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The Devonian of Austria[3]

by
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with 9 figures

Summary

Fossil bearing strata of Devonian age have been recognized in the Alps as early as 1843. Such classic regions comprise the surroundings of the city of Graz in Styria and its eastward continuation to southern Burgenland, the Carnic and Karawanken Alps at the Italian/Slovenian border, the Graywacke Zone of Styria, Salzburg and Tyrol and rather small occurrences of the so-called Gurktal Nappe of Middle Carinthia and parts of Styria (Fig. 1). Furthermore, based on rare microfossil occurrences and geochronologic data it may be concluded that a considerable part of the pre-Alpine crystalline complexes was also deposited during this time. However, this sedimentary and volcanogenic sequence of unknown thickness was affected by greenschist and amphibolite-grade metamorphism attributed to the Variscan orogeny of the late intra-Devonian.

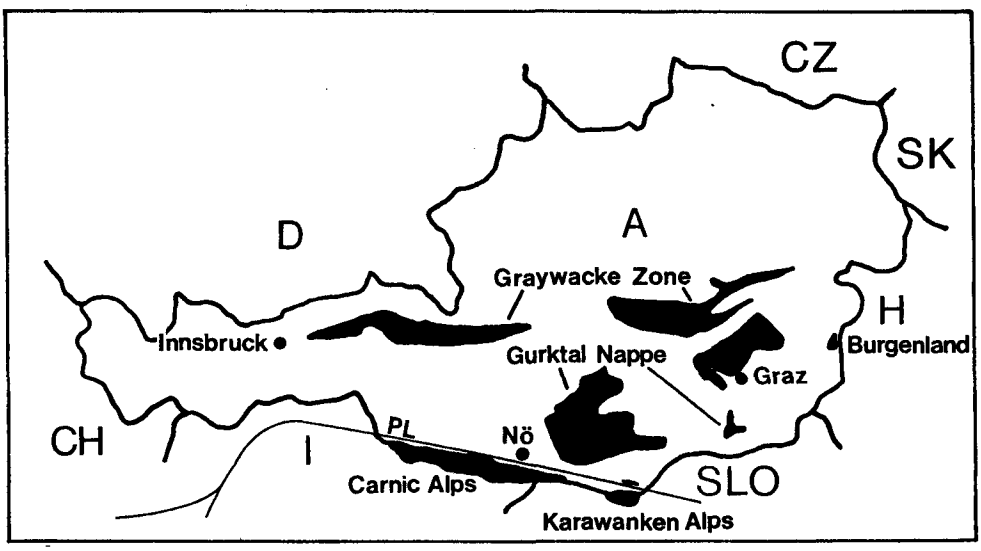

Fig. 1. Main regions with fossiliferous Paleozoic strata in the Eastern and Southern Alps (PL = Periadriatic Line, Nö = Nötsch).

In the Alps the equivalents of the Devonian Period are characterized by abundant shelly fossils and carbonate as well as clastic sequences of varying thicknesses. In addition some basic volcanics occur in the Graz Paleozoic and in the Graywacke Zone. The limestone development ranges from true reefs and carbonate buildups to slope and condensed cephalopod limestones of an open marine offshore environment on the sea-side and platform and coastal deposits on the land-directed other

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side. In the Carnic Alps, for example, the relationship between shallow water limestones and contemporary goniatite limestones is approx. 12 : 1 indicating an extensional regime of enhanced mobility accompanied in some areas by rifting related basic volcanism in the Lower and Middle Devonian prior to the climax of the Variscan perturbations.

For the Devonian strata of the Alps the analysis of climate sensitive lithologies suggests a setting within the tropical belt of 30° southern latitude. Biogeographically, close relations exist to coeval faunas and floras of Bohemia, the Urals, Kazachstan, Altai and Tienshan and less pronounced to the Eifelian Hills, the Ardennes and Northern Africa for the Lower Devonian. From the Middle to the Upper Devonian cosmopolites are dominating like ammonoids, trilobites, brachiopods, corals and algae which reflect an overall uniform character and are only of limited use to reconstruct old pathways (Schönlaub 1992 and Fig. 2). Whether or not several distinct Devonian microcontinents are assembled in an Alpine collage is yet not fully understood

In more detail the biogeographically relevant data from the Alps reflect the following relationships (Fig. 2):

- Lower Devonian faunal and floral affinities (brachiopods, corals, gastropods, trilobites, algae) exist with central and northern Europe and the Ural - Tienshan regions;
- Loose contacts are with northern Africa;
- During the Middle and Upper Devonian cosmopolites dominate;
- The Devonian is characterized by thick carbonate deposits and buildups with abundant shelly fossils;
- Volcanic events reflect a rifting stage;
- Locally (e. g., surroundings of Graz) a hypersaline environment developed..

In conclusion,

- ➢ for the Devonian of the Alps a paleolatitudinal position within the tropical belt of some 30° S or less is inferred;
- ➢ mobile basins were affected by extensional tectonics; the oceanic circulation system aided the dispersal of many organic groups;
- ➢ two terranes or microcontinents may have existed in the Alps suggesting latitudinal differences between the Southern Alps and the Graz Paleozoic;
- ➢ during the Devonian the relative plate motion of Africa changed resulting in a southward shift of Africa relative to the South Pole ("loop" of APWP).

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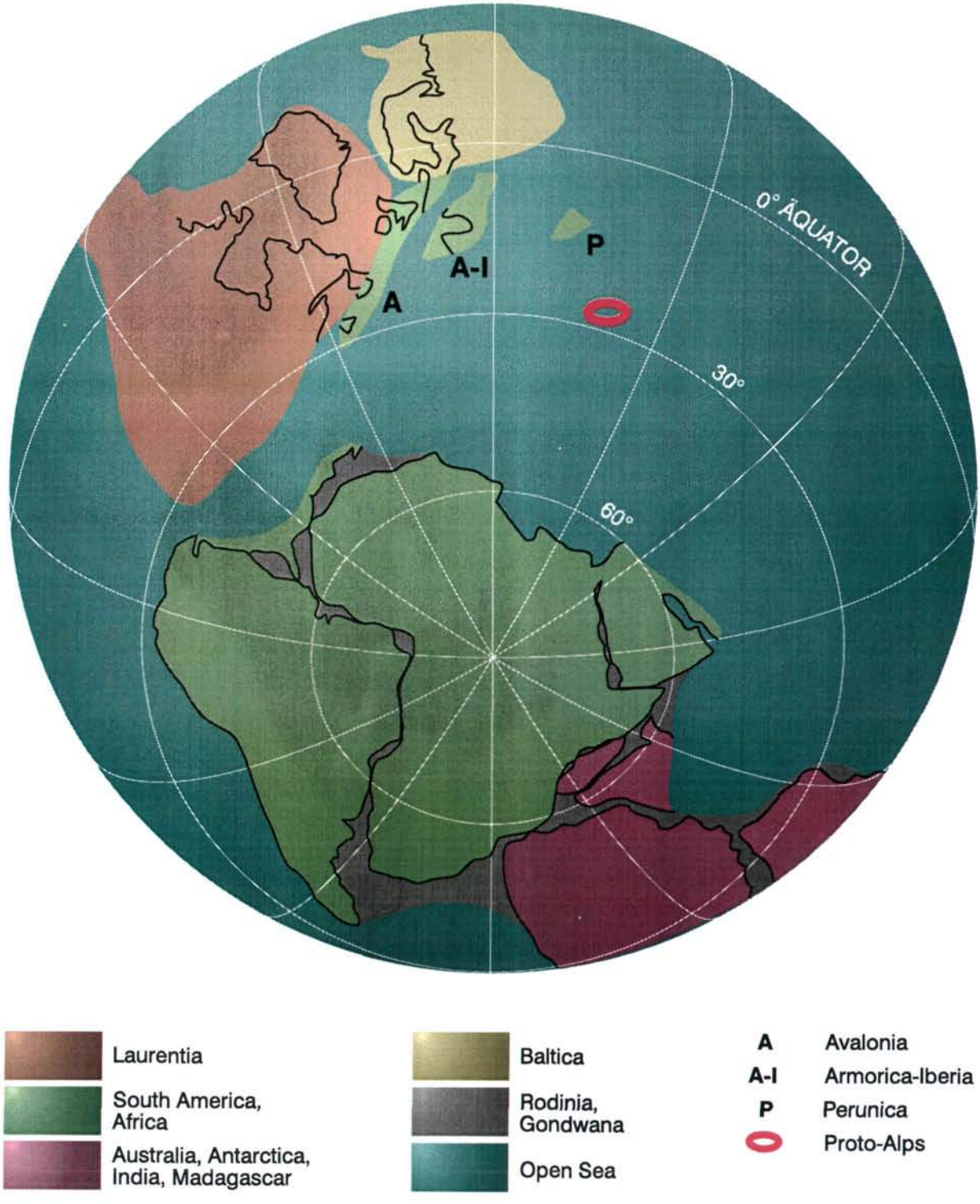

Fig.2.
Late Devonian (c. 360 Ma) paleogeographic reconstructions of the Atlantic bordering continents (after V. BACHTADSE et al. 1995, modified).

