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PETROCHEMISTRY AND PETROGENESIS OF SOME POST-TRAP ALKALINE GRANITE OF GABAL HUFASH, SURDUD AREA, YEMEN ARAB REPUBLIC

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ABSTRACT

The paper deals with the chemistry of the alkaline granites of Surdud area, Yemen Arab Republic. The chemical analyses of ten samples are presented for the first time. The chemical data are processed and utilized in the chemical evaluation of these granites applying several parameters. The examined granites are aegirine-riebeckite bearing and form a suite of post-trap granitic intrusions so widely distributed in Yemen.

INTRODUCTION

The present paper deals with the essential petrochemical characters of some post-trap granites of Surdud area, Yemen Arab Republic.

Broadly, post-trap granites are poorly represented among the basement rocks of Yemen.

Same as the crystalline basement rocks, the post-trap granites of Yemen are ill-defined and scarcely studied. GEUKENS' map of the Yemen Arab Republic [1966] represents, however, the only comprehensive work on the geology of Yemen Arab Republic. This map forms part of the geological map of the Arabian Peninsula published by the U. S. Geological Survey in 1972. Studies on the basement rocks of Yemen are almost lacking. However, recently the petrochemistry and petrogenesis of some Precambrian granitic rocks in Yemen have been undertaken by KABESH *et al.* [1979]. Moreover, the investigation of biotites of some Precambrian granitic rocks has been carried out by KABESH and ALY [1979].

The post-trap granites have been scarcely trated. However, the chemistry of arfvedsonites and riebeckites from post-trap alkali granites of Gabal Sabir, Taiz area, Yemen Arab Public has been recently studied. [REFAAT and KABESH, 1979].

According to GEUKENS, [1966], the post-trap granites defined as recent granites *(op.cit.)* protrude locally above the general topography carved in the volcanic trap series.

These granites form intrusive masses deforming the trap series on their flanks and thus they are dated as post-trap. GEUKENS further described some of these intrusions reaching 10 kms in length and few kms in width while others appear as letnicular dykes from 0.1—1.5 m wide.

Post-trap granites form very few and minor outcrops among the basement of Yemen. The general distribution of these granites is shown in *Fig. 1.*

The two major outcrops are represented by Gabal Sabir (Taiz area), and Gabal Hufash (Surdud area).

The present paper is intended to deal with the petrochemistry and petrogenesis of the post-trap alkaline granites of Gabal Hufash, Surdud area.

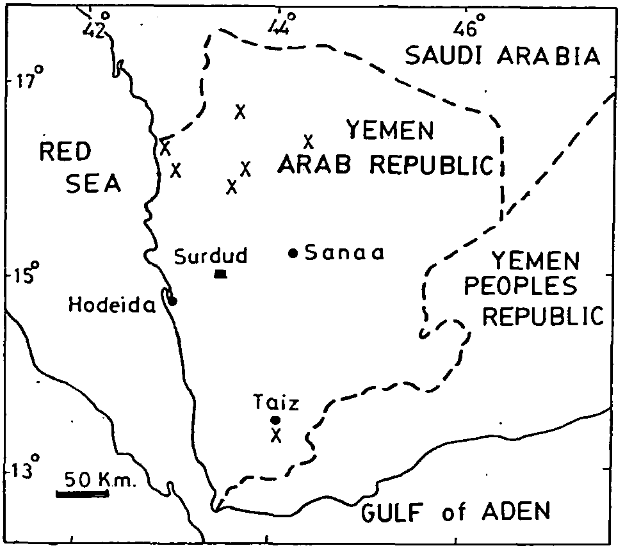

Fig. 1. Key map showing distribution of post trap granites in Yemen Arab Republic: ■ Examined area; X Other post trap granites

ANALYTICAL METHODS

The rock samples collected from Gabal Surdud area were selected for chemical analysis for major elements. SiO_2 was determined gravimetrically. Total iron oxides, P_2O_5, MnO and TiO_2 were determined colorimetrically. Al_2O_3, CaO and MgO were estimated by visual titration against standard EDTA solution. The value of FeO was obtained by titration against a standard solution of potassium permanganate and, by subtraction of FeO from total iron oxides, Fe_2O_3 was estimated. Na_2O and K_2O were determined by flame photometry.

