Upper Permian climate changes in the Dolomites

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Only in very few areas in the world, can we follow such a perfect biocoenosis between Permian and Triassic as in the Dolomites. Nevertheless, it attracted little attention for decades. But it is precisely the diverse living world that provides valuable clues about the changes in climate—from subtropical influences to increasingly desert till arctic conditions and a complete collapse of the ecosystem towards the end of the Permian. The evolving of plants and animals can not only tell us a lot about the climate before the world's biggest disaster, the Permo-Triassic catastrophe, but also about the first development of important plant families like the Abietaceae (*Majonica*), the Araucariaceae (*Ortiseia*), the Ginkgoales (*Ginkgoites*), the cycads (*Macrotaeniopteris, Taeniopteris, Nilssonia*) but also the development of the vertebrates, with many remains found in the different layers. This summary of the different Late Permian locations in the Dolomites provides good insight into the evolution of this world.

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Late Permian (Wuchiapingian, about 260 mio years), Ariche—Valli del Pasubio, Northern Italy
In the Upper Permian some landscapes of the Dolomites were even characterized by a richness in tropical till subtropical plants. Left below sprout the fern ***Angiopterites murchisonii.*** After that comes a rich cycad assemblage with the strange ***Pernerina pasubi*** and its megasporophylls, after that another cycad ***Macrotaeniopteris wachtleri*** with a male cone. Right is the Zamia-like ***Nilssonia brandtii*** visible with a male cone and its two seeded female cones. In the upper part left grows the Araucariaceae ***Ortiseia zanettii*** with female and male cones. After that follow the horsetails ***Equisetites siberi*** and ***Neocalamites benckeae,*** the last Calamitaceae recorded in Earth-history. On the right side can be seen a twig with male and female cones of the Abietaceae-progenitor ***Majonica alpina*.**

The Dolomites are distinguished by their unique Permo-Triassic successions, which will gain even more importance through future research. Especially the Paleozoic-Mesozoic climate change over 100 million years can be studied like nowhere else in the world. A particularly interesting area is the Upper Permian Grödner Sandstone, which demonstrates how the habitat changed in direction to the Permo-Triassic cataclysm.

Historical overview

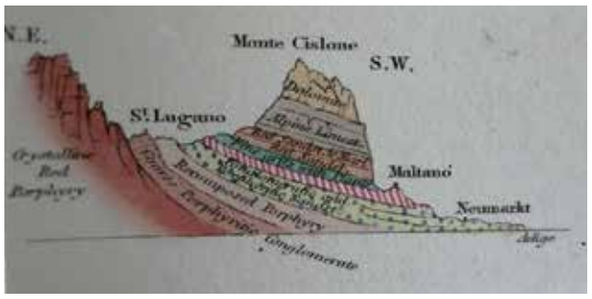
It was the clergyman and naturalist **Pietro Maraschini** (1774–1825) who in 1824—shortly before his death due to malaria (Dentilli & Boscardin, 2008)—in "*Sulle Formazioni Delle Rocce del Vicentino, Saggio Geologico*" pointed out the rich findings of fossil plants around Recoaro (Contrada Prechele in the Val Calda below the Monte Spitz, Valli del Prak and Maltauro) and the Valli del Pasubio (Chuchimuri) in the southern Dolomites. Although he was not up to the height to identify any individual plant more precisely, he nevertheless was able to connect the Upper Permian German Zechstein with the fossil rich sandstones in Recoaro and the younger sediments there with the Lower Triassic Buntsandstein; assessments that are still valid today.

Tommaso Antonio Catullo (1782–1869), native of the Dolomite town of Belluno, was another natural scientist who dealt intensively with the geological and palaeontological contexts of the Dolomites. In his book "*Saggio di zoologia fossile ovvero osservazioni sopra li petrefatti delle province austro-venete con la descrizione dei monti entro ai quali si trovano",* published in 1827 and richly illustrated for the time, he dealt on the one hand with the various strata in the southern Dolomites. He also referred in detail to the fossilized plants there. Still influenced by the general theories of the Flood, he was able to state that the plants found at Recoaro, Agordo and Zoldo, as well as in the Carnic mountains, "*are for the most part detrimental to the European climate, and have no prototypes at all in modern times"*.

