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Petrographic Studies of Yolde Formation Exposed at Gombe, Gongola Basin, N E Nigeria

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Abstract:- Geological mapping carried out in Gombe area revealed the presence of Yolde, Pindiga and Gombe Sandstone Formations. But in the case of this study, only the silicalstics of Yolde Formation are used for the Petrographic investigation. Petrographic analysis results indicate that Quartz is the dominant mineral in all the studied slides followed by potassium feldsper (Orthoclase), Iron oxide, altered feldspers, whereas Limonite and Zircon appear thrice each. Quartz framework grain is abundant due its greatest resistant to chemical decomposition and mechanical abrasion, Orthoclase is the only feldspers mineral present due to resistant than most of them. Altered feldspers is an opaque mineral visible only under cross-polar, it is believed to have been formed due to alteration of ferro-magnesian minerals. Zircon is the only non-stable opaque mineral present due to ability to withstand abrasion weathering, it is found in recycled sedimentary facies. Stable opaque present are Iron oxide and Limonite. Limonite results from dissolution of hematite and sometimes it is referred to as goethite or Iron ore. Iron oxide in this study is undifferentiated, because in theory, it represents both hematite and magnetite, then to a lesser extent, the rarer oxide mineral maghemite. It was observed in all the slides and this suggests that the Yolde Formation of the study area have been intensely weathered and most have travel some distance from source rock. Its provenance can be said to be from

Keywords:- *Petrograhic, Sandstone, Yolde Formation, Gombe and Gongola Basin.*

I. INTRODUCTION

The Benue Trough is a linear stretch of sedimentary cover trending NE-SW direction. It extends from the Niger Delta area around Onitsha through Makurdi following the course of River Benue up to Gombe and Yola. The Benue Trough is bounded to the west by the Basement Complex of Bauchi and to the east by the Calabar flank. The Benue Trough is further subdivided into the Upper, Middle and Lower. The Upper Benue Trough is located in the north-eastern part and is Y-shaped, made up of namely; E-W trending Yola arm and the N-S trending Gongola arm and the NE-SW trending Muri-Lau arm. The NE-SW trend is a sinistral strike fault composing of Gombe, Bima-Teli, Wuyo-Kaltungo and Burashika (Carter *et al*., 1963; Zaborski *et al*., 1997). The Middle Benue Trough covers Bashar, Amar, Muri and Zurak. The Lower Benue Trough covers Lafia, Awe, Arufo and Katsina Ala. (Zaborski, *et al*, 1997). The tectonic history and origin of the Benue Trough is associated with the break-up of African and South American (break-up of Gondwanaland) during the Early Cretaceous time (Benkhelil, 1989).

The Benue Trough in Nigeria is an aulacogen basin type located in Central West Africa. It is 1000km in length and 150km in width.

The study area lies in Gombe between latitudes 10^{o} 15^{I} 00^{II} – 10^{o} 20^{I} 00^{II} N and longitudes 11^{o} $15'00^{II}$- 11^{o} 20^{I} 00^{II}E. It was mapped on topographic sheet 152 Gombe NW. The main aim of this study is to map the general area and collect samples of Yolde Formation to determine its mineralogy so as to produce a detail geological map and present a Petrographic data of the formation.

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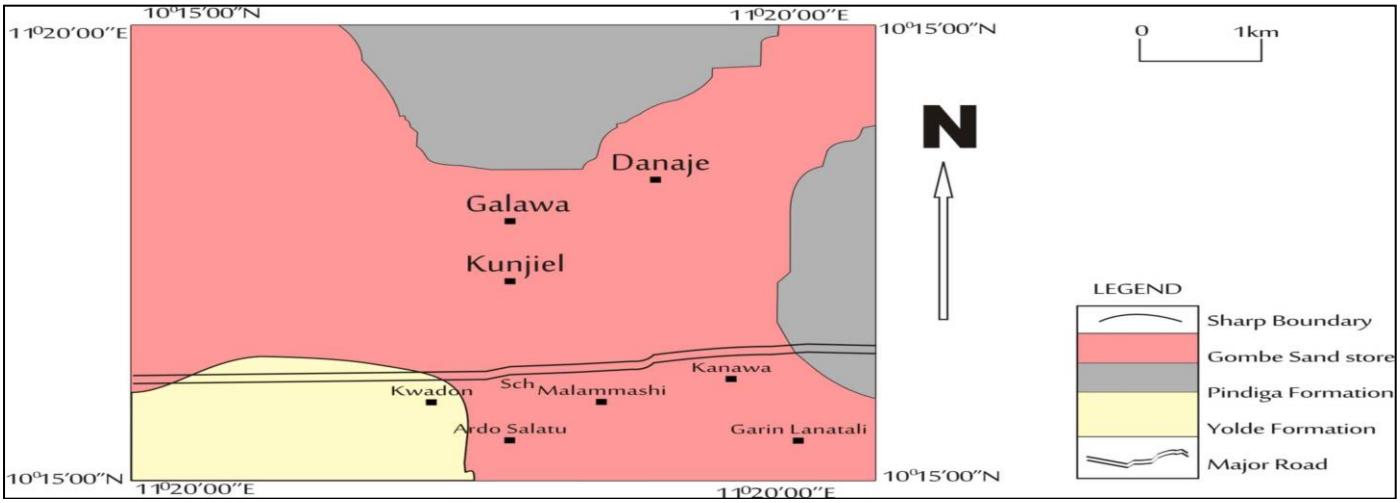

Fig 1 Geological Map of the Study Area.

➢ *Origin of the Benue Trough*

The Benue Trough developed along lines of lithospheric weakness (Maurin and Guiraud, 1993) under the influence of a mantle plume around the Niger Delta. Shear movements originating along Chain and Romanche transform faults of the Equatorial Atlantic due to differential opening between the Central and the South Ocean transmitted into the African Plate along the Benue Trough. These events resulted in rifting, stretching and subsidence along the Benue Trough and other African crustal plates in Early Cretaceous Period.

The Benue Trough is an integral part of the "West African rift system" of (Fairhead, 1986; Guiraud *et al*., 1992 and Genik, 1993). It is a long continental linear NE-SW trending Cretaceous sedimentary basin which overlies the West African mobile belt. It is about 1000 Km in length and 80 - 200 Km wide. The origin of the basin has been extensively debated, but the most appropriate model appears to be that of Olade (1975) which considered it as a failed arm (aulacogen) of a three - arm radial rift system initiated by mantle upwelling beneath a hot spot during the early Cretaceous. The other two arms having progressed by active sea-floor spreading and continental separation to form the South Atlantic and the Gulf of Guinea. The rift become the site of an epicontinental sea that extended the equatorial Atlantic, far into the mainland and led to the deposition of over 6000rn thick wedge of sedimentary rocks most of which were uplifted and folded during a major late Cretaceous tectonic.

