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Preliminary examination of vein type ore mineralization from Cindakko, Maros Regency, South Sulawesi, Indonesia

Introduction

The Cindakko area is situated at the tip of the Tertiary volcanic-plutonic arc in western Sulawesi, Indonesia (Carlile and Mitchell 1994). Based on the regional geological map of the Ujung Pandang, Benteng, and Sinjai scene (Sukamto and Supriatna 1982), the Baturappe-Cindakko Volcano is the host of mineralization around the contact between the Baturappe-Cindakko Volcano with mainly lava (Tpbl) and the eruption center (Tpbc). The occurrence of diorite intrusions (d) is controlled by the structure on the western side of the study area.

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Sukamto and Supriatna (Sukamto and Supriatna 1982) reported indications of galena mineralization in the Cindakko region, presented by Nur (Nur 2009, 2011; Nur et al. 2013), and that the Baturappe Region is prospective for metal ores, especially galena. The geological setting, especially the lithology and geological structure, controls the location movement and distribution of alterations and mineralization in the Cindakko region. The Cindakko volcanic rock member is a mineralization area, and geological structures control the transfer of hydrothermal fluid sites from its source. The characteristics of lithology and the orientation of geological structures have an influence upon the geometry, patterns, and distribution of their mineralization. Thus far, the reports remain based on the results of regional studies and preliminary investigation, with no detailed study having been performed on the Cindakko Prospect. Therefore, to address the lack of detailed information, this study concentrates on investigations of the genetic aspects of mineralization in the Cindakko Prospect.

1. Geological setting

1.1. Regional geology of Cindakko area

The regional geology of the Cindakko area is shown in Figure 1. According to the stratigraphic position from oldest to youngest, the following can be stated (Sukamto and Supriatna 1982):

1. The Tonasa Formation (Temt) consists of limestone, partially layered and as solid, corals, bioclastic, and calcarenite with napalm insertions, including Mollusca. The formation thickness is more than 1750 m.
2. The Camba Formation (Tmc) consists of marine sedimentary rocks intertwined with volcanic rocks, tuffaceous sandstone intertwined with tuff, sandstone, and claystone, with the insertion of marl, limestone, conglomerate and volcanic breccia, and coal. The formation appears between the Middle Miocene and Late Miocene.
3. The Baturappe-Cindakko (Tpbv) volcanic rock consists of lava and breccias with a slight tuff and conglomerate and is composed of basalt, mostly porphyritic with 1 cm of pyroxene. The diorite breakthrough complex (d) in the form of stocks and cracks in Baturappe and Cindakko is assumed as a former eruption center (Tpbc), whereby the surrounding rocks are strongly altered by amygdaloid with zeolite and calcite as secondary minerals. The Baturappe-Cindakko rocks are dominated by lava (Tpbl). The formation thickness is more than 1250 m from the Late Miocene, according to the stratigraphic position.
4. The Lompobattang volcanic member rocks mainly consist of breccia, lava deposits, and tuffs (Qlvb).

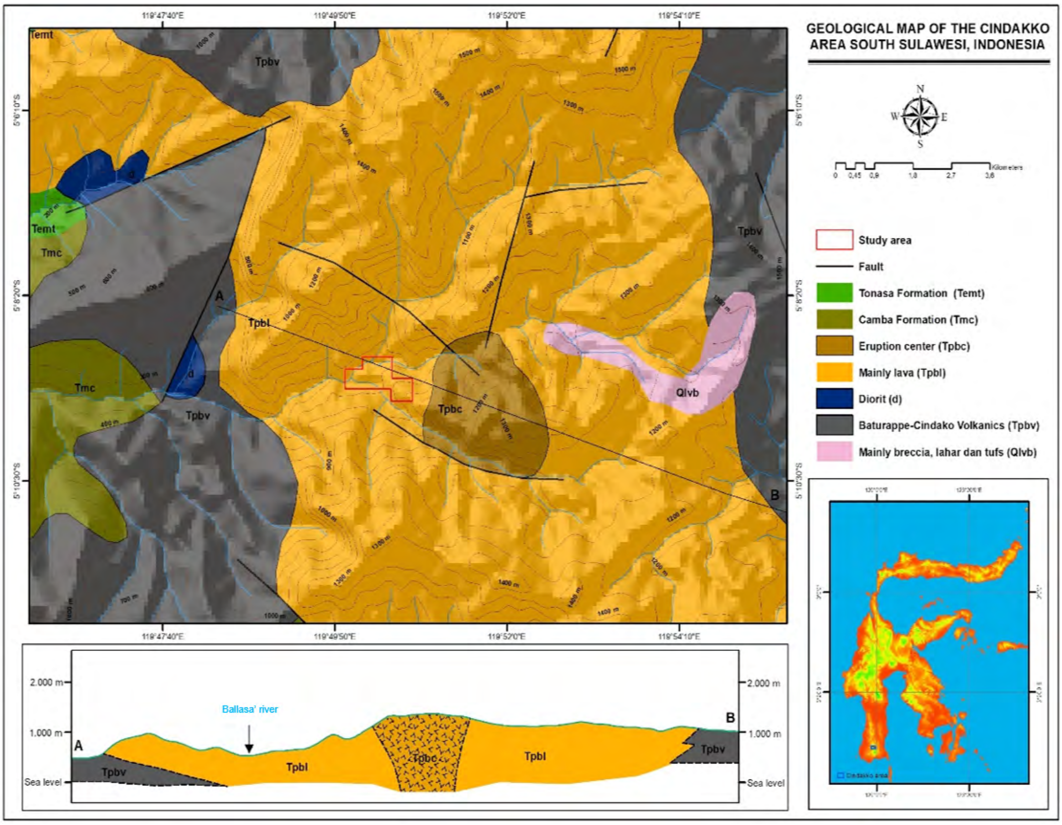

Fig. 1. Regional geological map and cross section of the Cindakko area in the Ujung Pandang, Benteng, and Sinjai scene (after Sukamto and Supriatna 1982)

