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TRIASSIC MACROFLORAS OF THE UDINE PROVINCE (EASTERN SOUTHERN ALPS)

MACROFLORE TRIASSICHE DELLA PROVINCIA DI UDINE (ALPI SUD-ORIENTALI)

Abstract - The Late Triassic macroplant fossil collections from Udine Province are unique but have only been partially studied so far. Here we provide an overview of the plant fossil assemblages from the Triassic of the Udine Province, stored at the Museo Friulano di Storia Naturale in Udine and at the Museo Geologico della Carnia (Udine Province, Italy), and their potential for further research. All fossiliferous localities yielding plant fossils are presented in chronostratigraphic order, starting with the Early Triassic, an epoch from which only very few plant fragments are known to date. In contrast, the Anisian (Middle Triassic) plant fossil assemblages are quite diverse, whereas the Ladinian outcrops yielded mainly conifer shoots. The diversity and number of fossiliferous sites of the Late Triassic is outstanding. While the assemblage of Cave del Predil/Raibl, the most important historical Carnian plant fossil locality, comprises a very diverse flora, other Carnian assemblages are represented by a wide range of plant fossils but are mainly dominated by an underestimated diversity of conifers. The Norian plant fossil assemblages of the Udine Province are among the most diverse and abundant in Europe, and the Norian-Rhaetian fossils are the only plant macroremains from the Southern Alps of putative Rhaetian age so far.
Key words: Palaeobotany, Triassic, Conifers, Museo Friulano di Storia Naturale, Museo Geologico della Carnia.

Riassunto breve - *Le collezioni di macroflore fossili del Triassico Superiore della provincia di Udine sono uniche, ma finora sono state studiate solo parzialmente. Qui viene fornita una panoramica delle collezioni di piante fossili del Triassico della provincia di Udine, conservate presso il Museo Friulano di Storia Naturale di Udine e presso il Museo Geologico della Carnia (Ampezzo, Udine), evidenziando il loro potenziale per ulteriori ricerche. Tutte le località fossilifere che hanno restituito fossili vegetali vengono presentate in ordine cronostratigrafico, a partire dal Triassico Inferiore, di cui sono noti, ad oggi, solo pochissimi frammenti vegetali. Al contrario, le collezioni di piante fossili di età anisica (Triassico Medio) sono piuttosto diversificate, mentre gli affioramenti del Ladinico hanno restituito principalmente rami di conifere. La diversità e il numero di siti fossiliferi del Triassico Superiore è eccezionale. Cave del Predil/Raibl, la più nota località storica con piante fossili del Carnico, comprende una flora molto diversificata. Altre collezioni di piante fossili del Carnico documentano un'ampia gamma di specie con un predominio, in prevalenza, di una sottovalutata diversità di conifere. Le collezioni di piante fossili del Norico delle Prealpi Carniche sono tra le più variegate e abbondanti in Europa, e i fossili norico-retici sono, finora, gli unici macroresti vegetali delle Alpi Meridionali di presunta età retica.*
Parole chiave: *Paleobotanica, Triassico, Conifere, Museo Friulano di Storia Naturale, Museo Geologico della Carnia.*

Introduction

The Triassic successions of the Southern Alps are historically famous for two plant fossil sites, Raibl (now Cave del Predil, Carnian in age) in the Julian Alps and Recoaro in the Venetian Prealps (Anisian in age; e.g., Schauroth 1855; Bronn 1858; De Zigno 1862; Schenk 1866-67; 1868; Stur 1868a; 1868b; Gümbel 1879). The historical plant and fish fossils from the Predil Limestone of Cave del Predil/Raibl, stored at the Natural History Museum of Vienna and GeoSphere Austria (formerly Geologische Bundesanstalt), were donated or sold by local miners (e.g., Bronn 1858; Schenk 1866-67; Kustatscher & Roghi 2014). The historical fossil plant collections of Recoaro (Catullo 1846; Massalongo 1857; De Zigno, 1862) are today stored mainly in the palaeontological collections of the Natural History Museums of Verona, Padova and Venice. More recently, important plant fossil collections were also recovered from the Dolomites, western Southern Alps, Carnic and Julian Alps.

The Carnian plant fossil assemblages from Monte Pora in the Prealps, north of Bergamo, and the Ladinian plant fossils from the UNESCO World heritage site Monte San Giorgio have been studied recently (e.g., Passoni, 1996, 1999; Passoni & Van Konijnenburg-van Cittert 2003; Stockar & Kustatscher 2010). The plant fossil assemblages of the Dolomites

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have been substantially reviewed in the last two decades (e.g., Broglio Loriga et al. 2002; Kustatscher et al. 2004; 2007; 2010a; 2010b; 2011; 2014; 2019; Kustatscher & Van Konijnenburg-van Cittert 2005; Van Konijnenburg-van Cittert et al. 2006; Todesco et al. 2008; Kustatscher & Roghi 2014; Forte et al. 2021, 2022; Roghi et al. 2022). Less well studied are the plant fossil assemblages of the easternmost part of the Southern Alps, located in the Udine Province (northeastern Italy). Only the Carnian plant fossil assemblage of Dogna has been studied extensively (Roghi et al. 2006), whereas plant fossils from other important outcrops such as the historically famous Cave del Predil/Raibl or the collections from the Norian Forni Dolomite (in Italian literature Dolomia di Forni) are studied only selectively in recent literature (e.g., Kustatscher & Roghi 2014; Kustatscher et al. 2018; Preto et al. 2019). However, the Late Triassic was a time of major environmental changes affecting vegetation compositions on a regional scale and preluding major steps in plant evolution. During this time several modern plant linages evolved (Kustatscher et al. 2018). Therefore, especially the rich Late Triassic assemblages of the Udine Province are of eminent importance for our understanding of vegetation dynamics during a key interval of plant evolution and environmental change (e.g., Kustatscher et al. 2018; 2019; Roghi 2022).

The aim of this paper is an integrative overview on the historical and unpublished Triassic plant fossil assemblages of the Udine Province, integrated in a modern (chrono-)stratigraphic framework. This gives important insights into the composition and diversity of the Triassic floras of the palaeotropics and shows the potential of so far underestimated collections. To achieve this, we study both major fossil collections and some isolated fossil specimens stored at the Museo Friulano di Storia Naturale in Udine (Udine Province, Italy).

Materials and methods

The Southern Alps, as considered in this paper, correspond to the part of the Eastern Alps lying south of the Periadriatic Line, and document the history of the northwestern Tethys and the microcontinent Adria (Schmid et al. 2008). The succession of the Southern Alps comprises mainly Permian to Cretaceous sediments, with limestones and dolomites being the most prominent lithologies.

The focus of the present compilation is on the Triassic successions cropping out in the Udine Province, the northeasternmost province of Italy, and includes the easternmost part of the Dolomites, the Julian Alps and Prealps, and the Carnic Alps and Prealps. In this area, several very important plant fossil localities of Triassic age crop out (Fig. 1) that, considered in a coherent stratigraphic context, correspond to the most complete Triassic palaeobotanical record of the northwestern Tethys.

For the present documentation of the current Triassic macrofossil treasures, records of fossils stored in different collections have been compiled, evaluated, and grouped in order to present them in a chronostratigraphic order. Additionally, fossils described in the literature but not retrieved in any collections in Udine or fossils from Udine Province stored in collections in neighboring provinces have been included. The fossils discussed here are stored mainly in the palaeontological collection of the Museo Friulano di Storia Naturale of Udine (prefix "MFSNgp"; about 3000 specimens), with some additional specimens deposited in the Museo Geologico della Carnia of Ampezzo (Udine, prefix "MGC"; about 50 specimens), the Natural History Museum of Vienna (prefix "NHMW"; about 150 specimens), and GeoSphere Austria (prefix "GBA", about 300 specimens). For an overview, localities are grouped on the geographic map (Fig. 1 and Tab. I), and details on individual localities are provided below.

Fossiliferous outcrops

The 51 fossiliferous outcrops and/or fossiliferous areas have been grouped according to geographic and chronostratigraphic considerations (Fig. 1). The number of plant fossils available from each locality ranges from one single specimen up to several hundred specimens. For each locality, the number of specimens stored at the two main repositories of the Udine Province (Museo Friulano di Storia Naturale of Udine and the Museo Geologico della Carnia of Ampezzo) is provided, as is any lithostratigraphic and chronostratigraphic information available on the outcrops.

For sites with sporadic discoveries, where it was not possible to check *in situ*, the data on the museum tag and a rapid lithological check were used. The following list also indicates, for these specimens, some possible stratigraphic alternatives.

