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# Biogeochemistry using Melastoma Malabathricum and fern from mineralised area in Sokor, Kelantan

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***Abstract:*** ***This research is about biogeochemistry which investigates the relationship of heavy metals concentration contained within plants versus soil samples in the selected area of Sokor, Kelantan. The identified lithology of the study area is argillaceous and calcareous units and the geological structures of folding which contribute to the current bed dipping and hydrothermal alteration through joint infilling has indicated an ore deposit region. Four sets of soil and plant samples had been collected and characterized through X-Ray Diffraction, X-Ray Fluorescence and Inductively Coupled Plasma Mass Spectrometry respectively. The main composition of soil is clay minerals, kaolinite, dickite and pyrophyliite which can indicate argillic alteration and possible supergene enrichment for ore deposition. Phyllic alteration has also been found in area close to the study area with mineral assemblage of pyrite, quartz and sericite. A relationship between the geomorphology, plant morphology and the ore element content in the soil also have been discussed. The metal elements concentration is found higher in lower elevation except aluminium and iron; the differential morphology of Melastoma Malabathricum can indicate iron concentration in the soil.***

***Index Terms: biogeochemistry, geology, gold indicator, Kelantan, plant, Sokor.***

## I. INTRODUCTION

Biogeochemistry is a method that using plant because it can uptake and store the heavy metal element inside them. The plants can be used as the sample medium for exploration as they could absorb, scavenge elements and translocate them to foliage, twigs, bark, flowers and root. The element distribution within plant body could locate the potential anomaly that will lead to ore finding. The common heavy metal elements that associates with the ore mineral are including Arsenic (As), Chromium (Cr), Zinc (Zn), Manganese (Mn), Silver (Ag) and Lead (Pb) [1], [2]. Some plants are able to solubilise gold (Au) by releasing ligand such as cyanide which observed in *Acacia* and *Eucalyptus sp.* based on exploration studies in Australia [1].

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Many plants can indicate the presence of characteristic metal minerals in the soils. These plants are called as metallocoles or metallophytes or in another term as hyperaccumulators [16], [18]. Malaysia is under tropical climate which experience dry and wet season throughout the year, thus the plants or called as hyperaccumulators are most

probably very different from those proposed at the temperate regions and four season country [3]-[6].

The benefit of this tool is easy and cheap as the sample of vegetation is widespread and have low environment impact. However, the levels of metals in plant are lower compared to soils, so care must be taken to minimise contamination during sampling. The elements of metals that commonly expected from the sample of plants are Fe, Al, Zn, Cu, As and Pb but some of the plants may accumulate typical pathfinder elements such as Au, As, Hg, Sb and Ag [1], [4], [7]. Define biogeochemical anomalies may indicate the presence of buried mineralization of gold especially [5], [17]. However, biogeochemistry has not been always adopted because biotic mechanisms of gold (Au) migration are poorly understood. Although, Au has been previously measured in plant samples, there has been doubt whether it was truly absorbed rather than merely adsorbed on the plant surface as aeolian contamination [6], [15].

Ulu Sokor in Tanah Merah, Kelantan (**Fig. 1**) is chosen as the study area because it is well-known with gold deposition and located within Central Gold Belt. According to [8] and [14], gold in Central Gold Belt has occurred at temperature ranging from 150 to 350°C, with formation depth 100-700m and fluid salinity of 0.5-4.8 wt%. Huge volcanic event during Permian to Triassic age is recorded to be the cause for massive sulphide deposition in Ulu Sokor. The decomposition and deposition process of volcanic event thus lead to the deposition of gold [9], [10]. In order to elucidate and have a deeper understanding towards the biogeochemistry of Sokor, geology of the Sokor should be well-understood to make connection between the geology and plant especially through the chemical pathway. Thus a geological mapping and study of plants, soils and rocks had been carried out to draw the relationship between these entities. This research may help to understand the gold deposition within the study area as well as the behavior of gold dispersion in the environment.

