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REVIEW OF THE LATE MIOCENE FLORA OF VEGORA, WESTERN MACEDONIA, GREECE

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ABSTRACT. The knowledge on the Late Miocene flora of Vegora, northern Greece, has been recently enriched by extensive research combined by cuticular analysis. So far 1 fern, 12 gymnosperms and more than 35 angiosperms have been identified. *Quercus sosnowskyi, Quercus drymeja/mediterranea* and *Hedera multinervis* link the flora with those of the Pontian and Lower Pliocene of Abkhasia. *Acer aegopodifolium, A. pyrenaicum* and other deciduous elements suggest connection with the Paratethys. Reconstructed forest vegetation corresponds to humid warm-temperate climate.

KEY WORDS: Late Miocene, flora, vegetation, palaeoclimate, Greece

INTRODUCTION

The locality of the fossil flora of Vegora is a large open-cast lignite mine situated south of a small town Amynteon, Florina District, in western Macedonia, northern Greece (Fig. 1). The Vegora lignite basin arose as part of the graben structure of Florina-Kozani-Ptolemais after the Late Oligocene Sava orogenic phase. At that time, most of Greece formed the consolidated massiv – Ägäis with several intermontane depressions scattered in the environs of Axias, Serres, Ptolemais, Vevi, Florina, but also in Peloponnes, Rhodos and Crete. They are filled with Neogene to Quaternary deposits. The Vegora lignite basin, also an intermontane, tectonically predisposed limnic basin, is limited by NW-SE faults parallel with the main axis of the Dinarids-Helenids mountain chains and transverse horst-structures. It belongs to the most important coal deposits in Greece. The geological and palaeontological research started in 1960s (Maratos 1960, Velitzelos 1974) and proceeds systematically till now. First plant fossils were recovered by the first author (E. V.) in 1970 and later on were reported in several papers (Schneider & Velitzelos 1973, Velitzelos & Schneider 1979, Velitzelos & Petrescu 1981, Velitzelos *et al*. 1983, Velitzelos & Gregor 1985, Velitzelos 1986, Knobloch & Velitzelos 1987, Mai & Velitzelos 1992, 1997). Since 1970, thousands of fossil plants have been collected and only partly worked out. Most of the collections are under the study by the present authors, particularly in view of leaf anatomical structures. The following review reports on the most interesting recent findings.

SEDIMENTARY SETTING AND VEGETATION

The available description of the geological section in the open cast mine Vegora (the situation from 1979–1980) shows a geological structure similar to that exposed today. The following layers can be distinguished in the Neogene strata starting from the top (Fig. 2):

25–30 m thick light yellow marl with diatoms of the lacustrine facies, mostly oxidized with plant-bearing horizons,
35–40 m thick light blue marl with diatoms of the lacustrine facies, deposited in the reduction zone with carbonized plant remains,
7–6 m of lignite,
2.5–0.4 m thick interbed of sandy marl with standing stems,
4 m of lignite,
0.2 m and deeper sandy marls and sands of the alluvial facies.

Deeper deposits are not exposed. They represent lignite interbeds within sands and sandy marls of the alluvial facies.

Two sedimentary settings and vegetation types can be recognized within the section:

According to taphonomical and coal-petrological studies of the lignite (Riegel *et al.* 1995), the coal-forming ecosystem is of the limnotelmatic type with intermixed swamp forest and marshland vegetation. The lignite accumulated in the backswamp river environment under the influence of fluviatile-lacustrine alluvial facies. Some parts of the seam belong to the lignite/xylite type and contain wood, logs, stubs, branches and woody particles, in which the Taxodiaceae (*Taxodioxylon gypsaceum*) prevail. Thicker parts of the seam contain matrix and tissue framework coal that originated from herbaceous mires. In the herb vegetation, several elements of the European Miocene have been identified, such as

Fig. 1. Geographic position of the Late Miocene floras in northern Greece: 1 Vegora, 2 Prosilion, 3 Lava, 4 Likudi

Spirematospermum wetzleri, Decodon globosus, Aldrovanda praevesiculosa, Cladium oligovasculare and others (Velitzelos & Gregor 1985, 1990, Velitzelos 1993). Also the record of rhizome bulbs of the endemic *Bolboschoenus vegorae* (Velitzelos *et al*. 1983) is noteworthy. The coal-forming ecosystem was suddenly replaced by a purely lacustrine regime as demonstrated by a sharp limit between the lignite seam and the overlying marl deposits of lacustrine origin.

