau et al., 2011) and in the Forez floodplain (Georges et al., 2004). Then, archaeological sites spread over the EFMC during Middle to Late and Recent Neolithic (incl. bell-beaker culture). For the Bronze Age (4.4–2.8 ka cal. BP), scattered discoveries – copper or bronze axes and daggers – are dominant, while numerous fortified sites are documented for the Final Bronze Age (3.3–2.8 ka cal. BP) in the whole region (Delrieu et al., 2015; Gabilot et al., 2016). For these periods, pathways and relationships between low-altitude (Loire, Allier, Arroux and Yonne floodplains) and mid-mountain sites for agro-pastoral purposes,

lithic and wood resources need to be considered (Georges et al., 2004; Martineau et al., 2011; Milcent and Mennessier-Jouannet, 2007).

During the Iron Age and the Roman period, the number of sites increased in the floodplains, but also in the uplands (Büntgen, 2008; Dendievel, 2017; Fassion, 2013; Kurzaj, 2012; Scholtès, 2019; Simonnet, 1984). At the end of the 1st and of the 2nd Iron Age (2.6–2.4 ka cal. BP and 2.1–2.0 ka cal. BP, respectively), significant fortified sites established on the eastern slopes of the EFMC (Delrieu et al., 2012; Kurzaj and Voruz, 2017). One may cite the Bibracte *oppidum* (Morvan Massif) heading one of the greatest and richest Gallic territories documented by roman texts and archaeology (Guichard, 2013, see also: www.bibracte.fr). After the Roman conquest, former hillforts were progressively abandoned and people usually moved to open-plateau or floodplain cities such as Autun (Morvan), Ambert (Livradois), Usson, Feurs and Moingt (Forez), Yssingeaux (Meygal), Saint-Paulien and then Le Puy-en-Velay (NE Devès Plateau). During this period, we assumed that economic activities were supported by a road network, partly preserved nowadays, connecting the uplands to the floodplains (“via Bolena”, “Pal road”, “Chassenard/Digoin bridges”, etc.) and used until the Modern Period. Examples of worship areas (*fanum*) and vast private domains (*villae*), sometimes equipped with baths, are well known in the EFMC (Fassion et al., 2011; Nouvel et al., 2009; Simonnet, 1984). In spite of few archaeological evidence, early water management is highlighted by the catchment of water from the Pilat to the Monts d’Or to supply the city of Lyon (*Lugdunum*) and by small reservoirs devoted to agro-pastoral purposes on the uplands. During the Late Antiquity and the Early Middle Ages, a lower population density is deduced from fewer archaeological sites, but small towns and some large domains persisted while land use certainly changed (Catteddu, 2009; Dendievel et al., 2019; Phalip, 2002).

From 1.3 to 0.5 ka cal. BP (Middle Ages), a significant increase of

archaeological sites is recorded by excavations and medieval texts with stages of castle building (Laffont, 2009) and the establishment of monastic orders (Benedictines, Cistercians, Carthusians: Bépoix and Richard, 2019; Bouvard, 2016). Agriculture and livestock breeding developed from the uplands to the eastern slopes (Bréchon, 1998; Scholtès, 2015). This period is associated to important water management: weirs, dams and ponds formed numerous small reservoirs used for various activities, while the water was delivered by diversion to sawmills or to roller-type mills devoted to floor or oil production (Bouvard, 2011; Véron, 2017). Modern Times (0.5–0.1 ka cal. BP) correspond to a demographic maximum for the EFMC uplands. The landscape was bare and highly cultivated. Moreover, a specialization in animal breeding led to intensive grazing and wetland drainage. The landscape was also managed for firewood production, provided to Paris by the means of fluvial transport (Morvan Massif: Benoit et al., 2004; Poux et al., 2011), or for the delivery of softwood lumber products to the Navy Shipyards of Toulon (Mézenec Massif: Bartoli and Boissier, 2018).

3. Methods

3.1. Sampling and dating basal layers on mires

In order to understand how local morphology could contribute to peat accumulation, a geomorphological approach was performed on the sites presented in this paper (Fig. 1). Usually, during field survey, topo-stratigraphical profiles were based on penetrometer transects (French, 2012). This operation was achieved at varied intervals following the topography complexity (Cubizolle et al., 2012). Each penetrometer-test was located by a Total Station coupled to a hand-handled GPS (e.g. Trimble GEOXT; infra-meter resolution) or directly with a Differential GPS (Stonex or Trimble devices). Subsequently, several cores were generally extracted by using a Russian manual peat corer (Belokopytov and Beresnevich, 1955), or motorised percussion corers (e.g. Makita HM1800) in order to reach basal peat. Cores were then conserved for palaeoecological studies.

The radiocarbon dating of basal peat layers might be difficult because the interface between peat and the underlying organo-mineral layers could be sharp or gradual, depending on local settings (Charman, 2002; Cubizolle et al., 2007). Thus, the presence of basal peat layers was supported by: (i) an accurate description of the peat stratigraphy according to the degree of peat decomposition (Von Post scale) and to the fibric texture, (ii) a consensus-based organic content >30–35% (Joosten et al., 2017), and (iii) by typical micro- or macrofossil assemblages such as Bryophyta fragments and spores (incl. *Sphagnum*), mire trees or shrubs (birches, alders) and herbs such as sedges (Cubizolle, 2019; Cubizolle et al., 2007, 2012). According to these characteristics, we distinguished two types of peat formation process and associated mire-types: terrestrialization of former lakes for minerotrophic mires (fens), paludification for ombrotrophic mires (bogs). For paludification cases, we especially considered the absence of lacustrine, gyttja or clayey deposits and a direct initiation of peat on superficial formations or on the geological basement.

Both AMS and conventional (conv.) radiocarbon dating were performed on the 112 studied sites, according to the quantity of available organic matter: small samples or selected macrofossils for AMS and bulk peat for conv. dating. The dataset is available online at <https://doi.pangaea.de/10.1594/PANGAEA.911851> (Dendievel et al., 2020). Beyond these technical differences, peat initiation is a long-term process which could take several centuries. Moreover, Holmquist et al. (2016) recently published a comparison between dates on bulk peat and on macrofossils from mire basal layers and found no significant difference. All radiocarbon measurements (for

labs details, please refer to Dendievel et al., 2020) were calibrated CALIB7.0 and the “IntCal13” curve; ages are expressed in thousand years before 1950 (ka cal. BP; 2σ , i.e. 95 %) (Reimer et al., 2013; Stuiver and Reimer, 1993). On some sites, the best interval for peat initiation was calculated by integrated Lithological and Palaeoecological Syntheses (LPS) implying a detailed pollen, macrofossil, diatoms, geomorphological and radiocarbon study at: La Narce du Béage (Dendievel et al., 2019), La Sauvetat, Le Péchay, and Marais de Limagne (Beaulieu et al., 1984); Ribains, Collanges, Freycenet, and La Gimberte (Serieysson et al., 2012; Tourman, 2007). Information was also obtained from textual archives (ARCH) for very recent mires (75–15 years cal. BP; i.e. AD 1875–1935).

3.2. Characterization of anthropogenic environmental impacts

Numerous palaeoecological works, especially pollen studies, were done in the EFMC since the 1940s with various extraction, counting and representation methods (Beaulieu et al., 1984; Coûteaux, 1984; Cubizolle et al., 2014; Dubois, 1946; Florschütz, 1955; Lemée, 1955, 1939). It is very difficult (or impossible) to accurately compare all of these data. For that reason, we based our synthesis on 26 palaeoecological works performed with modern standards, and associated with regular radiocarbon dating: Jouffroy-Bapicot et al. (2013) on the Morvan Massif, Argant and Cubizolle (2005) and Cubizolle et al. (2014) for the Livradois-Forez, Bois Noirs, Madeleine, and Pilat Mountains, Coûteaux (1984), Dendievel (2017) and Dendievel et al. (2019) for the Mézenec Massif, and Beaulieu et al. (1988, 1984) for the Devès Plateau. The sampling resolution varied from 1 to 10 cm according to peat accumulation or compaction on each site.

Palynological preparation followed standard techniques including organic matter, carbonates and silica removal (by using KOH or NaOH, HCl and HF acid, respectively), before a density segregation and a filtration of pollen grains (Faegri and Iversen, 1989; Moore et al., 1991) on the Morvan and the Béage Plateau (Dendievel et al., 2019; Jouffroy-Bapicot et al., 2013), while a concentration in a dense solution was performed on earlier studies from the Devès Plateau (Goery and Beaulieu, 1979) and on the Pilat, Livradois, Forez, Bois Noirs (Argant, 1990). After microscopic observations, the identification was achieved with literature references or keys (Beug, 2004; Reille, 1999) and by comparison with modern pollen collections (from the Chrono-Environment Laboratory of Besançon, the ARPA association, the Botanical Institute of the Innsbruck University, and the Aix-Marseille University). For all sites, at least 300 grains and spores per slide were counted and total pollen percentages were based on the sum of vascular plants, excluding wetland or aquatic taxa (e.g. Cyperaceae, *Sphagnum*). Micro-charcoals and Non-Pollen Palynomorphs, incl. microscopic fungal remains of erosion (*Glomus*) or dung indicators (*Podospora*, *Sordaria*-type, *Sporormiella*, etc.), were also taken into account, when available (Morvan and Mézenec Massif), to precise pastoral impact phases on wetlands (Cugny et al., 2010; Dietre et al., 2012; Van Geel and Aptroot, 2006).

