Mantle Xenoliths
Edited by P. H. Nixon

1
Greenland

B. H. Scott Smith

Mantle xenoliths from Greenland are rare (Fig. 2), particularly in East Greenland, despite the occurrence of many mantle-derived igneous rocks which could have acted as carriers. The majority of xenoliths are found in West Greenland and are derived from hypabyssal kimberlites. In contrast to their overall paucity, the xenoliths are unusually abundant when present in these kimberlites, and there are some spectacular outcrops (Fig. 3). Three isolated occurrences of rare xenoliths are known from other host rocks, two from the Tertiary basaltic volcanic provinces of West and East Greenland, and a third from an ultramafic lamprophyric rock within the South Greenland Proterozoic Gardar province. The mantle xenoliths from Greenland are mostly extremely fresh. Mineralogically they are unusual because olivine is by far the most abundant constituent. With a paucity of associated orthopyroxene, clinopyroxene, and garnet, the rock classifications are not used rigorously in this chapter, and the terminology is generally that of previous authors. The xenoliths have both coarse and deformed textures (terminology after Harte, 1977, 1983). There are also some reports of lower crustal xenoliths in both West and East Greenland (e.g. Andrews and Emeleus, 1971; Rucklidge *et al.*, 1980; Griffin and O'Reilly, Chapter 29).

Many so-called kimberlitic-lamprophyric-carbonatitic dykes occur in West Greenland. *Kimberlite* is composed of two generations of olivine (anhedral macrocrysts and euhedral phenocrysts) in a groundmass comprising several of the following minerals: phlogopite, carbonate, serpentine, clinopyroxene, monticellite, apatite, spinel, perovskite and ilmenite (as defined by Clement *et al.*, 1984; Mitchell, 1979b). Macrocrysts of phlogopite, picroilmenite, chromium spinel, magnesium garnet, chromium diopside, and orthopyroxene may also be present. Most of the mantle-bearing intrusions have been referred to as kimberlites. The Holsteinsborg kimberlites fall within the definition of Clement *et al.* (1984), but are unusual in certain respects when compared with many kimberlites elsewhere (for example, in phlogopite and spinel mineral chemistry). It is difficult to apply these definitions to the other areas of Greenland as insufficient data are available. In this section, therefore, the terminology of the previous authors is used. In West Greenland, the kimberlite dykes are often spatially associated with *lamprophyres* but inadequate information is available to classify them further (e.g., using the scheme of Rock, 1986). The lamprophyres, however, only rarely contain mantle xenoliths. Some of the dykes, to the south of the Holsteinsborg kimberlites, are classified as lamproites. *Lamproite* contains, as primary phenocrystal and/or groundmass constituents, variable amounts of leucite, phlogopite, clinopyroxene, amphibole, olivine, and sanidine, while other primary minerals may include priderite, perovskite, apatite, wadeite and spinel (Scott Smith and Skinner, 1984a, b; Mitchell, 1985). Elsewhere, lamproites are known to contain significant quantities of diamond (Scott Smith and Skinner, 1984b) and mantle xenoliths (Atkinson *et al.*, 1984), but those from West Greenland appear to contain only dunite microxenoliths.

Distribution and Composition

The known mantle xenolith localities mostly comprise coastal outcrops and are described in an anticlockwise direction starting in central West Greenland (Fig. 2). The geographical divisions of Greenland are from Fig. 473 in Escher and Watt

