INFLUENCE OF BEDROCK WEATHERING ON THE SHALLOW GROUND WATER SYSTEM AROUND FELSIC METASEDIMENT AND AMPHIBOLITES OF THE ILESHA SCHIST BELT

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Abstract:

This study attempts the evaluation of the geogenic release metals due to weathering of basement rock on the shallow groundwater system around Ilesha and environs. The study involves collection of twelve (12) soil samples over four (4) soils profiles. In addition to a total of nineteen (19) groundwater samples obtained from shallow dug wells <25m in areas surrounding the sampled soil profiles. Geochemical analysis revealed the presence of SiO_2, Al_2O_3, MgO, CaO, Na_2O, K_2O, MnO, P_2O5 and Cr_2O_3 as the major oxides. Ruxton Ratio depicts weathering intensity decreasing from Muscovite schist (MS) > Amphibolite (AS) > Talc schist (TS) > Quartzite quartz schist (QS). Physico-Chemical results of water samples revealed a slightly acidic to basic water with electric conductivity values of 443µS/cm, 94µS/cm and 267µS/cm for the AM, QS and MS respectively. Hydro-geochemical analysis of the groundwater samples indicate the presence of major cations and trace elements and further analysis revealed the order of mean cations abundance for the mafic unit to be $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$, and $Ca^{2+}>Na^{+}>K^{+}>Mg^{2+}$ for the felsic. Groundwater around the mafic bedrocks shows high concentration of the major cations, except for Potassium (K), thereby revealing a relationship that correspond to the mineralogy of the bedrock and weathered profile.

Keywords: Metasediment, Amphibolites, Hydrogeochemical, Groundwater, Basement rock

1. Introduction

Chemical weathering of rocks is one of the major processes in geochemical cycling of elements (Faure, 1998). An understanding of the processes of rock weathering and sediment formation requires not only a sound knowledge of geochemical behavior of elements during weathering, but also of sediment redistribution processes. Identification of such processes can provide fundamental information for environmental management. The mobilization and redistribution of major and trace elements during weathering is particularly complicated because these elements are affected by various processes such as dissolution of primary minerals, formation of secondary phases, co-precipitation and ion exchange on various minerals. During weathering of crystalline rocks, rock forming minerals are partly dissolved and hydrolysis and hydration take place. These play an important role in element transport because they redistribute elements between solid and solution.

Ilesha and environs falls within a schist belt with rich alluvial deposits that have been mined for gold at Itagunmodi, Ifewara e.t.c in the South-western part of Nigeria. The schist belt form part of the Precambrian basement rock unit notable for clay rich weathered horizons. The weathered profile thickness ranges between 3 – 10m, with talc-tremolite schist having the higher profile thickness. The profiles include geological structures with mixed soils and rocks originating from weathered parent rocks and remaining in-situ. This study therefore emphasize on the chemical change associated with the rocks due to weathering, the distribution of elements both major and trace, in order to make inference on the rate and intensity of chemical alteration of the rocks of the Ilesha schist belt, and their influence on the shallow ground water.

1.1 Ilesha Schist Belt and Previous Study

The study area, Ilesha and environ is in the South-western part of Nigeria. Ilesha lies between latitude N$7^0 25^1$ – N$7^0 45^1$, and longitude $4^0 35^1$E – $4^0 55^1$E. The relief of the area is undulating with several highs and lows in altitude; it lies within the tropical rainforest zone, of which the wet and dry climatic season is characteristic. Ilesha schist belt lies east of the Ibadan Achaean to lower Proterozoic massif. It has a N-S length of over 200km and reaches its maximum width of 60km in the south. Here it consists of two structural units with contrasting lithology, separated by the NNE- trending Ife fault zone (Hubbard, 1975). The Western unit consists of amphibolites, amphibole schist and pelitic schist with much intimately associated trondhjemitic granite, gneiss and pegmatite. It shows a moderately open style of folding with N –S axes. Metamorphism is mainly in the amphibolite facies, but locally in the green-schist facies. East of the fault, quartzite is dominant, occurring together with quartz schist, quartzo-feldspathic-gneiss and minor iron-rich schist and quartzite. The assemblage, named the Effon Psammite Formation shows amphibolites facies metamorphism and tight isoclinal folds. About 30km NE of Ilesha it apparently overlies amphibole schist of western type, although it is not known whether this is a stratigraphic superposition or an over-thrust relationship.

Series of work have been done on the Ilesha schist particularly focusing on the evolution of the Ilesha schist belt, which is the dominant geologic belt around the study area. (Hubbard, 1975) recognized two structural units with contrasting lithology, separated by the NNE- trending Ife fault zone. Elueze, (1981) studied the geochemistry and petro-tectonic setting of metasedimentary rocks of the schist belt of Ilesha area, S.W Nigeria. In this study, he used XRF to determine the whole rock major, minor and trace elements, and showed that the mafic schists are enriched in Fe_2O_3 (15%) and TiO_2 (~2%), but depleted in K_2O and Na_2O. Cr and V contents are over 500 and 200ppm respectively, and are likewise much above the values for normal metasediments. The Ilesha metasediments however are generally siliceous and most have more than 65% SiO_2. The quartzites have SiO_2>90%. He further expressed that the mica schists are comparatively high in CaO contents, whereas K_2O and Na_2O values are low and Al_2O_3 contents are <16% Ba, Sr, Rb and Zr concentrations are enhanced in majority of the Ilesha rocks and are generally higher than those of the amphibolites. Zn, Cu and Co values are generally low while Cr, Ni, and V contents are relatively high.

From hydro-chemical and hydrodynamic considerations, Ayodele Owoade et. al. (1989) stated in their study of the hydrogeology and water chemistry in the weathered crystalline rocks of Southwestern Nigerian in Ilesha that the stable clay mineral is kaolinite and this suggests that weathering products are being regularly flushed and transported away from the reaction centres. This proof that recharge is currently taking place, which is in accordance with the findings from stable isotope studies (Loehnert, 1980; Ogunkoya, 1986). Loehnert (1980) reported that the soil moisture is subjected to evaporation before percolating to join the groundwater. Kehinde-Philips and Tietz, (1995) worked on the mineralogy and geochemistry of the weathering profiles over amphibolites, antophyllite and talc-schists in the Ilesha schist belt, SW, Nigeria. Using XRF and XRD, it was revealed that the amphibolite in the schist belt of Ilesha area has undergone alteration as a result of hydrothermal and metamorphic processes. Emofurieta et.al. (1995) from their study of the secondary geochemical and mineralogical dispersion pattern associated with lateritization process in Ile-

Ife, SW, Nigeria around the schist belt disclose that Fe_2O_3, alkalis, MgO, TiO_2, Ni, Mn, Cu, Cr, Zn, Pb and Ca show greater abundance down the profile, while Al_2O_3, and SiO_2 are more abundant at the upper levels. They recorded high SiO_2 values (79.48% - 88.24%) in the A horizon and explained it as a result of the extensive leaching and transported nature of its constituents.

