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Original Article

Study of Homogenization Temperatures of Fluorites Hosted with Carbonatite Rocks of Ambadongar, Gujarat

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Abstract *- The present study aims at understanding the physico-chemical condition in which different coloured fluorites have been precipitated at Ambadongar. Although many techniques are available for genetic studies of rocks and minerals, in studying crystallization temperatures, the author has applied fluid inclusion techniques to conclude homogenization temperatures of Ambadongar fluorites. This study would also give an idea about the composition of the original magma from which fluid is generated and trapped in crystals during mineralization. Ambadongar fluorite occurs as vein and vug fillings localized along fractures within carbonatite and sandstones. Fluid inclusion studies of blue-green fluorite show that they crystallized at the highest temperature of all fluorites, with a temperature range of 168.2 to 192.1oC. Purple fluorite has been crystallized at a lower temperature than blue-green fluorite and possibly below 170oC. Yellow and colorless fluorites are late crystallized fluorites at low temperatures between 130.8oC and 119.3oC.*

Keywords *- Ambadongar, Carbonatite, Homogenization temperature, Fluid inclusion, Fluorite.*

1. Introduction

Primary and secondary fluid inclusions hosted by fluorites provide an opportunity to reconstruct the evolution of fluids in an alkaline carbonatite setting and study the composition of the fluids from which different coloured fluorites crystallized. Various types of inclusion, namely aqueous liquid–vapour (LV), two-phase aqueous (VL), three phases aqueous–carbonic (LLV) fluid inclusion, were studied to find homogenization temperatures of different coloured fluorites in Ambadongar.

The alkaline carbonatite complex of Ambadongar Latitudes 21º 58' 16" N to 22º 03' 30" N and Longitudes 74º 05'51" E to 74° 08' 24" E lies at 38 km in south of Chhota Udaipur in Gujarat (Fig.1). The Ambadongar carbonatite and alkaline silicate complex is located along the east–west-trending Narmada Rift, is contemporaneous with the main Deccan eruptive event (Basu et al. 1993). The entire region around Ambadongar is part of the Malwa plateau and occurs in the Lower Narmada Valley in West Central India (Bose, 1884). These rocks are the ones Sukeshwala and Udas (1963) verified as the first carbonatite discovered in India. Viladkar (1981) made note of alkaline rocks associated with the carbonatite rocks of Ambadongar. Gwalani (1981, 1984) covered the topic of petrologic and geochemical studies on the Deccan Traps and Bagh Beds of Padvani and Dugdha-Naswadi area. Viladkar (1986) has described the fenitisation of sandstone and pyroxene minerals and carbonatite rocks at the Ambadongar carbonatite alkalic complex. The carbon and oxygen isotope study of the carbonatite rocks was done by Viladkar and Wimmenauer (1992). Mitra (1981) worked on the genesis of the yellow and colorless fluorite of Ambadongar and investigated color centers in yellow and colorless fluorites by optical spectra and thermoluminescence (TL) studies, using normal as well as gamma-irradiated fluorite samples. Palmer *et al*. (1996) did stable isotope and fluid inclusion studies on carbonatite-hosted deposits at Ambadongar. They concluded that fluorite deposits have resulted from the mixing of late-state ortho-magmatic and meteoritic fluids at temperatures below 160ºC. The results of my experiments also support his views concerning purple, yellow, and colorless fluorites; however, blue-green fluorites crystallized at the highest temperature at the range of 168.2 to 192.1ºC.

2. Geological Setting

The Ambadongar carbonatite ring covering an area of 30 km^2 is located at the Northwest periphery of the Deccan province in the Chhota Udaipur district of Gujarat state, India (Fig. 1). Alkaline rocks were intruded into the Achaean basement gneiss, Bagh beds and Deccan basalts (Deans et al. 1972; Viladkar 1981). The dual nature of the Deccan basalt and Bagh, with radial dips of 30 to 60° near the Ambadongar carbonatite complex, ascribes an upward intrusion of carbonatite magma (Sukheswala & Udas 1963; Viladkar 1981; Gwalani et al. 1993).

The Ambadongar carbonatite complex (65 ± 0.3 Ma, Ray & Pande, 1999) comprises predominantly calico-carbonatite and ferrocarbonatites. Alkaline rocks, nephelinites and phonolites, basalts, and basaltic and doleritic dykes occur in association (Deans et al. 1972; Viladkar 1981). In the northern part, ferrocarbonatites have intruded into the early-formed carbonatite breccia and occur as small plugs and permeated veins in calciocarbonatites. The associated nephelinites in the area are exposed in low grounds near the main carbonatite complex. Later, hydrothermal quartz and fluorite veins were intruded into the pre-existing carbonatite rocks, a more prominent feature in the active mining area. The author has marked many dykes having a composition of dolerites and basalts.