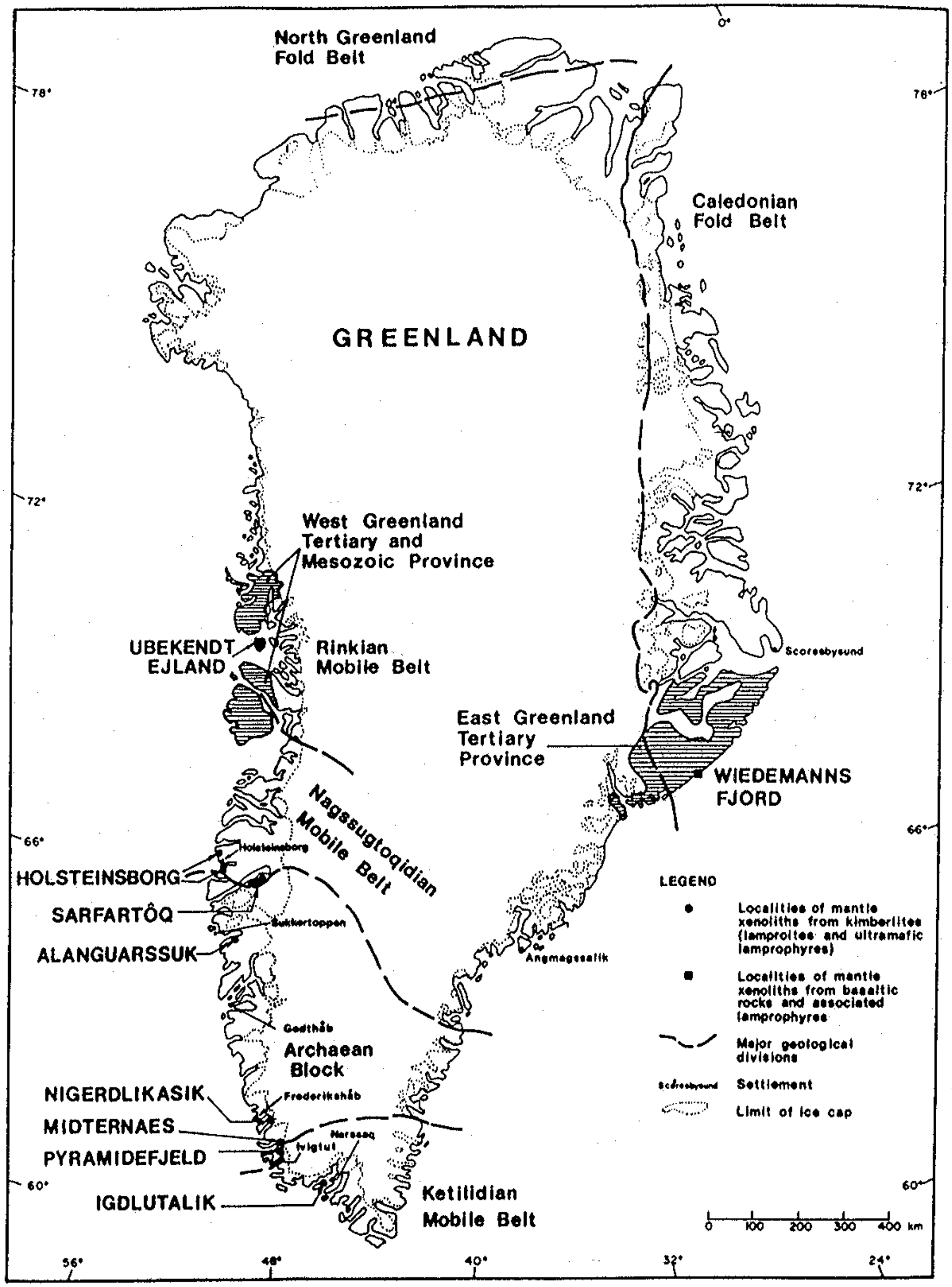

Figure 2. Map of Greenland showing the mantle xenolith localities and the main geological divisions (the latter after Escher and Watt, 1976a)

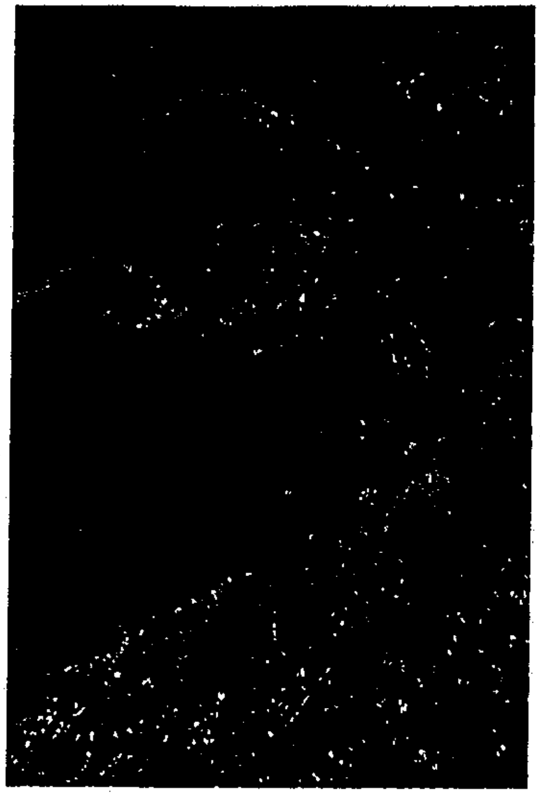

Figure 3. Abundant rounded mantle xenoliths in the central part of a kimberlite dyke from the Holsteinsborg area (Manitsorssuaq). (Graduations on hammer shaft at 10 cm intervals). *Reproduced by permission of the Commission for Scientific Research in Greenland*

(1976a). The geology and whole-rock geochemistry of the host rocks are summarised in Tables 2 and 3 respectively. Modal analyses for some xenoliths are given in Table 4.

Ubekendt Ejland

The mantle xenoliths from Ubekendt Ejland in central West Greenland are found both in a basanitoid lava, one of the uppermost alkaline lavas in this area (youngest of 63 to 54 m.y. lavas) as well as in a late (33 m.y.) monchiquitic lamprophyre dyke. Data for these localities are given by Clarke and Pedersen (1976), Larsen (1981, 1982) and Clarke *et al.* (1983).

The dunites from the basanitoid lava include both coarse and deformed types. They are composed of olivine ($Fo_{93.2-91.9}$), small amounts of enstatite ($En_{93.4-92.8}$) low in Al_2O_3 and CaO, and sometimes zoned chromium spinel (13–61% Cr_2O_3, 3–55 wt% Al_2O_3). A single lherzolite from the basanitoid lava has a porphyroclastic (deformed) texture and contains olivine (Fo_{94}), enstatite (En_{94}), chromium diopside, chromium spinel (58 wt% Cr_2O_3), and titaniferous phlogopite (11 wt% TiO_2) (Table 5) as well as hyalophane and chlorite. A single coarse lherzolite from the lamprophyre is composed of olivine, chromium diopside, enstatite, chromium spinel and small amounts of plagioclase and phlogopite. With low Mg/(Mg + Fe) ratios, this lherzolite has been interpreted as a high-pressure precipitate (Larsen, 1982). Pyroxenites and wehrlites are also reported from this dyke.

