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THE LATE GLACIAL AND EARLY HOLOCENE: CHRONOLOGY AND PALEOCLIMATE*

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RIASSUNTO - *Il Tardiglaciale e l'Olocene: cronologia e paleoclima* - Il Quaternario *Italian Journal of Quaternary Sciences* , **9**(2), 1996, 439-444 - Viene presentata una rassegna sulla cronologia e il paleoclima dell'intervallo di tempo compreso fra il Tardiglaciale e l'inizio dell'Olocene. Inoltre vengono esaminate criticamente le suddivisioni cronologiche adottate in Europa, in relazione ai problemi connessi alle datazioni ^{14}C. Lo studio fornisce sostanzialmente una rassegna sull'evoluzione del paleoclima sulla base di quanto riscontrato con carotaggi in Groenlandia.

ABSTRACT - *The Late Glacial and Early Holocene: chronology and paleoclimate* - Il Quaternario *Italian Journal of Quaternary Sciences* , **9**(2), 1996, 439-444 - This report presents a chronological and paleoclimatic overview of the time interval between the Late Glacial and the early Holocene. The principal chronological subdivisions currently adopted in Europe are discussed in connection with the problems involved in ^{14}C dating. This study provides an overview of the evolution of the paleoclimate mainly on the basis of the Greenland ice-core records.

Keywords: Paleoclimate, Late Glacial, Younger Dryas, Holocene, chronology.
Parole chiave: Paleoclima, Tardiglaciale, *Younger Dryas,* cronologia dell'Olocene

1. INTRODUCTION

The time interval that spans through the Late Glacial to the early Holocene is particularly significant and includes the entire part of the last climatic cycle, which saw the transition from full glacial to full interglacial conditions. Thus, it was during this interval that the Earth experienced the greatest climatic and environmental changes to have affected it in the last 20,000 years.

The characteristics and time scales of climatic transitions are of particular interest for an understanding the causes and mechanisms underlying climatic instability. Therefore, studies on the last major climatic transition — considerable evidence of which is still preserved — can contribute to the collection of data required for an understanding of present and future changes.

Although transition phases offer a wealth of information and are studied in various scientific disciplines, they also pose numerous problems in terms of stratigraphic, chronological and paleoclimatic issues. Integrating the various data into the required time scale (accuracy of at least 100 years) has proven to be a complex task. At present there is no general consensus regarding the accepted usage of stratigraphic nomenclature, chronology and the positions and ages defining the boundaries of the stratigraphic and chronological subdivisions. This is due to differences in: – the types of stratigraphic archives investigated; – the level of definition inherent in the methods utilized; – the time-transgressive climatic and environmental indicators, even on a regional scale and lastly, at least for the Holocene, to the difficulty of distinguishing the climatic signals from the background noise.

The paleoclimatic and paleoenvironmental literature on this subject is very large, especially in paleobiology sectors, which often presents difficulties in evaluating the significance of the presented data.

This paper will be limited to a brief report of an introductory nature, solely to providing an overview of the chronology and paleoclimate of Late Glacial and early Holocene. Specific issues or issues of a regional scope will not be discussed as they are dealt with in detail in the studies presented in this volume.

2. STRATIGRAPHY AND CHRONOLOGY

A stratigraphic and chronological overview is presented in Table 1, showing the latter part of the Late Pleistocene and the Holocene. Only the first two columns (series and stages) concern subdivisions that are well-established in international stratigraphic terminology. Moreover, the informal subdivision of the Holocene into three units, early, middle and late, is adopted, with boundaries at about 7,000 and 3,000 ^{14}C years B.P. However some authors adopt a two-part subdivision, splitting the Holocene at about 5,000 B.P. Such terms are not formal chronostratigraphic units and, as such, it would be misleading to attribute precise age to them (Roberts, pers. comm., 1997). Other informal terms that are often found

