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Contents

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HOST ROCKS' GEOCHEMISTRY AND MINERALIZATION POTENTIAL OF POLYMETALLIC EPITHERMAL QUARTZ VEINS AT SORIPESA PROSPECT AREA, SUMBAWA ISLAND, INDONESIA

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Abstract

The Soripesa prospect area is located at Maria village, Wawo district, Bima region in the eastern part of Sumbawa Island, Indonesia. This area is a part of Cenozoic Calc-alkaline volcanic inner Banda-Sunda Arc. There are five main polymetallic epithermal quartz veins in the Soripesa prospect area, namely, Rini vein, Jambu air vein, Dollah vein, Merpati vein, and Arif vein. The dominant lithology is a lithic-crystal tuff of andesitic and dacitic composition and bedded limestone. Major oxides and trace elements were analyzed by using X-Ray Fluorescence (XRF) to identify the host rock geochemistry. The main veins are hosted by andesitic and andesitic/basaltic volcanic host rocks. Major elements compositions are affected by alteration. Based on the trace element data, host rocks of all veins were formed in the volcanic arc basalt (VAB) and island arc basalt (IAB) tectonic settings. Host rocks of Rini vein contain higher amount of precious and base metal elements (Zn, Cu, Pb, and Ag.etc.) than those of other host rocks.

Keywords: *Soripesa prospect area, lithology, tectonic setting, mineralization.*

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1 Introduction

The Soripesa prospect area is located at Maria village, Wawo district, Bima regency, West Nusa Tenggara Province, Sumbawa Island, Indonesia. The 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, PT Bima Putera Minerals (Indomining Group) has a Mining Permit for those deposits. The prospect area is mainly occupied by andesitic and dacitic volcaniclastic rocks and small portion of Tertiary bedded limestones. There are five main veins in the Soripesa prospect area including Arif vein, Dollah vein, Jambu Air vein, Merpati vein, and Rini vein, which trend in nearly North-South direction. The main ore minerals are chalcopyrite, azurite, malachite, sphalerite and galena forming polymetallic epithermal quartz veins.

Soripesa prospect area is located in the eastern part of Sumbawa Island and in the eastern part of Sunda-Banda arc (Neogene). Sunda-Banda arc is the longest in Indonesia, extending from North Sumatra through Java, Bali, Lombok, and Sumbawa, to east Damar. Tectonic setting and genesis of vein host rocks are important for ore depositions. The purpose of this paper is to confirm the rock types, tectonic setting, and to identify their mineralization potential and the genesis of host rocks of polymetallic epithermal quartz veins in the Soripesa prospect area, East Sumbawa, Indonesia.

2 Tectonic setting and regional geology

The Sumbawa Island forms as a part of the Cenozoic calc-alkaline volcanic inner Sanda–Banda arc which is still active up to present. Sunda–Banda island arc is a volcanic arc formed by the interaction of plate subduction slab in the form of Indo-Autralia with Asian plate. 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 in the Middle to Upper Miocene including andesite, dacite, diorite, trachyte and syenite (Figure 1). A signature type of epithermal and porphyry copper mineralization can be recognized in those rock units.

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).

3 Geology of prospect area

The Soripesa prospect area is mainly occupied by lava and breccia of andesitic and basaltic composition, intercalation of andesitic tuff and crystalline limestone. It is collectively termed as the Tonggo Formation, (Old Volcanic Rock Unit) (Noya *et al.*, 2009). It is unconformity overlain by bedded limestone and tuffaceous sandstone of the Lesa Formation (Limestone Unit). Laterally, the Lesa Formation changed gradually into pyroclastic rocks (breccia) with mostly dacitic in composition (Volcanic Rock Unit). It crops out at the southern part of the prospect area. The geological map of the Soripesa area is shown in Figure 2.

Tertiary (lower Miocene) volcanic rock unit (Tlmv)

This rock unit is composed of lava and breccia of andesitic and basaltic composition. These rocks are commonly greenish grey, green and violet for the intercalation of tuff (Figure 3a). The rocks are propylitized, mineralized, silicified and contain quartz veins. Age and stratigraphic position of the unit are assumed to be the same as the limestone units. In Soripesa prospect area, this rock unit is mainly occurred in central part of the area. Economically, polymetallic epithermal quartz veins are hosted in this unit.

