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Variability of α ⁄ ß Inversion Temperatures of Natural Quartz

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Abstract: ***The α ⁄ ß inversion temperature of quartz at atmospheric pressure is 573 °C. This temperature shows some variability caused by source of quartz , particle sizes , heating rate and pressure (nitrogen atmosphere).The differential thermal analysis (DTA) of natural hydrothermal and pegmatite quartz indicate that ,1- the inversion temperatures of both natural pegmatite quartz and natural hydrothermal quartz with the same particle size (0.1 mm) and the same heating rate (10 °C /min.) are 582.14°C and 582.4 °C respectively with small differences (~0. 3°C - 0.5°C). 2- by changing the rate of heating from 10 °C / min to 15 °C /min , the inversion temperature of pegmatite quartz changed from 582.14 to 584.60 °C and hydrothermal quartz temperature changed from 582.40 °C to 585.10 °C with relatively large differences (~ 2.46°C – 2.7 °C). 3- by increasing the particle size of pegmatite quartz to 1.0 mm. at heating rate 10 °C / min, the inversion temperature increased to 587.0 °C . 4- by decreasing the particle size of pegmatite quartz to 0.05 mm at heating rate 10 °C /min., the inversion temperature disappeared.5-The hydrothermal quartz not show thermal activity above the inversion temperature but the pegmatite quartz has thermal activity above the α ⁄ ß inversion temperature.***

Keywords: Pegmatite, quartz, hydrothermal, DTA, α ⁄ ß inversion, heating rate, particle size.

1. Introduction

The room-temperature form of quartz, α-quartz, undergoes a reversible change in crystal structure at 573 °C to form β-quartz. This phenomenon is called an inversion, and for the α to β quartz inversion is accompanied by a linear expansion of 0.45%. This inversion can lead to cracking of ceramic ware if cooling occurs too quickly through the inversion temperature. Alpha ⁄ beta inversion temperature 573 °C at atmospheric pressure increases with increasing pressure. The temperature at which α ⁄ ß inversion occurs is highly pressure depending , increasing by ~ 25°C ⁄ k bar **(Koster van Groos and ter Heege ,1973).**

During the transition from α –to a ß –variant, the atoms in the crystal lattice only get slightly displaced relative to each other (based on alterations of the angles and lengths of the chemical bonds). Such a phase transition is generally called displacive without need to break chemical bonds. The high-temperature silica polymorphs all posses a higher symmetry than their low –temperature counterparts **(Heany et al ,1994**). The complete reconstructive transitions between polymorphs need a lot of time. Quick changes in temperature do not allow for the complete rebuilding of the crystal structure and the transition will be skipped.. Heating rate is a factor controlling a variation of peak temperature of alpha ⁄beta inversion. Determination of inversion temperature of quartz can used for the distinction of authigenic and detritus quartz crystals from sediments and can contribute to solving problems of sedimentary petrography. Authigenic quartz is hydrothermal origin and has rare and few fluid inclusions. Fluid inclusions preserve a valid record of the fluids coexisting with host minerals at the time of crystallization .Melt inclusions are more abundant in the barren pegmatite while the economic pegmatite has a preponderance of highly saline, polyphase fluid inclusions, commonly with carbon dioxide **(Jadhav et al ,1993).** Complete information on the heating rates used to determine inversion temperatures has not always been given in the literature. In many instances, however rates of 15°C/min and greater have been used .Slow heating rates yield a more accurate and truly representative inversion temperatures **(Raymond et al, 1958).** Both hydrothermal quartz and granite quartz show abundant fluid inclusion ruptures over the temperature range from 100°C to 550°C and in most cases, a prominent water release at the quartz alpha – beta transition (573°C). Fluid inclusion ruptures above this stage are rare **(Barker and Robinson, 1984)**

2. Geology and Samples

Two types of natural quartz have been thermally studied. One is from a zoned pegmatite (milky white quartz in the core followed by buff potash feldspar and then yellowish brown muscovite pockets on the rim) ,hosted in Pink Granite of Ras Barud area , 20 km. NW Safaga city , Eastern Desert of Egypt. The zoned pegmatite found as a large lens (~ 30 x 15 m.). The second type of quartz is taken from the fractures in the Pink Granite hosting the zoned pegmatite. It is occurs as translucent, isolated prismatic crystals with pyramidal ends (~ 0.5 x 5mm) growing on the fracture planes as groups, sometime stained by reddish color of iron oxides. Ras Barud area has old gold mines.

