Human impact at Lago di Mezzano (central Italy) during the Bronze Age: a multidisciplinary approach
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Abstract
The purpose of this contribution is to disentangle climate forcing and human influence in the catchment of Lago di Mezzano through the interfingering of data obtained by means of archaeological, geomorphological, sedimentological and palynological approaches. A systematic archaeological survey has been undertaken and three submerged settlement areas with piles, pottery and metal tools have so far been found. The artifacts indicate that the site was inhabited, although not continuously, during the Bronze Age. Geomorphological investigations and observations in some trenches dug out on the lake shore indicate that great variations in the lake’s size and strong changes in the catchment/lake surface area ratio occurred during the second half of the Holocene. Palynological, micro-charcoal, sedimentological and geochemical analyses carried out on long cores taken from the lake centre have indicated environmental changes due to either climatic influence or human impact. Even if human presence in the area has been detected during the whole Bronze Age period, the human populations caused a strong impact only in two periods centred around 3600 and 3200 cal. years BP when they settled along the lake shore, and around 3400 cal. years BP when they caused an increase in erosion leading to the beginning of the deposition of turbidites.

1. Site setting (C. Giraudi, L. Sadori)

Lago di Mezzano (Lazio, Central Italy, 42°37’N, 11°56’E, 452 m a.s.l.) is a maar lake lying inside the caldera formed by the collapse of the Latera volcano. The volcano evolved, starting about 300,000 years ago, mainly during the Middle and late Middle Pleistocene. The whole caldera forms the catchment basin of the Olpeta River, and can be divided into many smaller basins: some of these basins are connected by narrow valleys produced by the erosion of the sills of former lakes.

The geological study of the non-volcanic sediments has established that inside the Caldera di Latera some terraced lacustrine sediments, alluvial and colluvial deposits and a limited amount of travertine are exposed. The lacustrine sediments must be linked to different phases of the caldera’s evolution. They can be found at altitudes higher than the caldera rim, and must have formed when the volcano-tectonic activity was still strong. Others are older than the last volcanic activity.

In some places, the lacustrine sediments appear to be very well laminated, up to 20 m thick, and formed mainly by carbonates. The sediments forming the terraces surrounding the lake are younger than the final activity of the volcano, being Upper Pleistocene and Holocene in age.

Lago di Mezzano is the youngest of the caldera lakes and fills the bottom of a small crater produced by a phreatomagmatic eruption during the last phases of volcanic activity, about 100,000 years ago (Nappi et al., 1995). The lake is 800 m wide and has a maximum water depth of 31 m. The surface area is about 0.5 km², and the catchment area is about 1 km² with few, very small, surface inflows and one outflow. The present size of the lake is due to reclamation works which can be observed both in aerial photos and in the field. Before drainage, the lake catchment was much larger and the water flowed, across a sill at the north-eastern margin of the catchment area, to the river Olpeta which was the original outflow of the lake. The present outflow (Fosso delle Volpi) is man made, and other streams, formerly flowing to the lake from the northern basin, were artificially diverted to the Olpeta (Figs. 1 and 2).
The lake is characterised by mesotrophic to oligotrophic conditions, which are evidenced by low water conductivity and a very low phosphorous content, by a pH of around 8 and warm-monomictic behaviour with a single turnover in autumn. The reported conditions indicate that an anoxic hypolimnion is established during the summer months (Ramrath et al., 2000).

Situated between the Tyrrhenian Sea in the south-west and the Apennine mountains in the north-east, northern Lazio has a strong precipitation gradient according to a transition from the Mediterranean to the temperate climatic zone. Lago di Mezzano is located in the temperate region (Blasi, 1994) with a mean annual precipitation reaching 1000 mm (Fig. 3), mainly in autumn (October–December), and a not very pronounced summer aridity. The mean of the minimum temperature of the coldest month is between 1.2°C and 2.9°C. In Valentano, the closest town to the lake, the mean annual temperature is 13.1°C.

![Geological map of the Lago di Mezzano basin.](image)

**Fig. 1.** Geological map of the Lago di Mezzano basin. (1) Lacustrine and shore sediments; (2) volcanic materials; (3) landslide deposits; (4) alluvial fan; (5) terrace scarplet.

![Thermopluviometric diagram from Valentano](image)

**Fig. 3.** Thermopluviometric diagram from Valentano (modified from Blasi, 1994).

![Extension of Lago di Mezzano size](image)

**Fig. 2.** The extension of Lago di Mezzano size during three characteristic periods: present time, 16–17th centuries and Bronze Age. The 20th century extent of the lake was the result of reclamation works.
The natural vegetation around the site consists of deciduous oaks (*Quercus robur, Q. cerris*), hornbeams (*Ostrya carpinifolia, Carpinus betulus*) and chestnut with a tendency towards beech forest (*Fagus sylvatica* with *Ilex aquifolium*). At the lake shore, *Alnus, Salix* and *Populus* are the most common trees. At present the area around the lake is scarcely inhabited, being mostly cultivated or used for pasture.

