# LITHOLOGIC CHARACTERISTICS OF PARTS OF THE CRYSTALLINE BASEMENT COMPLEX OF NORTHERN NIGERIA IN RELATION TO GROUNDWATER EXPLOITATION

I. O. Olaniyan[1], J. C. Agunwamba[2] and J. O. Ademiluyi[2]
[1]Department of Agricultural Engineering, Kaduna Polytechnic, Nigeria
[2]Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria
E-Mail: dejoolaniyan@yahoo.com

**ABSTRACT**

The extent of relationship between lithologic characteristics and productivity of crystalline aquifers has been considered with respect to rural water supply in the Galma river basin in northern Nigeria. Five lithologic units delineated across the basin were lateritic top soil, silty clay, kaolinitic sandy clayey silt, the weathered granite and the lowermost fresh basement rock. The crystalline Basement rocks were found to have areas of weathered and deeply fractured regolith which constitute useful aquifers. The overburden thicknesses were observed to be larger at the central and western parts of the basin than at the south eastern tip. Statistical evaluation showed that the regression line of yield on weathered zone thickness has a regression coefficient of +0.232, while the Pearson Product Moment Correlation analysis gave a correlation coefficient of 0.233. This revealed a weak, linear and direct interrelationship between the yield and weathered zone thickness, which suggests that the thickness of the weathered zone has a low but positive level of influence on well yield, but yield is not entirely dependent on weathered zone thickness.

**Keywords**: model, ground water flow, lithologic characteristics, productivity, crystalline aquifers, Galma river basin, Nigeria

## 1. INTRODUCTION

The area under the Basement complex rocks in Nigeria is considerably large, covering about 50% of the total land area, and mostly falling within the semi-arid parts of the country where surface water is either seasonal or sometimes non-existent such that groundwater is an indispensable source of fresh water. Hence, despite its poor hydrogeological characteristics, this formation is still very important in groundwater studies. Groundwater exploration in this region, therefore, requires good understanding of the lithologic characteristics of the area.

In the northern and semi-arid climatic conditions of Nigeria, almost entirely underlain by crystalline formations, groundwater and surface water availability are scarce and problematic. The igneous and metamorphic rocks are mostly crystalline and they occur as granites, gneisses, migmatites, schists, phyllites, pegmatites or quartzites. They also include metasediments and volcanic rocks of different ages and petrography. Crystalline rocks weather more easily and deeply under humid conditions, and more water is available for storage under favourable rainy environments. But in arid and semi-arid conditions, the extent of weathering, fracturing and erosion is generally limited (Offodile, 1992). Despite this limitation, the prolonged in-situ weathering under tropical conditions has produced a lithologic sequence of unconsolidated material whose thickness and lateral extent vary extensively. The localization of groundwater within the lithologic zones is controlled by a number of factors such as type of parent rock, depth, extent and pattern of weathering, thickness of the weathered materials, the sand/clay ratio and the degree of fracturing, fissuring and jointing (Amadi and Teme, 1987; Odusanya, 1990).

This study considered the extent of relationship between lithologic characteristics and productivity of crystalline aquifers, with respect to rural water supply in the Galma river basin. The basin is located mainly in Kaduna State of Nigeria, but it extends partially to Kano and Katsina states. It is bounded by latitudes 10$^{o}$ 27'N and 11$^{o}$ 24'N and longitudes 7$^{o}$ 23' E and 8$^{o}$45'E. The Galma River is one of the major tributaries of Kaduna River in northern Nigeria. Its total catchment area covers approximately 6940 km$^2$.

### 1.1 Geological setting

Previous works on the Galma river basin and Kaduna state include WAPDECO (1991), Parkman (1994), Oluyide (1995) and Ogunjobi (2001). The crystalline Basement complex rocks are the oldest in the area, and they include both igneous and metamorphic types. The three divisions of the Basement rocks generally recognized in the area are the migmatites-gneiss complex, the metasedimentary rocks and the Older (or Pan African) granites. These rock units have been affected by many periods of orogenic movements resulting in extensive deformation and migmatization. Figure-1 shows the geological map of Kaduna State of Nigeria.

