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High-pressure metamorphism of basalts in the evaporite sequence of the Haselgebirge: An evidence from Bad Ischl (Austria)

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1 table and 4 fotoplates

Austria
Upper Austroalpine Unit
Haselgebirge sequence
Upper Permian-Lower Triassic
P-T conditions
metabasaltic fragments

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Nachweis von hochdruckmetamorphen Basalten im Haselgebirge des Salzkammergutes (Umgebung Bad Ischl, Österreich)

Zusammenfassung

Das petrologische und geochemische Studium von metabasaltischen Gesteinsfragmenten im oberpermischen bis untertriadischen Haselgebirge von Bad Ischl spricht für eine Herkunft der primär ozeanischen Basalte von tholeiitischen Magmen. Ihre Metamorphose fand unter Hochdruck/Niedertemperatur-Bedingungen statt. Die Metabasalte können mit jenen der Westkarpaten korreliert werden, die ihrerseits als charakteristische Gesteine des Meliata Ozeans interpretiert und einem Trias- bis Jura-Alter zugeordnet werden.

Abstract

The petrological study of the metabasaltic fragments in the Upper Permian – Lower Triassic evaporite sequence (Haselgebirge Fm.) from Bad Ischl suggests the existence of primary oceanic basalts of tholeiite magmatic trend. The fragments of basalts are metamorphosed in HP/LT conditions. The metabasalts can be correlated with occurrences in the Western Carpathians, which are interpreted as the Meliata Ocean Triassic to Jurassic in age.

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1. Introduction

The occurrences of metabasalts in the Permian-Triassic sequence, designated as the "Alpines Haselgebirge", are known from the literature since several decades ago. KIRCHNER (1980a, b) described in detail mineralogical and petrological features of these rocks. PLÖCHINGER (1984), SENGÖR (1985), LEIN in FLÜGEL & FAUPL (1987), TOLLMANN in FLÜGEL & FAUPL (1987), KOZUR (1990, 1991) and KOZUR & MOSTLER (1992 studied the tectonic position of the evaporite sequence, its lithofacial and paleotectonic development and the character of the Kimmerian stage in the North Alpine units and assigned its individual parts to stratigraphical horizons. KOZUR (l. c.), KOZUR & MOSTLER (l. c.), MANDL (1986, 1987) and MANDL & ONDREJIČKOVÁ (1991) studied the occurrences of critical sedimentary sequences in the tectonic zone interpreted as the Meliatic Zone (KOVÁCS, 1982, 1989; KOZUR, 1991), and considered as an equivalent of the Western Carpathian, Internide Meliatic Zone, well preserved in the southern Slovakia and in northern Hungary (MELLO & MOCK, 1977; MELLO in BAJANÍK et al., 1983; KOVÁCS, 1982, 1989; KOZUR, 1991). KOVÁCS (1982), KOZUR (1991), CSONTOS (1992), CSONTOS & VÖRÖS (1992) and HAAS, KOVÁCS, KRYSTYN & LEIN (1992) correlated the Meliaticum with the Vardar zone.

2. Location of basalts in the Haselgebirge Sequence

The basalts occur at several places along the southern border of the Northern Calcareous Alps in the Upper Permian - Lower Triassic evaporite sequence. Their host rocks were characterized as the saline sediments reworked into breccias. According to LOTZE (1938), SCHAUBERGER (1931, 1955, 1986), SCHINDL-NEUMAYER (1984) and KRAINER & SPÖTL (1989) this sequence is exclusively of sedimentary origin, but KOZUR (1991) and KOZUR & MOSTLER (1991) consider the tectonic reworking of this formation into a melange as more significant.

On the basis of chemical composition KIRCHNER (1980a) defined two types of basalt fragments in the breccia type rock environment, 1. oceanic tholeiites and 2. continental alkalic-potassium basalts. KIRCHNER (l. c.) also described the low-grade regional metamorphism and the formation of pumpellyite and Na-amphibole. The Na-amphibole alteration took place 108 or 118±9 m. a. ago (JÄGER in KIRCHNER, 1980a).

