

Original Research Article

PETROLOGY AND STRUCTURES OF THE ROCKS AROUND EKORI, WESTERN IKOM – MAMFE BASIN, SOUTHEASTERN NIGERIA

ABSTRACT

The study area (Ekori and environs) is part of the western flank of the Ikom – Mamfe basin and contains sedimentary rocks which are made up of basically sandstones with minor mudstone, limestone and shale all of which are intruded by hypabyssal dolerite sills and mushroom like gabbro plutons. The sandstones contain different types of fossils most notably *bivalves* and *brachiopods* and sometimes form semi – caves beneath which grey shale occur. The limestone and mudstone occur as thin beds within sandstone and shale are baked in some cases. The study area show evidence of high and low energy depositional environment characterized by shallow and deep marine transgression events which led to the deposition of limestone and black shale respectively. The bedding planes in the sedimentary rocks dip gently and are cut by fractures oriented in the NW – SE/ESE – WNW, NNW – SSE, ENE – WSW and NNE – SSW directions. The fracture characteristics support the occurrence of two episodes of deformation in this basin. While thin section analysis indicates the sandstones are probably lithic sub-arkosic sands with a parent material most likely of igneous or metamorphic origin.

KEYWORDS: Ikom – Mamfe basin, fracture, sandstone, limestone, shale.

1. INTRODUCTION

The study area is part of the Ikom-Mamfe basin 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 volcanic cover of the Cameroon volcanic line [1]. This

25 area is located in southeastern Nigeria (Fig. 1 a) and it forms part of the western flank of the
 26 Ikom – Mamfe basin (Fig. 1 b). The geology of Ekor and Ekor areas like Ugeb, Nko and
 27 Mkpani were studied and representative samples was collected for thin section analysis. The
 28 study area predominantly contains sedimentary rocks with some igneous intrusions (Fig. 1). Two
 29 (2) basic to intermediate igneous bodies (gabbro and dolerite) of Turonian age [2] having
 30 different sizes and shapes, mostly concordant to the country rock are found in Ekor area. These
 31 intrusions occur either as minor sills or as minor mushroom - like plutons [3]. While the dolerites
 32 occur as hypabyssal sills with overburden materials less than 1 m thick, the gabbro occurs as
 33 domal plutons. The sedimentary units consist of Albian sandstones and limestones followed by a
 34 sequence of Lower Turonian sandstones and shales. The oldest sedimentary sequence is the
 35 sandstones and the limestones which formed thin beds in between the sandstones. A series of
 36 interbedded grey to black shale and siltstone with frequent facies change to sandstone, calcareous
 37 sandstone, sandy limestone and sandy shale constitutes the rest of the area. The sedimentary rock
 38 units found in Ekor area are fossiliferous and based on lithology and fossil characters are
 39 considered to be part of the Eze Aku Formation [2]. This basin contains paralic sequences of the
 40 marine transgressive cycles. [4] noted that these cycles were from changes in sea level in which
 41 limestone and shale were deposited on fluvatile sandstones, providing a tool for the division of
 42 the basin into Eze-Aku Group (Late Cenomanian – Early Santonian) and Asu River Group
 43 (Albian-Early Cenomanian).