Most authors on the Nigerian Basement complex subscribe to the view that the rocks of the migmatites-gneiss-quartzite complex comprise largely a sedimentary series with associated minor igneous rocks which have been variably altered by metamorphic, migmatitic and granitic processes. This group of rock is the most widespread and occupies about 30% of the total surface area of Nigeria. It is a heterogeneous rock group and comprises largely of migmatites, biotite and granitic gneisses. In Kaduna State, the rock unit constitute the largest group of rocks, spreading from east of Birnin Gwari Local Government Area (LGA) to Jema'a and Ikara LGAs (Rahaman, 1988; Oluyide, 1995). In the Galma basin, the highly weathered migmatites and gneiss are degraded to a material containing large proportion of kaolinite. This stage of weathering is often found in the uppermost part of the zone and is associated with low permeability. At greater depth beneath the kaolinized layer, the degradation product has similar lithologic characteristics to a clayey grit and any joints or fractures tend to be open. The best prospect for groundwater production occurs in that part of the weathered zone between the kaolinized layers (WAPDECO, 1991).

The metasediments constitute the Schist Belts of Nigeria. They show lithologic similarities to schist belts from other parts of the world. McCurry (1976) and Rahaman *et al* (1981) have variously revealed the extent of this belt in Nigeria. The metasedimentary rocks are metamorphosed sedimentary and metavolcanic rocks and they occur in Kaduna State predominantly in the south-eastern parts. They consist mainly of phyllites and schists and thin bands of quartzite. The main constituents of these rocks weather to clay minerals (kaolinite) when highly degraded, and generally possess low permeability. However, a lower degree of weathering tends to open up planes of schistosity and thus enhances primary permeability (WAPDECO, 1991).

The Older (or Pan African) granites are characterized by lofty topography and inselbergs that usually resist erosion. The lithological varieties of the rock formation include coarse-grained porphyritic granite, biotite hornblende granite and fine-grained granites, and fayalite-quartz monzonite. The weathered zone on these rocks is normally thin and often absent. Joint systems are usually poorly developed. However, if a thick zone of weathering is present, acceptable well yield can be obtained (WAPDECO, 1991; Oluyide, 1995).

## 2. METHODOLOGY

This study is part of the recent groundwater flow modeling study of the Galma river basin (Olaniyan, 2010). The study commenced with the re-appraisal of previous works on the area. Geoelectric data, well completion data as well as aquifer characteristics, such as lithologic units and their depths, and weathered basement thicknesses were assessed with respect to productivity, with a view to determining the extent of inter-relationship or dependence between them.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Lithologic succession

The lithologic succession in the Galma basin as obtained both from drilling logs and geoelectric investigations showed that four to five geologic units can be delineated within the basin. The uppermost layer is a dark red brown lateritic top soil. Its resistivity varies from 150 to 1000 ohm-m, with thicknesses from 0.3m to 5m. This layer is generally underlain by a second horizon which consists of an orange to brownish silty clay having a resistivity range of 40 to 300 ohm-m, and ranging in thickness from 2m to 8m. The third layer is the grey-brown kaolinitic sandy clayey silt which is the finely weathered part of the basement. It varies in resistivity from 60 to 1100 ohm-m and is 6.6m to 15m thick. This layer was succeeded by the weathered and sometimes deeply fractured granite ranging in resistivity from 1500 to 4895 ohm-m and 18m to 55m thick. The lowermost layer is the fresh basement rock with resistivity of 5000 ohm-m and above, and whose bottom could not be reached during investigations.

