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Petrography of Ajali Sandstone in Ayogwiri – Fugar – Orame Area of Western Anambra Basin: Implication for Diagenetic and Depositional History.

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Abstract
The friability of the Ajali Sandstone was studied with photomicrographs of thin sections made from samples collected from the Formation in Ayogwiri, Fugar and Orame in the Western Anambra Basin in order to understand its diagenetic and depositional implications. This study shows that the Ajali Sandstone is a quartz arenite consisting of subangular to subrounded grains of quartz which were either monocrystalline or polycrystalline. Diagenetic fabrics of compaction, dissolution, alteration and corrosion were common features. Straition marks, fracture lines, some of which show filling, stress zonation were major compaction fabrics in the Sandstone. Authigenic quartz formed from the dissolution and recrystallization of quartz grains as well as quartz overgrowth occur. Reaction rims around grain margins indicating severe alteration and corrosion were seen growing from grain margins inward, leaving the Sandstone, which may have been indurated with little or no cementing material. Thus leading to the friability of the Sandstone and it's susceptibility to erosion.
Keywords: Petrography, Diagenesis, Authigenesis, Decementation, Cementation, Dissolution, Alteration, Corrosion,

1. Introduction

The Ajali Sandstone is a major clastic Formation of Campanian-Maastrichtian age occurring within the Anambra basin. Regionally, the Sandstone comprises thick succession of sandstones with thin beds of mudstone near the base and shales which occur as secondary lithology. The Formation is extensively cross stratified into different types of cross-bedding including: planar, trough and herringbone cross-bedding which occur at different stratigraphic levels. The crossbeds are large scale (over 1 meter high in places). The thicknesses of the beds are not uniform but appear to be uniform with parallel bedding planes which have low dipping beds. The beds consist of friable, moderately sorted sands with shapes of grains ranging from subangular to subrounded. Initially, the Formation was called the White False Bedded Sandstone and later changed to Ajali Sandstone (Reyment, 1965; Kogbe, 1976).

Akaegbobi and Adeleye (2001) showed in their studies that the Ajali Sandstone is poorly sorted, medium to coarse grain, negatively skewed and platykurtic. They interpreted the environment to be continental (fluviatile) and classified the sands as quartz arenites. From their thin section and heavy mineral studies, they claimed the Sandstones are mineralogically mature and texturally immature with varying degree of diagenetic changes as compaction, cementation and clay authigenesis which are responsible for the difference in porosity and permeability of sandstones when compared to their freshly deposited equivalent. In spite of the diagenetic effects, ferruginization and the presence of clay drapes noticed, they concluded that the Ajali Sandstone is a potential reservoir based on the measured reservoir properties.

This study aims at relating the friability of the Sandstone and it's susceptibility to erosion forces to diagenetic effects. Samples of the Sandstone in Western Anambra Basin were taken from three locations: Ayogwiri, Fugar and Orame where the Formation was well exposed in quarry sites and along road cuts (Fig 1). It was found that the Sandstone had undergone compaction, disilification, decementation, solution activities, intense alteration and corrosion especially at grain margins which have reduced or eliminated it's cementing materials, thus, resulting to the friability of the Sandstone and as well enhanced it's susceptibility to erosion.

2. Stratigraphy

The origin of many sedimentary basins in West Africa is associated with the splitting up of the Gondwana super continent. The Benue Trough is the failed third arm of a rift associated with this event and basins resulted from this differential subsidence of fault blocks. The Anambra Basin is a synclinal megastructure located at the southwestern edge of the Benue Trough in Nigeria. The Anambra Basin was a platform with reduced sedimentation before the Santonian tectonic event which uplifted the Abakaliki–Benue Trough into the Abakiliki Anticlinorium, and created the Anambra Basin and Afikpo syncline. Sedimentation in the Anambra Basin began in the Campanian - Maastrichtian with the deposition of the Nkporo Group, Mamu Formation, Ajali Sandstone and the Nsukka Formation. In the Quaternary, the Imo Formation, Ameki Formation and the Ogwashi – Asaba were deposited. These Formations were deposited in different depositional environment.

3. Methods Of The Study

Petrography focuses on detailed description of rocks. The detailed analyses of minerals by optical mineralogy are critical to understanding the origin of the rock. The heavy and light minerals were separated for studies. Light minerals were determined by petrographic studies of sands impregnated and slices cut and smoothened on one side by carborundum. The slice was put on a glass slip with heated balsam on it for the purpose of gluing. The thin sections made from each sample collected were analyzed under the petrographic microscope for the purpose of studying the light minerals such as quartz, feldspars etc. and to show the textural and diagenetic imprints of the Formation.

4. Results

The mineralogy, textural characteristics and diagenetic fabrics such as, compaction, dissolution, alteration, replacement and recrystallization, stress zonations were investigated. The Sandstone is a quartz arenite based on framework composition. The quartz constitutes above 95% of framework elements, the matrix is made up finer grains of quartz and the fabric is not cement supported.

