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Excursion

Montan University of Leoben, Peter-Tunner-Building (Applied Geosciences)
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THE KRAUBATH ULTRAMAFIC MASSIF

EXCURSION GUIDE
ÖMG CONFERENCE LEOBEN 2015, AUSTRIA

by

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Abstract

The Kraubath Ultramafic Massif, located ca. 30 km SW of Leoben, represents part of an Early Paleozoic ophiolite. The ultramafic rocks are composed of harzburgite, dunite, dykes of orthopyroxenite and a few small schlieren and bands of chromitite. The primary magmatic mineral paragenesis is formed by olivine, orthopyroxene and accessory chromite. Serpentinisation of the ultramafic rocks varies between 10 and 100%. The peridotites are interpreted as typical mantle restites, formed in the course of at least two partial melting events within a supra-subduction zone environment. The bronzitite dykes, most likely, represent small partial melt portions of one of these melting events. Chromite mineralisations occur as typical podiform small schlieren and folded lenses, as well as banded chromitites. Both types of chromitites are characterised by PGM mineralisations and elevated PGE-concentrations. Os-isotopes show a wide variation of $^{187}Os/^{188}Os$ ratios, indicating several events of partial melting over a time period of approximately 230 Ma.

Two occurrences of eclogites, intercalated in the serpentinites and close to the footwall of the Massif, were discovered recently. Preliminary results assume that the eclogites could be compared with those from the Hochgrößen Massif, representing fragments of oceanic crust, formed at Variscan times.

Cryptocristalline magnesite mineralizations in veins and networks (Kraubath type magnesite) formed by the interaction of the ultramafic rocks with fluids circulating along fault systems during the Neogen.

The rock materials from the Kraubath Massif are predominately used as hardrock.

Introduction

The Paleozoic Kraubath Ultramafic Massif is situated in the Mur valley, approximately 30 km SW of Leoben. It represents the largest ultramafic massif within the Eastern Alps, occupying an area of ca. 28 km^2. The Mur valley separates the W-E trending Massif into the Gulsen, located west of the Mur valley, and the Preger Massif that is situated east of the Mur valley (Fig. 1). Geologically, the Kraubath Massif forms part of the Muriden Unit of the Austroalpine crystalline basement, i.e. located within the Silvretta-Seckau nappe system (SCHMID et al., 2004). The Kraubath Ultramafic Massif represents part of an early Paleozoic ophiolite, which accreted as Speik terrane with magmatic arcs (Celtic terrane) of the Gondwana NW margin.

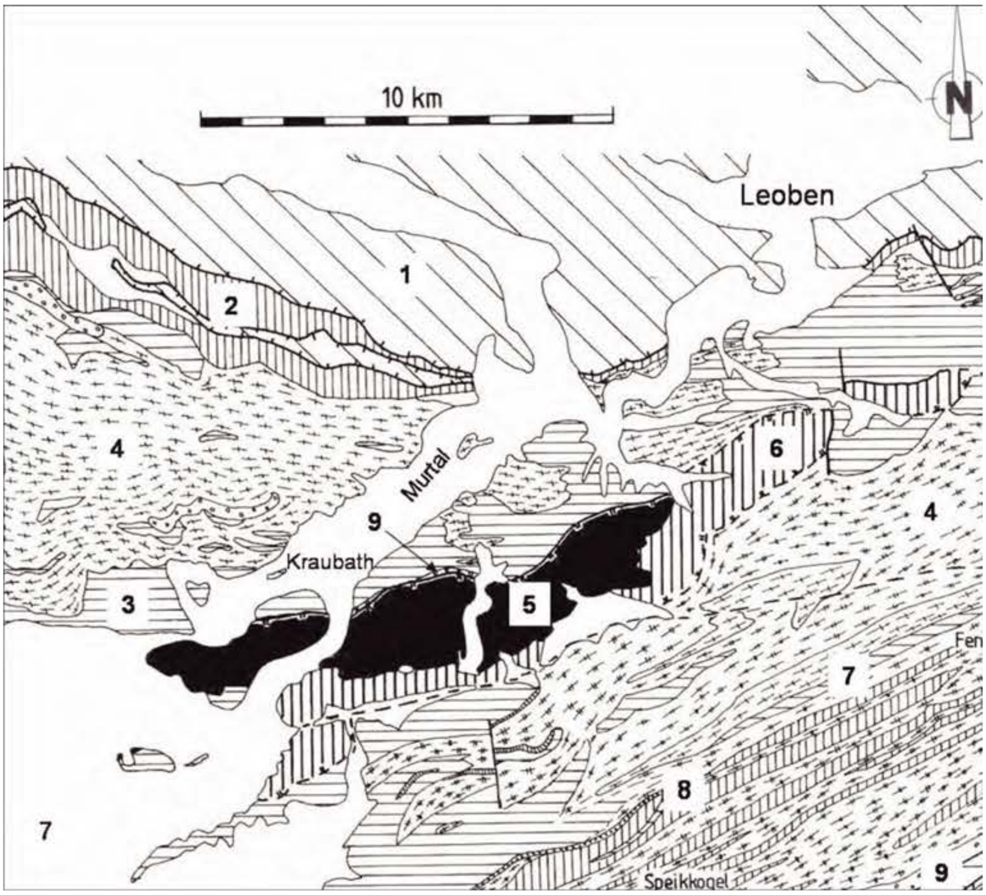

Fig. 1
Position of the Kraubath Ultramafic massif which is divided by the Mur valley into the western ("Gulsen") and the eastern ("Preg") part. Geological situation from NEUBAUER (1988). Signatures: 1 Graywacke zone; 2 Rannach-□Formation (Permotriassic); 3,4 Core complex (3 biotite plagioklas gneiss, 4 orthogneiss); 5, 6: Speik complex (5 serpentinite, 6 amphibolite); 7 Neuhof micaschist complex; 8 amphibolites; 9 augengneiss.

