MINERALOGY AND CHEMICAL EVALUATION OF GROUNDWATER POTENTIAL OF GRANITOIDS IN MINNA AREA, NORTHWESTERN NIGERIA

*Alabi, A. A., Waziri, H .S, Ako T. A.
Department of Geology, Federal University of Technology Minna Nigeria.
*e-mail: kola_rock@yahoo.com and alabiadekola@futminna.edu.ng
*Presenter and Correspondance.

ABSTRACT

The chemical and mineralogical variations of granitoids are related to a large number of factors, such as the composition of magmatic source and process of formation or crystallization. Granitoids form a dominant component of the Precambrian basement complex rocks of Nigeria. Water is usually tapped from the weathered and fracture zones of these rocks, and the tendency of any basement rock to trap enough water depends on its depth of weathering and aquifer connectivity system. The study of granitoids around Minna, is with the aim of evaluating the mineralogy, chemical and its alteration index so as to understand its groundwater potential. The study, further elucidates the depth of weathering on granitoids in the study area. Field study revealed that the granitoids consist of medium – coarsed grained biotite granite, biotite – muscovite granite and porphyritic granite. These rocks occurred as flat laying and as batholith and ridges. Structurally, most joints run parallel to one another and they are either healed or open joints. XRD study has revealedfour granitic lithologic varieties namely; syenite, granodiorite, alkali-feldspar and monzonite. X-RF analyses also revealed percentage major element oxides of SiO_2 range from 62.54% - 74.7%,Al_2O_3, 6.22% -13.90%, Fe_2O_3 1.76% - 12.60%, K_2O 1.97% - 9.12%, Na_2O 0.31% - 4.21%- CaO 2.29% - 7.94%, while other oxides are in trace. Mineralogical, the rocks contain quartz, albite, muscovite, microcline, sanidine and siderophyllite. Comparison of weathering index of granitic rocks in the study area show a relative weathering index range between 55% and 60% in granodiorite, and alkali- feldspar granite, 50% and 54% in syenite, granite and tonalite, and 46% in monzonite. Relative abundance of joints, small scale fractures and intense weathering of granodiorite and alkali-feldspar granite revealed from Chemical Index of Alteration (CIA) combined with field evidence show a reliable ground water potential for these rocks.

INTRODUCTION

The most useful and effective parameters in the classification of granitoids are chemical and mineralogy (modal) compositions (Streckisen, 1976.Streckisen and Lemaitre 1979). The chemical and mineralogy variations of grainitiods are related to a large number of factors, such as variable magmatic sources and crystallization process(es) (Clarke 1979). Geological events (such as metamorphism) can alter the mineralogical composition of granitoids. However, the genetic links between granitoids can be resolved by their chemical composition. Igneous and metamorphosed crystalline rocks generally have very little, if any, primary porosity. In order for these rocks to host ground water, there must be openings developed through fracturing, or weathering. Fractures are developed by tectonic movements, shrinking during cooling of the rock mass, and the compression and tensional forces caused by regional tectonic stresses. However the amount of fracturing and weathering decreases with depth. Chemical weathering of crystalline rocks can produce a weathering product called saprolite which has porosities of 40 to 50 percent and specific yield of 15 to 30 percent (Fetter, 2007); this act as a reservoir, storing infiltrated water and releasing it to wells intersecting fractures in the underlying crystalline rocks.

In the basement rocks, water is usually tapped from the weathered and fractured zones, and the tendency of these basement rocks to trap enough water depends on their depth of weathering and aquifer connectivity system. Variation in granitic outcrops on the surface account for partly by a differing resistance to weathering presented by the various rock types; the more acidic, homogeneous and massive being less likely to be weathered than the others.

The chemical and modal compositions are useful in the understanding of weathering intensity of granitoids. In addition to reflecting weathering, the Chemical Index of Alteration (CIA) may be sensitive to subtle geochemical changes such as hydro-fracture along fault and/or alteration at the water table. In Minna area, granitic rocks constituted about 85% of outcrops of which ground water can be tapped to meet water demand during the pick of dry season. Therefore, a systematic study on the granitic rocks from this area needs to be intensified. This study of granitoids around Minna, is with the aim of evaluating their mineralogy, chemical composition and alteration index with a view to understanding its groundwater potential. This study, further elucidates the depth of weathering on granitoids in the study area.