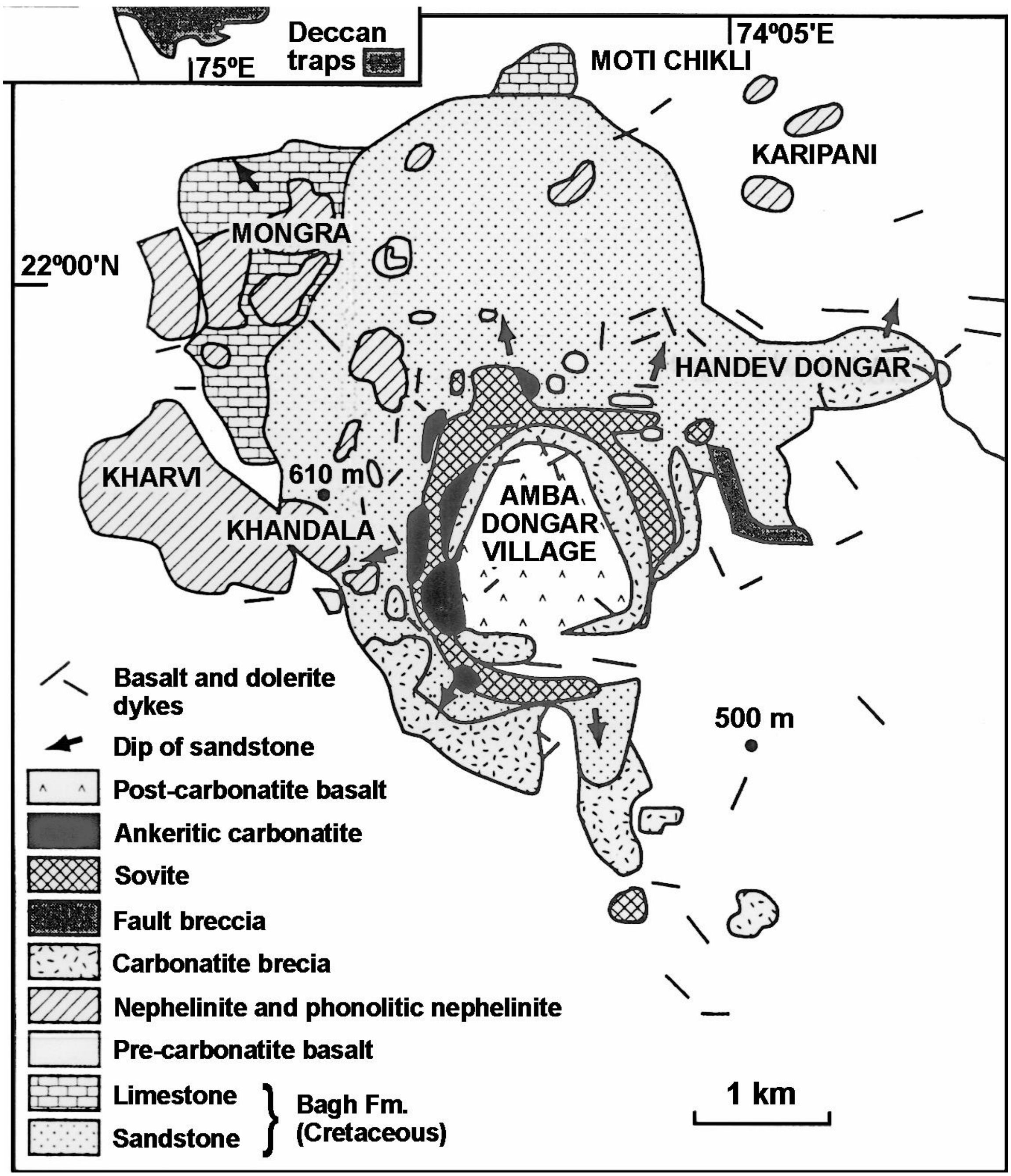


Fig. 1 Location Map of Ambadongar Complex (after Viladkar, 2015)

