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PALEOENVIRONMENTAL RECONSTRUCTION FROM LGM TO HISTORICAL TIME IN THE LOWER COASTAL PLAIN OF THE PIAVE RIVER. PRELIMINARY POLLEN ANALYSIS ON A 20 M CORE OF LAGOON AND FLUVIAL SEDIMENTS

Aldino Bondesan[1], Mirco Meneghel[1], Antonella Miola[2] & Gianna Valentini[2]
[1] Dept. of Geography, University of Padova, Via del Santo 26 - 35123 Padova
[2] Dept. of Biology, University of Padova, Via G. Colombo 3 - 35131 Padova

ABSTRACT
This work presents the first results of a multidisciplinary study in the flood plain of the Piave River located NE of the Venice Lagoon. The aim of the work is to reconstruct the late Quaternary geomorphological evolution of the area. This study is part of a wider research on the Veneto-Friuli plain based on geomorphological surveys, remote-sensing, sediment analyses, archaeological and historical map analyses. In the frame of this study, three cores of 20 m depth were collected along a N-S transect 20 km long between San Donà di Piave and the coast of the Adriatic Sea. The transect crosses the present course of the Piave River and its fluvial ridge, while the corings were performed on the surface of old flat marshes, now reclaimed. Pollen-stratigraphical data and ^{14}C dates are presented for the intermediate core of Palazzetto. The results of radiocarbon dating indicate that the sequence spans the Last Glacial Maximum (LGM) and the Holocene. At the base of the sequence, a peat layer (21,250±150 yr BP) is characterised by dominance of Cyperaceae (pollen, epidermal and roots fragments, fruits) as many other peat layers formerly described by other Authors in the Veneto and Friuli plain. Fine fluvial sediments attributed to the Piave River bury the basal peat. The changes in the local plant communities from fresh water to brackish/salt water communities have been recognised at the depth of ca. 6 m. This level testifies the Flandrian transgression not yet investigated in the San Donà di Piave area. The geochronological dating and the pollen analysis of the three cores will let us know the dynamic of the ingression of the sea at NE of the Venice Lagoon. At the top of the core the pollen assemblage of a peat layer (500±70 yr BP) suggests the presence of a marsh environment.

RIASSUNTO
Ricostruzione paleoambientale dell'area planiziale costiera del basso Piave dall'ultimo massimo glaciale all'Olocene. Analisi polliniche preliminari di una carota di 20 m di sedimenti fluviali e lagunari. *Questo contributo riporta i primi risultati di un'indagine multidisciplinare condotta nella pianura alluvionale del Fiume Piave a NE della Laguna di Venezia. Lo scopo della ricerca è di comprendere l'evoluzione geomorfologica dell'area nel Quaternario recente. Essa è parte di un vasto studio della Pianura veneto-friulana, condotto attraverso indagini geomorfologiche,* remote-sensing*, analisi dei sedimenti, analisi di mappe storiche e di reperti archeologici. In questo contesto sono stati eseguiti tre carotaggi fino a 20 m di profondità, collocati lungo un transetto N-S della lunghezza di una ventina di km tra San Donà di Piave e la costa settentrionale del Mare Adriatico. Il transetto attraversa l'attuale corso del Fiume Piave e il suo dosso fluviale. I carotaggi sono stati eseguiti in corrispondenza di antiche aree paludose, oggi bonificate. In questo lavoro vengono presentati i risultati dello studio della sequenza di Palazzetto, collocato circa a metà del transetto. Lo scarso contenuto pollinico dei sedimenti analizzati limita l'utilizzo dei dati pollinici alla ricostruzione dei cambiamenti avvenuti nell'ambiente di sedimentazione. I risultati della radiodatazione di quattro livelli di sedimenti organici fanno ritenere che la sequenza si sia deposta tra l'ultimo massimo glaciale e l'Olocene recente. Alla base sono stati individuati strati torbosi (21.250±150 a BP) a prevalenti Cyperaceae (polline, frammenti di radici e di epidermidi, frutti), caratterizzati dalla stessa flora pollinica di altri depositi torbosi, già descritti da vari Autori in sequenze della pianura veneta e friulana, di età compresa tra i 18.000 e i 22.000 anni BP. Le torbe basali sono ricoperte da depositi sabbiosi e limosi fluviali attribuiti alle esondazioni del Piave e depostisi in un breve periodo di tempo, circa 2000 anni. Le analisi polliniche indicano un radicale cambiamento nelle comunità vegetali locali nei sedimenti argillo-torbosi collocati a circa 6 m di profondità (6520±150 a BP): comunità vegetali di acqua dolce sono sostituite da comunità tipiche di ambienti di acque salate/salmastre. Questi sedimenti sono la prima testimonianza della trasgressione Flandriana nella zona di San Donà di Piave. Alla sommità della sequenza è stato analizzato uno strato torboso di età radiometrica di 500±70 a BP (Cal AD 1300-1500); l'associazione pollinica esaminata suggerisce la presenza locale di comunità di piante prevalentemente erbacee di palude e nessun indizio di insediamenti umani.*

Key words: Late Glacial Maximum, Holocene, stratigraphy, geomorphology, pollen and spores analysis, Piave River, North Adriatic.

Parole chiave: Ultimo massimo glaciale, Olocene, stratigrafia, geomorfologia, analisi di polline e spore, fiume Piave, Nord Adriatico.

INTRODUCTION

The paleoenvironmental reconstruction of the Venice area has been the aim of several multidisciplinary researches (Bortolami *et al.*, 1977; Castiglioni & Favero, 1987; Blake *et al.*, 1988; Correggiari *et al.*, 1996; Mullenders *et al.*, 1996; Serandrei Barbero *et al.*, 2001; Kent *et al.*, 2002). The main task of these studies is the improved knowledge of subsidence phenomenon in the past and the effects of human activities on its evolution. The nearby coast located NE is poorly known, even if its evolution in the past influenced or has been influenced by the hydrological conditions of the Venice area. Therefore a wider research on the Veneto-Friuli plain has started some years ago. It is based on geomorphologic surveys, remote-sensing, sediment analyses, archaeological and historical map analyses (Bondesan *et al.*, 1998; Bondesan, 2000; Bondesan & Furlanetto, 2000; Bondesan *et al.*, 2002a; Bondesan *et al.*, 2002b; Ghedini *et al.*, 2002). In the framework of this study, we collected three continuous cores along a 20 km long N-S transect that goes from San Donà di Piave to the coast of the Adriatic Sea (Fig. 1), hopefully contributing to the study of evolution in the Venetian coastal plain of the past by means of pollen and spore analysis. In this paper ^{14}C dates and pollen-stratigraphic data are

presented for the intermediate core of Palazzetto.