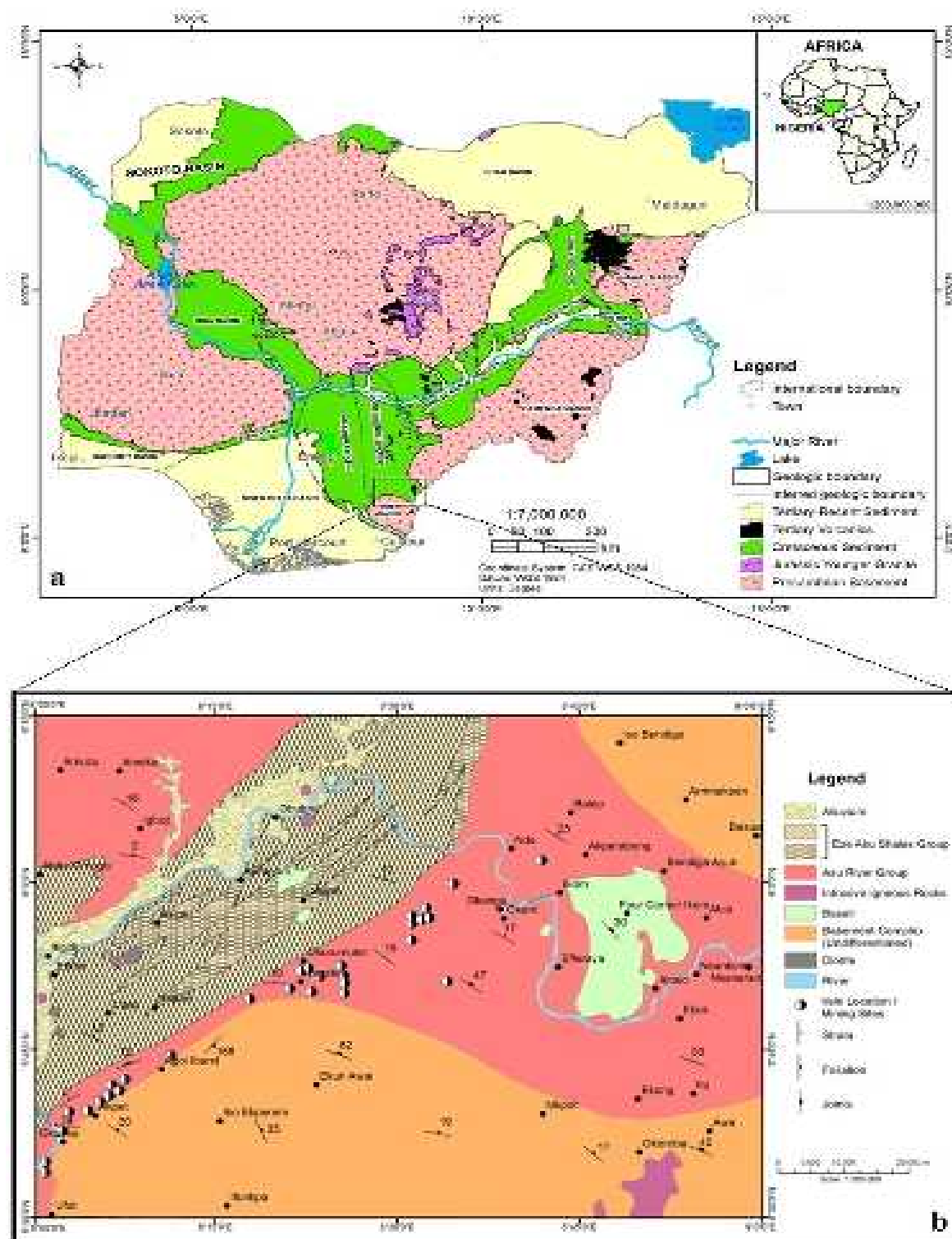


Fig. 1. (a) Geologic map of Nigeria; (b) Geologic and structural map of western Ikom – Mamfe basin, southeastern Nigeria (Modified after [5])

2. METHODOLOGY

This study involves the detailed mapping of rocks and structures within the study area. The field mapping was carried between May 2011 and June 2011. Detailed mapping of parts of the western flank of the Ikom – Mamfe basin was done on a topographic map with scale of 1:25,000 covering an area of over 80 Km². The map was sub divided into 25 grids with each grid covering about 3.45 Km². The geology and structure of each grid was mapped systematically. The major equipment's used for this study includes a Garmin 76 Global Positioning System (GPS), Silva Compass Clinometer and a measuring tape. While hydrochloric acid (HCl) was used in testing for the presence of carbonates in rocks (test for effervescence) in the field. The attitude of structures particularly bedding planes and fractures were measured using standard structural techniques and presented using stereographic projection and rose diagram. Thin sections were prepared for each lithologic unit identified in the field and the mineral constituents of the samples were identified.

3. RESULTS

3.1. Geology

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

Sandstones cover about 80% of the total area. Four (4) types of sandstones were observed which are calcareous sandstones, shaly sandstones, weakly consolidated sandstones and

highly consolidated/competent sandstones. All these sandstones are fossiliferous (Fig. 2 a) the weakly consolidated sandstones they are fractured to varying degrees. The calcareous sandstones are highly fossiliferous with frequent *brachiopod* cast/mould and they sometimes occurs as ves with underlying grey shale. They show little effervescence upon reaction with an acid indicating the presence of small quantity of carbonates; these were formed in a low energy environment as their grain size is fine. The calcareous sandstone is usually medium grained and usually grey in colour.

