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LATE-GLACIAL AND EARLY-HOLOCENE PALAEOENVIRONMENTS IN BRIANZA, N ITALY

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RIASSUNTO - *Paleoambienti del Tardoglaciale e del primo Olocene in Brianza (Italia settentrionale)* - Il Quaternario *Italian Journal of Quaternary Sciences* , 9(2), 1996, 653-660 - I diagrammi pollinici del Lago di Annone e del Lago del Segrino mostrano lo sviluppo della vegetazione in Brianza durante il Tardoglaciale e il Primo Olocene. Entrambi i laghi sono situati all'interno del sistema morenico prodotto dall'espansione glaciale massima del Würm. Dopo la ritirata del ghiacciaio dell'Adda si instaurò nella regione una vegetazione di steppe aperte, dominata da *Artemisia* e Gramineae. Un periodo con abbondante presenza di *Juniperus* e *Hippophaë* precedette l'espansione di *Betula* intorno al 13.700 BP, durante la quale i sedimenti dei due laghi cambiarono da melma siltosa (*silt*) a melma organico-calcarea (*gyttja* calcarea). Le foreste aperte di *Betula*, verso il 12.350 BP cambiarono in foreste più fitte di *Pinus-Betula*. Pochi secoli dopo, durante l'Allerød *Quercus, Ulmus, Tilia* e *Alnus* si propagarono, l'ultimo dei quali fu fortemente ridotto dalla deteriorazione climatica del Dryas Recente, mentre aumentarono invece *Juniperus, Betula, Artemisia* e alcune specie erbacee indicanti condizioni caratteristiche delle steppe. Il Dryas Recente può essere suddiviso in tre biozone che molto probabilmente rappresentano condizioni climatiche dissimili. Le percentuali assai alte di polline non arboreo (NAP) durante tutto il Tardoglaciale così come un Dryas Recente molto marcato con valori alti di *Artemisia*, Umbelliferae ed altri indicatori tipici dei climi secchi, suggeriscono che non soltanto la temperatura ma anche la precipitazione atmosferica deve essere considerata come fattore limitante la crescita delle specie arboree. L'inizo dell'Olocene è caratterizzato dalla diminuzione di *Betula* e di specie erbacee eliofili così come dall'espansione delle foreste a foglie decidue dominate da *Quercus, Ulmus* e *Tilia*.

ABSTRACT - *Late-glacial and early-Holocene palaeoenvironments in Brianza, N Italy* - Il Quaternario *Italian Journal of Quaternary Sciences* , 9(2), 1996, 653-660 - The Late-Glacial and early-Holocene vegetation development in Brianza is shown by the pollen diagrams from Lago di Annone (226 m a.s.l.) and Lago del Segrino (374 m a.s.l.), both situated just inside the moraine system of the maximum Würm glaciation. After the retreat of the Adda glacier an open steppe vegetation dominated by *Artemisia* and Gramineae spread in the area. A period rich in *Juniperus* and *Hippophaë* is recorded before the expansion of *Betula* at ca. 13,700 BP, which coincided with sediment changes from silt to calcareous *gyttja* in the lakes. The open *Betula* forests developed towards denser *Pinus-Betula* forests at around 12,350 BP, and *Quercus, Ulmus, Tilia,* and *Alnus* started to expand during the Allerød. The latter were seriously affected by the climatic deterioration of the Younger Dryas, whereas *Juniperus, Betula, Artemisia,* and some other herbs indicating steppic conditions became more frequent. The Younger Dryas can be divided into three biozones, most likely representing different climatic conditions. High percentages of NAP throughout the Late-glacial and a very pronounced Younger Dryas with high values of *Artemisia*, Umbelliferae, and other indicators for dry climate may suggest that the limiting factor for tree growth was not only temperature but also precipitation. The beginning of the Holocene is marked by decreases in *Betula* and heliophilous herbs and the expansion of deciduous forests dominated by *Quercus, Ulmus,* and *Tilia*.

