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Review on the Tectonic Terranes Associated with Metallogenic Zones in Southeast Asia

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ABSTRACT: The paper presents an overview of the relationships between the interior structures of tectonic terranes and the distribution of tectonic-metallogenic zones in Southeast Asia. Episodic tectonic activities occurred in this archipelagic area, generating metallogenic belts in multi-terranes. Since the Late Paleozoic, opening and closure of the Paleotethys and Neotethys led to multiple suture zones between different blocks, mainly between the Indochina terrane, the Nambung terrane, the Sibumasu terrane and the West Myanmar terrane. During the Mesozoic to Cenozoic, the formation of accreted terranes and their related islands was caused by subduction and collision processes between the Pacific and Australian plates toward the Eurasian Continent, forming Sundaland and its affiliated islands, the Philippines and its subsidiary islands, the Papua New Guinea terrane and its related islands and the Sunda epicontinental arc system. Within the margin of terranes resulted in the structural transfer zones, their secondary tectonic units can be divided into island arc belts, back-arc basins, suture zones, marginal fold belts and orogenic belts. The metallogenic assemblages are mainly distributed within these structural zones of the terranes. According to the relationship between these tectonic units and the distribution of mineral resources, the tectonic-metallogenic belts can be divided into 24 metallogenic belts in Southeast Asia. They are characterized by a diversity and frequency of metallogenic material combination which is likely to reflect the complexity of the material distribution during mineralization processes, mostly by the structural transformation during the dissociation- convergence process between multiple terranes. Therefore, the formation of ore deposits was not only restricted by the evolution (opening and closure) of Paleo- and Neotethys, but may also be controlled by the interaction of the terranes with different tectonic attributes which provided multiple sources of metallogenic material.

KEY WORDS: Southeast Asia, terrane groups, metallogenetic belt, subduction-collision, Tethys.

0 INTRODUCTION

Southeast Asia is categorized as an archipelagic ocean with complex geologic structural units (Sone and Metcalfe, 2008). The Sibumasu and Indochina terranes were first spliced at the end of the Paleozoic to form the "Paleotethys" suture zone (Metcalfe, 2012, 2002). At the end of the Mesozoic Era, the joining of the West Myanmar and Sibumasu terranes formed the "Neotethys" suture zone (Metcalfe, 2013). Some studies proposed the existence of a "Middle Tethys" (Zaw et al., 2014), but it can be either a branched ocean basin of Paleotethys or its relict (Fang et al., 1994). In the Cenozoic, the main body of Southeast Asia belonged to the Eurasian Plate. Since then it was also affected by the India-Australian and Pacific plates. It was eventually incorporated into the transition zones between the Eurasian, the India-Australia (Hutchison, 2010, 1988) and Pacific Plate (Fig. 1). Based on the spatial structural information, this region consists of grouped terranes (such as the Indochina, Sibumasu, West Myanmar and Nambung terrane), a number of separated terranes (such as the Philippine Islands and Sundaland), and also of island arcs and arc-continent collision belts (Khan et al., 2017). The latter are ascribed to plate subduction (such as New Guinea Terrane and Timor Island arc belt). Previous studies have made fundamental contributions to the division of the main structural units of Southeast Asia (Chen et al., 2017; Khan et al., 2017; Zaw et al., 2014; Shi et al., 2013; Lu et al., 2009). Some authors consider the regional complex metallogenic characteristics in Southest Asia as being distinguished from those of metallogenic domains of other Tethys zones and also of the Pacific area (Ueno et al., 2003; Hutchison, 1988). Yet, the differences can be either related to the "superposition or transformation" of the Pacific domain at the eastern end of the Tethys domain or ascribed to the interaction of all three plates

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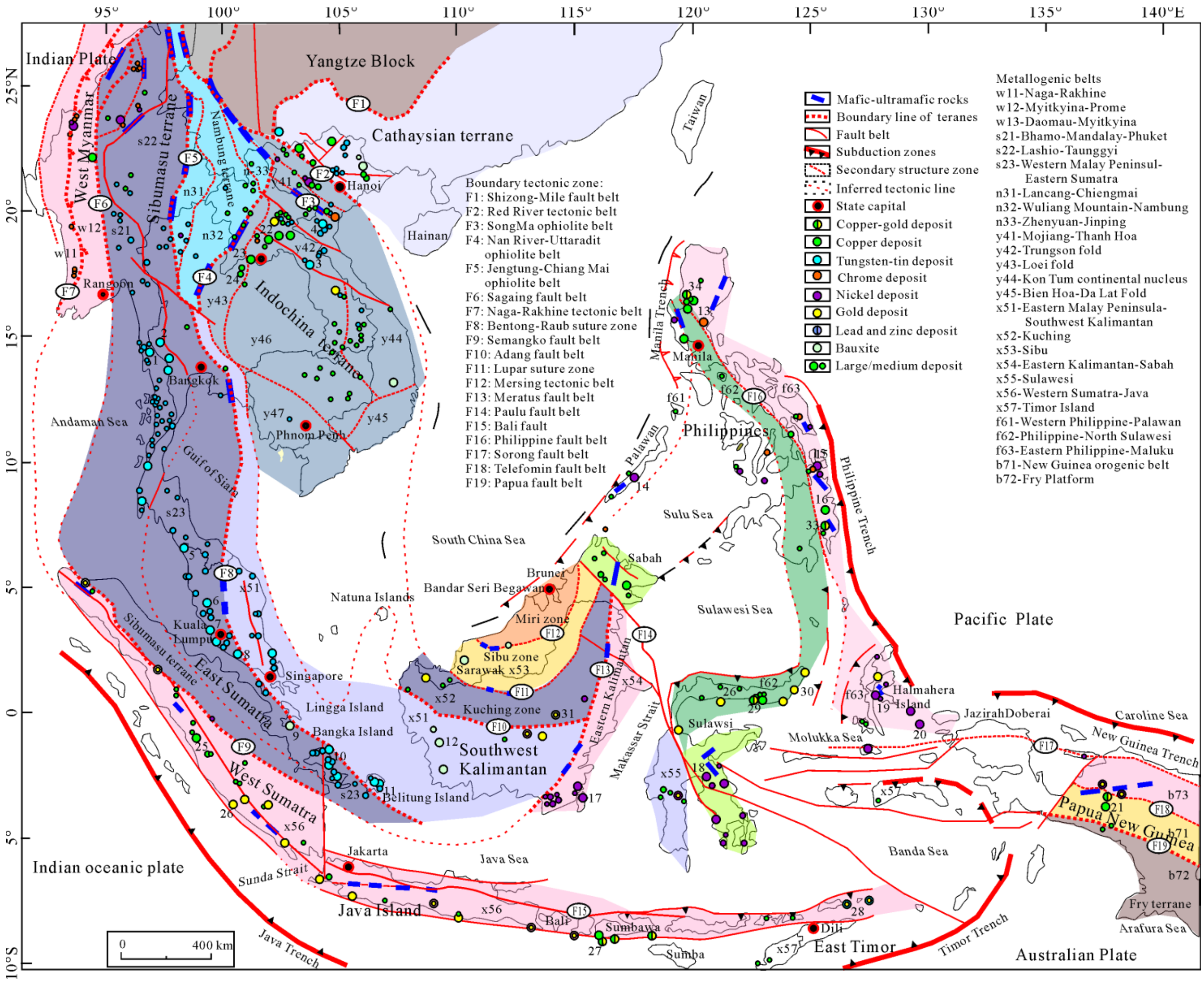

Figure 1. Tectonic sketch map of Southeast Asia and the distribution of terrain groups with Metallogenetic units (modified after Zaw et al., 2014). Name of deposit: (1) Hermyingyi tin and tungsten deposit; (2) Pilok tungsten and tin deposit; (3) Boneng tin ore field; (4) Tam Dao tin ore field; (5) Kakibukit tin deposit; (6) Kinta Valley tin ore field; (7) Kuala Lumpur tin ore mine; (8) Kesend tin deposit; (9) Tayang bauxite; (10) Bangka Island tin deposit; (11) Kelapa Kampit tin ore mine; (12) Air Rupas bauxite mine; (13) Acoje Cr ore field; (14) Rio Tuba Ni deposit; (15) Surigao Ni deposit; (16) Tampakan Cu deposit; (17) Pulau Sebuku Ni deposit; (18) Soroako Ni deposit; (19) Halmahera Ni deposit; (20) Gag Island Ni deposit; (21) Grasberg Cu-Au deposit;(22) Phu Kham Cu-Au deposit; (23) Puthep Fe-Cu(Au) deposit;(24) Phu Lon Cu-Au deposit; (25) Mudik porphyry Cu-Au deposit; (26) Manganiti epithermal Au deposit; (27) Batu Hijau porphyry Cu-Au deposit; (28) Lerokis submarine volcanic exhalation Au-Ag deposit; (29) Tombulilato porphyry Cu-Au deposit; (30) Mesel Carlin-type Au deposit; (31) Kelian epithermal Au deposit; (32) South Vietnam bauxite ore field; (33) Masara Au mine; (34) Baguio Au mine; (35) Tchwpone Au mine.

(Eurasian, India-Australian and Pacific plate), resulting in the lithospheric structural and compositional changes. In addition, different tectonic zones (mainly including suture zones, arc-magma belts, block-edge fold belts and internal orogenic belts) were formed due to subduction and collision between plates (or micro-landmass). This also resulted in the lateral growth of blocks and mineralization process(es). All the uncertainties and complexities in the Southeast Asia region require more comprehensive research to gain a better understanding of the relationships between the internal structure of different terranes and their metallogenic belts. We will explore the relationship between the regional metallogenic process(es) and the tectonic belts, and will also try to identify the characteristics of individual terranes and discuss their relationship to metallogenic processes.

Naga-Rakhine and Myitkyina-Prome metallogenic belt in West Myanmar Terrane; Bhamo-Mandalay, Lashio-Taunggyi, Sagaing-Phuket and Western Malay Peninsula-East Sumatra metallogenic belt in Sibumasu Terrane; Lancang-Chiang Mai and Wuliang Mountain-Nambung metallogenic belt in Nambung Terrane; Mojiang-Thanh Hoa, Trungson, Loei, Kon Tum and Da Lat metallogenic belt in Indochina Terrane.

