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New palynological and tephrostratigraphical investigations of two salt lagoons on the island of Mljet, south Dalmatia, Croatia

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Abstract. In the sediments of both of the investigated lakes, the tephra from the Mercato-Ottaviano eruption (Vesuvius, southern Italy) (ca. 7900 B.P.) could be identified. The palynological investigations show that from ca. 9000-7200 B.P. (8000-6000 cal B.C.) deciduous oak forests predominated, with only a few representatives of Mediterranean vegetation. At the transition to the central European Atlantic Period those forests changed to an open vegetation type, dominated by *Juniperus* and *Phillyrea*. At about 5500 B.P. (4400 cal B.C.), the *Juniperus-Phillyrea* vegetation was replaced by *Quercus ilex* woodland that still occurs on the island of Mljet today and is considered to be the natural vegetation of the Dalmatian coastland. The associated vegetation of the *Q. ilex* forests changed several times. At the beginning of the *Q. ilex* period, *Juniperus* values were still high, but soon they decreased and *Erica* spread. In more recent times the *Q. ilex* forests were partially replaced by plantations of *Pinus halepensis*. Indicators of human impact are sparse throughout the pollen record. Clear evidence for human influence exists only from ca. 3100 B.P. (1300 cal B.C.) when *Juglans* and *Pinus halepensis* were introduced to the area. Later, *Olea* and *Secale* cultivation can be suggested and further spreading of *Juniperus* indicates use of the land as pasture.

Key words: Vegetation history - Mercato-Ottaviano tephra - Vesuvius - Human impact - Climatic impact

Introduction

Mljet is the southernmost of the larger islands of south Dalmatia, Croatia (17°21'E, 42°47'N) (Fig. 1). The island is 32 km long and 2-4 km wide and lies 10 km away from the mainland, northwest of the town of Dubrovnik. It consists mostly of Cretaceous limestone with conspicuous karst phenomena (Schubert 1909). In the valleys, Cretaceous dolomite is found. At the southeastern end of the island there are large sand deposits of unknown origin. The highest hill of the island is Veli Grad (514 m a.s.l.).

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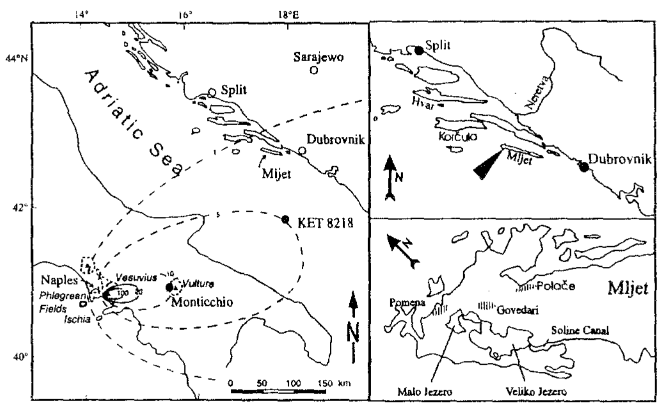

Fig. 1. Location of the island of Mjelt on the Dalmatian coast. Setting of Lago Grando di Monticchio and Adriatic sea core KET 8218 for comparison. Fallout fan of the Mercato Ottaviano eruption as deduced from the total pumice fall deposits near vent (Rolandi et al. 1993) and known distal tephra occurrences (thickness in cm). Position of Malo Jezero and Veliko Jezero on the island of Mljet

In 1985 Mljet was inhabited by 2000 people, who lived mainly from fishing. In the last decades tourism has become a more important economical factor. There is only small scale agriculture.

Today, up to 70% of the island is covered by woodland. The western part (3100 ha) became a national park in 1961. At the southern coast of the national park a narrow canal (Soline) leads from the sea into a large salt water lagoon, Veliko Jezero (Fig. 1). The lake consists of three basins, which are 46, 41 and 15 m deep and are separated from each other by shallower parts (Fig. 2). The westernmost basin is connected with another lake, Malo Jezero (29 m). Both lakes are Pleistocene poljes, depressions in the limestone landscape, which were flooded during a Holocene sea transgression.

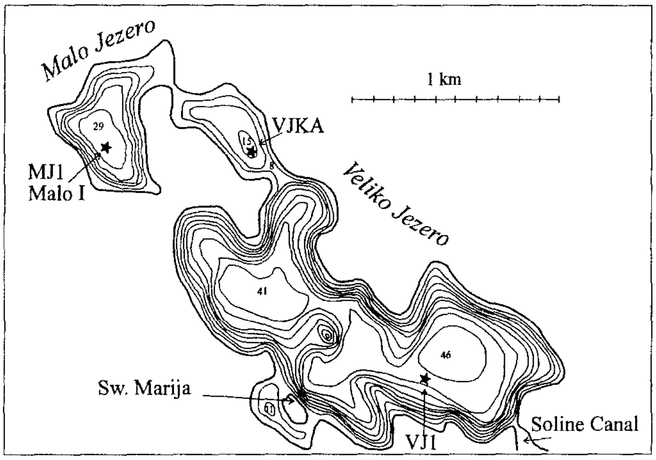

Fig. 2. Malo Jezero and Veliko Jezero (after Vuletic 1953) with coring sites

The canal connecting the two lakes is only 2.5 m wide and 0.2 m deep, and is considered to be artificial, in contrast to the natural mouth of the Soline canal into Veliko Jezero. At changing tide there is a strong current that was used in earlier times to run tide mills.

According to Buljan (1956) and Seibold (1958), the lowest 9 m of the water body of Malo Jezero is free of oxygen during nearly the whole year. However, this could not be confirmed by Schultze (1988/89) in 1986, 1987 and 1988. The water of Veliko Jezero is oxygenous during the whole year. In both lakes are karst springs, which deliver fresh water into the otherwise very salty water.

In 1956 Seibold took sediment cores with a maximum length of 180 cm from Malo Jezero. The sediments were investigated sedimentologically and geochemically (Seibold 1958; Seibold et al. 1958; Seibold and Wiegert 1960). Several of these cores contained a thick tephra layer in the lower part (Beug 1961b). In the upper part of some of the cores thin laminae were discovered which were considered to be annual layers. Pollen analytical investigations on these cores revealed a large part of the Holocene vegetation history (Beug 1961b, 1962, 1967). During the Boreal period, deciduous mixed oak woodland dominated the vegetation. Only with the beginning of the Atlantic period did the vegetation begin to show a Mediterranean character. In historical times, human impact on the vegetation could be shown. A first chronological classification was made possible by radiocarbon dating. The cores of Seibold did not include the last 2000 years, so the pollen diagrams published by Beug cease at latest around 0 A.D.

Investigations on several sites in the Neretva valley in Hercegovina allowed a comparison of the development of the vegetation between Mljet and the nearby mainland (Brande 1973). That study shows that a zonation from evergreen vegetation at the coast to a Submediterranean type further inland already existed in prehistoric times. Studies from the coastal area of Istria (Beug 1977) and northern Dalmatia (Grüger 1996) provided further information about the Holocene history of vegetation on the eastern Adriatic coast and human impact during the last millennia.

The investigations on Mljet could be continued in May 1986 when E. Schultze and R. Schmidt, Mondsee, Austria and J. Müller, Munich, Germany, sampled new and longer cores from Malo Jezero and Veliko Jezero. The sediments were investigated limnologically (Schultze 1988/89) and for diatoms (Schmidt 1993).

This study presents the results of new palynological and tephrostratigraphical investigations. Two of the cores contained the tephra layer which was already described in the earlier studies. It was analysed by electron microprobe at the Geomar-Forschungszentrum für marine Geowissenschaften, Kiel, Germany.

Three cores were studied palynologically with the aim of completing the parts that were not included in the diagrams from Beug (1961b, 1962) and to correlate the cores from Malo Jezero and Veliko Jezero. Human impact was investigated with modern methods of pollen analysis. Twelve radiocarbon dates provided a more detailed chronology for the steps in vegetation change.

In September 1990 more cores were taken from Malo Jezero for palynological investigations focusing on the youngest part of the vegetation history, from a core with annual layers.

The study area

Climate

The Dalmatian coast belongs to the area of Mediterranean climate with winter rain and summer drought. The islands are drier than the mainland, where the clouds accumulate around the mountains. Although the absolute minimum temperature in winter may drop below 0°C, the mean minimum temperature never lies below the freezing point (Table 1).

Table 1. Mean monthly and annual precipitation (mm) and temperature (°C) measured at the weather station Govedari, Mljet (after Cvetkovic 1986)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	ann. mean
mm	92	100	100	72	40	46	24	25	74	93	166	141	973
°C	8.2	8.6	11.5	13.6	17.7	21.7	24.8	24.3	21.6	17.8	13.2	10.8	16.2

From spring to autumn, the wind blows from a northern to a northwestern direction. In winter the Jugo and the Sirocco bring rain and mild temperatures from the southeast. During times of high pressure, the cold Bora wind blows from the mountainous mainland.

History

There are only few reports from prehistoric sites from the south Dalmatian islands and the neighbouring mainland. On the islands of Hvar and Korcula, cave dwellings from the Neolithic period were found (Müller 1994). Single archaeological finds from the Neolithic period are reported from all bigger south Dalmatian islands except Mljet (Batovic 1966). Early finds on Mljet date back to the Hallstatt I period (Marovic 1961/62). There are remains of Illyrian settlements mainly in the western and southeastern part of the island. Buildings from historical times are the Roman palace and the basilica in the harbour at Polace.

