Bulletin of the Geological Society of Malaysia, Volume 62, December 2016, pp. 1 – 6

Durbachite-like melagranite in Taiping Pluton of Bintang Batholith, Peninsular Malaysia

Long Xiang Quek[1]*, Azman A. Ghani[1], Mokhtar Saidin[2] & Zuhar Zahir Tuan Harith[3]

[1]Department of Geology, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2]Centre for Global Archaeological Research, University Sains Malaysia, 11800 Pulau Pinang, Malaysia
[3]University Teknologi Petronas, 31750 Tronoh, Perak, Malaysia
*Corresponding author: forestbreeze90@gmail.com

Abstract: Durbachite-type rocks are recently found in Taiping Pluton, Bintang Batholith, Peninsular Malaysia. Taiping durbachite-type rocks can be described as K-Mg rich, megacrystic to porphyritic, coarse grained melagranite. The melagranite also contain numerous biotite-rich enclaves/xenoliths of igneous appearance. Petrographic examination shows the rocks contain granite felsic mineral proportion with high amount of biotite, amphiboles with pyroxene relics and traces of pyroxene. The samples are ultrapotassic and most are intermediate in SiO_2 composition (59.2 – 65.5 wt. %) but show high MgO (3.0 – 6.4 wt. %) and Cr (233 – 568 ppm). They are also high in certain incompatible elements (Ba, Zr, Rb, Th) and LREE. In general, the durbachite-type rocks geochemistry is comparable to the Central European durbachite suite. The durbachite-type rocks petrogenesis is believed to be complex, requiring a crustal component and enriched lithospheric mantle source. Taiping Pluton itself is located at the Sibumasu plate and U-Pb zircon dating results (218 ± 1.3 Ma) indicate that the melagranite are emplaced during the Triassic Sibumasu-Indochina collision (200 – 220Ma), which most of the Main Range Granite province are emplaced. It is possible that the Taiping durbachite-type rocks emplacement setting is similar to Central European durbachite suite.

Keywords: durbachite, Taiping Pluton, Main Range Granite province

INTRODUCTION

Durbachite are coarse, porphyritic ultrapotassic plutonic rock which ranges from melagranite to melasyenite and sometimes up to ultramafic rocks. Such rocks are typically unique to Central Europe (Sauer, 1983; Holub, 1989; Ferre & Leake, 2001). They contain large phenocrysts of alkali feldspar, with high amount of Mg-rich biotite, plagioclase and some light green amphibole and pyroxene relics (Parat *et al*., 2010). Ferre & Leake (2001) listed the following assemblage minerals in durbachite: K-feldspar, quartz, plagioclase, biotite, amphibole, ± orthopyroxene ± clinopyroxene, with titanite, apatite and pyrite. Variety of cognate mafic microgranular enclaves (amphibole, biotite, ± pyroxenes) are commonly found within durbachite (Bowes & Kosler, 1993; Kotkova *et al*., 2010).

Durbachite SiO_2 content typically ranges from (55 – 70 wt. %) with the combination of high K_2Oc contents (4 – 9 wt. %) and Mg numbers (von Raumer *et al*., 2013) but low Na, Ca and Sr content (Holub, 1997). Their CaO/MgO ratio is usually less than 1 (Kusiak *et al*., 2010) and the A/CNK values are usually metaluminous (Janousek *et al*., 2000). They also display high content of incompatible elements (in certain LILE and HFSE) (Janousek *et al*., 1997) despite their relatively primitive nature in respect to elevated content of Mg, Cr and Ni (Holub, 1997). European durbachite high LILE/HFSE ratios and high Th/Ta support their parental magmas derivation from partial melting of subduction modified lithospheric mantle source (Holub, 1997; Holub, 2001).

This paper will report the durbachite-like geochemistry in the amphibole-bearing melagranite of Taiping Pluton, Bintang Batholith northwest of Peninsular Malaysia. The melagranite is known as Kupang and Buloh Pelang Granite (Burton, 1970; Foo, 1990; Cobbing *et al*., 1992) show many field and geochemical characteristics similar to the European Durbachite. The Batholith is part of the Main Range Granite province, Western Belt of Peninsular Malaysia which was regarded as a world standard for collision S-type granite (Pearce *et al*., 1984).