Keywords: Late-glacial, Younger Dryas, Early Holocene, palaeoecology, Brianza, N Italy
Parole chiave: Tardoglaciale, Dryas recente, primo Olocene, paleoecologia, Brianza, Italia settentrionale.

1. INTRODUCTION

The foothills of the Southern Alps are an interesting region for palaeobotanical work, because they are situated close to the glacial refuges of most of the important tree species (Huntley & Birks, 1983; Lang, 1994), and the reforestation of the area during the Late Glacial and early Holocene was not slowed down by mountain barriers across the migration route. A high relief, several big pre-alpine lakes, and a great number of valleys carved out by glaciers and rivers draining south to the Po plain cause a high climatic variability, ranging between insubrian/submediterranean and high-alpine climate and facilitating the development of vegetation belts. Possibly this inhomogenous topographic and climatic situation is one of the reasons why a comprehensive overview of the Late-Glacial vegetation development in the Insubrian area as it was worked out for the Swiss Plateau by Ammann & Lotter (1989) is still lacking. On the other hand very few pollen diagrams from the Southern Alps show a complete Late-Glacial sequence provided with radiocarbon dates. Schneider (1985) gives an overview of the palynological data available by 1985 and interpretations of the vegetation history in the different parts of the Insubrian area.

The goal of the palaeoecological investigations in the Lago di Como region is to study forest dynamics in the Late Glacial and Holocene with regard to climatic change, migration, fire, and other factors. In this paper the first results are presented.

2. THE STUDY AREA

Lago di Annone (226 m a.s.l.) and Lago del Segrino (374 m a.s.l.) are two of several lakes situated near the southern end of Lago di Como, in the transitional zone between the Southern Alps and the Po plain (Fig. 1). The bedrock geology consists of Mesozoic carbonates, *i.e.* mainly Cretaceous flysch around Lago di Annone and Liassic carbonates in the catchment of Lago del Segrino. The area partly is covered by Quaternary gravels and moraines. Although the lakes of Brianza are situated just inside the end-moraine system of the Adda glacier, they have their origin rather in topographic characteristics of the bedrock than in glacial deposition (Bini, 1995).

