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Supergene Enriched, Intrusion Related Low Suphidation Deposit, Binebase-Bawone, North Sulawesi, Indonesia

Deposit Sulfidasi Rendah yang Terkait Intrusi dan diperkaya Supergen, di Binebase-Bawone, Sulawesi Utara, Indonesia

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Abstract

Gold mineralization at East Asia Minerals' Binebase Prospect on Sangihe Island displays controls to mineralization typical of other Pacific Rim Intrusion related low sulphidation systems. Better gold grades are localized on EW dilatant structures at the intersection of NW trending structural corridors. Mineralization at Binebase was previously interpreted as being hosted in a high sulphidation style of alteration system. This assumption was based on surface observations of alunite and what was thought to be residual vuggy silica. Recent observations indicate that the alunite is a supergene mineral in nature and that the vuggy silica is the boxworked remnants of silica + pyrite alteration. Precious metal grades decline moving away from feeder structures and there has been significant supergene enrichment of gold in the oxide zone. Exploration drilling completed in 2008 by East Asia Minerals Indonesia resulted in an inferred resource of approximately 835,000 oz of contained gold at a cut off grade of 0.25 g/t Au. This resource included both oxide and hypogene sulphide mineralization. Drilling was reinitiated in 2011 to change the inferred to indicated resource, that drilling programme continued at the time of this publication. Various geophysical techniques were employed at both prospect and regional scales to aid exploration. Ground magnetics defined hydrothermal alteration and magnetite destruction which was coincident with mineralization at both Binebase and Bawone and an Induced Polarisation survey also produced an anomaly which was coincident with disseminated fine sulphide associated with clay alteration within the hydrothermal alteration. The southern part of the island was covered by an airborne geophysical survey in an attempt to understand the regional structural controls on mineralization and to define additional areas of hydrothermal alteration.

Keywords: supergene, enriched, intrusion, sulphidation, Binebase, Bowme

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Mineralisasi emas Prospek Binebase East Asia Minerals di Pulau Sangihe memperlihatkan kontrol terhadap mineralisasi yang khas pada sistem sulfidasi rendah yang terkait dengan Intrusi Tepian Pasifik yang lain. Kualitas emas yang lebih baik terlokalisasi pada struktur yang meluas berarah timur barat di interseksi koridor struktur berarah barat laut. Mineralisasi di Binebase sebelumnya diinterpretasikan berasal dari sulfidasi tinggi sistem ubahan. Asumsi ini didasarkan pada observasi permukaan terhadap alunit dan diperkirakan sebagai silika gerohong sisa. Observasi baru-baru ini mengindikasikan bahwa alunit tersebut bersifat supergen dan silika gerohong merupakan sisa pembentukan gerohong ubahan silika+pirit. Kualitas logam mulia menurun menjauhi struktur feeder dan terdapat pengayaan supergen signifikan terhadap emas dalam zona oksida. Pemboran eksplorasi oleh East Asia Minerals Indonesia yang selesai pada tahun 2008 memberikan hasil sumber daya tereka sekitar 835.000 oz kandungan emas dengan kualitas terendah 0,25 g/t Au. Sumber daya ini termasuk oksida dan mineralisasi sulfida hipogen. Pemboran dimulai kembali tahun 2011 untuk mengubah kategori tereka menjadi terunjuk dan program pemboran berlanjut sejak September 2011. Berbagai teknik geofisika digunakan pada skala prospek dan regional untuk membantu eksplorasi. Kajian magnetik permukaan menegaskan ubahan hidrotermal dan destruksi magnetit yang bertepatan dengan

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mineralisasi pada Binebase dan Bawone; juga survei Induced Polarisation menghasilkan sebuah anomali yang bertepatan dengan sulfida halus terdiseminasi yang berasosiasi dengan ubahan lempung dalam ubahan hidrotermal. Pada bagian selatan pulau ini dilaksanakan survei geofisika udara dalam upaya untuk mengetahui kontrol struktur regional pada mineralisasi dan untuk menentukan area tambahan ubahan hidrotermal.

***Kata kunci**: supergen, diperkaya, intrusi, sulfidasi, Binebase, Bawone*

Introduction

East Asia Minerals' tenement of Sangihe Island is located in the Sulawesi Sea falling under the Province of North Sulawesi (Figure 1). The East Asia has been actively exploring the southern part of the island since 2007. Exploration to date has defined several epithermal prospects of intermediate to low sulphidation system. Binebase and Bawone are areas where most of the drilling has focused, for the best defined mineralized systems.

Exploration History

The first record of mineral exploration on the island dates back to 1986 when PT Meares Soputan Mining, in partnership with Muswellbrook, undertook systematic stream sediment sampling, reconnaissance rock chip sampling, ground magnetics, and induced polarization surveys in the southern part of the island. These field programme led to the discovery of several copper-gold prospects and prompted unofficial artesinal mining of alluvial material and shallow quartz veins in the Taware area.

Drilling was completed from 1987-1988 at Taware and the surrounding area with no apparent success except for one hole which was reported to have intersected marginal grade, porphyry Cu-Au mineralization (Bautista *et al*., 1998). Results of extensive soil and outcrop sampling and limited geophysical surveys were used to develop drill targets. A 5,000 metre diamond drilling programme completed between 1989 and 1993 was mainly testing targets at Binebase and Bawone and to a lesser extent at Salurang. This work led to the discovery of gold mineralization at Binebase. Ashton Mining Ltd. of Australia acquired Muswellbrook's interest in the property in 1990. In 1993, Aurora Gold Ltd. was formed from the gold assets of Ashton Mining.

Following the relinquishment of the CoW area by Aurora and its Indonesian partner in 1994, Bre-X minerals of Canada in partnership with PT Sungai Sejati undertook exploration including diamond drilling at the Taware prospect under a new CoW. This CoW was suspended by the Indonesian Ministry of Mines and Energy following the collapse of Bre-X in 1997.

The only other record of exploration activity in the area is during 2006 when PT Kristalin Eka Lestari obtained a mining authorization license over the Binebase-Bawone-Salurang area. Limited trenching was undertaken by this company at the Bawone prospect.

