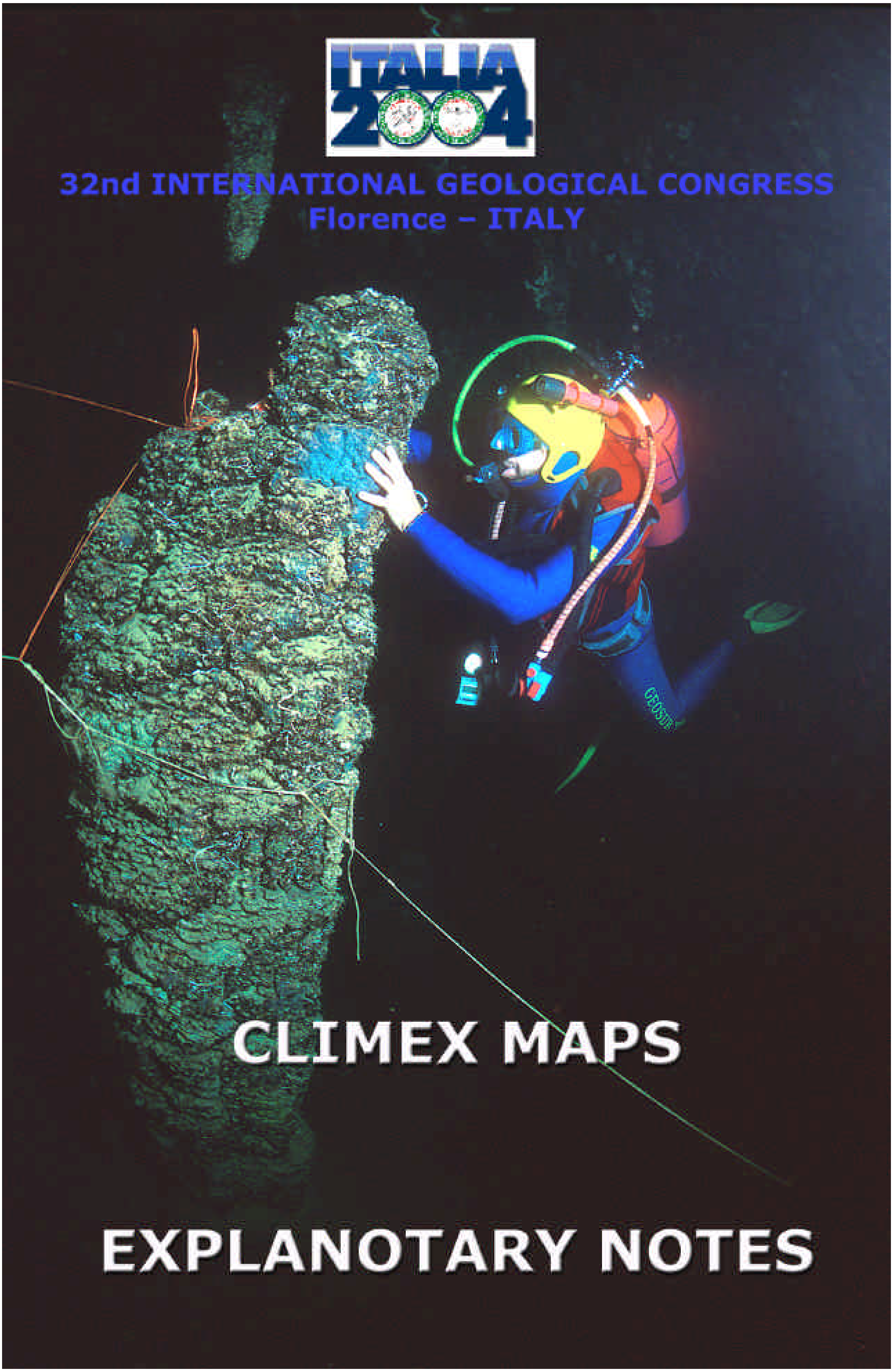

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Florence – ITALY

CLIMEX MAPS

EXPLANOTARY NOTES

PO PLAIN

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LGM

The construction of a reliable palaeogeographic and palaeoenvironmental framework for the Po Plain during LGM relies upon detailed stratigraphic and sedimentological studies that were carried out in the last decade on several tens of continuosly-cored boreholes, drilled by the Geological Survey of Regione Emilia-Romagna south of Po River. Early studies on scattered data were conducted in the southern Po Plain by Rizzini (1974), Ori (1993) and Bondesan et al. (1995). These were followed by detailed core investigations, leading to reconstruction of three-dimensional stratigraphic architecture at the basin margin (Amorosi & Farina, 1995; Amorosi et al., 2001) and beneath the present Romagna coastal plain (Amorosi et al., 1999; 2003). The stratigraphic linkage between the buried alluvial fan complexes and the coeval nearshore strata in the subsurface of southern Po Plain has been recently established by Amorosi & Colalongo (in press). By contrast, few detailed data are available at present for the subsurface of the Po Plain, north of Po River, with very few exceptions (Muttoni et al., 2003).

A huge alluvial plain developed over the entire northern Adriatic area during the pronounced phase of sea-level fall that culminated in the Last Glacial Maximum. At that time, a system of coalescing alluvial fans was formed at the southern (Apenninic) and northern (Alpine) margin of the Po Plain, resulting in a couple of gravel bodies elongated in NW-SE and W-E direction, respectively. The alluvial fans show lateral transition toward the basin axis to a sand-dominated alluvial plain, where braided rivers were following approximately the same paths as the modern Apenninic and Alpine tributaries of Po River. Lateral switching of these rivers into the adjacent floodplains was a common feature during LGM. This resulted in the construction of a laterally extensive, sheet-like sandy complex, 3 to 20 m thick, that is generally encountered at 10-25 m depth in the Po Plain (Amorosi et al., 1999; 2003). Subsurface data from unpublished studies show that during LGM the Po River flowed from W to E in a slightly southern position, but at comparatively short distance from its present path. Thick sand bodies that can be assigned to the trunk river have been identified south of Mantua, marking the boundary between Lombardy and Emilia-Romagna. During LGM, the Po River probably flowed in the Ferrara area, following the path of the abandoned Po di Volano, and entering the present Adriatic Sea in the Goro area.

LGM deposits can be easily identified in the subsurface of the Po Plain. Particularly, the boundary between LGM and overlying post-glacial, mostly Holocene deposits is marked invariably by an unconformity associated with a stratigraphic hiatus generally of more than 10 ky, bearing a distinctive geotechnical signature (Tosi, 1994; Amorosi & Marchi, 1999). It consists of an indurated and locally pedogenized horizon, representing a prominent stratigraphic marker that can be physically traced from the Po Plain to the Venice lagoon area (McClennen et al., 1997). This major regional erosional unconformity has the characteristics of an interfluve sequence boundary, being laterally correlative of thin lenticular fluvial and coastal-plain sediments, the deposition of which was restricted to broad, shallow, incised valleys (Amorosi et al., 2003).

HCO

Transgressive sedimentation in the Po Plain started mostly during the Late glacial and early Holocene. The Bølling-Allerød interstadial and the subsequent Younger Dryas cold event are only recorded in fast-subsiding areas, and even there as scattered spots only. After this period, rapid shoreline migration took place in response to the phase of rapid sea-level rise and reduced siliciclastic influx. This is testified by the backstepping of facies and coastal onlap of transgressive deposits onto the Last Glacial Maximum unconformity.

At time of maximum flooding (HCO), the paleoshoreline was located approximately 20 km west of its present position. Detailed facies analysis of cores (Amorosi et al., 1999; 2003) and interpretation of hundreds of piezocone penetration tests (Amorosi & Marchi, 1999) show a complex scenario of transgressive depositional environments, including coastal plains, lagoons, barrier islands, and shallow seas. Owing to rapid sea-level rise, fluvial mouths were converted into bay-head delta complexes that developed at the head of wave-dominated estuaries. The construction and rapid progradation of a wave-dominated, early Po-river delta, flowing 40 km south of modern delta (Ravenna area) and flanked by prograding strandplains, took place during the subsequent phase of sea-level highstand, starting with the Subboreal stage.

The maximum landward migration of the shoreline is marked by the innermost position of shell-rich, nearshore (foreshore plus shoreface) sands, separating lagoonal clays from offshore-transition clay-sand alternations. This sand body forms a continuous alignment extending from Ravenna to Adria, via Alfonsine, Ostellato and Codigoro (Amorosi et al., 1999; 2003; Preti, 1999). At more inland locations, the large amount of stratigraphic data available for the Po Plain allows to reconstruct the western extent of back-barrier (lagoonal and estuarine) environments, corresponding to the boundary between continental and coastal depositional settings. This is located 35 km west of present shoreline.

Sea Level at 8 and 22 ka cal BP on Italian coastline

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1. Method

Sea level change along the Italian coast is the sum of eustatic, glacio-hydro-isostatic, and tectonic factors. The first is global and time-dependent while the latter two also vary with location. In order to drawn the palaeocostline at 8 and 22 ka cal BP we used data published from Lambeck et al., 2004. This paper contain exhaustive description of ice-volume-equivalent sea level (**esl**) values, models, observed data and error bars of the marker used for the Italian sea level change occurred during last 20 ka.

"The dominant pattern of the sea levels for all epochs is determined by the hydro-isostatic contribution, with the sea basin floor subsiding under the additional water load. Thus observed sea levels from the island sites such as Pantelleria, between Sicily and Tunisia, Marettimo and Sardinia, should exhibit lower levels than sites on the Italian Peninsula for the same epoch. Along the central Tyrrhenian coast, between about Argentario and Palinuro, the isobases are nearly parallel to the shore and data from different locations can be combined into a composite regional sea-level curve if desired.

But this is not the case for the Adriatic coast where the glacio and hydro isostatic contributions combine to produce a well-defined north–south gradient such that levels in the northern Adriatic lie persistently above those further south. At 10 ka BP the isobases range from about 55 to 35 m below present level but the shallowest values occur where the sea has not yet encroached. Only by about 8 ka does the Adriatic take its present form. At 6 ka BP the sea levels begin to approach present-day values but the spatial variability remains significant, coastal levels ranging from -2 m at Gabes to -9 m in Sicily and Calabria. At the Roman period, 2 ka BP, levels fluctuated from about 0.5 in the north of the Adriatic to as low as 1.8 m in parts of Sardinia." from Lambeck et al., 2004. The esl values used for 8 and 20 ka shorelains are -13 and -149 m, see fig 12 of Lambeck et al., 2004, Fig. 1 and 2.

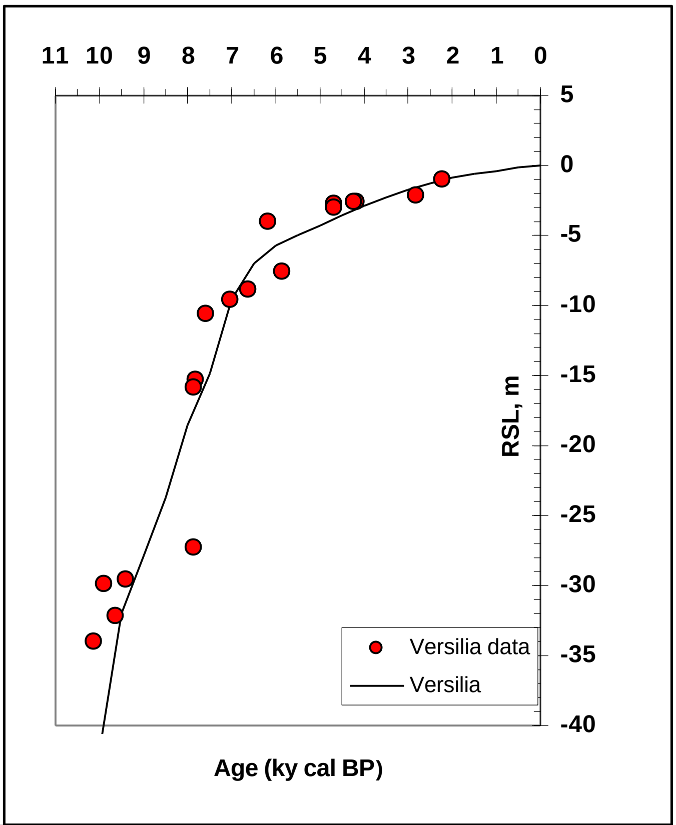

Fig. 1 Predicted sea level curve and observed data for the tectonically stable site of Versilia plain, central Italy, from Lambeck et al., 2004.

In this short note are described the sea level markers used in Italy to validate the Lambeck's

model., all calibrated with the same method (Bard, 1998) and studied on stable coastline (with the exception of Sybari and del Volturno sites). The 8 ka shorelines on the whole important delta coastal area was corrected on the basis of the presence of cores radiocarbon data (see numbers on the map). As regard the 20 ka shorelines it is important to underline that are not published observed data to confirm the predicted data by Lambeck that we used.
Such methodology is subject to error bars (model and ^{14}C ages) the positioning of the shorelines marked on the maps are intended as a first approximation.
The more complete the data set has been sampled on numerous cores in the northern Adriatic sea (Correggiari et al., 1997). Twenty-seven dates from 60 continuously-cored boreholes drilled in the subsurface of southeastern Po Plain provide the basis for detailed reconstruction of coastal paleogeography at 8 ka cal BP (Amorosi et al., 1999; 2003; in press). Data sampled on cores on Versilia, Cagliari and Sibari Plain was very useful for test and refine the Lambeck's model for Italy.

2. Data

The numbers in bold correspond to those marked into the HCO map.
1 Versilia ENEA core. It is an important data set: a core crossed 34 m of Holocene lagoonal sediments, sixsteen ^{14}C analyses allowed to built a precise Italian Holocene sea level curve. Two papers describe this stable site: Antonioli et al., 1999 and Nisi et al., 2004. On fig. 1 are compared the predicetd sea level curve of Lambeck et al., 2004, with the observed lagoonal radiocarbon data.
2 Argentarola speleothems. Sampling and aging serpulids overgrowths that coverd submerged speleothems allowed to reconscrutct a sea level rise data at the Argentario promontory during last semiglacial cycle. The samples were collected by scuba diving at depths from 3.5 to 21.7 m measured with a digital depth gauge Age control is provided by radiocarbon ages on marine and continental layers of the speleothems and range from 6.5 to 9.6 ka cal. BP (Alessio et al., 1992,1996; Bard et al., 2002; Antonioli et al., 2004.
3 Roma. "The data at this site comes from cores drilled 2 km apart, east from the present-day coastline of the prograding Tevere Plain near the silted-up ancient Roman harbour.Belluomini et al. (1986) used sea-level markers consisting of ^{14}C-dated peat, marsh and wood fragments found between –3 and –31 m. The corresponding calibrated ages are in the interval 5.9 - 11 ka cal. BP" from Lambeck et al., 2004.
4 Fondi. The Fondi Plain is a small coastal plain bordered by limestone relief, with outcroppings of Pleistocene and Holocene alluvial, aeolian, lagoon, and marine deposits.Samples containing *Cerastoderma* at -1.8 m previously gave an ^{14}C

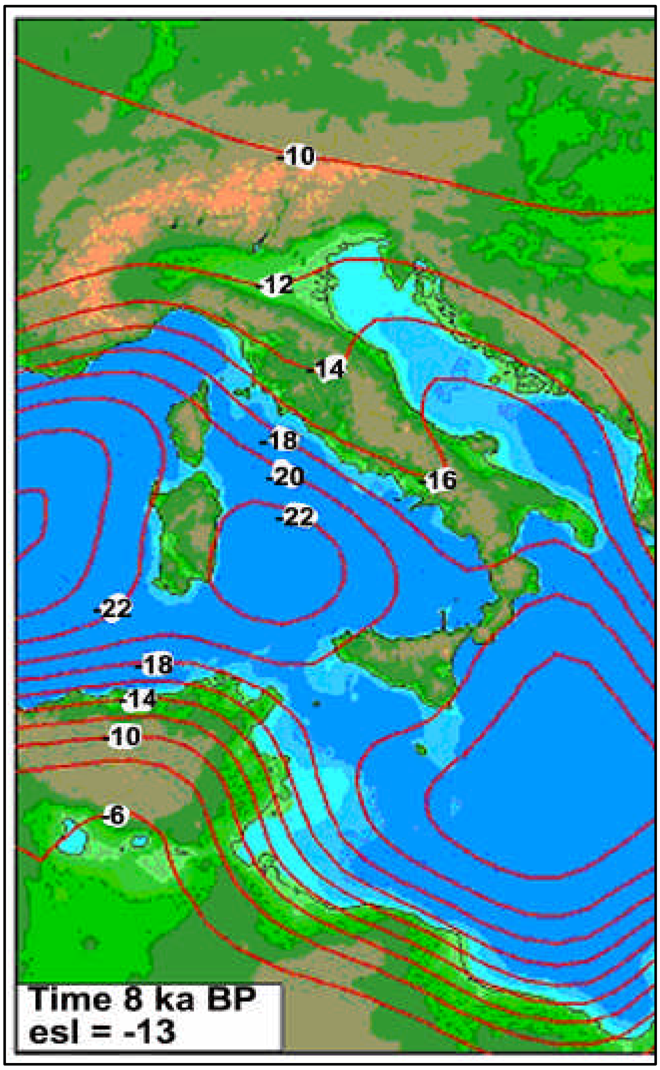

Fig.2a Palaeogeographic reconstructions at 8 and 20 ka cal BP for Italy. The red (negative) contours refer to the sea level change. Palaeo water depths are indicated by the change in shades of blue at depths of 25, 50, 100, 150 and 200 m. The ice-volume-equivalent sea level (esl) value are given in meters (from Lambeck et al., 2004).

age of about 7.5 ka cal. BP (Antonioli et al., 1988). More recently a continuously cored borehole was drilled (Devoti et al., 2004; Lambeck et al., 2004) near the outcrops that intersected marine sediments that filled a palaeo-valley carved during the LGM, at about 0.75 km inland from the present-day shoreline (N 41°18'12'' - EGw 13°17'24''). The core was detailed with sedimentological and micropalaeontological analysis; moreover, eleven biomarker samples (8 shell fragments, 1 peat sample, 1 *Cerastoderma glaucum* valve and 1 fragment of *C. caespitosa*) were collected for chronology with ^{14}C AMS dating. The dated samples were correlated with backshore deposits and shallow marine environment

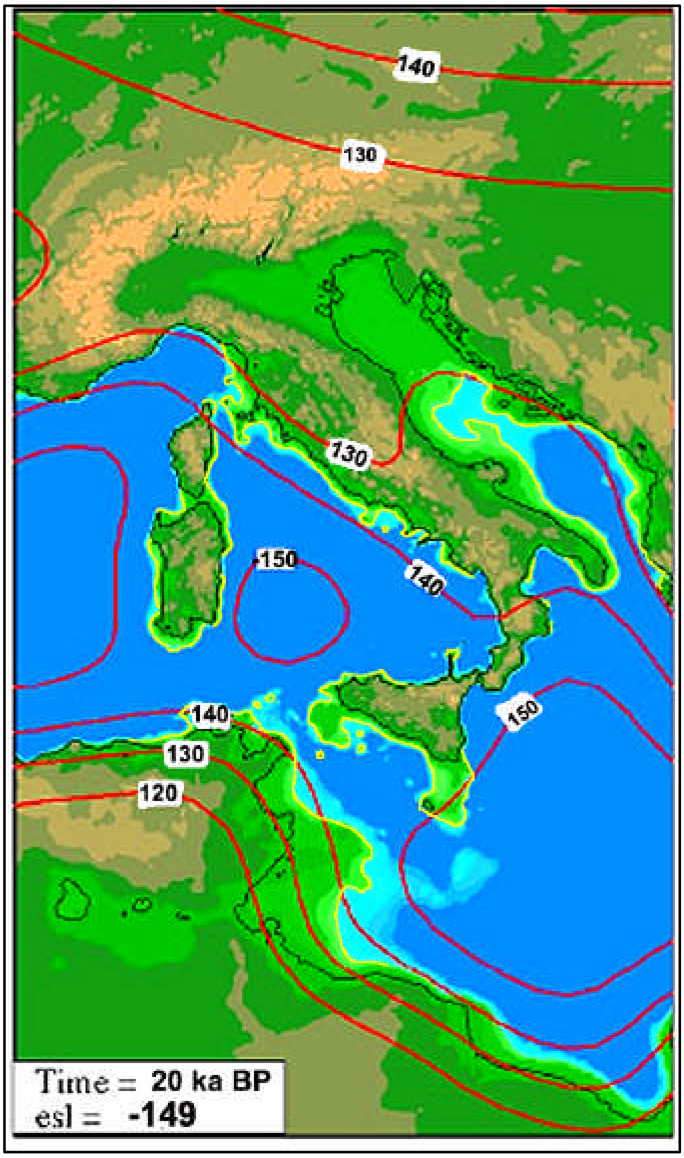

Fig.2b Palaeogeographic reconstructions at 20 ka cal BP for Italy (from Lambeck et al., 2004).

deposits; the palaeobathimetry of these samples may be estimated at about +2/-4 m. Marine shells between -3 and –33.7 m yielded calibrated ages in the interval 7.4 – 8.6 ka cal BP.

