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Full Length Research Paper

Structural controls of Pb-Zn mineralization of Enyigba district, Abakaliki, Southeastern Nigeria

Obarezi J. E.* and Nwosu J. I.

Department of Geology, Faculty of Physical Sciences University of Port Harcourt, East West Road P.M.B. 5323 Choba, Rivers State, Nigeria.

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The lead-zinc deposit of Enyigba and its environs are localized in the cretaceous sedimentary rocks of the Albian Asu River Group in the Lower Benue Trough, Southeastern Nigeria. The Albian Asu River Group is made up of shale, siltstone, sandstone and limestone. The deposits were formed epigenetically through the crystallization of hydrothermal solutions and are localized within the fractures, hence the need to study the trend of the fractures in the rock unit where the mineral deposits are being hosted. In order to study the fractures, two units of the formation were identified and designated as units A and B. The ore field extends to about 3.7 km strike length with an average width of 5 m. From the detailed field mapping, the identified structures that control the mineralization are fold, fault and joint/fractures in which the fractures predominate. The total measured identified fractures is 503 in number and are represented in rose diagram, histogram and stereographic net which shows that they trend NW-SE and N-S directions, and dip SW-NE direction.

Key words: Mineralization, stereographic net, shale, siltstone, sandstone, limestone, deposits.

INTRODUCTION

Enyigba district is located within Abakaliki and Ikwo Local Government Areas of Ebonyi State. The lead-zinc lode in the Enyigba district comprises of Enyigba, Ameri, Echara and Ameka (Figure1). These lodes are located within the Abakaliki anticlinorium in the Lower 4 Benue Trough. The occurrences of lead-zinc in the study area are associated with saline water intrusion in the sedimentary basin. Mineralization occurs along a narrow belt of approximately 30 to 50 km wide and extends for about 560 to 600 km length of the Benue trough in Adamawa, Taraba, Bauchi, Plateau, Nasarawa, Benue and Ebonyi States (Figure 2) (Umar et al., 2011; Cratchley and Jones, 1965; Farrington, 1952). Orazulike (1994) noted the usage of galena as a cosmetic and fishing net weight by the native of Enyigba before the advent of the Britons. Farrington (1952) recorded that the first production of the lead-zinc ore from the mine was in 1925 as systematic mining started shortly before the world war. But mining ceased at the onset of the civil war. Nwachukwu (1972), Orajaka (1965, 1972), Olade (1975, 1976) and Farrington (1952) noted that mineralization is hydrothermal and epigenetic in origin which formed at mesothermal conditions. Mineralization is restricted to the Albian Asu River Group sediment, and the mineralizing hydrothermal solutions are association with tertiary and recent volcanism. Mineralization occurs at the end of Santonian-Coniancian folding, meaning that, it is pre-Turonian in age. Mineralization is structurally controlled and localized within the fracture zone. This paper presents the result of the detailed field mapping of Enyigba district, revealing the

*Corresponding author. E-mail: peculiar_j@yahoo.com. Tel: 07031318991.

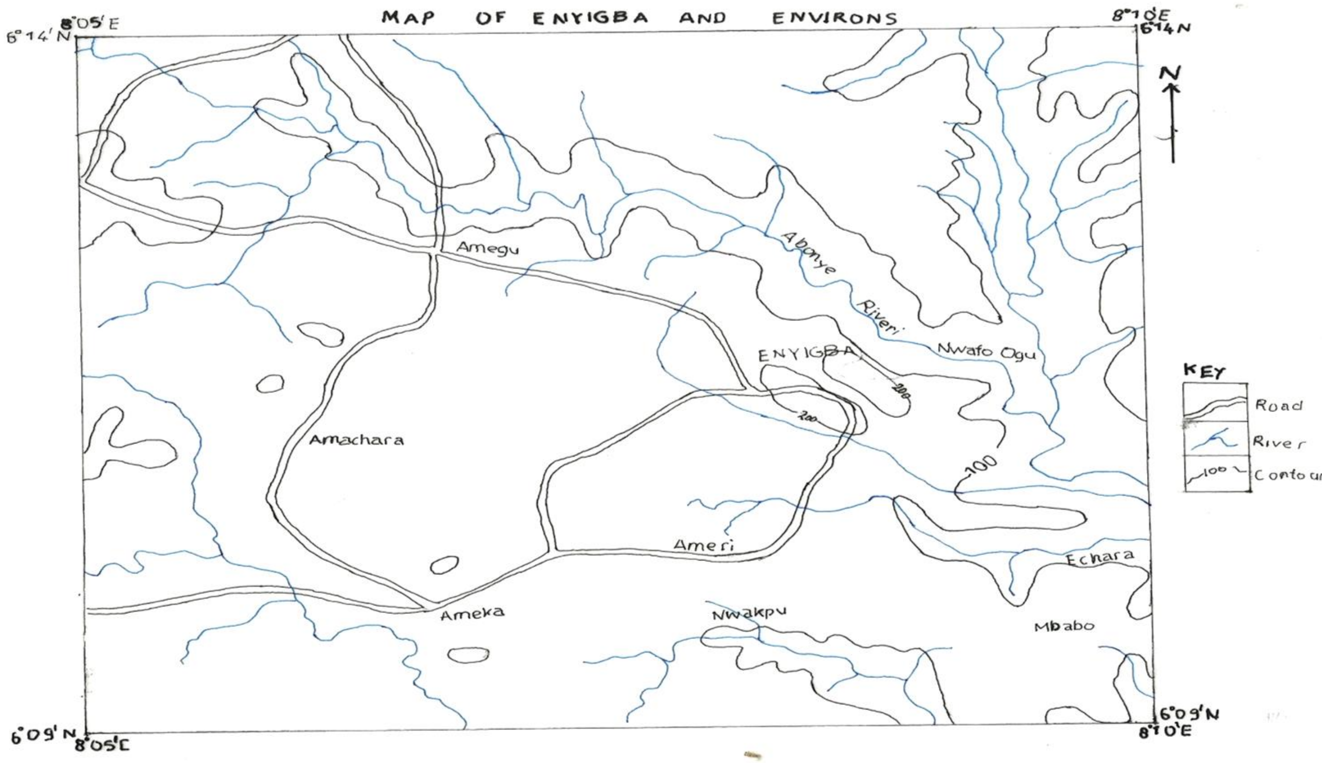


Figure 1. Topographic map of the study area (Scale - 1:25000).

