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Petrology of the Schluchsee and Bärhalde Granite Plutons, Southern Schwarzwald

by

Edward Retief

mit 11 Abbildungen und 5 Tabellen

Abstract:

Two Schwarzwald granites are described petrographically. Both are biotite-muscovite granites with only minor mineralogical differences. Primary plagioclase from the Schluchsee granite is more strongly zoned (An $_{9-37}$) than that from the Bärhalde granite (An $_{0-17}$). Alkali feldspar from both granites exhibits a variety of textural interrelationships with exsolved plagioclase. An apparent exsolution series characterized by an increase in the degree of unmixing and redistribution of albite, is developed. Albite rims around the primary plagioclase and myrmekite are related to the higher anorthite content of plagioclase in the Schluchsee granite. Bleaching of biotite is fairly widespread and this type of alteration has produced secondary muscovite. The geochemical data, considered in conjunction with the petrographic features, suggest a genetic relationship between the granites. They are believed to have originated from a common parent magma, with in situ differentation producing a comparable distribution pattern of minor elements in both plutons.

Zusammenfassung:

Der Schluchsee- und der Bärhaldegranit sind Biotit-Muskovit-Granite mit nur geringen Unterschieden in der mineralogischen Zusammensetzung. Der primäre Plagioklas des Schluchseegranites ist stärker zonar gebaut, als der des Bärhaldegranites (An_{9-37} bzw. An_{0-17}). Die Alkalifeldspäte beider Granite zeigen eine Vielzahl von Gefügebeziehungen mit entmischtem Plagioklas. Eine Entwicklungsreihe mit zunehmender Entmischung und Neuverteilung von Plagioklas ist zu erkennen. Albitsäume um primären Plagioklas und Myrmekit sind auf den höheren Anorthitgehalt des Plagioklases im Schluchseegranit zurückzuführen. Bleichung des Biotits und sekundäre Muskovitbildung sind weit verbreitet. Die geochemischen Daten lassen ebenso wie die petrographischen Befunde auf eine genetische Zusammengehörigkeit der Granite schließen; es wird angenommen, daß sie aus einem gemeinsamen Muttermagma stammen. In situ-Differentation erzeugte in beiden Plutonen ähnliche Verteilungspläne der Nebenelemente.

Anschrift des Verfassers: Dr. Edward Retief, National Physical Research Laboratory, C.S.I.R., Pretoria.

1. Introduction

The Schluchsee (60 km²) and Bärhalde (45 km²) plutons are situated in the Southern Schwarzwald between 750 and 1300 m a. s. l. (Fig. 1). Both plutons are elongated along a northwest—southeast axis, but the Bärhalde is more regularly shaped than the Schluchsee pluton. Low, discontinuous hills separated by shallow valleys — most of which are presumably of glacial origin — form the main topographic features and the main exposures are provided by isolated outcrops, quarries and road cuttings. The total outcrop area probably does not exceed c. 10 %.

The geological map (Fig. 1) has been compiled from data provided by METZ & REIN (1958) and DÖPEL (1963). The Schluchsee and Bärhalde granites (henceforth the abbreviations GSch and GBH will be used) were emplaced during the Upper-Carboniferous Asturian phase of the Variscan orogeny, in a frame of gneisses, Upper Devonian schists and greywacke, and Lower Carboniferous granites. The slightly older GSch is separated from the GBH by the Äule granite porphyry which, although it also dates from the Asturian phase, is later than both granites and it may intrude the GSch. METZ & REIN (1958) mention that the age relationship between the GBH and GSch can be deduced from the fact that where the two granites are in contact with one another, the GSch is impregnated with hematite.

Structurally, the GBH and GSch belong to the northern part of the Southern Schwarzwald granite area which abuts against the gneiss-anatexite basement of the Central Schwarzwald. The Variscan orogeny ended towards the Middle-Permian, after which the area was subjected to epeirogenesis during the Jurassic followed by faulting, rifting and doming during Tertiary and Quarternary times. The prominent structures have a northwest-southeast trend (METZ & REIN, 1958, Figs. 9 and 13).

2. Previous Investigations and Aim of Present Study

Since 1959 HAHN-WEINHEIMER and her co-workers have undertaken an elaborate geochemical investigation of the Malsburg (GM), Schluchsee (GSch) and Bärhalde granite plutons in order to determine the distribution patterns of some 17 elements in these intrusions. JOHANNING (1966) studied the GBH geochemically and investigated 110 composite samples from 79 localities. DÖPEL (1963 and 1966) used 104 composite samples from 67 localities for his geochemical investigation of the GSch.

The author joined Dr. HAHN-WEINHEIMER as a co-research worker in 1967 at the Technische Hochschule Munich, in order to make a petrographic study of the specimens which JOHANNING (1966) and DÖPEL (1966) had

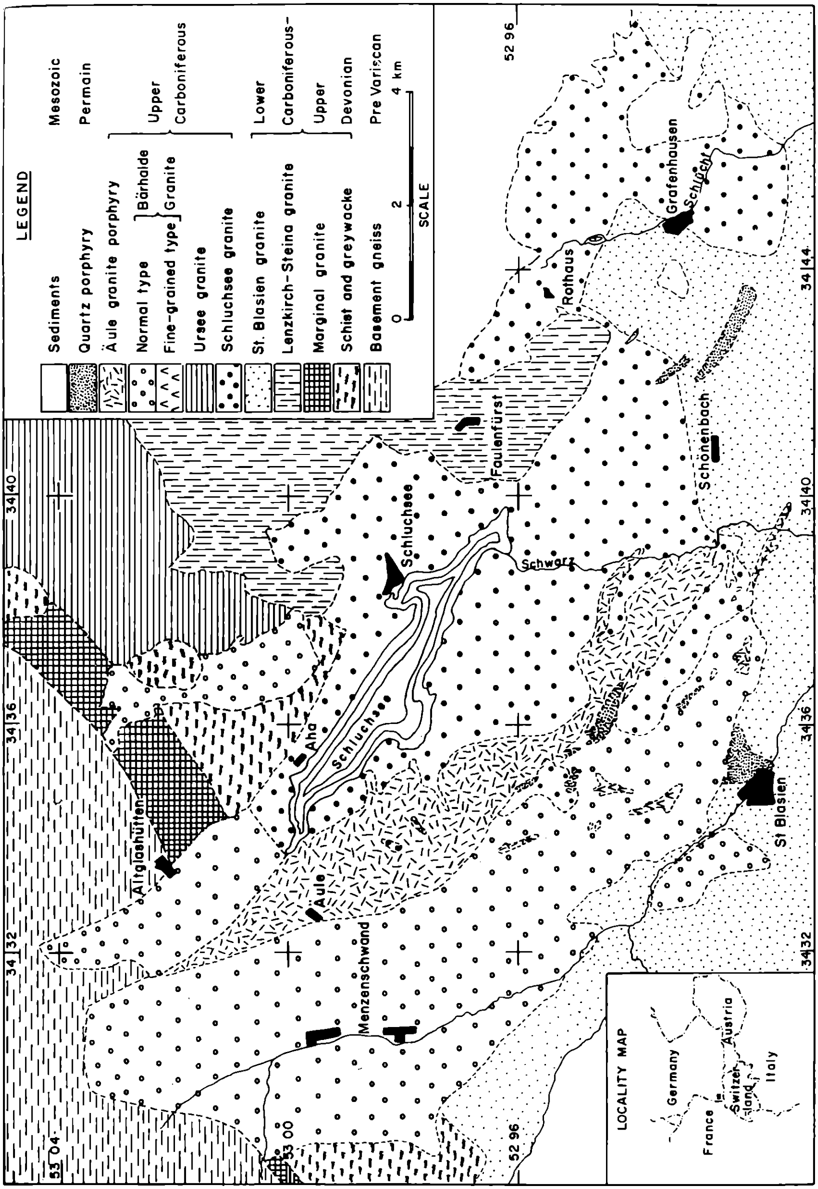

Fig. 1. Geological map of the Schluchsee and Bärhalde plutons. After METZ and REIN (1958) and DÖPEL (1963).

used. During the present investigation some 200 thin sections from these samples were studied. The specimens are from localities that are fairly evenly distributed over both plutons and during the field collecting care was taken to exclude any uncommon textural facies of both granites. The distribution of specimens mentioned in the text is shown in Fig. 2.

3. Petrography

3.1 Introduction and macroscopial features

Although, structurally, the GSch and GBH form two distinct plutons, these granites do not differ sufficiently to warrant separate descriptions. To avoid unnecessary duplication, they are therefore treated together except for the small but important differences listed in Table 4 and referred to where appropriate in the text.