Early Triassic

1 - Surroundings of Paularo (1 specimen): Werfen Formation

Middle Triassic, Anisian

2 - Sauris, Casera Chiansaveit surroundings, Mt. Bivera (1 specimen): Ambata or Dont Formation, Pelsonian/Illyrian (in the area also the Ladinian Buchenstein Formation crops out)

3 - Moggio Udinese, Val Aupa, Rio Fous (1 specimen), Rio dell'Andri (15 specimens), Saps (1 specimen): "Torbiditi d'Aupa", Illyrian

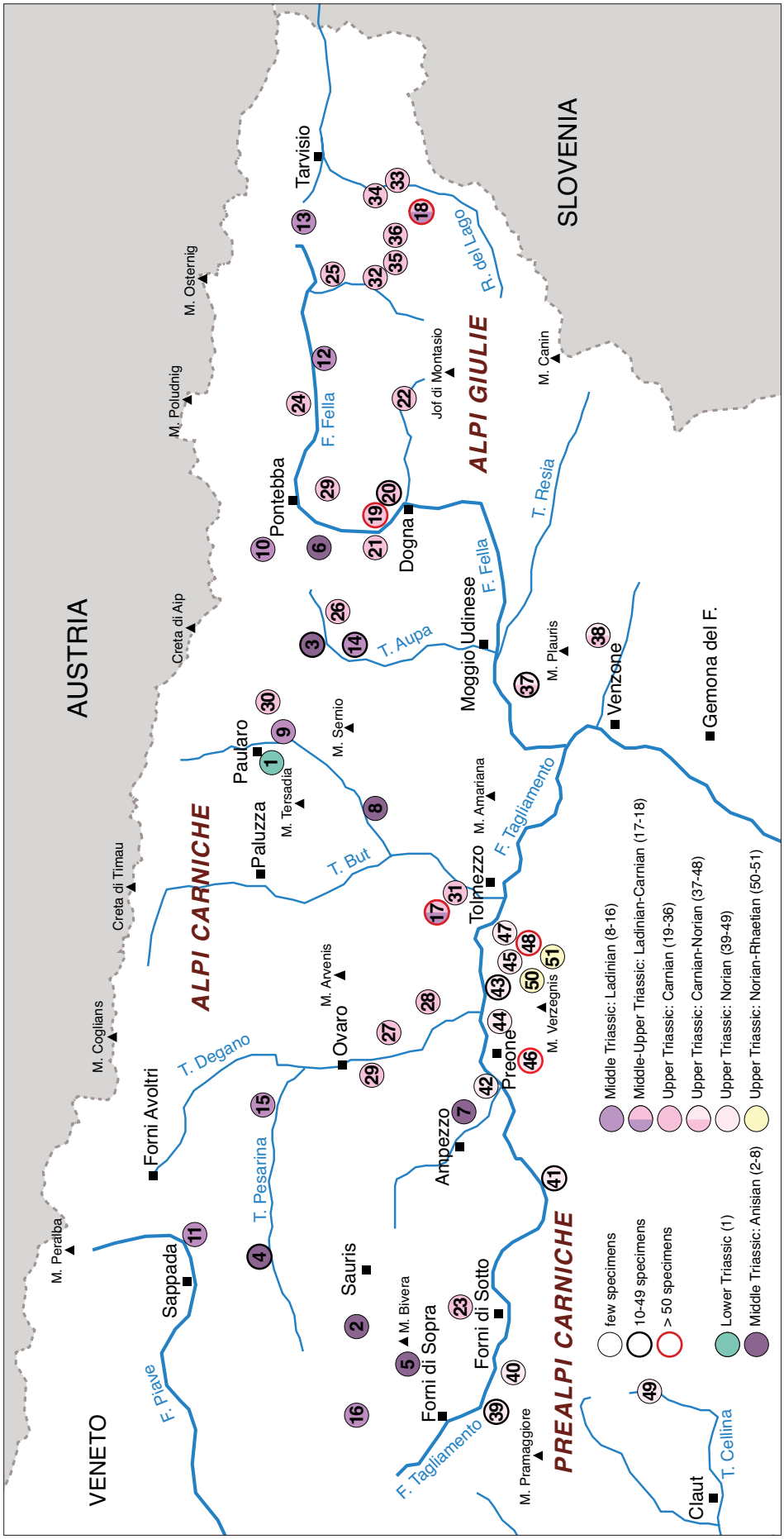


Fig. 1 - Map of the upper part of the Udine Province (Carnic and Julian Alps and Prealps) with the Triassic plant fossil localities. 1. Surroundings of Paularo; 2. Sauris: C.ra Chiansaveit, Mt. Bivera; 3. Moggio Udinese, Val Aupa: Rio Fous, Rio dell'Andri, Saps; 4. Prato Carnico, Val Pesarina: Tesis; 5. Forni di Sotto/Sauris: Mt. Bivera; 6. Pontebba: Plans, Gravon di Gleris; 7. Socchieve, Lungis: Torrente Lumiei; 8. Arta Terme: Rio Ambruseit; 9. Paularo, Dierico: Rio Peccol Lungo, Mueia and Vintulins; 10. Pontebba: Studena Bassa; 11. Sappada, Cima Sappada: Pian dei Nidi; 12. Malborghetto Valbruna: Mt. Nebria; 13. Tarvisio: Mt. Florianca, Val Bartolo; 14. Moggio Udinese, Val Aupa: Sella Bevorchians; 15. Prato Carnico, Val Pesarina: Fuina; 16. Forni di Sopra: Mt. Crusicalas; 17. Tolmezzo: Fusea; 18. Tarvisio, Cave del Predil: Rio dei Combattenti; 19. Dogna, Balador: Rio Lavaz; 20. Dogna: Rio Lavaz; 21. Dogna: Rio Pontuz; 22. Dogna: Sella Sompdogna; 23. Forni di Sotto; 24. Malborghetto Valbruna: Rio Bianco; 25. Malborghetto Valbruna; 26. Moggio Udinese, Val Aupa: Rio Broili; 27. Ovaro: Cludnico; 28. Lauco, Trava/Avaglio: Rio San Michele; 29. Ovaro, Agrons: Torrente Miozza; 30. Paularo: Rio Mueia, upper part; 31. Tolmezzo: Cazzaso, Casanova, Rio della Pieve; 32. Malborghetto Valbruna: Canale Placcia; 33. Tarvisio: Cave del Predil; 34. Tarvisio: Riofreddo; 35. Tarvisio, Val Saisera: Rio Klinken; 36. Tarvisio, Val Saisera: Canale Prasnig; 37. Resiutta: Rio Serai; 38. Lusevera, Monte Musi: Rio Zeleni; 39. Forni di Sopra: Rio Rovadia; 40. Forni di Sotto: Rio dai Clas; 41. Socchieve: Caprizzi, Borta, Priuso, Rio dei Laz, Rio Torzulis; 42. Socchieve: Mediis; 43. Enemonzo: Rio Forchiar; 44. Enemonzo: Rio Spisulò; 45. Enemonzo: Lavinal Lungo; 46. Preone: Rio Seazza, Rio Peraries, Valle di Preone, Val Tagliamento; 47. Villa Santina: Rio Plera; 48. Villa Santina: Rio Secco, 49. Claut, Grave di Gere: Ciol de la Prendera; 50. Villa Santina: Rio Secco, upper part; 51. Villa Santina: Casera Chiampomano.
- *Mappa della parte settentrionale della provincia di Udine (Alpi e Prealpi Carniche e Giulie) con le località di rinvenimento di flore triassiche.*

4 - Prato Carnico, Val Pesarina Tesis (1 specimen), Culzei (21 specimens): Voltago Conglomerate, Pelsonian
5 - Forni di Sotto/Sauris, Mt. Bivera (3 specimens)
6 - Pontebba, Plans (2 specimens), surroundings (1 specimen), Gravon di Gleris (1 specimen)
7 - Socchieve, Lungis, Torrente Lumiei (1 specimen)
8 - Arta Terme, Rio Ambruseit (1 specimen): "Torbiditi d'Aupa", Illyrian

Middle Triassic, Ladinian
9 - Paularo, Dierico, Rio Peccol Lungo, Mueia, Vintulins (6 specimen): Buchenstein Formation, Fassanian
10 - Pontebba, Studena Bassa (1 specimen)
11 - Sappada, Cima Sappada, Pian dei Nidi, Northern slope of Mt. Siera (5 specimens): Wengen Formation, Longobardian
12 - Malborghetto Valbruna, Mt. Nebria (1 specimen): Buchenstein Formation, Fassanian
13 - Tarvisio, Mt. Florianca (1 specimen), Val Bartolo (1 specimen)
14 - Moggio Udinese, Val Aupa, Sella Bevorchians (12 specimens): Buchenstein Formation, Fassanian
15 - Prato Carnico, Val Pesarina (3 specimens): Wengen Formation, Longobardian
16 - Forni di Sopra, Mt. Crusicalas (1 specimen): Mt. Regoladis Sandstone, Longobardian

Middle-Late Triassic
17 - Tolmezzo, Fusea (85 specimen, and about 1,000 fragments of carbonized plant remains): top of the Schlern Dolomite or base of the Val Degano Formation, late Ladinian-Julian, early Carnian
18 - Tarvisio, Cave del Predil, Rio dei Combattenti (48 specimen): top of the Schlern Dolomite or lower member of the Predil Limestone, late Ladinian-Carnian

Late Triassic, Carnian
19 - Dogna, Balador, Rio Lavaz (114 specimen): base of the Tor Formation
20 - Dogna, Rio Lavaz (20 specimens): base of the Tor Formation
21 - Dogna, Rio Pontuz (3 specimen): base of the Tor Formation
22 - Dogna (5 specimens), Sella Sompdogna (1 specimen): Cassian Dolomite, Julian
23 - Forni di Sotto (2 specimens)
24 - Malborghetto Valbruna, Rio Bianco (1 specimen)
25 - Malborghetto Valbruna, ascent to Mt. Lussari (2 specimen)
26 - Moggio Udinese, Val Aupa, Rio Broili (2 specimen): San Cassiano Formation, Julian
27 - Ovaro, Cludnico (1 specimen)
28 - Lauco, Trava/Avaglio, Rio San Michele (2 specimen)
29 - Ovaro, Torrente Miozza, Agrons (1 specimen): Heiligkreuz Formation, Julian-Tuvalian
30 - Paularo, upper part of Rio Mueia (1 specimen)
31 - Tolmezzo, Cazzaso and Casanova, Rio della Pieve (3 specimen)
32 - Malborghetto Valbruna, Canale Placcia (8 specimens): Predil Limestone, Julian
33 - Tarvisio, Cave del Predil/Raibl (158 specimens): Predil Limestone, Julian
34 - Tarvisio, Riofreddo (9 specimens)
35 - Tarvisio, Val Saisera, Rio Klinken (11 specimens): Predil Limestone, Julian
36 - Tarvisio, Val Saisera, Canale Prasnig (14 specimens) surroundings (11 specimen): Predil Limestone, Julian

