MINERALOGICAL ALTERATION OF KERRI-KERRI SANDSTONE EXPOSED IN GOMBE, GONGOLA BASIN

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ABSTRACT

The study was carried out in the outskirt of Gombe Town, Upper Benue Trough with view of determining the mineralogical composition and alteration of the exposed Kerri-Kerri Sandstone. The investigation reveals that minerals observed under cross-polar and polarized light include the following: quartz, feldspar, iron oxide and limonite. Quartz is more abundant in the samples collected and showed that the source is possibly quartz–bearing plutonic rock. Mineralogically, the sandstone is immature because the proportion of feldspar is greater than 20%. The alteration of the sandstone was prove by delicate external and internal morphologies which preclude sedimentary transport and spatial relationships of detrital and diagenetic components indicating an origin which post–dates deposition as an earlier diagenetic stage, and thirdly, compositions which differ radically from similar materials of detrital origin.

Keywords: Mineralogy, Alteration, Kerri- Kerri Sandstone, Gombe, and Gongola Basin.

INTRODUCTION

The Benue Trough is the most important of all the Cretaceous sedimentary basins in Nigeria (Zaborski *et al.*, 1997). Reviews of the origin and evolution of the linear, NE- SW trending megastructure have been presented by Benkhelil (1989) and Freeth (1990). As its northeastern end, an area commonly known as the Upper Benue Trough, it bifurcates into an E-W trending Yola Arm and a N-S trending Gongola Arm (Fig.1) shows the location of the Gongola Basin. Carter *et al.* (1963) produced the foundation work on the geology of the Upper Benue Trough. The Gongola Basin is separated from the Bornu Basin to the north by an anticlinal feature termed 'Dumbulwa–Bage–High". The purpose of this study is to determine the mineralogical characteristics of the sandstone and the level of alteration.

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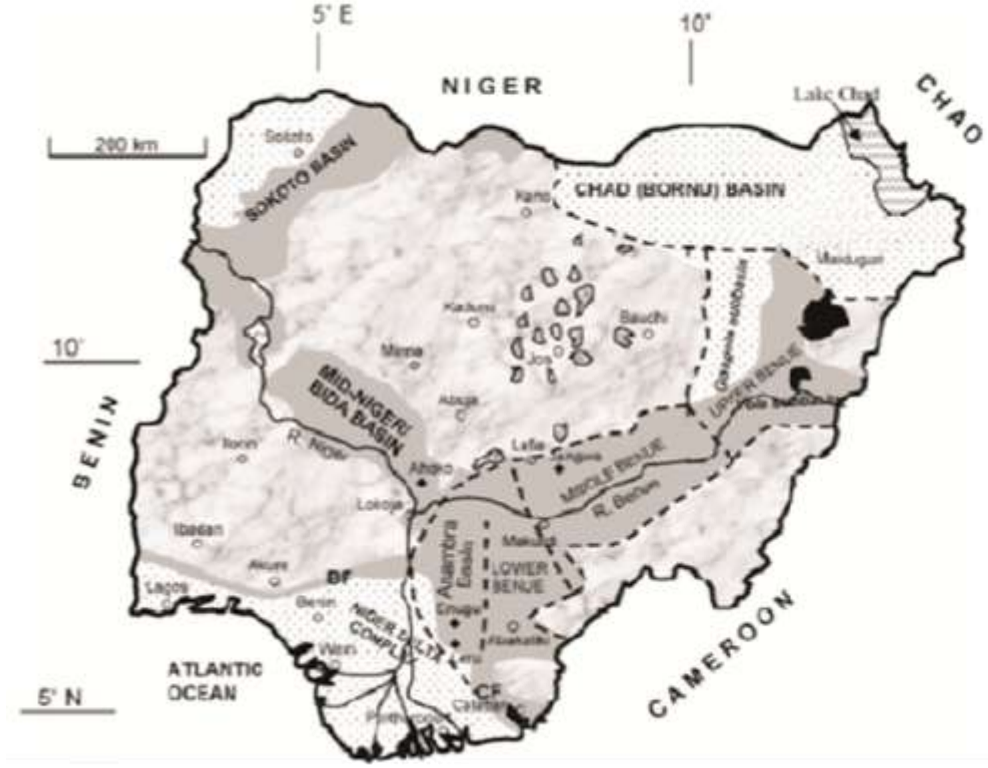

Figure 1: Geologic Map of Nigeria Showing the Gongola Basin Where the Study Area Lies (After Obaje *et al*., 2006)

GEOLOGY AND STRATIGRAPHY OF THE BENUE UPPER TROUGH

Stratigraphic description of sediments in the Upper Benue Trough (Gongola Basin) has been discussed in some details by (Carter *et al.,* 1963; Benkhelil, 1989; Popoff *et al*., 1986; Guiraud, 1993; Gebhardt, 1997; and Zaborski *et al*., 1997; and Zaborski, 1998). The Upper Benue Trough bifurcates into E-W trending Yola arm and N-S trending Gongola arm. These two are separated by an area structurally dominated by four major NE-SW trending sinistral strike-slip faults; Gombe, Bima–Teli, Kaltungo and Burashika faults (Zaborski *et al*., 1997).

BIMA GROUP

The continental Bima Group comprises of the oldest sediments in the Upper Benue Trough which directly overlie the crystalline basement rocks. Principally, the reference section is to the south in Lamurde Anticline, where Carter *et al.* (1963) and Allix (1983) gave the description of the sequences exposed and recognized a three subdivision. Further description of the Bima Group was also presented by Popoff *et al.* (1986), but comprehensive description of the Bima Group was done by Guiraud (1990a; and 1990b) into three as:

- The "Upper Bima Sandstone" ("B^3"), fairly arenaceous relatively mature, fine to coarse–grained sandstone with planar, convolute, and overturned cross- beds.
- The "Middle Bima Sandstone" ("B^2"), widely distributed, trough and tabular cross-bedding characterizes the sandstones, while clays and palaeosols also occur in the loops of individual cycles with overall thickness in some beds from 100m to 500m (Zaborski, 1998).

- The "Lower Bima Sandstone" ("B^1"), highly variable with an overall thickness of 0 to over 1500m, lacustrine deposits with interbedded clays, fine–grained sandstones and calcareous sandstones.

YOLDE FORMATION

The name "Yolde Formation" was first proposed by Carter *et al.* (1963) for "transition beds" recognized earlier by Falconer (1911) between the Bima Group and Pindiga Formation. A type section was recognized in the Yolde Stream, western part of Yola arm. Zaborski *et al.* (1997) reported that the Yolde Formation gives rise to a subdued topography often with a sparse vegetation cover. The formation has feldspathic sandstones mostly coarse–grained and cross–bedded and grey mudstones. Bioturbations (Planolites) is common towards the top while groove marks are present on some beds (Zaborski *et al.*, 1997).

PINDIGA FORMATION

The Pindiga Formation makes up the greater part of the Upper Cretaceous deposits in the Upper Benue Trough. Carter *et al.* (1963) referred age–equivalent beds in Gongola Basin to the "Gongila Formation" which is made up of a lower limestone- shale member and an upper sandstone–shale member, and to the "Fika Shales" for the overlying argillaceous beds. Zaborski *et al.* (1997) have characteristically described the Pindiga Formation to be best understood as consisting five members;

- Above, Fika Member, being the equivalent of the "Fika Shales" of Carter *et al.* (1963) and upper, shaly part of the Pindiga Formation.

- The Dumbulwa Member, being probable equivalent of the upper, sandstone-shale member of the "Gongila Formation" of Carter *et al.* (1963).

- The Deba Fulani Member, a previously unrecognized unit.

- The Gulani Member, being the "Gulani Sandstone" of Carter *et al.* (1963).