5 Volturno Plain. "The Volturno River coastal plain formed during the Holocene as a complex of beach-ridges and flat back-barrier depressions with lagoonal sedimentation. Lagoonal facies have been found in a core located at 2.5 km from the present beach over a depth range of 10 m. Radiocarbon ages of peats found in this core are given by Barra et al. (1996) and the calibrated ages span the interval from 4.8 ka at –3 m to 7.4 ka BP at -8 m " from Lambeck et al., 2004.

6 Palinuro Promontory.The analyses on serpulids overgrowths that coverd submerged speleothems in sea caves at Palinuro promontory allowed to reconscruct the sea level rise data at Palinuro promontory during Holocene. The samples were collected by scuba diving at depths from -18 to -49 m measured with a digital depth gauge Speleothems from the Scaletta cave were sampled at depths between 27 and 48 m and yielded ages from 8.4 to 10.2 ka cal. BP (Alessio et al., 1992,1996, Antonioli & Oliverio 1996).

7 Catania Plain. A stratigraphic and sedimentological study, accompanied by ^{14}C AMS dating, has been carried out by means of three boreholes in the most depressed coastal sector of the Catania Plain, the Pantano di Lentini. The boreholes showed that clear lagoon deposits, constituted by dark organic silts, are present only in the upper 2-3 m. Moreover, ^{14}C AMS dating on pulmonate gastropod indicated an age not older than 2.5 ka for these deposits. The remaining sediments, down to the Lower-Middle Pleistocene marly clayey substratum reached at depths variable between -20 and -39 m, are represented by infralitoral beach deposits containing rare lagoon levels. The ^{14}C AMS dating on shell fragments collected at various depths suggested an Holocene age, between 6.4 and 9.3 ka, for these deposits (Monaco et al., 2004).

8 Sybari Plain. "Archaeological excavations on the Sybari alluvial plain have led to the identification of three superimposed levels of occupancy from the 6th to the 1st century BC: the ancient Greek town of Sybaris, the Hellenistic town of Thurium, and the Roman Copia. This plain forms a graben that runs in an ENE-WSW direction, bordered by regional fault systems. The upper part of this depression is filled with ~ 400 m of deposits consisting of sands including fine clay-sands, coarse gravels and peat levels at various depth. A core from the plain yielded ^{14}C-based ages in the interval 5.3 to 11.1 ka cal. BP for peats and marsh deposits from depths of 3 to 55 meters below sea level (Cherubini et al., 2000)", from Lambeck et al., 2004.

9 North Adriatic. "The northern part of the Adriatic Sea is characterised by a shallow sea-bottom morphology (at 30-50 m depth) with sediments deposited by the Po River in the immediate offshore area. The low shelf gradient and the lower sediment input near the central part of the basin results in significant landward shifts of depositional environments at times of sea-level rise. In consequence, successive backstepping sequences do not completely overlap. Furthermore, transgressive deposits are not always covered by younger highstand sediments and they can, therefore, be selectively sampled using conventional gravity and piston coring (Correggiari et al., 1997). Sediment cores from a number of sites have yielded 23 depth-age data points within the depth interval from 26 to 52 m with radiocarbon-based ages of 9.3 to 12.9 ka cal. BP." from Lambeck et al., 2004.

10 Po Plain. A very high-resolution stratigraphic framework for the subsurface of the Po Plain has been constructed in the last decade on the basis of 27 ^{14}C dates from several tens of cores, at 40-200 m depth, which were made available by the Geological Survey of Regione Emilia-Romagna. This excellent data set provides a unique opportunity to depict the complex scenario of transgressive depositional environments during the Holocene in the subsurface of Ravenna (Amorosi et al., 1999), Ferrara (Amorosi et al., 2003) and Rimini (Amorosi et al., 2004) coastal areas, showing evolution from an early transgressive coastal plain/lagoonal environment (12-10 ka cal BP) to a backstepping barrier-lagoon system, with lateral transition to a wave-dominated estuary (up to approximately 7 ka cal BP); this was followed by extensive delta progradation during the ensuing highstand phase. Reconstruction of 3-D stratigraphic architecture beneath the modern coastal plain, combined with radiometric data from inland locations (Preti, 1999; Amorosi et al., in press) enables a precise identification of shoreline position at 8 ka cal BP, with a further distinction between the nearshore zone (boundary between marine and brackish-water environments) and the inner margin of the lagoon/estuary (boundary between brackish and continental environments).

11-12 Caorle an Marano Plains. "Several cores have been drilled in different lagoons between Venice and Trieste in which lagoonal shells and marsh deposits have been identified. Radiocarbon analyses indicate ages from 0.9 to 9 ka cal. BP at elevations of –0.90 to –8.30 meters (Marocco,1989; Galassi and Marocco, 1996)" from Lambeck et al., 2004.

13 Cagliari Plain. Tree cores have been drilled in lagoonal-marine sediments, in which lagoonal shells have been identified. Radiocarbon analyses indicate ages from 2 to 10.4 ka cal PB at elevations of -2 and -32m. The predicted sea level curve of this site is in particular agreement with observed data (Orrù et al., 2004).

14 Sardinian beachrock. "A great number of well-conserved palaeo-shorelines have been discovered in northern Sardinia on the continental shelf up to depths of -120 m. De Muro and Orrù (1998) observed beach deposits (sandstone and conglomerates) on an erosional platform of crystalline bedrock at depths ranging from 0 to 55 meters from two main localities; Orosei and northern Sardinia. The chronology has been established from ^{14}C dating of the carbonate matrix that was considered to correspond to early-stage magnesium-calcite cementation, with samples ranging in age from 0.2 up to 9.7 ka cal. BP at progressively deeper depths of 0 to 29 m below present sea level" from Lambeck et al., 2004.

Marine Sea Surface Palaeotemperature

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Introduction

The Mediterranean Sea is a semienclosed basin limited to the south by the Sahara Desert which is under the influence of subtropical highs and to the north by the European-Asian temperate-to-subtropical region.

The hydrography and circulation of the Mediterranean Sea is primarily driven by inflowing Atlantic surface water and outflow of intermediate waters at depth (Sparnocchia et al., 1994).

The outflow waters are derived from Levantine Intermediate Water (LIW), which forms in the eastern Levantine basin. The horizontal circulation structure is summarized in Fig.1. The surface basin circulation is dominated, in the northern part of both western and eastern basins, by large scale permanent cyclonic gyres. In the south-western Mediterranean and in the middle of the eastern basin, the circulation is characterized by a jet-like current both boundary intensified (Algerian Current) and free (Atlantic Ionian Stream and Mid-Mediterranean Jet). The south-eastern basin is dominated by anticyclonic large scale gyres (Fig.1) (Pinardi & Masetti, 2000).

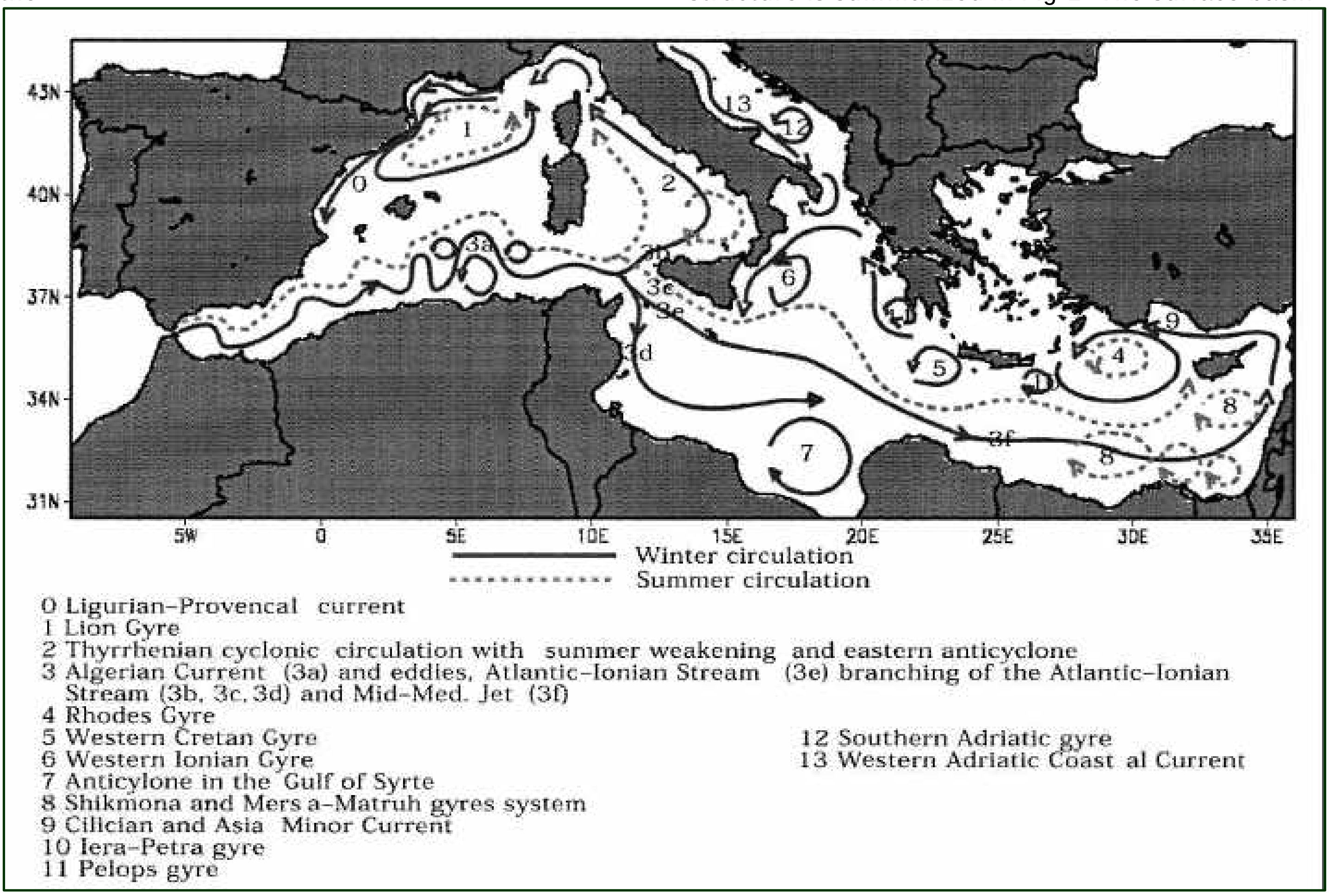

Fig. 1- The schematic of major basin current and gyres systems and their seasonal variability (from Pinardi & Masetti, 2000).

Under modern conditions, the evaporation exceeds the sum of precipitation, the river discharge and the freshwater balance of the Mediterranean Sea is negative.
During the Late Quaternary this area experienced drastic climatic changes affecting both the temperature regime and the circulation pattern as evidenced by paleoceanographic records (Grazzini et al., 1977; Kallel et al., 1997 a, b; Myers et al., 1998; Rohling et al., 1999; Ariztegui et al., 2000; Cacho et al., 2001; Sangiorgi et al., 2003).
In this work we tentatively reconstruct the sea surface paleotemperature condition during two extreme climatic intervals: the Last Glacial Maximum (LGM) and the Holocene Climatic Optimum (HCO). The reconstruction is based on oxygen isotope measurements of plankic foraminifera tests.

Methods

Marine Sea Surface Temperature (SST) were calculated by solving the general paleotemperature equation of Shackleton (1974).
$T = 16.9 – 4.38 (?\,^{18}O_{carb} - ?\,^{18}O_{water}) + 0.1 (?\,^{18}O_{carb} - ?\,^{18}O_{water})^2$
This method considers the oxygen isotopic values of Foraminifera shells ($?\,^{18}O_{Foram}$) .
The ? ^{18}O variations measured in calcareous shells reflect the sum of the global variations of the ocean water ? ^{18}O due to continental ice volume changes, the local sea surface ? ^{18}O variations due to changes in advection and freshwater budget and the isotopic fractionation between calcium carbonate and water, which depends upon the temperature at which foraminifera have formed their shell (Shackleton et al., 1974).
The sources of data are reported in Tab. 1 and 2 and were supplemented with new calculated values (see Tab.1 and 2). All data are from selected marine sediment cores with accurate age model (mainly based on Accelerator Mass Spectrometer (AMS) ^{14}C dates on planktic /benthic foraminifera already described in previous papers).

Oxygen isotopic composition of planktic foraminiferal carbonate

Recently Kallel et al. (1997a) compared the isotopic temperatures, calculated using the ? ^{18}O values of planktic foraminifera from many Mediterranean Sea core tops, with modern SSTs (Levitus, 1982). This comparison showed that the ? ^{18}O value of *Globigerina bulloides* is in isotopic equilibrium with the mean April-May SSTs (late winter-early spring) with a correlation coefficient r = 0.69 and the ? ^{18}O value of *Globigerinoides ruber* is in isotopic equilibrium with the mean October November SSTs (late summer - autumn)(r= 0.81).
These results are in agreement with the present planktic distributions in the Mediterranean Sea: *Globigerina bulloides* develops preferentially during the spring bloom when stratification of the water column starts and the superficial waters begin to warm (Pujol and Vergnaud-Grazzini, 1995), while *Globigerinoides ruber* mainly grows during autumn (Pujol and Vergnaud Grazzini, 1995). We assume that, at present, the blooming period for both species is probably the same as in the past.
Paleotemperature values are based on isotopic analyses performed on *Globigerina bulloides*, which is the most common planktic specimen measured in both time intervals.
In few cores the isotope values were available only on *Globigerinoides ruber* (see Tab.1 and Tab.2) we recalculated "virtual " values of *Globigerina bulloides* by taking into account the offset observed in cores with both measurements.
However, this correction represent an oversimplification because the response of different species to the same climatic/hydrographic change appears different in amplitude (Bemis et al., 2002; Rohling et al., 1999).

Oxygen isotopic composition of sea surface water

The oxygen isotopic composition of ocean water varies as a function of the evaporation-precipitation balance: the evaporation process extracts preferentially the light water molecules and the remaining ocean water becomes richer in oxygen -18; on the contrary, inflow of 18 O-depleted freshwater, by precipitation or river discharge, causes a decrease of ? ^{18}O values of the oceanic water. There is thus a direct relationship between salinity and ? ^{18}O values, which mirrors the water budget.
In the Mediterranean Sea the ?^{18}O distribution shows a south-north and west-east increase, which mirrors the distribution of surface salinity. The oxygen-18/salinity relationship at time zero is provided by Pierre et al. (1999).
Sea water ? ^{18}O variation in the past reflect both global changes due to continental ice volume variations and local changes in the freshwater budget. Salinity during the LGM variations were similar to those of the North Atlantic ocean near the entrance of the Mediterranean Sea and the

freshwater budget was not significantly different from the modern one (Kallel 1977b).
During the HCO, different paleoceanographic proxies document a strong salinity decrease associated with the deposition of organic rich layer known as a sapropel S1 (Vergnaud Grazzini et al., 1977; Tang and Stott, 1993; Rohling et al., 1999; Emeis et al., 2000). It was deposited between 9000 and 6000 years B.P. (Jorissen et al., 1993; Fontugne et al., 1994; Mercone et al., 2000) on the basis of accelerator mass spectrometry (AMS) ^{14}C dating.
Based on these assumptions, in our temperature reconstruction , oxygen isotopic composition of water was calculated following Kallel et al. (1977b) and data provided by Kallel et al. (1977a) for the LGM and HCO time respectively.
The temperature reconstruction during the LGM indicates that temperature was on average about – 7 ? 2° C lower today in late winther/spring. At time of the deposition of the sapropel S_1, the values of SST were similar to the present (? 1° C) with colder temperature in the norther part of the Tyrrhenian Sea (about 2.5° C) as already evidenced by Kallel et al., 1977.
This reconstruction is certainly speculative; however, our main objective in this work, is to provide a dataset of values calculated using the same methodology in order to estimate the gradients between the two investigated time intervals.

Core	Basin	Longitude	Latitude	Species	Isotopic Temperature Mean (April-May)	Data source
SC 125	Ligurian Sea	9,0317	43,6625	*Globigerina bulloides*	5,59	Testa et al., 1990
ET 91-18	Tyrrhenian Sea	9,8667	42,6000	" "	7,2	Capotondi et al., 1999
GT 85-5	" "	11,2500	40,3167	" "	7,5	Capotondi et al., 1999
KET 80-22	" "	11,7167	40,5833	" "	7	Paterne et al., 1986
AC 85-4	" "	11,7667	41,7500	" "	7,63	Capotondi et al., 1989
KET 80-19	" "	13,3500	40,5833	" "	7,24	Kallel et al., 1997b
KET 80-04	" "	13,5667	39,6667	" "	8,19	Paterne et al., 1986
BS 79-38	" "	13,5783	38,4000	" "	8,5	Cacho et al., 2001
BS 79-33	" "	14,0300	38,2500	" "	9	Cacho et al., 2001
KET 80-03	" "	14,5000	38,8167	" "	8,78	Kallel et al., 1997
KET 80-03	" "	14,5000	38,8167	" "	7,08	Paterne et al., 1986
C 106	" "	14,7067	40,4820	" "	7,58	Buccheri et al., 2002
CS 72-37	Strait of Sicily	12,2833	36,6833	" "	9,27	Kallel et al., 1997b
CS 70-05	" "	13,1833	35,7333	" "	9,1	Vergnaud Grazzini et al.,1988
KET 82-22	Ionian Sea	16,8833	37,9333	**Globigerinoides ruber*	10	Fontugne et al., 1989
MD 84-658	" "	17,6333	35,0333	" "	10,72	Fontugne et al., 1989
RC 9-191	" "	18,0333	38,1833	" "	7,5	Fontugne et al., 1989
IN 68-9	Adriatic Sea	17,9167	41,8000	*Globigerina bulloides*	6,92	Jorissen et al., 1993
KET 82-16	" "	17,9833	41,5167	**Globigerinoides ruber*	6,18	Fontugne et al., 1989

Tab. 1

Tab. 1- Summary of the data used for the reconstruction of the Mediterranea Sea Surface Temperature during the Last Glacial Maximum. Growth temperature of Globigerina bulloides and Globigerinoides ruber is found to be equivalent to the mean (April-May) SST and Mean (October-November) SST respectively. (*)In few cores the isotope values were available only on Globigerinoides ruber we recalculated "virtual " values of Globigerina bulloides by taking into account the offset observed in cores with both measurements (see the text). Temperature were calculated from the ?^{18}O data provided by the authors (final column).