1 GEOTECTONIC BACKGROUND

The Southeast Asia region is an evolving archipelago with an ocean structural system. It includes ocean basins and back-arc basins due to the long-time effect between the Pacific and Eurasian plates. Furthermore, the Eurasian and Australian plates gradually approach each other and their eventual amalgamation and accretion is preceded by micro-terranes (Schmidtke et al., 1990; Daines, 1985). It also includes an arc-continental collision belt due to the recent Pacific and

Australian Plate interaction (Abbott, 1995). The tectonic framework of Southeast Asia comprises mainly the Kon Tum Continent and Sundaland with its subsidiary tectonic units (Wikita, 2000).

In the Indochina Peninsula, there is the Kon Tum Continent core surrounded by the Trungson, Loei and Da Lat fold belts. Together, they form the Indochina terrane. It collided with the Sibumasu terrane which was detached from northern Gondwana in the Late Paleozoic, and eventually formed the Paleotethys suture zone (Metcalfe, 2002). This was followed by the formation of the Mojiang-Thanh Hoa fold belt, including the Song Ma and Song Da ophiolite belts caused by the amalgamation of the Indochina and Cathaysia terranes (Hutchison, 1975). At the end of the Mesozoic, the Sibumasu Block and the West Myanmar terrane converged to form the Sagaing tectonic zone (Metcalfe, 2002) forming the structural outline of the Indochina Peninsula (Van Leeuwen et al., 2007; Katz, 1993).

In Borneo, Sundaland is surrounded by the Kuching and eastern Malay Peninsula-Southwest Kalimantan fold belts (Metcalfe, 2011; Barber and Crow, 2009; Barber et al., 2005), that in turn are surrounded by the Sumatra-Java, Sarawak-Sabah, eastern Kalimantan and Sulawesi epicontinental tectonic belts which were formed in Mesozoic and Cenozoic (Bunopas and Vella, 1983). The Philippine Islands and the New Guinea terrane were also formed during Mesozoic and Cenozoic Era as a result of the subduction of Pacific Plate and also at the same time, the western Sumatra-Java-Timor Island arc formed due to the oceanic subduction of the India-Australian Plate. The boundaries between terranes are three types of structures: (1) The first type are suture zones formed by the aggregation of plates, e.g., the Paleotethys and Neotethys suture zones, marked by the Bentong-Raub ophiolite belt and the Sagaing structural belt, respectively. (2) The second type are subduction zones, like the Philippine Island complex subduction zone and the Sumatra- Java-Timor Island subduction zone, which are the outcome of subduction of the Pacific and India-Australian plates underneath the Eurasian Plate (Metcalfe, 2011). (3) The third type is collision zones between terranes, e.g., the New Guinea arc continental collision zone and the central Sumatra strike slip tectonic zone. They are the result of the terranes being stitched together after the translation and rotation during Mesozoic and Cenozoic Period (Rangin et al., 1990). Terranes and its boundary outlines are shown in Fig. 1.

2 THE TERRAIN GROUPS AND THEIR INTERNAL STRUCTURES

2.1 The Indochina Terrane

The center of the Indochina terrane still preserves the Precambrian basement, i.e., the Kon Tum continental nucleus. It is surrounded by the Trungson, Loei and Da Lat fold belts of Hercynian Age (Fig. 1). They amalgamated with the Cathaysia terrane during the Indochina Period to form the Mojiang-Thanh Hoa fold belt (Gatinsky and Hutchison, 1987). During the Mesozoic and Cenozoic Period, secondary tectonic units were developed, such as the Phnom Penh and the Da Lat Basin. The northern boundary of the Indosinian Block is the Red River fault belt (Qian et al., 2016; Hutchison, 1975), its northwest boundary is marked by the Nan River-Uttaradit ophiolite belt (Hayashi, 1988), and the southwest boundary is the Bentong-Raub ophiolite belt (Searle et al., 2012). Between the Indochina and Sibumasu terrane, the Tethys Ocean subducted westward and closed in the Permian (Metcalfe, 2013). Between the Indochina and the Cathaysia terrane, the Tethys Ocean was subducted southwestwards and was closed in the Triassic (Ridd, 1980). The Precambrian basement, from the Archean to Neoproterozoic, is mainly exposed in the Kon Tum continental nucleus, while most of it is covered by the Mesozoic Khorat Basin and the Cenozoic Phnom Penh basins. Paleozoic sediments are missing. Carboniferous–Permian limestone is mainly exposed at the northern margin of the terrane. The western Kele Basin and the southern Mekong Delta are made up mainly by Mesozoic to Cenozoic continental sediments. The Trungson fold belt may result from the closure of the Ailao Mountain-Song Ma Ocean, a branch of the Paleotethys Ocean (Lai et al., 2014). The fold belt contains the main occurrences of Paleozoic marine volcanic rocks and Early Permian–Triassic granites and volcanic rocks (Liu et al., 2012; Cromie et al., 2010). Late Permian to Triassic andesitic and rhyolitic volcanic rocks occurs in the Loei fold belt. Recently, Devonian–Carboniferous and Silurian magmatic rocks were discovered in this belt (Boonsoong et al., 2011). Triassic to Cretaceous sedimentary rocks and Early Jurassic to Cretaceous granites mainly occur in the Da Lat fold belt (Zaw et al., 2014). The Mojiang-Thanh Hoa fold belt belongs to Indochina orogenic epoch with the Early Paleozoic Sam Neua Island arc and the Late Paleozoic Song Da rift basin overlying the Precambrian basement (Konyukhov, 2009). During the Indosinian, composite folds were formed, that were intruded by granite and ultrabasic rocks along with the deposition of continental volcanic rock, and granite intruded again in Yanshanian Period.

2.2 The Nambung Terrane

The Nambung terrane is sandwiched between the northern Indochina and Sibumasu terranes. It is located between the Jengtung-Chiang Mai and Nan River-Uttaradit ophiolite and ends in the south at the Meiping fault belt (Fig. 1). The outcropping strata are dominated by Late Paleozoic, Mesozoic and Cenozoic sedimentary rocks while magmatic rocks are mainly found in the later Paleozoic to Triassic Jengtung-Chiang Mai magma arc. The Triassic granites comprise both S- and I-types but S-type dominate (Morley, 2002). The Nambung Terrane can be divided into the following subordinate structures:

(1) The Chiang Mai magma arc is a volcanic tectonic zone with an island arc superimposed onto the Neoproterozoic basement. It was disturbed by subduction activity between the Devonian and Carboniferous periods (351–280 Ma). Metamorphic rocks with high-pressure and low-temperature glaucophane shists (260–280 Ma) occurred as well as Variscan intrusive granites (295 Ma) and mafic-ultramafic rocks and ophiolites. During the Late Hercynian to Indochina orogenic period, the suture of the Sibumasu and Indochina terranes lead to a large area of deep-seated granite intrusions (244–210 Ma). They constitute the main bodies of this island arc belt and are accompanied by the formation of tin deposits (Lu et al., 2009).

(2) There is no obvious continental basement in the Wuliang Mountain-Nambung depression zone. The Upper Paleo-

zoic sediments is composed of carbonates, but also contain deep-sea facies graptolite shales of Silurian to Devonian age. In the Late Paleozoic, both eastward and westward subduction of the oceanic crust of the Paleotethys began and various rock types were deposited on both sides of the trench, such as andesitic basalts, tholeiites, andesites, tuffs and rhyolites. During the Late Hercynian to Late Indochina Period, the formation of fold belts resulted in the Paleotethys closed. Thereafter, fault-block activity led to a graben depression basin with more than ten thousand meters of Triassic to Paleogene sediments.

(3) The Zhenyuan Jinping fold fault zone (Fig. 1, n31) is sandwiched between the Honghe, Ailao Mountain and the Jiujia-Mojiang faults. The Ailao Mountain metamorphic terrane is the original basement of the Yangtze terrane, covered by a Late Paleozoic volcanic sedimentary rock series (Shi et al., 2013).

2.3 The Sibumasu Terrane

The west margin of Sibumasu terrane consists of the Sagaing fault and Mogok metamorphic belt with the Bentong-Ruab suture at its east end (Fig. 1). The Precambrian sedimentary strata, the Mogok series (Fuller et al., 1991), are mainly composed of higher grade metamorphic gneisses, migmatites, marbles and quartzites along with a large portion of pegmatites, syenites and granites formed by large-scaled migmatization. The Lower Paleozoic strata are miogeosyncline sediments of the Gaoligongshan Group in the west of the Nu River. The Upper Paleozoic strata mostly consist of carbonate rocks that are interlayered with clastic rocks, volcanic tuffs and basalts. In the western part of the Malay Peninsula, the ages of the detrital zircons from Late Cambrian and Early Ordovician sandstones overlap with the ages of detrital zircons from Tumbla-Gonda Ordovician sandstones in western Australia (Burrett et al., 2014; Hall and Sevastjanova, 2012). This supports a connection of the Sibumasu Terrane with the Australian Plate before the Middle Permian (Zaw et al., 2014). Due to a Late Hercynian orogenesis, there is a lack of Mesozoic sedimentary strata. The Sibumasu terrane can be divided into the following subordinate structures.

(1) The Mandalay-Phuket epicontinental arc zone. It comprises the Late Yanshanian tectonic belt, that sits on Precambrian basement with a western part close to the Myitkyina fault (suture line) (Shi et al., 2013) and an eastern part with high-level emplacements of hypersolvus granites (131, 77.50 Ma). (2) The Lashio-Taunggyi fault block area that represents the back-arc of the Lancang-Chiang Mai Island arc zone with exposures of Precambrian basement and Lower Paleozoic strata. Alkaline granites as well as intermediate volcanics and mafic-ultramafic rocks intruded along rifted valleys and along the edge of the basin. (3) The western Malay Peninsula-eastern Sumatra collision orogenic belt, an Indosinian orogenic belt overlay the Paleozoic sedimentary layers with massive granites from the Late Permian and Early Triassic. Melts from re-melted granites intruded into the collisional thrust belt, forming a huge central batholith (Yeap, 1993).