- Below, the Kanawa Member, being the "Kanawa Formation" of Thompson (1958) and the lower, shale–limestone members of the "Pindiga Formation" and "Gongila Formation" of Carter *et al.* (1963).

GOMBE FORMATION

The Gombe Sandstone is restricted to the western part of the Gongola Basin. It weathers to produce a ferruginous capping. There is a marked angular unconformity between the Gombe and the Kerri–Kerri Formation. Passing upward, the sandstone beds become more persistent and make up the greater part of what is here termed the "bedded facies".

POST – CRETACEOUS ROCKS

The Cretaceous Gongola Basin is concealed to the west by the Kerri–Kerri Formation and to the extreme east by the Biu Plateau Basalts (Zaborski *et al.*, 1997). It consists of coarse grained arkosic sands and grits with interbeds of sandy gravel, minor clays, silts and fine–grained members also occur (Thompson, 1958).

STRUCTURES

The Upper Benue Trough includes an E-W trending Yola arm and N–S trending Gongola arm. A series of N–S to NNE–SSW trending faults controls the trends of the Gongola Basin (Zaborski *et al.*, 1997).

Table 1: Lithostratigraphy of Upper Benue Trough (After, Zaborki *et al.*, 1997)

Formation	Age	Depositional Environment
Kerri–Kerri Formation	Palaeocene	Continental
Gombe Sandstone	Maestrichtian	Deltaic/Estuarine
Pindiga Formation unconformity unconformity Fika Member Dumbulwa/ Gulani Deba–Fulani Kanawa Member	Campanian	Marine
	Santonian	
	Coniacian	
	Upper Middle ŤŨŔŐŇĨĂŇ Lower	
Yolde Formation	Cenomanian	Transitional
Bima Group	Upper Bima Formation Albian Middle Bima Formation Aptian Lower Bima Formation Pre–Aptian	Continental

Crystalline Basement Complex

MATERIALS AND METHODS

About twelve samples where used for the petrographic work using a polarized microscope to determine the optical characteristics of the minerals. A thin slice of the sandstone was cut using the rock cutting tool, this slice of rock was mounted on a glass slide using araldite, and the slide is placed on a hot plate and heated to 90°C for 5 to 10 minutes. The sample is removed from the hot plate and kept it to cool to avoid cracking.

The mounted rock is gently pressed on the glass slide to remove excess araldite and air. The rock slice is deduced on thickness using abrasive powder by brushing until a thickness of 0.3mm is obtained. After this, it was polished and another glass slide was used to cover the prepared thin section to protect it. This prepared thin section was used for determination of mineral content under the polarized microscope.

RESULTS AND DISCUSSION

Petrographic Analysis

There are twelve (12) slides as representative samples of the sandstone member of the Kerri–Kerri Formation in the study area, polarize microscope was used for the investigation. Minerals were observed under both plane and cross polarized light. The mineral assemblages of each representative samples are presented on plates while petrographic informations were discussed.

The minerals presented in the Table 4.1 below were identified under both plane and cross polarized light with the aid of a microscope from twelve different slides which are presented in the appendices.

Table 2: Showing Optical Properties of the Minerals

Samples	Mineral Content	OPTICAL PROPERTIES OF THE MINERAL						
		Colour	Cleavage	From	Relief	Birefringence	Interference Colour	Extinction
L4Ca	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
L4Cb	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
L5a	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
L5b	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
L6a	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
L6b	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
L13a	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel

	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
L13b	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
L20a	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
L20b	Limonite	Black (opaque)	Absent	Anhedral	Moderate to high	Absent	Brown under cross polar	Absent
	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
L24a	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent
	Quartz	Colourless	Absent	Anhedral	Low	Weak	Grey to white	Parallel
L24b	Altered feldspar	Brown to red	Not well defined	Anhedral	Moderate to high	Moderate	Brown under cross polar	Absent
	Iron oxide	Black (Opaque)	Absent	Anhedral	High	Absent	Black (opaque)	Absent

OPTICAL PROPERTIES OF THE ANALYSED MINERALS

All the representative samples are sandstone member of the Kerri-Kerri Formation which was observed under polarizing microscope. Minerals identified on the slides, in decreasing order of abundance are quartz, altered feldspar, iron oxide and limonite. Optical properties of these minerals are described below:

Quartz

Quartz is a colourless mineral, recognized by its low relief, low birefringence, and lack of cleavage or twinning, non pleochroic and an anhedral form, grey to white interference colour of first order. It goes into parallel extinction but twinning cannot be observed in thin section because the twin segments have the same *c*-axis orientation.

Altered Feldspar

Is brownish in colour (due to alteration, otherwise is colourless), non pleochroic, having an intermediate relief and tabular form. It shows cleavage in two directions, moderate birefringence and grey interference colour of first order.

Iron Oxide

Is an opaque mineral and can be optically studied under reflected light, showing high relief but lacks twinning and extinction.

Limonite

Limonite is a variety of iron oxide, dark brown to brownish yellow, and has a yellow to brown streak, an earthy to dull luster, non pleochroic, having an intermediate relief and anhedral form. Limonite is black (opaque) under plane polarized light. Limonite fractures irregularly. It occurs as a secondary mineral from the weathering of iron in rocks and mineral deposits, and may accumulate to give iron-rich mineral deposits.

DISCUSSIONS

Petrographic analysis of the sandstone showed that the samples consist of minerals such as; quartz, feldspar, iron-oxide and limonite. The mineral in increasing abundance in the slide as observed under the microscope are the quartz, feldspar and iron-oxide(essential minerals) while the limonite is less in amount and is referred to as accessory mineral.

Quartz is often found with feldspars and can be distinguished from them in hand specimen by its lack of cleavage, concoidal fracture, and more vitreous luster. In thin-section it can be distinguished from twinned feldspars by its lack of twinning and cleavage. The high percentage of quartz in the Kerri-Kerri sandstone indicates possible extensive transport and exposures to weathering conditions in which the unstable minerals become depleted leaving behind greater proportions of stable quartz. From the sample analyzed, it has been observed that the percentage of feldspar is higher; this shows that the sandstone is chemically and mineralogically mature. This is because the sandstone is emanating from source and has not been transported far, before deposition.

Further Discussion

Sandstone fabric (grain to grain relations) varies for the units, but generally long contacts, concavo- convex contacts and point contacts between grains are most common, sutured grains are present, and floating grains occur only when there is abundant carbonate cement (Pettijon, 1972).

The shape framework grain varies within and between sandstone units and is in some cases dependent upon mineralogy. Generally, grains are sub-equant and sub-rounded, however, rounded grains (quartz occur commonly and are locally abundant and sub-angular grains (usually feldspar, occasionally rock fragments) are also present.

DIAGENETIC ALTERATION TYPES

Diagenetic alterations are defined as those physical and chemical changes which affect sediment subsequent to deposition. The criteria used to distinguish materials produced by diagenetic processes include;

1. Delicate external and internal morphologies which produce sedimentary transport,
2. Spatial relationship's of detrital or diagenetic components indicating an origin which post- dates deposition or an earlier diagenetic stage
3. Compositions which differ radically from similar materials of detrital origin, and
4. Textures which are unlikely to have been produced by depositional processes.

CONCLUSION

This research work was carried out in the outskirt of Gombe Town with the aim of geologically mapping the area to produce a detail map. Thin sectioning and petrographic studies of the samples collected from the field was carried out lab to for mineralogical investigation. Mineral abundance was determined and alteration of some minerals prior to deposition was also classified. Dominantly, quartz is the more abundant, followed by, K–feldsper, iron oxide and limonite. Their optical characteristics have been discussed in detail. The Kerri–Kerri sandstone member has been altered mineralogically. Therefore, the granitic origin can be inferred.

The Kerri-Kerri Formation is not texturally matured, but it is mineralogical matured because of its feldspar content.

