THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Aspects of the Geology and Hydrogeology around Awe Town, Nigeria

Aisha Abubakar Kana
Senior Lecturer, Department of Geology and Mining, Nasarawa State University, Nigeria
Wubon Raymond Japhet
PG Research Students, Department of Geology and Mining,
Nasarawa State University Keffi, Nigeria

Abstract:
Awe Town, Nigeria is popular for the occurrence of brine, the brine is mined for salt production and is the major economic activity going on in the town. The occurrence of brine has however always posed a problem for domestic water supply. To avoid the salty water, public water supply scheme provided by the government is situated about 8km away from the settlement thus access to fresh water is quite difficult. The present study was initiated to study at a smaller scale, aspects of the geology and hydrogeology of the area with a view to understanding the 'limit' of the brine issuing Awe Formation and in so doing, suggest aquiferous zones with less saline water. Geological and hydro geological mapping of the area around the town was done, which led to the production of a geological map and also a groundwater elevation contour map. In addition to this, borehole samples from four boreholes were analysed. Major ion concentration in groundwater samples was determined from XRF analysis. The main findings of the present study are that: three of the six sedimentary successions in the Benue Trough are exposed in the study area viz: Awe, Keana and Ezeaku Formations. The brine as already established by previous researchers is restricted to the Awe Formation which itself is only exposed at the core of the anticline; aquifers containing non-saline groundwater are present in sandy units of Keana and Ezeaku Formations. Groundwater in the saline region is of sodium chloride type while that in the non-saline region is of calcium bicarbonate type.

Keywords: *Geology, brine, sandstone, shale, salinity*

1. Introduction

Awe town is geologically popular for the occurrence of brines and for this reason a lot of studies have been done ranging from geology to hydrogeology and geochemical analysis on soil, rock and water (brine) samples (Offodile, 1984; Nwajide, 1990;Abiola et al., 2014; Jatau and Nandom, 2013; Sallau et al., 2017). Geologically, it forms part of the Middle Benue Trough which itself forms part of The Benue Trough and consists of the following sedimentary formations: Asu River Group, Awe Formation, Keana Formation, Ezeaku Formation, Awgu Formation and finally the youngest which is the Lafia Formation.

The present work is aimed at studying the geology through geological mapping on a scale of 1:25,000, and petrographic analysis of rock samples collected. Surface and groundwater configuration will also be studies through groundwater level measurements (in wells and boreholes); measurement of physical parameters i.e. pH, TDS, EC, major ions in water samples. This information will assist in delineating saline groundwater zones.

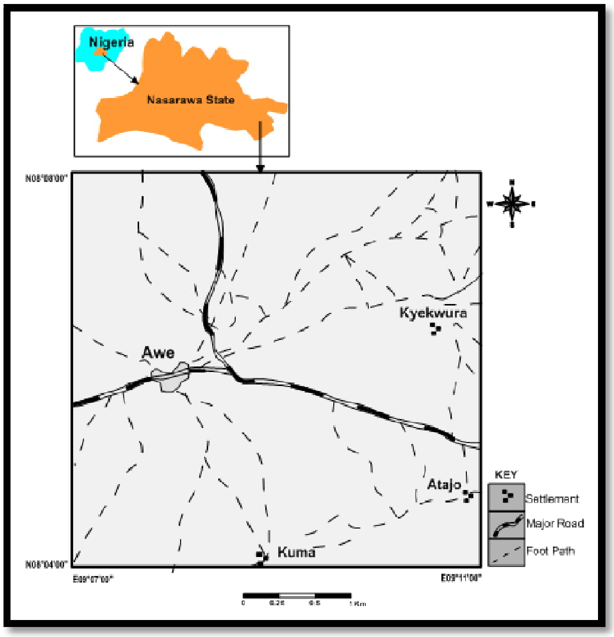

Figure 1: Location and Accessibility of the Study Area

2. Methodology

The approached to study here involved a series of field exercises and laboratory analyses. Field work consisted of geological mapping using compass traversing, areas with fresh outcrops were noted and their location was determined by the map. Observations of mode of occurrence, colour, texture and mineralogy were made. Representative samples of the rock units in the study area were collected for petrographic analysis. Structural features on the outcrops as well as hand specimens were observed and their orientations noted.

In the course of the fieldwork, four boreholes were drilled within the study area, close to the Awe Local Government Area Secretariat. Rock samples from these boreholes were collected and logged. Hydrogeological mapping in form of water level measurement and in-situ measurement of EC, pH and temperature was done.

