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TYPOLOGY AND MICROPROBE ANALYSIS OF ZIRCONS AS AN INDICATOR TO EVOLUTION AND GENESIS OF ABU EL-HASAN GRANITOIDS, NORTHERN EASTERN DESERT, EGYPT

M. L. KABESH[1], M. S. ATIA[2], M. DAWOUD[2]

[1] Dept. of Geological and Geophysical Sciences / National Research Center
[2] Geology Dept., Faculty of Science, Manoufia University

ABSTRACT

Zircons from the older and the younger granitoids of Abu El-Hasan granitic complex are typologically and geochemically characterized. Zircon populations of the older granitoids contain a wide variety of crystal shapes and do not show any overgrowths, outgrowths or corrosion. Zircons of the younger granitoids show much more regularity in distribution. Typological evolutionary trends of the studied zircons are suggested with decreasing age which may indicate some evolution. Microprobe analyses were carried out for different zircons from the granitic rocks to clarify the magmatic evolution, the crystal building and the crystallization of this accessory mineral. Back Scatter Electron (BSE) images of zircons are utilized to reveal zonal growth, crystal effect of the aggressive hydrothermal solutions and inclusions.

Chemical analyses were carried out from the core to the rim of the grains to deduce the variations through crystal growth and the magmatic evolution. Zr/Hf ratio is often between 40 and 30, but lower and higher values are also recorded. Generally, Zr/Hf ratio does not show clear trends from the core to the rim in the studied zircon. However, this ratio shows decreasing trend with differentiation for all the granitoids.

INTRODUCTION

Zircon is one of the most important accessorie in the rocks (if it is not the senior) because of many reasons. It shows a wide distribution in the different rocks, persistence in various environments, high resistance for erosion and stability against renewed high temperatures, pressures and anatexis. SPEER (1982) stated if for no other reason, zircon is a remarkable mineral because of its ubiquitous occurrence in the igneous, metamorphic and sedimentary rocks, meteorites and tektites. Importance of zircon, basically stems from two viewpoints:

1. The morphology and relative developing of its faces in prism(s) and pyramid(s) are tightly genetically related.

2. The ability of zircon to capture some radioactive elements gives it high prestige in age dating for the different types of rocks in different environments along the geological history; moreover a single crystal can tell us the historical geology, dating and geochemical variations through billions of years. Morphology of zircon as a petrogenetic indicator was discussed in some details by SPEER (1982).

The present study encompasses the morphological characters, microprobe analyses and BSE images of zircons with the aim to ascertain the origin and the evolution of the host granitoids of Abu El-Hasan, Northern part of the Eastern Desert, Egypt, (*Fig. 1*).

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[1] Cairo, Egypt
[2] Manoufia, Egypt

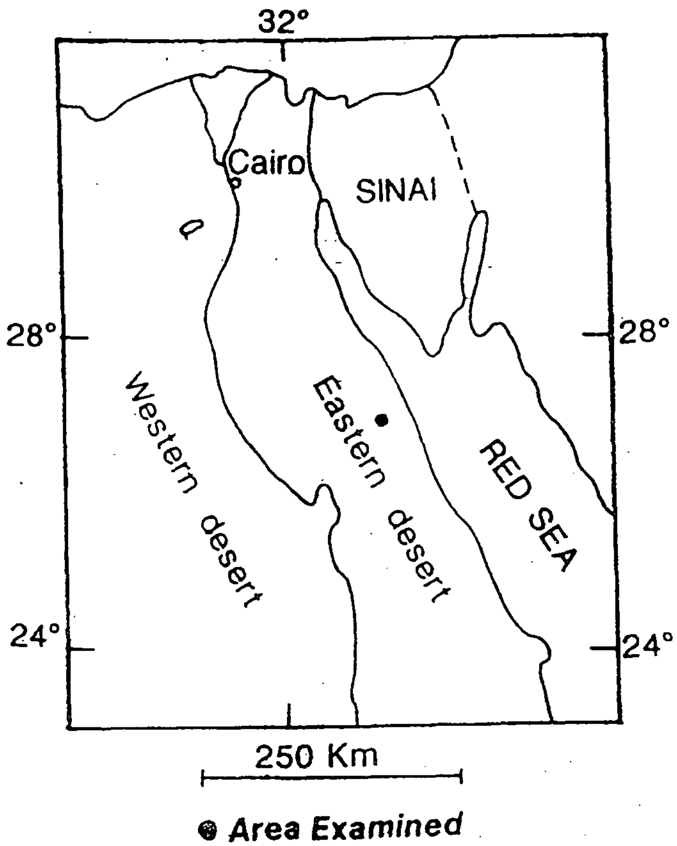


Fig. 1. Location Map

Broadly, the granitoids of Abu El-Hasan comprise older and younger types. However, details of field relations, petrography, tectonic setting and geochemistry of the granitoids of Abu El-Hasan are given by ATIA et al. 1998).

On the basis of typology of zircon population from granitic rocks PUPIN (1980) proposed a genetic classification with three main divisions: 1. granite of crustal or mainly crustal origin ('sub' autochtonous and aluminous granite); 2. granite of crustal + mantle origin, hybrid granites (calc-alkaline and sub-alkaline series granite); 3. granites of mantle or mainly mantle origin (alkaline and tholeiitic series granites). He also presented the spectacular theory that the relative size relations of two common zircon prisms {100} and {110} are controlled by temperature and can be taken as a direct measure for magmatic formation temperatures of granitic rocks, while the relative growth of zircon pyramids is connected with the characteristics of the crystallization medium. Subsequent works of PUPIN (1985, 1988) pointed out the relation between the genesis of the granitoid rocks and zircon morphology. PUPIN (op. Cit) constructed a typological classification „zircon habit chart" (*Fig. 4*) which has been used succesfully by several workers in the study of zircon in granitoids, such as RAJNDAR and HRABEAK (1989), CERGUNENKOF (1991), TONDER et al. (1990) and HUDUCH and LOESCHKE (1993).

REVIEW OF THE EGYPTIAN ZIRCONS

Several trials for studying of zircons from some Egyptian granitoid rocks were carried. Works of KHAFFAGY (1964), ZAGHLOUL and KHAFFAGY (1965), REFAAT (1970), RAGAB (1971), HEIKAL (1973), ABU EL-ELA (1973), ZAGHLOUL et al. (1981 a, b), ABD EL-MAKSOUD (1974) and ABD EL-GHAFFAR (1975) are such examples. Most of these studies are based on the description of the varietal features and the use of the Reduced Major Axis (RMA) as described by LARSEN and POLDERVAART (1957), to interpret the obtained data.

KABESH et al. (1976) clarified the significance of zircons as a guide to the petrogenesis of granites from Ras Barud area, Eastern Desert, and argued the formation of elbow twin to the crystallization from a melt which shows a sudden variation in the rate of crystallization. The presence of parallel growth to the high proportion of zircons crystallized early from a weakly viscous melt which permitted the movement and collision of growing zircon crystals. They noted also some necked zircons and attributed this to dissolution through a late stage of chemical corrosion. The examined zircons were characterized by sharply bounded crystals, uniformity of crystal, morphology and the elongation ratios mainly above two, all these led these authors (op cit.) to conclude a magmatic origin of the host granites.

ZAGHLOUL et al. (1981 a, b) recognized the value and efficiency of zircon study on subdivision of granitoid rocks of Gabal El-Shayib area into two genetically different groups: 1. Synorogenic group of metasomatic or granitization affiliation. 2. An intrusive magmatic group. They (op. cit.) also studied the distribution and abundance of zircons within these rocks and within the rock forming minerals and concluded that zircon was not entirely crystallized at an early stage but it appears to have a range of crystallization partly extending to the late stage.

HEIKAL et al. (1985) differentiated between the older and younger granitoids on the basis of dimensional parameters of zircons of Wadi El-Sheikh, southwestern Sinai. They also observed colour changes in the zircons of younger granitoid and this is attributed to progressively higher uranium and thorium contents, which could be correlated with the stage of differentiation of the younger granitoids. Zircon populations in the older granitoids contain a wide variety of crystal shapes, while those of the younger granitic rocks, become progressively more uniform in morphology rendering the magmatic origin for both.

EL-NASHAR (1992) presented a distinction between the two cycles of Samadai granitoid rocks, Eastern Desert, on the basis of HfO_2 enrichment in zircon. He also noted a change in Fe_2O_3 and Ce_2O_3 from the older to the younger granites, and he attributed this feature to the possibility of presence of two parental magmas.

Recently, EL-NASHAR (1998) studied the typological and geochemical characterization of zircons separated from some granitoids around Gebel Risasa, southeastern Sinai. According to this author, morphometric analyses of zircons proved useful in characterizing magmatic differentiation of the granitoid rocks and to distinguish calc-alkaline and alkaline granitic varieties. Moreover, the Zr/Hf ratios besides Y_2O_3 contents are useful in recognizing the major granitic series in the studied area.

BUDA et al. (1998) studied zircon grains from three different phases of the Precambrian granitoids of South Sinai in terms of complexity of crystal morphology, variability of forms and colour. According to these authors (op cit.) scanning electron microscope confirmed petrogenetic relation particularly those relating changes in zircon morphology to progressive differentiation of co-magmatic series. BUDA et al. (op cit.) further stated that zircon grains are broadly affected by post-magmatic equilibrations.