Macrofossil studies were also performed on the Forez (region iii: Fasson, 2013) and on the Mézenec Massif (region v: Dendievel, 2017). Based on macroscopic botanical remains (0.2–2 mm), local wetland vegetation and erosion changes were described. After volume measurement, macrofossils were sieved under a trickle of water, adding a deflocculant solution (KOH, 5%), if necessary. Plant remains (seeds, bud scales, leaves, wood fragments), zoological (beetles, fungi), and minerogenic particles (sand grains) were quantified, while the dominant remains were estimated (*Sphagnum* stems, Cyperaceae, and Ericaceae roots). Macrocharcoals were counted during routine analysis. Identifications were performed by using a stereomicroscope and based on reference collections and on

literature or photographic atlases (Berggren, 1981, 1969; Cappers et al., 2006; Lévesque et al., 1988; Mauquoy and van Geel, 2007).

Due to the relative data heterogeneity, the statistical comparison was based on the original and published palaeoecological zones established by stratigraphically constrained analyses (CONISS-type; Grimm, 1987). According to Jouffroy-Bapicot et al., (2013), we summed the palaeoecological information by attributing semi-quantitative scores to each zone based on (1) arboreal/non-arboreal pollen ratios that reflect the landscape openness, presence of (2) direct and (3) indirect anthropogenic indicators (Table 1; see Brun, 2011; Jouffroy-Bapicot et al., 2013). We also added macrofossil information, when available: macro-charcoal concentrations were included as a landscape openness indicator, *Euphorbia helioscopia*, *Molinia caerulea* and *Viola* sp. seeds, or *Juncus* seeds and capsules as direct or indirect anthropogenic indicators (Table S1). Guidelines for scoring followed Jouffroy-Bapicot et al. (2013) recommendations (Table 1): from 0 (absence) to 8 points (high impact) for direct indicators, while for openness and indirect indicators scores, the range was limited between 0 and 3 points because it also might derived from natural dynamics (climate change, natural fires, passage of wild animals, etc.). These data were tested by an ANOVA test (grouping by periods) followed by a Tukey HSD post-hoc analysis in R (R Core Team, 2018). Due to the study scale (28 cores along a 350 km long transect), we used a boxplot-type representation over time, but this approach most certainly smoothed individual site particularities (such as local interpretation of dominant taxa). In any case, such semi-subjective method was very useful to integrate a wide range of palaeoecological data produced during the last decades, in order to assess vegetation and land use changes at large scales.

4. Results and discussion: mires over the EFMC

4.1. Main trends of peat initiation

Based on an extended dataset of 112 radiocarbon dated sites (<https://doi.pangaea.de/10.1594/PANGAEA.911851>; Dendievel et al., 2020), we highlighted numerous cases of mire formed by paludification on the whole EFMC (95 sites = 85% of the dataset). Only few cases of terrestrialization are known, mainly located at south (17 cases = 15%). The best documented area is the Forez Massif (eastern part of zone iii – Fig. 1) where 47 sites were found (41% of the data), although the other regions are represented by 29 to 7 mires (Fig. 1).

Taking into account spatial and temporal trends of mire ecosystem developments, we confirmed the presence of two periods highly favourable to peat initiation in the EFMC (1) from 10 to 7 ka cal. BP and (2) from 4.2 to 0.5 ka cal. BP (Fig. 3-a). However, apart from this general schema, we assumed that some histic horizons developed between 15 and 11.7 ka cal. BP, at the end of the Late-Glacial period (from the Bølling-Allerød interstadial to the Younger Dryas). Contrary to high latitude areas, peat formation in the EFMC was mainly due to paludification on wet mineral soils occupied by former terrestrial and swamp vegetations (Kuhry and Turunen, 2006). According to the state of the art, there is no case

of “primary mire initiation” on newly formed mineral soil after crustal uplift or deglaciation, even if small ice caps and glaciers existed in the EFMC (Etlicher, 2005).

Then, peat initiation increased between 10 and 7 ka cal. BP (Fig. 3-a). At the beginning of this phase, from 10 to 9.2 ka cal. BP, paludification (bogs) and terrestrialization (fens) occurred together. The latter case generally happened in former maar craters and periglacial lakes on the southern part of the area, i.e. Devès Plateau and Mézenc Massif (Fig. 3-b). In such sites, the first peat layers were generally deposited underwater, after the sink of plant remains from floating peat mats for instance. A recent and detailed study achieved on the La Narce du Béage fen biostratigraphy (Upper Ardèche) described typical flora successions and a very high taxonomic diversity due to the coeval presence of underwater, floating, emergent taxa and terrestrial mire plants during the transition from the lake to the fen ecosystem (Dendievel et al., 2019, Dendievel et al., in press). This phase of regional peat initiation (EFMC) is consistent with other records from Canada to Norway, where numerous lakes filled, and evolved into limnogenous and minerogenic fens (Jones and Yu, 2010; MacDonald et al., 2006; Ruppel et al., 2013). The role of this first phase of peat initiation can also be discussed at a global level because fens are able to store organic carbon and release methane (CH₄). In concert with ice, snow cover, and permafrost melting, the fen formation process is known to be a high CH₄ producer (Beck et al., 2018; MacDonald et al., 2006). As shown by Fig. 3-a, the early period of fen formation in the EFMC was coeval with the highest methane (CH₄) concentrations recorded in Greenland ice cores (Beck et al., 2018; Brook et al., 1996). Then, peat initiation greatly increased at ca. 8.2 ± 0.9 ka cal. BP and was primarily driven by paludification process (Fig. 3-a). During this maximum, small to large ombrotrophic mires (bogs) established from the Morvan to the Ardèche Uplands: all EFMC areas are concerned. These developments of bogs, producing less CH₄, fitted with a major drop in the CH₄ emissions in the Northern Hemisphere (Beck et al., 2018). Interestingly, the maximum peak of mire initiation in the EFMC matches with a global climate change linked to the transition from the Early Holocene to the Middle Holocene (Walker et al., 2012). Actually, contrary to fens established after lake infillings and highly constrained by the geomorphological context, bog ecosystems are mainly supplied by rainfall, which is known to have greatly increased at ca. 8.2 ka cal. BP (e.g. Alley and Ágústsdóttir, 2005; Magny, 2013).

Peat initiation decreased between 7 and 4.4 ka cal. BP, and only few cases of new mires were observed (1 site/250 years) in zones i, iii, iv and v (Fig. 3-b). At Molhiac for instance, peat started to expand from two separate loci, and merged to one single mire after 8.8 ka cal. BP (Cubizolle et al., 2015). Although, on this site, peat lateral expansion continued to gradually increase (2.9–4.5 m² year⁻¹) until 5.45 ka cal. BP, before falling to very low expansion rates (less than 1.2 m² year⁻¹) during the Late Holocene. Lateral peat expansion also progressed in numerous sites in Northern Europe during this period (Ruppel et al., 2013). Interestingly, less mire creations and the only expansion of existing bogs observed at large scales fitted with the drop in CH₄ emission (Fig. 3-a). This coherence between CH₄ trend and local mire initiation also matched with

Table 1
Semi-subjective scores for Anthropogenic Impact Factors (AIF) attributed according to the degree of human impact observed in palaeoecological diagrams (after Jouffroy-Bapicot et al., 2013).

	None	Slight	Moderate	High
Degree of openness following arboreal/non-arboreal pollen ratios	0	1	2	3
Presence of indirect anthropogenic indicators	0	1	2	3
Presence of direct anthropogenic indicators	0	2	4	8
Maximum AIF cumulated scores achievable for each cluster (CONISS-type)	0	4	8	14

