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The Genesis of the Spitzer Gneisses and the Para-Rock Series of the Kamp Valley in the Lower Austrian Waldviertel

Part 1: Geology and structures

(With 1 plate and 16 diagrams)

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Abstract

The studied area represents the western limb of a major syncline with highly metamorphosed gneisses, schists, amphibolites, marbles, and quartzites. These rocks occur in two units: the Spitzer gneisses and the para-rock series which merge into each other without any sharp contact. New nomenclature: the "Dobra complex" and the "Krumau complex" is suggested for both units respectively. The area is mapped on the scale 1 : 10,000. The obvious state of prefered orientations of the principle minerals of the main rock types is studied.

Zusammenfassung

Das bearbeitete Gebiet stellt den Westteil einer großen Synclinale dar und weist hochmetamorphe Gneise, Schiefer, Amphibolite, Marmore und Quarzite auf. Diese Gesteine treten in zwei Einheiten auf: die Spitzer Gneise und die Paragesteinsserien, die ohne ausgeprägte Kontakte in einander übergehen. Neue Nomenklatur: „Dobra Komplex" und „Krumauer Komplex" werden für die beiden Einheiten vorgeschlagen. Das Gebiet wurde im Maßstab 1 : 10.000 kartiert. Die Verhältnisse der gesteinsbildenden Mineralien wurden untersucht.

Introduction

The investigated area covers an almost east-west strip of about 50 km^2 between latitudes 48° 35,13' & 48° 37,27' and longitudes 33° 1' & 33° 9,5', and is to be found on the topographic sheet "20 Gföhl, Wien 1960", with the Kamp river cutting its course in WE direction as a main topographic feature.

The area lies in the western part of the Moldanubian zone of the Bohemian Massif and is composed of the Spitzer gneiss body to the west and the para-rock series to the east. J. CZJZEK (1849 & 1854), F. BECKE (1882), A. MARCHET (1924), L. WALDMANN (1938 a & b and 1949) and A. KÖHLER (1941) dealt with these rocks in a general way as an integral part of the Austrian Waldviertel. They suggested an orthoorigin for the

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Spitzer gneisses, which are constantly intercalated by amphibolite bands and sheets, which are considered by them as younger intrusions of basic magmas.

CH. EXNER (1953) offered valuable observations concerning the gradual transition between the two rock units, together with the occurance of some paragneiss intercalations and a marble band in the body of the Spitzer gneisses at Schöberlberg. He attributed the transitional contact to granitisation due to metasomatic processes. According to him, the amphibolite intercalations in the gneisses are older and might be rests of precambrian formation. He also stated that the Spitzer gneisses might be of pure magmatic origin or a granitization product of the para rock series itself.

The present work is the first part of a series of publications dealing with the genetic problems of these rocks. In this part the geology and structures of both rock units are discussed on the basis of a detailed geological map drawn on the scale of 1 : 10.000 (Plate 1), together with a series of petrofabric analyses. The second part (M. KHAFFAGY, 1969 b) deals with the mineralogy and petrography of these rocks, while the third part (M. KHAFFAGY and E. SCHROLL, 1969) deals with their geochemistry.

General Geologic Settings

The studied area represents a highly metamorphosed rock series composed mainly of gneisses and schists, amphibolites, marbles and quartzites. Also minor intrusions, as fine grained granites, aplites, pegmatites and lamprophyre dikes are occuring.

As shown by the attached geologic map (Plate 1), the area represents two main rock units: A) the Spitzer gneiss body, extending from the contact of the Rastenberger granite pluton to the west to the Genitzbach area, and B) the para-rock series extending from the area around the Genitzbach to the contact of the Gföhler gneiss at the eastern end of the area. Both rock series are having some common geologic features:

1. Both are having the same structural trend, striking NS with a general dip to the east, though some local variations are there.

2. Similarity in lithology is existing as far as the major rock types are concerned.

3. The gradual transition at their contact suggests a strong genetical relation between them.

Consequently, it seems unfair to put a sharp demarcation between the two rock units, than to consider them two members of a major unit which underwent the same course of metamorphism and deformation.

