Palynology of the Miocene Bentonite from Gornja Jelska
(Mt. Moslavačka Gora, Croatia)

Krešimir KRIZMANIĆ

Key words: Palynology, Paratethys, Bentonite, Miocene freshwater sediments, Mt. Moslavačka Gora, Croatia.

Abstract
Deposits were studied from the bentonite clay mine in Gornja Jelska on Mt. Moslavačka Gora where the remains of Dinotherium bavaricum KAUP had been found. It was established by palynological methods that sediments had been deposited during the Upper Karpathian - Lower Badenian stage (between 15.5 - 17 my. ago). The climate was warm, subtropical. Sedimentation took place in swamp which was surrounded by meadows and hill-side forests.

1. INTRODUCTION
Vertebrate fossils have been found in Central Croatia on the Mt. Moslavačka Gora, about sixty kilometres east from Zagreb in the Draga pit of the bentonite clay mine Gornja Jelska situated some ten kilometres north of small town Popovača (Fig. 1). Later, it was determined that the remains belong to Dinotherium bavaricum KAUP but the geological age and the palaeoenvironment remained undetermined. This is the subject of the present palynological study.

2. GEOLOGICAL SETTING
The geological composition of Mt. Moslavačka Gora is characterised by two totally different rock complexes. The core of the massif is composed of Hercynian-Alpine metamorphic-crystalline rocks, which have been studied by many authors. Probably the best reviews of these papers are those by PLETIKAČI (1969) and PAMIĆ (1990). The second complex is composed of Tertiary-Quaternary rocks. These younger, cover sediments were first described by VUKOTINOVIC (1852a, 1852b) who showed them in relation to the crystalline base on the sketch entitled “Kamenopsina slika Gore Moslavačka” (Lithological picture of the Mt. Moslavačka Gora). A more serious stratigraphical survey of the area was made by KOCH (1899, 1906). He divided these rocks into two members: Archaic and Cenozoic. In the Cenozoic Era the Tertiary system, including Miocene and Pliocene, as well as the Diluvial system was distinguished. More recently, in relation to hydrocarbon exploration many geologists have been engaged in studies of the Tertiary complex (OŽEGOVIĆ, 1944, 1953). Most of these studies remain unpublished, stored in the Internal professional documentation of the national oil-company INA Naftaplín.

In the following research of the Tertiary complex on Mt. Moslavačka Gora some of the papers directly relate to the Gornja Jelska site. For example, KOCHAN-SKY-DEVIDÉ & SLIŠKOVIC (1975) undertook palaeontological analysis of cored clay-marl sediments from the borehole Novo Brdo, drilled in bentonite, located south of Gornja Jelska. They determined an Ottanngian, possibly Karpathian, age for the shallower deposits. Deeper, darker sediments were assigned to the Lower Helvetian (Ottangian). Outcrops of marls north of the village of Gornja Jelska were studied by BAJ-RÁK TAREVIĆ (1981). He established a Lower Badenian age for the sediments on the basis of foraminifera and calcareous nanoplankton analyses. The latest stratigraphical data on the Mt. Moslavačka Gora Tertiary rock complex were published in the Guide of the Geological Map, Sheet Bjelovar1 (KOROLJIJA et al., 1986).

1 The locality of Gornja Jelska should be printed on the yet unpublished Geological Map, Sheet Kutina, but one could use Geological Map, Sheet Bjelovar instead, since it contains 1/3 of entire area of the Mt. Moslavačka Gora.
3. LITHOLOGY

The sampled bentonite is composed of the phyllosilicates of montmorillonite - smectite group, with a very small amount of remaining unaltered crystalloclasts of quartz, feldspars, muscovite and biotite (Figs. 2, 3).

Bentonite is the alteration product of acid to neutral tuff under lower pH conditions. Beneath the bentonite beds is an argillaceous sediment of smectite-chlorite-calcite-illite composition (Figs. 4, 5).

It is probably the result of diagenesis of the tuffitic deposits which were a mixture of pelitic sediments and volcanic materials.

4. PALYNOLGY

4.1. METHODS AND MATERIALS

Rock samples for palynological analysis were taken in situ from the layer in which the bones of Dinotherium had been found at about 100 metres deep in the clay mine Gornja Jelenska and overlying and underlying strata.

Sediments were treated by the normal palynological method of maceration. Carbonates were dissolved in 18% HCl and the silicates in 48% HF. The obtained organic residuum was separated by flotation in ZnCl₂ (s.g. = 2.1 kg/l) and sieved using a 15μm sieve. Palynological slides were mounted using glycerine-jelly.

