GORTANIA
Geologia, Paleontologia, Paletnologia 40 (2018) 33-47 Udine, 10.XII.2019 ISSN: 2038-0410

Evelyn Kustatscher
Hendrik Nowak
Stanislav Opluštil
Josef Pšenička
Luca Simonetto

THE CARBONIFEROUS FLORA OF THE CARNIC ALPS: STATE OF THE ART

LA FLORA CARBONIFERA DELLE ALPI CARNICHE: LO STATO DELL'ARTE

Riassunto breve - Questo lavoro illustra lo stato dell'arte relativo alle località fossilifere, al loro inquadramento stratigrafico e a una visione generale della composizione della flora del Carbonifero delle Alpi Carniche. I fossili vegetali provengono per la maggior parte da un certo numero di affioramenti distinti (circa 30), all'interno di un *range* temporale che copre l'intero Pennsylvaniano. Un ridotto numero di esemplari e alcune microflore provengono dal Carbonifero inferiore (Mississippiano, Formazione del Hochwipfel). Le singole località da cui provengono i reperti conservati al Museo Friulano di Storia Naturale, sono state raggruppate in base alla loro posizione stratigrafica così come indicata in bibliografia.
Considerando che l'intervallo di tempo racchiuso nelle singole unità fossilifere del Pennsylvaniano è abbastanza ridotto, e che le varie formazioni riflettono soprattutto un succedersi di transgressione/regressione del livello del mare, si presume che le piante potessero crescere in ambienti diversi ma in un arco di tempo quasi coevo per ognuno dei gruppi di località fossilifere individuati.
Parole chiave: Carbonifero, Mississippiano, Pennsylvaniano, Diversità, Bacino di Pramollo, Alpi Carniche.

Abstract - *A state-of-the-art overview is given on the fossiliferous localities of Carboniferous floras of the Carnic Alps, their stratigraphic background and a general picture of the flora. The majority of fossil plant assemblages come from several distinct fossiliferous horizons (about 30), covering the upper part of Pennsylvanian. A smaller number of specimens and some microfloral assemblages come from the lower Carboniferous (Mississippian, Hochwipfel Formation). The localities from which the specimens stored in the Museo Friulano di Storia Naturale come, have been grouped according to their stratigraphic position as indicated in the bibliography.*
Due to the fact that the time constraints within the Pennsylvanian fossiliferous units are relatively narrow, and that the various formations reflect, for most part, sea level transgressions and regressions, we posit that the plants likely grew in different, but roughly coeval, habitats for each of the fossiliferous site groups identified.
Key words: *Carboniferous, Mississippian, Pennsylvanian, Diversity, Pramollo Basin, Carnic Alps.*

Introduction

The Carboniferous floras of the Carnic Alps belong to two different time intervals. The flora from the Rifugio Marinelli (Marinelli Hütte; e.g., Stur 1871; Frech 1894; Vinassa de Regny 1906a, 1906b, 1906c; Gortani 1905, 1906, 1910; Krause 1928; Francavilla 1966; Van Amerom et al. 1984) comes from the Hochwipfel Formation of middle Visean age (Van Amerom et al. 1984). This flora (e.g., Stur 1871; Frech 1894; Vinassa de Regny 1906a, 1906b, 1906c; Gortani 1905, 1906, 1910; Krause 1928; Francavilla 1966; Van Amerom et al. 1984) is characterized by lycophytes (*Lepidodendron*, *Stigmaria*), sphenophytes (*Calamites*, *Sphenophyllum*), fronds of ferns or seed ferns (*Neurodontopteris*, *Rhodeopteridium*, *Sphenopteris*, *Sphenopteridium*, *Cardiopteridium*) and dispersed seeds (*Trigonocarpus*, ?*Holcospermum*).

In their recent volume dedicated to the Hoch-wipfel Formation, Kabon & Schönlaub (2019) report for the whole succession (more then 1200 m thick), a high number of species (about 40), referable to the genera *Archeocalamites, Pothocites, Calamites, Sphenophyllum, Sphenophyllostachis, Lepidodendropsis, Lepidodendron, Bothrodendron, Stigmaria, Sphenopteridium, Archeopteridium, Cardiopteridium, Fryopsis, Adianites, Triphyllopteris, Rhodea, Megaphyton, Sphenopteridium, Calathiops, Zeilleria*, to which are added the seeds of *Trigonocarpus, Holcospermum* e *Nudospermum* (specifying that "*seeds are rare in the formation ...*").

More emblematic for the Carnic Alps are the excellent outcrops of Pennsylvanian age, which are often very rich in fossils. Thus, it is not surprising that these fossiliferous successions have attracted the attention of geologists and palaeontologists since the middle of the 19th century. Besides the diverse fauna preserved in

marine carbonates and siliciclastics, terrestrial deposits yielded exceptional plant assemblages.

The Carboniferous macrofloras of the Carnic Alps have been studied for more than 240 years. One of the oldest references is from 1783, when Hohenwart (1783) indicated in the context of a botanical excursion that plant fossils were already known from the area of the Stanglalpe at that time. Boué (1835) was among the first to describe a systematic collection and study of plant fossils from the area, emphasizing the diversity and richness of the fossil flora. Several plant genera were identified, including *Stigmaria*, *Lepidodendron*, *Asterophyllites*, *Calamites* and various types of ferns. Also Sternberg (1820-1838) figured some plants from the Stangalpe, such as *Neuropteris alpina* (Sternberg 1820-1838: p. 76, fig. 2, pl. 22; Unger 1840). Further reports of plant fossils, mostly indicated as "Farnkräuter" (fern remains), were made from Watschig near Hermagor (Morlot 1850), St. Oswalder Alpe (Anonym 1851) and near Ofenalpe (Höfer 1869; Unger 1869). In the latter paper, 19 different species were already indicated. Among the most prominent geologists/paleontologists reporting on plant fossils in the 19th century are Stur (1856, 1868, 1871, 1886; 50 species), Stache (1874), Zwanzinger (1876; 65 species), Tommasi (1889), Bozzi (1890; 14 species), Schellwien (1892), Frech (1894) and Geyer (1897).

Fossil plants were discovered in the area of Palon del Pizzul, north of Paularo village, at the end of the 19th century, whereas the rich deposits of plant fossils around Cason di Lanza and Monte Pizzul were not described before the beginning of the 20th century (e.g., Vinassa de Regny & Gortani 1905; Gortani 1906, 1912, 1905; Vinassa de Regny 1912, 1905). Studies on Carboniferous plant fossils proceeded almost exclusively on the Austrian side after WWI (e.g., Reichardt 1933; Heritsch et al. 1933; Kielhauser 1937; Jongmans 1938; Berger 1960; Riehl-Herwisch 1962; Remy 1969; Kaiser 1971; Fenninger & Schönlaub 1972; Francavilla 1974; Thiedig & Klusmann 1974; Van Amerom et al. 1976; Tenchov 1978, 1980).

As seen above, the number of recognized plant taxa changed substantially over the course of the 19th century, from 19 species according to Höfer (1869) to 50 and 65 species mentioned respectively by Stur (1886) and Zwanzinger (1876).

A first critical review of the Carboniferous (mainly Pennsylvanian) floras of the Carnic Alps reduced the number of species to 25 (Reichardt 1937; Jongmans 1938). At the end of the 20th century, Fritz and Boersma (Fritz 1980; Fritz & Boersma 1981, 1983, 1984a, 1984b, 1984c, 1984d, 1985, 1986b, 1986c, 1986d, 1987a, 1987b, 1988a; Fritz et al. 1986) published 17 "Fundberichte" (collecting reports), describing in detail (including in terms of sedimentology and taphonomy) more than 30 localities in Carinthia, primarily in the Carnic Alps, that had yielded Carboniferous to lower Permian floras. They also reviewed most of the historical collections (Fritz & Boersma 1984e, 1986a, 1988b, 1990a, 1990b; Fritz 1990a, 1990b; Fritz et al. 1990). Subsequently, Fritz & Krainer (1993, 1994, 1995,

Fig. 1 - Panoramic view from the south of the Pramollo area (Nassfeld). In the center, in the meadow area, Casera Auernig (photo I. Pecile).
- *Vista panoramica da Sud dell'area di Pramollo (Nassfeld). Al centro, nell'area prativa, Casera Auernig (foto I. Pecile).*

