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GEOCHEMICAL PROPERTIES OF LATERITE AND LATERITIZATION PROCESSES IN HPA-AN TOWNSHIP, KAYIN STATE

Hlaing Myo Nwe[1], Aung Kyaw Myat[2], Khin Maung Hla[3]& Mya Moe Khaing[3]

Abstract

The present research is carried out laterite and lateritic soils of the Hpa-an Township, Kayin State. In this area, Taungnyo Formation (Carboniferous to Early Permian), Moulmein Limestone (Middle to Late Permian) are exposed covering with older alluvium (Pleistocene) and younger alluvium (Holocene). Laterite altered from all kind of rocks such as igneous, sedimentary and metamorphic rocks. Geochemical analysis of lateritic soil samples is tested with EDXRF to differentiate the laterite type and lateritization processes. Geochemical study of laterite in Hpa-an area suggest that it is made up of within 24% - 64% of SiO_2 , between 16 % and 50 % of Fe_2O_3 , from 13 % to 27 % of Al_2O_3. Others oxides such as K_2O, MnO and CaO are composed of small amount. Trace elements are shown that S, Sr, Cr, V, Zr Cu, Zn,Y, Nb and Rb. The identification and analysis of laterites were made by Molar Ratio of laterite which is based on the ratios of sesquioxides (Fe_2O_3 + Al_2O_3) to silica (SiO_2). Molar ratio less than 1.33 is true laterite, between 1.33 and 2 is lateritic soil and greater than 2 is non-lateritic soil. Ternary Diagram is used to explore degree of lateritization. Four stages of alteration are recognized in lateritization process: (i) kaolinitization, (ii) weak lateritization, (iii) moderate lateritization and (iv) strong lateritization. Based on the results, Taunggalay and Myaing-gale areas have less than 1.33 in Molar ratio and moderate lateritization. Vicinity of Hpa-an and Ya-The Byan Taung display between 1.33 and 2 in Molar ratio. These areas pronounced lateritic soil and lied in weak lateritization zone. Southern parts of the study area show greater than 2 in Molar ration where it is non-lateritic soil zone and kaolinization stage.

Keywords: Sesquioxides, lateritization, Molar ratio

Introduction

The term ‘laterite’ was originally applied to Fe-rich material in Kerala (India) by Buchanan (1807). It was sufficiently consolidated to be cut into building blocks, which hardened on exposure. McFarlane (1976) adopted the definition of Sivarajasingham et al. (1962 “laterites are highly weathered material, depleted in alkalis and alkaline earths, composed principally of secondary oxides and oxyhydroxides of iron (goethite, hematite, maghemite) and hydroxides of aluminium (gibbsite). These oxides may incorporate other minerals including clays and other secondary minerals (kaolinite, anatase), resistant primary minerals (quartz, zircon) and weather able primary minerals (ilmenite, muscovite). Laterite was the product of alteration or weathering of an original rock.

Laterite is suitable as a base, subbase and select course for a medium traffic road or airfield. Besides, lateritization is economically most important for the formation of iron and nickel ore deposits.

The present research was investigated in the laterite and lateritic soils of the Hpa-an Township, Kayin State. The research area is bounded between North Latitude 16°44' to 16°58' and East Longitude 97°31' to 97°43' as shown in (Figure.1). This area can be easily accessible by car, train and various kinds of vehicle.

[1] Dr, Associate Professor, Department of Geology, Bago University (hmyonwe@gmail.com)
[2] Dr, Associate Professor, Department of Geology, University of Yangon (aungkyawmyat95@gmail.com)
[3] Dr, Professor and Head, Department of Geology, Bago University
[4] Dr, Associate Professor, Department of Geology, Bago University (myamoekhainggeol@gmail.com)

