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POLLEN DATA FOR A BIOSTRATIGRAPHY OF LGM IN THE VENETIAN PO PLAIN

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ABSTRACT
During the last forty years many works have been published on sedimentary sequences from the planitial area of north-eastern Italy. Many Authors refer about stratigraphic sequences which contained peat layers at different depths from the ground level. Radiocarbon dating of peats has been given ages ranging from 22,500 to 18,000 yr BP. The area with suitable conditions for the formation of peat, seems to cover all the Venetian planitial area for a brief period of time during the LGM. We are interested in the microfossil content of LGM peats, because it can contribute to the definition of past local hydrological conditions. We would like to answer to the following questions: i) can we say that the same type of vegetation has formed the LGM peats? ii) can we hypothesize that the same hydrological conditions were established during LGM in the plain? iii) can we use the peat horizon as a biozone for the Venetian Plain? We approach the topic by analysing new pollen data of peat sediments from a coastal area at the north of the Venice Lagoon, by means of a new statistical method of data analysis, namely the NonParametric Combination of Dependent Permutation (NPC) Tests (Pesarin, 2001). The statistical analysis of pollen data does not include the pollen records from other sites (Tab.1), since they are not entirely reported in literature; therefore a successful comparison was not achievable. The NPC Test results confirm that there aren't significant differences between the peat sediments. Hence we can assert that the area was mostly covered by Cyperaceae and Poaceae, and this confirm our hypothesis. Some other herbaceous taxa were present and many taxa of Fungi, Algae and Mosses. Studies for the identification of the latter and other plant fragments are in progress and they will lead to a finer characterization of the plant community.

RIASSUNTO
Elementi palinologici per una biostratigrafia dell'ultima espansione glaciale nella pianura padano-veneta.
Negli ultimi quarant'anni sono stati pubblicati molti risultati di ricerche su sequenze sedimentarie provenienti dall'area planiziale dell'Italia nord-orientale. Molti Autori hanno segnalato la presenza di strati torbosi di un'età compresa tra i 22.500 e i 18.000 a B.P., a profondità diverse dal livello di campagna. Ciò suggerisce l'ipotesi che condizioni adatte alla formazione di torbe si siano instaurate in un'area che copriva gran parte della pianura veneta per un breve periodo di tempo in corrispondenza dell'ultima massima espansione glaciale (LGM). Lo studio dei microfossili vegetali contenuti nelle torbe può contribuire alla ricostruzione delle condizioni idrologiche in cui si formarono le torbe e a rispondere alle seguenti domande: i) un unico tipo di vegetazione ha formato le torbe LGM della pianura veneta? ii) possiamo ipotizzare che le stesse condizioni idrologiche si siano instaurate nella pianura durante l'ultima espansione glaciale? iii) l'orizzonte torboso può essere considerato una biozona per la pianura veneta? Abbiamo iniziato ad affrontare queste problematiche analizzando nuovi dati pollinici ottenuti dall'esame di torbe estratte in quattro sondaggi eseguiti nell'area costiera a nord della Laguna di Venezia. I dati pollinici sono stati confrontati attraverso un nuovo metodo di analisi statistica, il NonParametric Combination of Dependent Permutation *(NPC)* Tests *(Pesarin, 2001), al fine di verificare l'esistenza di differenze tra i contenuti pollinici dei diversi campioni torbosi. I dati pollinici di altri Autori (Tab.1) non sono stati compresi nell'analisi eseguita, perché riportati solo parzialmente negli articoli pubblicati. L'NPC Test non ha individuato differenze tra i dati pollinici delle torbe esaminate, quindi possiamo ipotizzare che l'area a nord della Laguna di Venezia fosse occupata da una comunità di piante erbacee produttrici di torbe, caratterizzata dalla prevalenza di Cyperaceae e Poaceae, dalla presenza di* Callitriche, Caltha palustris, Hydrocharis morsus-ranae, Menyanthes trifoliata, Lemna, Myriophyllum verticillatum, Nuphar luteum, Potamogeton *subg.* P*. type e da molti taxa di funghi, alghe e briofite. Il riconoscimento di quest'ultimi, la cui analisi è tuttora in corso, sarà di ulteriore aiuto nella ricostruzione dell'intera comunità vegetale.*