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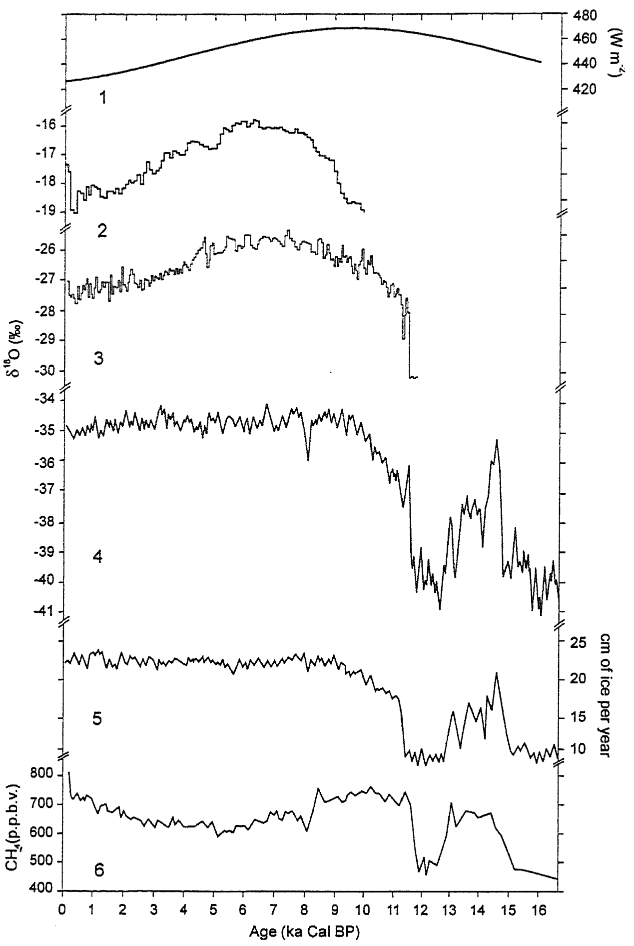

Fig. 1 - Late Glacial and Holocene paleoclimatic curves. 1 - Mid-month July insolation at 65° Lat. N, showing a maximum at 9-10 ka cal years B.P. (from Berger & Loutre, 1991). 2 - $\delta^{18}O$ curve from the Huascaran ice core (Peru) showing the warmest climate between 8,400 and 5,200 cal years B.P. (from Thompson *et al.*, 1995). 3 - The $\delta^{18}O$ curve from the Renland ice core (Greenland), showing a warmer Holocene optimum (9 - 5 ka cal years B.P.), followed by a slight drop in temperature (from Larsen *et al.*, 1995). 4 - GISP2 $\delta^{18}O$ curve (Summit, Greenland) showing Late Glacial temperature fluctuations and a stable Holocene (from Meese *et al.*, 1994 and Stuiver *et al.*,1995). 5 - Annual accumulation rate in the GISP2 ice core, showing Late Glacial fluctuations and a stable Holocene (from Meese *et al.*, 1994 and Kapsner *et al.*, 1995). 6 - Methane concentration in the GRIP ice core. Note the variation is in phase with $\delta^{18}O$ curve during the Late Glacial, the sharp drop at 8.2 ka, the minimum at 5.2 ka and the following increase during the late Holocene. The methane concentration is directly correlated with wetland extent (from Blunier *et al.*, 1995).

Curve paleoclimatiche per il Tardiglaciale e l'Olocene. 1 - Insolazione media mensile a 65°N, che mostra un massimo a 9-10 ka cal anni B.P. (da Berger & Loutre, 1991). 2 - La curva $\delta^{18}O$ dalla carota di Huascaran (Perù), che mostra un massimo termico tra 8400 e 5200 cal anni B.P. (da Thompson et al., *1995). 3 - Curva $\delta^{18}O$ della carota Reinland (Groenlandia), in cui è messo in evidenza un* optimum *termico olocenico tra 9 e 5 ka cal anni B.P., seguito da una lieve diminuzione di temperatura (da Larsen* et al., *1995). 4 - Curva $\delta^{18}O$ GISP2 (Summit, Groenlandia), che mostra le oscillazioni termiche del Tardiglaciale e la stabilità termica che caratterizza l'Olocene (da Meese* et al., *1994; Stuiver* et al., *1995). 5 - Velocità di accumulo annuale nella carota GISP2, che mostra le oscillazioni del Tardiglaciale e la stabilità dell'Olocene (da Meese* et al., *1994; Kapsner* et al., *1995). 6 - Concentrazione del metano nella carota GRIP. Si notino le variazioni in fase con la curva $\delta^{18}O$ durante il Tardiglaciale, una brusca caduta a 8.2 ka, un minimo a 5.2 ka e il successivo aumento durante l'Olocene superiore. La concentrazione del metano viene correlata con l'estensione delle aree umide sulla Terra (da Blunier* et al., *1995).*

