

## THE POLLEN RECORD OF THE 190 M CORE FERSINA 2, AN ENTIRELY LATE-GLACIAL SEDIMENT SEQUENCE IN THE ADIGE VALLEY AT TRENTO (NE ITALY).

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**ABSTRACT:** Pollen analysis of samples taken from the core of the water well Fersina 2 (Adige Valley, Prov. Trento, NE Italy) did not reveal any indication of an interglacial or Holocene age of the uppermost 190 m in the sediment sequence deposited in the over-deepened Adige River Valley. The sediment sequence dates entirely from late-glacial times. Four radiocarbon ages of pieces of wood indicate that about 165 m of the upper part of the profile are of Younger Dryas age. The lower part of the sequence dates from the Allerød or Bølling/Allerød and a preceding cold phase, probably the Oldest Dryas. Accordingly the deposition of the sequence took about 2500 or 3500 years and was completed long before the onset of the Neolithic. Our results are in excellent agreement with findings in other formerly glaciated alpine valleys (e.g. the Traun, Salzach and Enns valleys in the Northern Alps).

The final depth of the Fersina 2 well is 190 m. It is very likely that the sediment sequence found below this level in the nearby 423 m deep Fersina 1 well was also deposited after the deglaciation of the Adige Valley at the end of the last glacial period.

Key words: Trentino, Adige Valley, Fersina, Younger Dryas, stratigraphy, pollen analysis

### 1. INTRODUCTION

A fairly large number of pollen studies are available on the Late-glacial and Holocene vegetational development in the Italian Alps and the Apennine mountains (e.g. Vescovi et al., 2010; Drescher-Schneider, 2009; Ravazzi, 2007; Ravazzi et al., 2007; Vescovi et al., 2007; Filippi et al., 2007; Ravazzi et al., 2006; Pini, 2002; Gröger, 1968; Beug, 1964; etc.). These studies can help to date a series of pollen-bearing sediment samples from the 190 m deep water well Fersina 2 drilled in the city area of Trento (north-eastern Italy). The location of the coring site on the bottom of the Adige River Valley at an elevation of only about 200 m, the remarkable length of the core, and the fact that the sediment is lacustrine all combine to promise information about the development of the vegetation of the Trentino (southern Alps) since the deglaciation of the Adige Valley at the end of the Würmian glacial period. The results of the pollen study are presented below. Regional geology and sedimentology of the core sediments are from Fuganti et al. (1998, 2001).

Tab. 1 shows how the late-glacial biozones (based on biological phenomena) correlate with GRIP zones (based on Greenland ice core events). This system is increasingly used in more recent scientific publications on northern Italy.

### 2. GEOGRAPHICAL SITUATION, POLLEN SOURCE AREA AND SEDIMENTARY ENVIRONMENT

Almost all of the modern catchment area of the Adige and its tributaries (more than 10,000 km<sup>2</sup>) was glaciated during the maximum of the last glacial period (Würmian). When the ice margin of the Adige Valley

glacier retreated to the north from its southernmost position south of Trento, a vast lake formed in the over-deepened Adige Valley (e.g. Venzo, 1957). It must have been many km long, and it was probably as wide as the

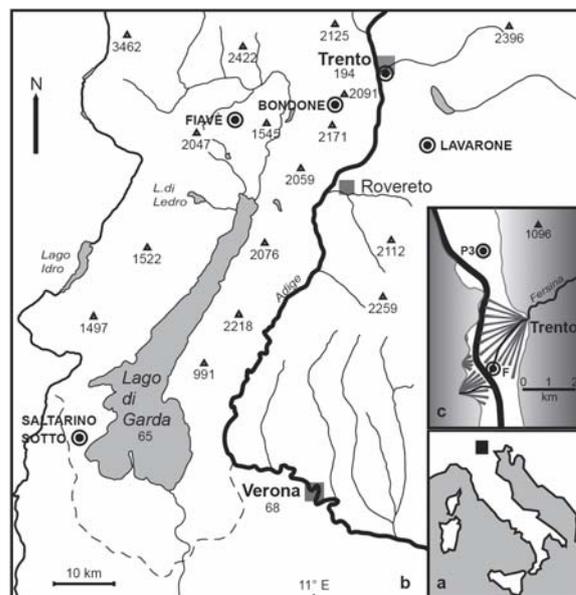


Fig. 1 - a) Position of the Lake Garda area (black square) in Italy. b) Lake Garda area. Sediment core sites mentioned in the text marked by encircled dots, elevations given in meters above mean sea level. The broken line delimits the southern border of the Würmian moraines south of Lake Garda. c) The alluvial fans of the Trento area (from Venzo 1957, changed), F = profile Fersina 2 (this paper), P3 = site studied by Venzo (1957). The non-shaded part of the inset marks the more or less flat, late-glacial bottom of the narrow Adige Valley.