On April 12th, 2007, East Asia Minerals announced that it signed a joint venture with PT Sangihe Mineral and PT Amsya Lyna to explore the Sangihe Property covering the southern half of Sangihe Island (42,000 ha). East Asia Minerals received the necessary approvals in principal from the government and was granted a preliminary exploration permit and finalized negotiations for the grant of its CoW. Exploration activities focused on the Binebase-Bawone areas. In the 2007-2008 period, 62 drillholes were completed at Binebase and 17 at Bawone. IP and magnetic surveys were completed over the Binebase-Bawone areas. A second phase drilling programme was initialized in 2011 to further define the resource at Binebase-Bawone, at September 2011, 11,258 m of drilling had been completed in both phase 1 and phase 2 drilling campaigns.

Regional Tectonic Frame Work and Metallogeny

The Sangihe volcanic island arc extends northwards over 400 km from the northeastern arm of Sulawesi to Mindanao in the southern Philippines (Figure 2). The arc geology is characterized by Miocene to active calc–alkaline stratovolcanoes, formed during westerly directed subduction of the

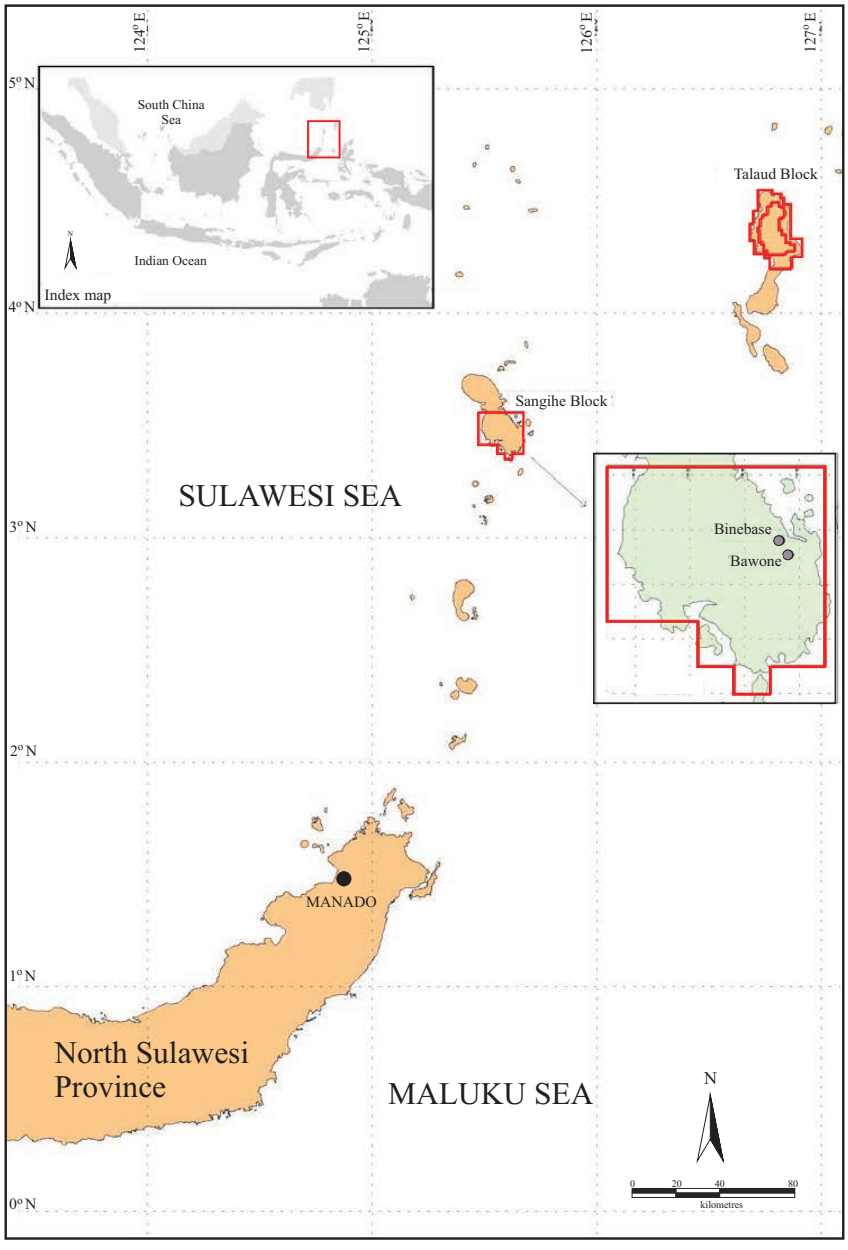


Figure 1. Location map of Binebase and Bawone in Sangihe Island.

Maluku Sea plate beneath the Sangihe arc and the northern arm of Sulawesi (Hamilton, 1979 and 1988). Subduction is inferred to have ceased along the east Sangihe trench, and been replaced by westward obduction of the Maluku Sea mélange towards the island arc. Easterly directed subduction of the Sulawesi Sea plate beneath the west Sangihe trench was initiated subsequent to this shift in subduction - obduction polarity.

The subduction formed the Tertiary-Quaternary magmatic arc which extends from the north arm of Sulawesi, Sangihe Island to Daguma Range in south central Mindanao. This arc constitutes a major metallogenic belt including significant metal deposits such as Gunung Pani (epithermal low sulfidation ~ 1 Moz Au), Tombulilato (porphyry Cu-Au 4.4 Moz Au), Mesel (sediment- hosted 2 M oz Au), Toka Tindung (epithermal low sulfidation

