An updated synthesis on landscapes and climate history in Val Camonica since the late Upper Paleolithic from off-site natural archives

Roberta Pini *, Cesare Ravazzi *, Amelia Aceti *, Lorenzo Castellano **, Renata Perego ***, Francesca Vallè ****

Summary

Sediments accumulated at the bottom of lakes and mires are valuable archives of past environmental and climate history. Plant micro- and macrofossils preserved therein allow for quantitative vegetation reconstruction at local and regional scale, and offer an off-site view to human history and activities. When palaeobotanical analysis are coupled with ^{14}C dating of upland plant remains, events can be set in a rigorous chronological frame. Multi-proxy analysis of stratigraphic sequences retrieved along the Val Camonica incision and lateral valleys trace the history of this prealpine sector since the last deglaciation and describe the effects of both climate change and human activities on plant landscapes. Palynological records so far used for palaeoenvironmental reconstructions can be revisited thanks to the recent development of statistical approaches of regression and calibration allowing pollen-based quantitative estimations of past climate variables (temperature and precipitation regimes). A valuable example from the study area is provided by the high-resolution Late Glacial - Holocene palaeoecological record from Pian di Gembro, where the first quantification of mean annual temperature for the last 15.5 ka was recently obtained from fossil pollen spectra.

Riassunto

I sedimenti deposti al fondo di laghi e torbiere costituiscono importanti archivi della storia dell'ambiente e del clima. I resti vegetali micro- e macroscopici ivi conservati consentono di ricostruire la storia della vegetazione locale e regionale. La maggior parte di questi archivi sono esterni agli insediamenti umani, ma registrano quantitativamente le attività dell'uomo (off-site records). Affiancando i dati paleobotanici a datazioni ^{14}C su resti di vegetali di ambiente terrestre è possibile collocare gli eventi in una sequenza cronologica rigorosa. L'analisi multi-proxy di successioni stratigrafiche provenienti dalla Val Camonica e dalle valli laterali ha permesso di tracciare la storia di questo settore prealpino a partire dall'ultima deglaciazione e di descrivere gli effetti sul paesaggio vegetale sia dei cambiamenti climatici che delle attività antropiche. Le registrazioni palinologiche, finora usate per ricostruzioni paleoambientali, possono essere rivisitate alla luce del recente sviluppo di tecniche statistiche di regressione e calibrazione che consentono di ottenere stime quantitative di parametri paleoclimatici (temperature e precipitazioni) su base pollinica. Un esempio per l'area di studio è rappresentato dalla sequenza pollinica tardoglaciale - olocenica del Pian di Gembro, da cui è stata di recente ottenuta la prima ricostruzione quantitativa delle temperature medie annue degli ultimi 15.5 ka a partire da dati pollinici fossili ad alta risoluzione.

Introduction

Anoxic conditions at the bottom of lakes and mires allow the preservation and fossilization of organic debris made up by micro- and macroscopic remains of plants and animals. These habitats are well-known as biodiversity hot spots, but their relevance as palaeoecological, palaeoclimatic and archaeological archives is often neglected. A wide geographic and altitudinal distribution, combined with their sensitivity in recording climate and environmental changes, actually make them a precious source to reconstruct the evolution of plant landscapes, climate and human history. Mountain ponds excavated for animal watering provide favourable conditions for sediment accumulation and archiving of environmental information, too.

This paper highlights the potential of stratigraphic sequences in Val Camonica and tributary valleys as archives of local and regional landscape history from the late Upper Paleolithic (Fig. 1). A synthesis of the current knowledges is presented, as evidenced by palaeoecological studies on mostly off-site natural archives (Fig. 2 - 3). Off-site sequences external to human settlements are not directly biased by human processes forming archaeological deposits. The first continuous Late Glacial - Holocene reconstruction of mean annual temperatures, based on the fossil pollen spectra from Pian di Gembro, is here presented. A previous palaeoecological study from this locality (Pini 2002) is revisited in a palaeoclimate perspective, showing that "old" data, when looked with different eyes, can provide further interesting information.

In 1979 UNESCO declared Val Camonica as World Heritage site as cradle of the most important rock art culture in the Alps. This area is therefore a hotspot for disentangling the history of ecological relationships between human civilizations, mountain environment and climate change. Despite extensive work so far done surveying and interpreting rupestrian art of the Camuni civilization from the middle Neolithic to the Middle Ages (Anati 2013), there are still many gaps in material culture and environmental frameworks.