2.4 The West Myanmar Terrane

The eastern boundary of the West Myanmar terrane is the Sagaing fault and the western border the active subduction zone (Fig. 1). The terrane started as Tethys Ocean and composite of a composite island arc zone between the Indian continental plate and the Sibumasu terrane. The Indian Plate was subducted under the Sibumasu Block along the Naga Mountain subduction zone, beginning in the Jurassic and ending with the Paleogene to Eocene (Wang et al., 2000; Ueno et al., 2003). There are two subordinate tectonic zones.

(1) The Naga-Rakhine tectonic-magmatic zone in the west: This zone is connected to the ultramafic belt of the Yarlung Zangbo River in the north and extends to the Andaman Sea and Nicobar Islands in the south (Metcalfe, 2013). The strata include Paleogene flysch sediments and Tertiary molasse deposits (Searle et al., 2012) along with Triassic and Cretaceous rock nappes, some area showing the characteristics of mélange accumulation. Ultramafic rocks of the Late Cretaceous to Eocene intruded Triassic, Cretaceous and Eocene strata in layers (Searle et al., 2012).

(2) The Prome composite island arc zone: It is a discontinuous narrow island arc band composed of intermediate grade metamorphic rocks, ophiolites and Triassic to Upper Cretaceous strata. It can be divided from west to east, into the Indian-Burmese outer arc, the Prome intra-arc trough and the Maing Kwan inner island arc (Morley, 2002). The outer arc consists of an Upper Triassic flysch formation, Cretaceous limestones and of basic to ultrabasic igneous belts. The island-arc trough can be subdivided into several Tertiary to Quaternary sedimentary basins (Morley, 2002). The inner arc is built up by Late Mesozoic and Cenozoic basic, intermediate and acid volcanics. Collision or strike slip movements in Late Mesozoic time lead to the splicing of the West Myanmar terrane and Sibumasu terrane (Mitchell, 1979). The Andaman-Sunda subduction probably began during Late Cretaceous (Barley et al., 2003), and continued intermittently from Eocene to present-day (Otofuji et al., 2012).

2.5 Sundaland and Its Affiliated Islands

The Sunda continental nucleus includes Southwest Kalimantan (south of Adang fault) and the east of the Malay Peninsula (east of Bentong-Raub suture) with exposures of Devonian to Permian slates, schists and limestones. They form the Hercynian folded basement and are overlain by Triassic to Neogene clastic rocks, carbonates and volcanics. Intermediate to acid magmas intruded during the Hercynian, the Indosinian and Yanshanian, respectively (Fig. 1). Around the continental nucleus consists of the epicontinental magmatic arc belt of the eastern Malay Peninsula, the Kuching epicontinental tectonic-magmatic belt and the Sumatra-Java Island arc, and the Mesozoic–Cenozoic eastern Kalimantan arc-continent collision zone.

The Eastern Malay Peninsula: Late Paleozoic shallow marine clastic sediments and volcano clastic rocks and also carbonates are underlain by a Precambrian basement. I-type granites intruded during the Late Permo–Triassic. Their formation is related to the eastward subduction of the Paleotethys (Oliver et al., 2011). Tin deposits are located in the contact zones of the intruded bodies. In Late Permian and Early Triassic, there was a large outpour of volcanic rocks, mainly of rhyolites and andesites through seabed eruptions. Jurassic to Cretaceous continental rhyolites and dacites are found in some areas and younger alkaline basalts and trachybasalt dikes are syngenetic with quaternary orogenesis.

Borneo: Borneo is the continental shelf island of Sundaland. Tectonically, it can be divided into a southwest basement area, the Kuching belt, the East Sabah area, the Miri belt, the Sibu belt and a southeastern accretion zone (Clements and Hall, 2008, 2007). Southwest Borneo is the basement of the Sundaland, with strata consisting of Upper Carboniferous slate and schists, overlying the Lower Permian to Tertiary sandstones and quaternary basalts, sandstones, mudstones, etc. The Kuching belt is located between the Lupar and Adang fault (Hutchison, 2010). The oldest rocks are Late Carboniferous to Permian crystalline schists which have been folded into flaky greenstone facies. Igneous rocks belong to the Late Triassic Seratn Group (Carlile and Mitchell, 1994). The Sibu belt is located in the north of the Kuching zone, and is the accretion zone during the Late Cretaceous to Paleogene Period (Hutchison, 2004). The Miri zone belongs to the miogeosyncline area, and its Upper Cretaceous to Neogene flysch formations developed over a continental basement (Hall, 2002). The eastern Sabah belt is an ophiolitic mélange belt with mainly basic to intermediate magmatic rocks and of metamorphites. The eastern Kalimantan accretion zone shows no cratonic affinity. Instead, it is characterized by deep-water sediments, mélange accumulation and an ophiolite suite (Hutchison, 2004).

Sulawesi Island: It was split form Borneo during Middle Paleogene rifting. Its western part is a volcanic-plutonic arc and central part a metamorphic belt. Ophiolites together with continental debris from the Banggai-Sula and Tukang Besi are the components of the east zone, and the north is an island arc (Hall, 2002). Paleomagnetic data show that Southwest Sulawesi was attached to the Malay Peninsula and to Kalimantan during the Cretaceous Period (Katili, 1989; Fuller et al., 1999). The eastern Sulawesi ophiolite originated as crust of the Indian Ocean (Mubroto et al., 1994). These geological bodies from different regions come together in the Early Miocene (25 Ma) to form Sulawesi Island (Parkinson, 1991).

Sumatra Islands: It is divided into the East and West Sumatra terranes (Gao et al., 2015; Hutchison, 1988; Barber et al., 2005). The East terrane is the southern extension of Sibumasu terrane which belongs to the tectonic domain of Paleotethys, a microcontinent splitted from Gondwana land, while the West terrane migrated from the margin of Eurasia (Hutchison, 1994). The two collided in the Mesozoic. The central Sumatra tectonic belt has strongly deformed tremolite-bearing schists that were probably metamorphosed during the Indochina phase (Rigby, 1998; Fontaine and Gafoer, 1989). In the southwest of Woy La Wyn Group (Middle Jurassic– Cretaceous) was pushed over the West Sumatra terrane as a large nappe. Intrusions of intermediate to acid rocks invaded during the Hercynian, Indosinian, Late Yanshanian and Early Himalayan periods and corresponding volcanic rocks also occur (Barber et al., 2005; Van Leeuwen and Muhardjo, 2005).

Java Islands: It is the island arc and proliferating products on the southern edge of Sundaland. Mesozoic rock formations are the volcanic sedimentary rocks and metamorphites occur along the southern margin of Sundaland (Wakita, 2000). Cenozoic rock formations are the igneous intrusions, volcanic sedimentary rocks, siliceous clastic sedimentary rocks and shallow marine carbonates, where are invaded by igneous rocks (Whitford et al., 1979). There were three stages of magmatic activity in this region (Katili, 1989).

2.6 Philippine Islands and Related Islands

Philippine Islands: On the east side of the Philippine Islands is the East Luzon and Philippine trenches, and west side is the Rutgers and Kota Komba trenches (Fig. 1). In the Philippine Islands, the rock formations mainly consists of ophiolites and volcanics in Cretaceous–Tertiary (Hall, 1997). The rock formations in West Philippine are composed of Carboniferous to Early Jurassic continental basement unconformably overlain by a strongly deformed ophiolite complex in Mesozoic to Oligocene. Folding and faulting (obduction) occurred in the Late Miocene, represented by mélange with blue schists (Villeneuve et al., 2001). The central part is composed of Cretaceous to Oligocene metamorphosed volcanic rocks and metamorphosed sedimentary rocks that were intruded by Oligocene to Early Miocene quartz diorites and granodiorites. Early to Middle Miocene limestones and volcanic clastic rocks unconformable overlay these strata. In addition, porphyritic calc-alkaline quartz diorites intruded into the upper part of the Miocene strata (Charlton et al., 2000). The eastern part of the Philippine Islands consists of thrusted ultramafic-mafic blocks and Cretaceous to Tertiary strata, and also of Early to Middle Miocene clastic rocks and limestones. These were intruded in the Miocene by quartz diorites and andesitic magmas (Hamilton, 1979).

Palawan Island: The oldest rocks on this island are Late Paleozoic schists, phyllites, slates and quartzites, overlain by Late Permian sandstones, tuffs and slates, quartzites and Middle to Late Permian limestones which are unconformably overlain by the Middle Triassic conodont cherts. An island arc in the south of Palawan is made up of ophiolites, amphibolites and greenschists (Rangin et al., 1990). These occur together with Late Cretaceous to Early Miocene sandstones, shales, mudstones and limestones (Faure et al., 1989; Hutchison, 1975).

Halmahera: It is located in the northeast of Sulawesi Island and belongs to the Philippine Plate (Foden and Vame, 1980). The Philippine trench is located in the east where the Philippine and the West Maluku oceanic plates are subducted westward. The east of Halmahera is an ophiolite body and the west a volcanic arc basement. Metamorphic rocks are mainly Paleozoic phyllites, mica schists, kyanite schists and granitic gneisses. The ultramafic and mafic rocks consist of gabbro and peridotite. In geological history, Halmahera has been moved together with the Philippines Sea Plate.

2.7 The Papua New Guinea Terrane and Related Islands

The main bodies of the Guinea Terrane are the Fry Platform, the Papua fold belt, the Papua orogenic belt and accretion arc body (Gow and Walshe, 2005). The Papua fold belt in the north of the Fry Platform is a foreland fold-thrusting zone composed of continental crustal rocks (Fig. 1). The Papua orogenic belt was formed by the welding of an Oligocene–Miocene allochthon and the Fry terrane (Pigram and Davies, 1987). Cenozoic volcanic rocks and granites are widely distributed. Middle to Late Miocene and Pleistocene granites consist of a large number of stocks and of small batholiths. They are closely related to the copper and gold mineralization in this region (Etrew, 1995). A series of volcanic arcs and Paleogene to Cenozoic arc-continental collision zones were created within the accretion arc and eventually thrusted over the Guinea Continent. Jazirah Doberai detached from the Australian Plate in the Meseozoic (Ali and Hall, 1995; Weniscnk et al., 1989). About 25 Ma ago, its northern margin was connected with the Philippine Sea Plate, followed by collision. The Papua fault separated the Fry Platform from the Papua fold belt. It is the thrust nappe belt formed in the Oligocene with strong activities continuing into the Late Miocene and Pliocene (Gow and Walshe, 2005). The Sorong fault is located in the north of New Guinea Island and of Cendrawasih. In this belt, tectonic mélange, ultramafic rocks and granites are the main products of the margin collision of the Philippine Sea Plate and the Australian Continent in the Late Miocene or Pliocene (Giddings et al., 1993).