Core	Basin	Longitude	Latitude	Species	Isotopic Temperature Mean (April-May)	Data source
SC 125	Ligurian Sea	9,0317	43,6625	*Globigerina bulloides*	12	Testa et al., 1990 □
ET 91-18	Tyrrhenian Sea	9,8667	42,6000	**Globigerinoides ruber*	12,15	Capotondi et al., 1999□
BS 78-13	" "	9,8833	42,3667	*Globigerina bulloides*	12,82	Capotondi L. (unpub. data)
GT 85-5	" "	11,2500	40,3167	" "	13,01	Capotondi et al., 1999□
CT 69-55	" "	11,2533	40,3333	" "	13,35	Capotondi L. (unpub.data)
AC 85-4	" "	11,7667	41,7500	" "	13,2	Capotondi et al., 1989□
KET80-19	" "	13,3500	40,5500	" "	13,75	Kallel et al., 1997a□
BS 79-38	" "	13,5667	38,4000	" "	14,5	Cacho et al., 2001□
KET80-04	" "	13,5667	39,6667	" "	13,83	Kallel et al., 1997□
DED87-07	" "	13,5833	39,6833	" "	13,83	Kallel et al., 1997□
BS 79-33	" "	14,0167	38,2500	" "	15	Cacho et al., 2001□
KET80-03	" "	14,5000	38,8167	" "	13,92	Kallel et al., 1997a□
C 106	" "	14,7040	40,4820	**Globigerinoides ruber*	15	Buccheri et al., 2002□
MC 82-12	" "	14,4167	39,7167	*Globigerina bulloides*	14,16	Aritzegui et al., 2000□
KET80-11	" "	15,0833	39,1667	" "	13,7	Kallel et al., 1997a□
KET80-40	Strait of Sicily	11,8167	36,7833	" "	16,01	Kallel et al., 1997a□
CS72-37	" "	12,2833	36,6833	" "	16,09	Kallel et al., 1997a□
CS 70-5	" "	13,1833	35,0667	" "	17,11	Grazzini et al., 1988□
KET 82-22	Ionian Sea	16,8833	37,9333	" "	17,04	Kallel et al., 1997a□
RC9-191	" "	18,0333	38,1833	**Globigerinoides ruber*	17	Kallel et al., 1997a□
M 25/4	" "	18,1833	37,9667	" "	17,74	Negri et al., 1999□
V10-67	" "	20,7167	35,7000	" "	17,81	Kallel et al., 1997a□
CM 92-43	Adriatic Sea	14,7167	42,8833	*Globigerina bulloides*	12,62	Aritzegui et al., 2000□
IN 68-21	" "	14,7833	42,8833	" "	14	Jorissen et al., 1983□
MD90-917	" "	17,6167	41,3000	" "	13,91	Siani et al., 2001□
IN 68-9	" "	17,9000	41,7833	" "	13,9	Jorissen et al., 1983□
KET 82-16	" "	17,9833	41,5167	" "	13,04	Fontugne et al., 1989□
IN 68-5	" "	18,5333	41,2333	" "	13,62	Jorissen et al., 1983□
AD 91-17	" "	18,6333	40,8667	" "	13,03	Sangiorgi et al., 2003□

Tab. 2 - Summary of the data used for the reconstruction of the Mediterranea Sea Surface Temperature during the Optimum Climaticum. Growth temperature of Globigerina bulloides and Globigerinoides ruber is found to be equivalent to the mean (April-May) SST and Mean (October-November) SST respectively. (*) In few cores the isotope values were available only on Globigerinoides ruber we recalculated "virtual " values of Globigerina bulloides by taking into account the offset observed in cores with both measurements (see the text). □ Temperature calculated from the ?^{18}O data supplied by the author; □ Temperature provided by the author.

Late pleistocene loess in italy

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Introduction
Loess deposits are widespread in Italy, similarly to the other countries surrounding the Mediterranean sea, and they are typical of the landscape of glacial phases (Coudé-Gaussen, 1990) because their formation and deposition were enhanced by poorly vegetated soil surfaces, dry climate, and strength of winds which are environmental features which occurred in these periods (Cremaschi, 1990b).

Age
While limited outcrops of Lower and Middle Pleistocene loess have been recorded at the pre- alpine margin, namely in the Visogliano cave where they were associated to bone fragments of *Homo erectus*, the bulk of loess deposits has to be referred to the Upper Pleistocene (Cremaschi, 1990b).
In recent years an effort has been made to obtain radiocarbon datings on the organic matter of some buried chernozem

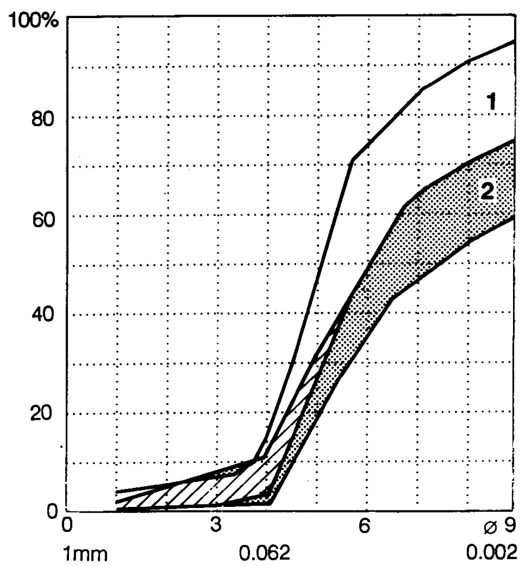

Fig. 1 - Grain size distribution for Italian loess

or on charcoal of cave deposits associated to loess deposit of anthropogenic fill of caves as for instance Riparo Tagliente and Grotta di Fumane, and by OSL on the quartz grains and by TL of fire-damaged flint artefacts buried in loess sequences (Ghiardo and Bagaggera) (Cremaschi et al., 1987; Cremaschi et al. 1990; Ferraro et al., 2004; Martini et al., 2001). Based on these data (Tab. 1), there are three main phases of Late Pleistocene deposition of loess , during the isotopic stage 4 (early Pleniglacial), in the late isotopic stage 2 (second Pleniglacial), and in Late Glacial

Characteristics
The term loess refers to silty sediments which have been transported and accumulated by aeolian activity. The term also includes those aeolian deposits which have been affected by syn- and post-depositional soil forming processes and slight colluviation (Cremaschi, 1990 a, b, e).
The loess in northern and central Italy is composed of silt and clay and is characterised by a single mode, sigmoid, asymmetric grain size distribution curve (fig. 1), with moderate to scarce sorting and median ranging from 5 to 7.5 phi and considerable asymmetry in the fine tail. The sand content is generally very low (1 - 5%), the clay fraction varies between 5 and 40%. Accumulation of clay in loess may often be related to post-depositional soil forming processes, while limited outcrops of sandy loess have been identified at Torino Hill (Forno, 1979), Copreno (Orombelli, 1970) and Val Sorda (Mancini, 1960).
From the mineralogical point of view, the loess of northern Italy is rather homogeneous, even if some slight local differences occur; the sandy fraction is mainly composed of quartz and to a lesser extent of feldspar and muscovite. The heavy minerals fraction consist mostly of minerals of metamorphic paragenesis (amphiboles, epidotes, disthene, garnets, etc.) that reflect the composition of the

fluvial and fluvioglacial Late Pleistocene deposits of the Po Plain which represent the main source of aeolian dusts (Cremaschi, 1978, 1987 a). It is interesting to observe, for example, that the heavy minerals of the loess deposits on the Susak Isle and on the Monte Conero plateau which are located on opposite sides of the present Adriatic sea, are of the same heavy mineral composition because they both derive from the deflation of the Upper Pleistocene alluvial plain formed by the Po sediments and today submerged by the Adriatic sea (Cremaschi, 1990c). To the south in the Marche region and particularly in the Gargano region, the loess is richer in pyroxenes and other minerals of volcanic paragenesis as its main source was the unconsolidated pyroclasts related to the Quaternary volcanic activity in the area (Cremaschi, 1990 b,e) (fig. 3).

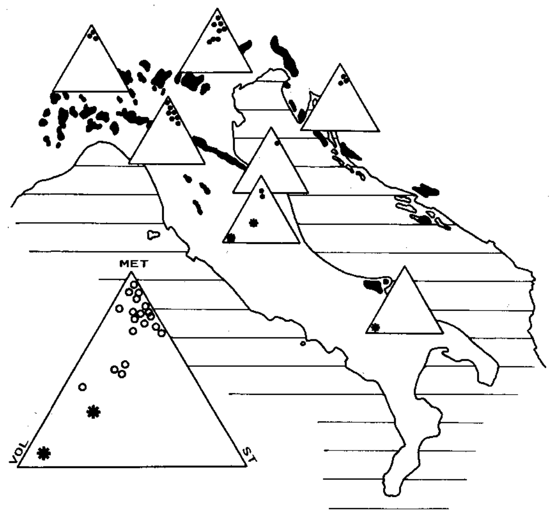

Fig. 2 - Mineralogical composition of Italian loess. Met - heavy minerals of metamorphic paragenesis, Vol - heavy minerals of volcanic minerals ; ST - heavy minerals resistant to weathering (zircon, tourmaline, titanium oxides).

Distribution

In northern and central Italy, loess deposits are well represented along the margins of the Po Plain and in the Pre-Alps, but they occur less frequently in the Marche province. Limited outcrops of loess have also been described in the Central Alps and within the Apennine range; therefore the south-western part of the Tuscan-Emilian Apennine chain should be regarded as a physiographic boundary to the loess sedimentation area. Furthermore extensive loess deposits occur in Istria, in the Dalmatian Archipelago and on the Croatian side of the Adriatic sea (Bognar, 1979). Loess sedimentation affected therefore both sides of Adriatic basin which thus should be regarded as a single loess basin. No loess deposit has been recorded up to now in the Tyrhenian side of the Italian peninsula; however, reinforcement of aeolian dust deposition during the Late Pleistocene has been recently described in lacustrine deposits of Central Italy (Narcisi, 2000). The loess of Northern and central Italy occurs in different geomorfologica situations:

- Loess on fluvial terraces of the Apennine fringe. It is distributed over a wide area displaying rather homogeneous characte-ristics. It occurs on the pede- Apennine fringe - from Piacenza to Forlì - covering fluvial terraces of different ages and it ranges in thickness from a few decimetres to a few meters, thinning out from NW to SE. It is also present on the isolated terraces that emerge from the Late Pleistocene plain of the Lombardia and Piemonte provinces and on the fluvial terraces in the Mugello basin (Toscana). The loess deposits turned to alfisols on top of thick policyclic paleosols (Fraenzle, 1965; Sanesi, 1965; Ferrari & Magaldi, 1968; Cremaschi, 1978; Biancotti & Cortemiglia, 1981, Cremaschi, 1987b; Busacca & Cremaschi, 1998).
- Loess on glacis and erosional surfaces has been identified in the Apennine range between the provinces of Liguria and Marche. It is composed by a thin shee t covering erosional surfaces cut in very different types of bedrock (mafic rocks in the Voltri plateau, Tertiary turbidites in the Selvapiana area) sometimes affected by deep weathering (Cremaschi, 1990 a).
- Loess on moraines and fluvioglacial deposits can be found at the southern margin of the Pre-Alps, from the Piemonte province to the Tagliamento river. It covers the surfaces of fluvioglacial terraces and moraine ridges which were deposited during the glacial stages previous to the last one (Mancini, 1960, 1969; Fraenzle, 1965; Ugolini & Orombelli, 1968; Orombelli, 1970; Billard, 1974; Meneghel, 1987; Cremaschi 1987a).
- Loess on karst-plateaux and included in the fill of caves or shelters is extremely widespread in the Pre-Alps of Lombardia

and Veneto provinces. I It covers the Monte Conero plateau, and has also been recorded on the Peninsula of Istria, on the Dalmatian Archipelago. It lies upon Terra Rossa type polygenetic soils, upon surfaces laid bare by periglacial processes, upon and within gelifraction slope deposits, or it may have been forced into dolinas by colluvial processes. In particular situations (Isle of Susak, Dalmatian Archipelago) it covers weathered fossils dunes and marine abrasion surfaces (Chardon, 1975; Bognar, 1979; Magaldi & Sauro, 1982).

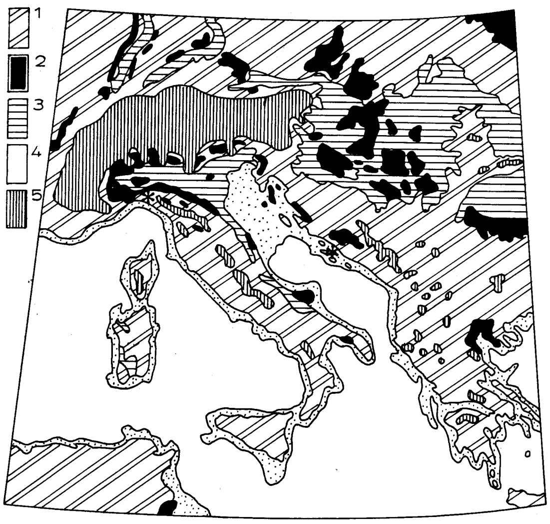

Fig. 3 - Distribution of the Italian loess related to the physiographic setting of the Last Glacial period. 1 - mountains ; 2 - loess ; 3 alluvial plain; 4 - areas out of the sea during the Last Glacial Maximum; 5 - extent of the glaciers during the Glacial Maximum.

Georarchaeology

Loess deposits are systematically associa-ted with middle and upper Palaeolithic archaeological evidence, both in rockshelters and in open air sites, indicating that the loess belt was densely occupied by Mousterian and upper Palaeolithic community and that its ecosystem was suitable for human subsistence. Faunal and botanical remains . preserved in cave deposits indicate an environment dominated by grass steppe and large mammals including *Elephas primigenius* (Sala et al., 1990; Cremaschi, 1990 a,d, e, 2000).

In the open air sites, almost only the stone artefacts survived the postdepositional soil forming processes that affected the loess, but the artifacts are fresh, with sharps edges, and they are still distributed in clusters which witness the primary organisation of hunting camps and workshops (Cremaschi et al. 1990, Cremaschi, 2000). Furthermore, some artefacts which have sharp edges, and therefore did not undergo postdepositional transportation, often have glossy surfaces, what is due to abrasion of aeolian quartz grains. These facts indicate that the artefacts which constitute the sites were not disturbed, after burial in loess by any erosion or colluvial reworking.

Conclusion

In the Po plain and the Adriatic basin, during the Late Pleistocene, the loess sedimentation, together with the general climate conditions (dry and cool) was enhanced by local environmental factors:

- A large supply of parent material, suitable for deflation, was produced by aggrading fluvial and fluvioglacial land forms in the north and by volcanic activity in the outh.
- Furthermore, the sea level drop of 150 m during the glacial period caused large extension of the Po Plain which exacerbated the continental characteristics of the climate, making the Po Plain and the adjoining Adriatic basin the western most reach of the Pannonian loess basin (fig. 3).

Loess areas were intensively settled by Mousterian and upper Palaeolithic communities which found in them ecological conditions suitable for their subsistence

Site	Unit/Sample name	Dating (y BP)	Laboratory number	Method
Val Sorda	VS130-165	27.880 ± 600	R.1854	^{14}C
	VS 210-280	36.000 ± 5000	Oxford Laboratories	OSL
Gajum	Unit 3	40.830 +7820 -3890	Gx 14 028	^{14}C
Ghiardo	II B23 cn	61.000 ± 9000	Mi96-Gh1	TL
Ghiardello	II B22t	73.000 ± 11.000	Mi96-Gh2	TL
Bagaggera	III B23t	60.500 ± 7500	OXTL - 750 f	TL
Fumane Cave	A4II	33.150 ± 600	Ox-6462 AMS	^{14}C
	A5	33.700 ± 600	Ox-6463 AMS	^{14}C
	A5+A6	38.250 ± 700	Ox-8023 AMS	^{14}C
	A6	34.950 ± 700	Ox-6464 AMS	^{14}C
	A6	50.000 ± 8.000	Mi97-Fu1	TL
	BR11	55.000 ± 7.000	Mi97-Fu2	TL
Tagliente shelter	t.12a	17.000 ± 3000	GL	TL
	t.39	54.000 ± 3000	GL	TL
	t.8-10	12.040 ± 170	R.371	^{14}C
	t.15-16	13.430 ± 180	R.605a	^{14}C

Tab.1 - Radiometric dating for loess deposits of Italy (modified from Cremaschi 1990 c)

The human presence in Southern Italy

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The sites of southern Italy which bring evidence of human occupation between 20,000 and 16,000 years BP are very scarce in number. Thus, only the rare stratified deposits supplying palaeo- enviromental data have been marked on the maps of this project.
This evidence apparently contrasts with the role played by one of the more southern areas of Europe, which must have acted as refuge during the Last Glacial Maximum. In fact we should expect an increase of peopling linked to the severe climatic conditions that forced prehistoric man to migrate towards lower latitudes. This contradiction is probably only apparent and the scarcity of known sites very likely corresponds to a gap of research. Actually, many areas in southern Italy are suitable for the Palaeolithic form of settlement (suffice it to consider the diffusion of limestone massifs), but only in few cases systematical surveys have been developed. So, rather than reasoning about factors related to the abundant or scarce Palaeolithic peopling, we had better to compare the actual knowledge with the effective number of researchers.
An important inner modification is known in the upper Palaeolithic culture about 20 Ka BP: the Gravettian, a relatively homogeneous culture widespread in Europe, shatters and gain differences on regional scale. This process leads, in Italy, to the transition toward the Epigravettian culture. The palaeoenviromental data linked to the anthropic layers mainly originate from the results of the archaeozoological analysis of animal remains (hunt-preys). The emerging climatic condition appears cold, sometimes severe. A fitting example comes from the cornerstone represented by the series of Grotta Paglicci, in the Gargano area: here there are findings of marmot restricted only within the lapse of time considered. The other climatic factor linked to cold is aridity, as normally happens during stadial peaks.
The corresponding environment should have been scarce in forest covering, fair to the presence of horses in plateau areas and ibex on rock slopes, even at low altitudes.
The period 9,000-7,000 years BP bring a progressive climatic improvement, and witness the establishment of Mesolithic cultures. The forest covering gradually reoccupies the open areas, leading to a change in the subsistence strategy of prehistoric man.
The use of bow and arrows is documented, starting from Preboreal, by rock paintings and the findings of geometric-shaped microlithic artifacts. The sequence of Mesolithic cultures begins with the Sauveterrian, followed by Castelnovian; this one persists till the beginning of Neolithic. Mesolithic sites of Southern Italy are rare and were descovered recently. More considerable traces are related to the Early Neolithic. This one, completely allochtho- nous, spreads in southern area about 7,500 years BP and brings a fundamental change in human history: the transition from a Palaeolithic form of economy based on hunting and gathering toward the food production. From this moment, agriculture and breeding becomes the basis of human subsistence.