2.0 Materials and Method

For the purpose of this study 12 soil samples were collected from four profiles, with 19 water samples which were collected around the weathering profiles. Reconnaissance survey of the study area was carried out to familiarize with the terrain of the study area for possible areas where complete soil horizon is exposed and sampling could be done. Water samples were collected into 75ml bottles and labeled appropriately. The 75ml water samples were acidified for cation/metal analysis. The depths to water table, depth of well and other physico-chemical parameters were recorded. Representative soil samples were taken from exposed weathered horizons along a fresh vertical profile, the surface was scratched with a shovel prior to sampling. The soils were collected in polythene bags and labeled based on profile and sample point. The topsoil was labeled A, the weathered unit B, and the saprolite C. Quarry sites, road cuttings, river cuttings and other exposed surface were sampled. The rocks were identified, observation recorded and samples were collected in sample bags.

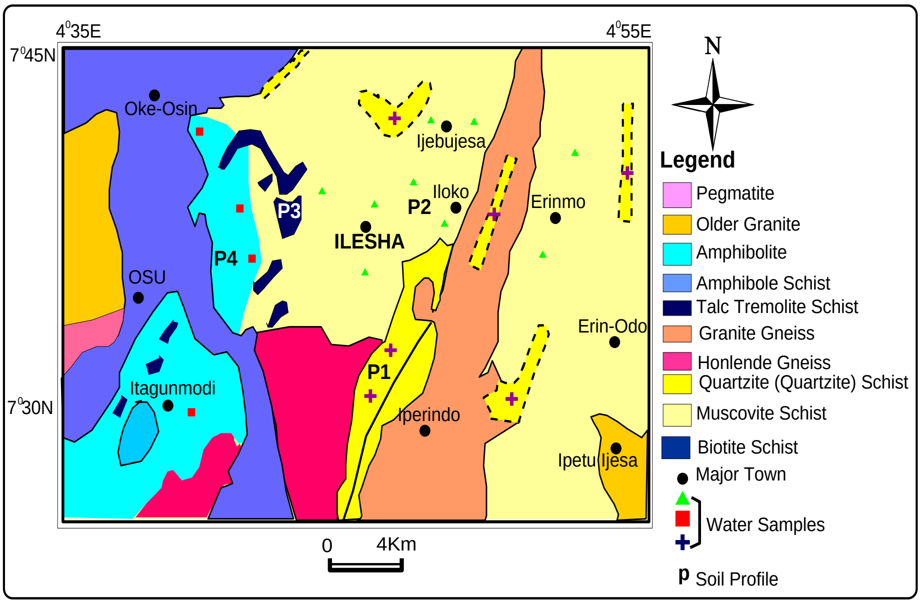

Figure 1: Geological map of the study area (Elueze, 1982). Sampling points, P1, P2, P3, and P4, representing, quartzite quartz schist, muscovite schist, talc-tremolite schist and amphibolite respectively.Fresh bedrock samples collected were cut into thin section with the

use of a Logitech thin sectioning machine brand at the thin section laboratory of the University of Ibadan, Ibadan Nigeria for petrographic study. The soil samples were hand pulverized using mortar and pestle, from which 5g was taken for analysis for both major oxides and trace metals. The soil was analysed by ICP-AES for major oxide and lithophile trace element concentration by acid digestion in closed beakers. Total abundances of the major oxides and several minor elements are reported on a 0.1g sample analysed by ICP-emission spectrometry following a Lithium metaborate/tetraborate fusion and dilute nitric digestion. While the water samples cation was analysed by ICP-MS machine brand ICPE 9000 for major metals and trace elements.

3.0 Results and Discussion

3.1 Profile modeling

Profile 1 (Quartzite Quartz Schist); has 0.2m thickness of *residual soil*, 0.8m thickness of *Horizon A* (whitish to reddish in colour, fine grain and high effect of ferruginization is visible). *Horizon B* is 1m thick (not as reddish as A horizon, loosely compacted, showing that the weathering is not just starting. medium-fine grain, with the original rock grain still visible). *Horizon C* is 1m thick (medium-fine grain, highly lithified and well compacted).

Profile 2 (Muscovite Schist); *residual soil* is 0.2m thick, the colour is dark brown. *Horizon A* (2m thick, colour is dark brown, medium-coarse grain, with presence of burrows due to plant root). *Horizon B* is 1.5m thick, (reddish in colour, coarse grain of weathered parent rock is visible. fine –medium grain size). *Horizon C* is 2.0m thick, (light reddish in colour, there is presence of foliation and well compacted than other horizons. It is fine grained).

Profile 3 (Talc-Tremolite Schist); *residual soil* is 0.8m thick, described as dark brownish red sandy clay. *Horizon A*, is 2.4m thick, (highly weathered and ferruginized, reddish-whitish clay. Presence of whitish talc is visible; most of the foliation is weathered off. *Horizon B* is 4m thick (whitish-grey in colour, with high presence of foliated baked dark talc schist with occurrence of quartz- intrusion). *Horizon C* is 2.8m thick, (dark in colour, it is baked, shows foliation compacted, and the dominant grain is sandy-clay).

Profile 4 (Amphibolite); *residual soil* is 0.4m thick, (described as dark brownish in colour). *Horizon A* is 1.1m thick (dark brownish sandy clay, with presence of burrows. medium grain size). *Horizon B* is 1.5m, (light grayish-whitish sandstone, fine grain, there is high presence of foliation, highly weathered and indurated). *Horizon C* is 2m thick. (dark grayish coarse sand. Moderately weathered, presence of biotite or hornblende is visible in hand specimen and highly indurated).