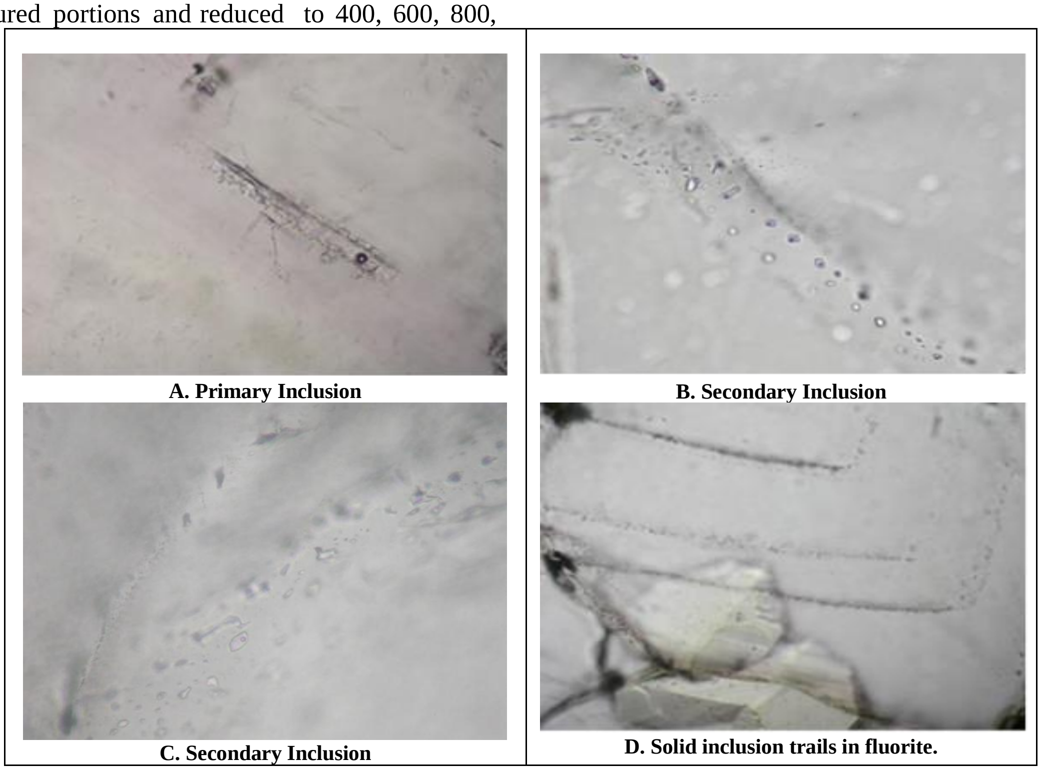
3. Mineralization

Fluorite deposits occur along the contact of the host rock carbonatite and the Bagh Orthoquartzites and are commonly found near small ankeritic carbonatite plugs. Veins of fluorite fill concentric fractures and dip from steep northerly to vertical. Host rocks surrounding fluorite occurrences are strongly silicified, typically to distances between 5 and 10 cm from the vein-wall rock contact. Silicification in the surrounding calcite carbonatite consists of fine-grained quartz, which, in turn, has been partially replaced by fluorite (Palmer et al. 1996). From field relationship, colors were determined to have been blue and purple fluorite, which is commonly inter-layered, followed by yellow and colorless fluorite varieties.

4. Methodology

Fresh fluorite crystals were taken from veins and collected in sample bags. In the lab, samples were cut from the least fractured portions and reduced to 400, 600, 800, 1000, and 2000 mesh sizes, respectively. The next process was canvas clothing of samples by using chromium oxide powder. Twenty-four doubly polished thin sections, six of each colored sample, were used for micro-thermometric analysis.

The fluid inclusion thermometric study was carried out in the lab using a THMSG 600 stage attached to a Leitz-Ortholux II-Pol microscope, which operates between temperatures 600°C to -196°C. Calibration was accomplished using synthetic CO_2 and H_2O treatments. In all samples, fluid inclusions were inspected in polarized light in a metrological microscope at the magnification of 50 x. In most of the samples, primary inclusions seen along the growth zone are large in size and show a random orientation in the cavity, Fig. 2A. Secondary inclusion occurs along a fracture (Fig. 2 B, C & D). It occurs in an array in the crystal.