The above information indicates that the general structure and the tectonometamorphic processes of this zone located south of the Northern Calcareous Alps and defined by TOLLMANN (1986) as the Juvavicum can be reinterpreted. Most basaltic fragments in the Haselgebirge sequences oc-

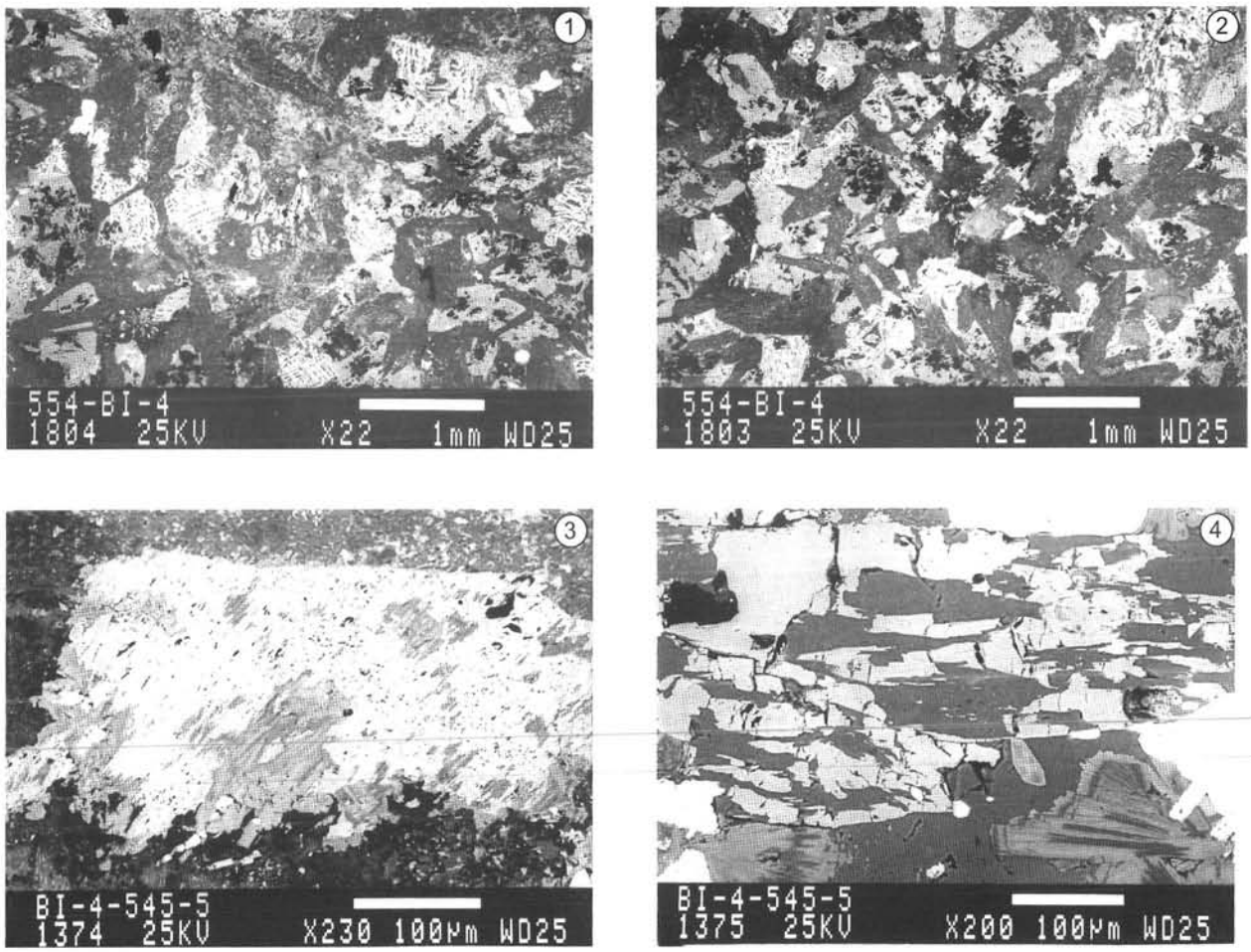


PLATE 1

Fig. 1, 2: Relics of subophitic textures in metabasalts.
Fig. 3: Grain of clinopyroxene altered to aggregate of chlorite, epidote. The most light-coloured inclusions of small grains correspond to titanite.
Fig. 4: Products of alteration: glaucophane + fan-like crystals of pumpellyite.