3 METALLOTECTONIC UINTS AND METALLOGENIC ASSOCIATIONS

In Southeast Asia, some terranes split in the Paleozoic from Gondwana, moved northward and eventually collided with the Eurasian Plate (Metcalfe, 2013; Sone and Metcalfe, 2008). When the two terranes combined, preceeding island arcs were transformed into suture zones, and then, in successive stages, into marginal fold or orogenic belts. In the Cenozoic, Southeast Asia was again modified by subduction and collision of the India-Australian and Pacific plates (Burrett et al., 2014; Morley, 2002), forming the Sumatra-Java Island arc belt, the Philippine composite island arc zone and the New Guinea arc-continental collision zone (Meldrum et al., 1994; Vroon, 1992). These different tectonic environments result in the different mineralizations so that the distribution of metallogenic belts is controlled by these tectonic belts (Fig. 1, Table 1).

3.1 Metallogenic Zones along Sutures

Many terranes from Gondwanaland experienced dissociation-convergence processes, when they were pieced together and connected to Eurasia. A series of suture zone is formed in the joints (Zhu et al., 2016; Liu et al., 2002). At the end of the Paleozoic, the "Paleotethys" suture zone is formed by the combination of the Sibumasu and Indochina terranes. In the Late Mesozoic, the "Neotethys" suture zone was formed by the amalgamation of the West Myanmar and Sibumasu terranes (Zaw et al., 2014). Their subduction during the Cenozoic is inclined towards the Euraisan Plate. In addition subduction and collision occuured between the India-Australian and Pacific plates, the main continental blocks of Southeast Asia belong to Eurasian Plate. They were joined together by the trench-arc-basin systems, continental margin arcs and orogenic belts together with thrust-strike slip tectonic zones which were formed during subduction and collision between the India-Australian and Pacific plates (Hall, 2002). Along these linear tectonic zones ophiolites or mafic-ultramafic associations are exposed (Fig. 1), and the metallogenic belts were formed.

The Jengtung-Chiang Mai ophiolite belt is located on the Paleotethys suture zone. The latter is joined by the Lancang River fault in the north and the Bentong-Raub suture zone in the south. It also includes some diachronous suture zones, e.g., the Boyan mélange in the Kuching belt of Kalimantan Island (Hall, 2002; Metcalfe, 2002; Hutchison, 1975). The Nan River-Uttaradit and Marang ophiolite belts may also belong to the relicts of the Paleotethys Basin (Zhang et al., 2013; Hutchison 1975). Mineralizations related to the Paleotethys suture zone are mainly nickel deposits, and minor chromium and copper ore deposits. The Meratus fault zone has a large laterite nickel occurrence (Hutchison, 1975), but it is not clear whether it belongs to the Paleotethys domain. A composite deposit of chromium and nickel (and platinum, copper and gold) developed on the Jinsha River-Ailao Mountain-Marang subduction zone (Trung et al., 2006).

The Neotethys suture zone is situated on the Naga-Rakhinc tectonic belt, connected to the Yarlung Zangbo River ophiolite belt in the north and extends south through the Andaman Sea to the Sumatra fault zone. Ophiolites are widely distributed in this region, such as some ophiolite belts in eastern Burma (Myitkyina, Mandalay). In addition, there is an ophiolite belt which is produced in the tectonic magmatic belt that includes the Chin Hills, Naga Hills and Kalaymyo, and Andaman-Nicobar ophiolite and the middle fault zone of the Sumatra (Hutchison, 1986). The emplacement time of the two ophiolite zones is Middle Jurassic and Late Cretaceous, respectively which are also the closure time of the Mesotethys and Neotethys Ocean Basin at subduction setting (Liu et al., 2016). The deposits related to the suture zone are large nickel deposit and medium-sized chromite deposit, accompanied by platinum. Nickel deposits are lateritic and chromite deposits originated by magmatic differentiation (Shi et al., 2013). Previous studies showed that the tectonic setting of the Andaman ophiolites is from above a Late Cretaceous subduction zone (Pedersen et al., 2010; Hutchison, 1975). Chromite deposits are closely related to the Aammam-Nicobar ophiolite belt (Vohra et al., 1989). Previous study on podiform chromite in lherzolites from the ophiolite belt also concluded that the ophiolites were formed in the lithospheric mantle above a subduction zone (Ghosh and Bhatta, 2014). A large number of ophiolites (Hutchison, 1975) and related Cu-Ni deposits are exposed within fault zones in central Sumatra Island.

Cenozoic subduction-collision zones mainly occur at the margin of the Southeast Asian Continent and between islands (Hall, 2002). Their ophiolites or mafic-ultramafic belts all have related mineral deposits. The Torricelli intrusive complexes in northern Papua New Guinea, the Aprill ultramafic zone and the Papua ultramafic belt in the east are the metallogenic zones for nickel, cobalt, gold and PGE's (Titley, 1975). The Late Oligocene to Early Miocene Sulawesi ophiolite belt has chromium and nickel deposits (Carlile and Mitchell, 1994, Carlile et al., 1990; Carlile and Kirkegaard, 1985). The Maluku magmatic arc and subduction complexes are composed of western and eastern half of Halmahera, and the distribution of nickel-cobalt ore deposit is controlled by the spatial distribution of ophiolites (Yumul et al., 2008; Yumul, 2001).

Table 1 Metallogenetic units and distribution of mineral resources in the Southeast Asia

Structural units	Tectonic metallogenic belts	Metallogenic associations and types of deposits	Surrounding rocks, intrusive bodies, and mineralogenetic epoch	Typical deposits
West Myanmar terrane	Naga-Rakhine structural-magma metallogenic belt	Mafic-ultramafic rocks: ophiolite chromite, magma copper, nickel, gold, hydrothermal type gold copper deposit	Mélange intruded by Late Cretaceous–Eocene Epoch ultromafic rocks, ore bodies in mafic-ultramafic rocks and wall rock	Mwetaung, Leganywa, and Zinbinkwin magma chromite; Sinakaling Hkamli hydrothermal type Au; Falam magma Au-cu(Mo); Tawnaw and Pangmawmaw magma Cr deposit
	Myitkyina-Prome composite island arcs metallogenic belt	Mafic-ultramafic rocks; magma nickel, chromium, kuruko copper; intermediate-felsic rock: porphyry copper, hydrothermal copper-gold-antimony	Outer arc: Cenozoic mafic-ultramafic rocks; inner island arc: Cenozoic–Pleistocene intermediate-acid volcanic rocks and Emplacement magma	Monywa porphyry Cu and VMS Cu, Kanbni Carlin-type gold, Kwinthonze hydrothermal gold, Wuntho-Myitkyina hydrothermal nervation Au deposits; Myitkyina Sanlaid and Tagaung Taung magma Ni deposit
Sibumasu terrane	Bhamo-Mandalay-Phuket arc-continent collision metallogenic belt	Granite: hydrothermal type tin, tungsten, antimony, orogenic gold; mafic-ultramafic rocks: magma chromite, gold, PGE deposits	Arc-continent collision, mafic-ultramafic rocks complex in island arc; Late Yanshanian granites into Indochina fold belt in epicontinent	Hermyingyi W-Sn, Pilok W-Sn, Modi Tang-Nankwe orogenic Au deposit, gunda chromite, Myitkyina mafic-ultramafic rocks Au-PGE deposits
	Lashio-Taunggyi fault block (back arc basin) metallogenic belt	Sedimentary-hosted: hydrothermal metasomatic lead zinc, silver, MVT lead zinc, mercury and antimony	Precambrian basement, after Hercynian block basin, Early Yanshanian granite and mafic-ultramafic rocks	Mae Sod, PaDaong, Song Tho MVT Pb-Zn deposit; Ban Muang Gid, Tham Talu hydrothermal Pb-Zn deposits; Bawdwin kuruko Pb-Zn-Ag, Bawsaing MVT Pb-Zn deposit
	Western Malay Peninsula continental-continental collision metallogenic belt	Granite: contact metasomatic-skarn tin tungsten; upper magma system: MS lead zinc, porphyry-epithermal gold deposits	Palaeozoic miogeosyncline sedimentary, Late Hercynian–Late Indosinian orogeny; Indosinian granite and porphyry intrude into Upper Paleozoic	Selibin Beatrice, Kelapa Kampit, Klian Intan tin deposit, Burlt Kaehi hydrothermal type tungsten, Belitung hydrothermal Pb-Zn, Raub Australian Au, Penjom gold deposits
Nambung terrane	Lancang-Chiengmai superimposed island arc metallogenic belt	S-type granite: hydrothermal tin-tungsten; porphyry: porphyry gold, Ophiolite belt: Ophiolite gold-antimony, hydrothermal metasomatic lead zinc	Precambrian basement, Neoproterozoic island arc overlaid by Hercynian and Indosinian subductions, and two period granit (S-type), Late Yanshanian granite	Mae Sariang tungsten tin, Mae Lamatin tungsten, Doi Mok contact metasomatic tungsten deposit, Pa Daeng zinc deposit, Muang Kut Mae Taeng base metals deposit
	Wuliang Mountain-Nambung fault depression basin metallogenic belt	Alkaline porphyry gold deposit; Carbonate-clastic rock: Carlin-type gold deposit, hydrothermal type antimony deposit	Late Hercynian–Early Indochina fold, then graben-shaped basin, P–T granite, J–K red layer of sedimentary rock, Himalayan fold	Krabin gold deposit, Chae Hom, Doi Pha Khan, Pha Had antimony deposit, Jinding Pn-Zn multi-metal deposit
	Zhenyuan-Jinping fault fold metallogenic belt	Fault fold belt: hydrothermal type gold, multi-metal; metamorphite: metamorphic copper nickel deposit	Precambrian metamorphite basement, Paleozoic epicontinental volcanic arc, Late Indosinian fault-fold belt	Laowangzhai gold deposit, Mojiang gold deposit, Daping gold- polymetallic deposit, Baimazhai copper, nickel deposit, Chang'an gold deposit
Indochina terrane	Kon Tum mineralization area with continental nucleus raised (Precambrian basement)	Basalt weathering crust: lateritic bauxite; Proterozoic metamorphite: hydrothermal multi-metal, skarn gold, hydrothermal quartz sulphide vein gold	Lower Paleozoic–Mesozoic down-faulted basins on Precambrian basement, Triassic rift clastic-carbonate rocks and rhyolite, Cenozoic basalt	Duc Bo Cu-Zn deposit, Quang Nghia iron deposit, Bong Mien, Nui Nua Au deposit; Anh Minh Pb-Zn deposit; Van Hoa bauxite deposit