The studied area is located along the modern course of the Piave River, at the north-eastern border of the Lagoon of Venice, into the coastal plain between Sile and Livenza Rivers. The territory is characterised by a dense hydrographical network, where the main rivers (Piave, Sile and Livenza) which are south-eastwards oriented, flow in connection with the artificial canals dug in XIII century by the Republic of Venice. Due to the hydraulic reclamation, a closed network of small canals and ditches crosses the whole plain. There are many evident traces due to the ancient shorelines, back from the present coastline; from them we can establish the existence of at least two paleo-Piave deltas, now extinct and buried. The plain surface is mainly constituted by agricultural fields, most of which laying below the sea level: the lower elevations are found northern of Caorle (Livenza mouth), where they locally reach values lower than 4 m below sea-level. Higher heights mainly stand along fluvial ridges and old dunes closed to present littoral. All this territory was scattered by wide swamps, marshes and lagoons until the end of XIX century when the reclamation started, joined with a strong reduction of old dunes and fluvial ridges.

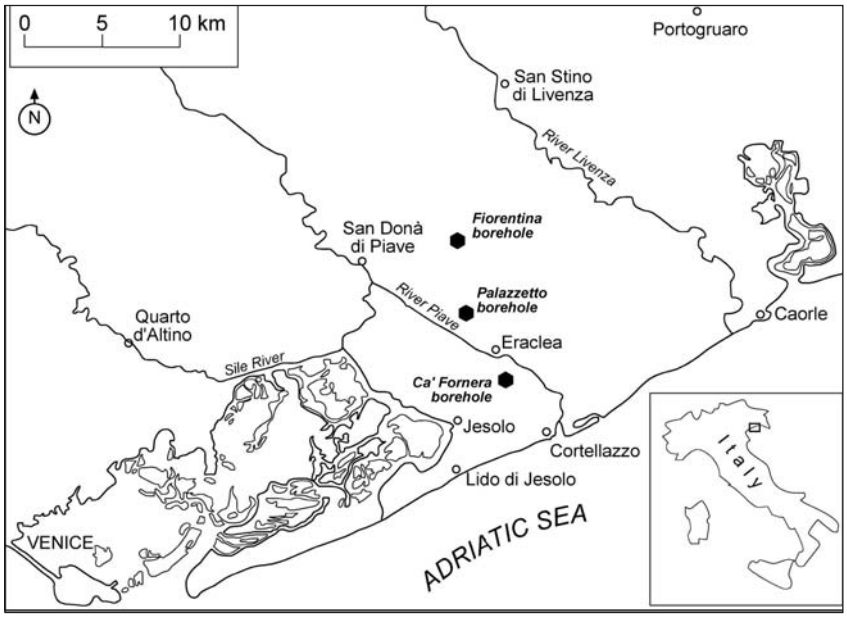

Fig.1 - Location map of the studied area.

It is well known that during the last strong cold pulsation of the Pleistocene the sea level dropped more than one hundred metres below the present one. Because of the shallowness of the Adriatic Sea, the coast in the LGM shifted towards south for more than 200 km to the latitude of Ancona. The present North Adriatic Sea was then a fluvial plain where all the rivers of the Po Plain converged and perhaps joined. The Venetian plain was then rich of marshes and swamps that left extended layers of peat dating from ca. 22,000 to 18,000 yr BP (Bondesan *et al.*, 2002b). At the same time, huge glaciers flowed south from the Alps and the majority of them reached the plain. The glacier of the Piave River basin had two snouts at Quero and Vittorio Veneto where it left its moraines. An end moraine of the Vittorio terminus has been dated to 17,670 ± 320 yr BP (Bondesan, 1999); from that date onwards the glaciers started to retreat as a consequence of the climatic improvement. Along with the glaciers retreat, the sea level started to lift and the coast shifted again to the north (Flandrian transgression). According to Brambati (1985) the coastline reached a position similar to the present one at about 7-6000 yr BP, while Correggiari et al. (1996) fixed the maximum sea ingression around 5000 calendars years BP, by the dating of lagoonal sediments.

The transgression probably joined with changes in the rivers hydrological state, and this led to an instability of the lower reaches of the rivers that could be affected by avulsions as happened for the Rhine and Mose Delta as described by Stouthamer (2001). An avulsion node is that of San Donà di Piave, from which starts the fluvial ridge crossed by the transect described in this paper.

GEOMORPHOLOGICAL OUTLINES

The plain belonging to the Piave River (Fig. 2) is a complex form, generated by deposition and erosion phenomena mainly due to fluvial sediments, with contributions of fluvio-glacial and marine deposits. Looking from the point where the mountains merge into the plain, at the height of Nervesa, we found a progressive change from the large fan of the foothills to the low plain and finally to the proper coastal plain, this last one being the result of the interference of marine and fluvial dynamics. Looking at the altimetry the surface lies between 80 m above sea level at Nervesa and 4 m below sea level along the coast. The system of the high plain is formed by a sequence of great, flat, gravelly alluvial fans that lie one overlaid to the other on the Prealpine border (Bondesan, 2000).

