Inclusions in Aquamarine from Vemireddipalle Area, Krishna District, Andhra Pradesh, India

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Abstract- Aquamarine is a greenish blue variety of Beryl family. It is one of the most popular gemstones for its beauty and rarity. The present study is aimed at the observation of Inclusions in Aquamarine samples from Vemireddipalle area, Krishna district, Andhra Pradesh, India. Dataset/points are examined using Electron Probe Micro Analyses (EPMA) and some of the inclusions are observed under the binocular microscope. From the study potash feldspar and altered sodium feldspar minerals is found as inclusion. In addition to these crystals and liquid fingerprints, two-phase, zircon hallows and raindrop are also recorded.

Keywords- Inclusions, feldspar, two phase, raindrop

I. INTRODUCTION

Aquamarine has been one of the most popular gem materials for centuries, prized for its beauty and rarity. The color of aquamarine ranges from the familiar light blue to blue-green hues (Adamo et al., 2008). In gemology, an inclusion is a characteristic enclosed within a gemstone, or reaching its surface from the interior. It is one of the most important factors when it comes to gem valuation. Inclusions are foreign materials (solid, liquid or gaseous) inside minerals. They can often be of great help in identifying a gemstone and particularly in deciding whether a stone is a natural, a synthetic or a simulant. Colored gemstones are categorized into three types as follows:

- Type I colored gems include gems with very little or no inclusions. They include aquamarines, topaz and zircon.
- Type II colored gems include those that often have a few inclusions. They include sapphire, ruby, garnet and spinel.
- Type III colored gems include those that almost always have inclusions. The gems in this category include emerald and tourmaline (https://en.wikipedia.org).

Previous Studies

Various studies have reported the presence of different types of inclusions in Aquamarine gemstones from various parts of the world.

Yang and Ren (2018) observed two-phase (fluid, gas) or three-phase, fingerprint inclusions are reported from Pakistan. These multiphase inclusions formed by different crystallization processes. Lum et al., (2016) encountered inclusion species in the beryl samples are schorl, quartz, muscovite, feldspar, iron oxides and cassiterite, clearly reflective of the host pegmatite mineralogy from Erongo, Namibia. These varieties encountered during Scanning electron microscope (SEM) examination include abundant iron oxide, along with tourmaline (schorl, rossmanite and foitite), quartz, zircon, muscovite, alkali and plagioclase feldspar, ilmenite, rutile, and cassiterite. Iron oxides occur as individual inclusions (presumably primary), as composite inclusions with a variety of other minerals, and also as fillings in cracks where it is assumed to be secondary in origin. By means of SEM identification, altered titanium oxide minerals were tentatively identified as pseudoferrobrookite and pseudorutile.

Gerasimova et al., (2014) studied two and one phase fluid inclusions and some varieties of solid inclusions like; elongated opaque black solids with the octagon cross section, occasional greenish-black inclusions, and light orange and reddish rectangular solids from the area Suprunovskoye Pegmatite deposit, Russia. They concluded that the solid phase in which two and one phase fluid inclusions was trapped is microcline. The liquid in the two-phase inclusions consists of H_2O and CO_2 and gas bubble contains H_2O and CO_2. The one phase inclusions contain water or liquid CO_2. Panjikar and Panjikar (2014) observed a variety of fluid inclusions, two-phase, three phase, liquid films, liquid filled capillaries, feathers, healed feathers, large cavities filled with original magmatic fluids from Karur, Tamilnadu. The study concluded that Nature of inclusions has helped to throw light on the crystallization of the aquamarine in the pegmatite. Kim and Shin (2014) reported commonly encountered inclusions from Gilgit Baltistan, Pakistan. Inclusions partially healed fissures with two-phase fluid and tantalite. Solid inclusions were uncommon. Danet et al., (2012) revealed that the reddish-brown platelets were hematite, whereas ilmenite was present as black platelets, black needles, and distinctive dark gray dendritic inclusions. This marks the first time these ilmenite dendrites have been documented in aquamarine from Madagascar.