2. Materials, methods and chronology (C. Giraudi, L. Sadori, A. Ramrath)

Although research is still in progress, the data already available allow assessment of the anthropogenic impact on the environment during the Bronze Age with a fair degree of reliability. From the methodological point of view, the integration of data deriving from the lake bed and from the catchment basin, but also from the surrounding areas, appears essential for the correct assessment of the complex mechanisms that control natural evolution both with and without ancient human settlements.

Lago di Mezzano seems a suitable site for interdisciplinary studies in order to determine the impact of ancient human settlements on the environment:

- three submerged settlements of pile-dwellings and numerous metal and pottery artifacts, attributable mainly to the Bronze Age, have been found near the lake shore;
- three sediment cores have been taken from the centre of the lake, two of which have been studied with palynological, sedimentological and geochemical methods;
- the catchment area of the lake has been studied from geological and geomorphological standpoints and a number of trenches have been dug in the sediments forming the lake shore.

The studies on the submerged archaeological settlements and sites identified around the lake basin provide information about the human occupation of the area, fauna, use of the natural resources, and past lake level variations. The geological and geomorphological studies demonstrate changes in the hydrological balance and in the drainage network discharging into the lake; these data further allows the lake level variations evidenced by archaeological settlements to be framed in a clear palaeogeographic context.

The study of the sedimentological and physical character of the sediment records, revealed from the deepest part of the lake, allows establishment of not only the biomass productivity, but also the deposition rate of minerals of chemical and detrital origin. These are directly related to climatic and environmental variations as, for example, changing erosion rates in the catchment. The sediment data has been compared and linked with those identified by means of geological studies of the catchment. The pollen record provides information on the vegetation cover and its variations over time and completes the data on environmental dynamics in the Mezzano lake catchment.

The comparison of data derived from these multidisciplinary studies focused on periods with or without human settlements near the Mezzano lake shore, gives evidence that not all observed changes can be explained simply as a consequence of climatic and environmental variations. For some periods a particularly strong human impact on the local landscape has to be assumed. However, it is very difficult to establish whether a continuous, weak human intervention affected the area during the whole studied period. The sediment record from the lake provided a continuous environmental framework to the human activity in the surroundings of Lago di Mezzano during the last few thousand years and was a useful tool to distinguish the human impact from natural trends.

Three parallel cores (A, B, C) were taken from the centre of the lake, each with a minimum length of 28 m, in May 1995 using a modified Livingstone piston corer (Usinger corer) by the GeoForschungsZentrum Potsdam. Cores A and B were investigated petrographically, geochemically and physically to obtain one single composite record for the last 34,000 years (*Ramrath, 1997*). A continuous series of large-scale thin sections (10 cm in length) were microscopically analysed.

The chronology of the record expressed in calendar years BP was established by *Ramrath* (1997) on the basis of varve counting, eight AMS radiocarbon dates, two tephras and interpolated sedimentation rates (*Ramrath, 1997; Ramrath et al., 2000*). The radiocarbon dates were calibrated using the calibration program of *Stuiver and Reimer* (1993). More than 5500 annual layers were counted and measured in the whole record. Varves have been found in the interval 5.10–5.36 m of the core portion considered in the present work. The age of the base of the record is estimated at 34,000 cal. years BP.

The chronological model proposed by *Ramrath* (1997) has been used to assess the chronology of the section of the core reported here, between 4.1 m and 5.9 m (Fig. 4), the Bronze Age period. This part of the record comprises a time interval of about 1200 years, from 2900 to 4100 varve years BP. In the graph, the AMS radiocarbon date of 3290±40 years BP (3625–3395 cal. BP) obtained from bulk sediment is also shown. At the depth of the dated sample (5.42–5.44 m) the age estimated through varve-chronology is outside of the 2 sigma interval, thus being significantly older, at minimum about 70 years (Fig. 4). Conventional radiocarbon ages of 20 samples of wood including piles and...
planks of deciduous oak, alder, maple, elm, beech, found in the Lago di Mezzano submerged archaeological settlements, cluster mainly around two periods, at about 3200 years BP and at about 2780 years BP (Alessio et al., 1975; Follieri et al., 1976–77). The calibrated dates suggest a first period of settlement at about 3400 cal. years BP and a second one at about 2900 cal. years BP. Considering the observed offset between the AMS 14C date of the sample in the sediment profile and the varve-based time-scale it appears that varve-based dating of the sediment sections corresponding to the settlement phases might be roughly 100–200 years too old.