After separation of Gondwana, this crustal segment became the Noric Composite Terrane, that accreted with the Laurasian continental margin during the Variscan orogeny. During the Alpine orogeny it was included into the upper Austroalpine Silvretta-Seckau crystalline system and finally it was effected by sinistral strike slip systems, operating during the Miocene along the Mur-Mürz valleys (THALHAMMER et al., 2010).

The ultramafic rocks are composed of harzburgite, dunite, dykes of orthopyroxenite and a few small schlieren and bands of chromitite. Locally, minor hornblendites and websterites are intercalated. The primary magmatic mineral paragenesis is formed by olivine, orthopyroxene and accessory chromite. Serpentinisation of the ultramafic rocks varies between 10 and 100%. Thus the ultramafites of Kraubath are generally termed "serpentinites". The secondary minerals comprise serpentine, chlorite, amphibole, talc, bruzite and magnesite. The peridotites are interpreted as typical mantle restites, formed in the course of at least two partial melting events within a supra-subduction zone environment. In the W and S the Kraubath Massif is underlain by amphibolites of several hundreds meters in thickness. These are interpreted as metagabbros. Recently, two eclogite occurrences, one hosted by serpentinite, the second associated with foot-wall amphibolites at the Gulsen mountain, were discovered (Fig. 2).

Fig. 2
Arial relief image (GIS Styria) of part of the Gulsen mountain, W oft he Mur valley, showing the eclogite occurrences (location numbers 1 and 6) within the Kraubath Ultramafic Massif.

In the 19th and 20th centuries small deposits of chromite and cryptocrystalline magnesite were mined in dunites and highly serpentinised harzburgites (HIESSLEITNER, 1951/1952; REDLICH, 1909). Some schlieren-type to banded chromitites may contain up to 4 ppm of PGE (THALHAMMER et al., 1990; MELCHER & MALI, 1998; MELCHER et al., 1999; MELCHER, 2000). At present the ultramafic rocks oft the Kraubath Massif are mined as road and rail construction material. Olivine-rich serpentinites are used for production of MgO-rich refractories.

Petrology and geochemistry of the Kraubath ultramafics

The Kraubath ultramafites represent, together with those from the Hochgrößen Massif, the oldest mantle relics of oceanic crust within the Eastern Alps. The Kraubath ultramafics are underlain by several hundred metres of thick amphibolites, which are interpreted as metagabbros and are supposed to be part of the ancient ophiolite. The dominating harzburgites and dunites show in most cases relics of the primary mineral constituents, i.e. Fo-rich olivine (Fo_{89-93}) with NiO contents of up to 0.8 wt%, enstatite (#Mg = 85-93) with A_2O_3 < 1 wt%, and accessory Cr-rich chromites, apart of secondary mineral phases such as antigorite, chrysotile tremolite, brucite, talk, chlorite, magnesite, calcite and various accessory sulphides and sulfarsenides (THALHAMMER et al., 2010). Harzburgites and dunites display a coarse-grained granoblastic, partly strongly deformed fabric under the microscope, which clearly proves mantle texture. Strongly serpentinised ultramifites show the typical "network" texture, defined by relics of primary mineral phases embedded within a dominating network of serpentine phases (i.e. antigorite dominates clearly). Bronzitites, occurring as veins and plugs within harburgites and dunites, with sharp boundaries and lack of contact haloes to the latter. They have a middle- to coarse-grained granoblastic fabric, which can be classified as an adcumulate texture. They are composed of > 90% of bronzite with identical chemical composition to orthopyroxene in harzburgites, and small amounts of amphibole, olivine serpentine, antophyllite and chlorite.

Probe	Harzb	Harzb	Dunit	Dunit	Opx	Opx
SiO_2	39.16	41.75	43.92	37.05	52.48	53.17
TiO_2	0.01	0.01	0.01	0.01	0.02	0.02
Al_2O_3	0.46	0.26	0.28	0.10	0.66	0.69
Fe_2O_3	8.12	9.17	9.06	9.22	6.07	6.46
MnO	0.11	0.13	0.13	0.13	0.10	0.13
MgO	40.62	44.81	40.98	43.50	34.37	34.40
CaO	0.53	0.07	0.26	0.26	0.75	1.16
P_2O_5	0.00	0.00	0.01	0.00	0.00	0.00
Cr_2O_3	0.37	0.43	0.39	0.32	0.33	0.48
LOI	10.08	3.60	5.51	9.55	5.40	4.16
Total	99.48	100.22	100.55	100.14	100.18	100.67
#Mg	90.83	90.64	89.96	90.13	91.81	91.34
Cr	2566	2929	2686	2216	2272	3310
Ni	1880	2030	1626	1951	385	489
Co	120	122	119	114	60	80
Cu	131	1	11	13	0	10
Zn	49	50	50	33	33	48
V	20.7	13.2	21.2	9.4	34.3	30.0

Table 1

Major and selected trace element composition of representative ultramafic rocks of the Kraubath Massif. Harzb = harzburgite, Opx = bronzitite. Major elements in wt %, trace elements in ppm (data from MELCHER et al. 2002).

The homogeneous chemical composition of the ultramafics, shown in Table 1, is characterised by Cr contents between 2000 and 3800 ppm, Ni up to 2200 ppm in harzburgites, whereas dunites carry Cr up to 5100 ppm and up to 2000 ppm Ni. The CaO contents are very low (i.e. harzburgites and dunites < 1 wt%, bronzitites around 1 wt%), clearly indicating the primary refractory character of the rocks. Some CaO might have been gone into solution during serpentinisation.