About 900 B.C. Phoenician sailors landed in Dalmatia. The Greeks founded the first settlements at the coast around 400 B.C. The native Illyrian tribes reacted with hostility to the Greek colonisation. At last the Greeks called the Roman army for help. The Romans destroyed the Illyrian capital on Mljet in 35 B.C. Dalmatia became part of the Roman empire in 12 A.D. Under the government of Augustus, Mljet became an exile place for banished Roman politicians. At the end of the 1st century the Roman poet Oppianus wrote the first reports about the island. During the Roman period the agriculture of the coastal area was developed, and especially the cultivation of olives and vine. The harbour at Narona (Metkovic) at the mouth of the Neretva was the centre of the trade to the islands.

After the decay of the western Roman empire, Dalmatia was ruled for a short period by the Gothic king Theoderic. At the beginning of the migration period in the 6th century the mainland of Dalmatia was devastated, whereas the islands remained nearly undisturbed. Later, Slavonic tribes settled in the area and the city of Dubrovnik (Ragusa) was founded. The land became part of the Frankish empire in 806 A.D. and in 877 A.D. joined the Byzantine empire.

In the 12th century, Mljet was donated to the Benedictinian order. The monks built the monastery of Sw. Marija on a small island in Veliko Jezero. In the 13th century Dalmatia came under Venetian, and in the 14th century under Austria-Hungarian government. The administration in Dubrovnik published the first edict for the protection of the forests 1436 A.D. At the end of the 15th century many new settlements were founded on Mljet.

The island was devastated in the war against the Ottoman empire in 1526 A.D. The mainland remained the scene of many wars and political change also during recent centuries. Since the last Balkan war in 1991-1996, Mljet has been part of the Republic of Croatia (after Cvetkovic 1986; Rother 1987).

Vegetation

The vegetation is described according to Horvat et al. (1974). In terms of the potential natural vegetation, the coastal area of Dalmatia belongs to the zone of Mediterranean evergreen woodland, which is formed in the Balkans by the *Quercion ilicis* alliance (Fig. 3). In Dalmatia this alliance is represented by the Adriatic association of the *Orno-Quercetum*.

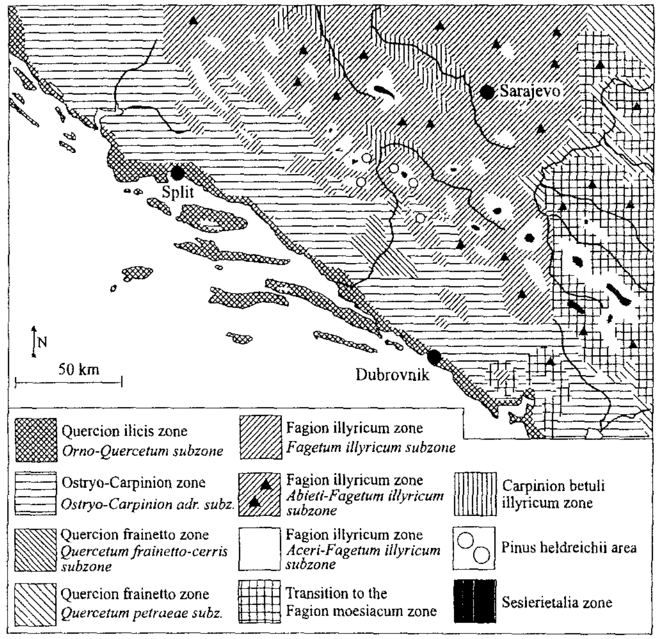

Fig. 3. Vegetation after Horvat et al. (1974)

On the mainland the evergreen woodland grows only as a narrow belt along the coast. In south Dalmatia it reaches an elevation of 350 m a.s.l., in Istria only 50 m a.s.l. On the islands, however, which are almost free of frost, the upper border lies significantly higher and *Quercus ilex* (holm oak) grows to an altitude of 700 m a.s.l. (Larcher 1970). In all relics of natural forests, which can also be found on Mljet, *Q. ilex* is the dominant species. It forms dense woodland with only scarce undergrowth.

Where the forests are degraded to maquis, the holm oak is mostly replaced by other woody taxa such as *Myrtus communis*, *Arbutus unedo* and *Pistacia lentiscus*. This kind of maquis is also sparsely distributed. Mostly, a nearly treeless vegetation called garigue (Horvatic 1958) grows in its place which is formed by dwarf scrubs and isolated bushes such as *Sarcopoterium spinosum*.

Today most of the holm oak forests are replaced by pine forests, partially as planted trees, which mainly consist of *Pinus halepensis*, and on Mljet the Aleppo pine is the most abundant tree. Older reports give the pine forests the status of an individual formation (Adamovic 1929). Since pine forest occurs mostly only as the first tree generation after wood clearing, this woodland of *P. halepensis* is nowadays considered to belong to other plant communities. In the Submediterranean mountainous area of the coastal region there grows woodland of *Pinus nigra ssp. dalmatica*, which occurs naturally in Dalmatia but not on Mljet (Domac 1965).

Further inland, the evergreen woodland is replaced by a Submediterranean deciduous mixed woodland which is represented in Dalmatia by the *Ostryo-Carpinion* alliance, with different species of *Quercus*, *Fraxinus*, *Carpinus* and *Ostrya*. This vegetation is less adapted to the summer drought than the evergreen taxa,

Table 2. Radiocarbon dates

Lab. Nr.	sample Nr.	depth (cm)	radiocarbon age (B.P.)	calibrated age (B.C./A.D.) 1σ
Hv 17650	Malo IX	43 - 45	245 ± 150	cal A.D. 1475-1893, 1905-1955*
Hv 17137	MJ1-10	12 - 17	1620 ± 175	cal A.D. 241-632
Hv 17128	MJ1-1	32 - 37	1570 ± 160	cal A.D. 268-275, 334-651
Hv 17129	MJ1-2	71 - 76	3115 ± 135	cal B.C. 1516-1251, 1249-1204
Hv 17130	MJ1-3	102 - 107	3955 ± 75	cal B.C. 2563-2524, 2501-2392, 2387-2337
Hv 17131	MJ1-4	145 - 150	4540 ± 100	cal B.C. 3370-3084, 3061-3043
Hv 17132	MJ1-5	154 - 159	4940 ± 150	cal B.C. 3942-3844, 3824-3628, 3562-3544
Hv 17133	MJ1-6	182 - 187	5455 ± 160	cal B.C. 4459-4215, 4203-4137, 4123-4084, 4051-4050
Hv 17138	MJ1-11	232 - 237	7030 ± 85	cal B.C. 5962-5759
Hv 17134	MJ1-7	254 - 259	7185 ± 205	cal B.C. 6185-5806
Hv 17135	MJ1-8	295 - 300	7365 ± 190	cal B.C. 6387-5988
Hv 17136	MJ1-9	342 - 347	8430 ± 90	cal B.C. 7536-7422

but more resistant to frost. Today the natural Submediterranean woodland of Dalmatia grows only in small areas, where not replaced by sibljak, deciduous brushwood.

At higher elevations (ca. 700-1500 m a.s.l.), without a dry period in summer, the mixed woodland is replaced by montane vegetation, mainly beech forests of the *Fagion illyricum* alliance. Further inland they border the *Fagion moesiacum* alliance. In the montane woodland pines grow in many places.

In contrast to the adjacent mainland coast, which is totally deforested, *Pinus halepensis* woodland grows frequently on Mljet, especially in the national park area around Malo and Veliko Jezero and on the eastern part of the island (Saplunara). It is a rather open woodland with a rich undergrowth of mostly evergreen taxa, mainly *Phillyrea latifolia*, *Ph. intermedia*, *Pistacia lentiscus*, *Juniperus phoenicea*, *J. oxycedrus*, *Arbutus unedo*, *Quercus ilex*, *Erica manipuliflora*, *E. arborea*, *Ruscus aculeatus*, *Cistus incanus*, *C. monspeliensis*, *Lonicera nigra*.

On some of the hills, there is pure holm oak woodland. At the border with the Aleppo pine forests, *Quercus ilex* occurs as undergrowth among the pines. In contrast to the open pine forests, the holm oak forests have a densely closed canopy which allows only scarce undergrowth.

Fieldwork

The cores MJ1, VJ1 and VJKA were taken with a modified Kullenberg corer (Schultze and Niederreiter 1990) at water depths of 28, 45 and 15m (Fig. 2). The cores Malo I and Malo IX were sampled with a Rumohr corer (Meischner and Rumohr 1974) at a water depth of 28 m.

Radiocarbon dating

Radiocarbon dating was carried out at the ^{14}C laboratory at Hanover on the sediment of core MJ1 (Table 2). One date was taken from a little piece of pine wood from the base of core Malo IX. The radiocarbon ages were calibrated with the Radiocarbon Calibration Program Rev 3.0 (Stuiver and Pearson 1993; Pearson and Stuiver 1993; Pearson et al. 1993; Linick et al. 1986). Calibrated ages used in the text are given as proposed by the calibration program.

