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Geodynamic evolution of the Sausal Paleozoic (Eastern Alps)

by *J. Schlamberger*[1]

Abstract

Low grade metamorphosed Paleozoic rocks of the Upper Austroalpine nappe system, the so called "Paleozoic of the Sausal", are exposed in the western part of the Neogene Styrian basin. Based on new geologic mapping a lithostratigraphic sequence is presented: A succession of acid volcanics, metapelites, metabasalts and metapsammites of probable Silurian age is followed by conodont-bearing pelagic limestones of the Early Devonian.

Analogies of that sequence with adjacent regions of similar geotectonic position show a typical sedimentary evolution of Upper Austroalpine realm.

The interpretation of geochemical analyses of the basaltic rocks together with the results of the modal and heavy mineral analyses of the metapsammites and the facies distribution of carbonates allow a geodynamic reconstruction: Metabasaltic rocks exhibit continental within-plate basalt affinity. They represent a juvenile rift stage of Silurian age. The sedimentation of the psammitic rocks are interpreted as turbidites near swells or near the margin of the basin. The pelagic limestones represent already the evolution to a passive continental margin during lower Devonian time. In this model, the acid volcanic rocks at the bottom of the sequence could be melting products of the continental lithosphere, caused by a mantle plume at the beginning of the evolution.

Keywords: Metabasalt, metasediment, rifting, Upper Austroalpine nappes, Sausal Paleozoic, Austria.

1. Introduction

The low grade metamorphosed Paleozoic rocks of the Sausal area are part of the Upper Austroalpine nappe system. The Paleozoic rocks are surrounded by Tertiary and Quarternary sediments of the Styrian basin (Fig. 1 and 2). This situation and the fact, that only rare outcrops are found, left the Paleozoic of the Sausal nearly unnoticed (latest treatise by SCHIMUNEK, 1958). So the exact paleogeographic and tectonic position within the basement rocks of the Austroalpine nappe system and the relationship to adjacent units (Paleozoic of Graz, Greywacke zone, Gurktal nappe) was unknown.

All rocks have been newly examined on the base of intense field work and petrographical and sedimentological analyses.

Standard procedures were used for heavy mineral studies. The dating of the limestones is based on conodonts.

The geochemistry of the metabasaltic rocks was carried out by X-ray fluorescence analyses at the Central Geochemical Laboratory of the University of Tübingen. Two samples of each locality were investigated. Much attention was payed on using only fresh samples without secondary alteration.

2. Results

2.1. STRATIGRAPHY

The lithostratigraphic sequence is shown in Fig. 3. A complete sequence was obtained by

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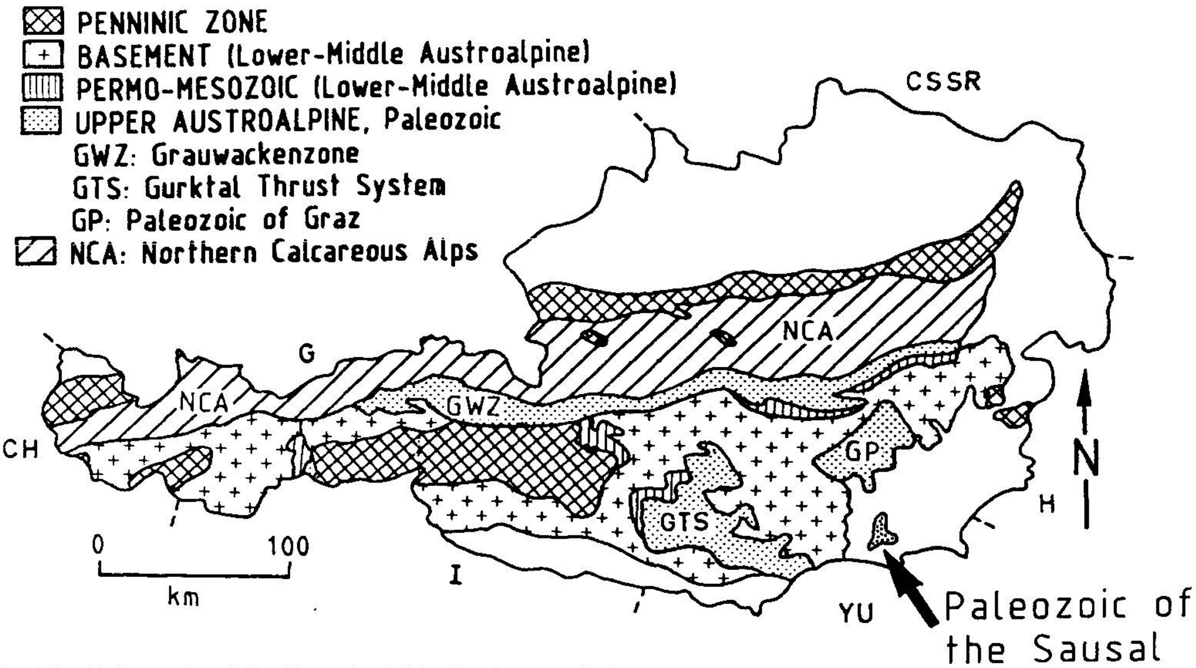

Fig. 1 The Paleozoic of the Sausal within the Austroalpine nappe system.

combination of profiles from the region of the Demmerkogel and the Grillkogel (Fig. 2).

The sequence starts with acid volcanic rocks followed by a metapelitic sequence composed of calcareous phyllites, phyllites, metatuffs, metatuffites and rare lenses of marbles.