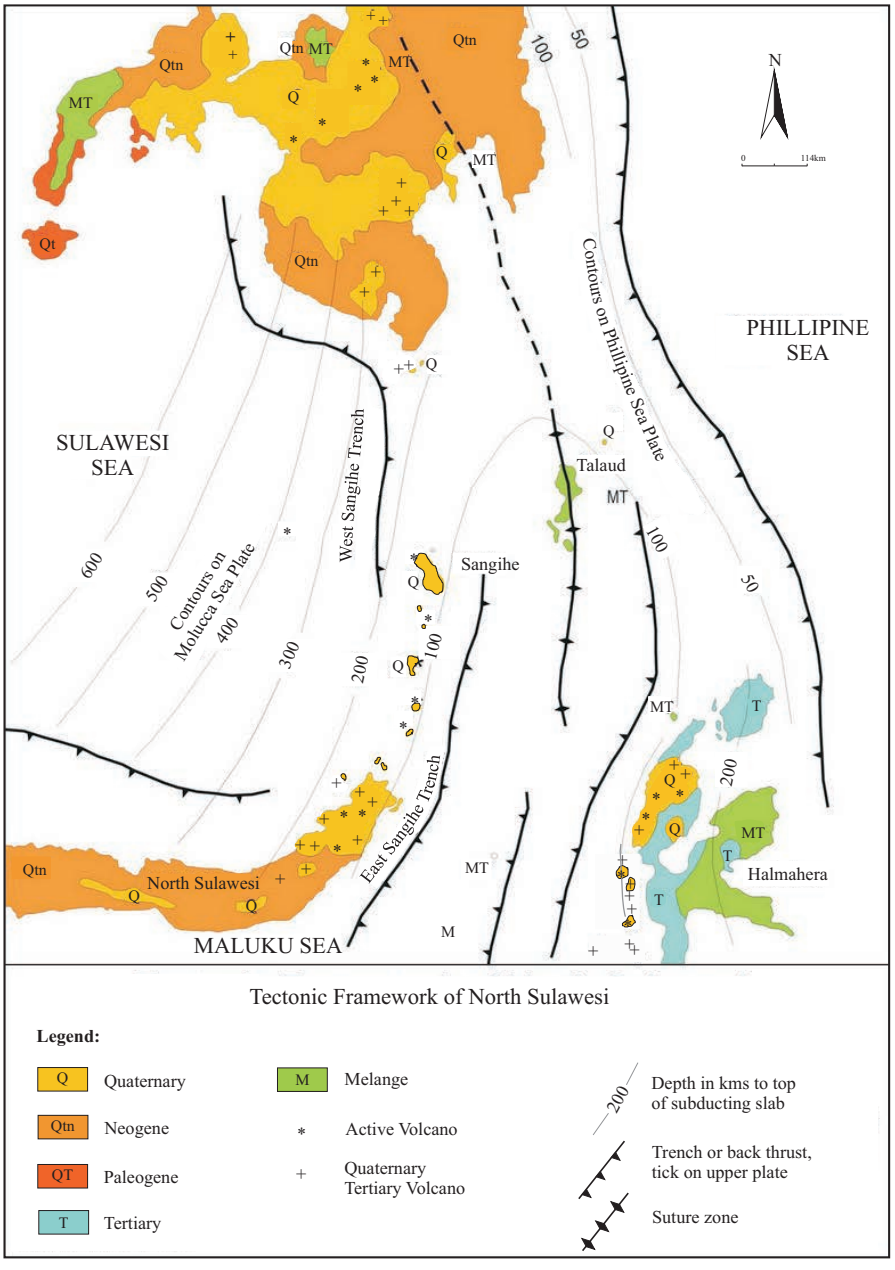


Figure 2. Tectonic framework of North Sulawesi (after Hamilton, 1979, 1988).

1.7 Moz Au and Tampakan-Mindanao (porphyry Cu-Au, 12.8 Mt Cu and 15.2 Moz Au) (Arodji and Johnnedy, 2009).

Sangihe Island is composed of volcanic rocks erupted from at least four volcanic centres (Figure 3), the active Awu Volcano (1320 m), which is in the north, Tahuna caldera immediately south of it, the dormant Tamako Volcano in the centre of the Island, and the deeply eroded Taware volcanic centre in the south. The occurrences of Bawone – Binebase deposits immediately to the west of Tamako may indicate a fifth volcanic centre, the remnants of this fifth volcanics can be observed in contrasting signatures of the magnetics. The geology of the area was gained from Garwin (1990), Bautista *et al.* (1998), and Arodji and Johnnedy (2009).

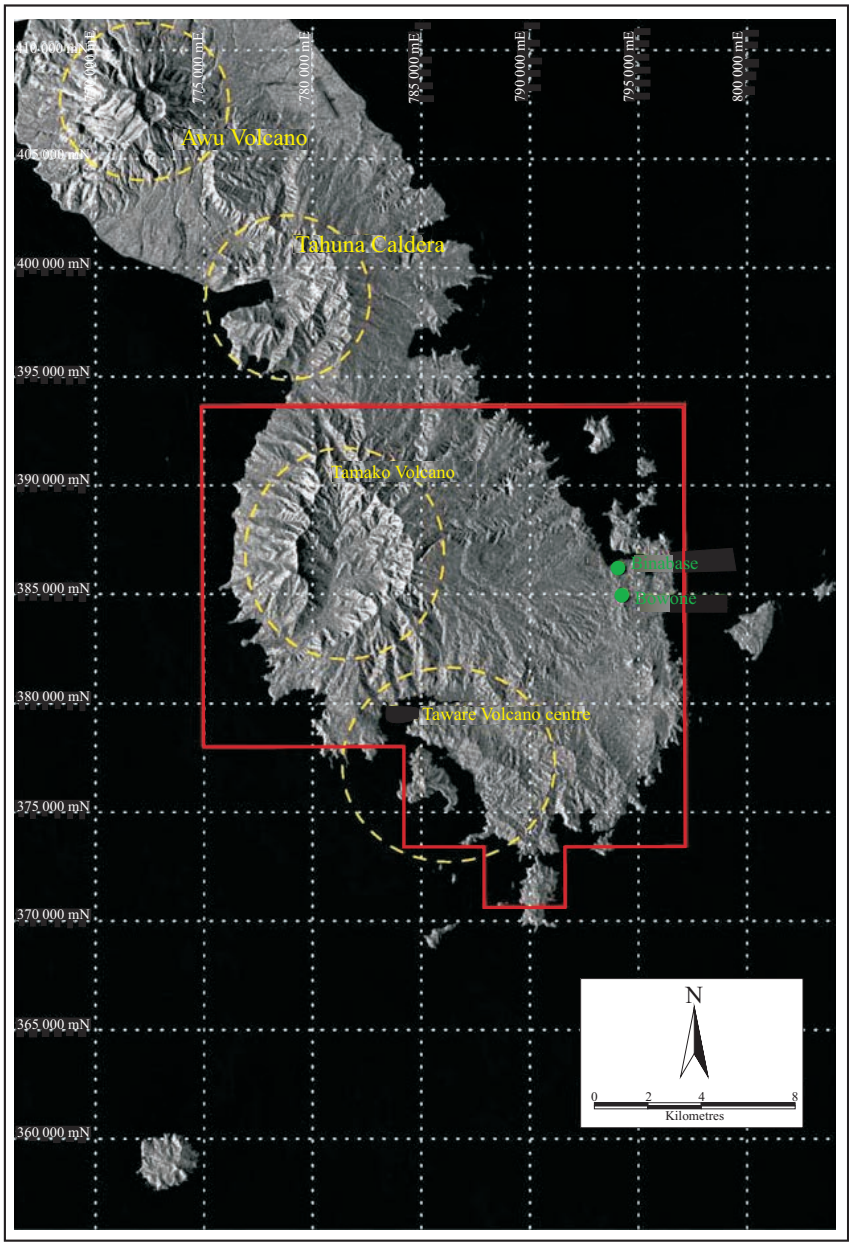


Figure 3. Eruptive volcanic centres of Sangihe Island.

