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A GEOLOGIC FIELD REPORT ON THE GEOLOGY OF AFIKPO BASIN, LOWER BENUE TROUGH, SOUTH EASTERN NIGERIA

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Abstract:

The study area is situated within the Afikpo Basin, lower Benue trough of Southeastern Nigeria. The origin of the Benue Trough is linked to riffing associated with the separation of South America from Africa in the cretaceous times. The vast igneous activities in the trough are thought to either precede the separation of the two continents or post-date Albian sediments deposited in the trough after the separation. The geology of northeast of Afikpo basin consists of two major Lithostratigraphic units of sandstone ridges and low lying shale's each of which forms significant component of the middle Albian ASU Rivers Group and Turonian Ezeaku formation. Also Dolerite, Hornfel and Gabbro were identified.

INTRODUCTION

The study area lies between longitudes $7^0 17^1$ E and $7^0 51^1$E, and latitudes $5^0 46^1$ N and $6^0 3^1$ N with the Afikpo syncline of the Cross River basin of the Benue trough.

The striking elongated appearance of the valley tends to suggest some kind of structural control for the sedimentary area and has led to a number of propositions on its origin (Fig.1 & 2)

It has been generally accepted that the Benue valley has a kind of rift structure due to major faults along it (Carter et al., 1963,) (Cratchley and Jones, 1965). Due to the emergence of the spreading sea floor and plate Tectonics hypotheses, Burke, Dessauvagie and Whiteman came up with a new theory for the origin of the valley. The Benue rift first opened in the cretaceous, as a result of spreading of a crustal ridge in the region of the present valley. This spreading according to Burke and others seized by late cretaceous and then was followed by a choosing episode of the North Atlantic and South Atlantic African plates in the Santonian. The resultant differential

