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PETROCHEMICAL INVESTIGATION ON EL EHENA PLUTON, WESTERN AL-QUWAYIYAH REGION, SAUDI ARABIA

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ABSTRACT

The El Ehena area represents a small circular granite intrusion intruded in a metasedimentary sequence. The rocks are coarse grained with hypidomorphic texture and consist mainly of quartz, K-feldspar mostly perthitic and sodic plagioclase. They are identified as syenogranite and monzogranite. Geochemical characteristics of the granitic rocks document alkaline affinity. They are peraluminous in nature.

All available data suggest that El Ehena pluton belongs to I type granite. The most likely model for the evolution of the granite is from volcanic arc magma, and represents transitional tectonic environment formed during the initial stage of back-arc spreading near continental area.

INTRODUCTION

The granitic rocks of Saudi Arabia range in size from batholiths to small intrusive plugs and are scattered almost all over the Arabian Shield covering about 40% of its total land area. According to Greenwood *et al.* (1976) and Delfour (1977) the granitic masses are divided into two kinds; an early island arc orogenic phase considered to be early Proterozoic, and a Postorogenic phase, late Proterozoic. The former is estimated to be 1165-680 Ma, while the latter is Pan African; 670-500 Ma.

The area of this study is located on Riyadh-Mekkah road (185 km west of Riyadh), in the western part of Al Quwayiyah region (Longitude 45 E, Latitude 24 N) at the easternmost part of the Arabian Shield, where the Precambrian basement is overlain unconformably by the limestone of the Permian Khuff Formation which represents an impressive morphologic feature.

Nebert (1970) divided the area into two major geological blocks. He produced a photogeological map based on all possible geological information obtained from aerial photographs at the scale of 1:60,000 combined with field study of several traverses (Fig. 1). On both sides of the North-South fault called Marjan line, the granitic rocks are present (Synorogenic and Postorogenic). The first always occupies the core of the anticlines in the three fold complex of El Mizil, El Jisala and Northern Khnaiguiyah valley, while the second composed of four scattered plutons of various shapes and sizes (Aba Al Rehi, Al Mizil, Al Jafara, and Northern Plutons) to the east of the Marjan fault line. The fifth pluton is the only granitic body in the western side of the fault line is called El Ehena Pluton named after Jabal El Ehena which is located 7 Km away from the Marjan line. It is intruded in Precambrian metasediments (Abt schist) which consist of chlorite and sericite schist affected by thermal metamorphism along the sharp contact line with the pluton. The landforms on this side of the fault attain only insignificant elevation, while on the eastern block the relief gives prominence to high hills or even mountains, also the granitic masses on this side were more or less flattened by severe denudation.

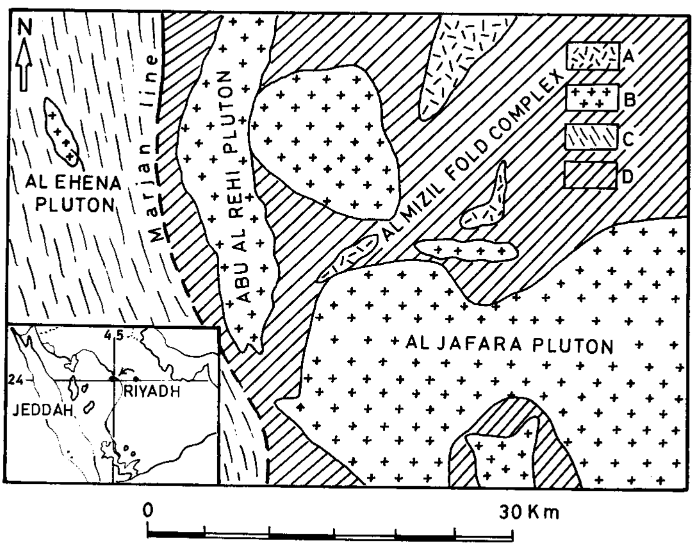

Fig. 1: Sketch map of western Al Quwayiyah region (modified after that in Nebert 1970) (A) Synorogenic granite; (B) Postorogenic granite; (C) Abt schist; (D) Halaban Formation.

The first extensive and definitive work on the granitic rocks of El Ehena was carried out by Nebert (1970) who described the geology of the western Al Quwayiyah region including the area of the study. Nebert (op. cit) considered El Ehena pluton as post orogenic granite and represent almost a stock, or, considering its circular ground plan a boss. He considered it as composed of a reddish granite with equigranular texture. Southwest of the area described by Nebert (op. cit), a number of more detailed studies bearing on the tectonic set up of the rocks and its relation to plate tectonic models have been made (Al Shanti & Gass 1983, Stoeser & Camp 1985). To the best knowledge of the author, no petrochemical investigations on El Ehena pluton have hitherto been carried out. The main purpose of this study is to present an attempt to clarify the petrochemical characteristics and tectonic setting of the granitic rocks in the area.

GEOLOGY AND PETROGRAPHY

The El Ehena granite outcrops in the form of a truncated cone about 15 Km^2 in area and 750 m in height. In plan, the main part of the mass is circular, measuring 2.5 Km in diameter, with well defined boundaries. Field evidences indicate that the granite was intruded at shallow crustal level. Different varieties of late proterozoic schists surround the entire mass. The country rocks are usually thermally metamorphosed over a distance of about 1 Km away from the contact, within the aureole the schists were metamorphosed to pelitic hornfels.