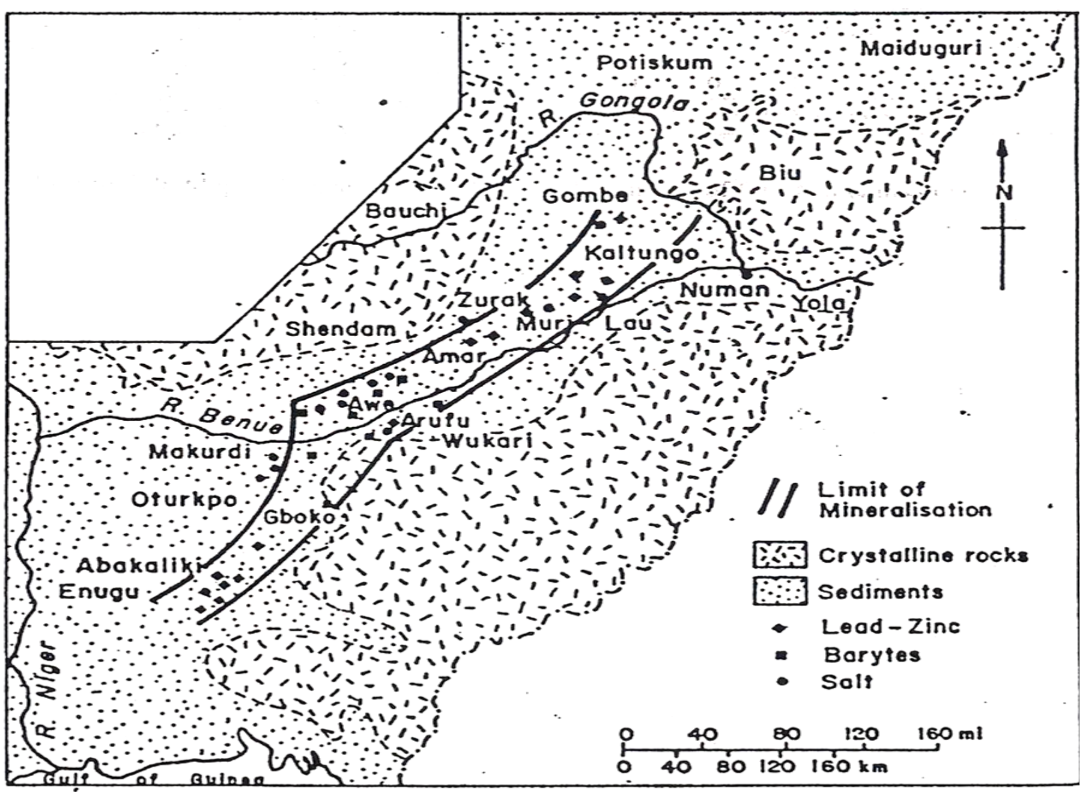


Figure 2. Map of Benue Trough Showing Locations of Ore Mineralization (Cratheley and Jones,1965).

prominent structures, evolution and its trend which control the mineralization.

REVIEW OF GEOLOGIC SETTING AND ORIGIN OF MINERALIZATION

The study area is located within Benue Trough. According to King (1950), Farrington (1952), Nwachukwu (1972), Murate (1970) and Jones (1965) noted that Benue Trough originated as a failed arm at the time of the opening of the South Atlantic Ocean during the separation of the African plate and the South American plate. Benue Trough is defined as an intercontinental cretaceous basin about 1000 km in length stretching in NE-SW direction and resting unconformably upon the Precambrian basement. Based on the trough corresponding geological and geomorphologic partition, it is subdivided into the upper, middle and lower region. The lower which is the southern Benue Trough, is the southwestern part of the Benue depression (Carter et al., 1963; Reyment, 1965). It comprises of the Abakaliki Anticlinorium, Afikpo Synclinorium to the east and Anambra Basin to the west. The first marine transgressive phase in the middle to late Albian resulted in the deposition of the Asu River Group sediment. Its lithostratigrahic pile includes sandstone, siltstone, shale and limestone occurrences, Reyment (1965). The occurrence of lead-zinc deposit in SE Nigeria is dominantly restricted to the Albian sediments, Nwachukwu (1972). Wright (1968) noted that the lodes were developed at the end of Santonian folding.

Mineralization is structurally controlled and is localized in fracture zones as gently dipping veins. Origin of lead-zinc deposit has so far not been well established; but on the basis of vein morphology and relationship to fracture, its origin maybe classified as a saline water intrusion. Vein deposits are considered as being epigenetic in origin. But the most controversies of the genesis are the natural sources of their ore forming fluids and mode of their transportation.

Farrington (1952), suggest that the mineralizing solution were derived from intrusive rocks. Orajaka (1972) and Reyment (1965) postulated a volcanic source for the ore-forming fluids, due to the volcanic activity in Abakaliki area based on the close proximity of few of the deposits. However there is no presence of igneous rocks about 21 km radius to the mineralized localities. Nevertheless, Olade (1976) and Grant (1971) suggested that lead-zinc mineralization in the Benue Trough is analogous to the Mississippi valley-type, and that ore forming fluids were connate brines, circulating under the influence of a deeper geothermal reservoir, as geothermal heat may be generated by plume activity which initiates a circulation of hot diagenetic pore fluid (connate water) or circulating through the sediments and evaporates via leaching of Na, K, and Cl. Such elements can extract the ore metals from clays and K-feldspars derived from the basement complex with Pb, Zn, Ag, Cu and Cd.

The above statement may be true because out of the 50 locations mapped, no intrusive or extrusive rocks were encountered; but the wall rock of the fracture system hosting the mineralization were hard with a minimal width to the adjacent rock. Combination of connate brines and meteoric brine can penetrate along fractures to deep levels in the crust and is, therefore, involved in widespread circulation throughout the crustal regime, and responsible for the formation of different types of hydrothermal ore deposits, especially those characterized by relatively low temperature transport and precipitation. More so, connate brine is either meteoric or sea water, but a formational water expelled as sediments is buried, compacted and litified. Such fluids can move through the fractures in the formation precipitating the ore deposits. Nwachukwu (1975), Olade and Morton (1980) resolved much of the controversies surrounding the origin through laboratory studies of fluid inclusions, sulfur and lead isotopes. They found out that the mineralization of lead-zinc ore were deposited by saline, low temperature ore fluids ranging from 100 to 176°C with a density greater than 1.0 g/cc^3. Thus, the most probable mode of origin is leaching of metals from sediments by heated connate waters during initial rifting and igneous activity in Albian to cenomanian times. Olade (1976) concluded that the age of the mineralization is uncertain. But Farrington (1952), Olade (1976), Nwachukwu (1975), Ofoegbu (1985), and Orajaka (1972) assumed that the ore deposit occupy the fracture created by the Santonian deformation, having speculated that it is post-santonian. They suggested that mineralization was probably pre-Turonian in age.

METHOD OF MEASUREMENT

The method of study to this research work was within the available materials and data acquired. However, research started with desk study, reviewing the literature of the area and reconnaissance survey to determine the accessible routes and to familiarize with the area. The base map was grided and traverse method were employed during the detailed mapping. The traverse was taken along the main road, footpath, the stream and the river channel. The rock units were logged and interpreted. Contacts were delineated using lithologic difference. The detailed mapping includes the measurement of strikes and dip of the formation, azimuths of the fractures, descriptions of the rock unit and delineation of its contacts using lithologic difference; study of the rock type, sample collection and logging of the unit.

