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FIELD RELATIONS AND CHEMISTRY OF SAPPHIRINE-BEARING ROCKS FROM THE BJØRNESUND AREA, FISKENÆSSET, WESTERN GREENLAND

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ABSTRACT

Two contrasting sapphirine-bearing assemblages are described: a highly magnesian one, developed sporadically at the upper contact of the Fiskenæsset Complex in association with layered ultramafic rocks, and the other, more iron-rich, in the amphibolite bordering the Complex. Mineral assemblages described are of two kinds: (1) iron-poor: enstatite - phlogopite - olivine - pargasite - sapphirine - spinel, gedrite - sapphirine - spinel, and enstatite - gedrite - phlogopite - sapphirine - spinel; (2) iron-rich: magnesiohornblende - sapphirine - spinel - anorthite. Only the iron-poor sapphirine-bearing assemblages and their associates are characterized by the presence of accessory apatite, rutile and zircon, which may indicate a possible sedimentary origin for at least some of the sapphirine-bearing material. The iron-rich assemblage is found within rocks considered to be entirely of igneous origin.

Keywords: sapphirine, west Greenland, chemistry, petrology, Fiskenæsset Complex.

SOMMAIRE

On décrit deux assemblages à sapphirine du complexe de Fiskenæsset (Groënland occidental). Le premier, très magnésien, apparaît par ci, par là au contact supérieur, associé aux roches ultramafiques stratifiées. L'autre, plus riche en fer, se trouve dans les amphibolites en bordure du complexe. On note les assemblages suivants: (1) dans les roches à faible teneur en fer: enstatite - phlogopite - olivine - pargasite - sapphirine - spinelle, gedrite - sapphirine - spinelle, et enstatite - gedrite - phlogopite - sapphirine - spinelle; (2) dans les roches riches en fer, magnésiohornblende - sapphirine - spinelle - anorthite. Seuls les assemblages à sapphirine pauvres en fer, et les assemblages qui leur sont associés, contiennent apatite, rutile et zircon comme minéraux accessoires, ce qui fait penser à une origine sédimentaire pour au moins une partie des roches à sapphirine. L'assemblage riche en fer, par contre, se trouve dans des roches dont l'origine est considérée comme purement ignée.

(Traduit par la Rédaction)

Mots-clés: sapphirine, Groënland oocidental, chimisme, pétrologie, complexe de Fiskenæsset.

INTRODUCTION

Sapphirine, first described from the Fiskenæsset district of western Greenland in 1809 by Giesecke (1910), has since been found worldwide in high-grade metamorphic rocks of diverse composition and history (Higgins *et al.* 1979). This paper describes three more sapphirine-bearing localities some 50 km east of the type locality. Herd *et al.* (1969) and Herd (1973) reinvestigated the Fiskenæsset locality, describing it in detail; the sapphirine was found to be associated with rocks marginal to the Fiskenæsset Complex (Windley *et al.* 1973).

The three occurrences described in this paper have similar field relations to the classic Fiskenæsset locality (Fig. 1). The local geology is dominated by a high-grade quartzofeldspathic gneiss terrane containing intercalated layers of amphibolite and outlying parts of the Fiskenæsset Complex. Petrographic evidence indicates that these rocks failed to enter granulite-facies conditions during late Archean metamorphism (Williams 1973).

Two types of sapphirine-bearing lithology are described, with contrasting mineralogy and mineral chemistry. Both fit into the classification system proposed by Herd *et al.* (1969).

PETROGRAPHY AND MINERALOGY OF SAPPHIRINE-BEARING LITHOLOGIES AND ASSOCIATED ROCKS

Iron-poor assemblages

Two examples of an iron-poor sapphirine-bearing assemblage occur at the contact between the Fiskenæsset Complex and amphibolite (Fig. 1b). Four distinct parageneses have been recognized (Table 1). Where present, sapphirine occurs as rims around spinel blasts up to 10 mm across in a matrix containing relics of olivine and enstatite within gedrite and phlogopite. The gedrite and enstatite are straw-colored in hand specimen and predominate over olivine, pargasite and phlogopite, which are irregularly distributed. Where sapphirine and spinel are present, amphibole and mica commonly radiate from them.

