

EARLY MIOCENE FLORA OF MILJEVINA (EASTERN BOSNIA)

Wczesno-miocenińska flora z Miljeviny (wschodnia Bośnia)

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ABSTRACT. The marly deposits overlying the coal seam of the Miljevina Basin near Foča (SSW of Sarajevo) yielded abundant plant remains, mostly leaf imprints and coniferal twigs. On the basis of morphological features of about 225 specimens and earlier descriptions by Engelhardt (1904), 3 species of conifers, more than 18 species of dicotyledons and 3 species of monocotyledons belonging to the families *Pinaceae*, *Taxodiaceae*, *Lauraceae*, *Ulmaceae*, *Fagaceae*, *Betulaceae*, *Myricaceae*, *Juglandaceae*, *Salicaceae*, *Leguminosae*, *Aceraceae*, *Sapindaceae*, *Potamogetonaceae* and *Palmae* have been determined. The flora belongs to the Early Miocene polyphase complex in sense of the regional stratigraphy. Climatic conditions were obviously seasonal subtropical to warm temperate.

KEY WORDS: Miocene, megafossils, flora, Bosnia

INTRODUCTION

In the present territory of Bosnia and Herzegovina, and the adjacent regions of Serbia, Montenegro and Croatia, a number of basins (palaeodepressions) arose during the Miocene, especially Early Miocene, where various terrestro-limnic deposits were formed. Many of these freshwater basins underwent a peat swamp phase that led to the formation of coal seams, mostly of economic significance. The beginning of palaeodepressions in Bosnia and Herzegovina is generally placed in the Late Oligocene. Main phases of swamps, or their sedimentary products, and the overlying beds of marl and limestone in Bosnia and Herzegovina (investigation data provided by Bosnian and Herzegovinan geologists) are associated with the 'Early Miocene polyphase complex'. It is in this sedimentation cycle that deposits rich in plant fossils have been found dominantly in the marl member of the cycle in many localities of Bosnia and Herzegovina and adjacent regions of Serbia, Montenegro and Croatia. The deposits often contain, in ad-

dition to plant remains, freshwater molluscs and occasionally mammal remains. This palaeontological content, however, does not allow an accurate dating of the deposits and hence significant problems arise in attempting to define more precise chronostratigraphic position of the fossil floras. The age of these limnic formations in Bosnia and Herzegovina, or a larger territory of Yugoslavia, has been both a problem and a challenge for more than one generation of national palaeontologists and stratigraphers.

Major contributions to the study of the Tertiary floras of Bosnia and Herzegovina were made by Engelhardt (a number of works in the years 1883–1913), who gave first of all detailed studies of systematic composition of the Bosnian-Herzegovinan Tertiary floras. Vasković (1929, 1931), Polić (1936, 1937) and Pantić (1957, 1961) gave much consideration after the Second World War to certain floras of Bosnia and Herzegovina for an accurate dating. Unfortunately, with few exceptions, all the papers were published in the Serbo-Croatian language, without or with only very short summaries in one of the world languages. This has made the numerous Bosnian-Herzegovinan floras hardly accessible to a wide circle of palaeobotanists over the world.

A rich collection of plant remains was made in 1988 in the Miljevina Basin (eastern Bosnia), which is considered in this paper. Some plant fossils from this locality previously referred to as Budanj were described by Bittner (1880 – *Glyptostrobus europaeus*), Krässer (1890 – *Acer trilobatum*, *A. productum*) and Engelhardt (1904 see Tab. 1.). The original specimens to these studies have not been available. The composition of the Miljevina flora gives a general picture of vegetational conditions found at several other localities in Bosnia and Herzegovina connected with the deposits overlying brown coal seams.

Table 1. List of species

taxon	number of specimens	illustrations by Engelhardt (1904)
<i>Pinus</i> sp.	2	
<i>Glyptostrobus europaeus</i>	51	pl. 1, fig. 18
<i>Taxodium</i> cf. <i>dubium</i>	2	
<i>Laurophyllum</i> sp. 1	4	
<i>Laurophyllum</i> sp. 2	1	
<i>Ulmus</i> cf. <i>braunii</i>	3	
<i>Zelkova zelkovifolia</i>	2	
cf. <i>Tremophyllum tenerrimum</i>	1	
<i>Fagus pristina</i>	7	?pl. 2, fig. 16
<i>Quercus</i> ex gr. <i>drymeja</i>	29	pl. 2, figs 12
<i>Quercus mediterranea</i>	9	pl. 1, figs 8, 9
		pl. 2, figs 5, 7
cf. <i>Trigonobalanopsis rhamnoides</i>	1	pl. 2, fig. 6, 8
<i>Alnus gaudinii</i>	41	
<i>Betula</i> sp.	1	
? <i>Betulaceae</i> gen. et sp.	6	pl. 1, fig. 12
<i>Myrica</i> cf. <i>laevigata</i>	16	

Table 1. Continued

taxon	number of specimens	illustrations by Engelhardt (1904)
<i>Juglandaceae</i> gen. et sp.	1	
? <i>Populus</i> sp.	1	
<i>Leguminosae</i> gen. et sp. 1	4	
<i>Leguminosae</i> gen. et sp. 2	1	
<i>Acer tricuspidatum</i>	28	
<i>Sapindus falcifolius</i>	1	
<i>Dicotyledonae</i> gen. et sp. indet.	12	pl. 2, fig. 14
<i>Potamogeton</i> sp.	2	
<i>Palmae</i> gen. et sp.	—	pl. 1, fig. 2
<i>Monocotyledonae</i> gen. et sp.	1	pl. 2, fig. 2

PHYSICAL SETTING

The coal basin of Miljevina is situated near the town of Foča, eastern Bosnia, between the extreme northern slopes of Zelengora and Lelija, eastern slopes of Treskavica, and southern slopes of Jahorina Mountains. The basin extends from west (Poljice) to east (Daničići) in a length of eight kilometers, and about three kilometers in the width, covering an area of about 24 square kilometers. The regional road Foča-Sarajevo passes along the basin (Fig. 1).

GEOMORPHOLOGY AND GEOLOGY

Geomorphology of the basin has been controlled by lithofacial features of deposits, erosional processes and tectonic events. Parts of the basin composed of marl, clay and sandstone are gently undulating flatland. Those of travertine form steep elevations (Nozdre 752 m). Plio-Quaternary deposits are often deeply eroded, forming various geomorphologic features (e.g. 'pyramids'). The basin lies in altitudes from 500 m at the Bistrica River to 760 m on the Debelo Brdo hill above the sea level.

Geology of the Miljevina coal basin has been investigated in several phases since 1899 (Grimmer 1899). Most attractive for exploration are coal deposits, which have been worked in open cast mines at Budanj-Grad.

The geology of the basin (Fig. 2), according to the available data, both earlier and those of the latest complex exploration, is summarized below (for more details see Vrabac & al. 1988).

Underlying Deposits

Deposits of this stratigraphic unit, up to 80 m thick, directly underlie the coal seam and consist of sandy incoherent marly clay with occasional coal clay intercalations, in-

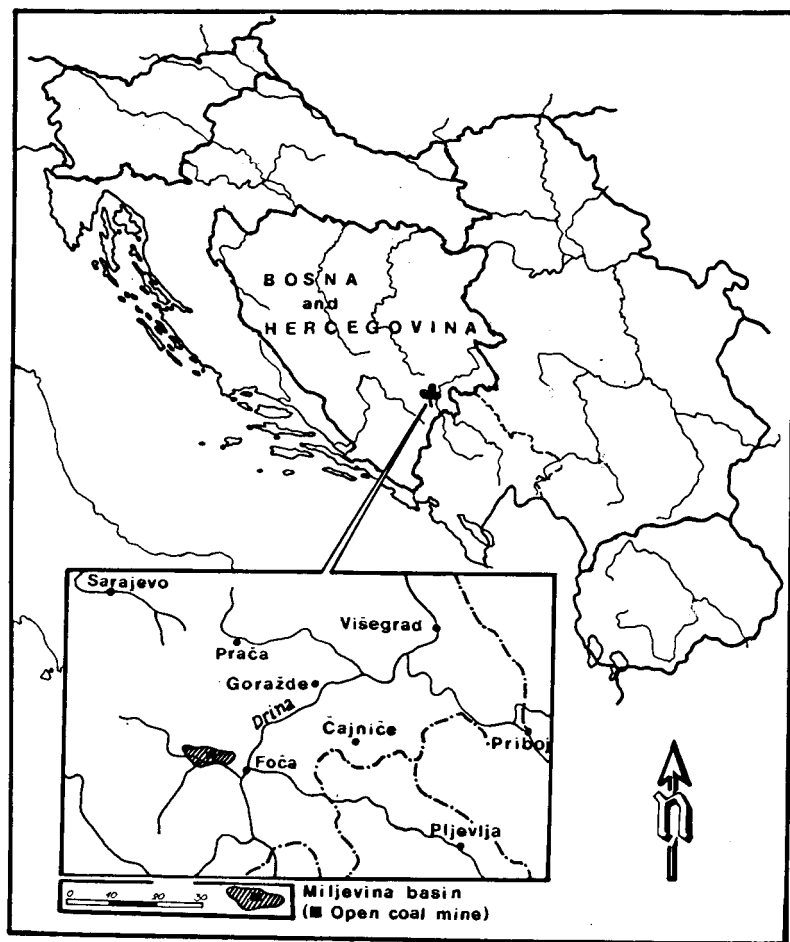


Fig. 1. Physical setting of the localities with plant fossils

terbeds or lenses of brecciated limestone, unconsolidated argillaceous sandstone, sand, and in places conglomerate. No fossils have been so far recovered in these oldest deposits of the lacustrine polyfacial complex.

Main Coal Seam

The most important lithostratigraphic unit of the Miljevina coal basin appears that part of the sedimentation cycle, in which deposition of coal-producing plant material started and ended. The seam, together with interbeds of coal shale, coal clay and sandy limestone, does not exceed 25 m in thickness. Sandy limestone contains an abundance of *Planorbis* and *Limnea*, and much fewer *Pisidium* and *Fossarulus*. The workable part of the seam is at most 10.22 m thick.