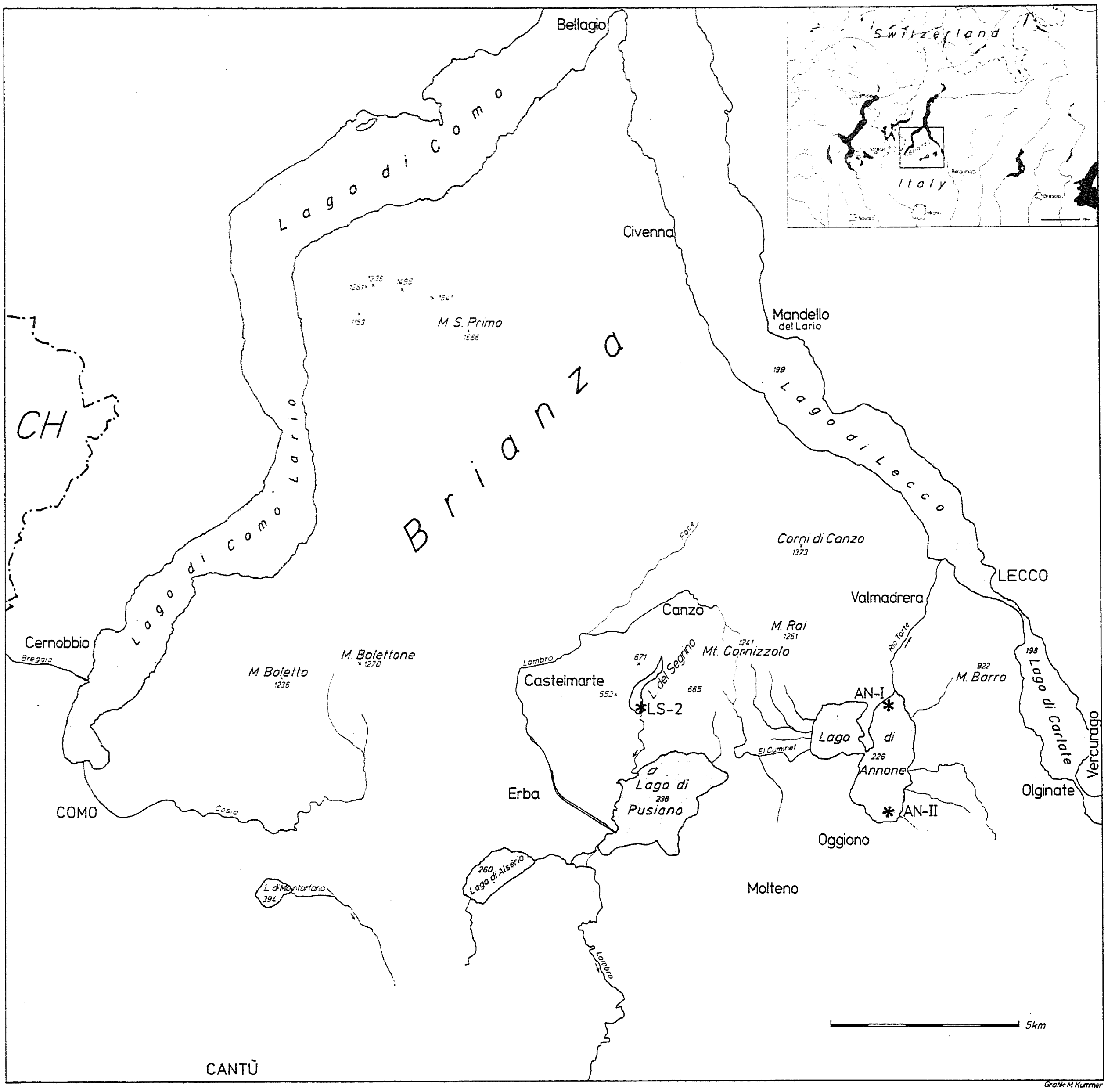

Fig. 1 - Geographical situation of the study area.
Situazione geografica dei laghi studiati.

Lago di Annone is a fairly big lake with a water surface of 5.5 km^2, a maximum water depth of about 14 m (in the eastern basin), and a catchment area of 22.5 km^2 reaching altitudes of 1261 m a.s.l. in the north (Mt. Rai) and 922 m at Mt. Barro in the northeast. It outlets into Lago di Lecco.

The narrow basin of Lago del Segrino is between two hill ridges with altitudes of up to 670 m. Its maximum water depth is 8.6 m, the water surface 0.38 km^2, and the catchment area 3 km^2 (de Bernardi *et al.*, 1985). The lake has no superface inlet; it is fed by surface water from the surrounding slopes and by subaquatic springs. The outlet goes into Lago di Pusiano.

The climate in the study area is of the Insubrian type characterised by relatively mild and dry winters and warm and humid summers with maximum precipitation in spring and autumn.

The natural vegetation in the surroundings of the lakes in Brianza is largely destroyed by man. The forest stands on the slopes around Lago del Segrino and at Monte Barro can be attributed to the submediterranean vegetation complex covering the lowlands at the foothills of the Alps in northern Italy up to about 800 m a.s.l. (Oberdorfer, 1964). It is characterised by open stands of *Fraxinus ornus* and *Ostrya carpinifolia* (Orno-Ostryon) on dry slopes and hilltops and by species-rich deciduous forests with *Castanea sativa, Fraxinus excelsior, Tilia cordata, Alnus glutinosa, Ulmus minor, Prunus avium,* and *Corylus* (*Salvio-Fraxinetum,* Carpinion) on fresher and richer soils. In the montane belt above 800-1000 m *Fagus silvatica* is the dominating tree species.

