The Chemical and Mineralogical Characteristics of Quaternary Volcanic Rock Weathering Profile in the Southern Part of Bandung Area, West Java, Indonesia

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Abstract: ***Upstream Citarum river basin is located in the southern part of Bandung Regency. This region is composed by Quaternary volcanic products. In general, the exposed rocks have been weathered with varying levels. Several studies have linked the chemical and mineralogical characteristic of the weathering process has been carried out, among them are Sukiyah et al (2000), Sukiyah et al (2005), Sukiyah (2009), Sukiyah et al (2010). The results showed that at certain weathering level will result soil with specific chemical and mineralogical characteristics as well. Nevertheless, the correlations among these variables have not been analyzed in detail. This study aimed to determine changes in the chemical and mineralogical of volcanic rocks at different levels of weathering and the correlation between them. Volcanic rocks in the study area can be grouped in alterated and unalterated rocks. Major oxides obtained from 33 rock samples with varying degree of weathering. The chemical characteristics data (major oxides) obtained by XRF methods performed in the laboratory. Meanwhile, the minerals data obtained through petrographic analysis using the polarizing microscope, XRD, and SEM. The probabilistic approach is used to analyze the data to determine the chemical and mineralogical characteristics at different levels of weathering. The analysis showed that major oxides proportion of altered volcanic rocks not influenced by the degree of weathering of rocks is significantly. Otherwise, the degree of weathering strongly correlate with the proportion of the major oxides in unaltered volcanic rocks. In unaltered volcanic rocks, SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O, K_2O, and TiO_2 form a significant chart patterns, contrarily P_2O_5 and MnO did not show any correlation. Increasing the degree of weathering resulted in a decrease in the SiO_2, CaO, MgO, Na_2O, and K_2O, instead Al_2O_3, Fe_2O_3, and TiO_2 increased significantly. In altered volcanic rocks, correlation between Al_2O_3 and P_2O_5 on LOI is not significant. In contrast, SiO_2, Na_2O_3, and K_2O have a significant correlation. Meanwhile, changes in Fe_2O_3, CaO, MgO, TiO_2, and MnO to the degree of weathering is fluctuating. In general, volcanic rock-forming mineral susceptible to weathering processes. In line with the increase in the degree of weathering, the cavity and iron oxide increased as well. At the advanced weathering, volcanic rock forming mineral have been altered entirely due to chemical reactions. $Al^{3+}$and Fe^{3+} are cation most vulnerable regardless when the weathering process begins. Increasing degree of weathering, the other cations also separated to form a new compound. They are more stable with the degree of weathering conditions. Based on USCS classification, soil formed belonging to the high plasticity silt (MH). Clay minerals dominated by halloysite and kaolinite. Halloysite is derived from the weathering of feldspar.They are found in soil of volcanic rocks weathering results. Kaolinite are relatively resistant to weathering, but can turn into gibsite if the silica content regardless.***

Keywords: chemistry, mineralogy, weathering, Quaternary volcanic rock

1. Introduction

Generally, southern part of Bandung area is composed by Quaternary volcanic rock. They can be grouped into several units based on the period of its formation. Most of the rocks are exposed at the surface have experienced varying degrees of weathering. The weathering product of various rock types will provide chemical and physical properties of its own. Weathering product of rocks at a certain level will produce soil in the grain sizes, i.e. clay, silt, and sand. The proportion of a particular grain size and mineral content can reflect the mechanical properties of the soil. The problem is how chemical-physical-mechanics of Quaternary volcanic rock at different levels of weathering.

Volcanic rock units that make up the southern part of Bandung area is rather difficult to distinguish. The condition is caused by a variety of volcanic products derived from various sources have similar variations. Nevertheless, there are certain characteristics that can be a reference for grouping lithologies. The distinctive feature of which is the difference in texture, hydrothermal alteration, pumice content, and the presence of fractures. Based on the physical characteristics, the volcanic rocks in the study area can be grouped into 13 lithologies (after Sukiyah, 2009). As for the rock units, sequentially from old to young age, namely (1) altered breccia, (2) altered tuff, (3) altered andesite, (4) lapilli tuff, (5) basalt, (6) breccia, (7) pumice breccia, (8) altered coarse tuff, (9) crystal tuff, (10) coarse tuff, (11) fractured basalt, (12) fine tuff, and (13) andesite.

Several studies have linked the chemical-mineralogical characteristics of volcanic rock weathering results and mechanical properties has been carried out. The researchers include Sukiyah and Suparka (2000), Sukiyah et al (2005), Sukiyah (2009), Sukiyah et al (2010). The research results showed that at a certain level of weathering will result soil with particular chemistry and mineralogy characteristics. This condition will reflect the physical-mechanical properties of the soil.

Figure 1: Location of research area

The study aims to determine the chemical-mineralogical characteristics of volcanic rocks at different levels of weathering that can reflect its mechanical properties. The research area is located in the southern part of Bandung area, precisely in upstream Citarum river basin (Figure 1).