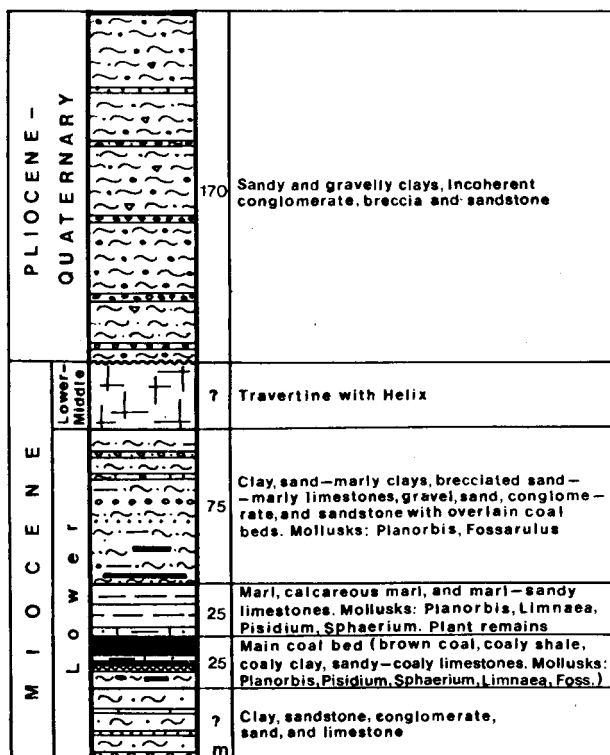


Fig. 2. Columnar section of the central Miljevina Basin

Calcareous marl, marl and marly-sandy limestone

The main coal seam is directly overlain with marly-sandy limestone abounding in molluscan remains (*Planorbis*, *Fossarulus*, *Limnea*, *Pisidium*). This limestone varies in thickness up to 3 m and is overlain with calcareous marl and marl (mostly about 15 m thick), which contain plant detritus and well preserved megafloora as well as molluscs. This part of the overburden does not exceed the thickness of 25 m (Fig. 3).

Clay, brecciated limestone, gravel, conglomerate, sandstone with the lower and upper overlying coal seams

This lithostratigraphic unit, 75 m thick, is represented by clay, which is often marly or sandy with carbonate concretions. Other lithologic types mentioned above occur in intercalations or lenses. The overburden includes two coal seams without economic importance. The lower seam lies 3–7 m above the marl or 20–30 m above the main coal seam. Its thickness is 2–3 m. The upper seam lies 12 m above the lower seam (borehole B-356) but does not extend all over the basin. Limestone overlying the upper coal seam contains molluscs (*Planorbis*, *Fossarulus*).

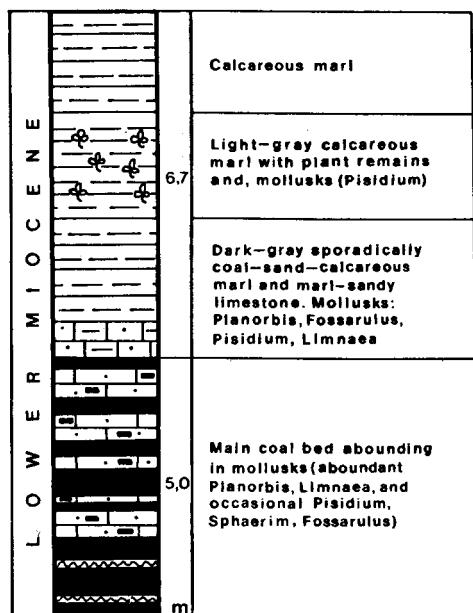


Fig. 3. Columnar section of the locality with plant fossils (Budanj opencast mine, southern bench)

Travertine

Travertine, identified only in the western part of the basin, is the closing unit of the Early Miocene polyfacial complex. It occurs in thick beds or sets of beds, which contain occasional remains of *Helix* and carbonized plant fragments.

Plio-quaternary deposits

In the eastern part of the Miljevina Basin, Early Miocene strata are unconformably overlain with the Plio-Quaternary deposits of sandy and gravelly clay (mostly red), unconsolidated conglomerate, breccia and sandstone. Clay is a dominant component.

SYSTEMATIC DESCRIPTIONS

Pinaceae

Pinus sp.

Pl. 1, figs 4, 5

1903 *Pinus megaloptera* Ett.; Engelhardt, p. 116, pl. 1, fig. 11 (Kakanj)

The figured pine seeds may belong to a single species in view of common features: small seed, not stretching out of the wing outline, wing with the straight dorsal side, proximally rounded, regularly convex on the ventral side. The fragmentary specimen figured by Engelhardt (1903) differs by a bluntly acute proximal part. Similar seeds were recorded by Kräusel (1938, sub. *Pinus* sp. 2) from the Early Miocene of Mainz-

Kastel or by Kovar-Eder & Berger (1987, sub *Pinus* sp., fig. 10) from the Late Oligocene of Unter-Rundling. A more exact comparison with fossil pine species, mostly established on the basis of cones (Mai 1986) could be misleading.

Taxodiaceae

Glyptostrobus europaeus (Brongniart) Unger

Pl. 1, figs 1–3, 7, 8

1903 *Glyptostrobus europaeus* Brongniart sp.; Engelhardt, p. 116, pl. 1, figs 6, 9, 10, 12–17 (Kakanj, Zenice, Visoko, Podastinje)

1903 *Widdringtonia ungeri* (?) Endl.; Engelhardt, p. 117, pl. 1, fig. 7 (Kakanj)

1904 *Glyptostrobus europaeus* Brongn. sp.; Engelhardt, p. 556, pl. 1, fig. 18 (Budanj)

Several branches, partly with attached female and male cones correspond in all details with this common hygrophile conifer, particularly with the Early Miocene material, e.g. from Evia (Kumi) or from the North Bohemian Basin.

Taxodium cf. *dubium* (Sternberg) Heer

Pl. 1, fig. 6

Fragments of foliage shoots with delicate acicular distichous leaves, hardly decurrent on the twig, match well with *Taxodium* leaf remains widely distributed in the late Paleogene and Neogene of Europe. The specific determination remains open because of the lack of female cones, which bear diagnostic features. A single shoot described by Engelhardt (1903, pl. 1, fig. 3) from Kakanj as *Sequoia langsдорфii* Brongn. may in fact belong to *Taxodium* as well.

Lauraceae

Laurophyllum sp. 1

Pl. 3, figs 9, 10

The leaves, which are united under this entity, are elliptic to lanceolate, entire-margined with cuneate to slightly decurrent base and acute apex and bear a characteristic brochidodromous venation with the secondaries irregularly spaced, steeper in the lower leaf part, thin and often of irregular course. The specific determination cannot be done in view of the lack of cuticular characters.

Laurophyllum sp. 2

Pl. 3, fig. 11

An entire-margined oblong fragmentary leaf impression suggests by brochidodromous venation and irregular course of secondaries, as well as reticulate pattern of higher order venation, possible affinities to *Lauraceae*. It differs from *Laurophyllum* sp. 1 by wider angles of the secondaries, which, of course, appears a very formal criterion to distinguish two species.

Ulmaceae
Ulmus cf. *braunii* Heer

Pl. 4, figs 8, 13, 14

Fragments of small, elongate to oval leaves with short acute apex. Dense straight secondaries are bent at the leaf margin, where they enter broad main teeth of the double serrate margin. Because of the lack of a monographic treatment dealing with fossil *Ulmus* foliage, the above suggested comparison is more or less formal.

Zelkova zelkovifolia (Unger) Bůžek & Kotlaba

Pl. 4, fig. 10

1903 *Planera ungeri* Kov. sp.; Engelhardt, p. 124, pl. 1, fig. 19 (Kakanj)

Incomplete, broadly ovate leaves, shortly petiolate, with a slightly cordate to truncate base and coarse simple teeth can safely be assigned to this common Arcto-Tertiary element, in spite of bad preservation of venation details.

cf. *Tremophyllum tenerrimum* (Weber) Ruffle

Pl. 4, fig. 9

A single small narrow ovate leaf with simple serrate margin and dense secondaries belongs undoubtedly to *Ulmaceae*. The teeth, one per a secondary vein, blunt and indistinct, compare well with the foliage of *Cedrelospermum* Saporta found attached to reproductive remains from Utah and Colorado, but only detached in Europe (Manchester 1989). We are aware of a possibility that our leaf form may merely represent a very small specimen of *Ulmus* (or *Zelkova*). No *Cedrelospermum* fruits have been found in the same horizon studied.

Fagaceae
Fagus pristina Saporta

Pl. 2, figs 1-3

1903 *Betula brongniartii* Ett.; Engelhardt, p. 119, pl. 2, fig. 18 (Kakanj)

1903 *Carpinus grandis* Unger; Engelhardt, p. 121, pl. 2, fig. 6, 11 (Kakanj)

1903 *Castanea ungeri* Heer; Engelhardt, p. 122, pl. 2, fig. 5, 9, 11, 12 (Kakanj)

1903 *Castanea atavia* Unger; Engelhardt, p. 123, pl. 3, fig. 14 (Zenica)

1903 *Ulmus longifolia* Unger; Engelhardt, p. 123, pl. 3, fig. 1 (Kakanj)

1904 *Castanea ungeri* Heer; Engelhardt, p. 558, pl. 1, fig. 16, 19, pl. 2, fig. 3, 4 (Beshirica)

1904 *Rhamnus rosmaessleri* Ung.(?); Engelhardt, p. 560, pl. 1, fig. 16 (Budanj)

1931 *Castanea atavia* Unger; Vaskovic, p. 88, pro parte, textfig. 18-21 (Kakanj)

Several, partly incomplete, longly oval, shortly petiolate leaves with broadly cuneate base and elongate apex attain up to 45 × 100 mm in size and bear typical features of the *Fagus* foliage: leaves entire-margined in the lower part, simply widely crenulate-bluntly toothed in the upper part, with a thin midrib and dense, straight secondaries, abmedially slightly bent in the basal leaf part, and nearly entering the margin (pseudocraspedodromous).

In the described specimens the number of secondaries varies about 16, in the earlier, distinctly toothed material (Engelhardt 1903, 1904) to 20. We follow Palamarev and

Petkova (1987) to assign such large-leaved populations to *Fagus pristina* Saporta (the type locality Manosque, Late Oligocene). Similar forms of *Fagus antipofii* Heer are distinguished rather geographically than by morphological features.