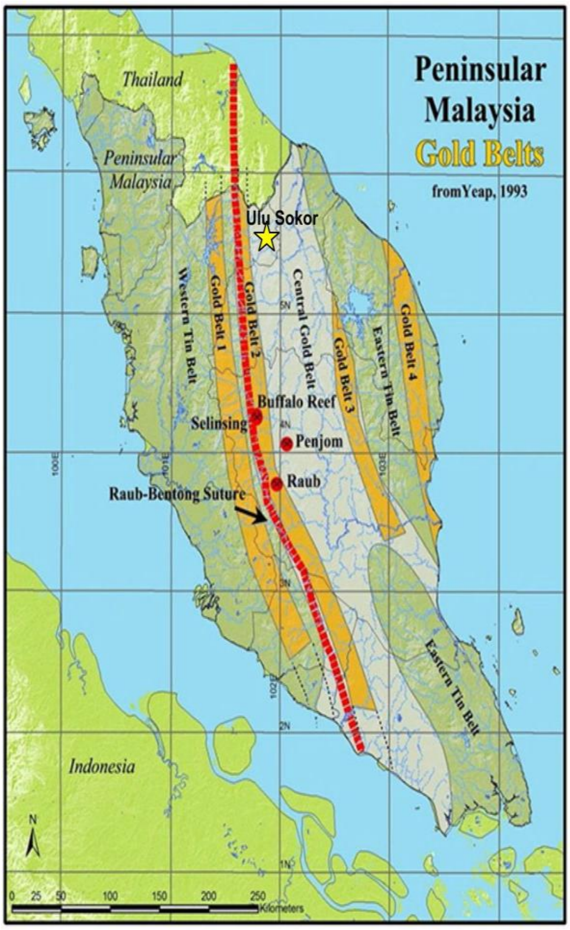


Fig. 1: Map of Peninsular Malaysia showing the 'Central Gold Belt'. Yellow star represents the location of Sokor (modified from [11]).

## II. METHODOLOGY

### A. Study area and sampling point

Sampling is done randomly according to the rock types and geological condition within the selected study area in Sokor. Four sampling points were selected in the study area of 25km$^2$ as shown in **Fig. 2**. Five soil samples of different colours; and four plant samples of two species had been collected (**Table 1**). The plants supposed to have same height before sampled.

**Table 1: Description of sampling point of study area.**

| No. | Sampling Point | Coordinate | Setting | Plant types (collected) |
|---|---|---|---|---|
| 1 | BXCHANG01 | N 05° 36' 33.8" E 102° 00' 14.9" | Off-Roadside | *Melastoma Malabathricum* |
| 2 | CHG1Y | N 05°36'05.209" E 102°0'50.145" | Slope | *Melastoma Malabathricum* |
| 3 | CHG1P | N 05°36'05.311" E 102°0'50.147" | Slope | *Melastoma Malabathricum* |
| 4 | CHG2 | N 05°35'05.235" E 102°0'11.36" | Slope Foot | *Melastoma Malabathricum* |
| 5 | CHG04(4) | N 05°33'55.901" E 101°59'47.57" | Riverbank | *Fern sp.* |