The data has to be regarded with care because the sediment has a high content of carbonate. Therefore the dates could be distorted by old carbonate and give too old an age. However, the tephra study in the layer which was identified at 296-297 cm in MJ1 and at 250-251 cm in VJ1 proves that at least the dates from the limnic sediments are reliable (see below). Beyond, the radiocarbon dates from older periods are in good agreement with those given in the study of Beug (1961b, 1962) and to those from the palynological study on the near mainland (Brande 1973). For the marine sediment a deviation of the ages must be assumed. The youngest samples from MJ1 show an almost identical age, so the chronology of the last two millennia is especially insecure. A special problem is connected with the date from core Malo IX, which derives from a little piece of wood. This date is

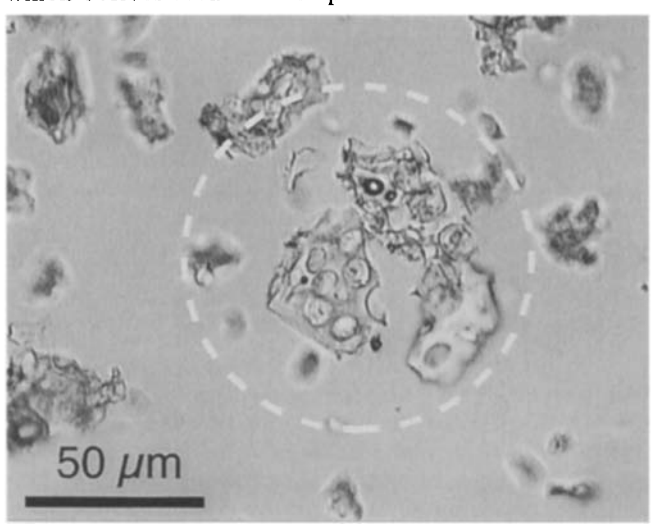

Fig. 4. Characteristic glass shard from the Veliko Jezero tephra

Table 3. Electron microprobe data from glass shards of the Veliko Jezero tephra

	Type A																			
Shard no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SiO_2	57.94	57.54	57.43	57.64	58.12	57.61	58.09	57.82	57.12	57.51	58.03	58.39	56.95	57.91	58.19	58.27	57.5	57.25	57.23	58.77
TiO_2	0.26	0.21	0.25	0.15	0.21	0.20	0.15	0.24	0.19	0.28	0.21	0.21	0.22	0.21	0.16	0.29	0.22	0.21	0.16	0.21
Al_2O_3	20.68	20.67	20.47	20.59	20.53	20.43	21.01	20.48	20.58	20.77	20.78	20.56	20.55	20.74	20.83	20.77	20.69	20.61	20.51	21.28
FeO	1.89	1.95	2.05	2.09	2.07	2.02	1.79	2.01	1.98	1.70	1.96	2.07	1.77	2.28	1.90	1.96	1.87	1.90	1.70	1.37
MnO	0.23	0.20	0.19	0.24	0.17	0.24	0.15	0.22	0.21	0.14	0.20	0.19	0.19	0.25	0.11	0.20	0.23	0.21	0.28	0.17
MgO	0.11	0.12	0.11	0.12	0.09	0.09	0.10	0.13	0.12	0.09	0.08	0.11	0.08	0.11	0.10	0.11	0.10	0.13	0.08	0.06
CaO	1.73	1.52	1.70	1.58	1.73	1.79	1.62	1.68	1.79	1.60	1.82	1.91	1.76	1.84	1.86	1.80	1.88	1.83	2.03	2.67
Na_2O	7.99	8.24	7.72	7.86	7.75	7.35	7.90	7.76	7.66	7.73	7.69	7.64	7.60	7.87	7.75	7.64	7.72	7.57	7.19	7.46
K_2O	7.91	7.42	7.84	7.60	7.76	8.06	7.54	7.61	7.56	7.46	7.60	7.70	7.35	7.39	7.36	7.51	7.22	7.32	7.22	6.56
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ(vol.-free)	98.75	97.86	97.77	97.87	98.43	97.79	98.33	97.96	97.23	97.28	98.37	98.79	96.48	98.60	98.26	98.54	97.42	97.04	96.38	98.55
SO_2	0.09	0.00	0.00	0.06	0.02	0.08	0.03	0.06	0.03	0.05	0.12	0.02	0.07	0.11	0.01	0.05	0.08	0.03	0.08	0.05
F	0.43	0.36	0.31	0.50	0.36	0.21	0.21	0.47	0.44	0.22	0.51	0.45	0.45	0.37	0.58	0.29	0.39	0.44	0.33	0.11
Cl	0.77	0.65	0.69	0.69	0.68	0.69	0.70	0.71	0.72	0.65	0.68	0.67	0.64	0.65	0.68	0.63	0.66	0.62	0.65	0.44
Total	100.04	98.87	98.77	99.12	99.48	98.77	99.28	99.20	98.42	98.19	99.68	99.92	97.63	99.73	99.53	99.51	98.55	98.12	97.45	99.14

Table 3 contd.

	Type B	Type C					
Shard no.	21	22	23	24	25	26	27
SiO_2	54.18	59.54	61.17	60.09	59.90	59.45	62.07
TiO	0.66	0.20	0.27	0.08	0.16	0.10	0.00
Al_2O_3	17.98	21.13	21.45	22.18	21.4	22.00	22.82
FeO	5.26	1.17	1.00	1.50	1.23	0.56	0.41
MnO	0.42	0.18	0.09	0.13	0.06	0.06	0.01
MgO	1.18	0.01	0.02	0.03	0.03	0.02	0.00
CaO	7.40	2.96	3.20	3.56	3.32	4.06	3.92
Na_2O	6.84	5.95	6.02	6.93	6.01	5.81	5.84
K_2O	5.67	6.60	6.40	5.36	5.89	5.17	5.39
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ(vol.-free)	99.58	97.74	99.62	99.85	97.99	97.22	99.46
SO_2	0.12	0.07	0.00	0.11	0.02	0.06	0.07
F	0.39	0.08	0.00	0.14	0.00	0.00	0.00
Cl	0.50	0.39	0.40	0.41	0.33	0.19	0.02
Total	100.59	98.29	100.01	100.51	98.34	97.48	99.55

ca. 2000 years younger than a comparable date from the lake sediment of MJ1 determined by pollen stratigraphy (Jahns 1992).

Tephra studies

Material and methods

In two cores from Malo Jezero and Veliko Jezero a single volcanic ash layer occurs within pollen zone A2 at 296-297 cm (MJ1) and 250-251 cm (VJ1) depth respectively. The tephra layer lies in sharp contact with the underlying sediment and shows minor reworking at its top.

The tephra is 1-2 cm thick, the maximum grain size of clasts is 150 µm in diameter. Its petrographical composition was studied in grain mounts. The tephra layer consists of unaltered, colourless subequant vesicular glass shards, angular vesicular shards bounded by vesicles and bubble wall glass shards, rare brown glass shards and crystals (Fig. 4). Minerals make up less than 1 % of the volume of the deposit and are dominated by potassium feldspars, with lesser amounts of plagioclase feldspar, pale green pleochroitic clinopyroxene, biotite and minor amphibole.

The chemical composition of volcanic glass shards was determined in polished thin sections by electron microprobe (Cameca SX 50, 15 keV, 6 nA). Instrument calibration was based on interlaboratory mineral and glass standards.

Electron microprobe analysis of single glass shards show that the tephra comprises a geochemically heterogeneous glass population. It consists of three different groups: a main glass shard population with phonolitic composition (type A), a second glass population with trachytic composition (type B), and rare glass shards with tephritic composition (type C). Glass shards with transitional phonolitic-trachytic compositions also occur (Fig. 5, Table 3).

Source of the tephra

The thickness of the tephra layer and the alkaline composition of the glass shards suggests that the tephra derived from an explosive eruption within the nearby Italian volcanic fields 350 km to the southwest. This episode of explosive volcanic activity with widespread fall-out layers is known from the Aeolian and the Campanian volcanic provinces (Ischia, Phlegrean fields and Vesuvius) (Fig. 1). Ash layers derived from these volcanic fields can be distinguished on the basis of their alkali contents (Paterne et al. 1988).

Within the time span of pollen zone A2 (ca. 7500-6000 B.C.), during which the Veliko Jezero tephra was deposited, a major explosive eruption from Somma-Vesuvio resulted in the 'Mercato-Ottaviano' airfall deposits (Walker 1977; Rolandi et al. 1993). According to ^{14}C data from the uppermost part of the paleosol underlying the pyroclastic deposits, the age of this eruption is determined as 7910 ± 100 B.P. (uncal) (Alessio et al. 1976; Delibrias et al. 1979).

In the vicinity of the vent, the Mercato-Ottaviano eruption emplaced pyroclastic flows, surge and fall-out deposits comprising phonolitic pumice lapilli and minor tephritic-phonolitic juvenile scoria (Santacroce 1987; Rolandi et al. 1993). Minerals described are feldspars, clinopyroxene, amphibole, mica and iron oxides.

Two distal tephra occurrences are correlated with the Mercato-Ottaviano eruption: tephra L4 at Lago Grande Monticchio core (Narcisi 1996) and tephra V1 in Adriatic sea core KET 8218 (Paterne et al. 1988) (Fig. 1). While glass shards from tephra V1 in the Adriatic core are phonolitic in composition and identical to whole rock pumice known from the Mercato type locality, glass shards from tephra L4 in the Monticchio core are trachytic in composition (Fig. 5).

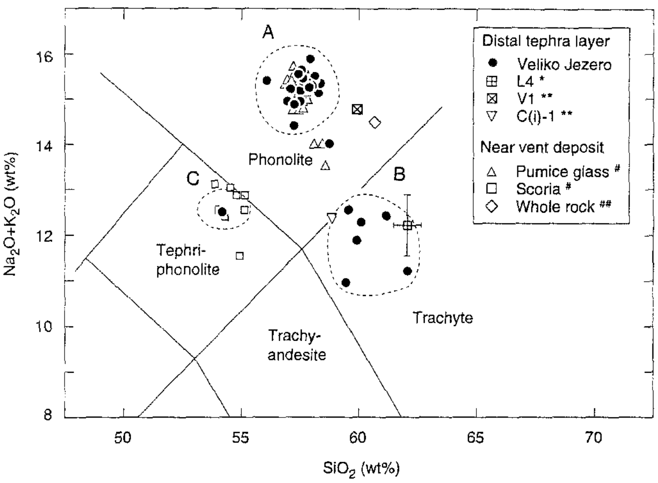

Fig. 5. Section of the Total Alkali-Silica (TAS) diagram showing the chemical composition of glass shards from the Veliko Jezero tephra (electron microprobe data). Data compared to near vent pumice and scoria glass composition from Mercato-Ottaviano deposits and tephra layers from L4 (Monticchio core), V1 and C(i)-1 (Adriatic core KET 8218). TAS classification diagram according to Le Maitre et al. (1989).
(* EMP data, mean and standard deviation of 10 glass shards, Narzisi 1996; ** SEM-EDS analysis, Paterne et al. 1988, # SEM-EDS analysis, Rolandi et al. 1993, ## XRF analysis, Santacroce 1987)

Conclusions

The Veliko Jezero tephra is correlated to the Mercato-Ottaviano fall-out deposits. The correlation is based on a) the age of the eruption, b) identical mineral assemblages and c) matching major and minor element composition of glass shards in near vent and distal deposits.