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The Devonian of the Carnic and Karawanken Alps of Carinthia

The Paleozoic Units of the Carnic and the Karawanken Alps represent the basement of the Southern Alps. They are separated from the Central Alps by the Periadriatic Fault system (Fig.1). The Carnic Alps extend in West-East-direction over 140 km from the village of Sillian in Eastern Tyrol to Arnoldstein in Carinthia. In the following Western Karawanken Alps the Variscan sequence is almost completely covered by rocks of Alpine age. To the east, however, the Lower Paleozoic sequence is well exposed in the Seeberg area south of the city of Klagenfurt. In this Eastern Karawanken region Lower Paleozoic rocks occur on both sides of the Periadriatic Fault. They are subdivided into a small northern and a more prominent southern part, the latter extending beyond the stae boundary to Slovenia.

The Carnic Alps

The Paleozoic of the Carnic Alps represents one of the very few places in the world in which an almost continuous fossiliferous sequence has been preserved (Fig. 3). Ongoing geological and paleontological research started in the middle of the last century. More recent investigations in the Devonian sequences were carried out during the last 30 years by Bandel (1969, 1972, 1974), Ebner (1973), Kreutzer (1989, 1990, 1992a/b), Oekentorp-Küster & Oekentorp (1992), Schönlaub (1979, 1985, 1992), Schönlaub et al. (1992), Schönlaub & Heinisch (1993), Schönlaub & Flajs (1975) on the Austrian part of the mountain range and by Ferrari & Vai (1965), Galli (1985), Schönlaub & Kreutzer (1993), Spalletta & Vai (1984), Spalletta et al. (1983, 1994) on the Italian side.

According to Kreutzer 1992a,b in the Carnic Alps the Devonian Period is characterized by the development of five north-northeast to south-southwest directed facies belts (Fig. 4). During the Variscan orogeny these belts were transformed into strongly deformed nappes which from top to base can be subdivided into the following tectono-stratigraphic units:

1: Southern shallow water facies (Cellon-Kellerwand nappe)
  a : Intertidal subfacies (Biegengebirge, Gamskofel)
  b : Back reef subfacies (Upper Kellerwand, Hohe Warte, Biegengebirge)
  c : Reef subfacies (Hohe Warte, Upper Kellerwand)
  d : Reef debris subfacies (Hohe Warte, Upper Kellerwand)
2: Transitional facies (Cellon nappe)
3: Pelagic limestone facies (Rauchkofel nappe)
4: Offshore pelagic basinal facies (Bischofalm nappe)
5: Northern shallow water facies (Feldkogel nappe)

During the Caradoc Series of the Ordovician sedimentation was dominated by siliciclastic deposits. Already in the following Ashgill Series a weak differentiation of facies is indicated by the development of different cool water limestones. According to Dullo (1992) the Wolayer limestone (south position) represents a near-shore parautochtoniuos cystoid facies and the Uggwa Limestone (north position) an off-shore basinal debris facies. However, the Ordovician reef evolution never exceeded a pioneer faunal stage with crinoids suggesting a biostromal tendency with low topographic differences. This setting together with the contemporary faunal relationships with neigbouring regions may correspond to a position of about 45° southern latitude (Schönlaub 1992).

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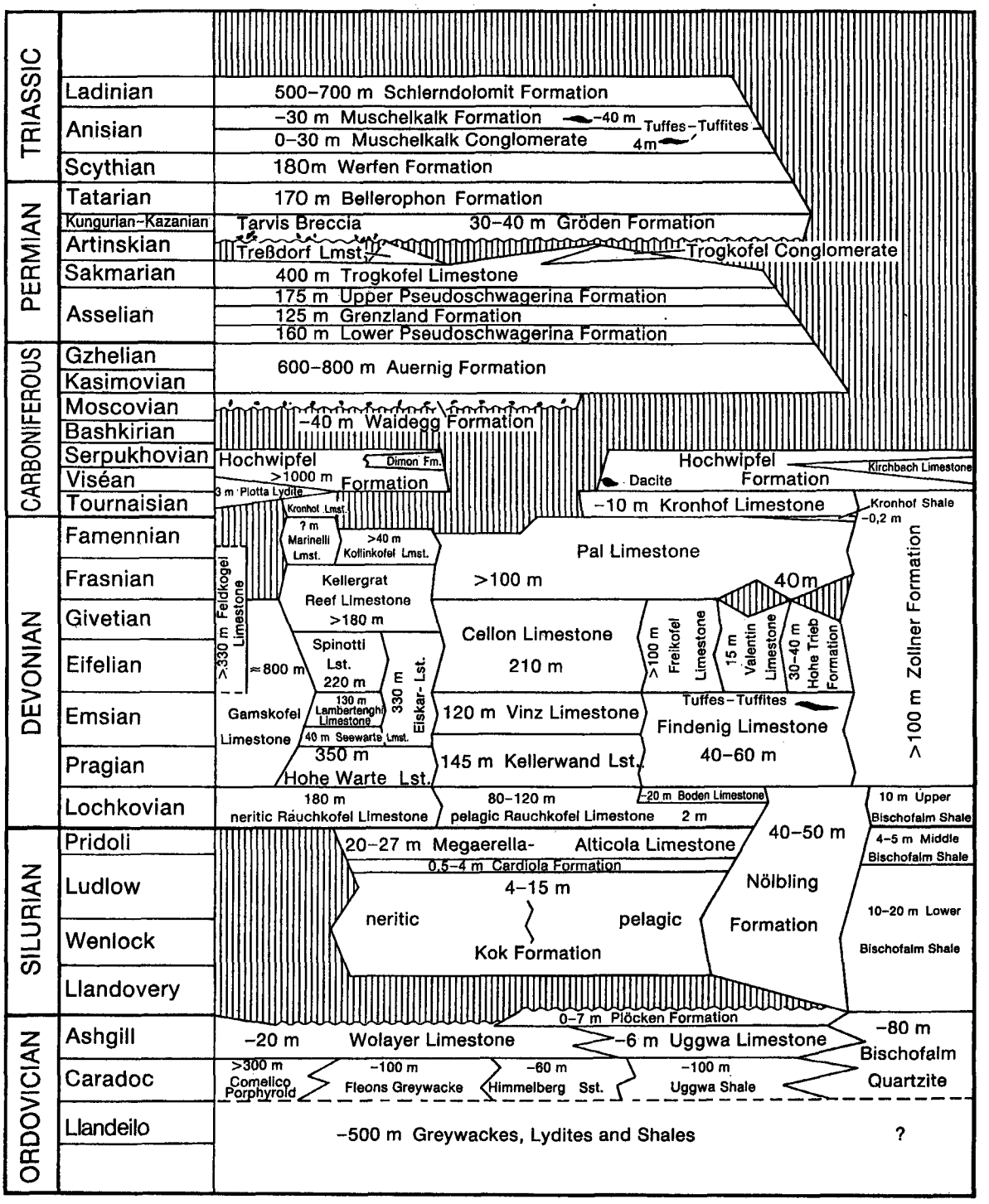

Fig. 3: Stratigraphy of the Paleozoic sequences of the Carnic Alps after Schönlaub (1986), modified by Kreutzer (1992b).

In agreement with other regions in the Carnic Alps the passage from the Ordovician to the Silurian is characterized by a regressive-transgressive relationship. The first is related to the retreat of the sea coupled with the glacial event in the Southern hemisphere during parts of the Hirnantian Stage while the latter may indicate the rising

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sea level following an abrupt end of the glaciation. Thus, in the Llandovery the transgressive Kok-Formation disconformably overlies the late Ordovician Plöcken Formation in all sections dominated by limestones (for example in the famous Cellon section representing a southern paleogeographic position). In other sections, e.g. in the Wolayer facies of the Seekopf section the Silurian sequence is considerably reduced; it represents a more northern position. According to Schönlaub (1992) the paleogeographical position of the Silurian is estimated at about 30 degrees southern latitude. Similar to the Ordovician development, the Silurian carbonate buildups suggest a rather low relief.

