PROSPECT OF MINERAL DEPOSITS IN THE CENTRAL FLORES ISLAND, EASTERN INDONESIA

PROSPEK CEBAKAN MINERAL DI PULAU FLORES BAGIAN TENGAH, INDONESIA TIMUR

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Abstract

Field data on the Central Flores Island, Eastern Indonesia (Sikka and Ende Regencies) together with chemical analyses allow us to discuss the prospect of mineral occurrences in this inner arc volcanic zone. Geologically, the area is dominated by Tertiary-Quaternary volcanic and sedimentary rocks, sitting unconformably on the siliceous sedimentary basement of Pre-Tertiary ages. The Tertiary volcanic rocks referred to as Kiro Formation consist of tuff, andesite lava, breccia and green tuff, while the sedimentary rocks are dominated by sandstone and claystone. The Pre-Tertiary basement rocks and the Kiro Formation were intruded by Late Miocene granite, granodiorite, diorite and andesite resulted in hydrothermal alteration and mineralization. The identified hydrothermal alteration includes chlorite, zeolite, kaolinite, jasper and silica. Ores deposits are represented by iron ore, manganese, gold, base metal and iron sands. Style of mineralization is disseminated features, cavity filling, replacement and veins. In general, quartz veins show vuggy, comb and bossa / bladed pseudomorph calcite texture. Sample analyses from quartz veins show that gold (Au) value ranges from 3 - 39 ppm, copper (Cu) : 15-133 ppm, lead (Pb) : 9 - 123 ppm, Zinc (Zn) : 7 - 31 ppm. Within silicified rocks, gold value ranges from <2 - 5 ppm, Cu : 6-546ppm, Pb : 28 - 1181 ppm, Zn : 18-3906 ppm. In contrast within altered rocks, Au : <2-55ppb, Cu : 9-199 ppm, Pb : 24 - 54 ppm, Zn: 40 - 142 ppm. The content of iron within ore veins range from 45.55 - 60.41%; manganese ranges from 231-8330 ppm (altered rock) and iron sands range from 4.22 - 50.83% magnetite. The result of the preliminary works in the area has been revealed that the Sikka and Ende Regencies could be traced for several mineral deposits occurrences such as epithermal, porphyry, skarn and volcanogenic massive sulfide of Kuroko type.

Keyword : sikka, green tuff, skarn, volcanogenic, porphyry, epithermal

Abstrak

Data lapangan di bagian tengah Pulau Flores Indonesia Timur (Kabupaten Ende dan Kabupaten Sikka) yang dilengkapi dengan analisa kimia dapat memberikan gambaran atas prospek endapan mineral di daerah zona busur gunung api dalam. Secara geologi daerah ini dikuasai oleh batuan gunung api dan batuan sedimen berumur Tersier sampai Kuarter. Keduanya menutup secara tidak selaras batuan alas berupa sedimen siliseous berumur Pra-Tersier. Batuan gunung api yang dinamakan Formasi Kiro disusun oleh tuf, lava andesit, breksi dan tuf hijau sedangkan, batuan sedimen dikuasai oleh batupasir dan lempung. Batuan alas Pra-Tersier dan Formasi Kiro diintrusi oleh granit, granodiorit, diorit dan andesit berumur Miosen Akhir yang menghasilkan alterasi hidrotermal dan mineralisasi. Alterasi hidrotermal yang teridentifikasi mencakup klorit, zeolit, kaolinit, jasper dan silika. Endapan bijih diwakili oleh biji besi, mangan, emas, logam dasar dan pasir besi. Bentuk (style) mineralisasi adalah tersebar, cavity filling, replacement *dan urat. Pada umumnya urat kuarsa memperlihatkan tekstur* vuggy, comb *dan* bossa / bladed pseudomorph calcite*. Hasil analisa geokimia terhadap urat kuarsa menghasilkan kandungan emas (Au) berkisar dari 3 - 39 ppm, tembaga (Cu) : 15 - 133 ppm, lead (Pb) : 9 - 123 ppm, seng (Zn) : 7 - 31 ppm. Untuk batuan tersilisifikasi kandungan emas berkisar dari <2 - 5 ppm, Cu : 6 -546 ppm, Pb : 28 - 1181 ppm, Zn : 18 - 3906 ppm. Sementara itu untuk batuan teralterasi kandungan Au : <2 - 55 ppb, Cu : 9 - 199 ppm, Pb : 24 - 54 ppm, Zn: 40 - 142 ppm. Kandungan besi dalam urat bijih berkisar dari 45,55 - 60,41%; mangan 231 - 8330 ppm pada batuan teralterasi and pasir besi 4.22 - 50.83% magnetite. Hasil studi awal di daerah ini menunjukan bahwa Kabupaten Sikka dan Ende memiliki tanda-tanda keberadaan ragam tipe endapan mineral seperti epitermal, porfiri, skarn dan sulfida masif volkanogenik tipe Kuroko.*