* CNR - Institute for the Dynamics of Environmental Processes, Research Group Vegetation. Climate and Human Stratigraphy, Laboratory of Palynology and Palaeoecology, Milano (I). Corresponding author Roberta Pini roberta.pini@idpa.cnr.it

** New York University, Institute for the Study of the Ancient World, New York (USA).

*** Integrative Prehistory and Archaeological Science, University of Basel (CH).

**** University of Milano - Bicocca, Dept. of Environmental and Earth Sciences, Milano (I).

After the withdrawal of the Oglio Glacier - the landscape of the Paleolithic hunters

The final collapse of the Oglio Glacier took place around 18.5 – 17.5 ka cal BP (Ravazzi *et al*. 2012) (Fig. 4). At the end of the Gschnitz advance, 16 - 15.3 ka cal BP (Ivy-Ochs *et al*. 2005), the valley floor and the largest alpine south-facing valleys were ice-free. Paraglacial conditions, persisting up to the onset of the Bølling - Allerød interstadial, prevented a fast colonization by woody vegetation. Pian di Gembro (Pini 2002), Passo del Tonale, Col di Val Bighera (Gehrig 1997) and Loa (Ravazzi *et al.* 2014a) peat bogs provide evidence of fast afforestation in Val Camonica at the interstadial onset. Some hundred years after the beginning of the Bølling - Allerød interstadial the treeline was located at ca. 1700 m asl and conifer forests were rapidly thickening (Fig. 4). The find of an Upper Paleolithic hearth dated to ca. 13.8 ka cal BP at Cividate Camuno (Poggiani Keller 1999) and an early rock art figure at Luine (Fig. 2), possibly Epigravettian in age (Martini *et al.* 2009), suggest a scattered and occasional human peopling during the interstadial inside the Val Camonica valley floor. The occurrence of human groups in the area can not be directly related to glacier withdrawal, given that deglaciation took place nearly 4 ka earlier. Animals sheltering in mountain forests were games for Upper Paleolithic hunters and gatherers, depending on the exploitation of natural resources (wild fruits, meat, skin and bones) for their survival.
The Younger Dryas (12.8 - 11.7 ka cal BP) climate deterioration led to the lowering of the forest limit down to ca. 1500 m asl and to a renewed expansion of xerophytic vegetation and grasslands in the montane and subalpine belts. No data exist about the dynamics and peopling of the valley floor in this time span.

From the Holocene onset to the Atlantic period, across the 8.2 ka cal BP event

A shift towards more negative isotopic $\delta^{18}O$ values is recorded in polar ice cores at 11.7 ka cal BP, giving the onset to the present interglacial, i.e. the Holocene. The climate amelioration led to a fast timberline rise in the Alps, later reaching a position as high as 2400 - 2500 m in the inner Alps (Tinner 2007). The continental climate characterizing the Alps during the first Holocene millennia ended at 8.2 ka cal BP, when moister conditions started to prevail (onset of the Atlantic period). According to Tinner & Ammann (2001) increasing humid air masses from west and north-west resulted in reduced annual temperatures and increasing precipitations along the Alpine Chain.
With the 8.2 ka cal BP event, *Picea abies* and *Abies alba* expanded at middle altitudes in Val Camonica (Pini 2002). Even afterwards, the treeline remained very high as testified by fossil *Pinus cembra* trunks in mires at 2400 m asl near Passo di Gavia (Aceti 2006). Mesolithic hunting activities and forest fires in the subalpine belt are testified in the Maniva Massif (Baroni 1997; Scaife, 1997). Here a *Picea* charcoal fragment from a hearth yielded an age of 7870±50 ^{14}C a BP (2σ calibration interval 8.55 - 8.8 ka cal BP, median probability 8.7 ka cal BP). A very similar age was obtained on charcoals from a pit with heat-fractured pebbles (7850±80 ^{14}C a BP, 2σ calibration interval 8.5 - 8.8 ka cal BP, median probability 8.67 ka cal BP).
The recent claim of Mesolithic occupation at Cemmo (Poggiani Keller *et al.* 2014) deserves a specific archaeobotanical investigation.
During the Atlantic period, the montane landscapes of Valtellina and Val Camonica were dominated by dense *Picea abies* and *Abies alba* mixed forests. These trees formed a wide altitudinal belt thriving both in oceanic conditions and in relatively more continental contexts.

