Hydrothermal Mineralization in Jailolo Waters, West Halmahera, North Maluku Province

Mineralisasi Hidrotermal Di Perairan Jailolo Halmahera Barat, Propinsi Maluku Utara

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(Received 11 January 2015; in revised form 15 May 2015; accepted 29 May 2015)

ABSTRACT: Halmahera Island tectonically is divided into two main regimes, those are East Arm Regime (EAR) and West Arm Regime (WAR). Both regimes have very different characteristics where the EAR consists of Cretaceous ultramafic rocks and old red shale, while the WAR composed of Neogene sediment. The study area is an area with active tectonism shown by recent seismic activities and volcanic eruptions. Hydrothermal activity is indicated by rocks alteration of andesite, dacite, and diorite such as kaolinite, argilic and montmorilonite. Primary metal type mineralization occured in a strong altered volcanic rocks, while the secondary mineralization occured in the sedimentary placer. AAS, petrographic analysis, and mineralografi obtained mineral pyrite, manganese, chalcopyrite in rocks from coastal and marine offshore up to depth of 100 meters. Analysis of the 36 examples of seabed sediments, showed the presence of anomalous metal minerals of Au, Cu, Mn, and Fe those are content of Au 0.01 - 0.03 ppm; Cu 14-150 ppm; Mn 23-1050 ppm; and Fe 2-10%.

Keywords: Jailolo waters, western arm regime (WAR), andesite, dacite and diorite intrusion rocks, mineralization of Au, Cu, Mn, and Fe.

ABSTRAK : *Pulau Halmahera tektonik dibagi menjadi dua rezim utama, yaitu East Arm Rezim (EAR) dan Westt Arm Rezim (WAR). Kedua rezim memiliki karakteristik yang sangat berbeda yang EAR terdiri dari batuan ultrabasa Kapur dan shale merah tua, sedangkan WAR*

Terdiri dari batuan sedimen berumur Neogen. Daerah penelitian sebagai daerah dengan tektonik dan vulkanik aktif yang ditunjukan dengan aktifitas gempa dan letusan gunungapi hingga sekarang. Aktifitas hidrothermal ditunjukkan oleh alterasi pada batuan andesit, dasit, dan diorite. Mineral ubahan yang terbentuk kaolinit, argilik dan montmorilonit. Tipe mineralisasi logam primer terdapat dalam batuan vulkanik terubah kuat, sedangkan mineralisasi sekunder terdapat dalam sedimen plaser. Hasil analisis AAS, petrografi, dan mineralografi didapatkan mineral pirit, mangan, kalkopirit pada batuan di pesisir dan laut lepas hingga kedalaman 100 meter. Hasil analisis terhadap 36 sedimen dasar laut, menunjukan adanya kandungan mineral logam Au,Cu, Mn, dan Fe dengan kadar Au=0.01 – 0,03 ppm; Cu 14-150 ppm; Mn 23-1050 ppm; dan Fe 2-10% .

Kata kunci : *Mandala lengan barat (MLB), batuan intrusi andesit, dasit, dan diorit, mineralisasi Au, Cu, Mn, dan Fe, Perairan Jailolo, Halmahera Barat.*

INTRODUCTION

Halmahera Island tectonically divided into two main geological regimes, those are East Arm Regime (EAR) and West Arm Regime (WAR). Both regimes have different characteristics (Supriatna S., 1980). The study area is located in the west arm regime and it is proposed as a good area for hydrothermal mineralization (Figure 1.a). The paper is made to encourage the presence of some metallic minerals such as gold, manganese and copper and other metals those are closely related to hydrothermalization process. East Arm Regime is characterized by ultramafic rocks composed of Cretaceous metamorphic rocks, serpentinite, gabbro, and basalt. While West Arm Mandala is characterized by a magmatic arc volcanic rocks of Oligo-Miocene (Darman 2000).

The mineralization on the study area is closely tectonic related with fault, fold and joints. These structures usually cut the Miocene-Pleistocene rocks. The fault is generally trending east-west with dextral strike slip fault and it is still active (Hamilton, 1979 and Asikin, 2007). This fault assumed to be related to the metal mineralization of Fe, Au, Cu, and Mn.

Tectonostratygraphically (Figure 1.b), the island of Halmahera is controlled by collision of the main plate Pacific with Eurasian plates and also the Philippines Plate from the north generate Cenosozoic sediments and volcanic intruded by Miocene granodiorite (Darman, 2000). Subduction complex consisting of marine sediments and dark grey andesitic-basaltic rock outcrops, andesitic-basaltic lava flows and andesitic-basaltic pyroclastic, generally hard and show vesiculer structure, local scoria has been altered due to tectonic and volcanic activities in this area.