3. METHODS

For the pollen analysis 1 cm^3 of sediment was treated using the standard methods with HF and acetolysis. Percentage calculations and printing of the pollen diagrams were carried out with the TILIA and TILIAGRAPH programs (Grimm, 1992). The pollen percentages are based on the pollen sum (100%) including trees, shrubs, and NAP (non arboreal pollen); aquatics and spores are excluded. The pollen diagrams are subdivided into local pollen assemblage zones (LPAZ) calculated using CONISS (TILIA).

4. RESULTS

4.1 The sediments

For the coring work in both lakes a modified Streif-Livingstone piston sampler was used. At Lago di Annone two sediment cores were taken at about 6 m water depth (Fig. 1). AN-1 from the northern part of the lake includes both Late Glacial and Holocene but shows a sediment gap of about 3000 years between ca. 4000 and 1000 y BP (Wick, in prep.). The sediments consist of calcareous *gyttja* with silt from the top to 704 cm, where there is a distinct change to silt and sand. A thick sand layer at 745 cm stopped the coring work. In core AN-2 a complete Holocene sequence is included in the upper 702 cm of calcareous *gyttja* (Wick, in prep.) followed by only 15 cm calcareous sediments representing parts of the Younger Dryas and the Allerød, and the lowest 680 cm consist of grey, homogenous and sandy silt with very low pollen content, probably dating to an early period of the Oldest Dryas. The coring was stopped before the moraine was reached. The gaps in both cores are likely to be due to sedimentary processes in the lake.

The sediment core LS-2 taken in the southeastern part of Lago del Segrino at 70 cm water depth is 1600 cm long and consists mainly of lake marl with an increase in minerogenic material between 700 and 870 cm (Younger Dryas), and a continuous transition from lake marl to silt at around 1100 cm. The time period between the Boreal and the Middle Ages is lacking in this sediment sequence (a hiatus of the same extent was also recorded in a shorter core taken west of LS-2 at 3 m water depth.

4.2 Datings

The radiocarbon datings on terrestrial plant remains from Lago di Annone AN-1 were done in the AMS-laboratories of Uppsala (G. Possnert/ M. Södermann) and Zürich (G. Bonani) and are given in uncalibrated years BP (Table 1). The dates on the pollen diagram of Lago del Segrino are transferred from AN-1.

Table 1 - AMS-radiocarbon datings from Lago di Annone, given in conventional, uncalibrated yr BP.

Datazioni al radiocarbone AMS del Lago di Annone indicati in anni BP conventionali, non calibrati.

Lab number	Depth [cm]	$\delta^{13}C$ %0 PDB	^{14}C age [yr BP]
ETH-10792	704	-25.1±1.2	13 690±105
ETH-10791	641	-23.3±1.2	12 340±100
Ua-10647	682-685	-27.58	13 330±190
Ua-10648	658-660	-27.92	12 325±90
Ua-10649	619-621	-25.04	11 440±85
Ua-10650	577.5-579	-27.79	11 000±110
Ua-10651	506-510	-27.98	10 510±100
Ua-10652	437.5-442.5	-26.50	9 170±95
Ua-10653	352-353.5	-27.12	7 890±70
Ua-10654	333-335	-26.70	7355±95

4.3 Late-Glacial and Early Holocene vegetation development in Brianza

Since the pollen diagrams of Lago del Segrino and Lago di Annone correspond to each other in their major characteristics (local pollen assemblage zones LPAZ), they are described and discussed together in order to give a general idea of late-glacial reforestation and forest dynamics in the eastern part of Brianza.

After the retreat of the Adda glacier an open steppe vegetation developed on the raw soils in the surroundings of the lakes as it is represented at the base of the Lago del Segrino diagram (LPAZ S-1a/1b). It was dominated by Gramineae, *Artemisia,* Chenopodiaceae, *Ephedra, Thalictrum,* and other pioneer plants, accompagnied by sparse scrubs of *Juniperus, Hippophaë* and *Salix.* The high percentages of *Pinus* pollen are probably due to long-distance transport from the Po plain.