Quercus ex gr. drymeja Unger

Fig. 4a, b, Pl. 2, figs 1-3, Pl. 3, figs 1-4

- 1859 *Quercus drymeja* Ung.; Gaudin & Strozzi, p. 44, pl. 4, fig. 1-10, pl. 7, fig. 1, 2 (Val d' Arno)
 1859 *Quercus laharpii* Gaudin & Strozzi, p. 45, pl. 3, fig. 5, 10 (Val d' Arno)
 1867 *Quercus lonchitis* Ung.; Unger, p. 50, pl. 5, fig. 1-17, 21, 22 (Kumi)
 1904 *Quercus lonchitis* Ung. ; Engelhardt, p. 558, pl. 1, fig. 7-9, 15, pl. 2, fig. 17 (Beshirica, Budanj)
 1986 *Quercus cf. drymeja* Ung.; Knobloch & Velitzelos, p. 10, pro parte, pl. 3, fig. 10, pl. 5, fig. 2, 7, 8 (Likudi)

Several leaf impressions, mostly lanceolate (to slightly oblanceolate or rarely elliptic), petiolate, with fine, widely spaced pointed teeth that are confined mostly to the upper part of the leaf or rarely reaching near the base, are connected with transitions to entire-margined forms of the same outline. Toothed and entire-margined impressions possess also the same kind of eucamptodromous (to craspedodromous) venation with arch-like secondaries, rarely forked, quite thin, looping together with intersecondaries along entire-margined parts of leaves, otherwise entering the teeth.

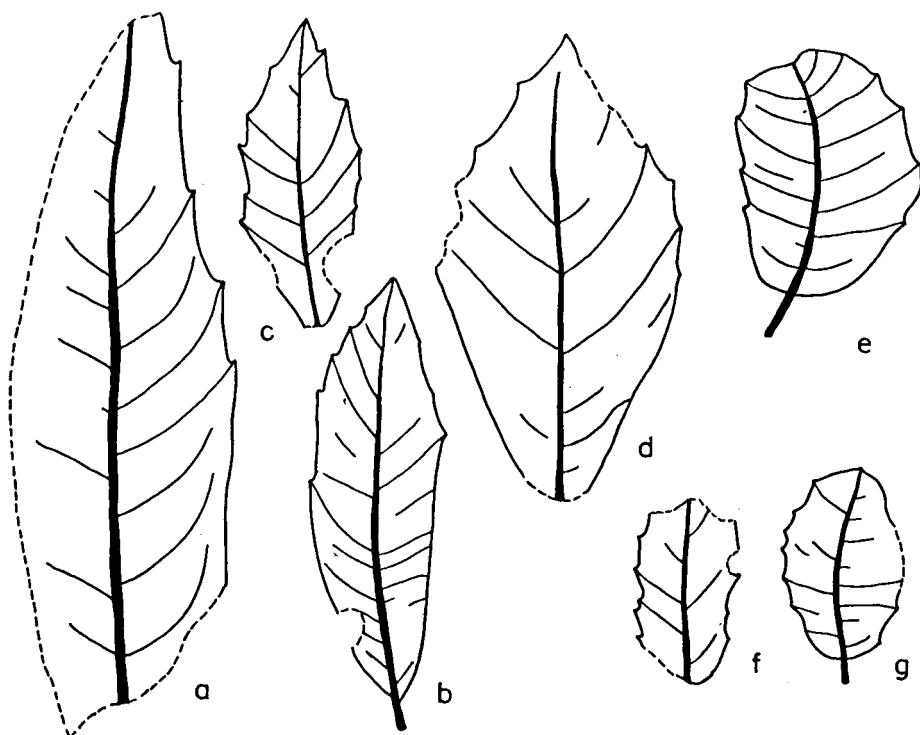


Fig. 4. a, b - *Quercus ex gr. drymeja* Unger, c-g - *Quercus mediterranea* Unger, nat. size

Similar oak populations can be encountered in the Neogene of southern Europe (Kumi, Likudi, Val d'Arno etc.). The type specimens of *Quercus drymeja* Unger from Parschlug (Unger 1847, pl. 32, fig. 1–4) differ by more prominent and regular marginal teeth. Unger (1867) used the name *Q. lonchitis* but we prefer to retain this entity for late Palaeogene oaks of this form (the type locality Socka). Similar leaf fossils were assigned to *Castanopsis* (D. Don) Spach, e.g. *Castanopsis elisabethae* Kolakovskii from the late Neogene of Abkhasia, which are, however, more robust and differ by a prominent dentation and partly semicraspedodromous venation. A preliminary observation on the material from Aliveri (coll. Prof. Velitzelos), which matches well with the above described forms, revealed massive hair bases of multiradiate trichomes, characteristic of many species of *Quercus*. The whole complex of *Quercus drymeja* Ung. and similar entities deserve a more detailed study and must be regarded as formal for the time being (Knobloch & Velitzelos 1986).

Quercus mediterranea Unger

Fig. 4c-g, Pl. 3, figs 5–7, Pl. 8, fig. 4

- 1904 *Quercus mediterranea* Ung.; Engelhardt, p. 558, pl. 1, fig. 14, 17, pl. 2, fig. 13 (Beshirica, Budanj)
 ?1904 *Alnus kefersteinii* Goepf. sp.; Engelhardt, p. 557, pl. 1, fig. 8 (Budanj)
 1904 *Ilex ambigua* Ung.; Engelhardt, p. 560, pl. 2, fig. 7 (Budanj)
 1904 *Ilex sphenophylla* Ung. ; Engelhardt, p. 560, pl. 2, fig. 5 (Budanj)

The leaf forms, which we unite under the above species, are variable from broadly elliptic to elliptic or obovate, rounded to slightly cordate at the base and obtuse to acute at the apex. They are invariably coarsely and sharply (to spiny) dentate except for the very base, petiolate. Widely spaced secondaries, usually with intersecondaries stand under angles of 90 to 60 (to 45) to the midrib and enter the teeth. Occasionally, reticulate higher-order venation can be seen. As a whole, the set of forms at hand well compares with the type specimens from Parschlug, as illustrated by Unger (1847, 1852). The thin, chartaceous texture (Kvaček & Walther 1989) suggests that this species was semi-evergreen, not much sclerophyllous, contrary to *Quercus* sect. *Ilex* Oerst. Hence traditional interpretations as to the autecology of *Q. mediterranea* may turn to be misleading (cf. Iljinskaja in Takhtajan 1982).

cf. *Trigonobalanopsis rhamnoides* (Rossmassler) Kvaček & Walther

Pl. 3, fig. 8

- 1904 *Cassia phaseolites* Ung.; Engelhardt, p. 561, pl. 2, fig. 6 (Budanj)
 ?1904 *Sapindus falcifolius* Al. Br.; Engelhardt, p. 559, pl. 2, fig. 9, 11 (Beshirica)

Elliptic entire-margined leaves with dense and regular brochidodromous venation and short petiole match well with this common thermophile European element (Kvaček & Walther 1988). Without anatomical evidence, however, such leaf imprints can be easily confused with entire-margined forms of other *Fagaceae*.

Betulaceae

Alnus gaudinii (Heer) Knobloch & Kvaček

Pl. 4, figs 1–4, Pl. 5, figs 1–5, Pl. 6, figs 1–5

- 1859 *Rhamnus gaudinii* Heer, p. 79, pl. 124, fig. 4–15, pl. 125, fig. 1, 7, 13 (Monod)
- 1859 *Rhamnus inaequalis* Heer, p. 80, pl. 125, fig. 8–12 (Monod)
- 1869 *Rhamnus gaudinii* Heer; Heer, p. 45, pl. 7, fig. 19d, pl. 11, fig. 1–11 (non 4b, 11b) (Svetlogorsk, Iantarnoe)
- 1869 *Rhamnus orbifera* Heer, p. 46, pl. 11, fig. 12 (Iantarnoe)
- 1903 *Myrica laevigata* Heer; Engelhardt, p. 118, pro parte, pl. 1, fig. 28 (Kakanj)
- 1903 *Betula prisca* Ettingshausen; Engelhardt, p. 118, pl. 1, fig. 26, 27 (Kakanj)
- 1903 *Alnus nostratum* Unger; Engelhardt, p. 120, pl. 4, fig. 25 (Kakanj)
- 1903 *Quercus valdensis* Heer; Engelhardt, p. 120, pl. 2, fig. 1 (Kakanj)
- 1903 *Rhamnus gaudinii* Heer; Engelhardt, p. 131, pl. 4, fig. 1, 3, 5 (Kakanj)
- ?1904 *Betula prisca* Ett.; Engelhardt, p. 557, pro parte, pl. 1, (Beshirica)

The suite of leaf imprints at hand shows longly petiolate, regular oval-ovate, rarely slightly obovate forms with the cuneate to rounded base and acuminate apex. Secondaries are dense, 9–15, gently bent, approaching the simple-double serrate margin with fine, blunt (or slightly swollen), outstretching teeth. Tertiaries, not well seen, partly percurrent, stand nearly perpendicularly to the secondaries.

Such a variability of leaf forms well compares with the above suggested complex of synonyms, which includes prevailingly medium sized elliptical leaves typically occurring in the Late Oligocene–Early Miocene populations. A clear-cut distinction towards the broad-leaved *Alnus rostaniana* Saporta (incl. *A. kefersteinii* sensu Saporta and *A. latior* Saporta) of Manosque or *A. schmalhauseni* Grubov of Kazakhstan is difficult to define without cuticular study. Late Miocene – Pliocene populations of this lineage, e. g. *A. gaudinii* (Heer) Knobloch & Kvaček sensu Mai & Walther (1988) from Berga, *A. angustifolia* Kolakovskii (1964) from Kodor seem to tend to narrower leaf forms, known even earlier (cf. *Rhamnus* sensu Bůžek 1971, Čermníky, Early Miocene).

Betula sp.

Pl. 4, fig. 7

A single fragment of a leaf apex with coarsely double toothed margin, straight craspedodrome secondary veins and distinct meshes of higher-order venation can safely be assigned to *Betula* L. In view of fragmentary preservation, the specific determination remains open.

? *Betulaceae* gen. et sp.

Pl. 4, figs 5, 6, 11, 12

- ?1904 *Betula dryadum* Brongniart; Engelhardt, p. 557, pl. 1, fig. 12 (Budanj)
- 1904 *Betula prisca* Ettingshausen; Engelhardt, p. 557, pro parte, pl. 1, fig. 5, 6 (Beshirica)

Several small petiolate, mostly elliptical leaves are finely simple serrate with dense and triangular teeth. Although they may in fact represent aberrant, extremely small specimens of *Alnus gaudinii*, they differ by a blunt apex and the character of margin. Similar forms were previously attached to *Betula prisca* Ettingshausen, but this species typified recently by Hummel (1991) on the basis of material from Arsenal (Austria), has

widely spaced secondaries and a different leaf form. Somewhat similar small forms were ascribed to *Rosaceae* by Menzel (1906) as *Sorbus alnoidea* Menzel from Rauno and transferred to *Alnus* by Knobloch (1986).