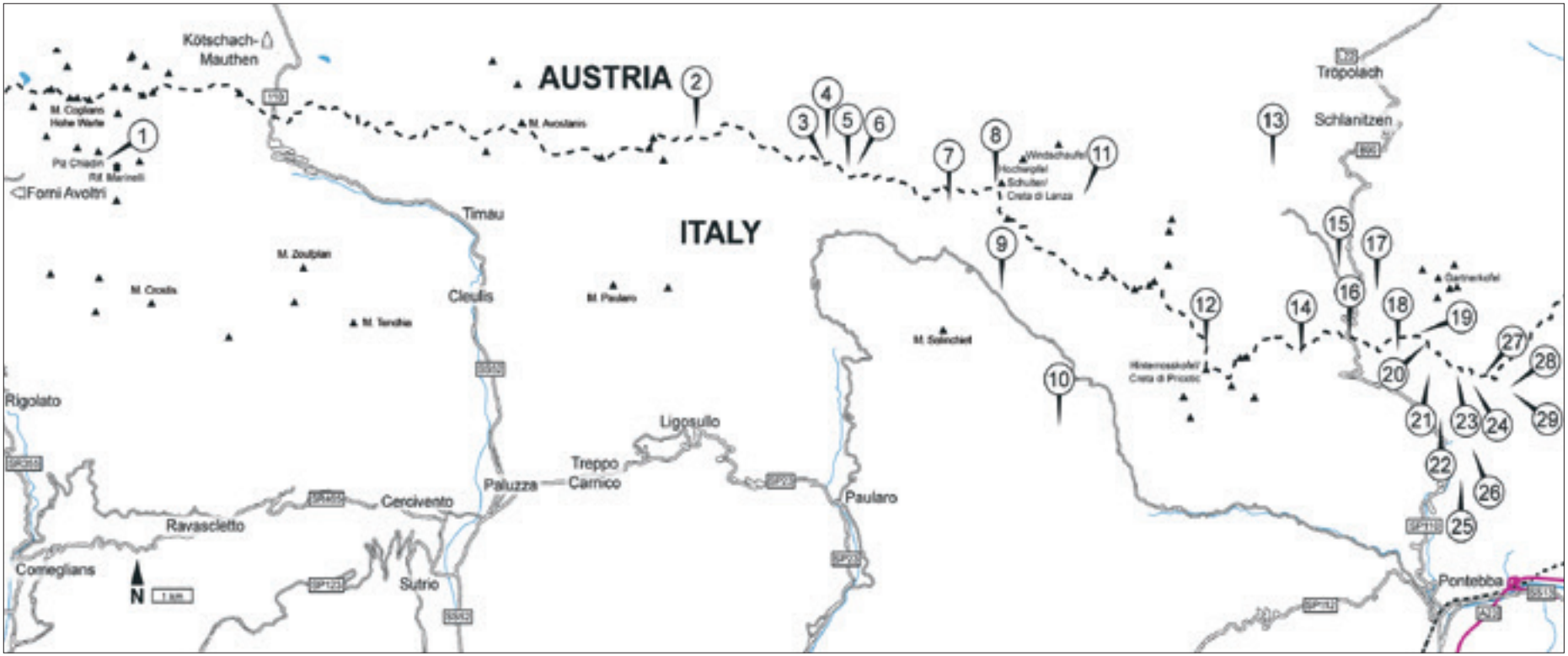

Fig. 2 – The studied area with the positions of the cited localities in the Carnic Alps, where Carboniferous floras have been found.
- L'area esaminata con la posizione delle località citate dalle quali provengono le flore del Carbonifero delle Alpi Carniche.

1 Rifugio Marinelli
2 Zollnersee
3 Straniger Alm 2
4 Straniger Alm 3
5 Straniger Alm 4
6 Straniger Alm 1
7 Casera Cordin Grande 1, 2
8 Schulterkofel 2
9 Passo Cason di Lanza/Lanzenboden (Rio del Museo)
10 Rio dai Amplis
11 Schwandgraben (Hüttengraben)
12 Rudnigsattel
13 Tomritsch
14 Madritschenkopf
15 Schlanitzer Almweg
16 Nassfeldsattel
17 Watschiger Alm
18 Monte Carnizza
19 Gugga 1-3, 5
20 Garnitzenberg 1-3, α, β
21 Frana Vecchia, Casera Auernig
22 Rio della Pioggia
23 Ofenalm West
24 Casera For/Ofenalm
25 Rio della Faglia
26 Rio Bruca
27 Monte Corona/Krone
28 "Contatto" Corrado Rosenfeld
29 Monte Corona towards Monte Cerchio

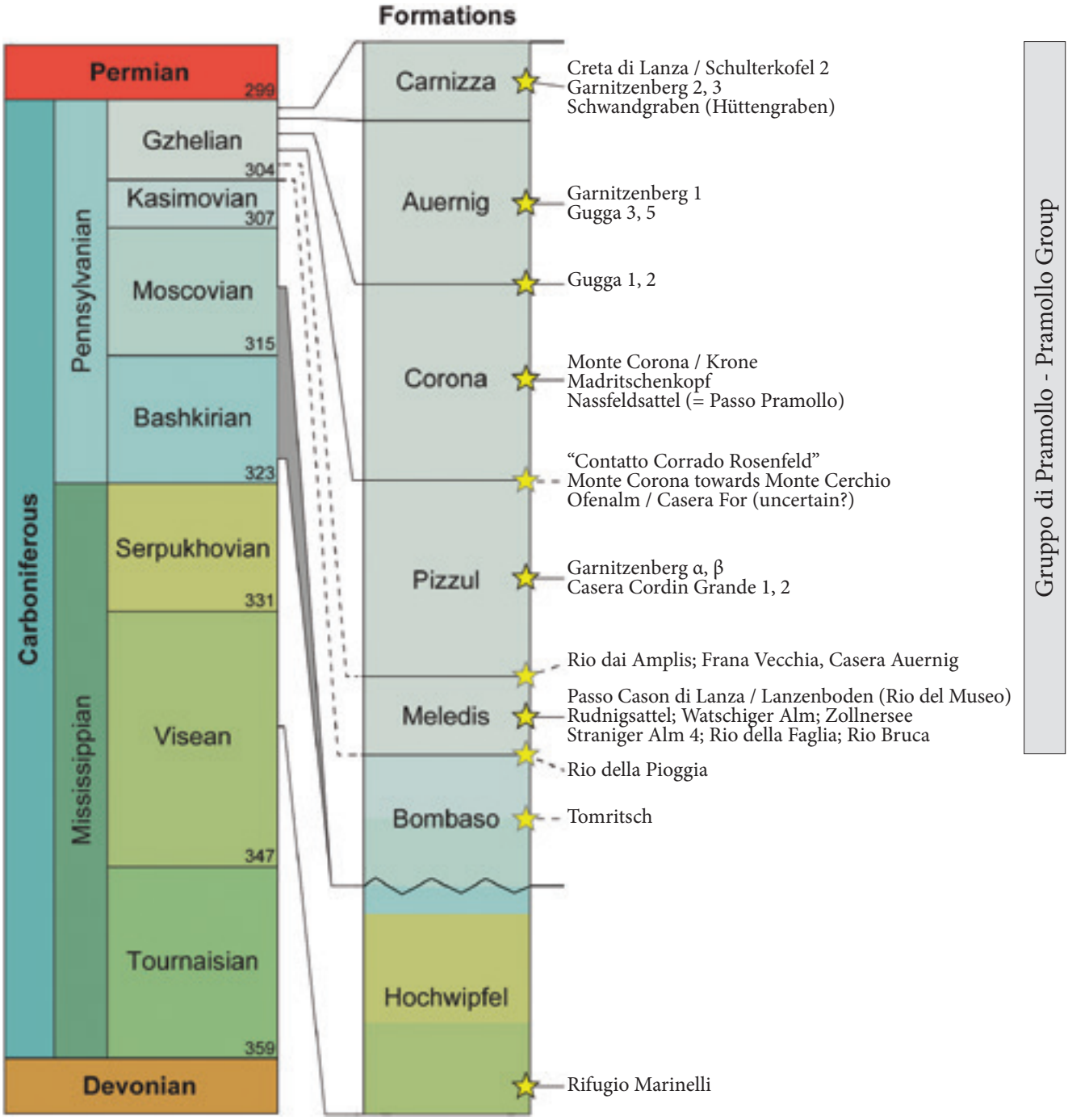

Fig. 3 - Stratigraphic positions of the cited localities in the Carnic Alps, where Carboniferous floras were found.
- *Posizione stratigrafica delle località citate dalle quali provengono le flore del Carbonifero delle Alpi Carniche.*

2006, 2007) described 92 taxa from these collections. The Carboniferous flora of the Carnic Alps became a famous reference flora, although these studies were mostly focused on plant assemblages from Austrian fossiliferous localities, whereas the plant assemblages from the Italian side are still poorly known.

A first detailed study of the plant assemblages of the Italian side and a preliminary revision of the historical plant assemblages from the Austrian side has recently been carried out within the Interreg VA Italy-Austria-Project ITAT2010 "GeoTrAC: Grenzüberschreitender GeoPark der Karnischen Alpen" - "GeoTrAC: Geoparco Transfrontaliero delle Alpi Carniche", giving for the first time an overview on the entire flora of the Carnic Alps (Opluštil et al. submitted).

Stratigraphy, materials and methods

Carboniferous deposits of the Carnic Alps have a noteworthy stratigraphic and palentological significance, and belong either to the Pre-Variscan sequence

(Corradini et al. 2015) or to the Permo-Carboniferous sequence (Selli 1963; Simonetto & Corradini 2006; Venturini 1990).

The marine environmental conditions that characterized the Upper Devonian (Pal Grande Formation and Zollner Formation) persisted in the lower Carboniferous, up to the Visean. At place, due to temporary subaerial exposures within the late Famennian and the Tournasian some karstic phenomena developed (Schönlaub et al. 1985; Pondrelli et al. 2015; Corradini et al. 2017) that give rise to hard grounds (Plotta Formation).

