Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

Band: 68 (1988)

Heft: 3: Geodynamik des eurpäoschen Variszikums : Kaledonisch-Variszische Strukturen in den Alpen

Artikel: Geodynamic aspects of the Silurian and Early Devonian sedimentation in the Paleozoic of Graz (Eastern Alps)

Autor: Fritz, H. / Neubauer, F.

DOI: https://doi.org/10.5169/seals-52074

SCHWEIZ. MINERAL. PETROGR. MITT. 68, 359-367, 1988

Geodynamic aspects of the Silurian and Early Devonian Sedimentation in the Paleozoic of Graz (Eastern Alps)

by *H. Fritz*[1] and *F. Neubauer*[1]

Abstract

The Silurian to Devonian geodynamics of the Graz area is reconstructed by means of biostratigraphy, geochemistry, sedimentology and petrology. The geodynamic situation reflects the formation of a passive continental margin: Rifting is documented by intracontinental volcanism of alkaline affinity in the Silurian time. Sediment accumulation of siliciclastics in an extensional regime is followed by progressive carbonate production due to decreasing subsidence in the Early Devonian.

Keywords: Geodynamics, passive margin, rifting, Paleozoic, Graz, Eastern Alps.

Introduction

Low-grade metamorphosed Paleozoic sediments in the Austroalpine realm have always been used to reconstruct the geodynamics of the Variscan period (e.g., FLÜGEL, 1977; SCHÖNLAUB, 1979). Mountain building processes during the Alpine time, however, destroyed primary features and made this task difficult. Displaced Paleozoic series now occur in different tectonic positions and are, in general, sheared off from basement rocks. The primary relations between the different Paleozoic nappes are till now not completely understood. Problems arise in the correlation of these single, sometimes very small occurrences of Paleozoic nappes, which mostly differ in their sedimentary evolution.

We present a study from the so-called Paleozoic of Graz which is part of the Upper Austroalpine nappe system (Fig. 1). The aim of this paper is to show how detailed sedimentary, biostratigraphic and petrological examinations give a clear picture of the Silurian to Early Devonian geodynamics although intense Alpine tectogenesis created a nappe pile of multiple deformed slices (FRITZ, 1988). Finally we present a new model of Silurian and Early Devonian geodynamics in the Austroalpine realm.

General situation

The thrust system of the Paleozoic of Graz consists of different nappes of low-grade metamorphosed sediments of Silurian to Carboniferous age which are all sheared off from their basement. Each of the nappes is characterized by different sedimentary evolution, but facies heterogenities occur also within a singular nappe (FENNINGER and HOLZER, 1978; NEUBAUER et al., 1986). In general, the basal parts of the sedimentary column is built up by Silurian metavolcanics, followed by Late Silurian to Early Devonian carbonatic to clastic sediments and topped by a differentiated carbonate-dominated sedimentation up to the Middle Devonian (FLÜGEL and NEUBAUER, 1984, and references cited therein).

Data

The concept, that the nappes in the Paleozoic of Graz may be recognized by repetitions of the sedimentary column but also by facies

[1] Institut für Geologie und Paläontologie der Universität, Heinrichstrasse 26, A-8010 Graz.

