THE CHEMISTRY AND ORIGIN OF SOME BASEMENT AMPHIBOLITES BETWEEN IVIGTUT AND FREDERIKSHÅB, SOUTH-WEST GREENLAND

BY

FEIKO KALSBEEK AND BERNARD E. LEAKE

WITH 12 FIGURES IN THE TEXT
AND 4 TABLES

Abstract

Chemical and modal analyses of 54 amphibolites, 5 biotite gneisses and 5 horn-blende-biotite gneisses, into which the amphibolites grade, confirm the field and petrographic evidence that the amphibolites were probably basic tuffs and lavas which, when mixed with varying amounts of quartzo-feldspathic sediment, gave rise to the hornblende-biotite gneisses on metamorphism.

Plotted in an alkali-silica diagram 34 samples fall in the field of tholeiite basalt and 20 in the field of alkali basalt while traces of normative nepheline, never exceeding 4 %, occur in only 10 samples.

It is shown that the sporadic occurrence of garnet and diopside and the occurrence of up to 15 % quartz are primarily controlled by the original composition of the samples. Garnet is entirely found in amphibolites with low Niggli mg values (0.36–0.45), diopside in samples with relatively high CaO, while modal quartz increases as mg falls. It is therefore possible that the more quartzose and garnetiferous amphibolites formed from late differentiates of the original basaltic magma, but the possibility cannot be excluded that contamination with sedimentary material has played a role, especially in increasing the modal quartz.

CONTENTS

INTRODUCTION

Large areas in south-west Greenland consist of migmatized gneisses and amphibolites, which KALSBEEK (1970) has investigated in detail in an area of about 120 km² approx. 50 km SSE of Frederikshåb. From this study it was concluded that most of the amphibolites were probably derived from basic lavas and tuffs, which have been partly mixed with
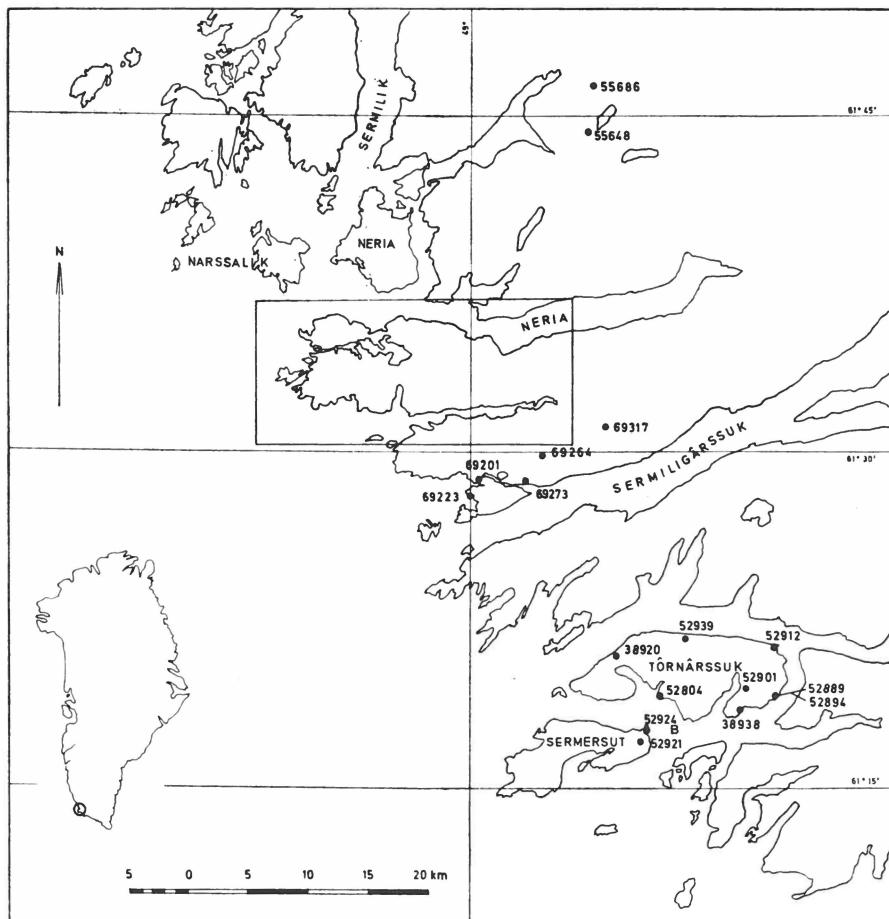

Fig. 1. Location of the analyzed samples in SW Greenland. Inset is the promontory between Neria and Qasigialik fjords. Samples collected from this area are shown in fig. 2.
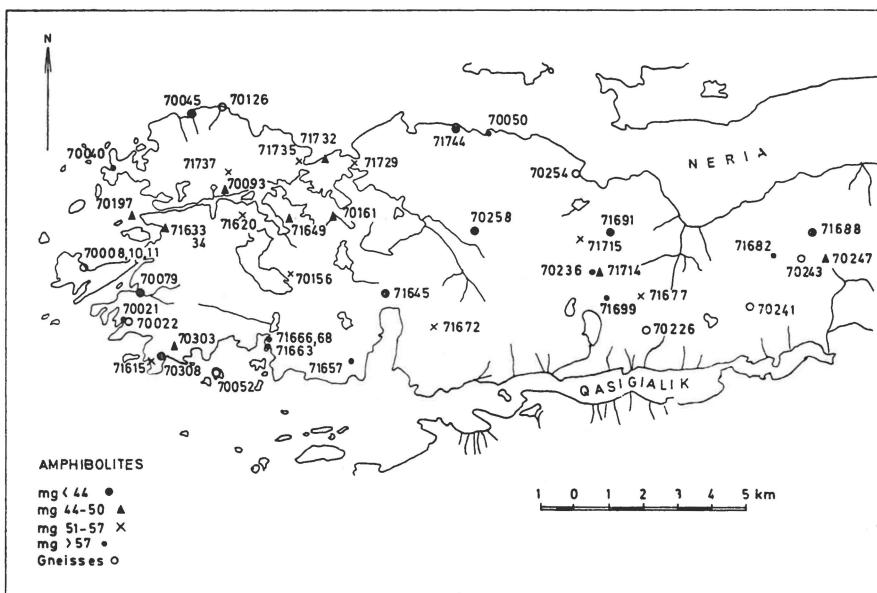
Fig. 2. Location of the analyzed samples collected from between Neria and Qasigialik fjords together with the Niggli mg (Mg/Mg + Fe + Mn) ratio of the samples. No correlation of locality and mg value is apparent.

normal sedimentary material. This is supported by a gradual transition from amphibolites through hornblende-biotite gneisses to fairly leuco-cratic biotite gneisses. The biotite gneisses were supposed to be meta-morphosed quartzo-feldspathic sediments and the amphibolites meta-morphosed basic igneous material.

The present account is concerned with the chemistry of these am-phibolites and 54 amphibolite specimens have been chemically analyzed for major elements and some trace elements. Thirty-seven of the ana-lyzed amphibolites come from the area described by KALSBEEK. The other samples come from adjoining areas, mapped by E. BONDESEN, N. HENRIKSEN and K. THAMDRUP. Figs. 1 and 2 show the locations of the analyzed samples. The chemical analyses were carried out by B. E. LEAKE and A. KEMP, at Bristol University, England, using a Philips fully automatic 1212 X-ray Spectrometer for all elements except FeO and H_2O, which were determined conventionally. As a full account of the X-ray method has been published (LEAKE et al., 1969) no descrip-tion of the analytical method is necessary.

FIELD RELATIONSHIPS AND PETROGRAPHY
OF THE AMPHIBOLITES AND GNEISSES

The area between Ivigtut and Frederikshåb mainly consists of variable banded gneisses and migmatites, in which amphibolites occur as impersistent bands concordant with the foliation of the gneisses. In many outcrops biotite gneisses are interbanded with hornblende-biotite gneisses which have mineralogical proportions in between those of the biotite gneisses and the amphibolites. Different bands of the hornblende-biotite gneisses have different hornblende contents so that samples of hornblende-biotite gneiss can be collected which completely bridge the gap between the biotite gneisses and the amphibolites which also occur within these banded gneisses. Usually the amphibolites are a few metres to a few tens of metres thick and locally they contain ultramafic lenses.

Peculiar rock types, occurring generally as lensoid masses in the gneisses, comprise the so-called 'gabbro-anorthosites' or 'anorthositic gneisses'. These rocks grade in composition from almost pure anorthosite to amphibolite rich in hornblende. They are characterized by very calcium-rich plagioclase and light green (Fe-poor) hornblende. Two of the samples analyzed (E.B. 52889 and F.K. 71715) have affinities with these gabbro-anorthosites.

Especially in the area mapped by KALSBEEK the rocks are strongly migmatized and folded. There the amphibolites often occur as lensoid or angular blocks lying in leucocratic pegmatoid or gneissic material. The contacts between the amphibolites and the surrounding leucocratic veins and migmatite are generally sharp, and give the impression that, during the migmatization, the amphibolite palaeosome in the migmatites was hardly changed in composition.

Table 1 shows the mineralogical composition and some additional information on the analyzed samples. A more detailed description of the different rock types in the area mapped by KALSBEEK is given in another paper (KALSBEEK, 1970).

The modal composition of the samples was determined using a Swift pointcounter and generally 2–4 thin sections per sample. Because of the common conspicuous layering, even in hand specimens, it was some-

times difficult to calculate the overall modal composition of the sample
from the thin sections point-counted. For the same reason it is difficult
to give values for the accuracy of the point-counter results. The number
of thin sections used per sample and the number of points counted are
given in table 1. The thin sections have always been made from rock
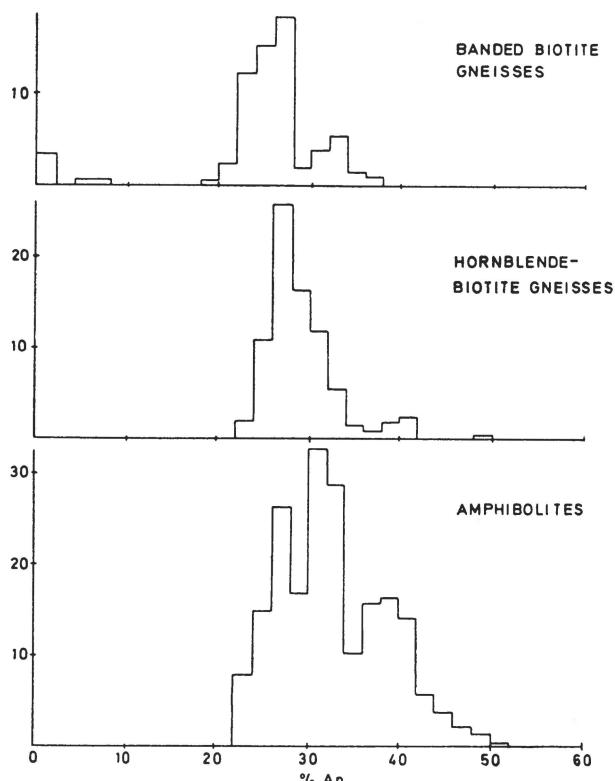
Fig. 3. Histogram of anorthite percentage of plagioclase in amphibolites, hornblende-
biotite gneisses and biotite gneisses.

slices cut directly on both sides of the slabs that were used for the che-
mical analysis. In this way the modal analysis is as close as possible to
the mineralogical composition of the chemically analyzed material.