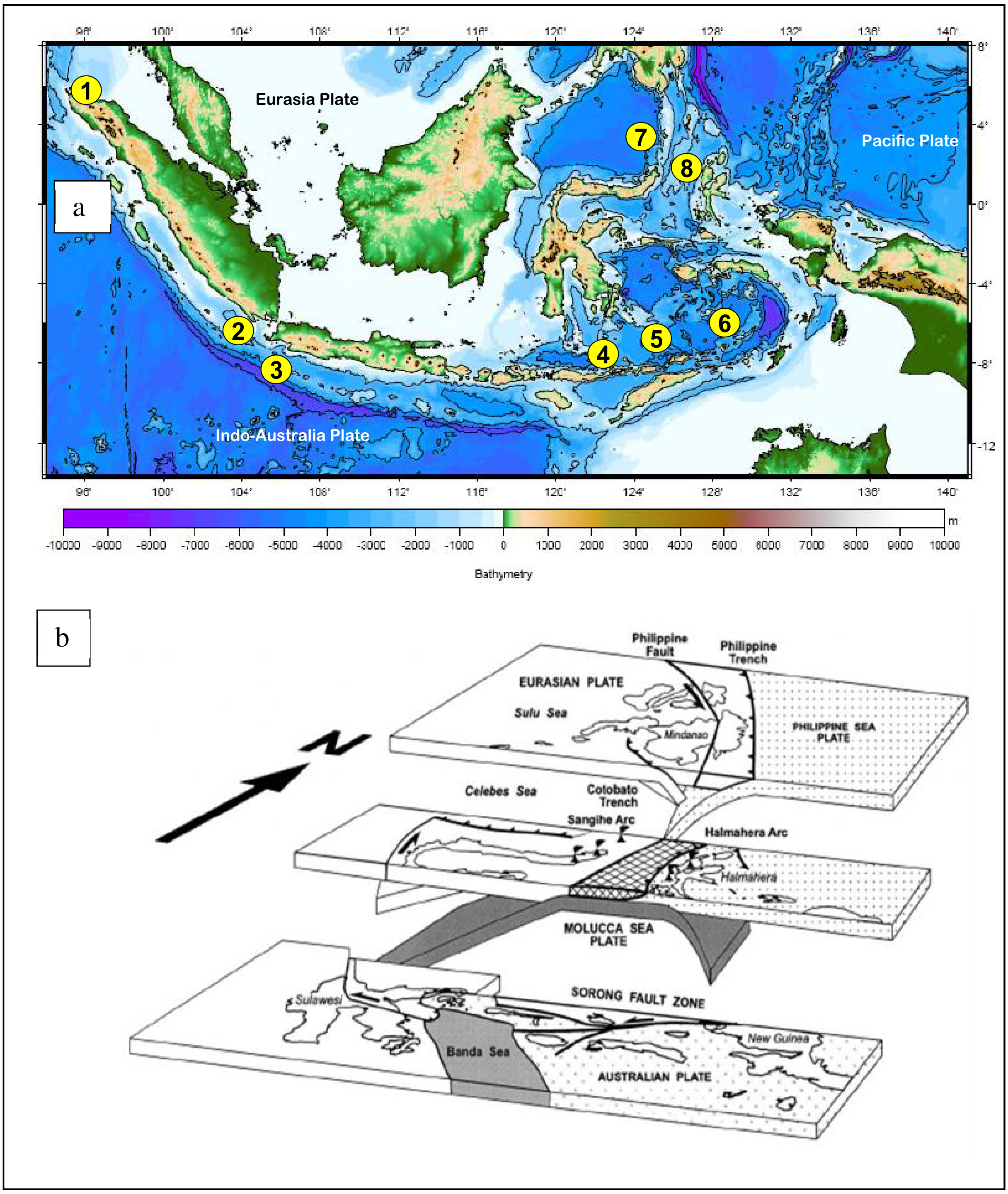


Figure 1.a. Geological Setting of the study area in relation to Indonesia Hydrothermal activities. 1.Sabang Island. 2. Semangko. 3.Bayat. 4. Komba. 5.Wetar. 6.Damar, Nila, Serua. 7. Kawio 8.Jailolo, Halmahera. (Lee, *et al.*, 1995; Sapi'ie, 2000; Konca, *et al*, 2005, Haryadi, *et al.*, 2009).
1.b. Model of complex double subduction of Molucca Sea Plate dan stratigrafi Halmahera *(Hall and Willson 2000).*

Volcanoclastic sediment units are also the product of volcanic rocks consisting of sandy tuffs and laharic deposit of fragmented agglomerates (Sunarya, 1999). The youngest rock units in Late Miocene-Early Pliocene is form of coral limestone. It is assumed that gold occurrences associated with volcanic eruptions and or intrusion of subvolcanic with trachy andesite and andesitic composition. This magmatic activity was continued until Late Pleistocene, but their distribution was limited. The youngest Magmatism Plio-Pleistocene took the form of andesitic basalt.