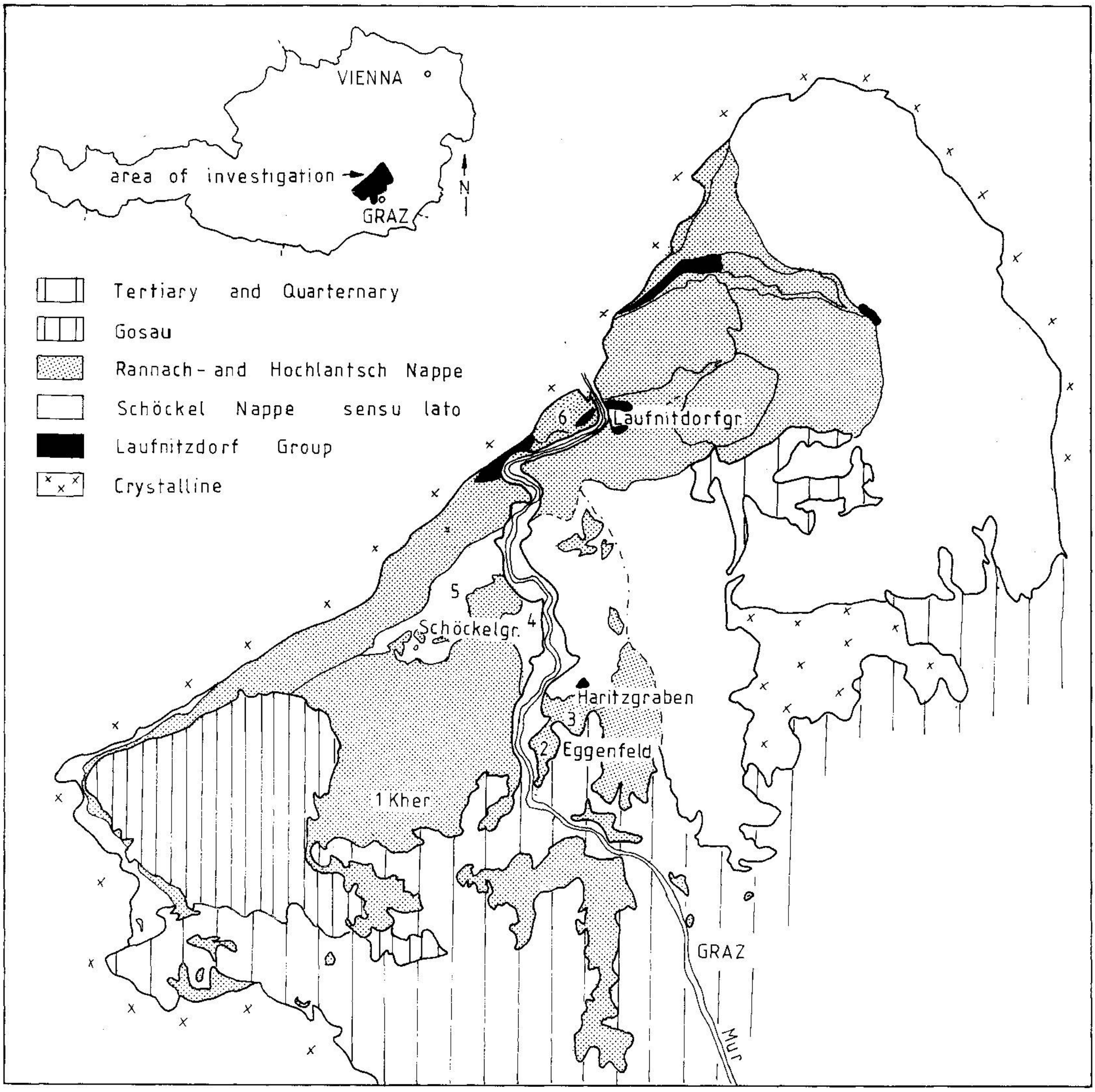

Fig. 1 The thrust system of the Paleozoic of Graz and the locations of the sections discussed. Rannach nappe: 1, Kher; 2, Eggenfeld; 3, Haritzgraben. Schöckel Nappe: 4 and 5; Laufnitzdorf Group: 6.

heterogenities is long known (FLÜGEL, 1975). The tectonic units which are treated here are:

The Schöckel Nappe at the base of the nappe pile, the Rannach Nappe resp. the Hochlantsch Nappe in the highest position, and the Laufnitzdorf Group which is split in different splays, but mostly it is located in an intermediate position. Detailed biostratigraphic investigations during the last decade yielded an exeptional clear picture of the sedimentary characteristics especially of the Devonian carbonate rocks (GOLLNER and ZIER, 1985; GOLLNER et al., 1982; EBNER, 1977). We focused our attention on the Silurian and Early Devonian volcanic and clastic sediments at the base of the sedimentary sequence. For a better understanding of the facies heterogenities we describe sections which are located in different nappes but enclose the same time span in one chapter.