The petrographic study of several thin sections show that El Ehena pluton is remarkably homogeneous in minerology and texture, with variations mainly resulting from alteration and deformation of the periphery. They are generally coarse grained leucogranites. The granites of El Ehena are considered epizonal in the sense of Agar (1986).

The typical granitic rock is pink, with some mottling caused by irregular distribution of biotite. The pink colour of the granite is attributed to the predominating potash feldspar. It generally consists of about 30-36% alkali feldspar, 24-32% quartz, 20-35% sodic plagioclase, and 8% mafic minerals, mostly biotite.

Quartz occurs commonly as large anhedral crystals with partly granulated and sutured edges (Fig 2). Minute crystals of quartz occupy the interstitial spaces between feldspars.

The K-feldspar is found as interstitial microcline and perthite, patchy perthite (Fig. 3 a+b) giving rise to hypersolvous texture.

Plagioclase is typically euhedral oligoclase, occasionally rimmed by perthite. Plagioclase in some varieties is characteristically zoned. Fine scale oscillatory zoning is superimposed on the characteristic normal zoning (Fig. 4). Some plagioclase crystals show signs of deformation effects (Fig. 5). Most of the plagioclase crystals exhibit lamellar, and albite carlsbad twinning.

Biotite is the most abundant ferromagnesian mineral, phenocrysts of brown biotite partially chloritised are present.

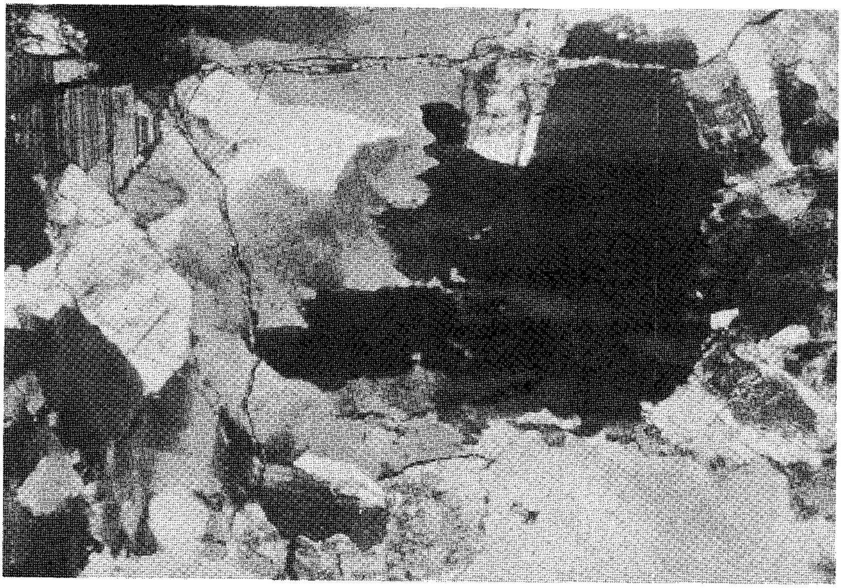

Fig. 2: El Ehena granite showing large anhedral crystals of quartz with partly granulated and sutured edges.

Hornblende is rare and occur only in some varieties, it is strongly pleochroic from yellow to dark green. They have ragged edges and are occasionally sieved by feldspar and quartz granules.

Accessory minerals are zircon, titanite and apatite. Alteration products include secondary chlorite, zoisite, sericite, and hematite.

Texturally, the granites consist of non porphyritic phase, medium to coarse grained and hypidiomorphic.

The modal analysis (Table 1, Fig. 6) classify the rocks as syenogranite and monzogranite according to the classification of Streckeisen (1976).

CHEMISTRY

Whole rock major and selected trace elements for 17 samples from the granitic rocks are given in table (2) as part of a reconnaissance geochemical study of the granite rocks in the western Al Quwayiyah region. The analyses have been done at the Institute of Minerology, Munster University, West Germany, using X-Ray fluorescence techniques.