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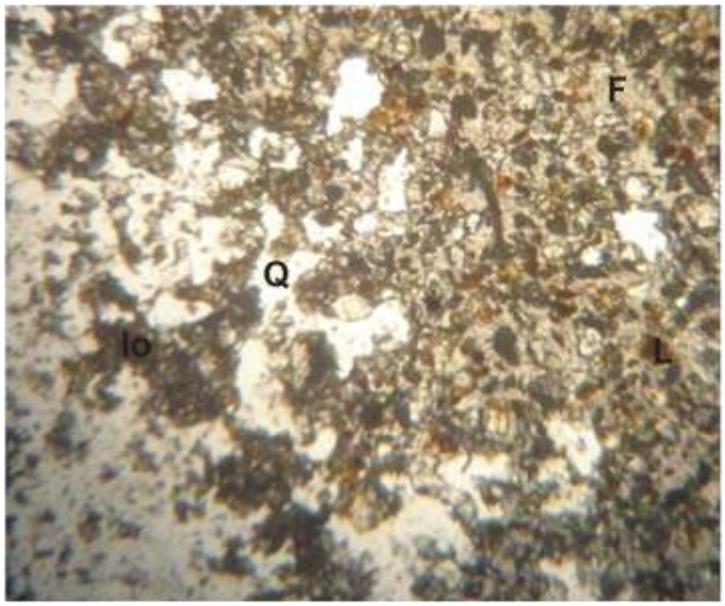
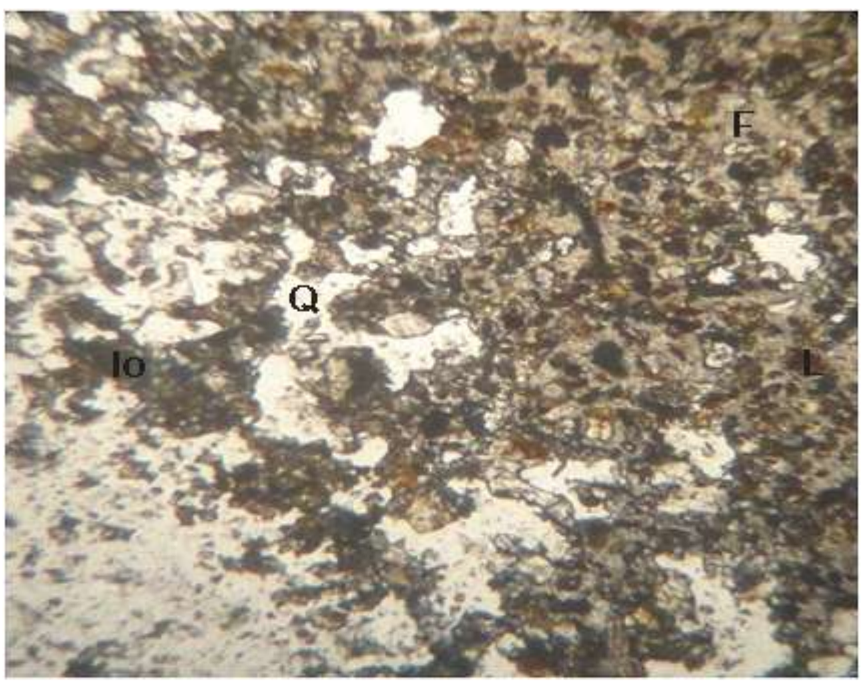
APPENDICES

PLATES

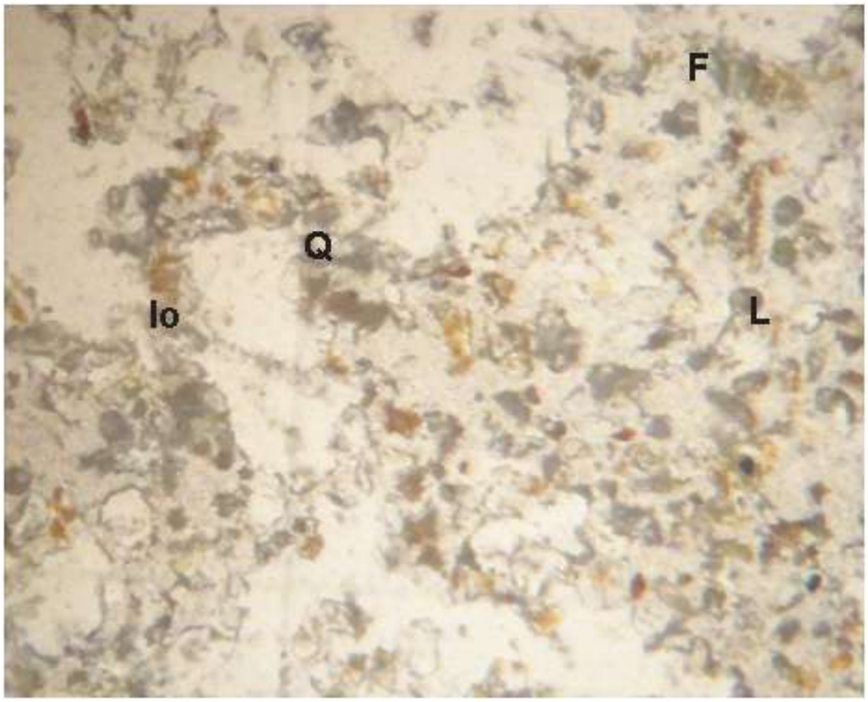


Mineral Observed Under Plane Polar



Mineral Observed Under Cross Polar

Plate 1: Showing Sample No. L4Ca



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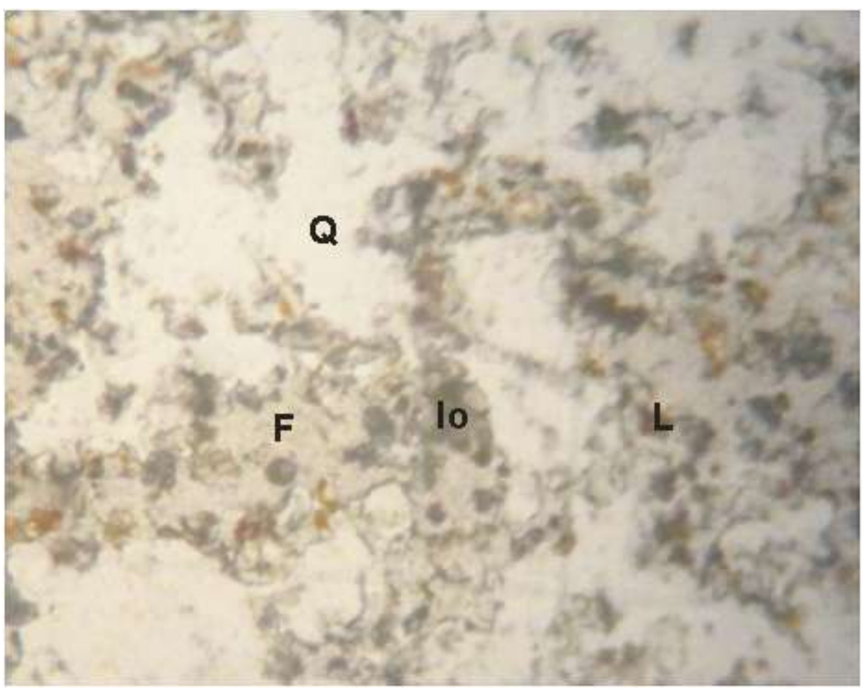
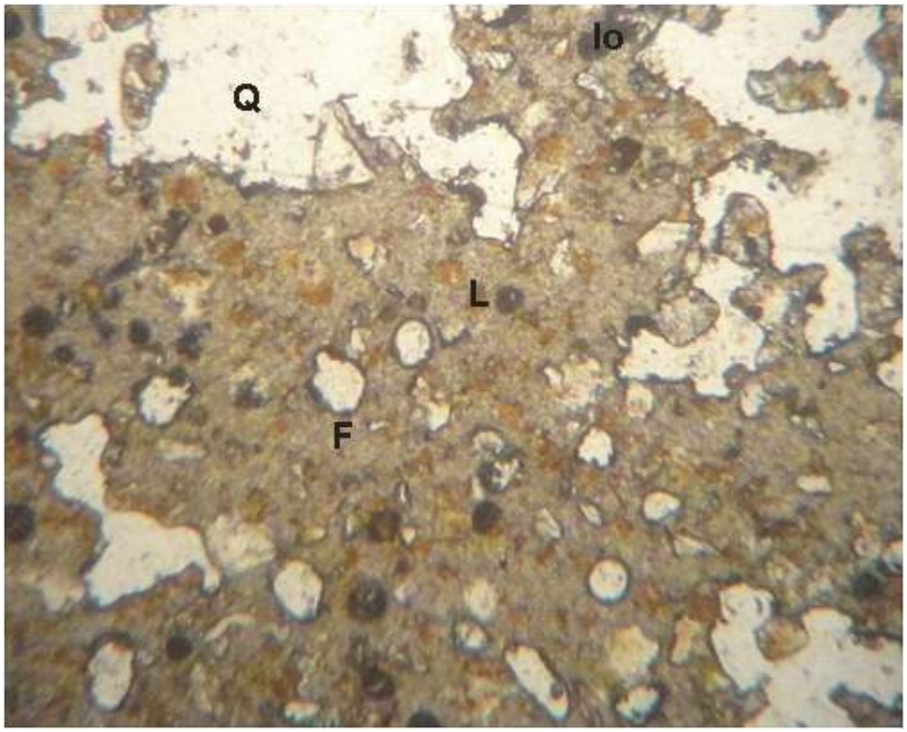


