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MINERALOGICAL AND FLUID INCLUSIONS EVIDENCE FOR THE GENESIS OF UMM ADDEBBAA-UMM KABU BERYL BELT, SOUTH EASTERN DESERT, EGYPT

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ABSTRACT

Beryl mineralization in quartz veins and pegmatites, are common deposits of tectonic–hydrothermal and/or igneous origin. The beryl-specialized granites association at Umm Addebaa–Umm Kabu belt is manifested in the field by the development of a system of beryl-bearing pegmatitic pods and quartz veins. The emplacement of these syn-tectonic pegmatitic leucogranites from which K- and Be-rich fluid phases were derived, are confined to the shear zones, as well as a broad zone of alkali metasomatism.

Microthermometic studies of primary fluid inclusions within beryl growth zones are consistent with beryl precipitation from H_2O-$CO_2 \pm CH_4$ bearing saline brines. The estimated fluid composition is approximately 0.88 mol% H_2O, 0.017 mol% $CO_2 \pm 0.001$ mol% CH_4 and 0.10 mol% NaCl (2- 11 wt.% NaCl eq.). Fluid inclusion results are consistent with that mineralization in pegmatites and quartz veins that are formed by two genetic stages. The first stage is characterized by temperature of formation in the range of 216.4 – 378.3 °C, with corresponding pressures along fluid inclusion isochore paths ranging from 1.04 to 2.25 bar. The second stage is of aqueous fluid represented with low temperature (177-255°C) and pressure ≤ 1 bar, but high saline (16-22 wt.% NaCl eq.) which might explain mixing of the early carbonaceous fluid with late meteoric water accompanied with pressure release. Thus, it can be inferred that the Be-bearing solutions were moderately saline, but CO_2 (and possible CH_4)-rich fluid implies that Be was most probably complexed by carbonate ($^+CH_4$) - chloride base.

The different paragenetic types of emerald and beryl associated with granitoid rocks indicates that the chemistry of the Be-bearing fluids (rather than that of the bulk rock), and syn-tectonic intrusions of leucogranites and pegmatites (Be deriving sources) along major ductile shear zones are the important factors controlling the crystallization of beryl.

INTRODUCTION

Beryl is one of the main sources of beryllium (Be) which is considered as a very important nuclear element. At the same time, some species of beryl can be considered as gemstones, e.g. emerald and aquamarine (Hassan and El-Shatoury 1976, Omar 2001). The usage of beryllium in the atomic energy is widely known. The demand for beryllium and its alloys are steadily increasing owing to its versatile application in the nuclear industries. Beryllium metal, oxide and its alloys are used as a basic material in the nuclear technology and also in industrial purposes (Pahler, 1995).

Beryl and emerald deposits occur in a ~ 30-km long NW-trending zone in Wadi El Gemal area in the Eastern Desert of Egypt and were exploited for gemstones since ancient times until the 1930's (Sadek, 1951, Omar, 2001, Takla et al., 2003 and Surour et al., 2003). These mining works resulted into huge mine dumps which contain significant amounts of beryl. These dumps are already mined for the Be ore, which attracted the attention of Nuclear Materials Authority as a valuable resource of Be. Emerald is thought to be rare because Be and Cr are not commonly found together in sufficient concentrations in iron poor medium temperature environments to stabilize Cr–emerald. Mafic and ultramafic rocks are generally enriched in Cr and V, whereas rock-enriched Be, Al and Si are pegmatites, evolved granites, and metamorphic rocks. Extensive works Schwarz and Giuliani, 2001; Giuliani et al., 2000 and Vapnik and Moroz, 2002) have shown that there are two general models for emerald mineralization, namely magmatic associated and tectonic– hydrothermal. Emerald deposits linked to magmatism are generally associated with granitic intrusions and surrounding rocks. The source of Be for emerald is generally surmised to be the granitic rocks with some contribution from the country rocks too. In this model, Cr is exclusively derived from the country rocks, which are generally mafics and ultramafics. According to Schwarz and Giuliani (2001), most of the emerald occurs in veins and associated alteration haloes. Emerald is precipitated during the metasomatic alteration of the host rocks by high-temperature fluids derived from the cooling intrusions. Abdalla and Mohamed (1999) had recognized two paragenetic types of beryl mineralization in the Precambrian rocks of Egypt: (1) emerald-schist; and (2) beryl-specialized granitoid associations. Geological and geochemical features of the emerald deposits substantiate the role of syn-tectonically emplaced leucogranites as a source for the Be solutions. Infiltration of such solutions through the nearby permeable sheared schist sequence and the intercalated serpentinite bands cause pervasive metasomatism of the serpentinites and schists into phlogopite-rich rocks and result in localization of emeralds.

