

Late Carboniferous floras of Slovenia – a review



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ABSTRACT

This paper provides a short review of the Late Carboniferous floras in Slovenia. The Namurian-Westphalian or Westphalian A (Langsettian) flora was collected in the Sava Folds, whereas the late Westphalian and/or Stephanian flora was documented in the Southern Karavanke Mts. The recovered assemblages are well represented by horsetails, arborescent lycopsids, fern-like foliage (ferns and pteridosperms) as well as gymnosperms, and they correspond to the general features of the Euramerican flora.

Keywords: megafloora, Late Carboniferous, Slovenia

1. INTRODUCTION

The purpose of this paper is to provide an overview of the Late Carboniferous floras of Slovenia which is poorly known to potential readers as information is mainly documented in local reports. The flora is generally much poorer, but comparable to those from the west and central European coal-fields, yet it is indisputably of significant importance for palaeogeographic considerations and stratigraphic correlations.

The post-Variscan Carboniferous and Permian strata with fossil megaflooras in Slovenia crop out in the geotectonic units of the Southern Alps and External Dinarides (Figs. 1, 2). In central Slovenia, Upper Palaeozoic rocks, particularly the clastic sedimentary deposits, provide a soft bed for the nappe structure of the External Dinarides (PLACER, 1999). Owing to the complicated tectonic structure, a lack of marker horizons and scarce fossil remains, the thick monotonous clastic sedimentary sequence underlying the Val Gardena Formation was assigned both Carboniferous and Permian ages. In central Slovenia, these strata are represented in the Sava Folds (WINKLER, 1923) that are composed mainly of quartz conglomerate, sandstone, siltstone and shaly claystone.

Occurrences of Palaeozoic flora of the Sava Folds were previously reported in the nineteenth century and in the first half of the twentieth century by MORLOT (1850), HAUER (1851), LIPOLD (1857, 1858), KOSSMAT (1913), TORN-

QUIST (1929) and RAKOVEC (1932). Later studies on the megafloora of the Sava Folds were published by KOLAR-JURKOVŠEK & JURKOVŠEK (1985, 1986, 1990, 2002a, 2002b, 2007).

Sections of the Late Carboniferous in the Southern Karavanke Mountains are commonly exposed in narrow belts or scattered outcrops as a result of strong Alpine tectonics (BUSER, 1980; JURKOVŠEK, 1987). The composite Carboniferous and Permian lithostratigraphical column can be well correlated with the standard zonation in the Carnic Alps that is formed of the Pontebba Supergroup, (Auernig Formation, Rattendorf Group and Trogkofel Group) (NOVAK, 2007). A Late Carboniferous megafloora from the Southern Karavanke Mountains was reported by MORLOT (1850), STUR (1886) and RAMOVŠ (1978).

2. MATERIAL

The Geological Survey of Austria in Vienna hosts the oldest but very small collection of plant fossils that was obtained by various field geologists during the Austrian-Hungarian Monarchy and determined by ETTINGHSAUSEN. Moreover, some other specimens are scattered in the collections of the Faculty of Natural Sciences and Engineering of the University of Ljubljana and the Slovenian Natural History Museum in Ljubljana.