Parole chiave: Pianura padano-veneta, analisi pollinica, NPC Test, Ultimo Massimo Glaciale

Keywords: Venetian-Po Plain, Pollen analysis, NPC Test, Last Glacial Maximum

INTRODUCTION

During the last forty years many works have been published on sedimentary sequences from the planitial area of north-eastern Italy. They report results of lithological, stratigraphical, geological and paleobiological studies (Bertolani Marchetti, 1967; Bortolami *et al.*, 1977; Paganelli, 1996a; Rizzi Longo, 1996; AA. VV., 1999; Serandrei Barbero *et al.*, 2001). These works have contributed to a better knowledge of the evolution of the area, during Late Quaternary. They show the importance of floodplain sediments as valuable sources of information for paleoenvironmental reconstruction. In the Venetian alluvial Plain the sedimentation has been greatly influenced by the evolution of the principal fluvial systems (Adige, Brenta, Piave and Tagliamento) and by the sea-level fluctuations (Castiglioni & Pellegrini, 2001; Bondesan *et al.*, 2002). Moreover the continental sedimentary sequences from different sites of the plain cannot be easily correlated using lithological data. As far as it concerns the microfossil content of the sediments, it is quite poor in sands, silts and sometimes also in clays: therefore this excludes the use of a biostratigrapic approach to correlate these kinds of sediments.

Nevertheless, many Authors refer about stratigraphic sequences, which contained peat layers at different depths from the ground level (Bortolami *et al.*, 1977; Accorsi *et al.*, 1984; Castiglioni *et al.*, 1987; Paganelli *et al.*, 1988; Accorsi *et al.*, 1989; Marocco, 1989; Calderoni *et al.*, 1996; Mullenders *et al.*, 1996; Paganelli, 1996b; Miola & Gallio, 1997; Lezziero, 1999; Iliceto *et al.*, 2001; Serandrei Barbero *et al.*, 2001). Radiocarbon dating of peats has been given ages ranging from 22,500 to 18,000 yr BP, i.e. the period of peat sedimentation is the LGM (Tab. 1). Pollen content has been analysed in some of them, but pollen data have not been correlated at a regional scale. The area with suitable conditions for the formation of peat during the LGM, seems to cover all the Venetian planitial area (Fig. 1). Studies on this topic are in progress at the Dept. of Geography (University of Padova). If they confirm that peat layers have been formed during a brief period of time, as some radiocarbon dates seem to suggest, and in an extensive regional area, their deposition may be considered a stratigraphic event for the Venetian Plain.

We are interested in the microfossil content of LGM peats. Peat originates mostly from the remains of plant communities, that live in waterlogged conditions. The quality of water, i.e. its dissolved mineral salts content, and the hydrological conditions determine the types of vegetation that live in a peatland (Goodwin, 1981). Therefore, pollen and spore analysis of peat sediments and the identification of other plant fragments can contribute to the definition of past local hydrological conditions.

We would like to answer to the following que-

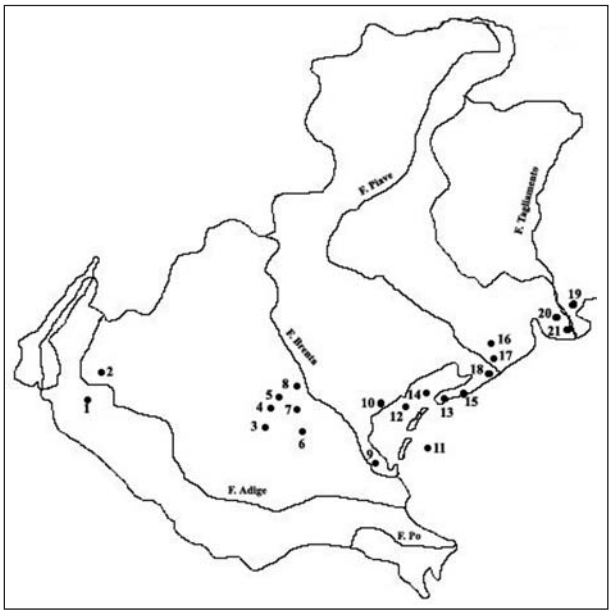

Fig. 1 - Location of sites where peat layers from 22,500 to 18,000 yr BP have been found.