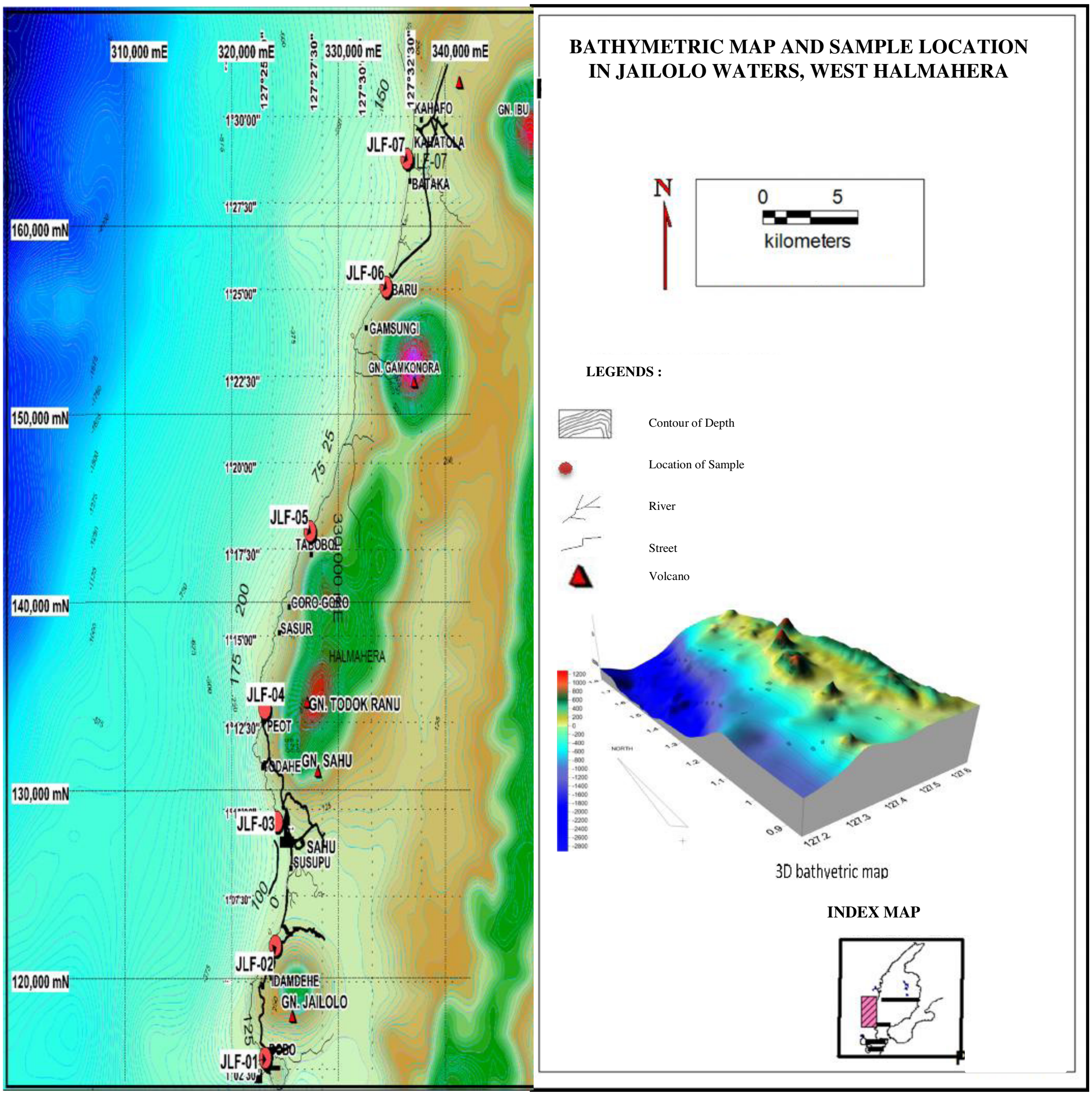
METHOD

The method of these activities are echosounding, single channel seismic reflection, grab sampler, hand drilling, and insitu rock sampling. These are continued by laboratories activities in Bandung, such as AAS laboratory analysis, SEM-XRD, petrography, and analysis mineral grains.

RESULTS

Morphology

This morphology of Jailolo Waters consist of mountains, hills and beaches have a low-steep slope. According to the depth (Figure. 2), the bathymetry in the study area can be divided into two different depths, those are in eastern part of Tanjung Bobo, it has a rugged relief which has a 40 meters depth at a distance of 200 meters from the beach, with contour lines fairly tightly. While in Desa Baru to Bataka waters the depth



Fugure 2. Bathymetric map and Sample Location (Widi, H.C., et al, 2014)

reaching 40 meters at a distance of1 kilometer from the beach with contour lines rather tenuous. The irregularity contours of this seabed presume to form the morphology in relation to tectonic from the subduction between Eurasian and Phillipine plates and resulting an active faults and emerge to the surface and showed by the emergence of some hot springs on the study area.