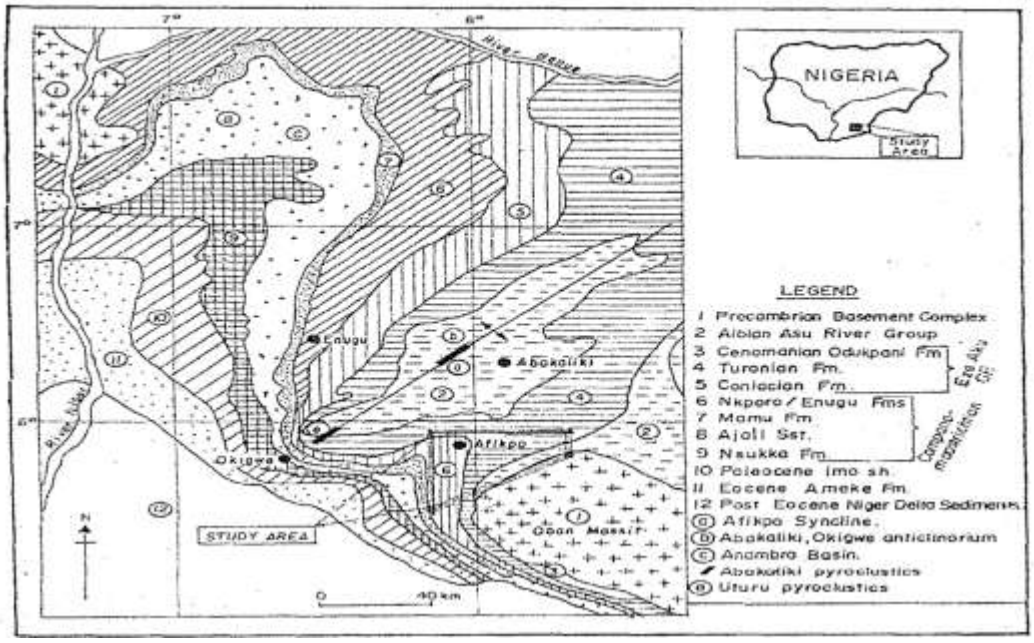


Fig 1: Geologic map of Southern Benue trough showing the study

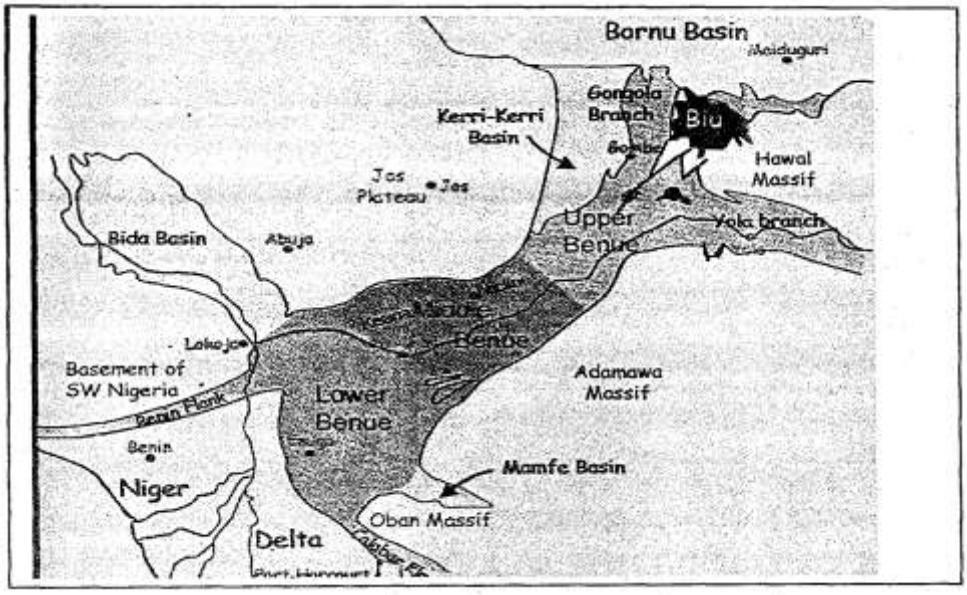


Fig 2: Showing geological units of the Benue Trough

motion of the two parts of the African plate, in their view, caused the Santonian folds and gave them their unique parallel and sub-parallel structure along the valley.

Ridges of sandstones, and plains and valleys of shale's form prominent and extensive topographic features in the study area.

Sandstones and shales are very important constituents of sedimentary processes and are therefore very crucial in the understanding of stratification history of their environments of deposition. The Southern end of the lower Benne Trough is hidden by the Tertiary Niger Delta. There are two main structural domains in the lower Benue Trough. The Arambra domain or Anambra Syncline and the Abakaliki domain or Abakaliki. Anticlinorium formed by the oldest Cretaceous sediments. (See Fig.1 & 2). Two minor structures are located in the south-eastern part of the Abakaliki domain. The Afikpo syncline parallel is the main structural directions, and the Mamfe basin. The Northern part of the Anambra domain is connected with the NW-SE trending Bida basin.

The present work is thus aimed at assessing and ascertaining structural development in the Benue Trough along with the relationship of the igneous activities and sedimentation deposition as compiled by several published reports.

Location and Accessibility

The study locations are all-along the Port-Harcourt-Okigwe Highway and Uturu-Afikpo road. They can be accessible by car or foot.

Accessibility to outcrops where made possible by minor roads and footpaths.

LITERATURE REVIEW

Several workers have worked on different localities within the basement complex. Such workers include Simpson (1965), Hoque (1980), Amajor et al (1988), Beka and Ukaegbu (2006), Ukaegbu (2008), Ukaegbu et al. (2008) among others.

According to Simpson (1955) and Reyment (1965), four lithologic units of Cretaceous ages have been recognized in Uturu with the marine shale of the Asu River Group forming the oldest unit and the Ajali Sandstone, the youngest unit.

The Santonian tectonism appears to have been accompanied by development of major faults and spates of volcanic activities (Hoque, 1980). Among the products of the volcanic

activities are pyroclastics, which are associated with the Cretaceous sedimentary series where the Nkporo shale oversteps the Asu River Group uncomformably.

Earlier workers relate the origin of the Benne Trough to the separation of South American continent for the African continent in early Cretaceous (Burke et al, (1971) and Wright (1981). Many scholars believe that South America finally separated from African in Santonian times and that the high level tectonic activities that occurred in Santonian times may be related to the separation of these two continents (Wright, 1988, 1972, Burke et al. 1971,

Nwachukwu, 1972, Hoque, 1980).

The swinging back of Africa due to the final separation from South America formed compression zones which may been responsible for the intense folding, faulting and volcanism in the Benue Trough, during the Santonian times (Ekwueme, 1994). Burke and Whiteman (1973) believed that the magmatism in the Benue Trough was andesite due to sea floor spreading.

The basaltic mineral composition of mainly pyroxene, plagioclase and melilite, and the dominance of fine to glassy texture and eruption along the axis of the Abakaliki anticlinorium suggest deep-seated source, which exploited the fissures created by the Cenomanian or Santonian tectonism resulting from separation of South America from Africa in the Crateceous times (Beka and Ukaegbu, 2016). The interactions of these two continents may have resulted to fluid accumulation in the axis of their stress field along the Abakaliki Anticlinorium, giving rise to expensive eruption of the magma from beneath. Thus, the pyroclastics appear to be products of widespread tectonism, which accompanied the separation of South America from Africa.