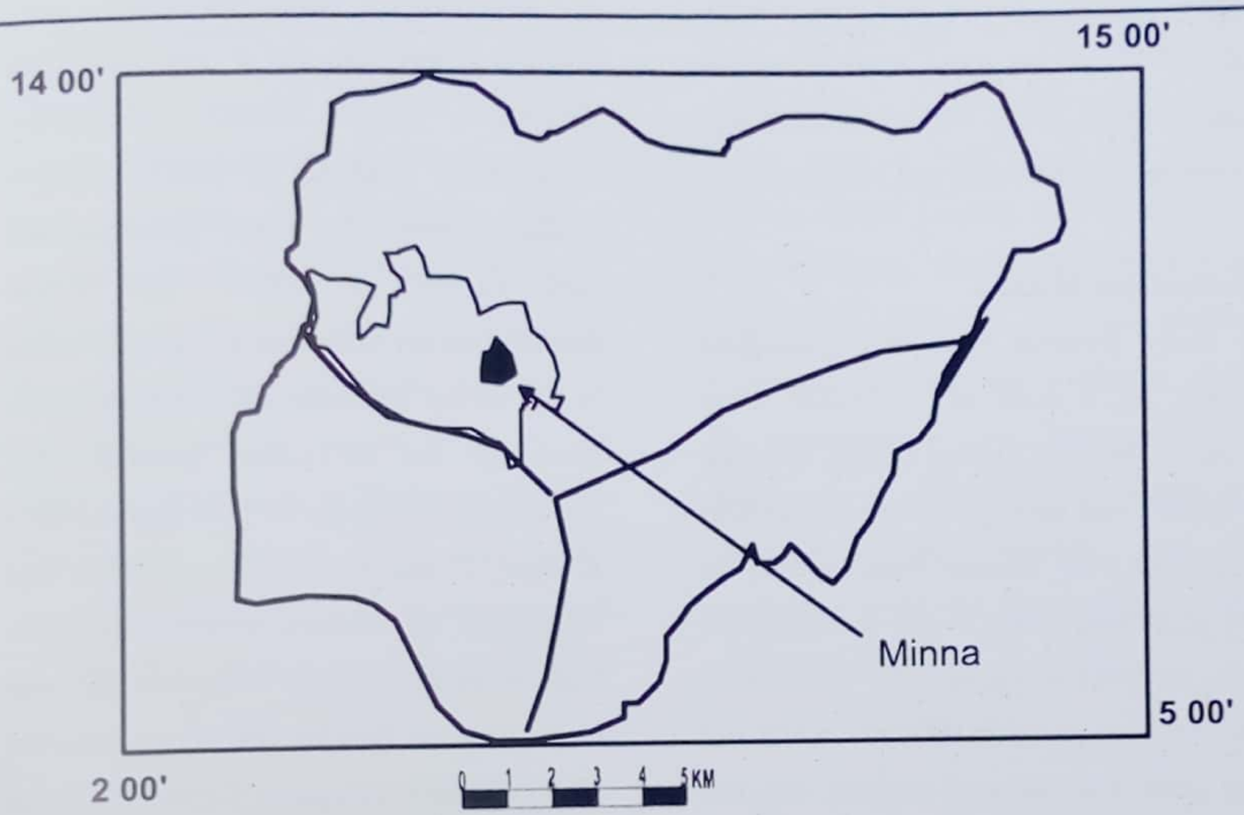


Fig. 1. Map of the Study Area

Geology of Minna area

Minna area is underlain entirely by rocks of the Nigeria basement complex which are grouped into three main sub-divisions of migmatite gneiss complex, the schist belts and the Pan-African granitic series. The study area is located between latitude $9^0$23'N and $9^0$43N' and longitude $6^0$23'E and $6^0$45'E. The area is comprised of five lithologic units of schist occur as flat laying narrow southwest – northeast belt with small quartzite ridge parallel to it. The gneiss occur as small suites at the northern and southern part of Minna forming a sharp contact with the granite (Alabi, 2011). Feldspar- rich pegmatites occur to the east with an average width of 65 meters and 100 meters long, and highly mineralized with tourmaline. Smaller bodies of Kushaka schist formation occur along the east – west segment of the Minna – Shiroro road, between Minna and Gulu (Ajibade et al., 2008). The contact between schist formation and tonalitic rock is exposed between Minna and Gwada, and formed a strike ridges. Granitic rocks dominate the rock types in the area and vary from porphyritic granite and coarse –porphyritic granite, medium tocoarse grained granite and granodiorite (Alabi, 2011). These rocks occurred as flat laying outcrops, and as batholiths and ridges as observed around Paiko and Minna areas.