### 3.2 Geologic profile

The geologic log of wells in the basin provided the lithologic sequence and horizons encountered during the process of drilling the wells. The lithologic information has been used to construct the geologic profile of the basin. Two geologic profiles were taken across the basin along two intersecting directions. The profile in the West-East direction spans through Sabon Gari Damari, Baushe, Matari, Fagachi, Bakura (Ungwan Dodo), Ribako, Dan Wata II and terminates at Kajirogo. This profile is presented as Figure-2. The second geologic profile was constructed in the North West-South East direction along the greatest length of the basin. The profile cuts through Likara Tasha, Ungwan Tsoho, Rangi, Chidau, Ribako, Sabon Kauran Bele, Kafi Kabau and terminates at GSS Zuntu. This profile is presented as Figure-3. These figures show that there is little or no lateral variation in the top soil, subsoil and the underlying rocks. This suggests the presence of relatively homogeneous soils across the basin. Also, the cross-sections showed that the ground surface is not flat as natural variations are depicted through the topography of the cross-sections.

### 3.3 Basement map

The depths to Basement complex rocks at each of the 91 well locations were used to plot the Basement map of the basin shown in Figure-4. The depths to Basement in the western part of the basin vary from 17.2m at Amana Gari to 51m at Dedeje and Sabon Gari Damari, from 18.2m at Dalla-A to 99.9m at Karofi in the central part, and from 26m at Malali to 37m at Kuzudo in the south-eastern part. The overburden thickness can be seen to be larger at the central and western parts of the basin than at the south eastern corner.

### 3.4 Regression line and correlation coefficient

The regression line of yield on weathered zone thickness is as shown in Figure-5. The regression coefficient of +0.232 is indicative of weak but positive relationship. The Pearson Product Moment Correlation analysis was also used to investigate the degree and nature of interrelationship between them. A correlation coefficient of 0.233 was obtained. These statistical values showed that the weathered zone thickness has a linear and direct relationship with the yield, but it is a weak relationship suggesting that it is not the only factor influencing well yield.

From the foregoing, it can be observed that the depth to the Basement complex rock is averagely about 8-

ARPN Journal of Engineering and Applied Sciences



10m. This agrees with Hazell *et al* (1992) who suggested an average of 8m after classifying the regolith according to grades of weathering from silty clay with no relict textures (Grade IV) down to the fresh rock (Grade I). The weathered or fractured Basement horizons are the principal targets for groundwater abstraction in the area. The thickness of the weathered Basement rather than the depth to Basement or intensity of weathering is inferred in this study as capable of influencing the yield of a well.

**4. CONCLUSIONS**

An inter-relationship has been established between aquifer yield and weathered zone thickness, in the crystalline basement rocks in northern Nigeria as observed in the Galma basin. Five lithologic units were delineated across the basin with little variation in lithologic characteristics, and the crystalline Basement rocks were found to have areas of deeply weathered and fractured regolith which constitute useful aquifers. The overburden thicknesses were observed to be larger at the central and western parts of the basin than at the south eastern tip. Statistical evaluation showed that the weathered zone thickness has a weak, linear and direct relationship with the yield, suggesting a low but positive level of influence on well yield.

**REFERENCES**

Amadi U.M.P. and Teme S.C. 1987. The engineering characteristics of soils around Abuja. Nigerian Journal of Mining and Geology. Vol. 23.

Hazell J.R.T., Cratchley C.R. and Jones C.R.C. 1992. The hydrogeology of crystalline aquifers in northern Nigeria and geophysical techniques used in their exploration. In: Wright E.P. and Burgess W.G. (Eds.) the hydrogeology of Crystalline Basement Aquifers in Africa. Geological Society Special publication No. 66, London.

McCurry P. 1976. The geology of the Precambrian to lower Palaeozoic rocks of northern Nigeria- A review. In: Kogbe, C.A. (Ed.): Geology of Nigeria, Elizabethan Publishing Company, Lagos. pp. 15-39.

Odusanya B.O. and Amadi U.M.P. 1990. An empirical resistivity model for predicting shallow groundwater occurrence in the basement complex. Water Resources - Journal of the Nigerian Association of Hydrogeologists. 2(1): 77-87.

Offodile M.E. 1992. An approach to groundwater study and development in Nigeria. Mecon Services Limited, Jos. pp. 67-68.

Ogunjobi M. 2001. Quantification of aquifer parameters in the Galma Basin of the crystalline Basement complex of northern Nigeria. Un-published PhD dissertation. Water Resources and Envir. Eng. Dept. Ahmadu Bello Univ. Zaria, Nigeria. p. 188.

