Comparative geochemistry of Archaean orthogneisses from the north-western quadrant of the Isukasia map sheet region, southern West Greenland

R. P. Hall

The Archaean gneiss complex of the north-western part of the 1:100 000 scale Isukasia map sheet region comprises predominantly of high-grade basic, intermediate and acid meta-igneous gneisses. Relict intrusive relationships clearly indicate the relative ages of most of the composite magmatic episodes. However, some relationships are not obvious and a geochemical reconnaissance has been made in an attempt to elucidate whether or nor any of the various units are genetically related. Since it is the preserved igneous geochemical affinities which are under investigation, the prefix 'meta' which should be applied to all of the lithologies is omitted.

Stratigraphic problems

The field relationships and stratigraphy of the area are described by Hall & Hughes (1982) and Garde *et al.* (1983) and reference should be made to the maps presented by these authors for details of the distribution of the lithologies discussed in this report. The oldest recognised rocks in the north-western area form a suite of gabbroic and metavolcanic pyroxene-bearing amphibolites, which locally include deformed pillow-structured units and which broadly correspond to the Malene gabbroic and metavolcanic units of the Godthåbsfjord region (McGregor, 1973; Hall, 1980a). These basic rocks were deformed and metamorphosed prior to their variable disruption during the injection of large bodies of diorite and tonalite, which were themselves fragmented by the intrusive precursors of the predominant leucocratic, trondhjemitic and granodioritic gneisses and granitic pegmatite. These combined dioritic to granitic rocks are believed to be equivalent to different generations of Nûk gneisses. The leucocratic gneisses are cut by thin dykes of pale grey gneiss and bodies of norite in the north and west of the area. The very large Taserssuaq tonalite body occupies the centre of the Isukasia map sheet region and forms the eastern boundary of the area under consideration.

Some stratigraphic problems which persist concern the possible genetic relationships between the Taserssuaq tonalites, the central diorite complex, the agmatised tonalitic rocks in the south of the area (referred to as 'southern tonalites') and the grey gneiss dykes within the leucocratic gneisses and the distinction between homogeneous, granulite facies noritic, gabbroic and dioritic rocks.

Comparative geochemistry

A full geochemical acount of all of the lithostratigraphic units is beyond the scope of this report. Analyses of two representative samples of each of the units in question are presented in Table 1 and a selection of major and trace elements are plotted against silica in fig. 17. The variation in Al, Na, P, Sr, Y and Zr is greater within than between the units and thus, these

Table 1. Representative analyses of rocks from the north-western part of the Isukasia map sheet area