Table 1 Continued

Structural units	Tectonic metallogenic belts	Metallogenic associations and types of deposits	Surrounding rocks, intrusive bodies, and mineralogenetic epoch	Typical deposits
	Loei fold epicontinental fold metallogenic belt (Hercynian belt)	Granite: contact metamorphic copper, multi metal; porphyry copper, gold, hydrothermal copper, multi-metal deposit	Upper Paleozoic miogeosyncline, Late Hercynian alkaline porphyry, Early Indosinian granite, Himalayan quartzdiorite porphyry	Phu Lon, Phu Hin Lek Fai and Phu Thong Daen porphyry Cu deposits; Khao Lek, Ban Bothong and Singto skarn Fe-Cu(Au) deposit; Pha Khum MS Pb-Zn deposit;
	Bien Hoa-Da Lat epicontinental fold metallogenic belt (Hercynian)	Intermediate-acid rocks: hydrothermal metasomatic tin tungsten, hydrothermal vein gold; granite: hydrothermal lead zinc; weathering crust: lateritic bauxite	Upper Paleozoic metamorphite on the Precambrian basement, Hercynian granite and dacite, Late Yanshanian intermediate-acid, Cenozoic basalt	Tra Nang tungsten tin gold, Da Trai tin tungsten; Chau Thai, Gia Bac, Thanh Pb-Zn deposits, Da Lat bauxite deposit
	Trungson epicontinental fold metallogenic belt (Hercynian)	Granite: skarn iron-REE deposit; porphyry copper gold deposit, hydrothermal metasomatic type tin, gold	Carboniferous–Permian limestone on the Pre-Devonian fold, Hercynian granite, Paleogene granite (porphyry) in nappe structural belt	Thack Khe iron-REE deposit, Sepon and Phu Kham porphyry-skarn Au-Cu; Phalek and Phu Nhuan skarn Fe, Tchwpone Au-Cu, Xieng Khouang Fe-Cu deposit
	Mojiang-Thanh Hoa epicontinental fold metallogenic belt (Indosinian)	Metamorphic copper and iron; ultromafic rocks: magma copper nickel chromite; sediment-hosted gold antimony; granite: hydrothermal metasomatic tin, lead, zinc	Early Paleozoic arc and Paleozoic and rift basin on Precambrian basement, Indochina composite fold, granite, ultromafic rocks, and continental volcanic rocks, Yanshanian granite	Co Dinh chromite, Ban Phuc Cu-Ni sulphide, Danh Xa Cu-Pb-Zn, Tan Quang Fe deposit, Thap Phuc lead zinc, Pia Qac and Thien Ke Sn deposit, Sinh Quyen Cu-REE, Bat Xat Fe deposit
Sundaland terrane and its affiliated islands	Southwest Kalimantan continental nucleus metallogenic areas (Indosinian fold)	Strata-bounded uranium, hydrothermal gold deposit; sedimentary metamorphic uranium deposits; granite and alkaline: Fe, Pb, Zn, Au, Mo, Hg; weathering: Al, Ni	Devonian–Permian slate, schist and limestone within fold basement, overlying Triassic–Paleogene clastic, carbonate rocks, Cretaceous granite	Granite, alkaline granite with iron, precious-base metals deposit, ophiolite with iron, Quaternary with tin, rare metal placer, bauxite and red nickel-iron, strata-bounded uranium
	Eastern Malay Peninsula precontinental arc magma metallogenic belt (Indosinian)	Granite: hydrothermal vein-type and skarn: W-Sn; porphyry Cu-Au; andesite-rhyolite: hydrothermal Pb-Zn-Sb; basalt: Al	Late Paleozoic eugeosyncline, Indosinian fold basement, Permian andesite-rhyolite, Hercynian and Indosinian granite, porphyry	Bukit Besi magnetite-skarn tin deposit, Kungai Lembing nervation tin deposit, Bukit Besi and Batu Tiga skarn tin deposit, Lusoko greisen-type tin; Mengpur Cu(Au) deposit
	Kuching epicontinental structural-magma metallogenic belt (Indosinian fold)	Porphyry-epithermal gold, porphyry copper, MS lead zinc, hydrothermal type lead zinc and antimony deposit; weathering crust: Al	Pre-Meseozoic epicontinental basement, Yanshanian basic-acid rocks, granite, Himalayan continental volcanic rocks and granite-quartz diorite	Muyup, Mirah, Kelian epithermal Au deposit; Bau, Selanjan, Pantianak skarn-epithermal Au-Cu deposit, Banyi copper-gold deposit, Searatak Pb-Zn deposit, Tayang bauxite, Kuching lateritic nickel
	Eastern Kalimantan arc-continental collision metallogenic belt	Lateritic nickel-chromium, porphyry-epithermal copper, gold, silver deposits	Jurassic–Miocene Subduction complex (ophiolite), unconformity overlying Neogene, Oligocene granite	Mamut porphyry Cu-Au(Ag) deposit, Pulau Sebuku nickel deposit, Pulau Sebuku nickel deposit、
	Sulawesi Subduction-magma and arc-continental collision metallogenic belt	Lateritic nickel-chromium, porphyry-epithermal copper (molybdenum gold silver), Carlin-type gold deposits	Northern Cenozoic arc volcanic rocks, quartzdiorite porphyry, eastern magma complex, wastern arc-continental collision I-type granite	Tomblato porphyry Au(Cu) deposit, Malala Mo(Cu) deposit, Mesel Carlin-type Au deposit, Baganiti epithermal Au deposit, Doup multi-metal deposit, Soroako nickel(cobalt) deposit

Table 1 Continued

Structural units	Tectonic metallogenic belts	Metallogenic associations and types of deposits	Surrounding rocks, intrusive bodies, and mineralogenetic epoch	Typical deposits
	Sumatra-Java arc metallogenic belt (Indosinian fold basement)	Porphyry copper-gold, epithermal gold, skarn and MS copper, lead zinc, gold-silver deposits; lateritic: Ni, Al	Sumatra Meseozoic–Cenozoic magma arc on the Sunda Continent (ultromafic rocks, granite and volcanic rocks), Java magma arc on the oceanic crust	Batu Hijau porphyry Cu-Au deposit, Lubuksulasih skarn Cu-Zn deposit, Mangani and Lebong epithermal Au-Ag deposit, Cikongdang Cirotan gold, Gosowong submarine volcanic exhalation Au-Ag deposit
Philippine Islands and related islands	Western Philippine arc-arc collision metallogenic belt	Porphyry: skarn iron deposit; ophiolite: magma chromite, MS copper; hydrothermal type copper gold deposits	West side Cenozoic subduction magma, Middle Cenozoic volcanic rocks, basement with ophiolite, complex, metamorphite, and diorite	Coto Acoje, Kinam, Jigon and Gahaiao chromite, Dizon and Tampakan porphyry Cu deposit, Bario ophiolite Cu deposit, Canatuan, Batotan VMS Au, Amnag, Liustre and Bayogo Besshi-type Cu deposits
	Philippine-North Sulawesi subduction-arc metallogenic belt	Porphyry Cu-Au, metasomatic Cu-Au; volcanic sedimentary rock: Pb, Zn, Fe hydrothermal Au, Pb, Zn deposits	Meseozoic schist and Cretaceous volcanic rocks covered by Miocene volcanic rocks, Cenozoic intermediate-acid rocks	Carmen, Far Southeast, Balance, Wildcut and Samar porphyry Cu; Masbate quartz vein Au, Surigao epithermal Au, Ayala ophiolite Cu-Au deposit
	Eastern Philippine-Maluku subduction-magma arc metallogenic belt	Ultromafic rock: ophiolite chromium-iron deposit, porphyry copper gold, kuruko copper deposit, Besshi-type copper deposit, lateritic nickel deposits	Pre-Cretaceous metamorphic basement, unconformable overlying lemistone, clastic rocks and volcanic rocks, with intermediate-acid and ultromafic rocks	Lamin and Larap Fe deposit, Mcatur and Glpor Los chromite; Polillo, Dinkidi, Kingking and Basav porphyry Cu, Bagacag kuruko Cu deposit, Masara Besshi-type Cu-Au-Ag, Bessemer skarn Cu; Gag Island lateritic nickel deposit
Papua New Guinea terrane and related islands	New Guinea island arc-continental collision metallogenic belt	Porphyry-skarn copper gold, porphyry-epithermal gold silver, MS Pb-Zn, lateritic nickel deposits	Cenozoic arc-continental collision orogenic belt, with ultromafic rocks, intermediate-acid rocks, porphyry and volcanic rocks	Grasberg and Frieda River Porphyry Cu-Au, Ok Tedi and Ertsberg skarn Cu-Au, Bogra and Heyden Valley porphyry-epithermal Au-Ag, Wafi River Cu-Au-Agdeposit
	Timor Island structural complex metallogenic belt	Porphyry-epithermal Cu-Au; ultromafic rocks: MS Cu; volcanic sedimentary: Au	Paleogene structural complex and metamorphite, without volcanic activity, Cenozoic porphyry	Kupang copper deposit, Timor copper deposit

3.2 Subduction-Collision Zones with Metallogenic Associations

Although many subduction-collision zones between blocks had evolved into suture zones before the Mesozoic, some areas still preserve the structural features of island arc and epicontinental magma tectonic zones (Metcalfe, 2002). A good example is the Cenozoic subduction-collision zone between the India-Australia and the Pacific Plate (Metcalfe, 2013, 2011). In general, subduction-collision process(es) occurred in Southeast Asia during the Paleotethys and Neotethys phases and also in the Cenozoic Era (Hutchison, 2010).