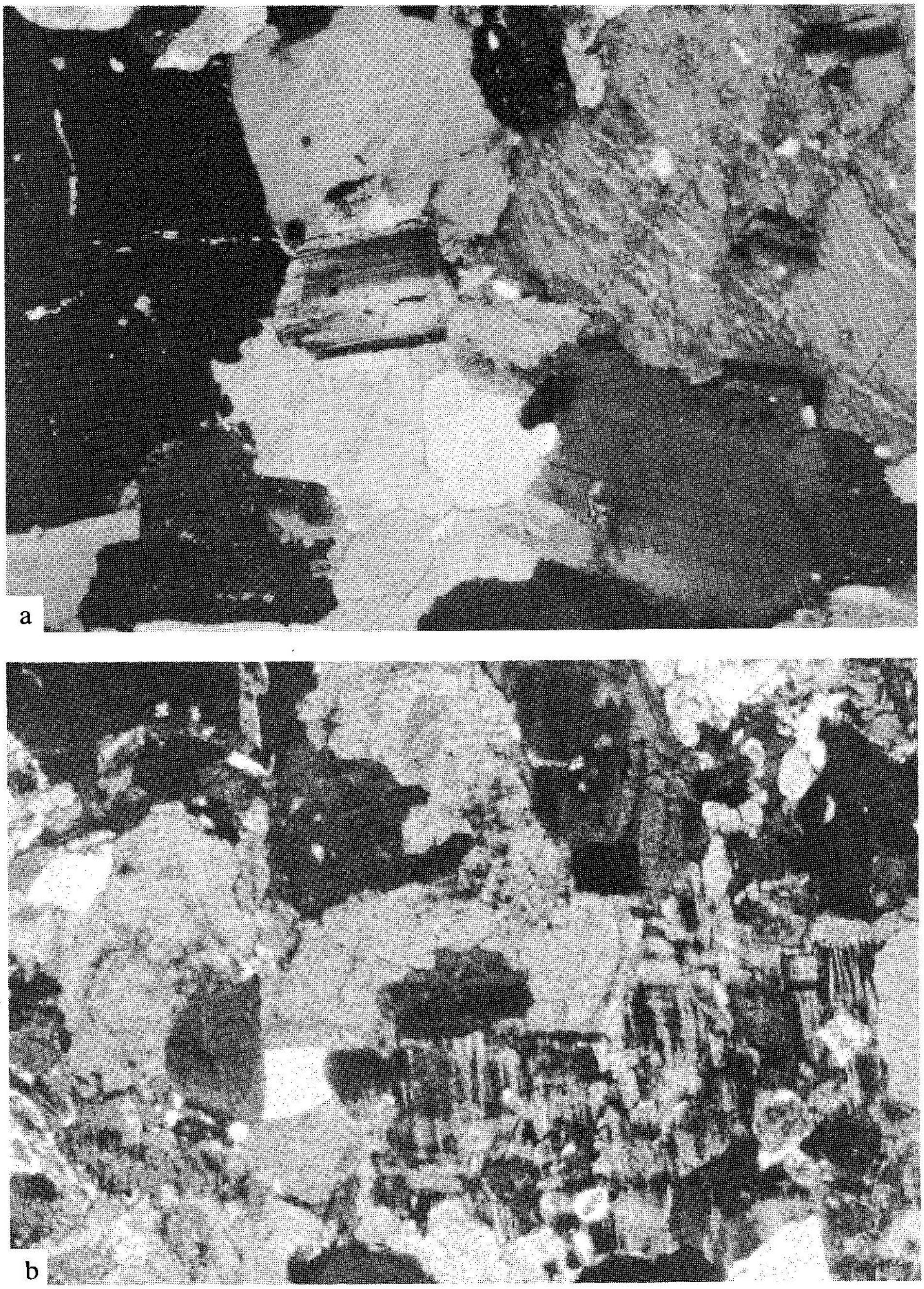

Fig. 3 (a+b): El Ehena granite showing K-feldspar as interstital microcline and perthite, patchy perthite giving rise to hypersolvous texture.

Fig. 4: Plagioclase crystal showing normal zoning been superimposed by fine scale oscillatory zoning.

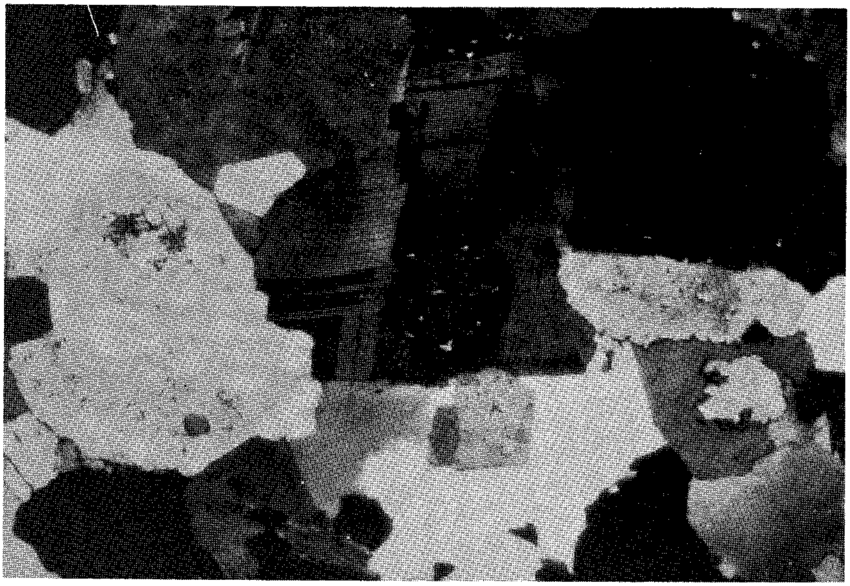

Fig. 5: Plagioclase crystals show sign of deformation effects and also exhibit lamellar and carlsbad twinning.