Materials and Method

The study involves systematic geological mapping on a scale of 1: 25,000 using Global Positioning System (GPS), compass clinometer, and geological hammer. Drilled log samples were obtained from the field for hand specimen, chemical and mineralogical study. In hand specimen, the rocks were classified base on color, mineral content and grain sizes. For chemical analysis, samples collected from the field were dried at 120°C, crushed, pulverized and sieved to -80 mesh. One gram of pulverized powdered sample was mixed with four grams of the flux lithium tetraborate and introduced into the crucible. A bead was produced after heating to about 200 °C. The bead was introduced into the sample cup and was carefully placed on the sample charger of Energy Dispersive X-Ray Flourescence (EDX-RF) machine. The elemental composition of the rock samples were determined by comparing absorbance of rock samples and those of artificial standard.

For mineralogical study, the samples were powdered, mounted on a glass slide and analysed using aXRD (Empyrean PANalytical machine of D4674 (20011) model), powered by 45KV generator, and tube current of 40KV. The X-rays bombarding are diffracted at planes of atoms in the crystal structure and a patterns were produced, the diffraction patterns were recorded at scan range of 1-75 degree with a K-alpha 1 and K-alpha 2 radiations, and interpreted by database produce by XPert high score plus which comprises of Joint Committee on Powder Diffraction Standard (JCPDS), and Inorganic Crystal Structure Database (ICSD). The following were also identified, Name/Formula, crystallographic systems of rock forming minerals found in the rock samples. The analysis was carried out in the geochemical laboratory of the Nigeria Geological Survey Agency (NGSA) Kaduna, Nigeria.

Result and Discussion

Field and hand specimen study revealed four rock types in the study area; the medium grained biotite granite which occur at the southern area of Paiko as batholiths and which form graditional contact with the granite gneiss towards Minna; the biotite – muscovite granite occurs northeast –

northwest of Minna occupying an area extend of about 180 km^2; the porphyritic granite form prominent ridge in the south – north direction, and the dark medium grained granodiorite outcropping mostly as flat lying and are relatively small (5km), on the eastern part around Tagwai dam and on the western part of Minna (Fig. 2). The rocks vary from grey to light grey in color. The intense regional deformation which accompanied and preceded the emplacement of the Older granite result in pronounced joints running parallel to one and another of which some are heal while others are open joints, most of these joints are widen by erosion. Cross jointing is well exemplified on granodiorite and alkali-feldspar granite. These joint mostly run in northwest-southeast direction and constitute conduits for ground-water flow. Fractures of small scale and of variable lateral displacement show a northwest-southeast and north-northeast- southwest fracture pattern in the study area (Fig. 2b).