Ubicazione dei siti nei quali è stata segnalata la presenza di strati torbosi di età compresa tra 22.500 e 18.000 anni BP.
1) Bernascone (VR), 2) Basso Acquar, 3) Orgiano (VI), 4) Villaga Barbarano (VI), 5) Rubano (PD), 6) Galzignano (PD), 7) Padova, 8) Alveo Brenta (PD), 9) Conca Romea (VE), 10) Motte di Volpego (VE), 11) Pozzo Venezia 1bis (VE), 12) La Fenice (VE), 13) Punta Sabbioni (VE), 14) Sant'Erasmo (VE), 15) Treporti (VE), 16) Fiorentina (VE), 17) Palazzetto (VE), 18) Ca'Fornera (VE), 19) Crosere (UD), 20) Latisana (UD), 21) Laguna di Marano (UD).

Sites	Depth from the ground level (m)	^{14}C conventional datings (yr B.P.)	Pollen analysis	References
Bernascone (VR)	5.6-5.7	18,870 ± 300	+	Accorsi *et al.*, 1989
Basso Acquar (VR)	16.0-21.0	18,800 ± 2000	+	Accorsi *et a*l., 1984
Orgiano (VI)	4.4-4.5	17,760 ± 160	+	Paganelli, 1996b
Villaga Barbarano (VI)	6.05-6.25	19,250 ± 210	+	Paganelli *et al.*, 1988 Paganelli, 1996b
Rubano 5 (PD)	9.40-9.46	19,200 ± 250		Castiglioni *et al.*, 1987
Rubano 4 (PD)	7.94-8.00	18,100 ± 700		Castiglioni *et al.*, 1987
Padova C. Scrovegni B	15.0	19,830 ± 220		Iliceto *et al.*, 2001
Galzignano (PD)	3.3-3.4	19,000 ± 1200	+	Calderoni *et al.*, 1996 Miola & Gallio, 1997
Alveo Brenta (PD)	15.5-15.9	20,250 ± 900		Bortolami *et al.*, 1977
Motte di Volpego (VE)	10.6	19,620 ± 315	+	Bortolami *et al.*, 1977 Bertolani Marchetti, 1967
Sant'Erasmo (VE)	19.0-19.4	19,250 ± 300		Bortolami *et al.*, 1977
Treporti (VE)	27.5	22,440 ± 500		Bortolami *et al.*, 1977
Punta Sabbioni (VE)	18.0-18.5	20,000 ± 400		Bortolami *et al.*, 1977
Conca Romea (VE)	13.2-13.4	20,950 ± 900		Bortolami *et al.*, 1977
Conca Romea (VE)	6.4-6.7	19,410 ± 800		Bortolami *et al.*, 1977
La Fenice (VE)	12.0	20,120 ± 90		Serandrei Barbero *et al.* 2001
Ponte Moro 1 (VE)	10.19	19,700 ± 250		Serandrei Barbero *et al.* 2001
P.zo Venezia 1bis (VE)	24.3	21,750 ± 730	+	Mullender *et al.*, 1996
Venezia	12.0-10.0	19,800 ± 250		Lezziero, 1999
Laguna di Marano S9	22.0	20,200 ± 720		Marocco, 1989
Candelù (TV)	20.3-20.5	19,170 ± 400		Bortolami *et al.*, 1977

Tab.1 - Peat layers and relative ^{14}C dates in the Venetian Plain from literature.

Età ^{14}C convenzionali di strati di torba rinvenuti nella Pianura Padano-Veneta già pubblicati.

stions: i) can we say that the same type of vegetation has formed the LGM peats? ii) can we hypothesize that the same hydrological conditions were established during LGM in the plain? iii) can we use the peat horizon as a biozone for the Venetian Plain?