2. Methodology

The volcanic rock samples at various stages of weathering used as a data source. Several variables associated with geochemical volcanic rocks and their weathering results used as the test material. The proportion of major oxides and lost on ignitation (LOI) at different levels of weathering of rocks obtained by x-ray fluorescence (XRF) method. Type of clay mineral and alteration minerals were analyzed using scanning electronic microscope - SEM (Welton, 1984), x-ray difraction (XRD), and Portable Infrared Mineral Analyzer (PIMA) methods (AusSpec International, 1996). Identification of rock forming minerals (RFM) and their weathering results using polarizing microscope. In addition, the analysis was also performed physical-mechanical properties of rock weathering results. The USCS classification is used for naming the type of soil (Jumikis, 1967).

Data of geochemical, mineralogical, and physical-mechanical properties od soil are grouped based on the type of lithology and their weathering level. Correlations performed between these variables. Analysis of the data using a probabilistic approach (Haneberg, 2000). The results of the data analysis further examined to determine the general pattern of chemical-mineralogical changes and implications for its mechanical properties due to weathering processes (Figure 2).

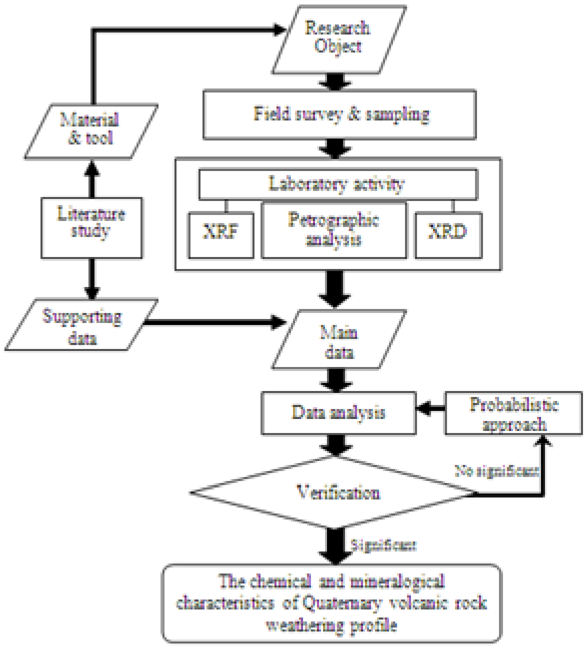

Figure 2: Research method mainframe

3. Result and Discuss

3.1 Weathering Potential Index (WPI) and LOI

The rate of weathering of rocks can be recognized by WPI and LOI. WPI is a visualization weathering rate based on the proportion of major oxide is displaying in index. Meanwhile, LOI used for the determination of the weathering rate is based on the physical aspects, i.e. the proportion of the material that is lost due to burning at a temperature of 1000°C. Weathering processes result in a variety of oxidation on the mineral constituent of rocks, especially RFM. The more weathered a rock, it will be more and more minerals are oxidized. This resulted in more and more proportion of material lost when burned. Data of LOI and WPI (Table 1 and Table 2) are grouped by rock condition, i.e. altered and unaltered rocks. The results of normality test of data distribution to both populations, suggesting that the normal distribution, respectively. The influence of weathering on rock major oxide composition is indicated by the average value of WPI is not unlike the LOI.

Table 1: The composition of main oxide, LOI, and WPI of Quaternary altered volcanic rock at shoutern part of Bandung (after Sukiyah, 2009)

No.	*Sample code*	*Composition (%)*	*WPI*
1	CRW-1	SiO_2 (57.1938), Al_2O_3 (21.0572), Fe_2O_3 (6.2981), CaO (0.9312), MgO (0.8451), Na_2O (1.4118), K_2O (2.0627), TiO_2 (0.6588), P_2O_5 (0.1342), MnO (0.1342), LOI (9.2519)	6.2104
2	CRW-2	SiO_2 (56.8988), Al_2O_3 (23.6603), Fe_2O_3 (5.0243), CaO (0.2532), MgO (0.2292), Na_2O (0.9698), K_2O (1.9717), TiO_2 (0.4464), P_2O_5 (0.0676), MnO (0.1381), LOI (10.3188) .	4.0007
3	CRW-3	SiO_2 (53.4618), Al_2O_3 (23.0737), Fe_2O_3 (4.3226), CaO (0.2001), MgO (0.1621), Na_2O (0.9065), K_2O (1.7911), TiO_2 (0.3202), P_2O_5 (0.0562), MnO (0.2361), LOI (15.4492).	3.7842
4	CRW-	SiO_2 (40.2399), Al_2O_3 (23.7237), Fe_2O_3	6.8941