Results of measurements of sea depth in the area studies generally show a steep slope morphology (T.Bobo), wavy (Peot) and weak-moderate way morphology in G.Baru – Bataka waters with depth variation from 5-150 meters which is located in the middle of the sea and outside of the study area, while the shallow depths generally in coastal areas and near of the islands.

The rocks on the study area consist of layered sandstones (Weda Formation), the unit of volcanic rocks (andesite, and basalt) and breccias, phyroclastic of Miocene-Pleistocene. Figure 3 shows mainly outcrops of Basaltic and andesitic lavas, while Figure 4 mainly shows a float of sedimentary breccia and sand. These rocks are older than the sedimentary rocks. The sedimentary rocks generally as a placer from seafloor sediments composed of sand and clay which are content of base metal such Au, Fe, Mn, Ag, etc. A primary gold (Au) found in the andesitic rocks that intruded a

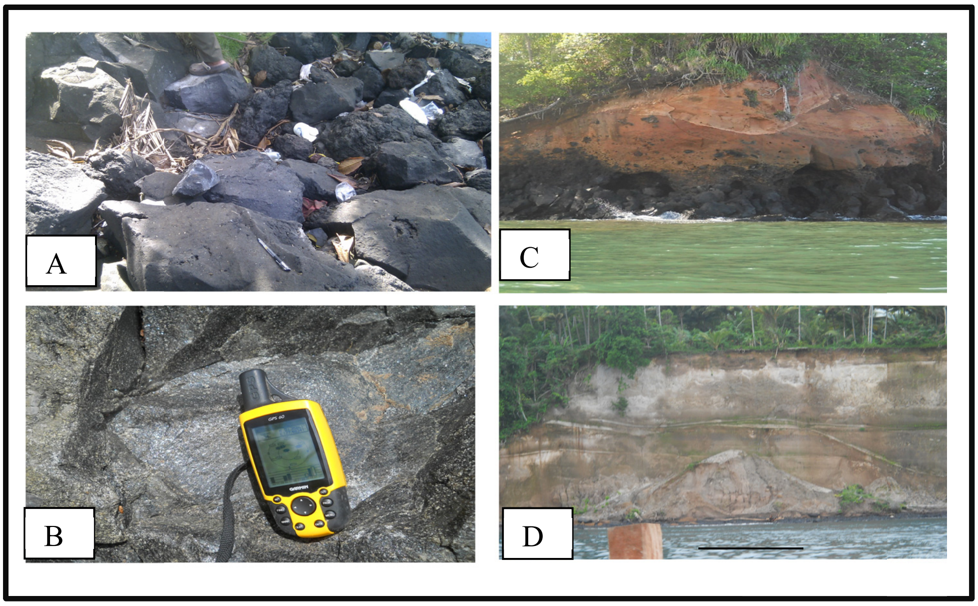


Figure 3 . Outcrop. A. Basaltic Lava (T.Bobo). B. Basaltic Lava (Kahatola). C. Andesitic Lava (slope in G. Gamkonora). D. Volcanic Sand (Sasur)

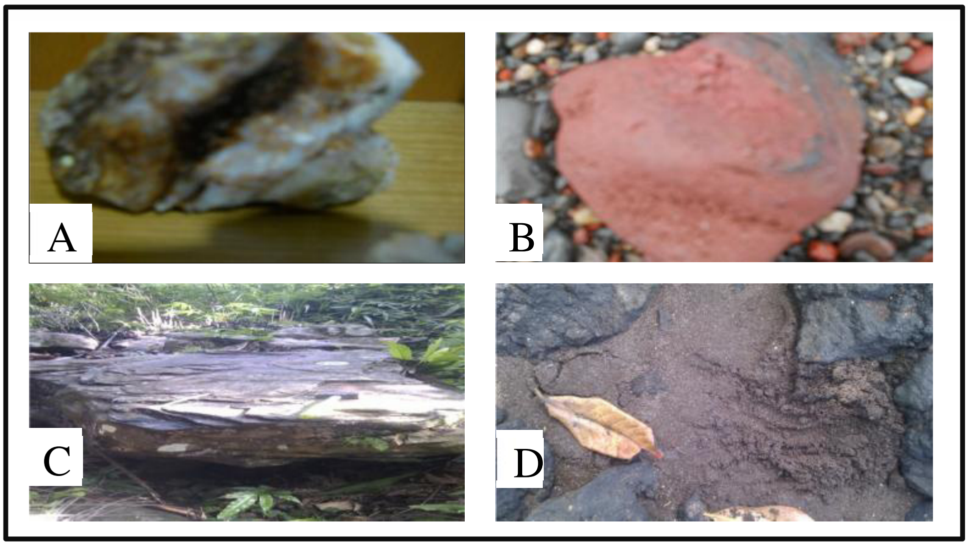


Figure 4. A. Float of hydrothermal Breccia (mineralization Au, Mn, Cu). B. Basaltic Lava (altered) C. Sand (Silification moderate-strong). D. Basaltic Lava (mineralization Au, Mn, Au, Altered moderate)

