

GEOCHEMICAL CHARACTERIZATION OF CONCRETION FROM WEATHERING PROFILE OF BASALTIC ROCK IN KUANTAN, PAHANG

Baba Musta¹, W.Fuad W. Hassan² & Mohamad Md. Tan²

¹School of Science & Technology, University Malaysia Sabah
88999 KOTA KINABALU, SABAH

²Faculty of Science & Technology, University Kebangsaan Malaysia
43600 BANGI, SELANGOR

ABSTRACT. *Chemical weathering of basaltic rock in Kuantan area produced concretions. Twenty-one samples of the concretions from five weathering profiles were analysed for major (in the form of oxides) and trace elements contents. The result of the analysis showed that Al_2O_3 and Fe_2O_3 were abundant constituents with their respective content range of (32.35% - 52.23%) and (14.96% - 33.99%). TiO_2 and SiO_2 are next in abundance with their respective content ranges of (3.03% - 6.62%) and (bdl - 8.07%). FeO , MnO and P_2O_5 were also found, with their contents of less than 1%. MgO , CaO , Na_2O and K_2O contents are mostly below detection limits. Base on these chemical data, the concretions have a bauxite composition with Al_2O_3 , Fe_2O_3 , SiO_2 and TiO_2 being the dominant constituents. Minerals detected in the concretions with the increasing abundance were gibbsite, hematite, goethite, kaolinite and quartz. The average concentrations of Cr, Zn, Ni, and Cu in concretions are 611 ppm, 35 ppm, 35 ppm and 28 ppm respectively. The plotted graphs of Ni versus Zn, Ni versus Cu and Zn versus Cu in concretions show positive correlation, suggesting their association in bauxite, particularly in gibbsite, hematite and goethite.*

KEYWORDS. Concretion, bauxite, basaltic rock, major and trace elements.

INTRODUCTION

Concretions were formed during the weathering of most igneous rocks. Tropical areas such as Western Kalimantan, Indonesia; Oure Pueto, Brazil; Cauca and Valle, Columbia and Southern Vietnam are common as areas of concretion formation (Bardossy & Aleva, 1990). Profile of basaltic rocks in Kuantan, Pahang (Figure 1) shows the same phenomenon in the

formation of concretion with various sizes due to the weathering processes. The genesis of concretion formation was explained by Tardy & Nahon (1985) and Nahon (1991). They reported that the parents rock and mineralogy were the external factors for concretion formation, whereas the internal factors were the water activity, pH, Eh (Norton, 1973), temperature, and particle size (Trolard & Tardy, 1987). The concretion formation ends with the formation of bauxite (Bardossy & Alewa, 1990). The bauxite formation rich in concretion was shown in several outcrop of basaltic rock profile in Johor (Grubb, 1982). Gibbsite, boehmite, goethite, hematite and kaolinite were the secondary minerals found in the concretions (Grubb, 1970; Tardy & Nahon, 1985; Trolard & Tardy, 1987; Nahon, 1991 and Mordberg, 1993). Wolfenden (1965) and Mordberg (1993a & 1993b) reported the trace element behavior in bauxite from Sarawak.