Mining for beryl was also conducted at several other sites within a 15 km radius of Wadi Sikait (including Gabal Zabara, Wadi Nugrus, Wadi Abu Rusheid, Wadi Umm Kabu, Wadi Umm Addebbaa, and Wadi El-Gemal) but only from the mid-6th Century AD onwards (Harrell, 2004). The Cr-dominant emeralds are commonly restricted to schists with subordinate slices of amphibolites and serpentinites which overly biotite ortho-gneiss. This sequence is intruded by leucogranite bodies and associated pegmatites (Abdalla and Mohamed, 1999). At Wadi Sikait, emerald occurs in the contact zone between quartz and pegmatite veins in a phlogopite schist (Basta and Zaki, 1961; El-Dogdoge et al., 1997; Abdalla and Mohamed, 1999 and Harrell, 2004). The veins, generally only a few cm thick but up to one meter in some places, are deformed and commonly appear as discontinuous bands and pods. Colorless, white and light green beryl crystals are found in the quartz and pegmatite veins but true emerald is restricted to the schist within tens of cm at the contact. Giuliani et al., (2000) used stable isotopic compositions of beryl mineralization and stated that the Egyptian emerald originated from magmatic water.

In the present study, the mineralogical, geochemical and fluid inclusions characteristics of emerald and beryl of the two associations are examined to elucidate the factors responsible for the localization of different paragenetic types of beryl mineralisation, even with similar Be-deriving sources. Two localities along Umm Addebbaa–Umm Kabu belt represent both of emerald-schist association and beryl granitoid association; were selected for the present investigation. The microthermometric study of fluid inclusions presented in the present paper may help to distinguish Egyptian emeralds from other emerald examples and can help to characterize their P-T conditions during their formation.

GEOLOGY OF UMM ADDEBBAA–UMM KABU BELT

The geology and structure of Umm Addebbaa- Umm Kabu belt has been dealt by many authors, among them Schneider and Arzruni (1892); MacAlister (1900); Couyat (1911); Stella (1934); Hume (1937); Basta and Zaki (1961); El-Shatoury et al., (1974); Hassan and El-Shatoury (1976); Soliman (1986); Awad (1993); Surour (1993&1995); Abdalla and Mohamed (1999); Omar (2001); Surour et al. (2003); Talka et al. (2003) and others.

Detailed mapping by Omar (2001) and field observations revealed that the beryl and emerald occurrences of Umm Addebbaa- Umm Kabu belt (Fig. 1) are characterized by the presence of many rock types namely, gneisses, schists (metasedimentary matrix), fragments of ultramafics, metagabbros, metavolcanics and phlogopite rocks in addition to intrusive bodies of mylonitized granodiorite, muscovite and biotite granite. Usually, biotite granite occurs as small unmappable masses. Mèlange rocks represent the most dominant unit which is dissected by several pegmatite dykes and pockets, barren and beryl-bearing quartz veins, which are boudinaged in parts.

Ophiolitic Melange Rocks

Field observations revealed that the mélange unit could be subdivided into ophiolitic mélange and metasedimentary matrix.

Ophiolitic fragments

These fragments are represented by ultramafics and their related rocks, foliated and massive metagabbros, metadiabases and amphibolites.

Ophioltics ultramafics are represented by serpentinites and talc-carbonates. Due to the presence of impurities, these fragments are usually dark green to grey but they may appear red or black depending on the type and amount of carbonates.

Sometimes, these ultramafic rocks occur as pebble-like fragments surrounded by thinly laminated talcose sheath towards the metasedimentary matrix. Along local shear planes, dunite is partly altered by CO_2^- and silica-metasomatism to talc-carbonates and talc-tremolite rock of schistose appearance, respectively.

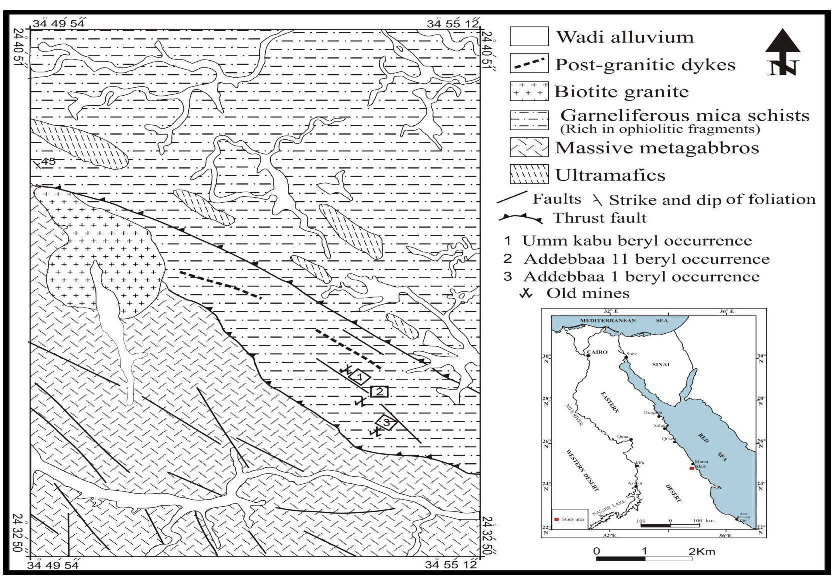

Fig. 1: Geological map of Umm Addebbaa-Umm Kabu belt, south Eastern Desert, Egypt (Omar, 2001).

