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ZIRCON IN GRANITOIDS FROM SINAI, EGYPT AND ITS GENETIC SIGNIFICANCE

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ABSTRACT

The granitic plutonism in the area around Wadi El-Sheikh, southwestern Sinai, Egypt is mainly represented by the Older and Younger Granitoid Rocks. The younger granitic rocks comprise in turn, two granitic phases, distinguished on field basis.

Morphological characters of zircon concentrates from the examined rocks have been statistically studied. Zircon populations in the Older Granitoids contain a wide variety of crystal shapes while in those of the younger granitic rocks, zircon crystals become prograssively more uniform in morphology. Distinction between zircons of the Older and Younger Granitoids is based mainly on their dimensional parameters. Similarity of the dimensional parameters of zirkons in the younger granitic phases renders their separation difficult. The significance of zircon as a guide to the petrogenesis of Wadi El-Sheikh granitoids is ascertained.

INTRODUCTION

Studies of zircon have generally emphasized that genetic relationships can be established for chemically similar igneous rocks on the basis that similar zircon populations are derivatives of one magma while dissimilar zircon populations are derived from different magma sources (LARSEN and POLDERVAART, 1957; ALPER and POLDERVAART, 1957; TAUBENECK, 1957; HALL and ECKELMANN, 1961; LARSEN and POLDERVAART, 1961; CLIFFORD *et al.*, 1962; SPOTTS, 1962; KARNER and HELGESEN, 1970). Recent studies have shown that the alumina/alkaline ratio and the temperature of the crystallization medium are the main factors controlling the growth of zircon typology (PUPIN and TURCO, 1972, 1975; PUPIN, 1976). In accordance, a genetic relationship is considered between a granite's zircon populations and its magma type. According to PUPIN (1980), the zircon populations in rocks reflect very accurately the origin of the magma, regardless of post-magmatic geochemical variations induced locally by deuteric processes.

Studies on zircon from Egyptian granites in the Eastern Desert of Egypt have been carried out by ZAGHLOUL and KHAFFAGY (1965), RAGAB (1971) and HEIKAL (1973). No study of zircon has ever been published pertaining to the extensive Precambrian granitoids of Southwest Sinai.

The present study encompasses the morphological characters of zircon and its dimensional parameters with the aim to ascertain the origin of the granitic rocks in Wadi El-Sheikh area *(Fig. 1)*. Moreover the study attempts to reveal whether the granitic rocks have been derived from the same or closely related magma or else

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differentiated, on the basis of zircon characteristics as morphology and elongation trends. The examined zircon crystals are believed to be representative of the granitic rocks around Wadi El-Sheikh.

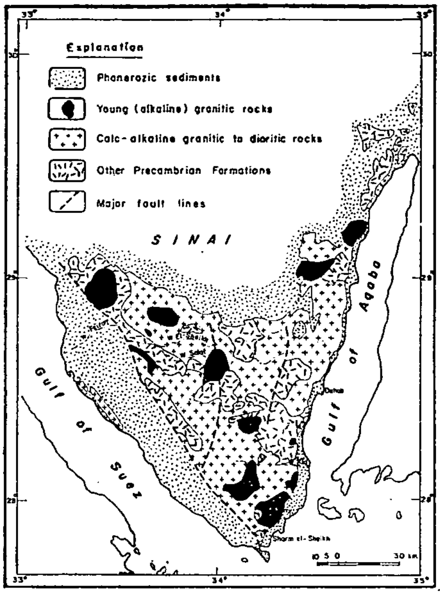

Fig. 1. Geological map of Sinai showing location of Wadi El-Sheikh area (simplified after SHIMRON' 1980).

GENERAL FEATURES OF WADI EL-SHEIKH GRANITOIDS

Two plutonic cycles are responsible for the formation of the granitic rocks in the area around Wadi El-Sheikh: *(1)* an old cycle that provided the Older Granitoid Rocks, and *(2)* a younger cycle that provided the Younger Granitoid Rocks. The younger granitoid rocks comprise in turn, two main granitic phases, distinguished on field basis, and corresponding to the second and third phases of the Younger Granitoids of the Eastern Desert of Egypt (SABET *et al.*, 1976).

The Older Granitoids of Wadi El-Sheikh area are two feldspar observed in subordinate amounts. Coloured minerals are represented by biotite and hornblende. Sphene is often abundant together with zircon and apatite. On the other hand, the Younger Granitoids are leucocratic, subsolvous rocks rich in K-feldspar, plagioclase and quartz. Biotite is the sole ferromagnesian mineral detected in these rocks.

Model classification (STRECKEISEN, 1976) of the Older Granitoids show that they are mainly represented by quartzdiorite, quartz-monzodiorite, tonalite and granodiorite. Granite and granodiorite are the two main rock units recognized among the granitic rocks of the second phase. Granitic rocks of the third phase are only represented by granite. The average modes of the studied granitic rocks are given in Table 1. Details of field relations and petrographic characters of the examined rocks are described by EL-SHESHTAWI (1984).

