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Petrology and Structure of the Riebeckite Gneiss from the Area near Gloggnitz in the Graywacke Zone of Austria

With 3 text-figures and 7 photos

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Zusammenfassung

Der Riebeckit-Gneis, der in der Nähe von Gloggnitz ansteht, ist das größte von 14 Vorkommen in der Grauwackenzone der Ostalpen. Dieser Gesteinskörper kommt in der Silbersberg-Serie vor, die mit Quarzporphyroiden, Quarziten, Phylliten und Lyditen die obere Grauwackenzone (Norische Decke) aufbaut. Der Riebeckit-Gneis scheint konkordant in die Nebengesteine eingeschaltet zu sein, jedoch konnte der Kontakt nirgends beobachtet werden, da es an Aufschlüssen fehlt.

Der Riebeckit-Gneis hat eine durchschnittliche mineralogische Zusammensetzung von Quarz + Feldspat 90,8%, Alkalipyroxen 3,3%, Riebeckit 4,5%, Muskowit 0,6% und 0,8% Akzessorien. Gegen den nördlichen Kontakt mit der Grauwackenzone geht das Gestein in einen feinkörnigen, aplitischen Typus über, der nahezu keinen Riebeckit und Alkalipyroxen enthält und somit vorwiegend aus Quarz und Alkalifeldspat besteht.

Die Lineation ist gut entwickelt und verläuft parallel zur Längsrichtung der dunklen Gemengteile; die s-Flächen sind EW-orientiert und fallen nach N ein. Das Gestein ist postkristallin deformiert, und nach den Ergebnissen der Gefügeanalyse sind mehrere Deformationsakte möglich.

Die Bewegung ist gegen N gerichtet. Aus den Feldbeobachtungen und aus der Petrographie ist es wahrscheinlich, daß das Gestein als Meta-Alkalirhyolith zu betrachten ist. Die Untersuchung der Spurenelemente, besonders das K/Rb-Verhältnis bestätigt diese Ansicht.

Abstract

The riebeckite gneiss occurring near Gloggnitz is the biggest of the 14 occurrences in the Graywacke Zone of Austria. This body occurs within the Silbersberg serie of the Graywacke Zone of Upper Eastalpine of Austria. The Silbersberg serie, together with the quartz porphyroids, quartzites, slates and lydites, belongs to the Noric Nappe (Norische Decke). The riebeckite gneiss shows a more or less concordant relation to the country rocks but the true relation to the country rocks could not be known definitely due to the lack of exposures.

The riebeckite gneiss has an average mineralogical composition of quartz + feldspar 90.8%, alkali pyroxene 3.3%, riebeckite 4.5%, muscovite 0.6% and accessories 0.8%. Towards the northern contact with the graywackes this rock grades into a fine-grained aplitic type and is almost free from riebeckite and alkali-pyroxene and is mostly composed of quartz and alkali-feldspar.

The rock shows a well developed lineation due to the parallel arrangement of the longer directions of the mafic constituents; and the s-planes in general strike in an east-west direction and dip towards north. The rock is strongly crushed and the results of the petrofabric analysis reveal a possibility of more than one phase of deformation and a movement in the north-south direction, may be, possibly towards north.

From the field occurrence, petrography and the chemical analysis of the rock it can be seen that the riebeckite gneiss is a metamorphosed alkali-rhyolitic (quartz-keratophyre) rock. Study of distribution of trace elements especially K/Rb ratio confirms this view.

Introduction

This work is based on field and laboratory investigations carried out by the author about the riebeckite gneiss and the adjoining rocks occurring near Gloggnitz in the Graywacke zone of the Upper Eastalpine of Austria. The riebeckite gneiss forms a small body within the Silbersberg serie which belongs to the Upper Noric Nappe (Norische Decke) together with porphyroids, quartzites, slates and lydites. The Silbersberg serie consists of finegrained and conglomeratic graywackes, phyllites and greenschists. A comparatively larger body of quartz porphyroid lies a few hundred meters west of the riebeckite gneiss. Some minor outcrops of plagioclase porphyroid and diabase (?) also occur in the area. In the region of investigation there is little or no folding to be observed and in general all the rock types strike in the east-west direction and dip towards north. The rocks are much crushed and effects of cataclastic metamorphism are well displayed in the rock structure. The problem of origin and the structure of the riebeckite gneiss is mainly discussed in the following pages.

Previous Work

The riebeckite gneiss from Gloggnitz was first described by G. H. Keyserling. According to him the riebeckite gneiss is a metamorphosed alkali-granite which was intruded after the emplacement of quartz porphyroids and diabases. Sigmund (1911) studied the ore minerals from the riebeckite gneiss near Gloggnitz and has described sphalerite, löllingite, chalcopyrite etc. J. Zemann (1951) studied these rocks in a great detail and has recorded nearly 13 occurrences within a distance of 20 km. in an east-west direction. He has described varieties ranging from light-coloured to dark coloured and strongly-deformed to very much less-deformed types. He assumed that sediments rich in silica and in potassium were transformed by contact metasomatism or under hydrothermal influences by the soda rich solutions given out by basic magma and resulted in a rock containing the alkali-amphibole and alkali-pyroxene. H. P. Cornelius (1951) has recorded one more occurrence in the same area — in addition to those studied by Zemann — in "Profil im Mitterbachgraben". At this locality he describes that the riebeckite-content gradually decreases from the center towards north and towards south and the rock grades into a white coloured finegrained aplitic gneiss bearing no riebeckite. He completely differs with Zemann and states that the riebeckite gneiss in the graywacke zone must be of magmatic origin; either as dykes parallel to the general strike or as tectonically deformed stocks.