In a fresh hand-specimen the coarse medium-grained[1] GSch varies from light coloured to very pale pink and occasionally also pale brown. Subhedral feldspars, which constitute the bulk of the granite, usually form larger grains than the other minerals, and phenocrysts of alkali feldspar are not infrequently observed. Nests of quartz with a waxy appearance generally carry biotite booklets. On the whole, the GSch has a fairly uniform texture and mineral composition although biotite is perhaps slightly more abundant in specimens from the eastern part. In the area east of Muchenland where the GSch is in directly contact with the GBH, the former carries megascopically visible muscovite and also reddish alkali feldspars.

The bulk of the GBH varies only slightly in its macroscopic features. At one locality a poorly developed pegmatitic facies was observed. Field observations indicate that the Bötzberg porphyry is an aplitic facies of the GBH.

The GBH, light coloured or pale pink, differs macroscopically from the GSch in so far as the former is slightly finer grained (medium-grained), carries no phenocrysts, and the various constituents are evenly distributed throughout the rock. Druses carrying relatively large (up to 2 cm long) feldspar, quartz and tourmaline crystals are sometimes observed in the quarry west of Menzenschwand in the GBH.

3.2 Microscopical features

Microscopically the granites exhibit a granitoid texture and they consist of subhedral primary plagioclase, anhedral alkali feldspar of which the un-

[1] Denotes upper limit of medium-grained (range: 1—10 mm).

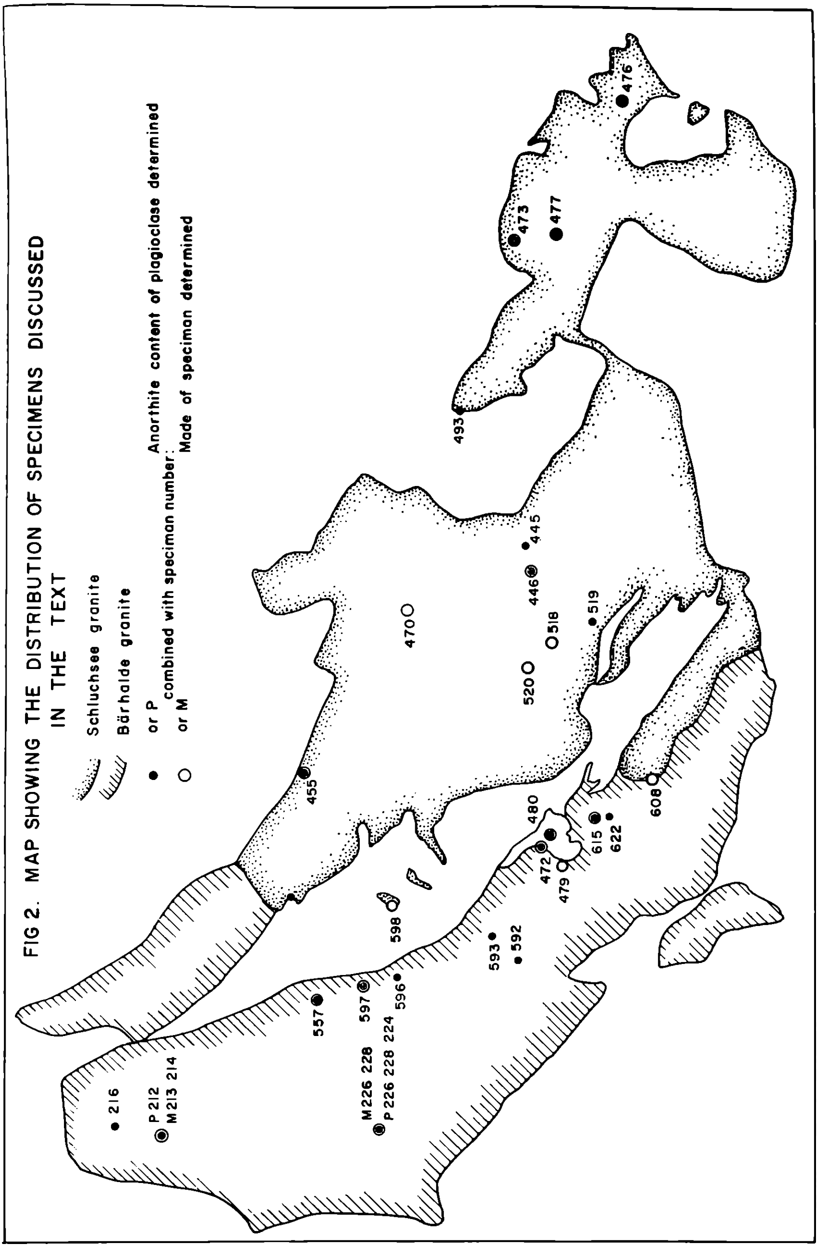

Fig. 2. Map showing the distribution of specimens discussed in the text.

Table 1

Modes of the GSch, GBH

No.	1	2	3	4	5	6	7	8	9	10
Locality No.	446	455	470	473	477	518	520	472	476	480
Primary plagioclase	11.4	15.5	10.3	39.8	16.8	15.9	17.9	18.7	19.1	21.2
Alteration products of primary plagioclase	12.0	11.0	2.7	3.3	1.6	6.9	7.7	4.9	0.8	9.1
Perthite	44.5	43.7	56.3	6.5	32.4	31.4	31.6	32.9	49.1	39.4
Quartz	24.4	22.1	26.7	32.8	38.6	36.8	35.4	35.8	20.5	21.6
Myrmekite	0.2	0.3	—	0.7	—	—	0.2	0.8	4.0	0.7
Micro-pegmatite	2.7	—	0.1	—	1.3	—	—	—	—	—
Biotite	2.1	2.5	0.5	15.5	6.1	3.4	2.9	1.8	3.6	3.1
Bleached biotite	—	—	—	—	—	—	—	0.3	—	0.2
Chlorite	1.4	3.1	0.5	0.6	0.8	3.2	2.4	1.3	2.0	0.4
Primary muscovite	0.3	0.8	2.5	0.1	0.4	1.4	0.6	2.7	0.1	2.3
Sericite aggregates	—	0.2	0.2	—	1.8	0.3	—	0.5	0.7	1.2
Apatite	0.2	0.1	0.1	0.6	—	0.2	0.1	—	0.1	0.1
Topaz	—	—	—	—	—	—	—	—	—	—
Zircon	0.3	0.3	—	0.1	0.1	0.2	0.2	—	—	0.3
Zoisite (?)	0.5	—	—	—	—	—	0.1	0.3	—	0.2
Other accessory minerals	—	—	—	—	—	—	0.1	—	—	0.1
Calcite, fluorite, hematite	—	0.4	0.1	—	0.1	0.3	0.8	—	—	0.1

Note: Specimens: 1—10: GSch; 11—17: GBH; 18—21: "Transition type" of granite; 6, 7, 11, 13 and

and "Transition type" Granite

11	12	13	14	15	16	17	18	19	20	21
213	214	226	228	557	615	592	479	597	598	608
14.3	18.6	23.1	26.6	22.5	15.1	11.3	23.5	22.8	7.1	8.9
2.6	2.6	0.8	1.3	1.3	3.6	2.8	3.9	5.5	2.7	1.2
32.0	33.4	36.9	31.8	27.1	31.0	49.5	20.0	25.3	38.1	32.4
40.1	33.2	29.9	30.5	39.4	38.4	28.0	47.9	36.3	45.6	53.2
—	0.1	—	—	0.2	—	—	—	0.1	0.3	—
—	—	—	—	—	—	2.6	—	—	—	—
3.9	0.2	0.6	1.4	3.7	4.0	3.6	1.7	6.5	0.4	1.8
3.1	3.5	2.7	1.2	0.4	1.6	0.1	0.3	0.2	1.3	0.2
0.4	1.5	1.1	0.5	0.8	0.5	1.5	0.3	1.3	3.3	0.3
2.7	4.9	4.5	6.0	3.1	4.0	0.4	2.4	1.6	1.1	1.3
0.3	1.0	—	0.5	1.5	1.7	—	—	0.1	—	0.4
—	—	—	—	—	—	0.1	—	0.1	—	—
0.6	0.2	0.1	—	—	—	—	—	—	—	—
—	—	0.1	0.1	—	0.1	—	—	0.2	0.1	0.2
—	—	—	—	—	—	—	—	—	—	—
—	—	0.1	—	—	—	—	—	—	—	0.1
—	0.8	0.1	0.1	—	—	0.1	—	—	—	—

19: average values of two thin sections.

mixed plagioclase phase forms a variety of textural intergrowths, quartz, biotite and its alteration products, muscovite, zircon, apatite (very rare in the GBH) and topaz (only in the GBH). The GSch and GBH are thus two-mica granites.

The GSch is inequigranular, coarse medium-grained and carries scattered alkali feldspar phenocrysts. In addition, some specimens from the north-eastern and southwestern parts of the pluton have a limited chilled facies (grains less than 0.5 mm in diameter) of primary plagioclase and quartz developed. The GBH on the other hand, is medium-grained and only slightly inequigranular. In general, the GBH exhibits less textural variations than the GSch. The estimated relative amounts of biotite and its alteration products, and muscovite in different thin sections of the GSch may vary markedly but somewhat unsystematically throughout the pluton. The ratio of these micas is more consistent in the GBH.