Serpentinities fragments are effected by highly sheared and exhibit well-developed conjugate fracture system. Many of these serpentinites are altered to cavernous talc-carbonate that is in some parts dragged along minor local thrust faults. Both serpentinites and talc-carbonates fragments sometimes grade into talc-graphite rocks at their outer peripheries. Beryliferous quartz veins are confined to the ultramafics. Associating minerals at the contact are actinolite-tremolite, tourmaline and ferrigneous calcite (ankerite). Others fragments are represented by lensoidal flaser metagabbros, oval-shaped to rounded metadiabase and amphibolite fragments. All types of fragments show remarkable deformation and they are sporadically embedded in the mélange matrix.

Metasedimentary matrix

These rocks are composed of pelitic, psammo-pelitic and mafic schists. The metasedimentary matrix can be correlated with the latest model for the structural evolution of the Wadi Hafafit Culmination (WHC) studied by El-Ramly et al. (1993). They are mostly represented by garnet-mica schists. The beryl-bearing quartz veins invade the mica schists, occurring mostly as lenticular boudinaged bands and stringers. The matrix schists are highly deformed with well-established mesoscopic structures that are marked by the presence of frequent boudinaged quartz that extends parallel to the foliation planes. They are folded, crenulated and wrinkled in a series of minor open and kink Chevron folds. Antiforms, syn-antiforms, recumbent and overturned folds are the main structural forms in the schists. The general strike of schistosity is almost NW-SE dipping 60° NE according to the equal area net (Omar, 2001). These rocks are intruded by white pegmatoidal granitic bosses and pegmatites. Also, they are affected by the same tectonics that result in folding. The matrix also is cut by barren and beryl-bearing quartz veins, which are commonly surrounded by phlogopite.

Granitic Rocks

Granitic rocks are composed of different types such as mylonitized granodiorite, biotite and muscovite granites. Mylonitized granodiorite is foliated and sends apophyses in the mica schists. It attains the composition of tonalite in some occurrences. The granodiorites are affected by faulting and jointing in different directions. Biotite granite is represented by small bodies, intruding the mélange unit in different places (Fig. 2). This granite is connected to some beryl mineralization at the contact with the mélange rocks. White muscovite granite also intrudes the tectonic mélange with remarkable chilled margins against schists in particular. These rocks are white in colour and commonly coarse-grained with big feldspars crystals reaching up to 5 cm long. In addition to these feldspars, quartz, coarse muscovite flakes and megascopic garnet are also present. Muscovite granites are often represented by voluminous bosses and off-shots that sometimes exhibit pegmatitic nature. Occasionally, separate masses of the mélange schists are taken as roof-pendant due to the emplacement of this granite variety.

Post-granitic Dykes, Pegmatites And Quartz Veins

These rocks are represented by granitic and pegmatitic dykes as well as beryl-bear-

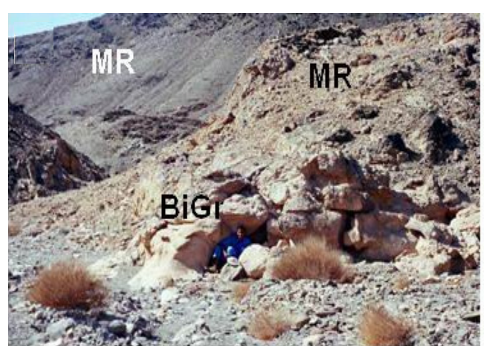

Fig. 2: Small body of biotite granite (BiGr) intruded in the mélange matrix (MR), Umm Addebbaa –Umm Kabu beryl belt

ing quartz veins and more commonly barren quartz veins. These dykes mostly follow the trend NW-SE which is the general trend of schistosity, but some dykes also trend in the NE-SW direction. Pegmatites intruding into the metasedimentary rocks (mélange schists) which are characterized by their pale pink colour, being very coarse-grained composed of feldspars, quartz and muscovite flakes. The trend of pegmatites is nearly N-S, dipping to 50°-70° E. They vary in thickness from 0.5-5 m and extend for a length over 20 m. Granitic dykes are intruded in the metagabbros with distinct pinkish colour and thickness over than 4 m with length of about 20 m. They are medium-grained with chilled margins against the metagabbros. Barren and beryliferous quartz-veins are very abundant, cutting all the rock types with variable thickness from few centimeters to 5 m and their length from one meter to 20 m. These veins are classified into three types:

a) Old quartz veins affected by intense tectonics, which also affected the mélange matrix. These exhibit folding and boudinage structures. They trend either in the same direction of foliation (NW-SE) or as boudinaged bodies along the foliation.

b) Quartz veins cutting the different rocks especially in the mélange matrix. These veins are white in colour and not associated with phlogopite and are not beryliferous. They also trend in the same direction of foliation (NW-SE and rarely in the NE-SW) dipping in the same dip direction of foliation.

c) Beryl-bearing quartz veins are always surrounded by dense and compact phlogopite sheath (Fig. 3). They also extend in the NW-SE direction, dipping 40°-70° to NE. These veins are surrounded by large amount of dump rocks that vary in thickness from 50cm up to ~22m (Fig. 4). The veins are dislocated along faults showing dextral sense of displacement. Beryl in this case associates both quartz and phlogopite. Beryl- free or barren quartz veins also show noticeable abundance in the ophiolitic mélange.