Myricaceae

Myrica cf. *laevigata* (Heer) Saporta

Fig. 5a-g, Pl. 7, figs 2, 3, 4, 6

1903 *Myrica hakeaefolia* Ung. sp.; Engelhardt, p. 117, pl. 1, fig. 24 (Kakanj, Zenica)

1903 *Myrica laevigata* Heer; Engelhardt, p. 118, pl. 1, fig. 25, 28, 30 (Kakanj)

The leaves included into this entity are mostly oblanceolate, rarely oblong-ovate, with narrowly cuneate, decurrent base, petiolate, mostly entire-margined, rarely finely denticulate-crenulate in the upper two thirds. The stout midrib gives off under wide angles (60–80°) dense brochidodromous secondaries and intersecondaries that join in regular rounded loops within the leaf margin. Our specimens closely recall also *Myrica*

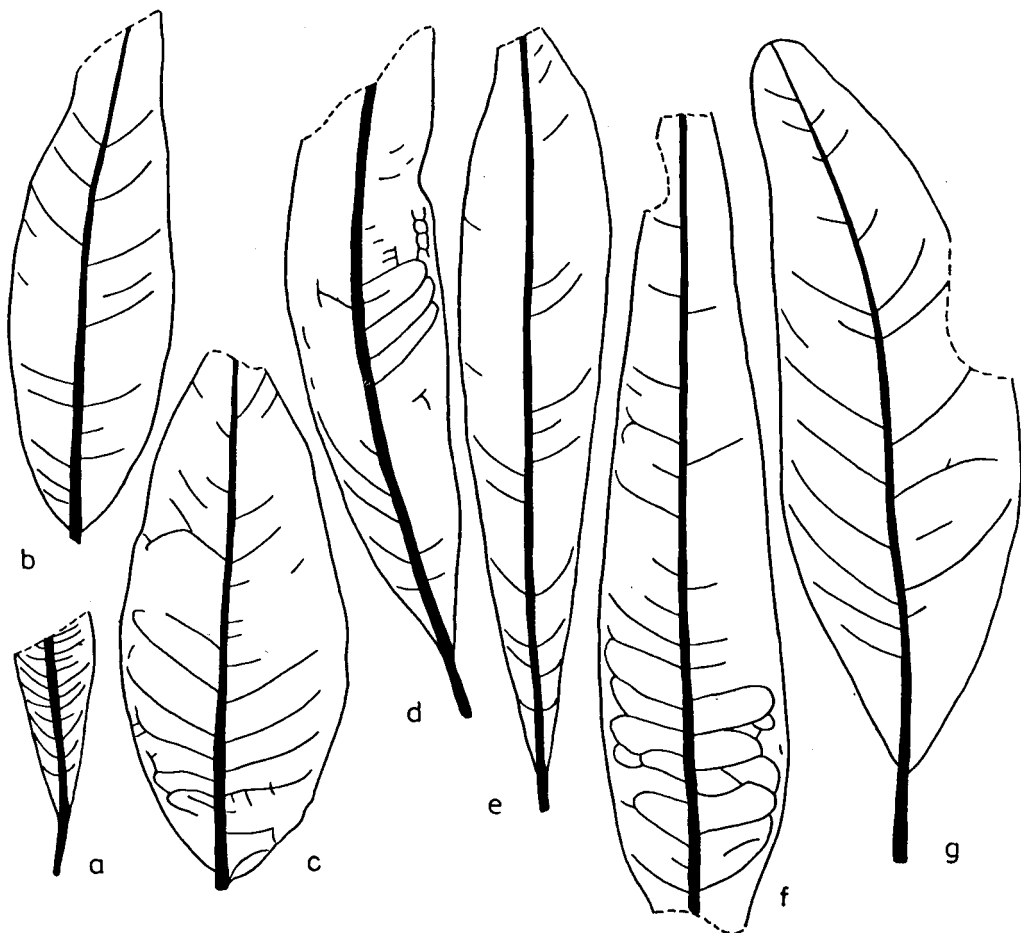


Fig. 5. a-g – *Myrica* cf. *laevigata* (Heer) Saporta, nat. size

lignitum (Ung.) Sap., in which, of course, linear forms, partly with teeth seem to prevail. Similar populations occur probably in the Early Miocene of Kumi (Unger 1867, pl. 9, fig. 1–15).

Juglandaceae
Juglandaceae gen. et sp.

Pl. 7, fig. 7

A single fragmentary elliptic, finely serrate leaf impression with an asymmetric base represents obviously a leaflet of *Juglandaceae*. Very regularly spaced, nearly straight secondaries join very near the margin in loops, from which thin side-veins contact the sinus and continue along the upper side of the tooth. This distinctive type of marginal venation can be met with in *Juglans* sect. *Rhysocarpon* and in *Carya aquatica* (Michx. f.) Nutt. (Manchester 1987). The foliage of *Fraxinus* can be distinguished by loose tertiary venation that form meshes, while in *Carya* or *Juglans*, and in our specimen as well, the tertiary veins are mostly percurrent, dense, obliquely oriented to the secondaries.

Salicaceae
Populus sp. ?

Fig. 6

A single leaf impression with poorly preserved venation recalls by a very long petiole, roundish form and condensate lower secondaries the poplar foliage, e.g. *Populus populina* (Brongn.) Knobloch.

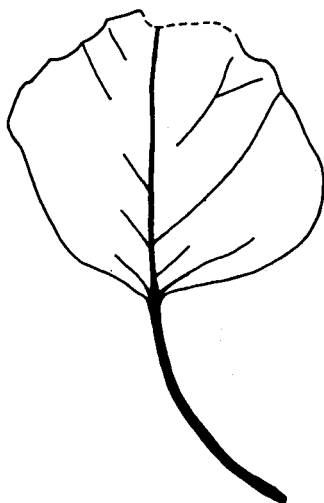


Fig. 6. *Populus* sp. ?, nat. size

Leguminosae
Leguminosae gen. et sp. 1

Fig. 7a-c

1903 *Cassia phaseolites* Ung.; Engelhardt, p. 133, pl. 3, fig. 21 (Breza)

Some sessile entire-margined elliptic leaf remains recall leaflets of *Leguminosae* by slightly asymmetric base and fine irregularly spaced brochidodromous secondaries. Although such fossils have been previously assigned to *Cassia* L., their relationship cannot be solved on the basis of characters available.

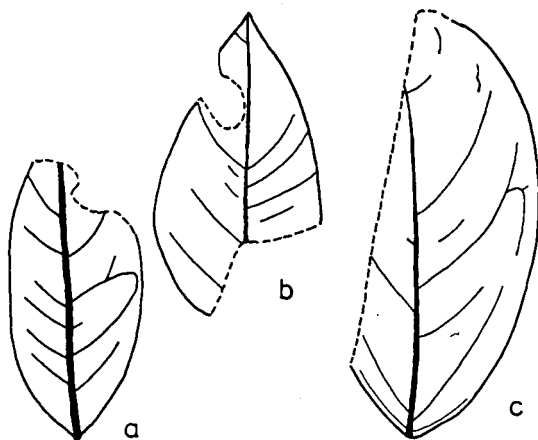


Fig. 7. a-c – *Leguminosae* gen. et sp. 1, nat. size

Leguminosae gen. et sp. 2

Pl. 7, fig. 1

Another form with linear leaflets can be compared with foliage of numerous *Leguminosae*.

Aceraceae

Acer tricuspidatum A. Braun & Agassiz

Pl. 7, fig. 8, Pl. 8, figs 1–3

1903 *Acer trilobatum* Stbg. sp.; Engelhardt, p. 120, pl. 4, fig. 10, 12, 14, 16–18 (Kakanj, Zenica)

1904 *Acer trilobatum* Stbg. sp.; Engelhardt, p. 559, pl. 2, fig. 15 (Beshirica)

1904 *Acer angustilobum* Heer; Engelhardt, p. 559, pl. 2, fig. 12 (Beshirica)

The maple leaves of the studied locality are usually 5-lobate, slightly cordate and coarsely double serrate. They correspond to the form '*crenatifolium*' and differ from the ordinary *A. tricuspidatum*, which has prevailingly trilobate leaves and smaller marginal teeth. However, '*crenatifolium*' forms can be encountered as extreme variants even within the typical populations of *A. tricuspidatum* (see Procházka & Bůžek 1975). On the other hand, Walther (1972) was able to prove some anatomical differences (hairy – hairless abaxial leaf side) between *A. tricuspidatum* and the fossils comparable to *A. crenatifolium* from the Late Miocene of Germany. This feature alone can hardly serve to discriminate between maple species, though. *Acer islandicum* Friedrich & Simonarson (Friedrich & Simonardson 1982) differs from all the mentioned forms by a deeply cordate leaf base.

Sapindaceae
Sapindus falcifolius Al. Braun

Pl. 7, fig. 5

An entire-margined lanceolate leaf impression of slightly falcate form, with asymmetric cuneate base, steep and dense secondaries, recalls a leaflet of *Sapindaceae*. Such forms are currently assigned to a somewhat formal species *Sapindus falcifolius*, widely recorded in the European Neogene.

fam. inc.

Dicotyledonae gen. et sp. indet.

Fig. 8a-e, Pl. 8, figs 5-8

Several leaf impressions, although complete and with venation details preserved, cannot be placed with certainty to a family nor do they show diagnostic features that would guarantee a specific identification. They may represent at least five other taxa, partly recalling *Magnoliaceae* (Pl. 8, figs 6, 7, Fig. 8c, d) or '*Sapindus*' *graecus* Ung. (Fig. 8e).