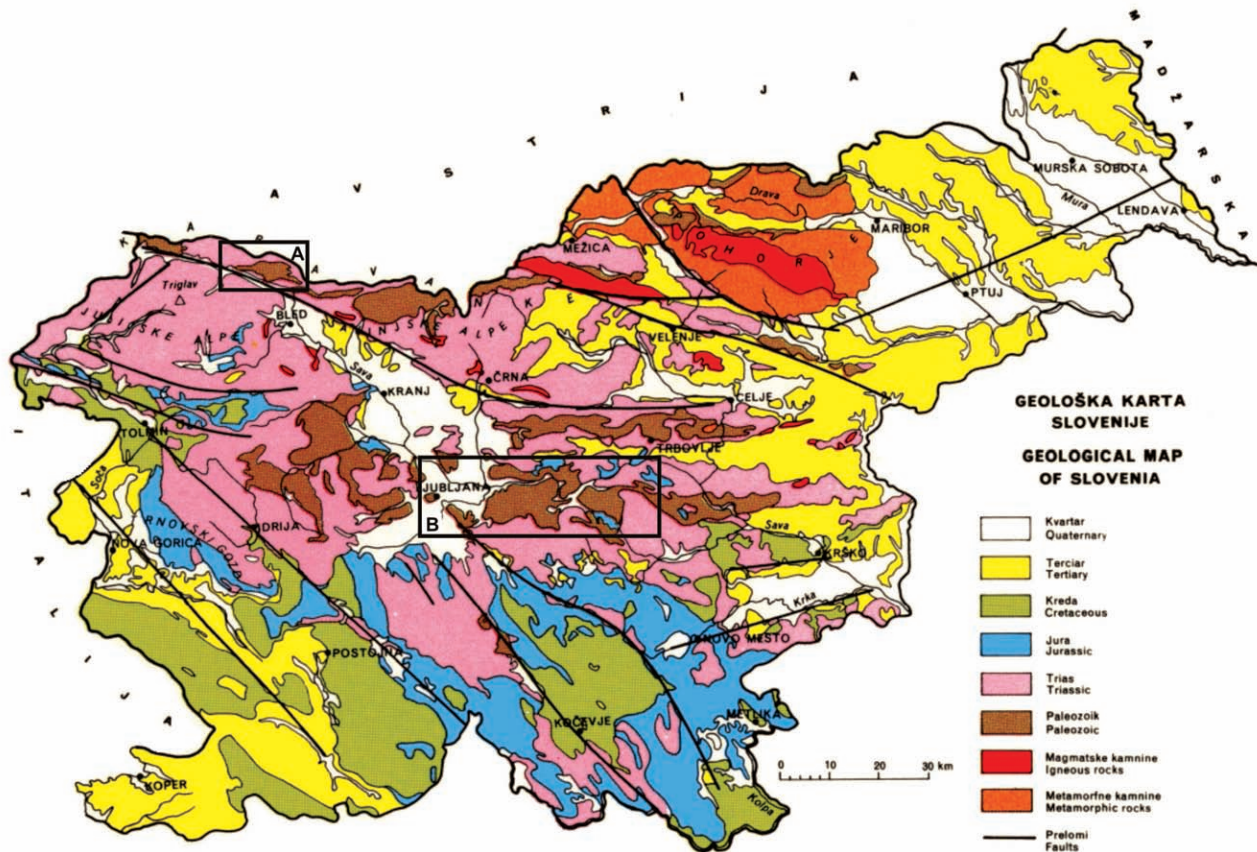


Figure 1: Simplified geological map of Slovenia based on data of the Basic Geologic Map of SFRY 1:100000 compiled by BUSER for the Geologic map of the Republic of Slovenia 1:250 000 (BUSER, 2010). A – Southern Alps, B – Sava Folds.

A significant flora from the Javorniki area containing about a hundred specimens is housed at the Gornjesavski muzej in Jesenice. This was collected by Jože BEDIČ and it still needs a detailed systematic description.

The material collected and studied by the present authors consists of about one hundred specimens and it was derived from the Sava Folds. It is housed in the Jurkovšek Palaeontological Collection that has been registered with the Slovenian Natural History Museum, as well as the Geological Survey of Slovenia, and it is partly exhibited at a permanent exhibition at Ljubljana Castle.

3 GEOLOGICAL SETTINGS AND PALEONTOLOGICAL REMARKS

3.1. Sava Folds

In the wider region of the Sava Folds, the Palaeozoic strata of the Trojane and Litija anticline form the basement of the shallow water (platform) carbonates of the External Dinarides. The basic lithological members are quartz conglomerate, quartz sandstone, siltstone and mudstone. Based on all previous knowledge and his own detailed investigations, MLAKAR (1987, 1994) increased understanding of the Sava Folds geological structure, by proposing subdivision of the Palaeozoic sequence into three superpositional units of the first order (Ca, Cb and Cc), that could represent three formations, or three members of the same formation (Fig. 3). The second superposition unit (Cb) was subdivided into four units. The Cb2 subunit has been dated on palaeontological data and attributed a Namurian – Westphalian A (Langsetian) age (KOLAR-JURKOVŠEK & JURKOVŠEK, 1985, 1986, 1990, 2002a, 2002b, 2007). The megafloora was collected from numerous localities between Ljubljana and Polšnik near Litija (Figs. 4, 5) and it is well-represented by horsetails (*Calamites*), arborescent lycopsids (*Lepidodendron*, *Sigillaria*, *Stigmaria*), fern-like foliage (ferns and pteridosperms), and gymnosperms (*Cordaites*).

