Geol.Paläont.Mitt.Innsbruck	Bd.10	7	S.243-255	Innsbruck, Jan.1981

Geological and geochemical investigation of the Kraubath ultramafic massif (Styria, Austria)+)

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Zusammenfassung

Die Importabhängigkeit der österreichischen Wirtschaft bei Kupfer, Nickel, Chrom und hochreinen Magnesia führte zur Suche nach entsprechenden Rohstoffen, die mittels des naßmetallurgischen Ruthner-Luwa-Mitterberg (RLM)-Verfahrens verwertet werden können. In den letzten Jahren wurden in diesem Zusammenhang verschiedene Ultramafite der Ostalpen und der Böhmischen Masse beprobt und hernach das Kraubather Massiv genauer geologisch, petrographisch und geochemisch untersucht. Die Ergebnisse dieser Forschung führten zur Festlegung eines Explorationszielgebietes, in dem inzwischen bereits einige Bohrungen niedergebracht wurden.

+) Um die deutsche Zusammenfassung erweiterte Fassung eines Beitrags zum Exkursionsführer des 8th International Geochemical Exploration Symposium (Hannover, April 1980)

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Insgesamt wird für Kraubath das Ziel einer integrierten Rohstoffnutzung, d.h. einer Verwertung aller bei der Verarbeitung des Rohmaterials anfallenden Produkte, angestrebt.

The critical situation in the supply of Austrian industry with different metallic ores and non-metallic minerals stimulated considerations with regards to an exploitation of low-grade mineral deposits. One possibility might be the hydrometallurgical processing of ultramafic rocks, especially the treatment of material from Kraubath.

Austria has to import many important raw materials, such as copper, nickel, cobalt, chromium and aluminium, but also certain industrial minerals, which are used to improve the quality of materials mined in Austria, such as iron-poor magnesite.

The situation is particularly critical in the field of chromium and nickel ores. It is well known that chromium supplies worldwide are possibly endangered by political constellations; the same applies to some extent to nickel. World production of these metals is derived from a few countries only.

In recent years Austria has made increased efforts to counteract problems of mineral supply by increasing exploration activities and investigations of integrated exploitation. This has resulted in the recognition of the necessity to increasingly mine polymineralic deposits in the future. In this context, hydrometallurgical processing opens up new possibilities. Hydrometallurgical processes have so far been applied only to Austrian copper and uranium ores. However, the newly developed Ruthner-Luwa-Mitterberg (RLM) process would facilitate the recovery of nickel from low-grade ores (ultramafic rocks), with simultaneous recovery of pure magnesia and SiO_2. Processing of the mineral raw material is envisaged in three steps:

1) Grinding and milling of the ore to less than 44 micron grainsize and dissolution in hydrochloric acid at 50-300°C.
2) Solvent extraction, which permits recovery of 99% of the acid used.
3) Thermal dissociation of the metal chlorides at 750°C ($NiCl_2$), respectively 900°C ($MgCl_2$).

Especially stage two, solvent extraction, requires the consideration of economically significant parameters
a) the ratio MgO: sum of Fe_2O_3 + Al_2O_3 + MnO_2 and
b) sum of CaO + K_2O + Na_2O

The former ratio is 3:1 in various Austrian ultramafic rocks, which is favourable compared with certain Italian and Greek ultramafics. In case the second ratio (CaO + K_2O + Na_2O) exceeds 1%, additional processing stages are required. The ultramafic rocks have, therefore, to be investigated particularly as regards calcium-bearing minerals (calcite, dolomite, clinopyroxene).

Pilot studies conducted by the Ruthner company have shown that it takes only 20 minutes of solvent extraction at 105°C to dissolve 98.0% of the nickel content. Investigations conducted by our research group aim to the utilization of all consistuents of an ultramafic rock, including magnesia, nickel oxide, fine-grained silica, Fe_2O_3, chromite etc.