Table 1

Average modes (in volume %) and average zirconium contents (ppm) of the examined granitoids

	Older Granitoids	Younger Granitoids	
		Phase II	Phase III
Plagioclase	56.0	35.6	18.8
K-feldspar	9.1	30.3	48.8
Quartz	16.6	29.2	31.0
Muscovite	—	0.1	0.1
Biotite	8.1	3.5	0.7
Hornblende	7.6	0.1	—
Opaques and accessories	2.6	1.2	0.6
Total	100.0	100.0	100.0
Zirconium content	153.0	124.9	106.8

DISTRIBUTION OF ZIRCON

The random distribution of the small number of minute zircon crystals in various host minerals, renders the study of thin sections of limited value. However, thin section study reveals that zircon crystals are preferentially associated with ferromagnesian minerals *(Fig. 2a)* but they are also enclosed in quartz and feldspars. *(Fig. 2b, c)*. It is argued that zircon in Wadi El-Sheikh granitic rocks has crystallized early and continued up to the end of the magmatic stage. In support of this conclusion, the works of Köhler (1970); and Pupin *et al.*, (1979) show that in magmas defficient in water, zircon crystallizes during an early magmatic stages. In water-rich magmas, zircon crystallisation begins early in the magmatic period and continues up to the end with the development of hydrozircon rich in some trace elements such as U, Th and Y.

Chemical studies on Wadi El-Sheikh granitic rocks (El-Sheshtawi, 1984 show that the zirconium content decreases from the Older to the Younger Granitoids *(Fig. 3)*.

A similar trend of zirconium descent has been detected by Greenberg (1981) for the Younger Granitoids of the Fastern Desert of Egypt. The partial melting of the mantle which was invoked by Hussein *et al.* (1982) to account for the calc-alkaline magma of the Older Granitoids of Egypt is also capable of concentrating appreciable quantity of zirconium inasmuch as this element is normally present in noticeable quantity in basic magmas (Chao and Fleischer, 1960; Pupin, 1980).

MORPHOLOGICAL AND STATISTICAL VARIATIONS IN ZIRCON

Preparation and measurement of zircon samples

Sample size is approximately 250 to 300 grams. After fine crushing, all the crushed material is passed through a 60-mesh U.S. Standard sieve (0.25 mm opening), caught on a 100-mesh sieve (0.149 mm opening). Thus two size fractions (−60+ 100 mesh and −100 mesh) of crushed material are obtained. The crushed samples

