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RECONSTRUCTING HOLOCENE PALÆOCLIMATE FROM POLLEN DATA IN THE EASTERN ALPS - I. PROJECT STRUCTURE

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RIASSUNTO - *Ricostruzione del paleoclima dell'Olocene nelle Alpi Orientali da dati palinologici - i. Struttura del progetto* - Il Quaternario, **7**(1), 1994, 343-350 - Viene descritta la struttura di un progetto finalizzato alla ricostruzione numerica del clima dell'Olocene medio e recente delle Alpi Orientali. Ciò sarà ottenuto dall'integrazione di dati actuopalinologici, vegetazionali, climatici e paleopalinologici. L'approccio numerico si basa sullo sviluppo di funzioni di trasferimento tra campioni actuopalinologici, la vegetazione ed il clima locale, poi applicati ai dati olocenici. Viene fornito un elenco dei siti attualmente sottoposti a campionamento actuopalinologico, unitamente ad una sintetica descrizione delle metodologie impiegate.

ABSTRACT - *Reconstructing Holocene palæoclimate from pollen data in the Eastern Alps - I. Project structure.* - Il Quaternario, **7**(1), 1994, 343-350 - The paper describes the structure of an on-going project aimed at the numerical reconstruction of mid- and late Holocene climate in the Eastern Alps. This will be achieved by integrating actuopalynological, vegetational, climatic and Holocene pollen data. The numerical approach used is that of the development of transfer functions between modern pollen samples, vegetation surrounding the site, and local climate; these are in turn applied to the Holocene set. A list of sites sampled for actuopalynological purposes, together with the sampling methodology used, is given.

Parole chiave: Paleoclima, Alpi Orientali, palinologia, actuopalinologia, Olocene, funzioni di trasferimento.
Key words: Palæoclimate, Eastern Alps, palynology, actuopalynology, Holocene, transfer functions.

1. INTRODUCTION

The paper outlines the structure of a long-term project begun in early 1993 which aims at the numerical reconstruction of mid- and late Holocene palæoclimate in the Eastern Alps. The research objective is the reconstruction of Holocene climate in the Eastern Alps using the extensive and good-quality pollen data available for the area. Pollen data is a proxy (or indirect) indicator of palæoclimate; using pollen data it is possible to determine the structure and composition of past vegetational units, both of which are ultimately determined by climate. Modern pollen-climate transfer functions, successively applied to Holocene pollen data for the Eastern Alps allows the quantitative reconstruction of palæoclimatic variables, in particular temperature and precipitation.

Figure 1 identifies the sample area in the Inner Alps; this has been selected because of extensive and detailed pollen surveying spanning the Holocene, as described in Schneider (1985) and Evans (1992a). Data for the Southern outer Alps is also available, but temporal and spatial coverage is limited.

2. METHODS

The basic approach (Imbrie & Kipp, 1971; Webb & Bryson, 1972; Prentice, 1980) used by transfer functions involves interrelating present-day environmental data to some climate variable by means of regression, through a two-step approach:

(i) present climate and present vegetational units at formation level are used to find regression coefficients;

(ii) similarity between modern and Holocene vegetational units can be used to infer past physical environments using the regression coefficients determined in step (i).

Organism communities differentiate as a result of different physical environments.The relationship between community structure and physical environments can be objectively established by means of modern data through a regression-like approach. In this relationship the same physical environment can therefore be estimated using community structure. Holocene physical environments can be inferred on the basis of similarity between modern and Holocene vegetational units.

The principle of uniformitarianism represents a limitation, since the transfer approach can only be applied when there is an overall similarity between modern and past vegetation units.

Palæovegetation units suitable for numerical reconstruction of climate in the present project date back to the Boreal, and even within this time period there are a number of units for which no modern analogue may be found (Evans, unpublished).