The next higher complex consists of metabasaltic rocks and metapsammites. These rocks are followed by pelagic nodular limestones of early Devonian age (Lochkov-Prag) and cherts of unknown age in the region of the Grillkogel.

The total thickness is about 300 meters. The lithostratigraphic sequence shows strong similarities to the Upper Austroalpine units of the Gurktal thrust system, Greywacke zone, and the Paleozoic of Graz (Fig. 3).

2.2. PETROGRAPHY OF THE METAPSAMMITES

The low grade metamorphic overprint of the metapsammites causes a destruction of sedimentary textures and falsifies the modal contents. Recrystallisation of quartz and sericitisation of feldspar increased the matrix content (Tab. 1).

Neglecting the matrix content, the metapsammites must have been originally quartz-rich (more than 50%) and feldspar-bearing sandstones. Heavy mineral analyses have been made to get more information about the source rocks. Apatite, tourmaline, zircon, epidote and garnet occur in all samples. Special attention

Tab. 1 Modal content of metapsammitic rocks.

Sample Nr.	Q	P	Kf, Ab	Mica	HM	Matrix
W6	28 %	3,6 %	7 %	5 %	-	56 %
W5	29,3 %	2,3 %	5 %	3 %	-	60 %
W4	28 %	3,3 %	2,3 %	2 %	-	64 %
W3	39 %	5 %	1,6 %	0,6 %	-	53,3%
S2	44,3 %	3,3 %	2,6 %	0,6 %	-	48,3%
S3	34,6 %	3,3 %	4,3 %	1,3 %	0,3 %	56 %
Sdst1	50,6 %	3,3 %	2,6 %	0,6 %	-	42,6%
Sdst2	45,6 %	6,6 %	6,6 %	0,6 %	0,3 %	40 %
Sdst3	49 %	10,3 %	13 %	0,6 %	0,3 %	26 %
28.1.	40,5 %	3 %	10 %	7 % (Biotite)		39,5%

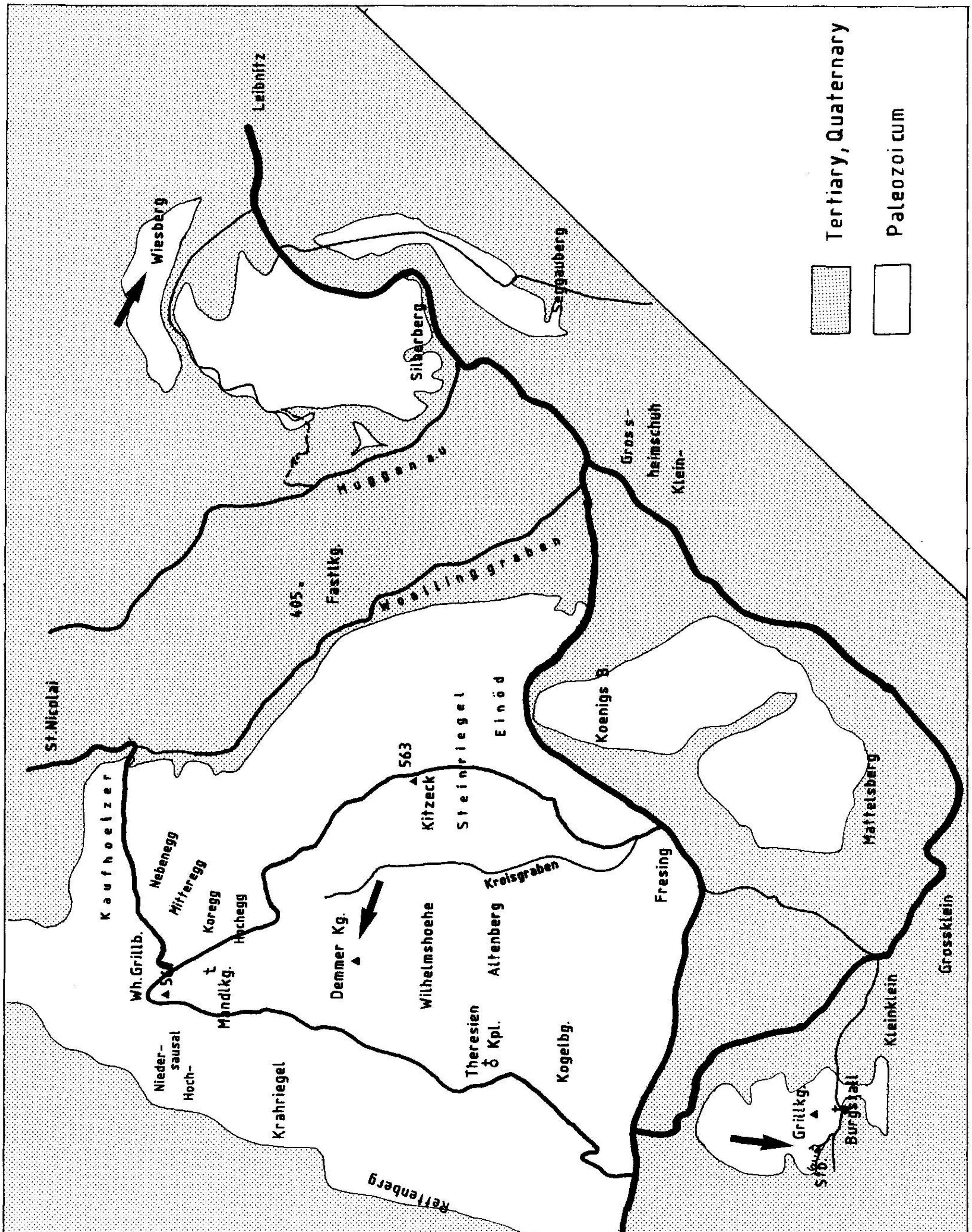

Fig. 2 The Sausal Paleozoic within the western Neogene Styrian Basin. Arrows indicate the localities of investigation for obtaining a complete sequence and of sample collection.

