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Weathering Profile of Schistose Rock from Geotechnical and Geochemical Parameters at Okpe, Igarra Schist Belt in Edo State, Nigeria

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ABSTRACT

This work focuses on the weathering profile study of Okpe Schistose Rock at the Igarra Schist Belt, Edo State, Nigeria. The aim is to understand the degree of weathering which is the removal of mobile elements by meteoric water and subsequent ionic concentration of stable weathering products in schistose rock. The two methodologies applied were geotechnical and geochemical data to determine the weathering profile of four layers. The results from geochemical analysis showed that S3L3 and S4L4 have been enriched with in Al_2O_3, K_2O, Fe_2O_3, and MgO, while the geotechnical data showed a highly weathered zone a layer S3L3 and S4L4 from the particle size distribution curve, specific density, bulk density, plasticity, colour index tests, respectively. In conclusion, the weathering profile of the Okpe Schist shows that it's ionic concentration and weathering profile increases downwards which gives rise to lateritic soils that is of great economic value.

***Keywords*:** Weathering Profile, Schistose Rock, Okpe Edo State, Lateralization, Geotechnical Parameters

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1. INTRODUCTION

Weathering is the process of degradation of rock components by the action of a physical, chemical and biological process that leads to the production of rock fragment or sediment. Weathering is known to reduce rock-bulk composition, specific gravity, particle size distribution, morphology of the rock (grain-size, shape, orientation, degree of roundness). The rate of rock disintegration depends on both external forces and rock type on which the rock is exposed. The impact of moisture, high-low temperature, air-movement, humans, plant and animal activities contribute to the rate of rock weathering. Engineering projects occur in weathered zone which varies laterally and vertically. Accurate description of weathering profile at site of an engineering project is sine-qua-non. Weathering factors include topography, vegetation and time, parent material, climate, nearness to settlement and chemical action which impact on the rock profile of a location.

The weathering profile of rock mineral is the capacity of elements, ions, and molecules to move from one compartment of soil to another when they combine and react with air and water to form new minerals. The specific reactions include oxidation, hydration, hydrolysis, and reduction. Mineral weathering takes place in micro-fissures, narrow solution channels and capillary water in such spatially restricted volume may be expected to be in close equilibrium or similar with primary minerals. The study seeks to assess the weathering profile of schistose rock at Okpe in Edo State.

2. MATERIALS AND METHODS

2. 1. Study Area

The study area is Okpe, which is located at Igarra in Akoko-Edo local government area of Edo State lies between longitude 06°15'E and Latitude 07°08'N to 07°40'N. The climate has dry season commonly from December to March, the period is characterized by low or no rainfall with average temperature of 26 °C, while the wet season is characterized by a drastic rainfall for a period of about seven to eight months, i.e., April to November; the conveying medium for this rain is the south-west trade wind which blows across the Atlantic Ocean. Rainfall at this geographical terrain is measured to about 2000 mm from May to October and about 500-750 mm from November to April. The nature of various sub-surface tectonic processes in geologic time scale gave rise to the relief of the area (Okpe) which is moderately a plane with small hills and valleys alternating each other. The highest elevation is found to be about 400 m above sea level (**Figs 1** & **2**).

2. 2. Geological Setting

Okpe Junction, a sub-area of Igarra, lies at a triaxial boundary that leads to Somorika, Aiyetore, Aiyegunle, and Ogugu areas, respectively. It lies in south-western Nigeria with the presence of primary and secondary roads, road cuts and recently blasted outcrops but at site. Generally, study has proven that the schist belt at Igarra, Okpe area is predominantly composed of basement rock as the dominant Igneous Rock type is Biotite Granite, having major rock type such as banded gneiss and granitic gneiss and minor rocks type such as quartz vein and pegmatite. It belongs to the Pan-African Orogeny, an Upper Proterozoic formation during the Precambrian Eon (600 ±150 mya).

