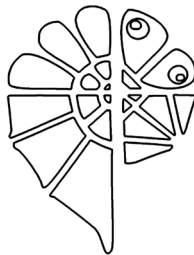


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**MIDDLE MIOCENE FLORA OF JASIKOVAC –
– COMPARATION WITH RECENT PINE-OAK
ASSOCIATIONS OF CENTRAL AMERICA**

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This paper presents the collection of Middle Miocene flora from the locality Jasikovac (Berane-Police Basin) in Montenegro. The main feature and significance of this paleoflora is its unusual composition, expressed through domination of willow-type oaks, pines and sequoias, and an almost complete absence of other phanerophyte *Gymnospermae* and *Angyospermae*. The paleoflora with such composition was so far never recorded at other localities in Serbia and neighboring countries, and out of recent floras it is most similar to the montane pine-oak forests from Central America. The eco-climatic conditions and the large similarity of floristic composition between the recent and the fossil association indicate the possibility that the Middle Miocene flora of Jasikovac used to inhabit greater altitudes and that there is a great probability that it was a part of the vegetation belt with a broader distribution.

Key words: *Quercus apocynophyllum*, *Quercus neriifolia*, Miocene, Berane-Police Basin, Jasikovac

MATERIAL AND METHODS

The Collection of Paleoflora from locality of Jasikovac (Berane-Police Basin, Montenegro) is stored at the Natural History Museum in Belgrade. It is mostly composed of imprints of leaves (*Quercus*), needles, twigs and cones (*Pinus*, *Sequoia*, *Quasisequoia*) in marl. As the imprints did not contain any preserved cuticle, the determination of the material had to be performed exclusively through comparison of morphoanatomy of leaves in fossil and recent material. The imprints represent large, often whole and single leaves. The fact that neither lumachelles nor detritus were recorded at the site indicates a gently and probably slow sedimentation in the deeper parts of the lacustrine environment. The whole large leaves also indicate that the fossil material did not undergo any longer transport to the deposition area and that the association had likely lived in the immediate vicinity of the lake.

GEOLOGICAL OVERVIEW OF THE BERANE-POLICE BASIN

In the structural-tectonic sense, Berane-Police Basin belongs to the Durmitor geotectonic unit of inner Dinarides (Živaljević 1989; Bulajić 2001). The rocks in the areas of basin rim and basin have originated within a long period from Carboniferous-Perm to Quaternary. According to similarities in lithostratigraphic and genetic characteristics and time of origin they are divided into Caledonian-Hercynian formations (of Paleozoic age) and Alpine formations (of Mesozoic and Cenozoic age) (Pajović 2000)(Map 1).

CALEDONIAN- HERCYNIAN FORMATIONS (CH)

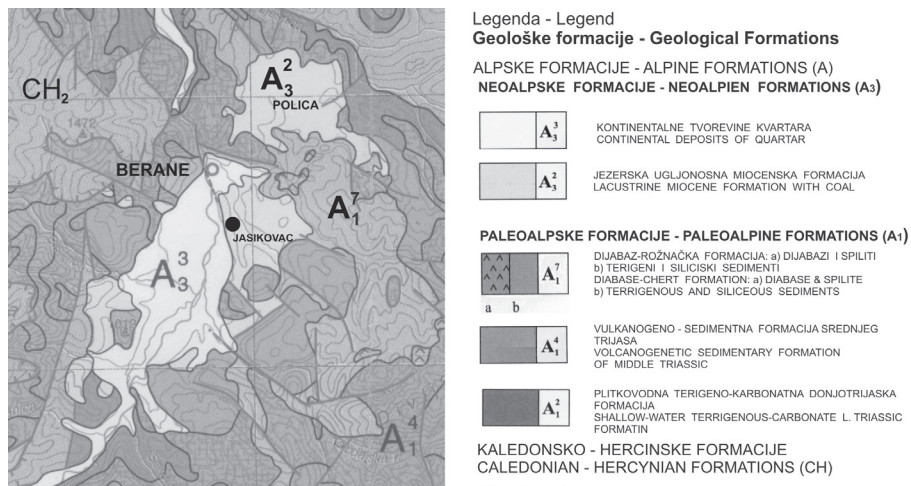
One part of eastern rim of the basin is composed of rocks belonging to terrigenous-carbonate formations of Carboniferous-Perm, represented with metasandstones and marls with inserted overcrystalized limestones in forms of lens and sublayers.