Olaniyan I. O. 2010. Groundwater flow modeling using finite element method. Un-published PhD Thesis. Department of Civil Engineering, University of Nigeria, Nsukka.

Oluyide P.O. 1995. Mineral occurrences in Kaduna state and their geological environments. Proceedings of workshop held by NMGS, Kaduna Chapter in collaboration with Kaduna state Government. 15 December. pp. 13-27.

Parkman Nigeria Limited. 1994. 400 Rural water supply borehole project. Final Report. Kaduna State Agricultural Development Project.

Rahaman M.A., Oshin I.O., Ajayi T.R. and Asubiojo F.O.I. 1981. Trace element geochemistry and geotectonic setting of Ile-Ife schist belt. In: Proceedings of First symposium on the Precambrian geology of Nigeria. Geological Survey of Nigeria, Kaduna.

Rahaman M.A. 1988. Recent advances in the study of the Basement complex of Nigeria. In: Precambrian Geology of Nigeria. Geological Survey of Nigeria Publication, Kaduna. pp. 11-43.

WAPDECO. 1991. Kaduna State Water Board rehabilitation study, Zaria water supply scheme. Final report of Water and Power Development Company Ltd. (WAPDECO), Part-1. p. 427.

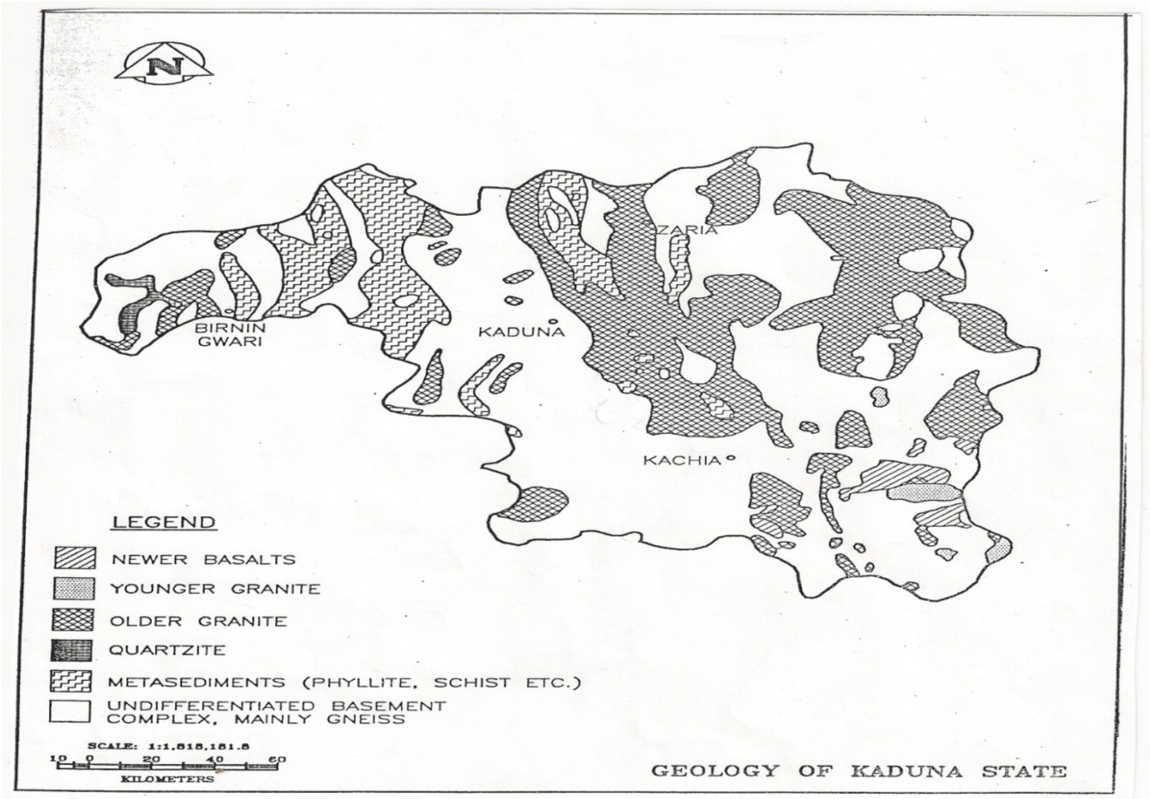