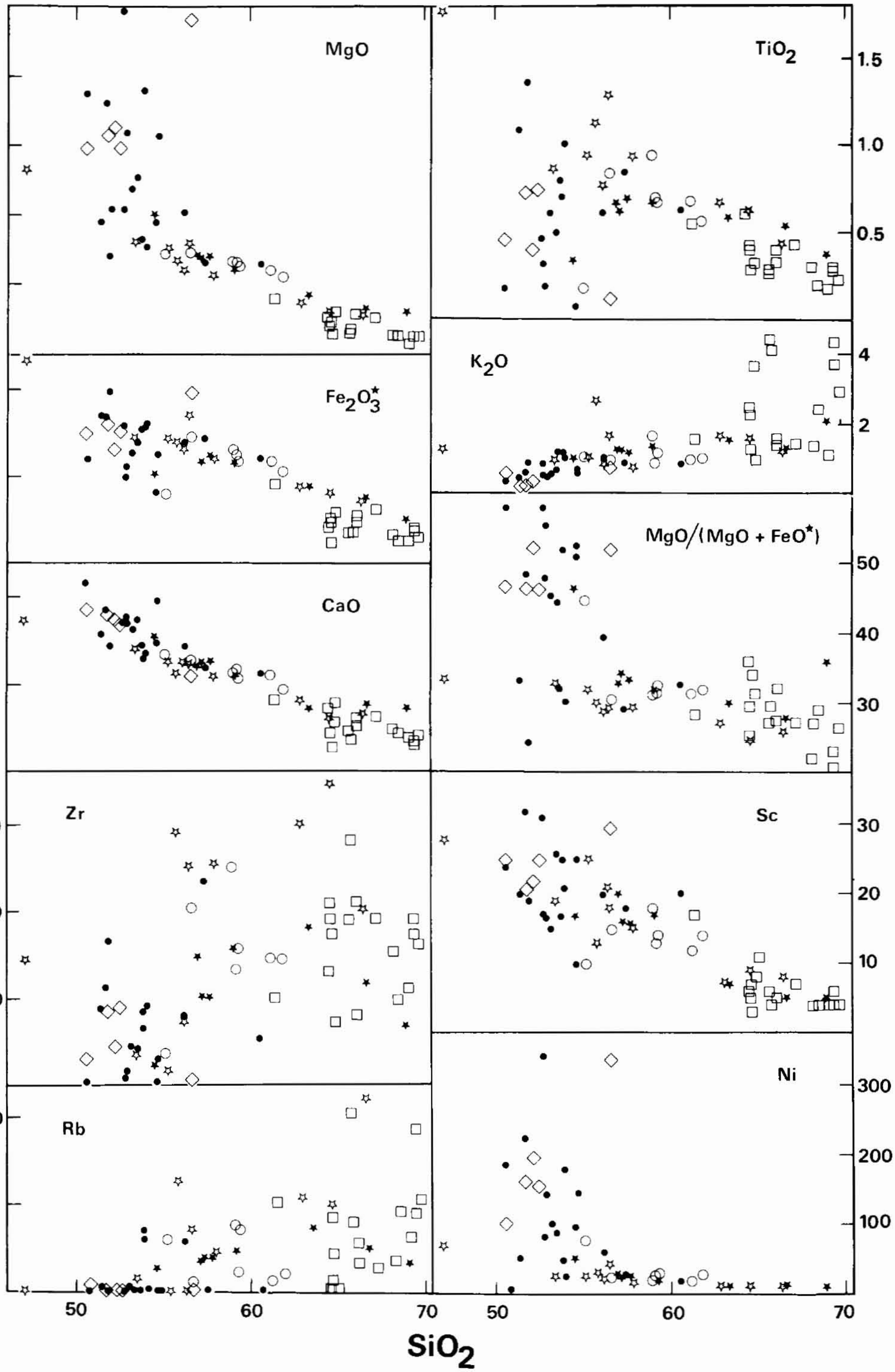
	Diorites		Southern Tonalites		Taserssuaq Tonalites		Grey Gneiss Dykes		Leucocratic Gneisses		Norites	
wt %	220556	220581	220573	220569	290544	290549	290590	290580	220561	290522	220525	220550
SiO_2	52.89	53.75	56.61	61.15	57.70	59.14	56.46	62.94	67.24	69.39	51.80	52.50
Al_2O_3	18.42	19.05	17.47	16.44	19.12	18.05	17.03	17.26	16.75	15.40	17.76	17.60
MgO	6.35	3.29	2.86	2.42	2.79	2.45	3.19	1.46	1.04	0.52	6.26	5.88
$Fe_2O_3^*$	5.64	7.74	7.32	5.90	6.23	5.84	8.55	4.37	3.11	1.91	7.97	7.61
CaO	8.77	7.25	6.35	5.50	6.29	5.50	6.16	4.00	3.14	1.70	8.98	8.35
Na_2O	3.12	3.68	4.91	4.93	4.48	4.44	4.13	5.21	5.12	4.51	4.20	4.04
K_2O	0.56	1.23	0.99	0.99	1.20	1.38	1.73	1.65	1.44	3.73	0.32	0.28
TiO_2	0.19	0.80	0.84	0.68	0.70	0.68	1.29	0.67	0.43	0.29	0.73	0.75
MnO	0.09	0.08	0.12	0.08	0.08	0.08	0.11	0.04	0.03	0.02	0.12	0.11
P_2O_5	0.04	0.32	0.35	0.21	0.18	0.16	0.50	0.19	0.14	0.10	0.23	0.25
Total	96.07	97.19	97.82	98.30	98.77	97.72	99.15	97.79	98.44	97.57	98.37	97.37
ppm												
Sc	17	17	15	12	16	17	18	7	7	4	21	25
Ni	142	48	23	17	23	21	42	9	n.a.	n.a.	157	154
Rb	3	36	6	7	20	24	36	54	14	45	n.d.	n.d.
Sr	620	670	486	442	666	564	407	367	695	540	650	631
Y	3	10	14	8	14	12	24	5	2	1	8	15
Zr	15	63	203	146	100	157	254	297	191	172	85	89

