The Holocene 19,7 (2009) pp. 987–1003

Lago di Bargone, Liguria, N Italy: a reconstruction of Holocene environmental and land-use history

G.M. Cruise,[1] R.I. Macphail,[2]* J. Linderholm,[3] R. Maggi[4] and P.D. Marshall[5]

([1]24 George Street, Leighton Buzzard LU7 3JX, UK; [2]Institute of Archaeology, University College London, 31–34 Gordon Square, London WC1H 0PY, UK; [3]Centre for Environmental Archaeology, Umeå University, SE-90187 Umeå, Sweden; [4]Direzione regionale per i beni culturali e paesaggistici della Liguria, Via Balbi 10, 16126 Genova, Italy; [5]Chronologies, 25 Onslow Road, Sheffield S11 7AF, UK)

Received 10 January 2008; revised manuscript accepted 30 April 2009

A HOLOCENE RESEARCH PAPER

Abstract: Sediment micromorphology, chemistry and magnetic susceptibility of basin edge deposits at the small, mid-altitude peat site of Lago di Bargone, eastern Liguria, Italy, is compared with a full Holocene palynological sequence and radiocarbon dates from the central part of the peat bog. Micromorphology and MS550 results show that Neolithic to Copper Age forest disturbances and clearings as inferred from the pollen diagrams, occurred during a period of lower water-tables and intermittent drying out of the basin edge deposits. Extensive deforestation and expansion of heath and grassland during the Iron Age and Roman periods is associated with increases in soil erosion and in micromorphological indications of burning. It is argued that the very fine size range of the charred fragments seen in thin sections and the seeming absence of charcoal of coarser size range suggest a system of light, controlled burning, possibly akin to the local tradition of using fire to control weeds and to encourage new grass and herbaceous growth, and not local *forest* clearance by fire. Micromorphology of the late-Holocene peat contains herbivore dung possibly indicating the use of the site as a watering hole by domesticated stock. The overlying colluvium displays evidence of deep-seated erosion of the local soils and geology which is most likely to have been associated with local mining activities.

Key words: Palynology, micromorphology, chemistry, land use, soil erosion, lake sediments, Italy, Holocene.

Introduction

The northern Apennines, Italy contain relatively few locations where buried soils or other open air sediments can be investigated because of their marked relative relief and long history of soil erosion. Caves, although contributing to palaeoenvironmental studies, do not contain organic sequences (Maggi, 1990, 1997; Macphail, 1992; Boschian and Montagnari-Kokelji, 2000). On the other hand, small basin peat sites located in mountainous regions that are susceptible to erosion offer the opportunity to examine the relationship between vegetation disturbances, as inferred from pollen diagrams, and evidence of soil and landscape disturbances that could have been related to such activities. The study of colluvia accumulated at a break of slope may reveal interdigitation of organic and colluvial deposits thereby providing opportunities for dating soil erosion and relating such events to land-use phases and climatic events, as inferred from other palaeoenvironmental data. Such historical information is of significance in mountainous areas, as exemplified by the northern Apennines, because of an increased interest in hazard prediction, and concerns regarding slope instability and erosion potential at a time of rural depopulation and abandonment of traditional rural practices (Bertolini *et al*., 2005; Brancucci and Paliaga, 2006). Moreover, small, mountain wetland sites, and the archives of palaeoenvironmental information they contain, as well as their flora and fauna, are increasingly threatened by a lack of traditional land use (eg, 'Wetland and other environmental archaeology sites as records of cultural landscapes', Genoa, 29–30 January 2009; www.dismec.unige.it/zum/).

The aim of this paper is to increase understanding of the development of those land-use practices from the prehistoric period onwards and to investigate the ways in which soil disturbances

*Author for correspondence (e-mail: r.macphail@ucl.ac.uk)

10.1177/0959683609343142

and erosion were connected to changing land use. A full Holocene pollen sequence from the deepest part of the small, mid-altitude peat site at Lago di Bargone, eastern Liguria, is compared with a study of its basin edge deposits. The latter includes colluvium and rockslide debris accumulated at the break of slope next to the peat bog. The basin edge deposits are studied using sediment micromorphology because this technique has been used successfully in the region to investigate archaeological soils (Allen and Macphail, 1987; Macphail, 1992). It has also contributed to identifying the causes of peat initiation of some shallow peats; soil disturbance, sediment inwash and early infilling was sometimes associated with burning and probable Copper Age forest clearances (eg, Courty *et al.*, 1989: 305–309; Cruise, 1990; Cristiano, 2009). The micromorphology of the edge deposits at Bargone is carried out within the context of standard geoarchaeological analyses of sediment chemistry and magnetic susceptibility, in order to provide an independent data set (see Goldberg and Macphail, 2006: 335–52). These sediment records are correlated with a pollen sequence using pollen stratigraphy and radiocarbon dating.

Lago di Bargone is situated about 9km north east of Sestri Levante in eastern Liguria (Figure 1). It contains one of a small number of full Holocene sedimentary sequences reported from the area, and remains the only identified palynological sequence from a mid-altitude, near-coastal environment in Liguria. Preliminary results from an earlier investigation carried out by one of the authors were reported in Macphail (1988). Subsequent coring carried out in 1989 (hitherto referred to as Bg89) showed that significant human activity was detectable within the pollen stratigraphy. Therefore in 1994 the Soprintendenza per i beni archeologici della Liguria opened up a trench across the edge of the site and overlying colluvial deposits, with the aim of finding more detailed evidence of human activity (hitherto referred to as Barg94; Figure 2).

The site and its surroundings

East Liguria is a mountainous region dominated by the NNW–SSE trending Upper Jurassic Ophiolites that comprise a complex of igneous rocks forming the major massifs of the region (Carta Geologica d'Italia, Sheet Nos 83 and 95). Valleys that cross the major structures are typically short, narrow and steep-sided (Figure 1). As a result of its position and topography, rainfall is relatively high in Liguria with 1145 mm at sea level rising to over 2000 mm in inland mountains. Rainfall maxima occur in autumn and spring, while summers are settled, warm and dry (Cantu, 1977). The prevailing winds are northerly but, as a result of topographic effects and differential heating of land and sea in summer, during the summer months the prevailing winds are modified diurnally by southerly sea breezes. For example, at Passo dei Giovi, southerly winds account for 73% of summer breezes recorded at 4.00 p.m. compared with 16% at 7.00 a.m. (unpublished data provided by Servizio Meteorologico). Typically for all mountainous regions, broad vegetation zones are characteristic of the various altitudes. In eastern Liguria these are: (a) a Mediterranean zone from 0 to 200 m, characterised by *Quercus ilex*, *Erica arborea* and cultivation of *Olea europea*, (b) a sub-mediterranean zone 200–1000 m characterised by *Quercus pubescens*, *Carpinus betulus*, *Ostrya carpinifolia* and *Castanea sativa*, and (3) a Montane zone above 1000 m characterised by *Fagus sylvatica, Corylus avellana* and occasional stands of *Abies alba* (Oberdorfer and Hofman, 1967; Orsino, 1969; Tomaselli, 1970).

Lago di Bargone (Figure 2) lies in a zone of serpentinite rocks at 831 m a.s.l., immediately below the local watershed and close to a pass that connects with Val di Vara to the north. It occupies a south-facing, roughly semi-circular basin (500 m diameter) set against an eroded cliff to the north and with spreads of rock debris mantling the surrounding slopes. An approximately 80 m diameter pond occurs in the centre of the basin but no stream enters the site, and in summer months the area of standing water shrinks by as much as two-thirds, with water levels falling by at least 1 m. The immediate catchment area is approximately 0.25 km^2. Nevertheless it is well established that pollen dispersal in mountain areas, where frequent turbulence, rising air currents and increased long-distant pollen transportation through a variety of altitudes, does not conform to the norms of pollen-vegetation models established for lowland areas (de Beaulieu, 1977; Markgraf, 1980; Court-Picon *et al*., 2005, 2006; Sjögren, 2006; Mazier *et al*., 2006).

In the central, wetter part of the site there are tall sedge hummocks while scrub communities (*Buxus sempervirens, Erica arborea, Juniperus* spp. and *Pteridium aquilinum*) occur on flatter slopes close to the site. More typically the vegetation of the area is composed of herb-rich, dry grass and heathland communities with much bare soil and exposed rock, although an absence of grazing in recent years has resulted in the development of more widespread scrub communities.

Scatters of artefacts of Middle Palaeolithic age and Neolithic and Copper Age–Early Bronze Ages have been recovered from within a few metres of the site (Figure 2). Artefacts of Copper Age–Early Bronze Age are particularly numerous (Campana *et al*., 1998). In addition to these local scatters, there are several important archaeological sites in the locality. For example, these include the jasper quarry at Valle Lagorara approximately 2 km NE, the Copper Age copper mines at Monte Loreto and Libiola, about 4 km to the south and southwest, respectively, and the Neolithic to Copper Age burial at Val Frascarese situated close to Monte Loreto. Excavation at these sites has demonstrated the economic importance of local ultramafic rocks during the prehistory of eastern Liguria, giving rise to a concentration of copper mining and jasper quarrying during the Copper/Early Bronze Age (Maggi *et al*., 1994; Campana and Maggi, 2002; Maggi and Pearce, 2005). Mining continued in this area until the twentieth century (McCullagh and Pearce, 2004).

Methods

Field and radiocarbon sampling

The Bg89 sequence was obtained by a series of overlapping cores removed from the deepest point of the site (434 cm) with a 60 cm piston corer of 5 cm diameter. In the laboratory four sample slices were cut from the same cores as those used for pollen analysis and submitted to the NERC radiocarbon dating laboratory at East Kilbride, UK (SRR-3813, 3814, 3815, 3816). The samples were processed according to methods outlined in Stenhouse and Baxter (1983) and dated using Liquid Scintillation Spectrometry (Noakes *et al*., 1965). The two radiocarbon measurements from Groningen, the Netherlands (GrN-14433, 14434) were obtained by one of the authors during a previous investigation of the site (Macphail, 1988). These samples were pre-treated using the acid/alkali/acid method (Mook and Waterbolk, 1985) and measured using gas proportional counting (Mook and Steurman, 1983). Approximate positions for these two dates (see Figure 4, Table 1) are based on biostratigraphical and depth comparisons with the Bg89 cores. As the precise vertical relationship of these two samples to the four measurements from the main core is unknown they have been omitted from the depositional modelling (see below). Outlier analysis showed a 62% probability that GrN-14433 was an outlier and 100% for GrN-14434.

In 1994 the Soprintendenza per i beni archeologici della Liguria opened up a 50 m long trench extending from the edge of the peat bog into the surrounding colluvial deposits in a westerly direction towards previously mapped scatters of Neolithic and Copper Age finds (Figure 2). Overlapping column samples were removed from the exposed section and subsampled for pollen, chemical and

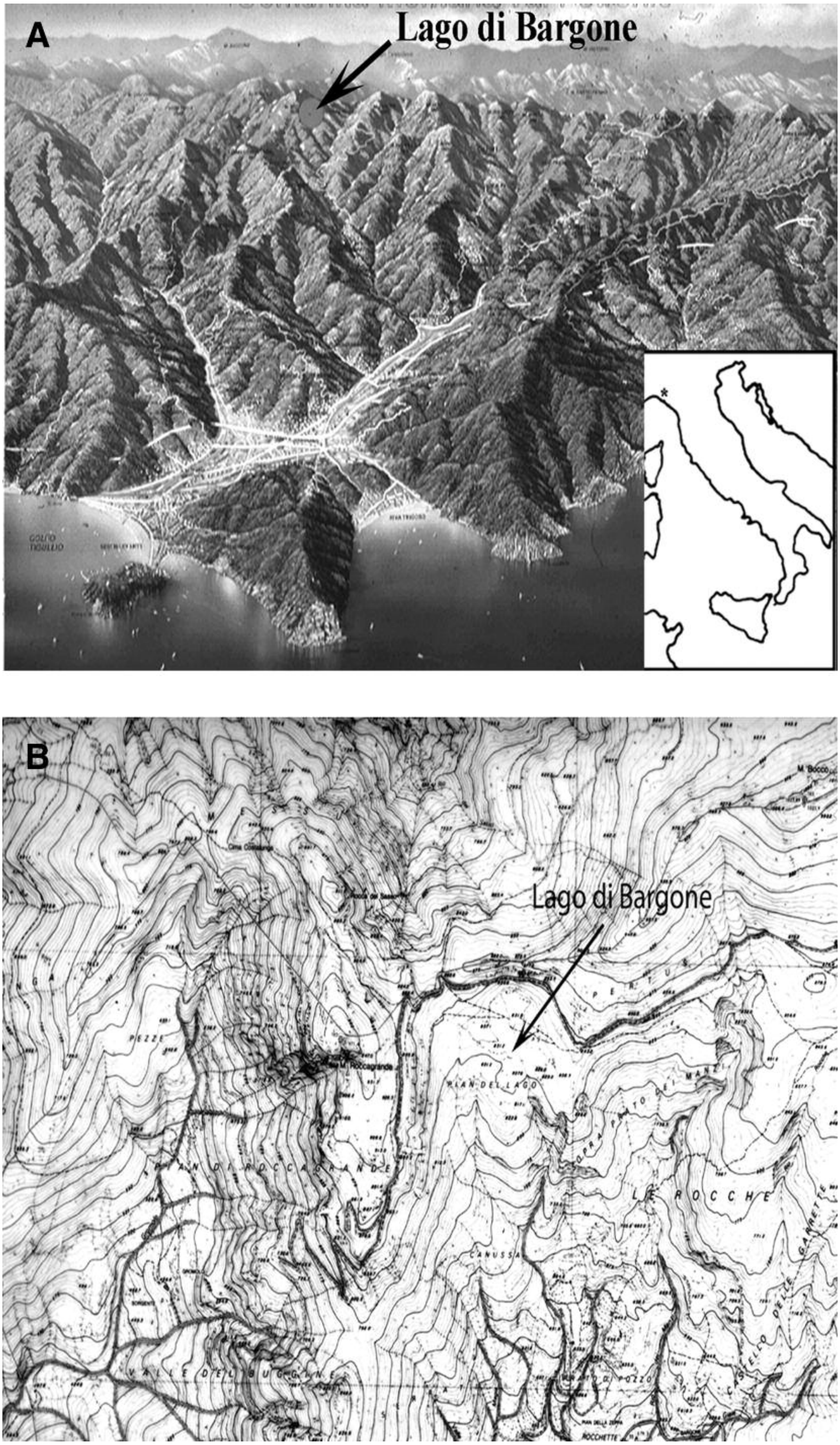


Figure 1 Maps showing location of Lago di Bargone, Italy. (A) Relief map reproduced by kind permission of La Comunita Montan val Petronio. (B) A section from Carta Tecnica Regionale 1:10 000, Sezione No. 232060, M. Tregin. Reproduced by kind permission of Roberto Maggi, Ministero per i beni e le attività culturali Direzione regionale della Liguria