**Figure-1.** Map showing geology of Kaduna state (After WAPDECO, 1991).

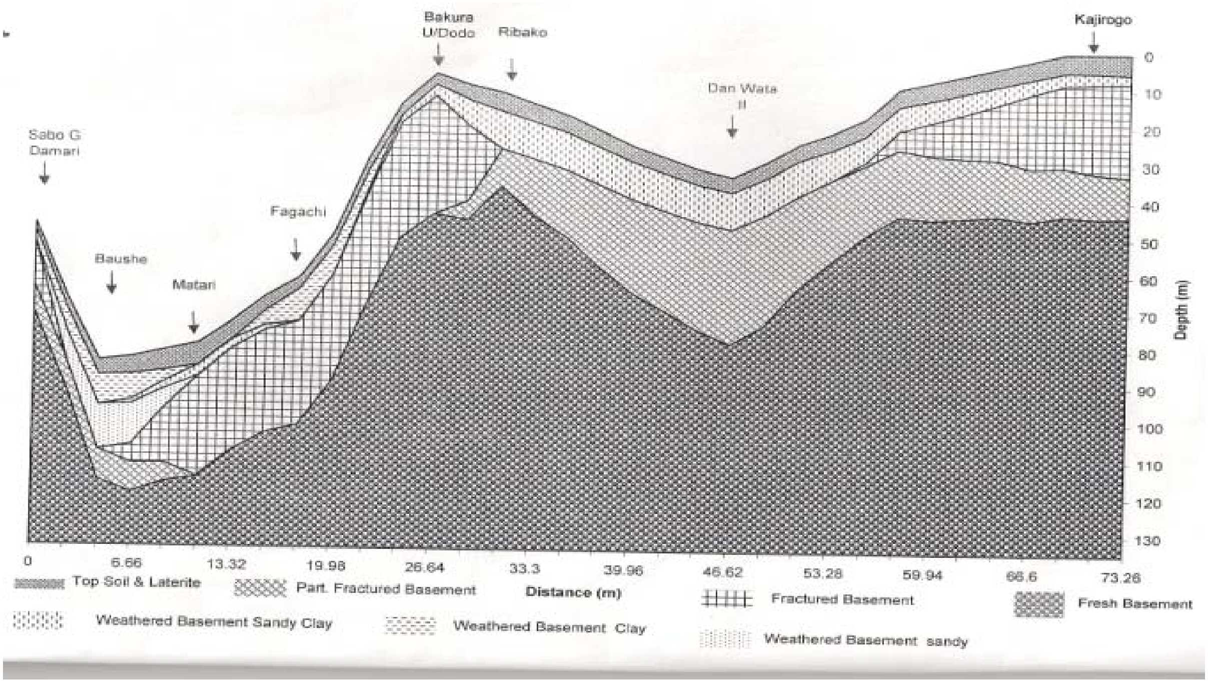


**Figure-2.** Geologic profile of Galma Basin in the West-East direction.

VOL. 5, NO. 7, JULY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

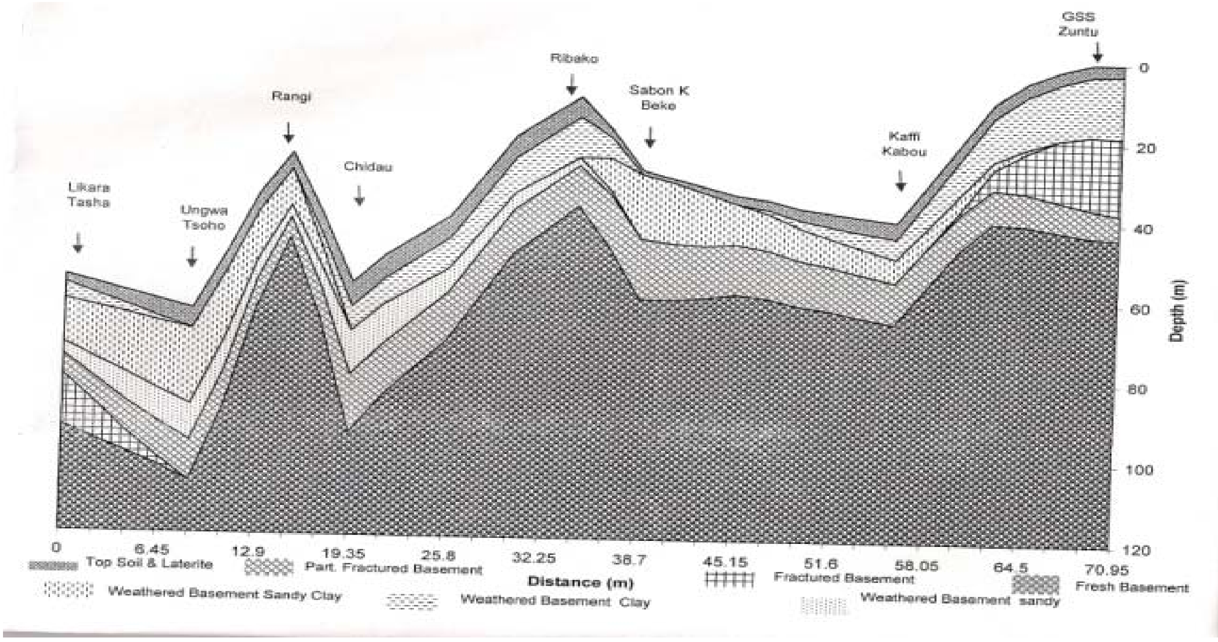


**Figure-3.** Geologic profile of Galma Basin in the North West-South East direction.

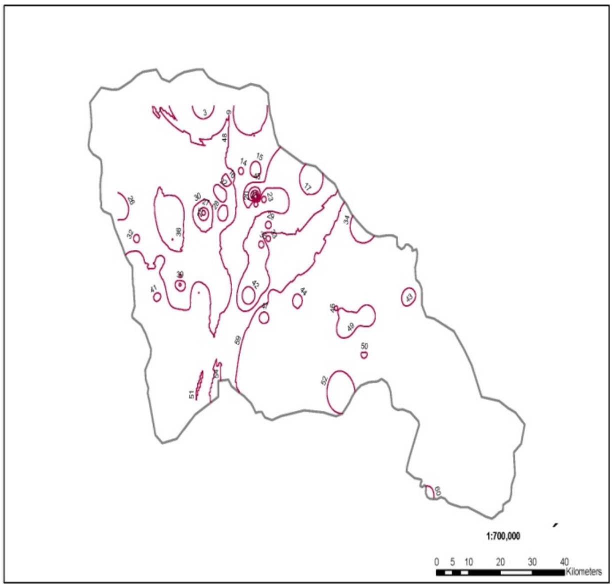


**Figure-4.** Depth to basement map of Galma Basin.

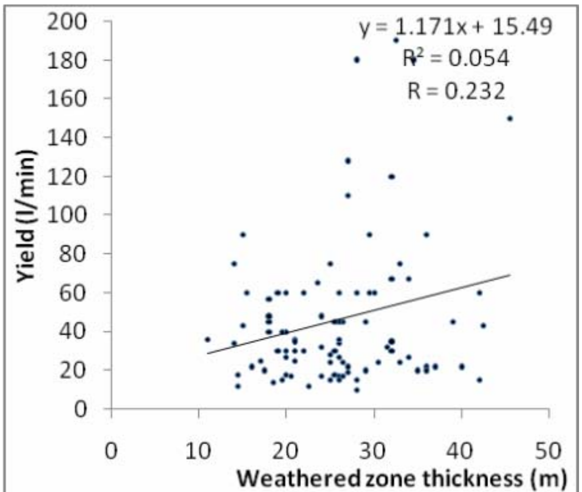


**Figure 5: Regression of Yield on Weathered zone thickness**