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X-Ray Diffractometer Analysis of Minerals in Rocks and Soils of Lau in Northern Taraba State, Nigeria.

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ABSTRACT

This work determined the presence of solid minerals in rocks and soils of Lau in Northern part of Taraba, Nigeria. The rocks and soils samples prepared were analyzed using X-Ray diffractometer. The result showed total number of seven (7) minerals identified in both rocks and soils of Lau. The result obtained revealed the presence of Quartz (SiO_3), Microcline ($KAlSi_3O_8$), Albite ($NaAlSi_3O_8$), Biotite ($K(Mg,Fe);3(AlSi_3O_{10})(F,OH)_2$), Phlogopite ($KMg_3(AlSi_3O_{10})(OH)_2$), Annite ($KFeAlSi_3O_{10}(OH)_2$) and Cronstedtite ($Fe^{2+} Fe^{3+} (SiFe^{3+})O_5(OH)_4$), respectively. 62%, 45.5%, 22% and 9% were highest amounts for Microcline, Albite, Quartz and Biotite at Jimleri, Jasi, Jutahore and Apawa, respectively. While lower minerals values were recorded for 30.7% Microcline, 22.8% Albite, 16% Quartz and 4% Biotite at Jasi, Minda, Jimleri and Jutahore, in rock samples accordingly. The soil samples revealed highest values of 66% Albite, 62.4% Microcline and 53% Quartz at Jimleri, Apawa, and Jutahore sample areas. While the lower soil minerals recorded 15% Albite, 21.8% Microcline, and 12% Quartz for Jimleri, Minda and Jasi sample areas. The three (3) crystal structures identified were Monoclinic, Hexagonal, and Anorthic.

Key words: X-ray diffraction (XRD), Minerals, Rocks, Soils, Crystal structure, Lau.

INTRODUCTION

Earth's crust has various types of rocks. The large area of the earth formed the soil, but it is a mixture of tiny rock fragments, decayed organic matter, water and air. Rocks are the most considerable accumulation of minerals cemented together, and hence generally, solid minerals constitute the crust of the earth (Ravisankar et al., 2002).

Man's developmental journey searches for the vast and explorative mineral resources available to him. Globally, the solid mineral has played a vital role in the emerging civilisation and technological applications. (Ajaka and Ogailhelemi, 2010).

Solid minerals are referred to as naturally occurring substances that are stable at room temperature. They are primarily inorganic with a fixed crystalline structure (Pipkin and Trent 2001).

Solid minerals are vital, and we study them because they play a significant role in our economy, industry and health, especially in the 21st century. We use many products every day that are made up of solid minerals and their derivatives. Minerals are all around us: for example, the graphite in pencil, the table salt, the plaster on walls and the trace amounts of gold in computer. In addition, the various consumer products, including paper, medicine, processed foods, cosmetics and many more, are minerals subsequently, everything made of metal, derived from minerals (Stephen, 2015).

In the same vein, quartz is used for oscillator plate optical work. At the same time, quartz sand is used for glass making and various building purposes (Areola, 1983). Tripoli and garnet are used as abrasives, feldspars are used in the manufacture of porcelain, kaolin is employed in pottery making, and clay is employed for brick making (Akpake and Ekwueme, 2001).

Minerals distribution occurs in different locations and varying amounts worldwide (Abaa and Najome, 2006).

Nigeria has abundant solid minerals resources distributed across the length and breadth of the land (Gushibet et al., 2015 and Shenpam et al., 2017). These solid minerals resources include coal, Gold limestone, bitumen, tin, iron ore, salt, among others and these minerals cut across the states of the federation. However, the dominance of oil as a significant foreign exchange earner has wholly overshadowed the different minerals in 500 known mineral deposits or locations across the 36 states and the federal capital. As a result, the dominance of oil has made Nigeria experience the Dutch disease (David et al., 2016). Also, the results have been a mono-product economy and an underdeveloped non-oil sector, specifically the solid mineral sector (Gushibet et al., 2015). In the same vein, this has led to a lack of growth, joblessness, underdevelopment and insecurity, to mention a few.

Therefore, due to the mono nature of Nigeria's economy and the Dutch disease experienced by the country, it's against this backdrop, that made the researchers to determine the quality of solid minerals in rocks and soil samples in the Lau local government area in the Northern part of Taraba state, using an analytical technique. The solid minerals that would be determine will serve as good supplement or substitute for crude which has been the major foreign exchange earner in the country.

MATERIALS AND METHODS

Apparatus/Equipment's

The following apparatus and equipment's were used. X-Ray diffraction spectrophotometer (Empyrean, USA), Auger, Pestle and Mortar, 2mm Mesh Sieve, Hammer, Chisel, Analytical Weighing balance, Polythene bags and Spade.