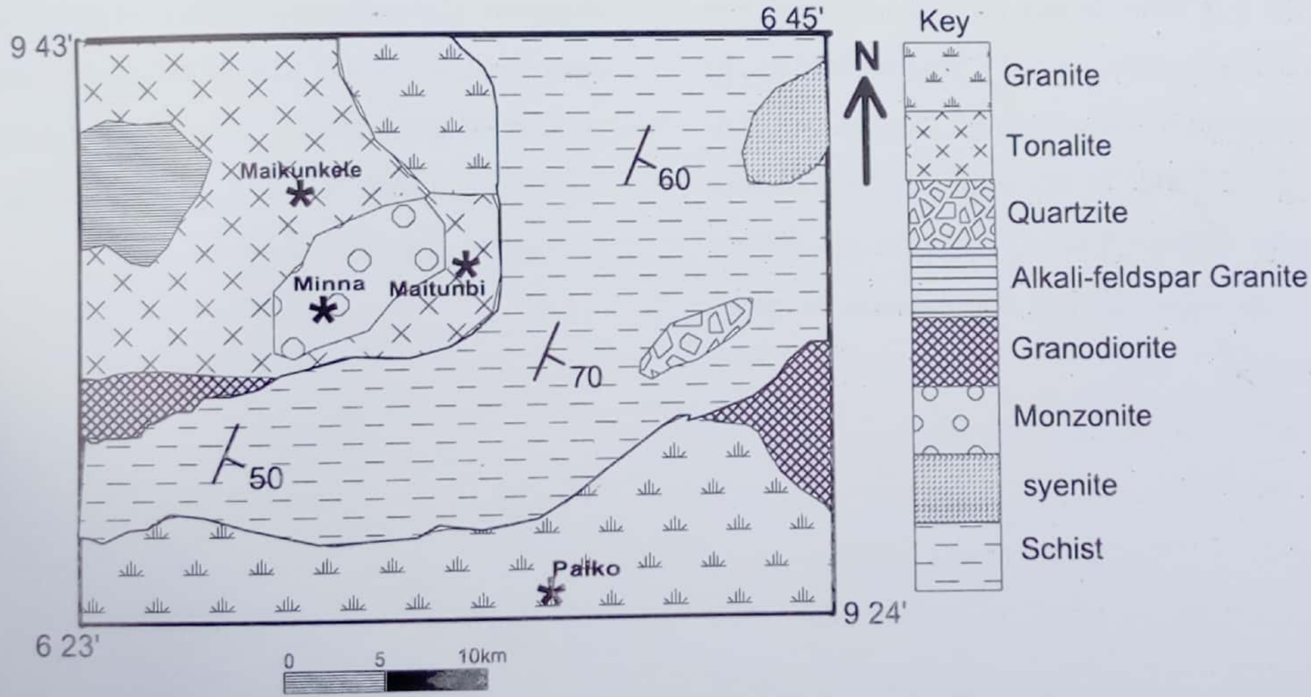


Fig. 2a. Geological Map of Minna Area (Modifeid after Alabi, 2011)

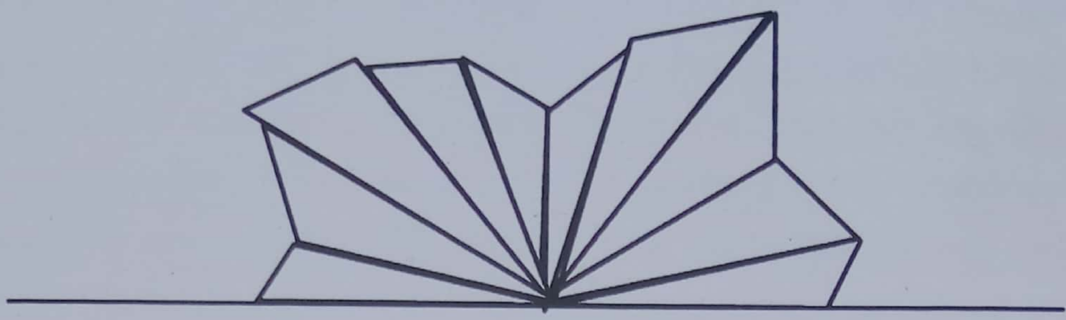


Fig. 2b. Rose diagram of measured fractured in the Minna Granitoids.

Geochemical Features

From the major and trace elements data (wt%) presented in Table 1, the rocks in the study area are generally siliceous, (SiO_2> 57%) with alkali-oxide content of Na_2O + K_2O > 6 wt%. Based on silica content, the rocks in locations 3 and 7 are intermediate in composition while those of locations 1, 4, 6, 8, 22, 27 and 34 are acidic in composition X-ray diffractogram (Figure 5a-5c) further reveals mineralogical composition of rocks in the study area to comprise of quartz, albite, muscovite, microcline, and sanidine. These mineralogical compositions are essential minerals in alkaline and acid igneous rocks. Also, plot of QAP ternary diagram (Streickeisen, 1976), revealed the geochemical broad classification of rocks around Minna ranging from granodiorite - syenite – alkali-feldspar - monzonite - tonalite to granite (Figure 4).

Table 1. Major element oxides composition (in wt%) of Granitoids in Minna area.

Oxide %	1	3	4	6	7	8	22	27	34
SiO_2	72.73	65.38	74.7	73.48	57.98	74.05	70.94	72.58	62.54
Al_2O_3	12.81	11.4	13.06	13.60	10.0	13.90	11.4	13.01	6.22
Fe_2O_3	2.92	3.28	1.76	2.15	8.91	2.73	6.59	2.37	12.60
MgO	0.66	0.52	0.27	0.28	5.96	0.86	0.61	0.48	0.53
MnO	0.23	0.092	0.18	0.12	0.844	0.21	0.15	0.078	0.29
CaO	2.01	2.77	1.54	2.29	3.34	2.34	5.14	3.74	3.94
TiO_2	1.34	0.37	0.40	0.33	0.925	0.769	0.51	0.36	1.40
K_2O	4.25	9.12	3.03	3.1	6.94	1.97	2.97	6.92	5.37
Na_2O	2.07	1.47	4.21	4.04	2.53	2.15	1.31	1.93	3.74
P_2O_5	0.024	0.32	0.33	0.06	-	0.04	-	-	-
Cr_2O_3	-	-	-	-	-	-	-	-	-
LOI	0.95	1.72	0.38	0.47	2.57	0.98	0.36	0.31	2.92
Total	99.99	99.44	99.86	99.92	99.95	99.99	99.98	101.7	99.61

1 and 8 = Granodiorite
34= Tonalite
4, 6 and 27= Alkali-feldspar
7= Monzonite
3 = Syenite
22= Granite

