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LATE PALEOZOIC OVERSTEP SEQUENCES OF THE EASTERN AND SOUTHERN ALPS

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Introduction

In the Eastern and Southern Alps Late- to Post-Variscan sedimentation processes started during the Late Carboniferous (Late Moscovian/Cantabrian). The Late- to Post-Variscan Molasse sediments of the Eastern and Southern Alps were deposited in NE - SW and E - W to ESE - WNW oriented intramontane basins which probably formed as a result of crustal thinning associated with strike-slip tectonics along megashear zones due to the eastward drift of the Eurasian plate and westward drift of the African plate respectively.

Tectonic processes and climate, respectively climatic changes, were the most important controlling factors of sedimentation processes, and based on major tectonic and climatic events as well as on fossil assemblages a close correlation between the Late- to Post-Variscan sequences of the Eastern and Southern Alps is possible.

The Late- to Post-Variscan sequence of the Eastern and Southern Alps is divided into two evolutionary cycles, which are separated by a major intra-Permian tectonic event.

The lower cycle (Late Carboniferous/Early Permian) is characterized by the formation of intramontane basins which were filled with sediments of different environments including volcanic rocks. Transgressive-regressive clastic-carbonate cycles within the shallow marine sequence of the Carnic Alps (Southern Alps) are related to eustatic sea-level fluctuations caused by the Gondwana glaciation. The climatic shift from humid to semiarid conditions near the Carboniferous/Permian boundary caused a significant change in sedimentary processes in the continental sequences of the Eastern Alps.

During the upper cycle (?Middle - Late Permian to Early Triassic) sedimentation patterns were more uniform and similar sequences developed in the Southern and Eastern Alps. During this time sedimentation was characterized by the transgression of the Tethys Sea from SE to NW and interfingering of shallow marine sediments with continental deposits. Sedimentation processes were also influenced by a climatic shift near the Permian/Triassic boundary and sedimentary cycles of the Scythian are probably caused by different spreading rates of midoceanic ridges.

The question where to draw the boundary between the Late- to Post-Variscan Molasse sediments and the following Alpidic sedimentation cycle still remains open.

Eastern Alps

In the Eastern Alps, Late- to Post-Variscan sediments are found in all major tectonic units (Penninic Unit, Lower Austroalpine, Middle Austroalpine = Central Austroalpine, and Upper Austroalpine Unit). In the Penninic (Upper Schieferhülle), Lower and Middle Austroalpine Units the Late- to Post-Variscan sequence is very similar and composed of coarse- to fine-grained clastic sediments, in the lower (?Permian) part with intercalated rhyolithic volcanic rocks and reworked volcanic clasts.

All Late- to Post-Variscan sequences of the units mentioned above have been deformed and overprinted by Alpine metamorphism to phengite- and sericite-schists, arkose-schists and arkose-gneisses, quartzites and porphyroides.

Age and depositional environment of all these metasediments are not exactly known due to strong deformation and metamorphic overprint. Further informations are found in Frasl and Frank

(1966), Frank (1972) (Penninic Unit); Tollmann and Faupl (1972), Tollmann (1964) (Lower Austroalpine Unit); Claasen et al. (1987), Krainer (1984), Krois and Stingl (1989), Schünemann et al. (1982) (Middle Austroalpine Unit), for summaries see also Tollmann (1964, 1972, 1977), Oberhauser (1980).

Upper Austroalpine Units

Although Late to Postvariscan sedimentation within the Upper Austroalpine Unit of Carboniferous (Stephanian) age are known from a few places (at the NW-margin of the Gurktal Nappe, the Steinach Nappe), bulk sedimentation did not start before the Earliest Permian (see Fig. 1).

Major progress in stratigraphy and depositional history has been achieved by extensive investigations in recent years (for example Angerer et al. 1976, Haditsch et al. 1978, Niedermayr and Scheriau-Niedermayr 1982, Stingl 1982, 1983, 1984, 1987, 1989, Mostler and Rossner 1984, Krainer 1982, 1985, 1987a,b, 1989a,c,d, 1990a,b, Krainer and Spötl 1989, Krainer and Stingl 1986, Niedermayr 1975, 1985, Poscher 1985, Sylvester 1989a,b).