with reference to the Holocene include the Hypsithermal (along with relatively equivalent terms such as the "Altithermal" and "climatic optimum") and Neoglaciation. The first term, Hypsithermal, refers to the warmest part of the Holocene, without any precise boundaries being designated. According to Porter & Denton (1967), it spans from about 9000 to about 2800 ^{14}C years B.P.

The other term, Neoglaciation, which partially overlaps the time span of the first one, indicates the time interval in which "most described and dated Holocene advances of mountain glaciers" occur (Porter & Denton, 1967; Denton & Porter, 1970), and it includes the last 5,300 ^{14}C years B.P. It should be kept in mind at this point that the term, Hypsithermal, has also in the past been used in the field of palynology, but with a different usage (with different, not well-defined limits), referring to a sequence of climatic intervals (Anathermal, Hypsithermal and Catathermal) that are overly schematic and unsuited to more complex stratigraphy. According to this subdivision, proposed by Von Post (1931) and adopted in Italy by Chiarugi (1936), the Holocene is divided into three climatic stratigraphic units: Anathermal (10 to 9 ^{14}C ka B.P.), Hypsothermal (9 to 4 ^{14}C ka B.P.) and Catathermal (4 to 0 ^{14}C ka B.P.). Unlike the Hypsithermal interval, the Hypsothermal unit does not include the lower and middle parts of the Subboreal chronozone.

The terms in current usage to define chronozones (column 4), were introduced by Blytt (1876) and Sernander (1910) to define biozones based on the macroscopic plant fossil content in Scandinavia, and later took on the meaning of pollen in Central and Northern Europe (Jessen, 1938; Firbas, 1949; 1954). In other words, they have taken on the meaning of biostratigraphic units. Mangerud *et al.* (1974) and Mangerud (1982) have proposed a chronostratigraphic system that is separate from the pollen stratigraphy, in which the units are defined by conventional radiocarbon dates. However, the system adopts the same terms created by Blytt and Sernander. Ages that are multiples of 1,000 or 500 conventional ^{14}C years have been arbitrarily assigned to the boundaries between the chronozones.

Later, Welten (1982) proposed dropping the term Older Dryas, by incorporating it in one chronozone ranging from 13,000 to 12,000 ^{14}C years B.P., to which the term previously used for the older chronozone (Bølling), would continue to be applied (De Beaulieu *et al.*, 1994; Lang, 1994).

The problems related to the definition of the boundaries for the chronostratigraphic subdivision of the Late Glacial and the Holocene and those related to the correlations between them are largely dependent upon the potential advantages and the limitations inherent in ^{14}C dating. The ages of the chronozone boundaries are listed in Table 1 (column 6 - 9), according to recently proposed different scales.