The rare Earth element (REE) concentrations are shown in Figure 3. Characteristic are U-shaped chondrite-normalised distribution patterns (i.e. 0.009 to 0.13 chondritic), typical for strongly depleted residual mantle rocks (MELCHER et al., 2002). On the basis of textural observations, chemical data, and particular the REE distribution patterns, harzburgites and dunites of the Kraubath Massif are interpreted as the result of at least two times partial melting episodes of a non-depleted mantle material, most likely within a supra-subduction zone environment (MELCHER et al., 2002; THALHAMMER et al. 2010). This interpretation coincides well with that from chromites and PGE (see below).

Bronzitites are not part of this genetic episode. They clearly show an intrusive character and their cumulate texture strongly indicates that they derived from small Si-, Mg-rich partial melt portions of mantle material. These melt portions were too small to escape from the partial melting site. They remained for a certain period of time at the partial melting site, approached equilibrium with the residual mantle material, before they intruded into the immediate surrounding (THALHAMMER et al., 2006; THALHAMMER et al., 2010).

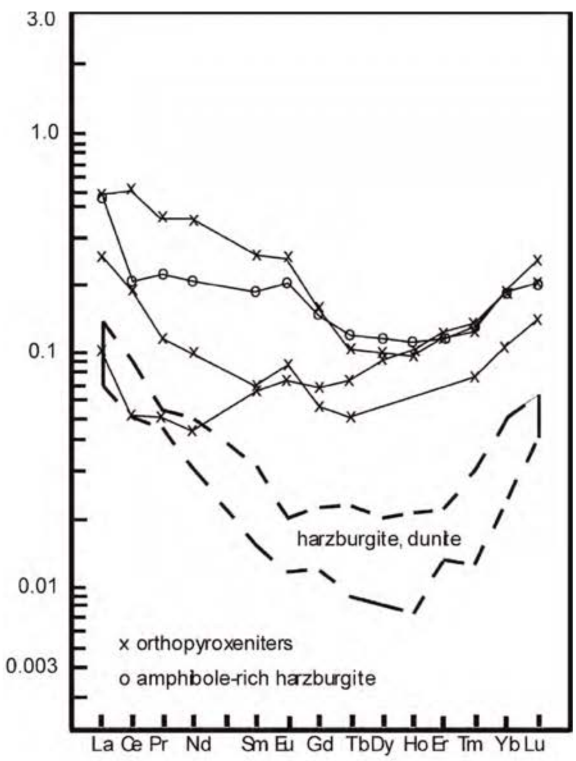

Fig. 3
Chondrite-normalised rare earth element distribution patterns of ultramafic rocks of the Kraubath Massif (data from MELCHER et al., 2002).

Chromite occurrences and platinum group elements (PGE)

Chromitites occur rarely as irregular schlieren, folded lenses, small stockwork veins and locally as bands that show lateral extension up to several tens of metres with a thickness of a few up to 15 cm (Fig. 4). Based on the shape and type of occurrence, two dominating types of chromitites can be distinguished: a) schlieren-type and small folded lenses of chromitites represent typical podiform chromitites, and b) thin layers of chromitites are considered as the banded-type (MELCHER, 2000; MALITCH et al., 2003a).

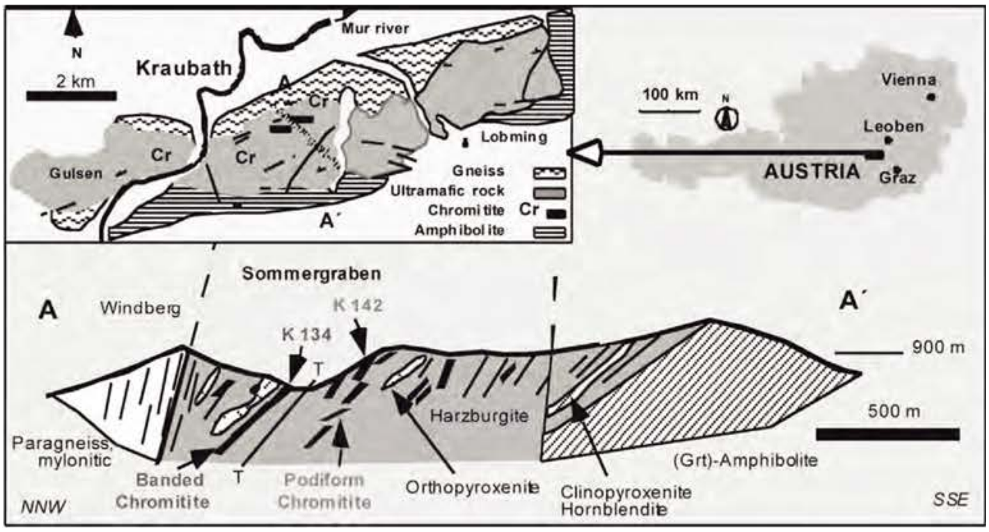

Fig. 4

Location of the Kraubath Massif, the lithology of the Massif and the location of the chromite mineralisations. Schematic cross section of the chromite occurrences in the Sommergraben (A-A after MELCHER (2000). Location of sample numbers K142 refer to chromite type 1, K134 to chromite type 2, respectively, after MALITCH et al. (2003a), are also shown.

Almost all chromites show chemical zonation (i.e. decrease of Al, Mg, Cr, and increase of Fe from core to rim; Fig.5) as the result of alteration during serpentinisation (THALHAMMER et al., 1990). Characteristic are, like in many other ophiolitic chromitites elsewhere, numerous inclusions of primary silicates (i.e. olivine, diopside), secondary silicates (i.e. chlorite, serpentine, tremolite, calcite, graphite, talk), sulphides (i.e. pentlandite, pyrrhotite, chalcopyrite), as well as some fluid inclusions (i.e. H_2O-CO_2, CO_2, NH_4) (THALHAMMER et al., 1990; MELCHER, 2000).