The vegetation recovered in the overlying marl corresponds to the riparian and mesophytic, predominantly broad-leaved deciduous forests that surrounded the lake.

FLORA

The flora of the marl includes remains of only one herbaceous plant, *Osmunda parschlugiana*. *Ginkgo adiantoides* occurs only rarely as leaf remains. The foliage of several conifers with preserved cuticles have been found (? *Pseudotsuga, Taxodium*) besides cones or seeds (*Cedrus vivariensis*, *Pinus hampeana, Pinus salinarum, Pinus vegorae, Keteleeria hoehnei, Glyptostrobus europaeus, Taxodium dubium, Cupressus rhenana*). On the basis of foliage morphology, also *Pinus* and *Sequoia abietina* were identified. Among the conifers mesophytic trees prevail.

The angiosperms are represented by various families, among which the Fagaceae is most diversified. Leaves of *Fagus gussonii* (Pl. 1, fig. 1) belong to the most frequent fossils. A single cupule of beech has been identified as *Fagus decurrens*.

The second dominant tree is *Quercus sosnowskyi* (Pl. 1, fig. 6), a highly variable sclerophyllous oak, with cuticle structure and gross morphology resembling that of the mediterranean *Quercus suber* and *Q. alnifolia.* The whole range of leaf forms from nearly entire-margined to coarsely toothed ones have been found. Oaks with slender and finely toothed coriaceous leaves of the *Quercus drymeja*/*Q. mediterranea* group (Pl. 1, figs 2, 7) are less frequent. New species might be present according to the cuticle structure among these fossils (Pl. 1, fig. 3).

Deciduous oaks are represented by the species common in the Middle-Late Miocene of the Boreal and Paratethys provinces: *Quercus gigas* (Pl. 1, fig. 4), *Quercus kubinyii, Quercus roburoides/Q. pseudocastanea* group (Pl. 1, fig. 5). We cannot rule out the possibility that some of these forms belong to *Castanea,* because *Castanea* fruits have been identified beside rare associated cupules of *Quercus sapperi* and *Q. cerrisicarpa*.

The next diversified family is the Betulaceae. Several alder species are represented by only scanty leaf remains: *Alnus cecropiaefolia, A. julianiformis* and *A. ducalis* (Pl. 2, fig. 9). The cuticles of the latter have been obtained for the first time. *Alnus* cf. *kefersteinii, Carpinus kisseri, C. betulus* foss. and *Ostrya nervosa* are documented carpologically. Leaves of the *Carpinus* and *Betula* types occur only rarely.

Maple leaves have been also found and belong to several species: *Acer tricuspidatum* is documented safely by cuticles, two late Neogene species are useful for stratigraphical considerations: *Acer pyrenaicum* (Pl. 2, fig. 7) and *A. aegopodifolium* (Pl. 2, fig. 8). The two others are rare accessory elements: *Acer palaeosaccharinum, A. integerrimum.* Other Arcto-Tertiary elements include *Platanus leucophylla, Pterocarya paradisiaca* (Pl. 2, fig. 3), *Ulmus carpinoides, Ulmus plurinervia* (Pl. 2, fig. 5), *Zelkova zelkovifolia, Fraxinus* and several *Populus* species (Pl. 2, fig. 2), mostly with cuticles.