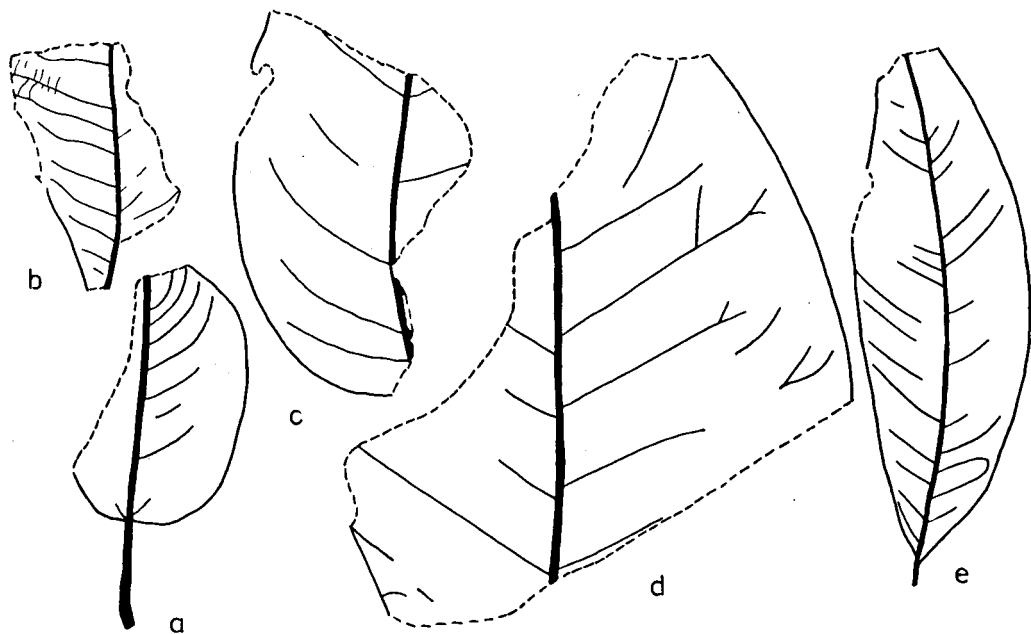


Fig. 8. a-e - *Dicotyledonae* gen. et sp. indet., nat. size

Potamogetonaceae
Potamogeton sp.

Pl. 8, figs 9

Although fruit remains of *Potamogeton* have been often recorded in Tertiary floras, leaf remains belong rather to rarities except for specific water plant horizons (e.g. at

Worth – see Kovar-Eder & Krainer 1990). The leaf fragments at hand with a prominent midrib and slightly bent subparallel secondaries mutually connected by oblique anastomosing tertiary veinlets differ from most other records, e.g. *Potamogeton bruckmannii* Al. Braun in Heer (1855), *P. martinianus* Sítár (1969), by a narrower form.

Palmae

Palmae gen. et sp.

1904 *Flabellaria* sp.; Engelhardt, p. 556, pro parte, pl. 1, fig. 2 (non fig. 3, 4) (Budanj)

A single fragment of a fan-leaved palm was described by Engelhardt (1904) but no other specimens were available in our collection. Similar remains occur in various Tertiary localities and usually are interpreted as *Sabal* Adans. The picture alone does not allow a more precise determination. The fruits assigned by Engelhardt (1904, pl. 1, fig. 3, 4) to the same plant are most probably acorns of *Quercus*.

fam. inc.

Monocotyledonae gen. et sp.

1904 *Phragmites oeningensis* A. Br.; Engelhardt, p. 556, pl. 2, fig. 2 (Budanj)

Such fragmentary ribbon-shaped leaf impressions with dense and parallel venation are usually referred to *Phragmites* L. or *Typha* L. They may testify shallow water habitats.

GENERAL PICTURE AND COMPARISONS OF THE FLORA AND VEGETATION

The complete list of the flora (Tab. 1) includes 3 species of conifers, 18 species and some more indeterminable dicotyledons and 3 species of monocotyledons. The major part of dicotyledons, i.e. 12 species, are woody plants with prevalingly dentate leaves. The value of the share between dentate and entire-margined forms cannot be exactly established in view of indeterminable entities with entire margin, and may vary about 40 % of entire-margined species. This refers to the Mixed Broad-leaved Evergreen and Deciduous forest in sense of Wolfe (1979) from East Asia. Dominant trees *Glyptostrobus* and *Alnus* with additional *Myrica* and *Acer tricuspidatum* attest to an azonal forest, well supplied by ground waters, in which, however, mesophytic elements, such as *Fagus*, xeromorphic oaks and legums, were intimately interspersed. The remains of *Lauraceae* and *Pinus* are scarce as well as those of water plants. This may be due to morphology of shore and quality of substrate not favorable either for pine and evergreen forest of acid soils or for marsh and water vegetation. The climatic conditions were surely subtropical, with occasional frosts, in view of oligotypic representation of Arcto-Tertiary elements, occurrence of palms, but with unstable, seasonal precipitations during growing season, as suggested by xeromorphous oaks or legums, and scarcity of *Taxodium*.

Most of the woody plants encountered are common elements of European Neogene floras. Large-leaved populations of *Fagus* in connection with *Glyptostrobus*, *Alnus*, *Ulmus*, cf. *Tremophyllum* and *Acer tricuspidatum* recall in many ways a much richer

Late Oligocene flora of Manosque, where, however, xeromorphous oaks are not represented.

On the other hand, the Miljevina flora has obviously common features with the Early Miocene flora of Kumi (Greece). According to Unger (1867), this flora occurring in the same lithological setting, i. e. in marls overlying a coal seam, is dominated by oaks (*Quercus lonchitis* sensu Unger, i. e. *Q. ex gr. drymeja* in our sense and *Q. mediterranea*), by '*Carpinus*' *betuloides* sensu Unger, i.e. *Alnus gaudinii* in our sense, and '*Sapindus*' *graecus*. Unger interpreted this assemblage as remnants of lighter forests with *Glyptostrobus* in the undergrowth. Two other elements, *Myrica* and *Acer tricuspidatum*, are further common links to the Miljevina flora. The differences, which stress in our opinion geographical rather than stratigraphical divergence are : 1. Arcto-Tertiary elements are far better represented in the Miljevina Basin (*Taxodium*, *Fagus*, *Ulmaceae*, *Acer*, *Alnus*). 2. Xeromorphic elements are less diversified there, some peculiar forms recalling *Proteaceae* are completely lacking (e.g. *Grevillea kymeana* Ung., *Hakea attica* Ung.).

The scarcity of *Lauraceae*, the lack of *Daphnogene*, *Engelhardia*, *Platanus neptuni* and other thermophile elements in the Miljevina flora would not allow to place this level into one of the climatic optimal phases. More detailed knowledge of other kinds of vegetation, and of course, of the flora as a whole, would be desirable to allow a more exact interregional correlation.

DATING PROBLEMS

As mentioned in the introduction, numerous fossil floras from Bosnia and Herzegovina have not their ages accurately defined using other guide (index) fossils. Marine and brackish faunas were used in quite reliable age determinations of a florula from western Herzegovina (Mihajlović 1990), which belonged to the Middle Miocene (Barritzian), and floras from the Tuzla area, NE Bosnia, of the Early Badenian, Early Sarmatian, and Late Pontian age (Pantić et al. 1988, Engelhardt 1901). Other numerous floras from various localities all over Bosnia and Herzegovina, mostly from coal basins, have not been well dated, as it can be noticed in very different age interpretations published in palaeobotanic and other papers devoted to the investigation of coal. For instance, certain fossil floras and fossil-bearing deposits are ranged from the Early Oligocene, 'Oligo-miocene' (in the commonest cases), to the Sarmatian. The wrong notion that prevailed after the Second World War (Anić 1951–1953) contributed much to the significant errors in dating. Anić maintained the persistent molluscan fauna, in particular *Congerina*, should be related to the caspiabrackish forms from the Pannonian stage of the Pannonian Basin. This was later proved wrong and *Congerina* from limnic deposits turned to have had a different evolution in the Early Miocene times (Kochansky-Devide & Slišković 1978).

With regard to the basically palaeobotanical kind of this paper, which deals with a fossil flora from one locality only, we shall consider merely some of the latest interpre-

tations of the age of Tertiary limnic deposits of Bosnia and Herzegovina, particularly those devoted to brown coal deposits. Čičić and Milojević (1977), in a synthesis based on a long-termed studies, distinguished three polyfacial complexes within the terrestro-limnic deposits: (1) Oligo-Miocene, (2) Early Miocene, and (3) Late Miocene, each representing an independent and complete cycle of sedimentation. The deposits of the Miljevina Basin possess lithological and palaeontological characteristics equivalent to those of the Early Miocene polyphase complex (beds with brown coal of good quality between the underlying clay and the overlying limestone and calcareous marl beneath pre-vaillingly clastic sediments). Although freshwater molluscan fauna is not quite reliable for dating purposes, Čičić and Milojević (1977) noted that a mass occurrence of *Congerina* in the Early Miocene polyphase complex was recorded some 300–400 m above the coal seams and an abundance of limnic molluscs (*Limnaeus*, *Pisidium*, *Planorbis*, *Sphaerium* etc.) in beds directly overlying the coal seams. A relatively small thickness of the Early Miocene overburden in the Miljevina Basin, the abundance of *Congerina* and a low position of strata with the fossil flora within the overburden of the main seam (Fig. 3) has lead to the conclusion that this fossil flora corresponds to lower levels of the Early Miocene polyphase complex. This can be important for future correlations with other fossil floras of Bosnia and Herzegovina taken for Early Miocene (i.e. up to Helvetian in older sense) and occurring both in lower and upper levels of brown coal overburdens.

Because nearly all fossil floras described by Engelhardt (1901, 1903, 1904), Vasković (1929, 1931) and Polić (1936, 1937), should be on one hand a subject of detailed taxonomic revisions, and on the other hand, it is impossible at present to establish the original stratigraphical position of the earlier described floras in local geological sections of many isolated limnic basins all over Bosnia and Herzegovina, it appears premature to compare in detail the Miljevina flora with the other ones of the Early Miocene polyphase complex.

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We appreciate discussions and suggestions by Prof. N. K. Pantić (Belgrade) on the floristic stratigraphy, and by Dr. Č. Bůžek and Dr. E. Knobloch (Praha) on the taxonomy of the studied assemblage. The research was carried out within the cooperation programme of the Czechoslovak and Serbian Academy of Sciences.

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STRESZCZENIE

W niniejszej pracy została opisana flora liściowa z osadów zagłębia Miljevina, wschodnia Bośnia. Po zbadaniu 225 okazów wyróżniono przedstawicieli rodzin *Pinaceae*, *Taxodiaceae*, *Lauraceae*, *Ulmaceae*, *Fagaceae*, *Betulaceae*, *Myricaceae*, *Juglandaceae*, *Salicaceae*, *Leguminosae*, *Aceraceae*, *Sapindaceae*, *Potamogetonaceae* i *Palmae*.