*All Fe expressed as Fe_2O_3. n.a.: not analysed; n.d.: not detectable.

elements have not proved very useful in distinguishing different lithologies. The most immediately recognised feature on the variation diagrams is the wide geochemical spread of many of the units. No unit is geochemically discrete from the others, but neither are any two units completely coincident.

The early dioritic rocks from the central part of the area are distinguished from the coarser, more quartz-rich southern tonalites. The latter tend to have higher Si, K and Rb and lower Mg, Fe, Ca, Sc and Ni contents. These two suites are thought to represent separate but penecontemporaneous early-Nûk intrusions. The central 'diorites' are in fact highly variable and range in composition from gabbroic to tonalitic types. The more basic members are almost indistinguishable from bodies of so-called 'norite' (Nielsen, 1976; Secher, 1983). In the field it is sometimes difficult to assign bodies of homogeneous, massive, mafic granulite facies rock to a gabbroic, noritic or dioritic origin, where all three rock types are known to occur. Basic rocks associated with the Malene supracrustal suite and the Ameralik dykes can be distinguished by their tholeiitic chemical affinities (Hall, 1980a, 1982; Chadwick, 1981), whereas all the units in the present study define a clear calc-alkali trend (fig. 18). The 'norites' have been reported to be Ni-rich (Nielsen, 1976), but the five

Fig. 17. Plot of selected major element oxides (wt %), trace elements (ppm) and MgO/(MgO + FeO*) against SiO_2 (wt %) where FeO* is all iron expressed as FeO. Diamonds: norites; dots: diorites; open circles: southern tonalites; filled asterisks: Taserssuaq tonalites; open asterisks: grey gneiss dykes; squares: trondhjemitic gneisses. No Ni data are available for the trondhjemitic gneisses.


MgO
TiO2
Fe2O3*
K2O
CaO
MgO/(MgO + FeO*)
Zr
Sc
Rb
Ni
SiO2
50
60
70

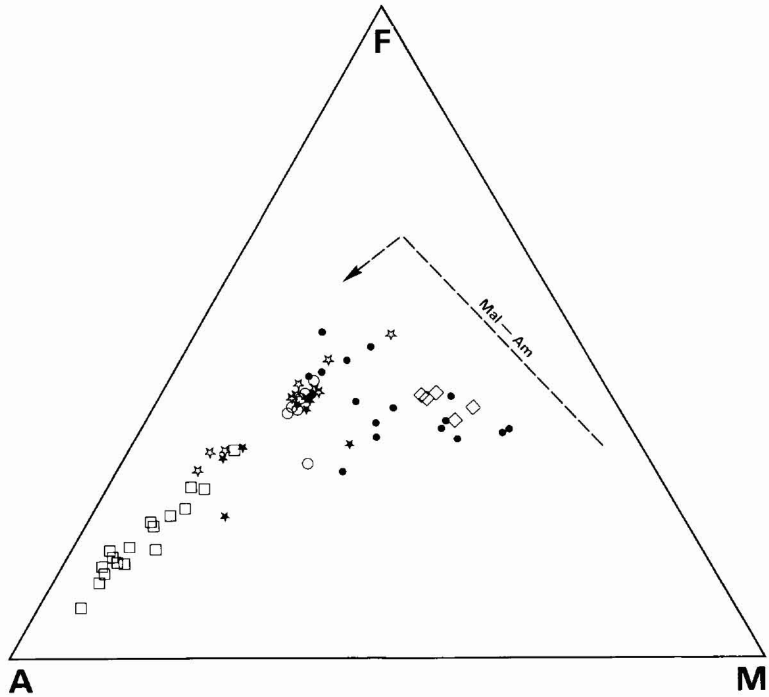


Fig. 18. Calc-alkali trend defined on an AFM plot ((Na_2O + K_2O) : (FeO^* + MnO) : MgO) of the various lithostratigraphic units in the north-western part of the Isukasia map sheet area. The tholeiitic trend of Malene metavolcanic and gabbroic units and Ameralik dykes (Mal-Am) is drawn schematically for comparison (see Chadwick, 1981; Hall, 1982). Symbols as for fig. 17.