The glass composition of the Mercato-Ottaviano pumice lapilli is identical to the type A glass of the Veliko Jezero tephra, the near vent scoria composition is represented in type C glass.

Average glass shard composition of tephra L4 is similar to type B glass shards of the Veliko Jezero tephra. Common to all tephra occurrences are high Al_2O_3 (> 20%) contents of the glass shards.

The heterogeneous composition of the Veliko Jezero tephra could be interpreted as mixing of tephra layers from different eruptions. But in this time interval there is neither a tephra with phonolitic composition known in the Monticchio core, nor is a tephra with trachytic composition described in the Adriatic core. The only other tephra layer known in this period is the trachy-phonolithic tephra layer C(i)-1 in the Adriatic deep sea sediment core (KET 8218, Paterne et al. 1988), which occurs stratigraphically below the Mercato-Ottaviano tephra and is correlated to the activity of the Campanian volcanic field (Paterne et al. 1988). A correlation of tephra C(i)-1 with one of the glass populations of the Veliko Jezero tephra can be ruled out: at similar alkali contents the tephra C(i)-1 shows higher K_2O/Na_2O ratios (~2.5) than all highly differentiated glass components of the Veliko Jezero tephra (≤1). The different glass populations in the Veliko Jezero tephra are more probably the result of a compositionally heterogeneous eruption from a mixed magma chamber. An eruption from a mixed phonolitic magma chamber has also been deduced from the composition of potassium feldspar crystals from the Ottaviano-Mercato deposits, which are not in equilibrium with their (host) pumice glass (Rolandi et al. 1993).

The apparently single populations of glass shards described from the distal tephra occurrences in the Monticchio and Adriatic sea cores could reflect different transport directions at compositionally different eruptive stages. More probably they reflect the selection of glass analyses given (Paterne et al. 1988) and the average of single glass compositions (Narcisi 1996).

The distribution of the Mercato-Ottaviano eruption products is mapped in detail near the vent: four distinguished airfall eruption phases show transport directions to the east (Rolandi et al. 1993) (Fig. 1). The thickness distribution of the distal tephra, as observed in Monticchio core (11 cm), in the Adriatic sea sediment core KET 8218 (5 cm) and in the Veliko Jezero core (1 cm) agrees with the near-vent easterly transport directions.

The Mercato-Ottaviano tephra represents a widely distributed marker horizon in the Adriatic area, connecting terrestrial and limnic records in Italy, marine records in the Adriatic sea and lake deposits on the Dalmatian coast. In the cores from the island of Mljet it forms a marker horizon at 7910 ± 100 B.P. (uncal), that allows an independent dating of the sediments.

Palynological study

Methods

For concentration measurement, the sample volumes were measured (1-2 ml) and *Lycopodium* spore tablets were added (Stockmarr 1971). Afterwards the samples were decalcified with concentrated HCl. Silicates were eliminated with concentrated HF and part of the organic material with hot 10% KOH. Afterwards, the samples were acetolysed and cleaned by ultrasonic sieving. Samples were counted with an interval of 5-10 cm at MJ1, VJ1 and VJKA and of 1 cm at Malo I. The pollen diagrams (Figs. 6-9, 11) present the results as percentage calculations based on the sum of arboreal pollen (AP), which ranges from 500-1000.

For pollen identification, the collection of recent pollen and spores of the Institute of Palynology and Quaternary Sciences, Göttingen, was used and the following literature: Beug (1961a, 1961c), Smit (1973), Moore and Webb (1978), Agwu and Beug (1982), F'gri and Iversen (1989). The diagrams were drawn with the programs TILIA 1.12 and CorelDraw 5.0.

Results and discussion

Again, no pollen bearing depositions from the Late Glacial or Preboreal were found. The pollen record from the three cores MJ1, VJ1 and VJKA is almost identical (Figs. 6-8). However, there are big differences in the sedimentation rate and the core tops and bases are of different ages. VJ1 contains the oldest sediments, MJ1 the youngest. The short cores Malo I (Fig. 9) and Malo IX (Jahns 1992) include only the last 2000-3000 years up to modern times, appending to the long profiles. Unexpectedly, the three long cores from Malo and Veliko Jezero cover almost the same period as the much shorter cores which were investigated by Beug (1961b, 1962) (Fig. 10).

The pollen diagrams can be divided into four main pollen zones, A, B, C and D, following the designation of Beug (1961b, 1962). Zones A, C and D can be further subdivided.

Zone A
Subzone A1 (VJ1): period of deciduous mixed oak woodland with *Pinus (nigra)*, older than 7500 cal B.C.
Subzone A2 (VJ1, VJKA, MJ1): period of deciduous

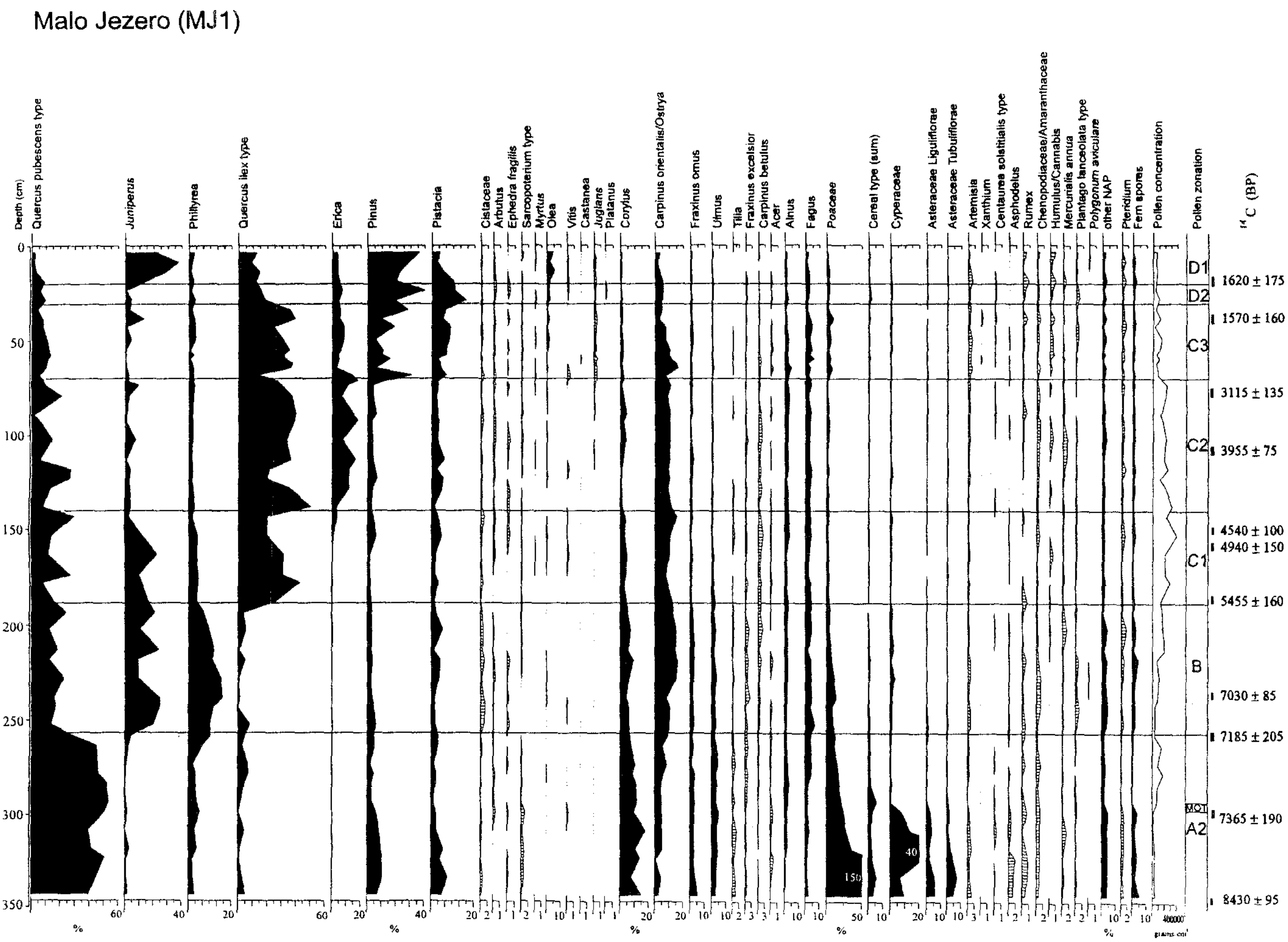

Fig. 6. Pollen diagram of Malo Jezero (MJ1), selected taxa in percentage AP, MOT = Mercato-Ottaviano tephra