Late Carboniferous - Early Permian (Lower Cycle)

The best exposed example of Late Carboniferous sediments, which has been intensively studied during the last years, is the Stangnock Formation at the NW-margin of the Gurktal Nappe (Krainer 1989a, c and references therein, Fritz, Boersma and Krainer 1990).

The Stangnock Formation comprises a sequence of more than 400m thick intramontane Molasse sediments and can be divided into 3 units:

A basal sequence consists of polymict conglomerates rich in gneiss clasts, and intercalated immature, coarse-grained sandstones (feldspathic lithic arenites). These sediments are interpreted as deposits of a proximal fluvial system.

The main part of the Stangnock Formation (Hauptserie) is built up by a few, indistinctly developed megasequences. At the base, these megasequences are characterized by a sharp, erosive boundary, starting with sediments of a gravelly braided river system, grading upwards into a gravel-sandstone facies, frequently showing features of a meandering river system. At the top of these sequences usually dark shales with thicknesses up to a few meters occur, which contain abundant, well preserved plant fossils. The shales, interpreted as overbank fines deposited on flood plains and in oxbow lakes, sometimes are overlain by thin anthracite seams.

Conglomerates are very rich in quartz clasts (>90%), sandstones are classified as moderately sorted, subangular lithic arenites and sublitharenites, subordinate lithic wackes, all containing high amounts of polycrystalline quartz.

The top sequence (Hangendserie) shows similar features, slight differences exist concerning the composition of the sediments: sandstones contain volcanic rock fragments, esp. volcanic quartz, referring to first volcanic activity during the Late Carboniferous in this area.

On account of current directions which show a significant eastward trend, it is concluded that the intramontane basin developed in an approximately east-west direction.

The sharp erosive base of the megasequences within the main sequence and top sequence is referred to synsedimentary fracture tectonics (block faulting).

Plant fossils (72 different taxa), which have been studied from more than 20 localities (summary in Fritz, Boersma and Krainer 1990) indicate that the Stangnock Formation is of Stephanian age.

The Stangnock Formation is overlain by Early Permian red beds (Werchzirm Formation).

Within the small Upper Austroalpine Steinach Nappe in western Austria (Tyrol) Late Carboniferous (Stephanian) sediments overlie the presumably Early Paleozoic Steinach Quartzphyllite, a diaphthoritic overprinted metamorphic complex (Frizzo and Visona 1981).

The poorly exposed Stephanian sequence is composed of various channel-, bar- and overbank sediments and thin anthrazite seams which have been mined. The composition is very similar to the sediments of the Stangnock Formation: Conglomerates are again very rich in quartz clasts. Sandstones are classified as lithic arenites, sometimes as lithic wackes (Krainer 1990a, see also Schmidegg 1949, Karl 1956).

According to the depositional history and composition the Late Carboniferous (Stephanian) sequence of the Steinach Nappe is very similar to the Stangnock Formation, especially to the conglomerate-sandstone facies of the main sequence.