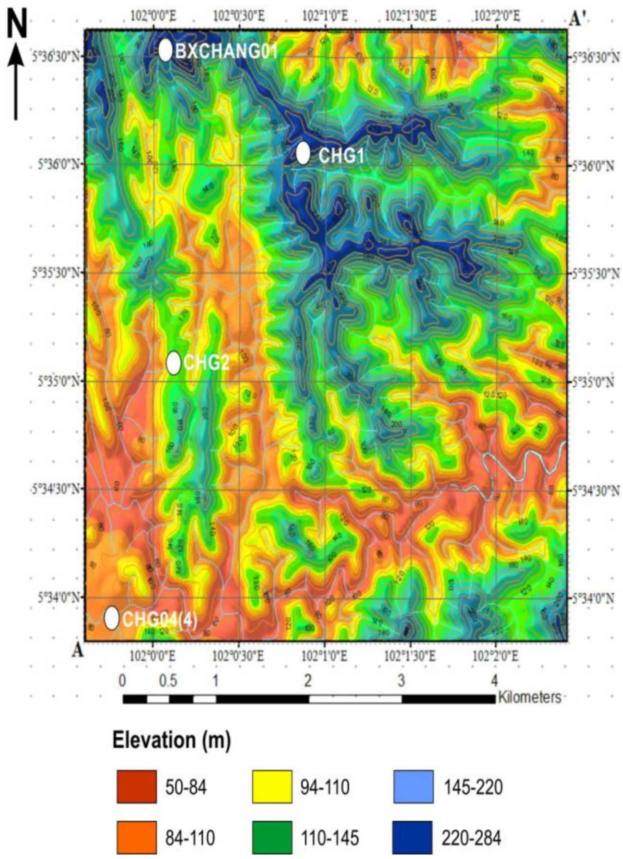


**Fig. 2: Topography map and location of sampling points (label with white dot) within the selected study area in Sokor.**

### B. Sample Preparation

The plant samples were cut into several parts and washed using tap water and deionised water before dried them properly using oven. About 2 gram of sample is placed in the crucible and turn into ash in 24 hours at 550°C by using muffle furnace. It then cooled to the room temperature. Next, 5ml of 20% hydrochloric acid (HCl) will be mixed with the plant sample for sample digestion and stir using glass rod. The plant sample was filtered for two times. For the second filtering, 0.45-micron syringe filter was used to prevent contamination. Then, the root samples were transferred into 50 ml volumetric flask and were diluted until it reaches the calibration mark. Lastly, the samples are transferred into the falcon tube and diluted using distilled water and then, were analysed by Atomic Absorption Spectrometer (AAS). Plant samples were also turned into ashes using Muffle furnace at 550°C for 9 hours and homogenised by rotary machine and passed through 2 mm sieve.

Soil samples were dried at 40°C, pulverised to reduce agglomeration, disintegrated and homogenised in a porcelain mortar and passed through 2 mm sieve. Each soil sample was then be split into three portions using a rotary divider, one of which was archived for further studies and the second was submitted for grain size analysis. The third portion was pulverized in an agate planetary mill to a grain size <0.063 mm, homogenised and divided into bottles to be submitted to the analytical laboratories [12].

## III. RESULTS AND DISCUSSION

The concentration of the metals in soil and plant samples were determined using Atomic Absorption Spectrometer (AAS), X-Ray Diffraction (XRD), X- Ray Fluorescence (XRF) and Laser Ablation Inductive Couple Plasma Micro-spectrometer (LAICPMS).

### A. Plant samples description

Plant samples of BXCHANG01, CHG1 and CHG2 were identified as *Melastoma malabathricum* species which have the striking characteristics of its purple flowers and buds as well as leaves of lanceolate shape, primary triverved and secondary parallel veins and their hairy surface. The plant morphology is shown in **Fig. 3**.


**Fig. 3: a) Melastoma Malabathricum at sampling point CHG1 b) leaf vein texture when dried, c) dried flower of Melastoma Malabatricum.**

CHG04(4) is *Blenchum indicum* or water fern or swamp fern in its general name. This can be identified through the simple vascular system, parallel veined compund leaves with spores on the back of leaves as gametophyte for reproduction as shown in **Fig. 4**.


**Fig. 4: a) Fern sp (Blenchum indicum) in CHG04(4), b) dried leaf vein c) vascular system and spores on the back of the leaves**

### B. Rock and soil samples description

The rock sample in sampling points BXCHANG01, CHG1 and CHG2 were identified as phyllite (**Fig. 5a)** except rock in CHG04(4) was identified as metamorphosed limestone inter-bedded with metamorphosed mudstone or phyllite. Most phyllite samples collected were highly weathered and difficult to be observed as thin section.

Quartz veins collected are shown as an evidence of hydrothermal alteration and part of ore path finding manifestation. Quartz vein are abundant in sampling point CHG1 with coordinate of N 05°36'05.209" E 102°0'50.145" with elevation of 244.68 m and some have shown alteration on the surface or within the quartz veins (**Fig. 5b, d)**. The minerals are younger than the quartz veins and most probably formed by development in the fissures of quartz vein or encrustation by ferromagnesian mineral grains.