Rys. 1. Regionalna mapa geologiczna i przekrój poprzeczny obszaru Cindakko w Ujung Pandang, Benteng i Sinjai

1.2. Tectonic-Volcanic setting and magma affinity

The South Sulawesi tectonic area is dominated by faults with a significant trend from NNW to SSE, the West Walanae Fault (WWF) and East Walanae Fault (EWF), which separates the western part of the eastern mountains by Walanae graben-aged Pleistocene (van Leeuwen 1981; Leterrier et al. 1990). The presence of Tertiary-aged calc-alkaline volcanic rock in South Sulawesi has led to various geodynamic models involving Tertiary subduction. Yuwono (Yuwono 1987) and Leterrier et al. (Leterrier et al. 1990) explained that the Miocene, Pliocene, and Pleistocene volcanic centers in South Sulawesi have K-rich shoshonitic (SH) to ultrapotassic (UK) characteristics reflected by SiO_2 and K_2O contents. Neogene and Quaternary K-rich volcanic rocks are exposed as outcrops with a north-south trend in

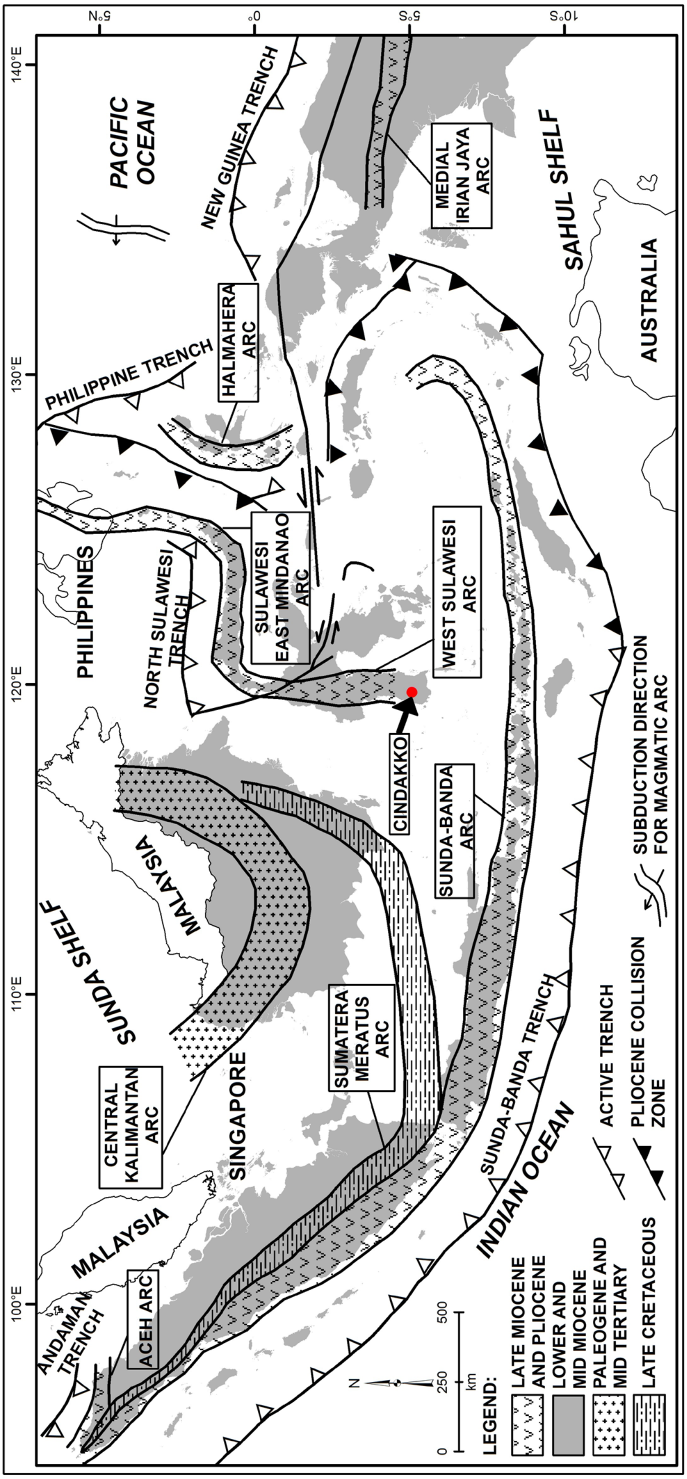

Fig. 2. Location of the study area on distribution and polarity map showing Late Cretaceous to Pliocene magmatic arcs in Indonesia (Carlile and Mitchell 1994)

Rys. 2. Lokalizacja obszaru badań na mapie rozmieszczenia i polaryzacji pokazującej łuki magmowe od późnej kredy do pliocenu w Indonezji the western mountains of South Sulawesi (Leterrier et al. 1990). In addition, it has also been explained that the magma affinity of the Baturappe volcanic rock is shoshonitic, reflected by the K_2O content at 2.78 wt.% and 1.45 wt.%, while SiO_2 features at 44.06 wt.% and 44.80 wt.% (Nur 2013).