From the Neolithic to the Copper Age

The onset of early agriculture in Val Camonica is not yet properly investigated and framed in time, despite the existence of good candidates for palaeoecological studies (Palù di Sonico, Fig. 5). This is a major gap in the understanding of the origin and development of one of the most representative civilizations of the Alpine prehistory. A research strategy document was prepared by the writing researchers (CNR-IDPA 2005) but has not received attention yet.
Sporadic pollen grains of meadow herbs point to pastures some km far from the mire of Pian di Gembro at 6.8 ka cal BP. First Cerealia pollen grains, grazing indicators and charcoal content appeared ca. 6 – 5.8 ka cal BP (Gehrig 1997). The oldest cereal pollen identified at Pian di Gembro dates back to ca. 6 ka cal BP. These data are consistent with the archaeological chronology of early settlements from Val Camonica. Indeed, the settlements of Lovere, Rogno, Luine, Cividate Camuno and Breno belong to the Square Mouth Pottery and Lagozza Cultures, dated to the IV millennium BC (Poggiani Keller 2010).
Concerning forest vegetation, a pronounced expansion of *Fagus sylvatica* started as early as 5.6 – 5.4 ka cal BP, synchronous to many other records in N-Italy (Magri *et al*. 2015; Valsecchi *et al.* 2008). Culturally, this forest change occurred in the late Neolithic, and continued in the early phases of the Copper Age. As observed at the SW-Alpine border (e.g. Brianza lakes), *Fagus* expansion followed a phase of decreasing abundance of *Abies alba* pollen in sediments and was possibly favoured by anthropic fires used by Neolithic populations for forest clearing (Wick, Möhl 2006). Other arguments, including synchronism at wide regional scale, support a concurrent climate trigger (Valsecchi *et al.* 2008). Phases of cooling and wet periods at the onset of the Copper Age (Baroni, Orombelli 1996) were responsible for a timberline depression in the Alpine realm (Tinner 2007). Consistently, at Passo di Gavia, the decline of cembran pine and expansion of *Alnus viridis* scrublands are dated to 5.8 – 5.5 ka cal BP (Aceti 2006).

The question of early mountain pastoralism

The timberline depression registered at Passo di Gavia in the first half of the IV millennium BC rises the question of climate change versus early mountain pastoralism and human impact on upper forest belts. Here we briefly summarize the status of the art in the Alps and in Val Camonica.

According to Barfield (*et al.* 2003) the origins of mountain pastoralism in the Alps can be framed in the IV millennium BC. The archaeological evidence indicate the spread of mountain and high-altitude sites, while the exploitation of high-altitude pastures is just inferred (see Marzatico 2007), being clearly documented only the agricultural practices in the mountain belt, without evidence of herding over the timberline. A positive palynological evidence, suggesting a permanent change in meadows vegetation, speaks for seasonal high-altitude herding at the onset of the Copper Age in Valle d'Aosta, Western Alps (Pini *et al.* 2013). Here the palaeobotanical evidence is supported by the analysis of coprophilous fungal spores and of nutrient cycling into an Alpine pond supposed to be used for animal husbandry (Pini *et al*., in preparation). Molecular methods yield a doubtful evidence for late Neolithic high-altitude pastoralism including cows in the Western French Alps (Giguet-Covex *et al.* 2013). In the Eastern Alps, the palaeobotanical evidence is restricted to the Copper / Bronze Age transition (Oeggl 1994). A later, Bronze Age onset of pastoralism is inferred at Passo di Gavia, at the headwall of Val Camonica (Aceti 2006) and at Pian Venezia, in the nearby Val di Sole (Speranza *et al*. 1996).

The climate framework for the Neolithic / Copper Age transition highlights a significant cooling, triggering forest depression, with coeval expansion of subalpine scrublands and Alpine grasslands between 5.8 - 5.4 ka cal BP. This natural setting was favourable for the onset of high-altitude herding, its effective establishment depending, however, on a number of particular local features – geographic (accessibility, steep slopes), climatic (amount of rainfall, temperature regime) and natural/ecological (size of upland pastures, water availability, etc.) - and on human cultural history.

The Bronze Age

Around 4 ka cal BP *Fagus sylvatica* was the dominant forest tree both at the prealpine margin and in the montane belt of outer Alpine valleys. Mixed stands of *Fagus*, *Picea* and *Abies* were common in the Central Alps up to the first half of the Subboreal period. However, in Val Camonica *Fagus* did not reach the high forest cover values reconstructed in adjacent mountain regions (Giudicarie range; Filippi *et al.* 2005).