Huong et al., (2011) revealed growth tubes and angular or elongated two-phase (liquid and gas) and fluid inclusions, Multiphase (liquid, gas, and a crystal). They concluded that liquid and gas phases as H_2O and CO_2. Multiphase inclusions within one sample were identified as calcite and albite. Hematite and biotite were found as mineral inclusions in one sample. Adamo et al., (2008) observed multi-phase fluid inclusions and various mineral inclusions, as well as internal growth structures from different sources like Brazil, Nigeria and Canada. Befi (2009) reported different inclusions from Pakistan. The author observed the impression of exploring the depths of the ocean, fingerprints composed of two-phase and it was identified as zircon.

Fingerprints, fractures, growth tubes, two and three-phase inclusions from Klein Spitzkoppe, Namibia were reported by Cairncross et al., (1998). Linnen et al., (2006) observed Fluid and different types of inclusions from Nigeria. The authors had reported aqueous liquid-vapor phases, liquid-only aqueous, vapor-rich carbonic and liquid-liquid vapor (aqueous-carbonic) inclusions and recorded three-component fluid mixing.
Danner (1989) reported various inclusions from Tongafeno, Madagascar, i.e., canal-like needles, 'rain-like', black pinpoints, two-phase, three-phase, multiple-phase inclusions consisting of gas, liquid, and many solid inclusions and proved them as anisotropic.
The present study is concentrated on Inclusions of Aquamarine gemstone from Vemireddipalle area, Krishna district, Andhra Pradesh, India.

II. METHODOLOGY

Two dataset/points are examined by using Electron Probe Micro Analyses (EPMA) and some of the inclusions are observed under the binocular microscope. The samples ranged from light to dark greenish blue in colour. By EPMA the following oxides were measured, i.e., K_2O, SiO_2, Na_2O, Al_2O_3, MgO, P_2O_5, CaO, TiO_2, Cr_2O_3, MnO, FeO and NiO. Microscopic observation shows a variety of inclusions. Details are presented under Results and discussion.

III. RESULTS AND DISCUSSION

The Aquamarine samples collected from Vemireddipalle area show the presence of feldspars, zircon, two-phase, crystal and liquid fingerprints, crystals, zircon halo and rain drop like inclusions. The details are incorporated in this section.
From the EPMA analysis of point 1 (Table 1 and Figure 1), it is observed that K_2O is present in higher quantities (28.77wt%), followed by SiO_2 (26.41%), Na_2O (7.80%) and Al_2O_3 (7.35%). Based on the wt%, the inclusion is identified as Potash feldspar. Minor amounts of MgO, P_2O_5, CaO, TiO_2, Cr_2O_3, MnO, FeO and NiO are observed at the point.

Table 1 EPMA analysis of Feldspar inclusions

Oxides	Data points	
	1	**2**
SiO_2	26.41	43.90
Al_2O_3	7.35	15.62
K_2O	28.77	0.61
Na_2O	7.80	20.06
FeO	0.25	0.55
MnO	0.00	0.00
MgO	0.08	0.11
CaO	0.07	0.22
P_2O_5	0.00	0.00
Cr_2O_3	0.06	0.00
TiO_2	0.00	0.00
NiO	0.02	0.02
Total	**70.82**	**81.09**