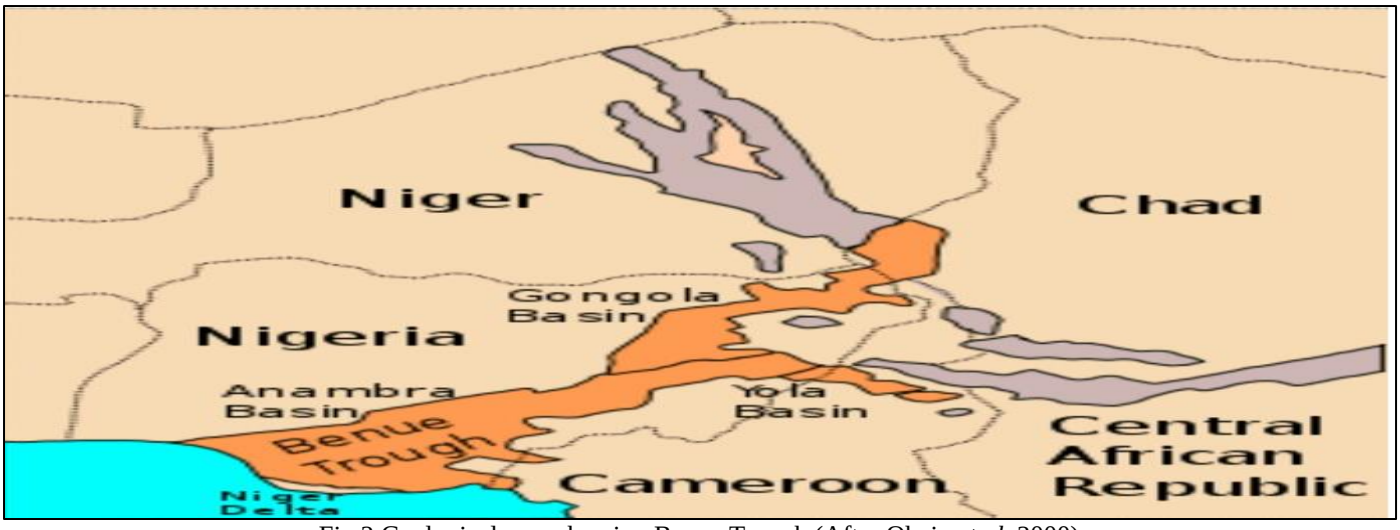

Fig 2 Geological map showing Benue Trough (After Obaje *et al*, 2000)

➢ *Stratigrapity of the Upper Benue Trough (Gongola Basin)*

The stratigraphy of the Upper Benue Trough has been studied by many geologists in the past such as Carter *et al*. (1963), who studied the stratigraphy of different depositional basins and the lithological units. The Benue Trough is generally divided into three (3), namely; Upper, Middle and Lower Benue Trough. For the purpose of this study, the Upper Benue Trough is the main focus. It includes the E - W trending Yola Arm and the N - S Trending Gongola Basin. The stratigraphy and structure of the Gongola Basin has been provided by (Wozny and Kogbe 1983; Popoff *et al.*, 1986; Guiraud *et al.*, 1992 and Zaborski *et al.*, 1997). Table 1 below shows a detail geological description of facies and their depositional environments.

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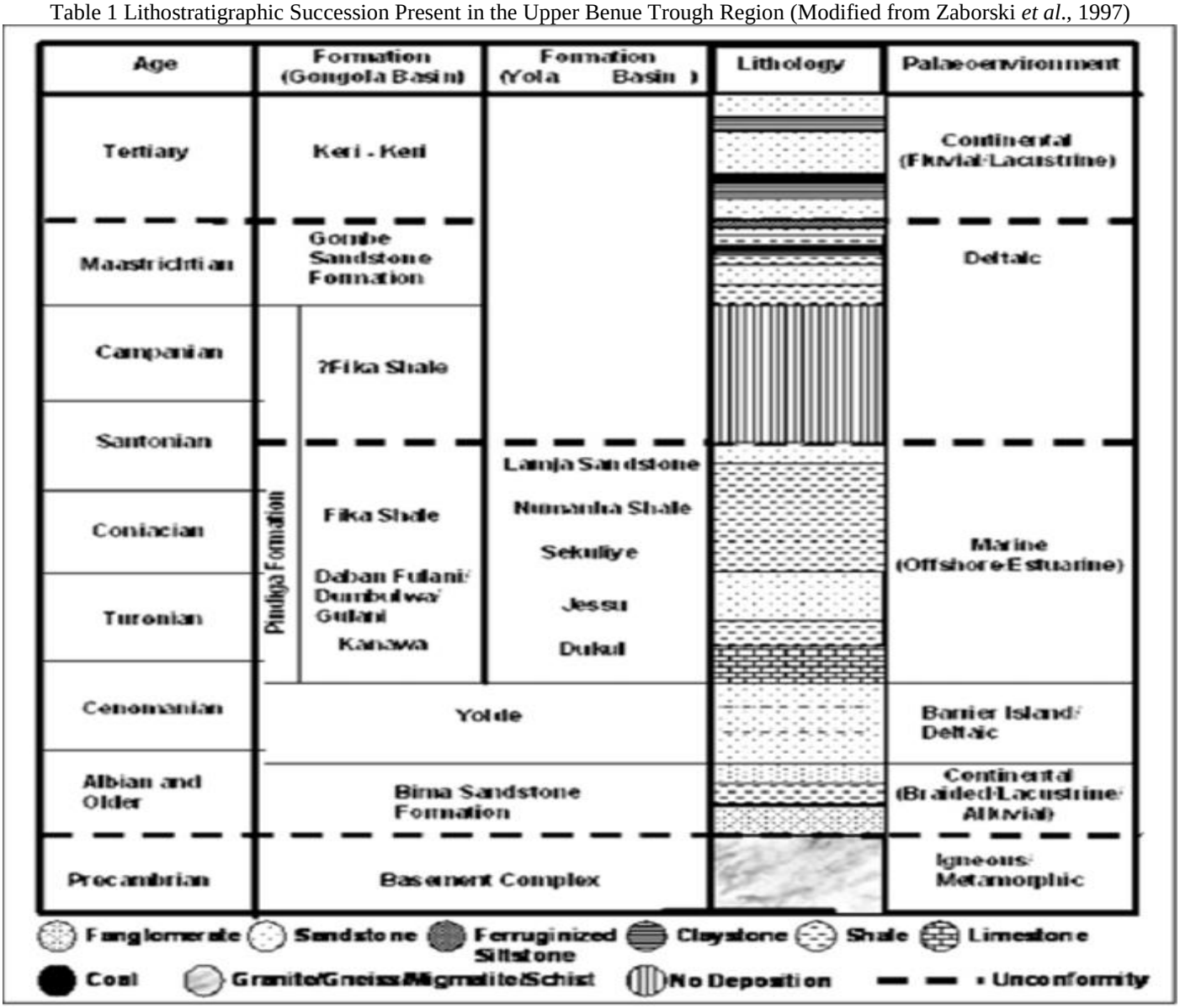
Table 1 Lithostratigraphic Succession Present in the Upper Benue Trough Region (Modified from Zaborski *et al*., 1997)