In this review, the ^{14}C ages are indicated in conven-

Table 1a | Table 1b

SERIES	EPOCH	STAGE / AGE	INFORMAL SUBDIVISIONS (*1)	CHRONO ZONES		Conventional ^{14}C yr B.P. (before A.D. 1950) ^{14}C yr B.P. — Mangerud et al., 1974, 82; Lang, 1994	Firbas, 1954	Burga, 1988	Beaulieu et al., 1994	cal ^{14}C yr B.P. (*2) — Stuiver and Reimer, 1993	Calendar age (before A.D. 1950) cal yr B.P. — Greenland Ice Cores annual layers	Tree rings	Varves	U-Th
HOLOCENE			LATE; NEOGLACIATION; 100–500 L.I.A.	Subatlantic	late	1000								
					middle									
					early	2000								
			2800 BP ca			2500	2500/2800	2800	2700	2728–2467				
			MIDDLE; HYPSITHERMAL	Subboreal	late	3000								
					middle	4000								
					early									
			5300 BP ca			5000	4500	4800	4700	5657–5855				
				Atlantic	late	6000								
					middle									
					early	7000								
			8000 BP ca			8000	7500	7500	8000	8672–8981				
			EARLY	Boreal										
						9000	8500/8800	8800	9000	9944 – 10.004				
				Preboreal										
						10.000	10.100	10.200	10.200	11.008 – 11.587	11.550 ± 70; 11.640 ± 250 (*3); 11.650 (*8)	11.150 (*4)	10.500–10.800; 10.630; 11.000–11.700 (*5)	11.200–11.500 (*6); 11.700 (* 7)
PLEISTOCENE		WURM = WISCONSINIAN = WEICHSELIAN	LATE GLACIAL	Younger Dryas										
						11.000	11.000	11.000	10.800	12.847 – 12.985	12.890 (* 8)			
				Allerød	Gerzensee oscillation (* 8)				LATE GLACIAL INTERSTADIAL		ca 13.200 (* 9)			
				Older Dryas		12.000	12.000	11.800		13.866 – 14.126	14.090 (* 8)			
				Bølling										
						13.000		13.000	13.000	15.280 – 15.573	14.680 ± 400 (* 8)			
				Oldest Dryas										
						(15.000)		ca 15.000	15.000					
			LAST GLACIAL MAXIMUM											

Table 1 - Late Glacial and Holocene chronostratigraphy and geochronology. 1a: Conventional ^{14}C ages B.P. (before A.D. 1950) and calibrated ages cal ^{14}C B.P. 1b: Calendar ages B.P. (before A.D. 1950) of major Late Glacial events/boundaries. The first two columns report the formal chronostratigraphic/geochronologic nomenclature. Chronozones are framed by conventional ^{14}C ages B.P., according to different authors.

Footnotes: (* 1) The subdivisions early, middle and late Holocene are informal, with boundaries at ca 7,000 and 3,000 B.P. Other authors prefer a subdivision in early and late Holocene with a boundary at around 5,000 B.P. The term Neoglaciation is used according to Porter & Denton (1967) and Denton & Porter (1970); the Hypsithermal is from Porter (1981). L.I.A. = Little Ice Age. (* 2) Calibrated ^{14}C age B.P. (before A.D. 1950). The calendar ^{14}C age B.P. has been calibrated with the program CALIB 3.0 elaborated by Stuiver & Reimer (1993). The calibrated ages are reported as one Sigma time intervals obtained using a standard deviation of ±50 yr on the conventional age. (* 3) Alley *et al.*, 1993; 11,550±70 GRIP ice core; 11,640±250 GISP2 ice core. (* 4) Becker & Kromer, 1993. (* 5) Björck *et al.*, 1992. (* 6) Bard *et al.*, 1992. (* 7) Fairbanks, 1990. (* 8) Stuiver *et al.*, 1995. (* 9) The Gerznersee oscillation is correlated to the intra-Allerød cold period (IACP) (Lehman & Keigwin, 1992; Stuiver *et al.*, 1995).

Cronostratigrafia e geocronologia del Tardiglaciale e dell'Olocene. 1a: età ^{14}C convenzionali B.P. (a partire dall'A.D. 1950) ed età ^{14}C calibrate cal B.P. 1b: età calendario B.P. (a partire dall'A.D.1950) dei maggiori eventi/limiti del Tardiglaciale. Le prime due colonne riportano la nomenclatura cronostratigrafica/geocronologica formale. Nella terza colonna sono indicate alcune suddivisioni informali. Sono inoltre indicate le età ^{14}C convenzionali B.P. che definiscono i limiti delle cronozone, secondo diversi autori.