The weakly consolidated sandstones are usually found along stream channels and are medium to coarse grained and are in some cases pebbly. They also occur as caves and are usually whitish in colour. They are completely devoid of fossils and they seem to be deposited in a higher energy environment

The highly consolidated/competent sandstone readily occurs in the study area and can be considered for construction due to their competence. Their exposure is usually small but is sometimes extensive and massive and has limestone within it (Fig 2 b). Macrofossil casts (*bivalves*) were also observed. They are usually fine grained and are grey to dark grey in colour. The highly competent sandstone was found to be lithic sub-arkosic sandstone after petrographic analysis.

The shaly sandstone is the least frequently occurring and is found only in a few locations. They occur with little grey shale, while pure grey shales are usually observed a short distance away. They are fine grained and dark grey in colour. In general, all these various sandstones were bedded and had bedding planes with dip angles between 4° to 20° mostly in the NE and SE directions.

Limestones are highly restricted to the southern part of the study area about 4-5km SW of Ekori town and covers about 5% of the mapped area. They occurred as thin beds (less than 1m

thick) between weathered sandstones but they remain fresh (Fig. 2 b). It showed high effervescence upon reaction with acid confirming the presence of carbonate minerals. They are light grey; fine to medium grained and had trace fossils (i.e. little burrows). Rapid marine transgression and regression could be the deposition mechanism of these thin bedded limestones between sandstones.

Shale exposures in the study area are usually very small and low lying. They are found mostly along road cut and generally cover about 5% of the total mapped area. They vary in colour from grey to black. The black shales are baked shales (Fig. 2 c) and these were baked by a gabbroic intrusion which has a sharp contact with the baked shale along a stream channel. Most of the grey shales occur underneath a sandstone cave and their extent is quite small compared to the overlying sandstone.

Dolerites in the study area are sills or sill-like bodies (Fig 2 d) which cover about 2 % of the total mapped area and were found in many locations. They sometimes (rarely) occur as minor dykes intruding sandstones (Fig 2 e). They are near surface intrusions and are overlain by muddy dark red soils which on the average are not thicker than 1 m (Fig 2d). They occur within the Ekorì main town and were not found anywhere else in the mapped 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 Ekorì 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 alteration. The dolerite sills

117 are generally parallel to the regional strike direction and show vertical and horizontal joint
118 patterns [2].

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

129

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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

3.2. Structural Analysis

This section serves to analyze the structural measurement gotten from the study area and their implication to the general geology of the area (Fig 3 a – d). A total of 143 joints were measured from the study area. It must be noted that majority of the joints were measured from the sandstones as joints were not penetrative in the shales and due to the occurrence of the limestone (i.e. as thin beds in-between sandstones) it was impossible to measure joints. Most of the joints have high angle dip (Fig. 3 a) and a few vertical/open joints were observed (Fig 3 d).

The joint data from the study area were projected on the Lambert equal area stereonet as poles (Fig 3 a) and also presented in a rose diagram (Fig. 3 c). From Fig. 3 a 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 poles to the joints are clustered around the periphery of the stereonet indicating that most of the joints have high angle dips. So poles occur round the stereonet indicating that all directions were represented but more poles are found in the NE-SW direction indicating that the general trend 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 bedding planes in the sedimentary rocks had variable strike values with low angle dips (4° - 20°) (Fig. 3 b). From the stereographic projections, the poles of the beds are clustered around the center of the stereonet indicating that most of the bedding planes have low angle dips.