ALPINE FORMATIONS (A)

PALEO-ALPINE FORMATIONS (A1)

The rocks belonging to Paleo-Alpine formations lay discordantly over the older rocks, forming most of the rim and underlying layer of Berane Basin. They are represented by the shallow-water terrigenous-carbonate formation of lower Triassic and volcanic-sedimentary

formation of mid Triassic, discordantly overlaid by rocks from diabase-hornstone formations of upper Jurassic.



Map 1. - Geological formations in the area of Berane-Police Basin (Pajović 2000; modified).

NEO-ALPINE FORMATIONS (A₃)

The rocks of Neo-Alpine formations (lacustrine coal-bearing Miocene formation and continental formations of Quaternary) lie discordantly over the rocks of Paleo-Alpine formations.

LACUSTRINE COAL-BEARING MIOCENE FORMATION

This formation includes three types of sediments: alluvial-proluvial, peat-mud and lacustrine. The alluvial-proluvial sediments lay transgressively over the Paleozoic-Mesozoic paleo-relief and are represented with: sands, sandy-gravelly clays, gravels and conglomerates. Peat-mud sediments are represented with: coal, clays, sandstones and marls. These sediments gradually turn into the lacustrine sediments represented by: marls with sublayers of sandstone, sandy marls and clayey marls (Živaljević *et al.* 1982).

At Berane-Police Basin, the peat-mud sediments were formed during three cycles of sedimentation. The first cycle included the northeastern part of Berane Basin (area of Budimlje) and resulted in formation of so-called underlying coal layer (which most probably originated in late Oligocene). The second cycle of sedimentation included the whole area

of Berane-Police Basin, resulting in formation of so-called main coal layer (formed during the Lower Miocene). The main coal layer has a complex structure as it includes several coal plates separated by barren sub-layers. According to the presence of a tuff layer in the upper part of main coal layer it was identified throughout the basin. In the eastern part of Police basin there are also some sediments belonging to third cycle of sedimentation of peat-mud formations. They include the so-called overlaying coal layer (most probably formed during Upper Miocene). The thickness of the sediments in the lacustrine coal-bearing formation is up to 300 m while the average thickness is about 180 m (Drobnjak *et al.* 1996; 1998). The layer of tuff (connected to acid volcanism), present in the main coal layer of the basin, matches the pyroclast-sediment facies of the younger subphase of subsequent volcanism of the Dinarides. The extrusive activity of subsequent volcanism of inner Dinarides happened in late Oligocene and early Miocene (the older subphase, connected to intermediary volcanism), and with longer or shorter breaks it lasted throughout the Lower and Middle Miocene (younger subphase, connected to acid volcanism), while it ended in the Upper Miocene (Ilić 1968). According to the collected teeth of *Indricotherium* sp., the age of the main coal layer was determined to Oligo-Miocene (Chattian-a-Aquitanian) or Lower Miocene (Aquitanian) (Petronijević & Thenius 1958).

CONTINENTAL FORMATIONS OF QUATERNARY

They are developed in the western and southern part of the basin and are represented by glacial-fluvial and alluvial sediments. They lay over the sediments of lacustrine Miocene formation. The thickness of these sediments is up to 30 m.

Age determination: The Middle Miocene age of Jasikovac paleoflora was determined only indirectly through relationship of its position and positions of other floras in the geological column (Fig. 1). The paleoflora from the localities Luge, Aluge and Haremi are definitively determined as Lower Miocene due to presence of *Indricotherium* sp. (Petronijević & Thenius 1958). According to the pollen analysis it is presently believed that the paleoflora from locality Goražde is of Upper Miocene age (Đorđević-Milutinović 1998).