Table 1. Result of AAS method from

o	KODE CONTO	Au (ppm)	Cu (ppm)	Mn (ppm)	Fe (%)
1	JLL-03	0,037	34	1544	4,08
2	JLL-04	0,041	29	354	2,91
3	JLL-08	0,030	10	160	1,58
4	JLL-10	0,055	15	280	2,98
5	JLL-11	0,033	16	197	2,07
6	JLL-12	0,038	15	199	2,01
7	JLL-13	0,026	15	311	2,58
8	JLL-20	0,096	18	501	3,98
9	JLL-21	0,022	18	260	2,04
10	JLL-25	0,023	13	295	2,78
11	JLL-27	0,017	15	257	2,39
12	JLL-28	0,016	9	106	1,09
13	JLL-30	0,031	22	220	2,37
14	JLL-32	0,019	39	219	2,49
15	JLL-33	0,089	18	428	3,38
16	JLL-34	0,048	17	304	3,89
17	JLL-36	0,008	17	453	3,75
18	JLL-37	-	16	208	2,34
19	JLL-39	0,037	18	452	4,69
20	JLL-42	0,008	18	384	3,56
21	JLL-43	0,035	17	354	3,90
22	JLL-45	0,001	17	300	3,37
23	JLL-46	0,047	20	320	3,11
24	JLL-47	0,011	22	424	3,43
25	JLL-52		19	190	2,28
26	JLL-53	0,025	19	237	2,54
27	JLL-54		33	260	2,54
28	JLL-58	0,099	26	163	1,52
29	JLL-59	0,036	52	267	2,16
30	JLL-60	0,002	21	441	3,98
31	JLL-61		19	429	5,03
32	JLL-63	0,002	28	406	5,43
33	JLL-65		28	395	4,79
34	JLP-04B	0,042	25	402	3.11
35	JLP-11D	0.006	27	813	5,18
36	JLP-20		32	762	2,48