With the onset of the Early Bronze Age, pollen types typical of pastures (*Rumex acetosa* and *acetosella* types, *Plantago lanceolata* type) and ruderal areas (*Urtica* and *Artemisia*) slightly increase at some sites so far studied (Pian di Gembro, Dos del Curù) testifying to a moderate expansion of meadows and alpine pastures at mid and high altitudes in Val Camonica (Fig. 4 and 6). No significant evidence for such an expansion emerges from the nearby Val Cavallina (Gehrig 1997; Pini, Ravazzi 2009). Evidence of subalpine pastures coeval to cembran pine withdrawal is available from the Passo del Gavia area. In the nearby Swiss Alps (Lower Engadin), cereal crop evidence at the montane and subalpine belt (Between 1200 and 1800 m asl) is dated to the very beginning of Bronze Age (ca. 2200 BC) and appears to be correlated to terracing construction (Zoller 1998: p. 162)

The growth of farming in the Iron Age

The Iron Age represents a main step of human demographic increase in the Alpine realm and is marked by the spread of metal tools for agriculture and forest exploitation. The development of protourban settlements and the need for wood for iron-smelting purposes promoted forest clearing and logging, especially in the valley floors. Cleared stands were then set to fire and exploited for pastoralism. However, large sectors of the Alps remained uninhabited.

Quantitative palaeoecological records from middle and high Val Camonica point to the spread of crop husbandry and pastoral activities, as seen close to the Cemmo sanctuary (Poggiani Keller *et al.* 2005). Increasing abundance of pastures, meadows and *Larix decidua* pollen are detected at Pian di Gembro (Pini 2002). Stable subalpine pastures developed also in the high Alpine belt, e.g. Passo del Gavia. From the VII century BC cereal pollen is regularly found in the stratigraphic record from Pian di Gembro, suggesting stable human settlements and cereal fields at few km distance.

A ritual deposition from the Iron Age at Spinera of Breno (Castiglioni, Rottoli 2010) contains offers of crops. Apart from cereals common in the Iron Age N-Italy, these ritual offers point to the importance of *Panicum miliaceum* in the ritual and domestic life of Lombardy. Palaeobotanical data from the archeological excavation of Cividate Camuno, via Ponte Vecchio 10, depict the plant landscape of the Val Camonica valley floor between the Late Iron Age and the Roman Period. Broad-leaved forests with oaks, hazel, lime and elm fringed the slopes, and stable cereal fields were widespread on flat areas and possibly on low-gradient slopes (Pini, Ravazzi 2010).

From the Roman time to the Middle Ages

In 16 BC Val Camonica was subdued and soon became part of the Roman system.

Iron-smelting activities developed further along the prealpine margin of Lombardy. The disruption of native conifer forests close to mines was the result of intense wood exploitation. *Larix* parkland expanded with stock breeding practices developing in more open forests. Increasing charcoal abundance in sediments indicate rising anthropic pressure in the lowland and higher up. Cereal cultivations took place in lowland areas from the II century AD. *Juglans regia* (walnut) and *Castanea sativa* (chestnut) were introduced in the valleys of Lombardy between the II century BC and the II century AD.

In the Middle Ages, intense logging for iron-smelting activities (Marziani, Citterio 1999) strongly reduced the range of *Abies alba* in Val Camonica and nearby valleys. Open areas were then used for agro-pastoral activities.

Contemporary dynamics – the link from the past to the future

In modern times (XIX-XX century), intensive coppicing, logging and clearing in the middle Val Camonica (Pini 2002; Pini, Ravazzi 2009) reduced *Abies* and *Fagus* and favoured *Picea abies*, which formed a large mountain belt. The abandonment of middle altitude fields and pastures after the Second World War promoted a further expansion of *Picea*, that today occupies a large belt compared to its natural range.

Reconstructing climate variables from pollen data: a numerical approach

In recent years, palaeoecologists assisted by statisticians and climate modellers started to explore the potential of fossil pollen as proxy for quantitative estimations of past climate variables. According to Juggins and Birks (2012) three requirements must be fulfilled to pursue this aim:

- the development of modern pollen-vegetation-climate training sets to understand the relationships between pollen rain, plant distribution and climate;
- the application of numerical techniques to the training sets, to model the relationships between pollen-vegetation occurrences and environmental conditions;
- the application of this model to pollen-stratigraphic data.

Palynological records obtained from off-site stratigraphies provide the unique opportunity to develop quantitative estimations of past temperature and precipitations. The first reconstruction available for northern Italy on a continuous Late Glacial to Holocene palynological record comes from the Pian di Gembro peat bog (Fig. 1 and 4).

Palaeotemperature reconstruction for the last 15.5 ka based on the Pian di Gembro pollen record

Vallé (*et al.* 2015) developed a pollen-based mean annual temperature reconstruction using the fossil spectra of Pian di Gembro. This reconstruction is the first direct estimation of past climate parameters in Val Camonica and nearby valleys, enabling the comparison with other climate proxies. The temperature reconstruction follows the methodology described in Pini (*et al*. 2014). It is based on 283 fossil pollen spectra from Pian di Gembro, provided with high taxonomic accuracy, a time resolution of 1 sample/60 years, a sound chronology of ten AMS ^{14}C dates from terrestrial plants and the recognition of biostratigraphic event at regional scale.