Comparing the Geologic age of the formation since the Azu River Group (Albian) is older than the pyroclastics as supported by inclusions its fragments in the pyrocastics and, on the other hand, the pyroclastics are older than the overlying Nkporo shale (Campco – Maastrichtian), then the pyroclastics were emplaced between the Albian and Campanian times. However, because there were two tectonic episodes between the Albian and Campanian times (Reyment, 1965, Nwachukwu, 1972, Uzuakpunwa, 1974, Olade, 1975), the eruption would have taken place during one of these two events (Fig.4)

Ukaegbu (2008) reflected on the stratigraphic relationship between the pyroclastics and the surrounding sedimentary units. He ascertained that the pyroclastics erupted after the deposition of Azu River Group shale (mid – Albian) but terminated before the deposition of the Nkporo shales. This corresponds to period between Cenomanian and Santonian and suggests a link to the tectonic events that post-dated the separation of South America from Africa.

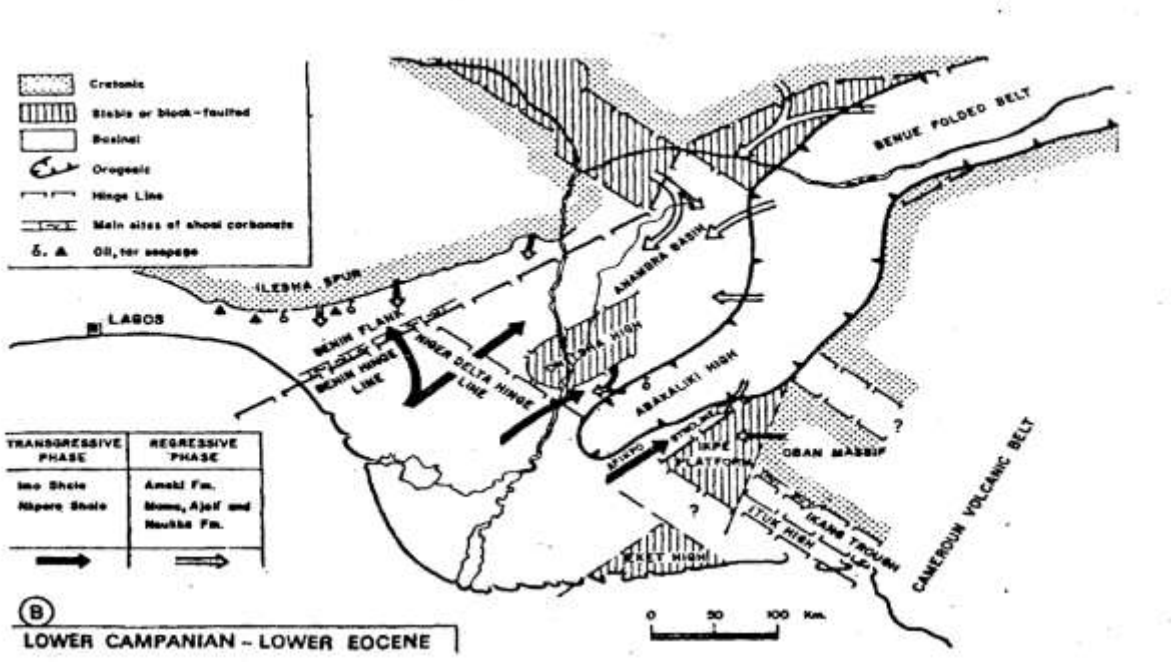


Fig. 3: Tectonic map of South-Eastern Nigeria during the Campanian to Eocene (adapted from Murat, 1970)

Murat (1972) was of the view that the Eze-Aku shale shows deposition of marine condition in a tectonically controlled basin (the Abakaliki Trough). He believed that sandstone deposits mark a period of regression, while the shale deposit indicates a period of transgression (Fig. 3)

In the Afikpo Basin (Fig 1), three main cretaceous lithostraphic units have been recognized, namely: The Azu Rivers Group, the

Eze – Aku Group and the post – Santonian proto – Niger Delta successions (Odigi, 2007). The area consists of some parallel low and high anticlines and synclinal structures that show outcrop.

AIM AND SCOPE of PRESENT STUDY

AIM:

The aim of the present field work is to study the depositional characteristics of formations within Afikpo basin and its relationship to lower Benue Trough. The field work also aims at giving graduate students opportunity to learn more about geologic investigations in the field, mapping procedures, minerals and work identification.

FIELD EQUIPMENTS:

The field equipments that are used during geologic field trip are:

- ✓ Compass Clinometers
- ✓ Hand lens
- ✓ Base map
- ✓ Hammer
- ✓ Measuring tape
- ✓ Photographic camera
- ✓ Sample bag
- ✓ Hard cover notebook

FIELD MAPPING PARAMETERS

The following are the parameters used in mapping the outcrops.

1. Dip: It is measured with the compass clinometers.

2. Strike: This is also measured with the clinometers.

Others are:

3. Direction of dip

4. General trend of outcrop

5. Orientation of outcrop

METHOD OF STUDY

The study was carried out by the use off physical or megascopic description and identification of outcrops, structural features and minerals. Measurement of structural features were done with the aid of tapes and compass clinometers while samples were collected with hammers and stored in sample bags photographs of outcrop were also taken.