Tertiary (Miocene) limestone unit (Tml)

In this unit, bedded limestone is the main lithology. The limestone is grey, compact, and some layers contain abundant fossils (Figure 3b). The rocks contain a lot of fauna such as foraminifera, coral, and moluscs. The unit is unconformably underlain by volcanic rocks and laterally changes into coarse pyroclastics and fine pyroclastics. Limestone unit is found in small amount near Soripesa river and central part of the prospect area. This unit may be formed at early Miocene to middle Miocene (Tertiary) in age.

Tertiary (Miocene) volcanic rock unit (Tmdt)

This unit is comprised by dacitic lava and breccias which are commonly grey in color and compact (Figure 3c). These rocks contain intercalations of dacitic tuff and calcareous tuff. Petrographic determination shows the rocks consist of dacite and porphyritic dacitic that locally contains many quartz veins. The rocks are silicified and mineralized. This rock unit mainly

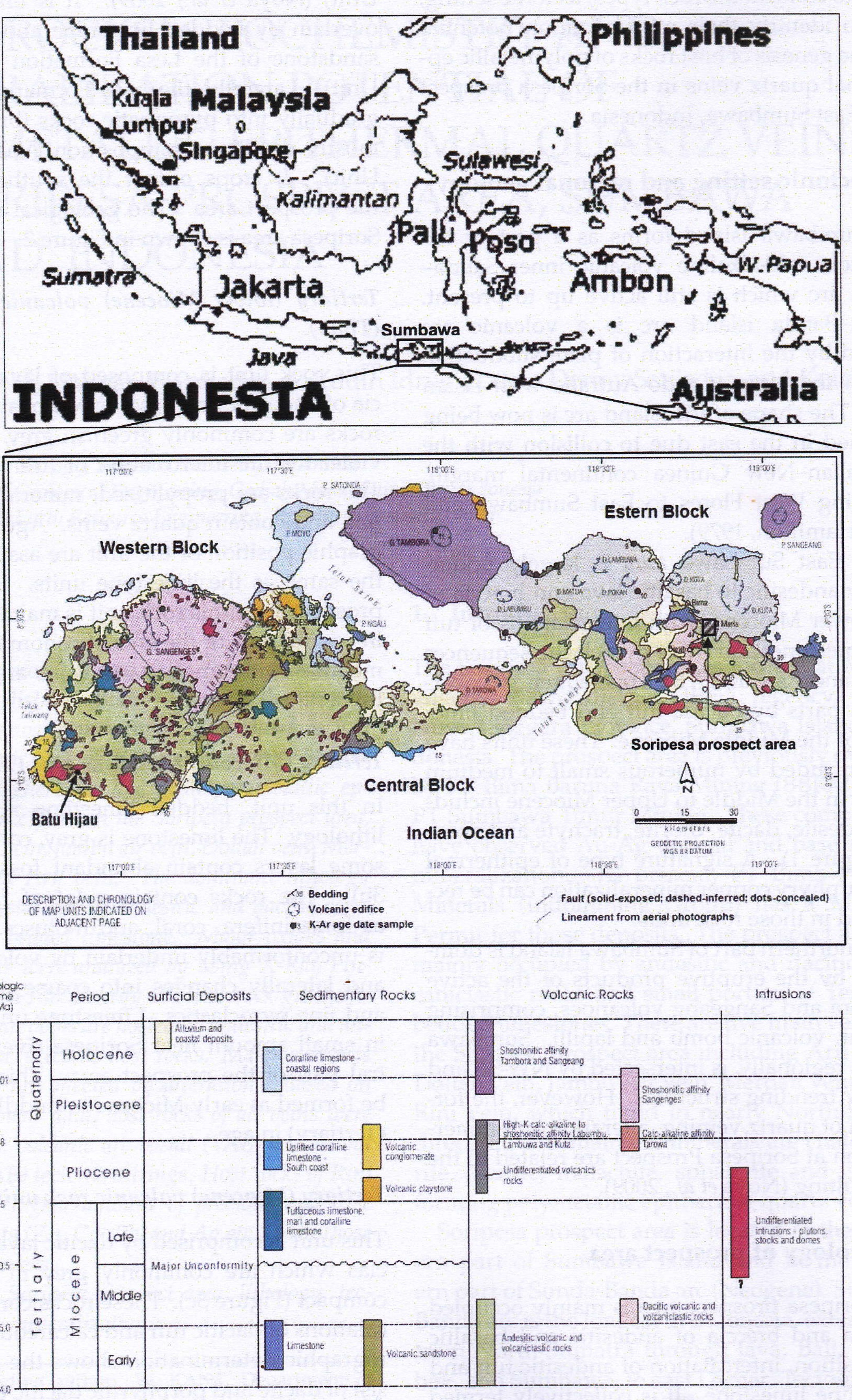
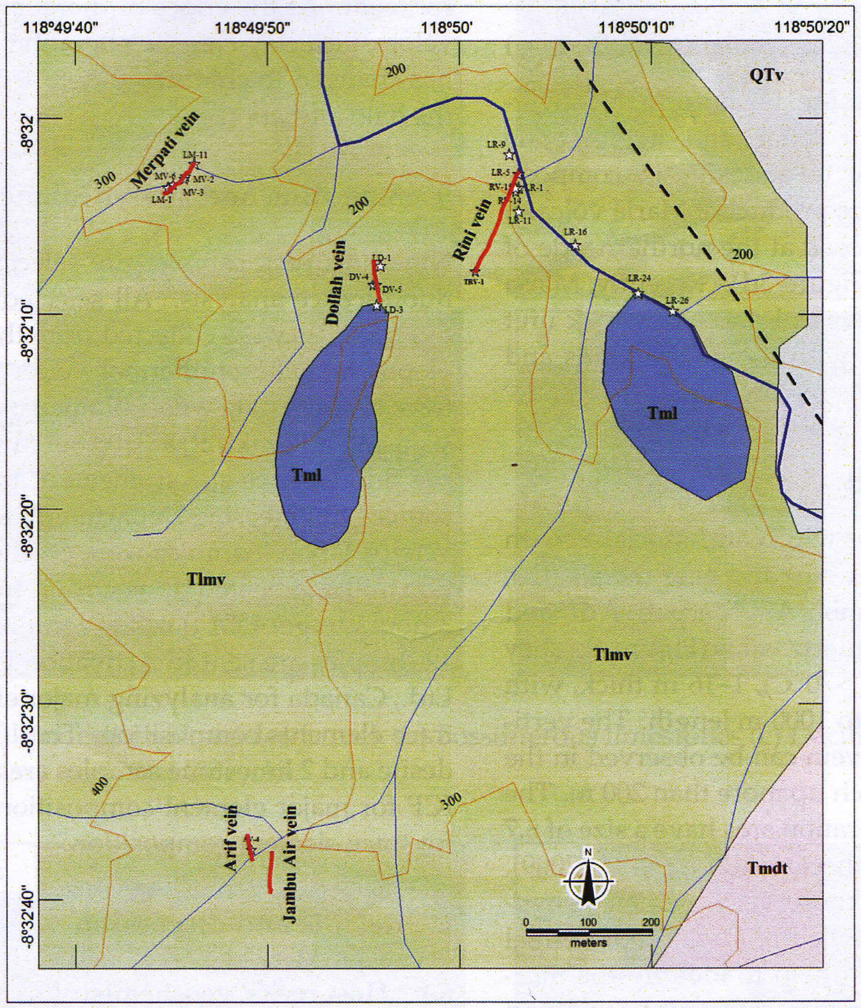