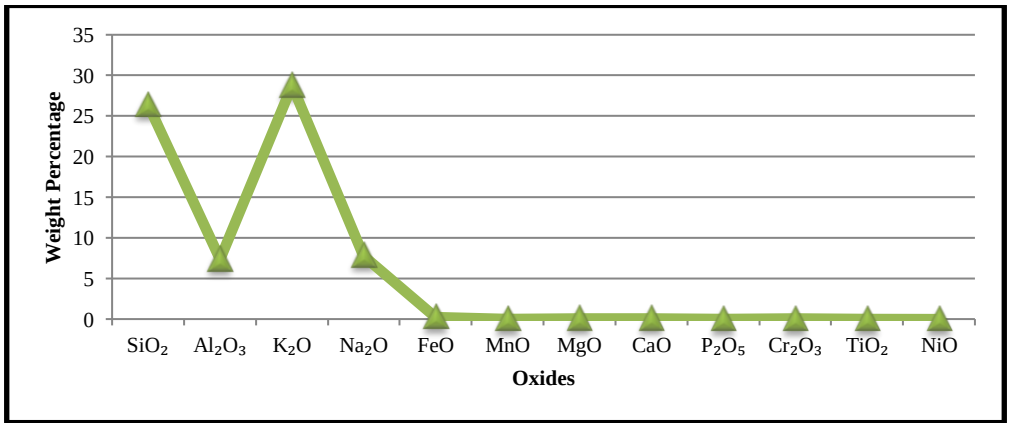

Figure 1 Oxide composition of Potash Feldspar (Point 1)

At point 2, SiO_2 is the highest (43.90), followed by Na_2O (20.06) and Al_2O_3 (15.62). These amounts suggest that inclusion is an altered sodium feldspar. MgO, P_2O_5, K_2O, CaO, TiO_2, Cr_2O_3, MnO, FeO and NiO are also noticed in lesser quantities (Table 1 and Figure 2).

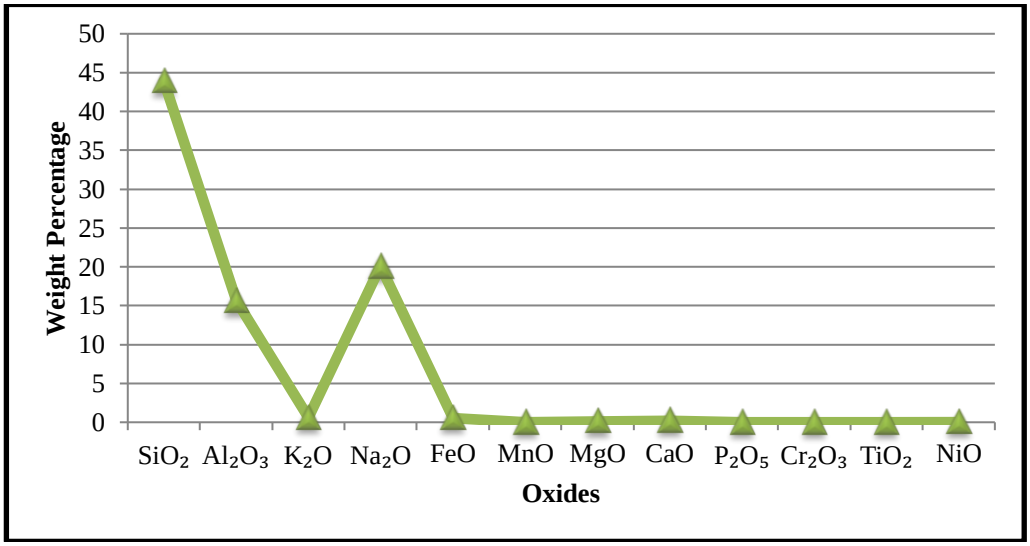

Figure 2 Oxides composition of Sodium Feldspar (Point 2)

Inclusions observed under a microscope

Crystal: Various types of crystals, such as elongated crystals and hexagonal crystals were observed in Aquamarine (Plates 1, 2 and 3).

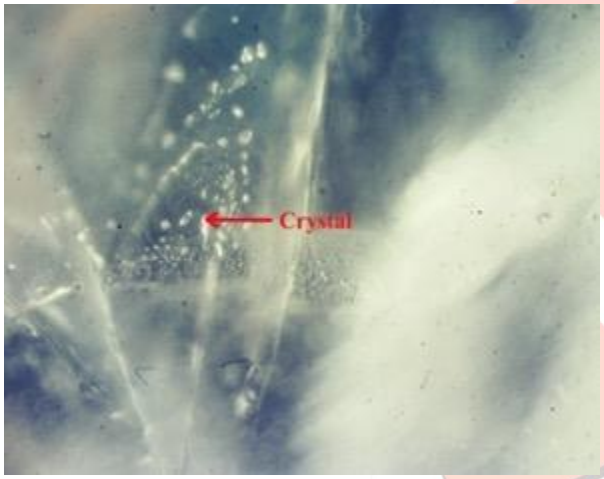

Plate 1 Highly encountered crystals in Aquamarine (Magnified 60X)