Oznaczone szczątki roślin pochodzą ze zbiorowiska wilgotnego lasu. Obok gatunków drzew takich jak *Glyptostrobus europaeus*, *Alnus gaudinii*, *Acer tricuspidatum* i *Myrica* cf. *laevigata* występowały

także składniki zbiorowisk leśnych zajmujących suchsze siedliska (*Fagus pristina*, *Quercus mediteranea*, *Quercus ex gr. drymeja*, *Leguminosae* i in.).

Pod względem klimatycznym flora ta ma charakter subtropikalny . Składem florystycznym jest bardzo zbliżona do flory miocenińskiej Kumi (Grecja), od której różni się przewagą elementów arktyczno-trzeciorzędowych. Ze względu na brak młodszych form flora Zagłębia Miłjevina zaliczono do kompleksu dolno-miocenińskiego.

PLATES

Plate 1

Glyptostrobus europaeus (Brongniart) Unger

1. Foliage shoot with male cones
2. Foliage shoot
3. Foliage shoot

Pinus sp.

4. Seed with wing
5. Seed with wing

Taxodium cf. *dubium* (Sternberg) Heer

6. Terminal part of a foliage shoot

Glyptostrobus europaeus (Brongniart) Unger

7. Female cones on twig
8. Female cones on twig

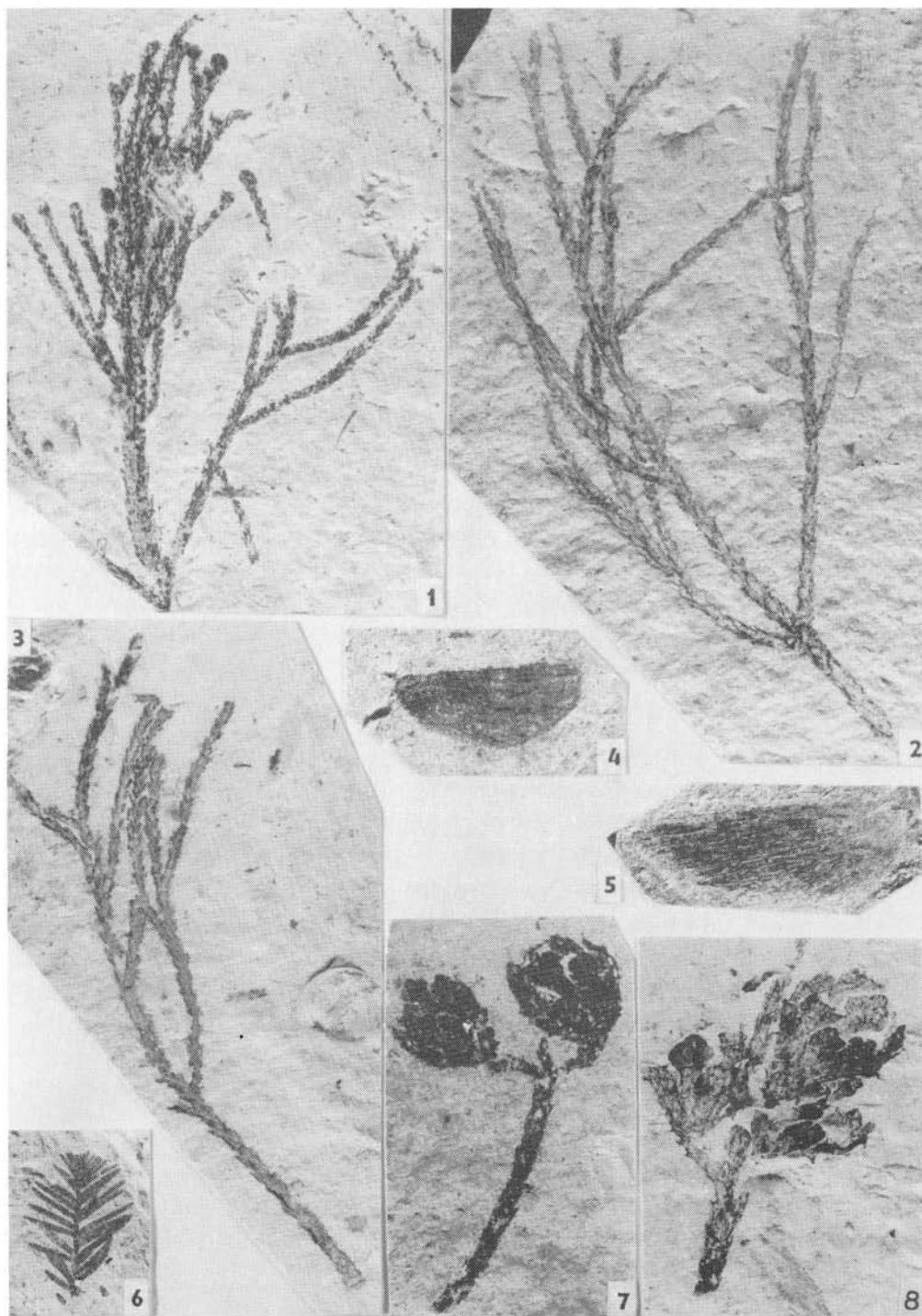


Plate 2

Fagus pristina Saporta

1. Leaf impression
2. Leaf impression
3. Basal part of leaf impression

Quercus ex gr. *drymeja* Unger

4. Slightly toothed leaf form
5. Entire-margined leaf form
6. Finely toothed leaf form
7. Nearly entire-margined leaf form