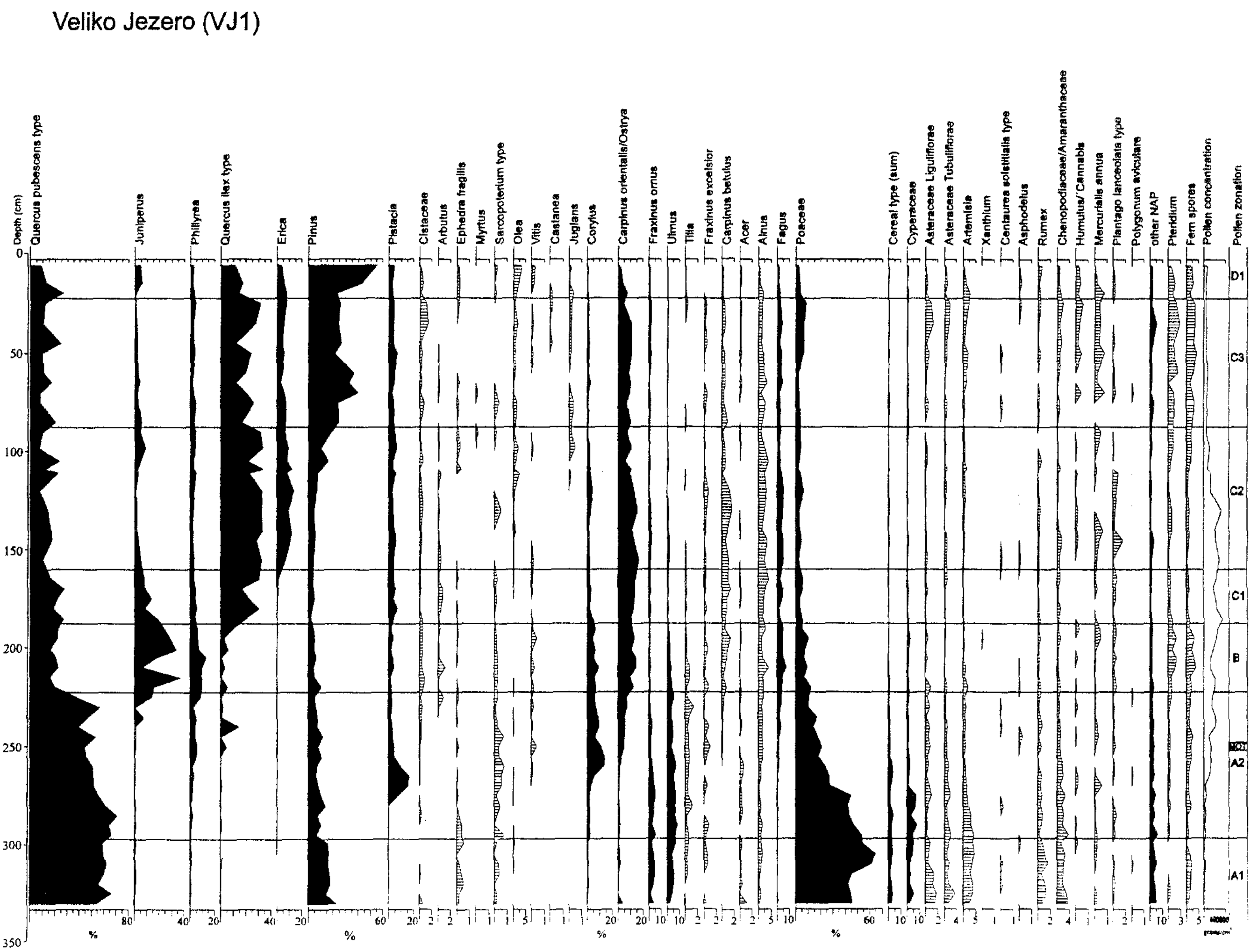

Fig. 7. Pollen diagram of Veliko Jezero (VJ1), selected taxa in percentage AP, MOT = Mercato-Ottaviano tephra

mixed oak woodland, ca. 7500-6000 cal B.C.
Zone B: period of *Juniperus* and *Phillyrea*, ca. 6000-4400 cal B.C.
Zone C
Subzone C1 (VJ1, VJKA, MJ1): period of *Quercus ilex* woodland with *Juniperus*, ca. 4400-3300 cal B.C.
Subzone C2 (VJ1, VJKA, MJ1): period of *Quercus ilex* woodland with *Erica*, ca. 3300-1100 cal B.C. (extrapolated)
Subzone C3 (VJ1, VJKA, MJ1, Malo I): period of *Quercus ilex* woodland with *Pinus (halepensis)*, ca. 1100 cal B.C.-0 cal A.D. (after Beug 1962)
Zone D
Subzone D1 (VJ1, VJKA, MJ1, Malo I): period of *Pinus (halepensis)* with *Quercus ilex* (no precise dating)
Subzone D2 (MJ1, Malo I): period of *Pinus (halepensis)* with *Juniperus* (no precise dating)
Subzone D3 (Malo I): period of *Pinus (halepensis)* until modern times

Vegetation development

Zone A; ca. 8000-6000 cal B.C. The pollen record starts within the Boreal period. The vegetation was dominated by deciduous oaks, mixed with other deciduous woody taxa, mainly *Corylus*, *Ulmus*, *Carpinus orientalis/Ostrya* and *Fraxinus ornus*. *Tilia*, *Acer*, *Fraxinus excelsior* and *Carpinus betulus* were less abundant.

In the oldest part of zone A in the profile VJ1 (subzone A1) the values of some deciduous trees (*Corylus*, *Ulmus*) are still low and *Pinus* values are relatively high. Although pine pollen occurs regularly in all parts of the diagrams, it displays such low values in zone B and most of zone C, that it is not certain whether it derives from the island or from the mountainous area of the Dalmatian mainland, since *Pinus* pollen is very well dispersed by wind. The high values in subzone A1, however, point rather to an occurrence of pine woods in the coastal area or on the island itself. Gigov and Nicolic (1960) found a *Pinus* period preceding a period of oak woodland at lower elevations in Croatia (undated diagram) and Grüger (1975) reports an early Holocene *Pinus* period followed by an oak period in a marine pollen record from the Adriatic sea. *Pinus nigra ssp. dalmatica* is a species which grows naturally in Dalmatia (Domac 1965). Maybe it played a more important role in the coastal area during the early Holocene than today. On the other hand the high *Pinus* values in subzone A1 might belong to relics of Preboreal pine forests on the mainland.

Quercus ilex (holm oak) is represented in zone A by single grains only. The ecology of deciduous and evergreen oak woodland has been intensively studied. Often the border between deciduous and evergreen sclerophyllous oak woodland has been interpreted as a result of increasing dryness (Walter 1956; Larcher and Mair 1969; Larcher 1970). According to Freitag (1975), however, the border between evergreen and deciduous oak woodland is not a result of drought but of frost. Although the holm oak survives frost periods to -15°C as a grown tree, seedlings and buds are damaged by short periods of only a few degrees below 0°C (Larcher 1970). In a climate with mild winter temperatures, the holm oak replaces the deciduous oaks, which need sunny locations and are not able to regenerate in the dark holm oak forests. Therefore the occurrence of deciduous oak forests in the Mediterranean area indicates a climate with regular frost periods, which excludes the occurrence of *Quercus ilex*. In contrast to Walter (1956), the modern stands of holm oak in especially dry habitats are considered by Meyer (1969) and Freitag (1975) to be due to human impact.

The occurrence of evergreen taxa in zone A, although very few in number, together with the taxa of the mixed deciduous oak forest suggests that the climate was not one with long periods of frost. However, the evergreen taxa might have been restricted in their spreading by cool winters. The higher values of *Pistacia* in MJ1 and especially in VJ1 can be attributed to the evergreen species *Pistacia lentiscus* and to the deciduous *Pistacia terebinthus* as well which also grows in the Mediterranean area. The pollen grains of the *Pistacia* species cannot be separated with the light microscope. Other Mediterranean taxa are *Ephedra fragilis*, *E. distachya* (MJ1, VJ1), Cistaceae (*Cistus incanus* type, VJKA and *Helianthemum*, MJ1, VJKA). Their occurrence indicates a relatively mild climate, so that the deciduous oaks can be assumed to be *Quercus pubescens* rather than *Q. robur* or *Q. petraea*.

In the mountains on the mainland, *Fagus* increased at the end of zone A (ca. 7200 B.P.) and reached values about 7% in zone B. In Slovenia the beech expanded during the Boreal period (Sercelj 1963), in northwestern Greece between 7500 and 6300 B.P. (uncal) (Willis 1992).