The purpose of this work is to approach the topic by comparing pollen data from peat sediments using a suitable statistical method. We recently analysed pollen and spores content of peat from a coastal area at the north of the Venice Lagoon. Peat samples from Palazzetto (PAL-1819, PAL-1834, PAL-2034, PAL-2039, PAL-2049), Fiorentina (FIO-1988, FIO-1992), and Ca' Fornera (CAF-1956, CAF-1967, CAF-1978, CAF-1989) have been drilled near the River Piave, between San Donà di Piave (Venezia) and the coast of the Adriatic Sea, at a depth of about 20 m from the ground level (Bondesan *et al.*, 2003). Latisana samples (LAT-410, LAT-420) have been drilled near the Tagliamento river at a depth of about 4 m. Latisana samples have been radiodated 18,100±100 yr BP (Fontana, pers. comm.). Radiodating of the other samples are in progress. All the samples are characterized by low percentages (<20%) of arboreal taxa, among which *Pinus* is the most abundant, followed by *Betula, Abies, Picea, Larix, Ephedra* and *Juniperus*. Boreal broadleaf plants are rare. The grasses are represented by local aquatic plants and by Cyperaceae, Poaceae, *Artemisia*, Chenopodiaceae, Caryophyllaceae, Asteraceae Asteroideae and Apiaceae. This fossil pollen assemblage is indicative of a very sparse arboreal vegetation, with cold-climate taxa and it is often correlated to the last pleniglacial period (Paganelli, 1996a)

We compared our pollen records by means of a new statistical method of data analysis, namely the NonParametric Combination of Dependent Permutation (NPC) Tests (Pesarin, 2001). This new method has been adopted because the data configuration is characterized by a relatively high number of variables, i.e. pollen taxa, compared to the number of statistical units, i.e. peat samples. In this situation a standard multivariate approach, as Principal Component Analysis, is not appropriate and applicable and in general it does not permit any kind of decision on the problem of determining whether there is an equal distribution of pollen associations among the sites. Moreover, a classical inferential approach as MANOVA (Multivariate Analysis of Variance), apart from the very strong assumption of normality, is itself not allowed with a relatively small sample size as in our case (Pesarin, 2002). On the contrary, the NPC methodology frees the researcher from stringent assumptions of parametric methods and allows a more flexible analysis by specifying both multivariate and univariate hypotheses. One of the most relevant features of NPC Test is that it does not need a modelling for dependence among variables.

Pollen records have been subdivided into three groups, Ca' Fornera (n° of records = 4), Fiorentina-Latisana (n° of records = 4) and Palazzetto (n° of records = 5). The considered pollen taxa are 20, but some of them have been joined and rare taxa and spore types have not been included. Pairwise comparisons between groups of the relative frequencies of taxa have been performed with the aim of determining whether an equal distribution of pollen association is supported or not by our data set.

The statistical analysis of pollen data does not also include pollen records from other sites (Tab.1), as they are not entirely reported in literature: hence a successful comparison was not achievable.

STATISTICAL ANALYSIS OF POLLEN DATA

Our statistical analysis starts with a descriptive overview of collected data. Table 2 shows the mean and the standard deviation of the relative frequencies for all the pollen taxa included in our analysis; they are divided by site and also pooled for all sites.

For the most important taxon, i.e. Cyperaceae, we also provide a frequency graph (Fig. 2), where an equal

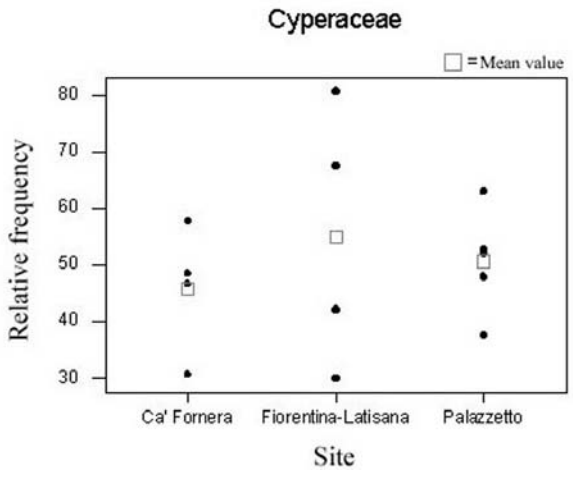

Fig. 2 - Frequency distribution of Cyperaceae on the three sites.