	4	(13.0634), CaO (2.3832), MgO (2.4072), Na_2O (0.3969), K_2O (0.1230), TiO_2 (0.9367), P_2O_5 (0.0910), MnO (0.2239), LOI (16.4113).	
5	CRW-5	SiO_2 (49.0827), Al_2O_3 (25.3721), Fe_2O_3 (5.7650), CaO (0.1271), MgO (0.0685), Na_2O (0.3423), K_2O (0.2852), TiO_2 (0.4574), P_2O_5 (0.0844), MnO (0.0695), LOI (18.3159).	1.0261
6	CRW-6	SiO_2 (43.0303), Al_2O_3 (28.0563), Fe_2O_3 (7.6672),CaO (0.1932), MgO (0.0678), Na_2O (0.2362), K_2O (0.0888), TiO_2 (0.7007), P_2O_5 (0.1041), MnO (0.0817), LOI (19.7085).	0.7441
7	TRJ-1	SiO_2 (59.8786), Al_2O_3 (18.6375), Fe_2O_3 (7.0566),CaO (2.1963), MgO (1.9750), Na_2O (1.3748), K_2O (2.0199), TiO_2 (0.5693), P_2O_5 (0.1266), MnO (0.1037), LOI (6.0616).	8.8416
8	TRJ-2	SiO_2 (60.491), Al_2O_3 (20.2289), Fe_2O_3 (9.0057),CaO (3.1267), MgO (2.5972), Na_2O (1.7361), K_2O (1.7457), TiO_2 (0.6942), P_2O_5 (0.1722), MnO (0.2022), LOI (7.4504).	10.2598
9	TRJ-3	SiO_2 (47.8591), Al_2O_3 (24.2073), Fe_2O_3 (10.0322),CaO (2.1309), MgO (2.7106), Na_2O (0.5586), K_2O (0.1973), TiO_2 (0.7519), P_2O_5 (0.1007), MnO (0.1731), LOI (11.2783).	6.8179
10	TRJ-4	SiO_2 (48.8269), Al_2O_3 (23.2128), Fe_2O_3 (9.6223),CaO (0.1461), MgO (1.78), Na_2O (0.5483), K_2O (0.5993), TiO_2 (0.8345), P_2O_5 (0.2181), MnO (1.78), LOI (12.4318).	3.7639
11	CKY-1	SiO_2 (62.3910), Al_2O_3 (26.3511), Fe_2O_3 (0.9569),CaO (0.0965), MgO (0.0), Na_2O (0.0946), K_2O (0.0071), TiO_2 (0.8036), P_2O_5 (0.1533), MnO (0.0034), LOI (8.9974).	0.2210
12	CKY-2	SiO_2 (37.0095), Al_2O_3 (34.0236), Fe_2O_3 (11.4157),CaO (0.0664), MgO (0.1117), Na_2O (0.4316), K_2O (0.0420), TiO_2 (1.0766), P_2O_5 (0.1158), MnO (0.0258), LOI (15.6813).	0.7904
13	CKY-3	SiO_2 (47.5200), Al_2O_3 (23.1473), Fe_2O_3 (7.5726),CaO (0.0979), MgO (1.8853), Na_2O (0.1550), K_2O (0.1854), TiO_2 (0.7468), P_2O_5 (0.0342), MnO (0.0253), LOI (18.6121).	2.9698
14	CKY-4	SiO_2 (36.8117), Al_2O_3 (28.6380), Fe_2O_3 (12.7113),CaO (0.4227), MgO (0.8424), Na_2O (0.1222), K_2O (0.0462), TiO_2 (1.1619), P_2O_5 (0.1112), MnO (0.1262), LOI (18.8716).	1.8340

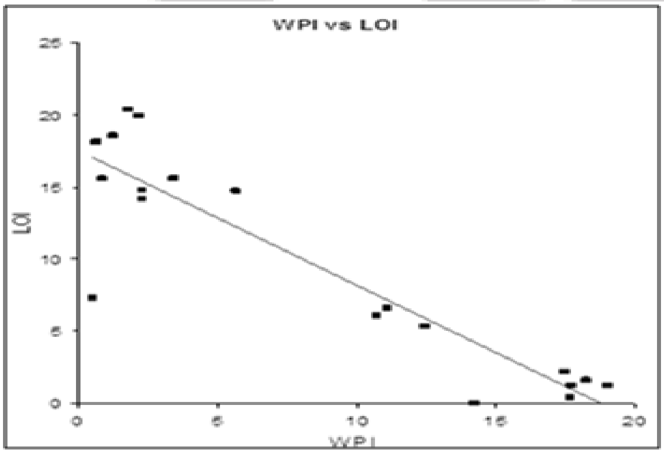

Figure 3: The correlation between WPI and LOI of various unaltered volcanic rocks with correlation coeficient 0.91 (very strong)

Based on the results of statistical tests, it is know that a major oxide proportion of altered volcanic rocks population are not influenced by the degree of weathering of rocks significantly, both the alpha 0.05, 0.10, and 0.20. Statistical analysis showed that the LOI and WPI has been linked to a variety of weathering rate of unaltered volcanic rock in the alpha of 0.05, with a correlation coefficient 0f 0.91. This phenomenon indicates that the unaltered volcanic rock, the physical changes that occur in the weathering process of volcanic rocks in line with changes in the chemical composition. Graph linear equations between WPI and LOI on variety of Quaternary volcanic rocks shown in Figure 3. The graph shows that the increase in the degree of weathering of Quaternary volcanic rocks inversely to the weathering index.