Note: *(*1) La suddivisione dell'Olocene in inferiore, medio e superiore, con limiti rispettivamente a 7000 e 3000 anni ^{14}C convenzionali B.P., è informale. Altri autori preferiscono una bipartizione in Olocene inferiore e superiore con limite a circa 5000 anni ^{14}C convenzionali B.P. Il termine Neoglaciazione viene impiegato secondo la definizione di Porter & Denton (1970) e Denton & Porter (1967); il termine* Hypsithermal *è ripreso da Porter (1981). L.I.A. = Piccola Età Glaciale. (*2) Età ^{14}C calibrate B.P. (a partire dall'A.D. 1950). L'età ^{14}C calendario B.P. è stata calibrata con il programma CALIB 3.0 elaborato da Stuiver & Reimer (1993). Le età calibrate sono riportate come intervalli di tempo di un sigma, ottenuti per calibrazione dell'età convenzionale impiegata da Mangerud* et al., *(1974, 1982) per i limiti delle cronozone. Ai fini della calibrazione, a ciascuna data limite è stata arbitrariamente attribuita una deviazione standard di ±50 anni. (* 3) Alley* et al., *1993; 11,550±70 carota GRIP; 11,640±250 carota GISP2. (* 4) Becker & Kromer, 1993. (* 5) Björck* et al., *1992. (* 6) Bard* et al., *1992. (* 7) Fairbanks, 1990. (* 8) Stuiver* et al., *1995. (*9) L'oscillazione di Gerznersee viene correlata con l'Intervallo freddo intra-Allerød (IACP) (Lehman & Keigwin, 1992; Stuiver* et al., *1995).*

tional ^{14}C years B.P. before 1950 A.D. (^{14}C years B.P.) or as calibrated ^{14}C years B.P. before 1950 A.D. (^{14}C cal years B.P.). Calendar ages are indicated in cal years B.P. before 1950 A.D.

Calibration of the conventional ^{14}C ages of the chronozone boundaries proposed by Mangerud *et al.* (1974) and Mangerud (1982) has provided the ages indicated in Table 1, column 10 (according to Stuiver & Reimer, 1993).

In the last decade, counts of annual layers in ice cores, in lacustrine varves, tree rings and Th-U dating, have supplied new estimates of the ages of the boundaries defining principal climatic events of the Late Glacial (Alley *et al.*, 1993; Stuiver *et al.*, 1995). These evaluations supply ages that are comparable to the calibrated radiocarbon ages (^{14}C cal years B.P.). Discrepancies are partly due to limitations of the ^{14}C method, lags in climatic variations in various regions of the Earth, and the fact that the calendar ages (Table 1, columns 11-14) refer to significant climatic events that do not necessarily coincide with the boundaries designated for the Late Glacial chronozones.

3. PALEOCLIMATE

Several paleoclimate curves which are considered to be particularly significant are shown in Figure 1. The main features of the evolution of the climate in the Late Glacial and in the Holocene can be identified in these curves, with a particular focus on mid and high latitudes of the northern hemisphere.

The transition from glacial climatic conditions, which persisted until about 15 ka cal years B.P., to interglacial conditions, was a process consisting of two phases (Fig. 2). A first rapid rise in temperature took place around 14.7 ka cal years B.P., accompanied by an increase in the methane concentration and in precipitation, marking the start of the Bølling interval. The isotopic curves obtained from the Greenland Summit ice core show an increase of about 7-8°C in the mean annual temperatures, a 100% increase in precipitation and about a 40% increase in the atmos-pheric methane concentration (Kapsner *et al.*, 1995; Johnsen *et al.*, 1995). According to Cuffey *et al.* (1995), the rise in temperature was even greater, about 15°C.

The rise in temperature reached a peak at about 14.4 ka cal years B.P., reaching levels comparable to present-day temperatures. It was followed by a cold period that was about 5°C cooler, between the end of the Bølling and the Allerød. Rapid temperature fluctuations were experienced in this phase and two main negative peaks are identifiable: the oldest is usually correlated with the Older Dryas, whereas the other, which is more marked, has been termed the Intra-Allerød Cold Period (IACP, Stuiver *et al.*, 1995). The latter is commonly correlated with a negative isotopic peak identified in a similar stratigraphic position in Lake Gerznersee, Switzerland (Gerznersee oscillation, Lotter *et al.*, 1992; Kapsner *et al.*, 1995). The temperature levels during the warm periods of the Allerød were slightly lower than present-day levels and are comparable to temperatures that are characteristic of the interstadial intervals.