Concerning the zircon of Abu El-Hasan, HILMY et al. (1994-1995) described the abundance, distribution, some morphological characters, length and beradth, evolution trends and the reduced major axes for the studied two phases (phase II and phase III) of the younger granitoids. They (op cit.) revealed the physicochemical conditions during zircon crystallization in the two phases, although uniform conditions prevailed in all parts of the pluton.

SAMPLE PREPARATION

Zircons are separated from samples representing the older granitoids and the various three phases of the younger granitoids in a trial to study similarities, differences and relation between their zircons and to give some lights on the evolution and genesis of the host rocks. About 100 gms of each sample were crushed in jaw crusher and then in oscillating disc till materials passed through 250 μm grid sieve. This relatively coarse size was chosen because some zircons in thin sections are coarse (about 0.3 mm). The crushed samples were washed by a jet of water dried at 105 °C. The sieved materials were further separated by settling in tetrabrommethane heavy liquid (D = 2.96), which were washed perfectly by isopropanal alkohol, dried, and then electromagnetically separated by Franz isodynamic separator. About 50-100 zircon crystals were picked and mounted in canada balsam on microscope glass slides beneath a cover glass. Although picking of the zircons takes much time otherwise it facilities the study because the samples have some quartz and feldspar grains.

The studied zircons show variation and gradation in colour, usually it is colorless to pale yellow in the older granitoids and the oldest phase of the younger granitoids. Their similarity in colour and also in morphology could reflect the consanguinity between these rocks, although the zircon of the older granitoids shows wider morphological forms and some crystals are believed to be xenocrysts. The colour of zircons of the leucocratic granites are usually yellow to reddish grey. The red colour increased in the red granites and the fine grained granites (i. e. the red color increases from phase II to phase III). FIELDING (1970) argued the red color to result from color centers of Nb_4^+ ions produced by the radiation-induced reduction of Nb_5^+ substituting for Zr_4^+. In the studied zircon the red color is more or less related to the colour of the rock and increases with increasing of the relative age. It is suggested that this color is directly connected with a late flood of red hematitic iron oxide fluid. This coloration is seen more along the cracks and not only in zircon, but also thorugh all the rock-forming minerals. It should be remembered that the red colour is nearly absent in zircons of the older (grey) granitoids and phase I of the younger granitoids (buff and white). This rule of coloration-causing fluid should be regional in all the Egyptian granitoids and responsible for the field coloration of the younger granitoids which may be buff, pink or red. Occasionally the zircon of the older granitoids shows some red pigments, this may be argued to adhesion of some percolating hematitic drops to the surface of zircon crystals, and is obvious in some samples from the bottom of the wadi. The hematitic material sometimes coats the grains and in some others acts as glue between zircons and the other rock-forming minerals which makes it difficult or impossible to identify the faces of the crystals. Some opaque zircons (malacon or metamict) are occasionally found especially in the red granite and the leucocratic granite. Metamictization is generally attributed to the radiation damage produced by radioactive decay of thorium and uranium (MITCHELL 1973), but in the studied zircons it is believed to be due to the attack of zircon by hematitic solutions.

