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Research Article **GEOLOGY**

Petrology and Zircon morphology of granitoid rocks at Um Bogma Environs, south west Sinai, Egypt

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KEY WORDS

Geology ; granitoid rocks ; zircon typology ; Sinai ;morphology

ABSTRACT

This paper studies the morphology of zircon crystals as well as geological and petrographical characteristics of granitoid rocks at Um Bogma environs, southern Sinai, Egypt to provide the rock nomenclatures and to deduce their origin and magma types. The field relations and observations display the presence of different masses of granitic intrusions represented by older and younger granites. Based on modal mineral compositions, the granitoid rocks are classified into tonalite, quartz diorite, monzogranite, syenogranite and alkali feldspar granite. Commonly, zircon is the most abundant accessory mineral in the studied granitoid rocks, which exhibits well crystalline and metamict forms. The morphologic examination of zircon crystals show some characteristic features such as color, regular oscillatory zoning, metamictization, fracturing, volume expansion and alteration. The typologic investigation of zircon population discriminates between different petrographic types of granites, where in tonalites S13 and S22 are the dominate types whereas in quartz diorite, S8 and S12 types of zircon are the most predominant types. Zircon of S8 type is the most predominant type in monzogranite, whereas P3 and P4 Zircon types occur in syenogranite. The most abundant zircon types in alkali feldspar granite are P5 and P4. Zircon investigations display that the quartz diorite has aluminous nature comparable with S-type granite, while tonalite, monzogranite and syenogranite have calc-alkaline affinity similar to I-type granite. On the other hand, the alkali feldspar granite has alkaline nature of A-type granite.

Introduction

The morphologic and typologic features of zircon are good indicators for extracting information on the prehistory and genesis of magmatic, metamorphic and sedimentary rocks. Since the 1950s, many attempts have been made to link systematically zircon morphology with petrogenesis of granitoid rocks, **(Poldervaart, 1955 and 1956; Larsen and Poldervaart, 1957; Pupin and Turco, 1972 a, b, & c; Kostov, 1973; Hoffmann, 1981).** Pupin (1980) published a typologic scheme relating the relative development of crystal forms with the temperature and the host-rock type.

Pupin (1980) suggested that the typological parameters of a zircon population can be used to describe the evolution of a magma system. His systematic examination of zircon typology has led to the establishment of the widely used "Pupin diagram", in which zircon crystals are classified according to the relative development of the {100}, {110} prisms and the {211}, {101} pyramids (Fig.1). The relative development of the prismatic faces is related mainly to the temperature of crystallization whereas the pyramidal faces were linked to chemical factors (Al/alkali) ratio. In general, zircon grains from relatively dry alkalic and tholeiitic igneous rocks tend to be dominated by {100} prism and {101} pyramid forms, where those from aluminous to calc-alkaline rocks exhibit various combinations of forms with a prominent presence of {211} pyramid, and finally those from water-rich granites and pegmatites tend to have {110} prism and {101} pyramid as their dominant forms. Vavra (1993) introduced a more sophisticated method to determine the relative growth rates of zircon forms in order to characterize the kinetics of a crystallizing environment. Benisek and Finger (1993) also showed that compositional factors have a significant effect on the development of prism faces in zircon. Jamshidibadr, (2016) studied zircon morphology of granitic rocks of Turkeh Dareh and mentioned that the origin and nature of intrusion magma results are consistent with results of field observations, mineralogy and geochemistry. Akin et al. (2019) concluded that zircon saturation and zircon crystallization temperatures are broadly consistent with typology temperature estimates, but temperature differences between these estimates are slightly higher or lower. However, these deviations may partly result from zircon typology relying on crystal shape, and thus the latest crystallization event, which could result in bias between the granitic rocks.

Geologic setting

The studied area is occupied by metamorphic, igneous and sedimentary rocks Fig. (2). The metamorphic rocks are represented by schist, orthogneiss and paragneiss. The igneous rocks are represented by granitoid and basaltic rocks with dykes and sills. The sedimentary rocks are represented by Mesozoic and Paleozoic sediments unconformably overlying the basement rocks.

The granitoid rocks are classified lithologically into rock units by many authors **(e.g. Akaad and El-Ramly 1960; El-Shazly 1964 and 1980; Schürman 1966; Sabet 1972; El-Gaby 1975; Akaad and Noweir 1980; and Hussein et al. 1982; El Bahariya 2021).** Most of these classifications indicate that the Egyptian granitoid rocks are categorized into three main cycles: The first one describes the emplacement of the older granites. The second cycle refers to what is collectively post-collisional regime, known as younger granites. The third cycle, however, is dominated by alkaline granites as intra-plate, anorogenic granites, formed by partial melting of pre-existing crustal rocks **(El-Ramly 1972)**. The studied area comprises different types of older and younger granitoid rocks forming relatively high relief mountains intruding the older metamorphic rocks (Fig. 3 A & B). The older granites are usually coarse to medium grained, of grey color and have contain mafic xenoliths or dispersed mafic xenocrysts with gradational contact with the host granite. The younger granites are usually coarse to medium grained, of pink color. They intrude the older rocks with sharp contacts (Fig.4). The exposures of older granites are limited relative to the younger granites.

Petrography

Modal analysis of 44 thin sections representing all the studied granitoid rocks in the study area was carried out to provide a proper nomenclature for the different varieties. The data of modal analysis are given in (Table 1). Quartz, alkali feldspar and plagioclase are recalculated to 100% and the obtained data are plotted in the ternary diagram of Streckeisen (1976) (Fig. 5). The QAP diagram reveals that the older granitoid rocks comprise tonalites and quartz diorites, whereas the younger granites comprise monzogranites, syenogranite and alkali feldspar granites.

Tonalites are coarse-grained, hard rock and are commonly of greyish color. They are composed mainly of Quartz, plagioclase and biotite, together with subordinate k-feldspar and hornblende. Zircon and apatite are accessories, whereas sericite, kaolinite, epidote and chlorite are secondary minerals. The essential minerals are crystallized giving the rock its hypidiomorphic texture (Fig. 6a). **Quartz diorite rocks** are medium to coarse-grained with greyish color. The rocks are composed mainly of plagioclase and hornblende, together with minor amounts of biotite and quartz (Fig. 6b). Zircon and apatite are the main accessory minerals, whereas chlorite and sericite are secondary minerals. **Monzogranites** are coarse to medium-grained rocks with pale pink color. They are composed essentially of quartz, potash feldspar and plagioclase, together with minor amounts of biotite and muscovite (Fig. 6c). Opaques, apatite and zircon are accessories, whereas sericite, epidote, chlorite and kaolinite are secondary minerals. The mineral constituents show hypidiomorphic texture. **Syenogranites** are coarse to medium-grained and of reddish to pink color. They are composed, mainly of quartz, potash feldspar and plagioclase, together with very subordinate biotite and muscovite (Fig 6d). Opaques, zircon, and allanite are accessories, whereas sericite, epidote kaolinite and chlorite are secondary minerals. **Alkali feldspar granites** are coarse to medium-grained rocks and of pink to red color mostly stained by iron oxides. They are composed mainly of quartz, potash feldspar, together with very subordinate plagioclase (Fig. 6e). Zircon, apatite and iron oxides are the main accessory minerals, whereas sericite, chlorite and kaolinite are secondary minerals.