Mineral Observed Under Cross Polar

Plate 2: Showing Sample No. L4Cb



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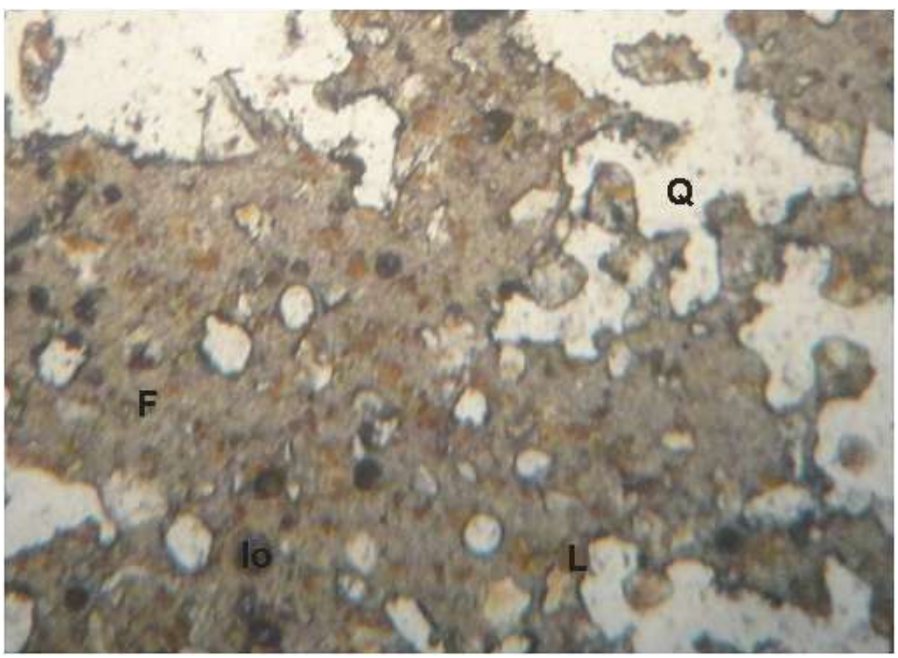
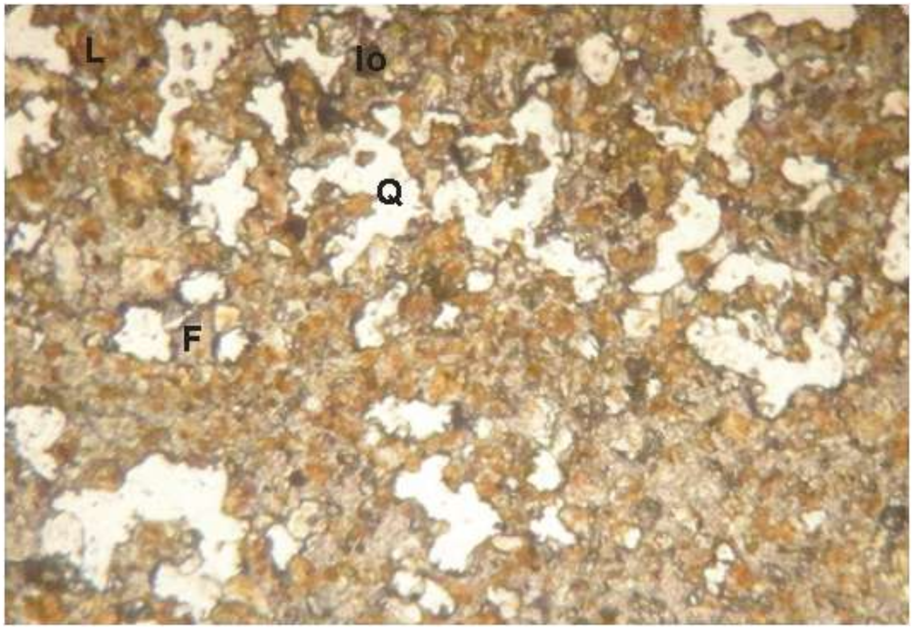


