STRUCTURAL GEOLOGICAL CONTROL ON THE MINERALIZATION ON TABUAN ISLAND,SEMANGKO BAY, SOUTH SUMATERA, INDONESIA

By :

Hananto Kurnio[1], Ulrich Schwarz-Schampera[2], Michael Wiedicke[2]

ABSTRACT

Mineralization have been discovered on Tabuan Island, Semangko Bay, South Sumatera, Indonesia. Tabuan Island belongs to the Neogene Sunda-Banda magmatic arc system. Tabuan Island is a tectonic horst structure which belongs to the subduction-related, magmatically active Barisan zone along the active continental margin of western Sumatera. Basaltic-andesitic volcanics of the late Oligocene to earliest Miocene Hulusimpang Formation are distributed in a broad zone along and subparallel to the regional Semangko Fault and are hosts for several epithermal-style auriferous deposits.

The occurrence of hydrothermal mineralization was first suggested from seismic identification of small intrusive bodies which form elongated northwest-southeast ridges passing through the island. Surface sampling campaigns on the island revealed significant hydrothermal alteration and mineralization with pervasive occurrences of sulphide minerals. Detailed mineralogical and geochemical studies at the Federal Institute for Geoscience and Natural Resources show pronounced disseminations and vein-type mineralization. Mineralization shows moderate enrichments in Au, Ag, Zn, Pb, Cu, As, Sb, Ba, and Mn.

The association of subaerial island arc volcanism and subvolcanic intrusive bodies, the regional extensional and strike-slip structural regime, and the occurrence of epithermal-style alteration and mineralization in the same volcanic sequence along the coastal zone of Semangko Bay and on Tabuan Island reveal the great potential of this region for epithermal type Au-Ag and base metal deposits.

On Tabuan Island, delineation of structural blocks and fault systems suggests that normal faults and margins of grabens may have acted as fluid channelling structures.

Key words: structural geology, mineralization, Tabuan Island, Semangko Bay

INTRODUCTION

The possible occurrence of epithermal-style mineralization was first suggested from prospective seismic data through recognition of small subvolcanic intrusive bodies. These elongated northwestsoutheast oriented ridges pass through Tabuan Island and were interpreted as a potential zone of economic mineralization. For the purpose of exploration, several surface sampling campaigns were conducted on the island; the first took place in 1996 close to Sawangbalak in the eastern part

1. Marine Geological Institute, Ministry of Energy and Mineral Resources, Bandung, Indonesia
2. BGR Federal Institute for Geoscience and Natural Resources, Hannover, Germany

of the island and the second was conducted in 2003 along the western coast surrounding Karangbuah village. Preliminary field survey showed hydrothermal alteration and mineralization with pervasive occurrences of sulphide minerals. The samples were studied in detail at the German Federal Institute for Geoscience and Natural Resources.

The detailed characterization of the elongated northwest-southeast trending magmatic ridge passing through Tabuan Island was carried out based on existing seismic data. The close spatial occurrence of the magmatic ridge and hydrothermal alteration suggests genetic relationships and a syngenetic epithermal-style mineralization on Tabuan Island is therefore proposed, also in analogy to similar deposits in the same volcanic sequence on the coastal shore surrounding Semangko Bay.

REGIONAL GEOLOGY

The area of interest in the Southeast of Sumatera Island belongs to the Sunda-Banda Neogene magmatic arc which extends for 3700 km from northern Sumatera through Java to eastern Indonesia (Carlile & Mitchell, 1994; Fig. 1). Lower Tertiary to Recent subduction of the oceanic Indo-Australian plate under Sumatera has given rise to the extensive magmatic arc of the Barisan Mountains in the western coastal zone. A well-defined latest Oligocene – earliest Miocene magmatic arc extends through much of western Sumatera, forming the “old andesites” of van Bemmelen (1949, in Carlile & Mitchell, 1994) which more or less coincides with the Neogene arc. The Neogene arc is followed by a well-defined andesitic arc of Middle Miocene to Pliocene age that extends through the Barisan Range of Sumatera. Magmatic rocks in the arc are predominantly eruptive andesites which include 12 and 13 Ma granite, granodiorite, and diorite intrusions (Carlile & Mitchell, 1994). The Neogene arc magmatism is related to oblique and low angle subduction in the present Java trench with collision rates of 7 cm/year. The magmatism is essentially andesitic and mainly calc-alkaline in composition, and erupted subaerially or in shallow marine environments. The sequences commonly include dacites and rhyolites which are confined to arcs underlain by continental crust (Carlile & Mitchell, 1994). Intrusive equivalents of the andesitic eruptives are diorite, quartz diorite, tonalite, granodiorite and porphyritic or sub-volcanic equivalents. Syn- to post-magmatic uplift, characteristic of andesitic arcs, is a result of magmatic inflation accompanying emplacement of batholiths or sills in the basement and is important because of its effect on the age and possible preservation of subaerial orebodies.