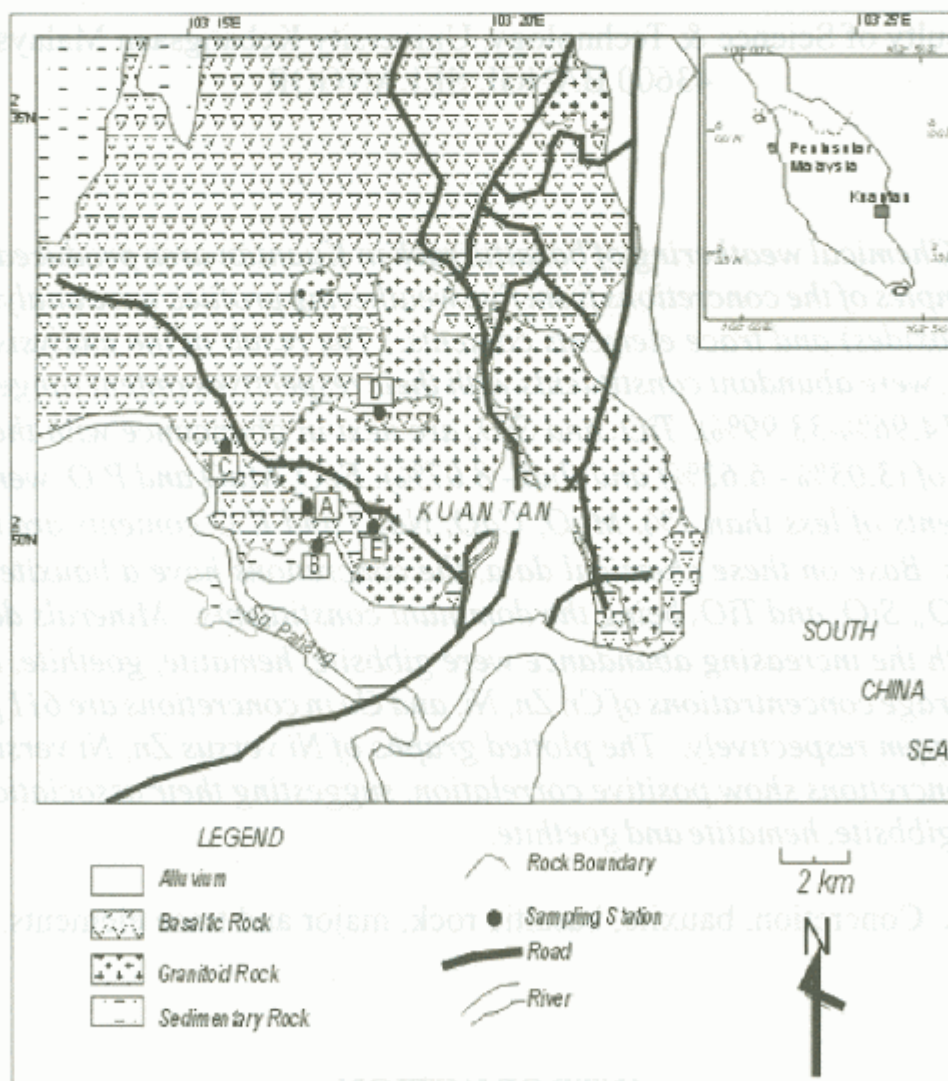


Figure 1. The map shows the rock distribution in studied area and the location of sampling station in Kuantan, Pahang. (Modified from Haile et.al, 1983)

This paper will discuss the abundance of trace elements in concretion from the basaltic rock of Kuantan, Pahang. The geochemistry and its relationship with the formation of concretion at different level of weathering profile will be discussed.

METHODOLOGY

Field observations and geochemical analyses were both involved in this study. Field observation of the concretion in the weathering profiles of basaltic rock pertains to description of texture measurement and colour changes, and their variation with depth. Twenty-one concretion samples from five weathering profiles were taken. The concretions were washed with distilled water to remove the soils, dried in open air, crushed, then ground to form powder before being analysed by X-ray fluorescence (XRF). The XRF analysis was used to analyse the major and trace elements, except for FeO which was determined using wet chemical method. The major elements were determined using fused discs, while pressure pellets were used for the trace elements (Norrish & Hutton, 1969). A "Philips PW 1480 X-ray Digital" instrument controlled by Digital Software X 44 microcomputer software was used for the purpose. The calibration graph followed that of 'Alphas on line' program (De Jongh, 1973 & 1979). For the mineralogical studies of the concretions microscopic observations and X-ray Diffraction (XRD) technique were employed.