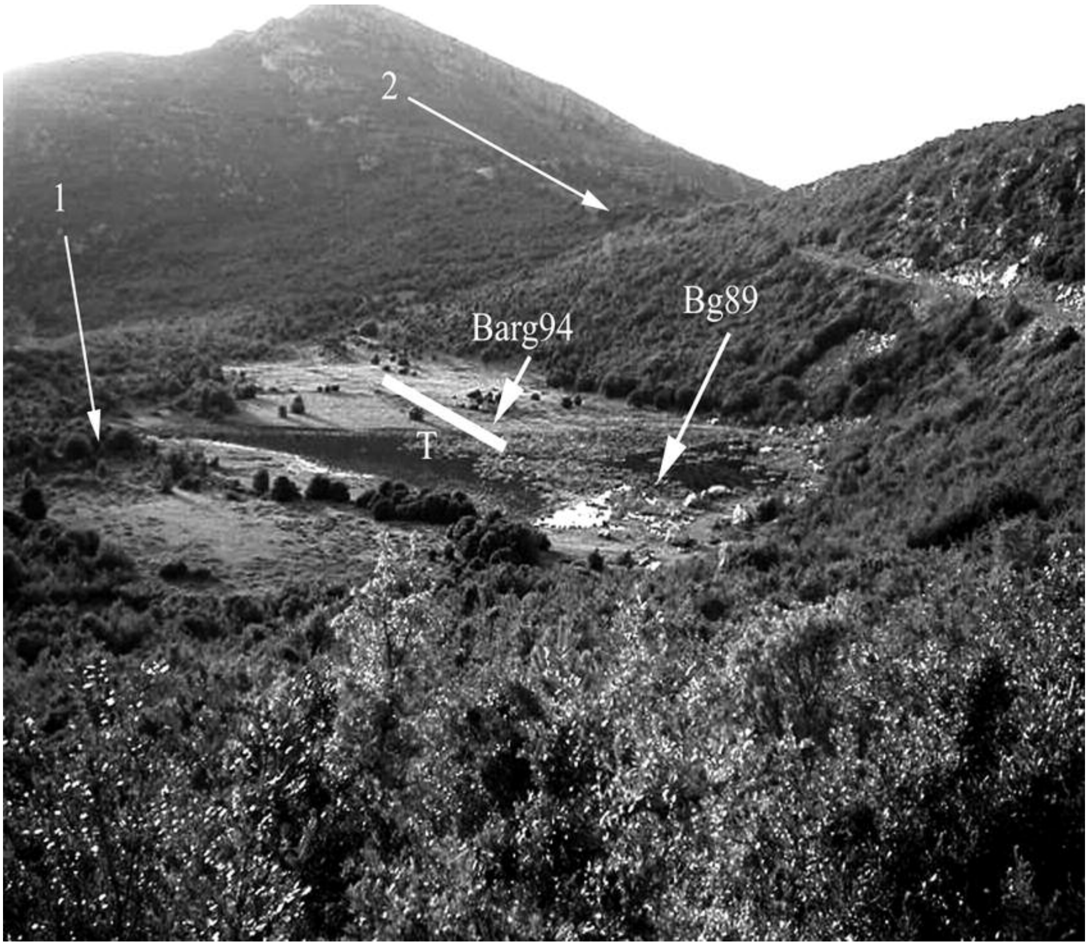


Figure 2 View of site (photograph taken November 2003) showing locations of Bg89 sampling position and Barg 94 trench. 1, mid Palaeolithic; 2, Neolithic and Copper Age

micromorphological analyses. In addition four samples of peat were taken for radiocarbon dating. These were sent to Groningen (GrN-21305, 21306, 21307, 21308) and pre-treated using the acid/alkali/acid method (Mook and Waterbolk, 1985) and measured using gas proportional counting (Mook and Steurman, 1983).

Pollen preparation methods and pollen counting

Pollen preparation methods, estimates of pollen concentrations and pollen preservation characteristics were carried out for both Bg89 and Barg94 according to the methods described in the published literature including the use of micromesh (10 µm) sieves (Stockmarr, 1971; Moore and Webb, 1978; Delcourt and Delcourt 1980; Moore *et al*., 1991). Pollen identifications were based on reference slides and published keys and photographs that were available at the time of counting (Punt and Clarke, 1976–1988; Moore and Webb, 1978; Dickson, 1988; Moore *et al*., 1991). Rare charcoal fragments observed on pollen slides were noted as present but were too few to warrant systematic counting.

Chemistry and magnetic susceptibility

Twenty bulk samples were analysed for loss-on-ignition (LOI at 550°C), low frequency magnetic susceptibility (MS – $\chi \times 10^{-8}$ SI/kg), and magnetic susceptibility after ignition at 550°C (MS550 – $\chi \times 10^{-8}$ SI/kg). In addition, 16 of these samples were also

Table 1 Lago di Bargone radiocarbon results

Laboratory number	Depth (cm)	Material	Radiocarbon age (BP)	Calibrated dates (95% confidence)	Posterior Density Estimate (95% probability)
Bg89					
SRR-3813	85–95	Peat	2375±45	740–380 cal. BC	*840–360 cal.* BC
SRR-3814	175–185	Peat	4625±50	3630–3130 cal. BC	*3390–3340 (2%) or 3220–2770 (93%) cal.* BC
SRR-3815	235–245	Peat	6075±45	5210–4840 cal. BC	*5220–4840 cal.* BC
SRR-3816	423–433	Silty peat	10 690±450	11 510–9280 cal. BC	*11 260–9740 cal.* BC
Barg 94					
GrN-21308	130–132	Peat	700±60	cal. AD 1210–1400	
GrN-21305	203–205	Peat	5390±60	4350–4040 cal. BC	
GrN-21306	250–252	Peat	8390±110	7600–7140 cal. BC	
GrN-21307	300–303	Silty peat	10 870±90	11 010–10 830 cal. BC	

analysed for 2% citric acid extractable P_2O_5 (Cit-P) and 2% citric acid extractable P_2O_5 after ignition at 550°C (Cit-PoI) (Arrhenius, 1934, 1955; see Goldberg and Macphail, 2006: chapter 16, 344–52). These methods have often been employed in association with soil micromorphology in order to provide independent evidence of organic matter and phosphate concentrations (eg, from animal concentrations), and inputs from topsoil and burned soils which have enhanced magnetic susceptibilities (Tite and Mullins, 1971; Macphail *et al*., 2000; Linderholm, 2007). For example, such methods were employed to investigate proxy land-use signatures in a series of humic and poorly humic prehistoric colluvial fills in Scania, Sweden (Engelmark and Linderholm, 2008: figures 11, 29); here also MS550 proved a useful proxy measurement of iron concentrations while it is recognised that normal magnetic susceptibility signals are often strongly depleted under waterlogged conditions (see also Crowther, 2003).

Sediment micromorphology and microprobe

Seven thin section samples were selected from the pollen monolith columns. These were manufactured into thin sections between 6 and 13 cm in length (Murphy, 1986) and studied using a petrological microscope at magnifications between ×20–400, under plane polarised light (PPL), crossed polarised light (XPL), oblique incident light (OIL) and using fluorescence microscopy (BL = blue light). Descriptions were carried out according to the published literature (Bullock *et al*., 1985; Macphail and Cruise, 2001; Stoops, 2003; Goldberg and Macphail, 2006). In order to understand better the formation of secondary minerals and microfabric impregnation, a microprobe study was carried out on two separate 3 cm long subsamples cut from two uncovered thin sections M5 (138–151 cm) and M3 (188–201 cm)(see Figure 7B). Soil micromorphology had previously been employed on several sites on the serpentinite of the Ligurian Apennines. Thus, the nature of the brown soils (eutrophic cambisols and luvisols) and pedogenic processes are thus reasonably well understood for the area (FAO-Unesco, 1988; Courty *et al*., 1989: 284–309; Cruise, 1990; Macphail, 1992: 208–209).

Results and interpretation

Pollen and dates

The radiocarbon results are given in Table 1, and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra, 1986). They are conventional radiocarbon ages (Stuiver and Polach, 1977). The calibrations of the results, relating the radiocarbon measurements directly to calendar dates, are also given in Table 1**.** All have been calculated using the calibration curve of Reimer *et al*. (2004) and the computer program OxCal v4.1 (Bronk Ramsey, 1995, 1998, 2001, 2009a). The calibrated date ranges cited in the text are those for 95% confidence. They are quoted in the form recommended by Mook (1986), with the end points rounded outwards to 10 years. The ranges quoted in italics are *posterior density estimates* derived from mathematical modelling (see below). The ranges in plain type have been calculated according to the maximum intercept method (Stuiver and Reimer, 1986). All other ranges are derived from the probability method (Stuiver and Reimer, 1993).

We have used a Bayesian approach (Buck *et al.*, 1992) for age-deposition modelling of the Bg89 sequence shown in Figure 3A, B (Bronk Ramsey 2008, 2009b). Details of Bayesian age–depth modelling can be found in Blaauw and Christen (2005), Blauuw *et al*., (2007a, b), Bronk Ramsey (2008) and examples of its implementation in Blockley *et al.* (2007, 2008) and Gearey *et al*. (2009). A *U-Sequence* or uniform deposition model (Bronk Ramsey, 2008) was run (Figure 3A) using outlier analysis as described by Bronk Ramsey (2009b). In this model the accumulation rate is unknown

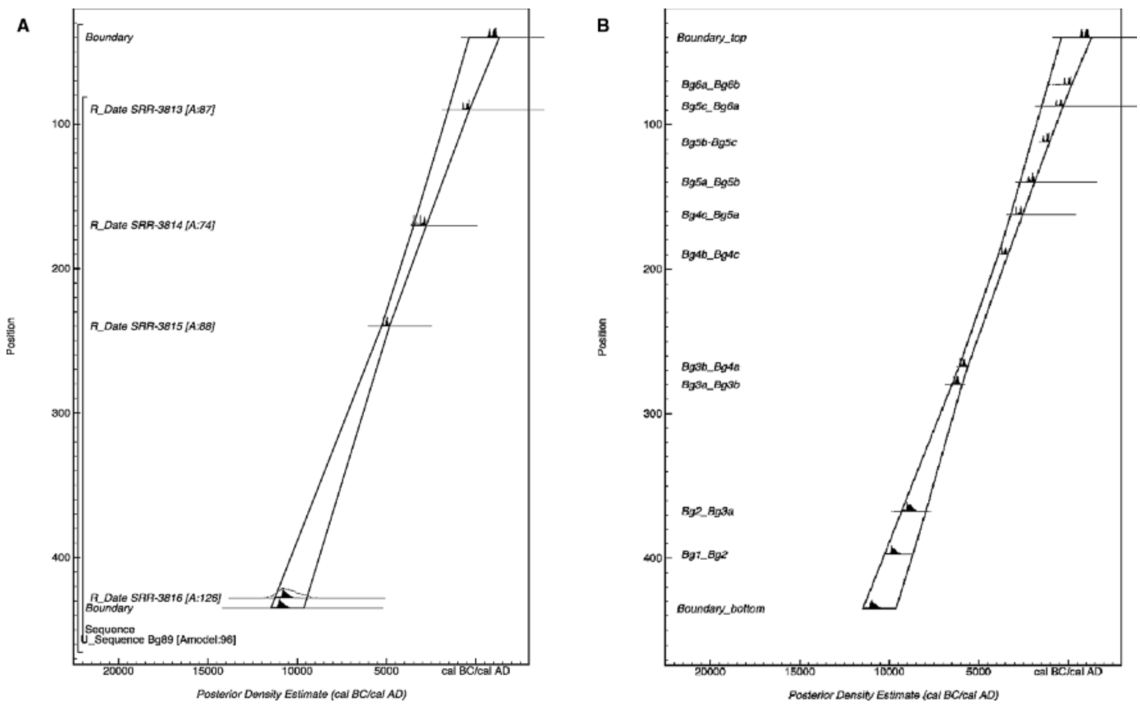
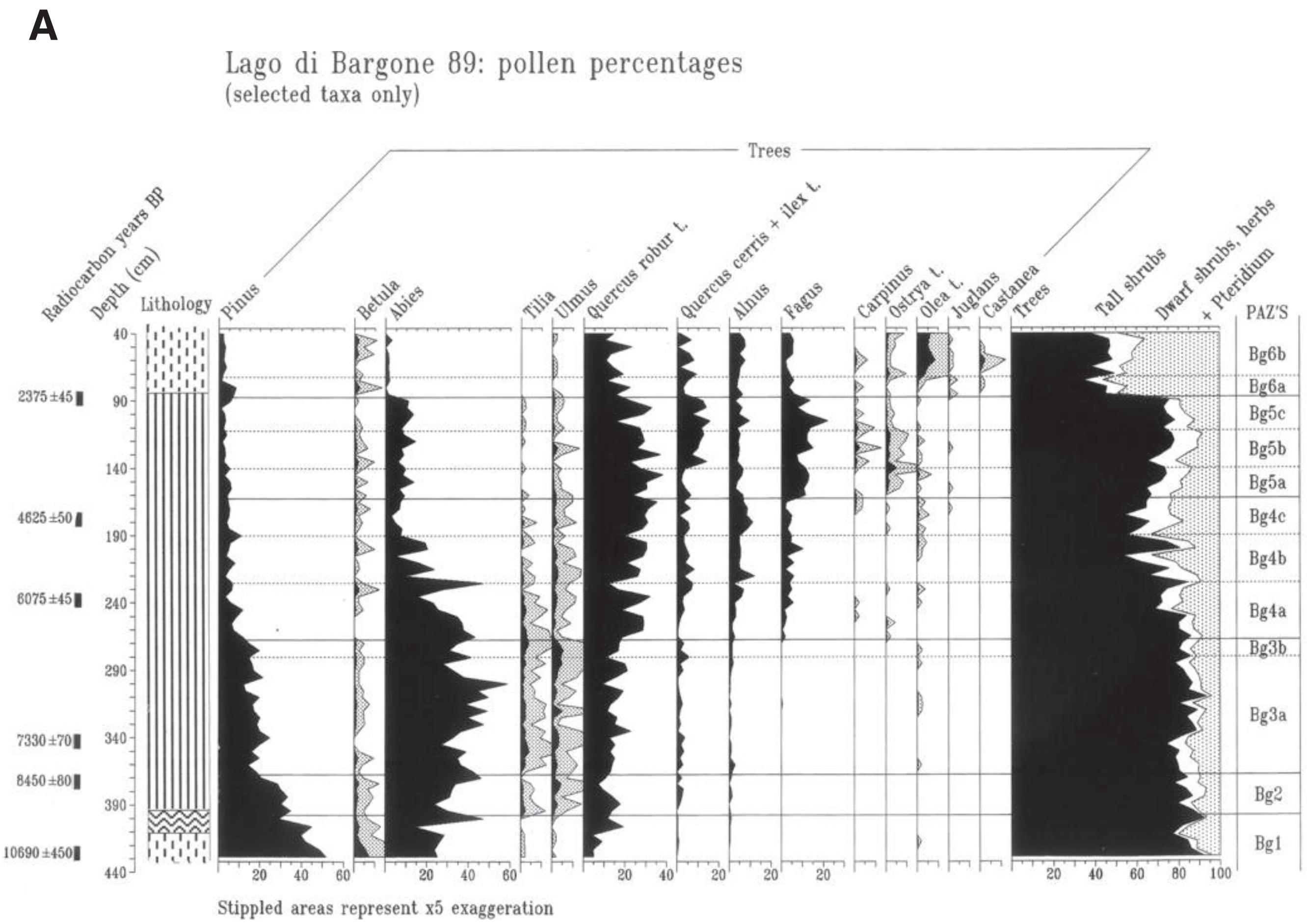


