IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861. Volume 5, Issue 2 (Nov. - Dec. 2013), PP 14-18
www.iosrjournals.org

Optical Studies on Eritrean Quartz

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Abstract: *A detailed geological history of quartz and industrial minerals present in different localities of Eritrea is given. Well-grown transparent quartz crystals reflecting the hexagonal crystallographic features and isolated, irregular shaped small milky quartz stones are found in western suburb of Asmara and the area between Molebso and Zara in central northern Eritrea. Mechanism of formation of growth features observed on the habit faces of transparent quartz crystals is briefly explained. Micro-topographical studies carried out on these crystals indicate that to begin with, they grow and develop under high supersaturating conditions.*
Most of the milky quartz stones are observed to be generally randomly scattered and devoid of gold. However, few such specimens having yellow colored dots on their surfaces contain gold particles. Energy dispersion of X-ray analysis (EDAX) indicates high content of gold to the tune of 48% present in such samples. Commercial implications related to quartz bearing gold are discussed. It is proposed that gold exists in large quantity in quartz veins deep beneath the surface of earth in this region.
Keywords*: Gold, Quartz, Crystal, Habit, EDAX.*

I. Introduction

Eritrea is a young state located in the northern-eastern part of Africa ((Figure1). According to old records [1], gold mining production in this country had started from the times of Portuguese occupation in the 17th century. Evidence of work of ancient miners is found in several places in the country like Debarwa, Galla Valley, Adi Nefas, Medrizien (Figure1, (1)) and Augaro, Hykota, Ketina Bisha-Okere, Shilalo (Figure 1, (2)). Modern mining, however, began with the Italian Colonization.

The range of identified deposits covers gold, polymetallics and several metals like copper and zinc hosted in Quartz veins and in massive sulphide type deposits. A variety of construction materials like marble, granite etc are also found in the country. At present, two main regions known for their primary gold; the central highland area (Figure1, (1)) which covers Medrizen, Adi Shemagle, Hara Hot, Adi Nefas, Adi Rassi, Debarawa and the Gash Barka (Figure 1, (2)) which includes Augaro, Damishoba, Antore and Suzena. Significant

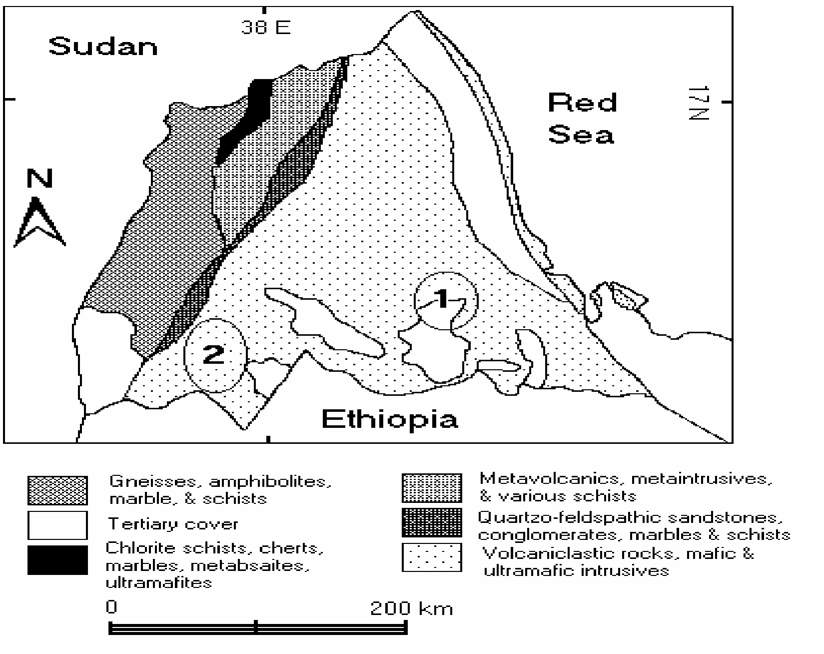

FIGURE-1
Simlified geological map of central and western Eritrea.The regions shown as 1 &2 in the fipure represent pold fields:
1) Medrizien,Adi-Shemagle,Hara-Hot,Adi-Nefas,Adi-Rassi, and Debarwa.
2) Augaro,Haykota, and Antore.