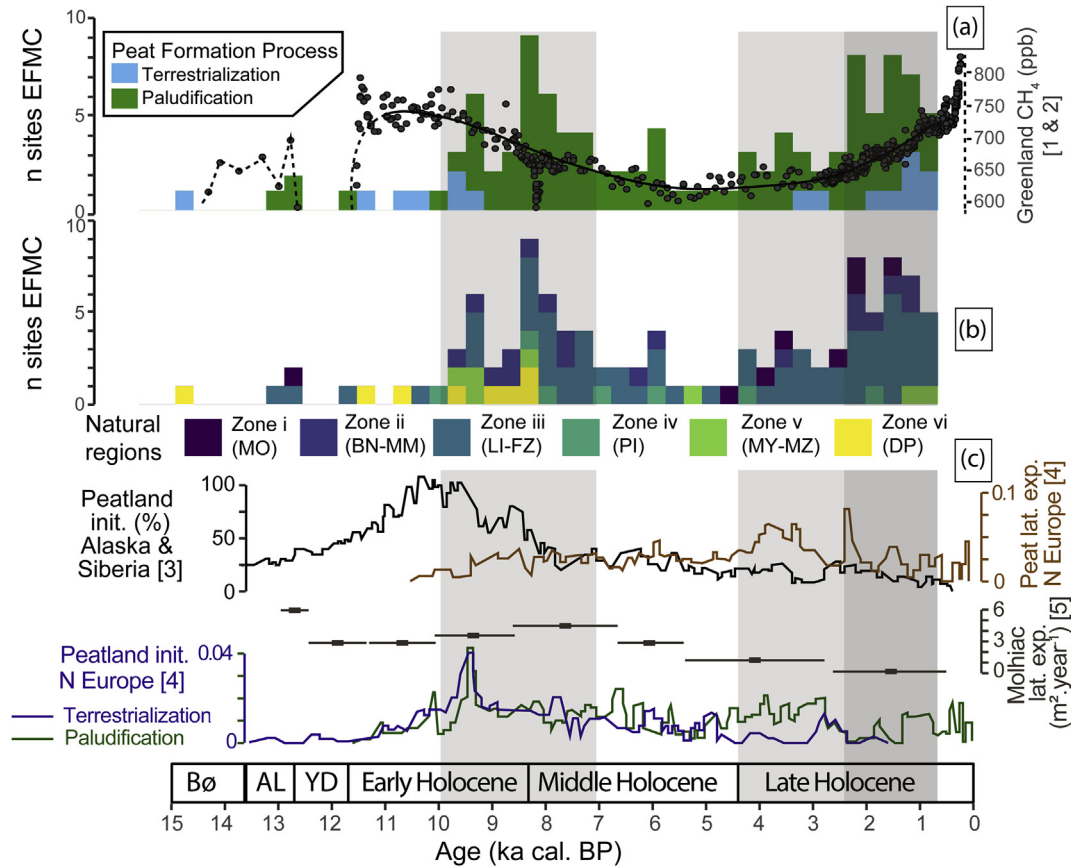


Fig. 3. Comparison of peat initiation trends on the EFMC and in the Northern Hemisphere since 15 ka cal. BP. a) Frequency histogram of peat initiation on the EFMC ($n = 112$) and comparison with CH_4 emission (points) recorded in the Greenland ice cores. [1] Continuous line = spline model established by Beck et al. (2018) [2] dashed line = model based on Brook et al. (1996). b) Peat initiation ages on each natural region of the EFMC: Zone i (MO) = Morvan; Zone ii (BN-MM) = Bois Noirs and Madeleine Mountains; Zone iii (LI-FZ) = Livradois and Forez; Zone iv (PI) = Pilat Massif; Zone v (MY-MZ) = Meygal and Mézenc Massif; Zone vi (DP) = Deves Plateau. c) Comparison with peatland initiation in the Northern Hemisphere: [3] Cumulative peatland initiation (init.) percentage in Alaska and Siberia (Jones and Yu, 2010); [4] Maximal occurrence frequencies for terrestrialization, paludification and peatland lateral expansion (lat. exp.) in Northern Europe (Ruppel et al., 2013); [5] Mire lat. exp. in the Molhac mire (EFMC, Cubizolle et al., 2015). Grey bars represent EFMC peat initiation phases. Abbreviations: Bø = Bolling, AL = Allerød, YD = Younger Dryas. For the new Holocene terminology, please refer to Cohen et al. (2018).

worldwide observation from Alaska-Siberia to Northern Europe (Fig. 3-c).

After ca. 4.4 ka cal. BP, the number of newly formed mires increased more and more (Fig. 3-a). The beginning of the phase was coeval with the Late Holocene (Meghalayan) onset and suggested a possible link with global climate changes (Bell and Walker, 2014; Walker et al., 2012). Paludification and terrestrialization occurred together during this period, although the sites are generally smaller than 3 ha, with a peat depth generally limited to 2 m according to Cubizolle et al. (2012). The Fig. 3-a clearly showed the absence of cyclicity in the peat initiation trends on the EFMC and refuted any link with climatic cycles. For example, Cubizolle et al. (2012) compared the EFMC mire phases (zones ii, iii, and iv) with the wet episodes of Magny (2004, 2013) and Barber et al. (2004). They did not identify a clear climate control on mire initiation from 4.4 to 2.5 ka cal. BP, while several cases of anthropogenic landscape modifications led to mire initiation (Cubizolle et al., 2012). Moreover, peat inception reached a maximum during the last 2.4 ka cal. BP (Fig. 3-a). It differed from high latitude sites, where the number of newly formed peatlands decreased since 2.4 ka cal. BP (Fig. 3-c). Indeed, our data suggested a regional development of mires on the EFMC, independent from global records. During the last 2.4 ka cal. BP, the impact of agro-pastoralism on mires have to be addressed in the EFMC, where monastic economic models – mostly working from 1.3 to 0.25 ka cal. BP – were based on extensive livestock

breeding and the related manure management (Bréchon, 1998). Other regions of Western Europe also presented similar trends, such as in North-Western Spain where fens mainly developed during the last 2.4 ka years (Pontevedra-Pombal et al., 2017). It is also highly probable that human activities during this period contributed to increase CH_4 emissions, due to fire activities (forest cleaning, grassland and arable land management), cattle breeding (incl. enteric fermentation) and agriculture intensification (Houweling et al., 2008).

4.2. Human impact – mire development relationships

In order to apprehend the links between landscape opening or agro-pastoral practices and mire initiation, we proposed an approach cumulating semi-quantitative scores of Anthropogenic Impact Factors (AIF) coming from 26 palaeoecological records on the EFMC (Fig. 4; see also Table S2). In spite of the heterogeneity of the dataset, this attempt to integrate various palaeoecological data on a region-scale area revealed several phases.

The phase 1 is comprised between 10 and 2.8 ka cal. BP (Fig. 4-b) and could be divided into two parts. From 10 to 4.7 ka cal. BP (Early and Middle Holocene; phase 1a), AIF scores displayed a very low median value of 2, with Q1 and Q3 ranging from 1 to 3 (Fig. 4-b). These scores suggested a densely forested situation and rare local human impacts. Indeed, archaeological sites were very scarce

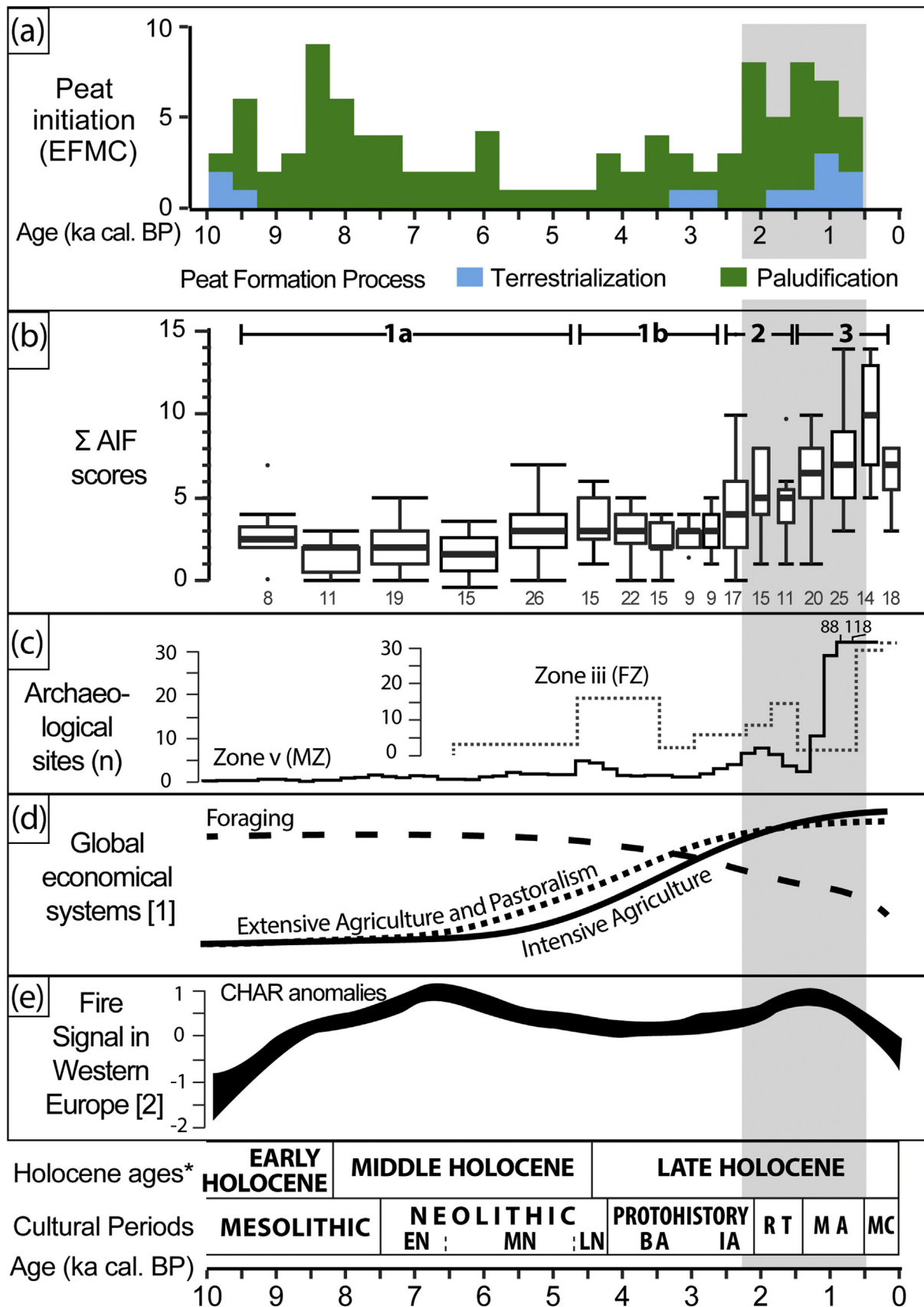


Fig. 4. Peat initiation and human impact during the last 10 ka cal. BP on the EFMC. The grey bar on the right represents the last peat initiation phase from Fig. 3 (since 2.4 ka cal. BP). The timescale indicated below refers to Holocene ages (*for new terminology, please refer to Cohen et al., 2018). Abridged cultural periods: EN = Early Neolithic, MN = Middle Neolithic, LN = Late / Recent Neolithic, BA = Bronze Age, IA = Iron Age, RT = Roman Times, MA = Middle Ages, MC = Modern and Current Times. a) Frequency histogram of peat initiation cases. b) Cumulated semi-quantitative scores for Anthropogenic Impact Factors (AIF) according to palaeoecological data. The three main phases are mentioned above, while the number of analyses is indicated below each boxplot. c) Synthesis of archaeological site frequencies in the studied area: Zone v (MZ; black line) = Mézenc Massif; Zone iii (FZ; dotted line) = Forez Mountains. d) Foraging and agriculture practises according to [1] Stephens and ArchaeoGLOBE Project authors (2019). e) Fire frequencies in Western Europe according to [2] Iglesias et al. (2019).

according to the state of the art in the EFMC, and at global scales too (Fig. 4-c and 4-d). This observation is also consistent with recent syntheses on past land use and occupation in South-Eastern France indicating that the landscape was not really open before 5.7–4.3 ka cal. BP, i.e. during the Final Neolithic Period (Berger et al., 2018, 2019). It suggests a lack of factual links between human activity and peat initiation for this period at the scale of the EFMC (Fig. 4-a). Even if early forest clearing and agriculture episodes existed in the southern zone of the EFMC, it did not modify significantly the hydro-sedimentary dynamics, even locally (Berger et al., 2018). Fig. 4-e also showed that fires notably increased during the main phase of peat initiation (Iglesias et al., 2019; Vanni re et al., 2011). In agreement with several authors such as Gallego-Sala et al. (2015), we propose a climate origin for the fens and bogs established during this period. Then, from 4.7 to 2.8 ka cal. BP (phase 1.b), despite an increase of the number of archaeological sites on the EFMC, especially during the Late Neolithic and the Late Protohistory (M zenc and Forez areas, Fig. 4-c), there was no significant increase of AIF scores (median = 3 ± 2; Fig. 4-b).