Strike and dip of bed were measured and carefully plotted into the map with the aid of a protractor, ruler and pencil. Azimuth of the fractures was equally measured with their dip direction and dip amount. Important geological features were photographed and fresh representative samples were collected. Geomorphologic features such as relief and drainage were noted. During the mapping, the technique adopted was the use of global positioning system, compass and traverse method in which distance between locations were estimated on the map. The mapping exercise was

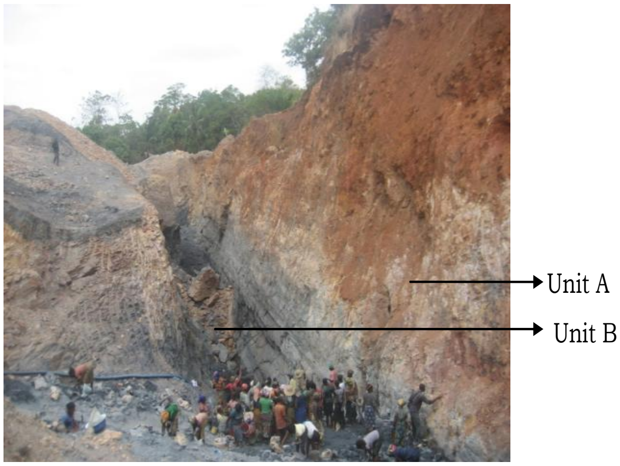
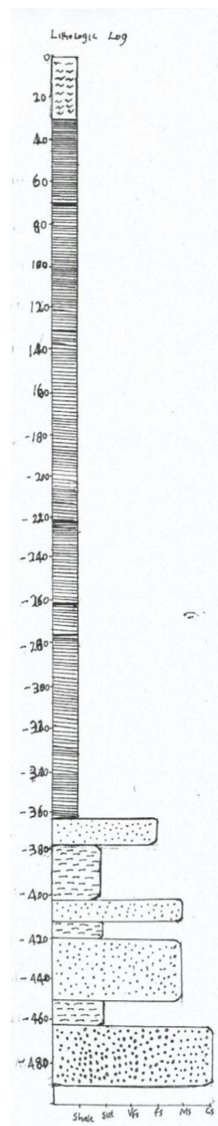


Figure 3. Picture showing the stratigraphy of the rock unit,arrow indicating the units.



DESCRIPTION	UNIT
Top lateritic ironstone	Unit B
Greyish brown to pinkish Red calcareous shale. The shale is fissile, thinly laminated and highly fractured and weathered.	
Very black to dark calcareous shale. Thinly laminated and fractured. Hosting the mineralization, very hard, compact and indurated fissle shale	Unit A
Sandstone siltstone, Fairly black to whitish in colour. Very hard.	

Figure 4. Lithostratigraphic section of the two units.

carried out with the help of the geological materials and equipments.

Meanwhile from the acquired geological and logged core data, the following were done: Rose diagram, histogram and sterographic net projection were used for structural analysis, trend identification and study of the mineralization control. Integrations of all the data and its interpretations reveal the trend and structure that controls the mineralization, mineralogy and the sequence of deformation.

STRUCTURAL ANALYSIS

From literature review, field work and core logged data, a lot of information was gathered which form a guide in the geology, structural deformation and analysis of the structures identified. During the course of this work, 50 locations were mapped and documented. A total of 645 fractures were measured across the locations within the study areas visited. However, they were grouped based on the localities as discussed below.

The lithologic unit underling the study area is mainly the shales of the Asu River Group and the Abakaliki shale formation (Reyment, 1965). Based on their lithologic characteristics, structures and stratigraphic positions, they were classified into two units designating unit A and unit B as shown in Figures 3 and 4. Unit A is a dark to black shale while unit B comprises of grayish brown, redish to pinkish weathered but bleached shale. The weathering and bleaching of the shale accounts for their division into two different units. Figure 5 shows the geologic map of the study area.

Enyigba

Enyigba is a mineralized zone. Outcrop in this locality are highly fractured. The mapped identified fractures were measured in the locations visited within this locality. The outcrop bed strikes NE-SW and dips NW with average dip amount of 24°. Enyigba outcrops are made up of one limb of anticlinal fold in the NW direction (Figure 11). Enyigba rose diagram and histogram (Figures 7a, b and c) shows that the measured fracture trends NW-SE direction with predominant trend of N45°W and the stereographic net projection indicates that the fractures dips steeply at NE-SW direction in angle 80-85°. However, the main fracture that controls the mineralization, trends N20° W (Figure 6). It has a strike length of 600 m and 3.64 m width. Enyigba host more galena than sphalerite, but the galena are of low grade compared to Ameri deposit.

Ameri

Ameri is one of the localities in Enyigba district that is a mineralized zone. Its minerals are mainly a high grade of sphalerite. Outcrop in this locality was a moderately to steeply folded. Fractures were not observed/identified at the exposed outcrop, but were seen controlling the mineralization as exposed by the core log section (Figure 8), which also reveals fault and folds. The bed strikes N20° E - N57° E having a dip direction of South-East as one of the limb of the anticlinal fold (Figure 11) with dip ranging from 9° to 31°. The fracture that controls the mineralization has trends N-S with a probably strike length of 950 m with 5.5 m width. The core log section in Figure 8 shows that the outcrop was fractured, moderately-steeply folded and also faulted. Ameri lode host more sphalerite than galena, but of a low grade than Enyigba.