Zircon separation and examination

A sample with suitable weight was selected from every granitic type, then crushed in a vibrating pulverize disk grinder at a coarse setting, with oscillating discs (about 15 seconds). The crushed product is hand-sieved using two small sieves (0.050 and 0.16 mm), and is passed through a 60-mesh US Standard sieve and concentrated by the panning method in a 1000 cm^3 beaker. After removing the magnetic minerals by a strong horseshoe magnet the crop in each case must repeatedly subject to heavy liquid separation (bromoform) followed by magnetic fractionation using Frantz isodynamic separator. The nonmagnetic portion was studied by binocular microscope to select the identified zircon grains. Unbroken zircon crystal representing the zircon populations were separated for typological investigations and some crystals were prepared for scanning electron microscope studies by using a scanning electron microscope JEOL

JSM 5600 at Central Labs of Nuclear Materials Authority, Cairo, Egypt.

The coordinates in (I.A and I.T) are calculated by the following formula:

$$I.A = \sum_{100}^{800} I.A \times n_{I.A}$$

$$I.T = \sum_{100}^{800} I.T \times n_{I.T}$$

Where $n_{I.A}$ and $n_{I.T}$ are the respective frequencies for each values of I.A and I.T.

The T.E.T. (Typological Evolutionary Trend) is drawn through the average in (IA, IT) with slope a = ST / SA, which is the tangent of the angle between the TET axis and the IA axis according to the following:

Standard deviation of A index:

$$SA = \sqrt{(A - A)^2}/N$$

Standard deviation of T index:

$$ST = \sqrt{(T - T)^2}/N$$

N= Number of zircon crystals

Results and discussion

In the following section some external features of zircons will be discussed.

Zircon morphology

Morphology of zircon is concerned with the study of the prism and pyramid faces of zircon crystals with some other features such as color, zoning, metamictization, expansion, fractures and alteration.

Colored and colorless zircons are abundant in the concentrates of the investigated samples of granitoid rocks. They show pale purple, dark purple color and colorless, together with minor crystals of gray, pale yellow, brown and purple colors (Fig. 7A).

Regular oscillatory zoning is observed in most zircons of the studied granitoid rocks which considered as a common phenomenon in magmatic zircons (Fig.7B). The growth zones in zircons of igneous rocks result from the change of physical and chemical conditions in the melt or solutions **(Speer, 1982)**. This leads to the conclusion that the majority of the investigated zircons could have crystallized in such environment.

Metamictization phenomenon is well pronounced in zircon crystals taken from the syenogranite, alkali feldspare granite and minor crystals were found in monzogranite rocks (Fig.7C).

Metamictization process is a result of the radioactive decay of U and Th, which were incorporated in the crystal lattice during crystal growth, and the decay of their radioactive daughters. The α-recoil nuclei, progressively transforms the zircon structure into an amorphous matrix, **(Rios et al., 2000)**.

Differential metamictization of zircon causes volume expansion of the U-rich domains with consequent fracturing of the more resistant and brittle low-U domains (Fig. 7D). Typically the fractures start at the interface with the more metamict domains or with high-U inclusions and develop radially outward across the low-U bands.

Chemical alteration is generally noticed in the studied zircons, especially those taken from the syenogranites. Due to the Metamictization processes, the fluids penetrate the grain boundary through the developed fractures to reach the internal structure of the crystal and new minerals are formed (Fig. 7E).

Zircon typology

The typologic distribution has been achieved after investigation of 56 to 65 unbroken zircon crystals for every granitic type. Most of the studied samples have major elongated zircons (1.0-3.0mm). Relatively, these zircons show high proportions of stubby crystals (L/B < 2.0 mm), or of long prismatic crystals (L/B >4.0). They most commonly occur in the form of idiomorphic crystals of prismatic habit. Some zircons, however, are hypidiomorphic. Various colors are recorded in zircon grains.

The analysis of zircon crystals taken from the tonalite exhibit S13, S22 as the dominate types while S7, S18, S17 and S12 are less dominant and S8, S19, S14 and S9 occur in minor amounts (Plate1 in Appendix) (Fig. 8A&B). The zircon crystals taken from the quartz diorite displayed that S8, S12 are the most predominant types whereas, S13, S18 and S11 are less dominant and S7 occurs in minor amount (Plate2 in Appendix) (Fig. 8C&D). S8 type is the most predominant type whereas S12, S13, S14 and S16 types are less dominant in zircon crystals taken from the monzogranite and S9, S17, S18 and S19 occur in minor amounts (Plate3 in Appendix) (Fig. 8E&F). P3 and P4 are the most predominate in zircon crystals taken from the syenogranite whereas S15, S13, S14 and S19 are less abundant and P5, S8, S9, S10, S18 and S20 occur in minor amounts (Plate4 in Appendix) (Fig. 8G&H). The most abundant types in zircon crystals taken from the alkali feldspar granite are P5 and P4 while, S20, S25 and S15 are less abundant (Plate5 in Appendix) (Fig. 8 I&J).

The morphometric analysis, mean point, and the coordinates (I. Ā. and I.T) and T.E.T after Pupin (1980) can determine the grade of magmatic differentiation and contamination of granitoid rocks where a distinction could be made between different types of granitic rocks. The distributions of zircon crystals type for every granitic rock were computed and the obtained data are shown in

(Table 2). The table shows that (I. Ā. & I. T̄.) of tonalite, quartz diorite, monzogranite, syenogranite and alkali feldspar granite are (357.81 & 540.63), (341.76&488.33), (378.57&491.07), (589.23&500) and (666.67&638.33), respectively. It also shows that the magma temperature as zircon index of tonalite is 770.3°C, quartz diorite is 744.15°C, monzogranite is 745.5°C, syenogranite is 750°C and alkali feldspar granite is 891.165 °C.

The results of mean point of the five investigated granitic varieties are plotted on the diagram in Fig. (9). The Figure shows that the tonalite and quartz diorite mean points plotted in the field of diorites, quartz gabbros and diorite, tonalite (1) while the monzogranite mean point plotted in the overlap of the two fields; granodiorite (2) and diorites, quartz gabbros and diorite, tonalite (1). The syenogranite mean point plotted in the overlap between the granodiorite field (2) and field of monzogranite and monzonite (3) but the alkali feldspar granite mean point plotted in the field of alkaline and hyperalkaline syenite and granite.

