

PAPER

A comparative study of Kuantan bauxite mineralogy as potential material in civil engineering

To cite this article: I N Iqhlina Najwa *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **244** 012002

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

A comparative study of Kuantan bauxite mineralogy as potential material in civil engineering

I N Iqhlima Najwa¹, A Haryati², P J Ramadhansyah² and A Mohamad Idris²

¹PhD Student Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, 26600 Pekan Pahang, Malaysia.

²Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, 26600 Pekan Pahang, Malaysia.

Email: haryatiawang@ump.edu.my

Abstract. This Known as residual rock formed due to chemical weathering of igneous parent rock, Bauxite is naturally occurring mixture of minerals rich in hydrated aluminium oxides. The origin mineral and geochemistry involved in Kuantan Bauxite forming is however, rarely unveil, in which cause to lacking experience and knowledge in handling bauxite as it causes air and water pollution to surrounding environment and public health. Mineral composition in a bauxite formation is primarily significant to be characterised as to define its geotechnical engineering properties and to decide suitable mining methods prior mining works shall be executed. Hence, this review based on previous research aims to identify bauxite distribution in Kuantan, outline the predominantly mineral composition that can be found in Kuantan Bauxite genesis in order to verify geotechnical properties of Kuantan Bauxite as potential to civil engineering material industry. Several review of previous mineralogy and geochemistry studies, shows that XRD is the preferable method in verifying mineral content in Bauxite deposits around the world. It is also found that Kuantan Bauxite is after Basaltic parent rock. Minerals content of Kuantan Bauxite after Basaltic are found as gibbsite, hematite, goethite and quartz. Gibbsite is found as dominant mineral in Kuantan Bauxite. This review is significant for future research that related to Kuantan Bauxite civil engineering materials as it creates better understanding of Bauxite background as demanding potential earth resources for economic growth of Malaysia.

1.0 Introduction

Chemical weathering of most igneous rocks, resulted in concretions, a hard, compacted mass of matter formed by the precipitation of mineral cement within spaces existed between particles, and eventually found as in sedimentary rock or as residual soil. The behaviour of elements during bauxitic weathering is determined by relative proportions of different mineral phases; concentrated in relatively insoluble accessory minerals and also dispersed in the main rock-forming minerals [1]. Bauxites after acidic rocks are relatively enriched by felsiphile elements. On the contrary, iron-rich bauxites after ultrabasic rocks contain high amount of femaphiles. Bauxites after alkali rock can contain very high amount of



Th, Nb, Zr and some other elements. According to “Bauxite: Development of Soil Science”, a book written by Ida Valetton in 1972, the important elements in bauxite genesis are mainly covered by Si, Al, and Fe. Extensive deposits exclusively or partly formed by the removal of silica result in relative enrichment of Al and Fe. These bauxites are characterized by the Al/Fe ratios corresponding to those of the source rocks. Such ferrallites are certain horizons of bauxites on igneous rocks and most of the karst deposits. Siallites (rocks rich in silica) develop if iron is removed faster than silica. They form the saprolite zone on igneous rocks (Figure 1) and develop highly aluminous clays and transitional stages to flint clay on sediments. Allite formation occurs by relative enrichment of aluminum through the selective removal of silica and iron.



Figure 1A & 1B. Example of Saprolite lithology and bauxite nodules found at Bangsal Lop area, in Pengerang, Johor [2]

Concretions formation are common found in Western Kalimantan, Indonesia; Oure Pueto, Brazil; Cauca and Valle, Columbia and Southern Vietnam. In Kuantan, similar phenomenon had found due to formation of concretion with various sizes due to the weathering processes [3]. Concretion or bauxite nodules are found typically 1 to 10 centimetres in diameter as shown in Figure 1B. The external factors of concretions formation are parents rock and mineralogy [4,5]. The water activity, pH, Eh is the internal factors [6]. On the other hand, the temperature and particle size are also the internal factors [7]. Laterites and bauxites predominantly are products of residual (relative) accumulation of sesquioxides [8]. If residual accumulation of sesquioxides is simply due to leaching of silica, alkalis and alkaline earths, then bauxites should be even more widespread than laterites [9]. In accordance with previous researchers, they consider favourable leaching and drainage conditions as the most relevant parameters for bauxite formation. This conclusion is supported by the result of thermodynamic calculations that Al-hydroxide in contrast to kaolinite is only stable in solutions with lowered contents of dissolved silica [10,11].

