



# The Late Quaternary flora, vegetation and landscape of the Massif Central (France) under climatic and anthropogenic constrains

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## Editorial

### The Late Quaternary flora, vegetation and landscape of the Massif Central (France) under climatic and anthropogenic constraints

The Massif Central is a large mountainous region that covers approximatively 85000 km<sup>2</sup> in the center of France. It displays, in geographical terms, a heart shape, with – from the north to the south – the Millevaches mountain plateau, the Chaine des Puys volcanic chain, the Sancy, the Dore, Cantal, and Aubrac mountains in the west, as well as the Morvan mountains, the Livradois-Forez, the Pilat, Margeride, Devès and Velay mountain entities in the east, before reaching the Tanargue, and Cevennes mountain margins in the south (Fig. 1). In between, these groups are separated by two low-elevation basins: the Limagne basin and the Stephanian basin with the main towns of Clermont-Ferrand and St-Etienne, respectively (Fig. 1). The whole Massif Central is a mid-mountain area, mainly composed by high mountain plateaus and more or less rounded peak areas. The highest mountain peak in the Massif Central is the top of the Massif du Sancy in Auvergne (1886 m a.s.l.).

The climate of the Massif Central is dominated by oceanic conditions with strong mountain effects, so that the mean annual temperature ranges are around 4–5 °C dependant of the location, with rather cold winters (mean in January of ca. – 6 °C) and warm summers (mean in July of ca. 20 °C). The average rainfall varies from 900 to 1200 mm/year (with a rather even distribution over the year) in most of the Massif Central; however, at altitudes above 1300 m a.s.l. it may also reach more than 1400 mm/year. The western part of the Massif Central and the south (Cevennes) are the areas with the highest rainfall. Generally, the rain is reaching its maximum in spring and autumn/winter (so-called cévenol floods, for instance), whereas from October to May precipitations frequently also consist of (heavy) snowfall.