The Nervesa fan, which constitutes the Nervesa Unit, is furrowed by the present Piave River bed (Bondesan *et al.*, 2002b); it started to form soon after the Upper-Pleistocene fluvial diversion of the Piave River from the Montebelluna to the Nervesa course. The fan is not very steep, showing a dip of 3-4‰ at the apex and 1.5-2‰ uphill of the alignment Treviso-Ponte di Piave; downhill it is less than 1‰. Its gravelly sandy sediments extend eastward up to Oderzo, coming close to River Livenza. There are five main recognizable fluvial ridges and all of them start from the fan apex at Nervesa; they are related to paleo-Piave beds and to the present fluvial ridge of the Piave River, which is continuously elevated on the plain as far as the mouth. Almost all the traces, visible on aerial photographs, situated on the left wing of the Nervesa fan, can be classified as braided streams; they have been dated from 4170±60 yr BP to present day. Descending towards the sea, the low plain is found where the hydrographical network becomes denser, the gradient decreases and the sediments become finer. Here we find fluvial ridges both along present river courses and also along abandoned rivers. Sometimes, a small watercourse interpre-

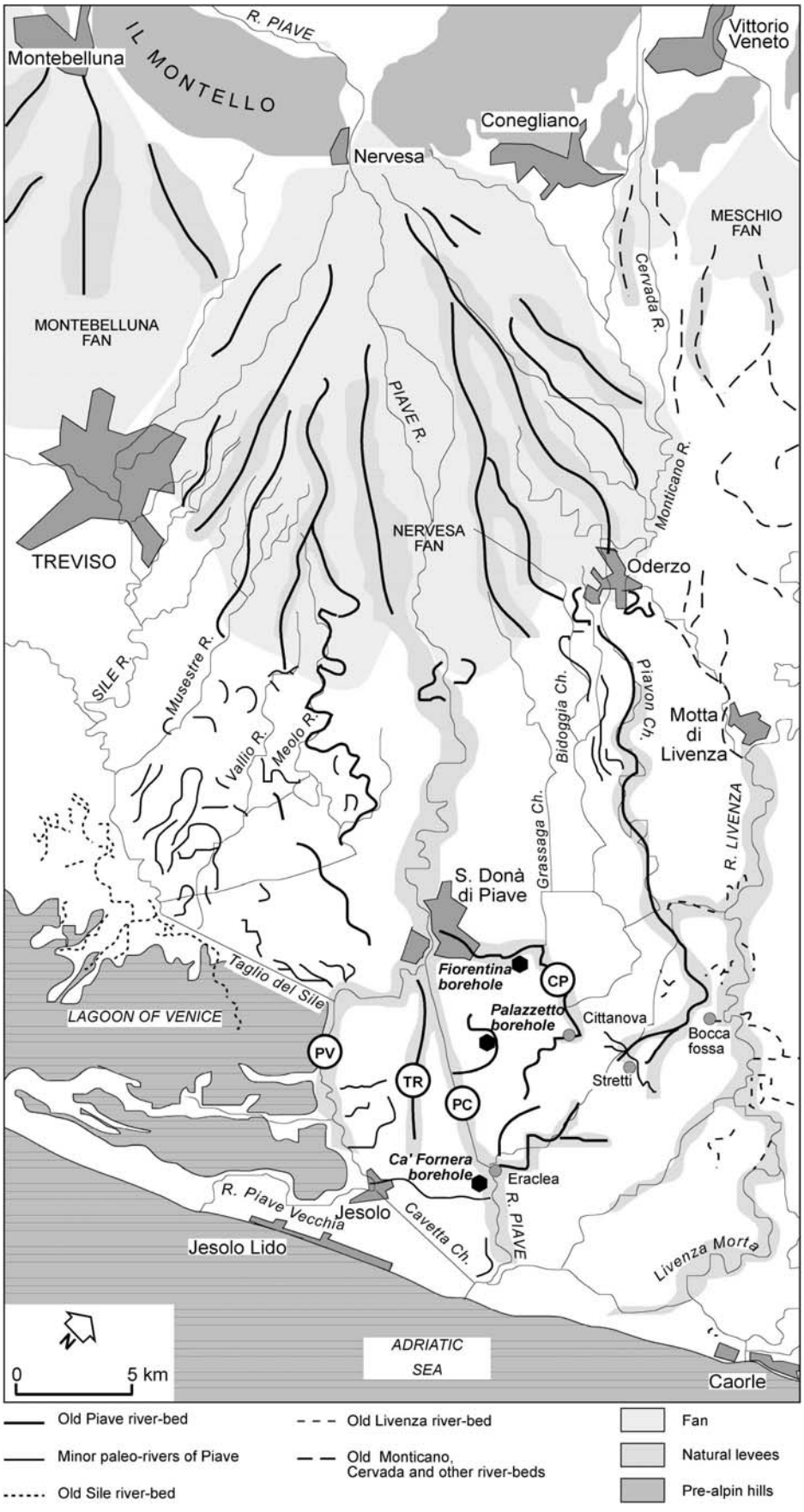

Fig. 2 - Geomorphological sketch map of the Piave River plain.

ted as relict hydrography remains on the top of the ridge. This process leads to the formation of a network of ridges surrounding closed or semi-closed hollows where the drainage is barred.

S. Donà di Piave constitutes an avulsion node, from which different watercourses in different times depart. There are four main ridges branching out from this point across the coastal plain. The western one is the Piave Vecchia ridge (PV in fig. 2), rimming the Venice Lagoon border. Eastwards, the Taglio da Re ridge (TR in fig. 2) gains the Cavetta Channel, back of Jesolo; it is the outreach of a diversion channel excavated by the Venetians in 1534. Nowadays the ridge is overflowed by a scant reclamation channel. The present main Piave River bed is artificially excavated and it gets Eraclea flowing straight for some kilometres. It follows the left flank of the ridge (PC in fig. 2), 3 km wide and 3 m height over the surrounding plain, probably created by a former ancient Piave. It shows branches and crevasse splays with traces of ancient channels well documented in antique and modern maps.

The Piovan (or Piveran) Channel (CP in fig. 2) is very interesting: it flows along a great ridge starting from S. Donà di Piave and it turns southeast after the confluence with the Grassaga Channel toward Stretti. The ridge is 3 km wide and 2 m high at S. Donà di Piave, but it becomes narrow and flat as far as it looses any morphological evidence. The Via Annia, an ancient Roman Way, follows the path of the ridge and changes its direction when it crosses the mound through a Roman bridge whose remains were found along the Grassaga Channel; then the ridge follows on to the archaeological site of Cittanova.