Figure 3 (A) Probability distribututions of dates from the Bg89 sequence: each distribution represents the relative probability that an '*event'* occurred at a particular time. For each of the radiocarbon dates two distributions have been plotted, one in outline, which is the result of simple radiocarbon calibration, and a solid one, which is based on the chronological model used (*U-Sequence*). The A values in brackets after the radiocarbon measurements are the individual index of agreement (Bronk Ramsey, 1995). This index provides a measure of how well the posterior distribution agrees with the prior distribution (for further details see Bayliss *et al*., 2007; Blockley *et al*., 2008). (B) Probability distributions of PAZ in the Bg89 pollen record (derived from (A)): each distribution represents the relative probability that a specific '*event'* (see Table 2) occurred at a particular time


A
Lago di Bargone 89: pollen percentages
(selected taxa only)
Trees
Radiocarbon years BP
Depth (cm)
Lithology
Pinus
Betula
Abies
Tilia
Ulmus
Quercus robur t.
Quercus cerris + ilex t.
Alnus
Fagus
Carpinus
Ostrya t.
Olea t.
Juglans
Castanea
Trees
Tall shrubs
Dwarf shrubs, herbs + Pteridium
PAZ'S
Bg6b
Bg6a
Bg5c
Bg5b
Bg5a
Bg4c
Bg4b
Bg4a
Bg3b
Bg3a
Bg2
Bg1
2375±45
4625±50
6075±45
7330±70
8450±80
10690±450
Stippled areas represent x5 exaggeration

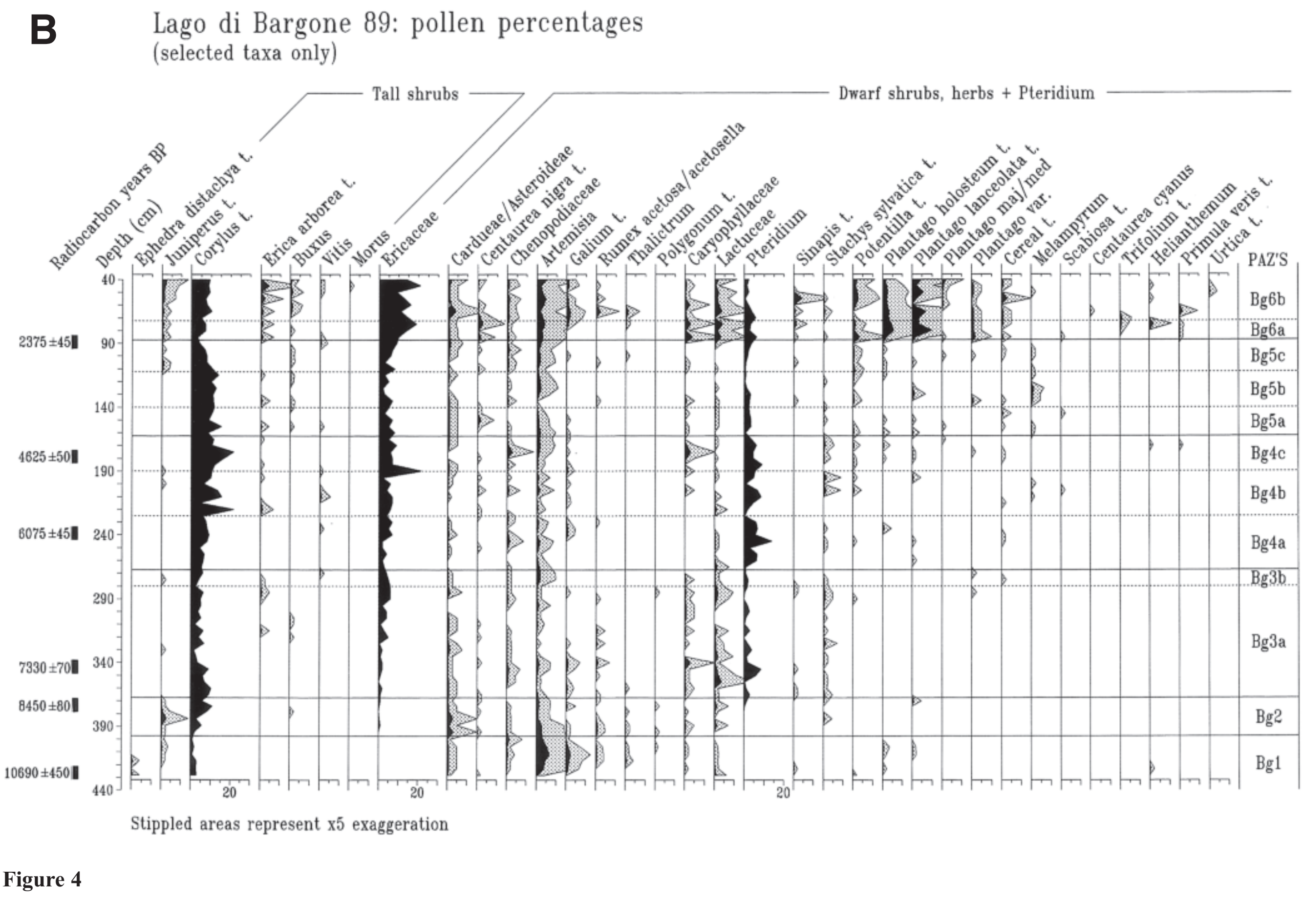

B
Lago di Bargone 89: pollen percentages
(selected taxa only)
Tall shrubs
Dwarf shrubs, herbs + Pteridium
Radiocarbon years BP
Depth (cm)
Ephedra distachya t.
Juniperus t.
Corylus t.
Erica arborea t.
Buxus
Vitis
Morus
Ericaceae
Carduеae/Asteroideae
Centaurea nigra t.
Chenopodiaceae
Artemisia
Galium t.
Rumex acetosa/acetosella
Thalictrum
Polygonum t.
Caryophyllaceae
Lactuceae
Pteridium
Sinapis t.
Stachys sylvatica t.
Potentilla t.
Plantago holosteum t.
Plantago lanceolata t.
Plantago maj/med
Plantago var.
Cereal t.
Melampyrum
Scabiosa t.
Centaurea cyanus
Trifolium t.
Helianthemum
Primula veris t.
Urtica t.
PAZ'S
Stippled areas represent x5 exaggeration

Figure 4

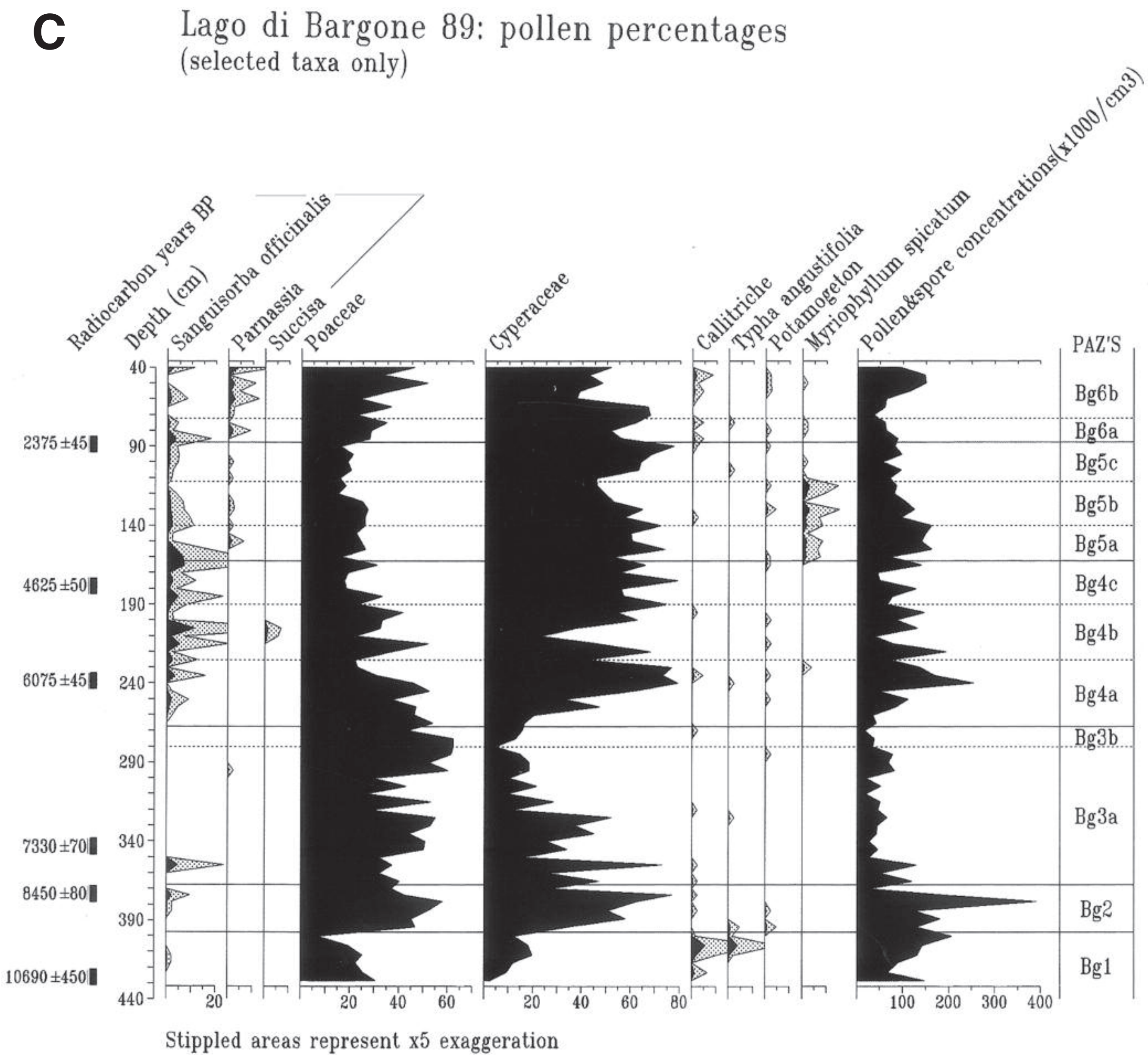


Figure 4 (*continued*) Bg89: pollen percentage diagrams (selected taxa only)

but is assumed to be constant (Christen *et al.*, 1995), an approach often favoured in palaeoecological research (eg, Chiverrell, 2001; Barber *et al.*, 2003). The *U-Sequence* model shows good agreement between the radiocarbon measurements and the assumption that the accumulation rate was approximately constant for the Bg89 sequence. In addition Figure 3B and Table 2 show the probability distribution of pollen assemblage zones identified in the Bg89 pollen record. Owing to problems that may arise in basin edge deposits, such as sedimentary discontinuities (see below), a constant accumulation rate could not be assumed for the Barg 94 sequence, so an age-deposition model Barg 94 is not presented here.

The lithostratigraphy of Bg89 and Barg 94 is described in Table 3. The pollen percentage and pollen concentration diagrams for Bg89 (Figure 4) and Barg94 (Figure 5) show the major taxa along with selected minor taxa that may have some ecological or archaeological significance. Pollen percentages for both Bg89 and Barg 94 are calculated on the basis of 200 Total Land Pollen (TLP). TLP includes the total of all trees, shrubs and herbs as well as *Pteridium* spores, but

Table 2 Posterior density estimates for pollen assemblage zones defined in Bg89. Derived from the models shown in Figure 3A and B

PAZ	Depth (cm)	*Posterior Density Estimate (95% probability)*
Bg1_start	435	*11 480–9910 cal. BC*
Bg1_end/Bg2_start	297.5	*10 270–8960 cal. BC*
Bg2_end/Bg3a_start	367.5	*9320–8220 cal. BC*
Bg3a_end/Bg3b_start	280	*6500–5930 cal. BC*
Bg3b_end/Bg4a_start	267.5	*6100–5600 cal. BC*
Bg4a_end/Bg4b_start	225	*4830–4400 cal. BC*
Bg4b_end/Bg4c_start	190	*3780–3360 (92%) cal. BC*
Bg4c_end/Bg5a_start	162.5	*3020–2540 (93%) cal. BC*
Bg5a_end/Bg5b_start	140	*2440–1870 (93%) cal. BC*
Bg5b_end/Bg5c_start	112.5	*1730–1050 (93%) cal. BC*
Bg5c_end/Bg6a_start	87.5	*770–280 (91%) cal. BC*
Bg6a_end/Bg6b_start	72.5	*670 cal. BC– cal. AD 200(93%) cal. BC*
Bg6b_end	35	*cal. AD 610–1230 (93%) cal. BC*

Table 3 Lithostratigraphy

Depth (cm)	Stratigraphy
Bg89	
0–35	Undecomposed surface root layer; not sampled
35–86	Brown to yellowish silty peat; moderately sharp lower boundary
86–396	Black, monocotyledonous peat with stones (2 mm) at 160–172 cm; silt recovered from sieves in samples from 195, 295, 325, 335 and 355 cm; gradual lower boundary
396–413	Light brown gyttja, some fine rootlets; gradual upper and lower boundaries
413–435	Brown silty peat
435+	Bedrock
Barg 94	
102–123	Stony soil, dark brown (7.5YR 5/8) with orange mottling upwards and becoming humic downwards
123–128	very dark grey to dark brown (7.5YR 3/0–3/2) organic clay and silt becoming more organic downwards and stony upwards
128–134	black (7.5YR 2/0) peat
134–136	very dark grey (7.5YR 3/0) organic silt and clay
136–173	dark grey (7.5YR 4/0) gyttja becoming dark brown on exposure; gradual upper and lower boundaries
173–202	dark grey (7.5YR 4/0), becoming black at depth, peat with silt, gradual upper and lower boundaries
202–259	black (7.5YR 2/0) fibrous peat, gradual upper and lower boundaries
259–261	as above becoming silty
261–279	brown to dark brown (7.5YR 4/2) gyttja becoming more organic downwards and with many fine rootlets
279–295	dark brown (7.5YR 3/2) variable silty peat and silts
295–314	brown to dark brown (7.5YR 4/2) gyttja
314+	bedrock

excludes Poaceae and Cyperaceae, aquatics and other Pteridophytes. Cereal t. pollen includes *Avena-Triticum* t. but excludes *Hordeum* t. because the latter occurs throughout the Bg89 sequence and may therefore represent wild grasses. Rare charcoal fragments (>10 µm) were found on pollen slides from Bg89 at depths 55, 215, 235, 245, 345, 365, 370 and 428 cm. None were observed in samples from Barg94.

