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Alteration Minerals and Quartz Textures of Epithermal Quartz Veins at Soripesa Prospect Area, Indonesia

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Abstract

The Soripesa prospect area is located at Maria village, Wawo district, Bima regency, West Nusa Tenggara Province, Sumbawa Island, Indonesia. This area is mainly occupied by andesitic volcaniclastic rocks, dacitic volcaniclastic rocks, bedded and fossiliferous limestone, and Quaternary volcanic rocks. Representative samples, collected from near five quartz veins were selected to make thin sections. Thin sections were analyzed using a polarizing light microscope. Selected nine samples were used to identify the quantitative mineralogy. XRD data were obtained by using a Rigaku RINT 2100 at the Earth Resources Engineering Department, Kyushu University, Japan. The primary minerals of host rocks of the veins are quartz, orthoclase, plagioclase, pyroxene, amphibole minerals, mica and other mafic minerals. The common alteration minerals in this prospect area are quartz, epidote, chlorite, pyrite, illite, and smiectite. Minor amount of other alteration minerals arekaolinite, alunite, rutile, and anatase. Propyllitic alteration (epidote + chlorite) occurs in most host rocks of the veins. Most common quartz textures of those veins in the research area are primary textures (comb, colloform bands, and crustiform bands, zonal, cockade, and moss).Alteration mineral are altered under in terms of interaction of near-neutral chloride fluids and are crucial in distinguishing low-sulphidation types of epithermal systems. Quartz textures in this research belong to typical characters of low-sulphidation epithermal system and they can help to identify the morphology of veins such as face-controlled and parallel-controlled. Quartz textures indicate that the epithermal quartz veins in the Soripesa prospect area are formed at the near surface.

Key words: epithermal, gold, mineralization, quartz textures

Introduction

The Soripesa prospect area is located at Maria village, Wawo district, Bima regency, West Nusa Tenggara Province, Sumbawa Island, Indonesia (Figure 1). This prospect area is previously owned by PT Bima Baruna Raya Mining (BBRM) and PT Sumbawa Timur Mining. These companies have observed Au-Ag deposit and base metal mineralization. At present, the concession area legally belongs to the PT Bima Putera Minerals (Indomining Group) that has a Mining Permit for the deposit. This area is mainly occupied by andesitic and dacitic volcaniclastic rocks.

There have five main veins in the Soripesa prospect area, including Arif vein, Dollah vein, Jambu Air vein, Merpati vein, and Rini vein. The main ore minerals are chalcopyrite, azurite, malachite, sphalerite, galena and electrum forming as polymetallic epithermal quartz veins. Alteration minerals can be used for interpreting the type of fluid and temperature of the environment. Moreover, different alteration mineral assemblages may occur with distance from veins, thus demonstrating the progress of the reactions and modification of the fluid as it moved into the away from the vein or fluid pathway. Textures of quartz can also be used to estimate the morphologies of vein systems and the nature and origin of the veins. The purpose of this paper is to elucidate the nature and origin of fluid and vein forms by using alteration minerals and textural characteristics of quartz from polymetallic epithermal quartz veinsatthe Soripesa prospect area.

Tectonic Setting and Regional Geology

The Sumbawa Island forms as a part of the Cenozoic Calc-alkaline volcanic inner Sunda-Banda Arc, which is still active up to present. The arc has been largely formed by

