Soil Development of Ultrabasic Rock and its Implication to the Contamination of Paddy Soil in Ranau Sabah

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Abstract

This paper discussed the development of soil from ultrabasic rock situated on the north to the east of Ranau Sabah and its implication to the contamination of paddy soil. The main objective of this study is to identify the minerals in soil samples and to determine its structure and texture. The second objective is to examine the distribution of heavy metals in the ultrabasic profiles and paddy soil. The field observation shows the thickness of soil developed from weathering processes varies from 0.5m – 10.0m. Sediment samples which transported from the river and drainage system for the water supply to the villages were also collected around the river tributary. The soil and sediment samples were air dried and ground into fine grain before identified the mineralogical content using X-Ray Diffraction (XRD). The micro structural analysis of soil were observed using Scanning Electron Microscope (SEM). The analysis of heavy metals was carried out using Inductive Couple Plasma Mass Spectrophotometer (ICP-OES). The geochemical data obtained from the weathering profile analyses indicated that the concentrations of Ni, Cr, Co in soil are highest compared to the parent material. X-ray Diffraction (XRD) and Scanning Electron Microscope (SEM) analyse indicate that all ultrabasic soil contain high iron oxide minerals; whereas iron oxide, kaolinite and quartz appeared in the paddy soil. As a conclusion the high concentration of heavy metals in river sediment mainly originated from the chemical weathering of ultrabasic rock.

Keywords: geochemistry; heavy metals; ultrabasic rock; paddy soil

Introduction

Ultrabasic rock can be found along the main road from Ranau to Telupid. Jacobson (1970) stated geologically Ranau area consists of several major rock units of ultramafic rocks, crystalline basementrocks, adamellite rock, Crocker Formation, Trusmadi Formation, Wariu Formation, Chert Spilit Formation, andtilloid deposit. The detailed mapping of the rock distribution included ultrabasic has been done by Jacobson (1970) as shown in Figure 1. The ultrabasic rock is a part of ophiolite complex originated from oceanic crust with Cretaceous age. The main ultrabasic rock type is serpentinitized peridotite, mainly harzburgite, with less abundant herzolite (Mohd Rozi Umor et. Al, 2003). Hutchison (2005) described the ultrabasic rock in Ranau are mostly strongly serpentinitized peridotite due to the metamorphism processes. Hall (2008) state the large ultrabasic bodies invariably have steeply dipping, intensely brecciated and serpentinized faulted margins. Sanudin and Baba (2008) reported the Sabah’s oldest rock units built by the ophiolite fragment also consists of ultrabasic and serpentinite rocks.

The ultrabasic rock in tropical climate has undergone intensive weathering processes to produced thick soil profiles. Baba Musta & Mohamad Md. Tan (1996) reported the thickness of soil originated from ultrabasic rock exposed in Telupid, Sabah was up to 14 meters. Main minerals content in ultrabasic soil was goethite, hematite and maghemite (Sahibin et. al, 1996). The development of iron oxide minerals in ultrabasic soil is mainly controlled by the type of parent rock. The development of secondary minerals and distribution of heavy metals in the paddy soil due to the weathering of ultrabasic rock from Ranau, Sabah have been not discovered. Therefore the objective of this study is to identify the mineralogy and distribution of heavy metals in paddy soil around Ranau, Sabah area.
Material and Method

Fieldwork has been conducted to study the geological characteristics of weathered ultrabasic rock and to identify the suitable soil profiles for sampling. Most of the ultrabasic profiles showed the appearances of parent rock, saprolite and thick soil. Two represented soil profiles which represented ultrabasic soil from the study area namely Kompleks Sukan Ranau (KSR) and Ranau Harrison Factory (RHF) (Figure 2) were identified for the detail mineralogical and microstructural study. About 500g samples with different depth were collected and put into plastic bag to maintain the moisture before brought to laboratory for further analysis. A total of 7 soil samples and 1 rock samples were collected from each KSR and RHF profiles. A total of 50 surface soil and sediment samples with 5cm depth were collected from the paddy field area.

The soil and sediment samples were air dried and ground into fine grain using agate mortar before further mineralogical identification. The mineralogical content of the soils were determined by X-Ray Diffraction with Philips XPERT-PRO (PW3040) instrument. Scanning Electron Microscope (SEM) analysis were used CARL ZEISS MA10 instrument were used for the mineralogical and microstructural analysis. Petrography analyses were used Polarizing Microscope Carl Zeiss Axio Scope and Leica DM2500. Images of minerals were observed and captured with 10, 25 and 50 magnifications.

Result and Discussion

Fieldwork Observation

The field observation shows the complete weathering profile of ultrabasic with the presence of soil, saprolite and parent rock with varies thickness. The field survey shows the thickness of soil developed from weathering processes varies from 0.5m – 10.0m. The ultrabasic profiles well recognized with red - brownish colour. The colour indicated the high concentration of secondary mineral especially iron oxide minerals. The type of soil also call as lateritic soil which is usually found in tropical climate due to the high annual rainfall and high intensity of chemical weathering processes (Beauvais & Colin, 1993).