Holsteinsborg and Sarfartôq

Mantle xenoliths were first noted in the Holsteinsborg area by Escher *et al.* (1970), Escher and Watterson (1973), and then by Secher and Larsen (1978) for the Sarfartôq area. At least 200 dykes occur in this general area and the most recent compilation of localities is given by Larsen (1980). The dykes include kimberlites, which contain most of the known xenoliths, lamproites and other varieties of lamprophyre. In the Sarfartôq area, the dykes are associated with a carbonatite. The apparent distribution 'gap' between Holsteinsborg and Sarfartôq may reflect a lack of exposure rather than the absence of these dykes (Larsen, 1980). More detailed information is given by Bridgwater (1971), Scott (1977, 1979, 1981), Brooks *et al.* (1978), Smith (1979), Larsen (1980), Secher and Larsen (1980), Thy (1982), Stecher and Thy (1982), and Larsen *et al.* (1983). Two microdiamonds were recovered from large bulk stream samples taken in the Sarfartôq valley. Narrow kimberlite dykes occur upstream from these samples and are thought to be the probable source. It is, however, likely that the dykes have a very low diamond content, as testing of these narrow bodies did not yield further diamonds.

Kimberlites

The Holsteinsborg mantle xenolith-bearing dykes are mostly clinopyroxene-bearing, phlogopite kimberlites, but carbonate may also be abundant. A total of 44 samples of dunites, 10 lherzolites, 9 wehrlites, and 8 harzburgites have been identified. Garnet was observed in only one coarse wehrlite and one lherzolite. Both coarse and deformed

TABLE 2. Summary of the host rock geology of the main mantle xenolith localities in Greenland

Locality	Host rock type	Intrusion type	Age	Mineralogy (primary, dominant)	Country rock
West Greenland					
Ubekendt Ejland	a. Basanitoid	Lava flow	ca. 60 m.y.	ol, cpx, plag,	Tertiary basaltic
	b. OL-monchiquite	Dyke	ca. 33 m.y.	cpx, ol, amph, biotite	lava pile
Holsteinsborg	Kimberlite	Dykes	ca. 587 m.y.	ol, phlog, cpx, carb	Nagssugtoqidian
	Lamproite	Dykes	1220 m.y.	phlog, ol, amph, leucite	Nagssugtoqidian
	Lamprophyre	Lens	not known	phlog, ol, ox	Nagssugtoqidian
Sarfartôq	Kimberlite	Dykes	ca. 600 m.y.	ol, phlog, carb	Nagssugtoqidian
Alanguarssuk	Kimberlite	Dyke	not known	ol, ilm, carb, serp	Archaean
Nigerdlikasik	Kimberlite	Dyke + Sills	ca. 200 m.y.	ol, carb, phlog	Archaean gneiss
Midternaes	Kimberlite	Sills	ca. 200 m.y.	ol, carb, phlog, cpx	Archaean gneiss + Ketilidian
Pyramidefjeld	Kimberlite	Sills	ca. 200 m.y.	ol, phlog, cpx, carb	Archaean gneiss
Igdlutalik	Ultramafic lamprophyre	Dyke	between 1150 and 1600 m.y.	oxide, mica	Ketilidian
East Greenland					
Wiedemanns Fjord	Camptonitic lamprophyre	Dyke	? 50 m.y.	cpx, ol, amph	Tertiary plateau basalts

(Fig. 4) varieties occur. The range in olivine compositions is $Fo_{82.5-92.5}$ (Table 6). The clinopyroxenes are chromium diopsides with fairly restricted compositions. Somewhat subcalcic clinopyroxene was found in the coarse garnet wehrlite ($Ca/(Ca+Mg) = 0.39$). The orthopyroxenes also have restricted compositions ($En_{89.7-92.9}$) but with variable Al_2O_3 up to 2.54 wt%. The garnets from the coarse lherzolite fall into Group 9 (chrome pyrope) of Dawson and Stephens (1975, 1976) and are typical of garnet lherzolite (and websterite). The garnets from the coarse wehrlite fall in Group 1 (titanian pyrope). Spinels (57–62.2 wt% Cr_2O_3) which are considered to be primary, occur in both coarse and porphyroclastic inclusions. The occurrence of phlogopite, usually in recrystallised parts of xenoliths and sometimes in vein-like structures, is probably indicative of modal metasomatism (Harte, 1983). The brown metasomatic phlogopites have greater than 1 wt% TiO_2 (analysis 56, Table 6) and no detectable NiO, which distinguishes them from the secondary phlogopites. One xenolith contains a vein network of ilmenite (Fig. 4) and is similar to ilmenite-bearing xenoliths described by Harte and Gurney (1975c) from Matsoku and probably also results from some metasomatic-related process. Garnet and ilmenite macrocrysts are not common but their compositions are typical of kimberlites elsewhere.