Figure 1: A photograph (Left) hydrothermal quartz (Right) pegmatite quartz, Ras Barud area, Egypt

Microscopic Examination

Milky white pegmatite quartz is colorless under P.P.L., shows first order white and grey interference colors and wavy extinction under X.N. Microcracks are recorded , as well as some fluid inclusions along these cracks. The prismatic isolated hydrothermal quartz is colorless, shows first order interference colors and parallel extinction. The mineral does not show undulose extinction ,exhibits fine cross striations, positive elongation and uniaxial interference figure .The anisotropy of thermal expansion of pegmatite quartz grains induce internal strain and consequently wavy extinction, This anisotropy does not matter too- much for a single , isolated crystal of hydrothermal quartz (**Dorothy Richter & Gene Simons ,1974; Kirsti Midttomme and Elen Roaldset ,1998**)

Experimental

The studied natural quartz samples have been crushed to sizes 1.0 mm, 0.1 mm and 0.05 mm and subjected to differential thermal analysis , heated by 10 ºC / min. and 15 ºC / min up to 1000 ºC under nitrogen atmosphere at Central Laboratories Sector of the Egyptian Mineral Resources Authority in Egypt and at the Center of Microanalysis of Cairo University. The specific gravity of both quartz samples has been determined at the laboratory of Physics Department, Faculty of Science, Zagazig University, Egypt. The hydrothermal quartz is lighter in the specific gravity (2.55) than the pegmatite quartz (2.64).

3. Thermal Analysis

Natural hydrothermal and pegmatite quartz have been subjected to differential thermal analysis (DTA) under nitrogen atmosphere and heating rates 15°C / min and 10°C / min with particles sizes (1.0 mm , 0.1 mm and 0.05 mm **).**The study indicates that, **1)** The α / ß inversion temperatures of hydrothermal quartz (particle size 0.1mm) at heating rate 10°C / min. are 582.4 °C increased to 585. 1°C at heating rate 15°C / min.(Fig. 2, 3) . **2)** The inversion temperatures of pegmatite quartz (particle size 0.1 mm) at heating rate 10°C / min. are 582.1°C increased to 584.6°C with increased rate of heating to 15°C / min (Fig .4, 5) .**3)** With increasing the particle size of pegmatite quartz from 0.1 mm to 1.0 mm., the inversion temperature 582.1°C at heating rate 10°C / min. increased to 586.7°C at the same rate of heating (Fig.6). **4)** With decreasing the particle size to 0.05 mm., the inversion temperature of pegmatite quartz at the same rate of heating has been skipped (i.e. there is no any thermal activity, instead, the heat is slightly adsorbed above temperature of ~ 500 °C (Fig. 7).**Thomas et al ,(2000); Noni et al ,(2009) ;Amoros et al , (2000) and Signorini E.(1991**) demonstrated that, the grinding quartz can cause a dispersion of the α / ß inversion over a temperature range of several degrees . **Simon (2001)** found that the decreasing grain size fractions of quartz correlate with a diminishing abundance of large inclusions. **5)** Hydrothermal quartz not show thermal activity above the α / ß inversion temperature but the pegmatite quartz has activity above the α / ß inversion temperature for particle sizes > 0.05 mm. **Barker and Robinson (1984),** concluded that, the high temperature water release (above the inversion temperature) from hydrothermal quartz is negligible but it is greater for the granite quartz. **6)**The thermal activity of hydrothermal quartz is recorded at endothermic peaks 272°C, 336.9°C and 482°C.These may be related to the homogenization of fluid inclusion at 272°C & 336.9°C and to decrepitating of fluid inclusion at 482 °C as a result of introducing thermal expansion microcracks). **Birkeland and Carstens (1969)**, demonstrated that, the cracking occurred at around 300-400 and increasing with raising temperature up to α / ß – quartz transition at 573°C.The decrepitation temperatures extending from ~200 to 700 and more fluid inclusions decrepitated in the 20 range from 560 to 580 (**Bodnar et**

