THE FEN DAMKJERNITE: PETROLOGY OF A "CENTRAL-COMPLEX KIMBERLITE"

W.L. Griffin and P.N. Taylor

Mineralogisk-Geologisk Museum, Oslo, Norway
Dept. of Geology, Oxford, England

The circular complex of carbonatites and alkalic rocks at Fen (Telemark, S. Norway) is cut by numerous diatremes and dikes of damkjernite, a porphyritic alkalic ultrabasic rock that megascopically resembles kimberlite. The diatremes contain numerous rounded fragments of spinel lherzolite, granitic gneiss and carbonatite. The damkjernite makes up only 7% of the surface area (versus 63% for the carbonatites), but gravity studies show that the carbonatites are only a thin (300-500 meter) cap on a pipe of very dense rock extending at least to the lower crust. Unbrecciated hypabyssal-facies damkjernite, which is common in dikes outside the circular complex, has the density (3.17 g/cc) needed to explain the gravity anomalies; we suggest that this is the dominant rock of the complex.

Analyses of inclusion-free damkjernite dike rocks show that, when its high content of primary calcite is disregarded, the damkjernite is similar in composition to other strongly undersaturated rocks of the monchiquite-ouachitaite-alnøite type (Table). The major differences are in the higher TiO_2, Fe/Fe+Mg, and Fe^3/Fe of the damkjernite dikes. The diatreme facies has lower Fe/Fe+Mg and TiO_2; this is partly due to mechanical contamination with lherzolite and crustal rocks. The damkjernite is higher in Al_2O_3, Fe/Fe+Mg, TiO_2 and Na_2O than most kimberlites.

Phenocrysts include biotite, clinopyroxene, nepheline (altered to albite, sericite and calcite), $ilmenite_{ss}$, $magnetite_{ss}$, and possibly perovskite. The groundmass consists of laths of pyroxene, biotite, chlorite and apatite, with interstitial sericite, albite, K-feldspar, nepheline, and locally melanite. Magnetite, ilmenite, rutile, pyrite and sphene are scattered abundantly through the groundmass. Some pyroxene phenocrysts have resorbed cores of high-P phases (ægerine-augite, acmitic titanaugite, kaersutitic hornblende). Overgrowths on these cores are zoned toward increasing Fe/Mg, but the trend is reversed at the outermost rims and the groundmass pyroxenes are more magnesian than the phenocrysts (Table). A similar trend, and a drop in Ti, are seen in the biotites. Large Il_{ss} grains contain up to 10% $MnTiO_3$ and 12% Hm; bulk compositions of large unmixed Mgt_{ss} grains imply Usp contents $>42\%$. Intergrowths of rutile with sphene and/or calcite are common; they appear to be psuedomorphs after perovskite phenocrysts. Calcite occurs as a late-magmatic interstitial phase, and as coarsely crystalline rounded globules, suggesting the presence of an immiscible carbonate melt.

The pyroxene cores are quite different from the clinopyroxenes of the lherzolite nodules, and no olivine, opx or spinel have been observed in the hypabyssal facies. The rounded megacrysts of these phases in the diatreme facies were derived by breakup of the lherzolite inclusions, which are probably accidental in origin.

Compositions of Fe-Ti oxides imply $T > 900°C$ and log $f_{O_2} > -12$ atm. during crystallization ($P \sim 1$ Kb). The composition of biotites crystallizing with magnetite and K-feldspar indicates that f_{H_2O} under these conditions was about 1-400 bar. The occurrence of albite and nepheline in the groundmass, and the alteration of perovskite to sphene (+rutile+calcite) require that log $a_{SiO_2} \approx -0.6$ for T=1000-1200°C. The lack of albite or sphene phenocrysts indicates that the magma was not buffered with respect to silica activity until emplacement; this magma would have been in equilibrium with the mantle represented by the lherzolite nodules at P= 13-18 Kb for T= 1000-1200°. These pressures are somewhat higher than those obtained for equilibration of the lherzolite nodules (9-11 Kb: Griffin, 1973).

Analyses of six dike rocks show no correlation between Sr 87/86 and 87Rb/86Sr. Initial ratios (assumed age, 550 m.y.) range from 0.70399 ±8 to 0.70465 ±6. The higher I.R. of one diatreme sample (0.7069 ±6: Mitchell & Crockett, 1972) may be due to admixture of gneiss fragments. One sample of søvite analyzed by M & C has I.R.= 0.7028 ± 6. The I.R. of the dikes is proportional to both $\%CO_2$ and ppm Sr, suggesting mixing of the silicate magma (I.R.~0.7035 ?) with a carbonatite magma contaminated by crustal Sr. This is also consistent with the higher Na content and Na/K of the more carbonate-rich rocks, since modern carbonatite magmas are rich in sodium.

Field evidence shows that the damkjernite was intruded after the søvite, but was accompanied or followed by ankeritic carbonatite. We suggest that the damkjernite magma was mixed with a previously-generated ankeritic carbonatite magma that had exchanged Sr isotopes with crustal rocks. This mixing may have taken place in a magma chamber at or near the base of the crust during the ascent of the damkjernite from its site of generation. Explosive eruption from this chamber entrained lherzolite nodules in the damkjernite dikes and diatremes emplaced around the complex. Subsequent or nearly simultaneous emplacement of ankeritic carbonatite magma caused metasomatism of damkjernite within the complex. The model suggests that the carbonatites and damkjernite may have had a common site of generation at P= 13-18 Kb, but that they were largely separated from one another at an early stage because of the immiscibility of the magmas at these low pressures and their differing physical properties.

The various associations of undersaturated rocks with carbonatite suggest that carbonatite magmas represent accumulations of the free or easily liberated volatile components of the upper mantle. The associated silicate rocks may be derived by reaction of these volatiles with mantle peridotite, accompanied by varying small degrees of partial melting at pressures ranging from <15 to >60 Kb. At Fen these processes appear to have taken place at relatively shallow depth and to have been the precursor of large-scale magmatic activity along a developing intracratonic rift system.

References:

Griffin, 1973: Contr. Min. Petrol. 38, 135-146.

Mitchell and Crocket, 1972: Jour. Pet. 13, 83-98.

Analyses

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O
1)	30.71	5.02	8.59	8.26	6.83	9.14	16.53	1.46	2.03
2)	37.2	6.0	15.4	---	7.2	18.8	0.0	0.6	9.4
3)	37.3	4.3	15.1	---	8.4	20.6	0.1	0.4	9.6
4)	38.1	3.0	14.6	---	8.0	21.1	0.0	0.5	9.3
5)	48.0	1.9	6.3	---	10.0	10.7	20.6	1.8	---
6)	47.6	2.9	6.0	---	6.4	13.4	23.4	0.6	---
7)	48.0	2.6	4.5	---	6.1	14.2	23.7	0.5	---

1, average of 6 analyses of damkjernite dikes (includes P_2O_5=1.60, H_2O=2.80, CO_2=6.14, F=0.40)

2, core of biotite phenocryst
3, rim of biotite phenocryst
4, groundmass biotite
5, resorbed core in clinopyroxene phenocrysts (aver. 2)
6, overgrowths on (5)
7, groundmass pyroxenes (aver. 4)