In petrographic section (Plate 1 and 2), amphibolite is medium–coarse in texture and predominantly composed of hornblende which is pleochroic from greenish to brownish tones. The modal percentage is as follows; Hornblende 60%, Quartz 6%, Plagioclase 20%, Biotite 4% others (actinolite, tremolite, chlorite) 10%. Small inequant crystals appear disseminated around the coarse hornblende and biotite crystals. The Talc-Tremolite schist in thin section is defined by parallel fibrous aggregate of transparent or rather colourless talc, and anhedral fibrous aggregates of tremolite. Chlorite appears to be opaque with green tones at the margins.

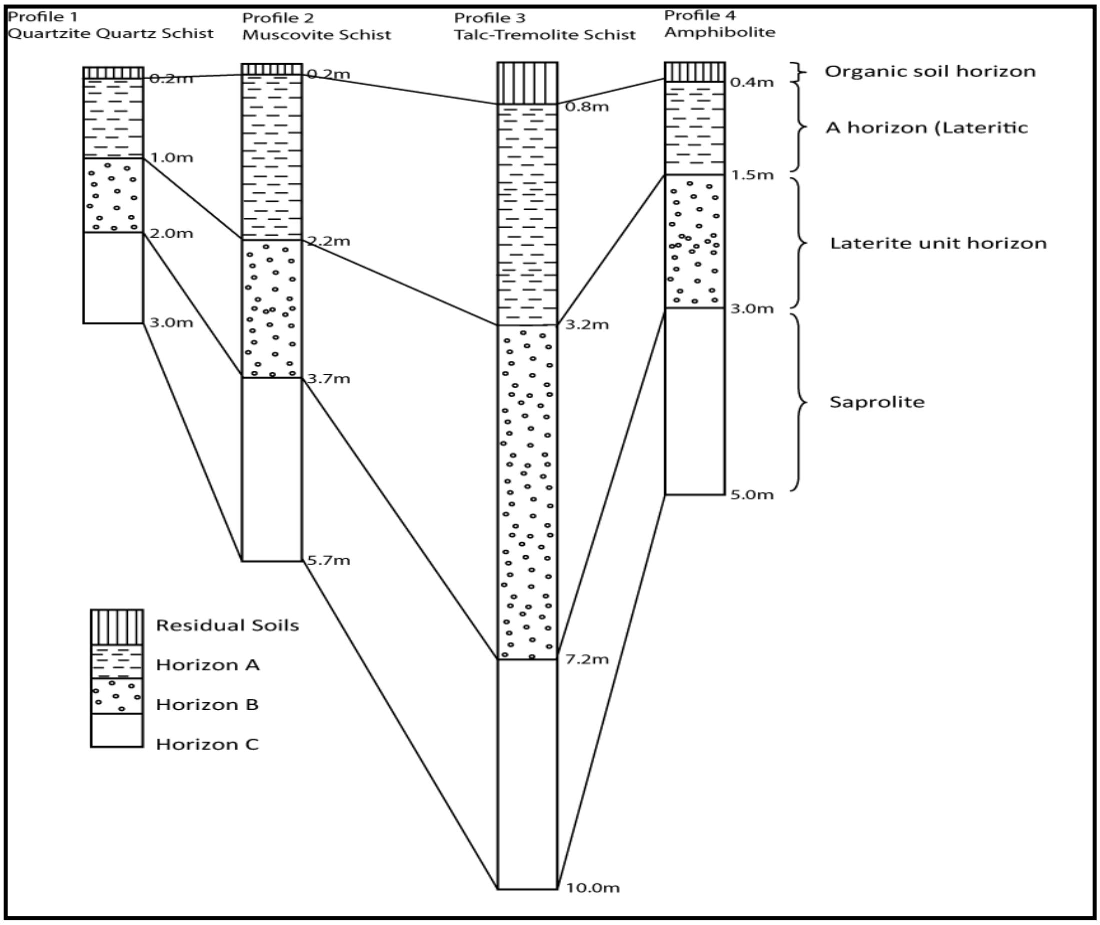

Figure 2: Diagrammatic illustration of the weathered profiles, indicating their thickness.

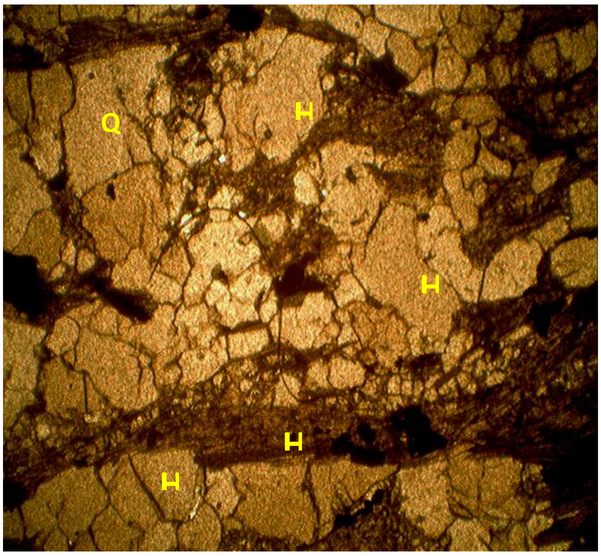

Plate 1: Photomicrograph of Amphibolite (plane polar); hornblende (H), foliated and occur as a porhyroblast within an inequant granular .matrix

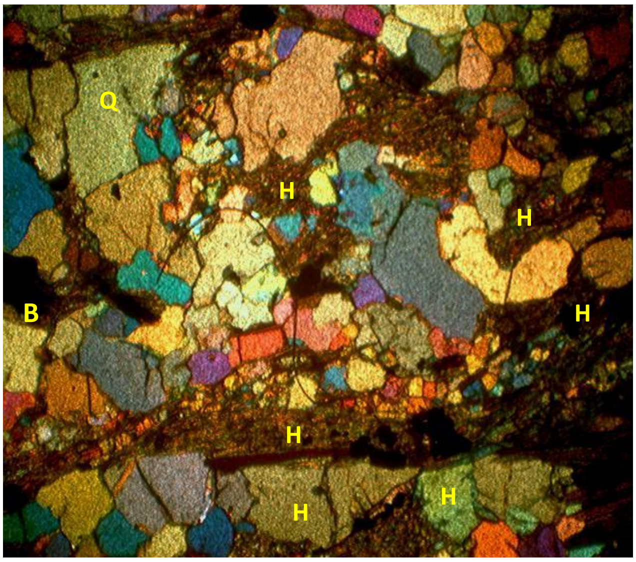

Plate 2: Photomicrograph showing the cross polar of amphibolite in thin section. Others minerals are Quartz (Q), Plagioclase (P), Biotite (B).