Greenland isotope zones		Start (yr BP)	Biozones (pollen assemblage zones)	Start (yr BP)
Holocene		ca. 11500	Holocene (Postglacial)	ca. 11500
GS-1, Greenland stadial 1		12877	Younger Dryas stadial	ca. 13000
GI-1, Greenland interstadial	GI-1a	12989	Allerød interstadial, final part	13835
	GI-1b	13274	Gerzensee oscillation	
	GI-1c	13908	Allerød interstadial, early part	
	GI-1d	14044	Older Dryas stadial	
	GI-1e	14685	Bølling interstadial	
GS-2, Greenland stadial 2			Oldest Dryas	

Table 1 - Correlation of late-glacial GRIP zones and Swiss biozones according Ammann et al., 2012 and van Raden et al., 2012.

Adige Valley. This lake was still in existence when the Younger Dryas glaciers which did no longer reach the Trento area melted down. Huge amounts of melt water were available at that time to transport an enormous sediment load to the south and thus to fill up the over-deepened Adige Valley. In the Trento area much of the infill material was contributed by the Torrente Fersina. This river, originating in the Dolomites, enters the Adige Valley in the area of the city of Trento and cascades down from a hanging valley about 200 m above the bottom of the modern Adige Valley (Fig. 1) forming an alluvial fan there on which part of the older quarters of the city of Trento and the Fersina coring site are located. The combined sediment input of Fersina and Adige caused an extraordinarily high sedimentation rate and thus a rapid filling-up of the vast lake basin. The stratigraphy of the Fersina cores (Fig. 2) shows that predominantly clay and silt, but also fine sand and some sandy gravel, were deposited in the Trento area.

In the study area the Adige Valley is bordered to the West and East by mountain ranges rising to more than 2000 m. The area is consequently characterized by a much diversified altitudinal zonation of the vegetation, including treeless alpine meadows. The pollen produced in these varied vegetational zones was brought to the coring site probably predominantly by the wind. Non-anemogamous species, even components of the bankside vegetation, had almost no chance to be represented in the sediment as the later coring site was probably about 1 km away from the nearest lake shore.

Additional pollen was transported to the Trento lake basin by the rivers from more distant regions, con-

temporary pollen and possibly also pollen reworked from older sediment well upstream from the coring site. An unknown quantity of the pollen floating on or suspended in the lake water was carried away with the excessive river water. Due to the great sedimentation rate (see below), complete mixing of the annual input of sediment might have been impossible. If so, the pollen contents even of different subsamples of the same annual layer might differ to some degree.

From the above, it follows that the sedimentary environment of the Fersina core was so different from that of smaller lake basins and peat bogs - the usual source of information on the former vegetation and of its changes - that a direct comparison of pollen values - especially of less frequent taxa - must not be done. The main features of the vegetational development, however, will remain visible despite loss of pollen and inadequate size of samples.

### 3. SAMPLING

The well Fersina 2 was drilled (percussion drill) in March/April 1997 in the southern part of Trento near the present-day confluence of the rivers Fersina and Adige (46° 02' 50" N, 11° 07' 08.5" E; 190.6 m a.s.l.). The drilling was ended at a depth of 190 m when the aquifer was reached. A continuous casing was used during drilling to prevent collapse of the well walls and hence incorporation of younger sediment in the samples. Therefore disturbances of the sedimentary and pollen record can be excluded. The samples were labelled according to the sampling interval of about 1 meter. A

Profile	Depth (m)	Dated material	<sup>14</sup> C-age <sup>14</sup> C a BP	Calendric Age years BC	Calendric Age cal a BP	95% range cal a BP	Wiggle matching cal a BP	Wiggle matching years BC
Fersina 2	32	Wood of <i>Juniperus</i>	9993 ± 74	9550 ± 156	11500 ± 156	11188 - 11812	11603±146	9653±146
Fersina 2	33	Wood of <i>Juniperus</i>	10078 ± 74	9703 ± 214	11653 ± 214	11225 - 12081		
Fersina 2	130	Wood of <i>Pinus cembra</i>	10282 ± 64	10159 ± 223	12109 ± 223	11663 - 12555	12280±142	10330±142
Fersina 2	139	Wood of <i>Pinus mugo/sylvestris</i>	10445 ± 33	10429 ± 166	12379 ± 166	12047 - 12711		
Fersina 1	33	Wood	10004 ± 28	9545 ± 131	11495 ± 131	11233 - 11757		
Fersina 1	142	Wood	10243 ± 83	10064 ± 231	12014 ± 231	11552 - 12476		
Via Verdi	11	Wood	4145 ± 23	2760 ± 80	4710 ± 80	4550 - 4870		

Calibration: CalPal-2007online. <http://www.calpal-online.de/> accessed 2010-09-01.