S. Galer (Cambridge University, personal communication) is undertaking an isotope study on a few Holsteinsborg xenoliths and their host rocks. Preliminary results for a garnet lherzolite give $^{143/144}Nd$ of 0.511887 and $^{87/86}Sr$ of 0.703165 (for clinopyroxene separates calculated at 570 m.y.). The data confirm that the xenoliths are not genetically related to the host kimberlite and also that they are similar to certain enriched alkali basalt xenoliths.

The kimberlites of the Sarfartôq region give ages of 593 to 656 m.y., with the associated carbonatite having an age of about 600 m.y. The kimberlite dykes are mostly phlogopite-bearing, but display variable mineralogy from olivine-poor to olivine-rich and the peridotite xenoliths are confined to the latter. In some instances, these dykes are similar to the phlogopite-kimberlites of the Holsteinsborg region, but the groundmasses of others differs in that they are dominated by carbonate and oxide minerals.

Only two samples of dunite xenoliths from the Sarfartôq area have been analysed (Table 6). L.-M. Larsen (personal communication) notes that

TABLE 3. Whole-rock compositions for the host rocks of mantle xenoliths from Greenland

	Kimberlite					Basaltic		
	1 PYR	2 NIG	3 ALANG	4 HOLS	5 SARF	6 UE-MON	7 UE-BAS	8 IGDL
SiO_2	29.5	26.45	23.80	30.88	30.70	43.26	44.30	35.58
TiO_2	1.81	1.88	4.50	4.72	3.21	1.43	2.28	3.52
Al_2O_3	2.70	2.02	1.59	2.43	2.04	14.50	14.11	6.04
Fe_2O_3	5.6	4.00	7.37	4.39	5.45	2.55	4.02	17.05[1]
FeO	7.9	5.31	5.44	9.56	7.15	5.82	7.10	—
MnO	0.21	0.42	0.21	0.19	0.17	0.16	0.19	0.29
MgO	27.1	28.00	32.88	26.98	26.47	8.57	10.14	24.12
CaO	10.7	12.33	7.01	9.55	9.36	12.89	11.18	5.98
Na_2O	0.47	0.23	0.16	0.24	0.11	2.29	2.87	0.19
K_2O	1.76	1.60	0.25	1.79	0.93	2.29	0.43	0.03
H_2O+	3.2	3.98	4.84	3.66	8.63	2.41	3.44	0.52
P_2O_5	0.54	0.66	0.11	0.49	0.41	0.38	0.65	—
CO_2	7.8	12.60	11.70	4.20	5.61	2.70	—	—
H_2O-	0.43	—	0.44	—	—	—	—	—
S	0.16	—	—	—	—	—	—	—
Total	100.00	99.67	100.30	99.08	100.24	99.25	100.71	(93.32)
V		190	50	616	376			
Cr		1300	900	1580	1758			
Ni		1200	400	873	847			
Cu			120	108	117			
Zn			50	89	66			
Rb	50			54	39			
Sr	780	1300	1100	1061	591			
Y				18	13			
Zr	270	280	60	264	198			
Ba		3400	900	693	355			
Co		130	60					

1 and 2, from Pyramidefjeld and Nigerdlikasik from Emeleus and Andrews (1975) – majors are averages of 6 and 2 analyses respectively; 3, from Alanguarssuk from Goff (1973) – majors for sample 87745 and traces for sample 87742, both aphyric kimberlite; 4, from Manitsorssuaq in Holsteinsborg area from Scott (1977); 5, from Sarfartup Nuna in Sarfartoq area from Scott (1977) – analyses 4 and 5 are actual host rocks of studied xenoliths; 6 and 7, for monchiquitic lamprophyre and basanitoid host rocks from Ubekendt Ejland from Larsen (1982); 8, matrix of sample GGU 181916 from Igdlutalik dyke – note only one analysis from data displaying variable geochemistry; analysts D. James and J. G. Fitton (B. G. J. Upton, personal communication).

the mantle xenoliths are mostly dunites, that lherzolites are less common, and that garnet lherzolites are present but rare. Her sample collection includes at least three garnet peridotites and a deformed garnet lherzolite containing ilmenite, sulphide, and spinel.

Lamproites

The lamproites to the south of the Holsteinsborg kimberlites are older (1214 to 1227 m.y.) and typically contain phlogopite, leucite, amphibole, feldspar, and some olivine. They contain deformed dunite microxenoliths with olivines which have Mg/(Mg + Fe) atomic ratios of 0.80 to 0.93.

An associated unusual micaceous, ultramafic lamprophyric intrusion contains a high concentration of rounded olivine-rich xenoliths including one coarse wehrlite. The host rock is composed of coarse (up to 1.5 cm) mica which encloses irregular opaque minerals, subhedral olivine, and occasional crystals of clinopyroxene.