3. Geology of the Study Area

3.1. Overview

The Geology of the study area is of sedimentary origin, its deposition took place under transition marine to fluviatile conditions during the Late Albian to Early Cenomanian regression, during which hypersaline lakes and swamps were developed. It is made up of sandstone, shale, limestones and mudstones. Three lithologies were mapped and are believed to be parts of three formations viz: Awe, Keana and Ezeaku Formations.

Awe Formation was mapped around Old Awe Town, where River Baki Abu has eroded the overlying Keana formation (Figure 2). It consists of thin alternating beds of sandstones, shales, and mudstones, brines were seen to issue from the shales of the Awe Formation.

Keana Formation was also mapped around Old Awe Town but seems to hem the outcrop of Awe Formation. It consists of thick beds of coarse grained sometimes pebbly sandstone, gray in colour. It is highly fractured with orthogonal joint sets; brines are seen to issue from these fractures that probably connect the Keana Formation to the Awe Formation.

Away from the Old Town towards the New Town or SabonGari as the locals call it i.e. east of the Old Town, thinly bedded light gray shales believed to be part of the Ezeaku Formation were mapped in a culvert adjacent the Local Government Lodge. Borehole logs collected in the course of geological mapping close to the Local Government Secretariat revealed the presence of the shale unit of the Ezeaku Formation. In the south-eastern part of the study area, around Atajo Settlement, light brown sandstone outcrops believed to be part of the Ezeaku Formation were mapped. The sandstones are relatively medium grained and light brown in colour.

Structural features mapped include the main anticline in the Old Awe town where the Awe Formation forms the core and follows the course of River Baki Abu, flanked by the younger Keana and Ezeaku Formations to the north, east and south. Smaller structures mapped include orthogonal joint sets especially in the Keana Formation, mud cracks and bedding plane partings.

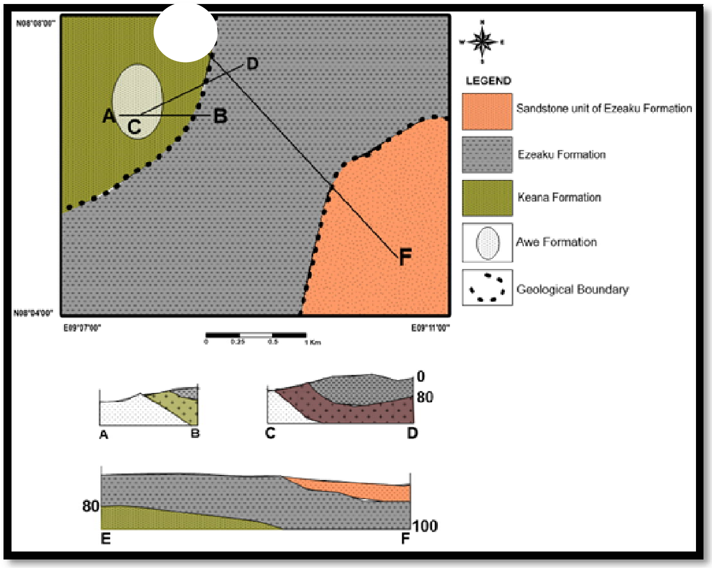

Figure 2: (A) Geological Map of the Study Area Showing Major Rock Units as Well as Inferred Boundaries between Them, (B), (C) and (D) Are Geological Cross – Sections across Lines AB, CD and EF Respectively

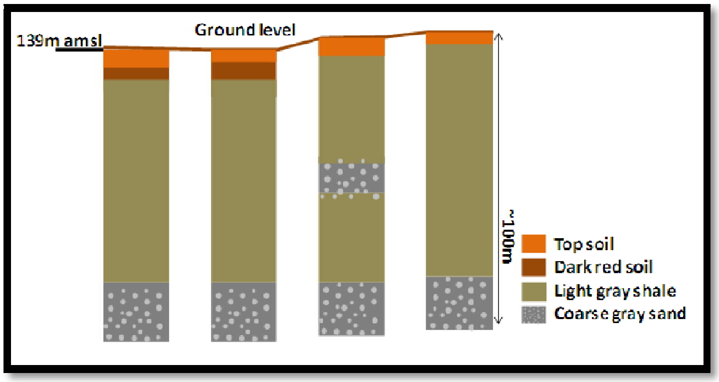

Figure 3: Lithological Logs of Boreholes Drilled During the Geological Mapping Exercise (See Borehole Locations on the Geological Map in Figure 2)

3.2. Geology of Awe Formation

The Awe Formation, from field relationships and previous studies, is the oldest outcropping, sedimentary formation in the study area. Its lowermost part from the sections mapped along the banks of River Baki Abu shows a sequence of alternating thin beds of mudstone, sandstone and shales (figure 4).