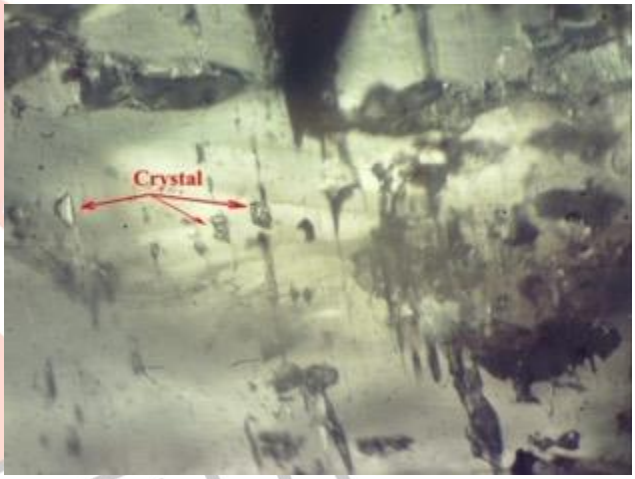

Plate 2 Observed Large crystal inclusions in Aquamarine (Magnified 60X)

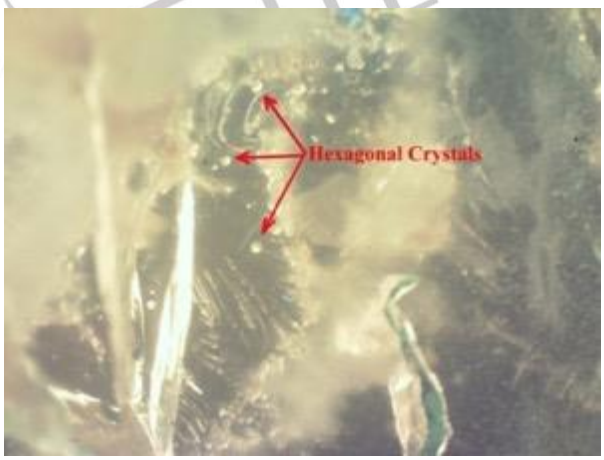

Plate 3 Hexagonal crystals, consistent with the beryl (Magnified 60X)

Finger prints: At any point after a crystal grows, it may fracture. Given the proper conditions, that fracture may later heal closed, leaving a scar-like inclusion typically known as a "fingerprint" (http://www.ruby-sapphire.com). Yang and Ren (2018), Befi (2009), Cairncross et al., (1998) and Danner (1989) reported fingerprints.

In the present microscopic study, two types of fingerprints, namely crystal and liquid, are observed. These inclusions encountered in plates 4, 5, 6 and 7.

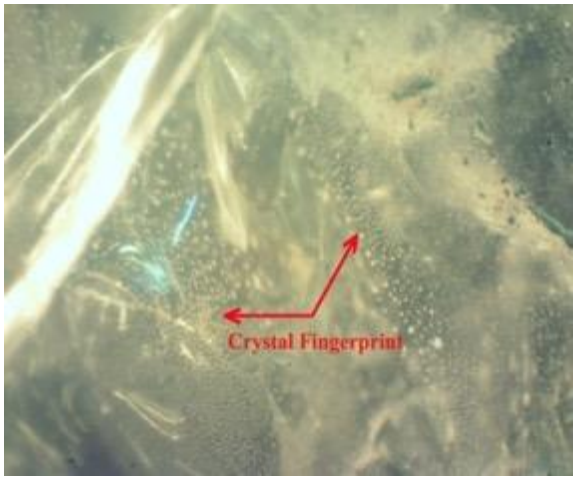

Plate 4 Crystal fingerprints documented in Aquamarine sample (Magnified 45X)