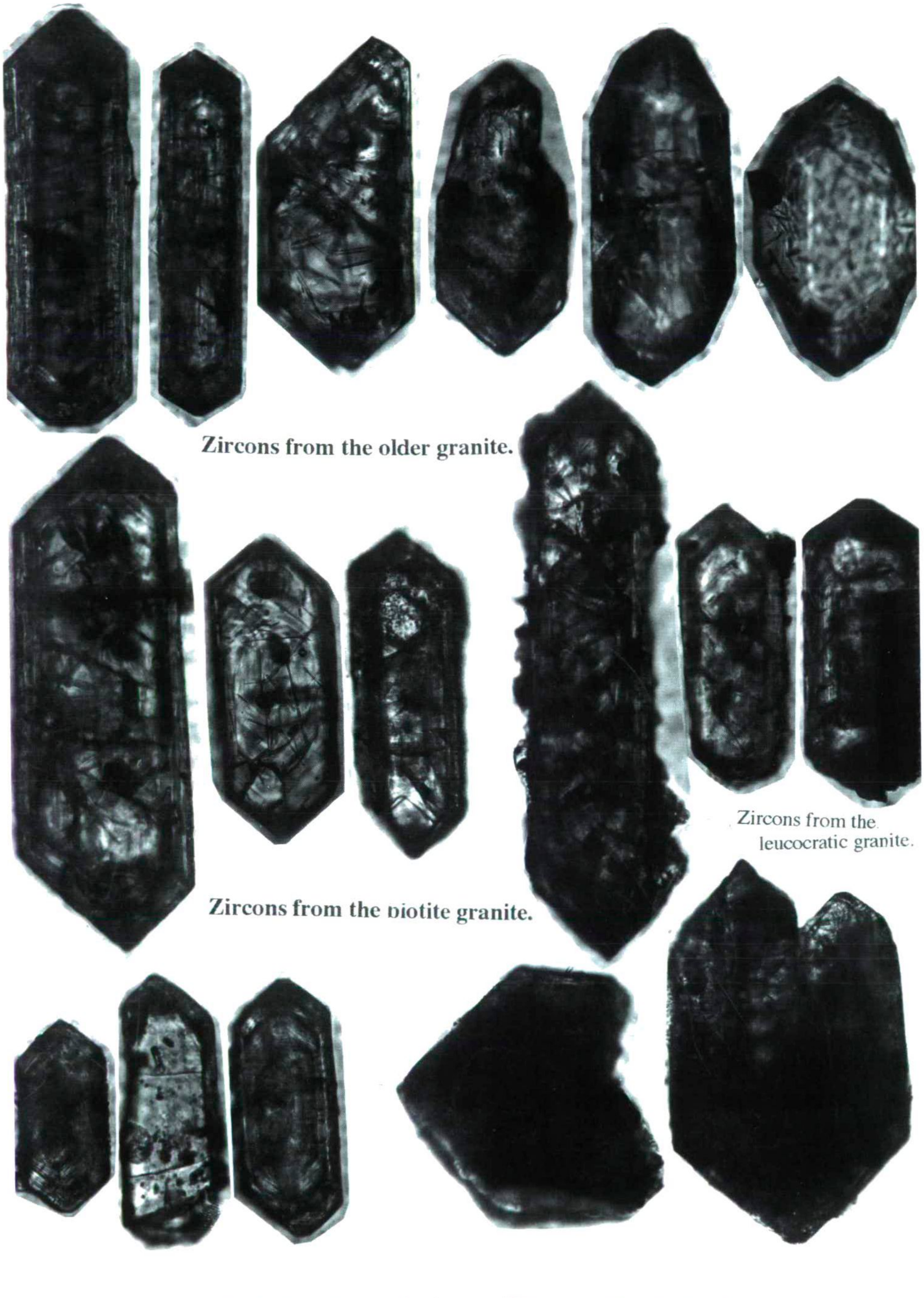


Fig. 2. Photomicrographs showing different varieties of zircons

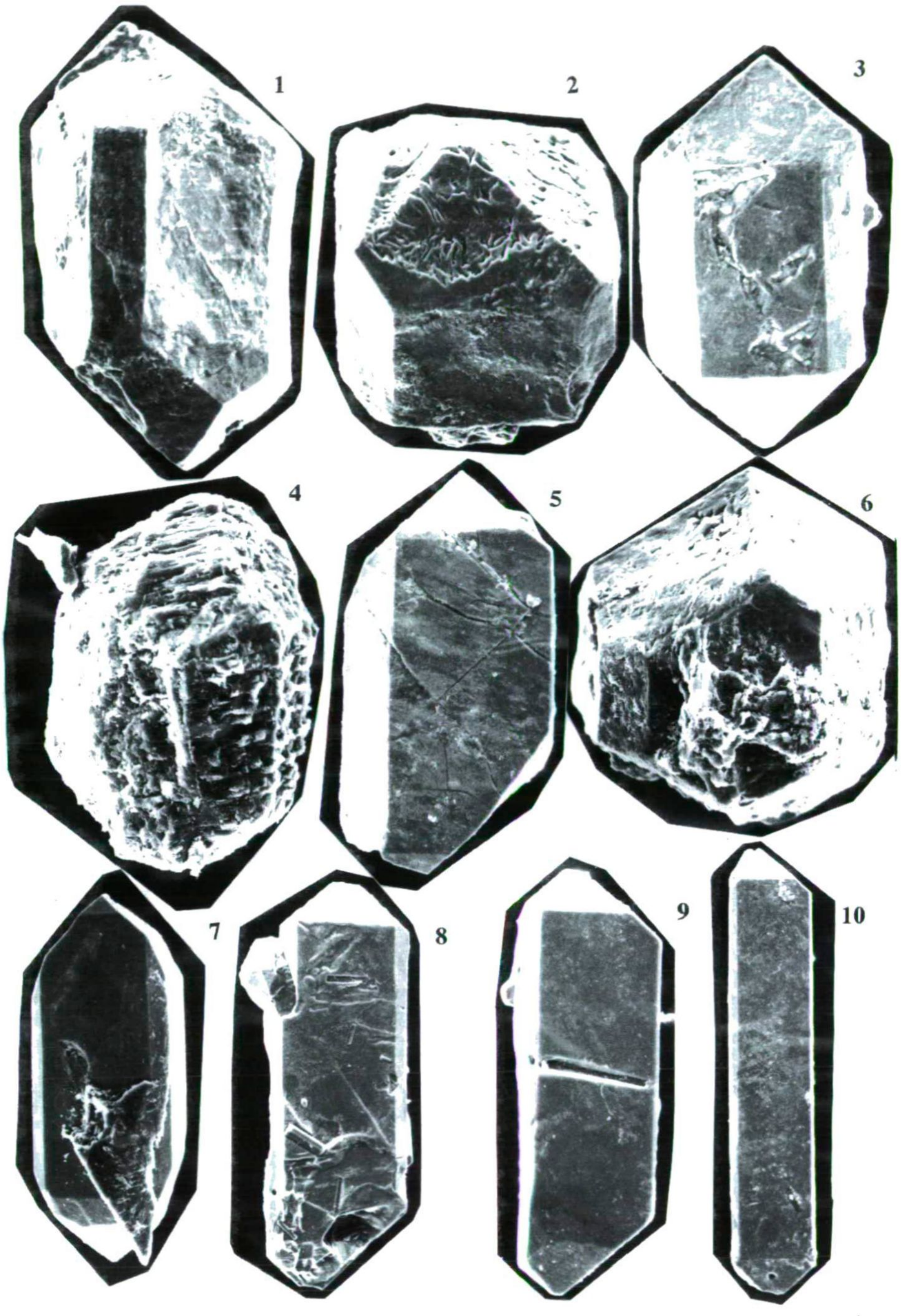


Fig. 2. Continued. SEM images for different varieties of Abu El Hasan zircon.

The abundance of zircon is varied in the studied granitoids and reaches its maximum in the biotite granite (phase I of the younger granites) which contains a fair amount. The older granitoids contain a bit lower. Zircons of both groups are more or less similar in many characters. Leucocratic granite (phase II), red granite and fine grained granite (phase III) have rather low abundance with more or less similar zircons. Some of the zircons of phase II and phase III are attacked by iron oxides or even completely replaced, so fragments and corroded zircons can be seen. Zircons are found as inclusions in the early formed minerals as hornblende, biotite and plagioclase, as well as in the later ones as orthoclase and quartz which supposes early to late crystallization of zircon, also water-rich magma (PUPIN et al., 1979). The zircons of the older granitoids and phase I of the younger granitoids are long prismatic to moderately prismatic in habit with length range from 150 to 300 μm and length / breadth 4 to 2, while those of phase II and III are moderately prismatic to stubby with length range between 250 and 60 μm and length / / breadth about 3 to 1.5. Nearly all the studied crystals are euhedral, but some are attacked and show corrosion canals.

The studied zircons have some inclusions which are mainly apatite, zircon, opaques and dust. These inclusions are haphazardly oriented and more abundant in zircons of the older granitoids. Some zircon crystals are free of inclusions especially those in phase II and III of the younger granitoids. Some of the inclusions are partly enclosed as minute biotite flakes and opaques. It should be mentioned that zircons of the older granitoids and phase I of the younger granitoids have much less cracks than those of phases II and III of the younger granitoids (their zircons are usually brittle and highly cracked).

Overgrowths are rarely seen but they are represented in considerable amount. Both the parallel and elbow twinning are relatively common in the fine grained rather than the other units which is attributed to sudden cooling. Some crystals are massive without any zoning, while zoned crystals are more common. Some of them show unzoned internal area with zoned periphery while others show rhythmic zoning throughout. *Fig. (2)* shows different varieties of the studied zircons.

ZIRCON TYPOLOGY OF ABU EL-HASAN GRANITOIDS

In this context a method which is based on the careful study of the morphology of zircons is used, plotting of the main subtypes, calculation of typological parameters (mean points A-, T-, T.E.T) were carried out according to PUPIN and TURCO (1972a) and results were interpreted principally according to PUPIN (1980).

Fig. (3) shows the typologic frequency distribution of the populations of Abu Al-Hasan zircon, it is clear that the older granitoids occupies larger area with various forms which support the belief that some of those are xenocrystals (with frequency less than 2 %) and could be inherited from more older rocks or digested xenofragments. Although these crystals are very clear and do not show any overgrowths, outgrowths, or corrosion as compared with the original crystals. Otherwise the younger granitoids show much more regularity in the distribution. It can be seen that only the pyramid {101} is the dominant in the older granitoids and the sole in the younger granitoids, while most of the zircons have the two prisms {100} and {110} with larger {100} prisms. It can be noted also that the zircon population moves down on the diagram with decreasing age of the rock units. According to PUPIN (1976) all the studied rocks either older or younger types plot in the fields of alkaline and hyperalkaline syenites and granites, while according to the genetic classification of PUPIN (1980) these rocks plot in the field of mantle or mainly mantle origin (alkaline and tholeiitic series granites). *Fig. (4)* shows the mean points and typological evolutionary trends of the studied zircons, there is a non-regular movement of the points down with decreasing age which may indicate some evolution or differentiation from the older to the younger rocks. Otherwise if we consider the approximate temperature scale proposed by PUPIN and TURCO (1972b) we will get non-plausible data whereby the older granitoids were formed during a wide range of temperature (600-900 °C) which increase gradually in the younger granitoids being in contradiction with the well known rules.

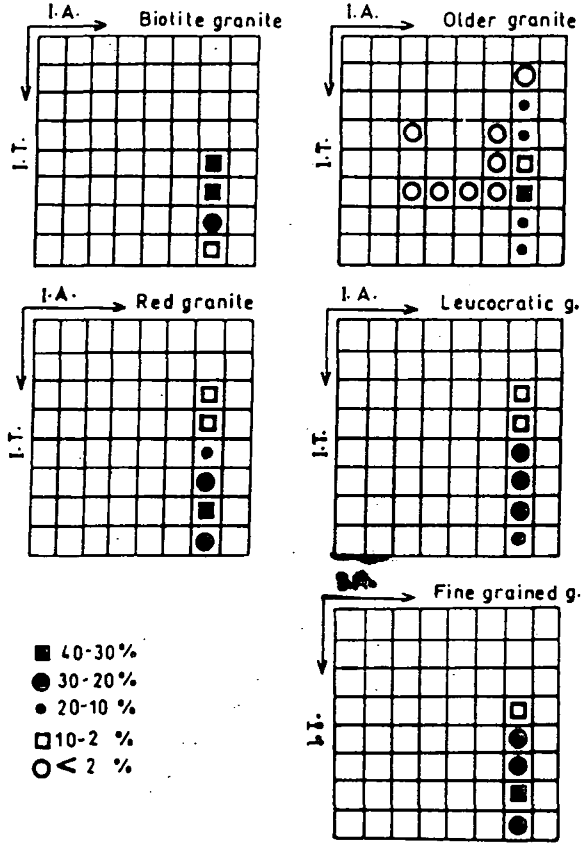
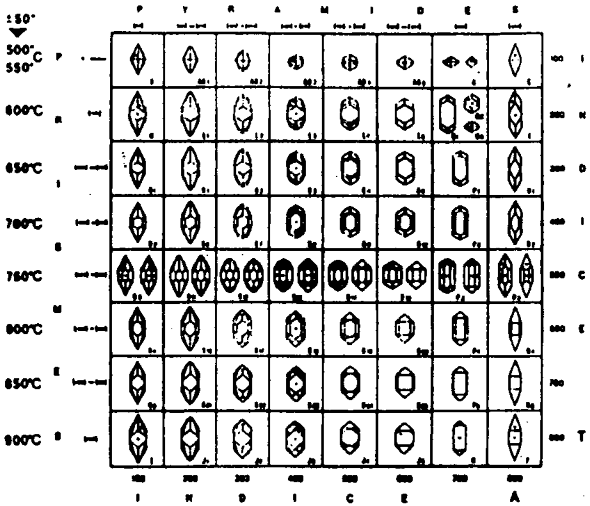


Fig. 3. Typological frequency distribution of the populations of zircons

MICROPROBE STUDY OF ABU EL-HASAN ZIRCON

Extensive microprobe analyses were carried out for different zircons from all the rock units in a trial to identify and study the magmatic evolution and the crystal building during the crystallization of this mineral. This can be done by studying cautiously the chemical variations in the different zones. Because it is believed that the zircon could be an early mineral, it also can tell about the parent magma and the preliminary stages of the magma evolution and composition.