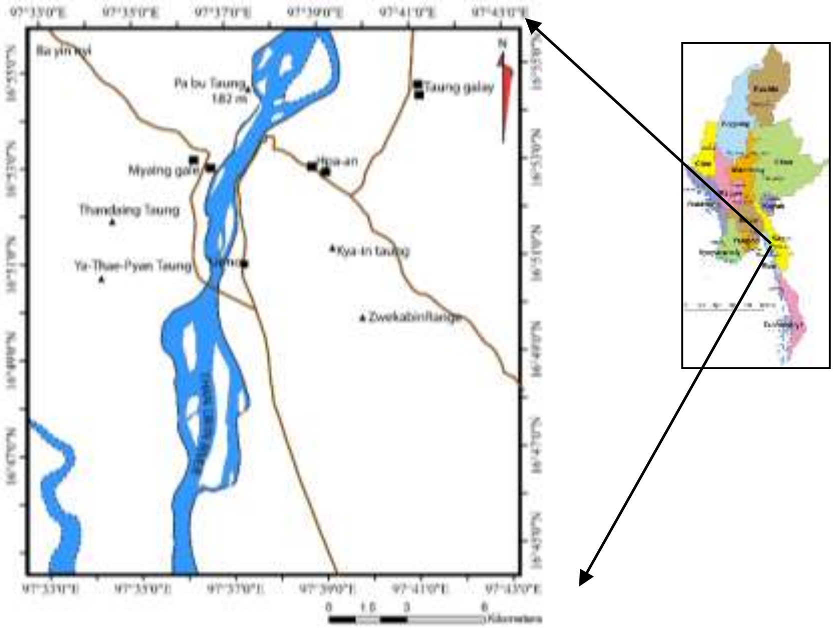

Figure 1 Location Map of the research area.

Geology of the research area

The rocks of Taungnyo Formation (Carboniferous to Early Permian), Moulmein Limestone (Middle to Late Permian), Older Alluvium (Pleistocene) and Younger Alluvium (Holocene) covered in the study area. The rocks of the Taungnyo Formation are exposed at the northern part of the Zwekabin Range and southern part of the Hpa-an area. The rocks are mainly composed of clastic units; thin bedded, whitish grey to pinkish colored siltstone, partly light grey to dark grey siltstone intercalated with thinly laminated shale, partly fine grained nodular sandstone.

Moulmein Limestone is mostly composed at the Zwekabin Range with gentle dipping. The other isolated hills with karst topography are also composed of Moulmein Limestone. The rocks consist of medium to thick bedded, light grey to grey colored micritic limestone, dolomitic limestone and brecciated limestone. Most of the flat plain along the western and eastern part of research area are covered by reddish brown to yellowish brown colored, thick lateritic soil. Besides, light grey to yellowish grey colored silty soils of younger alluvium expose along the central part of this area, especially Thanlwin River.

In northern part of Kya-in Taung, two layers of soil occur. Upper part is composed of recent soil that is overlain on the lateritic soil. This layer shows yellowish brown colour, medium to coarse grained soils with minute iron concentration (Figure.2 & 3). In the western part of Kya-in Taung, lateritic soil also occurs as yellowish brown colour with iron and aluminium oxides which is shown in (Figure.4 & 5). In the north western part of Zwekabin Range, reddish brown colour lateritic soil with iron concretions occurs as shown in (Figure.6) and also reddish brown colour lateritic soil occurs in northern part of Ye-thae-pyan Cave (Figure. 7). Laterite is more compacted and indurated in the Taunggaly and Myaing-gale areas (Figure. 8 & 9). They show red to reddish brown colour and wormlike appearance in one quarry, which one produce for local used. Samples are collected by using random method in the study area. Totally 18 laterite and lateritic soil samples are collected in the research area (Figure. 10).

Figure 2 Lateritic soil profile at the northern part of Kya-in Taung

Figure 3 Lateritic soil altered from bed rock at the northern part of Kya-in Taung

Figure 4 Lateritic soil profile at the western part of Kya-in Taung

Figure 5 Lateritic soil altered from bed rock at the western part of Kya-in Taung

Figure 6 Partially indurated lateritic soil at the north-western part of Zwekabin Range