analysed samples have only the same moderate Ni values (100–400 ppm) as the more basic members of the central diorite suite, which are lower than in the Malene komatiitic amphibolites (up to 1200 ppm) from Ivisârtoq (Hall, 1980a).

Occasionally the 'norites' contain abundant mixed inclusions of amphibolite and leucocratic gneiss (fig. 19). These and similar rocks with an apparently ultramafic matrix (Hall & Hughes, 1982) may be related to the 'ultrabasic pipe' found further to the north on the nunatak Majorqap alángua (Hall, 1980b). The diorite and norite suites are probably of different ages, separated by the formation of the leucocratic gneisses, although it is possible that the leucocratic fragments within the 'norite' represent older acid material pre-dating a single early-Nûk norite/gabbro/diorite intrusion.

The Taserssuaq tonalite is a variable but clearly more chemically evolved unit than the early central diorite complex (fig. 18). Rare earth element (REE) distribution patterns are similar in these two suites, both having moderately light REE-enriched profiles (fig. 20). The REE values tend to be a little higher in the more evolved Taserssuaq tonalites (Table 2), but the ranges in chondrite-normalised REE fractionation index Ce_N/Yb_N are the same for both suites (Ce_N/Yb_N = 5.8–20.1 and 8.7–25.7 in the diorites and Taserssuaq rocks respectively) and are similar to those of the early Nûk diorites and tonalites of the Buksefjorden

Fig. 19. Deformed intrusion breccia comprised of a mixture of pyroxene-amphibolitic and leucocratic gneiss xenoliths within a metanorite matrix in the north-western corner of the Isukasia map sheet area. Similar structures have been found within the early diorites (Hall & Hughes, 1982) and in rocks with an ultramafic matrix (Hall, 1980b; Hall & Hughes, 1982).

region (Compton, 1978). The differences in geochemistry between the diorites and Taserssuaq tonalites may reflect different stages of fractional crystallisation of similar parent magmas or different degrees of partial melting of the same amphibolitic(?) source (cf. Arth & Hanson, 1972). There is no petrographic evidence of feldspar accumulation to account for the slight positive Eu anomaly in the Taserssuaq tonalite samples 290545 and 277441.

The grey gneiss dykes vary from basic members (SiO_2 = 47 wt %) which correspond to 'intra-Nuk amphibolite dykes' from elsewhere in the region (cf. Coe, 1980; Coe & Robertson, 1982; Chadwick, 1981; Hall 1981) to intermediate and acid varieties of which similar late-stage dykes have also been reported from other areas (Bridgwater *et al.*, 1976; Hall, 1977). These dykes do not seem to form a geochemically coherent suite and whether they are all genetically related remains unclear. As a whole they tend to have slightly lower Mg and Ca and higher Fe, Ti, Zr and Rb values compared to Taserssuaq tonalites of equivalent silica content. This chemical discrepancy precludes the possibility that the grey dykes represent marginal emanations of the large Taserssuaq tonalite body.

The predominant leucocratic gneisses vary from tonalitic to granodioritic members, although most are trondhjemitic having low alkali feldspar and K_2O contents (cf. Barker, 1979). They are the most silica-rich rocks in the area and have relatively high Rb and K and low Mg, Fe, Ca, Mn, and Sc contents. K/Rb and Rb/Sr ratios (fig. 21) tend to support the

