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GROUNDWATER POTENTIAL ASSESSMENT OF PART OF KAZAURE, NIGERIA USING ERDAS IMAGINE, PCI GEOMATICA, ARCMAP AND EXPERT CHOICE SOFTWARE

***[1]Kankara, I. A. and [2]Ado, M.**

[1]Department. of Geology, Federal University Dutsin-Ma.
[2]Department of Geology, College of Advanced Studies, Tudun-Wada

*Corresponding authors' email: aibrahim@fudutsinma.edu.ng

ABSTRACT

The possibility of utilizing groundwater as a source of water supply for public use is always attractive This research was focused to evaluate the groundwater potential of Kazaure area, Nigeria. The methodology adopted were mainly primary data in which six different thematic maps were integrated to generate the groundwater potential model (GWPM. It was produced by Weighted Linear Combination (WLC) where each class individual's weight was multiplied by the map scores. In the research, Erdas Imagine 9.2, PCI Geomatica 10.0, ArcMap 9.3 and Expert Choice 10.0 in a GIS environment were used. Vertical electrical sounding (VES) was conducted using Ohmega resistivity meter with Schlumberger configuration. IP12win software was used in plotting the curves which revealed the resistivity, layers and thickness of the VES stations. Geological mapping was carried out using topographical map on a scale of 1:50,000Measurement of the depth to groundwater table in hand dug wells was carried out using dip meter. Water samples were collected and analyzed. Atomic Absorption Spectrometry (AAS) and X-Ray Fluorescence (XRF) were used in the analysis of water quality at the Multi-user laboratory, Chemistry Department, Ahmadu Bello University Zaria, Nigeria.

Keywords: Groundwater Potential, Erdas Imagine, PCI Geomatica, Arcmap, Expert Choice, Kazaure (Nigeria)

INTRODUCTION

Groundwater obtained from wells, boreholes and springs may not undergo considerable treatment before becoming potable due to the natural filtration process it has undergone through the soil horizons (Abdullahi*et al*., 2005). Because groundwater is widely known to be more hygienic than surface water, the possibility of utilizing it as a source of water supply for public use is always attractive (Abdullahi*et al*., 2005).

The aquifer systems in the basement complex rock are complex and as a result, targeting of groundwater in basement is not an easy task. Groundwater occurrence is limited to the weathered part of the basement and fractured zones. Different portions exhibit different permeability and porosity and therefore heterogeneous. Thus, crystalline rocks are multiple aquifer system instead of a single homogenous aquifer (Acworth, 1987; Danbatta, 2002; Garba, 2003).

Groundwater exploration in the basement complex rocks relies on the physical and chemical characteristics of water such as conductivity, salinity as well as subsurface element that could indicate its presence (Anuduet al, 2011) There are various methods of targeting groundwater, such as geological, hydrogeologic, and photogeological techniques. Most people in Asia (India) and Africa, particularly in Nigeria solely depend on geophysical method of groundwater exploration (Danhassan and Olurenfemi, 1994). Another important method, however, is the application of remote sensing (RS) technology (satellite image) in groundwater exploration. This technique is not a replacement for the geophysical method; instead, it complements the method. For large areas, RS method reduces the extent of geophysical exploration and thereby save cost. With its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time, it has become a very handy tool in assessing, monitoring and conserving groundwater resources (Du Preez and Barber, 1965; Schoeneich and Garba, 2010)

The importance of geologic structures in exploration of oil, gas, water and Ore deposits cannot be underestimated. These structures especially lineaments such as joints, fractures and faults, acts as a reservoir for the deposition of important Ores as well as oil, gas and water (Godebo, 2005).

These structures can be detected in the form of a lineament not only by ground mapping but also more easily using RS data (such as conventional aerial photographs and satellite imagery). The good correlation between structures mapped in the field and those mapped using the lineament system enable the lineament to be regarded as representative of the structural indication of a particular area (Raeburn and Jones, 1934). Application of RS technology in groundwater resources evaluation has been practiced for about three decades (Dairelli, 1989; Edet et al, 1998; Johnpaul, 2013; Fashal et al, 2014)

The aim of the study is to assess the Groundwater Potential of Part of Kazaure, Nigeria Using Erdas Imagine, PCI Geomatica, Arcmap and Expert Choice Software

MATERIALS AND METHODS

The Study Area

The area is located in northwestern part of Kano State, about 78 km away from the Kano metropolitan. It also covers part of Jigawa and Katsina States. The whole area is part of Kazaure schist belt, northwestern Nigeria. It lies between latitude 12º 30′ 00″ N to 12º 45′ 00″ N, and longitude 8º 15′ 00″ E to 8º 30′ 00″ E, covering an area of about 770.063 km² (Figure 2). It is accessible through major roads, namely: Kano-Danbatta-Kazaure-Daura road, Kazaure-Roni-Ingawa and Kazaure- Shuwaki-Lamba road. There are also numerous networks of footpath throughout the area (FSN, 1970)

The area is typical of Sudan Savanna tropical climatic zone of Nigeria, which is characterized by two distinctive seasons (dry and wet seasons). The dry season begins from October to April and is associated with low humidity, especially during the harmattan period. The wet or rain season commences from May to October, with mean annual rainfall of about 700 - 750 mm/a (Kankara, 2018; Figure 1). The annual range of temperature is between 27 to 34°c.