II. GEOLOGY OF THE STUDY AREA

The Upper Benue Trough is made up of three arms which are the E-W trending Yola arm, N - S trending Gongola arm and the NE - SW trending arm known as Muri - Lau sub-basin. These three arms or stratigraphic sub-division forms a Y-shape structure (Carter *et.al*., 1963; Wozny and Kogbe, 1976; Popoff, *et.al.*, 1986; Zaboski *et .al*., 1997).

The Bima Group is the oldest, most extensive and thickest of the Cretaceous Sedimentary successions in north-eastern Nigeria which directly overlies the crystalline basement rocks. The Bima Group is divided into Lower Bima (B1), Middle Bima (B2) and Upper Bima (B3), (Guiraud, 1990b). It has a maximum thickness of about 3300m.

The Lower Bima Formation (B^1) is the oldest and its subdivision has being described in the Lamurde anticline as consisting of red and purple clays with the occurrence of very coarse to medium grained feldspathic sandstones Carter *et.al*. (1963) and mudstone believed to have been deposited in a lacustrine environment. The most basal sequence of the B^1 is made up of sand and gravels with poorly defined planar cross bedding believed to have been formed in alluvial fans under humid climatic conditions (Guiraud, 1990b). Typical Fan - glomerate deposits composed of boulder beds with granite gneiss, boulders up to 0.8 meters in diameter interbedded with feldspathic sandstones were also reported by Carter *et al*., (1963). The B^1 has an average thickness between 0 - 1500 m.

The Middle Bima Formation (B^2) is composed of about 400 - 600 meters of medium to very coarse grained feldspathic sandstone showing both tabular cross-bedding with clay and shales (Guiraud, 1990b). The lithology ranges from fine to medium grain ranging in colour from light brown to purple parallel and ripple laminated sandstones occurring in the upper part of the fluvial cycles that makes up the formation (Zaborski *et. al.*, 1997).

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The Upper Bima Formation (B^3) is the most widely spread and has attained more than 1700 meters in thickness (Guiraud, 1990b). It has a relatively homogenous appearance consisting of tabular cross bedded, medium to coarse grained sandstones. This sequence was deposited in a fluviatile braided river system to deltaic environment (Carter *et al*., 1963).

Yolde Formation (the name Yolde Formation) was proposed by Carter *et al.* (1963) for the transitional beds recognized earlier by Falconer, (1911) and Barber *et al*., (1954). The Yolde Formation has been described in the Yola Arm by Carter *et al*. (1963) and Allix (1983) and in the Gongola Arm by Zaborski *et al*. (1997), it consists largely of the alteration of coarse to fine grained cross-bedded or rippled bedded sandstones and grey to greenish shales. Thin limestones or calcareous sandstones occur, especially in the upper part where Oyster beds are common (Zaborski *et al*. 1997). The Yolde Formation was deposited under a coastal marine environment between the Continental Bima Group and a sequence of the overlying Pindiga Formation (Zaborski *et al*. 1997). The lower part of the Yolde Formation is interpreted to be of fluvial origin while the upper part is composed of thin and regularly bedded bioturbated sandstones and low diversity of bivalve faunas are interpreted to be of shallow marine origin by (Zaborski *et al*. (1997). In the Upper Benue Trough, the thickness of the Yolde Formation ranges from 140 metres to a little over 200 metres (Thompson 1958; Carter *et al*., 1963; Allix, 1983; Zaborski *et al*., 1997).

The Pindiga Formation conformably overlies the Yolde Formation and represents a full blown marine incursion into the Upper Benue Trough. It is equivalent to the Gongila Formation at its base and Fika Shale towards its top in the Upper Benue Trough. Lithologically, the Pindiga Formation is composed of shale and limestones intercalation with limestone usually having pale colour (Carter *et al*., 1963). Later, Zaborski *et al*., (1997) regarded the Pindiga Formation as consisting of five Members, from the top to bottom, the members are;

- Fika Member
- Dumbulwa Member
- Gulani Member
- Deba-Fulani Member
- Kanawa Member

The Pindiga Formation was believed to be deposited under brackish, marsh water condition; for most part of the formation (Petters, 1978 and Carter, *et al*., 1963) based on ammonites (a lower Turonian Vascoceratids and *Pseudiotissotia*) age was suggested for the formation. Popoff *et al*, (1986) based on similar ammonites assemblages, established an Upper Cenomanian - Turonian age for the formation, observing that the Cenomanian - Turonian boundary is now globally redefined putting the Vascoceras species (previously defined as Lower Turonian fauna), in the Upper Cenomanian age (Carter *et al*.,1963).

The Gombe Sandstone overlies the Pindiga Formation and represents the youngest Cretaceous sediments in the Gongola Arm of the Upper Benue Trough. The Gombe Sandstone is a sequence of estuarine and deltaic sandstone, shales, siltstones and ironstones which overlies the Pindiga Formation. Falconer (1911) named Gombe Sandstone near Gombe Town as Gombe grits and clays and assigned an Eocene age to it. Raeburn and Jones (1934) described the Gombe Sandstone at Kware Stream as consisting of well bedded fine to medium grained sandstone, sandy and silty micaceous shale with occasional mudstones. Zaborski et al. (1997) described the Gombe Sandstone as consisting of three (3) major lithofacies; lower bed characterized by mudstones and ironstones, the fribble beds are composed of well bedded sandstones and siltstones while, the upper beds are composed of cross - bedded sandstones and siltstones. Dike (2002) stated that the lower part of the Gombe Sandstone contains the equivalent of the open or central lake shales and passing upward to pro - deltaic shales with ferroginous siltstones then to fine and very fine grained sub-arkose sands. This sequence represents a pro-graded mouth bar. Carter *et al*. (1963) reported occurrences of coal horizons in the Upper part of the Gombe Sandstone and dated it as Upper Maastrichtian, Lawal (1982) also confirmed the Maastrichtian age. The Gombe Sandstone is believed to have a thickness of over 310 meters (Carter *et al*., 1963 and Zaborski *et al*., 1997)

The Kerri - Kerri Formation represents the records of early Tertiary sedimentation in the north-eastern Nigeria and overlies the Cretaceous Gombe Sandstone unconformable in the Gongola Basin. The formation is essentially flat - lying to gently sloping at about 5^o (Carter *et al*., 1963). It consists of grits and ferruginous sandstones, siltstones and claystones which are often kaolinitic. The maximum thickness for the Kerri - Kerri Formation varies from 300 metres to over 320 metres (Dike, 1993). This sequence is deposited in a wide range of environment including; fluviatile, deltaic and marginal lacustrine (Dike, 1993).