The nomenclature "Spitzer gneiss" seams to be unfortunate, as it is applied to a gneiss body which extends from the Danube valley up to Waidhofen/Thaya (60 km) with a thickness ranging from 4 to 10 km. The name impresses the homogenity and uniformity of the whole body which is not the case. EXNER (1953) recorded the absence of the Fleckamphibolites from the studied area, which were encountered by WALDMANN and others, together with other basic rocks which reserve the eruptive textures, in the gneiss body around Göpfritz and Allensteig. Moreover, the considerable difference in composition of the gneisses from granitic (also aplitic) to granodioritic and sometimes dioritic (WALDMANN, 1952) is worth consideration. Also, the frequent occurrence of typical para-rock intercalations together with marbles which are conformable and concordent with the Spitzer gneisses is another feature crying against the orthoorigin and the homogenity of the Spitzer gneiss rocks. On the other hand, the amphibolites occuring in the studied area, also those belonging to the para-rock series, are not yet proved to be of definite paraorigin. Consequently, the author suggests the following terminology for these rock units: 1. The "Dobra complex" for the Spitzer gneisses and 2. the "Krumau complex" for the para-rock series of the studied area. This might serve for avoiding any confusions especially the genetic indications impressed by former names. This nomenclature will be further applied in this work.

The Dobra complex is composed mainly of gneisses which form with their schistose varieties about 70% of the field exposures. Other rocks are the amphibolites, marbles in the form of intercalations ranging in thickness from some centimeters to a few meters, the reason why these rocks were mapped as one unit. The contact between the Rastenberger granite and the Dobra complex to the west is masked by younger intrusions of finegrained granitic and aplitic dikes which may reach the thickness of 20 m. The contact follows a NS trend with a transition zone of crushed mylonitic granite (25 m) and migmatites (100 m) separating the typical rock types. While the normal Rastenberger granite contains Knaf (alkalifeldspars) porphyrocrysts as big as 2 × 5 cm, the porphyrocrysts in the mylonitic zone do not exceed 1 × 2 cm. The migmatitic zone that follows is formed essentially of banded gneisses due to the alternation of granitic and gneissic bands, not only of megascopic, but also of meso- and microscopic dimensions. These migmatites strike generally NS and dip either vertically or very steep (75°—85°) to E, and grade into an augen gneiss variety with big porphyroblasts of Knaf reaching 3 to 4 cm in length, oriented parallel to the strike of the rock. These rocks are irregularly cut by a set of fine-grained granitic and aplitic dikes with sharp contacts. It is not seldom to find some xenoliths from the country rocks and the Rastenberger granite in these intrusions. From this contact zone eastwards, the Dobra complex occurs in its typical form as regular, more or less rhythmic alternations between gneisses and amphibolites sometimes intercalated with marble bands. It comes to its end around the Genitzbach area where it gradually merges to the Krumau complex, which starts to occur as alternations between paragneisses and schists, marbles, amphibolites and quartzites. The marbles and amphibolites are more flourishing in this complex and acquire greater thickness if compared with those of the Dobra complex. Thickness of 100 m for the marbles and 200 m for the amphibolites are recorded. The amphibolites show a pronounced gradual increase in thickness from west to east. Another feature of this complex is the increase in grain size of its gneisses, schists, quartzites and partially the marbles from fine to medium grained in the western and middle parts, to coarse grained in the eastern part of the complex. At a distance of about 1.5 km in the contact zone to the Gföhler gneiss body, which cuts the Krumau complex very sharply, the whole series is injected by aplitic veins and dikes. This phenomenon is discussed by EXNER (1953), who stated that a similar injection zone lies symmetrically with this, immediately west to the Gföhler gneisses and that both of them might have resulted through the emplacement of the Gföhler gneiss body.

Field Descriptions of Main Rock Types

I. The Gneisses and Schists

These form the major rock type of the area in both complexes reaching about 70% of the Dobra complex and about 45% of the Krumau complex. Some of the field names applied here, after EXNER (1953), are purely descriptive and have no genetical indication.

A. The Dobra Gneisses

These gneisses are further classified in two main groups:

a) The typical Dobra gneisses which represent the major part of the gneiss exposures of the Dobra complex and can be estimated by 80% of the gneisses. The following varieties are recorded.