Figure 1: Simplified geologic map and chronology map units of Sumbawa island, Indonesia including Soripesa prospect area (Garwin, 2002).



EXPLANATION

QTv	Quaternary agglomerate to breccias andesitic volcanic, not consolidated matrix supported with fragments
Tmdt	Dacitic volcaniclastic, agglomeratic to breccias gradation to fine-grained tuff
Tml	Fossiliferous limestone
Tlmv	Andesitic volcaniclastic, agglomeratic to breccias gradation to fine-grained tuff

Quartz vein with base metals mineralization (azurite, chalcopyrite, malachite, galena, sphalerite, pyrite)

☆ Selected sample

Fault — River and stream — Contour (m)

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

occurred in Western and Southern part of the prospect area.

Quaternary lahar and agglomerate rocks (Qtv)

The intrusive rocks are unconformably overlain by Quaternary lahar and agglomerate rocks, with basaltic to andesitic in compositions. These rocks are product of Maria volcano and are mostly exposed at the northern side of the prospect area (Figure 3d). Recently, Maria volcano is an inactive volcano. This rock unit may not be related with the quartz veins and mineralization in this research area.

4 Mineralization

The main vein zones which are associated with precious metals (Au–Ag) and base metals (Cu, Pb, Zn) are Rini, Jambu Air, Merpati, Arif, and Dollah epithermal quartz veins (Figure 4). They are nearly vertical (>70°C), 1–16 m thick, with individual vein up to 1000 m length. The vertical outcrop of Rini vein can be observed in the field and it may reach up more than 200 m. The quartz vein and alteration area have a size of 6.7 × 4.7 km^2 or ±3150 hectares (Noya *et al.*, 2009). Quartz textures of those veins 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 (Khant *et al.*, 2012).

Within the veins, multiphases, vuggy, colloform, bedded to massive textures with chalcopyrite, galena, sphalerite, malachite, azurite, chalcocite, pyrite, and iron oxide minerals are observed. Weak to moderate clay-pyrite alteration is intensively developed in the volcanic rocks, especially in the west side of Soripesa. It could be influenced by NW–SE trending structures and andesite to porphyry dacite intrusive rock. The common alteration minerals in this prospect area are quartz, epidote, chlorite, pyrite, illite, and smectite. Minor amount of other alteration minerals are kaolinite, alunite, rutile, and anatase (Khant *et al.*, 2012). Temperature sensitive minerals include Ca-silicates such as epidote and chlorite (stable above 200–240°C), near the base of the epithermal environment. At the edges of the quartz veins develop silica clay-chlorite alteration; outward, it has changed to chlorite-epidote ± magnetite as the halo alteration.

5 Sampling and analytical methods

Nine host rock samples are selected for X-ray fluorescence analysis. All selected representative samples were collected from the host rocks of polymetallic epithermal veins. Major and trace element data were obtained by XRF analysis using a Rigaku RIX-3100 Serial VR 25006 X-ray fluorescence spectrometer at the Earth Resources Engineering Department, Kyushu University, Japan. Samples were crushed by vibration mill and heated by electronic furnace about 3 hours to get LOI (Loss of Ignition). Selected 12 samples are sent to Activation Laboratories, Ltd., Canada for analyzing major elements and trace elements composition. The 10 altered andesite and 2 limestone samples are analyzed by ICP for major element composition and INNA for trace element composition.

6 Results and discussion

6.1 Host rocks' geochemistry

Geochemical characteristics of host rocks are important to know the classification, their genesis, and environments in which they formed. Geochemical study can be used to confirm the rock types, tectonic setting, and to identify their mineralization potential and the genesis of the host rocks of polymetallic epithermal quartz veins. XRF, ICP, INNA analyze methods are used to know the composition of host rocks.

Major elements

The major element compositions of host rocks were determined by X-ray fluorescence (XRF) analysis and Inductively coupled plasma emission spectrometry (ICP) methods. The host rocks of quartz veins have a considerable spread in major element values. The range for SiO_2 is from 48.99 to 75.96 wt% and for the

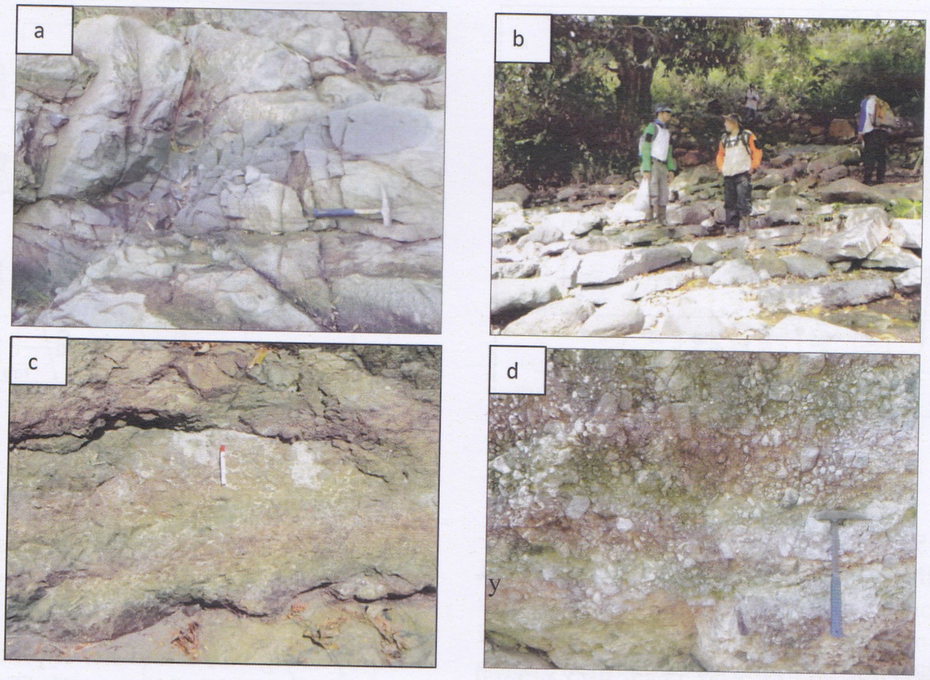


Figure 3: (a) Andesitic volcaniclastic rock (b) Fossiliferous limestones (c) Dacitic volcaniclastic rock (d) Quaternary agglomerate rocks.