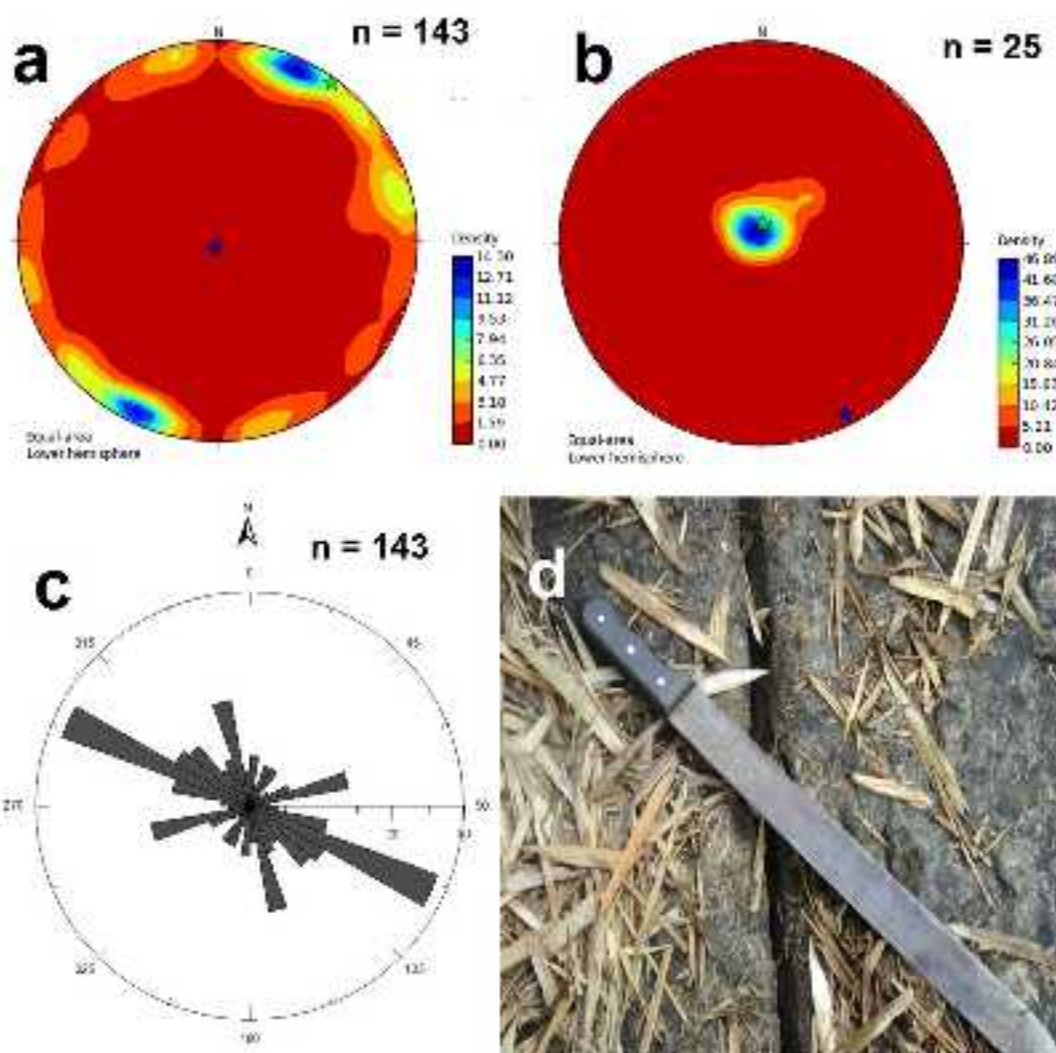


Fig. 3. (a) Stereographic projection of joints in the study area (b) Stereographic projection of bedding planes in the study area (c) Rose diagram of joints in the study area (d) Open joint in the study area

3.3. Petrology

Thin sections of representative samples of the rocks in the study area were prepared for microscopic analysis. There are three major sedimentary rocks in the study area, they are; sandstone, limestone and shale/baked shale. The texture of the sandstones collected from the study area is mostly fine grained and they are light grey in colour.

The modal composition of quartz, feldspar and the rock fragments (Fig. 4 a), suggests that this rock is most likely a lithic sub-arkosic sandstone. The occurrence of 50% of quartz and 20% of feldspar indicates that the parent material is most likely an igneous or metamorphic rock; a sedimentary parent rock would have produced sandstone with almost entirely quartz. The percentage of quartz also justified the high competence of the sandstone and its grey colour which was observed macroscopically in the field.

In a sandstone sample (Fig 4 b), the percentage of quartz (60%), feldspar (20%) and rock fragment (Fig. 4 b) again shows that this sandstone is most likely a lithic sub-arkosic sandstone but the percentage of feldspar indicates that the environment experienced rapid erosion and burial because feldspars are unstable in the sedimentary environment. This rock is also very competent and grey in colour.