In all the amphibolites the main minerals are hornblende and plagio-
clase. Variable amounts of quartz, biotite, garnet and diopside may oc-
cur and secondary minerals include epidote, chlorite, sericite, and biotite
after hornblende. The biotite gneisses consist mainly of plagioclase,
quartz and biotite. Minor amounts of microcline may be present. The
hornblende-biotite gneisses consist of the same minerals, with hornblende
in addition; with increasing hornblende content the amount of quartz

in relation to plagioclase decreases. Opaque ore minerals, sphene, apatite, and, especially in the gneisses, zircon and allanite, are accessory minerals.

The hornblende is a common green hornblende, often with a bluish green colour in the γ direction. Sometimes the hornblende cores are green to brownish green (γ), changing towards bluish green in the rim. According to SHIDÔ (1958) and MIYASHIRO (1958) the colour of horn-
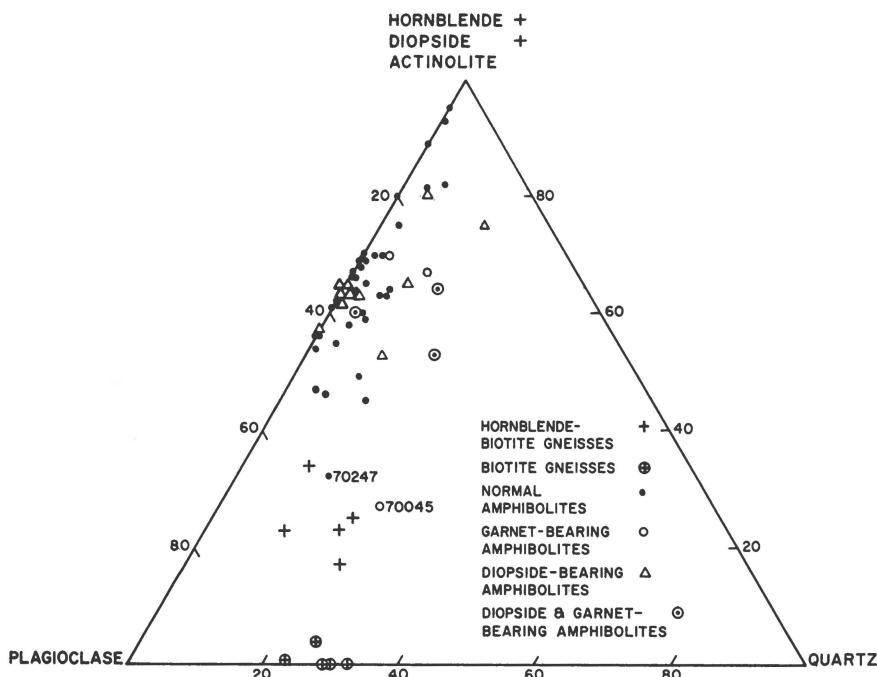

Fig. 4. Plot of modal contents of amphibole plus diopside, plagioclase and quartz in the amphibolites and gneisses. If more samples had been analyzed, the complete gradation from apmhibolite through hornblende-biotite gneiss to biotite gneiss, which is observed in the field, would be apparent.

blende depends on the temperature of formation, brownish green hornblende forming at a higher temperature than bluish green hornblende. The plagioclase is generally andesine in the amphibolites and a calcic oligoclase in most of the gneisses. There is a general decrease in An contents from the amphibolites through the hornblende-biotite gneisses to the biotite gneisses. Fig. 3 is a histogram of An contents determined by measuring $\alpha' \wedge 010$ in crystals cut perpendicular to the crystallographic a-axis.

The association of hornblende and andesine, and the presence of diopside in a number of samples, indicate that the metamorphism was of amphibolite facies. There is no direct evidence however, to show in which part of the amphibolite facies or to which facies series the rocks
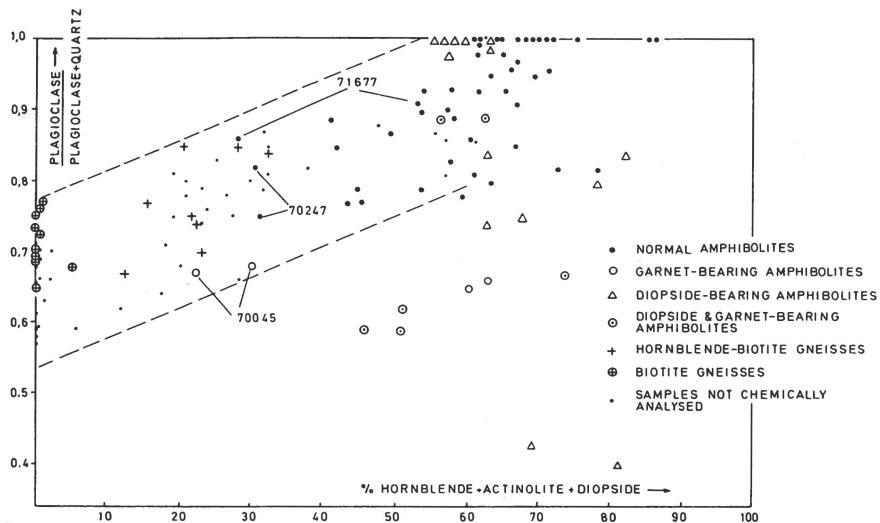
Fig. 5. Plot of amphibolites, hornblende-biotite gneisses and biotite gneisses modal amphibole plus diopside against plagioclase/plagioclase plus quartz.
Of most samples several thin sections were point-counted and the results have been plotted separately in the diagram.

belong and the associated gneisses are not helpful in this matter. The colours of the hornblende, however, indicate that recrystallization has taken place under conditions in the high temperature part of the amphibolite facies, giving rise to brownish green hornblende, and continued under falling temperature giving bluish green hornblende.

The gradual mineralogical transition between the banded biotite gneisses and the amphibolites is well illustrated by figs. 3, 4 and 5. It will be shown presently that chemically the hornblende-biotite gneisses also form a link between the biotite gneisses and the amphibolites. Fig. 5 emphasises the rather larger proportions of quartz relative to plagioclase in some of the garnet and diopside-bearing amphibolites; this will be discussed later.

CHEMICAL COMPOSITION OF THE AMPHIBOLITES AND GNEISSES

Table 2 gives the chemical analyses of 54 amphibolites, 5 horn-blende-biotite gneisses and 5 biotite gneisses. C.I.P.W. norms are given in table 3.

a) Origin of the amphibolites

In previous papers dealing with the origin of amphibolites (EVANS & LEAKE, 1960; LEAKE, 1963, 1964) it has been pointed out that in
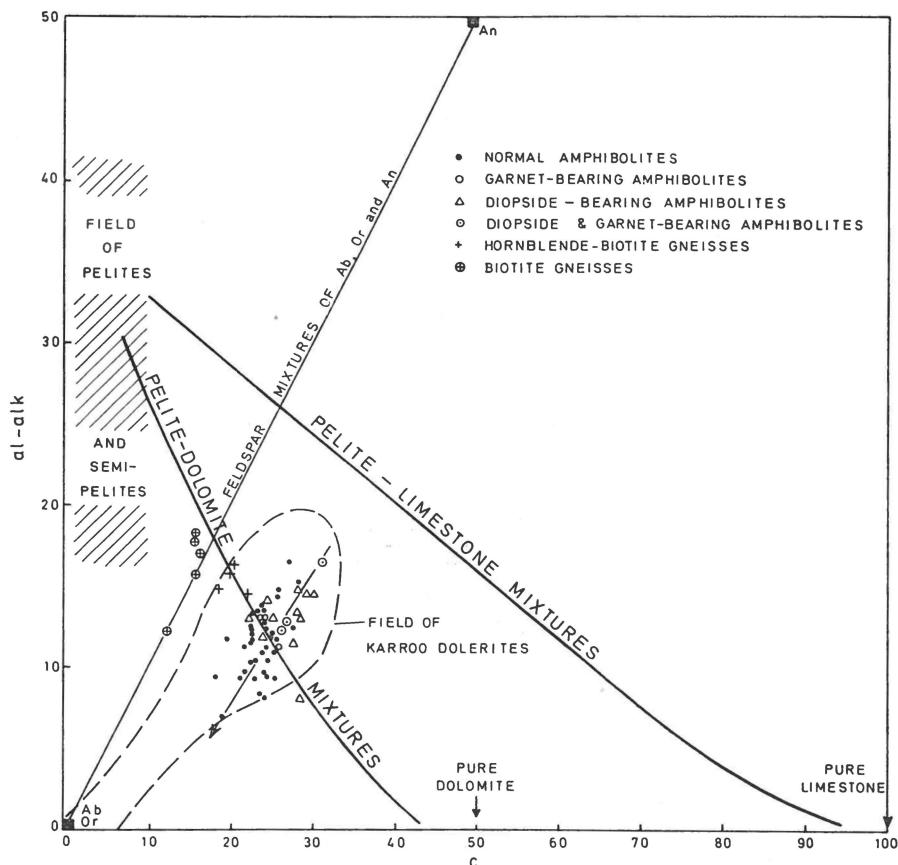

Fig. 6. Plot of Niggli c against al-alk. Amphibolites plotted fall within, or close to, the field of the Karroo dolerites and parallel to their trend of variation, taken as typical of basic igneous rocks. The biotite gneisses fall within the field of quartz-feldspar mixtures and the hornblende-biotite gneisses are intermediate between the amphibolites and the biotite gneisses.

general the most definite distinction between amphibolites formed from
metamorphosed basic igneous rocks and those which might be formed
from dolomite-clay sedimentary mixtures lies in comparing the trends
of variation of certain critical elements which show opposite trends in
igneous rocks from those found in sedimentary rocks.