The fluvial ridges define large low-laying interfluvial areas, where paleo-river beds and paleo-lagoon channels are clearly visible on aerial photo-

graphs. The medieval and modern ingression of the lagoon is marked along the stretch north of Taglio del Sile, going along the line linking S.Donà di Piave to Boccafossa (Livenza River) (Castiglioni & Favero, 1987; MURST, 1997). The lagoon deposits spill at the surface and we assert they are very recent. Organic samples of surface lagoon sediments gave a geo-chronological age of 1200±190 yr BP (Utc - 7801), 955±55 yr BP (Rome – 1180) and 658±39 yr BP (Utc - 7802) (personal communication of Henk Berendsen, 1998; Bondesan et al., in press-b). These data confirm that the lagoon sediment sealed the depressions between the older main fluvial ridges in historical times.

Along the coast we find the Littoral Unit (Bondesan *et al.*, 2002b) constituted by ancient coastlines and alignment of paleo-dunes, most of them now artificially levelled. The inner traces could be connected with the littoral deposits formed at Lio Maggiore and Lio Piccolo which are dated about 6500 yr BP (Blake *et al.*, 1988).

The ancient coastlines are distributed over the whole district between Rivers Piave and Sile. The general distribution of alignments shows at least four zones, each representing an advancing phase of the littoral, followed by an erosion event in all likelihood. The coastal stretch defines a cuspate delta, probably asymmetric, well developed in the area nowadays occupied by the Piave mouth, but perhaps much more protruded into the sea, and lately interested by an erosion phase. The development of the older paleo-delta is ascribed to the upper Atlantic, while during the transition Atlantic-Subboreal, the right portion of the Piave paleo-delta might have started. The formation of the more recent cuspate delta, whose traces are scarce, seems to have started in the second part of the Subboreal (Bondesan *et al.*, in press-a).

MATERIALS AND METHODS

The continuous core of Palazzetto was collected using a mechanic sampler, down to a depth of 21.71 m. The lithology of sediments is indicated at the left side of the diagrams, according to the Troels-Smith System.

We selected 42 samples (2 cm^3). The uppermost 80 cm (agricultural soil and sand) and the sediments from 6.96 m to 10.10 m and from 18.49 m to 19.39 m (sands) were not considered because unsuitable for pollen conservation. Tablets of a known concentration of *Lycopodium* spores were added to each samples prior to preparation so that fossil pollen concentration could be estimated. Samples were treated with HCl (37%), cold HF (50%) and boiling NaOH (10%). A sieve of mesh of about 200 µm was employed to isolate macrofossil and epidermal fragments from peat sediments. In the end, samples were acetolysed. Residues were mounted on slides, in glycerine.

All samples were analysed to count pollen and spores of ferns, bryophytes, algae and fungi; epidermal fragments were only identified. Identification and counting were made with a magnification of 400x and critical determination at 1000x. Identification was aided by a modern pollen and spore reference collection, and illustrations and keys including Reille (1992; 1998), Punt (1976), Punt & Clarke (1980; 1981; 1984), Punt *et al.* (1988) and Moore *et al.* (1991). “Saccate grains” indicates broken pollen grains of the Pinaceae family, but their genus or species are indeterminable. Type 303, is described by Van Geel *et al.* (1981). They do not identify it, but they report that it mainly occurs in the Late Glacial (Younger Dryas) and Early Holocene sediments. We record high values of Type 303 in peat that was rich of mosses fragments; therefore we put forward the hypothesis that one/more members of Bryophytes could produce it. Studies are in progress. Type 200 is described by Van Geel *et al.* (1989) and Kuhry (1997). The zygospores of the Zygnemataceae are described by Van Geel (1978), Van Geel & Van der Hammen (1978) and Van Geel *et al.* (1981). Identification of some epidermal fragments was aided by a modern collection. Pollen counting mostly continued until pollen sum (trees+shrubs+upland herbs) reached 100÷250 units, according to the pollen content of the sample. The percentage of helophytes and hydrophytes, of pterydophytes, of bryophytes, of algae, of fungi and of foraminifera remains, respectively, is calculated over the pollen sum added to each group’s total. Unknown grains did not show the characteristic features of pollen grains; therefore they were not included in the pollen sum. Indeterminable grains (degraded, corroded, broken, pyritized) have been counted, their percentage is calculated over the sum of all pollen grains (identified, indeterminable and hidden). The pollen diagrams were calculated and drawn using the programs TILIA and TILIA.GRAPH (Grimm, 1990). We present a pollen preservation diagram (Fig. 3), a pollen and spore concentration diagram (Fig. 4), a pollen and spore percentage synthetic diagram (Fig. 5), a pollen percentage diagram of selected taxa (Fig. 6) and a pollen percentage diagram of helophytes and hydrophytes (Fig. 7). When terrestrial pollen sum didn’t reach 100 units, we have marked the sporomorphs findings with a plus sign in the diagrams. The occurrence of epidermal fragments has been indicated with circle signs.

Four ^{14}C dates were obtained from sediment associated with a specific layer identified from the pollen diagrams (Tab. 1). Radiocarbon dating was conducted at the Beta-Analytic Inc. Miami – Florida.

Tab. 1 - Radiocarbon dates from Palazzetto core.

Lab. reference	Sample depth (cm)	^{14}C age (yr BP)	method
Beta - 173728	76-80	500±70	Standard
Beta - 168127	581-609	6520±50	Standard
Beta - 168128	1323-1333	19850±120	Standard
Beta - 168129	2049-2059	21250±150	Standard

RESULTS

We have analysed 42 samples from the Palazzetto core (Fig. 3), but 15 samples were virtually free of pollen (pollen sum<10 grains) and 8 samples were rather poor in pollen (pollen sum<100 grains).

Pollen concentration is generally low in the

sequence: it reaches the value of about 100 x 10^3 grains/cm^3 only at the depth of 20.34 m (peat) and at the depth of 5.84 m (organic clay) (Fig. 4). We believe that the scarcity of pollen grains was caused by a fast rate of silt and clay sedimentation in the floodplain environment. In fact unsuitable conditions of preservation are unlikely because of the good state of the rare grains we found, almost from the bottom to the depth of 5.84 m and the percentage of indeterminable grains (degraded, corroded, broken and pyritized) surpassing 20% only in the sample at the depth of 13.00 m (Fig. 3). In the upper part of the core the pollen preservation is poor, with up to 40% indeterminable pollen, probably resulting from physical transport of the pollen grains in the silt sediments. Grains infilled with crystals of pyrite (pyritized) are continuously present in the upper part of the core documenting chemically-reducing alluvial environment (Berglund & Ralska-Jasieviczowa, 1986).

