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Lamproite-orangeite transition in 159 Ma dykes of Dronning Maud Land, Antarctica?

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1. Introduction

Vestfjella 159 Ma ultrapotassic dyke swarm (VUDS) in western Dronning Maud Land (WDML), Antarctica, comprises a suite of dykes at Kjakebeinet (73˚47´ S 014˚51´ W) and two discrete dykes at Muren (73˚ 44´ S 015˚ 00´ W) (Fig. 1, Table 1). A minor suite was first discovered by the Finnish Antarctic Research Programme (FINNARP) expedition in 1998 and, subsequently, Luttinen et al. (2002) referred to these rocks as lamproites and pointed out a geochemical similarity to diopside madupitic lamproites from Leucite Hills, USA, and affinities to spatially and temporally related orangeites (group II kimberlites, Mitchell, 1995) of southern Africa (Fig.1). Here we report on the distribution, field appearance, and the mineralogical and geochemical traits of VUDS based on detailed mapping of nunataks during austral summer 2007.

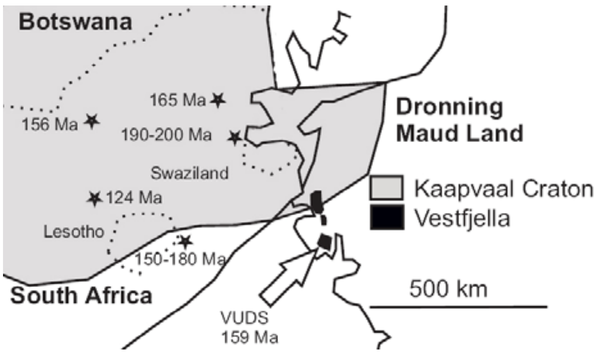

Fig. 1. Vestfjella ultrapotassic dyke swarm (VUDS), tectonic setting prior to Jurassic detachment at ~200 Ma. Stars indicate group II kimberlite fields of South Africa (cf. Mitchell 1995). Reconstruction of Gondwana after Lawver, Gacahan & Coffin (1992).

2. Regional geology

WDML records a geological history closely associated with southern Africa, from Archean to Mesozoic. The Precambrian basement of WDML comprises an Archean craton and a Proterozoic mobile belt that represent extensions of the Kaapvaal craton and the Natal belt of southern Africa, respectively (e.g. Groenewald et al., 1995, Moyes et al., 1995, Jacobs et al., 1996). Aeromagnetic studies imply that the 1000 Ma Grenvillean-age suture may be located beneath Vestfjella (Corner, 1994). Adjacent to the rifted continental margin, the exposed bedrock of Vestfjella is composed almost exclusively of Jurassic flood basalts belonging to the Karoo large igenous province. The basalts and the related dolerite dykes and gabbros have been correlated with the 180 Ma mafic igneous rocks of southern Africa (cf. Luttinen & Furnes, 2000, Vuori & Luttinen, 2003, Riley et al., 2005). Recent geochronological studies imply episodic intrusive events of basaltic magmas continued from 180 Ma until 165 Ma, possibly as late as 150 Ma (Matti Kurhila, pers comm. 2008), and may have been associated with previously dated hydrothermal events at 139 Ma and 150 Ma (Zhang et al., 2003). Numerous normal faults indicate post-volcanic tectonic activity that may have been associated with dyke emplacement. The ultrapotassic, mica-rich dykes were emplaced at 159 Ma, cross-cut Karoo flood basalts and related dykes (Fig. 2), and represent one of the last intrusive events in the area. Crustal xenoliths in the ultrapotassic dykes record emplacement through Grenvillian (~Kibaran) Maud Belt rocks (Romu & Luttinen, 2007).