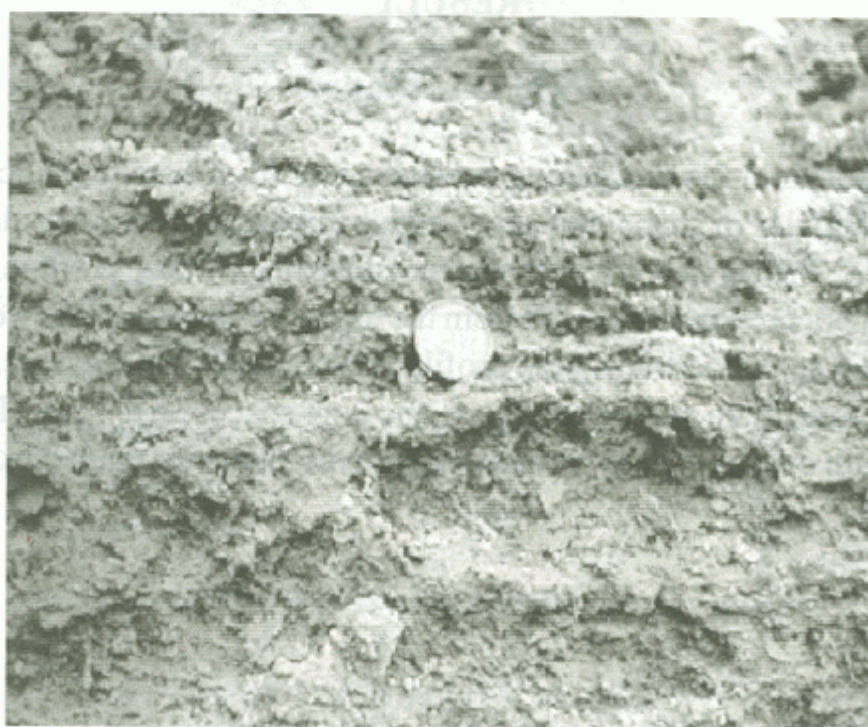
RESULT

Field Observation

The size of concretions in the weathering profile varies from 1cm to 10.0cm. Most of the concretions were angular in shape, but some highly spherical ones were also found. They were relatively hard, brown in color with matrix consisting of clay to silt-sized grains. The size distribution of concretions increased from the top to the middle of the weathering profile and decreased again to the bottom of the profile (Photograph 1). One concretion observed, had light brown colour, diameter about 20 cm, and pore spaces up to 1cm. These concretion were connected with one another to form branches with diameter ranged from 0.5 cm to 1.0 cm (Photograph 2).



Photograph 1: The weathering profile of basaltic rock shows the size distribution of concretions increased from the top to the middle and decreased again to the bottom of the profile



Photograph 2. The photo shows the concretion of soil profile are connected with one another to form branches with diameter ranging from 0.5 cm to 1.0 cm.

Mineralogy

Petrographic study of the concretion showed the presence of quartz, ilmenite and sphene. All of these minerals were relatively resistant to weathering (Ollier, 1969). X-ray diffraction study showed the presence of gibbsite, goethite, kaolinite, and quartz (Table 1), with gibbsite as the dominant mineral. The concretion was texturally porous, with the size of pore spaces varied from 1 to 3 mm.

Table 1: Minerals content in the concretion sample from Kuantan, Pahang using XRD.

Samples	Minerals
A3	gibbsite, hematite, goetite
B5	gibbsite, hematite, goetite
B6	gibbsite, hematite
C1	gibbsite, hematite, goetite
D1	gibbsite, hematite, goetite
D3	gibbsite, kaolinite, hematite
E2	gibbsite, quartz

Geochemistry

Table 2 and Table 3 showed the results of geochemical analyses for major and trace elements in the concretion samples. The major oxide elements in concretions are Al_2O_3 , Fe_2O_3 , SiO_2 and TiO_2 . Cr, Zn, Ni and Cu were present as traces.

DISCUSSION

Characteristics of Major Elements

Among the major elements present in the concretion, Al_2O_3 is the most abundant, having percentage range from 32.35 to 52.23 %, with average of 41.37 % and standard deviation of 5.06 %. Fe_2O_3 , being next in abundance, has a concentration range from 3.99 % to 14.96 % with average of 24.1 % and standard deviation of 5.04 %. The concentration of TiO_2 is between 3.03 % and 6.62 %, whereas SiO_2 ranges from below detection limit (bdl) to 8.07 %. According to Valeton (1972) a bauxite should have Al_2O_3 as the major element with percentages between 45 to 50, Fe_2O_3 of less than 20 % and SiO_2 between 3 to 5%.

From the present analyses, the major elements in the Kuantan bauxite (Table 2A Table 2B), except for samples B3, D1, D3, D4, and E3, meet the conditions set by Valeton. Following the classification by Patterson *et al.* (1986) the bauxite concretions from the study area can be regarded as a metal grade bauxite (Table 3).

Table 2A: Major elements and trace elements concentration in concretions from Kuantan, Pahang.

