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Structures and Petrology of the Rocks around Ekori, Western Ikom – Mamfe Embayment, Southeastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author EU designed the study, wrote the first draft of the manuscript and analyzed the data. Author EAA checked the protocol of the study and managed literature searches. Author BEE appraised data quality. Authors ANU and PAU checked the grammar and language. All authors read and approved the final manuscript.

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ABSTRACT

Ekori and adjoining areas is located in western part of the Ikom – Mamfe embayment. Sedimentary rocks such as sandstones, limestone, shale and few mudstones make up the sedimentary units in this area while intrusive bodies like dolerite sills and gabbro plutons constitutes the igneous rocks in the area. The sedimentary rocks of the study area contain different types of fossils most notably *bivalves* and *brachiopods* in sandstones and burrows in limestone. The calcareous sandstone sometimes form semi – caves beneath which grey shale occur. Fresh limestone usually occurs as thin beds within weathered sandstone. The presence of limestone and black shale suggests shallow and deep marine transgression events while the variation in sediment grain size from coarse to fine implies an intercalation of high and low energy depositional environment. Igneous bodies (dolerite and gabbro) intruded the sandstones and shale which baked some of the shales. The gently dipping sedimentary rocks are intensely fractured with NW – SE/ESE – WNW, NNW – SSE, ENE – WSW and NNE – SSW oriented fractures. The complex behaviour of tectonic fractures in this area implies

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the occurrence of multiple episodes of deformation. Thin section studies indicate the sandstones are lithic sub-arkosic sandstone with igneous or metamorphic parent material.

Keywords: Ikom – Mamfe embayment; fracture; sandstone; limestone; shale.

1. INTRODUCTION

The study area is part of the Ikom-Mamfe embayment which is 130 km long and 60 km wide, extending east from the Lower Benue Trough, Nigeria, into Cameroun where it narrows and terminates beneath the Tertiary to Recent Cameroon volcanics [1]. This area is located in southeastern Nigeria (Fig. 1a) and it occupies part of the western segment of the Ikom – Mamfe embayment (Fig. 1b). The geology of Ekori and adjoining areas like Ugep, Nko and Mkpani were studied and representative samples was collected for thin section analysis. The study area