The shale was baked as a result of a granitic intrusion (gabbro) which occurred nearby. The clay minerals cannot be delineated under the microscope, they show a black colour and occupied about 65% of the rock while pyrite (30%) was clearly observed with its colour (Fig. 4 c) which was also observed macroscopically. This rock is called “Baked shale”.

This rock is light grey in colour and showed high effervescence when reacted with Hydrochloric acid, this was justified by the occurrence of 60% of calcite (Fig. 4 d) which is the cementing material of the rock. The rock is thought to be a limestone.

The dolerite contains mostly plagioclase, pyroxene and quartz. Plagioclase and pyroxene constitute about 75% of the total mineral composition (Fig 4 e). 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 with sediments a few meters thick (usually not greater than 1 m).

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

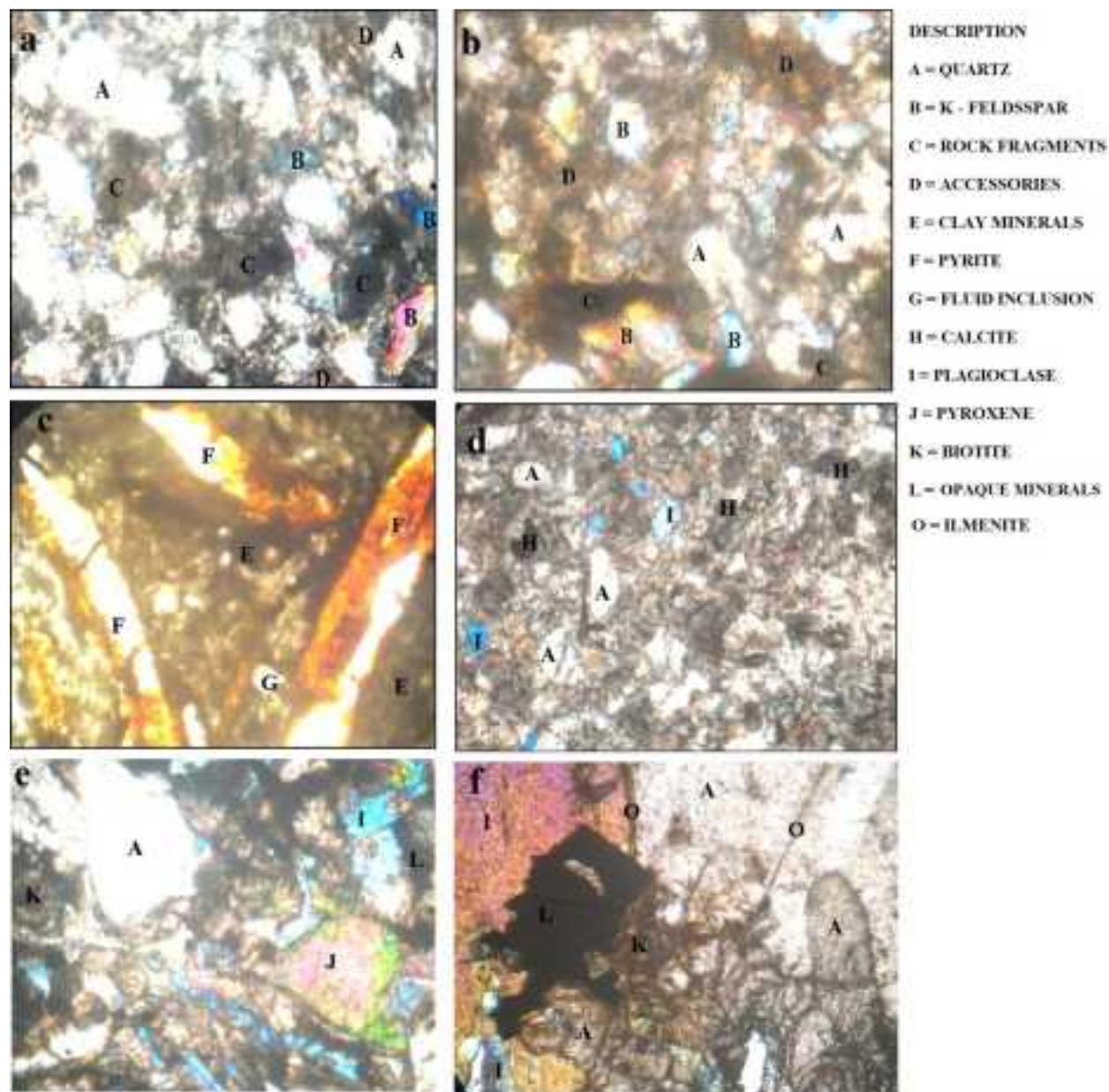


Fig. 4. Photomicrographs of rocks in the study area (a) sandstone (b) sandstone (c) baked shale (d) limestone (e) dolerite (f) gabbro