The A index versus T^{o}C for every granite variety is plotted on the diagram shown in Fig. (10). In this Figure Pupin (1980) has divided the diagram into several fields: the first field is specified for crustal granitoids (1, 2, 3) that include both leucogranites and aluminous monzogranite which have low I.A. and I.T. indices. The second field (4, 5) includes granitoids of hybrid origin which have calc-alkaline or sub-alkaline nature and those have I.A. indices higher than the crustal origin. The third field (6, 7) includes the mainly mantle granitoids origin and they have very high I.A. and I.T. indices. The quartz diorite zircon samples plotted within the intrusive aluminous monzogranites and granodiorites field (3) while tonalite& monzogranite zircons plotted in (4a, dark dotted area) granodiorites + monzonites field. Syenogranite zircons plotted in the sub-alkaline series granites field (5) while the alkali granite zircons had plotted in the alkaline series granites field (6). On the basis of petrological characteristics of granitoid rocks, it can be deduced that the first field (1, 2, 3) is specified for S-type granite while field (4, 5) is dominated for I-type granite and third field (6, 7) is characterizing the A-type granite **(Schermaier et al., 1992)**.

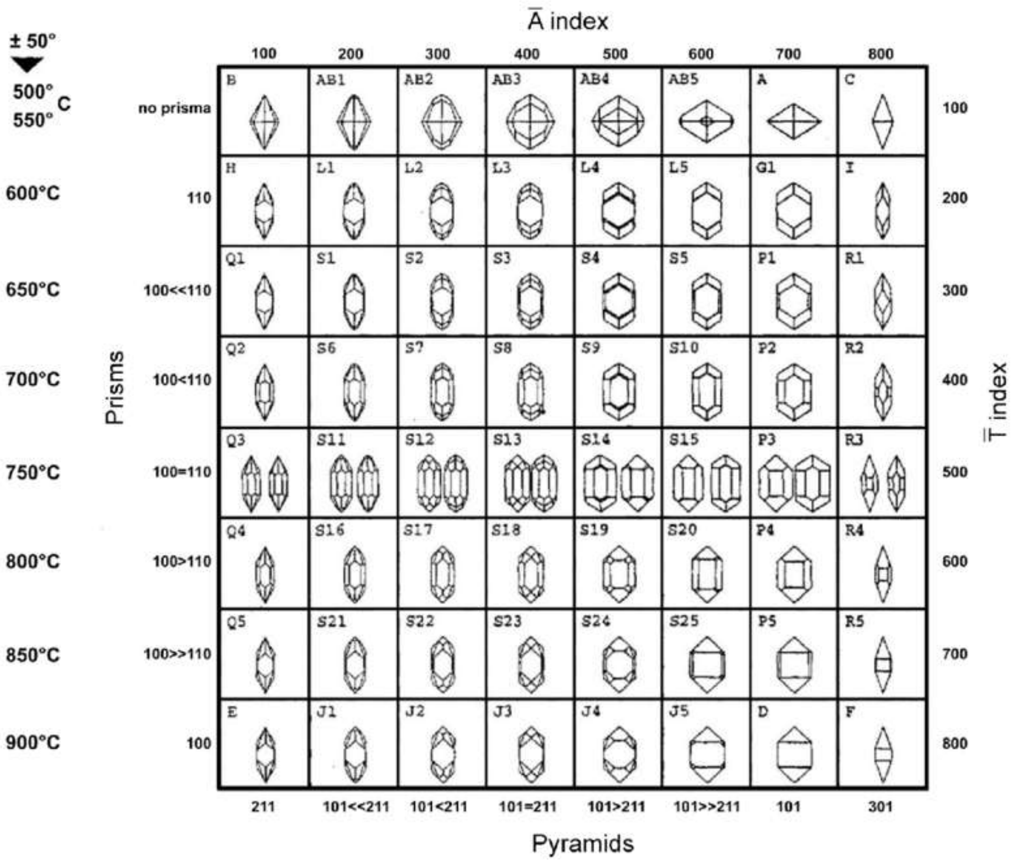


Fig. (1): Main types and subtypes of the typologic classification with two variables (IA, IT) Pupin (1980).