Figure 7 Lateritic soil exposure at the northern part of Ye-thae-pyan Cave

Figure 8 Indurated laterite outcrop at Myaing-gale area

Figure 9 Laterite exposure at Taunggalay area

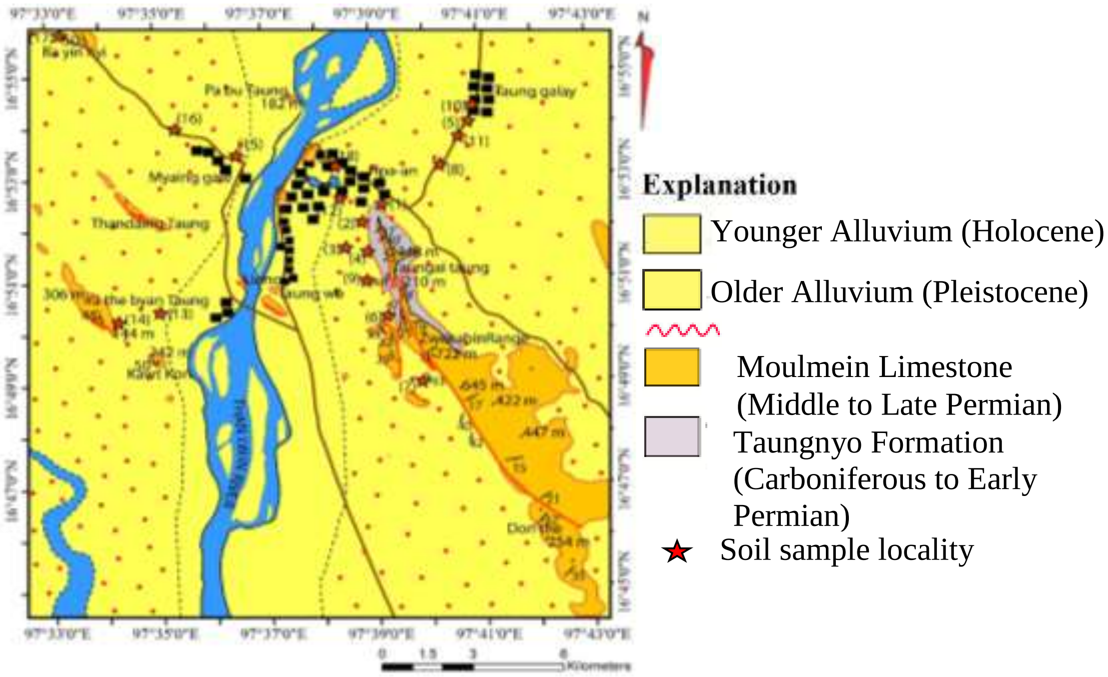

Figure 10 Geology Map showing soil sample localities of the research area

Aims and Objectives

This research aims to explore lateritization processes of the area analyzing on geochemical properties of laterite. Moreover, the main objectives are as follows;

- To observe the geology of the study area
- To analyze the geochemical properties of the laterite in research areas
- To identify the type of laterite
- To estimate degree of lateritization processes of this area

Methodology

It has studied a collection of all available geological data and geochemical data. Topographic map interpretation is plotted on the UTM map no. 1697-9, 10, 13 and 14 of Survey Department (Ministry of Forestry). Samples collections are made by using the GPS methods to get the distribution of lateritic soil samples. And then, all of soil samples are tested with EDXRF as the laboratory work to know the containing element in soils.

The identification and analysis of laterites were made by using Molar Ratio of Person, B.S (1970) which is based on the ratios of sesquioxides (Fe_2O_3 + Al_2O_3) to silica (SiO_2).

Diagram of Schellmann (1982, 1986) is used to explore degree of lateritization. This method is a useful, quantitative approach to the classification of laterite and it compares the extent of chemical alteration of a weathering product within the profile to the composition of the parent rock in order to define 'the degree of lateritization'. Of crucial significance, it is the fact that the scheme recognizes the importance of the nature of the protolith upon the composition of the weathering product. Using a SiO_2, Fe_2O_3 and Al_2O_3 ternary diagram, four stages of alteration are recognized in lateritization process: (i) kaolinitization, (ii) weak lateritization, (iii) moderate lateritization, and (iv) strong lateritization. Moreover, laterites distribution map of the area are built based on the above data.

Results and Discussions

Geochemistry of laterite in study area

Geochemical study of laterite in Hpa-an area is made up of (7) major oxides and (10) trace elements. Most of the samples, SiO_2 is highest amount, the second is Fe_2O_3, the third is Al_2O_3 and the fourth highest is TiO_2. Variation of these four major oxides is shown in (Figure.11). SiO_2 is influence within 24% - 64% of the area. Fe_2O_3 contain between 16 % and 50 % in all soils. Moreover, Al_2O_3 also contain from 13 % to 27 %. Others oxides such as K_2O, MnO and CaO are composed of small amount in all samples. Among the (10) trace elements, S is highest amount (83 ppm), but S doesn't contain in some sample. Sr, V and Cu occurred in all samples. Nb is least amount in all samples. The chemical results of lateritic soils from the Hpa-an area were analyzed by the result of EDXRF are shown in Table (1 and 2).