4. DISCUSSION

The sedimentary units of the study area **rocks** are made up of sandstones with minor mudstones, limestones and shales. The sandstones **were separated** into four types based on macroscopic observation, physical properties and mode of occurrence. **The different types of sandstones** include calcareous sandstones, shaly sandstones, weakly consolidated sandstones and highly consolidated/competent sandstones. The sandstones contain different types of fossils (Fig. 2 a), most notably *bivalves* and *brachiopods* and sometimes form semi – caves beneath which grey shales occur. The limestones and mudstones occurs as thin beds within the sandstones with the calcite in limestone displaying high relief which changes as the stage is rotated. In some cases, the shales are black in colour and baked with pyrite mineralization (Fig. 4 c) as a result of gabbro and dolerite intrusion which are wide spread in the Ikom – Mamfe basin [2, 3, 9]. The Ikom – Mamfe basin is quite similar to the Benue Trough in terms of tectonism, magmatism, stratigraphy, sedimentology and even mineralization. The Ikom – Mamfe basin just like the Benue Trough experienced repetitive cycles of marine transgression and regression [10] and this explains the occurrence of thin limestone beds within sandstones which indicates rapid shallow marine transgressive and regressive cycles. The presence of black shales in the area suggests the possibility of deep marine incursion in the region. The energy of the environment in which the sandstones were deposited varies between high and low – energy environments **we** have a combination of fine grained and pebbly sandstones in the study area.

The sedimentary units were intruded by basic – intermediate intrusions (dolerite and gabbro). These intrusives are very competent and can be quarried locally **for** construction works [9]. The intrusives of the Ikom – Mamfe basin 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 basin.

Two episodes of deformation are known to have affected this basin in the Lower Cretaceous and the Upper Cretaceous [2, 5, 8]. The fractures of the deformation episodes have been classified into ac_1 , bc_1 , ac_2 and bc_2 based on fracture kinematics and the relationship between fracturing and folding [8]. The ac_1 and bc_1 represent the extension fractures of the first episode of deformation (Lower Cretaceous) while ac_2 and bc_2 represent the extension fractures of the second episode of deformation (Upper Cretaceous). The fractures in the study area are mostly extension fractures with high angle dips (Fig. 3) and are perpendicular to the bedding planes which dips gently ($8^\circ - 20^\circ$) and it is mainly oriented in the NW – SE and NE – SW directions (Fig. 3). The fractures are oriented in the NW – SE/ESE – WNW, NNW – SSE, ENE – WSW and NNE – SSW directions (Figs. 3 a and c). The NW – SE and NNE – SSW are the most prominent fractures in the study area and they are the ac_1 and ac_2 fractures of the Lower and Upper Cretaceous deformation episodes respectively. This shows that the study area just like the entire basin have affected by two episodes of deformation. A thin section analysis revealed that the most of the sandstones are most likely lithic sub-arkosic sandstone and the occurrence of 50% of quartz and 20% of feldspar indicates that the parent material is most likely an igneous or metamorphic rock, a secondary parent rock would have produced a sandstone with almost entirely quartz. The percentage of quartz also justified the high competence of the sandstone and its grey colour which was observed macroscopically in the field.

5. CONCLUSION

The sedimentary rocks of parts of Ekorì and environs show different variety of sandstones with minor mudstones, thin bedded limestone and shales. The thin limestone beds intercalated with sandstone suggest the occurrence of shallow marine transgression and regression event in this basin. The presence of black shales indicates the possibility of deep marine incursion while the variety of grain size of sandstones from fine grained sandstones to pebbly sandstones suggest a mixture of low and high energy environment of deposition. All these sedimentary units have been intruded by hypabyssal dolerite sills and gabbro. Fracture behavior supports the occurrence of two episodes of deformation in this basin while thin section analysis indicates the sandstones are probably lithic sub-arkosic sandstone with a parent material is most likely of igneous or metamorphic origin.

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