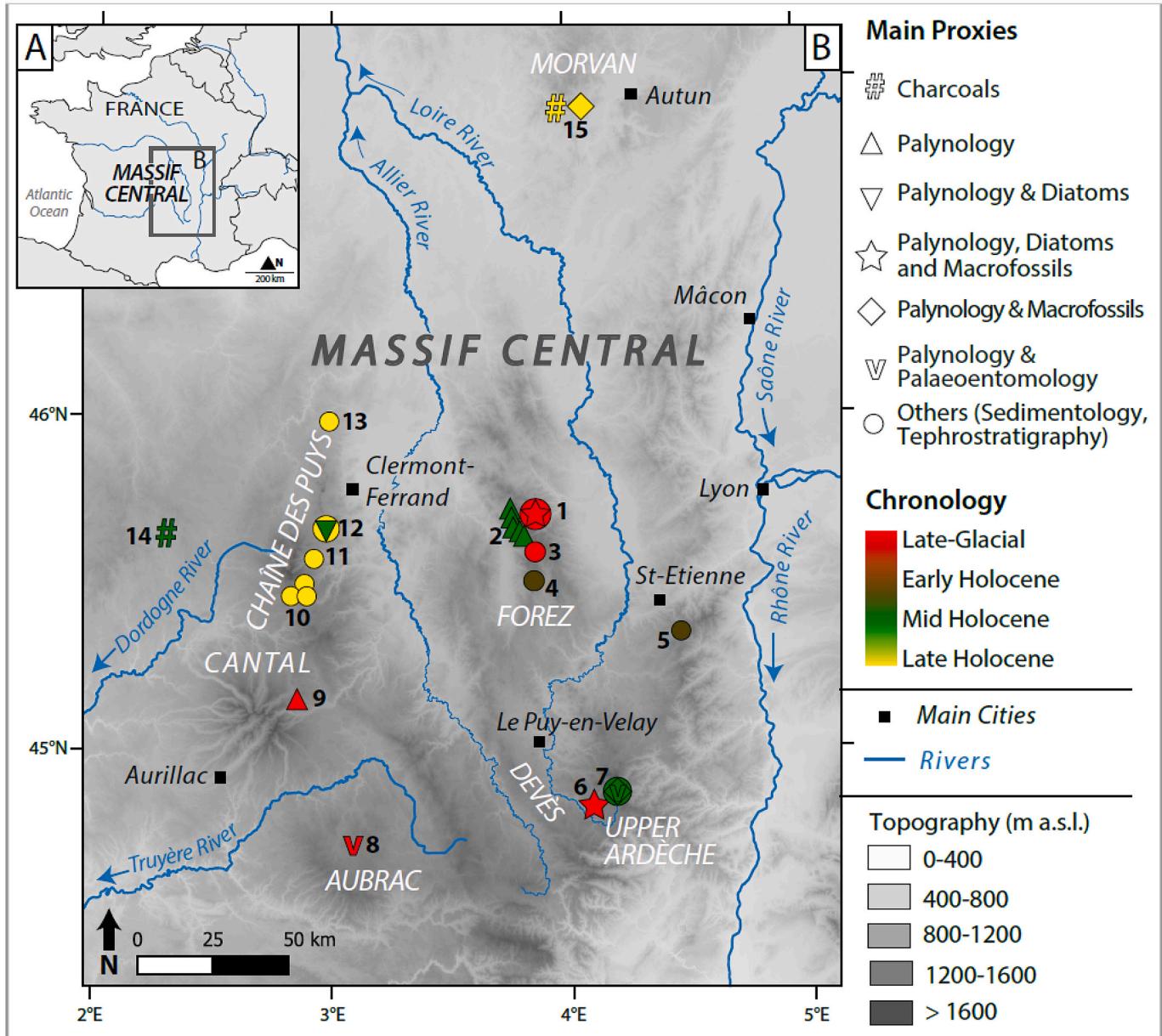
Geologically, large areas of the Massif Central are characterised by granite-migmatitic basements linked to the Variscan orogeny during the Late Paleozoic continental collision between Laurussia (Euramerica) and Gondwana (ca. 360–290 Ma) and resulting in the formation of the Pangaea supercontinent. Later, due to the regular volcanic activities in this mountain range, basaltic outflows as well as phonolitic protrusions affected the area since the Upper Miocene (11–7.5 Ma). The most recent volcanic events consisted of Maar explosions and Strombolian-type eruptions during the Late-Pleistocene (Devès, Upper Ardèche) and the Early to Late Holocene (Chaine des Puys volcanos; Fig. 1). During the Last Glacial Maximum (ca. 25000–18000 years ago) some of the highest mountain peaks of the Massif Central (above 1400 m a.s.l.) were glaciated with small ice caps (probably only up to 30 m thick). Thereafter, the today's soils (including histosols, i.e. peat) evolved with the start of the Late-Glacial ca. 18000 years ago. Late-Glacial and Holocene lakes, and subsequently mires, developed in volcanic craters or contemporary geomorphological structures (such as small basins), so providing very

valuable sedimentary archives for palaeoecological research.

The first palaeoecological studies related to the Massif Central were published as soon as a century ago (Braun-Blanquet, 1923), and in the subsequent years (Braun-Blanquet and Denis, 1926; Denis et al., 1927; Firbas, 1931; Kielhauser, 1936). During the 1940s, numerous studies of Georges Dubois, partly in collaboration with C. Dubois and F. Dubois, as well as G. Lemée, were at that time, pioneering for the European knowledge and understanding of Holocene vegetation changes (Dubois et al., 1942, 1944a,b, 1945; Dubois, 1944a,b,c; Dubois and Dubois, 1946; Dubois and Hartopp, 1943; Lemée, 1939, 1940, 1941, 1945, 1946, 1949). Interestingly, these studies on the history of the bogs and forests in the Massif Central were published during the Second World War, as the French government initiated them in order to evaluate the potential for the extraction of peat as fuel during these times of crisis (Laplace-Dolonde and Grégoire, 2009). These pioneering studies already identified important bioclimatic fluctuations during the Holocene, as well as for the Late Glacial, for example in the peat sequences from the Cantal Mountains. In addition, some palaeoecological studies were carried out on archaeological sites (Derville and Firtion, 1951).