Geological Setting of Sangihe

Five main volcanic rock groups and one sedimentary rock group have been identified in the area (Garwin, 1990 - Figures 4 and 5). The oldest groups are the Taware and Binebase Groups, which are overlain unconformably by the Malisang and Batunderang Groups. The youngest lithological units are the eruptive sequence from the Tamako Volcano (Tamako Group), epiclastic and marine sedimentary rock of the penecontemporaneous Pintareng Formation. Volcaniclastic rocks and lava flows of andesite composition dominate both the four earlier groups, and are accompanied by minor sills, dykes and porphyritic plugs of intermediate composition. The Binebase Group also contains thin dacite flows, which are found only in the vicinity of the Bawone - Binebase prospects. In contrast

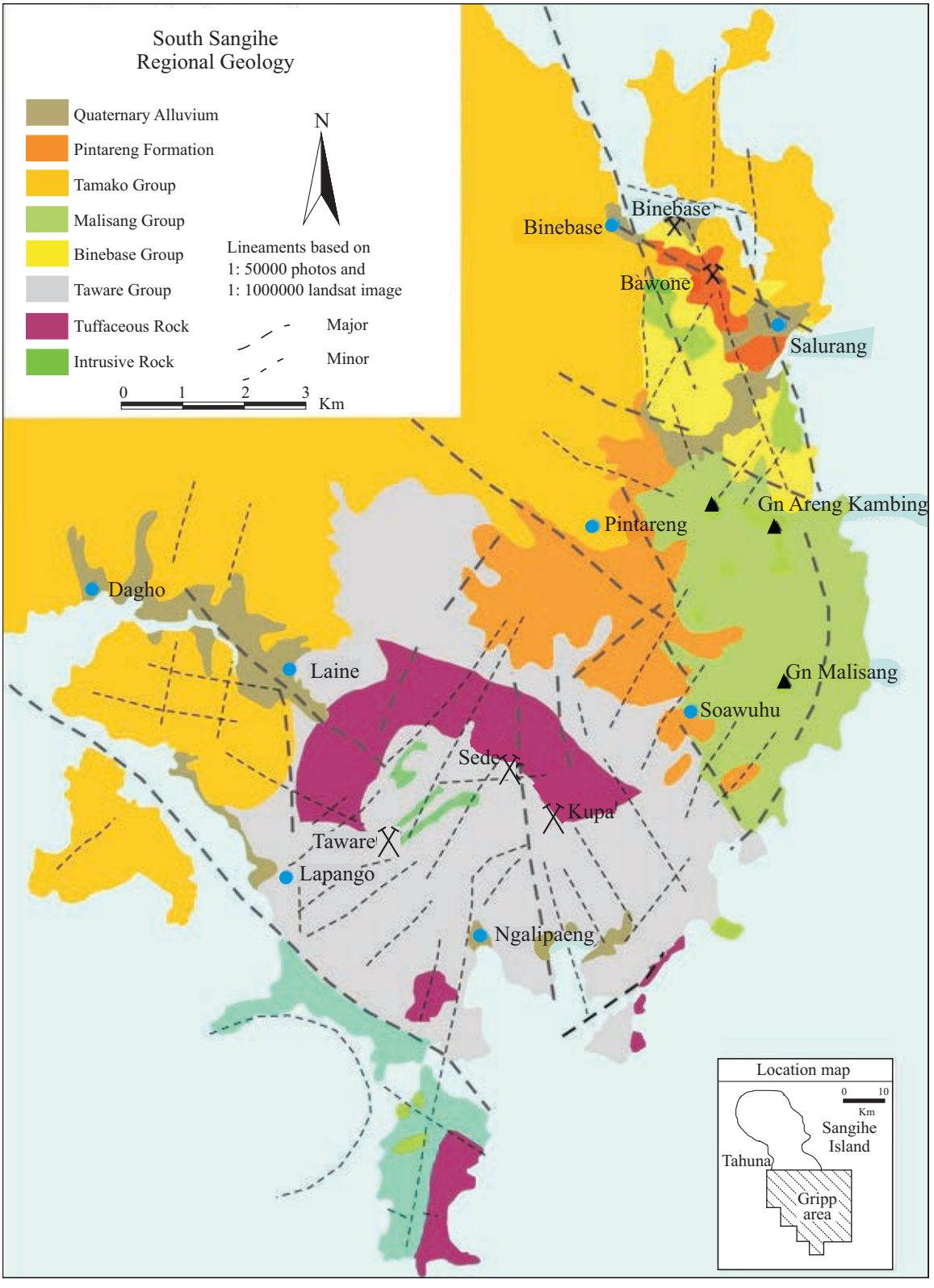


Figure 4. Prospect geology of South Sangihe (after Garwin, 1990).

