



# PALEOGENE FLORA OF SLOVENIA, CROATIA AND BOSNIA AND HERZEGOVINA

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Localities with Paleogene flora are situated in the NE and Central Slovenia, Istria and Central Dalmatia (Croatia) and SW Herzegovina (Bosnia and Herzegovina). Taxa are arranged in 87 families, 214 genera and 496 different species. Without doubt the composition of the paleo-phytoassociations indicates the paleotropical character of the determined flora (tropical-sub-tropical elements, holarctic elements, cosmopolitan and southern hemisphere elements). It was possible to position each locality in an adequate floristic complex: the localities Raša (Istria), Mt. Promina (Dalmatia) and those in the Herzegovina are situated in the Mediterranean Tethys bioprovince – Raša, Mt., Promina NW Herzegovina = *Montebolca floristic complex*; Mt. Promina and NW Herzegovina also = *Célas floristic complex*. The locality Socka, and localities situated in the Sava folds are a part of the trans-European Paratethys bioprovince – Socka = *Lábatlan floristic complex*; Sava folds (Zagorje, Trbovlje, Novi Dol) = *Kiscell floristic complex*.

**Key words:** Paleogene, Macroflora, Paleo-phytoassociations, Vegetation Type

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Lokaliteti s paleogenskom florom smješteni su u SI i središnjem dijelu Slovenije, Istri, središnjoj Dalmaciji, te u SZ Hercegovini. Taksoni su svrstani u 87 porodica, 214 rodova i 496 različitih vrsta. Sastav paleofitozajednica bez sumnje upućuje na paleotropski karakter determinirane flore (tropsko-suptropski elementi, holarktički elementi, kozmopolitski i elementi južne hemisfere). Svaki se lokalitet može smjestiti u odgovarajući floristički kompleks: Raša u Istri, lokaliteti Promine i onih u Hercegovini smješteni su u Sredozemnu tetijsku bioprovinciju (Raša, Promina, SZ Hercegovina = *Montebolca floristički kompleks*, a Promina i SZ Hercegovina djelimice imaju još i elemente *Célas florističkog kompleksa*). Lokalitet Socka i lokaliteti Posavskih bora bili su dijelovi Transeuropske paratetijske bioprovincije (Socka = *Lábatlan floristički kompleks*; Posavske bore [Zagorje, Trbovlje, Novi Dol] = *Kiscell floristički kompleks*).

**Ključne riječi:** paleogen, makroflora, paleofitozajednice, tipovi vegetacije

## INTRODUCTION

Localities with Paleogene flora are situated in the Savinja Alps (NE Slovenia) and Sava Folds (Central Slovenia), Istria and Central Dalmatia (Croatia) and SW Herzegovina (Bosnia and Herzegovina). According to fossil flora, fauna, coal seams and bauxite deposits, localities have been known for more than a century. Paleoflora in Slovenia is well known from the Socka Beds – Upper Eocene (UNGER, 1850; JELEN *et al.*, 1992; 1994; 2000) and the Trbovlje Formation [(PLACER, 1999), syn. »Socka Beds«, Pseudo Socka Beds or »Trbovlje« Beds (Zagorje, Trbovlje, Novi Dol etc.)] – Lower Oligocene (ETTINGSHAUSEN, 1885; MIHAJLOVIĆ & JUNGWIRTH, 1988). In Croatia fossil plants were found in Raša – Lower Eocene (MIHAJLOVIĆ, 1990), Promina Formation – Upper Eocene to Lower Oligocene (ETTINGSHAUSEN, 1855) and in Herzegovina in the »Paleogene Clastic Complex« – Lutetian/Biarritz (JUNGWIRTH, 1997).

The whole paleofloristic material was examined critically. Taxa are arranged in 87 families, 214 genera and 496 different species. In addition to preserved leaf imprints other morphological parts of plants have been found, i. e. **vegetative** (thallus – e. g. *Sphaerococcites flabelliformis* ETTINGSHAUSEN; rhizome fragments – *Zostera ungeri* ETTINGSHAUSEN; roots, stumps, stems, tree shoots – *Taxodium dubium* (STERNBERG) HEER, *Doliosrobis hungaricus* (RASZKY) BŪŽEK, HOLY & KVAČEK) and **fructifications** (flowers, seeds – *Tetraclynis brachiodon* (BRONGNIART) MAI & WALTHER, *Pinus megaloptera* ETTINGSHAUSEN, *P. palaeo-abies* UNGER, *P. palaeo-taeda* ETTINGSHAUSEN, *Abelia quadrialata* REID & CHANDLER, *Acer stenocarpum* ETTINGSHAUSEN, *Bumelia heliadum* ETTINGSHAUSEN, *Ostrya atlantidis* UNGER, *Craigia bronii* (UNGER) KVAČEK, BŪŽEK & MANCHESTER (=? *Ptelea intermedia* ETTINGSHAUSEN); legume – »*Acacia*« *sotzkiana* (UNGER), *Cassia berenices* UNGER, *Cassa sagoriana* ETTINGSHAUSEN and fruits). One of the most important problem areas presented by the determination of individual species of fossil leaves is connected with the complexity of classification (species, genus, family) by classic determinations (ECS are not possible) of architecture and leaf morphology.