PETROGRAPHY

Petrographic studies showed that the mineralogical composition of the Surdud granites comprises essentially quartz, orthoclase perthite, plagioclase, riebeckite, aegirine in addition to zircon, apatite, epidote and iron ores as accessories.

The quartz forms irregular clear grains occupying the interstices of the feldspars and mafics.

Plagioclase shows normal zoning with occasional alteration through sericitization and saussuritization.

Perthites are mostly due to the process of exsolution at high temperature and partly to replacement at relatively low temperature.

Alkali feldspars are represented by orthoclase which is largely kaolinized.

Riebeckite and aegirine form the dominant mafics in Surdud granites. The riebeckite is strongly pleochroic with x=green, y=greyish green and z=dark indigo blue.

Some samples are porphyritic in which megacrysts of plagioclase and alkali amphiboles are set in a groundmass of quartz and feldspars.

TABLE 1

Chemical data for the investigated granites

S.No.	1	2	3	4	5	6	7	8	9	10
SiO_2	71.05	72.53	71.06	71.45	70.88	71.26	72.15	70.64	71.92	70.78
Al_2O_3	11.55	11.65	11.75	11.05	12.00	11.55	11.75	12.11	11.22	11.94
Fe_2O_3	1.14	1.21	1.96	1.18	1.21	1.00	1.12	0.66	1.16	1.18
FeO	1.56	1.68	1.38	1.22	1.39	1.51	1.43	1.42	1.90	1.66
MnO	0.19	0.20	0.19	0.05	0.06	0.13	0.08	0.15	0.14	0.18
MgO	0.64	0.71	0.66	0.49	0.52	0.71	0.64	1.01	0.49	0.82
CaO	1.21	0.99	1.14	1.48	1.95	1.68	1.71	1.32	1.68	1.62
Na_2O	5.06	4.22	4.91	5.16	4.25	5.32	4.68	5.55	4.21	4.65
K_2O	5.32	5.03	5.21	4.22	4.97	4.72	4.94	5.38	4.86	5.08
TiO_2	0.39	0.33	0.41	0.68	0.41	0.37	0.33	0.40	0.60	0.51
P_2O_5	0.07	0.09	0.09	0.07	0.09	0.09	0.11	0.11	0.06	0.06
H_2O^-	0.32	0.41	0.22	0.50	0.38	0.38	0.28	0.39	0.40	0.35
H_2O^+	1.09	0.84	1.11	1.14	1.21	0.74	0.84	1.06	0.99	0.74
Total	99.59	99.88	100.08	99.19	99.92	99.46	100.11	100.20	99.63	99.57
Calculated alkalinity ratio	9.72	6.47	8.67	8.46	5.76	7.95	6.01	9.74	5.74	6.08
Agpaitic coefficient	1.22	1.06	1.17	1.26	1.11	1.20	1.11	1.24	1.09	1.10

PETROCHEMISTRY

The chemical characters of the granitic rocks under investigation have been reached through complete analysis of 10 selected samples, the data is presented in Table 1. The calculated Niggli-values and the CIPW Norms are given in Tables 2 and 3 respectively.

The data of the chemical analyses were plotted on histograms *(Fig. 2)* to illustrate their distribution. The plots show that the analyses are not strongly variable indicating the homogeneity of the rocks.

The relative abundance of K_2O+Na_2O, $FeO+Fe_2O_3$ and MgO are plotted on an AFM diagram *(Fig. 3)*. The diagram shows that these granites are enriched in alkalies and impoverished in magnesium and iron.

The plot of Mol Na_2O vs. Mol K_2O *(Fig. 4)* shows that the investigated granites are mostly potassic with rarely sodic tendencies according to RAGUIN's, [1965] suggestions.

The analyses have been plotted on the triangular diagram K_2O—Na_2O—CaO *(Fig. 5)*. The plot shows that the investigated granites lie near the mid point of K_2O-Na_2O line with some calcium present in minerals other than feldspars as indicated from the petrography.

The Niggli-value *fm* has been plotted *vs* the *al* value *(Fig. 6)* which indicate that the investigated granites are salic.