The Cindakko area is situated at the southern end of the Tertiary volcanic-plutonic arc west of Sulawesi, Indonesia (Figure 2). The Cindakko volcanic rock is of the Late Miocene age (van Leeuwen 1981; Leterrier et al. 1990). The rocks show the characteristics of the shoshonitic series (Peccerillo and Taylor 1976) reflected in the K_2O and SiO_2 content at 4.60 wt.% and 57.30 wt.%, respectively (van Leeuwen 1981). Based on the K-Ar dating, the Cindakko Formation has 8.21–0.41 Ma at the late Upper Miocene or early Lower Pliocene (van Leeuwen 1981; Leterrier et al. 1990).

2. Methods

This study consisted of two stages: field survey and laboratory investigation. The fieldwork was performed in the Ballasa and Muntia rivers, where fresh and altered rock samples, including sulfide minerals, were collected randomly and selectively from the surface. Eight collected samples were subjected to petrographic and XRD analysis and 2 representative samples for ore mineral assemblage, shown in Tables 1, 3, and 2, respectively. The laboratory investigation consisted of petrographic analysis and X-ray diffraction (XRD). Sample preparation for microscopic analysis began with making thin sections of rocks for petrography and polished sections for mineralogical study, with their observations using transmitted and reflected light microscope, respectively, conducted at the Optical Mineral Laboratory, Department of Geological Engineering, Hasanuddin University (Indonesia). Furthermore, for XRD analysis, altered rock samples were prepared in powder samples and then scanned using a Shimadzu Maxima X XRD-7000 type X-ray diffractometer. The diffraction patterns were recorded with 5–70° 2-theta scanning stages. The whole XRD scan results were then analyzed using the Impact Match software to identify the specific mineral contained in the sample. All stages of the XRD analysis activities, including sample preparation, scanning, analysis, interpretation and mineral identification, were conducted at the Mineral Exploration Laboratory of the Mining Engineering Department and the XRD Laboratory of the Geological Engineering Department, Hasanuddin University.

3. Results and discussion

This study suggests that basalts are the host rock in the Cindakko Prospect (Figure 3). Figure 3b presents basalt exposure as grayish black-moderate yellow-green in color (Figure 3b).

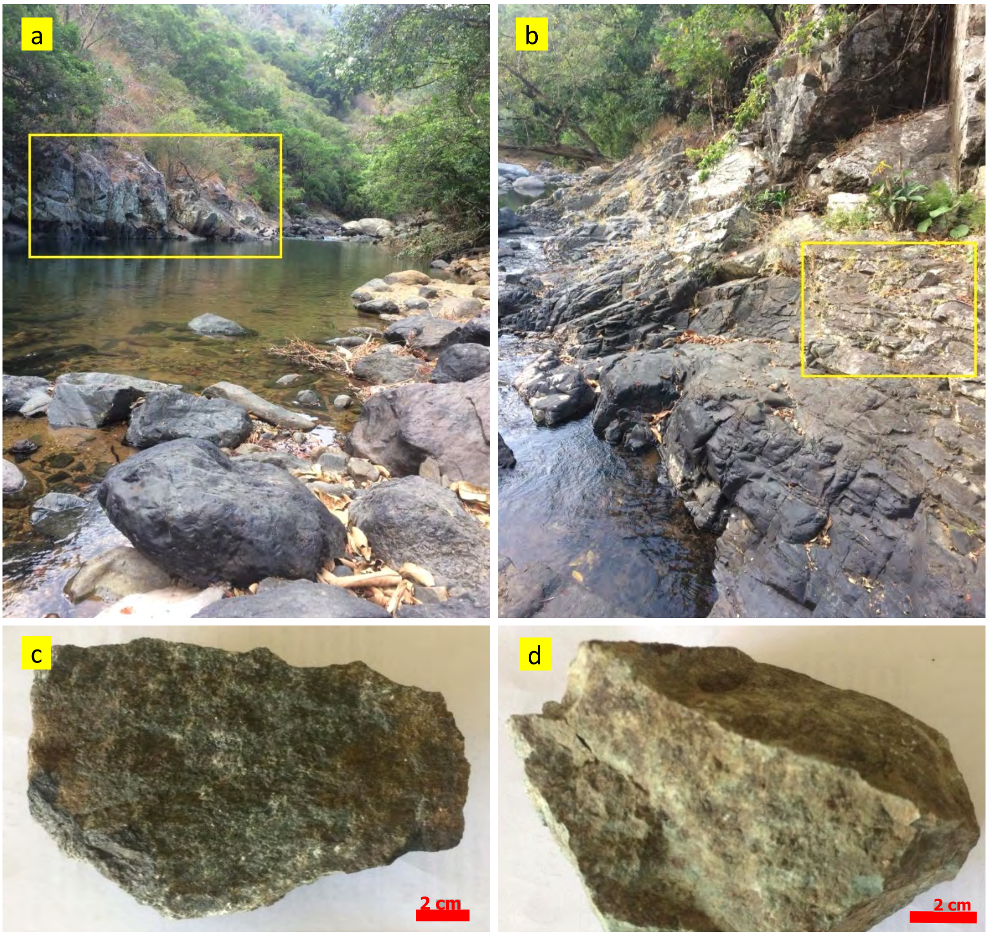

Fig. 3. (a) Basalt exposure at Ballasa River, (b) basalt exposure at Muntia River, (c) basalt sample (fresh), (d) basalt sample (altered) as a host rock of mineralization in the Cindakko area