## RESULTS AND DISCUSSION

The composition of the flora analyzed in succession in the construction of the Tethys phyto-geographic province from Lower Eocene to Lower Oligocene, shows that the palaeoflora changed its character. Eocene flora (Raša, Socka) expresses a tropical-subtropical xerophilous character. Middle Eocene to Upper Eocene floras (Promina Mt., NW Herzegovina) indicate the existence of a xerophyle and wet lauroid vegetation. The margin of the water basin was covered with mangrove vegetation and palms, as well. In addition to this paleotropic and xerophyte character, in the Sava folds (Zagorje, Trbovlje, Hrastnik, Novi Dol) fossil flora, the appearance of arctotertiary elements is also evident.

The composition of paleo-phytoassociations without doubt indicates the paleotropic character of the determined flora, which existed during the Paleogene on the northern shores of Tethys. The following floristic elements are present (*sensu* MAI, 1995):

## A. Tropical-subtropical elements

• »Paleotropic floristic elements« [e. g. *Ailanthus orionis* ETTINGSHAUSEN, *Bombax chorisiaefolium* ETTINGSHAUSEN, *B. sagorianum* ETTINGSHAUSEN, *Eotri-gonobalanopsis* (»*Dryophyllum*«) *furcinervis* (ROSSMÄSSLER) KRÄUSEL & WEYLAND, *Daphnogene cinnamomofolia* (BRONGNIART) UNGER forma »*lanceolata*«, *D. cinna-momofolia* (BRONGNIART) UNGER forma »*cinnamomofolia*«, *D. bilinica* (UNGER) KNOBLOCH & KVAČEK, *Engelhardtia macroptera* (BRONGNIART) UNGER, *E. ors-bergensis* (WESSEL & WEBER) JÄNISCHEN, MAI & WALTHER, *Ficus tiliaefolia* AL. BRAUN, *Laurophyllum* cf. *acutimontanum* MAI, *L. princeps* (HEER) KRÄUSEL & WEY-LAND, *Myrica banksiaefolia* UNGER, *M. hakaefolia* UNGER, »*Persea heeri*« ETTINGS-HAUSEN, *Sabal major* UNGER, *Santalum acheronticum* ETTINGSHAUSEN, *Sterculia labrusca* UNGER, *Sapindus dalmaticus* VISIANI, *S. falcifolius* AL. BRAUN, *Sotzkia longifolia* (UNGER) ZHILIN, *Symplocos radobojana* UNGER, *S. saviniensis* ETTINGS-HAUSEN, *Terstroemia bilinica* ETTINGSHAUSEN, *Zantoxylum europaeum* UNGER, *Z. sotzkiana* (ETTINGSHAUSEN) GREGOR etc.].

• »Makaronesian-Mediterranean elements« [*Ephedrites sotzkiana* UNGER, *Ilex sa-goriana* ETTINGSHAUSEN, *Laurus*, *Olea*, *Pinus*, *T. salicornioides* (UNGER) KVAČEK].

## B. Holarctic elements

• »Panholartic elements« [*Acer tricuspidatum* BRONN, *A. stenocarpum* ETTINGS-HAUSEN, *Alnus gaudinii* (HEER) KNOBLOCH & KVAČEK, *A. kefersteinii* (GÖP-PERT) UNGER, *Betula prisca* ETTINGSHAUSEN, »*Juglans acuminata*« (AL. BRAUN) HEINKE, *Populus leuce* UNGER, *Salix aquitanica* ETTINGSHAUSEN].

• »East Asian-North American elements« [*Carpinus grandis* (UNGER), *Corylus mac-quarii* HEER, *Fagus feroniae* UNGER, *Platanus leucophylla* (UNGER) KNOBLOCH].

• »Eurasian elements« [*Carya bilinica* UNGER, *C. heerii* ETTINGSHAUSEN, *C. serrifolia* (GÖPPERT) KRÄUSEL =? *Pterocarya denticulata* WEBER].

• »East Asian elements« [*Acer*, *Ailantus*, *Carpinus*, *Engelhardtia*, *Glyptostrobus eu-ropaeus* (BRONGNIART) KNOBLOCH, *Magnolia diane* UNGER, ? *Pterocarya*].

