

PERMIAN–TRIASSIC MACRO- AND MICROFLORAS OF THE SOUTHERN ALPS

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Extensive Permian and Triassic rock sequences crop out in numerous places in the Southern Alps and have yielded, among other things, several important palaeofloras. We here provide an overview of the stratigraphic distribution of fossil floras from the Permian and Triassic found so far in the Southern Alps (mostly northern Italy), including macrofossils as well as spore/pollen assemblages.

The Cisuralian (lower Permian) in the Southern Alps is mostly represented by the volcanic rocks of the Athesian Volcanic Complex, but with some sedimentary intercalations bearing fossils. Cisuralian plant fossils have been found in Collio in the Val Tompia (Collio Formation; Sakmarian–Artinskian; Remy & Remy, 1978), Sinich/Sinigo in the Etsch/Adige Valley (upper Artinskian; Fritz & Krainer, 2006), Tregiovo in the Val di Non (Tregiovo Formation, Kungurian; Forte et al., 2018) and Gerola Alta in the Orobic Alps (Ponteranica Conglomerate, undated; Kerp et al., 1996). Spores and pollen have also been found in Collio (Cassinis & Doubinger, 1991), Sinich/Sinigo (Hartkopf-Fröder et al., 2001) and Tregiovo (Forte et al., 2018), as well as in some chert layers within the Athesian Volcanic Complex (Hartkopf-Fröder et al., 2001).

No plant fossils of Guadalupian (middle Permian) age are known from the Southern Alps, although the basal part of the fossiliferous Gröden/Val Gardena Formation (also known as Grödner Sandstein/Arenarie di Val Gardena) may represent the latest Guadalupian (Capitanian). The main part of the Gröden/Val Gardena Fm. covers the Wuchiapingian (lower Lopingian = upper Permian), and it may reach the Changhsingian (upper Lopingian) in some places. Palaeofloras of the middle–upper Wuchiapingian were found in the Gröden/Val Gardena Fm. in the Bletterbach Gorge of the Dolomites (Kustatscher et al., 2017). Plant macrofossil assemblages of the Gröden/Val Gardena Fm. with uncertain ages are known from several localities in the Dolomites (Cuecenes, Sankt Ulrich/Ortisei: Florin, 1964; Alpe di Siusi/Seiser Alm: Jung, 1977; the Rosengarten/Catinaccio Massif: Kustatscher et al., 2014) as well as from Mölten/Meltina (Krainer, 2000), Auer/Ora (Leonardi, 1948), the Val di Non (Kustatscher et al., 2014), Recoaro (Vicentinian Alps; Massalongo, 1863; Gümbel, 1879), Somor, and the Passo San Pellegrino. Another upper Permian palaeoflora has been reported from Valtellina (Sondrio) in the Orobic Alps (Brambilla et al., 1989). The presence of spore/pollen assemblages is apparently common throughout the Gröden/Val Gardena Fm. in the Dolomites (Klaus, 1963; Massari et al., 1994). The Gröden/Val Gardena Fm. is overlain by the Changhsingian Bellerophon Formation. This formation is primarily marine and mostly void

of macroscopic plant fossils except for nondescript root casts (in the Western Dolomites), but a well-preserved fossil flora has now been found near Seis/Siusi. In addition, some roots in body preservation are present at the top of the Bellerophon Fm. in the Bletterbach Gorge. The Bellerophon Fm. in the Dolomites is generally rich in palynofloras with well-preserved spores and pollen (Cirilli et al., 1998; Klaus, 1963; Massari et al., 1994; Spina et al., 2015).

The Bellerophon Fm. is succeeded by the Werfen Formation (uppermost Changhsingian–Lower Triassic), which is also mostly void of plant macrofossils. A bed with roots was found at Seres (Val Badia) in the Tesero Member (the lowermost member). The Tesero and Mazzin members (uppermost Changhsingian–Induan [=lower Lower Triassic]; Cirilli et al., 1998; Looy et al., 2005; Nowak et al., in press; Spina et al., 2015) as well as the Val Badia and Cencenighe members (Olenekian; Visscher, 1974) have yielded spores and pollen. Some plant macrofossils have been collected in the upper part of the Werfen Fm. (Olenekian, upper Lower Triassic) in the Bletterbach Gorge.