The modal compositions of 21 specimens of GSch and of GBH are listed in Table 1. Specimens 18—21 constitute a transitional group of which the geochemical character seems to be intermediate between that of the GSch and GBH. These speciments are treated in more detail on pp. 22—23. The large grain-size of the felsic minerals (range: c. 0.3 to 8 mm) and their local irregular distribution demand much longer traverses than were feasible during the present study where the average traverse length is 420 mm — c. 1300 counted points (point interval: 0.3 mm) for all thin sections. The data in Table 1 therefore provide only an indication of the mineral composition of the granites. A generalized paragenetic sequence of the minerals in the granites is represented diagrammatically in Fig. 3.

3.3 Minerals

3.3.1 Primary plagioclase forms mainly stubby subhedral crystals which are from 0.5 to c. 4 mm long. Although primary plagioclase is the earliest chief mineral to have formed, small quartz grains are not infrequently enclosed. Scalloped borders with both quartz and alkali feldspar seem to indicate limited simultaneous crystallization of these minerals with the plagioclase.

In general, the plagioclase is mildly to strongly zoned in both granites and the estimated compositions listed in Table 2 have been determined on units which may exhibit the following structural interrelationships:

a) Regularly developed compositional zoning with a decrease in the An-content towards the margin of a grain. Reverse zoning is very seldom observed and then it cannot always be verified optically. Table 2 indicates that the primary plagioclase is more calcic and has a larger composition

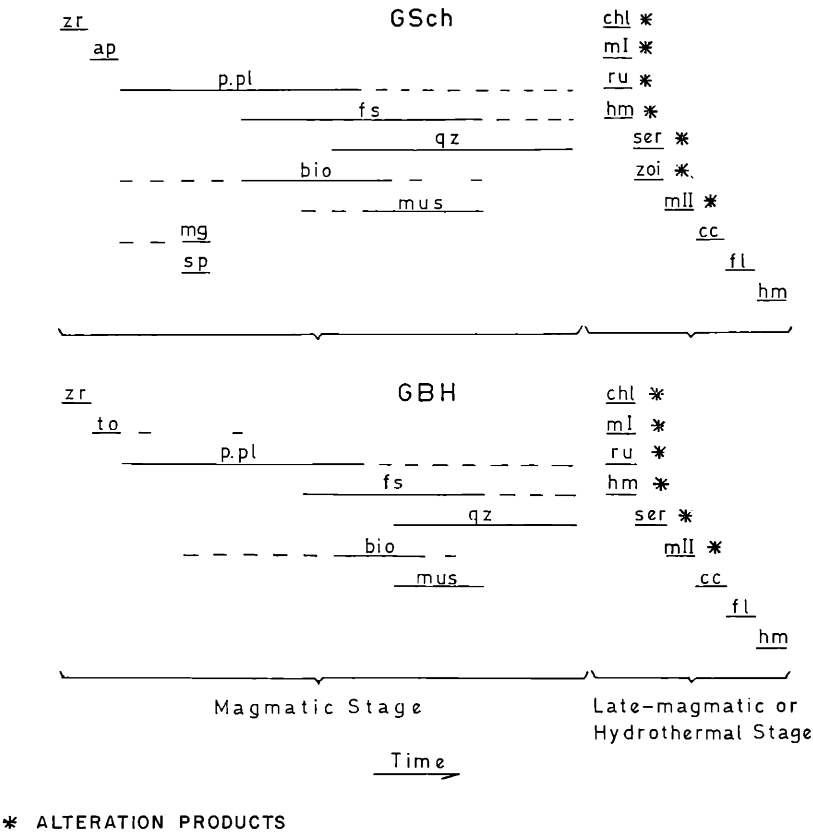

FIG. 3

Fig. 3. Generalized diagrammatic representation of the paragenetic sequence of constituents in the GSch and GBH. The abbreviations are:

zr — zircon	p.pl — primary plagioclase	ru — rutile
mg — magnetite	qz — quartz	— calcite
fs — alkali feldspar	bio — biotite	sp — sphene
mus — primary muscovite	chl — chlorite	zoi — zoisite
ap — apatite	ser — sericite	fl — fluorite
to — topaz		
hm — hematite	mI and mII — secondary muscovite I and II	

range in the GSch (An_{9-37}) than in the GBH (An_{0-17}). The two extreme values, An_{30} and $_{36}$ for the GBH specimens 597 and 592, do not fit into the general pattern. Geochemical data indicate that specimen 597 is one of the "transition type" which should possibly be grouped with the GSch (see p. 23). No explanation can be offered in the case of specimen 592.

METZ & REIN (1958) mention that zoned plagioclase in the GSch has the following composition: core ($An_{c. 13}$); reverse zoning (An_{18-22}) and rim (An_{15-22}). The GBH on the other hand, carries weakly zoned plagioclase (An_{2-10}).

b) Composite grains where early primary plagioclase is resorbed by later more sodic plagioclase. This phenomenon is well-developed in the GSch, but is also observed in the GBH.

c) Primary plagioclase which is enclosed by, or occurs in contact with perthite in the GSch, and is nearly always partially surrounded by a narrow rim (up to 80 μ wide) of albite-oligoclase (An_{0-18}). This phenomenon has been termed "secondary zoning" (Fig. 4). The An-content of the secondary zone is frequently quite different from that of the outermost zone of the original grain. In addition, the secondary zone may be zoned in itself and its twin pattern may be completely different from that of the host primary plagioclase. Secondary zoning is not developed in the GBH.

The character of primary plagioclase in both granites suggests crystallization under disequilibrium conditions. VANCE (1965) suggested the term patchy zoning for igneous plagioclase exhibiting irregular zoning consisting of corroded cores which are embayed and surrounded by more sodic plagioclase. He interprets the development of patchy zones in terms of (a) partial resorption of existing plagioclase as a result of a fall in pressure and (b) renewed crystallization at a lower pressure resulting in the precipitation of more sodic plagioclase.

The cores appear to be much more susceptible to the patchy alteration which affects all but a few of the primary plagioclase grains. Sericite is the most important alteration product and it may be accompanied by chlorite, zoisite (?) (only in the GSch), calcite, fluorite, and also hematite (Fig. 4). The fact that the plagioclase from the GSch is more strongly altered than that of the GBH could be due to the more basic composition of the cores and also to the feldspar in general. It is thus possible that the altered plagioclase cores in this granite were originally more basic than is suggested by the highest values in Table 2.

The plagioclase is characterized by well-developed twinning and twins after simple and parallel laws predominate greatly over those after complex laws. Untwinned grains are, however, not infrequently observed in both granites. In the GSch, myrmekite is extensively developed in plagioclase

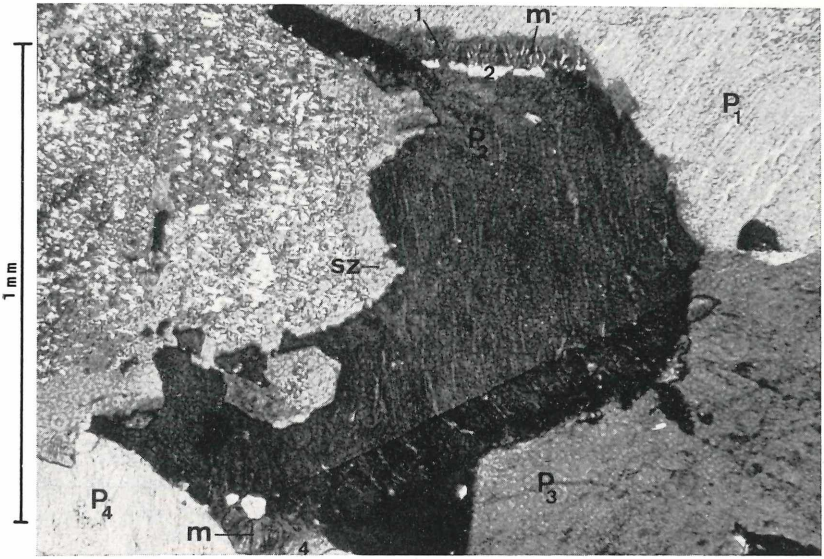

Fig. 4. Myrmekite (m) developed in intergranular plagioclase layers (1 and 4) separating two perthite grains (P_1 and P_2, and P_2 and P_4, respectively), and in an albite-oligoclase secondary zone (sz) which rims a partially resorbed primary plagioclase grain (core altered to sericite). Note double layer of intergranular plagioclase (1 and 2).
GSch; x Nic;

that forms the secondary zones. As the origin of this plagioclase is intimately connected with the development of perthite and also the intergranular plagioclase, these phenomena are discussed with the alkali feldspars.