III. METHODOLOGY

➢ *Petrographic Analysis*

Petrographic analysis carried out in the lab using seven (7) selected sandstone samples of Yolde Formation collected in the field. The analysis involves examining rock samples with the aid of polarized microscope to obtain mineralogical information on the constituent samples.

In preparation for thin sectioning, a thin slice of rock sample (Yolde Sandstone) was cut using the rock cutter and mounted on a glass slide using araldite. The mounted rock was heated gently and pressed hard on the glass slide to remove excess araldite and air present within it. The rock slice was scrubbed using abrasive powder and a thickness of 0.3mm was obtained. After this, it was polished and another glass slide was used to cover the prepared thin section. Then, the slides were viewed under microscope.

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IV. RESULTS AND DISCUSSIONS

Geological mapping carried in part of Gombe area reveals three (3) different Cretaceous successions, namely; Yolde, Pindiga and Gombe Sandstone Formations. Seven (7) sandstone samples from Yolde Formation were selected for Petrographic analysis after thin-sectioning. The are thus presented according to mineral framework observed under cross-polar as can be seen in the plates 1-7 presented below.

The sequence occurs as poorly consolidated, though indurated fine-medium grained sandstones occur. The colour varies from whitish, light brown, purplish and brown. The brown colouration is an indication of intense chemical alteration and dissolution of ferro-magnesian minerals.

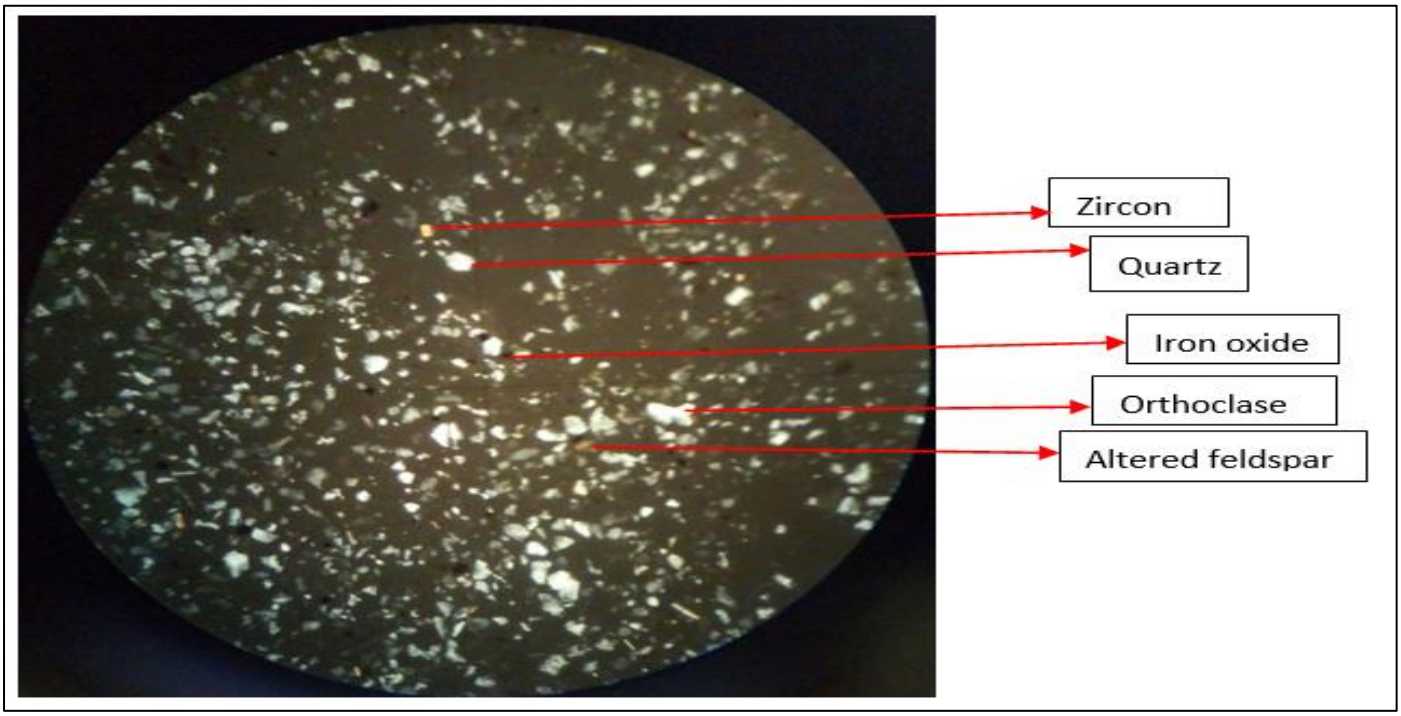

Plate 1. Photomicrograph of medium-grained sandstone of Yolde Formation with zircon, quartz, iron oxide, orthoclase and altered feldsper, N 10^{o} 15^{I} 994^{II} and E 11^{o} 15^{I} 362^{II}