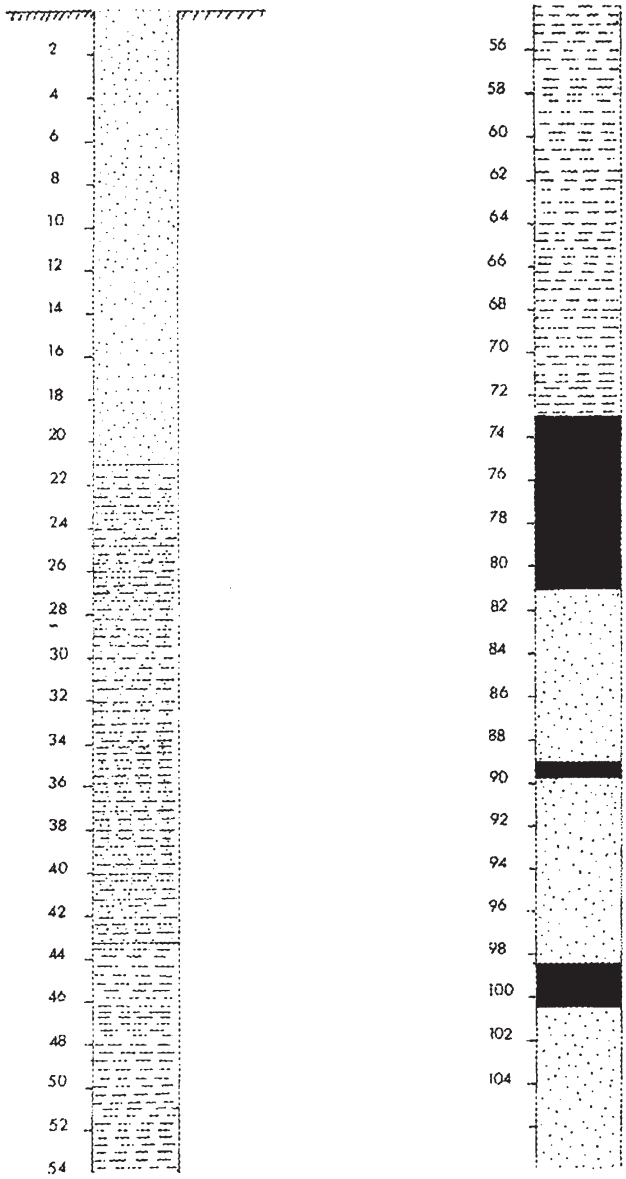

Fig. 2. Core No. 14 showing geological column of the Vegora Basin (sand – dotted; marl – dashed; diatomite marl – dotted/dashed; lignite – black)

Of the Lauraceae, only the deciduous *Sassafras ferretianum* (Pl. 2, fig. 6) occurs in larger quantity, while *Daphnogene* leaves, so common in the Oligocene and Early Miocene, are represented by a few specimens out of thousands leaf fossils recovered so far.

The newly recognized *Hedera multinervis* Kolakovskii in Kolakovskii & Shakryl (1978), (Pl. 2, fig. 4), an evergreen liana, stresses the relationship of the Vegora flora to Abkhasia .

Craigia fruits associated with *Dombeyopsis lobata*, and the leaves of *Byttneriophyllum* document plants growing in moist habitats. Their remains are rare in the assemblage.

So far only two woody monocotyledons, namely palms, have been demonstrated on the basis of unique foliage remains: *Chamaerops humilis* fossilis and *Phoenix theophrasti* fossilis.