A coeval increase of the number of mires in the EFMC and an intensification of human impact based on AIF scores was highlighted after 2.8 ka cal BP (phases 2 and 3; Fig. 4-a and 4-b). It was also suggested by other supra-regional studies, especially those discussing on the Holocene fire signal (Iglesias et al., 2019; Rius et al., 2009) which gradually increased in Western Europe due to

anthropogenic activities (Fig. 4-e; Vanni re et al., 2011). This phase was also related to the uppermost phases of extension of pastoralism and extensive agriculture in the Mediterranean area and worldwide (maximum after 3 ka cal. BP; Iglesias et al., 2019). Yet, this period was initially wet and cold, characterized by a significant climate deterioration during the Iron Age in Europe (Magny, 2013; Plunkett and Swindles, 2008). Such conditions could locally favour mire initiation as suggested by other works in Western Europe (Barber et al., 2004; Pontevedra-Pombal et al., 2017).

Thus, for the phase 2 (2.8–1.5 ka cal. BP; Fig. 4-b), direct consequences of human activities on peat initiation were very well highlighted. After this tipping point, the AIF median increased up to a value of 4, with Q1 and Q3 ranging from 3 to 6. This increase was mainly supported by the widespread occurrence of direct anthropogenic indicators in the studied sites. It coincided with a maximum of fire events in Western Europe (Fig. 4-e) and with the main periods of archaeological occupation on the studied area: from 2.4 to 1.5 ka cal. BP (end of the 2nd Iron Age – Roman Times) and since 1.3 ka cal. BP (Middle Ages). Agro-pastoralism and intensive agriculture reached almost all regions in the world after 2.5–1.5 ka cal. BP (Stephens and ArchaeoGLOBE Project authors, 2019). In the EFMC, palaeoecological data demonstrated that the landscape was massively deforested from the end of the 2nd Iron Age to the Early Middle Ages, i.e. from 400 BC to 700 AD (Cubizolle et al., 2014; Dendievel et al., 2019; Jouffroy-Bapicot et al., 2013).

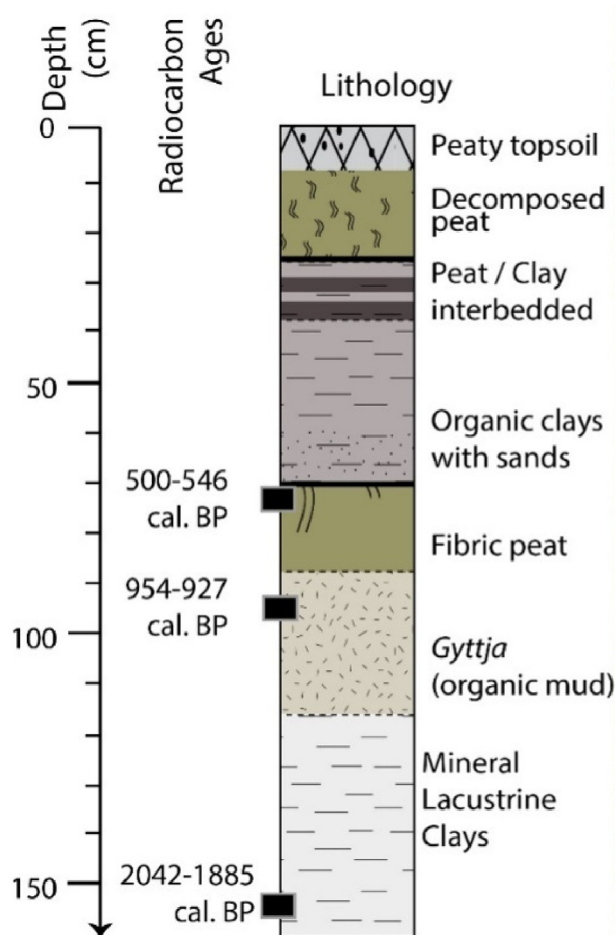


Fig. 5. Peat core, ages and map of the Pre-du-May mire and the Auze River. The Chevalier diversion was most certainly established to supply a mill during the modern period (since 0.5 ka cal. BP). Ages were calibrated with “the “IntCal13” curve (2σ, 95%; cf. Reimer et al., 2013).

Lastly, from 1.5 to 0.25 ka cal. BP (i.e. AD 500–1700; from the Early Middle Ages to the Modern Times), AIF scores continued to increase to a median value of 7, with Q1 and Q3 ranging from 6 to 8 (Fig. 4-b). These important scores are mainly caused by the co-occurrence of multiple direct anthropogenic indicators recorded in high percentages with a high degree of landscape openness (see Table S1 for details). Within this context, the two types of peat initiation process (terrestrialization and paludification) were of upmost importance to discuss. Indeed, the high level of human activities implied the need to have or to build water reserves, such as reservoirs or derivations, for agriculture and pastoralism purposes. After a phase of use related to local occupations, the abandonment of these water structures very likely led to mire initiation by terrestrialization (former ponds for instance) or by paludification (in terrestrial environments). A particularly complex and typical case was found at Pré-du-May, in the Meygal massif (zone v; Fig. 5). A pond most certainly built during the early roman period (ca. 2.0–1.9 ka cal. BP) terrestrialized and evolved into a fen after its abandonment during the Middle Ages (0.9 ka cal. BP). Then, this area was drained, and a diversion was built on the Auze River to supply the mill of Chevalier (Late Middle Ages and Modern Period). Finally, after the 19th century, the mill was decommissioned and the wetland, no longer drained, evolved again into a mire (Fig. 5). Although, without protection, this site is currently subject to increased erosion pressures due to agricultural activities, including overgrazing. Other anthropogenic cases are also known in the Forez massif (zone iii), for instance at Verdier where the building of a road blocked the water drainage and created a mire after 2.3–1.7 ka cal. BP (Cubizolle et al., 2012). At Sauvazoux, another example of mire initiation implied the establishment of a mire back from a dry stone wall after 1.6–1.4 ka cal. BP (Cubizolle and Thébaud, 2014). Major changes in the forest cover have also to be considered as regards local consequences on peatland ecosystems and water tables. Unfortunately, these cases are not well known in the studied region. On some sites, the Middle Ages deforestation led to an increase in surface runoff. At Jonzieq (Forez mountains), a network of ditches was dug to increase drainage and, after its abandonment, peat started to accumulate in the ditches during the last 300 years (Cubizolle et al., 2012). This and other cases suggest that the climate was also probably implied in the water table increase, which favoured mires (Little Ice Age period at Jonzieq), or in the lowering of water table, which enabled the development of trees, such as on the Limagne marsh (Cubizolle et al., 2009–2010). As demonstrated in this paper, coupling ^{14}C dating of basal peat layers, palaeoecological statistical data and geomorphological information provided new insights to apprehend the heritage of anthropogenic activities and climate changes in middle mountain areas where rare data were available.

5. Conclusion

In this paper, we provided an advanced study on mire developments of the Eastern French Massif Central (EFMC) over the last 15 ka cal. BP. Based on 112 well dated sites including minerotrophic and ombrogenic mires (fen and bogs, respectively), this work proposes a local contribution to the global reflexion on mire initiation and climate warming during the first half of the Holocene (e.g. Kremenetski et al., 2003). In a few cases, Late-Glacial histic horizons, accumulating peat during various periods of time, were found (before 11.7 ka cal. BP). Such phenomenon is not understood yet and more research is needed on this field. Then, a major development of mires occurred from 10 to 7 ka cal. BP, induced by climate changes. This episode combined mires formed by paludification (bogs) or terrestrialization (fens). The latter process provided limnogenous mires established on former periglacial

lakes at the beginning of the Holocene warming (Preboreal and Boreal chronozones) and was coeval with the apparition of numerous fens in the Northern Hemisphere, more widely. It also coincided with a global increase in atmospheric CH_4 , most certainly linked to methane gas emitted during this global phase of fen apparition and of climate warming. Then, after 9 ka cal. BP, only small ombrogenous, topogenous and soligenous mires (bogs, slope and spring mires) established, especially around the 8.2 ka cal. BP event. This generation ended when the number of new mires formed dropped after 7 ka cal. BP.