On the other hand, the colour of soil sample BXCHANG01 was in light brown colour, CHG1Y in brownish yellow, CHG1P is in reddish brown CHG2 in yellowish brown, and CHG04(4) in greyish yellow.

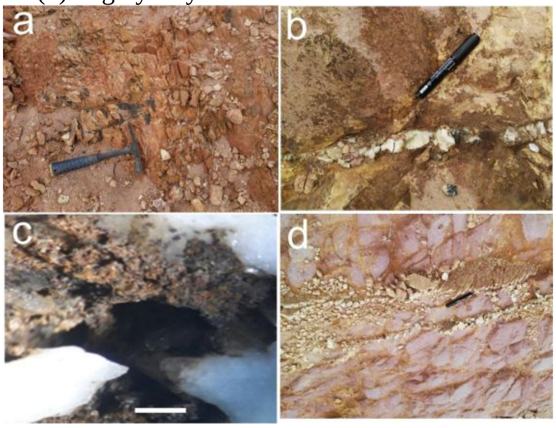


**Fig. 5 : Geology of rock sample around the sudy area in Sokor, a) Red phyllite in CHG1 b) Quartz vein consist of sulphide mineral c) vuggy texture in the quartz vein consists rusty metal (scale = 0.5cm)**

### C. XRD and XRF analysis of soil in Sokor

Based on the X-Ray Diffraction analysis (XRD) in **Fig. 6**, quartz (SiO2) has been found at the highest amount or peaks at 2Theta= 26.624 in all five soil samples analysed. Silica due to its atomic arrangement is resistant towards physical and chemical weathering thus can retain in the soil in a large amount. Cristobalite, a silica ($SiO_2$) polymorph found in silica rich volcanic ash and sedimentary environment has also found in a small amount as the evidence of pedogenesis from volcanic ash deposited during volcanic eruption million years ago.

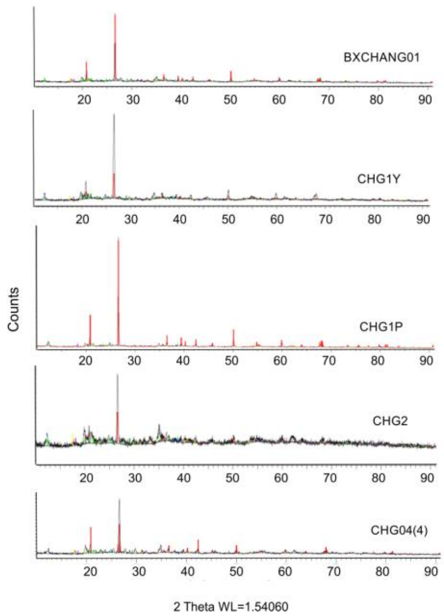


**Fig. 6: XRD results of soil samples.**

Other minerals found are clay minerals like halloysite, kaolinite, nacrite, dickite and pyrohyllite, aluminium hydroxide—gibbsite, as well as iron mineral such as hematite and goethite. Exception is in CHG1P where metahalloysite instead of halloysite was found and pyrohyllite was not found. Moganite, a type of silica and magnetite, an iron mineral were found in CHG04(4).

Quartz (SiO2) is always the main composition in soil which varied from 48 to 65%wt based on XRF analysis as shown in **Table 2**. Iron oxide composition were found to be range from 18 to 28%wt whilst potassium may ranging from 3 to 10wt%. Titanium, barium, nickel, chromium, vanadium and manganese oxides were also found in very low or minor percentage which mostly average less than 1wt% and some are below detection limit.