The Grotta dell'Uzzo site (Sicily)

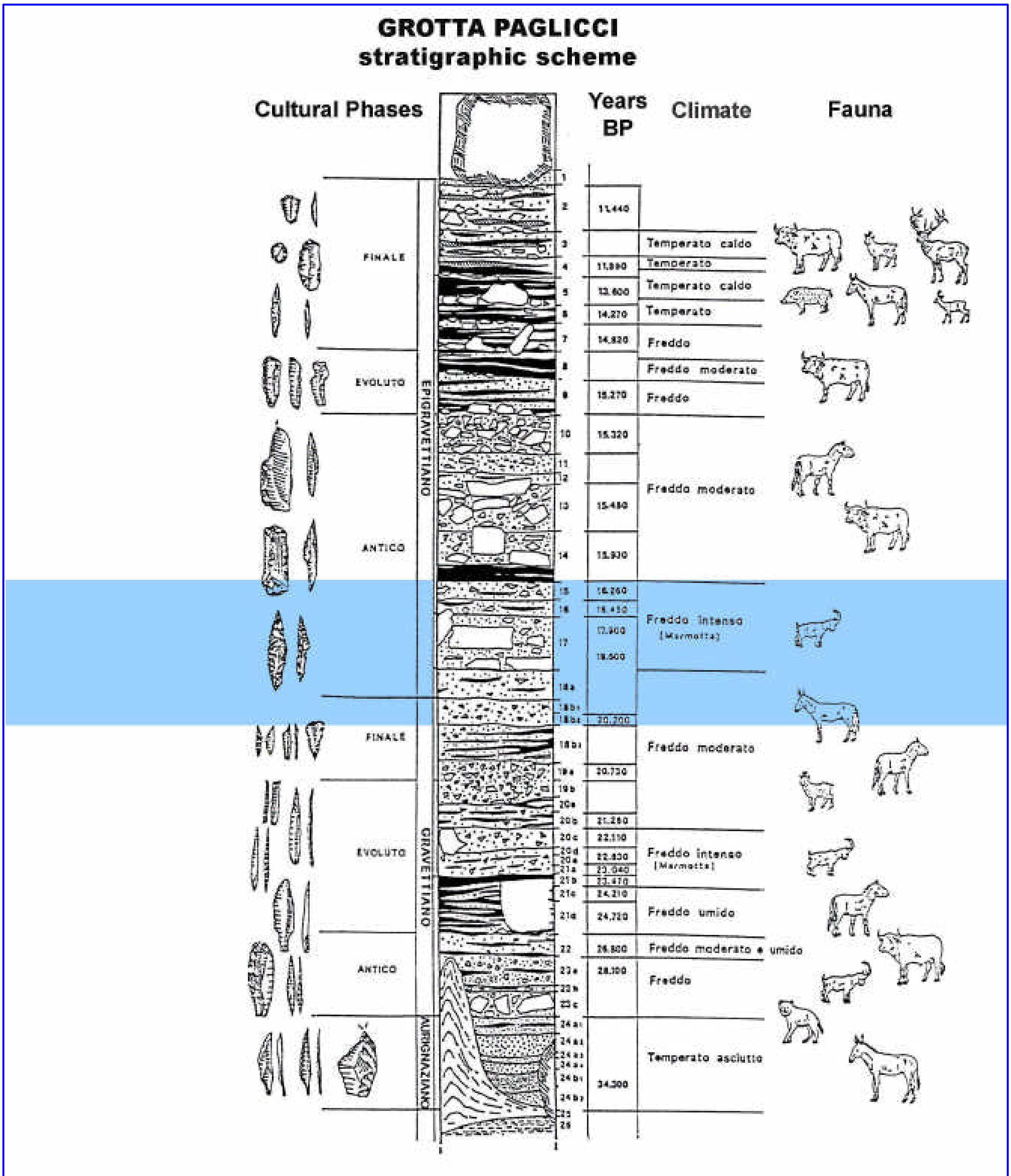

Fig 1 The Grotta di Paglicci stratigrapyh and Human recostruction.

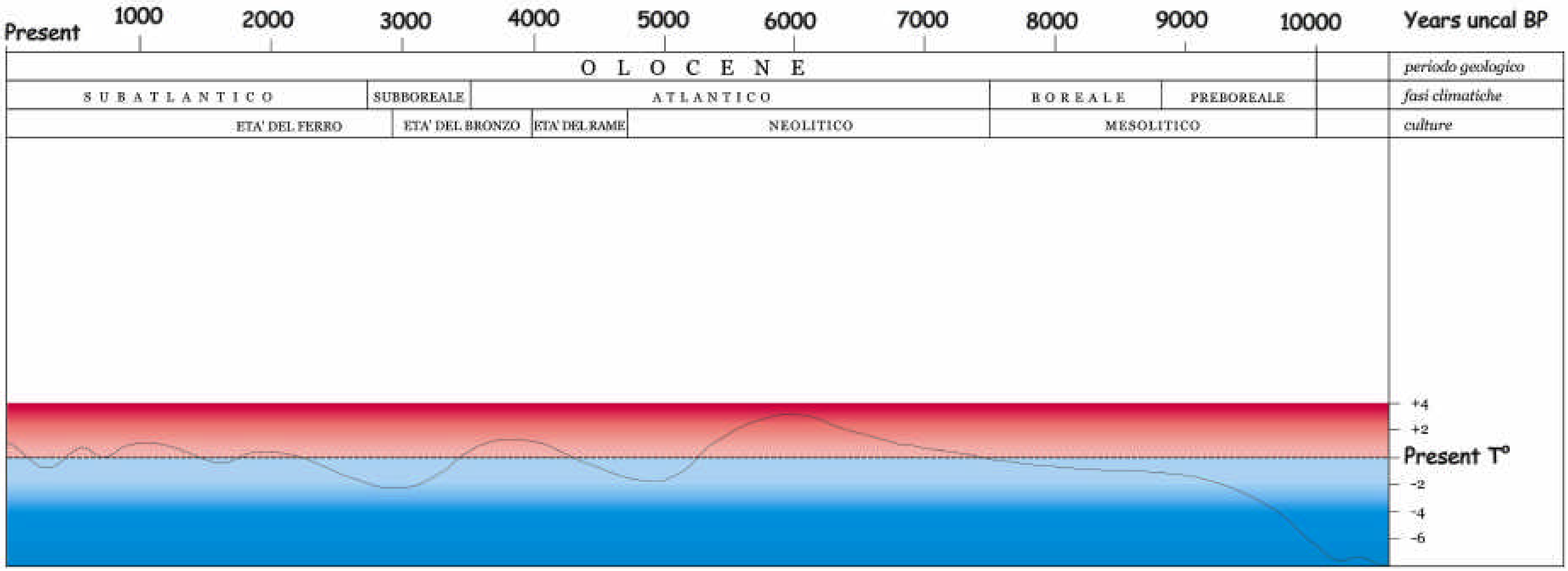

Fig 2 A reconstruction of Archaeological culture and Palaeotemperatures in Italy (Gambassini personal communication

Late Pleistocene to Holocene Apennine Glaciations (Italy)

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Introduction

The Apennines form the backbone of the Italian Peninsula, extended into the Mediterranean Sea between 38° N and about 44°30’ N. Traces of former glaciation have been known for the Apennines since the 19th century and have been the subject of many investigations. In the present work, however, only the most recent studies will be taken into consideration.

The highest peaks in the Apennines are found in the central sector, between about 42°50’ N and 41°30’ N where they include the Gran Sasso (2912 m), Maiella (2793 m), Velino (2486 m), Sibillini (2476 m) and Laga (2458 m) massifs, but numerous other peaks exceed 2000 m. In contrast, the mountains of the Northern Apennines exceed 2000 m only at Mounts Cusna (2121 m), Cimone (2165 m) and Prato (2054 m), and the mountains of the Southern Apennines exceed 2000 m only in Mounts Sirino (2005 m) and Pollino (2266 m).

During the Last Glacial Maximum (LGM) the great majority of the glaciers were present in valleys and glacial cirques orientated towards the north, while only a few developed in valleys orientated towards the west and the east, and hardly any occurred in valleys with a southern alignment.

At present only a single small glacier which is rapidly melting is found in the Apennines: the Calderone Glacier in the Gran Sasso.

The most recent summaries of data on the late Pleistocene glaciation of the Apennines were presented by Federici (1979) for the Central and Northern Apennines, Palmentola *et al.* (1990) for the Southern Apennines, by Jaurand (1994, 1998), and by Giraudi (2002; in press) for the whole mountain range.

In Federici (1979) the chronological framework of the glacial phases relied largely on the correlation between the local ELA (*equilibrium line altitude*) and those of the Alps. Palmentola *et al.* (1990), having no radiocarbon datings, relied on the local ELA oscillations for a correlation between the Southern Apennine glacial phases and the North European late-glacial climatic phases. Jaurand (1994, 1998) used also some radiocarbon datings reported in studies on local glaciers. Giraudi (2003; in press) used radiocarbon datings, tephra layers and aeolian deposits to obtain a more detailed chronological framework of the Last Glacial Maximum and Neoglacial glacier oscillations.

Upper Pleistocene glaciation, the Last Glacial Maximum and its retreat phases

Traces of the Upper Pleistocene Glaciation have been reported in a number of papers. For a complete list of reference in the last thirty years see Giraudi (2003; in press).

The present data derives from an updating of the data presented in Giraudi (2003; in press) and on Giraudi & Frezzotti (1997).

In the Central-Southern Apennines has been recognized a number of stratigraphic markers (tephra and aeolian sediments) which are fundamental for the dating and correlation of the glacial events on the different massifs.

- In all the glaciated areas (except for the Gran Sasso and Majella), the most recent moraines (ELA some 400-475 m higher than that of the LGM) are overlain by the Neapolitan Yellow Tuff tephra, radiocarbon dated 12,300?300 ^{14}C years BP.

- On the Matese Massif (Central Apennines) a tephra layer predating the Neapolitan Yellow Tuff overlies moraines which indicate a rise of the ELA of c. 300 m with respect to the LGM. The chemical composition appears very similar both to the tephra of the «Greenish» and «Basale» eruptions of Mount Vesuvius. Near the volcano, the products of the «Greenish» eruption cover palaeosols dated 15,500?170 and 14,420?160 ^{14}C years BP, and the tephra of the «Basale» eruption covers palaeosols dated 16,250?130 and 17,050?40 ^{14}C years BP.

- In all glaciated areas, at the bottom of closed depressions on glacial debris, a layer of loess was found. On Mounts Greco and Matese (Central Apennines) and on Mount Sirino (Southern Apennines), this loess consists mainly of quartz. Here it overlies moraines which indicate a rise of the ELA of c. 200-280 m with respect to the LGM, but is not present on the younger ones. The age of this loess is based on the following data:

- On the Gran Sasso Massif, eolian quartz form nearly 20% of the sediments of a proglacial lake dated around 22,680±630 ^{14}C.

- On the Aremogna Plain (Mount Greco - Central Apennines) the loess, which has been subject to

soil formation, was redeposited as colluvium and subsequently overlain by peat dated at 12,850±200 ^{14}C years BP.
- On Mount Matese (Central Apennines) the loess is older than the tephra layer similar to the products of the «Greenish» and «Basale» eruption of Vesuvius, datable at c. 14,000-15,000 and 16,000-17,000 ^{14}C years BP.

According to Narcisi (2000) In the core of sediments drilled in some maar lake in Central Italy, eolian quartz of Saharan origin has been recognized; the higher peaks of quartz occurred between 25,000 and 14,000 years B.P.
We can assume that the loess made of Saharan quartz, found on the Apennine moraines, can be dated between 25.000 and 14.000 years ago.

- The Cerchio Tephra, a tephra of as yet unknown origin, was identified on the moraines of the first recessional phases after the LGM (with an ELA some 125 m higher than at the LGM) of Mount Breccioso (Central Apennines). The first products of tephra reworking have been dated in the nearby Fucino Plain at 19,100±650 ^{14}C years BP.

Using radiocarbon dating on soil and sediments and the chronological data stated above, a chronology of the Apennine LGM and its retreat phases has been obtained.
The maximum glacial extent, i.e. the Campo Imperatore Stadial, was reached just before 22,680?630 ^{14}C years BP and lasted until ca. 21,450?250 ^{14}C years BP.
During LGM, ELA on the Apennines was conditioned by latitude and valley exposures, and varied between 1250 and 1900 m a.s.l. About 21,450?250 ^{14}C years BP the glaciers started the early phases of retreat, that lasted until 17,840?200 ^{14}C years BP. In this period at least two retreat moraines were formed, produced by glaciers having ELA 15-125 and 110-200 m higher than LGM; nevertheless in some massifs the retreat moraines can be three or more because of local topographic reasons.
Around 17,840?200 ^{14}C years BP a very marked retreat phase took place, and a large amount of outwash sediments was produced: such a rapid glacier melting must have been due to a strong climatic change, i.e. to the occurrence of an interstadial (Fornaca Interstadial).
The glacier melting ceased around 17,380?160 ^{14}C years BP, when a new stadial advance took place (Fontari Stadial). During this stadial the last valley glaciers were present on the higher massifs, and ELA was 200-280 m higher than during LGM.
Starting from 16,000 ^{14}C years BP, a glacial reduction took place. Two retreat moraines were formed: the former, dated about 15.000-16.000 ^{14}C years BP, by a glacier having ELA 290-390 m higher than during LGM, and the latter, dated around 14,000 ^{14}C years BP, by a glacier having ELA 400-475 m higher than during LGM.
Between 12,850?200 ^{14}C years BP and at least 11,760?160 ^{14}C years BP, the lack of glacial remnants and the presence of lakes in some former glacial cirques suggest a very small extension of the glaciers. This time lapse is called Venacquaro Interstadial and corresponds to the Bölling-Alleröd interstadial.
Later, between 11,760?160 and 8035?140^{14}C years BP, a new small glacial advance took place (M. Aquila Stadial) corresponding to the Younger Dryas chron.

It is clear that the dates obtained generally show an earlier age for the glacial events than assumed before.

Holocene Neoglaciation

The presence of glaciers in the Apennines during the Holocene is shown by the Calderone Glacier. This glacier, located on the Gran Sasso Massif, is the southernmost in Europe (Gellatly *et al.*,1994). It is found at an elevation above *c*. 2670 m in a cirque situated on the northern slope of the Corno Grande (2912 m). Its tongue is rapidly melting and is almost completely covered by debris. The glacier is situated at the head of the Cornacchie Valley: in the upper part there are some moraines, which were formed by glaciers with an ELA more than 800-1050 m higher than that of the LGM.

There are no precise dates for these oldest Holocene moraines: we only know they are older than about 4000 years. The moraines, which indicate a glacier with an ELA about 800 m higher than that of the LGM, may possibly represent the recessional phases of the Mount Aquila Stadial dated to the Younger Dryas Chron.

The moraines situated at the threshold of the Calderone Glacier cirque, with their ELA about 1000-1050 m higher than the LGM, are formed by three different tills. The glacial advance (Calderone 1 stadial) that formed the older moraine, is younger than a soil dated to 3890±60 ^{14}C years BP. The presence of a soil implies that, at least during the middle Holocene, the Calderone glacier was absent.
The datings of debris of glacial origin point out four more Holocene glacial expansions:

the first (Calderone 2) following 2650?60 ^{14}C years BP, the second (Calderone 3a) bracketed between 1450?40 and 670?40 ^{14}C years BP, the tird (Calderone 3b) following 670?40 ^{14}C years BP, the last one (Calderone 3c) datable to the XIX century. The Calderone 3b expansion, occurred during the Little Ice Age, can be considered the Neoglacial maximum.

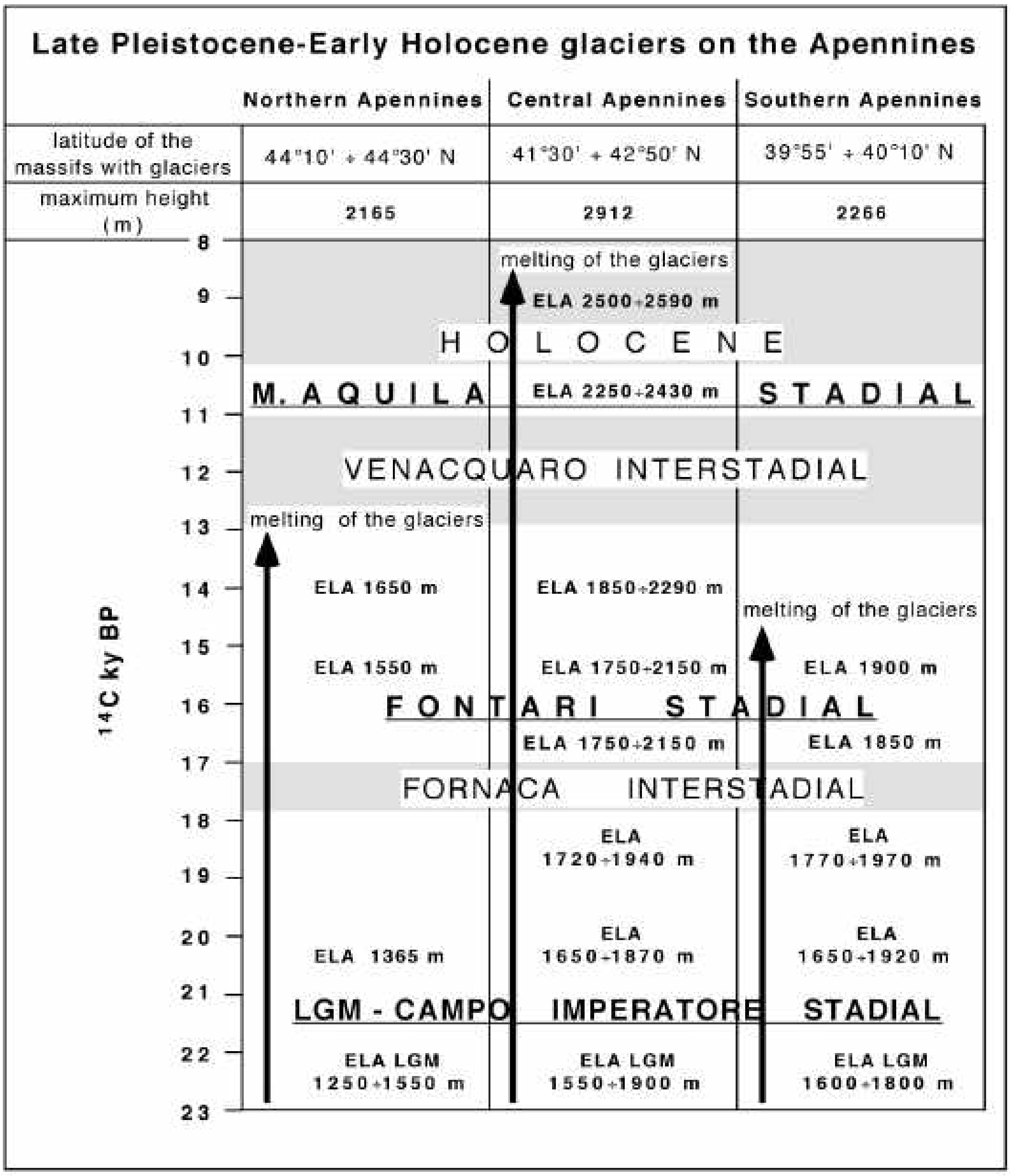

Fig. 1: Glacial stadials and Equilibrium Line Altitude (ELA) variations from Last Glacial Maximum to the early Holocene. The data from the Northern Apennines stadial ELA's are based on Val Parma glaciers facing North (from Jaurand, 1994, 1998). Maximum and minimum ELA values reported for the Central and Southern Apennines depend on the different massifs and valley orientations. In the Southern Apennines, the glaciers melted earlier than in the Northern Apennines despite the maximum elevation being higher. In the Northern Apennines the ELA is clearly lower than in the Central Apennines, while there is only a small difference between the Central and Southern Apennines.