2.0 Bauxite Geological Setting in Eastern Province of Malaysia

The Malaysian granitoids of the Southeast Asian tin belt have been conventionally separated by the Bentong-Raub Paleo-Tethyan suture that closed in the Late Triassic [12]. Divided into two parts, Permian to Late Triassic “I-type”– dominated arc-related Eastern province (Indochina terrane) and a Late Triassic “S-type”–dominated collision-related Main Range province (Sibumasu terrane). A simplified geological map of granitoids distributions in the Southeast Asian tin belt divided into the Eastern province and the Main Range province by the Bentong-Raub suture [13] is shown as in Figure 2. The dashed line in Figure 2 also represents the proposed boundary separating the Eastern and the Central [14]. The I- and S-type granite classification scheme was first applied to the Southeast Asian tin belt granitoids [15] (Figure 2). For the Malay Peninsula particularly, it was suggested that

granitoids to the east of the Bentong- Raub suture zone (Eastern province) are mostly hornblende-bearing I types formed above an east-dipping Paleo-Tethyan subduction zone (Figure 1). Although this model is accepted by many workers [14,15,16], the I- and S-type designation of the Malaysian granitoids has recently been challenged [16,17].

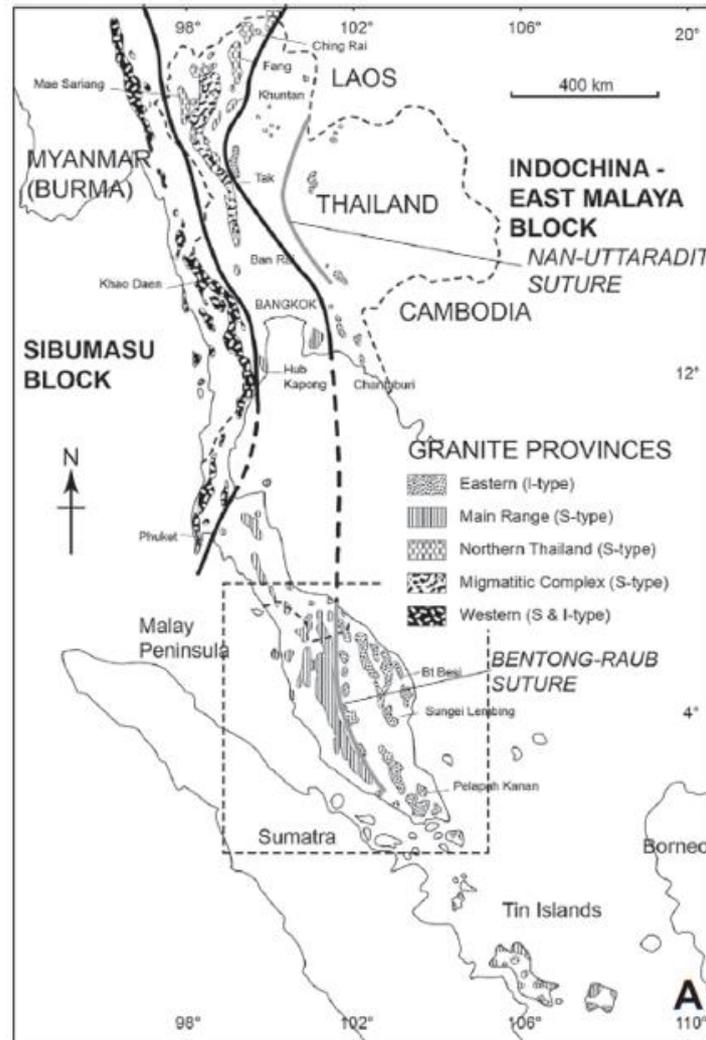


Figure 2. Simplified geological map showing the distribution of granitoids in the Southeast Asian

The Eastern Province in general comprises of wide spectrum of lithologies with small batholithic granitic bodies up to 1000 km² in size. Ranging from hornblende-biotite granodiorite to adamellite (quartz monzonite) to more fractionated biotite granite in the granite classification, there are also roof zones of the Eastern province granites are I-type granites but with hornblende free (Figure 3). Based on previous field relationships, it recommends that hornblende- biotite granitoids form the main body of the plutons, together with more fractionated are hornblende- free phases in which typically occurring at the roof zone.