Since 1975 almost all the known Austrian ultramafic massifs, which are of sufficient size to warrant such investigations, have been sampled. The results show that in view of the quality requirements only four areas deserve further study:

1) Ultramafic rocks within the Bohemian massif in the Dunkelstein forest, near Aggsbach, Lower Austria
2) Occurrences in the province of Burgenland
3) The ultramafic massif of Kraubath, Styria
4) An occurrence near Defereggen, Eastern Tyrol.

Of these, only the occurrences in Lower Austria and Styria offer the advantage of excellent accessibility. A comprehensive geoscientific investigation of the Kraubath massif was initiated in 1976. A detailed account to this will appear elsewhere (J.G. HADITSCH et al., 1980).

In view of the considerable amount of publications dealing with the geological structure and mineralogical details of the Kraubath massif, only a brief survey of the present state of our knowledge is given here. The Kraubath massif outcrops over about 14 km in East-West and 1.5-2km in North-South direction. It thus is the largest ultramafic body in Austria. It forms part of the "Gleinalmkristallin" and is situated on the border between the Seckau core in the North and the Gleinalm core in the South. Erosional features permit the investigation of outcrops over 400 m difference in altitude. The accessible volume is estimated as approximately 6 km^3.

The Kraubath massif can conveniently be subdivided into four parts (Fig. 1). Petrographically, a number of rock types can be distinguished. F. ANGEL (1964) established new names for the different rock types. Chemical analyses show that amongst 8 rock types, which have been formed by fractionation of a primary peridotite magma, pyroxene-peridotites dominate (Fig. 2). In addition, few samples represent pure dunites, pyroxene- resp. olivine-hornblende-peridotites and olivine-pyroxenites. Hornblende-pyroxenites, pyroxene- and olivine-pyroxene-hornblendites are rare (Tab. 1). Contrary to earlier publications, pure olivine rocks are rare and limited to the Augraben area.

The massif is lense-shaped and strikes 60/240^{o}. There is no metamorphic aureole and no evidence for intrusive contacts. Some sections suggest synclinal shape; the western part of the area investigated, however, is dominated by northwest-dipping structures.

Metamorphism has affected both, the ultramafics and their country rocks. Several phases of tectonism are indicated. Large scale mylonitization and faulting corresponds to the distinct foliation of the country rocks. Tectonic analyses reveal a b-axis, which lies horizontal and strikes Southwest-Northeast.

The Kraubath massif contains tectonic inclusions of garnet amphibolites and marble. The ortho-amphibolites can be interpreted as the metamorphic products of basaltic-gabbroic igneous rocks; they can be distinguished petrographically and chemically from other amphibolites of the Gleinalm massif. They are not interpreted as products of differentiation of the ultramafic rocks.

Contrary to HIESSLEITNER's (1953) interpretation of Kraubath as a layered magmatic complex with several zones (micaschist, border amphibolite, pyroxene-peridotite, intermediate amphibolite, mean dunite) PETERSEN-KRAUSS (in HADITSCH et al., 1980) was able to show by trend surface analyses an elliptic-concentric structure of the ultramafic complex, which has been affected by post-genetic tectonism and serpentinization (Fig. 3). These investigations also suggest, that a part of the ultramafic massif has been sheared off and displaced into depth towards the North. This view is supported by geophysical investigations which revealed an anomaly near St. Stefan ob Leoben (private communication, F. WEBER, Leoben).

The following petrogenetic evolution has been proposed by MEIXNER & WALTER (1939). Proceeding from the oldest to the youngest formations, they distinguish

1) Dunite-pyroxenite (with chromite)
2) Partial hydatogene chrysotilization of the olivines (with magnetite pigment)
3) Formation of vein antigorite (with kemmererite = chromium pennine, chromium smaragdite, zircon, clinochlor, talk, as well as copper and nickel minerals, such as pentlandite chalcopyrite , mackinawite and heazlewoodite)
4) Formation of vein-type chrysotile
5) Magnesite (with hematite, deweylite, sepiolite, chalcedony, opal)
6) Brucite association; hydrothermal sequence extending from

pyroaurite via brucite (at 250°C), aragonite, calcite, hydromagnesite to artinite

7) SiO_2-$CaCO_3$-phase (with chalcedony, opal, rock-crystal, calcite, aragonite, dolomite)
8) Recent formations with tenorite, cuprite, malachite, chrysocolla, bravoite, gypsum, epsomite, hydromagnesite, aragonite etc.