In thin section, amphibole and sapphirine are colorless; the spinel is palest blue and phlogopite is pale brown. Grains of amphibole and mica clearly replace olivine and enstatite. However, spinel may be intergrown symplectitically with gedrite, and is commonly rimmed by both gedrite and phlogopite. Spinel and olivine are found as large blasts with inclusions of rutile, zircon and apatite. Anorthitic plagioclase is rarely found but occurs enclosing eu-

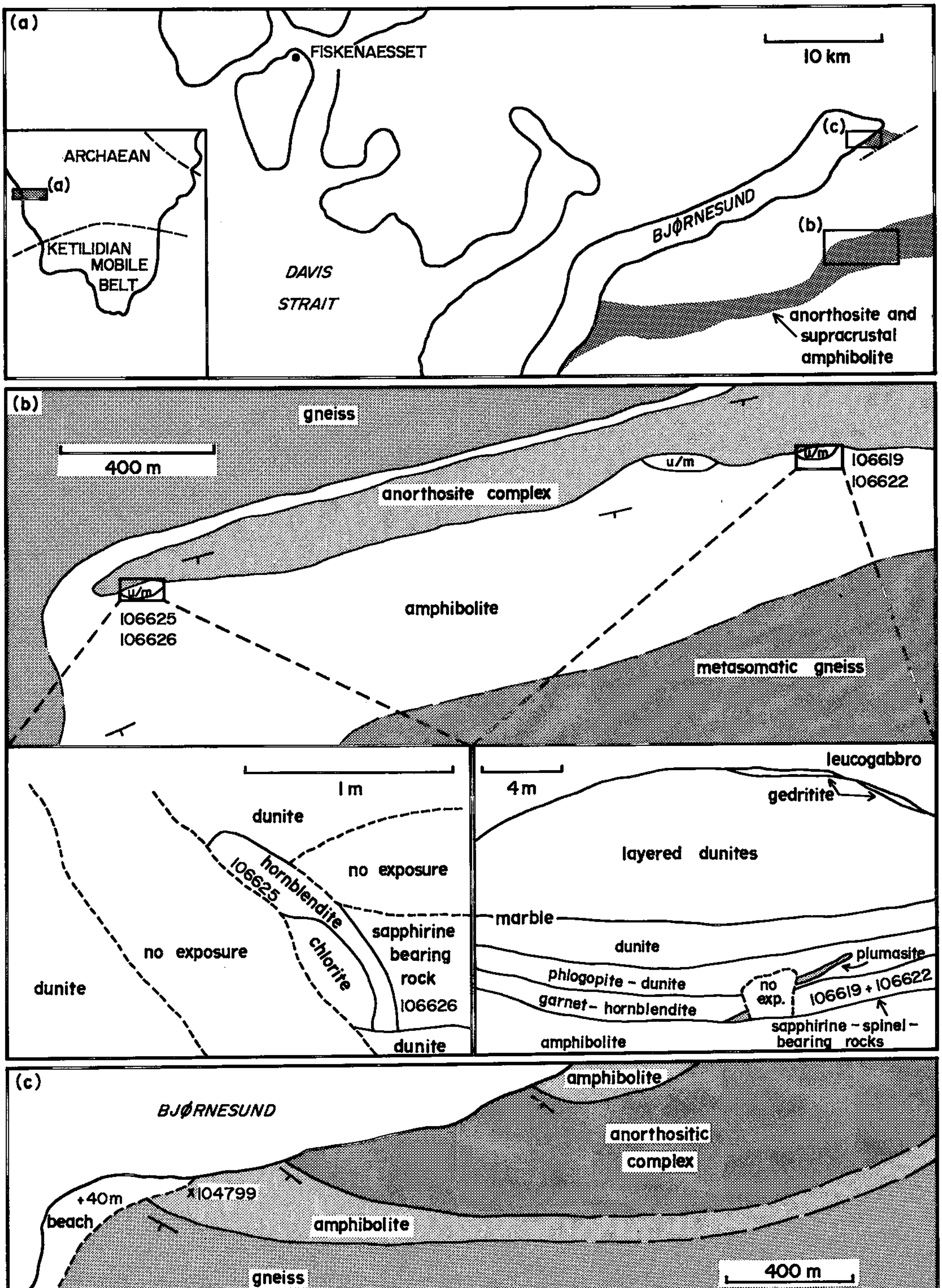

FIG. 1. (a) Map showing sapphirine localities; inset left indicates position of (a) within Greenland. Positions of Figure 1b and 1c are indicated. Stipple: amphibolite and anorthosite in the Bjørnesund area only. (b) Geological map of the two iron-poor sapphirine occurrences. Insets indicate detailed relationships. (c) Geological map of relatively iron-rich sapphirine occurrence.

hedral gedrite needles poikiloblastically. In general, these four lithologies show abundant textural evidence for mineral disequilibrium, with particularly complicated textural relationships.

The four lithologies are developed overlying and within magnetite- and pleonaste-rich dunites and peridotites, which occur as well-layered, discontinuous lenses along the upper anorthositic contact. Interlayered with these ultramafic units are thin layers of marble. High chromium and nickel concentrations in the ultramafic rocks suggest an igneous origin. Locally derived pegmatites of diverse 'granitic' compositions are commonly associated with the zone of contact between the ultramafic rocks and the amphibolite. They range in composition from true granite through syenite to subsilicic rocks containing only albite and corundum (plumasite).