Fig. 6 is one of a small number of critical plots chosen because they
show trends of igneous and sedimentary variation which are opposed.
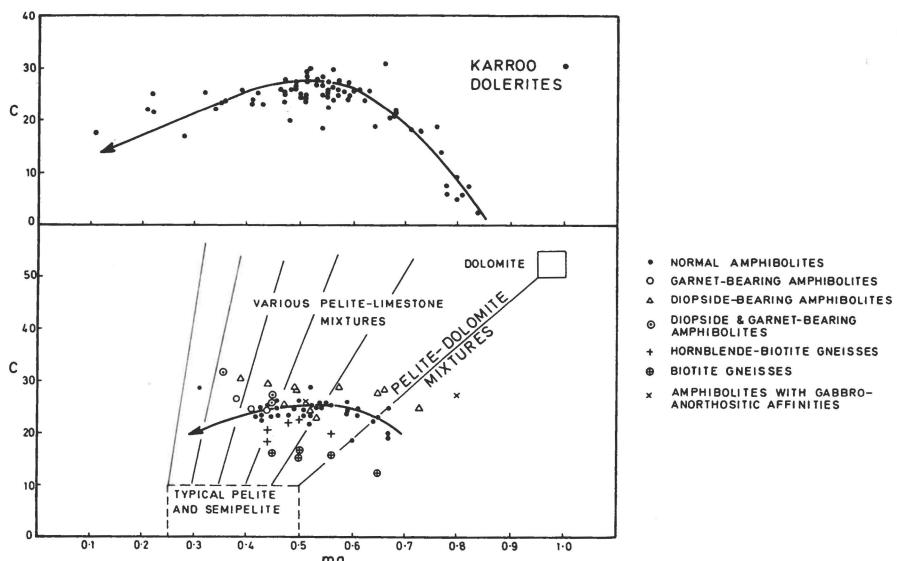
Fig. 7. Plot of Niggli c against mg for Karroo dolerites and the analyzed rocks.
Trend line from Karroo dolerites is partly superimposed on the present data to assist
in comparing the two series which both show igneous variation.

It is clear that the analyzed amphibolites fall almost entirely within the
field found for the Karroo Dolerites (EVANS & LEAKE, 1960, p. 355)
and that they have a similar trend of variation to that of the Karroo
Dolerites, which is almost at right angles to that shown by NIGGLI
(1954, p. 24) for dolomite-clay mixtures. Figs. 7 and 8 also show the
tendency of the amphibolites plotted to roughly parallel the trends
shown by basic igneous rocks and to be opposed to the trends expected
for various mixtures of sedimentary clay with dolomite or limestone.
Moreover the trace elements Cr and Ni have a marked positive correla-
tion with Niggli mg (fig. 9), which indicates control by igneous crystall-
ization and not by mixtures of clay and dolomite which give negative
correlations since dolomite with mg 1.00 is generally lower in Cr and Ni
than pelite. Figs. 6–9 clearly demonstrate that at least most of the amphi-
bolites investigated formed from basic igneous material.

The chemical composition of the rocks obviously does not indicate
whether this basic igneous material occurred as lavas, as tuffs or possibly
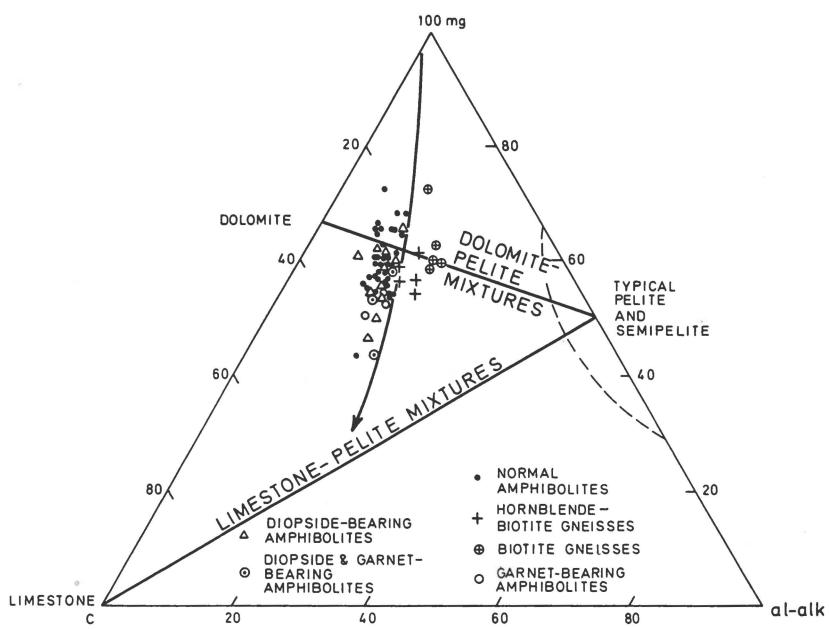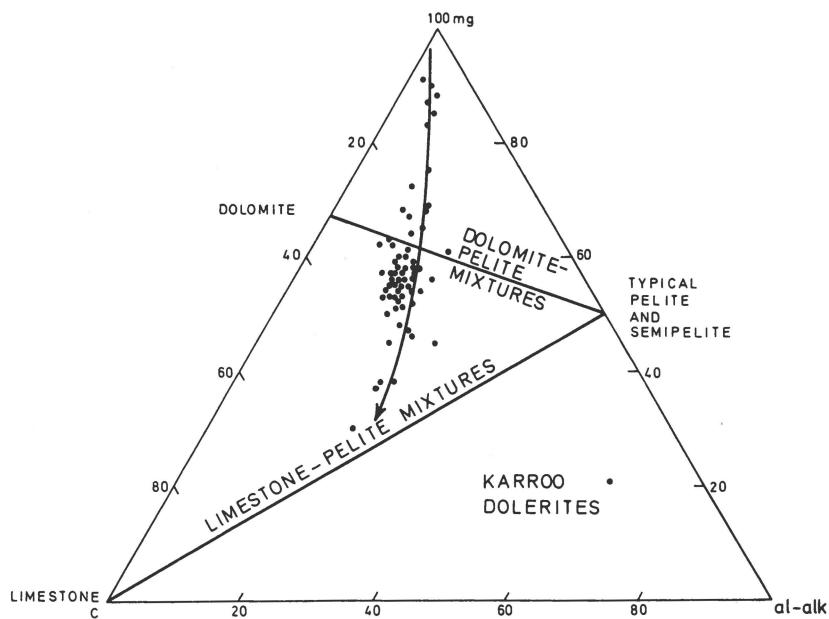
Fig. 8. Plot of 100 mg + (al-alk) + c = 100 for Karroo dolerites and the analyzed rocks. The trend of Karroo dolerites is superimposed on the present data for comparison. Amphibolites show an igneous trend of variation.
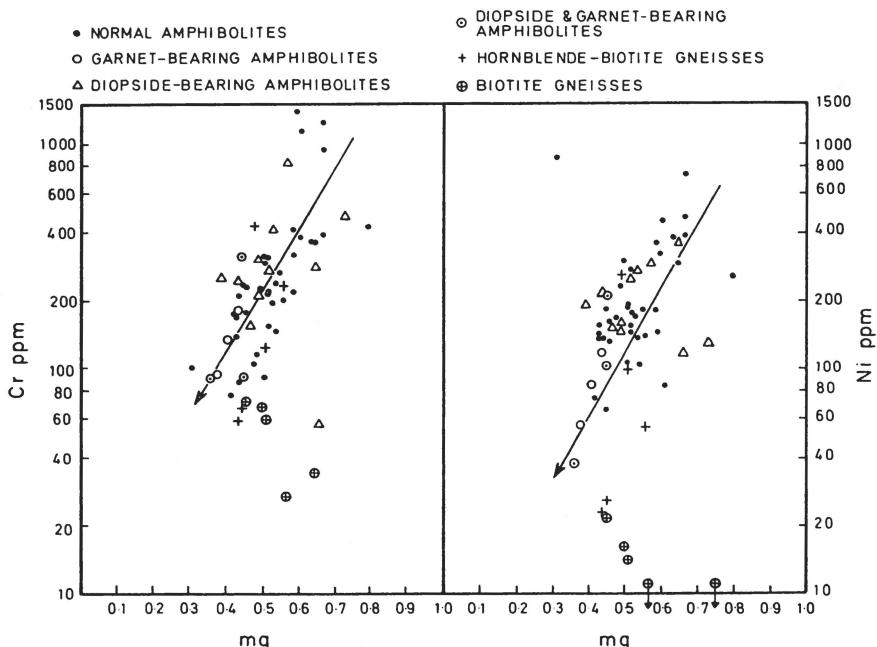
Fig. 9. Plots of Cr and Ni ppm against Niggli mg. Positive correlation is apparent for the amphibolites.

as intrusive sheets and sills. There are, however, strong arguments for the hypothesis that the hornblende-biotite gneisses formed from mixtures of igneous and normal sedimentary material (see next section), and this indicates that loose volcanic material (viz. tuffs or eroded lavas etc.) was present in large amounts during the deposition of the sediments. The clear banding in many amphibolites and hornblende-biotite gneisses fits well into the hypothesis that, although the material is mainly of igneous origin, most of the rocks are metasediments. It is reasonable to assume that, as in most volcanic areas, lava flows, sills etc. have also been present, and that in part the amphibolites are derived from such rocks. Metamorphic segregation may also have given these amphibolites a banded appearance. Only rarely will chemical or petrographical evidence indicate to which group a certain amphibolite belongs.

It is apparent from the norms of the analyzed amphibolites (table 3), using the criteria of YODER & TILLEY (1962, p. 354), that the original magma must have been of tholeiitic character with substantial norma-tive orthopyroxene and generally small amounts of olivine, only rarely reaching 25 %. The general absence of nepheline in the norms and the small amounts present in the few norms that do contain nepheline (maximum 3.67 %) show that the magma was not of alkali olivine basalt type according to YODER & TILLEY's (1962) definition.

