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 (Richthofen 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 (Stockar & 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), Cercenà, 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 Stuores Wiesen/Prati di Stuores 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. Kassian/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 Stuores Wiesen/Prati di Stuores 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).

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Digitale Literatur/Digital Literature

Zeitschrift/Journal: Geo.Alp

Jahr/Year: 2019

Band/Volume: 0016

Autor(en)/Author(s): Nowak Hendrik, Kustatscher Evelyn, Roghi Guido

Artikel/Article: Permian-Triassic macro- and microfloras of the Southern Alps 79-82