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Geochemistry of granite rocks in Ras Barud area, Eastern Desert, Egypt

ADEL M. REFAAT, MAHMOUD L. KABESH, MOHAMED E. HILMY AND ZEINAB M. ABDALLAH

Teachers' Institute of Education, El-Odylia, Kuwait; National Research Centre, Dokki, Cairo, Egypt; Faculty of Science, Ain Shams University, Cairo, Egypt; and Teachers' Institute of Education, El-Shamia, Kuwait

ABSTRACT

The distribution and occurrence of trace elements in the Ras Barud granite rocks provide information concerning the genesis of the çalc–alkaline rocks. Trace elements were analysed for 45 granite samples.

The trace elements of the granitic rocks show high concentrations of Ba, Sr, V and Zr at the early stage of crystallization of the magma, while Rb, Li and Ga are concentrated at the late crystallization stage of magma. Small differences in the K/Rb ratios of Ras Barud granitic rocks are observed. Low K/Rb ratios in some of the granodiorites are attributed to the high content of biotite.

It is concluded that a process of hybridization between mafic materials and granitic magma took place during the late stage of magmatic crystallization. This hybridization process led to the formation of some patches of dark grey granodiorites with high biotite content.

INTRODUCTION

This paper deals with the geochemistry of Ras Barud granitic rocks which form conspicuous plutons situated about 30 km north west of Safaga port. Gabal Ras Barud is one of the numerous granitic bodies of Safaga District in the Eastern Desert of Egypt (Fig. 1). The examined granitic rocks consist mainly of red, pink, buff, greyish white and white granites, in addition to adamellites, granodiorites and quartz diorites (Fig. 2). Petrographic studies of the investigated field rock units indicate the presence of 45 rock types according to their mineral constituents. Microscopically, the granites are composed of the following essential minerals: quartz, orthoclase, microcline, perthite, plagioclase, biotite and hornblende, and accessory minerals of zircon, apatite, sphene and iron ores.

Nine trace elements have been determined for each sample including Ba, Sr, Zr, Ga, Rb, Cs, Li, V and Sn (Tables 1–5). These elements were determined by using spectrographic methods.

DISTRIBUTION AND BEHAVIOUR OF TRACE ELEMENTS

The relationship between Rb (ppm) versus K percentage and K/Rb ratios are shown in

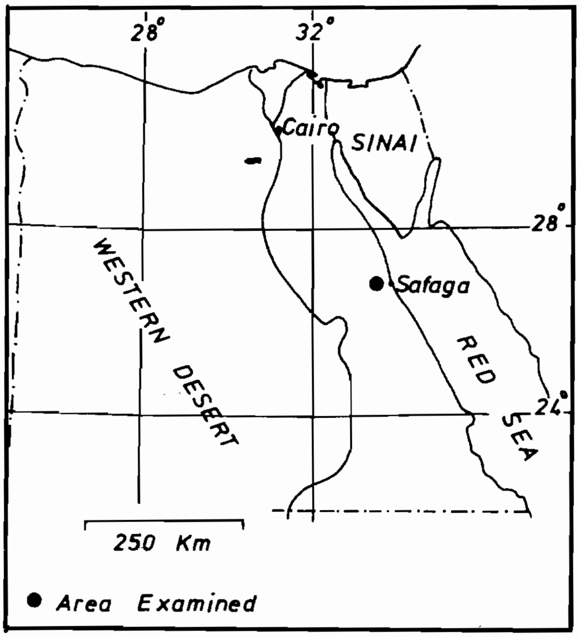


Fig. 1. Location map.

Fig. 3. Some of the granites possess low K/Rb ratios. Most of adamellites, granodiorites, and tonalites have intermediate and low K/Rb ratios. The low K/Rb ratios are mainly due to the enrichment in biotite which has large Rb ions (De Albuquerque 1971). Some samples of granite and adamellite are characterised by high K/Rb ratios. The small variation of K/Rb ratios in the examined granitic rocks is attributed to a highly differentiated magma. The concentration of Zr indicates the presence of zircon whereas the main portion of Ti indicates the presence of biotite (Winter 1968). The presence of high values of Zr and Ti in adamellites and granodiorites reflects the occurrence of zircon and biotite in these rocks. Some leucoadamellites and granites contain low Ti concentrations. The Ba–Sr correlation diagram is regarded as representation for the feldspar crystallization and differentiation. This diagram (Fig. 4) shows that granites occupy the lower part while the granodiorites and diorites occupy the upper part of the variation field, giving rise to a wide range of crystallization sequences. It is evident that the close petrogenetical relationship of both coexisting potash feldspars (Ba) and plagioclase (Sr) indicates that the examined granitic rocks have passed through a course of magmatic fractionation process (Madel 1975).

The adamellites, granodiorites and quartz diorites have high Sr and Ca contents reflecting the enrichment of plagioclase minerals, otherwise the opposite relation is observed in most granites. The trace elements of the examined rocks are plotted against (1/3 Si + K)–(Ca + Mg) (Tables 6–10) in Figs 5–8. In Fig. 5, Li, Rb and Ga show a progressive increase toward the felsic end of the series, while Sr and Ba decrease gradually in the same direction. Cs is mainly constant through the examined granitic series with the exception of some samples of adamellites and granites which show slightly high values of Cs. It appears that the granites are richer in Ga, Li, Rb and Cs

