DESILICATION OF ALKALI-SYENITE FROM THE WOLFE NEPHELINE BELT, ONTARIO

EDWARD C. APPLEYARD
Department of Geology, Bedford College, University of London, England

ABSTRACT

The contamination of alkali-syenite magma by nepheline-bearing alkaline gneiss has led to the production of nepheline-syenite. In other cases, contaminated but still saturated aegirine-, ferrohastingsite- or biotite-syenite has been produced. Chemical analyses support the field observations.

INTRODUCTION

Throughout the Haliburton-Renfrew nepheline belt of south-eastern Ontario, nepheline-bearing and associated alkaline gneisses are intruded at many localities by a characteristic suite of alkali-syenites which are restricted to the immediate vicinity of the nepheline gneisses. These alkali-syenites are nearly always saturated syenitic rocks composed of approximately equal proportions of albitic plagioclase and microcline. In a recent study of the Wolfe Nepheline Belt of northern Lyndoch township, Ontario, a search was made for undersaturated examples of this suite to determine whether they were genetically related to the igneous nepheline-bearing rocks from the Haliburton area described by Tilley & Gittins (1961). This paper describes the only example containing nepheline that was discovered.

The Wolfe Belt consists of an interlayered series of nepheline-bearing and related alkaline gneisses which are believed to have been metasomatically derived by "nephelinization" from a variety of sedimentary ancestors. The geological and geochemical data on which the above conclusion is based are incorporated in two unpublished theses (Appleyard, 1959; 1963). Papers describing the petrography, structure, mineralogy and geochemistry of the Wolfe gneisses are in preparation by the writer but the varied lithology has previously been summarized by Hewitt (1954, pp. 78–82). The present paper is therefore only a small part of a much broader study of the nepheline-gneiss problem.

The region is covered by the Brudenell 31 F/6 West Half topographic sheet of the Department of National Defence, Army Survey Establishment, Ottawa, and localities will be given the standard grid references based on it.

The Alkali-syenites

There are three main outcrop areas on the Wolfe Belt which are named, from west to east, the Kargus ridge, the Remus ridge and the Heiderman ridge (grid refs. 164225-172226, 175225-182228, and 198225-202224 respectively). Small intrusive sills, sheets, pods and stocks of buff, pink or white alkali-syenite are found on all three of these ridges. They form small bodies, seldom more than 20 feet in thickness, occasionally forming sills injected semi-conformably between layers of the gneiss but elsewhere forming transcurrent dykes.

Lithologically, the syenites are composed of albite and microcline in about equal proportions, a variable content of mafic minerals, usually aegirine or aegirine-augite, but also ferrohastingsite, yellow-green hornblende, biotite or magnetite, and occasionally small amounts of sphene, zircon, apatite, carbonate or fluorite. The mineralogically simplest type of syenite is a completely leucocratic two-feldspar rock. This mafic-free facies is usually restricted to the central zones of some of the larger bodies. Xenoliths, in the form of highly digested wisps, schlieren, streaks and angular patches, are abundant in the marginal zones of many syenite bodies. Since the syenites grade continuously from those possessing xenoliths whose angular outlines are clearly preserved, through those with diffuse mafic schlieren, to rocks in which the mafic minerals are relatively evenly distributed, it is believed that all mafic varieties owe their content of dark minerals to contamination with a greater or lesser degree of subsequent disruption of the xenoliths.