Pietro Maraschini, Library, Schio

It was a great time for free research across borders. Between the 30 September and the 7 October 1847, the most important geologists worldwide, during a scientific congress held in Venice visited the area around Recoaro. They were led by the English researcher

Left: The British geologist Roderick Impey Murchison (albumen-print about 1860, Dolomythos-Museum). Middle: Together with his wife Charlotte (albumen print, 1860), especially interested in paleontology, the Murchinson's travelled several times through the Dolomites. Right: The English writer Amelia B. Edwards (1831-1892), described in "*Untrodden Peaks and Unfrequented Valleys*" (1873) her journey through the Dolomites keeping attention to the history, botany and geology. She was one of the first to accept the Coral Reef Theory of Ferdinand von Richthofen. Photo by Frederick Richard Window, albumen carte-de-visite, 1860s, National Portrait Gallery, London.



A first mention of the fossilised plant horizons between Gleno and Mantana (Montan). Roderick Murchison and Adam Sedgwick (1835): "A sketch of the structure of the Eastern Alps" (Dolomythos-Museum, Innichen)

Roderick Impey Murchison (1792–1871), the name-giver for the Permian period, accompanied - and for that time unusual—by his wife **Charlotte Murchison**, née Hugonin (1788–1869), a fervour paleontologist. The Murchisons had already acquired a good knowledge of the Dolomites through their previous journeys in 1828, 1829 and 1830. With them were the French palaeontologist **Édouard Poulletier de Verneuil** (1805–1873), the German researchers **Leopold von Buch** (1774–1853) and **Julius Ewald** (1811–1891), the Italian paleobotanist Baron **Achille de Zigno** (1813–1892), **Alberto Parolini** (1788-1867) and the geologist Marchese **Lorenzo Pareto** (1800-1865). It was the local naturalist **Domenico Trettenero**, which showed them the interesting geological phenomenons of the Southern Dolomites.
The area around Recoaro, with its thermal baths, became more and more the Mecca

The father of Italian palaeobotany: Achille de Zigno

of palaeobotanists. In 1854, the German geologist **Carl Friedrich Freiherr von Schauroth** (1818–1893) published his "*Uebersicht der geognostischen Verhältnisse der Gegend von Recoaro im Vicentinischen*" *(Overview of the Geognostic Relations of the Area of Recoaro in the Vicentine Alps)*

Geological map of Recoaro elaborated by Abramo Massalongo (left) between 1858 and 1860. The fossil plants recovered by Massalongo from the Upper Permian near Recoaro were published after his premature death by Achille de Zigno (right).



The German palaeontologist Carl Friedrich Freiherr von Schauroth studied intensely the geology near Recoaro. With the help of the local physician Jacopo Bologna he elaborated a geological map of the area. One conifer found in the "*Arenaria antica"* (today: Upper Permian Grödner Sandstone) he described as *Palissya massalongi.*

with the description of the first Upper Permian plant of the Dolomites: *Palissya massalongi,* (later changed by De Zigno in *Taxites massalongi)* honouring **Abramo Massalongo** (1824–1860), a researcher from Verona, which in this time began studying the fossil flora of Recoaro. After the premature death of Abramo Massalongo, another outstanding Italian botanist, geologist and palaeontologist—Achille de Zigno—began to complete his findings.

His in 1862 published "*Sulle piante fossili del Trias di Recoaro raccolte dal Prof. A. Massalongo" (On the fossil plants of the Triassic of Recoaro collected by prof. A. Massalongo)* described and figured various fossil plants. The multilingual De Zigno—his mother was Irish—maintained for all his life excellent contacts even with the Austro-Hungarian research-colleagues. Till 1866 the Lombardo-Venetian Kingdom formed a part of the Austro-Hungarian empire and he was politically active as elected envoy. However, also De Zigno was not able to differentiate the stratigraphically different sediments. Therefore, he regarded as coeval the lycopods from the Carboniferous of the Carnic Alps with the conifers from the Upper Permian sandstone of Ulbe near Recoaro, or the Middle Triassic conifer-remains from Rovegliana and Scorte. To his credit, in the area of Recoaro the layers from different periods are relatively intimately interlocked. Thus, pertain the rocks near the church of Santa Giuliana or Ulbe, as well as many plant fossil sites in the Valli del Pasubio (Ariche, Cortiana, Casarotti) to the Upper Permian Grödner Sandstone, whereas other neighbouring places like Rovegliana or Scorte are of Early-Middle Triassic age.