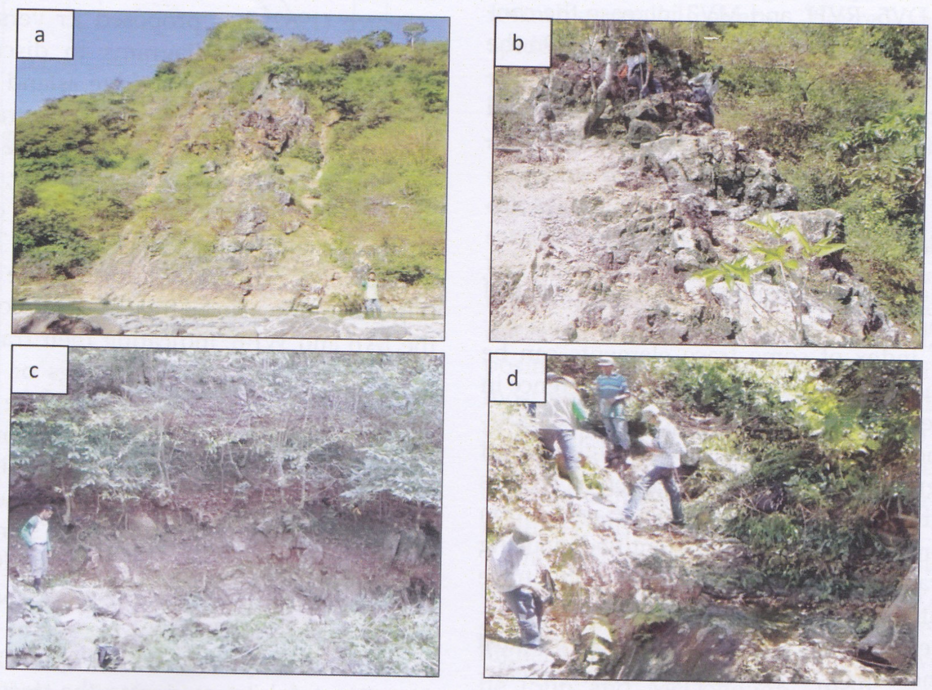


Figure 4: Some quartz veins at Soripesa prospect area (a) Rini vein with width view, (b) Dollah vein, (c) Arif vein with width view, and (d) Merpati vein.

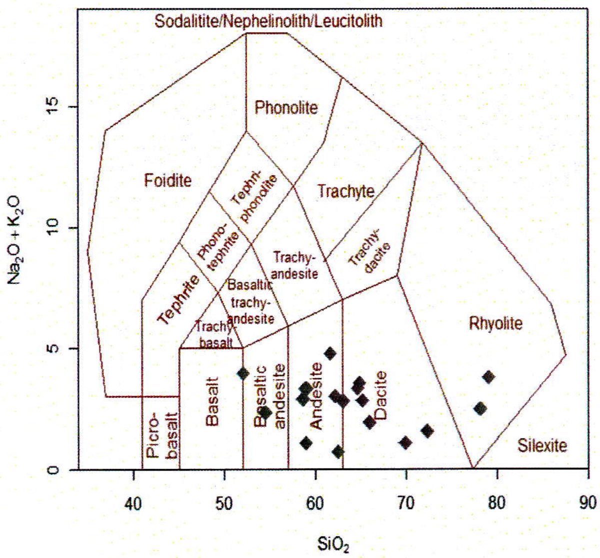


Figure 5: Volcanic rock classification plot diagram ((Na_2O+K_2O vs SiO_2) (after Middlemost, 1994).