Kata kunci : sikka, tuf hijau, skarn, volkanogenik, porfiri, epitermal

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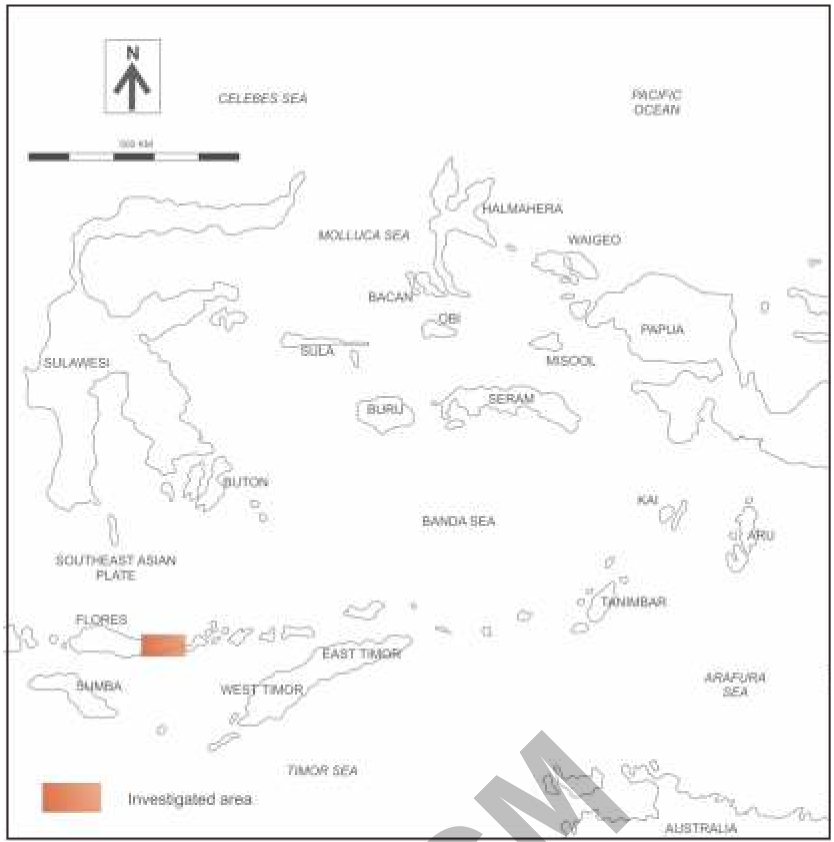

Figure 1. Location map of Eastern Indonesia, showing investigated area.

Introduction

Sikka and Ende Regencies are located in the central part of Flores Island, Nusa Tenggara Timur Province, Eastern Indonesia (Figure 1). The Flores Island extends East-West trending direction of approximately 600 km long. It is part of the Sunda - Banda Magmatic Arc that stretches from northern tip of Sumatra Island through Java to east Damar Island (Hamilton, 1979, Carlie and Mitchell, 1994) and known as the Inner Banda Arc zone (Fig. 2). Along this Magmatic Arc, several ore deposits have been identified (Sewell and Wheatley, 1994; Meldrum et al., 1994; Brian et al., 2004; Scotney *et al*., 2005; Abidin and Harahap, 2007; Abidin, 2008; Noya *et al*., 2009; Seran and Farmer, 2012; Garwin, 2012; Harrison, 2012). In the Inner Banda Arc zone itself in which the Flores Island is located two big size of deposits are present. The Batu Hijau porphyry copper-gold deposit (Meldrum *et al*., 1994) and a submarine exhalative deposit (Scotney *et al*, 2005; Seran and Farmer, 2012). The former is located in southwestern Sumbawa Island, that is on the west off of the Flores Island. While, the latter is located in Wetar Island, that is on the east off of the Flores Island. In Wetar, gold and silver were mined from high sulfidation volcanogenic massive sulfides (VMS) ore. Other deposits with much more smaller size are Sori-Pesa gold and base metal in east Sumbawa (Noya *et al*., 2009) and iron ore, manganese and gold in the western and central part of Flores Island (Djumari & Sumartono, 2001; DSM, 2000; IMR and GRI, 2008). The Sori-Pesa deposits (copper, lead and zinc) are hosted within the epithermal type of quartz veining.

The presence of ore deposits such as gold, base metal, iron ore and manganese in Sikka and Ende Regencies have so far not yet been interested by investors. Therefore, it is necessary to undertake a general investigation in order to evaluate the presence of ore deposits in the area. On the basis of the presence of ore deposits (copper and gold) in Sumbawa and Wetar Islands, it is believed that a similar deposit may also discovered in Sikka and Ende Regencies. To answer this question, more researches and works should be done.

During 2008, a geological team from the Centre for Geological Survey sponsored by Inter Mineral Resources (IMR), had been carried out a general geological survey in the area of approximately 200.000 hectares within Sikka Regenciy and a small