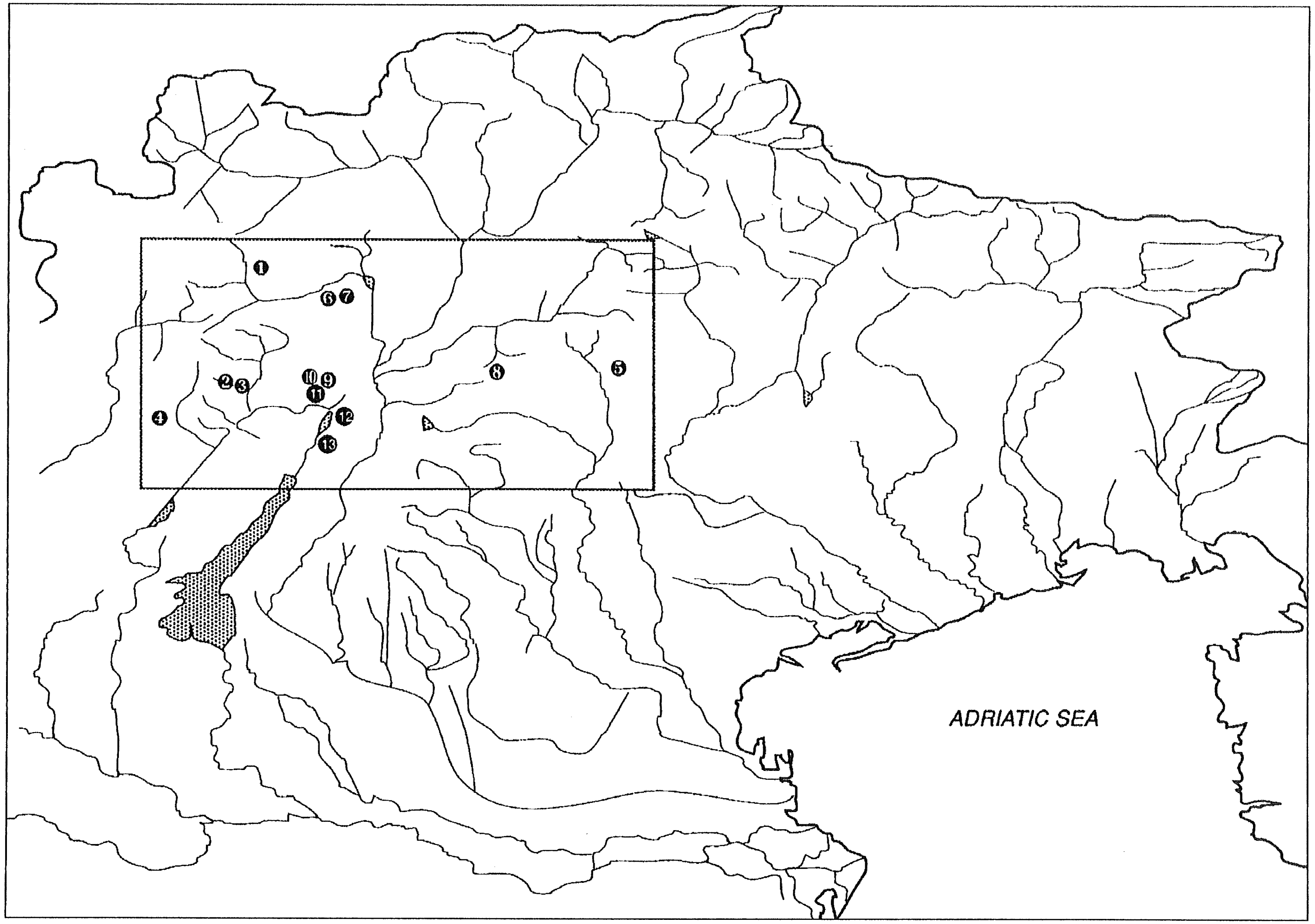

Fig. 1 - North Eastern Italy. The sample area is highlighted together with sites sampled for actuopalynological purposes (1-13).
Italia nord-orientale. Viene evidenziata l'area campionaria, un itamente ai siti campionati per analisis actuopalibologiche (1-13).

3. MATERIALS

Figure 2 presents a simplified flow-diagram of the project; the main steps are outlined and numbered ❶ ÷ ⑩. Each step of the project will be synthetically discussed in terms of objectives, materials and methods.

PHASE ❶ - Characterization of vegetation formations.

Objective: Identification of modern vegetational formations which characterize the sample area.