THE VOLCANIC SERIES AT THE BASE OF THE PALEOZOIC OF GRAZ

The uppermost nappes (Rannach Nappe, Hochlantsch Nappe) which suffered less me-

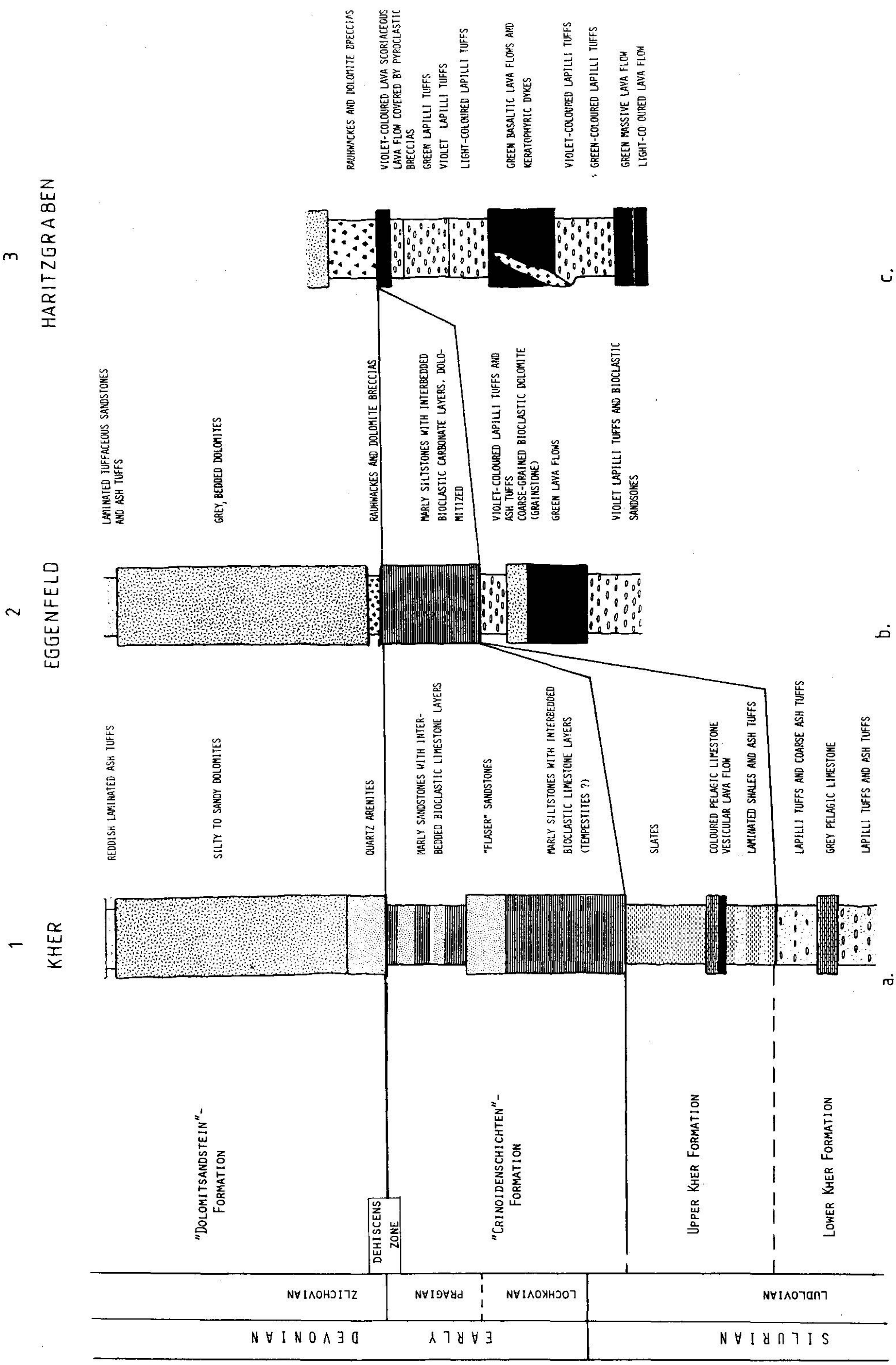

Fig. 2 Facies heterogenity in the Rannach Group. For locations, see Fig. 1.

tamorphic overprint offer the best chance to reconstruct the primary relations in this area (FRITZ, 1986; POLTNIG, 1984). Therefore the volcaniclastic sedimentary base of the Rannach Nappe, the so called Kher formation, is considered here in more detail. The variability which occurs even within one nappe is illustrated by three sections located at Haritzgraben, Eggenfeld and Kher (NEUBAUER et al., 1986; for location, see Fig. 1).

At Kher (Fig. 2a) the basal series are characterized by laminated ash tuffs, debris flows and agglomerates which include polymict volcanic and sedimentary components. Lava flows are rare. Intercalated limestones bear fossils (orthocers) which indicate an open marine environment. This sequence is contrasted by the situation in Haritzgraben (Fig. 2c). Here the succession is dominated by mafic lava flows, coarse-grained lapilli and bomb tuffs intruded by keratophyric dykes. Block lava on top of the volcanic sequence in Haritzgraben point to subaeric to very shallow marine sedimentation and lava flow extrusion.

An intermediate position is given at the locality Eggenfeld (Fig. 2b), where medium-grained pyroclastics are interlayered by lava flows. Biodetritical dolomites suggest sedimentation in a shallow marine, high-energetic environment. We suppose an environment near the wave base.

A similar section is given in the Schöckel Nappe. Scarce biostratigraphic data and strong dismembering due to deformation make the correlation between single localities difficult (Fig. 3). In general, a more uniform input of fine grained pyroclastic material in an open marine environment, as indicated by interca-