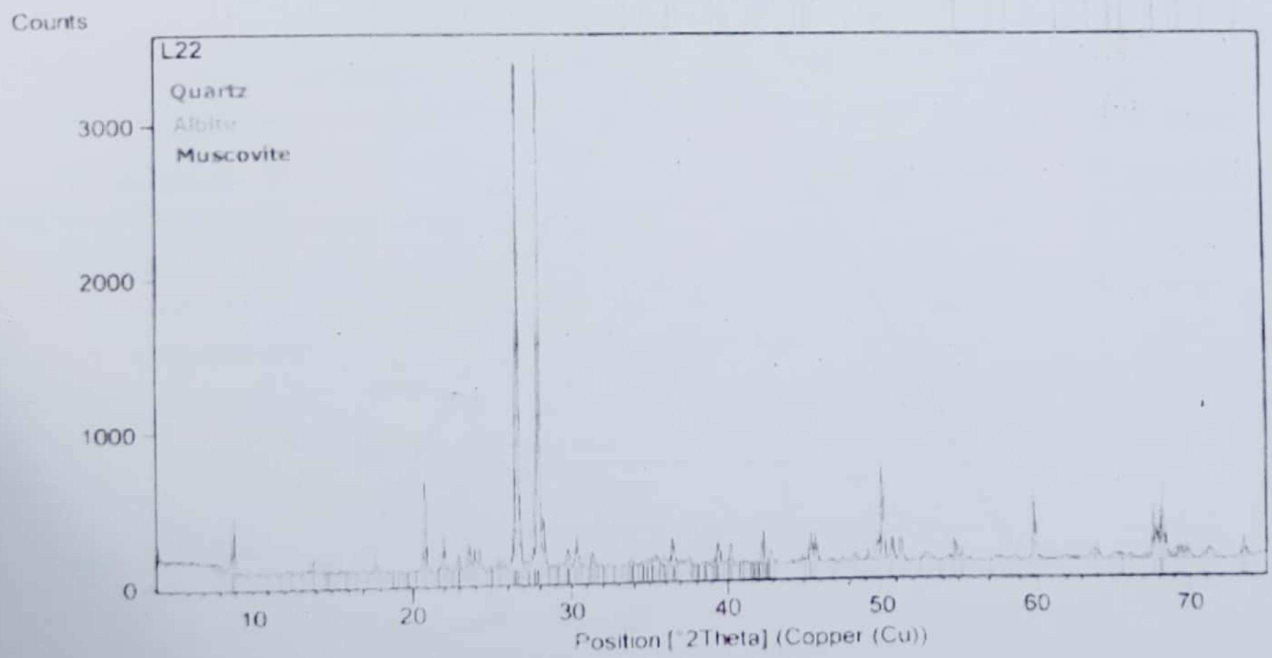


Fig. 3a.Refractogram of granitiod in Minna Area.