Photos by: J. Stankovič, 1995. Scanning micr. JEOL JSM-840. Dionýz Štúr Inst. of Geology, Bratislava.

cur near Bad Ischl and southwards (SCHAUBERGER, 1960; SCHLAGER, 1967; PLÖCHINGER, 1984; KIRCHNER, 1980a, b). Several boreholes were drilled in this area to explore the mineral potential of commercial prospection. The borehole BI-4, sunk in Bad Ischl, intersected more than 600 m of the Haselgebirge sequence that included metamorphosed basalts amidst the evaporite matrix with the fragments of shales, sandstones, quartzites, various types of carbonates and sporadic black siliceous fragments of lydite type. The fragments of basic volcanics occur at depth between 550–560 m and most are 1–3 cm in diameter, but compact blocks measuring 20 to 100 cm in diameter were intersected at depths 554–555 m and 555,8–556 m.

3. Petrographical characterization of the metabasalts

The metabasalts (borehole B I-4) are weakly recrystallized and have an indistinct grain. They contain the relics of magmatogenic clinopyroxenes, skeletal opacitized femic minerals and prismatic plagioclase pseudomorphs and remnants of the original subophitic texture.

On the basis of their chemical composition (Tab. 1), these clinopyroxenes belong to the group of Ca-Mg-Fe "quadrilateral" pyroxenes and according to the classification of MORIMOTO (1988) they fall within the augite group, close to salite.

The SiO_2:Al_2O_3 (according to LE BAS, 1962) and/or Ti:Ca+Na ratios (according to LETERRIER et al., 1982) can be used to genetically classify the clinopyroxenes. These discriminants suggest that the clinopyroxene relics developed from the magmas of normal or reduced alkalinity. This indicates their low content of Ti, Na and relatively low amount of Al_2O_3.

In thin sections the augites are colourless, have a high relief and contain the relics of a typical cleavage. These clinopyroxenes probably developed during the first magmatic stage of crystallization. It is also probable that during the low-grade alteration process, a reduction of Ca and an enrichment in Fe and Na (analyses px 5, 6 in Tab. 1) took place and the clinopyroxenes of the low alteration stage tend to acquire an aegirine-augite composition. Although, this conclusion is based on only two imperfect analyses, the difference from the first group of pyroxenes is evident. The Ti and Mg contents in the metamorphic clinopyroxenes are distinctly lower.