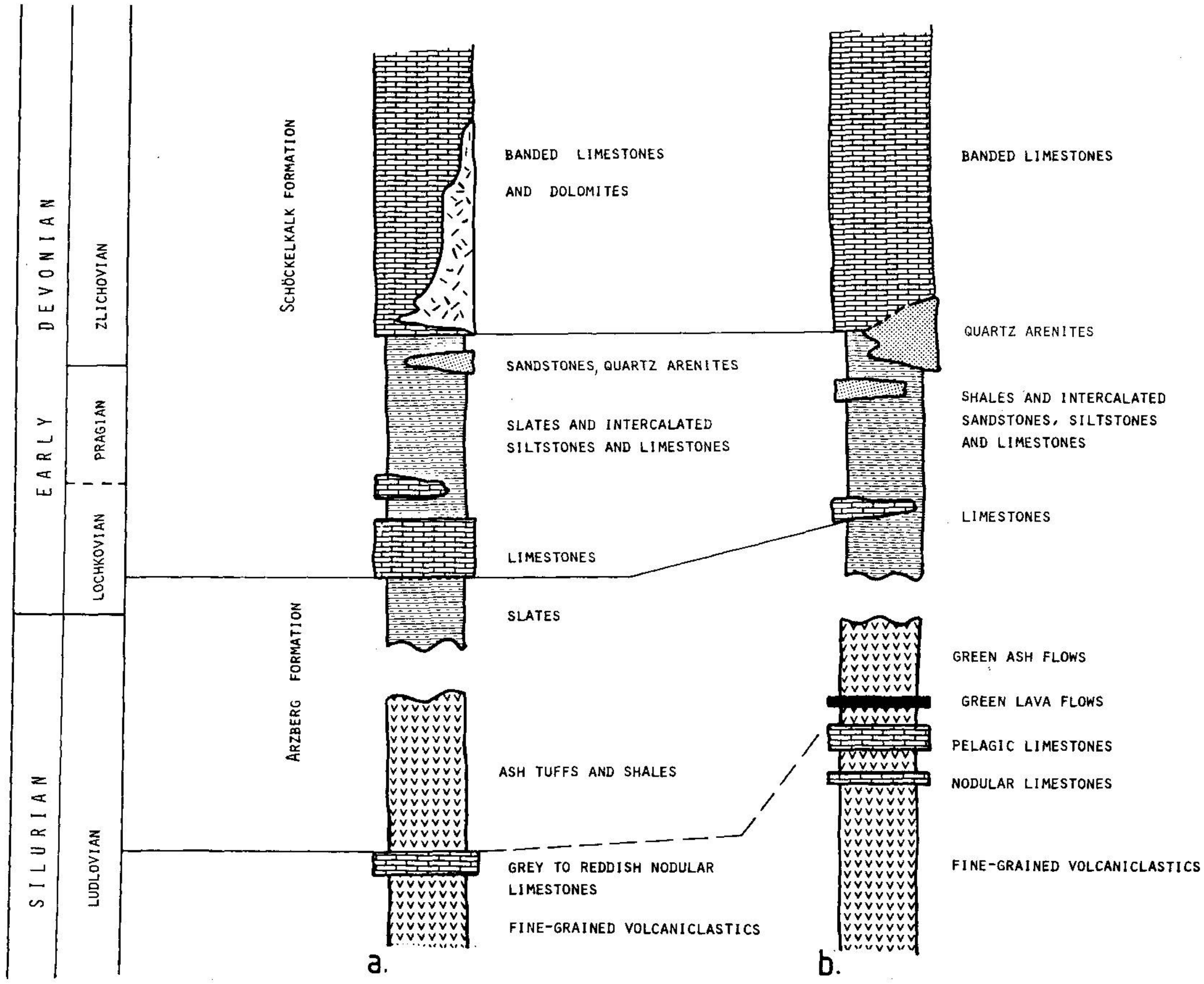

Fig. 3 Sections of the Schöckel Group. Fig. 3a is redrawn from TSCHELAUT (1985).

lated pelagic limestones, is mentioned. Indirect evidence for a differentiated basin is given by the subsequent clastic sedimentation as we discuss later.

In the Laufnitzdorf Group the volcanogenic input in Silurian time is restricted to some amygdaloid lava flows and tuffs (Fig. 4).

Detailed geochemical data from the various basaltic lavas from the Paleozoic of Graz are missing except some trace element data which were published by KOLMER (1978). These data show some within-plate-magma affinities of greenstones of the Schöckel nappe. Our analyses of 12 samples from the Kher formation (Rannach Nappe; localities Haritzgraben and Eggenfeld) are shown in Fig. 5 in a MORB-normalized pattern. The enrichment of large ion lithophile elements (Sr, K, Rb, Ba) as well as Nb, P, Zr and Ti on the rock/MORB-normalized diagram indicates a weak alkaline trend after PEARCE (1982).

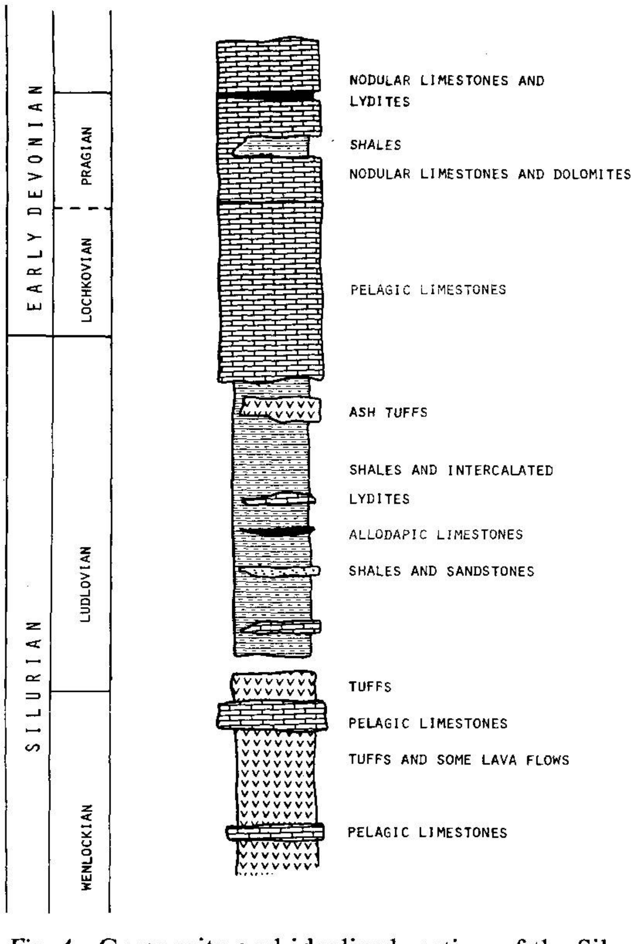

Fig. 4 Composite and idealized section of the Silurian and Lower Devonian of the Laufnitzdorf Group. Redrawn from GOLLNER et al. (1982).