• »North American elements« [*Acer*, *Castanopsis*, *Comptonia dryandroides* UN-GER, *C. schrankii* (STERNBERG) BERRY, *Cornus studeri* HEER, *T. dubium* (STERN-BERG) HEER, *Sequoia abietina* (BRONGNIART) KNOBLOCH].

## C. Other elements

• »Cosmopolitan elements« [*Nymphaea carpentieri* HEER, *N. gypsum* SAPOR-TA, *Potomageton foliosus* UNGER, *P. saviniensis* ETTINGSHAUSEN, *Typha latissima* AL. BRAUN].

• »Southern Hemisphere elements« [»*Banksia*« *dillenioides* ETTINGSHAUSEN, *Callitris brongniartii* (ENDLICHER) HEER = *Tetraclinis brachyodon* (BRONGNIART) MAI et WALTHER, ? *Casuarina sagoriana* ETTINGSHAUSEN, *Dryandra panacifolia* VISIANI, *D. sagoriana* ETTINGSHAUSEN, *Eucalyptus haeringiana* ETTINGSHAUSEN, *E. oceanica* UNGER, »*Grevillea*« *haeringiana* ETTINGSHAUSEN, *Hakea fraxinoides* ET-

TINGSHAUSEN, *H. macroptera* ETTINGSHAUSEN, *Leptomeria distans* ETTINGSHAUSEN, »*Acacia*« *microphylla* UNGER, »*A.*« *sotzkiana* UNGER, *Persoonia cuspidata* ETTINGSHAUSEN, *P. daphnes* ETTINGSHAUSEN].

On the basis of revised and studied fossil flora localities it was possible to recognise the following vegetation types:

## 1. Zonal type of vegetation

- **Para-tropical rainforest (Pluviosilvae – PRF)** – Arecaceae, Anacardiaceae, Burseraceae, Bombacaceae, evergreen Fagaceae, some Lauraceae, Sapotaceae, Sterculiaceae, Symplocaceae;

- **Evergreen broad-leaved forest (Laurisilvae – EBF)** – Aquifoliaceae, Ebenaceae, Fagaceae, Lauraceae, Moraceae, Myricaceae, Rhamnaceae, Rosaceae, Theaceae etc.;

- **Evergreen sclerophyllous forest (Sclerosilvae – ESF)** – Anacardiaceae, Apocynaceae, Caesalpiniaceae, Cupressaceae, Ericaceae, Myrtaceae, Oleaceae, Rhamnaceae, Thymeliaceae;

- **Deciduous broad-leaved forest (Aestisilvae – DBF)** – Aceraceae, Betulaceae, Fagaceae, Juglandaceae, Magnoliaceae, Platanaceae, Salicaceae, Ulmaceae;

- **Mixed mesophytic forest (Aestisilvae – MMF)** – *Ailantus*, *Carya*, *Castanea*, *Diospyros*, *Engelhardtia*, *Ficus*, *Magnolia*, *Symplocos*.

## 2. Azonal type of vegetation

- **Aquatic plant and swamp communities** – Characeae (*Chara langeri* ETTINGSHAUSEN, *Ch. ungeri* ETTINGSHAUSEN), Delesseriaceae (*Confervites capiliformis* ETTINGSHAUSEN), Fucaceae (*Cystoseira communis* UNGER), Girardinaceae (*Chondrites laurencioides* ETTINGSHAUSEN), Holoragaceae (? *Myriophyllum radicum* VISIANI), Najadaceae (*Najadonum longifolium* ETTINGSHAUSEN, *Najadopsis divaricata* ETTINGSHAUSEN), Nelumbonaceae (*Nelumbium buchii* ETTINGSHAUSEN), Nymphaeaceae, Poaceae (*Arundo göpperti* MÜNSTER, *Phragmites oeningensis* AL. BRAUN, *Poacites saviniensis* ETTINGSHAUSEN), Potamogetonaceae, Zosteraceae (*Zostera ungeri* ETTINGSHAUSEN, *Zosterites officinis* ETTINGSHAUSEN);

- **Shore plant communities** – *Acrostichum lanzaeanum* (VISIANI) CHANDLER,? *Casuarina*, *Cyperis laticostatus* ETTINGSHAUSEN, *Equisetum affine* ETTINGSHAUSEN, *E. repens* ETTINGSHAUSEN, *Equisetites erbrechi* ETTINGSHAUSEN, *Phragmites*, *Sabal*, Typhaceae etc.;

- **Riparian forest, bottomland forest** – *Acer*, *Alnus*, *Ilex*, *Populus*, *Salix*;

- **Swamp forest** – *Palmacites prominens* VISIANI, *Trachycarpus* (*Flabellaria*) *haerinfiana* (UNGER), *T. (F.) raphifolia* TACHT, *Comptonia*, *Glyptostrobus*, *Myrica*, *Taxodium* etc.