Rys. 3. (a) Odsłonięcie bazaltu w rzece Ballasa, (b) odsłonięcie bazaltu w rzece Muntia, (c) próbka bazaltu (świeża), (d) próbka bazaltu (zmieniona) jako skała macierzysta mineralizacji w rejonie Cindakko

Figure 3b also shows basalt exposure with a greenish-black appearance as an altered color featuring oxidized marking on its surface. The basalt sample in Figure 3c is black, slightly greenish-dusky brown in color, as per Figure 3b. Figure 3d represents the most altered sample with a dominant greenish color related to chlorite, a product of ferro-magnesian altered minerals, mainly pyroxene, is also found pyrite as fine sulfide grains that disseminate with the densely welded spatial distribution. Considering the physical features, lithology, and geographic setting, we concluded that this basalt should be classified as a rock assemblage of the Baturappe-Cindakko Volcano Formation, and thus based on K-Ar dating, the Cindakko Formation rock assemblage age is 8.21–0.41 Ma (Yuwono 1987).

Table 1. Petrographic description

Tabela 1. Opis petrograficzny

Sample	Rock type and texture	Phenocrysts or clasts	Groundmass	Remarks
ST.1	Basalt (lava)	Plagioclase + quartz + olivine + + pyroxene + biotite + epidote	Plagioclase microlites	Weakly altered; the phenocrysts are altered to epidote.
ST.2A	Basalt (lava)	Quartz + biotite + muscovite + + clinopyroxene + epidote + chlorite	Fine crystalline	Strongly altered; pyroxene is altered to chlorite, epidote, opaque; the crystalline groundmass is altered to chlorite, epidote, quartz, opaque.
ST.2B	Basalt (lava)	Quartz + plagioclase + biotite + + epidote + cholrite	Fine crystalline	Strongly altered; pyroxene is altered to chlorite, epidote; plagioclase phenocrysts is altered to quartz; the crystalline groundmass is altered to chlorite, epidote and quartz.
ST.6A	Basalt (lava)	Quartz + epidote + opaque	Fine crystalline	Strongly altered; pyroxene is altered to epidote and opaque; the crystalline groundmass is altered to quartz.
ST.6B	Basalt (lava)	Quartz + plagioclase + actinolite + + biotite + chlorite + epidote + + clay + opaque	Fine crystalline	Strongly altered; pyroxene is altered to chlorite, epidote, clay, opaque; plagioclase phenocryst is altered to quartz and actinolite.
ST.6C	Basalt (lava)	Quartz + epidote + opaque	Fine crystalline	Strongly altered; pyroxene is altered to chlorite, epidote, quartz, opaque; veinlet is filled by quartz; the crystalline groundmass is altered to quartz.
ST.7A	Basalt (lava)	Quartz + chlorite + epidote + + opaque	Fine crystalline	Strongly altered; pyroxene is altered to epidote, chlorite, opaque, quartz, clay; the crystalline groundmass is altered to quartz; veinlet is filled by quartz.
ST.7B	Basalt scoria (dyke)	Quartz + plagioclase + chlorite	Fine crystalline	Moderately altered; pyroxene and plagioclase are altered to chlorite and opaque; the crystalline groundmass is to quartz.

Generally, the rocks in the study area have been altered as a result of the influence of hydrothermal fluid. The percentage of hydrothermal alteration on each exposure in the study area varies, alternating from moderate (approximately 30–50 vol% of altered minerals in rock) to severe (approximately 90% altered). Moderately altered rock exposures (selective alteration) generally remain identified by macroscopic and microscopic observation. In contrast, severely altered rocks (pervasive alteration) are usually identified by their altered mineral products through macroscopic and microscopic observation in Table 1.

Mineralization of the host rock in the study area is generally altered intensively. Altered rock samples show color variations as grayish, greenish, and dusky brown. The remains of selectively altered rock samples could be identified by their field occurrence or macroscopic appearance, and the primary minerals could be identified under a microscope. Pervasively altered rock samples in which the primary minerals had altered to secondary minerals are unlikely as only a partial sample could be identified. The minerals identified on pervasively altered samples were analyzed using XRD as depicted in Table 2.

Table 2. XRD results

Tabela 2. Wyniki dyfrakcji rentgenowskiej (XRD)

Sample	Sample type	qtz	bi	chl	ep	act	ol	ccp	cv	py	tn	td	mg
ST.1	Basalt	*	*		*		*						
ST.2A	Altered basalt	*	*	*	*								
ST.2B	Altered basalt	*	*	*	*			*					
ST.6A	Basalt + quartz vein	*			*				*	*			
ST.6B	Basalt	*	*	*	*	*					*	*	
ST.6C	Basalt	*	*	*	*			*					
ST.7A	Basalt	*		*	*								
ST.7B	Basalt	*	*	*	*								*

qtz – quartz, bi – biotite, chl – chlorite, ep – epidote, act – actinolite, ol – olivine, ccp – chalcopyrite, cv – covellite, py – pyrite, tn – tennantite, td – tetrahedrite, mg – magnetite.

Figures 4a, 4c, and 4e display distinct colors of unaltered, selective and pervasive rocks. The unaltered samples are dusky brown-black grayish, while those pervasively altered are greenish and slightly brown on their surface owing to a trace of iron oxide. The greenish color in the sample (Figure 4c and 4e) indicates the occurrence of a secondary mineral: chlorite, which first forms as a product of ferro-magnesian altered minerals (e.g., olivine and pyroxene). Microscopic observation of the unaltered sample (Figure 4c) displays primary minerals that can still be identified, like plagioclase, pyroxene, olivine, and quartz which are still clearly euhedral to subhedral in shape, whereas both selective and pervasive altered samples depict dominant alteration minerals such as chlorite, epidote, and quartz with subhedral to anhedral shapes of plagioclase phenocryst of relict. In addition, phenocryst of pyroxene does not occur as it is already altered to chlorite (Figure 4d and 4f).