Lower *Pinus* values in LPAZ S-2 and A-1 indicate an increase in local pollen production due to a consolidation of the vegetation cover. The expansion of *Juniperus* and *Hippohpaë* as well as the immigration of *Betula* and an increase in species diversity are likely to be favoured by a climatic improvement.

LPAZ A-2/S-3 show the reforestation of the area by *Betula* and the immigration of *Pinus sylvestris.* In Lago di Annone fruits and fruit scales of birch trees are recorded from the beginning of LPAZ A-2 (13,690±105 y BP) when a sediment change from silt to calcareous *gyttja* is recorded. At the same time *Pinus cembra* and *Larix* were present in the area, too. Permanently high percentages of *Artemisia,* Gramineae, and other heliophilous herbs though suggest an open, tundra-like type of forest.

The mass expansion of *Pinus sylvestris* is dated to 12,340±100 y BP. The *Pinus-Betula* forests covering the area during the following ca. 1000 years (LPAZ A-3/S-4) were more closed; *Juniperus,* Gramineae, and *Artemisia* decreased, and most of the light-demanding steppic and/or alpine herbs (*e.g.* Chenopodiaceae, *Plantago alpina, Saxifraga oppositifolia*-t., *Polygonum alpinum, P. viviparum*) became more rare or disappeared. Increasing values of *Quercus* in this pollen zone suggest the immigration of *Quercus* in the area, and the beginning curves of *Ulmus, Tilia, Fraxinus, Acer, Alnus,* and *Corylus* indicate that these trees were not far away anymore.

The expansion of deciduous forests dominated by *Quercus, Ulmus, Tilia,* and *Alnus* can be dated to the younger Allerød (LPAZ A-4/S-5), when – due to the minimum values of NAP – the closest forest stands of the Late-glacial were recorded.