GENERAL GEOLOGY

The granite province of Southeast Asia are subdivided into (a) Eastern (East Peninsular Malaysia), (b) Main Range (South Thailand-West Peninsular Malaysia), and (c) Northern (Northern Thailand) and Western (Southwest Thailand-East Myanmar) granite provinces (Cobbing *et al*., 1992; Ghani *et al*., 2013).

The Eastern and Main Range Granite provinces primarily reside in Peninsular Malaysia, separated by the Bentong–Raub suture (Hutchison, 1994; Metcalfe, 2013). The Eastern granite province consists of Permian to Triassic granitoids which includes gabbro, diorite, tonalite and monzogranite (Cobbing *et al*., 1992; Ghani *et al*., 2013). The Triassic Main Range Granite province is composed of mainly granite to granodiorite (Ghani *et al*., 2013). Main Range province granitoids are dominated by S-type granite (Liew, 1983; Cobbing *et al*., 1992), formed during Triassic continental collision between Sibumasu and Indochina (Sevastjanova *et al*., 2011; Searle *et al*., 2012). It is only recently, the province is suggested to have both I and S-type characteristics (Ghani, 2000; Ghani *et al*., 2013).

Main Range Granite province consists of two major batholiths, the Main Range and the Bintang batholiths, plus several outlying plutons (Figure 1). Biotite granites are

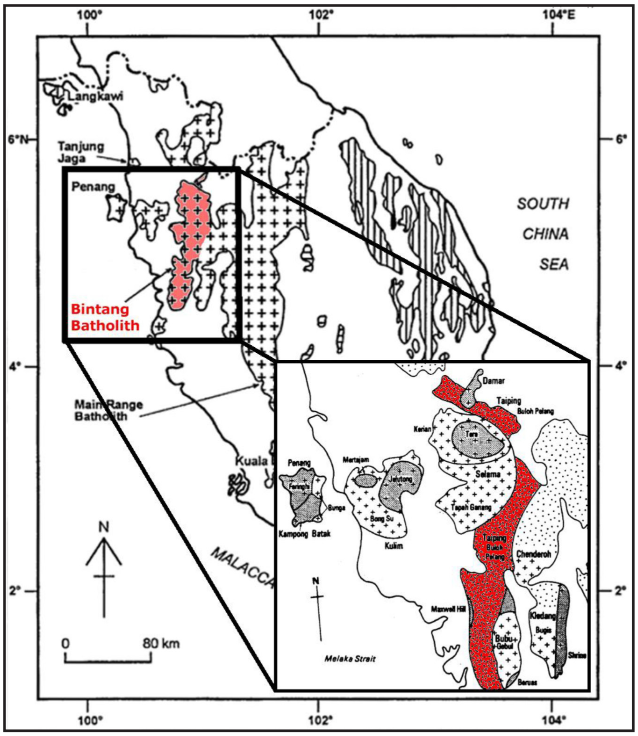

Figure 1: The location of Bintang Batholith in Peninsular Malaysia. Blow out: Red, Taiping pluton on Bintang Batholith

present in both batholiths but amphibole-bearing granites are more common in Bintang Batholith. The Bintang Batholith located at the northern part of the Main Range and form an N-S elongated shaped Batholith and consists of 4 main plutons that is Selama, Taiping, Bubu and Damar (Cobbing *et al*., 1992).

Taiping Pluton, an extremely long and narrow intrusion, houses most of the amphibole-bearing granites. Cobbing *et al*. (1992) divided the Taiping Pluton to two main facies, amphibole-bearing melagranite and the megacrystic tourmaline-bearing Maxwell Hill microgranite. The amphibole-bearing melagranite is known as Kupang Granite (Figure 2a) (Burton, 1970) in the northern part, is separated from the southern part, which is known as Buloh Pelang Granite (Figure 2b) (Cobbing *et al*., 1992), by the Bok Bak fault (Burton, 1970). The Buloh Pelang Granite and the Kupang Granite is (Cobbing *et al*., 1992) characterised by extremely coarse megacrystic, biotite amphibole melagranite. Both melagranite are melanocratic and contain amphiboles with pyroxene cores and enclaves containing biotite, amphibole, clinopyroxene and orthopyroxene. Euhedral K-feldspar phenocrysts are often aligned parallel to the microgranular enclaves.