Table 2: The composition of main oxide, LOI, and WPI of Quaternary unaltered volcanic rock at shoutern part of Bandung (after Sukiyah, 2009)

No.	Sample code	Composition (%)	WPI
1	CHW-1	SiO_2 (60.7420), Al_2O_3 (16.5562), Fe_2O_3 (6.7604), CaO (5.9991), MgO (4.0899), Na_2O (3.2617), K_2O (1.4941), TiO_2 (0.5272), P_2O_5 (0.0984), MnO (0.1190), LOI (0.3531)	17.6601
2	CHW-2	SiO_2 (60.3602), Al_2O_3 (16.7653), Fe_2O_3 (6.8351), CaO (2.6361), MgO (3.2061), Na_2O (1.4890), K_2O (1.6910), TiO_2 (0.6850), P_2O_5 (0.1420), MnO (0.0970), LOI (6.0931)	10.7458
3	CHW-3	SiO_2 (45.2678), Al_2O_3 (25.4524), Fe_2O_3 (12.1436), CaO (0.5841), MgO (1.0421), Na_2O (0.23), K_2O (0.0404), TiO_2 (0.8363), P_2O_5 (0.0837), MnO (0.1443), LOI (14.1753)	2.2888
4	CHW-4	SiO_2 (44.478), Al_2O_3 (25.1977), Fe_2O_3 (10.6302), CaO (1.018), MgO (1.2602), Na_2O (0.2144), K_2O (0.2622), TiO_2 (0.7936), P_2O_5 (0.3161), MnO (0.2174), LOI (15.6123)	3.4304
5	TUG-1	SiO_2 (62.354), Al_2O_3 (18.0129), Fe_2O_3 (6.0711), CaO (4.5884), MgO (0.8706), Na_2O (5.0793), K_2O (1.7632), TiO_2 (0.7634), P_2O_5 (0.2995), MnO (0.1473), LOI (0.02)	14.2316
6	TUG-2	SiO_2 (54.5967), Al_2O_3 (19.5401), Fe_2O_3 (8.9069), CaO (7.2414), MgO (3.728), Na_2O (2.5444), K_2O (1.1725), TiO_2 (0.6247), P_2O_5 (0.2207), MnO (0.1822), LOI (1.2423)	17.6850
7	TUG-3	SiO_2 (46.0775), Al_2O_3 (32.4118), Fe_2O_3 (12.4652), CaO (0.074), MgO (0.2199), Na_2O (0.0), K_2O (0.1807), TiO_2 (0.8544), P_2O_5 (0.1741), MnO (0.2656), LOI (7.2769)	0.5218
8	TUG-4	SiO_2 (40.9768), Al_2O_3 (24.3907), Fe_2O_3 (14.0118), CaO (2.4775), MgO (1.3439), Na_2O (0.4759), K_2O (0.2093), TiO_2 (0.9726), P_2O_5 (0.2005), MnO (0.239), LOI (14.702)	5.6773
9	TUG-5	SiO_2 (37.8321), Al_2O_3 (26.2995), Fe_2O_3 (18.1243), CaO (0.1756), MgO (0.4194), Na_2O (0.0), K_2O (0.1174), TiO_2 (1.0717), P_2O_5 (0.3091), MnO (0.0823), LOI (15.5686)	0.8661
10	CKW-1	SiO_2 (51.6623), Al_2O_3 (18.7084), Fe_2O_3 (11.5706), CaO (8.1392), MgO (4.0943), Na_2O (2.5589), K_2O (0.7909), TiO_2 (0.7828), P_2O_5 (0.2045), MnO (0.2317), LOI (1.2563)	19.0176
11	CKW-2	SiO_2 (52.4881), Al_2O_3 (21.575), Fe_2O_3 (9.1392), CaO (5.6586), MgO (1.4192), Na_2O (2.5539), K_2O (0.7608), TiO_2 (0.7669), P_2O_5 (0.207), MnO (0.0925), LOI (5.339)	12.4906
12	CKW-3	SiO_2 (50.6436), Al_2O_3 (22.4084), Fe_2O_3 (10.0034), CaO (5.1296), MgO (1.5598), Na_2O (2.013), K_2O (0.5464), TiO_2 (0.7635),	11.1357

		P_2O_5 (0.1963), MnO (0.1259), LOI (6.61)	
13	CKW-4	SiO_2 (46.7629), Al_2O_3 (25.1265), Fe_2O_3 (10.4082), CaO (0.736), MgO (1.098), Na_2O (0.0), K_2O (0.072), TiO_2 (0.786), P_2O_5 (0.103), MnO (0.101), LOI (14.8063)	2.3160
14	WGS-1	SiO_2 (52.9376), Al_2O_3 (19.1862), Fe_2O_3 (10.1556), CaO (8.1611), MgO (3.2576), Na_2O (2.873), K_2O (0.7483), TiO_2 (0.7373), P_2O_5 (0.1473), MnO (0.1603), LOI (1.6358)	18.2792
15	WGS-2	SiO_2 (51.4858), Al_2O_3 (22.2928), Fe_2O_3 (8.3623), CaO (7.8416), MgO (2.4536), Na_2O (3.4451), K_2O (0.6099), TiO_2 (0.9484), P_2O_5 (0.2083), MnO (0.1472), LOI (2.1932)	17.4702
16	WGS-3	SiO_2 (29.966), Al_2O_3 (24.1151), Fe_2O_3 (25.2071), CaO (0.1443), MgO (0.1463), Na_2O (0.1593), K_2O (0.0571), TiO_2 (1.5128), P_2O_5 (0.0611), MnO (0.4258), LOI (18.1339)	0.6394
17	WGS-4	SiO_2 (41.3488), Al_2O_3 (30.1155), Fe_2O_3 (7.3587), CaO (0.5076), MgO (0.1772), Na_2O (0.2032), K_2O (0.0859), TiO_2 (1.4717), P_2O_5 (0.0549), MnO (0.0517), LOI (18.5619)	1.2356
18	WGS-5	SiO_2 (37.4425), Al_2O_3 (27.4485), Fe_2O_3 (11.8166), CaO (0.9824), MgO (0.2904), Na_2O (0.2824), K_2O (0.1162), TiO_2 (1.2918), P_2O_5 (0.1292), MnO (0.1642), LOI (19.9279)	2.1789
19	WGS-6	SiO_2 (36.4699), Al_2O_3 (27.6178), Fe_2O_3 (12.3969), CaO (0.742), MgO (0.2543), Na_2O (0.2513), K_2O (0.1081), TiO_2 (1.3518), P_2O_5 (0.1142), MnO (0.2413), LOI (20.3478)	1.7725