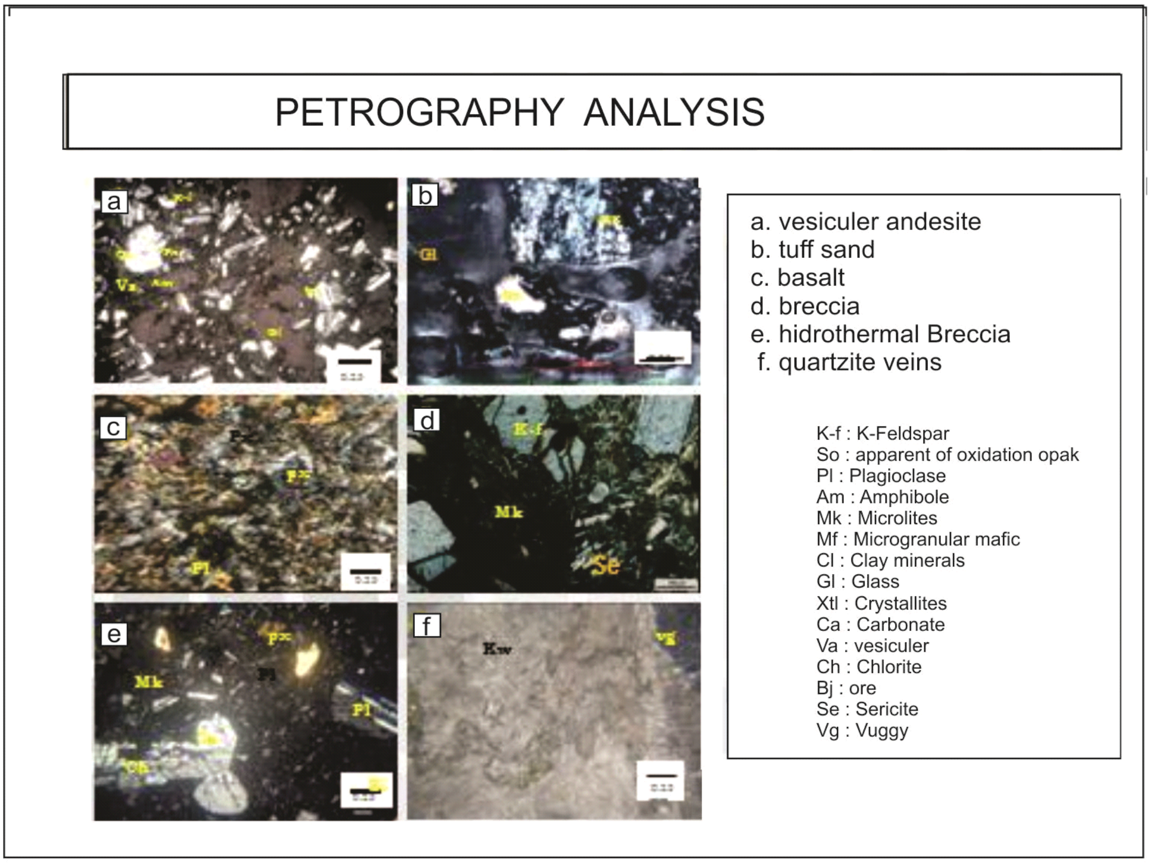


Figure 5. Petrography Analysis

sandstones layer and it has been mineralized. The other sources come from the secondary minerals in the placer sediment occured both on the sea floor or on the beach. For the detail information we can describe as follows : The analysis from an outcrop on the beach (onshore) they are containing gold from 0.01 to 0.043 ppm, and from placer deposit close to intrusion rocks they are containing gold of 0.04 to 0.006 ppm. While from seabed sediment (offshore) laterally contains of gold from 0.002 to 0.09 ppm (table 1).

Table 1. Result of AAS method from Petrographic analysis of the study area can be classified into several groups based on composition and percentage of minerals contained in the rocks, namely: vesikuler Andesite, tuff sand, Basalt, and Breccia (figure 5).

The result of mineralogical analysis for gold metal (Au) indicate in a very fine grained (0.22 to 40 micron) and they are also detected by element analysis and microscopic analysis, with levels ranging from 0.01 to 0.05 ppm. They are associated with rock fragments of diorite and andesite-basaltic which have been altered weakly-high. Calcopyrite ($CuFeS_2$) with yellow-pink color, anisotropic, cubic grain structure, as a single grain, found in small amounts, it has a 3 scale in hardness, it is 5 in density, found in vein as a result of hydrothermal processes in igneous rocks (Suyatno, Y.Y, 2004) associated with mineral calcopyrite, cuprite, and malachite (Figure 6).

The dominant alteration minerals on rocks samples megascopically consitst of limonite, hematite, chlorite, pyrite, clay minerals, chalcopyrite, calcite, silica, manganese, markasit, goethite, and feldspar. The result of rocks petrographic analysis on Jailolo showed an alteration process. There are an altered minerals like carbonate, clay minerals, quartzite, calsedone, and zeolites found in the layered sandstone, sandy tuffs, volcanic basalt, and andesite (Setia Graha, 1987). It also found a replacement minerals such as plagioclase to biotite, vitrification, calcification of ground mass, as well as weak oxidation.

Based on intensity of alteration and the altered mineral occurrences, it can be concluded that the most likely alteration zones located on the west cliff area, especially in the sandstone unit, and breccia. In some location show a potential content of metal element which are relatively higher than other parts, particularly elements of gold, manganese, iron, and copper. The host rock of this mineralization in the study area is predicted from sandstone and volcanic rocks which are intruded by andesite and diorite rocks.