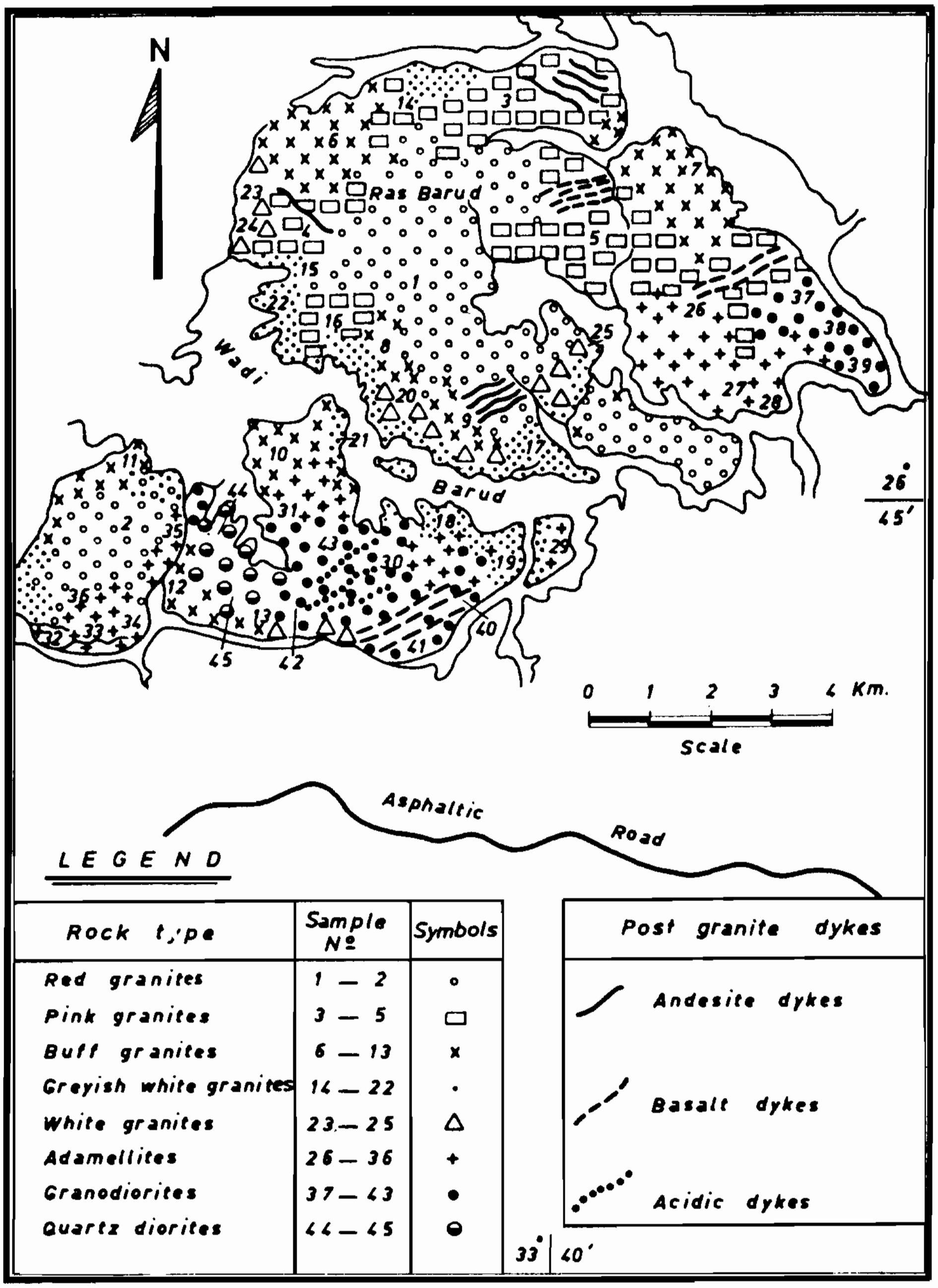
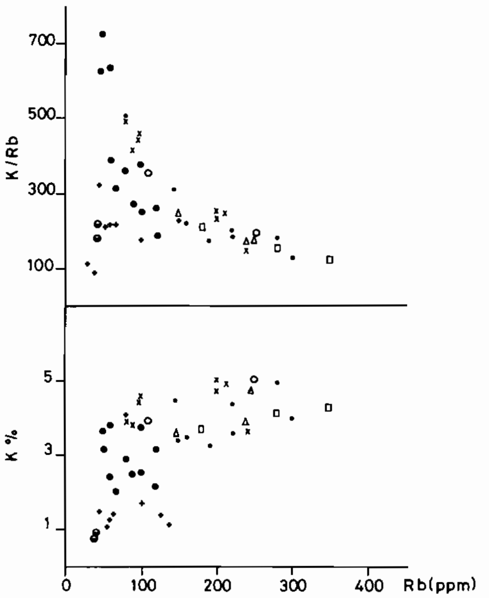


Fig. 2. Generalized geological map of Ras Barud area showing granitic rocks and sample location.



Explanation :

ROCK TYPE	SAMPLE No.	SYMBOLS
Red granites	1 - 2	o
Pink granites	3 - 5	□
Buff granites	6 - 13	x
Greyish white granites	14 - 22	·
White granites	23 - 25	Δ
Adamellites	26 - 36	●
Granodiorites	37 - 43	+
Quartz diorites	44 - 45	⊖

N.B : Symbols and numbers of the samples from Ras Barud granitic rocks are the same throughout the present work.

Fig. 3. Variation of Rb (ppm) against K% and K/Rb ratios.

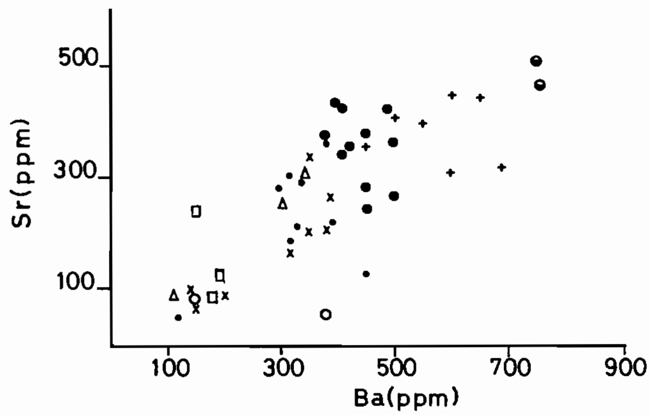


Fig. 4. Correlation of barium and strontium.

than granodiorites and adamellites, but Sr, Ba, V and Zr are more concentrated in granodiorites and adamellites than in the granites. The element ratios of $(Ga \times 10^3)/Al$ and $(Ga \times 10^3)/(Al + Fe^{+3})$ (Tables 11–15) are approximately constant throughout the examined granites but both ratios show a slight increase in passing from quartz diorite to adamellite. $(Ba \times 10^2)/(K)$ and $(Ba + 10^2)/(K \times Ca)$ ratios (Tables 11–15) decrease gradually towards the felsic end members (Fig. 6).

The enrichment of adamellites and granodiorites in biotite and muscovite explains the high content of Ba in these rocks. Ba replaces K in the lattice of biotite and muscovite.

It appears that the ratios of $(Sr \times 10^2)/Ca$ and $K/(Cs \times 10^{-2})$ (Tables 11–15)

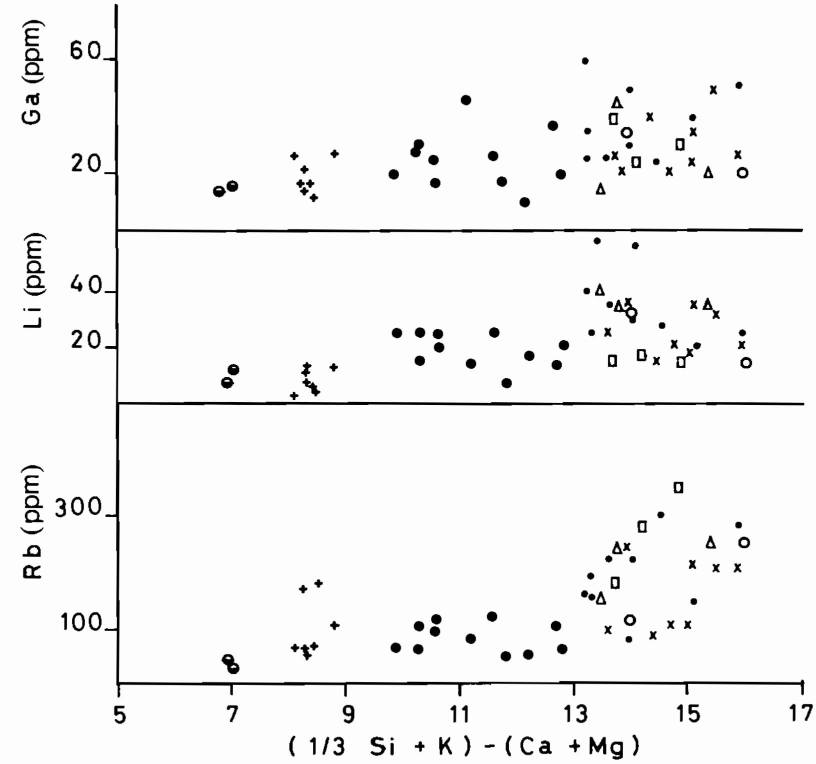


Fig. 5. Variation diagrams of the trace elements (ppm).