RESEARCH METHOD

The Marine Geological Institute of Indonesia (MGI) conducted numerous surveys in Semangko Bay between 1989 and 1996. In 1989, the study of the regional geology and the geophysical properties in coastal waters included seismic data acquisition. In 1996, the survey focused on the identification of shallow water (<50 m water depth) gold placer deposits in the northwestern to eastern coastal zone. Seismic single channel high resolution data from around Tabuan Island were collected during a marine geology campaign in 1995 using MGI research vessel Geomarin I. The interpretation of seismic data led to the identification of magmatic intrusives passing Tabuan Island and possible zones of preferred fluid flow, discharge and mineralization on a northwest-southeast trend across the center of Semangko Bay.

RESULTS

Sampling on Tabuan Island occurred along the western coast surrounding Karangbuah village. The field survey identified several zones of hydrothermal alteration and sulphide

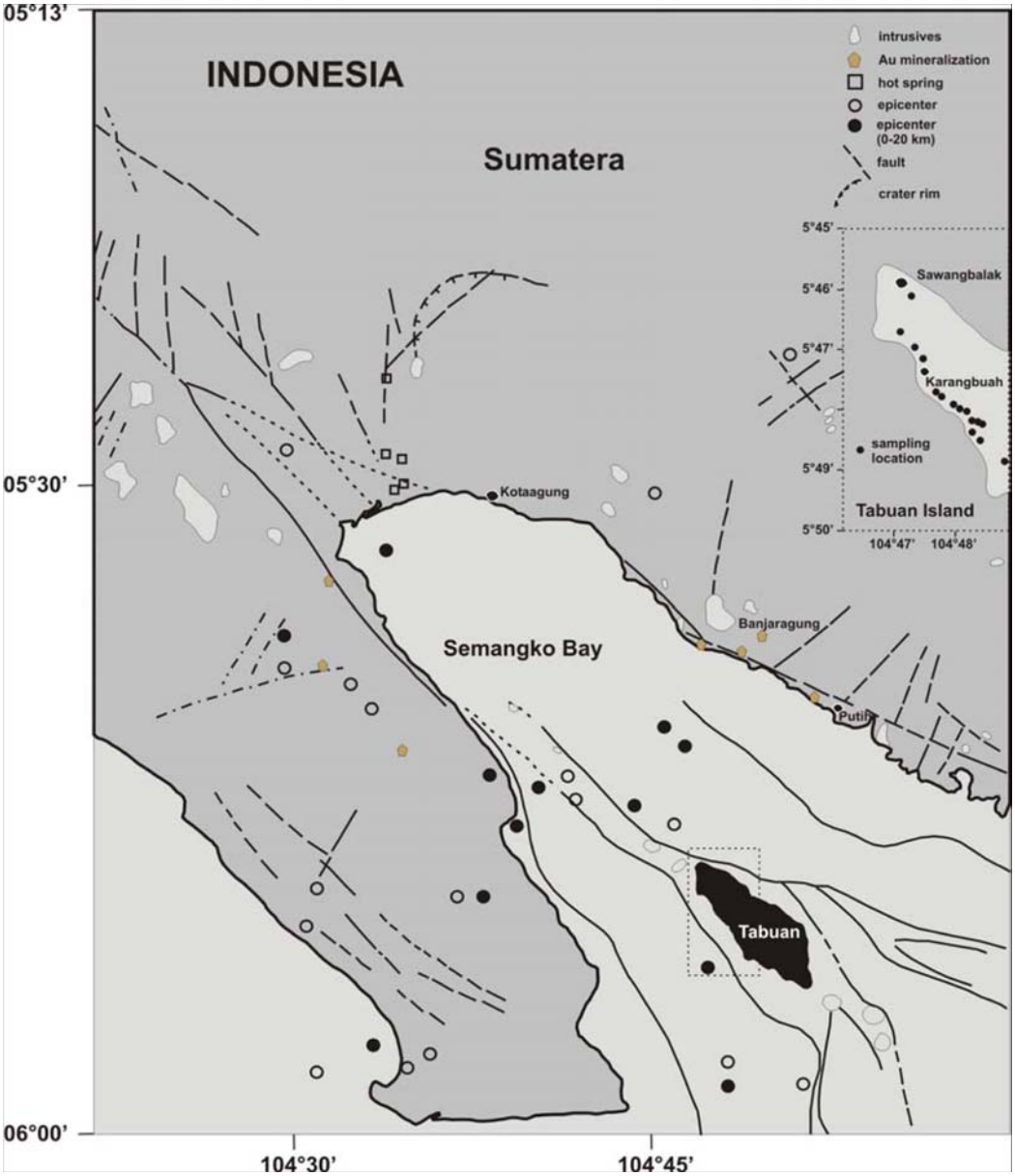

Figure 1: Location and simplified geological map of Tabuan Island in Semangko Bay, southwest of Sunda Strait, South Sumatera, Indonesia. The area around Semangko Bay is characterized by a number of auriferous mineralization and hot spring deposits. The occurrence of major tectonic elements and the location of shallow earthquake epicentres in the vicinity of Tabuan Island largely coincide with the regional Semangko Fault. The inset map shows the sampling locations of altered and mineralized andesites.