The westernmost locality of the Sava Folds is at Ljubljana Castle Hill and the age of the recovered plant assemblage here is based on the species *Neuropteris tenuifolia*

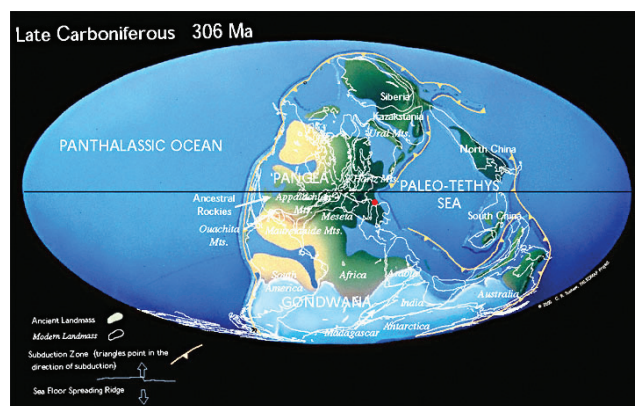


Figure 2: Distribution of tectonic plates in the Late Carboniferous. Red dot indicates the palaeogeographic position of Slovenia on the world map (SCOTSE, 2002).

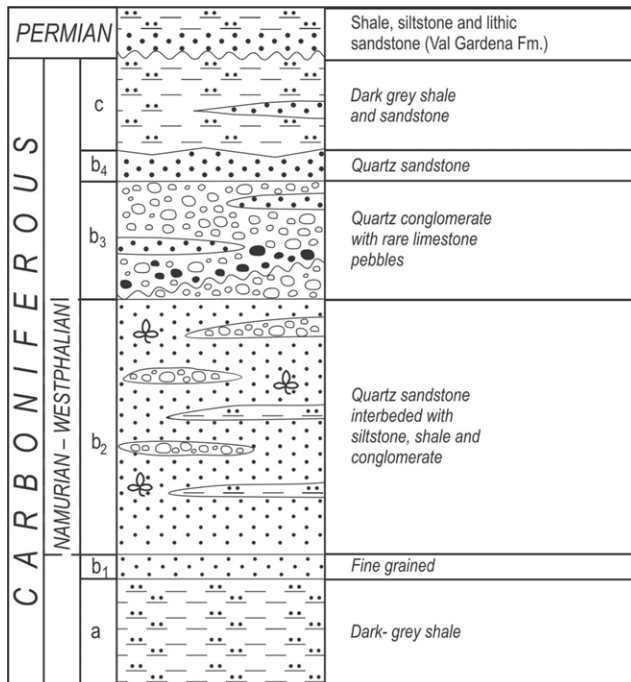


Figure 3: Lithostratigraphic subdivision of the first tectono-sedimentary cycle in the Sava Folds (modified after MLAKAR et al., 1993).



Figure 4: One of the richest localities of Carboniferous plant fossils in the Sava Folds at Zavrstnik near Litija. The fossiliferous bed is marked with the geologic hammer (KOLAR-JURKOVŠEK & JURKOVŠEK, 2002a). Photo Bogdan JURKOVŠEK.

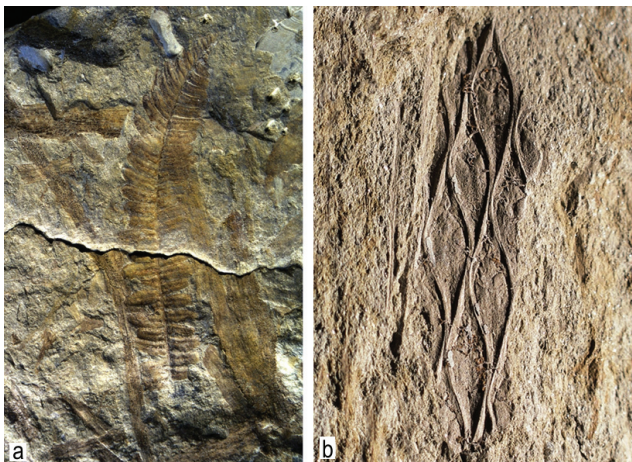


Figure 5: Plant fossils from Ljubljana environs (locality Bizovik). a – *Pecopteris* sp., specimen height 5.5 cm; b – *Lepidodendron* cf. *aculeatum* STERNBERG, specimen height 4 cm. Photo Bogdan JURKOVŠEK.