After a reduced phase of mire initiation (7–4.4 ka cal. BP), a second major generation of mires began during the last 4.4 ka cal. BP in the EFMC. Due to the absence of a systematic correlation with climate changes and the low number of archaeological sites, it is likely that mires formed during this phase resulted from either the local manifestation of climatic settings or human impacts. Finally, a major increase of peat initiation cases occurred during the 2.4 ka cal. BP (maximum). Both paludification and terrestrialization processes were involved. Most of these cases were clearly related to the anthropogenic landscape management as demonstrated by the comparison between the number of mires, the AIF scores (extracted from published pollen, spore and macrofossil data on the EFMC), and micro-regional archaeological syntheses (Dendievel et al., 2019; Scholtès, PhD in preparation). We assumed that an important number of mires was indirectly created by anthropogenic actions blocking the water drainage. This paper highlighted complex cases which include several steps of peat accumulation due to successive terrestrialization (after the infilling of a pond, for instance) and paludification processes (e.g. after the abandonment of drainage networks). Extensive agriculture and pastoralism very likely played a role for peat accumulation in middle mountain ranges by the building of water reservoirs, occupied by mire vegetation after abandonment. As mires are considered as high-value socio-ecosystems offering sustainable resources and services (water, biodiversity, carbon sinks), it is of upmost importance to take into account the anthropogenic origin of the numerous mires of the Late Holocene for the current and future management of these wetlands.

CRedit authorship contribution statement

André-Marie Dendievel: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Isabelle Jouffroy-Bapicot:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Jacqueline Argant:** Writing - original draft, Writing - review & editing. **Antoine Scholtès:** Writing - original draft, Writing - review & editing. **Arnaud Tourman:** Writing - original draft, Writing - review & editing. **Jacques-Louis de Beaulieu:** Writing - original draft, Writing - review & editing. **Hervé Cubizolle:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Acknowledgements

The authors are grateful to C. Oberlin and to all the radiocarbon dating team of the University Lyon 1 Claude Bernard for their valuable discussion and comments. We thank E. Bouvard (Archaeological Office of Lyon – SAVL), B. Dietre (UMR CNRS 6249 Chrono-Environnement and University of Innsbruck, Institute of Botany) and J.N. Haas (University of Innsbruck, Institute of Botany), who contributed to the previous studies on the Meygal and Mézenc Massif, respectively. We are also grateful to the editor (J. Carrión) for his comments that improved our research paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.quascirev.2020.106219>.

Data availability

The radiocarbon database compiled and used in this research paper is freely available internet hyperlink at <https://doi.pangaea.de/10.1594/PANGAEA.911851> (Dendievel et al., 2020). It includes site names, coordinates, elevation, detailed information about the dated material, and the radiocarbon ages. Method abbreviations (AMS, conv., ARCH, LPS) are also explained in the text.

References

- Alley, R.B., Ágústsdóttir, A.M., 2005. The 8k event: cause and consequences of a major Holocene abrupt climate change. *Quat. Sci. Rev.* 24, 1123–1149. <https://doi.org/10.1016/j.quascirev.2004.12.004>.
- Andrieu, J.P., 1988. Nature and management of tropical soils. *FAO Bull.* 59, 1–165. Available online at: <http://www.fao.org/3/x5872e/x5872e00.htm>.
- Antonetti, P., Brugel, E., Kessler, F., Berbe, J.-P., Tort, M., 2006. Cadre naturel et occupations humaines en Auvergne. In: Atlas de La Flore d'Auvergne. CBNMC, Chavaniac-Lafayette, pp. 26–33.
- Argant, J., 1990. Climat et environnement au Quaternaire dans le bassin du Rhône d'après les données palynologiques. *Doc. Lab. Geol. Lyon* 111, 1–199.
- Argant, J., Cubizolle, H., 2005. A new step towards a synthesis of the holocene history of the vegetation of the monts de la Madeleine, Forez, Livradois and Pilat (eastern massif central, France). *Quaternaire* 16, 119–142. <https://doi.org/10.4000/quaternaire.359>.
- Barber, K.E., 1993. Peatlands as scientific archives of past biodiversity. *Biodivers. Conserv.* 2, 474–489. <https://doi.org/10.1007/BF00056743>.
- Barber, K., Zolitschka, B., Tarasov, P., Lotter, A., 2004. Atlantic to Urals e the Holocene climatic record of mid-latitude Europe. In: Battarbee, R.W. (Ed.), *Past Climate Variability through Europe and Africa*. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 417–442.
- Beaulieu, J.-L. de, Pons, A., Reille, M., 1988. Histoire de la flore et de la végétation du Massif Central (France) depuis la fin de la dernière glaciation. *Cah. Micropaleontol.* 3, 5–36.
- Bartoli, M., Boissier, J.-M., 2018. La forêt au coeur de l'histoire Étude historique des forêts anciennes du Parc naturel régional des Monts d'Ardeche. *Ecosylve, Les Deserts*.
- Beaulieu, J.-L. de, Pons, A., Reille, M., 1984. Recherches pollenanalytiques sur l'histoire de la végétation des Monts du Velay (Massif Central, France). *Diss. Bot.* 72, 45–72.
- Beck, J., Bock, M., Schmitt, J., Seth, B., Blunier, T., Fischer, H., 2018. Bipolar carbon and hydrogen isotope constraints on the Holocene methane budget. *Biogeosciences* 15, 7155–7175. <https://doi.org/10.5194/bg-15-7155-2018>.
- Bell, M., Walker, M.J.C., 2014. *Late Quaternary Environmental Change: Physical and Human Perspectives*. Routledge, London & New-York.
- Belokopytov, I., Beresnevich, V., 1955. Giktorf's peat borers. *Torfanaa promyslennost* 8, 9–10.
- Benoit, P., Berthier, K., Boët, P., Rezé, C., 2004. Les aménagements hydrauliques liés au flottage du bois, leur impact sur le milieu fluvial (XVIe–XVIIIe siècles). In: Burnouf, J., Leveau, P. (Eds.), *Fleuves et Marais, Une histoire au croisement de la nature et de la culture*. CIHS, Paris, pp. 311–320.
- Bépoix, S., Richard, H. (Eds.), 2019. *La Forêt au Moyen Âge*. Les Belles Lettres, Paris.
- Berger, J.-F., Carozza, J.-M., Castanet, C., Cubizolle, H., Dendievel, A.-M., Deschodt, L., Franc, O., Ghilardi, M., Lespez, L., Salvador, P.-G., Sivan, O., Vannièr, B., Argant, J., Boulou, M., Brochier, J.-L., Carozza, L., Germain-Vallée, C., Lemer, L., 2018. Climat et environnements : les étapes de la première anthropisation de l'espace (6000–2000 BCE) en France. In: Guilaïne, J., Garcia, D. (Eds.), *La Protohistoire de La France*. Hermann, Paris, pp. 53–77.
- Berger, J.-F., Shennan, S., Woodbridge, J., Palmisano, A., Mazier, F., Nuninger, L., Guillon, S., Doyen, E., Begeot, C., Andrieu-Ponel, V., Azuara, J., Bevan, A., Fyfe, R., Roberts, C.N., 2019. Holocene land cover and population dynamics in Southern France. *Holocene* 29, 776–798. <https://doi.org/10.1177/0959683619826698>.