Main types and subtypes of the typological classification, PUPIN (1980)

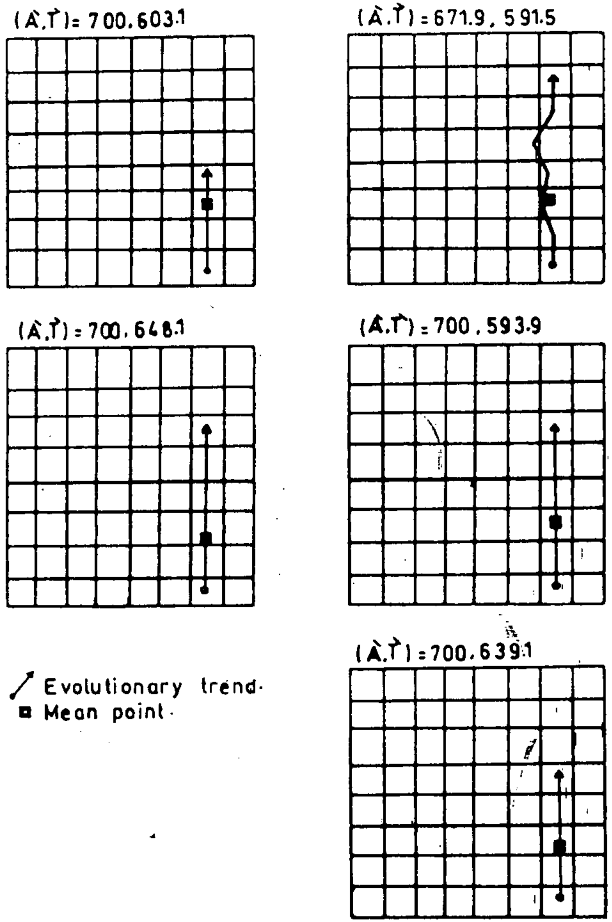


Fig. 4. Mean points (A', T') and typological evolutionary trends (T. E. T.) of zircons

Preparation of the samples and the analytical conditions

For better and accurate understanding of zoning we prepared oriented sections perpendicular to the C axis and others parallel to it, some details about the preparation of such sections were described by BENISEK and FINGER (1993). Briefly the zircons were aligned on a glass slide with glue perpendicular (or parallel) to arbitrary line and then cut cautiously till the middle using fine powder (1200) in the final stages (then the parallel sections were polished), then this slide was fixed perpendicular to another and cut till the zircon thickness reached 20-50 μm. The crystallographic orientation was noted and registered before the treatment, *Fig. 5* shows a sketch after BENISEK and FINGER (op cit.). Afterwards the sections were perfectly polished with 3 and 1 μm diamond.

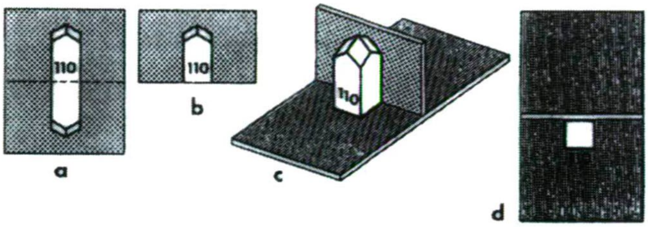


Fig. 5. Sketches showing how zircons were prepared for microprobe work, after BENISEK & FINGER

Microprobe work was carried out on the JEOL probe JXA-800 of Salzburg University. Spot analyses were made with a beam diameter about 1 μm using an accelerating voltage of 20 KV and a beam current of 40 NA. Elements Si, Zr, Hf, U, Th, Y, P, Ca, Al and Fe were routinely determined. Counting between 10-20 seconds per element were chosen. The detection limits reached with these conditions between 0.05 wt % (Y_2O_3) and 0.01 wt % Al_2O_3. Ca, Al and Fe can be detected in some spots and anomalously high values were recorded in the altered spots (up to 3 % CaO, 1.5 % Al_2O_3 and 2.5 % FeO). HREE, LREE, Y, Th and U were detected in some spots. Natural zircon, apatite and synthetic HfO_2, UO_2, ThO_2, $Y_3Al_5O_{12}$, YbF_3, $LuSi_2$, Fe_2O_3 served as standards for microprobe analyses. Raw concentrations were recalculated by applying normal ZAF corrections. Relative δ errors resulting from counting statistics are typically 3-5 % for the 1 wt % level and about 20% for the 0.1 wt % level. Back scatter electron (BSE) images were recorded with constant 20 KV accelerating voltage, but with different beam current and different gain of the photomultiplier to optimize the resolution for each grain. This means that zircon growth zones of similar chemical composition may have the same grey tone in the different BSE picture.

Description of the BSE images

Because these images are based on the differentiation between the mean atomic numbers (bright when they are high and black when they are low) these are very effective in revealing three main features in our zircons: 1. zoning and crystal growth. 2. effect of the aggressive hydrothermal solutions and 3. inclusions. The discrimination between the zircons of the different rock units is rather clear using these images. Zircons from the older granites often show central weakly (narrow-spaced) zoned or unzoned cores (about several tens of micrometers) and more obvious narrow – spaced rim (about 10-30 μm). The crystals have a lot of vugs (very difficult to get good polished surface) and cleavage can be seen. Mineral inclusions are nearly absent, some crystals show hydrothermal alteration which is thought to be of exogenic origin due to percolating aggressive surfacial or rain water. Zircons from the biotite granites often show nice large-spaced zoning (one zone ranges from few micrometers to few tens of micrometers), many apatite crystals and some vugs are included. It was noted that the cracks are concentrated in the dark zones rather than the bright ones, this can be attributed to the expansion of the bright zones because of the high radiation causing pressure leading to cracking in the dark zones. Zircons from the leucocratic granites show some similarity to those of the older granitoids having inner unzoned cores, and outer highly ragged rims because of hydrothermal alteration. These solutions draw very fascinating pictures which look like the carpets or brain structure. Cleavages and cracks are not uncommon in the altered parts where the solutions were flowing.

Zircons from the red granites show regular spaced zoning throughout the grain from the center to the rim (about 2 μm). The corrosion canals run parallel to the zoning causing low topography (usually dark) corroded zones alternating with high topography brighter zones. Such variation in surface topography makes it impossible to get good polishing. Large scale zoning is represented in some cases. Inclusions are nearly absent. Zircons from the fine grained granites are very fascinating because of the drawing caused by the hydrothermal alteration and they show variation in the structure in contrast to the zircons from other rock units. Some grains have unzoned core and narrow-spaced zoned rim, some others are totally unzoned or show large-spaced regular zoning. In many times alteration obliterated the original zoning and only relics can be seen. Some grains show very clearly the corrosion canals of the solutions. Cracks are common and cleavages are sometimes seen. Inclusions are rare or nearly absent while some vugs are present. *Fig. 6.* shows some BSE images for the different rock types.

It is noted that the effect of the hydrothermal solutions reaches its climax in the case of the leucocratic and fine grained granites, while it is less or absent in the older and biotite granites. These alterations are somehow correlated with the color of the rocks. What is interesting is that zircons of the red granites (the most reddish rocks) have not such apparent alterations but effect of these solutions can be interfered from the analyses and the surface texture of the grains, the infected spots by such solutions have much higher amounts in Fe, Ca and Mn and this is the case for all the spots of the red granites, while the corrosion canals can be detected in the low topography zones. Broadly two different processes can be invoked to explain the origin of these solutions:

1. Exogenic processes in which the source is surfacial or rain solutions. This happened in the case of the older and biotite granites where the rocks as whole are grey or whitish respectively and only some samples (and also some zircons) were infected by the solutions.
2. Endogenic processes which can be classified into secondary (or late magmatic) and primary (or syn-crystallization). The former is invoked for the solutions affecting the leucocratic and fine grained granties where a clear secondary solution effect. The primary or syn-crystallization solutions are thought to be homogenized with the magma which leads to the red granites crystallization where no clear secondary effect but only inferred.

CHEMICAL ANALYSES

Chemical analyses were carried out in spots from the core to the rim of the grains to deduce the variations through crystal growth and the magmatic evolution. Some spots are taken from the altered parts to see the effect of these solutions on the chemistry of the zircon (Table 1). All the studied zircons are typical zircon (CORRERIA NEVES et al.,

TABLE I

Representative chemical analyses of the studied zircon (Grain LG 1)