The Middle Triassic stratigraphy in the Southern Alps is complex, but well-resolved, with several formations containing well-dated palaeofloras. Anisian (lower Middle Triassic) macrofloras were found in the Valle San Lucano (Formazione di Agordo; Bithynian–Pelsonian; Kustatscher et al., 2010a), at the Kühwiesenkopf/Monte Prá della Vacca (Dont Formation; middle–upper Pelsonian; Kustatscher et al., 2010b), in the Val di Non (upper Pelsonian; Kustatscher et al., 2012), at Recoaro (VOLTZIA beds, Recoaro Formation; Pelsonian; Schenk, 1868) and Piz da Peres/Passo Furcia (Richtshofen Formation; lower Illyrian; Todesco et al., 2008). In addition, a macroflora of general Anisian age has been reported from the Val Duron (Kustatscher & Roghi, 2014a). Spore/pollen assemblages were reported also from the Dont Fm. at the Kühwiesenkopf/Monte Prá della Vacca (Kustatscher & Roghi, 2006), the Dont and Ambata formations in the Valle di Zoldo (Pelsonian–Illyrian; Roghi, 1995), the Marne della Val di Centa at Valsugana (Illyrian; Roghi, 1995) and from multiple stratigraphical units at Recoaro (Lower Sarl/Serla Dolomite, Gypsum Member, Gracilis Formation, Voltzia beds, Recoaro Limestone, Tretto Conglomerate; Aegean/Bithynian, Pelsonian, Illyrian; Brugman, 1986), as well as from Val Gola and a core taken at the Seceda (Buchenstein/Livinallongo Formation; Illyrian; Hochuli et al., 2015).

Ladinian palaeofloras have been described from the Meride Limestone (Fassanian) at Monte San Giorgio in Switzerland (Stöckar & Kustatscher, 2010), the Fernazza Formation (lower–middle Longobardian) at Seewald (Prags/Braies; Kustatscher

et al., 2004; Kustatscher & Van Konijnenburg-van Cittert, 2005) and Ritberg (Wengen/La Valle; Kustatscher et al., 2004; Kustatscher & Van Konijnenburg-van Cittert, 2005), the Wengen Formation (upper Longobardian) at Innerkohlbach, the Wengen Group (“Wengener Schichten” s.l.) at Pufels/Bulla, St. Leonhard im Abteital/S. Leonardo in Badia, Forcella Giau, Sappada, Cercena, Monte Sief, Corvo Alto, Corvara, Laste (Livinallongo), Cerčenà, Sappada, Spiz Agnelessa, Schgaguler Alm/Malga Scagul and Puflatsch/Bullaccia (Kustatscher & Van Konijnenburg-van Cittert, 2005), as well as the “Caotico eterogeneo” (between Buchenstein/Livinallongo Fm. and Wengen Group) at the Monte Agnello near Tesero (Kustatscher et al. 2014b). Spore/pollen assemblages from the Ladinian are known from the Buchenstein/Livinallongo Fm. (Val Gola, the Seceda core, Aschkler, Moena, Piave di Livinallongo, Pieve di Cadore; Fassanian and Longobardian; Hochuli et al., 2015; Roghi, 1995; Van der Eem, 1983), the Wengen Group (Pordoi, Pana-Scharte/Forcella Pana; Longobardian; Van der Eem, 1983) and the “Tufi a Pachicardie” at Seis/Siusi (Longobardian; Roghi, 1995). The uppermost Ladinian is represented by spores/pollen from the Stuoeres Wiesen/Prati di Stuoeres section (GSSP section for the base of the Carnian; Wengen/La Valle and St. Cassian/San Cassiano formations; Broglio Loriga et al., 1999; Roghi, 1995; Van der Eem, 1983).

