THE STRATIGRAPHY, PETROGRAPHY AND STRUCTURAL EVALUATION OF AKIRI AND ITS ENVIRONS, MIDDLE BENUE TROUGH, NIGERIA

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Abstract
The petrology of rocks occuring in the areas of Wuse and Akiri in the Middle Benue Trough of Central Nigeria have been studied. The sediments were sampled and analysed by petrological microscopes was undertaken to characterise the minerals and elucidate aspects of their formation. The area is underlain by the Eze Aku Formation comprising shales, siltstones and sandstones and in places, conglomeratic ironstone, mudstones and limestones also occur. The shales are variably massive, nodular and paper- thinly laminated with concretional nodules in places. The sandstones are massively bedded, texturally coarse to medium and variably indurated while the siltstones are thinly laminated. These lithologies were cut by E / W and NW / SE trending, variably microscopic to 2.5 m thick copper mineralized veins. Thin section petrography of the host lithologies revealed quartz, feldspars (Microcline, plagioclase) and muscovite in the sandstone. Akiri vein deposits has significant chalcopyrite mineralization which occur as dissemination, veinlets and stockworks with well developed wall-rock silicification (alteration).

Keywords: *Ironstone, Mineralized veins, Laminated, Dissemination, Stockworks, nodules*

Introduction
The copper veins at Akiri middle Benue trough of Nigeria are the largest copper deposits within the middle cretaceous (Cenomanian to Turonian) sedimentary sequences of the Benue rift structure. Copper lodes are located within the vicinity of Akiri in North-Eastern Nigeria (Fig. 1). These lodes are currently being mined for copper since the year 2006. Although there are no records of production, mining records since 2006 put the total production figures at over 7000 tons of copper ore in the area. In spite of the recent interest by mining companies investing heavily in copper mining activities in the middle Benue region, very little is known about the details of the mineralogy, texture and mineral paragenesis of the ore minerals and gangue in the deposits.

This present study examines the detailed geology, distribution, texture and mineralogy of the lithologies and ores and paragentic relationships of ore and gangue minerals to determine the features of the deposits. The studied area is located in the vicinity of Akiri which is north east of Azara town and east of Lafia, Nasarawa, Nigeria (Fig. 1). The Akiri ore veins are located 6 km SE of Akiri. The Copper iron sulphide vein mineralization occurring in the area of Akiri in the Middle Benue Trough of Nigeria has been examined for the geology, its distribution, texture and mineralogy of the lithologies, in the Akiri area.

Regional Geological Setting
Different opinions to the origin of the Benue trough have been published in literature with the rift hypothesis being widely favoured. Stonely (1966) put forward the graben model while the spreading ridge hypothesis was suggested in Burke et al (1970) and emphasized in Burke and Whiteman (1973). Grant (1971) proposed the extensional stresses along the third arm of the RRR triple junction. The collision of the continental plates without subduction was put forward in Nwachukwu (1972). Olade (1976) evoked an aulacogen model of evolution. Most recently Maurin *et al* (1986) and Benkhelil (1982, 1987, 1989) suggested that sinistral

wrenching was a dominant tectonic process for the development of the Benue trough sub basins. Sediment deposition in the Benue trough was controlled by progressive eustatic rise in sea level during the