3.3.2 Alkali feldspar is the most abundant feldspar present in the granites. The grains are generally anhedral or subhedral and range from c. 2 to 8 mm in length, although the sparse phenocrysts present in the GSch may be 4 cm long. In some specimens of GBH, alkali feldspar is intergrown with quartz in a uniform micrographic texture. This type of intergrowth often occurs in a zone surrounding a quartz-free perthite core. Primary plagioclase, biotite, muscovite and quartz may be enclosed by alkali feldspar. On the other hand, perthite is seldom enclosed by quartz.

Although the grains are generally turbid, secondary alteration products are only occasionally developed. Manebach and Carlsbad twins are rarely observed.

The alkali feldspar in both granites forms cryptoperthite and a variety of microperthites of which the following types are the best developed:

a) Cryptoperthite which constitutes optically homogeneous patches in some perthite grains and these areas may be traversed by sparse films and stringers of coarser unmixed plagioclase.

Table 2

Estimated Compositions of Plagioclase

in

A. G S c h

No.	Coll. No.	Anorthite Content (Range)	Type of Plagioclase and Remarks
1	445	0 — 3	Unmixed (blocky perthite)
2	446	20 — 27	Primary
3	455	12 — 32	Primary
		0 — 14	Rim on primary plagioclase; ± myrmekite
		0 — 5	Unmixed
		9	Intergranular
4	472	13 — 32	Primary
5	473	20 — 45	Primary
6	476	10 — 36	Primary
		0 — 11	Rim on primary plagioclase; ± myrmekite
7	477	18 — 32	Primary
		12 — 18	Rim on primary plagioglace; ± myrmekite
		5 — 18	Intergranular and unmixed
8	480	25 — 28	Primary
		3 — 12	Unmixed (blocky perthite)
9	482	9 — 29	Primary
10	493	15 — 37	Primary
11	506	20 — 23	Primary
12	519	18 — 30	Primary

Total number of determinations: 230

B. GBH

No.	Coll. No.	Antorthite Content (Range)	Type of Plagioclase and Remarks
1	212	3 — 6	Primary
2	216	0 — 3	Intergranular
3	224	0 — 16	Primary
		0 — 6	Unmixed
4	226	2 — 13	Primary
5	228	4 — 17	Primary
6	557	2 — 16	Primary
7	592	0 — 36	Primary
8	593	3 — 17	Primary
		1 — 3	Unmixed
9	596	3 — 16	Primary
10	597	13 — 30	Primary
11	615	3 — 12	Primary
12	622	5 — 6	Unmixed (blocky perthite)
13	625	0 — 12	Primary
14	626	0 — 5	Unmixed (blocky perthite)
		0	Unmixed (blocky perthite)

Total number of determinations: 172

C. Summary of Estimated Plagioclase Compositions

	Type of Plagioclase	GSch	GBH
		Anorthite Content (Range)	
1	Primary	9 — 37 (45)*	0 — 17 (30,36)*
2	Rims on primary plagioclase	0 — 18	not developed
3	Intergranular	5 — 18	0 — 3
4	Unmixed	0 — 12	0 — 6

Erratic values outside the general range are listed in brackets. The composition of the plagioclase have been estimated with the aid of orientation charts of BURRI et al. (1967) and with the extinction charts of DEER et al. (1963) for the RITTMAN-zonal-method.

b) Film perthite is formed by narrow (less than 5 μ), regularly oriented, unmixed plagioclase films which may be up to 1 mm long. The exsolution

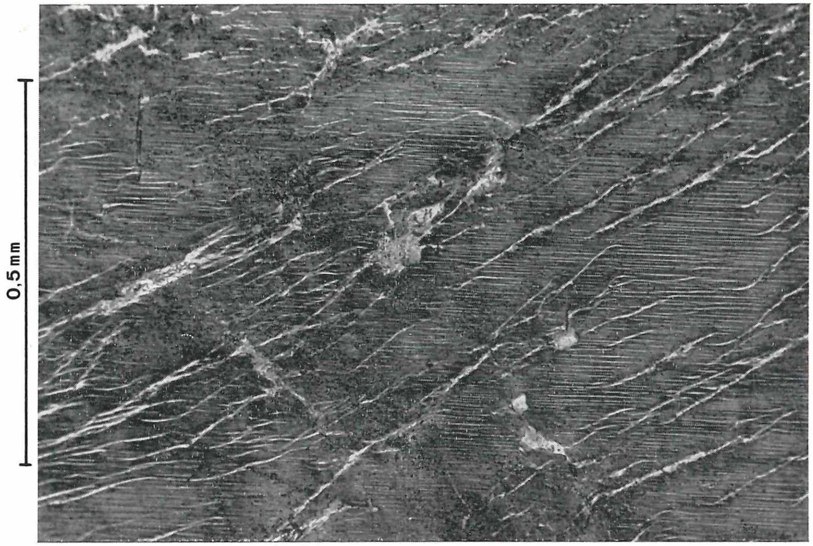

Fig. 5. Film and superimposed perthite. The albite films are less than 2 μ wide. GSch; x Nic;

plane describes an angle of 72° with (001), and is presumably ($\bar{6}01$) (Fig. 5). The lamellae may be extensively or incompletely developed in a particular grain.

c) Superimposed perthite is nearly always associated with the film type and it is characterized by unmixed plagioclase veinlets (up to 50 μ wide) cutting at any angle across the films although always maintaining optical continuity with the latter (Fig. 5). These stringers generally have a subparallel orientation but are sometimes irregulary scattered. The veinlets in Fig. 5 may either change their direction and continue over a short distance parallel to the films, or coalesce with the films themselves.

d) Patch and vein perthites are generally associated with each other and both are much more haphazard in their development than any of the above types. The patches may measure as much as 150 μ in diameter whereas the veins are generally c. 50 μ wide.

e) Blocky perthite is formed by roughly rectangular, elongated patches of plagioclase which are prominantly twinned after the Albite law and irregularly distributed in a potassium feldspar host (Fig. 6). These areas may range from c. 70 x 160 μ to 250 x 300 μ.

Fig. 6. Blocky perthite grain twinned after the Baveno law. The Albite twin planes of the plagioclase in the two units are orientated perpendicular each other. GBH; x Nic;

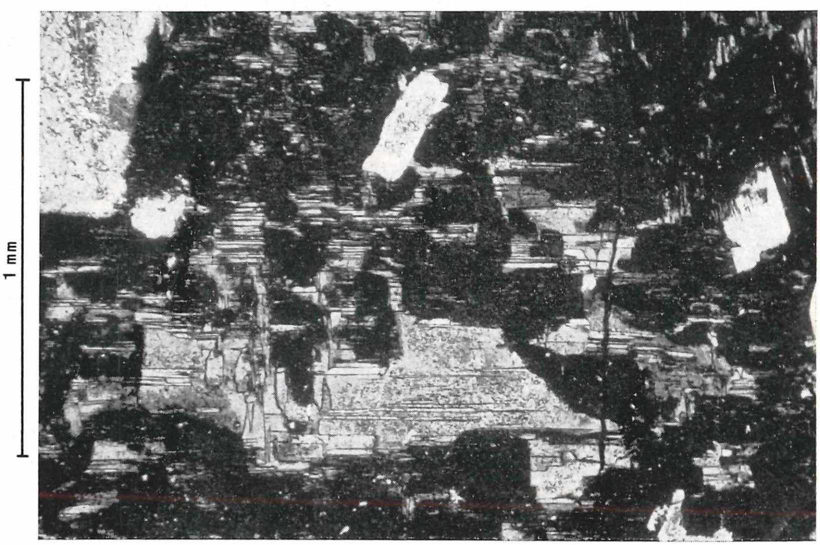

Fig. 7. Antiperthite — note the enclosed primary plagioclase grains (p) which are either slightly resorbed or unaffected. GBH; x Nic;

f) Antiperthite is formed by roughly rectangularly shaped, isolated areas of potassium feldspar set in a predominantly plagioclase host (Fig. 7). The size and distribution of the two feldspars may vary greatly within a grain. Enclosed primary plagioclase grains in the antiperthite may either be slightly resorbed or not affected by the potassium feldspar phase. The plagioclase host is distinguished from the exsolved plagioclase blocks in the blocky perthite by being frequently twinned after complex laws.

g) Intergranular plagioclase is grouped with the perthites only by virtue of the fact that this feldspar represents unmixed plagioclase which has been expelled from its original perthite host (Figs. 4 and 8). The intergranular plagioclase may form either layers which are usually fairly uniform in width (up to 200 μ) and occur at the interface of perthite grains (Fig. 8), or blebs (up to 80 μ in diameter). It is often observed that the intergranular plagioclase forms double layers or rows of blebs at an interface — each set related to a particular perthite grain — and these units are then in optical continuity with unmixed plagioclase in the grain farthest away. This type of relationship is illustrated in Fig. 8.