The outcrop of fresh rocks shows the grey-greenish colour with highly fractured and sheared. Talk mineral with white in colour and soft texture can be observed on the surface of slickenside. The growth of secondary quartz mineral also occurred in the rock fracture or joints system. The formation of quartz might be due to the silicification process through the metamorphism. Highly fractured rock known as serpentine was easily separated physically to small pieces and high slickenside was common feature in the outcrops. It is found that the soil from the rock profiles produced loose soil and be able to be transported to the lowland area.
Figure 1. Geological map and location of study area in Ranau Sabah (Source: Jacobson 1970)
Figure 2: Soil profiles and sampling stations at (A) KSR profile (N 05°59.433’ E 116°41.348”) and (B) RHF profile (N 05°59.236’ E 116°41.511”).

Mineralogy and microstructural analysis

Both peridotite and serpentinite rocks were prepared for thin section before petrography analysis. Rock samples were classified according to the classification by Streckeisen, at. al (1978). The result of petrography analysis shows the rock samples rich with olivine and orthopyroxene (Figure 3A), whereas chlorite, chloritoid and magnetite are present as accessory minerals. Chrysotile fibre is main mineral composition in serpentinite rock (Figure 3B).

The X-ray diffractograms pattern of ultrabasic soils indicates that mainly soil were made up by oxides and hydroxides of iron especially goethite, maghemite, hematite and magnetite. This result shows that most of rock forming minerals namely olivine and pyroxene were changed into oxide and hydroxide minerals. The soil collected from paddy area shows the appearance of iron oxide, kaolinite and quartz (Figure 4). This indicates the admixture processes of soil originated from the surroundings area notably ultrabasic, sandstone and mudstone.
Figure 4. (A) X-ray diffractogram of soil from ultrabasic profile and (B). X-ray diffractogram of soil from paddy soil showing the identification of minerals.
The scanning electron microphotograph of ultrabasic soil shows the appearance of iron oxide (Figure 5). The admixture of iron oxide, kaolinite and quartz was observed in paddy soil (Figure 6).

**Figure 5.** SEM image from KSR profile, ultrabasic soil show various structure of iron mineral.

**Figure 6.** SEM image shows the minerals and microstructural pattern in paddy soil.

*Geochemical analysis*

The result of geochemical analysis and the pattern of heavy metals concentration namely Co, Cr, Ni and Pb are shown in Figure 7. The result of analysis shows that the concentration of Co was at the range of 115 - 448 mg/kg, Cr was 2768 – 4593 mg/kg, Ni was 1138 – 4389 mg/kg and Pb was 4-8 mg/kg. The comparisons of heavy metals concentration in the study area with the normal range in soil, critical soil total concentration are given in Table 1. The geochemical distribution patterns showed that most of heavy metals were concentrated around the river tributary and around the irrigation system. There is no significant critical soil concentration around the paddy soil located on the other areas. This indicated that the weathering processes of rock from the surroundings area has contributed to the geochemical pattern around paddy soil. High concentrations of Cr and Ni around the river tributary and irrigation system was due to the transportation of soil from the nearest ultrabasic rock outcrops. According to Siebecker, (2010) serpentine originated soil are exceptionally rich in heavy metals notably chromium, nickels and cobalt which can cause an adverse effect on the environment.

**Table 1.** Concentrations of heavy metals in soils

<table>
<thead>
<tr>
<th>Element</th>
<th>Normal range in soils (mg/kg)</th>
<th>Critical soil total concentration (mg/kg)</th>
<th>Ultrabasic soil in Ranau (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co</td>
<td>0.5 - 65</td>
<td>25 - 50</td>
<td>115 - 448</td>
</tr>
<tr>
<td>Cr</td>
<td>5 - 1500</td>
<td>75 - 100</td>
<td>2768 - 4593</td>
</tr>
<tr>
<td>Ni</td>
<td>2 - 750</td>
<td>100</td>
<td>1138 - 4389</td>
</tr>
<tr>
<td>Pb</td>
<td>2 - 300</td>
<td>100 - 400</td>
<td>4 - 8</td>
</tr>
</tbody>
</table>

(Source: Bowen*, 1979; Kabata-pendas and Pendias#, 1992)
Figure 7. Distribution of (A) Co, (B) Cr, (C) Ni and (D) Pb in paddy soil collected around Ranau, Sabah.
Conclusion

i. Chemical weathering reaction on ultrabasic rock has altered the primary minerals olivine and pyroxene to produced iron oxide minerals.

ii. The combination of weathering, transportation and sedimentation processes has released and redistributed the heavy metals from the soil profiles to the lowland of the paddy field area.

iii. The main sources of high concentration of Co, Cr and Ni in the paddy soil mainly originated from the weathering processes of ultrabasic rock.

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