The *alk-al* plot is presented in *Fig. 7* which reveal that the investigated salic magma is peralkalic to relatively alkalic rich [BURRI, 1964]. WRIGHT [1969] has proposed a ratio given by

$$\frac{Al_2O_3+CaO+\text{total alkalies}}{Al_2O_3+CaO-\text{total alkalies}}$$

TABLE 2

Niggli-values for the investigated granites

S.No.	1	2	3	4	5	6	7	8	9	10
al	34.59	36.60	34.62	34.35	35.48	34.10	35.43	34.51	34.98	34.88
fm	16.65	18.89	18.87	14.14	14.54	15.95	15.85	16.04	17.51	18.10
c	6.59	5.60	6.11	8.36	10.48	9.02	9.38	6.84	9.52	8.60
alk	42.17	38.91	40.41	43.14	39.49	40.93	39.34	42.61	37.99	38.41
si	361.08	386.70	355.29	376.94	355.65	357.08	369.23	341.63	380.48	350.93
ti	1.49	1.32	1.50	2.70	1.55	1.39	1.27	1.45	2.39	1.90
p	0.15	0.20	0.19	0.16	0.19	0.19	0.24	0.23	0.13	0.13
h	23.90	22.23	22.18	28.86	26.61	18.72	19.12	23.39	24.53	18.03
mg	0.29	0.30	0.26	0.27	0.27	0.33	0.31	0.45	0.22	0.33
k	0.41	0.44	0.41	0.33	0.40	0.37	0.41	0.39	0.43	0.42
qz	115.15	137.98	111.03	130.74	109.72	113.84	123.59	95.48	137.57	107.87

TABLE 3

Norm values for the investigated granites

S.No.	1	2	3	4	5	6	7	8	9	10
ap	0.15	0.19	0.19	0.15	0.19	0.19	0.23	0.23	0.13	0.13
il	0.55	0.47	0.57	0.97	0.58	0.52	0.47	0.56	0.86	0.72
or	31.95	30.33	31.22	35.47	29.87	28.25	29.54	31.87	29.49	30.52
ab	32.14	34.57	33.83	36.15	36.76	35.62	35.38	34.41	33.41	35.75
na	3.00	—	1.19	3.47	0.97	2.77	0.91	3.98	0.38	0.76
ac	3.23	3.28	5.54	3.36	3.43	2.82	3.30	1.85	3.32	3.35
mt	—	0.06	—	—	—	—	—	20.78	—	—
ht	—	—	—	—	—	—	—	—	—	—
an	—	—	—	—	—	—	—	—	—	—
cor	—	—	—	—	—	—	—	—	—	—
wo	—	—	—	0.39	0.53	—	—	—	—	—
di	4.51	3.49	4.11	4.85	6.33	6.28	6.29	4.68	6.53	6.22
en	0.78	1.22	0.84	—	—	0.44	0.27	1.40	0.19	0.70
fs	0.96	1.50	0.86	—	—	0.46	0.28	0.94	0.33	0.67
q	25.92	24.88	23.74	26.45	22.62	23.69	24.57	20.78	26.62	22.44
or %	49.85	46.73	47.99	41.34	44.83	44.23	45.51	48.09	46.88	46.05
ab %	50.15	53.27	52.01	58.66	55.17	55.77	54.49	51.91	53.12	53.95
vn %	—	—	—	—	—	—	—	—	—	—
D.I.	90.01	89.78	88.79	88.07	89.25	87.56	89.49	87.06	89.52	88.71