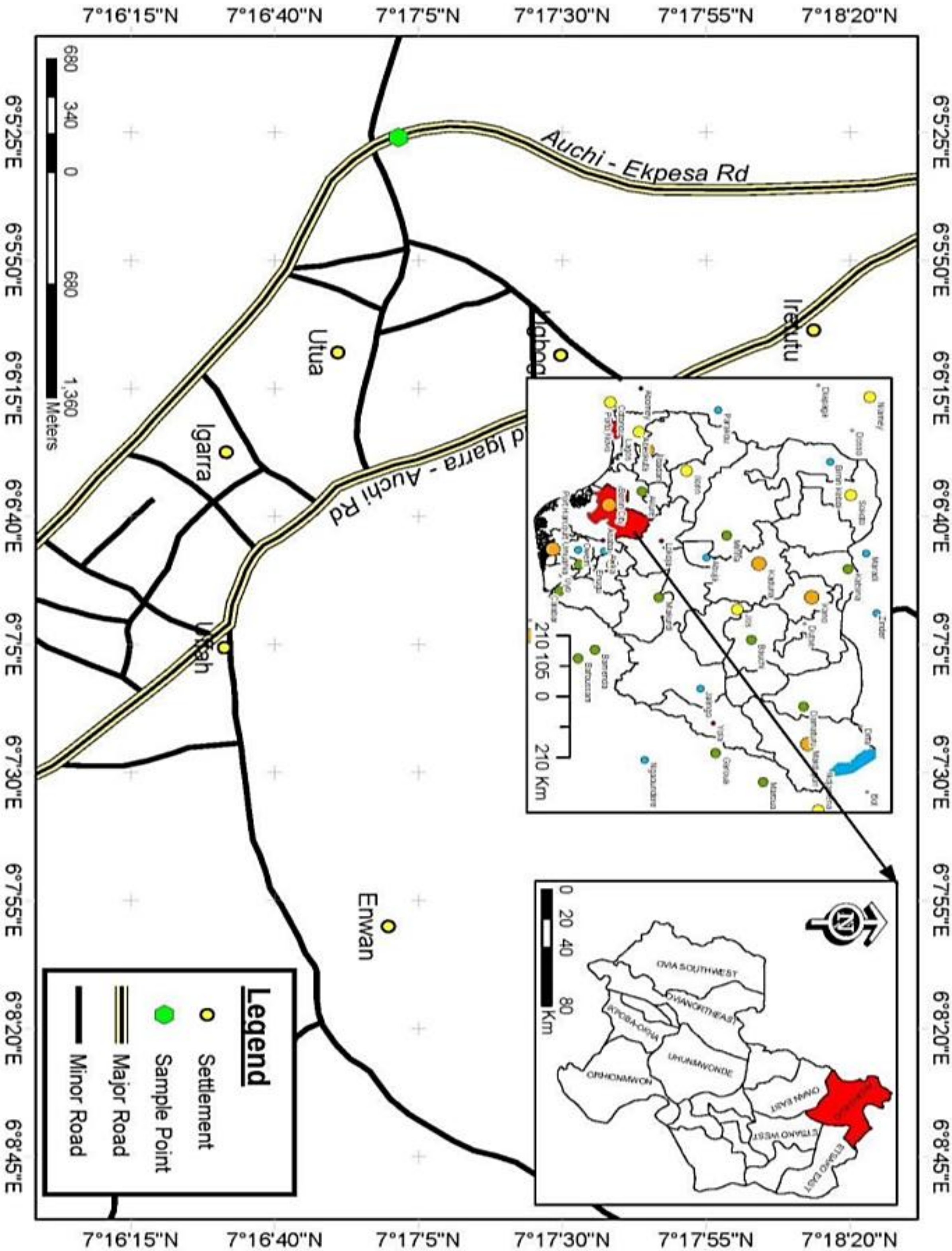


Figure 1. Site map indicating sampling site.

Mineralogically, Okpe consists of plagioclase, quartz, and biotite. The mafic bands present is composed of solely biotite, while felsic layer on the other hand has residues of quartzofeldspartic minerals. The banded gneiss present in Okpe Schistose is highly prone to weathering because of its exposure to axial planes of weakness and erosional surfaces. It consists of phenocryst of feldspar minerals infused in the matrix of feldspar and quartz.