Table 1 Major oxide and trace elements of location (1-9)

	Major Oxides (wt%)								
	1	2	3	4	5	6	7	8	9
SiO_2	43.14	56.30	43.24	37.79	24.20	40.26	57.03	55.39	42.95
Fe_2O_3	28.13	16.10	29.37	34.62	50.02	36.21	23.28	26.12	30.08
Al_2O_3	19.73	19.04	20.28	20.99	20.55	18.59	13.99	15.04	17.97
TiO_2	2.66	2.78	2.84	2.52	1.72	2.03	1.22	1.42	2.02
K_2O	4.79	5.02	3.36	3.10	2.61	2.09	1.43	0.89	3.88
CaO	0.82	0.00	0.00	0.00	0.00	0.30	2.26	0.30	1.81
MnO	0.14	0.10	0.05	0.08	0.07	0.07	0.56	0.13	0.44
	99.41	99.34	99.14	99.11	99.16	99.55	99.77	99.29	99.16
Trace Elements (ppm)									
	1	2	3	4	5	6	7	8	9
S	0	0	50	73	83	52	0	69	73
Sr	6	8	4	8	14	5	10	6	7
Cr	5	0	7	8	9	10	0	7	5
V	10	8	11	12	9	1	7	7	9
Zr	37	67	38	28	8	0	7	0	27
Cu	6	4	6	7	6	6	1	1	5
Zn	8	0	7	0	0	0	7	8	5
Y	5	4	5	4	0	3	0	4	4
Nb	2	0	0	0	0	0	0	0	0
Rb	6	8	5	0	0	0	2	0	0

Table 2 Major oxide and trace elements of location (10-18)

Major Oxides (wt%)									
	10	11	12	13	14	15	16	17	18
SiO_2	25.12	46.82	63.63	37.43	39.96	32.47	23.85	23.74	53.28
Fe_2O_3	40.33	26.80	19.24	32.39	30.23	37.60	41.78	40.92	27.71
Al_2O_3	25.27	17.93	12.96	23.00	21.94	22.90	25.61	26.93	15.57
TiO_2	2.50	2.30	0.95	2.42	2.71	3.01	4.50	3.61	1.29
K_2O	5.59	3.03	0.98	3.86	4.01	2.72	2.37	3.68	1.09
CaO	0.80	1.95	0.92	0.50	1.00	0.41	0.46	0.50	0.61
MnO	0.22	0.27	0.32	0.29	0.11	0.17	0.40	0.17	0.11
	99.83	99.10	98.99	99.89	99.96	99.29	98.81	99.55	99.66
Trace Elements (ppm)									
	10	11	12	13	14	15	16	17	18
S	51	60	88	0	55	0	39	44	50
Sr	9	5	53	3	4	8	6	4	6
Cr	7	8	9	6	7	7	6	8	6
V	14	8	5	11	14	14	18	15	5
Zr	29	40	7	43	49	49	65	44	0
Cu	8	7	5	8	7	7	10	8	1
Zn	11	12	9	6	7	6	8	6	0
Y	6	5	4	5	4	5	6	5	0
Nb	2	0	0	0	0	0	4	0	0
Rb	0	2	0	4	10	0	0	0	0