There are both monocrystalline and polycrystalline quartz occurring in the Formation. The grains are basically subangular to angular with few sub-rounded in places Quartz overgrowth is seen in some grains but a more common feature of the Sandstone is the occurrence of lots of fracture lines. Stress shadows and zones are also very prominent. Authigenic quartz grains are seen in the sections which have formed in situ as a result of dissolution of quartz at the grain margins and reformed into microcrystalline grains at favourable sites and conditions. Reactions rims and alterations characterize most of the grain margins. The alterations are observed growing from the margins inward. Detrital quartz is partially clouded with alteration products. Iron oxide acts as coating grains on quartz and etching of grains also occurs. Some of the quartz grains contain inclusions which are acicular and others are of irregular form while most do not contain inclusions.

The most common heavy mineral noticed is magnetite which occurs as small shapeless black grains. Heamatite also appears as brownish grains. Zircon, garnet and tourmaline were also among the heavy mineral suite.

4.1 Petrography of Ajali Sandstone in Ayogwiri

At Ayogwiri, the Sandstone is made up of heterolithic and large cossbedded facies, figs. 2- 6 represent the photomicrographs from ayogwiri. Samples taken from the heterolithic beds show fine quartz grains which are generally subangular to angular. They are moderately to poorly sorted layers with pebble grains in places. The large pebble grains are subrounded and show clear grain margins. Stress zones and fracture lines are not common on these grains. The surfaces of the grains are smooth with no etching. Most of the quartz grains are monocrystalline showing straight margins. Iron oxide coating is seen on some of the grains, The mineral glauconite occur and inclusions were also seen.

In between each of the beds are thin mudrapes that average about 5cm in thickness (fig. 4). These beds contain fine grain with so much fracture lines, alteration and corrosion of grain margins. Most of the surfaces are etched. Iron oxide coating is very common coat on the quartz grains.

The crossbedded facies of the Sandstone in Ayogwiri are also subangular to angular, moderately to poorly sorted beds. They show monocrystalline and polycrystalline quartz grains. Authigenic quartz is seen as quartz overgrowth (fig. 3). Most of the grain margins show alteration and corrossion along grain margins and fracture lines. Stress zones and shadows were also noticed on the grains.

4.2 Petrography of Ajali Sandstone in Fugar

Most of the grains of the Sandstone at this location are monocrystalline but polycrystalline quartz also occurs. The sands are moderately to poorly sorted, sub rounded to rounded grains. Most have clear margins, though a few samples are with corroded margins. Inclusions and alterations occur mainly within the grains. Cast of biogenic forms such as *Reophax sp, Haplophragmoides sp* occur in thin section. Infiltration of hollow molds with quartz mineral was also observed. Authigenic quartz occurs as microcrystalline grains formed in situ (figs

7-12).

4.3 Petrography of Ajali Sandstone in Orame 1 and 2

Similar features found in previous locations were also recorded in Orame 1 and 2: Inclusions, alteration and corrosion at grain margins, fracture lines, stress shadows, authigenic quartz. Rotation of some grains was observed. Iron oxide is seen coating some of the grains. Fracture lines, though present were not so common. The grains are mainly moderately sorted to poorly sorted. Most have sharp grain margins with corrosion of margins occurring in some. Some sections have sub angular grains while others were subrounded (figs.12 – 21).

5. Discussion

The petrographic examination of thin sections reveals a great deal of information about the depositional and diagenetic history of any sediment. The dominant mineral of the Sandstone is quartz, which is above 95% of the composition of the sediment. The occurrence of feldspar is very minimal. The Sandstone shows great compositional maturity. The Sandstone is poorly sorted to moderately sorted with subangular to angular grains, which implies textural immaturity. The subangular to angular grains indicate they have not travelled far distance. Smaller quartz grains form the matrix of the Sandstone and cementing material is almost nonexistent due to the diagenetic effects, though quartz overgrowth occurs in places. This has contributed to the friability of the Sandstone. Most of the grains have straight or tangential contacts. The quartz grains show one generation of quartz overgrowth, indicating one cycle of sedimentation. Monocrystalline and polycrystalline quartz occur, with the monocrystalline predominant. Some of the grains of the polycrystalline quartz are polygonal with straight simple boundaries, while a few have sutured contacts (fig. 3). Elongated and subspherical quartz occur. Some of the quartz grains display acicular and irregular types of inclusions and these are characteristic of igneous rock.
The heavy mineral suite (hematite, magnetite, zircon, tourmaline and garnet) in the Formation suggest both igneous and metamorphic origin for the sediments.

5.1 Diagenesis

The Sandstone show diagenetic fabrics due to compaction and chemical alteration. The compaction fabrics are related to mechanical and solution (chemical) compaction, while chemical alteration fabrics are divided into cementation, dissolution, alteration and mineral replacement (authigenic mineral formation).

5.1.1 Compaction

The Sandstone being a quartz arenite is near monominerallic and due to overburden, pressure on grain to grain contact has been achieved. Intense breakage or fracturing of grains, slippage of grains occur, some large grains fracture completely in to smaller ones due to overburden pressure. The occurrence of these fractures led to secondary porosity as most of them are not filled with cementing materials. Compaction by chemical processes as in solution at grain contact also occurred. No grain penetration is observed at grain contacts as most of the grains have straight contacts, though corroded and with reaction rims. Strain shadows or stress zonation, which are indicative of severe compaction, occur in all locations, especially in Orame 1 and 2.

5.1.2 Cementation

The solution at the grain contacts may have led to formation of silica that is the precursor mineral to the cementing material. Quartz overgrowth occurs growing conformably as cement on the detrital quartz grains. This occurs in all locations.