In 1868, the German scientist **August Schenk** published "*Ueber die Pflanzenreste des Muschelkalkes von Recoaro",* mainly based on the fossil plants collected by **Ernst Wilhelm Benecke** (1838–1917) and some other naturalists but also without distinction between Triassic and Permian floras. Another researcher who spent many years in the Dolomites was the German palaeontologist **Carl Wilhelm Gümbel** (1823–1898). In 1873, he described from the Grödner Sandstein around Neumarkt in the Etschtal conifers, like *Voltzia hungarica, Baiera digitata*, ferns and horsetails. Gümbel returned in 1878 again in the Dolomites with two assistants and began to study intensively the fossil plants of Recoaro (Gümbel, 1879). He was the first to split the plant horizons in one younger Triassic and an older Late Permian, located on the northeastern outcrops of the church of Santa Giuliana (probably the Contrada Ulbe). Gümbel compared the plants found in this grainy sandstone with the conifer *Ullmannia* or *Voltzia hungarica* of Neumarkt (South Tyrol) with plant findings from the German Zechstein of Upper Permian age. It was not an exact definition, but just a milestone in the research.

Abruptly the interest stopped, especially during the two World Wars. In 1946, the hotelier **Leo Perwanger** from the Zirmerhof in Radein mentioned first plants from the

Two outstanding palaeobotanists making researches in the Permian Dolomites: The German August Schenk and Carl Wilhelm Gümbel.

Bletterbach-gorge near Aldein. Based on this information the acknowledged Italian geologist **Piero Leonardi** (1908–1998) published in 1948 a first synthesis over the plants of the Bletterbach and a fern recovered by the geologist **Nino Dal Piaz** from the Upper Permian sandstone of Neumarkt, the old fossil site of Gümbel. Although the classifications today are not any more up-to-date (*Lepidodendron* was extinct in the Upper Permian, the fern today can better be inserted as *Lepidopteris martinsii* and not *Pecopteris (Cyatheites) miltoni;* it was a first step in a new era.

The Austrian palaeobotanist **Wilhelm Klaus** (1921–1987) achieved in 1963 a milestone in a very neglected field—the plant spores—with his research on the Upper Permian pollen residues from the Dolomites.

The year 1964 saw the next highlight in the palaeobotanical exploration of the Dolomites. Piero Leonardi edited in the "*Memorie Geopaleontologiche dell'Università di Ferrara*" the publication "*La Flora Permiana di Ortisei" (The Fossil Flora of Ortisei)* compiled primarily by the Swedish palaeobotanist **Rudolf Florin.** He described the new discovered Upper Permian conifer *Ortiseia leonardii* (Florin, 1964) from the Seceda mountains near Ortisei in the Gröden-Valley. Another article written by **Giovanni Charrier** has as content the fossilised wood *Dadoxylon atesinum* (Charrier, 1964), probably belonging to the conifer *Ortiseia*. The fossil site Cuecenes, meaning in the native Ladinian language "red valley" on the base of the Seceda-mountain was discovered by the indefatigable local collector **Heinrich Moroder** (1896–1974) around the 1950s. He handed all the material to Piero Leonardi, who then passed the fossils without comment to the famous palaeobotanist Rudolf Florin. Tragically not Moroder but Leonardi was honoured for this "postmaster service" with the name *Ortiseia* (the hamlet in the Dolomites where the Seceda-mountain lies) *leonardii.* Two further remarks by Florin are worth mentioning. Based on cuticular analyses he established that on the Seceda additionally at least two more conifers must occur, that due to the fragmentary material he was not able to categorise. Later studies confirmed this assumption. *Ortiseia* is effectively different from other conifer-genera known up to that time like *Voltzia, Pseudovoltzia* or *Ullmannia.* It became clearer that the research on fossil plants should be oriented less on the shape

Left: Heinrich Moroder discovered the Upper Permian plant fossil location Cuecenes in the Val Gardena (left). Piero Leonardi (middle) was honoured by the Swedish paleobotanist Rudolf Florin naming the Late Permian character conifer *Ortiseia leonardii.* Right the holotype stored in the Museum Gherdëina at Ortisei (St. Ulrich).