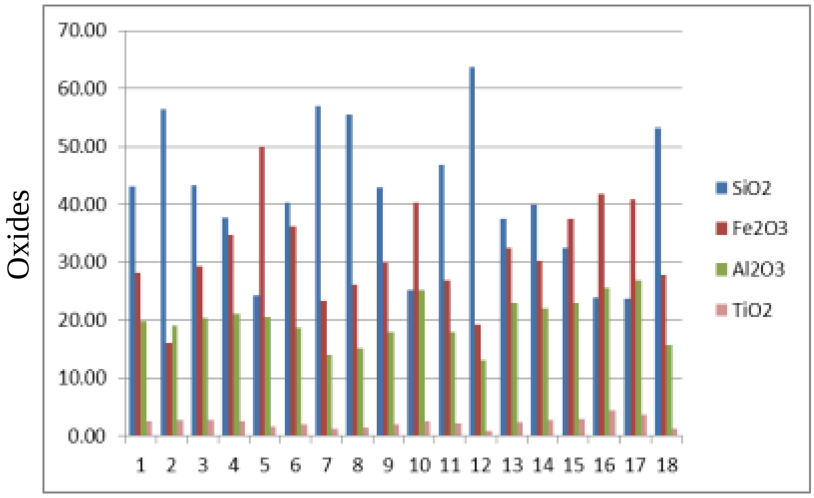

Figure 11 Four major oxides in laterite of the study area

Identification of Laterite

In the research area, based on composition of SiO_2, Fe_2O_3 and Al_2O_3 use to calculate according to Molar ratio for dividing laterite type. This equation is based on the ratios of sesquioxides (Fe_2O_3 + Al_2O_3) to silica (SiO_2), types of laterite can be identified. The silica/sesquioxide molar ratios were computed using the following equation.

$$\text{Silica/Sesquioxide Molar Ratio} = \frac{\%SiO_2/\text{Mol.Wt of } SiO_2}{\%Al_2O_3/\text{Mol.Wt of } Al_2O_3 + \%Fe_2O_3/\text{ Mol.Wt of } Fe_2O_3}$$

Molar mass of Si = 28.0g

Molar mass of O = 16.0g

Molar mass of Al = 27.0g

Molar mass of Fe = 56.0g

Molar weight of SiO_2 = 28 + (16 x 2) = 60.0g

Molar weight of Al_2O_3 = (27.0 x 2) + (16 x 3) = 102.0g

Molar weight of Fe_2O_3 = (56.0 x 2) + (16.0 x 3) = 160.0g

Ratio less than 1.33 is true laterite, between 1.33 and 2.0 indicate lateritic soils while those greater than 2.0 indicate non-lateritic soils (Person, B.S., 1970). Laterites can also be identified based on the value of sesquioxide ratio (Table.3).

Table 3 Identification of laterites based on value of sesquioxides ratio (Person, B. S, 1970)

Name	Sesquioxides ratio
True Laterite	< 1.33
Lateritic soil	1.33-2
Non-Lateritic soil	> 2

In the research area, the percentage of each of the three essential constituents must be related to a total of 100 when applying this means of identification. And then plot the results in triangular diagram (Figure.12). Laterite samples 5, 10, 15, 16 and 17 fall in laterite zone. In this zone, the contents of Al_2O_3 and Fe_2O_3 increase and SiO_2 content decreases. In lateritic soil zone, SiO_2 content is more than, and also Al_2O_3 and Fe_2O_3 are lower than the laterite zone. In this zone, samples no.1, 3, 4, 6, 9, 13 and 14 lie. Samples no.11 and 18 falls on line of lateritic soil. Samples no.2, 7, 8 and 12 fall in non-lateritic zone; these samples contain mainly the quartz than other zone. So, SiO_2 percent is higher than other samples.

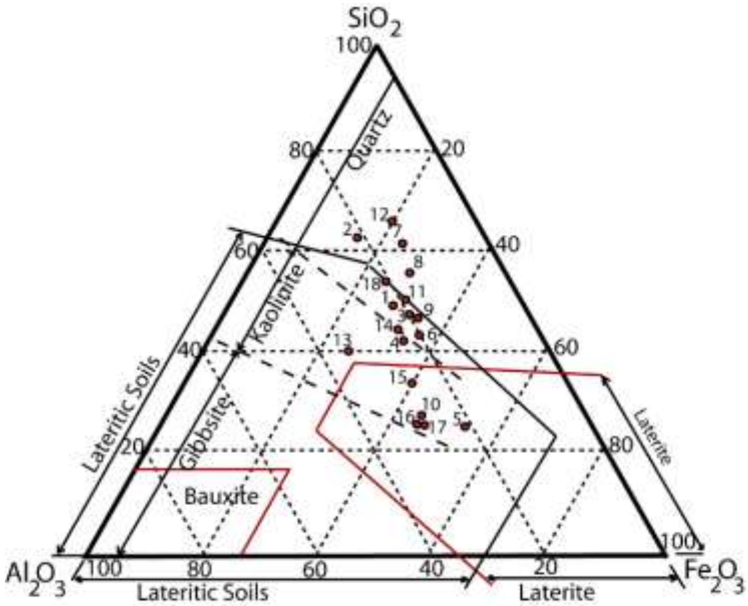

Figure 12 Identification of Laterite in study area based on Molar Ratio (Lukens, 1964)

Classification of laterite in study area

Ternary diagram is used to estimate the degree of lateritization in the study area. This diagram is also based on SiO_2, Fe_2O_3 and Al_2O_3 percentage and four stages of alteration are classified as lateritization processes: (i) kaolinitization, (ii) weak lateritization, (iii) moderate lateritization, and (iv) strong lateritization (Schellmann, 1982). The relative positions of these stages on the ternary diagram vary according to the chemical composition of the protolith. Accordingly, the Schellmann scheme is useful for determining the degree of alteration of laterites.

