A NOTE ON THE U, Th AND K CONTENTS IN THE NEPHELINE SYENITE AND CARBONATITE ON STJERNÖY, NORTH NORWAY

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Abstract. The nepheline syenite on Stjernöy is characterized by uniformly low U and Th contents. This observation, when regarded in conjunction with the high K contents of the rock, indicates that the nepheline syenite has not resulted from a liquid fractionation process governed by a liquid — solid equilibrium. If the nepheline syenite is magmatic, a separate vapor phase capable of selectively concentrating U and Th should have been active during the crystallization. The hypothesis is suggested that this vapor is related to the fluid which formed the carbonatite around the nepheline syenite, but the data are inconclusive. The carbonatite is higher than the nepheline syenite in both U and Th, and lower in K, however, the K content is higher than that typically associated with similar U and Th concentrations in magmatic rocks.

Introduction

The geology and petrology of the nepheline syenite, the carbonatite, and the surrounding rocks on Stjernöy is discussed by HEIER (1961). The sample numbers of the nepheline syenites in Table 1 are as in Table 8, HEIER (1961), and their position is marked on the map Fig. 12 in that paper.

Th, U, and K were determined by gamma ray spectrometry. The instrument, analytical method, and sample preparation was as described by HEIER and ROGERS (1962). 350 grams of powdered samples were used for the analyses.

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The nepheline syenite

Very little data are available on U and Th in alkaline rocks. ADAMS et al (1959) reported a range of 0.1 to 30 p.p.m. U with no Th values given. Apparently alkaline rocks have very variable contents of radioactive material, an observation which may have considerable petrogenetic importance, and may help in dist nguishing between nepheline syenites of different environments and petrogeneses.

The nepheline syenite on Stjernöy is characterized by low Th and U contents, Table 1. Th ranges between n.d. ($<\sim$ 0.03 p.p.m.) and 1.3 p.p.m., with an arithmetic mean of 0.55 p.p.m. U is between n.d. ($<\sim$ 0.01 p.p.m.) and 0.2 p.p.m. with an arithmetic mean of 0.09 p.p.m. The K content is remarkably constant across the major part of the body. The extreme S.E. (no. S—1, access tunnell, 110 m. above sea level), and N.W. (nos. 20, 21) areas of the nepheline syenite appear to be low in both U and Th. U was not detected in nos. 7 and 14, and it is very low in no. 5. Th was not detected in no. 12 and 14. Nos. 5, 7, and 12 are close to the contacts. No. 14 which is low in both U and Th, has the highest K content of all the examined rocks.

HEIER and ROGERS (1962) demonstrated a marked association between K, Th and U in magmatic rocks, including granites. According to their observations (their Figs. 12 and 13) K contents of between 6 and 7 per cent should be associated with concentrations of about 30 p.p.m. Th and 10 p.p.m. U in magmatic rocks that are unaffected by secondary processes. The arithmetic mean of the Th content in the nepheline syenite on Stjernöy is 50 to 60 times, and the U content 100 times less than this. (Similar low Th an U contents were found in the nepheline syenite from Blue Mountain, Ontario, Canada, Table 1.)

The Th and U contents in the nepheline syenite are less than those commonly found in basalts, though some tholeiitic basalts from orogenic areas have comparable concentrations, HEIER and ROGERS (1962). The alkali basalts are characteristically high in U and Th. Basaltic liquids may fractionate to either a silica rich (granitic) or nepheline rich (nepheline syenitic) residuum (see for instance YODER and TILLEY (1957, 1961) for the most recent discussion of this). The unusually low U and Th concentrations found in the nepheline syenite on Stjernöy indicate that this rock has not formed through a liquid fractionation process governed entirely by a liquid — solid equilibrium. If the ne-

TABLE 1.

Th, U, and K contents in nepheline syenite (nos 1 to 21 refer to Heier (1961), Table 8, Fig. 12).*

no.	Th p.p.m.	U p.p.m.	K per cent	Th/U
S1-tunnel	0.2	(0.02)	7.03	10
1			4.71	flame photom.
2			5.24	flame photom.
5	0.9	0.06	5.60	11
6	0.6	0.1	6.86	6
7	0.6	n.d.	6.82	
8	0.4	0.10	6.99	4
9	0.4	0.1	6.99	4
10	1.3	0.2	6.47	6
11	0.8	0.2	6.99	4
12	n.d.	0.1	7.05	
13	1.0	0.2	6.64	5
Between 13 and 14	1.1	0.1	6.54	11
14	n.d.	n.d.	7.19	
15	0.4	0.1	6.61	4
16	0.8	0.1	6.86	8
19	0.4	0.1	7.04	4
20	0.4	(0.03)	5.90	
21	(0.1)	(0.02)	5.93	
Arithmetic mean (n.d. = 0):	0.55	0.09	6.68	6
Blue Mountain, Ontario.				
1	0.5	0.2	3.95	2.5
2	0.4	0.1	5.08	4

* The estimated error of the Th and U determinations is large.

pheline syenite represents a magmatic fractionate, a separate vapor phase with a composition allowing it selectively to concentrate U and Th from the crystallizing magma must have been active. Indeed the presence of a vapor phase is often considered essential to the magmatic formation of subsilicic rocks (see for instance RINGWOOD, 1959). The composition of the vapor phase that is capable of so effectively removing both Th and U from a crystallizing magma is not known, however, consideration of the chemistry of U and especially of Th, suggests that the vapor phase was not only hydrous. HEIER (1961) postulated that a vapor phase rich in H_2O, $CaCO_3$, and K_2CO_3 was active in the petrogenetic evolution on Stjernöy.