Stratigraphy

Azu River Group

This is a sequence of marine shales occupying the core of the Abakaliki Anticlinorium. It has a thickness of about 6000ft, embedded with shale and micaceous sandstone and the shales are deeply weathered and contain radiolarian echinoids, pelecypods and gastropods. The age is Albian. The Azu river group with others formations found within the study area can be correlated with the sedimentary basins of other regions. (Table 1)

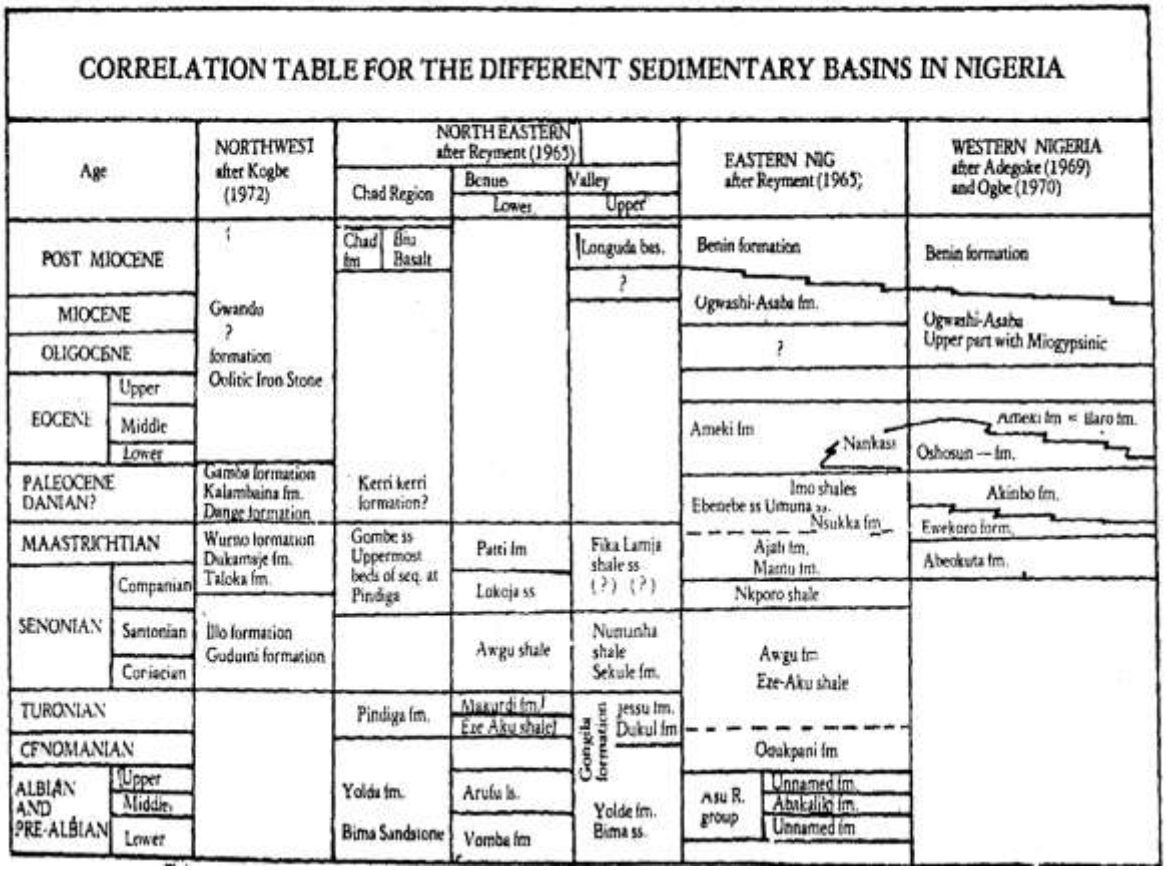
Eze-Aku Shale Group

The Eze-Aku shale group consists of hard grey to black shale having thick flaggy calcareous and non-calcareous shale. The Eze-Aku formation represents a shallow water deposit. The fossits consists of mainly pelecypods, gastropods, echinoids, etc, which indicates basal turonian age.

Agwu Shale

The Agwu Shale overlies the Eze Aku Shale conformably and is between Agwu and Ndeaboh in southern eastern Nigeria.

Table 1: correlation table for the different sedimentary basins in nigeria



Nkporo/Enugu Shale and Owelli sandstone:

Nkporo Shale of late Campanian age is the basal facies of the late Cretaceous sedimentary cycle in the Anambra basin.

Enugu shales consist mainly of carbonaceous shales and coals within the upper half deposited in lower flood plain and swampy environments. The sediments are normally associated with siderites and pyrites which are early diagenetic minerals.

The Owelli sandstone is the major sand member of the Enugu Shale formation and forms and elongate shoestring sand body elongated to the NE defining a meander belt of a fluvial/distributaries channel system.