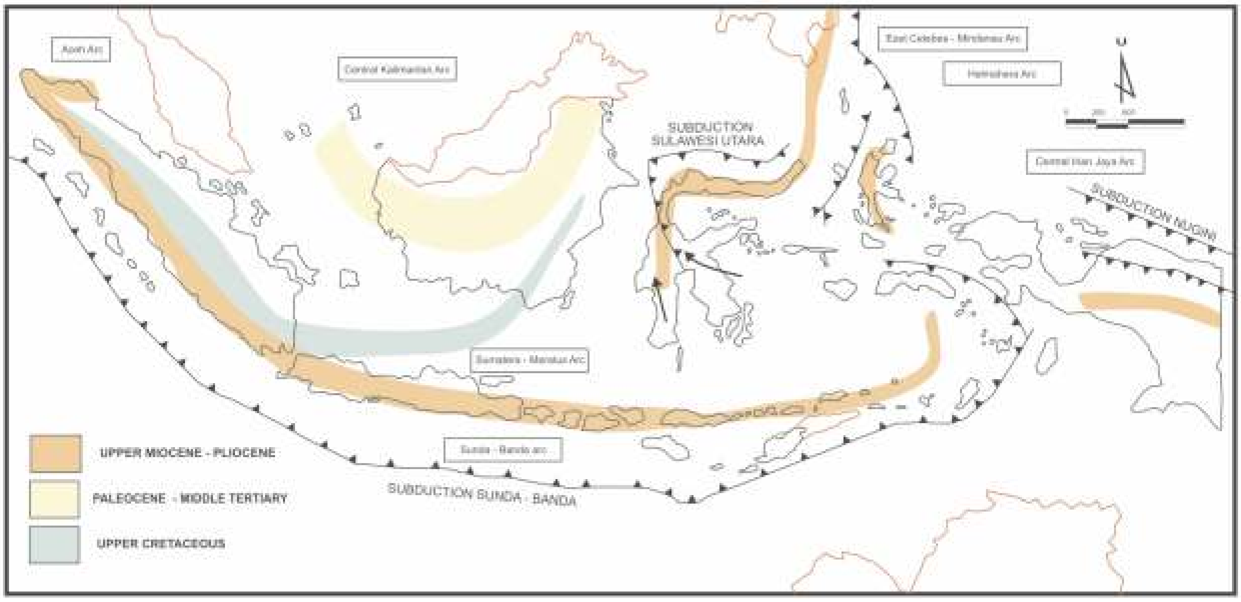

Figure 2. Tectonic and magmatic zone and its relation with mineraliztion of Indonesian islands (Carlie and Mitchell, 1994)

part in the Ende Regency. The survey includes geological mapping, geochemical exploration (soil sampling, stream sediment sampling, rock sampling) and a regional geophysical (geomagnetic) exploration.

Preliminary results of the survey concluded that the area of Sikka and Ende Regencies contain several ore deposits such as gold, base metal, iron and manganese. The deposits indicate characteristic feature of epithermal, porphyry, skarn and volcanogenic massive sulfide (IMR and GRI, 2008).

This paper is focused to obtain a general conclusion about mineralization in order to reveal and classify type of ore deposits in Sikka Regency.

Methods

The field survey was carried along the river, track and road by using four whell drive vechicle and on foot. Geographic names such as river, village and other places mention in this paper are not shown, but a general drained pattern is shown elsewhere at the end. A total of thousands of samples (stream sediments, pan concentrate, fresh, altered and mineralized rocks, and soils) has been collected for laboratory analyses and hand specimens. Selected samples have been analysed for ore contents, polished section, mineral alteration etc. The analyses have been conducted in the Centre for Geology Resources Laboratory and GeolLab of the Centre for Geological Survey. A complete chemical analyses result is available in the Centre for Geological Survey and can be discussed further for anybody who need more information about these analyses.

Geology

Figure 2 shows regional tectonic map of Eastern Indonesia. The collision between Australian plate and the Banda Arc is assigned to be continued up to now where the Pleistocene and pra-Pleistocene rocks are faulted and folded while the Recent rocks have experienced a low dipping strata. The Recent tectonic activity in the area is shown by the presence of more oftenly earthquakes (Rosidi *et al*., 1979) and followed by uplift and subsidence as well as intermittent volcanic activities (Kelimutu and Egon) (Tjokrosapoetro, 1978; Charlton *et al*., 1991).

The morphology of Sikka and Ende Regions is dominated by an undulating hilly country and minor flat areas. It is drained by several rivers, such as Lowo Ria, Lowo Wajo, Lowo Mego, Dagesinge, Lowosiu and Wainapundulo. The area of study is occupied by volcanic rocks, granitoid body and sedimentary rocks of Tertiary and Quaternary in age. A such area is important because from which indication of ore deposits have been detected.

The regional geology of the central part of Flores based on published geologic maps and landsat imagery is shown on Figure 3 (Suwarna et al., 1989), while a rock units relationship and mineralization is shown on Figure 4. The oldest rock formation (probably Pre-Tertiary in age) crops out on the Mego River (not shown on the map) consists of interbedded well bedded siltstone and sandstone.