Volumetric sediment samples covering 1-cm slices were taken every 5 cm and analysed for dry density (DD), total carbon (TC) and total inorganic carbon (TIC). TC was measured by standard LECO combustion at $1350^\circ C$. The amounts of CO$_2$ liberated were measured by infrared absorption spectrometry. TIC was analysed by coulometry, which is based on the analysis of the amount of CO$_2$ produced after sample treatment with 85% phosphoric acid. TOC was calculated by subtraction of TIC from TC. Cores A and B were investigated petrographically (Ramrath, 1997) with observation of thin sections under the microscope. Geochemical analyses were carried out on the continuous record composed of cores A and B, while pollen and micro-charcoal analyses were carried out only on core B.

Sediment samples for pollen and micro-charcoal analyses from core B were prepared at 8 cm (time resolution roughly 50 years) intervals from 4.11 to 5.96 m. About $0.5 g$ of dry sediment was chemically processed with HCl (37%), HF (40%) and hot NaOH (10%). *Lycopodium* spore tablets were added to calculate the pollen and micro-charcoal concentrations. The preservation of the pollen grains was generally good, the number of indeterminable grains (degraded, corroded and broken) exceeded 5% of the basic pollen sum only once. The mean count of terrestrial spermatophytes pollen was 502 pollen grains. In 17 of the 23 analysed samples AP (pollen of arboreal plants) percentages were higher than 80% and only in 1 sample lower than 70%. The pollen percentages were calculated using different pollen basis sums, following Berglund and Ralska-Jasiewiczowa (1986). Local pollen zones, defined on the basis of the visual inspection of both diagrams, are numbered from the base upwards, and prefixed by the core portion designation M-B (Mezzano, Bronze Age).

Microscopic charcoal concentration counts were carried out at a 400-times magnification, using 12 size classes, measuring even charred particles smaller than 10 µm. As particles smaller than 20 µm, being present almost continuously, are not significant (Tolonen, 1986), charcoal data are summarised in two concentration curves (1) fragments between 20 and 50 µm, and (2) fragments >50 µm and compared with concentration and percentage of arboreal plant pollen (AP).

3. Lake level changes and detrital sedimentation
(C. Giraudi)

Geological and geomorphological studies in the Lago di Mezzano basin revealed the presence of lacustrine terraces, both erosional and depositional, around the lake, as well as alluvial fans and a flat area formed by lacustrine sediments (Fig. 1). The plain lying north of the present shore is as large as the lake and slightly higher than the present water level. It was part of the former lake bed, reduced by reclamation works and by the digging of the drainage channel, acting as an outflow, which controls the lake level (Fig. 2).

Before the modern drainage works, natural conditions led the lake to change its level and extension: during periods with a positive hydrological balance the lake was able to flood the nearby flat area. That occurred in several periods, also before and after the Bronze Age. Excavations made on the lake shore and in the flat area have shown many lacustrine deposits outside of the present lake.

Some of these sediments, for example peat layers, have been dated at cal. 14C 6735–6450 BC and 160–435 AD. Furthermore, excavation on the sill where the drainage channel flows into the Olpetta River, revealed lacustrine shore sediments containing charcoal dated at 1450–1665 AD. Between the peat layers dated at
cal. 6735–6450 BC and 160–435 AD, an erosional surface was recognised. This was produced by running water during one or more phases of low lake level. Before the artificial drainage, when the level was very high and the lake larger than at present (e.g. during the XV—XVII centuries), the water reached the sill level forming an outflow towards the Olpeta River.

At periods of high water level the catchment to lake surface ratio was 2.6 calculated from the approximate catchment size of 3.57 km² and a lake area of about 1.36 km². When the lake level was very low, the basin became endorheic. The streams of the northern part of the catchment reached the lake in the southernmost place, flowing through the former lake bed. Such a scenario is assumed for the Bronze Age period with a catchment to lake surface ratio of ca. 9 and a lake area of only about 0.4 km² (Fig. 2).

During periods of high lake level, the sediment loads carried by streams and running waters were deposited on a larger lake bed, partly in shallow water and partly in deep water, and detrital sedimentation must have been low. With declining lake level (in some periods between 3230 ± 50 and 2680 ± 50 uncalibrated ¹⁴C years BP according to Alessio et al., 1975), deposition of detrital sediments took place in a small deep water lake. Detrital sedimentation must have been a lot higher during this period. Moreover, when the lake level was low, the stream flowing from north to south on the former lake bed, must have caused, at least in the early period, erosion of the exposed non-consolidated lacustrine sediments of high water level stages. This seems proven, for example, by the presence of an erosional surface younger than 6735–6450 BC. To summarise, the detrital sedimentation rate must have been higher during low lake level stages and low during periods of high lake level.