Alluvial gold is also known at Shillalo and southern Seraya. The average head grade in most of the mines was reported to be as high as 25-45 grams per ton, with reasonably good recovery after milling. The primary gold deposits in Eritrea occur in veins associated with quartz.

Well-grown transparent quartz crystals reflecting the hexagonal crystallographic features and randomly scattered some irregular shaped small milky quartz stones are found in the area between Molebso and Zara in central northern Eritrea.

Several surface micro-topographical features are indicative of the conditions of mechanism of growth of the crystals. The present paper relates to micro-topographical observations of transparent natural quartz crystals of Eritrea and scanning electron microscopic (SEM) and energy dispersive X-ray analytical (EDAX) studies carried out on the irregular shaped milky quartz specimens.

II. Observations and discussion

II.1. Striations and hillocks on habit faces:

Most of the quartz crystals were found to be remarkably transparent and lustrous with usually flat surfaces. These crystals were thoroughly cleaned with usual reagents, then coated with silver films to enhance the contrast and examined under a metallurgical microscope.

Figure 2 illustrates a built-up picture of Striations observed on a $(10\bar{1}0)$ prism face, which are smooth, non-uniformly spaced and perpendicular to c-axis. All the crystals by and large revealed generally the presence of such striations on their prism faces. The observations of striations presented here is rather striking because usually the prism faces of natural quartz are characterized by horizontal striations perpendicular to c-axis and almost devoid of growth hillocks, but here, the edge nucleation resulting into a hillock is seen on the left hand side of the figure. Corner nucleations on some of the crystal faces were not uncommon. It needs to be mentioned that all the habit faces having edge and corner nucleation were, in fact, found to have impurities on their habit faces i.e. tiny black spots seen in the figure.

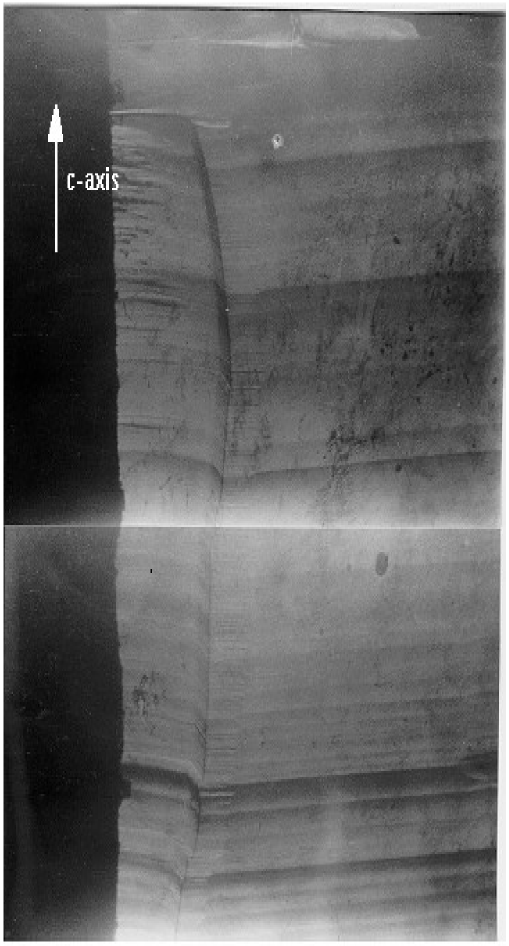

FIGURE 2

A built -up picture of irregularly spaced striations observed on a $\{10\bar{1}0\}$prism face. On the left is seen formation of a hillock due to edge nucleation.

John, Rakovan and Jaszczak [2] have proposed a possible mechanism in which migration and clustering of impurities is correlated to the kink formation by using differential interference microscopy and atomic force microscopy for the study of the micro-topography of (001) surfaces of single crystals of graphite from Nambia.