- Berggren, G., 1981. *Atlas of Seeds and Small Fruits of Northwest European Plant Species (Sweden, Norway, Denmark, East Fennoscandia and Iceland) with Morphological Descriptions*. Part 3. Salicaceae-Cruciferae. Swedish Museum Natural History, Stockholm, Sweden.
- Berggren, G., 1969. *Atlas of Seeds and Small Fruits of Northwest-European Plant Species with Morphological Descriptions*. Part 2, Cyperaceae. Swedish Museum Natural History, Stockholm, Sweden.
- Beug, H.J., 2004. *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete*. Pfeil, München.
- Bouvard, E., 2016. Empreintes monastiques en moyenne montagne du XIIe siècle à l'Actuel. *Archéologie des espaces et des paysages cisterciens dans les anciens diocèses de Clermont et du Puy*. PhD Thesis, Université Lumière Lyon 2. Lyon. Available online at: http://theses.univ-lyon2.fr/documents/lyon2/2016/bouvard_em#p=0&a=top.
- Bouvard, E., 2011. L'aménagement hydraulique des sites cisterciens d'Auvergne et du Velay. *Des procédés vernaculaires audacioux*. *Archéopages* 32, 62–71.
- Bréchon, F., 1998. Contribution à une histoire de la transhumance sur les rebords sud-est du Massif Central : les troupeaux de l'abbaye de Saint-Chaffre-du-Monastier à la fin du Moyen Âge. In: Framond, M. de, Lauranson-Rosaz, C., Sanial, B. (Eds.), *Les Bénédictins de Saint-Chaffre du Monastier, histoire et archéologie d'une congrégation*. Actes du colloque du CERCOR, 7, 8 et 9 Novembre 1997. Mémoires de la Jeune Loire et du Mézenc, 1. Office culturel du Pays de la Jeune Loire et du Mézenc, Le Monastier-sur-Gazeille, pp. 49–64.
- Brook, E.J., Sowers, T., Orcharado, J., 1996. Rapid variations in atmospheric methane concentration during the past 110,000 years. *Science* 273, 1087–1091. <https://doi.org/10.1126/science.273.5278.1087>.
- Brun, C., 2011. Anthropogenic indicators in pollen diagrams in eastern France: a critical review. *Veg. Hist. Archaeobotany* 20, 135–142. <https://doi.org/10.1007/s00334-010-0277-8>.
- Büntgen, S., 2008. *Peuplement, cultures et gestion de l'espace dans le Forez de la Préhistoire à l'Antiquité*. PhD Thesis, Université de Franche-Comté, Besançon.
- Bussièr, B., Payette, S., Fillion, L., 1996. Déboisement et entourbement des hauts sommets de Charlevoix à l'Holocène supérieur : origine des étages alpin et subalpin. *Géogr. Phys. Quaternaire* 50, 257–269. <https://doi.org/10.7202/033099ar>.
- Cappers, R.T.J., Bekker, R.M., Jans, J.E.A., 2006. *Digitale Zadenatlas Van Nederland*. Barkhuis Publishing. Groningen University Library, Groningen.
- Caseldine, C., Hatton, J., 1993. The development of high moorland on Dartmoor: fire and the influence of Mesolithic activity on vegetation change: studies in palaeoecology and environmental archaeology. In: Chambers, F.M. (Ed.), *Climate Change and Human Impact on Landscape*. Chapman & Hall, London, pp. 119–131.
- Catteddu, I., 2009. *Archéologie médiévale en France. Le « premier Moyen Âge » (Ve–Xle siècle)*. Archéologies de la France. Inrap - La Découverte, Paris.
- Charman, D., 2002. *Peatlands and Environmental Changes*. John Wiley, Chichester.
- Cohen, K.M., Harper, D.A.T., Gibbard, P.L., Fan, J.-X., 2018. The ICS international chronostratigraphic chart V2018/07. International commission on stratigraphy. Available online at: <http://stratigraphy.org/ICSChart/ChronostratChart2018-07.pdf>.
- Coûteaux, M., 1984. *Bilan des recherches pollenanalytiques en Ardèche (France)*. *Bull. Soc. R. Bot. Belg.* 117, 181–217.
- Cubizolle, H., 2019. Les tourbières et la tourbe. *Géographie, hydro-écologie, usages et gestion conservatoire*. Lavoisier, Paris.
- Cubizolle, H., Argant, J., 2006. Les facteurs de la mise en place des tourbières du Massif Central oriental granitique à l'Holocène. In: Miras, Y., Surmély, F. (Eds.), *Environnement et peuplement de la moyenne montagne, du Tardiglaciaire à nos jours*. Annales littéraires de l'Université de Franche-Comté, 799. Série Environnement, littératures et archéologie, 9. Presses Univ. de Franche-Comté, Besançon, pp. 93–108.
- Cubizolle, H., Argant, J., Fassion, F., Latour-Argant, C., Deng-Amiot, Y., Dietre, B., 2014. Vegetation history from the end of the late-glacial and human impact from the mid-holocene in the eastern Massif Central (France). *Quaternaire* 25 (3), 209–235. <https://doi.org/10.4000/quaternaire.7060>.
- Cubizolle, H., Bonnel, P., Oberlin, C., Tourman, A., Porteret, J., 2007. Advantages and limits of radiocarbon dating applied to peat inception during the end of the Lateglacial and the Holocene: the example of mires in the Eastern Massif Central (France). *Quaternaire* 18 (2), 187–208. <https://doi.org/10.4000/quaternaire.1049>.
- Cubizolle, H., Fassion, F., Argant, J., Latour-Argant, C., Galet, P., Oberlin, C., 2012. Mire initiation, climatic change and agricultural expansion over the course of the Late-Holocene in the Massif Central mountain range (France): causal links and implications for mire conservation. *Quat. Int.* 251, 77–96. <https://doi.org/10.1016/j.quaint.2011.07.001>.
- Cubizolle, H., Sacca, C., Grégoire, F., 2013. When human activities launch peat accumulation or how anthropogenic fens are changing our perception of mires. *Géocarrefour* 88, 257–271. <https://doi.org/10.4000/geocarrefour.9252>.
- Cubizolle, H., Sacca, C., Tourman, A., Porteret, J., Thébaud, G., 2004. The mires of the Loire upstream catchment (Eastern Massif central): heritage value, phytoecnotic interest and economic uses. *Noroi* 192, 95–115. <https://doi.org/10.4000/noroi.943>.
- Cubizolle, H., Thébaud, G., 2014. A geographical model for the altitudinal zonation of mire types in the uplands of western Europe: the example of Les Monts du Forez in eastern France. *Mires and Peat* 15 (Art. 2). Available online at: <http://www.mires-and-peat.net/pages/volumes/map15/map1502.php>.
- Cubizolle, H., Thébaud, G., Seytre, L., Porteret, J., Tourman, A., 2009–2010. Les causes du développement de l'arbre sur les tourbières du Massif Central oriental (France) au cours du XXème siècle. *Ann. Sci. Rés. Bios. Trans. Vosges du Nord-Pfälzerwald* 15, 140–170.
- Cubizolle, H., Tholly, J., Oberlin, C., Tourman, A., 2015. Peat initiation and lateral expansion of mires during the lateglacial and the holocene on the eastern region of French Massif Central: the case of Molhiac mire in les monts du Forez mountain range. *Quaternaire* 26 (4), 293–306. <https://doi.org/10.4000/quaternaire.7460>.
- Cugny, C., Mazier, F., Galop, D., 2010. Modern and fossil non-pollen palynomorphs from the Basque mountains (western Pyrenees, France): the use of coprophilous fungi to reconstruct pastoral activity. *Veg. Hist. Archaeobotany* 19, 391–408. <https://doi.org/10.1007/s00334-010-0242-6>.
- Daugas, J.-P., Raynal, J.-P., 1989. *Quelques étapes du peuplement du Massif central*

