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Tectonics and metallogeny of mainland Southeast Asia — A review and contribution

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ABSTRACT

The Southeast Asia region is endowed with a diversity of mineral resources, notably porphyry-related skarn, epithermal and sediment-hosted/orogenic gold deposits. Formation of these deposits was associated with a long and complex tectonic history of Gondwana supercontinent break-up, arc magmatism, backarc basin development, together with arc–continent and continent–continent collisions that created the present-day mainland SE Asia. This paper summarizes historical and current SE Asian geological research and ore deposit studies. Here we present a new tectonic and metallogenic model for Phanerozoic mainland SE Asia. From this model, we conclude that incipient arc/backarc basin magmatism is the key to the formation of many important ore deposits in the Truong Son and Loei fold belts, the two major metallogenic belts in mainland SE Asia. In addition, Triassic to Cenozoic arc–continent and continent–continent collisions have led to the formation of many sediment-hosted/orogenic gold deposits in the Sukhothai and the Sibumasu terranes. Oblique Cretaceous to Recent subduction along the Andaman–Sunda trench was responsible for gold and copper–gold–molybdenum porphyry and epithermal mineralization along the Kawlin–Wutho–Mt Popa arc in Myanmar in the north and the Sumatran volcanic arc in the south. We anticipate that the present emphasis on exploring for shallower level epithermal deposits will increasingly lead to exploration for deeper level porphyry- and porphyry-related skarn systems in the coming decades.

1. Introduction

This introductory paper provides a summary of the geology and tectonics, major ore deposits and the potential for mineral exploration in mainland SE Asia, which includes Cambodia, Laos PDR, Myanmar, Peninsular Malaysia, Sumatra (Indonesia), Thailand, Vietnam and Yunnan (China). This special issue "Tectonics and metallogeny of mainland SE Asia" aims at resolving some of the major outstanding tectonic and metallogenic problems in SE Asia, particularly regarding the timing and processes concerning the rifting of SE Asian crustal blocks derived from Gondwana and their amalgamation into present-day SE Asia, as well as how these processes and their temporal superimposition led to ore deposit formation. We have tackled these problems from a wide range of perspectives, notably geochronology (e.g., U–Pb zircon and monazite dating), geochemistry (whole rock, mineral and isotope), structural geology, sedimentology, paleontology, metallogeny, modern tectonic analogs and regional geological correlation.

2. Regional geological and tectonic setting

2.1. Background

Mainland SE Asia is endowed with a diversity of mineral resources and consists of a collage of continental blocks or fragments, together with accreted volcanic arcs/backarc basins. Major fragments, e.g., Indochina, Sibumasu and West Myanmar terranes, rifted away from the northwestern Gondwana margin at different periods in the Phanerozoic, and led to the opening of the Palaeo-, Meso- and Neotethyan (or Cenotethys) Oceans (Metcalfe, 2011, 2012, 2013). In this introductory paper, we use the non-genetic term "terrane" to describe tectonic units such as block, massif, orogenic belt or microplate, with each terrane having a distinctive tectonostratigraphic and magmatic history following Howell (1995) and Burrett et al. (2014).

Throughout the long history of the Gondwana supercontinent break-up and subsequent mainland SE Asia amalgamation, various subduction and arc–continent/continent–continent collisions and interactions have occurred among these SE Asian terranes and fold belts (e.g., Sone and Metcalfe, 2008; Metcalfe, 2011). The associated

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magmatism, tectonism and metamorphism have generated many mineralized fold belts at most of the terrane margins, with major ones including the Truong Son and Loei fold belts (Fig. 1).

The northward-drift and subsequent accretion of these fold belts and terranes onto the southern Eurasia margin and the amalgamation of mainland SE Asia have produced multiple episodes of arc magmatism (e.g., Panjasawatwong et al., 2003; Tran et al., 2008; Liu et al., 2012), opening and closure of backarc basins (e.g., Phajuy et al., 2005; Fan et al., 2010) and ophiolitic obduction (e.g., Singharajwarapan and Berry, 2000; Yumul et al., 2008). These accreted island arcs, ophiolitic slivers and broad deformation zones delineate the boundaries of the major continental terranes. In part, these deformation zones or fold belts represent the sites of former ocean basins or suture zones. Throughout the journey from NW Gondwana to present-day SE Asia, complex and multiple tectono-magmatic–metamorphic–hydrothermal interactions in and between the SE Asia continental fragments were fertile 'breeding grounds' for a wide variety of mineral resources. Major types of mineral resources in the region include sediment-hosted/orogenic gold, porphyry-related copper (gold) skarn, epithermal deposits, intrusion-related gold, volcanic-hosted massive sulfide (VHMS) deposits, tin–tungsten, rare earth element (REE) and gemstone deposits. In addition, there is substantial potential for porphyry copper–gold–molybdenum and iron oxide–copper–gold (IOCG) deposits (Khin Zaw, 2008a,b, 2009, 2012).