No.	1	2	3	4	5	6	7	15	Aver. Fresh	8	9	10	11	12	13	14	Aver Alt.
SiO_2	30.08	30.57	30.78	30.56	30.60	29.72	32.15	30.51	30.62	29.81	29.39	28.54	28.61	28.23	27.96	28.95	28.78
HfO_2	1.74	1.88	2.07	2.08	1.87	1.77	1.99	1.97	1.92	1.74	1.72	1.61	1.69	1.71	1.60	1.61	1.67
Yb_2O_3	0.19	0.49	0.38	0.15	0.09	0.26	0.33	0.00	0.24	0.31	0.28	0.38	0.42	0.52	0.65	0.72	0.47
Al_2O_3	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.02	0.01	0.09	0.08	0.00	0.00	0.30	0.29	0.42	0.17
Er_2O_3	0.24	0.10	0.00	0.11	0.00	0.20	0.33	0.00	0.12	0.14	0.00	0.11	0.27	0.27	0.60	0.30	0.24
MgO	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.05	0.01	0.02	0.02	0.00	0.02	0.02
CaO	0.03	0.00	0.02	0.00	0.08	0.04	0.03	0.04	0.03	1.77	1.79	2.06	1.58	1.43	1.22	1.45	1.61
FeO	0.00	0.00	0.00	0.07	0.06	0.00	0.00	0.04	0.02	1.99	1.95	2.32	1.05	1.40	1.22	1.12	1.58
Gd_2O_3	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.10	0.03	0.10	0.00	0.16	0.14	0.00	0.15	0.11	0.09
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.42	0.47	0.28	0.16	0.27	0.26	0.32
Eu_2O_3	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sm_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.01	0.00	0.00	0.00	0.11	0.21	0.12	0.10	0.08
Pr_2O_3	0.18	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.04	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Nd_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.01	0.00	0.00	0.00	0.00	0.18	0.15	0.32	0.09
TiO_2	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sc_2O_3	0.06	0.00	0.11	0.00	0.00	0.00	0.06	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.01
P_2O_5	0.14	0.07	0.04	0.00	0.06	0.14	0.12	0.00	0.07	0.09	0.13	0.07	0.11	0.10	0.20	0.15	0.12
Ce_2O_3	0.00	0.08	0.06	0.00	0.06	0.06	0.09	0.06	0.05	0.07	0.08	0.06	0.00	0.27	0.17	0.33	0.14
La_2O_3	0.05	0.00	0.10	0.00	0.07	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01
UO_2	0.62	0.70	0.30	0.20	0.00	0.82	0.40	0.11	0.39	0.71	0.64	0.68	0.69	0.42	0.46	0.37	0.57
ThO_2	0.46	0.45	0.23	0.00	0.08	0.62	0.20	0.00	0.26	0.32	0.36	0.46	0.40	0.26	0.48	0.30	0.37
Nb_2O_3	0.00	0.00	0.00	0.11	0.00	0.13	0.00	0.00	0.03	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.03
ZrO_2	65.08	64.31	63.29	63.89	64.72	62.39	62.74	64.27	63.84	58.45	59.01	57.51	58.23	57.19	56.07	56.80	57.61
Y_2O_3	1.23	1.20	0.89	0.15	0.30	1.07	0.90	0.36	0.76	0.95	0.98	1.09	0.78	1.74	2.55	0.84	1.28
Total	100.1	99.85	98.35	97.59	98.18	97.22	99.51	97.54	98.54	97.33	96.88	95.53	94.38	94.41	94.23	94.24	95.29

Representative chemical analyses of the studied zircon (Grain LG 2)

No.	1	2	3	4	5	6	7	8	9	Aver. Fresh
SiO_2	31.33	31.29	31.97	31.88	32.12	32.44	32.29	32.53	32.76	32.07
HfO_2	2.15	2.04	2.19	1.96	1.77	1.94	2.05	5.57	6.03	2.86
Yb_2O_3	0.19	0.22	0.23	0.08	0.11	0.00	0.12	0.07	0.10	0.12
Al_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Er_2O_3	0.11	0.13	0.08	0.15	0.11	0.13	0.00	0.00	0.00	0.08
MgO	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
CaO	0.03	0.00	0.00	0.00	0.00	0.04	0.00	0.03	0.03	0.01
FeO	0.00	0.00	0.00	0.04	0.00	0.04	0.04	0.06	0.11	0.03
Gd_2O_3	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.15	0.05
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01
Eu_2O_3	0.09	0.00	0.00	0.13	0.00	0.06	0.00	0.00	0.00	0.02
Sm_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.02
Pr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nd_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.00	0.08	0.00	0.05	0.00	0.00	0.08	0.06	0.00	0.03
Sc_2O_3	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01
P_2O_5	0.11	0.08	0.06	0.00	0.04	0.00	0.05	0.04	0.00	0.04
Ce_2O_3	0.06	0.13	0.08	0.00	0.00	0.10	0.10	0.00	0.00	0.05
La_2O_3	0.00	0.00	0.08	0.00	0.00	0.09	0.00	0.00	0.00	0.02
UO_2	0.48	0.41	0.25	0.00	0.11	0.00	0.09	0.25	0.19	0.20
ThO_2	0.19	0.33	0.13	0.10	0.12	0.00	0.07	0.13	0.00	0.12
Nb_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZrO_2	62.56	63.26	63.88	64.71	65.43	64.31	63.87	63.63	60.09	63.53
Y_2O_3	0.63	0.66	0.37	0.00	0.39	0.25	0.22	0.00	0.00	0.28
Total	97.93	98.64	99.32	98.98	100.2	99.75	98.99	102.5	99.51	99.54

TABLE 1 continued

Representative chemical analyses of the studied zircon (Grain FG 1)

No.	23	24	25	31	Aver. Fresh	26	27	28	29	30	31	32	33	34	35	36	Aver Alt.
SiO_2	33.00	32.18	31.68	31.55	32.10	29.39	26.67	25.09	28.88	25.74	31.55	28.45	27.36	23.57	25.30	30.62	27.51
HfO_2	1.66	1.34	1.65	2.67	1.83	1.50	1.67	1.73	1.78	2.34	2.67	1.41	1.34	3.66	1.83	2.13	2.01
Yb_2O_3	0.16	0.09	0.00	0.19	0.11	0.74	0.49	0.51	0.47	0.29	0.19	0.48	0.47	0.31	0.43	0.43	0.44
Al_2O_3	0.00	0.00	0.02	0.00	0.01	0.02	1021	1043	0.00	1.26	0.00	0.08	0.34	1.33	1.46	0.00	0.65
Er_2O_3	0.00	0.00	0.00	0.14	0.04	0.52	0.30	0.32	0.34	0.16	0.14	0.29	0.37	0.12	0.37	0.13	0.28
MgO	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.00	0.05	0.00	0.01	0.03	0.06	0.06	0.00	0.03
CaO	0.05	0.03	0.03	0.05	0.04	0.45	1.25	1.43	0.98	1.67	0.05	0.64	1.52	1.55	1.58	0.66	1.07
FeO	0.15	0.10	0.06	0.13	0.11	1.21	2.45	2.20	0.61	2.26	0.13	1.19	2.46	2.50	2.10	1.55	1.70
Gd_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.25	0.00	0.00	0.00	0.11	0.20	0.00	0.00	0.08
MnO	0.00	0.00	0.00	0.00	0.00	0.15	0.20	0.13	0.19	0.15	0.00	0.16	0.14	0.15	0.13	0.22	0.15
Eu_2O_3	0.00	0.00	0.11	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01
Sm_2O_3	0.00	0.00	0.08	0.00	0.02	0.00	0.00	0.11	0.00	0.00	0.00	0.13	0.16	0.12	0.00	0.00	0.05
Pr_2O_3	0.25	0.00	0.00	0.00	0.06	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Nd_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.01
TiO_2	0.00	0.00	0.09	0.00	0.02	0.00	0.00	0.11	0.10	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.02
Sc_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.06	0.05	0.00	0.05	0.00	0.02
P_2O_5	0.06	0.04	0.08	0.12	0.08	0.33	0.49	0.61	0.28	0.62	0.12	0.56	0.29	0.64	0.62	0.22	0.43
Ce_2O_3	0.17	0.05	0.00	0.11	0.08	0.05	0.14	0.18	0.00	0.18	0.11	0.08	0.06	0.15	0.16	0.00	0.10
La_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
UO_2	0.00	0.09	0.07	0.37	0.13	0.94	0.89	0.88	0.77	0.62	0.37	0.89	0.83	1.04	0.64	0.70	0.78
ThO_2	0.00	0.09	0.00	0.00	0.02	0.32	0.28	0.38	0.41	0.39	0.00	0.58	0.25	0.14	0.28	0.29	0.30
Nb_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZrO_2	65.73	63.85	64.70	63.04	64.33	58.47	50.47	56.69	57.93	55.96	63.04	57.87	56.20	58.72	59.29	59.32	58.54
Y_2O_3	0.19	0.18	0.11	0.32	0.21	1.67	1.06	1.27	1.17	0.96	0.34	1.50	1.51	0.68	1.29	1.13	1.14
Total	101.4	98.04	98.66	98.71	99.21	96.03	97.73	93.53	94.16	92.65	98.71	94.38	93.49	95.00	95.75	97.46	95.35

TABLE 1 continued

Representative chemical analyses of the studied zircon (Grain FG 2)

No.	1	2	3	4	5	6	7	Aver. Fresh	8	9	10	Aver. Fresh
SiO_2	31.14	30.86	31.09	31.50	31.96	31.98	31.94	31.50	28.39	26.10	25.38	26.62
HfO_2	2.12	2.18	2.09	2.17	2.00	2.05	2.16	2.11	1.86	1.89	1.67	1.81
Yb_2O_3	0.23	0.36	0.28	0.27	0.13	0.13	0.16	0.22	0.32	0.65	0.96	0.64
Al_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.68	1.10	0.60
Er_2O_3	0.17	0.22	0.09	0.09	0.00	0.00	0.00	0.08	0.14	0.46	0.67	0.42
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.02
CaO	0.00	0.05	0.05	0.03	0.03	0.05	0.06	0.04	1.18	0.79	0.92	0.96
FeO	0.00	0.00	0.04	0.00	0.09	0.08	0.03	0.03	0.46	1.07	1.23	0.93
Gd_2O_3	0.00	0.12	0.00	0.00	0.00	0.15	0.00	0.04	0.13	0.34	0.14	0.17
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.15	0.14	0.17
Eu_2O_3	0.00	0.00	0.12	0.06	0.11	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Sm_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.20	0.42	0.26
Pr_2O_3	0.22	0.00	0.00	0.00	0.00	0.25	0.00	0.07	0.17	0.00	0.16	0.11
Nd_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.00	0.10	0.44	0.18
TiO_2	0.05	0.00	0.12	0.12	0.00	0.05	0.00	0.05	0.00	0.00	0.06	0.02
Sc_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.02
P_2O_5	0.09	0.01	0.08	0.03	0.00	0.05	0.09	0.05	0300	0.76	0.85	0.54
Ce_2O_3	0.00	0.13	0.06	0.00	0.00	0.10	0.11	0.06	0.09	0.17	0.40	0.22
La_2O_3	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.01	0.00	0.00	0.00	0.00
UO_2	0.47	0.57	0.49	0.10	0.00	0.08	0.00	0.24	0.54	0.67	0.69	0.63
ThO_2	0.31	0.00	0.00	0.10	0.00	0.18	0.10	0.10	0.32	0.39	0.30	0.34
Nb_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.03	0.00	0.00	0.00	0.00
ZrO_2	63.41	62.69	64.14	64.59	65.03	65.49	64.15	64.36	59.27	56.68	53.09	56.35
Y_2O_3	0.88	0.84	0.84	0.60	0.25	0.39	0.14	0.56	0.90	2.06	3.42	2.13
Total	99.09	98.03	100.5	99.66	99.6	101.1	99.22	99.6	94.22	93.16	92.49	93.29