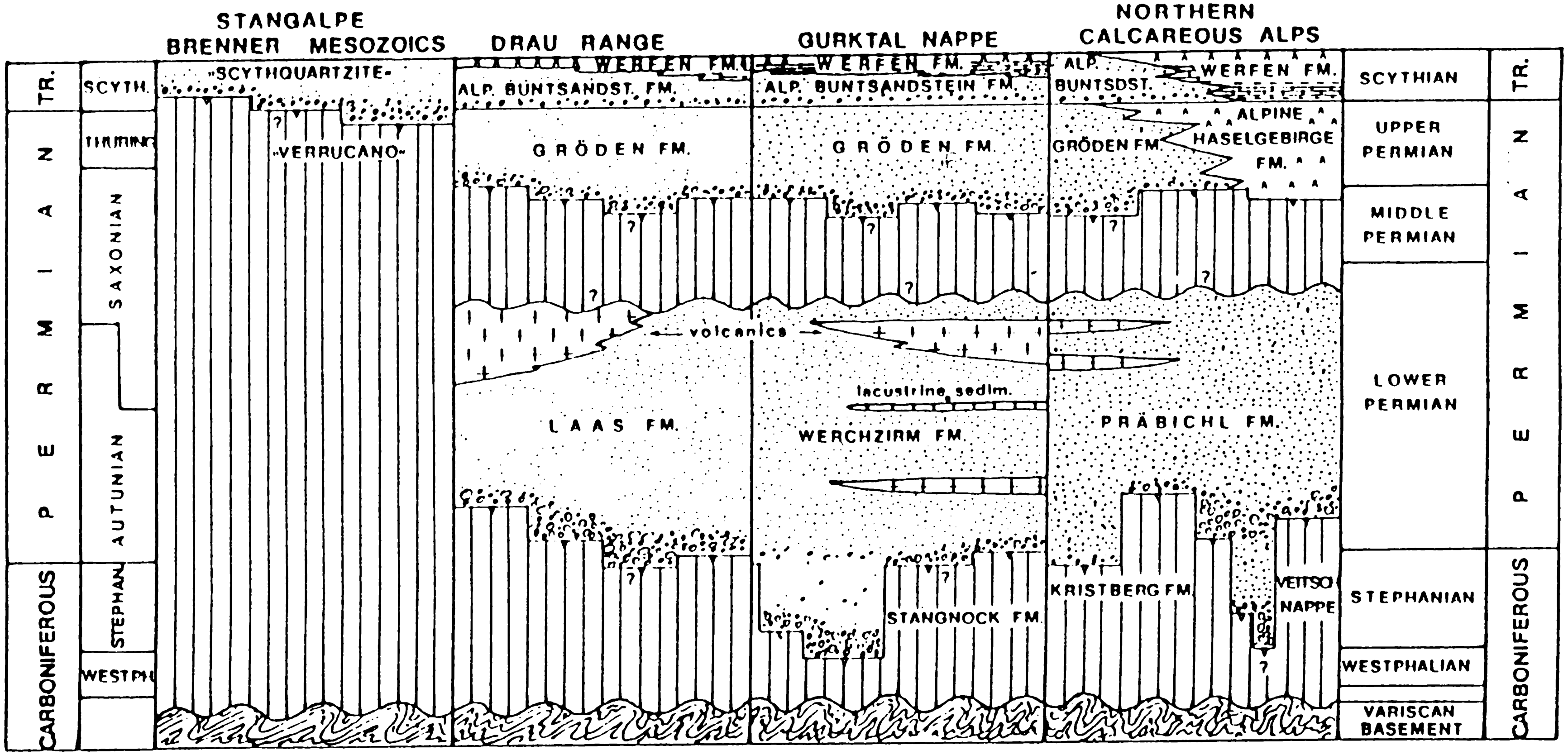

Fig.1: Schematic stratigraphic framework of late- to post-Variscan (Late Carboniferous to Early Triassic) sediments in some Austroalpine Units (Centralalpine and Upper Austroalpine). Legend see Fig. 3.

The Late Carboniferous sediments of the Steinach Nappe are also interpreted as intramontane Molasse sediments, which probably have been formed in the same basin system as the Stangnock Formation.

Shales contain plant fossils (about 30 different taxa are known) pointing to Early Stephanian (Cantabrian/Barruelian) age.

The Permian sequence of the Upper Austroalpine Unit, which rarely contains fossils, is divided into two lithostratigraphic units, separated by a major hiatus ("Saalian movements"): the Early Permian lithostratigraphic unit of the lower cycle, and the Late Permian lithostratigraphic unit of the upper cycle (see Fig. 2).

