ABSTRACT

The Late Paleozoic – Mesozoic geological evolution of the South East Asian metallogenicprovince including Bangka and Belitung islands is marked generally by S-type granitoid emplacement coevally witha regional tin mineralization. However, Sibolga Granitoid Complex of North Sumatra shows contrastingly characteristic of A-type granitoid.The FeO$_{(total)}$/MgO ratio versus SiO_2 show an effective discriminant and most granitoids of Sibolga Complex falling in A-type field as well as higher ratios than the I- or S-type granitoids. Eight facies have been identified based on texture and mineralogy, biotite granites, biotite syenites, hornblende syenites, rhyolite, dacite, trahyte and trahy-andesite. The biotite granites occupy most of the granitoid complex, whereas biotite syenites and meta-rhyolites are exposed as an east-west trending belt in the central part of the pluton. Their chief minerals include quartz, K-feldspar (mostly microcline), plagioclase albite, biotite, minor hornblende and accessory minerals (monazite, zircon, allanite, fluorite and uraninite).The Sibolga granitoid has invaded the rocks of Kluet Formation, radiometric dating of the granitoid by K/Ar methods on biotite yields ages of 219±4 Ma and 211.5±2.6 Ma by Rb/Sr on biotite. The pluton is composed of equigranular biotite granite and porphyritic biotite syenite (Late Permian – Late Triassic) by mafic dyke. The granitiod rocks, show SiO_2 contents of ~69-76%,and are enriched in alkalis, highRb, Zr and Ga with high Ga/Al ratios, but depleted in Ba, Sr and transition metals. The rock chemistry indicated by slightly, metaluminous to peraluminous composition. Other geochemical signatures suggest that the granitoid belong to transisitional environment between late orogenic and anorogenic as well as within plate environment. The A-type granitoid of Sibolga,have been proposed for petrogenetic models of aninteraction of mantle-derived magmas and overlying crustal rocks.The comprehensive petrology and geochemical analyses that coupled with Late Paleozoic-Mesozoic history of Sumatra, suggested that the A-type granitoid of Sibolga associated with anorogenic or rift related environment. The facts of extensive outcrop of mafic dyke swarms and enclaves surrounding Aloban area support also the contribution of granitoid magma mingling with the upper mantel materials. Molybdenum anomalies in rhyolite of Rampah area further implythat the Sibolga granitoid magmas were most probably derivedby partial melting of Late-Paleozoic lower-crustal rocks. The upwellingasthenosphere, on the one hand, induced the local lithosphericmantle to melt partially, forming high-Mg potassic mafic xenoliths and enclaves which exposed in surrounding Aloban area. Pulsatory injection of suchhigh-temperature magmas into the mafic mantel crustal sourceregion induced them to partially melt and generate the A-typemagmas of the Sibolga granitic rocks.The SiO_2-Fe_2O_3/FeO diagram distinguishes Magnetite - from Ilmenite-series including a comparation of three major magmatic-hydrothermal ore-bearing environment (copper, molybdenum, and tin porphyries-granites). The bulk of the Sibolga igneous rocks are falling in the Magnetite-Series and occupied an area copper- through molybdenum-porphyries and clearly different series compared to SE-Asian Tin Granite Belt and Erzgebirge-Germany. All samples from the tin granites province are falling in the Ilmenite-Series. A gravity anomaly map of NorthSumatra has been constructed using 2400 gravity stations and 2.67 gr/cc*

Bouger density. The area around the discontunity is characterized by a very low gravity anomaly closure in the center. It indicates the existence of alow density body of mantle material intruded by a higher density igneous material in the center. The maps density variation with depth constructed from 3D deconvolution of gravity anomalies and a 2.5 D gravity model, show that this patern reflects the thinning of the crust beneath North Sumatra are due to regional tensional stresses of the mantle at a depth of approximately 20 km. Integration of these geophysical results and new geochemical information on the granitoids and the regional geology leads to a tectonic model that has an implication for other parts of rifted Gondwana land. Subsequent gravitational collapse during Late Permian to Late Triassic of the in active slab resulted in the production of large amounts of granitoid and mafic dyke swarms and enclaves. The rock chemistry shows relatively high Na_2O and K_2O contents. Thorium content is moderate, whereas uranium content is moderate to high with moderate Th/U ratios (close to 4). These features, including the presence of uranium-bearing accessory minerals suggest good prospect for uranium mineralization. The three granitoid facies and meta-rhyolites differ from each other in their nature of uranium distribution; uranium is contained mainly in the accessory minerals of the granitoid facies, whereas the meta-rhyolite shows uranium mineralization along fractures as product of injection of uranium-molybdenum rich hydrothermal fluids. Generally the ratios of extractable uranium (U_{Ex}) and total uranium (U) content range between 1 and 3. Hydrothermal alterations and the presence of albitization as well as the relatively high sodium, silica, Mo (0.23 wt.%) and U in rhyolite of Rampah show similar characteristics with the famous Henderson porphyry -Mo deposit of of USA that associated with A-type granitoid intrusion.