Thereafter, most palaeoecological studies were done by a few researchers, only, generally using palynological methods up to the 1950s–1960s (Lemée, 1951, 1952, 1953a,b, 1955, 1956; Elhai, 1969). In parallel, however, first groundbreaking macrofossil studies were performed for the Massif Central by Lang and Trautman (1961) such to allow the reconstruction of very local flora and vegetation changes. Then, at the end of the 1970s and until the 1990s, a wave of studies and publications emerged, mainly carried out by palynologists and palaeoecologists of the Laboratory of Historical Botany and Palynology at the University of Marseille, France (lead by Armand Pons, Jacques-Louis de Beaulieu, Maurice Reille), as well as from the Laboratory for Palaeobotany and Palynology at the University of Utrecht, The Netherlands, lead by C. Roel Janssen (Coûteaux, 1978, 1984a,b; de Beaulieu, 1974; de Beaulieu et al., 1982, 1984, 1985b, 1988, 1991; Denèfle et al., 1980a,b; Reille and de Beaulieu, 1981, 1990; Janssen and van Straten, 1982; Camping, 1984; Pons, 1985; Marbus, 1987; Reille et al., 1985, 1992; Guenet, 1986; van de Laarschot, 1987; Guenet and Reille, 1988, 1990; Pons et al., 1988; Lutgerink et al., 1989; Reille, 1989, 1991; Swertz, 1989; Janssen, 1990).

In 1984, the University of Marseille research team led by Armand Pons and Jacques-Louis de Beaulieu had the chance to organise an excursion of the 11th International Meeting of the European Quaternary Botanists to the Massif Central (June 28 – July 2, 1984), which allowed to present in-situ (Fig. 2) major palynological sequences to the leading International palaeoecologists of that time (de Beaulieu et al., 1985a;



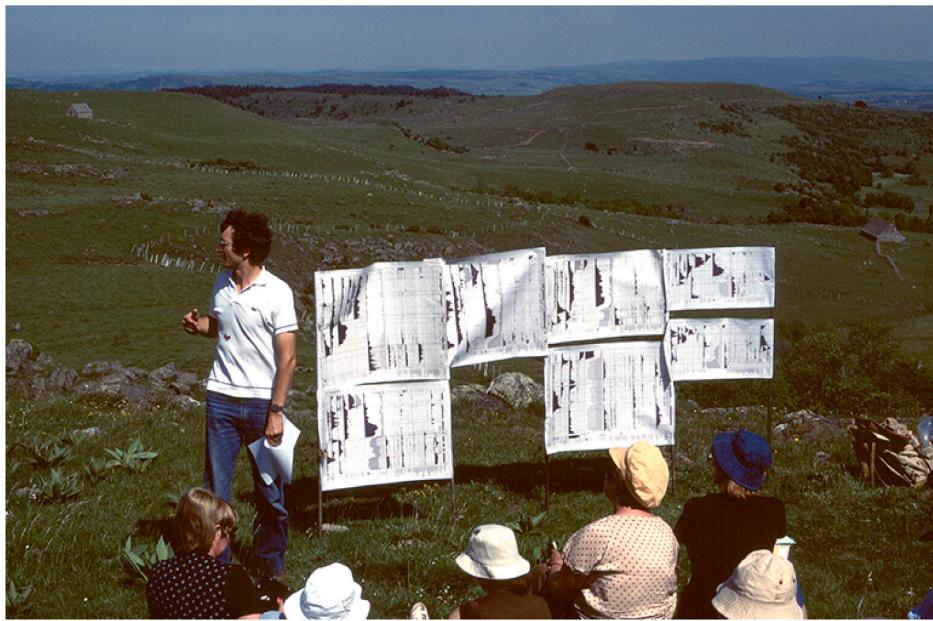
**Fig. 1.** A. Location of the Massif Central in France, and B. Location of the main Late Quaternary palaeoecological and palaeoclimatological sites studied across the Massif Central region (France) and from which the results are reported in this special issue of *Quaternary International*. The location of the main proxies and sediment stratigraphies (from lakes, peat-bogs, and soil profiles) are shown on the topographical map, as well as the timespan and chronology the sites deal with. The site numbers and names are: 1) Gourd-des-Aillères ([Cubizolle et al., 2022](#), this volume; [Bos et al., 2022](#), this volume; [van der Knaap et al., 2022](#), this volume), 2) Gros Fumé, Colleigne, Petit Char, Pierre-sur-Haute, Source Captée ([van der Knaap et al., 2022](#), this volume), 3) Gourgon ([Jouannic et al., 2022](#), this volume), 4) Molhiac ([Jouannic et al., 2022](#), this volume), 5) La Digonnière ([Jouannic et al., 2022](#), this volume), 6) La Narce du Béage ([Dendievel et al., 2022a, 2022b](#), this volume), 7) Pialeloup ([Dendievel et al., 2022a, 2022b](#), this volume), 8) Les Roustières ([Ponel et al., 2022](#), this volume), 9) Lapsou ([Duprat-Oualid et al., 2022](#), this volume), 10) Pavin, Chauvet, Montcineyre ([Chassiot et al., 2022](#), this volume), 11) Chambon, Lacassou ([Chapron et al., 2022](#), this volume), 12) Aydat ([Beauger et al., 2022](#), this volume; [Chapron et al., 2022](#), this volume), 13) Tazenat ([Chapron et al., 2022](#), this volume), 14) Mirambel ([Bal and Garcia-Alvarez, 2022](#), this volume), 15) Mont Beuvray, Bibracte ([Petřík et al., 2022](#), this volume). Cartography A.-M. Dendievel (University of Lyon, Université Claude Bernard Lyon 1, ENTPE, France).