Materials: Modern vegetation at stand and formation levels is characterized in the literature. This is accompanied by vegetational mapping developed from aerial photography, and confirmed with ground survey (Fenaroli, 1970; Tomaselli, 1973; Pedrotti, 1968-1968; 1978; 1980; 1985; Ozenda, 1985); phytosociological data are also available concerning structure and dominance patterns. Detailed forestry inventories, developed for forestry management purposes, are also used to characterize dominant vegetation (San Michele all'Adige, unpublished data).

Modern vegetation formations used in step ❺ will be selected on the basis of: composition; dominance structure; area

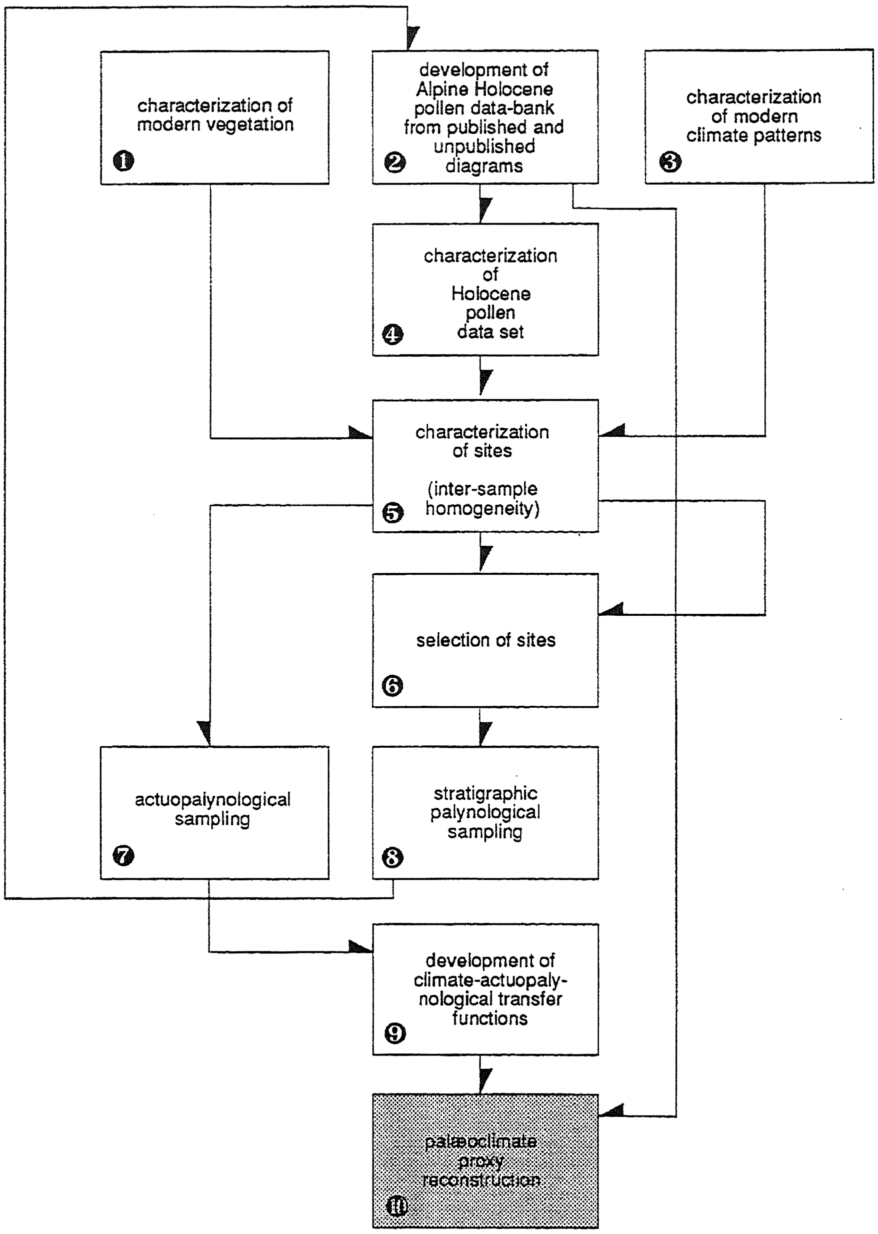

Fig. 2 - Simplified flow diagram of the project structure.
Diagramma di flusso semplificato del progetto.

coverage; soil type etc.

PHASE ❷ - Holocene pollen data bank.