5.1.3 Dissolution

Dissolution fabric occurs very prominently in the Sandstone and corrosion of quartz grains occur along grain margins and fracture lines. Dissolution in the subsurface generated secondary porosity and also resulted to slight corrosion of the detrital grains. Progressive selective dissolution of cements and grain within the sediment led to attack of the whole mineral which commonly commenced by corrosion along cleavage plane and margins. This is because, quartz is a stable mineral and selective dissolution is restricted to strain boundaries and corroded margins. Continued dissolution led to the collapse of remains of grain fragment and with time removed entire detrital grains. In addition, subsequent collapse of grain coatings whether original or produced at earlier diagenetic alteration occured (Tucker,1988). Examples abound in all locations. This corrosion affected both large and small quartz grains and resulted in intragranular or partial intragranular secondary porosity. This occurred as the previously formed cementing materials and grain margins have been corroded contributing to the friable nature of the Sandstone.

5.1.4 Alteration and Replacement

Tucker (1988) says, dissolution in the subsurface is commonly associated with alteration and replacement of minerals and diagenetic changes that take place in super mature quartz sandstones are limited, unless pore fluids are extremely aggressive and that considerable dissolution is unconformity related where active meteoric circulation can remove less stable minerals. In Ajali Sandstone, dissolution, alteration and replacement fabric occur prominently which imply the extreme aggressiveness of the pore fluid. Much alteration of the quartz grains occur especially at grain margins and authigenic euhedral quartz grains formed as replacement minerals within the sediment. Several examples abound in all four locations.

5.2 Paragenesis

Textural relationship of the grains and the cementing material in the Sandstone indicate the following order of diagenesis

Mechanical compaction of grains, resulting, to fracturing and breakage of grains.

Solution at contacts and recrystallization of silica as microcrystalline quartz and quartz overgrowth.

Dissolution, corrosion, alteration, at margins of quartz grains and recrystallization of silica as microcrystalline quartz grains at favourable conditions and sites.

Development of iron oxide coating on quartz grains and over corroded margins.

6. Conclussion

The dominant mineral is quartz which is above 95%, with very minimal feldspar in places. The matrix is made up of smaller quartz grains that may have fractured from the larger grains. Quartz overgrowth occurs but the sands are very friable. The Sandstone shows compositional maturity but texturally immature.

The heavy mineral suite includes tourmaline and zircon, magnetite, hematite and garnet. The observed mineral suites suggest metamorphic and igneous origin for the sediments

Ajali Sandstone may have been indurated initially and due to severe compaction, dissolution, alteration, recrystallization and replacement, have become friable over time. From petrography, the quartz grains show lot of striation marks, stress zones and fracturing. Corrosion, alteration and reaction rims occur at most of the grain margins, which must have destroyed any known cementing material that initially existed. Replacement and recrystallization of silica into microcrystalline authigenic quartz and quartz overgrowth also occur. The very large granular quartz grains are fractured and collapsed into smaller angular grains due to compaction as they show so much stress zones. The intense dissolution, corrosion, alteration, noticed in the Sandstone may not be unrelated to basin morphology and sediment motion, which have imparted pore fluid aggressiveness that has enabled the dissolution, corrosion and alteration of the very stable quartz grains.

These diagenetic changes have rendered the sandstone very friable and very vulnerable to erosion forces.