Although there are clear dangers in averaging a number of amphibolite analyses which themselves show a systematic range of variation, it is significant that amphibolites from so many areas have average compositions close to those of basalts and the average of all 54 amphibolites analyzed (table 4) on a waterfree basis is closely similar both to the average of 200 amphibolites computed by POLDERVAART (1955) and to NOCKOLDS's (1954) average tholeiite basalt. This average can however be criticised on the grounds that as there is a gradation from amphibolite to hornblende-biotite gneisses which are believed to contain sedimentary quartz and feldspar, some of the amphibolites may very well contain small amounts of sedimentary quartz and feldspar.

If the chemical analyses are plotted on a Kuno alkali against silica diagram such as that used by MACDONALD & KATSURA (1964, p. 87) for the Hawaiian basalts, then the results straddle both the tholeiite and alkali basalt fields (fig. 10). The rather low alumina (only four samples exceed 16 % Al_2O_3) rules out the possibility of a high alumina basalt magma and the distribution of the points is very similar to that found by MACDONALD & KATSURA for Hawaiian basalts.
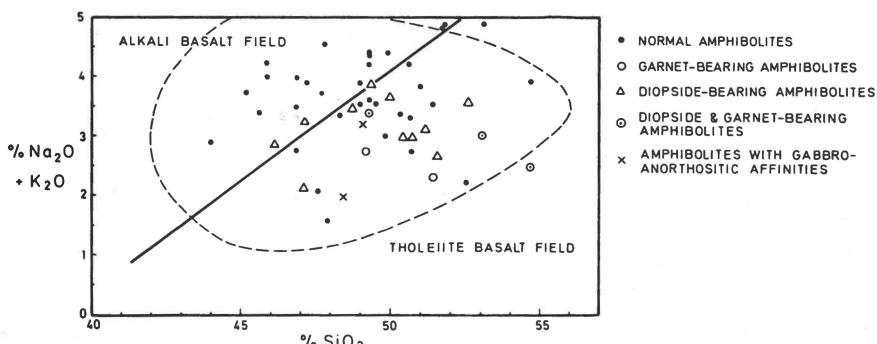
Fig. 10. Plot of $Na_2O + K_2O$ weight percent against SiO_2 weight percent with the Hawaiian alkali and tholeiite basalt fields outlined from MACDONALD & KATSURA (1964, p. 87).

If the amphibolites were derived from basic igneous material, it follows that they have hardly changed their chemical composition during the large-scale migmatization. Many of the samples from KALSBEEK's area represent amphibolites dissected by hosts of leucocratic veins, or even amphibolitic inclusions in leucocratic gneisses or pegmatoid material. If the chemical composition of these amphibolites was appreciably changed they could hardly fit so well the trends of variation in figs. 6–9, nor have an average composition so close to that of other amphibolites and basalts.

b) Origin of the hornblende-biotite gneisses

The modal and field gradation from the biotite gneisses through the hornblende-biotite gneisses into the amphibolites clearly suggests that the hornblende-biotite gneisses are formed from mixtures of basic igneous material and sedimentary material. This is confirmed in detail by the chemistry, for figs. 6–9 show that the hornblende-biotite gneisses are not only intermediate in composition between the amphibolites and the biotite gneisses, but they depart from the trends shown by the amphibolites, being systematically displaced in the direction that mixtures of basic igneous material and sedimentary quartzo-feldspathic material would give. This suggests that either basaltic tuffs were erupted and deposited in a quartzo-feldspathic sedimentary series or else eroded basaltic material was mixed and deposited with the sedimentary material. The increased silica and soda of the hornblende-biotite gneisses and the relatively slight increases in al-alk show that quartz and feldspar were the dominant sedimentary minerals with lesser mica and clay minerals.

c) Origin of the garnet-, diopside- and quartz-bearing amphibolites

Out of the 54 amphibolite samples, 14 contain diopside. It is significant that seven of these samples have over 11 $\%$ CaO, while only 3 diopside-free samples (F.K. 70040; E.B. 52889 and N.H. 69317) out of the remaining 40 samples have over 11 $\%$ CaO. This indicates that the occurrence of diopside is primarily controlled by the rock composition, in particular the lime content.

Only 6 samples contain garnet and these have normal MnO contents so that this oxide is not critical, as it is in some garnetiferous amphibolites. The 6 samples are, however, notably richer in FeO, averaging 9.5 $\%$ compared with 7.6 $\%$ for the 48 garnet-free samples, and poorer in MgO (5.0 compared with 7.9) and Fe_2O_3 (2.8 compared with 4.2); consequently the garnetiferous amphibolites have much lower oxidation and Niggli mg ratios. Thus the six analyses average 0.42 mg, there being a range from 0.36 to 0.45 (fig. 11), while the remaining samples average 0.54 mg. The oxidation ratios range from 0.10 to 0.33, averaging 0.21, which is markedly lower than the average for the 48 other samples which is 0.34. The garnetiferous samples also tend to be poorer in potash (average 0.59 $\%$ compared with 1.07 for the remaining samples) and this has prevented the crystallization of much biotite which would have consumed the FeO, MgO and Al_2O_3 necessary for the garnet growth. Accordingly, it is clear that the presence of garnet, as with diopside, is primarily related to suitable composition. Sometimes, when only accessory amounts of these minerals are present, local compositional
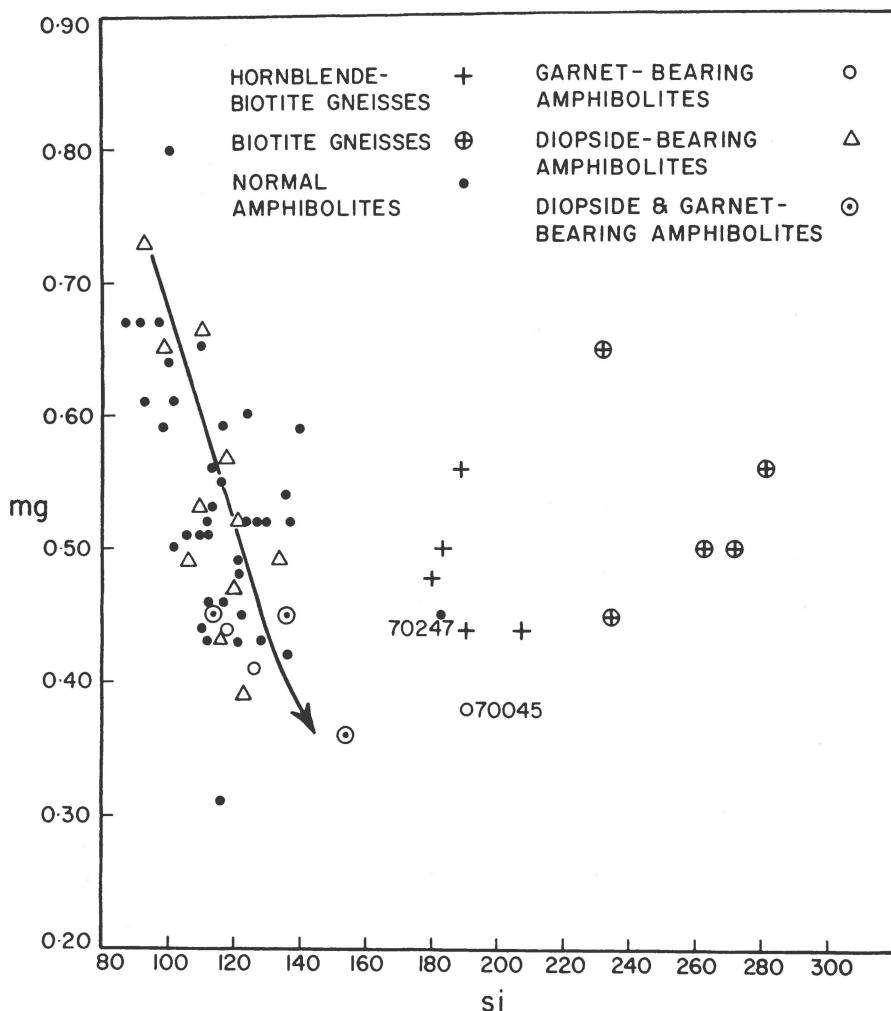
Fig. 11. Plot of Niggli mg against si. Increase of si with decrease of mg is apparent for most of the amphibolites while the occurrence of garnet is restricted to low mg values.

heterogeneity may promote the nucleation of these minerals although the bulk composition of the rock overlaps the range of diopside- and garnet-free amphibolites.

The presence of garnets in samples with low mg values is now familiar, having been found in many metamorphic terraines, *e.g.* Dalradian of Scotland (WISEMAN, 1934, p. 37a), Dalradian of Connemara, Ireland (EVANS & LEAKE, 1960, p. 360) and the Adirondack amphibolites (LEAKE, 1963, p. 1202). It indicates that garnets preferentially develop in late stage differentiates as a consequence of the low thermal stability of iron-rich amphiboles, and the wide stability field of garnet, especially almandine.
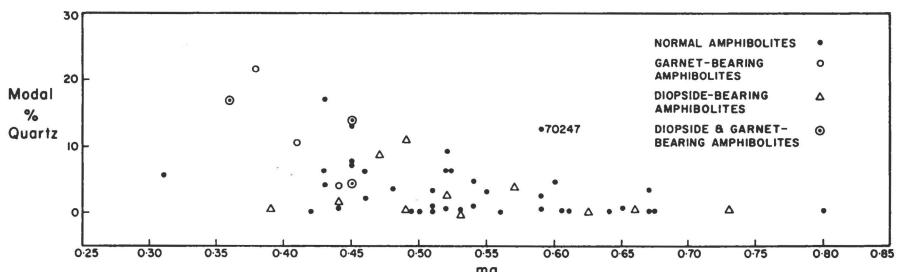
Fig. 12. Plot of modal quartz against Niggli mg showing increasing amounts of quartz with decline of mg.

The occurrence of quartz would also appear to be largely controlled by the degree of differentiation of the original basaltic magma and figs. 11 and 12 show a general increase in Niggli si and modal quartz with decline in Niggli mg. The quartzose amphibolites may therefore be the later differentiates though it is likely that F.K. 70247 and F.K. 70045 have had some admixed sedimentary quartz. Because these samples have normal al-alk values, clay minerals or micas were not included in the sediment but feldspar probably was, for both the al and alk values are exceptionally high. However, as there is a gradation into hornblende-biotite gneisses it is quite possible that some of the other amphibolite samples have also suffered contamination with sedimentary material, especially quartz and feldspar, but not to such a marked extent as these two samples. Therefore the quartz content of the amphibolites is probably not entirely due to original differentiation though this is apparently important.

d) Areal distribution of amphibolites with varying mg numbers

The Niggli number mg roughly indicates the degree of igneous differentiation the original basic rocks had undergone before they became metamorphosed. In some regions (e.g. Connemara, Adirondacks) a decrease in mg in the amphibolites has been detected in passing upwards through the stratigraphy. This can be ascribed to the progressive differentiation of the magma either as later and later extrusions occurred, or else as higher and higher sills and dykes were intruded as the magma worked its way upwards in the crust. It is therefore reasonable to investigate whether amphibolites with different mg numbers concentrate in different parts of the area. Fig. 2 shows the localities of amphibolites with different mg numbers in the area mapped by Kalsbeek and no regular distribution of rocks with comparable mg numbers is evident. If such a regular distribution existed earlier, it must have been destroyed during the intense deformations the rocks have undergone.