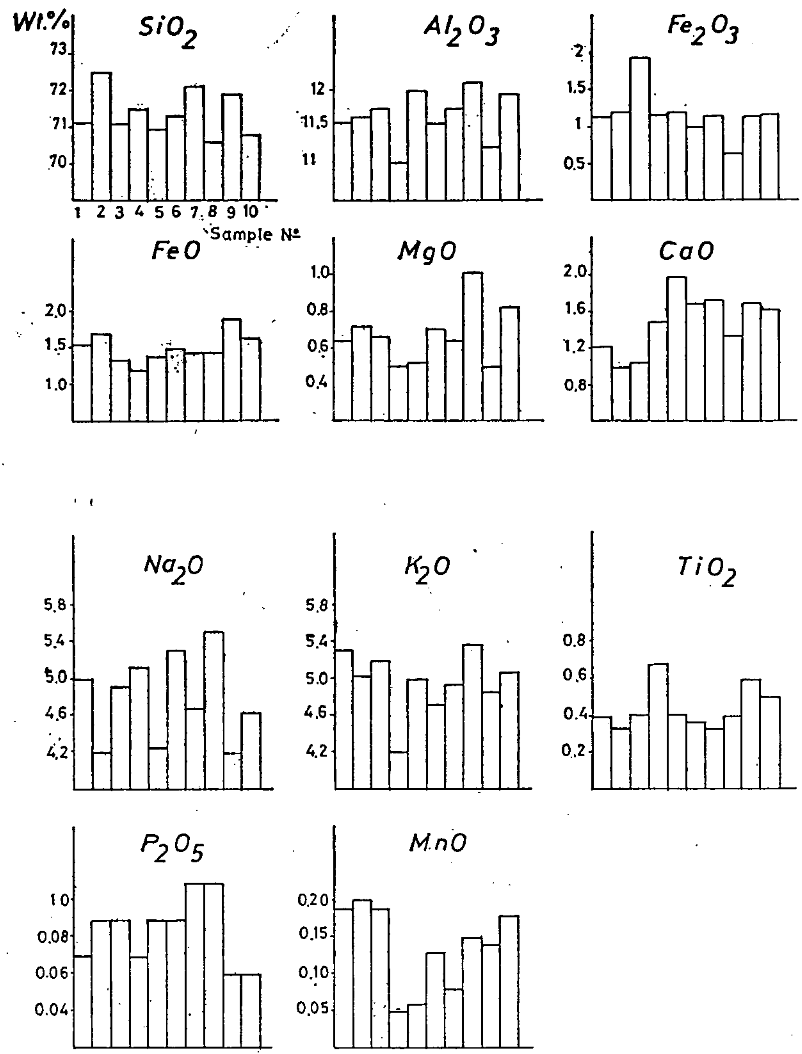

Fig. 2. Histograms showing distribution of the major oxides in the granites investigated

(all in weight percent) as a parameter for the alkalinity ratio. If silica exceeds 50% and K_2O/Na_2O is $>1<2.5$, 2 Na_2O is used in place of total alkalies. In the present work $K_2O:Na_2O$ is not always 1 and so the alkalinity ratio is calculated as given above. The ratio has been tested on some well documented igneous suites in the form of variation diagram by plotting it versus SiO_2 on semilog scale.

The alkalinity ratios for the investigated granite samples have been calculated (Table 1), and plotted against silica *(Fig. 8)*. The diagram indicates the alkaline to peralkaline nature of the investigated granites. The alkalinity ratio ranges from 5.74 to 9.72.

