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POLLEN ANALYSES OF THE SEDIMENTS OF PLITVIČKA JEZERA (LAKES OF PLITVICE)

METKA CULIBERG and *ALOJZ ŠERCELJ*

(Slovene Academy of Sciences and Arts, Ljubljana)

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Introduction

The National Park of Plitvička jezera (the Lakes of Plitvice, 15°35′E Greenw., 44°51′N) is known world-wide for its unique beauty owing to its continuously growing and changing water falls and lakes. These are formed as a consequence of the deposition of calcareous tuffa that created so many barriers and lakes along the river bed of the Korana river.

To get some information about the age of the deposits and the rate of growth of barriers of tuffa, palynological investigations were planned upon initiative of the Department for Nature Conservation of the Park Administration which also provided some financial support.

The first borings were carried out in August 1977 on a peat marsh on both sides of the brook Matica, which is a tributary to the uppermost lake Proščansko jezero.

The cores were acquired by means of a modified Dachnowsky sampler to a depth of 800 and 850 cm, from alternate bore-holes, each in two series. The field work including borings and palynological investigations were performed by the authors.

Core 1 was taken in a side valley, Kmezina bara, (639 m elevation) and core 2 in a side valley, Luličina draga, (640 m), both covered by very thick peat banks (Fig. 1). The water level of Proščansko jezero is at 636,5 m elevation (1958).

Extraction procedures and problems

The standard chemical treatment used for extraction and concentration of pollen from the samples of both cores proved inefficient in some cases, as too much sterile organic matter remained in the samples. Larger

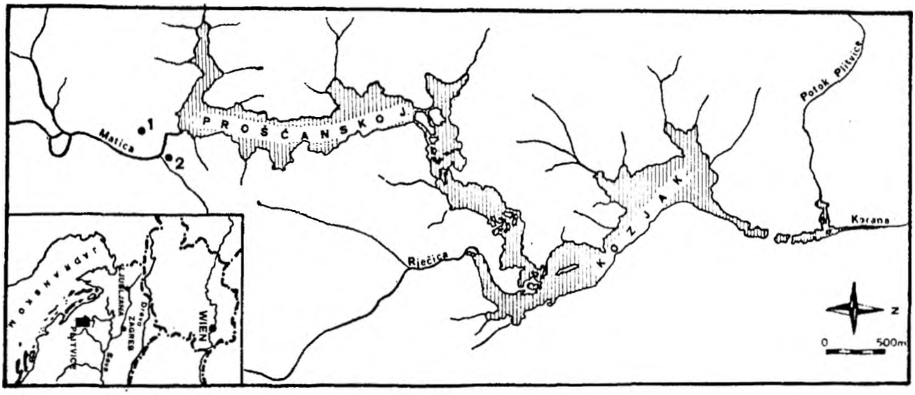

Fig. 1. Plitvice, location of the two corings

organic particles could be removed by sieving, but small detrital particles of the size of some micrometers passed the sieves but could not be dissolved by acetolysis, being probably mostly lignitic débris of branchlets. The precipitated colloid fraction of humates could not be removed either by acetolysis or by flotation. As a consequence, the concentration of pollen was not satisfactory in many samples, which were so poor that only a small number of pollen grains could be found in several slides of the same sample.

Results

Stratigraphy

Core 1 — Kmezina bara (639 m)

0— 5 cm	*Sphagnetum*, recent.
5— 80 cm	Mainly *Phragmites* peat.
80—400 cm	*Caricetum* peat, partly weathered to a watery, dark brown pulp.
400—600 cm	Coarse detritus peat consisting largely of branchlets, dark brown colour.
600—780 cm	Organic detritus (gyttja) mixed with mineral particles.
780—800 cm	Dolomitic sand mixed with fine organic detritus.

Core 2 — Luličina bara (640 m)

0— 10 cm	Turf
10—615 cm	Brown moss peat, heavily weathered, dark colour.
615—655 cm	Plant detritus of disintegrated branchlets, organic gyttja.
655—675 cm	Fine débris of branchlets, mollusc shells.
675—855 cm	Plant débris mixed with mineral particles and fragments of mollusc shells.