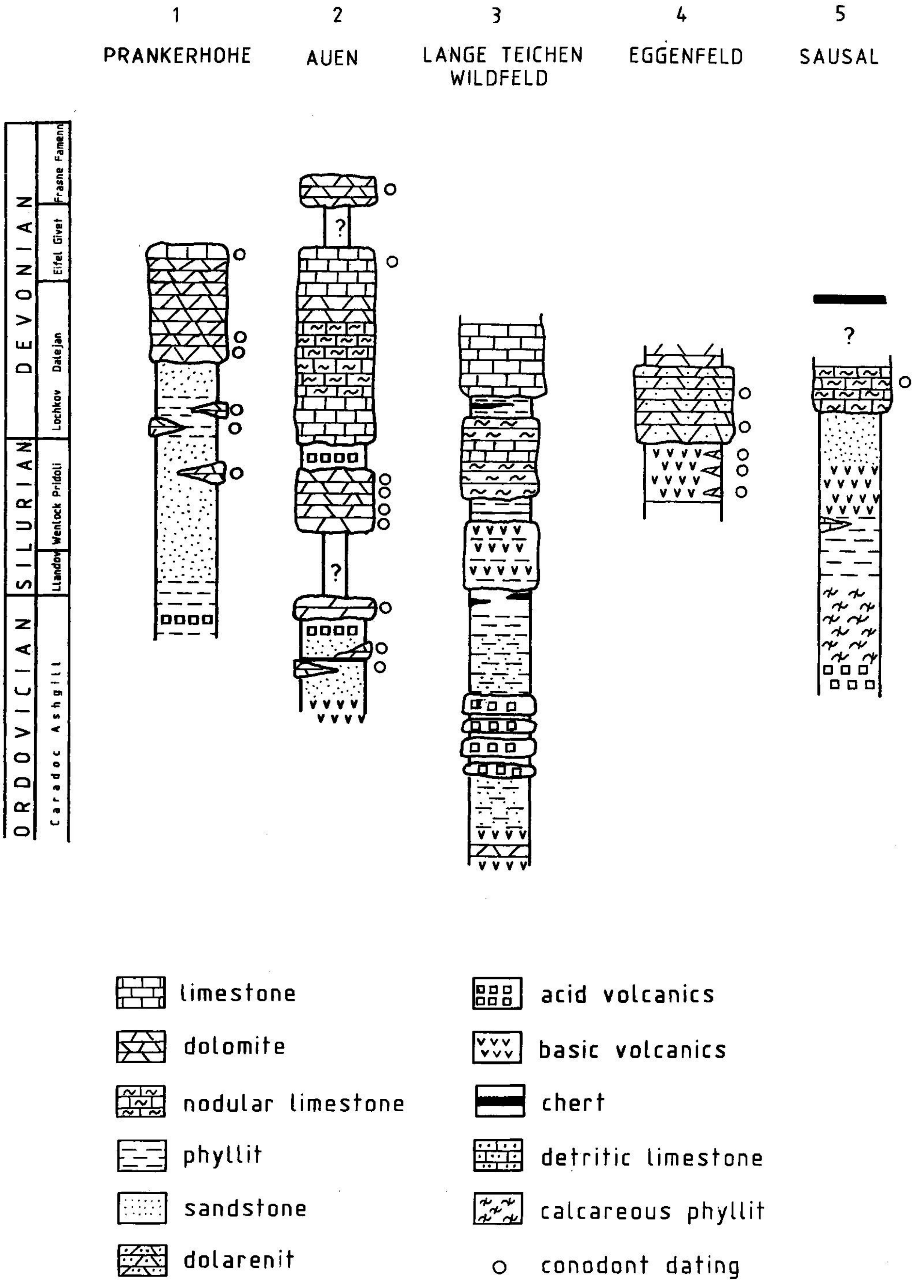

Fig. 3 The section of the Sausal Paleozoic in comparison with adjacent fossil bearing sections of the Upper Austroalpine nappe system. Section 1 and 2: Gurktal nappe (after NEUBAUER and PISTOTNIK, 1984); section 3: Greywacke zone (after SCHÖNLAUB, 1979); section 4: Paleozoic of Graz (after EBNER, 1976; NEUBAUER et al., 1986).

was given to distinguish between different zircon types. The following morphologic characteristics have been studied: Roundness, surface morphology, colour variations, inclusions, and zonation. The dependence between the several variables was tested in different histograms following TRAUTNITZ (1980). As a result, four different zircon populations could be recognized:

a) rounded, pink zircons;
b) rounded, brown zircons;
c) idiomorphic to hypidiomorphic zircons with inclusions;
d) clear, rounded zircons.

These results allow some conclusion about source rocks:

- Rounded zircons are the result of long-lasting, polycyclic deposition and transport events, so they can be taken from continental sediments (BRIX and LOSKE, 1987).

- Idiomorphic to hypidiomorphic zircons bear bubble-like and rod-shaped inclusions. The provenance of these zircons are volcanics (BRIX andLOSKE, 1987). Together with the high content of alkali feldspar and the high amount of apatite in the metapsammites, the volcanics should have had an acid composition.