During the Visean, faults already activated in the latest Devonian due to rifting caused some sectors of the Carnic basin to subside, while other areas remain exposed. Several levels of breccias and conglomerates slide down in the deepest basins, forming a thick turbiditic sequence (Hochwipfel Fm), overlain by basic volcanic eruptive (Dimon Fm), related to the crustal thinning due to rifting. These conditions continue up to the Bashkirian (late Carboniferous), when the Variscan orogenic cycle begins in the Carnic area, marking the end of the deposition of the Pre-Variscan Sequence.

The uplift of the Paleocarnic chain (Bashkirian-Moscovian) generates an erosional depositional sedimentary gap. In some places (Forni Avoltri, Pramollo and Tarvisio sectors) the gap is earlier interrupted during the latest Moscovian, because of subsidence related a to strike-slip tectonic system. The Permo-Carboniferous Sequence unconformably overlies the Pre-Variscan Sequence. It is mainly constituted by alternances of fluvio-deltaic and marine deposits, regulated by frequent eustatic variations due to Permo-Carboniferous glacialism. The sequence starts with the Bombaso Fm., resulting from the erosion of the Paleocarnic Chain. This unit is overlain by the Pramollo Group, made up of 5 formations (the Meledis Fm, the Pizzul Fm, the Corona Fm, the Auernig Fm and the Carnizza Fm), characterized by frequent transgressive-regressive cycles, alternating fluvio-deltaic clastic sediments and calcareous shallow water deposits.

In the Lower Permian, calcareous facies are dominant; the three formations (Lower Pseudoschwagerina Fm, Val Dolce Formation. and Upper Pseudoschwagerina Fm), grouped in the Rattendorf Group, indicate a general transgression with more stable marine conditions. The overlying Trogkofel Group ends the Permo-Carboniferous Sequence of the Carnic Alps.

The upper Carboniferous successions yielding plant fossils in the Carnic Alps crop out in the Pramollo (or Pramollo-Nassfeld, Fig. 1) Basin (Venturini 1990). Several important localities (e.g., Passo Pramollo, Cason di Lanza, Monte Corona, Monte Carnizza; Fig. 1)

Fig. 4 - Fossiliferous outcrop along the Rio del Museo (Lanza Pass).
- *L'affioramento fossilifero lungo il Rio del Museo (P*asso del Cason di Lanza).

Fig. 5 - "Frana Vecchia" (Old landslide) locality at the slope of Mt Carnizza (Pramollo Pass).
- *La località detta "Frana Vecchia" alle pendici del Monte Carnizza (Passo Pramollo).*

yielded rich plant assemblages from the Pennsylvanian Pramollo Group (also known as Auernig Group or Auernig Formation; Fig. 3). The latter is up to 1200 m thick and composed of the Meledis, Pizzul, Corona, Auernig and Carnizza formations (Selli 1963). The Meledis, Corona and Carnizza formations are dominated by clastic sediments, whereas the Pizzul and Auernig formations are composed of clastic sedimentary rocks interbedded with thick fossiliferous limestone horizons (McCann 2008). The Meledis Formation and the lower part of the Pizzul Formation are considered Kasimovian in age, the other formations were assigned to the Gzhelian Stage (Schönlaub & Forke 2007; McCann 2008). The age attribution of the formations is mainly based on fusulinids (e.g., Kahler 1983, 1985, 1986, 1989; Krainer & Davydov 1998; Davydov & Krainer 1999; Forke & Samankassou 2000; Pasini 1963; Vachard & Krainer 2001). Plant remains are preserved in every formation of the Pramollo Group. Historically, the most abundant, best preserved and most diverse plant assemblages and also some coal-rich levels of up to 30 cm thickness came from the fine sandstones and pelitic levels of the Corona Formation (Selli 1963; Massari et al. 1991). Therein, sphenophyte trunks are preserved in situ (with a diameter of up to 20 cm; Selli 1963). Plant assemblages were also collected also from the other formations of the Pramollo Group and probably from the Bombaso Formation (Rio della Pioggia, Tomritsch).

The preservation of the plant remains varies strongly between different localities. Most are compressions or impressions (adpressions) with varying morphological details. The well-preserved plant compressions of some localities show clear pinnule veins and/or details of the reproductive organs. Other fragments have only a poorly preserved morphology. Cuticles and *in situ* spores/pollen could be present in some of the better-preserved plant compressions, although this has not been tested so far.

Most of the plant fossils from the Italian Carnic Alps are stored in the Museo Friulano di Storia Naturale in Udine (MFSN, about 2,500 specimens). Most samples have been recovered during systematic excavations in the last few decades by employees of the museum and local collectors. Plant remains were collected from numerous localities, such as Casera Auernig, Casera Cordin Grande, Cason di Lanza, Monte Carnizza, Monte Corona, Passo Pramollo, Pontebba, Rio Bombaso, Rio Bruca, Rio Cordin, Rio dai Amplis, Rio degli Uccelli (Vogelbach), Rio del Museo, Rio della Faglia and Rio della Pioggia. Some specimens coming from some of the same localities are also stored in the Museo Geologico della Carnia (Ampezzo, Udine, MGC).

The historical collections from the Carnic Alps are deposited mainly at the Naturhistorisches Museum Wien, and in the Geology and Paleontology section of the Museum of Natural History in Florence and the Landesmuseum für Kärnten, Klagenfurt. Some specimens (mainly collected by Michele Gortani) are also stored in the Museo Geologico Cappellini in Bologna.

The principal localities where most of the material came from are Garnitzenberg 1-3, Garnitzenberg Südost α and β (= Monte Carnizza), Gugga 1-3, Hüttengraben (= Schwandgraben), Kronalpe, Krone (= both Monte Corona), Madritschenkopf (= Monte Madrizze), Nassfeldsattel (= Passo Pramollo), Ofenalm (= Casera For), Lanzenboden (Piani di Lanza), Rudnigsattel Süd 3-4, Rudnigsattel Nord, Schlanitzer Almweg, Schulter, Straniger Alm 1-3, Tomritsch 1-2, Watschiger Alm, Treßdorfer Alm and Zollnersee 2-3 (Fritz et al. 1990; Figs 2, 3).

Plant remains

The plant remains from the Italian side of the border are currently being restudied. In the interim, the com-

Fig. 6 - Area of the excavation organized by the Museo Friulano di Storia Naturale on Mt Corona (Krone) in 1985.
- *L'area dello scavo organizzato dal Museo Friulano di Storia Naturale sul Monte Corona nel 1985.*

Fig. 7 - *Alethopteris* from the Meledis Formation, Rio del Museo (Lanza Pass; MFSN gp 1117).
- Alethopteris *dalla Formazione di Meledis, Rio del Museo (Passo del Cason di Lanza; MFSN gp 1117).*

position of the Upper Carboniferous flora of the Carnic Alps can only be assessed based on studies carried out since the 1980's in Carinthia. There, the floras have been grouped stratigraphically (e.g., Fritz & Krainer 2006, 2007; Fritz et al. 1990). Starting with the oldest post-variscan flora, the Bombaso Formation crops out at the Tomritsch 1 and 2, and putatively Rio della Pioggia localities. The localities Straniger Alm 1-4, Zollnersee 2-3, Cason di Lanza, Watschiger Alm, Rudnigsattel, Rio del Museo (Fig. 3), Rio della Faglia and "Rio Bruca" pertain to the Meledis Formation. The Rio dai Amplis and the "Frana Vecchia" (Fig. 5) localities yielded plant remains coming both from the Pizzul Formation and/or from the Meledis Formation. The fossiliferous horizons, Garnitzenberg α and β, and Casera Cordin Grande 1-2 are known for the Pizzul Formation. Also the specimens from Casera For could come from the Pizzul Formation, but this assignment is uncertain due to the high number of small outcrops in the area, belonging to different formations.

The Corona Formation yielded plant fossils at the Ofenalm, Nassfeldsattel, Madritschenkopf, and Krone/Monte Corona. The samples labelled as "Contatto Corrado Rosenfeld" and "Monte Corona, presso il Contatto, verso il M. Cerchio" could belong to the Corona or the Pizzul formations since both formations are cropping out in close proximity due to faults. Gugga 1 and 2 lay at the boundary between the Corona