The development of local and upland vegetation has not been continuously documented in the sequence because of the presence of sterile sand layers (see lithology), and because of the scarcity of pollen grains in fluvial sediments. Nevertheless indicative local environments may be reconstructed from the following stratigraphical-pollen data to recognise transgressive trend of the coast line at the north of Venice Lagoon. The chronology of the sequence is based on radiocarbon dates (Tab.1).

Hereafter the most important features of the pollen analysis are described.

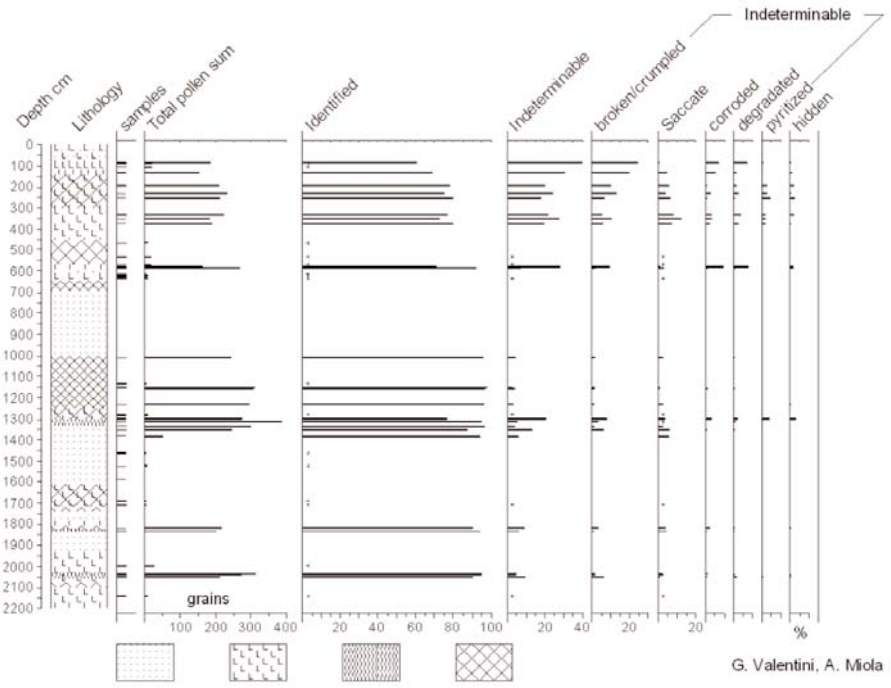

Fig. 3 - Pollen preservation in the sediment of Palazzetto core (Total pollen sum: trees, shrubs, upland and wetland herbs, indeterminable, hidden pollen grains).

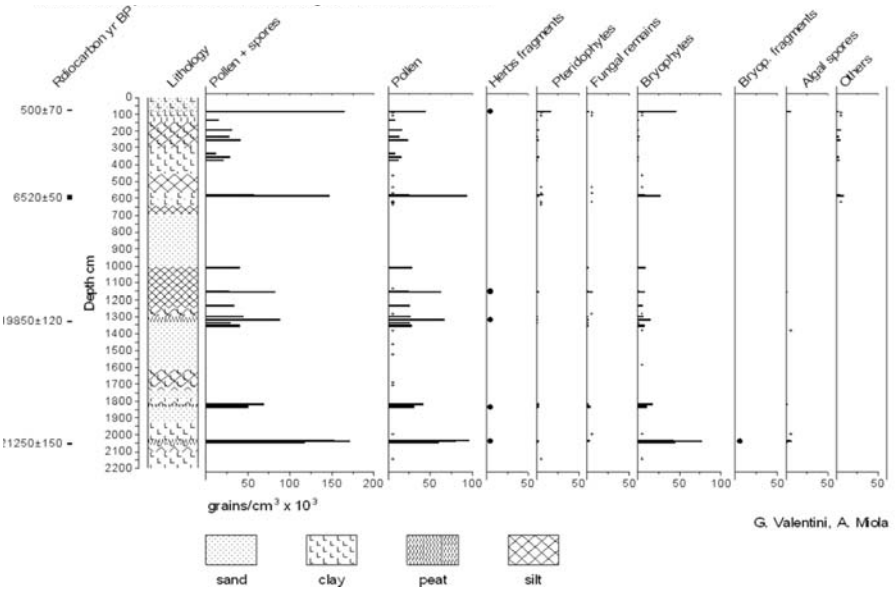

Fig. 4 - Pollen and spores concentration diagram of Palazzetto core.

21.44÷18.19 m. The basal peat (20.59÷20.34 m) contains a high percentage of uplands herbs (NAP) including Poaceae (53% average), *Artemisia*, that reaches its highest value for the entire record (12%), Chenopodiaceae, Asteroideae undiff. and *Thalictrum*. Trees and shrubs are represented by low percentage: *Pinus* (6% average), *Betula, Ephedra fragilis* type, *Larix* type, *Abies, Fagus sylvatica* type and *Acer campestre* type. The local wetland vegetation is mostly represented by Cyperaceae pollen (93% of helophytes+hydrophytes - Fig. 7) and by aerial fragments, roots and fruits of *Carex* species. We also find pollen of *Lemna, Potamogeton* subg. *P*. type, *Nuphar*, and *Sparganium emersum* type. High percentage of algal spores (*Zygnema* type) is recorded in this layer. The presence of mosses in the local environment is indicated by the highest value (67%) of spore percentage in the entire sequence and by many fragments of leaves and little stems. The dominant type of spores is Type 303. Upland local vegetation is dominated by *Populus* (16%) that could occur in the area surrounding the depressions, among grassy vegetation of Poaceae. The pollen and bryophytes concentrations decrease in the peat layer

at 18.34÷18.39 m but the pollen assemblage does not change. The fungal spore concentration increases. The dominant type is Type 200. The occurrence of pollen in the next layers up to 13.84 m is very low.