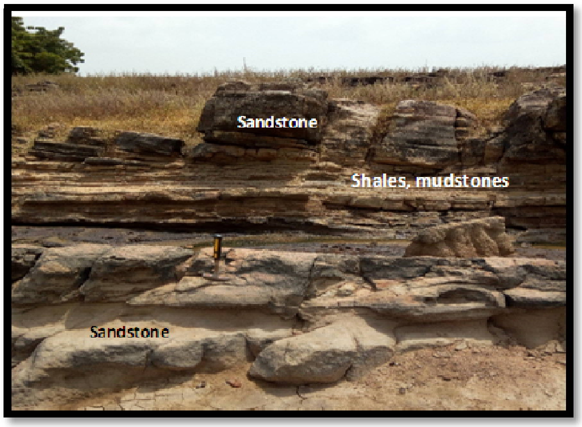

Figure 4: Exposure of Awe Formation on the Bank of River Baki Abu

3.3. Geology of Keana Formation

3.3.1. Field Description

As mentioned in section one, Keana Formation hems the outcrop of Awe formation in the Old Awe Town. Three samples were taken for petrographic analysis. It is light gray in colour, coarse grained and and well jointed with orthogonal joint sets (figure5). It was also logged in the boreholes drilled in the course of geological mapping (figure 3). Keana Sandstone from the borehole logs extends from 63m above mean sea level, one borehole sample was taken for XRF analysis. Table 1. summarizes the percentage composition of major oxides in the sandstone sample. An attempt to classify the sandstone using the major oxide concentration showed that the sandstone is a quartz arenite (figure 6)

Figure 5: (Left) Outcrop of Keana Formation in Old Awe Town, Note Orthogonal Joint Sets and Efflourescence of Brines Issuing from the Joints (Right) Borehole Sample of Keana Sandstone Collected at about 80m Below Ground Surface

Oxides	Percentage composition	Element	Concentration ppm
SiO_2	87.40	V	10.00
CaO	6.07	Cr	Not Detected
MgO	0.89	Cu	31.00
K_2O	3.59	Sr	950.00
Na_2O	1.09	Zr	1000.00
TiO_2	0.93	Ba	80.00
MnO	0.14	Sc	20.00
P_2O_5	Not Detected	Zn	Not Detected
Fe_2O_3	1.06	Ce	11.00
Al_2O_3	1.06	Pb	Not Detected
SO_3	Not Detected	Sb	Not Detected
LOI	0.46	Ga	11.00
		As	11.00
		Y	15.00
		Ru	4.50

Table 1: (A) Percentage Composition of Major Oxides and (B) Trace Element Concentration in Keana Sandstone, Determined from XRF Analysis

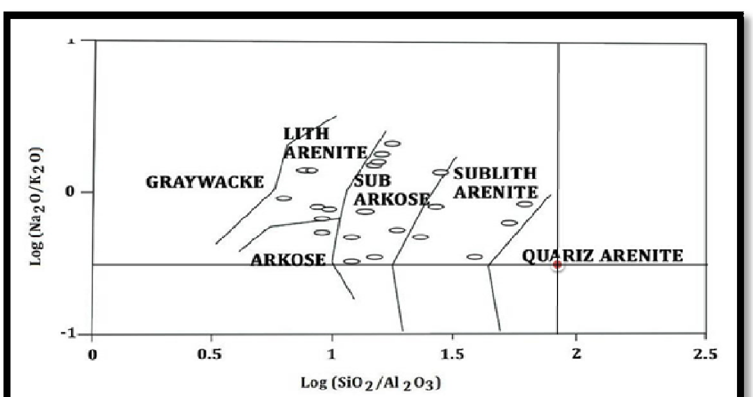

Figure 6: Classification of Terrigeeous Sandstones Using Log(Na_2O/K_2O) Vslog(Sio_2/Al_2O_3) from Pettijohn Et Al., (1972); Boundaries Redrawn by Herron (1988), the Sandstone Sample Plots in the Qartz Arenite Field

3.3.2. Petrography

Three samples of the Keana Sandstone were collected around Old Awe town for petrographic analysis. The thin sections show that the rock is light in colour, coarse grained with well formed crystals of quartz. Minerals identified are quartz and feldspar (plagioclase and microcline).