OSTRACODES

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Ostracodes are aquatic, mainly benthonic microcrustaceans, widespread at all latitudes, which inhabit marine, brackish and freshwater environments. They are very sensitive to environmental parameters such as temperature, salinity, depth, substrate, pH, nutrient and oxygen content, thus they proved through time to be a valuable tool for the palaeoenvironmental and palaeoclimatic reconstructions. Thank to their different reproduction strategies, many ostracodes are capable to colonize wide geographical areas (Horne et alii, 1998). Several species, particularly freshwater forms, are characterised by resting eggs which are desiccation-resistant or freeze-resistant, thus tolerate even long periods of adverse environmental conditions and can be passively transported by aquatic birds, amphibians or insects. Some species are parthenogenetic, other, even if amphigonic, carry out brood care inside the female shell and, in this way, their passive dispersal is more successful. Consequently, freshwater ostracodes are potentially a useful group inside which it would be possible to recognize “northern” or “southern” guests whose geographical distribution is shifted latitudinally during climate changes. Anyway, only the temperature of shallow freshwater basins supplied by rain or superficial waters are linked to air temperature. In these cases the geochemistry of the freshwater ostracode shell has been successfully used to estimate the air temperature at the Pleistocene/Holocene transition (von Grafenstein, 2002). Freshwater basins fed by subterranean waters are temperature-indipendent. Thus, the concept of “northern” and “southern” guests is not easily applied even if, in some cases it is recognizable the southwards shift of some species as *Pseudocandona insculpta* and *Fabaeformicandona caudata* during cold climate intervals. Generally, it is preferable to use ostracode assemblages as palaeoenvironmental and paleodepth indicators, assuming that, both in marginal marine and in continental basins, a low-stand water level points to a cold/arid period while a high-stand water level with a high trophic status suggests a warm/humid one (Griffiths & Holmes, 2000).

In the Last Glacial Maximum map and in the Holocene Climatic Optimum map, localities in which ostracode analyses have been carried out have been reported. As it is possible to see, they are few and scattered along Italy. Unfortunately, literature data are scarce and only during the last years Late Pleistocene and Holocene brackish and freshwater ostracodes have been used as palaeoenvironmental and climatic indicators. Three case-histories are summarized here to illustrate the ostracode methodological approach, the first two concerning two marginal marine environments located one in the Romagna coastal plain (Adriatic coast, northern Italy) (Amorosi et alii, 1999), the other at Albinia on the southern Tuscany coastal plain (Tyrrhenian coast, central Italy) (Mazzini et al., 1999); the third case, on the contrary, illustrates a freshwater environment at Ripa Sottile (Latium, central Italy) (Ricci Lucchi et al., 2000; Gliozzi, 2000).

Romagna coastal plain (Adriatic coast)

Seventeen continuous boreholes, 40 to 170m deep, have been investigated along the Romagna Adriatic coast, between the Valli di Comacchio and the city of Ravenna. Ten ^{14}C dates provide the necessary constrains for the palaeoenvironmental recostruction along the Late Pleistocene-Holocene times. In the lower part of the cores the development of an alluvial plain system is recorded by the presence of *Cytherissa lacustris*, *Ilyocypris gibba*, *Ilyocypris bradyi*, *Ilyocypris* aff. *I. monstrifica* and several Candoninae species, among which *Candona angulata* and *Candona neglecta* are dominant. This interval is comprised between 35,000 and 25,000 a BP. A long stratigraphic hiatus has, then, been recognized along the cores (25,000-8,800 a BP), corresponding to the maximum sea-level low-stand reached during Last Glacial Maximum. From 8,800 to 6,000 a BP, brackish ostracode assemblages dominated by *Cyprideis torosa* and Leptocytherinae testify the setting of a lagoon system linked to the rapid sea-level rising.

Albinia (Tyrrhenian coast)

Along the Tuscan coast-plain, near the Albinia village, a 51m deep borehole was drilled, which sediment core records the palaeoenvironmental history of the area during the Late Glacial-Ancient Holocene and the relationships between the sea and the local Albegna River. As in the Romagna coastal plain, the bottom-core sediments corresponding to the Glacial Maximum point to a fluvial environment. Here, the vicinity of the Albegna River caused the deposition of gravels and sands, barren of ostracods. Going upwards the sediments become fine-grained and rich in ostracodes and molluscs. Ostracode assemblages show the gradual transition from a fluvial freshwater environment to a brackish coastal lagoon which becomes progressively fed by more saline waters, paralleling the rising of the sea-level. At around 8,350-7530 a BP , in correspondence with the end of the high-rate sea-level rising (Alessio et al., 1997) the lagoon reaches the maximum salinity (polihaline) with a rich ostracod assemblage dominated by *Loxoconcha elliptica*, *Cyprideis torosa* and accompanied by Leptocytherinae, *Propontocypris pirifera*, *Xestoleberis communis*, *Xestoleberis aurantia* and *Cytherois fischeri*.

Ripa Sottile (Rieti intramountain basin)

The Ripa Sottile Lake occupies a quadrangualar depression inside the Rieti Basin (Latium, central Italy). Two boreholes were drilled and a composite 60m deep sediment-core was investigated from sedimentological, palaeo-magnetical, geochemical and paleontological point of view. ^{14}C analyses provided the chronological constrains. The bottom-core (60m of depth), aged 11,800±80 a BP, thus corresponding to the Younger Dryas, bears an ostracode assemblage referable to the *candida* fauna, centered on the presence of the cold-stenothermal species *Candona candida*, accompanied by *Potamocypris zschokkei* and *Prionocypris zenkeri*. Together with steppe-dwelling molluscs, these ostracodes points to an unstable shallow waterbody characterised by cold and stagnant waters often disturbed by fluvial inputs. At around 44m of depth (ca. 8,200 a BP, by means of pollen analyses) a truly deep, persistent lacustrine environment is recorded, testified by the presence of the *Cytherissa lacustris*-*Candona meerfeldiana* assemblage. The lake is feeded by bicarbonate-rich waters and this suggests increases in temperature, in particular during summer. At around 33m of depth (5,200±90 a BP), a new shift to a different ostracode assemblage occurs: even if not dominant, here it is recorded the presence of *Metacypris cordata*, a thermoeuryplastic species typical of shallow, permanent mesotrophic to eutrophic waters.
The turnover from the Late Glacial *candida*-fauna to the Holocene *cordata*-fauna, recorded at Ripa Sottile, is well documented also in central and north-western Europe (Absolon, 1973; Griffiths & Evans, 1995) as the marker of the Last Glacial/Holocene transistion in freshwater habitats

Cyprideis torosa

The Italian Large Mammals of the Climatic Optimum

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In western Europe the period of 8,000 ± 10,000 BP (non-calibrated), is a critical instant of cultural change, known as the Neolithization, which collectively represents a variety of processes ranging from a predatory economy of hunting and gathering to a productive economy based on agriculture and breeding. The acquisition of this new cultural process generated different degrees of interest in the various areas of the Italian peninsula, taking foot early on in the southern regions and on the islands, and later in the northern areas. This cultural revolution influenced considerably the natural environment because the breeders and the farmers burnt and reduced forest areas to obtain open grazing spaces for herds and to cultivate corn.

At the beginning of this period, Mesolithic cultures were still widely spread across northern Italy. The sites of this period are very numerous in all of Italy's north and occupy areas that vary from plains to the high altitude alpine regions, with a different fauna at the latter location. The fauna in the Vatte di Zambana, Romagnano III and the Predastel shelters, situated in the Valley of Adige near Trento (Boscato and Sala 1980), consist entirely of wild forms. The predominant ungulates included ibex (about 9.000 years before present), deer (from 8.000 and onward) as well as chamois, roe-deer, and wild boar, attesting to an economy still based on hunting. These sites are frequently located in humid environments and the mammals hunted are much more numerous, as they also include beaver, fox, wolf, badger, otter, marten, brown bear, wild cat and lynx.

At high altitudes sites, such as the one at Mondeval (Val Fiorentina, Belluno), human presence during the summer is evident up to about 2.150 m above sea level. The scarce faunal remains found at these altitudes cannot be representative of resident animals, but rather of prey hunted further down in the valleys. In fact, other than red-deer, which is more common than ibex and marmot, a tusk of a wild boar and the telemetacarpal bone of elk, was found in a burial, among the funeral equipment. The latter two ungulates could have been hunted in distant valleys (Guerreschi, personal communication).

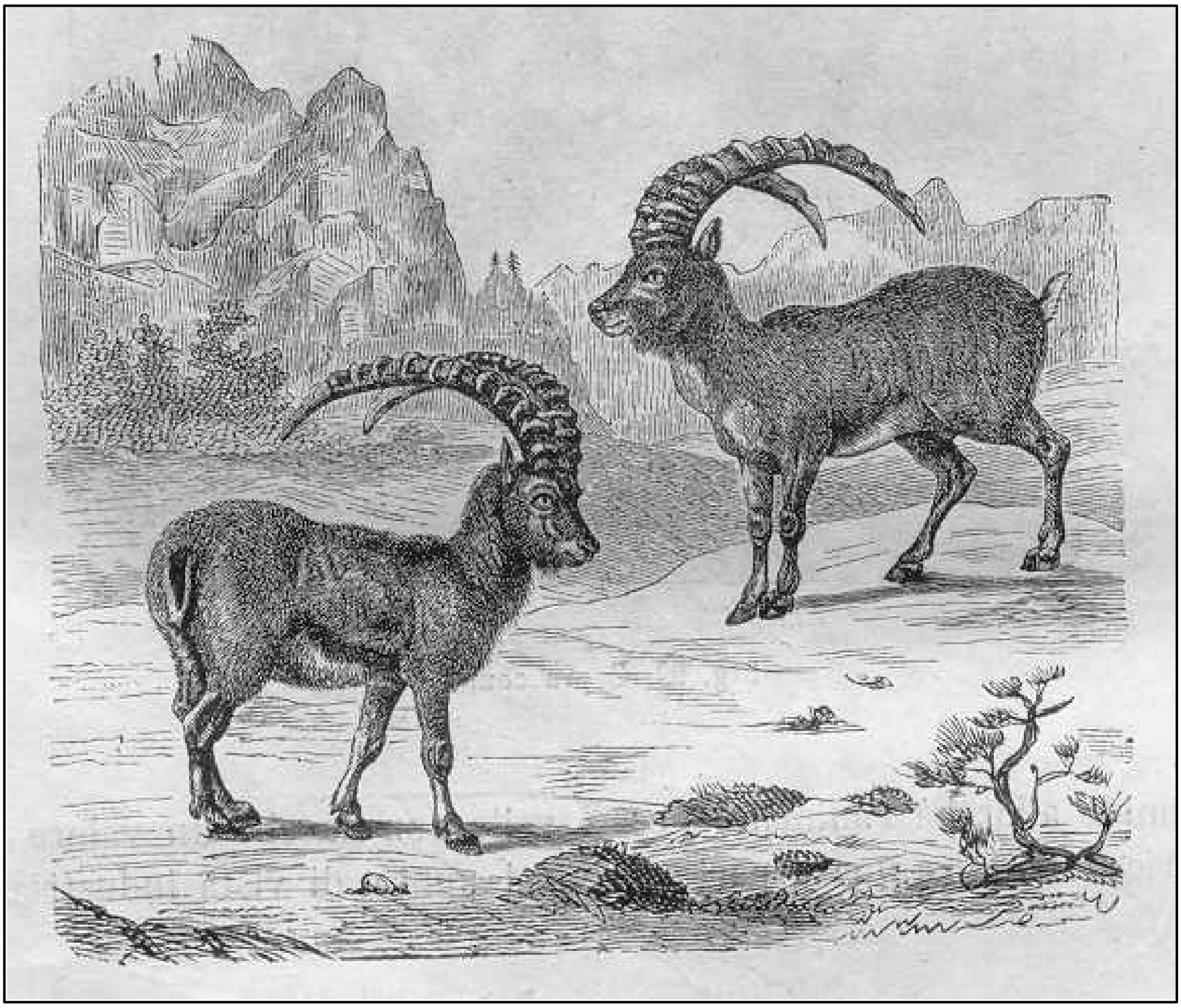
In the far western regions of Liguria, at the Mesolithic M levels of the Arene Candide (Savona) only wild animals were present, with red-deer as the most common of a variety of species, such as the ibex, and other forest species including roe-deer, wild boar and squirrel (Cassoli and Tagliacozzo 1994). In contrast to the high altitude sites, occupation of this cave was continuous.

The sole presence of wild animals in Mesolithic deposits is a condition documented also in the central tract of the Po basin (Madonna di Campiano and Gazzaro, Reggio Emilia) (Biagi *et al*. 1980).

Documentation of central Italy's fauna for the period of interest originates primarily from deposits of the Fucino basin, in the Appennine mountains of Abruzzo. Here, the transition from the Paleolithic economy, characterised by the exploitation of large mammals, to the typical Mesolithic activities of fishing and hunting of small mammals and birds can be clearly seen.

In the Mesolithic layers of the Continenza cave (Fucino basin, Wilkens 1991) a predominance of wild forms is noted, including deer, wild boar and a small number of ibex and marmots. In these deposits, and those of others in the region, including the hills of S. Stefano (Radi and Wilkens 1989), Paterno and Trasacco (Wilkens 1991), domestic forms only become numerous in the Neolitihic layers during a more recent time period than what is considered here.

In southern Italy and on the islands the displacement of the previous culture by the Neolithic is evident earlier. The introduction of cattle, including ovicaprines, by allochthonous populations, is likely to have accelerated the Neolithization process, so that already during the earliest phase of this event domestic animals were more common than wild forms. The latter, represented primarily by aurochs, red-deer and wild boar, present in rather low numbers, are hardly of much significance as a means of subsistence. Among the ancient Neolithic sites of Apulia, Rendina (Melfi) (Bökönyi 1982) and Scamuso (Cassoli and Tagliacozzo 1986) are noted for the presence of the highest proportion of domestic species, indicating that the rearing of stock predominates over hunting there. At both sites, ovicaprines are most common, while, ox, pig and dog are present in lower proportions, pointing to the more recent domestication of these species. Description of the cave at Uzzo at the promontory of San Vito lo Capo (TP), which is located at the furthest northwestern tip of Sicily, is particularly important for the well documented Mesolithic to Neolithic transition evident there, owing to the continuous stratigraphic sequence at this site. Based on the data obtained from these deposits (Tagliacozzo 1993), it is clear that the cultural change was gradual, with a reduction in the number of finds attributed to red-deer and an increase in those of ox, and ovicaprines. This introduction of domestic species is also documented by the original finds from the cave of Latronico 3, in Basilicata, at about 760 m above sea level (Sorrentino 1978). At this site of the Appennine zone, during the phase characterised by imprinted ceramics, breeding does not represent the main source of subsistence, while hunting of wild boar continuous to prevail. Domestic fauna becomes predominant only in the successive levels, with an increase in the number of ovicaprines.



LAKES

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INTRODUCTION

Lakes with sediments suitable for climate change reconstruction are varied in origin, in geographical distribution, in age, and in chemistry. Sedimentary archives provide a rich source of information about the past history of lakes and their catchment areas; here we report climate and palaeoenvironmental information derived from our own studies and from a number of published palaeolimnological studies. No pollen data are included in this report.

The work reviews the evidence for past abrupt climatic changes and terrestrial environment changes in the Mediterranean region and perialpine region. A database structure was developed to integrate these data with related information.

In Italy a large amount of data from lacustrine environments already exists although few were addressed specifically to climate change. In addition, more interdisciplinary studies are needed with respect to specific time-windows and more comprehensive regional correlation of past environmental changes. Although precise and efficient dating methods (e.g., radiocarbon with AMS, micro-tephra analysis) are now available and employed here, many problems still exist in establishing an accurate and robust chronology. Chronology is of paramount importance in any study like the one reported here.

Most of our data concern the Central-Southern region of Italy. This geographical area is located in a zone of transition between major climatic provinces: (1) northern Europe and (2) the south around the Mediterranean and N. Africa. It is therefore a critical location from the point of view of climate model validation and global climate reconstruction. Our understanding of the lacustrine palaeoenvironments of the Late Pleistocene and Holocene is relatively good for the central and southern regions of Italy based on sedimentary and palynological research in many lake basins and in marine sediments (Guilizzoni and Oldfield, 1996; ELDP-ESF Report, 1998, 1999, 2001; Magri and Sadori, 1999; Zolitschka *et al.*, 2000; Sadori and Narcisi, 2001).

It is quite clear now that the Mediterranean experienced numerous very short-lived climate variations during the Pleistocene and Holocene were synchronous with those in the North Atlantic (Guilizzoni and Oldfield, 1996; Asioli *et al*., 1999; Allen *et al.,* 1999; Guilizzoni *et al*., 2000; Chondrogianni *et. al*., 2004). It seems, therefore, that palaeoceanographic changes were driving the main climate variations affecting the land areas adjacent to the Mediterranean (Vigliotti *et al*. 1999; Asioli *et al.*, 2001; Oldfield *et al.*, 2003). It has been also shown that these climate variations resulted in dramatic changes in the dominant ecosystems on both land surfaces and in freshwater lakes. Therefore, from existing data we have the basis for reconstructing these changes in great detail, and to provide the data set for modelling climate-water-ecosystem interactions, at scales of use to planners and management decisions.

This study focuses on the sedimentary records of some crater lakes in central and Southern Italy (Albano, Nemi, Martignano, Mezzano and Lago Grande di Monticchio). The main goal was to describe lacustrine trophic conditions from the biological (algae and animal remains) and primary productivity data. Succession of taxa and primary productivity in lakes depends on several factors that are climatically related (for example, nutrient supply, light regime, water temperature and water stratification). As indicated in the general coordinated project (CLIMEX), our specific time-windows of interest are the two extreme climatic events of 20 and 8 yr cal BP.

The main objectives were:

1 To overview the papers reporting climate data on the two selected time windows during the past 20,000 years of natural climate variability in the central and southern Italy.

2. To describe the response of continental ecosystems to climate oscillations.

4. To give input to a database for this climatic map.

Specific objectives were:

1.To quantify the magnitude of climatic variations using multi proxy biological data obtained from lacustrine records.