Fig. 3: Beryl-bearing quartz vein (QzV) (>5m thick) surrounded by phlogopite (Phl), Umm Addebbaa –Umm Kabu beryl belt

Fig. 4: Big amount of dump extracted from the gallery of beryl minerals, Umm Addebbaa –Umm Kabu beryl belt

PETROGRAPHY

Beryl-bearing Rocks of Umm Addebbaa Occurrences

According to the field and petrographic observations, beryl is often recorded in pegmatites and quartz veins as well as some injections in the adjacent country rocks that are mainly represented by phlogopite-actinolite rock of ultramafic parentage, pegmatitic and quartz veins.

Phlogopite-actinolite rock

This ultramafic variety is mainly composed of talc and actinolite, both are extensively altered to phlogopite as result of K-metasomatism due to the felsic injection (pegmatitic veins). Actinolite occurs as long radiating crystals showing corrosion by talc and phlogopite. Corrosion of coarse actinolite crystals by phlogopite is common along crystal peripheries and cleavage planes.

In some specific cases, this rock variety bears some kinked chlorite flakes. In addition, there are frequent pyrite cubes that are oxidized to goethite. Phlogopite itself is corroded and enclosed by both quartz and beryl. In some weathered sample, phlogopite is altered to amorphous iron material of yellow brown colour. It is noticed that most phlogopite is associated with metamict or radioactive zircon and non-radioactive apatite.

Pegmatite veins

The pegmatite veins of Umm Addebbaa beryl occurrences are essentially composed of beryl, plagioclase, phlogopite, quartz, tremolite, actinolite and calcite. Beryl is commonly cracked and dissected by thin veinlets of quartz. Euhedral beryl crystals invade plagioclase. Some coarse beryl crystals corrode long the actinolite laths. Some pegmatite veins are rich in coarse phlogopite flakes that are partly engulfed by beryl. Also, beryl is soaked by carbonates.

Quartz occurs either as rounded crystals or irregular injections in beryl in addition to some coarse crystals showing serreated boundaries. All quartz generations corrode beryl and plagioclase. Both quartz and plagioclase, in addition to some beryl, contain fine tremolite inclusions. Some coarse beryl crystals contain few coarse inclusions of actinolite. Calcite is the latest phase in the paragenetic sequence and it dissects all minerals. Also, it occurs as an interstitial phase.

Quartz veins

These types are mainly composed of beryl, phlogopite, chlorite and quartz. Sometimes, beryl is coarse (3 mm wide and 5-7 mm long). Beryl occurs as perfect hexagonal crystals and some of them are fractured in the vicinity of cleavage along which calcite does also occur (Fig. 5). Cracks in beryl are filled by two generations of quartz, one is microcrystalline and the other is coarse and strained. Beryl also contains fine inclusions of phlogopite. Two generations of beryl are identified based on size and shape of crystals. Some beryl crystals are invaded by sericite veinlets. In some samples, phlogopite is highly altered to chlorite. Quartz is saccaroidal and is usually associated with phlogopite (Fig. 6).

Beryl-bearing Rocks In Umm Kabu Occurrences

Phlogopite-actinolite rocks

These rocks mainly consist of actinolite,

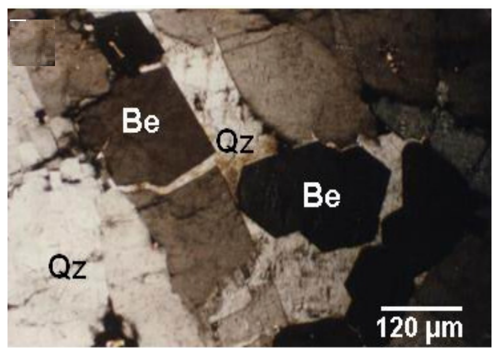

Fig.5 : Six-sided beryl crystals (Be) are fractured and dissected by veinlets of quartz (Qz) Umm Addebbaa –Umm Kabu beryl belt, XPL

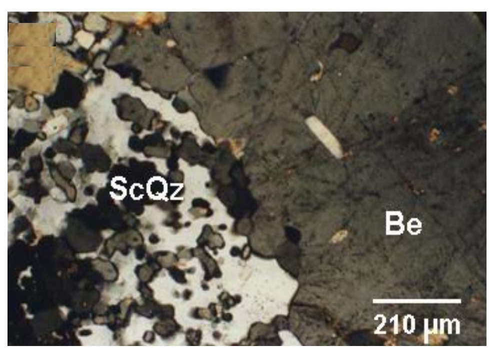

Fig. 6: Saccorroidal quartz (ScQz) is corroding big beryl crystal (Be) which contains inclusions of phlogopite, Umm Addebbaa–Umm Kabu beryl belt, XPL

phlogopite, beryl, quartz and carbonates. Actinolite is altered to phlogopite due to K-metasomatism. Phlogopite by its own is retrograted to chlorite that is affected by radioactive haloes due to the presence of metamict zircon inclusions. Beryl contains numerous inclusions of phlogopite and dissected by quartz and carbonate veinlets.