Carnian (lower Upper Triassic) palaeofloras were found at St. Cassian/San Cassiano (St. Cassian/San Cassiano Fm.; lower Carnian; Kustatscher et al. 2011), Dogna (Rio del Lago Formation; lower Carnian; Roghi et al., 2006a) and Raibl/Cave del Predil (Predil Limestone; lower Carnian; Dobruskina et al., 2001). Carnian spore/pollen assemblages have been described from the Stuoeres Wiesen/Prati di Stuoeres section (St. Cassian/San Cassiano Fm.; Broglio Loriga et al., 1999; Roghi, 1995; Van der Eem, 1983), Dogna (Roghi and Kustatscher, 2006) and from the area of Raibl/Cave del Predil (Predil, Rio del Lago, Conzen, Tor and Carnitza formations; lower and upper Carnian; Roghi, 2004). A palaeoflora from Bergamo (Monte Pora) approximately represents the boundary between lower and upper Carnian (Passoni & Van Konijnenburg-van Cittert, 2003). The Heiligkreuz/Santa Croce Formation (upper Carnian) yielded plant macrofossils and amber at the Rifugio Dibona near Cortina d’Ampezzo and at Pralongià (Lastoni di Formin; Roghi et al., 2006b). Norian (middle Upper Triassic) floras are known from the Dolomia di Forni in the Carnic Prealps and the Calcari di Zorzino in the Bergamasc Alps (Dalla Vecchia, 2000). Norian/Rhaetian spore/pollen assemblages are known from the Hauptdolomit/Dolomia Principale in the Carnian and Julian Alps (Jadoul et al., 2005).

REFERENCES

- Brambilla, G., Lualdi, A., Penati, F. (1989): Primo ritrovamento di macrofossili vegetali nel Permiano della Valtellina (Sondrio-Italia sett.). – Atti Ticinesi di Scienze della Terra, Note Brevi, 32: 7–9.
- Broglio Loriga, C., Cirilli, S., Zanche, V.D., Bari, D.D., Gianolla, P., Laghi, G.F., Lowrie, W., Manfrin, S., Mastandrea, A., Mietto, P., Muttoni, G., Neri, C., Posenato, R., Rechichi, M., Rettori, R., Roghi, G. (1999): The Prati di Stuoeres/Stuoeres Wiesen section (Dolomites, Italy): A candidate global stratotype section and point for the base of the Carnian Stage. – Rivista Italiana di Paleontologia e Stratigrafica, 105: 37–78.
- Brugman, W.A. (1986): A Palynological Characterization of the Upper Scythian and Anisian of the Transdanubian Central Range (Hungary) and the Vicentinian Alps (Italy). – Rijksuniversiteit te Utrecht.
- Cassinis, G., Doubinger, J. (1991): On the geological time of the typical Collio and Tregiovo Continental beds in the south-alpine Permian (Italy), and some additional observations. – Atti Ticinense di Scienze della Terra, 34: 1–20.
- Cirilli, S., Pirini Radrizzani, C., Ponton, M., Radrizzani, S. (1998): Stratigraphical and palaeoenvironmental analysis of the Permian–Triassic transition in the Badia Valley (Southern Alps, Italy). – Palaeogeography Palaeoclimatology Palaeoecology, 138: 85–113.
- Dalla Vecchia, F.M. (2000): Macrovegetali terrestri nel Mesozoico italiano: un’ulteriore evidenza di frequenti emersioni. – Natura Nascosta, 20: 18–35.
- Florin, R. (1964): Über *Ortiseia leonardi* n.gen. n.sp., eine Konifere aus den Grödner Schichten in Alto Adige (Südtirol). – In: Leonardi, P. (Ed.), La Flora Permiana di Ortisei, pp. 3–18, Ferrara.
- Forte, G., Kustatscher, E., Roghi, G., Preto, N. (2018): The Permian (Kungurian, Cisuralian) palaeoenvironment and palaeoclimate of the Tregiovo Basin, Italy: Palaeobotanical, palynological and geochemical investigations. – Palaeogeography Palaeoclimatology Palaeoecology, 495: 186–204.
- Fritz, A., Krainer, K. (2006): Eine Rotliegendeflora aus dem Seesedimenten des Bozner Vulkanitkomplexes bei Sinich (Südtirol). – Geo.Alp, 3: 33–45.
- Gümbel, C.W. (1879): Geognostische Mitteilungen aus den Alpen. V. Die Pflanzenreste führenden Sandsteinschichten von Recoaro. – Bayerische Akademie der Wissenschaften Mathematisch Physikalische Klasse, 9: 33–90.
- Hartkopf-Fröder, C., Wood, G.D., Krainer, K. (2001): Palynology of the Permian Bolzano Volcanic complex, Southern Alps, Italy, Part 1: Miospore preservation, quantitative spore colour and quantitative fluorescence microscopy. – IX Int. Palynological Congress, pp. 79–97, A. Foundation, Houston, Texas, USA.
- Hochuli, P.A., Roghi, G., Brack, P. (2015): Palynological zonation and particulate organic matter of the Middle Triassic of the Southern Alps (Seceda and Val Gola-Margon sections, Northern Italy). – Rivista Italiana di Paleontologia e Stratigrafica, Special Issue on Changing flora and vegetation in Italy through time, 218: 28–47.
- Jadoul, F., Galli, M.T., Calabrese, L., Gnaccolini, M. (2005): Stratigraphy of Rhaetian to lower Sinemurian carbonate platforms in Western Lombardy (Southern Alps, Italy): Palaeogeographic implications. – Rivista Italiana di Paleontologia e Stratigrafia, 111(2): 285–303.