SCHANTL (1975) was the first to show that brucite also occurs as a rock forming mineral.

Table 1

	Average chemical composition (without H_2O)							
	A	B	C	D	E	F	G	H
SiO_2	41.75	45.64	47.15	53.64	51.93	55.86	53.05	54.31
MgO	48.69	44.05	39.55	35.23	32.50	23.90	23.49	21.91
CaO	0.37	0.41	2.45	0.86	4.36	8.81	14.42	14.56
Cr	0.39	0.38	0.37	0.30	0.30	0.19	0.22	0.29
Ni	0.22	0.24	0.17	0.12	0.08	0.04	0.03	0.03

A = dunites (6 samples)
B = pyroxene-peridotites (190 samples)
C = pyroxene-hornblende-peridotites (6 samples)
D = olivine-pyroxenites (6 samples)
E = olivine-hornblende-pyroxenites (8 samples)
F = hornblende-pyroxenites (3 samples)
G = olivine-pyroxene-hornblendites (3 samples)
H = pyroxene-hornblendites (5 samples)

Accordant to PETERSEN-KRAUSS (1979) three petrogenetic phases of a discontinuous differentiation can be distinguished:

1) During a first stage, chromium and nickel are enriched in dunites and pyroxene peridotites, which results in an increase of CaO, FeO and MnO concentration of the melt. Separation of olivine was not very advanced at that stage, and a crystal mush may be envisaged.
Olivine-pyroxenites were formed as local relict cumulates. The chromite lenses and "Schlieren" at Kraubath may be interpreted as early cumulates. Characteristic podiform chromite has not been recorded. The end of the first stage (during which the bulk of the magma crystallized) is marked by the formation of pyroxene-hornblendites.

2) Components such as Si, Ca, Fe, Mn, which have been enriched in the interstitial residual magma may grade into the peripheral zones, and contribute to the formation of hornblende-rich rock types (pyroxene-hornblende-peridotite, olivine-pyroxene-hornblendite).

3) During the third (postmagmatic) stage there follows serpentinization with partial mobilization of magnesium. SiO_2, Al_2O_3, FeO, CaO and Cr are not mobilized. Serpentinization was autometasomatic - metasomatic under conditions of retrograde metamorphism, and proceeded from geological structures. All stages of serpentine formation can be observed. The H_2O-content of serpentinized rock decreases from Northwest towards Southeast. Trend surfaces of H_2O distribution coincide with the strike of minor lineaments. These H_2O-trend surfaces also control the distribution of magnesite occurrences, which have been mined in the past. Additional factors significant in this context are the MgO-content of the host rock and tectonic features.

The average composition of Kraubath ultramafic rocks corresponds to that of mantle peridotites.

Various mineral raw materials contained in the Kraubath ultramafic intrusion are presently being mined; dunites and peridotite rocks are quarried in Lobming. Chromite had been recovered from about 1810 until 1915 at several small workings at Lichtensteiner, Mitter, Fedl and Gulsenberg. The same applies to cryptocrystalline magnesite in Sommergraben and in Gulsen and to lateritic iron stones on Lichtensteinerberg.

FRIEDRICH and ROBITSCH conducted a first informative sampling of the Kraubath massif in 1938. The samples were then analysed by MÜLLER who also considered the question of hydrometallurgical recovery of nickel (MÜLLER, 1939).