Pons, 1985). This excursion and the subsequent scientific conference was attended by more than 50 palynologists and palaeoecologists (Fig. 3), and impacted very much on the long-term setting up of a strong, still active, palynological and palaeoecological research unit at the University of Marseille (now University of Aix-Marseille).

In the Limousin, Chaîne des Puys, Morvan and Forez Mountains some palaeoenvironmental studies were subsequently combined with geomorphological and geological studies (Valadas, 1984; Etlicher, 1986; Etlicher et al., 1987; Juvigné et al., 1996; Vergne, 1989; Juvigné and Bastin, 1995; Juvigné and Stach-Czerniak, 1998), and were followed by

other studies up to the early 21st century (Richard, 1996; Allée et al., 1997; Allée, 2003; Miras, 2004; Miras et al., 2003, 2004a; Ballut et al., 2006; Prat, 2006).

Multidisciplinary studies (combining archaeology, geomorphology, geochemistry, diatomology, palynology, and historical documents) were performed to reconstruct specific local vegetation trends, as well as the landscape development since the Neolithic period more than 7000 years ago (Daugas and Raynal, 1987, 1989; Michelin, 1995; Michelin et al., 2001; Miras et al., 2004b; Stebich et al., 2005; Prat and Cabanis, 2006; Trément et al., 2007; Ballut et al., 2008, 2012; Macaire et al., 2010;



**Fig. 2.** Jacques-Louis de Beaulieu presenting the palynological results from the Brugeroux site during the excursion of the 11th International Meeting of the European Quaternary Botanists to the Massif Central (June 28 – July 2, 1984). Photo Harry John Betteley Birks (University of Bergen, Norway).



**Fig. 3.** Group photo of the participants of the 11th International Meeting of the European Quaternary Botanists at the University of Marseille (July 1984). Photo Jacques-Louis de Beaulieu (University of Aix-Marseille, France).

Lavrieux et al., 2013; Miras and Guenet, 2013; Ballut and Michelin, 2014; Ledger et al., 2015; Miras, 2015; Defive et al., 2018). All these studies illustrated main palaeoecological changes due to anthropogenic action since the Neolithic period due to small-scale agrarian development. During the Bronze Age and first part of the Iron Age (Hallstatt period), the agricultural sustainability system became more complex and varied in the Massif Central, probably mainly due to short- and long-term climatic fluctuations. Then, from the second part of the Iron Age (La Tène period) onwards, and during the Roman Period, the human impact on the landscape massively increased, including the active drainage of wetlands. This often resulted in an increase in erosion and/or geomorphological instability until the end of the Late Antiquity and during the Early Middle Ages (4th to 6th century AD). Thereafter, during the High and Late Middle Ages and the Modern Era, the Massif Central was characterised by further, large-scale drainage activities in order to allow a rather intensive agriculture as well as extensive live-stock husbandry.