Alanguarssuk

At Alanguarssuk, near Sukkertoppen, in southern West Greenland, a xenolith-bearing kimberlite occurs among a suite of lamprophyric, carbonate-rich dykes (Goff, 1973). Larsen *et al.* (1983) and L.M. Larsen (personal communication) note that kimberlite and lamprophyre dykes occur scattered throughout the Sukkertoppen area (in the vicinity

TABLE 4. Modal analyses of mantle xenoliths from Greenland

Host rock	Kimberlite									Lamp.*	Basanitoid	
Locality	Pyramidefjeld		Nigerdlikasik			Holsteinsborg				Ubekendt Ejland		
Analysis number	1	2	3	4	5	6	7	8	9	10	11	12
Sample number	39654	39660C	59200G$_1$	72501G$_1$	58198S$_1$	5518	5524	5698(1)	5984	1730123B	163717	163719
Olivine	98.1	77.7	78	68	80	82.8	60.8	84.2	85.6	73‡	77(+16‡)	80(+6‡)
Orthopyroxene	—	8.3	13	17	17	6.8	—	—	3.8	10	1	7
Clinopyroxene	0.2	10.8	4	3	2	2.8	22.0	12.2	7.8	15	—	5
Garnet	—	—	5	13	—	—	16.0	—	2.6	—	—	—
Spinel	0.8	—	—	—	1	1.6†	—	—	0.2†	2	3	0.7
Phlogopite	0.9	3.2	—	—	—	6.0	1.0	3.6	—	—	—	0.7

* = monochiquitic lamprophyre; †opaques; ‡sheet silicates presumed to be mostly after olivine. 1 to 5 from Andrews and Emeleus (1971); 6–9 data for relatively olivine-poor xenoliths (this study); 10 to 12 from Larsen (1982), 12-only visual estimate; 11 includes 3% carbonate, 12 includes 0.7% feldspar. 5- and 6-digit sample numbers refer to GGU samples.
Note: Analyses given here in most cases represent relatively olivine-poor xenoliths.

of the Jurassic Qaqarssuk carbonatite), but only garnet megacrysts and no mantle xenoliths have been found.

The Alanguarssuk kimberlite contains olivine (two generations), ilmenite, carbonate, serpentine and occasionally trace amounts of phlogopite. The age is not known, but the nearby Qaqarssuk carbonatite and lamprophyre give ages of 169 to 176 m.y.

Three small xenoliths have been described from this kimberlite and include a garnet mica wehrlite, a garnet wehrlite and a chromium pyrope enclosing

TABLE 5. Selected mineral compositions of mantle xenoliths from the Ubekendt Ejland and Wiedemanns Fjord basaltic rocks (from Larsen, 1982; and Brooks and Rucklidge, 1973, respectively)

Locality	Ubekendt Ejland							Wiedemanns Fjord			
Mineral	ol	opx		cpx		spinel	phlog	ol	opx	cpx	spinel
Sample No.	163728	163719	170123B	163719	170123B	163715	163719	—	—	—	—
Host rock*	Bas	Bas	Lam	Bas	Lam	Bas	Bas	—	—	—	—
Analysis No.	1	2	3	4	5	6	7	8	9	10	11
SiO_2	40.8	58.5	57.2	56.3	53.9	—	37.9	40.8	56.5	51.0	—
TiO_2	n.d.	n.d.	n.d.	0.01	0.13	0.03	11.6	0.01	0.11	0.13	0.12
Al_2O_3	0.02	0.08	0.43	0.68	2.84	3.91	12.1	0.02	1.94	4.55	33.0
Cr_2O_3	0.01	0.06	0.06	1.76	0.56	61.0	—	0.00	0.91	0.60	34.3
Fe_2O_3	—	—	—	—	—	8.11	—	—	—	—	4.81
FeO	7.40	4.16	8.50	1.77	4.07	13.11	4.57	7.49	4.96	2.83	11.2
MnO	0.10	0.11	0.25	0.08	0.16	0.42	0.03	n.d.	n.d.	n.d.	0.14
NiO	0.24	—	—	—	—	—	—	51.4	35.6	15.9	—
MgO	50.7	38.2	32.3	19.5	15.8	12.2	18.7	0.03	0.46	22.3	17.1
CaO	n.d.	0.15	0.49	18.9	20.7	n.d.	0.05	—	n.d.	0.02	—
Na_2O	—	0.09	0.03	1.21	1.03	—	0.88	—	n.d.	0.60	—
K_2O	—	0.03	n.d.	n.d.	n.d.	—	10.35	—	—	—	—
Total	99.3	101.4	99.3	100.2	99.2	98.8	96.8	99.8	100.5	98.9	100.7

*Lam = lamprophyre; Bas = basanitoid lava. n.d. = not detected. 1, from dunite; 2 to 7, from lherzolite – 7 includes 0.14 BaO, 0.45 F, 0.06 Cl; 8, 9 and 11, probably from xenolith; 10, megacryst. 5- and 6-digit sample numbers refer to GGU samples.