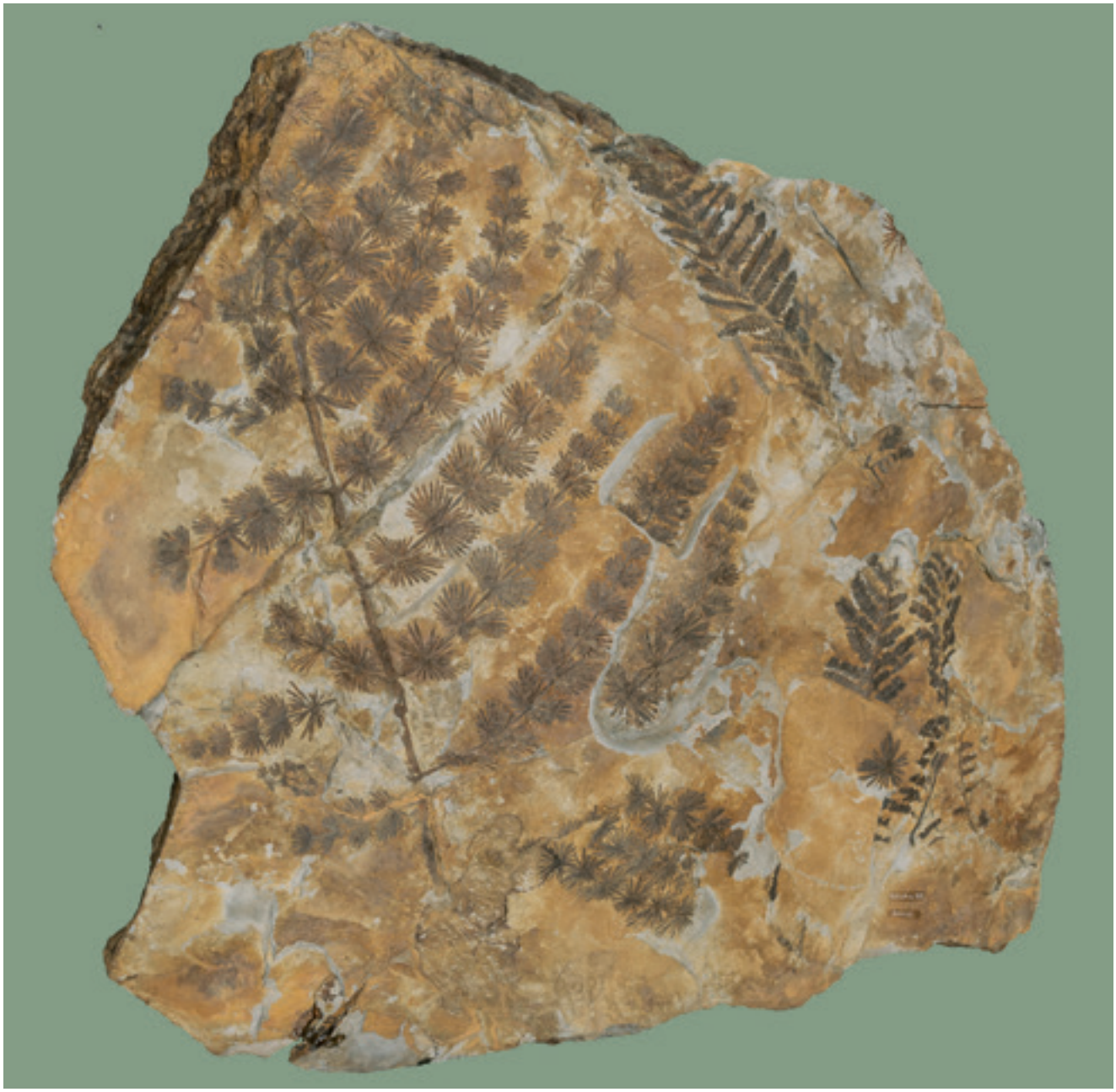

Fig. 8 - *Annularia carinata* and *Polymorphopteris* from the Late Carboniferous of Mt Corona (Pramollo Pass; MFSN gp 985).
- Annularia carinata *and* Polymorphopteris *dal Carbonifero superiore del Monte Corona (Passo Pramollo; MFSN gp 985).*

Fig. 9 - *Polymorphopteris* from the Upper Carboniferous of Mt Corona (Pramollo Pass; MGC 332001).
- Polymorphopteris *dal Carbonifero superiore del Monte Corona (Passo Pramollo; MGC 332001).*

Fig. 10 - Part of the trunk of an sphenophyte (*Calamites carinatus*) from Mt Corona (Pramollo Pass; MFSN gp 989).
- *Parte del tronco di un equiseto (*Calamites carinatus*) dal Monte Corona (Passo Pramollo; MFSN gp 989).*

and the Auernig formations, whereas Gugga 3 and Garnitzenberg 1 are assigned respectively to the lower and upper part of the Auernig Formation. It is difficult to assign the samples from the "Monte Carnizza" site to any formation, since the area is subjected to strong tectonic disruptions. The most likely assignement is to the Auernig Formation, although this interpretation is far from certain. The Carnizza Formation is the youngest Carboniferous formation yielding plant remains, mostly in the outcrops of Garnitzenberg 2 and 3, Hüttengraben and Schulterkofel. The specimens from Creta di Lanza probably belong to the Carnizza Formation. In any case they come from the upper part of the Pramollo Group. Additional localities (e.g., Rio degli Uccelli, Passo Pramollo, Pontebba, Rio Bombaso) are not localized geographically well enough for the assignment to any specific stratigraphic level.

The strictly clastic formations (Meledis, Corona and Carnizza) are much more fossiliferous than those characterized by an alternation of siliciclastic and marine beds (Pizzul and Auernig formations). Although plant remains are abundant throughout the stratigraphic succession of the Pramollo Group, the relative abundance and richness of specific taxa changes through time.

The Bombaso Formation has only few fossiliferous layers, with few taxa of sphenophytes (*Annularia sphenophylloides, Calamites cistii, Sphenophyllum oblongifolium*), lycophytes (*Cyperites bicarinatus, Leptostrobophyllum lanceolatum, Stigmaria ficoides, Syringodendron* sp.) and ferns or seed ferns (*Callipteris pteridium*, *Linopteris neuropteroides*, *Pecopteris candolleana, P. polymorpha, P. schlotheimii* and *P. unita*).

Lycophytes are rare in the plant assemblages of the Carnic Alps. Nonetheless, they are represented by a

Fig. 11- Branch of a sphenophyte (*Annularia sphenophylloides*) from the Corona Formation (Upper Carboniferous), Mt Corona (Pramollo Pass; MFSN gp 1121).
- *Ramo di un equiseto arboreo (*Annularia sphenophylloides*) dalla Formazione del Monte Corona (Carbonifero Superiore) Monte Corona (Passo Pramollo; MFSN gp 1121).*

surprising diversity (9 taxa), with isolated sporophylls (*Lepidostrobophyllum triangulare*, *L. lanceolatum*), fragments of strobili (*Sigillariostrobus* sp.), leaves (*Cyperites bicarinatus*), root fragments (*Knorria* sp., *Stigmaria licoides*) and different types of stem fragments (*Syringodendron* sp., *Sigillaria brardii*, *Asolanus camptotaenia*). *Cyperites bicarinatus* has been found in most fossiliferous localities and is missing only from the Pizzul Formation. Lycophytes are rare in the Pizzul Formation (*Syringodendron*) and the Auernig Formation (*Cyperites*), the two formations that show a marine influence in the succession.

The sphenophytes are much more abundant and diverse and are represented by both arborescent and herbaceous plants (21 taxa in total). Both foliage, stems and fertile organs of the arborescent sphenophytes are preserved. With four different species, the genus *Annularia* (Figs. 8 and 11) is the most diverse among adpressions, including both isolated whorls and leafy shoots bearing several whorls of leaves (*Annularia radiata*, *A. sphenophylloides*, *A. stellata*, *A. spicata*). On the other hand, *Asterophyllites equisetiformis* is very rare. *Calamites cistii*, *C. cruciatus*, *C. suckowii*, *C.* (*Diplocalamites*) sp. and *Mesocalamites schutzeiformis* are mostly fragments of large single stems preserved as pith casts in sandy siltstone, sometimes with visible branch scars, more rarely as impressions of the external surface with leaf scars. Cone fragments with articulated and vertically striated axes and perpendicularly attached bracts are rare but relatively diverse with three different taxa (*Calamostachys tuberculata, Macrostachya infundibuliformis, Palaeostachya* sp.). Remains of sphenophyte roots (*Radicites* sp.) are restricted to the lower part of the succession.

The herbaceous horsetails are predominantly represented by isolated leaf whorls or parts of leafy axes of *Sphenophyllum* species (*S. alatifolium*, *S. angustifolium*, *S. fimbriatum*, *S. incisum*, *S. longifolium*, *S. oblongifolium, S. thonii* var. *minor*). In this case as well, the siliciclastic formations are characterized by a considerably higher diversity and abundance in sphenophyte remains. In the Auernig Formation, the sphenophyte remains are restricted to stems (*Calamites* (*Diplocalamites*) sp.) and corresponding whorls of micophylls (*Annularia sphenophylloides*, *A. stellata*). The stratigraphically older Pizzul Formation, on the other hand, yielded stems (*Mesocalamites schutzeiformis*) and reproductive organs (*Palaeostachya* sp.) of arborescent sphenophytes but also axis fragments of herbaceous sphenophytes (*Sphenophyllum fimbriatum*, *S. oblongifolium*).

The group of the Pteridophylla is the most diverse in the flora, containing putative fern, seed fern and even putative cycadophyte taxa. The ferns are represented by two different orders, the Marattiales and the Filicales. The Marattiales are the most diverse and abundant. The most diverse genus is *Pecopteris* with 11 different species or varieties (*P. acuta, P.* aff. *miltonii, P. arborescens, P. candolleana, P. feminaeformis, P. hemitelioides, P. oreopteridia, P. polymorpha* v. *major, P. polymorpha* v. *minor, P. schlotheimii, P. unita*). They are commonly preserved as penultimate pinna fragments with several ultimate pinnae and pinnules. In most cases, only the sterile fronds are present, fertile fronds occur rarely. The other genera of Marattiales are much rarer with only up to three different species, such as the fertile genus *Asterotheca* (*A. sternbergii, A. schlotheimii, A. sternbergii*) and the sterile genus *Acitheca* (*A. polymorpha*). Also assignable to the Marattiales are the different types of *Aphlebia* (*A. adnascens, A. elongata, A.* sp.). *Sphenopteris* is a genus of fern-like leaves with generally uncertain botanical affinity. Three taxa of sterile fragments of penultimate pinnae have been identified in the flora (*S. nummularia, S. rutaefolia, Sphenopteris* sp. div.).