In this context lots of geomorphological, palynological, diatomological, macrofossil, as well as palaeoecological studies were performed since the late 1990s by the research group of Hervé Cubizolle at the University of Saint-Etienne (France), thanks to the interdisciplinary environmental PIREN-Program ("Programme Interdisciplinaire de Recherches sur l'Environnement") of the French National Research Centre (CNRS), which since 2001 became the "Zone Atelier Loire". This research was also supported by the Regional Directorate of Cultural Affairs (DRAC), the AGES program ("Ancient Geomorphological EvolutionS of the Loire"), and the "Etablissement Public Loire" (Argant and Cubizolle, 2005; Cubizolle, 2005; Cubizolle et al., 2005, 2012, 2013, 2014, 2015, 2016; Serieyssol et al., 2011, 2012; Dendievel et al., 2015, 2019, 2020; Fassion et al., 2015; Dendievel, 2017). In addition, substantial palaeoecological studies concerned the formerly neglected areas, such as the Morvan Mountains (Jouffroy-Bapicot, 2010; Jouffroy-Bapicot et al., 2008, 2013).

Besides all these studies dealing with the Late-Glacial and Holocene

vegetation and landscape changes in the Massif Central, the Velay volcanic craters also provided rare long Late-Pliocene and Pleistocene pollen sequences (Ablin, 1991; de Beaulieu and Reille, 1992; Degeai et al., 2013; Reille et al., 1998, 2000; Argant and Bonifay, 2011; Argant, 2022/in press).

Interestingly, only few summarizing reviews were published on the past Quaternary vegetation and landscape changes in the Massif Central (Reille et al., 1992; Reille, 2013) summarizing 23 years of palynological work by the author, including a large number of Massif Central sites. These reviews and the large attention the Massif Central got by the palaeoecological researcher community due to International excursions organised since 1984 inspired us during the preparation of this special issue for *Quaternary International*.

The success of the 1984 excursion lead the Swiss and International palynologists and palaeoecologists to visit the Massif Central as during the 14th International Moor Excursion in 1990 (Sept. 3–9, 1990). This excursion was organised by Brigitte Ammann and Gerhard Lang from the University of Bern, Switzerland, together with Maurice Reille from the University of Marseille (Wick, 1990), and was attended by 30 International specialists in their field.

After more than 25 years, the 41st International Moor Excursion returned back to the Massif Central in 2017, and was organised by the Austrian/French team of Jean Nicolas Haas (University of Innsbruck), as well as Hervé Cubizolle and André-Marie Dendievle, both from the University of Jean Monnet Saint-Etienne (now University of Lyon). More than 50 palynologists and palaeoecologists from all over the world (Figs. 4 and 5) visited 20 palaeoecological sites throughout the Massif Central (Fig. 1). Here in the field, the idea came up, to publish most of the research presented orally in the field by the according researchers themselves (and some additional ones of colleagues unable to attend) within this special issue of *Quaternary International*.

The present volume therefore comprises 13 contributions on the Quaternary vegetation history of the Massif Central from 72 authors out of nine countries (France, Austria, Canada, the Czech Republic, Norway, Sweden, Switzerland, The Netherlands, and The United States of America). Thanks to more than 40 International reviewers and the

handling editor of *Quaternary International*, Alexander Francke (University of Adelaide, Australia), this volume allows an up-to-date view on the standings of Late Quaternary palaeoecological research on the Massif Central.

The publications included in this special issue are presented in the Late Quaternary chronological order of their subjects, and absolute ages of the sediment stratigraphies studied. These contributions deal with the following subjects (in alphabetical order): Agro-pastoral activities, altitudinal forest limits, archaeological finds, beetles (Coleoptera), bog and fen environments, chironomids, climatic change, cultural landscapes, cyanobacteria akinetes, diatoms, ecosystem acidification, *Fagus sylvatica*-*Abies alba* forests, floods, forest history, geoarchaeology, geochemistry, historical documents, the Holocene, human impact, hydro-acoustic surveys, lacustrine sediments, landslides, land-use changes, the Late-Glacial, macrofossils, metal pollution, mire development, modern analogue methods, Modern Times, Mutual Climatic Range Methods, non-pollen palynomorphs, palaeobotany, palaeoclimate, palaeo-earthquakes, palaeoecology, palaeoenvironments, palaeolimnology, peat mires, pedoanthracology, pollen and cryptogam spores, quantitative organic petrography, quantitative climate reconstructions, radiocarbon dating, sedimentology, soil erosion, tephra, terrestrialisation, transfer functions, vegetation history, wood determinations, woodland ancientness, as well as XRF-analyses.