Area of Investigation

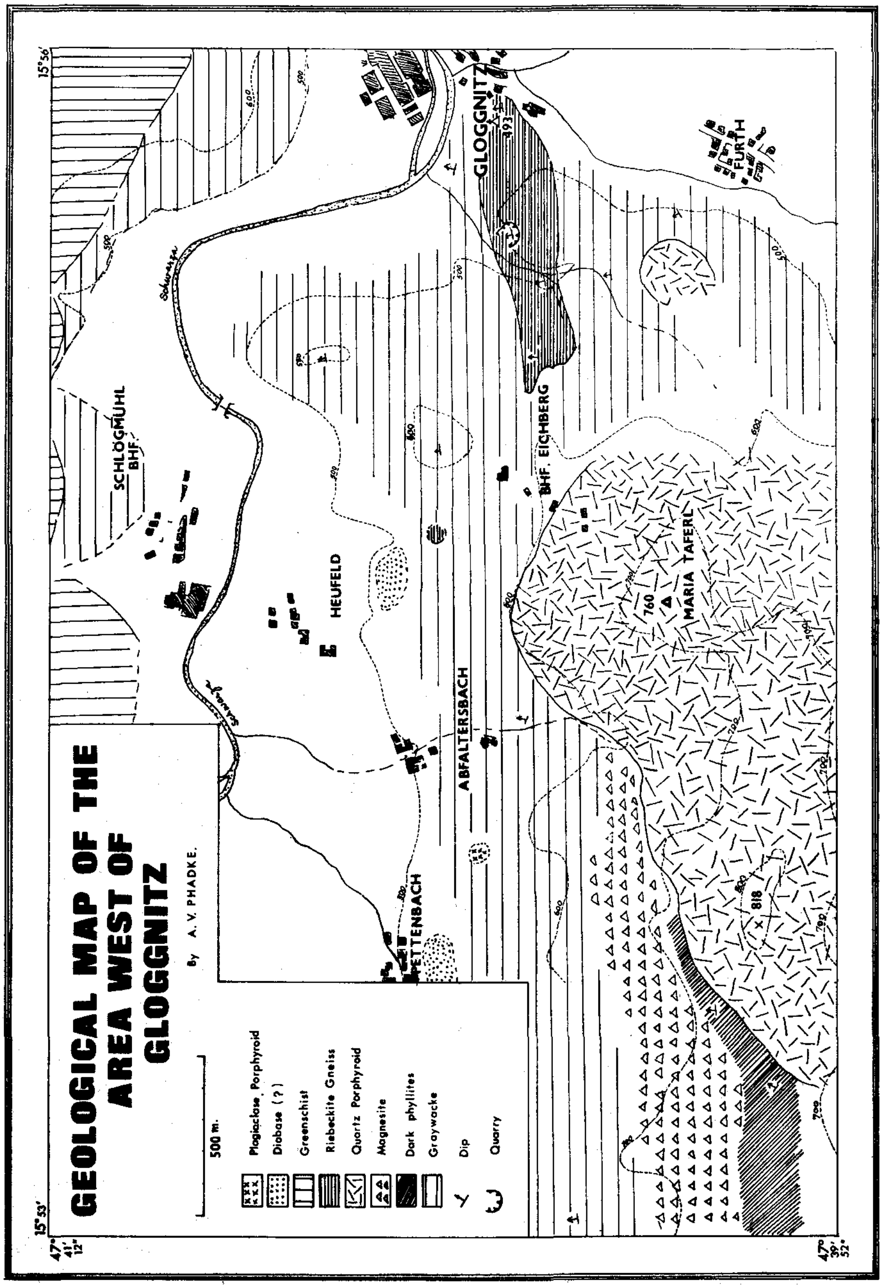
The area of investigation covers about 8 to 9 square kilometers roughly between latitudes 47° 40' : 47° 41' N; and 15° 53' : 15° 56' E. (Topo sheet No. 105 Neunkirchen) and lying west of Gloggnitz. No other important towns worthy of mention are located in the area though the north-west and the south-west portions are much more well inhabited. From point of view of pilgrimage Maria Taferl (760 m.) is the only important place located in the area.

Physiography is very simple and there is little of diversity. In the northern portion of the area the river Schwarza flows from west to east following a zig-zag course and near the eastern end of the area takes a turn towards South and after flowing for a short distance up to the western end of Gloggnitz resumes its easterly course. Small streams dessecting the east-west ranges of low-lying hills in the north and the south flow into the river.

Though in the area of investigation the natural outcrops are very acutely lacking — partly due to inhabitation and partly due to the thick covering of soil and development of agriculture — a quarry of riebeckite gneiss just west of Gloggnitz, road cuttings and natural cuttings by the streams and the river provide a valuable geological information.

Method of Work

Mapping of the area on a scale of 1 : 10,000 was carried out in about three to four weeks time. A particular attention was given to the riebeckite gneiss and its relation to the country rocks. Most of the measurements of structural elements were done in the quarry of riebeckite gneiss west of Gloggnitz. Different rock-types were studied in detail from their thin sections and modal analysis was done by using an "integrating occular". Magnetite was separated from the rock at the northern boundary of riebeckite gneiss by using Franz Isodynamic Separator and the Ti-content in it was determined by colorimetric methods. Petrofabric analysis of the riebeckite gneiss was done by preparing thin sections of the samples — which were oriented in the field — and by plotting the poles of "c" axes of quartz grains. In order to get more information as regards the origin of the riebeckite gneiss, quantitative and semi-quantitative estimation of the distribution of trace elements was done by means of spectrochemical and X-ray fluorescence methods.