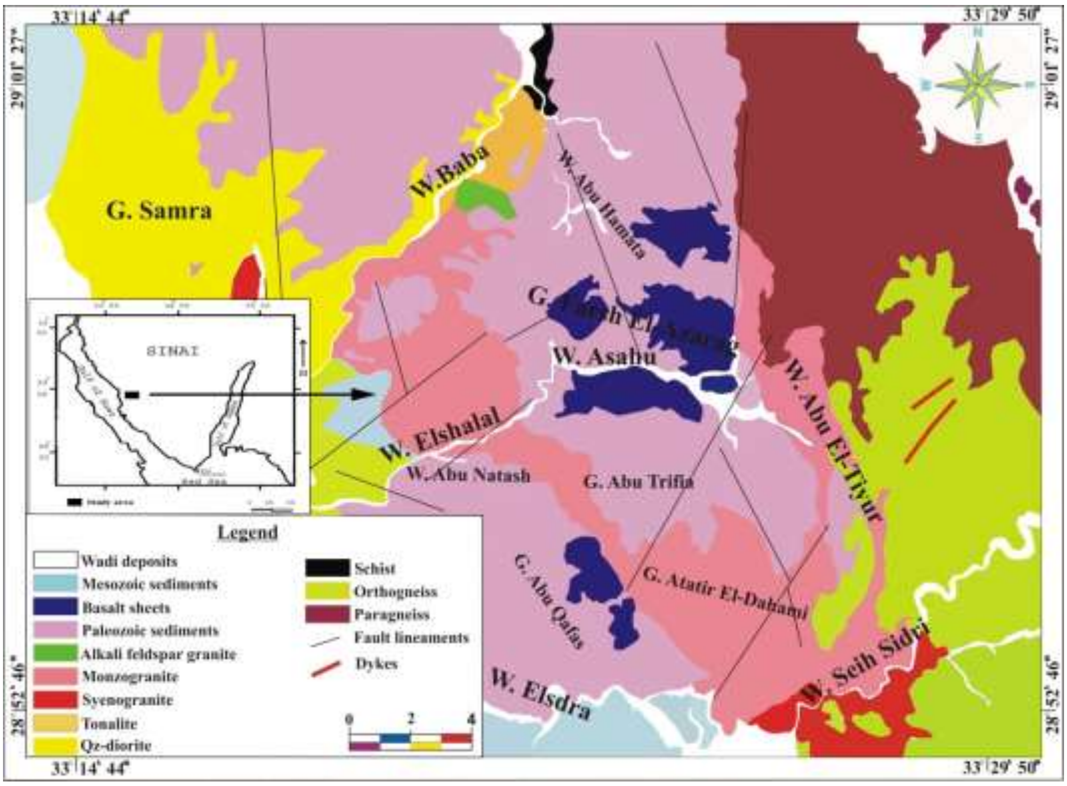


Fig. (2): Location and geological map of the studied area

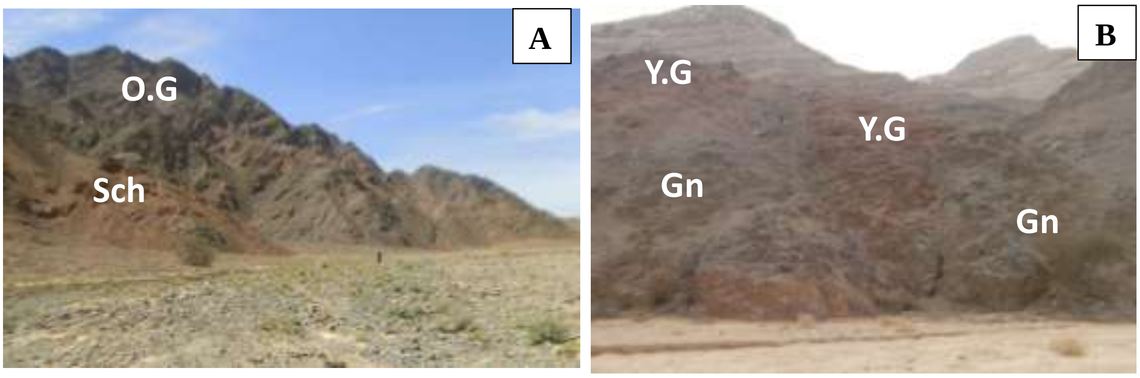


Fig. (3): Field photograph showing: A) sharp contact between highly weathered schist (Sch) and older granites (O.G) and B) offshoots of younger granite (Y.G) intruding Gneiss (Gn).

Fig. (4): Field photograph showing Younger granites (Y.G) intruding the older granites (O.G)

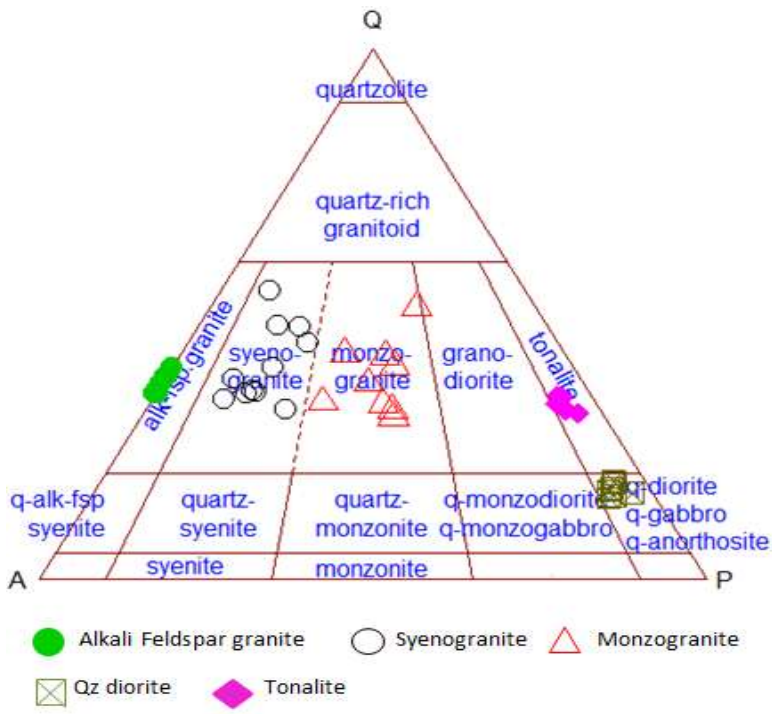


Fig. (5): Modal classification of the granitoid rocks according to Streckeisen (1976)

Table (1): Results of modal analyses of the studied granitoid rocks

Sample no.		**Qz**	**Plg.**	**k-feld.**	**Bio.**	**Hb.**	**Mus.**	**Chl.**	**Acc.**	**Opqs.**
B6-1	**Alkali granite**	36.1		61.8	0.2				1.3	0.1
B6-2		35.1		63	0.2				1.1	
B6-3		34.3	0.4	63.6					0.9	
B6-4		36.7		61.1					1.3	
B6-5		38.1	0.1	60	0.1				0.6	0.2
B6-6		36.8		61.7			0.2		0.2	
B6-7		39.3		58.9					1.2	
B6-8		35.5		63.4	0.1				0.4	
B6-9		34.5		64.4					0.2	0.1
B6-10		37.8		60.9					0.1	
B-7	**Syenogranite**	46.40	11.50	39.20	1.20		1.50		0.1	0.1
B-8		36.04	13.51	40.44	6.31		2.7	0.1	0.8	
B-9		33.2	10.5	54.2	1.8		0.3			0.1
B-10		30.74	20.19	45.19	1.92		0.96	0.04	0.96	
B-11		43.56	14.08	33.8	7.04		0.72		0.7	0.1
S-7		35.1	14.1	49.3	0.8			0.1	0.6	
S-8		53.36	7.37	37.53	1.29		0.21		0.13	0.11
S-9		34.1	14.5	48.1	2.3		0.71	0.12	0.17	
S-10		39.51	16.05	33.33	7.41		2.47		1.23	
SHL-4		34.1	13.4	50.1	0.8		1.5			0.1
Tur-3		37.15	10.23	50.96	1.13			0.2	0.33	
SHL-1	**Monzogranite**	48.72	29.31	16.79	3.1		1.72		0.36	
SHL-2		30.5	35.5	29.8	1.3		1.6	0.4	0.7	0.2
SHL-3		38.33	31.69	25.32	0.31		2.79		1.56	
SHL-5		29.5	36.5	30.5	1.4		1.1	0.1	0.7	0.2
TUR-1		40.48	29.76	26.19	2.07		1.19		0.31	
TUR-2		32.21	24.96	39.3	2.31		0.99		0.17	0.06
TUR-4		31.5	33.48	30.5	2.4		1.12	0.1	0.7	0.2
TUR-5		41.27	23.81	31.75	0.99		1.59		0.59	
FLV		35.23	29.56	30.56	2.23		2.65		0.55	0.22
B-1	**Qz diorite**	12.81	63.47	2.3	11.47	8.74		0.3	1.18	
B-2		15.53	66.02	3.88	7.83	5.77			0.97	
B-3		13.26	67.61	6.09	5.21	6.96			0.87	
S-1		13.61	68.09	5.16	6.87	5.11		0.2	0.96	
S-2		13.8	62.48	4.48	9.77	8.5			0.97	
S-3		15.63	65.11	4.01	9.8	4.43			1.02	
S-4		14.37	66.7	5.49	6.29	5.85		0.1	1.2	
B-4	**Tonalite**	28.66	55.24	4.53	7.96	3.01			0.63	
B-5		29.41	51.24	4.24	10.15	4.32		0.09	0.64	
B-12		30	53.21	3.77	9.37	3.1			0.47	
B-13		29.38	53.22	4.18	9.16	3.48		0.21	0.58	
B-14		27.46	54.42	4.43	8.92	4.2			0.57	
B-15		28.62	52.72	5.1	9.22	3.9			0.44	
B-16		27.2	56.5	3.1	8.1	5.1		0.1		

Qz= quartz, Plg.= plagioclase, K-feld= k-feldspar, Bio= biotite, Mus= muscovite, Chl= chlorite, Acc= accessories, opqs= opaques.