The age of the syenite relative to that of the nepheline-gneisses is important, both from the point of view of its origin and of the origin of the gneisses themselves. Wherever syenites intrude nepheline-bearing gneisses they are surrounded by aureoles of widths up to several tens of feet in which the nepheline has been replaced by felty aggregates of secondary micas and zeolites. Occasionally zones of altered nepheline are found which are not immediately related to exposed syenite but these are in areas where syenite is abundant and therefore it is possible that they too are related to adjacent but unexposed syenite bodies. This very close spatial relationship suggests a genetic relationship between the alteration of the nepheline and the crystallization of the syenite. In addition, the syenites are not nephelinized themselves so that it seems clear that they are post-nephelinization in age. The syenites also appear to be later than the main folding as they cut across folded structures in the gneisses without being appreciably folded themselves and are preferentially, but not exclusively, located in the axial zones of the major folds which affect the Wolfe Belt. They have a metamorphic texture, sometimes containing porphyroblasts of perthite of replacement type up to one inch in length. They possess no sign of a chilled margin and the extensive assimilation of country rock xenoliths in such small intrusive masses suggests that the process was encouraged by relatively high environmental temperatures and pressures. It is probable, however, that at the time of intrusion the main period of metamorphism had begun to wane, for otherwise the fine-grained alteration products pseudomorphing the nepheline would have recrystallized under the upper amphibolite facies conditions that characterized the metamorphism of this area at its peak. The rare association of small crystals of epidote with the alteration products suggests that the metamorphic grade by this time had subsided to greenschist or epidote-amphibolite facies conditions. It therefore seems certain that the syenites intruded gneisses which were nepheline-bearing at the time.

As noted before, only one locality was found where the syenite contained nepheline. This was a 14-inch thick apophysis of syenite extending outwards from a large mass of non-feldspathoidal syenite into nepheline-bearing gneisses 450 feet north-west of the Remus barn (grid ref. 179227).

The country rocks in this outcrop are nepheline-oligoclase-microcline-ferrohastingsite-aegirine gneisses. The bulk of the felsic minerals consists of separate grains of oligoclase and microcline with only rare perthitic intergrowths of the two. Nepheline is only slightly altered and, as is typical in these gneisses, forms either large patches engulfing other minerals or thin intergranular ribbons. The amphibole and the aegirine apparently co-exist in equilibrium. Apatite is the only prevalent accessory mineral.

The main mass of syenite is only slightly contaminated in the vicinity of the apophysis being described. It is a porphyroblastic, leucocratic variety which is nepheline-free. The apophysis from it, however, contains numerous xenoliths. These have been intensely assimilated and are now represented by diffuse wisps and patches of ferrohastingsite and a little biotite. The nepheline occurs in ribbon-like strips between feldspar grains and also as stumpy subhedral crystals up to one inch long. It is distributed throughout the rock but is more abundant in the portions containing the largest amounts of xenolithic material.

Analyses

Considering the small size of the dyke involved and the adjacent large body of alkali-syenite, it is unlikely that the xenolithic material was other than of immediately local derivation. Analyses, therefore, were made of the nepheline-syenite dyke and of the nepheline gneisses that form the country rock there. These are presented in Table 1. Tabulated with them

TABLE 1. ANALYSES OF NEPHELINE-SYENITE DYKE, NEPHELINE GNEISS AND AEGIRINE-SYENITE FROM THE WOLFE BELT AND LEUCOCRATIC ALKALI-SYENITE FROM OTTER CREEK, MONMOUTH TOWNSHIP.

	1.	2.	3.	4.
SiO_2	51.29	61.63	61.76	65.52
TiO_2	0.36	0.14	0.19	nil
Al_2O_3	16.34	19.63	18.28	20.09
Fe_2O_3	6.15	1.51	2.92	0.41
FeO	6.33	1.90	1.23	
MnO	0.24	0.06	0.09	nil
MgO	1.61	0.41	0.81	0.28
CaO	5.66	1.48	1.94	0.56
Na_2O	7.74	8.24	5.39	7.66
K_2O	3.92	4.80	5.92	5.20
H_2O+	0.66	0.47	0.26	0.14
H_2O-	nil	0.01	0.01	nil
CO_2	0.06	0.35	0.22	0.14
P_2O_5	0.24	0.02	tr.	nil
Total	100.60	100.65	99.02	100.00

1. Nepheline-feldspar-ferrohastingsite-aegirine gneiss, Wolfe Belt, grid ref. 179227. Analyst: E. C. Appleyard.
2. Nepheline-bearing alkali-syenite, Wolfe Belt, grid ref. 179227. Analyst: E. C. Appleyard.
3. Aegirine-bearing contaminated alkali-syenite, Wolfe Belt, grid ref. 181225. Analyst: Ontario Department of Mines Assay Office.
4. Leucocratic alkali-syenite, Otter Creek, Monmouth township. Analyst: J. Gittins.

are two other analyses, one of a saturated but also contaminated alkali-syenite from another part of the Wolfe Belt (grid ref. 181225) and the other of a leucocratic pink alkali-syenite which cuts nepheline-syenites at Otter Creek, Monmouth township. Since the Otter Creek alkali-syenite is mineralogically identical to the least contaminated syenite on the Wolfe Belt this analysis was chosen to represent the primary syenite.