3.2 Chemical Weathering Analysis

3.2.1 Major Oxides

The geochemical trend shows the distribution patterns of the major elements, which are reflections of the compositional changes during chemical weathering with resultant lithogenic (natural) release and enrichment of elements within the weathered saprolite unit (Price and Velbel, 2003; Tijani et. al., 2006). Table 1, shows the major oxides (SiO_2, Al_2O_3, MgO, CaO, Na_2O, K_2O, MnO, P_2O5 and Cr_2O_3) concentration as well as their mean compositions in the profile of the studied bedrock type. Quartzite quartz schist shows the highest concentration of SiO_2, it has 80.72%, 75.15%, and 80.34%, in the saprolite, weathered unit and top soil respectively. Al_2O_3 ranges from 11.6%, 13.3%, and 10.8% in the saprolite, weathered horizon and top soil respectively with a mean composition of 11.9%. Fe_2O_3 ranges from 1.77% in the saprolite, to 3.39% in the weathered unit and the top soil to 2.23%. Na_2O is depleted upwards in the weathering profiles, while K_2O, MnO, CaO, MgO, and TiO_2 are enriched in the weathered unit.

For the muscovite schist, SiO_2 ranges from 60.1% in the saprolite to 59.15% with mean composition at 59.63%. Al_2O_3 ranges from 19.69% in the saprolite to 20.15% in the weathered horizon and mean composition of 19.92%. Fe_2O_3 ranges from 8.49% in the saprolite to 9.24% in the weathered unit, with a mean composition of 8.87%. MgO, K_2O, TiO_2 and MnO are enriched in the weathered unit. While in the talc tremolite schist, SiO_2 shows an unusual value in the weathered horizon 71.3%, unlike the compositional value of

54.49% and 53.38 for the saprolite and top soil respectively. Al_2O_3 ranges from 13.54% in the saprolite to 12.42% in the weathered horizon and 16.63% in the top soil. Fe_2O_3 ranges from 12.3%, 6.13%, and 15.07% in saprolite, laterite unit and top soil respectively. CaO and MgO are depleted upwards in the weathering profile. Na_2O and K_2O are enriched in the weathered unit of the weathered profile of talc-tremolite schist.

SiO_2 composition in the amphibolite weathered profile ranges from 46.08%, 60.39% and 50.81% in the saprolite, weathered unit, and top soil respectively. The mean composition of SiO_2 is 52.43%. Al_2O_3 has average compositions of 16.57%, 17.48 and 15.00% in the saprolite, laterite, and top soil. Fe_2O_3 is enriched in the saprolite with 12.92%, and 6.64%, 13.83%, in weathered and top soil respectively. MgO and CaO are enriched in the saprolite, while Na_2O and K_2O are enriched in the weathered unit.

Table 2, shows the trace element composition of Ba, Ni, Sr, Zr, Y, Nb and Sc. Ba, Nb, and Sc is enriched in the weathered unit of the quartzite quartz schist profile, while Ni is relatively low when compared to the other weathering profile, Sr, Zr and Y is depleted upwards in the profile.

In the muscovite schist Ba, Ni, Sr, Zr, Nb and Sc are concentrated in the weathered unit. Ba has the highest concentration in the weathered horizon of the talc-tremolite schist profile. Ni, Zr, Y, Nb, Sc is depleted in the laterite horizon, Sr shows a mean composition in the range 7%, 20%, and 7% in the saprolite, laterite and top soil respectively. Ba and Sr is higher in composition in the laterite horizon of the amphibolite similar to the talc-tremolite schist, while Ni, Zr, Y, Nb, and Sc have been strongly depleted in the laterite horizon, this however correspond to the geochemical pattern generally observed in the soils and regolith in Ilesha. Figure 5 shows the general trend of the trace metals within the four profiles.

The abundance of SiO_2 in the weathering profile of the felsic metasediments as shown in figure 3, reflects the high quartz content of the metasedimentary rocks which is over 90% in quartzite and >50% in the muscovite schist as stated by (Elueze, 1981). The high concentration of SiO_2 in the weathered unit of the mafic and ultra-mafic soil profile is mainly due to the quartz intrusion within their weathered horizon. Kehinde-Phillips (1995) explained that during the weathering of the amphibolites, hydrolysis of amphiboles took place, during which silica was released into the weathering solution. The solution became saturated with silica and under favourable conditions of pH; silica was precipitated as secondary amorphous quartz. Krausporf et. al. (1995), has noted that part of the silica especially from amphibole and pyroxene may not dissolve in the weathering profiles.

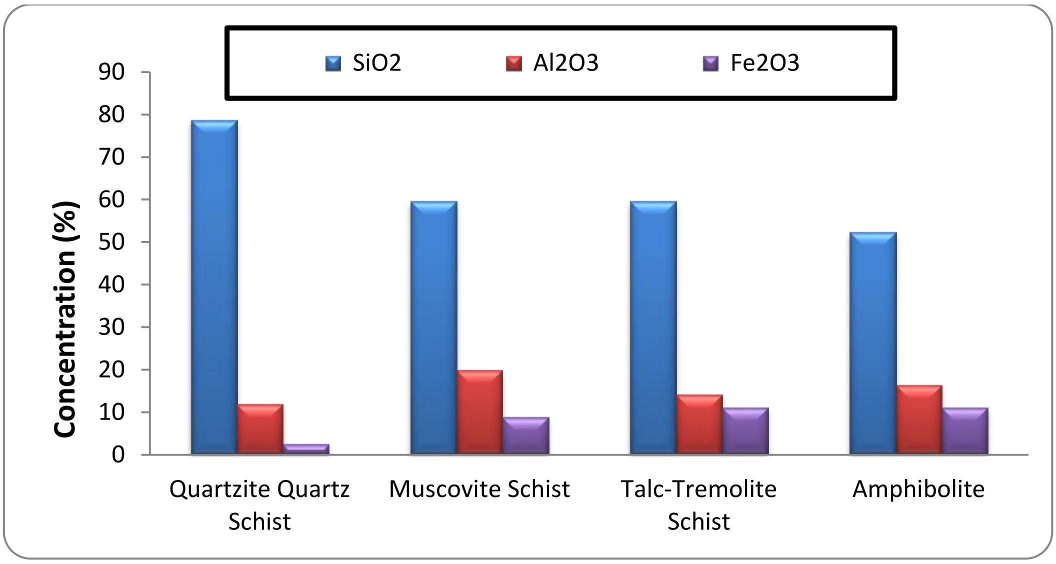

Figure 3 Mean compositions of SiO_2, Al_2O_3, and Fe_2O_3 in the weathering profile