1. The granitic biotite gneiss is a medium to fine grained, hard and compact gneiss having besides its main constituents (feldspars and quartz) a considerable amount of biotite, hence giving it a granitic appearance. It exhibits an excellent lineation and foliation. Lineation is mainly due to the parallel alignment of the biotite in the s-planes of the rock.

2. The biotite-free aplitic gneiss is comparable with the above mentioned gneiss, but almost biotite-free, finer in grain size and lighter in color.

3. The banded gneiss that results from alternations of thin bands of the two above mentioned varieties in mesoscopic and microscopic dimensions.

4. The augen gneiss is a special case of the granitic biotite gneiss with Knaf augen ranging in length from 1 to 3 cm. Pegmatitic dimensions more than 5 cm are rare. The augen are mostly aligned parallel to the lineation of the rock.

It is to be noted that these gneiss varieties do merge into each other and also in the other gneiss varieties of the Dobra complex described hereafter.

b) The typical Dobra para-gneisses are mainly sillimanite bearing gneisses and schists, two mica or muscovite rich varieties and calc-silicate rocks generally associated with marbles. Besides the already known occurance at Schöberlberg (EXNER, 1953), these findings are recorded by the writer:

1. The major occurance of these rock types extends along the road-wall cut on the road Ottenstein—Dobra from the mouth of the Dobrabach to opposite the Ruine Dobra, intercalating the previously mentioned typical types of the Dobra gneisses. Some of these gneisses are sillimanite bearing whose amounts vary between accessory — at the peripheries — and increase to reach the maximum opposite to the Schloteinbach mouth. These gneisses are highly weathered, if compared with the other varieties, fine to medium grained, yellowish brown in color and relatively more friable. Other para-gneisses are garnet-bearing or graphitic. The whole series is cut by aplitic veins.

2. The second occurance is along the Schloteinbach itself in the form of two-mica and muscovite-rich gneisses and schists. These are highly feldspathic, very light colored and acquire a wide range of grain size from medium to coarse grained, sometimes also obviously augenised.

3. Another new finding is about 1 km NW of Franzen, in the form of mica and two mica gneisses overlying a marble band (15 m). The gneisses are intercalated by biotite schists and are cut by pegmatitic quartz veins. An extension 250 m to the south for this occurance was lately noticed by the author in summer 1968 when a new road cut was done running WE. The same rock varieties occur again in several alternations over 200 m distance. Moreover a 30 cm graphite band does occur.

B. The Krumau Gneisses and Schists

These are the predominating rock types of this complex. They acquire a wide range of composition and show a pronounced rapid change in lithology. However, they are unique in proving to be of definite para origin, occuring in the form of parallel beds, which reserve the stratigraphic nature of the parent rocks. They are formed of the following main varieties, though intermediate varieties do occur.

1. The pelitic gneisses and schists are rich either in biotite or muscovite or in both micas distributed all over the complex and differ in grain size from fine to medium grained in the western side to coarse grained in the eastern contact. Their colors differ according to the dominating mica from dark grayish brown to milky white. Some schists are garnet bearing sometimes with porphyroblasts up to 6 mm in diameter. Sillimanite also occurs in noticeable amounts. Other minerals are feldspars (mainly plagioclase) and quartz.

2. The quartzo-feldspathic gneisses and schists composed mainly of quartz and feldspars very poor in mica. Some of

them are even mica free. Others are very quartz rich forming a transition to quartzites. They often bear garnet but rarely sillimanite.

3. The augite rich gneisses are fine to medium grained, mostly light gray to greenish in color. They acquire an extraordinary grain size at the eastern contact to the Gföhler gneiss, and occur mostly at the contacts of marbles.

4. The graphite and graphite rich schists represent the least abundant types and occur in the form of thin bands intercalating the other rock types. Some of them are composed mainly of graphite, others are graphite rich but very often pyrite bearing.