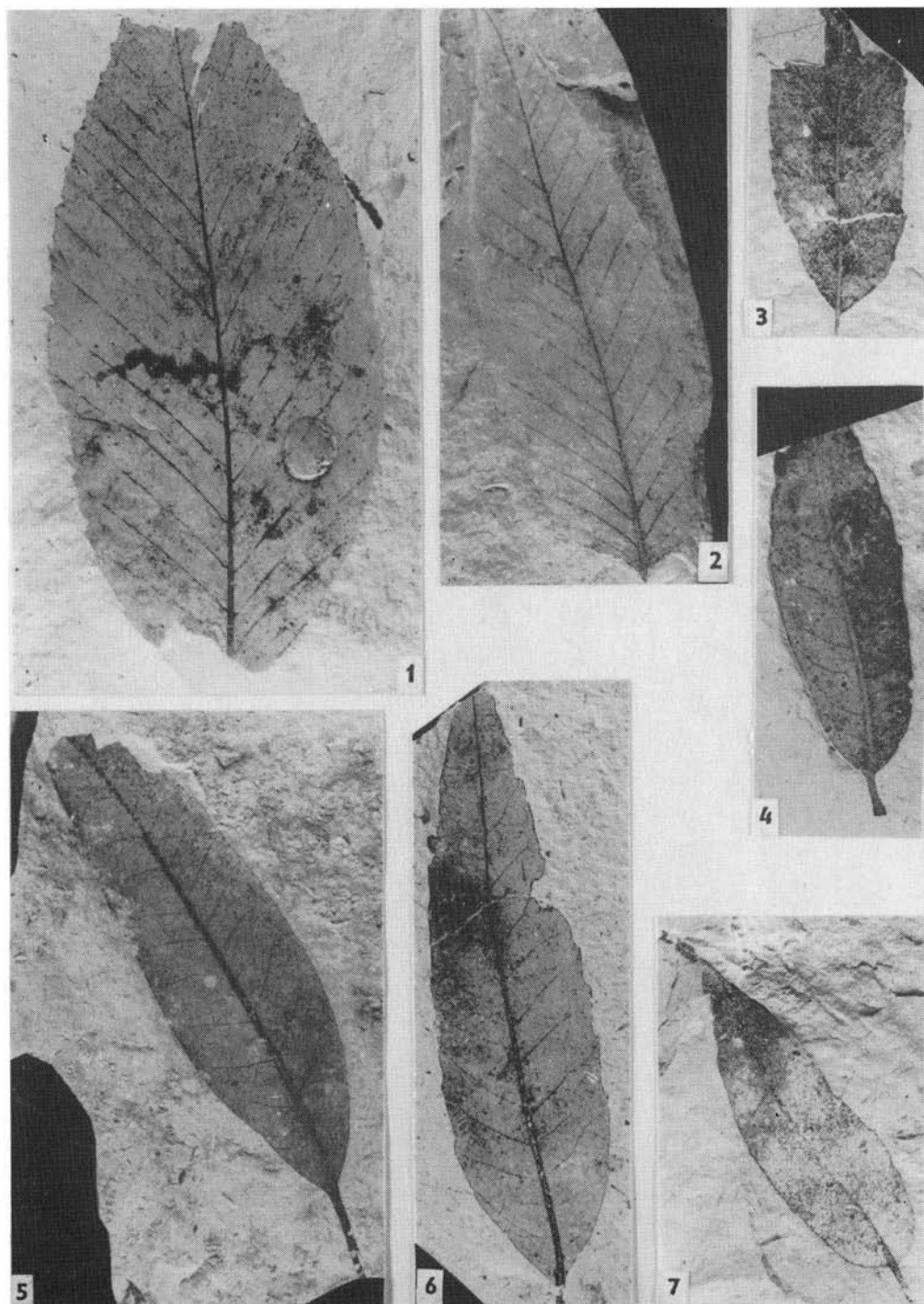


Plate 3

Quercus ex gr. drymeja Unger

1. Slightly toothed leaf form
2. Falcate and toothed leaf form
3. Entire-margined leaf form
4. Entire-margined leaf form

Quercus mediterranea Unger

5. Leaf impression
6. Leaf impression
7. Leaf impression

cf. *Trigonobalanopsis rhamnoides* (Rossmässler) Kvaček & Walther

8. Fragmentary leaf impression

Laurophyllum sp. 1

9. Basal part of leaf impression
10. Leaf impression

Laurophyllum sp. 2

11. Fragmentary leaf impression

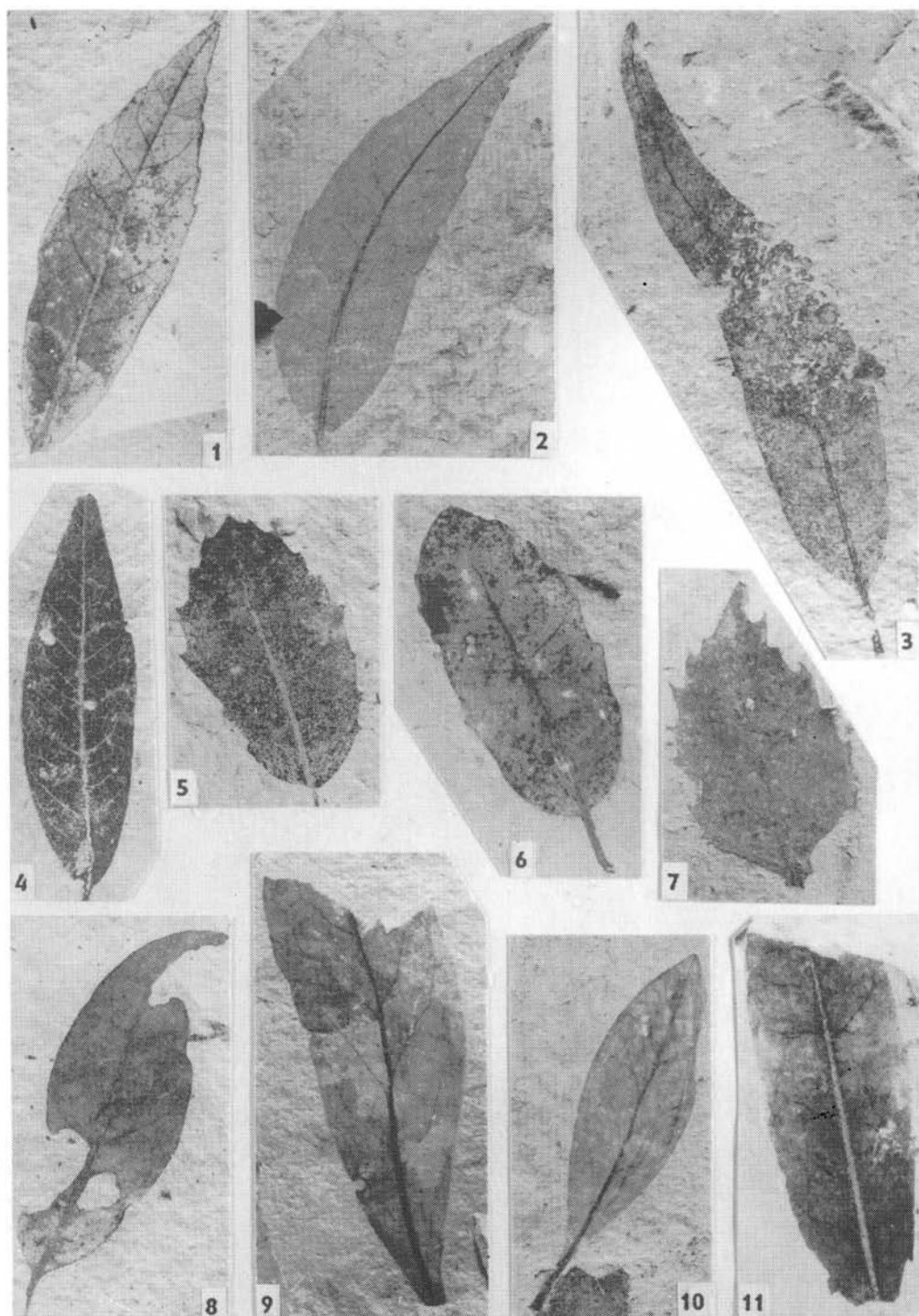


Plate 4

Alnus gaudinii (Heer) Knobloch & Kvaček

1. Two leaf impressions
2. Leaf impression
3. Leaf impression
4. Apical part of leaf impression

? *Betulaceae* gen. et sp.

5. Leaf impression
6. Leaf impression

Betula sp.

7. Apical part of leaf impression

Ulmus cf. *braunii* Heer

8. Fragmentary leaf impression

cf. *Tremophyllum tenerrimum* (Weber) Rüffle

9. Leaf impression

Zelkova zelkovifolia (Unger) Bůžek & Kotlaba

10. Incomplete leaf impression

? *Betulaceae* gen. et sp.