- Jung, W. (1977): Oberpermische Koniferenreste aus dem Sandsteinsockel des Schlernmassivs (Südtiroler Dolomiten). – Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie, 17: 235–247.
- Kerp, H., Penati, E., Brambilla, G., Clement-Westerhof, J.A., Van Bergen, P.F. (1996): Aspects of Permian palaeobotany and palynology. XVI. Three-dimensionally preserved stromatolite-incrusted conifers from the Permian of the western Orobic Alps (northern Italy). – Review of Palaeobotany and Palynology, 91: 63–84.
- Klaus, W. (1963): Sporen aus dem südalpinen Perm (Vergleichsstudie für die Gliederung nordalpiner Salzserien). – Jahrbuch der Geologischen Bundesanstalt, 106: 229–361.
- Krainer, K. (2000): Mölten im Wandel der Erdgeschichte: Eine Einführung in die Gesteins- und Fossilwelt von Mölten und Umgebung. – Gemeinde Mölten.
- Kustatscher, E., Roghi, G. (2014): La flora del Triassico dell'Italia Settentrionale/The Triassic flora of northern Italy. – In: Kustatscher, E., Roghi, G., Bertini, A. & Miola, A. (eds), La storia delle piante fossili in Italia/Paleobotany of Italy, Pubblicazione del Museo di Scienze Naturali dell'Alto Adige, 9: 116–135.
- Kustatscher, E., Van Konijnenburg-van Cittert, J.H.A. (2005): The Ladinian Flora (Middle Triassic) of the Dolomites: palaeoenvironmental reconstructions and palaeoclimatic considerations. – Geo.Alp, 2: 31–51.
- Kustatscher, E., Wachtler, M., Van Konijnenburg-van Cittert, J.H.A. (2004): A number of additional and revised taxa from the Ladinian Flora of the Dolomites, Northern Italy. – Geo.Alp, 1: 57–70.
- Kustatscher, E., Giordano, D., Riva, A. (2010a): La flora anisica della Valle di San Lucano. – In: L'armonia fra uomo e natura nelle Valli Dolomitiche Atti delle giornate di studio, Agordo, 131–146.
- Kustatscher, E., Wachtler, M., Van Konijnenburg-van Cittert, J.H.A. (2010b): Lycophytes from the Middle Triassic (Anisian) locality Kühwiesenkopf (Monta Prà Della Vacca) in the Dolomites (Northern Italy). – Palaeontology, 53: 595–626.
- Kustatscher, E., Bizzarrini, F., Roghi, G. (2011): Plant fossils in the Cassian beds and other Carnian formations of the Southern Alps (Italy). – Geo.Alp, 8: 146–155.
- Kustatscher, E., Bauer, K., Reich, M. (2012): A new Middle Triassic (Pelsonian) Plant locality in the Non Valley (Trentino, northern Italy). – Geo.Alp, 9: 60–73.
- Kustatscher, E., Forte, G., Roghi, G. (2014a): La flora del Permiano dell'Italia Settentrionale. – In: Kustatscher, E., Roghi, G., Bertini, A., Miola, A. (eds), La storia delle piante fossili in Italia/Paleobotany of Italy, Pubblicazione del Museo di Scienze Naturali dell'Alto Adige, 9: 84–97.
- Kustatscher, E., Dellantonio, E., Van Konijnenburg-van Cittert, J.H.A. (2014b): The ferns of the late Ladinian (Middle Triassic) flora from Monte Agnello (Dolomites, N-Italy). – Acta Palaeontologica Polonica, 59(3): 741–755.
- Kustatscher, E., Van Konijnenburg-van Cittert, J.H.A., Looy, C.V., Labandeira, C.C., Wappler, T., Butzmann, R., Fischer, T.C., Krings, M., Kerp, H., Visscher, H. (2017): The Lopingian (late Permian) flora from the Bletterbach Gorge in the Dolomites, Northern Italy: a review. – Geo.Alp, 14: 39–61.