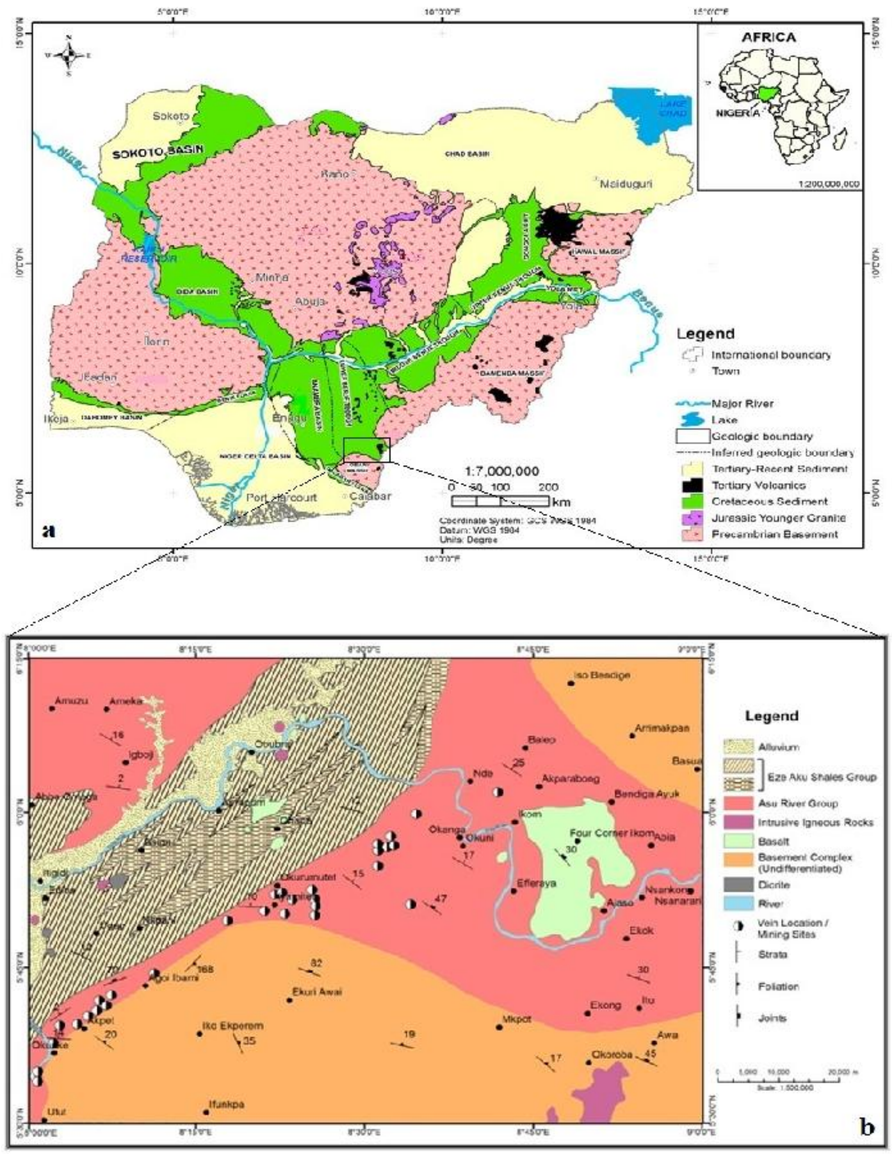

Fig. 1. (a) Geologic map of Nigeria; (b) Geologic and structural map of western Ikom – Mamfe embayment, southeastern Nigeria (Modified after [5])

predominantly contains sedimentary rocks with some intrusives (Fig. 1) such as gabbro and dolerite of Turonian age [2]. The dolerites occur as minor sills with overburden materials less than 1 m thick while the gabbros are found as minor mushroom – like, domal plutons [3]. The sedimentary units consist of a sequence of Lower Turonian sandstones and shales overlying Albian sandstones and limestones. The oldest sedimentary unit is sandstones and the limestone with a series of interbedded grey to black shale and siltstone with frequent facies change to sandstone, calcareous sandstone, sandy limestone and sandy shale constituting the rest of the area. The sedimentary rock units contain fossils and considering their lithology and fossil characters, they are most likely part of the Eze Aku Formation [2]. This embayment contains paralic sequences of the marine transgressive cycles. [4] noted that these cycles were from changes in sea level in which limestone and shale were deposited on fluviatile sandstones, providing a tool for the division of the embayment into Eze-Aku Group (Late Cenomanian – Early Santonian) and Asu River Group (Albian-Early Cenomanian).

2. METHODOLOGY

Geologic and structural data were collected using direct observation and measurement techniques. Detailed study of parts of the western segment of the Ikom – Mamfe embayment was carried out using a 1:25,000 topographic map, covering an area of over 75 Km^2. The area was sub divided into 25 grids with each grid covering about 3.45 Km^2 and each grid was studied in detail. Equipments used for this study includes a Garmin 76 Global Positioning System (GPS), Silva Compass Clinometer and a measuring tape. Hydrochloric acid (HCl) was applied to ascertain the concentration of carbonates in rocks (test for effervescence). The strike and dip of structures particularly were measured using simple structural methods and represented by stereographic projection and rose diagram. Thin sections were made for each observed lithology and the mineral composition of the rocks were established.

3. RESULTS

3.1 Geology

The study area predominantly contains sedimentary rocks (90-95%) with some igneous intrusions (Fig. 1). Sandstones, mudstone, limestone and shale are the most common sedimentary rock and these were deposited between the Albian and Lower Turonian. Thus the geology of this region is part of or similar to the Asu River Group and the Eze Aku Formation.

The study area contains four (4) types of sandstones which cover about 80% of the total area. These are calcareous sandstones, shaly sandstones, weakly consolidated sandstones and competent sandstones. These sandstones are fractured and contain fossils (Fig. 2a) except the weakly consolidated sandstones. Fossils (*brachiopod* cast/mould) are more common in the calcareous sandstones and they sometimes form caves within underlying grey shale. Their carbonate content is very low as reaction with hydrochloric acid shows little effervescence. The grain size of the grey coloured calcareous sandstones is fine to medium which indicates that their genesis can be traced to a low energy environment of deposition.

The pebbly medium to coarse grained weakly consolidated sandstones is usually found along stream channels. The pebbly nature of these white coloured rocks which entirely lack fossils strongly suggests that they were deposited in a high energy environment.