Table 2 - Calibration of the conventional radiocarbon dates from Trento and wiggle matching of the Fersina 2 dates.

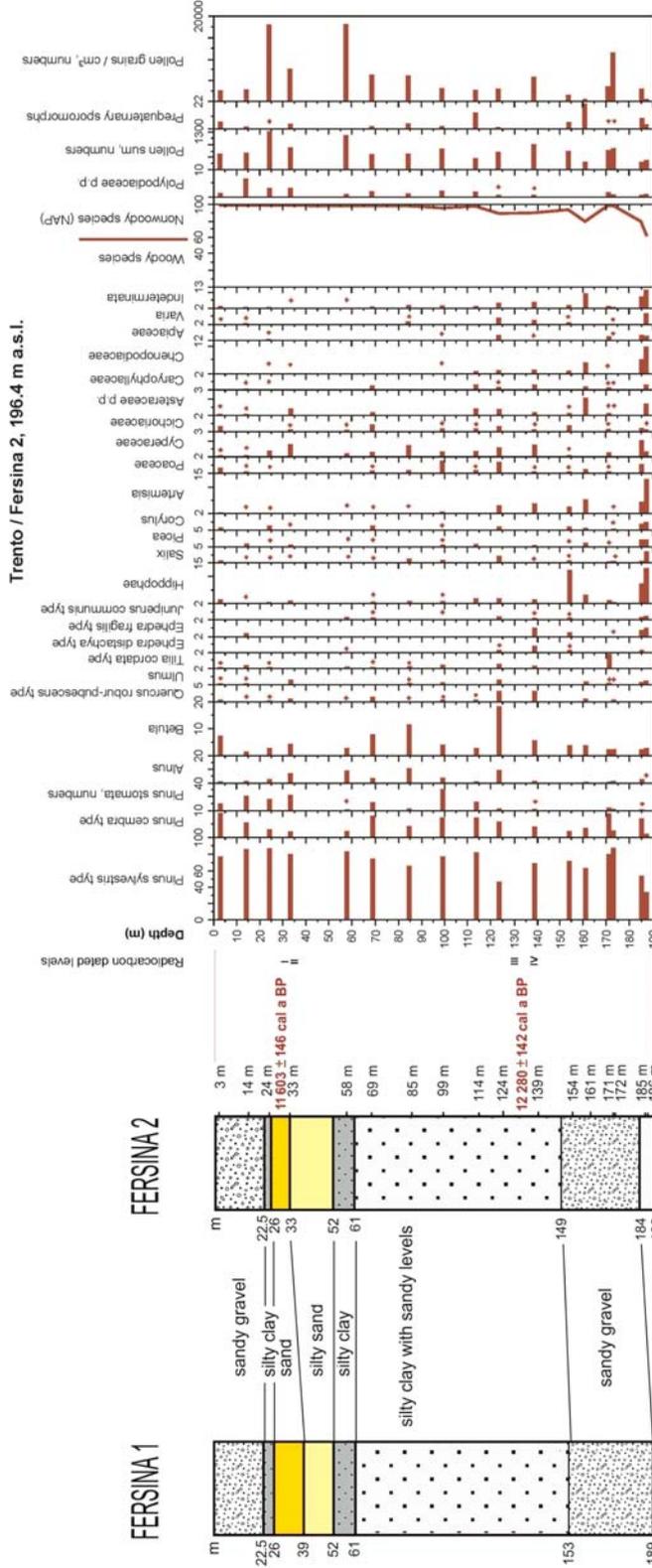


Fig. 3 - Pollen diagram. The pollen values are shown as percentages of the pollen total. Pollen sum, pollen concentrations, and amounts of stomata are given as numbers. Note that the scales change in order to save space. Dots denote where the percentage values are  $\leq 0.3$  or where only one stoma of Pinus was found. Radiocarbon dated levels: I: 11500 ± 156 cal a BP; II: 11653 ± 214 cal a BP; III: 12109 ± 223 cal a BP; IV: 12379 ± 166 cal a BP.