of the branches and needles than on their fertile organs, scales or cones (Jung, 1977). Therefore, the Dutch researcher **Johanna Clement-Westerhof** started intensive studies and published first results in 1984 based mainly on the fructifications and the cuticles, establishing as part of the genus *Ortiseia* two new Upper Permian species: *Ortiseia jonkeri* and *Ortiseia visscheri* (Clement-Westerhof, 1984). They were found in other localities in the Dolomites (Bletterbach) and the Vicentinian Alps (Recoaro and Valli del Pasubio). Nevertheless Clement-Westerhof was not able to classify the *Ortiseia* species in one of the existing families, especially the Araucariaceae, and inserted them—influenced by Florin—in the doubtful family of the Walchiaceae, comprising mainly all Permian conifers, stating that *"unambiguous descendants remain unknown"* (Clement-Westerhof, 1984).

In 1987, Johanna Clement-Westerhof described the first winged seed conifer worldwide, naming it *Majonica alpina* (after her family). But she was not able to recognize, that she has found the oldest ancestors of the Abietaceae.

After that **Michael Wachtler** focused his researches to the Valli del Pasubio and Recoaro (2013). Sometimes the layers were characterized by an amazing quality, whereas other sediments were rich in fertile organs. In the most fine-sandy sediments all the particular details of winged seeds, or the cones as well the different features of single leaves are recognizable.

To understand better the blueprint, especially the fertile organs of *Ortiseia leonardii,* Wachtler additionally focused his researches in the following years on the locus typicus Seceda/Cuecenes. The exact locality was shown to him by Alfons Moroder, the son of Heinrich Moroder. There several slightly age-different plant-bearing layers crop out for several hundred metres. Some are characterized by their excellent quality and also the possibility to recover bigger branchlets. Unfortunately, the cuticle is so fragile and not connected with the slabs that they peel of immediately in the sun light or only under normal temperature conditions. In the past the fossil plants were soaked in glue and their surfaces then coated with nitrocellulose lacquer with the effect that the fine leaves were darkened so that their structures were hardly visible between the just grey-black sediments. Wachtler used a hairspray, because the covering must occur immediately. Other varnishing methods were not so efficient, because the water saturated

The Upper Permian plant-fossil-sites in the Vicentinian Dolomites

Cortiana: It is a Contrada (hamlet) of the municipality Valli del Pasubio. The fossil outcrops are situated near an old stone-quarry. It is the locus typicus of *Ortiseia jonkeri.*

Ariche: This Contrada of the community Valli del Pasubio is rich in the conifers *Ortiseia zanettii* and well-preserved fertile organs of *Majonica alpina.* Additionally, a fair amount of cycads (*Macrotaeniopteris wachtleri, Nilssonia brandtii, Pernerina pasubi)*, the fern *Angiopterites murchisonii* and *Neocalamites benckeae* horsetails were discovered.

Ulbe: This outcrop near the Church Santa Giuliana in Recoaro generate *Ortiseia jonkeri,* as well as *Taxodium* conifers (*Ulbius vicetinus)* and horsetails (*Equisetites siberi*).

rocks formed a reaction, creating otherwise an unsightly white film. So far it's not the most optimal method but it helped to stabilize the fragile plant plates. Thus, a unique ecosystem could be brought to light, composed of fish and tetrapod remains, as well as plants.

Geology and time-dating

Large parts of the landscape around Bolzano, between the Etsch- and Eisack valleys and the Cembra-Valley in Trentino, are shaped by former volcanic eruptions, which became known as the "Bozner-Porphyry Plate" (now Athesian Volcanic Group), com-

The Upper Permian plant-fossil-sites in the Tyrolean Dolomites:

Bletterbach: This spectacular gorge near Aldein-Radein is the locus typicus of *Majonica alpina* and *Ortiseia visscheri*. Also some *Ginkgoites* remains, as well as cycads were found there.

Cuecenes: The layers on the base of the Seceda-mountains near Ortisei in the Gröden Valley are the locus typicus of *Ortiseia leonardii, Majonica clementwesterhofae* and *Ginkgoites murchisonae*, but also the amphibian skeleton *Dolomitiphibium nicolaswachtleri* and the semionotid fish *Acentrophorus robustus*.