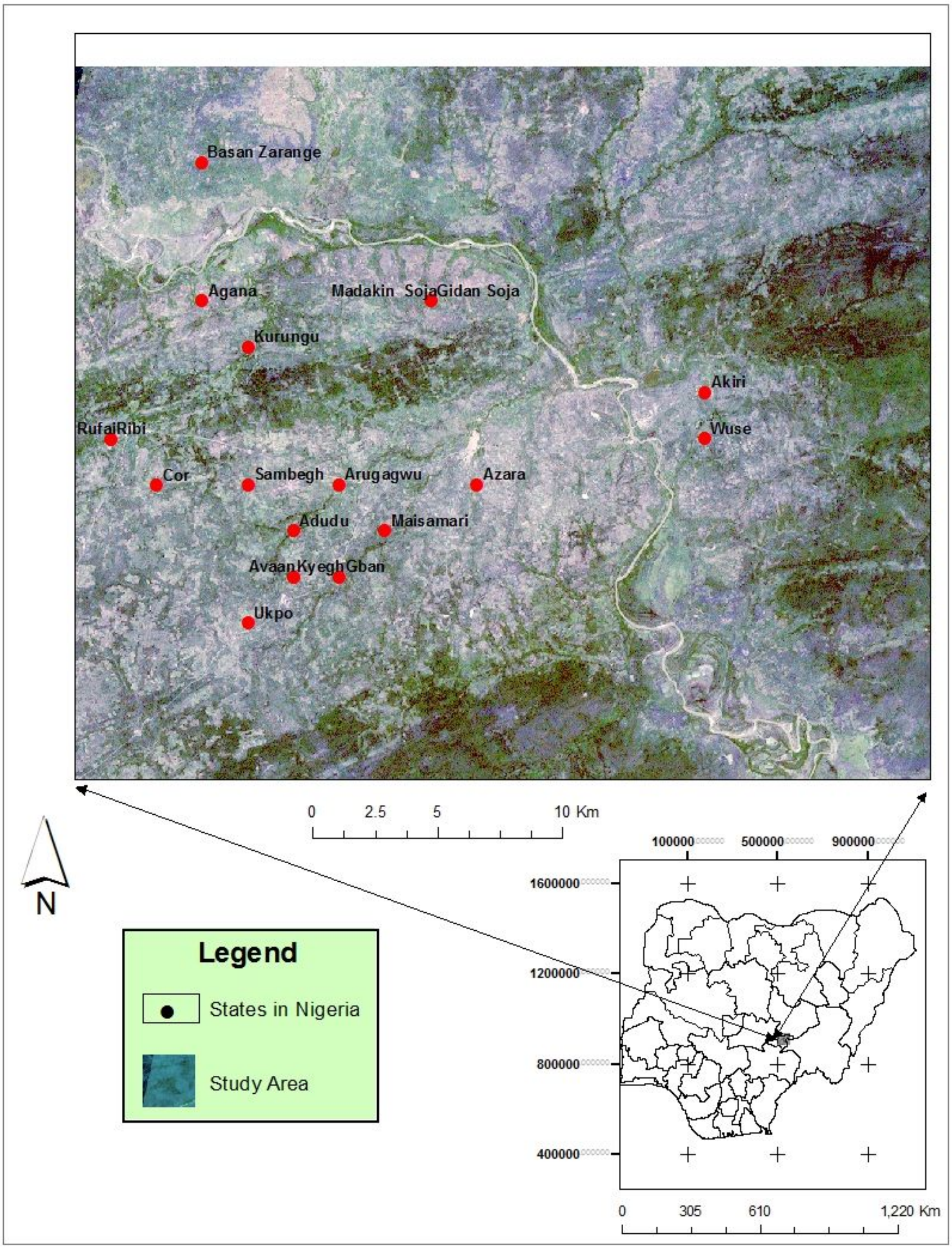

Fig. 1: Location map of Akiri, Nasarawa, Nigeria

Albian transgression accompanied by subsidence and submerging of continental margins. The sedimentary infills in the Benue trough were deposited during three cycles interrupted by uncornformities (Table 1). The first depositional cycle was during the Albian lasting until the early Cenomanian. The middle Cenomanian was a period of non deposition especially in the Lower Benue trough (Peters, 1987). The second depositional cycle occurred from late Cenomanian to Coniacian when there was renewed transgression and deposition of marine sediments. The Santonian was a period of non-deposition. At this time, sediments of the first and second cycles were folded, faulted and intruded by alkaline basalts, dolerites and syenites (Murat, 1972).

Detailed description of the stratigraphy, tectonics and evolution of the Trough have been described previously by the authors mentioned above and will not be presented here. The formations recorded by the above mentioned aurthors from the oldest to the youngest are as follows: Asu River Group (Albian), Awe formation (late Albian - early Cenomanian), Keana Formation (middle Cenomanian), Eze Aku Formation (late Cenomanian – early Turonian) and the youngest Lafia Formation (Campanian mastrichian) (Offodile 1976; Offodile and Reyment 1976) (Table 1).

The Asu River Group is Albian in age and represents the earliest sediments that were deposited unconformably on the subsiding basement topographical depressions during the first marine transgressions into the Benue trough (Burke, Dessauvagie and Whiteman1970). A Turonian regression in the Trough led to the deposition of shale argillite and carbonate of the Eze aku formation which is overlain by 1000km thick shales of the Awgu formation (Senonian) Nwachukwu (1975).