PETROGRAPHY

The common mineral assemblage in Taiping amphibole-bearing melagranite (Figure 2c) is K-feldspar + plagioclase + biotite + quartz + amphibole (Figure 2d) ± orthopyroxene ± clinopyroxene. Accessories minerals are: apatite, zircon, opaque minerals, titanite and allanite. The twinned, perthitic K-feldspar phenocrysts show a patchy internal texture and inclusions of plagioclase, biotite and quartz, indicator of K-feldspar growth during magma evolution. Plagioclase phenocrysts with patchy texture are sometimes found. Quartz is small and anhedral. Pyroxene relics in amphibole are often found (Figure 2e, 2f). Zircon is enclosed mostly in biotite and amphibole. Titanite is often shapeless and strained; though euhedral grains do occur.

GEOCHEMISTRY

Geochemical analyses are carried out at Acme Analytical Laboratories, Canada. The 39 amphibole-bearing melagranite samples underwent $LiBO_2$ fusion followed by X-ray fluorescence (XRF) analysis for major elements and loss of ignition (LOI). Trace elements are determined by inductively coupled plasma mass spectrometry (ICP-MS).

Taiping amphibole-bearing melagranite can be considered as ultrapotassic, following Foley *et al*. (1987) ultrapotassic chemical screen (K_2O > 3 wt. %, K_2O/Na_2O > 2 and MgO> 3 wt. %). These rock are metaluminous to weakly peraluminous (A/CNK = 0.65 – 1.06) with an intermediate SiO_2 range from 58.4 to 68.3 wt. %. They have a high magnesium number (54.24 – 66.38) comparable to intermediate durbachite (Janousek *et al*., 2000). Their CaO/MgO ratio falls between 0.41 and 1.09, similar to durbachite where the CaO/MgO ratio is less than 1 (Kusiak *et al*., 2010).

Taiping amphibole-bearing melagranite is high in most of the incompatible elements (Rb, Ba, Th, La, Ce, Zr) and transition metals (Cr, Ni, V, Zn). Typical durbachite have high Th/U value, usually up to 12-13 (Scarrow *et al*., 2009), as they are strongly enriched in Th and high Rb/Sr (0.7 to 1.2) (Holub, 1997). The amphibole-bearing melagranite have similar features; they are generally enriched in Th relative to U with Th/U ratio that spread between 2.38 and 12.8, also, they show high Rb/Sr ratio (0.82 – 6.64).

The chondrite normalized rare earth element (REE) diagram after Boynton (1984) (Figure 3) shows the Taiping amphibole-bearing melagranite REE pattern compared with the European durbachite suite. Overall, the patterns do not differ much. Taiping amphibole-bearing melagranite shows a larger LREE range and a more negative Eu-anomaly compared to the typical durbachite. The difference in Eu-anomaly indicates a slightly stronger plagioclase fractionation (Weill & Drake, 1973). Still Taiping amphibole-bearing melagranite show typical durbachite features (Janousek *et al*., 1997; Holub, 1997): high ΣREE, high LREE/HREE ratios, elevated LREE content and moderate Eu-anomaly (Eu/Eu*).

The primitive mantle normalized multi-element variation diagram (Figure 4) after Mcdonough & Sun (1995) shows the geochemical patterns for the Taiping amphibole-bearing melagranite and European durbachite suite. The patterns show elevation in some LILE such as Cs, Rb, Ba and HFSE such as Th, U, Zr but show clear Ta-Nb-Ti (TNT) negative anomaly relative to the adjacent elements.