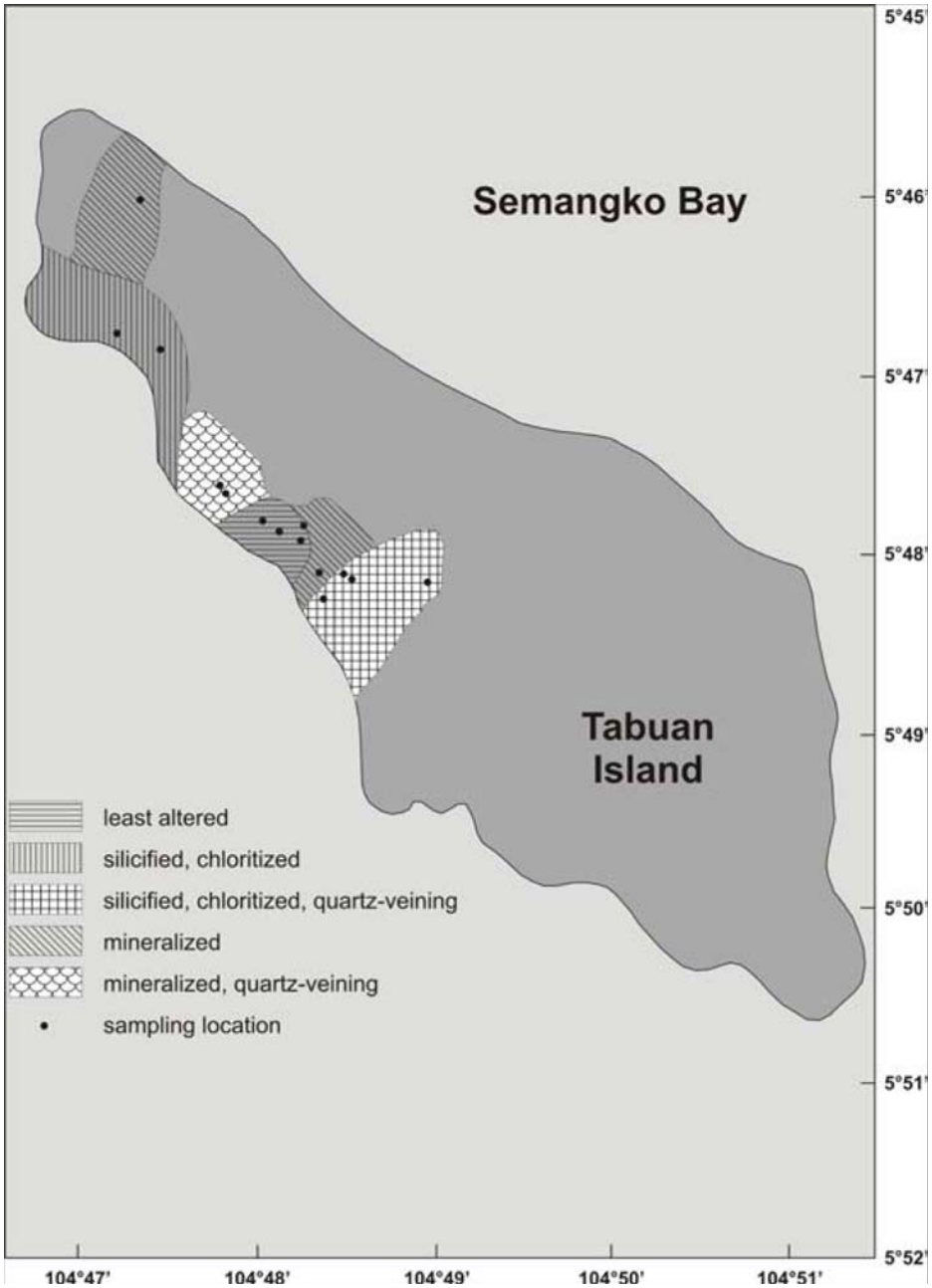

Figure 2: Overview of the sampling locations and approximate outlines of alteration zones and mineralization along the western coast surrounding Karangbuah village on Tabuan Island, Semangko Bay, South Sumatera, Indonesia.

mineralization in this area that are given for overview in Figure 2.

The mineralized and altered rock samples analyzed for this study are shown in Figure 3. Analyses include alteration mineralogy, sulphide microanalysis, and host rock geochemical composition.

Preliminary seismic interpretation of data collected inside Semangko Bay and Sunda Strait revealed that the island represents the uplifted horst of a larger graben structure that separate two sub-basins to the northeast (at 300 m water depth) and southwest (500 m water depth). The island formed on a continuous ridge of northwest-southeast faulted arc basement blocks (Lelgemann et al, 2000) that are interpreted as basement for sedimentation in Sunda Strait as well as in Semangko Bay (Susilohadi, 2004 pers. communication). Evidence of basement elevation of the ridge from seismic observations correlates well with morphologic highs concluded from positive free-air gravity anomalies 80 mGal (Reichert, 1999; in Lelgemann et al, 2004). Actually, Tabuan Island is one out of several horst structures that separate subgrabens younger than Late Miocene or Pliocene. From seismic data, it can be concluded that volcanic activity in the graben occurred during the Pliocene possibly triggering hydrothermal activity on Tabuan Island.

Basaltic-andesitic volcanics of the late Oligocene to earliest Miocene Hulusimpang Formation are distributed in a broad zone along and subparallel to the Semangko Fault and are related to the subductionrelated volcanism at the active continental margin.

Figure 3: Overview of the altered and mineralized rock samples from Tabuan Island, Semangko Bay.