II. The Amphibolites

The amphibolites in the whole area are ubiquitous and appear whereever gneisses are recognised, constituting the second major rock type. They increase both in abundance and thickness in a WE direction from the Dobra complex to the Krumau complex. In the Dobra complex, they occur in the form of thin intercalated bands and sheets ranging in thickness from a few centimeters to maximum one meter, quite concordant and simultaneously folded with the enclosing gneisses. In the Krumau complex, they occur in the form of thick bands, gradually increasing in thickness in the eastern direction till they reach a maximum thickness of 200 m at the contact to the Gföhler gneiss. They are almost uniform in thickness and persistant along the strike and lie parallel to the lineation of the gneisses. At the contact zone to the Gföhler gneiss, the amphibolites show a remarkable increase in their garnet content.

In the more obviously deformed parts of the gneiss complexes, the amphibolites occur in the form of lenses, boudins, intricately folded forms and sometimes breccias. Their textures vary from granoblastic, gneissose and schistose where most of the amphibolites are distinctly foliated and lineated. The very thin layers and the margins of thicker sheets are finer grained and are more schistose than the cores of the thick sheets. Commonly these schistose margins have a stronger lineation due to the parallel orientation of the hornblende prisms. This phenomenon gives the appearance of relict chilled zones, or it may be due to crushing and incipiant crystallisation during metamorphism.

The difference in thickness of the amphibolites in both complexes seems to be an early premetamorphic phenomenon. There is also no evidence of a third, pre-existing rock type, intercalated with or separating gneisses from amphibolites. Also there is no indication along or across the strike of the amphibolites to a parent rock of a composition that muchly differs from them.

The interlayered form of the amphibolites is typical all over the area. This coupled with the similarity in the bulk mineral composition throughout suggests a common origin for them.

A worth mentioning feature is the occurance of an abnormally thick dike like amphibolite body (15 m) in the Dobra complex opposite to the Ruine Dobra. It cuts the Dobra gneisses together with its amphibolite intercalations discordantly with an angle of 60°. It is also protruding the gneisses with a tongue (9 m) which is nearly concordant with the general strike of the gneiss. It is a black, fine grained, granoblastic and biotite free variety. 300 m to the west of this occurance, there are also two other similar amphibolite bodies in the form of concordant walls (sills?) lying parallel to the local strike. Both are relatively thick (each about 4 m). Between them is a distance of 7 m composed of the typical Dobra gneiss bands (5—50 cm) intercalated and simultaneously folded with the normal amphibolite sheets (5—20 cm). These three occurances may represent a younger generation of amphibolites which differs in origin from the normal amphibolite intercalations.

III. The Marbles

The distinctly layered form of the Krumau complex with its famous marble occurances furnished the earliest clues to its metasedimentary origin. Meanwhile, the occurance of considerable amounts of such marbles in the Dobra complex, may lead to the conclusion that the parent rock of the Dobra complex must have been also formed under similar sedimentary conditions. This is actually the only possibility to explain the occurance of these marbles in the body of the Dobra complex.

The major belts of marbles, insofar as they are known in the studied area, occur in the Krumau series, with special predominance around Krumau town, the Töpenitzbach and along the road Tiefenbach—Thurnberg. In this complex, they are more flourishing and acquire greater thickness than those in the Dobra complex, reaching sometimes 100 m. Their contacts with the associated rocks are fairly straight. It can happen that they capture some boudins from other rock types especially the amphibolites. Minor folds with gentle to moderate plunge are abundant. They show also very often prominent lineation parallel to that of the associated gneisses and amphibolites.

The marbles in both complexes show an appreciable variation in grain size and color. Most of them are fine to coarse grained but some are also coarse grained. Their colors differ from snow white (Töpenitzbach) to gray to dark gray where banded varieties (white and gray) do also occur (Schöberlberg).

The marbles of the Dobra complex occur mainly in the following localities:

1. Around the main meander of the Kamp river opposite to the mouth of Schloteinbach along the road Ottenstein—Dobra dam. Five main bands of marbles can be recognised intercalating the previously mentioned paragneisses and schists. They are quite concordant with the general trend of

the rocks and vary in thickness from 1 m to 10 m. The following sequence can be traced from west to east:

a) Fine grained white compact variety.

b) Medium grained, brownish, highly friable variety with brown mica flakes.

c) Medium grained grayish graphite bearing variety.

d) Fine grained compact variety with greenish bands and spots of forsterite.

e) Fine grained grayish marble band.