Mineral Observed Under Cross Polar

Plate 3: Showing Sample No L5a



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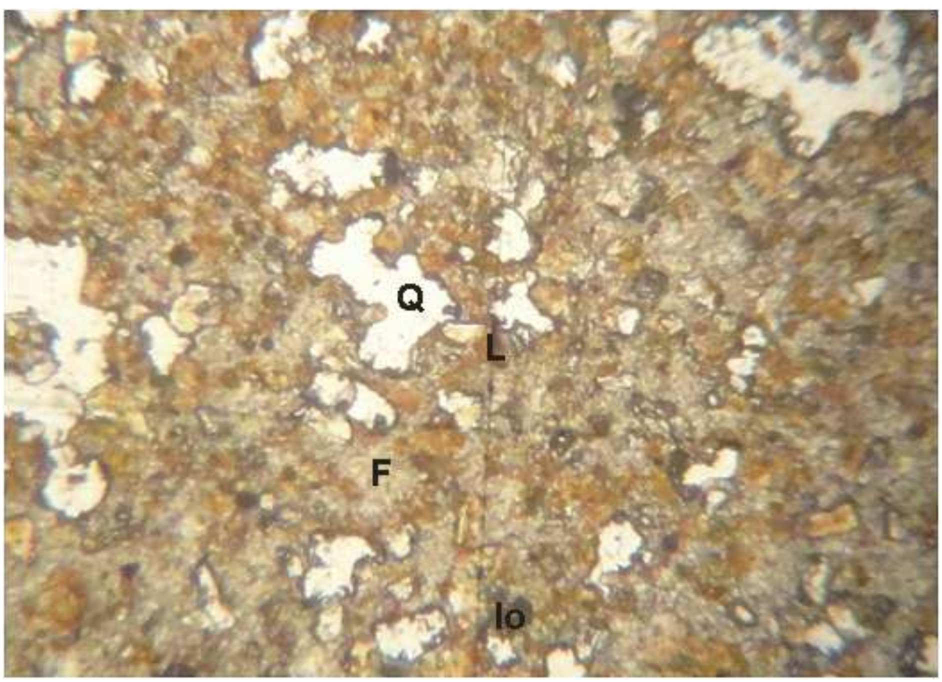
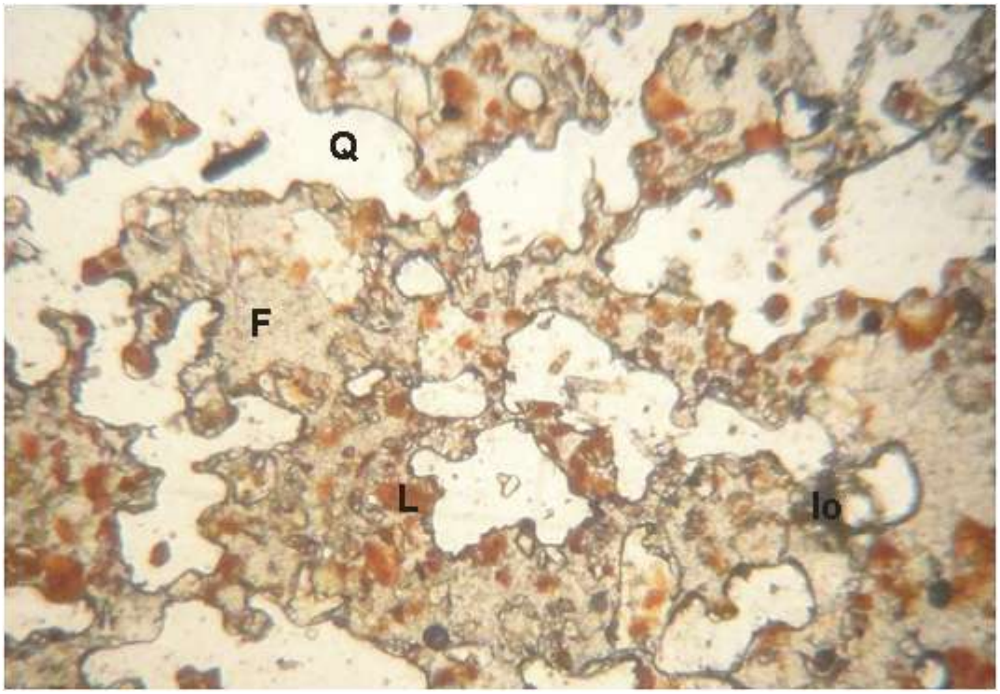
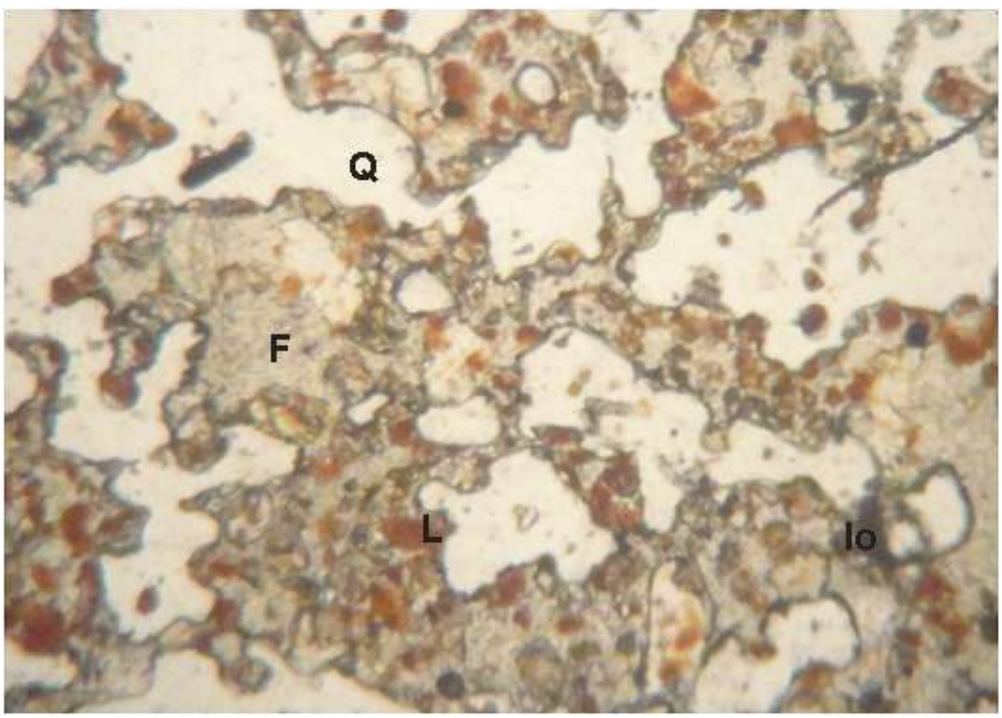