In plane polarized light, quartz is colourless, has a low relief, euhedral in shape and does not exhibit cleavage. Some quartz grains have fractures or cracks in them (figure 7). Under cross polarised light, quartz eshibits interference color from gray to white and even extinction.

Microcline under plane polarized light is colourless, has a low relief, subangular to subrounded in shape, and is slightly fractured, grain. Under cross polarized light, microcline shows and interefrernce color of gray to white. It exhibits a cross-hatched twining and an oblique extinction.

Under plane polarized light, Plagioclase is colourless, has a low relief, subangular in shape, having one directional cleavage. It exhibits interference colour: gray to white in cross polarized light, a polysynthetic twining and an extinction angle of 32^0

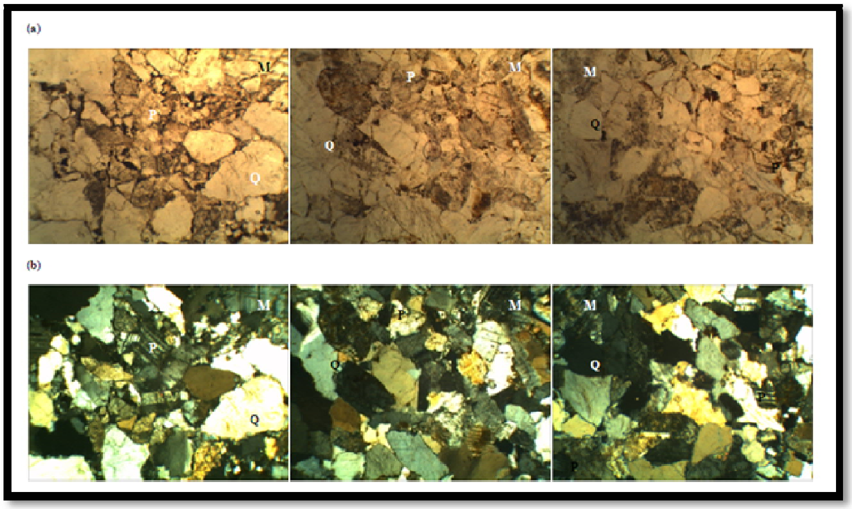

Figure 7: Photomicrographs of Keana Sandstone in (a) Plane and (b) Cross Polarized Light, Magnification: X8. M = Microcline; Q = Quartz and P = Plagioclase

3.4. Geology of Ezeaku Formation

3.4.1. Field Description

Shale unit of the Ezeaku Formation was mapped along a culvert behind the Local Governemnt Lodge, Sabon Gari area. The shale unit was also logged in boreholes behind te Local Governemtn Secretariat. The shales in the culvert were weathered as such samples were not taken for thin section analysis. Borehole samples of the shale were light gray in colour, fine grained and had a soapy feel. Towards the southern part of the portion around Atajo settlement, light brown, medium to coarse grained sandstones were mapped and are believed to be sandstone units of the Ezeaku Formation. Samples of the outcrop were taken for thin sectioning and subsequent petrographic analysis.

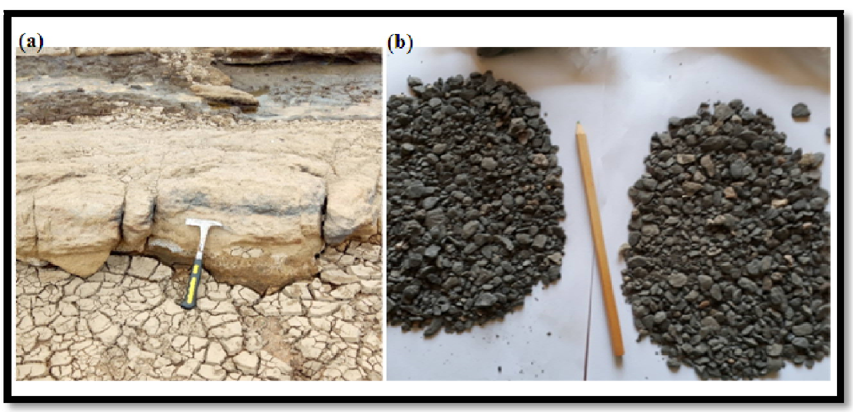

Figure 8: (A) Outcrop of Sandstone Unit of the Ezeaku Formation Around Atajo, (A) Borehole Sample of The Shale Unit Collected at about 40m Below Ground Surface

One shale sample from the borehole was taken for XRF analysis. Table 2 shows the concentration of oxides and trace elements in the shale sample. Although the composition was determined for only one sample, an attempt to classify the shale sample was done and presented in figure 9.