- The high content of garnet in some samples (up to 14%) indicates metamorphic rocks in the source area.

Due to the absence of any information on transport mechanisms no interpretation about the distance of the source rocks is given, although the unmaturity of the sediment and the high content of easy weathering minerals (apatite, garnet, feldspar, detritic mica) might be explained by a short distance from the source area.

2.3. GEOCHEMISTRY OF THE METABASALTS

At the Wiesberg, the Demmerkogel and the Grillkogel metabasalts are found in close contact with the metapsammites (localities see Fig. 2). First descriptions of the "Diabas of Wiesberg" are given by HOERNES (1889), LEITMEIER (1907, 1908) and ANGEL (1924).

All metabasalts show well preserved volcanic textures. They form dark greenish to black massive dykes. Idiomorphic to hypidiomorphic plagioclase crystals (44%–55% of the

Tab. 2 Geochemical analyses of metabasalts.

		Accuracy	Sensivity	WIE I/1	WIE I/2	WIE II/1	WIE II/2	DEM1	DEM2	BUR1	BUR2
SiO_2	%	0.59	1.46	47.88	48.53	48.28	48.43	49.39	51.00	46.35	48.24
TiO_2	%	0.03	0.05	2.35	2.29	2.36	2.31	1.74	1.69	2.28	2.34
Al_2O_3	%	0.12	0.24	13.84	13.65	14.10	14.56	16.52	15.95	14.12	14.09
Fe_2O_3	%	0.10	0.20	13.43	13.05	12.97	12.84	10.93	10.51	12.25	11.12
MnO	%	0.00	0.01	0.20	0.19	0.19	0.19	0.15	0.15	0.20	0.18
MgO	%	0.09	0.16	6.64	6.55	7.00	7.05	5.81	5.66	6.19	5.31
CaO	%	0.19	0.35	7.63	8.11	6.98	7.11	8.63	7.78	5.67	5.69
Na_3O	%	0.08	0.15	4.18	4.24	4.23	4.26	3.27	3.62	3.86	4.32
K_2O	%	0.09	0.17	0.00	0.00	0.03	0.03	0.17	0.21	0.06	0.08
P_2O_5	%	0.02	0.03	0.24	0.24	0.25	0.26	0.22	0.21	0.26	0.28
Ba	ppm	17	33	197	212	299	244	179	198	275	545
Cr	ppm	19	38	71	71	87	135	140	140	74	71
Nb	ppm	2	4	20	17	19	21	11	15	18	22
Ni	ppm	22	41	-	-	-	-	-	-	-	47
Rb	ppm	3	7	-	-	-	-	9	11	8	8
Sr	ppm	9	16	299	319	382	397	402	370	423	586
V	ppm	7	15	333	308	311	312	307	302	325	307
Y	ppm	5	11	18	20	20	19	28	28	20	22
Zn	ppm	4	9	94	87	97	102	97	97	101	88
Zr	ppm	11	22	138	141	146	149	166	157	149	161
Ignition Loss				3.15	2.95	3.39	3.17	3.11	2.94	8.82	7.75
Total		0.66		99.66	99.90	99.88	100.31	100.08	99.83	100.13	99.51

modal content) can be observed, which are partly sericitized, chloritized or altered into zoisite. Orthopyroxene (27%–28% of the modal content) is partly altered to uralitic hornblende. Additionally, there exist aggregates of serpentine minerals. Ilmenomagnetite (7%–9%) is altered to lamelles of ilmenite and leucoxene.

Two samples of each metabasalt locality have been analyzed for major, minor and trace elements (see Tab. 2). Much attention was payed to chemical alteration by metamorphism and/or spilitisation because all samples have undergone low grade metamorphism. Furthermore, only diagrams concerning immobile element ratios were used.

2.3.1. Secondary alteration

Spilitisation causes decreasing CaO- and SiO_2-contents in contrast to higher contents of alkalies, H_2O and CO_2. In the diagram following MULLEN, 1983 (Fig. 4) the relationship between Na_2O and CaO is used to show the difference between spilites and unaltered basalts. All investigated samples plot near the line of separation, lying on the line or in the field of unaltered basalts. Therefore, a limited spilitisation can be assumed.

To find out the behaviour of individual elements, all trace and some minor elements are plotted against the immobile element Zr in Fig. 5. Elements which have not been influenced by submarine weathering and metamorphism lie on a linear regression line with a high correlation coefficient (above 0.9; in Fig. 5 continuous lines). This is valid for the elements Ti, P, Zn, Ba, Sr, Cr. A low mobility can be recognized for Mn, V, Y (correlation coefficient between 0.8–0.9; dashed lines in Fig. 5).

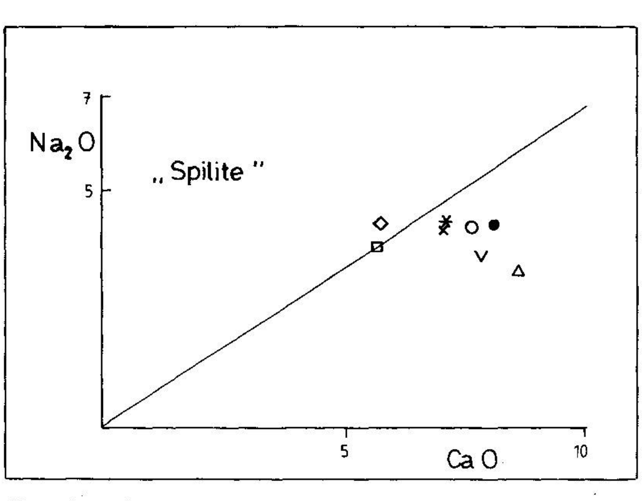

Fig. 4 Diagram after MULLEN (1983) for discrimination between spilites and unaltered basalts.
∇, ∇ Demmerkogel basalt,
□, ◇ Burgstall basalt,
○, ●, x, ★ Wiesberg basalt.