By counting 300 palynomorphs in each macerate statistical data on the quantitative proportions of the particular Phylum representatives in the entire microflora associations were obtained (Fig. 6).

4.2. KEROGEN AND MICROFLORA CONTENT

Total organic residuum in macerates is very well represented. Ligninumous kerogen clasts occur as equidimensional, oxidised, black, opaque fragments, as well as irregular brown higher plant debris in which the woody structure can be observed. Together they consti-
tute approximately 40% of the total organic content. Amorphous matter represents about 30%, comparable with the liptinite kerogen component which is for the most part composed of microfloral remnants.

In the microflora taphocoenose, spermatophyte taxa prevail, where the gymnosperms predominate over the angiosperms (Fig. 6). The greater genus and species abundance and diversity of the angiosperms over the gymnosperms must be noted (Table 1). Among the rest of determined taxa representatives of the Pteridophyta stand out. Representatives of the Bryophyta, Mycophyta and Chlorophyta were also recognised (Fig. 6).

4.3. PALAEOCLIMATE

In order to determine the palaeoclimatic conditions, particular macrofloral genus and species as well as the entire fossil flora assemblages were compared to recent floral taxa and vegetation taking into consideration their ecological requirements. The botanical affiliation of the palaeomicroflora was made on the basis of palynological papers by KRUTZSCH (1963-1971), PLANDE-ROVÁ (1990) and NAGY (1969, 1985, 1992).

The microflora is characterised by an abundance of tropical taxa in palynoassociation (37%). The tropical mosses Saxosporis gracilis and Rudolphissorsrudolphii, different species of the club-moss genus Echinatisporis, several species of fern genera Osmundacialetes, Meccesispolorites and Bifacialisporites were observed. The tropical angiosperms Sapotaceoideaepollenites and Engelhardtioides microcorystaeus were also recognised (Table 1).

Subtropical palaeo-vegetation is considerable too (31%) represented by different species of the fern genera Leiotorules and Laevigatosporites. Regarding subtropical spermatophytes the taxa of both angiosperms and gymnosperms are present. Fossil microflora remains of Mediterranean vegetation are poorly represented (5%). Plants which characterise moderately warm climate areas comprise 27% of the assemblage. In this group floral species of moderate realm and arcto-tertiary plants are included together. In recent northern polar regions in pre-Tertiary time a relatively warm climate existed. During global climate change the representatives of this vegetation (e.g. Pinus, Salix, Bisetula, Quercus, Acer,...) intruded towards the south and after the Oligocene they inhabited the rest of Europe as well. The arcto-tertiary, moderately thermophilous flora become the base from which the recent European flora outside the Mediterranean basin has been developed. Due to the fact that both of these groups represent plants of the moderate climate areas, they were collated together regardless of their origin.
Finally, the palaeochemical composition indicates that during sedimentation of the studied rocks from Mt. Moslavča Gora the climate was warm and subtropical.

Such a definition of the palaeoclimatic in the Upper Karpathian to Lower Badenian period - including sometimes the Middle Badenian as well (NAGY, 1993) - corresponds to research in Slovakia (PLANDEROVÁ, 1990), Hungary and neighbouring areas (NAGY, 1992). A relatively large proportion of moderate region vegetation surely is connected with global cooling from the Oligocene to the Pliocene. Such a situation is also supported by a slightly cooler climate in the Upper Ottungian and Lower Karpathian age. The explanation for the appearance of the great number of tropical species is related to the fact that a large number of tropical species from pre-Tertiary time were still not extinct so the warm climate of the Upper Karpathian and Lower Badenian again gave the opportunity for them to flourish (PLANDEROVÁ, 1990).

4.4. PALAEOENVIRONMENT

The vegetation of a certain area mostly depends on ecological conditions, thus any floral association is characteristic for a specific environment.

The fossil microflora assemblage in Gornja Jelenska is rich in autochthonous green algae. Cosmopolitan algae such as Botryococcus braunii, but also taxa of diverse species of freshwater thread-like chlorophytes from the Zygnemataceae family have been observed. The swamp cypress Taxodium and leafy swamp plant Nyssa (both common in deep swamps) were also determined. Fossil pollen of water plants which inhabit the shallower parts of swamps, water-lilies and lotuses from the family Nymphaeaceae were also recognised.

A riparian marsh area was defined by numerous moss taxa. The most important is the genus Stereisporites which botanically belongs to the genus Sphagnum. Sphagnidae are peat-moss plants. They live in marshy spots building big pillows or even covers.