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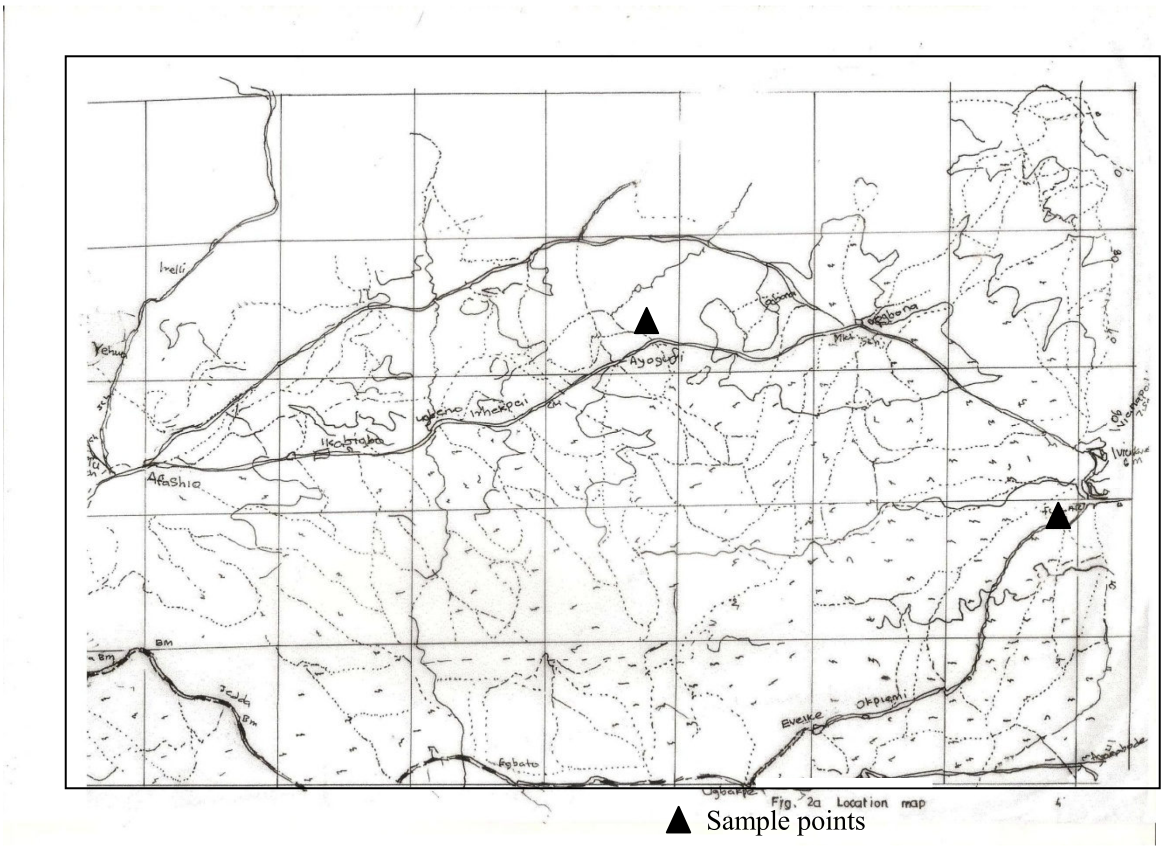
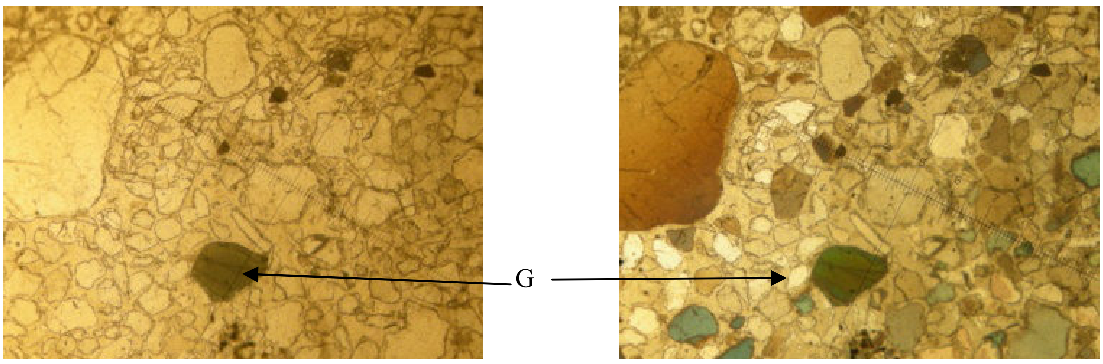


Fig. 1 Showing sample locations of the Ajali sandstone in the Western Anambra basin

Photomicrographs of Ajali Sandstone in Ayogwiri



PPL XPL

Fig. 2: Poorly sorted, sub rounded grains. Iron oxide coating on quartz grain, Glauconite grain (G)

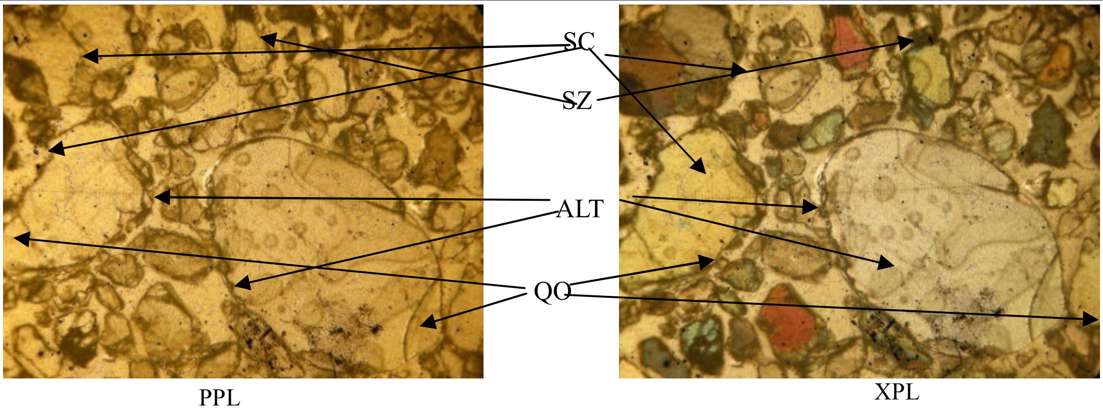


Fig. 3: Stress zonation (SZ), Corrosion and alteration at grain margins (ALT); Sutured contact in polycrystalline grain (SC); Quartz overgrowth (QO)