Objective: Development of a Holocene pollen data bank for the Eastern Alps. All available pollen spectra from the sample area are converted into numbers and form the Eastern Alpine Holocene Pollen data bank.

Materials: Holocene pollen data from almost all sampled sites on the Italian side of the Eastern Alps have already been inputted into a data-base (ASCII format, available for personal and VAX-mini computers) (Evans, 1992a); the Alpine pollen data bank (Oeggl, pers. comm.) groups together a large number pollen diagrams throughout the Alps; other data bases (Huntley & Birks, 1983; Huntley & Prentice, 1988) are also available; a number of unpublished diagrams are known. All data sets will be fused and arranged with the following information:

- site name	- site coordinates	- author
- ^{14}C dates	- other dating	- site characteristics (bog; lake etc.)
- total depth (m)	- number of samples	- species identified
- sedimentary sequence	- mapping of sampled sites	

- conversion into numerical format of pollen curves for each species

PHASE ❸ - Characterization of modern climate patterns for the sample area.

Objective: development of a modern climate data base for the period 1930÷1960.

Materials: Published meteorological data is available from a number of different sources: the IIASA climate data base (Leemans & Cramer, 1991); the climatology of the Alps and of the Tyrol (Fliri, 1975; 1984); Osservatorio Climatologico di Roncafort; Osservatorio Climatologico Provincia Autonoma di Bolzano; Ufficio Idrografico e Mareografico di Venezia; Ufficio Idrografico e Mareografico di Parma; the Austrian Meteorological Service. Unpublished climate data is available at the Istituto Agrario della Provincia Autonoma di Trento.

The reference time period selected is 1930÷1960, given the relative stability of climate (Leemans & Cramer, 1991).

All time series from each set and and for the selected time period will be fused and arranged with the following information:

- site name	- site coordinates	- instrumental characteristics
- mean monthly temperature	- mean monthly insolation	- mean monthly precipitation

PHASE ❹ : Characterization of the Holocene pollen set.

Objective: Definition of Holocene vegetational units.

Materials: Holocene pollen data will be characterized in order to highlight the main patterns in the data, after an independent time scale is developed.

An independent radiocarbon time scale has been proposed by Evans (1992a); Holocene vegetational units have been outlined in Evans (unpublished) following methodology described in Evans (1992b).

A number of problems are however evident, resulting from the history of pollen research in the Eastern Alps. Figure 3 describes, for example, the migration pattern of *Pinus* for 8,000 years BP for data developed before and after 1958 (Evans, unpublished): two different migration routes are identified.

The objective is to define the main vegetation types for each time period and throughout the Holocene, along a radiocarbon timescale.

PHASE ❺ : Characterization of data.

Objective: Evaluation of data quality in order to highlight information gaps.

Materials: Data homogeneity, both vegetational, palynological and climatic will be assessed in order to evaluate data quality through the use of similarity indices: squared chord distance, double mass analysis etc.

Climatic data will be compared with modern vegetation types in order to highlight variance within vegetation types and viceversa.

Pollen data will be evaluated accordingly; a temporal pattern has already been highlighted in the Italian set (Schneider 1985; Evans 1992a) and has lead to the separation of the set into 2 groups (pre-1958 and post-1958). A similar pattern may also be evident in the Austrian set (see ❶).

PHASES ❻ : Site selection.

Objective: Selection of sampling sites.

Materials: Sites for actuopalynological and for further stratigraphic pollen analyses have been selected on the basis of the structure of modern vegetation units in different climate settings as identified in ❺. Sampling is being carried out around small lakes (ø ~100 metres) and peat bogs characterized by homogeneous vegetation, in order to evaluate the local and extra-local vegetation pollen signal.

Figure 1 locates sampled actuopalynological sites, identified in Table 1.Vegetation around each site is as follows:

Site 1 - High altitude stand with a prevalence of *Larix decidua*, more recently of *Pinus cembra* and *Picea excelsa*. Undergrowth of *Juniperus communis* ssp. *nana, Rhododendron ferrugineum, Vaccinium vitis-idæa, V. myrtillus, Calamagrostis arundinacea, Homogyne alpina, Hieracium murorum* and *Potentilla tormentilla.*

Soil: ranker, superficial, sandy and gravelly, loose.