3.2 Major oxides at different levels of weathering

Based on LOI data, the unaltered volcanic rocks as product of Malabar-Tilu Mount and Guntur-Pangkalan-Kendang Mount can be grouped into 4 populations. They are population-1 with LOI between 0.0000 and 2.0000; population-2 with LOI between 2.0001 and 7.0000; population-3 with LOI between 7.0001 and 15.0000; and population-4 with LOI > 15.0000.

Statistical analysis was used to determine changes in the proportion of major oxides due to weathering processes. The results of data distribution normality test of nine major oxides population 1, 2, 3, and 4 of weathered volcanic rocks, indicate that data are normally distributed. The analysis result of the *r product moment* distribution table with n=15 and alpha is 0.05, r_{table} value obtained by 0.456. Meanwhile, the result of calculation of the correlation coefficient ranges from 0.65 to 0.93 for populations of SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O, K_2O, and TiO_2. Because the $r_{calculation}$ value is greater than the r_{table} value, it is acceptable that the correlation is formed between the populations of major oxide are significant.

On unaltered volcanic rock, some oxides (SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O, K_2O, and TiO_2) formed significant chart patterns, while other oxides (P_2O_5 and MnO) showed no significant correlation to the degree of weathering. Increasing the degree of weathering will result in a decrease in the proportion of SiO2, CaO, MgO, Na2O, and K2O. Conversely, due to increased weathering makes proportions of Al_2O_3, Fe_2O_3, and TiO_2 increased significantly. Figure 4 shows patterns that are formed between the proportion of SiO2 and LOI proportions, which reflect the degree of weathering of rocks.

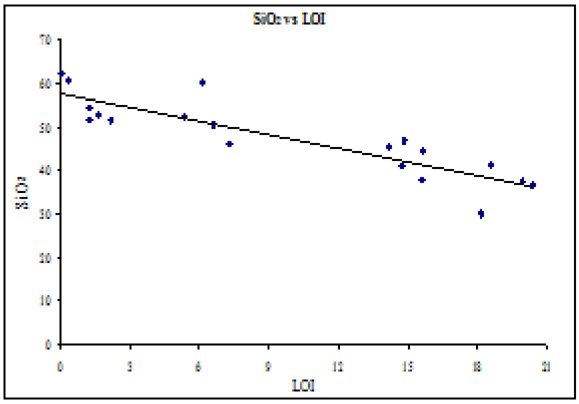

Figure 4: The correlation between SiO_2 proportion and LOI proportion of unaltered volcanic rock with correlation coefficient 0.88 (very strong)

Altered volcanic rocks in the study area have LOI ranges between 6.01 and 19.71. Referring to the LOI classification established, and then the data can be grouped into three populations, namely population-2 (weak weathered), population-3 (weathered), and population-4 (strong weathered). Given the limited data in population-2 (only one data), then the population-3 and population-4 were tested with a probabilistic approach. To facilitate statistical tests, the WPI population data should be aligned with the LOI data at the appropriate level of weathering. The initial value of WPI for the LOI of population-2 is 8, then all the data necessary plus 8 to fit the criteria at the level of weathering. Variance and standard deviation values were not different when compared to the WPI data before it is modified.

The analysis showed that pairs of variables, homogeneous variance, correlation coefficient between the WPI and LOI (r) = 0.65, then used the two sides average difference test (t-test) to the correlated sample with dk = n_1+n_2-2. In the real level (α) are 0.05 and 0.10, was between WPI and the LOI is no different. These conditions indicate that there is a correlation between physical changes and chemical changes due to the weathering process of altered volcanic rocks. The pattern of the scatter diagram between the two variables tend to form a graph polynomial equation $y = 0.0265x^2 – 1.1383x + 14.156$ and correlation coefficient is 0.65 (Figure 5).