In the course of our investigations 227 samples have been quantitatively analysed for Si, Al, Fe, Mn, Mg, Ca, Cr and Ni (Fig. 4). In addition, several amphibolites and weathered ultramafics have been analysed for comparative purposes. The results are summarized in Table 1 (after PETERSEN-KRAUSS, from J.G. HADITSCH et al., 1980): They reveal a distinct distributional pattern of economically interesting elements. In contrast to chromium, nickel shows a positive correlation with MgO. There are no significant differences between altered and non-altered rocks. Investigations in transmitted and reflected light have shown that the Kraubath dunites and peridotites carry mainly finely disseminated chromite ("seed chromites", ANGEL, 1964). Higher grade spotted and massive ores have previously been mined in various places. The irregular distribution of the stringer- and lense-shaped orebodies prevented economic recovery in the long run, although the quality of the ore is high (up to 55% Cr_2O_3). Further exploration by drilling or adits was considered excessively risky.

The following products are potentially recoverable by hydrometallurgical methods:

- nickel, from sulphides or from olivine where it occurs as isomorphous substitution
- chromite
- magnesia with 99.4-99.6% MgO
- rocksand (with a grainsize of $\geq$ 0.1 mm, rock flour (with grainsize of $<$ 0.1 mm) and contents of

SiO_2	90 - 94	%
Fe_2O_3	0.5 - 3	%
Al_2O_3	0.3 - 4	%
Cr_2O_3	0.5 - 3.0	%
CaO	0.05 - 0.6	%
MgO	0.4 - 6.0	%
Ni	0.01 - 0.1	%

- red slimes (with low contents of watersoluble salts, but significant acid contents).

Based on the average chemical composition as shown in Table 1, the following quantities of end products might be obtained from the processing of 350.000 t of dunites and pyroxene-peridotites from Kraubath:

MgO	135.000 - 145.000	t
Ni	665 - 735	t
Cr	1.150 - 1.200	t
SiO_2	125.000 - 140.000	t

Rest is iron-rich red slimes.

A synoptic representation of elemental distribution at Kraubath shows that the most interesting and promising area is situated in the Tanzmeister Valley between Lichtensteinerberg and Nissenberg. Here, chemical composition, homogeneity, estimated reserves and accessibility, as well as the environmental situation are favourably combined. Future investigations will therefore concentrate on this area and should be preceded by exploratory drilling. The VÖEST-ALPINE Corporation has already drilled four holes in this area (Fig. 5).

Rocks with a minimum olivine content of 90% and a fayalite content of less than 8% may also be suitable for the production of foundry sands and refractory products. The mol relation $MgO:SiO_2$ should exceed 1.8:1.

This M/S ratio and the water content are the most important criteria for the technological value of olivine-rich raw materials.

For 188 analyses of serpentinized rocks a medium M/S value of 1.38 (s:0.25) was obtained. For 169 rocks with M/S values between 1.06 and 1.80 the medium value was 1.45 (s:0.15). The water content for these 188 samples was 11.49% (s:2.96).

These values thus are far below those demanded by BAUMGART (1971). Practical experiments have, however, shown that the suitability of some Kraubath rock types for the above purposes is limited.
Summarizing the above considerations, the Kraubath dunites and pyroxene-peridotites emerge as quantitatively and qualitatively interesting for the integrated recovery of various mineral raw materials (HADITSCH, 1979).

The geochemical and analytical work was performed by Mr. D. PETERSEN-KRAUSS, Dipl.Geol., in the Institute of Geochemistry, Economic Geology and Petrology of the University of Frankfurt am Main. We are grateful to the directors of the Institute, Prof. K.v.GEHLEN and H. KRUMM, for their generous support. We are indebted to the Provincial Government of Styria (Steiermärkische Landesregierung) for financial support and for the permission to publish, and to Prof. E.F. STUMPFL for the English translation.

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Nachtrag:

HADITSCH, J.G. (1979): Erze, feste Energierohstoffe, Industrieminerale, Steine und Erden. - In: Grundlagen der Rohstoffversorgung, 2: Lagerstätten fester mineralischer Rohstoffe in Österreich und ihre Bedeutung, 5-45, Wien.