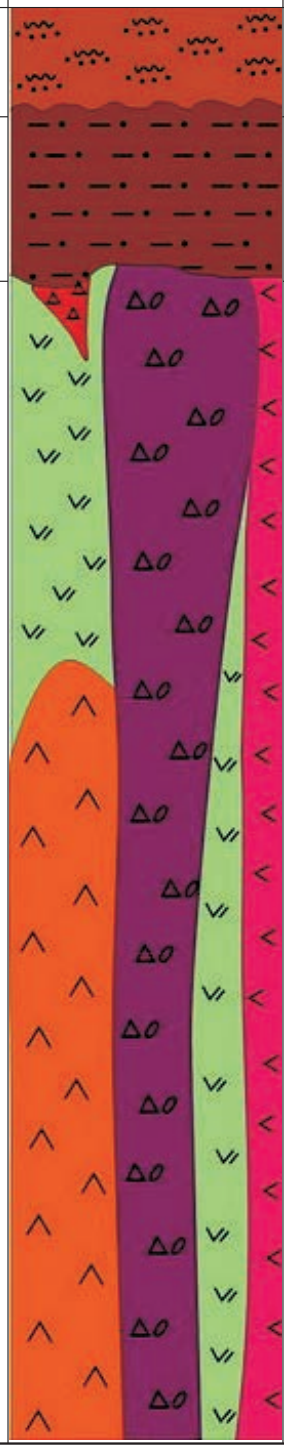
Formation	Lithology types	Schematic section	Comments
Recent soil and Alluvium	Soil and alluvial gravels		Ake Tukade creek and other small drainages
Pintareng Formation (>30m)	Reworked rock volcaniclastics, dominant.		Found in drillholes BOD-01 & BOD-03 though to thicken to the north &northwest
Altn and min	Alteration and mineralization		The andesite/diorite units are fault bounded and confine the tuffaceous unit and alteration and mineralization.
Polimictic breccia intrusive	Polimictic breccia intrusive, polimictic clast, consists of andesitic tuff and intrusive rocks, granule-pebble clast size dominant set in sandy matrix of similar composition, subrounded-rounded shape that shows miling process. intersected in BOD-02, 07, 08, 09, and BOD-10		
Dacite flow	Dacite flows associated with dome and related diatrema activity mapped in Bawone central west zone; dacitic flows intersected in bottom of drillhole BOD-03 and top of BOD-04		The dacite flows are unreceptive to alteration and mineralization. The alteration front ends abruptly at the contact with tuffaceous units. They also limit mineralization towards the south within Bawone central at section BOD-01 & BOD-03
Andesite porphyry	Bio-hbl andesite porphyry & intrusive dykes and high-level apophyses to deeper stocks. This unit or units are mapped on surface to the southwest of Bawone central. It forms the northern boundary to the tuffaceous units and mineralization intersected in BOD-01, 02, 03, 07, 08, 09, 10. In BOD-06 the mineralization forms in contact of fine-grained andesite porphyry and crystall tuff.		
Andesitic tuff	Andesitic crystal, lithic, and ash tuff. with intercalated andesite flows and breccias		The tuffaceous units of the Binebase Formation is thought to be distal to source and is the main host to alteration and gold mineralization.
Binabase (>20m)			

Figure 5. Binebase-Bowone stratigraphy (after Arodji and Johnnedy, 2009).

to the older groups, the Tamako Formation consists mainly of basaltic andesite flows and volcaniclastic rocks. However, hornblende-phyric lavas and intrusive rocks, and volcanic breccias are exposed locally. The Pintareng Formation comprises polymictic breccias (locally wood-bearing), sandstone, mudstone, and coralline limestone. Lahars of the Tamako Groups and breccias of the Pintareng Formation contain fragments of hydrothermally altered volcanic rock; in the case of the former, these fragments include silica and pyrite.

There has been no dating of the rocks on Sangihe Islands, although the reported occurrence of Stegodon tooth fossils in the Pintareng Formation has been used to infer an age of ~ 2 Ma for this unit, (Garwin, 1990). However Williamson-Jones (2008) stated: *"Given the excellent state of preservation of the Tamako volcanic edifice and the high rate of erosion on Sangihe Island, we consider it likely that the Pintareng Formation and Tamako group rocks, with which it is coeval, formed very much more recently, and may be as little as a few thousand or tens of thousands of years in age"* It is noteworthy that Stegodons only became extinct during the Late Pleistocene and some survived in Flores Island until 12,000 years ago (van den Bergh *et al*., 2001.)

Prospect Structure

The majority of structures as delineated by the magnetic survey are:

- NNE-NE trending structures transect south Sangihe Island and control the regional alteration and dyke intrusion in SW Sangihe Island.
- NNW trending corridor of structures is defined by magnetic lineaments and localizes mineralization in the Bawone-Binebase area at the intersections with the throughgoing NE structures. The subdued topography is indicative of a possible graben nature for this corridor. The WNW orientation of mineralization at many locations on Sangihe may be due to dilation produced during synmineral sinistral rotation of these structures.
- NW-WNW trending structures transect Sangihe Island as less major, possibly late structures formed in an orthogonal relationship to the more major NE structures. These structures display pre- and postmineral faulting at Bawone and control the orientation of the inferred fluid flow and hence mineralization at Binebase .

Geophysical Exploration

Ground magnetics was successfully used to identify the extent of mineralization as defined by the magnetite destructive hydrothermal fluids. The core of the magnetite destructive zone at Binebase is coincident with zones of resistivity which can be attributed to zones of fluid upflow and silicification. The magnetic destructive anomaly is also coincident with an IP anomaly, attributed to disseminated pyrite with the hydrothermal alteration.

An induced polarization survey (Figure 6) successfully defined the hydrothermal alteration at Binebase where brecciation and clay alteration with associated disseminated pyrite in the altered volcanics. At Bawone, narrow breccias hosted mineralization was identified by the survey.

Outcrop in southern Sangihe is generally poor. Silicification forms subtle topographic highs while the dominant topographic highs are typically late, barren andesite plugs. An airborne magnetic/radiometric survey was completed in mid 2011 with a view to better understand the structural and temporal emplacement of mineralization and to look under cover for any concealed anomalies. Magnetic highs and lows were interpreted from the Reduced to Pole magnetic dataset (Figure 7), while the structure was interpreted from Reduced to Pole 2nd Vertical derivative (Figure 8). Magnetics can be used to subdivide the volcanics into two sets, the older volcanics to the south east and the younger volcanics to the north west (erupted from the Tamako Volcano). Emplacement of the younger volcanic is interpreted as being contemporaneous with the formation of mineralization as seen by weak hydrothermal alteration in the young Pinterang Sediments.

Structural lineaments can also be subdivided into two subsets older north east to east west trending structures which have been truncated by younger north west trending structures. Most known mineralization is located at the dilatational junction of these two structural sets. The late north west trending lineaments are coincident with corridors of magnetic highs which correspond to late andesite plugs (Figure 9).