Paleotethys: The main metallogenic belts related to convergence of the oceanic crust during the Paleotethys phase are (Table 1) as follows.

(1) The Lancang-Chiang Mai superimposed island arc metallogenic belt that was formed during westward subduction of the Paleotethys oceanic crust underneath the Sibumasu Terrane. Glaucophane-bearing high-pressure and low-temperature belts, volcanic rocks and granites as well as ultramafic rocks and ophiolites were formed during the Middle Hercynian Period (Turekian and Wedepohl, 1961). Deep-penetration and high-level emplacement granites were formed in the subduction-collision zone from the Late Hercynian to the Indochinian Period. They are closely related to the tin-tungsten deposits in this region. The main deposits are: tungsten and tin at Mae Sariang, tungsten at Mae Lamatin, contact metasomatic tungsten at Doi Mok, zinc at Pa Daeng, and base metals at Muang Kut Mae Taeng (Shi et al., 2013).

(2) The Lashio-Taubggyi fault block. The metallogenic belt was formed in a back-arc setting in the west part of the Lancang-Cheingmai Island arc. A number of hydrothermal lead, zinc, silver, mercury and antimony ore deposits were formed. The main deposits are the Mae Sod, PaDaong, Song Tho MVT Pb-Zn deposits; the Ban Muang Gid, Tham Talu hydrothermal Pb-Zn deposits; the Bawdwin Kuruko Pb-Zn-Ag and the Bawsaing MVT Pb-Zn deposits **(**Kamvong et al., 2014**)**.

(3) The eastern Malay Peninsula: Metallogenesis in this epicontinental magmatic arc metallogenic belt was caused by the eastward subduction of the Paleotethys oceanic plate underneath the Indochinian Plate. Subduction induced the formation of I-types granites in the Late Permian–Triassic Period (Schwartz et al., 1995). The main metal occurrences are skarn, and greisen-type tin deposits and orogenic gold ore bodies. Typical deposits are Selibin Beatrice, Kelapa Kampit and Klian Intan with tin, Burlt Kaehi with hydrothermal tungsten, Belitung with hydrothermal Pb-Zn, Raub Australian and Penjom with gold, Kungai Lembing with tin in veins, Bukit Besi and Batu Tiga with in skarns and Mengpur with copper and gold (Taylor and Polard, 1986).

(4) The Mojiang-Thanh Hoa metallogenic fold belt: The closure of the Ailao Mountain-Marang Ocean branch formed fold belts during the Indochinian phase (Lai et al., 2014). Subduction-collision related metallogenesis resulted in Cr-Fe deposits in Marang ophiolite belt (Co Dinh chromite). Au, Sb and Fe deposits are associated with Triassic granite intrusions (e.g., the Langciao gold (silver) deposit, the Langlong antimony (gold) deposit and the Tan Quang iron deposit). Triassic volcanic and sedimentary processes lead to zinc deposits in back-arc basin settings like in Ban Phuc with Cu-Ni sulphide, Danh Xu with Cu-Pb-Zn, and at Pia Qac, Thien Ke with Sn and Sinh Quyen with Cu and REE.

Neotethys: The metallogenic belt related to the closure of the oceanic crust of Neotethys (Table 1) includes: **(**1) The Naga-Rakhine tectono-magmatic metallogenic belt: It is an ultramafic belt associated with the Naga Mountain subduction that developed on the basis of the island arc belt in West Burma (Metcalfe, 2013; Mitchell, 1979). Its emplacement time may be Late Cretaceous to Eocene (Barley et al., 2003). The ore bodies related to ophiolites are chromite, copper-molybdenum sulphide deposits and also gold-bearing quartz veins in ultramafic rocks (Otofuji et al., 2012). The typical deposits include magmatic chromite at Mwetaung, Leganywa and Zinbinkwin, hydrothermal type Au at Sinakaling Hkamli, magmatic Au-Cu (Mo) at Falam and magmatic Cr at Tawnaw and Pangmawmaw.

(2) The Myitkyina-Prome complex island arc metallogenic belt: It consists of an outer arc, an inner arc trough and an inner arc. An ultrabasic igneous rock belt spreads along the outer arc with nickel, chromium, jadeite, noble metal and PGE deposits. The inner arc is composed of a Mesozoic and Cenozoic belt with basic, intermediate and acid volcanics that produced Kuroko-type copper ores, porphyry copper deposits and epithermal gold deposits. The main deposits are Monywa with porphyry Cu and VMS Cu, Kanbni with Carlin-type gold, Kwinthonze with hydrothermal gold, Wuntho-Myitkyina with hydrothermal nervation Au deposits and Myitkyina Sanlaid and Tagaung Taung with magmatic Ni.

(3) The Bhamo-Mandalay-Phuket arc-continental collision metallogenic belt. It was formed by the subduction of the Myitkyina Ocean eastward under the Sibumasu Terrane and the Late Yanshanian–Paleogene granites associated with subduction (Mitchell et al., 2012). There are greisen-type and skarn tin polymetallic ore deposits. Basic and ultrabasic rocks also developed in the island arc that is related with chromite, gold and PGE mineralization. Also, orogenic gold deposits occur in the Mogok metamorphic system. Representations are W-Sn ores at Hermyingyi and at Pilok, the orogenic Au ores at Modi Tang-Nankwe, chromite ores at Gunda and Au-PGE ores within Myitkyina mafic-ultramafic rocks.

(4) The eastern Kalimantan arc-continental collision metallogenic belt belongs to a complex subduction belt of the Late Yanshanian phase on the margin of Sundaland. Mafic to ultramafic and intermediate to acid magmas intruded into this belt in Late Cretaceous with the formation of Fe, Co, Ni and Cr residuary deposits and skarn iron deposits. In the Late Miocene adamellite intrusions occurred linked with the formation of porphyry copper deposits (Imai, 2000; Kosaka and Wakita, 1978). The main deposits are the Mamut porphyry Cu-Au(Ag) and Pulau Sebuku nickel deposits.

Since Cenozoic the main metallogenic belts are (Table 1) as follows.

(1) The Sulawesi metallogenic belt that originated by magmatism in subduction zones and during accretion by arc-continent collision (Carlile et al., 1990). Nickel deposits occur in eastern Sulawesi with the main deposit in mafic-ultramafic rocks at Soroako. Porphyry copper-gold (molybdenum) and epithermal gold deposits occur mainly in the northern

part of Sulawesi. Typical sediment-hosted Carlin-type gold deposits are found at Mesel (Elburg and Foden, 1998). The epithermal gold deposit at Baganiti is connected with intermediate to acid sub-volcanic rocks (Turner et al., 1994). Examples are the sulfide-poor Mintu, Lanut, and Tonbongan gold deposits that occur in andesites, and the sulphide-rich Motomboto deposit, the Tombulilato porphyry gold-copper deposit (Etrew, 1995; White et al., 1995) and the Malala Mo (Cu) deposit (Van Leeuwen et al., 1994). The Bulagidun and Cabang Kiri East copper deposits and the Paleleh and Sumalata multi-metal deposits are also related to porphyry copper mineralization. In central Sulawesi, there are the Awak Mas gold and the Sangkaropi lead-zinc deposits.

(2) In the Sumatra-Java Island arc metallogenic belt, the main types are porphyry copper (gold) and epithermal copper-lead-zinc ores (Mitchell et al., 2012). The main ore deposits are the Batu Hijau porphyry Cu-Au (Meldrum et al., 1994), the Lubuksulasih Cu-Zn, the Mangani and Lebong epithermal Au-Ag (Jobson et al., 1994, Milesi et al., 1994), and the Cikongdang Cirotan gold deposits. Synsedimentary submarine volcanic exhalation deposits are in Gosowong with Au-Ag mineralization (Van Leeuwen et al., 1994) and in Dairi with Pb-Zn (Cu-Ag) mineralization (Carlile et al., 1998; Sewell and Wheatley, 1994).

(3) The western Philippine arc-arc collision metallogenic belt: The folded basement is composed of a ophiolite mélange and sedimentary rocks. Suture zones were formed by collision between island arcs on both sides. Pliocene to Pleistocene volcanic rocks constitute the mountain ridge (Senior et al., 2006). Typical ores are the chromite deposits from Coto Acoje, Kinam, Jigon and Gahaiao, the porphyry copper deposits from Dizon and Tampakan, the Bario ophiolite copper deposit, the VMS gold deposits from Canatuan and Batotan and the Besshi-type copper deposits of Amnag, Liustre and Bayogo.

(4) The Philippine-North Sulawesi subduction-island arc metallogenic belt: The southern part is connected to the north Sulawesi volcanic and plutonic arc. An Early Cretaceous–Paleogene folded basement is unconformably overlain by basaltic to andesitic lavas and sandstones of mid to Late Miocene and Neogene. The mineralization of copper and gold is ascribed to porphyritic quartz diorite intrusions (Bacuta et al., 1990). The main gold deposits are porphyry ores at Carmen, Far Southeast, Balance, Wildcut and Samar, the Masbate quartz vein, epithermal Au ores at Surigao, the Ayala ophiolitic Cu-Au ore and the Siana contact metamorphic gold ore body. Porphyry copper deposits with an island arc origin are the Balenc, Wildcut and Samar deposits. Other ore deposits are the Mankuyus hydrothermal copper deposit and the Lobo contact metamorphic copper deposit.