4. Submerged settlements of the Bronze Age (P. Petitti)

As far as the archaeological aspects are concerned, an analysis of the relationship between the Lago di Mezzano settlement and the surrounding natural environment must consider also the events characterising the occupation of the Caldera di Latera. Inside the Caldera, an area well defined by natural boundaries, an organic system of population developed, of which the lake is an integral part. In relation to the problem of human impact on the environment during the prehistory, the analysis cannot distinguish the chronological aspects from the modalities of occupation both of the lake shore site and of the surrounding area, because different modalities correspond to different capability of changing environments.

4.1. Chronological framing

The lake has revealed traces of occupation along the north-eastern arc of the shore (Petitti, 2000, Fig. 5). To the south of the Fosso delle Volpi mouth, along the eastern shore, evidence of presence become sporadic and isolated. In the south-east is the area marked M2. Archaeological dating of the settlement has been carried out especially on the basis of metal artifacts, which are one of the guiding complexes of the mid-Tyrrhenian side of the peninsula. The chronological framing of the Early Bronze Age also uses a relative chronological system, based on the study by combinatorial analysis of the Early Bronze Age hoards. Such complexes enable to recognise subsequent horizons formed, objectively, by contemporaneous groups of archaeological items. The bronze objects from M1 are distributed between the passage from the II to the III horizon to the late III horizon/IV horizon of the hoards of the Early Bronze Age (Pellegrini, 1993); to these should be added a pin coming from M2, attributed, on the basis of a first analysis, to the end of the Early Bronze Age (Petitti, 2000).

The indications from bronze objects (Fig. 6) should be integrated at least by some data obtainable from pottery, as this poses considerable difficulties for the still unresolved problems relating to the framing of the Early Bronze Age and of its subdivision into phases. The discovery in the area marked M3 of pottery items that may be assigned to a late moment of the Early
Bronze Age, according to the chronological schemes commonly followed, enables us to envisage that in this phase the settlement covered the whole north-eastern arc of the shore, apart from the southernmost part of M2. A bronze axe (Fig. 6) and, more hypothetically, a silver spiral have been assigned to the initial phases of the Middle Bronze Age. A dagger blade from M2 may be attributed to the Middle Bronze Age 2 (unpublished). However, there are no bronzes attributable to the third phase of the Middle Bronze Age, and it is not by chance that also in the production of pottery a considerable complex of such materials at the beginning of the Middle Bronze Age is followed by a definite decline in the presence of clay objects attributable to the successive Apennine phase. The Caldera also shows a consistent occupation in the Early Bronze Age which, even with the displacement of the villages, grew further in the initial Middle Bronze Age, after which it was appreciably reduced in the Apennine Middle Bronze Age (Conti et al., 1993).

The series of metal objects from the lake is resumed with a group of finds covering the entire span of the first phase of Late Bronze Age, and concerning two areas, M3 and M2. The concentration in such a short time span (XIII and part of the XII century BC) of so many bronze items is not accompanied by any such substantial presence of pottery. In addition, particular techniques resulting from the metallographic analyses indicate that at least part of the finds were votive offerings. Hence, the occupation of the lake during the first phase of the Late Bronze Age seems to have been based also on ideological values. The Caldera, as a whole, presents no documents relating to the first phase of the Late Bronze Age, although this could be due to a lacuna in our knowledge. The lack of evidence could be due to the “casualness” which marks the taking of archaeological samples.

During the final part of the age, when the lake (on the basis of the data so far possessed) was completely abandoned, the Caldera records a fresh phase of very intense occupation. Particularly important traces of this occupation have been identified both in the southern part of the basin (Monte Starnina and Poggi del Mulino) and in the northern part, where the important site of Poggio Evangelista (Di Gennaro, 1986) is located on the highest point of the crest of the Caldera rim, far not from the highest point of the lake’s catchment area. As mentioned before, radiocarbon dating on 20 wooden fragments of piles found at the lake bed during the 1973 campaign (Franco, 1982) provide age clusters around 3200 and 2780 14C years BP (Alessio et al., 1975).

4.2. Human impact

The lack of systematic excavations means that the problem of the impact that these communities had in the course of the time on the surrounding natural environment can be addressed only in a general way. It is impossible to define one or more models of exploiting the resources. The size of the inhabited area cannot be automatically correlated with the anthropic pressure on the environment. This is not only because variations in the size of the area occupied in the successive phases cannot be identified in detail but, above all, because the size of a place does not automatically indicate the type of presence, which, for example, could imply successive cycles of occupancy, and the dimensions of the basic unit of society.