Table 1
Modal composition of the granitic rocks at El Ehena area

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Quartz	24.0	25.0	27.0	26.0	26.0	26.0	27.0	26.0	28.0	29.0	26.0	26.0	27.0	28.0	31.0	30.0	32.0
Perthite	36.0	38.0	28.0	41.0	28.0	27.0	29.0	32.0	41.0	41.0	29.0	38.0	35.0	36.0	28.0	29.0	34.0
Plagioclase	29.0	25.0	31.0	20.0	34.0	35.0	32.0	30.0	20.0	21.0	35.0	26.0	29.0	25.0	32.0	33.0	24.0
Biotite	6.6	8.3	5.3	8.0	7.2	7.5	6.7	8.0	6.5	6.0	8.5	7.0	7.0	8.0	6.5	4.0	7.0
Opaques	1.6	1.3	1.8	1.8	1.5	1.5	2.1	1.3	4.6	1.3	0.6	1.4	1.0	1.0	1.0	1.5	1.0
Alteration	1.7	1.5	1.8	1.8	1.4	1.5	1.9	1.3	1.7	1.0	0.4	0.6	0.5	1.5	0.5	1.0	1.2
Accessories	1.1	0.9	1.2	1.4	1.9	1.5	1.3	1.4	1.2	0.7	0.5	1.0	0.5	0.5	1.0	1.5	0.8

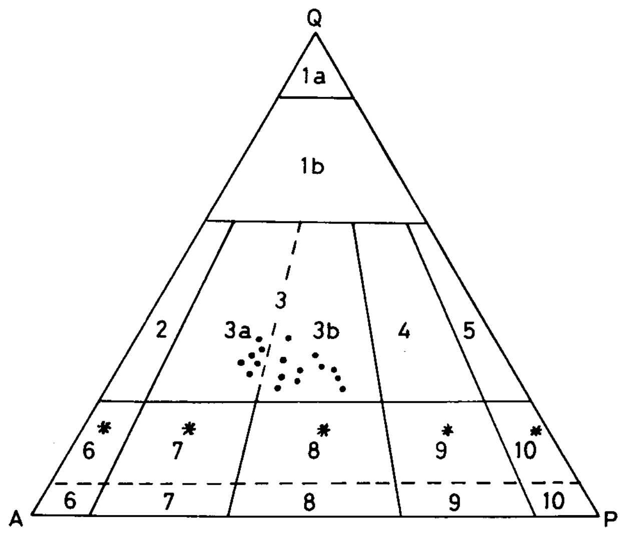

Fig. 6: El Ehena plotted on a modal QAP diagram (After Streckeisen, 1976).

1a - Quartzolite.
1b - Quartz rich granitoids.
2 - Alkali feldspar granite.
3 - Granite.
3a - Syanogranite.
3b - Monzogranite.
4 - Granodiorite.
5 - Tonalite.
6* - Alkali feldspar quartz syanite.
7* - Quartz syanite.
8* - Quartz monzonite.
9* - Quartz monzodiorite.
10* - Quartz diorite.
6 - Alkali feldspar syanite.
7 - Syanite.
8 Monzonite.
9 - Monzodiorite, Monzogabbro.
10 - Diorite, Gabbro.

Table 2
Major and trace elements analysis of El Ehena granitic rocks

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SiO_2	68.18	69.79	70.00	70.07	70.26	70.27	70.50	70.60	70.85	71.39	71.56	72.27	72.53	73.25	73.93	74.79	75.18
Al_2O_3	13.36	13.80	12.39	14.32	13.88	14.16	13.70	14.13	13.87	13.92	13.90	13.44	13.24	13.51	12.94	12.80	12.82
TiO_2	0.24	0.26	0.17	0.24	0.24	0.25	0.25	0.23	0.23	0.24	0.22	0.09	0.12	0.09	0.13	0.04	0.04
Fe_{O3}	2.44	2.60	1.84	2.32	2.34	2.42	2.43	2.19	2.12	2.23	2.34	1.40	1.36	1.61	1.52	0.76	0.72
MnO	0.07	0.06	0.04	0.05	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.03	0.03	0.01	0.01
MgO	0.55	0.62	0.38	0.49	0.71	0.65	0.63	0.51	0.48	0.49	0.51	0.20	0.20	0.04	0.35	0.06	–
CaO	1.92	2.09	1.27	2.00	1.00	1.88	1.80	1.95	1.84	1.46	1.80	1.01	1.10	0.96	0.98	0.69	0.72
Na_2O	4.62	4.81	4.14	4.47	4.44	4.65	4.55	4.98	4.47	4.48	4.23	5.00	4.51	4.53	4.27	3.87	4.14
K_2O	3.34	3.34	4.04	4.13	4.22	3.65	3.71	2.98	3.92	3.93	3.81	4.31	4.55	4.76	4.39	5.19	5.01
P_2O_5	0.08	0.08	0.05	0.08	0.24	0.08	0.07	0.08	0.08	0.08	0.08	0.04	0.06	0.02	0.05	0.03	0.02
Ba	498.00	493.00	512.00	683.00	612.50	529.00	446.00	386.00	610.00	578.00	583.00	264.00	276.00	99.00	249.00	103.00	54.00
Cr	20.00	21.00	21.00	14.00	21.00	16.00	20.00	15.00	14.00	25.00	18.00	21.00	23.00	17.00	18.00	17.00	17.00
Cu	5.00	12.00	18.00	8.00	11.00	11.00	8.00	8.00	5.00	20.00	5.00	5.00	5.00	5.00	7.00	107.00	49.00
Ga	21.00	20.00	15.00	17.00	19.00	19.00	19.00	22.00	16.00	17.00	18.00	27.00	24.00	29.00	16.00	14.00	14.00
Nb	15.00	14.00	9.00	10.00	13.00	10.00	14.00	16.00	10.00	12.00	14.00	16.00	36.00	15.00	10.00	10.00	6.00
Pb	16.00	17.00	12.00	13.00	14.00	14.00	16.00	16.00	16.00	17.00	12.00	28.00	24.00	28.00	17.00	31.00	16.00
Rb	226.00	169.00	127.00	151.00	211.00	163.00	180.00	203.00	179.00	178.00	148.00	389.00	327.00	311.00	158.00	164.00	170.00
Sc	5.00	6.00	3.00	5.00	4.00	5.00	6.00	6.00	5.00	4.00	5.00	3.00	3.00	5.00	3.00	3.00	3.00
Sr	167.00	240.00	178.00	182.00	294.00	200.00	172.00	166.00	175.00	166.00	176.00	65.00	82.00	38.00	155.00	79.00	60.00
V	33.00	36.00	21.00	29.00	32.00	32.00	33.00	28.00	27.00	26.00	29.00	14.00	14.00	11.00	20.00	11.00	11.00
Y	51.00	56.00	28.00	42.00	52.00	44.00	41.00	75.00	33.00	44.00	46.00	99.00	125.00	233.00	51.00	36.00	33.00
Zn	70.00	53.00	30.00	41.00	53.00	52.00	45.00	39.00	46.00	38.00	40.00	37.00	30.00	27.00	21.00	117.00	13.00
Zr	153.00	159.00	124.00	155.00	160.00	156.00	154.00	147.00	165.00	169.00	153.00	107.00	164.00	155.00	120.00	64.00	67.00