Fig. 2 - Stratigraphy of the cores Fersina 1 and Fersina 2, design by A. Fuganti, changed by G. Morteani and C. Preinfalk, depths of pollen samples added by E. Gröger.

Depth (m)	3	14	24	33	58	69	85	99	114	124	139	154	161	171	172	185	186
Acer			1														
Abies											1						
Ostrya type									1							1	
Brassicaceae	1										3	1	2				
Epilobium				1				1							1		
Vaccinium type													1				
Helianthemum nummularium type		2						1		1							1
Rosaceae p.p.			1														1
Rumex acetosa-scutatus type																1	
Rubiaceae								1			1						
Sparganium type			1	1													
Botrychium lunaria type		3	1				1			1							
Polypodium vulgare type							1	1							1		
Selaginella selaginoides		1							1				1				
Sphagnum															1		
Hystrichsphaeridae		1					1	4					8				

Table 3 - Rare pollen and spore types (numbers).

sediment sample called, e. g., “37 m” represents the sediment found between 36 and 37 m depth. In total, 100 irregularly shaped lumps of sediment (100 to 200 cm<sup>3</sup>) were available for pollen analysis. All samples consist of white silt, clay, and fine sand.

The well Fersina 1, located some 36 m from Fersina 2, was drilled in the same year. This drilling was stopped at 423 m without yet having reached bedrock. No pollen samples are available from this well, but the huge thickness of the sediment clearly shows that the Adige River Valley was over-deepened at least up to Trento.

Fig. 2 shows the stratigraphy of the cores Fersina 1 and 2 (Fuganti et al., 2001 and own data).

#### 4. RADIOCARBON DATING / WIGGLE MATCHING

Four pieces of wood found in the Fersina 2 sediment were radiocarbon dated (Table 2). The resulting conventional and calibrated radiocarbon ages were published by Fuganti et al. (1998). Since an improved calibration data set is now available (Reimer et al., 2009), the radiocarbon ages from Trento were re-calibrated using the CalPal software (Weninger & Jöris, 2008). Following a proposal of M. Geyh, the former director of the Hannover radiocarbon laboratory, the radiocarbon ages of the four pieces of wood were submitted to “wiggle matching”, kindly carried out by B. Weninger (University of Cologne).

To accomplish wiggle matching, a calendric distance of 10 ± 50 calyrs was assumed for the two younger pieces of wood, and a distance of 90 ± 50 calyrs for the two older pieces. Thus fitted into the Cal-Curve, radiocarbon ages of 11,603 ± 146 cal a BP (final year) and of 12,281 ± 142 cal a BP (final year) result for the two pairs of pieces of wood.

#### 5. POLLEN ANALYSIS

##### 5.1. Pollen preparation and pollen diagram

The aliquots for pollen analysis (2.3 to 14 cm<sup>3</sup>, average 5.2 cm<sup>3</sup>) were taken in the laboratory from the inner part of the cored material to prevent contamination with recent pollen. The standard mode of sample preparation, with HCl and HF and wet ultrasonic sieving as the final step (width of meshes 8 µm), did not produce a pollen concentration sufficient for a reliable pollen count. Treatment with HCl and NaOH, followed by flotation with sodium tungstate solution (Na<sub>2</sub>WO<sub>4</sub>, D = 2.05) as described by Eisele et al. (1994), but without acetolysis, proved to be more effective.

To allow the calculation of pollen concentrations, one *Lycopodium* spore tablet (containing 10,679 ± 191 spores) was added to each pollen sample at the beginning of the treatment (Stockmarr, 1971). The pollen counts range from 204 to 1225 (mean 592) grains per sample. Four samples only contained fewer than 484 pollen grains. The complete results of pollen analysis are presented in Fig. 3 and Table 3. Supplementary data are available at doi:10.1594/PANGAEA.793027. The pollen diagram was drawn using PanPlot (Diepenbroek et al., 2001), with graphical details being improved with microsoft paint. All given pollen values are percentages of the pollen total.