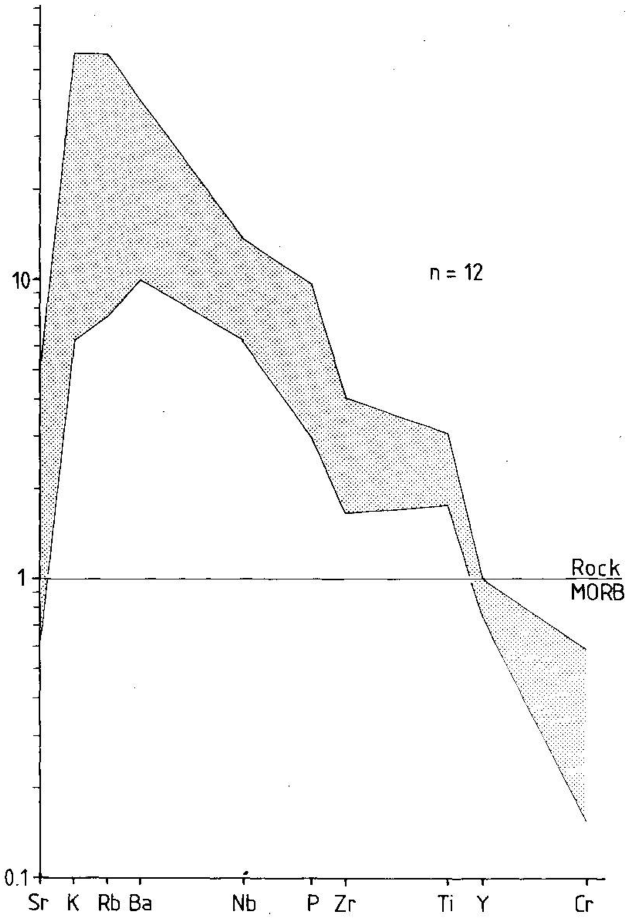

Fig. 5 Rock/MORB normalized diagramm shows alkaline affinity from basalts of the Rannach Nappe. n, number of samples. Normalization values after PEARCE (1982).

THE CARBONATIC-CLASTIC SEDIMENTATION

In the Rannach Nappe the carbonatic-clastic sedimentation of the so called "Crinoidenschichten" reflects different bathymetric conditions resulting from the earlier volcanic activity (NEUBAUER et al., 1986). The thickness of this formation varies from approximately 100 m in the west of the Paleozoic of Graz (e.g. Kher) to 0 m in the central part (e.g. Haritzgraben). The composition of the sediments also changes with the neighbourhood to the volcanic centre. Marly slates and interbedded graded siltstones and allochthonous limestones, which we interprete as tempestites, overlie the laminated tuffs and pelagic limestones at Kher. At Eggenfeld the few meters thick limestone-marl sequence without evidence of coarse-grained siliciclastic input points to cyclic sedimentation above the storm-wave base and at Haritzgraben the carbonatic-clastic Crinoidenschichten formation is absent at all. Here coarse block lava is directly overlain by rauhwacke of Early Devonian age.

The sandstones of all the basal formations of the Rannach Group reflect the sedimentary evolution. They are always rich in quartz, but minor constituents differentiate the three formations: Sandstones of the Kher fm. include lithic volcanogenic components and plagioclase, those of the "Crinoidenschichten" plagioclase and white mica, whereas the sandstones of the Dolomitsandstone fm. are rich in potassic feldspar. Following the work of DICKINSON and SUCZEK (1979), the sandstone composition of the Rannach Group is compatible with a continental derived one. The feldspar input possibly reflects the volcanism due to a rift process.

The sedimentary evolution of the deeper Schöckel Nappe has always been called the "Tonschiefer Fazies" (FLÜGEL et al., 1952) which illustrates the predominance of shales. Conodont findings in limestones of the pelitic Upper Arzberg formation during the last years (GOLLNER, 1985; NEUBAUER, 1984; TSCHELAUT, 1985) allow a good correlation to the Crinoidenschichten formation of the Rannach Nappe. Black shales are accompanied by plenty of sulphide mineralization (mostly pyrite and lead-zinc; TUFAR, 1972; WEBER, 1983) and by graded silt- and sandstones. The black shales suggest a deposition in an anoxic environment and episodical clastic input from a continental source. Carbonatic phyllites and lense-shaped sandstones replace this slaty sequence laterally, especially in the higher parts of the Arzberg formation. EBNER and WEBER (1978) postulate a well differentiated basin due to the occurrence of slump structures and due to the distribution of ore minerals. They suppose sulphide mineralization (Pb, Zn, pyrite) to be locked to anoxic basins, whereas the baryte mineralization is assumed to be typical for submarine swells surrounding the basins.

The Laufnitzdorf group, the third lithofacial group we consider here, occurs now in different tectonic levels due to Alpine deformation. Pelites and intercalated lydites dominate the sedimentation during the Silurian time (GOLLNER et al., 1982). In contrast to the Rannach Nappe and Schöckel Nappe the volcaniclastic input is restricted to some amygdaloid lava beds. The occurrence of nodular limestones, which bear orthocers, indicate pelagic sedimentation. The characteristics of open marine environment continue throughout the Silurian and Devonian time.

THE LOWER TO MIDDLE DEVONIAN CARBONATES

The clastic sedimentation of the Rannach Nappe is progressively replaced by carbonate production but the volcanogenic topography is still preserved: Quartz-arenites are accumulated in the formerly basins, whereas evaporitic sediments are deposited on the former volcanic centres. The basal sandstones are quartz arenites with heavy minerals of metamorphic origin (FENNINGER and HOLZER, 1978). Decreasing subsidence caused the subsequent sedimentation of more uniform dolomites of the Dolomitsandstein formation. This up to 300 m thick dolomitic sequence is interrupted by pyroclastic rocks in the lower part.

The carbonatic sequence of the Schöckel Nappe is built up by banded limestones of assumed Middle Devonian age and lense-shaped quartz-arenites at the base. Thus the sedimentary environment is thought to be similar to that of the Rannach Group.