- français dans leur contexte paléoclimatique et paléogéographique. In: Laville, H. (Ed.), Variations des paléoclimats et peuplement préhistorique. Actes du colloque du comité français de l'I.N.Q.U.A. - Talence, 3-4 Mars 1986. "Relations entre les variations des paléoclimats, le peuplement préhistorique et l'occupation du sol." Cahiers du Quaternaire, 13. Editions du CNRS, Paris, pp. 67-95.
- Défve, E., Meinard, Y., Courrioux, G., Ledru, P., Poiraud, A., Prognon, C., Bertin, C., 2011. Carte géologique de la France, feuille n° 816, Le Monastier-sur-Gazeille, carte et notice. Editions du BRGM, Orléans.
- Delrieu, F., Brunaux, L., Dendievel, A.-M., Dubuis, B., Dutreuil, P., Furestier, R., Guichon, R., 2015. L'habitat fortifié à l'âge du Bronze et au 1er âge du Fer sur le versant oriental du Massif Central. Départements de l'Ardèche, de la Loire et du Rhône. Rapport 2014 de Programme Collectif de Recherche. SRA Rhône-Alpes, Lyon.
- Delrieu, F., Dutreuil, P., Granier, F., 2012. L'habitat fortifié à l'âge du Bronze et au 1er âge du Fer sur le versant oriental du Massif central, départements de l'Ardèche de la Loire et du Rhône, rapport de prospection thématique. SRA Rhône-Alpes, Lyon.
- Dendievel, A.-M., 2017. Holocene Palaeoenvironments of the Béage Plateau (Mézenec Mountains, Massif Central, France): Climatic Change and Anthropogenic Activities Revealed by Macrofossil Analyses from Peat and Gytja Deposits. PhD Thesis. University of Lyon, Saint-Etienne.
- Dendievel, A.-M., Dietre, B., Cubizolle, H., Hajdas, I., Kofler, W., Oberlin, C., Haas, J.N., 2019. Holocene palaeoecological changes and agro-pastoral impact on the La Narce du Béage mire (Massif Central, France). *Holocene* 29, 992-1010. <https://doi.org/10.1177/0959683619831416>.
- Dendievel, A.-M., Jouffroy-Bapicot, I., Tourman, A., de Beaulieu, J.-L., Cubizolle, H., 2020. Radiocarbon Ages on Basal Peat Layers from the Eastern Massif Central Region (France). *PANGAEA*. <https://doi.pangaea.de/10.1594/PANGAEA.911851>.
- Dendievel, A.-M., Serreyssol, K., Dietre, B., Cubizolle, H., Quiquerez, A., Haas, J.N., (in press). Late-Glacial and Early Holocene environmental changes affecting the shallow lake basin of La Narce du Béage (Ardèche, Massif Central, France). *Quat. Int.* <https://doi.org/10.1016/j.quaint.2019.09.014>.
- Dietre, B., Gauthier, É., Gillet, F., 2012. Modern pollen rain and fungal spore assemblages from pasture woodlands around Lake Saint-Point (France). *Rev. Palaeobot. Palynol.* 186, 69-89. <https://doi.org/10.1016/j.revpalbo.2012.07.002>.
- Dubois, G., 1946. Connaissance actuelle de l'histoire du peuplement forestier des montagnes françaises. *Rev. Géogr. Alp.* 34, 57-68.
- Etlischer, B., 2005. French and Belgian uplands. In: *Koster, E.A. (Ed.), The Physical Geography of Western Europe*. Oxford University Press, Oxford, pp. 231-250.
- Faegri, K., Iversen, J., 1989. *Textbook of Pollen Analysis*. John Wiley & Sons, Chichester.
- Fasson, F., 2013. Occupation humaine et interactions sociétés-milieu dans les massifs du Livradois-Forez (Massif Central, France) de la fin du second Âge du Fer au haut Moyen Âge. PhD Thesis. Université Laval/Université Blaise Pascal/Université Jean Monnet, Laval/Clermont-Ferrand/Saint-Etienne.
- Fasson, F., Argant, J., Cubizolle, H., 2011. Le livradois-forez. In: Trément, F. (Ed.), *Les Arvernes et leurs voisins du Massif Central à l'époque Romaine*. Revue d'Auvergne, vol. 125, pp. 409-450, 600-601.
- Faure, M., Lardeaux, J.-M., Ledru, P., 2009. A review of the pre-Permian geology of the Variscan French Massif Central. *Compt. Rendus Geosci.* 341, 202-213. <https://doi.org/10.1016/j.crte.2008.12.001>.
- Florschütz, F., 1955. Diagramme pollinique de la tourbière de Saint-Front. *Bulletin historique, scientifique, littéraire, artistique et agricole illustré publié par la Société scientifique et agricole de la Haute-Loire XXXIV*, pp. 72-73.
- French, C., 2012. Geoarchaeological and soil micromorphological studies in wetland archaeology. In: Menotti, F., O'Sullivan, A. (Eds.), *The Oxford Handbook of Wetland Archaeology*. Oxford University Press, Oxford, pp. 555-568.
- Gabillot, M., Chevrier, S., Bohard, B., 2016. Le Morvan à l'Âge du Bronze : dynamique d'occupation d'après les données archéologiques. *RAE* 65, 279-288. Available online at: <http://journals.openedition.org/rae/8881>.
- Gallego-Sala, A.V., Charman, D.J., Harrison, S.P., Li, G., Prentice, I.C., 2015. Climate-driven expansion of blanket bogs in Britain during the Holocene. *Clim. Past* 11, 4811-4832. <https://doi.org/10.5194/cpd-11-4811-2015>.
- Georges, V., Verrier, J., Verrier, J., 2004. Occupation humaine et dynamique fluviale de la Loire en Forez, du Néolithique à l'époque gallo-romaine (France, 42). In: Petit, C. (Ed.), *Occupation, Gestion et Paléoenvironnement Des Plaines Alluviales de l'âge Du Fer à l'Antiquité*, Environnement, Sociétés et Archéologie. Presses Univ. Franche-Comté, Besançon, pp. 121-134.
- Goery, C., Beaulieu, J.L. de, 1979. A propos de la concentration du pollen à l'aide de la liqueur de Thoulet dans les sédiments minéraux. *Pollen Spores* 21, 239-251.
- Gorham, E., Lehman, C., Dyke, A., Janssens, J., Dyke, L., 2007. Temporal and spatial aspects of peatland initiation following deglaciation in North America. *Quat. Sci. Rev.* 26, 300-311. <https://doi.org/10.1016/j.quascirev.2006.08.008>.
- Grimm, E.C., 1987. CONISS: a FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Comput. Geosci.* 13, 13-35. [https://doi.org/10.1016/0098-3004\(87\)90022-7](https://doi.org/10.1016/0098-3004(87)90022-7).
- Guichard, V., 2013. Les recherches archéologiques du Mont Beuvray. *Bibracte. Centre Archéologique Européen, Glux-en-Glenne*.
- Holmquist, J.R., Finkelstein, S.A., Garneau, M., Massa, C., Yu, Z., MacDonald, G.M., 2016. A comparison of radiocarbon ages derived from bulk peat and selected plant macrofossils in basal peat cores from circum-arctic peatlands. *Quat. Geochronol.* 31, 53-61. <https://doi.org/10.1016/j.quageo.2015.10.003>.
- Houweling, S., van der Werf, G.R., Klein Goldewijk, K., Röckmann, T., Aben, I., 2008. Early anthropogenic CH4 emissions and the variation of CH4 and 13CH4 over the last millennium. *Global Biogeochem. Cycles* 22, GB1002. <https://doi.org/10.1029/2007GB002961>.
- Hughes, P.D.M., Barber, K.E., 2003. Mire development across the fen-bog transition on the Teifi floodplain at Tregaron Bog, Ceredigion, Wales, and a comparison with 13 other raised bogs. *J. Ecol.* 91, 253-264. <https://doi.org/10.1046/j.1365-2745.2003.00762.x>.
- Iglesias, V., Vannière, B., Jouffroy-Bapicot, I., 2019. Emergence and evolution of anthropogenic landscapes in the western Mediterranean and adjacent Atlantic regions. *Fire* 2, 53. <https://doi.org/10.3390/fire2040053>.
- Jones, M.C., Yu, Z., 2010. Rapid deglacial and early Holocene expansion of peatlands in Alaska. *Proc. Natl. Acad. Sci. Unit. States Am.* 107, 7347-7352. <https://doi.org/10.1073/pnas.0911387107>.
- Joosten, H., Clarke, D., 2002. *Wise Use of Mires and Peatlands. Background and Principles Including a Framework for Decision-Making*. International Mire Conservation Group and International Peat Society.
- Joosten, H., Tanneberger, F., Moen, A., 2017. *Mires and Peatlands of Europe. Status, Distribution and Conservation*. Schweizerbart Science Publishers, Stuttgart, Germany.
- Jouffroy-Bapicot, I., Vannière, B., Gauthier, É., Richard, H., Monna, F., Petit, C., 2013. 7000 years of vegetation history and land-use changes in the Morvan Mountains (France): a regional synthesis. *Holocene* 23, 1888-1902. <https://doi.org/10.1177/0959683613508161>.
- Korhola, A., Ruppel, M., Seppä, H., Väliranta, M., Virtanen, T., Weckström, J., 2010. The importance of northern peatland expansion to the late-Holocene rise of atmospheric methane. *Quat. Sci. Rev.* 29, 611-617. <https://doi.org/10.1016/j.quascirev.2009.12.010>.
- Kremenetski, K.V., Velichko, A.A., Borisova, O.K., MacDonald, G.M., Smith, L.C., Frey, K.E., Orlova, L.A., 2003. Peatlands of the Western Siberian lowlands: current knowledge on zonation, carbon content and Late Quaternary history. *Quat. Sci. Rev.* 22, 703-723. [https://doi.org/10.1016/S0277-3791\(02\)00196-8](https://doi.org/10.1016/S0277-3791(02)00196-8).
- Kuhry, P., Turunen, J., 2006. The postglacial development of boreal and subarctic peatlands. *Ecol. Stud.* 188, 25-46. https://doi.org/10.1007/978-3-540-31913-9_3.
- Kurzaj, M.-C., 2012. *Peuplements et échanges entre Gaule interne et Gaule méditerranéenne dans le Sud-Est du Massif Central à la fin du Second âge du Fer (160-25 avant J.-C.)*. PhD Thesis. Université de Bourgogne, Dijon.
- Kurzaj, M.-C., Voruz, J.-L., 2017. Les sites de hauteur du Velay, de 1400 à 450 av. J.-C. *Documents d'Archéologie Méridionale* 40, 17-36.
- Laffont, P.-Y., 2009. *Châteaux du Vivarais. Pouvoirs et peuplement en France méridionale du haut Moyen Âge au XIIIe siècle*, Archéologie et culture. Presses Univ., Rennes, Rennes.
- Laine, J., Silvola, J., Tolonen, K., Alm, J., Nykänen, H., Vasander, H., Sallantausta, T., Savolainen, I., Sinisalo, J., Martikainen, P.J., 1996. Effect of water-level drawdown on global climatic warming: northern peatlands. *Ambio* 25, 179-184.
- Lemée, G., 1955. L'évolution de la forêt française au cours du Quaternaire d'après les analyses polliniques. *Rev. For. Fr. (Nancy)* 6, 442-460.
- Lemée, G., 1939. Recherches sur l'évolution forestière post-glaciaire en Auvergne. Analyses polliniques dans la partie méridionale des Monts Dore. *Rev. Sci. Nat. Auvergne* 5, 37-61.
- Lévesque, P.E.M., Diné, H., Larouche, A., 1988. *Guide illustré des macrofossiles végétaux des tourbières du Canada*. Ministère des approvisionnements et services Canada (Ottawa, Canada).
- MacDonald, G.M., Beilman, D.W., Kremenetski, K.V., Sheng, Y., Smith, L.C., Velichko, A.A., 2006. Rapid early development of circumarctic peatlands and atmospheric CH4 and CO2 variations. *Science* 314, 285-288.
- Magny, M., 2004. Holocene climate variability as reflected by mid-European lake-level fluctuations and its probable impact on prehistoric human settlements. *Quat. Int.* 113, 65-78. [https://doi.org/10.1016/S1040-6182\(03\)00800-6](https://doi.org/10.1016/S1040-6182(03)00800-6).
- Magny, M., 2013. Orbital, ice-sheet, and possible solar forcing of Holocene lake-level fluctuations in west-central Europe: a comment on Bleicher. *Holocene* 23, 1202-1212. <https://doi.org/10.1177/0959683613483627>.
- Manneville, O., Vergne, V., Villepoux, O., Groupe d'étude des tourbières, 2006. *Le monde des tourbières et des marais*. France, Suisse, Belgique, Luxembourg. Delachaux et Niestlé, Paris.
- Martineau, R., Linton, J., Affolter, J., Francisco, S., Saligny, L., Basset, L., 2011. Le Néolithique du Morvan : état des connaissances. *RAE* 60, 5-44. Available online at: <http://journals.openedition.org/rae/6520>.
- Martini, I.P., Martinez Cortizas, A., Chesworth, W., 2006. Peatlands. Evolution and Records of Environmental and Climate Changes, Developments in Earth Surface Processes. Elsevier, Amsterdam & Oxford.
- Mauquoy, D., van Geel, B., 2007. Mire and peat macros. In: Elias, S.A. (Ed.), *Encyclopedia of Quaternary Science*. Elsevier, Oxford, pp. 2315-2336.
- Mergoil, J., Boivin, P., 1993. Le Velay, son volcanisme et les formations associées, notice de la carte à 1/100 000. *Géologie de la France* 3, 96. Available online at: http://geofrance.brgm.fr/sites/default/files/upload/documents/revues_articles_gf1-3-1993.pdf.
- Meurisse-Fort, M., 2008. *Enregistrement haute résolution des massifs dunaires: Manche, mer du Nord et Atlantique. Le rôle des tempêtes*. Editions Publibook.
- Milcent, P.-Y., Mennessier-Jouanet, C., 2007. *Entre déterminisme environnemental et processus historiques : formes et modalités d'occupation du sol en Basse Auvergne du Bronze final au début du second âge du Fer*. In: Richard, H., Magny, M., Mordant, C. (Eds.), *Environnements et Cultures à l'âge Du Bronze En Europe Occidentale, Documents Préhistoriques*. CTHS, Paris, pp. 227-242.
- Moore, P.D., 1988. The development of moorlands and upland mires. In: Jones, M. (Ed.), *Archaeology and the Flora of the British Isles: Human Influence on the Evolution of Plant Communities*, Oxford University Committee for Archaeology