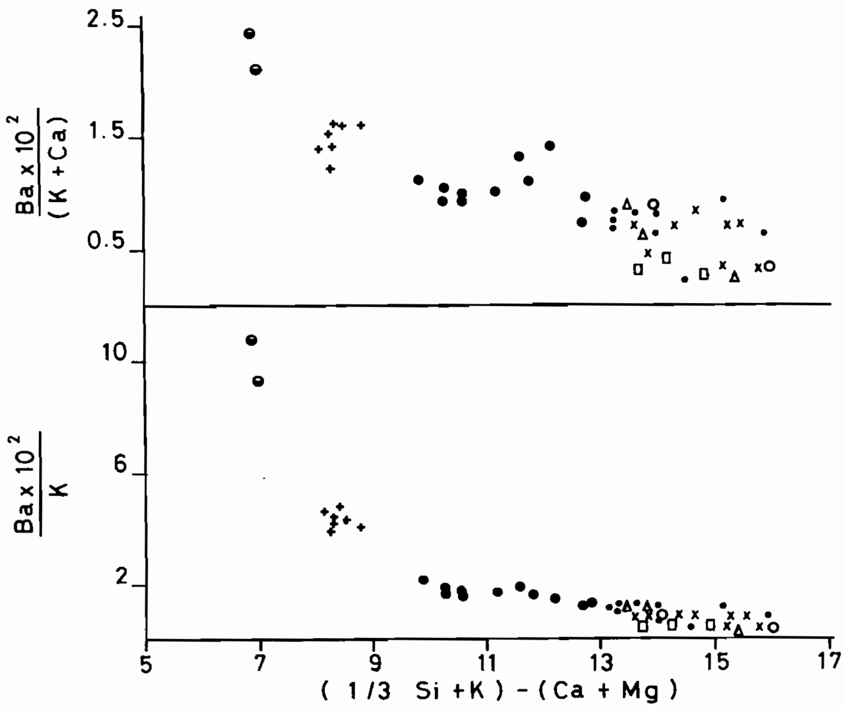


Fig. 6. Variation diagrams of the Ba/K and Ba/K + Ca) ratios.

increase from the quartz diorites to granites passing through granodiorites and adamellites. Fig. 7 shows that the Ba/Sr ratio (Tables 11–15) remains constant through tonalites, granodiorites and adamellites, but increases slightly towards the granitic varieties, which represent the most felsic members. Nockolds (1966) attributed this behaviour of the Ba/Sr ratio to the small differences between the ionic radii of Sr (1·27 Å) and Ba (1·46 Å) and also to the great concordance between the total bonding energies of Sr (191 K cal/mol) and Ba (180 K cal/mol). Therefore, this may lead to a high Ba/Sr ratio at the end of differentiation process. The Rb/Cs ratio (Tables 11–15) is partially constant throughout the tonalite, granodiorite and adamellite series. A slight increase of the Rb/Cs ratio is observed in granite varieties at the end of the felsic members (Fig. 8). The K/Rb ratios (Tables 11–15) of adamellites are slightly higher than those of granodiorites, while K/Rb ratios of the granites represent the lower values (Fig. 8). The low ratios of K/Rb in granites and granodiorites are attributed to the enrichment of biotite in these rocks.

The wide range of differentiation index (DI) (Thornton & Tuttles 1960) (Tables 6–10) through the granitic rocks reflects a highly differentiated calc–alkali magma characterized by a great chemical variation in their trace element contents.

In Figs 9 to 11 the differentiation index (DI) is plotted against trace element concentrations and trace element ratios. Fig. 9 shows that Ba, Sr, V and Zr decrease with the increase of DI. Fig. 10 shows that Rb, Li and Ga increase with the increase of DI. Cs is mostly constant throughout tonalites, granodiorites, adamellites and granites. It appears that the high concentrations of Ba, Sr, V and Zr were present at an early stage of crystallization in which tonalites and granodiorites were formed. Rb, Li and Ga were present in fair amounts at a late stage of crystallization which is represented by the granite varieties. The adamellites are characterized by intermediate concentrations of trace elements. The differentiation index of the examined rocks varies from 67·7 to 92·8 showing a highly differentiated magma characterized by salic to semi-salic nature in which a gradational chemical variation in the concentration of trace elements is concluded throughout the magmatic crystallization of these rocks.

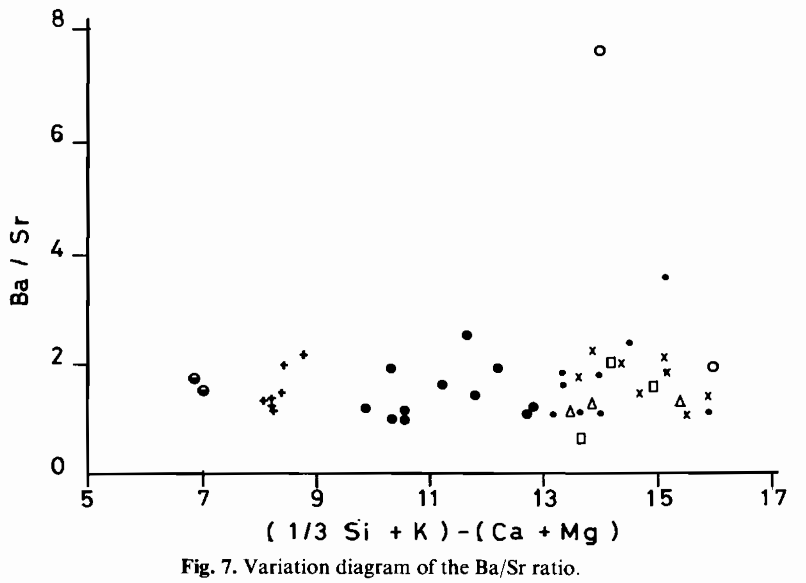


Fig. 7. Variation diagram of the Ba/Sr ratio.

Therefore, the previous behaviour of trace elements against DI supports the differentiated magmatic origin for the investigated granitic rocks (Stephenson 1974). The ratio of Ba/Sr, Rb/Cs and Sr/Ca (Tables 11–15) increase slightly from quartz diorites to granites, while the Ba/Rb and Ba/K ratios (Tables 11–15) decrease in the same direction. The K/Rb ratios (Tables 11–15) of both granites and granodiorites are lower than the same ratio from adamellites (Fig. 11). The low ratios of K/Rb in granites and granodiorites are due to the enrichment of biotite in these rocks. It is evident that a stage of hybridization of mafic materials with granitic magma took place leading to the crystallization of dark grey granodiorites with high biotite contents.