Study Area

The study area is Lau Local Government area and is situated in Northern part of Taraba State, Nigeria. Lau has an area of 1660 km^2, with latitude of 9.20827 and longitude of 11.2754. The GPS coordinates are 9°12' 29.77" N and 11°16' 31.48" E. The sampling sites are Apawa, Jasi, Jutahore, Jimleri and Minda respectively

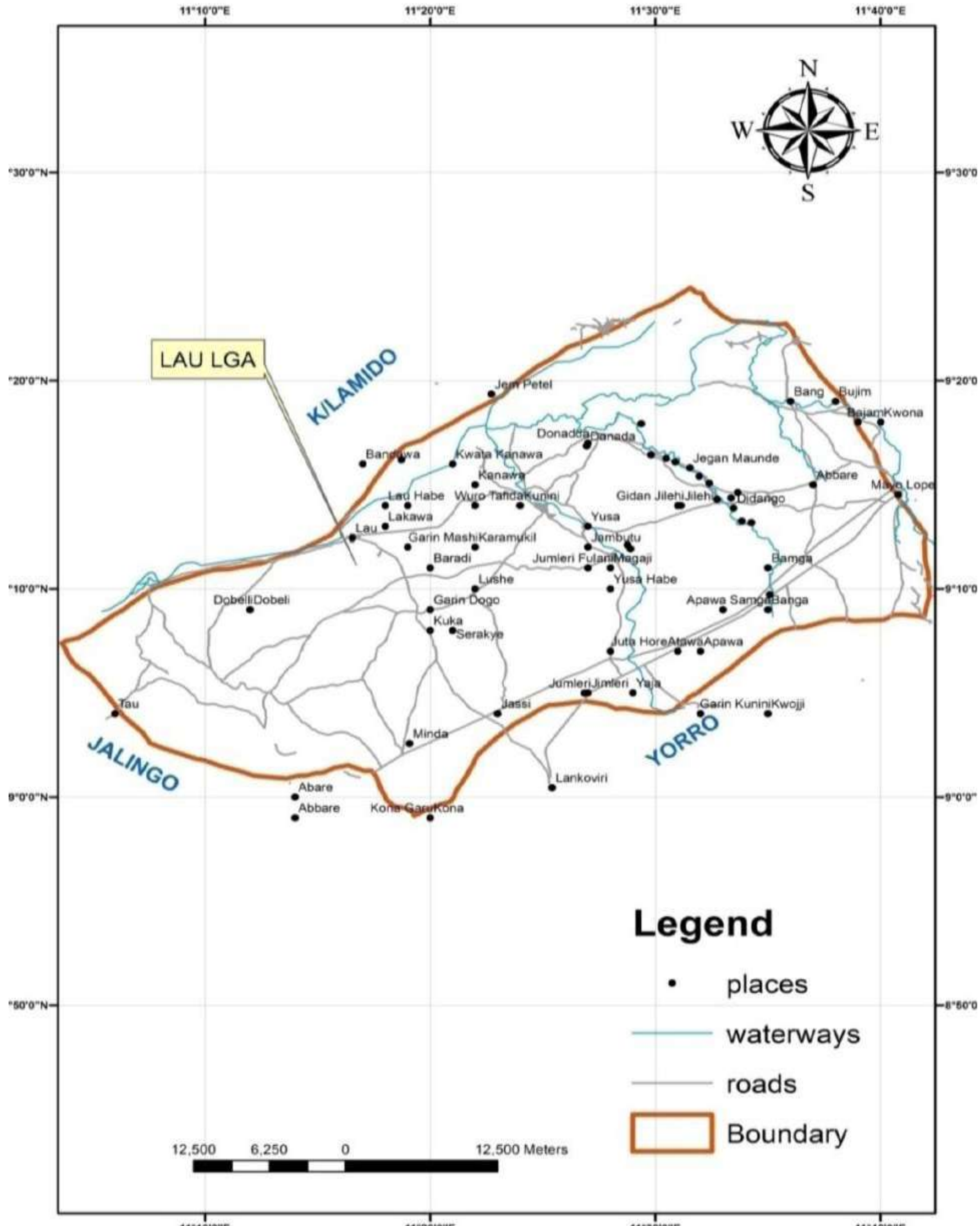

Figure 2: Map of Lau Local Government Showing Study Area
Source: ARC/G I S 10.2.2

Sampling and Sample Preparation

Rock Sampling

The Rock samples was chiseled and hammered out from four different locations or coordinate points and mixed to give a representative sample. The samples was kept in a polythene bag to preserve it and taken to the laboratory for further processing as described by Penuel et al., (2017)

Soil Sampling

The samples were collected according to the standard methods as reported by Tazabia et al., (2019). The soil samples were collected with an auger, hoe and shovel. The soil was sampled from four coordinates of the sampling site at an interval distance of 10 meters and 0 to 30 cm below the soil surface in triplicate and homogenized. The samples was kept in a polythene bag to preserve it and taken to the laboratory for further processing as described by Tadzabia et al., (2019).

Rock Sample Preparation

The rock samples were dried for about 12 hours. Then, it was subjected to mechanical attrition into the smaller pieces and ground to a fine powder using the mortar and pestle and sieved to obtain a fine powder (Zhang et al., 2017). Finally, the sieved rock samples were subjected to coning and quartering method to obtain a representative sample, and it was stored in a polythene bag for further analysis.

Soil Sample Preparation

Soil samples were dried by spreading them on a clean polythene sheet in the laboratory for seven days. The soil samples were ground using mortar and pestle and sieved through a 2mm mesh sieve to obtain fine powder form. Gross samples were reduced to test sample sizes through the process of cone and quartering. The method involves forming a cone shape with the sample, dividing it into four equal portions, and taking the two opposite sides of the quarter while the other two quarters were discarded. The two quarters retained were recombined, and the process repeated until about 100g of the sample was obtained (Maitera et al, 2015., and Okunola et al., 2008).