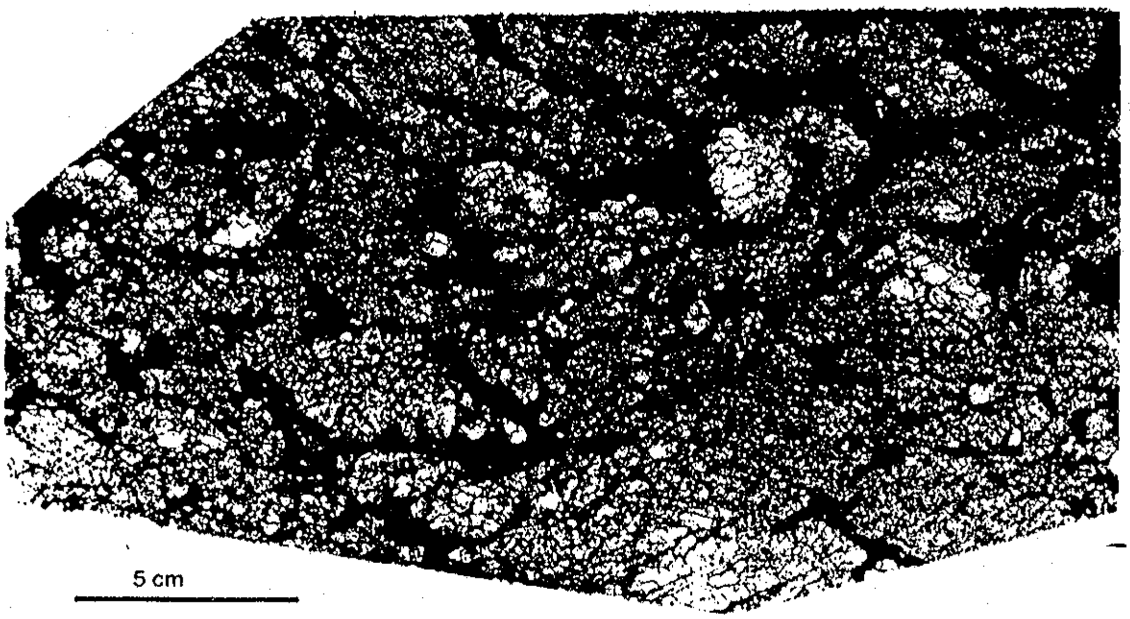

Figure 4. A mosaic-porphyroclastic (deformed) dunite xenolith veined by ilmenite, in kimberlite, Manitsorssuaq, Holsteinsborg area

TABLE 6. Selected mineral chemistry of mantle xenoliths and xenocrysts from kimberlites in the Holsteinsborg and Sarfartôq area (Scott, 1977) and at Alanguarssuk (Goff, 1973)

Locality	Holsteinsborg									Sarfartôq	Alanguarssuk		
Mode of occurrence	Xenoliths								Xenocryst	Xenolith	Xenolith		Xenocryst
Mineral	ol	opx		cpx	gt	spinel	phlog	ilm	gt	ol	cpx	gt	opx
Sample no.	551801	551801	5698(2)	5961	5524B	5698(1)	5698(1)	5988	5603	5914(3)	X1	X1	4
Analysis no.	265	501	507	498	487	48	56	511	80	406	1	2	3
SiO_2	41.64	56.61	58.21	54.58	42.28	0.09	41.7	n.d.	42.92	39.93	53.87	41.43	57.13
TiO_2	n.d.	0.02	0.09	0.15	0.67	2.54	1.05	52.16	0.51	--	0.10	n.d.	1.09
Al_2O_3	n.d.	2.49	0.03	1.13	21.76	1.95	11.54	0.34	20.66	--	4.54	21.90	0.80
Cr_2O_3	n.d	0.56	0.18	1.51	0.93	59.49	0.36	1.43	3.38	0.06	2.72	3.27	0.35
Fe_2O_3		-			---	8.00	---	7.70	-		--	--	
FeO	7.51	4.99	5.19	3.09	9.03	16.90	3.36	27.70	6.57	12.17	3.17	10.70	7.46
MnO	0.10	0.11	0.16	0.11	0.25	0.89	0.03	0.25	0.30	0.13	0.15	0.92	0.14
NiO	0.35	0.04	0.09	0.05	0.03		n.d	0.08	--	0.28			
MgO	51.24	34.73	35.60	16.46	20.60	11.23	25.10	10.62	21.80	46.62	13.91	18.30	33.44
CaO	n.d.	0.39	0.56	21.31	4.52	0.09	n.d	0.03	4.77	0.06	17.31	4.27	0.69
Na_2O	0.03	0.09	0.05	1.40	0.05	n.d	0.24	n.d.	0.07			n.d.	n.d
K_2O	n.d.	0.01	0.02	0.03	n.d.	n.d.	9.97	0.03	n.d.	--	n.d	n.d.	n.d
Total	100.87	100.04	100.18	99.82	100.12	101.18	93.52	100.34	100.98	99.25	95.77	100.79	100.10

265, 501, from coarse lherzolite; 507, 48, 56, from porphyroclastic lherzolites; 498, from coarse wehrlite; 487, from coarse garnet wehrlite, 511, from granuloblastic, ilmenite-bearing dunite; 56, phlogopite in apparent textural equilibrium, 406, from coarse dunite, 1 and 2, from ol-cpx gt xenolith n.d. = not detected chromium diopside. Macrocrysts and/or megacrysts (cf. Clement *et al.*, 1984) of olivine, garnet, orthopyroxene, clinopyroxene, phlogopite, and ilmenite are common. Olivine (Fo_{92}) is the most abundant of these minerals (and some contain garnet) and is thought to be derived from deformed peridotites. The garnets (Table 6) include both orange eclogitic and typical purple, pyrope-rich, peridotitic varieties.

Small (less than 1 cm) polymineralic, ilmenite-bearing nodules consist of diopside-ilmenite, olivine-ilmenite, diopside-pyrope-ilmenite, pyrope-ilmenite and enstatite-olivine-ilmenite. The olivine-ilmenite nodules are fragments of deformed dunites veined by ilmenite similar to that in Fig. 4. In other instances, the ilmenite appears to be in textural equilibrium with other phases.