Regional vegetation history

The Holocene pollen sequence (Bg89, Figure 4, Table 2) compares well with other pollen stratigraphical data from Italy, providing a 'half-way house' between the relatively low-lying lakes of central Italy (Kelly and Huntley, 1991; Magri, 1999; Colombaroli *et al*., 2007, 2008) and montane sites (1100–1500 m O.D.) situated on north-facing slopes of the northern Apennines (Lowe, 1992; Lowe and Watson, 1993; Watson, 1996). In central Italy, the Lateglacial–early Holocene transition is marked by a reduction of herbaceous taxa, and expansion of arboreal species after 10 850 BP (*c*. 10 900 cal. BC) (Magri, 1999). In the northern Apennines, *Pinus* frequencies declined and thermophilous arboreal taxa expanded at around 10 500 to 10 300 BP (10 550–10 100 cal. BC (Lowe, 1992; Lowe and Watson, 1993). The basal sequence from Bg89 shows a similar decline in *Pinus* and rise in *Abies*, *Quercus, Tilia* and *Ulmus* that indicates the broad acceptability of the date 11 510–9280 cal. BC (10 690±450 BP). *Abies*-dominated pollen assemblages such as in Bg3a are typical of early- to mid-Holocene pollen sequences from the northern Apennines. In Bg4a, the date 5210–4840 cal. BC (6075±45 BP) identifies the first of a series of major declines in *Abies* percentages at this time, this being comparable with lowland forests in the southern Alps where *Abies* began to disappear from below 1000 m a.s.l. from around 5100 cal. BC (*c*. 6180 BP) (Tinner *et al*., 1999; Keller *et a*l., 2002; Wick and Möhl, 2006).

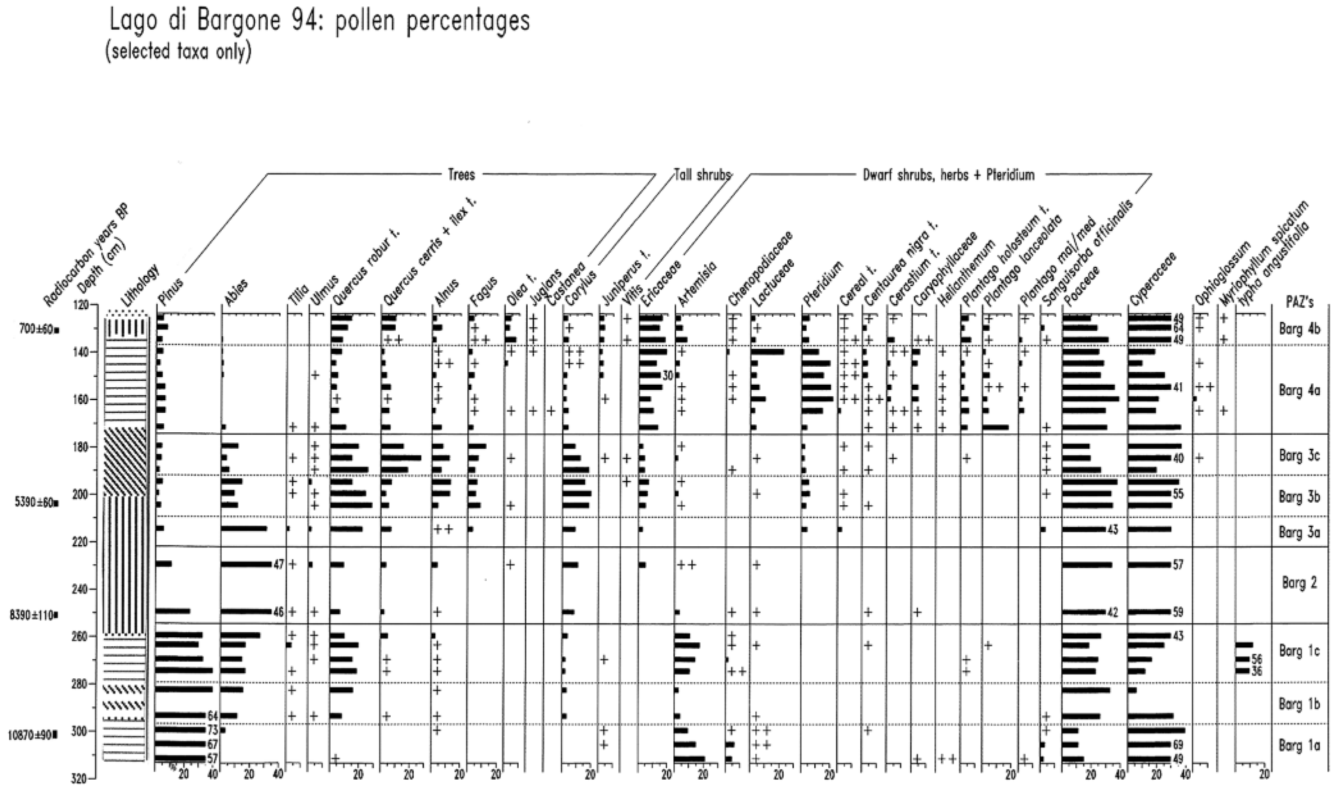


Figure 5 Barg 94: pollen percentage diagram (selected taxa only)

After this, deciduous oaks dominate the Bargone pollen spectra, comparable with that found throughout northern and central Italy at lower to mid altitudes (Kelly and Huntley, 1991; Pini, 2004; Finsinger and Tinner, 2006; Valsecchi *et al*., 2006). *Fagus* was present in significant numbers in central Italy after about 8000 BP (*c*. 6900 cal. BC) (Magri, 1999). At Lago di Bargone, *Fagus* is recorded in Bg4a (*6100–5600 cal. BC; (95% probability; Bg3b_Bg4a;* Figure 3B) and increases to around 10% in Bg5a (*3020–2540 cal. BC*; *93% probability; Bg4c_Bg5a*; Figure 3B) from which time it increased markedly throughout montane regions of the northern Apennines (Watson, 1996). It also shows a later increase in mediterranean oak species to 15% in Bg5b (*2440–1870 cal. BC; 93% probability; Bg5a_Bg5b*; Figure 3B). This is surprising given the mid-altitude location of the site, although it may be, in part, a reflection of the proximity of south-facing slopes.

Major deforestation and the development of heath and grassland communities occurred at Lago di Bargone after 740–380 cal. BC (2375±45 BP; SRR-3813) during the Iron Age and Roman periods. This is typical of the period for many areas of Europe (eg, Greig, 1988; Andrieu-Ponel *et al*., 2000; Gobet *et al*., 2000; Guillizzoni *et al*., 2002; Bertran, 2004; Cyprien *et al*., 2004). Estimates for the dates of increases in *Olea* t., *Juglans* and *Castanea* curves in Bg6b places these events in the Iron Age and Roman periods (Bg6b estimated to begin *670 cal. BC–AD 200 cal.*), this being typical for the expansion of arboriculture in northern Italy (eg, Gobet *et al*., 2000; Branch, 2004)

Core correlations (Table 4, Figures 4 and 5)

Despite problems of lack of resolution and probable sediment discontinuities there is broad agreement between the Holocene pollen stratigraphy of Barg 94 and that of Bg89, and this, in turn, provides a context for the study of the sediments. The most difficult part of the sequence to reconcile between the two cores is that found in the basal deposits (Barg 1a, 1b, 1c) where fluctuations in the *Artemisia* curve together with a date of 11 010–10 830 cal. BC (10 870±90 BP;GrN-21307) appear to be anomalous when compared with the tripartite Lateglacial sequence found elsewhere in northern Italy (Lowe, 1992; Lowe and Watson, 1993). The sediment micromorphology (M1, M2, see Figure 7A) suggests that sediment mixing of the basin edge deposits is a possibility. New investigations of this site being carried out by University of Genoa may clarify this issue.

The early–mid Holocene phase of dominant *Abies* of Bg2, Bg3a, 3b is clearly apparent in Barg 2, along with the subsequent decline in *Abies* frequencies and increase of *Quercus robur* t., *Fagus, Corylus* t. and Ericaceae (Barg 3a, 3b). The date of 4350–4040 cal. BC (5390±60 BP; GrN-21305) appears to be consistent with those of Bg89. Lack of resolution, however, makes precise correlation and dating very difficult. In addition, the occurrence of sediment discontinuities at the basin edge is a distinct possibility (see below). The later rise in *Quercus cerris + ilex* curve (Barg 3c) is correlated with the same feature in Bg89 (Bg5b,c). The major rise in NAP, especially Ericaceae and *Plantago* species, is also clearly apparent in both sequences (Barg 4a, Bg6a). A rise in *Olea* t. frequencies in Barg 4b appears to be consistent with a similar feature in Bg6b, although in contrast to the *posterior density estimate* of an Iron Age/Roman date for Bg89, the Barg 94 date of 1210–1400 cal. AD (700±60 BP; GrN-21308) places this phenomenon in the late Middle Ages. This discrepancy is difficult to reconcile at the present time.

Barg 94 sediments

Chemistry and magnetic susceptibility

The stratigraphical sequence from Barg 94 (Figure 6) shows very high LOI, which rises to nearly 80% at about 200 cm (Barg 3B). Above 190 cm, the sediments become far more minerogenic although a thin peat band is reflected in a rise in LOI at 130 cm. The lowest LOIs (11%) are recorded in the overlying minerogenic, colluvial deposits. Phosphate concentration (Cit-PoI) declines upwards from 293 cm (Barg 1b) to 195 cm (Barg 3b), but increases again in Barg 4a and reaches a peak of 321 ppm at 126 cm (Barg 4b). Magnetic susceptibility is very low until Barg 4a when moderate MS values (average 25 $\chi \times 10^{-8}$ SI/kg) are recorded. The highest MS values (700–800 $\chi \times 10^{-8}$ SI/kg) are recorded in the uppermost samples at 126 cm and 106 cm. In contrast, MS550 shows a far greater pattern of variation throughout the log, with

Table 4 Pollen stratigraphical correlations (Bg89 and Barg94)

Bg89			Barg 94		
PAZs	Calibrated dates (95% confidence)	Pollen stratigraphy	PAZs	Calibrated dates (95% confidence)	Pollen stratigraphy
Bg6b		NAP-scrub-*Olea t.-Castanea*	Barg4b	1210–1400 cal. AD?	NAP-scrub-*Olea* t.
Bg6a		NAP-scrub	Barg4a		NAP-scrub
Bg5c	740–380 cal. BC	*Qu.rob*.t.-*Qu.cerr.+ilex* t.-*Fagus*-scrub			
Bg5b		*Qu.rob*.t.-*Qu.cerr.+ilex* t.-*Fagus-Corylus t.*	Barg3c		*Qu.rob*.t.-*Qu.cerr.+ilex* t.-*Fagus-Alnus*
Bg5a		*Qu.rob*.t.-*Fagus-Corylus* t.-NAP			
Bg4c	3630–3130 cal. BC	*Qu.rob.* t.-*Corylus t.*-NAP			
Bg4b		*Qu.rob*.t.-*Abies-Corylus* t.-NAP	Barg3b	4350–4040 cal. BC	*Qu.rob*.t.-*Fagus-Corylus* t.-*Alnus*
Bg4a	5210–4840 cal. BC	*Qu.rob.* t.-*Abies-Tilia-Pteridium*	Barg 3a		*Qu.rob.t.-Abies*
Bg3b		*Abies-Qu.rob*.t.-*Ulmus-Tilia* (1st records for cereal t. and *Vitis*)			
Bg3a		*Abies-Qu.rob*.t.-*Ulmus-Tilia*	Barg2	7600–7140 cal. BC	*Abies*
Bg2		*Abies-Pinus-Qu.rob*.t.-*Ulmus-Juniperus* t.			
Bg1	11 510–9280 cal. BC	*Abies-Pinus-NAP*	Barg1c		*Abies-Pinus-Qu.rob.* t.-*Artemisia-Typha ang.*
			Barg1b	11 010–10 830 cal. BC ?	*Pinus-Abies-Qu.rob*.t
			Barg1a		*Pinus-Artemisia*