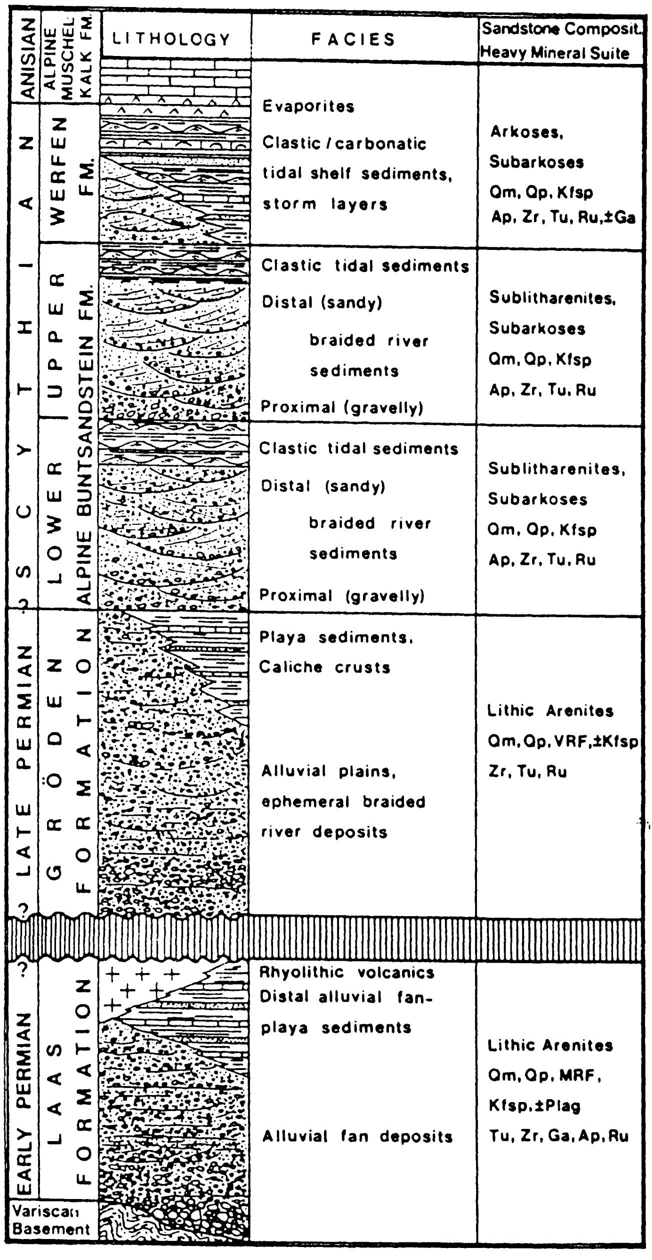

Fig.2: Generalized lithostratigraphic column of Permian and Early Triassic (Scythian) se-diments of the Drau Range with depositional environment, sandstone composition (Qm= monocrystalline, Qp= polycrystalline quartz, Kfsp= kalifeldspar, Plag= plagioclase, VRF= volcanic rock fragments, MRF= metamorphic rock fragments) and heavy mineral assemblages (Ap= apatite, Ga= garnet, Ru= rutile, Tu= tourmaline, Zr= zircon).

Proximal to distal alluvial fan sediments (red colored breccias, conglomerates, immature sandstones), grading into fine-grained sandflat-playa complexes with caliche-crusts and rare thin algal layers at some places, characterize the Early Permian throughout all tectonic units (Basalbreccia and Präbichl Formation in the Northern Calcareous Alps, Laas Formation in the Drau Range, Werchzirm Formation in the Gurktal Nappe, maximum thickness about 150m; see Krainer 1987b, 1989d, 1990b, Krainer and Stingl 1986 a,b, Niedermayr and Scheriau-Niedermayr 1982, Stingl 1983, Sylvester 1989a,b). In most cases, these sediments overlie the Variscan basement, which is formed of crystalline rocks. (schists, gneisses etc., Drau Range) or different, weakly metamorphosed Variscan sediments. At the NW-margin of the Gurktal nappe, Early Permian red beds overlie Late Carboniferous sediments (Stangnock Formation). The Early Permian sediments are rich in clasts derived from the local basement, especially weakly metamorphosed old Paleozoic rocks (polymict conglomerates, lithic arenites and wackes).

In some places plant fossils of the Callipteris conferta Zone are known from the base of this Early Permian sequence indicating lowermost Permian age (Van Amerom et al. 1982, Fritz and Boersma 1987a,b, 1988, Fritz, Boersma and Krainer 1990).