OCCURRENCES OF COMPARABLE ROCKS

Amphibolites derived from basic tuffaceous sediments mixed with semipelitic or quartzo-feldspathic sediments will show in the field the characteristics of metasediments, being layered within themselves and interbanded with other metasediments, and may contain rounded zircons (KALSBEEK, 1965). Unmetamorphosed sediments of this type have been described by EDWARDS (1950) from Papua. Here basic sediments, with graded bedding, have the composition of andesites, being eroded and redeposited andesitic tuffs, and reach 15 000 feet in thickness. VAN DE KAMP (1967) has pointed out, in discussing the possible rocks which could on metamorphism give amphibolites, that the erroneous supposition has crept into the literature that basaltic tuffs do not occur in sedimentary rocks (*e.g.* ENGEL & ENGEL, 1962, p. 76). VAN DE KAMP (op. cit.) has, however, listed numerous descriptions of such rocks ranging from NORIN's (1940) account of thin tuff layers in the Eocene of Denmark through MASON's (1949) and SCHOFIELD's (1951) descriptions of basaltic tuff in the Oligocene of New Zealand, to NAYUDU's (1964), BUDDINGTON & CHAPIN's (1929) and BREW & MUFFLER's (1965) accounts of the basaltic tuffs in Alaska and the Gulf of Alaska. In the Scottish Highlands, in the Dalradian rocks, there are thick sequences of basaltic tuff in the Green Bed Series and extensive basaltic pillow lavas and tuffs in the Tayvallich Series. VAN DE KAMP (1970) has convincingly demonstrated the origin of the Green Beds by mixing of basaltic tuff and varying amounts of pelitic material while BARROIS (1889) noted the existence of tuffs deposited with limestone in Finistere, France, and VAN DE KAMP (1968) suggests a similar origin for some of the Grenville para-amphibolites.

Accordingly the sedimentary parents suggested for part of the present amphibolites and for the hornblende-biotite gneisses are not unique or unusual rocks but occur in many other places.

Within the last few years a great many amphibolite series have been chemically analyzed and critically scrutinized by methods similar to the presently used ones. No series has yet been found in which variation from pelite to limestone or dolomite has given true amphibolites, *i.e.* plagioclase-hornblende rocks. It is now clear that the common amphibolites, which are ubiquitous in metamorphic regions, are mostly of basaltic origin, either intrusive or extrusive, and their banding results from either metamorphic segregation or sedimentary layering or both.

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F. KALSBEEK   B. E. LEAKE

Institut for Petrologi   Department of Geology
Østervoldgade 5   University Walk
Dk–1350 København K   Bristol 8 BS8 1TR
Denmark   England

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APPENDIX

Tables 1–4

Table 1 A. *Mineralogical composition of the analyzed amphibolite samples*

Sample number	quartz	plagioclase	hornblende	biotite	garnet	diopside	actinolite	epidote	chlorite	carbonate	sphene	apatite	opaque	zircon	allanite	N	comp. plagioclace % An.
E.B. 38920 (2)[1] ...	..	33	56	1.9	..	+	4.8	1.3	+	..	2.4	+	0.3	..	..	1600	39–50
38938 (2)	4.1	25[2]	68	2.0	+	..	..	..	0.3	..	+	+	0.2	?	..	1600	28–46
52804 (2)[1] ...	..	37	53	1.6	..	..	7.4	+	..	+	0.1	+	0.3	..	..	1900	–
52889 (2)[3] ...	..	39	61	0.1	..	..	+	+	..	..	..	..	+	..	..	1600	
52894 (1)	3.1	21	72	2.8	..	..	..	+	..	..	+	0.1	0.4	..	..	1400	27–29
52901 (2)[1] ...	..	34	54	3.1	..	+	7.6	+	..	+	+	..	+	..	..	2000	–
52912 (2)[1] ...	0.4	42	53	3.5	..	..	+	+	0.3	0.7	+	+	+	..	..	1600	37–38
52921 (2)[1] ...	11	35	52	2.5	..	+	×	+	+	..	+	+	+	..	..	2000	–
52924 B (2)[1] ..	..	40	50	8.6	..	..	..	0.4	+	..	+	+	0.1	..	..	1600	–
52939 (2)[4] ...	..	18	71	10	..	..	+	0.2	+	+	+	+	+	..	..	2000	37–38
K.T. 55648 (2)	5.5	11	80	..	..	..	..	+	..	..	1.7	0.1	1.4	..	..	1600	40–50
55686 (3)[1] ...	0.3	6.1	83	..	..	..	..	0.4	10	..	..	0.3	+	?	..	1300	–
N.H. 69201 (2)[1] ...	1.0	43	52	0.4	..	..	×	2.1	+	..	0.7	..	0.1	..	..	1600	26–28
69223 (2)	2.7	32	58	1.5	..	1.1	×	3.2	..	..	+	+	0.2	?	+	1600	25–27
69264 (2)	0.5	30	65	0.5	..	..	+	1.9	+	..	0.9	+	+	..	..	1400	25–27
69273 (2)[1] ...	3.4	40	38	1.6	..	..	13	2.5	+	0.1	0.4	0.1	+	..	..	1900	41–46
69317 (2)	6.1	33	57	2.1	..	..	+	0.5	+	..	0.1	+	0.3	..	..	1600	27–31
F.K. 70021 (2)	..	33	51	0.3	..	6.4	4.0	4.7	..	..	0.1	+	+	..	..	1600	42–60
70040 (2)	..	4.5	85	5.8	..	..	+	2.2	+	..	0.9	0.8	+	+	+	1600	37–40
70045 (4)	22	44	24	4.8	1.3	..	..	0.2	+	..	+	0.4	0.9	+	+	3200	29–32
70050 (2)[1] ...	4.4	32	54	8.4	..	..	..	1.2	..	+	0.1	+	+	..	+	1600	–
70079 (2)	17	26	47	+	0.9	1.0	+	3.0	..	..	3.0	0.5	0.9	..	..	1600	42–48
70093 (4)	13	22[2]	63	0.1	0.1	+	..	+	..	..	+	0.1	0.2	+	+	3400	27–40
70156 (4)	4.6	46[2]	46	0.4	..	..	+	1.5	..	..	+	0.2	+	+	+	3200	30–36
70161 (2)	0.5	28[2]	58	1.0	..	..	7.5	4.0	..	..	0.2	+	0.1	..	..	1600	28–45
70197 (3)	7.0	28[2]	62	0.4	..	..	..	..	+	..	+	0.2	0.9	+	+	2400	18–42
70236 (4)	..	9.1	72	17	..	..	+	0.7	..	..	+	+	+	..	..	3200	26–27

Sample																
70247 (4)[5] ...	13	51[2]	31	0.1	..	..	+	3.7	..	..	0.5	0.2	+	?	+	2960	26–32
70258 (4)[6] ...	0.2	35[2]	45	..	..	14	+	2.9	..	..	1.0	0.1	0.3	..	..	3250	24–36
70303 (2).....	6.1	26	55	9.0	..	..	..	0.9	+	..	1.8	+	0.2	..	+	1600	24–26
70308 (3).....	10	20[2]	62	..	6.4	..	×	+	..	..	+	+	0.4	..	..	2400	32–45
71615 (2).....	1.1	33[2]	65	+	..	..	..	0.1	+	..	0.1	+	0.1	..	..	1600	20–45
71620 (4).....	2.9	30[2]	59	0.1	..	..	3.4	4.0	+	..	0.1	0.1	+	..	..	3200	23–36
71633 (2).....	4.3	34[2]	54	..	+	5.2	+	0.8	..	..	0.3	+	0.5	..	..	1600	32–45
71634 (2).....	1.3	34[2]	50	+	..	14	+	0.5	..	..	0.3	+	+	+	..	1600	33–40
71645[1]	×	××	××	+	..	..	..	×	×	..	+	+	+	..	..		—
71649 (2).....	8.8	25	61	+	..	4.1	+	+	..	..	+	0.2	+	..	..	1600	32–36
71657 (4).....	3.4	13[2]	74	8.5	..	..	..	..	+	..	+	+	0.1	..	..	3200	24–31
71663 (2).....	+	29[5]	65	5.5	..	..	+	+	..	..	..	+	+	?	..	1600	30–40
71666 (2).....	..	42	48	+	..	7.3	0.4	1.2	..	..	..	0.1	0.2	..	..	1600	38–45
71668 (2).....	12	41[2]	40	+	..	..	4.4	1.6	..	..	+	+	+	+	+	1600	27–33
71672 (2).....	0.5	33	66	0.2	..	..	+	0.2	..	..	+	+	+	..	..	1600	27–30
71677 (3).....	5.9	44	43	5.4	..	..	+	0.5	+	..	0.7	+	+	..	+	2400	24–29
71682 (2).....	..	27[2]	61	11	..	..	..	+	+	..	+	+	+	..	+	1600	30–39
71688 (2).....	1.7	27[2]	67	2.0	..	..	+	0.2	+	..	1.4	0.1	0.2	..	..	1600	25–29
71691 (2).....	6.1	30[2]	61	1.0	..	..	..	0.4	..	..	1.1	0.1	+	..	+	1600	22–27
71699 (2)[5] ...	2.5	26[2]	69	0.8	..	..	×	0.3	+	..	+	+	0.2	..	..	1600	22–29
71714 (2).....	..	33[2]	66	0.2	..	..	..	0.7	+	..	0.1	0.1	+	..	..	1600	32–40
71715 (2)[3] ...	..	29[2]	70	+	..	..	..	0.2	+	..	..	+	+	..	..	1600	68–86
71729 (4).....	3.9	15	73	+	..	7.3	+	0.2	..	..	0.1	+	+	..	..	2400	22–25
71732 (2).....	2.0	32[2]	60	2.2	..	..	+	1.1	..	..	2.2	+	0.1	..	..	1600	24–27
71735 (5).....	12	10	75	1.8	..	0.3	..	+	..	..	..	+	0.1	..	..	4000	25–28
71737 (3)[1][4]..	9.3	38[2]	45	3.1	..	..	×	1.8	0.3	0.7	0.2	+	0.1	..	..	2400	27–35
71744........	4.0	36[2]	55	3.6	..	..	..	0.7	+	..	0.3	+	+	..	..	1600	23–28

N: number of points counted.