Al_2O_3 and Fe_2O_3 are concentrated in the weathered unit of the felsic metasediments, showing that there was considerable leaching of Al and Fe in top soil, this shows that the elements of the sampled weathered profiles have higher enrichments in the intermediate saprolite horizon compared to the upper topsoil zone. This was attributed to vertical translocation by leaching and other geo-pedological process. In the mafic profile, Al_2O_3 and Fe_2O_3 are strongly depleted in the weathered unit; this could be explained with reference to Kehinde-Phillips (1995) explanation of the hydrolysis of amphiboles and precipitation of secondary amorphous quartz within the weathered horizon of the mafic profile.

Amphibolites and talc-tremolite schist have the highest percentage of water content relative to quartzite quartz schist and muscovite schist. This shows the abundance of the hydroxyl mineral in the mafic suite of the Ilesha schist belt.

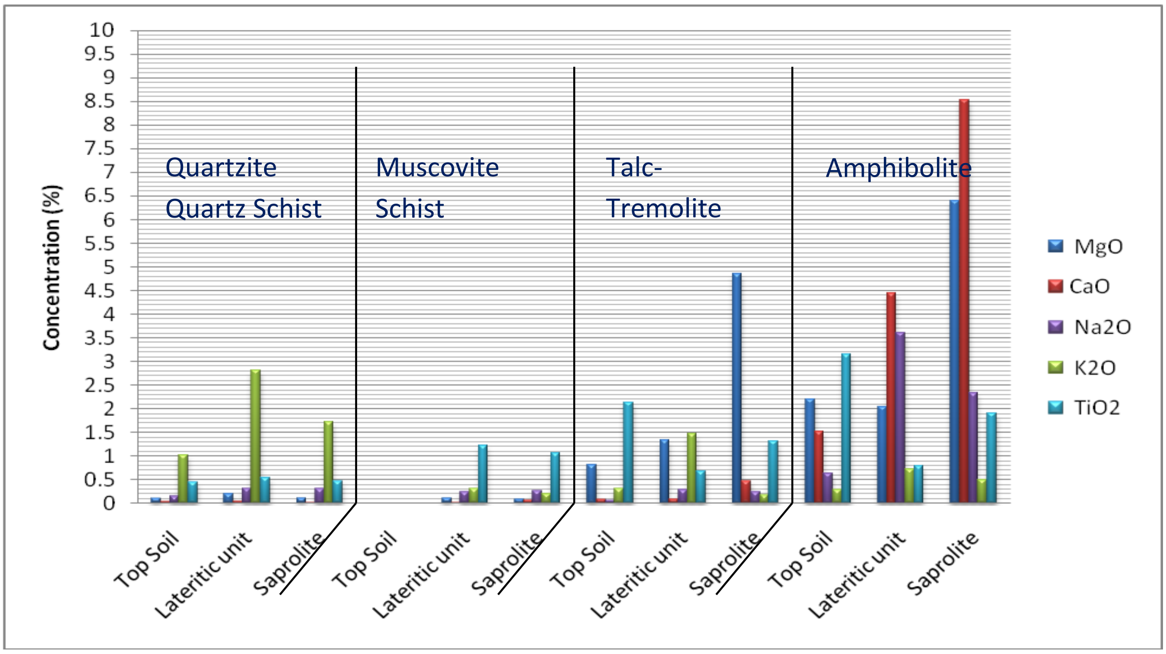

Figure 4: Histogram showing the abundance of the major oxides in the weathered profile of each bedrock.

Weathering profile of the mafic rocks has higher concentration of metallic oxides of CaO, MgO, and Na_2O, except for K_2O which is relatively higher in the metasediments, it therefore reflects the chemistry of their bedrock, and explains the soapy, whitish colour of the weathered unit and saprolite of the mafic rocks. Generally, CaO, and MgO, shows a downward increase in concentration from the top soil to the saprolite, this is because alkali and alkali earth metals are highly mobile and migrate readily downwards to the ground water. K_2O and Na_2O however, are concentrated in the weathered unit. From this pattern it can be asserted that the alkali earth metals are heavily leached compared to the alkali metals and are expected to makeup higher concentration in the ground water.

Behaviour of the trace metals from the results, show the relationship between the bedrock, and the weathering profile. Ba and Sr are concentrated in the weathered region; they show a trend similar to CaO and MgO. Ni and Zr have not been altered strongly in the felsic metasediments, but are strongly depleted in the weathered unit of the mafic rocks. This also justifies possible felsic enrichment within the weathered unit which masked their concentration. The groundwater surrounding the mafic bedrock is expected to have higher concentration of trace metals compared to the felsic metasediments, with Ba and Zr having the highest values.