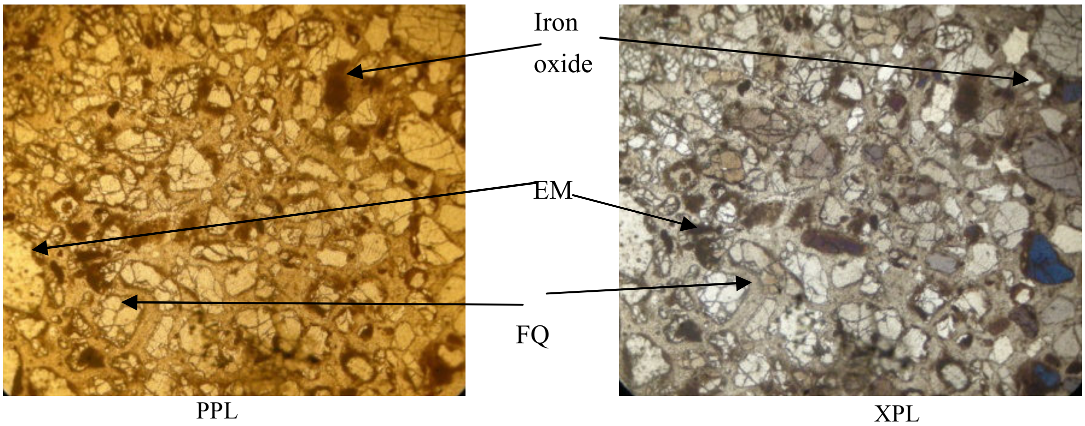


Fig. 4: (Mudrape): Severely fractured grains; Iron oxide coating on quartz grains, Fractured quartz (FQ), Etch marks (EM).

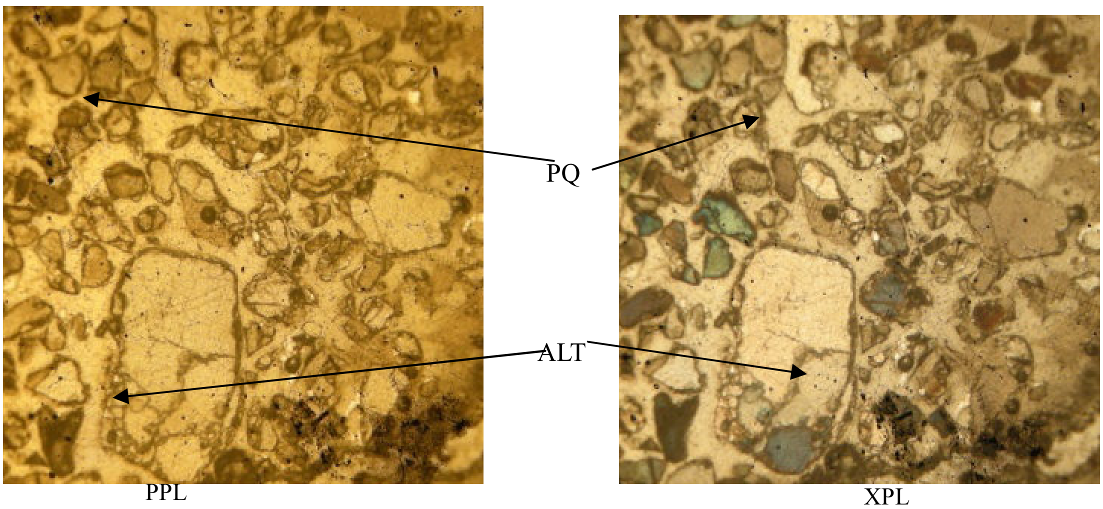


Fig. 5: Polycrystalline quartz (PQ); Alteration (ALT) along fracture lines and grain margins

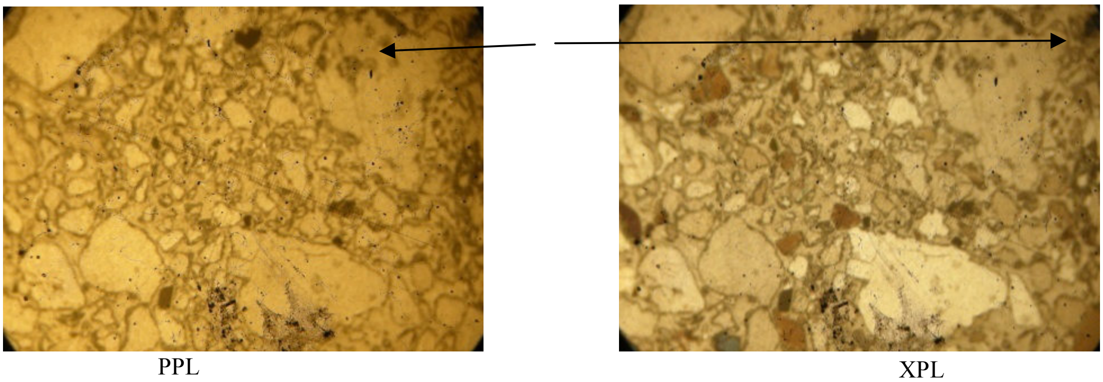


Fig. 6: Fine grains with pebbles, -No fracture lines, Inclusions (I).