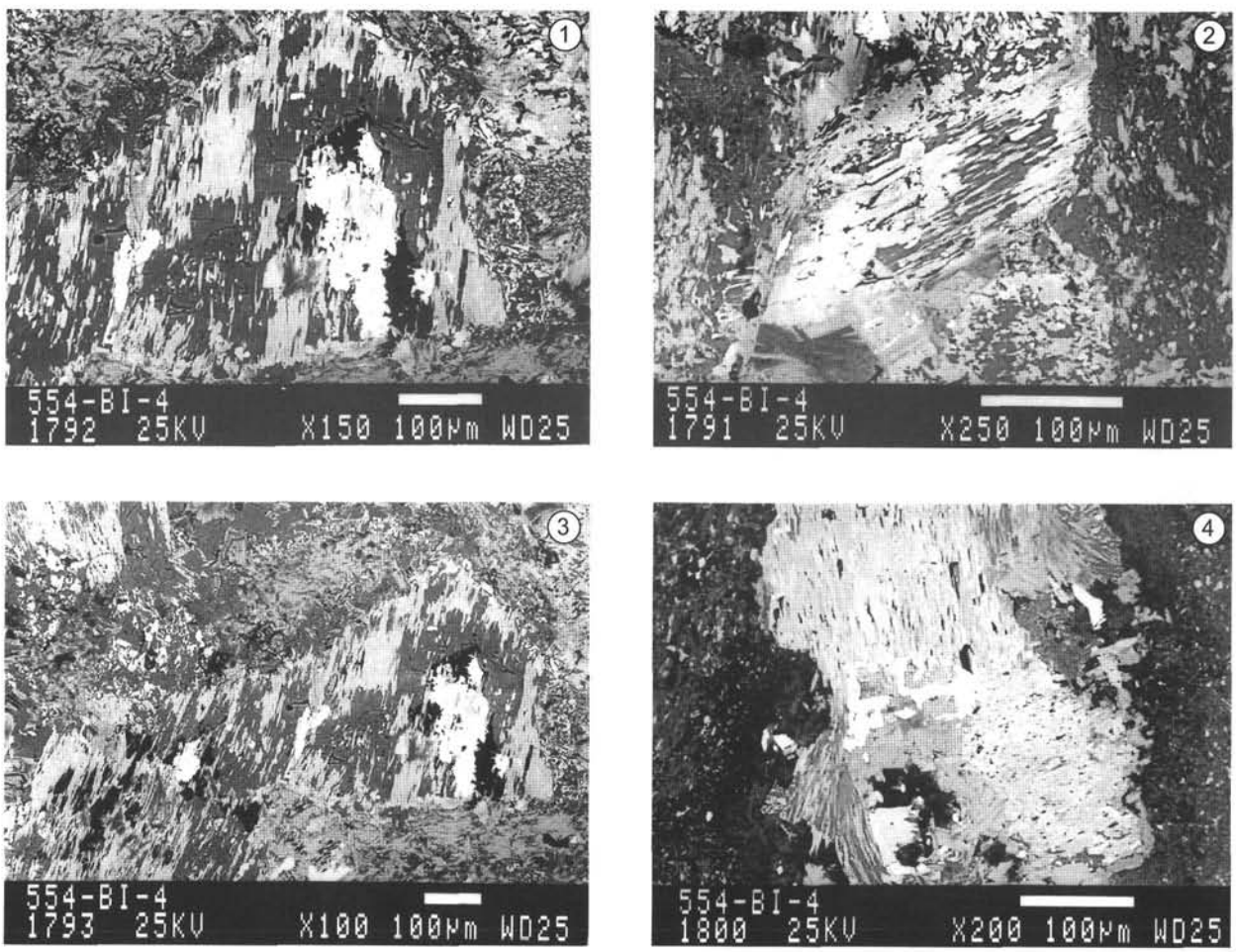


PLATE 2

Fig. 1–4: Alteration of clinopyroxenes.
Acicular crystals of glaucophane at rims of crystals.

Photos by: J. Stankovič, 1995. Scanning micr. JEOL JSM-840. Dionýz Štúr Inst. of Geology, Bratislava.

Tab. 1
Representative analyses of pyroxenes and glaucophane

	px 1	px 2	px 3	px 4	px 5	px 6	gln
SiO_2	51.360	49.790	50.640	48.390	51.290	51.670	51.870
TiO_2	0.930	0.980	0.770	1.320	0.190	0.120	0.040
Al_2O_3	1.660	3.620	1.760	3.190	0.950	0.790	0.830
FeO	11.710	8.440	11.460	11.460	20.300	20.310	18.070
MnO	0.440	0.200	0.270	0.280	0.930	1.050	0.840
MgO	15.410	16.070	16.230	14.580	5.500	5.560	5.780
CaO	17.870	19.570	18.830	20.410	12.260	12.520	11.590
Na_2O	0.370	0.490	0.500	0.690	8.810	8.210	7.570
K_2O	0.010	0.000	0.000	0.000	0.010	0.000	0.020
Cr_2O_3	0.270	0.020	0.090	0.000	0.000	0.020	0.000
Suma	100.030	99.180	100.550	100.320	100.240	100.250	96.610
Si	1.926	1.866	1.895	1.832	2.022	2.033	7.981
Al^{IV}	0.073	0.134	0.078	0.142	0.000	0.000	0.019
Al^{VI}	0.000	0.026	0.000	0.000	0.044	0.037	0.132
Ti	0.026	0.028	0.022	0.038	0.006	0.004	0.005
Fe^{+2}	0.367	0.265	0.359	0.363	0.669	0.668	2.325
Mn	0.014	0.006	0.009	0.009	0.031	0.035	0.109
Mg	0.861	0.898	0.906	0.823	0.323	0.326	1.326
Ca	0.718	0.786	0.755	0.828	0.518	0.528	1.910
Na	0.027	0.036	0.036	0.051	0.673	0.626	2.258
K	0.000	0.000	0.000	0.000	0.001	0.000	0.004
Cr	0.008	0.001	0.003	0.000	0.000	0.001	0.000
Mg/Mg+Fe	0.701	0.772	0.716	0.694	0.326	0.328	0.363