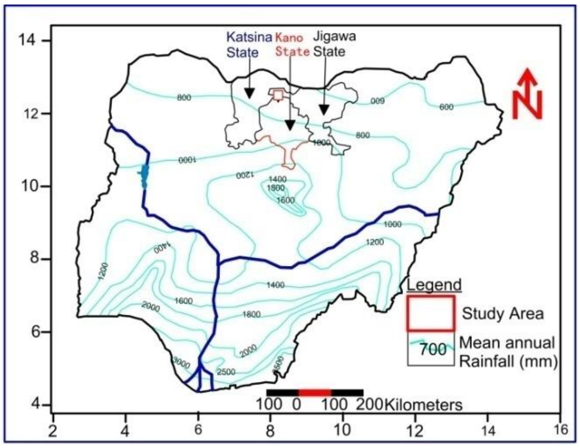


Figure 1: Map of Depth of Rainfall in Nigeria

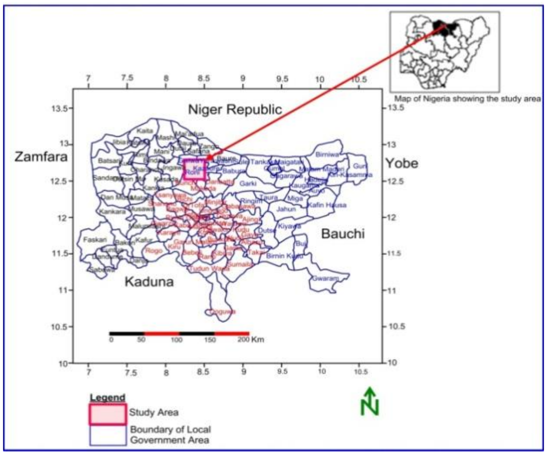


Figure2: Location Map of Kazaure Area (Source: Present work)

Generally, the landforms conform to that obtainable in many parts of Northern Nigeria. It is characterized by flat to undulating relief. The noticeable features are the discontinuous ridges of metasedimentsthat trended NE-SW. The granitic rocks which are dome to whaleback occur in the northwestern part of the area. The peak point is on the BabbanDutse ridge near Kazaure town, and is about 106 m above the plain (Danbatta, 1999 and Ibrahim, 2003). The lowest relief is located around GadarKazaure southeastern part of the mapped area (Caponelli, 1989; NGSA, 2006)

Data Collection

The materials used in this study include; satellite imageries, GIS and RS softwares, review of the relevant existing literature such as text books, journals, topographic and geological maps, metric tape andcombined meter Mi 806 (4 in 1), Global positioning system (GPS), compass clinometers etc. The methodology employed for this work is divided into three (3) phases. These are: (1) Remote Sensing interpretation of satellite imageries (2) field work (3) laboratory analysis

Geologic mapping was carried out on a scale of 1:50,000. It involved observing and recording (in the field notebook), occurrence of rock outcrops and exposures, noting geographical location, recording co-ordinate position obtained from Global Positioning System (GPS). Colour of rock, texture, mineralogy and structures were also examined. Strike and dip of foliation were measured with compass-clinometer and plotted on the base map. Traverses used include rivers and streams channels, foot paths and roads network. Rock samples were labeled using waterproof markers and stored in the sample bag for petrographic studies. From the data obtained, a geological map was drawn with boundaries between lithologies inferred.

Hydrogeological Mapping

The depth to the static water level (SWT) which is also called depth to water level, of 10 hand dug wells was measured using metric tape. The first measurement was done during the peak of dry season in May 2015, while the later took place at the end of rainy season in October 2015. The tape had a metal base which allowed tying small piece of metal to it. This help in stretching and preventing of sagging of the tape, since most wells were deep (more than 40 m depth). Measurements were made during the day time. It was easy to observe when the tape makes contact with the surface of water in the wells. Consequently, the tape was lowered until it made contact with the water in the well and the depth of the static water level was calculated by noting the length of the tape from the surface of the water to the ground level. Special caution was taken to ensure that measurements of SWT were made with reference to the ground surface around the well and not the head or cover of the wells. This procedure was repeated for all the sample locations and was done for both the end of wet season and the peak of the dry season.

Procedure of Groundwater Modeling and Lineament Maps

Structural lineaments were extracted from ASTER DEM. Manipulation was done in three GIS environments. Erdas Imagine 9.2 GIS Environment was used to generate the shaded relief**;** PCI Geomatica 10.0 GIS Environment was used for automatic generation of lineaments out using ArcMap 9.3 software GIS Environment was used to determine the coincidence between the two extracted lineaments and these points formed the lineaments that were digitized and used for the lineament density thematic map.

The lineament map was prepared using the automatic line extraction from shaded relief image using PCI Geomatica 10.0. However, prior to automatic lineament extraction, shaded relief images were prepared using Erdas Imagine 9.2 software. Successive shaded relief images were created by varying the azimuth (Sun Angle) of DEM from 0^0 to: 45^0, 90^0, 135^0, 180^0, 225^0, 270^0, and 315^0. Solar Azimuth was set at 0^0, solar elevation at 30 and ambient light at 0.2 to ensure good contrast as shown by Abdullahi*et al.*, (2010). Two combined shaded relief images were created by respective overlay of shaded relief images with azimuth 0^0, 45^0, 90^0, and 135^0; and azimuth 180^0, 225^0, 270^0, and 315^0.

ArcMap 9.3 software was used to determine the coincidence between the lineaments extracted from the two combined shaded relief images and these points formed the lineaments that were digitized and used for the lineament density thematic map.

Geological Map

The geological map was created from on screen digitization of the geology map of the area in the ArcGis environment. Classification was done on the basis of weights obtained from pair-wise comparisons done with the help of Expert Choice 10.0 software.

Drainage Density and Drainage Proximity Maps

The drainage map was also obtained from on screen digitization of the drainage channels revealed in the topographical map in the ArcGis environment. The drainage density map was done from first order streams using the spatial analyst>kernel density menu in ArcGis. Reclassification was done and weights assigned based on influence on groundwater potential.

Drainage proximity map was done from second and third order streams respectively after on screen digitization. Buffer zones around the streams were created and classified with the buffer zones distances around third order streams having more influence on groundwater potential than buffer zones around second order streams.