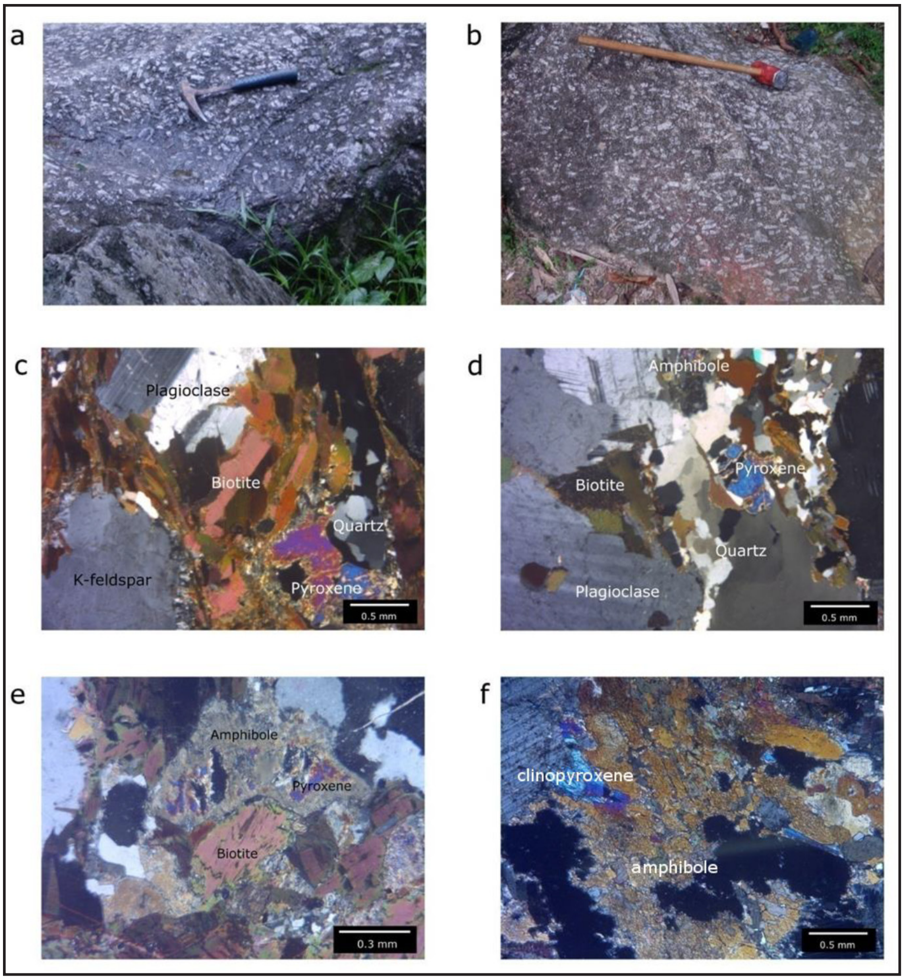

Figure 2: (a) Amphibole-bearing melagranite at Bukit Berapit. Scale: Hammer (30 cm), (b) Melagranite at Bukit Berapit. Scale: Hammer (1.0 m). Thin section photomicrograph of (c) Melagranite rock from Lenggong, (d) Melagranite rock from Bukit Berapit, (e) Large amphibole in a melagranite rock from Baling-Gerik road, (f) Amphibole with pyroxene relics surrounded by biotite. Scale bar is 0.5 mm across.

GEOCHRONOLOGY

Age dating on an amphibole-bearing melagranite sample from Bukit Berapit was performed by laser ablation (LA) ICP-MS (in Pacific Centre of Isotopic and Geochemical Research (PCIGR), Vancouver, Canada), using methods after Tafti *et al*. (2009). The ICP-MS time-integrated signals were analysed using Iolite software (Paton *et al*., 2011). Final interpretation and plotting of the analytical results (Figure 5) are done using Ludwig (2003) ISOPLOT software. The Th/U ratios for BB-1 range from 0.11 to 0.93. All of the analyses are concordant, and the $^{206}Pb/^{238}U$ ages for BB-1 scatter between 213.3 ± 5 and 223.5 ± 7.6 Ma, giving a weighted mean age of 218.0 ± 1.3 Ma.

DISCUSSION

Geochemical and field characteristic of this amphibole-bearing melagranite is similar to the K-Mg rich Durbachite series from Central Europe. It contain hornblende, clinopyroxene, orthopyroxene and geochemically have intermediate to high SiO_2 content, high Rb/Sr, Th, LREE, LILE and low Ca and Na. Comparison of the Taiping amphibole-bearing melagranite with durbachite from Central Europe are shown in Table 1 (Sauer, 1983; Holub, 1989, 1997; Ferre & Leake, 2001; Janousek *et al*., 1997; Janousek & Holub, 2007; von Raumer *et al*., 2013).

In other part of Peninsular Malaysia, Benom high Ba-Sr alkali syenite associated with monzonite and gabbro (Ghani, 2006) that form a large part of Benom Pluton could be equivalent to the Taiping amphibole-bearing melagranite. Although they share the same age, U-Pb zircon age of the Benom granite range between 213 to 224 Ma, both suite of rocks occur in a different tectonic setting. The Taiping melagranite occur in Sibumasu terrane and the Benom high Ba-Sr syenite occur in a Indochina terrane, both terrane separated by segment of the Devonian to Middle Triassic Palaeo-Tethys ocean, known as Bentong Raub Suture. Occurrence of these suite of highly potassic rock in both side of the suture suggested that the mantle penetration during the subduction in both side of the suture.