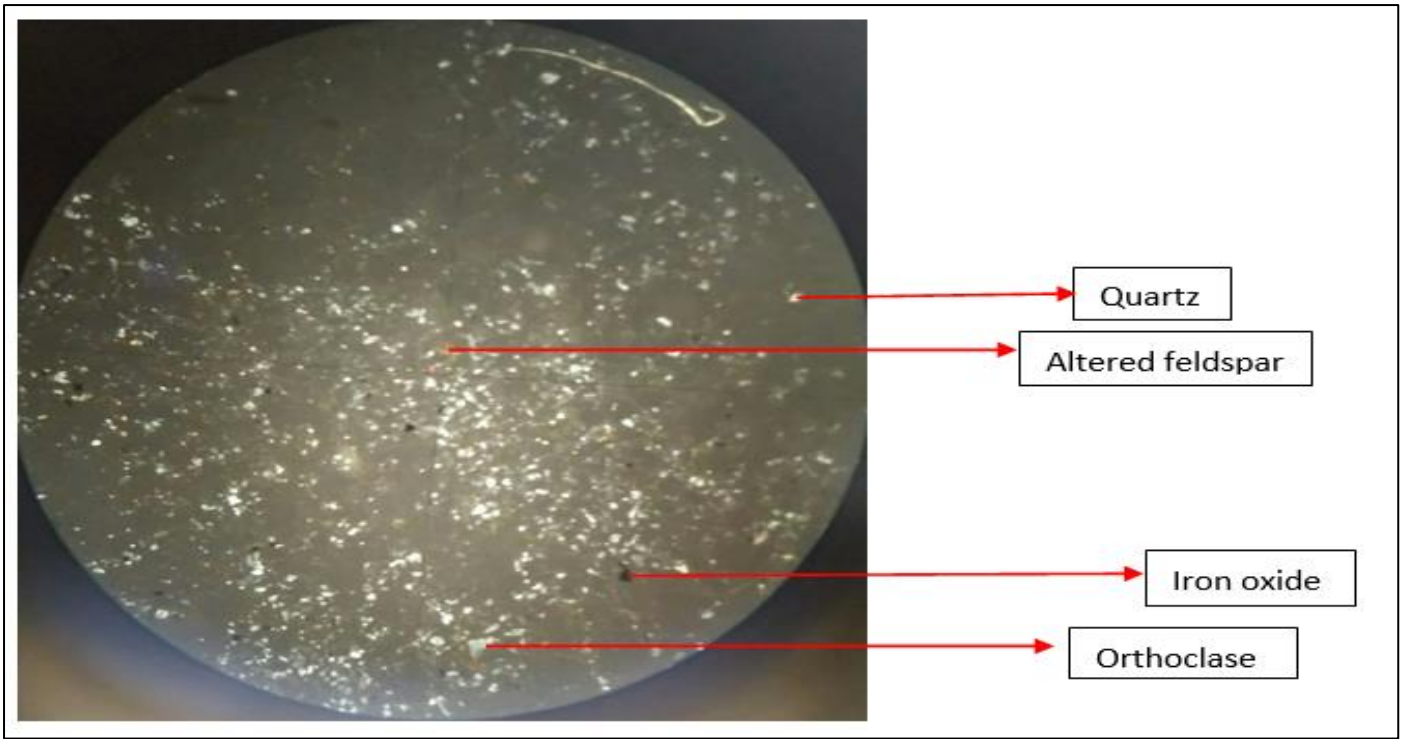

Plate 2. Photomicrograph of fine-medium grained sandstone of Yolde Formation with Quartz, Altered feldsper, Iron oxide and Orthoclase, N10^{o} 15^{I} 994^{II} and E 11^{o} 15^{I} 438^{II}

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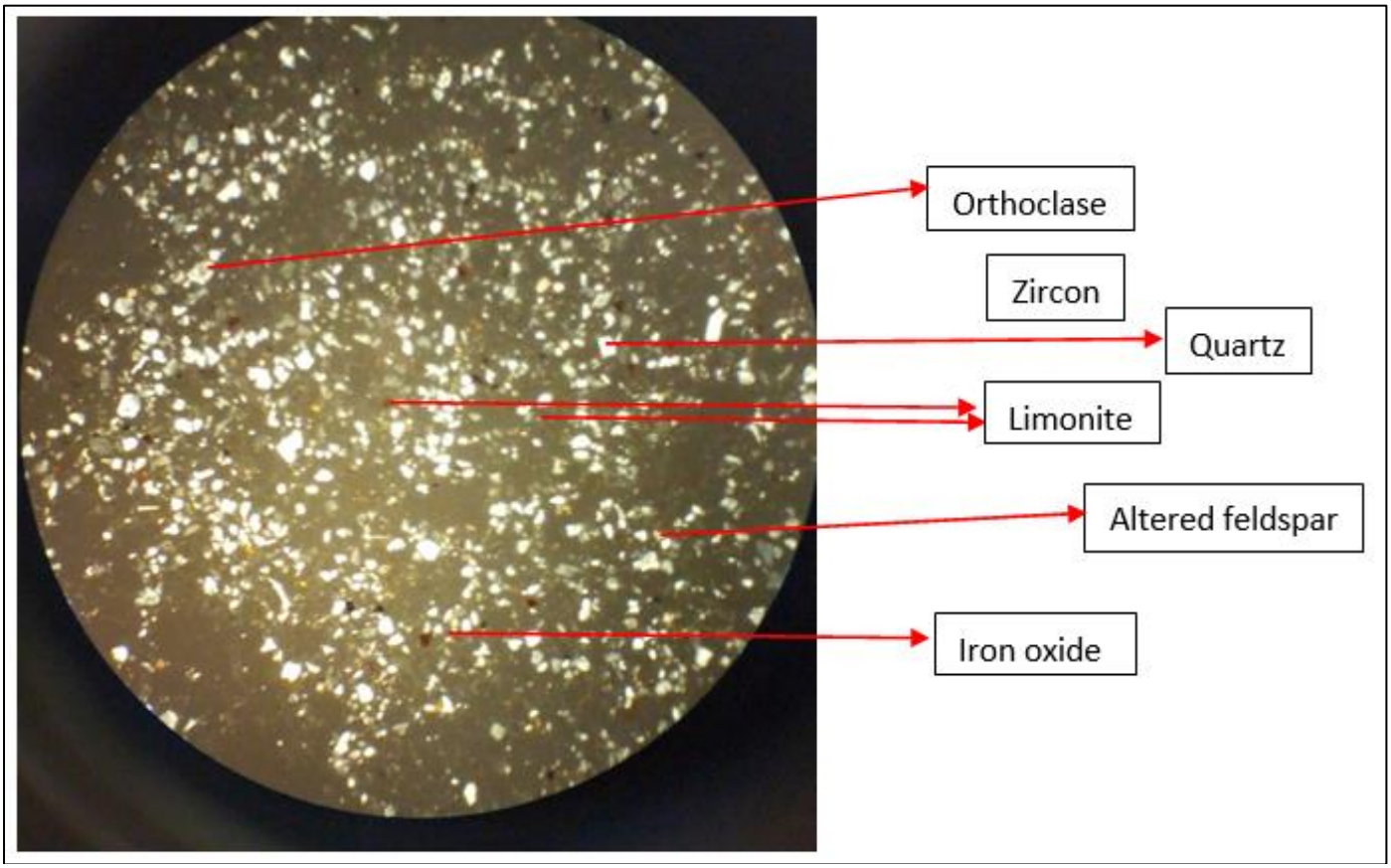

Plate 3. Photomicrograph of fine-grained sandstone of Yolde Formation with Quartz, Zircon, Orthoclase, Limonite, Altered feldsper and Iron oxide, N 10^{o} 16^{I} 252^{II} and E 11^{o} 16^{I} 177^{II}