al. 1989). The inversion of the low to the high form of cristobalite occurred at 250°C to 260°C on heating **(Sandford s. &Cole, 2011). 7)** The heat absorbed by the hydrothermal quartz (- 141 m J) is greater than that of pegmatite quartz (- 56.6 m J) during the inversion of low quartz to high quartz (Figs.3 and 5).This may be attributed to the higher specific heat of hydrothermal quartz than that of pegmatite quartz. Healing in fluid –filled cracks in quartz is rapid above 400 °C and is thermally activated as the specific heat of hydrothermal quartz is so higher than that of pegmatite quartz (**Susan et al, 1990**).The study reveals that, hydrothermal quartz is lighter in the specific gravity (2.55) than the pegmatite quartz (2.64), so it is more sensitive to heating than the pegmatite quartz and has higher thermal expansion coefficient and lower thermal conductivity. This introduces a lot of strain that causes the material to crack by heating.**8)** pegmatite quartz has one endothermic peak at 296°C , may be related to the homogenization of fluid inclusion or to converting the amorphous silica to cristobalite .**9)** Pegmatite quartz has thermal activities above the alpha / beta inversion temperature of quartz at 700°C ,798°C & 887°C (Figs. 5, 6) ,may be related to homogenization of melt inclusions (**Jadhav et al , 1993)**. The complete miscibility is attained at the critical point 712°C **(Thomas et al , 2000). Chryssoulis and Rankin (1988)** found that **,** quartz is not stable at 870°C and do not converted into tridymite in the absence of fluxes.**10)** The variations in decrepitating activities can used as an aid to mineral exploration in granite terrains.

4. Conclusion and Utilization

The study revealed the following conclusions:

1. Hydrothermal isolated crystals of quartz does not show undulose extinction but shows thermal expansion microcracks at 482°C.The pegmatite quartz shows undulose extiction as a result of the anisotropy of thermal expansion of quartz grains in groups
2. The decrepitation temperatures extending from ~270°C to 780°C, but more fluid inclusions decrepitated in the 5°C range from 582°C to 587°C (α / ß inversion temperature)
3. Slow rate of heating is accurate for differentiation between hydrothermal and pegmatite quartz. The first has thermal activity below the alpha-beta inversion temperature, and the second has thermal activity above the inversion temperature.
4. Slow heating rates yield a more accurate and truly representative inversion temperature.
5. Increasing degree of grinding makes disappearance of the inversion temperatures
6. The alpha- beta inversion temperature of natural quartz is strongly affected by the change in pressure , particle sizes , heating rate but slightly affected by the source of quartz (regardless the thermal activity below and above the inversion temperature for both quartz types)
7. Description and identification of fluid inclusions in natural quartz taking in consideration the factors affecting the inversion temperature is good tool in mineral explorations and can be used for the distinction between the authigenic and detritus quartz of sediments.

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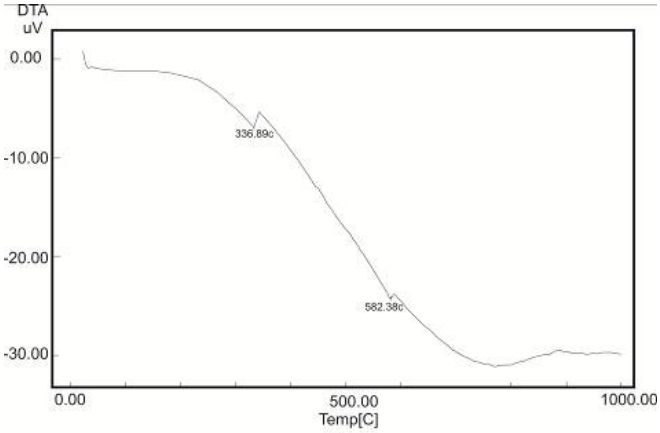

Fig. 2: DTA curve of hydrothermal translucent prismatic quartz, (heating rate 10 °C/min, particle size 0.1mm)

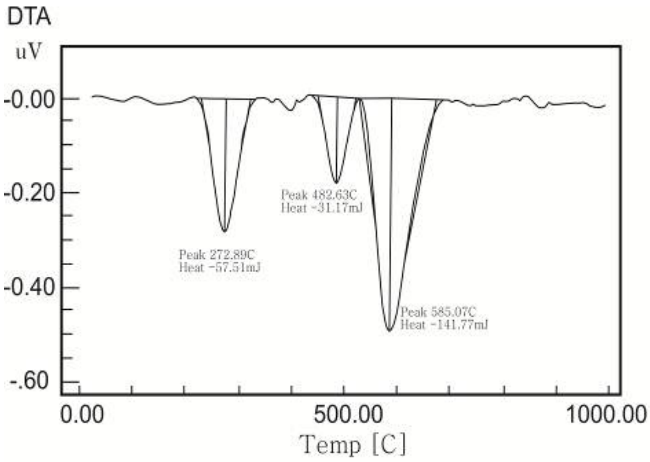

Fig. 3: DAT curve of hydrothermal translucent prismatic quartz, (heating rate 15 °C/min, particle size 0.1mm)