Nigerdlikasik, Midternaes, Pyramidefjeld

In South West Greenland, xenolith-bearing kimberlites have been reported by Andrews (1969), Bridgwater (1970), Andrews and Emeleus (1971, 1975, 1976), Emeleus and Andrews (1975), and Larsen *et al.* (1983). Just to the north of these kimberlites (approximately 10 km SSE of Frederikshåb) some lamprophyre-carbonatite dykes (Walton, 1967; Larsen and Møller, 1968) contain abundant crustal xenoliths, but Walton and Arnold (1979) suggest that single crystals of olivine may be of mantle origin. Eight microscopic diamonds have been reported from rock samples in this general area (Prast, 1973).

The xenolith-bearing bodies are carbonate-rich, phlogopite-rich (± clinopyroxene) kimberlites. These kimberlites are considered to be Mesozoic, although a variety of ages is quoted. The rounded mantle xenoliths consist predominantly of olivine with smaller amounts of orthopyroxene, clinopyroxene, garnet, spinel, and phlogopite. They include coarse and deformed varieties. Most of the periodotites are reported to be lherzolitic with an aluminous phase (either garnet, spinel or phlogopite). Olivines fall within the range of $Fo_{89.5-92.5}$ (Table 7). Lower values were obtained for one deformed xenolith. The chromium diopsides range in Al_2O_3 up to 5 wt% and Cr_2O_3 up to 2.5 wt%, contents which are relatively enriched in the clinopyroxene from the spinel and phlogopite peridotites respectively. The Al_2O_3 (0.2 to 3.5 wt%), in the otherwise uniform orthopyroxene, increases from phlogopite, to garnet, to spinel peridotites. The garnets fall into Group 9 of Dawson and Stephens (1975, 1976). Phlogopite

TABLE 7. Mineral compositions of mantle xenoliths from the kimberlites in South-West Greenland (Emeleus and Andrews, 1975)

Mineral	ol	opx	cpx	gt	spinel		phlog
Sample No.	59903	59200	59200	126732	59198	126732	126741
Locality	NIG	NIG	NIG	PYR	NIG	PYR	PYR
	1	2	3	4	5	6	7
SiO_2	40.4	56.4	54.6	41.9	—	0.00	41.0
TiO_2	—	—	0.13	0.09	—	0.44	0.22
Al_2O_3	—	1.49	2.48	20.0	48.8	11.8	12.1
Cr_2O_3	—	0.49	1.69	5.49	20.2	53.5	0.53
Fe_2O_3	—	—	—	—	0.20	6.54	—
FeO	8.02	5.09	2.44	7.78	11.4	15.4	3.87
MnO	0.08	0.09	0.07	0.52	—	0.87	0.00
NiO	0.37	—	—	0.08	—	0.16	0.23
MgO	50.7	34.2	16.5	18.4	18.3	11.7	24.7
CaO	—	0.67	20.1	6.17	—	0.11	0.00
Na_2O	—	—	1.83	0.05	—	—	0.32
K_2O	—	—	—	—	—	—	10.1
Total	99.6	98.4	99.8	100.4	98.9	100.5	93.1

NIG = Nigerdlikasik, PYR = Pyramidefjeld; 1, 2, 3, 4 and 6, from garnet peridotite; 5, spinel peridotite; 7, phlogopite peridotite
5- and 6-digit sample numbers refer to GGU samples.

shows the greatest textural variation and, in some cases, appears to be in equilibrium with the other phases, suggesting modal metasomatism (after Harte, 1983).

Igdlutalik, South Greenland

Mantle xenoliths occur in an altered ultramafic lamprophyre dyke at Karra, Igdlutalik Island (12 km WSW of Narssaq), South Greenland (B. G. J. Upton, personal communication). The age of the Igdlutalik dyke is bracketed between 1150 and 1600 m.y. (probably less than 1350). Most of the xenoliths are extensively altered and many show prominent concentric zoning. They are now composed of tremolitic amphibole, talc and chromium spinel. Fresh pyroxene is present in the cores of some xenoliths. Breakdown products of garnet may also be present. These xenoliths were probably originally peridotitic. Other, more scarce, glimmerite xenoliths are composed of pale phlogopitic mica with accessory apatite, Fe-Ti-oxides, zircon, sphene, and calcite.

Wiedemanns Fjord, East Greenland

The only reported occurrences of mantle xenoliths from East Greenland are from a lamprophyric dyke at Wiedemanns Fjord (Brooks and Rucklidge, 1973). It is one of a suite of camptonitic/monchiquitic lamprophyre dykes (52 m.y., Beckinsdale *et al.*, 1970), which cut plateau basalts of the East Greenland Tertiary Province. The dyke consists of megacrysts and phenocrysts of augite, megacrysts of orthopyroxene, megacrystal and groundmass kaersutitic amphibole as well as olivine, titanium salite, Fe-Ti-oxides, calcite, chlorite, serpentine, and plagioclase. The xenoliths are composed of olivine, orthopyroxene, and chromium spinel (Table 5).