C.I.P.W. norms are given in table (3). The results are displayed on SiO_2 variation diagrams (Fig. 7). The rocks have a narrow range in SiO_2 content, they range between 68%-75% SiO_2. The major oxides Al_2O_3, MgO, CaO, TiO_2, decrease with increasing silica, while Na_2O and K_2O have positive relation.

The most striking features of the chemical data are the small variation in composition, and the consistently high SiO_2. The majority of the analysed samples have higher Na_2O than K_2O content. They contain less than 15% Al_2O_3, low Na_2O/K_2O ratio. They contain low Nb content 16-9 PPm (Fig. 8), indicating volcanic arc trend.

They display alkaline affinity on AFM diagram (Irvine & Baragar 1971), and show a trend approximately parallel to the AF side (Fig. 9) on the alkalinity variation diagram of Wright 1969, (Fig. 10), they also plot in the alkaline field.

Most of the granite samples are characterised by values more than 1.5 when plotted on A/CNK molar ratio indicating peraluminous nature (Fig. 11). On the ACF

Table 3
C.U.P.W. norm calculations for El Ehena granitic rocks.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Q	24.52	24.61	27.91	24.01	25.36	24.89	25.79	25.91	25.95	26.77	28.16	25.08	26.98	26.90	30.12	30.99	30.57
Or	19.73	19.73	23.87	24.40	24.93	21.56	21.92	17.60	23.16	23.22	22.51	25.46	26.88	28.12	25.93	30.66	29.60
Ab	39.08	40.69	35.02	37.81	37.56	39.33	38.49	42.13	37.81	37.90	35.76	42.29	38.15	38.32	36.12	32.74	35.02
An	5.86	6.21	3.30	6.82	4.37	6.99	6.01	7.40	6.21	6.27	7.69	1.42	2.45	2.46	3.18	2.23	6.82
Di	2.45	2.83	2.04	2.16	—	1.41	1.92	1.36	1.86	0.35	0.55	1.07	1.05	0.97	0.46	—	2.16
Hy	0.23	0.23	—	0.22	1.77	0.96	0.86	0.64	0.33	1.06	1.01	—	0.01	—	0.66	0.45	0.22
Mt	1.79	2.15	0.19	1.34	1.76	1.63	1.66	0.98	0.75	1.05	1.52	—	—	—	—	—	1.34
Hm	0.51	0.28	1.54	0.82	0.53	0.63	0.60	1.06	1.21	1.02	0.67	1.59	1.62	1.59	1.63	1.54	0.82
Il	0.46	0.49	0.32	0.46	0.46	0.47	0.47	0.44	0.44	0.46	0.42	—	—	0.11	—	—	0.46
Tn	—	—	—	—	—	—	—	—	—	—	—	0.60	0.40	0.08	0.54	0.70	—
Wo	—	—	0.02	—	—	—	—	—	—	—	—	0.46	—	0.33	—	—	—
Ap	0.19	0.19	0.12	0.12	0.21	0.19	0.16	0.19	0.19	0.19	0.19	0.09	0.14	0.05	0.12	0.07	0.12
C	—	—	—	—	0.41	—	—	—	—	—	—	—	—	—	—	—	—
Ru	—	—	—	—	—	—	—	—	0.61	—	—	—	—	—	—	0.61	—

diagram (Fig. 12) which differentiate between I and S type granite (Chappel and White, 1974), the samples show an accumulation clot in the I type granite field.

When plotted on normative Or, Ab, An diagram (Fig. 13) El Ehena granite samples are close to the Or − Ab side. They show a typical syenogranite and monzogranite according to the classification of Streckeisen (1976).