K does not show any correlation among the samples. That means, K was affected by submarine weathering and/or metamorphism. This can also be seen from Fig. 6, where K has undergone strong depletion. The removing of K causes albitisation of alkali feldspars, which is indicated by chess-board albites.

Individual deviating samples were not considered for calculating the correlation coefficient. The samples of the Demmerkogel basalt deviate from the other samples for most of the elements.

2.3.2. Type of magma and geotectonic position

The geochemical analyses are shown in Fig. 6, normalized to an average tholeiitic N-type MORB (normalisation values after PEARCE, 1983).

The selective enrichment of the elements from Sr to Ti and the depletion of Y, Yb, Sc and Cr is typical for within-plate basalts. The strong depletion of K is explained by secondary alteration effects, as described above.

The within-plate basalt characteristics are also shown in the Ti-Zr-Y-diagram (PEARCE and CANN, 1973; Fig. 7) through relatively high Zr and Ti values in comparison to low Y values.

The trend from tholeiitic to alkalic basalts is characterized by strong enrichment of Nb in contrast to Y. In the Nb/Y-Ti/Y diagram following PEARCE, 1982 (Fig. 8), the basalts of the Demmerkogel plot in the tholeiitic field, the other samples indicate a transitional character.

The tholeiitic character of the Demmerkogel basalts is also evidenced from other diagrams, e.g. from the Y-FeO^+/MgO diagram after WINCHESTER and MAX (1982) and the basalt tetrahedron after YODER and TILLEY (1962) (Fig. 9).

This interpretation is also supported by the Nb-Zr-Y diagram of MESCHEDE (1986) (Fig. 10) where the Demmerkogel basalts plot in the field of continental tholeiites (field C).