×: important amounts; ××: large amounts; +: small amounts.

[1]) Sample relatively strongly altered.
[2]) Plagioclase normally zoned.
[3]) Sample with affinities to the gabbro-anorthositic rocks.

[4]) Sample contains some rutile.
[5]) Sample contains some microcline.
[6]) Contains 0.3 % microcline and 0.6 % skapolite.

Table 1 B. *Mineralogical composition of the analyzed gneiss samples*

Sample number	quartz	plagioclase	microcline	hornblende	biotite	white mica	epidote	chlorite	sphene	apatite	opaque	zircon	allanite	N	comp. plagioclace % An.
F.K. 70008 (2)..................	29	58	..	..	12	..	0.7	+	+	0.1	0.1	+	+	1600	31–36
70011 (2)..................	22	58[5])	..	3.0	14	..	2.5	+	0.1	+	0.1	+	+	1600	29–36
70052 (2)..................	25[5])	59	..	..	13	+	1.5	+	+	0.3	0.3	+	+	1600	19–22
70126 (2)..................	23[5])	59	0.7	..	15[5])	+	0.5	..	0.4	+	+	+	0.4	1600	23–27
70254 (2)..................	19	63	1.4	0.4	15	..	0.3	..	0.3	0.2	0.1	+	0.3	1600	23–27
70010 (1)..................	10	56[5])	..	20	10[5])	..	1.4	+	0.9	0.3	0.2	+	0.1	1000	30–33
70022 (2)..................	19	39	..	14	13	..	3.9	+	0.7	0.5	0.2	+	+	1600	28–32
70226 (2)..................	8.6	50[5])	1.2	30	5.0	..	4.0	+	0.6	+	+	..	..	1600	23–26
70241 (1)..................	18	54	..	21[5])	4.8	..	0.4	+	0.3	0.3	0.5	+	..	1000	32–36
70243 (2)..................	19	48[5])	0.1	23	8.5	..	0.1	..	0.2	0.3	+	+	+	1600	25–30

Table 2A. *Chemical analyses of 54 amphibolites, together with Niggli numbers. Trace elements in parts per million*

	EB 38920	EB 38938	EB 52804	EB 52889	EB 52894	EB 52901	EB 52912	EB 52921	EB 52924(B)
SiO_2.....	46.13	49.19	49.88	48.47	46.96	47.14	49.35	52.57	49.34
Al_2O_3....	15.07	13.36	13.29	16.35	13.19	13.88	15.50	13.63	15.71
TiO_2.....	1.41	1.81	0.95	0.21	1.79	0.44	0.73	0.67	0.98
Fe_2O_3....	4.68	3.86	5.32	2.26	5.31	4.21	3.40	3.35	4.17
FeO	8.00	10.45	6.61	3.28	8.94	5.71	5.81	7.34	7.04
MgO	6.75	6.35	8.39	12.45	8.02	10.24	9.29	5.59	5.81
CaO	11.81	9.57	10.36	12.49	9.98	12.44	9.72	10.63	9.43
Na_2O	1.47	1.95	2.14	1.42	2.36	2.03	3.26	1.90	2.81
K_2O	1.39	0.76	0.86	0.53	1.13	1.20	1.07	1.63	1.54
MnO	0.17	0.20	0.20	0.11	0.20	0.14	0.17	0.19	0.16
P_2O_5	0.21	0.28	0.26	0.24	0.19	0.22	0.03	0.27	0.27
H_2O+ ...	1.90	1.48	1.82	1.90	1.66	1.90	2.26	2.56	1.36
S	0.07	0.21	0.11	0.03	0.03	0.03	0.01	0.10	0.03
	99.06	99.47	100.19	99.74	99.76	99.58	100.60	100.43	98.65
Cr.......	307	175	201	429	92	286	362	210	119
Co	37	14	16	37	24	39	39	14	39
Ni	160	117	140	256	105	362	296	146	233
Ba	138	86	108	40	98	72	585	118	200
Ce	27	42	31	27	32	29	26	34	52
si	104.3	117.8	114.0	101.4	104.2	99.1	110.2	133.3	120.7
al	20.1	18.8	17.9	20.2	17.2	17.2	20.4	20.4	22.6
fm	46.1	50.9	50.7	48.3	52.4	49.0	47.8	43.5	43.6
c........	28.6	24.5	25.4	28.0	23.7	28.0	23.2	28.9	24.7
alk	5.2	5.7	6.0	3.6	6.7	5.7	8.6	7.3	9.1
ti	2.4	3.3	1.6	0.3	3.0	0.7	1.2	1.3	1.8
p	0.2	0.3	0.3	0.2	0.2	0.2	0.0	0.3	0.3
k	0.39	0.20	0.26	0.19	0.24	0.28	0.18	0.36	0.27
mg	0.49	0.44	0.56	0.80	0.51	0.65	0.65	0.49	0.49

Table 2A (continued)

	EB 52937	KT 55648	KT 55686	NH 69201	NH 69223	NH 69264	NH 69273	NH 69317	FK 70021
SiO$_2$	45.23	47.67	47.97	49.37	50.69	48.39	50.67	50.74	47.11
Al$_2$O$_3$	12.97	11.81	8.64	14.53	12.88	13.82	13.04	14.66	15.45
TiO$_2$	0.78	2.02	0.52	0.78	0.63	0.96	0.88	0.57	0.43
Fe$_2$O$_3$	5.48	5.06	6.36	4.77	5.40	4.84	6.23	4.17	2.33
FeO	7.36	12.35	7.60	6.60	7.30	8.03	7.52	6.48	6.61
MgO	10.75	4.25	11.90	7.27	7.54	7.68	6.94	6.30	13.09
CaO	10.67	10.97	10.98	9.89	9.63	9.37	9.06	11.09	11.77
Na$_2$O	2.14	1.52	0.72	2.47	1.82	2.29	2.11	1.76	1.49
K$_2$O	1.59	0.55	0.85	1.13	1.17	1.06	1.19	0.98	0.66
MnO	0.20	0.23	0.26	0.21	0.27	0.21	0.20	0.21	0.16
P$_2$O$_5$	0.17	0.27	0.22	0.17	0.21	0.25	0.22	0.24	0.22
H$_2$O+	1.59	2.16	3.80	2.40	2.04	2.50	2.34	2.14	0.94
S	0.03	0.03	0.01	0.05	0.01	0.07	0.09	0.03	0.02
	98.96	98.89	99.83	99.64	99.59	99.47	100.49	99.37	100.28
Cr	387	101	1143	239	274	214	104	314	477
Co	52	60	29	18	32	39	38	25	29
Ni	406	882	84	102	250	176	169	275	130
Ba	84	115	58	102	89	130	128	107	72
Ce	39	37	43	32	46	35	37	34	31
si	93.0	115.7	101.7	116.5	120.6	112.4	121.6	123.9	93.3
al	15.7	16.9	10.8	20.8	18.1	18.9	18.4	21.1	18.0
fm	54.4	50.2	61.7	47.5	51.4	51.0	51.6	44.2	53.3
c	23.5	28.5	24.9	25.0	24.5	23.3	23.3	29.0	25.0
alk	6.3	4.4	2.6	7.3	6.0	6.7	6.7	5.7	3.7
ti	1.2	3.7	0.8	1.4	1.1	1.7	1.6	1.0	0.6
p	0.1	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
k	0.33	0.20	0.44	0.23	0.30	0.24	0.27	0.27	0.23
mg	0.61	0.31	0.61	0.54	0.52	0.52	0.48	0.52	0.73

Table 2A (continued)

	FK 70040	FK 70045	FK 70050	FK 70079	FK 70093	FK 70156	FK 70161	FK 70197	FK 70236
SiO_2	44.04	60.60	51.79	54.67	53.08	53.14	47.75	49.57	45.93
Al_2O_3	12.05	13.43	13.19	13.76	12.64	15.74	14.66	14.41	11.26
TiO_2	1.17	1.03	0.51	1.60	1.03	0.60	1.06	1.16	0.58
Fe_2O_3	4.05	1.75	3.41	1.19	2.18	3.18	4.06	2.84	3.88
FeO	7.45	6.35	7.40	9.35	10.11	5.43	9.91	10.51	8.31
MgO	13.02	2.81	8.88	3.31	5.62	5.61	6.16	6.04	13.77
CaO	11.81	7.90	7.32	10.50	9.68	9.44	10.14	9.12	8.99
Na_2O	1.29	3.90	2.34	1.98	2.23	4.06	2.69	3.05	1.28
K_2O	1.60	0.90	2.47	0.51	0.75	0.81	1.03	0.48	2.96
MnO	0.20	0.17	0.22	0.21	0.21	0.13	0.23	0.19	0.25
P_2O_5	0.81	0.31	0.13	0.58	0.22	0.24	0.24	0.27	0.15
H_2O	2.28	0.76	2.26	1.56	1.18	0.76	1.98	1.90	2.18
S	0.03	0.02	0.01	0.90	0.04	0.05	0.04	0.05	0.01
	99.80	99.93	99.93	100.12	98.97	99.19	99.95	99.59	99.55
Cr.........	396	94	1403	90	91	148	210	234	1250
Co	34	7	33	19	35	24	28	24	69
Ni	392	56	326	38	102	138	138	184	748
Ba	421	231	236	150	135	164	185	204	173
Ce	96	67	40	54	45	39	34	46	34
si	86.6	191.3	124.4	154.4	135.8	135.5	109.8	119.5	91.9
al	14.0	25.0	18.7	22.9	19.0	23.6	19.9	20.5	13.3
fm	56.7	34.6	53.3	39.0	47.7	39.3	47.6	48.4	61.2
c	24.9	26.7	18.8	31.8	26.5	25.8	25.0	23.2	19.3
alk	4.5	13.7	9.2	6.3	6.7	11.3	7.5	7.9	6.3
ti	1.7	2.4	0.9	3.4	2.0	1.1	1.8	2.1	0.9
p	0.7	0.4	0.1	0.7	0.2	0.3	0.2	0.3	0.1
k	0.45	0.13	0.41	0.15	0.18	0.11	0.20	0.09	0.61
mg	0.67	0.38	0.60	0.36	0.45	0.54	0.44	0.45	0.67