TECTONIC SETTING

Pearce *et al.*, (1984) have proposed several trace elements discrimination diagrams to illustrate the tectonic set up of granitic rocks. Using the Rb−(Y+Nb) discrimination diagrams (Fig. 14), El Ehena granites fall in the upper corner of the volcanic arc granite field (VAG), with the exception of three samples lying in the field of within plate granite (WPG). The Nb−SiO_2 diagram (Pearce and Gale, 1977), for El Ehena granite (Fig. 15) shows that the majority of samples fall in the field of volcanic arc magmas, while only four samples lie in overlap area between volcanic arc and within plate magmas. Moreover, using the diagram of Pearce and Norry, (1979), El Ehena granite fall in the field of volcanic arc (Fig. 16).

In the lights of the present study, El Ehena granite clearly shows mainly volcanic arc magma but near within plate granite boundaries, and their origin must be transitional tectonic environment. Bruhn *et al.*, (1978), Saunders *et al.*, (1979), and Weaver *et al.*, (1979), attributed these transitional settings to the occurrence of

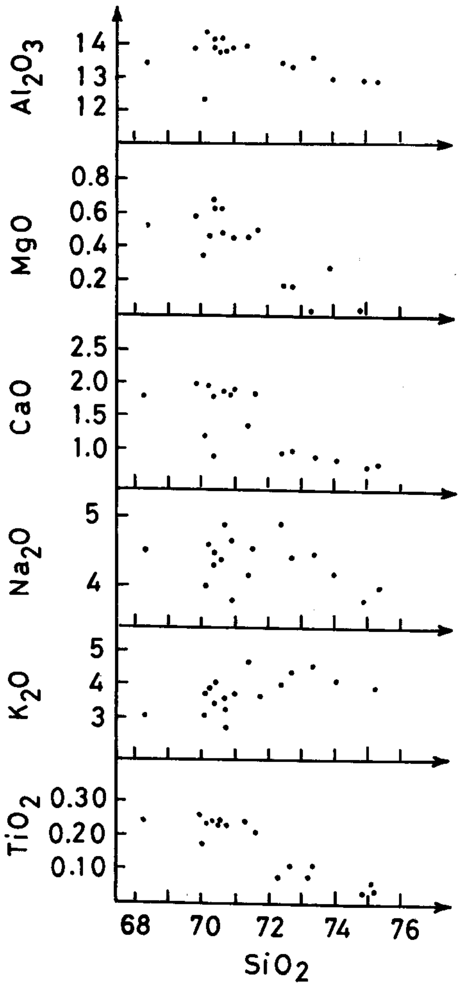

Fig. 7

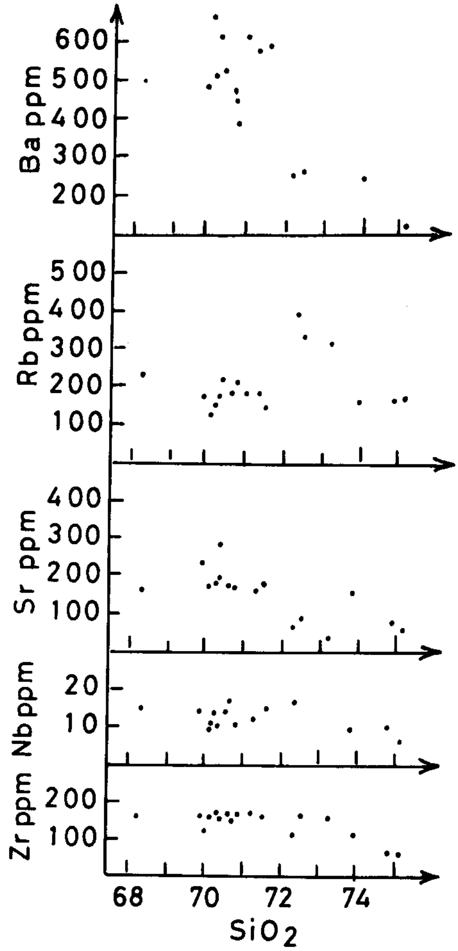

Fig. 8

Fig. 7: SiO_2 versus major elements variation diagram.

Fig. 8: Sio_2 versus trace elements variation diagram.

volcanic arc adjacent to the continental areas during the initial stages of back-arc spreading or rifting. This is in accordance with the microplate accretion model of Stoeser and Camp, (1985), who divided the Arabian Shield into five microplates separated by suture lines, the three Western plates considered to be of oceanic affinity, while the other two Eastern plates exhibit continental affinity with transitional stage.

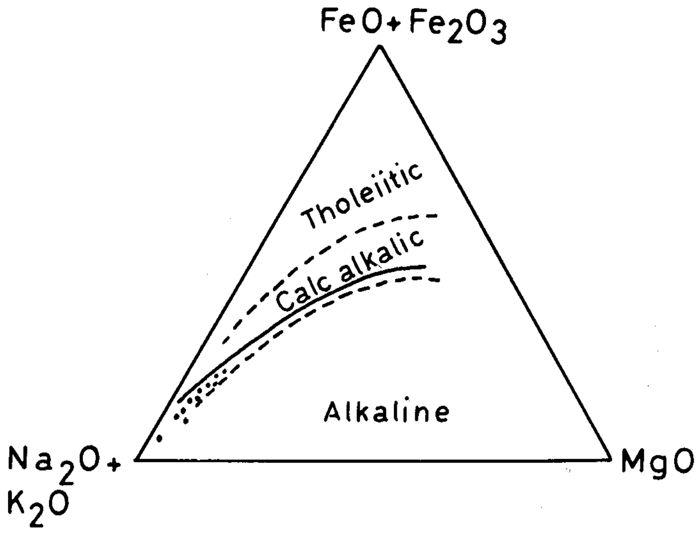

Fig. 9: AFM variation diagram for the examined granitic rocks.