Table 1: Generalized stratigraphy of the middle Benue trough (Offodile, 1976)

Post-Cretaceous	Age	Formations
Late Cretaceous	Maastrichtian	Lafia Formation
	Santonian-Campanian	Volcanics
	Coniacian	Awgu Formation
	Late Turonian	Hiatus
	Early Turonian	Ezeaku Formation
	Late Cenomanian Early Cenomanian	Keana Formation Hiatus
		Awe Formation
Early Cretaceous	Middle-Late Albian	Asu River Group

Methodology

Thin section preparation was carried out on forty samples from Akiri and environs at the workshop, of the department of Geology, University of Ilorin. Samples were cut into slices of 1.5cm thickness. The surface was smoothened with carborandum 90 grit to remove saw marks on the surface. This was then followed by 400 grit to smoothen the surface before mounting on a glass slide. After solidification, mounted samples were allowed to cool at room temperature before reduction to 3mm - 4mm by Logitech machine. This was followed by grinding and smoothening with caborandum 400,600,800 grits with occasional checking under microscope till thinning gets to 0.03mm. Friable samples after disintegrating mixed with small Canada basalm are then heated in a hot flame for a period of 30 minutes before thinning begins. The thin section interpretation for host lithologies was carried out at the laboratory of the Department of geology and Mineral sciences, University of Ilorin using the Zeiss NP 107 T petrographic microscope.

Results and Interpretation

Geology of the study area

In this study, detailed mapping and description of various lithofacies association of Keana, and Eze Aku Formations that characterize Akiri was carried out. Geological map produced of akiri and environs was produced (Fig. 2) Detailed logging of the sections was undertaken at different locations within Akiri (Fig: 3, 4 & 5). The lithologies identified include: sandstones, siltstone, shale, limestone, mudstones and ironstones. The five principal facies association delineated are described below.

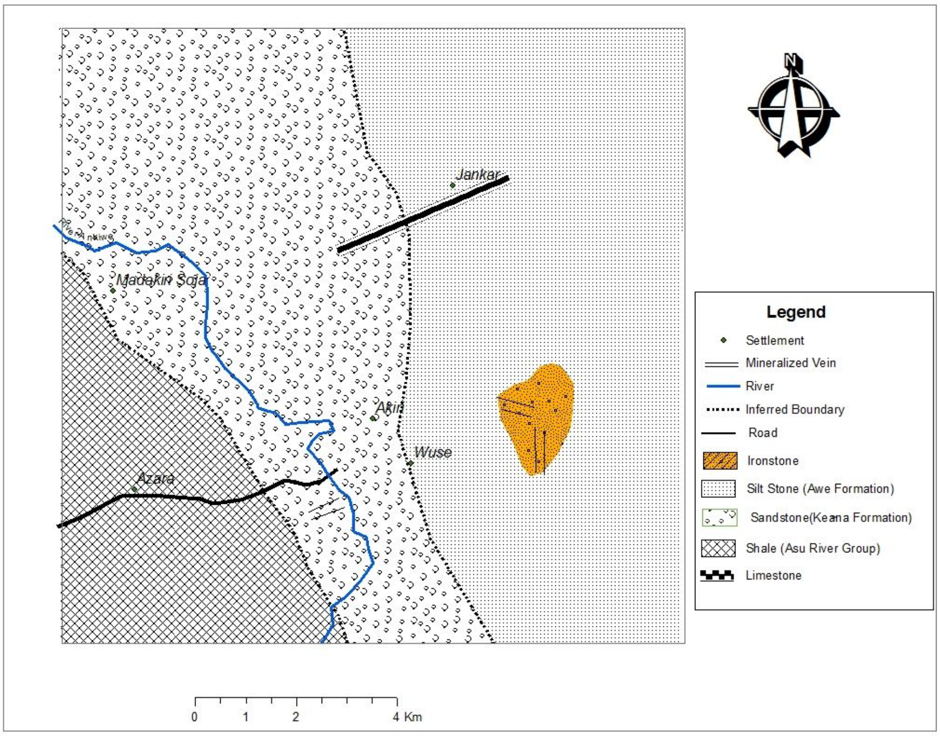

Fig. 2: Location Map of the Studied Area around Akiri, Wuse and Azara, Middle Benue Trough, Nigeria