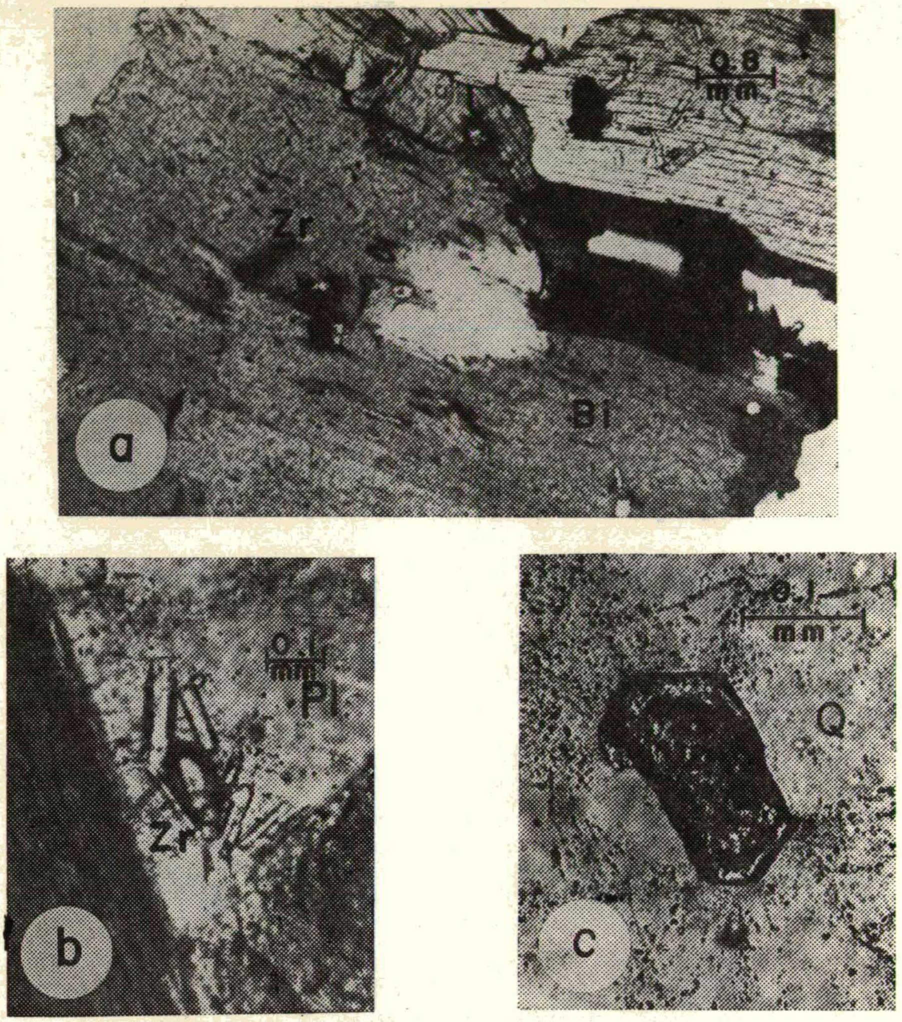

Fig. 2. a) Textural association of zircon (Zr) with biotite (Bi). Note pleochroic haloes surrounding the zircon crystals due to their content of radioactive elements, plane polarized light
b) and *c)* Zircon (Zr) enclosed in plagioclase (Pl) and quartz (Q), plane polarized light

are individually separated with bromoform (sp. gr. 3.3). Mineral fractions with densities greater than 3.3 were purified by passing through a Frantz Isodynamic Separator following directions given by ROSENBLUM (1958). Side tilt at 15°, forming tilt at 25° with the magnet set at 1.7 amps. are the best extractions conditions. Permanent mounts of the entire nonmagnetic residues of each sample are prepared. Both coarse and fine fractions of each sample are prepared and mounted separately.

Zircon is most abundant in the −100 mesh fraction. The predominance of doubly terminated crystals in most samples suggests only minor breakage during crushing. A mechanical stage is used in measuring and counting unbroken zircon crystals observed along regularly spaced intervals. 100 doubly terminated zircon crystals are measured at high magnification (×250) with an ocular micrometer.

Description of zircon in concentrates

The morphological characters of zircon crystals are focussed on colour, shape, form, habit, elongation, zoning, inclusions, outgrowths, overgrowths and coincidence of crystal length and *c*-axis. Representative zircon crystals as well as some of the less common types are pictured in *Fig. 4*.

Study of zircon concentrates revealed that zircon of the Older Granitoids is predominantly colourless to pale green. Pale pink and pale yellow crystals are uncommonly encountered. Zircon of the second phase granitic rocks shows similar colours. In addition, metamict zircon is rarely observed. On the other hand, zircon of the third phase granitic rocks is predominantly brown, with a relatively higher percentage of metamict varieties *(Fig. 4v, w)*.

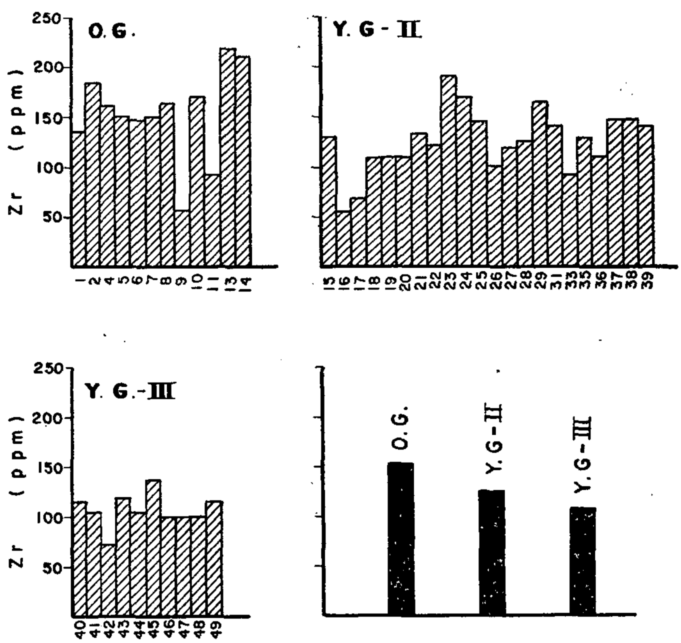

Fig. 3. Frequency histograms showing distribution of zirconium in Wadi El-Sheikh granitoids. O. G.: Older Granitoids; Y. G. — II: Younger Granitoids of the second phase, Y. G. — III: Younger Granitoids of the third phase

Nearly, all the crystals examined are euhedral *(Fig. 4b, c, p, w)*. Less than 5% show slight to moderate rounding of crystal edges and terminations (*Fig. 4f, s)*. Rounded zircons (rounded terminations) rarely occur *(Fig. 4k, l, o)*, most probably due to magmatic resorptions. SPOTTS (1962, p. 1228) proposed that such zircons may have produced during the cooling of magma.