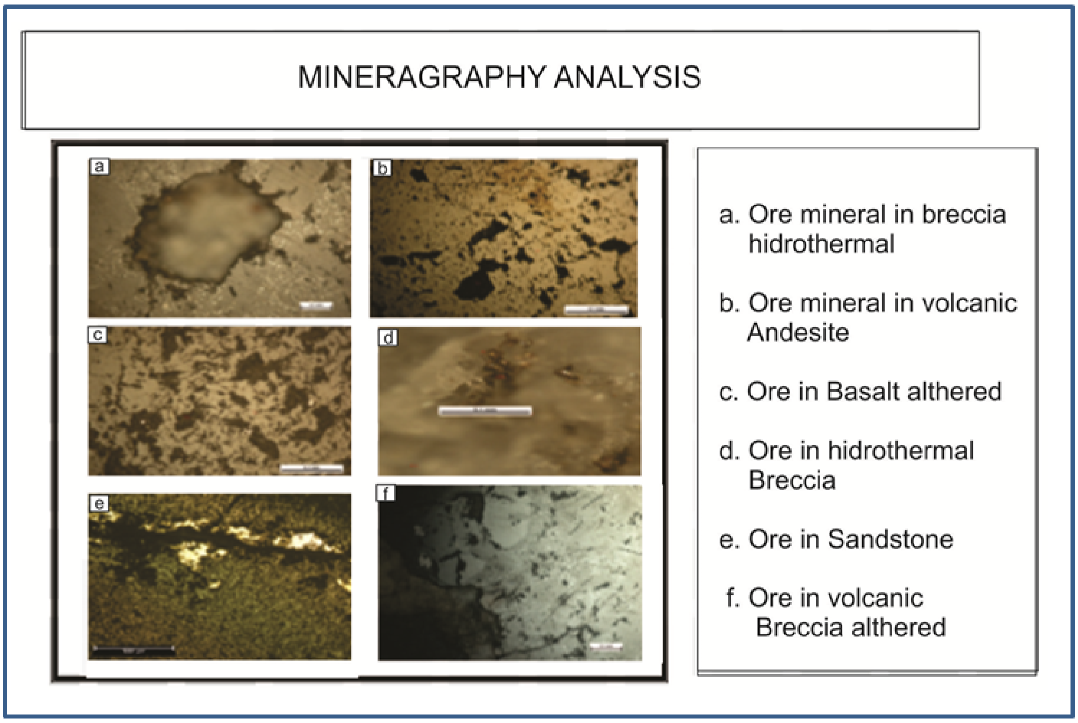


Figure 6. Mineragraphy Analysis

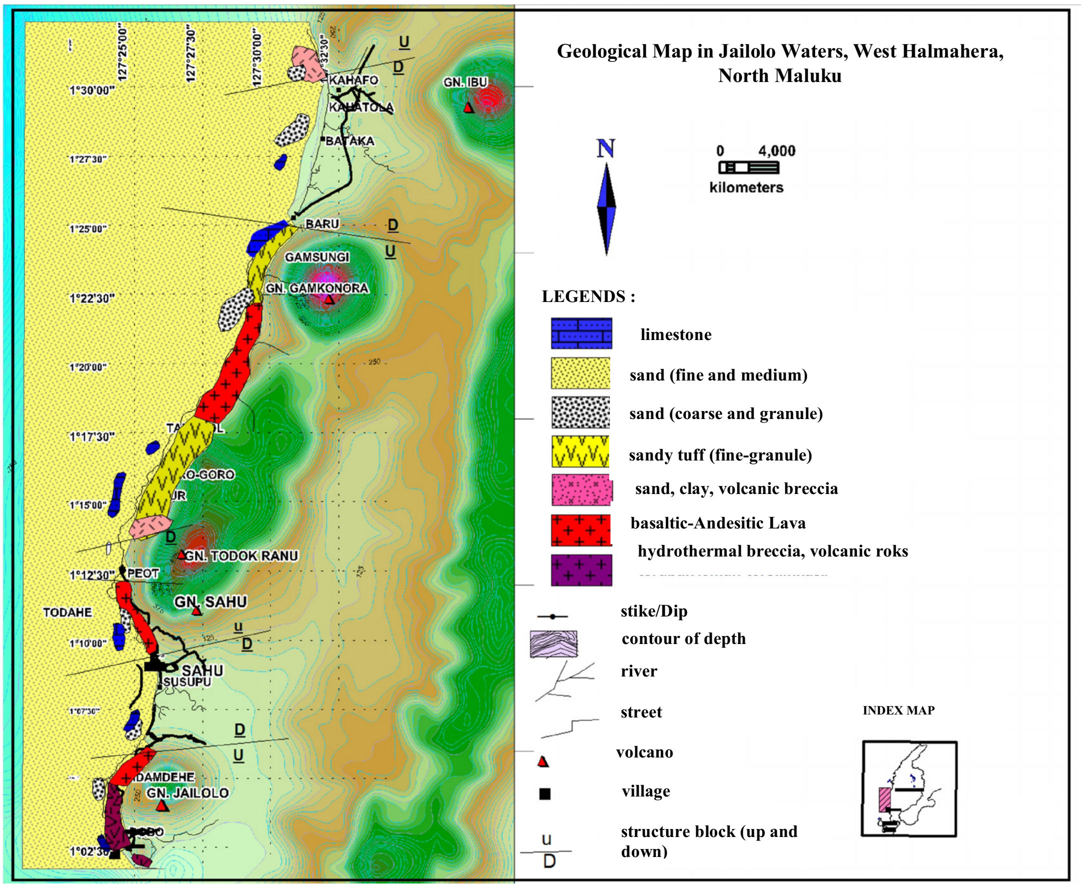


Figure 7. Geological Map of The Study Area (Widi, H.C., et al, 2014)