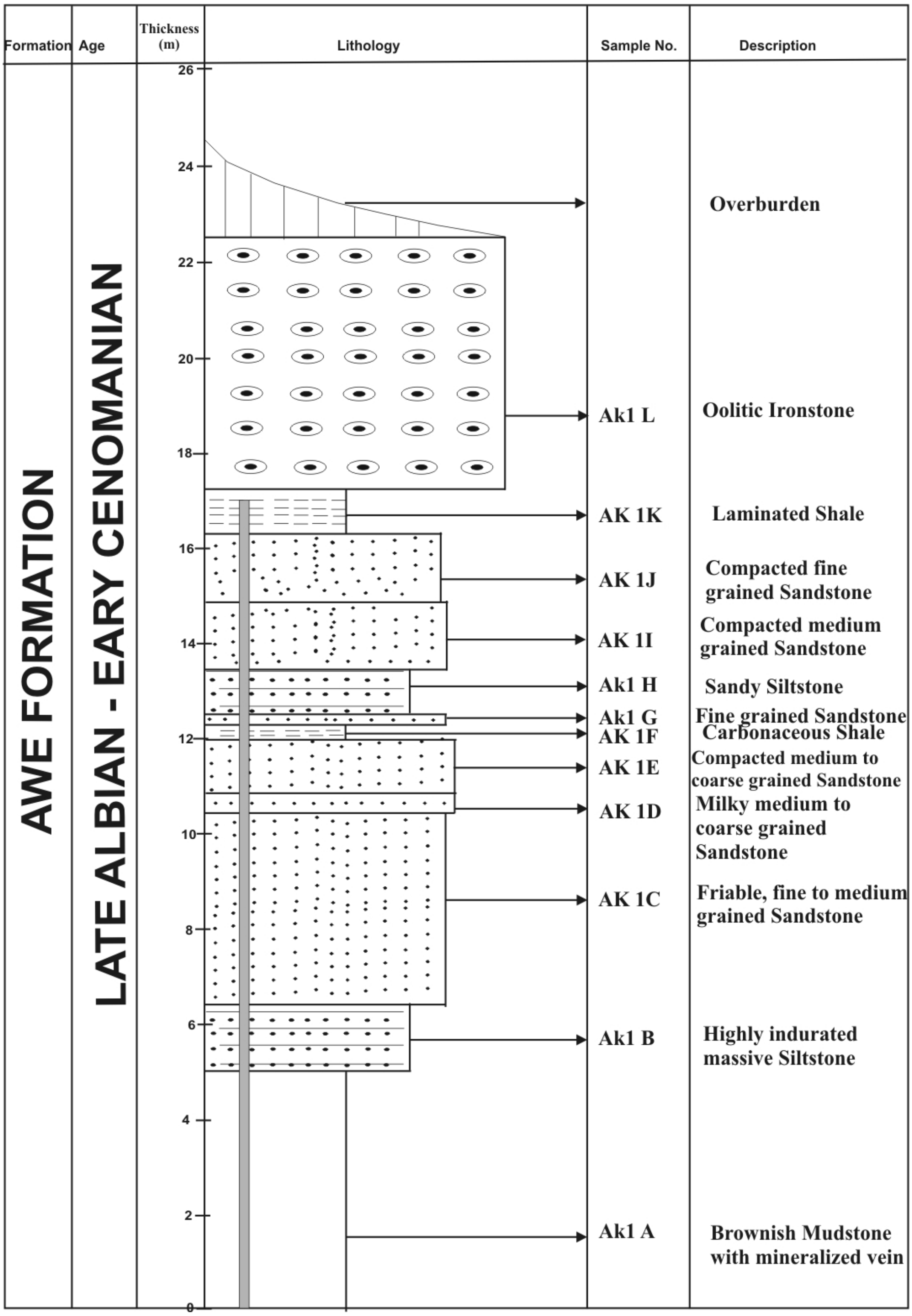

Fig. 3: Litho - Stratigraphic section of Akiri pit 1 (Scale I.0cm : 2m)