Geophysical Investigation

Vertical Electrical Sounding (VES) was carried out using an ABEM Terrameter SAS 300C. This survey was run by Global Earth Solve LTD Kano, within a period from 2008 up to 2014. A total of 30 VES stations across the study area were conducted. This data were obtained from this organization. It was interpreted and processed qualitatively and quantitatively using partial curve matching computer software techniques IPI2win to obtain the resistivity values of the total VES locations, their different subsurface layers and corresponding thickness. This permit drawing the geoelectric section profiles of some selected VES stations.

Physico-Chemical Analysis

Forty water samples from twenty different wells locations were collected. Plastic bottles were used for collection of the water sample, and at each sampling point the bottle was rinsed with the water to be sampled before the water was collected. Two water samples from each of these twenty wells, one acidified and the other non- acidified were carefully collected and packaged, labeled and transported to the laboratory. The acidified water samples were used for the analysis of cations whiles the other non-acidified water samples for the anions. Few drops of concentrated solution of nitric acid were added to the samples at the sampling points for the purpose of keeping the ions in solution and also to minimize reaction with the container wall. Coordinates of each of the wells were taken during the field work. During the collection of these samples, physical parameters such as temperature, conductivity, pH and total dissolved solids were obtained with the help of four-in-one meters (brand of the measuring meter was Mi 806 combined meter).

Part of the samples were analyzed at Multi-User Research Laboratory in Chemistry Department in ABU Zaria while, some at the Federal Ministry of Water Resources, Department of water quality control and sanitation, Zonal Office, Kano. The techniques for the analysis were Atomic Absorption Spectrophotometric (AAS), Flame photometer and Water Kit technology.

RESULTS AND DISCUSSION

Geology and field relationship of the Kazaure Area

The study area is underlain by three major and one minor lithological unit. These are muscovite schist, porphyritic granite and sandstone (Chad Formation) with quartzite occurring as the minor lithology. The metasediments were intruded by Older Granitic rocks during the Pan Africa Orogeny; while the Plio-Pleistocene Chad Formation overlies these Precambrian rocks. The area is underlain by rock units, such as muscovite schist, porphyritic granite and Chad Formation. Quartzite also occurs as minor rock in the area. The major structural features mapped in the area include joints, fractures and foliations with most trending in the NE-SW direction.

*Quartzite*Quartzite occurs as a patches normally at the top of the metasediment ridges, trending NE-SW direction. It is coarse grained, reddish brown in colour,associated with ferroginzed iron.

*Muscovite Schist*The rock unit occupied the northeast, central and southern part of the study area. It is fine to medium grained and reddish to brownish colour. Reddish colouration is imparted by the Banded Iron Formation (BIF), as Ibrahim, (2003) reported it, in the western part of the area (Plate I, A)

In hand specimen the rock unit is highly foliated by the presence of mica group of minerals. In thin section minerals observed are muscovite, biotite, and feldspar. The strong foliation can be observed in thin section from preferred orientation of minerals such as muscovite and biotite (Plate I, C, C′ and II E, E′).Biotite shows a mild relief, pleichroism from greenish brown to green, and displays a parallel cleavage. Muscovite is colourless in thin section and exhibited high order interference colours and extinction (Plate II, E). Quartz often occurred as polycrystalline crystals, displaying undulose extinction on rotating the stage as well as low grey interference colour. The boundaries between crystals are sutured (Plate II, E). This is the characteristics of quartz from metamorphic source (Danbatta, 2002).