Pegmatite veins

Phlogopite, plagioclase, beryl, quartz, zircon and titanite are the main recorded minerals in such type of beryliferous varieties. Phlogopite is rich in radioactive zircon. Plagioclase is slightly altered to sericite or is corroded by quartz, and occasionally deformed. Beryl is dissecting by quartz and calcite. Few crystals of zoned beryl were observed. Some other idiomorphic beryl crystals contain quartz and phlogopite inclusions.

Quartz veins

These veins are essentially composed of beryl, quartz, calcite, phlogopite and apatite. Beryl is dissected by quartz and calcite veinlets. Also, beryl is injected by irregular quartz and contains another earlier generation of beryl in addition to phlogopite. Both generations of beryl are characterized by imperfect cleavage. The early beryl generation is fine and zoned. It is noticed that beryl is cut by saccroidal quartz (Fig. 7). Long apatite crystals also cut beryl. On the other hand, calcite forms veinlets and corrodes all minerals.

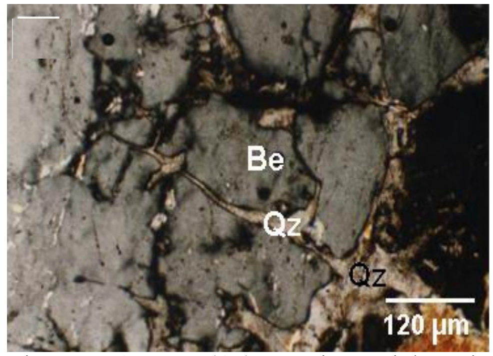

Fig. 7: Quartz (Qz) micro-veinlets in xenomorphic beryl (Be), Umm Addebbaa–Umm Kabu beryl belt, XPL

MICROTHERMOMETRIC MEASUREMENTS

The investigations of trapped inclusions were conducted for 25 doubly-polished wafers sections, (0.1-0.2mm thick), polished on both sides after detailed petrographic studies. The microthermometric measurements were conducted with USGS gas heating/freezing stage at the Applied Geology Department of Curtin University for Technology in Australia. Freezing measurements on the fluid inclusion were made before any heating because of possible deformation and decrepitating of inclusions at high temperatures taking in consideration that CO_2 rich inclusions commonly decrepitate before final homogenization. All fluids were homogenized to the liquid state and the data were processed using Bulk Program of Baker (2003). Fluid inclusions were studied at temperatures between -190 °C and + 500 °C with a FLUID INC. heating-freezing stage. The accuracy of temperature measurements is about ± 0.5 °C in the low-temperature range (-190 to + 50 °C) and ± 2 °C in the high-temperature range (100-500 °C).

Morphology and Types Of Fluid Inclusions

Most of large fluid inclusions range in size from 5 to 35 µm and are included in quartz crystals. They have well defined regular boundaries but some notably larger irregular ones that are characterized by liquid-vapour aqueous phases. The smallest fluid inclusions (1 to 15 µm) are included in beryl crystals. Based on number, nature and proportion of phases at room temperature, the fluid inclusions were classified into 3 types (Figs.8-11):

1-Mono-phase fluid inclusions consist of either liquid (L) or vapour (V). They are small (≤ 5 µm), spherical in shape, so no measurements can be done. The vapour fluid inclusions (V) usually co-exist with the vapour liquid (VL) one which may indicate boiling fluids (Fig. 8). The vapour phase in this case

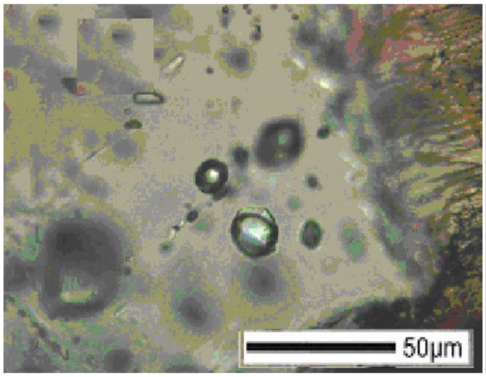

Fig. 8: Photomicrograph of Type (1) mono-phase fluid inclusions

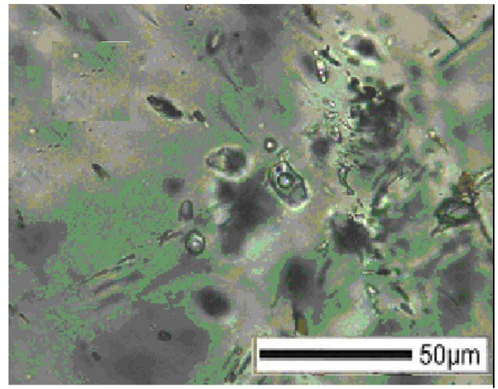

Fig. 9: Photomicrograph of Primary aqueous type (2) fluids inclusions

is similar to that of the secondary inclusions (i.e. CO_2-rich but the percentage of possible CH_4 probably higher).

2-Aqueous fluids (LV) $H_2O_{(L)}$+ $H_2O_{(v)}$ composition. They are primary inclusions common in quartz crystals with liquid ratio ≥75% (Fig. 9).