TABLE 1continued

Representative chemical analyses of the studied zircon (Grain RG 1 and RG2)

No.	1	3	4	5	6	7	8	9	10	Aver. Fresh	16	17	18	19	20	21	22	Aver Alt.
SiO_2	27.51	27.85	27.78	29.59	28.15	27.13	30.08	29.69	28.12	28.43	30.29	26.47	28.68	30.23	32.59	30.90	27.25	29.49
HfO_2	1.97	1.70	1.64	1.78	1.87	1.92	2.22	1.98	2.39	1.94	1.88	1.75	1.65	1.73	2.08	1.90	1.59	1.79
Yb_2O_3	0.55	1.14	0.35	0.56	0.62	1.01	0.18	0.06	0.13	0.51	0.24	0.18	0.50	0.36	0.09	0.12	0.82	0.33
Al_2O_3	0.88	1.11	0.54	0.86	1.12	1.22	0.01	0.00	0.19	0.66	0.37	0.70	0.75	0.93	0.04	0.30	1.00	0.58
Er_2O_3	0.39	0.66	0.14	0.53	0.45	0.91	0.00	0.09	0.18	0.37	0.11	0.52	0.38	0.17	0.14	0.00	0.61	0.28
MgO	0.02	0.04	0.02	0.04	0.03	0.03	0.01	0.00	0.00	0.02	0.01	0.00	0.03	0.02	0.00	0.03	0.03	0.02
CaO	0.91	1.25	1.17	0.77	1.09	1.24	0.04	0.05	0.39	0.77	0.58	0.98	0.28	0.58	0.14	0.76	1.21	0.65
FeO	1.27	1.10	1.42	0.77	0.83	0.81	0.06	0.12	0.30	0.74	0.39	0.44	0.08	0.23	0.00	0.30	0.49	0.28
Gd_2O_3	0.35	0.37	0.11	0.00	0.10	0.29	0.00	0.00	0.00	0.14	0.18	0.24	0.00	0.00	0.00	0.00	0.22	0.09
MnO	0.00	0.05	0.12	0.00	0.11	0.07	0.00	0.00	0.12	0.05	0.00	0.10	0.00	0.07	0.00	0.00	0.13	0.04
Eu_2O_3	0.00	0.07	0.06	0.00	0.07	0.00	0.10	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sm_2O_3	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.04	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.03
Pr_2O_3	0.43	0.00	0.00	0.00	0.17	0.19	0.00	0.16	0.00	0.11	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.02
Nd_2O_3	0.13	0.00	0.14	0.00	0.11	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.14	0.00	0.00	0.136	0.17	0.06
TiO_2	0.06	0.00	0.00	0.06	0.07	0.17	0.00	0.00	0.05	0.05	0.12	0.08	0.00	0.00	0.00	0.00	0.140	0.04
Sc_2O_3	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.00	0.00	0.05	0.00	0.00	0.00	0.02
P_2O_5	0.59	1.04	0.25	0.47	0.85	1.05	0.04	0.05	0.22	0.51	0.46	0.77	0.60	0.36	0.07	0.47	0.90	0.52
Ce_2O_3	0.13	0.19	0.06	0.05	0.00	0.13	0.00	0.00	0.00	0.06	0.00	0.12	0.11	0.00	0.15	0.00	0.13	0.07
La_2O_3	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.06	0.00	0.16	0.00	0.03
UO_2	0.55	0.47	0.36	0.27	0.46	0.51	0.08	0.15	0.13	0.33	0.32	0.10	0.23	0.17	0.00	0.07	0.24	0.16
ThO_2	0.34	0.22	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.09	0.12	0.08	0.00	0.06	0.00	0.00	0.09	0.05
Nb_2O_3	0.00	0.00	0.00	0.13	0.39	0.70	0.00	0.00	0.00	0.14	0.00	0.14	0.26	0.00	0.10	0.00	0.38	0.12
ZrO_2	59.54	55.81	59.51	61.56	58.70	55.11	66.10	66.02	63.75	60.68	61.62	64.97	60.77	60.98	63.01	63.30	59.70	62.05
Y_2O_3	2.69	4.37	1.29	1.12	2.78	4.52	0.11	0.10	0.52	1.94	2.08	0.55	2.88	1.13	0.14	1.13	3.55	1.64
Total	**98.37**	**97.78**	**95.1**	**98.56**	**97.97**	**97.15**	**99.03**	**98.62**	**96.49**	**97.67**	**98.88**	**98.34**	**97.52**	**97.13**	**98.55**	**99.57**	**98.61**	**98.37**

TABLE 1 continued

Representative chemical analyses of the studied zircon (Grain BG 1 and BG2)

No.	1	2	3	4	5	6	7	8	9	Aver. Fresh	1	2	3	4	5	Aver. Fresh	6	7	8	Aver Alt.
SiO_2	32.02	32.16	32.55	32.66	32.62	32.87	32.42	32.11	32.50	32.45	32.51	32.68	32.73	32.46	32.77	32.63	30.11	30.45	29.63	30.06
HfO_2	1.47	1.52	1.75	1.71	1.81	1.76	2.25	1.96	2.28	1.83	1.82	1.81	1.77	2.16	2.85	2.08	2.94	2.77	2.66	2.79
Yb_2O_3	0.24	0.10	0.18	0.07	0.00	0.00	0.314	0.15	0.21	0.12	0.00	0.13	0.00	0.369	0.33	0.17	0.46	0.25	0.22	0.31
Al_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.07	0.20	0.34	0.20
Er_2O_3	0.11	0.00	0.14	0.00	0.00	0.12	0.13	0.00	0.09	0.07	0.00	0.10	0.00	0.30	0.35	0.15	0.28	0.12	0.18	0.19
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.00	0.04	0.03	0.02
CaO	0.00	0.00	0.02	0.05	0.03	0.05	0.00	0.00	0.04	0.02	0.00	0.03	0.00	0.00	0.00	0.01	1.98	2.34	2.04	2.12
FeO	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.28	1.34	2.72	1.45
Gd_2O_3	0.00	0.00	0.19	0.00	0.00	0.11	0.00	0.00	0.00	0.03	0.12	0.14	0.00	0.00	0.14	0.08	0.19	0.00	0.19	0.13
MnO	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.11	0.10
Eu_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.01	0.00	0.17	0.00	0.06
Sm_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pr_2O_3	0.21	0.00	0.30	0.00	0.00	0.00	0.22	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.20	0.00	0.14
Nd_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.03
TiO_2	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.12	0.02	0.00	0.05	0.00	0.02
Sc_2O_3	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.02	0.10	0.00	0.00	0.03
P_2O_5	0.11	0.00	0.07	0.06	0.07	0.09	0.07	0.09	0.04	0.07	0.06	0.00	0.03	0.15	0.16	0.08	0.15	0.12	0.11	0.13
Ce_2O_3	0.00	0.00	0.00	0.09	0.07	0.00	0.11	0.00	0.00	0.03	0.00	0.00	0.08	0.14	0.00	0.04	0.06	0.05	0.16	0.09
La_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UO_2	0.00	0.00	0.17	0.00	0.07	0.19	0.18	0.39	0.18	0.13	0.09	0.00	0.00	0.58	0.74	0.28	0.96	0.68	0.59	0.74
ThO_2	0.07	0.00	0.00	0.00	0.09	0.08	0.16	0.08	0.10	0.06	0.00	0.00	0.00	0.26	0.08	0.07	0.28	0.23	0.00	0.17
Nb_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.02	0.09	0.00	0.00	0.03
ZrO_2	64.75	65.36	65.89	66.53	65.98	65.08	64.96	63.73	65.44	65.30	65.20	64.87	66.77	64.47	63.34	64.93	58.70	57.90	56.71	57.77
Y_2O_3	0.79	0.46	0.27	0.23	0.24	0.14	0.66	0.52	0.42	0.41	0.10	0.25	0.15	0.78	0.63	0.38	0.93	0.63	0.59	0.72
Total	**99.77**	**99.71**	**101.5**	**101.4**	**101.3**	**100.5**	**101.3**	**99.03**	**101.3**	**100.6**	**99.98**	**100.1**	**101.6**	**101.8**	**101.6**	**101**	**97.79**	**97.72**	**96.38**	**97.30**