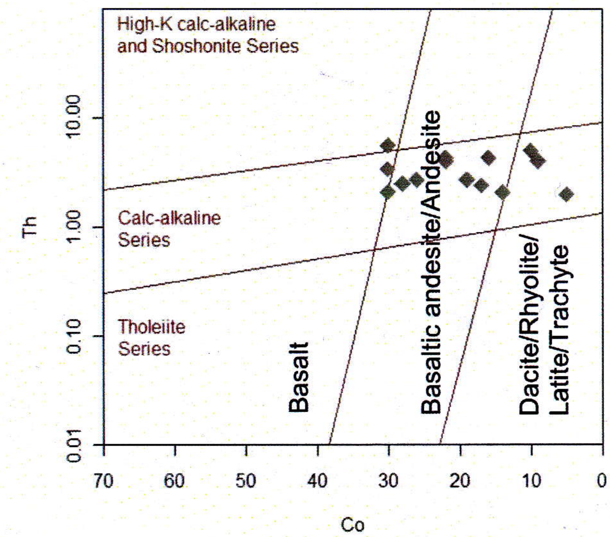


Figure 6: Co vs Th plot diagram showing volcanic rock classification (after Hastie *et al.*, 2007).

other elements' Al_2O_3 8.79–17.52; FeO as total iron 1.52–12.07; TiO_2 0.52–1.47; MnO 0.01–0.85; MgO 0.37–9.03; CaO 0.14–19.5; Na_2O 0–1.52 and K_2O 0.01–3.24. Some host rocks samples such as DV5, RVH, and MV3 increase the content of SiO_2 because of alteration effect. On the diagram (SiO_2–Na_2O+K_2O), host rocks therefore are plotted in basalt, andesite, dacite, and rhyolite fields, respectively, based on the various content of SiO_2 (Figure 5).

Trace elements

Trace element compositions of the host rocks of all veins are listed in Tables 1, 2, and 3. Ratio and index of some trace elements can be used quantitatively to describe the difference in trace elements from different type of host rocks. To some degree, this difference might reflect the degree of magma crystallization as well as source regions. The volcanic rock classification therefore was estimated and identified by using a diagram that contains the incompatible trace elements (Co and Th).

In the Co versus Th diagram (Figure 6), most of the host rocks of all veins are shown in calc-alkaline series and are falling in the fields of basaltic andesite and andesite. The volcanic rock classification was also estimated and identified by using Nb/Y and Zr/Ti plot diagram (Figure 7). In the Nb/Y versus Zr/Ti diagram, the host rocks of quartz veins show high Zr contents and are also falling in the fields of basaltic andesite and andesite.

Pearce (1982) has proposed Zr versus TiO_2 and Zr versus Ti diagrams to discriminate basalts from mid-oceanic ridge, island arc, and within plate settings. In these diagrams, the host rock samples are plotted in the field of MORB (Figure 8a and 8b). However, the outlined MORB field overlaps the fields of island arc basalts and within plate basalts. Thus, Cr vs Y plots of host rock samples in the diagram (Figure 8b) can also be treated as to plot both in the IAB and WPB, indicating their transitional nature between the two settings or between MORB. It is also possible that the overlap is due to the involvement of sub-continental lithosphere in magma genesis as pointed out by Watters and Pearce (1987). In the Zr and TiO_2 plot diagram, most of rock samples fall into IAB (volcanic arc basalt) and MORB setting. But, there is no sample in the MORB field in Figure 8b).

A modified version of the spider diagram is most useful in comparing the trace element characteristics of different types of basalts (Wilson, 2007). Chondrite-normalized trace ele-

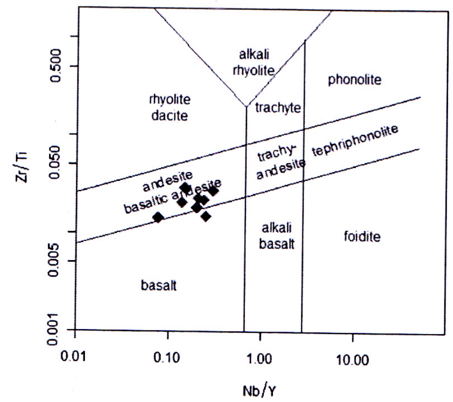


Figure 7: ZrTi vs NbY plot diagram showing volcanic rock classification (after Pearce, 1996).