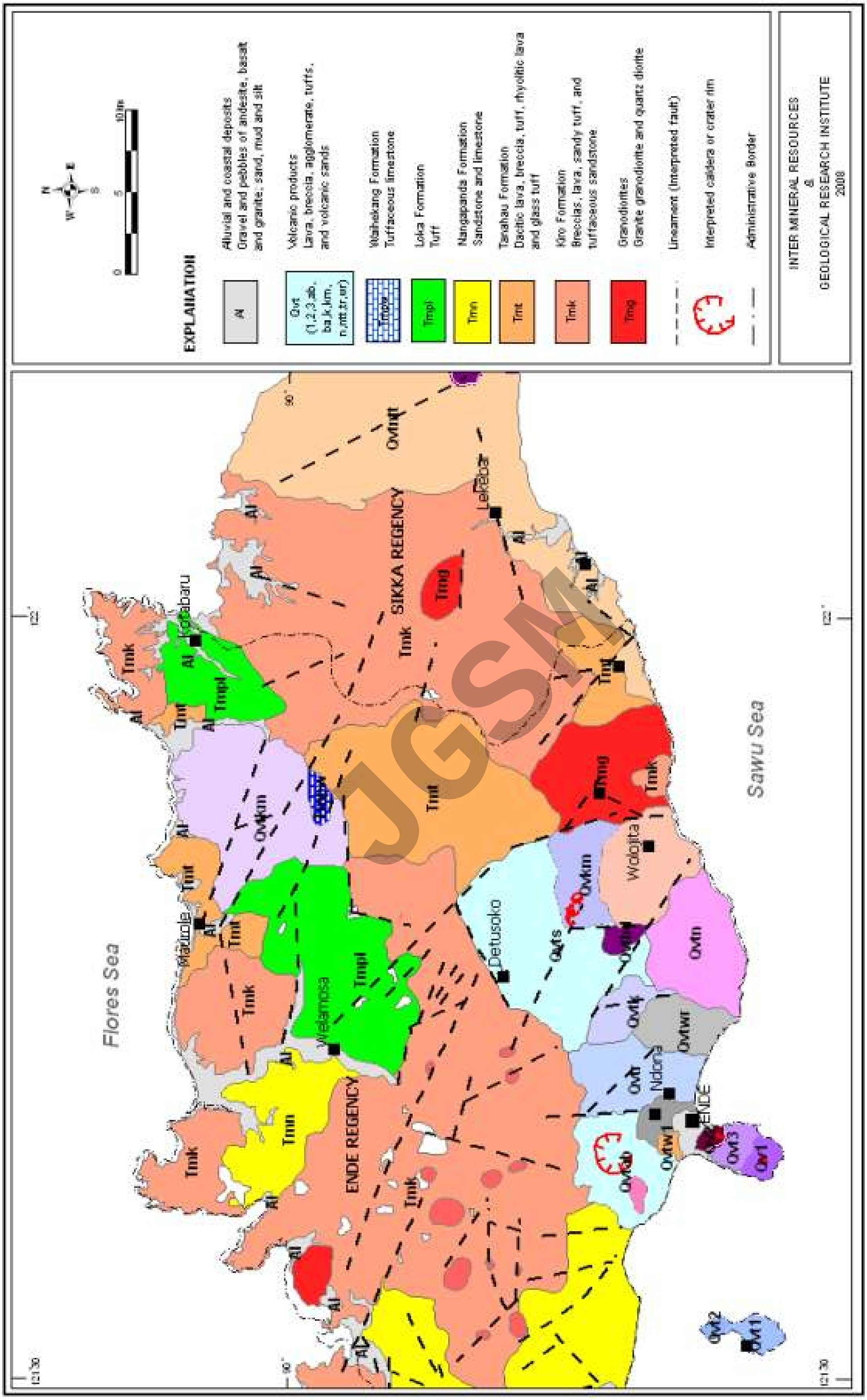

Figure 3. Geologic map of Sikka - Ende based on published geologic map (Suwarna et al., 1989) and landsat imagery.

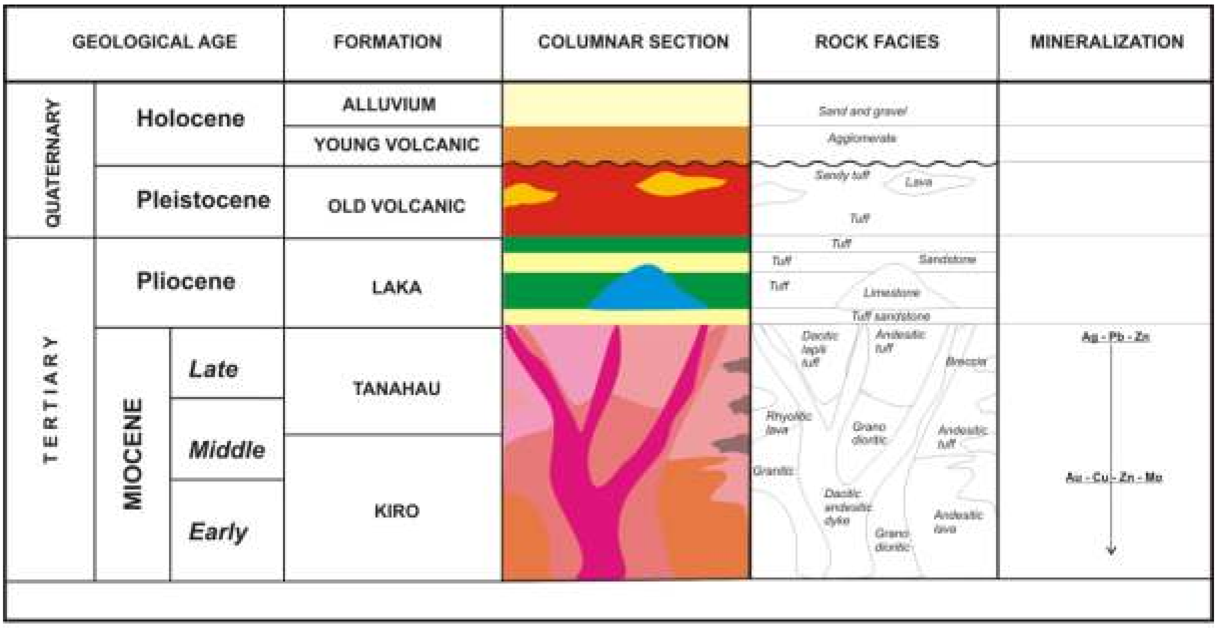

Figure 4. Schematic relationship of rock units and mineralization in Sikka - Ende (modified from DSM, 2000).

It is unconformably overlain by volcanic rocks of 7.858 - 9.69 Ma (Upper Miocene) age (Saefudin, 1995) known as Kiro Formation which consists of breccias, tuffs and andesitic lava. Breccia is dark grey in color, monomictic, volcanic components. Tuff is hard, various colors from light grey to green in color, very fine to medium grained, brecciated, well-bedded, weakly to strongly altered (silicified). The tuff thickness range from thinly to thickly beds (10 to 40 cm). In some palces, a sedimentary and laminated structures are seen suggesting that it was deposited in the water condition (submarine). In general, this rock is well exposed along the Paga beach and some places along the main road between Maumere-Paga (Tana Wawo, Paga, Mego and Magepanda). Andesite is dark grey in color, porphyritic texture and mostly altered. It is randomly distributed in the whole areas. The Kiro Formation is unconformably overlain by the Tanahau, Nangapanda, Loka and Wahekang Formations of Upper Miocene age. These formations are dominated by volcanic sequence in exception of the Nangapanda Formation that comprises dominantly sedimentary sequence of sandstone and limestone. The rocks of the Nangapanda Formation have also been weakly to strongly altered. In places, mineralization as pyrite is commonly found.