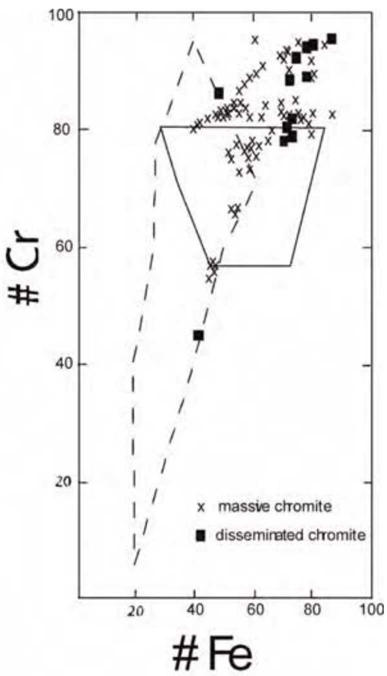

Fig. 5

Representative chromite compositions from the Kraubath Massif in the #Cr (100Cr/Cr+Al) vs. #Fe (100Fe^{2+}/Mg+Fe^{2+}). Data from THALHAMMER et al. (1990), MELCHER (2000) and PUHL (2000). Strippled field = alpine-- type chromitites, field with full line = stratiform chromitites, after DICK & BULLEN (1984).

The first platinum group mineral phases (PGM), occuring as inclusions within chromite, very rarely observed in interstitial spaces between chromite grains, were discovered by THALHAMMER & STUMPFL (1988). Subsequent investigations, using various comminution and separation techniques, led to the discovery of a great variety of PGM (summarised in THALHAMMER et al., 2010). Podiform chromitites are characterised by Ir-Os, Pt-Fe alloys, Ru-Os sulfides and PGE sulfarsenides, whereas banded chromitites display predominantly Pt-Pd arsenides, Pd antimonides and Pd-Sb-As phases (MALITCH et al., 2003a). Maximum PGE concentrations lie between 3.4 and 4 ppm, where Ir/Pt ratios are < 1 for podiform chromitites and up to Ir/Pt = 6 for banded chromitites. Os isotope data from PGM inclusions within chromites (i.e. using NTI-MS and LA MC-ICP-MS techniques) reveal $^{187}Os/^{188}Os$ ratios of 0.11580 – 0.12437 for PGM in podiform chromitites, whereas PGM from banded chromitites show $^{187}Os/^{188}Os$ ratios of 0.13080 – 0.13212 (MALITCH et al., 2003a; 2003b). The less radiogenic Os isotope ratios of podiform chromitites are typical for ophiolites and indicate Os derivation from a primitive almost chondritic mantle material. The higher radiogenic Os isotopes from PGM in banded chromitites indicate Os derivation from a supra-chondritic mantle (MALITCH et al., 2003b). Consequently, banded chromitites are considered to have formed within a higher stratigraphic position of the ophiolite magmatic stratigraphy, most likely in the "transition zone", i.e. close to the mantle/crust boundary (MALITCH et al., 2003a).
The occurrence of chromitites, predominantly as schlieren and irregular lenses, the chemical composition of chromites, the PGE distribution patterns and the PGE-mineralogy clearly indicate that the chromitites of the Kraubath Ultramafic Massif are predominantly of the typical podiform-type and form part of an ophiolitic mantle section. Numerous hypotheses regarding the genesis of podiform chromitites were published in the last 40 years; no single model is really able to explain all the typical characteristic features of podiform chromitites (summarised in THALHAMMER et al., 2010). However, it can be suggested that the Kraubath chromitites were formed within a supra-subduction zone environment, the mantle source was most likely depleted material of almost chondritic composition. It is further suggested that chromitites crystallised from small Mg-Cr-rich, S-poor partial melt portions in conduits. The occurrence of fluid inclusions within chromites indicates the presence of reducing fluids during chromite formation. PGM inclusions, most likely, were generated at an early stage of chromite crystallisation under high temperature, S-poor conditions (i.e. formation of Os-Ir, Ir-Os and Pt-Fe alloys) and successively under increasing S-activity, leading to formation of PGE-sulphides and arsenides. The significantly large heterogeneity of $^{187}Os/^{188}Os$ isotopic ratios indicate, on the one hand heterogeneous mantle source, and on the other hand may give an indication on the time period of the partial melting episodes. Thus, Os isotopic results mirror a long time genesis of the ancient ophiolite, whereby the formation of the ultramafites of the Speik-Komplex were generated during a time period from 780 Ma to 550 Ma (MELCHER et al., 2002, THALHAMMER et al., 2010).

Cryptocrystalline magnesite

The Preger Massif, east of the Mur valley, hosts the highest concentration of cryptocrystalline magnesite of the so-called Kraubath-type (POHL, 1990; EBNER et al, 2004). In the Lobming-Graben, Sommer-Graben and Au-Graben of the Preger Massif, cryptocrystalline magnesite was mined until the end of the 19^{th} century.

The predominant network- and vein-type magnesite mineralisation was first described by REDLICH (1909) and is strictly related to strongly deformed ultramafics which are controlled by a fault system (i.e. Noric Fault) trending parallel to the Mur valley (HADITSCH et al., 1982). Thus, the Kraubath magnesites are of syn-deformational origin. Five types of magnesite occurrences can be distinguished (WENINGER, 1981):

a) Magnesite veins with a thickness of a few cm up to a few metres. The veins are often bordered by slickenslide surfaces, magnesite occurs partly as breccias.
b) Cryptocrystalline magnesite forming the matrix of breccious serpentinite.
c) Thin veinlets of magnesite within serpentinite forming a network structure.
d) Cauliflower magnesite (Bela Stena-type).
e) Redish magnesite colored due to impurities of hematite.