Previous workers (Janousek *et al*., 1997; Holub, 1997; Janousek & Holub, 2007; von Raumer *et al*., 2013) have suggested that durbachite petrogenesis requires a crustal component with a lithospheric mantle source with a complex history of depletion (indicated by low Na, Ca, Sr, Ca/Mg and relatively high Si) (Holub, 1997) and re-enrichment by hydrous, K-rich, LILE- and LREE-bearing fluids. The geochemical similarity of the Taiping amphibole-bearing melagranite with rocks from Central Europe suggests comparable sources and formation processes; through melting of anomalous lithospheric mantle sources,

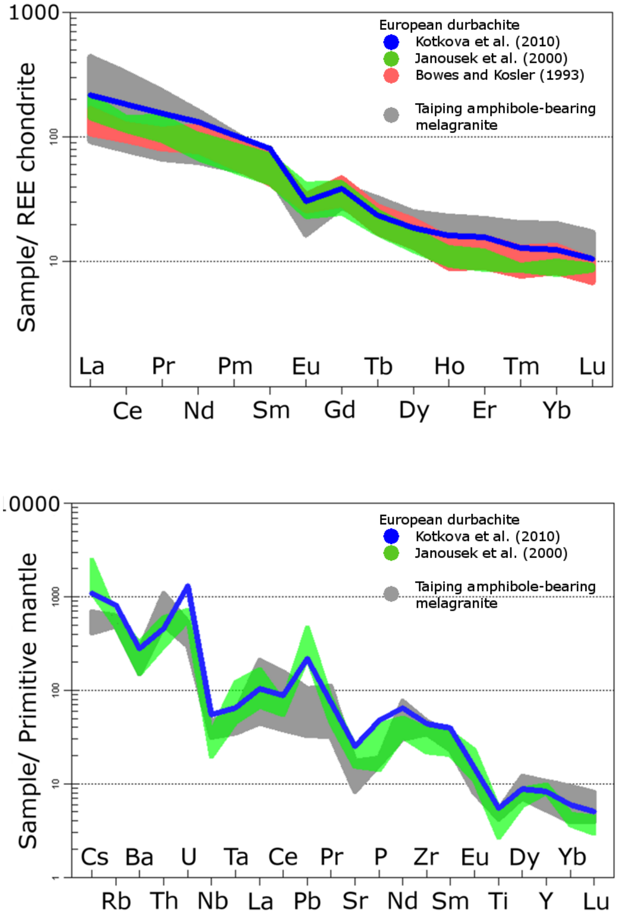

Figure 3: Top: Chondrite normalized REE plot (Boynton, 1985). Grey: Taiping "durbachite"; Blue: Trebic mafic durbachite (1 sample, melagranite) from Kotkova *et al*. (2010); Green: CertovoBremeno suite from Janousek *et al*. (2000); Red: Bowes and Kosler (1993) durbachite. Bottom: Primitive mantle normalized multi element variation diagram (Mcdonough and Sun, 1995). Grey: Taiping "durbachite"; Blue: Trebic mafic durbachite (1 sample, melagranite) from Kotkova *et al*. (2010); Green: Certovo Bremeno suite from Janousek *et al*. (2000).