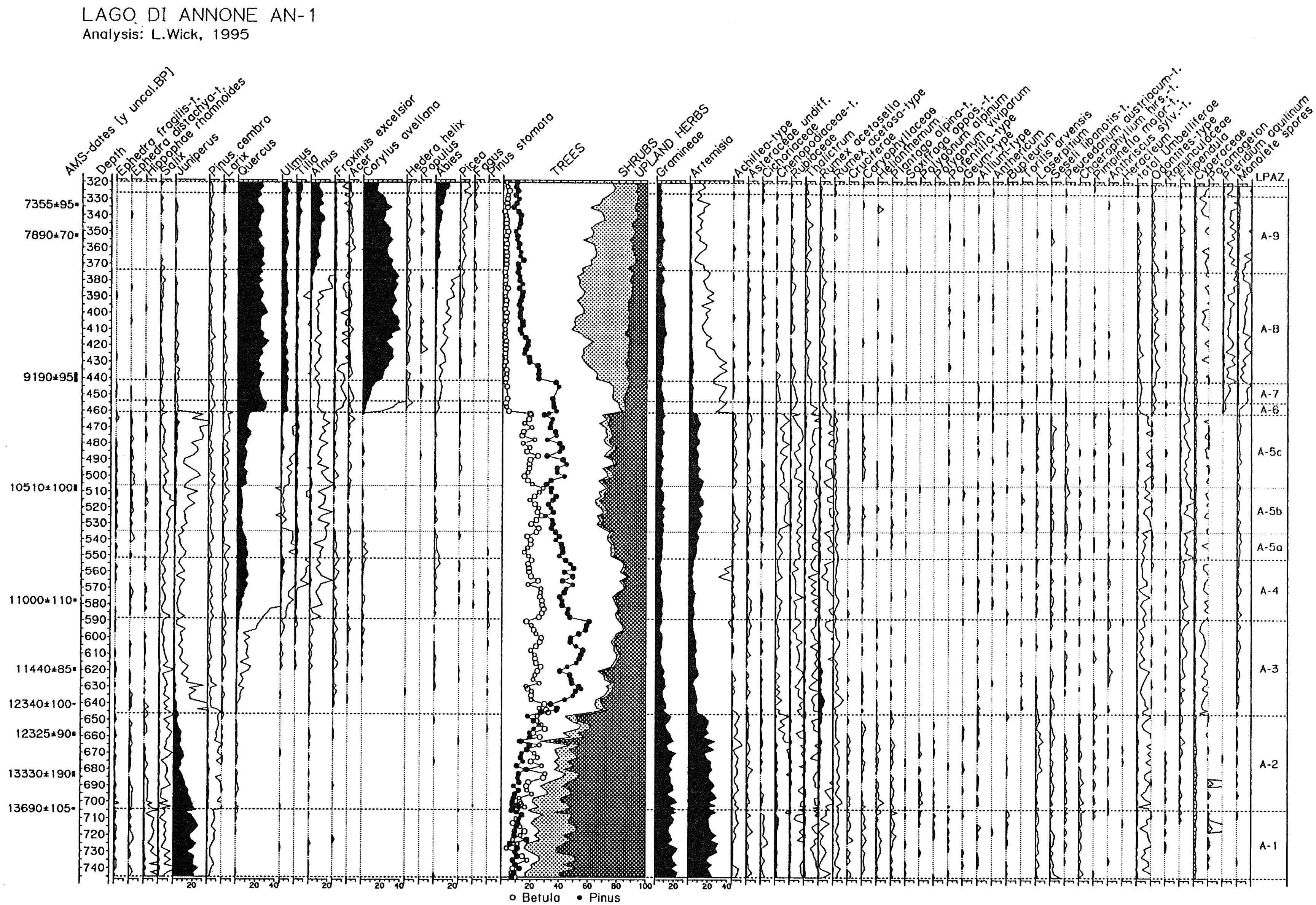

Fig. 2 - Late-Glacial and early-Holocene pollen diagram of Lago di Annone including the most important species only.
Diagramme pollinico del Tardoglaciale e del Primo Oloceno del Lago di Annone, con rappresentazione delle specie di maggior rilievo.