The competent sandstones readily occur in the study area and can be considered for construction due to their competence. This fine grained, grey to dark grey colour, competent lithic sub-arkosic sandstone outcrops is frequently small however extensive exposures also occurs which usually contains thin limestone layers and fossil casts (*bivalves*).

The shaly sandstone is not common in the study area. They are fine grained, have a dark grey colour and are usually intercalated with grey shale. Their grain size and close proximity to pure grey shale suggest a low energy environment of deposition.

Limestones are strongly restricted to the southern part of the area about 4-5 km SW of Ekori town and covers about 5% of the studied area. These light grey, fine to medium grained rocks with trace fossils (burrows) are found as thin layers (< 1 m in thickness) between weathered sandstones although the limestones are not weathered (Fig. 2b). The dominance of carbonate minerals in this rock was confirmed from the high effervescence it displayed when reacted with hydrochloric acid. Rapid marine transgression and regression could be the deposition mechanism of these thin bedded limestones within sandstones.

Shale exposures in the study area are usually very small, low lying, occur underneath sandstone caves and generally cover about 5% of the total studied area. They are grey to black in colour and are found mostly along road cuts or stream channels. The black shales are baked (Fig. 2c) by a gabbroic intrusion which has a sharp contact with the baked shale.

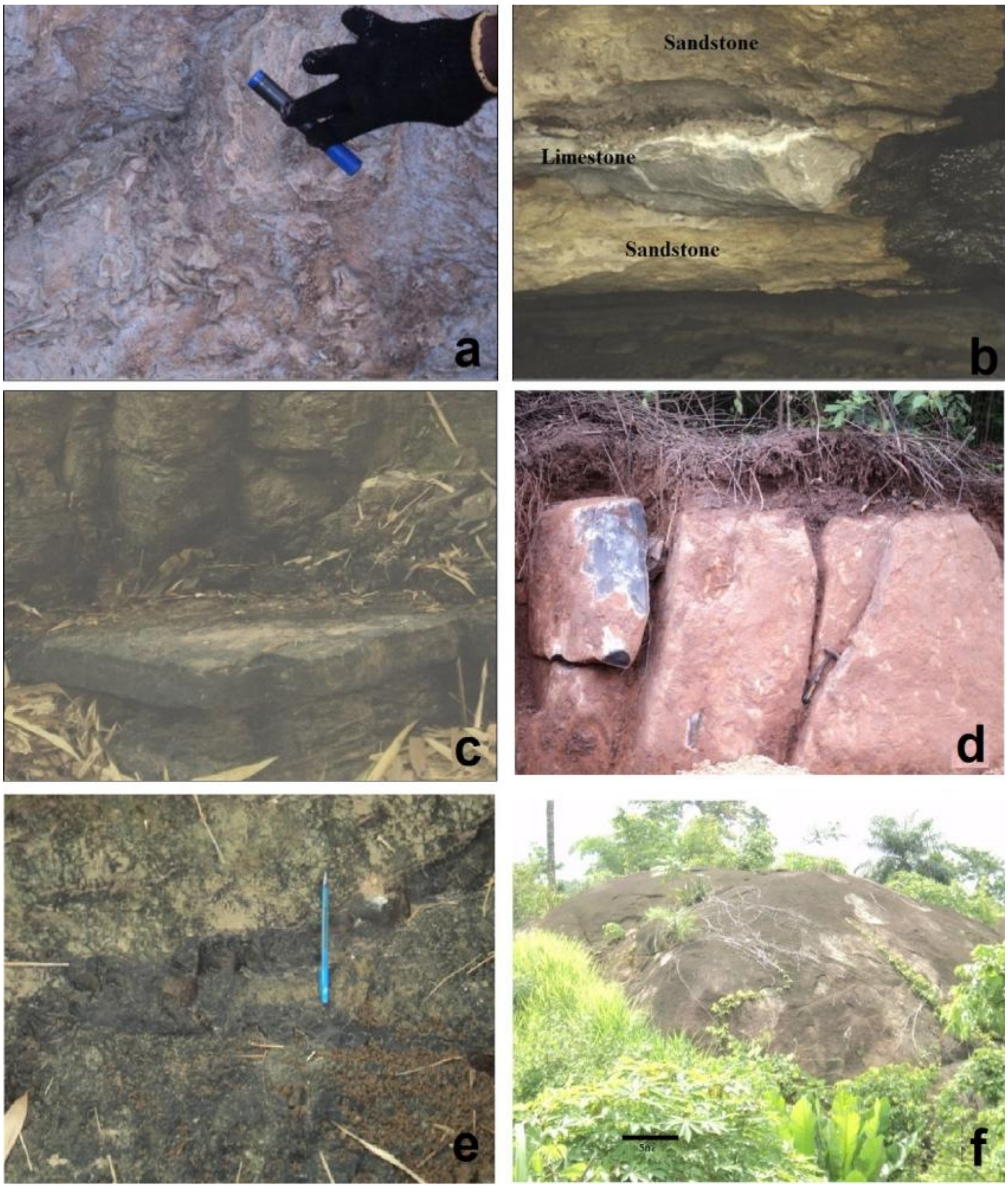

Fig. 2. (a) Fossils in sandstone (b) Limestone sandwiched between weathered sandstones (c) Baked shale in the study area (d) Dolerite sill in Ekori (e) Minor dolerite dyke in Ekori (f) Domal gabbro intrusion in Ekori

Dolerites in the study area are sills or sill-like bodies (Fig. 2d) covering about 2% of the total studied area and were found in many locations. They sometimes occur as minor dykes intruding sandstones (Fig. 2e). They are near surface intrusions and are over-lain by muddy dark red soils which on the average are not thicker than 1 m (Fig. 2d). They occur within the Ekori main town and were not found anywhere else in the studied area. There are muddy red soils which are strictly associated with the dolerite as they were not observed anywhere else in the area. These soils could be as a result of weathering of dolerites [6] which shows an orange to brown colour from the top inwards or from the side inwards [7]. The Ekori dolerites are emplaced in the sandstones of the Eze Aku and Asu River Formations. They are dark coloured, medium to fine grain with ophitic to sub-ophitic (doleritic) texture. Most of these dolerites are fresh and do not show much effect of weathering or hydrothermal alternation. The dolerite sills are generally parallel to the regional strike direction and show vertical and horizontal joint patterns [2].