Late Triassic, Carnian-Norian
37 - Resiutta, Rio Serai (23 specimens): Monticello Member, Main Dolomite, late Carnian(-Norian)
38 - Lusevera, Monte Musi, Rio Zeleni (3 specimens): Monticello Member, Main Dolomite, Carnian-Norian or Resartico Member of Norian age

Late Triassic, Norian
39 - Forni di Sopra, Rio Rovadia (23 specimens): Forni Dolomite, late Alaunian/early Sevatian
40 - Forni di Sotto, Rio dai Clas (2 specimens): Forni Dolomite, late Alaunian/early Sevatian
41 - Socchieve, Caprizzi, Borta, Priuso, Rio dei Laz, Rio Torzulis (14 specimens): Forni Dolomite, late Alaunian/early Sevatian
42 - Socchieve, Mediis (1 specimen): Forni Dolomite, late Alaunian/early Sevatian
43 - Enemonzo, Rio Forchiar (23 specimens): Forni Dolomite, late Alaunian/early Sevatian
44 - Enemenzo, Rio Spisulò (43 specimens): Forni Dolomite, late Alaunian/early Sevatian
45 - Enemonzo, Lavinal lungo (1 specimen): Forni Dolomite, late Alaunian/early Sevatian
46 - Preone, Rio Seazza, Rio Peraries (486 specimens): Forni Dolomite, late Alaunian/early Sevatian
46 - Preone, Valle di Preone (2 specimens), Val Tagliamento (3 specimens): Forni Dolomite, late Alaunian/early Sevatian
47 - Villa Santina, Rio Plera (4 specimens): Forni Dolomite, late Alaunian/early Sevatian
48 - Villa Santina, Rio Secco (65 specimens): Forni Dolomite, late Alaunian/early Sevatian
49 - Claut, Grave di Gere, Ciol de la Prendera (2 specimens): Bituminous levels in the Main Dolomite, Norian

Late Triassic, Norian-Rhaetian
50 - Villa Santina, Rio Secco (2 specimens): Chiampomano Limestone, late Norian-Rhaetian
51 - Villa Santina, Casera Chiampomano (2 specimens): Chiampomano Limestone, late Norian-Rhaetian.

Age		Anisian					Ladinian						L/C	Carnian					C/N	Norian							R
Localities in this paper		Monte Bivera	Pontebba	Moggio Udinese, Val Aupa	Val Pesarina	Val Tagliamento	Bevorchians, Val Aupa	Dierico, Paularo	Tarvisio and surroundings	Malboghetto	Sappada	Unknown locality Carnic Alps	Fusea, Tolmezzo	Balador, Dogna	Tarvisiano, recent samplings	Val Aupa, Moggio Udinese	Cave del Predil/Raibl, Riofreddo/Kaltwas. (hist)	Rio Prasnig	Rio Serai	upper Val Tagliamento	Preone, surroundings	Rio Forchiar	Rio Rovadia	Rio Seazza, other localities	Rio Secco di Villa Santina	Socchieve	Rio Secco di Villa Santina
Lycophytes	*Lycopia dezanchei*				cf.																						
Horsetails	*Equisetites arenaceus*			cf.		x											x										
	Equisetites sp.			x									x				x										
	sphenophyte indet.		x	x					x		x					x								x		
Ferns	*Anomopteris mougeotii*		x	x	x				x																		
	Chiropteris lacerata																x										
	Cladophlebis leuthardtii										x						?										
	Cladophlebis ruetimeyeri																x										
	Clathropteris spp.*																x										
	Danaeopsis sp.												x				x										
	Gordonopteris lorigae										x																
	Neuropteridium elegans										x						x										
	Neuropteridium grandifolium																x										
	*Rhacopteris raiblensis**																x										
	*Rhacophyllum crispatum**																x										
	Rhacopteris sp.*																x										
	"*Speirocarpus*" sp.*																x										
Seed ferns	*Peltaspermum* sp.				x																						
	Ptilozamites sandbergeri											x		x	x		x										
	Sagenopteris sp.																x										
Cycads	*Cycadites suessii**																x										
	Dioonitocarpidium sp.																x										
	Macropterygium bronnii																x										
	Macrotaeniopteris sp.																x										
	Nilssonia sp.																										x
Bennettitales	*Pterophyllum filicoides**																x										
	*Pterophyllum giganteum**																x										
	Pterophyllum sp.*																?										
Conifers	*Albertia* sp.				x																						
	Brachyphyllum sp.																x	x			x			x			
	*Cephalotaxites raiblensis**																x										
	Pagiophyllum sp.																				x	x	x	x		x	
	Pelourdea vogesiaca				x									x			x			x	x	x	x	x	x	x	
	Pelourdea sp.													x			x	x		x	x	x	x	x	x	x	
	Podozamites sp.*																?										
	Voltzia dolomitica						cf.			x	x																
	Voltzia edithae				cf.																						
	Voltzia foetterlei										x						x										
	Voltzia haueri													x			x										
	Voltzia raiblensis																x										
	Voltzia recubariensis				x																						
	Voltzia spp.				x		x	x			x		x	x	x	x	x	x	x	x	x	x		x	x	x	
	Cheirolepidiaceae-type conifer																				x	x	x	x	x		x
	Walchiaceae-type conifer													x													
	female conifer cone						x											x	x	x	x	x	x	x		x	x
	Willsiostrobus sp.													x								x		x			
	ovuliferous complex		x																		x			x			
Incertae sedis	*Carpolithes* sp.				x		x				x													x	x		
	Phylladelphia strigata																x										
	Taeniopteris sp.										x																
	Radicites sp.																							x			
	charcoal	x											x											x			

Tab. I - Stratigraphic distribution of the plant taxa in the main fossiliferous sites of the Triassic of the Udine Province. Taxa marked with * are taken from literature without any taxonomical revision.

- *Distribuzione stratigrafica dei taxa vegetali nei principali siti fossiliferi del Triassico della provincia di Udine. I taxa indicati con * sono tratti dalla letteratura senza alcuna revisione tassonomica.*

Fig. 2 - Werfen Formation, locality 1, surroundings of Paularo: sphenophyte stem fragment, MFSNgp 999.
- *Formazione di Werfen, località 1, dintorni di Paularo: frammento di ramo di sfenofita, MFSNgp 999.*

Details of the most important fossiliferous outcrops

Moggio Udinese, Val Aupa (Rio dell'Andri, outcrop 3 in Fig. 1) yielded plant fossils (site 6 in Dalla Vecchia 2006, and site 9 in Dalla Vecchia 2018) mainly from the "Torbiditi d'Aupa", an Illyrian (late Anisian) formation deposited in a shallow water environment, probably in proximity of the so-called "Anisian Paleocarnic Ridge". The main outcrop is famous for its mostly marine reptiles (e.g., Dalla Vecchia 2008, 2021) including specimens of tanystropheids, ichthyosaurs, nothosaurs, and archosaurs. Close to this locality lies Sella Bevorchians (outcrop 14 in Fig. 1), which is famous for its historical findings of invertebrates (Gortani & Desio 1927). These findings are mainly derived from geological mapping activities by Michele Gortani (1893-1966), who assigned the sediments to the Buchenstein Formation (Fassanian, early Ladinian).

At Prato Carnico, Val Pesarina (outcrop 4 in Fig. 1), some macrofloral remains have been found during road construction on a forest trackway leading from Tesis to the Passo Siera. They were embedded in yellow to light brown sandstones and pelites belonging to the Voltago Conglomerate (sensu Venturini ed. 2009), which is Pelsonian (Anisian) in age.

At Fusea, 2 km northwest of Tolmezzo (outcrop 17 in Fig. 1), scientific excavations have been carried out by the Museo Friulano di Storia Naturale of Udine to collect vertebrate remains. Numerous plant fossils were collected as well, although about 1000 specimens correspond to indeterminate carbonized fragments. The most interesting fossiliferous beds are at the boundary between the top of the Schlern Dolomite and the base of the Val Degano Formation, representing the Ladinian-Carnian transitional zone or the early Carnian (e.g., Venturini et al. 2009; Dalla Vecchia & Simonetto 2018).

Near Tarvisio, Cave del Predil and Rio dei Combattenti (outcrop 18 in Fig. 1), one of the excavation sites of the Museo Friulano di Storia Naturale of Udine crops out. During excavations for fossil fishes (e.g., Tintori & Castelnuovo 2023), several plant fossils were collected as well. The outcrop is at the boundary between the Schlern Dolomite and the lower member of the Predil Limestone; the fossiliferous horizon is in the lower member of the Predil Limestone and is Carnian in age (Roghi 2004; Dal Corso et al. 2018). The fish association, however, suggests that these levels could still belong to the Ladinian (Pers. Comm. Tintori; Tintori & Castelnuovo 2023). Plant fossils were found in other sites of this area (the well-known Cave del Predil/Raibl, Canale Prasnig, Rio Klinken; localities 33-36 in Fig. 1) within the Carnian Predil Limestone (Julian; *Trachyceras aon* Subzone-base of the *Austrotrachyceras austriacum* Zone).

In the surroundings of Dogna (Rio Lavaz, Balador; outcrops 19-20 in Fig. 1, probably the same locality), a succession of the Carnian (lower part of the Tor Formation) crops out, composed of clays, marls, and bioturbated to nodular wackestone-packstones, that yield a rich reptile fauna (placodonts, eusauropterygians, etc.) and also numerous plant fossils (Dalla Vecchia & Simonetto 2018). The Triassic macroflora has been described by Roghi et al. (2006) and dated to the early Carnian.