In this work, the relation between plant biomass and these communities is considered. Until recent times, the plant biomass constituted the greatest existing energy reserve. The availability of fuel is a factor that has conditioned a considerable range of needs, from daily life to such activities as the production of pottery, considered in this phase of prehistory still as a domestic activity, and metallurgy, a specialised craft which needs considerable supplies of fuel of plant origin.

The local production of metal objects, pointed out by the distinctive features of the finds themselves, may be regarded as certain by the finding of a clay tuyere in the M1 area. The tuyere is the incombustible end of a bellows which, poked inside the furnace, causes an inflow of air under pressure so as to maintain the temperature necessary both for melting the ore and for the successive metal-working phases. Based on the dating of other materials found in the M1 area, this tuyere may be attributed to the Early or Middle Bronze Age I. There are traces of local metal-working also in the Late Bronze Age not in the lake settlement but in the Poggi del Mulino area, where both semi-finished material (part of a copper ingot) and a fragment of a sandstone mould have been found. Lastly, numerous cases of deforestation due to intensive exploitation, even
in the oldest historical periods, have been reported (Lugli and Pracchia, 1994).

Plant biomass has been exploited also for another purpose: it is a diversified source of raw material. On the lake bed there are areas with a dense concentration of piles which protrude from the mud only with their eroded ends. Systematic excavation of more favourable sites (e.g. the large settlement in the peat bog at Fiavè Carera, Trento) has shown the existence within the same settlement of different structures—always with a more or less impressive wooden component—following each other in time and space (Perini, 1984). A parallel may be proposed between M2 and zone 2 at Fiavè, which presents a structure interpreted as a traditional palafitta: according to a count made in both sites there is an average of about 50 piles embedded in a sector of 4 x 4 m span. These systems required considerable quantities of wood, even spread over a lengthy time span, in view of the necessity of maintenance measures or renewals, also demonstrated archaeologically.

Wood was used for the production of mobile finds: the dimensions of the objects are variable, ranging from lake crafts, which can be several meters long (Calderoni et al., 1996), to small objects of everyday use. In any case, it must be indicated that the raw material or rather the particular compatibility between raw material (species, natural form, type of plant tissue, etc.) and functional object represents a constant criterion of production with all that this involves in terms of exploitation of resources (Petitti, 1990–1991). For instance, from the pile dwellings of northern Italy come a number of classes of recipients, which require the availability of the entire basal part of the stem. This implies cutting a tree of a certain type and then using the remaining parts for other purposes (Perini, 1987).

The pressure on the natural environment is documented also in land-use changes linked to the intentional reduction of the wood for agriculture and stock raising and to the introduction of new plant species. This process started with the onset of the subsistence economy but developed in time with different modalities and techniques. The archaeological context of Lago di Mezzano has provided only generic indications: a large number of grindstones and vases with an internal strip, traditionally interpreted as recipients for processing milk, and the remains of bones of domestic animals, mingled with the other finds on the lake bed.

5. Pollen and micro-charcoal analyses (L. Sadori)

In the Mediterranean basin, in regions in which man has been present since the Palaeolithic age, and whose impact on the environment became stronger and stronger with the passing of the millennia, the difficulty exists of singling out the changes induced by man on vegetation. Human populations could modify flora and vegetation in three main ways: introducing or favouring edible plants, opening up woods for animal husbandry and at the same time using natural resources such as wood for heating, building, or producing metals. Each of these three ways would produce a characteristic vegetation pattern, whose traces should be found in the pollen and micro-charcoal record.

Most edible plants such as cereals, pulses and fruit trees are native to Mediterranean regions and are found during the whole Holocene and even before in the pollen diagrams. A typical example is the cereal pollen type which includes pollen of cultivated, spontaneous cereals and even of other grasses (Andersen and Bertelsen, 1972). It should be mentioned that also Olea europaea L. (olive) and Vitis vinifera L. (grape vine) are native to the region of Lago di Mezzano. Forest clearance should be easily detected by a decrease of AP (pollen of arboreal plants) percentages, but a similar change could also be caused by a climate variation in regions very sensitive to climatic change. A good tool for disentangling climate change and human impact is the combined interpretation of pollen percentage and concentration data of which the latter may be considered as an estimate of the biomass amount.