Analyses 1, 2 and 4 were carried out in the research laboratory of the Department of Mineralogy and Petrology, University of Cambridge, under the supervision of Mr. J. Scoon. Standard gravimetric methods were used for SiO_2, Al_2O_3, CaO, MgO and H_2O. TiO_2, MnO and P_2O_5 were measured colourimetrically and Na_2O and K_2O by the flame photometric method. Iron was reduced by passing the solution through a silver reduction column followed by titration with ceric sulphate to determine Fe^{total}. FeO in analyses 1 and 2 was determined volumetrically on a separate sample by the ammonium vanadate—ferrous ammonium sulphate method. CO_2 was evolved by boiling the sample in phosphoric acid and collecting the gases in an absorption train. Specimens weighing 250 to 600 grams were crushed for analysis depending on the degree of inhomogeneity of the rock. Details of the methods used in obtaining analysis 3 are not available.

Figure 1 is a Harker diagram illustrating the chemical relationship

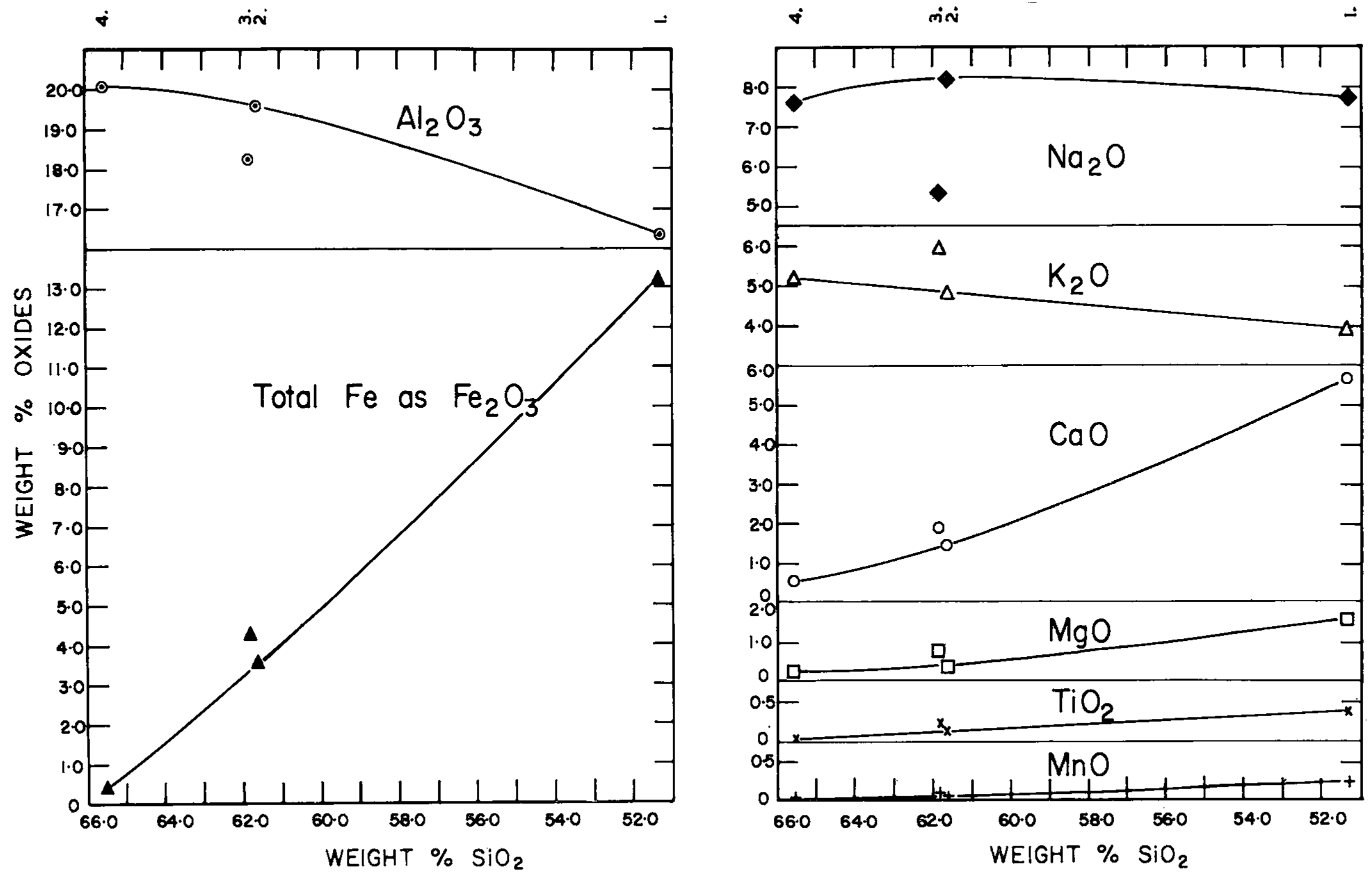

FIG. 1. Diagram illustrating the course of contamination of alkali-syenite by leucocratic alkaline gneiss.

between these four samples. The almost linear character of the trend lines is evidence that the nepheline syenite (no. 2) could have been formed by mechanical mixture of the alkali-syenite (no. 4) and the adjacent nepheline gneiss (no. 1). The field evidence strongly supports this. The slight curvature of the Na_2O and Al_2O_3 trends is probably due to the bulk composition of the country gneiss that was incorporated being slightly richer in these components than the analyzed gneiss. The country rock contains occasional thin secretion veinlets of pure nepheline or nepheline and feldspar lying in the foliation plane. The incorporation of one of these in the contaminating material, or simply a slightly more nepheline-rich gneiss as the contaminant, would be sufficient to make the trend lines straight.