Mineral Observed Under Cross Polar

Plate 4: Showing Sample No. L5b

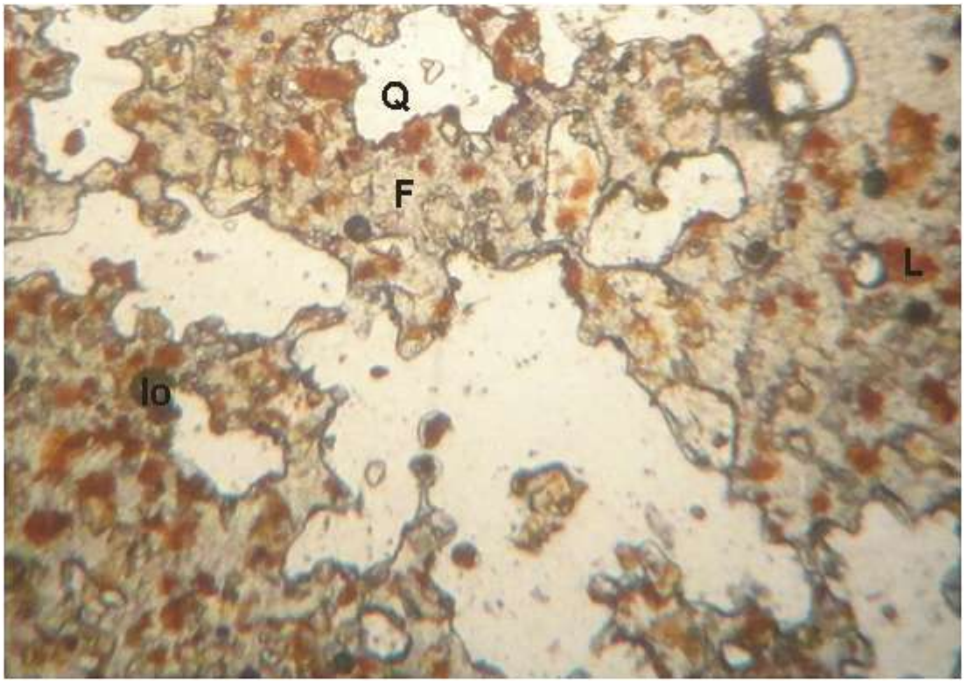


Mineral Observed Under Plane Polar

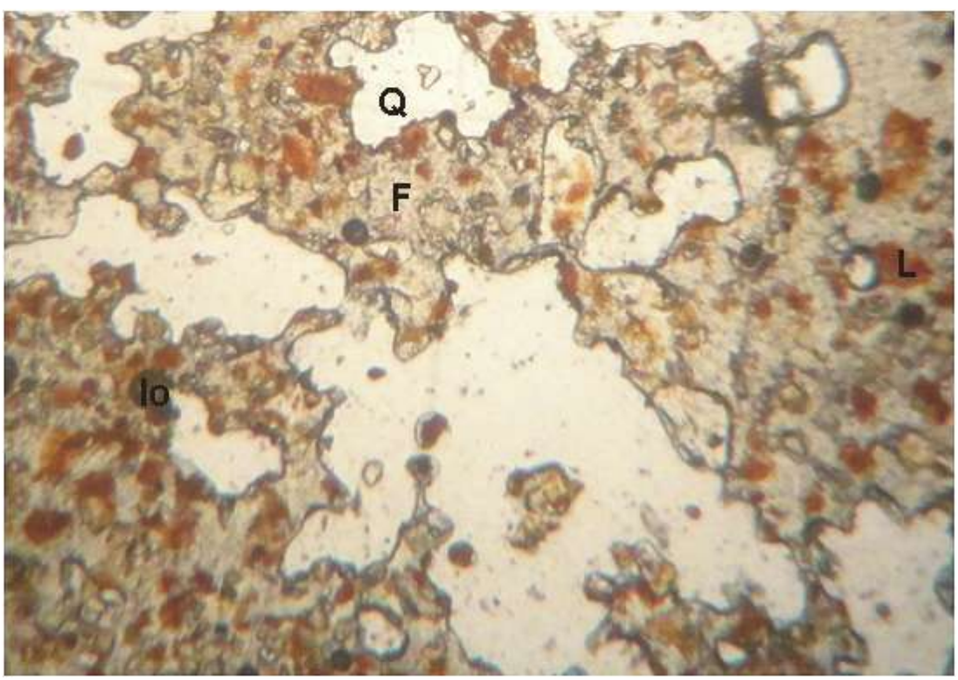


Mineral Observed Under Cross Polar

Plate 5: Showing Sample No. L6a

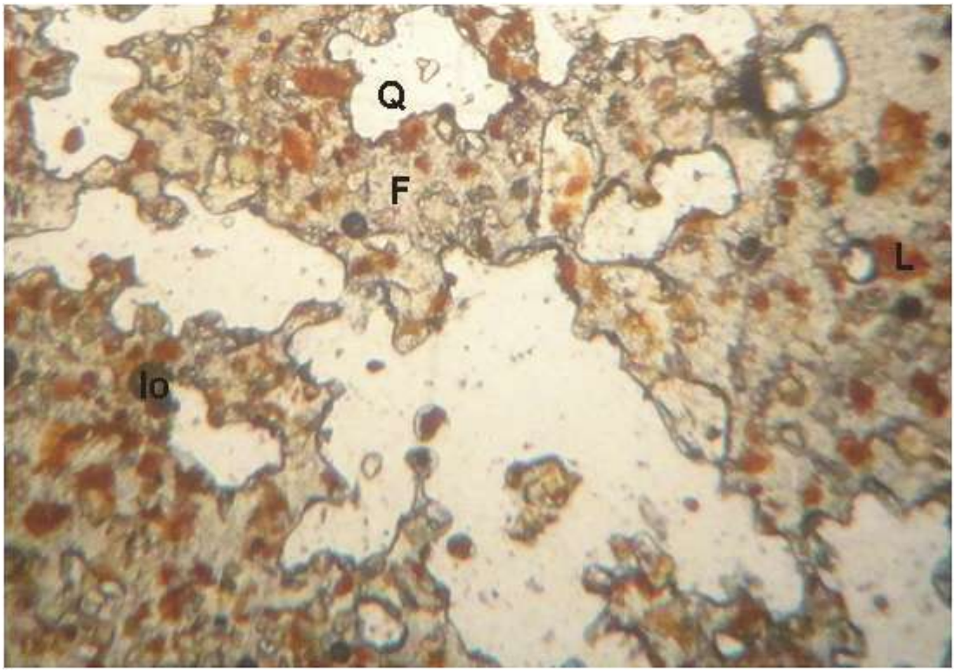


Mineral Observed Under Plane Polar

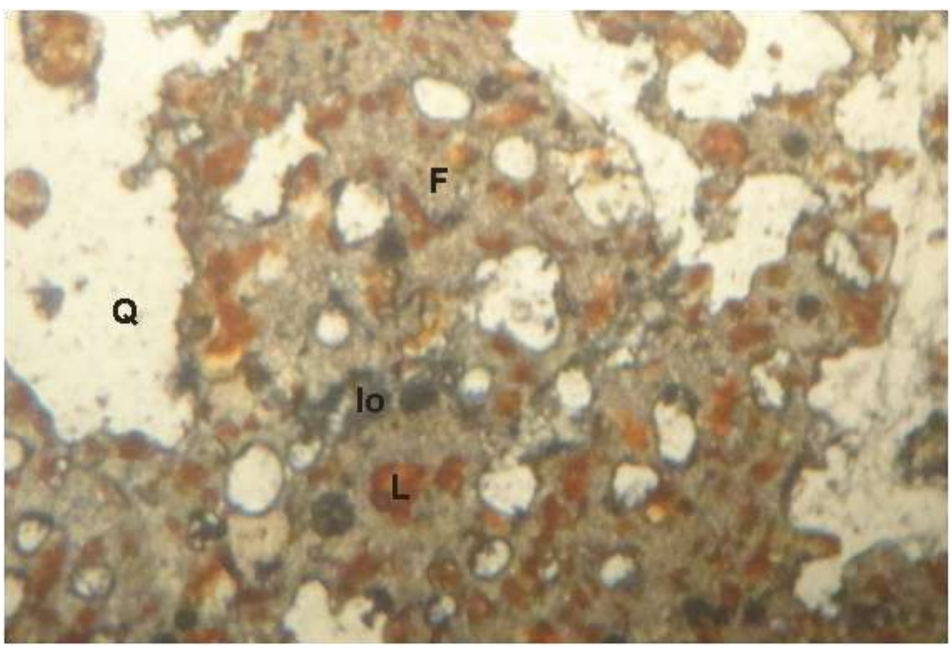


Mineral Observed Under Cross Polar

Plate 6: Showing Sample No. L6b

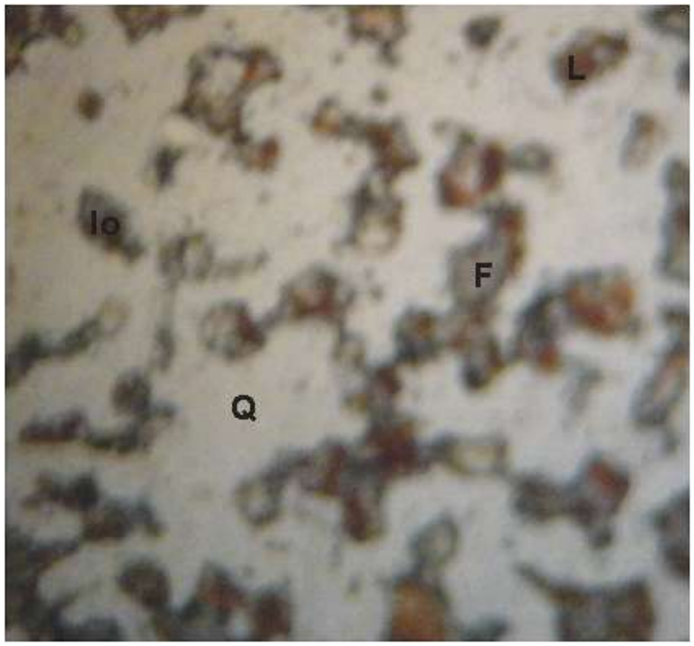


Mineral Observed Under Plane Polar

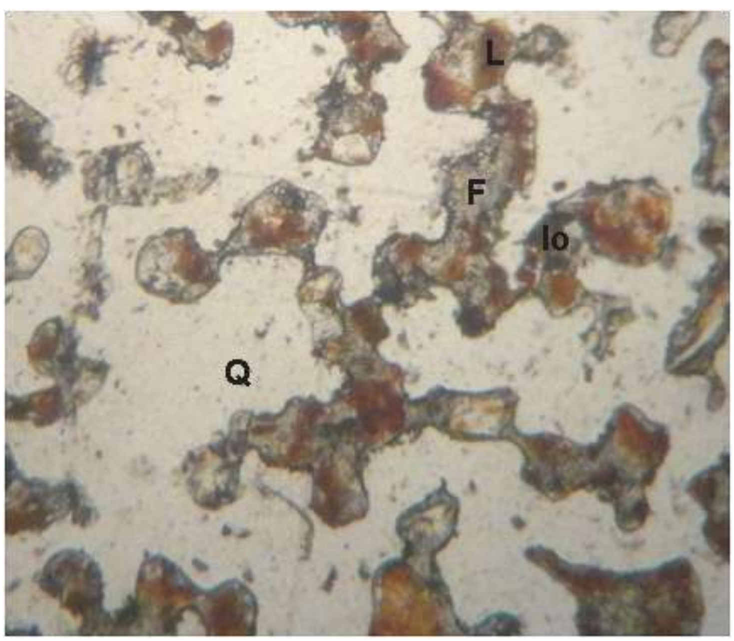