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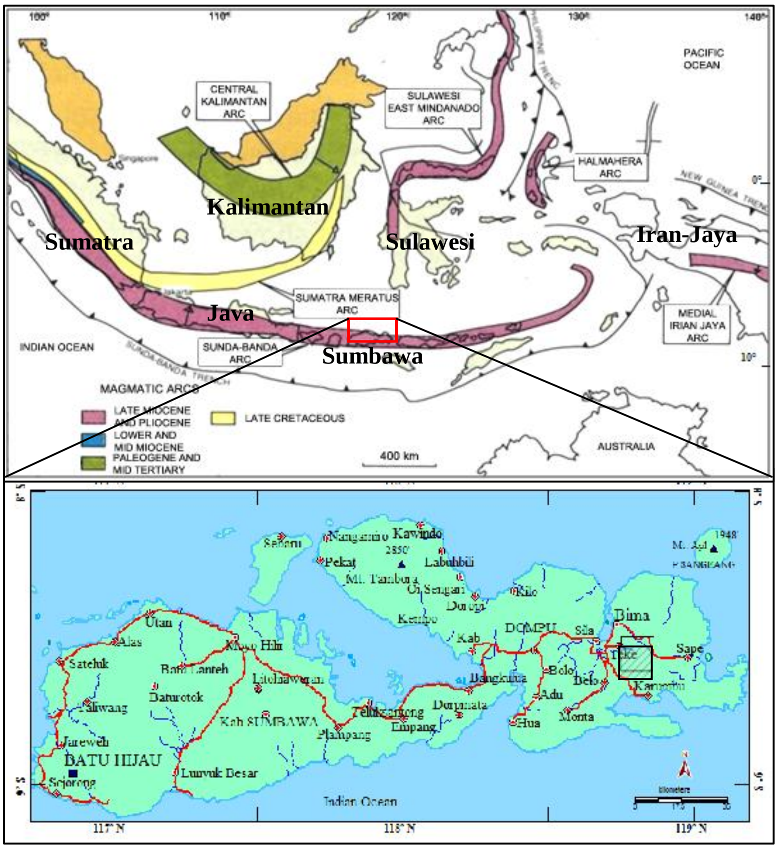
northward subduction of Indo-Australia Plate (Figure 1). However, the shape of the island arc is now being modified in the east due to collision with the Australian–New Guinea continental margin, including West Flores to East Sumbawa and Alor (Hamilton, 1979). The East Sumbawa area is largely underlain by andesitic to basaltic lava and breccia of the Lower Miocene, with intercalations of tuff and limestone, and fresh pyroclastic sequences (Nana and Aswan, 1978). This sequence is overlain in parts by dacitic tuff and bedded limestone of the Middle Miocene. These units have been intruded by numerous small to medium bodies (several km) in the Middle to Upper Miocene including andesite, dacite, diorite, trachyte and syenite (Figure 2).

The northern part of Sumbawa Island is dominated by the eruptive products of the active Tambora and Sangeang volcanoes, comprising of lahar, volcanic bomb and lapilli. Sumbawa Island, regionally, is intersected by NW-SE and NE-SW trending structures. However, the formation of quartz veining, alteration and mineralization at Soripesa Prospect are related to the N-S faulting (Noya *et al.*, 2009).



▨ Research area

Figure 1. Location map of study area (Sumbawa Island and Soripesa prospect area) which is situated within a east-west trending Sunda Banda magmatic arc (modify after, Carlile and Mitchell, 1994).