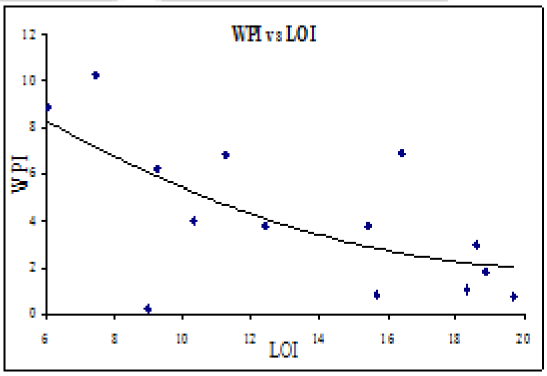

Figure 5: The correlation between WPI and LOI of altered volcanic rock at different level of weathering with correlation coefficient 0.65 (strong)

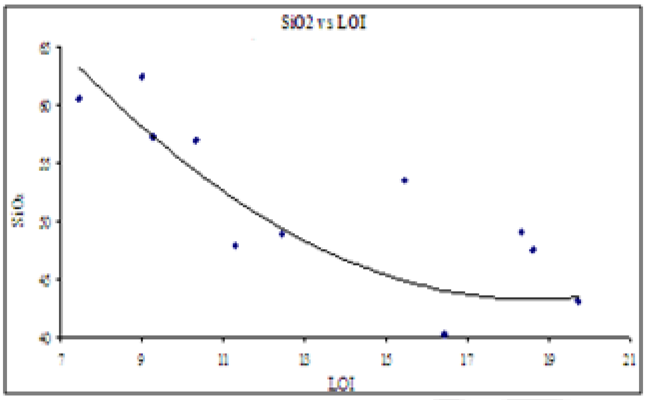

Figure 6: The correlation between SiO_2 and LOI of altered volcanic rock at different level of weathering with correlation coefficient 0.82 (very strong)

Along with the increasing degree of weathering of altered volcanic rocks, then some specific oxide decreased and others increased. The significance test of correlation between related populations are using product moment correlation test. In table of "r" distribtion with $\alpha = 0.05$ and $n = 14$ values obtained "r_{table}" for 0.532. Results of correlation analysis between several major oxides and LOI in altered volcanic rocks derived "$r_{calculation}$" value which ranged from 0.48 to 0.82. The coefficient of correlation between Al_2O_3 and LOI is 0.48 which is smaller than r_{table}, and then the hypothesis that a significant correlation was rejected, as well as for the correlation coefficient between P2O5 and LOI is 0.53. Other oxides, namely SiO_2, Na_2O_3, and K_2O have a significant correlation to the degree of weathering (Figure 6). Meanwhile, some other oxides (Fe_2O_3, CaO, MgO, TiO_2, and MnO) do not have a clear relationship to the degree of weathering. The increase and decrease in the proportion of these oxides on the degree of weathering fluctuated.

3.3 Mineralogy on weathering of volcanic rocks

The proportion changes of some major oxides of volcanic rocks, both which are unaltered or altered in line with the appearance of changes in mineral proportions. Volcanic rock-forming minerals (igneous rock and pyroclastic), in general, is a mineral that is susceptible to weathering processes. The most common example is plagioclase which undergoes oxidation that was surrounded by brownish yellow material (Figure 7-A_2-B_2).

Figure 7: Microscopic appearance of fractured basalt with LOI = 0.0200 (A_1-B_1) and LOI = 7.2769 (A_2-B_2), with (A) parallel-nicol and (B) cross-nicol.

Figure 7 shows the microscopic appearance of basalt. Some minerals are easily recognized include plagioclase, pyroxene, micro-feldspar, etc. Figure 7 (A) shows the microscopic appearance of fresh basalt (LOI = 0.02), in general, the mineral is still quite clear. Plagioclase is present as phenocrysts looks fresh, subhedral - anhedral, reaching 1.40 mm in size, twin carlsbad-albite and albite, zoned composition, type of andesine - labradorite (An 44 – An58), sometimes clumped. Presence of pyroxene is rare form of fresh ortho-pyroxene and clino-pyroxene, subhedral - anhedral size until 1.20 mm. In addition, magnetite is present in the anhedral form. Groundmass in the form of a mixture of isotropic glass without the structure, needles and microlith-feldspar which sometimes shows the direction, as well as very rare pyroxene and magnetite. The presences of secondary minerals are rare, form of anhedral microcrystalline quartz replacement glass, clay minerals, sericite, and iron oxide all of which encountered uneven. The whole appearance in Figure 7 (A) is very different from the appearance in Figure 7 (B), even though both are derived from similar rock samples with different degrees of weathering. Microscopic appearance in Figure 7 (B) with LOI = 7.2769 relatively more opaque, shape and texture of the mineral is less clear, emerging iron oxide (yellow brown), there are gaps that reflect the presence of cracks, cavities are even former mineral that seemed detached. This phenomenon indicates that the changes in the proportion of major oxides are also reflected by changes in the mineral, which can be identified microscopically.