General Geology

The riebeckite gneiss occurs within the Silbersberg serie (consisting of finegrained and conglomeratic graywackes, phyllites and greenschists) of the Graywacke Zone of the Upper East-Alpine. This series, together with the quartz porphyroids, quartzites, slates and lydites belongs to the Noric Nappe an the lower (younger) part of the Graywacke Zone belongs to the Veitscher Nappe. A comparatively large body of quartz porphyroid occurs near and to the west of the riebeckite gneiss. No sharp contact between the riebeckite gneiss and the graywackes which surround it from all sides could be observed. But a gradation to a fine grained type containing no riebeckite is exposed in the Wolfschlucht and a little to the north-west of it; and this may possibly be the northern contact with the graywackes. In the south-western portion of the area dark phyllites are in contact with the quartzporphyroids. Near the western boundary of the quartz porphyroid, partly digested xenoliths of dark phyllites could be observed. To the north of these dark phyllites there occurs a zone of worked over deposits of magnesite. This zone has a width of about two to three hundred meters in the north west direction and extends in the east west direction for about a kilometer or so. Some outcrops of greenschists occur in the northeast portion of the area but these have no direct contact with the riebeckite gneiss. Some minor outcrops of diabases (?) and plagioclase porphyroid occur near Prettenbach and Heufeld.

The true field relation of various rock-types could not be known quite exactly due to the lack of natural outcrops. The rocks in general strike in the east-west direction — though some local variations could be observed — and dip towards north and no folding is to be seen. In the quarry of riebeckite gneiss, mentioned earlier, two steeply inclined east-west faults were observed. These faults are characterised by crushed zones in which highly micacious (65% muscovite) material has been developed. Thin quartz veins, apparently of much later origin, are seen to cross the riebeckite gneiss at various angles. The area has been much affected by crushing and even the quartz porphyroids have acquired a schistose appearance.

Petrography

Of all the rock-types, riebeckite gneiss was the only one studied in detail.

1. Graywackes:

In this area these are gray or brownish-gray coloured rocks of distinctly sedimentary origin. Many times these rocks show a silver white lustre due to the development of sericite. These rocks are composed of poorly sorted sediments consisting chiefly of grains of quartz and quartzites, The grains are not much rounded and many times show irregular boundaries and show undulose extinction due to crushing. The matrix is chiefly composed of sericite and some dusty opaque ore, and sometimes limonite. Texturally these rocks vary from fine-grained phyllitic type to a much coarser grained conglomeratic type. At some places graded bedding could also be observed in field but the true relation to the finegrained types and conglomeratic types could not be studied. The rocks have clearly undergone cataclastic metamorphism and the author prefers to call these rocks as "meta-quartz graywackes".

2. Quartz Porphyroid:

It is a buff coloured light rock showing megacrysts of quartz in a fine-grained ground mass. The rocks have been much deformed and have acquired a distinct foliation. In general the foliation surfaces dip towards north and strike east-west. The megacrysts of quartz are also much elongated and sometimes it is difficult to distinguish it from the graywackes. In thin sections the rock shows megacrysts of quartz embedded in a groundmass chiefly composed of sericite and a little limonite. The quartz grains are somewhat elongated and show severe effects of crushing (see Photo 1) with undulose extinction and even development of "Boehm lamellae". In some instances recrystallisation of quartz has also taken place along the fractures in the megacrysts. This may be after local melting along the fractures due to the development of heat fritting.

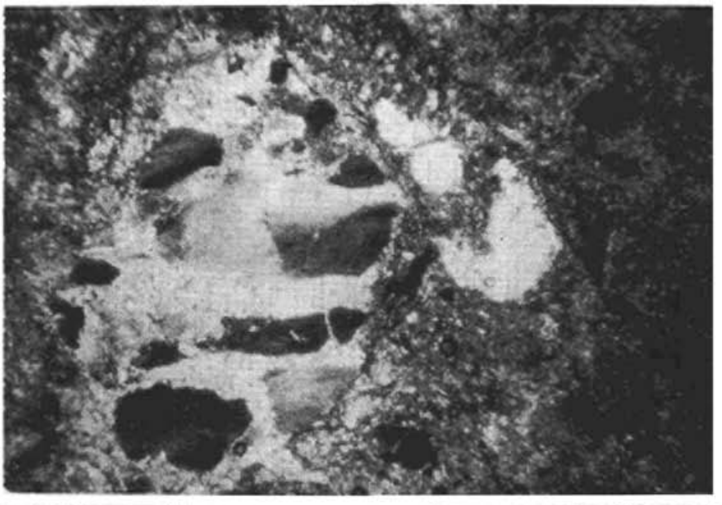


Photo 1. Effects crushing on quartz megacrysts in quartz porphyroid (× 15).

3. Riebeckite Gneiss:

It is a light coloured, strongly deformed, hard and well jointed rock. A more or less parallel arrangement of the longer directions of the dark constituents (alkali-amphibole and alkali-pyroxene) together with the light-coloured constituents (quartz and alkali-feldspar) give rise to a well marked gneissic texture. On an average the rock has a medium to coarse fabric but towards the northern boundary of the outcrop it grades into a light-coloured fine grained aplitic type and which is almost devoid of dark constituents. This finegrained type is exposed in the Wolfschlucht, a little to the north-west of the quarry, and also near the north-western end of the outcrop.

In thin sections the rock shows a medium to fine grained gneissic texture. The mafic constituents, along with quartz and feldspar, show a more or less linear arrangement with their longer directions parallel to each

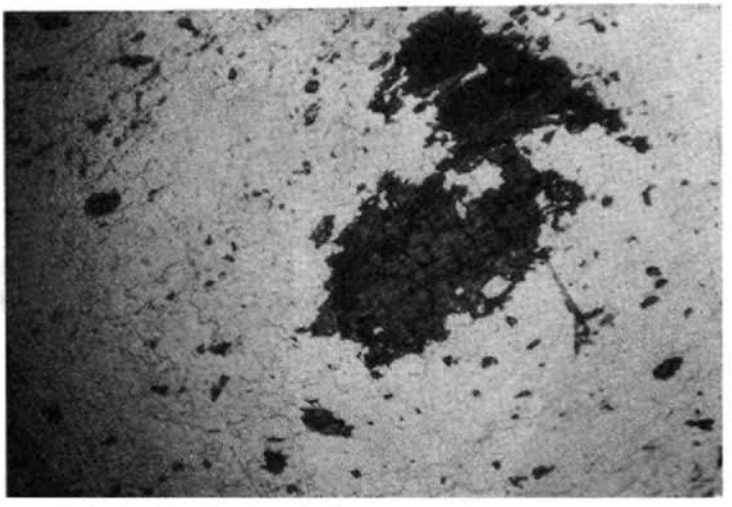


Photo 2. Primary riebeckite in riebeckite gneiss (× 35).