##### 5.2. The pollen record

The salient feature of the pollen diagram (Fig. 3) is the dominance of the *Pinus sylvestris* type in all pollen spectra (88.4 to 34.3 %, mean 71.5 %). Next in frequency are the *Pinus cembra* type (8.8 to 1.3 %, mean 5.1 %) and *Betula* (1.5 to 18.3 %, mean 5.2%). All other tree pollen types were found less frequently; indeed, their pollen values rarely exceed 1%. Tree species with such low pollen values – among them the thermophilous tree species – can hardly have been of any importance in the area or were even missing when the profile Fersina 2 was deposited. But pine trees occurred in the area, as evidenced by *Pinus* stomata being present in 14 out of 17 samples. Temporary increases of the NAP (nonarboreal pollen) values combined with a frequent

occurrence of pollen grains of shade intolerant species indicate former changes of the vegetation. Details will be discussed in the following.

The two lowermost samples (185 and 186 m) are comprised of clay. They show the highest NAP values recorded in the pollen diagram (21.3 and 39%, respectively). Up to 12.7 % of the pollen total was produced by the shade intolerant genus *Artemisia*. *Artemisia* species never occur in a forest. The same is true for the Chenopodiaceae (9.8 and 5.3 %). The percentages of the indeterminate pollen types (Indeterminata), certainly not pollen of woody species, are high (11.1 and 6.6 %). The diversity of nonarboreal pollen types (NAP) was never greater than at the time of deposition of these two samples. Among the woody taxa, the pollen frequencies of the pioneer shrub *Hippophae* (7.4 and 13.3 %), of *Juniperus* (0.4 and 0.6 %), and of two *Ephedra* -pollen types (up to 1 %) are of special interest. These shrubs are sunlight-demanding and cannot thrive in the shade of trees. On the other hand, no other sample of the profile contains more pollen of *Picea* (2.0 and 2.2 %), *Corylus* (0.8 and 1.0 % - not much for this shrub!), and *Ulmus* (0.4 and 0.6 %) than these two samples. Pollen of *Quercus* and *Tilia* was not found. Pollen concentration is medium in sample 185 m, but very low in sample 186 m (see Fig. 3). A low pollen concentration is caused either by the absence of pollen-producing plants or by a high rate of sedimentation.

Never during the deposition of the Fersina 2 sediment was the vegetation around the coring site more open and the climatic conditions less favourable than at the time when the clay below the sandy gravel (i.e. below 184 m, Fig. 2) was deposited. The region was not forested, but was probably not treeless. The pine values are lower than further up in the profiles, but – together with the occurrence of one stoma of a pine needle – possibly sufficiently high to assume the presence of some pine trees in the area. The comparatively high values of *Picea*, *Ulmus* and *Corylus* are somewhat confounding. It is possible that these pollen grains come from the reworking of older sediments. The presence of the mentioned species in the area is unlikely in view of the reconstructed situation.

The pollen spectra of the samples 172 and 171 m, taken in a layer of sandy gravel (Fig. 2), indicate warm conditions during the time of their sedimentation. High pine pollen sums (91.3 and 89.3 %), the very low NAP values (1.9 and 3.3 %), and the only occasional occurrence of pollen grains of shade intolerant taxa indicate that the region was forested when the two samples were deposited. Pollen of the thermophilous trees *Quercus* and *Ulmus* is rare. On the other hand, *Tilia cordata*-type pollen is in no sample more frequent than in sample 171 m (1.8 %).

The pollen spectrum of sample 161 m, taken from sandy gravel, shows with 5.2 % *Artemisia*, 3.9 % Chenopodiaceae, 8.2 % Indeterminata, and a NAP sum of 21.5 % pointing to a return to climatic conditions similar to those prevailing when the clay of samples 185 m and 186 m was deposited. Evidently the forest had disappeared again. Only a few tree specimens may have been left in the area. It is remarkable that in this sample

the prequaternary reworked sporomorphs reach their absolute maximum, probably a result of intensive erosion of prequaternary pollen-bearing sediments by the rivers Fersina and Adige. Consequently the pollen concentration is low. With only 396 pollen grains per 1 cm<sup>3</sup> of sediment it is the lowest concentration value in our series of samples.

The samples 154 m (sandy gravel) (Fig. 2), 139 and 124 m (silty clay with sandy levels) document, with NAP values around 10 % and the occurrence of shade intolerant taxa, climatic conditions that were similar, although probably somewhat less severe, than those indicated by the pollen preserved in the lower part of the profile, below and above the 171 and 172 m samples (see above). Pieces of well-preserved wood prove the presence of *Pinus cembra* (sample 130 m) and of *Pinus mugo/sylvestris* (sample 139 m) in the region. The two pieces of wood were radiocarbon dated by wiggle matching to 12,280 ± 142 cal a (Table 2).