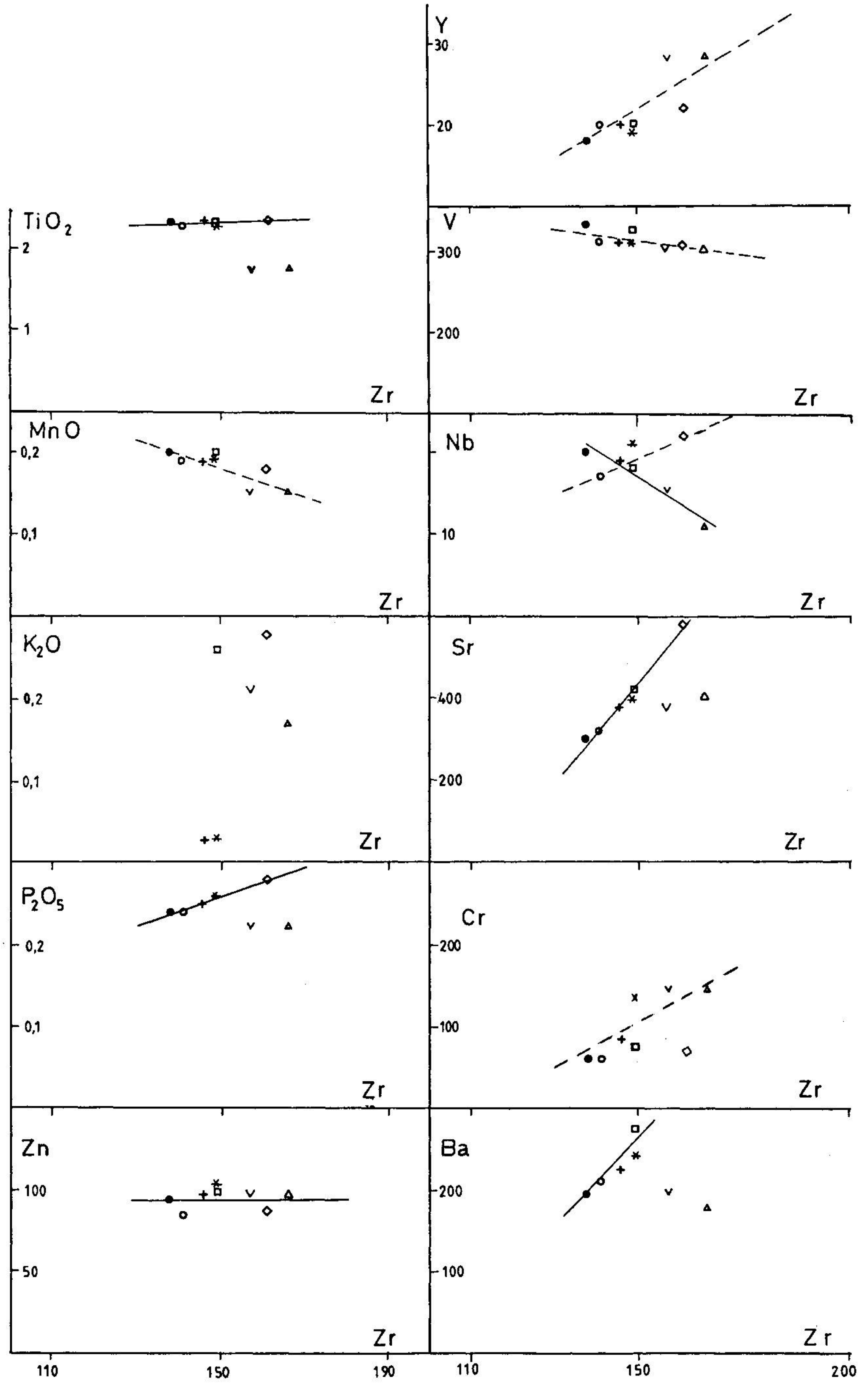

Fig. 5 Identification of mobile elements using the approach of Cann (1970). The correlation matrix of all trace and some minor elements is examined. If the correlation coefficient for a pair of elements is high, the ratio of these elements has not been altered. (Continuous line: correlation coefficient above 0.9; dashed line: correlation coefficient between 0.8–0.9)
For signatures see Fig. 4.

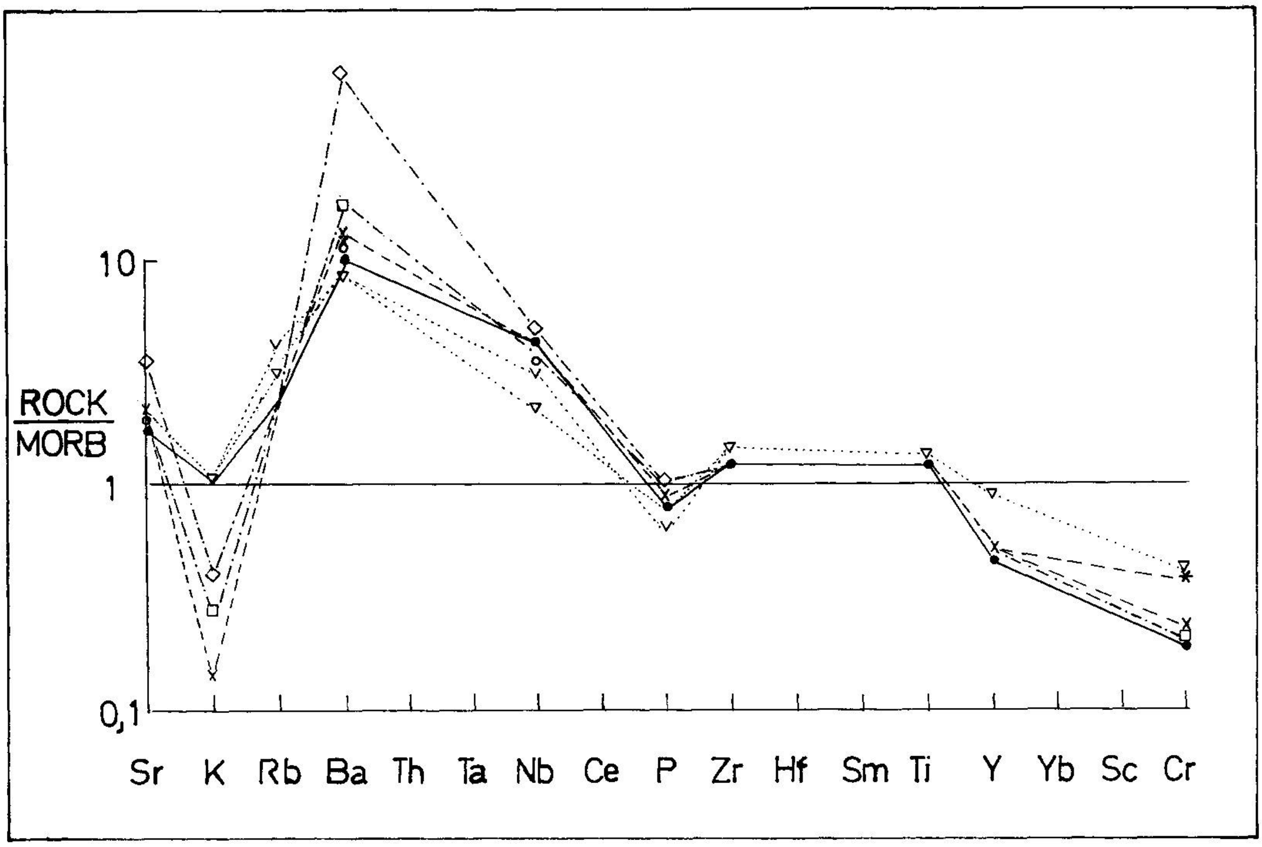

Fig. 6 Geochemical analyses of the basalts of the Sausal normalized to an average tholeiitic (N-type) MORB (after PEARCE, 1983). The selective enrichment of the elements from Sr to Ti and the depletion of Y and Cr is typical for within plate basalts. The depletion of K is explained by secondary alteration effects. For signatures, see Fig. 4.