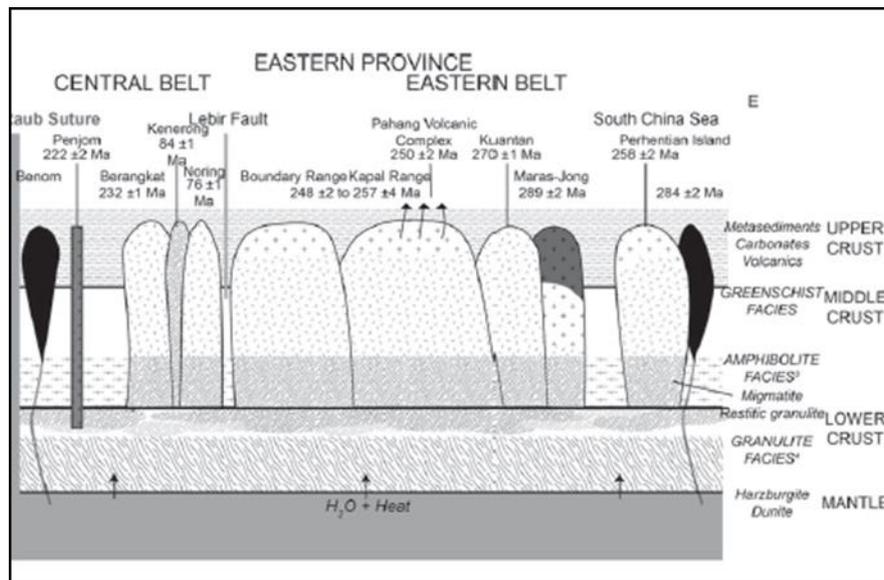


Figure 3. Simplified petrogenetic model for the formation granite belts [5]

In addition, gradual textural and mineralogical variation characterise the transitions of granitoid bodies into more fractionated portions. The roof zone is usually associated with indications of hydrothermal activity, such as chloritization of biotite and sericitization of feldspars and vein development. These greisenized plutonic roof zones are the host environment for primary Sn-W mineralization in the Malay Peninsula [8,9]. In the Eastern province granitoids, accessory minerals are typically including apatite, secondary epidote, zircon, allanite, sphene, and magnetite. Although magnetite is the dominant iron- oxide phase, ilmenite is also detected in these rocks, suggesting that both magnetite-series and ilmenite-series granitoids are found in the province [11,12]. Mafic enclaves are found in some Eastern province granitoids, but these are not common. Bauxite have four grade according to distinctive percentage content of SiO_2 , Fe_2O_3 , Al_2O_3 , TiO_2 and LOI [16]. Table 1 show the bauxite classification with different grades.

Table 1. Bauxite classification with grade [16]

Grade	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	L.O.I (%)
Metal	1.0 -20.0	0.0 - 4.0	40.0 - 61.0	1.0- 30.0	26.0 - 31.0
Chemistry	3.5 - 6.0	2.5 - 2.8	58.5 - 60.0	1.0 - 1.5	30.0 -31.0
Abrasive	1.0 -5.5	3.0 - 4.8	82.0 - 88.0	2.0 - 8.0	0
Refractory	5.0 - 7.5	3.0 - 4.0	84.0 - 89.0	1.5 - 2.5	0

3.0 X-Ray Diffraction Method (XRD) and X-Ray Fluorescence Method (XRF) Testing

Major element compositions were determined by X-ray fluorescence (XRF) using the Rigaku RIX-2000 spectrometer and trace element analysis by inductively coupled plasma–mass spectrometry uses an Agilent 7500cx quadrupole spectrometer [8]. Recently studied, the whole-rock XRD was carried out using the Japanese Rigaku D/Mac-RC and $\text{CuK}\alpha_1$ radiation with the following operating conditions: voltage 40 kV, beam current 80 mA, graphite monochromator, continuous scanning, scanning speed $8^\circ/\text{min}$, slit $\text{DS}=\text{SS}=1^\circ$, ambient temperature 18°C , humidity 30%. Bauxite Quality Classification by Shrinkage Methods based on advanced regression methods (modelling computation) is recently used to provide a realistic and integral classification, the mineral information and the geochemical composition of bauxite samples were accompanied to each other. In this paper, it reviews previous major element data obtained from conventional method of XRF and XRD.