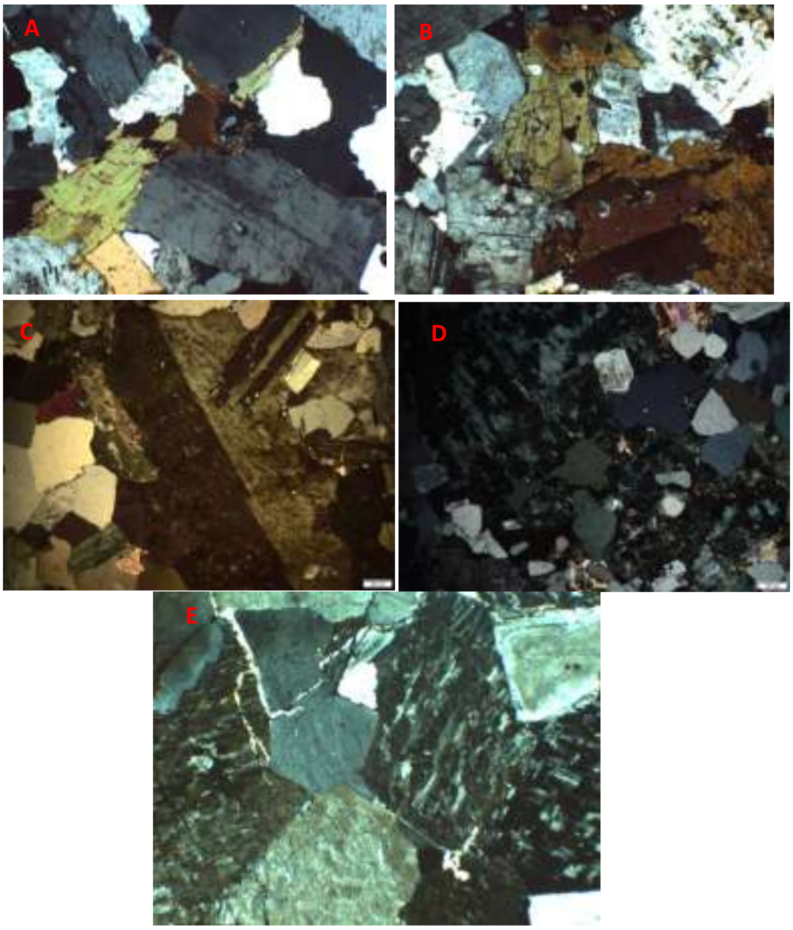


Fig. (6): Photomicrographs show the petrographic compositions of granitoid rocks: a) tonalite; b) quartz diorite; c). monzogranite; d) syenogranite; e) alkali feldspar granite

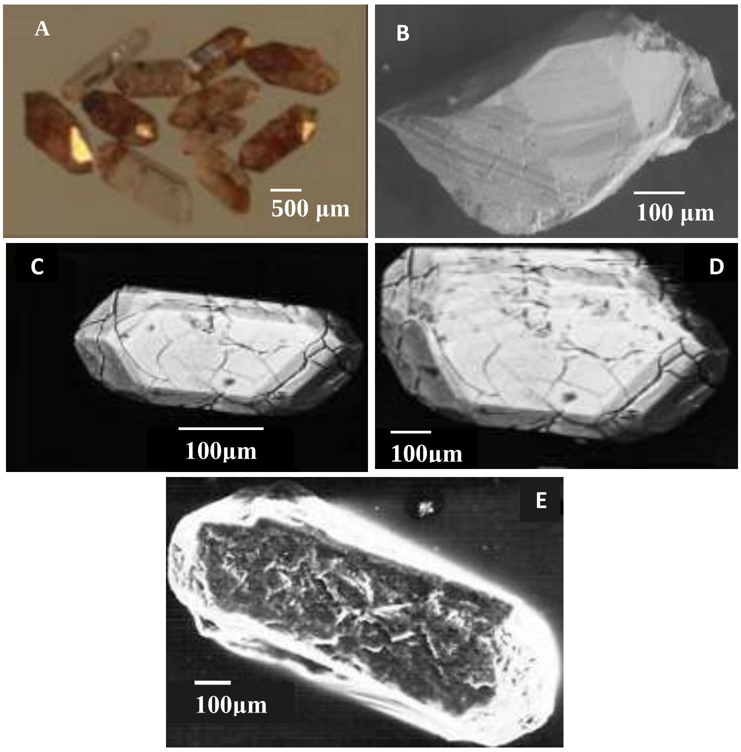
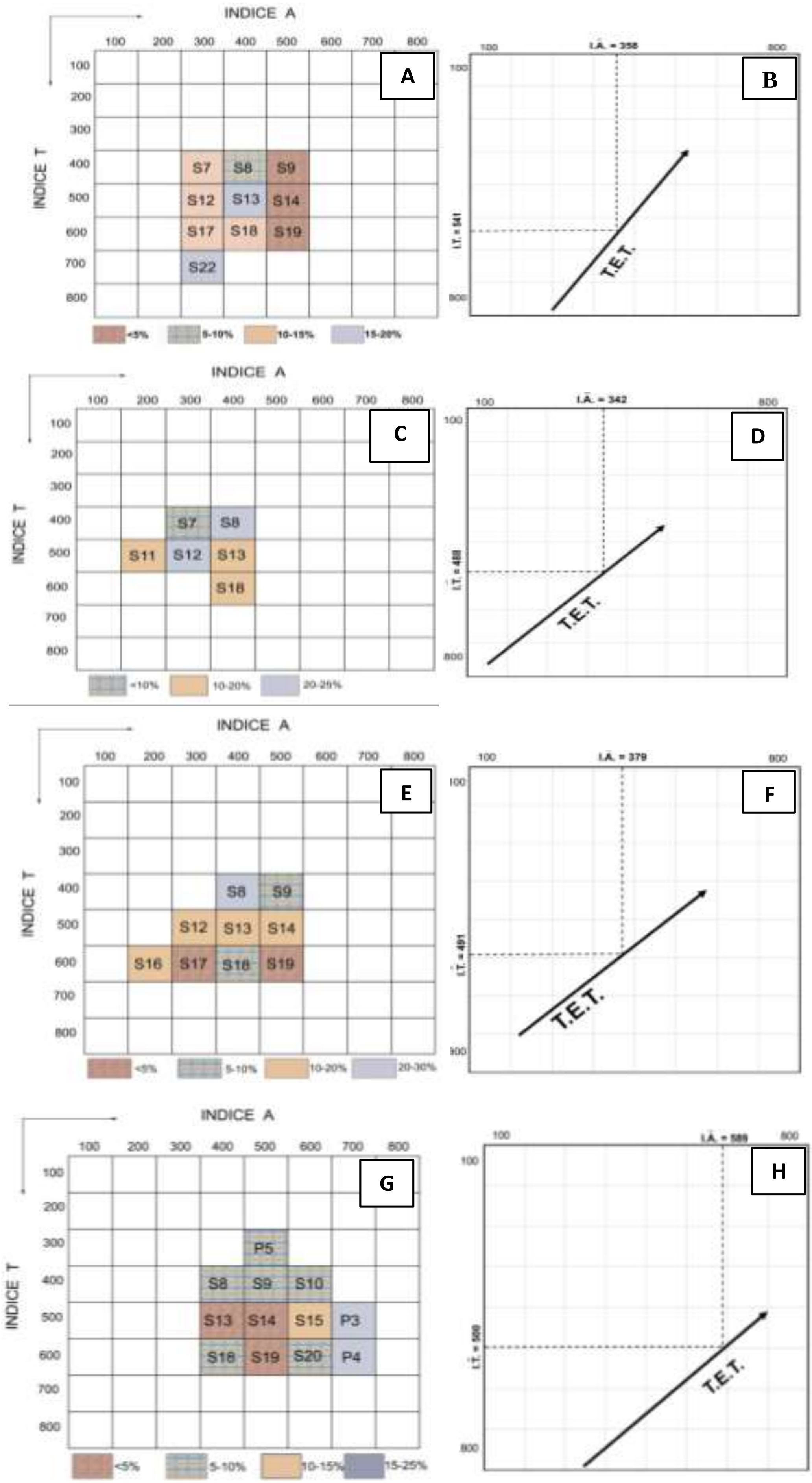