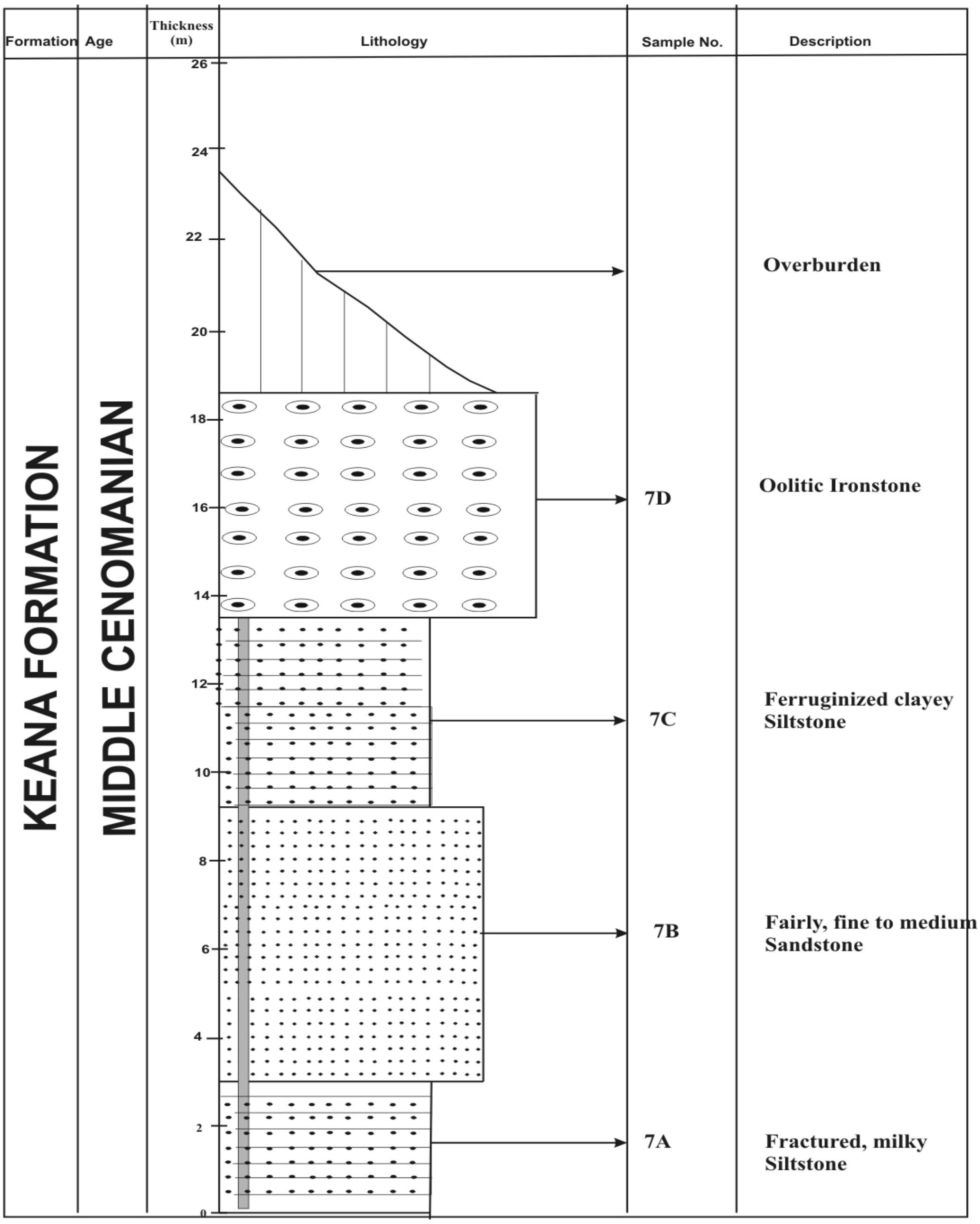

Fig. 4: Local Litho - stratigraphic section of Akiri pit 2 (Scale 1cm : 2m)