4.0 Bauxite Distribution in Kuantan

Bauxite mining in Kuantan, Pahang started in early 2013 with small-scale mining in Balok and later expanded to Bukit Goh, Bukit Sagu and Sungai Karang. Due to rapid expansion, from 343,000 tonnes to 3.72 million tonnes of mining (January to September 2015), coupled with uncontrolled and unsustainable legal and illegal mining activities, thus has resulted in environmental issues. Table 2 summarized three major bauxite locations in Kuantan. The content of SiO₂ and Al₂O₃ for Bukit Tanah Merah were found as 1.0 -7.0% and 33.0 - 44.0%. Whereas for Ladang Bukit Goh, 1.44 - 25.2% and 26.0 - 48.0% respectively. Bukit Tanah Merah and Ladang Bukit Goh have acceptable metal bauxite as compared to other study [11,12]. Ladang Jeram however contained 21.0 - 39.0% of Al₂O₃, lower than 40% the bottom range of Al₂O₃. The geological profile of bauxite in Kuantan should be studied as to predict the total depth of bauxite in these locations.

Table 2. Bauxite distribution in Kuantan and its major element data

Location	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	L.O.I
Bukit Tanah Merah	1.0 -7.0	2.56 - 4.88	33.0 - 44.0	21.0 - 30.0	21.4 - 27.0
Ladang Jeram Kuantan	1.9 - 21.8	3.60 - 5.20	21.0 - 39.0	25.0 - 40.0	20.6 - 27.1
Ladang Bukit Goh	1.44 - 25.2	2.40 - 4.96	26.0 - 48.0	22.0 - 26.0	20.1 - 28.3

4.1 Mineralogy of Bauxite in Kuantan

Table 3 show the characterised different type I granitoids [8]. Indicative minerals included in I-type are hornblende, biotite, sphene and magnetite, in which SiO₂ range is between 53% to 76%. Meanwhile, maximum value of SiO₂ bauxitic formation shall only up to 20.0%, unless it is lateritic. Even though bauxite formed due to extensive weathering of granite, roof zones - hornblende free area shall represent the bauxitic area in Kuantan region.

Table 3. Comparison between type of granites

Characteristics	I - type granitoids
Indicative minerals	Hornblende, biotite, sphene, magnetite
Enclaves	Mafic to dioritic micro granular enclaves
SiO ₂ (%)	53 - 76

Although I and S type granitoids model is accepted by many workers [8,9,10]. Previous study found that bauxite in Kuantan Pahang areas were after basaltic instead of granitoids and some were also found after sedimentary and least were alluvium [16,17]. Bauxite deposits after basaltic in Kuantan, the concretion are concentrated with 32.35% - 52.23% Al₂O₃, 14.96% - 33.99% Fe₂O₃, 3.03% - 6.62% SiO₂ and below detection level (bdl) - 8.07% TiO₂ as shown in Table 4.

Table 4. Major element data of collective Kuantan samples from 5 locations

Major element	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	LOI
Weight (%)	3.03 - 6.62	(bdl) - 8.07	32.35 - 52.23	14.96 - 33.99	23.08 - 29.84

A map shown location of samples were taken from 5 locations, A(Basaltic), B(Sedimentary), C(Basaltic), D(Basaltic) & E(Basaltic) [4] were shown in Figure 4. This bauxite was characterized as metal bauxite according to previous study [17]. Value of Al₂O₃ from Table 3 (3.03 - 6.62%) was within the range of bauxite grade i.e. 40.0 - 61.0% for metal grade.