The microscopic examination of zircon crystals proves the frequent occurrence of the following forms: tetragonal prism, tetragonal bipyramid and basal pinacoid. These forms are combined in different ways giving rise to different crystal habits *(Fig. 4d, e, i, t, u)*. Rare complex forms of zircon showing many crystal faces are rarely encountered *(Fig. 4q)*. The relative development of the prism with respect to the bipyramid is found to vary considerably *(Fig. 4a, j, t)*. Hemimorphic crystals are also detected.

Zoning predominates in the studied zircon. Although a detailed analysis of zoning is not attempted, several groups of zoned crystals are recognized: *1*—zircons with uniform zoning throughout *(Fig. 4q)*, *2*—zoned zircons enclosing an unzoned central area *(Fig. 4u, x)*, *3*—zoned zircons with unzoned periphery *(Fig. 4b)*. In most cases, zoning runs parallel to the periphery of the crystal *(Fig. 4u)*. In some cases, irregularities have been observed e.g. zones are shifted from the centre of the crystal.

Generally, zircon of the Younger Granitoids is poor in inclusions, while inclusions in zircon of the Older Granitoids are numerous and diverse. Commonly, inclusions are of apparently random distribution *(Fig. 4j, n)*. However, inclusions oriented parallel to the c-axis *(Fig. 4c)* or to the bipyramidal faces *(Fig. 4t)* are rarely observed. Concerning the composition of these inclusions, several kinds of zircon inclusions are distinguished. Some of the inclusions are possibly transparent acicular rutile (?) *(Fig. 4j)* and others are typically irregular opaque matter *(Fig. 4h, j)*. Opaque inclusions are observed *(Fig. 4b, j, g, u)* mainly in zircon of the Older Granitoids. Transparent colourless to light brown fluid inclusions are observed, being of a spherical bubble-like *(Fig. 4f)* or tubular form *(Fig. 4i, p)*. A final group consists of small zircon inclusions (euhedral, rounded or both) *(Fig. 4g, h, s)*. Augustithis (1973) considered the central rounded zircons as representing a sedimentogenic phase and the overgroths as representing a later generation under the influences and conditions of granitisation. In contrast, *Fig. 4g* shows an euhedral zircon inclusion representing the first zircon generation. A sedimentary origin could not be invoked for the explanation of such euhedral crystals. However, the rounded zircon inclusions, are suggested by the present authors to represent the first zircon generation, which was later corroded by magmatic corrosion and the overgrowths represent a second generation formed in the same magmatic phase of crystallization.

Zircon with outgrowths are very rare, not exceeding fraction of a percent. Outgrowths may have a spherical shape *(Fig. 4o)* or a rectangular form attached with its base to the bipyramid face *(Fig. 4v)*. Outgrowths with irregular shapes have been rarely detected *(Fig. 4n)*. These outgrowth when met with, are identical in properties and appearance with their supporting zircon grains *(Fig. 4v)*.

Parallel growth is quite rare in the examined zircons *(Fig. 4r)*. The formation of parallel growth suggests that zircon crystals crystallized early from a melt of low viscosity permitting the movement and collision of growing zircons (Jocelyn and Pidgeon, 1974).

The coincidence of the crystal length with *c*-axis in all the crystals studied is very clear.

Zircon elongation studies

Statistical investigations of zircon elongation are made on 11 samples by measurement of length and breadth of euhedral (unbroken) crystals in each sample. The length and breadth frequencies of zircon are given in Table 2. The elongation frequencies of zircon are given in Table 2. The elongation frequencies are given in Table 3. Length and breadth are represented graphically by frequency curves of length, breadth and elongation *(Fig. 5)*. *Fig. 6* illustrates the dimensional differences between the Older and Younger Granitoids. An attempt to correlate the dimen-