Sample Elements	A1	A2	A3	A4	B1	B2	B3	B4	B5	B6
SiO ₂	bdl	bdl	0.75	bdl	bdl	bdl	bdl	2.17	8.07	3.42
TiO ₂	4.07	4.31	4.60	4.35	3.14	3.96	4.62	3.63	5.24	3.42
Al ₂ O ₃	42.44	41.96	42.68	41.71	18.03	43.59	42.76	44.89	36.02	41.50
FeO	0.54	0.38	1.37	0.73	0.97	1.35	1.07	0.12	0.37	0.80
Fe ₂ O ₃	24.49	26.05	24.24	27.41	18.82	23.62	28.86	23.67	32.06	16.14
MnO	0.09	0.11	0.05	0.09	0.07	0.08	0.08	0.08	0.10	0.08
MgO	bdl	bdl	0.23	bdl	bdl	bdl	bdl	bdl	0.42	0.07
CaO	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.01	0.02
Na ₂ O	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl
K ₂ O	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.01	bdl
P ₂ O ₅	0.22	0.27	0.21	0.29	0.20	0.21	0.31	0.20	0.24	0.08
L.O.I	27.15	16.92	25.86	26.20	28.77	27.19	24.28	27.41	23.34	29.84
Total	100.00	100.00	99.97	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Cu	165	202	0	155	123	105	140	236	0	0
Zn	?	36	20	52	31	28	33	16	26	29
Ni		36	27	33	34	32	17	42	27	34
Cr	58	477	791	506	434	648	563	457	628	413

* bdl: below detection level

Table 2B: Major elements and trace elements in concentration from Kuantan, Pahang.

Sample Elements	C1	C2	C3	D1	D2	D3	D4	D5	E1	E2	E3
SiO ₂	3.42	1.23	3.53	2.22	3.56	1.32	bdl	5.08	0.15	8.4	15.22
TiO ₂	3.03	4.92	2.82	5.00	4.40	6.62	5.04	4.06	3.07	3.84	6.13
Al ₂ O ₃	45.00	40.15	48.60	36.49	41.03	33.97	32.35	40.07	52.23	40.36	33.03
FeO	0.74	0.74	0.86	0.40	1.33	0.68	11.77	0.98	0.63	0.79	1.42
Fe ₂ O ₃	15.75	28.90	23.29	33.99	31.67	24.34	14.96	21.03	14.96	21.03	22.99
MnO	0.05	0.09	0.09	0.06	0.04	0.05	0.09	0.10	0.08	0.07	0.18
MgO	0.18	0.30	0.17	0.29	Bdl	0.15	bdl	bdl	bdl	0.32	0.23
CaO	bdl	0.01	bdl	0.00	Bdl	bdl	bdl	bdl	bdl	0.04	0.01
Na ₂ O	bdl	bdl	bdl	bdl	Bdl	bdl	bdl	bdl	bdl	bdl	bdl
K ₂ O	0.01	bdl	bdl	0.04	Bdl	bdl	bdl	bdl	bdl	0.03	bdl
P ₂ O ₅	0.13	0.26	0.19	0.26	0.13	0.15	0.31	0.27	0.24	0.21	0.15
L.O.I	28.71	28.44	28.44	26.35	26.34	23.08	28.77	25.10	28.64	24.92	320.64
Total	100.02	100.00	100.00	99.96	100.01	100.01	100.00	100.00	100.00	100.01	100.00
Cu	0	0	106	0	0	0	125	189	96	0	0
Zn	11	31	36	32	32	27	53	55	28	42	48
Ni	19	17	40	32	27	28	34	72	58	35	51
Cr	409	583	557	575	1227	609	719	577	940	561	575

* bdl: below detection level

Table 3. Bauxite classification with grad (Patterson, *et. al*, 1986)

Grade	Al ₂ O ₃ (%)	SiO ₂ (%)	Fe ₂ O ₃ (%)	TiO ₂ (%)	L.O.I (%)
Metal	40.0-61.0	1.0-20.0	1.0-30.0	0.0-4.0	26.0-31.0
Chemistry	58.5-60.0	3.5-6.0	1.0-1.5	2.5-2.8	30.0-31.0
Abrasive	82.0-88.0	1.0-5.5	2.0-8.0	3.0-4.8	0
Refractory	84.0-89.0	5.0-7.5	1.5-2.5	30-4.0	0