Fig. 8. Intergranular plagioclase layer (1) which is related to perthite P_1, replaces potassium feldspar of perthite P_2, layer 2, in turn, replaces perthite P_1. Unmixed plagioclase films of P_2 project into the intergranular plagioclase. GBH; x Nic;

The intergranular plagioclase associated with a perthite grain, may selectively replace only the potassium feldspar phase of an adjoining perthite and thus partially envelop the unmixed albite lamellae of the second grain (Fig. 8). The replacing plagioclase may also form a lobe-shaped contact with the replaced perthite (Fig. 8). The composition of this plagioclase has been determined as An_{5-18} in the GSch, and An_{0-3} in the GBH.

The intergranular plagioclase is genetically related to the albite-oligoclase rims around primary plagioclase in the GSch, and both frequently carry myrmekite (Fig. 4). Intergranular plagioclase is developed only at the interface of two perthite grains.

The obliquity ($\triangle$) of the potassium feldspar phase of three microperthites from the GSch has been determined with the aid of a Guinier camera recording. The 131 reflections on all films are slightly broadened which indicates that the bulk of the feldspar is orthoclase with $\triangle = 0$, and a small amount extends to $\triangle = 0.3$. The estimated composition of perthitic plagioclase ranges from An_{0-12} in the GSch, to An_{0-6} in the GBH (Table 2).

Most of the terms used above to define the different types of perthite in the GSch and the GBH, have already been employed by various authors. The terms "superimposed" and "blocky" are, however, introduced for the first time. RUDENKO (1954, Table 2) describes a segregation perthite that carries isometric or irregularly shaped plagioclase blebs and this type seems to resemble the blocky perthite.

TUTTLE (1952) groups the alkali feldspars found in salic rocks into an "exsolution series" which ranges from homogeneous crystals through sub-X-ray, X-ray, crypto- and microperthites, and perthite to discrete grains of albite and orthoclase (or microcline). The alkali feldspars in the GSch and GBH constitute an exsolution series which is characterized by the following stages:

a) Initial stage: increasing degree of unmixing of cryptoperthite → microperthite.
b) Middle stage: increasing degree of redistribution of unmixed plagioclase;
   film and superimposed perthite → vein and patch perthite.
c) Final stage: increasing degree of mobility of unmixed plagioclase which is expelled from its host; unmixed plagioclase → intergranular plagioclase and secondary zones.

Optically homogeneous cryptoperthite unmixes to form a film perthite of which the plagioclase films are regularly oriented. The superimposed perthite is thought to have formed at approximately the same stage or slightly later, through the break-down of cryptoperthite. The subparallel orientation which some of the stringers exhibit seems to indicate that the plagioclase represents original fracture fillings and the cracks could have originated either as the result of contraction of the grains during cooling, or might have been caused by mechanical deformation. EMMONS et al. (1953, Plate 6) describe a film and shadow perthite which is remarkably similar to the present film and superimposed perthites. They believe that fractures were filled with plagioclase partly derived from the immediate walls to give rise to the shadow perthites. According to RUDENKO's classification (1954, Table 2) these are decomposed (German: *Zerfall*) perthites.

The vein and patch perthites are believed to have formed at the expense of film and superimposed perthites by migration and redistribution of unmixed plagioclase. RUDENKO (1954, Table 2) regards these types as segregation perthites.

The blocky perthite differs greatly in concentration, size, shape and distribution of the plagioclase blocks in different grains and the following possible modes of origin should be considered:

a) Unmixing of a homogeneous alkali feldspar.
b) Simultaneous precipitation of both feldspar phases.
c) Incorporation of partially resorbed primary plagioclase remnants.

An exsolution origin for the blocky perthite is strongly supported by the following characteristic features:

a) Some grains show incipient formation of blocky perthite from optically homogeneous cryptoperthite.
b) In blocky perthite grains which are twinned after the Baveno law, the (010) twin planes of the plagioclase blocks in the two components are perpendicular to each other.

On the other hand, rectangularly shaped remnants of corroded primary plagioclase grains are often enclosed by alkali feldspar. Such relationships have been observed in both the GBH and GSch and, in turn, they provide equally strong evidence in favour of incorporation of partially resorbed primary plagioclase as a mode of formation of the blocke perthite. It is, however, rather difficult to determine the composition of these remnants which, if the above interpretation is correct, should agree with the ranges established for primary plagioclase. Simultaneous precipitation of both feldspar phases is believed to be a highly improbable mode of origin for blocky perthite.

In the case of the antiperthite it is necessary to consider the same possible modes of formation as for the blocky perthite. However, the fact that the plagioclase of the antiperthite distinguishes itself from both the primary plagioclase and the plagioclase in blocky perthite by virtue of its type of twinning, suggests that unmixing of a homogeneous alkali feldspar might have played a role. Unfortunately, there is very little literature dealing with this type of intergrowth.

Fig. 8 illustrates a serrated contact between intergranular plagioclase and alkali feldspar P 2 which is caused by perthite lamellae of P 2 being partially incorporated. Unfortunately, observations on the albite-oligoclase rims provide no such clear-cut evidence that the potassium feldspar was replaced, albeit this is suggested by the irregular contact between the plagioclase rim and alkali feldspar in some specimens.

RAMBERG (1962) studied albite rims on plagioclase and intergranular albite at alkali feldspar interfaces in Brazilian gneises, and most of his observations and illustrations are remarkably similar to those described above. He offers explanations for the exsolution of plagioclase from a supersaturated alkali feldspar and subsequent replacement of potassium feldspar, in terms of lattice strain. The present author, however, believes that contraction of the grains upon cooling and the expulsion of plagioclase from its alkali feldspar host could have made available a limited amount of space.

In the case of the albite-oligoclase rims another possible mode of origin should be considered, namely, that albite was added or anorthite was subtracted from the rim of the original primary plagioclase. Although such a mechanism accounts for the compositional zoning of the albite-oligoclase rims (An_{0-18}) the sharp break with the primary plagioclase and also the development of myrmekite within the rim would remain unexplained.

EMMONS et al. (1953) and RUDENKO (1954) both consider that migration of unmixed plagioclase can produce modified perthites. TUTTLE (1952) and RAMBERG (1962) went further in recognizing that unmixed plagioclase can be expelled from its original host. The mobility of unmixed plagioclase in the GSch and GBH is indicated by an anastomosing plagioclase vein that transects two grains of patch and vein perthite. The part of the vein in a particular grain assumes the optical orientation of the unmixed plagioclase in that grain.

Myrmekite intergrowths are fairly widespread in the GSch, but are very rarely developed in the GBH. The following modes of occurrence have been observed:

a) In albite-oligoclase rims of primary plagioclase which is the most abundant type.
   - aa) Although the quartz vermicules are confined mainly to the secondary zones, they sometimes occur also in the primary plagioclase itself (Fig. 4).
   - ab) The vermicules are usually perpendicular to the outer contact of the secondary zone. In some cases the degree of orientation is poor. In cross sections the vermicules appear as small (less than 4 μ), oval-shaped blebs.

b) In intragranular plagioclase where the vermicules are usually poorly oriented.

A number of workers, notably SHELLEY (1964 and 1970), ROQUES (1955, as quoted by RAGUIN, 1965) and DRESCHER-KADEN (1948) have occupied themselves with the origin of myrmekite. The recrystallization of strained quartz groundmass which is enclosed by plagioclase, is the most important feature of SHELLEY's (1970) hypothesis. The granitized rocks and migmatites studied by DRESCHER-KADEN and ROQUES respectively, most probably contain recrystallized quartz and in this major aspect they differ from the GSch.

The following characteristics of myrmekite in the GSch should be taken into account when considering a possible mode of formation:

a) Quartz vermicules are associated mainly with plagioclase (range: An_{0-18}) which has been expelled from perthite.
b) Potassium feldspar is either in contact with the myrmekite or occurs in the immediate vicinity.
c) No recrystallized quartz or evidence of metasomatic action is present.

A modification of existing theories is preferred to explain the formation of myrmekite in the GSch. The expulsion of unmixed plagioclase from the perthite presumably took place at relatively low temperatures and possibly at a stage when hydrothermal fluids became active in the rocks. This plagioclase constitutes the bulk of the quartz-vermicule-bearing plagioclase which reached its present position partly by replacing potassium feldspar. The liberation of quartz and the amount thereof are dependant on the An-content of the plagioclase. Potassium and aluminium released in the process might have been removed by the hydrothermal fluids and could have contributed towards the formation of sericite or secondary muscovite. The virtual absence of myrmekite in the GBH is interpreted as being due to the sodic composition of (An_{0-3}) of the expelled perthitic plagioclase.

The crystallization of the feldspars seem to have followed the same pattern in both granites. The only difference being that a greater degree of equilibrium was attained in the case of the GBH than in that of the GSch.