South of Resiutta, at the base of the Mt. Plauris massif (Rio Serai, outcrop 37 in Fig. 1), the Monticello Member crops out, at the base of the Main Dolomite (in German literature Hauptdolomit, in Italian Dolomia

Principale) in this area (Ponton 2017). It is a succession of 300 m of dark dolomites and marls, but in the Rio Serai, the Val Resia Fault reduces it to a thickness of 100 m. The unit is dated late Carnian (Roghi & Dalla Vecchia 1997; Gianolla et al. 2003). Probably, the same unit crops out on the southern flank of the Mt. Plauris massif (outcrop 38 in Fig. 1). The detailed chronostratigraphic position of the fossiliferous horizons is currently under investigation to determine the age more precisely.

The Norian Forni Dolomite crops out in several outcrops (late Alaunian/early Sevatian) that are rich in plant fossils, invertebrates and vertebrates (Roghi et al. 1995). The best-known fossiliferous locality is the Rio Seazza valley (Preone) from where more than 500 specimens are stored today at the Museo Friulano di Storia Naturale of Udine (Dalla Vecchia 2012). The Forni Dolomite is a succession that originated in an anoxic basin in proximity to the Main Dolomite platform. It is over 700 m thick and constits mainly of black to light brown dolomite sometimes with chert.

The plant fossil assemblages

The Early Triassic plant fossil assemblage

The so far only specimen of Early Triassic age in the region comes from the Werfen Formation in the surroundings of Paularo (MFSNgp 999; Fig. 2). The specimen is an internal mold of a long sphenophyte stem with the typical impressions of the vascular bundles on the outer surface. The specimen does not show any division into nodes and internodes, which could also be due the fact that the stem fragment is partially covered by sediment.

The Anisian (Middle Triassic) plant fossil assemblage

The Anisian flora is more diverse. Lycophytes are represented by two axis fragments from Val Pesarina resembling *Lycopia dezanchei* Kustatscher et al., 2010, originally described from the Pelsonian of the Kühwiesenkopf/Monte Prà della Vacca (Kustatscher et al. 2010a). The sphenophytes are represented by *Equisetites arenaceus* (Jaeger) Schenk, 1864 axis fragments (Fig. 3/b) and smaller stem fragments that cannot be assigned to any species (Fig. 3/a). The ferns are represented only by frond fragments of *Anomopteris mougeotii* Brongniart, 1828 (Fig. 3/c). While the neighbouring Anisian floras of the Dolomites have generally diverse fern associations, including genera such as *Neuropteridium* (Schimper) Weiss, 1869, *Cladophlebis* Brongniart, 1849, and *Gordonopteris* Van Konijnenburg-van Cittert et al., 2006 (Van Konijnenburg-van Cittert et al. 2006; Kustatscher et al. 2009; 2010; 2011b; Val di Non, Agordo, Predazzo), these seem to be missing so far in the outcrops of the Udine Province. The seed ferns are represented by a female reproductive organ assigned to *Peltaspermum* sp. (Fig. 3/d). No cycadophytes were found so far from the Anisian of the Udine Province, whereas conifers are represented by the most characteristic Middle Triassic genera such as *Albertia* Schimper in Voltz, 1837 (Fig. 3/e, h) and *Voltzia* Brongniart, 1828 (Fig. 3/f). Whereas the fragments belonging to *Albertia* could not be assigned to any species, among the fragments assigned to the genus *Voltzia*, the species *Voltzia recubariensis* (De Zigno, 1862) Schenk, 1868 and shoot fragments resembling *Voltzia edithae* Forte et al., 2022 could be identified. Other fragments, too poorly preserved for a detailed determination, are assigned to *Voltzia* spp. The typical Middle Triassic large-leaved conifer *Pelourdea vogesiaca* (Schimper et Mougeot) Seward, 1917 and ovuliferous seed complexes are also present (Fig. 3/g). From the area of Val Pesarina, which has so far yielded the most diverse plant fossil assemblage, two seeds of uncertain affinity (*Carpolithes* sp.) are stored in the collections, whereas fragments of Anisian charcoal were found at the Monte Bivera.

The Ladinian (Middle Triassic) plant fossil assemblage

The Ladinian flora of Udine Province is of similar diversity as the Anisian one. No confidently identified lycophyte or cycadophyte remains have been found so far, and sphenophyte axis fragments are too poorly preserved to permit any attribution at the genus level. Also, the specimens mentioned by Leonardi (1964) as *Equisetites* sp. are not well enough preserved to be assigned to this genus. Frond fragments belong to the typical Middle Triassic ferns *Anomopteris mougeotii* (Fig. 4/e) or *Neuropteridium* sp., and seed ferns by leaf fragments of *Ptilozamites sandbergeri* (Schenk) Kustatscher et Van Konijnenburg-van Cittert, 2007 (Fig. 4/d). The conifers are represented by branch and shoot fragments of *Voltzia dolomitica* Wachtler et Van Konijnenburg-van Cittert, 2001 and further *Voltzia* sp. shoot fragments (Fig. 4/a, c, f) too poorly preserved for a determination at species level. Seeds and female cones (Fig. 4/b) have also been identified. The macrofloral composition for most localities (Tab. I) is established based on the collections in the Museo Friulano di Storia Naturale of Udine, except for the plant fossil assemblage from Sappada, which is based on the revision of a paper by Giuseppe Leonardi (1964), since the location of the original material is unknown.

The Carnian (Late Triassic) plant fossil assemblage

The Carnian flora of the Udine Province includes the historical localities Cave del Predil/Raibl and Riofreddo/

Fig. 3 - Anisian, locality 3, Moggio Udinese, Val Aupa: a) *Equisetites* sp., MFSNgp 46841; c) *Anomopteris mougeotii*, MFSNgp 46838; locality 7, Socchieve, Lungis, Torrente Lumiei: b) *Equisetites arenaceus*, MFSNgp 49430; locality 4, Prato Carnico: d) *Peltaspermum* sp., MFSNgp 26603; e) *Albertia* sp., MFSNgp 26559; f) *Voltzia recubariensis*, MFSNgp 26802; h) *Albertia* sp., MFSNgp 40373; locality 6, Pontebba: g) ovuliferous seed complex, MFSNgp 37548.

- *Anisico, località 3, Moggio Udinese, Val Aupa: a)* Equisetites *sp., MFSNgp 46841; c)* Anomopteris mougeotii, *MFSNgp 46838; località 7, Socchieve, Lungis, Torrente Lumiei: b)* Equisetites arenaceus, *MFSNgp 49430; località 4, Prato Carnico: d)* Peltaspermum *sp., MFSNgp 26603; e)* Albertia *sp., MFSNgp 26559; f)* Voltzia recubariensis, *MFSNgp 26802; h)* Albertia *sp., MFSNgp 40373; località 6, Pontebba: g) complesso ovulifero, MFSNgp 37548.*