Gabbros in the study area occur as mushroom-like plutons with a domal outcrop (Fig. 2f). They cover about 1% of the total studied area and they occur in pockets close to each other at four (4) locations all about about 2 – 3 km ENE of Ekori main town. They are grey to dark grey in colour, coarse-medium grained and sub-ophitic texture. Although the nomenclature of this intrusive rock is not certain, its texture, macroscopic and thin section analyses indicates that it is most likely a gabbro. A very similar rock was observed by [2] at Ugep and he named it microdiorite. The difference between the two rocks is the fact that the Ugep intrusion observed by Hossain is somewhat finer in texture and it is not as massive as the rock observed in Ekori. This rock weathers in sheets i.e. they show ex-foliation weathering while titanium iron oxide (ilmenite) is observed to weather out of the rocks and is deposited along the foot paths.

3.2 Structural Analysis

The structural data from the study area were projected on the Lambert equal area stereonet as poles (Fig. 3a and b) and also shown by a rose diagram (Fig. 3c). 143 joints were measured and analysed. Most of the structural data were measured from sandstones for the following reasons i) sandstones occupies most parts of the study area thus they can provide a composite result ii) joints in shales not penetrative thus they are most likely not tectonic in origin iii) limestone occur as thin layers within sandstones thus it was impossible to measure any structural data iv) the dolerites which are near surface sills lacked fractures.

From Fig. 3a and c, at least four fracture sets can be identified in the rocks of this region. A dominant NW – SE/ESE – WNW fracture set is supported by minor NNW – SSE, ENE – WSW and NNE - SSW sets.

The clustering of poles to the joints around the periphery of the stereonet indicates that most of the joints have high angle dips (Fig. 3a). The occurrence of more poles to joints in the NE-SW direction indicates that the major orientation of the joints is NW-SE which is typical of the first deformation episode of the Cretaceous [5,8]. These high angle dips are typical of the ‘ac’ extension and ‘bc’ tensile fractures [5,8].

The sedimentary units are characterized by varied orientations and low to moderate angle dips (4°-20°) (Fig. 3b). This is evident from the clustering of the poles to planes of bedding planes around the center of the stereonet (Fig. 3b).

3.3 Petrology

There are five main rock types in the study area. These are sedimentary sandstone, limestone and shale with igneous dolerite and gabbro. The texture of the sandstones collected from the study area is coarse to fine grained and they are light grey in colour. The limestone, shale and dolerite is fine to medium grain [9] while the gabbro is mostly coarse grained.