BIOSTRATIGRAPHY, CORRELATION AND CLIMATE

So far no direct biostratigraphical dating on the basis of marine microfossils, evertebrate or mammal fauna is available for the Vegora basin. According to the present knowledge of palaeofloristic correlation, the lignite of Vegora originated during the Late Miocene. A very similar flora has been collected about 80 km south of the Vegora basin in a suite of outcrops at Likudi (Knobloch & Velitzelos 1986, Velitzelos & Gregor 1986). The Likudi flora differs in the absence of the Taxodiaceae and *Quercus sosnowskyi* but it shares the aspects of the broad-leaved deciduous mesophytic forest with the dominating *Fagus gussonii, Quercus drymeja-mediterranea* and *Q. pseudocastanea* groups. In both floras, a similar spectrum of Arcto-Tertiary elements is represented. The Likudi flora comprises moreover *Cathaya, Abies*, *Salix,* Leguminosae and *Laurophyllum* (Velitzelos & Gregor 1990, Mai & Velitzelos 1992). Mai ranges his "Florenkomplex Likudi-Vegora" (Mai 1995) into the Late Miocene before the salinity crisis of the Messinian (Mai & Velitzelos 1997). The Vegora flora includes Miocene elements, which immigrated into the Paratethys/Tethys provinces during the Middle and Late Miocene, e. g. *Alnus ducalis, Acer aegopodifolium, Quercus roburoides, Quercus gigas.* On the other hand, the Lauraceae are very rare with exception of the deciduous *Sassafras*. Very striking is a mass representation of oaks, namely *Quercus sosnowskyi*, which links the flora with those of the Pontian and Early Pliocene of Abkhasia (Kolakovskii 1964, Kolakovskii & Shakryl 1978, Shakryl 1992). Also *Chamaerops* and *Hedera multinervis* are shared between these two areas. Much less affinities are seen with the Messinian floras of Italy, which seem to be more thermophilous. *Tetraclinis, Trigonobalanopsis, Ocotea* and *Sabal* survived there from the Early Miocene times and some more mediterranean elements, e.g. *Ruscus,* appeared (coll. Museo Civico F. Eusebio, Alba). In the Late Neogene, the Fagaceae-rich floras – like that of Vegora – are obviously concentrated in the Eastern Mediterranean to Colchis. Many arboreal elements of the riparian forest, e.g. *Alnus cecropiaefolia, Alnus ducalis, Platanus leucophylla, Populus balsamoides, Acer aepodifofolium, A. pyrenaicum* (= *A. ilnicense* Iljinsk.)*, Byttneriophyllum* are shared with the sites in the Paratethys area, where also the deciduous *Quercus gigas, Quercus kubinyii* and roburoid oaks are typical. Palaeofloristically, the Vegora flora presents a transition between the Paratethys and Tethys provinces (Velitzelos 1986).

The climate as reflected by the Late Miocene mesophytic vegetation at Vegora is certainly of the Cfa-type, so it is hardly comparable with the present submediterranean/mediterranean type (Velitzelos & Gregor 1990). A high proportion of deciduous broad-leaved trees versus evergreen (mostly oaks) and the scarcity of thermophilous elements (the lack of *Tetraclinis, Engelhardia, Laurophyllum, Trigonobalanopsis*) characterizes a warm-temperate (– subtropical), less equable regime with cooler winters. An upland position of the site at a higher altitude may be responsible for its cooler aspects. Trends to the continental type of climate can be noticed, probably due to large-scale regressions of the sea from the Mediterranean area during the Late Miocene. Several arboreal elements, which are well represented in the Vegora flora, have survived in the Mediterranean-Colchis areas till the present times – *Cedrus, Cupressus, Fagus, Quercus suber, pontica* and *ilex* groups, *Castanea, Ostrya, Zelkova, Pterocarya, Platanus, Chamaerops.*

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PLATES

Plate 1

Examples of the Fagaceae foliage in the Vegora flora (scale = 10 mm)

1. *Fagus gussonii* Massal.
2. *Quercus drymeja* Ung.
3. *Quercus* sp. n.
4. *Quercus gigas* Goepp. emend. Walther & Zastawniak
5. *Quercus roburoides* Mass.
6. *Quercus sosnowskii* Kolak.
7. *Quercus mediterranea* Ung.