- Monograph. Oxford University, Committee for Archaeology, Oxford, pp. 116–122.
- Moore, P.D., Webb, J.A., Collinson, M.E., 1991. *Pollen Analysis*. Blackwell, Oxford.
- Nehlig, P., Boivin, P., de Goër, A., Mergoil, J., Prouteau, G., Sustrac, G., Thiéblemont, D., 2003. Les volcans du Massif Central. *Géologues numéro spécial* 41.
- Nomade, S., Sascó, R., Guillou, H., Scao, V., Kissel, C., Genty, D., 2014. Dating of the youngest volcanoes of Ardèche (Massif Central, France) using $40\text{Ar}/^{39}\text{Ar}$ and unspiked K/Ar . *Geophys. Res. Abstr.* 16. EGU2014–4901–2. Available online at: <https://meetingorganizer.copernicus.org/EGU2014/EGU2014-4901-2.pdf>.
- Nouvel, P., Poitout, B., Kasprzyk, M., 2009. De la ferme au palais. Les établissements ruraux antiques de Bourgogne du Nord, Ile-IVe siècles p.C. In: Leveau, P., Raynaud, C., Sablayrolles, R., Trément, F. (Eds.), *Les Formes de l'habitat Rural Gallo-Romain. Colloque AGER VIII. Aquitania suppl. 17*. Bordeaux, pp. 361–389.
- Phalip, B., 2002. Organisation de l'espace auvergnat aux temps médiévaux. In: Martin, D. (Ed.), *L'identité de l'Auvergne: mythe ou réalité historique. Essai sur une histoire de l'Auvergne des origines à nos jours*. Editions Créer, Nonette, pp. 113–130.
- Plunkett, G., Swindles, G.T., 2008. Determining the Sun's influence on Lateglacial and Holocene climates: a focus on climate response to centennial-scale solar forcing at 2800cal.BP. *Quat. Sci. Rev.* 27, 175–184. <https://doi.org/10.1016/j.quascirev.2007.01.015>.
- Pontevedra-Pombal, X., Castro, D., Carballeira, R., Souto, M., López-Sáez, J.A., Pérez-Díaz, S., Fraga, M.I., Valcárcel, M., García-Rodeja, E., 2017. Iberian acid peatlands: types, origin and general trends of development. *Mires Peat* 19, 1–19. <https://doi.org/10.19189/MaP.2016.OMB.260>.
- Poux, A.-S., Gob, F., Jacob-Rousseau, N., 2011. Discharge reconstruction of artificial water releases for timber floating in the Morvan Massif (central France, 16th–19th centuries) from historical archives and geomorphological observations. *Geomorphol. Relief, Process. Environ.* 17, 143–156. <https://doi.org/10.4000/geomorphologie.9351>.
- R Core Team, 2018. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna (Austria). Version 3.5.2 Eggshell Igloo.
- Reille, M., 1999. *Pollen et spores d'Europe et d'Afrique du Nord*, 2nde ed. Laboratoire de botanique historique et palynologie, Marseille.
- Reimer, P., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P., Bronk Ramsey, C., Buck, C., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P., Guilderson, T., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T., Hoffmann, D., Hogg, A., Hughen, K., Kaiser, K.F., Kromer, B., Manning, S., Niu, M., Reimer, R., Richards, D., Scott, E.M., Southon, J., Staff, R., Turney, C., Plicht, J. van der, 2013. Intcal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55, 1869–1887. https://doi.org/10.2458/azu_js_rc.55.16947.
- Renou-Wilson, F., Moser, G., Farrell, C., Müller, C., Wilson, D., 2019. Rewetting degraded peatlands for climate and biodiversity benefits: results from two raised bogs. *Ecol. Eng.* 127, 547–560. <https://doi.org/10.1016/j.ecoleng.2018.02.014>.
- Rialland, Y., Letterlé, F., 2013. Le Néolithique en Auvergne : bilan provisoire. In: *Bilan d'Activité 2012. Journée Régionale de l'Archéologie 2013*. Ministère de la culture et de la communication, DRAC SRA Auvergne, Clermont-Ferrand, pp. 54–86.
- Rius, D., Vannière, B., Galop, D., 2009. Fire frequency and landscape management in the northwestern Pyrenean piedmont, France, since the early Neolithic (8000 cal. BP). *Holocene* 19, 847–859. <https://doi.org/10.1177/0959683609105299>.
- Ruppel, M., Väliaranta, M., Virtanen, T., Korhola, A., 2013. Postglacial spatiotemporal peatland initiation and lateral expansion dynamics in North America and northern Europe. *Holocene* 23, 1596–1606. <https://doi.org/10.1177/0959683613499053>.
- Sascó, R., 2015. Développement d'un outil chronostratigraphique pour les archives climatiques : datations absolues (K/Ar , $^{40}\text{Ar}/^{39}\text{Ar}$) et paléomagnétisme appliqués aux laves. PhD Thesis. Université Paris-Sud, Paris.
- Scholtès, A., 2019. Archéologie des plateaux du Béal : communes de Chalmazel (42), Saint-Pierre-la-Bourlhonne et le Brugeron (63). Rapport de prospection inventaire. SRA Auvergne-Rhône Alpes, Lyon.
- Scholtès, A., 2015. Occupation du sol et dynamique de peuplement du Néolithique au Moyen Âge classique dans la partie méridionale des Monts du Forez (Massif Central oriental, France). Master Degree. Université Blaise Pascal, Clermont-Ferrand.
- Scholtès, A., PhD in preparation. Pratiques agro-sylvo-pastorales sur les Hautes-Chaumes des monts du Forez (Massif Central oriental). PhD Thesis in preparation, University of Lyon, Saint-Etienne.
- Serreyssol, K., Cubizolle, H., Tourman, A., Latour-Argant, C., 2012. Holocene evolution of two ponds on the Deves plateau in the French Massif Central. *Diatom Res.* 27, 189–211. <https://doi.org/10.1080/0269249X.2012.711994>.
- Simonnet, L., 1984. *Le peuplement dans l'antiquité en Velay. Occupation des sols et économie*. Les Cahiers de la Haute-Loire, Le Puy-en-Velay.
- Stephens, L., ArchaeoGLOBE Project authors, 2019. Archaeological assessment reveals Earth's early transformation through land use. *Science* 365, 897–902. <https://doi.org/10.1126/science.aax1192>.
- Stuiver, M., Reimer, P.J., 1993. Extended 14C data base and revised CALIB 3.0 14C Age calibration program. *Radiocarbon* 35, 215–230. <https://doi.org/10.1017/S0033822200013904>.
- Surmély, F., de Hervé, Goër, de, A., Errera, M., D'Amico, C., Santallier, D., Forestier, F.-H., Rialland, Y., 2001. Circulation des hâches polies en Auvergne au Néolithique. *Bull. Soc. Prehist. Fr.* 98, 675–691. <https://doi.org/10.3406/bspf.2001.12569>.
- Thébaud, G., Cubizolle, H., Petel, G., 2003. Étude préliminaire des hauts-marais ombrotrophes du Forez septentrional et des Bois-Noirs (Massif central, France) : végétation, évolution et dynamique actuelle. *Acta Bot. Gall.* 150, 35–57. <https://doi.org/10.1080/12538078.2003.10515985>.
- Tourman, A., 2007. *Fonctionnement, dynamique et intérêt paléo-environnemental des tourbières du plateau volcanique du Devès (Velay, Massif Central)*. PhD Thesis. Université Jean Monnet, Saint-Etienne.
- Van Geel, B., Aptroot, A., 2006. Fossil ascomycetes in Quaternary deposits. *Nova Hedwigia* 82, 313–329. <https://doi.org/10.1127/0029-5035/2006/0082-0313>.
- Vannière, B., Power, M.J., Roberts, N., Tinner, W., Carrión, J., Magny, M., Bartlein, P., Colombaroli, D., Daniau, A.L., Finsinger, W., Gil-Romera, G., Kaltenrieder, P., Pini, R., Sadori, L., Turner, R., Valsecchi, V., Vescovi, E., 2011. Circum-Mediterranean fire activity and climate changes during the mid-Holocene environmental transition (8500–2500 cal. BP). *Holocene* 21, 53–73. <https://doi.org/10.1177/0959683610384164>.
- Véron, C., 2017. *Moulines. Technique, espace et société au bord de l'eau*. Editions du Chassel, Lagorce.
- Walker, M.J.C., Berkelhammer, M., Björck, S., Cwynar, L.C., Fisher, D.A., Long, A.J., Lowe, J.J., Newnham, R.M., Rasmussen, S.O., Weiss, H., 2012. Formal subdivision of the holocene series/epoch: a discussion paper by a working group of INTIMATE (integration of ice-core, marine and terrestrial records) and the sub-commission on quaternary stratigraphy (international commission on stratigraphy). *J. Quat. Sci.* 27, 649–659. <https://doi.org/10.1002/jqs.2565>.
- Whitehouse, N.J., Bunting, M.J., McClatchie, M., Barratt, P., McLaughlin, R., Schulting, R., Bogaard, A., 2018. Prehistoric land-cover and land-use history in Ireland at 6000 BP. *Global Change* 26, 24–25. <https://doi.org/10.22498/pages.26.1.24>.