In contrast, the pelagic environment in the Laufnitzdorf Group persists throughout the Silurian and Devonian time as documented by conodont-rich nodular limestones (GOLLNER et al., 1982).

Discussion and conclusion

Although the Silurian to Devonian sediment pile of the Graz area is displaced by orogenic processes during the Alpine time the rearrangement may be done by means of fieldwork, conodont biostratigraphy, facial and petrographic analyses. We postulate:

1) A well differentiated basin developed due to volcanic activity in the Silurian time. This topographic relief controlled the subsequent sedimentation. It is seen most clearly in the Rannach Nappe (Fig. 6). The relief heterogenity persists throughout the Silurian and Early Devonian time and is compensated at the Early/Middle Devonian boundary by sediment accumulation in the former basins. Different bathymetric conditions can also be re-

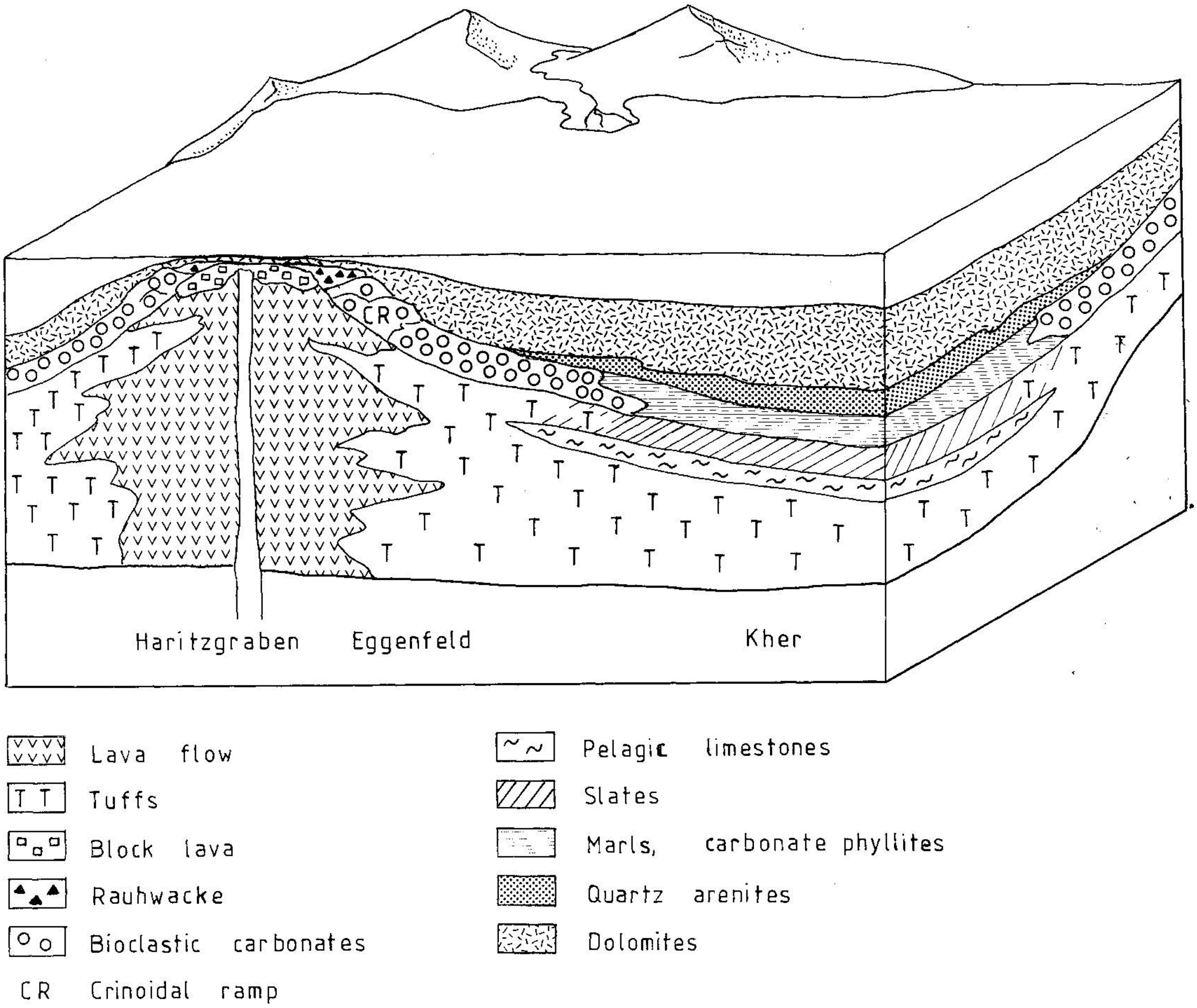

Fig. 6 Early Devonian sedimentation controlled by the Silurian volcanism in the Rannach Nappe.

cognized in the Schöckel Nappe and in the Laufnitzdorf Group. The increased accumulation of clastics, however, points to deeper basins. The Laufnitzdorf Group is deposited in a deep basin with a restricted input of allodapic limestones and sandstones.