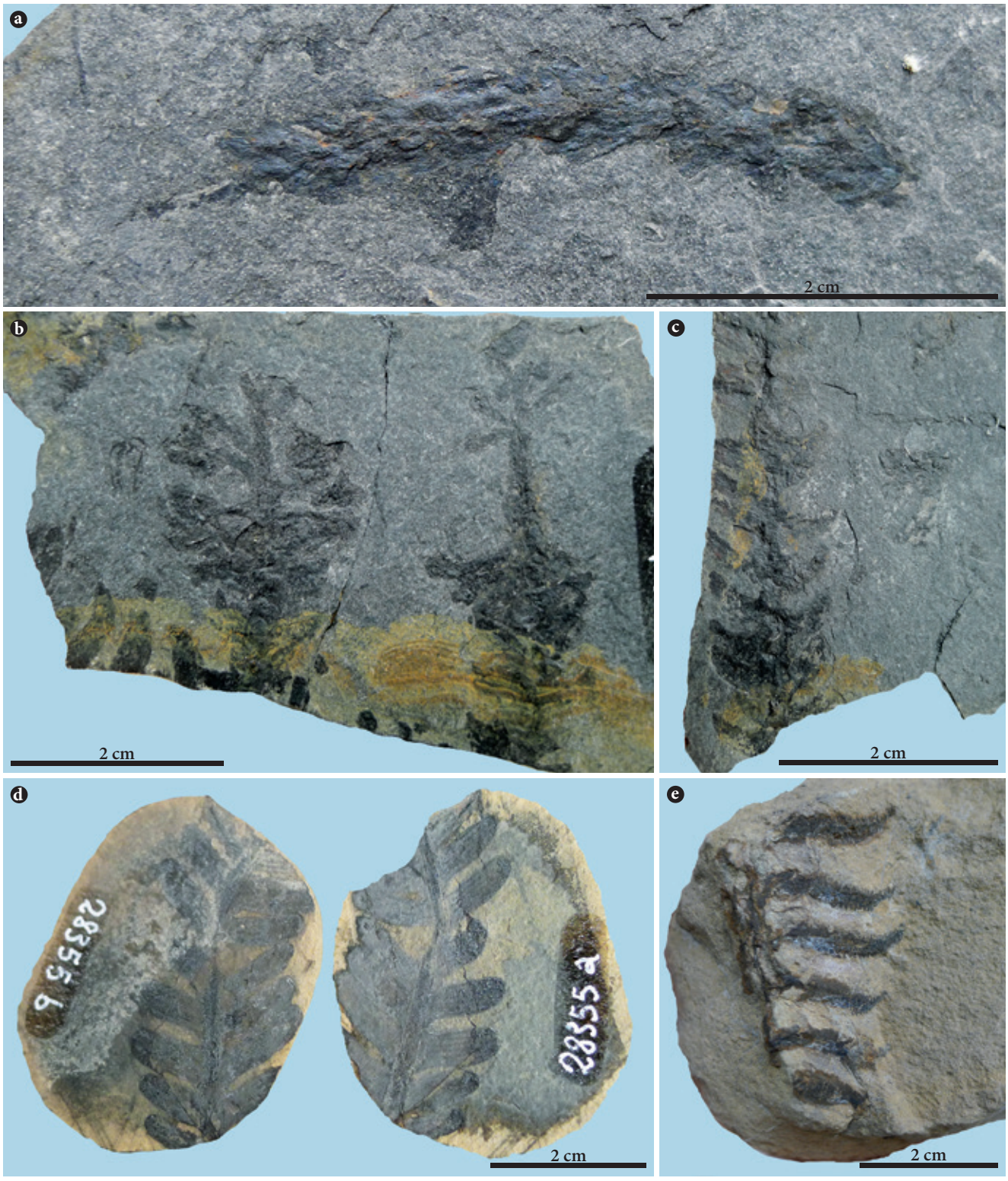


Fig. 4 - Ladinian, locality 14, Moggio Udinese, Sella Bevorchians: a) *Voltzia* sp., MFSNgp 5980; b) female cones, MFSNgp 5991; c) *Voltzia* sp., MFSNgp 5990; unknown locality of Carnic Alps: d) *Ptilozamites sandbergeri*, MFSNgp 28355; locality 13, Tarvisio: e) *Anomopteris mougeotii*, MFSNgp 37634; locality 9, Paularo, Dierico: f) *Voltzia* sp., MFSNgp 28332.
- *Ladinico, località 14, Moggio Udinese, Sella Bevorchians: a)* Voltzia *sp., MFSNgp 5980; b) cono femminile, MFSNgp 5991; c)* Voltzia *sp., MFSNgp 5990; località sconosciuta delle Alpi Carniche: d)* Ptilozamites sandbergeri, *MFSNgp 28355; località 13, Tarvisio: e)* Anomopteris mougeotii, *MFSNgp 37634; località 9, Paularo, Dierico: f)* Voltzia *sp., MFSNgp 28332.*

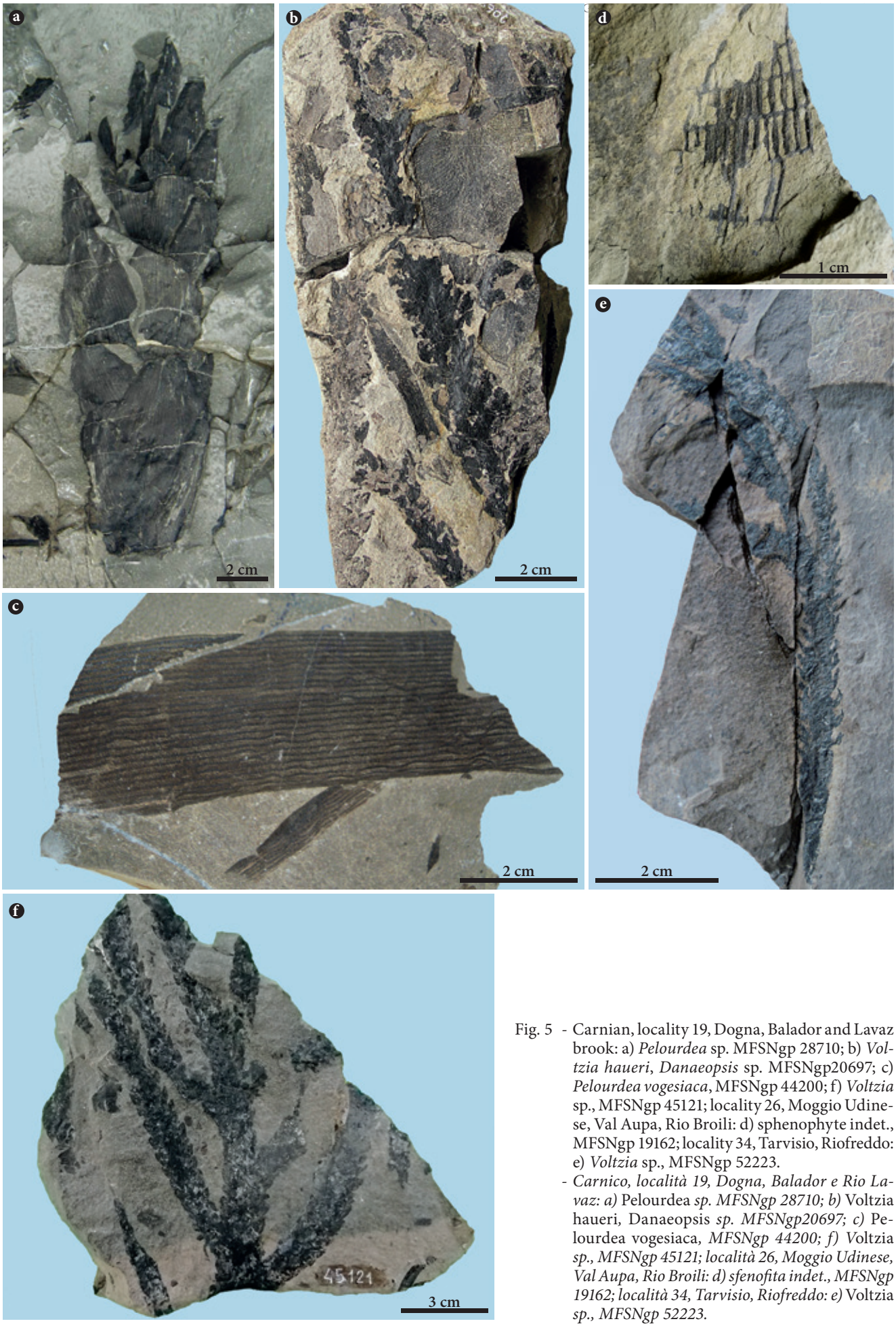


Fig. 5 - Carnian, locality 19, Dogna, Balador and Lavaz brook: a) *Pelourdea* sp. MFSNgp 28710; b) *Voltzia haueri*, *Danaeopsis* sp. MFSNgp20697; c) *Pelourdea vogesiaca*, MFSNgp 44200; f) *Voltzia* sp., MFSNgp 45121; locality 26, Moggio Udinese, Val Aupa, Rio Broili: d) sphenophyte indet., MFSNgp 19162; locality 34, Tarvisio, Riofreddo: e) *Voltzia* sp., MFSNgp 52223.

- *Carnico, località 19, Dogna, Balador e Rio Lavaz: a)* Pelourdea *sp. MFSNgp 28710; b)* Voltzia haueri, Danaeopsis *sp. MFSNgp20697; c)* Pelourdea vogesiaca, *MFSNgp 44200; f)* Voltzia *sp., MFSNgp 45121; località 26, Moggio Udinese, Val Aupa, Rio Broili: d) sfenofita indet., MFSNgp 19162; località 34, Tarvisio, Riofreddo: e)* Voltzia *sp., MFSNgp 52223.*

Fig. 6 - Carnian, locality 33, Tarvisio, Cave del Predil/Raibl (historical collection, Wien): a) fern indet., CP Raibl 5; b) *Cladophlebis* sp., GBA2007-072-0012; c) *Macropterygium bronnii*, GBA2007-072-0047; d) *Ptilozamites sandbergeri*, GBA2005-0008-004; e) *Pterophyllum* sp., GBA2007-072-0078; f) *Macrotaeniopteris* sp., GBA2007-072-0070; g) *Pelourdea vogesiaca*, GBA1986-2-128A; h) *Voltzia haueri*, GBA2007-072-0063; i) *Voltzia* sp., GBA1986 2 6; l) *Voltzia foetterlei*, GBA1986-2-12; m) *Phylladelphia strigata*, GBA2007-072-0013A.

- *Carnico, località 33, Cave del Predil/Raibl (Collezioni storiche, Vienna): a) felce indet., CP Raibl 5; b)* Cladophlebis *sp., GBA2007-072-0012; c)* Macropterygium bronnii, *GBA2007-072-0047; d)* Ptilozamites sandbergeri, *GBA2005-0008-004; e)* Pterophyllum *sp., GBA2007-072-0078; f)* Macrotaeniopteris *sp., GBA2007-072-0070; g)* Pelourdea vogesiaca, *GBA1986-2-128A; h)* Voltzia haueri, *GBA2007-072-0063; i)* Voltzia *sp., GBA1986 2 6; l)* Voltzia foetterlei, *GBA1986-2-12; m)* Phylladelphia strigata, *GBA2007-072-0013A*.