Dramatic and rapid tree pollen concentration drops, not necessarily matching tree percentage decreases, have been pointed out during forest phases in many pollen diagrams of the Lazio region during the last hundreds of thousands of years (Follieri et al., 1988; Magri, 1999; Magri and Sadori, 1999) and interpreted as vegetation responses to climate changes. It is hard to imagine that a prehistoric population could induce sudden, enduring, dramatic phytomass reductions of the forest at a large scale. The possibility of human induced fires has been checked using micro-charcoal concentrations as indicators of either local or regional forest fires, or human presence (Tolonen, 1986). AP percentage changes are generally taken into account to explain anthropogenic influence.

The data of the part of the core reported here (4.10–5.96 m covering the period 2900–4100 cal. years BP, the Bronze Age) are shown in synthetic pollen percentage (Fig. 7) and concentration (Fig. 8) diagrams and in micro-charcoal curves (Fig. 9). A pollen zonation, based on the whole data set, is proposed to simplify the description of main floristic and vegetational changes. The chronological scale in calendar years BP was drawn following the chronology (Fig. 4), established by Ramrath (1997), with on average one pollen sample every 50 years.

In the oldest zone (M-B1) percentages of AP (pollen of arboreal plants) are high (> 90%) and AP concentrations are very high (750,000–1,500,000 pollen grains/g). A dense mixed oak forest with Fagus and evergreen elements developed during that period in the
surroundings of the lake preventing erosion in the area; a large number of Alnus trees lined the lake shores. No signs of either cultivation or of tree cutting are found, but the presence of Rumex pollen could suggest grazing. The most significant local fire, probably of natural origin, indicated by a micro-charcoal peak in the first sample, caused a temporary AP concentration decrease.

At around 3800 cal. years BP (zone M-B2) the main change of the diagram is found: a sudden, strong climatic change to drier conditions is assumed from a drop in AP concentration (from more than 1,500,000 to 280,000 pollen grains/g), whereas AP percentages do not show any immediate changes. Therefore, human impact as a triggering factor can be ruled out for this shift. Moreover, no evidence of major fires matches this dramatic change of vegetation. After this event AP concentration remains very low (between 40,000 and 90,000 pollen grains/g), exceeding 350,000 pollen grains/g again only at the end of the zone. AP percentage values follow the decreasing trend in concentration with a delay of one century and Gramineae are the main increasing herb types. The presence of Rumex, indicating opening of the wood, from the beginning of the zone is worth noting.
Clear signs of human impact are indicated for about two centuries, from about 3700 to 3500 cal. years BP. The main signal is evident from a change in floristic composition and in micro-charcoal accumulation. Micro-charcoals are very abundant. The >50 μm particle concentration curve shows a Gaussian trend, peaking at 3600 cal BP as also smaller micro-charcoal particles do. For the same period, AP shows an opposite trend, a relative minimum in concentration and the absolute minimum in percentage terms. The local human presence is striking and intensive land-use is detected not only by fires and decreasing forest cover for living and producing metals use, but also by cultivation, deduced by cereal type and legume pollen which reach maximum values. The fact deserves mention that for pollen morphological, dispersal and fertilisation features of the two mentioned taxa, their percentages are meaningful, even if low. These plant crops are accompanied by weeds and ruderals such as *Rumex*, *Cichorioideae*, *Artemisia*, *Chenopodiaceae*, *Caryophyllaceae*, and *Asteroideae*. It has to be stressed that pollen grains of *Plantago lanceolata*, a good anthropogenic indicator, cannot be distinguished from other steppe species of *Plantago* native to the region (Reille, 1992). Probable forest clearance is recorded for the same time (3600 cal. BP) in the pollen curves of deciduous *Quercus* and *Alnus*, while grazing could be deduced by the presence of *Rumex*. The expansion of Gramineae could be related to the invasion of new flat areas available after opening up the woods and/or decrease of the lake level. It would be hazardous to hypothesise that this expansion of grasses could be due to hay-making, even if this possibility cannot be excluded a priori.

The natural forest clearance at 3800 cal. years BP, probably was continued and intensified by the prehistoric populations through fires and grazing. In zone M-B3 a slight recovery of the vegetation is found, indicated by the concentration diagram. AP percentages again rise, attaining 90%. The transition between the zones M-B2 and M-B3 indicates a climate change towards wetter conditions as suggested by a sharp increase of tree pollen concentration. At the same time human pressure on the site became weaker as anthropogenic indicator pollen values are lower or even disappear and micro-charcoals decrease. Soon after 3400 varve years BP, a fire occurred in the region, but not at the site, as deduced from a peak in the 20–50 μm curve. *Alnus* shows an increasing trend, suggesting that longer shores to be colonised became available after an increase in lake water level and size (Fig. 2).