The concentration of Rb, Ba and Sr, recalculated to 100% for the examined granitic rocks are plotted on a triangular diagram (Fig. 12). It appears that the granite varieties occupy the portion between Ba and Rb, but adamellites, granodiorites and tonalites show high concentration of Sr and Ba. The behaviour of the three trace elements is

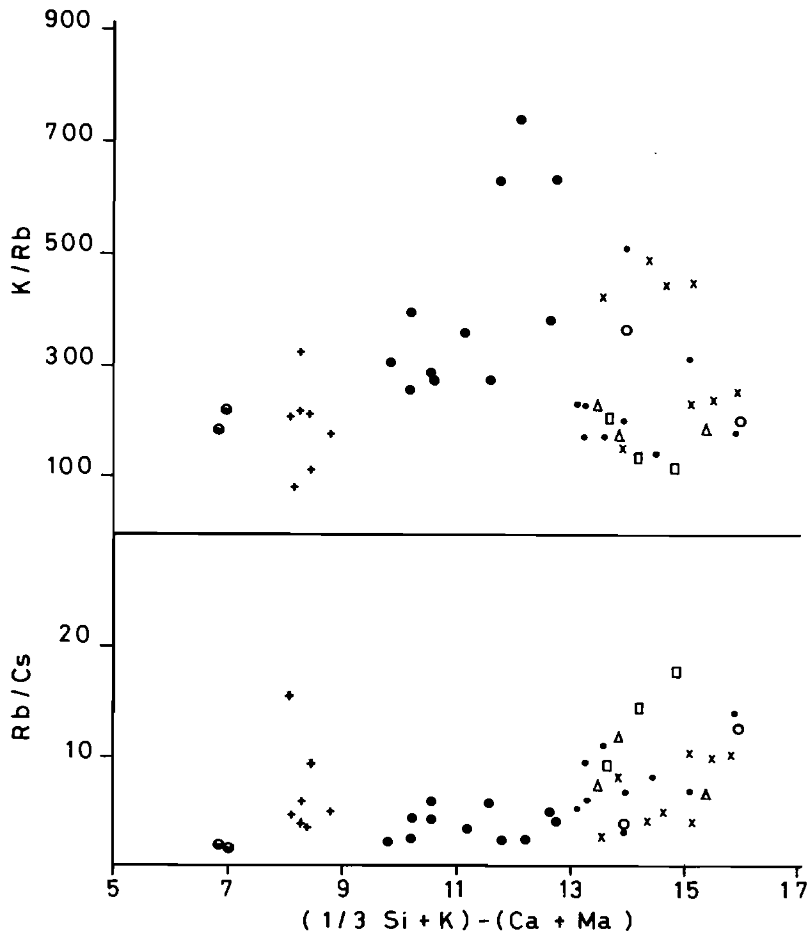


Fig. 8. Variation diagrams of the K/Rb and Rb/Cs ratios in the granitic rocks.

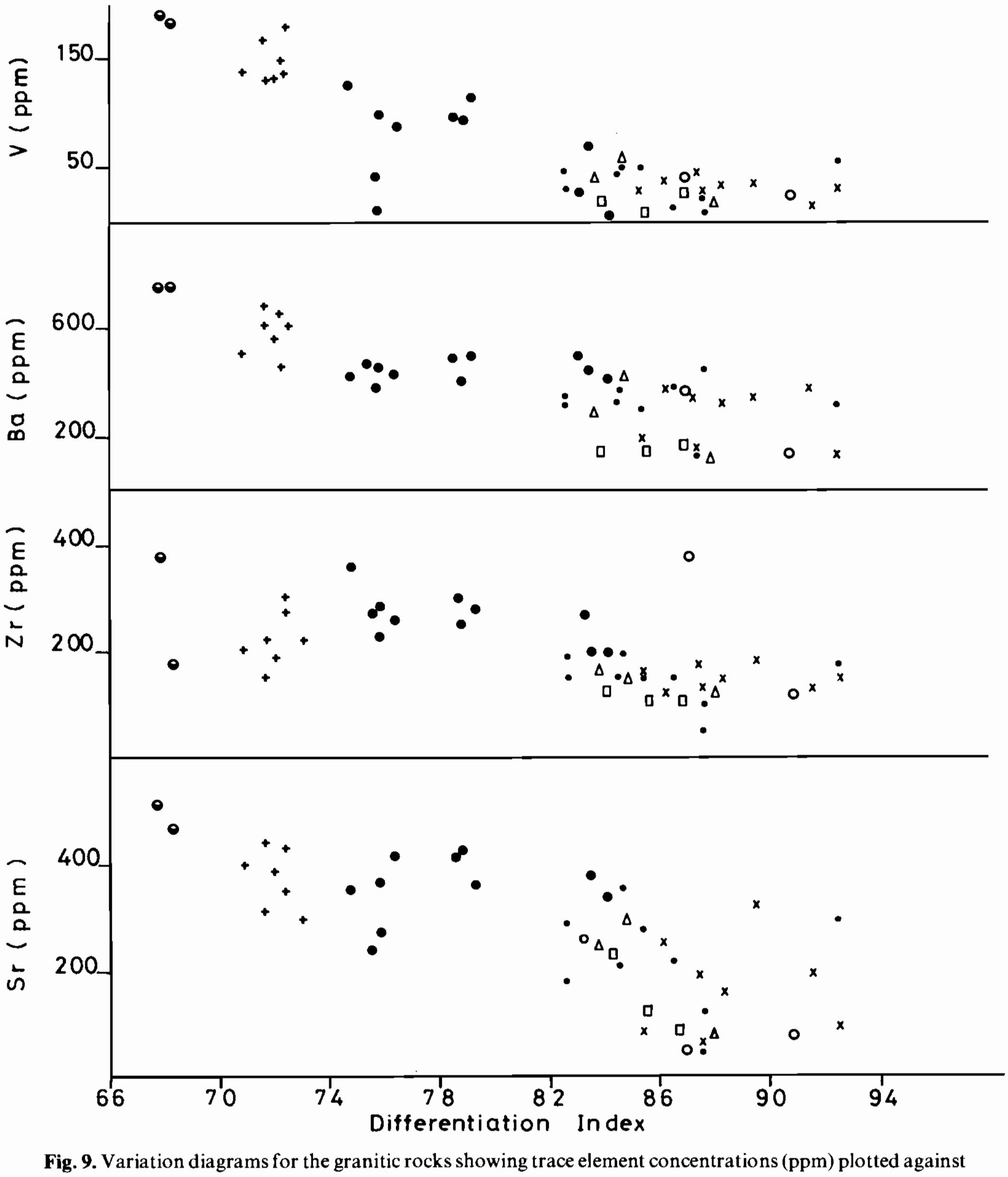


Fig. 9. Variation diagrams for the granitic rocks showing trace element concentrations (ppm) plotted against differentiation index.