Analyses performed with JEOL-733 Superprobe, Geol. Survey of Slovak Republic

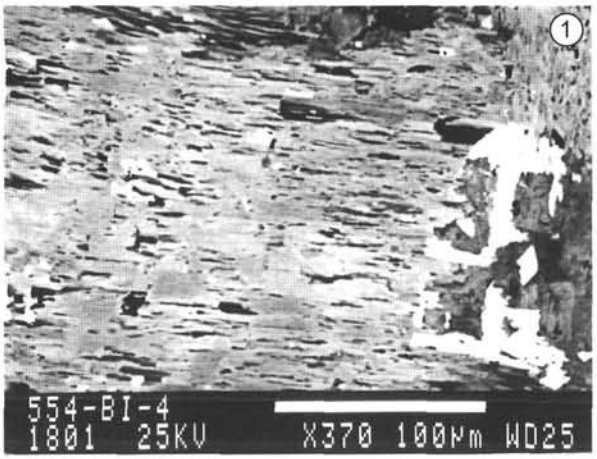
The original magmatogenic plagioclases were replaced by pseudomorphs filled with fine-grained aggregate of light-coloured mica, albite and needles of glaucophane and lawsonite.

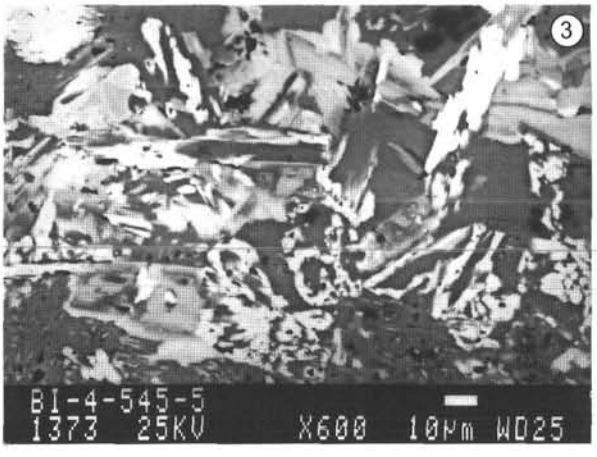
The alteration of magmatogenic augites proceeded along the rims and joints. The products of alteration are Ca-Na clinopyroxenes, low-ferric and low-aluminium chlorite, with Fe/(Fe+Mg):Si ratio indicating a pycnochlorite composition with Fe/(Fe+Mg)=0,34. Other products of alteration are acicular crystals of bluishgreen and blue amphibole, pumpellyite and scarce epidote.

The microprobe analyses indicate that the amphibole belongs to the group of glaucophane, characterized by a high content of Na in M4 position, by a relatively high content of SiO_2 and variable contents of Al_2O_3 (Tab. 1, anal. gln).

Because the Mg/(Mg+Fe) ratio varies within the range 0.318 to 0.558, the amphiboles either fall within the field of normal glaucophane or of ferro-glaucophane.

As already mentioned, the plagioclase pseudomorphs are composed of a fine-scaled light-coloured, mica-fengite aggregate and albite. Some albites occur between the relics of magmatic pyroxenes and associate with acicular crystals of glaucophane.