In general, the chemical composition of cryptocrystalline magnesite may reach 100 wt% $CaCO_3$, but commonly contents of SiO_2, Fe_2O_3 and CaO in the range of around 3 wt% lower the quality of magnesite. The magnesite of Kraubath reveals SiO_2 contents up to 5.4 wt%, Fe_2O_3 up to1 wt%, CaO up to 0.5 wt%, and are locally characterised by high Ni and Cr concentrations (Tab.2).

	Hauptelemente											
wt %	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
KB 12.2	1,3	< 0.01	0,08	0,02	47,25	0,38	< 0.01	< 0.01	< 0.001	< 0.01	51,15	100,2
KB 4.6	1,22	0,01	0,05	0,02	46,31	0,52	< 0.01	< 0.01	< 0.001	< 0.01	51,2	99,35
LO 4.4	4,17	0,01	0,63	0,04	46,09	0,31	0,04	< 0.01	0,003	< 0.01	49,2	100,5
LO 4.9	2,2	0,03	0,47	0,03	47,15	0,3	0,03	0,02	0,003	< 0.01	50,46	100,7
MA 2.1	5,47	0,02	0,99	0,08	45,41	0,11	0,05	< 0.01	0,003	< 0.01	48,28	100,4

	Spurenelemente																	
ppm	Sc	Be	V	Ba	Sr	Y	Zr	Cr	Co	Ni	Rb	Nb	Sn	Hf	Ta	W	Th	U
KB 12.2	< 1	< 1	< 5	5	5	< 2	7	< 20	1	< 20	< 2	< 1	< 1	< 0.2	< 0.1	21	< 0.1	< 0.1
KB 4.6	< 1	< 1	< 5	7	11	< 2	< 4	< 20	2	< 20	< 2	< 1	< 1	< 0.2	< 0.1	33	< 0.1	< 0.1
LO 4.4	2	1	11	< 3	2	7	58	80	8	110	6	16	9	1,4	0,6	10	2,3	0,2
LO 4.9	< 1	< 1	< 5	8	8	< 2	5	90	7	120	< 2	< 1	< 1	< 0.2	0,1	34	< 0.1	< 0.1
MA 2.1	< 1	< 1	< 5	5	4	< 2	7	200	16	270	< 2	< 1	< 1	< 0.2	< 0.1	14	< 0.1	< 0.1

	Selten-Erd-Elemente													
ppm	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
KB 12.2	0,1	<0.1	<0.05	0,1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.05	<0.1	<0.04
KB 4.6	<0.1	0,1	<0.05	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.05	<0.1	<0.04
LO 4.4	2,4	5,3	0,56	1,7	0,5	<0.05	0,6	0,2	1,4	0,3	1	0,15	0,9	0,1
LO 4.9	<0.1	0,1	<0.05	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.05	<0.1	<0.04
MA 2.1	<0.1	<0.1	<0.05	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	0.05	<0.1	<0.04

Table 2

Contents of major-, trace- and RE-elements of magnesite samples of the Kraubath Ultramafic Massif. KB - Augraben and Sommergraben, LO - Lobminggraben, MA - Mangehube.

The general genetic concept, namely that cryptocrystalline magnesite forms as a by-product of serpentinisation (i.e. the decomposition of olivine and orthopyroxene to form serpentine mineral phases) in the presence of CO_2, is widely accepted. Further more, two general types of cryptocrystalline magnesite are distinguished nowadays: a) the Kraubath-type, magnesite closely related to and occurring within ultramafic rocks, and b) the Bela Stena-type, that is related to younger sediments above or in the surroundings of ultramafics (POHL, 1990; EBNER et al., 2004). Genetic discussions particularly focus on the source of CO_2 and whether the serpentinising fluids are ascending or descending. The C-isotopic composition of magnesite offers a tool in order to detect possible CO_2 sources, such as those from the mantle (mantle exhalation), from decarboxylation of carbonate rocks, or from water of alkaline lakes, or descending fluids from the surface (biogenic origin). Positive $\partial^{13}C_{VPDB}$ values (i.e. -2 to +4.4) are characteristic for the Bela Stena-type, whereas negative $\partial^{13}C_{VPDB}$ values (i.e. -22 to -3) are typical for the Kraubath-type. This is illustrated in Figure 6, where magnesite samples from Kraubath clearly show negative $\partial^{13}C_{VPDB}$ values from -12 to -20. A clearly defined source of CO_2 for the cryptocrystalline magnesite of Kraubath is ambiguous. A multiple, possible mixed CO_2 source seems most plausible, i.e. from C-rich metasediments in the basement, and CO_2 degassing from the lithosphere (HORKEL et al., 2009; THALHAMMER et al., 2010). O-isotopic results provide indication for the formation temperature of the cryptocrystalline magnesite. The $\partial^{13}C_{SMOW}$ values for the Kraubath magnesites lie between 25 and 27, consequently a formation temperature around 64°C can be calculated (Fig. 6, HORKEL et al., 2009; THALHAMMER et al., 2010).