**Table 2: XRF analysis for soil samples.**

| Oxides | Oxide Percentage in Soil Sample (%) | | | | |
|---|---|---|---|---|---|
| | BXCHANG 01 | CHG1Y | CHG1P | CHG2 | CHG04(4) |
| $SiO_2$ | 58.37 | 65.06 | 75.27 | 47.89 | 56.07 |
| $Fe_2O_3$ | 26.51 | 25.91 | 18.98 | 44.43 | 28.20 |
| $K_2O$ | 6.86 | 6.95 | 3.55 | 5.83 | 10.22 |
| $TiO_2$ | 7.68 | 0.91 | - | 1.76 | - |
| BaO | - | 0.60 | 1.62 | - | 4.92 |
| NiO | - | 0.40 | 0.41 | - | 0.20 |
| $Cr_2O_3$ | - | 0.16 | 0.17 | - | - |
| $V_2O_5$ | 0.42 | - | - | 0.10 | 0.39 |
| MnO | 0.16 | - | - | - | - |

## D. Inductive Couple Plasma Spectrometer (ICPMS)

Only plant samples have been characterized under ICPMS and the total metal content in ppm had been tabulated in **Table 3**. Gold is not traceable in all plant samples and silver was also detected to be very low concentration as well. The gold concentration in soil sample for CHG1Y is found to be less than 0.001 ppm based on AAS analysis specifically for gold.

**Table 3: ICPMS results of plant samples.**

| Element | Total Metal Content in Plant Sample (ppm) | | | | |
|---|---|---|---|---|---|
| | BXCHANG 01 | CHG1 | CHG2 | CHG04(4) | |
| | | | | BI | DL |
| Mn55 | 63.8 | 30.95 | 19.57 | 2.68 | 48.9 |
| Fe57 | 66.14 | 14.82 | 223.09 | 157.78 | 44.31 |
| Zn66 | 0.46 | BDL | 0.77 | 0.14 | 68.86 |
| As75 | 0.07 | 0.01 | 0.19 | 0.23 | 0.05 |
| Pb208 | 0.1 | 0.02 | 0.23 | 0.32 | 0.24 |
| Pb206 | 0.17 | 0.04 | 0.4 | 0.54 | 0.42 |
| Ag107 | 6.75E-03 | 1.47E-03 | 1.10E-01 | 2.24E-02 | BDL |
| Cu65 | 0.17 | 0.19 | 0.27 | 0.22 | 1.99 |
| Al27 | 44.62 | 62.1 | 95.5 | 94.16 | 42.71 |

(* BI = *Blenchum indicum*, DL= *Dicranopteris Linearis*, both are fern species)

## E. Relationship between mineralogy and geochemistry of soil from the study area

The main composition of soil samples is clay minerals based on XRD and XRF results. The soil samples collected are strongly leached clay accumulated soil, ultisol and intensive weathered oxisol. In general sense, red coloured soil has a high content of iron but in CHG1P which is the most reddish soil among all soil samples analysed surprisingly has the lowest iron content as shown in XRD and XRF results. This can be explained that red soil is from well drainage zone where the readiness to be oxidized is higher than other soil and more susceptible to leaching. Yellow to yellowish brown soils as in BXCHANG01, CHG1Y, CHG2 and CHG04(4) are more compacted and have more hydrated iron minerals thus no rusty colour is formed. The greyish colour in CHG04(4) represents a very poor drainage soils where this anaerobic condition has favoured the reaction between manganese and iron minerals.

Clay minerals from the soil sample can be used to predict the parent materials which potentially from feldspar group according to the hydrothermal alteration that has been observed around Sokor area. Two types of alterations have been observed: argillic and phyllic alteration which formed at different temperature. The prevalent argillic alteration is producing the kaolinite and dickite to replace plagioclase and amphibole at low temperature while the pyrophyllite which form under temperature higher than 300°C are also present.

Quartz deposition is also common in the study area. This kind of hydrothermal alteration can have ore deposit named as supergene enrichment through weathering by circulation of meteoric water percolates primary sulphide ore minerals and redistribute the minerals through reaction between leaching minerals and the primary minerals thus accumulate below the water table in an enrichment zone which is at the base of the oxidized portion of an ore deposit.