Two sandstone samples were analysed, the first showed the occurrence of 50% of quartz and 20% of feldspar which indicates that the parent material is most likely an igneous or metamorphic rock. The mineralogical composition of the first sandstone sample (Fig. 4a) suggests that this rock is most likely a lithic sub-arkosic sandstone. The colour and competence of the sandstone which was observed macroscopically was justified by the quartz content in the rock.

The mineralogical composition of the second sandstone sample (Fig. 4b), indicates that quartz occupied 60% of the rock while feldspar covers 20%. The remaining 20% is rock fragment and accessory minerals (Fig. 4b). This is similar to the first sample the conspicuous amount of feldspar in the rock suggest that rapid erosion and burial was active during the formation to the sandstone because feldspars are unstable in sedimentary environments.

The shale sample analysed microscopically is the baked shale. Clay minerals occupies about 65% of the rock while pyrite (30%) was clearly observed with its golden colour (Fig. 4c).

The occurrence of shales and limestone in the Ikom – Mamfe embayment proved that this embayment experienced some marine influence as opposed to earlier studies [10]. Furthermore marbles have been observed and studied in this basin [11] and this also confirms the marine influence on the Ikom – Mamfe basin which is largely but not completely fluvatile. Limestone from this study showed 60% calcite (Fig. 4d) and its mode of occurrence (as thin layers within sandstones) suggests an environment that experienced rapid trangressive and regressive events.

The dolerite contains mostly plagioclase, pyroxene and quartz. Plagioclase and pyroxene share about 75% of the total mineral composition (Fig. 4e). These minerals (plagioclase and pyroxene) are the primary minerals of dolerite [6]. The field occurrence of the rock is hypabyssal i.e. it is overlain by sediments a few meters thick (usually not greater than 1 m).