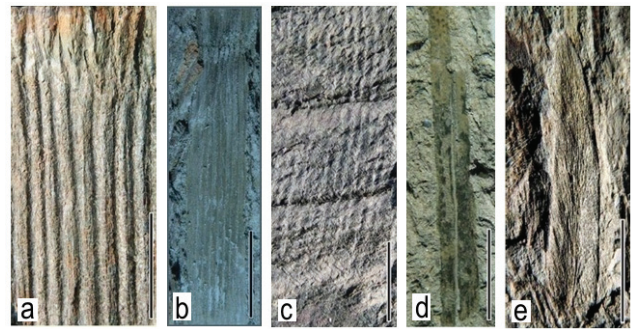


Figure 6: Fossil flora from Ljubljana Castle Hill: a – *Calamites* (*Mesocalamites*) *roemeri* GOEPPERT, b – *Calamites* (*Mesocalamites*) cf. *cistiiformis* STUR, c – *Calamites* sp., d – *Cyperites bicarinatus* LINDLEY & HUTTON, e – *Neuropteris tenuifolia* SCHLOTHEIM. Photo Bogdan JURKOVŠEK.

SCHLOTHEIM, *N. cf. heterophylla* BRONGNIART and *Cordaites palmaeformis* (GOEPPERT), as well as the presence of certain mesocalamite-like forms (*Calamites* (*Mesocalamites*) *roemeri* GOEPPERT, *C. (M.) cf. cistiiformis* STUR) (Fig. 6). Therefore the strata with flora from this locality are attributed to the lower part of the Westphalian A (Langsetian Substage) (KOLAR-JURKOVŠEK & JURKOVŠEK, 2007).

3.2. Southern Karavanke Mts.

Late Palaeozoic beds in the Southern Karavanke Mountains are commonly exposed in narrow bands or scattered outcrops as a result of a strong overprint by Alpine tectonics. However, the composite lithostratigraphic column displays a very similar succession compared to the Pontebba Supergroup (Auernig Formation, Rattendorf Group and Trogkofel Group) in the Carnic Alps, which are a morphological and orographic continuation of the Southern Karavanke Mountains (KAHLER, 1985; SCHÖNLAUB, 1985; KRÄINER, 1993; NOVAK & SKABERNE, 2009).

The Pennsylvanian rocks of the western Karavanke Mountains were described as the Javornik beds based on fusulinid foraminifera (KOCHANSKY-DEVIDE & RAMOVŠ, 1966; RAMOVŠ & KOCHANSKY-DEVIDE, 1979). Later, NOVAK (2007) considered the Javornik beds to be an equivalent of the Auernig Beds, and he presented a new lithostratigraphic subdivision with the Kasimovian (Protriticites) beds in their lowermost part (Fig. 7). In general the Auernig Formation consists of conglomerates, sandstones and shales with lenses of limestones containing fusulinid and conodont faunas. Fossil megaflores were collected mostly in the Gzhehian strata of the Javornik beds in the area north of Jesenice, and the determined list includes *Polymorphopteris polymorpha* (BRONGNIART) and *Annularia stellata* (SCHLOTHEIM) (Fig. 8), as well as *Lepidodendron* cf. *scutatum* LESQUER-EUX and *Sigillaria brardi* BRONGNIART as reported by RAMOVŠ (1978).