The character of the floristic composition of every locality is paleontologically well documented, footwall and overlying sediments, and the reconstruction of paleogeographic evolution during the Paleogene age enables each locality to be positioned in an adequate floristic complex (JUNGWIRTH, 2002 a; b):

1. Localities Raša (Lower Eocene), Mt. Promina (Middle and Upper Eocene to Lower Oligocene) and those in the Herzegovina (Biarritz) are situated in the Mediterranean Tethys – bioprovince. The paleoflora of Raša is equivalent to the so-called *Montebolca floristic complex* (Verona). The localities of Mt. Promina and NW Herzegovina, as well as to the Montebolca complex, are also very close to *Célas floristic complex* (NW of Alés in the south of France).

2. The locality of Socka (Upper Eocene) was a part of the trans-European Paratethys bioprovince. The fossil plant community is equivalent to the *Lábatlan floristic complex* (near Dorog – Hungary).

3. Localities situated in the Sava folds (Lower Oligocene) as a part of trans-European Paratethys bioprovince are equivalent to the *Kiscell floristic complex* (near Budapest – Óbuda in Hungary).

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## S A Ž E T A K

Paleogenska fosilna flora Slovenije, Hrvatske  
i Bosne i Hercegovine

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Lokaliteti s paleogenskom florom u Sloveniji (Soca, Posavske bore), Hrvatskoj (Istra, Pl. Promina) i Bosni i Hercegovini (SZ Hercegovina) pripadali su kao dio neovisne fitohorije Tetijskoj biljno-geografskoj provinciji, koja je kao suptropski do paratropski pojas vegetacije tzv. »kišnih šuma«, te kao subkserofitni i kserofitni pojas vegetacije, egzistirala samo tijekom starijeg paleogena.

Rekonstruiran je slijed paleoflora koje su se tijekom paleogena (od donjeg, preko srednjeg i gornjeg eocena do kraja donjeg oligocena) mijenjale od tropsko-suptropske flore s obilježjima izražene kserofilnosti, preko vegetacije koja uz svoja kserofilna obilježja ima još osobinu vlažnih lovorovih šuma uz obod morskoga bazena obraslog mangrovom paprati i palmama, do vlažnih kišnih šuma i kserofilne vegetacije ovisne o sezonskim kišama s prvim pojavama (u svezi zahlađenja) predstavnika umjerene flore.

Sukcesivni slijed proanalizirane fosilne flore (496 različitih vrsta) pokazuje da je flora mijenjala svoje osobine. Eocenska flora (Raša, Soca) iskazuje tropsko-suptropski kserofilni karakter. Srednjo do gornjoeocenske fosilne flore (Pl. Promina, SZ Hercegovina) upućuju na postojanje kserofilne i vlažne lauroidne vegetacije. Rubovi vodenih bazena bili su obrasli magrovom vegetacijom (Pl. Promina; Hercegovina – Zagorje) i palmama. Pored paleotropskog i kserofitnog karaktera fosilna flora u Posavskim borama (Zagorje, Trbovlje, Hrastnik, Novi Dol) pokazuje prisutnost i prvih pravih arkotercijarnih elemenata.

U skladu s florističkim sastavom svakog lokaliteta, koji je paleontološki dobro dokumentiran, kako s obzirom na podinske tako i na krovinske naslage, te na temelju paleogeografskog razvoja tijekom paleogena, moguće je svaki od njih smjestiti u odgovarajući floristički kompleks:

1. Raša (donji eocen), Pl. Promina (srednji i gornji eocen – donji oligocen) i oni u Hercegovini (biarritz) smješteni su u mediteransku Tetis bioprovinciju. Paleoflora Raše odgovara *Montebolca florističkom kompleksu* (Verona). Lokaliteti okoline Pl. Promine i SZ Hercegovine pored Montebolca kompleksa približuju se i *Célas florističkom kompleksu* (Alés na jugu Francuske).

2. Soca (»socka« ili »soteške naslage« – gornji eocen) bila je dio transeuropske Paratetis bioprovincije. Zajednica fosilnih biljaka odgovaraju *Lábatlan florističkom kompleksu* (blizu Doroga u Mađarskoj).

3. Lokaliteti Posavskih bora (»Trbovlje« formacija ili »Trbovlje« naslage – donji oligocen) kao dio transeuropske Paratethys bioprovincije odgovaraju *Kiscell florističkom kompleksu* (pokraj Budimpešte – Óbuda u Mađarskoj).