2. To reconstruct the changing limnological conditions of the lakes (e.g. salinity, water temperature, water level, trophic status, redox, etc.).
3. To transfer the data to modellers for a detailed mapping of the climate change events

Main proxy-records

In palaeolimnology most of the approaches used to reconstruct climatic variables are indirect, and their use requires an understanding of the relationship between water-column processes and climate. Interglacial or interstadial sediments are usually organic-rich with a substantial sub-fossil record allowing a large range of physical, chemical and biological analyses to be performed. These provide information about the nature of the lake, the lake catchment and the atmosphere.
The main parameters that were used for a palaeoenvironmental and palaeoclimate reconstruction are:
Geochemistry; total organic matter, organic carbon and organic nitrogen, algal and bacteria pigments, biogenic silica.
Biological remains; diatoms, chrysophytes, Cladocera, chironomids, ostracods.
Main lakes; Central and Southern Italy: Albano, Nemi, Mezzano, Martignano, Monticchio Grande.
Northern Italy; Lugano

LAST GLACIAL MAXIMUM IN CENTRAL AND SOUTHERN ITALY - A SYNTHESIS -

The presence in Lake Albano of benthic diatom species throughout the different lithological units as well as the dominance of littoral cladoceran taxa (Guilizzoni and Oldfield, 1996), indicate a generally low water level (3-20 m) characteristic of littoral or sublittoral lacustrine facies for the entire period between 15,000 and 23,000 cal yr B.P. Anoxic intervals (warmer summers) are indicated by increased algal productivity as inferred from concentrations of total algal carotenoids and intense calcite precipitation (Fig. 1 and 2). Conversely, sedimentation during oxic intervals (bioturbated units) indicates a lake level lowering, stronger winds and increased seasonality, all due to longer periods of holomixis (long winters with ice cover/short summers). A shallow (<5 m) high energy environment is indicated by the dominance of relatively coarse siliciclastic material and the absence of benthic ostracods. Generally colder conditions are reliably confirmed by moss remains which are typical for cold, oligotrophic, high altitude lakes and wetlands in polar regions. The excellent correlation of magnetic susceptibility between the littoral and the pelagic area (core 1D/E) only could have been preserved by the existence of ice cover (Fig.1).
Therefore, we interpret the oxic intervals to represent cold climatic conditions and the anoxic events to indicate warmer periods. A lake level change of at least 10 m is required to create the described facies changes between cold and warm intervals. Accordingly, the lake level rise during warm episodes must be attributed to wetter conditions.
Three main factors, *i* increased input of dissolved nutrients, *ii* warming of the local climate, reducing the duration and severity of ice cover, and *iii* enhanced nutrient supply from sediments at the sediment-water interface during periods of anoxia - either acting alone or in combination- may have caused the recurrent increases in higher aquatic productivity.
Thus, the increased productivity phases were probably responses to shifts to warmer and moister climate and deeper water, while the minima in fossil remains, pigments and, in most cases, carbonate concentrations, probably reflect cooler, drier periods with shallower water. These inferences are fully consistent with both the pollen and lithological data from other sites (Lake Mezzano, Ramrath *et al.*, 1999), Lago Valle di Castiglione (Follieri *et al.*, 1988), Lago Grande di Monticchio (Allen *et al.*, 1999) and from the Adriatic Sea cores (Guilizzoni and Oldfield, 1996).
According to the geographical distribution of the modern d^{18}O values of precipitation (IAEA/WMO network; Rozanski *et al.*, 1993) the negative oscillations during the oxic intervals can be related to a strong northeasterly wind component with prevailing cold and dry climatic conditions. In contrast, the anoxic, high level stands are characterized by wet and warmer conditions due to a southwesterly source of moisture (Chondrogianni *et al.*, 2004).
In total, we can distinguish five wet-warm/dry-cold cycles between 24,000 and 15,000 cal yr B.P. documented by several paleoecological parameters (Fig.2). The overall trend from H3 towards H2 and from H2 to H1 shows generally increasing anoxia in the deeper portion of lake (core 1D/E) thus indicating a steady decrease in wind strength during summer and a larger fraction of colder winter seasons with ice cover. Furthermore, we can identify two of the warm periods as severe wet events related to sudden warming occurring just after Heinrich events H3 and H2. The first wet event is indicated by the onset of sedimentation in core 1D/E at ~28,000 cal. yr B.P. following Heinrich event H3 (~29,000 cal yr B.P.) with a phase shift of~1000 years,

leaving the shallower core 6A/B position (Fig.1a,b) still exposed. The second event entails the onset of sedimentation in core 6A/B position, thus implying that a major lake level rise of ~30 m (Fig.1b) occurred at ~23,000 cal yr B.P. following Heinrich event H2 (~24,000 cal yr B.P.) with a similar shift of 500-1000 years. However, no major wet event can be inferred following Heinrich event H1 (~16,500 cal yr B.P.). Instead, the lag deposit marking the abrupt termination of sedimentation in core 6A/B at ~15,200 cal yr B.P. indicates extreme lake level lowering and increased erosion which can be attributed to the brief cooling episode at ~15,000 cal yr B.P. (Oldest Dryas) documented in several marine Mediterranean records and most intense in the Thyrrenian Sea (Cacho *et al*., 2001).

The ecological evidence provided by the multiproxy record indicates that the facies changes in the lake sedimentation reflect the response of the aquatic system to external climatic factors such as temperature, wind strength and seasonality. Variations in the concentration of several pollen taxa, reconstructed from other Italian lakes (Allen *et al.*, 1999), strongly support this conclusion. However, the high resolution record 6A/B provides additional detailed information: within the major cold and warm periods outlined, generally unstable conditions are inferred from the flickering behaviour of the data presented in figure1. Interdecadal variations (~40–45 yr) become most obvious in the bioturbation index, whereas alteration of dark to light lamination visualized by radiographic images reveals interannual periodicities of 3 to 8 years (Fig.1) (Chondrogianni *et al.*, 2004). The microscopical ly counted irregular periodicities of 3 to 8 years strongly resemble the ones known from the Pacific as induced by the El Niño/Southern Oscillation (ENSO). A similar ENSO-like feedback mechanism has been intensively discussed for the equatorial Atlantic and linked to variations in the NAO index (Chang *et al.*, 1997). No other climate regime is known to operate in such irregular periodicities. Therefore, we suggest that the hydrologic changes reflect relationshipto the NAO index. Rapid climate changes during the late Pleistocene based on the d^{18}O record in the GISP-2 ice core reveal periodicities of 150, 210, 520, 1,050 and 3,300 years (Stuiver *et al*., 1995) which are similar to the cycles calculated above from Lake Albano. Similarity also exists between the 1,150-year period reported as characteristic of SW monsoonal variability in the Arabian Sea (Sirocko *et al*., 1996), and the highest significant period of 1,250 years recorded in Lake Albano. The best match, however, is revealed by comparison with periodicities reported for paleotemperature variations in upwelling off west Africa during the last deglaciation (~200 -300, 750 and 1,250 years), which are in turn related to variations in the intensity of trade and upwelling winds over the tropical North Atlantic (Eglinton *et al*., 1992). A close relationship between climate changes in Italy and ice-rafting events has also been suggested by results from Lake Monticchio (Allen *et al*., 1999), whereas sapropel formation in the Mediterranean has been closely related to intensification of summer monsoons (Ariztegui *et al.*, 2000). The Late Pleistocene between Heinrich events H2 and H1 is known as a relatively stable cold period and is distinctly subdivided in five cold and four warm intervals of variable duration (centennial–millennial). Furthermore, of particular interest are the "decadal" (3-8a) oscillations identified in the radiographs (Fig. 2) as well as the interdecadal (~40 a) periods in the frequency spectra of the bioturbation index which are either at the 95% - or well above the 50%-confidence line. Decadal to interannual climate variations are well known to reflect ocean-atmosphere interactions and exchanges between the tropics and extratropics manifested as ENSO phenomena in the Pacific (Gu and Philander, 1997). Dust concentrations in Greenland ice cores also reveal periodicities of 3 –10 years during the last deglaciation, implying major changes in wind strength (Taylor *et al.*, 1993). The Lake Albano record indicates major reorganizations of the main wind trajectories and atmospheric moisture circulation during the LGM that may be related to variations of NAO - or ENSO-like phenomena (Chondrogianni *et al.*, 2004).

HOLOCENE

Lake Albano and Nemi. Although high productivity levels characterise the entire Holocene sequence as estimated by reconstructed trophic status (Ryves *et al*., 1996), early Holocene deposits are particularly organic-rich, as shown by high total organic content (TOC) as well as by high pigment values. During this interval (between ca. 9.8 and 6.6 ka B.P.) TOC values were relatively stable (average 6% dry wt.) and the laminated nature of the lake deposits suggests that hypolimnetic anoxia developed in relatively deep waters. Analogously, it has been shown that the cyanobacteria dominance indicates an increasing stabilisation of the water column in warming climates. Between 8.1 and 7.6 cal. ka. B.P., however, there is a decrease in TOC fluxes and a substantial decrease in pigment concentrations, a marked decrease in isorenieratene ratios and dominance of diatoms over other types of algae, all of which suggests a short-lived episode of reduced anoxia contemporaneous with a decline in primary productivity and/or preservation. In addition, there has been reported a drop in concentration and diversity of chydorids (small crustaceans) during this short interval to values characteristic of the Würm late-glacial period, suggesting that a short-lived cold event affected the region during the mid-Holocene (Manca *et al*., 1996).

Algae and Cladocera responded promptly to the most important natural variations in the lake water level and climate and /or anthropogenic events, with changes in concentrations as well as in community structure. High erosion rates, low primary productivity, high water level and mainly aerobic conditions characterised the early Holocene (11.2-10 kyr BP; zone I). Then, from ca. 10 kyr BP, high productivity levels appeared during the first half of the Holocene, a period in which inferred primary productivity (and total water phosphorus concentrations) reached values found in very eutrophic lakes today (climatic optimum). However, in both lakes Albano and Nemi, six clear major abrupt changes in pigment concentrations (and to some extent LOI, also) occurred during the early-mid Holocene, probably associated with climatic deterioration such as the widespread cold event at ca. 8.0-8.4 kyr BP. The balance of evidence from Lake Albano sediments (e.g. presence of varves, high percentages of planktonic communities) points to substantially lower lake levels during minimum pigment concentrations.

Oscillations in lake productivity, as inferred for the fossil pigments and diatoms mainly, can be compared with major terrestrial vegetation changes (forest clearance) reported for the lakes (Tab. 1). The close link between catchment surface processes and in-lake productivity is shown by the relationship between forest clearance and the cladoceran assemblages of lakes Albano and Nemi, which shifted from *Daphnia* to *Bosmina*. This study confirms that the Holocene in central Italy was not a stable period and that climate changes and anthropogenic disturbances had very important impacts on lake ecosystems (Ariztegui *et al*., 2001). In general, most of the major observed changes and signals reflect regional events rather than local hydrological variables. This is confirmed by a recent study in which Holocene changes which occurred in lakes Albano and Nemi correlated well with the timing of Mediterranean Sea changes e.g. the warm and humid, high productivity period of sapropel formation between 9.5 to 6.0 kyr BP, the mid-Holocene and the 8.5-7.5 cool phase with low productivity (Ariztegui *et al*., 2000; Oldfield *et al*., 2000).

Lake Lugano. A study of Lake Lugano reveals similar short but weak climatic deteriorations in early Holocene (9000-8000 yr BP) time that are superimposed on a trend of rapid warming (Niessen and Kelts, 1989). During the late Glacial, nearly-synchronous lithological units were deposited in lakes north and south of the Alps dominated by detrital muds and no indication of high lake productivities. In contrast, the Holocene development appears to differ between sites of the Alps. After 10000 yr BP, the differences in primary productivity are interpreted as changes in local climate patterns and perhaps the climatic divide the Alps became more prominent at that time.

A subdivision of the Holocene into two time intervals is evident from the lithological changes in the perialpine lakes between 4,600 and 3,800 yr BP (Tab. 2). These changes were attributed to the end of the Holocene climate optimum. However, there are many uncertainties in the understanding of the timing of mechanisms for climatic amelioration during mid Holocene time. In Europe, dates for the end of the optimum scatter over spans between 5,000 and 2,500 yr B.P., depending on localities. Besides, in term of the palaeolimnology of Lake Lugano, since about 5,000 yr BP it is difficult or impossible to distinguish between anthropogenic impacts and changes due to the growing influence of earlier human activities on terrestrial ecosystems. An increase of bioturbation occurring since 4,600 yr BP is interpreted as evidence of more vigorous winter circulation of the lake water. This suggests a gradual cooling of climate between 4,400 and 3,600 yr BP rather than increased anthropogenic overprint (Niessen and Kelts, 1989).

Lake Albano	Lake Nemi
207	112-160
700-730	575-680
1160	1800
1800	3240
3000	3500-3890
3650-4000	4100-4900
5100	5040-5500
6450-6680	6740
10150-10450	9900-10200

Tab. 1. Occurrence of de-forestation (cal. yr BP) in the catchments of lakes Albano and Nemi (years calibrated BP).

Years BP	Lake Lugano events
3,800-3,600	Sudden increase in productivity; increase terrestrial runoff; high calcite/dolomite ratios
4,400	Increase in lake circulation; end of climate optimum, cooler evidence; more bioturbation
6,000	Low productivity, anoxic bottom conditions; laminations
9,000-7,000	Climate temperature fluctuations evidence

Tab. 2. Major changes in the sedimentary records of Lake Lugano

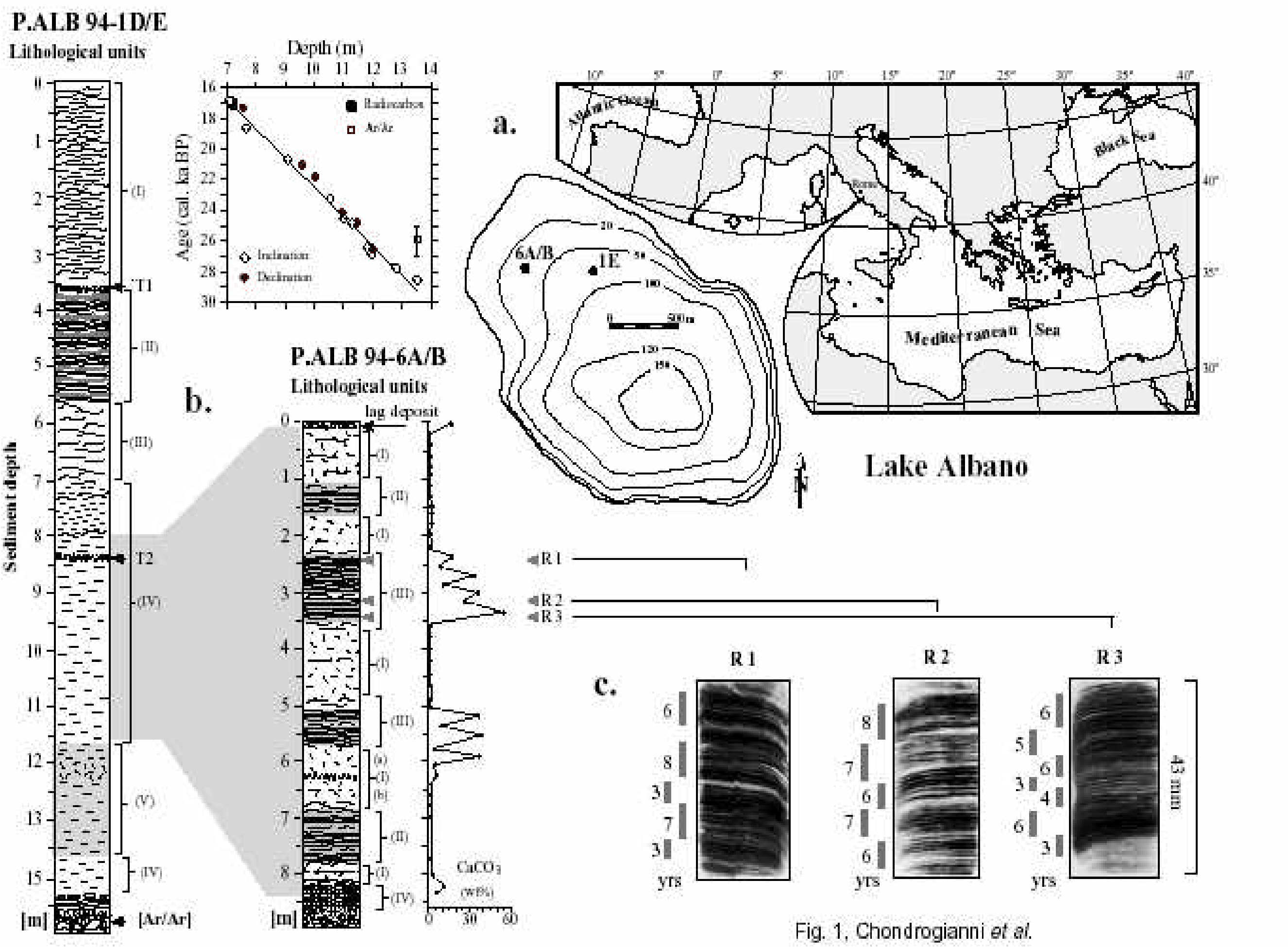

Figure 1. Study area and chronology: a) Map of the Mediterranean showing the location of Lake Albano in central Italy, and bathymetric map of the lake indicating the core positions. b) Seismic profile across the transect between the positions of cores 6A/B and 1D/E including interpretation of the major reflectors. c) Age / depth diagram of core 1 D/E showing the different dating methods; all ages are calibrated years B.P. (CALIB; Stuiver and Reimer, 1993). d) Magnetic susceptibility in cores 1D/E and 6A/B outlining the core-to-core correlation and including placement of three major wet events, tephra layers (T1, T2), the Oldest Dryas event (OD), the Bølling-Allerød period (B/A), the Younger Dryas event (YD) and Heinrich events H1-H3 according to Bond and Lotti, 1995; Broecker, 1994.