Discussion

Mantle xenolith-bearing rocks are relatively rare in Greenland, despite the occurrence of many mantle-derived igneous rocks which could have acted as carriers. The known xenoliths, however, occur in a variety of rock types which display a wide range of ages from Tertiary to Precambrian (ca. 30–1350 m.y.) and occur in different tectonic settings. Most of the xenoliths occur in Cambrian and Triassic, hypabyssal kimberlites from central and southern West and South-West Greenland where they may be locally abundant. A few xenoliths have also been reported from the extensive Tertiary basaltic provinces of both West and East Greenland. Rare xenoliths are noted from a Proterozoic ultramafic lamprophyre dyke within the South Greenland Gardar Province. Other mantle xenoliths have been found in an unusual micaceous lamprophyre and a few deformed dunite microxenoliths occur in Proterozoic lamproites. The xenolith localities occur both within the Archaean Block as well as in younger mobile belts.

The xenolith-bearing kimberlites, although they mostly fall within current definitions of kimberlite, in detail differ in certain respects from

TABLE 8. Compilation of available geothermometry and geobarometry for Greenland xenoliths

Locality	*P*(kb)	*T*(°C)	Host rock
West Greenland			
Ubekendt Ejland (1)		820–1081*	monchiquitic lamprophyre
		1125–1241	basanitoid lava
Holsteinsborg (2)		1000–1100†	kimberlite
	40	1300	kimberlite
Alanguarssuk (3)	27–30	970	kimberlite
	37–41	1050	kimberlite
Nigerdlikasik (4)	38	980	kimberlite
Pyramidefjeld (5)	38	900	kimberlite

1 = Larsen (1982); 2 = Scott (1977, 1981); 3 = Goff (1973); 4 & 5 = Emeleus and Andrews (1975); * = interpreted as high-pressure precipitate (Larsen, 1982); † = range for several xenoliths.

kimberlites elsewhere. Also these kimberlites are often spatially and, in some instances, temporally, associated with carbonatites and lamprophyres and such an association is unusual (cf. Mitchell, 1979b). Like the kimberlitic host rocks, the xenoliths are also somewhat unusual. They are olivine-rich and are commonly dunites (particularly at Holsteinsborg). Also, in some peridotites (Pyramidefjeld and Holsteinsborg), clinopyroxene is more abundant than orthopyroxene, which is the reverse of that typically found in xenolith suites from kimberlites elsewhere. Dunites also appear to be more common than lherzolites at Ubekendt Ejland. Other features of these xenoliths are similar to those elsewhere in that both coarse and deformed varieties are found. Modal metasomatism and related processes are probably reflected in the occurrence of phlogopite and ilmenite.

The mineral compositions of the Greenland xenoliths are similar to those from other areas. Some pressure and temperature estimates are available for a few xenoliths (Table 8) but it should be noted that the quality of the data is somewhat variable. With the paucity of data, wide geographical distribution, and wide age range (Precambrian to Tertiary) it is not possible to compile geotherms for Greenland but the available results are compared with other examples (Fig. 5). Most of the data indicate that the xenoliths are 'cold' but one appears to be 'hot' (terminology after Harte, 1983). The paucity of pressure/temperature data in part results from lack of xenoliths with suitable mineral assemblages.

This review has highlighted a paucity of data for xenoliths from Greenland. Comparing the available data, however, with other well studied areas (such as South Africa) indicates some differences in the nature of the xenoliths and the kimberlite host rocks as well as an unusual association of kimberlite with carbonatites and lamprophyres. These features may indicate that certain mantle processes in parts of Greenland may be different from that documented elsewhere. There is, therefore, much scope for further work on Greenland xenoliths and their host rocks.

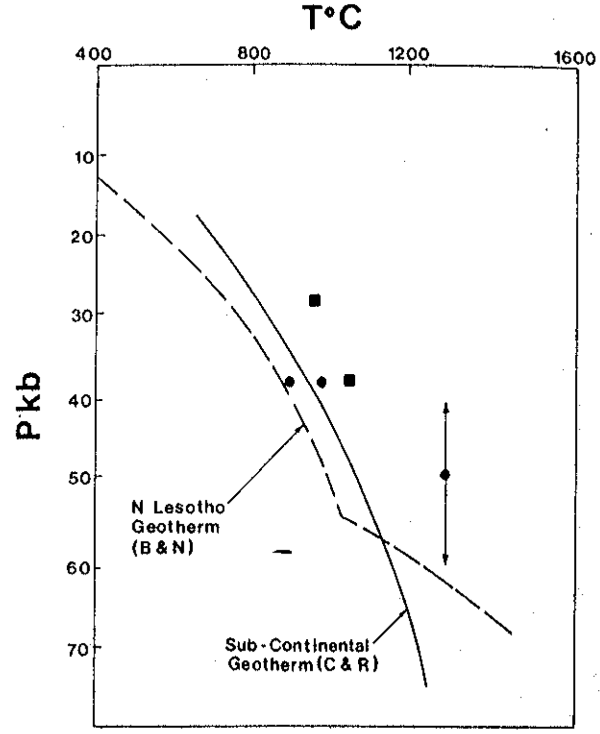

Figure 5. Pressure–temperature estimates (from Table 8) compared with the geotherms of Clark and Ringwood (1964) and Boyd and Nixon (1975). Circle, kimberlite host; square, basaltic host

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