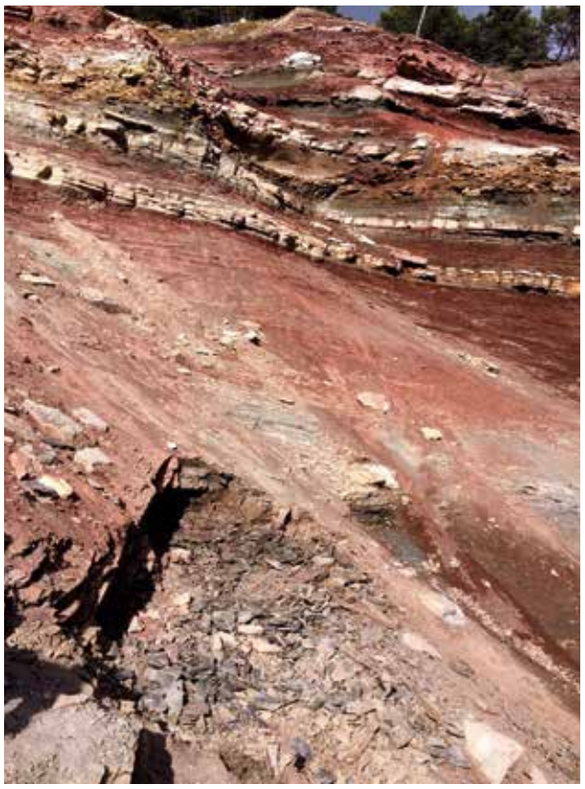
posed of andesites, extrusive and ignimbritic rhyolites. It was once, in the Early-Middle Permian, one of the largest contiguous volcanic areas in Europe, covering an area of about 4,000 square kilometres. Over the course of the following millions of years, these have been eroded away by rainfall and weather-circumstances. Across the Dolomites and as far as Slovenia, Lombardy and in the south as far as the Vicentinian area the products of their abduction can still be traced today. They went down in history as a Grödner-Sandstone.

Partially, at the Seceda or in the Bletterbach-gorge, the porphyry decayed to the size of sand grains and formed sediments up to 500 metres thick. Now this part of the Grödner Sandstone is characterized by alternations of reddish–greyish fluvial siliciclastics, evaporites and mixed carbonate–siliciclastics.

At other places, however—such as the Kreuzberg Pass near Sexten—coarse-grained conglomerates together with fine sludge cemented themselves into layers of some 200 metres thick. In them, the different ecosystems can still be seen today. Rivers carried everything with them, ripping and unregulated coarse rubble, in other places mighty floodplains were formed, in which mud and the finest sludge were solidifying.

Many small lakes and ponds were also able to form, with a variety of vegetation spreading along their shores. Abundantly left behind in the mud of the Seceda or the Bletterbach-gorge were tracks of the most diverse animals, from pareiasaurians to caseids, gorgonopsids, amphibians, tecodonts and other saurians were left. These made the Dolomites World Heritage a parade finding site of geological research. There, as well as at Recoaro up to the Valli del Pasubio, we can still derive the appearance of the landscape of that time from the fossilized plants.

The area of the Dolomites was in the Late Permian beyond the equator and drifted further and further north. Towards the end of the Permian, the first foothills of the Tethys Sea approached. More often wave ripples are found, especially in the Bletterbach-gorge and at the Seceda, and for the first time cephalopods (known in the Bletter-