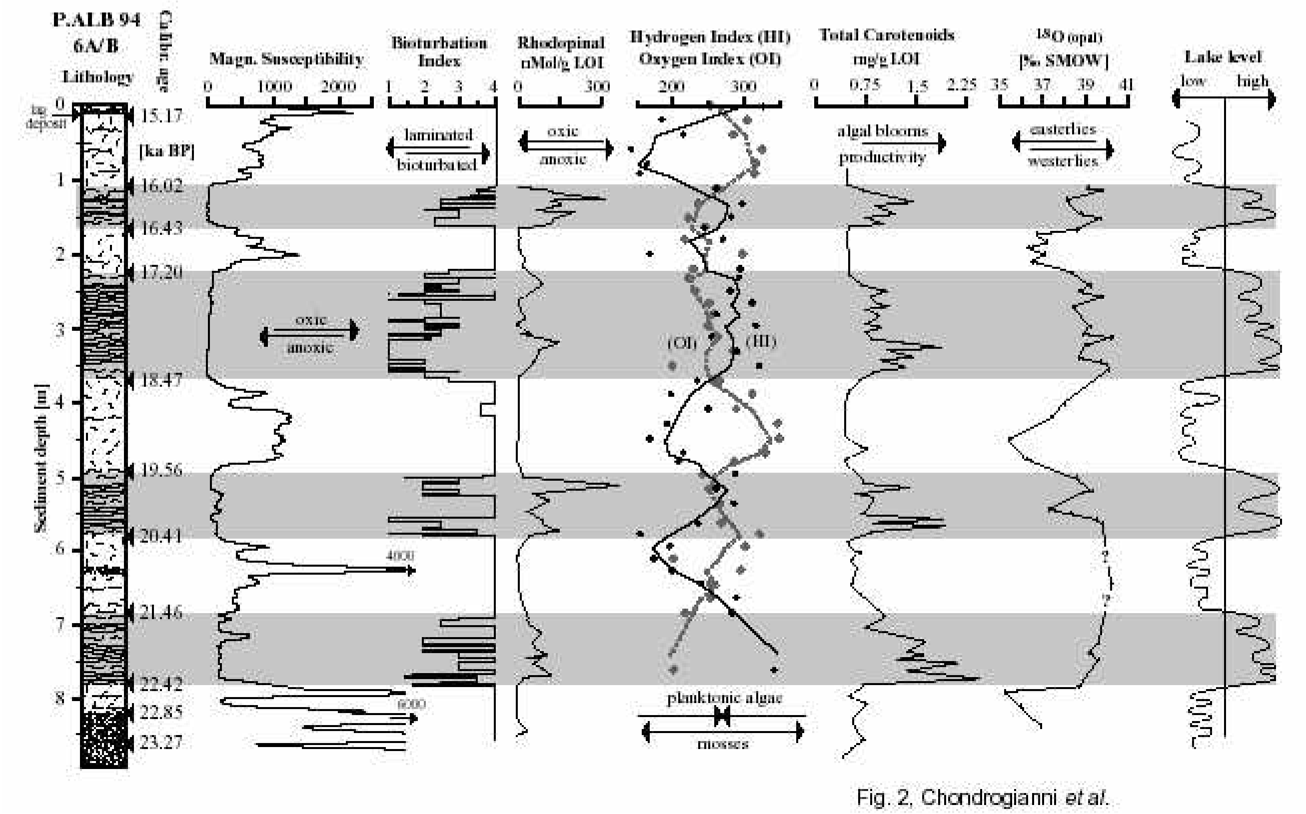

Figure 2. Core 1D/E: Lithological units and placement of tephra layers (T1, T2), the beginning of the Bølling-Allerød period (B/A) and the termination of the Younger Dryas event (YD) as inferred from pollen analyses (Lowe et al. 1996). Core 6A/B: Outlined core-to-core correlation, lithological units, carbonate content and selected X-ray radiographs illustrating the lamination and outlining periodicities of changing sedimentation conditions (grey scale).

Apennine foothills

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The Po Plain is a late Tertiary foredeep basin that gradually filled up to become land since about 1 Ma. It is constrained by the Apennine thrust belt verging to the north and the Southalpine thrust front pointing to the south. The present foothill margins outline a plain about 46,000 square km wide (Castiglioni et al., 2001), and do not coincide with the tectonic fronts of the two opposite chains which extend widely in the subsurface coming almost in contact each other north of Piacenza.
The boundary between the Apennine foothill margin and the southern wing of the Po Plain is mainly gradual being represented by a continuous belt of anastomosed alluvial fans from the Monferrato to the Riminese hilss. Some segments, however, present a steeper structural slope which follows a re-juvenated front of the chain, as for the Reggiano, Bolognese and Cesenate areas.
The inner part of the Apennine fan belt is more than 10 km wide, and forms a quite steep (mean dip > 2%) poly-terraced high plain, which is deeply incised by the present streams. The remnant surfaces of this high plain which were sedimentary inactive since the early Last Glacial Maximum (LGM) have preserved on their top pedogenic relics of loessic covers of the main Middle to Late Pleistocene stadials, especially those related to the last two climatic extremes.
The outer and more recent part of the Apennine fan belt forms a less steep (mean dip < 2%) intermediate plain, fed by river wandering at their outlet of the valleys, that buries the older surfaces by aggradation. The intermediate plain was formed mainly during the latest Pleistocene to earliest Holocene under climatic condition of solid and liquid discharge of the Apennine rivers higher than today. During the Holocene Climatic Optimum (HCO) and later, the outermost part of the fan belt in turn became site of major overflooding sedimentation especially in its eastern position, as witnessed by burial depths exceeding 12 metres for Neolithic sites (e.g. near Lugo di Romagna).
The final effect of this composite evolution was a progressive widening width of the Apennine wing of the Po Plain from a few km as in the narrows of San Colombano (near Pavia), mostly occupied by the Po River bed, up to tens of km in the central and eastern zones flanking directly the Po delta area.

Last Glacial Maximum

Restoration of the palaeogeographic setting of LGM time was based on scattered geognostic and chronological data, and on the assumption of a Po Plain thalweg perhaps more depressed than the present one as a result of the eustatic sea-level drop.
As for the inactive alluvial areas on the Apennine margin of the Po Plain, a belt of high plains and palaeosurfaces wider than the present one was represented. In fact, it was later eroded in the inner side and onlapped by finer alluvial sediments in the outer side since latest Pleistocene.
The high plain belt was followed downslope by an intermediate belt of coarse-grained fans (gravel and sand). Although this belt was partly incised during the LGM, it has to be considered as sedimentary active because of the assumption made to represent in the map a time lap of about 4,000 years. When drawing the outer limit of this belt which is presently buried, the few available data have been extrapolated in excess based on the high thickness values of the coarse-grained alluvial bodies in their apical areas.

Holocene Climatic Optimum

Restoration of the palaeogeographic setting at the HCO is reasonably more reliable than at the LGM because more geognostic and chronologic data are available and overall conditions were more like to the present.
The belt of the high plains and palaeosurfaces is very similar to the present one; instead, the belt of coarse-grained fans is wider taking into account the high detrital supply during the deglaciation and climatic warming at the transition from Pleistocene to Holocene. The outer edge of the coarse-grained fan belt was inferred from the areal extent of dark palaeosol horizons witnessing the main Holocene depositional hiatuses. The horizons are easily cored at shallow depth in the fine-grained Holocene wedge and are mostly younger than 10,000 years BP, thus representing almost the mapped time interval (Marabini et al., 1987).

Latest Pleistocene to Holocene transition. Flat-lying grey Deglacial mud and peat layers are overlain by brown to cream Holocene silty to clayey loam deposits in the Romagna alluvial plain. The HCO is marked by a dark paleosol (S. Martino) horizon. Total thickness to water table is 14 metres (Brunori quarry, Bubano, north of Imola)

The peopling of northern and central Italy at the LGM

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Only a few archaeological sites have been radiocarbon-dated to the LGM. Most are either caves or rockshelters: Grotta delle Arene Candide and Arma dello Stefanin in western Liguria (BIETTI & MOLARI, 1994; BIETTI, 1997; MAGGI *et al.*, 1995); Büs dei Lader, Grotta di Trene, Grotta di Paina and Riparo del Broion in the northern and north-eastern fringes of the Po valley (BROGLIO 1994, 1996); Gr. di Settecannelle in Tuscany (UCELLI GNESUTTA, 1998); Ponte di Pietra (Lollini *et al.*, in press) and Fosso Mergaoni in the Marche region (SILVESTRINI *et al.*, in press), which are the only open-air settlements to have been so far excavated. Some of the Balzi Rossi sites, also in Liguria, are to be included in this short list, after the evidence provided by lithic tool typology: Grotta dei Fanciulli (also known as *Grotte des Enfants* in the French literature), level F (ONORATINI & DA SILVA, 1978; PALMA DI CESNOLA, 1979); Barma Grande (MUSSI *et al.*, 1976; MUSSI unpublished data); and Riparo Mochi lev. C (PALMA DI CESNOLA & BIETTI, 1983). The lithic industries have been variously labelled as “Arenian” or as “Early Epigravettian” by different scholars, but consistently include a number of shouldered points and blades, which, after comparisons with better dated collections from Southern France, Italy, Slovenia and Croatia, are indicative of an age in the range of 20 to 18 ka BP. Some shouldered points were also discovered at Grotta Tronci and Riparo Maurizio (RADMILLI, 1963), two sites of the central Apennine which are next to each other and should probably be entered as a single site; and at Riparo del Sambuco in northern Latium (MUSSI & ZAMPETTI, 1985).

The accuracy of typo-technological dating should not be underestimated, nor the effectiveness of radiocarbon overemphasised. As discussed by Housley *et al.* (1997), direct dating of human bones, or of humanly-modified animal bones, allows to date accurately an archaeological level; while unmodified animal bones – often used in ^{14}C analysis – can be totally unrelated to any human settlement. At the sites of northern Italy details are rarely provided, but sometimes the chosen samples are plainly irrelevant for solving archaeological problems. This is the case at Barma Grande, a site excavated in the late XIXth century and discussed by Bolduc *et al.* (1996). One hundred years after the stratigraphic sequence had been quarried off, Bisson *et al.* (1996) radiocarbon-dated a few bone fragments from an old collection. Some results point to the LGM: 17,200±80 BP (Gif-A95072) and 19,280±220 BP (Gif-A95073). The first sample, however, is a rodent femur, i.e. of an animal unrelated to the human occupation; while the second, a deer antler fragment, was supposedly found at the level of the Aurignacian, also documented in the cave, which in turn implies a minimum age of 30 ka BP. A different problem is exemplified by the ^{14}C dating of two *Cyclope neritea* shells from the decorated bonnet or cap of Barma Grande 1, a ceremonial burial estimated to be c. 25,000 years old (MUSSI, 2001; MUSSI, in press): one was found to be 20,220?260 BP (Gif-A88316), the other one 28,780?560 BP (Gif-A88202) (HENRY-GAMBIER, 2001). Fossil carbonates in shells, and the effect of the marine reservoir, can well have produced inconsistent results.

The patchy archaeological record is to some extent the result of a lack of scientific investigation. There is little doubt, however, that the southern margin of the Po valley is characterised by a dearth of archaeological evidence, all over the Upper Palaeolithic (LENZI & NENZIONI, 1996). Furthermore, the peopling of the plain itself can only be speculated upon, as the latter is now covered by thick alluvial and marine deposits, or submerged by rising sea levels. Contacts across the area are suggested by similarities in the lithic industry of sites in north-eastern Italy, and in Slovenia (Jama v Lozi, Ovcja Jama, Ciganska Jama) and Istria (Šandalja, lev. c) (BROGLIO, 1994). Liguria, on the opposite, is linked to adjacent Provence, both after lithic industry (ONORATINI, 1983), and after the extant evidence on flint circulation (NEGRINO & STARNINI, 2003).

Site size is also different in Liguria and north-eastern Italy, the two better investigated areas. Some substantial or even large sites are known at sea level in Liguria at the Balzi Rossi. Grotta delle Arene Candide, further east, is possibly another major site. It was excavated in the XXth century, that is later than most of the Balzi Rossi caves. Accordingly, there is good stratigraphic control and many ^{14}C dates. The LGM levels, however, were only reached over a few square meters in levels P3 to P9, and not much material was unearthed, as underlined by

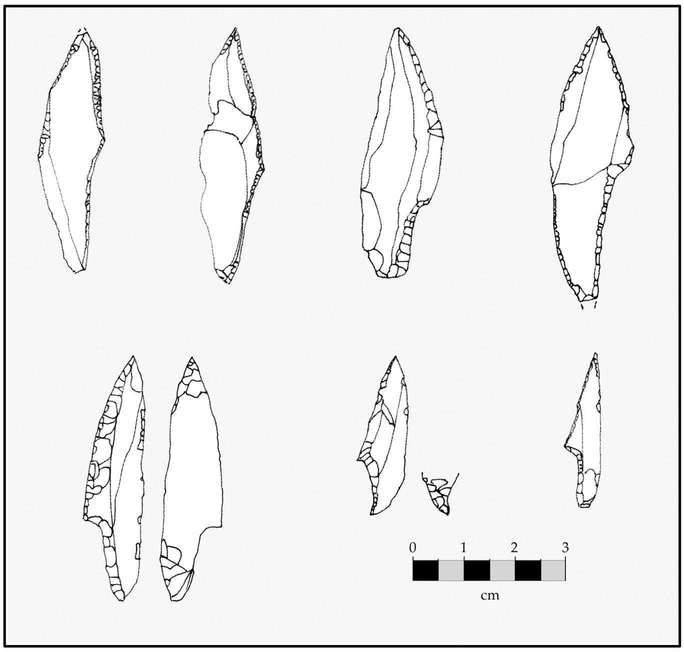
Bietti (1994). The only inland site, Arma dello Stefanin, at 440m asl in Val Pennavaira, yielded limited evidence of human occupation in levels XVI to X, with a very few tools - some of which are backed, and other ones shouldered - suggestive of hunting activity (LEALE ANFOSSI, 1972). A fragmented animal mandible, which was eroding from the stratigraphic section, was retrieved later (MAGGI, pers.com. to MP), and dated to 18,710±210 BP (GX-16486-G).

On the north-eastern margin of the Po valley, in the Monti Berici, at some 300m above the underlying alluvial plain, and in a marginal position, a string of caves and rockshelters with scanty archaeological remains have been investigated: Grotta di Trene (LEONARDI, 1959), Grotta di Paina (BARTOLOMEI *et al.*, 1987-88) and Riparo del Broion (BROGLIO *et al.*, in press). Apparently, it is all what is left of a much more complex settlement system, which once possibly stretched all over the plain, with centrally located sites now deeply buried and out of reach. The lithic assemblages are dominated by backed and/or shouldered projectile points. At a similar level above the plain is Büs dei Lader, on the right side of Chiese river valley: the only archaeological remain is a marginally retouched point (BIAGI, 1976, 2000). One shouldered point was collected at Castellon del Brosimo, again in the Monti Berici, within mixed materials of later ages (LEONARDI, 1951), which is worth mentioning as the only evidence in the open. Dwelling structures (Riparo del Broion), typological imbalance and impact scars (Riparo del Broion, DE STEFANI *et al.*, in press; Grotta di Paina, BROGLIO *et al.*, 1993), consistently suggest short-lived campsites, a restricted set of activity, and hunting parties. There is a Gravettian assemblage at Grotta di Paina (layer 7) and at Riparo del Broion (layer 1c), and an Early Epigravettian assemblage at Grotta di Paina (layer 6) and at Grotta di Trene (layer B).

Ponte di Pietra and Fosso Mergaoni, further south in east-central Italy, provide evidence of quarry activity next to good-quality flint outcrops. At both the sites, reduction sequences aiming at the production of blades and bladelets are well documented, but most of the blanks were exported out of the area which has been investigated (LOLLINI *et al.*, in press; SILVESTRINI *et al.*, in press). The shouldered points of valle delle Vibrata, are further evidence of the circulation of prehistoric human groups on the Adriatic side of the Italian peninsula (BRAVI, 1951-1952). The finds, however, lack of any stratigraphic control.

This is also the case of the shouldered points collected in the open on Elba Island, by then a promontory of Tuscany, and in Umbria as well, which are recorded by Vaufrey (1928). On the Tyrrhenian side of central Italy, the only stratified sites are Grotta di Settecannelle, still under excavation, with dates in the range of 16-16,5 ka BP for level 16 (UCELLI GNESUTTA, 1998); and Riparo del Sambuco, which was excavated too early to provide any detailed information (MUSSI & ZAMPETTI, 1985).

Grotta Tronci and Riparo Maurizio are located at the edge of the Bacino di Avezzano, a tectonic depression of the central Apennine. A vast grazing area and a shallow lake were in existence in the basin, with herds of equids and other herbivores (GIRAUDI & MUSSI, 1999). At 715m asl, and surrounded by mountains up to 2000m high, Grotta Tronci and Riparo Maurizio are the highest sites in our database, and point to an early recolonisation of the Apennine. There is no such evidence at a similar elevation in the pre-Alps, or elsewhere in Europe, as in the thoroughly investigated Alpes du Nord of eastern France (BINTZ & EVIN, 2002).



Glacier extent over the Italian Alps

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First attempts to reconstruct the Pleistocene extension of glaciers over the Italian Alps were made in the second half of the 19th century, but only in the past century, when adequate topographic bases became available, detailed maps of the geographic distribution and the extent of glaciers at the Last Glacial Maximum (LGM) were produced for large areas or for the entire Alpine range.
These maps reflect the geomorphologic and stratigraphic knowledge existing at the time of their compilation and are affected by insufficient time control, that only recently started to be implemented.
The map "Italy in the Quaternary Era" stands out among the others: compiled by B. Castiglioni (1940) at the scale 1:1,200,000 the map shows, with a sharp and detailed colour drawing, the limits of ice covered areas and the 100 m contour lines of the glacier surface. As mentioned in the accompanying notes, the author's purpose was to reproduce on a map the geographic conditions in Italy at the end of the last glacial period. Other remarkable documents concern limited sectors of the Alps, such as the map by Haupt (1938) on the Würmian glaciers in the Orobic Alps, the map by Jäkly (1970) on the glaciers in Switzerland at the Würm maximum, including parts of the Italian Alps, the map by Habbe (1972) on the Adige and Lake Garda glacier tongues, and the map by Van Husen (1987) on the LGM glacier extent in the eastern Alps (Austria and NE Italy).
Recently, the LGM extension of the Italian glaciers has been reconsidered in the volume edited by Ehlers & Gibbard (2004), with contributions by G.B. Castiglioni, Bini & Zuccoli, Carraro & Giardino.
A mention must be made for the LGM reconstruction recently proposed for the central (Swiss) Alps by Florineth & Schluchter (2000), although only marginally concerning the Italian Alps. According to these authors, the area considered was covered by an ice field with three domes in the Rhone, Rhine and Inn catchments.
The extent of the glaciers in the present LGM map was critically derived from the existing maps. For its high detail, the map of B. Castiglioni (1940) was selected as starting document. From this map the limits of the glaciers and the contour lines in the accumulation zone were taken, with minor corrections where new data were available. The extent of glaciers in the ablation zone and at their fronts inside the valleys or at their outlet in the Po Plain, were drawn from Carraro & Giardino (2004) for the western sector (Piedmont and Aosta Valley), from Bini & Zuccoli (2004) for the central sector (Lombardy) and from Castiglioni (2004) for the eastern sector (Veneto and Friuli – Venezia Giulia regions). Further details were obtained from Ravazzi (2003) for the Orobic Alps, and from Avigliano, Monegato & Mozio (pers. comm.).
Although the obtained map is derived from non homogeneous sources, it can be considered adequate to represent the main features of the ice cover at the LGM, if we take into account the scale used.
During the LGM, the Italian Alps were almost entirely occupied by mountain glaciers forming (particularly in the eastern sector) an ice field, characterized by a network of interconnected glaciers, mainly confined in the valleys, but locally expanding into the plain with piedmont lobes.
The total surface of the LGM glaciers in the Italian Alps may be estimated at about 30,000 km^2 , the present glacier surface beeing about 500 km^2 (Orombelli, 2003).
The shape and the extent of the glaciers were controlled by the topography of the Alpine range and by the climatic conditions. In particular, from west to east, the size of the glaciers increased along with the increasing extent of the southern slope of the Alps, and not depending on the elevation. In fact, the maximum development of glaciers was to be found in the eastern Alps, less elevated but with the maximum length from the divide to the plain border. The equilibrium line altitude (ELA), estimated with the accumulation area ratio (AAR), decreased from west (around 1800 m) to east (around 1400 m), possibly due to a longitudinal precipitation gradient, connected to a deflection of the atmospheric circulation pattern, with a stronger southern component in the eastern Alps (Florineth & Schluchter, 2000).