(5) The eastern Philippine-Maluku subduction-magma arc metallogenic belt: the main unites are pre-Cretaceous metamorphitic rocks that are unconformably overlain by strata of layered limestones, clastic rocks and volcanic rocks with an island arc setting. There are also Tertiary ophiolites and felsic intrusions in this belt. The main deposits yielded primary ores with chromium and nickel and secondary deposits with copper, bauxite and manganese (Ogura et al., 1987). The main occurrences are the Lamin and Larap iron ores, the Mcatur and Glpor Los chromites, the porphyry copper of Polillo, Dinkidi, Kingking and Basav, the Bagacag Kuruko copper deposit and the Masara Besshi-type Cu-Au-Ag ores. Additional occurrences are copper skarn ores at Bessemer, the lateritic nickel deposits of Gag Island and the Mcartur and Glpor Los layered chromite and lateritic nickel deposits.

(6) Timor Island tectonic mélange-metamorphite metallogenic belt: it is composed of tectonic mélange in the outer Banda arcs and a metamorphic belt. The main deposits are porphyry copper deposits at Kupang and Timor, MS copper deposits in gabbros and volcanic exhalative gold deposits (Vroon, 1992).

3.3 Margin Fold Belts of the Terrane with Metallogenic Associations

On the ancient continental nuclei or terrane margins, tectono-magmatic zones, termed margin fold belts, developed by the multiple-stage tectonic movement, such as the Kon Tum old continental nucleus, the Sunda continental nucleus and the Fry terrane margin. This was connected with the formation of metallogenic fold belts. There are gold deposits within quartz veins of Proterozoic metamorphic rocks, e.g., the Pengmiao deposit and Feshan Au deposits. Other typical metal deposits are the Ducbo Cu-Zn, and Dianmeng Pn-Zn ores. The major metallogenic fold belts (Table 1) surrounding old continental nuclei are as follows.

(1) The Loei metallogenic belt, a multi-stage fold belt, formed after the Late Hercynian (Kamvong et al., 2014, 2007; Barr and Charusiri, 2011; Boonsoong et al., 2011). Triassic granite and porphyric andesitic intrusions caused the formation of the Phu Long, Phu Hin Lek Fai and Phu Thong Daen porphyry copper deposits (Kamvong and Zaw, 2005), the Khao Lek, Ban Bothong and Singto skarn Fe-Cu(Au) deposits, the Phu Kham porphyry-skarn Cu-Au deposit (Manaka et al., 2008) and the Chatree epithermal Au-Ag deposit (Salam et al., 2014) as well as the Pha Khum MS Pb-Zn deposit. Cretaceous to Quaternary gold deposits are related to quartz diorite porphyry.

(2) The Trungson metallogenic belt is a product of Hercynian tectono-magmatism with multi-stage granite emplacement and Fe-Cu-Au mineralization. The main deposits are the skarn iron-REE deposits of Thack Khe, the Au-Cu porphyry-skarns Sepon and Phu Kham (Cromie et al., 2010), the Fe skarns of Phalek and Phu Nhuan, Au-Cu at Tchwpone, Fe-Cu at Xieng Khouang and epithermal Cu-Au at Ban Houayxai (Manaka et al., 2014).

(3) The Da Lat metallogenic belt: Devonian to Carboniferous cap rocks overlie Proterozoic metamorphic basement with Hercynian granite intrusions (Lu et al., 2009). The major deposits include Tra Nang with W-Sn-Au, Da Trai with tin and tungsten, Chau Thai, Gia Bac, Thanh with Pb-Zn and the Da Lat bauxite deposit. The Tra Nang gold deposit occurs in Jurassic volcanics and intermediate to acid intrusive rocks in a fault zone; the Chau Thai MS Pb-Zn polymetallic deposit is related to Late Jurassic to Cretaceous volcanic rocks; the quartz vein type Sn-W deposit of Da Trai with wolframite and cassiterite is closely related to small, Late Cretaceous porphyritic granite intrusions and gold at Okvau occurs in quartz-sulphide veins (Zaw et al., 2014). The Vietnamese Balao lateritic bauxite

deposit was formed by weathering basaltic crust.

(4) The Wuliang Mountain-Nambung fault basin metallogenic belt: During Late Hercynian and Indochina, a Late Paleozoic fold belt was formed due to the closure of the ocean. Subsequent fault block movements formed a graben depression basin. Tungsten-tin mineralizations are probably related to Permo-Jurassic granite intrusions. Major gold mineralization is located in the Nanfu gold belt associated with alkaline porphyries. The Yanshanian granites and ultramafic rocks contain lead, zinc, copper and molybdenum mineralizations. The generation of gold and associated stibnite, fluorite and barite deposits is connected with basic, intermediate and acid volcanic extrusions (Morley, 2002). (5) The Zhenyuan-Jinping metallogenic belt belongs to the early continental margin deposits of the Hercynian. It is controlled by faults of the late-stage Indochina Period. In the Himalayan zone, it experienced structural processes such as nappe and ductile shear transition to strike-slip. Typical deposits are the Laowangzhai, Mojiang and Chang'an gold deposits, the Daping gold-polymetallic deposit and the Baimazhai copper, nickel deposit.

There are metallogenic zones along the Southwest Kalimantan continental nucleus (McClay et al., 2000), in which Triassic basic, intermediate and acid rocks are parental rocks to the Tayang and Air Rupas lateritic bauxites (Bardossy et al., 1994). Metallogenic fold belts developed around the ancient continental nuclei mainly including (Table 1).

(1) The eastern Malay Peninsula continental margin belt located in a Late Paleozoic margin basin. Sedimentary marine strata are sandwiched between intermediate and acid tuffs and volcanoclastics in the west of the Sunda continental nucleus and the Hercynian to Indochina Yanshanian granite intrusions. The main metal ores are tin, followed by tungsten, iron, gold, lead, zinc and bauxite. The typical deposits in this belt are the Bukit Besi magnetite-tin-skarn, the Kungai Lembing nervation tin deposits, Bukit Besi and Batu Tiga skarn tin deposit, the Lusoko greisens-type tin and the Mengpur Cu (Au) deposit.

(2) The Kuching marginal tectonic-magmatic metallogenic belt is located on the northern margin of the Sunda continental nucleus, consisting of Paleozoic to Mesozoic sediments and volcanic rocks that were intruded by Cretaceous granites and Cenozoic granodiorites and quartz diorites. The major metals are gold, copper, antimony and mercury. Bau-Pantianak is a porphyry copper gold deposit and Muyup-Mirah a epithermal gold deposit (Chung, 1993). Further ore bodies are the Muyup, Mirah and Kelian epithermal Au deposit; the Bau, Selanjan, Pantianak skarn-epithermal Au-Cu deposits, the Banyi copper-gold and the Searatak Pb-Zn deposits. Bauxite occurs at Tayang and lateritic nickel is mined at Kuching.

3.4 Orogenic Belts within Terranes with Metallogenic Associations

Many small blocks in the Tethys domain joined together to form large blocks via convergence processes. Orogenic belts were formed inside the blocks and the corresponding metallogenic provinces are called continental collision metallogenic belts. Due to subduction of plates, the arc zone collides with continental blocks to form arc-continental collision zones with corresponding metallogenic zones called arc-continental collision metallogenic belts (Table 1).

(1) The Western Malay Peninsula-continental collision metallogenic belt: This orogenic belt was formed by the collision of the Sibumasu Terrane and the East Sunda epicontinental basin in the Triassic. Tin deposits are closely related to the Late Triassic Bujang Melaka S-type granites (Cobbing, 2005). These are the Bukit Besi magnetite-skarn tin deposit, the Kungai Lembing nervation tin deposit, the Bukit Besi and Batu Tiga skarn tin deposit and the Lusoko greisens-type tin deposit. Tin deposits occur at Belitung Tikus, Kelapa Kampit (Schwartz and Surjono, 1990) and Tebrong (Schwartz et al., 1995). Mengpur is a Cu(Au) deposit (Schwartz and Askury, 1989) and Raub is an Australian epithermal gold deposit (Chu and Singh, 1986).

(2) The New Guinea Island arc-continental collision metallogenic belt: Cenozoic mafic-ultramafic rocks and adakitic intermediate to acid intrusive and eruptive rocks are widely distributed there (Mason and McDonald, 1978; Titley et al., 1978). Ore bodies are porphyry, skarn and epithermal Cu-Au deposits and lateritic nickel (cobalt). Grasberg (Pollard et al., 2005; Cloos et al., 1997), Ok Tedi and Yandera (Titley et al., 1978) are porphyry Cu-Au deposits, Ertsberg (McDowell et al., 1996; Mertig et al., 1994) and Ok Tedi (Rush and Finlayson, 1990; Davies et al., 1978; Bamford, 1972) skarn Cu-Au deposits. The Wanagon porphyry- epithermal gold deposit is a disseminated gold deposit related to metasomatism in carbonate rocks while the Bogra epithermal gold deposit is related to alkaline porphyries (Hetley et al., 1990; Rock et al., 1990; Richards and Kerrich, 1993). The low-sulfur epithermal Au-Ag(Cu) deposit in Heyden Valley is related to adakite (Carswell, 1990; Nelson et al., 1990) and the high-sulfur epithermal Cu-Au deposits in Golph and Wafi River (Funnel, 1990) are related to porphyry hydrothermal systems.

In general, there were five stages of orogenesis in Southeast Asia since the Late Paleozoic. Late Paleozoic orogenesis with Late Carboniferous to Early Permian granites resulted in Sn-W, Au and base metal deposits in East Malaysia (Schwartz et al., 1995). Early Meseozoic orogenic activities brought Sn deposits associated with Middle to Late Triassic S-type granites in the northwest of Indochina Peninsula, Southern Thailand and Western Malay Peninsula (Schwartz and Askury, 1989). Late Mesozoic orogeny in the western part of Burma and Middle and Southwest Kalimantan lead to Cu-Au ore belts related to Cretaceous intermediate to acid magmatism (Soeria-Atmadja et al., 1999). The tin deposits in Southeast Vietnam, Sumatra, Java and Kalimantan are ascribed to Paleogene porphyritic granites formed during Early Cenozoic orogeny (Zaw et al., 2014). Late Cenozoic orogeny in the center of New Guinea Island lead to Cu-Au deposits which are related to Miocene–Pleistocene adakitic intermediate to acid calc-alkaline complexes (Mason and McDonald, 1978; Titley et al., 1978).