Iron-rich assemblage

An example of an iron-rich sapphirine-bearing assemblage (GGU 104799) is found near the northern end of Bjørnesund (Fig. 1c), and has the paragenesis magnesio-hornglende – sapphirine – spinel – anorthite ± magnetite ± corundum ± zoisite (Herd type B_2). The sapphirine is contained within a saccharoidal hornblende-rich rock found within fine-grained amphibolites lying structurally above the Fiskenæsset Complex. Composed chiefly of slightly foliated pale green granoblastic magnesio-hornblende, the rock contains medium blue, pleochroic sapphirine and olive green aluminous spinel as elongate grains up to 1 mm across. Sapphirine commonly includes spinel and, in some instances, perhaps replaces it.

TABLE 1. MINERAL ASSEMBLAGES AND HERD CLASSIFICATION OF IRON-POOR SAPPHIRINE-BEARING AND ASSOCIATED ROCKS

Sample	Paragenesis	Herd Class
106619	Enstatite-phlogopite-olivine-pargasite-sapphirine-spinel-zircon±anorthite	A/B_1
106622	Gedrite-sapphirine-spinel-rutile-apatite	C
106625	Gedrite-phlogopite-anorthite	No sapph. Type 3
106626	Enstatite-gedrite-phlogopite-sapphirine-spinel-zircon-rutile	A/C

Samples are identified by their Greenland Geological Survey (G.G.U.) number. Material is housed at the University of Exeter, U.K.

Anorthite-rich plagioclase, magnetite and corundum occur as accessories, in bands parallel to the foliation. Corundum and magnetite appear to have formed from the breakdown of spinel, whereas zoisite formed from the degradation of anorthite. The general texture of amphibole, spinel, sapphirine and anorthite is one of mineral equilibrium, with simple grain-boundaries and triple-point contacts.

Mineral Chemistry of the Sapphirine-bearing Lithologies

The sapphirine-bearing lithologies and associated rocks have been analyzed (Table 2). Except for 106619, there is little evidence of compositional zoning; therefore, the compositions are considered to represent the typical chemistry of each phase. The composition of olivine, enstatite and phlogopite in

TABLE 2. COMPOSITION OF SAPPHIRINE AND ASSOCIATED MINERALS

	106622[1]				106626[1]				106619[1]				104799[2]		
	Spr #	Spl	Opx	Ged	Spr	Spl	Opx	Ged	Phl	Hbl	Opx	Ol	Spr	Spl	Hbl
SiO_2	13.2	tr.	56.1	46.4	14.0	-	56.4	51.5	40.3	50.7	58.6	42.7	13.3	tr.	45.7
TiO_2	tr.	0.02	0.1	0.3	0.04	tr.	0.03	-	0.6	0.77	0.07	0.01	0.02	0.02	0.2
Al_2O_3	66.1	68.3	3.47	17.4	62.5	68.5	3.01	16.4	17.2	9.09	2.11	tr.	63.5	65.0	15.2
FeO	3.1	10.1	6.54	5.5	2.4	8.1	6.31	5.27	2.13	1.62	3.82	4.48	5.91	18.8	7.16
MnO	tr.	0.03	0.03	0.06	-	-	-	-	-	0.03	0.11	0.06	0.06	0.09	0.12
MgO	19.4	21.9	34.8	25.7	20.4	23.6	35.0	26.8	24.5	21.3	37.3	53.6	17.6	15.5	16.0
CaO	-	-	0.03	0.63	tr.	-	0.03	0.46	tr.	12.9	0.05	0.03	0.01	0.02	11.6
Na_2O	-	-	-	1.84	-	-	tr.	-	0.94	1.11	tr.	tr.	-	-	1.14
K_2O	-	-	-	0.03	-	-	0.02	-	7.8	-	-	-	-	-	0.16
Cr_2O_3	-	0.12	0.02	0.02	-	-	-	-	-	0.02	tr.	tr.	0.16	0.28	0.05
Total	101.8	100.4	101.0	97.7	99.3	100.0	100.7	100.4	93.4	97.4	101.9	100.8	100.4	99.6	97.1
Mg/(Mg+Fe)	0.92	0.78	0.90	0.89	0.94	0.84	0.91	0.90	0.95	0.96	0.95	0.96	0.84	0.60	0.80

1. See Table 1 for iron-poor assemblages. 2. Iron-rich assemblage. # Analyst, J.C. Bevan. Abbreviations: Spr sapphirine, Spl spinel, Opx orthopyroxene, Ged gedrite, Phl phlogopite, Hbl hornblende, Ol olivine, tr. trace. Total iron calculated as FeO. Probe conditions 15 kV, 20 nA, correction program "MAGIC" adapted by R.N. Wilson.

the iron-poor lithologies is extremely magnesian, in contrast to the adjacent ultramafic rocks, which are characterized by the assemblage forsterite - calcite - magnetite - pleonaste.