2) Although no basement of the sediment pile may be found in the Paleozoic of Graz, we have much indirect evidence for a continental hinterland and for a basement by sediment composition and metamorphic components of agglomerates. Agglomerate deposition with crystalline components in Kher and in tuffs of the Dolomitsandstein fm. (HANSELMAYER, 1960) and heavy minerals of metamorphic origin like garnet in the sandstones argue strongly for metamorphic, continental source rocks. Another argument for an intra-plate, possibly continental position of the Paleozoic of Graz is the geochemistry of basalts which shows alkaline within-plate affinity. Continental derived quartz-rich sandstones accompanied by alkaline magmatism suggest intracontinental rifting.

3) Facial heterogenities between the three units reflect the sedimentary processes in an extensional regime during Silurian time. Different subsidence of the basins and the strongly differentiated relief of each basin is interpreted as sedimentation on rotated blocks due to extension, whereas the maximum sediment accumulation occurs in the halfgrabens (Fig. 7). Block rotation is seen at the locality Eggenfeld where the rotated "Crinoidenschichten" are overlain by the "Dolomitsandstein" fm. with a weak angular unconformity. Depth of water as

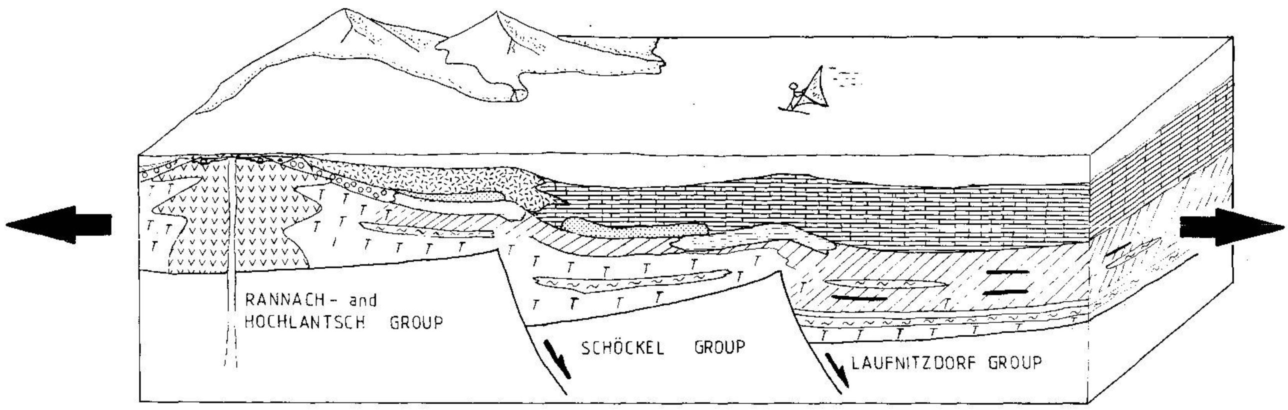

Fig. 7 Block rotation due to horizontal extension caused different bathymetric conditions in the different basins. For explanation see text.

well as the pelagic conditions increase from Rannach Group to Laufnitzdorf Group, but a maximum water depth of about 500 m is not exceeded as indicated by the presence of amygdaloid lavas.

4) Volcanic input and subsidence decreased and caused the more uniform sedimentation up to the Early/Middle Devonian. Progressive carbonate production may be interpreted as a result of climatic change, that means warming due to equatorial approximation of the plate which included the Paleozoic of Graz.

All these results favour horizontal stretching of the lithosphere due to intracontinental rifting in Silurian time. The basin evolution of the Paleozoic of Graz reflects the formation of a passive continental margin which may have evolved to an oceanic basin. As neither strong Variscan deformation nor Variscan metamorphism is mentioned (FRITZ and KRALIK, 1986) this area maintained in a foreland position during Variscan orogeny.

Recently numerous arguments for a differentiated passive continental margin in the Austroalpine realm are found by many authors. HEINISCH (this volume) reinterpreted the volcanoclastic series of the basal parts of the western Greywacke Zone. He dated the mafic volcanism by means of conodont biostratigraphy (HEINISCH, 1987) and suggested intraplate volcanism for the Devonian time. Geochemical and petrological data from the Sausal area yielded a clear model for rift-to-drift transition due to sandstone petrography and basalts with transitional affinity (SCHLAMBERGER, this volume). Similar results are given by GIESE (1987) for the western Stolzalpe Nappe. Thus all data indicate an overall rift model for Upper Austroalpine basement rocks.

References

DICKINSON, W. R. and SUCZEK, C. A. (1979): Plate tectonics and sandstone composition. Am. Ass. Petr. Geol. Bull. 63, 2164–2181, Tulsa.

EBNER, F. (1976): Das Silur/Devon-Vorkommen von Eggenfeld – ein Beitrag zur Biostratigraphie des Grazer Paläozoikums. Mitt. Ges. Geol. Bergbaustud. 37, 275–305, Graz.

EBNER, F. (1977): Die Gliederung des Karbons von Graz mit Conodonten. Jb. Geol. B.-A. 120, 449–493, Wien.

EBNER, F. and WEBER, L. (1978): Die geologisch-tektonischen Verhältnisse zwischen Tannebenstock und Rötschgraben (Grazer Paläozoikum). Mitt. Naturw. Ver. Stmk. 108, 95–113, Graz.

FENNINGER, A. and HOLZER, H.-L. (1978): Die Genese der Dolomitsandsteinfolge des Grazer Paläozoikums. Mitt. österr. Geol. Ges. 69, 109–162, Wien.

FLÜGEL, H. (1975): Die Geologie des Grazer Berglandes. 2. Aufl. Mitt. Abt. Geol. Joanneum, Sdh. 1, 288 p., Graz.