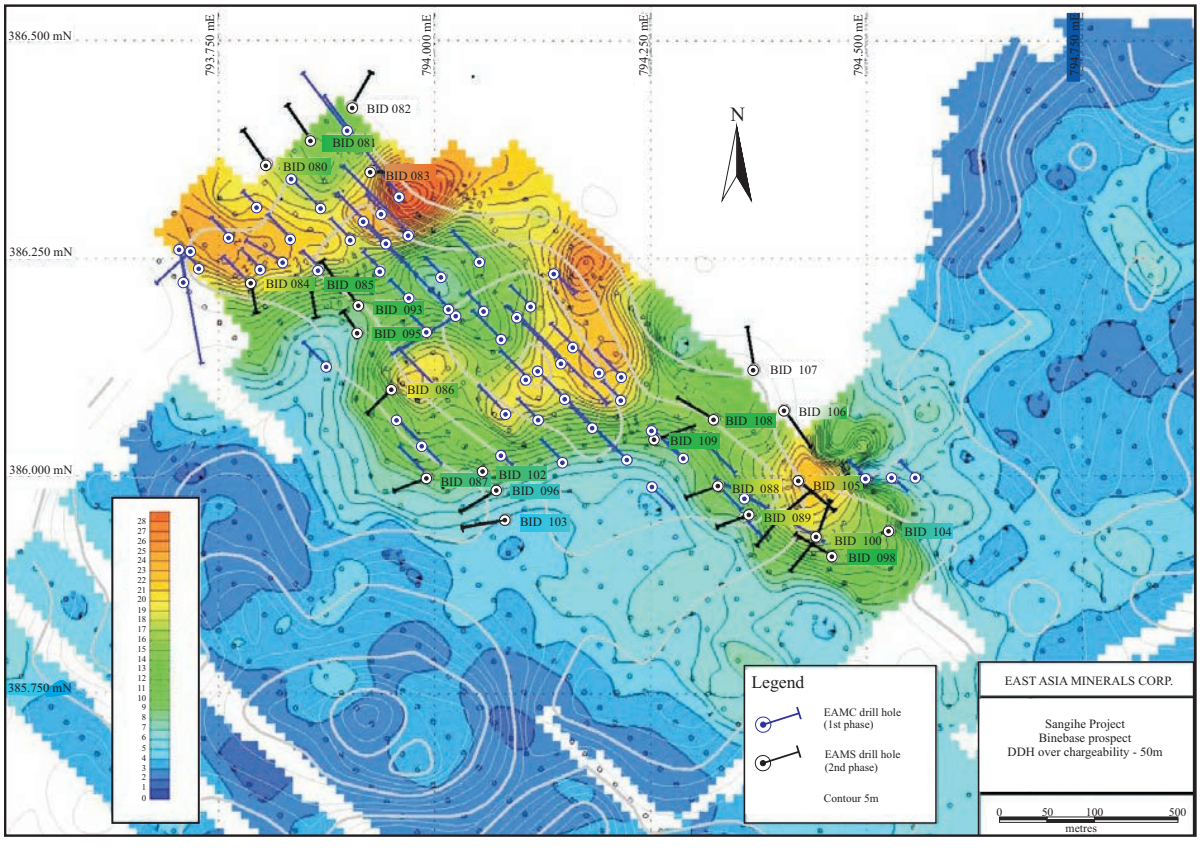


Figure 6. Binebase chargeability, 50 m contour slice.

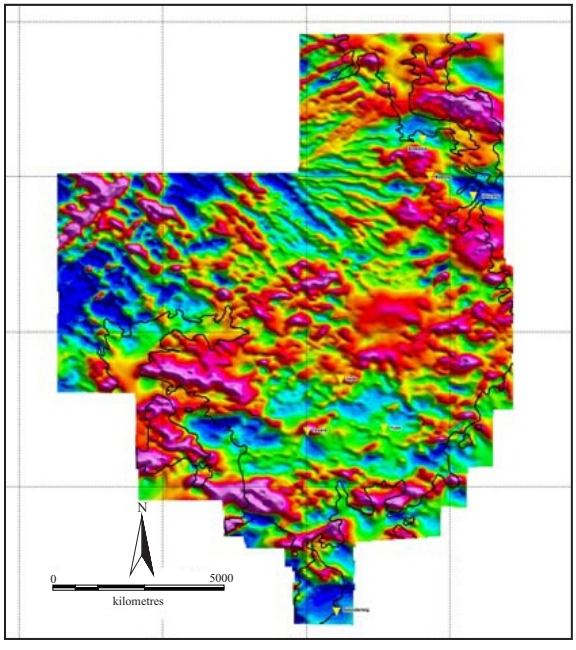


Figure 7. Airborne geophysics. Reduced to Pole.

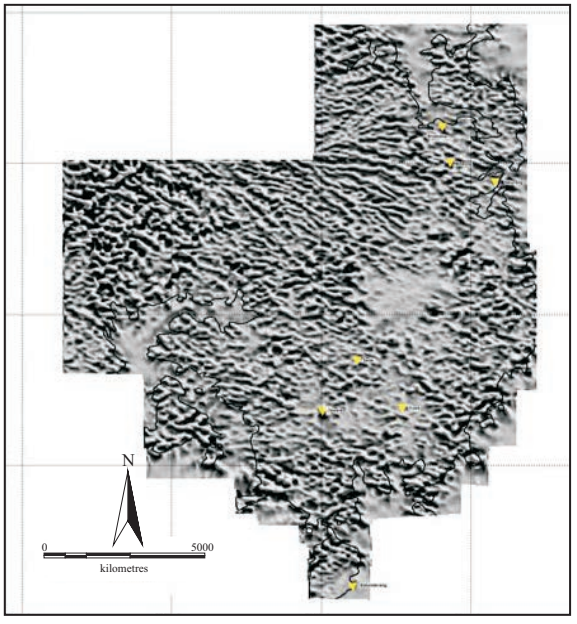


Figure 8. Airborne = geophysics. Reduced to pole 2nd Vertical Derivative.