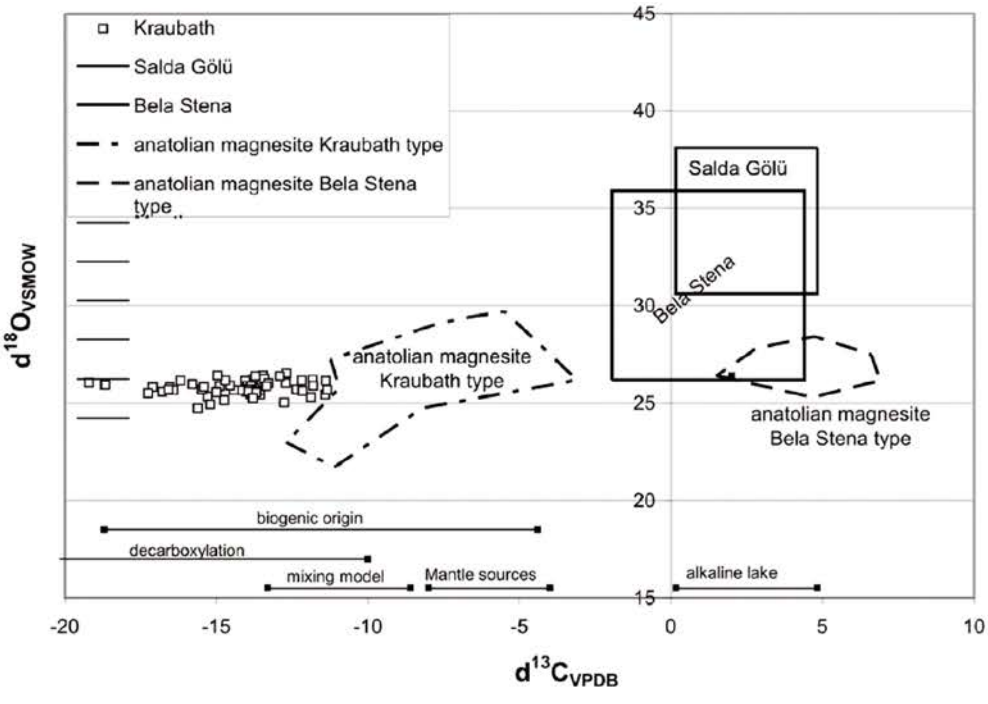

Fig. 6

∂O[18]/∂[13]C diagram of cryptocrystalline magnesite from Kraubath (Kraubath-, Bela Stena- and zebra network-type) in comparison with those from Anatolia and recent Salda Lake data (from THALHAMMER et al., 2010).

Eclogites

Very recently, two eclogite occurrences were discovered in the SW part of the Gulsen mountain, west of the Mur valley. One eclogite occurrence forms a 3 m thick layer intercalated within serpentinites, the second one is exposed between footwall amphibolites and hanging wall serpentinites (Fig. 2). The eclogites are strongly deformed and are composed of almandine, omphacite and amphibole, sometimes they contain zoisite and/or quartz and albite (Fig. 7). Intergrowths of amphibole, omphacite and albite form symplectites. Trace minerals are potassium feldspar, ilmenite, titanite, rutile, pyrite, zircon, apatite, allanite and chlorite. Garnet comprises about 25 – 50 modal% of the eclogite and all crystals are broken. The cracks of retrogressed garnets are filled by quartz, sericite and chlorite. Subhedral to anhedral almandine (up to 9.5 wt% MgO) reaches sizes of 6 mm at maximum and shows zonation with an inclusion rich core and an outer rim. The core might have grown before eclogitisation, the rim is grown at peak metamorphic conditions most probably, and might have equilibrated to some extent during Variscan and/or Alpine metamorphism. Quartz is the most common inclusion mineral. Omphacite forms elongated broken laths of up to 5 mm in length and comprises 5 - 20 modal% of the rock. Na_2O contents of up to 5.6 wt% suggest a minimum formation pressure of 15 kbars. The crystal borders are always transformed to symplectite in variable amounts, no primary contacts to garnet and amphibole are preserved at all. However, the structure of the intergrowths proofs the cogenetic formation of omphacite, garnet and amphibole.

This eclogite discovery is presently under investigation. However, tentatively it is suggested that these eclogites can be compared with those from the Hochgrößen Massif, that are supposed to have formed at Variscan times and most likely representing fragments of oceanic crust of Cambrian age (MELCHER et al., 2002).

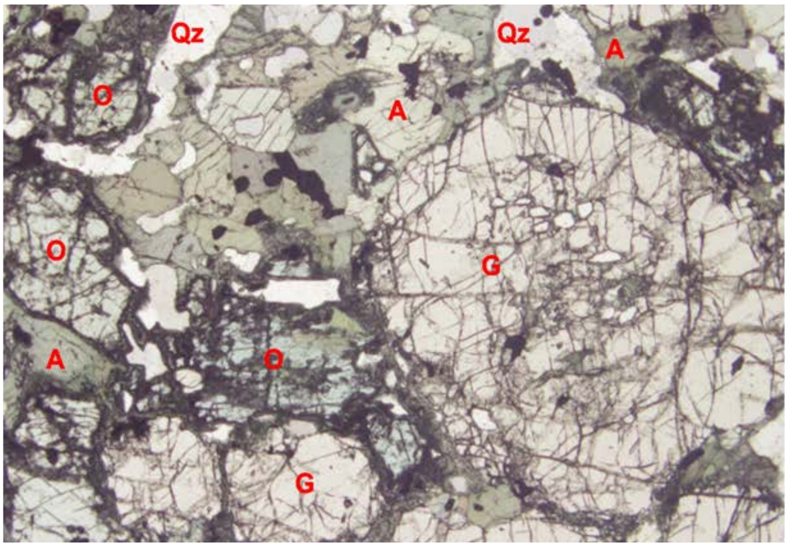

Fig. 7

Microphotograph in transmitted light under paralle polarisers. Zoned garnet with inclusions of quartz, amphibole and ilmenite/rutile. Amphibole (green-brown), omphacite (greenisch-blue) with dark symplectite seams and quartz. Width of photograph equals to 4,425 mm.