The 13 publications of this special issue line up as follows: The special issue starts with six contributions on the Late-Glacial vegetation and landscape evolution of the Massif Central, such as on:

- Environmental changes during the Late-Glacial and Early Holocene at the Gourd des Aillères mire in the Monts du Forez Mountains (Massif Central, France) by Cubizolle et al. (2022, this volume).
- The Würmian Late-Glacial and early-Holocene vegetation and environment of Gourds des Aillères in the Monts du Forez (Massif Central, France) based on pollen and macrofossil evidence by Bos et al. (2022, this volume).
- Late-Glacial palaeotemperatures and palaeoprecipitations in the Aubrac Mountains (French Massif Central) reconstructed from



**Fig. 4.** Group photo of the participants of the 41st International Moor Excursion to the Massif Central (September 2017) at the Béage site. Photo André-Marie Dendievle (University of Lyon, Université Claude Bernard Lyon 1, ENTPE, France).



**Fig. 5.** Hervé Cubizolle, Jean Nicolas Haas and Jacques-Louis de Beaulieu (f.l.t.r) discussing the palynology of the Ribains Maar Lake site during the 41st International Moor Excursion to the Massif Central in September 2017. Photo Michael O'Connell (National University of Ireland Galway).

multiproxy analyses (Coleoptera, chironomids and pollen) by Ponel et al. (2022, this volume).

- Late-Glacial and Early Holocene environmental changes affecting the shallow lake basin of La Narce du Béage (Ardèche, Massif Central, France) by Dendievel et al. (2022b, this volume).
- High-frequency vegetation and climatic changes during the Late-glacial inferred from the Lapsou pollen record (Cantal, southern Massif Central, France) by Duprat-Oualid et al. (2022, this volume).
- Developing and expanding the Late-Glacial and Holocene tephro-chronological framework of France: A new contribution from the Chaîne des Puys volcanic field in the Massif Central by Jouannic et al. (2022, this volume).

The special issue continues with another seven contributions on the Holocene vegetation and landscape evolution of the Massif Central, most of them dealing with climatic changes during the Holocene, as well as with the human impact since the Neolithic revolution more than 7000 years ago. The contributions are dealing with the:

- Holocene vegetation succession and forest history in the upper Monts du Forez, Massif Central, France by van der Knaap et al. (2022, this volume).
- Multi-proxy study of the Pialeloup Bog (SE Massif Central, France) reveals long-term human environmental changes affecting peat ecosystems during the Holocene by Dendievel et al. (2022a, this volume).
- Evaluating Holocene natural hazards in the French Massif Central from a regional lake sediment approach by Chapron et al. (2022, this volume).
- Anthropogenic versus natural control on lacustrine sediment yield records from the French Massif Central by Chassiot et al. (2022, this volume).
- 6700 years of diatom changes related to land use and climatic fluctuations in the Lake Aydat catchment (Auvergne, France): Coupling with cyanobacteria akinetes cyanobacteria, pollen and non-pollen palynomorphs data by Beauger et al. (2022, this volume).
- Landscape evolution around the oppidum of Bibracte (Northern Massif Central, France) from the Late Iron Age to the Post-Mediaeval period by Petřík et al. (2022, this volume).

- Inferring the ancientness of the Mirambel woodland from soil charcoal: A local exception to the regional pattern of the Millevaches plateau (Limousin, Massif Central, France) by Bal and Garcia-Alvarez (2022, this volume).

During the last three decades, the research on the Quaternary flora, vegetation, climate and anthropogenic impact in the Massif Central has received increased attention from Quaternary palynologists and palaeo-ecologists worldwide, due to the high number of peatlands and lakes ideal for this research. In addition, the key location of this mid-mountain area inbetween the Atlantic Ocean and the European continental climatic systems makes it a perfect place to test hypotheses on the past local and regional climatic systems, being so relevant for whole Central Europe.

In addition, increasing archaeological evidence of early settlements and agricultural activities since the Neolithic period more than 7000 years ago, makes it possible to test hypotheses of past human impact in the area, and have brought the area in the forefronts of the according research. So, and as shown in this special issue, the current research on the Late Quaternary vegetation and landscape in the Massif Central is highly active and deserves greatly our attention. In this context, it has to be stated that the palaeoecological research on the Late Quaternary flora, vegetation and landscape evolution already started exactly 100 years ago, so that the Massif Central was one of the first mountain areas worldwide to have been studied in details in palynological and palaeoecological terms.

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