PALEOFLORA

The paleoflora of Jasikovac represents the remains of a very specific oligodominant association dominated by representatives of genera *Quercus*, *Pinus*, *Sequoia* and *Quasisequoia*. The genus *Quercus* was represented by narrow-leaved, willow-type oaks: *Q. neriifolia* and *Q. apicyrophyllum* (Pantić 1987).

Pinus hepios (Unger) Heer includes the two-needled pines. The length of the needles is up to 10 cm, but many of them are missing the top part so they might have been significantly longer. The equivalent in the recent flora: *Pinus halepensis* Mill. (Pantić 1956) and other Mediterranean two-needled pines.

Pinus taedaeformis (Unger) Heer includes the three-needled pines. The length of the needles was about 10 cm or longer. The equivalent in the recent flora: *Pinus taeda* L. in North America (Pantić 1956).

Pinus paleostrobis Ettinghausen includes the five-needled pines. The length of the needles was about 9 cm, but many were missing the top so they were probably even longer. The equivalent in the recent flora: *Pinus strobus* L. (eastern part of Northern America).

Sequoia abietina (Brongniart) Knobloch: The twigs were up to 5 cm long; the leaves were strongly lanceolate, narrow, up to 1 cm long, apex acute. The twigs do not bear terminal cones. The leaflets are comb-like and clearly separated. The equivalent in the recent flora: *Sequoia sempervirens* (D. Don) Endl.

Quasisequoia couttsiae (Heer) Kuzmann (syn. *Sequoia couttsiae* Heer): The twigs, up to 7 cm long, bear tiny scale-like, spirally distributed leaflets. Cones are present at terminal part of a large number of imprints. The possible equivalent in the recent flora: *Sequoiadendron giganteum* (Lindl.) Buchh.

During Miocene the sequoias were widely distributed throughout Europe and represented with a large number of species. At the Balkan Peninsula (in FYR Macedonia) they were present until the beginning of the Ice Ages (Černjavski 1948). The recent sequoias *Sequoia sempervirens* and *Sequoiadendron giganteum* are endemorelict species considered to be on path to extinction, so their present distribution

(western coast of USA) is not sufficient to determine their role in the physiognomy of Miocene associations.