After the deposition of sample 124 m, the ecological situation changed markedly. Starting with sample 114 m, the NAP values are distinctly lower than before (mostly less than 5 %). *Pinus* stomata are more frequent. Pollen of *Hippophae* and *Artemisia*, although present in all but one (*Hippophae*) and three (*Artemisia*) of the 17 studied samples, is rare. *Ephedra* pollen was found in two of the nine pollen samples above the 124 m level only (3 pollen grains). These changed conditions lasted throughout all the time represented by the rest of the profile. Birch was probably present. Pollen of thermophilous deciduous trees like *Quercus*, *Ulmus*, and *Tilia* is recorded as before, with variable, but low, values. A few specimens of these trees only can have grown in the vicinity if their pollen grains did not come with the wind from more distant sites or was reworked.

In a layer of sand two pieces of *Juniperus* wood (samples 32 and 33 m), but no pollen grains of this shrub, were found. The radiocarbon age of the two pieces of wood is 11,603 ± 146 cal a BP (wiggle matching, Table 2).

## 6. DISCUSSION

### 6.1 The age of the sediment of the Fersina 2 well – general remarks

The deposition of the lacustrine sediment studied can have started only after the retreat of the Adige glacier to the north beyond the Trento area. The sediment met by the Fersina 1 and 2 wells can therefore be of late-glacial up to postglacial age only.

The following dating relies on pollen analyses and on four radiocarbon dates. Pollen analytical dating is based on the fact that most European tree species and important groups of herbs are anemogamous. Because such plants let the wind disperse their pollen grains, pollen diagrams of large areas are usually similar to each other. Therefore, a new profile can usually be dated by comparing the composition of its pollen assemblages and their changes with that of other not-too-distant, reliably dated pollen sequences.

The sampling sites next to Trento with pollen dia-

grams suitable for a comparison with the Fersina pollen data are mentioned below and are shown in Fig. 1. They are not the only pollen diagrams from this area, but the others are not detailed enough to be useful for our purpose, e.g. the preliminary diagram (with only seven pollen curves) from a peat profile at Isera near Rovereto, about 20 km south of Trento in the Adige Valley (Calderoni et al., 1996) and Kofler's diagrams from Bondone and Lago delle Buse (Kofler, 1994).

### 6.1.1 The Postglacial

Three detailed pollen analytical studies from the Trento area are available to answer the question whether the Fersina 2 profile can be of postglacial age. Two of the studied profiles come from filled-up lakes (Grüger, 1968), namely Bondone, at 1550 m, only 8 km southwest of Trento, and Fivè, at 654 m, about 25 km off Trento, west of Bondone. The third profile is from the extant lake of Lavarone, at 1115 m, about 20 km southeast of Trento (Filippi et al., 2007).

The most remarkable event during the early Postglacial was the expansion of the thermophilous deciduous tree genera *Quercus*, *Ulmus*, *Tilia*, *Fraxinus*, and *Acer* and of *Corylus* during the Preboreal (11,500 to 10,200 cal a BP), the first biozone of the Postglacial. Although the center of the distribution of these species lies in the lower altitudinal zones, the sum of their pollen values rises at Fivè (at 654 m) from low values to 30%, at Lavarone (1115 m) to 25 %, and to around 10% further up at Bondone (1550 m). It should be expected that the contemporary sedimentation in the Adige Valley produced, at least in the uppermost part of the profile Fersina 2, values not less than those found at Fivè and Lavarone; but the Fersina pollen data are mostly much lower. In 11 of the 17 studied samples the pollen values of the thermophilous deciduous tree genera are  $\leq 1\%$ , and in a further four samples between 1 and 2%. Only in samples 124 and 139 m are higher percentages reached (4.3 and 3.5 %, respectively, mainly oak pollen). These two samples can, however, not be of postglacial age if the results of the radiocarbon dating are accepted.

Also no hints can be found in the Fersina 2 pollen diagram of later important vegetational events like the immigration and spreading of *Fagus* and *Abies* trees, which were present in the area from about 8000 cal a BP. The pollen curve of *Fagus*, an important constituent of the montane forests, climbs to more than 40 % of the tree pollen sum at Lavarone and to more than 10 % at Bondone, and *Abies* reaches more than 15 % at both localities (J. Grüger, unpublished, counts available under <http://doi.pangaea.de/10.1594/PANGAEA.763901>). In the Fersina 2 samples, not a single pollen grain of *Fagus*, and only one pollen grain of *Abies* have been found.