TABLE I continued

Representative chemical analyses of the studied zircon (Grain OG 1 and OG2)

No.	1	2	3	4	5	6	7	8	Aver Fresh	1	2	3	4	5	Aver. Fresh	6	7	8	Aver Alt.
SiO_2	32.56	32.84	32.74	33.13	32.88	32.76	32.13	31.23	32.53	31.38	31.52	31.17	31.96	32.54	31.71	28.27	28.45	29.30	28.67
HfO_2	1.67	1.73	1.71	1.69	1.47	1.88	2.36	2.10	1.83	3.10	3.14	3.13	3.29	2.87	3.11	2.71	2.80	2.73	2.75
Yb_2O_3	0.00	0.00	0.14	0.00	0.07	0.24	0.12	0.26	0.10	0.19	0.28	0.27	0.10	0.11	0.19	0.22	0.31	0.28	0.27
Al_2O_3	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.03	0.09	0.07
Er_2O_3	0.00	0.18	0.09	0.00	0.00	0.19	0.011	0.09	0.08	0.21	0.10	0.24	0.00	0.00	0.11	0.22	0.18	0.00	0.13
MgO	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
CaO	0.03	0.05	0.14	0.00	0.07	0.02	0.07	0.07	0.06	0.04	0.03	0.05	0.03	0.04	0.04	3.10	3.18	3.03	3.10
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.79	0.75	0.84
Gd_2O_3	0.00	0.11	0.16	0.00	0.10	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.02	0.00	0.00	0.12	0.00	0.00	0.04
MnO	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.04
Eu_2O_3	0.00	0.00	0.07	0.10	0.00	0.10	0.00	0.11	0.05	0.12	0.00	0.16	0.00	0.00	0.06	0.00	0.00	0.00	0.00
Sm_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pr_2O_3	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.04	0.18	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Nd_2O_3	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.12	0.02	0.00	0.00	0.00	0.00
TiO_2	0.06	0.09	0.00	0.00	0.00	0.00	0.13	0.00	0.04	0.00	0.00	0.00	0.13	0.07	0.04	0.05	0.08	0.09	0.07
Sc_2O_3	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.02
P_2O_5	0.04	0.11	0.00	0.04	0.00	0.15	0.03	0.08	0.06	0.07	0.10	0.10	0.07	0.04	0.08	0.10	0.10	0.07	0.09
Ce_2O_3	0.00	0.06	0.07	0.00	0.00	0.07	0.00	0.00	0.03	0.09	0.00	0.09	0.00	0.08	0.05	0.15	0.06	0.10	0.10
La_2O_3	0.00	0.08	0.00	0.00	0.00	0.00	0.08	0.00	0.02	0.00	0.00	0.00	0.00	0.06	0.01	0.00	0.00	0.00	0.00
UO_2	0.00	0.00	0.00	0.08	0.00	0.44	0.37	0.47	0.17	0.50	0.52	0.90	0.31	0.09	0.46	0.57	0.68	0.38	0.54
ThO_2	0.00	0.00	0.00	0.08	0.00	0.09	0.08	0.15	0.05	0.15	0.26	0.24	0.00	0.10	0.15	0.36	0.28	0.00	0.21
Nb_2O_3	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
ZrO_2	64.88	66.23	63.87	65.65	63.66	63.55	63.36	63.15	64.29	63.74	63.09	61.73	61.19	62.23	62.40	54.93	55.96	57.41	56.10
Y_2O_3	0.00	0.08	0.08	0.00	0.00	0.68	0.27	0.59	0.21	0.33	0.27	0.65	0.23	0.18	0.33	0.60	0.49	0.43	0.51
Total	**99.34**	**101.7**	**99.07**	**100.8**	**98.26**	**100.5**	**99.14**	**98.3**	**99.64**	**100.3**	**99.31**	**98.73**	**97.33**	**98.53**	**98.83**	**92.47**	**93.39**	**94.83**	**93.56**

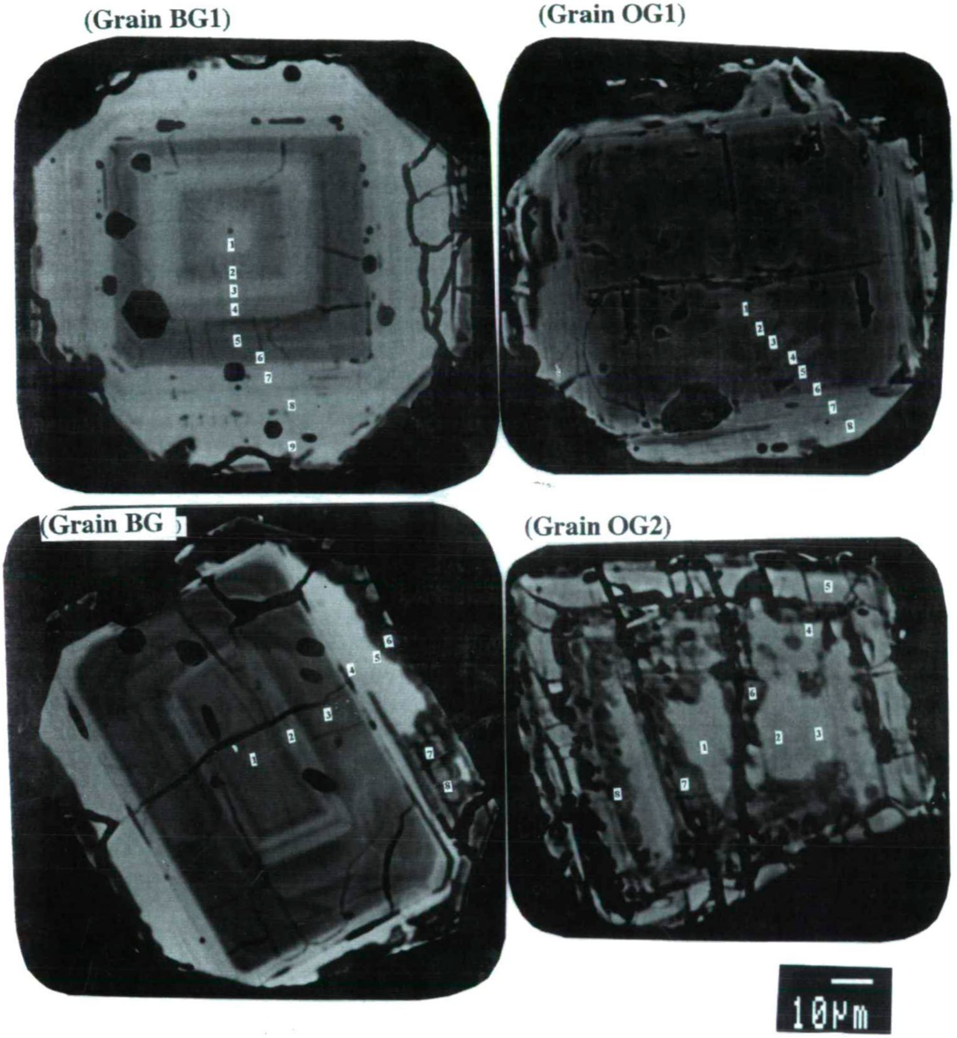


Fig. 6. Representative back scatter electron images (BSEI) for some zircon grains

1974), with HfO_2 ranging mostly between 1 and 2 % but sometimes a bit more than 3 % in a grain from the older granitoids. Moreover the rim of one grain from the leucocratic granites has HfO2 up to 5 or 6 % (hafnian SiO_4 zircon) which is traditionally interpreted as solid solution between ZrSiO4 and HfSiO4. Zr/Hf ratio is often between 40 and 30 but lower and higher values are also recorded. The grain from the older granites which has a high Hf content shows lower Zr/Hf ratio, about 20, while the spots from the rim of grain of the leucocratic granite have Zr/Hf ratio around 10. Zr / Hf ratio generally does not show clear trends from the core tho the rim in the studied zircons, except for those from the biotite granite where it roughly increases towards the rim. Although this ratio shows decreasing trends with differentiation for all the rock groups in the whole rock analyses it is not clear why such trend is not obvious in all zircons. Y and some REE are found in