The felsic minerals present, consist of quartz, muscovite flakes, and high amount of feldspar while the mafic mineral consists of biotite and other accessory minerals. The mafic minerals present are randomly distributed within the porphyritic granite which is an associate of the basement rock complex. The migmatite located at the central part of Igarra is made up of leucocratic components alternates with basic components.

Figure 2. Location of study area

2. 3. Sampling methodology

Table 1. Soil type and recommended sampling type.

S/N	Soil Type	Type of sampling
1	Granular Soils	Split-tube
2.	Plastic (cohesive) Soils (N<30)	Alternate split-tube and thin-wall
3.	Plastic (cohesive) Soils (N>30)	Split-tube
4.	Organic Soil	Thin-wall

Soil samples were collected at Okpe quarry site with the aid of a hand auger. The hand auger was drilled laterally from 0 – 213.36 cm, respectively with 12.70 cm sampling intervals to get 16 samples, as shown in **Table 1**. The samples thereafter were packaged in a black cellophane, labeled and taken to the lab within 36 hours of collection and kept in a refrigerator until analyzed. Sample preparation and handling was carried out according to APHA 1999.

2. 4. Laboratory Studies Method

15 grams of soil samples were weighed, washed and dried with stainless pan in oven at 105 ºC for 24 h; thereafter they were reweighed to determine moisture content.

$$\%\ \text{moisture} = \frac{\text{weight of moist soil} - \text{weight of dry soil}}{\text{weight of dry soil}} \times 100\% \tag{1}$$

2. 5. Geotechnical Study Method

2. 5. 1. Sample Preparation

Soils were sieved to remove stones and gravel (>2 mm diameter). Three types of sieving was adopted for sieving soil samples depending on the soil's physical characteristics of stones, concretions and plant debris contained.

2. 5. 2. Particle Size Analysis

100 grams of soil samples were weighed on 0.053 mm sieve, washed into a 100 mL measuring cylinder and oven-dried at 105 ºC for 24 h; thereafter they were reweighed before transfer into ASTM Sieve No. 200 with different mesh size in the following order: 0.5 µm; 0.25 µm; 0.106 µm; 0.053 µm and Pan to determine particle size distribution. The mass of each sand fraction (coarse, medium, fine and very fine sand) was weighed and expressed as a percentage (%) of the weight of the soil sample.

2. 5. 3. Bulk Density

The bulk density of the soil, ρ_{sand} (mg/m^3) was calculated using the equation;

$$\rho_{soil} = \left(\frac{\text{mas of soil excavated}}{\text{mass of soil required to fill the hole}}\right) \times \rho_{sand} \tag{2}$$

where bulk density of the sand, ρ_{sand} (mg/m^3):

$$\rho_{sand} = \frac{\text{weight of sand}}{\text{volume of sand (100ml)}} \tag{3}$$

2. 5. 4. Specific Gravity

The weight of dry specific gravity bottle with stopper was weighed accurately designated as W_1. 10 g of the oven dried soil was transferred into the bottle reweighed and assigned to W_2. Distilled water was added to the bottle until excess air bubbles were expelled using a desiccators and wiped water from the outside bottle and weighed as W_3. Then, distilled water was added to dry empty bottle to top-lid and weighed as W_4. The specific gravity, G_s is given as:

$$\frac{\text{Mass of soil particles}}{\text{Mass of equal volume of water}} = \frac{W_2 \quad W_1}{(W_4 - W_1) - (W_3 - W_2)} \tag{4}$$

The procedure was repeated for three times to get average of soil samples.

2. 5. 5. Soil Colour Test

It was determined using Munsell Soil Colour Chart.

2. 6. Geochemical Analysis Method

1 g of samples was digested in a conical flask using 100 ml of total volume H_2SO_4, HNO_3, and HClO in the ratio of 40%, 40%, 20% and mixed together which was done in a fume cupboard before analysis of Fe_2O_3, MgO, Al_2O_3, and K_2O using atomic adsorption spectrophotometer (AAS).