Geological Sketch Map

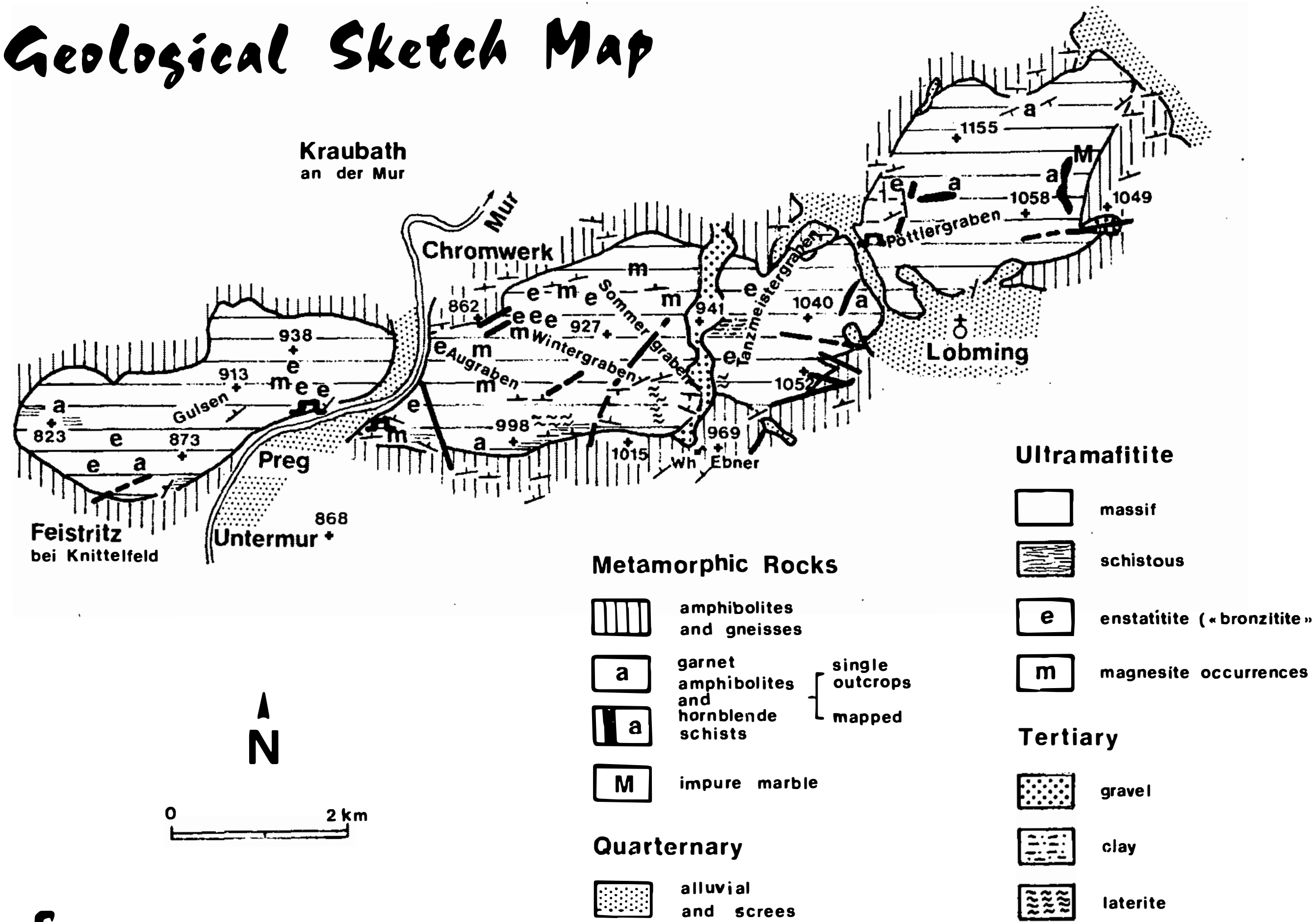
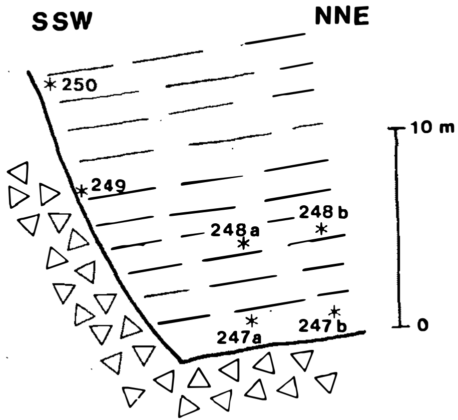