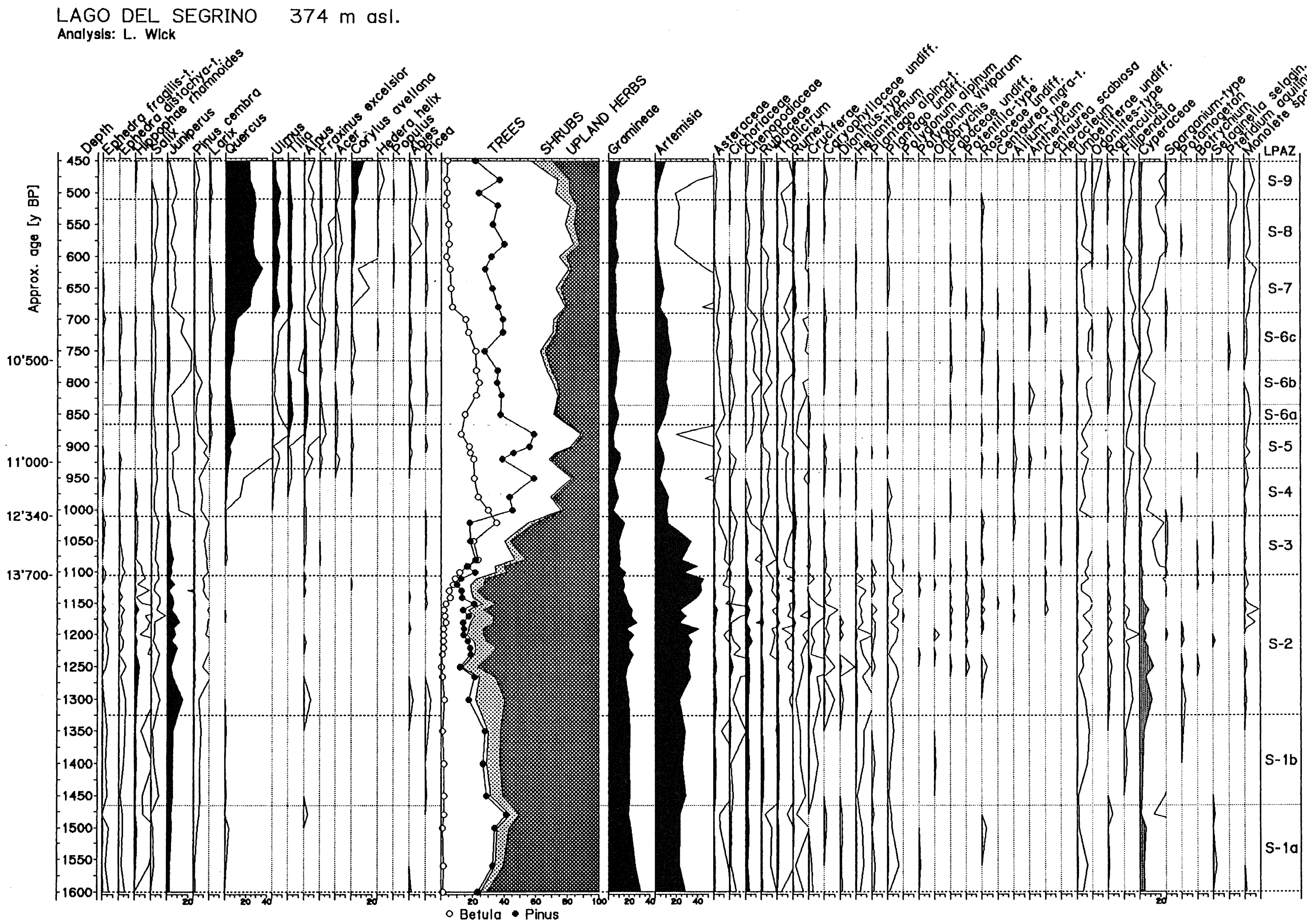

Fig. 3 - Late-Glacial pollen diagram of Lago del Segrino (preliminary results).

Diagramma pollinico del Tardoglacialedel Lago del Segrino (risultati preliminari).

The climatic deterioration of the Younger Dryas is included in LPAZ A-5 and S-6, respectively. It is characterised by increasing *Betula* and decreasing *Pinus* percentages (in Lago del Segrino more pronounced than in Lago di Annone) and increases in NAP, such as *Artemisia,* Chenopodiaceae, Rubiaceae, *Rumex,* Umbelliferae. The Younger Dryas can be devided into three parts, most likely representing different climatic conditions. The climatic cooling at the beginning of the Younger Dryas (LPAZ A-5a/S-6a) mainly affected *Ulmus, Quercus* showed only little reaction, and *Tilia* and *Alnus* even became more frequent. In LPAZ A-5b/S-6b the percentages of all the thermophilous trees decrease, whereas the curves of *Betula, Juniperus,* and *Salix* increase. *Artemisia* shows maximum values (15%), and steppic and alpine herbs become more frequent, suggesting that during this most unfavorable period of the Younger Dryas the vegetation did not suffer from climatic cooling only but most likely also from dryness. A great number of different Umbelliferae pollen types in the pollen diagram of Lago di Annone, most of them indicating rather dry and open environments, support this idea. The presence of *Larix* in the area during this period is proved by several needles found in the sediments of Lago di Annone. In LPAZ A-5c/S-6c increasing percentages of *Quercus, Ulmus, Tilia,* and *Pinus* combined with slight decreases in *Artemisia* and other heliophilous herbs point to a climatic improvement in the younger part of the Younger Dryas (ca. 10,500 y BP) which favoured the reestablishment of deciduous woodlands to a certain degree.