Mamu formation

The Mamu formation overlies the upper Campanian lateral facies associations described above. The age ranges from lower to middle Maastrichtian from south to north. Depositional environments include distributaries/estuarine channels, barrier foot, swamp and tidal flats.

The Ajali sandstones

The Ajali sandstones consist of mineralogically much matured, medium to coarse grained, moderately well sorted quarts grains and intercalation of thin laterally extensive clay beds of normally less than 1m. The formation thickness is about 300m extending across the entire basin and unto the middle Niger basin and slightly diachronous, ranging from middle to late Maastrichtian from south to north.

Nsukka Formation

It is also refers to as upper Coal Measure and lies conformably on the Ajali sandstone. It occurs from the north of Awka to the upper Ankpa sub-basin, with lithology of mainly shales, siltstone, sands and coals and lateritic cover. Age of the formation is from upper Maastrichtian to Devonian. The depositional environment is similar in many respects to the Mamu formation (Lower coal measures) consisting of transitional/shoreline mudflats and swamps, deposited during a largely regressive phase of sea level changes.

GEOLOGIC FEATURES OF LOCATION

Stop I: The first stop was at the bank of Imo River. This is a major river channel depositing recent sediment. Its global position station is $N4^{0}$ 53^{1} and E 7^{0} 8^{1}. It has a lower gradient indicating laminar flow.

Stop 2: The second stop was at Ubakala environ. This marks the boundary between the Niger Delta and the lower Benue trough. Although, the boundary is not sharp. The geologic feature observed was ironstone indicating a reducing environment.

Stop 3 (Location I): This location is Ogwashi-Asaba formation which lies between latitude 5^{0} 30^{11} and longitude 7^{0} 27^{11}. It is mainly of kaolin deposit with presence of lignite. The significant

of lignite in an environment indicate a plant origin which means they are flood plain deposits. There is presence of bauxite observed at this location.

Stop 4 (Location 2) This location lies between latitude 5^0 33' 57" and longitude $7^0$26'6". It is associated with Ameki formation. It has cross bedded sandstone with the presence of skolithos. The grains are fining upward which indicate transgressive event. The grains are also bioturbated due to the occurrence of skolithos. The sandstone's coarse grain size indicates the high energy of deposition. There is intercalation of sand and clay deposit. The shale and ironstone were observed as well. The presence of ironstone shows an erosion surface in past times.

Stop 5 (Location 3) This is the only exposure along the Enugu/Port Harcourt Express-road. Its rock type is shale. It shows fissility and dips southward. The shale is associated with Imo Shale. The strike and dip obtained respectively S159^{0}E and N6^0 E.

Stop 6 (Location 4) This location is associated with Usukka formation. It lies between latitude $5^0$38' 52" and longitude 7^0 25" 25" and its elevation is 10m. The upper part of this formation is made up of sandstone. The basal part around Enugu axis contains coal seams, making them upper coal measures. The age is Maastrichtian.

Stop 7 (Location 5) This is Ameki formation and lies between latitude $5^0$39' 37" and longitude 7^0 25' 17" with elevation about 87m. This location shows the Ameki formation laying unconformable on the Nsukka formation. The sandstones' grain sizes are well sorted which indicate a laminar deposit.

LOCATION 6

This is Ajali sandstone formation and lies between latitude 5^0 51' 3.2" and longitude 7^0 20' 9.4'' with elevation of about 150m. The Ajali sandstone is a friable type with extensive cross beds. The sandstone unit shows a coarsening upward sequence indicating a typical regressive phase. There is intercalation of clay drapes. The cross bed shows the pale current direction. Clay drape indicates terminal end of the deposition.

LOCATION 7

This is Mamu Formation. It lies between latitude 15^0 51' 52" and longitude 7^0 21' 28" with elevation of 223m. It shows a sharp contact between the Manu and Ajali sandstone. The shale observed shows high degree of fissility. The shale present grades into coal at the base (Lower Coal Measures).

LOCATION 8

This location is situation at Leru and lies between latitude 5^0 55' 01", and longitude 7^0 24**' 35".** Five formation are formed within this environ. They are

- ✓ Nsukka formation
- ✓ Ajali Sandstone
- ✓ Mamu Formation
- ✓ Nkporo Formation
- ✓ Eze –Aku Formation

LOCATION 9

It lies between latitude 5^0 56' 10" and longitude 7^0 25' 22" with elevation of about 145m. This location is part of Azu Rivers Group. It is situated at Lekwesi. Intrusion embedded into the Azu River Group was observed (Basalt will Dolerite)

LOCATION 10

This location is situated at Lokpanta and lies between latitude 5^0 58' 39.4" and longitude 7^0 27' 38.2" This location is associated with Eze-Aku formation. This is the terminal of the Abakaliki anticlinorium. There is presence of trace fossil which termed the formation to be marine origin.