Oxides	Percentage Composition	Elements	Concentration ppm
SiO_2	47.10	V	33.00
CaO	7.90	Cr	17.00
MgO	0.76	Cu	40.00
K_2O	2.83	Sr	740.00
Na_2O	1.03	Zr	840.00
TiO_2	1.87	Ba	30.00
MnO	2.66	Sc	Not Detected
P_2O_5	Not Detected	Zn	21.00
Fe_2O_3	6.40	Ce	Not Detected
Al_2O_3	18.00	Pb	51.00
SO_3	1.00	Sb	20.00
LOI	10.42	Ga	10.00
		As	Not Detected
		Y	2.00
		Ru	4.20

Table 2: (A) Percentage Composition of Major Oxides and (B) Trace Element Concentration in Shale of Ezeake Formation, Determined From XRF Analysis

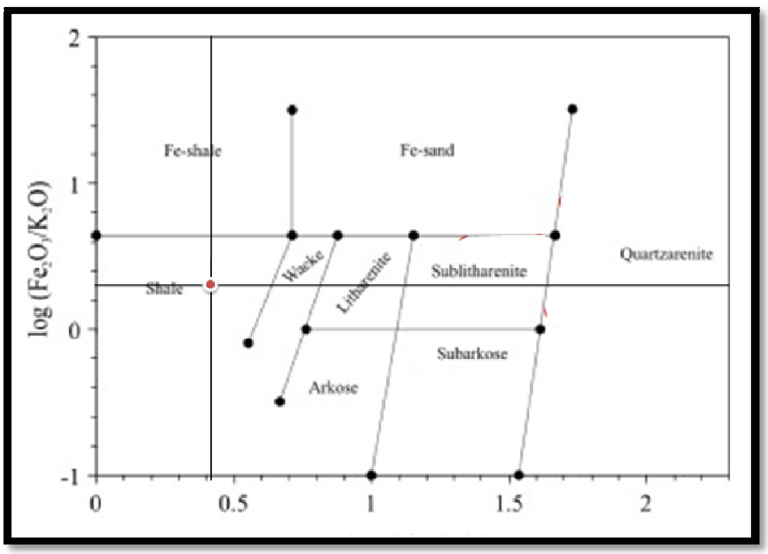

Figure 9: Classification of Terrigeeous Sandstones and Shales Using Log(Fe_2O_3/K_2O) Vslog(Sio_2/Al_2O_3) from Pettijohn Et Al., (1972), after Herron (1988), the Shale Sample Plots in The Shale Field

3.4.2.Petrography of the Sandstone Unit

Three samples of the sandstone were collected around Atajo for analysis. The thin sections show that the rock is light in colour, medium to coarse grained with well formed crystals of quartz. Minerals identified are quartz, feldspar (microcline) and muscovite.

In plane polarized light, quartz is colourless, has a low relief, euhedral in shape and does not exhibit cleavage. Some quartz grains have fractures or cracks in them (plate 4.4). Under cross polarised light, quartz eshibits interference color from gray to white and even extinction.

Microcline under plane polarized light is colourless, has a low relief, subangular to subrounded in shape, and is slightly fractured, grain. Under cross polarized light, microcline shows and interefrernce color of gray to white. It exhibits a cross-hatched twining and an oblique extinction.

Muscovite under plane polarised light is colourless, non-pleochroic, has a lowrelief, found as micaceous flakes or tablets with irregular outlines, most commonly displays a tabular or lathlike habit, Under cross polarized light, muscovite shows vivid second order blues and greens and a parallel extinction.