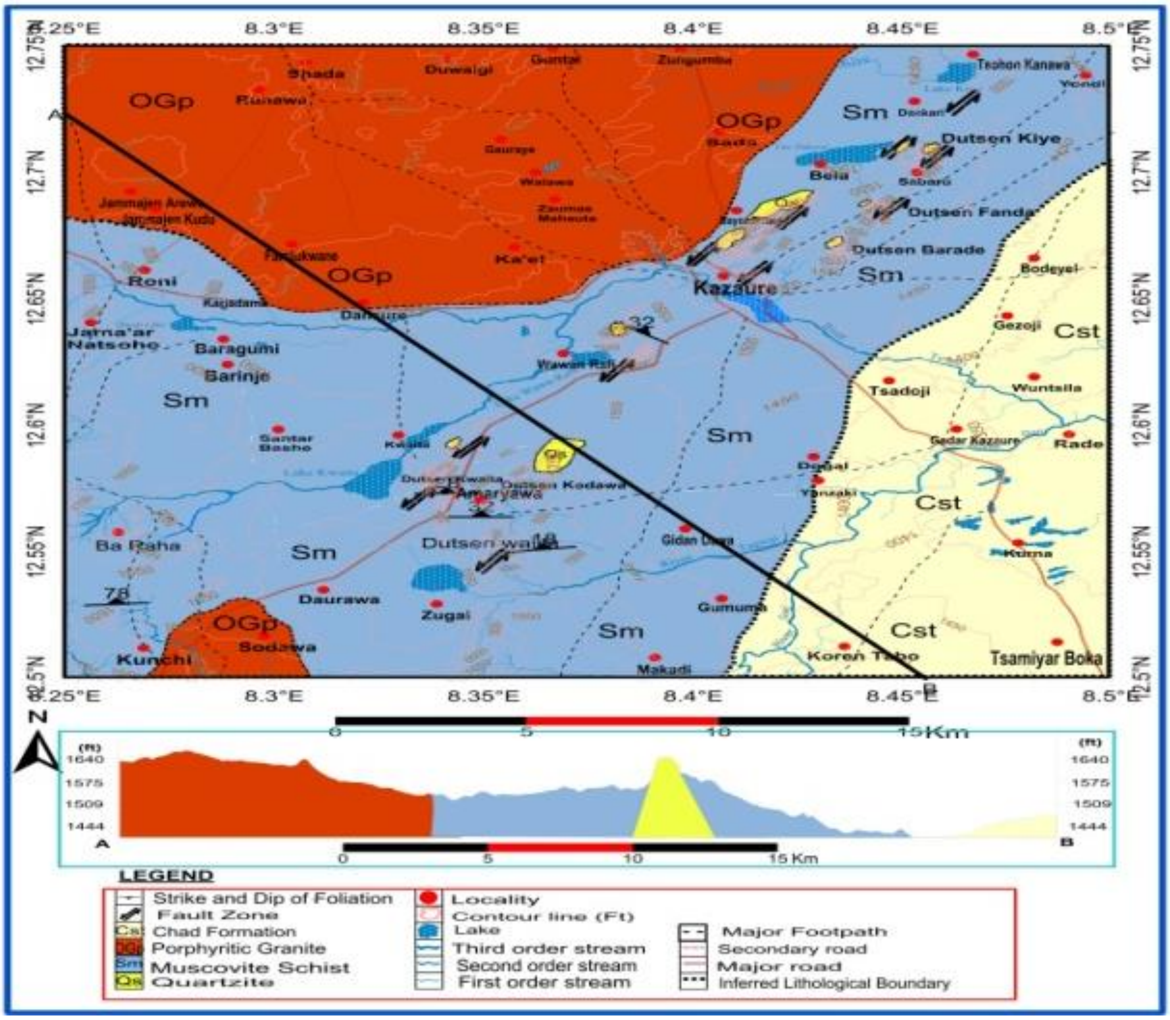
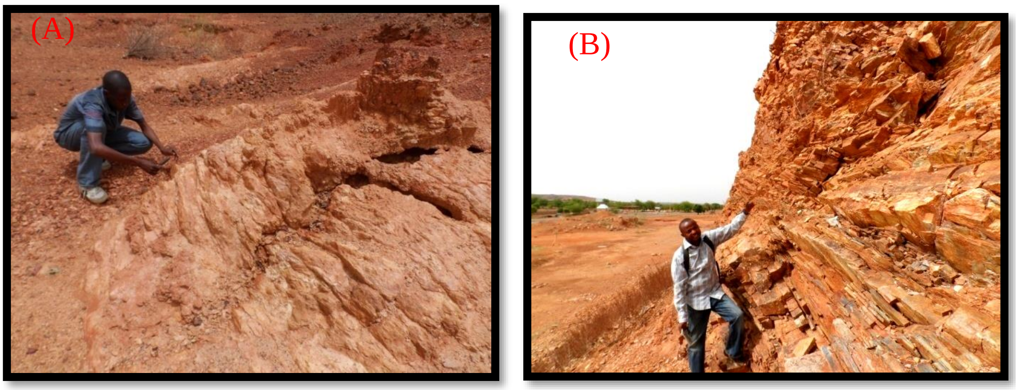


Figure 3: Geological Map of Kazaure. (Source: Present work)



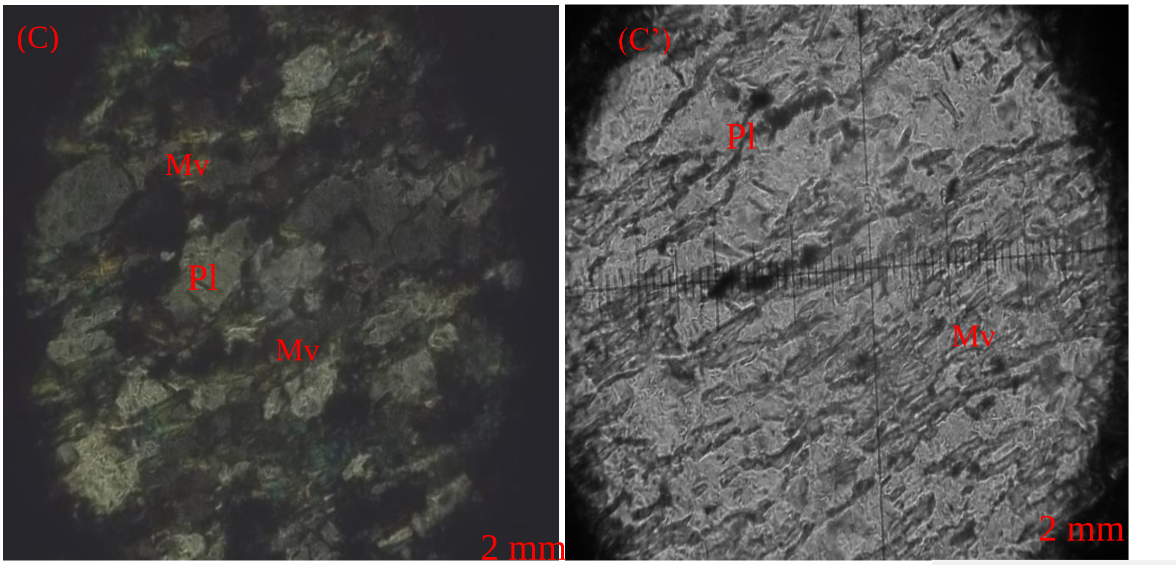


Plate 1: (A and B) Muscovite Schist (12˚31′45.9″N, 08˚15′44.7″E) (B) (12˚34′18.1″N, 08˚20′26.1″E) (C Photomicrographs of Muscovite schist XPL; (C′) of Muscovite Schist PPL; **NOTE**: **Mv** = Muscovite and **Pl =** Plagioclase feldspar