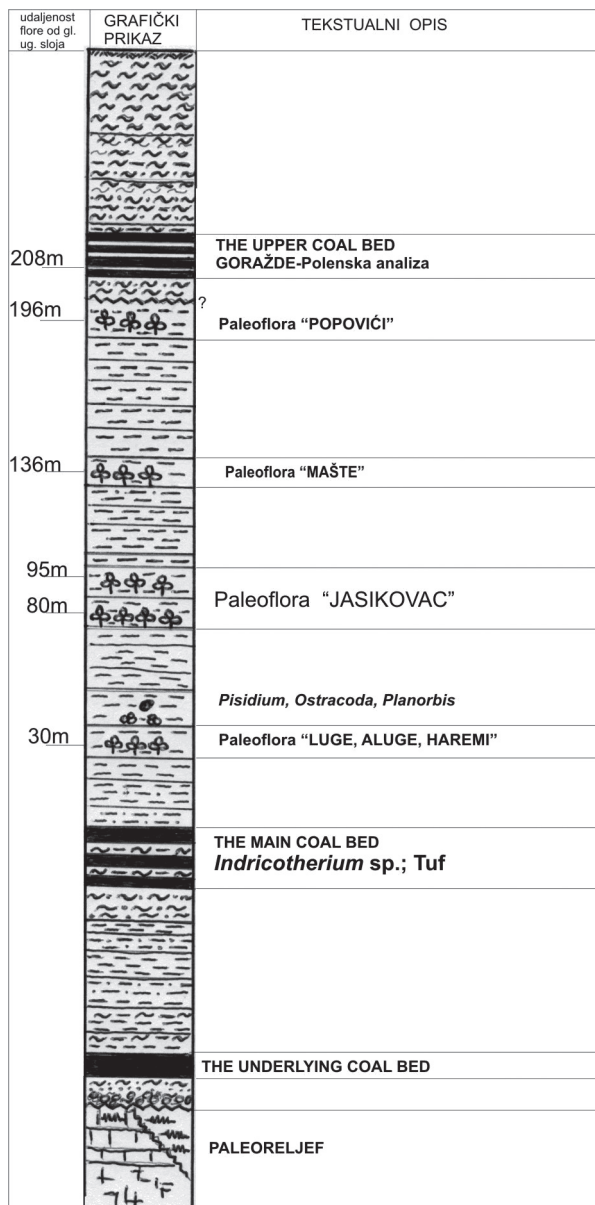


Fig. 1. - Position of paleofloras of Berane-Police Basin related to the studied flora of Jasikovac and the main coal layer where *Indricotherium* sp. was recorded.

Quercus apocynophyllum Ettinghausen: The leaves are elongated-lanceolate, 7-12 cm long and 1.5-3 cm wide. The top is acute and the base mostly cuneate. The leaf stalk is strong, short and continues into the midrib. The secondary veins are brachidodromous (Ruffle 1979). The margins are entire, in certain specimens it might be pronouncedly undulate, but without any traces of teeth. The type of the imprint and the shape of 3° and 4° veins indicate the possibility that the leaves were stiff and covered with thicker, shiny cuticle.

Quercus neriifolia Al. Braun: Leaves large, stiff, widely or narrowly lanceolate. Leaf size may not be precisely determined as the imprints usually miss either the base or the top. In average they are about 10 cm long and up to 3.5 cm wide. The top is acute to oblong, while the base is ellipsoid, cuneate or slightly cordate. The petiole was mostly not preserved. The midrib is strong and the secondary veins branch at the angle of about 80°. The secondary veins are camptodromous. In contrast to the previous species, almost all leaves of *Q. neriifolia* show damage by insects. This type of damage is characteristic mostly for the leaves with thinner cuticle, so we may assume that representatives of *Q. neriifolia* had thinner cuticle than *Q. apocynophyllum*.

Equivalents in the recent flora:

Both species are compared with recent oaks from North and Central America such as *Q. gentryi* C.H. Mull., *Q. cuajimalpana* Trel. and *Q. elliptica* Nee. There are numerous species of recent willow-type oaks with very similar leaves, so species may be identified only on the basis of reproductive organs. We have to use the same way of thinking in order to discuss the almost certain possibility that *Q. apocynophyllum* and *Q. neriifolia* also include a larger group of real species that used to have similar leaf morphology.

Besides the mentioned genera *Quercus*, *Pinus*, *Sequoia* and *Quasisequoia* which were recorded in greater numbers, the flora of Jasikovac also included: *Leguminosae*, *Alnus*, *Populus*, *Salix*, *Phragmites* and *Typha*. However, their participation in total flora, when compared to that of above-mentioned species, is minor and they should not be considered to be edifiers or more important participants of Jasikovac paleoflora.

IMPORTANCE OF PALEOFLORESTIC COMPOSITION OF JASIKOVAC ASSOCIATION

The paleoflora of Jasikovac indicates presence of an oligodominant association, dominated by willow-type *Quercus* species, *Pinus* species with 2, 3 or 5 needles and representatives of sequoia group. There is a pronounced complete lack of common species of azonal riparian forests (*Alnus*, *Populus*, *Salix*) and the edificers of marsh forests *Taxodium* and *Glyptostrobus*, the species that are otherwise the characteristic representatives of almost all Miocene floras in Balkan region.

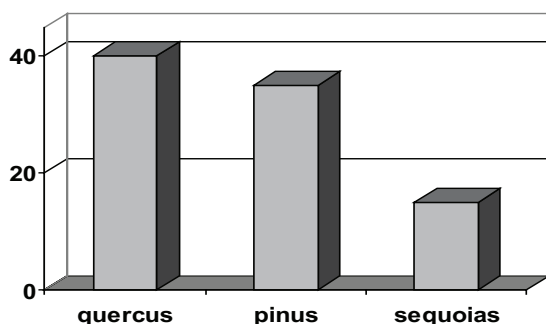


Fig. 2. - Approximate percentage representation of various genera in paleoflora of Jasikovac.