2. In the northern part of the area, near Franzen in the previously mentioned quarry in which para gneisses were also discovered. It occurs in the form of medium grained, compact, finely banded, gray marble of about 15 m thickness.

3. In the neighbourhood of Strones in a quarry 200 m in diameter (EXNER, 1968, oral discussion). This marble is milky white, medium grained and intercalated in some places with amphibolite bands.

4. At the mouth of the middle tunnel Dobra-Krumau intercalating an amphibolite band. This is a medium grained, gray, tremolite bearing marble band, about 1 m thick.

5. In the Schöberlberg para-rock occurance in the form of three thin intercalations, similar to that of occurance 4.

East of the Genitzbach, the marbles start to flourish suddenly giving the Krumau complex its stratigraphic and metasedimentary nature, and acquire different compositions, being sometimes graphite, pyrite, augite, hornblende and/or diopside bearing. Siliceous and highly siliceous varieties as a transition to quartzite do occur. These contain quartz either as disseminated grains or as coagulated nodules. Occurances of stinkstone marbles were often detected. At the contact of two marble occurances, in Krumau and at the Töpenitz Graben (EXNER, 1953), two diopsidite bands (1 m & 10 m thick respectively) were detected, composed of big prismatic crystals of diopside reaching 5 cm in length and 3 cm in breadth.

IV. The Quartzites

The quartzites are restricted to the Krumau complex in the form of narrow interlayers with maximum thickness of 50 cm. Virtually, every known belt of marble contains thin laminae and thicker beds of quartzite intercalating the carbonates. It is worth mentioning here that such fine quartzitic intercalations were nowhere recorded in the amphibolites. The quartzites include relatively pure quartz types as well as feldspathic, micaceous, graphitic but never hornblendic. Cross-bedding is not noticeable in them, though it could have been existing prior to metamorphism.

V. The minor Intrusions

The minor intrusions which cut the above mentioned types of rocks in the form of dikes and/or veins are the following:

1. Fine grained gray and pink granites occur with special predomenance at the contact to the Rastenberger granite, otherwise they were seldom detected.

2. Aplitic veins and dikes are widely distributed all over the area especially at the contact to the Gföhler gneisses where they are often ptygmatically folded.

3. The pegmatitic dikes and veins accompany the aplites wherever they occur. A thick pegmatitic quartz vein (50 cm thick) is found behind the Dobra dam at the beginning of the Ottenstein road.

4. Lamprophyre dikes detected in three localities, opposite to the Schloteinbach mouth, near the mouth of the middle tunnel Dobra-Krumau and near Krumau. The first is an odinite 70 cm thick, the second and the third are minette-kersantites and are 50 and 60 cm respectively. The three dikes differ in grain size from fine to middle to coarse grained.

Structural Features

As shown on Plate 2, the rocks strike generally NS with a general dip to the east, forming the western limb of a major syncline whose eastern limb crops out east of the Gföhler gneisses (Exner, 1953). However, local differences in dip and strike are not seldom.

An asymetric anticline in the area is detected opposite to the Schloteinbach mouth. Where the rocks at the western contact to the Rastenberger granite strike NS and dip vertically, the strike in this area has a NW-SE direction with a dip of 30—60° SW. Following the outcrops to the east of this locality, the strike is found to be NE-SW with a dip of 35° SE. From this locality eastwards to the Gföhler gneiss, the general trend of the rocks remain without significant changes, except around the Ruine Dobra where the s-planes exhibit some rotated dirctions resulting in the formation of some local folds reaching sometimes the range of 100 m.

The development of microfolds is commonly observed all over the area especially in the marbles. They are of small amplitudes varying between a few centimeters and 50 cm. Their axial planes show various attitudes, but generally they strike NS and dip either to the east or to the west, sometimes also to the S and very rarely to the N. Their axes are mostly plunging to the S with angles between 20 & 40°.

Together with folding, rupturing of the rocks is commonly exhibited by crush zones indicated by mylonitic bands and joints. Two main sets of joints are predominant, strike-joint and dip-joint systems.