X-Ray Diffraction Spectrophotometer (XRD) Analysis of Samples

X-Ray Diffractometer was used for the identification and evaluation of mineralogical contents of the rock and soil samples. First, the powdered rock and soil samples were smeared uniformly on a glass slide, assuring a flat upper spread surface and pack into a sample container, then placed in a sample stage. The X-rays generated by the cathode ray tube are filtered to produce monochromatic radiation, collimated to concentrate, and directed toward the sample and irradiated with an X-ray. The electronic detector is coupled on the other side of the sample from the x-ray tube, and a goniometer rotates both the x-ray tube and the detector to produce angles from 0 to 90 degrees. As a result, diffraction of the X-ray occurs by the sample. The detector records and processes this X-ray signal and converts it to a count rate, then output it to a device such as a printer or a computer monitor.

RESULTS AND DISCUSSION

X-ray diffraction (XRD) is a rapid analytical and non-destructive technique primarily for phase identification of a crystalline material and can also provide information on unit cell dimensions identified. The analysed material is finely ground, homogenised, and the average bulk composition is determined accordingly. Figures 1 to 10 presents X-ray diffraction (XRD) in rocks and soils of the study area.

Figure I X-Ray Diffraction Spectral for Apawa Rock Sample

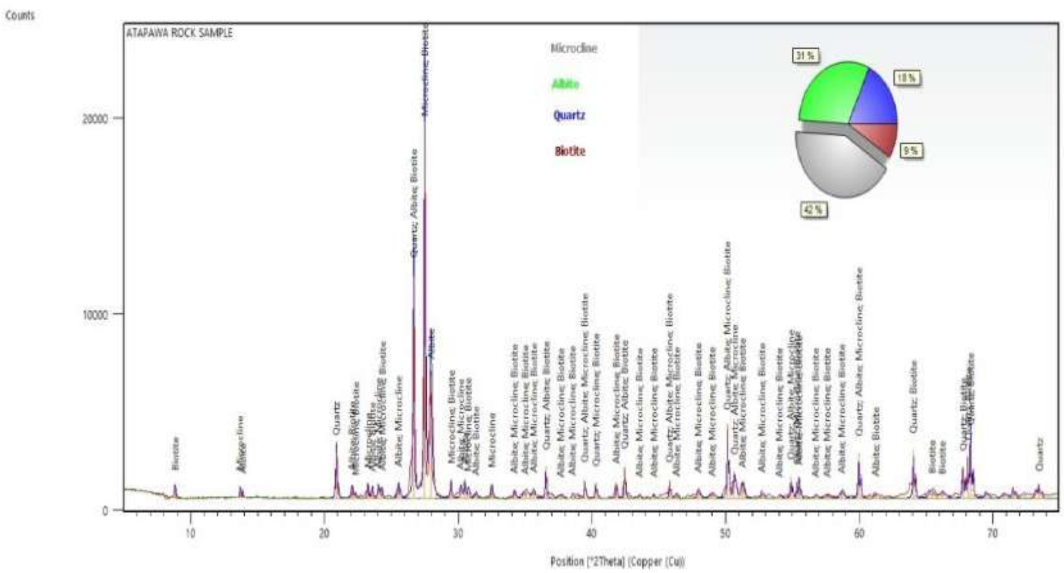

Figure 2 X-Ray Diffraction Spectral for Jasi Rock Sample

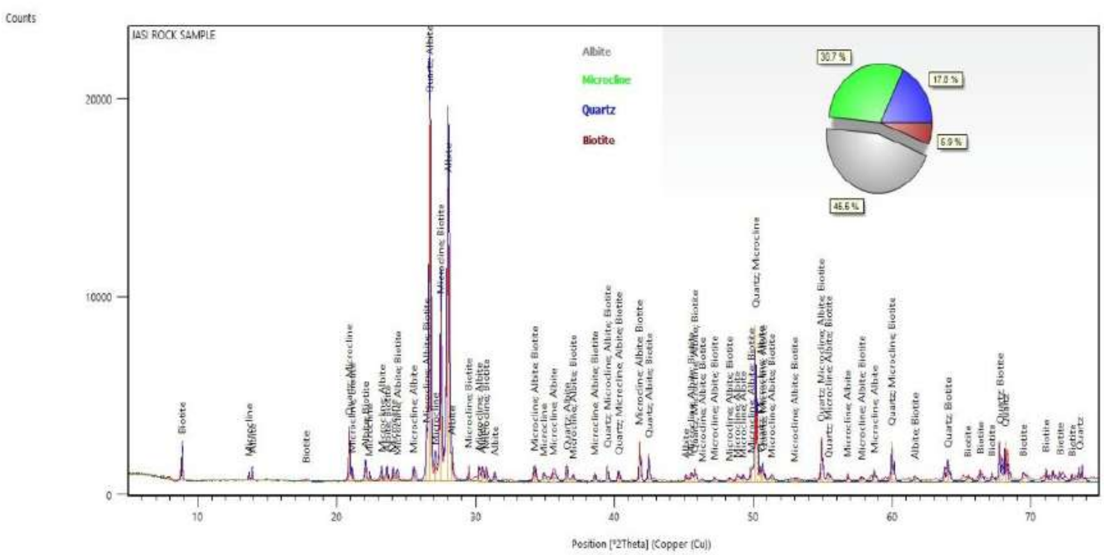

Figure 3 X-Ray Diffraction Spectral for Jimleri Rock Sample

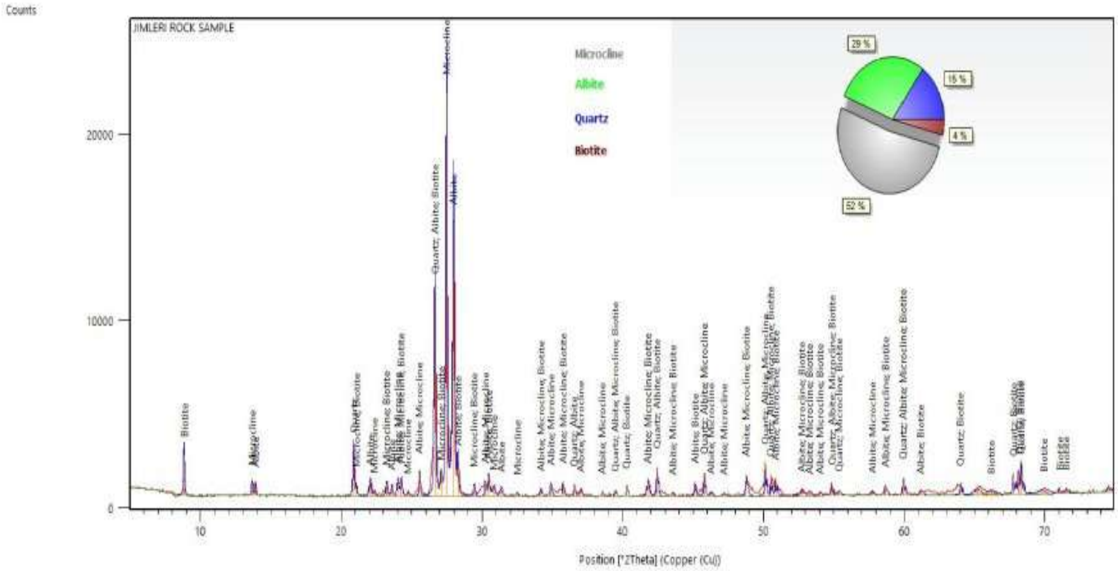

Figure 4 X-Ray Diffraction Spectral for Jutahore Rock Sample

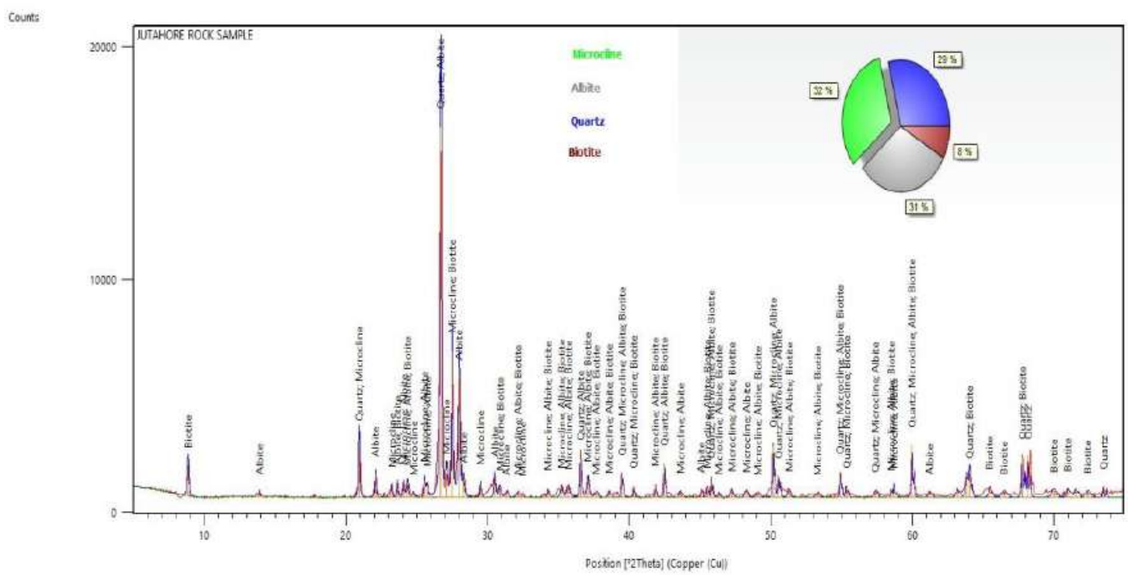

Figure 5 X-Ray Diffraction Spectral for Minda Rock Sample

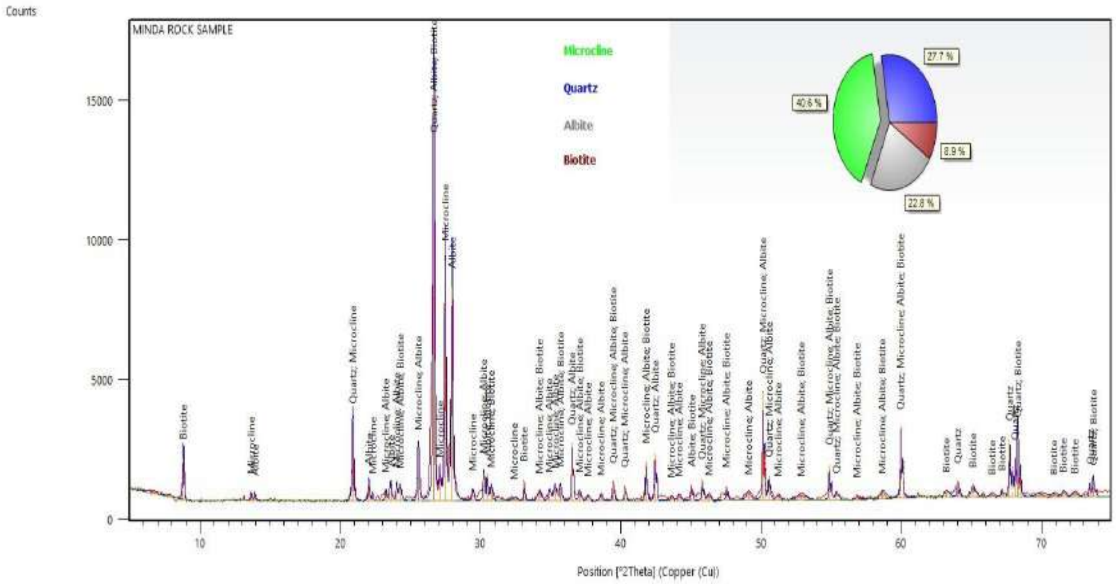

Figure 6: X-Ray Diffraction Spectral for Apawa Soil Sample

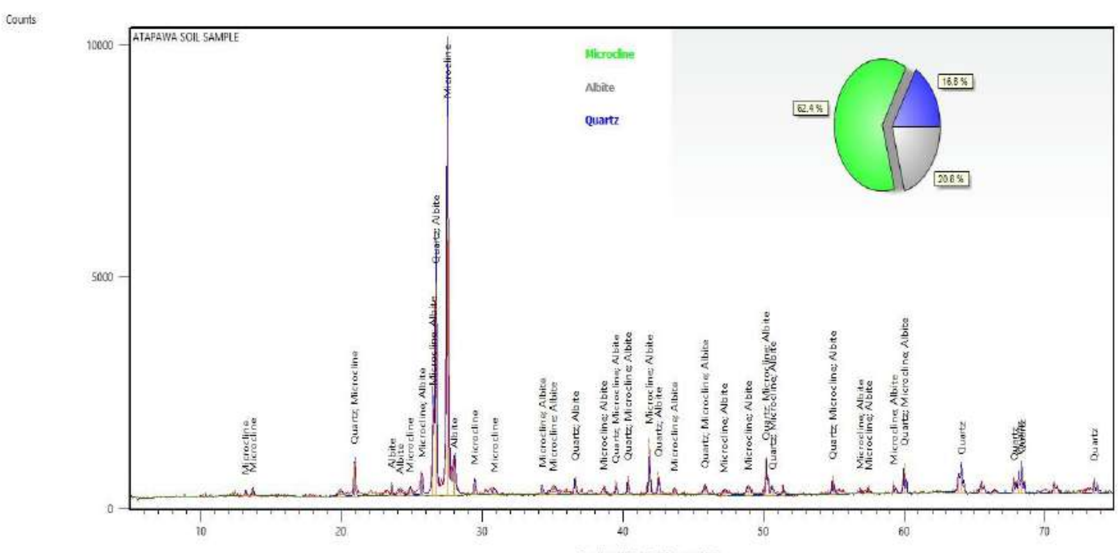

Figure 7: X-Ray Diffraction Spectral for Jasi Soil Sample

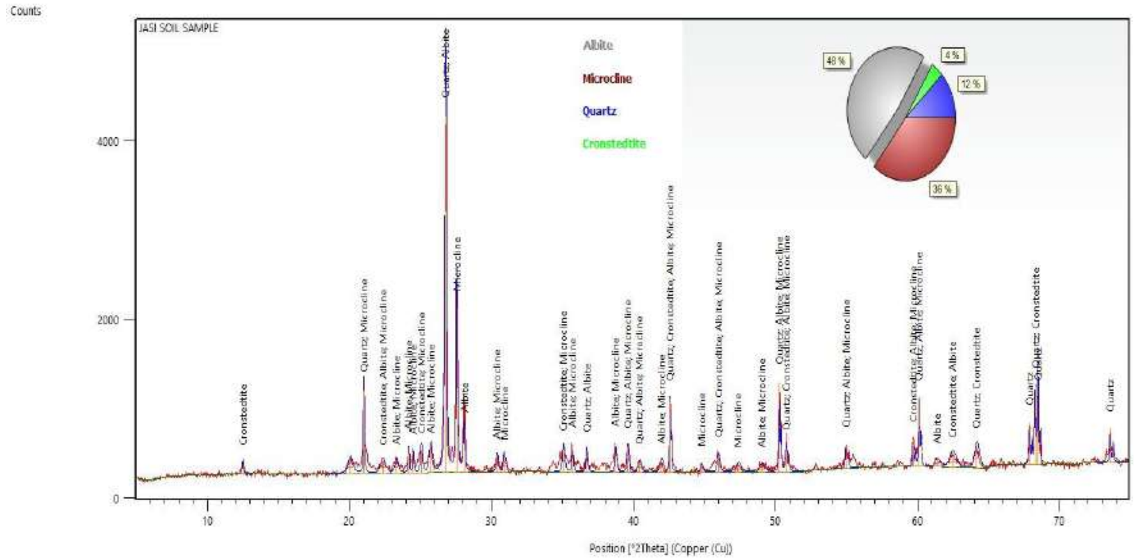

Figure 8: X-Ray Diffraction Spectral for Jimleri Soil Sample

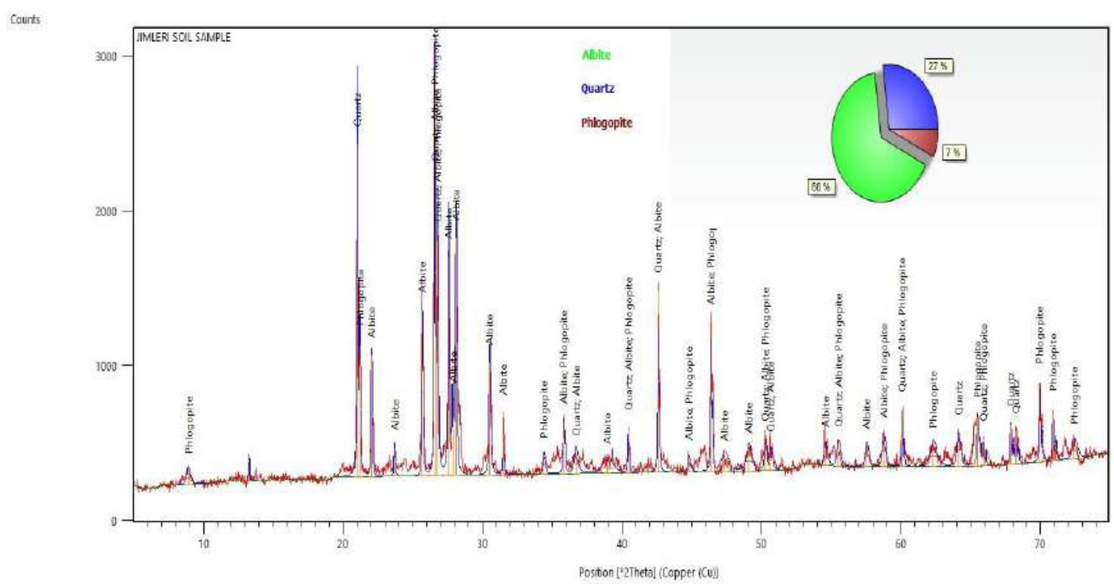

Figure 9: X-Ray Diffraction Spectral for Jutahore Soil Sample

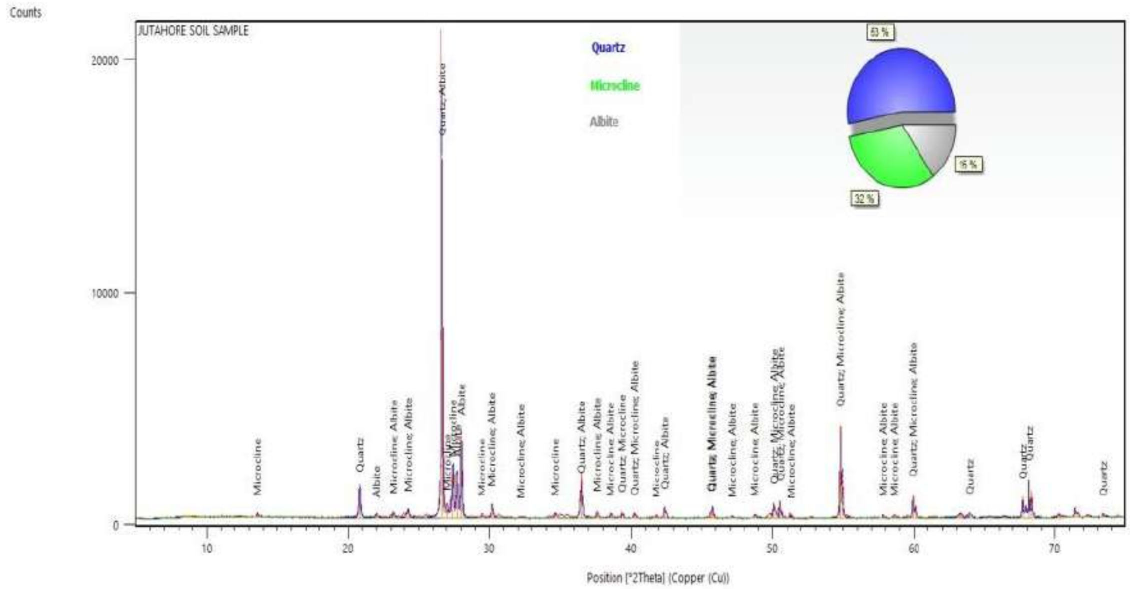

Figure 10: X-Ray Diffraction Spectral for Minda Soil Sample

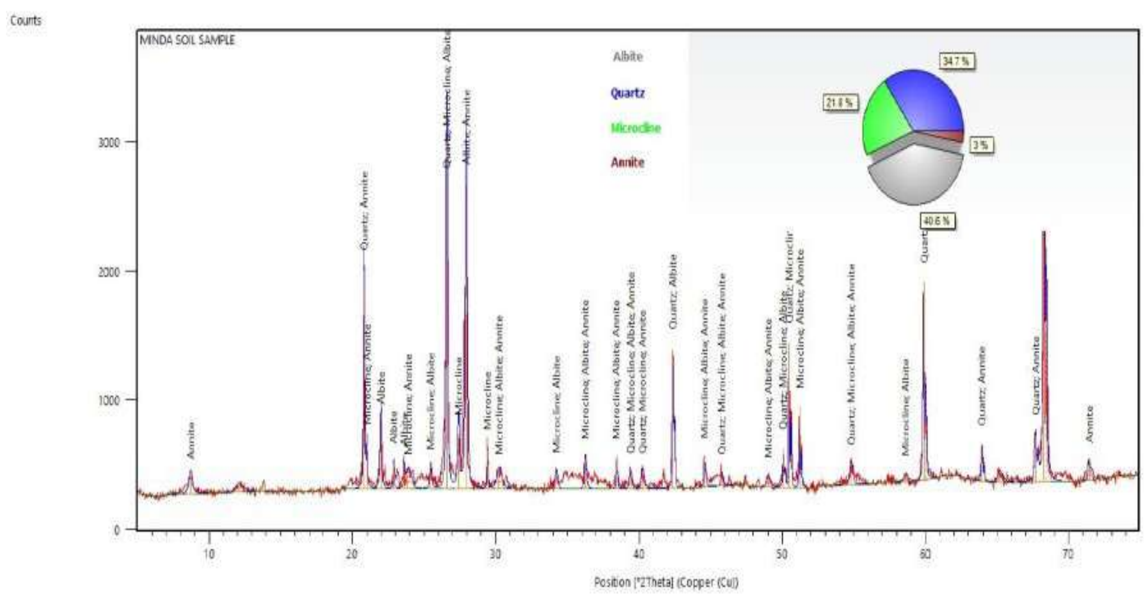