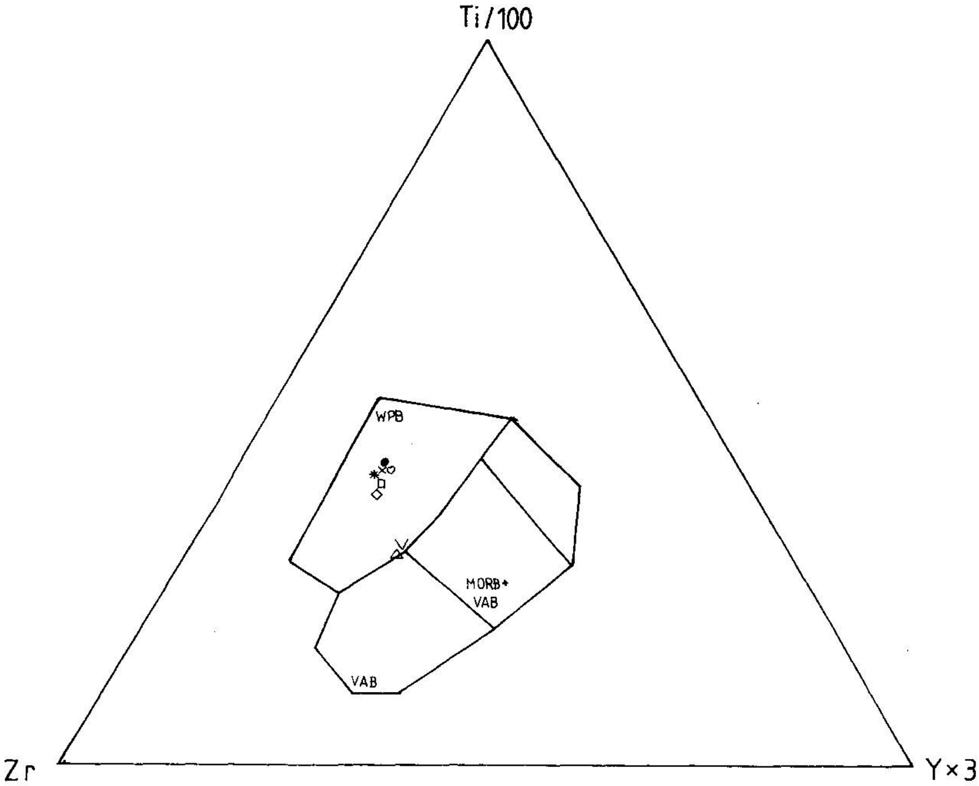

Fig. 7 Ti–Zr–Y diagram after PEARCE and CANN (1973) for identification of within-plate basalts (WPB). VAB-volcanic arc basalt. MORB-mid ocean ridge basalt. For signatures, see Fig. 4.

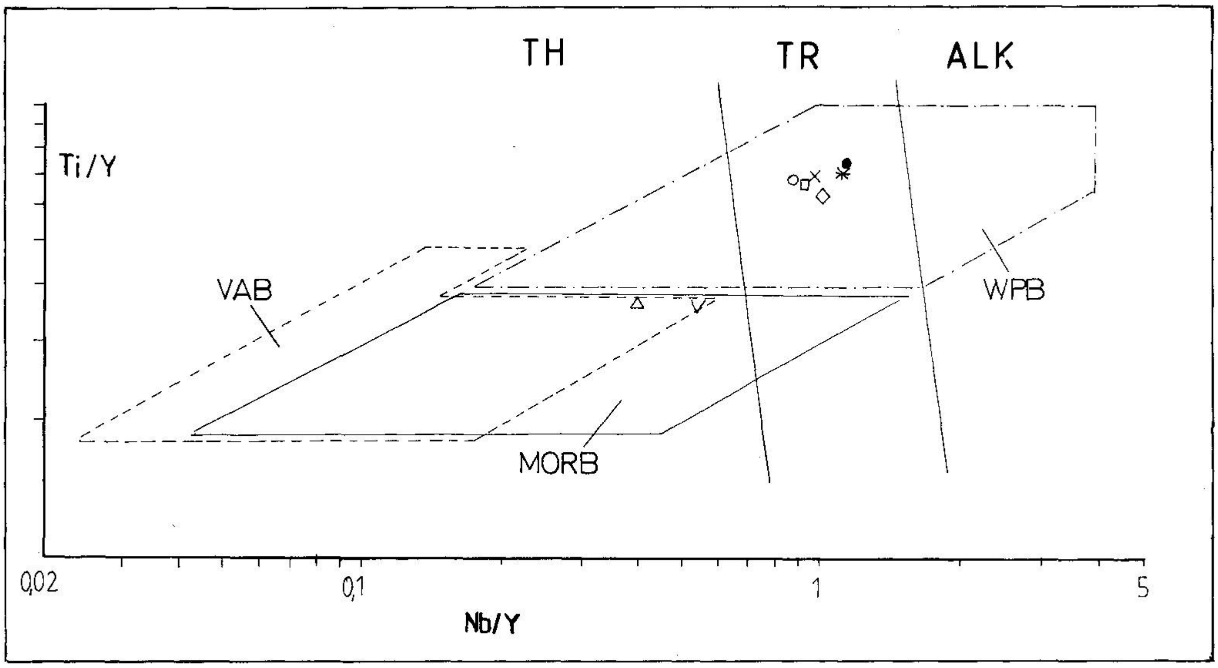

Fig. 8 Ti/Y-Nb/Y diagram after PEARCE (1983) for subdividing basalts in tholeiitic (TH), transitional (TR) and alkalic (ALK) magma types. The differences between the Demmerkogel basalt (tholeiitic) and the other basalts (transitional) appear clearly. For signatures, see Fig. 4.