The diagram (Fig. 2) shows the percentage representation of main genera of studied paleoflora. Genus *Quercus* includes about 40% of total material, *Pinus* about 35%, and *Sequoia* and *Quasisequoia* about 15%. This type of composition is highly unusual for Miocene paleofloras of Balkan Peninsula, as they usually do not have such a high percentage of conifers and willow-type oaks. For Serbia a well-known Oligocene flora is that of Bogovina (Pantić 1956) which includes a large number of sequoias but no willow-type oaks.

At the territory of **Serbia** there are two main **types of paleoflora** (Fig. 3):

Type 1: matches the associations in warm humid climate, with conspicuous presence of both the broad-leaved subtropical species of *Laurus*, *Daphnogene*, “*Ficus*” and the temperate-continental species of *Ulmus*, *Carpinus*, *Populus*, *Alnus*, *Salix* etc. (Mihajlović 1977; 1988; Milovanović & Mihajlović 1984; Pantić 1956).

Type 2: matches the associations in drier, colder climate. There is a dominant arcto-tertiary floristic element, mostly the representatives of riparian forests (*Alnus*, *Populus*, *Salix* etc.), as well as the co-dominant element of xeromorphic species of *Leguminosae*, hard-leaved (*Ilex*-type) *Quercus*, *Mahonia*, *Ilex* etc. (Mihajlović 1978; Mihajlović & Lazarević 2004; Pantić 1956; 1961).

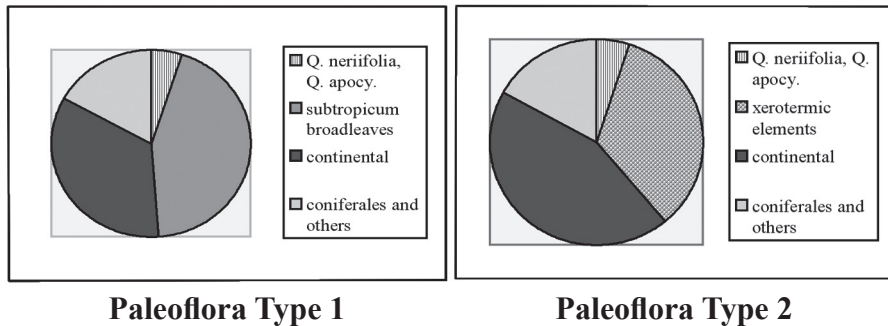


Fig. 3. - Average ratios of dominant floristic elements in Miocene paleofloras of Serbia and neighboring areas.

The following element in both types includes the marsh dendroflora with genera *Taxodium*, *Glyptostrobus* and *Nyssa*. It must be noted that *Q. neriifolia* and *Q. apocynophyllum* appear in both types of floras but that their abundance is negligible as a rule.

In contrast to the previously described paleofloras, the diagram representing Jasikovac paleoflora (Fig. 4) shows a completely different association dominated by willow-type oaks, pines and sequoias.

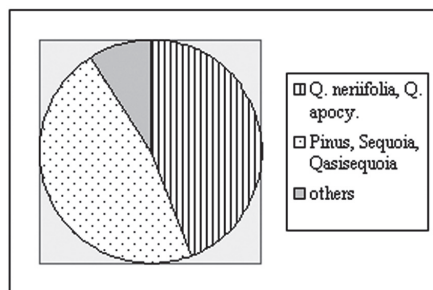


Fig. 4. - Approximate representation of various floristic elements in the paleoflora of Jasikovac.

PINE-OAK FORESTS

Comparison of various recent associations had shown a high degree of similarity between the paleoflora of Jasikovac and the recent pine-oak forests that inhabit the mountain belt of North America (WWF 2001 NT0307; WWF 2001 NT0303; WWF 2001 NT0308.)