Minor structural features are the ptygmatic folding and the boudinage structures. The ptygmatic folding is mostly represented by aplitic veins in the gneisses and the associated rocks at the contact to the Gföhler gneiss. The boudinage structures are represented by rounded and lenticular segments of amphibolites in the associating marbles and gneisses.

Both rock series exhibit a well defined lineation which is generally parallel to the strike, mostly horizontal, or slightly dipping with 4°—10° either to N or S. Very seldom this dip angle exeeds 30°, as along the Dobrabach and Schloteinbach and in the north along the Töpenitzbach. This indicates local folding of the b-axis of the major fold.

Petrofabric analyses

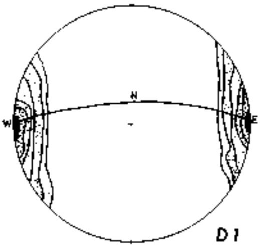
The obvious state of prefered orientation of the principal constituent minerals of the main rock types is studied. The optic axes of quartz, the poles of cleavage in biotite and muscovite, and the optic axes together with twinning lamellae in carbonates (calcite and dolomite) were measured, and represented in 16 diagrams. The first 6 diagrams were kindly offered by G. Deshpande (1966, personal communication).

Diagram 1 represents the poles of (001) cleavage of 300 grains of biotite in an augen gneiss variety of the Dobra gneisses occuring in the big quarry at the western part of the area (Waldreichs). The rock strikes NS and dips almost vertically, with obvious gneissose structure due to the parallel arrangement of biotite, feldspar and quartz. Myrmekitic and perthitic intergrowths are frequent. The diagram shows an excellent maximum with a high density without any girdles or elongated aggregations. The fabric symmetry is axial. The maxima of the biotite cleavage coincide with the pole of the s-plane. This indicates that the mica flakes are concentrated and elongated in the s-plane with their cleavage parallel to it.

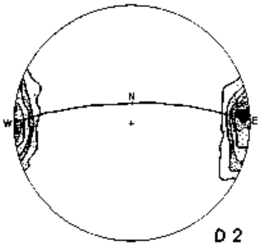
Diagram 2 represents also the poles of (001) cleavage of 300 biotite flakes of a banded gneiss variety of the Dobra gneisses from the same locality as the previous sample with the same strike and dip. The rock is obviously gneissose and composed mainly of quartz, alkali and plagioclase feldspars and biotite. The diagram shows monoclinic symmetry determined by two maxima (major and minor) lying so close together that a & b cannot be exactly constructed.

Diagram 3 represents the optic axes of 200 quartz grains of a biotite muscovite gneiss occuring nearly opposite to the Schloteinbach mouth, striking 145° and dipping 50° SW. It is composed mainly of quartz, feldspars, biotite, muscovite, and sillimanite. The gneissose structure is mainly due to the prefered orientation tendency of the mica flakes and sillimanite aggregates. The diagram shows a girdle with monoclinic symmetry indicated by two close maxima with 5% density each, lying nearly in a symmetrical position with reference to the plane of symmetry. The position of one of them is 012°/60° and that of the other is 355°/35°. This gives the "a" direction parallel to which the quartz grains oriented themselves during deformation. The girdle pole is in the center of the diagram having the position 180°/40°. This means that the lineation is NS with a dip of 40° to the S, which is slightly different from the field measurement and may indicate that local variations have taken place in the attitude of the lineation.

Diagram 4 represents the optic axes of 300 quartz grains in a gneiss occuring 1 km N 52° W of the Ruine Dobra, striking 125° and

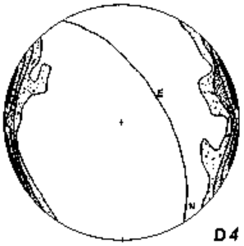


D1



D2

D3



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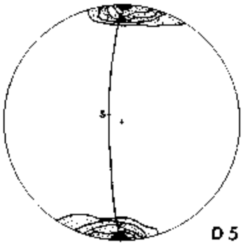

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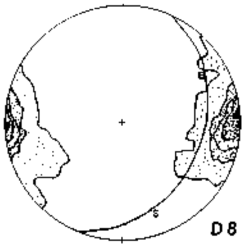


