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NEPHELINE – PLAGIOCLASE INTERGROWTHS OF METASOMATIC ORIGIN FROM THE COLDWELL COMPLEX, ONTARIO

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ABSTRACT

Feldspar-porphyry xenoliths, incorporated into nepheline-syenite magma, have been subjected to metasomatism which has formed vermicular nepheline–plagioclase intergrowths as coronas about relict andesine phenocrysts. The nepheline is thought to have developed by a Na–K cation exchange mechanism, which caused partial desilication of the andesine phenocrysts. The metasomatism has not, however, formed nepheline in the groundmass surrounding the xenoliths; instead, alkali feldspars with a wide compositional range have developed.

SOMMAIRE

Des xénolites de porphyre feldspathique dans un magma de syénite à néphéline ont subi l'action du métasomatisme, qui a produit des intercroissances vermiculaires néphéline–plagioclase entourant d'une corona les phénocristaux reliques d'andésine. La néphéline s'est probablement formée par un mécanisme d'échange cationique Na–K, qui aurait causé la désilicification partielle des phénocristaux d'andésine. Toutefois, le métasomatisme n'a pas donné de néphéline dans la pâte englobant les xénolites; on y trouve, par contre, des feldspaths alcalins couvrant un domaine étendu de composition.

INTRODUCTION

Nepheline syenite from Centre 2 of the Coldwell alkaline complex (Mitchell & Platt 1978) contains a wide variety of volcanic and plutonic xenoliths. These are best observed in the breccia zones found along the west side of Redsucker Cove and on Highway 17, east of Mink Creek. Common amongst this suite are ovoid (20–50 cm) xenoliths of blue-grey porphyry containing rectangular to rhomb-shaped andesine phenocrysts. Metasomatic nepheline, intimately associated with the andesine phenocrysts, has developed within these porphyritic xenoliths.

NEPHELINE SYENITE HOST-ROCK

The host rock of the xenoliths is the eastern marginal phase of a fault-bounded block of nepheline syenite lying between Mink Creek and Redsucker Cove. This marginal phase has been recrystallized to a flinty, porcellaneous rock with a granuloblastic polygonal texture. As mineral compositions in the igneous-textured nepheline syenite are identical to those in the recrystallized nepheline syenite (Mitchell & Platt, in prep.), we conclude that recrystallization has occurred isochemically.

The recrystallized nepheline syenite is composed essentially of nepheline ($Ne_{73}Ks_{15}Q_{10}An_2$–$Ne_{76}Ks_{14}O_8An_2$) and alkali feldspar ($An_1Ab_{37}Or_{62}$–$An_0Ab_{26}Or_{74}$) together with clinopyroxene ($Ac_9Hd_{49}Di_{42}$–$Ac_{10}Hd_{64}Di_{26}$) and ferroedenitic hastingsite. These mafic phases commonly occur as xenoblastic plates or as round crystals at triple junctions formed between felsic minerals. Accessory minerals include natrolite, apatite and spinel. Representative analyses of feldspars and nephelines are given in Table 1. Note that all mineral end-member compositions are quoted in molecular percentages.

XENOLITHS

The feldspar-porphyry xenoliths consist of large (up to 2 cm) relict laths of andesine ($An_{46}Ab_{54}Or_1$–$An_{37}Ab_{62}Or_1$) which are partially or wholly replaced by nepheline/plagioclase intergrowths. These are set in a granuloblastic polygonal groundmass of sodic oligoclase/albite ($An_{12}Ab_{87}Or_1$–$An_6Ab_{88}Or_6$), alkali feldspar ($An_3Ab_{67}Or_{30}$–$An_0Ab_{13}Or_{87}$), clinopyroxene ($Ac_9Hd_{50}Di_{42}$–$Ac_{11}Hd_{55}Di_{35}$) and ferroedenitic hastingsite. Representative analyses of the felsic phases are given in Table 1 and are illustrated in Figure 1.

The similarity of groundmass texture and mafic mineralogy between the xenoliths and the host nepheline-syenite suggests that the xenoliths have been recrystallized and metasomatized after incorporation in the nepheline-syenite magma.