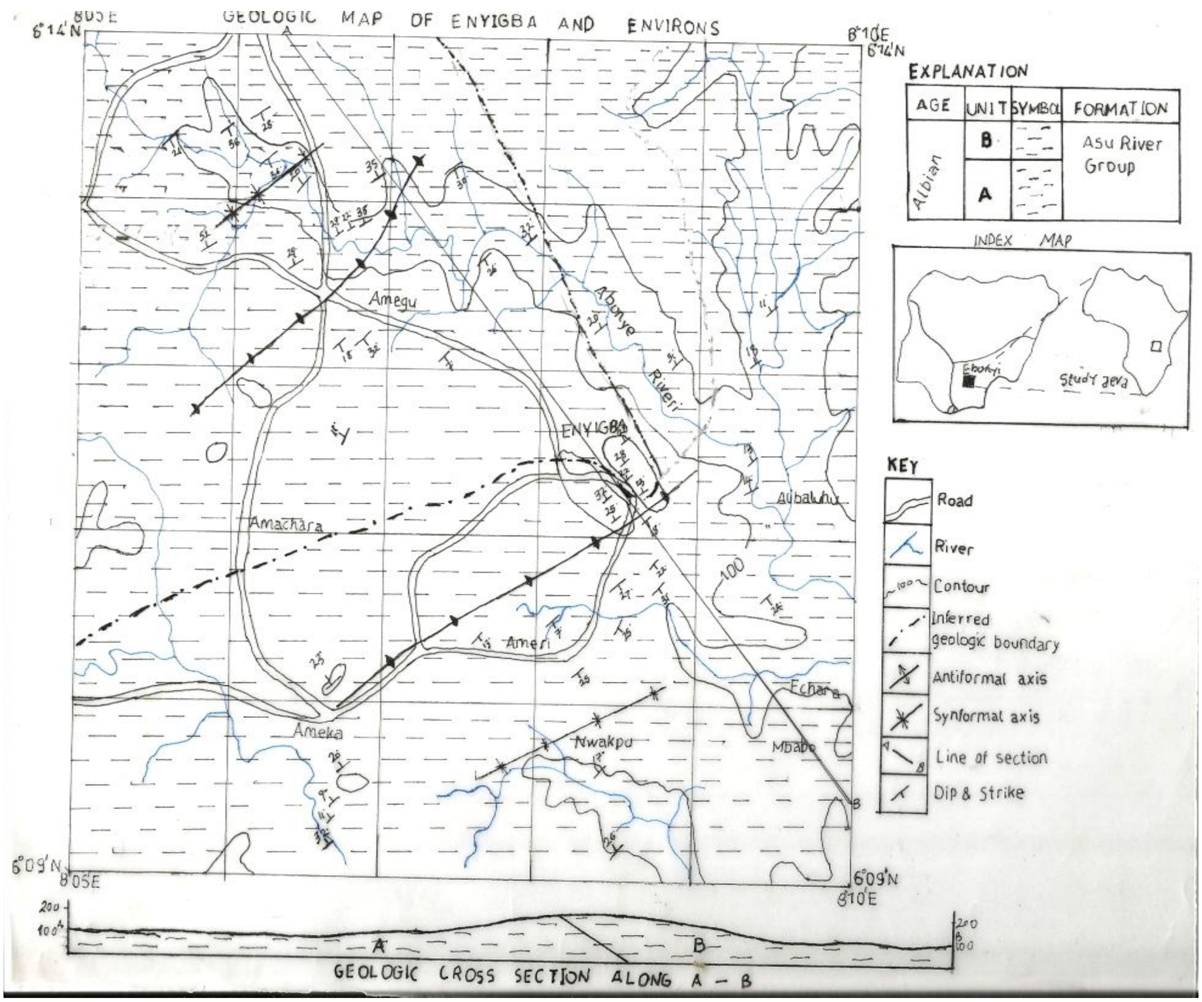
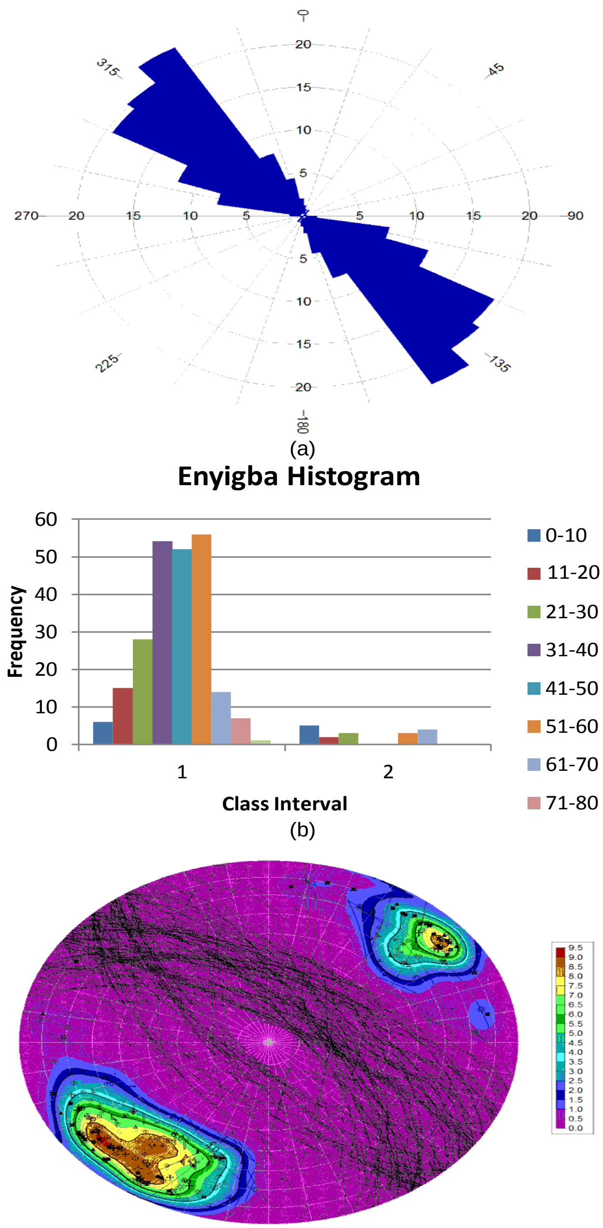


Figure 5. Geologic map of the study area.

Figure 6. Picture showing the mineralization trend at Enyigba as indicated by the arrow.



(a) (b) (c)

Figure 7. Diagram showing the trend of fractures at Enyigba. (a) Rose diagram and (b) Histogram shows that the Predominant trend of the fractures is at N45^{0}W. (c) Steronet indicates that the fracture dips NE-SW.

Echara

This locality is one of the known lodes and its minerals are of low grade. Outcrop is fractured, striking N50° E and dips in SE direction with 25° dip amount. The fractures identified were measured (Figure 9). The plot of Echara rose diagram and histogram reveals that the fracture trends NW-SE with a predominant fracture trend of S45°E. Stereographic net projection indicates NE-SW dip direction of fractures, but steeply dipping at SW direction. The fractures that controls the mineralization trends N45° W with a probably strike length of 250 m and 1.5 m width.

Ameka

Ameka is one of the known localities that host both equal mineralization of low grade. Ameka outcrop are folded, faulted and fractured. It strikes NE-SW having a dip direction of NW-SE with average dip amount of 35°. The identified fractures were measured. The plot of histogram and rose diagram shows that the fractures trend NW-SE with the predominant trend of N50°W, while stereographic net projection indicates NE-SW direction with steeper dip of 88° at the SW direction (Figure.10a, b, c). The main fracture that controls the mineralization trends N-S direction with 1800 m strike length and 5 m width. Ameka host massive deposit of the mineralization but of a shallow deposit with a low grade compared to Enyigba and Ameri. Figure 11 is the structural map of the study area.

DISCUSSION

Based on vein morphology, lead-zinc deposits are of epigenetic origin being mineralized by hydrothermal fluids (Orajaka, 1965; Mackay, 1946; Farrington, 1952; Olade, 1976). This was confirmed by the non occurrence of intrusive and extrusive rocks at the 50 locations mapped. The ore were deposited by low temperature hydrothermal fluid ranging from 100 to 176°C (Nwachukwu, 1975; Olade and Morton, 1980). Olade (1976) suggested that the mineralization is pre-Turonian in age. Lead-zinc occurrences in the study area are associated with saline water intrusion of the cretaceous calcareous sedimentary rock of the Albian Asu River Group and are hydrothermal in origin. The minerals of the ore deposit are sphalerite, galena, chalcopyrite, pyrite, cerussite, which are primary minerals. The secondary minerals are malachite, azurite, limonite and native silver. While the gangue minerals are siderite, calcite, barite, quartz, and fluorite. The lithologic unit underling the area is the shales of the Asu River Group. The shale was delineated to have two units designated as Unit A and Unit B.