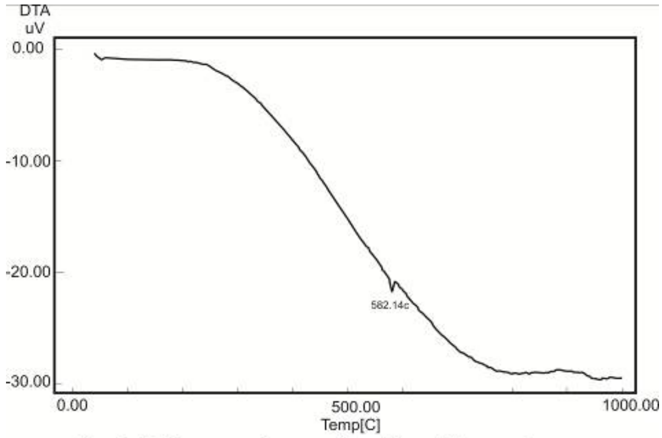

Fig. 4: DTA curve of pegmatite milky white quartz (heating rate 10 °C/min, particle size 0.1mm).

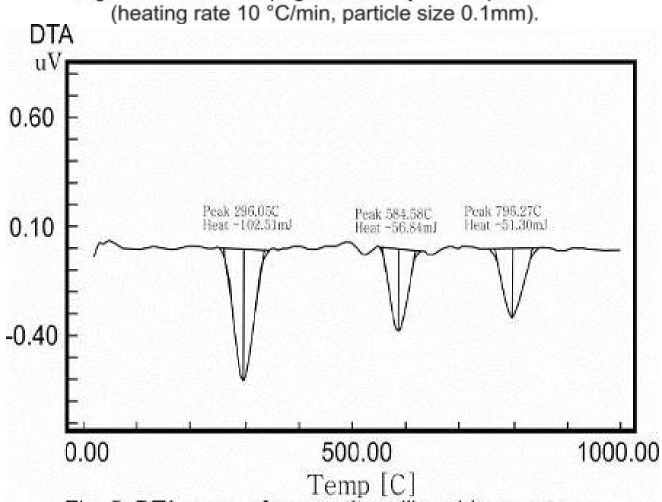

Fig. 5: DTA curve of pegmatite milky white quartz (heating rate 15 °C/min, particle size 0.1mm).

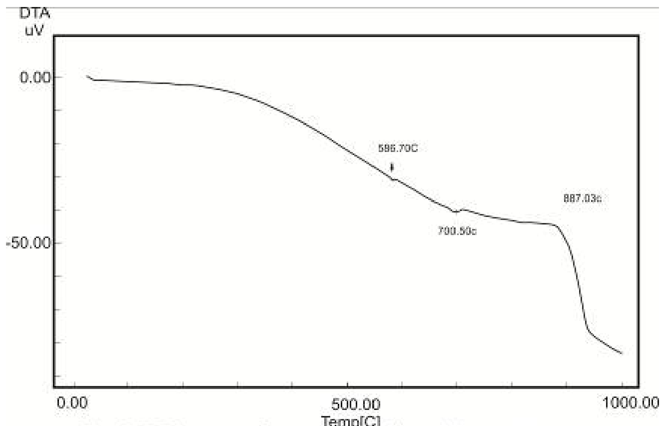

Fig. 6: DTA curve of pegmatite milky white quartz (heating rate 10 °C/min, particle size 1.0 mm).

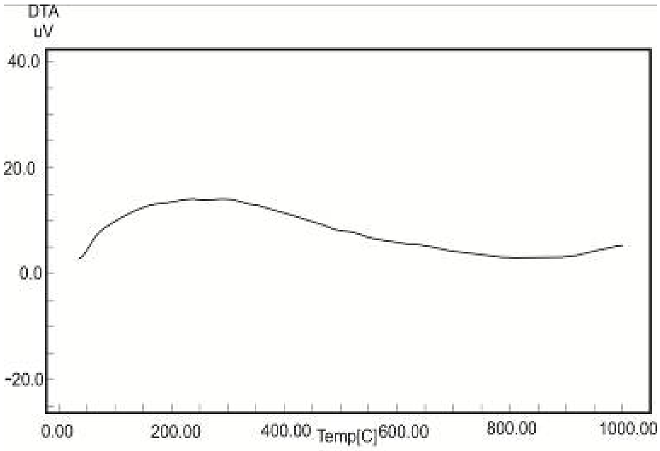

Fig. 7: DTA curve of pegmatite milky white quartz, (heating rate 10 °C/min, particle size 0.05mm)