4 SUMMARY AND DISCUSSION

Southeast Asia, an archipelagic ocean, consists of complex geologic structural units, including subduction collision zones formed either via collision between plates or during interactions between small terranes. The amalgamation of some terranes was caused or controlled by dissociation-convergence processes within the Tethys Ocean. Island arc zones still remain on the edges of some terranes. These can be further divided into suture zones, marginal fold belts and orogenic belts. Within the island arc zone there are porphyry copper-gold deposits related to arc magma mineralization and also some epithermal deposits. In suture zones, copper, nickel, and chromium deposits associated with ultramafic rocks tend to be formed. The fold belts along terrane margins, which are the active tectono-magmatic zones caused by the continuous convergence stress, are usually rich in porphyry copper-gold, hydrothermal lead-zinc and gold deposits. Orogenic belts within the terranes were formed during continent-continent collision. Granite-related tungsten-tin deposit and intermediate to acid rock-related copper-gold deposits are connected with them. The diversity and frequency of metallogenic associations in these tectonic metallogenic belts are likely to reflect the results of interaction between different small terranes with distinct basement components at multiple stages of structural transformations caused by the dissociation-convergence processes. Besides, Southeast Asia located at the where the Eurasian Plate, India-Australian Plate and Pacific Plate are joined. Interactions occurred between/among these plates with different tectonic attributes which is also an important factor for the diversity of mineralization in this region.

4.1 Deposit Assemblage and Distribution

The Southeast Asian region is located at the intersection of the Eurasian, India-Australian and Pacific plates (Metcalfe, 2013). In addition to island arcs related to plate subduction, there are also many terranes pieced together by the dissociation-convergence processes within Tethys. The former includes the Philippine, Maluku and Sunda Islands while the latter includes the West Myanmar, Nambung, Indochina and Sunda terranes, and the Fry Platform (Zaw et al., 2014). The metallogenic assemblages and their distribution are controlled by the geological structures: (1) In island arc belts with the Philippines, Maluku and Sunda as the main magmatic arcs (Metcalfe, 2011). A large number of porphyry-type copper, gold, lead-zinc deposits and epithermal deposits occur. (2) In back arc basins, the main lead-zinc, gold, silver, mercury and antimony deposits are related to by hydrothermal activities. (3) Within the terranes (continental nuclei), a variety of deposits with iron, copper and rare earth metals are closely related to metamorphic process(es) in the sedimentary basement. (4) At the continental margins, lateritic nickel and bauxite deposits are the result from weathering in the Mesozoic to Cenozoic (Sone and Metcalfe, 2008). (5) In junctional zones of terranes and suture zones along terrane boundaries such as the Prome and the Bentong-Raub suture zones and the Sarawak-Sabah ophiolite, chromite and copper-nickel sulphide deposits are related to ultramafics and mafic magmatic activity (Lu et al., 2009). Also some chromium, iron, nickel, copper, gold and tungsten-tin deposits are ascribed to collision and ensuing magmatic belts. (6) The fold belts of terrane margins, e.g., Trungson, Loei and Kuching (Zaw et al., 2014), contain hydrothermal vein-type W-Sn deposits associated with S-type granites, porphyry-related Cu-Au mineralizations and Au-bearing quartz-sulfide veins and orogenic gold deposits (Searle et al., 2012; Metcalfe, 2011; Mahéo et al., 2006). (7) In orogenic belts, orogenic-type gold deposits, tin-tungsten skarn deposits at the contacts with granite, and hydrothermal lead-zinc, porphyry-epithermal gold deposits are related to continent-continent collision (Searle et al., 2012; Metcalfe, 2011; Mahéo et al., 2006). The nature of these deposits is not only controlled by tectonic movement, magmatic activity and metamorphism at different times (Hercynian, Indosinian, Yanshanian and Himalayan periods) (Morley, 2004, 2002; Bertrand and Rangin, 2003) but also by the geochemical features of the different terranes (Lu et al., 2009).

Previous studies show that the geology for the metallogenic provinces of the Tethys and Pacific domains is quite different. The former is an orogenic system formed during the separation of Gondwana and the proliferation of Eurasia and its metallogenic system is related to continents (Yang et al., 2017; Hou and Zhang, 2014; Zaw et al., 2014). The latter is an oceanic subduction or arc-continental collision system, where ultramafic rocks dominate at the oceanic side while, towards continents intermediate to acid rocks dominate. Obviously, there are two kinds of obvious structural systems, and the latter has the retrofit effect on the former. The mineralization is closely related to the formation of these diverse magmatic rocks (Cheng et al., 2018; Zhang and Ye, 2017; Sillitoe, 1997; White et al., 1995).

4.2 Multiphase Transformation of the Metallogenic Geological Environment

The Southeast Asian region is characterized by a diversity of metallogenic tectonic units and also by a high frequency of structural transformations which can be attributed to the following factors: (i) One is that there are multiple chemical element sources from terranes with distinct origins in this region, e.g., the West Myanmar, Sibumasu and other terranes originally belonged to the Gondwana Supercontinent (Zaw et al., 2014), while the Indochina terrane has a close relationship with the Cathaysia terrane, and the core of Sunda was formed by the proliferation of the Eurasian margin in the Late Triassic (Clements and Hall, 2008, 2007). The Mesozoic accretion zones along the southern fringe of Sunda show affiliations with the Australian Plate (Wakita, 2000), the southeast part of Sunda and also Borneo lack cratonic properties (Hall, 2002; Hamilton, 1988) and the Lajang tectonic zone on northwest margin is likely to be linked to the aggregation of the Luconia Block that was driven by the expansion of South China Sea (Huchon et al., 2001; Taylor and Hayes 1983). (ii) Another factor is the multiple cycles of tectonic activities: The terranes were first separated and moved northward from the northwest margin of the Gondwana supercontinent during different geological periods, which lead to the opening of the Paleotethys and Neotethys oceans (Zaw et al., 2014). There were multiple stages and different types of subduction, arc-continent collision and continental-continental collision among different terranes (Metcalfe, 2011; Sone and Metcalfe, 2008). In the Late Paleozoic and Cenozoic re-convergence and splicing of terranes lead to different collision zones, like the Marang belt, the Chiang Mai belt and the Sagaing strike slip shear zone, etc. Different subduction-magmatic arc belts were also formed at different periods, like the Variscan subduction-magmatic arc belt in Malay Peninsula, the thrust magmatic belt in Western Malay Peninsula during the Indochina Period and the Cenozoic subduction-magma arc composite belt in the Philippines. (iii) The third factor is the complex internal structure units in each terrane, including oceanic trenches, immature island arcs, mature island arcs with continental crust and also micro terranes. Furthermore, multiple stages of island-arc magmatism occurred in some terranes (Panjasawatwong et al., 2006, 2003), and also the opening and closure of back-arc basins (Fan et al., 2010; Phajuy et al., 2005) as well as obduction of ophiolites (Yumul et al., 2008; Singharajwarapan and Berry, 2000). All these processes result in a very complex system which includes island arcs, ophiolite bands, micro blocks and large deformation zones. (iv) The dynamic variety of the structural transformation in Southeast Asia: after the amalgamation of the terranes, arc can develop into suture zone or tectonomagmatic belt, further into marginal fold or orogenic belt. Therefore, the above elements are likely to provide multiple sources of ore-forming elements, and also lead to different stages of differentiation as well as multiple-stage transformation of the metallogenic geological environment.

4.3 Metallogenic Belt Division and Problems

According to the distribution of secondary tectonic units and arc magmatic tectonic belts, 24 metallogenic belts were identified so far in Southeast Asia (Table 1) whereby their main metallogenic combinations reflect the attribute of the main tectonic event(s). The metallogenic belts are classified as follows: (1) Island arc metallogenic belts: They include the Myitkyina-Prome composite island arc metallogenic belt, the Lancang-Chiang Mai superimposed island arc metallogenic belt, the Sumatra-Java arc metallogenic belt, the Philippine-North Sulawesi subduction-arc metallogenic belt, the eastern Philippine-Maluku subduction-magma arc metallogenic belt and the Timor Island structural complex metallogenic belt; (2) Arc-continental collision zones: They include the Bhamo-Mandalay-Phuket arc-continent collision metallogenic belt, the eastern Kalimantan arc-continental collision metallogenic belt, the Sulawesi arc-continental collision hyperplastic metallogenic belt, the Western Philippine arc-arc collision metallogenic belt and the New Guinea Island arc-continental collision metallogenic belt; (3) Back arc basins: They comprise the Lashio-Taunggyi fault block metallogenic belt and the Wuliang Mountain-Nambung fault depression basin metallogenic belt; (4) Continent-continent collision structural-magma belts which are often accompanied by suture zones like the Naga-Rakhine structural-magma metallogenic belt, the eastern Malay Peninsula precontinental arc magma metallogenic belt and the Kuching epicontinental structural-magma metallogenic belt; (5) Margin fold belts: They include the Zhenyuan-Jinping fault metallogenic fold belt, the Loei epicontinental metallogenic fold belt, the Bien Hoa-Da Lat epicontinental metallogenic fold belt, the Trungson epicontinental metallogenic fold belt and the Mojiang-Thanh Hoa epicontinental metallogenic fold belt; (6) Continent-continent collisional orogenic belts: They are the western Malay Peninsula continental-continental collision metallogenic belt, and other collisional orogenic belts (superimposed on other tectonic belts); (7) Continental nuclei: They include the Southwest Kalimantan continental nucleus metallogenic areas and the Kon Tum mineralization area with continental nucleus uplift areas. It should be noted that within one structural metallogenic belt, the corresponding ore deposits may have formed at different times because of multiple stages of structural transformation during different geological periods. The main purpose of this paper is to describe and summarize the relationships between the main metallogenic assemblages and metallogenic structures. We are not able to make detailed geochronological distinctions for most ore deposits in the metallogenic belts.

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