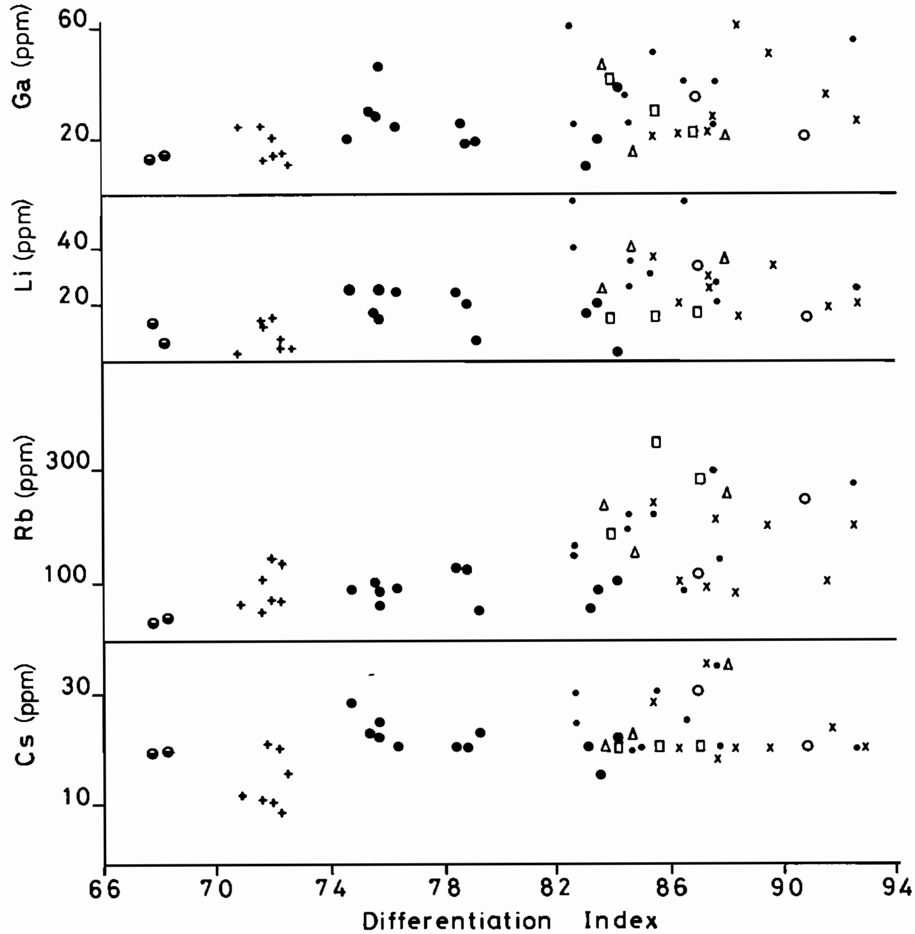


Fig. 10. Variation diagrams for the granitic rocks showing trace element concentrations (ppm) plotted against differentiation index.

attributed to the enrichment of Sr and Ba at an early magmatic crystallization stage during the formation of plagioclases. On the other hand, Rb and Ba are concentrated at a late stage of crystallization of the magma in which potash feldspars were crystallized (El-Gaby 1975).

CONCLUSIONS

The examined granitic rocks show little change in their K/Rb ratios which vary from 150 to 400 ppm. It is concluded that the investigated rocks were formed through major phases of differentiation processes, i.e. a highly differentiated nature of acid and intermediate magma crystallized forming series of rocks ranging in composition from granites to tonalites. The presence of low K/Rb ratios in some granodiorites is attributed to the enrichment of biotite which mostly clarifies that a process of hybridization between mafic materials and granite magma took place during the late

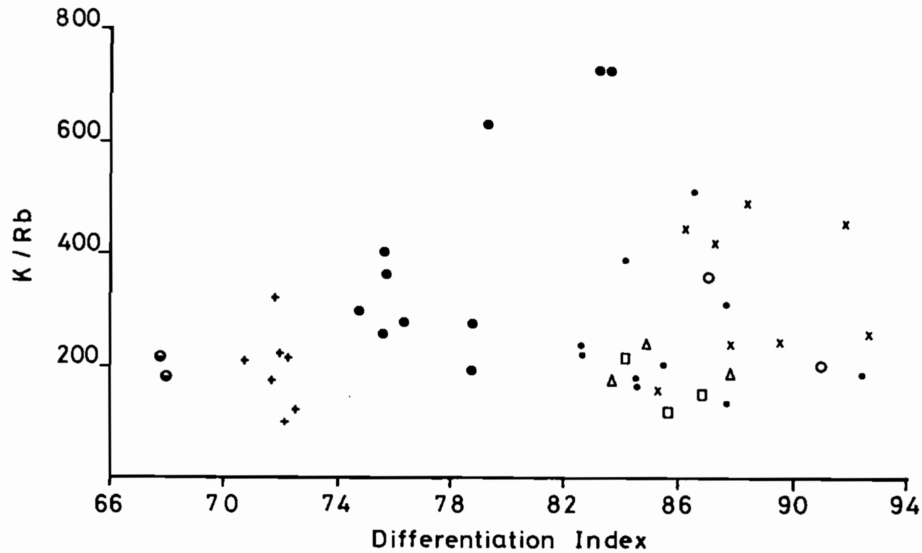


Fig. 11. Variation diagram for the granitic rocks showing K/Rb ratios plotted against differentiation index.

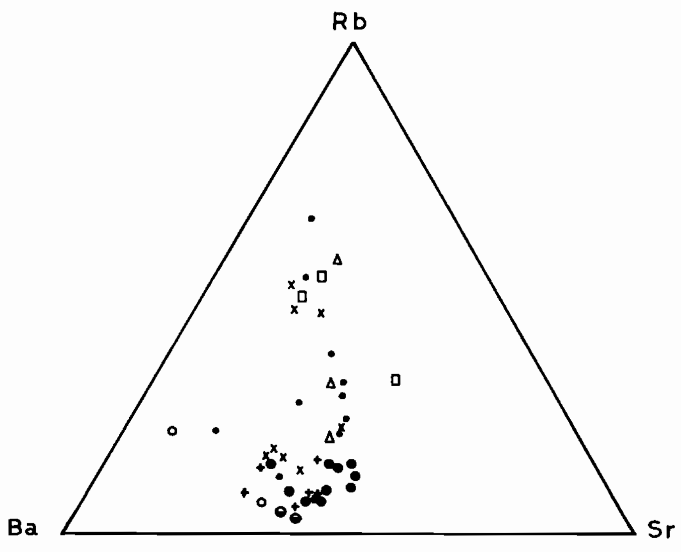


Fig. 12. Ternary diagram showing relative distribution of Sr, Ba and Rb in the studied granitic rocks.

stage of crystallization of the primary magma. This process led to crystallization of granodiorites with high biotite content. The enrichment of granodiorites with biotite and muscovite explains the high content of Ba in these rocks. The close relationship of both Ba (K feldspars) and Sr (plagioclases) in the examined granitic rocks shows that these rocks passed through magmatic fractionation.

High concentrations of Ba, Sr, V, Zr are present in the earliest crystallized rocks, while Rb, Li and Ga are present in moderate amounts at the late stage of crystallization of the magma. Cesium is mainly constant through the granitic rocks. Strontium follows calcium in all stages of the granitic rocks. The occurrence of these trace elements and their ratios agree to a great extent with the characters of calc–alkaline granitic rocks.

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Table 1. Trace element analysis of Ras Barud red and pink granites (in ppm)

	Red granites (Sample No.)		Pink granites (Sample No.)		
Element	1	2	3	4	5
Ba	380	150	150	190	180
Sr	50	80	240	125	90
Zr	380	120	130	110	110
Ga	35	20	40	30	22
Rb	110	250	180	350	280
Cs	30	20	20	20	20
Li	32	15	15	15	18
V	40	25	20	10	33
Sn	4	—	8	—	—
Ba%	70·4	31·3	26·3	28·6	32·7
Sr%	9·3	16·7	42·1	18·8	16·4
Rb%	20·3	52·0	31·6	52·6	50·9

Sample numbers referring to various granitic rocks are the same throughout the present study. See list, p. 149.