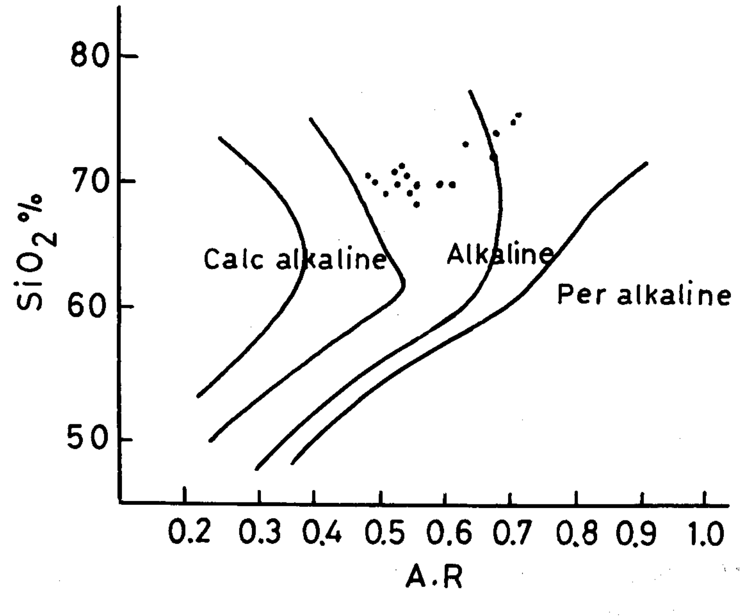

Fig. 10: Plot of the granites from El Ehena area on the alkalinity variation diagram of Wright (1969).

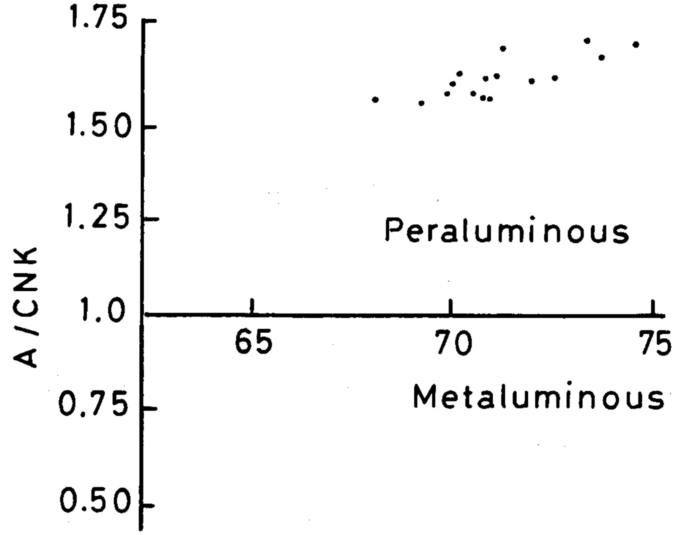

Fig. 11: A/CNK versus silica diagram.

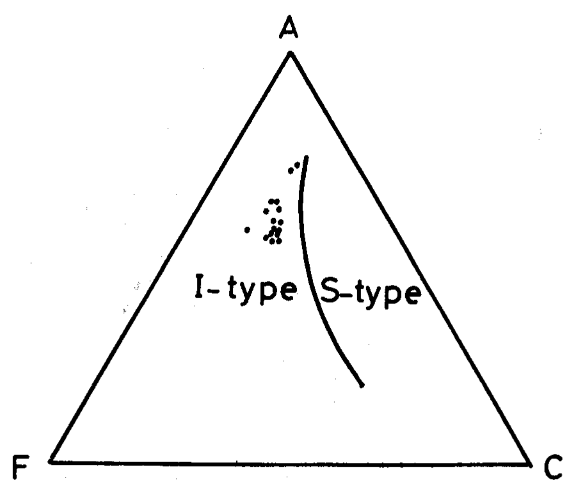

Fig 12: ACF diagram (molar ratio, A:$Al_2O_3-Na_2O-K_2O$, C:CaO, F:FeO + MgO for the examined granite.

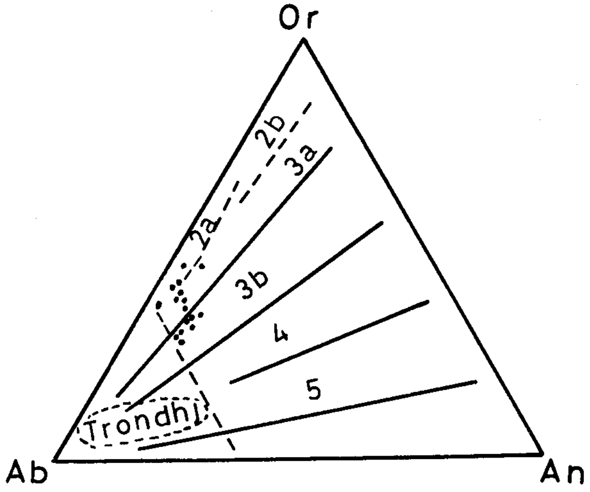

Fig. 13: Classification of Streckeisen (1976).