Photomicrographs of Ajali Sandstone in Fugar

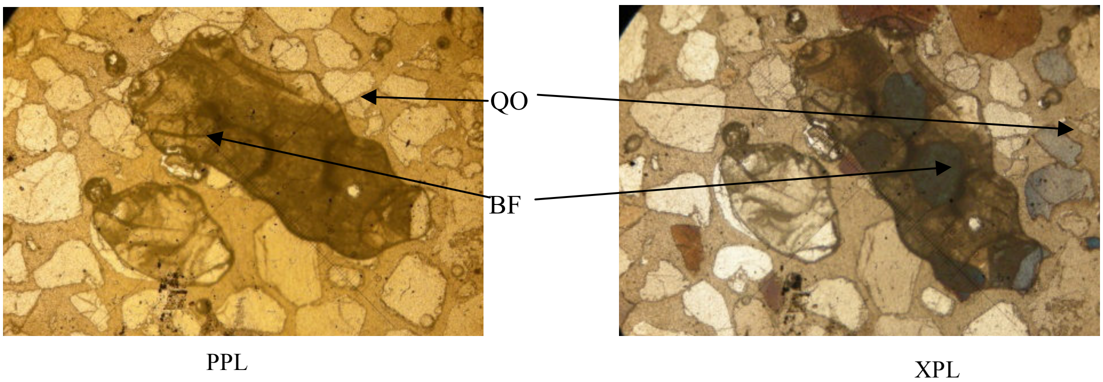


Fig. 7: Biogenic form (BF) – *Haplophragmoides sp.* Quartz overgrowth (QO).

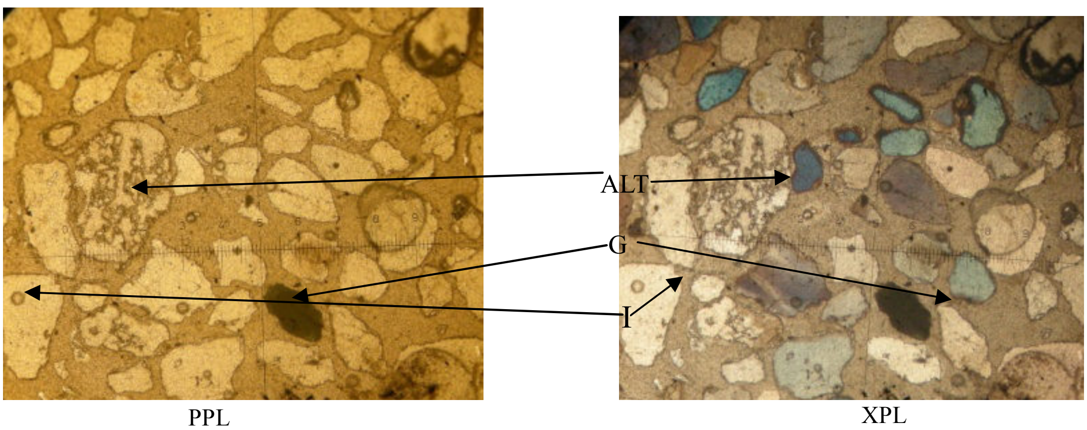


Fig. 8: Monocrystalline qtuatz grains, Alteration (ALT) and disintegration or collapse of grain, Inclusions (I), glauconite (G) Grains are moderately sorted.

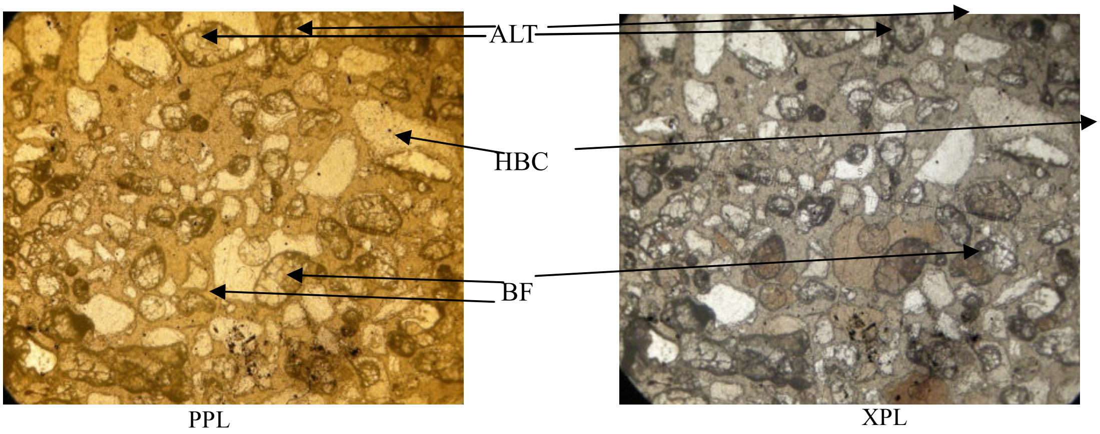


Fig. 9: Polycrystalline quartz, Biogenetic form (BF) –*Reophax sp.* poorly sorted grains., Alteration of Qtz grain, Reaction rims with corrosion at margins, Hollow cast (HBC).

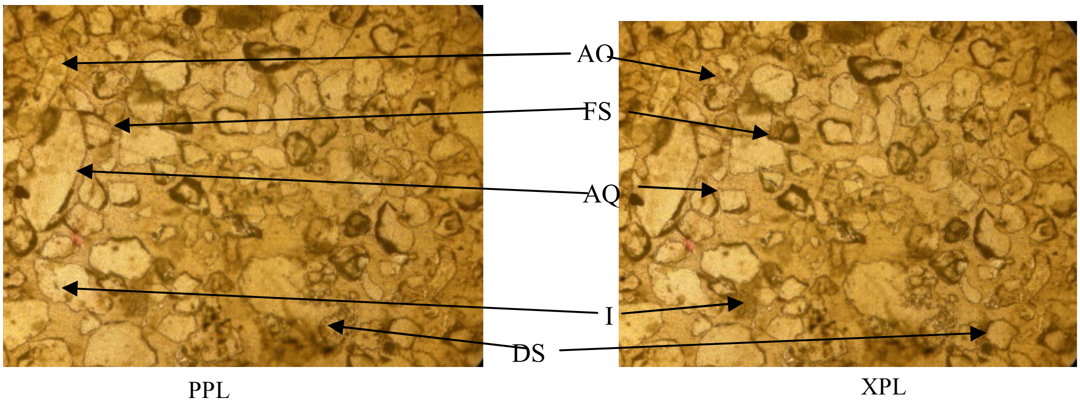


Fig. 10: Epsillon bed, dissolution and corrosion at grain contacts (DS); Authigenic quartz grains (AQ), Feldspar grain (FS). Inclusions (I)