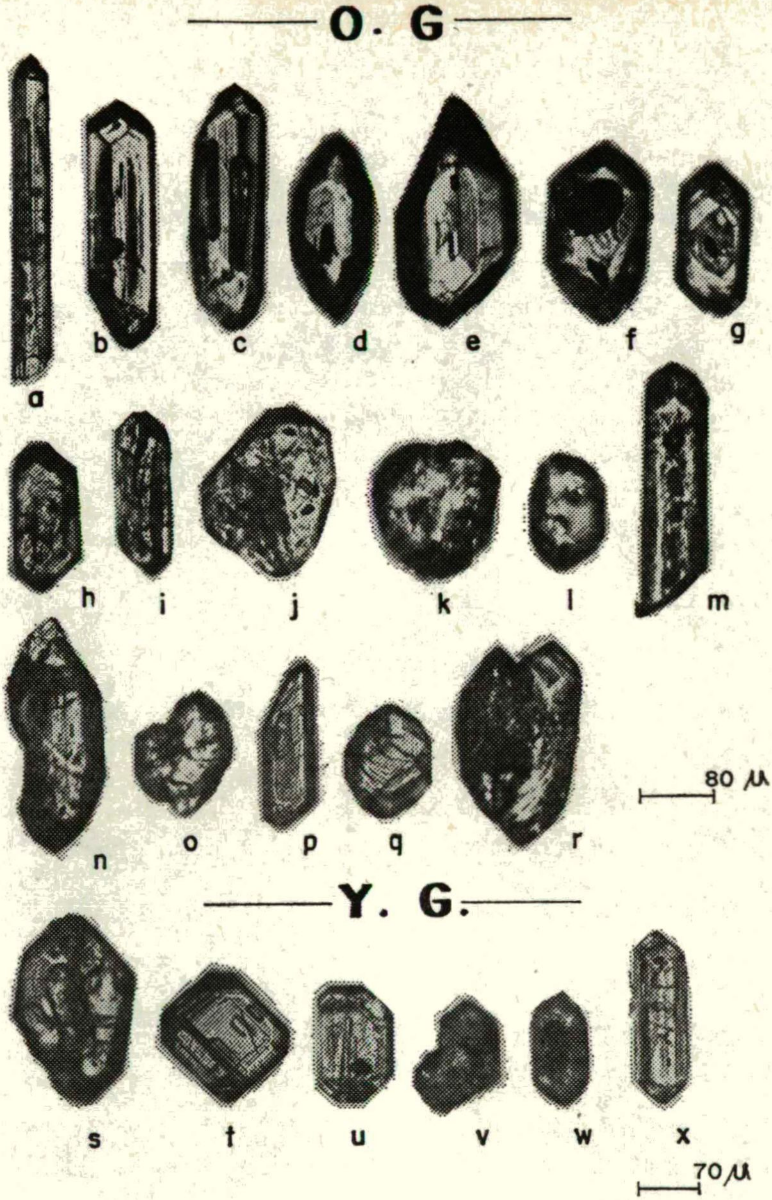

Fig. 4. Zircon crystals from Wadi El-Sheikh granitoids. (Details in the text)

sional parameters of the second and third phases of the Younger Granitoids, is shown on the same graph.

Of the dimensional parameters, the width of zircon crystals varies far less than their length. The mean width of zircon in the studied granitic rocks falls in the narrow range 0.06—0.08 mm. The mean length falls in the range 0.10—0.21 mm. Zircons in the Older Granitoids are typical longer than those in the Younger Granitoids. Zircon crystals in the second phase granites are slightly longer than those in the third phase. The mean elongation ranges from 1.57 to 2.63. Zircon crystals in the third phase granite have a majority of short stubby crystals, while normal prismatic crystals characterize the zircon populations in the other granitic rocks.

Results of the statistical parameters $\bar{x}$ (mean of x), $\bar{y}$ (mean of y), S_x (standard deviation of x), S_y (standard deviation of y), r (correlation coefficient) and Dd (correlation of relative dispersion about RMA) or zircon of various granitic samples