The mineral content of bauxite as reported in Grubb (1970) and Bardossy & Aleva (1990) consists of gibbsite, boehmite, diaspor, goethite, hematite, and kaolinite. In the Kuantan area, the minerals identified by the XRD consist of gibbsite and hematite, followed by goethite and quartz. This mineralogy is supported by the geochemical data which shows a high content of Al₂O₃, Fe₂O₃, and SiO₂. A strong negative correlation is shown between Fe₂O₃ and Al₂O₃ (Figure 2A), which suggests that the increase of gibbsite is followed by the decrease of the Fe-oxide. This is perhaps due to the substitution between Al³⁺ and Fe³⁺ during chemical weathering. The Fe-oxide is hematite and goethite, which is confirmed by the brown color of the soil. Bauxite formation is controlled by pH, which needs to be higher than 4, and Eh of lower than +4 (Peterson, 1971). The formation of gibbsite by the chemical reaction of feldspar and kaolinite is shown by the following expressions (Tardy & Nahon, 1985):



The weak negative correlation between SiO₂ and Al₂O₃ (Figure 2B) indicates that a small amount of gibbsite comes from the hydrolysis of kaolinite but the bulk amount is contributed by the dissolution of feldspar. The removal of TiO₂ is always followed by the bauxite formation, and this is supported by the strong negative correlation between Al₂O₃ and TiO₂ (Figure 2C). At the same time the components of anatase, rutile and ilmenite decrease. This phenomenon explains the formation of gibbsite and the removal of TiO₂ minerals in the bauxite of Kuantan. According the Grubb (1970) the appearance of anatase at high pH will cause unstability if precipitated with the other gel component. The correlation between Fe₂O₃ and TiO₂ (Figure 2D) suggests the formation of ilmenite in concretion. The minor elements such as FeO, MnO, MgO, CaO, Na₂O, K₂O and P₂O₅ are lower than 1%, due to leaching during the weathering.

The appearance of secondary minerals and pore space can be explained by the dissolution of particularly the primary silicate minerals. The dissolution of these minerals will create pore spaces which occupied by secondary minerals later on.

Characteristic of Trace Elements

The abundances of trace elements in bauxite in tropical area have been reported by several researchers (Wolfenden, 1965; Mordberg, 1993 and Bardossy & Aleva, 1990). In the Kuantan bauxite, trace elements in concretion are probably associated with Fe-oxide and kaolinite. As shown in the Table 2A and Table 2B the concentration of Cr ranges from 409 ppm to 1227 ppm with a mean of 611 ppm and a standard deviation of 188 ppm. The next highest element is Zn with a concentration range from 11 ppm to 55 ppm, and Ni with concentration range from 17 ppm to 58 ppm. Copper (Cu) is also detected with concentration values from below detection limit up to 165 ppm. The positive correlations between Ni and Zn (Figure 2E), Ni and Cu (Figure 2F), Zn and Cu (Figure 2G), and Cu and Cr (Figure 2H) indicate that the elements are associated in the gibbsite and goethite by adsorption. There is no correlation between Cr and the other elements, but Cr may be adsorbed by Fe-oxide and kaolinite as reported by Wolfenden (1965) in the other part of the Tropics. The fast decrease of Zn, Ni, and Cu compared to Cr in the bauxite could be explained by their higher mobilities in the leaching processes (Mordberg, 1993).

CONCLUSION

The geochemical study of the major elements in the weathering profiles shows that chemical weathering of basaltic rocks produce the concretion. Most of the concretions can be classified as a metal-grade bauxite. The concentration ranges of Al_2O_3 , Fe_2O_3 , SiO_2 and TiO_2 in the concretions are 32.35% -52.23%, 14.96%-33.99%, 3.03% - 6.62%, and below detection limit - 8.07% respectively.

The average concentrations of Cr, Zn, Ni and, Cu, are 611 ppm, 35 ppm, 35 ppm and 35 ppm respectively. The concentrations of these elements are controlled by their mobilities and are leached during weathering. As a result the concentration of Zn, Ni and Cu are relatively low in the concretion.

Minerals detected in concretions with the increasing abundance are gibbsite, hematite, goethite, kaolinite and quartz. The high concentration of the trace elements is probably due to adsorption in the secondary minerals such as gibbsite, hematite and goethite.