In the present case it is suggested that the edge and corner nucleation results due to the effect of adsorbed impurities on the growth process. There is always a very high probability of the presence of impurities in various forms present in nature which can get incorporated in the crystals during the process of growth or the impurity molecules would be pushed to the edge of one face where they become trapped by the growth layers spreading from neighboring face. Even in this trapped position they can behave as nuclei for fresh growth. Also, if these impurity molecules are pushed along the edge to a corner, corner nucleation can occur. The prism faces of several quartz crystals exhibited the presence of growth hillocks. It is known fact that once a crystals grow in size, independent growth can take place on their habit faces and in later stages result into hillock formation by two-dimensional nucleation process by spreading and piling up of growth layers on the individual faces and by interaction of growth sheets spreading on prism faces with those on dome faces [3, 4, 5, 6, 7, 8]. In fact, a lot of data is available about the mechanism of formation of hillocks on quartz crystals and

also various growth morphologies of crystals [9, 10]. We did not see evidence of etching on any of the habit faces of crystals.
The observations presented here, suggest that to begin with, crystals of quartz develop and grow under high super saturation conditions. Formation of hillocks, other growth structures and absence of growth spirals support this view. Further variation in super saturation values and fast evaporation rates can take place in nature and help in the development of changing growth patterns

II.2 Milky quartz Specimens containing gold particulars

On some of the milky quartz specimens, very tiny yellow colored dots could be seen through 10 X magnifying lens but when examined under higher magnification through a microscope, content of gold in the form of yellow colored tiny particles and/ or patches could be observed. A scanning electron micrograph record on one of the regions of a specimen containing gold is shown in Figure 3a. It depicts elevated and irregularly shaped growth structure of light yellow color patch. Energy dispersive X-ray spectra recorded on the surface near to structure of Figure 3a is shown in Figure 3b.

FIGURE- 3 a

SEM showing elevated growth of gold (yellowpatch) of Milky quartz specimens.

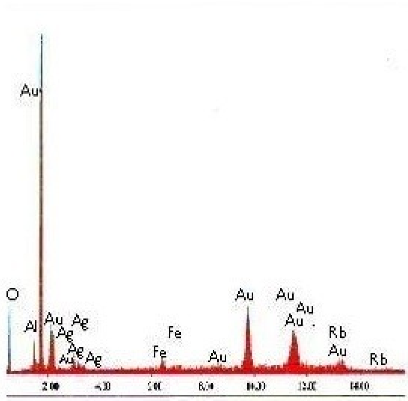

FIGURE 3b

Energy dipersive X-ray spectra recorded on the surface of elevated structure of figure 3a showing presence ofgold, silver, etc...

The results obtained on comparative basis suggest that light yellow colored abnormal growth structure is that of gold accompanied by Ag, Fe,& Rb as impurity with their peaks corresponding to significantly low values of 3.48%, 1.63% and 5.38% in comparison to gold varying from 1. 5% to 48.27%.. It is important to mention that the content of gold was found to vary from specimen to specimen. It varied between1.5% to 48%. When such samples are properly cleaned and polished, they could be used as gold quartz nuggets or for jewellery manufacturing. Therefore, in the interest of national economy, It will important to search such samples in the region by means of metal detectors.

II.3 Milky Quartz devoid of gold

Most of the specimens of milky quartz specimens were found to be devoid of gold particles. SEM of one such specimen with randomly oriented impurities is shown in Figure4a and its record of corresponding energy dispersive X-ray spectra is

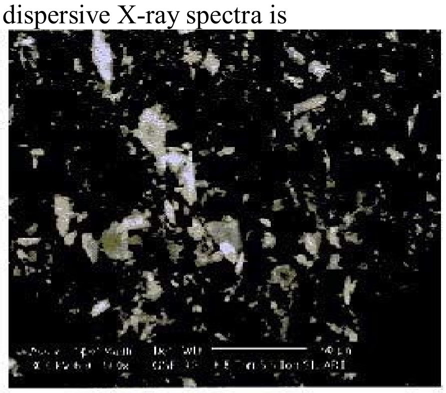

FIGURE -4a

SEM of a Milky quartz specimen devoid of gold particles showing randomly oriented impurities