In that part of world, along the whole mountain range from Arizona to the northern part of South America, at the altitude of 1500-2600 m there are pine-oak forests forming a vegetation belt stretching through Mexico, Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Panama etc. At the lower altitudes there is the typical tropical climate while in the mountain areas there is a cooler climate and somewhat drier vegetation dominated by various types of oaks (*Q. aata*, *Q. costaricensis*, *Q. copeyensis* etc.) and pines (*P. caribaea*, *P. oocarpa*, *P. patula* etc.). The pine-oak forests grow in the areas of high humidity and many of them are included in “cloud forest” (fog forest) association (Wilson & Townsend 2007; WWF 2001: NA0526).

It should be noted that sequoias, which are missing in the recent pine-oak associations, also inhabit the areas of permanent fog – the cloud forests.

The comparison of fossil flora of Jasikovac with the modern pine-oak associations showed a high level of similarity, expressed in following characters:

- Both associations are oligodominant
- The edificatory species are various species from genera *Quercus* and *Pinus*
- Both associations develop under the influence of some type of humid subtropicum.

The main difference between the studied communities is the distinct presence of sequoias in the paleoflora of Jasikovac. However it should be noted that in the Central American pine-oak forests pines are joined by other species of *Coniferales*, for example representatives of *Cupressus* and *Pseudotsuga*, indicating the appropriate conditions for development of these warmth-loving conifers in this associations.

ECOLOGICAL CHARACTERISTICS OF THE STUDIED FOSSIL ASSOCIATION

The paleoflora of Jasikovac represents the remains of a forest association, possibly of zonal character. This used to be an oligodominant association and its edifiers were various species of willow-type oaks, pines and sequoias. Considering the large abundance of *Pinus* we may assume that these forests were well illuminated. The comparison with the recent pine-oak forests and habitats of recent sequoias indicates a possibility that they belonged to the type of cloud forest (fog forest). The very good level of preservation of fossil material indicates that this association lived in the immediate vicinity of the deposition environment, that is, the lake where it was fossilized. The banks of the lake used to be steep and without shallow parts, as indicated by the almost complete lack of representatives of gallery forests and marsh plants such as *Taxodium* and *Glyptostrobus*.

In the Miocene of the Balkans there were no tropical conditions similar to those present today in Central America, but mostly a humid subtropicum or a mediterranean-type climate (Utescher *et al.* 2007). This climate was in many aspects similar to the present climate of the mountain parts of Central America.

If in the tropical zone the mountain areas have a subtropical climate, then in a subtropical or mediterranean zone the mountain areas will have an even colder climate. According to this rule we may conclude that the association of Jasikovac, in contrast to recent pine-oak forests which in the tropical zone ascend to 2600 m, never entered such high altitudes but instead probably inhabited the hill or montane areas within the global subtropical/mediterranean climate of the Balkans.

According to its ecological needs, the paleoflora *Quercus-Pinus-Sequoia* is the closest match to the primary Mediterranean forests, while its oligodominant composition indicated the possibility that it inhabited the habitats with decreased competition level. These were most probably some rocky hill or montane habitats close to the lakes.

CONCLUSION

The paleoflora of Jasikovac, dominated by willow-type oaks, pines and sequoias, may not be matched with any other paleoflora of Serbia and neighboring region according to its oligodominant composition. This association may also not be matched with any recent association in Europe as the last willow-type oaks in Europe became extinct.

The studied association shows a large similarity with high-mountain associations of the tropical belt of Central America, where tropical-subtropical montane pine-oak forests stretch for thousands of kilometers through Mexico, Guatemala, Honduras, Costa Rica, Panama etc.

The association at Jasikovac had inhabited the hill or lower montane areas near a large Miocene lake, while its shores were lacking both swamps and azonal riparian forests. This hypothesis is supported by the fact that the studied taphocenosis included neither *Taxodium* and *Glyptostrobus*, the typical representatives of lowland marsh areas, nor the representatives of gallery forests (*Salix*, *Alnus*, *Populus*) which are very common in many Miocene associations.