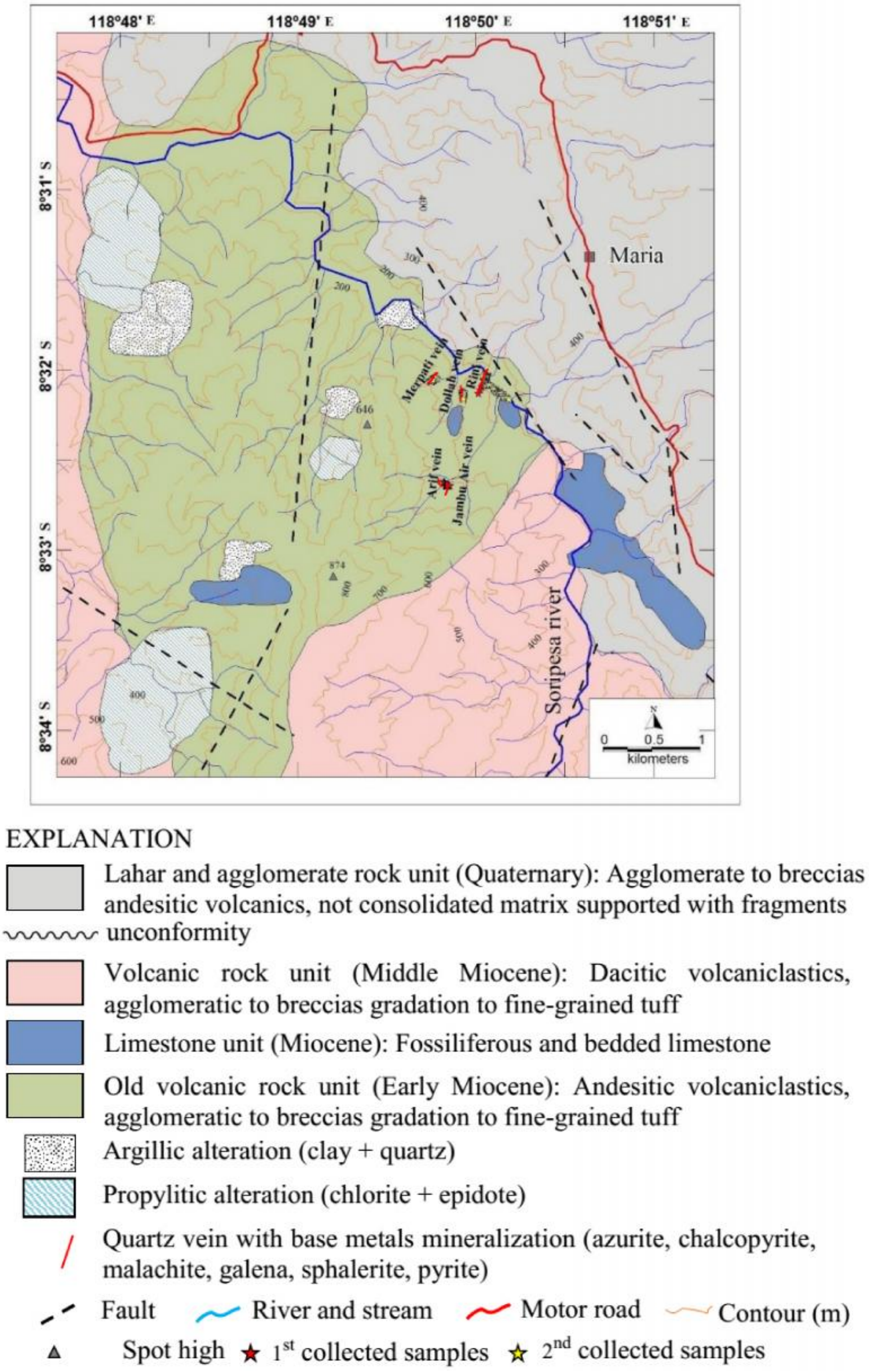


Figure 2. Geological map of the Soripesa prospect area and surrounding area. (modified after Noya *et al*., 2009)

Analytical Methods

Petrographic Microscope

Representative samples collected from near five quartz veins from dacitic volcaniclastic rock unit. Those samples were selected to make thin sections. Thin sections were analyzed using a polarizing light microscope. The polarizing light microscope was used to confirm the rock type(s) and the alteration minerals, including additional alteration minerals not observed by the binocular microscope, and to study the mineralogical evolution of the alteration minerals. For textures of quartz, both hand specimens and thin sections were used for analyses.

X-ray Diffraction (XRD)

For XRD analyses, selected nine samples were used to identify the quantitative mineralogy. XRD data were obtained by using a Rigaku RINT 2100 at the Earth Resources Engineering Department, Kyushu University, Japan. The main focus is to calculate the composition of non-clay minerals and clay minerals, especially for hydrothermal minerals that occur in epithermal environment. The RockJock program software was used to calculate the composition of the minerals. RockJock is a computer program that determines quantitative mineralogy in powdered samples by comparing the integrated X-ray diffraction (XRD) intensities of individual minerals in complex mixtures to the intensities of an internal standard.