Kaltwasser. These are the most diverse and best-sampled fossiliferous outcrops of Carnian age in the Udine Province. The Cave del Predil/Raibl and Riofreddo/Kaltwasser collections stored at the Natural History Museum Vienna and GeoSphere Austria evidence how rich and diverse the Carnian flora of the Southern Alps has been (for the historical lists, partly revised here, see Bronn 1858; Schenk 1866-67, Stur 1868a; 1885; Dobruskina et al. 2001). These collections include, among the sphenophytes, internal stem casts and stem fragments belonging to *Equisetites arenaceus* (Kustatscher et al. 2011a, 2019). The fern frond fragments (Fig. 6/a) belong to the Marattiales (*Danaeopsis* sp., *Rhacopteris raiblensis* Stur, 1885, *Rhacophyllum crispatum* (Münster in Sternberg) Kustatscher et Van Konijnenburg-van Cittert, 2011), Osmundaceae (Fig. 6/b, *Cladophlebis* cf. *leuthardtii* Leonardi, 1953, *C. ruetimeyeri* (Heer) Leonardi, 1953, *Neuropteridium elegans* (Brongniart) Schimper, 1879, *N. grandifolium* (Schimper et Mougeot) Compter, 1883, *Speirocarpus* sp.), Dipteridaceae (*Clathropteris* spp.), or are of uncertain botanical affinity (*Chiropteris lacerata* (Quenstedt) Rühle von Lilienstern, 1931). The seed ferns are represented by simple pinnate leaves of *Ptilozamites sandbergeri* (Fig. 6/d) and leaflets of *Sagenopteris* sp. The first undisputed Bennettitales leaves (*Pterophyllum giganteum* Schenk, 1865, *Pt. filicoides* (Schlotheim) Zeiller, 1906; Fig. 6/e) in the Italian fossil record appear during the Carnian. The cycads include leaves of *Macropterygium bronnii* (Schenk) Weber, 1996 (Fig. 6/c) and *Macrotaeniopteris* sp. (Fig. 6/f), as well as fragments of macrosporophylls assignable to *Dioonitocarpidium* sp. and *Cycadites suessii* Stur, 1885 (e.g., Stur 1885; Dobruskina et al. 2001; Kustatscher et al. 2019). Conifers are dominated by shoot fragments of several *Voltzia* species, such as *V. foetterlei* Stur, 1885 (Fig. 6/l), *V. haueri* Stur, 1885 (Fig. 6/h), and *Voltzia* sp. (Fig. 6/i). *Brachyphyllum* sp. and *Cephalotaxites raiblensis* Stur, 1885 (Dobruskina et al., 2001; Kustatscher et al., 2019) occur more rarely. Long lanceolate leaves, historically assigned to the genus *Noeggerathia* Sternberg, 1821 (Bronn, 1858), are here assigned to *Pelourdea vogesiaca* (Fig. 6/g). *Phylladelphia strigata* Bronn, 1858 (Fig. 6/m) is of unknown botanical affinity (Kustatscher & Van Konijnenburg-van Cittert 2008).

The other plant fossil assemblages besides Cave del Predil/Raibl and Riofreddo/Kaltwasser include mainly undetermined axis fragments of sphenophytes (Fig. 5/d), pinnae fragments of *Danaeopsis* sp. (Fig. 5/b)

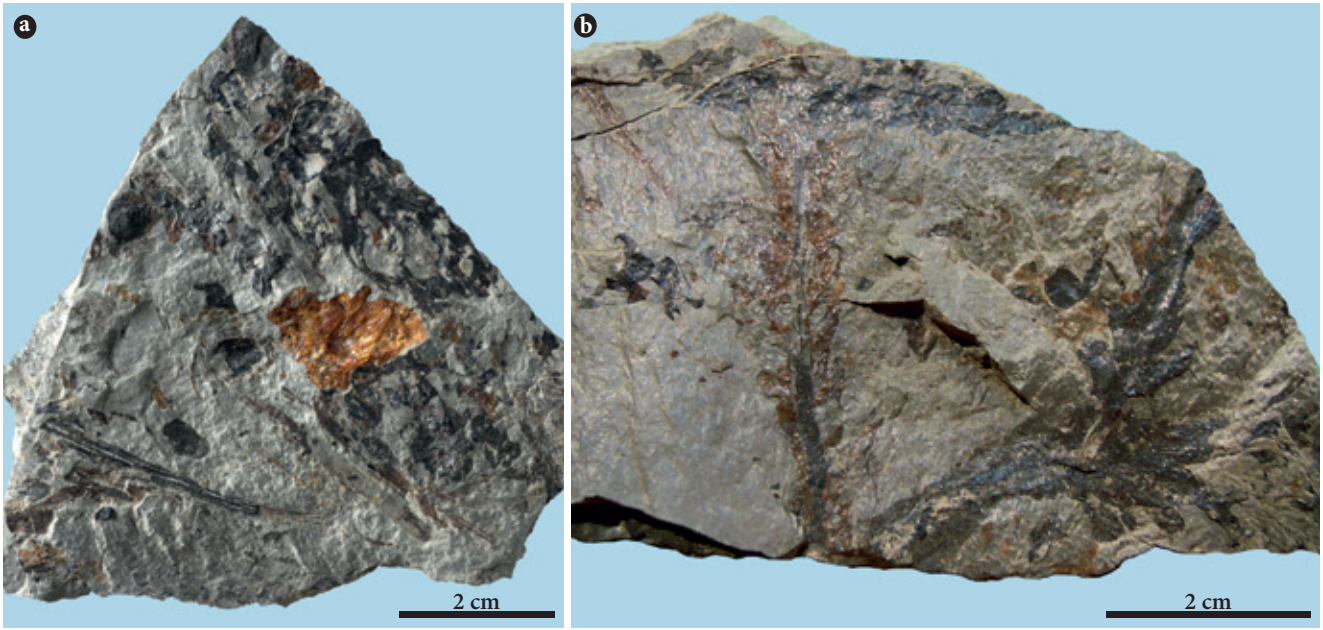
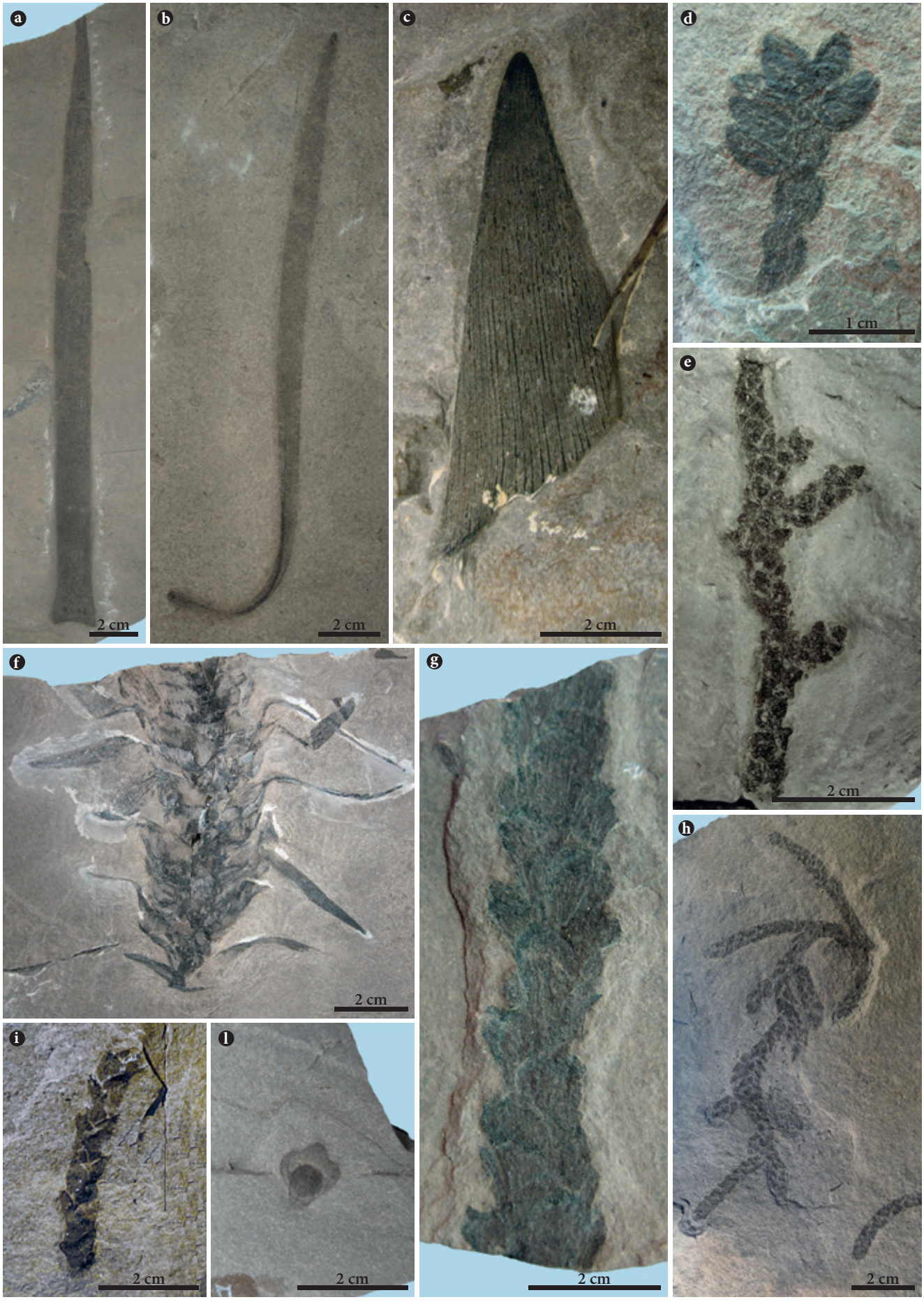


Fig. 7 - Carnian-Norian, locality 37, Resiutta, Rio Serai: a) amber, MFSNgp 42540; b) amber and *Voltzia* sp., MFSNgp 42544.
- *Carnico-Norico, località 37, Resiutta, Rio Serai: a) ambra, MFSNgp 42540; b) ambra e* Voltzia *sp., MFSNgp 42544.*