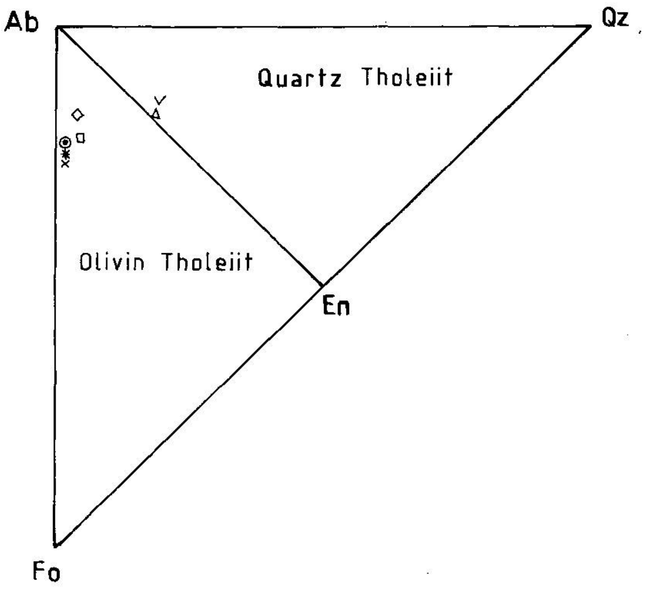

Fig. 9 The basal triangle albite (Ab)-forsterite (Fo)-quartz (Qz) of the basalt tetrahedron after YODER and TILLEY (1962) for subdividing basalts. The line Fo-Ab is the critical thermal line dividing alkali basalts from tholeiitic basalts. The line Ab-En (enstatite) is the thermal line between silica saturated and silica-unsaturated lavas. Here clear differences between Demmerkogel basalt (quartz tholeiites) and the other basalts (olivin tholeiites) are seen. Ab, Qz, Fo are CIPW normative minerals. For signatures, see Fig. 4.

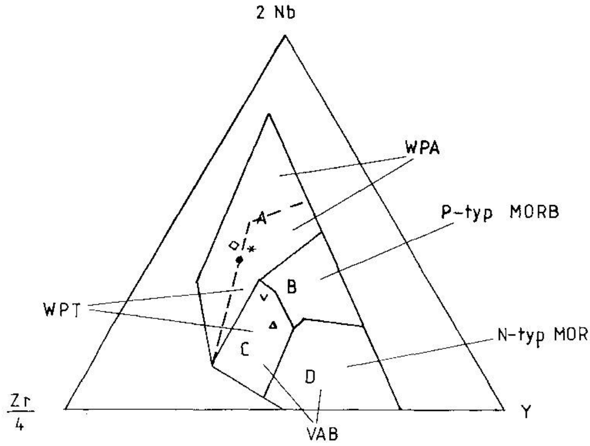

Fig. 10 Diagram after MESCHEDE (1986) discriminating between continental within-plate alkali basalts (WPT), «normal» Mid Ocean Ridge Basalts (N-type MORB) and basalts from plume influenced regions (P-type MORB). Continental within-plate tholeiitic basalts plot in field C. For signatures, see Fig. 4.

The plate tectonic position - within-plate basalts - is the same for all investigated basalts. Nevertheless, the basalts of the Demmerkogel show clear differences in most of the diagrams (see Fig. 8, 9, 10) in comparison with the Wiesberg basalt and the Burgstall basalts. Further investigations are necessary to clear whether those differences depend on secondary alteration effects, on different degrees of melting or on two different magma chambers producing different melts.

3. Discussion and conclusion

All results must be taken into account for an exact interpretation of the geodynamic situation during late Ordovician to Devonian times.

As shown in Tab. 1, the metapsammites must have been originally rich in quartz (more than 50%) and feldspar, which is typical of passive continental margins (MAYNARD et al., 1982). Two different locations are possible for within-plate basalts: continental basalts or ocean island basalts. Considering the presence of quartz dominated sandstones and the geochemistry of the metabasalts, the volcanism must be explained as continent derived.

Looking for recent examples of within plate basalts with tholeiitic to transitional affinity, the situation in the East African rift system, the Afar triangle and the Red Sea offers a good idea for the possible paleogeographic situation of the Sausal area during late Ordovician to early Devonian times.

Studies in the Afar region have shown that magmas of a transitional character are indicators of a "proto-oceanic" crust during complete rupturing of the continental crust (KAMPUNZU et al, 1984).

For the Sausal-Paleozoic the following model is presented:

Arching of the mantle leads to an attenuation of continental lithosphere, causing horst- and graben structures with deep faults. Basaltic magmas could well up through those structures during Silurian times. The transitional basalts indicate the change to a rifting stage, during which still no oceanic crust was produced. From swells or from the margins, turbidites pour into the basin. In early Devonian times, a carboante-shelf evolution of a passive continental margin is documented by the coloured nodular limestones.

The acid volcanic rocks on the bottom of the section could be seen as melt products of continental crust, caused by the upwelling of a mantle diapir at the beginning of the evolution described above.

Similar geotectonic interpretations of comparable lithostratigraphic sequences are given by HEINISCH (pers. comm.) for the western Greywacke zone, by GIESE (this vol.) for the Gurktal nappe and by FRITZ and NEUBAUER (this vol.) for the Paleozoic of Graz.

Silurian within-plate basalts of alkalic character can be found in the Gurktal nappe (GIESE, this vol.) and the Paleozoic of Graz (KOLMER, 1978, FRITZ and NEUBAUER, this vol.). They might prove the initial stage of continental rupturing.

Therefore the Paleozoic of the Sausal, as part of the Upper Austroalpine nappe system, documents the evolution of a passive continental margin during late Ordovician, Silurian and early Devonian times. Real oceanic crust could not be found.

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