In the study area, sample no. 2, 7 and 12 lie in kaolinization stage. Sample no.1, 3, 4, 6, 8, 9, 11, 13, 14 and 18 fall in weak lateritization stage. Five samples fall in moderate lateritization stage. They are sample no. 5, 10, 15, 16 and 17. (Figure.13)

According to two diagrams, laterites around the Taunggalay area and Myaing-gale areas are true laterite. They are moderate lateritization. Hence, they are more indurated than other areas. Small laterite quarries occurred in Taunggalay area for local uses. Laterites are also used as building stone. Results of other samples show weak lateritization zone. The results of molar ratio are between 1.33 and 2. Hence, lateritic soil of these areas is used for subbase of road construction. Non-lateritic soils greater than 2 (molar ratio) are considered as earlier stage of actual lateritization (kaolinization). Real laterite has suffered a stronger transformation than merely kaolinized rocks.

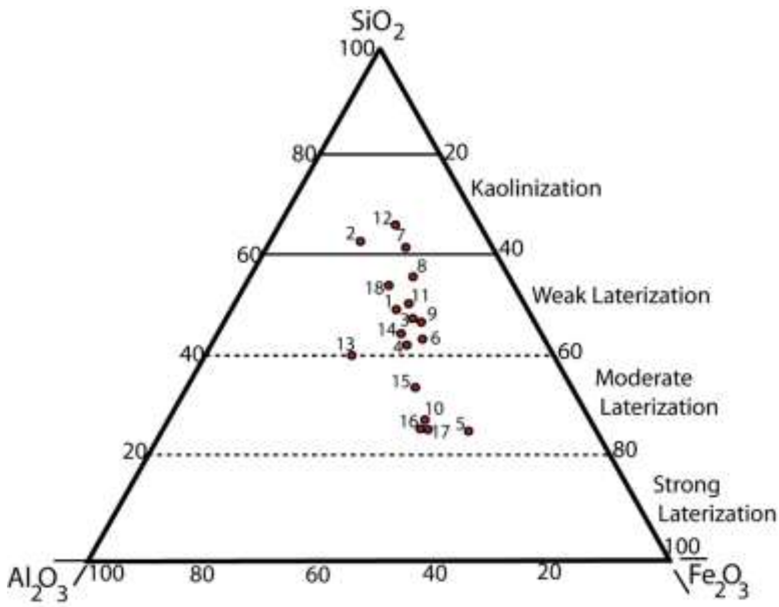

Figure 13 Ternary diagram to estimate lateritization processes

Distribution of Laterite and Lateritic Soil

The laterite distribution map is based on the above two diagrams (Figure.14). This map has been constructed on molar ratio. Northern part of the study area composed of true laterite. The middle part of this area shows lateritic soil and southern part is covered with non-lateritic soil. The degree of weathering typically diminishes with depth. Laterite profiles consist of a progression from unaltered protolith at the base, up through increasingly altered parent rock (or saprolite), iron enriched zones (mottled zone), and culminating at the top as an iron-rich laterite duricrust (Widdowson, M 2009).

The southern parts of the study area are near the host rock, so this area can be altered from bed rock containing with unaltered bed rock in a soft matrix. Middle part is first stage of weakly-lateritised zone in which some primary lithological characteristics remain. Iron percent are higher than non-lateritic soil. Northern part of the area is more iron segregation and vermiform textures where lies in moderately lateritized zone. Hence, true laterite is found in northern part of study area especially in the Taunggalay and Myaing-gale areas.