Seed ferns are abundant in the flora and represented by two different orders. The Callistophytales include the two leaf genera *Dicksoniites (*represented by *D. plukenetii*) and *Pseudomariopteris* (with the species *P. busquetii*). The more abundant and diverse order are the Medullosales, with the typical late Paleozoic leaf genera *Alethopteris* (*A. ambigua, A. bohemica*), *Neuropteris* (*N. auriculata, N. cordata, N. ovata, N. ovata* f. *ovata*), *Odontopteris* (*O. alpine, O. brardii, O. minor*), *Callipteridium* (*C. gigas, C. pteridium*) and *Linopteris* (*Linopteris neuropteroides*, *L. neuropteroides major*). The seeds *Pachytesta gigantea* and *Trigonocarpus* sp. also belong to the Medullosales. The medullosalean family Cyclopteridaceae is represented by *Cyclopteris fimbriatum* and *Cyclopteris* sp.

The last group documented from the flora is the order Cordaitanthales. It is represented by leaves (*Cordaites principalis*), reproductive organs (*Cordaitanthus* sp.) and seeds (*Samaropsis fluitans*).

Of unknown botanical affinity is *Kahleria carinthiaca*, which was described for the first time from the Carboniferous of the Carnic Alps, as well as the seeds assigned to *Carpolithes* sp., the reproductive organ *Ptychocarpus unitus* and the leaf genus *Taeniopteris*, present with two species (*Taeniopteris jejunata*, *T. multinervis*).

Discussion

The so far most complete overview of the Carboniferous (Pennsylvanian) flora of the Carnic Alps reported 92 taxa from the Pramollo Group (Fritz 1990; Fritz & Boersma 1990). However, this number also includes various disarticulated organs of the same plants (foliage, stem, roots, decorticated sigillarian stem *Syringodendron*) or sterile and fertile equivalents of the same plant in the case of ferns (e.g., *Pecopteris unita* and *Ptychocarpus unitus*). For this reason, these 92 species do not represent the biological plant diversity of the Pramollo Group. Moreover, modern stratigraphy and taxonomy of Pennsylvanian floras from Europe developed progressively over the last century. This is why a systematical revision of the flora is currently being carried out.

The overview of the historical collections was based on Fritz et al. (1990), where 78 taxa are plotted against 19 different sampling levels arranged in in their stratigraphic position within the Pramollo Group. These 78 taxa represent about 48 whole-plant species (12 sphenophyte, 5 lycopsid, 14 fern, 16 pteridosperm and 2 cordaitalean taxa), which are more reflective of biological diversity.

Concerning diversity in individual formations of the Pramollo Group, substantial differences have been observed between the exclusively clastic formations Meledis, Corona, Carnizza and the marine-influenced Auernig and Pizzul formations. The sediments of the Bombaso Formation are probably too coarse to yield well-preserved plant remains. The Carnizza Formation, on the other hand, yielded the most diverse plant assemblages.

Although the examined material is relatively rich and allows for an estimation of the diversity of major plant groups, the analysis of relative abundances of plant groups is problematic. This is because the collection material represents a selection of fossils found in debris only, and does not necessarily represent the original proportions of populations of major plant groups in the vegetation cover, with the exception of the excavations by the Museo Friulano di Storia Naturale in Udine (Fig.

5), where the collecting bias can be considered to be very low. Moreover, the sometimes poor preservation of the plant remains makes species (and sometimes also genus) assignments difficult.

Considering the possible age of the various formations, the Bombaso Formation could be attributed to a "Cantabrian" (Moscovian-Kasimovian) age (Krainer in Venturini 1990; Fritz & Krainer 1995, 2006). The presence of *Linopteris neuropteroides* var. *major*, *Sphenophyllum angustifolium* and *Pseudomariopteris busquetii*, as well as the high abundance of *Neuropteris cordata* and *N. ovata* would assign the Meledis Formation to the Gzhelian *Sphenophyllum angustifolium*-Zone (e.g., Fritz & Krainer 2006).

The presence of *Pseudomariopteris busquetii* attributes the plant assemblages of the Pizzul Formation and the lower Corona Formation to the *Sphenophyllum angustifolium*-Zone (see Fritz 1980; Fritz et al. 1990; Fritz & Krainer 1993, 2007). *Linopteris neuropteroides* and *Neuropteris cordata* disappear in the upper part of the Corona formation, while an appearance of *Lebachia* has been observed (Fritz & Krainer 1993, 2006). The plant assemblage from the Auernig Formation is characterized by the appearance of *Autunia conferta* (Fritz & Boersma 1983; Fritz & Krainer 2007).

Microflora

The Carboniferous microfloras of northern Italy is poorly studied. A palynological study was carried out in the Hochwipfel Formation, the oldest succession containing plant remains (Francavilla 1966). This microflora is dominated by spores such as *Laevigatosporites vulgaris, Dictyotrilites bireticulatus, Verrucosisporites firmus, Lycospora torquifer* and *Densosporites faunus* (Francavilla 1966). The age of the formation is still disputed. The macrofossils (plants and animals) indicate a middle Visean-Bashkirian age for this formation (Venturini et al. 2009), the palynomorphs would restrict its age to the lower Bashkirian ("Namuriano B" according to Francavilla 1966).

Recently, Kabon & Schönlaub (2019) refer the lower part of this formation to the middle to upper Visean, the middle part to the Serpukhovian and the upper part to the Bashkirian-Moscovian.

Conclusions

The plant diversity of the Carboniferous (Pennsylvanian) flora of the Carnic Alps is quite high (48 whole-plant species) and is comparable in diversity and species composition to coeval floras from Spain (Wagner & Álvarez-Vázquez 2010), the Czech Republic (Opluštil & Cleal 2007) and the Karawanks (Pšenička et al. 2015). This indicates that the Carnic Alps flora is a potentially important stratigraphic pillar for the southern part of Europe. The fact that the plant-bearing succession of the up to 1200 m thick Pramollo Group is intercalated with marine bands (mostly limestones) provides more detailed biostratigraphic constraints and enables the correlation of biostratigraphic zones between marine and terrestrial environments (Vai & Venturini 1997). This, however, will require a more detailed study of the Carboniferous floras and faunas of the Carnic Alps.

Manuscript received on 13.IX.2019, accepted on 11.X.2019.

Acknowledgements

This pubblication has been published within the framework of the Interreg Italia-Austria 2014-2020 project "GeoTrAC - Transborder Geopark of the Carnic Alps".

Thanks to Carlo Corradini for his useful contribution.

References

Anonym. 1851. Notizen. *Carinthia* 40 (19): 76.

Barretti, M. 1879. Studi geologici sulle Alpi Graie Settentrionali. *Reale Accad. dei Lincei. Serie 3a, Mem. Cl. sc. fisiche, matem. nat.,* 3, seduta del 6 aprile 1879.

Berger, W. 1960. Neue Funde von Oberkarbonpflanzen in den Auernigschichten (Kärnten). *Verhandl. Geolog. Bundesanst.* 1960: 253-61.

Boué, A. 1835. Constit. Géolog. Des provinces illyriennes. *Mém. Soc. géol. de France* 2: 53-5.

Bozzi, L. 1890. La Flora carbonifera del Monte Pizzul. *Boll. Soc. Geol. It.* 9: 71-85.

Curioni, G. 1865. Di alcuni vegetali dell'epoca carbonifera scoperti nei monti della Val Camonica. *Rend. Reale Ist. Lombardo* 2: 214-6.

Curioni, G. 1870. Osservazioni geologiche sulla Val Trompia. *Mem. Reale Ist. Lomb. scienze e lettere* serie III, 2: 1-60.

Davydov, V., & K. Krainer. 1999. Fusulinid Assemblages and Facies of the Bombaso Fm. and basal Meledis Fm. (Moscovian-Kasimovian) in the Central Carnic Alps (Austria/Italy). *Facies* 40: 157-96.

De Zigno, A. 1858. Del terreno carbonifero delle Alpi Venete. *Atti Ist. Veneto scienze, lettere ed arti* serie III, 3: 1-12.

Fenninger, A., & H.P. Schönlaub. 1972. Das Paläozoikum der Karnischen Alpen. In *Führer zu den Exkursionen der 42. Jahresversammlung der Paläontologischen Gesellschaft Graz*, 1972: 18-60.

Forke, H.C., & E. Samankassou. 2000. Biostratigraphical correlation of Late Carboniferous (Kasimovian) sections in the Carnic Alps (Austria/Italy): Integrated paleontological data, facies, and discussion. *Facies* 42: 177-210.

Francavilla, F. 1966. Spore nel Flysch Hochwipfel. *Giorn. Geol.* 2: 493-526.

Francavilla, F. 1974. Stratigraphie de quelques paléoflores des Alpes Carniques. *C. R. Congr. Int. Str. Géol. Carbonif.* 3: 89-110.