The distinction between the two sapphirine-bearing groups of rocks based on host lithologies and mineral assemblages is confirmed by the Mg/Fe ratio of the component minerals. The distribution of iron and magnesium between sapphirine and spinel (Fig. 2) shows that whereas the values of the Mg/Fe ratio of the coexisting minerals are very different, the distribution coefficient K_D for both is similar, and identical to that determined by Lal *et al.* (1978).

The sapphirine compositions, plotted on an Al_2O_3-SiO_2-(MgO+FeO) diagram, lie within the linear zone (Fig. 3) defined by most previous data [*cf.* Higgins *et al.* (1979)].

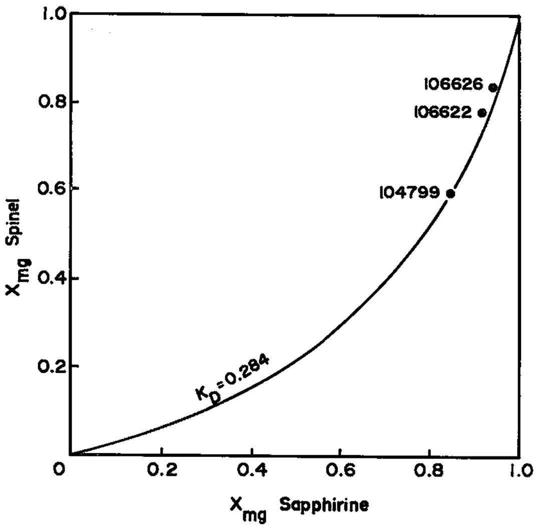

FIG. 2. Magnesium-iron distribution diagram for sapphirine - spinel pairs. K_D line after Lal *et al.* (1978).

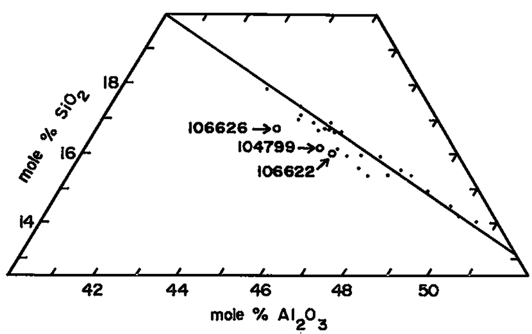

FIG. 3. Sapphirine compositions (microprobe data) from Table 2 plotted in a portion of the (Mg,Fe)O - Al_2O_3 - SiO_2 ternary system. Line joins ideal compositions 2:2:1 and 7:9:3, and represents the locus of compositions involving MgSi = AlAl solid solution. Solid circles represent compositions from Higgins *et al.* (1979), from whose work the figure is adapted. Open circles represent compositions of Bjørnesund sapphirine.

DISCUSSION

The compositional data for the minerals indicate that the sapphirine-bearing rocks are typically aluminous and subsilicic. Whereas rocks of this composition commonly are also magnesian, the assemblage in specimen 104799 shows that the presence of iron does not preclude the formation of sapphirine. The late-stage nature of both amphibole and mica in the iron-poor rocks suggests that they grew during movement of alkalis from neighboring quartzofeldspathic rocks into the aluminous lithologies, a process documented by Fowler *et al.* (1981) as having occurred over significant areas in the Fiskenæsset region.

Iron-rich aluminous spinel (pleonaste) and magnetite so characteristic of the layered ultramafic units are not found in the iron-poor sapphirine-bearing rocks, despite their very close association in space (Fig. 1b inset). Perhaps this is an indication that the sapphirine-bearing rocks were not derived from them. This is supported by the common presence of rutile, apatite and zircon in the sapphirine-bearing rocks, but not in the ultramafic rocks. Preservation of undoubted metasediments at an identical stratigraphic horizon elsewhere in the region (Windley *et al.* 1973) reinforces the mineralogical evidence for a sedimentary protolith for the sapphirine-bearing rocks.

The relatively iron-rich sapphirine assemblage on the Bjørnesund shore contains no evidence of a possible sedimentary origin; in general, the surrounding lithologies are thought to be the metamorphosed equivalents of a supracrustal volcanic assemblage.

The two contasting types of sapphirine-bearing assemblage re-emphasize the work of Warren (1979), that chemical requirements for sapphirine formation are diverse and sufficiently lax to allow the mineral to form in a variety of aluminous environments at high grades of metamorphism.

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