Results and Discussions

Primary Minerals

Lithology of the Soripesa prospect area is occupied by andesitic to basaltic lava and breccia, dacitic tuff and limestone, and fresh pyroclastic sequences. Most of host rocks of the veins are andesite and andesitic/basaltic volcaniclastic rocks. The primary minerals of host rocks of the veins are quartz, orthoclase, plagioclase, pyroxene, amphibole minerals, mica and other mafic minerals. The primary minerals found in the area are those normally contained in intermediate to basic rocks. The degree of primary textures is a function of formation permeability and the type, abundance, and grain size of primary minerals.

Alteration Minerals

Propyllitic alteration (epidote+chlorite) occurs in most host rocks of the veins. Weak to moderate clay-pyrite alteration intensively developed in the volcanic rocks, especially in host rocks of the Merpati vein. It could be influenced by NW – SE trending structures and andesite to porphyry dacite intrusive rock. In near quartz veins, hydrothermal alteration minerals appear both as replacement of the primary minerals, as well as fillings in vesicles, vugs and fractures.

The main alteration minerals are quartz, chlorite, epidote, pyrite, and clay minerals (kaolinite, illite, and smectite). There have minor amount of alunite, anatase, and rutile minerals in host rocks. Table 1.shows the common alteration minerals that occur in the epithermal environments and Soripesa prospect area, Sumbawa Island.

Quartz

Quartz may act as both replaced and primary minerals. Quartz is colourless to white in colour and occurs in euhedral to subhedral crystals. It is identified both as open space (vesicle) fillings and vein filling mineral. Euhedral open space quartz crystals up to 2 mm long were formed later than chalcedony in andesitic host rocks. Some quartzs are replaced in plagioclase phenocrysts (Figure 3a). In XRD data, some samples contain high amount of quartz because of alteration affect, especially DV5, MV3, and RAH.

Table 1. XRD mineralogical quantification for non-clay and clay mineral compositions (normalized wt%) of host rocks near epithermal quartz veins from the Soripesa prospect area.

	Non clay minerals							
Samples	Qtz	Epi	Alu	Py	Rut	Ana	Jar	Cal
AV4	21.80	76.00	0.90	0.10	0.30	0.00	0.10	0.00
DVA	41.60	23.40	1.40	0.00	1.10	0.00	0.00	0.00
DV5	72.27	2.80	1.90	0.00	0.50	0.00	0.00	0.00
MV2	45.10	0.00	0.60	2.90	0.00	1.60	0.00	0.00
MV3	72.27	0.00	0.80	1.00	0.00	0.60	0.00	0.00
MV6	56.44	0.00	0.90	1.90	0.00	1.20	0.00	0.00
RVB	16.38	22.18	5.29	0.00	0.90	0.00	1.20	0.00
RVH	67.03	8.39	1.60	0.00	0.00	0.00	0.20	0.00
RVT	48.30	20.70	2.80	0.10	1.90	0.00	0.00	0.30
	Clay minerals							
	Ill	Sme	Kao	Chl	Bio			
AV4	0.00	0.10	0.00	0.60	0.00			
DVA	7.20	6.00	4.60	14.70	0.00			
DV5	5.71	4.10	0.90	11.81	0.00			
MV2	12.60	3.10	2.10	32.00	0.00			
MV3	15.32	9.41	0.00	0.60	0.00			
MV6	11.69	8.09	0.00	19.78	0.00			
RVB	3.60	9.89	3.40	35.76	1.40			
RVH	0.00	7.39	1.00	12.99	1.40			
RVT	3.40	5.30	0.20	16.80	0.20			

Pyrite

Pyrite minerals occur as euhedral to anhedral crystals under thin section. Pyrite is opaque minerals under X.P.L and P.P.L. Tiny cubic pyrite crystals were deposited in fractures, vesicles and veins and as disseminations in the groundmass (Fig.3b). Pyrite also occurred as replacement minerals. Samples from host rocks in Merpati vein have higher amount of pyrite minerals than other host rock samples.