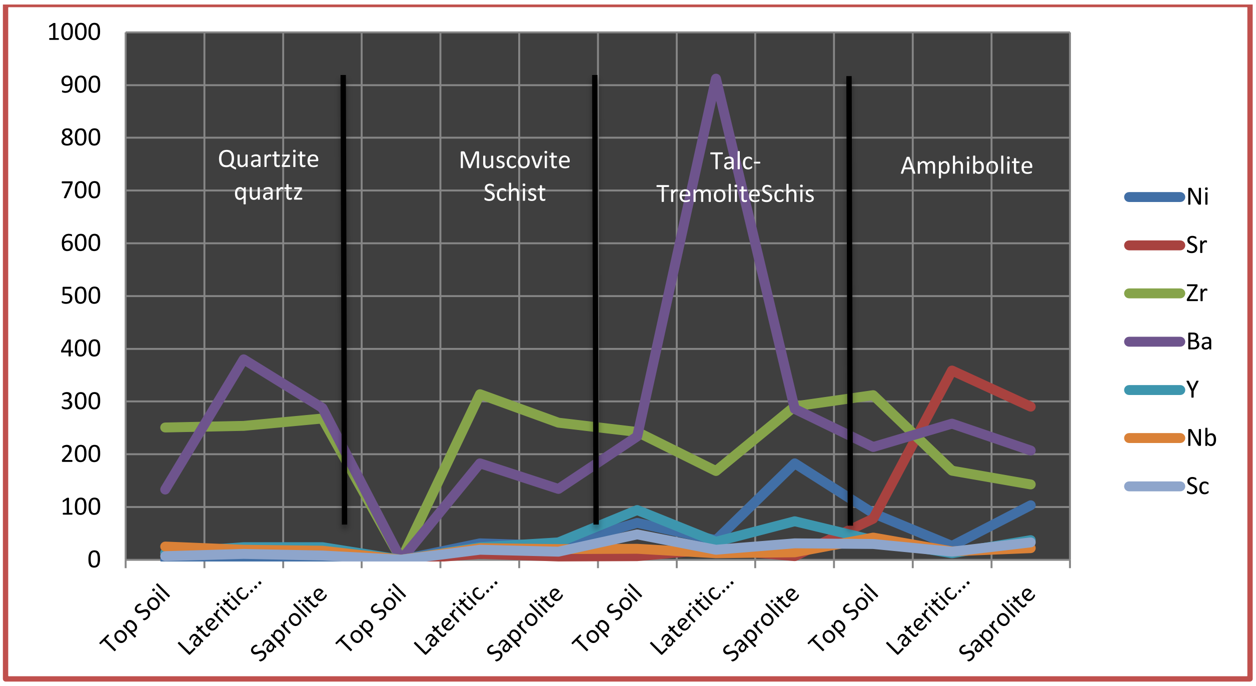

Figure 5 Plot of trace elements in the soil profile

3.2.2 Intensity of weathering using Ruxton Ratio

Developed by Ruxton, (1968), it's one of the weathering indices use to calculate the intensity of weathering. R.R values <2.9 is in the upper boundary value for highly weathered materials.

$$\text{Formula} = SiO_2/Al_2O_3$$

From the study, the rocks of the schist generally have high R.R values indicating their resistance to weathering. Quartzite-quartz schist has the average R.R value of 6.62, while muscovite schist, talc tremolite schist and amphibolites have average R.R values of 2.99, 4.21 and 3.21 respectively. From this value, it can be shown that the weathering intensity increases from muscovite schist >amphibolite >talc tremolite schist >quartzite quartz schist. The R.R values for the muscovite is rather low compared to the mafic rocks, this could be as a result of the unusual accumulation of quartz in the weathered horizon of the mafic rocks increasing their silica constituent. Likewise, the muscovite schist soil profile characteristics indicate the influence of anthropogenic activities affecting the rock to weather more quickly.

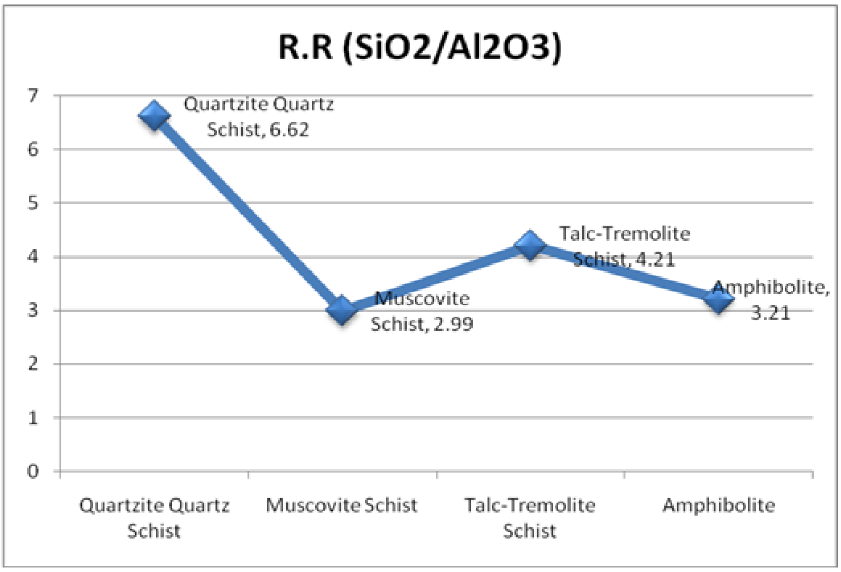

Figure 6 Plot of the Ruxton Ratio of the soil profiles.

3.2.3 Hydrochemical Analysis

It has been proven that weathering and leaching/erosion constitute major sources of geogenic metal inputs into the environment (Green et.al, 2006 and Islam et.al, 2002). However, direct effects of rock weathering and metal mobility are usually reflected on the composition of soils and surface water (Taylor and Eggleton, 2001). Depending on the climatic condition such effects can easily extend to the groundwater systems through leaching by percolating/recharging water. (Tijani et.al, 2006). The groundwater sample discussed is tapped from shallow aquifers (weathered zones) surrounding the representative soil profiles analysed. The aquifers averaged depth is <25m and in some places as low as 5m. Results of the hydrochemical analysis are presented in the Table 3.

Amphibolites

Amphibolites water pH values range from 7.10 – 9.10 showing moderately alkaline waters and indicating its basic nature. Electrical conductivity is relatively high, likewise the total dissolved solids (TDS). The water is usually turbid indicating the influence of the mafic minerals with $Ca^{2+}$and Mg^{2+}, predominant in concentration with an average concentration of 36.5mg/l and 31.6mg/l respectively. While Na^{+} and K^{+} average concentration are 22.32mg/l and 17.15mg/l respectively.

Quartzite quartz Schist

The pH of the quartzite quartz schist ranges from 6.90 – 8.8. It shows a slightly acidic to slightly alkaline waters. The EC and TDS are relatively low with mean value of 94.98µScm-1 and 123.5 respectively. Chemical nature of the cations shows Ca^{2+} with concentration ranging from 7.92mg/l – 20.88mg/l, and an average concentration of 15.48mg/l. this is comparatively higher than that of Muscovite schist but lower compared to Amphibolite. The relatively high cations are suspected to have its source from the surrounding mafic rock, from which the shallow ground water must have flow from. Mg^{2+}, Na^{+}, K^{+}, has mean value of 2.39mg/l, 5.39mg/l, and 5.34mg/l respectively.