A. Primary Inclusion

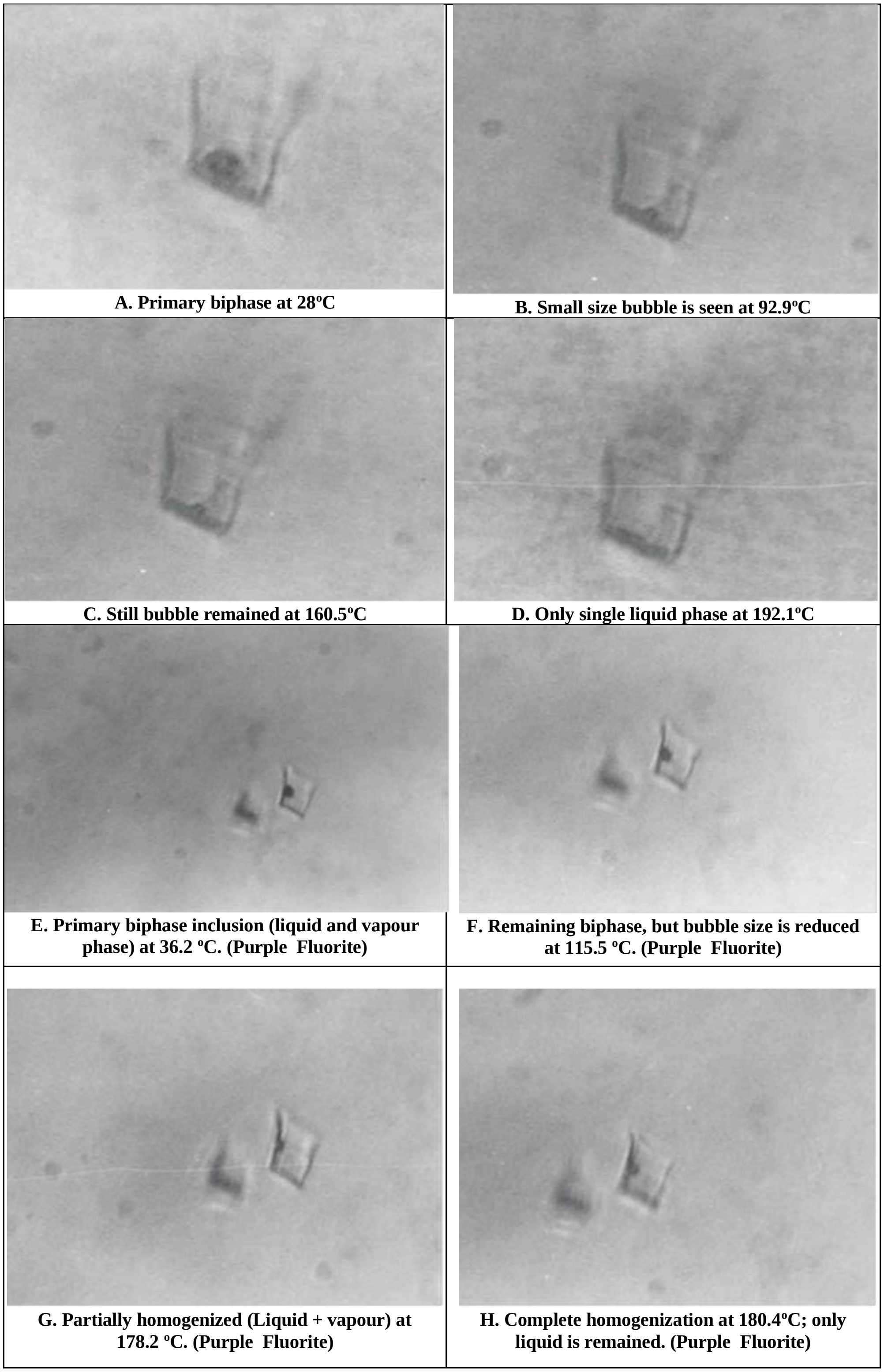
B. Secondary Inclusion

C. Secondary Inclusion

D. Solid inclusion trails in fluorite.

Fig. 2 A. Primary fluid inclusion in fluorite occurs along the growth zone (L+V). B, C & and D are Secondary biphase inclusions in fluorite that appear along fractures. (Field of view: 4mm).

Some pieces of doubly polished fluorite wafers with very good inclusions ranging from 10 to 50 microns and variable degrees of fill were used for heating and freezing studies at the lab. Primary biphase inclusions were used in micro thermometric analysis. At the start, two phases (Liquid + vapour) are seen, with a bubble shifting from the side corner to the center of the cavity. In the later stage, the fading of the bubble is marked, and finally, the bubble disappears completely and becomes a single phase. T_H and Tm_{Ice} of different colored fluorite viz. purple, bluish-green, and yellow is given in Table. 1. Microthermometric data for various stages of fluid inclusion of blue-green fluorite is shown in Fig. 3.