The beginning of the Younger Dryas, dated 12,890 cal years B.P. (Stuiver *et al.*, 1995), corresponds to an episode of sharp climatic deterioration, marked by an abrupt beginning and end, especially in the polar records (Alley *et al.*, 1993; Kapsner *et al.*, 1995).

In the Younger Dryas, temperature and precipitation returned to levels characteristic of the glacial stages. For the upper boundary of the Younger Dryas (= Pleistocene/Holocene boundary), there are discrepancies (Table 1b) between the ages obtained with ^{14}C calibration, tree-ring and count from annual ice layer and varves (Hajdas, 1995). Becker & Kromer (1993) suggest that these differences are not solely attributable to the uncertainties inherent in the dating methods used, but also to an actual lag in the climatic change existing between Greenland and Central Europe. Stuiver *et al.* (1995) indicate an age of 11,650 cal years B.P. for the Pleistocene/Holocene boundary. The Younger Dryas/Pre-boreal transition is considered to have occurred within a time span of a few decades, with a rise in temperature of about 7°C and a 100% increase in precipitation (Alley *et al.*, 1993).

The Holocene is characterized by marked stability in the polar isotopic curves, with the exception of a brief negative peak evident in the GRIP and GISP2 ice cores (central Greenland), at 8.2 ka cal years B.P.

This negative peak can also be seen in the methane concentration curve and it is attributed to a brief arid period (Blunier *et al.*, 1995). On the other hand, the chronozone boundaries subdividing the Holocene, do not appear to correspond to abrupt, marked variations in climate.

In the temperate regions, numerous paleoclimatic records reveal an interval in the first half of the Holocene, with slightly higher temperatures than those of today ("the Holocene optimum"). The isotopic curves 2 and 3 in Figure 1 reveal a maximum between 9 and 4 ka cal years B.P. The methane concentration curve shows an initial maximum between 11.5 and 8.5 ka cal years B.P., followed by a sharp negative peak at 8.2 ka cal years B.P. Between 7 and 5 ka

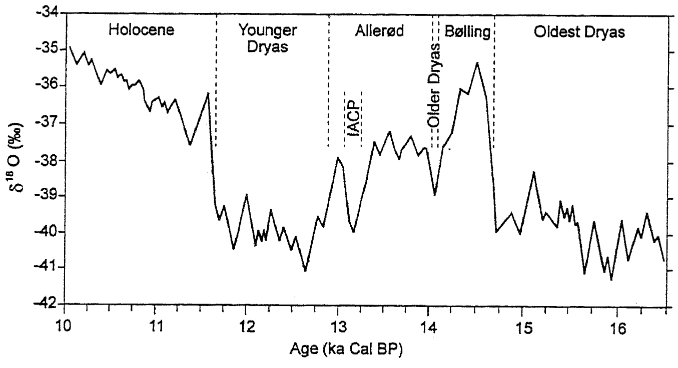

Fig. 2 - Late Glacial and early Holocene $\delta^{18}O$ curve from the GISP2 core and chronozone boundaries (from Stuiver *et al.*, 1995, redrawn and modified). IACP = Intra-Allerød Cold Period.

Curva $\delta^{18}O$ del Tardiglaciale e dell'Olocene nella carota GISP2 (Summit, Groenlandia). Sono indicati i limiti tra le cronozone (da Stuiver et al.*, 1995, ridisegnato e modificato). IACP = Intervallo freddo intra-Allerød.*

cal years B.P., the methane concentration drops to the minimum Holocene value. This drop is attributed to a reduction of low latitude wet-land areas, which were very extensive in the Late Glacial-early Holocene. The variations in the hydrologic balance, particularly in the areas that are presently arid and hyperarid, had a much greater role in the environmental changes during the Holocene, compared to the role played by temperature variations.