Muscovite Schist

With pH range of 6.4 – 8.4 it tends towards slightly acidity to moderately alkaline waters. Sample no. MS06 and MS08 show an unusual behaviour in both its physical and chemical parameters. This is suspected to have resulted from anthropogenic influence on the shallow groundwater system. Major areas of the Muscovite schist rocks are densely populated. The impact of urbanization and over-population coupled with poor environmental sanitation cannot be exempted among the factors responsible for the hydrochemical character displayed by the samples (MS06 and MS08) on one hand and the shallow groundwater system on the other. However, the Muscovite schist average values are EC of 84.83 and TDS of 63.63mg/l respectively. Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} are the major cations with values of 16.97mg/l, 6.07mg/l, 18.18mg/l, and 22.22mg/l respectively.

Generally, Hydrochemical results of the shallow groundwater system indicate that the mafic rocks show a distinct basic chemical concentration, with relatively higher concentration of cations compared to felsic metasediments. The order of mean cations abundance is $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$. The felsic metasediments tends toward an acidic composition with the order of the mean abundance of cations in $Ca^{2+}>Na^{+}>K^{+}>Mg^{2+}$.

4.0 Conclusion

Ilesha falls within the Ilesha schist belt of the basement complex of SW part of Nigeria. The Schist belt comprises of an amphibolite complex mainly, amphibolite, talc-tremolite schist, gneiss complex (major rocks are; granite gneiss, hornblende gneiss, and biotite gneiss), metasediments (quartzite quartz schist, muscovite sericite schist, and biotite schist), and intrusive (older granite and pegmatite). Soil profiles were obtained from the amphibolite complex (amphibolites and talc-tremolite schist) and the metasediments, (quartzite quartz schist and muscovite schist) for the purpose of this study. Comparing the mineralogy of the rock types show that amphibolite are dominated by the amphibole group and plagioclase with quartz occurring as accessory mineral, the metasediments have high proportion of quartz, feldspar and biotite.

The weathered unit of the mafic rocks displays an unusual character peculiar to the Ilesha area, with high concentration of SiO_2. This was however proven to have resulted from the precipitation or rather intrusion of quartz in the laterite horizon. Using Ruxton ratio to indicate the intensity of weathering, it showed muscovite schist < amphibolite < talc schist <quartzite quartz schist in the order of the intensity of weathering.

However, the hydrochemical analysis of the water samples reveal an abundance of Ca^{2+}, and K^{+} in the water surrounding the amphibolite complex and metasediments respectively. The amphibolite is slightly basic in nature, while the felsic metasediments tends towards a slightly acidic to slightly alkaline environment. TDS of the amphibolite are moderately high with average value of 244mg/l, and that of the felsic metasediments ranging from 94.98 – 200.5 mg/l. Gibb's diagram showed that the water chemistry is weathering controlled, therefore high interaction between the rocks and water, with the percolating water contributing largely to the underground water. Its soil profile chemistry is therefore important to the quality of the shallow groundwater of the study area. The major and trace elements show similar patterns for the weathered unit and fresh sample, the trend which is also correlative in the shallow ground water chemistry.

Reference:

Elueze, A.A. Petrographic studies of metabasic rocks and meta-ultramafites in relation to mineralization in Nigerian schist belt: Nig. Journ. of Mining and Geology 1981Vol. 18, pp 31

Elueze, A.A. Geology of the Precambrian Schist belt in Ilesha area, Southwestern Nigeria. Precambrian Geol. Nigeria; Publ. Geol. Survey Nigeria. 1988 pp. 72-82.

Emofurieta W.O, Aladesawe A.I, Ogunseiju, P. Secondary Geochemical and Mineralogical Dispersion Patterns associated with lateritisation process in Ile-Ife, SW Nigeria: Journal of Mining and Geology. 1995 Vol. 31, pp39 – 51.

Faure, G. Principles and application of Geochemistry.Prentice Hall: New Jersey. 1998

Gibbs, R.J. Mechanisms controlling World Water Chemistry: Science. 1970 1088-1090.

Green, E.G, Dietrich W.E, Banfield J.F. 2006. Qualification of chemical weathering rates across an actively eroding hill slope: Earth Planet Science. 242:155-169.

Hubbard, F.H. Precambrian crustal development in Western Nigeria: indications from Iwo region. Geol. Soc. Am. Bull. 1975 86: 548 – 554.

Islam, M.R, Stuart R, Risto A.V. Mineralogical changes during intense chemical weathering of sedimentary rocks in Bangladesh: Journal of Asian Earth Science 2002 20:889-901.

Kehinde-Phillips, O.O, Tietz, G.F. The Mineral and Geochemistry of weathering profiles over Amphibolites, Antophyllite and Talc-Schists in the Ilesha schist belt, SW, Nigeria: Journal of Mining and Geology. 1995 Vol. 31, pp 53-62.

Kehinde-Phillips, O.O. Compositional variations within lateritic profiles over mafic and ultra-mafic rock units of the Ilesha Schist SW Nigeria: Unpb. Ph.D. Thesis. University of Ibadan, 1991 201pp.

Krauskopf, K.B, and Bird D.K. Introduction to Geochemistry: McGraw-Hill, Inc., New York. 1995

Loehnert, E.P. Groundwater quality aspects of dug wells in southern Nigeria: Studies in Environ. Sci. 1980 17, 147-153.

Ogunkoya, O.O. Quality of base flows as an index of aquifer yield in the basement complex of south western Nigeria: Environ Management. 1986 22, 291-300.

Owoade, A. Moffat, W.S. Groundwater prospects in south western Nigeria. *15th*WEDC Conference on water engineering and development in Africa, Kano, Nigeria.April 3r to 7th, 1989, pp 129-131

Price, J.R, and Velbel, M.A. Chemical weathering indices applied to weathering profiles developed on heterogeneous felsic metamorphic parent rocks: Chem. Geol. 2003 202, 397-416.

Suh, C.E. Primary metal dispersion patterns for gold exploration in the amphibolites of Ife-Ilesha schist belt. M.Sc.Thesis; Obafemi Awolow University, Ile-Ife. 1993 145pp.

Taylor, G.R and Eggleton, R.A. Regolith geology and geomorphology: Wiley NY. 2001 375p.

Tijani, M.N, Okunola A.O. and Abimbola, A.F. Lithogenic concentration of trace metals in soils and saprolites over crystalline basement rock: Journal of African Earth Sciences; Vol 46, Issue 5, Dec 2006, pp 472-438.