The hypothesis of assimilation of limestone or dolomite causing a desilication of the magma, and the formation of alkaline rocks, originally proposed by DALY in 1910, may be considered as having been effective in the petrogenic evolution on Stjernöy. Th and U contents in carbonate rocks are well known, averaging 1.7 p.p.m. Th (range 0.1 to 7 p.p.m.) and 2.2 p.p.m. U (range 0.1 to 9 p.p.m.), ADAMS et al (1959). The concentrations of Th and U in the nepheline syenite are at the low extreme end of the ranges in carbonate sediments. Dilution of the magma, by carbonate assimilation, would probably not directly result in the low Th and U contents of the nepheline syenite. The effect of carbonate assimilation on the U and Th concentrations must, if this process was operative, have been in changing the composition of the vapor phase.

The formation of the nepheline syenite by some sort of alkali metasomatic process may effectively disturb the association between K and the actinides. Thermodynamic considerations do not explain why Th and U should follow K during metasomatism, however, metasomatic processes are not well known. The only geochemical characteristic common to Th, U, and K is a pronounced oxyphile character. Possibly relevant to this discussion is the fact that most granites exhibit a K — actinide association.

The carbonatites

HEIER (1961) indicated that the carbonatite "magma", or the fluid which formed the carbonatite, was high in both K_2CO_3 and H_2O in addition to $CaCO_3$. This fluid may in some way have been related to the postulated vapor phase which acted on the nepheline syenite magma, and which may have concentrated Th and U. 16 samples of the carbonatite from the entire area were examined, Table 2. Owing to weathering, a danger of radioactive disequilibrium exists in many of the samples. The possibility of disequilibrium may be checked by measuring two energy peaks for each element in the gamma ray spectrum. In this case both U and Th were determined from the 0.61 MeV peak in addition to their determination from the 2.62 MeV peak (for Th), and the 1.76 MeV peak (for U). Each specimen in which the two inde-

TABLE 2.

Th, U, and K contents in the carbonatite.

No.	Th p.p.m.	U p.p.m.	K per cent	Th/U
C-1	7.0	0.6	1.73	12
C-2	3.4*	0.7*	1.39	5
C-3	5.1	1.2	3.36	4
C-4	3.2	0.6	2.38	5
C-5	3.7*	0.5*	0.92	7
C-7	1.1*	0.2*	3.00	6
C-8	1.5*	0.3*	3.33	5
C-9	2.5	0.4	3.58	6
C-10	3.0*	0.7*	2.88	4
C-11	2.7*	0.3*	3.47	9
C-12	1.4*	0.4*	2.55	4
C-13	1.8*	0.2*	2.94	9
C-14	3.4*	0.8*	0.68	4
C-15	4.8*	0.3*	1.40	16
C-16	8.1	0.5	1.70	16
C-17	11.5	1.1	1.00	11
Arithmetic mean	4.0	0.55	2.27	

pendent determinations differed significantly are marked with an asterix in Table 2. The two determinations are always within the same order of magnitude. U is always higher when determined from the 0.61 MeV channel, and the two channels may differ as much as by a factor of four. Either of the two channels may give the maximum Th content but do not differ by more than a factor of three. (The determination from the 1.76 MeV and 2.62 MeV peaks are the ones given in Table 2). Comparision with the six cases indicating no disequilibrium demonstrates that the concentrations given are not in serious error. The range of concentration of the six equilibrated samples approximately covers the range of all specimens analyzed in this investigation.

The average Th and U contents in the carbonatite are higher than those in the nepheline syenite by a factor of approximately six but considered in relation to the K contents (average 2.27 per cent) the Th and U values are considerably lower than those typically found in magmatic rocks of similar K contents, HEIER and ROGERS (1962). The K in the carbonatite is mainly in biotite which occurs in biotite-rich bands throughout the carbonatite.

The Th/U ratio in the carbonatite differs from that found in carbonate sediments (average Th/U ratio in 6045 sediments was reported as 1 ± 0.3 in ADAMS et al (1959)). Because most of the Th and U in the carbonatite is probably contained in the biotite rich bands, the Th/U ratio cannot be used as indicator of a non sedimentary origin of the carbonate in the carbonatite.

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