Evidently no part of the Fersina 2 pollen diagram shows characteristics of the Holocene forest development. No section of the profile Fersina 2, the uppermost sandy gravel included, can be of postglacial age. The sediment of the entire Fersina 2 profile must have been deposited during late-glacial times, with the only exception of the colluvial material forming the modern surface in the area, a layer being too thin to be shown in the

stratigraphical scheme (Fig. 2).

### 6.1.2 The Late-Glacial

The Younger Dryas, the final part of the last glacial period, started around 12,700 cal a BP; it ended when the Holocene vegetation began to develop in the study area about 11,600 to 11,500 cal a BP (Vescovi et al., 2007). The radiocarbon ages of the four pieces of pine and juniper wood found in the Fersina 2 sediment (Table 2) prove that these tree species had been growing in the study area during Younger Dryas times. Being well preserved, these pieces of wood were probably not repeatedly transported, exposed, and temporarily embedded, so they most likely date the sediment in which they were discovered. If so, at least the part of the core between 32 and 139 m must be of Younger Dryas age.

The pollen spectra of the samples 3, 14, and 24 m do not distinctly differ from those of proven Younger Dryas age below. Apparently a Younger Dryas type of vegetation was still present in the Trento area when the uppermost 30 m of sediment (mainly sandy gravel) were deposited so that this sediment can hardly be of postglacial age. The radiocarbon age of the upper piece of wood (Table 2) allows, however, a deposition time of a few decades only so that a huge annual sedimentation rate must be assumed. To explain this one must not assume a climatic change, it is sufficient to consider the special conditions of sedimentation on an alluvial fan. Rivers usually shift over their alluvial fans. Where they flow they can accumulate huge amounts of sediment in a short time. The coarseness of the uppermost sediment indicates that at the time of the deposition of this material the River Fersina flowed and dropped its sediment load where the Fersina core was taken. Thus the thickness of the uppermost layer of sandy gravel cannot be used as an argument against a Younger Dryas age of this part of the profile as proposed by the pollen data.

Younger Dryas vegetation is documented in the profile downwards to sample 161 m. The next older pollen spectra (171 and 172 m) indicate distinctly warmer, though not interglacial, conditions. These spectra can only be of Allerød age.

Samples 185 and 186 m, the oldest samples of the Fersina 2 profile, contain a pollen flora which indicates cold conditions. This climatically unfavourable period can either be the colder middle part of the Allerød or one of the preceding cold phases of the late-glacial, namely the Older Dryas or the Oldest Dryas.

The Allerød is a tripartite interstadial, that is, it has a climatically less favourable phase sandwiched between warmer phases at its beginning and before its end. The cooler phase, called the Gerzensee oscillation, lasted a few hundred years only (250 years according to Greenland ice core isotope data, GRIP zone GI-1b, Björk et al., 1998, or 400 years according to Swiss lake sediment isotope data, Schwander et al., 2000). Although distinct in the oxygen isotope records, only a weak reaction of the vegetation is recorded by the pollen data. In Switzerland (sites Gerzensee and Leysin; Wick, 2000) and western Germany (site Meerfelder Maar; Stebich, 1999), a decrease in the importance of *Betula* pollen (percentages as well as concentrations and influx) is the most indicative reaction. The more

thermophilous vegetation growing at that time in Tuscany, 340 km south of Trento (Lago dell'Accesa, Drescher-Schneider et al., 2006), however, responded distinctly to the changed conditions as is clearly indicated by lowered *Quercus* and higher NAP (mainly Poaceae) values, and by a series of minor changes of a few further pollen curves (Accesa II oscillation). The pollen diagrams from the Trento area, Bondone, Fivè (Grüger, 1968) and Lavarone (Filippi et al., 2007) do not show any indication of a climatic deterioration during the Allerød, probably as no plant species requiring higher temperatures were present at that height and were at best rare at lower altitudes. The pollen diagram of Saltarino Sotto only, a low-lying site (194 m) 75 km southwest of Trento near Lake Garda (Grüger, 1968), shows changes in the Allerød time samples (320 cm and 325 cm) which most likely are the expression of a cooler climate. *Betula* values diminished by about 9 %, while NAP (about 10 %, mainly Poaceae and *Artemisia*) and juniper values (>1 % instead of 0.4 % before and 0.8 % after the oscillation) increased. The rise of the QM (*Quercetum mixtum*) curve – here mainly oak – stopped, but the rise continued when the climatic conditions improved, so that QM values of 30% were reached at the end of the Allerød. The QM values dropped to a much lower level during the following Younger Dryas stadial.