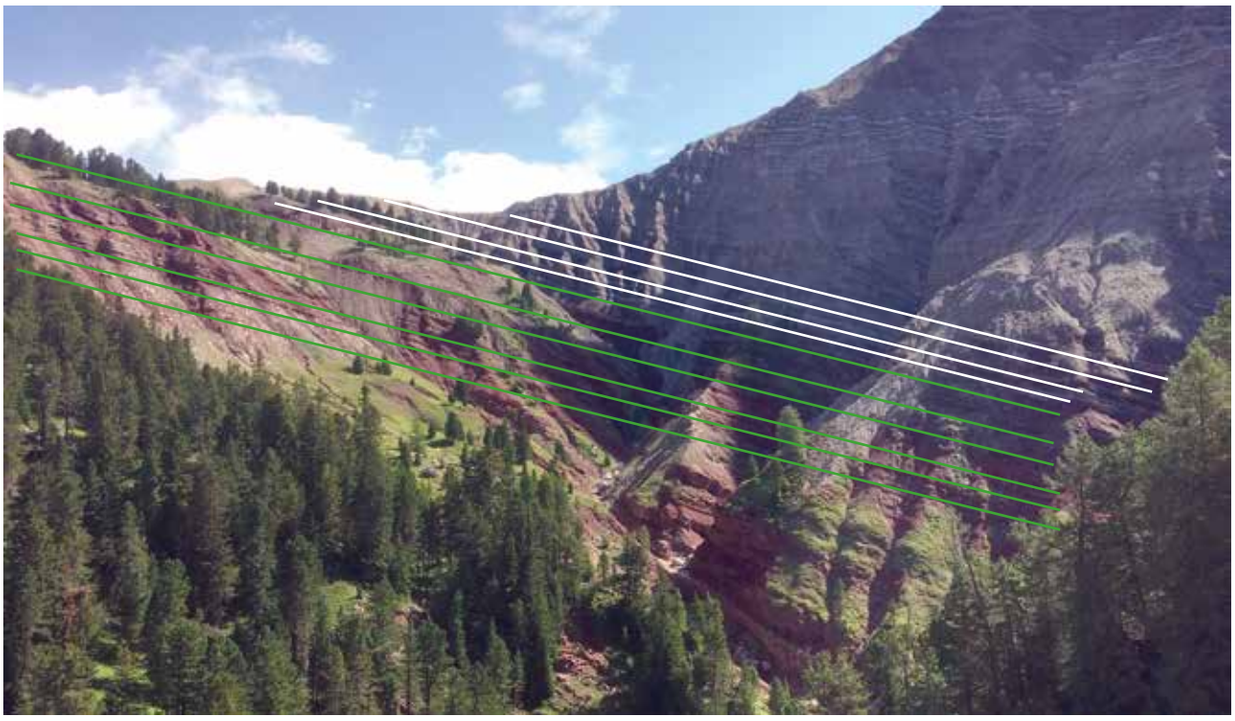
Amazing *Majonica*-winged seeds or *Ginkgoites*-remains can be recovered in former shallow water-pumps. There the best deposition conditions with the least destruction persisted. Here the unique amphibian skull of the Grödner Sandstone *Dolomitiphibium nicolas-wachtleri* was also recovered.

The *Ullmannia edwardsae* fossil site on the Seceda. It was especially rich in this berry-seeded conifer. Additionally, also *Ortiseia leonardii* branchlets were found.

bach-gorge as Cephalopoden-Bank), clear evidence of a deep sea flooding that lasted for many millions of years. In some places, tubers and crusts of limestone, dolomite, sometimes gypsum formed; evidence of drying out in a hot climate (Wachtler, 2019). After that the Gröden-Formation will be topped by the Bellerophon Formation, which documents a massive marine ingression.
Unfortunately, from the possibility of dating, the Gröden-Formation is only well-constrained in its oldest parts. Radiometric dating (U/Pb) indicates a Kungurian age of 274.1±1.4 Ma for the top of the underlying volcanic Ora Formation (Marocchi et al., 2008). The base of the Gröden-Formation is characterized by an angular unconformity corresponding to a gap of at least 14 Ma of duration (Morelli et al., 2007; Marchetti et. al., 2020). About 260 Ma ago began in the Dolomites a phase of changing marine ingression with subsequently drying out of large areas. Because in these layers no macrofloras can be found, a deposition of the plants in the Lopingian, and more restrained in the Wuchiapingian can be accepted, whereas a complete marine inundation occurred beginning from the Changhsingian age. Probably the German Zechstein with its richness in plants and vertebrates is slightly younger—pertaining to the late Wuchiapingian or Early Changhsingian and ending with the Permo-Triassic-boundary (most parts of the Zechstein flora will be found in the Werra-Folge, a time interval lasting 2 million years between 258 and 256 million ago).