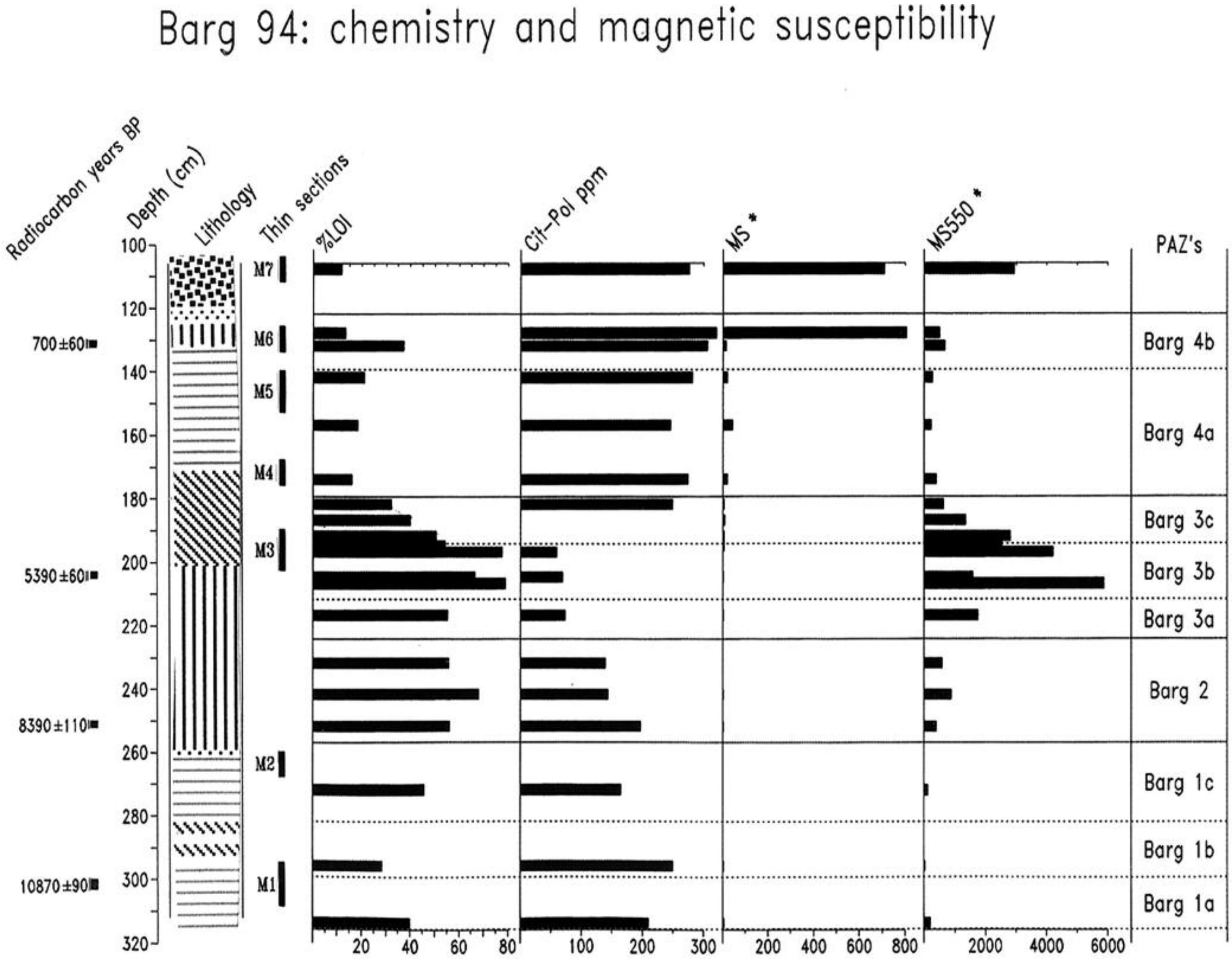


Figure 6 Barg 94: composite diagram showing stratigraphical position of thin sections (M1–M8), results of percent loss-on-ignition (%LOI), Total Phosphate (Cit-PoI ppm), MS*, MS 550* (%) (* = $\chi \times 10^{-8}$ SI/kg)

measurements of >1000 $\chi \times 10^{-8}$ SI/kg and a maximum of > 5000 $\chi \times 10^{-8}$ SI/kg between 214 cm and 183 cm. Above this, MS550 declines until there is a another sharp rise at 106 cm.

Sediment micromorphology (Figure 7)

For reasons of space only very brief details of the sediment micromorphology are provided here. More detailed information may be obtained from the authors (R.I. Macphail) upon request. The thin sections M1 and M2 (Figure 7A) record diatom-rich, finely laminated silty organic layers (gyttja) with some evidence of reworking and textural pedofeatures indicative of episodic muddy conditions (the terminology used here is in accord with the conventions of thin section description, eg, Bullock *et al*., 1985; see also Dinç *et al*., 1976; Schoute, 1984, 1987). In M3 (Figure 7B), the sediment is a highly organic, mainly laminated peat composed of both amorphous organic matter and plant remains. It also contains many very fine charcoal particles (5–10 μm) within the amorphous organic laminae. The peat is well rooted and a small area at the top of the thin section shows homogenisation by burrowing mesofauna (cf. Dinç *et al*., 1976). Microprobe mapping of a subsample of the peat at 188–191 cm (Figure 7B) confirms the presence of Fe and Fe-Ca impregnation of the peat at this depth (see also M5 below).

Thin section M4 reveals a well-sorted, moderately diatom-rich sediment with depositional layering of organic matter, plant fragments and silt (gyttja). In M4 sedimentation included inputs of occasional to many fine (<10 μm) charcoal fragments together with trace amounts of burned (rubefied) mineral grains. In thin section M5 (Figure 7C) the sediment is generally a well sorted, moderately silty peat, but also contains anomalous inclusions of gravel-size serpentinite, rare rubefied grains and abundant fine charred organic matter. A fragment of fine sand-size, charred peat was also noted as well as rare coarse charcoal (<0.5 mm). Microprobe analysis showed mean values of 2.20% Al, 11.0% Si, 3.32% Fe and 0.266% Ca. Elemental mapping revealed areas of strongly Fe-impregnated peat and silty peat, with areas of minor Fe-Ca impregnation.

The micromorphology of the lower half of M6 (Figure 7D) shows laminated and well-sorted minerogenic organic matter with abundant diatoms. In contrast to the peat examined from lower in the sequence, here the organic matter is characterised by amorphous organic matter fragments and sediment staining; humified organic matter, and weakly ferruginised, amorphous stained organic matter, also occur. Some of this material (Figure 7E) can be identified as probable dung from reference material and analogue studies (Courty *et al*., 1989: 114; Macphail *et al*., 1999, 2004). In upper M6 and thin section M7 (Figure 7F) the colluvium is composed of very poorly sorted coarse gravel to sand-size rock fragments and soil clasts. The last include peat, topsoil and subsoil fragments, as well as clasts of burned soil. Soil clasts also contain fine charcoal and rubefied grains. The colluvium coarsens up-profile from sand and gravel-size material, to gravel-size (3.5 mm) deposits.

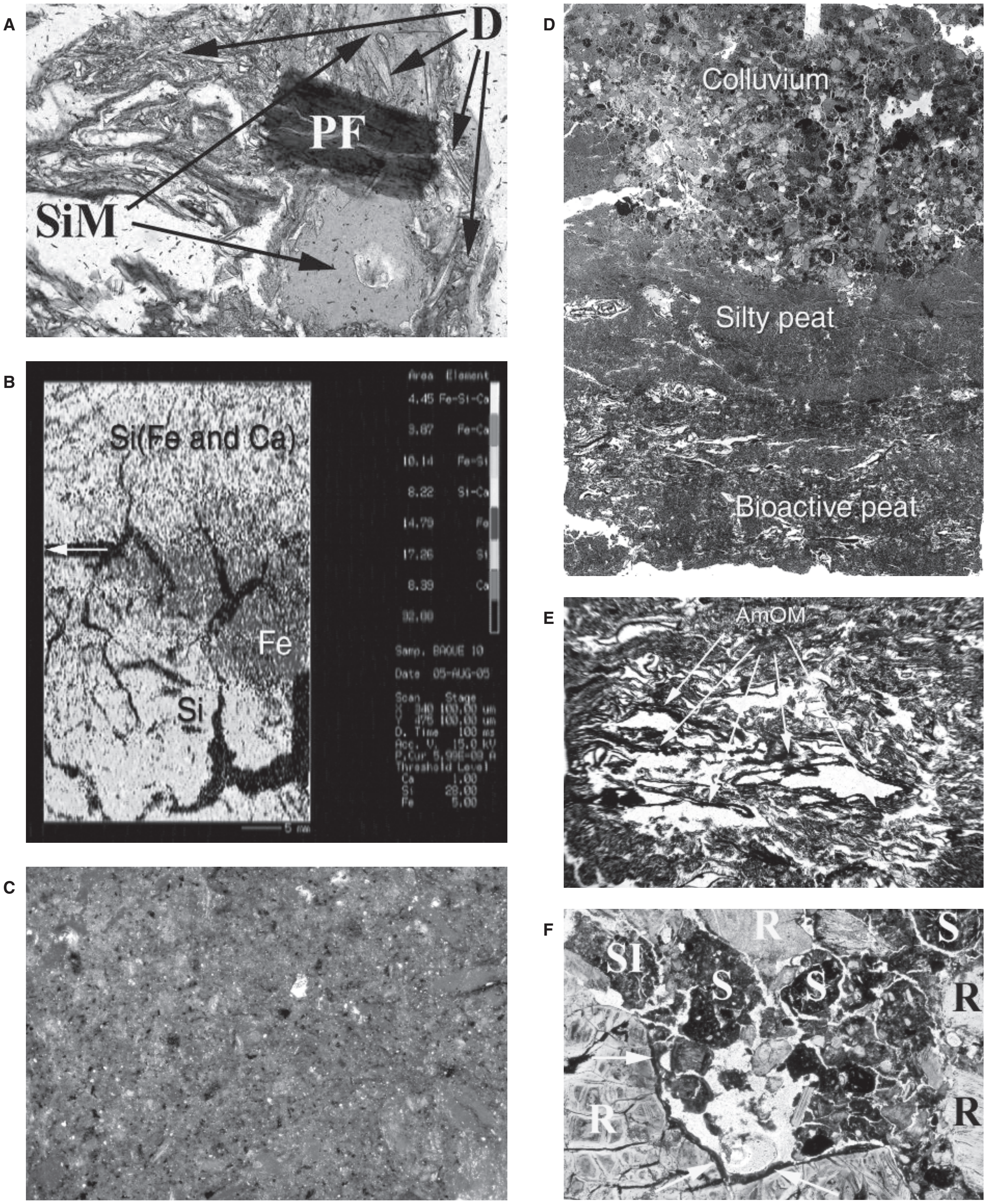


Figure 7 Barg 94: Sediment micromorphology of the Holocene sequence. (A) Photomicrograph of thin section M2: 258–266 cm; detail of peat composed of layered plant remains and diatom-rich (D) minerogenic sediment. Note inclusion of plant fragment (PF; probable humified leaf) and infill of siliceous mud (SiM) as evidence of sediment inwash. Rounded fragments of siliceous mud are found elsewhere as evidence of local reworking. Plane polarised light (PPL), frame width is ~0.92 mm. (B) Microprobe image of element mapping of subsample of thin section M3; scan of subsample (M3: 188–191 cm) from thin section M3 (188–201 cm), employed for microprobe analysis; the peat has a massive with crack and channel microstructure; image analysis mapped areas include Ca, 8.39%; Fe, 14.79%; Si, 17.26%; Fe-Si, 10.14%; and Fe-Ca, 3.87%; quantitative grid (n =30) analysis of 13 elements from four areas found 0.062% Ca, 0.580% Fe and 2.82% Si (mean values). Frame width is ~30 mm. Arrow shows top. (C) Photomicrograph of thin section M5: 138–151 cm; oblique incident light image of patch of fine charcoal in the peat. Frame width is 2.3 mm. (D) Scan of thin section M6:124–132 cm, showing the uppermost peat levels dating to 641 cal. BP, buried by chaotic bedded colluvium composed of stones and soil clasts; a massive structured silty (diatom rich) peat overlies a burrowed bioactive peat (see Figure 7E). (E) Photomicrograph of M6:124–132 cm: the humic bioactive peat (see Figure 7D). This is characterised by meso-fauna burrowing and their organic excrements and fragments. Here probable herbivore dung is recognised from its shape, and the layered plant fragments typically enriched with amorphous organic matter (AmOM). PPL, frame width is ~6 mm. (F) Photomicrograph of thin section M7: 102–110 cm, showing chaotic bedded coarse colluvium composed of gravel and coarse sand-size rock fragments (R) including serpentinite from the local geology, and soil clasts (S), including both blackened (burned) humic topsoil and poorly humic subsoil. Colluviation also led to soil inwash (SI) into voids. Fluctuating water-tables led to iron-panning in the form of ferrihydrite grain coatings (arrows). This layer has enhanced magnetic susceptibility values, which are presumably associated with the inclusion of eroded burned soil. PPL, frame width is ~4.6 mm

Interpretation of sedimentological data (Figures 6, 7A–F).

The magnetic susceptibility record (Figure 6) is of particular interest. Peats, like other waterlogged deposits, often have a poor magnetic susceptibility signal. On the other hand, the presence of secondary iron is reflected in measurements such as χmax (Crowther, 2003) and MS550 (Macphail *et al*., 2000; Engelmark and Linderholm, 2008) and may, therefore, be used as a proxy guide to iron content. Microprobe analysis has confirmed the presence of iron as identified in the thin sections (Figure 7B). The occurrence of iron is significant because in the forms identified in thin section (ie, *not* pyrite) it can only be precipitated in aerobic conditions (eg, Fe^{2+} to Fe^{3+}; Duchaufour, 1982), and thus records episodic exposure and associated water-level fluctuations. Its occurrence therefore in the Barg 94 sequence, reflects fairly significant, intermittent drying out of the basin edges during the period represented by depths 214 cm to 183 cm. The reduction in phosphate concentrations here is also consistent with geogenic effects and a fluctuating water-table leading to the loss of phosphate. Micromorphological analysis of M3 also identified instances of biological working of the sediment ie, peat ripening (Buol *et al*., 1997: 113). It is probable that sediment discontinuities would have occurred during this period, although lack of resolution prevents this from being identified with any degree of certainty. Comparison of the pollen stratigraphy from Barg94 and Bg89 (Table 4, Figures 4 and 5) suggests this phase would have occurred during the period represented by Barg3a, 3b and part of Barg3c, which is correlated with Bg4a, 4b, 4c, 5a and 5b. Fluctuations in the Poaceae, Cyperaceae, *Sanguisorba officinalis* and *Myriophyllum spicatum* curves at these levels are also consistent with fluctuations in water-table. *Posterior density estimates* for Bg89 pollen assemblage zones (Figure 3B, Table 2) suggest a time period spanning *6100–5600 cal.* BC to *1730–1050 cal.* BC. It is noted that fluctuating but generally low lake levels during much of this period are well documented in the recent literature on lakes in Switzerland, eastern France and Italy (Magny, 2004; Sadori *et al*., 2004; Finsinger and Tinner 2006; Magny *et al*., 2006; Valsecchi *et al*., 2006).