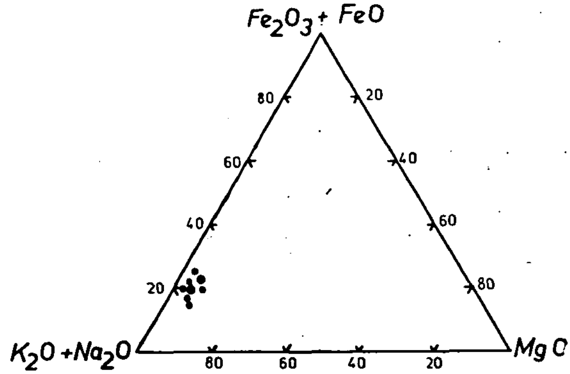

Fig. 3. AFM diagram for the investigated granites

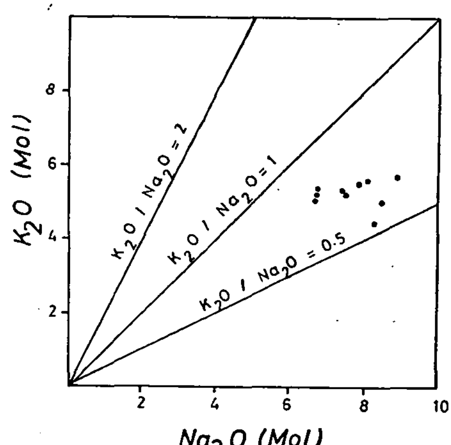

Fig. 4. Mol Na_2O *vs* Mol K_2O for the investigated granites

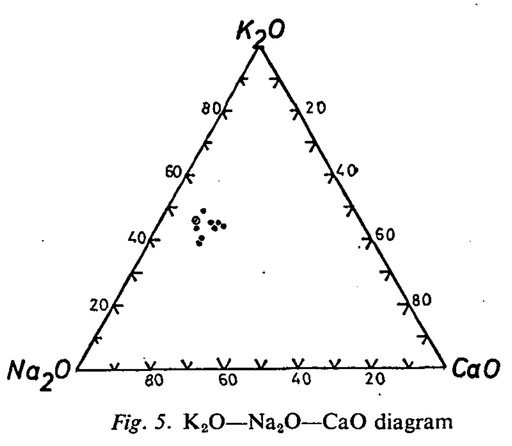

Fig. 5. K_2O—Na_2O—CaO diagram

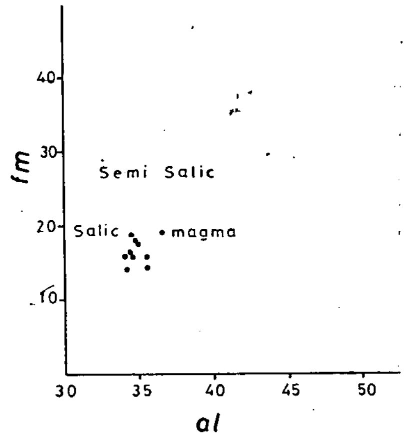

Fig. 6. fm vs al diagram of NIGGLI

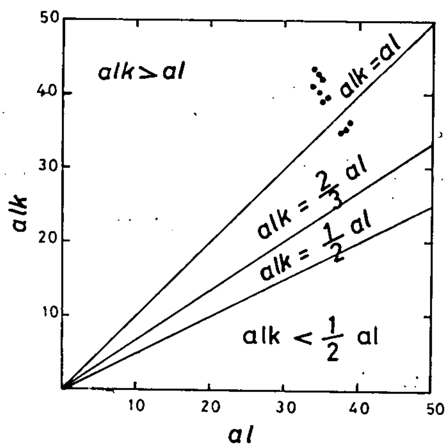

Fig. 7. alk—al diagram of NIGGLI. Classification principles of magmas after BURRI [1964]:

alk > *al*	peralkalic
alk > $\frac{2}{3}$*al*	relatively alkalic rich
alk > $\frac{1}{2}$*al*	intermediate alkali
alk < $\frac{1}{2}$*al*	relatively alkali poor

The peralkalinity index, the agpaitic coefficient from Zavaritski-parameters (*c.f.* BAILEY and MACDONALD, 1970) is plotted against SiO_2 to illustrate the peralkalinity nature of the post-trap granites. Accordingly the studied granites may be classified into two main groups: the agpaitic and the miaskitic types with agpaitic coefficient more or less than 1 respectively. It is clear that nearly all the studied samples are classified as an agpaitic type i.e. Mol ratio of Na_2O+K_2O/Al_2O_3 exceeds unity (*Fig. 9*), and the excess of the strong bases has to combine with trivalent ions other than Al (e.g. Fe^{+++}) in order to form minerals like aegirine or riebeckite. RAGUIN [1965] stated that amongst the alkaline granites, the hyperalkaline granites contain less Al_2O_3 molecules than (Na_2O+K_2O) molecules, which results in the appearance of alkaline amphiboles or pyroxenes in the rock.