The beginning of the Holocene is marked in the pollen diagrams (LPAZ A-6/S-7) by increasing percentages of thermophilous trees and decreases in *Betula, Pinus, Juniperus, Artemisia,* Umbelliferae, and other herbs. The early-Holocene forests in Brianza were dominated by deciduous trees, such as *Quercus, Ulmus,* and *Tilia,* but *Pinus* still was important. *Corylus* immigrated in the area in the early Preboreal (LPAZ S-8), but it expanded rather slowly (LPAZ S-8). The fast increase of the *Corylus* curve and the abrupt changes in some of the other curves at the beginning of LPAZ A-6 point to very low sediment accumulation rates or even a hiatus in Lago di Annone during the Preboreal. LPAZ S-7 and S-8 most likely correspond to LPAZ A-6. In the pollen diagram of Lago del Segrino slight decreases in the curves of *Ulmus* and *Tilia* together with a plateau in the increasing *Quercus* values and a peak in *Artemisia* (LPAZ S-7) suggest a climatic oscillation in the Preboreal, although the temporal resolution of the analysis is not sufficient enough to be sure.

During the Boreal (9000-8000 y BP, LPAZ A-8) deciduous forests dominated by *Quercus, Corylus,* and *Ulmus* grew in the surroundings of the lakes. The expansion of *Abies alba* is indicated by continuously increasing pollen values in LPAZ A-8 and A-9. *Alnus* started to become an important tree in the forests of Brianza around 8000 y BP (LPAZ A-9) when the optimum period of *Corylus* came to an end.

5. DISCUSSION

One of the characteristics of the Late-Glacial reforestation in the Southern and Southeastern Alps is the early presence of *Pinus cembra* and *Larix,* which can be explained by glacial refuges in the unglaciated lowlands near the southern border of the Alps (Casadoro *et al.*, 1976; Lang, 1994). At Lago di Annone the expansion of these two trees is contemporary with the *Betula* expansion dated at ca.13,700 y BP, *i.e.* 400-500 years earlier than former datings suggest (Bertoldi, 1968; Schneider, 1978). At low altitudes, though, *Pinus cembra* and *Larix* were not able to compete with *Pinus sylvestris,* but a pollen diagram from Lago della Bolla (Val d'Intelvi, 1050 m a.s.l.) includes a short Late-Glacial sequence indicating that they played a major role in the montane forests (Wick, unpubl.).

Our knowledge of the climatic conditions in the Southern Alps during the Late Glacial is very little. Stable-isotope curves from several lakes including Lago di Annone and Lago del Segrino did not provide the expected informations (Eicher, unpubl.). Though the high values of *Artemisia,* Umbelliferae (*e.g. Bupleurum, Laserpitium, Seseli libanotis*-type, *Torilis arvensis*), and other steppic plants in the pollen diagrams indicate that the climate was rather dry during great parts of the Late Glacial. The response of the vegetation to the climatic deterioration of the Younger Dryas is much more pronounced in the study area than in the lowlands of the Swiss Plateau (Wick, in prep.), suggesting that south of the Alps not only temperature but also precipitation was an important factor for Late-Glacial forest dynamics. Evidence for this idea may be found in the tripartite structure of the Younger Dryas, which is already known from lakes west of Brianza (Schneider, 1978; Schneider & Tobolski, 1985; Drescher-Schneider, 1996). At the beginning of the Younger Dryas there was sufficient humidity for the growth of *Quercus, Tilia,* and *Alnus.* The decreases of these trees in favour of *Artemisia* and other heliophilous herbs in a second phase may point to decraesing humidity combined with cool temperatures. The climatic conditions started to improve towards the end of the Younger Dryas.

In Lago di Annone and Lago del Segrino there is little evidence of minor climatic oscillations as recorded in Swiss lake sediments (Lotter *et al.*, 1992; Wick, in prep.). More detailed pollen analysis at Lago del Segrino combined with oxygen-isotope ratios in shells of fossil ostracodes (*v.* Grafenstein, in progress) are expected to improve our knowledge of Late-Glacial environments south of the Alps.

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