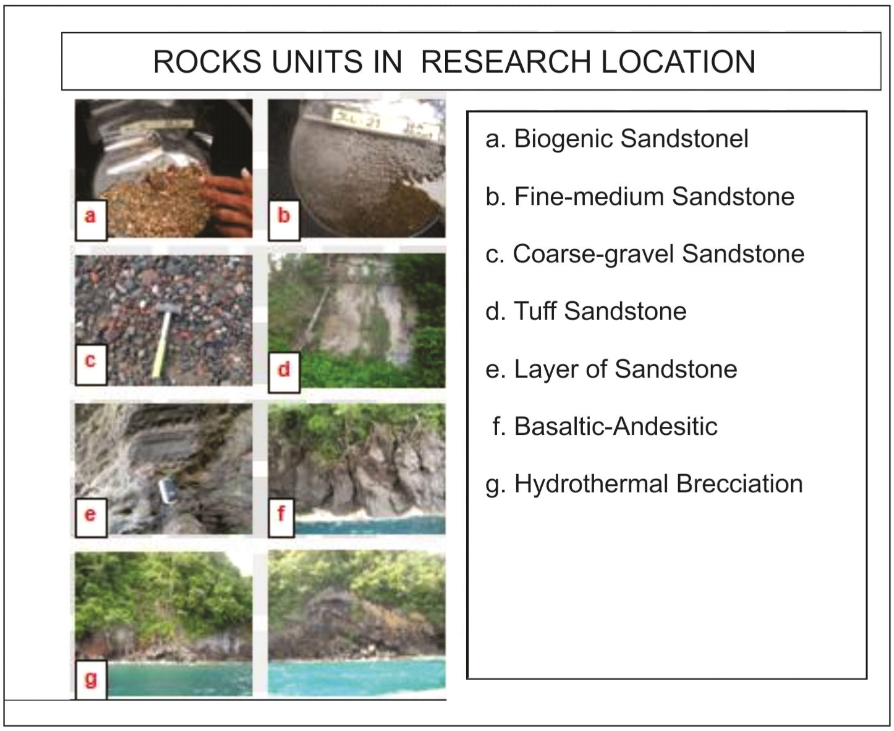


Figure 8. Rock Units in Research Location

Mineralization on precious metals and base metals originated from Miocene igneous intrusions exposed in Tanjung Bobo. The area is started from a hilly steep slopes on distribute up to the bottom of the sea. The mineralization with gold contents occured at granodiorite intrusion, hydrothermal breccia with strong silisification with appearance of perforated quartz, parallel quartz laminate, and colloform bedding. The alteration are shown as argillic types, kaolinite, carbonate, magnesium. Tanjung Bobo and Peot have several alteration rocks (figure 4).

Primary mineralization at Tanjung Bobo found in the form of alteration zone and hydrotermal breccia due to an acid to intermediates igneous rocks activities intruded sedimentary rocks and lava basaltic andesite (Figure 7). These outcrop are expected to distribute continuously up to the bottom of the sea (Figure 8). Ore minerals encountered in this area are: gold, manganese, copper, iron ore with gold contents 0. 001 to 0.004 ppm. Forms and types of gold metal mineralization shown as an outcroped in the form of stockwork with fracture filled by quartz and iron oxides. We found also quartz-calcite filled with fine veining of sulphide masives those are associated with faults structure and fractures.

DISCUSSION

Mineral resources of ores minerals in the study area of West Halmahera is potetial, especially those on the seabed at a depth of 5-100 meters. Primary mineralization at Tanjung Bobo on land found in the form of alteration zone and hydrotermal breccia due to an acid to intermediates igneous rocks activities intruded sedimentary rocks and lava basaltic andesite. These outcrop are expected to distribute continuously up to the bottom of the sea.

While a secondary minerals with plaser gold deposit both are found on the beach or offshore of Bataka, Peot, Todahe, Susupu and Tanjung Bobo. They were partly originated from sedimentary transport of some rivers as Muara A and Jailolo. The source rocks derived from volcanic rocks which has been eroded and transported by big rivers and that end up at Susupu and surrounding area.

The presence of either from submarine sedimentary placer with gold content mostly from onland and or might be from submarine rocks itself but it should be approved by detil analysis of seabed sediments.

The study can be developed into detail exploration stages. Data of mineral resources with the existing potential has not been cultivated optimally. For ore minerals especially in the seabed has not been developed, hopefully the results of this study make a new thing for finding of gold metal on the seabed and it will be a new flagship commodity in this region.

CONCLUSION

Mineralization occurs from the primary source rock such as andesite, dacite, and diorit. The occurence of altered minerals approved by high Fe and Mn. The primary mineralized hydrothermal encountered in the form of stockwork, vein quartz, with a fracture/vein filled by quartz, calcite and sulfides masives, with perforated quartz, colloform bended, sugar quartz and all them are associated with metals of Au, Cu, Mn, Fe, Au from 0,2 to 0.41 ppm. While, for secondary mineralization on plaser deposit both from source rocks of submarine or coastal areas with gold contents of 0.12- to 0,3 ppm.

ACKNOWLEDGEMENT

The author wish to thanks to Head of Marine Geological Institute, Head of Mining Exploration at Jailolo, West Halmahera, all editors of Bulletin of The marine geology as well as to our colleagues in Marine Geological Institute who were helping during preparing the manuscript.

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