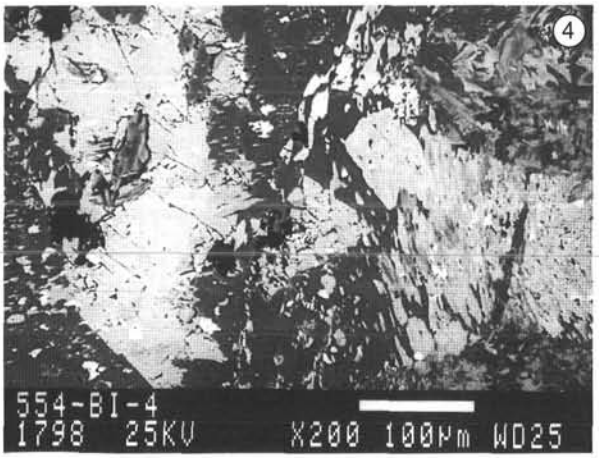


PLATE 3

Fig. 1: Detail of aggregate of glaucophane crystals.
Fig. 2: Aggregate of glaucophane crystals associated with zonal crystals of pumpellyite and grains of titanite.
Fig. 3: Aggregate of pumpellyite and epidote crystals.
Fig. 4: Secondary veinlet (right) with anhydrite. To the left texture of metabasalt with glaucophane and pumpellyite.

Photos by: J. Stankovič, 1995. Scanning micr. JEOL JSM-840. Dionýz Štúr Inst. of Geology, Bratislava.

The metamorphic Ca-Na pyroxenes form narrow hems around the magmatogenic augites. They coexist with the epidote + chlorite + pumpellyite + Na-amphibole association and are accompanied by titanite, fengite and magnetite. Calcite is absent.

Similar metabasalts with the Ca-Na pyroxenes + chlorite + pumpellyite were described by MARUYAMA & LIOU (1985) from the low-grade, high-pressure metamorphic belt of Sanbagawa. This association is incompatible with the critical minerals of the pumpellyite-actinolite facies.

The alteration of the metabasalt was terminated by the process of post-tectonic alkalic metasomatism, manifested by the microcline formation and K-metasomatism of albite. The rock contains epigenetic veinlets filled with albite + pumpellyite. These veinlets contain scarce crystals and aggregates of anhydrite (retransformed from the surrounding evaporite facies rocks).

4. P-T conditions of metamorphism – discussion

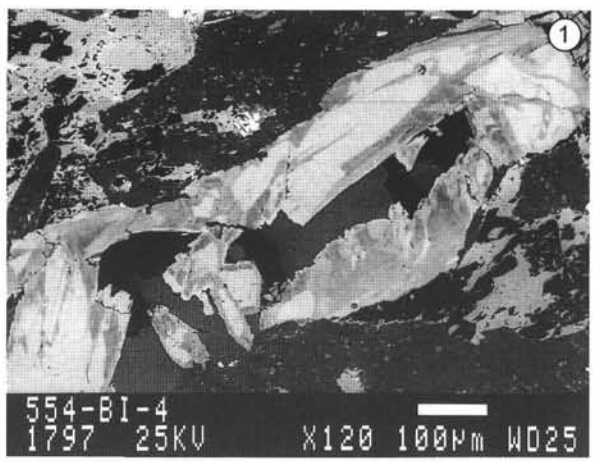
The association of metamorphic minerals represented mainly by glaucophane and pumpellyite, subordinate chlorite, sphene and scarce epidote and albite indicates that the pressures certainly exceeded 3 kbar, but did not reach the values of calcite/aragonite inversion.