The other contaminated syenite from the Wolfe Belt (no. 3) is nepheline-free but contains 18.4 vol. per cent aegirine. This mineral is scattered more-or-less evenly throughout the rock. The wall rock at this locality was not analyzed but is, in part, a gneiss containing 53.8 per cent oligoclase, 22.6 per cent microcline, 19.1 per cent biotite, 3.7 per cent carbonate and 0.8 per cent apatite. A more biotite-rich facies of this gneiss would approach the theoretical contaminant closely but in this case a close chemical relationship with the wall rock may not exist. The scattered distribution of the aegirine may indicate that the contamination occurred before the syenite reached its present position, and also, the syenite at this locality cuts across the foliation in the banded alkaline-gneisses. Adjacent layers in the gneiss can differ appreciably in chemical composition so that one specimen would not be expected to represent the bulk composition of the contaminant even if it were of immediately local derivation. The fact that the analysis of the aegirine-syenite plotted on figure 1 only differs from the trend lines for the previous example of contamination with respect to K_2O, Na_2O and Al_2O_3 means that it has been contaminated by a very similar rock. By comparing the calculated composition of the aegirine-syenite, derived from its modal composition, with its chemical analysis it appears that the low total of the latter is due to a low determination of the Al_2O_3 component. If this is true, only the alkalies of the aegirine-syenite would depart appreciably from the trend lines.

Conclusions

Two examples of contamination of alkali-syenite have been described. In one, the contaminant was a nepheline-bearing gneiss which led to the production of a nepheline-syenite; in the other the contaminant was probably nepheline-free gneiss which resulted in the formation of a still saturated aegirine-syenite. The fact that only one example in which undersaturation was achieved amongst the many examples of contaminated alkali-syenites that were observed suggests that this process was not responsible for the production of any appreciable quantity of undersaturated magma. The igneous nepheline-bearing rocks described by Tilley & Gittins (1961), for instance, are considerably earlier than the alkali-syenites in age and therefore could not have been derived from them in this manner.

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