other. This is not strictly observed — especially by alkali-pyroxene — and at times the mafic constituents are rudely oriented. The major constituents

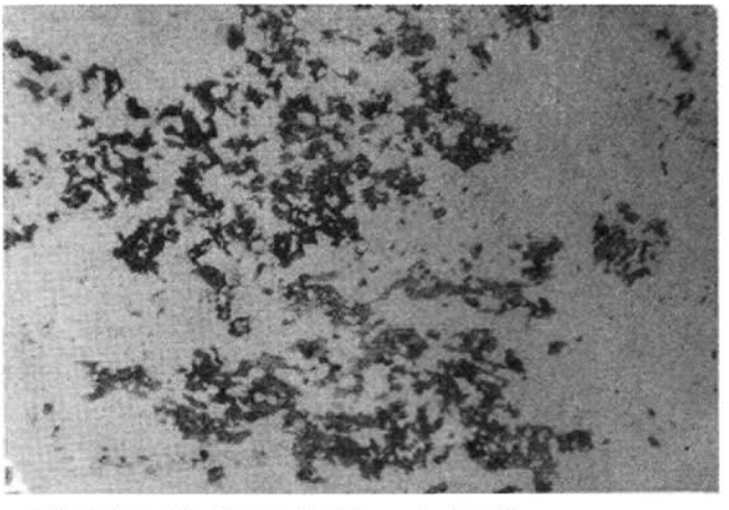


Photo 3. Secondary riebeckite in riebeckite gneiss (× 35).

are quartz, alkali feldspar, riebeckite and alkali-pyroxene (aegirine and aegirine-augite) and the accessories include magnetite, muscovite, haematite and limonite. Quartz is present mostly in the form of elongated grains showing undulose extinction and development of "Boehm lamellae". Feldspar is mostly microcline and in rare cases plagioclase and at times alteration to kaolinitic and sericitic material. The rock is very much crushed and

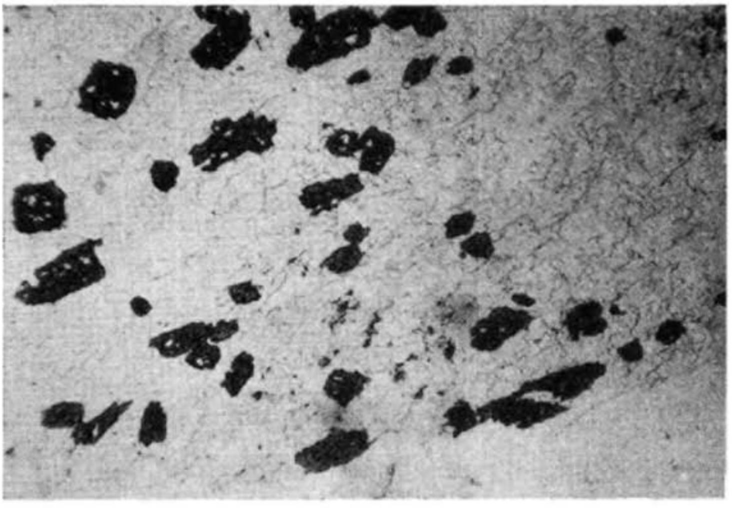


Photo 4. Aegirine with well developed outlines in riebeckite gneiss (× 35).

in most cases it is difficult to distinguish between the quartz and feldspar. As such quartz and feldspar were taken together in the modal analysis of

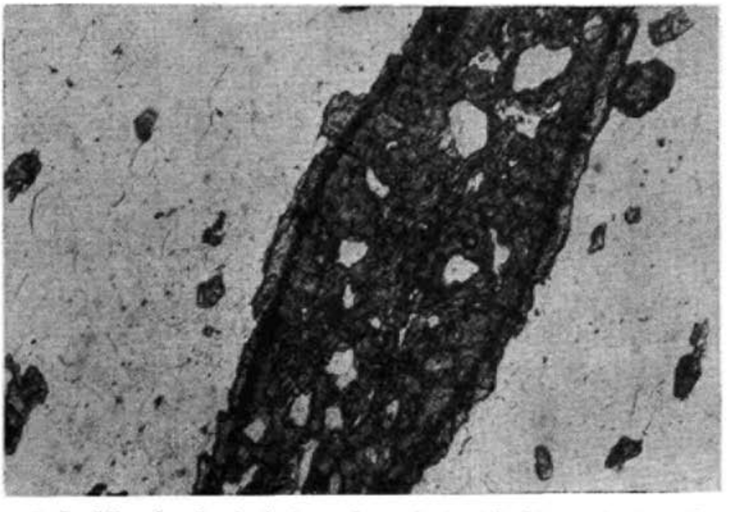


Photo 5. Aegirine showing inclusions of matrix in riebeckite gneiss (× 60).

the rock. In occasional instances tabular megacrysts of feldspar are noticeable. These megacrysts may perhaps be of primary magmatic origin. Riebeckite is bluishgreen and strongly pleochroic. It shows irregular form and there is no development of crystal faces. Two generations of riebeckite could be clearly observed. The first type shows large irregular crystals with fractures and marginal corrosion and having some inclusions of magnetite.