3. Field relationships

	Dyke	Location	Lat (o ' ")	Lon (o ' ")	Strike	Dip dir.	Dip
D 01	KRRO-07-33	Kjakebeinet	73 47 47.5	014 51 31.6	340.5	80.5	80
D 02	AL/KB1-03	Kjakebeinet	73 47 44.5	014 54 30.1	Boulders, probably weathered *in situ*		
	AL/KB6-98		73 47 02.5	014 52 21.5	352.5	80.5	82
D 03	AL/KB8-98	Kjakebeinet	73 47 00.6	014 52 23.8	350.5	80.5	74
	KRRO-07-28		73 47 01.9	014 52 22.5	355.5	265.5	86
D 04	KRRO-07-25	Kjakebeinet	73 47 06.0	014 52 29.1	340.5	70.5	80
D 05	AL/KB21-98	Kjakebeinet	73 47 54.5	014 51 23.1	354.5	84.5	84
D 06	AL/KB1-31-98	Kjakebeinet	73 47	014 55	Boulder		
D 07	KRRO-07-36	Kjakebeinet	73 47 54.1	014 51 04.8	330.5	60.5	82
D 08	KRRO-07-11	Kjakebeinet	73 47 50.6	014 55 00.8	350.5	80.5	83
D 09	KRRO-07-19	Kjakebeinet	73 47 53.7	014 55 14.0	350.5	80.5	88
	KRRO-07-20		73 47 56.4	014 55 36.7	350.5	80.5	80
D 10	KRRO-07-21	Kjakebeinet	73 47 56.2	014 55 38.0	350.5	80.5	80
	KRRO-07-22		73 47 56.2	014 55 38.6	350.5	80.5	82
D 11	KRRO-07-45	West Muren	73 44 02.6	015 06 22.2	0.5	90.5	86
D 12	KRRO-08-89	East Muren	73 44 11.8	014 58 33.0	336.5	76.5	82

Table 1. Dyke (D01-D12) locations; strikes and dip directions (Dip. dir) corrected for magnetic declination by factor 9.5°.

Twelve broadly N-S trending dykes and small groups of dykes (Table 1) have been discovered as a result of detailed mapping of nunataks Kjakebeinet (~20 km^2) and Muren (~7 km^2) in southern Vestfjella. The steeply dipping (74-88 deg ESE) dykes are relatively narrow (0.3 to 2.4 m, mainly <1 m) and crop out as individual dykes or small groups of 3 (Table 1). Mica rich dykes have not been reported outside this area, but detailed mapping of South Vestfjella has not been completed. Individual dykes cannot be laterally or vertically traced for more than ca. 50 m. Most of the dykes have disctictively zoned appearance and fenitized margins are common. Two relatively wide dykes (D 01 & 02) contain abundant xenoliths of granitoids and gneisses show well-defined strike-parallel zonation.

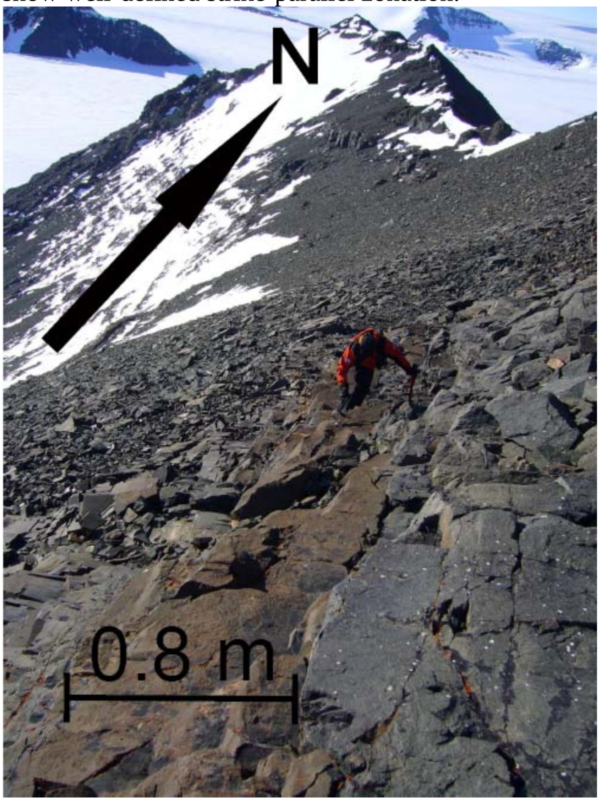

Fig. 2. Dyke D 03 cross-cuts basalt lavas and is closely associated with basalt and diabase dykes at the summit of Kjakebeinet.