Epidote

Epidote minerals mainly occur in the host rocks from Rini, Dollah, and Arif veins. Especially, host rocks of Arif and Jambu Air vein have higher amount of epidote minerals because of epidotization. But host rocks of Merpati vein do not contain epidote minerals. Epidote minerals show yellow to green color in second order and high relief (Figure 3c). Epidote crystals are shown in euhedral toanhedral and formed fine-grained aggregates. Epidote is found filling in fractures, vesicles, and replacing primary plagioclase and pyroxene and in most cases forms mineral associations with mainly quartz, chlorite and sometimes calcite, and pyrite.

Chlorite

Chlorite occurs in all host rocks of the veins. Chlorite shows a wide distribution and a big variation in colors, forms and textures. It varies in color from light-to-dark green, has a low birefringence and occasionally shows anomalously blue, brown or purple interference colors (Figure 3d). Chlorite is idiomorphic, forming radial aggregates in veinlets and vugs in association with quartz, epidote, amphibole and pyrite. Within veins, chlorite occurs as microspherules enclosed within quartz or epidote, but it may also replace primary pyroxene.

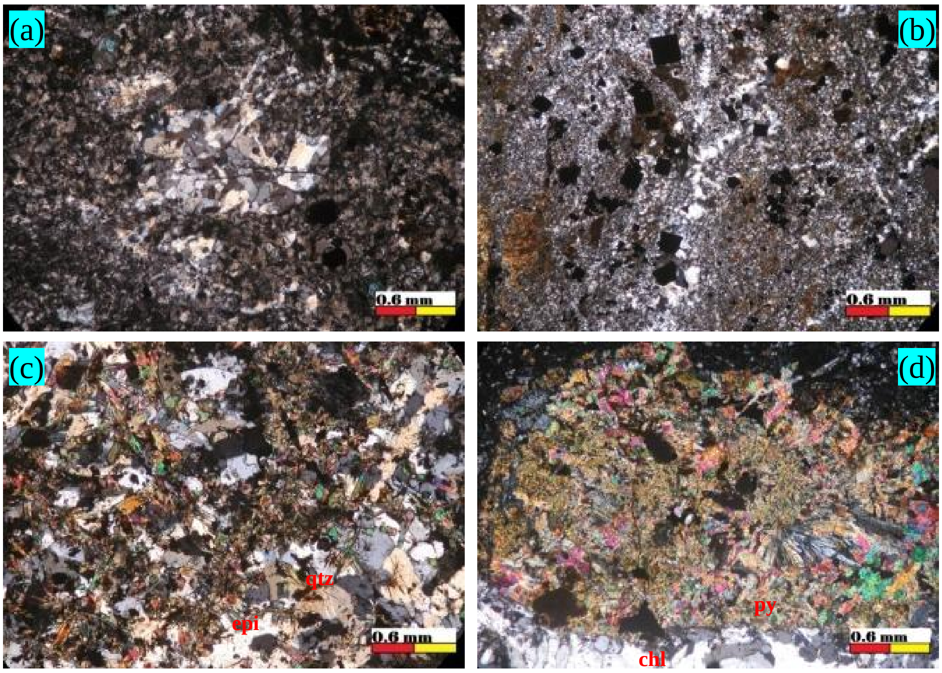


Figure 3. Alteration minerals (a) Photomicrograph showing quartz crystals replaced in plagioclase phenocryst in andesitic volcaniclastic rock under X.P.L. (b) Photomicrograph showing euhedral pyrite crystals scattered in altered andesitic rock under X.P.L. (c) Photomicrograph showing scattered euhedral epidote crystals under X.P.L. (d) Photomicrograph showing chlorite and epidote minerals replaced in plagioclase phenocryst under X.P.L. (qtz=quartz, py=pyrite, epi=epidote, chl=chlorite, and X.P.L =Cross polarized light)