As a whole the older rocks (e.g. Pre-Tertiary siltstone and sandstone and Kiro Formation) were intruded by Late Miocene granite, granodiorite, quartz diorite and andesite. The granite granodioriteand quartz diorite are well distributed in the Wolowaru District. They are light grey in color, medium to coarse grained, foliated, strongly weathered and locally cut by rhyolite dyke. The granite, granodiorite and quartz diorite rocks are geochemically belong to tholeiite affinities (Dirk, 1994 and 1996). The microdiorite is dark grey, medium grained, hard, and partly altered. Andesite is dark grey, porphyritic in texture, hard, compact, dense, massive, sheetting and columnar joints and in places strongly altered. The microdiorite and andesite rocks are distributed in Tana Wawo, Mego and Magepanda Districts.

The Quaternary sediments consist of interbedded sandstone and claystone. Sandstone is grey in color, medium grained, thick bedded, partly massive and loose. Claystone is light grey, thick bedded, massive and soft. This rock well crops out in Nita District and Maumere. At some places, this rock has been used for home building construction.

The Quaternary volcanics is a product of Timbang Boleng, Egon and other volcanoes. The volcanics comprise interbedded breccia, andesite lava and tuff. The breccia is dark grey, monomictic, massive and less compact. The andesite is dark grey, hard, dense, porphyritic in texture, vesicular and amygdaloidal. The tuff is light grey in color, soft, thickly bedded to massive. It is classified into dacitic and rhyolitic pumice tuffs.

The youngest rocks formation is alluvial deposit, consisted of cobbles, pebbles, sands and clay. It is deposited along the beach, rivers and alluvial plains.

Alteration

As a consequence of the intrusive body and subvolcanic intrusions, several zones of hydrothermal alteration and mineralization have been formed (Fig. 5) eg. silicification, prophylitic, and argillic assemblages. Figure 6 - 13 show various type of alteration mineralization and texture in the study area. The silicification is characterized by the presence of silica and pyrite (Figure 6). It is formed within green tuff, rhyolitic tuff and andesitic tuff. It is well distributed in the Magepanda, Paga, Mego, Wolowaru and Tanah Wawo Districts.

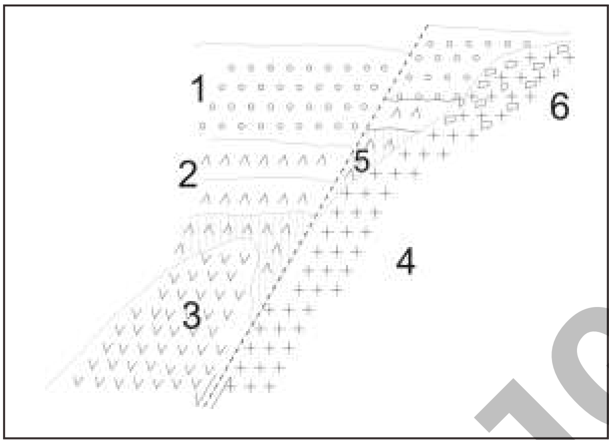

Figure 5. Geological sketch of alteration and mineralization processes in Rema-Pemo area (not to scale). 1 Silicified dacitic tuff, 2 Silicified andesitic tuff, 3 Andesitic intrusion, 4 Granitoid intrusions (granite, granodiorite, diorite) 5 Meta dacitic tuff, 6 Granite/Granodiorite with andesite as xenolith

Figure 6. Siliceous alteration consists of quartz grains (phyric quartz), chlorite, sulfide minerals (pyrite and chalcopyrite), jasper and jarosite (location 08/F/I/147).

The prophylitic zone is known by the existence of chlorite, epidote, rutil and zeolite (Figure 7). It is randomly distributed in the whole areas of the Sikka Regency. The argillic assemblage is always associated with clay minerals (illite, kaolinite and monmorillonite). In general, the argillic assemblage is light grey in color and slightly soft. A such alteration zone is distributed in Wolowaru, Mego and Magepanda Districts. In the field, these three zones are sometimes overprinting.

Mineralization

Indication of mineralization in the area is known as the presence of pyrite, gold, base metals (Cu, Pb, Zn), Fe and Mn (analytical results are available in the first author). In addition, iron sands as an alluvial deposit is also present. Pyrite is commonly found either associated with altered volcanic rocks (tuff and andesite) and altered diorite or as a vein in the area. In general, pyrite is disseminated within the rocks, replaces the mineral composition of the rocks.

Gold is found within quartz vein and altered rocks. It is associated with pyrite, chalcopyrite and sphalerite. So far, gold is difficult to see by the naked eye within the vein or the rocks. However, on the basis of some selected samples analyses, gold content range from 2 to 5 ppm (silicified rocks), <2 to 55 ppb (altered rocks) and 3 to 39 ppm (quartz vein).

Galena (Pb-ore) is found as veins and disseminated feature within the altered rocks. It is in the form of fine grained and dissemination replaced rock composition and filled the cracks. In quartz vein, it is occurred as cavity filling within the vein vugs.

Figure 7. A propylite alteration shows green in colour of chlorite and epidote (location Mego River).