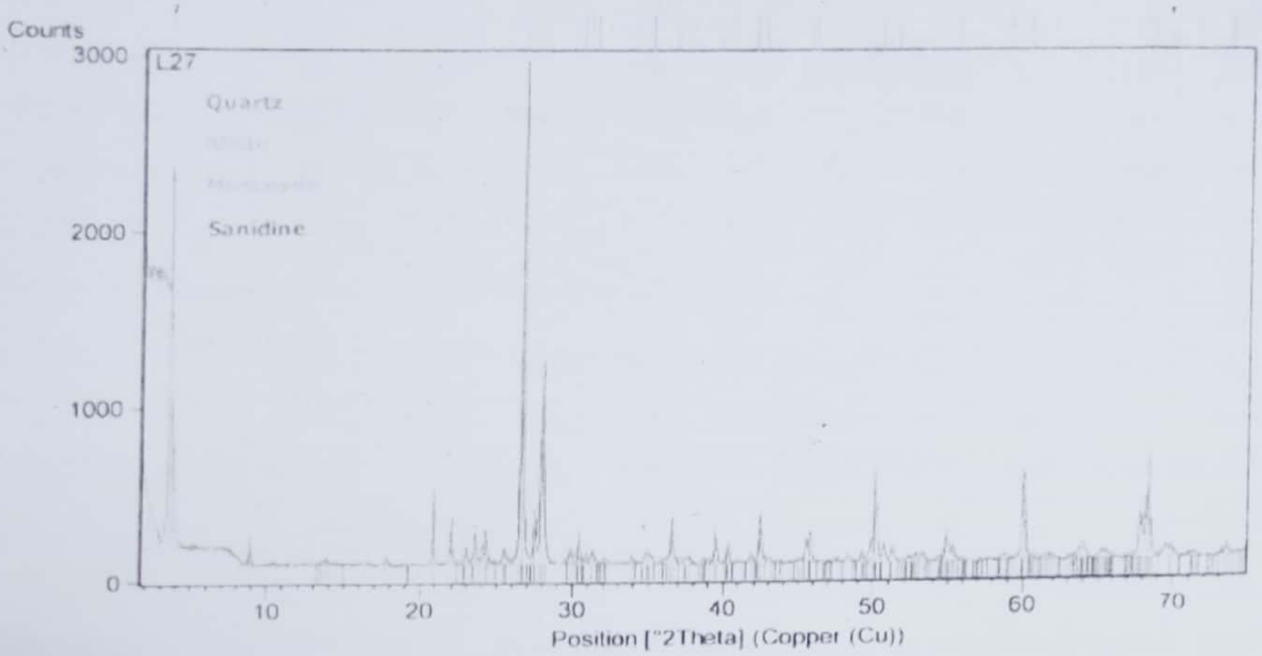


Fig. 3b. Refractogram of granitoid in Minna Area

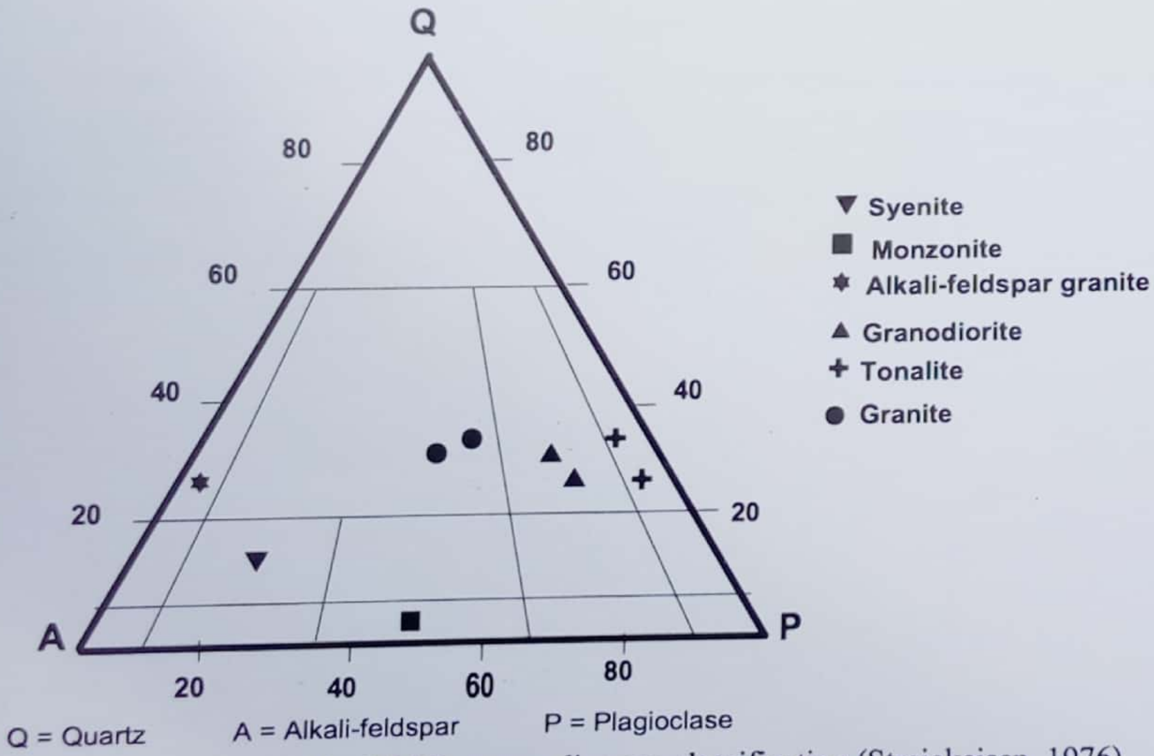
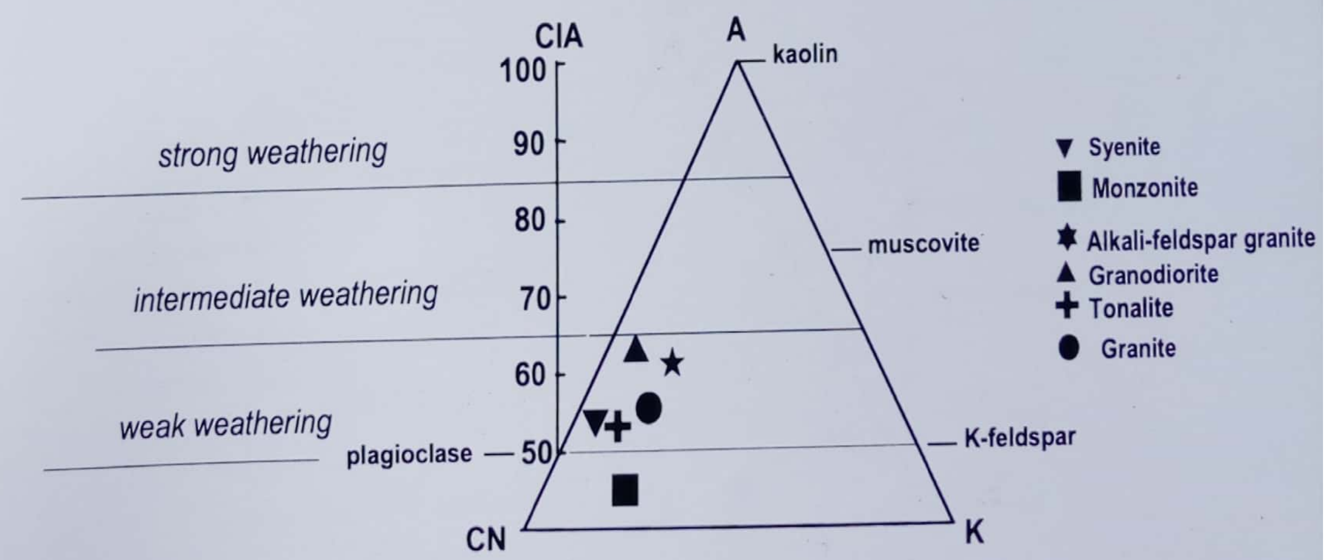