Unit A: dark to black shale

This is the oldest unit underling the study area. It is very dark black calcareous carbonaceous heard shale. It is moderately to highly fractured occurring as a cross joint perpendicular to the folded axis. At Ameri, the shale is steeply folded. The shale hosts the mineralization without its occurrences at the sandstone or siltstone lithology. It contains patches to stringers of pyrite, chalcopyrite and massive deposit of galena, sphalerite, siderite, quartz and carbonate materials. The general trend of the shale is in NE-SW direction, with dip direction in NW-SE having a common dip amount of 4 to 32°. The shale is very fissile and do break along its fissility plane. It is moderately to very compact hard, and is highly to moderately fractured in some places. It is thinly laminated and it is papery in nature. Despite its fissility it is stronger than unit B and is also thicker and blocky. It has a high organic content which may have contributed to its fissility.

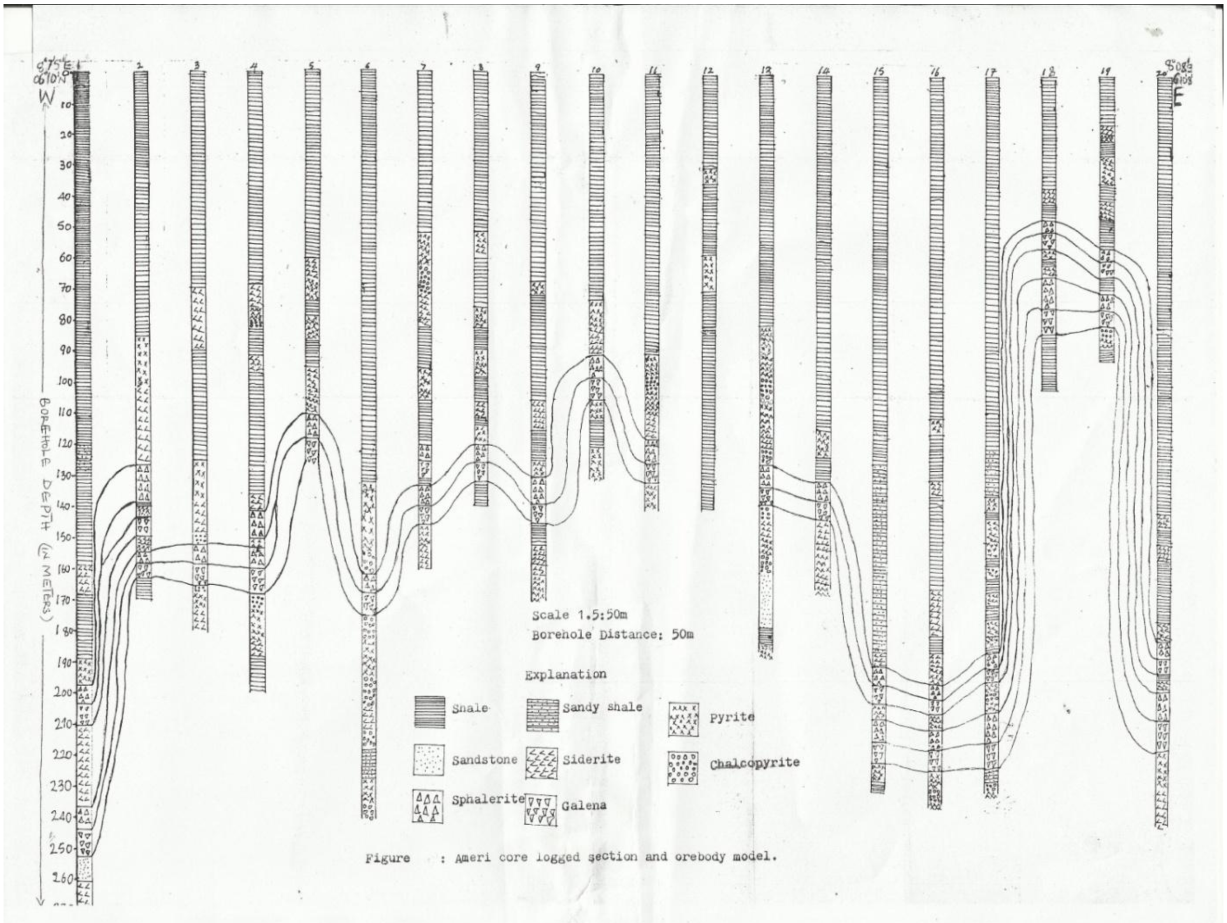


Figure 8. Ameri Core logged section.

There is obvious evidence of alternation of micaceous minerals, silt and mud in the shale. I believe that the variations in the rate of supply of deposition due to the nature of rising and falling of the surge of water brought about the contrasting character responsible for this phenomenon. The black to dark nature of the shale was as a result of the organic richness of the shale. They are just but the rapid fall in sea level with deceleration rise of the sea level in a low energy environment where clay and silt are held in suspension for a long time brought about by the phenomena.

Unit B: greyish to pinkish brown

The shale in this unit is the younger of the two units in the study area. The shale is underlain unit A. Its color varies from grayish brown, reddish to pinkish brown. It has a general trend of NE-SW direction with dip direction in NW-SE at Enyigba having dip amount ranging from 18 to 52°. The shale is fissile and breaks along its fissile planes. It is very thinly laminated and bedded. The exposure of the calcareous shale at Enyigba Akpara stream channel is hard to fairly compact, blenched to pinkish and grayish brown. It is fairly to highly fractured, but intensive fracture occurs almost in one direction, and the fractured zone is very weak.

However, in all the locations visited, the shale has the blend of greyish brown to reddish brown with top lateritic sediment that is ironstone. The shale is rich in clay minerals, although only micaceous minerals are seen in hand specimen. Aguman (1989) documented that Abakaliki shale dominate clay minerals of chlorite, illite, kaolinite and some smectite. Illite and chlorite increases with depth of burial due to diagenetic convention of kaolinite to illite and chlorite or smectite to illite. The shale is equally laminated.