Site 2 - Adult mixed-age stand with a prevalence of *Picea excelsa* accompanied by *Larix decidua*. Undergrowth of *Betula pendula, Lonicera nigra, Sorbus aucuparia, Vaccinium vitis-idæa, V. myrtillus* and *Dryopteris filix-mas*.

Soil: brown, averagely deep and compact, sandy with large stone blocks on surface.

Site 3 - Adult mixed-age stand with a prevalence of *Larix decidua* and *Picea excelsa*. Undergrowth with *Betula pendula, Alnus viridis, Lonicera nigra, Sorbus aucuparia, Vaccinium vitis-idæa, V. myrtillus, Dryopteris filix-mas, Homogyne alpina* and *Oxalis acetosella*.

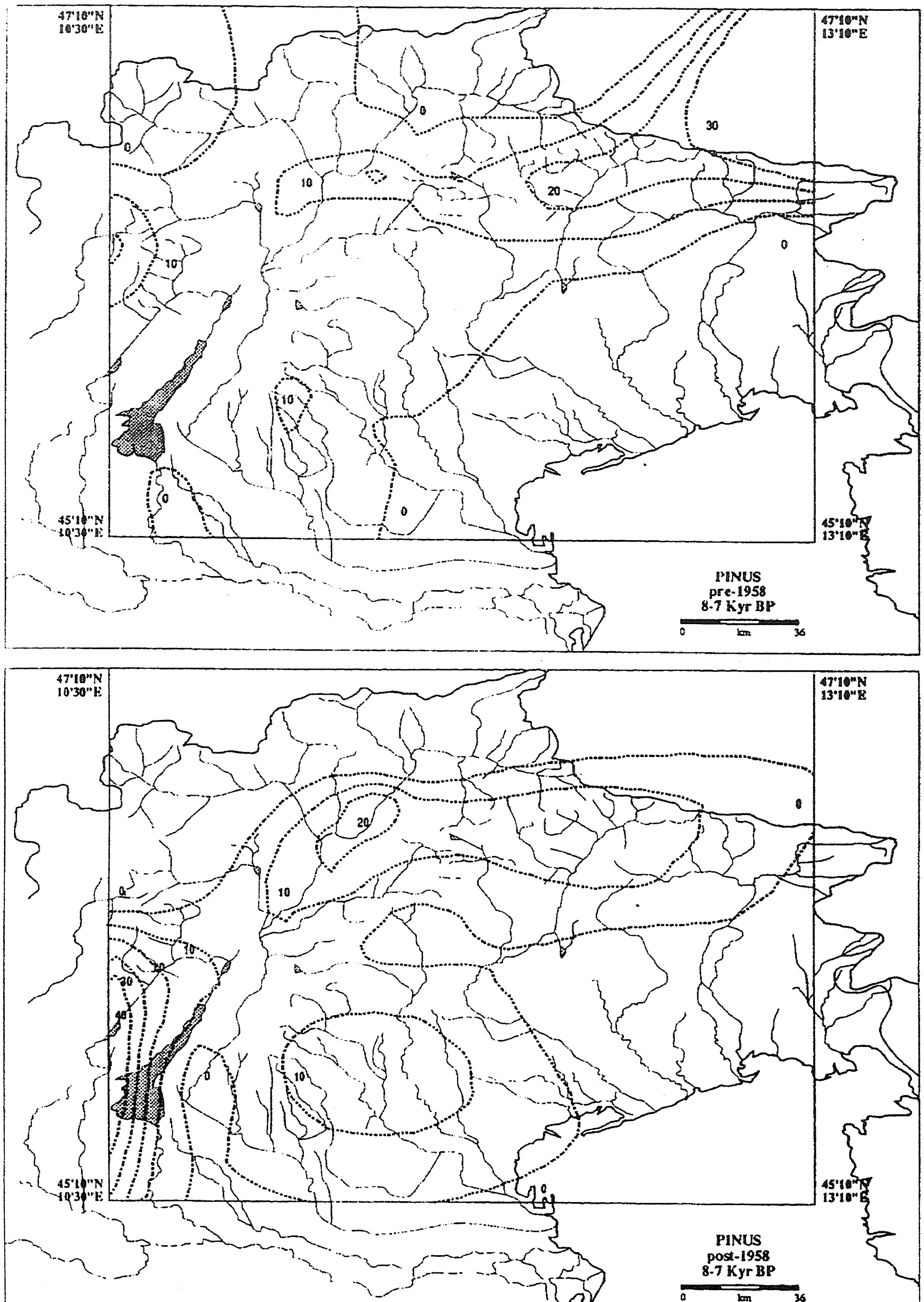

Fig. 3 - Percentage concentrations (%) of *Pinus* reconstructed using pollen data developed before 1958 (top) and after 1958 (bottom) for the period 8-7 ky B.P.