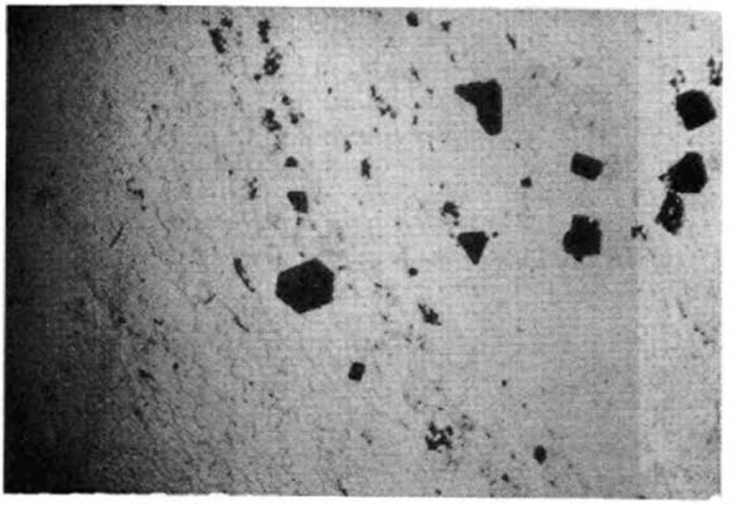


Photo 6. Magnetite with well developed faces in the marginal zone of riebeckite gneiss (× 35).

(see Photo 2). These larger patches of riebeckite have given rise to the name "Forellenstein" or "Fischstein" to the rock (KEYSERLING, 1903). The second

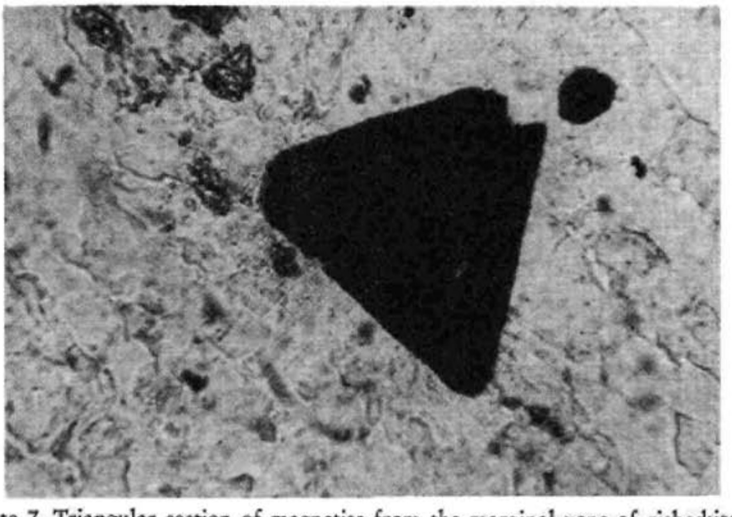


Photo 7. Triangular section of magnetite from the marginal zone of riebeckite gneiss (× 350).

type shows small prismatic needles and smaller irregular plates which are also strongly pleochroic but do not show any inclusions of magnetite (see Photo 3). Riebeckite shows a large angle of 2 V and is optically negative.

c/X = 3 to 7 degrees. The first type appears to be of primary magmatic origin and the second one seems to be the one that has grown during metamorphism. The alkalipyroxene is more or less in equal proportion as that of riebeckite. The pyroxene shows well developed crystal outlines (see Photo 4) with a strongly pleochroic core of aegirine which is surrounded by a narrow rim fo less pleochroic aegirine augite. The pyroxene in most cases in poikiloblastic with inclusions of quartz (see Photo 5). In many instances a narrow rim of limonite surrounding aegirine could be seen. In rare cases it is possible to see twinned pyroxene with a core of aegirine augite and having no inclusions of quartz (in this inclusions of quartz are restricted to the margins). This type of pyroxene may perhaps be representing the primary magmatic origin. The aegirine is optically negative and shows a 2 V of about 62 to 70 degress and c/X = 3 to 8 degrees.

Table 1. Modal Analysis of Riebeckite Gneiss from Gloggnitz

Constituent	PHADKE	ZEMANN
Quartz + feldspar	90.85%	92.2%
Riebeckite	4.50%	4.2%
Alk-pyroxene	3.25%	2.7%
Muscovite	0.6%	—.—
Accessories	0.8%	0.9%
	100.0%	100.0%

Table 1 shows the modal analysis (average of 40 settings of an "Integrating Occular") of the rock. This shows quite a good agreement with the one calculated by ZEMANN (1951). ZEMANN has also calculated the vol.%-age of the various constituents from the chemical analysis of the rock (see Table 2).

Table 2. Chemical Analysis of Riebeckite Gneiss from Gloggnitz

	I	II	Mineral composition calculated from the chemical analysis.	
SiO_2	76.03%	76.60%		
TiO_2	0.10%	0.09%		
Al_2O_3	11.74%	10.75%		
Fe_2O_3	2.44%	2.42%	Quartz	34.1%
FeO	0.65%	1.10%	Albite	32.8%
MnO	0.04%	0.03%	Alk-feldspar	25.2%
MgO	0.04%	0.08%	Riebeckite	4.7%
CaO	0.11%	0.19%	Aegirine	3.0%
Na_2O	4.74%	4.68%	Titanite	0.2%
K_2O	4.07%	4.06%		
H_2O +	0.28%	0.27%		
H_2O —	0.04%	0.06%		
	100.28%	100.33%		

The fine-grained light coloured rock type (a gradation of riebeckite gneiss towards the margins), exposed in the Wolfschlucht, is almost composed of quartz and feldspar with a considerably increased (2 to 3 per cent) amount of perfectly euhedral magnetite (see Photo 6). ZEMANN (1951) has raised a doubt that this magnetite may be pseudomorphous after aegirine. This seems to be quite improbable and one can see even perfectly triangular sections (see Photo 7), which are certainly not representing the form of pyroxene. Table 3 gives the chemical composition of magnetite that was separated from the rock by means of "Franz Isodynamic Separator".

Table 3. Chemical Analysis of Magnetite from the Marginal Zone of Riebeckite Gneiss near Gloggnitz

Constituent	Wt. %		
FeO	23.71%	63.87%	
Fe_2O_3	39.80%		
TiO_2	0.36%		difference:
Silicate + water	36.13		Silicats + water
Total:	100.00%		

4. Greenschists:

It is a greenish-gray coloured rock which is chiefly composed of albite, hornblende, chlorite and quartz and epidote. The accessories include sphene and black opaque ore. These rocks have some similarity with preddazites and the true nature of these greenschists cannot be known without a detailed study.