A float of massive galena vein is found in Kuru area (Ende Regency). The vein consists of fine grained galena ore with the thickness of approximately 30 cm. So far, the origin of such float is unknown. Analytical results of the lead in quartz veins, silicified rocks and altered rocks range from 9 to 123 ppm, 28 to 1181 ppm and 24 to 54 ppm respectively.

Copper ore is represented by chalcopyrite, bornite and secondary copper ore as malachite and azurite. Chalcopyrite is associated with lead and sphalerite. It is also disseminated within the altered rocks and occured as cavity filling within the vein (Figure 8). Bornite is so far in the form of traces within the highly altered rocks. Secondary copper ores as malachite and azurite are in the form of leaching rocks (Fig. 9). It is found in several locations in the areas of Sikka and Ende, and closely associated with the primary copper ores of chalcopyrite and bornite. Analytical results of selected samples indicate that the content of copper ore in quartz veins, silicified rocks and altered rocks ranging from 15 to 133 ppm, 6 to 546 ppm and 9 to 199 ppm respectively.

Sphalerite is dark grey, hard and dense, and occurred as cavity filling within the quartz veins. It is associated with chalcopyrite and lead. Results of selected sample analyses indicate that sphalerite contents in quartz veins, silicified rocks and altered rocks range from 7 to 31 ppm, 18 to 3906 ppm and 40 to 142 ppm respectively.

The occurrence of iron ore in Central Flores is associated with altered volcanic rocks, granodiorite and limestone. The iron ore is in the form of veinlets within the volcanic rock, and is found within altered andesite and rhyolitic tuff in Reuma area (Tana Wawo) and Paga areas. It is interpreted, that the occurrence of iron veinlets within the rocks due to the nearby intrusions (Wolowaru Granite). The iron ore mineral in this area belongs to magnetite and hematite. In Mego River, disseminated iron ore is found within the propylitic assemblages of strongly altered granodiorite Analyses result of iron ore in this area reach up to 60.41% of Fe-total. Massive iron ore with thickness range from 20-40 cm is found in Wololea District. However, little information about this due to remote and also prohibited areas by the locals. Iron ore as hematite is also found to be associated with limestone in Magepanda area (Sikka Regency). The hematite replaces the limestone in form of discontinuous vein and interpreted as skarn type deposit.

Manganese is found within the volcanic breccia in Magepanda area. The manganese is disseminated within matrix or cements of the black volcanic breccia, It is difficult to observe due to very fine grained Mn ore. The area is typically bold, hilly, steep valley occupied by black monomict breccia with physicly very hard and dense rocks. Analytical results of selected samples indicate that Mn content within the black breccia is up to 20% while, within the lavas it ranges from 231- 8330 ppm. Manganese is also occurred as cavity filing in the quartz vein (Figure 10).

Iron sand is distributed in southern part of the Sikka Regency and widespread along the beach in the Paga District. It is up to 50 cm in thickness, black in color, magnetic in composition, medium to fine grained, well roundness and loose. The magnetite content of the iron sands range from 4.22 – 50.83%.

Figure 8. Malachite (green) and limonite (brown) cavity filling in quartz vein (Road between Watumasi and Mauweru, Location no 08/F/IV/263). This sample contain up to11529 ppm Cu.

Figure 9. Secondary copper ore of malachite (green in color) within the ore body of chalcopyrite, magnetite and hematite. The brown color is limonite (location Ongaria River 08/F/III/1009)

Quartz textures and green tuff

Quartz textures are commonly found within quartz veins either associated with mineralized quartz vein or unmineralized quartz vein. Such textures are vuggy (Figure 11), comb (Figure 12), bottroidal (Figure10) and bossa/bladed pseudomorph calcite (Fig. 13). These textures characterize a typical hydrothermal deposit. For example, the bossa texture is one of hydrothermal texture which may classify that the deposit belongs to epithermal low sulfidation (Corbett and Leach, 1995; 1998). It is interpreted that during the formation of bossa texture, which is also followed by the boiling fluids took placed and it is effectively deposited during which gold within the vein. Moreover, the type of quartz texture also gives information that the origin of the deposit is in shallow or deep level environments.

Besides this, the widespread distribution of green tuff in the area may be also important. A such rock may indicate a typical deposit, e.g. massive volcanogenic deposit of the Koroko type (Sato, 1977). The presence of the green tuff suggest that submarine volcanic environment activites occurred where it may associated with the volcanic massive deposit. Radar imagery interpretation of the area suggest that the volcanic rocks are present in the area associated with submarine condition (Suyanto and Siregar, pers. com.). At present, several volcanoes are still submerged beneath the submarine. The Flores region which belongs to the Inner Banda Arc Zone is similar condition to the Sumbawa and Wetar Islands.

Figure 10. Vein quartz with vugs filled by manganese. At the vugs margin contain chalcopyrite. Bottroidal structure typical of epithermal system (low temperature). Location 08/F/IV/38.

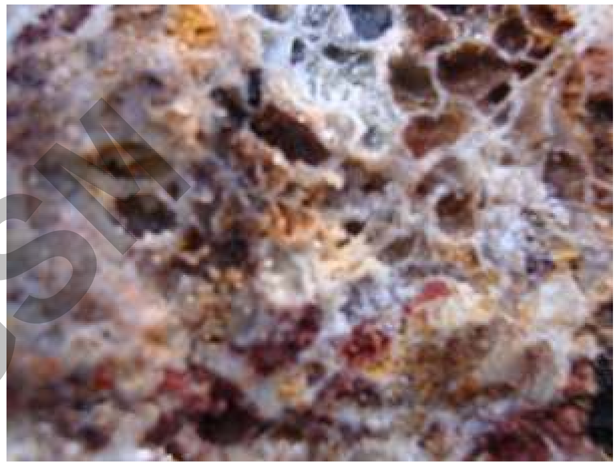

Figure 13. Bossa texture (bee nest structure) in siliceous alteration. Some holes contain pyrite and galena. Location Lowo Mitedoke River (08/F/I/431)

Figure 11. Vuggy texture in siliceous alteration, contain pyrite, jasper (red) and jarosite (yellow). Location Lowo Mitedoke River (08/F/I/431).