A dramatic fall in LOI to less than 22% and associated rise in phosphate concentrations (average 262 ppm), is accompanied by palynological evidence for extensive deforestation (Barg4a, Bg6a) after 740–380 cal. BC (2375±45; SRR-3813). These phenomena therefore are probably related to land-use practices beginning in the Iron Age and subsequent Roman periods. Evidence for accelerated soil erosion rates during the Iron Age/Roman periods peaking during the Middle Ages, is widespread in Europe (eg, van Vliet-Lanoë *et al*., 1992; Marchetti, 2002; Bertran, 2004). In thin sections M4 and M5 frequencies of very fine (<10 μm) charcoal increase, becoming abundant in M5 (Figure 7C) attesting to an increase in the use of fire over time. Further evidence of burning is provided by inclusions of fine, burned mineral grains, as well as weakly enhanced MS values recorded throughout this period. In thin section M5 a coarse burned peat fragment suggests that, on occasions, fires may have extended onto the peat surface itself (*cf.* Courty *et al*., 1989: 309, plate Vd).

Comparison of the organic matter observed in thin section M6 with reference material and reference to analogue studies (Courty *et al*., 1989: 114; Macphail *et al*., 1999, 2004) allows us to confirm that at least some of the organic matter at the top of the Barg 94 sequence, derives from herbivore dung inputs (Figure 7E). The presence of dung within the pond edge sediments clearly points to the site being used as a watering hole by domesticated stock during this period. A fluctuating water-table would have had the effect of locally mobilising phosphate and redepositing it with iron along the base of the minerogenic colluvium rather than in the underlying peat (Thirly *et al*., 2006). Thus the full phosphate content of this faecal-enriched material, is recorded at the iron-stained base of the overlying colluvium (Figure 6, 321 ppm at 126 cm). Significantly, in thin section M6, the junction between the organic layer and overlying colluvium is sharp, with little discernible ageing or weathering effects on the organic material below. Thus, burial by the colluvium would have occurred rapidly, shortly after deposition of the organic matter. The colluvium itself as observed in thin section M7 (Figure 7F) contains very poorly sorted coarse gravel to sand-size rock fragments, and soil clasts. It is evident that both the local soils as well as the underlying geology were eroded, which demonstrates the devastating impact of local activities here. In addition, the use of fire is indicated by the inclusion of abundant clasts of charred and burned soil, as well as the highest recorded MS values (806 $\chi \times 10^{-8}$ SI/kg, 710 $\chi \times 10^{-8}$ SI/kg).

Discussion

Neolithic to Copper/Early Bronze Age

Although in present-day north and central Italy *Abies alba* is associated with montane environments, there is evidence that in the past it would have occupied a much wider range of habitats and altitudes including sea level, than today (Colombaroli *et al*., 2007). *Abies* is often under-represented in pollen diagrams (de Beaulieu, 1977), so high frequencies of 30–50% suggest stands of fir trees very close to the site at Lago di Bargone. It is probable that fir trees would have extended to the bog edge where moister soils would have provided ideal conditions for the regeneration of fir seedlings (Barbero and Bono, 1970; Tan, 1987; Ellenberg, 1988) while *Quercus* species may have extended up the more freely draining slopes. Throughout much of the early Holocene there would have been a mixed coniferous-deciduous forest with *Abies*, deciduous *Quercus*, *Tilia* and *Ulmus* around a boggy, grassy hollow. The first traces of human presence occur in Bg3b (Figure 4) where the first cereal t. and *Vitis* pollen grains are both recorded. These early records are followed by strong indications of disturbances in Bg4a, 4b and 4c. The date of 5210–4840 cal. BC (6075±45 BP, SRR-3815) is consistent with early Neolithic, middle altitude archaeological sites in eastern Liguria (Biagi *et al*., 1986; Maggi and Starnini, 1990; Campana and Negrino, 2002), as well as palynological and archaeobotanical records for early Neolithic cereals found elsewhere in northern Italy (Branch, 1997; Pini, 2004). Fluctuating and falling *Abies* frequencies, growing scarcity of *Tilia* and *Ulmus* pollen, increased deciduous *Quercus* and *Pteridium* frequencies, fluctuations in *Corylus* t. and Ericaceae, and increases in herbaceous pollen all point to successively more open conditions. It is probable that by the Copper Age (Bg4c) the environment at Lago di Bargone would have consisted of a mosaic of deciduous oak woodland interspersed with open areas of heath and grassland.

Similar developments have been observed in pollen diagrams from the southern Alps and Tuscany, where high resolution pollen and charcoal studies (Tinner *et al*., 1999; Colombaroli *et al*., 2007, 2008) have suggested a strong causal link between Neolithic forest fires and the local extinction of fire-sensitive plants (*Abies, Tilia, Ulmus*, *Fagus, Quercus ilex*) and increase in fire-tolerant taxa (*Corylus* t., *Alnus, Pteridium*, Ericaceae). On the other hand, the modelling study of Wick and Möhl (2006) concluded that a complex of factors must be considered, including forest fires, warm, dry climate conditions, Neolithic grazing, browsing and the use of trees as fodder, and a lack of genetic variation and adaptability of northern Italian and central European populations of silver fir (cf. Konnert and Bergmann, 1995). In spite of some similarities with the pollen assemblages reported from those areas, at Lago di Bargone there is little evidence for burning during the Neolithic and Copper/Early Bronze Age. Charcoal was only rarely found in pollen preparations from Bg89, although this could be in part due to a lack of resolution (5 cm sampling interval in Bg89). Magnetic susceptibility measurements and LOI from the basin edge deposits (Barg 3A, 3B) provide no evidence of either soil erosion or burned soils that would be expected if forest fires had occurred on the slopes surrounding the site. The only indications of fire during this period were the presence of very fine charcoal particles (5–10 μm) noted in the thin section M3. This size range for charred particles would not appear in pollen preparations because of the use of micromesh sieves as part of the preparation procedures. As charcoal particles in the size range 10 μm–500 μm are normally used to reconstruct regional rather than local fire history (Tinner *et al*., 1999; Colombaroli *et al*., 2008), these tiny (<10 μm) particles are far more likely to be related to regional fires than to local fire events at Lago di Bargone. In general, evidence for fires during the Neolithic and Copper/Bronze Age in Liguria is patchy, most frequently occurring in montane areas (Courty *et al*., 1989: 305–309; Branch, 2004; Ottomano, 2004; Menozzi *et al*., 2009), although investigations at the mid-altitude archaeological site at Grotta del Bandito (Campana and Negrino, 2002: 317) have shown a link with soil erosion and probable forest clearance.

At Lago di Bargone micromorphology of M3, microprobe and MS550 data are all consistent in indicating a periodically lowered water level at the pond edge during the mid Holocene. It is probable that periodic moisture stress during the Neolithic to Copper Age (Bg4a–4c) would have adversely affected the regeneration of moisture-loving fir seedlings on the driest soils upslope from the site. In addition, the position of the site close to natural routeways along watersheds and ridges (Maggi, 1990), a reliable water supply, archaeological evidence of Neolithic and Copper Age presences, the early Neolithic introduction of domesticated herbivores to Liguria (Rowley-Conwy, 1997) and the Copper/Early Bronze Age spread of pastoralism and transhumance (Maggi and Nisbet, 1990; Maggi, 1997), all lend support to the hypothesis that Lago di Bargone would have been used as a watering hole by prehistoric pastoralists and their domesticated herbivores. Recent forest ecology studies have demonstrated the susceptibility of *Abies* to the effects of grazing and browsing (Paluch, 2005; Heuze *et al*., 2005). Apparently deer as well as cattle and other domestic animals have a special liking for fir saplings (Ellenberg, 1988; Motta, 1996). It is also well established that leaf and twig foddering was the main source of winter feed for stock during the Neolithic, with *Ulmus*, *Tilia* and deciduous *Quercus* being some of the preferred fodder species (Rasmussen, 1993; Nisbet, 1997; Akeret *et al*., 1999).

It is argued therefore, that the mid-Holocene vegetation developments at Bargone are more strongly linked to warm, dry climatic conditions together with local grazing, browsing and fodder collection than to forest burning and clearance. The absence of any indications of soil disturbance suggests low stocking rates (Maggi, 2004, estimates a Neolithic family would have needed to manage a hectare of woodland in order to raise two cows). The Bg98 pollen data also indicates this may have been part of a larger, regional subsistence system. Studies of pollen–vegetation relationships in southern European mountains have shown that low frequencies of 'anthropogenic indicator' pollen types are more indicative of land use at a regional scale. For example, low frequencies of some wind-pollinated herbaceaous taxa such as *Artemisia* and Chenopodiaceae have greater significance as indicators of anthropogenically disturbed soils at extra-local and regional scales (Court-Picon *et al*., 2006; Mazier *et al.*, 2006). Cereal type pollen is transported over long distances in mountains by animal and human movements (Vuorela, 1973; Moe; 1983; Robinson and Rasmussen, 1989; Court-Picon *et al*., 2005).

Bronze Age

A rise in arboreal frequencies and reduction in herbs and Ericaceae in Bg5a and Bg5b suggest a general reduction of exploitation and scrub and tree regeneration during the Bronze Age at Lago di Bargone. The *Fagus* and *Ostrya* t. curves are suggestive of secondary colonisation of former Neolithic and Copper Age clearings as these taxa are known to be favoured by forest clearings (Gobet *et al*., 2000; Watkins, 2004) although dispersal over long distances, especially of *Ostrya* t., suggest a regional, rather than local significance (Conedera *et al*., 2006). The rise in the *Quercus ilex* + *cerris* curve after *2440–1870 cal. BC* (93% probability) in Bg5b is puzzling. As mediterranean oak species in present-day Liguria normally grows below around 200 m, this could indicate colonisation of dry south-facing slopes by mediterranean oak species during the Bronze Age. Nevertheless, it is also possible that mediterranean oaks could have extended their range into higher altitudes than is usual today (*Quercus ilex* normally grows below 200 m). This may possibly be consistent with either the 'aridification' phases identified by Jalut *et al.* (2000) for the western mediterranean, or even a type of woodland management designed to produce acorns as feed for pigs (Lewthwaite, 1982).

Iron Age/Roman to Mediaeval and post-Mediaeval

All of the available data from Lago di Bargone point to local soil disturbances and deforestation during the Iron Age to Roman periods. Major declines in all of the major arboreal taxa attest to significant deforestation at both regional and local scales during Bg6a. *Abies* in particular, was a preferred timber for construction, tool-making and, sometimes, ship-making in much of the Roman Empire (Nakagawa *et al*., 2000). Fir frequencies also slumped in inland, montane Liguria from about 2000 years BP (Macphail, 1988). There is also a dramatic fall in LOI to less than 22%, a rise in phosphate concentrations (average 262 ppm) and weakly enhanced MS values. In thin sections M4 and M5 there is evidence of silty inwash and an increase in very fine (<10 μm) charcoal fragments becoming abundant in M5 (Figure 7C). In contrast to earlier records of microcharcoal in M3, here the charred plant fragments are accompanied by inclusions of fine, burned mineral grains, and in M5 a coarse burned peat fragment suggesting that, on occasions, fires may have extended onto the peat surface itself (cf. Courty *et al*., 1989: 309, plate Vd). While it seems certain that fires would have occurred locally at Lago di Bargone, the very fine size range of the charred fragments and the seeming absence of coarser size range again do not suggest local *forest* clearance by fire. Rather it is necessary to envisage a system of light, controlled burning possibly akin to the local tradition of using fire to control weeds such as *Erica arborea* and to encourage new grass and herbaceous growth (Grove and Rackham, 2001). Until recently, the tradition of using fire to control weeds was widespread in this area. Locally, it may have been an area of open grazing that saw the development of widespread heath and grassland communities. The presence of dung as identified within the pond edge sediments (thin section M6), points to the site being used as a watering hole by stock. It is very likely that the pastures at Lago di Bargone could have been part of a large-scale regional system of seasonal grazing and transhumance that is known to have been widespread in Roman Italy (Grove and Rackham, 2001), and possibly associated with the common grazing rights of 'compascuo' (Maggi, 1999; Mannoni, 2000).

The regional expansion of arboriculture in eastern Liguria is suggested by *Olea* t., *Juglans* and *Castanea* pollen types (Bg6b, Barg4b). New varieties of olives were introduced to the western Mediterranean during the classical and Mediaeval periods (Terral *et al*., 2004), but it is improbable that olives were cultivated at this altitude. As *Olea* t. pollen is over-represented in pollen diagrams from mountains (de Beaulieu, 1977), the increase in *Olea* t. pollen here is more likely to be indicative of olive cultivation in settlements of the coastal valleys close to Lago di Bargone.

It has already been argued on the basis of sediment micromorphology (see Bargone 94 sediments) that colluvium would have rapidly buried the underlying organic deposits. In particular, the inclusion of rock fragments within the overlying colluvium (M7) points to a devastating impact of human activities. There is no evidence of cultivation of the steep slopes here and it seems unlikely that grazing alone could have caused such deeply seated erosion. On the other hand, it is known that mining continued in this area until the nineteenth and twentieth centuries (McCullagh and Pearce, 2004). It is argued therefore, that the accumulation of colluvial deposits and rockslide debris at Lago di Bargone today is very likely to have been influenced by local mining.

Conclusions

A sedimentological investigation of basin edge deposits including colluvium and rockslide debris together with a palynological study from the central area of the peat bog at Lago di Bargone, has allowed the identification of soil disturbances and erosion to be related to some of the changes in land use as inferred from the pollen diagram. Although archaeological and palynological data suggested significant Neolithic and Copper/Early Bronze Age presence and local forest disturbances, such activity was too light in intensity or on too small a scale to register soil disruption and erosion within the limitations of the methodologies used. On the other hand, sediment micromorphology, microprobe and MS550 all pointed to periodic drying out of the basin edges and lowering of the local water-table during this period. It is suggested that periodic moisture stress during the warm, dry climatic conditions of the mid Holocene would have contributed to the decline of moisture-sensitive forest taxa such as *Abies* from around the site. It is also argued that light grazing around a watering hole, by domesticated herds belonging to Neolithic and Copper Age pastoralists, would also have been a significant factor. In addition, there is no evidence to support a history of forest fires scenario as described elsewhere in northern Italy. There was far greater impact upon local soils from the Iron Age/Roman periods with evidence for colluviation, deforestation and the development of heath and dry grassland communities. Micromorphological evidence indicates light, controlled burning to maintain pastures, whereas forest clearance by fire is less likely. It is suggested that the area around Lago di Bargone was probably an area of open grazing that could have been part of a large-scale regional system of seasonal grazing and transhumance during the Roman period. Subsequently, deep-seated erosion of soil profiles resulted in the accumulation of colluvial deposits and rockslide debris at Lago di Bargone today. This latest devastating impact on local soils is likely to have been influenced by mining, an activity that is known to have continued in the area until recently. Although mining is no longer a threat to the site, Lago di Bargone and other similar small wetland sites in the Ligurian Apennines are today threatened more by a diminution of traditional land management practices particularly a reduction of grazing and controlled burning. It is anticipated that new studies being carried out by the University of Genoa will contribute to the continued development of a more detailed appreciation of the climatic, palaeoecological, erosional and land-use history of this area.