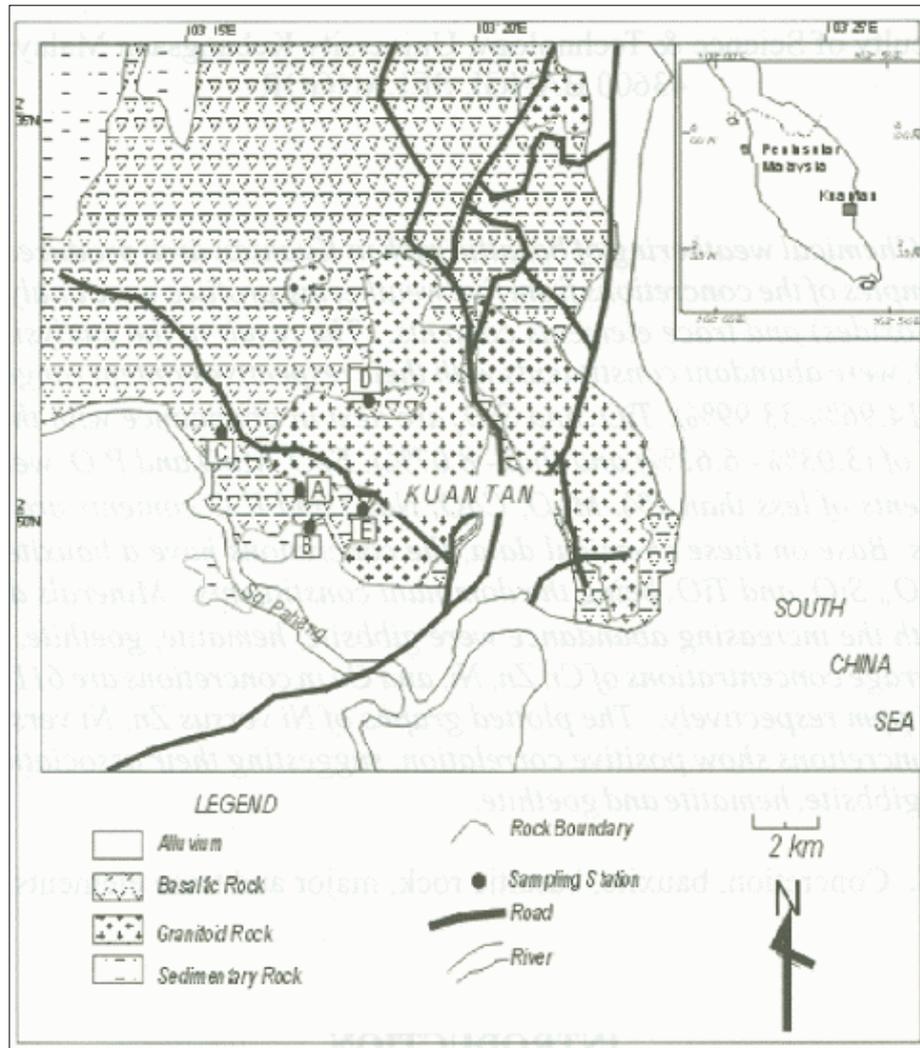


Figure 4. Rock distribution studied area and sampling location at Kuantan

Based on X-Ray Diffraction analysis, the value of SiO_2 was found 74.17% (see Table 5), in which not within the range. High value of SiO_2 indicates that the process of leaching the silica is minor. Similar condition to value of Al_2O_3 content was found as 13.69% in which lower than 40.0% compared to Al_2O_3 content [16]. The existence of hornblende-biotite minerals shown that the formation was far away from bauxitic weathering. Thus, the sample was not from bauxitic formation.

Table 5. Major element data of a Kuantan sample [1,2]

Major element	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	LOI	Sum
Weight (%)	74.17	0.12	13.69	1.46	1.46	100.91

5.0 Conclusion

A number of studies have been carried out and it is found that bauxite at Bukit Tanah Merah and Ladang Bukit Goh were acceptable as metal bauxite. The content of SiO_2 and Al_2O_3 for Bukit Tanah Merah were found from 1.0 - 7.0% and 33.0 - 44.0%. Whereas for Ladang Bukit Goh, 1.44 - 25.2% and 26.0 - 48.0% respectively. There are wide study gap in terms of the Kuantan Bauxite geotechnical engineering, geophysical and geological characterisations of the deposit. These characterisations are very important as Bauxite is deposited in wide area and involves as foundation for roads, highways,

buildings and many engineering structures. It is expected that detail study, engineering characteristics of Kuantan Bauxite can be gathered, prior extended research on Kuantan Bauxite as building materials can be executed.