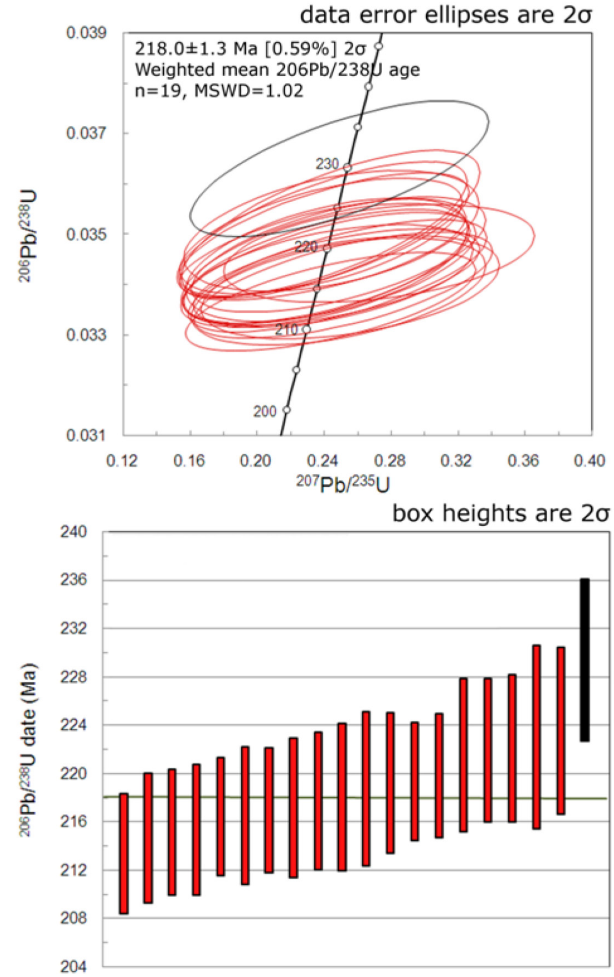

Figure 4: Top: Concordia diagram with the results of zircon dating. Bottom: Weighted average plot with the results of zircon dating.

metasomatized and contaminated by crustal material. Phlogopite harzburgite (phlogopite-clinopyroxene-bearing metasomatized peridotite) has been suggested as a possible source for Central Europe durbachite as it is strongly enriched in K, Rb, Cs, Th, U and some other incompatible elements (Holub, 2001; Parat *et al*., 2010).

The tectonic model (Mitchell, 1979; Metcalfe, 2000, 2011; Sevastjanova *et al*., 2011; Searle *et al*., 2012; Oliver *et al*., 2013) explain that the Main Range Granite province is emplaced during the collision between Sibumasu and Indochina around late Triassic (200-220 Ma), where the Paleo-Tethys Ocean from Sibumasu side subducted under Indochina plate before the collision. This places the Taiping durbachite-type suite (218.0 ± 1.3 Ma) early with respect to the collision event.

It is possible for extension to occur during the early collision on the Sibumasu side. Slab pull created by subduction of a higher density oceanic lithosphere could results in extensional deformation within the subducted slab below the area of the slab bend (Sacks & Secor, 1990). The durbachite source will then be heated by the upwelling of asthenospheric mantle from lithosphere necking, creating durbachite-type magma. If both continents continue to converge, the compressive tectonic regime can be re-established (Sacks & Secor, 1990). This can cause such extension episode to be short lived.

CONCLUSION

Concluding, we present new petrographic and geochemical data, suggesting the existence of durbachite type magmatic rocks of Triassic age in the Taiping Pluton of Peninsular Malaysia. They are comparable in their genetic evolution to those observed in the Central European Variscan domain. A proper tectonothermal event (e.g. slab bend) is needed to trigger the partial melting of the durbachite source underneath Sibumasu to form the durbachite-type amphibole-bearing melagranite

Table 1: Characteristics of durbachite.

Characteristic	Taiping durbachite-type rocks	European durbachite
Occurrence	Bintang Batholith (within Taiping Pluton, an N-S elongated Pluton)	Bohemian massif, Saxothuringian, French Central Massif, Vosges, Black forest, Massif de Maures, External Massifs, Tauern Window Corsica, Central Iberia, Tisia Massif, Moesian Platform
Hand specimen	Porphyritic to megacrystic melagranite	Granitoid texture with K-feldspar phenocrysts
Petrographic characteristic	K-feldspar + plagioclase + biotite + quartz + amphibole ± orthopyroxene ± clinopyroxene	K-feldspar + quartz + plagioclase + Mg-rich biotite actinolitic + hornblende ± clinopyroxene ± orthopyroxene
Geochemical Characteristic	Ultrapotassic, intermediate SiO2 content, high Rb/Sr, Th, LREE, LILE, low Ca, Na	Ultrapotassic, intermediate SiO2 content, high Rb/Sr, Th, LREE, LILE, low Ca, Na

ACKNOWLEDGEMENT

The work is partly sponsored by University Malaya UMRG Grant No. RG263/13AFR and UM/MOHE High Impact Research Grant (UMC/HIR/MOHE/SC/27). The samples for this study are taken from core sample of Archaeological Research of Bukit Bunoh, Peninsular Malaysia, Grant no.: 1002/Parkeo/910202DE2012 headed by Prof. Dr. Mokhtar Saidin from University Sains Malaysia.