Fig. (7): Some morphological features in zircon. (A) Zircon colors, (B) Regular oscillatory zoning, (C) Metamictization, (D) volume expansion, (E) Chemical alteration.


INDICE A
INDICE T
A
B
S7 S8 S9
S12 S13 S14
S17 S18 S19
S22
<5% 5-10% 10-15% 15-20%
I.A. = 358
I.T. = 541
T.E.T.
C
D
S7 S8
S11 S12 S13
S18
<10% 10-20% 20-25%
I.A. = 342
I.T. = 488
E
F
S8 S9
S12 S13 S14
S16 S17 S18 S19
<5% 5-10% 10-20% 20-30%
I.A. = 379
I.T. = 491
G
H
P5
S8 S9 S10
S13 S14 S15 P3
S18 S19 S20 P4
<5% 5-10% 10-15% 15-25%
I.A. = 589
I.T. = 500

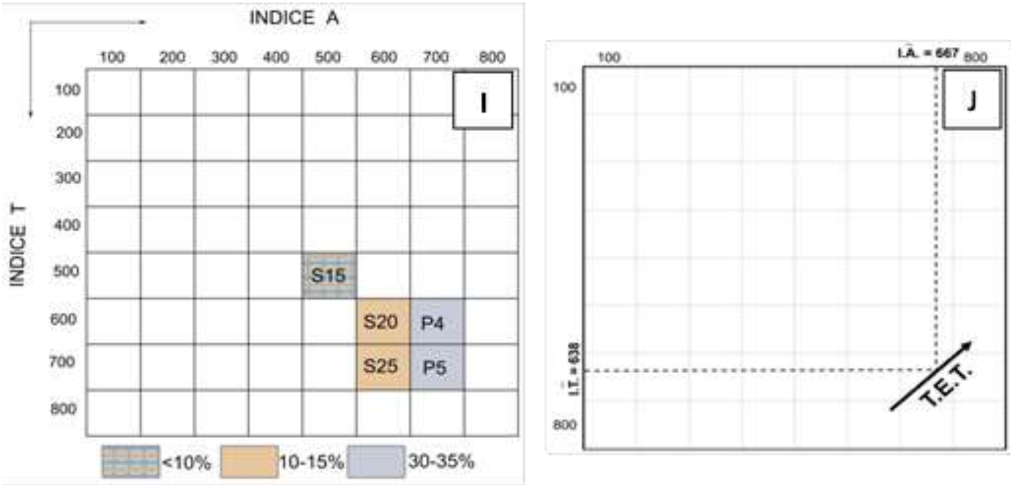


Fig.(8): Typologic distribution of zircon populations from the studied granitoids and their Typological Evolutionary Trend (TET): (A, B) Tonalite, (C, D) Quartz diorite, (E, F) Monzogranite, (G, H) syenogranite, (I, J) Alkali feldspar granite.

Table (2): Typologic data of the studied zircons

Rock type	IA	IT	SA	ST	α (°)	Zircon typology temperature
Tonalite	357.81	540.63	68.02	99.56	55.56	770.3
Quartz diorite	341.67	488.33	73.69	68.54	42.92	744.15
Monzogranite	378.57	491.07	92.03	78.55	40.48	745.5
Syenogranite	589.23	500.00	600.74	506.10	40.11	750
Alkaline granite	666.67	638.33	524.93	491.25	43.1	819.165

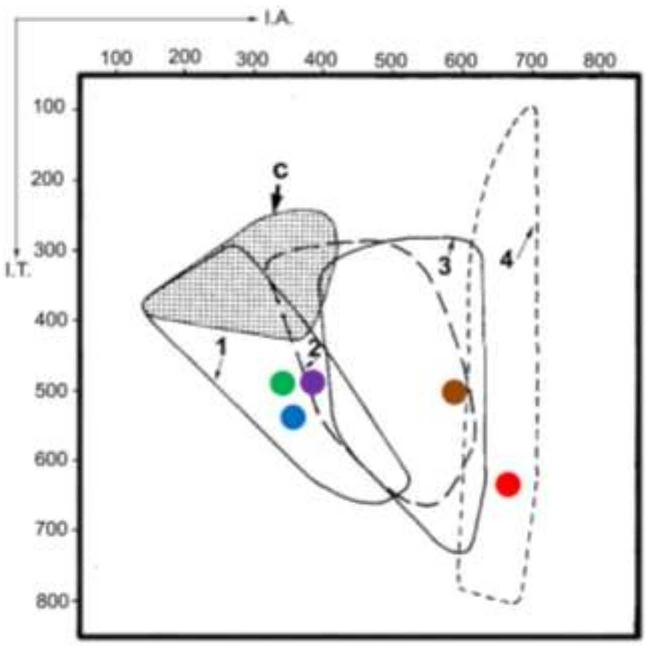


Fig. (9): The typologic diagram for the Distribution of plutonic rocks (after Pupin 1980): (1) diorites, quartz gabbros and diorites, tonalites; (2) granodiorites; (3) monzogranites and monzonites; (4) alkaline and hyperalkaline syenites and granites; (c) cordierite bearing rocks