ABSTRAK

Evolusi geologi Paleosoik Akhir – Mezosoik pada provinsi metalogenesis Asia Tenggara termasuk kepulauan Bangka-Belitung umumnya dicirikan oleh endapan granitoid tipe-S dengan mineralisasi timah.Walaupun demikian, Kompleks Granitoid Sibolga di Sumatra Utara memperlihatkan karateristik yang sangat berbeda, yaitu granitoid tipe-A.Pluton granitoid Sibolga terletak berbatasan dengan pantai barat Sumatra Utara. Berdasarkan identifikasi tekstur dan mineralogi, daerah penelitian dibagi menjadi empat fasies, yaitu granit biotit, sienit biotit, sienit hornblende dan meta-volkanik. Granit biotit mencakup fasies yang terluas di daerah penelitian, sedangkan sienit biotit dan meta-volkanik terdapat dibagian tengah dengan arah penyebaran barat-timur.Mineral-mineral utama pembentuk batuan terdiri dari kuarsa, K-felspar ortoklas, mikroklin, plagioklas albit, biotit, dengan sedikit hornblende.Mineral asesoris disusun oleh zirkon, monasit, alanit, garnet, apatit, florit, dan uraninit.Granitoid Sibolga mengintrusi batuan meta-sedimen berumur Karbon Formasi Kluet. Penentuan umur radiometri menggunakan metoda K-Ar pada biotit granit menghasilkan 219±4 juta tahun sedangkan Rb-Sr pada sienit biotit 211,5±2,6 juta tahun. Pluton Kompleks Granitoid Sibolga yang berumur Perm Akhir-Trias Akhir ini dipotong oleh intrusi berupa korok batuan mafic. Batuan granitoid Sibolga umumnya mempunyai kandungan SiO_2 antara 59-76%, alkali total relative tinggi 8-11%, kaya akan Rb, Zr dan Ga serta nilai perbadingan tinggi Ga/Al, tetapi rendah kadar Ba, Sr dan logam transisi. Pengayaan Mo-U dapat dijumpai di beberapa tempat. Berdasarkan saturasi aluminina, batuan Sibolga teridentifikasi sebagai batuan transisi antara metaluminus ringan hingga peraluminus dengan kisaran A/CNK 0,8 hingga 1,3. Ciri-ciri geokimia lainnya adalah granitoid Sibolga cenderung berasosiasi dengan lingkungan tektonik *late-orogenic* hingga *anorogenic* serta *within plate granite (WPG).* Dibantu dengan bukti-bukti dilapangan berupa himpunan mafic enclaves dan senolit di sungai Bair, daerah Aloban, granitoid tipe-A mengindikasikan pengaruh interaksi antara magma dengan mantel bagian atas. Selain kehadiran mafic enclaves, diferensiasi magma granitoid dengan kontribusi material mantel diperkuat oleh adanya mineralisasi hidrotermal molybdenum dan uranium di sungai Rampah, Sitahuis.Injeksi magma bertahap dari kerak bagian bawah bertemperatur relativ tinggi dan membawa material mantel yang sepenuhnya belum padat kemungkinan menyebabkan magma mingling dan asimilasi yang menghasilkan komposisi granitoid tipe-A. Diagram diskriminan menggunakan SiO_2-Fe_2O_3/FeO pemisah seri magnetit dan ilmenit serta membedakan lingkungan mineralisasi porfiri tembaga (Cu) dan molibdenum (Mo) dengan porfiri timah (Sn), memperlihatkan kecenderungan granitoid Sibolga pada porfiri Cu-Mo yang sangat berbeda dengan jalur Asia Tenggara yaitu porfiri Sn. Anomali negatif (2,5 gram/cm^3) ditengah Sumatra-Utara dari pengolahan gayaberat 2400 statision pengamatan, mengindikasikan penipisan kerak sekitar 20km dibawah permukaan. Gabungan antara indikasi penipisan kerak ditengah Sumatra Utara dengan interpretasi petrologi serta geokimia yang menggolongkan granitoid Sibolga tipe-A, late orogenic – anorogenic dan *Within Plate Granite* serta penemuan mafic enclave dapat menguatkan bahwa granitoid Sibolga atau sebagian dari Sumatra Utara berasosiasi dengan pemekaran di pedalaman kontinen (*continental rifting*). Asal muasal

granitoid tipe-A di Sibolga kemungkinan berasosiasi dengan saat mulai pecahnya kontinen besar Gondwana pada Perm Akhir-Trias Akhir yang dilanjutkan dengan pembentukan jalur intrusi dan volkanik .Mineralisasi urat hidrotremal Mo-U yang berasosiasi dengan riolit yang kaya silika mengindikasikan kemiripan dengan endapan porfiri Mo di Henderson – Amerika yang pluton granitoidnya juga tipe-A. Pengayaan Mo di Sibolga hingga mencapai kadar 0,23% menunjukan difererensi magma tingkat lanjut yang dimulai dari kerak yang dalam atau mantel bagian atas.