Figure 8 shows the microscopic appearance of altered glass tuff samples at different levels of weathering, which is reflected by the LOI. Figure 8 shows the glass altered tuff with strong intensity, so that many components have been replaced rocks into secondary minerals, especially chloritic-clay. Looks pyroxene grains are oxidized edges. At the time of preparation, the rock sample is heated, so that the components of which have been partially oxidized to disappear. However, the original structure and texture of rock can still be observed, pyroclastic rocks that are supported by oxidized glass groundmass. Plagioclase has carlsbad-albite twin size reaches 1.40 mm, oligoclase - andesine, altered fractures, and spread rather evenly. The presence of quartz uneven and fine sized. Clino-pyroxene is strongly oxidized edges present uneven. The glass groundmass has been altered into clay minerals associated with iron oxide. In line with the increase in the degree of weathering (Figure 8 A_2 until A_4), there appeared to be an increase in cavities and iron oxide. Volcanic rock-forming minerals have been altered completely due to chemical reactions in the environment events aeration.

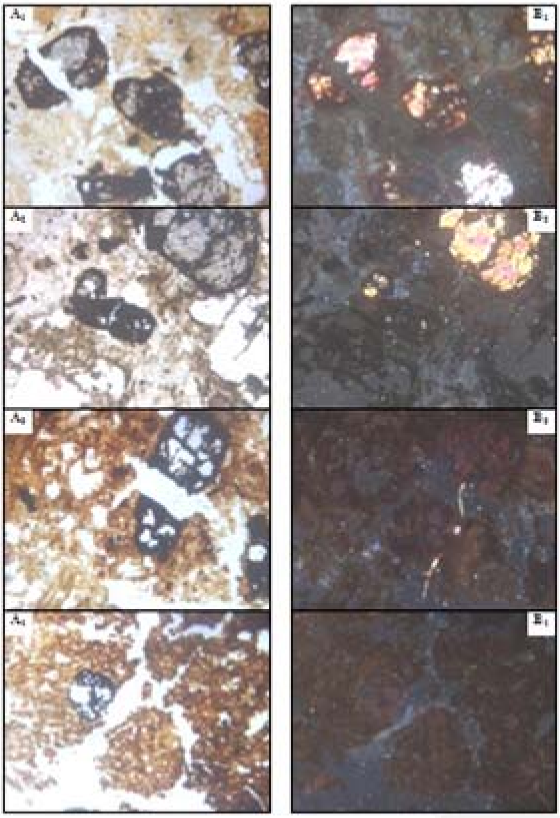

Figure 8: Microscopic appearance of altered tuff at different level of weathering (LOI), i.e. 1 = 9.2519; 2 = 10.3188; 3 = 15.4492; 4 = 16.4113, with (A) parallel-nicol and (B) cross-nicol.

Some chemical reactions in the weathering process, which are hydration, hydrolysis, and oxidation. Hydration is the absorption of water molecules in the crystal structure of a mineral. Hydrolysis is a chemical reaction that produces or taking H^+ or OH^- ions. Oxidation is a chemical reaction of a material with oxygen, a characteristic of the aeration environment in zone of weathering.

Table 4 shows the sequence of cations release due to an increase in the degree of weathering. Al^{3+} and Fe^{3+} are the most vulnerable regardless cations when the weathering process begins. Increasing degree of weathering, the other cations also separated to form a new compound that is more balanced with the degree of weathering conditions. Changes in types of minerals due to weathering processes can be explained chemically (Figure 9).

$$\underset{\text{K-feldspar}}{2KAlSi_3O_8} + \underset{\text{water}}{3H_2O} \longrightarrow \underset{\text{kaolinite}}{Al_2Si_2O_5(OH)_4} + \underset{\text{silica}}{4SiO_2} + \underset{\text{potash}}{KOH}$$

$$\underset{\text{K-feldspar}}{3KAlSi_3O_8} + \underset{\text{water}}{2H_2O} \longrightarrow \underset{\text{illite}}{KAl_2(AlSi_3)O_{10}(OH)_2} + \underset{\text{silica}}{6SiO_2} + \underset{\text{potash}}{2KOH}$$

$$\underset{\text{Albite}}{2NaAlSi_3O_8} + \underset{\text{water}}{9H_2O} \longrightarrow \underset{\text{halloysite}}{Al_2Si_2O_5(OH)_4 2H_2O} + 2H_2SiO_3 + 2NaOH$$

$$\underset{\text{Illite}}{2KAl_2(AlSi_3)O_{10}(OH)_2} + \underset{\text{water}}{5H_2O} \longrightarrow \underset{\text{kaolinite}}{3Al_2Si_2O_5(OH)_4} + 2KOH$$

$$4Fe^{++} + 3O_2 + 6H_2O \longrightarrow \underset{\text{Limonite}}{2(Fe_2O_3.3H_2O)}$$

Figure 9: The chemical reaction that occurs in some minerals weathering process (Loughnan, 1969)

Table 4: Cation mobility of weathering process (Loughnan, 1969)

	Sequence	Cation	Explanation
An increase in the degree of release ↑	1	Ca^{++}, Mg^{++}, Na^+	The sooner separated under *leaching* condition
	2	K^+	The faster off under leaching conditions but can be inhibited by fixation in illite structure.
	3	Fe^{++}	The degree of release depends on the redox potential and the rate of leaching.
	4	Si^{4+}	Separated by slow in leaching conditions.
	5	Ti^{4+}	Limited mobility when the rest of the parent mineral as $Ti(OH)_4$, if in the form of TiO_2 becomes immobile.
	6	Fe^{3+}	Immobile at oxidation condition.
	7	Al^{3+}	Immobile at pH 4.5 until 9.5.