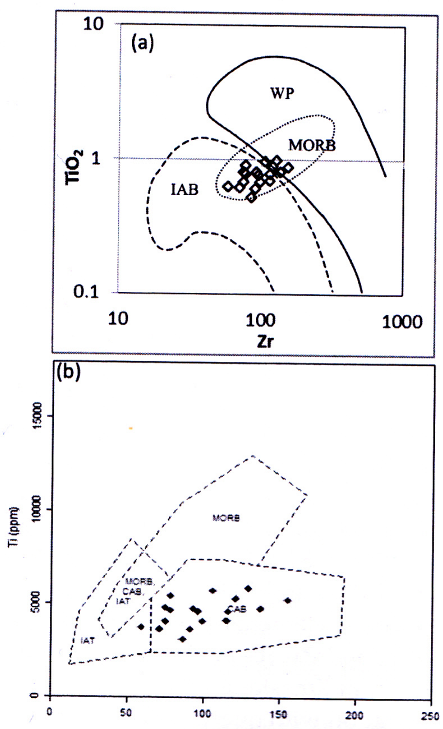


Figure 8: Binary diagrams for the tectonic setting of the volcanic host rocks from the Soripesa prospect area. (a) Zr vs TiO_2 (Pearce, 1982) and (b) Cr vs Y (Pearce, 1982). MORB: Mid-Oceanic Ridge Basalt, IAB: Island Arc Basalt, WPB: Within-Plate Basalt, VAB: Volcanic Arc Basalt.

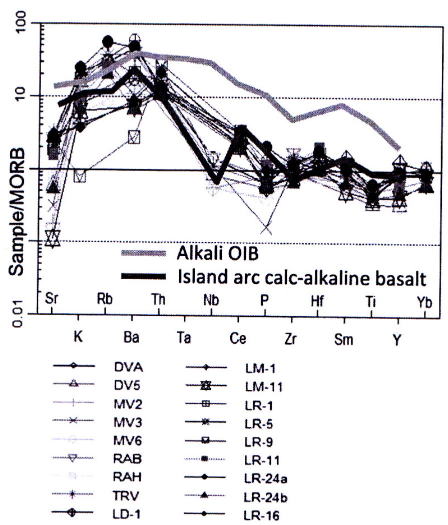


Figure 9: Typical spider diagram patterns for mid-ocean ridge (MORB), oceanic-island (OIB), island-arc basalts and rock samples from this research, normalized according to Sun (1980).

ment spider diagrams for andesite and basaltic andesite rocks exhibit generally similar conformable parallel patterns. Figure 9 shows the spider diagram patterns for typical mid-ocean ridge, island-arc and oceanic-island basalts including samples from Soripesa prospect area. Comparing with three typical spider diagrams of MORB, alkali OIB, and island arc calc-alkaline basalts, spider diagram of the samples from this research resemble with island arc calc-alkaline basalts. In the chondrite-normalized spider diagrams, all samples show the negative anomalies in Nb, Sr, P, Ni, Ti and positive anomalies in K, Ba, Rb, and Th. The most persistent feature of the spider diagrams of volcanic-arc basalts is the marked Nb trough, which has been explained in terms of retention of these elements in the source during partial melting (Wilson, 2007).

The relationships of Nb, and Y with Zr are shown in Figure 10a and 10b. The Zr/Y and Zr/Nb ratios of these host rocks are much higher in comparison with the primitive mantle (Sun and McDonough, 1989), indicating their enriched source characteristics of the elements. Zr/Nb has been widely used to discriminate between enriched and depleted sources

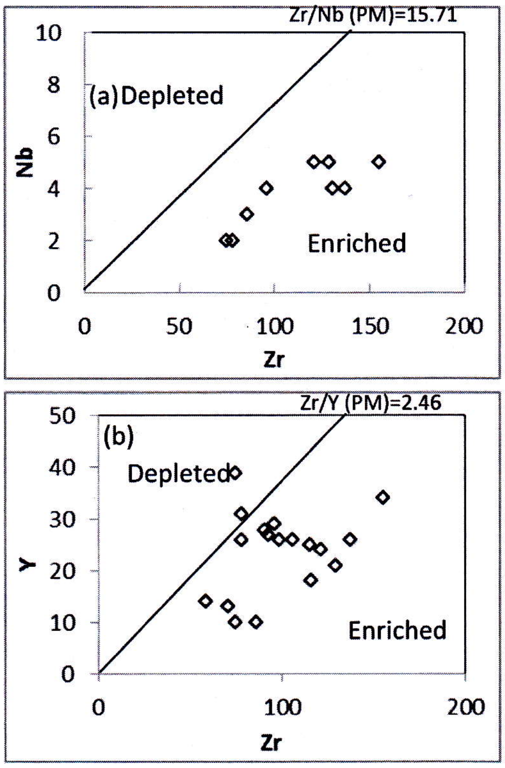


Figure 10: Plots of Zr versus (a) Nb and (b) Y for volcanic host rocks showing the less mobile nature of these elements and illustrating the sensitivity of these element ratios to source composition. Primordial mantle ratios after Sun and McDonough (1989).