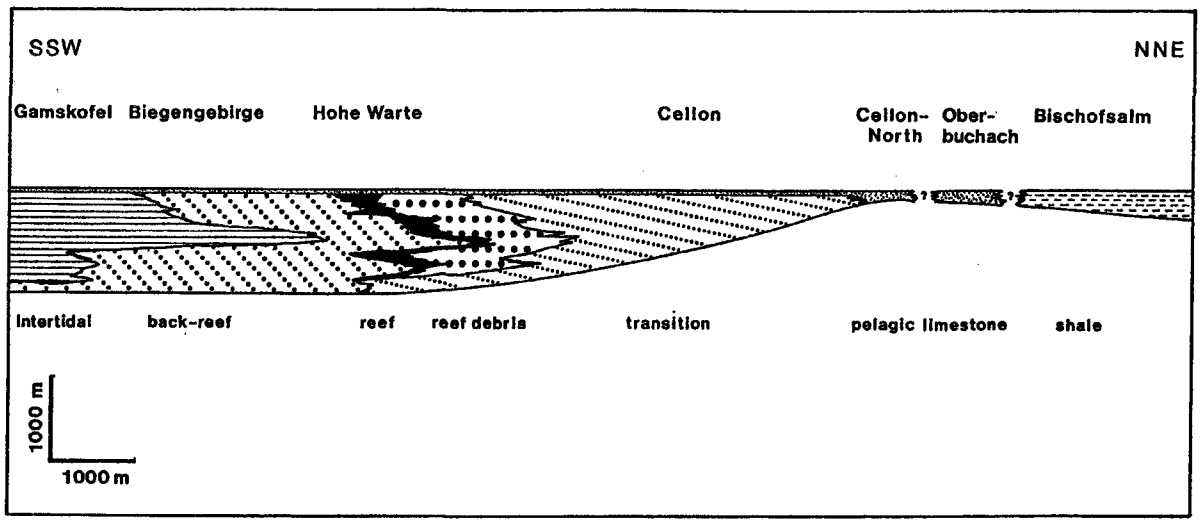

Fig. 4. Palinspastic profile of the Carnic Alps at the Devonian/Carboniferous boundary (Kreutzer 1992a). Gamskofel, Biegengebirge, Hohe Warte: Southern shallow water facies (Kellerwand nappe); Cellon: Transitional facies (Cellon nappe); Cellon-North, Oberbuchach: Pelagic limestone facies (Rauchkofel nappe); Bischofalm: Offshore pelagic basinal facies (Bischofalm nappe). Somewhere to the north the northern shallow water facies of the Feldkogel nappe occurs.

During the Lochkovian and Pragian Stages corals and stromatoporoids slowly proceeded and first patch reefs started to grow. At the same time in the southern realm of the Kellerwand nappe a shallow water subfacies developed. Schönlaub (1992) estimated the global position of the Carnic Alps in the Middle Devonian at about 30 degrees southern latitude.

In the Carnic Alps the prominent and more than 1300 m high cliffs of the Kellerwand and of the Hohe Warte (altitude 2784 m above sea level) represent the centres of the Devonian reefs (Fig. 5) having their climax in the Givetian and Frasnian Stages. The strongly varying thicknesses of the facies belts during the Devonian (see Fig. 5) indicate a differently subsiding mobile basin in an extensional regime which contrasts with the foregoing Silurian Period. In fact, during the time from the Lochkovian to the Frasnian in the facies belt 1 about 1100 metres of shallow water limestones were deposited (Kreutzer, 1990). They correspond to coeval pelagic cephalopod limestones with markedly reduced thicknesses of some 100 m of facies belt 3. Between this two facies belts a transitional environment with changing thicknesses is developed representing the facies belt 2. In conclusion, the different lithologies of the limestone development can be attributed to at least 13 microfacies types (Kreutzer 1990, 1992a/b).

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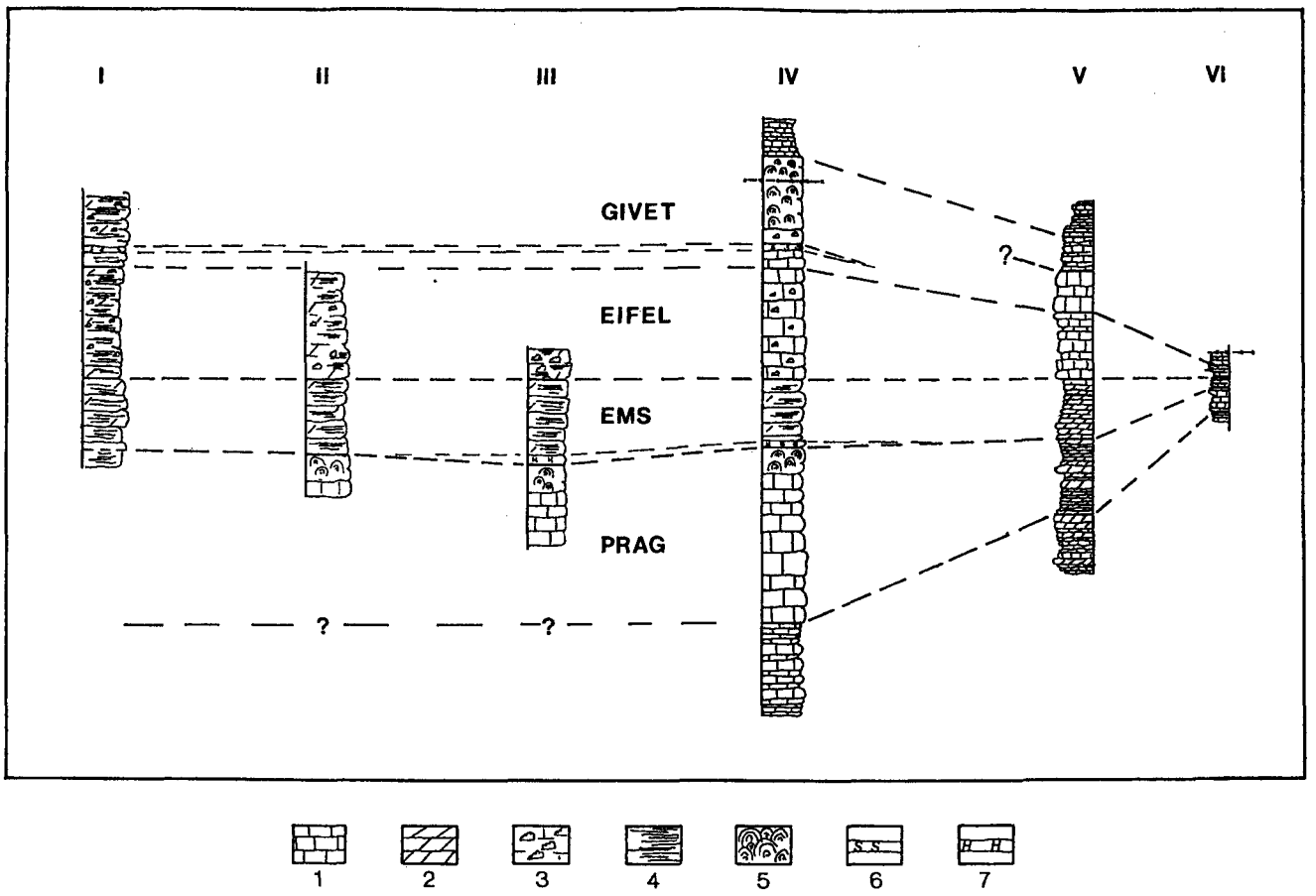

Fig. 5: Correlation of Devonian sequences in the Carnic Alps (Kreutzer 1992a).
Southern shallow water facies: I = Gamskofel; II = Biegengebirge (Austriascharte); III = Biegengebirge (Seekopf); IV = Hohe Warte, Upper Kellerwand
Transitional facies: V = Lower Kellerwand, Cellon
Pelagic limestone facies: VI: Oberbuchach
1: Bedded limestone; 2: Dolomite; 3: Birdseye limestone; 4: Laminite; 5: Reef buildups; 6: *Stringocephalus* layer; 7: *Hercynella* layer

The reef development ended in the upper *gigas* Zone (Kreutzer 1990, 1992a/b). During the following Famennian Stage the environment reflects a general trend towards a uniform pelagic setting which was finally established at the beginning of the Carboniferous Period (Fig. 3). The Lower Carboniferous Kronhof Limestones represents such a cephalopod-trilobite bearing wackestone.