Table 2. Trace element analysis of Ras Barud buff granite (in ppm)

	Sample No.							
Element	6	7	8	9	10	11	12	13
Ba	350	140	390	380	150	200	350	320
Sr	200	100	260	200	70	90	330	160
Zr	180	150	125	130	130	160	180	150
Ga	25	25	20	35	23	20	50	40
Rb	90	200	100	100	210	240	200	80
Cs	35	20	20	24	20	28	20	20
Li	25	20	20	19	25	35	32	15
V	45	30	38	15	35	33	38	38
Sn	9	7	10	9	—	—	9	4
Ba%	54·7	31·8	52·0	55·9	34·9	37·7	39·8	57·1
Sr%	31·3	22·7	34·7	29·4	16·3	17·0	37·5	28·6
Rb%	14·0	45·5	13·3	14·7	48·8	45·3	22·7	14·3

Table 3. Trace element analysis of Ras Barud greyish white and white granites (in ppm)

	Greyish white granites (Sample No.)									White granites (Sample No.)		
Element	14	15	16	17	18	19	20	21	22	23	24	25
Ba	320	450	380	330	300	320	340	390	120	300	340	110
Sr	180	125	360	210	280	300	290	220	50	250	300	90
Zr	190	50	200	150	150	180	150	150	100	160	150	130
Ga	25	40	25	35	50	55	60	30	25	45	16	20
Rb	150	145	220	190	220	280	160	80	300	240	150	250
Cs	25	20	20	20	30	20	30	25	35	20	20	35
Li	49	20	35	25	30	25	40	48	28	25	40	37
V	28	10	50	45	50	55	45	12	20	45	55	20
Sn	9	—	12	9	—	—	—	10	—	—	14	—
Ba%	49·2	62·5	39·6	45·2	37·5	35·6	43·0	56·5	25·5	38·0	43·0	24·4
Sr%	27·7	17·4	37·5	28·8	35·0	33·3	36·7	31·9	10·6	31·6	38·0	20·0
Rb%	23·1	20·1	22·9	26·0	27·5	31·1	20·3	11·6	63·9	30·4	19·0	55·6

Table 4. Trace element analysis of Ras Barud adamellites (in ppm)

	Sample No.										
Element	26	27	28	29	30	31	32	33	34	35	36
Ba	410	450	380	450	400	410	490	500	450	420	500
Sr	420	280	370	240	430	340	420	260	380	350	360
Zr	260	230	290	180	250	200	300	270	200	360	280
Ga	24	45	27	30	18	37	25	10	20	20	18
Rb	90	80	60	100	120	100	122	50	60	65	50
Cs	20	22	25	22	20	20	20	20	15	28	23
Li	24	15	25	16	20	13	24	17	20	25	7
V	90	11	100	45	80	10	90	30	70	130	115
Sn	11	—	12	—	—	—	—	—	—	12	—
Ba%	44·5	55·5	47·0	57·0	42·0	48·0	47·0	62·0	50·6	50·3	55·0
Sr%	45·7	34·6	46·0	30·0	45·0	40·0	41·0	32·0	42·7	41·9	40·0
Rb%	9·8	9·9	7·0	13·0	13·0	12·0	12·0	6·0	6·7	7·8	5·0

Table 5. Trace element analysis of Ras Barud granodiorites and quartz diorites (in ppm)

	Granodiorites (Sample No.)							Quartz diorites (Sample No.)	
Element	37	38	39	40	41	42	43	44	45
Ba	450	500	550	600	650	600	690	760	750
Sr	350	400	390	440	435	300	310	460	500
Zr	270	200	190	150	300	220	220	160	370
Ga	14	25	20	12	15	10	25	14	15
Rb	140	55	60	45	65	135	100	40	37
Cs	9	12	10	11	20	15	20	20	20
Li	6	3	12	11	5	4	11	7	12
Sn	—	14	5	—	6	—	8	25	6
V	135	130	128	127	150	180	165	185	190
Ba%	47·9	52·3	55·0	55·0	56·5	58·0	63·0	60·0	58·0
Sr%	37·2	41·9	39·0	41·0	37·8	29·0	28·0	37·0	39·0
Rb%	14·9	5·8	6·0	4·0	5·7	13·0	9·0	3·0	3·0

Table 6. Elements recalculated from oxides of red and pink granites*

	Red granites (Sample No.)		Pink granites (Sample No.)		
Element	1	2	3	4	5
Si	34·24	35·07	34·36	34·28	34·57
Al	7·41	7·25	7·38	7·94	7·47
Fe^{+2}	1·02	0·73	1·19	0·72	0·67
Fe^{+3}	0·69	0·55	0·92	0·53	0·38
Mg	0·47	0·14	0·58	0·16	0·28
Ca	0·86	0·54	0·93	0·65	1·06
Na	2·30	1·64	1·71	1·14	1·94
K	3·93	4·95	3·74	4·32	4·06
Ti	0·08	0·08	0·08	0·11	0·15
$(\frac{1}{3}Si + K) - (Ca + Mg)$	+14·01	+15·96	+13·68	+14·94	+14·24
D.I.†	86·98	90·89	84·06	85·58	86·86

* The elements of the granitic rocks (Tables 6–10) are recalculated from oxides which are taken from unpublished analyses by the authors.

† Thornton & Tuttle (1960).

Table 7. Elements recalculated from oxides of buff granites

Element	Sample No. 6	7	8	9	10	11	12	13
Si	34·02	34·62	34·31	34·58	33·95	34·52	34·59	35·08
Al	7·61	7·32	7·85	7·30	7·93	8·17	7·40	6·88
Fe^{+2}	0·82	0·83	0·83	0·64	0·76	0·67	0·75	1·02
Fe^{+3}	0·39	0·50	0·55	0·46	0·53	0·33	0·60	0·53
Mg	0·59	0·14	0·49	0·17	0·43	0·29	0·17	0·50
Ca	0·94	0·50	0·70	0·61	0·69	0·95	0·60	0·70
Na	2·82	2·35	1·56	2·52	1·81	1·82	1·76	2·12
K	3·75	5·00	4·42	4·47	4·85	3·61	4·72	3·91
Ti	0·07	0·08	0·07	0·13	0·08	0·13	0·11	0·01
$(\frac{1}{3}Si+K)-(Ca+Mg)$	+13·56	+15·90	+14·67	+15·22	+15·05	+13·88	+15·48	+14·40
D.I.	84·43	92·59	86·17	91·64	87·69	85·44	89·52	88·28

Table 8. Elements recalculated from oxides of greyish white and white granites

Element	Greyish white granites (Sample No.)									White granites (Sample No.)		
	14	15	16	17	18	19	20	21	22	23	24	25
Si	33·84	34·31	34·08	34·19	33·34	34·55	34·23	34·04	34·93	34·05	34·13	35·16
Al	7·85	7·34	7·82	7·79	8·28	7·29	7·58	7·70	7·26	7·75	7·86	7·28
Fe^{+2}	1·28	1·51	1·07	1·39	0·77	0·82	1·27	0·87	0·69	1·35	1·19	0·63
Fe^{+3}	0·74	0·75	0·62	0·65	0·60	0·50	0·68	0·62	0·44	0·78	0·63	0·55
Mg	0·35	0·17	0·32	0·32	0·51	0·14	0·67	0·59	0·26	0·58	0·57	0·47
Ca	1·08	0·60	0·98	1·04	1·00	0·51	1·08	0·79	0·94	0·86	0·79	0·65
Na	1·92	1·79	1·94	1·98	2·18	2·36	1·79	2·21	1·84	1·74	2·15	1·19
K	3·41	4·47	3·56	3·29	4·40	5·04	3·49	4·06	4·01	3·88	3·49	4·76
Ti	0·31	0·13	0·29	0·22	0·07	0·07	0·08	0·07	0·14	0·07	0·07	0·07
($\frac{1}{3}$ Si+K)−(Ca+Mg)	+13·26	+15·14	+12·62	+13·33	+14·00	+15·91	+13·15	+14·03	+14·45	+13·79	+13·51	+15·36
D.I.	82·60	87·69	84·56	84·46	85·39	92·48	82·59	86·53	87·56	83·82	84·90	88·02