STRUCTURAL INTERPRETATION

The structures dominating the area are faults, folds and fractures. These deformative structures observed was as a result of the tectonic events which occurred during the

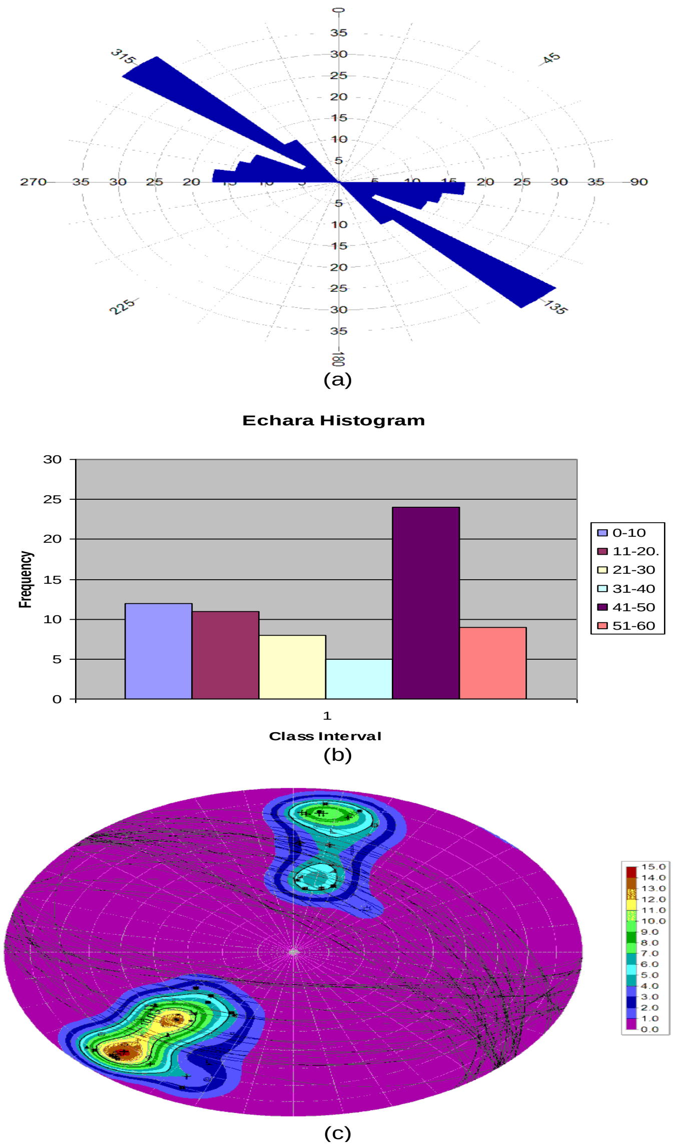


Figure 9. Diagram showing the trend of the fractures at Echara. (a)Rose diagram and (b) Histogram shows predominant fracture trend at S45^{0}E. (c) Steronet indicates that the fractures dip steeply in NNE-SW direction.

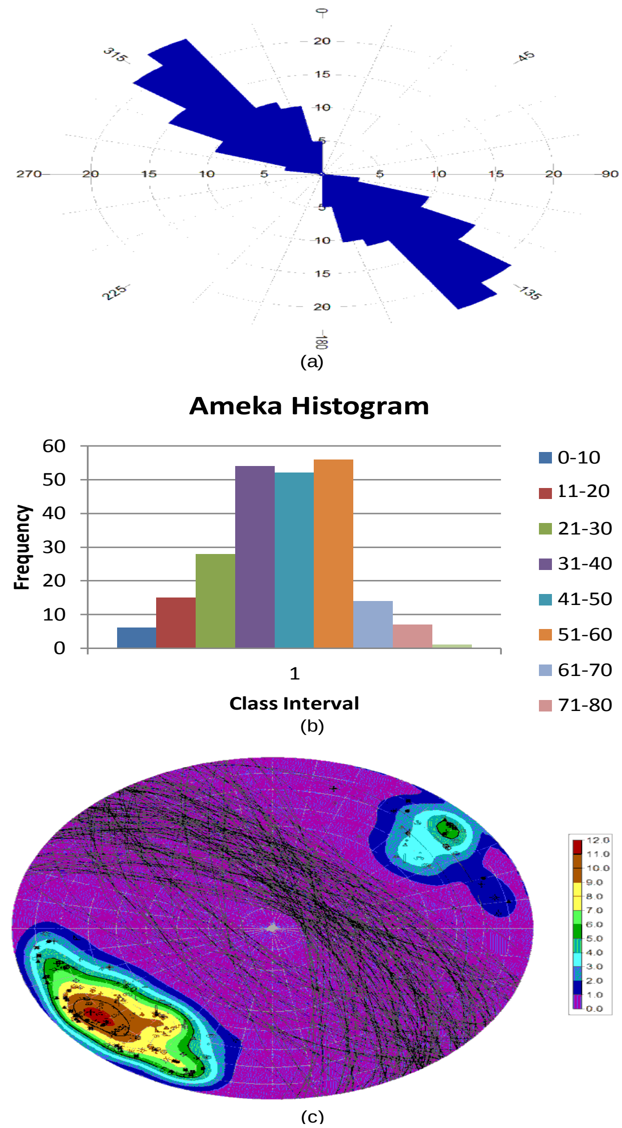


Figure 10. Diagram showing the trend of the fractures at Ameka. (a) Rose diagram and (b) Histogram showing the predominate fracture trend of the fractures is at N50^{0}W. (c) Steronet indicates that the fractures dip steeply in SW-NE direction.

Santonian-Coniacians times, at which the Albian and Turonian sediments were deformed along northwesterly trending axes, producing numerous gently folds. Fractures, fault and folds are the structural features observed in the study area.

Fold

The fold occurred as a result of comperssional forces acting at the sediment. From Figure 11, it can be seen that series of fold occurrence at the study area transacted the sediment with syncline and anticline. However, the sediment is highly folded. Figure 8 indicates that the mineralization was gently to steeply folded, and it is obviously folded at the eastern part of the section throwing the deposit up to 50 m close to the surface. This indicates series of tectonic events which occurred within the Santonian-Coniacian times.

Fault

Fault was also observed in the study area. Ameri core logged section shows the presence of fault by the discontinuity of the mineral of interest. Orajaka (1975) commented that the anticlinal axis of the shale body