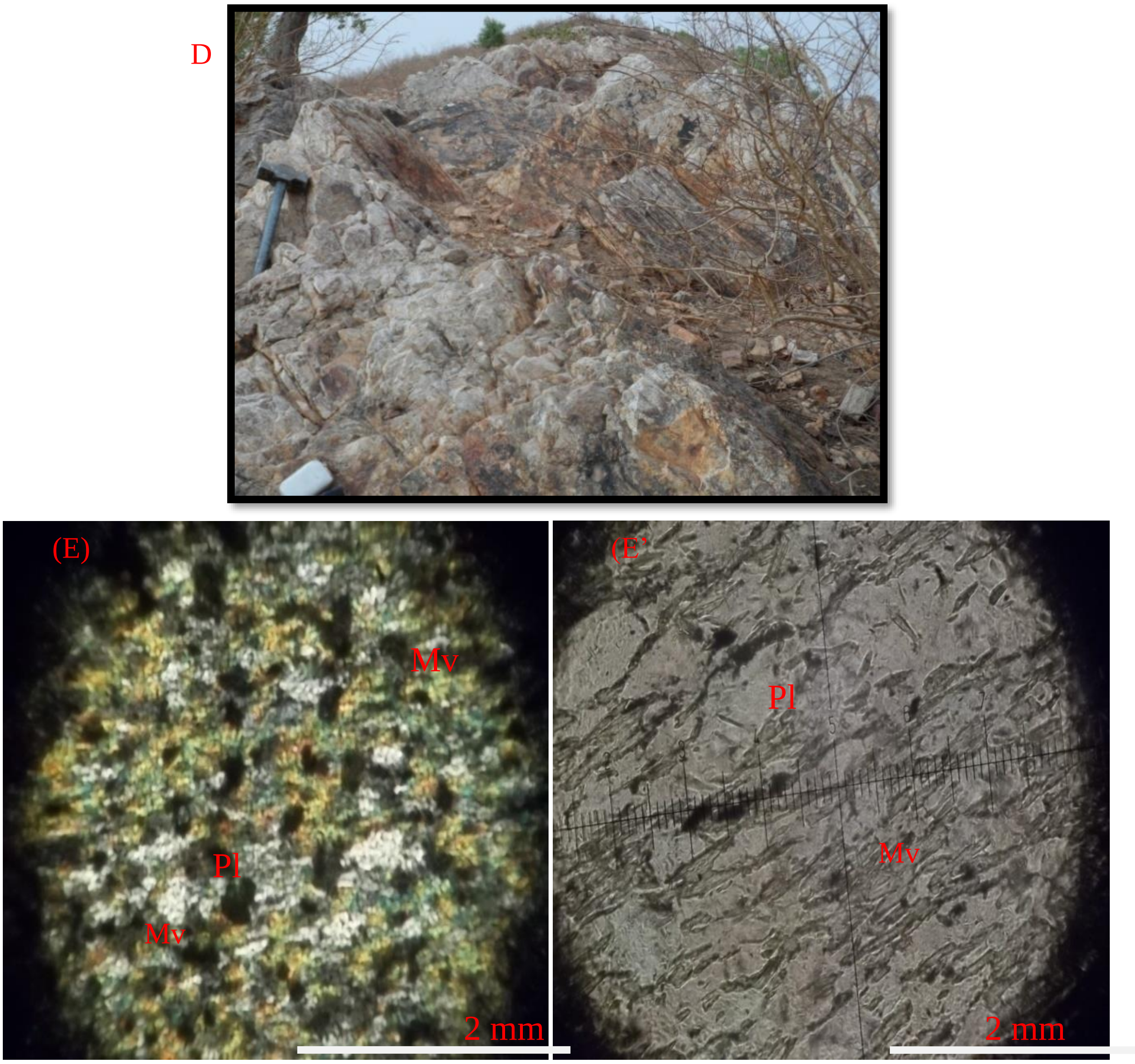


Plate 2: (D) Muscovite Schist, (12˚40′03.5″N, 08˚24′09.2″E) (E) Photomicrographs of Muscovite Schist XPL; (E′) of Muscovite Schist PPL; **NOTE**: **Pl** = Plagioclase, **Mv** = Muscovite.

Porphyritic Granite

This rock unit occurs mostly to the northwestern and as small pocket in the southern periphery of the study area. The rock is generally, coarse grained, whitish grey in colour and this colouration is imparted by the presence of plagioclase feldspar (Plate III F, G and H). The rock is not foliated and also intruded the matasediment rocks of the area (Figure 3).

In hand specimen, the minerals that can be identified include feldspar, quartz, biotite and muscovite in order of their abundance. Texturally, grains of feldspars and/or quartz up to 3 cm in diameter were measured (Plate III, H).

Thin section visual observation and deduction of the mineral modal composition shows that quartz has (74 %), microcline (11 %), plagioclase (5 %), orthoclase (7 %), muscovite (2 %) and biotite (1 %). The distinctive characteristic of quartz in this sample is occurrence as polycrystalline crystals. The microcline occurs as large subhedral crystals which are characterized by cross-hatched twinning. Plagioclase occurs as subhedral elongated crystals which are easily distinguished by their albite twinning (Plate III, H and H′).

Chad Formation

The Chad Formation exists in the south-eastern part of the study area. It mostly occurs as sediments directly overlying the crystalline basement which frequently outcrops in this area. It appear as medium to coarse grained, yellowish white sand.