3. RESULT AND DISCUSSION

3. 1. Geotechnical Properties Results

The weathering schist has a brownish clayey shale residual soil at the sub surface layer, running from 0 m to 0.70 m. The first layer that runs from 0.70 m to 15.80 m is slightly weathered from the top layer. The second layer contains high amount of lateritic soil which makes it a completely weathered zone and it ranges from 15.90 m to 21.60 m. The third layer is underlained by a mixture of highly weathered Schistose and it runs down to 30.10 m depth. The fourth layer is moderately weathered as it contains a dark brown schist and it ranges from 30.20 m to 44.54 m from the top. The final layer is the bed rock which is orange brown and gradually weathering because of its contact with water, a major agent of weathering.

3. 1. 1. Particle Size Distribution

Table 2. Particle Size Distribution of Okpe SCHIST

Sieve diameter	Mass of soil Retained (g)				Mass passing (g)				% passing			
	S_1L_1	S_2L_2	S_3L_3	S_4L_4	S_1L_1	S_2L_2	S_3L_3	S_4L_4	S_1L_1	S_2L_2	S_3L_3	S_4L_4
2 mm	0.00	3.00	10.00	3.90	4.00	38.00	71.30	10.00	100.00	92.68	87.70	71.94
1 mm	0.30	2.60	5.40	1.60	4.60	35.40	65.90	8.40	93.88	86.34	81.06	60.43
500 μm	0.50	3.40	7.60	1.50	4.10	32.00	58.30	6.90	83.67	78.05	71.71	49.64
250 μm	1.30	6.20	19.00	2.00	2.80	25.80	39.30	4.90	57.14	62.93	48.34	35.25
150 μm	2.40	8.70	17.80	2.00	1.40	17.10	21.50	2.90	28.57	41.71	26.45	20.86

75 µm	0.40	3.20	3.10	0.90	1.00	13.90	18.40	2.00	20.41	33.90	22.63	14.39
Pan	1.00	13.90	18.40	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3 shows particle size distribution of residual soils from various depths of the Okpe schistose, the first portion (0 to 15.80 m depth) had a fines content of about 39% and was plastic (M, Unified Soil Classification System). At deeper depths (15.90 m to 21.60 m) the fine content is 50%. The coarse-grained portion is less than the fine-grained portion present, and the soil type postulates lateritic soils (MH, Unified Soil Classification System) [9] and so, it is completely weathered. The third layer with a depth of (21.70 m to 30.10 m) has fines of 35% which is highly weathered. This implies that the fines content decreases with depth as the degree of weathering decreases. In addition, above average of the soils from different depths of the Okpe Schistose are mainly composed of coarse-grained, with fines contents varying from 25% and 47%. It is also observed that there is no standard variation in the particle size distribution with various depths observed for residual soils at the Shistose exposure.