Frech, F. 1894. Die Karnischen Alpen. Ein Beitrag zur vergleichenden Gebirgstektonik. *Abhand. Naturforsch. Gesellschaft* 18: 1-514.

Frech, F. 1894. *Die Karnischen Alpen. Ein Beitrag zur vergleichenden Gebirgstektonik*. Halle: Max Niemeyer.

Fritz, A. 1980. Fundberichte über Pflanzenfossilien aus Kärnten 1980. *Carinthia II* 170/90: 221-38.

Fritz, A. 1990a. Stratigraphisch-floristischer Rückblick. *Carinthia II* 180/100: 173-80.

Fritz, A. 1990b. Zur Geschichte der paläobotanischen Forschung in Kärnten. *Carinthia II, Sonder.* 49: 181-91.

Fritz, A., & M. Boersma. 1981. Fundberichte über Pflanzenfossilien aus Kärnten 1981, Beitrag 2: Pflanzengroßreste aus dem Stefan (Oberkarbon) der Schulter, Karnische Alpen. *Carinthia II* 171/91: 387-414.

Fritz, A., & M. Boersma. 1983a. Fundberichte über Pflanzenfossilien aus Kärnten 1983, Beiträge 3 und 4. *Carinthia II* 173/93: 19-41.

Fritz, A., & M. Boersma. 1983b. Fundberichte über Pflanzenfossilien aus Kärnten 1983, Beitrag 5. *Carinthia II* 173/93: 315-37.

Fritz, A., & M. Boersma. 1984a. Fundberichte über Pflanzenfossilien aus Kärnten 1984. Beitrag 6: Ofenalm (Stefan), Karnische Alpen. *Carinthia II* 174/94: 9-20.

Fritz, A., & M. Boersma. 1984b. Fundberichte über Pflanzenfossilien aus Kärnten 1984. Beitrag 7: Schlanitzer Almweg (Stefan), Karnische Alpen. *Carinthia II* 174/94: 21-35.

Fritz, A., & M. Boersma. 1984c. Fundberichte über Pflanzenfossilien aus Kärnten 1984. Beitrag 8: Grenzlandbänke (Rudnìgsattel, Unterperm), Karnische Alpen. *Carinthia II* 174/94: 59-69.

Fritz, A., & M. Boersma. 1984d. Fundberichte über Pflanzenfossilien aus Kärnten 1984. Beitrag 9: Krone (Stefan), Karnische Alpen. *Carinthia II* 174/94: 145-75.

Fritz, A., & M. Boersma. 1984e. Beitrag zur Oberkarbonflora der Königstuhl-Nordwand, Aufsammlung Dr. E. Ebermann. *Carinthia II* 174/94: 267-86.

Fritz, A., & M. Boersma. 1985. Fundberichte über Pflanzenfossilien aus Kärnten 1985. Beitrag 10: Watschiger Alm (Stefan), Karnische Alpen. *Carinthia II* 175/96: 311-34.

Fritz, A., & M. Boersma. 1986a. Makropaläobotanische Ergebnisse zur Stratigraphie jungpaläozoischer Ablagerungen in den Karnischen Alpen, Österreich. *Carinthia II* 176/96: 19-37.

Fritz, A., & M. Boersma. 1986b. Fundberichte über Pflanzen-fossilien aus Kärnten 1986 Beitrag 11: Tomritschrücken (Unter-Stefan), Karnische Alpen. *Carinthia II* 176/96: 69-85.

Fritz, A., & M. Boersma. 1986c. Fundberichte über Pflanzenfossilien aus Kärnten 1986 Beitrag 13: Zollnersee (Unter-Stefan), Karnische Alpen. *Carinthia II* 176/96: 147-65.

Fritz, A., & M. Boersma. 1986d. Fundberichte über Pflanzenfossilien aus Kärnten 1986 Beitrag 14: Hüttengraben (Ober-Stefan), Rattendorfer Alm, Karnische Alpen. *Carinthia II* 176/96: 241-62.

Fritz, A., & M. Boersma. 1987a. Fundberichte über Pflanzenfossilien aus Kärnten 1987. Beitrag 15: Wunderstätten (Unterperm), St. Pauler Berge. *Carinthia II* 177/97: 381-94.

Fritz, A., & M. Boersma. 1987b. Fundberichte über Pflanzenfossilien aus Kärnten 1988 Beitrag 16: Kötschach, Gailtaler Alpen (Unterperm). *Carinthia II* 177/97: 395-407.

Fritz, A., & M. Boersma. 1988a. Fundberichte über Pflanzenfossilien aus Kärnten 1988 Beitrag 17: Ulrichsberg (Unterperm) Kärnten. *Carinthia II* 178/98: 437-46.

Fritz, A., & M. Boersma. 1988b. Beitrag zur Flora des Königstuhl-Karbons Aufsammlung Dr. E. Ebermann Nachtrag 1988. *Carinthia II* 178/98: 495-502.

Fritz, A., & M. Boersma. 1990a. Die steinkohlenzeitliche Pflanzenwelt Kärntens in ihrer fossilen Überlieferung. *Carinthia II, Sonder.* 49: 15-108.

Fritz, A., & M. Boersma. 1990b. Die Paläofloren Kärntens: OberKarbon/UnterPerm. *Carinthia II, Sonder.* 49: 133-72.

Fritz, A., & K. Krainer. 1993. Eine neue Megaflora aus dem Stefan der Kronalpe. *Carinthia II* 183: 485-517.

Fritz, A., & K. Krainer. 1994. Die Megaflora „Garnitzenberg-Südost alpha" aus der Auernig-Schichtgruppe der Karnischen Alpen. *Carinthia II* 184/104: 441-65.

Fritz, A., & K. Krainer. 1995. Die Megaflora Tomritsch-3 und Tomritsch-6 aus den oberkarbonen Auernigschichten der Karnischen Alpen. *Carinthia II* 185/105: 553-83.

Fritz, A., & K. Krainer. 1997. Eine oberkarbone Megaflora von der Nordseite des Stangnocks, Gurktaler Alpen. *Carinthia II* 187/107: 325-56.

Fritz, A., & K. Krainer. 2006. Vegetationsgeschichtliche und florengeographische Untersuchungen im Oberkarbon und Unterperm der Ost- und Südalpen (Teil 1). *Carinthia II* 196/116: 93-120.

Fritz, A., & K. Krainer. 2007. Vegetationsgeschichtliche und florengeographische Untersuchungen im Oberkarbon und Unterperm der Ost- und Südalpen (Teil 2). *Carinthia II* 197/117: 91-148.

Fritz, A., H.P. Schönlaub & M. Boersma. 1986. Fundberichte über Pflanzenfossilien aus Kärnten 1986 Beitrag 12: Eine Oberstefan-Flora aus den „Grenzlandbänken" der Treßdorfer Alm (Karnische Alpen, Naßfeld). *Carinthia II* 176/86: 125-33.

Fritz, A., M. Boersma & K. Krainer. 1990. Steinkohlenzeitliche Pflanzenfossilien aus Kärnten, *Carinthia II, Sonderh.* 49: 1-120.

Geinitz, H.B. 1869. Über fossile Pflanzenreste aus der Dyas von Val Trompia. *Neues Jahrb. Miner. Geol. Paläontol.*: 456-61.

Geyer, G. 1897. Über die geologischen Verhältnisse im Pontafeler Abschnitte der Karnischen Alpen. *Jahrb. K.-K. Geol. Reichsanst.* 46, 127-234.

Gortani, M. 1905. Relazione sommaria delle escursioni fatte in Carnia dalla Società Geologica Italiana nei giorni 21-26 agosto 1905. *Boll. Soc. Geol. It.* 24 (1): 64-75.

Gortani, M. 1906. Sopra alcuni fossili neocarboniferi delle Alpi Carniche. *Boll. Soc. Geol. It.* 25: 257-76.

Gortani, M. 1910. Osservazioni geologiche sui terreni paleozoici dell'alta valle di Gorto in Carnia. *Rend. Reale Ass. Scient.* 1910: 9.

Gortani, M. 1912. Rinvenimento di filliti neocarbonifere al Piano di Lanza (Alpi Carniche). *Boll. Soc. Geol. It.* 30: 909-12.

Heer, O. 1876. *Flora fossilis Helvetiae*. Zürich: Wurster & Co.

Heritsch, F., F. Kahler & K. Metz. 1933. Die Schichtfolge von Oberkarbon und Unterperm. In *Stratigraphie von Oberkarbon und Unterperm in den Karnischen Alpen*, cur. F. Heritsch, 162-89. Mitteilungen der geologischen Gesellschaft Wien 26.

Höfer, H. 1869. Vorläufige Notiz über das Anthrazit-Vorkommen in der Nähe der Ofenalpe bei Pontafel. *Jahrb. Naturhist. Landesmuseums Kärnten* 10: 182-9.

Hohenwart, S. von. 1783. Tagebuch einer Reise nach der Stangalpe unweit Turrach in Steyermarck, vom Jahre 1779.

Fragmente zur mineralogisch und botanischen Geschichte Steyermarks und Kärnthens 1: 19-35.

Jongmans, W.J. 1938. Die Flora des „Stangalpe"-Gebietes in Steiermark. In *C. R. 2e Congr. Pour l'avancement des études de Stratigraphie Carbonifere, Heerlen 1935,* Tome III: 1259-98. Maastricht.