Mineral Observed Under Cross Polar

Plate 7: Showing Sample No. L13a

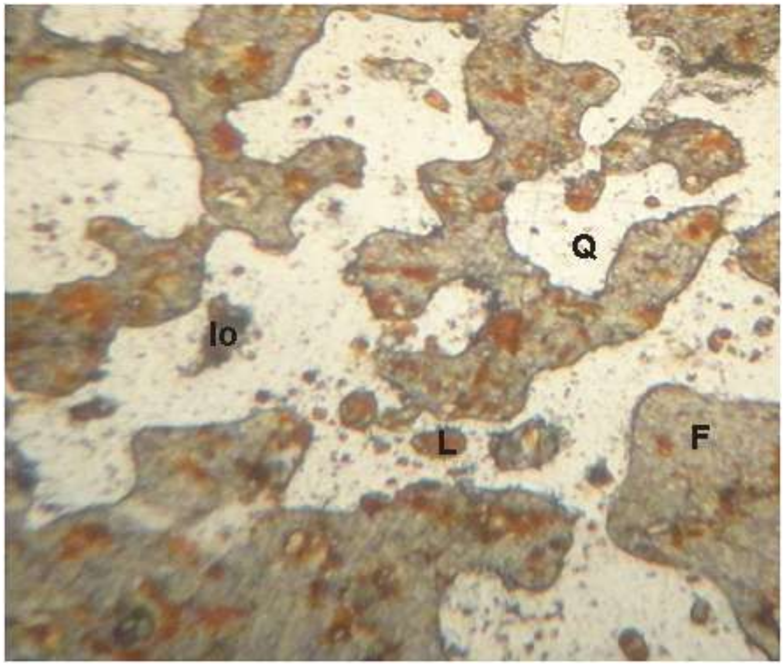


Mineral Observed Under Plane Polar

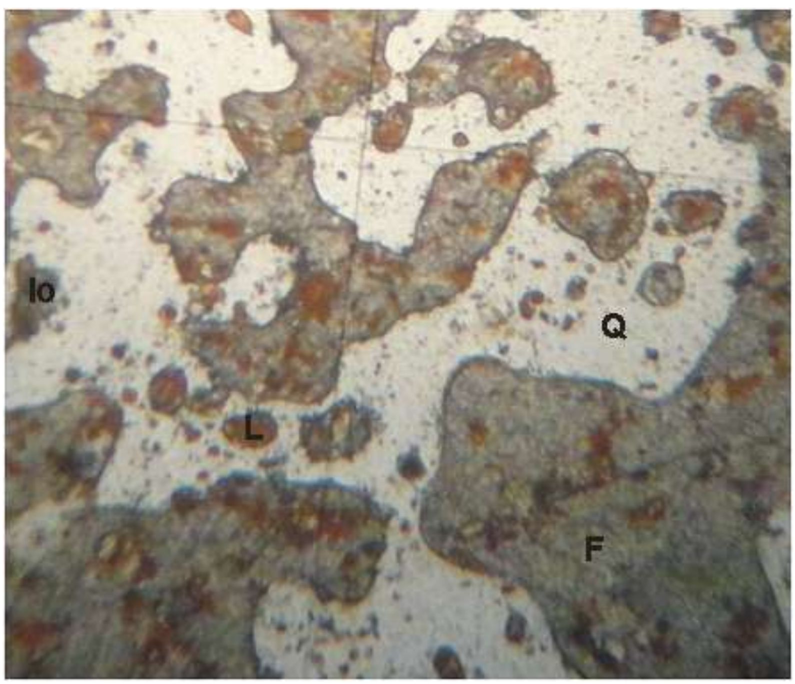


Mineral Observed Under Cross Polar

Plate 8: Showing Sample No. L13b

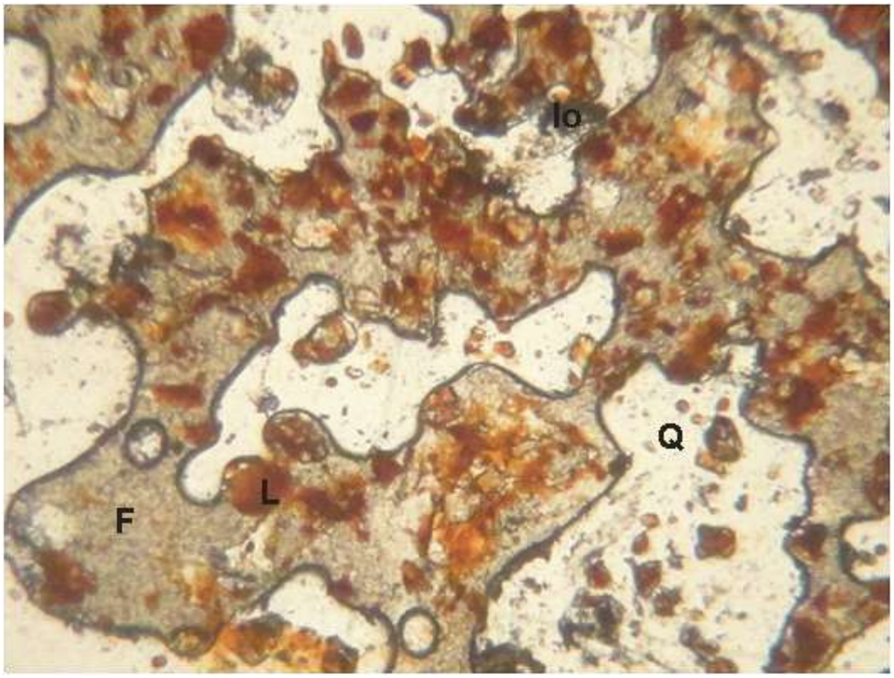


Mineral Observed Under Plane Polar

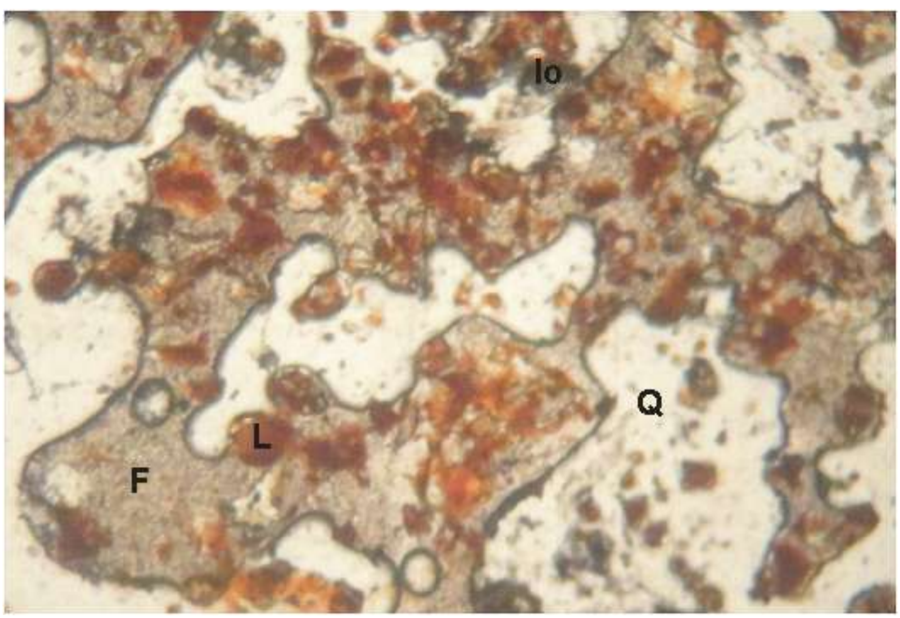


Mineral Observed Under Cross Polar

Plate 9: Showing Sample No. L20a



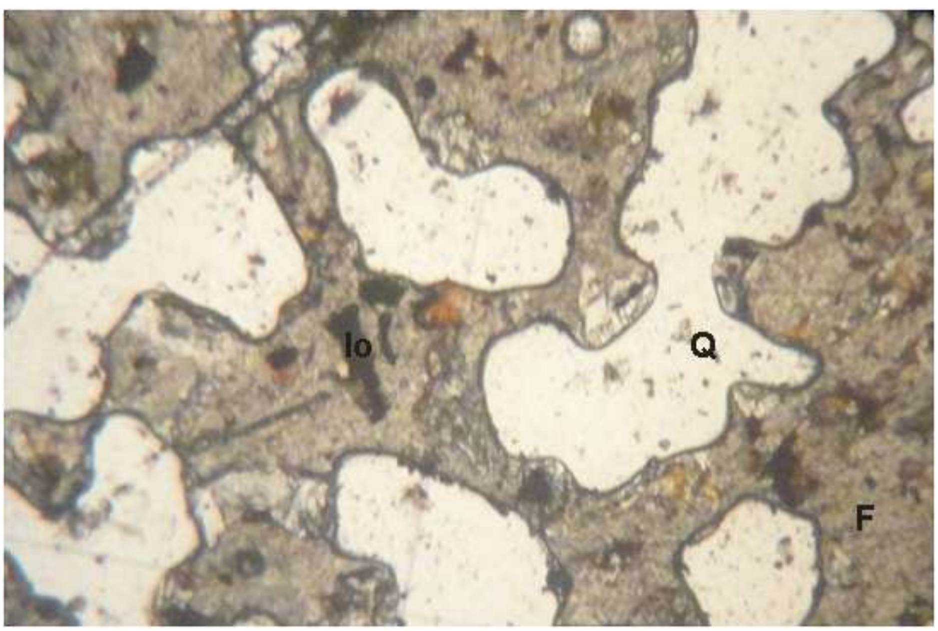
Mineral Observed Under Plane Polar



Mineral Observed Under Cross Polar