REFERENCES

Bowes, D.R. & Kosler, J., 1993. Geochemical Comparison of the Subvolcanic Appinite Suite of the British Caledonides and the Durbachite Suite of the Central-European Hercynides - Evidence for Associated Shoshonitic and Granitic Magmatism. Mineralogy and Petrology, 48, 47-63.

Boynton, W. V., 1984. Cosmochemistry of the rare earth elements: meteorite studies. In: Rare Earth Element Geochemistry (P. Henderson, ed) Elsevier, Amsterdam.

Burton, C. K., 1970. The geology and mineral resources of the Baling area, Kedah and Perak (Vol. 12). Geological Survey Headquarters, Ipoh.

Cobbing, E.J., Pitfield, P.E.J., Darbyshire, D.P.F. & Mallick, D.I.J., 1992. The granites of the South–East Asian tin belt. British Geological Survey, Keyworth.

Ferre, E.C. & Leake, B.E., 2001. Geodynamic significance of early orogenic high-K crustal and mantle melts: example of the Corsica Batholith. Lithos, 59, 47-67.

Foley, S.F., Venturelli, G., Green, D.H. & Toscani, L., 1987. The Ultrapotassic Rocks - Characteristics, Classification, and Constraints for Petrogenetic Models. Earth-Science Reviews, 24, 81-134.

Foo, K.Y., 1990. Geology and mineral resources of the Taiping – Kuala Kangsar area, Perak Darul Ridzuan. Geological Survey Headquarters, Kuala Lumpur.

Ghani, A.A., 2000. The Western Belt granite of Peninsular Malaysia: some emergent problems on granite classification and its implication. Geosciences Journal, 4, 283-293.

Ghani, A.A., 2006. Field evidence of magma mixing in plutonic rock from the Benom Complex, Central Belt of Peninsular Malaysia. Geol. Soc. Malaysia Bull., 52, 55-58.

Ghani, A.A., Searle, M., Robb, L. & Chung, S.-L., 2013. Transitional I S type characteristic in the Main Range Granite, Peninsular Malaysia. Journal of Asian Earth Sciences, 76, 225-240.

Holub, F.V., 1989. Durbachite. In: Bowes, D.R. (ed.) Encyclopedia of Igneous and Metamorphic Petrology. Springer-Verlag Berlin Heidelberg.

Holub, F.V., 1997. Trace-element patterns in ultrapotassic rocks of the Bohemian Massif: implications for heterogeneity of their mantle sources. Journal of the Czech Geological Society, 42, 9.

Holub, F.V., 2001. Ultrapotassic Intrusions of the Bohemian Massif: Insights into the Variscan Sub-continental Lithospheric Mantle? Geolines, 13, 61-62.

Hutchison, C.S., 1994. Gondwana and Cathaysian Blocks, Palaeotethys Sutures and Cenozoic Tectonics in South-East Asia. Geologische Rundschau, 83, 388-405.

Janousek, V., Holub, F.V., Rogers, G. & Bowes, D.R., 1997. Two distinct mantle sources of Hercynian magmas intruding the Moldanubian unit, Bohemian Massif, Czech Republic. Journal of the Czech Geological Society, 42, 10.

Janoušek, V., Holub, F. V. & Gerdes, A., 2003. K-rich Magmatism in the Moldanubian Unit, Bohemian Massif—a complex story featuring variably enriched lithospheric mantle melts and their interaction with the crust. Geolines, 16, 48-49.

Janousek, V. & Holub, F.V., 2007. The causal link between HP-HT metamorphism and ultrapotassic magmatism in collisional orogens: case study from the Moldanubian Zone of the Bohemian Massif. Proceedings of the Geologists Association, 118, 75-86.

Kotkova, J., Schaltegger, U. & Leichmann, J., 2010. Two types of ultrapotassic plutonic rocks in the Bohemian Massif - Coeval intrusions at different crustal levels. Lithos, 115, 163-176.

Kusiak, M.A., Dunkley, D.J., Suzuki, K., Kachlík, V., Kędzior, A., Lekki, J & Opluštil, S., 2010. Chemical (non-isotopic) and isotopic dating of Phanerozoic zircon-A case study of durbachite from the Trebic Pluton, Bohemian Massif. Gondwana Research, 17, 153-161.