Those on the surface grow from year to year while deeper layers die gradually eventually becoming peat. Peat-moss is calcifobic and requires a certain acidity, that is, an acid substratum of pH 3-4.

Riparian vegetation from nearby freshwater areas were indicated by the existence of numerous liver-wort spores of the genus Rudolphisporis (botanically Anthoceros), which makes moss-like mats. Also there are some thermophilous ferns (e.g. Mecsekisporites, Bifacialisporites), gymnosperm pollen (Pinuspollenites) and angiosperms (e.g. genera Carya, Alnus, Quercus, Salix).

The discovery of a herbaceous pollen (Chenopodiopollis, Graminidites) illustrates the existence of meadows in the vicinity of a swamp or in open forest areas. The ancient piedmont forests with a drier substratum were determined by the angiosperm genera Tricoloporporollenites, Momipites, Innavtrisporopollenites, Zelkovaepollenites, Sapotaceoidaelpollenites and gymnosperm genera Podocarpidae, Pinuspollenites.

Both, autochthonous and allochthonous microflora taxa in the palynoassociation of the microflora suggest an environment with developed forests on surrounding hills of medium altitude and meadows which were partly flooded and temporarily a low marshy area. The depositional environment was the swamp with gently inclined shores, allowing the existence of floating hydrophytes of the genera Nymphaeapollenites (FERGUSON, 1993), but probably with deeper water areas.

4.5. PALYNOSTRATIGRAPHY

Index-fossils Rudolphisporis mcekeensis (Pl. I, Fig. 33), Mecsekisporites zengoevarkonyensis (Pl. I, Fig. 32), Mecsekisporites miicaenicus, as well as the species which appeared for the first time, like Vaclavippolitis sooiiana (Pl. I, Fig. 30), Echinatisporis spinosus, Echinatisporis wiesaensis and so on (NAGY, 1985, 1992; PLANDEROVÁ, 1990) in association with other determined taxa (Table 1) show that sedimentation occurred 15.5 to 17 Myr ago between the Upper Karpathian and Lower Badenian (STEININGER et al., 1988). As vegetation is related to the climate, it is very rarely possible to define the age of the strata on the basis of fossil spores and pollen, which ideally correspond to one particular stage in the chronostratigraphic division. It is
CHLOROPHYTA

Botryococcus braunii KÜTZIG 1849
Zygnemataceae div. sp.

MYCOPHYTA

Ustilaginales sp.

BRYOPHYTA

Saxosporis sp. (Pl. I, Fig. 5)
Saxosporis gracilis W. KRUTZSCH & PAELTOVA 1963 (Pl. I, Fig. 8)
Radulophisporis rudolphii (W. KRUTZSCH 1959) W. KRUTZSCH & PAELTOVA 1963 (Pl. I, Fig. 9)
Radulophisporis meesekeventis NAGY 1968 (Pl. I, Fig. 33)
Stereisporites steriloides steriloides (R. POTONIÉ 1934) THOMSON & PFLUG 1953
Stereisporites steriloides steriloides (R. POTONIÉ 1934) THOMSON & PFLUG 1953
Stereisporites sp. (Pl. I, Fig. 7)
Stereisporites intratenuis W. KRUTZSCH 1963 (Pl. I, Fig. 22)
Bryophyta gen. et sp. indet. (Pl. I, Fig. 4, Fig. 17)

BRYOPHYTA

LYCOPODIOPSIS ORTHITIDES SP.

Verrucinulatisporites undulatus NAGY 1963 undulatus (Pl. I, Fig. 27)
Verrucinulatisporites sp.

Echinatisporis echinoides W. KRUTZSCH 1963
Echinatisporis longechinas W. KRUTZSCH 1959 (Pl. I, Fig. 21)
Echinatisporis micracenicus W. KRUTZSCH & SONTAG 1963
Echinatisporis viexaezis W. KRUTZSCH 1963
Echinatisporis ladosensis NAGY 1985 (Pl. I, Fig. 25)
Echinatisporis gnaunos NAGY 1985

Echinatisporis sp.

Osmandacidites sp.

Osmandacidites primarius (WOLFF 1934) NAGY 1985
Osmandacidites norm (WOLFF 1934) NAGY 1985 (Pl. I, Fig. 15)
Leiotiles sp.