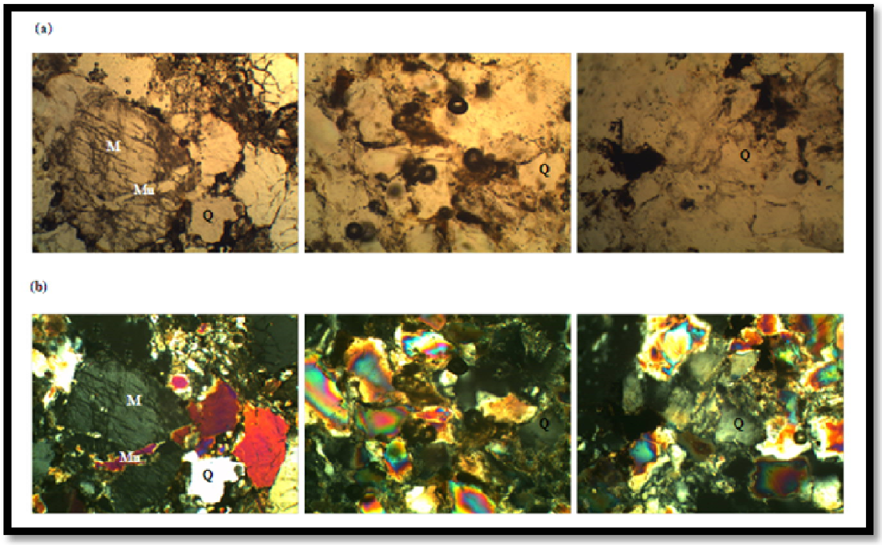

Figure 10: Photomicrographs of Ezeaku Sandstone in
(A) Plane and (B) Cross Polarized Light, Magnification: X20. M = Microcline;
Q = Quartz and Mu = Muscovite

3.5. Structural Geology

It is noticeable that in the studied area, some structures were formed at the time of sedimentation while others were formed after sedimentation and it is against this observation that the structures have been sub-divided into syn-sedimentary and post-sedimentary structures.

3.5.1. Syn-Sedimentary Structures

These are structures formed contemporaneous with sedimentation and are produced as a result of changes in the pattern of sedimentation, usually changes in sediment composition, grain size and current direction. Bedding and bedding plane partings were observed as syn-sedimentary structures in the shale and sandstone units mapped. Bedding and bedding plane partings are structures layering greater than one centimetre and are bounded above and below by bedding planes. They are produced usually by changes in sediment composition or grain size. This type of structure was observed in all the rock units encountered. Bed thicknesses range in size, typically, shale units range in thickness between 5 and 30cm, while sandstone units are considerably thicker (up to 40cm)

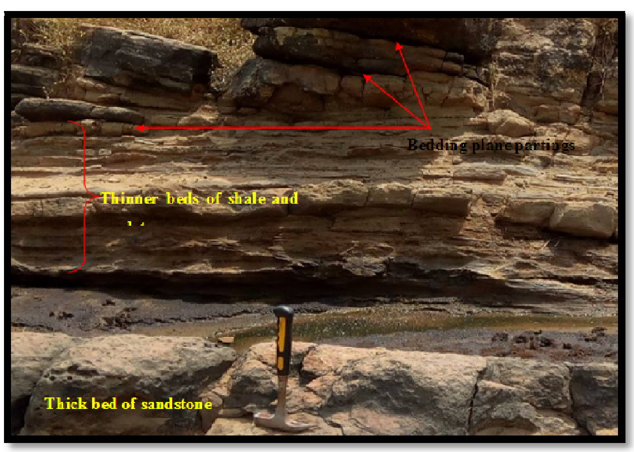

Figure 11: Bedding Observed in Awe Formation,
The Shale and Mudstone Units Are Thinner Than the Sandstone Units
Also, Evident Here Are Bedding Plane Partings, Sometimes
Large Enough for an Aperture to Be Measured

3.5.2. Post-Sedimentary Structures

These are formed as a result of the deformation of pre-existing sedimentary rocks. They are usually formed at the end of sedimentation. The post-sedimentary structures encountered during the field mapping exercise were formed as a result of deformational forces which acted upon the rocks. The following post-sedimentary structures were observed;

Folds: The term fold refers to a flexure in a rock causing an originally planar geological surface to be curved or angular. This phenomenon usually causes originally horizontal beds to dip at a certain angle. If the flexure, takes form of an arch it

Awe Town is one of the major post-sedimentary structures observed in the area. The anticline has been eroded such that the Awe Formation is exposed at the core of the anticline; Keana and Ezeaku Formations hem the core of the anticline, gently dipping away from the Old Awe town towards the north, south and east.