Pollen diagram I

The diagram (Fig. 2) represents the development of the Postglacial vegetation. This means that the entire peat bank cannot be older that 10000 years, and according to the curve of *Abies*, not much more than 7000 years.

Pinus — Pollen of the pine, a pioneer and heliophilic forest component, is poorly represented throughout the whole diagram. This means that the forest by that time was at advanced and still undisturbed stages, admitting no pioneer elements. The rise of *Pinus* curve at the depth of 250 cm may be regarded as a consequence of a temporary disturbance in the forest either by man or by a natural event.

Picea — Uniformly low percourse of the curve of spruce shows that the participation of this tree in the forest vegetation persisted at a relatively constant level and hence it has but slight indicatory value for pollen zonation.

Abies — The fir starts in the diagram with high pollen values. This fact may be considered as reliable evidence that the fir had spread here prior to the period represented in the pollen diagram. According to Kral (1972, 1979) *Abies* joined these territories as late as the Boreal or only at the beginning of the Atlantic period, coming from its refugial places in the Appenine mountains of Central Italy. It remains to be checked whether *Abies* could have had any refugia in the Balkan Peninsula as well.

As for the Adriatic Coast *Abies* seems to have been absent for the most part, at least during the Holocene period. Beug (1961) for instance found only sporadic pollen grains of *Abies* in the sediments of Malo jezero on the Isle of Mljet. On the contrary, Brande (1973) found in the sediments of the delta of the Neretva river more than 15% of *Abies* in beds older than 5195 ± 175 radiocarbon years B. C. (= 7195 y. B. P.).

Even more convincing are the results of palynological investigations of Bottema (1974) in the interior of northern Greece. He found high pollen percentages of *Abies* in different pollen zones of pollen diagrams from different localities and at different periods in the interval from the early Würmian to the Late-Glacial and throughout the Holocene. For example Khimaditis I 9345 ± 85 to 3995 ± 60 y. B. P.; Khimaditis II 8020 ± 75 y. B. P.; Joannina I prior to 10190 ± 90 y. B. P.; Joannina II 45800 ± y. B. P.; Edessa 8050 ± 70 y. B. P.

Thus, conclusive evidence is provided that, also in the southern part of the Balkan Peninsula, at least in the inland, *Abies* had its refugial places during the Würm glacials and interstadials, during the Late-Glacial and during the early Holocene periods as well. From those places it could have started to migrate northwards. What its migration pathways along the inner parts of the Balkans were, and at what time it happened, remains unknown as yet.

In any case the fir, reaching the area of Plitvička jezera as one of the last forest constituents incorporated into the pre-existing beech forests, gave rise to the climax formation of *Abieti-Fagetum*. That could have occurred as late as the end of the Boreal or the beginning of the Atlantic period. So that is possibly the time of the starting point of the lower part of this digram.

Juniperus — Juniper, whose pollen appears only in one spectrum (170 cm), can be regarded as an indication of locally degraded forest, possibly as a consequence of the pasturing of sheep.

Betula — Birch as a heliophilic and pioneer element cannot be expected to reach high pollen values in the frame of advanced forest stages since its natural period of maximum spreading is the Late-Glacial.

Alnus — Alder as a marsh and shore dweller sometimes influenced to a lesser degree the general feature of pollen precipitation.

Corylus — The extremely low pollen percentages of hazel indicate a dense forest vegetation of advanced stages, where the dense tree canopy did not admit heliophilic elements to grow. The time of the natural Holocene phase of *Corylus* had passed as well.

Juglans — The walnut-tree, although its pollen is present in one spectrum only, is indicative enough of man's activity in this area.

Fagus — Beech, jointly with the fir, the most important constituent of the climax forest, is dominant throughout the pollen diagram. Slight declines in the middle of the diagram might be interpreted as a consequence of human activity in clearing the woods on better soils for pasture and farming.