REFERENCES

- Bardossy, G. & Aleva, G. J. J., 1990. *Lateritic Bauxites*. Developments in Economic Geology, **27**. Elsevier.
- De Jongh, W. K., 1973. X-ray fluorescence analysis applying theoretical matrix corrections. *Stainless steel. X-ray Spectrometry*. **2**(151).
- De Jongh, W. K., 1979. The atomic number $z=0$: Loss and gain on ignition in XRF analysis treated by the JN-Equations. *X-ray Spectrometry*. **8** (52).
- Grubb, P. L. C., 1970. Mineralogy, Geochemistry and genesis of the bauxite deposits on the Gove and Mitchell Plateau, Northern Australia CSIRO. Melbourne Australia: University of Melbourne.
- Mordberg, L. E., 1993a. Patterns of distributions and behavior of trace elements in bauxites. *Chemical Geology*, **107**: 241-244.
- Mordberg, L. E., 1993b. Impact of crystalline basement magmatic rock composition on the geochemistry of bauxites types. *Chemical Geology*, **107**:245-249.
- Nahon, D. B., 1991. Self-organization in chemical lateritic weathering. *Geoderma* **51**: 5-13.
- Norrish, K. & Hutton, J. T., 1969. An accurate X-ray spectrographic method for the analysis of a wide range of geological samples. *Geochim. Et Cosmochim. Acta* **33**: 431-453.
- Norton, S. A., 1973. Laterite and bauxite formation. *Economy Geology* **68**: 353-361.
- Olleir, C. K. 1969. *Weathering*. Oliver and Boyd, Edinburgh.
- Patterson, S. H., Kurtz, H. F., Olson, J. C. & Neeley, C. L., 1986. Bardossy, G & Aleva, G.J.J., 1990 (Ed.). *Lateritic Bauxites*. Developments, in Economic Geology, **27**. Elsevier
- Peterson, U., 1971. Laterite and bauxite formation. *Economic Geology*. **57**: 1185-1206.
- Tardy, Y. & Nahon, D., 1985. Geochemistry of laterites, stability of Al-goethite, Al-hematite and Fe^{3+} Kaolinite in Bauxites and Ferricretes: An approach to the mechanism of concretion formation. *Amer. Journal of Science* **285**: 865-903.

- Trolard, F. & Tardy, Y., 1987. The stabilities of gibbsite, boehmite, aluminous goethites and aluminous hematites in bauxites, ferricretes and laterites as a function of water activity, temperature and particle size. *Geochim. Et Cosmochim. Acta* **51**: 945-957.
- Tlorad, F. & Tardy, Y., 1989. A model of Fe^{3+} -kaolinite, Al^{3+} -goethite, Al^{3+} -hematite equilibria in laterites. *Clay Minerals* **224**: 1-21.
- Valeton, I., 1972. *Bauxites*. Elsevier Publishing Company.
- Wolfenden, E. B., 1965. Geochemical behaviour of trace elements during bauxite formation in Sarawak, Malaysia. *Geochim. Et Cosmochim. Acta* **29**: 1051-1062

ABSTRACT. Bamboo and rattan have been termed as non-wood resources. These resources are the most important after timber in terms of economic importance. In Sabah, the bamboo industry and rattan industry have gained prominence among government and private agencies and have received attention by the scientific community. Scientists at Forest Research Centre Sandakan and Lusaong Forest Center, Tawau have researched on the species from various techniques through to silvicultural trial.

There are several important commercial bamboo and rattan species found in Sabah and mostly being used by the ethnic groups either as furniture, flooring, walls, frames, shingles, doors and in other parts of the house. Some of the species can even be found cultivated around their houses and alleys in the village surroundings.

Bamboos are found mostly on hill slopes and along rivers and are commonly found to grow best on slopes at forest margins. Some agencies in Sabah have started to plant them on small scale for their own consumption. Agencies like FELDA usually used them as poles to harvest their oil palm fruits and so on. In the case for rattans, Jengragit Corporation of Tawau Sabah has planted more than 10000 ha of rattan in their forest area in Lusaong. There are other agencies that have planted rattan in the state.

This paper highlights the current status of bamboo and rattan resources in particular its conservation status, complexity of biodiversity base and development of its strategic programmes in Sabah Malaysia.

KEYWORDS. Rattan, bamboo, plantation, industry, conservation status