2.2. Indochina Terrane

The Indochina Terrane is the largest tectonic unit in mainland SE Asia (Fig. 1). The terrane borders the South China Terrane along the Ailaoshan–Song Ma Suture to the north and northwest. The Truong Son Fold Belt is located along the northeastern margin of the Indochina Terrane, and contains mainly Palaeozoic marine volcanic rocks and Early Permian–Triassic granitoids and volcanics (Carter and Clift, 2008; Lepvrier et al., 2008, 2011). The Tam Ky–Phuoc Son Suture marks the boundary between the Truong Son Fold Belt and the highly-metamorphosed Kontum 'Massif' in central Vietnam (Tran et al., 2014). Recent geochronological studies have yielded a Mesoproterozoic inherited core (U–Pb zircon: ca. 1404 Ma; Nam et al., 2001) with Middle

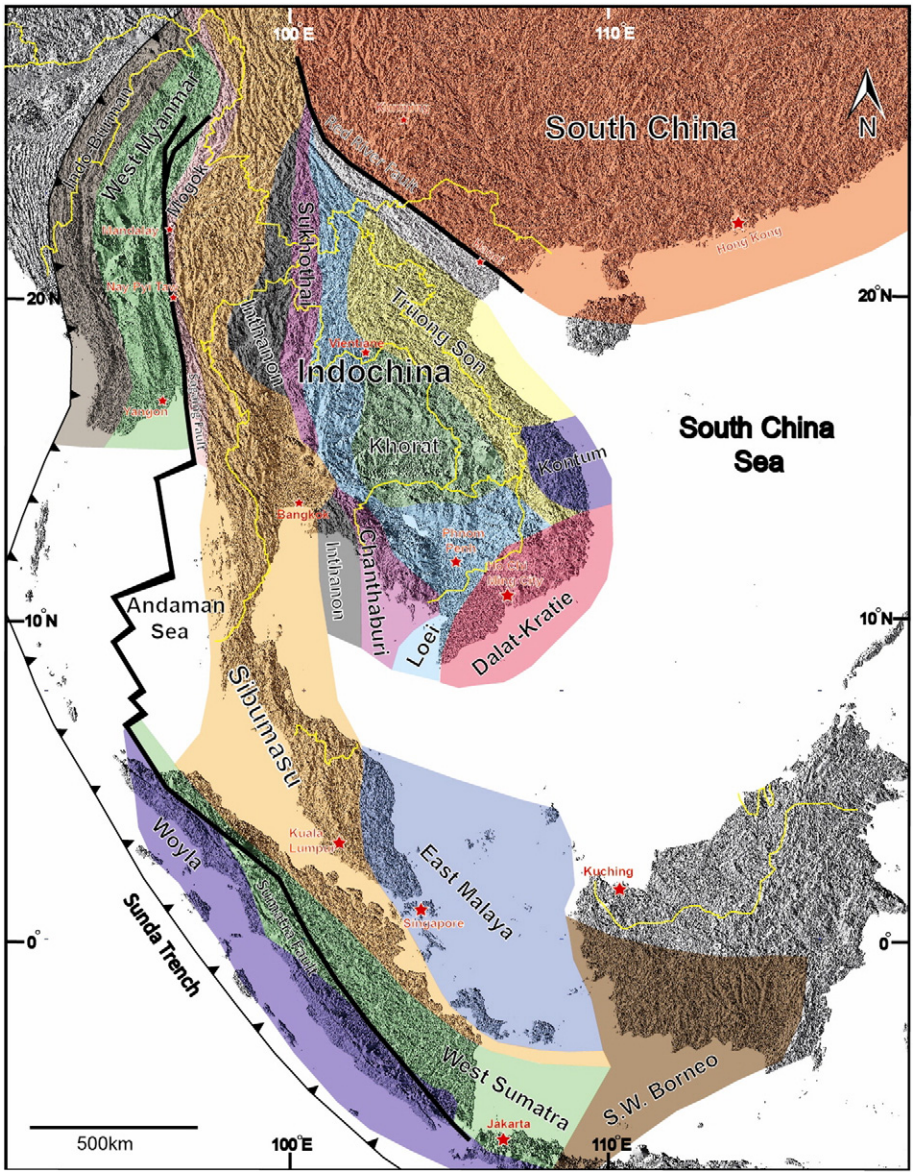

Fig. 1. SE Asia regional tectonic map showing major component terranes and fold belts.
SRTM data from http://srtm.csi.cgiar.org/; geological map modified after e.g., Barber and Crow (2003), Metcalfe (2013) and Burrett et al. (2014).