D8

Diagram 1: Contours are 18, 15, 12, 9 and 3%.
Diagram 2: Contours are 14, 12, 8, 4, 2 and 1%.
Diagram 3: Contours are 5, 4, 3, 2 and 1%.
Diagram 4: Contours are 8, 6, 4 and 2%.
Diagram 5: Contours are 20, 16, 12, 8 and 4%.
Diagram 6: Contours are 4, 3, 2 and 1%.
Diagram 7: Contours are 3, 2 and 1%.
Diagram 8: Contours are 20, 15, 10 and 5%.

dipping 38° SW and composed mainly of quartz, alkali and plagioclase feldspars and biotite. The diagram shows girdlelike elongated aggregations with two symmetrically distributed maxima. The fabric symmetry is nearly orthorhombic. Both maxima lie in the "a—c" plane symmetrically on both sides of "c" (147°/50°). The pole of the girdle has the attitude 272°/30°. If the field positions of the s-plane and the fold axis are considered, the pole of this girdle will be the "a" direction. This is a typical example of petrofabric coordinates which indicate that, due to the presence of the former s-plane, the former "a" acted as "b" during later deformation.

Diagram 5 represents the poles of (001) cleavage of 250 muscovite flakes in a banded muscovite- sillimanite bearing gneiss occuring 500 m west of the Ruine Dobra, striking NS and dipping vertically. It has an obvious gneissose structure characterised by alternations of biotite poor and biotite rich bands, and mainly composed of quartz, alkali and plagioclase feldspars, biotite, muscovite, and sillimanite. The diagram shows no girdle or no elongated aggregations. The maximum has a high density, and the fabric symmetry is axial, where the poles of the muscovite cleavages coincide with the pole of the s-plane, indicating the concentration of the mica flakes in the s-plane.

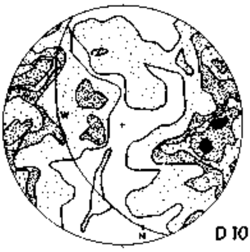
Diagram 6 represents the optic axes of 300 quartz grains in a biotite gneiss occuring near the Dobra dam, striking N 20° E and dipping 42° SE, and composed mainly of quartz, alkali and plagioclase feldspars and biotite. The diagram shows an imperfect girdle. Only some minor maxima are arranged along the circumference, giving a triclinic symmetry. Two close maxima with a density of 4% in the positions 260°/00° and 250°/10° are to be seen, which should lie in the "a—b" plane. This may be due to the presence of a former s-surface which influenced the orientation of quartz axes during the later deformation, suggesting the superimposition of a later deformation on the former s-plane.

Diagram 7 represents the optic axes of 300 quartz grains of a quartzite sample occuring in Schmerbach valley, striking N 15° E and dipping 40° E. It is composed of quartz, plagioclase with biotite, muscovite, tourmaline as accessories. The diagram shows triclinic symmetry with an aggregation of some maxima in the direction E 30°—50° S, which is nearly perpendicular to the b-axis in the field (N 15° E/5° N). Also if the s-plane is considered, this maxima aggregation can be interpreted as the "a" direction. Three other minor maxima with random positions are also present.

Diagram 8 represents the (001) poles of 300 biotite flakes of a paragneiss variety occuring in Krumau, striking N 20° E and dipping 60° E, composed of quartz, biotite and plagioclase feldspars as essentials, and tourmaline, chlorite, opaques, and apatite as accessories. The diagram shows a well developed distribution density, giving a pronounced orientation of (001) biotite poles of N 15° E/60° E. The overoccupied field of the diagram shows a remarkable elongation around a pole of N 50° E/ 45° E. This should be the direction of the "b" axis, but it does not coincide with the field measurement.