In the Drau Range, Gurktal Nappe and the westernmost part of the Northern Calcareous Alps, rhyolithic volcanics (ignimbrites and pyroclastic flows) with thicknesses up to about 100 m are widespread on top of this Early Permian sequence. From these volcanics no radiometric age determinations exist, but based on palynological data from lacustrine sediments within the equivalent Bolzano Volcanic Complex of the Southern Alps, the Early Permian sequence, including the rhyolithic volcanics, probably reaches up to Late Artinskian - Kungurian (Hartkopf-Fröder and Krainer 1990).

Late Permian - Early Triassic (Upper Cycle)

With a hiatus caused by block faulting ("Saalian movements"), Late Permian siliciclastic sediments (conglomerates, sandstones, shales of red bed type) of ephemeral braided rivers and playas termed Gröden Formation overlie Early Permian sediments and mark a sudden and significant change in sedimentation. This hiatus marks the boundary between the lower and upper cycle and is equivalent to that between the Bolzano Volcanic Complex and Gröden Formation or between the Trogkofel limestone and Tarvis breccia in the Southern Alps. The sediments of the Gröden Formation contain high amounts of reworked volcanic fragments derived from the volcanic rocks on top of the Early Permian sequence, and are lacking stratigraphically significant fossils (Krainer 1987b, 1989d, 1990b, Niedermayr and Scheriau-Niedermayr 1982, Stingl 1983, Sylvester 1989a,b). In the Drau Range and Gurktal Nappe the maximum thickness is about 350m, in the Northern Calcareous Alps about 800m.

In the central and eastern realm of the Northern Calcareous Alps a few hundred meters of halite-bearing marine evaporites were deposited in an approximately E-W-trending Late Permian rift, now represented by a strongly deformed decollement horizon at the base of the Northern Calcareous Alps (Spötl 1987, 1988a,b, 1989). Stratigraphical and paleoenvironmental data (S-isotopes of sulphate minerals, bromide content in halites, pollen and spores as well as scarce marine bivalves) unequivocally support a marine origin for this Late Permian evaporites ("Alpine Haselgebirge") (Spötl 1989).

The boundary between the late Permian Gröden Formation and Scythian Alpine Buntsandstein Formation is documented by an abrupt change in the depositional environment and composition of the sediments, caused by a climatic change to slightly more humid conditions. This boundary presumably corresponds to the Permian/Triassic boundary (Brandner et al. 1986, Krainer 1987a).

Based on transgressional and regressional events, the Scythian sequence of the Drau Range and Gurktal Nappe can be subdivided into three fining upward megasequences: Lower and Upper Alpine Buntsandstein Formation and Werfen Formation (Krainer 1985, 1987a).

Lower and Upper Alpine Buntsandstein Formations are built up by quartz- rich conglomerates of a gravelly braided river system, grading upward into small-scale fining-upward cycles of a sandy braided river system. Some sections contain clastic shallow-marine sediments developed on top. Compared to the Permian sandstones (uncemented, poorly sorted angular lithic arenites rich in volcanic fragments), Scythian sandstones are better sorted and rounded, well cemented by authigenic overgrowths of quartz and feldspar and carbonate cements in most cases, and contain more quartz and detrital feldspars. The heavy mineral composition also differs significantly. The regressive event at the base of the Upper Buntsandstein Formation can be compared with the regressive "Campill Event" in the Southern Alps based on palynomorphs. The dominantly siliciclastic sediments of the Werfen Formation, containing thin intercalated fossiliferous limestone beds, were deposited on a shallow-marine, tidally influenced epicontinental shelf.

Southern Alps

In the Southern Alps Late Carboniferous-Permian sediments lie on the variscan basement with a classical unconformity. This basement was folded and, in the western part, slightly metamorphosed during Westphalian times. Within the Late to Post-Variscan sedimentary sequence, two cycles can be recognized, which are separated by a main unconformity (Figs 3, 4; see Massari 1986).