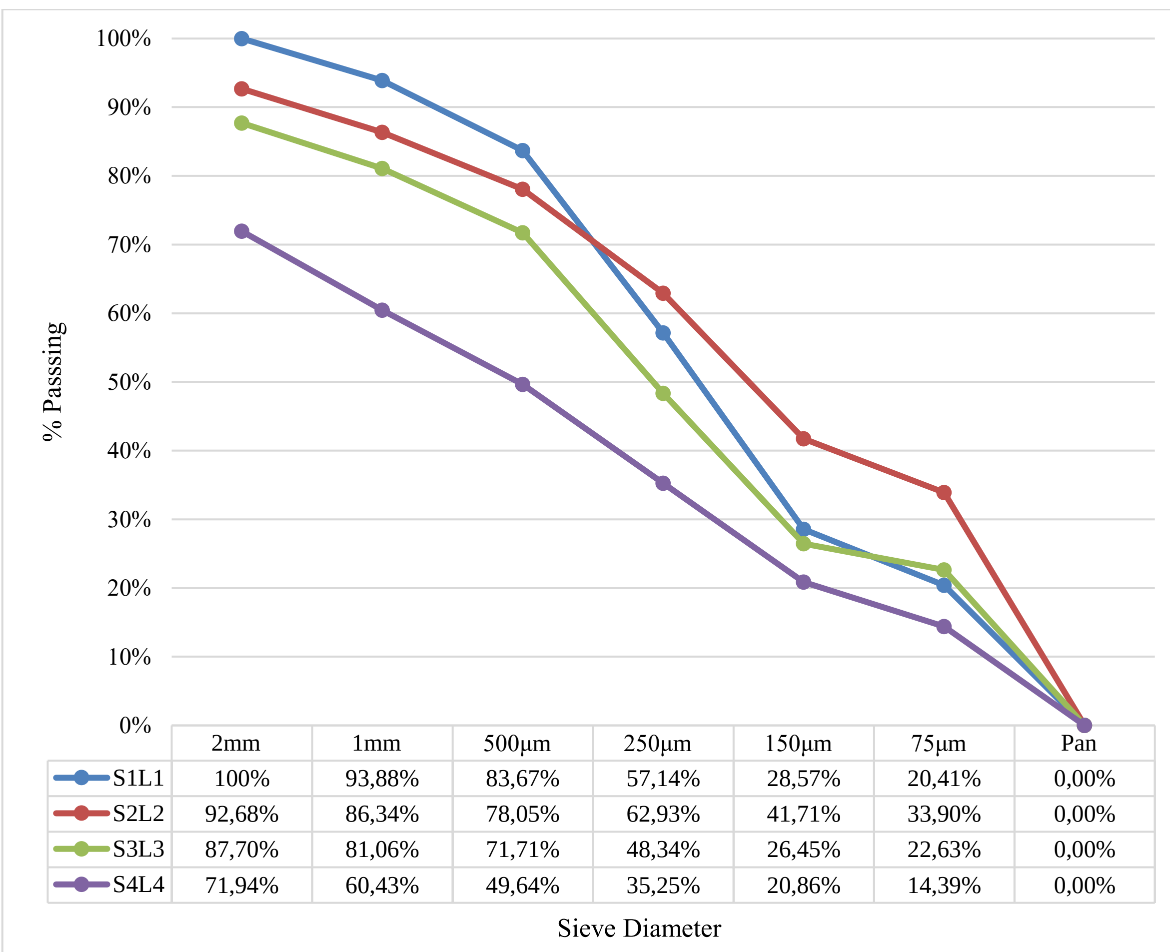


Figure 3. Particle Size Distribution Curve of Okpe Schist

3. 1. 2. Bulk density and specific gravity

Figure 4 tells us about the volume that replaced by water and air in the porous structure. S1L1 gives residual soils (regoliths), porosity and void ratio are higher. Therefore, the water and air phases occupy more space compared to the S2L2, S3L3 and S4L4. As a result, the bulk density of the residual soils from the Okpe Schist ranged from 1.22 to 1.54 g/cm^3 with increasing depth down the basement. For both residual soils the void ratio appeared to decrease with depth (Fig. 4) reflecting the variation in the degree of weathering.

For the Specific Gravity; this depends on the soil mineralogy and it reflects the weathering history. The specific gravity of S1L1 is 2.03 g/cm^3, S2L2 is 2.49 g/cm^3 indicating the presence of Feldspatic arenite at that layer, S3L3 is 2. 55g/cm^3 which indicates a very high degree of weathering and amounts of Kaolinite mineral at that profile, and S4L4 is 2.21g/cm^3. These results are similar to the results of [Rahardjo, 2004] (i.e. gravity range of 1). This is due to the presence of different minerals other than quartz in the deeper layers that have a higher specific gravity than quartz mineral.