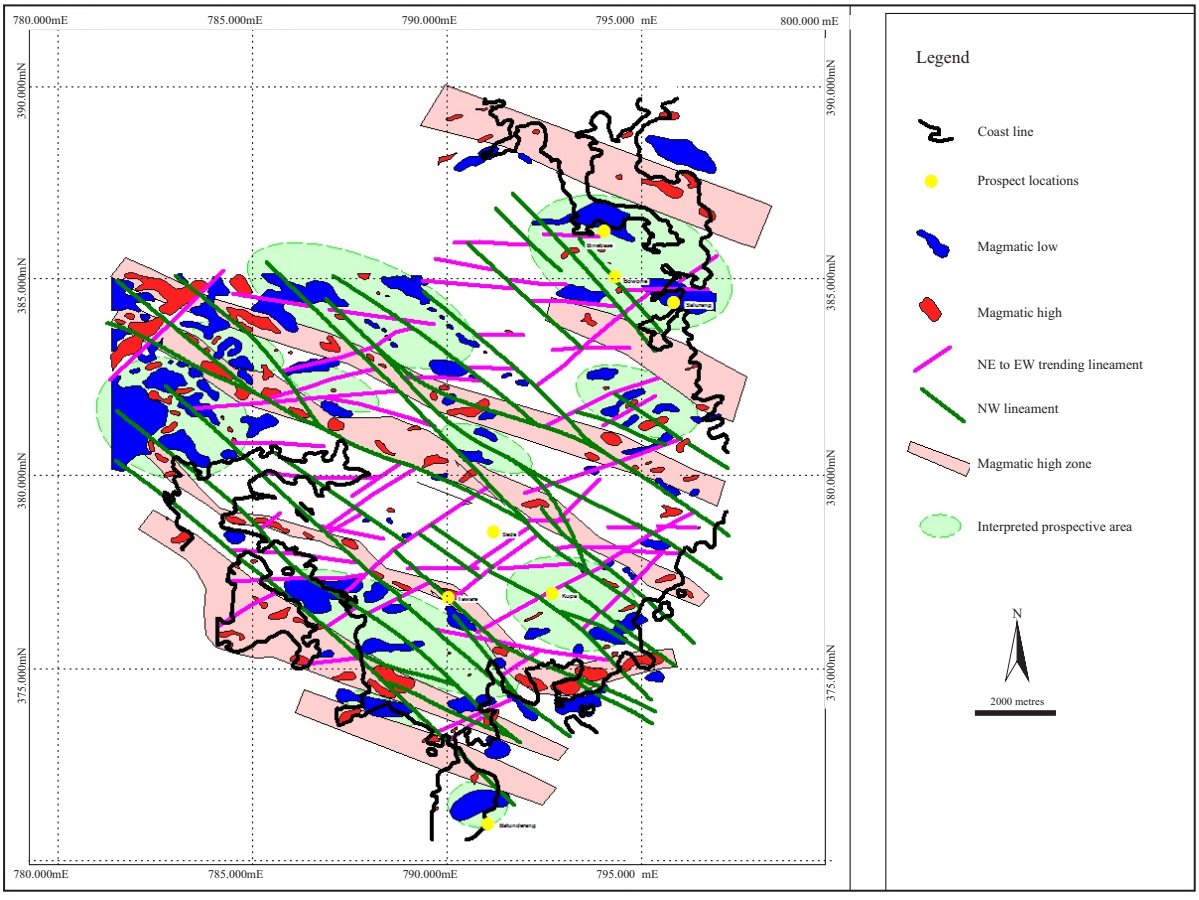


Figure 9. Structural and magnetic interpretation from combined reduced to pole and reduced to pole 2nd vertical magnetic data.

Mineralization

Mineralization at Sangihe is typical of epithermal, Pacific Rim systems as described by Corbet and Leach (1995). All mineralization observed at Binebase, and Bawone is breccia hosted, multiphasal, silica + pyrite + gold associated (Figure 10). Silica + pyrite occurs as pervasive flooding of permeable volcanic, massive fracture fill of competent volcanics/porphyry and as matrix to the brecciated above.

Host rock permeability plays an important role in the nature of mineralization and ultimately in precious metal endowment. Permeable volcanic breccias such as in Figure 11 is a poor receptor to mineralizing fluid with fluid dispersing into the wallrock to produced a weakly anomalous, clay rich host rock which does not brittle fracture to produce open space for subsequent mineralizing fluids (Figure 12).

Mineralisation hosted in andesitic lava (Figure 13) and in hornblende andesite porphyry such as Bawone produces narrow, higher grade mineralization than the more permeable host rocks as mineralizing fluids are better constrained.

Supergene enrichment plays an important role in producing economic precious metal grades. Economic mineralization at Binebase is largely restricted to the oxide zone with gold grades quickly diminishing away from feeder zones. Silver grades become significant toward the base of oxidation. Economic precious metal at Bawone by contrast are hosted in hypogene sulphide mineralization.

Mineralization at Binebase was originally interpreted as a high sulphidation type due to the presence of residual vuggy silica and associated alunite. The 'vuggy'silica is in fact the oxidized, boxworked (Figure 14) remnants of silica + pyrite breccia (Figure 15) wheres alunite is supergene in nature.

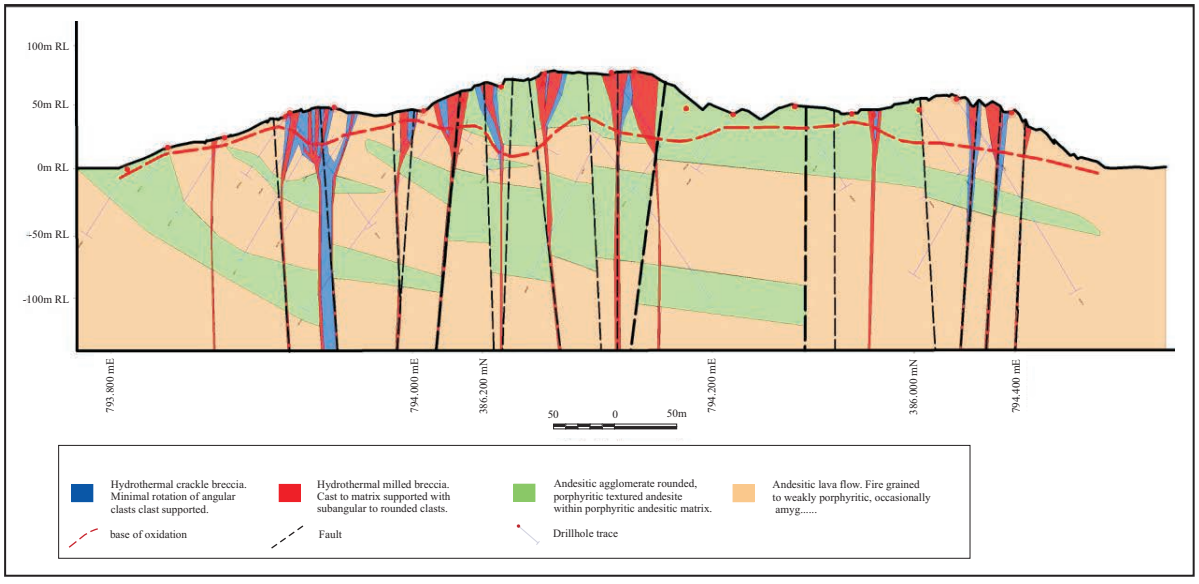


Figure 10. Binebase interpretive long section.