5. Diabase (?):

This occurs to the south of Prettenbach and another outcrop is observed south of Heufeld. The outcrops are very small and the true field relation of this rock could not be known. This rock is a dark coloured porphyritic rock and composed chiefly of plagioclase, chlorite and little quartz. The plagioclase forms more than 40% of the volume and its An-content is about 28 to 34 percent and is twinned mostly after complex laws such as Albite-Ala, Manebach-Acline complex and Albite-Carlsbad complex law. In some cases it is twinned after simple albite law. This rock may be a meta-quartz diabase.

6. Plagioclase Porphyroid:

Only one small outcrop of this rock was observed south of Heufeld. It is a light coloured rock composed mainly of quartz and phenocrysts of plagioclase which is in most cases albite or oligoclase. The quartz is much crushed and the feldspar phenocrysts show a linear arrangement. Some chlorite and a little secondary calcite is also seen.

The dark phyllites and Magnesite: Not studied.

Structure

The rocks in the area of investigation show a well developed lineation and foliation. The foliation planes in general have a strike in the east-west direction and a dip towards North. Some local variations from the general

East-West strike are, of course, seen. The riebeckite gneiss is well jointed and dip-joints and joints striking north-by-north west-south-east — by south and dipping towards south-west — by-west with an amount of about 50° are prominent. Steeply inclined strike faults which are characterised by crushed zones are seen in the quarry of riebeckite gneiss; but these faults could not be traced any further from the quarry. These faults are characterised by crushed zones and the material in these zones resemble muscovite schist (mica 65% by volume). The arrangement of riebeckite and alkali-pyroxene have given rise to a well marked lineation in the east-west direction. The s-planes, formed by the alkali-pyroxene and riebeckite, dip towards North with an amount of 58° to 70°. No folding is observed in the area and the rocks have a more or less concordant relation to the country rocks (graywackes).

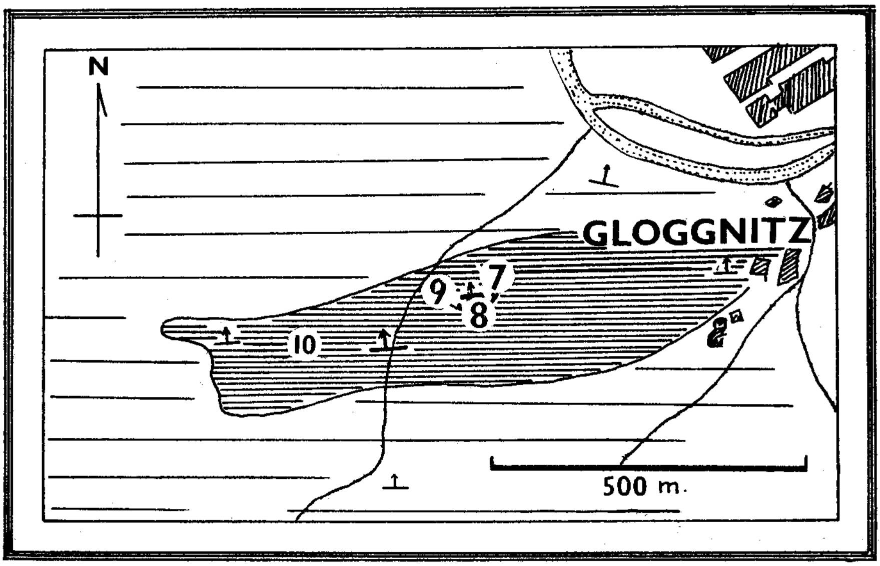


Fig. 2. Map showing the localities from where samples for Petrofabric Analysis were collected.

Petrofabric Analysis

In order to get more information about the structural elements of the riebeckite gneiss, petrofabric analysis with reference to the orientation of the optic axes of quartz grains was carried out. The poles of s-planes formed by the mafic constituents were also plotted on an equal-area net (lineation measurements done in the quarry of riebeckite gneiss, west of Gloggnitz).

Diagram 1:
50 poles of s-planes formed by the riebeckite and alkali-pyroxene. Contours 35%, 25%, 10%, 5%, 3% and 1%.
Locality: Quarry of riebeckite gneiss (just west of Gloggnitz) (7, 8, 9).

Neglecting the lower contours, one can see that the diagram shows an axial symmetry with a maxima having a density of 35% situated at a position 176°/36°. As this represents the position of S-plane poles, it must be coinciding with the petrofabric coordinate "c". The interpretation of the diagrams 2, 3, 4, 5 and 6 is done with reference to the diagram 1 for the samples were collected in this quarry.

Diagram 2:
300 poles of Optic axes (0001) in quartz.
Contours 5%, 4%, 2%, 1%.
Locality: Quarry of riebeckite gneiss (7).
Specimen No. and Section No.: 7 (a).

The diagram shows a girdle with monoclinic symmetry and having its pole at 077°/06°. A maxima with a density 5% is situated at 340°/40°. This must be the petrofabric coordinate "a" and hence it can be seen that the girdle is "a—c" girdle with its pole coinciding with "b" which also more or less coincides with the visible lineation.

Diagram 3:
300 poles of optic axes (0001) in quartz.
Contours 6%, 4%, 2%, 1%.
Locality: Quarry of riebeckite gneiss (7).
Specimen No. and Section No.: 7, 7 (b).

If the minor maxima situated at 245°/36° is neglected the diagram shows an "a—c" girdle with „a" situated at 350°/35° and having a density of 6%. The pole of the girdle is at 258°/05°.

Diagram 4:
400 poles of optic axes (0001) in quartz.
Contours 4%, 3%, 2%, 1%.
Locality: Quarry of riebeckite gneiss (8).
Specimen No. and Section No.: 8, 8 (a).