NEPHELINE–PLAGIOCLASE INTERGROWTHS

The nepheline–plagioclase intergrowths occur

TABLE 1. REPRESENTATIVE ANALYSES OF FELDSPARS AND NEPHELINES FROM NEPHELINE SYENITE AND METASOMATIZED PORPHYRY XENOLITH

	1	2	3	4	5	6	7	8	9	10		11	12	13	14
SiO_2	67.0	65.9	57.4	59.2	66.9	67.0	66.5	65.4	64.4	64.2		45.3	45.2	45.8	45.1
Al_2O_3	19.3	18.7	26.7	25.5	21.4	20.2	19.8	18.5	22.2	22.8		32.6	33.2	32.6	33.3
Fe_2O_3	0.1	0.1	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.0	0.3	0.2	0.2
CaO	0.1	0.0	8.7	7.5	2.4	1.2	0.8	0.0	3.5	4.1		0.8	0.6	1.2	1.2
Na_2O	4.1	2.7	6.1	6.9	9.8	9.6	6.8	1.4	9.1	8.8		16.1	15.3	14.9	15.1
K_2O	10.5	12.0	0.2	0.1	0.1	1.0	5.5	14.5	0.2	0.2		4.7	4.9	4.5	5.1
TOTAL	101.1	99.4	99.4	99.4	100.8	99.2	99.6	99.9	99.6	100.3		99.5	99.5	99.2	100.0
Structural Formula based on 32 oxygens															
Si	11.970	12.030	10.340	10.620	11.640	11.830	11.880	12.000	11.390	11.290		8.644	8.607	8.716	8.566
Al	4.072	4.019	5.664	5.379	4.382	4.212	4.163	4.003	4.628	4.723		7.332	7.457	7.315	7.451
Fe^{3+}	0.007	0.019	0.042	0.030	0.029	0.027	0.022	0.030	0.028	0.023		0.000	0.042	0.030	0.026
Ca	0.023	0.000	1.675	1.439	0.440	0.233	0.159	0.000	0.656	0.771		0.164	0.120	0.247	0.251
Na	1.424	0.960	2.113	2.389	3.299	3.277	2.354	0.492	3.121	3.011		5.953	5.655	5.509	5.554
K	2.400	2.803	0.041	0.0297	0.024	0.232	1.243	3.404	0.034	0.045		1.144	1.178	1.096	1.246
Mol.% end member molecules											Mol.% end member molecules				
An	0.6	0.0	43.8	37.1	11.7	6.2	4.2	0.0	17.2	20.1	FeNe	0.0	0.5	0.4	0.4
Ab	37.0	25.5	55.2	61.9	87.7	87.6	62.7	12.6	81.9	78.7	An	4.0	3.1	6.2	6.3
Or	62.4	74.5	1.0	1.0	0.6	6.2	33.1	87.4	0.9	1.2	Ne	74.1	71.9	69.6	69.8
											Ks	14.2	15.0	13.8	15.7
											Qz	7.7	9.5	10.0	7.9

1-2 alkali feldspar, host nepheline syenites; 3-4 andesine phenocrysts, 5-8 groundmass feldspars, feldspar porphyry xenolith; 9-10 oligoclase from intergrowths with nepheline; 11-12 nepheline, host nepheline syenite; 13-14 nepheline intergrown with oligoclase, feldspar porphyry xenolith.

in two general forms. Intimate vermiform intergrowths of nepheline and untwinned oligoclase (Fig. 2) generally occur immediately adjacent to the unaltered andesine phenocrysts, with which they have a sharp contact. Embayments of the vermiform intergrowths into the phenocrysts are common (Fig. 2). Untwinned oligoclase and nepheline also occur as relatively coarse intergrowths in which optically continuous plates of each are conspicuous. Where both types of intergrowth occur together, the vermiform type forms the inner zone adjacent to unaltered phenocryst. Replacement of the phenocryst occurs both marginally and adjacent to cross-cutting fractures.

Nepheline in the intergrowths has a similar composition to that in the host nepheline syenite but differs in having appreciably higher CaO contents (Table 1). This feature has also been noted in nepheline from intergrowths from the Marangudzi complex (Henderson & Gibb 1972). The oligoclases of the intergrowths are different in composition to the feldspars of both the host nepheline-syenite and the xenolith groundmass (Table 1, Fig. 1).

Discussion

A number of nepheline–plagioclase intergrowths have been described and a number of theories expounded for their formation. Tilley (1957), for example, describes nepheline–albite intergrowths surrounded by albite from the York River gneiss belt, Ontario. He attributed these to a replacement/overgrowth phenomenon with nepheline partially replacing an existing feldspar; these are subsequently overgrown by a later feldspar.

Henderson & Gibb (1972) report nepheline–andesine (An_{45-47}) patch intergrowths from the Marangudzi complex, Rhodesia. They consider these intergrowths to be replacement phenomena formed as a result of the resorption of plagioclase by late-stage magmatic fluids.

Rao & Murthy (1974) observed patch nepheline–oligoclase (An_{20-28}) intergrowths from the Eastern Ghat syenites, India, and concluded that nepheline (together with microcline perthite) was formed by an alkali-exchange metasomatic process which caused replacement of the plagioclase.