The pollen of herbs (NAP) is weakly represented except that of aquatics and marsh plants. Lack of herbs can be interpreted as an indication of dense forests.

Pollen diagram II

At Luličina draga the core reached somewhat deeper (Fig. 3). Hence it is concluded that the growth of peat was different from that of core I. The sediments, mostly peat of different provinence, are weathered to a great extent; that means also a bad preservation of pollen.

Pinus — The pine curve keeps throughout at low percentages, which is evidence of the forest being undisturbed to some extent during this period.

Picea — The pollen percentage of the spruce follow normal percourse without any noticeable fluctuation.

Abies — The pollen curve of the fir starts at low percentages to increase to high values, an indication that the climax forest, *Abieti-Fagetum*, at this point was in its early stages. A comparison to core I, in which a fully developed *Abieti-Fagetum* is met already at the beginning of the diagram, leads to the conclusion that this core reaches a somewhat earlier period than core I. A correlation is possible at the depth of 595 cm in this diagram to 390 cm in the diagram I.

A marked increase in the pollen percentages of *Abies* is characteristic of both pollen diagrams, though at different depths. Whether this increase can be correlated to a similar rise of the *Abies* curve at the end of the Eneolithic or copper age at Ljubljansko barje (Šercelj 1955, Culiberg, Šercelj, 1978, in print), is a supposition at present, but because of the great similarity of the diagrams, this coincidence should be pointed out.

Betula — Pollen percentages of the birch remain at low values, which could be a sign of undisturbed forest.

Alnus — *Alnus* may represent a local marsh vegetation along the shores of the lake; nevertheless, it reaches as high pollen values as those in core I.

Corylus — Hazel starts with relatively high percentages, perhaps thus representing the decline of its original pollen zone in the Boreal time, with marked recession towards the top of the diagram.

Carpinus — Hornbeam attained slightly higher percentages than in daigram I.

Mixed oak forest (*QM*) remains at nearly the same values as in profile I.

Fagus — Beech starts at the bottom of the pollen diagram with low pollen values which then rise in the upper parts of the diagram. Perhaps this represents the early peak of the *Fagus* curve known from Slovenia (Šercelj 1963), dated presumably to the end of the Boreal time. This can be regarded as additional evidence to date the pollen profile II earlier than profile I.

Fraxinus excelsior cannot be regarded in this case as a constituent of QM.

Salix — Willows as common shore vegetation are not indicative of postglacial vegetation.

Pollen occurrence of *Cornus, Ligustrum, Hedera* are sporadic.

NAP — herbaceous plants:

Cyperaceae represent a common marsh vegetation especially in the lower parts of the core, while *Gramineae* and *Compositae* prevail at the upper levels.

Hydrophytes are represented by *Nuphar, Nymphaea, Myriophyllum, Potamogeton, Sparganium* and *Typha*.

Filices — monolete spores prevail including those of *Dryopteris* and *Athyrium*, while trilete, which are less common, belong to *Pteridium*. Unexpectedly also spores of *Selaginella selaginoides* are present at one level. They may be derived either from the mountain chain of Plješivica or may be a redeposition from possible Pleistocene sediments upstream of the brook.

Chronological correlation

According to the vegetation and successions represented in both pollen diagrams they are to be put into the Holocene. However, when a more detailed zonation is attempted, insuperable difficulties are met.

First, for these territories, there is no stratotype set up as yet and hence the course of postglacial successional steps in the forest vegetation is unknown to us. Similarly the absolute chronological situations of single forest stages, which are different at different geographical situations, are unknown. We have therefore no basis to put both profiles into the frame of the Holocene vegetation.

Besides all this, some levels of the peat profiles are heavily decayed, so much so that their pollen content has been either partly or completely destroyed. There is therefore no evidence for the continuity of the existing profiles. In core II, for instance, the pollen occurs partly from a depth of 5 m upwards to 3 m, but above that depth it is totally destroyed. For a reliable dating radiocarbon analyses are yet to be made. The samples from the first core programme are not suitable and new samples should be taken from the specific horizons.