The forementioned pelagic limestones facies grades to the north-northeast into the coeval siliciclastic Zollner Formation of facies belt 4. At the base of the Pragian Stage this lithology succeeded the Silurian to Lochkovian graptolite bearing Bischofalm Formation and continued into the Lower Carboniferous. Yet, only few localities are known in which interbedded limestones and siliciclastic layers occur (Dellachalm Shale). Schönlaub (1985) interpreted these green shales as a transition between the phacoid Findenig Limestone and the Zollner Formation.

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The Karawanken Alps

The Devonian outcrops in the Karawanken Alps occur within a tectonic window called "Seeberg Aufbruch" (Rolser & Tessensohn 1974, Fig. 6) and "Eisenkappel Aufbruch", respectively, the latter being located close to the Periadriatic Fault (Fig. 1). Along the river Trögern the Eisenkappel Aufbruch ranges from the Upper Ordovician to the Permian. The Ordovician limestones resemble those from the Carnic Alps. According to Tessensohn (1983) the Silurian succession exhibits rich occurrences of biostratigrahically important faunas which is closely related to coeval faunas of the Carnic Alps. With regard to the Devonian reef environment, the Seeberger Aufbruch represents the most important structure of the whole Karawanken Alps. In this area the following tectonic units can be subdivided from top to base (Fig. 6):

- Triassic of Steiner Alpen
- Reef Unit ("Riffkalkeinheit" - pelagic, near reef and reef core and volcanic Devonian)
- Banded limestone Unit ("Bänderkalk" - Upper Devonian to Lower Carboniferous striated banded limestones)
- Basal Unit (exposed in the "Seeberg - Fenster" - Upper Carboniferous shales and limestones)

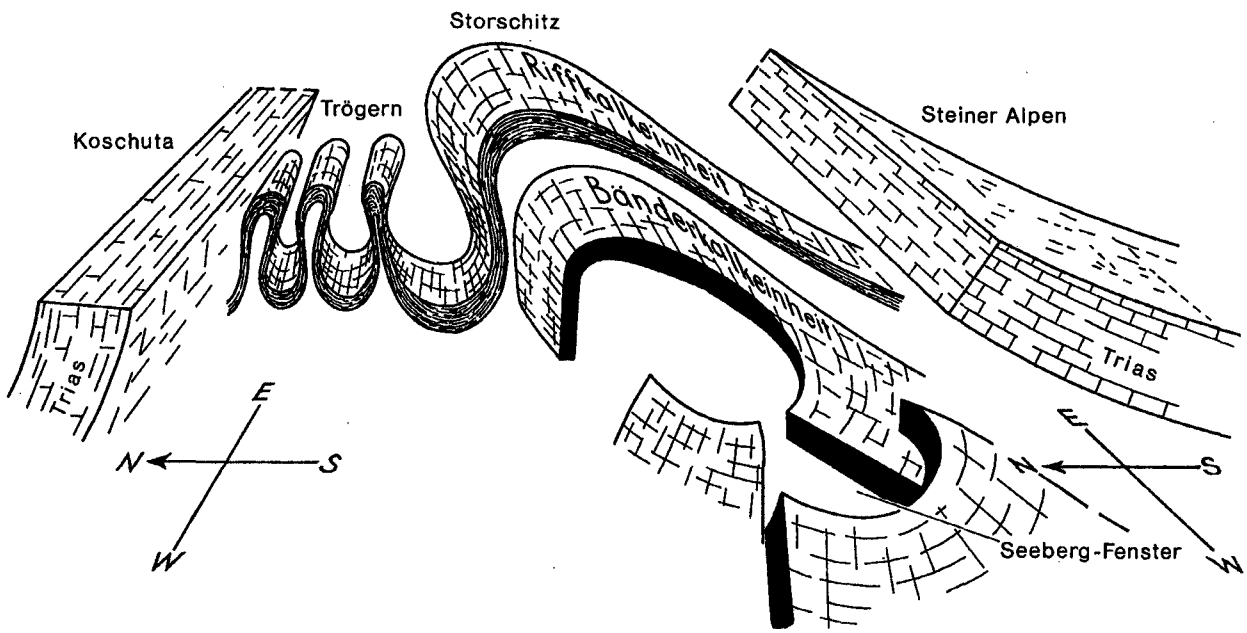

Fig. 6. The main tectonic units of the Seeberg area of the Eastern Karawanken Alps (after Rolser & Tessensohn 1974).

A revision of older stratigraphic data and introduction of new methods including study of the petrofacies were carried out by Kupsch et al. (1971) and Tessensohn (1974a,b). According to these authors the Seeberg realm represents Paleozoic sediments which range from the Silurian to the Permian. More recently, Rantitsch (1992) studied the relationship between the different Devonian lithologies and in particular the reef limestone development wich were strongly dislocated by Alpine tectonics.

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The Devonian limestone sequences comprises the Devonian to Carboniferous banded limestone ("Bänderkalk") and the reef limestone unit forming an anticlinal structure. Both units are underlain and covered by clastic rocks. According to Tessensohn (1974a, 1983) the limestone sequences of the reef unit comprises an environment which ranges from reef buildups to reddish pelagic phacoidal limestones of Devonian to Lower Carboniferous age. The main reef environment is exposed in the centre of the Seeberg Aufbruch at the localities "Storschitz", "Gut Haller"and "Christophorus-Rock" and is represented by massive limestones. Recently these strata were restudied by Rantitsch (1992) who confirmed 8 different types of microfacies for the near reef realm of the back-reef, the reef-core and the debris facies. As the centre of the reef-core he identified a Stromatoporoid-*Renalcis* facies with a debris area in front. On the back side of the reef core lagoonal and platform carbonates are developed. Rantitsch concluded a reef system in which the facies belts interfinger within short distances. According to Tessensohn 1983 southwest of the locality Sadonig-Höhe clastic rocks occur within the Reef unit. In the shales and greywackes basic to intermediate tuffs as well as some phacoidal limestone beds are intercalated. Based on conodonts a Middle Devonian age has been demonstrated for these beds by Loeschke & Rolser (1971).

In addition to the main reef development in the Karawanken Alps also an inter reef mudstone facies can be recognized suggesting a simultaneous sedimentation between single reef cores. Such a pattern may be compared with modern days atoll reefs (Rantitsch 1992).

Comparison and Conclusions:

The facial environment of the Devonian of the Karawanken Alps and its different microfacies types (Rantisch 1992) display many similarities with coeval strata of the Carnic Alps by Kreutzer (1990, 1992a,b). In both areas the biohermal reef growth lasted from the Lower Emsian to the Frasnian (Kreutzer 1990, Tessensohn 1974 a,b, 1983).

Rantitsch determined a carbonate content between 95 and 100 % indicating a very low terrigeneous influence. Similar conditions were concluded by Kreutzer (1990) for the Carnic Alps. According to Tessensohn (1794a, 1983) and Rantitsch (1992) the fauna of the reef and back-reef area are dominated by representatives of *Favosites, Heliolites, Thamnopora, Renalcis, Amphipora, Thamnophyllum*. The same association occurs in the Carnic Alps (Kreutzer 1990, 1992a,b, Oekentorp-Küster & Oekentorp 1992). In the Devonian of the Carnic Alps Kreutzer estimated the transition from intertidal flats to the pelagic limestone facies within a distance of less than 9 km. A short transition was also postulated by Rantitsch for the facial belts of the Karawanken Alps. In addition Rantitsch proposed a model with atoll reefs in the Devonian of the Karawanken Alps. According to Kreutzer (1990) in some areas of the Carnic Alps reef core sedimentation is interrupted by low energy sediments. Yet, the only proof of volcanic activity in the Devonian of the Carnic Alps are layers resembling tuffites which are intercalated in the Lower Devonian Findenig Limestone. Finally, with consideration to the very low terrestrail influx of the limestone sequences the intertidal realm of the Biegengebirge area of the Carnic Alps suggests an island setting.

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In conclusion, during the Devonian the Carnic and the Karawanken Alps exhibit a closely similar environment. According to new investigations carried out in the past 30 years, a barrier reef belt is suggested which grades to the north into a basinal areas and to the south into a back reef lagoon or platform development. Yet, any indication of a nearby land area is missing from which a clastic input may be derived. In conclusion, the microfacial environment and the facial belts of the Carnic and Karawanken Alps closely correspond to the "model for reef and shallow water platform" of Machel and Hunter (1994).