Primary plagioclase was the first feldspar to have formed under disequilibrium conditions which resulted in zoning and partial resorption of this phase which was later joined by alkali feldspar. Primary plagioclase grains were enclosed and corroded by the alkali feldspar (Figs. 4, 6 and 7). A number of perthite grains in the GSch carry conspicuous bands of plagioclase which seem to represent poorly developed or incipient formation of a rapakivi texture and thus indicate disequilibrium crystallization (STEWART, 1959).

3.3.3 Quartz is the most important mineral after the feldspars and it forms anhedral grains (c. 0.3—3 mm in diameter) which exhibit undulatory extinction. Sutured contacts are developed when grains are grouped in clusters. The quartz seems to have had a long period of formation and crystallized together with primary plagioclase, alkali feldspar and the micas, although the bulk formed after these minerals which may enclose small quartz grains.

In the GSch quartz distinguishes itself by forming a chilled phase in some specimens whereas in others it may be intergrown in a micropegmatitic fashion with alkali feldspar.

3.3.4 Micas. In general, biotite predominates over muscovite in both granites. A cursory examination of thin sections os the GBH suggests that a near colourless, brightly polarizing mica which closely resembles muscovite, is more abundant than biotite. However, a careful study of this mica reveals that it is in fact a bleached biotite (secondary muscovite I) with only a slight trace of pleochroism. In the GSch, on the other hand, the estimated amount of muscovite in thin sections range from very subordinate to roughly equal to that of biotite, or even slightly more in some specimens. This variation does not seem to follow a clearly recognizable pattern within the pluton. Some specimens from the eastern part of the GSch may be enriched in biotite (Table 1, no. 3). The relative amounts os secondary muscovite I and primary muscovite given in Table 1 are subject to error as it is often difficult to distinguish between these two micas during modal analysis.

The following micas have been recognized in the GSch and GBH:

a) **Biotite** forms subhedral flakes which measure c. 0.5 x 1.5 mm and enclose primary minerals such as apatite (only small amounts in the GBH), zircon, iron ore and occasionally also granules of quartz and alkali feldspar. The outlines of the flakes are often embayed because of penecontemporaneous crystallization with primary plagioclase, quartz and alkali feldspar. Biotite in the GSch may enclose quartz poikilitically, whereas in both granites this mica is rarely enveloped by primary plagioclase. Specimens with a chilled facies from the eastern part of the GSch often carry large biotite flakes which have been mechanically deformed.

Biotite in both granites is usually altered in some way or another and the following are the most common alteration products:

aa) Chlorite is the most widespread alteration product of biotite in the GSch, whereas secondary muscovite I is the more important product in the GBH. Chloritization initially affects the host in streaks parallel to the basal cleavage and the characteristic dark brown and light brown pleochroism, and marked birefringence of the biotite are replaced by a pale green, nonpleochroic chlorite with abnormal interference colours. An intermediate stage of alteration is represented by a greenish product with low birefringence. The pleochroic haloes of zircon embedded in the biotite first fade and eventually disappear completely during alteration.

Were it not for the inclusions of zircon and apatite, the chlorite might be mistakenly regarded as a primary mineral instead of a pseudomorph after biotite.

Limited amounts of a second generation of late stage hydrothermal chlorite is present in some specimens of GSch where it forms fine-grained, pale green aggregates which replace sericite in the plagioclase, and also muscovite.

Chlorite is often accompanied by some or all of the following alteration products, namely: rutile, hematite and zoisite (?) (only in the GBH). Chlorite is frequently replaced by sericite.

Table 3

Optical Data on Micas from

A. GSch

1. Muscovite:
   $2V\alpha = 44°—46°$ (8 determinations on 5 thin sections)
2. Biotite:
   $2V\alpha = 0°—22°$ (60 determinations on 12 thin sections)
   One zoned grain gave: $2V\alpha$ = 19° core
   = 8° zone
   = 0° rim

B. GBH (Specimen No. 228)

1. Muscovite:
   $2V\alpha = 36°—50°$ (8 determinations)
2. Biotite:

Grain No.	Optic axial angle ($2V\alpha$) and Dispersion	Pleochroic colours	Remarks
	9.5°		
	10.5° r>v (weak)	Variable; rather dark	
	11.0°	brown and light brown	
	12.5°		
b	11.5°	Pale brown	Slightly bleached
	9.5°	Light brown	
	10.5°		
	12.0°		
	12.0°		

Grain No.	Optic axial angle (2 $V\alpha$) and Dispersion	Pleochroic colours	Remarks
d	18.5° 18.5°	Light brown	Slightly bleached
	18.0° r>v (strong) 18.5° 19.0°	Pale brown to very pale greyish brown	Few chlorite patches; pleochroic zircon haloes
f	18.0° r>v 31.0° r>v	Very pale brown to pale greyish green	Relatively high birefringence; few chlorite streaks
	38.0° 42.0°	Very pale green	Remnants of zircon haloes; few chlorite streaks
h		(i) Very pale greyish green or nearly colourless	Birefringence: 0.0454 (Bleached part)
		(ii) Dark brown and light brown	Birefringence: 0.0642 (Fresh biotite)
		Nearly colourless	Birefringence: 0.0377

ab) Bleached biotite constitutes a complete range of different stages of alteration from fresh biotite with dark reddish brown and light brown pleochroism and normal birefringence, on the one hand, to a mica with extremely pale brownish green pleochroism on the other (Fig. 9). The phases of the different stage of bleaching are often observed in a single grain where they form patches which merge into each other (Fig. 9).

The optical data of some of these phases as well as of muscovite from both granites are listed in Table 3. Although present in both granites, the bleached biotite is best developed in the GBH.

From the above data it seems as though the alteration of biotite through bleaching is accompanied by the following physical changes:

Pleochroism fades from dark reddish brown and light brown through light to very pale brown, to brownish green, greyish green or nearly colourless.

The optic axial angle increases from c. 9.5° to 42° in the GBH and from c. 0° to 22° in the GSch.

The birefringence seems to decrease from c. 0.064 to 0.045.

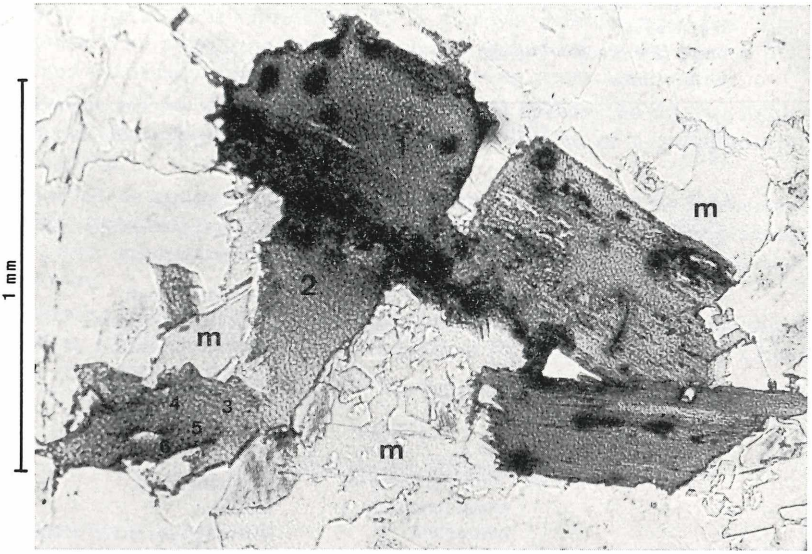

Fig. 9. Bleached biotite which exhibits a gradual change in colour from top to bottom. Dark areas are pleochroic haloes around zircon; streaks are chlorite. Optic axial angle (2Vα) of the biotite varies as follows: 1—18°; 2—18.5° 3—11°; 4—10.5°; 5—12.5°; 6—9.5°. Note the sharp contact between biotite and the surrounding primary muscovite (m; 2Vα = 41°). GBH; x Nic;

MÜLLER (1966) made a detailed study of the physical and chemical changes that affect biotite from granitic rocks under conditions of late magmatic and/or hydrothermal alteration. Many of his microscopic observations and optical data of the alteration products agree with those described above. MÜLLER favours the idea that all the muscovite intergrown with the biotite represents an alteration product of the latter.

b) **Muscovite** is usually subordinate to biotite in both granites, but it may predominate in some specimens of GBH (Table 1). On the other hand, muscovite is relatively rare in GSch specimens which bear evidence of chilling. Its mode of occurrence and relationship towards other minerals enable the recognition of the following types of muscovite:

ba) Primary muscovite forms large flakes up to c. 3 mm in diameter which may occur singly, in clusters or intergrown with biotite and its alteration products (Fig. 9).

Anastomosing stringers or broad veinlets which consist of tattered muscovite flakes, frequently transect alkali feldspar which may also carry irregularly shaped patches or flakes.