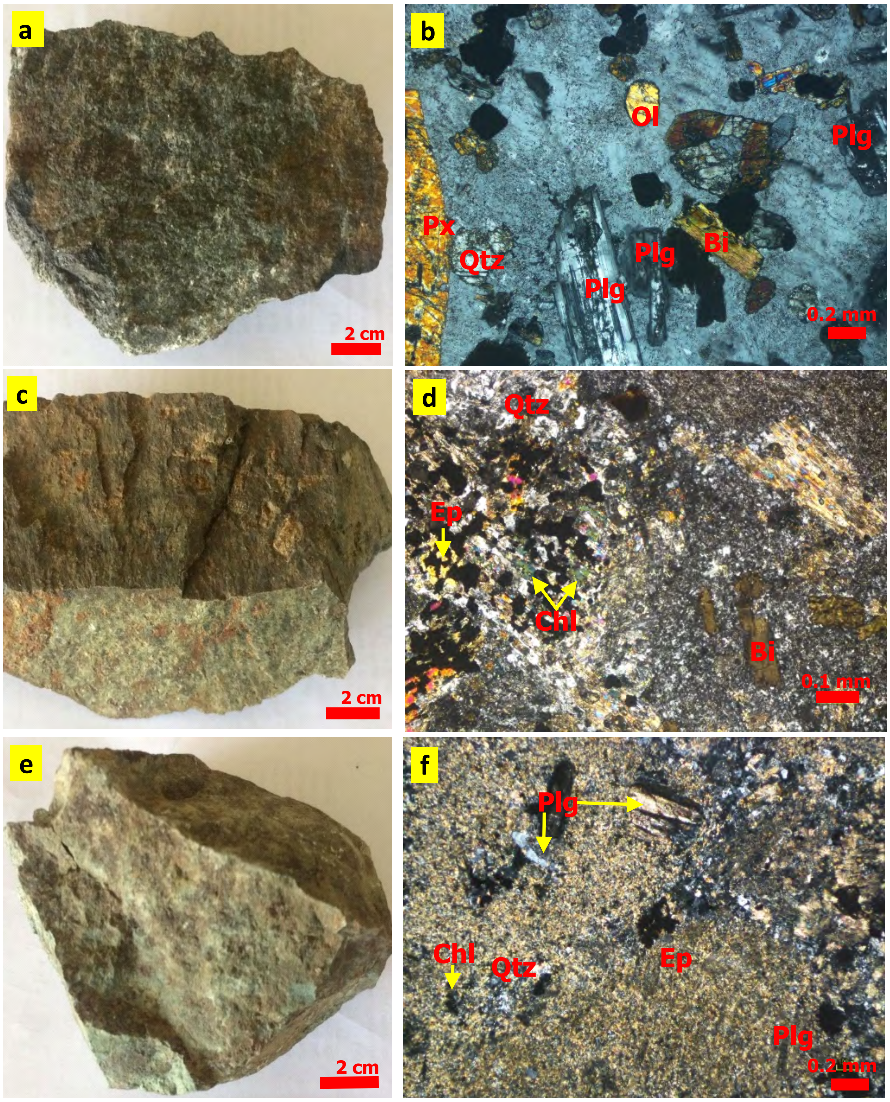

Fig. 4. (a) unaltered basalt of ST-1, (b) microscopic appearance of ST1, (c) hand specimen sample of altered sample in ST-2A, (d) microscopic appearance of ST-2A, (e–f) pervasively altered rock in ST-2B with microscopic photograph, successively. Chl – chlorite, Ep – epidote, Bi – biotite, Plg – plagioclase, Qtz – quartz, Ol – olivine, Px – pyroxene

Rys. 4. (a) niezmieniony bazalt ST-1, (b) wygląd mikroskopowy ST1, (c) próbka ręczna zmienionej próbki w ST-2A, (d) wygląd mikroskopowy ST-2A, (e–f) wszechobecnie zmieniona skała w ST-2B ze zdjęciem mikroskopowym, kolejno skróty: Chl – chloryn, Ep – epidot, Bi – biotyt, Plg – plagioklaz, Qtz – kwarc, Ol – oliwin, Px – piroksen

Petrographic observation and XRD data showed mineral assemblages in basalt host rocks: quartz, olivine, plagioclase, pyroxene, chlorite, epidote, biotite, and chalcopyrite. Relatively, the analyzed samples led to the identification of mineral assemblage of hydrothermal alteration (Table. 3), while both the analyzed petrographic and XRD, such as quartz, chlorite, epidote, biotite, actinolite, and opaque, were identified as pyrite and chalcopyrite.

Consideration of these mineral assemblages through the use of classification and hydrothermal alteration terminology in the exploration field (e.g., Thompson and Thompson 1996; Hedenquist et al. 1996, 2000) led to the conclusion that the alteration zone in this study area is of a propyllitic type, mainly indicated by chlorite and epidote occurrences (Table 4).