The Graz Palaeozoic

The Graz Palaeozoic, part of the Upper Austroalpine nappe system, comprises an outcropping area of approx. 1250 km^2. Presumably, the Ordovician to Carboniferous sequences overly a metamorphic basement which is well preserved in a marginal position: In the northern and western part fossiliferous Paleozoic rocks are overthrust upon the Middle Austroalpine Unit, i. e. the Gleinalm crytalline complex and in the eastern part upon the Lower Austroalpine Unit, i.e. the Raabalpen complex. In its western sector the Palaeozoic succession is unconformly overlain by the Upper Cretaceous Kainach Gosau. To the south it is covered by Neogene sediments of the "Styrian Basin".

The Graz Paleozoic represents a pile of nappes. These nappes are composed of different facies or a mixing of several facies (Flügel and Neubauer 1984). Considering lithological similarities, the tectonic position, and metamorphic superposition, a lower, an intermediate, and an upper group of nappes can be differentiated (Fig. 7):

(1) The Lower Nappe System (Upper Silurian to Lower Devonian) comprises the 'Schöckl-Group', the 'Passail-Group' and the 'Anger Crystalline Complex'. Besides the common Alpine (Early to Late Cretaceous) deformation of the Graz Paleozoic in this basal nappe system minor Variscan deformation under upper greenschist-grade overprints with exceptionally occuring amphipolite-grade conditions have been documented. Generally, volcanoclastics dominate the Late Silurian to Early Devonian, and carbonates the Middle Devonian time span.

(2) The Intermediate Nappe System (Early Silurian to Upper Devonian) consists of the 'Laufnitzdorf-Group' and the 'Kalkschiefer-Group' (Early to Upper Devonian). Both nappe groups occur in different structural levels. The former development pelagic limestones, shales and volcanoclastics are the dominating lithologies, in the latter limestones and siliciclastics.

(3) The Upper Nappe System (Upper Silurian to Upper Carboniferous) comprises the 'Rannach- and Hochlantsch-Group'. Both groups display a comparable development of facies, in particular from the Emsian to the Givetian Stages.

With regard to the palaeogeographical interpretation of the entire Palaeozoic succession, the 'Rannach- and Hochlantsch group' are considered as a nearshore development, while the 'Laufnitzdorf group' may represent an offshore setting. According to Hubmann 1993 the 'Schöckl group' occupies an intermediate position.

The overall lithologies reflect a sedimentary regime changing from a passive continental margin with a continental breakup (alkaline volcanism) to shelf and platform

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geometries during Silurian and Devonian times (Fritz et al. 1992). During this period the lithologic development, i.e. the alternation of dolostones and limestones (Hubmann 1993) and the occurrences of stratigraphic gaps and mixed conodont faunas (Ebner 1978) may be attributed to sea-level changes and probably also synsedimentary tectonics. An overview of the lithologic development is shown in Fig. 7. In this figure traditional lithostratigraphic names are still used although a revision is in preparation (Flügel in prep.).

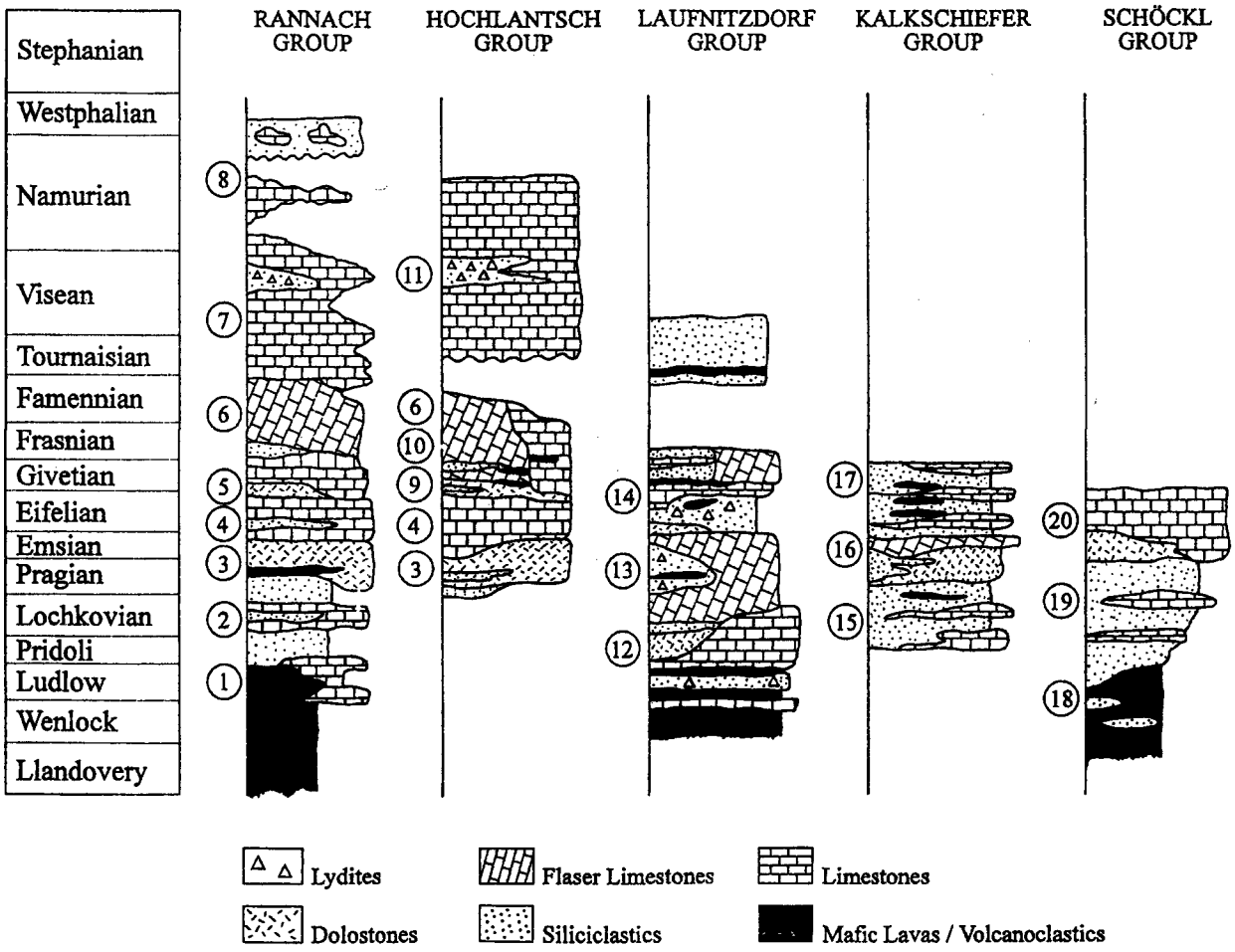

Fig. 7: Schematic stratigraphic development of the Graz Paleozoic after Hasenhüttl (1994) and Hubmann & Hasenhüttl (1995).
1 Kher Formation, 2 Parmasegg Formation, 4 Barrandei Limestone, 5 Kanzel Limestone, 6 Steinberg Limestone, Platzlkogel Formation, Höllererkogel flaser limestone, Grösskogel flaser limestone, 7 Sanzenkogel Limestone, 8 Dult Formation 9 Tyrnaueralm Formation, 10 Hochlantsch Limestone, 11 Mixnitz Formation, 12 Hackensteiner Formation, 13 Harrberger Formation, 14 Schattleitner Formation, Dornerkogel Formation, 15 Kogler Formation, 16 Heuberg Formation, Sommeralm complex, 17 Gschwendt Formation, 18 Passail Formation, Waldstein Formation, 19 Arzberg Formation, 20 Schöckl Limestone, Hochschlag Limestone.

Efforts to demeonstrate the faunal relationships between the Paleozoic of Graz and other remnants of the Paleozoic of Central Europe, especially the Rhenohercynian zone date back to the pioneering phase of paleontological research in the surroundings of Graz. In particular the very fossiliferous late Emsian to Eifelian formations of the Graz Paleozoic e.g., the Barrandei Limestone-Formation are well suited for

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faunal relations due to its diversified and abundant list of fossils (Flügel 1975). However, there is a strong need to revise older identifications and to demonstrate its potential for comparison beyond such a limited geographic area like the Alps. For example, the taxonomy of some Green Algae and tabulate corals was recently the subject of detailed studies (Hubmann 1990, 1991, in prep.) to demeonstrate rather close biogeographic links with the Rhenohercynian Zone, the Moravian Karst and the Cantabrian Mountains (Hubmann 1991, 1995, Herrmann & Hubmann 1994).