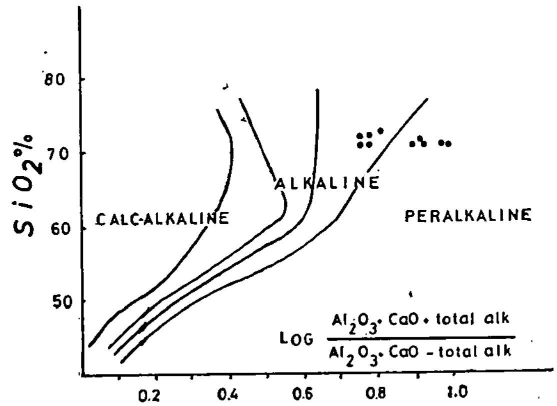

Fig. 8. Plots of calculated alkalinity rations of the investigated granites on the alkalinity variation diagram of WRIGHT [1969]

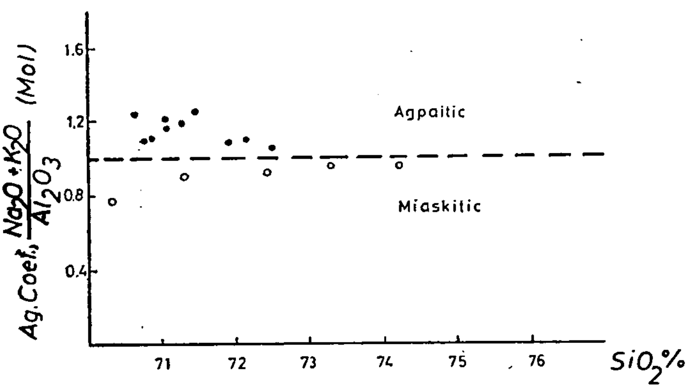

Fig. 9. The agpaitic index — silica diagram:
- Investigated granites
- o Precambrian granites of Yemen

The previous observation has been confirmed by thin section study of the examined granites.

For the sake of comparison, one sample from each of five previously investigated Precambrian granitic rocks of Yemen are included in the plot *(Fig. 9)* which show the miaskitic nature of these granitic rocks.

The *T*-value is suggested by RITTMANN [1967] and GOTTINI [1968] as a solid indicator for the distribution of simatic and sialic material, where *T* is given by:

$$T = \frac{Al_2O_3 - Na_2O}{TiO_2}$$

The plot *T* value *vs.* SiO_2 *(Fig. 10)* show that nearly all the investigated granites fall in the sialic field.

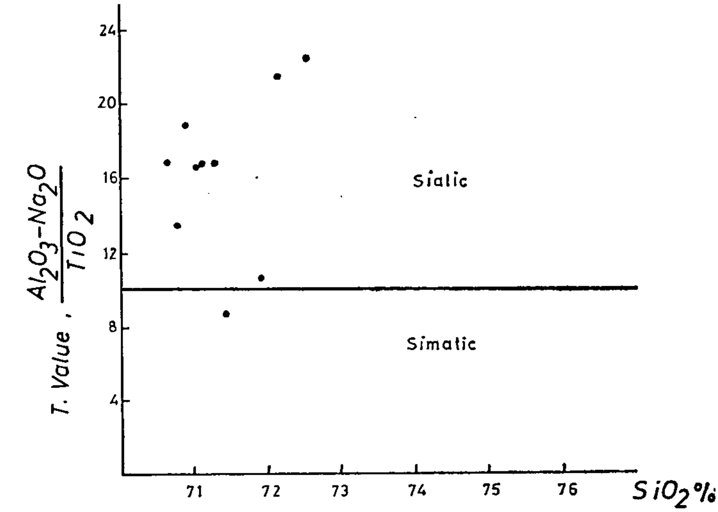

Fig. 10. T value *vs* SiO_2 for the investigated granites

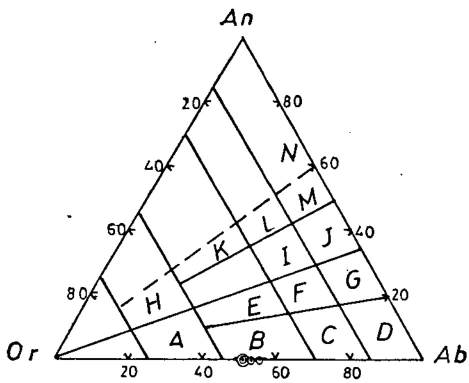

Fig. 11. Triangular diagram for *An, Ab,* and *Or* normative ratio in the investigated granites [HIETANEN, 1963].

CHEMICAL CALSSIFICATION

HIETANEN, [1963] suggested a scheme of chemical classification based on the relative abundance of the feldspars *(Fig. 11)* where *An, Or* and *Ab* are plotted in a trilinear relation.