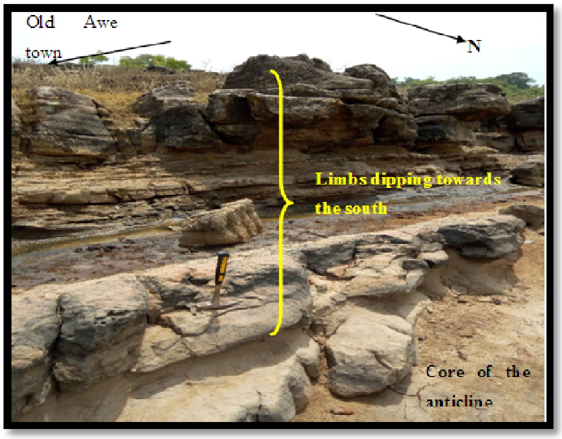

Figure 12: Core of the Awe Anticline and Southwards DippingLimbs Oobserved in Old Awe Town

3.5.2.1. Joints

The term joint refers to a fracture in a rock in which there is no observable relative movement. It could also be seen as a fracture which is nearly normal to the bedding and along which there is no relative displacement. Joints were observed on all the rock units mapped. Major trends are NE-SW and NW-SE these form orthogonal joint sets especially in Keana Sandstone and the sandstone unit of the Ezeaku Formation.

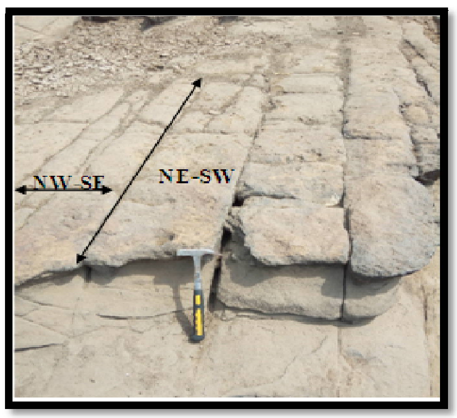

Figure 13. Orthogonal Joint Sets Mapped on Keana Sandstone Around Old Awe Town

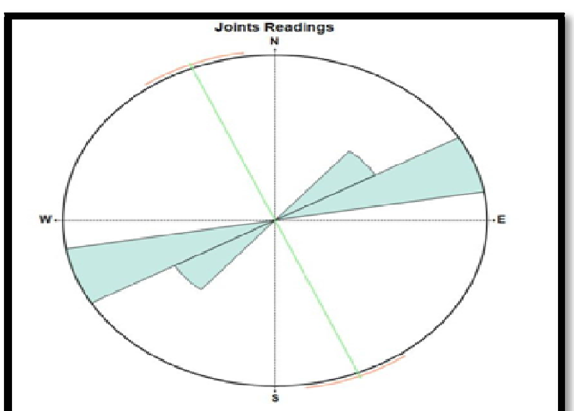

Figure 14: Rose Diagram of Joint Orientation Measued in the Rock Units in The Study Area Number of Data Points = 30

3.5.2.2. Mud Cracks

These are vertical to sub-vertical shrinkage cracks which are formed from the construction of cohesive muddy sediments. Muds formed from the weathering of shale are found covering the floors of many rivers as well as streams in the studied area. In the dry season when these sediments lose pore water, they Contract forming spindle shaped cracks as observed around Old Awe and some part of the area.

Figure 15: Mudcracks Observed in the Stduy Area Adjacent an Exposure of the Sandstone Unit of the Ezeaku Formation

3.6. Geologic Setting

Geologic setting of the study area starts with the Asu River Group sediments of the Middle Benue Trough were deposited directly on the Basement Complex by the initial transgression from the Gulf of Guinea in the Middle Albian. The Upper Albianfacies, as the Awe Formation were deposited during regression that followed. The transgression was facilitated by subsidence in the southern and the middle segment of the Benue Trough. The Awe Formation (lithologies) outcrops around Old Awe town. The Awe Formation is underlain by the Keana Formation; this was mapped in the Old Awe town as well as from borehole cuttings in the SabonGari area. The youngest rock unit mapped in the area is the Ezeaku Formation. Structural elements include the anticline structure in the Old Awe town and also joints cutting across all rock units in the study area.

3.7. Hydrogeology

Three main aquifer units exist in the study area, viz: sandstone nits of the Awe, Keana and Ezeaku Formations. Ground water is found in pore spaces of these rocks. Static water level in the study area ranges from 109.6 to 126.9 meters above mean sea level. Contour map of the groundwater elevation is shown in figure 7; groundwater moves in a geeral east to west direction. Electrical conductivity of the water ranges from 879μS/cm to 7554μS/cm. the higher values of electrical conductivity are associated with the brines in the area of the old Awe town. Away from the Old Town, towards Sabon Gari and Kyekwura, electrical conductivity improves. The implication of this is that water from the boreholes in the Sabon Gari area are good for domestic water supply since eectrical conductivity is favourable.