Fig. 4. Minna Granitoids in the field of QAP ternary diagram classification (Streickeisen, 1976)

The mineralogical composition of the rocks is an indication of acidic – intermediate in their original magma.

Qualitative estimation of the Chemical Index of Alteration (CIA) (Nesbitt and Young, 1982) of granitoid in Minna area using whole rock geochemical data is archived using ACNK ternary diagram (Figure 5). A comparison of weathering index of rocks in the study area show a relative weathering index range between 55% -60% in granodiorite and alkali-feldspar granite, 50% - 54% in syenite, granite and tonalite and 46% in monzonite. This is an indication of variable degree of chemical weathering induced by groundwater affecting labile minerals (feldspar), leading to increase in permeability of rocks with weathering index between 55% -60% (granodiorite, alkali-feldspar granite).

2



$A = Al_2O_3$ $CN = CaO + Na_2O$ $K = K_2O$

Fig. 5. ACNK plot for the Minna Granitoid rocks (Nesbitt and Young, 1982)

A Comparison of variable degrees of sub-surface chemical weathering in Minna area with borehole drilling log (Figure 6a – 6d) reveal weathering depth of 33m in alkali-feldspar granite, 34.5m in granodiorite,12m in granite and 11m in tonalite. This show the depth of induced weathering to be well pronounced in alkali-feldspar granite, and granodiorite than in granite, tonalite and syenite. It suggest that the vulnerability of alkali-feldspar granite, and granodiorite to sub-surface geochemical weathering, and hence tendency to fracture and joint widening which in-turn increases water reservoir potential of these rocks (alkali-feldspar granite, and granodiorite).

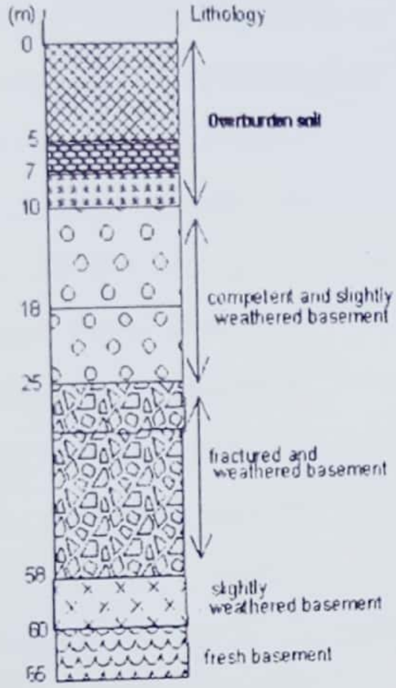


Fig. 6a. Log for Borehole drilled on alkali-feldspar granite (Cemaco, 1998)