- Leonardi, P. (1948): Contributi alla conoscenza della flora delle Arenarie di Val Gardena (Permiano medio-inf.) dell'Alto Adige: La nuova flora di Redagno e una felce di Egna. – Memorie degli Istituti di Geologia e Mineralogia dell'Università di Padova, 16: 3–15.
- Looy, C.V., Collinson, M.E., Van Konijnenburg-van Cittert, J.H.A., Visscher, H., Brain, A.P.R. (2005): The ultrastructure and botanical affinity of end-Permian spore tetrads. – International Journal Plant Sciences, 166: 875–887.
- Massalongo, A. (1863): Costituzione geologica di Recoaro e dei suoi dintorni. – Atti del Reale Istituto Veneto, 9: 95–104.
- Massari, F., Neri, C., Pittau, P., Fontana, D., Stefani, C. (1994): Sedimentology, palynostratigraphy and sequence stratigraphy of a continental to shallow-marine rift-related succession: Upper Permian of the eastern Southern Alps (Italy). – Memorie di Scienze Geologiche, 46: 119–243.
- Nowak, H., Mette, W., Petti, F. M., Roghi, G., Kustatscher, E. (in press): Palynology, microfacies and ostracods of the Permian–Triassic boundary interval in the Rosengarten/Catinaccio Massif (Southern Alps, Italy). – Austrian Journal of Earth Sciences.
- Passoni, L., Van Konijnenburg-van Cittert, J.H.A. (2003): New taxa of fossil Carnian plants from Mount Pora (Bergamasco Alps, Northern Italy). – Review of Palaeobotany and Palynology, 123: 321–346.
- Remy, W., Remy, R. (1978): Die Flora des Perms im Trompia-Tal und die Grenze Saxon/Thuring in den Alpen. – Argumenta Palaeobotanica, 5: 57–90.
- Roghi, G. (1995): Analisi palinologica del Trias medio del Sudalpino (Ph.D. thesis). – Università degli Studi di Padova, Padova.
- Roghi, G. (2004): Palynological investigations in the Carnian of the Cave del Predil area (Julian Alps, NE Italy). – Review of Palaeobotany and Palynology, 132: 1–35.
- Roghi, G., Kustatscher, E., Van Konijnenburg-van Cittert, J.H.A. (2006a): Late Triassic Plant from Julian Alps (Italy). – Bollettino della Società Paleontologica Italiana, 45(1): 133–140.
- Roghi, G., Ragazzi, E., Gianolla, P. (2006b): Triassic amber of the Southern Alps. – Palaios, 21: 143–154.
- Schenk, A. (1868): Über die Pflanzenreste des Muschelkalkes von Recoaro. – Geognostisch-paläontologische Beiträge, 2: 58–87.
- Spina, A., Cirilli, S., Utting, J., Jansonius, J. (2015): Palynology of the Permian and Triassic of the Tesero and Bulla sections (Western Dolomites, Italy) and consideration about the enigmatic species *Reduviasporonites chalastus*. – Rivista Italiana di Paleontologia e Stratigrafica, Special Issue on Changing flora and vegetation in Italy through time, 218, 3–14.
- Stockar, R., Kustatscher, E. (2010): The Ladinian Flora from the Cassina beds (Monte San Giorgio, Switzerland): a first report. – Rivista Italiana di Paleontologia e Stratigrafia, 116(2): 161–176.
- Todesco, R., Wachtler, M., Kustatscher, E., Avanzini, M. (2008): Preliminary report on a new vertebrate track and flora site from Piz da Peres (Anisian–Illyrian): Olang Dolomites, Northern Italy. – Geo.Alp, 5: 121–137.
- Van der Eem, J.G.L.A. (1983): Aspects of Middle and Late Triassic palynology. 6. Palynological investigations in the Ladinian and lower Karnian of the Western Dolomites, Italy. – Review of Palaeobotany and Palynology, 39: 189–300.
- Visscher, H. (1974): The Impact of palynology on Permian and Triassic stratigraphy in Western Europe. – Review of Palaeobotany and Palynology, 17: 5–19.