Leiotiles microspinaeoides W. KRUTZSCH 1962 (Pl. I, Fig. 2)
Leiotiles seidewitschii W. KRUTZSCH 1962
Leiotiles triangulatoeoides W. KRUTZSCH 1962 (Pl. I, Fig. 23)
Leiotiles woffii W. KRUTZSCH 1962 woffii (Pl. I, Fig. 13)
Polypodiaceosporites torosus NAGY 1969
Polypodiaceosporites sp.

Polypodiaceosporites corraranus NAGY 1985 (Pl. I, Fig. 29)
Polypodiaceosporites triangularis NAGY 1985 (Pl. I, Fig. 28)
Polypodiaceosporites gracillimum NAGY 1963 (Pl. I, Fig. 26)
Bifacialisporites tenuis NAGY 1963 minor (Pl. I, Fig. 18)
Mesecikospores zeugogomerycens NAGY 1968 (Pl. I, Fig. 32)
Mesecikospores sp.

Mesecikospores miocenicus NAGY 1968
Mesecikospores arbus NAGY 1968
Laevigatosporites haardii (R. POTONIÉ & VENITZ 1934) THOMSON & PFLUG 1953 (Pl. I, Fig. 14)

LAEVIGATOSPORITES GRACILIS WILSON & WEBSTER 1946
Polypodisporites fayus (R. POTONIÉ 1931) R. POTONIÉ 1933
(Pl. I, Fig. 24)
Polypodisporites sp.
Macropleoploides krutzsi NAGY 1961

SPERMATOPHYTA

GYMNOSPERMAE

Pinuspollenites puceformis (ZAKLINSKAJA 1957) PLANDEROVÁ 1990 (Pl. I, Fig. 1)
Pinuspollenites sp. (Pl. I, Fig. 10)
Pinuspollenites labados (R. POTONIÉ 1932) R. POTONIÉ 1958
Taxodaceoaeollenites sp.
Cupressacites bockwitzensis W. KRUTZSCH 1971
Podocarpidites sp. (Pl. I, Fig. 31)
Bisaccites gen. et sp. indet.

ANGIOSPERMAE

Magnoliaceanpollenites sp.
Nympheaceaeollenites pseudoceatarius (W. KRUTZSCH 1970) PLANDEROVÁ 1990
Nympheaceaeollenites sp.
Nyssapollenites sp.
Acerapollenites sp.
Cleropollenites proplagi (R. POTONIÉ 1934) R. POTONIÉ 1960
Triolcopollenites sp.
Intratropolpollenites insculptus MAI 1961 (Pl. I, Fig. 20)
Intratropolpollenites intractor (R. POTONIÉ 1931) THOMSON & PFLUG 1953
Intratropolpollenites sp.
Oleaceaeollenites sp.
Cichoraceae pollinis (NAGY 1969) NAGY 1985 (Pl. I, Fig. 6)
Chenopodipollis multiplex (WEYLAND & PFLUG 1957) W. KRUTZSCH 1966
Vaucheria pollinis scolona NAGY 1973 (Pl. I, Fig. 30)
Sapotaceaepollenites sp.
Porolcolpollenites latiporos PFLUG & THOMSON 1953 (Pl. I, Fig. 3)
Zelkovaceanpollenites poionici NAGY 1969
Abietopollenites verae R. POTONIÉ 1934 (Pl. I, Fig. 16)
Fagapollenites sp.
Quercopollenites sp.
Triolcopollenites sp.
Caryopollenites simplicis (R. POTONIÉ 1931) RAATZ 1937 (Pl. I, Fig. 19)
Engelharditites microcorypheus (R. POTONIÉ 1931) R. POTONIÉ 1960 (Pl. I, Fig. 12)
Pratyxypollenites miocenicus NAGY 1969 (Pl. I, Fig. 11)
Monitpecies sp.
Myricites sp.
Myricites raceri (PFLUG & THOMSON 1953) NAGY 1969
Myricites intermedius (KEDVES 1974) PLANDEROVÁ 1990
Salixpollenites sp.
Graminidites sp.

Table 1 Systematic list of the microflora taxa.

especially the case with sediments in Paratethys due to the fact that the climate, although showing a general trend of cooling, has oscillated. Therefore a few warmer Miocene time periods in Paratethys are well known (NAGY, 1992, 1993: PLANDEROVÁ, 1990). One such warmer period was that which lasted through the Upper Karpathian and Lower Badenian, so the vegetation of these times were very similar and must be interpreted uniquely.
5. CONCLUSIONS

On the basis of the palynological analyses the following data have been gathered about the stratigraphy, palaeoecology and depositional environment in which the studied bentonite deposits from the clay mine Gornja Jelenjska on Mt. Moslavacka Gora were formed:

- the sediments were deposited during the Upper Karpatian to Lower Badenian (in the period between 15.5 – 17 m.y. ago);
- the climate was warm, subtropical;
- sedimentation took place in a swamp with gently inclined shores, but with existing deeper water areas;
- the forests on surrounding medium elevated hills were developed together with meadows which were partially flooded and turned into a low marshy areas.