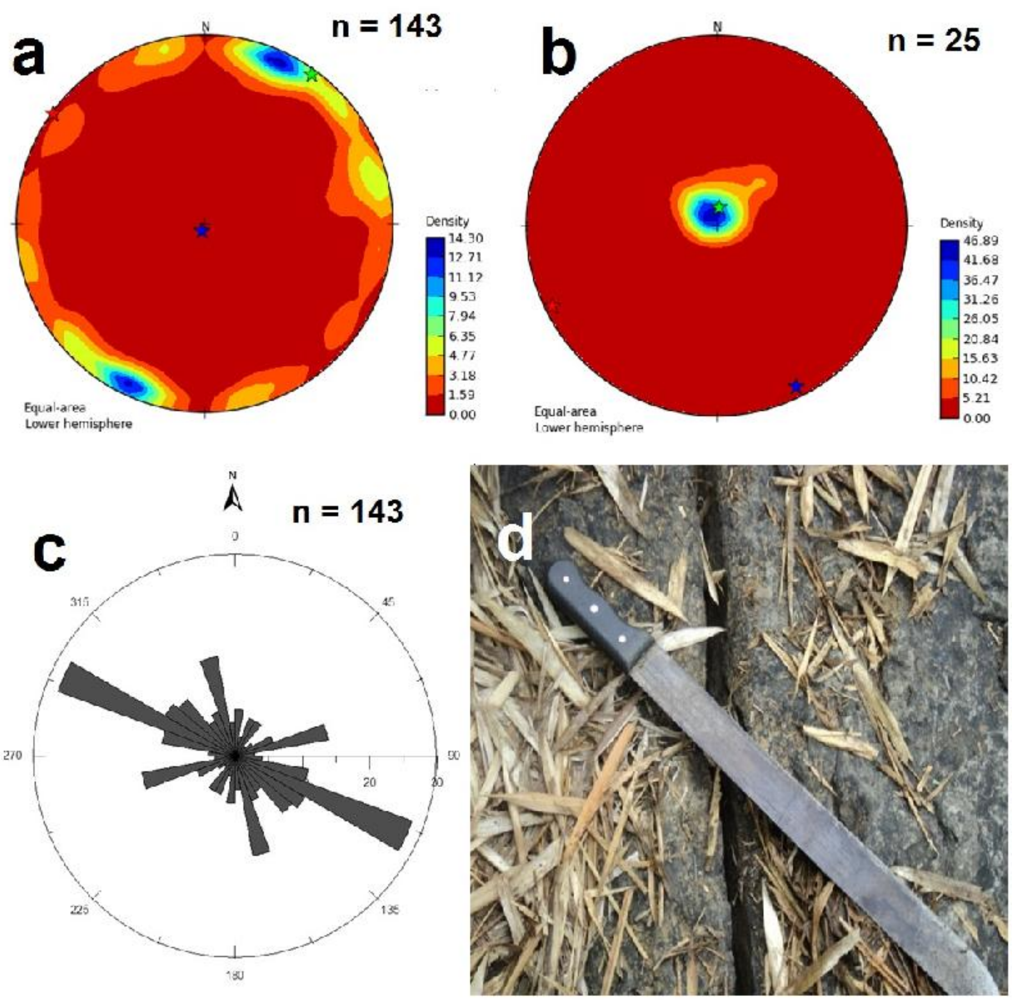

Fig. 3. (a) Stereographic projection of joints in the study area (b) Stereographic projection of bedding planes in the study area (c) Rose diagram of joints in the study area (d) Open joint in the study area

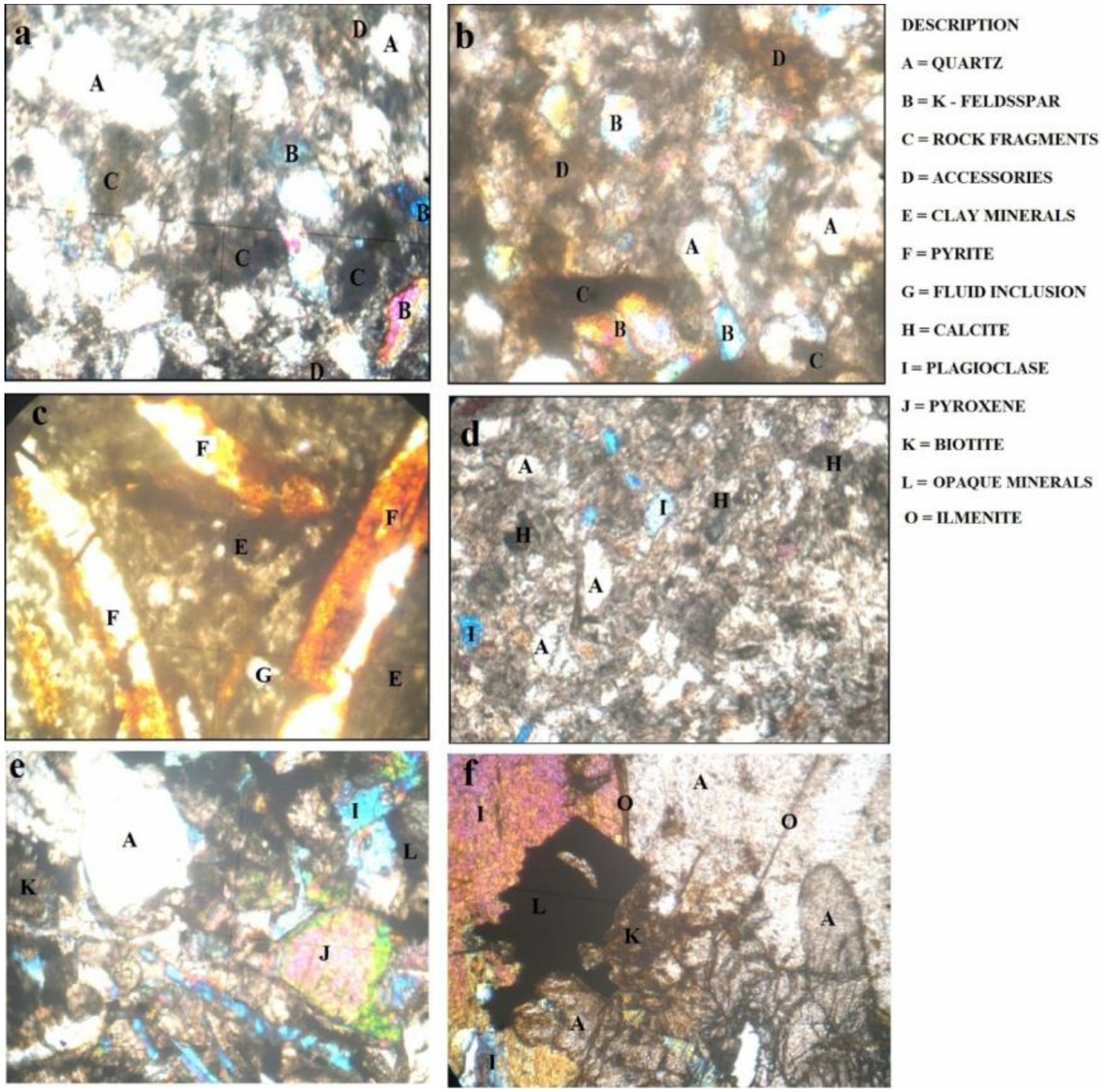

Fig. 4. Photomicrographs of rocks in the study area (a) sandstone (b) sandstone (c) baked shale (d) limestone (e) dolerite (f) gabbro