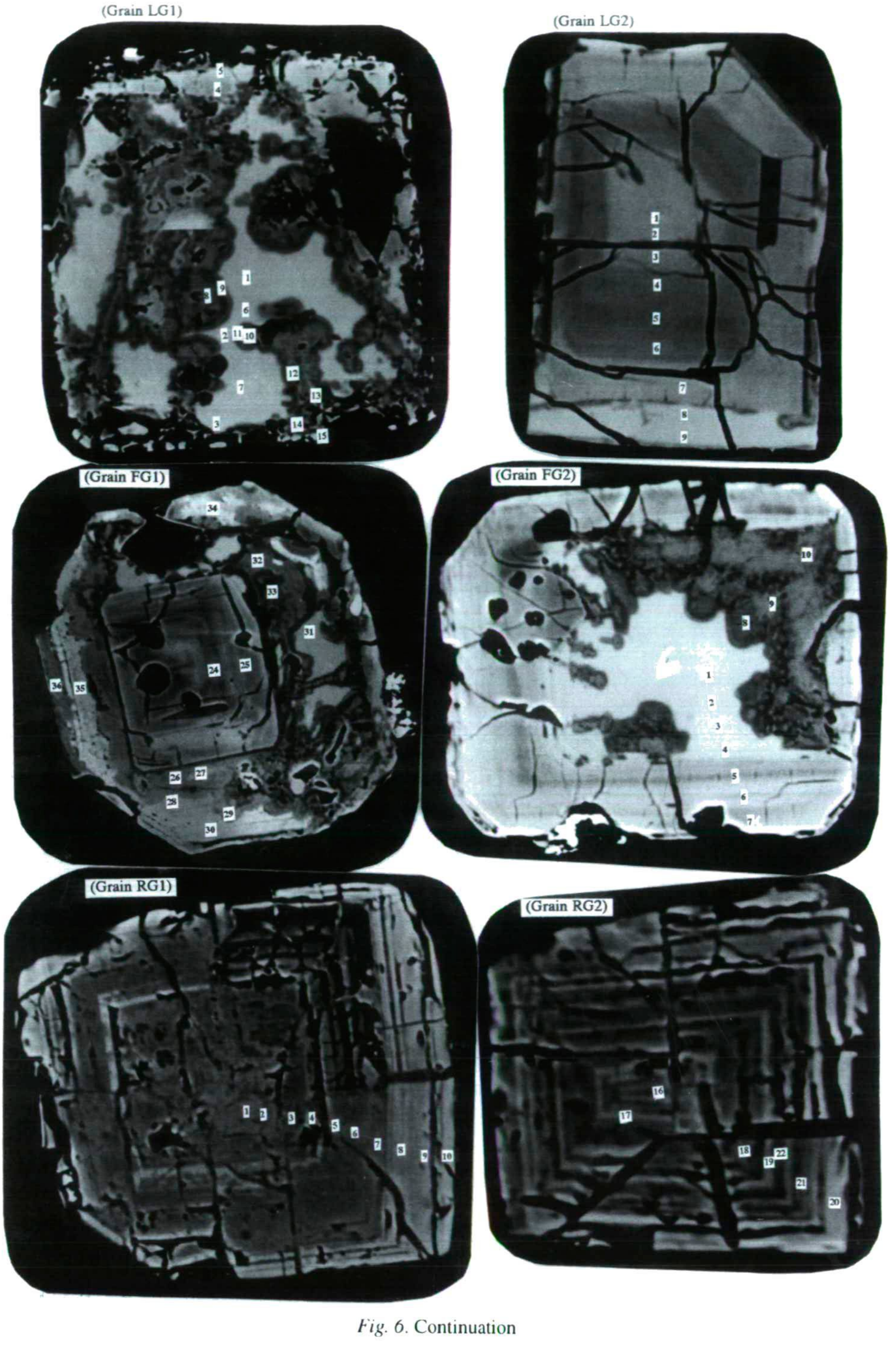


Fig. 6. Continuation

detectable amounts in many spots. The most common are Y and Yb which show a cognate relation and reach the maxima in zircons from the red granite. Their relation with Hf is not clear. Y is mostly below 1 % but reaches more than 4 % in some spots from the red granites in which Yb reaches more than 1 %, although it is often lower than 0.3 %. Th and U are detected in many spots but are under detection limit in others, U/Th ratio is mostly between 2 and 4 although in the whole rock it usually ranges between 0.33 and 0.25. In the older granites it reaches 0.12, SPEER (1982) attributed such phenomenon either to preferential inclusion of U (r = 1.00 A°) or cocrystallization with Th-enriched phases such as allanite, monazite and thorite or both. In our case the second possibility is not well supported because the biotite granites which are the most enriched in allanite show the same ratio as the other units, so may be the first probability is more realistic. Other elements as Al, Mg, Ca, Fe, Mn, Ti, Sc, P and Nb stayed often below or around the detection limits, but they are detected in more amounts in the altered spots and this is an advantage for analyzing such uncommon elements.

On chemical bases, the variation in zircon compostion (within the same grain) is less in the older granites and biotite granites than the other groups, which could reflect more stable conditions during the crystallization. Zircons from the older granites are somewhat strange while one gratin had high Hf averages 3.11 oxide percent, another one has low Y averages 0.21 oxide percent indicating a very different chemistry of the melt and in turn could also indicate a different span of time for crystallization of zircons in the older granitoids. This is also clear from the widespread zircon typology on Pupin diagram. One grain out of five from the biotite granites show decrease in Y from the center to the end of its core and increases in the outher rim which could be explained by cocrystallization of Y incorporating minerals (only local effect) as hornblende or sphene. The same effect is also seen in grains from the leucocratic granites and fine grained granites. Zircons from the red granites show strong oscillatory zoning although this is not clear in Hf. They are also enriched in Al, Ca, Fe, P, Mn and Y, low in Si, and Zr and look like the altered spots from the other zircons. *Fig. 7.* shows the variations of some elements through chemical traverses in zircons.

The effect of aggressive hydrothermal solutions is very clear in the back scatter electron images (BSEI). These solutions caused dissolution of the zircon and changed its chemistry. They led to decrease in Si and Zr and enhanced all the other elements. The solutions affecting the older granitoids were more rich in Ca (spot analysis of zircon for CaO = 3.1 %) than in the biotite granites (CaO = 2.12) in the leucocratic granites (CaO = 1.61 %) and that of the fine grained granites (CaO = 1.07 %). The reverse is shown in iron where the solutions affecting the older granitoids are less (FeO = 0.84 %) than the others (FeO = 1.45) in biotite granites, 1.58 in the leococratic granites and 1.70 in the fine grained granites, while in the red granites the effect of such solutions is not apparent as mentioned before. It seems that the composition of these solutions is rather compatible with the bulk chemistry of the rock. Two possibilities could be invoked for the explanation of the origin of these solutions: 1. They are residual from the same magma after consolidation, and then can carry the chemical imprints of their original magma. They started to react with the rock in the pneumatolytic stage. If this assumption is correct it requires that the reaction is widespread all over the rock and grains and this is not achieved in the case of the older granites and biotite granites, but could be correct in the other cases. 2. These solutions are exotic and acquired the chemical characteristics of the rocks through the penetration and dissolution of some parts of the rocks. This case could be realistic for the older and biotite granites where the effect is limited to some zircon grains. In the case of the red granites these solutions could be syn-crystallization.

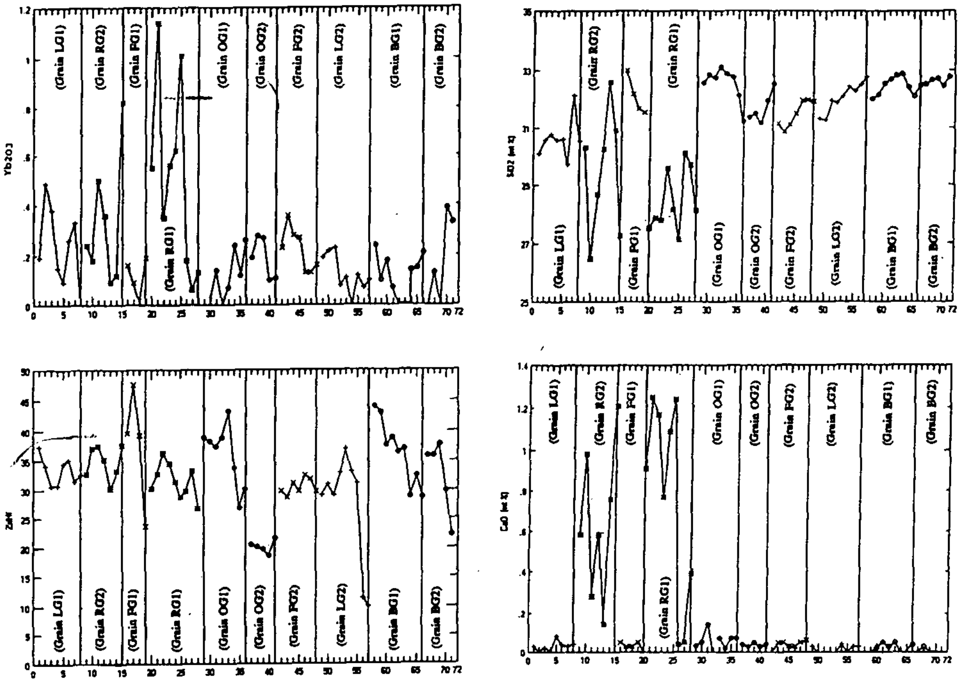


Fig. 7. Variation of some elements during zircon growth from core to rim

CONCLUSIONS

Zircons of the older granitoids of Abu El-Hasan, Northern Eastern Desert, Egypt, exhibit wide variations in crystal shapes. They do not show any overgrowths, outgrowths or corrosion, whereas those of the studied younger granitoids show much more regularity. BSE images of zircons reveal zonal growth, inclusions and different crystal effects due to hydrothermal solutions.

Zr/Hf ratios for zircons range from 40 to 30 with some anomalies. These ratios do not show clear trends from the core to the rim of the zircon grains, whereas they decrease with differentiation for all the studied granitoids.

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