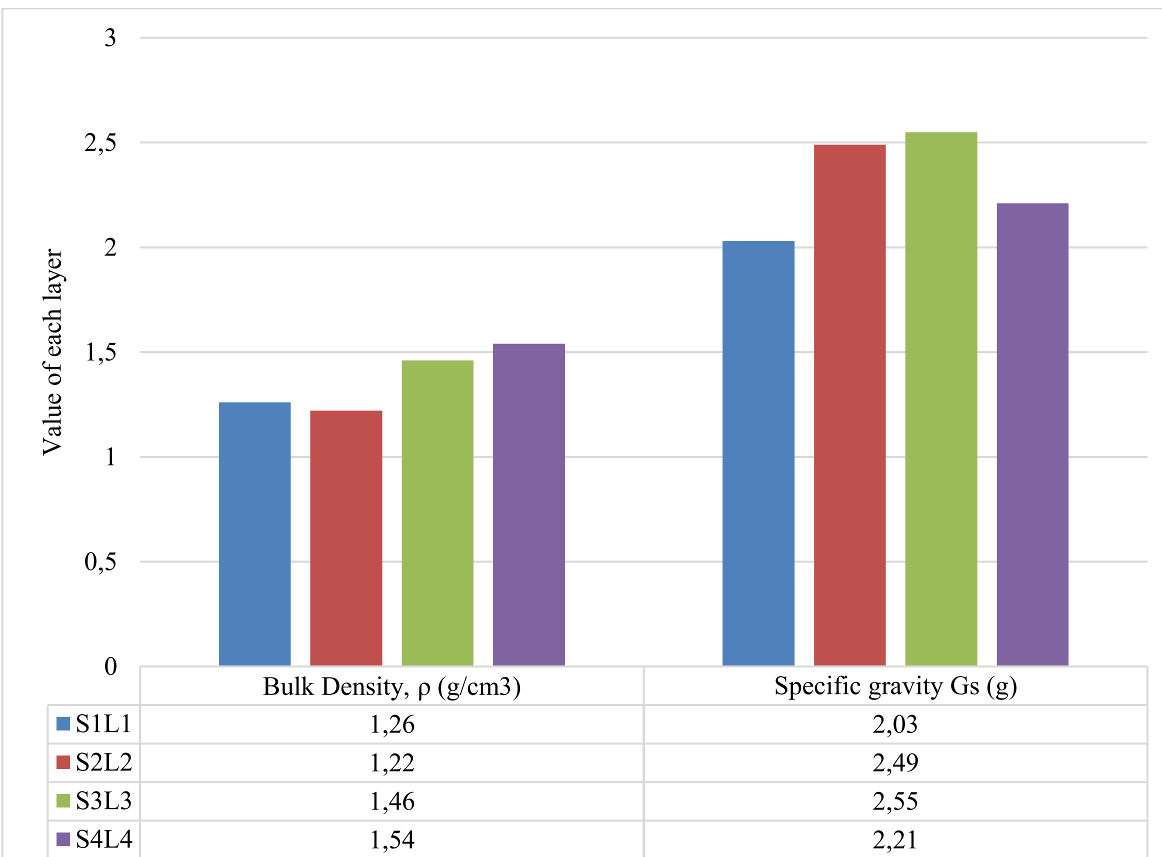


Figure 4. Bulk Density and Specific Gravity of Okpe Schist

3. 1. 3. Soil Colour Chart

Figure 5 shows the use of Munsell Soil Colour chart as a standard. The soil colour ranged from reddish-brown to orange brown. S1L1 at depth of 0.70 m to 15.80m indicated a dark brown colour, S2L2 at depth 15.90 m to 21.60 m indicated an orange brown colour, S3L3 at depth 30.10 m, indicated a milky orange colour that was observed and indicated a highly weathered zone and also a lateritic soil. S4L4 at depth of 30.20 m to 44.54 m showed a gradual colour transition from orange-brown to yellowish-brown with white spots.