The Kraubath Ultramafic Massif - part of an early Paleozoic ophiolite within the Speik Complex – Summary

The Kraubath Ultramafic Massif represents an integral part of the Speik Complex (NEUBAUER & FRISCH, 1993). Further rock sequences of the Speik Complex of comparable lithology to the Kraubath Ultramafic Massif are the ultramafics from the Lärchkogel (Triebener Tauern), the Hochgrößen Massif within the Rottenmanner Tauern, and garnet amphibolites, plagioclase-bearing amphibolites, serpentinites and marble lenses within the central Gleinalpe, as well as the serpentinites of Traföss in the Mur valley and amphibolites within the southern Stubalpe. The age of the Speik Complex is only defined by its overlying Micaschist – Marble Complex, where a Silurian to Devonian age is suggested (BECKER, 1981; FRISCH & NEUBAUER, 1989). Thus, an Early Paleozoic age of the ancient, strongly fragmented ophiolite of the Speik Complex is presumed. Together with underlying amphibolites and plagioclase-gneisses (i.e. the Keltic Terrane), the Speik Complex represented a Late Cambrian to Early Paleozoic magmatic belt at the NW rim of Gondwana. In Silurian to Lower Devonian times this crustal segment of magmatic-sedimentary sequences (i.e. the Noric Composite Terrane) separated from Gondwana, drifted to N, and accreted with the Laurasian continental margin during the Variscan orogeny (FRISCH & NEUBAUER, 1989; NEUBAUER et al., 1998). All portions of an ancient ophiolite, i.e. serpentinites as the upper mantle section, layered ultramafics and meta-gabbros as the crustal ultramafic cumulate sequence, various amphibolites representing the crustal mafic cumulate suite, as well as garnet amphibolites, banded amphibolites and mica-schists, marbles and quartzites representing extrusive rocks and oceanic sediments, are present, except the sheeted dyke sequence. During the alpine orogeny the Speik Complex becomes overprinted by greenschist to most likely amphibolite metamorphism, accompanied by ductile and brittle shear deformation during successive dropping temperatures (NEUBAUER, 1988). Finally, particularly the Kraubath Massif was affected by sinistral shear deformation during the Neogene which led to the formation of Neogene basins such as the Fohnsdorfer-Seckauer basin, located E of the Kraubath Massif. Relics of these Neogene sediments occur on top of the ultramafics at Gulsen.

Description of excursion stops

1. AU-GRABEN

Biotite-schists, biotite-gneisses with intercalations of augen-gneisses and quartzites dominate the first part of the road cuttings into the Au-Graben. Following the road, garnet amphibolites and banded amphibolites together with subordinate marbles become more abundant. This rock sequence is suggested to form part of the Neuhof-mica-schist-Complex, according to NEUBAUER (1988), representing the tectonic footwall of the Speik Complex. The Speik Complex was trusted over the Neuhof-mica-schist-Complex in Carboniferous times (i.e. during the Variscan orogeny). At an altitude of ca. 710 m serpentinites follow with cryptocrystalline magnesite mineralisation. The host rock is predominantly strongly serpentinised harzburgite. Locally, thin (i.e. a few cm in thickness) pyroxenite dykes can be observed. The magnesite occurs along E-W trending fault zones. At least three types of magnesite occurrences (i.e. vein-type, network mineralisation, breccia-type) are observed along the road exposure (ca. 100 m).

2. GULSEN ROAD-SECTION

Along the road strongly serpentinised and partly weathered harzburgites and minor dunites are exposed with intercalation of bronzitite dykes. The bronzitite dykes show a thickness of a few cm up to more than 5 m, the latter could possible considered as a plug. The rock is composed of > 90% of bronzite and displays an adcumulate texture. Remarkable is the sharp contact to the serpentinised harzburgites with lack of any contact zone. Locally the bronzitite dykes carry amphibole blasts up to several cm in size.

3. GULSEN NEOGEN OUTCROP

The footwall of this road-cut is formed by serpentinised harzburgites, which are remarkably brecciated. The matrix of the ultramafic breccia is composed of coarse sand with traces of magnesite. In parts cauliflower magnesite (Bela Stena-type) becomes visible.

Two several cm thick conglomerate layers are intercalated in the hanging wall of the breccia. These conglomerates, showing well rounded crystalline components, lack any magnesite and are interpreted as debris flow sediments and represent formations of the rim of the Fohnsdorf-Seckaer Neogen basin (SACHSENHOFER et al., 2000; 2010).

4. RAMBERG ROAD – W GULSEN

Along the road a 150-250 m thick layer of zoisite-amphibolite with diopside, almandine, rutile, sphene, chlorite, olivine (Fo_{60}) is intercalated within strongly serpentinised harzburgites. Further, folded amphibolite and layers of calcitic marble are intercalated within the serpentinite. Between the amphibolite and the serpentinite eclogite is outcropping over a length of ~10 m on a forest road cut. The exposed thickness is 3 m.

5. SOMMER-GRABEN

The Sommer-Graben represents the "type-locality" of chromitite occurrences within the Kraubath Massif. Unfortunately, most of the cromitite occurrences in and close to old mine edits had been destroyed recently! However, if time allows it, some findings of schlieren-type chromitites and one block hosting banded chromitite will be shown.

Literature

BECKER, L.P. (1981): Zur Gliederung des Obersteirischen Altkristallins (Muriden). Mit Bemerkungen zu den Erzvorkommen in den einzelnen Kristallinkomplexen. - Verh. Geol.B.-A., 1981: 3-17, Wien.

EBNER, F., MALI, H. & PROCHASKA, W. (with a contribution of AZIM ZADEH, A.M.) (2004): Excursion to Magnesite, Siderite and Talc Deposits in Austria. - IGCP No. 443, Final Field Meeting, Guidebook, 1-40, Leoben.

FRISCH, W. & NEUBAUER, F. (1989): Pre-Alpine terrane and tectonic zoning in the eastern Alps. - Geol. Soc. Amer. Spec. Pap., 230: 91-100.

HADITSCH, J.G., KRAUSS, P. & YAMAC, D. (1982): Beiträge für eine geologisch-lagerstättenkundliche Beurteilung hinsichtlich einer hydrometallurgischen Verwertung der Kraubather Ultramafitmasse. - Mitt. Abt. Geol. Joanneum, 42: 3-78, Graz.