Figure 12. Quartz vein showing comb texture with limonite coating (brown color). (Road between Watumasi and Mauweru, Location no 08/F/IV/263)

Discussion

The Sunda-Banda Arc metallogenetic province is of main importance for Indonesia due to the presence of the established ore deposits (Lebong Tandai, Pongkor, Batu Hijau etc). This belt has developed along the volcanic arc chance (Westerveld, 1962; Abidin and Hakim, 2005; Djaswadi, 2006). The deposits are commonly associated with Late Miocene-Pliocene volcano-intrusive complexes of calc-alkaline series (Carlie and Mitchell, 1994). The most significant deposits are those containing gold, silver to some extent copper, and are accompanied by arsenic, mercury and iron. Several known ore districts are distinguished such as Pongkor in West Java (Marcoux and Milesi, 1994) and Batuhijau in Sumbawa Island (Meldrum et al., 1994; Garwin, 2012). The deposits characterized hydrothermal-epithermal, vein types of Au and other metals (Ag), and also porphyry copper deposits respectively.

Other deposits are located in Wetar Island (Scotney et al., 2005) and Tumpangpitu (Harrison, 2012) that are characterized by a submarine exhalative gold and silver deposit, and porphyry copper - gold deposit respectively.

Geologically, the presence of intrusive and volcanic rocks of the Tertiary age in the Flores Island have triggered to inisiate the formation of ore deposits. In the central part of the Flores Island especially the Sikka and Ende Regencies is potential for base metal, gold and copper. The Tertiary volcanic rocks in this area known as Kiro Formation are very similar to the Old Andesite Formation (OAF) in Western Sunda Arc (Bemmelen, 1949; Pringgoprawiro and Ryanto, 1988). The Kiro volcanics intruded by felsic rocks of granite, granodiorite and diorite with andesite dyke in places resulting extensive alteration and mineralization. So far, on the basis of field observation and laboratory analyses, the hydrothermal alteration assemblage as shown on Figure 14 can be divided into three zones such as silicification, prophylitic and argillic with Fe and Mn mineralization. There are at least four types of ore deposits are identified in Sikka and Ende Regencies,

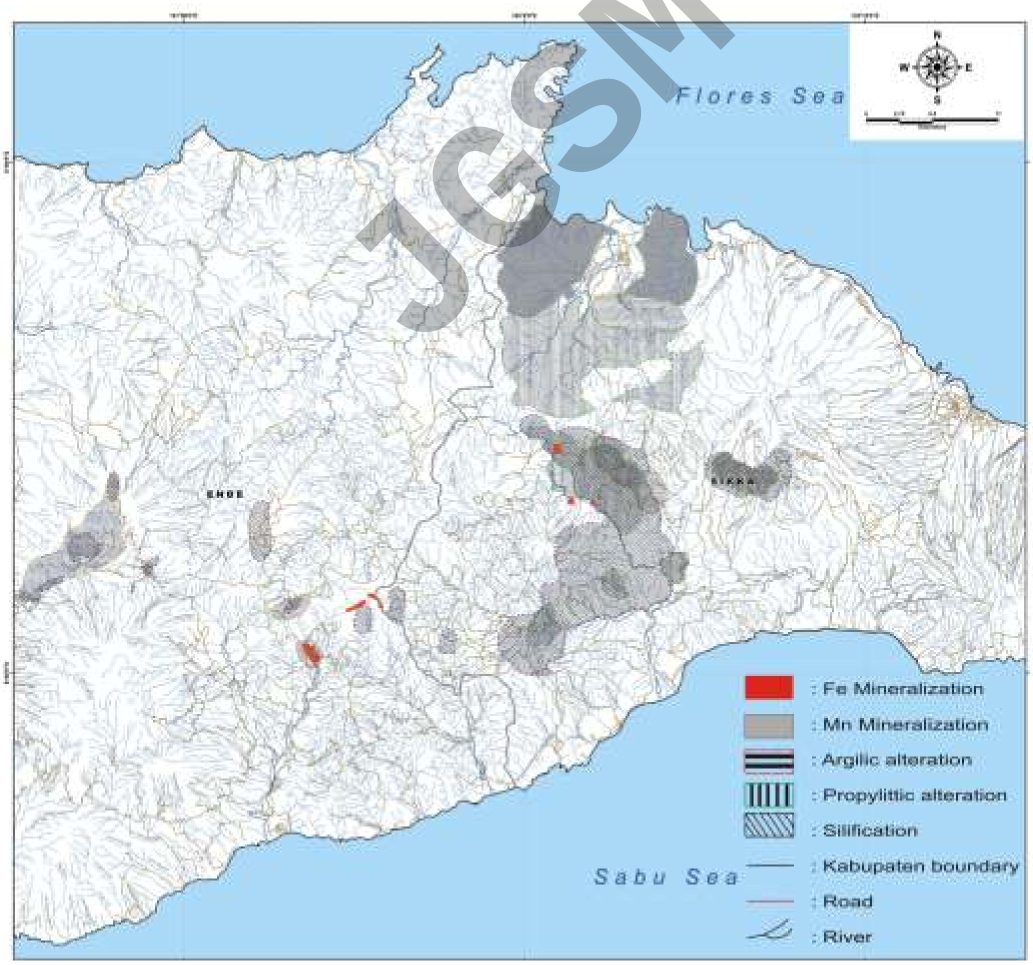

Figure 14. Alteration and mineralization map of the Ende & Sikka Region.