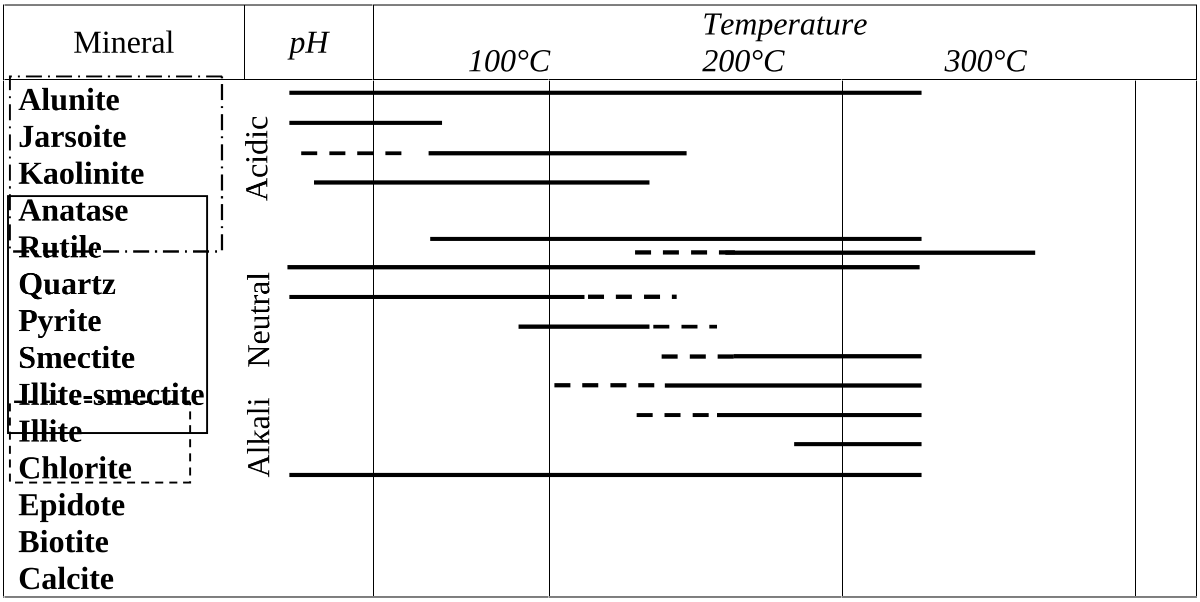
Clay Minerals

Based on the XRD data, clay minerals occur in host rocks of all veins and illite are the most abundant among the other clay minerals. Host rocks of the Merpati vein contain much more abundant clay (illite) than those of other vein host rocks, suggesting host rocks of the Merpati vein had been mostly affected by clay, quartz, and pyrite alteration. Smectite also occur in host rocks of all veins but not too much like illite. Kaolinite also present little amount in all samples. These clay minerals replaced plagioclase.

Thermal Stability and pH Conditions

Hydrothermal minerals that occur in the epithermal environment under acid neutral-pH conditions and the typical temperature range are shown in Table 2. The common alteration minerals in this prospect area are quartz, epidote, chlorite, pyrite, illite, and smiectite. Minor amount of other alteration minerals are kaolinite, alunite, rutile, and anatase. Temperature-sensitive minerals include Ca-silicates such as epidote and chlorite (stable above 200-240°C), near the base of the epithermal environment. Quartz and pyrite minerals occur in a wide range of thermal stability. Alteration minerals such as quartz, pyrite, epidote, chlorite, illite, and smectite, are formed under the neutral pH condition. There are also small amount of alteration minerals such as aluniteanatase, jarsoite, and kaolinite that are under the acidic pH condition.