Fig. 8 - Norian, locality 46, Preone, Rio Seazza: a) *Pelourdea vogesiaca*, MFSNgp 1826; b) *Pelourdea* sp., MFSNgp 5560; c) *Pelourdea* sp., MFSNgp 16039; d) *Brachyphyllum* sp., MFSNgp 5551; l) ovuliferous seed complex, MFSNgp 44397; locality 43, Enemonzo, Rio Forchiar: e) *Brachyphyllum* sp., MFSNgp 50365; f) *Pelourdea* sp. attached to its stem, MFSNgp 40305; locality 41, Socchieve, Caprizzi, Borta: g) shoot fragment of cheirolepidiaceous conifer, MFSNgp 5572; i) *Pagiophyllum* sp., MFSNgp 34282; locality 39, Forni di Sopra, Rio Rovadia: h) *Brachyphyllum* sp., MFSNgp 40306.
- *Norico, località 46, Preone, Rio Seazza: a)* Pelourdea vogesiaca*, MFSNgp 1826; b)* Pelourdea *sp., MFSNgp 5560; c)* Pelourdea *sp., MFSNgp 16039; d)* Brachyphyllum *sp., MFSNgp 5551; l) complesso ovulifero, MFSNgp 44397; località 43, Enemonzo, Rio Forchiar: e)* Brachyphyllum *sp., MFSNgp 50365; f)* Pelourdea *sp. attaccata al suo ramo, MFSNgp 40305; località 41, Socchieve, Caprizzi, Borta: g) frammento di conifera cheirolepidiacea, MFSNgp 5572; i)* Pagiophyllum *sp., MFSNgp 34282; località 39, Forni di Sopra, Rio Rovadia: h)* Brachyphyllum *sp., MFSNgp 40306.*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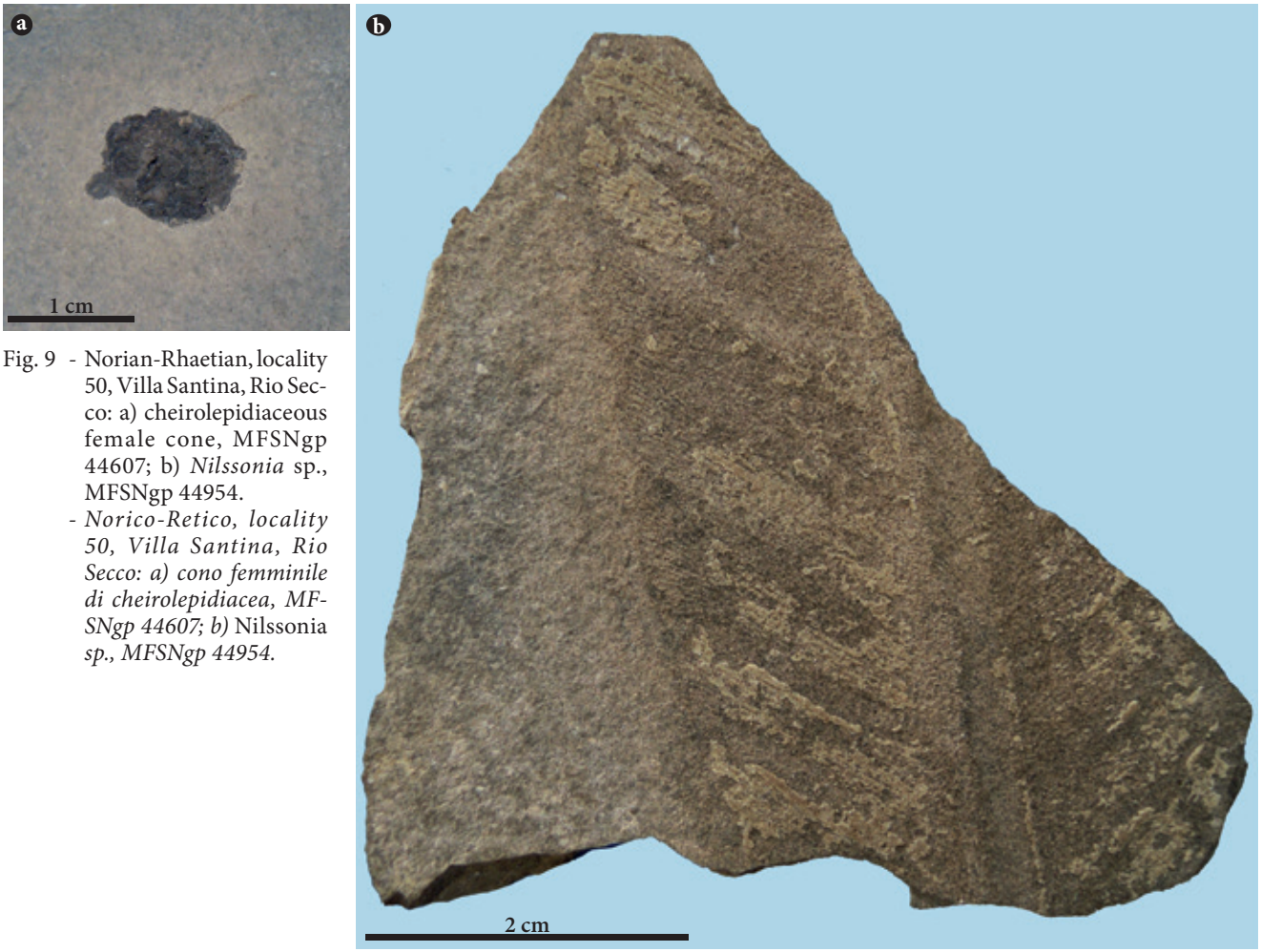

Fig. 9 - Norian-Rhaetian, locality 50, Villa Santina, Rio Secco: a) cheirolepidiaceous female cone, MFSNgp 44607; b) *Nilssonia* sp., MFSNgp 44954.
- *Norico-Retico, locality 50, Villa Santina, Rio Secco: a) cono femminile di cheirolepidiacea, MFSNgp 44607; b)* Nilssonia *sp., MFSNgp 44954.*

among the ferns, leaf fragments of *Ptilozamites sandbergeri* among the seed ferns, and among the conifers the broad-leaved genus *Pelourdea* Seward, 1917 (Fig. 5/a, c), as well as branches and shoots of the needle-leaved conifer genus *Voltzia* (Fig. 5/b, e, f). The shoots assigned to *Voltzia* spp. are, however, heterogeneous and include several species. This is obvious not only in their macromorphology but also in their cuticle characters. Conifer shoot fragments from Dibona yielded cuticles showing that among the conifers at least three different groups can be distinguished. These include *Voltzia haueri*, a conifer with big and stout leaves that detach distinctively from the axis. The second taxon is characterized by smaller shoots bearing delicate leaves with typically cheirolepidiaceous cuticles, whereas the third conifer type has falcate, strongly embricate leaves with a cuticle resembling the Permian family Walchiaceae (Roghi et al. 2006a; 2006b).

In addition to these remains, Dalla Vecchia (2000) mentioned and figured a female conifer cone, at least two different types of *Voltzia* shoots, a fragment of a *Pelourdea* leaf from Rio Prasnig, stored at the Museo Paleontologico Cittadino di Monfalcone (MPCM), and several elongated leaves stored at the Museum "Capellini" of Bologna.

The Carnian-Norian (Late Triassic) plant fossil assemblage

The Carnian-Norian plant fossil assemblages are restricted to the localities Resiutta, Rio Serai, and Lusevera, Monte Musi, where plant remains were found in the Monticello Member of the Hauptdolomit/Dolomia Principale. The few plant remains are, however, exceptional since not only Voltzian-type conifers (Fig. 7/b), but also amber (Fig. 7/a) were found.

The Norian (Late Triassic) plant fossil assemblage

The Norian outcrops yielding plant fossils in the Southern Alps are so far restricted to the Udine Province, almost all records stem from the Forni Dolomite in the Carnic Prealps (Dalla Vecchia 2000; 2012). Most plant remains are conifer shoots, primarily shoot fragments assignable to the genera *Voltzia*, *Elatocladus* Halle, 1913 or *Pagiophyllum* Heer, 1881. Specimens of the genus *Voltzia* include several morphotypes that are not described in detail in this paper, suggesting a higher diversity of taxa. These include shoot fragments with triangular, strongly imbricating leaves (Fig. 8/e, h) similar to those assigned to *Brachyphyllum* sp. 2

by Kustatscher et al. (2017) from the Norian flora of Seefeld and *Brachyphyllum* Brongniart, 1828 by Dalla Vecchia (2012, fig. 8.159-160). Conifer shoots with more elongated leaves with a rounded apex that are almost perpendicularly attached to the axis (Fig. 8/d) resemble *Brachyphyllum* sp. 3 *sensu* Kustatscher et al. (2017) and are partly figured by Dalla Vecchia (2012, fig. 8.165) as fertile conifer remains. The shoot fragments here assigned in general to the genus *Pagiophyllum* with longer, falciform leaves with a pointed apex (Fig. 8/i) resemble *Pagiophyllum* sp. 1, *Pagiophyllum* sp. 2, and *Pagiophyllum* sp. 3 *sensu* Kustatscher et al. (2017) or *Pagiophyllum sensu* Dalla Vecchia (2012, fig. 8.161). Dalla Vecchia (2012, fig. 8.162) assigned some of the shoots to the genus *Cyparissidium*, an assignment that needs further investigation. In addition to the shoot fragments of cheirolepidiaceous conifers (Fig. 8/g) with thick, broad leaves (indet. conifer in Dalla Vecchia 2012, fig. 8.164), several types of female cones, ovuliferous seed complexes (Fig. 8/l), and male cones have been found. Leaves and leaf fragments of *Pelourdea*, perhaps *Pelourdea vogesiaca* (Fig. 8/a), are also present. However, there are clearly morphological differences within this group, with the normal *Pelourdea vogesiaca* type of leaves having distinct veins (Fig. 8/a). In addition, there are also broad lanceolate leaves with a broad attachment area (Fig. 8/c), resembling the leaf fragment described by Kustatscher et al. (2017) from the Norian of Seefeld. Other leaves are much narrower and more delicate than the typical *Pelourdea* leaf (Fig. 8/b), showing folds or curvations in the leaves. These were indicated as possible bennettitalean leaves (Dalla Vecchia 2000) and later identified as leaves of *Pelourdea* (Dalla Vecchia 2012). All leaf types of *Pelourdea* are found dispersed in the sediment as well as attached to stem fragments (Fig. 8/f). In addition to the various conifer remains, there are also stem fragments of sphenophytes, various types of seeds, root fragments, and small fragments of charcoal.