Table 3. Microscopic description of ore

Tabela 3. Opis mikroskopowy rudy

Sample	Sample type	Metal assemblage	Remarks
ST.6A	Basalt (crustiform--banding vein)	Pyrite + + chalcopyrite + + sphalerite + covellite	Pyrite in pale yellow color with >0.1 mm anhedral--subhedral crystal. Open-space filling texture originated by deformation that caused fractures which might allow sphalerite to fill them; pyrite was replaced by sphalerite. Chalcopyrite inclusions in pyrite were replaced by covellite.
ST.6B	Basalt disseminated ore	Pyrite + chalcopyrite + + sphalerite + bornite + + tennantite + covellite	Pyrite occurs as 0.1–0.5 mm crystal that was replaced by chalcopyrite, then chacopyrite was replaced by covellite. Chacopyrite intergrowth with sphalerite showed exolution texture. While tenantite occurred as secondary mineral that replaced bornite and on its border was replaced by covellite.

Table 4. Mineral assemblages and type of hydrothermal alteration

Tabela 4. Zbiorowiska mineralne i rodzaj przemian hydrotermalnych

No.	Sample	Altered minerals	Alteration type
1	ST-1	Quartz, biotite, epidote	Propyllitic
2	ST2A	Quartz, epidote, chlorite, biotite	Propyllitic
3	ST-2B	Quartz, epidote, chlorite, biotite	Propyllitic
4	ST-6A	Quartz, epidote	Propyllitic
5	ST-6B	Quartz, epidote, chlorite, biotite, actinolite	Propyllitic
6	ST-6C	Quartz, epidote, chlorite, biotite	Propyllitic
7	ST-7A	Quartz, epidote, chlorite	Propyllitic
8	ST-7B	Quartz, epidote, chlorite, biotite	Propyllitic

The identified hydrothermal alteration mineral assemblages in the Cindakko area were used to estimate the alteration presumed temperature and hydrothermal fluids pH: chlorite, epidote, and actinolite. These minerals were chosen due to their sensitive temperatures. Chlorite is formed at 145–320°C, epidote at 200–320°C (Nur et al. 2011), and actinolite at 280–300°C (Corbett and Leach 1997; Browne 1978).

The estimated temperatures of alteration and hydrothermal fluid pH suggest that the Cindakko area has hydrothermal alteration at a presumed temperature of approximately 200–320°C with a pH of around 7.

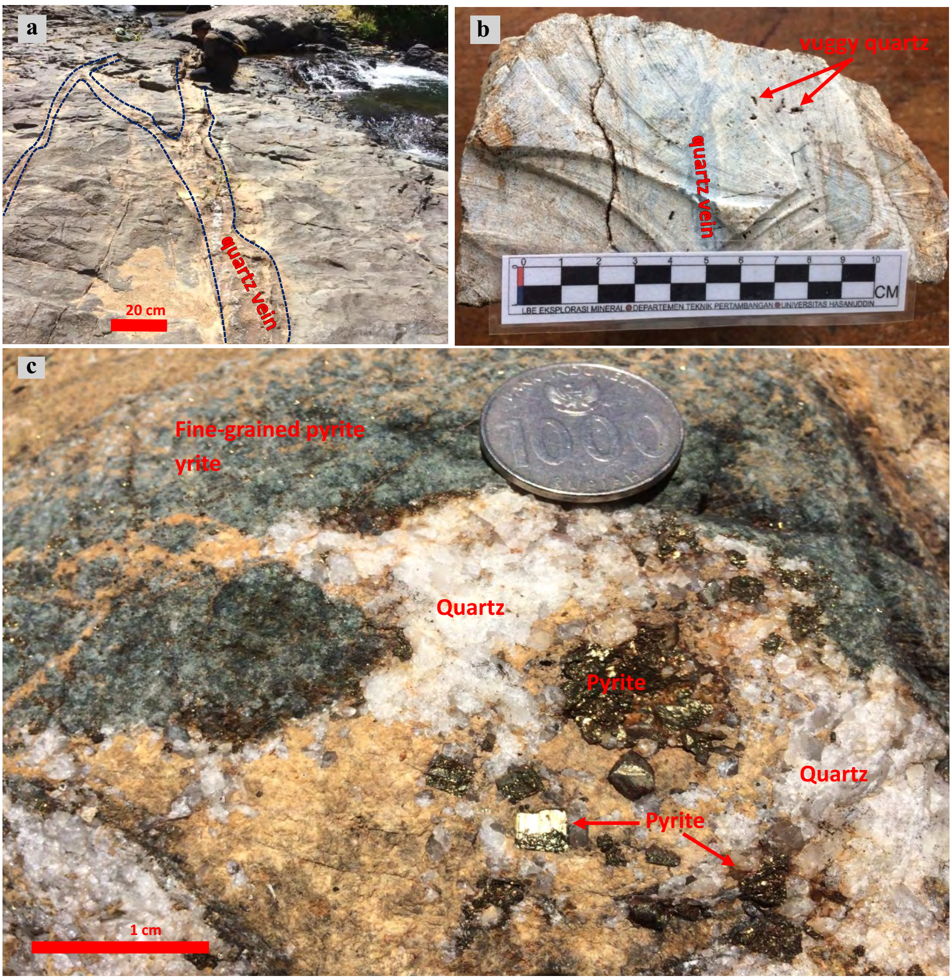

Fig. 5. (a) Quartz veins cut through the host rock, basalt exposure (N65°E/75),
(b) crustiform-banding texture of quartz vein sample in ST-6, with vuggy quartz and disseminated pyrite occurring,
(c) pyrite (disseminated) >1 cm and a quartz vein in the host rock

Rys. 5. (a) Żyły kwarcowe przecinające skałę macierzystą, ekspozycja na bazalt (N65°E/75),
(b) tekstura próbki żyły kwarcowej w ST-6 z pasmami skorupiastymi, z występowaniem grubego kwarcu
i rozsianego pirytu, (c) piryt (rozsiany) >1 cm i żyła kwarcu w skale macierzystej

Mineralization in the Cindakko Prospect generally formed in three types of textures: quartz veins with crustiform-banding texture as a main feature of epithermal deposit (Hedenquist et al. 2000); disseminated and vuggy quartz textures in which the sulfide ore minerals are grouped and disseminated with densely welded spatial distribution even on quartz gangue and on the pervasively altered host rock.