Distribuzione di frequenza delle Cyperaceae nei tre siti.

Table 2 - Descriptive statistics for all considered taxa within each site.

Statistiche descrittive per i taxa analizzati in ogni sito.

Tags	POOLED		Ca' Fornera		Fiorentina-Latisana		Palazzetto	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Abies + Picea	0.8	1.2	0.2	0.2	2.0	1.7	0.2	0.2
Betula	1.0	0.9	1.0	0.3	0.6	0.9	1.3	1.3
Ephedra + Juniperus	1.1	1.5	1.9	1.4	1.6	2.1	0.2	0.2
Larix	0.7	1.1	0.5	0.1	0.1	0.2	1.4	1.6
Broadleaves + Shrubs	1.6	1.8	1.6	1.9	0.2	0.2	2.7	1.8
Pinus undiff.	6.4	3.3	5.6	1.7	8.0	4.2	5.7	3.7
Riparial trees	3.6	5.7	0.4	0.4	6.5	8.9	3.8	4.3
Other herbs	0.9	1.1	1.5	1.7	0.6	1.1	0.8	0.3
Apiaceae	0.3	0.3	0.5	0.4	0.1	0.2	0.3	0.3
Artemisia	3.4	2.7	2.2	1.9	3.8	3.3	4.0	2.9
Asteroideae	0.4	0.4	0.6	0.3	0.2	0.4	0.4	0.4
Caryophyllaceae	0.4	0.5	0.7	0.7	0.4	0.5	0.1	0.2
Chenopodiaceae	0.6	0.7	0.7	0.7	0.4	0.5	0.7	0.9
Cyperaceae	50.6	14.4	45.9	11.3	55.1	23.1	50.7	9.2
Hydrophytes	3.2	3.6	4.9	4.3	2.4	4.3	2.5	2.8
Plantago lanceolata type	0.2	0.3	0.4	0.3	0.0	0.0	0.3	0.3
Poaceae	16.0	9.4	8.4	3.6	17.7	11.8	20.8	7.8
Potamogeton	0.9	0.7	1.4	0.5	0.3	0.6	1.0	0.6
Equisetum	7.4	11.5	20.8	13.2	0.2	0.4	2.5	2.8
Ferns	0.5	1.0	0.9	1.5	0.0	0.0	0.7	0.8

distribution among sites could be possible.

By means of a boxplot (Fig. 3) we also provide a visual measure of the pooled distribution for the most relevant taxa or group of taxa, that are *Pinus* undiff., Cyperaceae, Poaceae and hydrophytes.

A simple descriptive analysis is only the first step of the work but we are not able to take a decision concerning a possible equal distribution of the relative frequencies of taxa among the sites. For this purpose we perform a NPC Test analysis, considering each single taxon and the global distribution of all taxa considered together.

The NPC Test hypothesis system can be expressed in the following formal form,

$$\begin{cases} H_0\colon [P_A = P_B] = \left[\boldsymbol{X}_A^{\,d} = \boldsymbol{X}_B\right] \\ H_1\colon [P_A \quad P_B] = \left[\boldsymbol{X}_A^{\,d} \quad \boldsymbol{X}_B\right] \end{cases} \Rightarrow \begin{cases} H_0\colon \left[\bigcap_{i=1}^{k} X_{Ai}^{\,d} = X_{Bi}\right] = \bigcap_{i=1}^{k} H_{0i} \\ H_1\colon \left[\bigcup_{i=1}^{k} X_{Ai}^{\,d} \quad X_{Bi}\right] = \bigcup_{i=1}^{k} H_{1i} \end{cases}$$

where *A* and *B* represent two sites, and X_i represents the frequency of a given taxon (the *i*-th). The null hypothesis H_0 states an equal global (multivariate) distribution between the two groups of all taxa (letter **X** bold) considered together. The global null hypothesis is broken down into a set of *k* (20 in our study) partial null subhypotheses H_{0i} which states an equal single (univariate) distribution for the i-th taxon between the two groups. For a detailed introduction and explanation of NPC Test methodology we refer to Pesarin (2001). NPC Test solutions are provided by the new and innovative statistical software NPC Test 2.0 (more details at www.methodologica.it) that implements the NPC methodology offering both flexibility and a user-friendly interface.