(Le Roex *et al.*, 1983). The Zr versus Nb plots of volcanic host rocks of all veins suggests their derivation from moderately enriched source.

For the magmatic evolution processes, SiO_2 and some of major oxide elements can not be used due to alteration effect. Therefore, incompatible element Zr is used instead of SiO_2. Abundances of compatible elements such as Cr decrease with increasing fractionation as measured by the abundance of an incompatible element such as Zr, whereas the abundances of incompatible elements such as Sr, Zn, and Ba increase continuously with fractionation.

6.2 Mineralization potential based on ore-forming elements

The abundance of ore elements and incompatible elements (mineralizing agent) in rocks is one of the important criteria to evaluate the potential of mineralization: the higher these elements in rocks, the greater the mineral potential (Yongqing *et al.*, 2009). It can be seen clearly that the main ore forming elements are Pb, Cu, and Zn. The order of ore-forming elements abundance (ppm) in host rocks of Arif vein is: Pb 216, Zn 799, Cu 97, As 56, Sb 9, Mo 3; in host rocks of Dollah vein: Pb 1768, Zn 1147, Cu 1390, Sb 6, Mo 1, Ag 22; in host rocks of Merpati vein: Pb 78, Zn 406, Cu 76, As 18, W 36, Sb 3, Mo 1, Ag 4, Sn 4, Au 1.28; and host rocks of Rini vein: Pb 1840, Zn 956, Cu 678, As 57, W 49, Sb 2, Mo 1, Ag 4, Sn 4. Figure 11 shows the graph with the content of ore-forming elements of host of quartz veins. These data indicate that galena (gn), sphalerite (sph) and copper oxide and sulphide minerals can be found as common ore minerals in host rocks of polymetallic epithermal quartz veins at Soripesa prospect area, Sumbawa island. In limestone units, rock samples (LR-26 and LD-3) have small amount of ore forming elements (ppm) such as Cu 9–11, Pb 11–12 , and Zn 10–14. It indicates that rock samples from limestone units have no effect of mineralization with quartz veins.

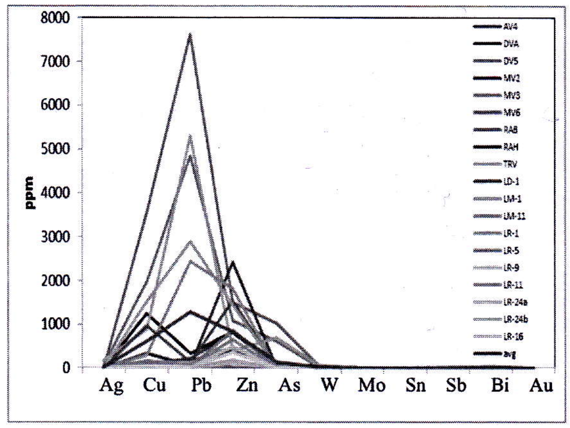


Figure 11: Ore-forming elements compositions of the host rocks.

7 Conclusion

The Soripesa prospect area is located in the eastern part of Sumbawa Island, Indonesia. Recently, according to tectonic setting, Sumbawa Island is a part of Cenozoic Calc-alkaline volcanic inner Sunda-Banda Arc. The arc has been largely formed by northward subduction of Indian oceanic crust. Most host rocks of all veins in the Soripesa prospect area are andesitic, dacitic, and andesitic/basaltic volcaniclastic rocks. According to the geochemical data, host rocks of all veins at the Soripesa prospect area are in andesitic and andesitic/basaltic fields. Host rocks therefore may be formed on medium to thicker continental crust above subducting lithosphere. The trace element data (Zr, Y, Cr, and Ti) indicates that most of the vein host rocks formed in volcanic arc basalt (VAB) and island arc basalt (IAB) tectonic settings. The Zr versus Nb plots of volcanic host rocks of all veins suggest their derivation from moderately Zr enriched source. Binary plots of Zr and selected trace elements (Rb, Zn, Ba, and Sr) suggest that the host rocks were formed from fractional crystallization processes. Based on the ore forming elements, host rocks of Rini vein is the highest potential mineralization. But, host rocks of Merpati vein contain lesser amount of ore elements and have a lowest potential of mineralization.

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