Table 1 shows the minerals identified by x-ray diffraction analysis (XRD). The result revealed the presence of Quartz, Microcline and Albite in the rocks of Apawa. In the same vein, Biotite, Albite, Microcline and Quartz were identified in the rocks of Jutahore. The mineral content of Jimleri rock was Quartz, Microline, Albite and Biotite, respectively. Also, Quartz, Microcline, Albite, and Biotite were identified in Minda rocks, respectively. The result revealed that minerals reported in Table 1; were found in rocks of all studied locations except biotite which was absent in the rock samples of Apawa. The absence of biotite in experimental samples from Apawa; may be due to some principal factors that cause metamorphism. The results obtained are comparable to the one reported by (Osemeahon et al., 2019).

Biotite is a widespread mineral group. The mineral group occurs in metamorphic and igneous rocks. It is much less in sedimentary because it yields clay minerals in the weathering environment. Biotite is one of the two familiar members of the mica group, and the other one is muscovite (Deer et al., 1996). Biotite mineral is dark brownish–brown or black and even yellow when weathered. It has a monoclinic crystal system and hardness of 2.5 – 3 on the Mohs scale of hardness. Biotite is used extensively to constrain the ages of rocks by potassium-argon dating. Additionally, it is also valuable for assessing the temperature histories of