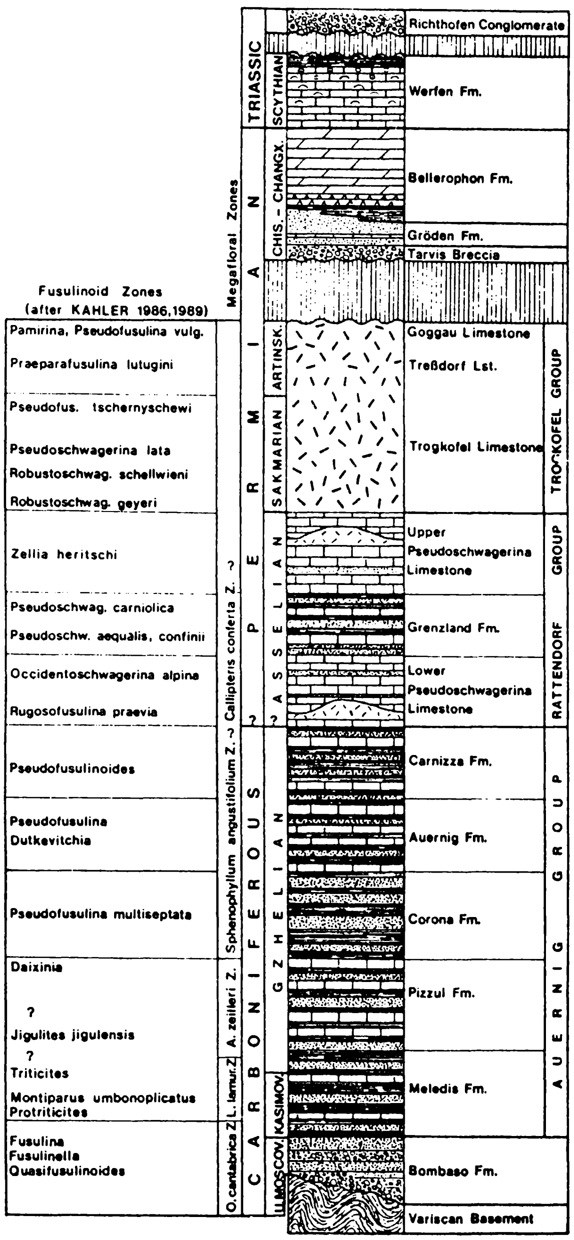

Fig.3: Generalized stratigraphic column through the late- to post-Variscan (Late Carboni-ferous to Early Triassic) sequence of the Carnic Alps in the Trogkofel - Gartnerkofel area.

The first cycle is characterized by Late Carboniferous-Early Permian sediments and volcanic rocks which were accumulated in intramontane basins formed by block- and wrench-faulting. In the Carnic Alps and Southern Karawanken Mountains, the sequence of the first cycle is represented by cyclic deltaic and shallow marine clastic and carbonate sediments, the Bombaso Formation, Auernig, Rattendorf, and Trogkofel Group, ranging from Late Moscovian to Late Artinskian.