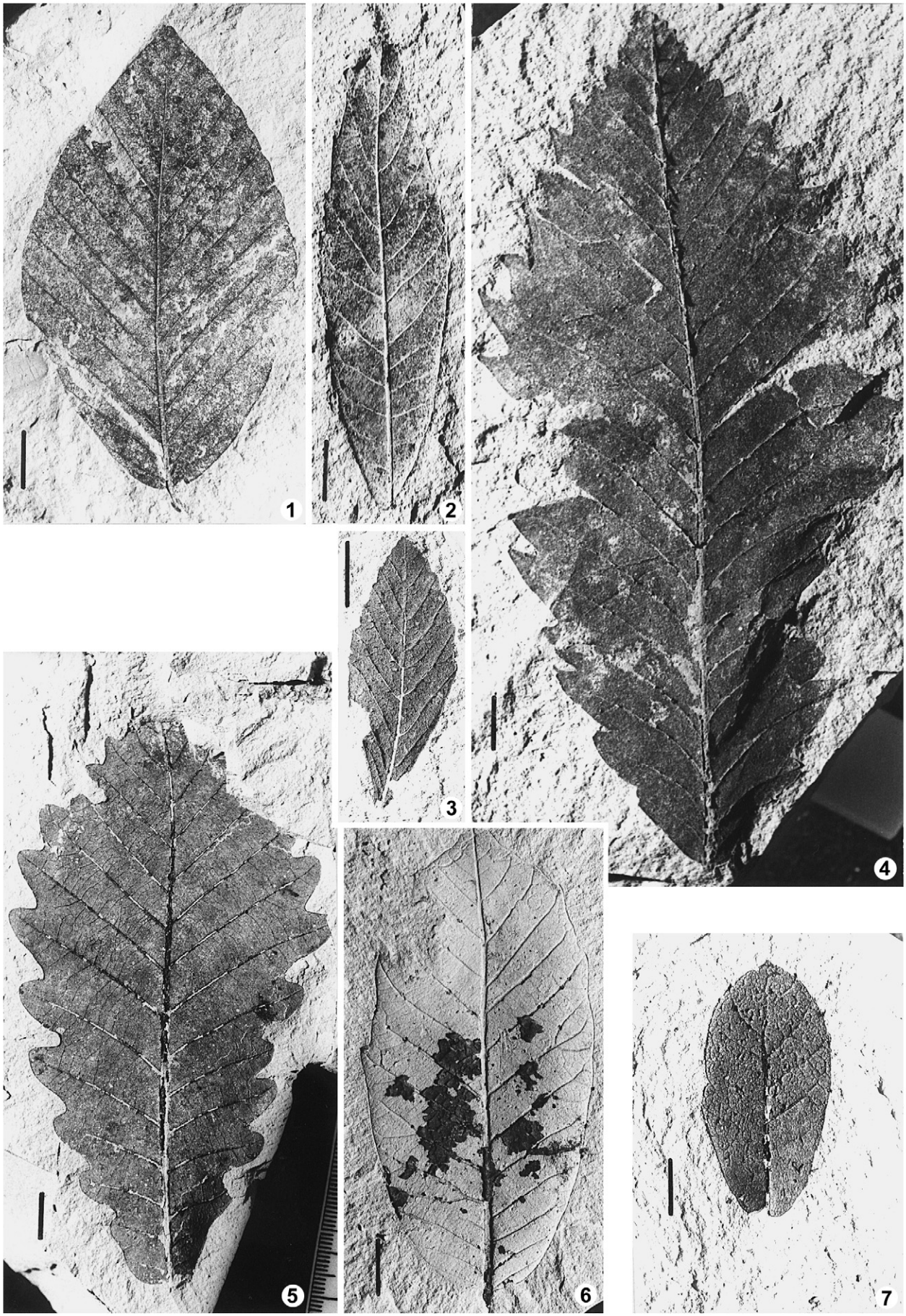
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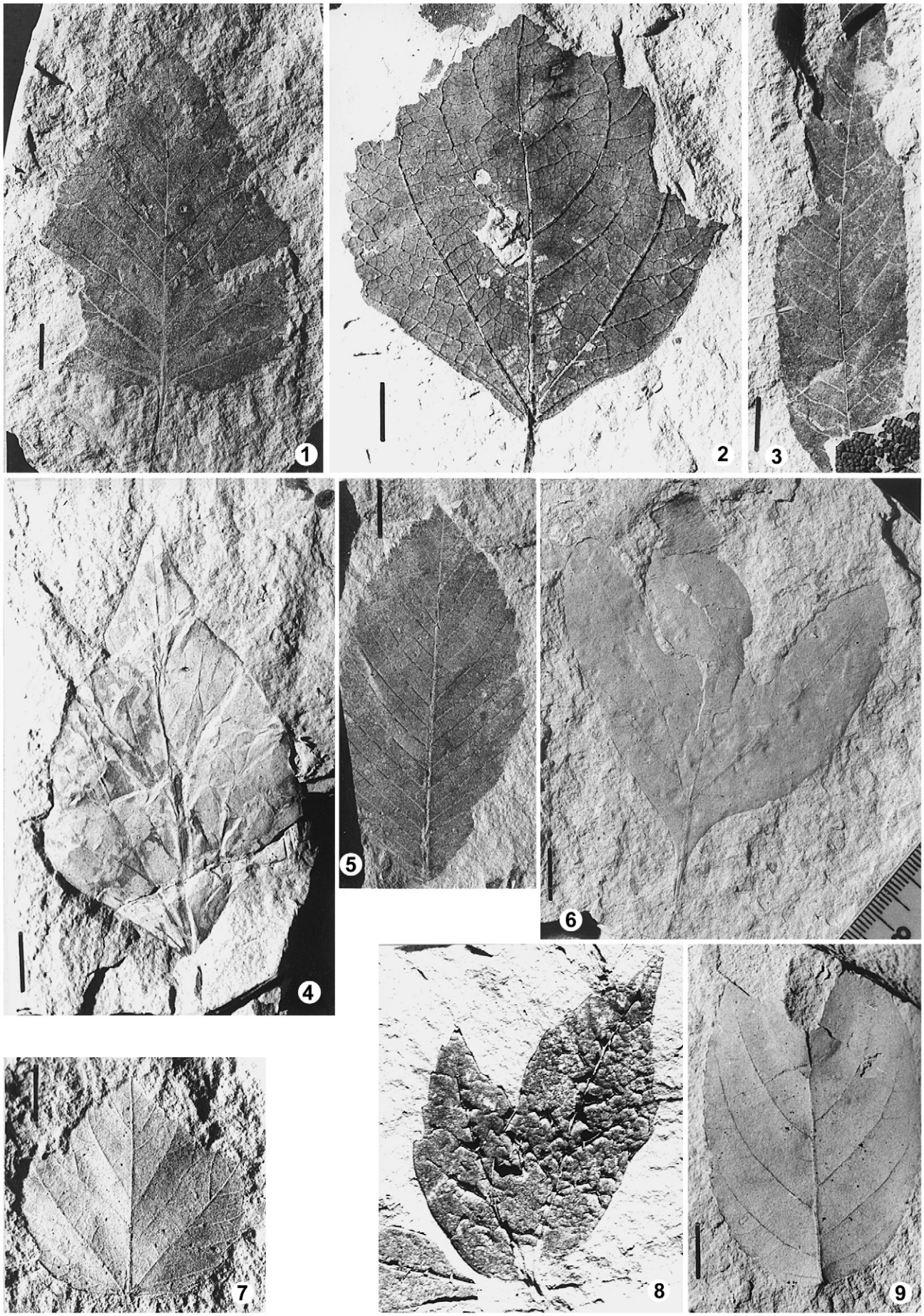
Plate 2

Examples of other broad-leaved woody elements in the Vegora flora (scale = 10 mm)

1. *Betula subpubescens* Goepp.
2. *Populus* sp. n.
3. *Pterocarya paradisiaca* (Ung.) Iljinsk.
4. *Hedera multinervis* Kolak.
5. *Ulmus multinervis* Ung.
6. *Sassafras ferretianum* Massal.
7. *Acer pyrenaicum* Rér.
8. *Acer aegopodifolium* (Ung.) Iljinsk.
9. *Alnus ducalis* (Gaud.) Knobl.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