Table 9. Elements recalculated from oxides of adamellites

	Sample No.										
	26	27	28	29	30	31	32	33	34	35	36
Si	32·20	32·24	32·38	32·38	33·19	33·09	32·54	33·00	32·62	32·10	32·34
Al	8·06	8·07	7·73	7·70	8·05	8·22	8·18	7·91	8·46	8·26	8·43
Fe^{+2}	2·00	1·86	1·92	2·01	0·85	0·77	1·65	0·76	0·85	2·03	1·54
Fe^{+3}	0·95	0·85	0·90	0·92	0·61	0·62	0·95	0·62	0·58	0·93	1·20
Mg	0·66	0·63	0·83	0·82	1·09	0·53	0·92	0·46	0·52	0·92	0·85
Ca	1·98	1·78	2·07	2·18	1·61	1·65	1·50	2·02	1·31	1·80	1·33
Na	2·79	2·13	2·78	2·75	2·82	2·90	2·52	2·89	2·70	2·76	2·60
K	2·47	2·87	2·37	2·50	2·22	3·83	3·18	3·66	3·78	1·96	3·16
Ti	0·32	0·32	0·35	0·30	0·31	0·10	0·09	0·07	0·31	0·07	0·32
$(\frac{1}{3}Si+K)-(Ca+Mg)$	+10·56	+11·21	+10·26	+10·29	+10·58	+12·68	+11·61	+12·18	+12·82	+9·94	+11·76
D.I.	76·31	75·81	75·81	75·60	78·93	84·09	78·70	83·10	83·52	74·65	79·36

Table 10. Elements recalculated from oxides of granodiorites and quartz diorites

	Granodiorites (Sample No.)							Quartz diorites (Sample No.)	
Element	37	38	39	40	41	42	43	44	45
Si	31·68	31·46	31·40	31·26	31·44	31·59	31·63	30·04	30·51
Al	8·29	8·09	8·29	8·18	8·33	8·05	8·26	8·92	8·42
Fe^{+2}	2·04	2·75	2·08	2·47	2·02	2·41	2·03	2·98	2·78
Fe^{+3}	0·94	0·98	0·95	0·09	0·95	0·89	0·93	1·32	1·69
Mg	0·91	1·12	0·92	1·13	0·89	1·09	0·92	1·39	1·19
Ca	2·50	2·40	2·57	2·43	2·61	2·32	2·51	2·49	2·79
Na	3·54	3·59	3·56	3·60	3·54	3·56	2·98	4·30	3·86
K	1·14	1·11	1·31	1·45	1·38	1·39	1·71	0·72	0·81
Ti	0·32	0·31	0·34	0·35	0·33	0·31	0·34	0·10	0·11
$(\frac{1}{3}Si+K)-(Ca+Mg)$	+8·29	+8·08	+8·29	+8·31	+8·36	+8·51	+8·82	+6·85	+7·00
D.I.	72·33	70·87	72·03	71·80	72·30	72·48	71·67	68·07	67·74

Table 11. Some elemental ratios of red and pink granites

	Red granites (Sample No.)		Pink granites (Sample No.)		
Element	1	2	3	4	5
K/Rb	357·3	198·0	207·8	123·4	145·0
Sr/Ca	0·006	0·015	0·026	0·019	0·008
Ba/K	0·010	0·003	0·004	0·004	0·004
Ba/Sr	7·60	1·80	0·63	1·52	2·00
Ba/Rb	3·45	0·60	0·83	0·54	0·64
Rb/Cs	3·7	12·5	9·0	17·5	14·0
$\frac{Sr \times 10^2}{Ca}$	0·6	1·5	2·6	1·9	0·8
$\frac{Ba \times 10^2}{K+Ca}$	0·8	0·3	0·3	0·2	0·4
$\frac{Ba \times 10^2}{K}$	1·0	0·3	0·4	0·4	0·4
$\frac{Ga \times 10^3}{Al+Fe^{3+}}$	0·4	0·3	0·5	0·4	0·3
$\frac{Ga \times 10^3}{Al}$	0·5	0·3	0·5	0·4	0·3
$\frac{K}{Cs \times 10^{-2}}$	13·1	25·0	18·7	21·6	20·0

Table 12. Some elemental ratios of buff granites

Element	6	7	8	9	10	11	12	13
	Sample No.							
K/Rb	416·7	250·0	442·0	447·0	231·0	150·4	236·0	488·8
Sr/Ca	0·021	0·020	0·037	0·033	0·010	0·009	0·055	0·023
Ba/K	0·009	0·003	0·009	0·009	0·003	0·006	0·007	0·008
Ba/Sr	1·75	1·40	1·50	1·90	2·14	2·22	1·06	2·00
Ba/Rb	3·89	0·70	3·90	3·80	0·71	0·83	1·75	4·00
Rb/Cs	2·6	10·0	5·0	4·2	10·5	8·6	10·0	4·0
$\frac{Sr \times 10^2}{Ca}$	2·1	2·0	3·7	3·3	1·0	0·9	5·5	2·3
$\frac{Ba \times 10^2}{K+Ca}$	0·7	0·3	0·8	0·7	0·3	0·4	0·7	0·7
$\frac{Ba \times 10^2}{K}$	0·9	0·3	0·9	0·9	0·3	0·6	0·7	0·8
$\frac{Ga \times 10^3}{Al+Fe^{3+}}$	0·3	0·3	0·2	0·5	0·3	0·2	0·6	0·5
$\frac{Ga \times 10^3}{Al}$	0·3	0·3	0·3	0·5	0·3	0·2	0·7	0·6
$\frac{K}{Cs \times 10^{-2}}$	10·7	25·0	22·0	18·63	24·0	13·0	23·60	20·0

Table 13. Some elemental ratios of greyish white and white granites

	Greyish white granite (Sample No.)									White granites (Sample No.)		
Element	14	15	16	17	18	19	20	21	22	23	24	25
K/Rb	227·3	308·3	161·8	173·2	200·0	180·0	218·1	507·5	133·7	161·7	232·7	190·4
Sr/Ca	0·017	0·021	0·037	0·020	0·028	0·058	0·027	0·028	0·005	0·029	0·038	0·014
Ba/K	0·009	0·010	0·011	0·010	0·007	0·006	0·009	0·010	0·003	0·008	0·01	0·002
Ba/Sr	1·78	3·60	1·06	1·57	1·07	1·07	1·17	1·77	2·40	1·20	1·13	1·22
Ba/Rb	2·13	3·10	1·72	1·73	1·36	1·14	2·12	4·88	0·40	1·25	2·26	0·44
Rb/Cs	6·0	7·3	11·0	9·5	7·3	14·0	5·3	3·2	8·6	12·0	7·5	7·1
$\frac{Sr \times 10^2}{Ca}$	1·7	2·1	3·7	2·0	2·8	5·9	2·7	2·8	0·5	2·9	3·8	1·4
$\frac{Ba \times 10^2}{K+Ca}$	0·7	0·9	0·8	0·8	0·6	0·6	0·7	0·8	0·2	0·6	0·8	0·2
$\frac{Ba \times 10^2}{K}$	0·9	1·0	1·1	1·0	0·7	0·6	1·0	1·0	0·3	0·8	1·0	0·2
$\frac{Ga \times 10^3}{Al+Fe^{3+}}$	0·3	0·5	0·3	0·4	0·6	0·7	0·7	0·4	0·3	0·5	0·2	0·3
$\frac{Ga \times 10^3}{Al}$	0·3	0·5	0·3	0·4	0·6	0·8	0·8	0·4	0·3	0·6	0·2	0·3
$\frac{K}{Cs \times 10^{-2}}$	13·6	22·3	18·0	16·0	11·0	27·0	11·6	16·0	11·5	13·8	13·5	15·4