The observation and field measurement showed that the mineralized quartz veins are oriented to the southwest–northeast (N65°E/75) with a thickness of 30 cm (Figure 5a); disseminated sulfide fine grain mineralization, pyrite (Figure 5c), and a vuggy quartz texture (Figure 5b) were also found.

Figure 6 displays the microscopic imaging of the presented ore minerals: pyrite, chalcopyrite, sphalerite, bornite, tennantite, and covellite. Figure 6a–b shows pyrite with a 0.2 mm euhedral to subhedral and striated, while subhedral to anhedral chalcopyrite and sphalerite

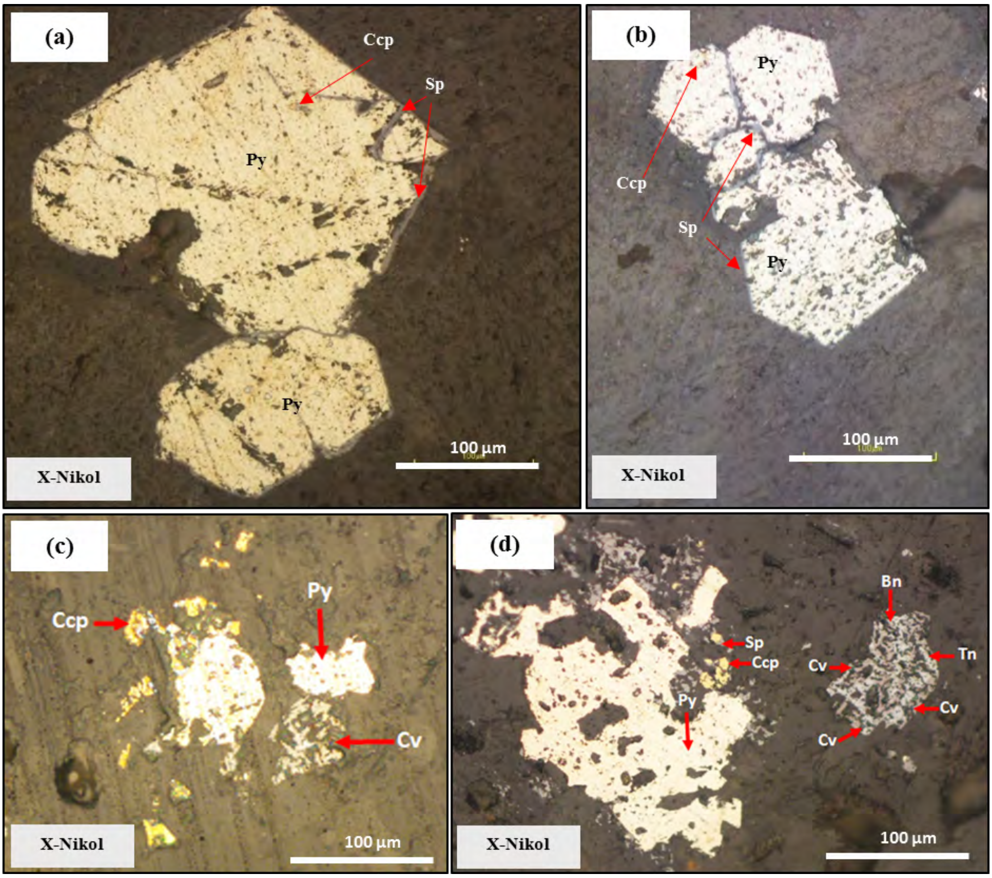

Fig. 6. (a–b) Microscopic images of ST-6A and (c–d) ST-6B.
Py – pyrite, Ccp – chalcopyrite, Sp – sphalerite, Bn – bornite, Tn – tennantite, Cv – covellite

Rys. 6. (a–b) Obrazy mikroskopowe ST-6A i (c–d) ST-6B.
Py – piryt, Ccp – chalkopiryt, Sp – sfaleryt, Bn – bornit, Tn – tennantyt, Cv – kowelit

can be seen in Figure 6a–b; bornite and tennantite occurrences are presented in Figure 6d, and anhedral covellite is shown in Figure 6c–d.

Figure 6a–b shows that sphalerite occurred as a replacement of pyrite, where the former pyrite deformed and caused fractures that might allow sphalerite to fill them (open-space filling). Figure 6c–d shows that pyrite is replaced by chalcopyrite and, on its border, is replaced by covellite, then chalcopyrite is replaced by sphalerite (Figure 6d). Tennantite occurs as a sulfosalt mineral in Figure 6d, replaced by bornite and on the border replaced by covellite.

Two major textures based on the ore mineral textures identified using microscopic analyses: replacement and open-space filling. With regard to both textures, it was concluded that paragenesis ore mineral successions formed first-end in the order pyrite, chalcopyrite, sphalerite, bornite, tennantite as a hypogene ore mineral, and covellite as a supergene mineral. These hydrothermal alteration characteristics (mineral assemblages), interpreted by temperatures and hydrothermal fluids pH, ore mineral assemblages, and quartz veins in the Cindakko area are mainly the features of epithermal deposits (White and Hedenquist 1995; Hedenquist et al. 1996, 2000).