The diagram shows a girdle with three maximas having a density of 4% and having their positions at 346°/36° the one coinciding with "a" and the other two being situated close to and symmetrically with "c". The pole of the girdle is at 250°/14°.

Diagram 5:
300 poles of optic axes (0001) in quartz.
Contours 5%, 3%, 2%, 1%.
Locality: Quarry of riebeckite gneiss (8).
Specimen No. and Section No.: 8, 8 (b).

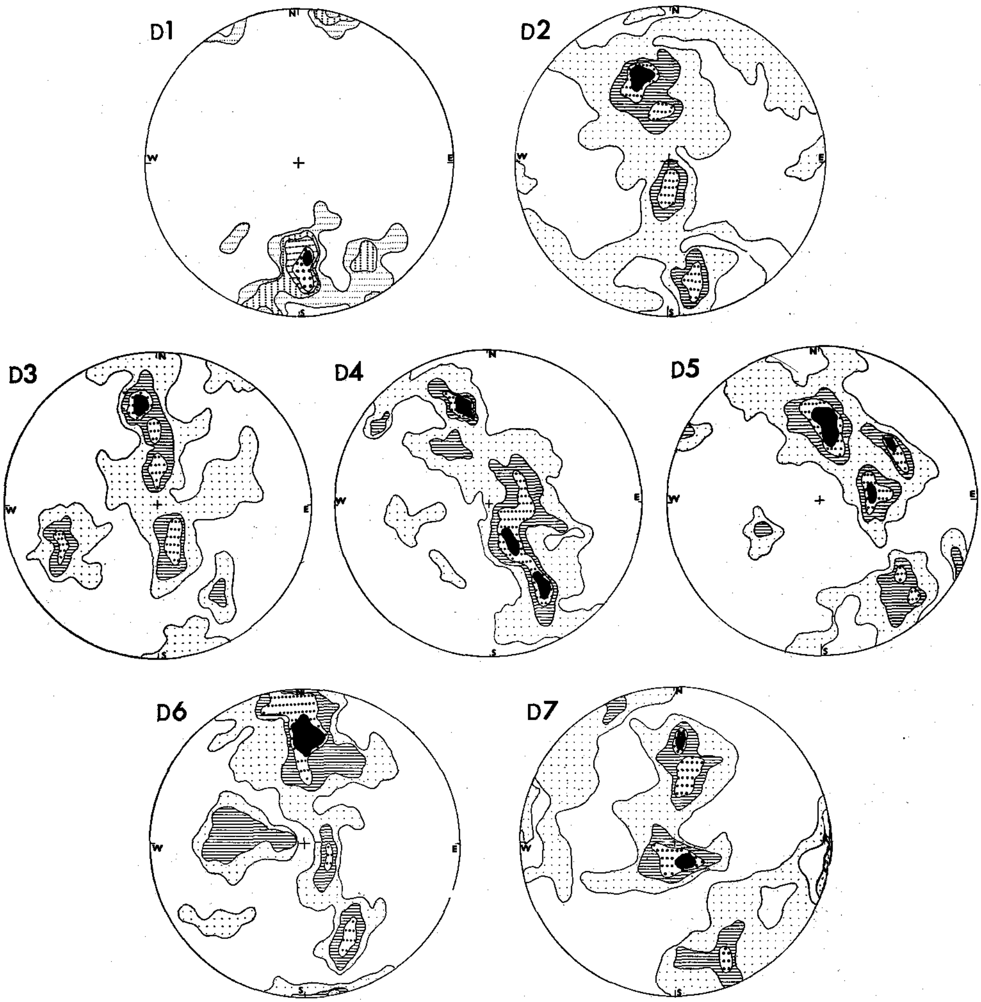


Fig. 3. Petrofabric diagrams (for explanation see text).

The diagram shows a triclinic symmetry with three maximas of 5% density. Comparison with the diagrams 1, 2, 3 and 4 shows that the one situated at 005°/40° must be coinciding with 'a'. The other two maximas are situated at 053°/42° and 084°/65°. The girdle hat its pole at 240°/36°. This deviation from the other diagrams may be a very local variation or may be due to an inaccuracy in preparing a thin section.

Diagram 6:

300 poles of optic axes (0001) of quartz grains.
Contours 7%, 5%, 3%, 1%.

Locality: Quarry of riebeckite gneiss (9).
Specimen No. and Section No.: 9,9.

The diagram shows an "a—c" girdle with a monocline symmetry. A strong maxima with 7% density is situated at 000°/30° which is "a". The girdle has its pole at 260°/10°. A large concentration of 3% density at 270°/50° distorts the symmetry.

D i a g r a m 7:

400 poles of optic axes (0001) in quartz.
Contours 6%, 4%, 2%, 1%.

Locality: 200 meters west of quarry of riebeckite gneiss (10).
Specimen No. and Section No. 10,10.

The diagram shows a girdle with monoclinic symmetry. A maxima with 6% density and situated at 000°/25° is representing the petrofabric coordinate "a". This interpretation is based on comparison with the other diagrams as the general attitude of the rock is the same as that shown in the quarry. The other maxima is situated at 147°/72°.

In all the above diagrams the "a" direction is more or less well represented. This position of "a" — in most cases — is not coinciding exactly with the one interpreted from the diagram 1. This may perhaps be due to the fact that the diagramm 1 shows the poles of s-planes formed by the mafic constituents and the diagrams 2, 3, 4, 5, 6 and 7 represent the optic axes of quartz grains; and also due to the fact that the number of measurements done for the s-planes is small.

Another interesting thing is that the symmetry of the diagrams is not rigid and is in most cases distorted by lower concentrations. It is conceivable that these diagrams represent more than one phase of deformation and it would be necessary, with more samples, to carry out an axial distribution analysis, and study the different phases of deformation.