Zone B; ca. 6000-4400 cal B.C. At the transition from zone A to zone B a distinct change in the vegetation took place. The deciduous oak woodland was replaced by a vegetation type which was dominated by the evergreen taxa *Phillyrea* and *Juniperus*. *Phillyrea* was especially

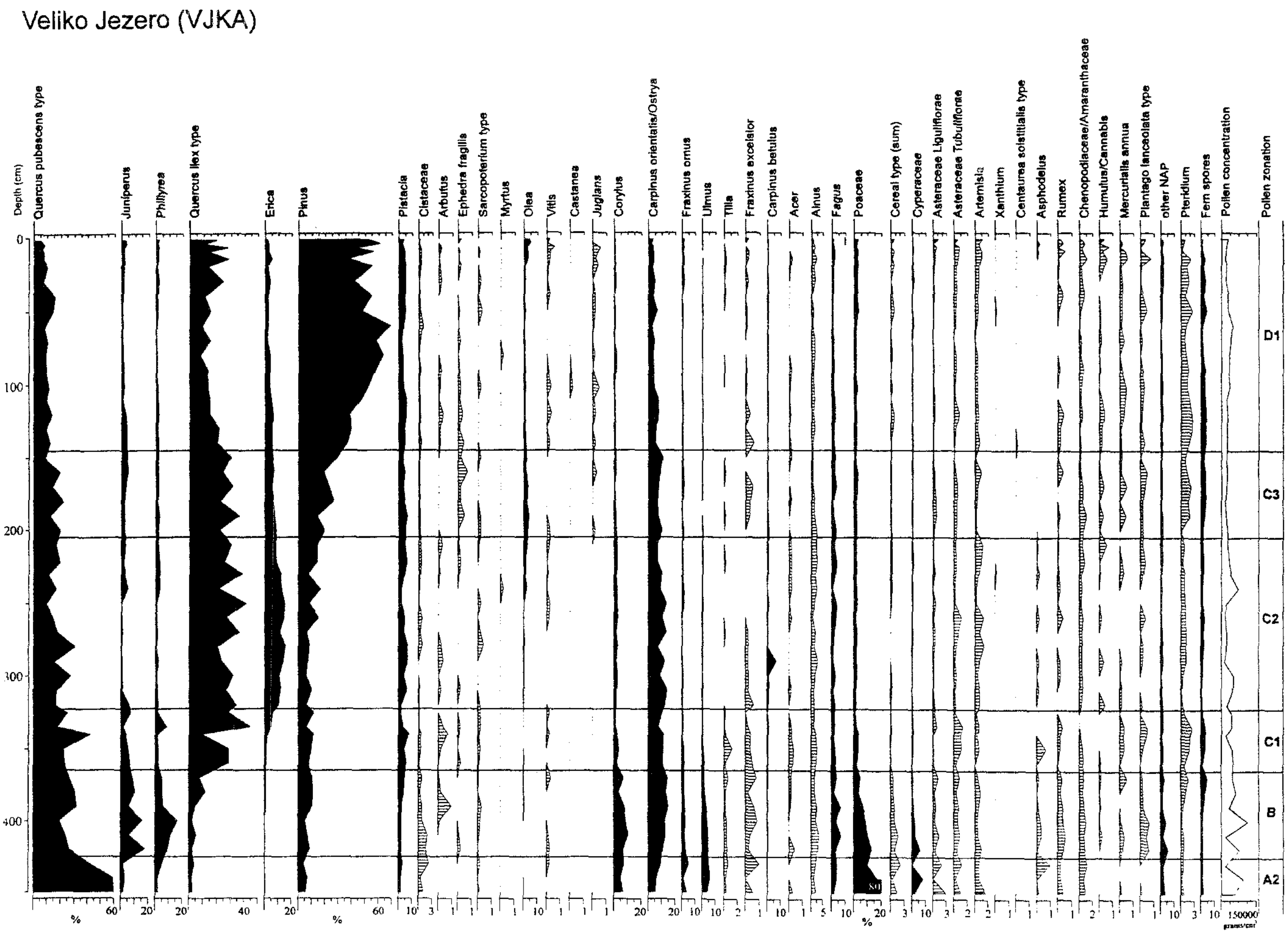

Fig. 8. Pollen diagram of Veliko Jezero (VJKA), selected taxa in percentage AP

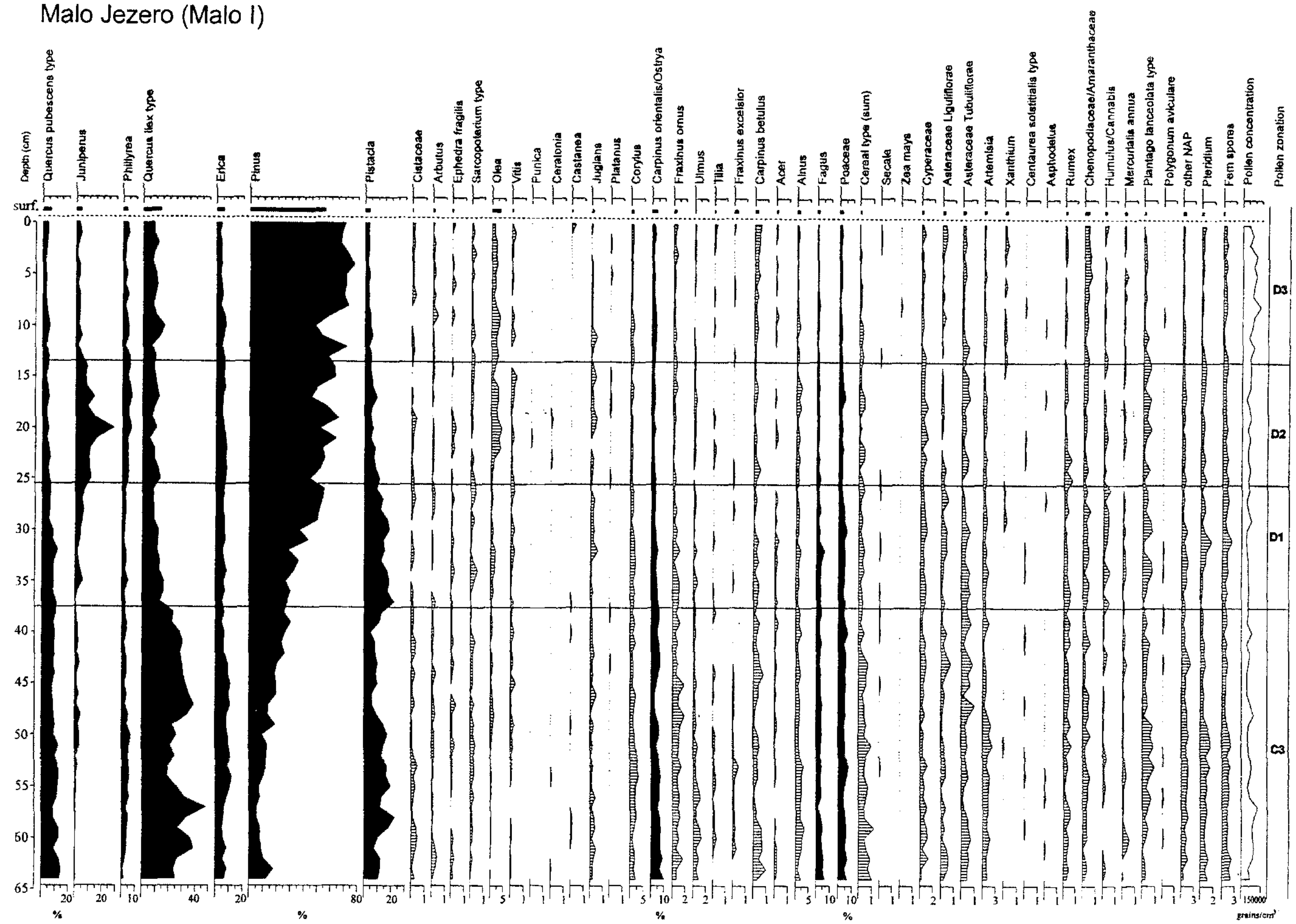

Fig. 9. Pollen diagram of Malo Jezero (Malo I), selected taxa in percentage AP

abundant in the older parts of zone B. Other evergreen taxa also occur more frequently, but the deciduous taxa were still important. It is difficult to tell how this *Juniperus-Phillyrea* vegetation might have appeared, because such a vegetation type does not exist today. In the modern vegetation of Dalmatia, *Juniperus oxycedrus* and *J. phoenicea* are common and, more rarely, at higher elevations *J. communis* (Polunin 1980). There is no similar past vegetation known in the Mediterranean which is not a result of human impact (Pons 1981). The composition of trees and shrubs in zone B indicates an open vegetation, although no increase of Poaceae and other non-arboreal pollen can be observed. Such an enlargement of the area covered by evergreen vegetation has been described by several authors as a result of human impact (for example, Beug 1977; Pignatti 1983). So it is tempting to attribute this change in vegetation to human activity. Spreading of *Phillyrea* maquis due to human impact could be shown at the Istrian coast by Beug (1977) and *Juniperus* is well-known as a good indicator of pasture (Behre 1981). However, it is questionable if such a drastic change in vegetation around 6000 B.C. really can be attributed to Neolithic settlers. So far no Neolithic settlements are known on Mljet, although that does not mean they did not exist. Batovic (1966) attaches more importance to fishing and possibly to livestock than to tillage in Neolithic times, although Neolithic cereal cultivation is known from Dalmatia and Hercegovina (Hopf 1958; Müller 1994). Even today, tillage on a larger scale is not possible on the island because of the restriction of arable land to the small poljes. Around Malo and Veliko Jezero there are mostly steep slopes. A change in vegetation as a response to increased burning should be traceable in the sediments, but no charcoal could be found at the transition to zone B.

These considerations and the observation that *Juniperus* and *Phillyrea* also spread on the mainland at the same time (Brande 1973, 1989; Grüger 1996) suggests rather a change in vegetation as response to climatic change. According to the interpretation of Beug (1961b, 1967) the increasing temperature at the beginning of the Atlantic period led to drier summers and milder winters, which was favourable for the evergreen taxa. The deciduous oak woodland was reduced to patchy stands, in which *Juniperus* and *Phillyrea* grew in the open spaces. The holm oak had not yet immigrated into the area, or was still in an early period of spreading.

The assumption that the climate was dry in zone B is in agreement with the results of the palaeolimnological investigations of Schultze (1988/89), who considers a conspicuous concentration of pigments in the sediments of Malo Jezero in zone B to be a result of a lowered lake level.

The values of *Carpinus orientalis/Ostrya* increase during zone B and they remain on a high level up to subzone C3. Pollen of *Carpinus orientalis* and *Ostrya* *carpinifolia* cannot be separated. Both species grow in Dalmatia today in the Submediterranean area. *Carpinus orientalis* grows mainly at lower elevations, *Ostrya carpinifolia* higher up (Horvat et al. 1974). Today, both species, especially the oriental hornbeam, are abundant in the sibljak, where they are favoured by human impact. This factor is reflected in pollen diagrams from northern Italy, Istria and southern Greece (Beug 1964, 1977; Greig and Turner 1974; Jahns 1993) but for much later periods. Earlier occurrences of the two species in Dalmatia and northern Greece are not necessarily connected to human influence (Wijmstra 1969; Brande 1973; Bottema 1974, 1979; Willis 1992).