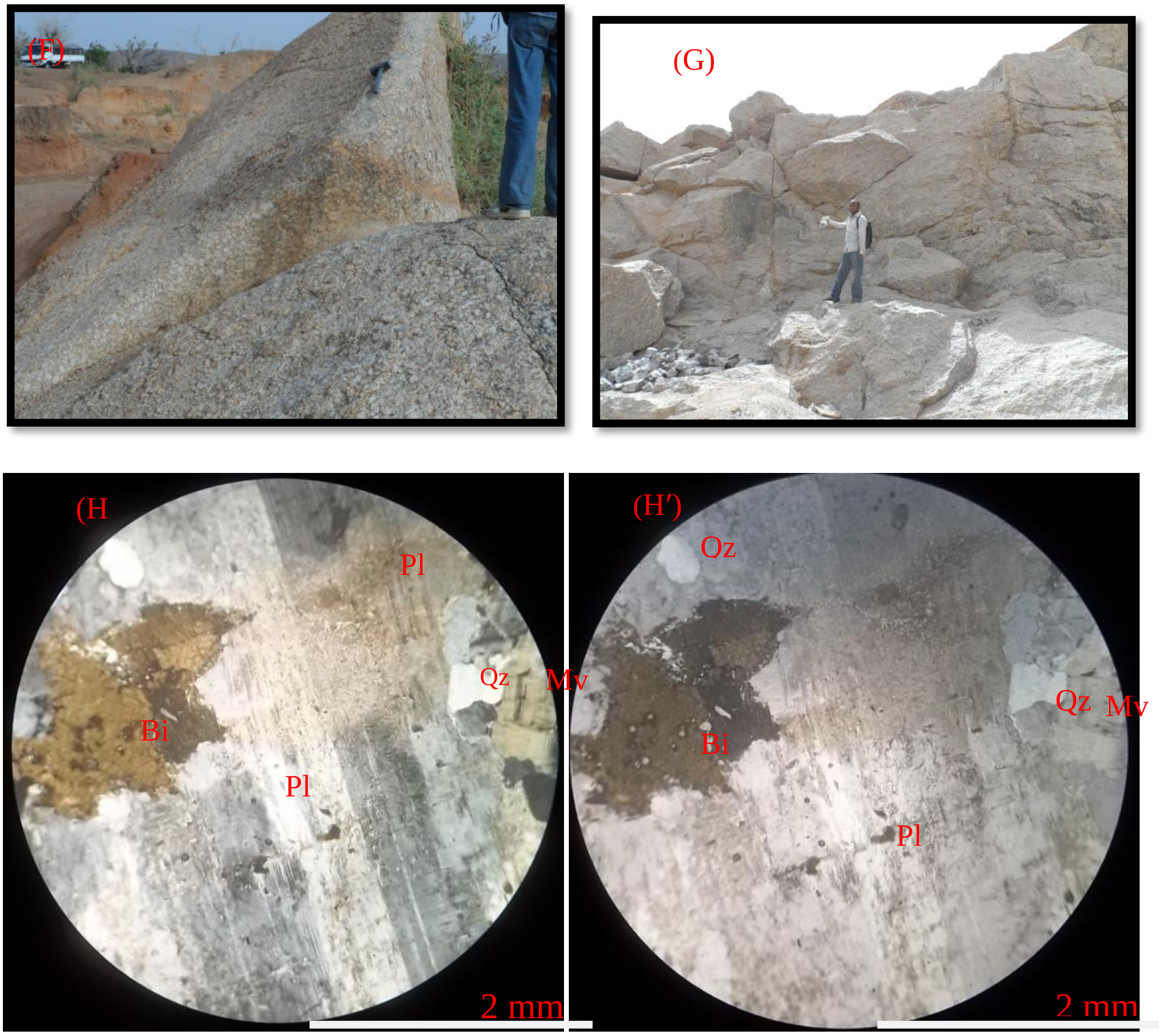


Plate 3: (G) Exposure of Porphyritic Granite, (12˚41′49.1″N, 08˚24′10.0″E) (H) Joints in Porphyritic Granite, (12˚39′22.2″N, 08˚18′00.4″E) (H) Photomicrographs of Porphyritic Granite XPL; (H′) of Porphyritic Granite PPL; **NOTE**: Bi = BiotiteQz = Quartz, Mv = Muscovite, Pl = Plagioclase feldspar.