e.g. epithermal, porphyry, skarn (replacement) and VMS. The epithermal system is characterized by the presence of hydrothermal alteration such as silicification, prophylitic and argillic assemblages. Silicification is characterized by the presence of silica-pyrite within silicified rocks. Prophylitic alteration is known with the existence of chlorite, epidote and zeolite. The argillic assemblage is the presence of clay minerals such as kaolinite, monmorillonite, illit with pyrite and gold. Besides this, the presence of various textures such as bossa / bladed calcite, comb and vugs within the quartz vein also indicate the epithermal type deposits of low sulfidization (Corbett & Leach, 1995). Bladed texture is also indicative of boiling hydrothermal fluid during which the deposition of gold is very active (Henley, 1985). The mineralogy of epithermal deposit is gold with minor pyrite, galena and sphalerite. Such type of deposits is found in Reuma (Tana Wawo), Mego and Magepanda areas.

The skarn type deposit in the study area is found in the Magepanda area. It is associated with intercalated limestone within the Kiro Formation. Mineralization is in the form of a reddish brown hematite that replaced the calcareous rock of limestone as a discontinuous vein.

The indication of porphyry system is found in the Kuru area (Ende Regency). The deposit is characterized by the presence of disseminated pyrite, trace of chalcopyrite and bornite. In addition, secondary copper ore as malachite and azurite are found as patches within the altered rock.

The indication of the Kuroko type deposit or VMS is always associated with the submarine volcanic environment (Sato, 1977; Solomon & Walshe, 1979). The deposit is followed by exhalite body interpreted as a siliceous chemical precipitates (Riddler and Shilt, 1974). The most important formation of exhalite is chert followed by any four facies of iron formation, such as oxide (Fe+3 and Fe+2), carbonate (Ca, Mn), sulfide (Cu, Pb, Zn, Au, Ag) and silicate (Mg) (Sangster, 1980; Riddler & Shilt, 1974). As a matter of fact, such characteristics are identified in the Sikka Regency. The presence of silicified green tuff (cherty volcanic) may indicate the exhalite type in the area. The rock is strongly cherty, silicified and altered. Results of analysis of some cherty rock samples in the area shown that the silica and Loss of Ignition contents range from 58.46-77.3 wt.% and 2.31-6.41 wt% respectively. It means the rock has increased in both silica content (silicified) and moderate to strongly altered. In contrast, the metal contents within the green tuff range from 31.9 to 3984.7 ppm (Pb), 49.928 to 112.5 ppm (Zn), 483.0 to 861.0 ppm (Mn), 66.8 to 888.8 ppm (Ba) and 1.2 to 3.19 % (Fe). The cherty green tuff is assumed to be deposited in the submarine environment and may associated with the VMS. On the basis of the radar imagery, several volcanoes around the Flores area are seen but still submerged within the sea (Suyanto and Siregar, pers. com.). The presence of barite may indicate a submarine hydrothermal activity (Sewell & Wheatley, 1994). Other than this characteristic features, the presence of Mn as sulfide within the black volcanic breccia also supported the indication of VMS. The analysis result of selected black volcanic breccia from the northern part of Central Flores Island (Magepanda areas) indicate that the content of Mn range from 13 to 20%. The presence of massive iron ore as oxide in Wololea area could also support the presence of VMS in the area. As a matter of fact, in West Flores have been found such indication (Wiji, pers.com). However, because the study is still a preliminary, it is necessary to carry out more detailed study in this area to confirm this interpretation.

Conclusions

The preliminary investigation in the area of Sikka and Ende Regencies has obtained more data either geology or mineralization. Geologically, the area is dominantly occupied by Tertiary volcanic and sedimentary rocks. Others are intrusive rocks that comprises granodiorite, granodiorite and quartz diorite, and andesite dykes. Based on field geological observation, Pre-Tertiary fine clastic sediments consisting of interbedded sandstone and siltstone is the basement of the area (Wiji, pers. com). The Teriary volcanic rocks of Kiro Formation is the most dominant rock type in the central part of Flores Island and it has been moderate to strongly altered. The lithology consists of green andesitic and rhyolitic tuff, volcanic breccias, rhyolitic to dacitic tuff breccia and andesitic to dacitic lava.

The hydrothermal alteration assemblages in the central part of Flores Island can be divided into three zones such as silicification, prophylitic and argillic. While, the mineralization is classified into epithermal, porphyry, skarn and volcanogenic massive sulfide. They are in the forms of disseminated features, a characteristic of a veinlets and quartz veins within the altered rocks. Texture evidence such as bossa shows low sulfidation ephithermal system. The mineralogy of these deposits are gold with minor chalcopyrite, galena and zinc (epithermal), chalcopyrite, bornite and secondary copper minerals (porphyry), hematite (skarn) and lead-zinc-barite (VMS). The host rocks of ore deposits are breccia, tuff, andesite of the Kiro Formation and sandstone (Nangapanda Formation). The high contents of Au (3 - 39) ppm and the moderate value of basemetal (Zn-Cu-Pb-Ag) should be more attractive for further exploration in this area. The presence data suggests that the Sikka and Ende region should be more studied in order to clarify various mineral deposits as well as to evaluate the economic value of the deposits. Because the Flores is lying on the same arc zone as Sumbawa and Flores, it is also expected that similar ore deposit could be discovered in Flores Island.

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