Table 1: Major oxide composition and Ruxton Ratio of the soil samples

	Rock type	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	Cr_2O_3 %	LOI %	R.R
Quartzite Quartz Schist														
QSA	Top Soil	80.34	10.8	2.23	0.1	0.04	0.15	1.02	0.44	0.04	<0.01	0.006	4.8	7.44
QSB	Weathered unit	75.15	13.3	3.39	0.21	0.05	0.31	2.81	0.55	0.03	<0.01	0.007	4.1	5.65
QSC	Saprolite	80.72	11.6	1.77	0.11	0.02	0.31	1.71	0.46	0.04	<0.01	0.005	3.2	6.96
Ave		78.74	11.9	2.46	0.14	0.04	0.26	1.85	0.48	0.04	0.01	0.006	4.03	6.62
Muscovite Schist														
MSA	Top Soil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MSB	Weathered unit	59.15	20.15	9.24	0.11	0.02	0.24	0.31	1.21	0.07	0.04	0.018	9.3	2.94
MSC	Saprolite	60.1	19.69	8.49	0.09	0.07	0.27	0.21	1.05	0.06	0.04	0.016	9.8	3.05
Ave		59.63	19.92	8.87	0.1	0.05	0.26	0.26	1.13	0.07	0.04	0.017	9.55	2.99
Talc-Tremolite Schist														
TSA	Top Soil	53.38	16.63	15.07	0.81	0.08	0.06	0.31	2.13	0.11	0.23	0.024	11	3.21
TSB	Weathered unit	71.3	12.42	6.13	1.34	0.09	0.29	1.46	0.68	0.06	0.09	0.01	5.9	5.74
TSC	Saprolite	54.49	13.54	12.35	4.85	0.46	0.24	0.18	1.32	0.11	0.19	0.103	11.9	4.02
Ave		59.72	14.2	11.18	2.33	0.21	0.2	0.65	1.38	0.09	0.17	0.045	9.6	4.21
Amphibolite														
AMA	Top Soil	50.81	15	13.83	2.19	1.52	0.64	0.29	3.16	0.1	0.3	0.028	11.9	3.39
AMB	Weathered unit	60.39	17.48	6.64	2.04	4.44	3.6	0.71	0.79	0.07	0.12	0.005	3.6	3.45
AMC	Saprolite	46.08	16.57	12.92	6.4	8.52	2.34	0.49	1.9	0.28	0.22	0.019	4.0	2.78
Ave		52.43	16.35	11.13	3.54	4.83	2.19	0.5	1.95	0.15	0.21	0.017	6.5	3.21

Table 2 Trace element concentration in the soil samples of the weathering profile.

Rock Type	Sample description	Ba (ppm)	Ni (ppm)	Sr (ppm)	Zr (ppm)	Y (ppm)	Nb (ppm)	Sc (ppm)
Quartzite Quartz Schist								
QSA	Top Soil	133.0	<20	13.0	251.0	13.0	25.0	7.0
QSB	Weathered unit	380.0	<20	18.0	254.0	24.0	19.0	11.0
QSC	Saprolite	288.0	<20	18.0	268.0	24.0	17.0	8.0
Ave		267.0		16.3	257.7	20.3	20.3	8.7
Muscovite Schist								
MSA	Top Soil	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MSB	Weathered unit	183.0	31.0	11.0	314	24.0	22.0	19.0
MSC	Saprolite	134.0	26.0	6.0	260	33.0	20.0	15.0
Ave		158.5	28.5	8.5	287	28.5	21.0	17.0
Talc-Tremolite Schist								
TSA	Top Soil	234.0	70.0	7	242	94	21	48
TSB	Weathered unit	912.0	37.0	20	168	34	12	19
TSC	Saprolite	286.0	183	7	291	73	14	31
Ave		477.3	96.7	11.33	233.67	67	15.67	32.67
Amphibolite								
AMA	Top Soil	214	88	78	312	37	42	30
AMB	Weathered unit	258	26	359	169	12	16	15
AMC	Saprolite	207	103	290	143	37	22	33
Ave		226.33	72.33	242.33	208	28.67	26.67	26

N/A: Note Available

Table 3: Physico-Chemical characteristic of associated groundwater around the rock types.

SAMPLE NO.	EC µS/cm	pH	TDS	TEMP^0 C	Ca^{2+}mg/l	Mg^{2+}mg/l	Na^{+}mg/l	K^{+}mg/l
AMPHIBOLITE SAMPLES								
AM 01	517	8.7	387.7	27.8	65.4	21.8	32.0	11.4
AM 02	50	7.1	66.8	28.7	5.2	2.6	5.3	1.8
AM 03	590	9.1	442.5	28.5	38.0	29.3	22.3	51.6
AM 04	618	8.7	79.0	29.4	37.5	14.9	29.9	61.6
Ave	443.8	8.4	244.0	28.6	36.5	31.6	22.4	17.2
QUARTZITE SAMPLES								
QS 01	145.0	7.6	210.0	28.9	17.0	3.7	12.1	1.8
QS 02	126.0	7.7	7.4	26.6	11.0	0.6	4.4	16.9
QS 03	89.0	7.2	66.8	28.6	16.3	1.0	1.4	1.1
QS 04	123.0	6.9	92.3	28.6	7.9	2.8	9.1	7.7
QS 05	100.0	7.5	75	27.5	20.9	1.1	2.5	1.4
QS 06	158.0	8.8	118.5	27.8	19.8	5.1	2.9	3.3
Ave	95.0	7.6	123.5	27.3	15.5	2.2	5.4	5.3
MUSCOVITE SCHIST								
MS 01	210	7.4	157.5	28.3	18.71	6.18	13.43	7.8
MS 02	22.0	6.9	16.5	26.2	2.66	0.93	2.41	1.9
MS 03	42.0	7.0	31.5	27.8	7.63	1.1	3.37	3.2
MS 04	700	8.4	525	27.5	37.45	14.91	29.93	61.6
MS 05	52.0	6.5	39.0	28.1	2.85	2.18	4.07	2.4
MS 06	197	6.0	147.7	28.3	3.93	1.22	33.86	5.0
MS 07	88.0	6.4	66.0	27.2	2.01	0.96	14.52	3.8
MS 08	1000	8.1	750.0	27.0	75.47	24.4	49.6	111.9
MS 09	95.0	6.9	71.3	26.5	2.0	2.8	12.5	2.4
Ave	267.3	7.1	200.5	27.4	16.9	6.1	18.2	22.2