Figure 11. Volcanic breccia/hyaloclasite from Salurang. The relatively high permeability of this unit results in pervasive clay alteration and ultimately poor permeability and poor fracturing to host mineralization.

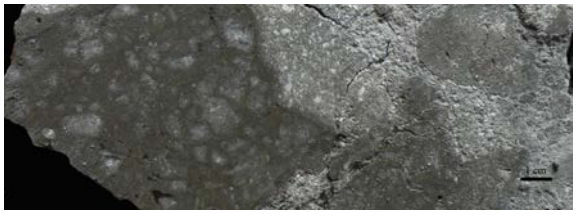


Figure 12. Drillhole BID081_75.50-75.70m : Pyrite + silica flooding of andesitic volcanic breccia. Silica + pyrite preferentially in breccia matrix. Strong clay alteration of clasts.

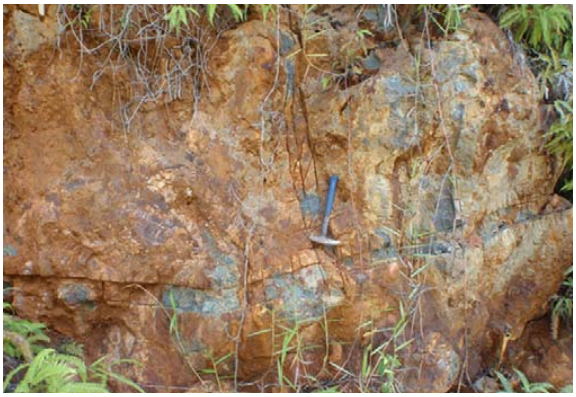


Figure 13. Silica + pyrite alteration crosscutting brecciated andesitic lava. The competent nature of this unit results in brittle fracturing and open space for the deposition of mineralization. (Location, NW Binebase).

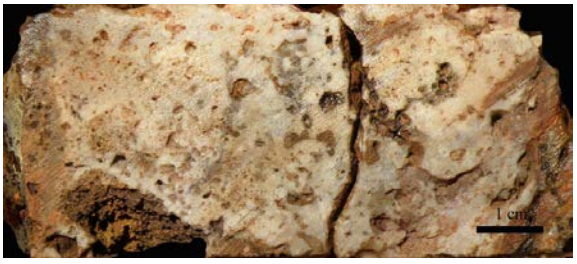


Figure 14. Drillhole BID011_14.80-14.85m: Chalcedonic to saccharoidal epithermal quartz as infill to breccia matrix. Not clasts of gossan after pyrite.

Figure 15. Drillhole BID081_21.90-21.95m: Multiphasal breccia. Pyrite clasts after andesitic volcanics in a matrix of pyrite + silica.

Two phases of barite fracture fill are evident at Binebase and are observed crosscutting the silica + pyrite events. The earlier barite phase is anhedral in nature and often has associated sphalerite + galena + rare chalcopyrite. Sphalerite at Binebase is generally iron poor and white to yellow in colour. The second phase of barite is massive and generally lacks base metal mineralization. The origin of the barite mineralization may be from the interaction of hydrothermal fluids and seawater. This seawater/hydrothermal fluid interaction may also have had a buffering effect on possibly weakly acid fluids. Copper, lead, and zinc grades are insignificant, being associated only with the late sporadic barite veining.

Discussion and Conclusion

Host rock competency of the volcanic host rocks associated with volcanism of the Taware eroded volcanic centre provides a major contributing factor to the localization of economic mineralization at the Binebase-Bawone systems. Mineralization on the island is restricted to this early volcanic event and appears to have been waning at the time of the eruption of the Tamako Volcanic Centre. The Pinterang Formation which formed from the erosion of the Tamako Volcanics and overlays the earlier Taware Volcanic Sequence, only displays weak silica-pyrite alteration.

An early silica + pyrite event was localized along EW dilatant structures. Where these fluids found competent lavas, fluids were constrained and resulted in the silicification of the host rocks. Where the mineralizing fluids hosted within volcanic agglomerates/breccias, poor silicification resulted. Subsequent reactivation of the structures resulted in brittle deformation of the silicified host rock and resulted in open space as a receptor for second phase silica + pyrite + rare chalcopyrite. Gold mineralization is associated with the second phase silica + sulphide phase. Gold associated with pyrite is readily released by weathering and at Binebase there is an appreciable increase in gold in the supergene environment. Enrichment of silver at the base of oxidation is indicative of supergene processes.

Several phases of barite fracture fill were observed crosscutting the silica + sulphide alteration. Early phase barite is typically massive to weekly crystalline with associated galena + sphalerite and rare chalcopyrite. Sphalerite is typically yellow to green in colouration and indicates the low iron fugacity of the base metal bearing fluids. Late phase barite is typically coarse and devoid of base metal mineralization. The amount of barite fracture fill decreases with depth and may indicate that the source of barium may be from seawater.

The hydrothermal fluids associated with the mineralization resulted in clay alteration and associated magnetite destruction. The use of magnetics assisted in understanding prospect and regional scale structure and the location of hydrothermally altered volcanics under cover. the induced polarisation survey was successful in delineating the extent of silicification with associated gold mineralization at Binebase.

Regional mapping and the Regional Airborne Geophysical Survey indicate that much of the altered and potentially mineralized Taware Volcanics are obscured by the Tamako Volcanics, particularly to the North West and that area still remains highly prospective.

Exploration drilling completed in 2008 by East Asia Minerals Indonesia resulted in an inferred resource of approximately 835,000 oz of contained gold at a cutoff grade of 0.25 g/t au. This resource included both oxide and hypogene sulphide mineralization. Drilling was reinitiated in 2011 to change the inferred categorization to indicated, that drilling programme continued at the time of this publication.

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