The Paleozoic of southern Burgenland

Since the last century rocks of presumably Devonian age have been known from southern Burgenland. They comprise shales, limestones and dolomites of unknown cumulative thickness which occur in some scattered outcrops near the villages of Hannersdorf and the town of Güssing, respectively. A newly discovered fossil assemblage of conodonts, rugose and tabulate corals and crinoid debris clearly indicates an Upper Emsian age for at least parts of the carbonate sequence. Based on these new biostratigraphic data as well as the general facies development in this region an original close connection with the neighbouring fossiliferous sequences in the surroundings of Graz seems well established (Schönlaub 1994). This conclusion is strongly supported by frequently occurring dolomitic rocks of Lower Devonian age in the subsurface of the Tertiary Basin of eastern Styria (Ebner 1988).

The Gurktal Nappe

The Gurktal Nappe represents one of the uppermost tectonic units within the pile of nappes of the Eastern Alps. It covers a wide area in Middle Carinthia but extends beyond the provincial boundary to parts of western Styria. The whole sequence comprises a variety of greenshist-grade metamorphic rocks of volcanic and sedimentary nature, such as basic and acid volcanics of mainly Ordovician and Silurian age, siliciclastics and carbonate rocks, the latter being of predominantly Devonian age (Fig. 8). Already in the first half of this century from a few localities fossils of Lower Paleozoic age were recorded indicating the above mentioned age assignments and thus an almost equivalent facies with parts of the Graywacke Zone in the northern Alps.

After application of research methods for microfossils, in particular conodonts many new data have been provided which are summarized in Fig. 8 . Apart from some brachiopods and crinoids occuring in marbles of the underlying "Phyllite Complex", strata equivalent to the Devonian comprise bedded limestones, nodular limestones and dolomitic rocks with intercalations of shales and graywackes.

Based on the available biostratigraphic and lithological data in the central part of the Gurktal Nappe two distinct Devonian facies occur. The first one named "Althofen facies" is dominated by different types of up to 100 m thick shallow-water and partly bioclastic limestones, the other one named "Magdalensberg facies" by mostly pelitic rocks with rather small lenticular accumulations of limestones. One of the best examples for the Devonian limestone dominated succession is displayed at the famous quarry "Aich" near Treibach-Althofen showing a complete record through the Devonian except for parts of the Middle Devonian (Schönlaub 1971). The opposing pelitic facies is dominated by fine and coarse grained clastics with some tuffaceous and limestone intercalations the tickness of which varies from 2 to 9 m. Based on

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conodonts different levels within the Lower, Middle and Upper Devonian (up to the Frasnian Stage) have been recognized (Buchroithner 1979, Neubauer & Pistotnik 1984).

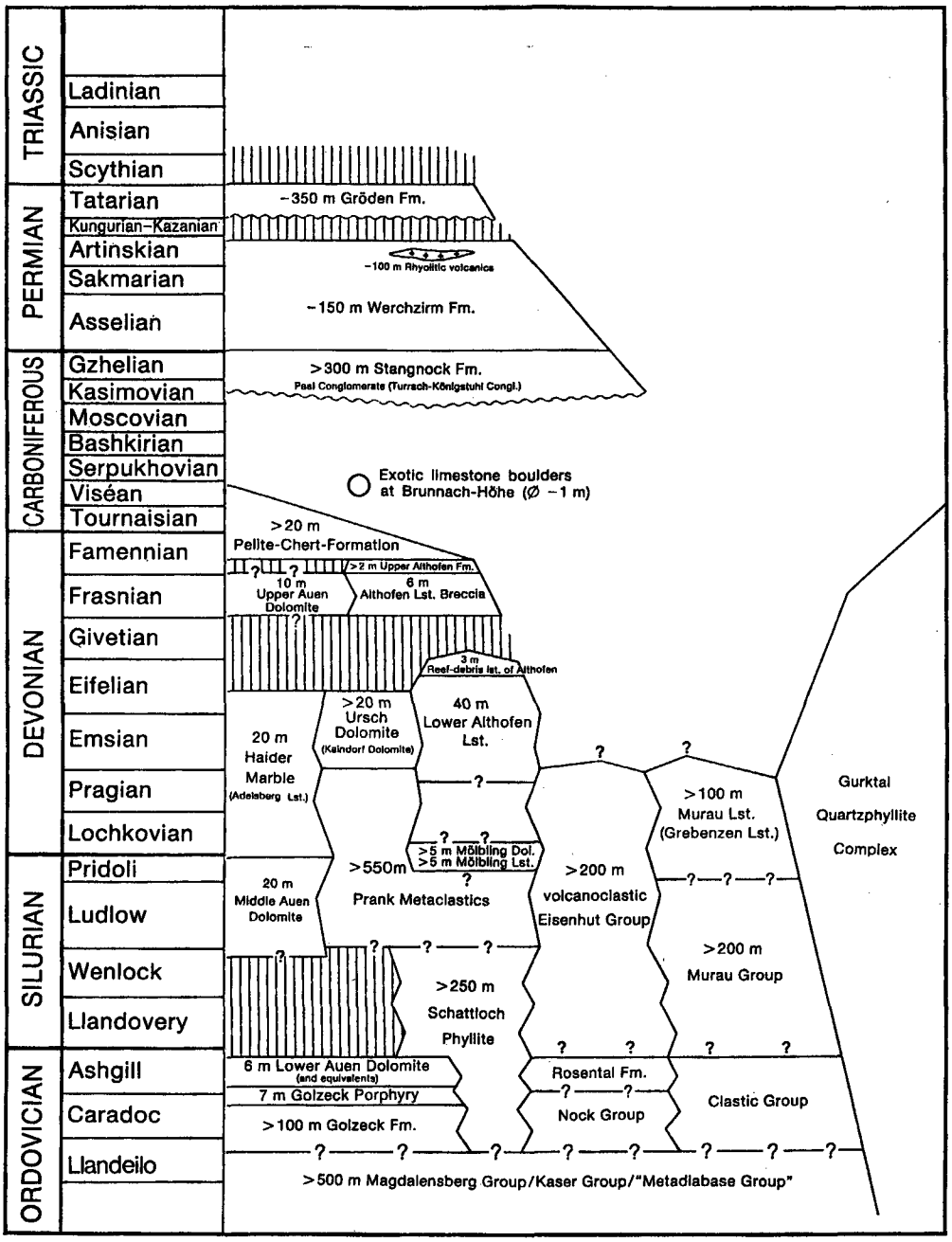

Fig. 8. Stratigraphy of the Variscan sequence of the Gurktal Nappe of Middle Carinthia and the surroundings of Murau (SW Styria). Modified from Buchroithner (1979) and Neubauer & Pistotnik (1984). (From H. P. SCHÖNLAUB 1992).

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The Graywacke Zone

The Graywacke Zone represents the Paleozoic basement of the Northern Limestone Alps. The West-East-directed belt of Lower Paleozoic and Carboniferous rocks extends over a distance of some 450 km and a maximum width of 23 km from the Province of Vorarlberg in the west to the town of Ternitz in Lower Austria in the east. In the following Vienna Basin the eastern continuation is covered by sedimentary rocks of Tertiary age.

Although in the Graywacke Zone fossil remains have been found as early as 1847 main progress towards a modern biostratigraphic framework was not achieved until the early 1960s when conodont studies were first employed in the Styrian and Tyrolean part of this zone. Since then a great deal of new and fundamental data were supplied accompanied by analysis of facies, geochemical analysis of volcanics and new maps (see summary by Schönlaub & Heinisch 1993).

In the Eastern Graywacke Zone limestone sedimentation passed without any breaks from the Silurian into the Devonian. Different from other regions in the Alps splitting of facies is less pronounced in the Devonian. Generally, the equivalents of the Lower Devonian are charakterized by platy limestones which laterally pass into dacryoconarid bearing reddish limestones with marly and bioclastic interbeds.

In the eastern part of the Graywacke Zonethe majority of the Devonian sections end at or close to the Lower/Middle Devonian boundary. At few localities, however, strata equivalent to the Frasnian and basal Famennian overly unfossiliferous rocks suggesting that sedimentation may have lasted through the entire Devonian. During this time 200 to 300 m limestones were deposited. The Devonian sequence is disconformably overlain by a limestone breccia and the 100 to 150 m thick clastic Eisenerz Formation of Lower to Middle Carboniferous age (Fig. 9).