13.84÷12.81 m. NAP continues to dominate the pollen assemblage. The higher value of total pollen concentration (60 x 10^3 grains/cm^3) corresponds with a peat layer (13.18÷13.16 m). Poaceae are the dominant *taxon* (maximum value 85%). Cyperaceae's percentage shows a declining trend. The sediments at the top contain the highest percentage of hydrophytes (61% of helophytes + hydrophytes). Instead *Artemisia* and Chenopodiaceae percentages decrease. Arboreal *taxa* are mostly represented by *Pinus* (*P. cembra, P. mugo/P. sylvestris*) and "Saccate grains". *Populus* and *Salix* show increasing percentages, while *Alnus* is rare. *Picea* and *Castanea sativa* type are recorded for the first time.

12.81÷10.00 m. NAP continues to dominate the pollen assemblage and Poaceae are the dominant *taxon*: the highest concentration value corresponds to a layer of organic clay at the depth of 11.54÷11.52 m. Cyperaceae pollen percentage increases. Hydrophytes show lower concentration and percentage values if compared to the previous layers. We do not find any significant changes in the other herbaceous pollen *taxa*, as *Artemisia*, Chenopodiaceae, Asteroideae undiff. and Cichorioideae undiff. *Pinus* undiff. prevails even if with low percentages; *Betula, Picea, Larix* type, *Abies* are present with only few pollen grains.

7.00÷3.76 m. A 3 m thick layer of sand separates these layers by the previous ones. The pollen content of the samples from 7.00 m to 5.76 m is very low (<10 grains per slide). We have identified few pollen *taxa*: *Pinus* undiff., *Picea, Larix* type, *Salix*, Poaceae and Cyperaceae. The occurrence of 3 inner organic linings of *Ammonia beccarii* at the depth of 6.20 m, is very interesting, mostly because of the poorness of samples. We have continuously found it from this layer up to the top of the core.

The pollen assemblage of the organic clay samples (5.86÷5.78 m) is characterised by the dominance of NAP as in the previous layers, but it shows some changes in pollen *taxa* distribution. Some of the previously most important *taxa* decrease: helophytes and hydrophytes are rare, Poaceae decrease to a percentage values of about 10%, Chenopodiaceae pollen is abundant for the first time: it attains a maximum of 44%. New *taxa* of Plumbaginaceae are found: *Limonium vulgare* type A and *Armeria maritima* type A and B, that include species living in salt marshes as *L. narbonense* Miller. Plumbaginaceae undiff. pollen attains its highest frequency in the core (7%). Arboreal pollen does not dominate in the pollen assemblage but some *taxa* show their maximum concentration value in the core: *Quercus robur* group, *Corylus, Fagus sylvatica* type, *Pinus* undiff., "Saccate grains", *Betula. Carpinus* type firstly occurs. *Castanea sativa* type (<1%) is continuously represented from here up to the top of the core with values ranging around 2-3%. The inner organic lining of *Ammonia beccarii* ("Other" in fig. 5) attains a maximum concentration value in the core.

Silty grey clay sediments constitute the upper layer and they are virtually barren of sporomorphs.

3.76m÷1.08 m. The pollen assemblages are characterised by: i) the dominance of AP; ii) the first notable increase of several broad-leaf trees *taxa*; iii) the contemporaneous presence of *Quercetum s.l.* elements, of *Pinus* (decreasing) and *Betula*, and of *Picea, Fagus* and *Abies*. AP percentage value attains 90% at the bottom of these layers, but it shows a declining trend in the upper layers. The palynological richness attains its maximum value of 19 arboreal pollen *taxa* and 14 herbaceous pollen *taxa*. Riparian plants, such as *Alnus, Populus* and *Salix*, show increased percentages. Poaceae slightly increase from the bottom to the top.

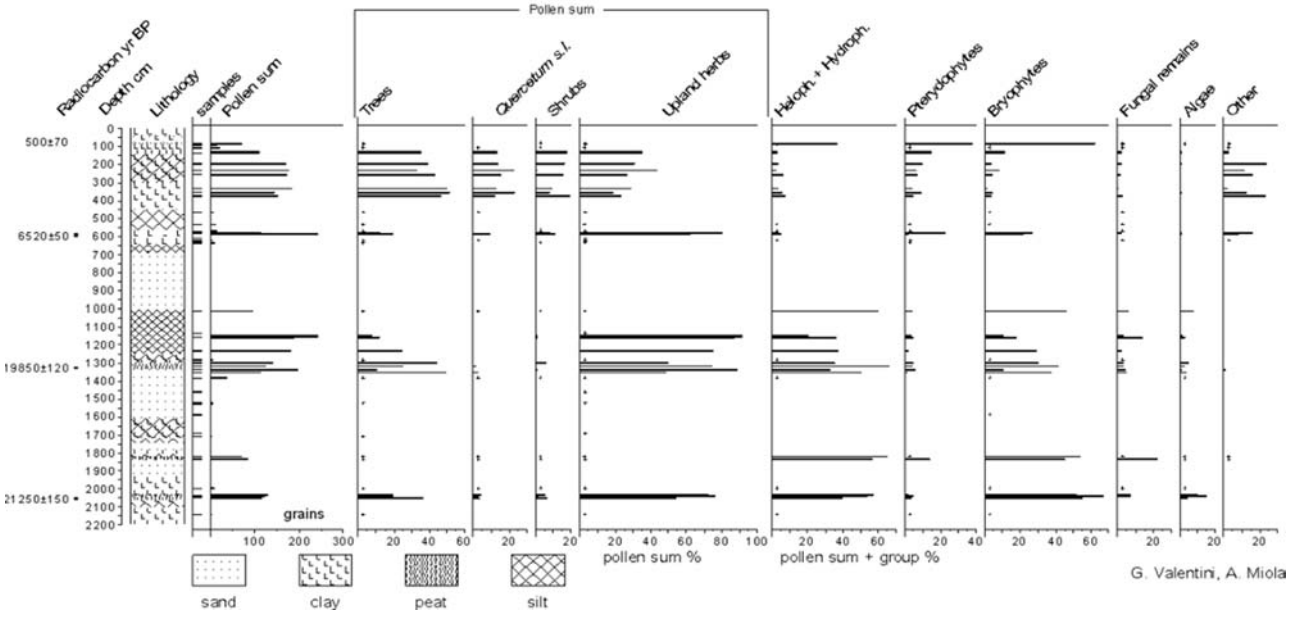

Fig. 5 - Pollen and spore percentage synthetic diagram of Palazzetto core.