From approximately the late middle Miocene to the Pleistocene, the volcanic rocks of the Barisan zone became more diverse ranging from andesitic-basaltic to dacitic-rhyolitic compositions, essentially related to increasing differentiation and maturity of the volcanic arc. Final volcanic episodes are characterized by unconformable subaerial tuffaceous and pumiceous rhyolites, possibly associated with a major Plio-Pleistocene orogenic event that produced widespread wrench faulting along the Semangko Fault. As a consequence, local tensional pull-apart structures developed which probably acted as volcanic conduits.

Investigation of crustal structure and evolution using bathymetric imagery, seismic reflection and refraction was conducted by Lelgemann et al (2000) from the entrance of Semangko Bay to the south of the Indian Ocean. The oblique convergent geodynamic setting of the Sumateran trench results in transtensional tectonics, indicated by faulted blocks of arc basement and active normal faults on both sides of a large graben. Based on high resolution bathymetry data, two sub-basins were separated by a basement ridge that continued to Tabuan Island to the northwest. This ridge separates a shallower basin to the east and a deeper graben to the west.

Mineralization in Tabuan Island belongs to vein systems of high-level epithermal-type origin comprising low-temperature opalinechalcedonic silica precipitates. The epithermal-style mineralization and alteration is related to the Tertiary volcanic rocks, especially the altered basaltic-andesitic breccia, tuff and lava units of the Hulusimpang Formation (Amin et al, 1994). The silica is massive or colloform banded, with evidence of various degrees or episodes of hydraulic fracturing and brecciation. Mineralization occurs as pervasively disseminated pyrite with minor amounts of base metal sulfides.