In the western Graywacke Zone of Tyrol and Salzburg an obvious heterogenity of facies has recently been recognized. According to Heinisch et al. (1988) within short distances two distinct facies are developed which comprise the Wildseeloder and the Glemmtal Unit, respectively (Fig. 9). In the first in the Upper Silurian a carbonate platform formed which lasted until the early Upper Devonian. It consists of shallow water lagoonal dolomites, a local reef development and pelagic limestones of Frasnian age (Mostler 1970, Schönlaub 1979). The Glemmtal Unit is distributed to the south of the former. The Devonian part consists of siliciclastic sediments with intercalations of condensed cephalopod limestones and interbedded cherts and black siliceous shales named Klingler Kar Formation. In addition, in the Pragian and presumably also in the Middle and Upper Devonian (?)2 to several hundred meters thick intercalations of basic magmatites occur ranging from lavas, pyroclastic rocks and tuffites. Based on trace elements they are of intraplate origin. They also interfinger with medium to fined grained sandstones, siltstones and shales termed Löhnersbach Formation. Both the clastic and limestone sequences are overlain by the unfossiliferous Schattberg Formation. In conclusion, during the Silurian and the Devonian in the western segment of the Graywacke Zone the shallow water platform regime of the Wildseeloder Unit existed contemporaneously to the basin and "seamount" facies of the Glemmtal Unit. The only connecting link was the Ordovician Blasseneck Porphyry which, however, also reflects some lithological differences in both tectonic units.

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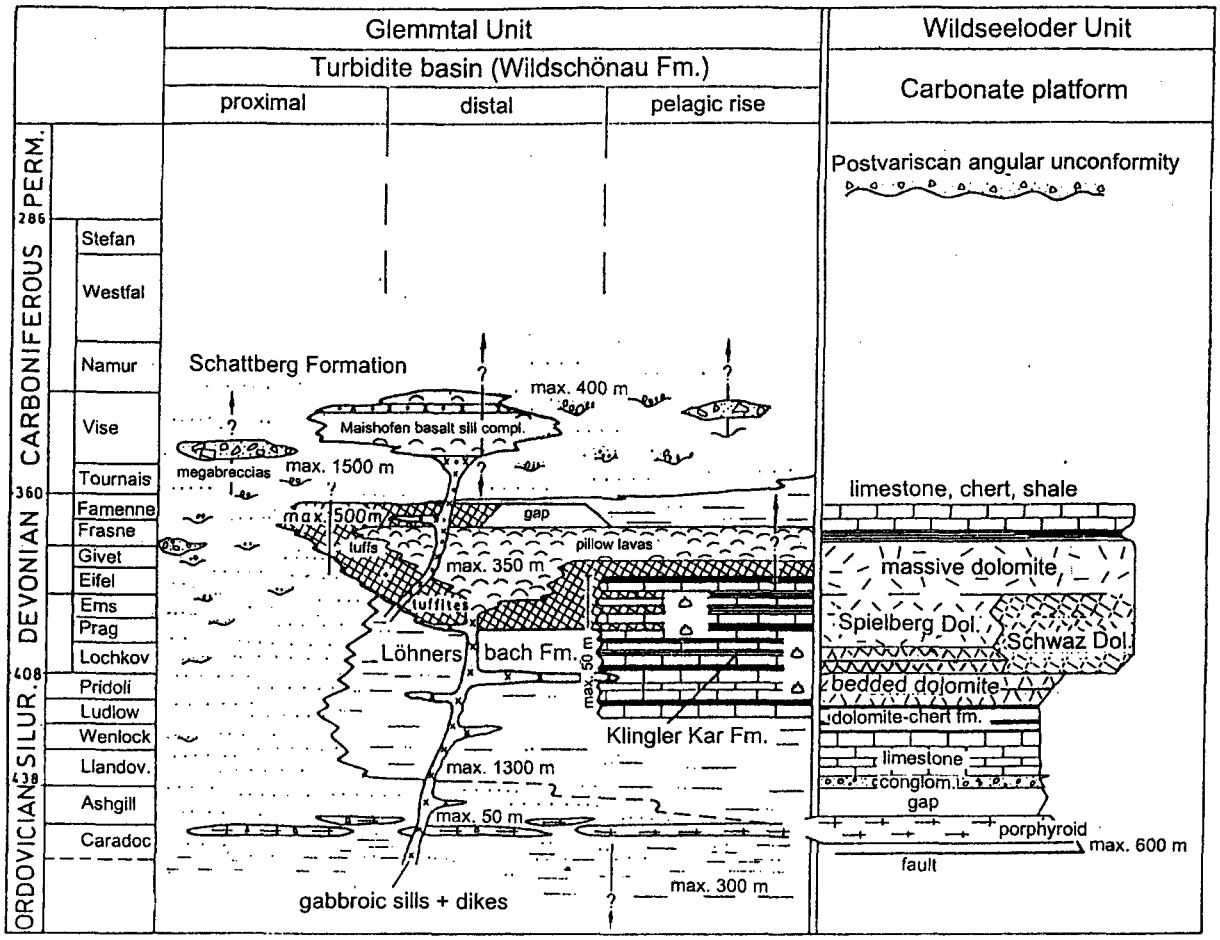

Fig. 9. Stratigraphy of the Graywacke Zone in the surroundings of Kitzbühel and Saalbach (after H. Heinisch 1988).

References

BACHTADSE, V., TORSVIK, T. H., TAIT, J. A. & SOFFEL, H. C. (1995): Paleomagnetic Constraints on the Paleogeographic Evolution of Europe During the Paleozoic. In: Pre-Permian Geology of Central and Eastern Europe, Dallmeyer et al. (eds.), 567 - 578.

BANDEL, K. (1969): Feinstratigraphische und biofazielle Untersuchungen unterdevonischer Kalke am Fuß der Seewarte (Wolayer See, Zentrale Karnische Alpen).- Jb. Geol. B.-A., 112: 197-234, Wien.

BANDEL, K. (1972): Palökologie und Paläogeographie im Devon und Unterkarbon der Zentralen Karnischen Alpen.- Palaeontographica, 141, Abt. A: 1-117, Stuttgart.

BANDEL, K. (1974): Deep-water limestones from the Devonian-Carboniferous of the Carnic Alps, Austria.- Spec. Publs. Int. Ass. Sediment., 1974/1: 93-115, Oxford.

BUCHROITHNER, M. F. (1979): Biostratigraphische und fazielle Untersuchungen im Paläozoikum von Mittelkärnten. - Carinthia II, 169/89: 71-95, Klagenfurt.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

DULLO, W.-C. (1992): Mikrofazies und Diagenese der Oberordovizischen Cystoideen-Kalke (Wolayerkalk) und ihrer Schuttfazies (Uggwakalk) in den Karnischen Alpen.- Jb. Geol. B.-A., 135/1: 317-333, Wien.

EBNER, F. (1973): Foramminiferen aus dem Paläozoikum der Karnischen Alpen.- Mitt. Abt. Geol. Paläont. Bergb. Landesmus. Joanneum, 34: 3-24, Graz.

EBNER, F. (1978): Stratigraphie des Karbon der Rannachfazies im Paläozoikum von Graz, Österreich.- Mitt. Österr. Geol. Ges., 69: 163-196, Wien.

EBNER, F. (1988): Das Paläozoikum in den RAG-Bohrungen Blumau 1, 1a und Arnwiesen 1 (Oststeirisches Tertiärbecken). - Jb. Geol. B.-A., 131, 563 - 573, Wien.

FERRARI, A. & VAI, G.B. (1965): Richerche stratigraphiche e paleoechologiche al Monte Zermula.- Giorn. Geol., 33: 389-406, Bologna.

FLÜGEL, H.W. & NEUBAUER, F. (1984): Steiermark. Erläuterungen zur Geologischen Karte der Steiermark.- Geol. B.-A., 1-127, Wien.

FLÜGEL, H.W. (1975): Die Geologie des Grazer Berglandes.- Mitt. Abt. Geol. Bergbau Landesmus. Joanneum, 1: 1-288, Graz.

FRITZ, H., EBNER, F. & NEUBAUER, F. (1992): The Graz Thrust-Complex (Paleozoic of Graz).- Alcapa-Field Guide, IGP/KFU: 83-92, Graz.

GALLI, G. (1985): Depositional Environments in the Devonian Limestone Succession of the Cima Ombladet (Carnic Alps, Italy).-Facies, 12: 97-112, Erlangen.

HASENHÜTTL, C. (1994): Eine Wärmegeschichte des Grazer Berglandes.- Unpubl. Doctoral Thesis Univ. Graz: 1-165 + i-xvii, Graz.

HEINISCH, H. (1988): Hinweise auf die Existenz eines passiven Kontinentalrandes im Altpaläozoikum der Nördlichen Grauwackenzone. - Schweiz. Mineral. Petrogr. Mitt., 68, 407 - 418.