Development of the Coldwell intergrowths by a plagioclase-resorption mechanism caused by late magmatic reactions of the xenoliths with the host nepheline magma (hypothesis of Henderson & Gibb) seems unlikely. The intergrowths were apparently never in direct contact with the magma, being shielded by the xenolith

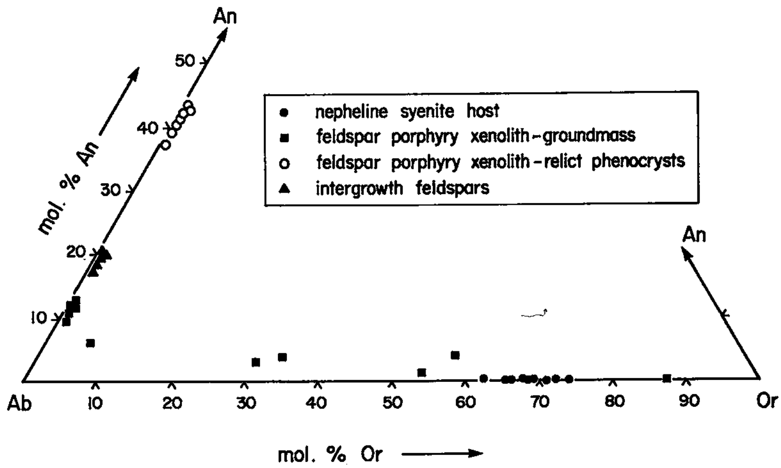

FIG. 1. Compositions of feldspars from nepheline syenite and metasomatized-porphyry xenolith plotted in the system albite (Ab)–anorthite (An)–orthoclase (Or).

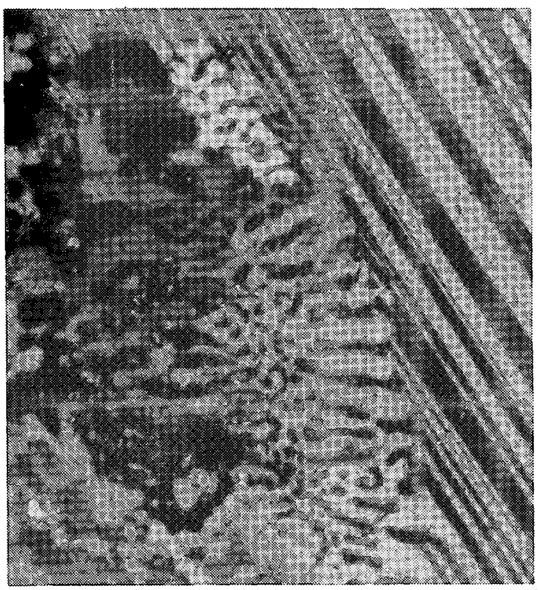

FIG. 2. Vermiform intergrowth of nepheline (dark) and oligoclase replacing an andesine phenocryst. Magnification x80.

groundmass. Moreover, although textural and mineralogical evidence (previously mentioned) suggests that the groundmass has been recrystallized and metasomatized and therefore presumably readjusted chemically, no nephelinization has occurred. The nepheline is only found associated with the andesine phenocrysts. This perhaps indicates the absence of "calcic" plagioclase from the original groundmass.

We postulate that Na and K metasomatism of the feldspar-porphyry xenoliths, after incorporation into the nepheline-syenite magma, leads to the formation of alkali feldspars in the groundmass, possibly by replacement of sodic plagioclase. The lack of uniformity in the compositions of the groundmass alkali-feldspars and their difference in composition compared to the alkali feldspars from the host nepheline-syenite indicate a lack of equilibrium in the metasomatic process.

The same Na–K metasomatic event may have developed the nepheline/oligoclase intergrowths by desilication of the calcic portion of the andesine phenocrysts. Such a desilication of calcic plagioclase can be achieved by a cation exchange mechanism of the type advocated by Rao & Murthy (1974): $CaAl_2Si_2O_8 + K^+ + Na^+ \rightarrow NaAlSiO_4 + KAlSiO_4 + Ca^{2+}$. This exchange is most probably catalyzed by volatile-rich chloride fluids.

In this reaction no exchange with the albite component of the plagioclase occurs, and consequently the residual plagioclase associated with the exsolved nepheline becomes more sodic. With complete Ca exchange, the ultimate product of metasomatism should be a nepheline–albite intergrowth of the type described by Tilley (1957). Thus, the York River nepheline–albite intergrowth may not result from the addition of nepheline to a pre-existing albite as suggested by Tilley (1957); rather, both minerals might be the metasomatic products of an earlier, more calcic feldspar.

Support for the cation-exchange desilication of plagioclase is provided by Duffin's (1964) experiments involving heating of feldspars with NaCl. Nepheline is formed in these reactions only where calcic plagioclases are present. Albite alone results in sodalite formation. Duffin's (1964) experiments are, however, not directly comparable with the incorporation of xenoliths in fluid magmas, as they were carried out anhydrously in the solid state.

In conclusion we propose that the nepheline–plagioclase intergrowths described here were formed by Na–K metasomatism of plagioclase at high temperatures. The source of the metasomatic fluids is thought to be the host nepheline syenite.

Acknowledgements

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