References

- [1] Angélica RS, H. K., S.P.A. Paz 2018 A proposal for bauxite quality control using the combined Rietveld - Le Bail - Internal Standard PXRD method – Part 2: Application to a gibbsitic bauxite from the Paragominas region, northern Brazil." *Minerals Engineering* 122: 148 - 155
- [2] Baba M. Geochemical Characterization of Concretion From Weathering Profile of Basaltic Rock in Kuantan, Pahang. *Borneo Science*. 7: 33 - 43.
- [3] Bardossy, G, Aleva, G. J. J 1990 *Lateritic Bauxites. Development in Economic Geology*, 27. Elsevier.
- [4] Farhad A, H. Z., Batoul T, Alireza Z, Roberto B, Somayeh S E 2017 "Mineralogical and geochemical evolution of the Bidgol bauxite deposit, Zagros Mountain Belt, Iran: Implications for ore genesis, rare earth elements fractionation and parental affinity." *Ore Geology Reviews* 86: 756 - 783.
- [5] Gore, M. S. 2015 *Geotechnical Characterization of Bauxite Residue*. Research Gate: 312.
- [6] Hassan Z, F. A., Alireza Z 2016 "Mineralogical and Geochemical Investigations of the Mombi Bauxite Deposit, Zagros Mountain, Iran." *Chemie der Erde*: 13 - 37.
- [7] Jiahao C, Q. W., Qizuan Z, Emmanuel J M C, Jiaqi W 2018 "Mineralogical and Geochemical Investigations on the Iron-Rich Gibbsite Bauxite in Yongjiang Basin, SW China." *Journal of Geochemical Exploration* 188: 413 -426.
- [8] Johannes V, A. M., Chiara B, Päärn P, István E S, Bart B, Alan H T, Vicky V, Dimitrios P 2018 "Modes of occurrences of scandium in Greek bauxite and bauxite residue." *Minerals Engineering* 123: 35 - 48.
- [9] Malaysia, A. S. 2017 *Sustainable Mining: Case Study for Bauxite Mining in Pahang*: 78.
- [10] Mordberg, L. E. 1996 "Geochemistry of trace elements in Paleozoic bauxite profiles in northern Russia." *Journal of Geochemical Exploration* 57: 187 - 199.
- [11] Nahon, Y T D 1985 "Geochemistry of laterites, stability of Al-goethite, Al-hematite, and Fe (super 3+) -kaolinite in bauxites and ferricretes; an approach to the mechanism of concretion formation." *American Journal of Science* 285: 865 - 903.
- [12] Norton, S A 1973 "Laterite and Bauxite Formation." *Economic Geology* 68.
- [13] Platon N, Gamaletsos, A. G., Takeshi K, Nathan S C, Alexios P D, Jörg G, Ralph S, Alexey B, Yiannis P, Evangelos T, Thomas B, Anestis F 2017 "Nano-mineralogy and -geochemistry of high-grade diasporic karst-type bauxite from Parnassos-Ghiona mines, Greece." *Ore Geology Reviews* 84: 228 - 244.
- [14] Samuel W P N, S.-L. C., Laurence J, Robb M P S, Azman A A, Martin J W, Grahame J H O, Masatoshi S, Nicholas J G, Muhammad H R. 2015 "Petrogenesis of Malaysian granitoids in the Southeast Asian tin belt: Part 1. Geochemical and Sr-Nd isotopic characteristics." *Geological Society of America Bulletin*.
- [15] Schellmann, W 1994 "Geochemical differentiation in laterite and bauxite formation." *CATENA* 21: 131 - 143.
- [16] Tutmez, B 2018 "Bauxite quality classification by shrinkage methods." *Journal of Geochemical Exploration* 191: 22 - 27.
- [17] Yongzhen L, G. C., J L, Dexian Z, Hao S 2018 "Uranium enrichment in a paleo-karstic bauxite deposit, Yunfeng, SW China: Mineralogy, geochemistry, transport – deposition mechanisms and significance for uranium exploration." *Journal of Geochemical Exploration* 190: 424 - 435.

Acknowledgement

The support provided by Universiti Malaysia Pahang in the form of a research support