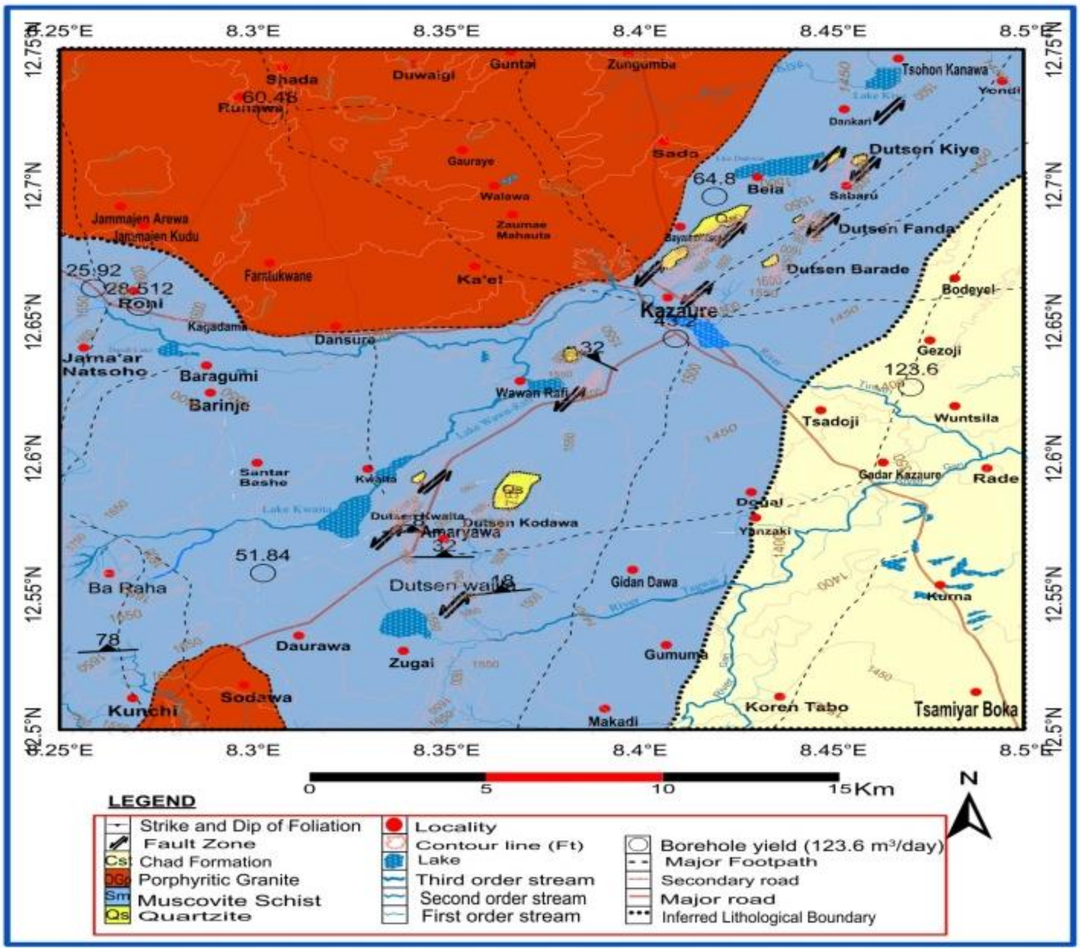


Figure 4: Borehole yield superimposed on the geology map of Kazaure Area

Cations and Anions

Calcium (Ca^{2+}): Calcium ion concentration in the water sampled within the study area is found to range from the values of 4 to 27 mg/l with an average of 7.85 mg/l. The highest value observed, is also far below the recommended limits of 75 to 200 mg/l of (NIS, 2007) and 100 mg/l of (WHO, 2011)Major sources of this element are from rock-water interaction of silicate minerals in granitic rocks. Calcium is essential for the human body development, especially bone and teeth (Bala, 2001). Accordingly, calcium-deficient children show rickets, the condition of undermineralized bone resulting in structural deformities of growing bones, while bone undermineralization in adults is involved in osteoporosis with associated increases in fracture risk (WHO, 2009).

Sodium (Na^{+}): Sodium concentration range from 0.00 to 120 mg/l with an average of 33 mg/l. These values are far below those of (NIS, 2007) and (WHO, 2011) for drinking and domestic uses (Table 1). Presence of sodium in groundwater is believed to be released by weathering of plagioclase feldspars in porphyritic granite of the Kazaure Area (Figure 3 and 4).

Potassium (K^{+}): Potassium concentration ranged from 5 to 165 mg/l with an average of 27.885 mg/l. It is observed that, some of the hand dug wells and borehole are within the permissible limit set by (NIS, 2007) and (WHO, 2011). It was also observed that, there is high concentration of potassium in some locations where sample was taken. These locations are Kwagga (12.61452778˚N, 8.48388889˚E), Yanzaki (12.5673333˚N, 8.42988889˚E), Jada (12.73116667˚N, 8.40055556˚E) and Karaftayi (12.62077778˚N, 8.37575˚E). It is also associated with application of fertilizer, since these points are located within the rural area, where agricultural activities is taking place for irrigation and wet season farming. The residential effluent also contributed to the high concentration of potassium.

Magnesium (Mg^{2+}): magnesium in both hand dug wells and boreholes range from 0.00 to 22.1 mg/l with an average of 4.5375 mg/l. Sources of this ion in groundwater of the area is mostly from the weathering of silicates minerals. It is also falls far below of permissible limit of (WHO, 2011) which is about 50 mg/l.. Magnesium is very essential element needed to stimulate bone and teeth in human body (WHO, 2009).

IRON (Fe^{2+}): Ironconcentration in the Kazaure area ranges from 0.02 mg/l to 4.13 mg/l with an average of 1.168 mg/l. These values when compared with standards shows that, most of the samples have high concentration of iron (Table 1). The locations that have high level of iron concentration include, Kurna, (12.54419444˚N, 8.48005556˚E), Roni, (12.65580556˚N, 8.27055556˚E), Tsabawa (12.72197222˚N, 8.29905556˚E), Shada, (12.74208333˚N, 8.3093333˚E) and Ka'el, (12.65430556˚N, 8.3375˚E). The high concentration mostly resulted from the leaching weathering of iron bearing minerals. Since this area is mostly composed of matasediment material which bear minerals like mica (biotite and muscovite), amphiboles and pyroxenes (Plate I C and C′). It has already been observed from the result of in-situ measurement of the water from the hand dug wells and borehole within the study area, that most of the water samples are acidic. The acidity of the water may have causes high concentration of iron in groundwater, which make Fe^{2+} very soluble especially most of the aquifer in the area is very deep. This high level concentration of iron in drinking water for domestic use is objectionable because it impacts brownish colour on laundered cloth, leaves brown deposit in water, cause growth of iron bacteria, affects taste of drinking water as well as beverages such as tea and coffee (WHO, 2011).

Manganese (Mn^{+2}): Manganese concentration range from 0.018 to 0.807 mg/l with an average of 5.62745 mg/l. This high concentration of manganese is also related to acidity of water of the area. In addition, the source of manganese within the Kazaure area is similar to that of iron.

Lead (Pb^{2+}): the concentration of Lead in groundwater of the study area range from 0.035 to 0.128 mg/l with an average of 0.0832 mg/l (Table 1). All the boreholes and hand dug wells samples analysed are above the maximum permissible limit of 0.01 mg/l (Table: 1). This high concentration is favoured by anthropogenic activities, like wet season farming, irrigation, through the application of herbicides and pesticides. Since, almost all the water sample analyzed showed a low pH value that is acidic. The water which is acidic condition also increased the rate of solubility of lead compound as it leaching into the soil and rocks. The common compound used in the area for herbicide include, weedkillers (example:paraquat and glyphosate) while for pesticide are organochlorines, organophosphates and carbamates. Lead is also known to cause injury to the central and peripheral nervous systems, which results in headache, dizziness, memory deficits and decreased nerve conduction velocity and severe kidney damage.