Concentrazioni percentuali (%) di Pinus *ricostruite utilizzando dati pollinici realizzati prima del 1958 (sopra) e dopioil 1958 (sotto) per 8-7 ky B.P.*

Soil: brown, averagely deep, clayey-gravelly, loose.

Site 4 - Adult mixed-age stand with a prevalence of *Picea excelsa*. Scanty undergrowth with *Alnus viridis, Laburnum alpinum, Sorbus aucuparia, Vaccinium vitis-idæa, V. myrtillus* and *Oxalis acetosella*.

Soil: podsol, averagely deep, sandy and loose with large stone blocks on surface.

Site 5 - Adult mixed-age stand made of in equal parts of *Picea excelsa, Abies alba* and *Fagus sylvatica*. Undergrowth with *Corylus avellana, Lonicera nigra, Vaccinium myrtillus, Oxalis acetosella, Hieracium murorum* and *Dryopteris filix-mas*.

Soil: brown, averagely deep, gravelly to stony, loose.

Site 6 - Almost pure mixed-age stand of *Picea excelsa*, with a scarce presence of *Larix decidua*. Undergrowth with *Laburnum alpinum, Sambucus racemosa, Lonicera nigra, Vaccinium idæa, V. myrtillus, Sorbus aucuparia, Oxalis acetosella* and *Homogyne alpina*.

Soil: brown, deep, clayey-loam, compact.

Site 7 - Adult mixed-age stand with a prevalence of *Picea excelsa* and a presence of *Larix decidua*. Undergrowth of *Alnus viridis, Fagus sylvatica, Corylus avellana, Laburnum alpinum, Sambucus racemosa, Lonicera nigra, Vaccinium vitis-idæa, V. myrtillus, Sorbus aucuparia, Oxalis acetosella* and *Homogyne alpina*.

Soil: brown, averagely deep, clayey and compact with stone blocks on soil surface.

Site 8 - Absence of arboreal vegetation: sparse clumps of *Alnus viridis, Juniperus communis* spp. *nana, Vaccinium* sp. and locally *Pinus cembra*.

Soil: ranker, superficial, stony, averagely compact.

Table 1 - Sites selected for actuopalynological sampling. Site number, name, height (m a.s.l.), exposition, coordinates and vegetation type are identified.
Siti actuopalinologici campionati. Viene riportato il numero, il nome, la quota in m s.l.m., l'esposizione, le coordinate ed il tipo vegetazionale presente in ciascun sito.

Site n°	Name	Height (m a.s.l.)	Exposition	Coordinates	Vegetation
1	Cogolo, Malga Levi	2100	W	46°22'25" 10°42'50"	*Larix-Pinus cembra* wood
2	Val Seniciaga, Malga Seniciaga	1570	NW	46°09'15" 10°41'21"	*Larix-Pinus cembra* wood
3	Val Seniciaga, Malga Germenega	1670	NW	46°09'00" 10°41'05"	*Picea-Larix* wood with adjacent peat bog
4	Valle di Leno	1520	N	45°59'58" 10°29'47"	*Picea* wood with adjacent peat bog
5	Val Noana	1100	NE	46°07'49" 11°50'42"	*Abies-Fagus* wood
6	Croviana, Malga Selva	1680	N	46°19'42" 10°55'59"	*Picea* wood
7	Croviana, Malga Clesera	1700	N	46°19'50" 10°55'59"	*Picea* wood
8	Passo Manghen	2110	top	46°10'28" 11°26'24"	Pasture with no arboreal vegetation
9	Molveno, Brocon	1170	W	46°09'39" 10°56'52"	*Abies-Picea* wood
10	Molveno, Marocai	1280	S	46°09'51" 10°56'22"	*Abies-Fagus* wood
11	Molveno, Val dell'Arca	1200	E	46°09'41" 10°56'35"	*Abies-Picea* wood
12	Lagolo	1100	W	46°02'33" 11°01'09"	*Fagus* wood
13	Drena	500	NW	45°57'50" 10°57'58"	*Quercus* wood