As result of NPC analysis (Tab. 3), we obtain for each pairwise comparison a set of 20 *p*-values concerning with each taxon and finally another one *p*-value relating to the global null hypothesis. We should remember that a *p*-value less than the adopted significance α-level (in our case 5%, i.e. 0.05) means that there is a significant difference in the frequency distribution between the groups.

CONCLUSIONS

The NPC Test results confirm that there aren't significant differences between peat sediments of the three groups if we look at their pollen associations (all global *p*-value are greater than 0.05). Therefore we can support our hypothesis, that a plant community mostly consisting of Cyperaceae and Poaceae covered the entire area. Some other herbaceous taxa were present, e.g. *Callitriche, Caltha palustris*, *Hydrocharis morsus-ranae, Menyanthes trifoliata, Lemna, Myriophyllum verticillatum, Nuphar luteum, Potamogeton* subg. *P*. type and many taxa of Fungi, Algae and Mosses. Studies for the identification of the latter and other plant fragments are in progress and they will lead to a finer characterization of the plant community.

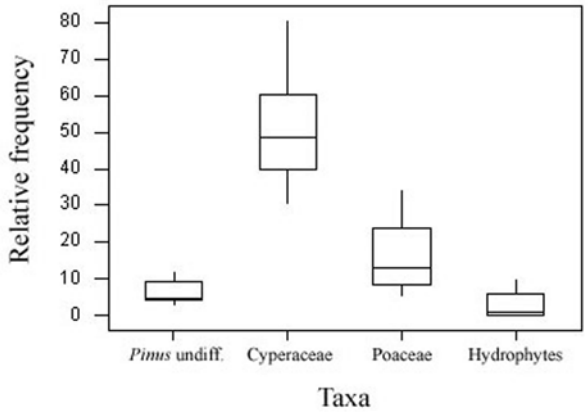

Fig. 3 - Relative frequencies distribution of the most relevant taxa.

Distribuzione delle frequenze dei taxa più rilevanti.

Our results agree with the literature, in fact pollen analyses in Tab. 1, showed dominance of herbaceous plant pollen, mostly of Cyperaceae and Poaceae, but little information about the other herbaceous plants.

Our research is continuing with pollen and fungi, algae and bryophytes microfossils analysis of LGM peats from other sites of the Venetian Plain in Padova and near Treviso.

Tab. 3 - *P*-values table provided by NPC Test analysis.
Bold characters indicate values which are lower than the adopted significance α-level (0.05).
Tabella dei p-values ottenuta con l'analisi NPC Test. I numeri in grassetto indicano il valore di significatività inferiore allo 0,05.

Taxa	Ca' Fornera vs Fiorentina-Latisana	Ca' Fornera vs Palazzetto	Fiorentina-Latisana vs Palazzetto
Abies + Picea	**.029**	.716	**.008**
Betula	.411	.945	.425
Ephedra + Juniperus	.830	**.048**	.206
Larix	.059	.367	.190
Broadleaves + Shrubs	.087	.387	**.014**
Pinus undiff.	.399	.985	.350
Riparial trees	.286	.079	.594
Other herbs	.463	.500	.796
Apiaceae	.254	.354	.362
Artemisia	.509	.327	.917
Asteraceae Asteroideae	.117	.359	.529
Caryophyllaceae	.572	.129	.418
Chenopodiaceae	.479	1.00	.649
Cyperaceae	.510	.513	.725
Hydrophytes	.451	.332	.975
Plantago lanceolata type	.141	.737	.169
Poaceae	.119	**.031**	.653
Potamogeton	.058	.249	.119
Equisetum	**.029**	**.008**	.158
Ferns	.428	.687	.165
GLOBAL	.166	.086	.070

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