The following characteristics seem to suggest that the muscovite is not secondary after biotite but had crystallized directly from the magma:

Large flakes are sometimes twinned on (001), whereas no twinning was observed in the associated biotite.

The flakes are entirely free from zircon or apatite inclusions.

The contact between muscovite and biotite or its alteration products is always sharp and it often seems as though biotite has been replaced (Fig. 9).

Cross-sections of most of the muscovite flakes are roughly equidimensional whereas the biotite flakes are alongated parallel to the cleavage.

Rutile or ilmenite which frequently accompany secondary muscovite, according to MÜLLER (1966), have not been observed in the vicinity of muscovite.

The relationship between the muscovite stringers and enclosed flakes, on the one hand, and alkali feldspar on the other, is not clear and the following possible modes of formation of muscovite should be considered:

Simultaneous precipitation of muscovite and alkali fedspar.

Formation of muscovite from alkali feldspar.

Replacement of alkali feldspar by muscovite.

The patchy and vein-like mode of occurrence of the muscovite is not quite the type of intergrowth that would be expected from simultaneous crystallization. On the other hand, the sericitization of alkali feldspar in the GSch and GBH as well as in the granitic rocks investigated by MÜLLER (1966), is negligible. MÜLLER states that fine-grained muscovite forms from feldspar, albeit his illustrations and subtitles indicate that he clearly refers to plagioclase.

Although the above two possibilities are not entirely ruled out as probable modes of formation, a typical relationship between muscovite and alkali feldspar where muscovite stringers and patches are in optical continuity with a large flake which partially surrounds a perthite grain, strongly suggests replacement of the feldspar by primary muscovite.

bb) Secondary muscovite I — in the present investigation a nearly colourless mica which resembles the primary muscovite in all respects except for the faint colour of the former — is regarded as the end-product of the bleaching of biotite. MÜLLER's (1966) observations suggest that the end-product is in fact a true colourless muscovite and the presence of hematite-ilmenite lamellae, rutile and enclosed zircon and apatite are only criteria which support the secondary origin of this mica.

Some flakes of colourless muscovite in the GSch and GBH carry hematite lamellae and granules which could have formed either from iron liberated during the bleaching of biotite, or as the result of hematitization. It is therefore highly probable that the mica which is regarded as primary muscovite in the GSch and GBH, includes some muscovite which has been formed from biotite, and allowance is thus made for secondary muscovite I.

bc) Secondary muscovite II forms relatively small grains of less than 0.3 mm in diameter which are usually intricately intergrown with fine-grained aggregates of chlorite, bleached biotite or sericite in both granites. It is often rather difficult to identify and distinguish this muscovite from the other colourless micas present because, for example, aggregates of bleached biotite may have a similar mode of occurence. Its mode of occurrence and grain-size serve to identify secondary muscovite II.

Plagioclase frequently carries secondary muscovite II flakes of less than 0.25 mm in diameter, in addition to sericite. Rosettes of secondary muscovite II flakes of roughly the same diameter have been observed in interstitial sericite aggregates.

The origin of this mica is certainly not clearcut and it seems as though both of the following processes might have contributed towards its formation:

Formation at the expense of primary plagioclase.

Recrystallization of primary muscovite, secondary muscovite I or sericite.

If WRIGHT and SULHOF's (1957) upper limit of 0.25 mm for the diameter of sericite is accepted, then most of the secondary muscovite II should be regarded as coarse-grained sericite and it is therefore though that this limit is too high.

c) Sericite is confined mainly to the anorthite rich cores of partially altered primary plagioclase grains but, in addition, it may also form sparse interstitial aggregates in the GSch, or aggregates which replace muscovite and/or bleached biotite in the GBH. Sericite is frequently replaced by hematite.

3.3.5 Zircon and apatite are the two accessory minerals present in the GSch and although they occur mainly in biotite and its alteration products, these accessories are not infrequently enclosed by primary plagioclase or perthite in the vicinity of biotite flakes. In the GBH, on the other hand, zircon is rather widespraed whereas apatite has been observed in only two specimens. Zircon, which is the earlier mineral and enclosed by apatite in a few cases, forms subhedral, anhedral or rounded grains measuring up to 0.4 mm along their c-axes. The characteristic halo which surrounds the grains in fresh biotite gradually fades as the degree of chloritization or bleaching of the host increases, and eventually disappears. Despite their minuteness, a few metamict grains have been observed.

Apatite may form equidimensional or elongated (c. 0.2 mm long) but slightly rounded grains.

3.3.6 Topaz is a fairly common accessory in the GBH, especially in specimens from the Caritas quarry, and it forms rounded, subrounded or irregularly shaped grains ranging from c. 0.15 to 1.5 mm in diameter. Although single grains of topaz are usually set in quartz, feldspar or mica, aggregates are often developed. This mineral seems to be concentrated in the western and southwestern parts of the Bärhalde granite pluton. Topaz is completely absent from the GSch.

The topaz often exhibits a well developed cleavage, has an optical axial angle ($2V\gamma$) of 57°—60°, and is nearly always replaced by veinlets and patches of sericite and another weakly birefringent, fibrous mineral. TRÖGER (1967) states that topaz may under hydrothermal conditions alter to gilbertite which is a fine-grained felt-like sericite.

3.3.7 Sphene is sporadically distributed in the GSch and the very limited amounts usually occur as irregularly shaped grains, which might indicate that the mineral probably formed at a late stage.

3.3.8 Rutile forms needles and fine-grained aggregates which are invariably associated with the other alteration products of biotite in both granites.

3.3.9 Zoisite (?) has been observed in a few specimens of the GSch where it occurs whit the alteration products of either primary plagioclase or biotite. The radial clusters of small elongated prisms (c. 0.1 mm long), which is the usual mode of occurrence, are too minute to permit a detailed microscopical study. The limited optical data available seem to suggest that the mineral is probably a member of the epidote group.

3.3.10 Hematite is widespread in both granites and its mode of occurrence suggests two generations, namely:

a) A first generation of granular and lamellae hematite which is intimately associated with the alteration products of biotite. The hematite has formed from iron which had been liberated during the alteration of biotite.

b) A second generation of hematite grains and veinlets which may replace all the micas and feldspars to a limited extent. This hematite seems to have been introduced into the granite at a fairly late stage, presumably under hydrothermal conditions.

Fresh biotite flakes in the GSch may carry rounded or irregularly shaped, massive grains of an iron oxide which seems to be magnetite.

3.3.11 Calcite is sporadically distributed in the granites and is associated mainly with the alteration products of primary plagioclase although it may also replace biotite.

3.3.12 Fluorite has a mode of occurrence similar to that of calcite, but it is less abundant.

3.4 Discussion

Despite the fact that the GSch and the GBH are petrographically fairly similar, the following differences can generally be observed in thin sections:

Table 4
Comparison Between the Petrographic Features of the GSch and GBH

	GSch	GBH
1. Alkali feldspar:	Phenocrysts may be present	Absent
2. Primary plagioclase:	Strongly zoned (An_{9-37}); well-developed secondary zoning (An_{0-18})	Mildly zoned (An_{0-17}); secondary zoning completely absent
3. Myrmekite:	Extensively developed in intergranular plagioclase and albite-olgioclase rims	Very rarely developed
4. Biotite:	Chloritization is more widespread than muscovitization	Muscovitization is more widespread than chloritization
5. Muscovite:	Usually subordinate to biotite	Usually subordinate to biotite, but nevertheless an important constituent
6. Apatite:	Present in most specimens	Very rarely present
7. Topaz:	Absent	Present in most specimens

After the period of magmatic crystallization, both granites were mildly altered during a late-magmatic stage which was probably followed by a hydrothermal stage. All the mineralogical changes in the GSch and the GBH can be explained in terms of autometamorphic retrograde alteration. In general, very little evidence of metasomatic activity was found and hematite is probably the only mineral which might have been partly introduced in such a way.

In general, it is rather difficult to deduce accurately under the microscope the crystallization sequence of minerals which may, of course, vary slightly in different specimens. Fig. 3 should therefore be regarded only as a rough approximation of the order of crystallization of the minerals. MÜLLER (1966) investigated various granitic rocks in which biotite was the first major silicate mineral to have crystallized. Primary plagioclase in both granites seldom encloses biotite and the feldspar seems to be the earliest major constituent present. Biotite flakes may, however, project into plagioclase grains which indicates that there was an overlap in the crystallization periods of these minerals. The reverse textural relationship has also been observed.

DÖPEL'S mapping (1963) and also the subsequent geochemical investigation of specimens from the GSch and GBH by himself (1966) and by JOHANNING (1966), revealed some samples that seemed to be transitional between the two granites. These specimens (Table 1) which are regarded as representing a "transition" type of granite are characterized by the following features:

a) They are from the eastern part of the GBH, the western part of the GSch, and from enclaves in the granite porphyry (Figs. 1 and 2).

b) It is difficult to decide from a hand-specimen whether these samples belong to the GSch or GBH.