4. Conclusions

Based on the results and discussions, this study shows that the vein-type mineralization host rocks are basalt – one of the Late-Miocene Baturappe-Cindakko volcanic rock assemblages. The quartz vein-related hydrothermal mineral alteration assemblages are relatively abundant with quartz, chlorite, epidote, and actinolite. These minerals are generally and genetically distributed proximal to the mineralized quartz veins. The type of mineralization is mineralized quartz veins with crustiform-banding, vuggy quartz and disseminated textures containing hypogene ore minerals of pyrite, chalcopyrite, sphalerite, bornite, tennantite and covellite as supergene ore minerals. The ore mineral textures are identified by petrographic observation are intergrowth, replacement, open-space filling and exsolution. The hydrothermal fluid responsible of the Cindakko prospect was interpreted as being a neutral pH fluid and the formation temperature, using the hydrothermal alteration minerals stability temperatures (i.e., chlorite, epidote, and actinolite) ranges from 200 to 320°C. The characteristics of hydrothermal alteration (mineral assemblage), ore mineral assemblage and their texture variation, the type of mineralization, formation temperatures, and the pH of hydrothermal fluids suggest that the mineralization in the Cindakko Prospect is typical of epithermal-type mineralization.

Final remarks

For the development of future study in the area in order to obtain more detailed results about the characteristic of the deposit, the conducting of geochemical characterization including their fluid inclusion analysis is highly recommended for investigating the evolution of the ore deposit potential in the future. Furthermore, the deep drilling prospection method would also be beneficial for observing the occurrence of the base metal deposit (Cu, Pb, and Zn).

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PRELIMINARY EXAMINATION OF VEIN TYPE ORE MINERALIZATION FROM CINDAKKO, MAROS REGENCY, SOUTH SULAWESI, INDONESIA

Keywords

sulfide mineralization, hydrothermal alteration, propyllitic alteration, epithermal type

Abstract

There is a sulfide mineralization vein type in the Cindakko area, Maros Regency, South Sulawesi. The results of mineralogical studies on the Cindakko prospects for sulfide ore mineralization are explained in this paper. Petrographic, mineragraphic, and XRD methods analyzed the mineralization and alteration samples from the research area. The results showed that the host rock mineralization is basalt, a member of the Baturappe-Cindakko Volcano from the Late Miocene age. The identified hydrothermal alteration mineral associations include quartz, chlorite, epidote, biotite, actinolite, and pyrite, generally formed in propyllitic alteration zones mainly characterized by chlorite. The analysis provides the occurrence of mineralization types: crustiform-banding quartz veins, vuggy quartz, and disseminated, contain hypogenic pyrite, chalcopyrite, sphalerite, bornite, and tennantite ores, and supergene ore minerals in the form of covellite. Ore textures recognized under a microscope are intergrowth, replacement, open-space filling, and exsolution. Based on the interpretation of temperature stability of hydrothermal alteration minerals, it is concluded that it was formed at approximately 200 to 320°C with the hydrothermal fluid pH almost neutral. The fundamental characteristics of hydrothermal alteration, ore mineral assemblage and texture, mineralization type, temperature range form, and hydrothermal fluid pH indicate that the mineralization in the Cindakko Prospect is an epithermal type.

WSTĘPNE BADANIE MINERALIZACJI RUDY TYPU ŻYŁY Z CINDAKKO, MAROS REGENCY, SOUTH SULAWESI, INDONEZJA

Słowa kluczowe

mineralizacja siarczkowa, przemiana hydrotermalna, przemiana propylolityczna, typ epitermalny

Streszczenie

Na obszarze Cindakko, w regionie Maros, w południowym Sulawesi, występuje żyła mineralizacji siarczkowej. Wyniki badań mineralogicznych dotyczących mineralizacji rudy siarczkowej w obszarze Cindakko są przedstawione w niniejszym artykule. Metodami petrograficznymi, mineralograficznymi i dyfrakcji rentgenowskiej (XRD) przeanalizowano mineralizację i próbki zmian z obszaru badań. Wyniki wykazały, że skałą macierzystą mineralizacji jest bazalt, składnik wulkanu Baturappe-Cindakko z późnego miocenu. Zidentyfikowane związki mineralne zmian hydrotermalnych obejmują kwarc, chloryt, epidot, biotyt, aktynolit i piryt, generalnie uformowane w strefach zmian propyllitowych, charakteryzujących się głównie chlorytem. Analiza wskazuje na występowanie typów mineralizacji: żyły kwarcowe o strukturze skorupowej, kwarc w formie wugów i jest rozsiane, zawierają hipogeniczne rudy pirytu, chalkopirytu, sfalerytu, bornitu i tennantytu oraz supergeniczne minerały rudne w postaci kowelitu. Tekstury rudy rozpoznawane pod mikroskopem to wrastanie, zastępowanie, wypełnianie otwartych przestrzeni i rozpuszczanie. Na podstawie interpretacji temperatury stabilności minerałów zmian hydrotermalnych, stwierdza się, że powstały one w temperaturze od około 200 do 320°C przy prawie neutralnym pH płynu hydrotermalnego. Podstawowe cechy charakterystyczne dla zmian hydrotermalnych rudy i tekstury, rodzaju mineralizacji, zakresu temperatur i pH płynu hydrotermalnego wskazują, że mineralizacja w obiekcie poszukiwawczym Cindakko jest typem epitermalnym.