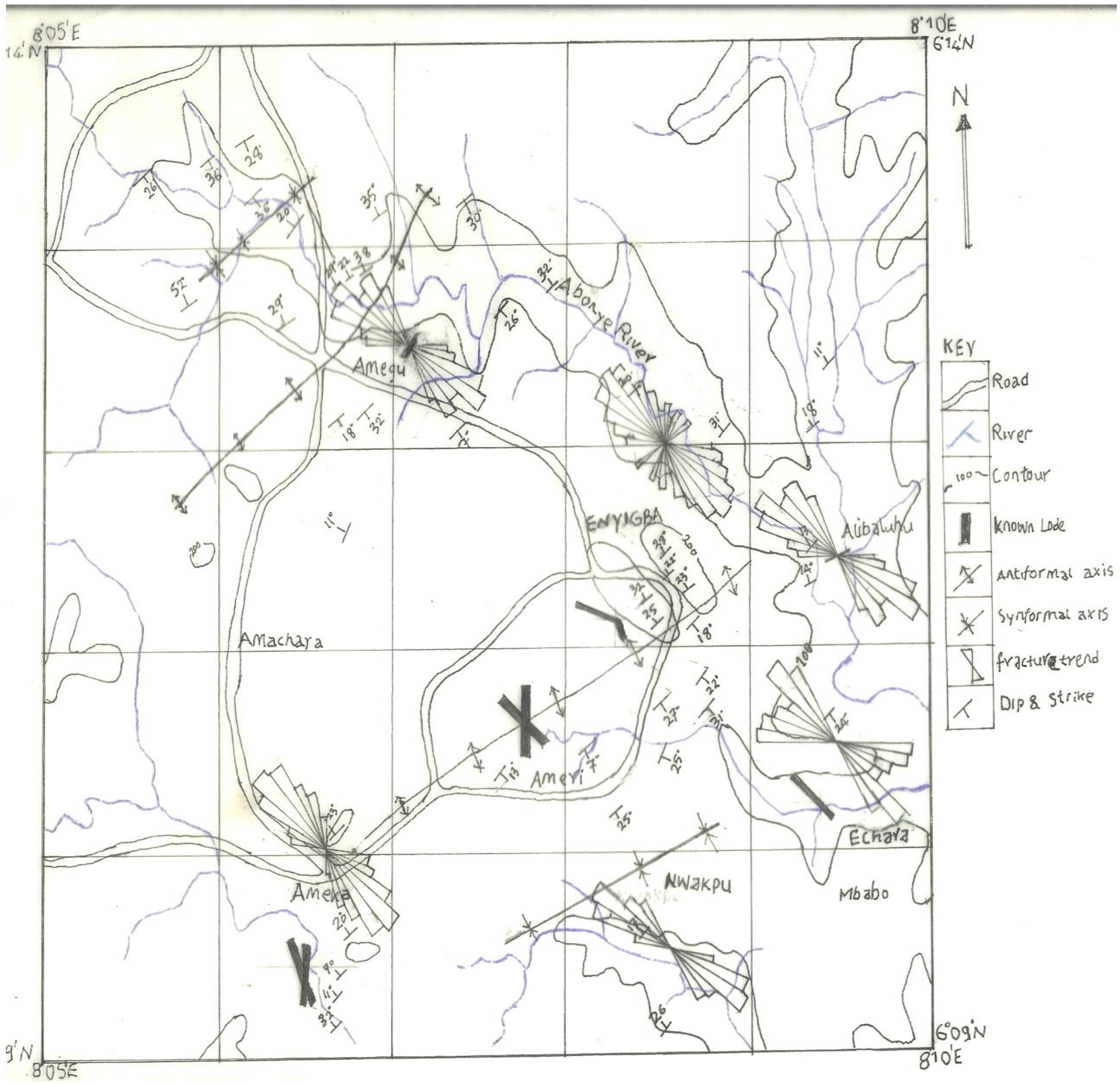


Figure 11. Structural map of the study area showing the fractural trends, the folds and the lead-zinc lode.

passes up to Ameka village as seen in Figure 11, that this axis has been evidently displaced at Ameka in the neighborhood of the North shaft and Portuguese lode of Ameka lode of the ore deposit. The fault is as a result of the movement along the open fracture.

Fracture

Fracture is the major structural feature that controls the mineralization. The fractures trend NW-SE and N-S directions. The fractures make the deposit to be an open space filling. At Enyigba, the main fracture that controls the mineralization generally trends N20° W with a strike of 600 m length and 3.64 m width. The deposit here has a high grade of sphalerite (Table 1). At Ameri, the main fractures that controls the mineralization trends N-S directions with a strike length of 950 m and width of 5.5 m. It hosts more Zinc deposit than Lead, but Zinc is of lower grades compared to Enyigba deposit (Table 2). At Echara, the fracture that controls the mineralization trend N45° W direction with the strike length of 250 m and 1.5 m width (Table 3). At Ameka, the main fracture that controls the mineralization trends N-S directions with a strike length of 1800 m and a width of 5 m. Ameka mineralogy has a low grade of ore deposit compared to Enyigba and Ameri. This means that the hydrothermal solution flows from Enyigba down to Ameka and beyond.

Table 1. Enyigba frequency table.

Fractural trend	Class interval	Frequency	
		NW-SE	NE
N64°W,S57°E,S52°E,S58°E,N29°W,N4°W,S65°E,S10°E,S80°E,S52°E,N45°W,S52°E,N69°W,N78°W,N32°W,N60°W,S52°EN19°W,N24°W,S52°E,N59°W,N21°W,S53°EN19°W,N40°W,S53°E,N49°W,N70°W,S50°E,N69°W,N46°W,N39°W,N70°W,N35°W,N	0 – 10	6	5
15°W,N25°W,N24°W,N42°W,N32°W,N45°W,N46°W,S56°E,N74°W,N72°W,S48°E,N74°W,N19°W,S30°EN37°W,N28°W,S80°E,S76°E,S35°E,S26°ES65°E,S51°E,N38°W,S10°E,S15°E,N28°WN24°W,N29°W,S51°E,N21°W,N33°W,S80°E,S43°E,S22°E,N15°	11 – 20	15	2
W,S55°E,N24°E,N23°EN26°E,N62°E,N55°E,N56°E,N66°E,N64°EN68°E,N15°E,N55°E,S38°E,S40°E,S45°E,S48°E,S50°E,S53°E,S46°E,S47°E,S49°E,S45°E,S55°E,N45°W,S53	21 – 30	28	3
°E,S50°E,S55°E,S56°E,S55°E,N54°W,S47°E,S49°E,S55°ES42°E,N65°W,N35°W,N45°W,N16°W,S55°EN55°W,N23°W,S55°E,N52°W,N25°W,N23°W,N22°W,N20°W,N34°	31 – 40	54	-
W,N55°W,S45°E,N54°W,N55°W,S55E,NI6°W,N23°W,N25°W,N22°W,NI7°W,N48°W,N53°W,N9°W,N3I°WN2O°W,N33°W,N34°W,N34°W,S25°E,S45°E,S60°ES36°E,S38°E,S34°E,S53°E,S52°E,S45°E,S52°E,S42°E,N41°W,N40°W,N35°W,S45°E,N42°W,N4	41 – 50	52	-
0°W,S44°E,S34°E,S34°E,N45°WN40°W,N39°W,S86°E,N48°W,N25°W,S53°E,N50°W,N53°W,S78°E,N53°W,N51°W,S37°EN54°W,N37°W,S6°E,N26°W,N26°W,N35°W,N	51 - 60	56	3
25°W,N17°W,N45°W,N42°W,N12°W,N41°W,N25°W,N60°W,N38°W,N34°W,NI0°W,N49°E,N50°E,N44°W,N37°W,N40°W,N43°W,N52°W,N50°W,N51°W,N55°W,N3	61 - 70	14	4
3°W,N45°W,N55°W,N45°W,N46°W,N2°E,N10°E,N8°E,N12°E,N6°EN49°W,N56°W,N60°W,N65°W,N63°W,N66°W,N58°W,N57°W,N56°W,N72°W,N65°W,N67°W,N61	71 - 80	7	-
°W,N55°W,N53°W,N56°W,N59°W,N60°W,N77°W,N83°W,N78°WN34°W,N32°W,N3I°W,N36°W,N37°W,N35°W,N34°W,N40°W,N38°W,N34°W,N36°W,N35°W,NI5°W,NI4°W,NI3°W,N3I°W,N30°W,N36°W,N38°W,N32°W,N31°WN35°W,N16°W.	81 - 90	1	-

From the core logged section, it can be seen that fracturing, folding and faulting were present at Ameri ore deposit, although there is obvious dominance of folding and fracturing.