Palaeoecology and Palaeoclimatology

In the late Carboniferous, the Dolomites were located on the Southern Tropic at about the 23rd latitude. Alice Springs in Australia, the Kalahari or the Atacama Desert, as well as the Southern part of Madagascar have today the same position on the Tropic of Capricorn. The all-dominant Gondwana Ice Age that on the Carboniferous-Permian border noticeably changed the climate was towards the end Permian mainly finished. In the following millions of years, they moved closer and closer to the equator. Then during the deposition of the Gröden-Formation, the Dolomites lay on the equator and about 260 million years ago they started to cross the equator slowly towards the north.
Climate changing in a short time: Who would have believed that in the Late Permian a tropical vegetation in the immediate vicinity of the ocean was predominant would have to be disappointed. It is true that certain layers are extremely rich in fossil floras. But only the Contrada Ariche

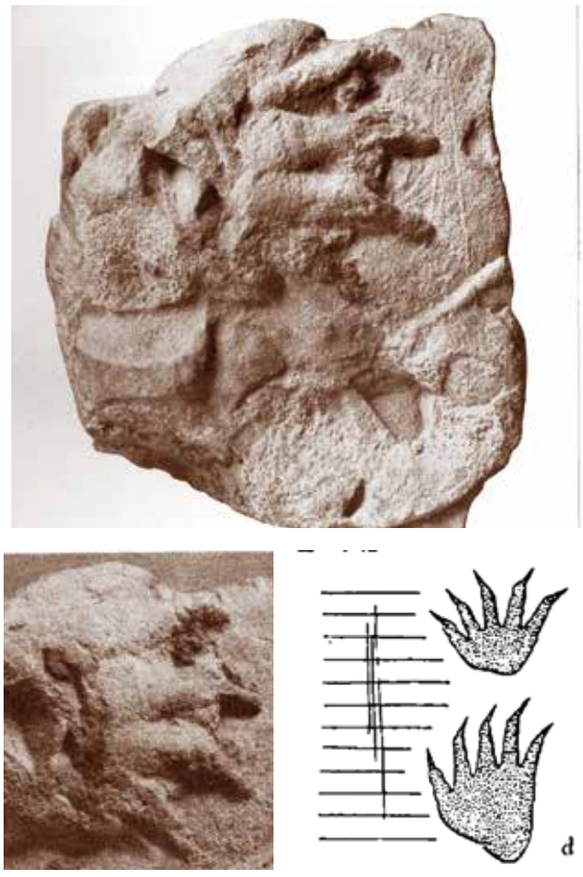


Plant lenses (green) on the Seceda-mountain in the Gröden-Valley. Towards the end of the Permian, increasing massive aridization caused the deposition of gypsum layers (white).

in the Valli del Pasubio held additionally to the omnipresent conifers (Ortiseia, Majonica), many cycads (*Macrotaeniopteris, Taeniopteris, Nilssonia)*, as well as horsetails (*Neocalamites, Equisetites*) and ferns (*Angiopterites, Sphenopteris*). The Contrada Ulbe near Recoaro is also rich in horsetails *(Equisetites siberi*) additionally to *Ortiseia jonkeri* conifers. The Bletterbach near Aldein-Radein and Cuecenes (Gröden-Valley) evidence a mainly exclusive conifer association (*Ortiseia, Majonica*) with a fair amount of *Ginkgoites*. In the Bletterbach-gorge, we encounter additionally rarely another conifer Voltzia, whereas at Cuecenes isolated *Ullmannia* remains can be recovered. The ferns (*Sphenopteris*) or seedferns (*Lepidopteris, Peltaspermum*) stand largely behind all others. What are the causes of this impoverishment? Probably they can be searched in some time-different layers. A general aridisation is strongly noticeable especially on the Seceda-mountain, where straightly after the plant lenses follow desertic and lifeless gypsum-lenses in direction to the Permo-Triassic cataclysm.