2a- Alkali granite. 2b- Alkali feldspar granite.
3a- Syenogranite. 3b- Monzogranite.
4 - Granodiorite. 5 - Tonalite.

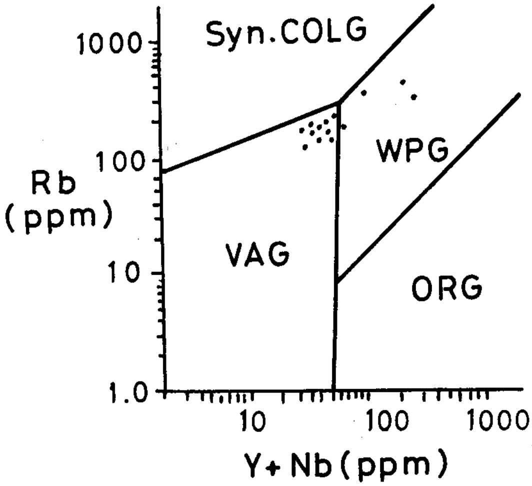

Fig. 14: Rb versus Y + Nb (ppm) for El Ehena granite. (WPG) Within plate granite, (ORG) Ocean ridge granite, (Syn. COLG) Syncollision granite, (VAG) Volcanic arc granite diagram. (after Pearce *et al.*, 1984).

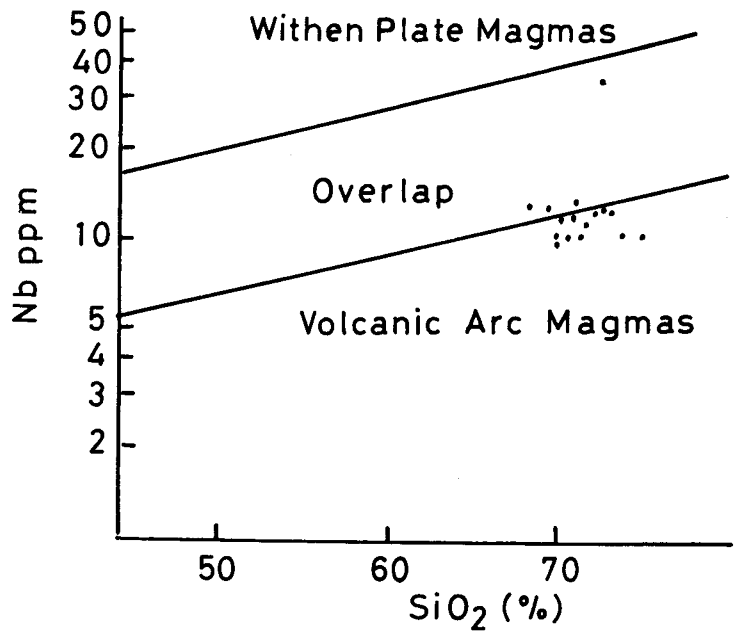

Fig. 15: Nb$-SiO_2$ diagram for the El Ehena granite. The dividing lines are after Pearce and Gale (1977) and indicate the overlap between volcanic arc magmas and within plate magmas.

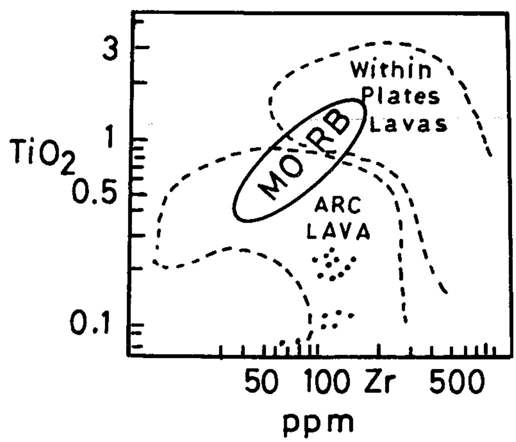

Fig. 16: TiO_2 versus Zr variation diagram for El Ehena granite diagram (after Pearce and Norry, 1979).

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دراسة بتروكيمائية على متداخل العهن ، غرب منطقة القويعية المملكة العربية السعودية

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الكلمات الدالة : جرانيت العهن ـ بتروكيمائية ـ المملكة العربية السعودية

تتكون منطقة العهن من جسم جرانتي دائري ، متداخل في تتابع متحول ذا أصل رسوبي . وصخوره ذات نسيج خشن ، (ذو بلورات ناقصة الأوجه) مكوناته الأساسية كوارتز وفلسبار بوتاسي . معظمه بيرثيت وبلاجيوكليز صودي . صنفت صخوره على أنها سيانوجرانيت ومونزوجرانيت وخواصها الكيمائية تؤكد قلويتها وأنها ذات طبيعة بيرالومنية ، كما تشير النتائج إلى أن متداخلة العهن تتبع نوع (I) جرانيت ، كما أنها تكونت من مجماً ناشئة عن أقواس بركانية وتمثل مرحلة تكتونية انتقالية تكونت خلال المراحل الأولى لانتشار قوس خلفي بالقرب من حافة قارية .