A decrease in pollen concentration and a slight increase in NAP percentages mark the beginning of zone M-B4. Deciduous *Quercus* shows a recovery, while *Fagus* and especially *Alnus* decrease. This could suggest a slight aridification trend leading to a lowering of the lake level and, consequently, a shorter shore length. A culmination of evergreen *Quercus* seems to confirm this hypothesis. The possibility of an artificial opening of the small *Alnus* woods growing along the lake shores to obtain timber and/or new flat areas for cultivation should be taken into account. For this zone, human presence is again without doubt, even if less important than in zone M-B2. Herb pollen of cultivated crops (cereals and pulses) and anthropogenic indicators show contemporaneous spots, inducing a slight decrease of AP percentage values. Neither fires, nor any sizable
use of wood for cooking or for producing metals are locally (by the lake) found in the pollen data of this zone. In the youngest zone of the Bronze age (M-B5) both AP percentages and total pollen concentration show a trend towards recovery, while cultivated crops and plants indicating human presence almost disappear. Deciduous *Quercus* shows highest percentages in this period and *Alnus* increases again, suggesting another increase in lake level. The micro-charcoal curves confirm the hypothesis of human absence or scarce presence.

The general behaviour of the vegetation is that, in periods when pollen concentrations are high or very high, a local human presence is not detected, while it is evident for periods with low pollen concentrations. This pattern could be ascribed either to the fact that luxuriant vegetation with well developed forests could probably mask a limited human impact and even human presence at all (opening of small areas in a forest with a thick canopy could not influence the pollen rain) or to the fact that in periods with a high lake level and water available in the surroundings, the prehistoric populations did not settle by the lake. The strongest human impact is found in the pollen record when woods were already opened by climate change and man could easily influence the relative presence of plants.

6. Sedimentological and geochemical data (C. Giraudi)

Sedimentological and mineralogical analyses (Ramrath, 1997; Ramrath et al., 1999a, b, 2000; Sadori and Ramrath, 2000) as well as organic geochemistry (Wilkes et al., 1999) document environmental changes of natural and anthropogenic origin. Here, data from the core section between 4.1 and 5.9 m have been interpreted taking into account the observed variations in lake size and level which might have influenced lacustrine sedimentation. Another important factor to be considered is the human settlement on the lake shore and in the catchment. It can be assumed that construction works have caused instabilities of shoreline sediments and slopes.

The sediments of the studied core section are formed by homogeneous and laminated gyttia with interbedded layers of turbidites. In Fig. 10 several analysed proxies are shown as DD, total organic carbon (TOC), TIC, AP concentration, and the thickness of the turbidites (from Ramrath, 1997; Sadori and Ramrath, 2000). For the Mezzano record TOC has been interpreted as a measure of biogenic productivity as characteristic for warmer climatic conditions. TIC reflects the amount of carbonates in the sediment. These can be either of detrital origin or authigenic formation. Detrital components are indicative for clastic material flux caused by erosion, whereas authigenic carbonate formation might be linked to either evaporation or biological productivity in the lake. DD represents the total amount of minerogenic components including carbonates and siliciclastic material. The major controlling factor is erosion in the catchment which in turn is dependent from vegetation cover, climate and human activities. Turbidite layers document single events of flows of water with a high sediment load.

Fig. 10. Diagram showing the dry density (DD), total organic carbon (TOC), and total inorganic carbon (TIC) percentages, AP concentration and turbidites thickness (TT) values in the Lago di Mezzano core between 4100 and 2900 cal. years BP. Sedimentological phases are in Roman numerals, pollen zones in Arabic numerals preceded by the M-B initials.
From a combination of these data, as well as AP concentration, four different phases can be distinguished in the studied section (Fig. 10). Phases I and III have completely different characteristics and phase II represents a transition period between both situations and is similar to phase IV.

- Phase I: high concentration of pollen, generally low values of DD and of TIC, and high TOC concentrations. The end of this phase coincides with the collapse in the pollen concentration which occurred around 3800 varve years BP.
- Phase II: subdivided into parts IIA and b. Phase IIA shows an increase in DD and a decrease in the TIC, TOC and AP concentrations. Phase IIb is characterised by a decrease in DD, by a sudden increase in the TOC, and by a more gradual increase in AP concentrations. This phase ends around 3400 cal. years BP.
- Phase III: characterised by the appearance of turbidites during the peak of AP concentration, and later by a considerable increase in DD, a decrease in the TOC and the AP concentration, an increase in the TIC. The phase ends around 3000 cal. years BP.
- Phase IV: characterised by a decrease in DD and an increase in the TOC and the AP concentration.

There is a general tendency of negative correlation between DD and TIC on the one hand, and TOC and AP concentrations on the other. An exception is the period between about 3600 and 3500 varve years BP with low DD and high TOC, but low AP concentrations. The main increase in TIC is contemporaneous with an increase in DD and the onset of turbidite deposition at about 3400 varve years BP. An exceptionally high TIC value is measured at about 3200 varve years BP.