LOCATION 11

The location is associated with Ajali sandstone situated at Uturu, Abia State. If lies between latitude 5^0 49' 44.6" and longitude 7^0 24' 3.3" with elevation of about 218m.

The exposure is mostly of sandstone with cross beds and skolithos burrows. The formation has intercalation of fine- medium, fine-course, grains as a result of high to low energy

regime. There is presence of clay drapes and ironstone concretion separating one sandstone body from another. This is an indication of end of a particular deposition cycle and reduction in water current or tidal current depositing the sand body.

LOCATION 12

This location can be associated with Ajali sandstone situated at Uturu environ, Abia State. The outcrop is located few metres away from location 11. This is an outcrop exposing the Mamu formation being overlain by the Ajali sandstone.

LOCATION 13

This is Setraco Quarry Mining Industry and lies between latitude 5^0 51' 31: and longitude 7^0 25' 11". The outcrop is located at the Setraco quarry mining site. It exposes the intrusion of Nkporo Shales. The contact between the intrusion and the Nkporo shales formed contact metamorphic rock called hornfel. In most places during the intrusion, the area contains shallow water which forms evaporites.

LOCATION 14

This is associated with Eze-aku River at Ugwueke, Abia State. It lies between latitude 5^0 54' 38.2" and longitude 7^0 42' 42.1". The location is where the first name of Eze-Aku formation was derived.

LOCATION 15

This is Eze-Aku sandstone and lies between latitude 5^0 53' 44.6" and longitude 7^0 54' 52. 6" with elevation about of 66m. The formation has both fine and coarse grain sandstone. This is an indication of high energy environment typical of coarser grain size of sandstone and low energy environment due to fine grain size. Eze-Aku group is Tertian in age.

LOCATION 16

This is Afikpo sandstone and lies between latitude 5^0 53' 5.4" and longitude 7^0 55' 5.4'' with elevation of about 94m. The following were observed in the location:

- Presence of cross beds at the lower side of the formation.
- Tidal bundles were located on an outcrop in minutes form.
- Laminar deposit can be linked to the Afikpo sandstone.

LOCATION 17

This outcrop exposed by road cut situated at Afikpo junction, Ebonyi State. It lies between latitude 5^0 53' 37.8" and longitude 7^0 55' 18.7" with the elevation of about 100m. This location can be termed as cyclic sedimentation because coarsening upward sequence of sand grains that are fine to coarse grains. This denotes the alternation of high to low energy level.

LOCATION 18

This is part of Afikpo sandstone formation which lies between latitude 5^0 53' and longitude 7^0 56' with elevation of 159m. The sandstone' grain size managing from fine course grain size along with ironstone and clay. There is presence of trace fossil e.g skolithos. The ironstone observed at the middle part of the outcrop shows that nearer the parent rock. As we approached up the peak or cliff, coarser sandstones' grains were observed and this indicates that we are getting closer to the original rock. Clay (bauxite) observed at the middle of the ridge shows that the source rock is closer.

LOCATION 19

This outcrop is situated at Eze-Aku valley along Abakaliki Road. It lies between latitude 5^0 89' and longitude 7^0 30'. This is part of Eze-Aku formation consisting sandstone with medium to coarse grain size. It dips due east and strike direction is due to south-west. Its strike amount is S 240^0 W while dip is S 40^0 E.

LOCATION 20

This is Asu River Group situated in Ebonyi State. It lies between latitude 5^0 58' 15'' and longitude 7^0 58' 56''. The Asu River Shale observed has been deformed due to the orientation of strike and dip. Its strike amount and direction is S 64^0 W while its dip is N 10^0 E.

METAMORPHIC GEOLOGY

The term, metamorphism is derived from the Greek, word, meta-morphe, which means change of form: metamorphism can be defined as the sum total of all processes that cause changes in mineral composition, texture and structure of rocks below the zone of sedimentary activities, without passing a fluid phase. (Ukaegbu, 2008).

In the map area, hornfel is significantly formed the contact between the igneous intrusion and Nkporo shales.

HORNFEL Hornfels is a very fine –grained, nonfoliated, metamorphic rock whose parent rock is most commonly shale or basalt. If it forms from shale, characteristically only microscopically visible micas formed from the shale's clay minerals. Sometimes, a few minerals grow large enough to be seen with the naked eye; these are minerals that are especially capable of crystallizing under the particular temperature attained during metamorphism, if hornfels forms from basalt, amphibole, rather than mica, is the predominant fine-grained mineral produced (Charles et al., 2010)

Hornfel observed at Setraco Quarry formed from Nkporo shale's through the process of contact metamorphism.

IGNEOUS ACTIVITY Igneous rocks are named based on their texture and chemical composition. The texture of an igneous rock gives you information on where that rock formed, whether beneath the surface as an intrusive igneous rock or on the surface as an extrusive igneous rock.