Site 9 - Mixed-age stand with a prevalence of *Abies alba, Picea excelsa* and *Fagus sylvatica*. Undergrowth of *Sorbus aucuparia, Rhododendron hirsutum, Vaccinium myrtillus, Polygala chamæbuxus, Cyclamen europæum* and *Athyrium filix-fœmina*.

Soil: brown, averagely deep, gravelly to stony, loose.

Site 10 - Mixed-age stand with a prevalence of *Abies alba, Picea excelsa* and *Fagus sylvatica*. Undergrowth of *Sorbus aucuparia, Rhododendron hirsutum, Vaccinium vitis-idæa, Erica carnea, Homogyne alpina, Hepatica nobilis* and *Pinus mugo* (marginal).

Soil: brown, averagely deep, gravelly to stony, loose.

Site 11 - Mixed-age stand with *Abies alba, Picea excelsa* and *Fagus sylvatica*. Undergrowth of *Sorbus aucuparia, Rhododendron hirsutum, Vaccinium myrtillus, Polygala chamæbuxus, Cyclamen europæum, Athyrium filix-fœmina, Galium odoratum* and *Pinus mugo* (marginal).

Soil: brown, averagely deep, gravelly to stony, loose.

Site 12 - Even-aged deciduous stand with a dominance of *Fagus sylvatica,* with an uphill presence of *Ostrya carpinifolia* and *Fraxinus ornus*.

Soil: brown, averagely deep, loam to gravelly, averagely compact.

Site 13 - Young deciduous stand with a dominance of *Ostrya carpinifolia,* with *Fraxinus ornus, Quercus* sp., *Sorbus aria, Corylus avellana, Pinus sylvestris* and *Larix decidua*. Undergrowth of *Juniperus communis, Hedera helix, Cotinus coggygria, Erica carnea, Polygala chamæbuxus, Cyclamen europæum, Fragaria vesca, Hepatica nobilis, Viburnum lantana* and *Amelanchier ovalis*.

Soil: rendzina, superficial, stony with stone blocks on surface, loose.

PHASE ❼ - Actuopalynological sampling.

Materials: Modern pollen is captured using Tauber gravimetric samplers, consisting of a 5 l cylindrical container, closed by a convex lid provided with a circular aperture in the centre (ø 5 cm), protected by a gauze mesh. Each trap is placed into the soil with the lid parallel to the soil surface, and 4 traps are placed at each sample site. 700 cc of a water : glycerine : alcohol solution (1:1:1 ratio) to which 2 g l^{-1} phenolic acid have been added. Tauber traps were positioned in Autumn 1993; the solution will be replaced twice yearly, in Spring and Autumn.

Gaps in the Holocene pollen record currently available are also being filled: one site in Val Cembra has been sampled for palynological purposes, and the core is currently being analyzed; samples for radiocarbon dating have also been taken.

PHASE ❽ - Stratigraphic palynological sampling.

New sites for palynological sampling of Holocene deposits have been identified and will be sampled in the coming year (1995). Particular attention has been paid to the selection of mid-high altitude sites located in inter-morenic depressions, in order to (i) exclude an extra-local component in the signal due to water-borne pollen; (ii) include oscillations in peat formation as proxy climate indicators; (iii) reconstruct timberline oscillations at specific time intervals during which changes in timberline have been observed (6 ky BP).

PHASE ❾ - Transfer functions.

Objective: Development of transfer functions.

Materials: Surface response functions and transfer functions will be developed between actuopalynological ÷ climate information (Atkinson *et al.,* 1987; Huntley & Prentice, 1988; Guiot *et al.*, 1989) and successively applied to the Holocene pollen set(s).

Results form Phase ❿, which will develop maps of Holocene climate conditions at different post-glacial time intervals, and which will be placed alongside maps describing Holocene palæovegetation, currently being developed at time intervals of 2,000 years starting from 12 ky BP. An example of the work in progress may be found in Evans (submitted).

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