Symbols: ● Tonalite, ● Quartz diorite, ●Monzogranite, ● Syenogranite, ● Alkali granite

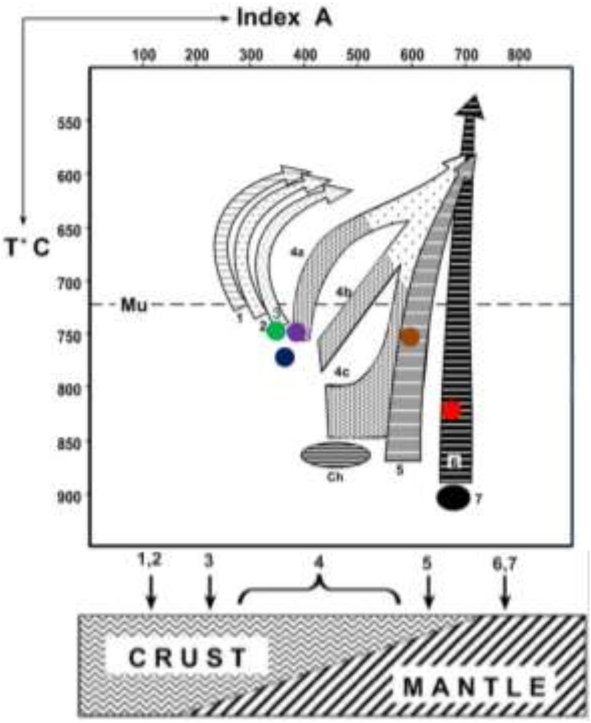


Fig. (10): Distribution of mean points and mean T.E.T of zircon populations (Pupin 1980) from; Granites of crustal or mainly crustal origin (1, 2, 3).Granites of crustal + mantle origin, hybrid granites (4a, b, c) calc-alkaline series granites (dark dotted area = granodiorites + monzogranites); clear dotted area = monzogranites + alkaline granites; (5) subalkaline series granites. Granites of mantle or mainly mantle origin: (6) alkaline series granites: (7) tholeiitic series granites. Mu, limit of muscovite granites (I.T ‹ 450); Ch, magmatic charnokites area. (modified after Pupin, 1980) Symbols as in Fig. (9)