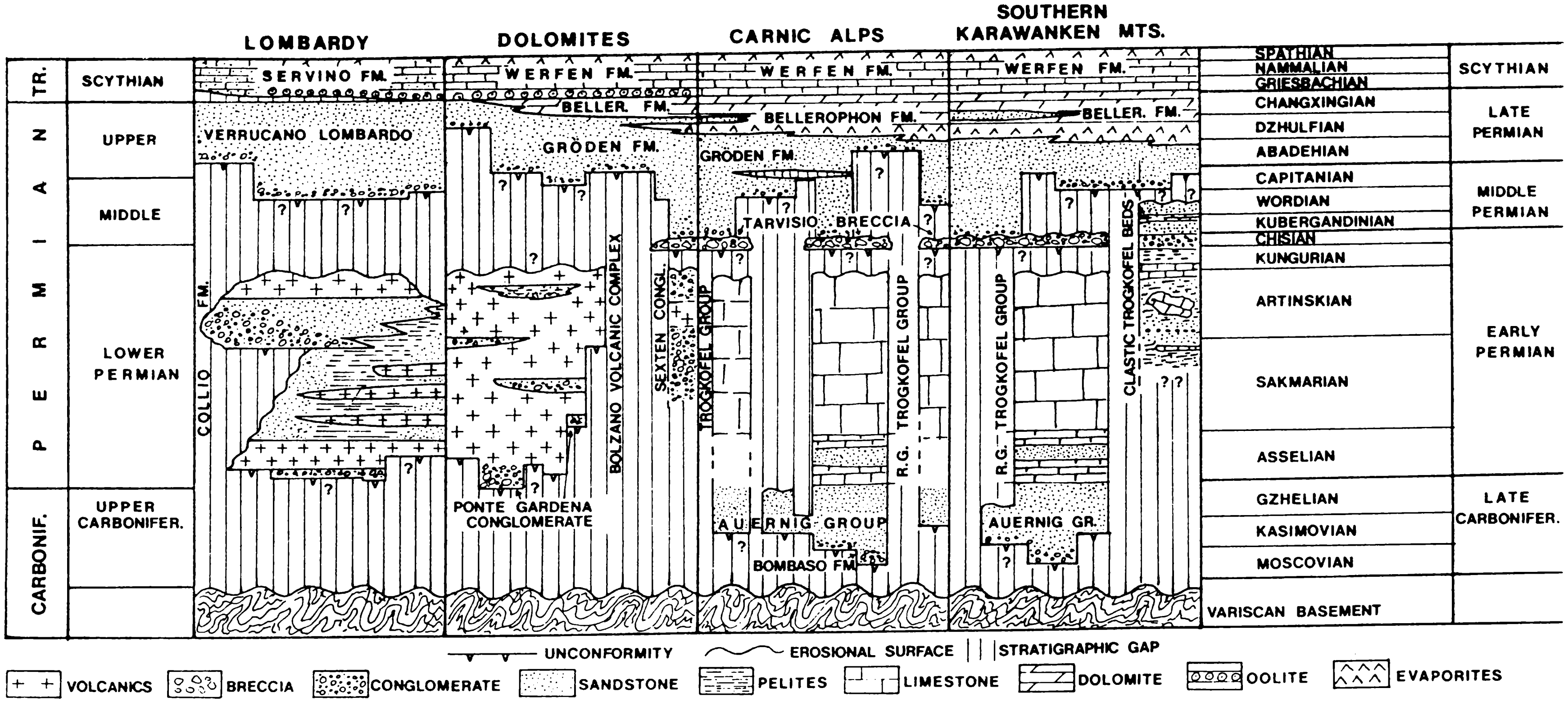

Fig.4: Schematic stratigraphic framework of late- to post-Variscan (Late Carboniferous to Early Triassic) sediments of the Southern Alps (after ITALIAN RESEARCH GROUP 1986, p.37 and Massari et al. 1988, varified and supplemented). RG = Rattendorf Group.

In the Dolomites, the first cycle is formed by the local development of thin alluvial fan sediments (Ponte Gardena/Waidbruck Conglomerate). It is followed by a thick volcanic sequence of latiandesitic to rhyolitic tuffs, ignimbrites and lavas with intercalated fluvial and lacustrine sediments (Bolzano Volcanic Complex) of Early Permian age. In the Lombardian Alps, south of the Adamello Massif, different intermontane basins formed, which were filled with thick sequences of volcanic rocks and clastic sediments (Collio Formation).

With a hiatus (?)Middle -Late Permian sediments of the second cycle, which are more widely distributed but not restricted to discrete basins, unconformably overlie Early Permian or even older rocks. In the Southern Karawanken Mountains, Carnic Alps and Dolomites, the second cycle starts with continental to shallow marine clastic sediments of the Gröden Formation which repeatedly interfinger with and grade upwards into the shallow marine evaporitic and carbonate sediments of the Bellerophon Formation. The Bellerophon transgression prograded slowly westwards over a very low-gradient and flat landscape. Sabkha-sediments formed on this very shallow and wide, evaproitic transition zone sabkha-sediments formed. During prograding transgressional events, fossiliferous limestones of open-lagoon shallow water environments were deposited. West of the Dolomites, the second cycle is represented by continental red beds of the "Verrucano Lombardo" and by shallow marine sediments of the Servino Formation (see summary in Krainer 1992).

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