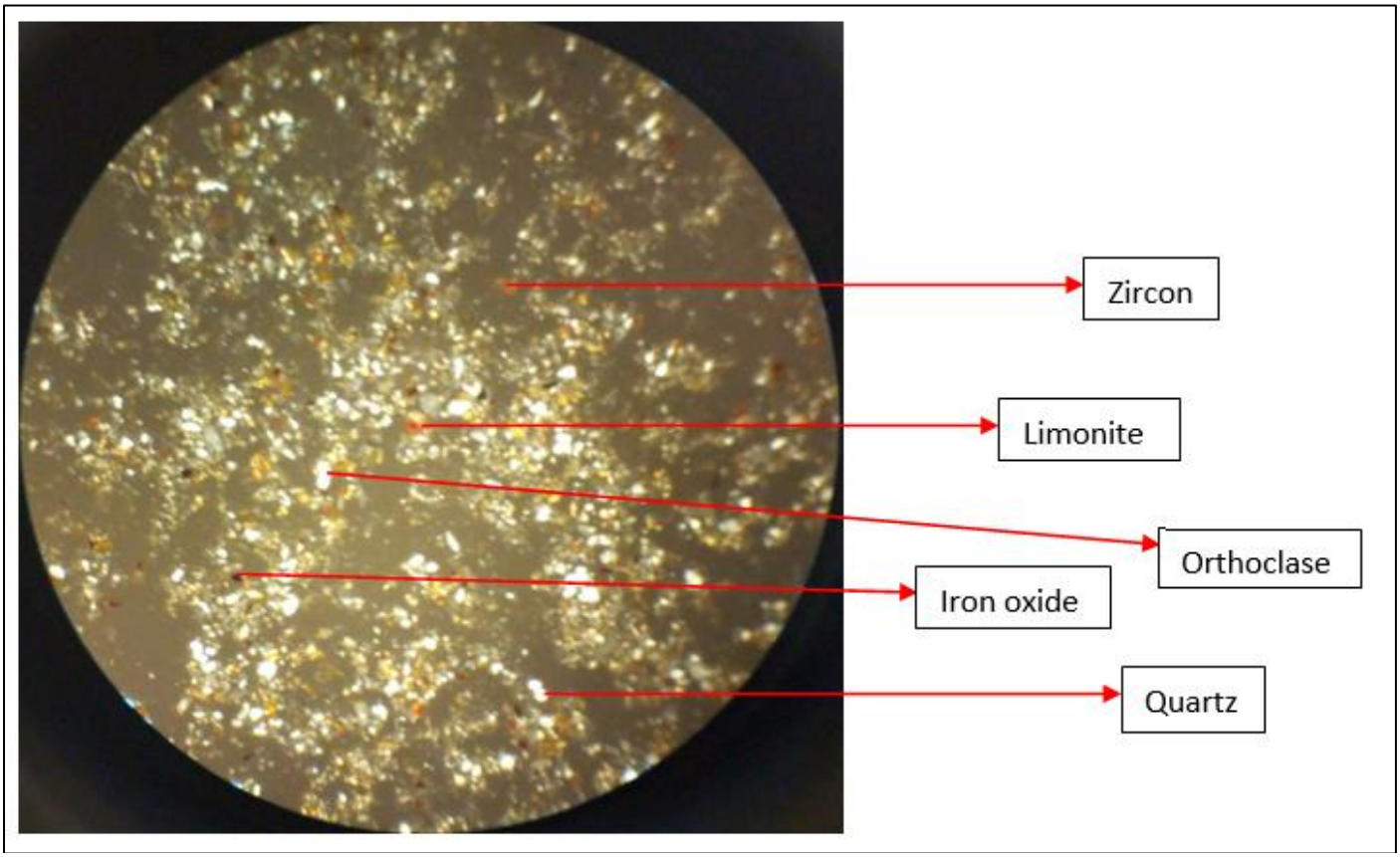

Plate 4. Photomicrograph of fine-medium grained sandstone of Yolde Formation with Quartz, Zircon limonite, Orthoclase, and Iron Oxide, N 10^{o} 16^{I} 139^{II} and E 11^{o} 18^{I} 883^{II}

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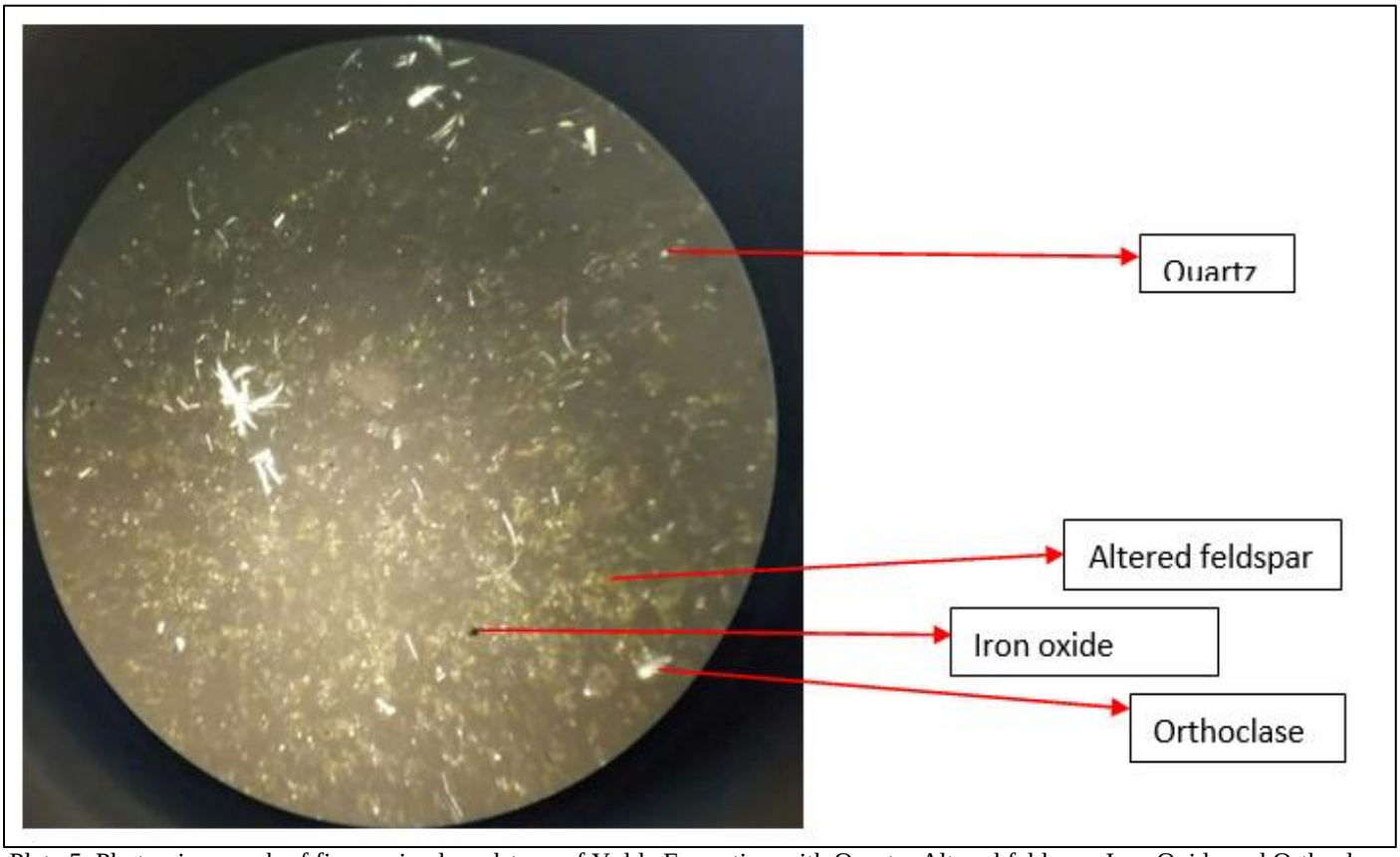