Table 2A (continued)

	FK 70247	FK 70258	FK 70303	FK 70308	FK 71615	FK 71620	FK 71633	FK 71634	FK 71645
SiO_2.......	59.69	49.99	49.32	51.44	49.02	49.96	49.29	48.69	52.56
Al_2O_3......	14.11	15.59	13.47	12.83	13.81	13.27	14.62	15.79	11.35
TiO_2.......	0.46	0.70	1.31	1.23	0.88	0.64	0.93	0.79	1.43
Fe_2O_3......	2.88	3.39	4.17	3.09	4.72	4.96	4.68	3.34	4.67
FeO	4.22	8.18	9.53	12.16	8.28	6.55	8.56	8.37	10.30
MgO	3.21	4.15	6.38	5.77	7.45	7.77	5.87	5.07	5.83
CaO	7.98	11.55	9.16	9.34	10.08	10.45	10.98	11.66	8.40
Na_2O	4.95	2.76	2.68	2.08	3.21	2.75	2.91	2.84	1.56
K_2O.......	0.67	0.88	1.52	0.18	0.33	0.66	0.46	0.60	0.66
MnO	0.13	0.21	0.21	0.24	0.21	0.19	0.22	0.21	0.24
P_2O_5	0.25	0.31	0.28	0.28	0.25	0.23	0.26	0.28	0.26
H_2O+	1.00	0.89	1.92	0.98	1.40	2.30	1.64	1.84	2.72
S	0.04	0.05	0.03	0.02	0.16	0.02	0.09	0.05	0.06
	99.59	98.65	99.98	99.64	99.80	99.75	100.51	99.53	100.04
Cr........	91	256	230	134	295	268	315	244	76
Co	16			14	21	39	52	31	32
Ni	66	196	131	85	187	185	208	218	73
Ba	130	65	199	72	42	134	97	95	100
Ce	39	35	40	41	35	37	34	33	41
si	182.7	123.3	117.2	125.5	111.4	116.1	114.4	115.5	136.1
al	25.4	22.7	18.9	18.4	18.5	18.2	20.0	22.1	17.3
fm	32.4	38.8	49.4	51.9	49.4	48.7	45.5	40.9	54.4
c.........	26.2	30.5	23.3	24.4	24.5	26.0	27.3	29.6	23.3
alk	16.0	8.0	8.5	5.2	7.5	7.2	7.2	7.4	5.0
ti	1.1	1.3	2.3	2.3	1.5	1.1	1.6	1.4	2.8
p	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.3
k	0.08	0.18	0.27	0.06	0.06	0.14	0.11	0.12	0.22
mg	0.45	0.39	0.46	0.41	0.51	0.55	0.45	0.44	0.42

Table 2A (continued)

	FK 71649	FK 71657	FK 71663	FK 71666	FK 71668	FK 71672	FK 71677	FK 71682	FK 71688
SiO_2.......	50.40	46.97	45.94	49.34	54.73	49.03	51.87	47.29	46.99
Al_2O_3......	13.65	13.67	16.47	16.25	14.59	14.19	13.90	14.62	13.92
TiO_2.......	0.94	0.54	0.56	0.32	0.52	0.92	0.88	0.52	1.00
Fe_2O_3......	4.92	4.98	3.32	2.72	2.10	3.60	4.98	3.64	4.58
FeO	8.56	6.64	7.75	5.02	6.15	8.28	6.34	7.07	10.28
MgO	6.51	12.61	8.73	8.24	6.62	7.41	6.78	10.67	6.24
CaO	10.07	9.05	10.53	11.89	9.51	10.17	8.33	9.89	10.38
Na_2O	1.94	1.69	2.57	3.33	3.19	2.96	3.65	2.37	3.00
K_2O.......	1.04	1.06	1.43	0.53	0.71	0.93	1.22	1.53	0.98
MnO	0.21	0.20	0.19	0.14	0.16	0.18	0.21	0.17	0.22
P_2O_5	0.28	0.22	0.25	0.29	0.23	0.25	0.30	0.24	0.28
H_2O+	1.64	1.44	1.74	1.36	1.46	1.78	2.10	1.66	1.70
S	0.04	0.03	0.02	0.10	0.02	0.04	0.02	0.02	0.11
	100.20	99.10	99.50	99.53	99.99	99.74	100.58	99.69	99.68
Cr.........	153	955	221	57	322	197	155	368	174
Co	27	57	50	35	22	35	29	47	15
Ni	155	475	362	118	146	171	145	385	138
Ba	158	127	178	97	192	82	172	138	115
Ce	40	37	33	24	41	38	44	37	41
si	119.7	97.2	98.7	110.9	140.2	112.6	127.3	100.3	105.9
al	19.1	16.7	20.9	21.5	22.0	19.2	20.1	18.3	18.5
fm	49.2	58.5	47.6	41.9	42.8	47.8	47.4	52.3	48.5
c..........	25.6	20.1	24.2	28.6	26.1	25.0	21.9	22.5	25.1
alk	6.0	4.8	7.3	8.0	9.1	7.9	10.6	6.9	8.0
ti	1.7	0.8	0.9	0.5	1.0	1.6	1.6	0.8	1.7
p	0.3	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.5
k	0.26	0.29	0.27	0.09	0.11	0.17	0.18	0.30	0.18
mg	0.47	0.67	0.59	0.66	0.59	0.53	0.52	0.64	0.43

Table 2A (continued)

	FK 71691	FK 71699	FK 71714	FK 71715	FK 71729	FK 71732	FK 71735	FK 71737	FK 71744
SiO_2	49.94	51.02	45.67	49.05	51.54	47.84	51.19	51.49	50.68
Al_2O_3	13.34	12.05	16.18	13.97	10.14	13.79	9.47	14.57	15.16
TiO_2	1.13	0.58	1.08	0.89	0.73	1.34	0.79	0.68	0.76
Fe_2O_3	5.57	3.84	4.87	4.75	3.63	5.07	4.37	4.39	3.91
FeO	8.50	7.54	7.39	8.08	8.40	8.29	9.36	6.35	8.42
MgO	5.94	8.89	6.87	7.22	8.82	6.15	8.56	6.38	5.17
CaO	8.72	9.88	10.97	10.88	11.97	9.94	9.70	9.06	8.62
Na_2O	3.07	2.92	2.74	2.86	1.94	3.32	1.95	2.53	2.80
K_2O	1.32	0.91	0.65	0.33	0.70	1.23	1.14	1.00	1.39
MnO	0.24	0.18	0.18	0.20	0.20	0.21	0.23	0.16	0.20
P_2O_5	0.25	0.24	0.29	0.27	0.28	0.31	0.22	0.01	0.00
H_2O+	2.08	1.74	2.34	1.29	1.44	2.30	1.86	2.90	2.46
S	0.05	0.03	0.05	0.09	0.01	0.12	0.06	0.06	0.01
	100.15	99.82	99.28	99.88	99.80	99.91	98.90	99.58	99.58
Cr........	140	420	223	309	823	178	420	217	170
Co	29	34	27	27	45	32	30	32	27
Ni	143	183	301	190	291	160	277	155	156
Ba	120	99	93	68	110	87	94	233	209
Ce	44	35	39	34	40	31	42	40	36
si	120.7	116.8	102.5	111.2	116.7	111.6	112	129.9	127.9
al	19.0	16.3	21.4	18.7	13.5	19.0	18.8	21.7	22.5
fm	49.2	51.7	45.4	48.2	52.2	46.9	52.8	46.1	45.1
c.........	22.6	24.2	26.4	26.4	29.0	24.8	22.8	24.5	23.3
alk	9.2	7.8	6.9	6.8	5.3	9.3	5.6	7.8	9.1
ti	2.1	1.0	1.8	1.5	1.2	2.4	1.3	1.3	1.4
p	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.0	0.0
k	0.22	0.17	0.14	0.07	0.19	0.20	0.28	0.20	0.25
mg	0.43	0.59	0.50	0.51	0.57	0.46	0.53	0.52	0.43

Table 2 B. *Chemical analyses of 10 gneisses, together with Niggli numbers.*
Trace elements in parts per million

	FK 70008	FK 70011	FK 70052	FK 70126	FK 70244	FK 70010	FK 70022	FK 70226	FK 70241	FK 70243
SiO_2	67.99	65.55	64.98	66.13	62.86	62.04	58.52	59.58	58.15	61.88
Al_2O_3	16.96	17.14	16.37	17.17	17.76	17.11	16.64	15.84	16.87	15.93
TiO_2	0.30	0.43	0.50	0.59	0.73	0.61	0.93	0.62	0.69	0.54
Fe_2O_3	0.23	0.53	1.37	0.76	1.29	1.82	1.77	2.28	1.62	1.24
FeO	2.23	3.12	2.38	2.61	2.73	3.87	4.92	4.14	4.69	3.90
MgO	1.79	2.05	3.72	1.92	1.79	2.56	2.95	3.59	3.21	3.65
CaO	3.56	3.98	3.29	3.70	3.98	5.23	5.93	6.90	6.66	5.51
Na_2O	4.95	4.50	5.45	4.50	5.27	4.30	3.90	4.65	4.20	3.95
K_2O	1.40	1.65	1.65	1.90	1.80	1.25	1.50	1.20	1.80	1.35
MnO	0.03	0.04	0.03	0.03	0.06	0.19	0.13	0.14	0.15	0.13
P_2O_5	0.15	0.16	0.20	0.18	0.22	0.14	0.08	0.10	0.18	0.17
H_2O+	0.85	0.95	0.65	0.74	1.07	0.86	1.73	1.09	1.45	1.34
	100.44	100.10	100.59	100.23	99.56	99.98	99.10	100.13	99.67	99.59
Cr	27	67	34	59	70	67	59	124	428	235
Co	17	29	12	27	26	51	73	65	51	29
Ni	5	16	0	14	22	26	23	100	263	55
Ba					985			135		
Ce					97			41		
si	281	253	231	262	233	212	190	183	180	208
al	41.2	39.0	34.3	39.9	38.8	34.4	31.7	28.5	30.7	31.5
fm	19.6	23.6	30.7	22.4	22.2	29.4	32.3	32.7	31.1	32.9
c	15.8	16.5	12.6	15.7	15.8	19.2	20.6	22.6	22.1	19.9
alk	23.5	20.9	22.5	22.0	23.2	17.0	15.4	16.1	16.1	15.8
ti	0.9	1.3	1.4	1.8	2.0	1.6	2.3	1.4	1.6	1.4
p	0.3	0.3	0.3	0.3	0.4	0.2	0.1	0.1	0.2	0.2
k	0.16	0.20	0.17	0.22	0.18	0.16	0.20	0.15	0.22	0.18
mg	0.57	0.50	0.65	0.51	0.45	0.45	0.44	0.51	0.48	0.56

Sample nos 70008, 70011, 70052, 70126 and 70254 represent biotite gneisses.
Sample nos 70010, 70022, 70226, 70241 and 70243 are hornblende-biotite gneisses.