All in all, there is no clear evidence to attribute the change from deciduous woodland to a more open vegetation to human impact. As long as no intensive settlement activity of Neolithic people can be proven this question must remain unanswered. The present knowledge supports the climatic interpretation of Beug (1961b, 1967).

Zone C; ca. 4400 cal B.C.-0 A.D. (after Beug 1962). With the beginning of zone C the vegetation changed again and the holm oak became the dominant tree. At the same time the holm oak spread in the coastal area of the mainland (Brande 1973). From zone C onward the vegetation on Mljet and on the mainland shows the character of the *Quercion ilicis* alliance, which is considered to be the natural vegetation of the Dalmatian coast (Horvat et al. 1974). Evergreen woody taxa become more important than deciduous taxa. The values of *Phillyrea* decrease soon after the increase of *Quercus ilex*. The high *Juniperus* values, however, persist during the early *Q. ilex* period (subzone C1). Perhaps the decrease of the light demanding *Phillyrea* and later of *Juniperus* was a result of the closing canopy of the holm oak woodland. The climate should have been favourable for the holm oak already in zone B. Therefore its late occurrence must be attributed rather to its migration history than to climatic conditions (Beug 1961b, 1967). Again it is the question whether human impact favoured the spreading of the holm oak as could be shown in western Mediterranean coastal areas (for example, Reille 1992; Reille and Pons 1992). A new pollen diagram from the Eumediterranrean zone from Italy (Lago d'Averno, near Naples), however, proves that *Quercus ilex* woodland must be considered as potential natural vegetation in that area (Grüger and Thulin 1998).

The *Quercus ilex* period can be divided into three subzones (C1-C3). While the *Q. ilex* curve remains at a relatively constant level, the associated vegetation changed several times. In subzone C1 the *Juniperus* values are still high, in subzone C2 *Juniperus* was replaced by *Erica* (*E. arborea* and *E. manipuliflora*) and in subzone C3 *Pinus* spread, now certainly on the island itself.

Maybe the frequent occurrence of *Erica* in subzone C2, which can also be observed on the mainland (Brande 1973), could be due to burning or grazing during the Bronze Age. *Erica arborea* could, however, also be part of the natural coastal vegetation (Reille 1992). The increase of *Pinus* in subzone C3 can be attributed to an introduction of *P. halepensis* on Mljet by Greek or Roman settlers. Measurements of the pollen grains allow the conclusion that the high values of *Pinus* derive from Aleppo pine, while the higher values in zone A1 belong to smaller pollen of the size of, for among others, *P. nigra* (Agwu and Beug 1982). It can be assumed that *P. halepensis* was introduced to the Balkans by the Roman settlers, while *P. nigra* grew in the natural vegetation (Horvat et al. 1974; Domac 1965). Because of the large number of broken grains, the real proportion of *P. halepensis* in subzone C3 cannot be stated.

Along with the increase of the pine, *Juglans* shows an almost closed curve, *Olea* displays higher values and single grains of *Ceratonia* appear for the first time (Malo I). This shows clearly the impact of Greek or Roman settlers on the island of Mljet. *Juglans* is a tree that was introduced by the Greek or Romans to the Balkan area (Bottema 1980). The age of ca. 1300 B.C. for its appearance on Mljet is maybe too old compared to a date of 163 B.C. from the mainland (Brande 1973).

Zone D; ca. 0 A.D. (after Beug 1962) - modern times. This pollen zone is subdivided into three subzones D1-D3. The increase of *Pinus* in subzone C3, which dates back to the Greek and Roman colonisation of Dalmatia, started the transition to a vegetation dominated by *P. halepensis*. In the diagrams from Malo Jezero, *Pistacia* shows maximum values, while in all diagrams *Quercus ilex* and *Carpinus orientalis/Ostrya* decrease. *Buxus* and *Punica* occur for the first time. The picture resembles the modern vegetation: open *Pinus halepensis* forests with an undergrowth of *Quercus ilex* and *Pistacia lentiscus*.

Olea displays maximum values, but they do not exceed 5%. *Olea* is a good pollen producer, especially as a cultivated tree (Bottema 1982, 1984). The values displayed in zone D would be relatively low for olive cultivation (Bottema and Woldring 1990; Jahns 1993;

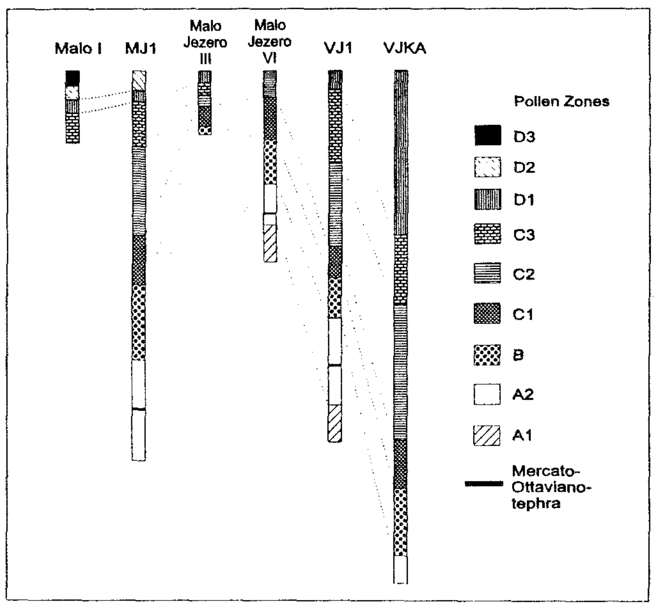

Fig. 10. Pollen stratigraphical correlation of the cores of the present study and of the cores Malo Jezero III and VI from the studies of Beug (1961b, 1962)

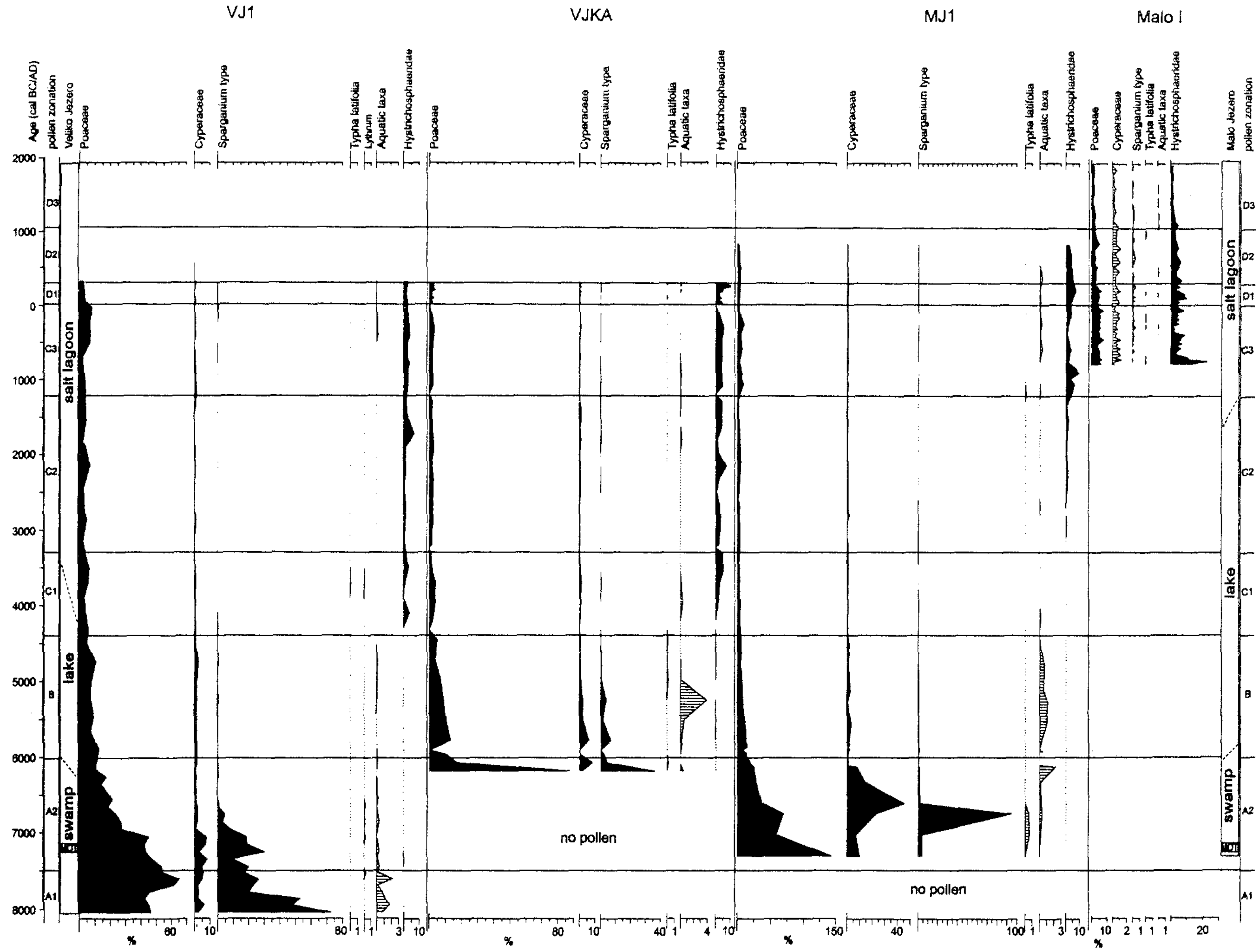

Fig. 11. The lake development as reflected in the pollen record (percentage AP). The group of aquatic taxa includes *Potamogeton, Myriophyllum, Utricularia* and *Nymphaea*. MOT = Mercato-Ottaviano tephra

Zangger et al. 1997). If olives were planted near the lakes they could not have been abundant. However, olive cultivation in Roman times is plausible and it is proven for the 5th century (Cvetkovic 1986). The low *Olea* values can be explained by the shortage of arable land in the vicinity of the lakes.