A. Primary biphase at 28ºC

B. Small size bubble is seen at 92.9ºC

C. Still bubble remained at 160.5ºC

D. Only single liquid phase at 192.1ºC

E. Primary biphase inclusion (liquid and vapour phase) at 36.2 ºC. (Purple Fluorite)

F. Remaining biphase, but bubble size is reduced at 115.5 ºC. (Purple Fluorite)

G. Partially homogenized (Liquid + vapour) at 178.2 ºC. (Purple Fluorite)

H. Complete homogenization at 180.4ºC; only liquid is remained. (Purple Fluorite)

Fig. 3 Micro-thermometric data of Fluid Inclusion of Blue, Green, and Purple Fluorite.

Blue Green Fluorite: A. Primary biphase (liquid and vapour) inclusion having rectangular shape at 28.0 ºC. B. Bubble reduced to very small size yet remained biphase at 92.9ºC. C. Water phase expanded, but still bubble remained at 160.5ºC D. Only a single liquid phase appeared homogenization at 192.1ºC.
Purple Fluorite: E. Primary biphase inclusion (liquid and vapour phase) at 36.2ºC. F. Remaining biphase, but bubble size is reduced at 115.5 ºC. G. Partially homogenized (Liquid + vapour) at 180ºC. D. Complete homogenization at 180.4ºC; only liquid has remained.

Table 1. Homogenization Temperatures of Purple, Blue-Green, Yellow, and Colorless Fluorites

Color	No of inclusions	T_H range (ºC)	Mean (ºC)	No. of inclusion	Range of Tm Ice (- ºC)	Mean (- ºC)
Blue-green	18	168. 2 - 192.1	182.2	8	0.8 - 1.0	0.9
Purple	12	1 62.2 - 180.4	170.1	9	0.7 - 1.0	0.8
Yellow	20	1 24.6 - 136.3	130.8	8	0.5 - 0.7	0.6
Colorless	11	110.1- 122.2	119.3	6	0.4 - 0.6	0.5

5. Discussion and Results

The fluid inclusion study reveals distinct homogenization temperatures for each colored fluorite, namely purple, yellow, and bluish- green. The inclusion of blue- green fluorite homogenizes at the highest temperature. It ranges from 168.2 to 192.1ºC, having a mean value of 182.2ºC (See, A, B, C & D). Purple fluorite seems to be crystallized at lower temperatures than blue- green fluorite shows a range of homogenization temperature between 162.2 and 180.4ºC. It completely homogenizes at 180.4ºC. The mean value is 170.1ºC (See, E, F, G & H). Yellow and colorless fluorite reveals the low temperature of crystallization with the mean values of 130.8ºC and 119.3ºC, respectively. Most of the inclusion in blue behaves like they were formed at low vapor pressure. Homogenization temperatures of the final ice melting of all fluorites have differed from one another. Early-formed blue, green, and purple fluorites show low ice melting ranges of 0.9 to -0.8 ºC. However, Inclusions in yellow fluorite reveal a melting range between 0.6 and 0.9 ºC.

The mean value is 0.6 ºC. Colorless fluorites have the highest ice melting point with values ranging between 0.4 to 0.6 ºC. This study shows the earliest fluorite precipitated was blue-green fluorite, followed by purple, yellow, and colorless fluorites precipitated at lower temperatures. Fluid inclusion studies done by Palmer et al. (1996) concluded that fluorite deposits of Ambadongar crystallized below 160ºC temperature. Our research also follows his results; however, our experimental data shows that blue-green fluorites crystallized at the highest temperature in the range of 168.2 to 192.1ºC.

6. Conclusion

Based on homogenization data of blue-green, purple, yellow, and colorless fluorite, it can be concluded that Blue-green fluorites are crystallized earliest from the fluid having a temperature of approximately 192ºC. Later, purple fluorite crystallized at lower temperatures between 175ºC and 180ºC. Yellow and colorless fluorites homogenize even at lower temperatures, which indicates that they crystallize at lower temperatures than Blue-green and Purple fluorites. Early crystallized blue-green fluorite occurs as small veins with green fluorites, apatite, and quartz, while yellow fluorites occur as thick veins, sometimes as a separate veins. The composition of liquid and vapor phases in biphase fluid inclusions was difficult to identify during studies. However, further experimentation with microprobe analysis of samples is required to identify the composition of the liquids present in the inclusions.

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