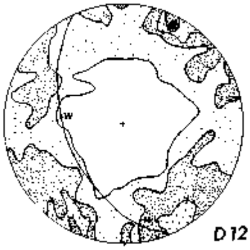
Diagrams 9, 10, 11 and **12** represent the poles of (0001) of 200 dolomite grains (diagrams 9 & 10), and the poles of "f" lamellae of 266 dolomite grains (diagrams 11 & 12) in two perpendicular thin sections from a marble sample respectively. It occurs in Krumau striking 340°/ 38° E, and is composed of dolomite with tourmaline and muscovite as

D9

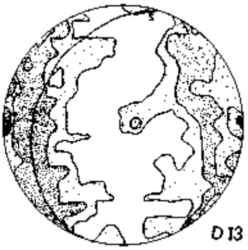


D10

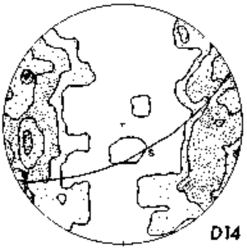
D11



D12

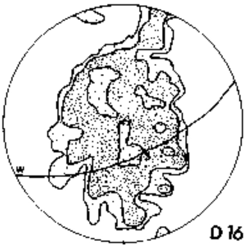


D13



D14

D15



D16

Diagram 9: Contours are 5, 3, 2, 1 and 0.5%.
Diagram 10: Contours are 5, 3, 2, 1 and 0.5%.
Diagram 11: Contours are 5, 3, 2, 1 and 0.5%.
Diagram 12: Contours are 5, 3, 2, 1 and 0.5%.
Diagram 13: Contours are 7, 5, 3, 1 and 0.5%.
Diagram 14: Contours are 7, 5, 3, 1 and 0.5%.
Diagram 15: Contours are 7, 5, 3, 1 and 0.5%.
Diagram 16: Contours are 3, 1 and 0.5%.

accessories. The c-axes (0001) measurements show in one thin section (diagram 9) two maxima lying near 270°/60° E and in the other thin section (diagram 10) one maximum near 220°/60° E. The real difference in the angle between them is 24°. Usually the c-axes maxima orientation of calcite and dolomite coincide with the poles of s-surfaces. In this rock the "a—b" plane is N 25° W/30° E, which approximately coincides with the field measurement which is 340°/38° E. The poles of the twinn lamellae (f lamellae) of the dolomite grains in both thin sections (diagrams 11 & 12) show more or less a random orientation.

Diagrams 13, 14, 15 and 16 represents the measurements done in two perpendicular thin sections of a second marble sample occuring at the northern bank of the Kamp river near Gföhler Hütte, striking N 15° E and dipping 65° E. It is composed of calcite and dolomite with apatite and sphene as minor accessories. Diagrams 13 and 14 represent the measurements of the c-axes of 250 calcite and dolomite grains, while diagrams 15 and 16 represent the plots of $(2\bar{1}\bar{1}0)$ of 247 calcite and dolomite grains in the two perpendicular thin sections respectively. The $(2\bar{1}\bar{1}0)$ pole is the pole of the plane containing the c-axis and the pole of "e" or "f" lamella of the same carbonate crystal.

The c-axes plots show a maximum distribution density of 295°/20° E in diagram 13 and of 285°/20° E in diagram 14. This difference can be due to the existence of other few minor maxima which occupy slightly extended patchs in both diagrams. The zones which are free from any plots assume the trend of the s-surface to be N 15° E/65° E. It is also clear from both types of diagrams that the areas occupied by $(2\bar{1}\bar{1}0)$ are the same areas free from the c-axis. These zones give general trend of the s-plane. The $(2\bar{1}\bar{1}0)$ poles show an elongated concentration in this zone where a maximum is well developed only in diagram 15 with a trend of 084°/50° E. This does not coincide with the "b" trend given by the field measurement.

Relation between Crystallisation and Deformation

In the gneisses studied for petrofabric analyses, also in the quartzite sample, the quartz exhibits nearly always an obvious undulose extinction due to strain effects. It also occurs in the form of elongated crystals with a special orientation, being sometimes one of the reasons of the remarkable gneissosity of these rocks. It is also often found that the twinning lamellae of the plagioclases are clearly bent. The same happens also to the biotite and muscovite flakes, in the biotite and two-mica gneisses studied. In the sillimanite bearing gneiss, the sillimanite is intensively microfolded. Also in the studied marbles, the twinning lamellae of the calcite and dolomite are often bent. These observations indicate that deformation was post crystalline.

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