metamorphic rocks (Hodson, 2006). In the same vein, Biotite can be used as a filler and extender in paints and an additive for drilling mud and as an inner filler and mould-release agent in rubber products and as a non-stick surface coating on the surface asphalt –shingles and rolled roofing (Hobart, 2021).

Quartz is a metamorphic rock composed essentially of the minerals quartz. It is formed by solutions high in silica that cement quartz sands to such a degree that it may not detect the original quartz grains. Quartz has a hardness of 7, and it does not change or weather (break down) easily. As a result, quartz rocks are residual or lag materials (Brown and Holroyd, 2006). It also suggests why quartz was the most predominant mineral in rocks and soil analysed (John and Steve, 2011). Quartz has found applications as oscillators in radios, watches and pressure gauges, and optics research (John and Steve, 2011). It is used to produce silicon carbide, silicon metal, and alloys (ferrosilicon).

Microcline is one of the most common feldspar minerals. It can be colourless, white, cream to pale yellow, Salmon pink to red or bright green to blue-green. Microcline is used in the manufacture of glass, porcelain, and enamel (Berry et al., 2004).

Albite commonly occurs in igneous and sedimentary rocks. It is a plagioclase mineral.In addition, albite is used in ceramics and as a gemstone (Berry et al., 2004).

Table 1: Minerals Identified in Rock samples by X-Ray Diffraction in Lau Local Government Area

Location	Minerals	Compound Name	Chemical Formula	Crystal System
Apawa	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Microcline	Potassium Aluminum Silicate	$KAlSi_3O_8$	Anorthic
Jasi	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Biotite	Potassium Iron Aluminum Magnesium Silicate	$K(Mg,Fe);3(AlSi_3O_{10})(F,OH)_2$	Monoclinic
	Microcline	Potassium Aluminum Silicate	$KAlSi_3O_8$	Anorthic
Jutahore	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Biotite	Potassium Magnesium Iron Aluminum Silicate	$K(Mg,Fe);3(AlSi_3O_{10})(F,OH)_2$	Monoclinic
	Microcline	Potassium Aluminum Silicate	$KAlSi_3O_8$	Anorthic
Jimleri	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Biotite	Potassium Magnesium Iron Aluminum Silicate	$K(Mg,Fe);3(AlSi_3O_{10})(F,OH)_2$	Monoclinic
	Microcline	Potassium Aluminum Silicate	$KAlS_3O_8$	Anorthic
Minda	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Biotite	Potassium Magnesium Iron Aluminum Silicate	$K(Mg,Fe);3(AlSi_3O_{10})(F,OH)_2$	Monoclinic
	Microcline	Potassium Aluminum Silicate	$KAlSi_3O_8$	Anorthic