As all pollen diagrams from the glacial moor at Trstenik near the village of Gomance, Snežnik (Gigov, Nikolić 1960, Šercelj 1971) start in the Late-Glacial, we have there at least one basis to gain some insight into the initial vegetation and its relationship to the postglacial one.

As opposed to that, the diagrams of Plitvice start in full Postglacial, at the climax stage of *Abieti-Fagetum*. The phases of *Pinus-Betula, Quercetum mixtum* and partly *Corylus* are past already. It should be stressed that both pollen diagrams from Plitvice comprise this unique forest type, namely *Abieti-Fagetum*.

Likewise, in both pollen diagrams, the curve of *Abies* rises to dominant values at the top of the diagrams. A parallel to this feature can be found in the pollen diagrams at Ljubljansko barje at the level of Eneolithic Lake-dwellers' culture, e. g. lake-dwelling near the village of Kamnik at the foot of the mountain Krim (Šercelj 1955) and at its contemporary settlement Parti, some 10 km eastwards (Culiberg, Šercelj 1978, Šercelj, Culiberg in print). We can hardly ascribe the intensive recession of *Fagus*, at whose enpense *Abies* gained so much, to the activity of man. But it is worth mentioning that the beech is by far the most sensitive to forest fire, and prehistoric man could have used it to enlarge open areas, as did man in the near past.

If this is true, it can be assumed that at the same time, i. e. at the end of the Eneolithic period, man who settled the area of Plitvička jezera and the Lake of Ljubljana as well, could have destroyed by fire the beech forests in his surroundings. This would have created a favourable situation for the fir, which attained absolute dominance for a limited time.

Archaeological findings of lithic, bronze and iron implements within the area of the Lakes of Plitvice (Ljeskovac, Korenica, Plitvice, Drežnik, to name some of them) provide a firm testimony that Eneolithic, bronze-age and Hallstatt man lived here (Čulinović 1958). The same can be said for Ljubljansko barje which had been settled throughout the same periods.

Therewith a chronological correlation can be set also for the upper part of the diagrams exhibiting the dominance of *Abies:* Eneolithic to Bronze-age, i. e. 5000—4000 B. P. The presence of man during that time is proved by the pollen of cereals (*Triticum*) and walnut tree (*Juglans*).

With this time palynological evidence expires, because in the upper levels of the peat the pollen was destroyed by weathering processes.

Summary

In the area of Plitvička jezera (Lakes of Plitvice) two core holes were drilled to a depth of 8 m. Palynological analyses show Holocene forest vegetation, namely the climax *Abieti-Fagetum* as described by Plavšić-Gojković, Plavšić, Golubović (1974). Initial postglacial forest phases which preceded Abieti-Fagetum are not represented in the pollen diagram. Hence the conclusion can be drawn that the vegetation, as shown in the diagrams, starts as late as the end of the Boreal period, i. e. at about 8000—7000 years B. P. The short-term dominance of *Abies* at the top of the diagrams may coincide with a similar rise of *Abies* at Ljubljansko barje, contemporary to Eneolithic settlement, which is the period between 5000 and 4000 years B. P. At this time interval, 8000—4000 y. B. P. both pollen diagrams can be dated. Thereby also a direct indication is provided as to the time and the extent of the growth of the barrier and the rise of the water-level of Prošćansko jezero.