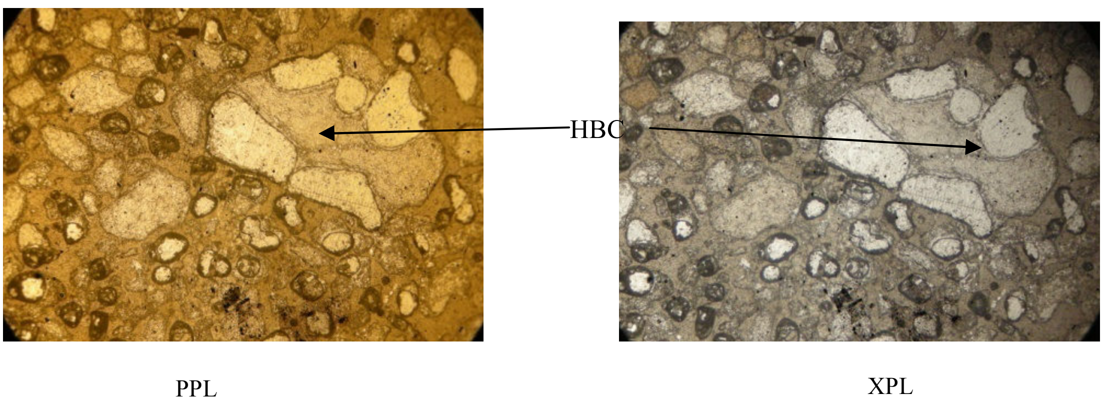


Fig. 11: Polycrystalline quartz, Mineralized hollow biogenic cast (HBC), Reactions and alteration at grain margins

Photomicrographs of Ajali Sandstone in Orame 1 and 2

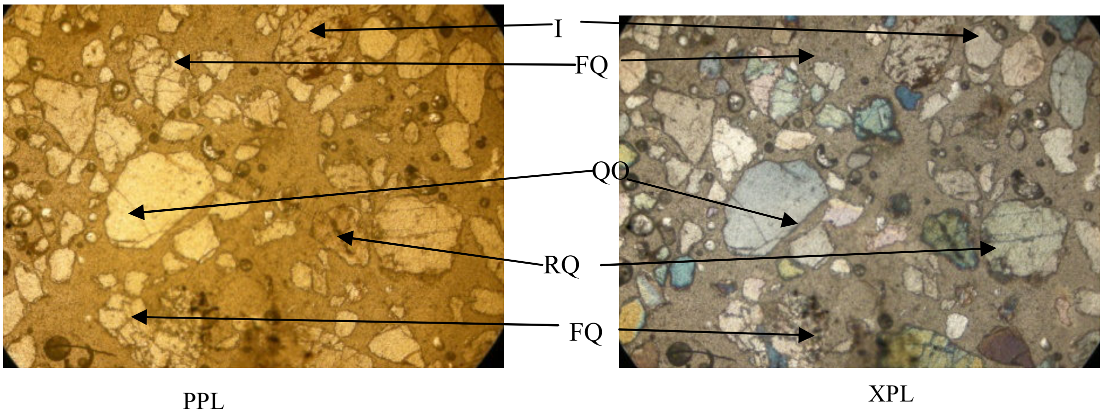


Fig 12: SP3 Alteration and reaction at rims, collapse of grain into smaller grains (FQ), Rotated (RQ)

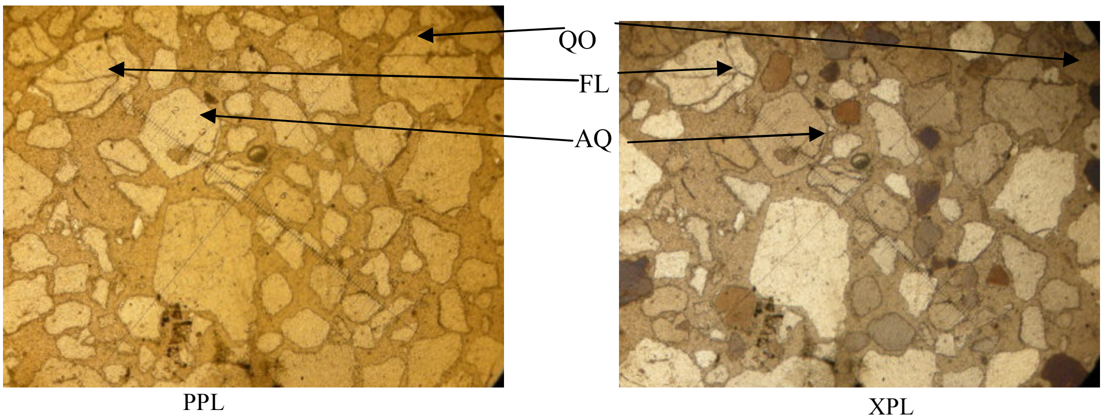


Fig 13: Subangular grains with fracture line (FL), Authigenic quartz (AQ) and Quartz overgrowth (QO).