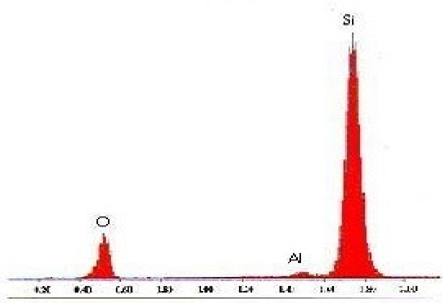

FIGURE 4b

Energy dispersive X-ray spectra recorded on the surface (illustrated in figure 4a) showing aluminium as impurity shown in Figure 4b. It shows Al as impurity to the tune of 1.3%. Such mineral can form in contact with quartz at high temperature and pressure [11].

Hydrothermal dissolution experiments carried out in the laboratory on quartz crystals [12] indicate that quartz can be dissolved in ordinary water under high pressure and temperature quickly in about a week's time and this duration is nothing as compared to millions of years of rock history, wherein the conditions of dissolution in the environment are duplicated very slowly deep in the earth's crust. Water is a universal solvent in earth's crust and most minerals in rocks grow from water solutions, come in contact with growing quartz and thereby get trapped in the environment. Reports also show that hydrothermal reservoirs are involved in gold mineralization [13].

In fact, association of gold and quartz forms one of the most common types of "primary gold deposits"[14,]. Gold-containing quartz rocks are found in areas where volcanic hydrothermal activity takes place in the geologic past. The areas include the regions around old gold mines. Gold is transported through the Earth's crust dissolved in warm to hot salty water. These fluids are generated in huge volumes deep in the Earth's crust as water-bearing minerals dehydrate during metamorphism. Any gold present in the rocks being heated and squeezed is sweated out and goes into solution as complex ions. In this form, dissolved gold, along with other elements such as silicon, iron and sulphur, migrates wherever fractures in the rocks allow the fluids to pass. This direction is generally upwards, to cooler regions at lower pressures nearer the Earth's surface. Out of several minerals that are likely to fall out of the solution, quartz is only the first that falls out of the solution and gold is one of the last minerals to be deposited out of solution. Under these conditions, the gold eventually becomes insoluble and begins to crystallize, most often enveloped by masses of white silicon dioxide, known as milky quartz. When erosion occurs, transport of some of gold quartz stones could take place and such specimen may appear on the surface of earth during long periods of geological time.

Gold-Bearing quartz is one of the world's rarest forms of natural gold. It is found underground by hard rock miners in only a few locations in the world. This unique formation is being mined 1,500 to 2,500 feet below the earth's [15]. On similar lines and in light of our observations, it is suggested that exploring the possibilities of deep mining would perhaps help to locate gold deposits in veins associated with quartz. It is quite likely that gold may exist in bulk beneath the surface.

III. Conclusions:-

1. Eritrean quartz crystals develop and grow under high super saturation conditions. Hillock formation on their habit faces result by two-dimensional nucleation process.
2. As the content of gold in some of the milky quartz specimens has been observed to vary from a low value of 1.5 % to a high value of 48 %, an exquisite piece of jewelry can be created after cutting & polishing them in an appropriate manner or alternatively gold can be extracted from the samples through gravitation separation process. The income generated through this process could play an important role for the improvement of Eritrean economy.
3. Experimental evidence collected indicates that gold in bulk exists in quartz veins deep below the surface of the located region. Exploration of gold bearing quartz veins in this region would be an important addition to the already existing gold mines of Eritrea.

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Acknowledgement
The authors wish to thank Mr. Alem Kibreab, Director General, Department of mines, Mr. Asmerom Mesfin, Director of mines control, and Mr. Tesfamichael Keleta, Director of Geological Survey of Eritrea for providing valuable information about mining and mapping activities and literature about past mining records.