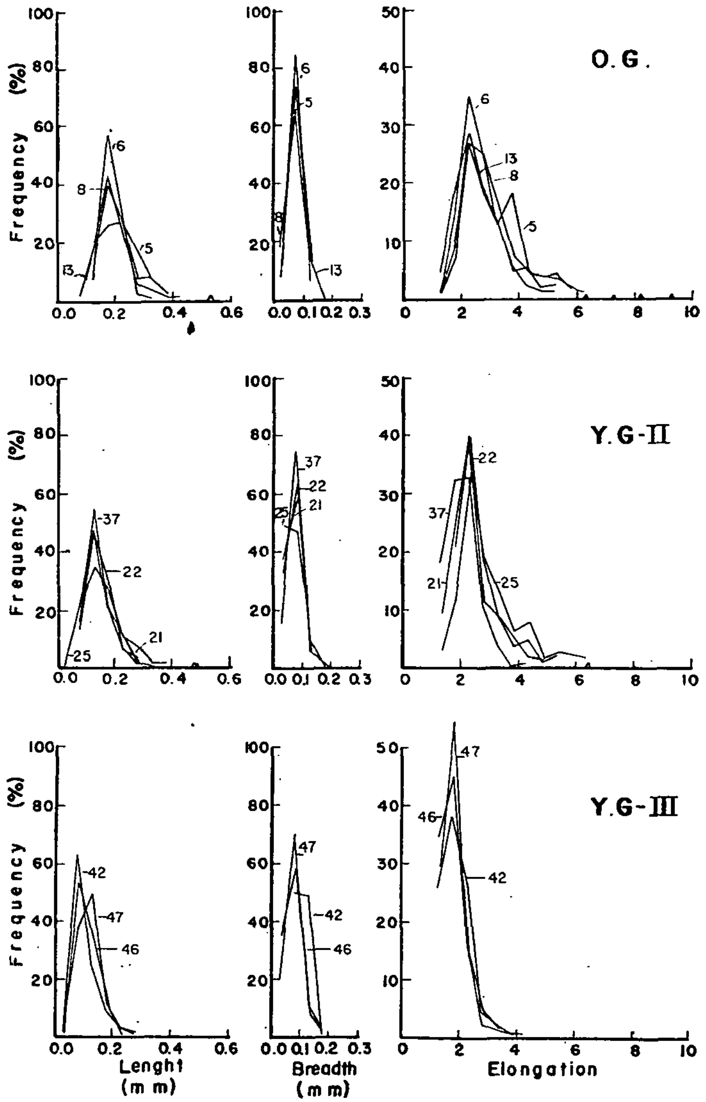

Fig. 5. Size frequency curves for zircon in the examined granitoids

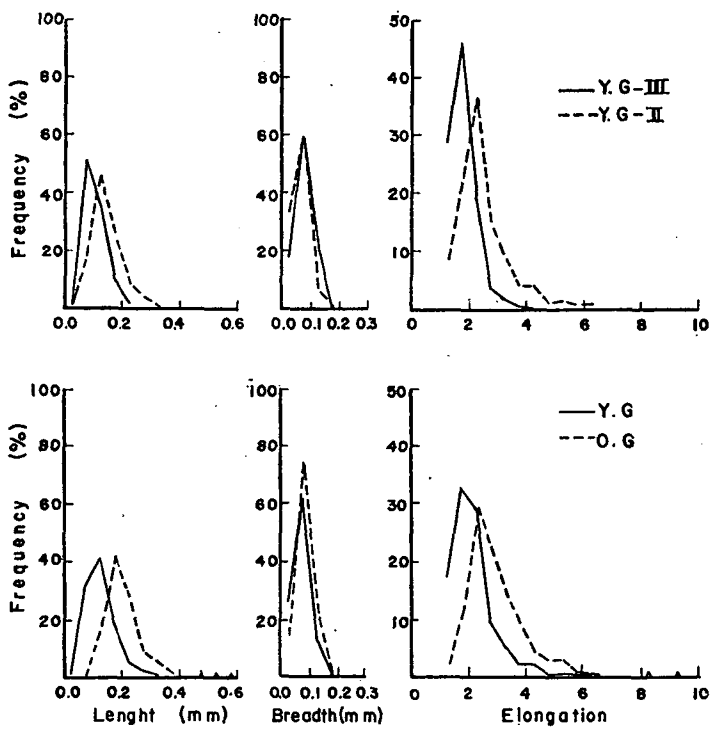

Fig. 6. Frequency curves for mean lengths, widths and elongation values for zircon populations in Wadi El-Sheikh granitoids

are given in Table 4. Reduced major axes of zircons are plotted in *Fig. 7*, where a distinction between the Older and Younger Granitoids is marked. The axis of the older granitoids have a longer length than that of the younger granitic rocks. Furthermore, their point for mean length *versus* mean breadth plots to the right of that of the Younger Granitoid Rocks.

DISCUSSION AND CONCLUSION

It is well established that granites of magmatic origin have a majority of euhedral zircons, in contrast to detrital zircon suites which usually contain a high percentage of rounded zircon (Poldervaart, 1955, 1956). The high percentage of sharply bounded, euhedral zircons in Wadi El-Sheikh granitic rocks suggests their magmatic origin. The enclosure of zircon in early and late constituent minerals suggests that zircon has crystallized early and continued up to the end of the magmatic stage.

With respect to the criterion of the coincidence of crystal length and *c*-axis, it is resonable to predict that during sedimentary transport, some elongate zircons will tend to break at angles other than 90° to their long axes, leading to the formation of rounded segments whose long axes does not concide with the *c*-axis (extinction position) of the original crystal. Murthy and Siddiquie (1964) found that well rounded zircons from some Indian metasedimentary rocks possess angles between

TABLE 2

Length and breadth frequencies of euhedral zircon in Wadi El-Sheikh Granitoids
(frequencies are given as percentages)