Jongmans, W.J. 1950. Mitteilungen zur Karbonflora der Schweiz. Part I. *Eclogae Geologicae Helvetiae* 43 (2): 95-104.

Kabon, H., & H.P. Schönlaub. 2019. *Das geologische Geheimnis der Hochwipfel Formation der Karnischen Alpen (Österreich/Italien)*. Klagenfurt: Naturwissenschaftlicher Verein für Karnten.

Kahler, F., & G. Kahler. 1980. Fusuliniden aus den Kalken der Trogkofel-Schichten der Karnischen Alpen. In *Die Trogkofel-Stufe im Unterperm der Karnischen Alpen*, cur. E. Flügel, 183-254. Carinthia II, Sonderh. 36.

Kahler, F. 1983. Fusuliniden aus Karbon und Perm der Karnischen Alpen und der Karawanken. *Carinthia II, Sonderh.* 41: 1-107.

Kahler, F. 1985. Oberkarbon und Unterperm der Karnischen Alpen. Ihre Biostratigraphie mit Hilfe der Fusuliniden. *Carinthia II, Sonderh.* 42: 1-93.

Kahler, F. 1986. Ein Normalprofil der Fusuliniden-Stratigraphie im Oberkarbon und Unterperm der Karnischen Alpen. *Carinthia II* 176/86: 1-17.

Kahler, F. 1989. Die Fusuliniden. In *Foraminifera Palaeozoica*, cur. F. Ebner & F. Kahler, 87-272. Anzeiger der österreichischen Akademie der Wissenschaften in Wien, Catalogus Fossilium Austriae II/B/1.

Kaiser, S. 1971. *Beitrag zur Geologie des Raumes um den Ulrichsberg NNW von Klagenfurt, Kärnten*. Unpub. PhD, Wien.

Kielhauser, G.E. 1937. Eine Karbonflora von Hüttengraben (Rattendorfer Alm) in den Karnischen Alpen. *Anzeiger österreich. Akad. Wissenschaften in Wien* 1-3.

Knight, J.A., & R.H. Wagner. 2014. Proposal for the recognition of a Saberian Substage in the mid-Stephanian (West European chronostratigraphic scheme). *Freiberger Forschungshefte* C548 (22): 179-95.

Krainer, K., & V. Davydov. 1998. Facies and biostratigraphy of the Late Carboniferous/Early Permian sedimentary sequence in the Carnic Alps (Austria/Italy). *Geodiversitas* 20 (4): 643-62.

Krainer, K. 1990. Zur faziellen Entwicklung Pflanzenfossil-führender Oberkarbon und Unterpermsedimente Kärntens. *Carinthia II, Sonderh. 49*: 109-32.

Krainer, K. 1992. Fazies, Sedimentations prozesse und Paläogeographie im Karbon der Ost- und Südalpen. *Jahrb. der Geol. Bundesanst.* 135 (1): 99-193.

Krause, P.G. 1928. Über *Asterocalamites scrobiculatus* (Schloth.) Zeiller im Kulm der Karnischen Hauptkette. *Jahrb. der preußischen geologischen Landesanstalt Berlin* 49: 634-40.

Magnani, M. 1946. Sulla presenza di terreni spettanti al Carbonifero nei monti di Menaggio (Valle Sanagra). *Atti Regia Accad. Sc. Torino* 80 (1): 199-206.

Massari, F., M. Pesavento & C. Venturini. 1991. The Permian-Carboniferous cyclothems of the Pramollo Basin sequence (Carnic Alps). *Giorn. Geol.* 53 (1): 171-85.

McCann, T. 2008. *The Geology of Central Europe. Volume 1: Precambrian and Palaeozoic*. London: The Geological Society.

Morlot, A. von. 1850. Über die geologischen Verhältnisse von Oberkrain. *Jb. K.-K. Geol. Reichsanst.* 1 (3): 389-411.

Novak, M., & D. Skaberne. 2009. Upper Carboniferous and Lower Permian. In *The Geology of Slovenia*, cur. M. Pleničar, B. Ogorelec & M. Novak, 99-136. Ljubljana: Geološki zavod Slovenije.

Opluštil, S., & C.J. Cleal. 2007. A comparative analysis of some Late Carboniferous basins of Variscan Europe. *Geological Magazine* 144: 417-48.

Opluštil, S., M. Schmitz, C.J. Cleal & K. Martínek. 2016. A review of the Middle-Late Pennsylvanian west European regional substages and floral biozones, and their correlation to the Global Time Scale based on new U-Pb ages. *Earth Science Review* 154: 301-35.

Pasini, M. 1963. Alcuni fusulinida della serie del M. Auernig (Alpi Carniche) e loro significato stratigrafico. *Riv. Ital. Paleont*. 69(3): 337-82.

Pittau, P., M. Del Rio & A. Funedda. 2008a. Relationships between plant communities characterization and basin formation in the Carboniferous-Permian of Sardinia. *Boll. Soc. Geol. It. (Italian Jour. Geosciences)* 127 (3): 637-53.

Pittau, P., M. Del Rio, F. Cotza, A. Ronchi, G. Santi & R. Gianotti. 2008b. Pennsylvanian miospore assemblages from the Bèdero Section, Varese, Italian Southern Alps. *Revue de Micropaléont.* 51: 133-66.

Placer, L. 1999. Contribution to the macrotectonic subdivision of the border region between Southern Alps and External Dinarides. *Geologija* 41: 223-55.

Pšenička, J., S. Opluštil, A. Ronchi & Z. Simunek. 2012. Revision of the Pennsylvanian flora from Val Sanagra in western part of the southern Alps (Italy). *Folia* 46 (1-2): 31-71.

Pšenička, J., S. Opluštil A. Ronchi, Z. Simunek, G. Santi & A. Selva. 2013. The oldest flora from the Southern Alps (Italy): the Val Sanagra Pennsylvanian flora revisited. In *The Carboniferous-Permian Transition*, cur. S.G. Lucas et al., 325-6. New Mexico Museum of Natural History and Science, Bulletin 60.

Pšenička, J., T. Kolar-Jurkovšek, S. Opluštil & M. Novak. 2015. Stephanian fossil flora from paralic Carboniferous deposits of the Jesenice Area (Slovenia) and its comparison with Czech Localities. *Folia Musei Rerum Natur. Bohemiae Occid. Geol. Paleobiol.* 48: 21-64. 10.2478/fbgp-2014-0003.

Reichardt, W. 1933. Eine Flora aus den höchsten Auernigschichten des Schulterkofels (Karnische Alpen). *Anzeiger Akad. Wissensch.* 1933: 1-2.

Reichardt, W. 1937. Die ostalpinen Naßfeldschichten - eine Brücke zwischen Mitteleuropa und Russland. In *C. R. 2e Congr. pour avancement des études de Stratigraphie Carbonifere, Heerlen 1935* Tome II: 919-1055. Maastricht.

Remy, W. 1969. Das höhere Stefan in den Karnischen Alpen und das Alter der Transgression der Auernig-Schichten. *Argumentae Palaeobotanicae* 3: 65-9.

Riehl-Herwisch, G. 1962. Vorläufige Mitteilung über einen Fund von pflanzenführendem Oberkarbon im Bereich des Christofberges, Mittelkärnten. *Der Karinthin* 45/46: 244-6.

Ronchi, A., E. Kustatscher, P. Pittau & G. Santi. 2012. Pennsylvanian floras from Italy: an overview of the main sites and historical collections. *Geologia Croatica* 65 (3): 299-322.

Schellwien, E. 1892: Die Fauna des karnischen Fusulinidenkalks. Teil I. *Palaeontographica* 39: 1-56.

Schneider, J.W., S.G. Lucas, F. Scholze, S. Voigt, L. Marchetti, H. Klein, S. Opluštil, R. Werneburg, V.K. Golubev, J.E. Barrick, T. Nemyrovska, A. Ronchi, M.O. Day, V.V. Silantiev, R. Rössler, H. Saber, U. Linnemann, V. Zharinova & S. Shen. in press. Late Paleozoic-early Mesozoic continental biostratigraphy - links to the Standard Global Chronostratigraphic Scale. *Palaeoword*.

Schönlaub, H.P., & H.C. Forke. 2007. Die post-variszische Schichtfolge der Karnischen Alpen - Erläuterungen zur Geologischen Karte des Jungpaläozoikums der Karnischen Alpen (1:12.500). *Abhand. Geolog. Reichsanst*. 61: 3-157.

Selli, R. 1963. Schema geologico delle Alpi Carniche e Giulie occidentali. *Giorn. Geol.* 30 (2): l-121.

Simonetto, L., & C. Corradini. 2006. Il Paleozoico Carnico. In *Guida alle escursioni, Giornate di Paleontologia 2006*, cur. R. Melis, R. Romano & G. Fonda, 84-94. Trieste: Edizioni Università di Trieste.

Sordelli, F. 1896. *Flora fossile insubrica. Studi sulla vegetazione in Lombardia durante i tempi geologici*. Milano: Tipografia Cogliati.

Squinabol, S. 1887. Nota preliminare su alcune impronte fossili nel carbonifero superiore di pietratagliata. *Giornale della Società di Letture e Conversazioni Scientifiche di Genova* 10: 6-7.