Acknowledgements

The authors would like to thank the Soprintendenza per i beni archeologici della Liguria for assistance and funding, and Kevin Reeves, Institute of Archaeology, UCL, and Andrew Haggart, Department of Pharmaceutical, Chemical and Environmental Sciences, University of Greenwich, for assistance.

References

Akeret, O., Haas, J.N., Leuzinger, U. and **Jacomet, S.** 1999: Plant macrofossils and pollen in goat/sheep faeces from the Neolithic lake-shore settlement Arbon Bleiche 3, Switzerland. *The Holocene* 9, 175–82.

Allen, M.J. and **Macphail, R.I.** 1987: Micromorphology and magnetic susceptibility studies: their combined role in interpreting archaeological soils and sediments. In Fedoroff, N., Bresson, L.M. and Courty, M.A., editors, *Soil micromorphology*. Association Française pour l'Étude du Sol, 669–76.

Andrieu-Ponel, V., Ponel, P., Bruneton, H., Leveau, P. and **de Beaulieu, J.L.** 2000: Palaeoenvironments and cultural landscapes of the last 2000 years reconstructed from pollen and Coleopteran records in the Lower Rhone Valley, southern France. *The Holocene* 10, 341–55.

Arrhenius, O. 1934: Fosfathalten i skånska jordar. *Sveriges Geologiska Undersökningar*, Ser. C, 394.

—— 1955: The Iron Age settlements on Gotland and the nature of the soil. Valhagan II. In Stenberger, M., editor, *Valhagan II.* Munksgaard, 1053–64.

Barber, K.E., Chambers, F.M. and **Maddy, D.** 2003: Holocene palaeoclimates from peat stratigraphy: macrofossil proxy climate records from three oceanic raised bogs in England and Ireland. *Quaternary Science Reviews* 22, 521–39.

Barbero, M. and **Bono, G.** 1970: Les sapinières des Alpes maritimes, de l'Authion à la Ligurie et de la Stura au Tanaro. *Veröffentlichungen des Geobotanischen Institutes der Eidgenoessische Technische Hochschule Stiftung Rubel in Zürich* 43, 140–68.

Bayliss, A., Bronk Ramsey, C., van der Plicht, J. and **Whittle, A.** 2007: Bradshaw and Bayes: towards a timetable for the Neolithic. *Cambridge Archaeological Journal* 17, 1–28.

Bertolini, G., Guida, M. and **Pizziolol, M.** 2005: Landslides in Emilia-Romagna region (Italy): strategies for hazard assessment and risk management. *Landslides* 2, 302–12.

Bertran, P. 2004: Soil erosion in small catchments of the Quercy region (southwestern France) during the Holocene. *The Holocene* 14, 597–606.

Biagi, P., Maggi, R. and **Nisbet, R.** 1986: *Primi dati sul Neolitico della Liguria Orientale*. In *Il Neolitico in Italia*. Atti della XXVI Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, 523–32.

Blaauw, M. and **Christen, J.A.** 2005: Radiocarbon peat chronologies and environmental change. *Applied Statistics* 54, 805–16.

Blaauw, M., Christen, J.A., Mauquoy, D., van der Plicht, J. and **Bennett, K.D.** 2007a: Testing the timing of radiocarbon-dated events between proxy archives. *The Holocene* 17, 283–88.

Blaauw, M., Bakker, R., Christen, J.A., Hall, V.A. and **van der Plicht, J.** 2007b: A Bayesian framework for age modeling of radiocarbon-dated peat deposits: case studies from the Netherlands. *Radiocarbon* 49, 357–68.

Blockley, S.P.E., Blaauw, M., Bronk Ramsey, C. and **van der Plicht, J.** 2007: Building and testing age models for radiocarbon dates in Lateglacial and early Holocene sediments. *Quaternary Science Reviews* 26, 1915–26.

Blockley, S.P.E., Bronk Ramsey, C., Lane, C.S. and **Lotter, A.F.** 2008: Improved age modelling approaches as exemplified by the revised chronology for the Central European varved lake Soppensee. *Quaternary Science Reviews* 27, 61–71.

Boschian, G. and **Montagnari-Kokelji, E.** 2000: Prehistoric shepherds and caves in the Trieste Karst (northeastern Italy). *Geoarchaeology* 15, 331–71.

Branch, N. 1997: Palynological study of the early and middle Neolithic cave deposits of Arene Candide: preliminary results. In Maggi, R., editor, *Arene Candide: a functional and environmental assessment of the Holocene sequence.* Memorie dell'Istituto Italiano di Paleontologia Umana, Nuova Serie 5, 89–102.

—— 2004: Late Würm Lateglacial and Holocene environmental history of the Ligurian Apennines, Italy. In Balzaretti, R., Pearce, M. and

Watkins, C., editors, *Ligurian landscapes, studies in archaeology, geography and history*. Accordia Research Institute, 7–69.

Brancucci, G. and **Paliaga, G.** 2006: The hazard assessment in a terraced landscape: preliminary result of the Liguria (Italy) case study in the Interreg III Alpter project. In Nadim, F., Pöttler, R., Einstein, H., Klapperich, H. and Kramer, S., editors, *2006 ECI conference on geohazards, Lillehammer, Norway.* http://services.bepress.com/eci/geohazards/16

Bronk Ramsey, C. 1995: Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon* 37, 425–30.

—— 1998: Probability and dating. *Radiocarbon* 40, 461–74.

—— 2001: Development of the radiocarbon program OxCal. *Radiocarbon* 43, 355–63.

—— 2008: Deposition models for chronological records. *Quaternary Science Reviews* 27, 42–60.

—— 2009a: Bayesian analysis of radiocarbon dates. *Radiocarbon* 51, 337–60.

—— 2009b: Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon* 51, in press.

Buck, C.E., Litton, C.D. and **Smith, A.F.M.** 1992: Calibration of radiocarbon results pertaining to related archaeological events. *Journal of Archaeological Science* 19, 497–512.

Buck, C.E., Cavanagh, W.G. and **Litton, C.D.** 1996: *Bayesian approach to interpreting archaeological data*. WileyBlackwell.

Bullock, P., Fedoroff, N., Jongerius, A., Stoops, G. and **Tursina, T.** 1985: *Handbook for soil thin section description*. Waine Research Publications.

Buol, S.W., Hole, F.D., McCracken, R.J. and **Southard, R.J.** 1997: *Soil genesis and classification (4th edition).* Iowa State University Press.

Campana, N. and **Maggi, R.,** editors 2002: *Archeologia in Valle Lagorara.* Origines.

Campana, N. and **Negrino, F.** 2002: Considerazioni sull'uso della grotta. In Campana, N. and Maggi, R., editors, *Archeologia in Valle Lagorara*. Origines, 317.

Campana, N., Maggi, R. and **Negrino, F.** 1998: Val Bargonasco. In Del Lucchese, A. and Maggi, R., editors, *Dal diaspro al bronzo. L'Età del Rame e l'Età del Bronzo in Liguria: 26 secoli di storia fra 3600 e 1000 anni avanti Cristo.* Quaderni della Soprintendenza Archeologica della Liguria, n.5, 133–37.

Cantu, V. 1977: The climate of Italy. In Wallen, C., editor, *Climates of central and southern Europe.* World Survey of Climatology, 6. Elsevier, 127–73.

Chiverrell, R.C. 2001: A proxy record of late Holocene climate change from May Moss, northeast England. *Journal of Quaternary Science* 16, 9–19.

Christen, J., Clymo, R. and **Litton, C.** 1995: A Bayesian approach to the use of C-14 dates in the estimation of the age of peat. *Radiocarbon* 37, 431–41.

Colombaroli, D., Marchetto, A. and **Tinner, W.** 2007: Long-term interactions between Mediterranean climate, vegetation and fire regime at Lago di massaciucoli (Tuscany, Italy). *Journal of Ecology* 95, 755–70.

Colombaroli, D., Vannière, B., Emmanuel, C., Magny, M. and **Tinner, W.** 2008: Fire–vegetation interactions during the Mesolithic–Neolithic transition at Lago dell'Accesa, Tuscany, Italy. *The Holocene* 18, 679–92.

Conedera, M., Tinner, W., Crameri, S., Torriani, D. and **Herold, A.** 2006: Taxon-related pollen source areas for lake basins in the southern Alps: an empirical approach. *Vegetation History and Archaeobotany* 15, 263–72.

Court-Picon, M., Buttler, A. and **de Beaulieu, J-L.** 2005: Modern pollen–vegetation relationships in the Champsaur valley (French Alps) and their potential in the interpretation of fossil pollen records of past cultural landscapes. *Review of Palaeobotany and Palynology* 135, 13–39.

—— 2006: Modern pollen/vegetation/land-use relationships in mountain environments: an example from the Champsaur valley (French Alps). *Vegetation History and Archaeobotany* 15, 151–68.

Courty, M.A., Goldberg, P. and **Macphail, R.I.** 1989: *Soils and micromorphology in archaeology*. Cambridge University Press.

Cristiano, N. 2009: Soil micromorphology in the wet area of Mogge di Ertola (Genova). Poster paper presented at Wetlands as archives of the cultural landscapes: from research to management, January 2009, Genova.

Crowther, J. 2003: Potential magnetic susceptibility and fractional conversion studies of archaeological soils and sediments. *Archaeometry* 45, 685–701.

Cruise, G.M. 1990: Holocene peat initiation in the Ligurian Apennines, northern Italy. *Review of Palaeobotany and Palynology* 63, 173–82.

Cyprien, A.L., Visset, L. and **Carcaud, N.** 2004: Evolution of vegetation landscapes during the Holocene in the central and downstream Loire basin (Western France). *Vegetation History and Archaeobotany* 13, 181–96.

de Beaulieu, J.L. 1977: Contribution pollenanalytique à l'histoire tardiglaciaire et holocène de la végétation des Alpes méridionales française. Thèse présentée a l'Université d'Aix-Marseille III. C.N.R.S. No. A.O. 12669.

Delcourt, P.A. and **Delcourt, H.R.** 1980: Pollen preservation and Quaternary environmental history in the southeastern United States. *Palynology* 4, 215–31.

Dickson, C. 1988: Distinguishing cereal from wild grass pollen: some limitations. *Circaea* 5, 67–71.

Dinç, U., Miedema, R., Bal, L. and **Pons, L.J.** 1976: Morphological and physio-chemical aspects of three soils developed in peat in The Netherlands and their classification. *Netherlands Journal of Agricultural Science* 24, 247–65.

Duchaufour, P. 1982: *Pedology.* Allen and Unwin.

Ellenberg, H. 1988: *Vegetation ecology of Central Europe.* Fourth edition. Cambridge University Press.

Engelmark, R. and **Linderholm, J.** 2008: *Miljöarkeologi Människa och Landskap – en komplicerad dynamik*., Malmöfynd Nr 15. Kulturmiljö.

FAO-Unesco 1988: *Soil map of the world.* Resources Report 60 edn. FAO.

Finsinger, W. and **Tinner, W.** 2006: Holocene vegetation and land-use changes in response to climatic changes in the forelands of the south-western Alps, Italy. *Journal of Quaternary Science* 21, 243–58.

Gearey, B.G., Marshall, P. and **Hamilton, D.** 2009: Correlating archaeological and palaeoenvironmental records using a Bayesian approach: a case study from Sutton Common, South Yorkshire, England. *Journal of Archaeological Science* 36, 1477–87.

Gobet, E., Tinner, W., Hubschmid, P., Jansen, I., Wehrli, M., Ammann, B. and **Wick, L.** 2000: Influence of human impact and bedrock differences on the vegetational history of the Insubrian Southern Alps. *Vegetation History and Archaeobotany* 9, 175–87.

Goldberg, P. and **Macphail, R.I.** 2006: *Practical and theoretical geoarchaeology*. Blackwell Publishing.

Greig, J. 1988: Some evidence of the development of grassland plant communities. In Jones, M., editor, *Archaeology and the flora of the British Isles*. Oxford University Committee for Archaeology, 39–54.

Grove, A.T. and **Rackham, O.** 2001: *The nature of Mediterranean Europe: an ecological history*. Yale University Press.

Guilizzoni, P., Lami, A., Marchetto, A., Jones, V., Manca, M. and **Bettinetti, R.** 2002: Palaeoproductivity and environmental changes during the Holocene in central Italy as recorded in two crater lakes (Albano and Nemi). *Quaternary International* 88, 57–68.

Heuze, P., Schnitzler, A. and **Klein, F.** 2005: Is browsing the major factor of silver fir decline in the Vosges Mountains of France? *Forest Ecology and Management* 217, 219–28.

Jalut, G., Esteban Amat, A., Bonnet, L., Gauquelin, T. and **Fontugne, M.** 2000: Holocene climatic changes in the western Mediterranean, from south-east France to south-east Spain. *Palaeogeography, Palaeoclimatology, Palaeoecology* 160, 255–90.

Keller, F., Lischke, H., Mathis, T., Möhl, A., Wick, L., Ammann, B. and **Kiennast, F.** 2002: Effects of climate, fire and humans on forest dynamics: forest simulations compared to the palaeological record. *Ecological Modelling* 152, 109–27.

Kelly, M.G. and **Huntley, B.** 1991: An 11 000-year record of vegetation and environment from Lago di Martignano, Latium, Italy. *Journal of Quaternary Science* 3, 209–24.

Konnert, M. and **Bergmann, F.** 1995: The geographical distribution of genetic variation of silver fir (*Abies alba,* Pinaceae) in relation to its migration history. *Plant Systematics and Evolution* 196, 19–30.

Lewthwaite, J.G. 1982: Acorns for ancestors: the prehistoric exploitation of woodland in the west mediterranean. In Bell, M. and Limbrey, S., editors, *Archaeological aspects of woodland ecology.* Symposia of the Association for Environmental Archaeology No. 2. BAR International Series 146, 217–30.

Linderholm, J. 2007: Soil chemical surveying: a path to a deeper understanding of prehistoric sites and societies in Sweden. *Geoarchaeology* 22, 417–38.

Lowe, J.J. 1992: Lateglacial and early Holocene lake sediments from the northern Apennines, Italy – pollen stratigraphy and radiocarbon dating. *Boreas* 21, 193–208.

Lowe, J.J. and **Watson, C.** 1993: Lateglacial and early Holocene pollen stratigraphy of the northern Apennines, Italy. *Quaternary Science Reviews* 12, 727–38.