Sample №		0.00—0.05	0.05—0.10	0.10—0.15	0.15—0.20	0.20—0.25	0.25—0.30	0.30—0.35	0.35—0.40	0.40—0.45	>0.45
5*	x	—	—	20.5	26.0	27.0	16.5	7.0	2.5	—	0.5
	y	16.0	72.0	12.0	—	—	—	—	—	—	—
6	x	—	—	7.5	57.5	31.5	2.5	1.0	—	—	—
	y	8.5	85.0	6.5	—	—	—	-	—	—	—
8	x	-	-	15.0	40.0	28.0	8.5	8.5	—	—	—
	y	20.0	67.5	12.5	—	—	—	—	—	—	—
13	x	—	1.0	19.0	43.5	24.0	6.0	3.5	1.5	1.5	—
	y	12.0	73.5	14.0	0.5	—	—	—	—	—	—
O.G.	$\bar{x}$	—	0.1	15.5	41.8	27.6	8.4	5.0	1.0	0.4	0.1
	$\bar{y}$	14.1	74.5	11.3	0.1	—	—	—	—	—	—
21	x	—	21.0	46.5	19.5	10.5	1.5	0.5	—	—	0.5
	y	36.0	58.0	5.5	0.5	—	—	—	—	—	—
22	x	—	12.5	46.5	30.5	6.5	3.5	—	—	—	0.5
	y	32.0	63.0	5.0	—	—	—	—	—	—	—
25	x	0.5	21.5	34.5	25.5	9.5	6.5	1.0	1.0	—	—
	y	48.5	46.5	5.0	—	—	—	—	—	—	—
37	x	—	15.5	55.0	21.0	7.0	1.5	—	—	—	—
	y	15.5	74.5	9.5	0.5	—	—	—	—	—	—
	$\bar{x}$	0.1	17.6	45.6	24.1	8.4	3.3	0.4	0.3	—	0.2
	$\bar{y}$	33.0	60.5	6.3	0.3	—	—	—	—	—	—
42	x	1.6	62.5	23.4	8.6	3.1	0.8	—	—	—	—
	y	—	50.0	49.2	0.8	—	—	—	—	—	—
46	x	1.0	54.0	34.5	10.0	0.5	—	—	—	—	—
	y	34.0	58.0	7.5	0.5	—	—	—	—	—	—
47	x	1.0	36.5	49.0	11.0	2.0	0.5	—	—	—	—
	y	19.5	69.5	10.5	0.5	—	—	—	—	—	—
	$\bar{x}$	1.2	51.0	35.6	9.9	1.9	0.4	—	—	—	—
	$\bar{y}$	17.8	59.2	22.4	0.6	—	—	—	—	—	—
Y.G	$\bar{x}$	0.6	31.9	41.3	18.0	5.6	2.0	0.2	0.1	—	0.2
	$\bar{y}$	26.5	59.9	13.2	0.4	—	—	—	—	—	—

* Older Granitoids: 5—13; Younger Granitoids (Second phase): 21—37; Younger Granitoids (third phase): 42—47

TABLE 3

Elongation frequencies of euhedral zircon in Wadi El-Sheikh Granitoids
(frequencies are given in percentages)

Sample No.	100—14.9	1.50—1.99	2.00—2.49	2.50—2.99	3.00—3.49	3.50—3.99	4.0—4.49	4.50—4.99	5.0—5.49	5.50—5.99	6.0—6.49	<6.49
5	1.0	9.0	26.5	18.0	12.5	18.0	4.5	3.5	4.0	1.5	1.0	0.5
6	1.0	13.0	35.5	25.5	13.5	6.0	2.5	1.5	1.5	—	—	—
8	1.0	7.0	27.0	25.0	17.0	7.5	4.5	4.0	3.5	2.0	1.0	0.5
13	4.5	18.5	29.0	19.0	13.0	4.5	5.5	2.0	2.5	—	0.5	1.0
Mean (O.G.)	1.9	11.9	29.5	21.9	14.0	9.0	4.3	2.8	2.9	0.9	0.6	0.5
21	8.5	25.0	38.5	11.0	8.5	5.0	1.5	1.0	—	—	1.0	—
22	3.5	20.5	39.5	17.5	8.0	3.5	4.5	1.0	2.0	—	—	—
25	3.0	11.5	33.5	18.5	12.5	6.0	7.5	1.5	2.5	2.0	1.5	—
37	18.0	32.5	3.3	11.0	0.5	1.0	—	—	—	—	—	—
Mean	8.3	22.4	36.1	14.5	8.3	3.8	3.6	0.9	1.1	0.5	0.6	—
42	25.8	38.3	27.3	4.7	2.3	0.8	0.8	—	—	—	—	—
46	34.5	45.0	15.0	4.0	1.5	—	—	—	—	—	—	—
47	26.5	54.5	15.5	2.0	1.0	0.5	—	—	—	—	—	—
Mean	28.9	45.9	19.3	3.6	1.6	0.4	0.3	—	—	—	—	—
Mean (Y.G.)	17.1	32.5	28.9	9.8	5.4	2.3	2.2	0.5	0.6	0.3	0.4	—