Stache, G. 1874. Die paläozoischen Gebiete der Ostalpen. *Jahrb. K. -K. Geolog. Reichsanst*. 24 (2): 135-274.

Stefani, C. de.1887, II Permiano ed il Carbonifero nelle Alpi Marittime. *Atti Soc. Tosc. Sc. Nat.* 6: 5-12.

Sternberg, G.K. 1820-1838. *Versuch einer geognostisch–botanischen Darstellung der Flora der Vorwelt*. Leipzig/ Prag.

Stur, D.J.R. 1856. Die geologischen Verhältnisse der Täler der Drau, Isel, Möll und der Gail, ferner der Carnia im venezianischen Gebiet. *Jahrb. K.-K. Geol. Reichsanst* 7: 405-59.

Stur, D.J.R. 1868. Fossile Pflanzenreste aus dem Schiefergebirge von Tergove in Croatien. *Jahrb. Geol. Bundesanst.* 18: 131-8.

Stur, D.J.R. 1871. *Lunzer Sandstein. Geologie der Steiermark*. Graz: Verlag des geognostisch-montanen Vereines für Steiermark.

Stur, D.J.R. 1886. Obercarbonische Pflanzenreste vom Bergbau Reichenberg bei Assling in Oberkrain. *Verhandl. Geol. Reichsanst.* 1886: 383-5.

Taramelli, T. 1905. Adunanza straordinaria del 22 agosto 1905. *Boll. Soc. Geol. It.* 24: 56-7.

Tenchov, Y. 1978. Stratigraphy of the Carboniferous from Stangalps, Austria. *Geologica Balcanica* 8.1.

Tenchov, Y. 1980. Die paläozoische Megaflora von Österreich. *Verhandl. Geolog. Bundesanst.* 1980 (2): 161-74.

Thiedig, F., & D. Klusmann. 1974. Limnisches Oberkarbon an der Basis der postvarisischen Transgressionsserie in den St. Pauler Bergen Ostkärntens (Österreich). *Mitteil. Geol. -Paläontol. Instit. Universität Hamburg* 43: 81.

Tommasi, A. 1889. Sulla scoperta del Carbonifero del Monte Pizzul nel Alta Carnia. *Boll. Soc. Geol. It.* 8: 564-5.

Unger, F. 1840. Über ein Lager vorweltlicher Pflanzen auf der Stangalpe. *Steiermarkische Zeitschrift* 5 (1): 140-53.

Unger, F. 1869. Anthracit-Lager in Kärnthen. *Sitzungsber. Österreich. Akad. Wissensch. Wien, Mat. -Nat. Kl.* 60: 777-94.

Vachard, D., & K. Krainer. 2001: Smaller foraminifers of the latest Carboniferous Auernig Group, Carnic Alps (Austria/ Italy). *Riv. It. Paleont. Strat.* 107: 147-68.

Vai, G.B., & C. Venturini. 1997. Moskovian and Artinskian rocks in the frame of the cyclic Permo-Carboniferous of the Carnic Alps and related areas. In *Peri-Tethys: stratigraphic correlations*, cur. S. Crasquin-Soleau & P. de Wever, 173-86. Geodiversitas 19 (2).

Van Amerom, H.W.J., M. Boersma & G. Niedermayr. 1976. Notes of sedimentology and paleobotany of the Werfener Schichten in the western Gailtaler Alps near Kötschach (Carinthia, Austria). *Geologie en Mijnbouw* 55 (3-4): 218-26.

Van Amerom, H.W.J., & H. Kabon. 2000. Neue fossile Floren aus dem Nötscher Karbon 2. Teil. *Carinthia II* 190/110: 483-516.

Van Amerom, H.W.J., G. Flajs & G. Hunger. 1984. Die "Flora der Marinelli-Hütte" (mittleres Visé) aus dem Hochwipfel-flysch der Karnischen Alpen (Italien). *Mededelingen Rijks Geolog. Dienst* 37 (3): 1-41.

Van Amerom, H.W.J., M. Boersma & G. Riehl-Herwirsch. 1976. Zum Alter des "Karbons von Christophberg", Kärnten, Österreich. *Geologie en Mijnbouw* 55 (3-4): 211-2.

Van Amerom, H.W.J., M. Boersma, G. Niedermayr & E. Scheriau-Niedermayr. 1976. Das permische Alter der "Karbon"-Flora von Kötschach (Kärnten, Österreich). *Carinthia II* 166/86: 93-101.

Venturini, C., cur. 1990. *Field Workshop on Carboniferous to Permian Sequence of the Pramollo-Nassfeld Basin (Carnic Alps), Guidebook*. Udine: Arti Grafiche Friulane.

Venturini, C. 1990. *Geologia delle Alpi Carniche centro-orientali.* Udine: Pubbl. Mus. Friul. St. Nat. 36.

Venturini, C. 2002. La sequenza Permo-Carbonifera. In *Alpi e Prealpi Carniche e Giulie (Friuli Venezia Giulia)*, cur. G.B. Vai, C. Venturini, G.B. Carulli & A. Zanferrari, 31-7. Guide Geol. Reg. SGI 9.

Venturini, C. 2006. *Evoluzione geologica delle Alpi Carniche*. Udine: Pubbl. Mus. Friul. St. Nat. 48.

Venturini, C., C. Spalletta, G.B. Vai, M. Pondrelli, S. Delzotto, C. Fontana, G. Longo Salvador & G.B. Carulli. 2009. *Note Illustrative al Foglio 031 Ampezzo, Carta geologica d'Italia alla scala 1:50.000*. Università di Bologna, Apat-Servizio Geologico Nazionale.

Venzo, S., & L. Maglia. 1947. Lembi carboniferi trasgressivi sui micascisti alla "Fronte sedimentaria subalpina" del Comasco (Acquaseria di Menaggio-Bocchetta di S. Bernardo) e del Varesotto (Bèdero). *Atti Soc. It. Sc. Nat.* 85/86: 33-70.

Venzo, S. 1951. Les gisements nouveaux du Carbonifère (Westphalien) dans les Alpes Lombardes. In *C. R. du 3e Congrès de Stratigraphie et de Géologie du Carbonifère, Herleen 1951*, 647-9.

Vinassa de Regny, P. 1905. Rinvenimento della *Neurodontopteris auriculata* presso il Ricovero Marinelli. *Boll. Soc. Geol. It.* 24: 56-57

Vinassa de Regny, P. 1906a. Zur Kulmfrage in den Karnischen Alpen. *Verhandl. Geolog. Reichsanst.* 7: 238-40.

Vinassa de Regny, P. 1906b. Sull'estensione del Carbonifero superiore nelle Alpi Carniche. *Boll. Soc. Geol. It.* 25: 221-32.

Vinassa de Regny, P. 1906c. A proposito della esistenza del Culm nelle Alpi Carniche. *Rend. Reale Accad. Lincei* 5 (15): 647-9.

Vinassa de Regny, P. 1912 Piante neocarbonifere del Piano di Lanza (Carnia). *Riv. It. Paleont.* 18: 12-7

Vinassa de Regny, P., & M. Gortani. 1905. Fossili carboniferi del M. Pizzul e del Piano di Lanza nelle Alpi Carniche. *Boll. Soc. Geol. It.* 24 (2): 461-604.

Wagner, R.H., & C. Alvárez-Vázquez. 2010. The Carboniferous floras of the Iberian Peninsula: a synthesis with geological connotations. *Review Palaeobot. Palyn.* 162: 239-324.

Zwanzinger, G.A. 1872. Die urweltlichen Pflanzen Kärntens nach ihrem Alter und ihren Lagerstätten verzeichnet. *Carinthia II* 62: 97-104.

Zwanzinger, G.A. 1876. Die urweltlichen Pflanzen Kärntens nach ihrem Alter und ihren Lagerstätten verzeichnet. *Jahrb. des Naturhist. Landesmuseums Kärnten* 12: 71-90.

Zwanzinger, G.A. 1891. Die Steinkohlen-Flora der Kronalpe und ihre Stellung jene der Stangalpe, von Bleiberg, Afsling und der Wurmalpe bei Kaisersberg nächst Leoben. *Carinthia II* 81: 91-5.

Indirizzi degli Autori - Authors' addresses:
- Evelyn Kustatscher
  Museum of Nature South Tyrol
  Bindergasse/Via Bottai 1, I-39100 BOZEN/BOLZANO
  e-mail: Evelyn.Kustatscher@naturmuseum.it
- Hendrik Nowak
  Museum of Nature South Tyrol
  Bindergasse/Via Bottai 1, I-39100 BOZEN/BOLZANO
  e-mail: Hendrik.Nowak@naturmuseum.it
- Stanislav Opluštil
  Institute of Geology and Palaeontology, Faculty of Science
  Charles University, Albertov 6, CZ-12843 PRAGUE
  e-mail: oplustil@natur.cuni.cz
- Josef Pšenička
  Centre of Palaeobiodiversity, West Bohemian Museum in Pilsen
  Kopeckého sady 357/2, CZ-30100 PLZEŇ 3
- Luca Simonetto
  Museo Friulano di Storia Naturale
  via Sabbadini 22-32, I-33100 UDINE
  e-mail: luca.simonetto@comune.udine.it