The chemistry of an igneous rock tells us about the origin of the margin and how it evolved before finally solidifying. Because margin can either cool slowly in a magma chamber, forming an intrusive rock, or cool rapidly on the surface, forming an extrusive rock, one name is give to the coarse –grained intrusive version and another to the fine-grained extrusive version.

In the map area various types of igneous rock were identified. They are:

(1) Syenite: This is an intermediate igneous rock found at the Mimico quarry. Its grain size is medium- coarse.

(2) Dolerite: It is shallow-seated igneous rock. This a basic rock whereby there is little or no quartz present. Its grain size is fine-medium. The level of intrusion hyperbyssal.

(3) Gabbro: This is also a basic igneous rock with coarse grain size. Its level of intrusive is plutonic. This deep seated igneous rock and are form by very slow cooling. Both plutonic and hyperbyssal rocks are referred to as intrusive rocks.

(4) Basalt: This is a basic igneous rock which is of fine grain size. Its level of intrusion is extrusive forming lava rock.

(5) Quartz Veins: Most of them occurs as in fill of fractures in the granite rock.

ECONOMIC GEOLOGY AND HYDROGEOLOGY

The study areas have been affected by igneous and metamorphic processes as well as the deposition of the cretaceous sediments. The mineralization accompanying igneous and metamorphic activities as well as the sedimentary processes has given the area a high economic prospect. Sand from Ajali sandstone can be quarried and used for building. It is also used in glass industries.Quarry of gravel, pebbles, etc from granite rock can be used for road construction and building, etc Kaolin is used for producing paint, and hence it will be required by paint industries.

WATER RESOURCES

There are network of streams which acts as source of water for both domestic and agricultural purposes.

GEOLOGIC HISTORY OF THE AREA

The Afikpo basin (fig 2) became the centre of major deposition following the Santonian folding in South-Eastern, Nigeria. Compressional uplift of the lower Benue Trough succession (Albian to Coniacian) along NE-SW axis was accompanied by tectonic in version and down warping of the Afikpo platform. Estimates of total sediment thickness in the Afikpo Basin from gravity measurements range from 3-6km, out of which between 3 & 5km were deposited during the late cretaceous sedimentation phase (upper Campanian to Maastrichtian).

Five tectonic elements characterize the region during this sedimentation phase. These include the Abakaliki Anticlinorium to the east the Onitsha and Ankpa subbasins separated by the Nsukka High, and the Afikpo syncline to the SE. The two sub basins of the Anambra and

Afikpo experienced different subsidence rates resulting in greater sediments accumulation in southern area. This differential sedimentation pattern also reflects differences in the extents of the eustatic sea level rise which began in early Maastrichtian times and culminated in the Paleocene. Thus, eustacy and subsidence controlled the basin volumes to be in filled (i.e relative sea level), the distribution of the sedimentary facies and the depositional characteristics of each formational unit within the succession. The lower coal measures (Mamu Formation) clearly demonstrate this in its depositional pattern with changes in relative sea level.

These characteristics of the basin fill have been used to reconstruct a sequence stratigraphic framework for the Afikpo basin. Eight formational units have been defined from the basin (Upper Campanian –Eocene) some of which are lateral equivalents (Fig. 3) Together these constitute the largest order of cyclic ties which can be recognized (maga-tectonic phases) from indirect subsurface ie from seismic.

The low stand assemblages which dominate much of the total succession include the Nkporo and Enugu formation, the Owelli and Afikpo sandstones, Mamu formations (lower coal measures) and the Ajali sandstone (false bedded sandstone). The acme of the transgression corresponding to the maximum flooding surface is the Paleocene Imo formation which is restricted to the southern Onitsha sub basin were subsidence rate was higher.

SUMMARY AND CONCLUSION

Geologic mapping project especially in such an area with heterogeneous geology should be a necessity to all graduate and under-graduate students as it will serve as a tool for better field practices.

From the field relationship, the cretaceous tectono-sedimentary evolutions of the Afikpo-domains are presented through six stages.

The first (A) stage involved the breaking of Afro-Brazilian plate at the triple junction.

The second (B), Benue Trough developed as a graben between the on-shore extensions of oceanic fracture zones.

The third (C) stage encompassed the formation of the Benue Trough as a rifted depression in response to a regional stress field due to active or passive lithospheric extension.

The fourth (D) stage involved minor folding in parts of the Trough (Late Cenomanian); renewed transgression and regression and the deposition of the late Cenomanian-Coniacian rocks (Eze-Aku Group).

The fifth (E) stage involved compressional folding, tectonic inversion, faulting, and alkaline-sbakaline magmatism (including volcanic bills, dykes, Afikpo dokerites, dolerites-micrograbbros etc). the folding resulted into the formation of the Afikpo Basin. The deformed and uplifted (Benue-Abakaliki) trough became a positive element to shed sediments, the depressed platforms Afikpo became the major depocenters.