Different floras between the Grödner Sandstone and the Zechstein: Interestingly the plant assemblages between the mainly coeval Zechstein results very different. Whereas there *Ortiseia (florinii*) (Ulrich, 1964) and Majonica are seldom, the berry-seeded *Ullmannia* and *(Pseudo)Voltzia* are common, which are rare (only some isolated *Voltzia sjerpii* and *Ullmannia edwardsae*) in the Gröden-Formation. Ginkgoites murchisonae with fan-shaped-leaves will be replaced in the Zechstein by the needle-like *Baiera digitata. Macrotaeniopteris* and *Nilssonia*-cycads from the Dolomites are substituted by *Taeniopteris eckardtii.*

Reptile tracks and fishes: The Grödner Sandstone is regarded as the most diverse, best preserved and abundant ichnoassociation from the Late Permian worldwide (Bernardi et. al., 2017; Marchetti et al., 2020). Because the Tethys-ocean was at this time nearby it also serves as an excellent comparison for a living community occurring at sea level. Abundant were the huge tracks of the pareiasaurs (classified as *Pachypes dolomiticus*), small parareptiles (*Procolophonichnium tirolensis)*, dicynodont therapsids that are regarded as potential mammalian ancestors and amphibians like *Batrachichnus* and *Capitosauroides*. Furthermore, we encountered the tracks from neodiapsids, that gave rise later probably to the evolu-



Herpetichnium acrodactylum, the oldest known ichnospecies from the Alps. It was found by F. Glassner and first mentioned by Ernst Kittl in 1891. Othenio Abel described and figured the track in 1929 and classified it as belonging to pelycosaurs an order composed of primitive mammal-like reptiles or turtle-ancestors. The locality Neumarkt (between Gleno and Montan, Monte Cislon) belongs to the Grödner-Sandstone. In vicinity Roderick Murchison (1830) and Wilhelm Gümbel recovered also his Upper Permian plants (1877).

tion of lepidosaurs (*Rhynchosauroides pallinii*) or early archosaurs (*Protochirotherium*). For some, like *Herpetichnium acrodactylum* (described by Abel in 1929) or *Paradoxichnium problematicum* an exact classification is controversial. The role of amphibians, which still dominated the landscape in the early Permian, should not be underestimated. This is proved by the discovery of a completely preserved skull (*Dolomitiphibium nicolaswachtleri,* Wachtler, 2021, the first preserved skeleton in the Grödner-Sandstone ever. Probably it can be correlated with some teeth-less lissamphibian temnospondyl that left the tracks of *Dolomitipes accordii* or *Capitosauroides*. It can be placed in the family of amphibamids as the closest relatives of modern amphibians like the Anura (frogs) or Urodela (salamanders, newts). More skeletal finds are expected in the next years.

Frequent marine ingression in the upper part: That the marine influences increased especially towards the end of the Permian in the Grödner Sandstone is proven by the abundance of the small-sized brackish water fish *Acentrophorus robustus* (Brandt, 2021). Its parented relative—*Acentrophorus glaphyrusis* considered as one of the character fishes from the German and English Zechstein Sea. *Acentrophorus robustus* indeed preferred a shallow water, rich in washed in plants. This is proven by specimen found on the Seceda by Michael Wachtler (2020) or together with terrestrial animal tracks in the Bletterbach.

A million-year-long gap record between Kungurian and Wuchiapingian: The area of the Dolomites with the Carnian Alps contain one of the richest plant communities in the world beginning from the Late Carboniferous (Bashkirian-Moscovian-Kasimovian) over the Early Permian (Artinskian, Kungurian). From the Kungurian on (274.1±1.4 Ma) follows a mysterious gap of almost 14 million years, which cannot be explained by any theories so far, covering the whole Guadalupian epoch (Capitanian, Wordian, Roadian stage; from 272,95 till 259,1), in which no fossil record is encountered. Only beginning from the Lopingian the rich plant-fossil deposits reappeared. The reasons for this gap have not yet been explored.

Extraordinary desertic climate near the Permo-Triassic border: Another unresolved problem is why did the climate near the end of the Permian in the Dolomites be-

The new described Semionotide and probably the oldest known representative of Neopterygian-fishes *Acentrophorus robustus* from the Seceda (CUEC 417, Coll. Michael Wachtler, Dolomythos Museum)

come so arid. It is true that for the whole Late Permian a Mediterranean till subtropic climate with probably seasonally dry periods prevailed. This is also the reason for the almost entirely absence of ferns or horsetails. In the Changhsingian age more and more frequent gypsum layers displaced the rich fossil plant deposits. And this was till the Early Triassic. Even this phenomenon can only be explained by a climate collapse.

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