Plate 5. Photomicrograph of fine-grained sandstone of Yolde Formation with Quartz, Altered feldsper, Iron Oxide and Orthoclse, N 10^{o} 16^{I} 327^{II} and E 11^{i} 17^{I} 265^{II}

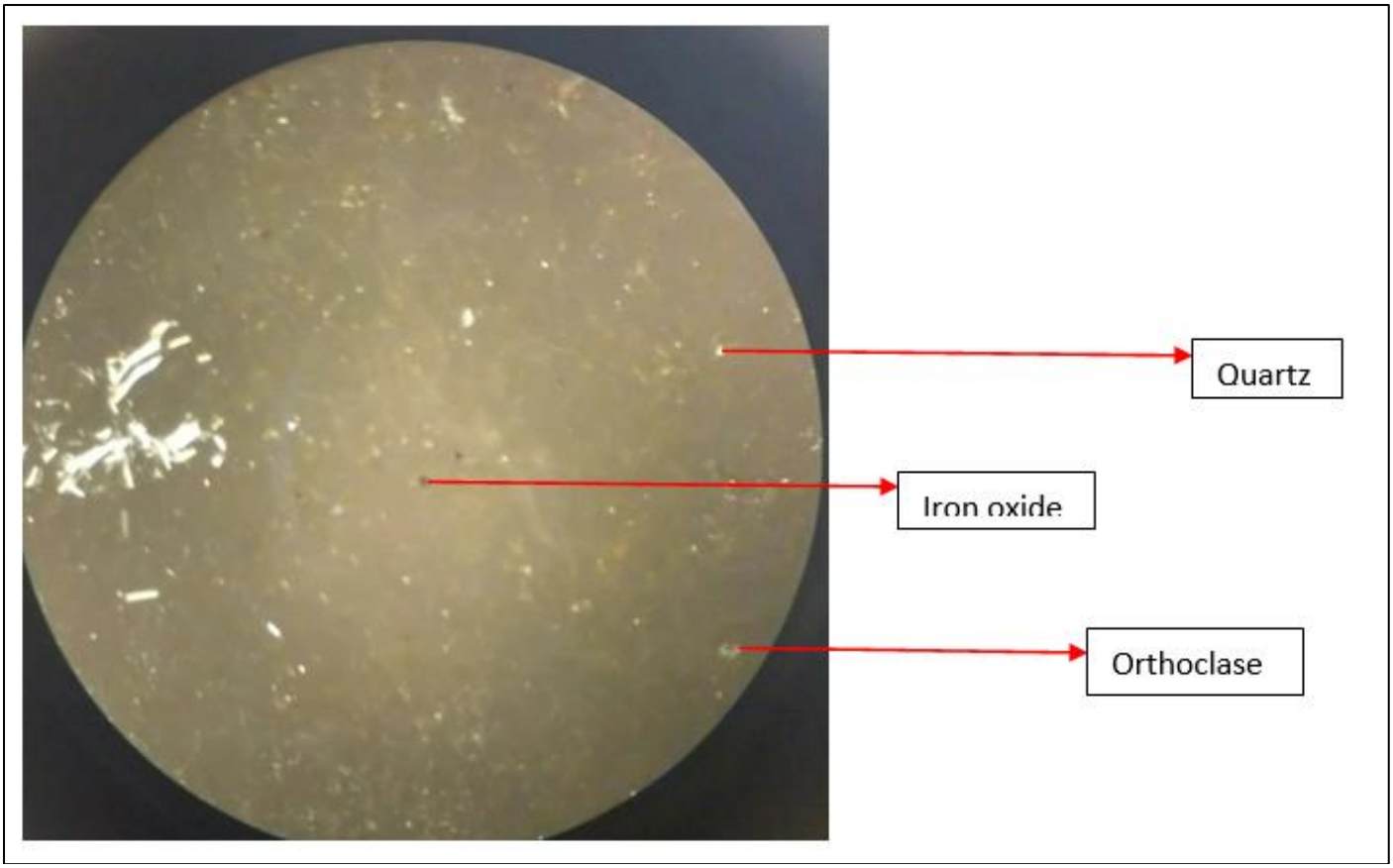

Plate 6. Photomicrograph of Fine-grained sandstone of Yolde Formation with Quartz, Iron Oxide and Orthoclase, N $10^{o}16^{I}$ 026^{II} and E 11^{o} 15^{I} 321^{II}