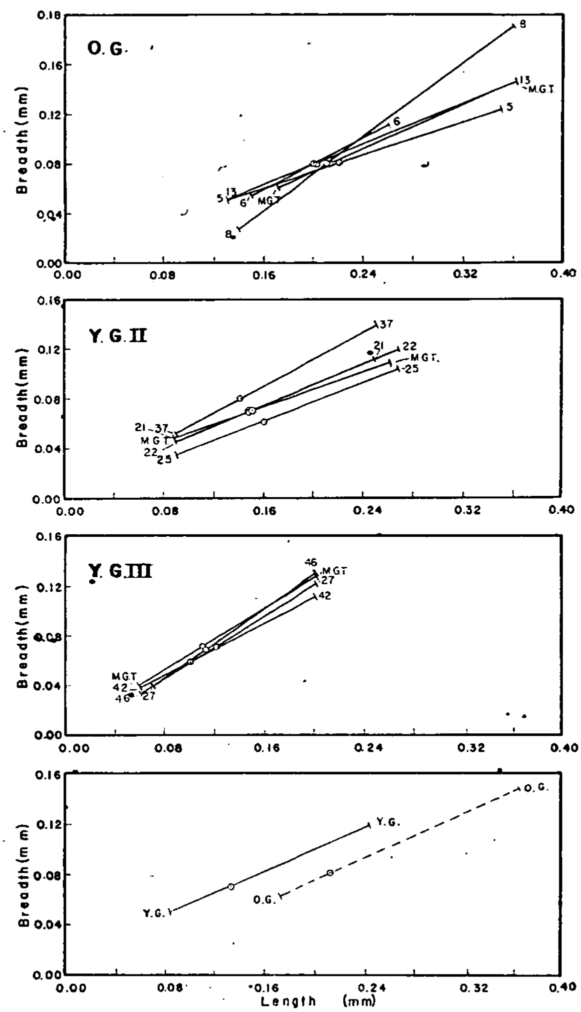

Fig. 7. Reduced major axes of zircon samples from Wadi El-Sheikh granitoids. MGT: mean growth trend of a zircon population

their length and *c*-axis in the range 13.28°—21.10°. Igneous rocks which have not been transported in the sedimentary cycle should exhibit a coincidence of crystal length and *c*-axis. This is true for all the studied suites.

The zircon percentage in the examined granitic rocks decreases from the older to the younger rocks. The distinction between the zircon populations in the two granitic groups is based mainly on their dimensional parameters. The populations in the Older Granitoids contain a wide variety of crystal shapes while those of younger granites become progressively more uniform in morphology. The RMA plots clearly show such distinction. In addition, inclusions in zircon of the older granitic rocks are abundant and diverse while zircons of the younger granites are inclusions poor. According to Pupin (1980) zircons of the sialic origin granites are inclusions poor

TABLE 4

Dimensional zircon data for Wadi El-Sheikh Granitoids

Sample No.	x (mm)	y (mm)	S_x (mm)	S_y (mm)	a	r	Dd
5	0.22	0.08	0.0681	0.0231	0.3392	0.4586	31.74
6	0.20	0.08	0.0326	0.0167	0.5123	0.1319	22.41
8	0.21	0.08	0.0576	0.0264	0.4583	0.4489	29.60
13	0.20	0.08	0.0602	0.0241	0.4003	0.3123	35.30
MGT* (O. G.)	0.21	0.08	0.0546	0.0226	0.4275	0.3379	29.76
21	0.15	0.07	0.0603	0.0250	0.4146	0.6347	33.46
22	0.15	0.07	0.0495	0.0207	0.4182	0.5237	31.75
25	0.16	0.06	0.0611	0.0244	0.3993	0.6028	34.32
37	0.14	0.08	0.0411	0.0220	0.5353	0.4848	29.35
MGT	0.15	0.07	0.0530	0.0230	0.4419	0.5615	32.22
42	0.10	0.06	0.0443	0.0232	0.5237	0.7293	31.55
46	0.11	0.07	0.0339	0.0240	0.7080	0.7489	22.58
47	0.12	0.07	0.0357	0.0227	0.6359	0.7961	19.44
MGT	0.11	0.07	0.0380	0.0226	0.6225	0.7581	24.52
MGT (Y. G.)	0.13	0.07	0.0466	0.0231	0.5193	0.5551	28.92

* MGT: Mean growth trend

while inclusions in zircons of granite of crustal and mantle origin are numerous and diversified. The partial melting of the mantle as proposed by HUSSEIN *et al.* (1982) for the origin of the Egyptian Older Granitoids, may account for this criterion.

The similarity of the dimensional parameters of zircons in the younger granitic phases of Wadi El-Sheikh area renders their separation difficult. However, elongation values change gradually from the second to the third phase granithes. In addition, colour of zircon changes (from colourless or pale green to brown and nearly black). The observed colour changes are probably due to progressively higher uranium and thorium contents, which could be correlated to the stage of differentiation of the Younger Granitoids of Wadi El-Sheikh area.

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