3-CO_2 rich fluids (VL) consist of $H_2O_{(L)}$ + $CO_{2(L)}$ + $CO_{2(V)}$, that sometimes form one gaseous phase. Most of inclusions are secondary and posedosecondary in origin (Fig. 10). They are common in the beryl crystals. Some fluids are decrepitated due to overheating by later hydrothermal fluids. The primary large fluids are sometimes surrounded by monophase smaller inclusions.

In contrast to the primary inclusions, secondary and pseudosecondary fluid inclusions are associated with some solid protogenetic inclusions (quartz) which supports the petrographic conclusion that emerald is earlier in the paragenetic sequence than quartz but later than the phlogopitizied amphiboles (Fig. 11).

Freezing Runs

Temperature of first melting or cotectic hydrohalite melting, (T_e) indicates that some of the vapour phase in few of the primary inclusions (near the rim) and nearly in

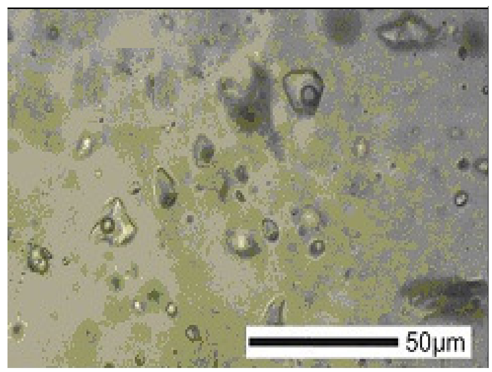

Fig. 10: Photomicrograph of Trail bound secondary type (2) fluid inclusions

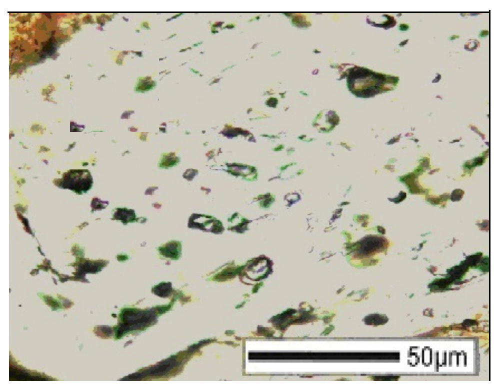

Fig. 11: Photomicrograph of CO_2 rich fluid inclusions type (3)

all the secondary and pseudosecondary inclusions are not only composed of CO_2 but CH_4 or salts are also present as mentioned above. The temperature of final ice melting (T_m) ranges from -5.7 to -4.9 ˚C (primary inclusions) and from -5.0 to -5.7 ˚C (secondary and pseudosecondary inclusions). With cooling to temperature of -180 to -190 ˚C, no sort of phase nucleation was observed. The presence of two different vapour-liquid inclusions (CO_2- rich and CO_2-poor) suggests that there are some differences in density that indicates an immiscibility between liquid and vapour (Cook, 1979). Such immiscibility in beryl takes place during crystallization when different compositions of fluids are trapped at different times during the course of crystallization. At +9.5 ˚C, the clathrate started to melt which increased to +11.5 ˚C in the inclusions in the rim zone supporting again that CH_4 increases towards the rim (especially in the secondary vapour-rich inclusions) which indicates that the mineralizing fluid became more reduced at the late stages of crystallization. Table (1) indicates that the temperature of cotectic melting (T_m CO_2) decreases in the secondary and pseudosecondary inclusions to averages of -57.8 ˚C and -59.6 ˚C, respectively. CH_4-free CO_2- rich inclusions always have T_e of about -56.6 ˚C (Roedder, 1984). The decrease of T_m of clathrate of the CO_2-rich inclusions at the rim zone indicates that the salinity and density decrease at the same manner suggesting that crystallization occurred at pressure conditions of about 1.5-2.5 bars (Durant et al., 1980).

Heating Runs

Based on the study of fluid inclusions in the studied emerald crystals that are comparable to those of Zhang et al., (1999). Within the emerald veins, there are $H_2O±CO_2$ inclusions and the estimated homogenization temperatures for pegmatite veins and quartz veins are 200 - 350 °C and 231 - 280 °C, respectively. Salinities were also estimated to be 5 to 12 and 8 to 14 wt% NaCl equivalents for pegmatite veins and quartz veins respectively. The

Table 1: Microthermometric analyses of the carbonic fluids are in the studied samples

T_iCO_2	T_mCO_2	T_mcl	T_hCO_2	T_h total
-86.2	-56.3	9.2	30.4	292.2
-80	-55.6	9.1	27.9	316.1
-77.1	-55.4	7.2	31.2	306.5
-79.2	56.2	7.7	29.7	309.6
-89.3	-57.2	8.2	31.1	303.1
-90	-58.2	8.1	29.5	340
-88.3	-57.7		24.8	268.7
-89.8	-56.8		29.2	208.7
-81.1	-56.3		31.1	329.5
-90.3	-55.2	9.1	30.9	350.3
-91	-56.8	9.4	31.2	297.5
-89.2	-55.7	9.9	30.9	292.7
-88.7	-54.8		31.4	288
-89.2	-55.1		30.9	378.3
-91.2	-56.7		31.1	250.8
-90	-57		30.2	312.2
-91.2	-57.9		30.9	250.8
-83.2	-56.4		29.4	288.7
-80.1	-56.1		30.1	216.4
-82.1	-56.3		30	266.1