Table 2. Thermal stability of various hydrothermal minerals that occur in the epithermal environment under acid and neutral-pH conditions, and the typical temperature range for deposition of epithermal ore (source: Hedenquist *et al.,* 1996). Bold minerals are found in this prospect area.



In low-sulphidation deposits, the alteration mineral assemblage is produced by near-neutral pH thermal waters.

Textures of Quartz

Most of the hydrothermal veins are formed from silica-bearing fluids that originate from (Jia and Kerrich, 2000): (1) igneous intrusions; (2) deeply convecting meteoric fluids; (3) metamorphic devolatilisation; (4) mantle-derived fluids. Quartz veins are commonly found in low-grade rocks, typically within or above the brittle-ductile crustal stress field, forming around 2–3 kbar and 200–350°C (Bons, 2001). Hydrothermal veins can be syntectonic to post-tectonic. The textures have been grouped into three major classes (primary, recrystallization, and replacement) to aid interpretation of their origin and environment of formation. Primary growth textures represent initial open-space vein fill. Recrystallization textures reflect the transformation of amorphous silica or chalcedony to quartz. Replacement textures represent partial or complete pseudomorphs of other minerals by silica minerals within veins.

Most common quartz textures of those veins in the research area are primary textures (comb, colloform bands, and crustiform bands, zonal, cockade, and moss).

Comb Textures

Comb texture is typically formed in open space from a hydrothermal solution which is slightly supersaturated with respect to quartz, but undersaturated with respect to chalcedony (Fournier, 1985a. This slight silica supersaturation is possibly brought about by slow cooling of the system and uniform growth from multiple nuclei along a vein wall (Figure 4a).

Colloform Texture

This term was first proposed by Rogers (1917). For silica minerals, this texture is a characteristic feature of chalcedonic aggregates in fine rhythmic bands (Figure 4b). Colloform texture in chalcedonic quartz is inherited from the original silica gel. The strong surface

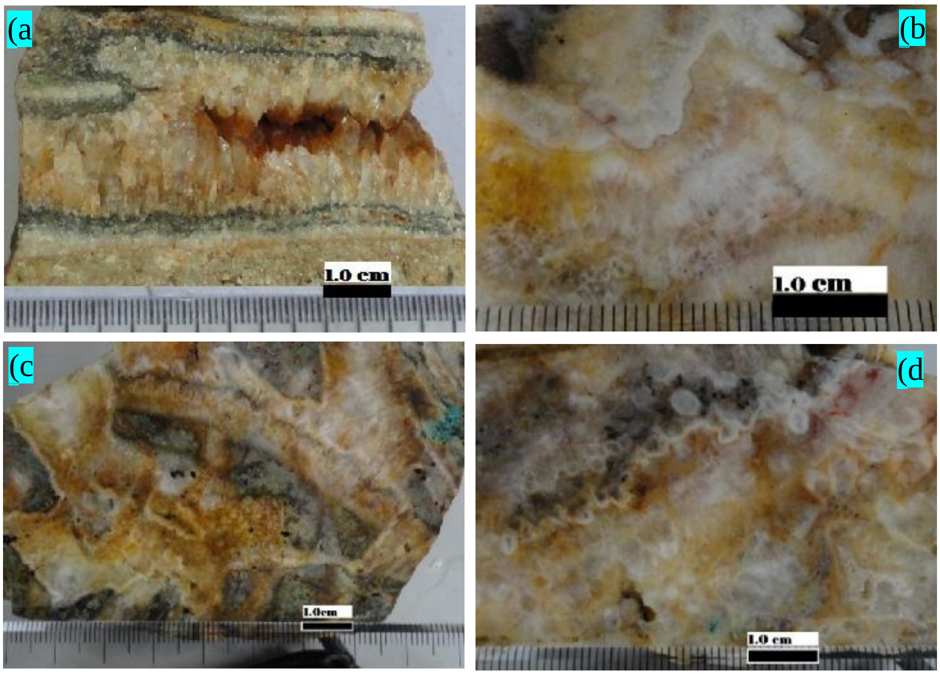


Figure 4. Textures of quartz (a) Clear to grey quartz band consisting of tightly packed subparallel crystals oriented perpendicular to the band wall giving the appearance of a comb. (b) Crustiform-colloform banded vein with chalcedonic and comb quartz bands. (c) Isolated fragments surrounding concentric crustiform bands (cockade texture). (d) Zone quartz crystals (euhedral quartz crystals with alternating clear and milky zones parallel to growing crystal faces).