HEINISCH, H., SPRENGER, W. & WEDDIGE, K. (1987): Neue Daten zur Altersstellung der Wildschönauer Schiefer und des Basaltvulkanismus im ostalpinen Paläozoikum der Kitzbüheler Grauwackenzone (Österreich). - Jb. Geol. B.-A., 13: 163-173, Wien.

HERRMANN, R. & HUBMANN, B. (1994): Devonian Udoteacean Green Algae from the Cantabrian Mountains (Santa LucŸa Formation), NW-Spain.- Rev. Espanola Paleont., 9/2: 195-202, Oviedo.

HUBMANN, B. - (1991): Alveolitidae, Heliolitidae und Helicosalpinx aus den Barrandeikalken (Eifelium) des Grazer Devons.- Jb. Geol. B.-A., 134/1: 37-51, Wien.

HUBMANN, B. (1990): Udoteaceen (Grünalgen) aus dem Grazer Paläozoikum/Österreich (Barrandeikalke, Eifelium).- Facies, 22: 147-158, Erlangen.

HUBMANN, B. (1993): Ablagerungsraum, Mikrofazies und Palõoökologie der Barrandeikalk-Formation (Eifelium) des Grazer Paläozoikums.- Jb. Geol. B.-A., 136/2: 393-461, Wien.

HUBMANN, B. (1995): Middle Devonian shallow marine deposits of the Graz Paleozoic: fact and fiction for deposition under ecological stress.- Beitr. Paläont., 20: 107-112, Wien.

HUBMANN, B. & HASENHÜTTL, C. (1995): Zur Entwicklung der hohen Deckengruppe des Grazer Paläozoikums. Exkursionspunkte zu ausgewõhlten Profilen.- Exkursionsführer 2. Tagung Österr. Paläont. Ges., 1-43, Graz.

KREUTZER, L.H. (1989): Reef-basin distance in the Devonian of the Carnic Alps.- Ann. Soc. Geol. Belg., 112: 159-163, Liège.

KREUTZER, L.H. (1990): Mikrofazies, Stratigraphie und Paläogeographie des Zentralkarnischen Hauptkammes.- Jb. Geol. B.-A., 133/2: 275-343, Wien.

KREUTZER, L.H. (1992a): Palinspastische Entzerrung und Neugliederung des Devons in den Zentralkarnischen Alpen aufgrund von neuen Untersuchungen.- Jb. Geol. B.-A.; 135/1, 261 - 272, Wien.

KREUTZER, L.H. (1992b): Photoatlas zu den variszischen Karbonat-Gesteinen der Karnischen Alpen (Österreich/Italien). - Abh. Geol. B.-A., 47: 1-129, Wien.

KUPSCH, F., ROLSER, J. & SCHÖNENBERG, R. (1971): Das Altpaläozoikum der Ostkarawanken.- Z. dt. geol. Ges., 122: 89-96, Hannover.

LOESCHKE, J. & ROLSER, J. (1971): Der altpaläozoische Vulkanismus in den Karawanken (Österreich).- Zt. dt. geol. Ges., 122: 145-156, Hannover.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

MACHEL, H.G & HUNTER, I.G. (1994): Facies Models for Middle to Late Devonian Shallow-marine Carbonates, with Comparisons to Modern Reefs: a Guide for Facies Analysis.- Facies, 30:155-176, Erlangen.

MOSTLER, H. (1970): Struktureller Wandel und Ursachen der Faziesdifferenzierung an der Ordoviz/Silur-Grenze in der Nördlichen Grauwackenzone (Österreich). - Festbd. Geol. Inst. 300-Jahr Feier Univ. Innsbruck: 507-522, Innsbruck.

NEUBAUER, F. & PISTOTNIK, J. (1984): Das Altpaläozoikum und Unterkarbon des Gurktaler Deckensystems (Ostalpen) und ihre paläogeographischen Beziehungen. - Geol. Rdsch.,73, 149-174, Stuttgart.

OECKENTORP-KÜSTER, P. & OECKENTORP, C. (1992): Rugose Korallenfaunen des Mittel- und Ober-Devons der zentralen Karnischen Alpen.- Jb. Geol. B.-A., 135/1: 233 - 260, Wien.

RANTITSCH, G (1992): Fazies und Diagenese devonischer Riffkalke des Seeberger Aufbruchs (Kärnten, Österreich).- Jb. Geol. B.-A., 135/1: 273-285, Wien.

ROLSER, J. & TESSENSOHN, F. (1974): Alpidische Tektonik im Variszikum der Karawanken und ihre Beziehung zum Periadriatischen Lineament.- Geol. Jb., A25: 23-53, Hannover.

SCHÖNLAUB, H. P. (1971): Die Althofener Gruppe - eine neue stratigraphische Einheit im Devon Mittelkärntens (Österreich). - N. Jb. Geol. Paläont., Mh., 1971: 288-305, Stuttgart.

SCHÖNLAUB, H.P. (1979): Das Paläozoikum in Österreich.- Abh. Geol. B.-A., 33: 3-124, Wien.

SCHÖNLAUB, H.P., ed. (1985): Arbeitstagung der Geologischen Bundesanstalt 1985, Kötschach-Mauthen.- Geol. B.-A., 1-87, Wien.

SCHÖNLAUB, H.P. (1992): Stratigraphy, Biogeography and Paleoclimatology of the Alpine Paleozoic and its Implications for Plate Movements.- Jb. Geol. B.-A., 153/1: 381-418, Wien.

SCHÖNLAUB, H. P. (1994): Das Altpaläozoikum im Südburgenland. - Jub. Schrift 20 Jahre Geol. Zusammenarbeit Österreich-Ungarn, Teil 2, Geol. B.-A., 365-377, Wien.

SCHÖNLAUB, H.P., ATTREP, M., BOECKELMANN, K., DREESEN, R., FEIST, R., FENNINGER, A., HAHN, G., KLEIN, P., KORN, D., KRATZ, R., MAGARITZ, M., ORTH, C.J., SCHRAMM, J.-M. (1992): The Devonian/Carboniferous boundary in the Carnic Alps (Austria) - A multidisciplinary approach. - Jb. Geol. B.-A., 135/1: 57-98, Wien.

SCHÖNLAUB, H.P. & FLAJS, G. (1975): Die Schichtfolge der Nordwand der Hohen Warte (Mt. Coglians) in den Karnischen Alpen (Österreich).- Carinthia II, 165/85: 83-96, Klagenfurt.

SCHÖNLAUB, H.P. & HEINISCH, H. (1993): The Classic Fossiliferous Paleozoic Units of the Eastern and Southern Alps.- In: J. F. von RAUMER & F. NEUBAUER, eds.) Pre-Mesozoic Geology in the Alps: 395 - 422. - Springer Verl. Berlin.

SCHÖNLAUB, H.P. & KREUTZER, L.H. (1993): Lower Carboniferous Conodonts from the Cima di Plotta Section (Carnic Alps, Italy).- Jb. Geol. B.-A., 136/1: 247-269, Wien.

SCOTESE, C. R. & McKERROW, W. S. (1990): Revised World maps and introduction. In: McKERROW, W. S. & SCOTESE, C.R. (Eds.): Paleozoic Palaeogeography and Biogeography. - Geol. Soc. Mem, 12: 1-21, London.

SPALLETTA, C., PERRI, M.C. & VAI, G.B. (1983): Pattern of conodont reworking in the Upper Devonian of the Alps: palaeoenvironmental and palaeotectonic implications.- Lethaia, 16: 51-66; Oslo.

SPALLETTA, C. & VAI, G.B. (1984): Upper Devonian intraclast parabreccias interpreted as seismites.- Marine Geology, 55: 133-144, Amsterdam.

SPALLETTA, C. & VENTURINI, C. (1994): Late Devonian-Early Carboniferous syn-sedimentary tectonic evolution of the Palaeocarnic domain (Southern Alps, Italy). - Giorn. Geol., 56/2: 211-222, Bologna.

TESSENSOHN, F. (1974a): Zur Fazies paläozoischer Kalke in den Karawanken.- Verh. Geol. B.-A., 1974: 89-124, Wien.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

TESSENSOHN, F. (1974b): Schichtlücken, Diskordanzen, Mischfaunen. Neue stratigraphische Ergebnisse zu einer Faziesanalyse im Devon der Karawanken.- Carinthia II, 164: 137-160, Klagenfurt.

TESSENSOHN, F. (1983): Eisenkappler und Seeberger Paläozoikum.- In: Erläuterungen zur Geologischen Karte der Karawanken 1:25.000, Ostteil. - Geol. B.-A., 32 - 45, Wien.

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