A small flora from the Planina locality below the Golica Mt. was studied but not illustrated by TAKŠIĆ (1947), and the following species were determined: *Pecopteris* aff. *arborescens* BRONGNIART, *Alethopteris serlii* BRONGNI-

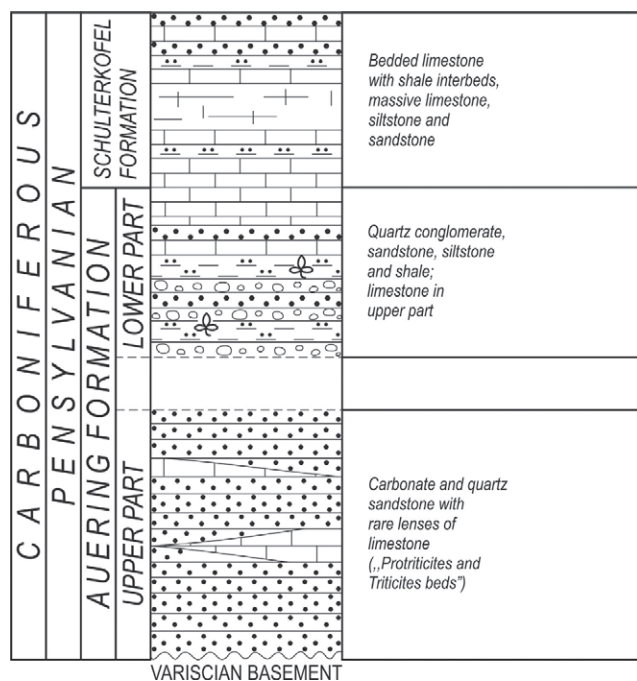


Figure 7: Stratigraphic column of Carboniferous strata in the South Karavanke Mountains (modified after NOVAK & SKABERNE, 2009).



Figure 8: Upper Carboniferous fossil plants *Polymorphopteris polymorpha* (BRONGNIART) and *Annularia stellata* (SCHLOTHEIM). Planina pod Golico, Karavanke Mts. Sample width 14 cm. Photo Jože BEDIČ.

ART, *Alethopteris grandini* BRONGNIART, *Neuropteris ovata* HOFFMANN, *Neuropteris* sp., *Sphenophyllum* sp., *Annularia stellata* (SCHLOTHEIM) WOOD, *Calamites rimosus* ARTIS, *Calamites* sp. and *Lepododendron rimosum* STERNBERG. TAKŠIĆ (1947) compared this flora with the flora from certain locations in Austria and regarded it as being of Asturian or Early Stephanian age (highest Westphalian D or Lower Stephanian),

Table 1: Comparison of Pennsylvanian flora in the investigated localities of the Sava Folds based on the original determinations of the authors (after KOLAR-JURKOVŠEK & JURKOVŠEK, 2007).

	Litija environs	Bizovik	Ljubljana Castle Hill
<i>Calamites (Mesocalamites) haueri</i> STUR	x		
<i>Calamites (Mesocalamites) ramifer</i> STUR	x		
<i>Calamites (Mesocalamites) cf. ramifer</i> STUR		x	x
<i>Calamites (Mesocalamites) roemeri</i> GOEPPERT	x	x	x
<i>Calamites (Mesocalamites) cf. roemeri</i> GOEPPERT			x
<i>Calamites (Mesocalamites) cistiiformis</i> STUR	x		
<i>Calamites (Mesocalamites) cf. cistiiformis</i> STUR	x		x
<i>Calamites (Stylocalamites) suckowi</i> BRONGNIART	x	x	
<i>Calamites (Stylocalamites) cf. suckowi</i> BRONGNIART		x	
<i>Calamites (Stylocalamites) cf. cisti</i> BRONGNIART		x	
<i>Calamites (Stylocalamites) undulatus</i> STERNBERG		x	x
<i>Calamites (Stylocalamites) cf. undulatus</i> STERNBERG		x	x
<i>Calamites (Calamitina) sachsei</i> STUR	x		
<i>Calamites (Calamitina) schuetzeiformis</i> KIDSTON & JONGMANS	x		
<i>Calamites</i> sp.	x	x	x
<i>Equistetites cf. hemingwayi</i> KIDSTON	x		
<i>Lepidodendron cf. aculeatum</i> STERNBERG	x	x	
<i>Lepidodendron lycopodioides</i> STERNBERG		x	
<i>Lepidodendron</i> sp.	x	x	x
<i>Lepidostrobus</i> sp.		x	
<i>Asolanus comptotaenia</i> WOOD		x	
? <i>Asolanus</i> sp.			x
<i>Sigillaria boblayi</i> BRONGNIART	x		
<i>Sigillaria cf. boblayi</i> BRONGNIART	x		
<i>Sigillaria mamillaris</i> BRONGNIART	x		
<i>Sigillaria elegans</i> (STERNBERG) BRONGNIART	x		
<i>Sigillaria</i> sp. (<i>Syringodendron</i> – <i>Rhytidolepis</i>)	x	x	x
<i>Sigillaria</i> sp.	x	x	
<i>Cyperites bicarinatus</i> LINDLEY & HUTTON			x
<i>Stigmaria ficoides</i> (STERNBERG) BRONGNIART		x	x
<i>Stigmaria ficoides</i> var. <i>undulata</i> GOEPPERT	x		