Pyrite has been found near to the study area together with quartz and sericite, a typical phyllic alteration assemblage. Phyllic alteration occurs through hydrogen-ion metasomatism in permeable rock by hydrothermal fluid circulation. Through this high temperature acidic condition, plagioclase is altered to sericite while mafic minerals are altered into quartz. The hydrothermal fluid activities in Sokor also have been studied by [13] using fluid inclusion method. Structures which are similar to thin selvages had also been found in the study area indicating a highly altered area of deep environment where the outer mafic minerals replaced by chlorite while plagioclase by sericite.

## F. Relationship of plant morphology and element concentration adsorption

CHG2 represented by *Melastoma Malabathricum* species has shown the highest iron and silver found in ICPMS, which can be correlated with the highest iron found in soil sample CHG2 through XRF and XRD. Thus, the best hyperaccumulation has shown in sampling point CHG2. In the other end, CHG1 *Melastoma Malabathricum* has the lowest iron and silver content as soil sample CHG1P has the lowest iron found thus the iron accumulation is the lowest in this plant. Since the same species has been employed in both sampling point, it can be deduced that the accumulation of metal in plant is dependent on soil which is the source of absorption. According to plant morphology, sample CHG2 which consists the striking purple flowers and buds, also have higher green colour intensity for leaves compared to those of CHG1 which is without any flowers.

Thus, the flower and leaf colour potentially indicate the iron content of the particular plant as well as the soil where the elements are absorbed.

### G. Non-absorptability of elements by plant

No gold was detectable in plant samples using ICPMS as well as silver in sample CHG04(4) *Dicranopteris Linearis*. At CHG04(4), two different fern species of similar height were collected: *Blenchum Indicum* and *Dicranopteris Linearis* were sampled at the same time and same locality but show a different absorption ability on the same elements. *Blenchum Indicum* has a better absorption on iron, arsenic, lead, silver and aluminium while *Dicranopteris Linearis* has a better absorption on manganese, zinc and copper. These may due to the different enzyme persent in the different fern species thus having different nutrient requirements.

In term of plant physiology the gold maybe too little to be absorbed by the small plants collected or even too fast to be disposed through leave falling while larger plant has a longer bioaccumulation thus will have more detectable element concentration. This also can be explained based on the soil samples because too little amount or no gold at all has been analysed in soil sample. It may due to the distance between the gold ore and the plant root system is too far for the root to reach the gold as shown in **Fig. 7**. It can also indicate the absence of gold placer deposit in the sampling points or perhaps the gold has been transported to a lower elevation by erosion. Otherwise, it would be no gold found in the study area. Thus, no concrete relationship can be drawn between gold, silver or any untraceable element with plant in this research.

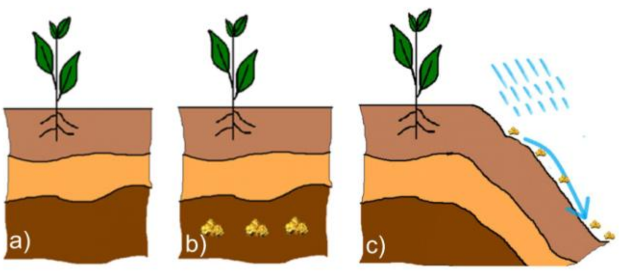


**Fig. 7: Schematic diagram shows the possible geographical reason for particular metal not been absorbed by plant: (a) there is no such metal in the setting; (b) the ore is seated too far from the roots; (c) the original seated minerals have already been eroded.**

## IV. CONCLUSION

The metal concentration in plants such as *Melastoma Malabathricum*, *Blenchum Indicum* and *Dicranopteris Linearis* from mineralized area in Sokor showed promising values because the variation could reach hundred ppm especially for iron elements based on ICPMS results. Even though the samples are quite limited for the selected species, iron and silver elements have indicated a positive relationship between the plant and soil. However, no traceable gold was identified from the ICPMS analysis, thus a braver prediction of the relationship between the precious element, gold and plant cannot be drawn directly in this research.

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