According to this diagram the investigated granites fall within the field of granite with *Or—Ab* feldspars and *An* is almost absent.

PETROGENESIS

When plotting the ionic weight percentages of Ca, Na and K of the granites in a trilinear diagram including the suggested field for magmatic rocks [RAJU and RAO, 1974] *(Fig. 12),* nearly all the analyses fall in the field representing granites of magmatic origin.

The normative quartz, orthoclase and albite proportions of the granitic rocks (Table 3) are plotted and the results compared with the experimental data of TUTTLE and BOWEN, [1958] *(Fig. 13)*. It is observed from *Fig. 13* that all the investigated granites have their compositions close to minimum melting point at high water vapour pressures in the $NaAlSi_3O_8-KalSi_3O_8-SiO_2-H_2O$ system.

The normative orthoclase, albite and anorthite proportions of the investigated granites (Table 3) have been plotted in a ternary diagram *(Fig. 14)*. All the plots fall around the plagioclase field, mostly close to the isobaric univariant curve, indicating the crystalliquid equilibrium was the dominant mechanism involved in the genesis of these granites [JAMES and HAMILTON, 1972].

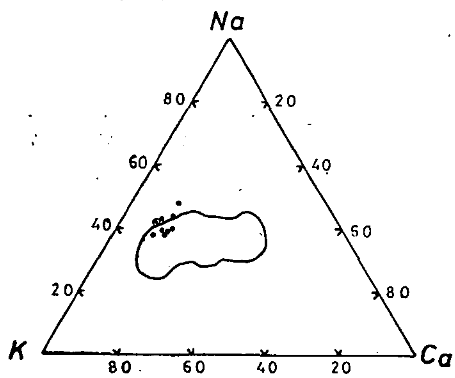

Fig. 12. Plots of Ca, Na and K proportions of the granites. The field representing granitic rocks of magmatic origin suggested by RAJU and RAO [1974] is included

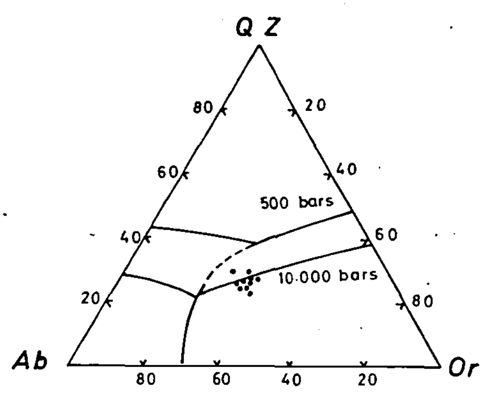

Fig. 13. Normative albite — orthoclase — quartz of the investigated granites, plotted in the system $NaAlSi_3O_8$—$KAlSi_3O_8$—SiO_2—H_2O. Field boundaries at 0.5 and 10 Kbars are shown. Dotted line represents the trace of the isobaric minimum or eutectic point at intermediate water pressures [after LUTH *et al.*, 1964]

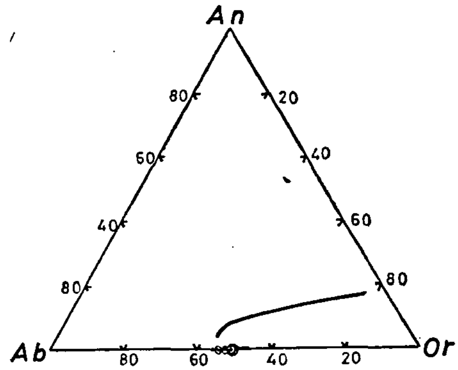

Fig. 14. Normative *Or—Ab—An* proportions for the investigated granites. The solid line represents the two feldspar boundary curve for the quartz saturated ternary feldspar system at 100 bars water pressure [JAMES and HAMILTON, 1969]

CONCLUSION

The alkaline granites of Gabal Hufash-Surdud area Yemen Arab Republic are chemically characterized. They belong to the post-trap lacolithic intrusions widely distributed in Yemen.

They are alkaline to peralkaline aegirine-riebeckite bearing and represent sialic material of magmatic origin. It is argued that crystallization proceeded under relatively high pressure conditions.

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