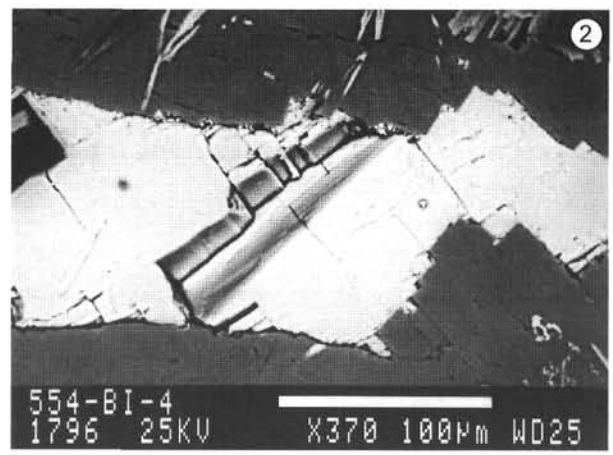
The experimentally established stability field for glaucophane varies in its lower part around the temperatures 250–300 °C and the pressures 10–20 kbar (CARMAN and GILBERT, 1983). Due to chemical composition of volcanic rocks the pumpellyite (Ca-Al-Mg) formed instead of lawsonite. This critical mineral association indicates a low geothermal gradient, corresponding to 10–15 °C/km.

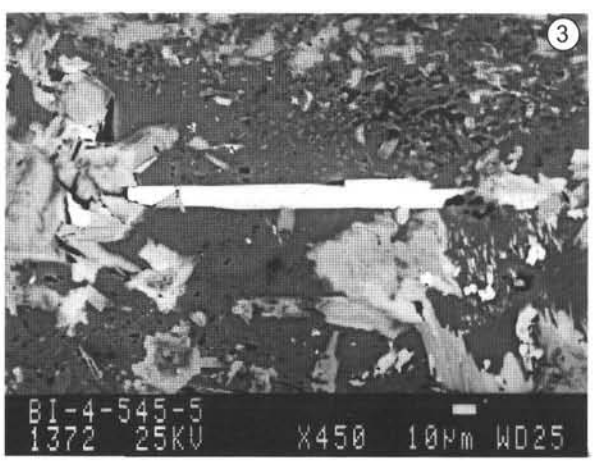
However, the composition of the Ca-Na pyroxenes in these metamafic rocks indicates a relatively narrow range of the P-T conditions at the boundary between the prehnite-pumpellyite and pumpellyite-actinolite facies of metamorphism. According to the amount of the jadeite component in the pyroxenes and on the basis of the Ca-Na pyroxene composition (MARUYAMA and LIOU, 1985) the pressures around 7–8 kbar and the temperatures around 300 °C were estimated.

5. Conclusion

The information obtained from the petrological study of the metabasaltic fragments in the Upper Permian - Lower







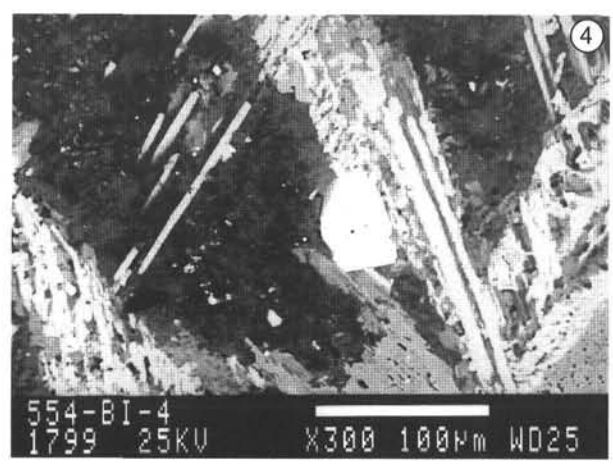


PLATE 4

Fig. 1: Crystals of pumpellyite and albite on secondary veinlet.
Fig. 2: Anhydrite and albite on secondary veinlet.
Fig. 3, 4: Acicular crystals of apatite.

Photos by: J. Stankovič, 1995. Scanning micr. JEOL JSM-840. Dionýz Štúr Inst. of Geology, Bratislava.

Triassic Haselgebirge sequence allows to draw the following conclusions:

1. The alteration grade calculated on the basis of pyroxene composition corresponds to the P-T conditions of 7–8 kbar and 300 °C.
2. The metabasalts were classified as the oceanic tholeiites and may be correlated with the Triassic-Jurassic volcanics of the zone of the Meliata – Vardar Ocean.
3. Their occurrence in the Haselgebirge sequence in the form of fragments indicates a tectonic origin and a source rock of the oceanic crust origin located below the nappe units of the Northern Calcareous Alps.

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