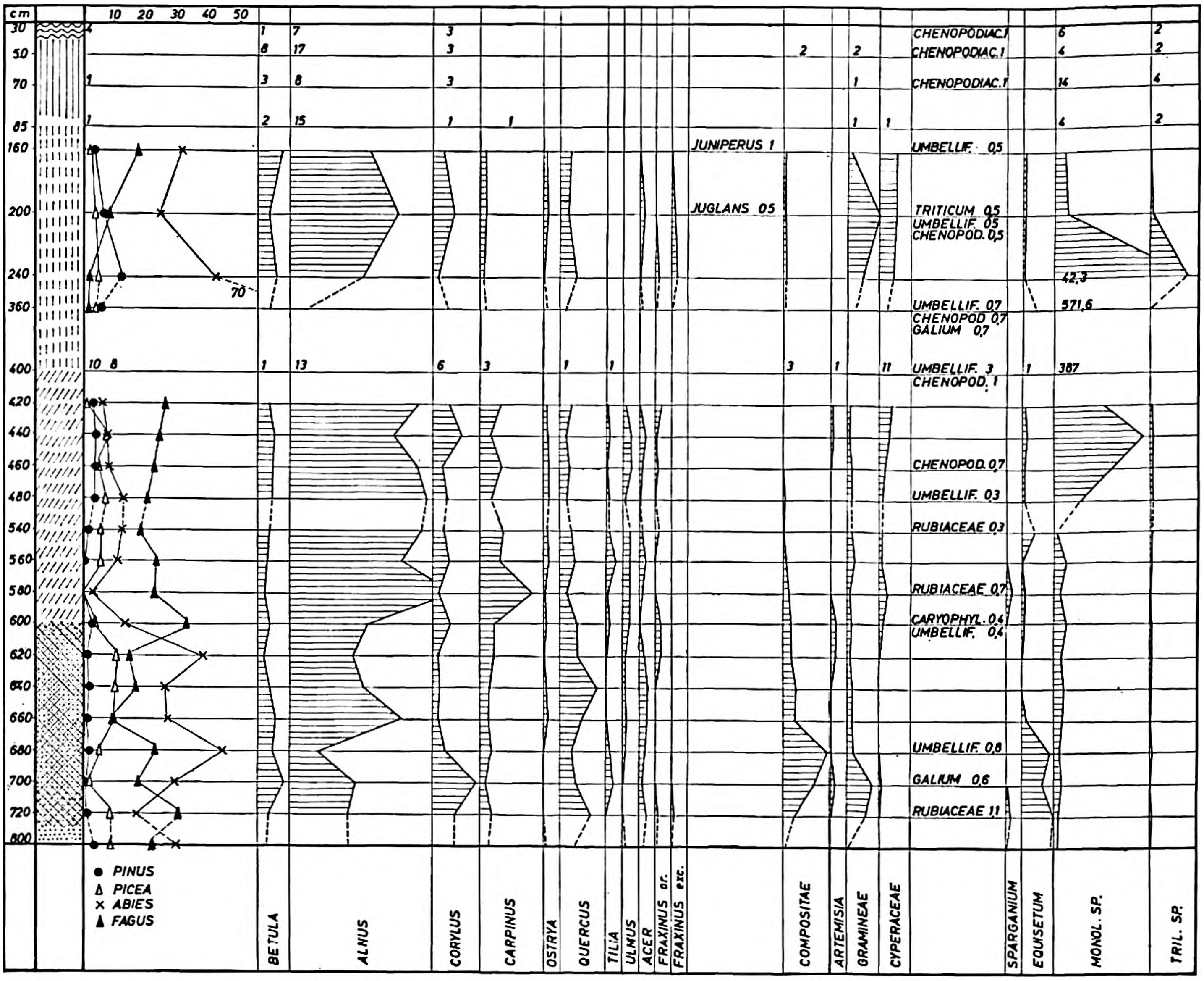

Fig. 2. Pollen diagram I — Kmezina bara

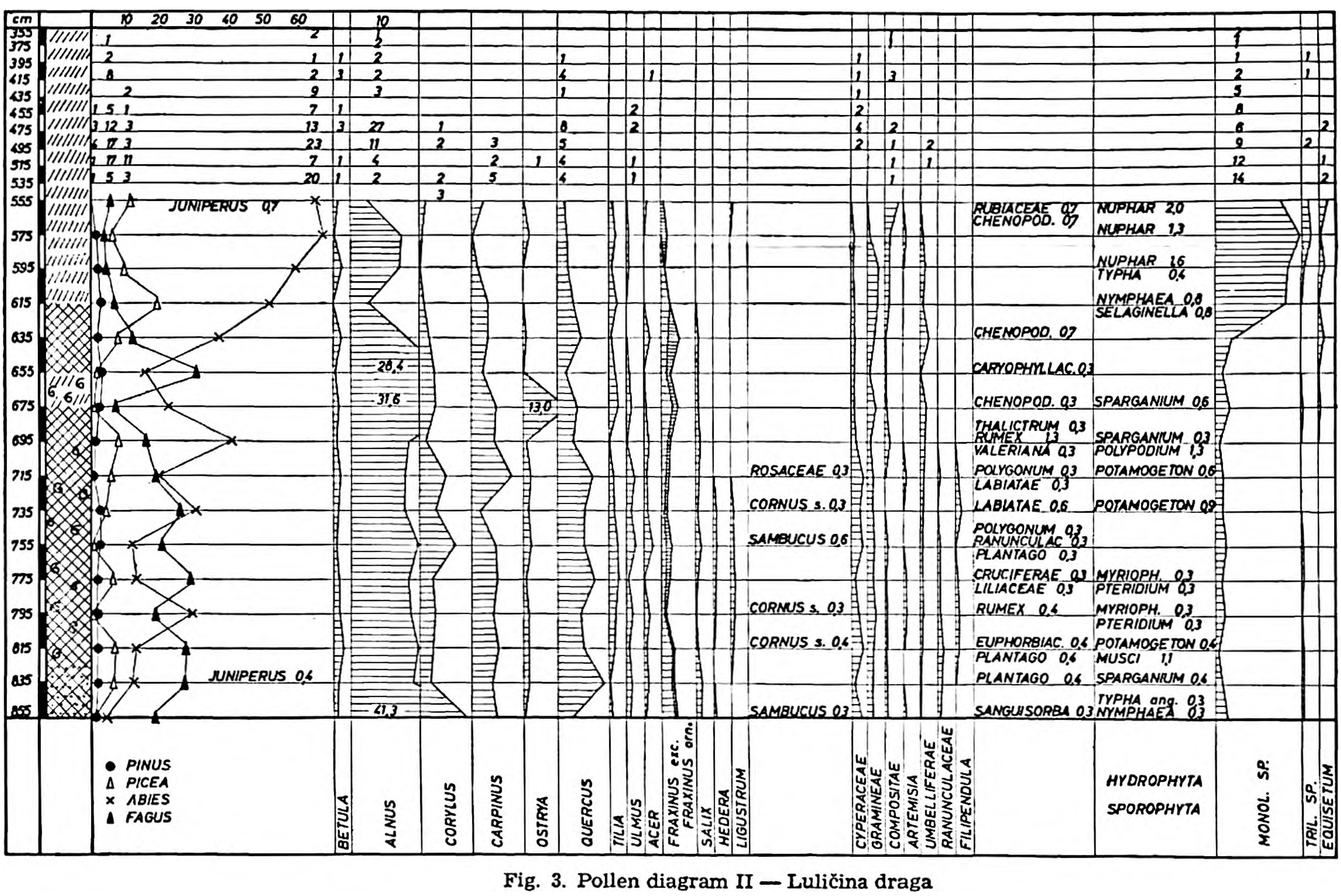

Fig. 3. Pollen diagram II — Luličina draga

References

Beug, H. J., 1961: Beiträge zur postglazialen Floren- und Vegetationsgeschichte in Süddalmatien: Der See »Malo Jezero« auf Mljet. Flora *150*, 4, 600—631.

Brande, A., 1973: Untersuchungen zur postglazialen Vegetationsgeschichte im Gebiet der Neretva-Niederungen (Dalmatien, Herzegovina). Flora *162*, 1—44.

Bottema, S., 1974: Late Quaternary vegetation history of northwestern Greece. Groningen.