11. Leaf impression
12. Leaf impression

Ulmus cf. *braunii* Heer

13. Apical part of leaf impression
14. Fragmentary leaf impression

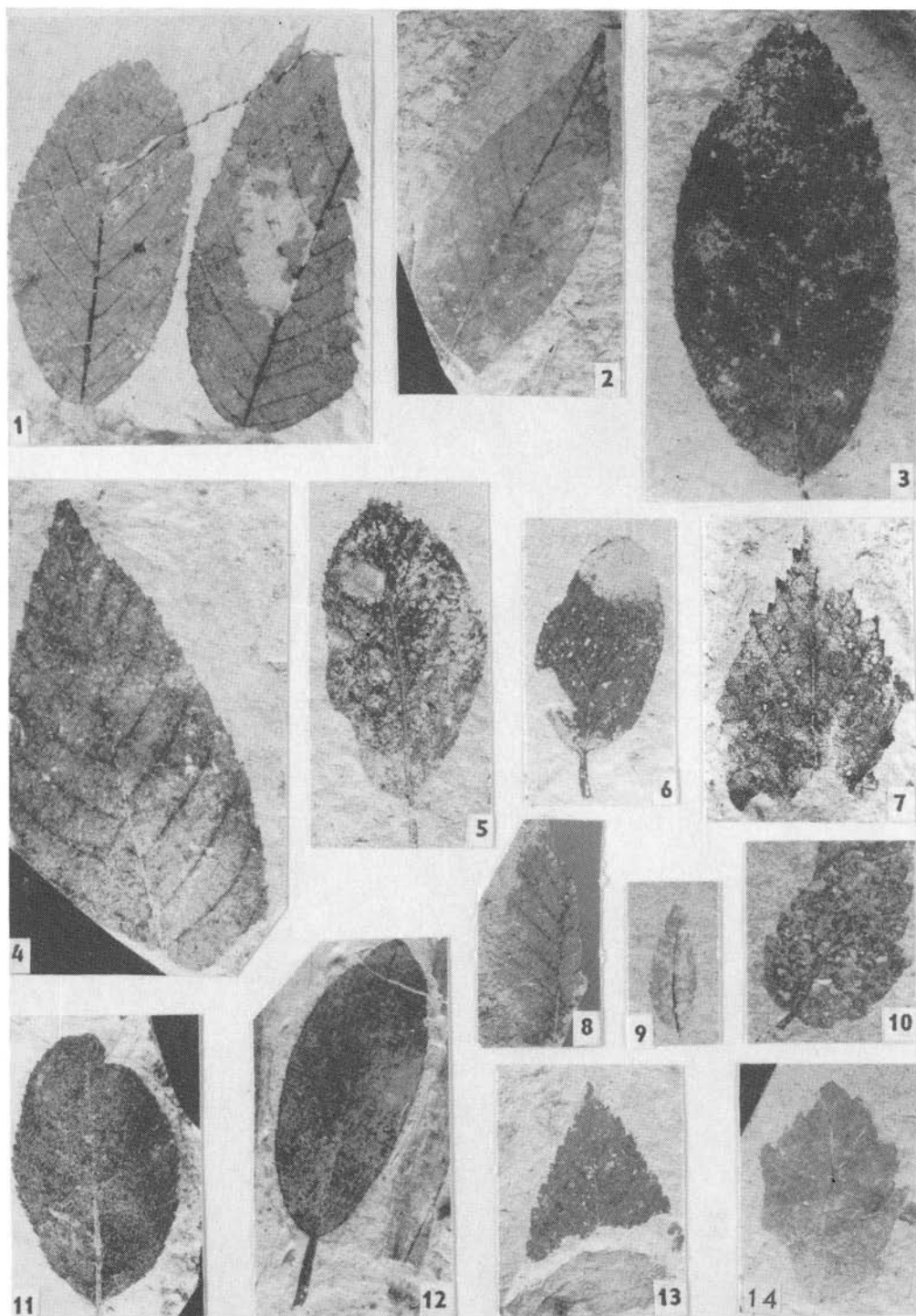


Plate 5

Alnus gaudinii (Heer) Knobloch & Kvaček

1. Broader leaf form
2. Broader leaf form
3. Slender leaf form
4. Intermediate leaf form
5. Slender leaf form

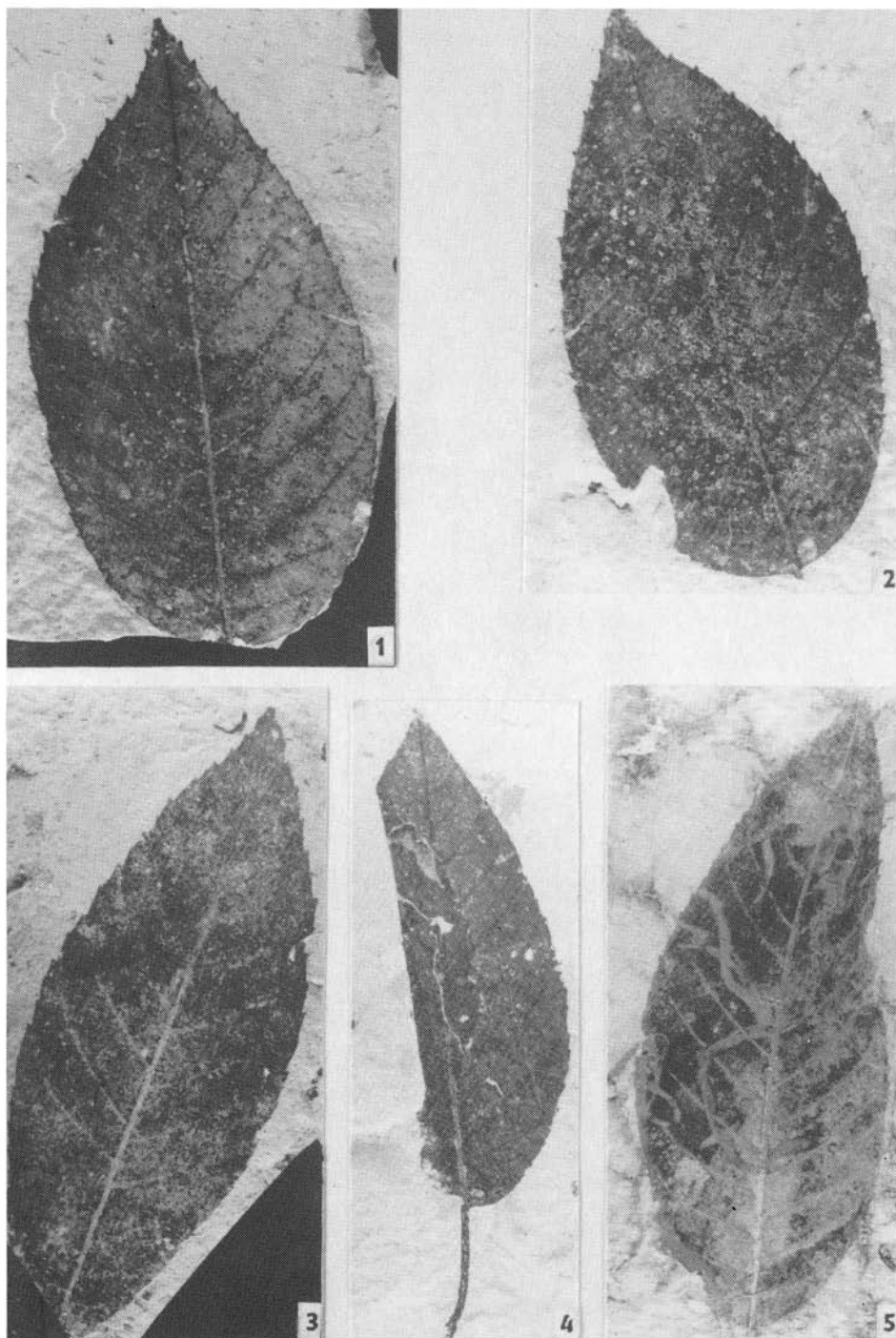


Plate 6

Alnus gaudinii (Heer) Knobloch & Kvaček

1. Broader leaf form
2. Leaf fragment
3. Slender leaf form
4. Intermediate leaf form
5. Intermediate leaf form

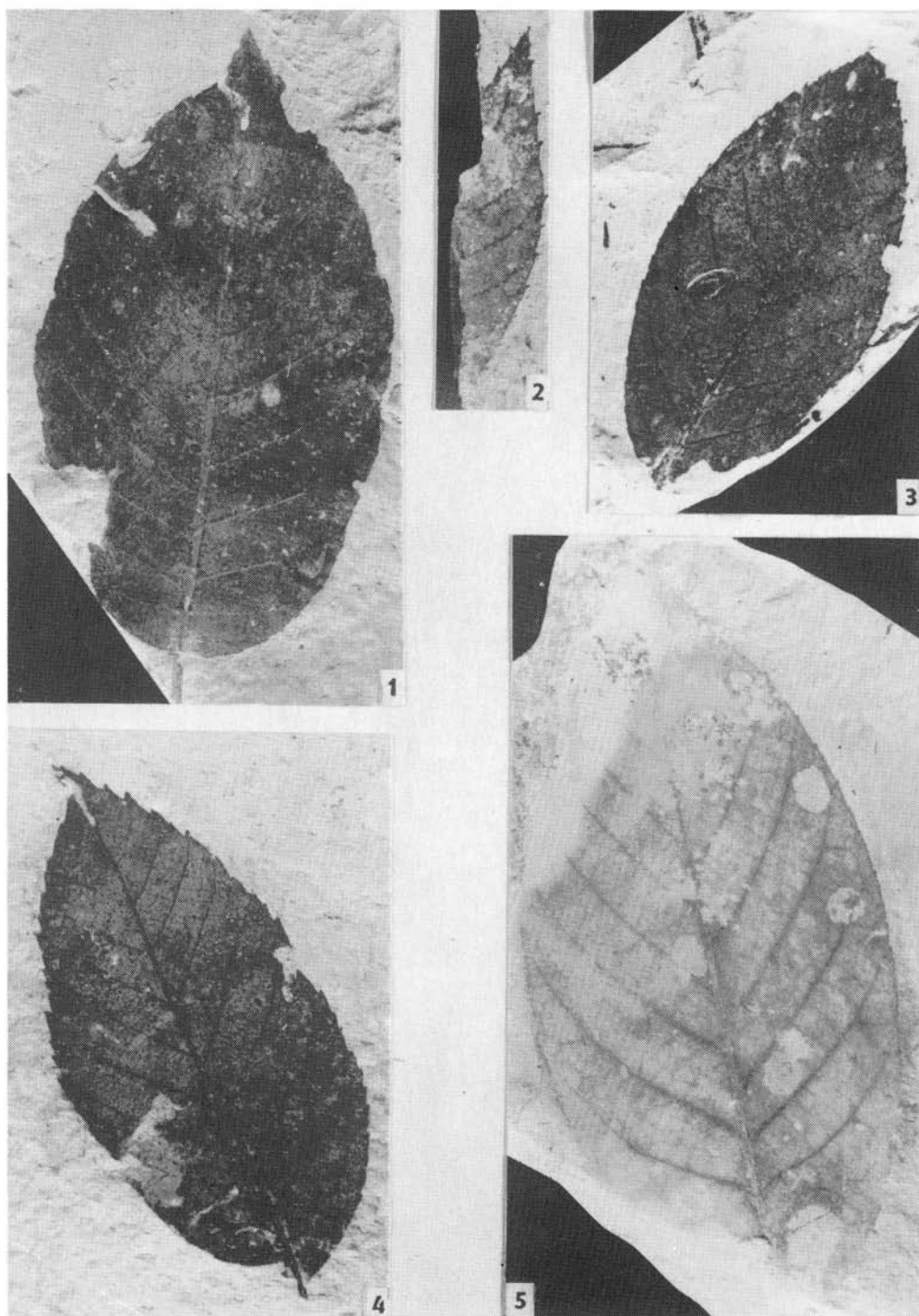


Plate 7

Leguminosae gen. et sp. 2

1. Leaflet impression

Myrica cf. *laevigata* (Heer) Saporta

2. Crenulate leaf form
3. Entire-margined leaf form
4. Aberrant small leaf form

Sapindus falcifolius A. Braun

5. Leaflet impression

Myrica cf. *laevigata* (Heer) Saporta

6. Aberrant small leaf form

Juglandaceae gen. et sp.

7. Leaflet fragment

Acer tricuspidatum A. Braun & Agassiz

8. Leaf impression

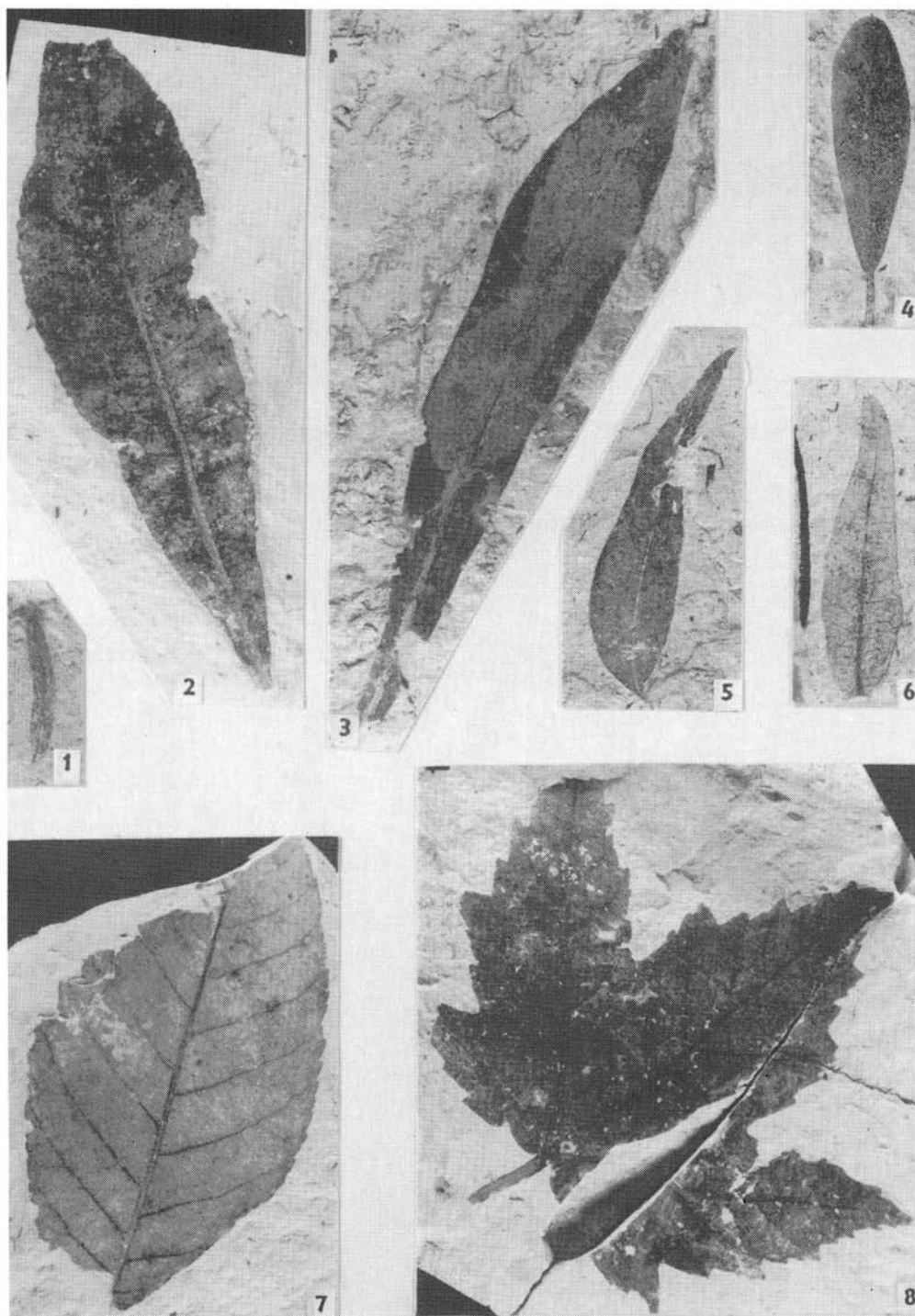


Plate 8

Acer tricuspidatum A. Braun & Agassiz

1. Fragment of leaf impression
2. Fragmentary leaf impression
3. Fragmentary leaf impression

Quercus mediterranea Unger

4. Leaf impression

Dicotyledonae gen. et sp. indet.

5. Fragmentary entire-margined leaf impression
6. Entire-margined leaf form
7. Entire-margined leaf form
8. Denticulate leaf form

Potamogeton sp.

9. Fragment of leaf impression