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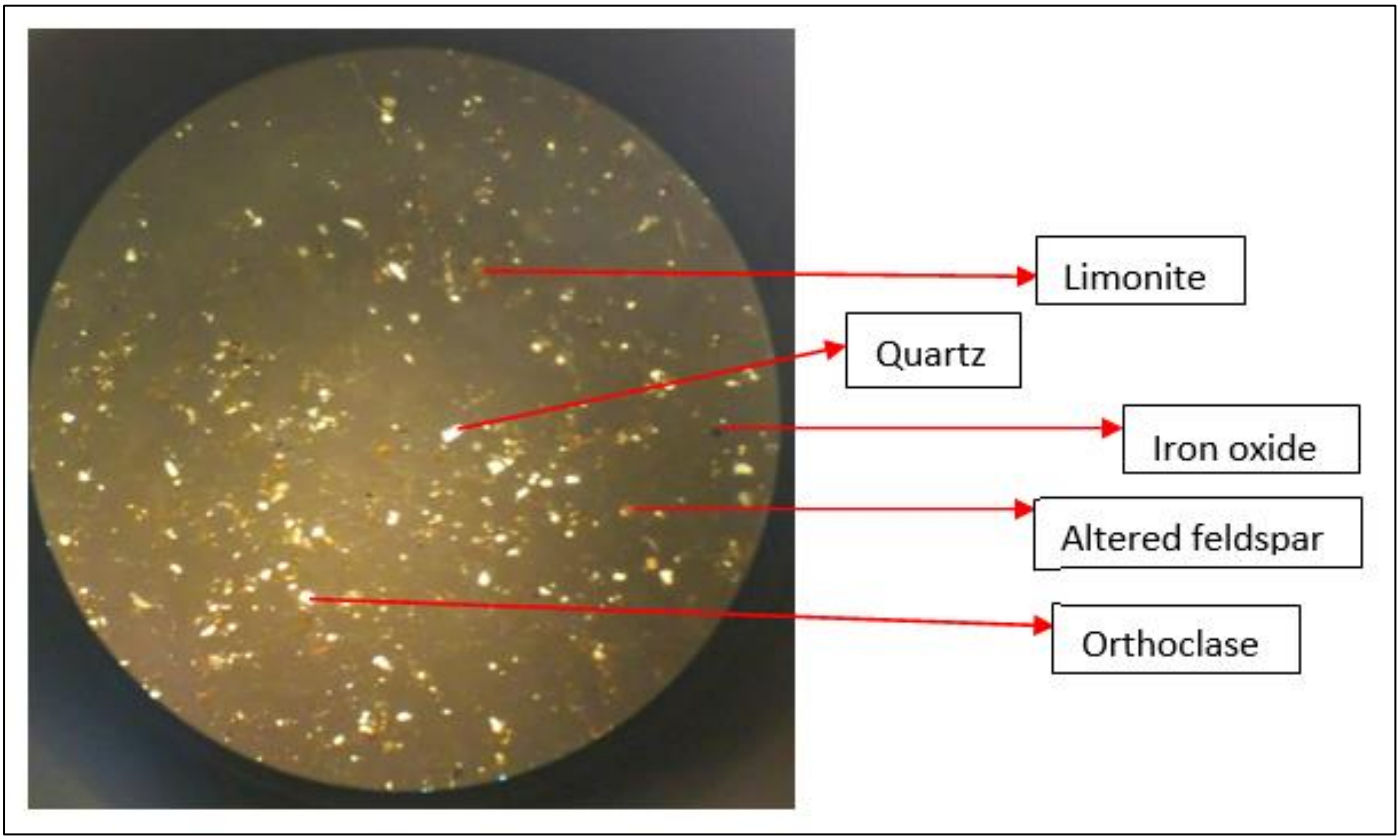

Plate 7. Photomicrograph of fine-medium grained sandstone of Yolde Formation with Quartz, Altered feldspar, Iron Oxide, Orthoclase,and limonite, N $10^{o}16^{I}$ 374 and E 11^{o} 17^{I} 613^{II}

➢ *Microscopic Interpretation*

Minerals observed under the polarized microscope are: Quartz, Iron oxide, Limonite, Orthoclase, Zircon, and Altered feldspar.

Quartz- been the most abundant and common mineral in sandstones is present in the 7 studied slides with considerable composition of more than 65% framework grain. It interlocks other minerals with an undulose extinction with high polycrystalline grain.

Feldspers- Orthoclase is the second most abundant framework grain in the studied slides though it is also present in all slides as well but has limited composition than quartz, it is the only potassium feldspers present, sodic and calcic plagioclase are absent. It is differentiated from quartz with its calbarg twining.

Stable Non-Opaque minerals- Zircon is the only non-opaque mineral present. It occurs in plates 1,3, and 4, its present tend to reveal to different episodic evolution depending on the degree of roundness. It is a very good interpreting source rocks provenance.

Stable Opaque Mineral- Limonite is present in plates 3, 4 and 7, whereas Iron oxide (hematite) is present in all the studied plates 1-7. Limonite (Geothite) usually occurs as a secondary material formed from the weathering of hematite (Iron oxide) magnetite and pyrite. It also occurs as pseudomorph and coatings in walls of fractures. Some limonite is found is stratified deposits where hydrous Iron oxide form precipitate of sediment on the floor of shallow swamps as in the case of Yolde Formation in this study. It is an Iron ore consisting of hydrated Iron (II) oxide- hydroxide in composition FeO(OH). Limonite is not a true mineral. Iron oxide refers to 2 minerals; hematite and magnetite to a lesser extent, the rarer oxide mineral maghemite.

Altered Feldspers- may fall under the group of opaque amourphous compound that are not recognised as crystals. It is basically a dark mineral under the cross-polar and not visible under polarized light. This is a feldspers that have weathered and possibly contains ferro-magnesian mineral**.**

Clay Minerals- they are the main abundant minerals in sandstone, they occur as matrix and are not visible under polarized light. They are not investigated in this study.

Mineral Cement- they are the authigenic minerals in the pore spaces that bound together framework grains.

➢ *Provenance Significance of Mineral Composition*

The kinds of siliclastic minerals and rock fragments preserved in sedimentary rocks provide evidence of the lithology of the source rocks.

Potassium feldspers such as Orthoclase identified in this study often suggests alkaline plutonic igneous and metamorphic rocks. The provenance of **Quartz** is relatively complex to deduce depending on the type of extinction it exhibit on the slides, whether undulose or nonundulose. Low-grade metamorphic source rocks: high percentage of

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Quartz with undulose extinction greater than 5" combined with a high polycrystalline grain containing more three crystal units per grain. The undulose extinction is caused by deformation of Quartz after crystallization which results in displacement of crystals. High- grade metamorphic rocks/Plutonic Igneous source: non-undulose Quartz and polycrystalline Quartz containing less than three crystal units per grain. Zircon identified this study is not the rounded type sourced from recycled sedimentation, rather it originated from crystallization of plutonic igneous rock, whereas Iron oxide is mostly sourced from basic igneous and volcanic rocks.

V. CONCLUSION

Detail geological mapping carried out revealed 3 different lithological units namely; Yolde, Pindiga and Gombe Sandstone Formations occur within the study area. But for the purpose of this study only the siliclastic of the Yolde Formation was used for the Petrographic analysis. The investigation showed the presence of Quartz, Orthoclase, Altered Feldspers, Iron oxide, Limonite and Zircon. Their source can be attributed to igneous intrusive.

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