Culiberg, M., A. Šercelj, 1978: Ksilotomske in palinološke analize rastlinskih ostankov s kolišča na Partih pri Igu — izkopavanja leta 1977. Xylotomische und palynologische Analysen der Pflanzenüberreste aus dem Pfahlbau Parti bei Ig, Ausgrabung 1977. Poročilo o raziskovanju paleolita, neolita in eneolita v Sloveniji VI, 95—99. Ljubljana.

Čulinović, F., 1958: Plitvička jezera u prošlosti. Die Plitvizergegend in der Vergangenheit. Plitvička jezera — Nacionalni park, 21—48, Zagreb.

Gigov, A., V. Nikolić, 1960: Rezultati analize polena na nekim tresavama u Hrvatskoj. Analyses polliniques de quelques tourbières en Croatie. Glasnik Prir. muz. ser. B., *15*, 2—26. Beograd.

Kral, F., 1972: Grundlagen zur Entstehung der Waldgesellschaften im Ostalpenraum. Ber. Deutsch. Bot. Ges. *85*, H. 1—4, 173—186. Berlin.

Kral, F., 1979: Spät- und postglaziale Waldgeschichte der Alpen auf Grund der bisherigen Pollenanalysen. Veröff. Inst. f. Waldbau Univ. Bodenkultur. Wien.

Plavšić-Gojković, N., M. Plavšić, W. Golubović, 1974: Čorkova uvala — prašuma u nacionalnom parku Plitvičkih jezera. Plitvička jezera — čovjek i priroda, 67—70, Zagreb.

Šercelj, A., 1955: Palinološki profil kolišča pri Kamniku pod Krimom. Un profil palynologique dans le village lacustre près de Kamnik sous le Krim. Arheol. vestn. *6* (2), 260—271, Ljubljana.

Šercelj, A., 1963: Razvoj würmske in holocenske gozdne vegetacije v Sloveniji. Die Entwicklung der Würm- und der Holozän-Waldvegetation in Slowenien. Razpr. *4*. r. Slov. akad. znan. umetn. *7*, 363—418, Ljubljana.

Šercelj, A., 1971: Postglacialni razvoj gorskih gozdov v severozahodni Jugoslaviji. Die Postglaziale Entwicklung der Gebirgswälder im nordwestlichen Jugoslawien. Razpr. 4. r. Slov. akad. znan. umetn., *19/9*, 267—294. Ljubljana.

Šercelj, A., M. Culiberg: Paleobotanične raziskave kolišča na Partih — iskopavavanja 1978. Paläobotanische Untersuchungen des Pfahlbaus Parti — Ausgrabung 1978. Poročila o raziskovanju paleolita, neolita in eneolita v Sloveniji (in print.).

SAŽETAK

POLENOVA ANALIZA SEDIMENATA PLITVIČKIH JEZERA

Metka Culiberg i *Alojz Šercelj*

(Slovenska akademija znanosti in umetnosti, Ljubljana)

U području Plitvičkih jezera izbušene su bile dvije ručne bušotine do dubine 8 m. Palinološkom analizom obaju profila utvrđena je isključivo holocenska šumska vegetacija klimaksnog tipa *Abieti-Fagetum*, kakav opisuju Plavšić-Gojković, Plavšić, Golubović (1974). Početne postglacialne faze nisu zastupljene u polenovu dijagramu. Iz toga se može zaključiti da u dijagramu predstavljena vegetacija počinje na kraju borealnog doba, približno prije 8.000—7.000 godina. Kratkotrajna dominacija jele na vrhu obaju dijagrama mogla bi se korelirati sa sličnom dominacijom u području Ljubljanskog barja u eneolitsko doba, prije 5.000—4.000 godina. U taj vremenski interval, 8.000—4.000 godina, mogli bismo staviti oba naša dijagrama. Tako se dobiva izravan dokaz, u koje vrijeme i za koliko se uzdizala sedrena barijera i razina vode Prošćanskog jezera.

Metka Culiberg
Dr Alojz Šercelj
Slovenska akademija
znanosti in umetnosti
Novi trg 3
YU-61000 Ljubljana (Jugoslavija)