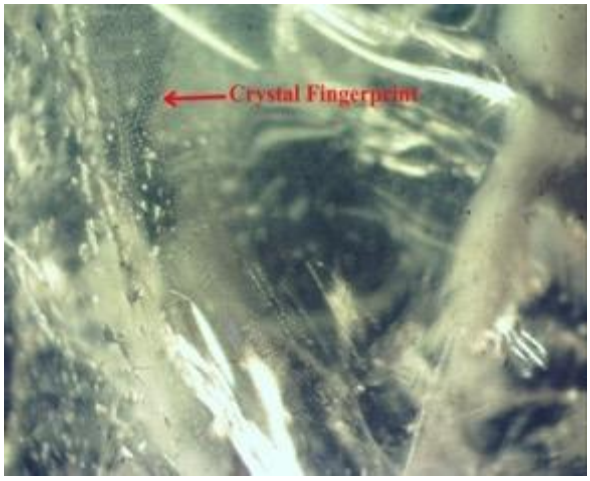

Plate 5 Crystal fingerprints in Aquamarine (Magnified 50X)

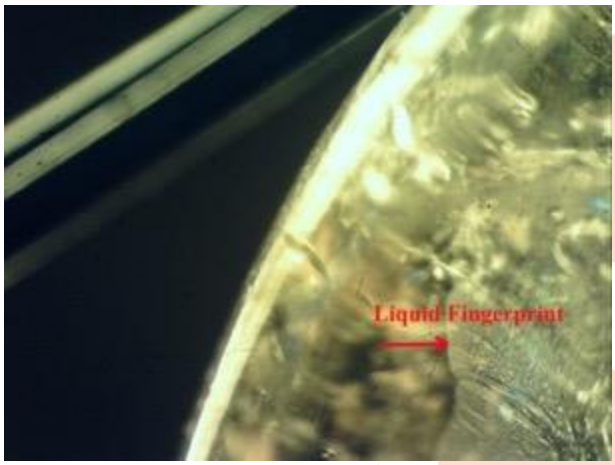

Plate 6 Liquid fingerprints were observed in Aquamarine (Magnified at 35X)

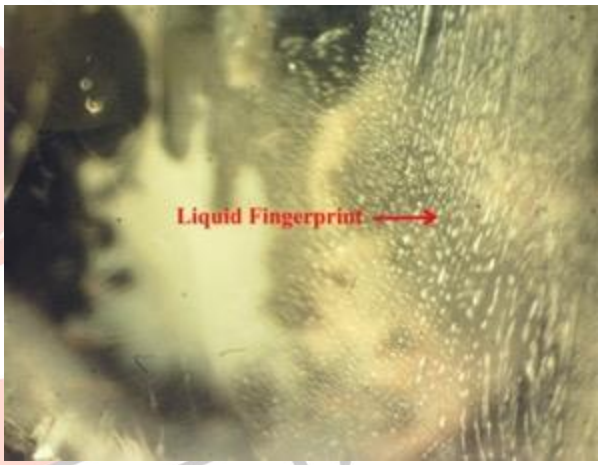

Plate 7 Liquid fingerprints" in Aquamarine (Magnified 45X)

Two-phase inclusion: This can take the form of a void containing either a liquid and a gas bubble (found in quartz, topaz, tourmaline and beryl) or a liquid and a crystal. Yang and Ren (2018), Gerasimova et al., (2014), Huong et al., (2011), Cairncross et al., (1998) and Danner (1989) reported two-phase inclusions.

Two-phase inclusions are observed in Vemireddipalle samples (Plate 8 and 9).