The reconstructed mean annual temperature curve for the last 15.5 ka (method: LWWA, Locally-Weighted Weighted Averaging) is presented in Fig. 4. This palaeotemperature reconstruction pinpoints events in agreement with the NGRIP record of hemisphaeric variability, such as the temperature rise during the Bølling-Allerød interstadial and at the Holocene onset, the Younger Dryas and Preboreal coolings, the 8.2 ka event. Secular events taking place in the last 3 thousand years, such as the Early Iron Age cold phase, are detected in our temperature reconstruction. They can be compared with oscillations of large alpine glaciers (Aletsch Glacier, Holzhauser *et al*. 2005; Mer de Glace, Le Roy *et al.* 2015; not shown in Fig. 4). This reconstruction is open to further elaborations. Moreover a more complete set of reconstructed past climate variables (monthly to seasonal temperature and precipitation) is needed for a detailed comparison with other climate proxies, but this first test highlights the potential of fossil pollen spectra for quantitative estimations of past temperatures.

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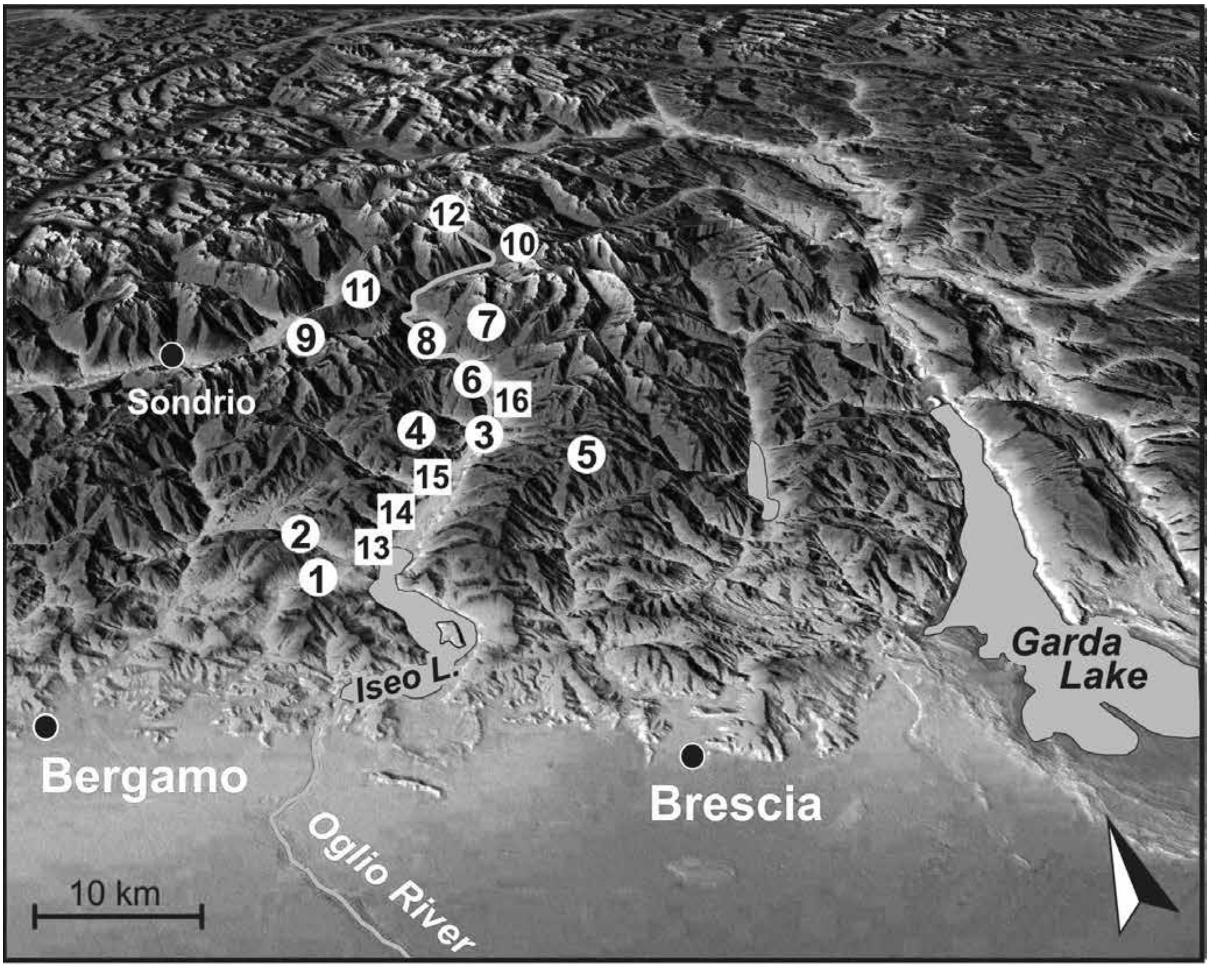
Fig. 1 - Panoramic view of the Pian di Gembro peat bog (1350 m asl, watershed between Valtellina and Val Camonica). This site provides one of the most detailed record of environmental and climate changes in a mountain habitat during the last ca. 16 ka.