4. Compositional characteristics

Field appearance and mineralogy

All the dykes are inequigranular, heterogenous and show strike-parallel variation in grain size and/or composition and distribution of macrocrysts. The dykes have a fine-grained groundmass, show variation in texture, amount and type of macrocrysts and xenolithic fragments, as well as phenocryst ± macrocryst to groundmass ratio. Phenocrystal and microphenocrystal phases commonly observed in the dykes are titanian aluminous phlogopite (2-8 wt-% TiO_2, 8-16 wt-% Al_2O_3); low Al and low Ti diopside (1-3 wt-% TiO_2, 2-6 wt-% Al_2O_3); olivine show altered to Mg-rich talc or dolomite, calcite, and Fe-oxides; prismatic apatite; and Ti-magnetite. Both homogeneous and zoned phlogopite phenocrysts have been observed. The latter type has distinctive discrete, iron-rich (19-30 wt-% FeO), aluminium depleted (Al_2O_3 6-10 wt-%) annite rims. Euhedral to anhedral pseudomorphs after olivine are mainly mantled by phlogopite similar in composition to phenocrystal mica. Typical groundmass phases include major sanidine (FeO <1 wt-%), dolomite, apatite, phlogopite-annite, Ti-magnetite, and Ti-oxide, which encloses monazite. Chlorite, talc, and zeolites has been observed. In general groundmass mica, when present, is similar to the rims of zoned phlogopite rims. Sanidine and dolomite ± anatase ± aegirine augite ± quartz ± calcite form leucocratic segregations, which show forms ranging from irregular patches with gradational boundaries to globular segregations and ocelli. Macrocrystal phases in the order of abundance include aluminous (~10 wt-% Al_2O_3) diopside lower in MgO and SiO2 relative to phenocrystal diopside, magnetite, Fe-oxide-phlogopite nodules, phlogopite, and annite.

Geochemistry

Eight of the analyzed dyke and boulder samples (n=11) are ultrabasic (SiO2 41-45 wt-%), ultrapotassic (cf. Foley et al., 1987) (K_2O 3.4-8.3 wt-%, molar K_2O /Na_2O 3.0-21.0, MgO 9.6-15.6 wt-%), and exhibit low Al_2O_3 relative to total alkalis (molar K_2O/ Na_2O 0.6-0.8, molar (K_2O/Na_2O)/ Al_2O_3 0.7-1.0). Three of the samples (D 10-12) are basic (SiO2 46-50 wt-%) and otherwise similar to ultrabasic ones, but the most SiO2–rich sample, from dyke 12, is enriched in Al_2O_3 (16.9 wt-%), Na_2O (4.3 wt-%) and depleted in MgO, TiO_2 (3.8 and 1.2 wt-%, respectively), Cr, and Ni relative to the other samples. All samples are enriched in incompatible elements, for example, the ranges of Ba (3000-4800 ppm), Sr (1440-4100 ppm), La (140-280 ppm), and Zr (750-1539 ppm).

5. Discussion and conclusions

The VUDS shows features typically associated with ultramafic lamprophyres, lamproites, and orangeites. The assemblage of abundant mica, diopside, and carbonate is common in ultramafic lamprophyres and orangeites, but not in lamproites. Absence of Ti-rich garnet in the dykes bear mineralogical evidence against classification as bona fide ultramafic lamprophyres (cf. Tappe et al. 2005). Lamproite affinity is exemplified by compositional data on mica phenocrysts that show mild depletion of Al and Ti enrichment towards the rims. In contrast, in some samples mica zoning shows Al depletion combined with Fe enrichment and ~constant Ti indicating an orangeite-like cooling history. The whole rock data of dyke 12 shows obvious contamination with crustal material. MgO (9.2-15.7 wt-%) of the dykes is fairly low relative to unevolved orangeites (Michell & Bergman, 1991), but similar to average lamproites and evolved orangeites (Tainton, 1992). Concentrations of Zr (279-1515 ppm) and Nb (92-206 ppm) reflect affinities to olivine lamproites (eight of 11 samples), orangeites (two of 11 samples), and leucite lamproites (one of 11 samples) whereas all Nb/La and Ce/Sr ratios (0.44-1.01; 0.13-0.22, respectively) are more similar to orangeites (Taylor et al., 1994). Previously published Nd-Sr data (Luttinen et al., 2002) indicates radiogenic Nd atypical of ultramafic lamprophyres but typical of lamproites and orangeites. In summary, the dykes are best considered as members of the lamproite – orangeite suite; further studies on mineral chemistry, however, will be done as here we presented preliminary results on the mineralogy and geochemistry of VUDS.

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