Table 2 presents the mineral distribution in soils of Lau local government area. The mineral detected in the soil of Apawa were quartz, microcline and albite. There was no variation in the mineral content of both the rock and soil in Apawa, respectively. The mineral detected in Jasi soil were quartz, Microline, albite and cronstedite, which differ slightly from that of rock due to the presence of cronstedite, not detected in the rock samples perhaps, due to chemical reactions or the incorporation of organic matter in the soil.The four minerals identified in the soil of Jutahore, are quartz, microline, albite and biotite. The mineral content in the soil of Jutahore was consistent with that of the rock sample. Also, albite, quartz and phlogopite showed in soil samples of Jimleri. Mineral content in the soil of Jimleri differs significantly from rocks due to the absence of microcline and biotite.

Nevertheless, phlogopite was present in the soil, which was not detected earlier in the rock. The difference in the mineral content may be due to the metamorphosis of minerals in rocks as it undergoes weathering (Pepkin et al., 2005). The soil samples of Minda shows the presence of quartz, microcline albite and annite. The result showed a significant difference, due to absence of biotite in the soil and the presence of annite which was absent in the rock, that absence of biotite in the soil may be a result of metamorphic processes. The result obtained may be comparable to one reported by (Tadzabia et al., 2019).

Phlogopite is a typical member of the mica mineral group. Phlogopite is usually precipitated in metamorphic rock. It is present in igneous rocks; it is yellow-brown to reddish-brown colour. Phlogopite is monoclinic, and it has a value of 2-2.5 on Moh's hardness scale and has been applied in plastics and composite body parts for automobiles. Phlogopite increases the stiffness of the plastics, provides more excellent dimensional stability and reduces distortion upon temperature change. Ground phlogopite serves as a substitute for asbestos in automobile brake linings and clutch plates. It is added to industrial coatings to increase strength, stiffness and improve resistance to heat, chemical, and ultraviolet rays. It increases the strength of epoxides, nylons and polyesters. Phlogopite is used in the electronics industry to make stiff heat-resistant non-conducting boards for electronic components (Hobart, 2011).

Cronstedtite is an iron-rich phyllo-silicate whose crystal layer formed tetrahedral (T) and Octahedral (O) sheets (T-O or 1:1 layer). It also means that small Mg^{2+} and Al^{3+} may accompany all cations occupying sites by iron (both Fe^{2+} and Fe^{3+}) as reported by Hybler et al. (2000); Hybler et al.(2002) and Kogure et al. (2002), respectively. Cronstedtite colour is brownish-black, greenish-black, dark brown, black, with a hardness of 3.5 copper penning 3.35 (Geology page.com. 2014). Cronstedtite is used for the investigation of polytypism because it exhibits a variation of polytypes

Anite has a brown to black, brownish-white streak and submetallic to vitreous lustre, a specific gravity of 3.21 and 2.5 to 3 on Moh's hardness scale. It has a monoclinic crystal system (Redhammer and Roth, 2002). Annite is used to find the absolute age of an article older than 1,000 years (John and Steve, 2011).

Table 2: Minerals Identified in Soil Samples by X-Ray Diffraction in Lau Local Government Area

Location	Minerals	Compound Name	Chemical Formula	Crystal System
Apawa	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Microcline	Potassium Aluminum Silicate	$KAlSi_3O_8$	Anorthic
Jasi	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Microcline	Potassium Aluminum Silicate	$KAlSi_3O_8$	Anorthic
	Cronstedite	Iron (II) Iron (III) Silicon Iron (III) Oxygen Hydroxide	$Fe^{2+} Fe^{3+} (SiFe^{3+})O_5(OH)_4$	Hexagonal
Jutahore	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic Monoclinic
	Biotite	Potassium Magnesium Iron Aluminum Silicate	$K(Mg,Fe);3(AlSi_3O_{10})(F,OH)_2$	
	Microcline	Potassium Aluminum Silicate	$KAlSi_3O_8$	Anorthic
Jimleri	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Phlogopite	Potassium Magnesium Aluminum Silicate Hydroxide	$KMg_3(AlSi_3O_{10})(OH)_2$	Monoclinic
Minda	Quartz	Silicon Oxide	SiO_3	Hexagonal
	Albite	Sodium Aluminum Silicate	$NaAlSi_3O_8$	Anorthic
	Microcline	Potassium Aluminum Silicate	$KAlSi_3O_8$	Anorthic
	Annite	Potassium Iron Aluminum Silicon Hydroxide	$KFeAlSi_3O_{10}(OH)_2$	Monoclinic

CONCLUSION

Solid minerals have played an essential role in human civilization and industrial development. The present study has confirmed the presence of different solid minerals in rocks and soils of the study area using X-ray diffraction analysis. The solid minerals detected are Quartz, Albite, Microcline, Biotite, Cronstedite, Phlogopite and Annite. Therefore, it can be concluded that the solid minerals detected may have the potential for industrial and economic development, respectively.

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