Considering the weak response of the vegetation around Saltarino Sotto to the Gerzensee oscillation, it appears unlikely that the change from forest (samples 171 and 172 m) to an open type of vegetation (185 and 186 m) at Trento was caused by this climatic deterioration. Consequently, part of the lower sandy gravel (Fig. 2) must represent the entire Allerød, the Bølling possibly included, interstadials during which the annual sedimentation rate was apparently much reduced compared to that of Younger Dryas time.

The two lowermost samples of core Fersina 2 (185 and 186 m) must date from either the Older or the Oldest Dryas. It is not possible to decide which of these two stadial phases is the one truly represented.

Fig. 2 shows that the lowermost clay of the profile Fersina 2 can be correlated with the uppermost part of a thick sequence of rather homogeneous fine grained lacustrine sediment in the 423 m long profile Fersina 1. As no drastic changes in the composition of the sediments are apparent, it is likely that the lower part of the profile Fersina 1 is also of late-glacial age. Older sediment is not likely to have escaped erosion by the water running off under the large, melting Adige glacier, especially in the middle of the valley where the coring site is located. Pre-Würmian sediment can be preserved only in rare sheltered positions.

## 7. CONCLUSIONS

In contrast to that supposed so far, the Fersina 2 profile does not reach back in time to the last interglacial. Instead, it was deposited totally during the youngest part of the Late-glacial, i.e., during Upper Palaeolithic times. The sedimentation of Fersina 2 (190 m of clay, sand and gravel) took only about 2500 to 3500 years, and it was finished before the Holocene (= Post-glacial) development of species-rich forests began. This

happened in the Trento area around 11,500 cal a BP, in archaeological terms, during Mesolithic times, several thousand years before the Neolithic culture reached the Trento area. The Ancient Neolithic units at the archaeological sites Riparo Gaban and Ala le Corone in Trento date from 6749-6993 and 6551-6892 cal a BP, respectively (Angelucci & Bassetti, 2009).

That the entire Fersina 2 sediment sequence was deposited during the Late-glacial is in agreement with the situation in the Eastern Alps, where the filling up of glacially over-deepened valleys was completed before the Postglacial started (van Husen, 1979).

The results of the Fersina 2 study necessitate re-considering the dating of the 193 m long profile P3, taken about 5 km north of Fersina 2 in the industrial zone of Trento at an elevation of 190 m (Venzo, 1957, 1979). Venzo stated that "The stratigraphical and sedimentological data testify to the existence of an ancient lacustrine basin immediately following the last glaciation in the Adige River Valley (*I dati stratigrafici e sedimentologici della serie testimoniano l'esistenza nella zona di Trento di un antico bacino lacustre di grande estensione, immediatamente successivo al ritiro dell'ultima glaciazione*)". Venzo called the basin also a "bacino lacustre post-würmiano", "a post-glacial lacustrine basin", definitely referring to the proper Postglacial (=Holocene). Venzo totally disregarded the preceding more than 15,000-year-long late-glacial period, during which the Adige Valley of the Trento area was ice free, a necessary condition of the deposition of the Fersina 1 and 2 sediment. As Venzo's site P3 (Venzo 1957) must have been located in the area of the same late-glacial lake as the Fersina 2 site, the P3 profile must also be of late-glacial age. This is even in agreement with Venzo's note cited above on the formation of the lake basin.

The same applies to the 30 m deep well Via Giuseppe Verdi in the center of Trento, 3 km north of the Fersina 1 and 2 wells (Fuganti et al., 1998). It may be surprising that in the core of this well, 11 m below the modern surface, a piece of wood with a radiocarbon age of only  $4710 \pm 80$  cal a BP (Table 2) was found in late-glacial sediment. This discrepancy can be explained if it is assumed that the meandering rivers Adige and Fersina cut channels into the late-glacial sediment which were later filled with material from the surroundings containing wood of (in this case) subboreal age.

The number of pollen types found in the Fersina 2 samples is low when compared with the Younger Dryas pollen samples of the other mentioned profiles. This difference results from the fact that their Younger Dryas samples contain the pollen rain of many years (e.g. about 14 and about 20 years, respectively, in the profiles Saltarino Sotto and Bondone) whereas the Fersina 2 samples contain, due to the huge annual sedimentation rate, less than one year's pollen precipitation only. As pollen analytical dating is mostly based on common pollen types, the Fersina 2 pollen data are sufficient to date the core, they but are not detailed enough to discuss problems of the North Italian vegetation history.

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