Fig. 2 - Location of natural archives considered for this review circles: 1 - Gaiano (Val Cavallina); 2 - Cerete; 3 - Cividate Camuno; 4 - Lago di Lova; 5 - Laghetti del Crestoso (Maniva Massif); 6 - Cemmo; 7 - Dos del Curù, 8 - Palù di Sonico; 9 - Pian di Gembro; 10 - Passo del Tonale; 11 - Col di Val Bighera; 12 - Passo del Gavia. Early settlements mentioned in the text squares: 13 - Lovere; 14 - Rogno, 15 - Luine; 3 - Cividate Camuno; 16 - Breno.



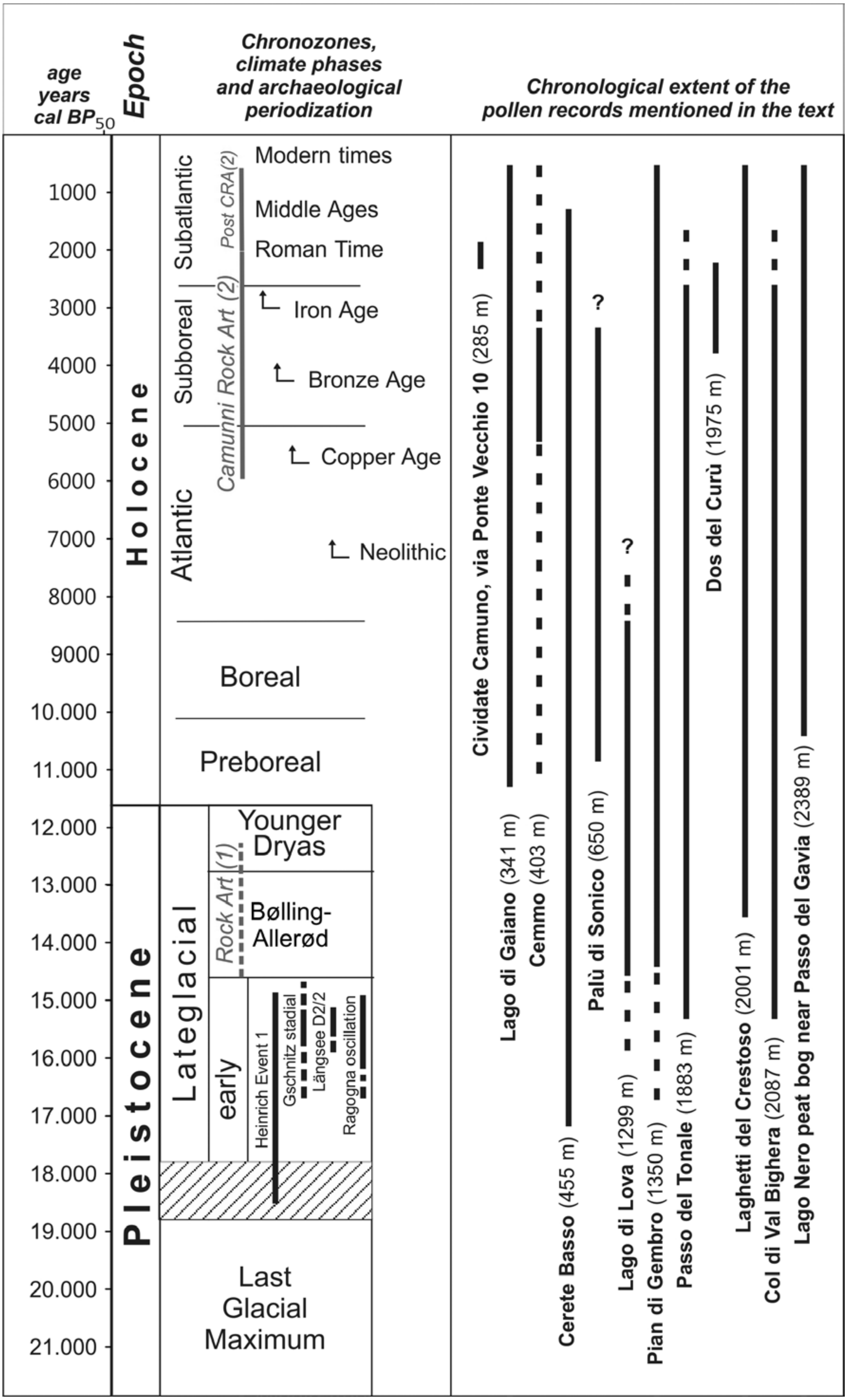


Fig. 3 - Chronozones, archaeological periodization and chronological extent of the paleoecological records available from Val Camonica. For references on the chronostratigraphic subdivisions used in this scheme, see Fig. 4.