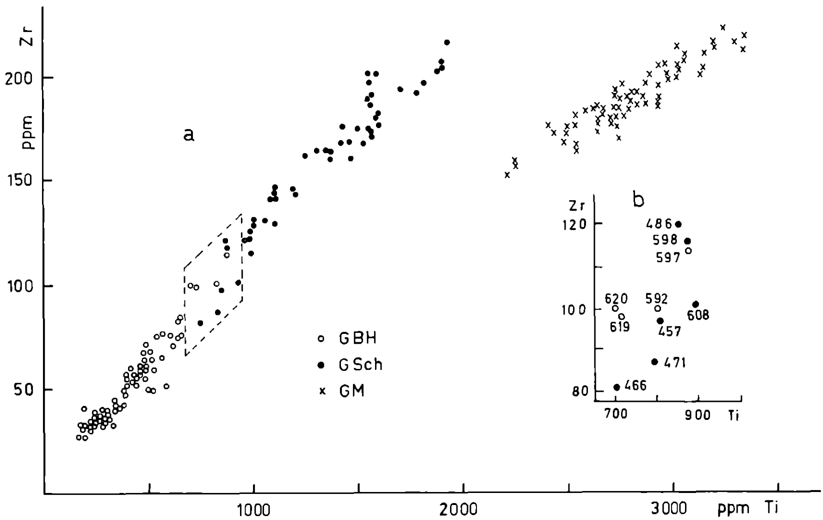

Fig. 10 a. Relationship between Zr and Ti in GBH, GSch and GM.
b Enlarged portion of Fig. 10 a in which specimens representing the "transition" type of granite predominate.

c) In thin sections, however, certain characteristics facilitate their classification, but no unequivocal decision is possible.

d) On the geochemical variation diagrams (Figs. 10 a und 10 b, and 11 a and 11 b) of the GSch and GBH these transition type specimens plot in an area that bridges the respective fields of the two granites.

In a general way, the character of the micas and the alkali feldspar and the presence of apatite (although not always encountered during modal analysis) suggest that specimens nos. 19, 20 and 21 (Table 1) should be grouped with the GSch. In the case of specimen no. 19 which was previously regarded as GBH, the rather high anorthite content of the plagioclase (An_{30} — Table 2) is too extreme for the general range of GBH plagioclase (An_{0-17}). Attempts to determine the plagioclase composition of the other transitional samples were unsuccessful. Specimen no. 18 (Table 1), on the other hand, is petrographically closer to the GBH than to the GSch.

4. Petrochemistry

4.1 Major Elements

A complete chemical analysis of the GSch is provided by DÖPEL (1963), whereas HAHN-WEINHEIMER & JOHANNING (1963) supplemented two partial chemical analyses of the GBH and GM with calculated average concentrations of certain elements. These data together with CIPW norms are given

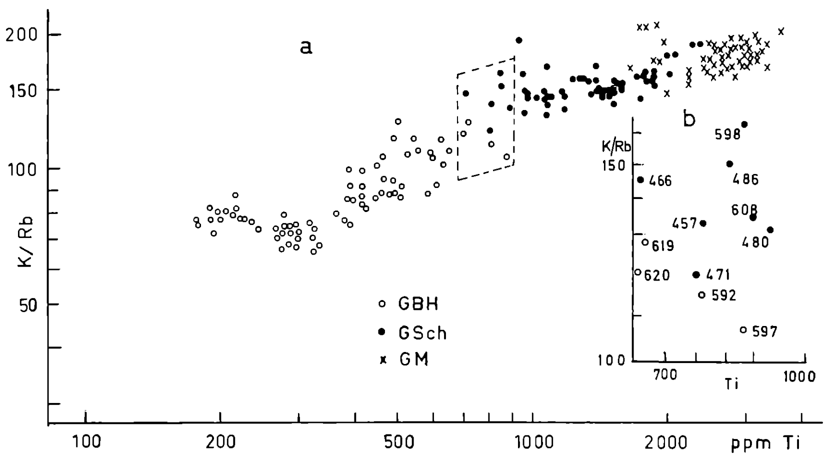

Fig. 11 a. Relationship between K/Rb and Ti in GBH, GSch and GM.
b Enlarged portion of Fig. 11 a in which specimens representing the "transition" type of granite predominate.

in Table 5. The difference in bulk composition of the GBH and Gsch is marked and this is reflected in their norms (Table 5), the modal percentage of certain minerals, e. g. biotite and its alteration products (Table 1), and in the composition of their plagioclase (Table 2).

Table 5

Chemical Compositions and CIPW Norms of Certain Schwarzwald Granites

Wt. % Oxide	GBH*	GSch*	GM*
SiO_2	75.36	71.00	67.80
TiO_2	0.06	0.30	0.45
Al_2O_3	13.41	14.09	15.05
Fe_2O_3	1.27**	1.74	2.69
FeO	—	1.03	—
MgO	0.21	0.63	1.62
CaO	0.39	1.20	1.74
BaO	0.03	n. d.	n. d.
SrO	—	—	0.03
Na_2O	3.55	3.12	3.89
K_2O	4.73	5.49	4.96
Rb_2O	0.06	0.03	0.03
ZrO_2	0.01	0.02	0.02
P_2O_5	0.21	0.09	0.17

Q	36.01	28.77	20.35
Z	—	0.05	0.04
C	2.01	1.14	0.39
or	28.17	32.34	29.39
ab	29.90	26.43	32.94
an	1.06	5.06	7.82
di	0.22	1.57	4.06
mt	1.30	2.45	2.18
hm	—	0.06	—
il	0.10	0.61	0.83
ap	0.34	0.31	0.31
Q+or+ab	94.08	87.54	82.68

After HAHN-WEINHEIMER & JOHANNING (1963).

Total iron as Fe_2O_3; in order to calculate the CIPW norm, sufficient Fe_2O_3 was converted to FeO to build ilmenite and magnetite.

4.2 Minor Elements

The distribution patterns of certain minor elements in the GSch and the GBH have been investigated by HAHN-WEINHEIMER & JOHANNING (1963) and JOHANNING (1966) — both deal with the GBH — and DÖPEL (1963 and 1966) — in the GSch. HAHN-WEINHEIMER & JOHANNING (1968) reviewed the interrelationships of these patterns in the GSch, GBH and GM (Malsburg Granite).

Although the variation in the concentration of minor elements in these granites is significant in itself, the changes cannot be checked easily in terms of mineral composition. For example, REIN (1961) established a systematic variation in the concentration of certain minerals from the fine grained GM only after a painstaking modal analytical study involving some 685 thin sections. Statistically reliable data on the coarser grained GSch and GBH can thus be obtained only by integrating much larger areas.

HAHN-WEINHEIMER & JOHANNING (1968, Figs. 3, 4 and 5; the first two are reproduced here as Figs. 10 a and 11 a) present diagrams showing the relationships between Zr and Ti, K/Rb and Ti, and P and Ti, in the GBH, GSch and GM. The distribution of values suggests a close relationship between the GBH and GSch. The few values from these granites which overlap in the diagrams (boxed areas — enlarged in Figs. 10 b and 11 b) are mainly from specimens of the "transition type" of granite.

5 Conclusions

However inconclusive the observations on the age relationship between the GSch and GBH may seem (METZ & REIN, 1958), these granites were probably emplaced within a relatively short period of geological time. Most of the petrographical differences between these rocks are of a rather minor nature and can, to a large extent, be explained in terms of different conditions under which the granites had crystallized. Geochemical data (Figs. 10 a and 10 b, and 11 a and 11 b), on the other hand, seem to point to a close genetic relationship between the GSch and GBH, and it is thus possible that these granites have originated from a common parent magma. It is thought that differentation of this magma at depth produced initial differences in the bulk composition of the GSch and GBH liquids which were drawn off at different stages. In situ differentation of these liquids followed the same pattern in each pluton, namely Zr, Ti and the K/Rb decrease with progressive crystallization.

Under these circumstances it is reasonable to expect that in situ differentiation produced "extreme fractions" which, for the present purpose, can be regarded as the earliest and latest portions that crystallized in each pluton. If the GSch and GBH originated from a common parent magma, then the latest portion ("extreme fraction") of the GSch should share some geochemical characteristics with the earliest portion ("extreme fraction") of the GBH. Such a relationship is suggested in Figs. 10a and 11b by the limited overlaps between the respective fields of the two granites. In practice, this means that there are some specimens from both granites with fairly similar Ti, Zr and Rb contents, but although specimens from a particular granite share the geochemical character of a few specimens from the other granite (and vice versa), they still belong to their host pluton of which they represent an "extreme fraction" Such specimens also share petrographic features and together they constitute the so-called "transition type" of granite.

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