In the Piedmont sector of the Alps, mountain glaciers followed a dendritic pattern; they were entirely confined into the valleys and had a maximum length of few dozen kilometres, with the exception of the Dora Riparia Glacier, occupying the Susa Valley, that was some 50 km long and expanded onto the plain with a small lobate piedmont glacier. The Aosta Valley (Dora Baltea drainage) was occupied by a large valley glacier, with many confluent tributary glaciers, surrounded by the most elevated peaks of the Italian Alps. It was more than one hundred kilometres long and locally more than 1300 m thick. The Dora Baltea glacier advanced into the plain for twenty kilometres, forming a wide piedmont glacier.

In the central sector of the Italian Alps (Toce, Ticino, Adda and Oglio drainage basins) a network of valley glaciers was present, interconnected through cols and transfluence and diffluence bifurcations. The Toce-Ticino glacier system formed a piedmont lobate glacier just south of present Lake Maggiore, and the Adda glacier, more than 150 km long and locally more than 1500 m thick, expanded into the plain, forming four piedmont glaciers (Bini et al., 2001). The Oglio glacier was connected to the Adda and Adige glaciers through the Aprica and Tonale cols; it was about 100 km long and terminated with a small piedmont glacier, just south of the present Lake Iseo.

The largest LGM Italian glacier was the Adige glacier, which received the ice flowing from the Isarco, Avisio, Brenta and, in part, from the Sarca drainages basins. It formed an ice field about 40 km long and 20 km wide, between Bolzano and Trento. Down valley it forked in two tongues, a larger one along the present Lake Garda and a thinner and shorter one in the present Adige valley. The Lake Garda glacier tongue spread out in the plain forming the largest piedmont glacier south of the Alps.

More to the east, the Piave glacier, together with the ice flowing from the Dolomites, formed an ice field about 100 km^2 wide, in the Belluno intermontane basin, before to reach the plain with a small lobe near Vittorio Veneto. The Tagliamento glacier, although nourished by a small drainage basin (but possibly with high precipitations) was quite large and formed a wide regular piedmont glacier on the Friuli plain.

Minor mountain glaciers such as cirque glaciers, valley glaciers and small ice caps were present on the Lombardian and Venetian Pre-Alps. , Small ice caps developed over plateaus , as in the case of the Asiago glacier.

A reconstruction of the glaciologic and climatic conditions on the Alps at the LGM, was attempted by Haeberli & Penz (1985), showing a clear contrast between northern and southern Alpine glaciers, as also suggested by geomorphic evidence. South of the Alps higher basal shear stress, surface velocity and balance gradient were present, indicating more humid and less cold climatic conditions than north of the Alps, where very cold and dry continental climate prevailed.

Glacier extent over the Italian Alps during the Holocene Climatic Optimum

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The real extent of glaciers on the Italian Alps during the Holocene Climatic Optimum is not directly known, since the neoglacial advances completely cancelled the relevant geomorphic evidence.

For a few glaciers the pre-neoglacial minimum extent can be conjectured on the basis of stratigraphic evidence. The Rutor Glacier in the Western Alps, for instance, during the HCO was less extended than at present, since a sequence of peat dating from 10000 to 6000 cal yr B.P., is present at its terminus. The possible location of the front can be supposed to have been at least 700 m up valley of the present one (Orombelli, 1998).

The "Alpine Iceman", discovered at the upper edge of the Niederjoch Glacier (Eastern Alps) and dated to 5300-5050 cal yr B.P., is a further evidence for a severe reduction of the Alpine glaciers just before the start of the Neoglaciation (Baroni, Orombelli, 1996).

It can be supposed that the majority of the small glaciers disappeared on the Italian Alps during the HCO or were reduced to a minimum size, that cannot be represented on a 1 million scale map.

Glaciers of the most elevated mountain groups (Gran Paradiso, M. Bianco, M. Rosa, Bernina-Disgrazia, Ortles-Cevedale, Adamello, Palla Bianca) were possibly still present, although with a smaller size. On the whole, during the HCO only the largest glaciers with high elevation accumulation-area continued to exist, while all the others disappeared, with a few surviving where protected from ablation in a sheltered niche or by debris cover.

Therefore on the HCO map, only the largest and highest Italian glaciers were mapped, reducing their extent, particularly in the ablation zone, conforming to a 100-200 m rise of the equilibrium line altitude.

The Italian Large Mammals of the Glacial Maximum

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A number of prehistoric deposits, taken into consideration for the discussion of the Glacial Maximum, were excavated in recent years, and convincingly document the faunal characteristics of the time period. Primarily the Arene Candide (western Liguria, Cassoli and Tagliacozzo 1994), the Paglicci cave (Gargano, Sala 1983) and the cave of the Cala (Marina di Camerota, Salerno, Sala 1983) with highly preserved informative stratigraphic sequences are discussed here. The other deposits have either yielded few faunal remains, such as the l'Arma dello Stefanin (western Liguria, Leale Anfossi 1972), the cave of Paina (Berici hills, Vicenza, Bartolomei *et al*. 1988), il Covolo di Trene (Berici hills, Vicenza, Leonardi *et al*. 1959) or had been studied in the distant past, like the Fanciulli cave (western Liguria west, Boule 1906). For this reason frequencies of the ordered fauna are not known, and the validity of determinations and interpretations of the stratigraphic sequence are questionable.

Nonetheless, using pure data obtained from deposits that did not supply an unambiguous paleontological record, or were not dated by radiocarbon methods, but are still sufficiently informative with respect to paleontological content, or contain rich sequences of the late Wurmian (e.g. cave of the Broion, Berici hills, Sala 1980; Riparo Tagliente, Monti Lessini, Capuzzi and Sala 1980), one can paint a general picture of the faunal distribution of large mammals of the Glacial Maximum for a large part of Italy.

The distribution of the continental fauna in Italy during the Quaternary show a subdivision into the well known temperate Ligurian-Tyrrhenian-Ionic band, and the Padano-Adriatic band which is characterised by a harsher climate.

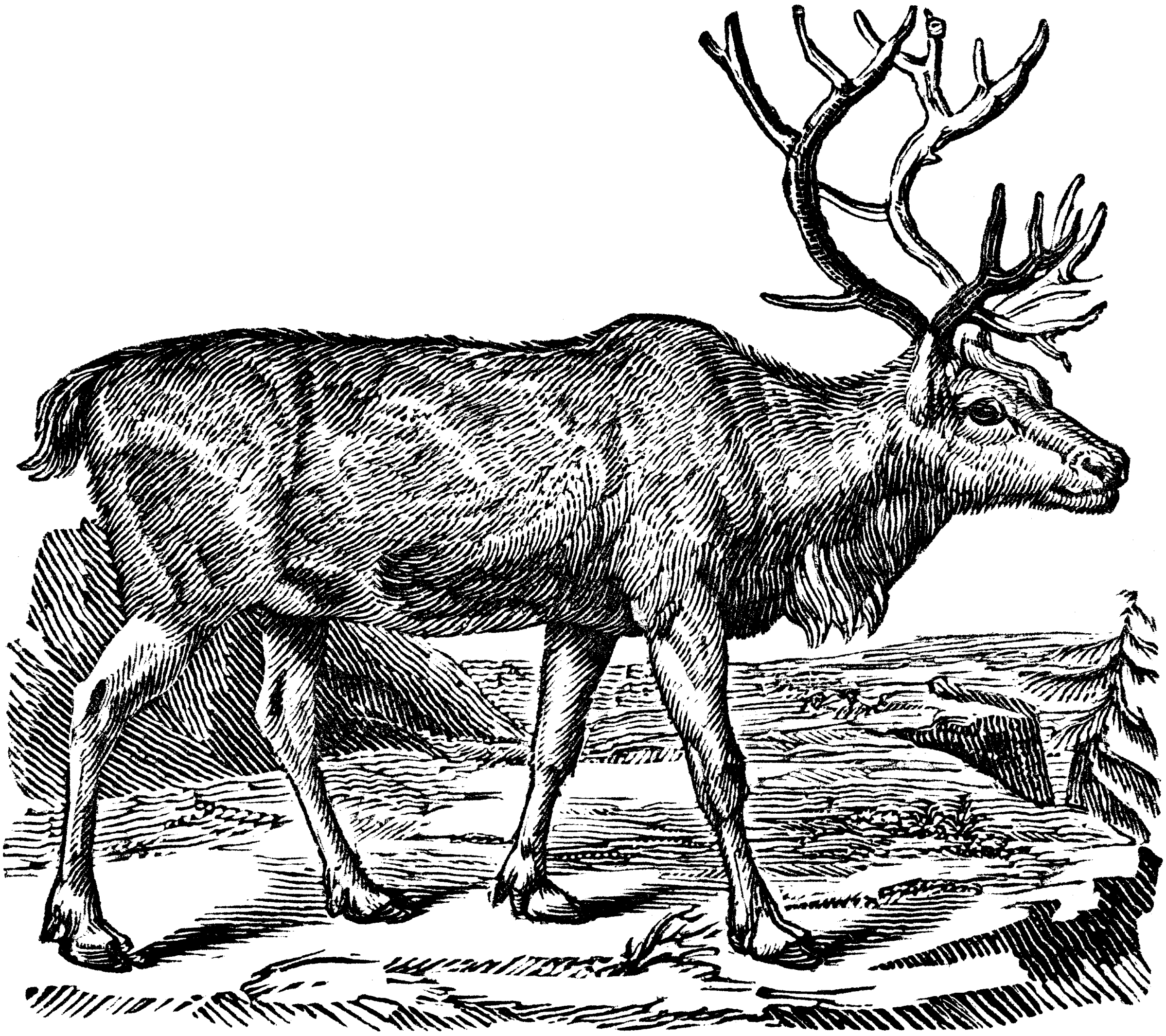
During the Glacial Maximum in the steep areas of Liguria (Fanciulli cave, Arma dello Stefanin, Arene Candide), the predominant species is the ibex, followed by red-deer, along with species restricted to forest habitats, such as the wild boar and the roe-deer. Red-deer was presumably more common in the areas that are less steep. Further on the western coast, signs of the presence of giant deer (*Megaloceros giganteus*) and mammoth are in evidence (Arene Candide). However, the age of the latter could not be confirmed because a recent datation of a find failed (Stuart, pers. com.). Furthermore, up to the province of Savona, rein-deer have been documented that did not manage to reach the Riviera di Levante and the rest of Italy, remaining relegated to the proximate part of Rodano valley. Some finds at the Fanciulli cave have been identified as fallow-deer remains (*Cervus somonensis*), but the identifications from the beginning of the 1900's (Boule 1906), is highly questionable.

In addition, in the foothills and hills of the northeast (Paina, Trene, Broion, Tagliente) the ibex is the most common species, while the bison of the steppes, along with the elk (Settepolesini of Bondeno, Ferrara, Sala 2001), is more widely distributed in plains. The deer and the roe-deer are very rare as are the Equidae. The last cave bear finds are still found in the Berici hills. Mammoth, woolly rhinoceros and giant deer, present during the middle Wurmian, have already disappeared. This supports the notion that the path in central Slovenia that served as a passage from the Pannonic basin and the Balkans for many mammals during the Glacial Maximum became inaccessible, perhaps because of too much snow-cover.

Still on the Adriatic side, as well as in Apulia, the most widespread species is the ibex, along with the horse, and frequently *Equus hydruntinus* also. Further south the bison is replaced by the aurochs, which are numerous there, while red-deer and wild boar are rare.

Along the central-southern part of the western coast of Italy the red-deer is the most dominant species, accompanied by other forest types such as the roe-deer, aurochs and the wild boar (Polesini cave, Rome, Cala cave, Marina di Camerota, Sala, 1983) as well as mountain-dwelling forms, ibex and the chamois, pointing to a period of cold climatic conditions. Only in the areas that descend steeply to the sea, such as the Amalfi coast (Erica and Mezzogiorno caves, Sala 1983) and some locations in Cilento (S. Maria cave, Scario, Boscato 2000), or the Appennines (Riparo del Romito, Papasidero Cosenza, Boscato *et al*. 1998) could the ibex and the chamois predominate until the closure of the Tardiglacial.

The view that the account of the above species depicts is that during the Glacial Maximum, already along the most western strip in Liguria, the biodiversity in Italy has experienced an immediate drastic reduction that came to be further emphasized upon the closure of the Tardiglacial. The fauna of most of Italy indicate cold but relatively humid conditions, as forest ungulates are always present in the foothills and the plains, and often dominating the Ligurian-Tyrrhenian coastal band.



SST from Serpulids overgrowths on Submerged Speleothems

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Introduction

In this session are abstracted SST proxy data for the Holocene Climatic Optimum (HCO ; 8 ka BP) as deduced by oxygen isotope data from Polychaeta serpulid overgrowths on speleothems. The samples were collected in three submerged caves located along the Tyrrhenian coast in Italy:

1) Cape Palinuro (Lat. 40.02°N – Long. 15.16°EGw)
2) Argentarola Island (Lat. 42.26°N– Long. 11.07°EGw)
3) Marettimo Island (Lat. 37.58° N– Long. 12°03 EGw).

Speleothems were collected by means of scuba diving to -21 m below sea level in the cave of Argentarola, down to -48 m in the cave at Palinuro and to –23 m in the cave at Marettimo; discussion and complete references on their using are available in Antonioli et al. (2001 and 2002).

Materials and methods

In the Tyrrhenian Sea, serpulids are typical dwellers of submerged caves, which offer a dark and sheltered environment, with restricted water flow.
Holocene serpulid colonies grown on submerged speleothems are typically 5 to 12 cm thick. At the time of sampling, the outermost layer of each colony was alive.
Optical microscopy observations coupled with Scanning Electron Microscopy allowed us to rule out diagenetic alteration of the Serpulid tubes and recognize the absence of dissolution voids and abiogenic cements. The growth patterns were also recognized: commonly, new individuals encrust the underlying dead Policheta, thus forming a dense colony of intertwined tubes. Serpulid colonies developed on continental speleothems when the rising sea level reached the speleothem tips. All the colonies have been constructed by the gregarious *Serpula massiliensis*, whose tubes consist of 100% calcite (Milliman, 1976), as confirmed by X-ray diffraction. Fossil *Serpula massiliensis* tubes also consist of 100% calcite, as determined by X-ray diffraction.

For $d^{18}O$ reconstruction each subsample analized (2 mm wide) was powdered (average 4 mg), roasted in vacuum at 350° for 30 minutes to pyrolize organic matter and treated with 100% H_3PO_4 at 25°C for 6 hours. The CO_2 released by the reaction and purified by using a liquid nitrogen-ethyl alcohol slash at about -80°C, was measured in a Finnigan Delta mass spectrometer. Mean standard deviation of ?^{18}O measurements was typically ?0.1 ‰ (2?).
Radiocarbon dating was carried out on 11 colonies. ?^{18}O series were based on 9 colonies: 6 at Argentarola cave, 2 at Cape Palinuro and 1 in Marettimo cave (Alessio et al 1996, Antonioli and Oliverio 1996; Antonioli et al., 2001 and 2002).
The age at which serpulid colonies commenced growing was calculated by ^{14}C dating results and by using a mathematical model that assumes linear growth rates. The assumption is also based on the fact that the colonies do not show any apparent growth hiatus.
The model assumes that growth rates remained constant during the Holocene. The sample used for radiocarbon dating is a slab cut through the whole colony, from the fossil bottom to the living top. Conventional radiocarbon dating is thus carried out on a sample encompassing the whole time span through which the colony grew. The model allowed us to obtain the age of the bottom of the colony. The age thus obtained is correct only if there was constant growth. The mathematical method (Alessio et al., 1992) was, therefore, tested by AMS ^{14}C dating on the skeletons of the first marine dwellers (table 1) for the following samples: OS-2655 (Palinuro –27 m) and OS-2656 (Palinuro –41.5 m). AMS results yielded ages similar to those obtained through the model on the samples R-2358 (Palinuro –27 m) and R-2377 (Palinuro –41.5 m). Our assumption that growth rates remained constant, therefore, appears to be valid.
The validity of the model is supported by another AMS date obtained for the outermost layer of a stalactite (Argentarola cave, –18.5 m) in contact with the marine overgrowth.
The ?^{18}O data vs. time for each serpulid colony have been reconstructed through extrapolation from linear interpolation by assuming constant growth rate.

The outermost layers (active serpulids) from different colonies sampled in different caves and at different depths have a similar mean ?^{18}O value (2.1 ‰).
Polychaete serpulids are believed to secrete calcium carbonate close to ?^{18}O equilibrium with sea water and do not show metabolic effects on oxygen isotope fractionation (Videtich, 1986). The ?^{18}O value of serpulid tube calcite, therefore, should be a function of the ?^{18}O value of sea water and of the ambient temperature (e.g. O'Neill et al., 1969). Any discussion about variables which should be accounted for when interpreting the ?^{18}O signal of Tyrrhenian serpulids are in Antonioli et al. 2001.

Sea Surface Temperature reconstruction

If we assume that Tyrrhenian sea water ?^{18}O composition mainly reflects the SST variation, time changes in ?^{18}O of serpulid tube calcite could reflect SST trends (cooling vs. warming) averaged over about 200 years, which is the mean time span encompassed by a 2 mm^2 sample.
The measured present-day ?^{18}O value of sea water both within and outside the submerged caves is constant, and is 0.9 ‰ (SMOW). However, the SST measured within this submerged caves ranges from 17° in winter to 24°C in summer, and the SST outside the caves ranges from 14° in winter to 25° in summer. Cave waters are therefore less subjected to seasonal temperature variations, and can be considered as representative of average mean annual temperature. In the submerged caves at both Palinuro, Argentarola and Marettimo we did not record the presence of a thermocline. This physical characteristic of the coastal caves makes it possible to compare the ?^{18}O signals extracted from colonies sampled at different depths, and permits the assumption that serpulids long-term records of mean annual temperature changes of near-surface sea water averaged over 200 years.
Information on serpulid growth rates is available for harbour and brackish-water species (Bianchi and Morri, 1996), for which maximum tube growth occurs in summer. Faster growth rates during warm seasons were also documented for aragonite serpulids from a submarine cave off the coast of Belize (Videtich, 1986). Serpulids of tropical origin, such as *Serpula massiliensis* put most of their energy into reproduction in autumn and winter. They spend their energies to grow in summer, following their biological rhythm. Their annual growth rate is considered, however, constant as for other Mediterranean invertebrates, and independent from temperature. So we infer that serpulids commonly grew in summer throughout the Holocene, and that their growth rate was season-dependent, not temperature dependent, and that their calcite ?^{18}O signal records summer sea surface temperature trends within and outside the caves.
We exclude the possibility that ?^{18}O changes reflect the influence of karstic freshwater on the basis of the observation that *Serpula massiliensis* are not present in caves where there is freshwater percolation (Belloni and Bianchi 1982).
By application of Epstein et al. (1953) equation we calculated the SST-near-shore values for OPT map in these three sites of the Tyrrhenian Sea, as summarized in Tab. 1.

Location	Age (ky cal BP)	d ^{18}O (permil PDB)	SST (°C)
Argentarola Is.	7.81±1.77	1.37±0.39	14.5±1.6
Palinuro Cape	7.36±1.19	1.76±0.30	12.9±1.2
Marettimo Is.	8.00±1.64	0.80±0.72	16.9±3.0

Tab. 1. d ^{18}O and derived SST data shown in the HCO map.

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