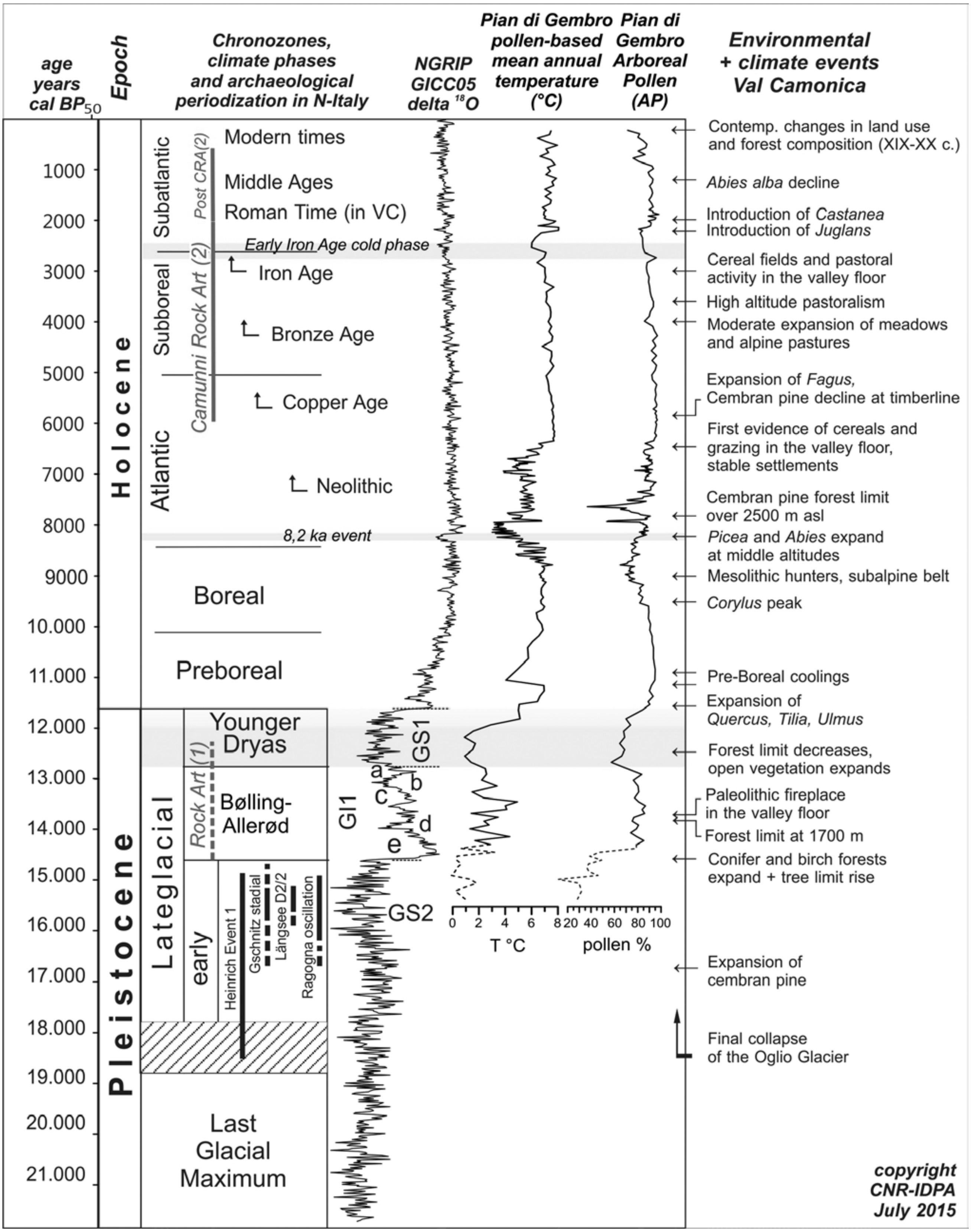


Fig. 4 - Stratigraphic scheme summarizing the main events recorded in the vegetation, climate and cultural history of Val Camonica since the last deglaciation. Chronology and climate stratigraphic subdivisions are from Mangerud *et al*. (1974), Orombelli & Ravazzi (1996), Ravazzi *et al*. (2007); Rasmussen *et al*. (2008). Duration of global LGM refer to Lambeck *et al*. (2002), Clark *et al*. (2009); Heinrich Event I to Stanford *et al*. (2011); Ragogna oscillation to Monegato *et al*. (2007), Ravazzi *et al*. (2014); Längsee cold phase to Schmidt *et al*. (2010); Gschnitz stadial to Ivy-Ochs *et al*. (2005). The