FLÜGEL, H. (1977): Paläogeographie und Tektonik des alpinen Variszikums. N. Jb. Geol. Mh., 659–674, Stuttgart.

FLÜGEL, H., MAURIN, V., NEBERT, K. (1952): Zur Altersfrage von Schöckelkalk und Grenzphyllit im Grazer Paläozoikum. Verh. Geol. B.-A., 129–138, Graz.

FLÜGEL, H. and NEUBAUER, F. (1984): Steiermark, Geologie der österreichischen Bundesländer in kurzgefassten Einzeldarstellungen. Geol. B.-A., 127 p., Wien.

FRITZ, H. (1986): Zur Geologie des nordwestlichen Grazer Paläozoikums (im Bereich Schartnerkogel-Parmaseggkogel). Unpubl. Doct. Thesis Univ. Graz, 209 p., Graz.

FRITZ, H. (1988): Kinematics and geochronology of Early Cretaceous thrusting in the Paleozoic of Graz (Eastern Alps). Geodyn. Acta (in press).

FRITZ, H. and KRALIK, M. (1986): Finite und Incremental Strain, Untersuchungen im Paläozoikum von Graz und Möglichkeit einer Deformationsdatierung. Symposium Strukturgeologie, Kristallingeologie, Tektonik (TSK 1); (Kurzfassungen) 23-27, Tübingen (Attempto).

GIESE, U. (1987): Altpaläozoischer Vulkanismus am NW-Rand der Gurktaler Decke. Kaledonisch-Variszische Strukturen in den Alpen, 3. Rundgespräch "Geodynamik des europäischen Variszikums"; Kurzfassungen, p. 8, Fribourg.

GOLLNER, H. (1985): Bericht 1984 über geologische Aufnahmen und biostratigraphische Untersuchungen auf Blatt 134, Passail. Jb. Geol. B.-A. 129, 292-293, Wien.

GOLLNER, H. and ZIER, CH. (1985): Zur Geologie des Hochlantsch (Grazer Paläozoikum, Steiermark). Jb. Geol. B.-A. 128/1, 43-73, Wien.

GOLLNER, H., THALHAMMER, O., TSCHELAUT, W. and ZIER, CH. (1982): Die Laufnitzdorf-Gruppe - eine pelagische Fazies im Grazer Paläozoikum. Mitt. Naturw. Ver. Stmk. 112, 63-74, Graz.

HANSELMAYER, J. (1960): Petrographie und Chemismus der devonischen grünen Diabastuffe vom Plabutsch-Bergzug (Graz). Mitt. Naturw. Ver. Stmk. 90, 25-40, Graz.

HEINISCH, H. (1987): Neue Daten zur Geologie der Kitzbüheler Grauwackenzone und ihre Konsequenzen für die Geotektonik des alpinen Altpaläozoikums. Kaledonisch-Variszische Strukturen in den Alpen, 3. Rundgespräch "Geodynamik des europäischen Variszikums"; Kurzfassungen, 10-11, Fribourg.

KOLMER, H. (1978): Die Verteilung von Ti, Sr, Y und Zr in spilitischen Gesteinen der Steiermark. Mitt. Naturw. Ver. Stmk. 108. 31-43, Graz.

NEUBAUER, F. (1984): Bericht 1980 über Aufnahmen auf Blatt 134, Passail. Verh. Geol. B.-A. 1981, A77-A79, Wien.

NEUBAUER, F., GOLLNER, H. and SCHALK, L. (1986): Volcanism controlled sedimentation. The Silurian and Early Devonian facies distribution in the Rannach Fazies, Paleozoic of Graz, Austria. IGCP No. 5; Abstracts, 59-60, Sardinia.

NEUBAUER, F. and PISTOTNIK, J. (1984): Das Altpaläozoikum und Unterkarbon der Gurktaler Decke und ihre paläogeographischen Beziehungen. Geol. Rdsch. 73, 149-174, Stuttgart.

PEARCE, J.A. (1982): Trace element characteristics of lavas from destructive plate boundaries. In:. THORPE, R.S. (ed.), Andesites: Orogenic Andesites and Related Rocks, 525-548, Chichester (Whiley).

POLTNIG, W. (1984): I. Beitrag zur Geologie westlich von Gösting bei Graz. II. Fischreste und Eridostraca aus dem Unterdevon von Graz (Stmk). Unpubl. Doct. Thesis Univ. Graz, 106 p., Graz.

SCHÖNLAUB, H.P. (1979): Das Paläozoikum in Österreich. Verbreitung, Stratigraphie, Korrelation, Entwicklung und Paläogeographie nichtmetamorpher und metamorpher Abfolgen. Abh. Geol. B.-A. 33, 124 p., Wien.

TSCHELAUT, W. (1985): Über das Alter der Arzberg Schichten und der Blei-Zink Vererzungen im Grazer Paläozoikum. Jb. Geol. B.-A. 128/2, 241-243, Wien.

TUFAR, W. (1972): Zur Blei-Zink-Vererzung des Grazer Paläozoikums. Min. Mitt. Joanneum, 64-75, Graz.

WEBER, L. (1983): The stratiform Lead-Zinc mineralization of the "Paleozoic of Graz" (Styria, Austria). Min. Dep. Alps, 81-87, Berlin.

Manuscript received June 6, 1988; accepted October 1, 1988.