Table 14. Some elemental ratios of adamellites

Element	Sample No.										
	26	27	28	29	30	31	32	33	34	45	36
K/Rb	274·4	358·8	395·0	250·0	185·0	383·0	260·7	732·0	630·0	301·2	632·0
Sr/Ca	0·021	0·016	0·018	0·011	0·027	0·021	0·028	0·013	0·029	0·019	0·027
Ba/K	0·017	0·015	0·016	0·018	0·014	0·011	0·019	0·014	0·012	0·021	0·016
Ba/Rb	4·55	5·62	6·33	4·50	3·33	4·10	4·01	10·00	7·50	6·46	10·00
Rb/Cs	4·0	3·6	2·4	4·6	6·0	5·0	6·1	2·5	4·0	2·3	2·2
Ba/Sr	0·98	1·60	1·03	1·88	1·07	1·20	2·50	1·92	1·18	1·20	1·38
$\frac{Sr \times 10^2}{Ca}$	2·1	1·6	1·8	1·1	1·9	2·1	1·6	1·3	2·9	1·9	2·7
$\frac{Ba \times 10^2}{K+Ca}$	0·9	1·0	0·9	1·0	0·8	0·7	1·3	1·4	0·9	1·1	1·1
$\frac{Ba \times 10^2}{K}$	1·7	1·6	1·6	1·8	1·4	1·1	1·9	1·4	1·2	2·1	1·6
$\frac{Ga \times 10^3}{Al+Fe^{3+}}$	0·3	0·5	0·3	0·3	0·3	0·4	0·3	0·1	0·2	0·2	0·2
$\frac{Ga \times 10^3}{K}$	0·3	0·5	0·3	0·4	0·3	0·5	0·3	0·1	0·2	0·2	0·2
$\frac{K}{Cs \times 10^{-2}}$	12·0	13·0	9·0	11·4	11·0	19·2	16·0	18·3	7·6	7·0	13·7

Table 15. Some elemental ratios of granodiorites and quartz diorites

Element	Granodiorites (Sample No.)							Quartz diorites (Sample No.)	
	37	38	39	40	41	42	43	44	45
K/Rb	81·42	201·80	218·30	322·20	212·30	102·99	171·00	180·00	218·90
Sr/Ca	0·014	0·017	0·015	0·018	0·017	0·013	0·012	0·018	0·018
Ba/K	0·039	0·045	0·042	0·041	0·047	0·043	0·040	0·105	0·093
Ba/Sr	1·28	1·25	1·41	1·36	1·49	2·00	2·23	1·65	1·50
Ba/Rb	3·21	9·09	9·17	13·33	10·00	4·44	6·90	19·00	20·30
Rb/Cs	15·55	4·60	6·00	4·10	3·30	9·00	5·00	2·00	1·90
$\frac{Sr \times 10^2}{Ca}$	1·4	1·7	1·5	1·8	1·7	1·3	1·2	1·8	1·8
$\frac{Ba \times 10^2}{K+Ca}$	1·2	1·4	1·4	1·5	1·6	1·6	1·6	2·4	2·1
$\frac{Ba \times 10^2}{K}$	3·9	4·5	4·2	4·1	4·7	4·3	4·0	10·6	9·3
$\frac{Ga \times 10^3}{Al+Fe^{3+}}$	0·2	0·3	0·2	0·1	0·2	0·1	0·3	0·1	0·1
$\frac{Ga \times 10^3}{Al}$	0·2	0·3	0·2	0·1	0·2	0·1	0·3	0·2	0·2
$\frac{K}{Cs \times 10^{-2}}$	12·7	9·3	13·1	13·2	6·9	9·3	8·6	3·6	4·1

List of samples

Sample no.	Rock type
	Red granites
1	Biotite granite
2	Porphyritic leucogranite
	Pink granites
3	Biotite granite
4	Porphyritic muscovite microcline granite
5	Porphyritic graphic leucogranite
	Buff granites
6	Biotite muscovite granite
7	Hornblende microcline perthite granite
8	Biotite microcline granite
9	Muscovite granite
10	Muscovite microcline granite
11	Brecciated muscovite granite
12	Microcline leucogranite
13	Porphyritic biotite granite
	Greyish white granites
14	Microcline hornblende biotite granite
15	Biotite granite
16	Biotite muscovite granite
17	Muscovite biotite microcline granite
18	Muscovite granite
19	Brecciated muscovite granite
20	Hornblende granite
21	Porphyritic biotite granite
22	Porphyritic perthite leucogranite
	White granites
23	Biotite granite
24	Biotite muscovite granite
25	Leucogranite
	Adamellites
26	Biotite adamellite
27	Biotite microcline adamellite
28	Biotite muscovite microcline adamellite
29	Hornblende muscovite adamellite
30	Muscovite adamellite
31	Muscovite microcline perthite adamellite
32	Hornblende muscovite perthite adamellite
33	Leucoadamellite
34	Perthite microcline leucoadamellite
35	Porphyritic biotite perthite microcline adamellite
36	Porphyritic hornblende adamellite
	Granodiorites
37	Biotite granodiorite
38	Hornblende muscovite granodiorite
39	Biotite hornblende granodiorite
40	Hornblende perthite granodiorite
41	Hornblende granodiorite
42	Porphyritic biotite granodiorite
43	Porphyritic hornblende granodiorite
	Quartz diorite
44	Hornblende biotite quartz diorite
45	Hornblende quartz diorite

جيوكيمائية الصخور الجرانيتية في منطقة
راس بارود بالصحراء الشرقية بمصر

عادل محمد رفعت
معهد التربية للمعلمين ، العديلية ،
الكويت

محمود لطفي كابش
المركز القومي للبحوث ، الدقي ،
القاهرة ، مصر

محمد عز الدين حلمي
كلية العلوم بجامعة عين شمس ،
القاهرة ، مصر

زينب محمد عبد الله
معهد التربية للمعلمات ، الشامية ،
الكويت

خلاصة

أمكن ـ في هذه الدراسة ـ القاء الضوء على كيفية تكون الصخور الكلس قلوية في رأس بارود ، وذلك من خلال دراسة توزيع العناصر النادرة فيها . وقد تم تحليل العناصر النادرة في ٤٥ عينة تشمل كل الانواع المختلفة للصخور المدروسة . ولقد دلت الدراسة على ان عناصر الباريوم والاسترانشيوم والفاناديوم والزركونيوم كانت مركزة في المراحل الاولى لتبلور الصهير ، بينما اتضح ان عناصر الرابيديوم والليثيوم والجاليوم كانت مركزة في المراحل المتأخرة من تبلور الصهير . لقد لوحظ ان هناك فرقا بسيطا في نسبة بوتاسيوم/رابيديوم للصخور الجرانيتية براس بارود ، كما لوحظ ايضا ان بعض صخور الجرانوديوريت تحوى نسبة منخفضة من بوتاسيوم/رابيديوم مما يدل على ان نسبة معدن البايوتيت في هذه الصخور مرتفعة ، ويمكن استنتاج ان عملية تهجين بين معادن مافية وصهير جرانيتي قد حدثت اثناء المراحل المتأخرة من تبلور الصهير ، وقد ادت عملية التهجين الى تكوين بعض صخور الجرانوديوريت ذات اللون الرمادي الداكن والتي تحوى نسبة مرتفعة من معدن البايوتيت .