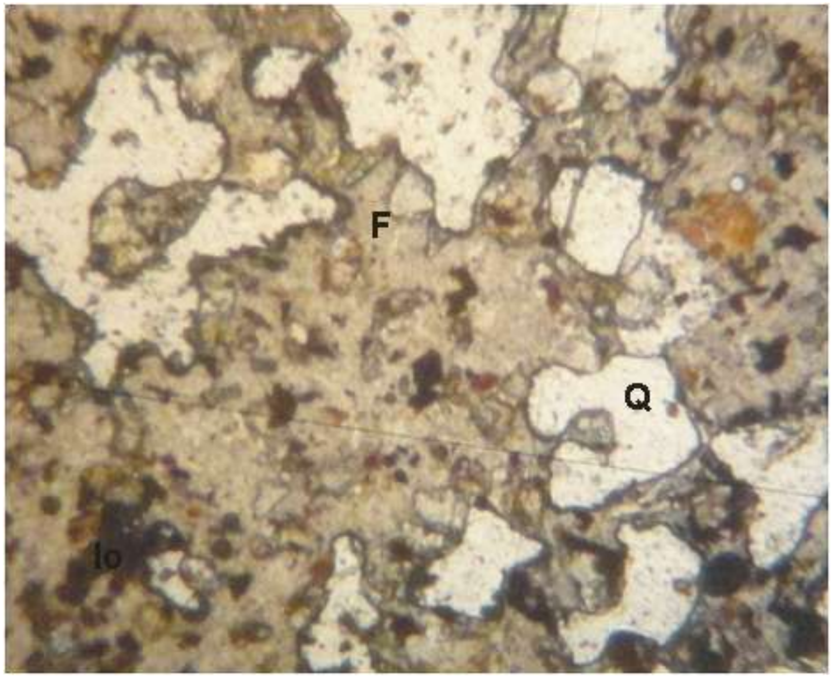
Plate 10: Showing Sample No. L20b

Mineral Observed Under Plane Polar

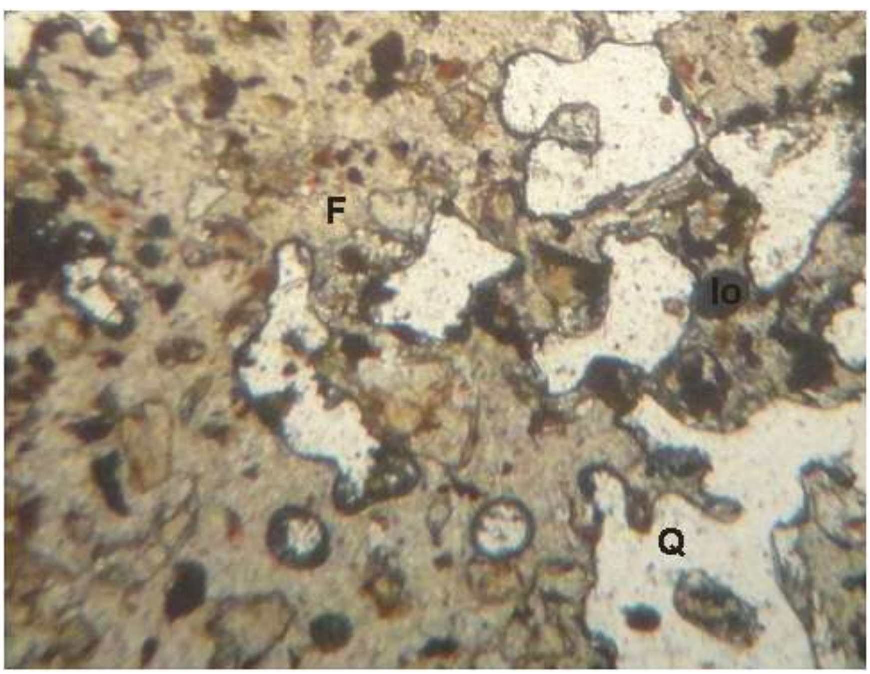


Mineral Observed Under Cross Polar

Plate 11: Showing Sample No. L24a



Mineral Observed Under Plane Polar



Mineral Observed Under Cross Polar

Plate 12: Showing Sample No. L24b

Reference to this paper should be made as follows: Y.B. Mohammed and M.W. Sidi (2014), Mineralogical Alteration of Kerri-Kerri Sandstone Exposed in Gombe, Gongola Basin. *J. of Environmental Sciences and Resource Management,* Vol. 6, No. 1, Pp. 96 – 118.