Appendix

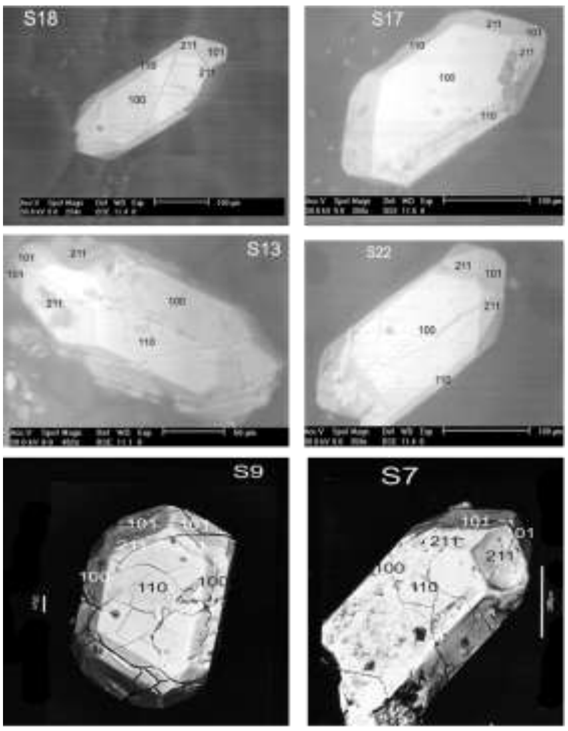


Plate 1

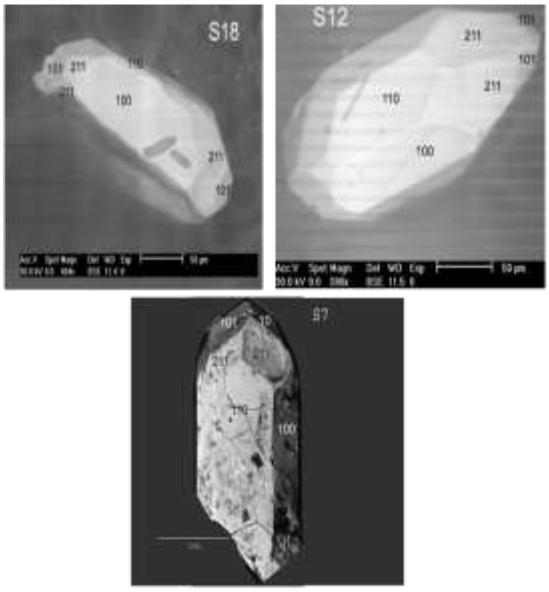


Plate 2

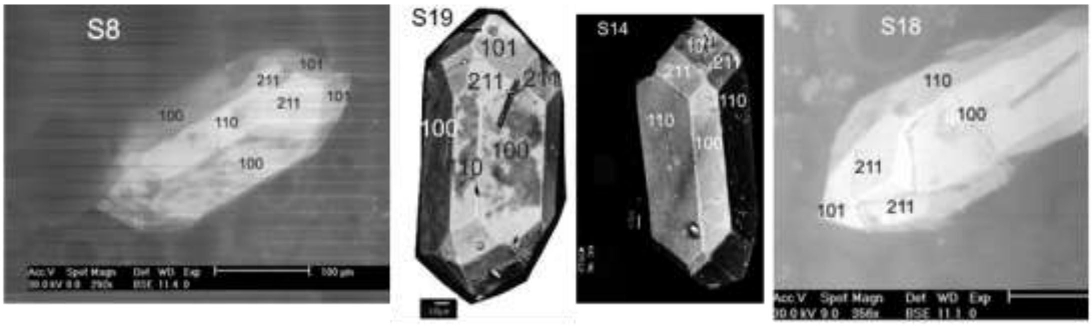


Plate 3

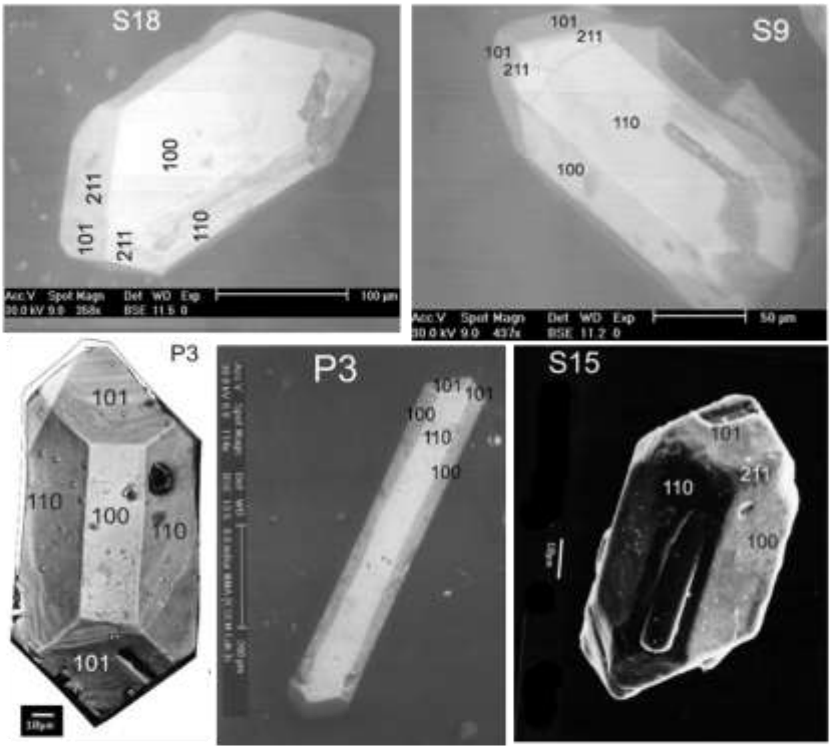


Plate 4

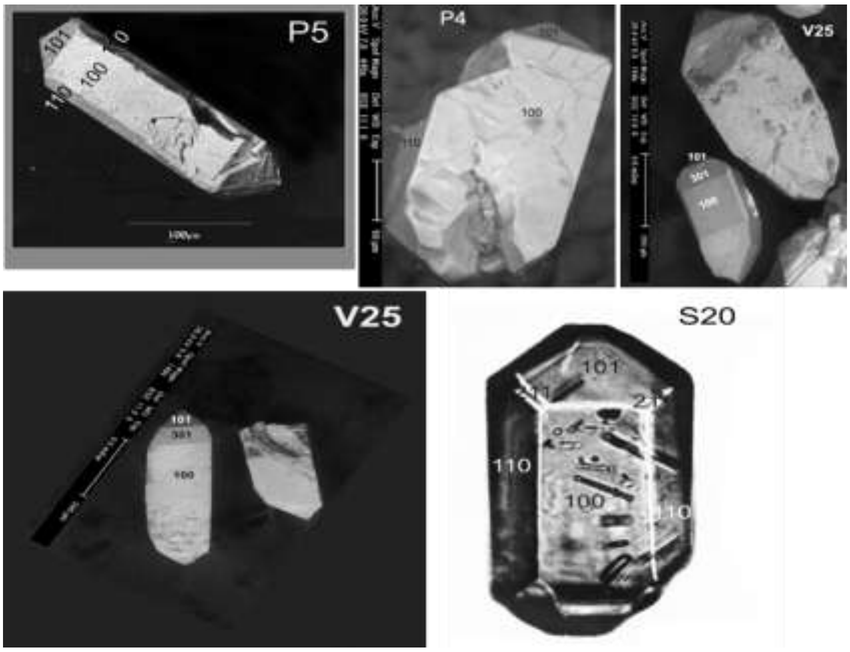


Plate 5

Summary and conclusion

The investigated granitoid rocks include tonalite and quartz diorite (older granites) and monzogranite, syenogranite and alkali feldspar granite (younger granites). In the studied zircon some morphologic features were recorded such as colors, zoning, metamictization, volume expansion and alteration. The typology of zircons display that the classification of the studied granitoids is conformed, to a large extent to that obtained by the petrographic classification. The quartz diorite has aluminous nature while tonalite, monzogranite and syenogranite have calc-alkaline nature. On the other hand, the alkali feldspar granite has alkaline nature. According to **(schermaier et al., 1992)**, the quartz diorite is belonging to S-type granite while tonalite, monzogranite and syenogranite are I-type granite and alkali feldspar granite is A-type granite.

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"بترولوجية ومورفولوجية الزيركون فى صخور الجرانيت بمنطقة أم بجمة وما حولها، جنوب غرب سيناء – مصر"

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يتناول البحث تصنيف الصخور الجرانيتية بمنطقة أم بجمة وما حولها بناءً علي بتروجرافية وتيبولوجية, وأشكال بلورات الزيركون فى هذه الصخور. وتتكون الصخور الجرانيتية بمنطقة الدراسة من صخور الكوارتز دايورايت والتوناليت (الجرانيت القديم)، المونزوجرانيت،السيانوجرانيت وجرانيت الفلسبار القلوي (الجرانيت الحديث). وتتميز صخور الكوارتز ديورايت بلون رمادي وتتكون بشكل رئيسي من البلاجيوكليز والهورنبلند، بالإضافة إلى كميات صغيرة من البيوتيت والكوارتز. أما صخورالتوناليت فإنها تتميز بلونها الرمادي إلى الأبيض الوردي، وهي تتكون من الكوارتز والبلاجيوكليز والبيوتيت، بالاضافة الى الفلسبار البوتاسى والهورنبلند. من ناحية اخري تتميز صخور المونزوجرانيت باللون الوردي وتتكون بشكل أساسي من الكوارتز والفلسبار البوتاسى والبلاجيوكليز، بالإضافة إلى كميات صغيرة من البيوتيت والمسكوفيت. وتعتبر صخور السيانوجرانيت الاكثر انتشارا بين أنواع الجرانيتات الحديثة الأخرى بمنطقة الدراسة، وتتكون بشكل رئيسي من الكوارتز والفلسبار البوتاسى والبلاجيوكليز بالاضافة الى البيوتيت والمسكوفيت. أما صخور جرانيت الفلسبار القلوي فلها لون وردي إلى أحمر وتتكون من الكوارتز والفلسبار البوتاسى بالإضافة إلى البلاجيوكليز.

تم فصل معادن الزيركون من أنواع الجرانيتات المختلفه قيد الدراسه، حيث سجلت بعض الخصائص المورفولوجيه لبلورات الزيركون مثل اللون والتمنطق والتحلل واعادة التبلور.

وأشارت الدراسه الي أن صخور الكوارتز ديوريت ذات طبيعه فوق ألومينية من النوع (S- type)، بينما يتميز التوناليت والمونزوجرانيت والسينوجرانيت بطبيعته الكلسية القلوية من النوع (I- type). من ناحية أخرى، جرانيت الفلسبار القلوي له طبيعة قلوية هو جرانيت من النوع (A- type).