HIESSLEITNER G. (1951/1952): Bericht an die Veitscher Magnesitwerke AG. Über die Frage der Erschließbarkeit neuer bauwürdiger Chromitlager im Kraubather Chromerz führenden Serpentinmassiv. - Archiv FRIEDRICH, Unveröff. Bericht, 1-6, (Geol. B.-A.) Wien.

HORKEL K., EBNER F., MALI H., UNTERWEISSACHER T. & SPÖTL C. (2009): $\delta^{13}C/\delta^{18}O$ isotope studies - of cryptocrystalline magnesite in Anatolia (Turkey) and Kraubath (Austria). - 9th Austrian Stable Isotope User Group Meeting, Abstract, Innsbruck.

MALITCH, K. N., THALHAMMER, O. A. R., KNAUF, V. V. & MELCHER, F. (2003a): Diversity of platinum-group mineral assamblages in banded and podiform chromitite from the Kraubath ultramafic massif, Austria: evidence for an ophiolitic transition zone? - Mineralium Deposita, 38: 282-297.

MALITCH, K.N., JUNK, S.A., THALHAMMER, O.A.R., MELCHER, F., KNAUF, V.V., PERNICKA, E. & STUMPFL, E.F. (2003b): Laurite and ruarsite from podiform chromitites at Kraubath and Hochgrössen, Austria: new insights from osmium isotopes. - Canad. Mineral., 41: 331-352.

MELCHER, F. (2000): Chromite and platinum-group elements as indicators of mantle petrogenesis. - Habilitationsschrift, 1-406, (Montanuniversität Leoben) Leoben.

MELCHER, F. & MALI, H. (1998): Platingruppenminerale in Chromititen von Kraubath. - Mitt. Abt. Miner. Landesmus. Joanneum, 62/63: 39-48, Graz.

MELCHER, F., PUHL, J., MALI, H. & MEISEL, T. (1999): Chromite and platinum-group element mineralization in ultramafic rocks of the Speik Complex, Eastern Alps. - (In: STANLEY, C.J. et al. (Eds.): Mineral deposits: Processes to Processing 1), 739-742, (Balkema) Rotterdam.

MELCHER, F., MEISEL, T., PUHL, J. & KOLLER, F. (2002): Petrogenesis and geotectonic setting of ultramafic rocks in the Eastern Alps: constraints from geochemistry. - Lithos, 65: 69- 112, Amsterdam.

NEUBAUER, F. (1988): Bau und Entwicklungsgeschichte des Rennfeld-Mugel- und des Gleinalm-Kristallins (Ostalpen). - Abh.Geol. B.-A., 42: 1-136, Wien.

NEUBAUER, F. & FRISCH, W.(1993): The Austro-Alpine Metamorphic Basement E of the Tauern Window. - (In: RAUMER, J.F. & F. NEUBAUER (Eds.): Pre-Mesozoic Geology in the Alps), 515-536, (Springer) Berlin.

NEUBAUER, F., FRISCH, W., SCHMEROLD, R. & SCHLOSER, H. (1989): Metamorphosed and dismembered ophiolite suites in the basement of the Eastern Alps. - Tectonophysics, 164: 49-62, Amsterdam.

NEUBAUER, F., EBNER, F., FRISCH, W. & SASSI, F.P. (1998): Terranes and tectonostratigraphic units in the Alps. - Ann. Geol. Des Pays Helleniques, 37 (1996/97): 219-244, Athens.

POHL, W. (1990): Genesis of magnesite deposits - models and trends. - Geol. Rdsch., 79: 291-299, Stuttgart.

REDLICH, K.A. (1909): Types of magnesite deposits. - Zeit. für prakt. Geol., 17: 300-310, Berlin.

SACHSENHOFER, R.F., STRAUSS, P., WAGREICH, M., ABART, R., DECKER, K., GOLDBRUNNER, J.E., GRUBER, W., KRIEGL, C. & SPÖTL, C. (2000): Das miozäne Fohnsdorfer Becken - Eine Übersicht. - Mitt. Ges. geol. Bergbaustud. Österr., 44: 173-190, Wien.

SACHSENHOFER, R.F., GRUBER, W. & DUNKL, I. (2010): Das Miozän der Becken von Leoben und Fohnsdorf. - Journal of Alpine Geologie, 53: 9-38, Wien.

SCHMID, S.M., FÜGENSCHUH, B., KISSLING, E. & SCHUSTER, R. (2004): Tectonic map and overall architecture of the Alpine orogen. - Eclogae Geol. Helv., 97: 93-117, Bern.

THALHAMMER, O.A.R. & STUMPFL, E.F. (1988): Platinum-group minerals from Hochgrössen ultramafic massif, Styria: first reported occurrence of PGM in Austria. Trans. Inst. Mining Metall. Appl. Earth Sci., 97: B77-B82.

THALHAMMER, O.A.R., PROCHASKA, W. & MÜHLHANS, H.W. (1990): Solid inclusions in chrome-spinel and platinum group element concentrations from the Hochgrössen and Kraubath ultramafic massifs (Austria). - Contrib. Mineral. Petrol. 105: 66-80.

THALHAMMER, O.A.R., MACKELSON, J. & LOIDL, G. (2006): The Guli Dunite Complex, Taimyr Province, northern Siberia, Russia: a highly metasomatised astenospheric mantle portion? - (In: DISTLER, V.V. (Ed.): Understanding the Genesis of Ore

Deposits to meet the demands of the 21st Century), 12th IAGOD Symp. Moscow, 162-165.

THALHAMMER, O.A.R., EBNER, F., HORKEL, K.& MALI, H. (2010): The Kraubath Ultramafic Massif – Pangeo 2010 Exkursionsführer.- J. of Alpine Geology, 53, 137-158.

WENINGER, H.P. (1981): Kraubath/Steiermark: Der Ultramafit von Kraubath und seine Mineralien. - Lapis, 6/10: 27-33.