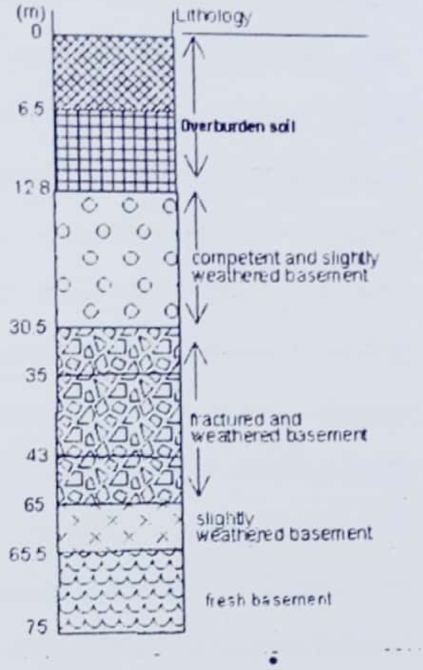


Fig. 6b. Log of Borehole Drilled on Granodiorite (Geo-explore, 2011)

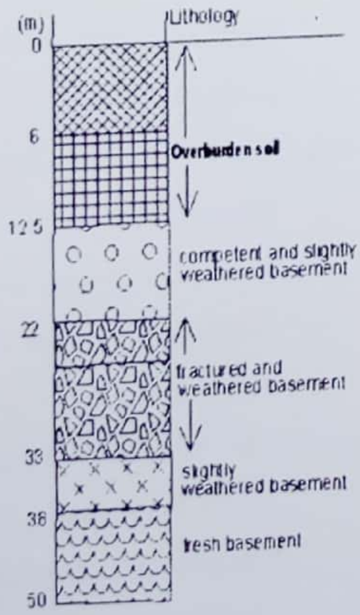


Fig. 6c. Log Borehole drilled on Tonalite (Geo-explore, 2012)

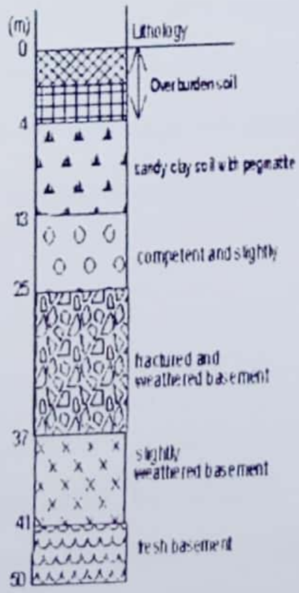


Fig. 6d. Log of Borehole drilled on Granite (Geo-explore 2012)

Conclusion

Systematic geological mapping, chemical and mineralogical evaluation of granitoid rocks around Minna, indicate that the granitoid range from medium grained biotite granite to porphyritic in texture. Mineralogically ,the rock ranges from granite, granodiorite, alkali-feldspar granite, syenite, granite, tonalite, and monzonite, these confirm the rocks are granitic. Joints and small scale fracyure are well pronounced in the granodiorite and alkali-feldspar granite which facilitate groundwater movement and weathering process. Calculation of Chemical Index of Alteration (CIA) compared with borehole logs show that granodiorite and alkali-feldspar granite are averagely induced by groundwater and hence increases permeability of these rocks and increases their groundwater potential.

References

Alabi, A. A. (2011). Geology and environmental impact assessment and benefit of Granitic rock of Minna area, northwestern Nigeria.Ethiopian Journal of Environmental studies and Management Vol. 4 No.4. pp 39 – 45.

Ajibade, C. A., Ayanwu,N. P. C., Okoro, A. U. and Nwajide, C. S. (2008). The Geology of Minna area .Nigeria Geological Survey Agency Bulletin No. 43. Pp 55 – 63.

Cemaco Nig. Ltd. (1998). The daily report and descriptive logging report on functional handpump operated borehole drilled at permanent site of Federal University of Technology, Minna.

Fetter, C. W. (2007).Applied hydrogeology, 2nd edition,CBS Publisher PVT. Ltd. Pg 296-297.

Geo-explore Nig. Ltd. (2011) and (2012). The daily report and descriptive logging report on borehole drilled in parts of Minna.

Clarke, B. W. (1979). Geology of the older Precambrian rocks of Grand Cayon part III.Petrology of mafic schist and amphibolites. Precambrian Res. 8: pp 219 – 224.

Nesbitt, H. W. and Young, G. M. (1982). Early Proterozoic Climate and plate Motions inferred from major element chemistry of Lutites. Nature 1999; pp 715 -717.

Streckiesen, A.(1976).To each plutonic rock its proper name. Earth Sciences Reviews 12, 1-33.

Streckiesen,A. and Lemaitre, R.W. (1979). A chemical approximation to theModal AQPF classification of the igneous rocks. NevesJährbuch fur Mnerallogie, Abhandlungen 136, 169-206.