Starting from 5 ka cal years B.P. there was a phase tending towards a drop in temperatures. However, this trend was modulated by brief climatic episodes, sometimes with conflicting local effects. The Atlantic-Subboreal boundary appears to coincide with a generalized glacial advance. According to several researchers (Porter & Denton, 1967), this episode gave rise to a period of greater extension of glaciers in Northern America and in Europe. This period persisted, although in alternating phases, until the present century and is indicated as the Neoglaciation (Porter & Denton, 1967). There is some evidence of a renewal of glacier activity in the Alps at about the midpoint of the Holocene (Baroni & Orombelli, 1996; Orombelli & Mason, in press). A critical climatic environmental episode appears to have taken place in the late Holocene, around 2,800-2,700 cal years B.P., coinciding with the Subboreal-Subatlantic transition. The isotopic curves show a slight drop, along with larger variations and greater frequency, and numerous paleoclimatic indicators at the mid latitudes indicating a climatic change tending towards cooler and wetter conditions (Van Geel *et al.*, 1996; Orombelli, in press). Away from the glaciated areas, and above all in the Mediterranean environment, evidence of these slight changes in the climate of the Holocene are infrequent. Moreover, the evolution of the environment differs substantially from the central European area (Magri & Follieri, 1989).

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REFERENCES

Alley R.B., Meese D.A., Shuman C.A., Gow A.J., Taylor K.C., Grootes P.M., White J.W.C., Ram M., Waddington E.D., Mayewski P.A. & Zielinski G.A., 1993 - *Abrupt increase in Greenland snow accumulation at the end of the Younger Dryas event.* Nature, **362**, 527-529.

Bard E., Arnold M., Fairbanks R.G. & Hamelin B., 1993 - *^{230}Th-^{234}U and ^{14}C ages obtained by mass spectrometry on corals.* Radiocarbon, **35**, 191-199.

Baroni C. & Orombelli G., 1996 - *The Alpine "Iceman" and Holocene Climatic Change.* Quat.Res., **46**, 78-83.

Beaulieu de J.L., Richard H., Ruffaldi P. & Clerc J., 1994 - *History of vegetation, climate and human action in the French Alps and the Jura over the last 15,000 years.* Dissertationes Botanicae, **234**, 253-275.

Becker B. & Kromer B., 1993 - *The continental tree-ring record-absolute chronology, ^{14}C calibration and climatic change at 11 ka.* Palaeogeogr., Palaeoclimatol., Palaeoecol., **103**, 67-71.

Blunier T., Chappellaz J., Schwander J., Stauffer B. & Raynaud D., 1995 - *Variations in atmospheric methane concentration during the Holocene epoch.* Nature, **374**, 46-49.

Blytt A., 1876 - *Essay on the immigration of the Norwegian Flora during alternating rainy and dry periods.* Kristiania.89 pp.

Chiarugi A., 1936 - *Ricerche sulla vegetazione dell'Etruria marittima. - I. Cicli forestali post-glaciali nell'Appennino Etrusco attraverso l'analisi pollinica di torbe e depositi lacustri presso l'Alpe Tre Potenze e il Monte Rondinaio.* Nuovo Giornale Botanico Italiano, **43**, 3-61.

Cuffey K.M., Gary D.C., Alley R.B., Stuiver M., Waddington E.D. & Saltus R.W., 1995 - *Large Arctic Temperature Change at the Wisconsin-Holocene Glacial Transition.* Science, **270**, 455-458.

Denton G.H. & Porter S.C., 1970. *Neoglaciation.* Sci. Am., **222**, 100-110 (Italian version in: Le Scienze, **25**, 75-84).

Firbas F., 1949. *Spät- und nacheiszeitliche Waldeschichte Mittel-europas nördlich der Alpen.* Erstrer Band: Allgemeine Waldgeschichte, Jena, 480 pp.

Firbas F., 1954 - *Die Synchronisierung der mitteleuropäischen Pollendiagramme.* Danm. Geol. Unders., **II/800**, 12-21.

Geel van B., Buurman J. & Waterbolk H.T., 1996 - *Archaeological and palaeoecological indications of an abrupt climate change in The Netherlands, and evidence for climatological teleconnections around 2650 B.P.* J. Quat. Sci., **11**(6): 451-460.

Hajdas I., 1995 - *Radiocarbon and Absolute Dating of the Younger Dryas Climatic Event.* PAGES, News, **3**(1).