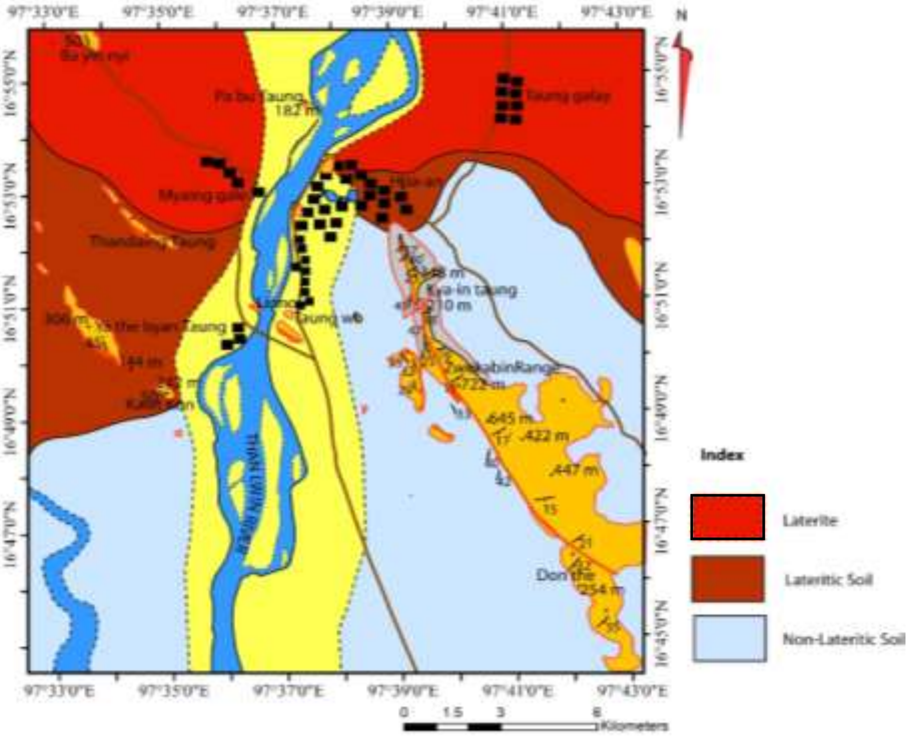

Figure 14 Laterite and lateritic soil distribution map of the research area.

Conclusion

The present research is carried out the laterite and lateritic soils of the Hpa-an Township, Kayin State. The rocks are composed of Taungnyo Formation (Carboniferous to Early Permian), Moulmein Limestone (Middle to Late Permian), Older Alluvium (Pleistocene) and Younger Alluvium (Holocene). Most of the flat plain along the western and eastern part of research area are covered by reddish brown to yellowish brown colored, thick lateritic soil. Laterite is more compacted and indurated, red to reddish brown colour in the Taunggaly and Myaing-gale areas.

Geochemical study of laterite in Hpa-an area is made up of (7) major oxides and (10) trace elements. Most of the samples, SiO_2 is highest amount, the second is Fe_2O_3, the third is Al_2O_3 and the fourth highest is TiO_2 as EDXRF results.

Based on Lukens Diagram, samples 5, 10, 15, 16 and 17 fall in laterite zone where the contents of Al_2O_3 and Fe_2O_3 increase and SiO_2 content decreases. Samples no.1, 3, 4, 6, 9, 13 and 14 lie in lateritic soil zone in which SiO_2 content is more than, and also Al_2O_3 and Fe_2O_3 are lower than the laterite zone. Samples no.11 and 18 falls on line of lateritic soil. The last zone is non-lateritic zone. Samples no.2, 7, 8 and 12 fall in this zone where this zone contains more clay minerals than other zone. Hence, SiO_2 percent is higher than other samples.

According to Ternary diagram, laterites in Taunggalay area and Myaing-gale areas can be moderate lateritization. Hence, the laterites in this area are more indurated than other areas. . In Taunggalay area, geochemical properties of laterite have SiO_2 (23-24%), Fe_2O_3 (40-50%) and Al_2O_3 (20-25%).These laterites are used as building stone and it is also suitable for base and subbase for a medium traffic road. Small laterite quarries occurred in Taunggalay area for local uses. Results of other samples show weak lateritization zone. Lateritic soils are well suited for rubber tree plantations, fruit growing and horticulture.

Moreover, molar ratio is between 1.33 and 2. Non-lateritic soils greater than 2 (molar ratio) are considered as earlier stage of actual lateritization (kaolinization). So, it can be concluded that this area can be affected by moderate lateritization and weak lateritization.

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