Macphail, G.M. 1988: Pollen stratigraphy of Holocene peat sites in eastern Liguria, northern Italy. Ph.D. thesis, City of London Polytechnic (Unpublished).

Macphail, R.I. 1992: Soil micromorphological evidence of ancient soil erosion. In Bell, M. and Boardman, J., editors, *Past and present soil erosion.* Volume Monograph 22. Oxbow, 197–216.

Macphail, R.I. and **Cruise, G.M.** 2001: The soil micromorphologist as a team player: a multianalytical approach to the study of European microstratigraphy. In Goldberg, P., Holliday, V. and Ferring, R., editors, *Earth science and archaeology*. Kluwer Academic/Plenum Publishers, 241–67.

Macphail, R.I., Cruise, G.M. and **Mellalieu, S.J.** 1999: Soil micromorphological and diatom analysis of thin sections and microchemical analysis of polished blocks. In Niblett, R., editor, *The excavation of a ceremonial site at Folly Lane, Verulanium.* Britannia Monograph No. 14. Britannia, 365–84.

Macphail, R.I., Cruise, G.M., Engelmark, R. and **Linderhom, J.** 2000: Integrating soil micromorphology and rapid chemical survey methods: new developments in reconstructing past rural settlement and landscape organisation. In Roskams, S., editor, *Interpreting statigraphy, volume 9.* University of York, 71–80.

Macphail, R.I., Cruise, G.M., Allen, M.J., Linderholm, J. and **Reynolds, P.** 2004: Archaeological soil and pollen analysis of experimental floor deposits; with special reference to Butser Ancient Farm, Hampshire, UK. *Journal of Archaeological Science* 31, 175–91.

Maggi, R., editor 1990: *Archeologia dell'Appennino Ligure. Gli scavi del Castellaro di Uscio: un insediamento di crinale occupato dal Neolitico alla conquista romana.* Istituto Internazionale di Studi.

—— editor 1997: *Arene Candide: a functional and environmental assessment of the Holocene sequence.* Memorie dell'Istituto Italiano di Paleontologia Umana, Nuova Serie 5.

—— 1999: Coasts and uplands in Liguria and northern Tuscany from the Mesolithic to the Bronze Age. In Tykot, R., Morter, J. and Robb, J.E., editors, *Social dynamics of the prehistoric central mediterranean*. Specialist Studies on the Mediterranean 3, Accordia Research Institute, 47–65.

—— 2004: *I monti sun eggi*: the making of the Ligurian landscape in prehistory. In Balzaretti, R., Pearce, M. and Watkins, C. editors, *Ligurian Landscapes, studies in archaology, geography and history.* Accordia Resarch Institute, 71–82.

Maggi, R. and **Nisbet, R.** 1990: Prehistoric pastoralism in Liguria. In Maggi, R., Nisbet, R. and Barker, G., editors, *Archeologia della pastorizia nell'Europa meridionale, vol. 1.* Rivista di Studi Liguri, 56, 265–96.

Maggi, R. and **Pearce, M.** 2005: Mid fourth-millennium copper mining in Liguria, north-west Italy: the earliest known copper mines in Western Europe. *Antiquity* 79, 66–77.

Maggi, R. and **Starnini, E.** 1990: L' industria litica scheggiata. In Maggi R., editor, *Archeologia dell'Appennino Ligure. Gli scavi del Castellaro di Uscio: un insediamento di crinale occupato dal Neolitico alla conquista romana.* Istituto Internazionale di Studi, 63–88.

Maggi, R., Campana, N., Negrino, F. and **Ottomano, C.** 1994: The quarrying and workshop site of Valle Lagorara (Liguria – Italy). *The Accordia Research Papers* 5, 73–96.

Magny, M. 2004: Holocene climate variability as reflected by mid-European lake-level flucuations and its probable impact on prehistoric human settlements. *Quaternary International* 113, 65–79.

Magny, M., Leuzinger, U., Bortenschlager, S. and **Haas, J.N.** 2006: Tripartite climate reversal in Central Europe 5600–5300 years ago. *Quaternary Research* 65, 3–19.

Magri, D. 1999: Late Quaternary vegetation history at Lagaccione near Lago di Bolsena (central Italy). *Review of Palaeobotany and Palynology* 106, 171–208.

Mannoni, T. 2000: Trent'anni di archeologia in Liguria. Il problema dei Liguri. In Balbi, S., Patrone, S. and Ribolla, P., editors, *Canegrate/Liguria. Cultura materiale ed ambiente dalla media Età del Bronzo all'Età del Ferro nel Levante ligure.* I Quaderni della Massocca, 31–54.

Marchetti, M. 2002: Environmental changes in the central Po Plain (northern Italy) due to fluvial modifications and anthropogenic activities. *Geomorphology* 44, 361–73.

Markgraf, V. 1980: Pollen dispersal in a mountain area. *Grana* 19, 127–46.

Mazier, F., Galop, D., Brun, C. and **Buttler, A.** 2006: Modern pollen assemblages from grazed vegetation in the western Pyrenees, France: a numerical tool for more precise reconstruction of past cultural landscapes. *The Holocene* 16, 91–103.

McCullagh, M. and **Pearce, M.** 2004: Surveying the prehistoric copper mine at Libiola (Sestri Levante-GE), Italy. In Balzaretti, R., Pearce, M. and Watkins, C., editors, *Ligurian landscapes, studies in archaology, geography and history.* Accordia Resarch Institute, 93–95.

Menozzi, B.I., Bellini, C., Guido, M.A., Placereani, S. and **Montanari, C.** 2009: Moglie di Ertola: the palynological records. Poster paper presented at Wetlands as archives of the cultural landscapes: from research to management, January 2009, Genova.

Moe, D. 1983: Palynology of sheep faeces: relationship between pollen content, diet and local pollen rain. *Grana* 22, 105–13.

Mook, W.G. 1986: Business meeting: recommendations/resolutions adopted by the twelfth international radiocarbon conference. *Radiocarbon* 28, 799.

Mook, W.G. and **Streurman, H.J.** 1983: Physical and chemical aspects of radiocarbon dating. In Mook, W.G. and Waterbolk, H.T., editors, Proceedings of the First International Symposium 14C and Archaeology. *PACT* 8, 31–55.

Mook, W.G. and **Waterbolk, H.T.** 1985: *Radiocarbon dating: European Science Foundation handbook for archaeologists 3*. Strasbourg.

Moore, P.D. and **Webb, J.A.** 1978: *An illustrated guide to pollen analysis.* Hodder and Stoughton.

Moore, P.D., Webb, J.A. and **Collinson, M.E.** 1991: *Pollen analysis*. Blackwell Scientific Publications.

Motta, R. 1996: Impact of wild ungulates on forest regeneration and tree composition of mountain forests in the western Italian Alps. *Forest Ecology and Management* 88, 93–98.

Murphy, C.P. 1986: *Thin section preparation of soils and sediments*. AB Academic Publishers.

Nakagawa, T., de Beaulieu, J-L. and **Kitagawa, H.** 2000: Pollen-derived history of timber exploitation from the Roman period onwards in the Romanche valley, central French Alps. *Vegetation History and Archaeobotany* 9, 85–89.

Nisbet, R. 1997: Arene Candide: charcoal remains and prehistoric woodland use. In Maggi, R., editor, *Arene Candide: a functional and environmental assessment of the Holocene sequence.* Memorie dell'Istituto Italiano di Paleontologia Umana, Nuova Serie 5, 103–12.

Noakes, J.E., Kim, S.M. and **Stipp, J.J.** 1965: Chemical and counting advances in Liquid Scintillation Age dating. In Olsson, E.A. and Chatters, R.M., editors, *Proceedings of the sixth international conference on radiocarbon and tritium dating*. Washington, 68–92.

Oberdorfer, E. and **Hofman, A.** 1967: Beitrag zur Kenntnis der Vegetation des nordapennin. *Beitrage zur Naturkundlichen Forschung in Südwestdeutschland – Dtl.* 24, 83–139.

Orsino, F. 1969: Lineamenti geobotanici della Liguria. *Archivio Botanico e Biogeografico Italiano* 45, 207–34.

Ottomano, C. 2004: Calvari-Cian dei Tenente e Isolalunga. Aspetti sedimentologici e micromorfologici della successione stratigrafica. In Spinetta, R., editor, *Neirone, Natura Stori Arte.* Genova, 106–107.

Paluch, J.G. 2005: The influence of the spatial pattern of trees on forest floor vegetation and silver fir (*Abies alba* Mill.) regeneration in uneven-aged forests. *Forest Ecology and Management* 205, 283–98.

Pini, R. 2004: Late Neolithic vegetation history at the pile-dwelling site of Palù di Livenza (northeastern Italy). *Journal of Quaternary Science* 19, 769–81.

Punt, W. and **Clarke, G.C.E.** 1976–1988: *The northwest European pollen flora, vols. I–V*. Elsevier Scientific Publishing Company.

Rasmussen, P. 1993: Analysis of goat/sheep faeces from Egolzwil 3, Switzerland: evidence for branch and twig foddering of livestock in the Neolithic. *Journal of Archaeological Science* 20, 479–502.

Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Bertrand, C., Blackwell, P.G., Buck, C.E., Burr, G., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Hughen, K.A., Kromer, B., McCormac, F.G., Manning, S., Bronk Ramsey, C., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J. and **Weyhenmeyer, C.E.** 2004: IntCal04 terrestrial radiocarbon age calibration, 0–26 cal kyr BP. *Radiocarbon* 46, 1029–58.

Robinson, M. and **Rasmussen, P.** 1989: Botanical investigations at the Neolithic lake village at Weier, north-east Switzerland: leaf hay and cereals as animal fodder. In Milles, A., Williams, D. and Gardner, N., editors, *The beginnings of agriculture*. Symposia of the Association for Environmental Archaeology No.8. BAR International Series 496, 149–63.

Rowley-Conwy, P. 1997: The animal bones form Arene Candide (Holocene sequence): final report. In Maggi, R., editor, *Arene Candide: a functional and environmental assessment of the Holocene sequence.* Memorie dell'Istituto Italiano di Paleontologia Umana, Nuova Serie 5, 153–278.

Sadori, L., Giraudi, C., Petitti, P. and **Ramrath, A.** 2004: Human impact at Lago di Mezzano (central Italy) during the Bronze Age: a multidisciplinary approach. *Quaternary International* 113, 5–17.

Schoute, J.F.T. 1984: *Vegetation horizons and related phenomena. A palaeocological-micromorphological study in the younger coastal Holocene of the northern Netherlands (Schildmeer Area)*. Strauss & Cramer, 270 pp.

—— 1987: Micromorphology of soil horizons developed during semi-terrestrial phases in transgressive and regressive sedimentary sequences in the Northern Netherlands. In Fedoroff, N., Bresson, L.M. and Courty, M.A., editors, *Soil micromorphology*. Association Française pour l'Étude du Sol, Plaisir, 661–67.

Sjögren, P. 2006: The development of pasture woodland in the south-west Swiss Jura Mountains over 2000 years, based on three adjacent peat profiles. *The Holocene* 16, 210–23.

Stenhouse, M.J. and **Baxter, M.S.** 1983: 14C dating reproducibility: evidence from routine dating of archaeological samples. *PACT* 8, 147–61.

Stockmarr, J. 1971: Tablets with spores used in absolute pollen analysis. *Pollen et Spores* XIII, 615–21.

Stoops, G. 2003: *Guidelines for analysis and description of soil and regolith thin sections.* Soil Science Society of America, Inc.

Stuiver, M. and **Kra, R.S.** 1986: Editorial comment. *Radiocarbon* 28, ii.

Stuiver, M. and **Polach, H.A.** 1977: Reporting of 14C data. *Radiocarbon* 19, 355–63.

Stuiver, M. and **Reimer, P.J.** 1986: A computer program for radiocarbon age calculation. *Radiocarbon* 28, 1022–30.

—— 1993: Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. *Radiocarbon* 35, 215–30.

Tan, B.S. 1987: Étude de l'influence de quelques facteurs écologiques sur les premiers stades de la régénération du sapin (*Abies alba*) à l'étage montagnard du Jura. *Revue d'Écologie et de Biologie du Sol* 24, 623–35.

Terral, J-F., Alonso, N., Buxó i Capdevila, R., Chatti, N., Fabre, L., Fiorentino, G., Marinval, P., Pérez Jordá, G., Pradat, B., Rovira, N. and **Alibert, P.** 2004: Historical biogeography of olive domestication (*Olea europea* L.) as revealed by geometrical morphometry applied to biological and archaeological material. *Journal of Biogeography* 31, 63–77.

Thirly, M., Galbois, J. and **Schmitt, J-M.** 2006: Unusual phosphate concretions related to groundwater flow in a continental environment. *Journal of Sedimentary Research* 76, 866–77.

Tinner, W., Hubschmid P., Wehrli, M., Ammann, B. and **Conedera, M.** 1999: Long-term forest fire ecology and dynamics in southern Switzerland. *Journal of Ecology* 87, 273–89.

Tite, M.S. and **Mullins, C.E.** 1971: Enhancement of magnetic susceptibility of soils on archaeological sites. *Archaeometry* 13, 209–19.

Tomaselli, R. 1970: Note illustrative della carta della vegetazione naturale potenziale d'Italia. *Collana Verde* 27, 4–63.

Valsecchi, V., Tinner, W. and **Finsinger, W.** 2006: Human impact during the Bronze Age on the vegetation at Lago Lucone (northern Italy). *Vegetation History and Archaeobotany* 15, 99–113.

Van Vliet-Lanoë, B., Helluin, M., Pellerin, J. and **Valadas, B.** 1992: Soil erosion in Western Europe: from the last interglacial to the present. In Bell, M. and Boardman, J., editors, *Past and present soil erosion.* Monograph 22, Oxbow, 101–14.

Vuorela, I. 1973: Relative pollen rain around cultivated fields. *Acta Botanica Fennica* 102, 1–27.

Watkins, C. 2004: The management history and conservation of terraces in the Val di Vara, Liguria. In Balzaretti, R., Pearce, M. and Watkins, C., editors, *Ligurian landscapes, studies in archaology, geography and history.* Accordia Resarch Institute, 141–54.

Watson, C. 1996: The vegetational history of the northern Apennines, Italy: information from three new sequences and a review of regional vegetational change. *Journal of Biogeography* 23, 805–41.

Wick, L. and **Möhl, A.** 2006: The mid-Holocene extinction of silver fir (*Abies alba*) in the southern Alps: a consequence of forest fires? Palaeobotanical records and forest simulations. *Vegetation History and Archaeobotany* 15, 435–44.