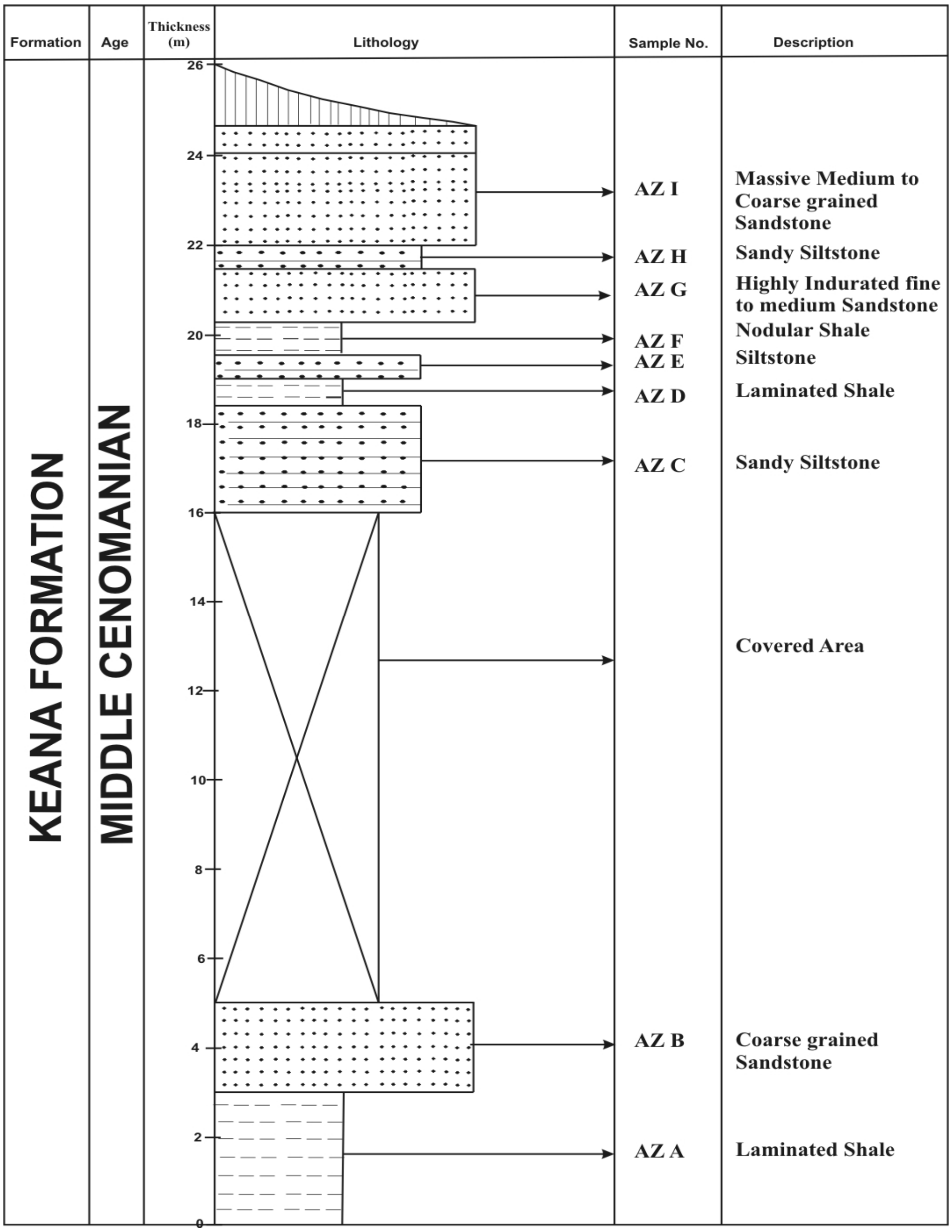

Fig. 5: Litho - stratigraphic section of Azara area pit 3 (Scale 1cm : 2m)

Lithofacies Association

Ironstone Conglomerate: The Ironstone facies of the Eze Aku formation exposed at Akiri are reddish brown in colour (Fig. 6). They contain oolitic nodules. They exhibit gradational texture of coarsing upward. The ironstone bed comformably overly the shale facies with a thickness of about 4 meters. At the top, it contains conglomerate size grain and pebble sizes at the base. They are not cut by the network of vein signifying that they were deposited (formed) after the veins have been formed. They exhibit grain matrix contact.

Siltstone: Siltstone occurs within sedimentary exposures at many of the locations studied. The siltstones are texturally massive and medium to very fine grained with micro-laminations. They are generally friable to well indurated. Mineralized veins with siderite sideritic mineral phases cut across the siltstones at many locations in Akiri (Fig. 7).

Limestone

The occurrence of thin limestone bed north of Akiri village was sampled and mapped (Fig. 8).

Lithofacies 1 – Sandstone

Sandstone was virtually found in all the locations. The texture ranges between coarse - very fine grained. These are variously crosscut by mineralized veins. The thickness of the sediments logged in Akiri was 22 m (Fig. 2). The mineral constituents are quartz, feldspars, mica and of course sandstone that have impacted colouration i.e burf-reddish colouration to the sediments undergoing laterization/ferruginization in Akiri. The sandstones in this area are very well compacted only few are friable (Fig. 9).

Shale

The shale units of the Awe formation exposed at Akiri are greyish to dark grey in colouration. They are carbonaceous, fissile, and massive or paper laminated in Akiri (Fig 10). The shale is interbedded with siltstone/sandstone. The shales display spherical weathering on exposure in Akiri. They are highly fractured and intruded in Akiri by veins and it has also been apparently baked by heat generated during the vein formation. The shales are also characterized in Akiri by occurrence of nodules (Fig. 11).