Subzone D2 is characterized by a strong increase of *Juniperus* and a distinct decrease of *Quercus ilex, Carpinus orientalis/Ostrya* and *Pistacia*. The *Juniperus* species which expanded during subzone D2 were most probably *J. phoenicea* and *J. oxycedrus*. Today both species are abundant in the Mljet national park. The presence of *J. oxycedrus* is shown by a pollen grain of the parasite *Arceuthobium oxycedrus*. The spreading of juniper indicates that the woodland was reduced in size, maybe as a result of grazing. Increased findings of *Secale* possibly indicate rye cultivation. Unfortunately up to now it is not possible to date this period precisely.

In subzone D3 *Juniperus* values decrease again. This could be the result of reduced human impact. Brande (1973) describes a distinct decrease of *Juniperus* in the surroundings of the Roman town of Narona after its decay during the 7th century.

In subzone D3 the vegetation was dominated completely by pines. Although one has to keep in mind that *Pinus* pollen is strongly over-represented in pollen records, the frequency of *Pinus* in subzone D3 is in agreement with the presence of *P. halepensis* in the modern vegetation of the Mljet national park. The pollen composition and percentage values of subzone D3 are similar to those of lake bottom surface samples from Malo Jezero (Fig. 9). A pollen grain of *Zea mays* shows an age later than the 16th century (Huber 1962). Since zone D2 a distinct decrease of the beech can be observed, which could be attributed to forest clearing in the mountains.

Swamp vegetation and lake level rise. Malo Jezero and Veliko Jezero existed already during the Pleistocene as dry poljes (Schultze 1988/89). During the early Holocene the poljes were filled up during a transgression of the Adriatic Sea and a connected rise of the ground water table. First both poljes became swamps, which are the source of the high amounts of Poaceae, Cyperaceae and *Sparganium* type (including *Typha angustifolia*) in zone A. The successive flooding of the poljes explains why the maximum values of these local taxa are not found synchronously in the profiles MJ1, VJ1 and VJKA. Fig. 2 shows the core position below the recent lake level. A rise of the ground water table would have filled the poljes starting at the position of VJ1 continuing to MJ1 and at last to VJKA. This is exactly what can be observed in the pollen diagrams (Fig. 11).

Later the swamps were flooded and became first shallow, and later deep lakes. This continuous process is shown by a decrease of Poaceae, Cyperaceae and *Sparganium* type in zone A. The lake shore steepend and the swamp and shore vegetation disappeared with the rise of the lake level. Instead taxa indicating open water increased, such as *Utricularia*, *Myriophyllum*, *Nymphaea* and *Potamogeton*. These taxa disappeared when the lakes were flooded by the Adriatic sea, at Veliko Jezero between 4400 and 3300 B.C. and at Malo Jezero only around 1400 B.C., and marine Hystrichosphaeridae appeared instead. Considering the age of 1400 B.C. for this change in Malo Jezero as perhaps too old it seems possible that the connection between Malo and Veliko Jezero was built by Greek or Roman settlers.

For a more detailed picture of the lake development a diatom and sedimentological study on the lake sediments was undertaken, which will be published separately (J. Müller personal communication).

The record of non-arboreal pollen (NAP) and the question of herbaceous anthropogenic indicators

All diagrams show that there was never a period of large scale deforestation on Mljet as could be shown on the mainland (Brande 1973, 1989), not even during Medieval times. The extremely high amounts of Poaceae and Cyperaceae pollen in zone A certainly have their source in the local swamp vegetation when the flooding of the poljes started. The same holds true for the relatively high values of large sized Poaceae pollen grains, the central European cereal type (Beug 1961a). In the Mediterranean area this cereal type often comes from wild grasses (Behre 1990) and it is therefore mostly of limited significance as an indicator of human impact. Relatively high values of Asteraceae pollen in zone A should also derive from the local swamp vegetation.

Since the flooding of the swamps, however, the values of Poaceae, Cyperaceae and other NAP remain at a low level throughout the whole pollen record even during zone B and subzone D2 where the composition of trees and bushes indicates a more open vegetation. Herbaceous taxa occurring in the pollen record which could be considered as secondary indicators of human impact in terms of Behre (1990) are *Artemisia*, *Xanthium*, *Centaurea solstitialis* type, *Asphodelus*, *Rumex*, Chenopodiaceae/Amaranthaceae, *Humulus/Cannabis*, *Mercurialis annua*, *Plantago lanceolata* type, *Polygonum aviculare* and *Pteridium* (Bottema 1982; Bottema and Woldring 1990; Behre 1981, 1990, among others). All these taxa occur throughout the pollen record, even in zone A, where no human impact can be expected. All of them also occur in the natural vegetation. They display relatively low values and show only small fluctuations. They do not increase suspiciously in a special pollen zone.

The thin layers of Malo Jezero

The investigations of Seibold (1958) and Seibold and Wiegert (1960) revealed already that part of the sediments of Malo Jezero contains thin, most probably annual, layers. One aim of the present study was to investigate these layers, which were comprised in the short cores Malo I and Malo IX. Dr. J. Merkt from the Niedersächsisches Landesamt für Bodenforschung, Hanover, kindly tried to make thin sections of the sediment to get a good chronology for the youngest parts of the pollen record. Unfortunately the thin sections did not harden properly because of the high salt content in the sediments and the layers could not be counted well. It was not possible to show whether the thin laminae are really annual layers, although it can hardly be doubted (J. Merkt personal communication). The counting of the layers of Malo I gave a maximum age of 700 years. In this case subzone C3 would date to the Medieval period. This would be a clear contradiction to the radiocarbon dates from MJ1 and to the present knowledge about the introduction of *Juglans* in Dalmatia and Istria (Brande 1973; Beug 1977). The radiocarbon date of the base of core Malo IX, a parallel core of Malo I, causes further confusion. It was obtained from a little piece of wood and therefore cannot be distorted by old carbonate, but gave an age of 245 ± 150 B.P. (cal A.D. 1658) for subzone C3 (Jahns 1992). This would mean that the whole sediments of zone D would have been deposited during the last 300-400 years. This does not seem very likely and so this second investigation of the annual layers in Malo Jezero has opened questions which demand a third one.

Conclusions

New palynological investigations on three long and two short cores from the two salt lagoons Malo Jezero and Veliko Jezero on the island of Mljet, south Dalmatia gave pollen records that span a period of the last 9000 years. They confirm the results of older palynological studies on Malo Jezero (Beug 1961b, 1962, 1967) and extend the knowledge of vegetation history to the last 2000 years.

The lakes were formed by flooding of dry Pleistocene poljes as a result of a Holocene sea transgression and a connected rise of the ground water table. Until ca. 6000 B.C. they were swamps, later they became deep lakes, first with fresh to brackish water. Between 4400 and 3300 B.C. Veliko Jezero was connected to the Adriatic sea, Malo Jezero only much later. Perhaps the connection between the two lakes was built by Greek or Roman settlers.

Pollen records of the three long cores (MJ1, VJKA, VJ1) include the same periods which were defined in the study of Beug (Fig. 10). The bases of the three pollen records, however, are of different ages because the flooding of the poljes did not happen synchronously. The sedimentation rates of the cores show very big differences. Core VJKA from the western bay of Veliko Jezero is especially variable. Comparing the sedimentation rate of core MJ1 to the cores from Malo Jezero of Beug (1961b, 1962), large variations are also visible.

The pollen record shows a period of mixed deciduous oak woodland until ca. 7200 B.P. (6000 cal B.C.). Evergreen taxa were rare but not absent. At the transition to the Atlantic period the dense oak woodland changed to apparently patchy stands of trees with *Juniperus*, *Phillyrea* and other evergreen taxa growing in the open places. With the immigration of *Quercus ilex* around 5500 B.P. (4400 cal B.C.) dense holm oak forests were formed which are considered to be the natural vegetation of the Dalmatian coast. Neither the spreading of *Juniperus* and *Phillyrea* nor later of *Quercus ilex* can be linked to Neolithic human impact. With the present knowledge about the Neolithic settlement history a response of the vegetation to increasing dryness during the Atlantic period and later to immigration of the holm oak in the area seems more plausible.

Around 3000 B.P. (1100 cal B.C.) the holm oak forests were partially replaced by Aleppo pine as a result of human impact. This picture corresponds to the modern vegetation on the island of Mljet. The date of 3000 B.P. can be considered as too old because of old carbonate in the sediments.

Extensive deforestation as on the Dalmatian mainland did not happen on Mljet, not even in historical times. Human influence is not reliably traceable until ca. 3100 B.P. (1300 cal B.C.) (maybe even later, see above) and afterwards it is scarce due to the shortage of arable land near the lakes. *Pinus halepensis*, *Juglans*, *Platanus*, *Castanea*, *Ceratonia* and *Punica* were introduced to the island. An increase of *Olea*, *Secale* and *Juniperus* values can be attributed to agriculture.

The new palynological study has completed the knowledge about the development of the vegetation on Mljet. The regional aspects should be transferable to the other south Dalmatian islands. Still, this exceptional site would justify a third investigation focusing on precise dating of the youngest sediments and the annual layers of Malo Jezero.

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