Native gold has been reported from quartz veins in silicified and propylitised rocks of the Hulusimpang Formation at Banjaragung, Cukuhbalak district, east coast of Semangko Bay. At Banjaragung, the gold is presently being mined by small-scale local companies and is thought to be intrusive related.

Crow et al. (1994) reported numerous auriferous quartz veins in Oligo-Miocene volcanics exposed along the eastern shore of Semangko Bay (Fig. 1). Samples of these quartz veins contain gold from less than 0.5 ppm up to 43 ppm, are low in base metal sulphides and have distinctive textures including stockworks, vugs, banding and crustification, all of which suggesting an epithermal-style origin. The veins are fractured and tectonically controlled by faults and jointing. On the west peninsula of Semangko Bay (Fig. 1), boulders of fine-grained quartz veins and brecciation were found having elevated gold and silver contents (0.8-2.0 ppm Au and 18-45 ppm Ag, respectively). Other occurrences of fine-grained quartz vein containing abundant pyrite were also found on other locations of the western peninsula. These deposits contain up to 9 ppm Au and 79 ppm Ag.

Rocks samples from Tabuan Island are best described as hydrothermally altered scoriaceous volcaniclastic (sized 0.25 - 8 mm) basaltic-andesites and porphyritic andesitic breccias with pervasive argillic-chlorite alteration and disseminations of pyrite and base metal sulfides (chalcopyrite, phalerite, galena). The original mineralogy of the precursor includes phenocrysts of mainly plagioclase, rare pyroxenes and minor quartz and is preserved in relics only. The matrix is fine-grained but recrystallized and forms a dense intergrowth of lath-like crystals. The pervasive alteration includes silicification, propylitization, and argillization. Some samples show fractures (width 0.2 – 0.5 mm), voids and open spaces that are filled with quartz and pyrite.

Based on the diagram by Winchester and Floyd (1977) using the selected elements ratios Nb/Y and Zr/TiO2, most of the volcanic rocks correlate with andesitic compositions while others spread into more basaltic and even alkaline compositions (Fig. 4). The basaltic to andesitic affinity most likely represents the original composition whereas the alkaline trend is likely related to alteration processes, i.e., the mobilization of Nb and/or Y, and analytical uncertainties. Compared with standard composition of andesite rocks from USGS (USGSAGV- 1), the studied rock samples show elevated values of Au, Ag, As, Cu, Pb, Zn, Sb, F and Mn. This element suite is regarded typical for epithermal-style mineralization and therefore attests to hydrothermal overprint and related mineralization on Tabuan Island.