tension of silica gel is responsible for the rounded or kidney-like external surface.

Crustiform texture

Crustiform texture is so common that it is considered a diagnostic feature of epithermal veins (Buchanan, 1981). Repetitive bands of different composition or texture reflect fluctuating concentrations of elements in solution and fluctuating fluid conditions during precipitation (Fig. 4b). These fluctuations are commonly ascribed to periodic boiling of the hydrothermal fluid.

Zonal Texture

Zonal texture displays alternating clear and milky zones within individual quartz crystals (Fig. 4d). Milky zones are usually crowded with fluid or solid inclusions and are always parallel to crystal growth faces. Zonal texture is confined to quartz crystals that grow directly from a hydrothermal fluid. This requires the hydrothermal fluid to be only slightly saturated with respect to quartz, suggesting slow changing or very mildly fluctuating conditions during crystal growth (Fournier, 1985).

Cockade Texture

This is a subtype of crustiform texture, as described previously by Taber in Adams (1920) and Purr (1926). In breccias, concentric crustiform bands surrounding isolated fragments of wall rocks or early vein materials produce a cockade texture (Fig. 4c).

Moss Texture

This texture has features similar to the micro-botryoidal gel structure described by Adams (1920). Under the microscope, groups of spheres (usually ranging from 0.1-1 mm in diameter) are highlighted by the distribution of impurities within aggregates of silica minerals. Some spherical impurities also show an internal concentric pattern. Moss texture may gradate to colloform texture if the spheres become interconnected.

Vein textures that can be recognized in the field are very important because these can help in assessing not only the nature and origin of the vein, but also the associated mineral system. Vearncombe (1993) examined vein morphologies based on growth direction of quartz and vein textures. Parallel and radiating textures are characteristic of gold deposits formed at the near surface. The face - control shows a range of conditions from the near surface to midcrustal (Vearncombe, 1993). Vein textures and corresponding explanations are listed in Table 3.

Table 3.Quartz texturesand their explanation of polymetallic quartz veins in the Soripesa prospect area, modified after Vearncombe (1993)

Vein texture	*Explanation*
Comb	Face-controlled, long axis of quartz crystals perpendicular to the cavity or wall rocks; crystals have rhombohedral terminations; zoning
Colloform	Parallel-controlled, concretionary, reinform and spherical textures; bands at various scales
Crustiform	Parallel-controlled; successive bands parallel to vein wall; defined by variable grain form and size
Zone	Face-controlled, long axis of quartz crystals perpendicular to the cavity or wall rocks; crystals have rhombohedral terminations; zoning
Cockade	Parallel-controlled, concentrically banded

Conclusion

Hydrothermal alteration in epithermal systems can be considered in terms of interaction of (1) acidic fluids; (2) near-neutral chloride fluids; and (3) alkaline fluids (Pirajno, 2009). According to the mentioned above alteration mineral assemblage, these minerals can be altered under in terms of interaction of near-neutral chloride fluids and are crucial in distinguishing low-sulphidation types of epithermal systems.

Quartz textures also can be used to identify the nature and origin of vein and associated mineral system. Quartz textures in this research belong to typical characters of low-sulphidation epithermal system and they can help to identify the morphology of veins such as face-controlled and parallel-controlled. These parallel-controlled and face-controlled indicate that the epithermal quartz veins in the Soripesa prospect area are formed at the near surface.

Acknowledgements

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