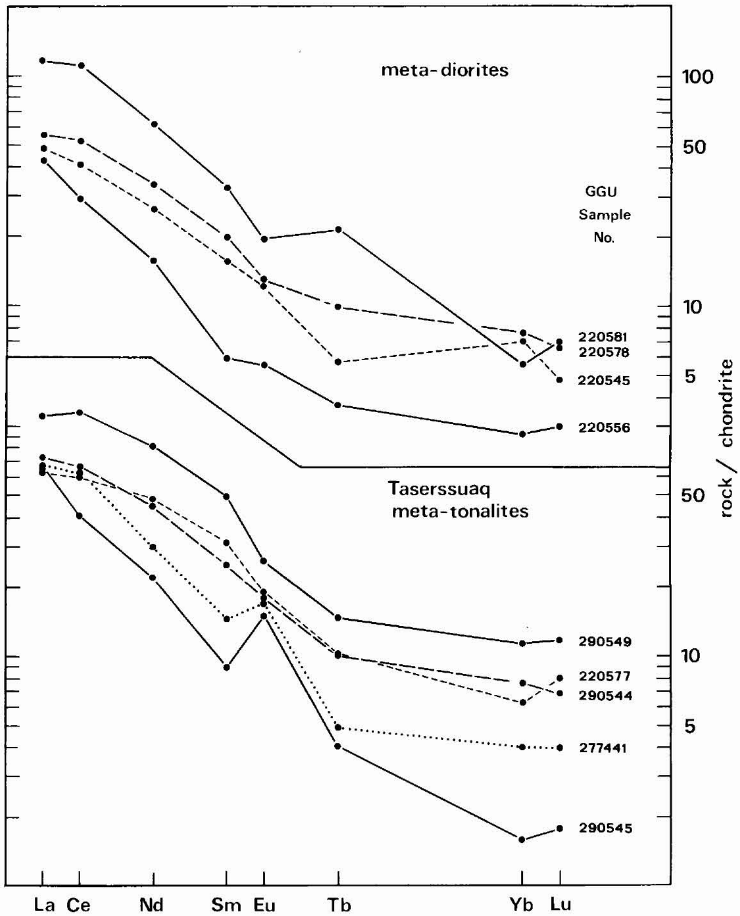


Fig. 20. Chondrite-normalized REE distribution patterns in four metadiorite and five Taserssuaq metatonalite samples. The average chondrite values are taken from Nakamura (1974) with an interpolated Tb value of 0.05 ppm.

hypothesis that *some* of the late-stage leucocratic gneisses and the grey gneiss dykes were intruded during the post-granulite facies retrograde metamorphism (Hall & Hughes, 1982). Granulite facies rocks are known to have higher K/Rb and lower Rb/Sr ratios than their amphibolite facies equivalents (e.g. Tarney & Windley, 1977; Wells, 1979). Some of the gneisses and dykes show no petrographic evidence of retrogression from granulite facies and have K/Rb values less than 500 and Rb/Sr greater than 0.05, suggesting that they have only attained amphibolite grade. However, as these chemical ratios are best used for discriminating granulite and amphibolite grade gneisses of similar bulk compositions, the comparison of, for example, the granulite facies diorites with possibly amphibolite facies trondhjemites and granodiorites is only partially successful. Although the Taserssuaq tonalites also only in rare instances show petrographic indication of their having been retrogressed from granulite

Table 2. Neutron activation rare earth element analyses

Diorites GGU Sample No	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Ce_N/Yb_N
220545	15.92	35.79	16.80	3.19	0.96	0.30	1.57	0.16	5.8
220556	14.18	25.44	9.86	1.24	0.43	0.19	0.62	0.10	10.4
220578	18.37	45.51	21.31	4.01	0.99	0.51	1.70	0.23	6.8
220581	39.24	97.43	39.19	6.59	1.50	1.14	1.23	0.24	20.1
Taserssuaq Tonalites									
290544	24.12	58.00	28.83	5.13	1.41	0.53	1.70	0.24	8.7
290545	22.12	35.34	13.63	1.82	1.16	0.21	0.35	0.06	25.7
290549	36.34	99.21	51.72	9.88.	2.01	0.77	2.52	0.40	10.0
220577	20.94	52.78	30.18	6.36	1.45	0.51	1.40	0.27	9.6
277441	21.25	53.92	18.86	2.96	1.31	0.26	0.89	0.14	15.5