The quartz shows undulose extinction and also development of "Boehm-lamellae". This shows that the deformation in general is postcrystalline. Deformation during crystallisation as suggested by CORNELIUS (1951) is also possible. This may be seen from the diagrams Nos. 3, 4 and 7. All the diagrams show strong "a—c" girdles indicating a movement in the north-south direction. Considering the history and the general geology of the area it is possible to see that the movement may have taken place in a direction towards north.

Study of Distribution of Trace Elements

In order to know more about the origin of the riebeckite gneiss study of the distribution of trace elements was undertaken. An average sample of this rock from the quarry near Gloggnitz and an average sample of finegrained type exposed in Wolfschlucht were analysed. An average sample of quartz-porphyroid from Maria Taferl was also analysed for comparison.

The determination of K, Rb, Ca, Sr and Ti was done through X-ray fluorescence methods by using a Phillips equipment. The elements Mn, Cr, Ni, Co, V, Zr, Ba, Cu, Sc and Y were determined through spectrochemical methods by using the equipment of the "Jarrell Ash" firm. The details of this method are given below.

Finely crushed material was mixed with a 0.03% Pd-Coal mixture in a proportion of 1 : 1 by using an automatic Wig-1-bug. The conditions of exposure were as detailed below:

Range: 2400/4700 A°. Order: I. Gitter 600. Vorschub: 2 mm.
Spaltbreite: 20 μ. Höhe 1.9 mm. Filter: Sector 8/100%.
Focus 18 Camera 90 mm.
Belichtung: 150 seconds.
PLATES: Rotseitig — Gevaert std. 32 B-50
Blauseitig — Gevaert std. 32 B-50
Entwickler: Gevaert stientia.
Volt 220, Ampere: 10, Schaltung: Anodisch.
Electrode Form: 3, Art: Rw 1, Gegen Form 8 Art: Rw 1.

Calculating board was used to calculate the obtained values. The values were compared with the standard samples G-1, W-1 and S-1 of the Geological Bureau of Standards USA, the Canadian Association for Applied Spectroscopy and the French Standard Sample GR.

The results of the trace element studies are tabulated below:

Sample No. 7 p. Average riebeckite gneiss.
Sample No. 11 p. Northern contact of riebeckite gneiss with the graywackes.
Sample No. 46 p. Average sample of quartz porphyroid from Maria Taferl.

Element	7 P	11 P	46 P
K %	3.70	4.00	3.10
Ca %	0.036	0.031	1.30
Rb ppm.	258	220	130
Sr ppm.	10	10	195
Ti ppm.	800	1100	3200
Mn ppm.	180	80	156
Cr ppm.	—	—	35
Ni ppm.	—	—	15
Co ppm.	—	—	4
V ppm.	5	15	9
Zr ppm.	250	820	65
Ba ppm.	100	180	800
Cu ppm.	32	30	11
Sc ppm.	—	3	5
Y ppm.	—	10	10

The above distribution of trace elements, especially the K/Rb and Ca/Sr ratios, indicate that the original rock may be a trachy liparitic type.

Origin of Riebeckite Gneiss

Before coming to any conclusions regarding the origin of the riebeckite gneiss following points should be considered.

1. Field association.
2. Petrography and texture of the rock.
3. Presence of large crystals of riebeckite showing no inclusions of the matrix.
4. A gradation of the rock into a fine-grained type towards the contact with the graywackes.
5. Absence of any evidence of alkali-metasomatism in the country rocks.
6. Chemical analysis of the rock.
7. Distribution of the trace elements.
8. The mineral composition of the rock.

As regards the origin of this rock two possibilities are to be considered.

A. That they are metasomatically altered sediments rich in SiO_2 and alkalies.

B. That they are metamorphosed alkali granitic rocks.

A: ZEMANN (1951) has suggested that under the influence of soda rich solutions given out by the basic magmas (which are now green-schists), sediments rich in quartz and feldspar were metasomatically altered to riebeckite gneiss. Such an explanation is not quite satisfactory unless an association of this rock with basic rocks is clearly demonstrated. It is possible that under the influence of contact metasomatism brought about by soda rich solutions given out by basic rocks, sediments may alter and development of alkali mafic constituents such as alkali-pyroxene and riebeckite may take place as shown by JUN SUZUKI and YOSHIO SUZUKI (1959) in case of riebeckite-quartz schists in Kamuikotan Metamorphic Complex in Japan. But in the present case H. P. CORNELIUS (1951) has clearly shown that there is no such a relation and more over he points out that the geological connection with the partly soda rich diabases of the Werfener schist as assumed by ZEMANN is totally improbable. The diabases belong to the initial magmas of the alpidic cycle where as the riebeckite gneiss and the graywacke zone doubtless was affected by Variscian metamorphism or perhaps may be Caledonian (Pre-Siluric Sardic Phase). ZEMANN's theory also does not explain the presence of an aplitic marginal zone in which riebeckite and alkali-pyroxene are almost absent.

B: It is possible that these rocks are metamorphosed alkali granitic rocks. Presence of relict structures such as large fractured crystals of riebeckite and alkali-feldspar may be representing the primary porphyritic texture of the rock. The presence of fine-grained aplitic marginal zone is a very good indication for an assumption of an igneous origin of the rock. The chemical analysis of the rock points towards an alkali-aplitic magma type (BURRI-NIGGLI). The field occurrence, petrography, mineral composition and the texture of the rock indicate that this is a metamorphosed quartz-keratophyre rock. Alkali amphibole is stable during epizonal metamorphism and therefore in this case it is easy to consider the intercalation of greenschists and the riebeckite gneiss in the Silbersberg series as an example of epizonal metamorphic "Spilite-Keratophyre Association" as described by TURNER. The study of distribution of trace elements indicate that the original rock may be of trachyliparitic nature.

Conclusion

From the above discussion it is clear that the riebeckite gneiss occurring near Gloggnitz is a metamorphosed quartz-keratophyric rock, a view confirmed from the study of distribution of trace elements.

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