Acknowledgements

I am grateful to geological technicians Ivanka TO-LJAN and Ljeka JURATOVAČ for making the palynological slides. Thanks go also to my colleagues Renata SLAVKOVIĆ and Željka MARIC-DUREKOVIC for SEM interpretation as well as petrographical and lithological analyses. They are all employees of INA-Naftaplın.

I would like to thank Dr. Eszter NAGY (Hungarian Geological Institute, Budapest), Dr. Miklós KEDVES (Attila József University, Szeged) and one anonymous referee for their very helpful suggestions, comments and critical reviews of the manuscript.

6. REFERENCES


KOROLIJA, B., VRAGOVIĆ, M., CRNKO, J. & MAMUŽIĆ, P. (1986): Tumač za Osnovnu geo-

lošku kartu SFRJ 1:100000, list Bjelovar.- Institut za geološka istraživanja, Zagreb, Sav. geol. zavod, Beograd, 45p.


PAMIĆ, J. (1990): Alpinski granitoidi, migmatiti i metamorfiti Moslavacke gore i okolne podloge Panonskog basena (Sjeverna Hrvatska, Jugoslavija).- Posebna izdanja Razreda za prir. znan. JAZU, 10, 7-121, Zagreb.


PLATE I
The Gornja Jelenska Clay Mine Floral Assemblage
Upper Karpathian - Lower Badenian

1 Pinuspollenites piceiformis (ZAKLINSKAJA 1957) PLANDEROVÁ 1990, 500x.
2 Leiopterites microsinosoides W. KRUTZSCH 1962, 500x.
3 Porocolopollenites latioris PFLUG & THOMSON 1953, 500x.
4 Bryophyta gen. et sp. indet., 500x.
5 Saxosporis sp., 500x.
6 Cichoreacidites gracilis (NAGY 1969) NAGY 1985, 500x.
7 Stereisporites sp., 500x.
8 Saxosporis gracilis W. KRUTZSCH & PACLTOVA 1963, 500x.
9 Rudolphsporis rudolphi (W. KRUTZSCH 1959) W. KR. & PACLTOVA 1963, 500x.
10 Pinuspollenites sp., 500x.
11 Platycaryapollesites miocaenicus NAGY 1969, 500x.
12 Engelhardtoidites microcoryphaeus (R. POTONIÉ 1931) R. POTONIÉ 1960, 500x.
13 Leiopterites wolfi W. KRUTZSCH 1962, 500x.
14 Laevigatosporites hardii (R. POT. & VENITZ 1934) THOMSON & PFLUG 1953, 500x.
15 Osmundacidites namus (WOLFF 1934) NAGY 1985, 500x.
16 Alnispollens verus (R. POTONIÉ 1934) medius PLANDEROVÁ, 500x.
17 Bryophyta gen. et sp. indet., 500x.
18 Bifacialisporites murosisis NAGY 1963 minor NAGY 1969, 750x.
19 Caryapollesites simplex (R. POTONIÉ 1931) RAATZ 1937, 500x.
20 Intratropopollenites incocus MAI 1961, 500x.
21 Echinatisporis longechinus W. KRUTZSCH 1959, 750x.
22 Stereisporites infrastructuris W. KRUTZSCH 1963, 500x.
23 Leiopterites triangulatoides W. KRUTZSCH 1962, 500x.
24 Polyptodiisporites favus (R. POTONIÉ 1931) R. POTONIÉ 1933, 500x.
25 Echinatisporis hidasensis NAGY 1985, 750x.
26 Polyptodiaceoisporites graciillimus NAGY 1963, 500x.
27 Verbrunculatisporites undulatus NAGY 1963 undulatus W. KRUTZSCH 1967, 500x.
28 Polyptodiaceoisporites triangularis NAGY 1985, 500x.
29 Polyptodiaceoisporites corructoratus NAGY 1985, 500x.
30 Vaclavipollis sooiana NAGY 1973, 750x.
31 Podocarpidites sp., 500x.
32 Meczeksporites zengoervarkonyensis NAGY 1968, 750x.
33 Rudolphsporis mesekensis NAGY 1968, 750x.