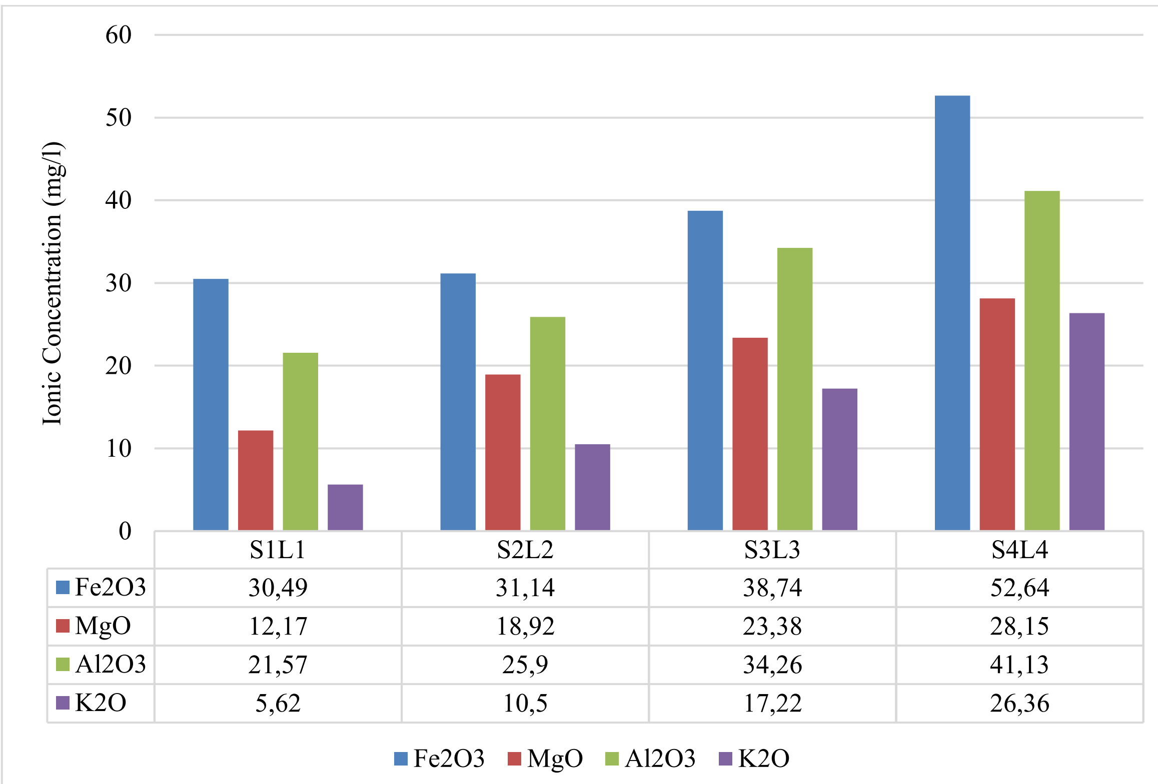
The colour changed gradually from brownish to grey with yellow and white spots.

The most apparent manifestation of residual soil at this layer was the rough texture of soil particles.

Figure 5. Soil colour of Okpe Schist

3. 2. Geochemical Results

Figure 6 gives the study of the core ionic concentration values from of the four layers to determine the variables in Fe_2O_3, Al_2O_3, K_2O, and MgO. There is an increase of Fe_2O_3 and Al_2O_3 at S3L3 and S4L4; which postulates a downward increase in the weathering of Schistose rock. The ionic concentration also gives an insight on the oxidation and the production of new elements that are similar to the primary elements.



	S1L1	S2L2	S3L3	S4L4
Fe2O3	30,49	31,14	38,74	52,64
MgO	12,17	18,92	23,38	28,15
Al2O3	21,57	25,9	34,26	41,13
K2O	5,62	10,5	17,22	26,36

Figure 6. Line graph indicating mean anion concentrations in different locations

4. CONCLUSION

In conclusion, this study revealed the geotechnical, and geochemical properties of the Okpe schist from various reconnaissance surveys, field exercises, and laboratory analysis. Although in some areas the degree of weathering of the residual soils from Okpe Schistose rock appeared to be not uniform, as the third layer has the highest weathered zone while the fourth one is moderately weathered. This study has led to a conclusion that the degree of weathering increases as we go down, the weathered zone at the third layer is having a depth range of 15.00 m – 21.40 m which facilitates laterization of the weathered schist to obtain laterites. The results of this work will be of immense benefit for economic value, and a higher degree of weathering would result in a higher pore volume and a larger range of pore-size distribution. It is therefore possible to use the variation in the pore volume and the pore size distribution through a weathered profile as an indication of the variation in the degree of weathering with depth.

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