study of fluid inclusion identified a number of two-phase (L+V) saline fluid inclusions within the quartz, fluorite and emerald. Ice melting temperatures between -30 °C and -45 °C were most commonly observed, as were eutectic temperatures between -8 °C and -23 °C and ice melting temperatures above -6.5 °C. They are corresponding to salinities ranging up to approximately 10 wt% NaCl equivalent for the general inclusion population. Total homogenization temperatures vary widely, with the bulk of the data falling between 175 °C and 230 °C. Total homogenization temperature data for inclusions within zoned emerald (Fig.12) were better constrained, ranging from 200 °C to 260 °C. Moroz et al. (2001) reported similar results for some emeralds from Tanzania. The obtained high *P-T* conditions confirm the suggestion that emerald growth takes place during high-grade metamorphic events (Kazmi and Snee, 1989). The

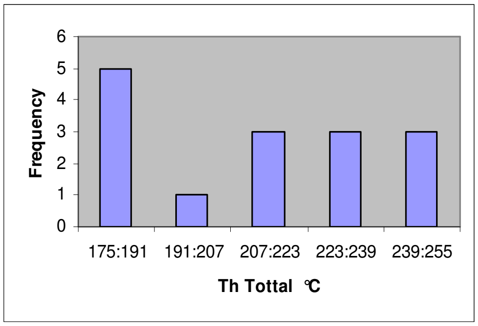

Fig. 12: Histogram for T_h°C values in the aqueous fluids

finding of CO_2 and saline inclusions along the growth faces of the emeralds can be used to suggest heterogeneous trapping of fluid inclusions (Giuliani et al., 1990 and 1997).

RESULT AND DISCUSSION

The present fluid inclusion data is too close to that conducted by Abdalla and Mohamed (1999). Fluid inclusion data of the examined beryl (Table 2) indicate homogenisation temperatures ranging from 175-237°C and a salinity of 13.7- 21.95 wt% NaCl eq. for the aqueous fluid inclusion types (Fig. 12). However, carbonic fluids show salinity range (12.9 -19.7 wt% NaCl eq.) corresponding to homogenisation temperature interval of 200-380 °C (Table 1). This may indicate incorporation of low salinity inclusions related to fluid activity associated with a later tectonic episode (Fig. 13).

However, the CO_2-H_2O -rich inclusions show final melting of the CO_2 solid phase (T_mCO_2) in the range of -55.6 to -58.2 °C, reflecting the presence of another gas, most probably CH_4 (as no phase changes below -120°C was detected to report the presence of N_2). The large compositional, density and volume percent variation of the CO_2 (CH_4) phase in the inclusions of the same population suggests a heterogeneous entrapment of fluids that have been unmixed into H_2O (NaCI)- rich fluid and CO_2-rich vapour (Bowers and Helgeson 1983; Alfonso and Melgarejo, 2003).

The aqueous fluid inclusions examined in beryl associated with granitoids (Table 2 and Fig.12) show a sequence of formation with decreasing temperatures and salinities in beryl pegmatite and quartz veins. The two fields shown by the aqueous and the carbonic inclusions in the pegmatite beryl can be related to two distinct events of fluid evolution (Fig. 14).

Table 2: Microthermometric analyses of the aqueous fluids in the studied samples

T_h°C total	Salinity wt% NaCl eq
197.2	20.21
195	17.5
175.3	21.95
191	19.7
199	15.77
217	17.34
237	15.4
231	13.7
230	19.06

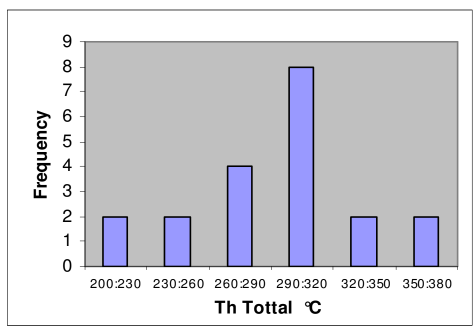

Fig. 13: Histogram for T_h°C values in the carbonic fluids

CONCLUSIONS

Geological and geochemical features of the emerald deposits substantiate the role of syn-tectonically emplaced leucogranites as a source for the Be solutions. The beryl mineralization in quartz veins and pegmatites, are