Mudstone

This facies exposure of mudstone facies was map at Akiri. The facies is predominantly massive showing no identifiable sedimentary structure. At Akiri the bed is 5m thick (Fig. 3).


Fig. 6: Exposure of clast-supported pebbly ironstone conglomerate, Weathered Clast-supported pebbly ironstone conglomerate and shale lithology at Akiri pit 1.

Fig. 7: Highly indurated siltstone bed at Akiri. Note the veins cutting vertically across the bed.


Fig.8: Highly indurated Limestone of Eze Aku Formation exposed at Jankar, 6 Km north of Akiri

Fig.9: Highly compacted coarse grained Sandstone of the Keana Formation exposed at Akiri

Fig. 10: Nodular shale within Eze Aku formation NE of Akiri. Fig. 11: Rubbly carbonacious shale bed within Eze Aku formation, NE of Akiri

Lode distribution

The Akiri veins are hosted primarily in gently dipping Turonian sediments of the Eze Aku formation. These sediments include shales, sandstones, siltstones, mudstones and conglomeratic ironstones. Vein mineralization is generally open space in filling of a series of steeply dipping fractures (Fig. 12) which occur at the flanks of domal structures. Three sets of fractures, the N/S, NEE/SWW and NNW/SSE trending fractures characterizing the middle Benue Trough were prominently found in the study area of Akiri and environs (Fig. 13). Mineralized veins generally trend NEE/SWW and NNW/SSE occurring as discordant bodies with strike length of veins is between 50 -150 meters and width of few centimeters to about 3.5 meters.

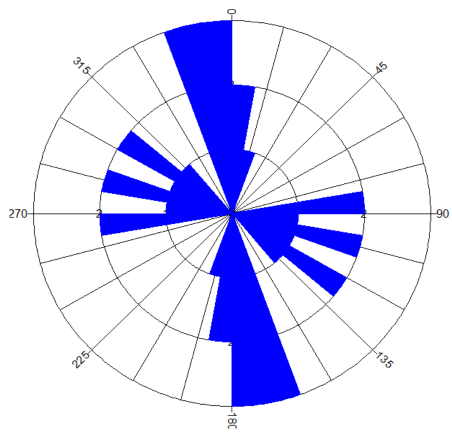

Fig. 12: Vein mineralization occupying steeply dipping fractures
Fig. 13: Rose Diagram of Akiri veins/ linearment

Mineralogy

Sandstone: Thin section studies shows that the grains are angular to sub-angular, consisting of quartz, feldspar and muscovite (Figs. 14, 15 and 16). Quartz and feldspar content of the sandstone constitute 55% and 28% respectively. Other constituent include muscovite 1.5% matrix 12.5% and cement (hematite, iron oxide – 3%). Feldspars include plagioclase and microcline. Feldspar have been intensely kaolinitized and converted to clay minerals in Akiri. Mucsovite is less abundant. The quartz grains consist of deformed polycrystalline grains. Texture of the rock is medium to coarse grained.

Siderite: Siderite is the primary host mineral for the chalcopyrite mineralizations. It exhibits nearly 90^o degree cleavage angle under the microscope (Fig. 17).

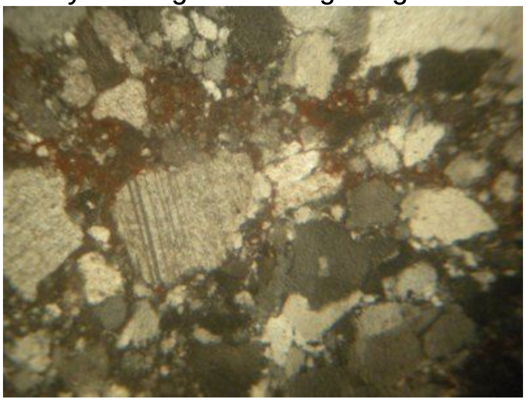
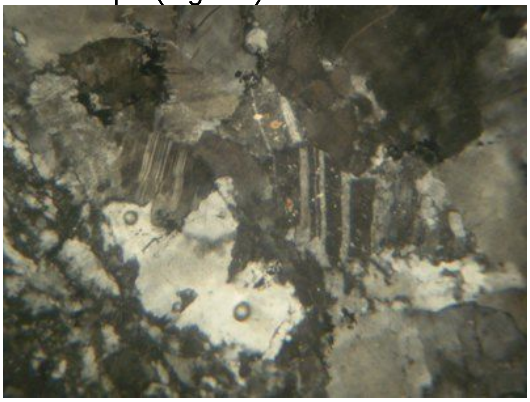