The hydrothermal fluids migrating along the open space created by the fracture crystallizes the ore deposit due to fall in temperature. This also indicates that there are two episodes of tectonic events that affected the sediment. The first event caused the fracturing and faulting of the sediment followed by the migration of the hydrothermal fluid along the open space and the crystallization of the ore deposit. The next event is the folding and upliftment of the sediment together with the ore deposit. However, upliftment causes the ore deposit to be very close to the surface up to 50 m at the East side of the core logged section. These two events are probably series or stages of the tectonic episodes that occur at the Santonian-Coniancian time which affected the Albian Asu River Group sediments. Nwakpu, Amagu, Alibaruhu mapped (although data was not reported in this paper due to absence of mineralization) has no ore deposit but were highly fractured. The barren nature of these locations may be due to lack of circulation of the hydrothermal fluids along the fractures, probably due to lack of permeability caused by faulting of the sediment against such areas. The mineralization is a vein type deposit which occurs along the fractures. The grade of this mineralization diminishes along a common trend from Enyigba down to Ameka. But at Enyigba the deposit is characterized with a high grade of sphalerite which has a small deposit compared to massive deposits of lead that is low grade in nature. In the same trend at Ameri and Echara, the mineralization is characterized with massive deposits of low grade Sphalerite and small deposits of high grade lead. Meanwhile at Ameka, the grade of the mineralization is very low with a shallow but massive deposit of both minerals. The primary and secondary minerals have been mentioned above with its accessory minerals.

Conclusion

The lead-zinc deposit is epigenetic in origin formed by saline water intrusion of the rocks of the Asu River Group in the Lower Benue Trough, since it is a vein type deposit. The deposit is localized within the open space created by the fracturing. During the mapping, no intrusive or extrusive igneous rocks were encountered.

Table 2. Frequency table of Echara.

Fractural trend	Class interval	Frequency
S6°E,N43°W,N44°W,S7°E,N38°W,N43°W	0 --10	12
S2°E,N44°W,N41°W,S3°E,N45°W,N45°W,S6°E,N44°W,N36°W,	11 -- 20	11
S2°E,N38°W,N45°W,S6°E,N46°W,N40°WS2°E,N46°W,N45°W,	21 – 30	8
S°7E,N44°W,N45°W,S3°E,N49°W,N46°W,S6°E,N41°W,N40°W,	31 – 40	5
S6°E,N43°W,N44°W,N46°W,N44°W,N45°W,N47°W,N52°W,N	41 – 50	24
51°W,N53°W,N40°W,N44°W,N51°W,N53°W,N55°W,N56°W,	51 –60	9
N57°W,S11°E,S13°E,N25°W,N21°W,S12°E,N23°W,N30°W,S14	61 –70	
°E,N28°W,N26°W,S14°E,N22°W,N24°W,S15°E,S14°E,S17°ES1	71 –80	
8°E,S20°E,S19°E,S20°E.	81 – 90	

Table 3. Frequency table of Ameka.

Fractural trend	Class interval	Frequency
N80°W,N68°W,N70°W,N60°W,N65°W N55°W,N62°W,N63°W,N56°W,N56°W N45°W,N40°W,N44°W,N40°W,N47°W	0 -- 10	
N50°W,N57°W,N35°W,N55°W,N55°W N65°W,N66°W,N55°W,N58°W,N53°W N72°W,N74°W,N34°W,N32°W,N76°W	11 -- 20	12
N78°W,N31°W,N79°W,N38°W.N33°W, N22°W,N20°W,N21°W,N33°W,N31°W,N25° W,N37°W,N35°W,N45°WN25°W,N29	21 -- 30	14
°W,N25°W,N50°W,N45°W,N39°W,N45°W,N 64°W,N45°W,N39°W,N45°W,N64°W,N60°W, N50°W,N26°W,N55°W,N51°W,N	31 -- 40	31
61°W,N22°W,N35°WN70°W,N35°W,N34°W, N35°W,N40°WN55°W,N52°W,N39°W,N33° W,N35°WN85°W,N52°W,N41°W, N19°W,N20°WN70°W,N55°W,N60°W,	41 -- 50	40
N63°W,N32°W,N55°W,N56°W,N65°W, N55°W,N60°W,N62°W,N64°W,N58°W,N70° W,N73°W,N55°W,N60°W,N53°W,N65°W,N8 5°W,N83°W,N84°W,N72°W,N74°	51 -- 60	44
W,N85°W,N88°W,N20W°,N20°W,S55°E,S52 °E N16°W,S49°E,S42°E,N18°W,S48°E, S49°E,N20°W,S50°E,S80°E,S51°E,S45°E ,S42°E,S35°E,S52°E,S32°E,S40°E,S72°E,	61 -- 70	21
S70°E,S80°E,S78°E,S50°E,S45°E,S34°E, S37°E,S54°E,S59°E,S50°E,S48°E,S49°E, S58°E,S50°E,S55°E,S60°E,S62°E,S54°E,	71 -- 80	16
S46°E,S46°E,N43°W,N42°W,N39°W, N45°W,N42°W,N32°W,N41°W,N43°W, N56°W,N50°W,N55°W,N40°W,N49°W, N49°W,N58°W,N54°W,N60°W,N53°W, N56°W,N54°W,N74°W,N53°W,N76°W ,N75°W,N45°W,N44°W,N54°W,N20°W, N18°W,N11°W,N35°W,N21°W,N30°W, N25°W,N28°W, N24°W.N18°W.	81 -- 90	6

From the mapped locations, two units of the shale were delineated designated as unit A and unit B. Unit A is a very dark to black calcareous shale hosting the mineralization, while unit B is grayish brown, reddish to pinkish brown weathered shale that is highly fractured.

The ore fields extend to about 3.7 km strike length of NW and NS trend direction of the mineralization within an average width of 5 m. The ore deposits occur at Enyigba, Echara, Ameri and Ameka within the study area. The areas which were barren of the mineralization though highly fractured seem to have no access to the fluid. The structures that control the mineralization are folds, faults and fractures. But fractures and folds mainly control it, trending NW-SE and N-S directions which are both linear and perpendicular to the strike of the shale formation.

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