There is a reduction of helophytes and hydrophytes. Indeterminate grains (mechanically damaged) and "Saccate grains" are continuously found with the highest concentration and percentage values at the top of the core. There is a notable reduction of pollen content at the top: total pollen concentration drops to 8 x 10^3 grains/cm^3. *Ammonia beccarii* inner organic linings are found in each sample.

1.08÷0.82 m. The pollen concentration increases at the top of the core, but deciduous plants disappear except for *Populus* and *Salix*. Helophytes and hydrophytes pollen prevail on the other *taxa*. The spores of pterydophytes and bryophytes are very abundant. We do not find pollen that indicates the nearby presence of human activities.

INTERPRETATION OF RESULTS

The lithology of sediment, along with pollen and macrofossil records point to the fact that the sedimentation environment at the bottom of Palazzetto core, changed from an open water stage (22.00÷21.00 m), probably with a high rate of sedimentation, to a mire *stadium* (20.49÷20.34 m), with *Carex* species and brown mosses at 21,250±150 yr BP. The presence of a water table close to the surface or other geomorphological conditions, i.e. shallow closed depressions or lasting snow cover, are suggested by the ecological *optimum* of some *Carex* species (*C. ferruginea* Scop., *C. limosa* L., *C. rostrata* Stokes), which is characterised by a good water availability (Buffa & Sburlino, 2001; Bragazza, 1999). The assemblage of spores of *Zygnema* type and aquatic *taxa* (*Lemna, Potamogeton, Callitriche*, and *Nuphar*) pollen points to the local occurrence of pools in some shallow depression of the mire. The conditions of sedimentation change significantly at the depth of 19.30 m. Silt and sand layers indicate an active nearby fluvial system. In the upper peat layer (18.34÷18.39 m) the occurrence of fungal Type 200 could be indicative of marked table fluctuations during the growing season and of relatively dry microhabitats in temporary desiccating bottoms of pools. The pollen concentration and assemblage are typical of a cold and dry climate, that corresponds to the radiocarbon dating results.

The low pollen concentration found in the analysed sediments until 13.84 m could be linked to the high rate of sedimentation suggested by the radiocarbon dates. From the depth of 13.84 m the local conditions gradually change: the total pollen concentration increases in concomitance with the development of a new mire *stadium* (13.16÷13.18 m). Initially high percentage and concentration values of aquatic plants pollen suggest that aquatic conditions prevail. Poaceae (perhaps *Phragmites* sp.) and Cyperaceae stands, grow around the basin but they gradually fill it up, until the formation of a mire (13.16÷13.18 m).

The lithology of sediments from 12.81 m to 7.00 m (roughly represented in this paper) suggests that the sedimentation environment changed many times, but we didn't note significant changes in pollen associations.

From the age of 6520±150 yr BP (6.09÷5.81 m), many records suggest local development of a lagoon environment. Plumbaginaceae (*Limonium vulgare* type A and *Armeria maritima* type B include *L. narbonense* Miller), Poaceae, Cheno-podiaceae and Asteraceae Asteroideae undiff. represent the local vegetation. We suppose that modern analogue could be found in pioneer vegetation of silt and silty sands, living in salt marshes of the lagoons in the northern Adriatic coast. *Lymonium narbonense* Miller, *Spartina maritima* (Curtis) Fernald and some species of Chenopodiaceae form the association *Limonio narbonensis-Spartinetum maritimae* that changes in *Limonio narbonensis- Puccinellio festu-*

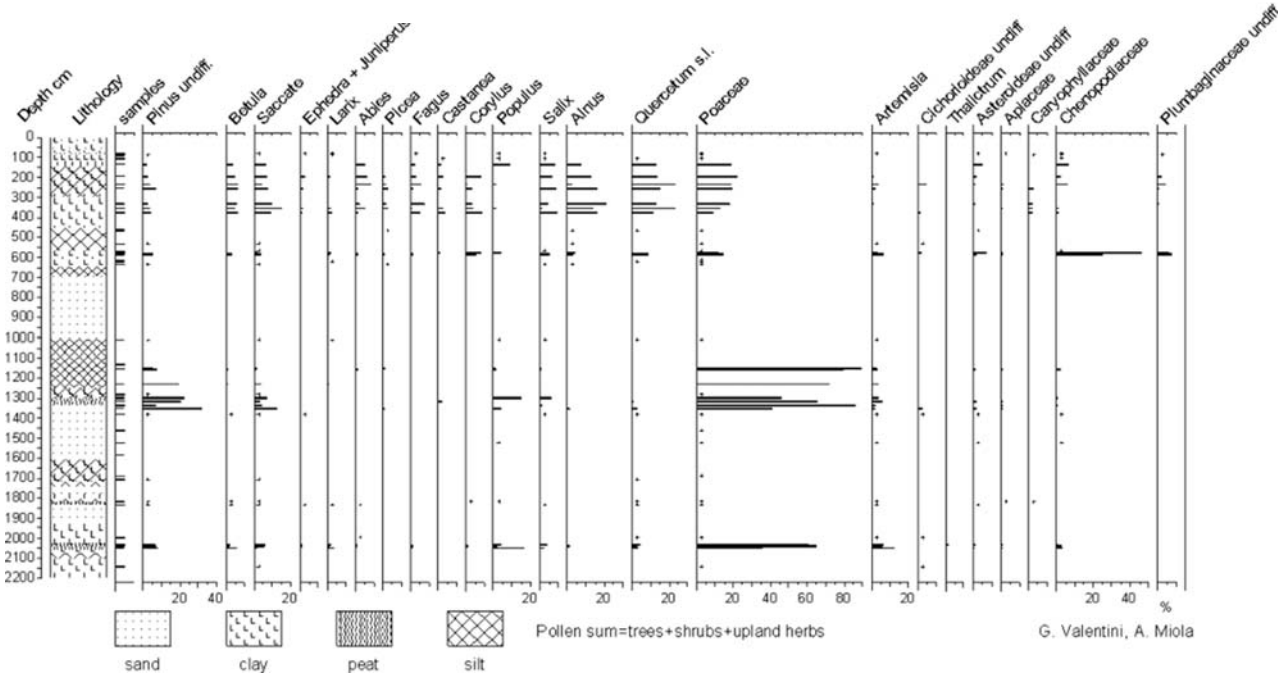

Fig.6 - Pollen percentage diagram of selected taxa of Palazzetto core.