Cadmium (Cd^{2+}): the concentration of cadmium in the study area ranges from 0.0012 to 0.019 mg/l with an average of 0.01525 mg/l. Application of fertilizers produced from phosphate ores constitute a major source of diffuse cadmium pollution. The solubility of cadmium in water is influenced to a large degree by the water acidity; suspended or sediment-bound cadmium may dissolve when there is an increase in acidity. The water analyzed from the study area, shows that almost all samples are acidic water which favoured solubility of cadmium. High concentration of cadmium causes cancer, kidney damage as well as reproductive system toxicity.

Zinc (Zn^{2+}): the concentration of zinc range from 0.00 to 0.9472 mg/l with an average of 0.130055 mg/l. The concentration of this ion in Kazaure area is within the acceptable limit set by NIS, 2007 and WHO, 2011 (Table 1)

Chromium (Cr^{2+}): The concentration of chromium in groundwater of the study area ranges from 0.00 to 0.442 mg/l with an average of 0.1694 mg/l.The level concentration of this ions conformed to a agreeable standard by NIS, 2007; WHO, 2011 (Table 1)

Bicarbonate (HCO_3^-): the concentration of bicarbonate varies from 24.4 to 213.5 mg/l, on average 93.025 mg/l. Bicarbonate ion in groundwater is derived from the weathering of plagioclase feldspar. All the water samples analyzed have bicarbonate concentration far below the recommended limit of WHO, 2011 put at 500 to 1000 mg/l respectively.

Table 1: Comparison of Field Data (Author's Result) with NIS (2007) and WHO (2011) Recommended Values for Physical and Chemical Parameters of Water for Drinking and Domestic uses.

Parameters	Unit	WHO 2011	NIS 2007	Author's Result 2015 Range	Average	Remark
Water Temp.	C°	–	–	28.8 – 33.9	30.59	Good
Conductivity	µS/cm	–	1000	10 – 910	208.5	Excellent
pH	–	6.5 – 8.5	6.5 – 8.5	4.74 – 6.59	5.5365	Low
TDS	mg/l	1000	500 – 1500	0.00 – 530	120	Excellent
Ca^{2+}	mg/l	100	75 – 200	004 – 027	7.85	Low
Na^{+}	mg/l	200	200	0.00 – 120	33	Low
K^{+}	mg/l	10 –15	–	005 – 165	27.885	High
Mg^{2+}	mg/l	50	0.2	0.00 – 22.1	4.5375	Low
Fe^{2+}	mg/l	0.3	0.3	0.02 – 4.13	1.168	High
Mn^{2+}	mg/l	0.1	0.2	0.018 – 0.807	5.62745	High
HCO_3^-	mg/l	500 –1000	–	24.4 – 213.5	93.025	Low
Cl^-	mg/l	250	250	28.4 – 85.2	51.15	Good
SO_4^{2-}	mg/l	250	100	1.42 – 14.2	4.7205	Low
NO_3^-	mg/l	50 – 100	50	10.0 – 21.4	14.765	Excellent
F^-	mg/l	1.5	1.5	0.46 – 0.60	0.5295	Excellent
Cd^{2+}	mg/l	0.003	0.003	0.012 – 0.019	0.01525	High
Pb^{2+}	mg/l	0.01	0.01	0.035 – 0.128	0.0832	High
Zn^{2+}	mg/l	0.1	3	0.00 – 0.9472	0.130055	Good
Cr^{2+}	mg/l	0.05	0.05	0 – 0.442	0.1694	Good

Chloride (Cl^-): High values of chloride indicate organic pollution of water, which gave a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste. The source of chloride is from minerals which contain chlorine as essential constituents as well as dissolution of the readily soluble salts of chloride ions precipitated in the soil zone due to high rate of evapotranspiration and minimal recharge. The concentration of chloride in groundwater of the study area ranges from 28.4 to 85.2 mg/l with an average of 51.15 mg/l. The concentration is far below the NIS, 2007, and WHO, 2011, recommended limits of 250 mg/l. This indicates that, water from the area is suitable for drinking and other domestic uses. The chloride content or concentration shows that, the water samples analyzed are of meteoric in origin.

CONCLUSION

Groundwater potential modeling of the area revealed three zones of groundwater potential. These include zones of: low potential coinciding with rugged, high relief areas and low transmissivity0.504625 m^2/day; medium potential zone coinciding with areas on crystalline basement, lower relief and transmissivity of about 1.401027 m^2/day; and high potential areas which occur in the sedimentary terrain, near the third order streams, water bodies and transmissivity of about 51.4 m^2/day. The observed physical parameters of pH, TDS, Temperature and Conductivity are within the WHO permissible limits for drinking water, except pH that falls below the standard level. High concentration of iron, cadmium and lead in groundwater of the area might be a result of acidic nature of the water analyzed. Lead ions also might have resulted from the application of pesticides chemicals, during wet season and irrigation farming. From the water quality analysis it was observed that the dominant water facie in the study is Na^{+}-HCO_3^{-}. This might have been as a result of rock-water interaction of plagioclase feldspar of porphyritic granite. Result from salinity hazard of the water samples has indicated that, water of the area is good for irrigation. Generally, the result shows that the water of the Kazaure area is safe for drinking and domestic uses, based on the comparison with both NIS and WHO.

It is recommended that the Federal Government of Nigeria should establish a meteorological station in the area, to enable the rate of evapotranspiration and rate of recharge from precipitation to be established, for the appropriate management of the water resources. Also, the rate of groundwater exploitation does not exceed the recharge rate in order to avoid over abstraction.

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