There is a different situation regarding turbidites. These appear in Phase III, mainly in sediments characterised by increasing DD and TIC and lowering TOC and AP concentration. On the contrary, in Phases I, IIA and IIb, even at times of high DD and a low AP concentration, there are no turbidites. Hence Phase III is a peculiar one in this respect. Nevertheless, at around 3400 cal. years BP, there is a further anomaly: while there is an increased AP concentration, the start is observed of the sedimentation of turbidites.

The turbidites cannot have been produced by water flowing down the steep sides surrounding part of the lake. On these slopes there are only a few shallow incisions made by streams which are so small as to be insufficient to convey turbid currents of any size. Moreover in the phases prior to III, with analogous AP concentrations, no turbidites were deposited. The cause of this difference may reside in the fact that accompanying the decrease in lake level, as testified by the pile dwellings at various depths below the present level, there was also a considerable reduction in the lake area. Therefore, streams that drained the northern part of the catchment basin transported sediments eroded from a much larger area into a far smaller lake than before. In addition, at the low lake level stand the shallow water zone north-east to the deepest part of the lake had disappeared.

During Phase II, lake levels were low and the archaeological settlements demonstrate the use of the shores, but there was no sedimentation of turbidites. About Phase III, it might be speculated that anthropogenic impact on the catchment played a role because in the same period there was human occupation (Poggio Evangelista site) near the highest and northernmost point of the catchment. It should be mentioned that *Pseudoschizaea*, a palynomorph indicating erosion in the basin (Pantaleón Cano Villanueva, 1997), has been found in Phase III. The presence of *Pseudoschizaea* confirms the erosional phase pointed out by the sedimentological interpretation.

Another anomaly appears in the period between around 3600 and 3500 varve years BP, in which very low AP concentrations coincide with low DD and high TOC values. On the basis of these data, therefore, clastic sedimentation must have been limited and there cannot have been any significant detritic contribution from the northern streams. To explain this situation it is speculated that the steep slopes were protected against erosion through vegetation cover, but that the flat area to the north-east of the lake (lacustrine terraces, small alluvial fans) was treeless. The only explanation for such a scenario is selective tree cutting by humans: the trees on the flat area could have been felled in order to obtain piles or burnt to provide land for agriculture and/or animal husbandry.

Regarding the anomaly during the period around 3200 varve years BP, i.e. to the TIC peak in a period of very low AP concentration, we suggest the following. As inorganic carbonate is concerned, and as the lake basin consists entirely of volcanic materials without carbonates, in general the enrichment of this mineral is attributed to precipitation of chemical and biochemical origin. Such precipitation must therefore have been produced by the evaporation of the lake water in the course of a particularly warm phase and/or by an increase of algal productivity as a consequence of eutrophication, perhaps caused by humans. The low AP concentration during this period might well be linked to anthropogenic activities.

The combined interpretation of data from sediment cores, prehistoric settlements and field studies in the catchment basin allows better interpretation of the variations in the sediment parameters. It is probable that some of the observed excursions were caused by anthropogenic impact.
7. Conclusions (C. Giraudi, P. Petitti, L. Sadori)

The sediment core records climatic change and human history at Lago di Mezzano during the Bronze Age. The dynamics of human impact during this period, its duration, and the type of land use, becomes clearer combining the pollen data with the sedimentological and geochemical data. The environmental framework is in good agreement with the archaeological evidence.

The aridity crisis of 3800 varve years BP, well known in many other pollen diagrams from central Italy, caused a natural deforestation and the lowering of the water level and of the size of the lake. Between 3700 and 3500 years BP (Early/Middle Bronze Age) man’s local presence is clear and causes a strong environmental impact at 3600 years BP: cultivated plants, weeds and ruderals spread, and forest clearance is found. The human populations which settled along the lake shores took advantage of water, which had become an essential resource, and/or of the newly emerged areas available for cultivation.

In the period 3500–3300 cal. years BP the lake shores seem to have been abandoned by prehistoric populations. The sudden change in sedimentological features and in micro-charcoal records at 3400 years BP is due to a considerable human impact in the northern part of the catchment basin.

A new local human presence is detected from around 3300 years BP, becoming more effective at about 3200 years BP. However, the type of land exploitation is less intense than that of the pile-dwelling settlement of the Early/Middle Bronze Age.

Lago di Mezzano proved to be a key site in the Lazio region where human impact on vegetation during the Bronze Age overlapped a climate change towards aridification. It is now clear that human populations alone did not produce devastating effects on the environment, but emphasised a climatic process causing modifications on an already open landscape.

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