ciformis when the ground level increases (Caniglia *et al.*, 1997). Pollen morphology does not allow any identification of *Spartina maritima* (Curtis) Fernald or *Puccinellia palustris* (Seen.) Hayek or different species of Chenopodiaceae; therefore the stage of vegetation dynamics is not given to know. Studies are in progress to recognise epidermal fragments of roots. The presence of *Ammonia beccarii* inner organic linings is another important feature of the zone, because *A. beccarii* is the dominant *taxon* among the foraminifera that today are living in the water of Venice Lagoon (Serandrei Barbero *et al.*, 2001). Its occurrence is indicative of an open salt/brackish water environment too. Upland vegetation abruptly changes: we note that pollen percentage of *Pinus* is overtaken by pollen percentage of thermophilous broad-leaf plants. Rizzi Longo (1996) reviewed pollen records from Friuli plain sequences. She underlies that *Pinus* decreases during the passage from Pre-Boreal to Boreal period and the association of oaks and other broad-leaf trees grows. In the plain belt mixed oak forest dominates until historical times. Radiocarbon dating and the results of our preliminary pollen analysis is in full accordance with these data.

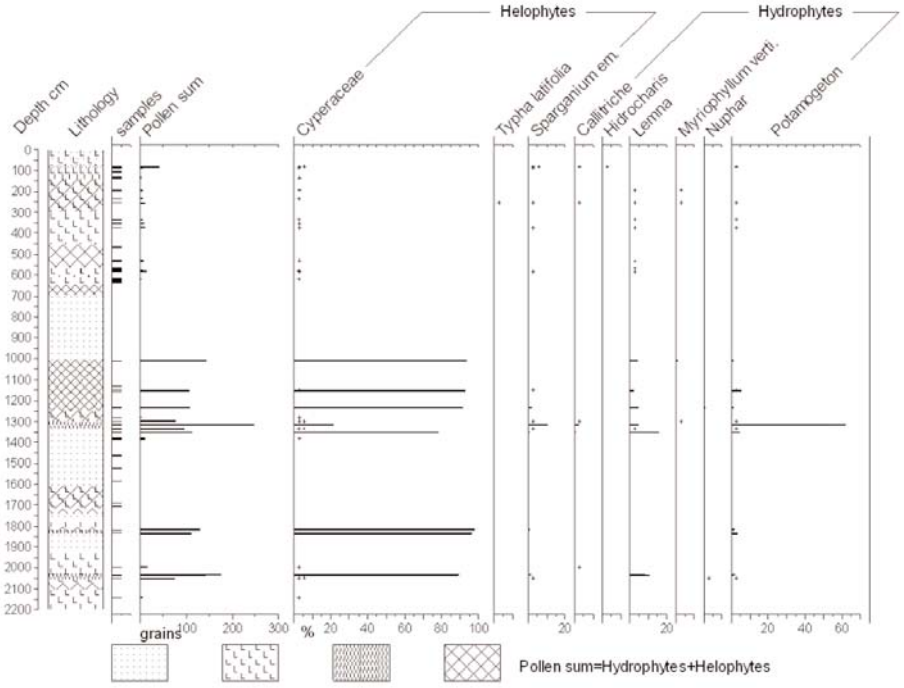

Fig. 7 - Helophytes and hydrophytes percentage diagram of Palazzetto core.

From the depth of 3.76 m an open water environment covered the area and upland forest vegetation was probably near the banks: riparian plants, such as *Alnus*, *Salix* and *Populus* lived near the basin, mixed oak forest covered the surrounding areas. The low percentage of Cyperaceae, aquatic plant pollen, and fresh-water algal spore, and the constant presence of *Ammonia beccarii* indicate a salt/brackish quality of water. Dominance of *Quercetum s.l.* decreases towards the top of the core; *Castanea* and *Corylus* pollen are constantly present and do not change their trends. These are common features of Friuli plains pollen diagrams and they are dated to historical times (Rizzi Longo, 1996).

Drastic changes in pollen association suggest the development of new environmental conditions at the age of 500÷70 yr BP (Cal AD 1400 to 1450). The disappearance of tree pollen and the consistent presence of pterydophytes spores could be the signs of the late Middle Age human activity in the area (Cagnin, 2000). The presence of Type 200 fungal spore indicates that the area was subject to marked fluctuations of the water table, during the growing season. The decline in *Ammonia beccarii* and increased frequencies of fresh-water plants suggest a lower influence of seawater.

CONCLUDING REMARKS

The results from radiocarbon dating suggest that the Palazzetto sequence spans the LGM and the historical times. The depositions of silt and sand layers interrupted the pollen and lithological sequence, and therefore the history of the local environment is fragmented. Probably the studies in progress of the other two cores (Ca' Fornera and Fiorentina) will add further elements to the history of the area.

Cyperaceae peat layers were deposited at the bottom of the core during the end of the last glacial period. These layers could be correlated with similar peat layers from the Veneto and Friuli Plain, already described by other Authors (Bortolami *et al.*, 1977; Mullenders *et al.*, 1996; Serandrei Barbero *et al.*, 2001; Bondesan *et al.*, 2002b): studies are in progress. Four events of fluvial sedimentation, attributed to the Piave River, follow the deposition of the basal peats at the depth of about 19 m, 17.5 m, 15 m and 11 m. They occurred before the beginning of the Holocene. The last important fluvial sedimentation (10÷7 m) occurs before the development of brackish/salt communities in the area, at the age of ca. 6520±150 yr BP. Pollen and spore association at the depth of ca. 6 m, documents the development of a lagoon environment, connected to the Flandrian transgression not yet described in the San Donà di Piave plain. In the nearby Venice Lagoon, first lagoon sediments after the Flandrian transgression have been dated to 5090±100 yr BP by Serandrei Barbero *et al.* (2001). The geochronological dating and pollen analysis of the three cores will let us verify the dynamics of the ingression of the lagoon.

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