Figure 1

Figure 2

Gulsen Quarry

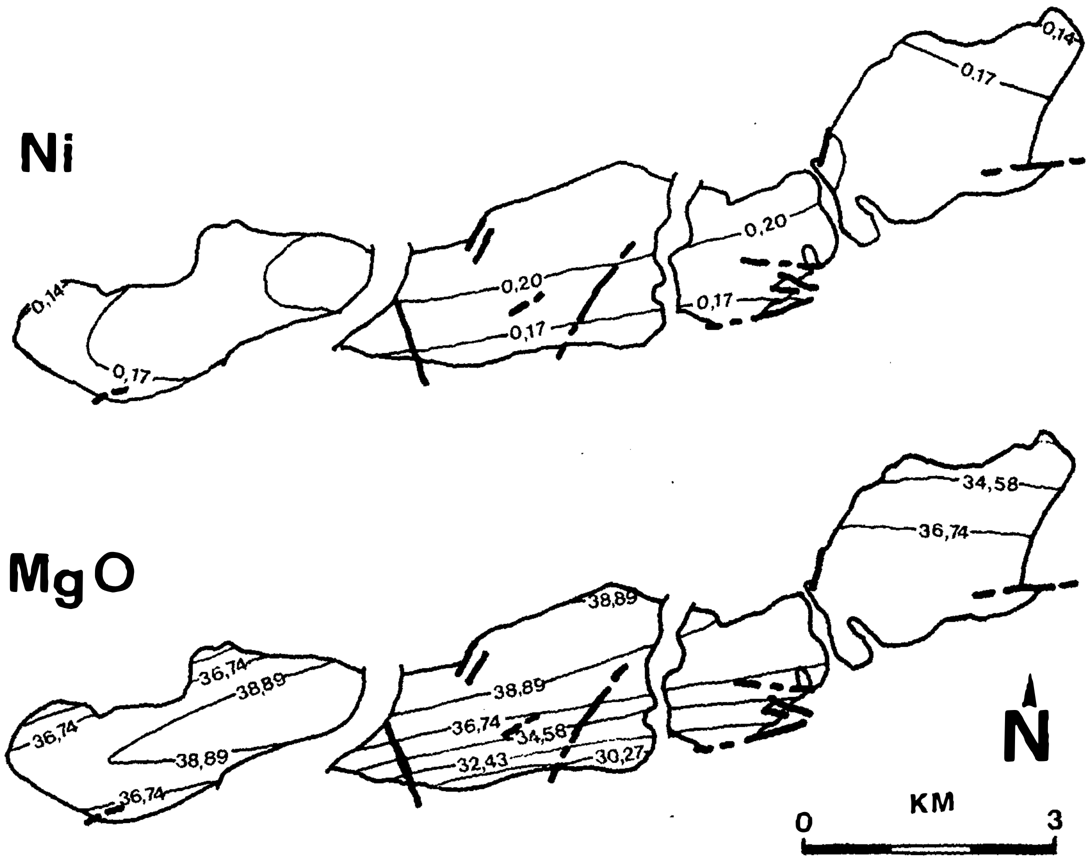


PROFILE SECTION

	247a	247b	248a	248b	249	250
SiO_2	39,12	35,54	38,63	38,70	38,80	38,65
Al_2O_3	0,59	0,48	0,55	0,63	0,64	0,71
FeO	6,89	6,91	6,86	6,81	6,77	6,67
MnO	0,12	0,12	0,12	0,12	0,12	0,12
MgO	39,26	40,96	40,53	40,39	38,74	38,94
CaO	0,69	0,20	0,58	0,50	0,62	0,62
Cr	0,26	0,42	0,27	0,29	0,30	0,24
Ni	0,17	0,18	0,19	0,19	0,17	0,16
H_2O	12,91	14,21	12,74	12,69	13,02	14,32
Σ	100,01	99,02	100,47	100,32	99,18	100,43