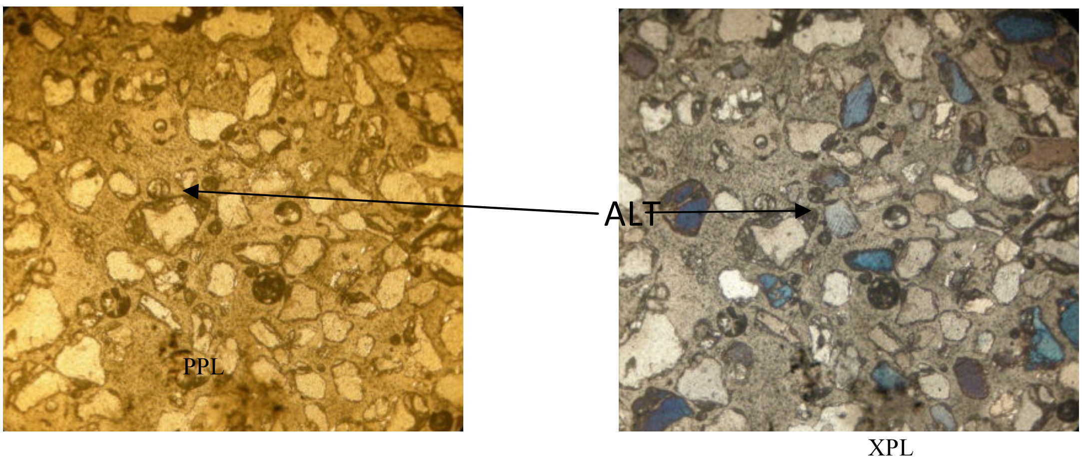


Fig 14: Angular grains, moderately sorted, large quartz grains, movement of alteration (ALT) and reactions rims from grain margins towards the center.

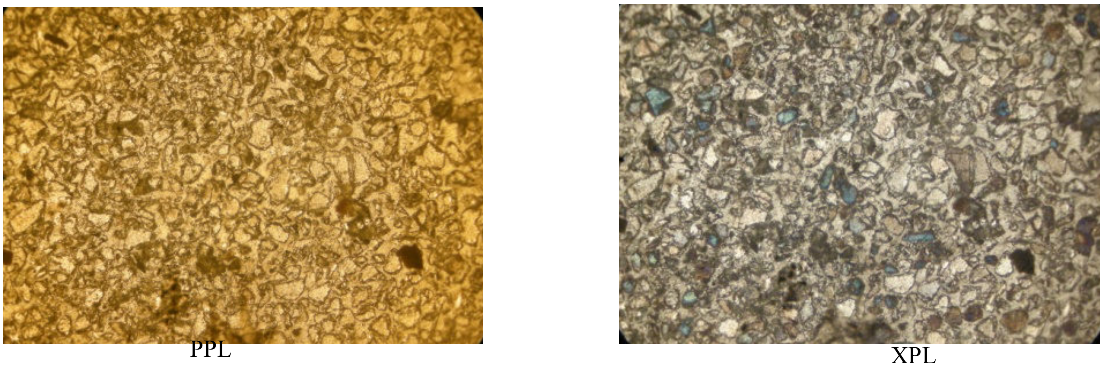


Fig 15: Dissolution, alteration and recrystallization at margins of fine grain

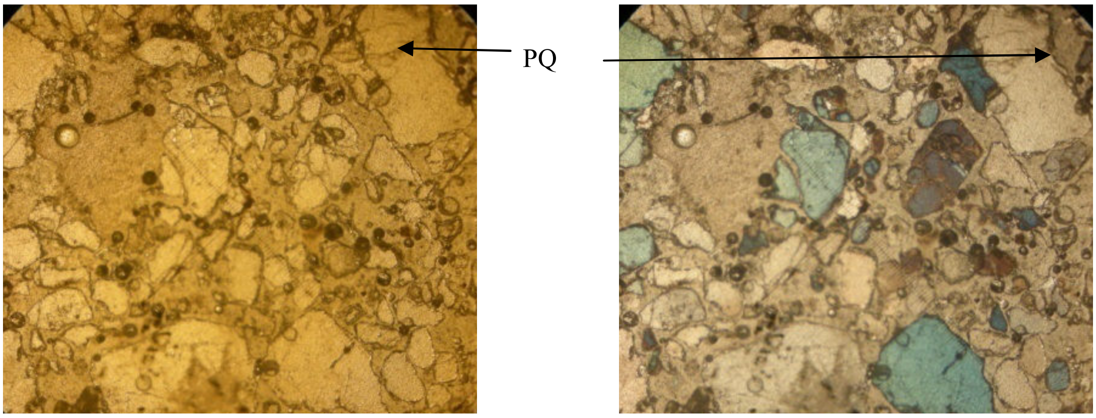


Fig 16: Very coarse angular grains, Polycrystalline quartz (PQ).