Kapsner W.R., Alley R.B., Shuman C.A., Anandakrishnan S. & Grootes P.M., 1995 - *Dominant influence of atmospheric circulation on snow accumulation in Greenland over the past 18,000 years.* Nature, **373**, 52-54.

Jessen H., 1938 - *Some west Baltic pollen diagrams.* Quartär, **1**, 124-139.

Johnsen S.J., Clausen H.B., Dansgaard W., Fuhrer K., Gundestrup N., Hammer C.U., Iversen P., Jouzel J., Stauffer B. & Steffensen J.P., 1995 - *Irregular glacial interstadials recorded in a new Greenland ice core.* Nature, **359**, 311-313.

Lang G., 1994 - *Quartäre Vegetationsgeschichte Europas.* Fischer, Jena, 462 pp.

Larsen E. Sejrup H.P., Johnes S.J. & Knudsen K.L., 1995 - *Do Greenland ice cores reflect NW European interglacial climate variations?* Quat. Res., **43**, 125-132.

Lotter A.F., Eicher U., Siegenthaler U. & Birks H.J.B., 1992 - *Late-glacial climatic oscillations as recorded in Swiss lake sediments.* J. Quat. Sci., **7**(3), 187-204.

Magri D. & Follieri M., 1989 - *Caratteri della biostratigrafia pollinica dellíOlocene in Italia Centrale.* Mem.

Soc. Geol. It., **42**, 147-153.

Mangerud J., Anderson S.T., Berglund B.E. & Donner J., 1974 - *Quaternary stratigraphy of Norden, a proposal for terminology and classification.* Boreas, **3**, 109-128.

Mangerud J., 1982 - *The Chronostratigraphic Subdivision of the Holocene in Norden; a Review.* Striae, **16**, 65-70.

Meese D.A., Gow A.J., Grootes P., Mayewski P.A., Ram M., Stuiver M., Taylor K.C., Waddington E.D. & Zielinski G.A., 1994 - *The accumulation record from the GISP2 core as an indicator of climate change through the Holocene.* Science, **266**, 1680-1682.

Orombelli G., in press - *Le condizioni climatiche durante il II millennio a.C.* In: *Guida alla mostra sull'Età del Bronzo nella Pianura Padana a sud del Po.*

Orombelli G. & Mason P., in press - *Holocene glacier fluctuations in the Italian Alpine region.* In: *Paleoklimaforschung* (Frenzel B., Ed.), 24. Fischer, Stuttgart.

Porter S.C., 1981 - *Glaciological evidence of Holocene climatic change.* In: *Climate and History* (Wigley T.M.L. *et al.,* Eds.), 148-179. Cambridge University Press, Cambridge.

Porter S.C. & Denton G.H., 1967 - *Chronology of Neoglaciation in the North American Cordillera.* Am. J. Sci., **265**, 177-210.

Sernander R., 1910 - *Die schwedischen Torfmoore als Zeugen postglzialer Klimaschwankungen.* In: *Die Veränderungen des Klimas seit dem Maximum der letzten Eiszeit, Stochkolm.* p. 197-246.

Stuiver M. & Reimer P.J., 1993 - *Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program.* Radiocarbon, **35**, 215-230.

Stuiver M., Grootes P.M. & Braziunas T.F., 1995 - *The GISP2 $\delta^{18}O$ Climate Record of the Past 16,500 Years and the Role of the Sun, Ocean, and Volcanoes.* Quat. Res., **44**, 341-354.

Thompson L.G., Mosley-Thompson E., Davis M.E., Lin P.N., Henderson K.A., Cole-Dai J., Bolzan J.F. & Liu K.B., 1995 - *Late Glacial stage and Holocene tropical ice core records from Huascaràn.* Science, **269**, 46-50.

Von Post L., 1931 - *Problems and working-lines in the Post-Arctic Forest History of Europe.* Report of Proc. Fifth Int. Botanical Congr., Cambridge 1930, 48-54.

Welten M., 1982 - *Stand der palynologischen Quartärforschung am schweizzerischen Nordalpenrand.* Geogr. Helv., **2**, 75-83.

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