Arboreal Pollen curve from Pian di Gembro is from Pini (2002). Rock Art (1) from Martini *et al*. (2009); Rock Art (2) from De Marinis (1992).

Fig. 5 - The peat bog complex called "Palù of Sonico" is a unique natural archive for the history of the valley floor of Valle Camonica, and is very close to the main areas with rock art. It deserves a specific protection and it is a good candidate for the paleobotanical research related to the early history of agriculture with the Camuni civilization.

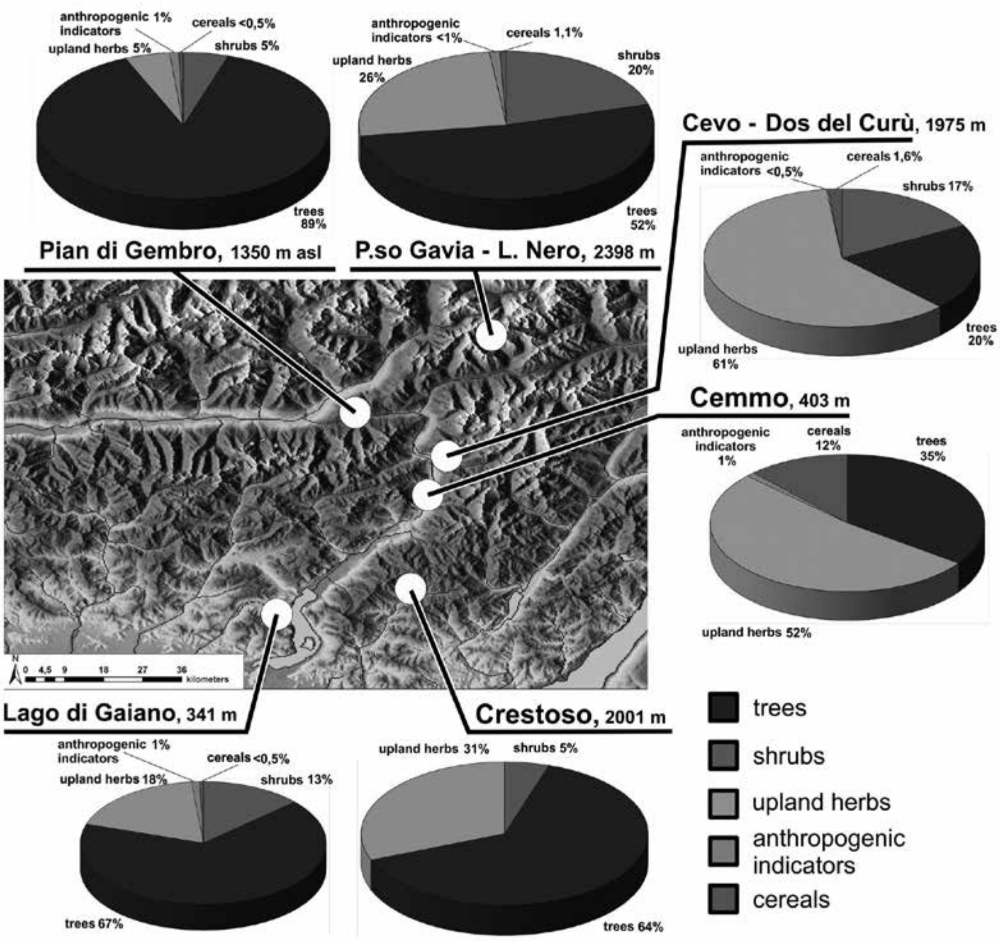


Fig. 6 - Comparison between mean pollen compositions in Bronze Age sites in the Oglio River catchment (from Ravazzi *et al.* 2014a)