Table 1: continued.

	Litija environs	Bizovik	Ljubljana Castle Hill
<i>Stigmara</i> cf. <i>ficoides</i> (Sternberg) BRONGNIART	x		
<i>Pecopteris</i> (<i>Senftenbergia</i>) cf. <i>plumosa</i> (ARTIS) BRONGNIART		x	
<i>Pecopteris</i> sp.		x	
<i>Eusphenopteris</i> sp.		x	x
? <i>Mariopteris</i> sp.		x	
<i>Neuropteris tenuifolia</i> SCHLOTHEIM		x	x
<i>Neuropteris</i> cf. <i>heterophylla</i> BRONGNIART			x
<i>Neuropteris</i> sp.		x	x
? <i>Neuropteris</i> sp.		x	
<i>Linopteris neuropteroides</i> (GUTBIER) ZEILLER		x	
<i>Linopteris</i> sp. ali <i>Reticulopteris</i> sp.		x	
<i>Linopteris</i> sp.			x
<i>Trigonocarpus</i> sp.	x	x	x
? <i>Carpolithus</i> sp.	x		
<i>Noeggerathia</i> sp.			x
<i>Cordaites palmaeformis</i> (GOEPPERT)			x
<i>Cordaites principalis</i> (GERMAR)			x
<i>Cordaites</i> cf. <i>principalis</i> (GERMAR)		x	
<i>Cordaites</i> sp.	x	x	x
<i>Cordaicladus</i> sp.		x	
<i>Artisia approximata</i> LINDLEY & HUTTON	x		
? <i>Artisia</i> sp.	x		

4. CONCLUSIONS

The Upper Palaeozoic deposits, exposed in a broad belt between Ljubljana and Polšnik, have been the subject of detailed palaeontological, sedimentological, and structural studies for many years. They were the basis for various, and often conflicting interpretations of accurate age, depositional environment, and structure of the so-called Permo-Carboniferous beds of the Sava Folds. The recovered assemblages which were collected during recent decades in the second superposition member (Cb2) can be considered as representing the hydrophile to hygrophile flora that populated wet habitats of the swamp area. A large proportion of pteridosperms and the presence of cordaites suggest growth on somewhat elevated parts of the river bank, at the margin of the flood area, as indicated by the abundant presence of articulates.

The age of the determined assemblages can be estimated based on the stratigraphic ranges of certain neuropterid species that range in the Westphalian, however some of them already appear in the Namurian. The presence of some mesocalamites-like forms in the locations close to Ljubljana in-



Figure 9: Reconstruction of Upper Carboniferous landscape based on fossils collected in Slovenia (by Barbara JURKOVŠEK, 2006).

dicates the lower part of the Westphalian (KOLAR-JURKOVŠEK & JURKOVŠEK, 2002a, 2007) (Tab. 1).

The fossil flora of the Karavanke Mts. occurs in the Javornik beds and shows a great similarity with the flora of the Auernig Beds of the Pontebba Supergroup. A well preserved megafloora was collected in some locations in the area north from Jesenice. However, most assemblages have not been part of a detailed study. The megafloora is abundantly represented in the Upper Carboniferous strata and the recognized assemblages are similar to the late Westphalian and/or early Stephanian floras of the Carnian Alps.

The recovered plant assemblages from the localities of the Sava Folds (Fig. 9) and Southern Karavanke Mountains are similar to the coeval fossil floras of neighbouring areas (FRITZ et al., 1990; RONCHI et al., 2012; SREMAC, 2012) and they correspond in their general features to the Euramerican flora.

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