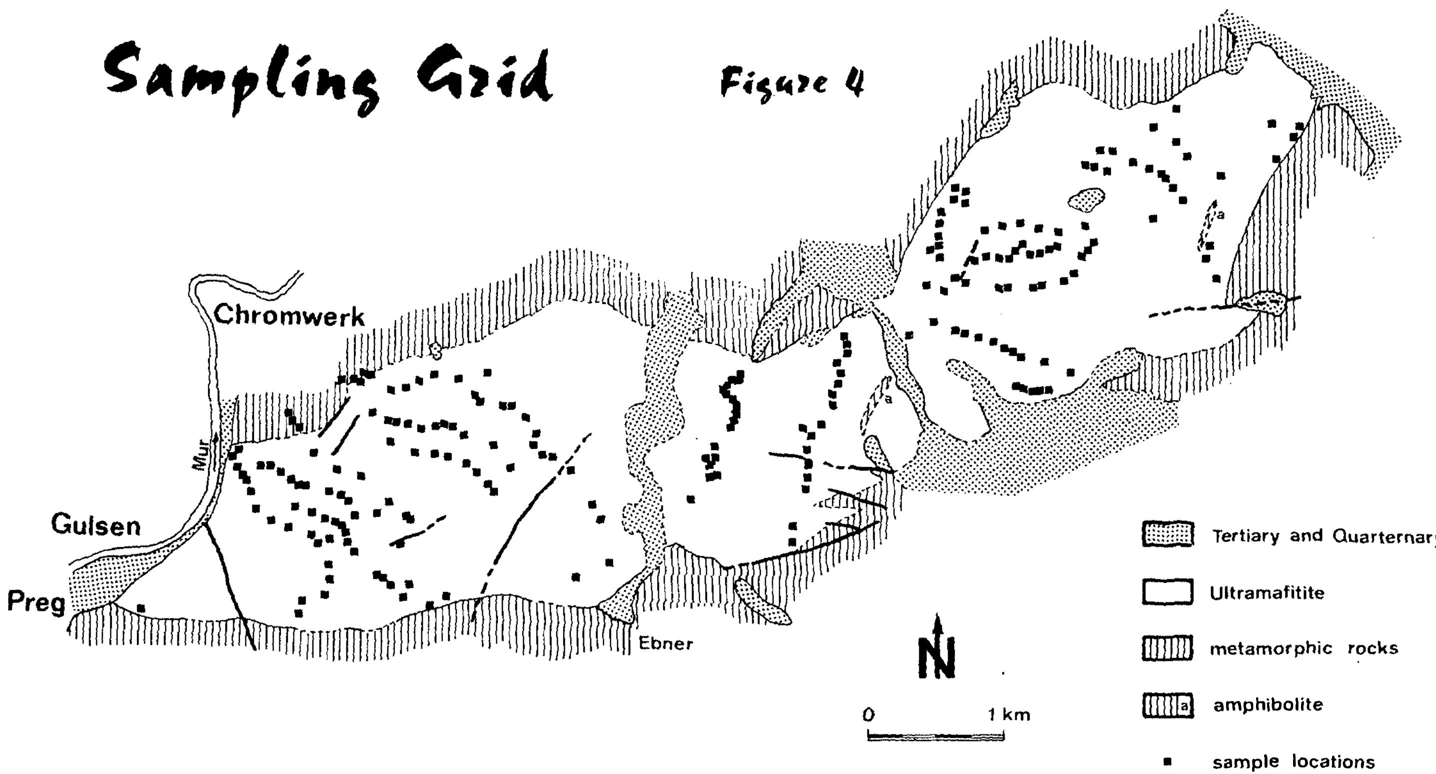
Trend Surfaces

Figure 3



Sampling Grid

Figure 4



Element Distribution in the Kraubath Ultramafic Massif East of the River Mur

Figure 5