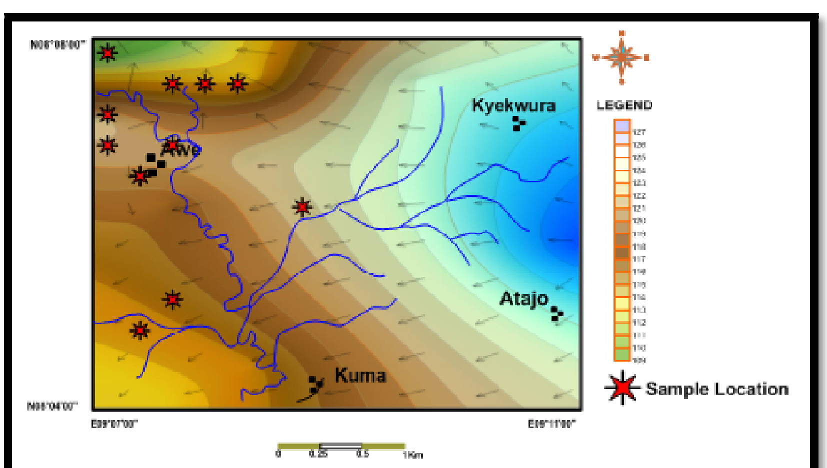

Figure 16: Surface and Groundwater Movement in the Study Area

Six groundwater samples were analysed for major anion and cation coposition, the results are presented in table 3.

Location	Ca	Mg	K	Na	Fe	Mn	Cl	HCO_3	SO_4	NO_3	TDS
SABON GARI	48.5	0.5888	2.5	34.2	0.405	0.801	0.5	9.4	0.705	0.021	93
SABON GARI	50.7	0.5831	2.5	30	0.263	0.239	1.2	9.6	0.116	0.021	108
SABON GARI	46.8	0.61624	3.8	43.9	0.993	0.0169	0.8	3.2	0.94	0.0105	80
SABON GARI	42	0.5064	3.3	53.1	0.73	0.0163	1	13.6	7.288	0.0175	113
OLD TOWN	1180	0.7206	65.7	3580	0.756	0.0259	960	11.6	0.705	0.014	64000
OLD TOWN	935	0.7002	63.4	2775	0.671	0.0698	825	6.1	1.411	0.049	55000

Table 3: Major Ion Concentration in Mg/L of Groundwater Samples from the Study Area

TDS values recorded for groundwater samples from the old own are orders of magnitude higher than those from the new town samples. This is further evidenced by the higher concentrations of the ions: calcium, potassium, sodium and chloride. The water type in the old town is saline, sodium bicarbonate while that of the new town is fresh calcium bicarbonate type. The control on the water type can be linked to the brines in the old town area.

4. Conclusions

The present study was aimed at studying the geology and groundwater configuration of Awe Town. Key findings here are that the outcrop of the brine issuing Awe Formation is restricted to the core of the Awe anticline, specifically around the Old Awe Town. Aquifers in the area are found in the Awe Formation itself, as well as the sandstone unites of Keana and Ezeaku Formations. Away from the old town, the geological succession consists of about 70 meters of shales of Ezeaku Formation, followed by the sandstones of the Keana Formation for a thickness of about 30m.

5. References

i. Abiola, K.A., Funmilola, A., Medugu, N. I., and Ayuba, H. K. (2014). Variability of brine water quality in Keana and Awe, Nasarawa State, Nigeria. Unique Journal of Engineering and Advanced Sciences, 2(4); pp 36-45

ii. Jatau, B. S., and Nandom, A. (2013). Morphology of Parts of the Middle Benue Trough of Nigeria from Spectral Analysis of Aeromagnetic Data (Akiri Sheet 232 and Lafia Sheet 231). International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering, 7(9); pp 622-627.

iii. Nwajide, C.S. (1990). Cretaceous Sedimentation and Paleogeography of the Central Benue Though. In:Ofoegbu, C.O; (Ed.), The Benue. Tough structure and Evolution International Monograph Series, Braunschweig, pp. 19-38.

iv. Offodile, M.E. 1976. "The Geology of the Middle Benue Nigeria". Cretaceous Research,Paleontological Institute: University of Uppsala. Special Publication.

v. Offodile, M. E. (1984). The geology and tectonics of Awe brine field. Journal of African Earth Scences,2(3);191-202

vi. Sallau, A. Momoh, A, Opuwari, M., Akinyemi, S., and Lar, U. (2017). An overview of trace elements in solid of Kean-Awe Brine Fields, Middle Benue Trough. Transactions of the Royal Society of South Africa, 72(1); pp 47-54