The Rhaetian (Late Triassic) plant fossil assemblage

Only a few plant fossils from the Udine Province have a putatively Rhaetian age. These come from the Chiampomano Limestone. The small but stratigraphically outstanding collection includes a fragment putatively assigned to *Nilssonia* (Fig. 9/b), a putative cheirolepidiaceous type of female cone (Fig. 9/a), and a conifer shoot fragment.

Amber

Triassic amber is rare and occurs concentrated in specific intervals in the Middle and Late Triassic. The most famous amber findings come from the Carnian Heiligkreuz Formation, close to Cortina d'Ampezzo. This fossil resin is associated with conifer shoots and cuticle fragments, partly in palaeosols (Roghi et al. 2006b; 2022; Schmidt et al. 2012; Sidorchuk et al. 2015; Seyfullah et al. 2018). More amber findings come from the Carnian of Dogna in the Julian Alps (Roghi et al. 2006a) and from the Carnian-Norian transition of the Rio Serai (Resiutta) locality (Fig. 7/a). Whereas Carnian amber is found in many different localities in Europe, North America, and Southern Africa (Schmidt et al. 2012; Roghi et al. 2022), Middle Triassic amber is much rarer (Roghi et al. 2017; Forte et al. 2022). Amber production has been linked to stressed conditions during humid events in the otherwise arid

	Lycophytes	Horsetails	Ferns											Seed ferns			Cycads					Bennettitales	Conifers							Incertae sedis			
	Lycopia	*Equisetites*	*Anomopteris*	*Chiropteris*	*Cladophlebis*	*Clathropteris**	*Danaeopsis*	*Gordonopteris*	*Neuropteridium*	*Rhacophyllum**	*Rhacopteris**	*Speirocarpus**	*Peltaspermum*	*Ptilozamites*	*Sagenopteris*	*Cycadites**	*Dioonitocarpidium*	*Macrozamites*	*Macrotaeniopteris**	*Nilssonia*	*Pterophyllum*	*Albertia*	*Brachyphyllum*	*Cephalotaxites**	*Pagiophyllum*	*Pelourdea*	*Voltzia*	*Willsiostrobus*	*Carpolithes*	*Phylladelphia*	*Taeniopteris*	*Radicites*
Rhaetian?																				?							x						
Norian		o															o						x		x		x	x	x			x
Carnian-Norian																											x						
Carnian		x		x	?	x	x			x	x	x	x			x	x	x	?		x		x	x			x	x	x		x		
Ladinian		x	x	o	x		o	x	x					x			o		x	o	o?	o				o	x	o	x	x			
Anisian	x	o	x				o	o	o				x	o	o		o					x				x	x		x		o	o	

Tab. II - Chronostratigraphic occurrences of plant macrofossil genera in the Triassic of the Udine Province (x) in comparison with additional occurrences of those genera in other areas of the Southern Alps (o). Genera not described from the Udine Province are not included. Genera marked with * have been taken from literature without a taxonomical revision.

- *Presenza cronostratigrafiche dei generi di macrofossili vegetali noti per il Triassico della provincia di Udine (x) a confronto con le ulteriori presenze di tali generi in altre aree delle Alpi meridionali (o). Sono esclusi i generi non descritti per la provincia di Udine. I generi indicati con * sono tratti dalla letteratura senza revisione tassonomica.*

Triassic climate (Gianolla et al. 1998; Roghi et al. 2006b; 2017; Forte et al. 2022). The Southern Alps represent the largest Triassic amber deposit known to date.

Chronostratigraphic distribution of the plant remains

The Triassic flora of the Udine Province is diverse, with at least 50 different taxa, although the (chrono-) stratigraphic ranges of these taxa are still scattered. Some plant assemblages, such as the historical collection of the Cave del Predil/Raibl and Riofreddo/Kaltwasser areas, are extremely diverse and rich in plant taxa (32 taxa), reflecting exemplarily the richness of the Carnian flora (Tab. II). Most plant fossil assemblages are, however, less diverse and dominated by conifers. This could be because the Triassic was mainly a hot and arid period in Earth history (e.g., Preto et al. 2010 and ref. therein), but taphonomic reasons need to be considered as well. Most of these plant remains were found in basinal successions, meaning that they have been transported from the terrestrial environments where they lived with the aid of wind and water to the seaside and deposited there. This strongly influences the composition of the plant fossil assemblage because delicate plant remains will be destroyed during this transport and will be missing in the plant fossil assemblage. This includes mostly pinnate leaves such as ferns and cycadophytes as well as herbaceous plants such as lycophytes and horsetails, whereas more robust plant remains, such as conifer shoots, will be overrepresented in the fossil record.

This is well visible in the overall composition of the Triassic plant fossil assemblages of the Udine Province. The lycophytes and horsetails are represented by only one taxon each and otherwise by occasional findings of poorly preserved material that is not included in Tab. II. Ferns are diverse, and represented by ten different genera, but restricted to the Middle and early Late Triassic. The relatively high number of *taxa* is due to the richness of the historical Cave del Predil/Raibl plant fossil assemblage. The same is mostly true for seed ferns and cycadophytes, with the exception of the genus *Nilssonia*, putatively present also in the Rhaetian. The conifers, here represented by only seven genera, are more diverse than their taxonomical assignment shows, as discussed above, and are furthermore represented throughout the Triassic.

This influences, of course, the chronostratigraphic distribution of plant fossils at generic level, with only *Voltzia* being present throughout the Middle to Late Triassic in the Udine Province. Some groups like the Bennettitales, the cheirolepidiaceous conifers, as well as dipteridaceous ferns, appear for the first time in the Carnian, whereas lycophytes, horsetails, ferns, and seed ferns are missing so far in the fossil record of the Udine Province after the Carnian.

Comparison with the other plant fossil assemblages of the Southern Alps

Comparing the plant fossil assemblages of the Udine Province with those of other parts of the Southern Alps, the importance of this area for our understanding of the evolution of terrestrial ecosystems becomes quickly evident. This paper describes the so far first confident plant remains from the Werfen Formation of the Udine Province, although it is an undetermined stem fragment of a sphenophyte. It is important to note that the Lower Triassic of the Alps is generally devoid of confidently identifiable plants. The Anisian and Ladinian successions in the Udine Province have abundant plant fossils preserved, but their diversity is relatively low in comparison with some of the more important plant fossil assemblages of the Dolomites and surrounding areas, such as Kühwiesenkopf/Monte Prà della Vacca (e.g., Broglio Loriga et al. 2002; Van Konijnenburg-van Cittert et al. 2006; Kustatscher et al. 2009; 2010a; 2010b; Forte et al. 2021; 2022), Piz da Peres (Todesco et al. 2008), Seewald, Ritberg (Wachtler & Van Konijnenburg-van Cittert 2000; Kustatscher et al. 2004; Kustatscher & Van Konijnenburg-van Cittert 2005), Corvo Alto (Kustatscher & Van Konijnenburg-van Cittert 2005), Agordo (Kustatscher et al. 2011b), Monte Agnello (Kustatscher et al. 2014; Wappler et al. 2015), and Recoaro (Catullo 1846; Massalongo 1857; De Zigno 1862) among others (for more details see Kustatscher et al. 2019 and references therein). The higher diversity in those plant fossil localities relates to tens of species that have been described there but have not been found in the Udine Province so far (Tab. II).

Contrastingly, there are no known Upper Triassic fossiliferous outcrops yielding as numerous and diverse plant fossil assemblages in Northern Italy outside of the Udine Province. In the case of the Carnian, not even the Dibona section - the reference section for the Carnian Pluvial Event (Dal Corso et al. 2018; Preto et al. 2019; Roghi et al. 2022) - has yielded such a diverse plant fossil assemblage as Cave del Predil/Raibl. The only other Alpine floras comparable in diversity and abundance are Lunz (Austria; Stur 1885; 1888; Krasser 1909a; 1909b; 1917; Kräusel 1948; 1949; 1953; Pott 2007; Pott et al. 2007a: 2007b; 2007c; 2007d; 2007e; 2008a; 2008b; 2018; Pott & Krings 2010; Nowak et al. 2022; 2023) and Neuewelt (Switzerland; Schlotheim 1822; Heer 1865; Leuthardt 1903; 1904; Kräusel 1955; 1959; Kräusel & Schaarschmidt 1966). Finding similarly diverse and abundant plant fossil assemblages of Norian age is even more difficult. In the Alps, the only fossiliferous locality outside of the Udine Province so far is Seefeld (Poleschinski 1989; Dobruskina, 1993; 1994; Daxer 2015; Kustatscher et al. 2017). No other Rhaetian plant fossil assemblage has so far been described from the Alps.

Conclusions

The Triassic plant fossil assemblages from the Udine Province have been collected from 51 main outcrop areas (Fig. 1). Among these, the Cave del Predil/Raibl area (e.g., Bronn 1858; Schenk 1866-67) has been known for more than a century, but the majority of the other outcrops have not been known for plant fossils until the second part of the 20th century. The fact that the Museo Friulano di Storia Naturale of Udine today stores one of the most important plant fossil collections of the Alps is thanks to scientific excavations that have been initiated by the museum in collaboration with local citizen scientists. This first study evidences the enormous potential of the plant fossil collection, especially for studies on Late Triassic vegetation and for our understanding of the composition of terrestrial ecosystems and their evolution through time during a period of elevated species radiation and the evolution of modern fern and conifer families. The historical collection of Cave del Predil/Raibl is in urgent need of taxonomic revision, whereas the Carnian and Norian collections need a detailed study, including cuticle analyses, in order to determine the diversity among the conifers. It will only then be possible to understand the timing and dynamics of the establishment of modern plant groups.

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