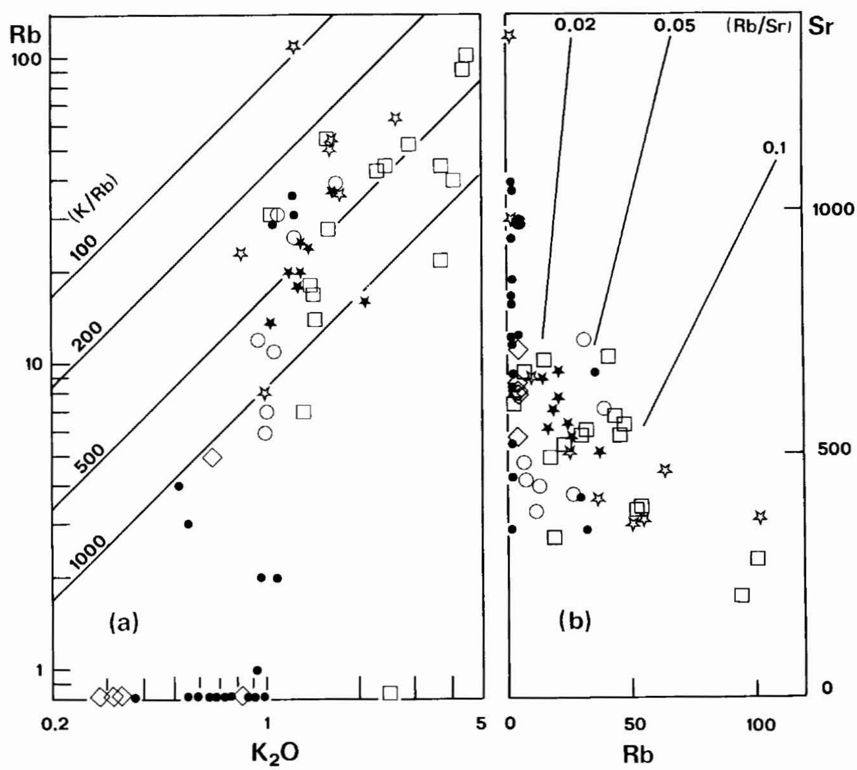


Fig. 21. (a) Contoured Rb (ppm)–K_2O (wt %) and (b) Sr–Rb (ppm) variation diagrams. Symbols as for fig. 17.

facies (Garde *et al.*, 1983), the analysed Taserssuaq samples have relatively low Rb/Sr (around 0.03) and slightly high K/Rb ratios (fig. 21).

Conclusions

Problems in attempting to correlate or distinguish certain lithological units in the northwestern part of the Isukasia region have been partially resolved by the geochemical differences between them. It appears that the various basic, intermediate and acid orthogneisses identified in the field represent discrete lithostratigraphic units and originally separate magmatic events. They comprise a complex which is equated with the Nûk gneiss complex of the Godthåbsfjord region. Difficulties remain in distinguishing disrupted bodies of homogeneous 'norite' and 'diorite' where no primary igneous features are preserved.

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Department of Geology,
Portsmouth Polytechnic,
Burnaby Road,
Portsmouth PO1 3QL,
U.K.

Field work between Fiskefjord and Godthåbsfjord, southern West Greenland

Adam A. Garde

Introduction

The 1980–1981 field work in Precambrian basement rocks for the Fiskefjord map sheet was continued in 1983. V. R. McGregor mapped granulite facies gneisses south of outer Fiskefjord in the south-western part of the map sheet area. The author worked inland between Godthåbsfjord and Fiskefjord from the eastern map sheet boundary at 50°54′E westwards to 51°45′E (fig. 22) and some notes concerning the lithologies, geometry and geochronology of this area are presented below.

The GGU cutter *K. J. V. Steenstrup* and a Jet Ranger helicopter on weekly charter from Godthåb provided logistic support for the two Fiskefjord teams and for four teams mapping in the Ivisârtoq area (see Brewer *et al.*, this report) as well as for the GGU glaciological station at Qamanârssûp sermia.

Lithologies and field relations

The area mapped by the author (fig. 22) is underlain by uniform and homogeneous orthogneisses, equivalent to the Nûk gneisses of the Godthåbsfjord region, in which there