Also, according to the composition of recent pine-oak forests, we can conclude that the Jasikovac association of *Q. apocynophyllum* and *Q. neriifolia* included a larger number of oaks species that may not be distinguished from each other solely on the morphoanatomy of leaves. This viewpoint assumes that these two morphotypes include not two but many species of willow-type oaks that we are unable to distinguish from each other solely on leaf morphology.

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СРЕДЊЕМИОЦЕНСКА ФЛОРА ЈАСИКОВЦА – – ПОРЕЂЕЊЕ СА САВРЕМЕНИМ БОРОВО-ХРАСТОВИМ ЗАЈЕДНИЦАМА ЦЕНТРАЛНЕ АМЕРИКЕ

ДЕСА ЂОРЂЕВИЋ-МИЛУТИНОВИЋ, ГОРАН ЋУЛАФИЋ

РЕЗИМЕ

На локалитету Јасиковац (Беранско-полички басен, Црна Гора) нађени су фосилни остаци олигодоминантне заједнице у којој преовлађују представници врболиких храстова, борова и секвоја: *Pinus hepios* (Unger) Heer, *Pinus taedaeformis* (Unger) Heer, *Pinus paleostrobis* Ettinghausen, *Sequoia abietina* (Brongniart) Knobloch, *Quasisequoia coultisiae* (Heer) Kuzmann (syn. *Sequoia coultisiae* Heer), *Quercus apocynophyllum* Ettinghausen, *Quercus neriifolia* Al. Braun.

Средњемииоценска старост Јасиковачке палеофлоре одређена је посредно у односу на положај осталих флора у геолошком стубу (Сл. 1). Због наласка *Indricotherium* (Petronijević & Thenius 1958),

старост палеофлоре са локалитета Луге, Алуге и Хареми одређена је као доњемииоценска. На основу поленске анализе утврђено је да је палеофлора са локалитета Горажде горњемииоценске старости (Ђорђевић-Milutinović 1998).

Заједница оваквог састава до сада није нађена на другим локалитетима Србије и околних подручја тако да се не може поредити ни са другим фосилним заједницама, ни са рецентним шумама Европе, с обзиром да у Европи нема врболиких храстова. Јасиковачка флора показује највећу сличност са рецентним борово-храстовим шумама које насељавају планинска подручја централне Америке.

На основу изгледа и очуваности фосилног материјала, геолошког стуба, климатских фактора, поређења палеофлоре и рецентних заједница, као и карактеристика рецентних еколошких еквивалената закључено је:

Јасиковачка палеофлора представља остатке шумске заједнице, могуће зоналног карактера. То је била олигодоминантна заједница чији су едификатори различите врсте врболиких храстова, борова и секвоја. С обзиром на присуство великог броја *Pinus* можемо претпоставити да су ове шуме биле добро осветљене. Поређењем са рецентним борово-храстовим шумама и стаништима рецентних секвоја могуће је да су ове заједнице насељавале подручја сталне магле. Веома добра очуваност фосилног материјала показује да је заједница живела у непосредној близини депозиционе средине, тј. језера у коме се и фосилизовала. Обале језера биле су стрме и без плићака на шта указује готово потпуно одсуство представника галеријских шума као и мочварних биљака попут *Taxodium* и *Glyptostrobus*.

У миоцену на Балкану нису постојали тропски услови какви данас владају у централној Америци, већ је углавном био заступљен влажни суптропикум или клима слична медитеранској (Utescher *et al.* 2007). Ова клима у многоме одговара клими која данас влада у планинским пределима централне Америке. На основу тога можемо закључити да је јасиковачка заједница насељавала брдске или ниже планинске пределе у оквиру глобалног суптропско/медитеранског климата Балкана, за разлику од рецентних борово-храстових шума које у тропској зони насељавају подручја до 2600 m.

По својим еколошким захтевима, палеофлора *Quercus-Pinus-Sequoia* највише одговара примарним медитеранским шумама а по свом олигодоминантном саставу указује на станишта смањене конкуренције и то највероватније на стеновите брдске или планинске пределе у близини језера.