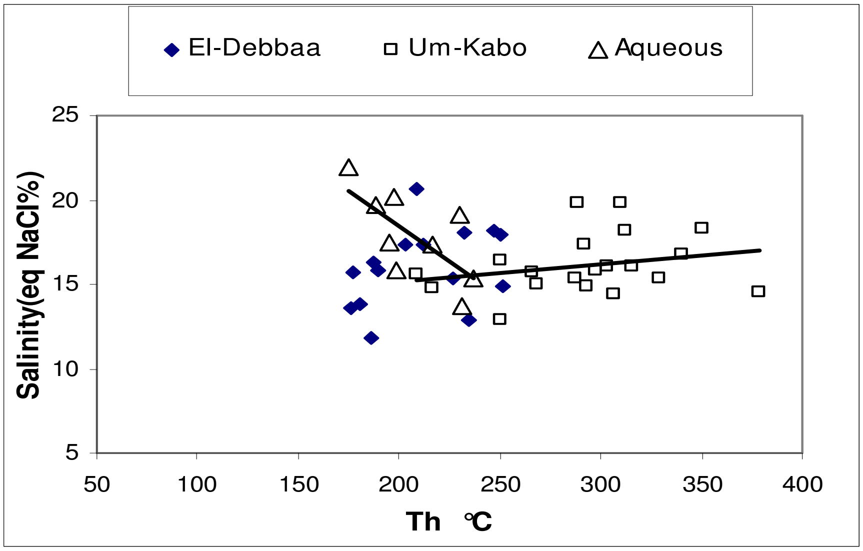

Fig. 14: T_h°C versus salinity (wt% NaCl eq) for the different inclusions in the studied samples

common to deposits of tectonic–hydrothermal origin and of igneous origin. From the data materialized in the present paper, two paragenetic types of Egyptian beryl mineralization are clearly characterized. (1) emerald-schist; and (2) beryl-specialised granitoid associations. The present study sheds light on the importance of emplacement within this sequence of syn-tectonic pegmatitic leucogranites from which K- and Be-rich fluid phases were derived. This is manifested in the field by the development of a system of beryl-bearing pegmatitic pods and veins confined to the shear zones, as well as a broad zone of alkali metasomatism.

Microthermometic studies of primary fluid inclusions within beryl growth zones are consistent with beryl precipitation from H_2O-CO_2 ± CH_4 bearing saline brines. The estimated fluid composition is approximately 0.88 mol% H_2O, 0.017 mol% CO_2 ± 0.001 mol% CH_4 and 0.10 mol% NaCl. Fluid inclusion results consistent that mineralization within pegmatites and quartz veins formed in two genetic stages. The first stage is characterized with formation temperature range from 216.4–378.3°C, with corresponding pressures along fluid inclusion isochore paths ranging from 1.04 to 2.25 bar. The second stage is of aqueous fluid represented with low temperature (177 - 255°C) and pressure ≤ 1 bar, but high saline (16 - 22 wt.% NaCl eq.) which explain mixing of the early carbonaceous fluid with late meteoric water accompanied with pressure release. Thus, it can be inferred that the Be-bearing solutions were moderately saline, but CO_2 (CH_4)-rich which is implied that Be was most probably complexed by carbonate ($^+CH_4$)- chloride base as suggested by Beus et al. (1963). Beryl and emerald deposits are generally formed when geological conditions bring Be together with Cr. The former is assumed to have been derived locally from the mafic and ultramafic rocks during hydrothermal alteration, whereas Be is most likely derived from the adjacent granite intrusions.

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دلالة التركيب المعدني والمكتنفات السائلة في نشأة البيرل بحزام أم الضباع- أم كابو، جنوب الصحراء الشرقية، مصر

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من المعروف أن تمعدنات البيرل مرتبطة بالنشاط الحرمائي التكتوني المرتبط بتكوين الجرانيت. وتظهر تمعدنات البيرل جلية داخل عروق الكوارتز وفي جيوب البجماتيت التي تكونت من طور متأخر غني بالمحاليل القلوية الغنية بالبوتاسيوم والبريليوم والمرتبطة ارتباطا لصيقا بنطاق القص وبعض مظاهر التحول القلوي.

لقد أثبتت الدراسات الحرارية الدقيقة للمكتنفات السائلة الأولية الموجودة في المحورالرئيسي لتبلور معدن البيرل انه تكون من محاليل شديدة الملوحة محملة بثاني أكسيد الكربون والماء و CH_4 وتركيبها الكيميائي 0.88 mol% H_2O, 0.017 mol% $CO_2 \pm 0.001$ mol% CH_4 وكذلك 10 mol% NaCl وذات ملوحة .(14.2 wt % equ. NaCl) كما اثبتت دراسة المكتنفات السائلة ان تمعدنات البيرل الموجودة في عروق الكوارتز وفي البجماتيت تكونت علي مرحلتين، المرحلة الاولي كانت ذات درجة حرارة تتراوح من ٢١٦,٤° الي ٣٧٨,٣°Cوتحت ضغط يتراوح من ١,٠٤ الي ٢,٢٥ بار بينما تتميز المرحلة الثانية بدرجة حرارة تتراوح من ١٧٧ الي °C ٢٥٥ وتحت ضغط اقل من ١ بار وذات ملوحة عالية (16 - 22 wt.% NaCl eq.) مما يدل علي اختلاط المحاليل المحتوية علي ثاني اكسيد الكربون في المراحل الاولي بمياة الامطار في مراحل متاخرة ونتيجة لانخفاض الضغط نتيجة للتكسير عبر نطاق القص لهذا فان بالرغم من وجود مرحلتين من المحاليل الحاملة لتمعدنات البريل في عروق الكوارتز وكذلك في البجماتيت داخل متداخلة الجرانيت فان هذا يؤكد ان تكوين هذة التمعدنات مرتبطة اساسا بنطاق القص اللين العظيم الذي يعتبرعامل هام في تكوين تمعدنات البيرل.