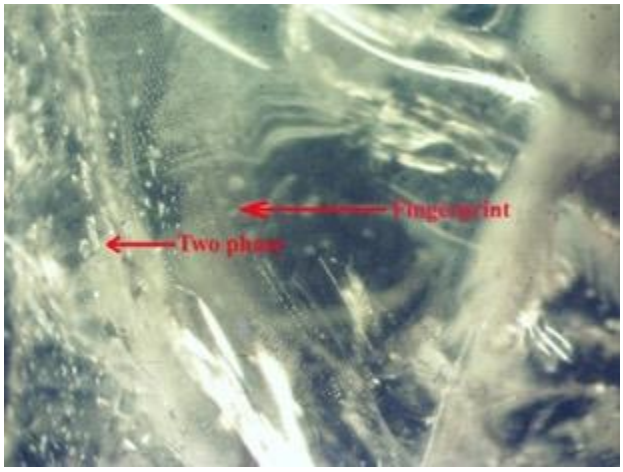

Plate 8 Two phase and Fingerprint inclusions were seen in Aquamarine (Magnified 60X)

Plate 9 Two-phase and elongated two-phase Crystal fingerprint (Magnified 60X)

Rain drop: These inclusions appear like a series of short parallel needle-like inclusions. Danner (1989) identified rain drop like inclusion. These inclusions are noticed in the centre and top portions of the Plates 10 and 11.

Plate 10 Rain drop like inclusions in Aquamarine from Vemireddipalle area (Magnified 60X)

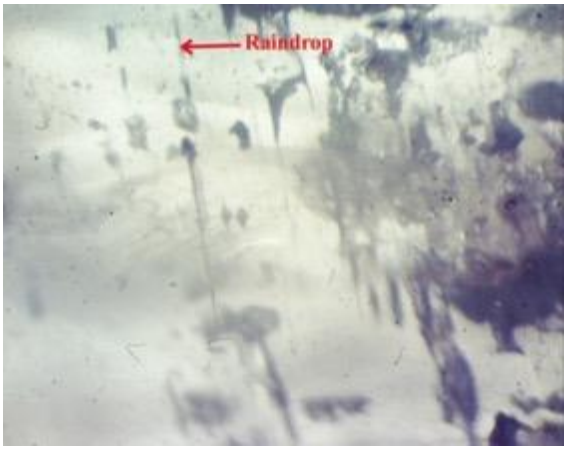

Plate 11 Rain drop like inclusions in Aquamarine (Magnified 50X)

Zircon Halo: It is a stress crack surrounded by a zircon crystal. Lum et al., (2016), Befi (2009) and Cairncross et al., (1989) observed zircon inclusions. This zircon halo is observed in the Aquamarine plate 12.

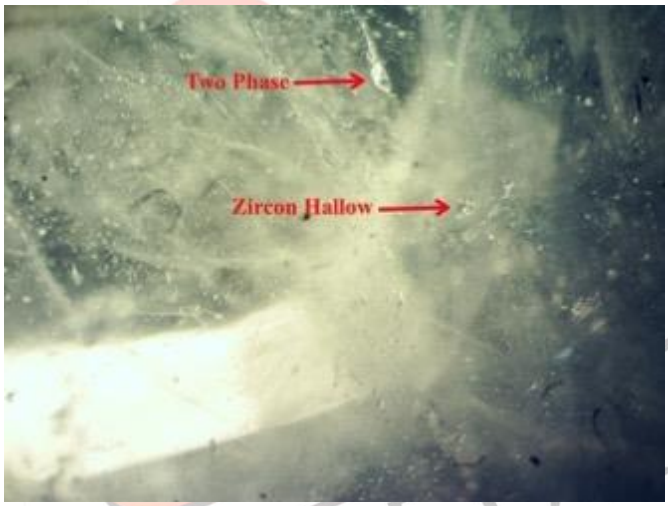

Plate 12 Zircon hallows and liquid two-phase inclusion in Aquamarine (Magnified 60X)

IV. CONCLUSION

EPMA and Microscopic observations helped to identify various inclusions in the Aquamarine samples. Feldspar mineral inclusions are recorded at the data set/points. In addition to these minerals, Crystals and liquid fingerprints, two-phase, zircon hallows and raindrop like inclusions is also observed under a microscope. Based on these inclusions the gemstone is identified as a natural Aquamarine.

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