Liew, T.C., 1983. Petrogenesis of the Peninsular Malaysia granitoid Batholith. Unpubl. doctoral dissertation, Australia National University, Canberra, 291 pp.

Ludwig, K., 2003. Isoplot/Ex, version 3: A geochronological toolkit for microsoft Excel: Berkeley. Geochronology Center Berkeley, California.

Mcdonough, W.F. & Sun, S.S., 1995. The Composition of the Earth. Chemical Geology, 120, 223-253.

Metcalfe, I., 2000. The Bentong-Raub suture zone. Journal of Asian Earth Sciences, 18, 691-712.

Metcalfe, I., 2011. Tectonic framework and Phanerozoic evolution of Sundaland. Gondwana Research, 19, 3-21.

Metcalfe, I., 2013. Gondwana dispersion and Asian accretion: Tectonic and palaeogeographic evolution of eastern Tethys. Journal of Asian Earth Sciences, 66, 1-33.

Mitchell, A. H. G., 1979. Rift, subduction and collision-related tin belts. Geol. Soc. Malaysia Bull, 11, 81-102.

Oliver, G., Zaw, K., Hotson, M. & Manka, T., 2013. U–Pb zircon geochronology of Early Permian to Late Triassic rocks from Singapore and Johor: A plate tectonic reinterpretation. Gondwana Research, 76, 214-224.

Parat, F., Holtz, F., Rene, M. & Almeev, R., 2010. Experimental constraints on ultrapotassic magmatism from the Bohemian Massif (durbachite series, Czech Republic). Contributions to Mineralogy and Petrology, 159, 331-347.

Paton, C., Hellstrom, J., Paul, B., Woodhead, J. & Hergt, J., 2011. Iolite: Freeware for the visualisation and processing of mass spectrometric data. Journal of Analytical Atomic Spectrometry, 26, 2508.

Pearce, J. A., Harris, N. B. & Tindle, A. G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology, 25, 956-983.

Sacks, P. E. & Secor, D. T., 1990. Delamination in collisional orogens. Geology, 18, 999-1002.

Sauer, A., 1893. Der Granitit von Durbachimnordlichen Schwarzwald und seine Grenzfacies von Glimmersyenit (Durbachit). Mitt. Badisch. Geol. Landesamt, 2, 233-276.

Scarrow, J.H., Bea, F., Montero, P. & Molina, J.F., 2009. Shoshonites, vaugnerites and potassic lamprophyres: similarities and differences between ‘ultra’-high-K rocks. Earth and Environmental Science Transactions of the Royal Society of Edinburgh, 99, 159-175.

Searle, M.P., Whitehouse, M.J., Robb, L.J., Ghani, A.A., Hutchison, C. S., Sone, M., Ng, S. W.-P., Roselee, M. H., Chung, S.-L. & Oliver, G. J. H., 2012. Tectonic evolution of the Sibumasu-Indochina terrane collision zone in Thailand and Malaysia: constraints from new U-Pb zircon chronology of SE Asian tin granitoids. Journal of the Geological Society, 169, 489-500.

Sevastjanova, I., Clements, B., Hall, R., Belousovac, E.A., Griffinc, W.L. & Pearson, N., 2011. Granitic magmatism, basement ages, and provenance indicators in the Malay Peninsula: Insights from detrital zircon U-Pb and Hf-isotope data. Gondwana Research, 19, 1024-1037.

Tafti, R., Mortensen, J.K., Lang, J.R., Rebagliati, M. & Oliver, J.L., 2009. Jurassic U-Pb and Re-Os ages for the newly discovered Xietongmen Cu-Au porphyry district, Tibet, PRC: implications for metallogenic epochs in the southern Gangdese belt. Economic Geology, 104, 127-136.

von Raumer, J.F., Finger, F., Veselá, P. & Stampfli, G., 2013. Durbachites-Vaugnerites - a geodynamic marker in the central European Variscanorogen. Terra Nova, 0, 1-11.

Weill, D.F. & Drake, M.J., 1973. Europium Anomaly in Plagioclase Feldspar: Experimental Results and Semiquantitative Model. Science, 180, 1059-1060.

Manuscript received 9 May 2015
Revised manuscript received 29 June 2016
Manuscript accepted 11 July 2016