Table 5: Soil characteristic of Quaternary volcanic rock weathering product based on SEM and PIMA analysis

Sample	*Soil type*	*Composition & Texture*	*Characteristic of soil mechanic*
TRJ-4	MH	SEM: kaolinite (80%); clinoptilolite zeolite $[Na_6(Al_6Si_{30}O_{72}).24H_2O]$ (15%); limonite & rutile (<5%); sporinite (<1%). PIMA: halloysite & muscovite (cericite) Kaolin is irregular textured; zeolites x-tall is tabular form & euhedral	Porosity (53.96%); Plasticity index (21.19%); clay (18%); silt (46%); sand (36%); Cohesion (0.109 kg/cm^2); Internal friction angle (15.4^o)
TUG-4	MH	SEM: kaolinite (70%); smectite (25%); limonite & rutile (<5%). PIMA: halloysite Kaoline is irregular textured; smectite is wave textured (crenulated)	Porosity (64.36%); plasticity index (38.45%); clay (43%), silt (53%), sand (4%); cohesion (0.091 kg/cm^2); Internal friction angle (6.96^o)
WGS-5	MH	SEM:kaolinite (80%); clinoptilolite zeolite $[Na_6(Al_6Si_{30}O_{72}).24H_2O]$ (15%); limonite & calcium oxide (<5%). PIMA: halloysite & muscovite (cericite) Kaolinite is irregular textured; zeolites x-tall is tabular form & euhedral	Porosity (58.39 %); plasticity index (28.77%); clay (12%), silt (44%), sand (42%), gravel (2%); cohesion (0.073 kg/cm^2); Internal friction angle (9.84^o)

The results of SEM and PIMA analysis of the soil as result of weathering of altered hydrothermal rough tuff, coarse tuff, and fractured basalt shown in Table 5.

Based on the USCS soil classification, a third sample was high plasticity silt (MH). Type of clay minerals dominated by halloysite based on PIMA analysis, and kaolinite based on SEM analysis (Figure 10). Halloysite has the chemical formula $Al_4Si_4(OH)_8O_{10}.8H_2O$, microscopic colorless-white, non-pleocroic, tabular shaped and very small size. Formed from the weathering of feldspar and is commonly found in soil as result of volcanic rocks weathering. Kaolinite has the chemical formula $Al_4(Si_4O_{10})(OH)_8$, colorless to pale yellow or slightly turbid to gray, shaped plates are very small. Kaolinite is relatively resistant to weathering, but can be gibbsite caused by the release of silica. Smectite has the chemical formula $(1/2Ca,Na)_{0,7}(Al,Mg, Fe)_4[(Si,Al)_8O_{20}](OH)_4.nH_2O$, colorless - pale pink - brown or green.

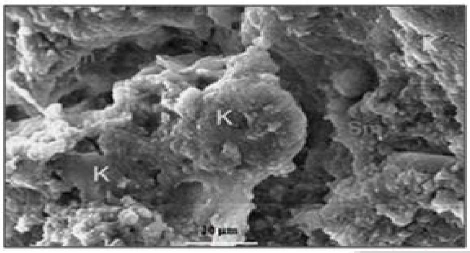

Figure 10: SEM Microphotograph of high plasticity silt (MH) as product of fractured basalt weathering, show kaolinite (K), smectite (Sm), and iron oxide + rutile (Ti).

4. Conclusions

The Quaternary volcanic rock in southern part of Bandung can be grouped into altered rock and unaltered rock. Soil of weathering result of these rocks has relatively high plasticity properties. These properties are physically represented in the proportion of clay and silt is relatively higher than the proportion of coarse size fraction. Based on the results of statistical tests, it is known that the proportion of major oxides in the altered Quaternary volcanic rocks not influenced by the degree of weathering of rocks significantly. LOI and WPI have been linked to various levels of unaltered volcanic rock weathering in the real level (α) of 0.05. The strength of the relationship is indicated by the correlation coefficient (r) = 0.91. This phenomenon indicates that the rocks did not undergo hydrothermal alteration, physical changes that occur in volcanic rock weathering processes in line with changes in the chemical composition.

In volcanic rocks are not hydrothermal alterations, some oxides (SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O, K_2O, and TiO_2) forming a significant chart pattern, while other oxides (P_2O_5 and MnO) showed no significant correlation to the degree of weathering. The increase in weathering (LOI) will result in a decrease in the proportion of SiO_2, CaO, MgO, Na_2O, and K_2O. Conversely, due to increased weathering makes proportions Al_2O_3, Fe_2O_3, and TiO_2 increased significantly. Meanwhile, the altered volcanic rocks only are SiO_2, Na_2O_3, and K_2O which has a correlation with the degree of weathering. Halloysite and kaolinite are the dominant clay minerals make up soil of volcanic rock weathering results. Halloysite is derived from the weathering of feldspar. Kaolinite are relatively resistant to weathering, but can turn into gibsite if the silica content regardless.

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