The texture of the gabbro from field observation is subhedral granular with large crystals. The occurrence of over 10% of mafics, 30% of quartz and 30% of plagioclase suggest that this rock is most likely a gabbro. Iron bearing minerals like ilmenite was also present. The ilmenites (iron – titanium oxide) are needle like in thin section (Fig. 4f).

4. DISCUSSION

The sedimentary units of the study area are made up of sandstones, limestones and shales. The sandstones are classified into four types based on macroscopic observation, physical properties and mode of occurrence. They include calcareous sandstones, shaly sandstones, weakly consolidated sandstones and highly competent sandstones. The sandstones contain different types of fossils (Fig. 2a), most notably *bivalves* and *brachiopods* while trace fossils such as burrows are found in the limestones. The limestone occurs as thin beds within the sandstones with the calcite in limestone. The shales are usually grey colour however, the baked shales are black in colour with pyrite mineralization (Fig. 4c) as a result of gabbro and dolerite intrusion which are wide spread in the Ikom – Mamfe embayment [2,3,9]. The Ikom – Mamfe embayment is comparable to the Benue

Trough in terms of tectonism, magmatism, stratigraphy, sedimentology, brines and even mineralization (compare [2,5,10–22]). The thin layers of limestone beds within sandstones which indicates a rapid shallow marine transgressive and regressive cycle is explained by the repetitive cycles of marine transgression and regression which the embayment experienced just like the Benue Trough [19]. The occurrence of black shales indicates the possibility of deep marine incursion in the region [20]. The presence of both fine grained and pebbly sandstones in the study area suggests that the energy of the environment in which the sandstones were deposited varies between high and low – energy environments.

The sedimentary units were intruded by basic – intermediate intrusions (dolerite and gabbro). These intrusives are very competent and can be quarried locally for light construction works [9]. The intrusives of the Ikom – Mamfe embayment were formed during the Cenomanian and Santonian Periods [2], however from fracture studies; [8] proposed a syn – tectonic emplacement for some of the gabbro and basalt in the embayment.

The Ikom – Mamfe embayment was deformed by two episodes of deformation in the Lower Cretaceous and the Upper Cretaceous [2,5,8]. Considering fracture kinematics and the relationship between fracturing and folding, the fractures in the Ikom – Mamfe embayment have been classified into ac_1, bc_1, ac_2 and bc_2 [8]. The joints in Ekori and adjoining areas are basically extension fracture which are mainly oriented in the NW – SE and NE – SW directions (Fig. 3) and have high angle dips (Fig. 3). Generally, joints in the study area are oriented in the NW – SE/ESE – WNW, NNW – SSE, ENE – WSW and NNE – SSW directions (Figs. 3a and c). The most conspicuous fracture sets are the NW – SE and NNE – SSW sets which a designated ac_1 and ac_2 fractures of the Lower and Upper Cretaceous deformation episodes, respectively. Microscopic studies revealed that the sandstones in the study area are lithic sub-arkosic sandstone with an igneous or metamorphic rock parent material.

5. CONCLUSIONS

The structures and petrology of Ekori and adjoining areas in the western segment of the Ikom – Mamfe basin have been studied in detail. The presence of limestone and shale is an indication of marine influence on this embayment. The occurrence of limestone as thin layers within weathered sandstones as well as the presence of grey shale suggests that this area experienced a rapid shallow marine trangressive and regressive event with the possibility of deep marine incursion form the observation of black shale. The sediment grain size in the study area varies widely which shows that the energy of the environment of deposition was not consistent but varied from high to low energy environments. Fracture characterization shows that two episodes of deformation affected the study area which contains lithic sub-arkosic sandstone with an igneous or metamorphic parent material. Igneous activity in the Ikom – Mamfe embayment is represented by the occurrence of dolerite and gabbro which intruded the sedimentary sequence.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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