Fig.14: Thin section photomicrograph of well cemented medium-to coarse-grained sandstone

Note the quartz, plagioclase feldspar and slight hematization, Awe formation? (Sample HR 24) Crossed nicol. X10. Fig. 15 Thin section photomicrograph of sandstone. Note the Quartz - Q and Plagioclase – P feldspars (Sample P 1B) Crossed nicol. X10

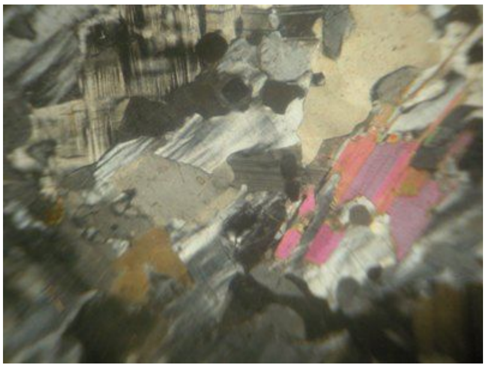
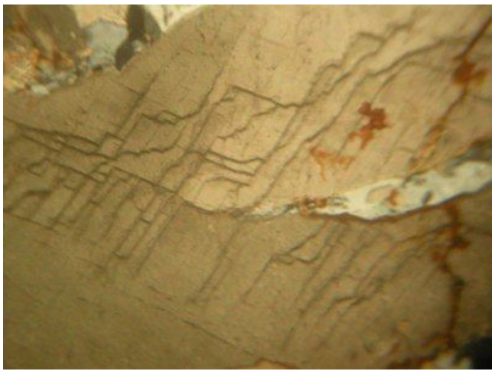

Fig. 16: Thin section photomicrograph of sandstone
Note the microcline, plagioclase and muscovite,biotite chlorite (Sample 16).

Fig. 17: Thin section photomicrograph of siderite
Note the near 90^0 cleavage angle (Sample L42G) Crossed nicol. X10.

Ore minerology
A major vein constituent is chalcopyrite occurring mainly within massive coarse-crystalline siderite mineral phases (Figs. 18, 19, 20 and 21) and also within shales, quartz, siltstone and sandstones (Figs. 22 and 23). The constituent in places is associated with pyrite. Apart from the major chalcopyrite, there are malachite, azurite and bornite occurring as accessory minerals. Observed field relations in the lodes indicate sharp vein-wall rock contact, and breccias texture at the margins (Akande and Mucke 1993).

Fig. 18: Vein siderite within SE of Akiri showing disseminated chalcopyrite core, siderite middle and outer quartz silification.

Note the white quartz

Fig. 19: Sulphide vein mineralization in siderite.

Fig. 20: Vein sulphide mineralization in siderite

Fig. 21: Disseminated Sulphide ore in compacted sandstone and brecciated siderite

Fig. 22: (a) Laminated Mineralization in shale

Fig. 23: Stockwork or Vein Mineralization siltstone

Based on geological mapping, petrographic and structural evaluation carried out in Akiri and environs, the following occurrences were noted:

(i) The geology of the area lies within the Eze Aku and the keana formation.

(ii) Network of veins which are epigenetic occur within anticlinal structure parallel to the fold axis (EW), while others are perpendicular to the fold axis (NS) (Fig. 12).

(iii) Ore veins are open filled fractures which generally trend NNW/SSE and NEE/SWW.

(iv) Some of Akiri veins are characterized by significant occurrence of copper which is currently being mined by artisan miners.

(v) The veins are found in host rocks ranging between Cenonanian and Turonian.

(vi) Mineralizations occur close to salt bodies located close to hot spring i.e the Akiri hot spring.

(vii) Lack of nearby Igneous rocks but volcanic (basalt) at Kanje about 40 km away.

Conclusion

This study intends to reveal the presence of copper deposits in Akiri, Nasarawa, Nigeria where there is no published data on such topic. It is noteworthy that the mineralization is mainly chalcopyrite rich with no associated Lead or Galena unlike the situation in other parts of the Benue Trough. Gangue minerals include siderite, quartz and barite. Secondary mineral enrichment includes Malachite and Azurite. Further work on the mineralogy of the area is on-going.

Acknowledgement

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