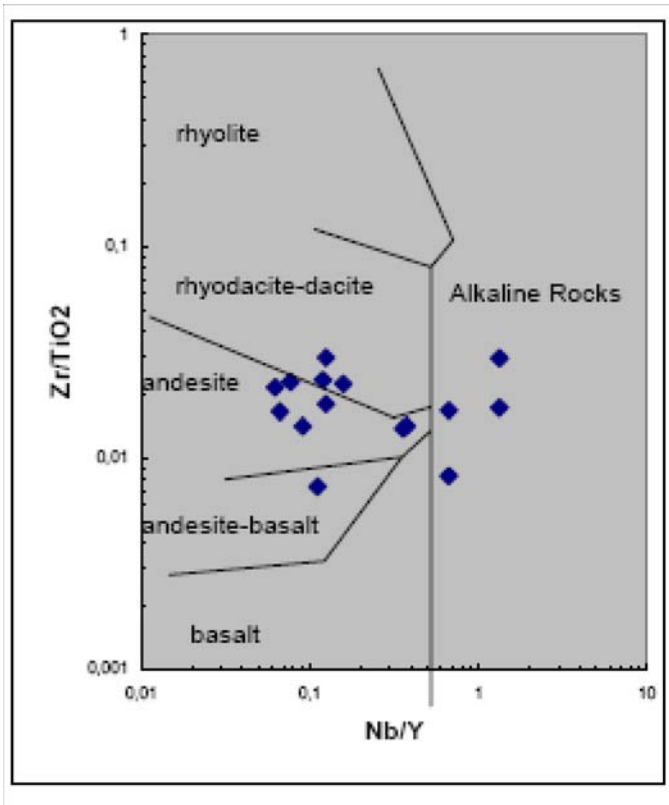

Figure 4. Spread of geochemical data points of hydrothermally altered volcanic rocks from Tabuan Island in the Nb/Y versus Zr/TiO2 diagram after Winchester and Floyd (1977). The elements Nb, Y, Zr, TiO2 are considered relatively immobile during hydrothermal processes and alteration and therefore can best discriminate the original magma composition. The vast majority of data points attest to a primary andesitic composition of the Tabuan volcanic rocks. Affinities to alkaline compositions of a suite of samples are most likely related to alteration and/or weathering processes.

CONCLUSIONS

Tabuan Island, in the west of Sumatera, is part of the Sunda-Banda magmatic arc above active subduction of the Indo-Australian plate underneath the Eurasian plate. Preliminary offshore seismic data around Tabuan Island indicated a possible zone of mineralization passing the island in a northwest-southeast direction.

The occurrence of epithermal-style mineralization in the same volcanic sequence and structural setting around Semangko Bay suggests regional syngenetic mineralization and support the high potential for epithermal Au-Ag deposits on the island.

Preliminary onshore sampling campaigns indicate the existence of volcanic-related hydrothermal systems at shallow depth on

Tabuan Island and suggest the formation of epithermal-type Mineralization.

Mineralization on Tabuan Island share important characteristics of low-sulfidationstyle epithermal-type deposits.

The structural pattern on Tabuan Island reveals the existence of normal faults and margins of grabens. It is suggested that these structures may have represented the channelways for regional fluid flow and the sites of hydrothermal discharge.

The mineralization formed in a subaerial basaltic-andesitic succession in a regional extensional and strike-slip structural regime.

Alteration and mineralization display a significant potential of epithermal-style precious and base metal deposits. Potential is drawn from preferential geological conditions on Tabuan Island as well as the similarities in structural and lithological geology and the occurrence of auriferous mineralized quartz veins along the coastal zone of Semangko Bay.

REFERENCES

Amin, T.C., Sidarto, Santosa, S. and Gunawan, W., 1994. Geology of the Kotaagung Quadrangle, Sumatera. Quadrangle 1010. Scale 1:250.000. Geological Research and Development Centre, published

Anonymous, 2004, USGS Open File Report 98-466. Part 5, internet search

Carlile, J.C. and Mitchell, A.H.G., 1994. Magmatic arcs and associated gold and copper mineralization in Indonesia. Journal of Geochemical Exploration vol. 50, p.91-142.

Crow, M.J., McCourt, W.J. and Suganda, E., 1994. Regional Geochemistry Kotaagung Quadrangle (1010) Southern Sumatera. The simplified Geology and known metalliferous mineral occurrence, Kotaagung Quadrangle Southern Sumatera. Southern Sumatera Geological and Mineral Exploration Project. BGS-DSM.

Kurnio, H., Dwiyanto, B., and Sukmana, N., 1998. The sea, the source of future Indonesian gold reserves. Inonesian Mining Journal vol. 4 No.1-2 February-June 1998, pp.79-82.

Lelgemann, H., Glutscher, M-A, Bialas, J., Flueh, E.R., Weinrebe, W. & Reichert, C., 2000. Transtensional Basins in the Western Sunda Strait. Geophysical Research Letters (downloaded from internet).

Naibaho, B., & Hartoto, D., 1991. Laporan bimbingan pertambangan Lampung pada wilayah KP Eksplorasi PT Swarna Dwipa Internusa, di daerah Way Ruguk, Desa Pekondoh, Kecamatan Cukuh Balak, Kabupaten Lampung Selatan Propinsi Lampung. Proyek Bimbingan dan Konservasi Pertambangan. Direktorat Teknik Pertambangan SubDirektorat Bimbingan, Jakarta, unpub. (In Indonesian)

Panteleyev, A., 1996, Epithermal Au-Ag: Low Sulphidation, in Selected British Columbia Mineral Deposit Profiles, Volume 2 – Metallic Deposits, Lefebure, D.V. and Hoy, T, Editors, British Columbia Ministry of Employment and Investment, Open File 1996-13, pages 41-44.