Table 3A. *C.I.P.W. norms of amphibolites*

	q	or	ab	an	ne	di	hy	ol	mt	cm	il	ap	pr
EB 38920.........	–	8.22	12.42	30.37	–	21.79	12.41	1.86	6.79	0.06	2.68	0.50	0.13
38938.........	4.21	4.50	16.48	25.42	–	16.65	20.63	–	5.60	0.04	3.44	0.66	0.39
52804.........	2.77	5.09	18.09	24.08	–	20.49	17.51	–	7.71	0.04	1.80	0.62	0.21
52889.........	–	3.13	12.00	36.63	–	18.74	15.22	7.82	3.28	0.09	0.40	0.57	0.06
52894.........	–	6.68	19.95	22.03	–	21.22	9.98	6.65	7.70	0.01	3.40	0.45	0.06
52901.........	–	7.10	15.72	25.18	0.78	27.97	–	13.45	6.10	0.06	0.84	0.52	0.06
52912.........	–	6.33	26.55	24.46	0.54	18.92	–	15.17	4.93	0.07	1.39	0.07	0.02
52921.........	6.34	9.64	16.06	23.81	–	22.23	12.84	–	4.86	0.04	1.27	0.64	0.19
52924 B.......	–	9.11	23.75	25.66	–	15.76	12.98	1.46	6.05	0.03	1.86	0.64	0.06
52939.........	–	9.40	13.19	21.05	2.65	24.61	–	16.61	7.95	0.09	1.48	0.40	0.06
KT 55648.........	6.77	3.25	12.85	23.75	–	24.26	14.06	–	7.34	0.01	3.84	0.64	0.06
55686.........	3.68	5.03	6.09	17.81	–	28.11	24.52	–	9.22	0.25	0.99	0.52	0.02
NH 69201.........	0.75	6.68	20.88	25.18	–	18.34	16.52	–	6.92	0.04	1.48	0.40	0.09
69223.........	5.43	6.92	15.38	23.48	–	18.51	18.31	–	7.83	0.06	1.20	0.50	0.02
69264.........	0.31	6.27	19.35	24.26	–	16.68	20.53	–	7.02	0.04	1.82	0.59	0.13
69273.........	5.83	7.04	17.83	22.56	–	16.91	16.61	–	9.03	0.03	1.67	0.52	0.17
69317.........	5.92	5.80	14.87	29.17	–	19.68	14.06	–	6.05	0.07	1.08	0.57	0.06
FK 70021.........	–	3.90	12.59	33.48	–	18.78	6.48	19.35	3.38	0.10	0.82	0.52	0.04
70040.........	–	9.46	8.64	22.33	1.23	24.77	–	21.10	5.87	0.09	2.22	1.92	0.06
70045.........	14.73	5.32	32.96	16.45	–	17.32	7.16	–	2.54	0.01	1.96	0.73	0.04
70050.........	–	14.61	19.78	18.15	–	14.03	22.73	2.09	4.94	0.29	0.97	0.31	0.02
70079.........	14.66	3.02	16.48	27.25	–	17.69	11.45	–	1.73	0.01	3.04	1.37	1.69
70093.........	7.00	4.44	18.85	22.23	–	20.23	19.35	–	3.16	0.01	1.96	0.52	0.07
70156.........	0.50	4.79	34.31	22.30	–	18.59	11.55	–	4.61	0.03	1.14	0.57	0.09
70161.........	–	6.09	22.73	24.85	–	19.71	7.64	8.42	5.89	0.04	2.01	0.57	0.07
70197.........	–	2.84	25.78	24.29	–	15.35	21.03	1.19	4.12	–	2.20	0.64	0.22

	q	or	ab	an	ne	di	hy	ol	mt	cm	il	ap	pr
FK 70236.........	–	17.51	7.16	16.20	1.98	22.00	–	25.44	5.63	0.27	1.10	0.35	0.02
70247.........	10.13	3.96	41.84	14.28	–	19.28	3.41	–	4.18	0.01	0.87	0.59	0.07
70258.........	1.34	5.21	23.33	27.51	–	23.07	10.25	–	4.92	0.06	1.33	0.73	0.09
70303.........	–	8.99	22.65	20.20	–	19.24	15.11	2.64	6.05	0.04	2.49	0.66	0.06
70308.........	6.76	1.06	17.58	25.11	–	16.20	24.46	–	4.48	0.03	2.34	0.66	0.04
71615.........	–	1.95	27.13	22.27	–	21.17	11.67	4.78	6.84	0.06	1.67	0.59	0.30
71620.........	0.95	3.90	23.24	21.88	–	22.87	15.63	–	7.19	0.06	1.22	0.54	0.04
71633.........	0.15	2.72	24.59	25.44	–	22.39	14.24	–	6.79	0.07	1.77	0.62	0.17
71634.........	–	3.55	24.00	28.53	–	22.70	8.42	3.41	4.84	0.06	1.50	0.66	0.09
71645.........	12.96	3.90	13.18	21.99	–	14.85	20.25	–	6.77	0.01	2.72	0.62	0.11
71649.........	4.77	6.15	16.40	25.43	–	18.55	17.64	–	7.13	0.03	1.79	0.66	0.07
71657.........	–	6.27	14.28	26.54	–	13.48	17.45	10.81	7.22	0.21	1.03	0.52	0.06
71663.........	–	8.46	15.08	29.14	3.60	17.42	–	17.61	4.81	0.04	1.06	0.59	0.04
71666.........	–	3.13	25.55	27.79	1.40	23.47	–	11.41	3.94	0.01	0.61	0.69	0.19
71668.........	4.59	4.20	26.96	23.36	–	18.14	16.68	–	3.04	0.07	0.99	0.54	0.04
71672.........	–	5.50	25.02	22.65	–	21.31	7.21	8.66	5.22	0.04	1.75	0.59	0.07
71677.........	0.54	7.22	30.85	17.91	–	17.27	15.09	–	7.22	0.03	1.67	0.71	0.04
71682.........	–	9.05	18.85	24.69	0.64	18.33	–	19.64	5.28	0.07	0.99	0.57	0.04
71688.........	–	5.80	24.52	21.59	0.45	23.15	–	13.07	6.64	0.03	1.90	0.66	0.21
71691.........	0.81	7.81	25.95	18.69	–	18.72	15.20	–	8.08	0.03	2.15	0.59	0.09
71699.........	–	5.38	24.68	17.06	–	24.54	15.97	3.16	5.57	0.09	1.10	0.57	0.06
71714.........	–	3.84	23.16	29.89	–	18.32	0.16	11.71	7.06	0.04	2.05	0.69	0.09
71715.........	–	1.95	24.17	24.28	–	22.68	14.70	1.42	6.89	0.06	1.69	0.64	0.17
71729.........	3.06	4.14	16.40	16.87	–	32.99	17.58	–	5.26	0.18	1.39	0.66	0.02
71732.........	–	7.28	27.67	19.06	0.21	22.97	–	9.57	7.35	0.04	2.55	0.73	0.22
71737.........	5.00	5.91	21.38	25.41	–	15.76	15.43	–	6.37	0.04	1.29	0.02	0.11
71744.........	1.63	8.22	23.66	24.65	–	14.96	16.88	–	5.67	0.03	1.44	–	0.02

Table 3 B. *C.I.P.W. norms of hornblende-biotite gneisses*

	q	c	or	ab	an	di	hy	mt	il	ap
70010........	15.71	–	7.39	36.34	23.66	1.14	10.78	2.64	1.16	0.33
70022........	11.58	–	8.87	32.96	23.43	4.51	11.42	2.57	1.77	0.19
70226........	9.06	–	7.10	39.30	18.77	12.02	8.08	3.31	1.18	0.24
70241........	7.56	–	10.65	35.50	21.82	8.26	10.37	2.35	1.31	0.43
70243........	15.48	–	7.99	33.38	21.71	3.68	12.81	1.80	1.03	0.40

Table 3 C. *C.I.P.W. norms of biotite gneisses*

	q	c	or	ab	an	hy	mt	il	ap
70008........	22.46	1.17	8.28	41.84	16.69	7.93	0.33	0.57	0.35
70011........	19.87	1.08	9.76	38.03	18.71	9.77	0.77	0.82	0.38
70052........	13.85	0.10	9.76	46.06	15.03	11.76	1.99	0.95	0.47
70126........	20.98	1.40	11.24	38.03	17.19	8.04	1.10	1.12	0.43
70254........	13.50	0.41	10.65	44.54	18.32	7.32	1.87	1.39	0.52

Table 4. *Average composition and C.I.P.W. norms for the amphibolites compared with other amphibolite averages*

	(1)	(2)	(3)
SiO_2	51.05	50.73	50.3
Al_2O_3	14.13	15.29	15.7
TiO_2	1.03	1.90	1.6
Fe_2O_3	4.23	3.94	3.6
FeO	8.04	8.74	7.8
MgO	7.63	6.69	7.0
CaO	9.85	7.73	9.5
Na_2O	2.55	3.90	2.9
K_2O	1.03	0.61	1.1
MnO	0.20	0.22	0.2
P_2O_5	0.25	0.25	0.3
q	0.96	–	–
or...................	6.09	3.61	6.51
ab	21.55	32.96	24.51
an	24.03	22.38	26.53
ne...................	–	–	–
di	18.81	11.68	15.11
hy	19.88	15.17	16.14
ol	–	4.30	2.25
mt	6.13	5.71	5.22
il	1.96	3.61	3.04
ap	0.59	0.59	0.71

(1) Average of all 54 amphibolites analyzed.
(2) Average Connemara striped amphibolite. (EVANS & LEAKE, 1960).
(3) Average of 200 amphibolites computed by POLDERVAART (1955, p. 136).