The sixth (F) stage was characterized by tectonic inversion, deformation, faulting and magmatism of post- sentonian sediments including the Afikpo microgabbros marking the termination of cretaceous sedimentation and the evolution of the cenozonic Niger Delta

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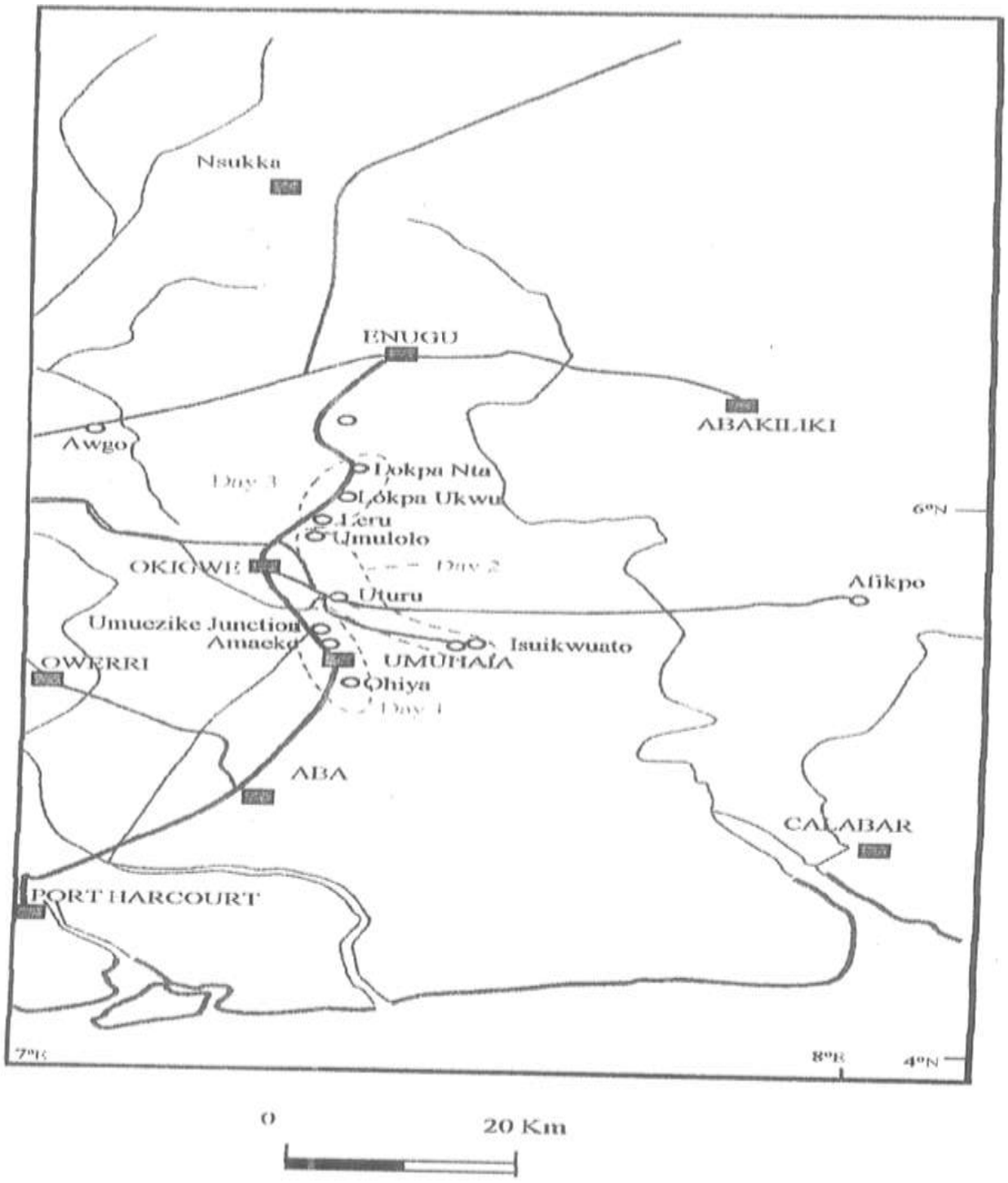
LOCATION MAP OF THE STUDY AREA



PHOTOGRAPHIC PLATES OF SITE LOCATIONS

Fig. 4: showing kaolin in the study area

Fig.5: showing intercalation of ironstone and clay

Fig. 6: showing nkporo shale

Fig. 7: Showing sandstone in the study area

Fig. 8: showing cross bed and skolithos burrow in sandstone body

Fig. 9: showing igneous intrusion (dolerite and gabbro)

Fig.10: showing azu-river shale that had undergone several deformation episodes

Fig. 11: showing igneous rock (Syenite) in the study area