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Petrographic Study of Basaltic Rocks of the Kerang Twin Volcanoes Within the Panyam Volcanic Line, Jos Plateau, Central Nigeria.

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ABSTRACT

The Kerang twin volcanoes are located at Kerang town and its environs in Mangu Local Government Area, Jos Plateau, Central Nigeria. The study area covers an aerial extent of 40 km² and is bounded between Latitudes 9°20'02" and 9°22'05"N and Longitudes 9°08'02" and 9°14'02"E, part of Pankshin Sheet 190 (NW). The Kerang twin volcanoes, as the name implies, are clusters of two (2) large volcanoes which are major landmarks in the southeastern Jos Plateau Volcanic Province, Central Nigeria. The traverse mapping method was used to map the area. Fifteen samples from the field were subjected to petrographic analysis using the polarized petrological microscope in the Department of Geology University of Jos, Jos, Nigeria. The nature, size, and physical characteristics as well as the outcrop pattern of the Kerang twin volcanoes were determined. Field findings showed that the Kerang twin volcanoes extruded the pre-existing porphyroblastic gneisses complex, and the Pan-African porphyritic biotite granite rocks. The volcanic rocks collected for this research project are essentially basaltic rocks which are products of cinder and composite volcanoes. Nodules of orthopyroxenes and crystals were observed both in hand specimen and microscopically in the basaltic rocks of the study area. Mineralogically, these rocks from the Kerang twin volcanoes, which are essentially basaltic, are composed of majorly: phenocrysts of clinopyroxenes, titan augites, olivines, orthopyroxenes, and labradorites embedded in finer groundmass and less commonly ilmenites and iron oxides. Some of the olivine crystals exhibit overgrowth features and interlocking grains (grains of olivine and clinopyroxene) which are a result of reaction between the olivine crystal and the magma which is presumably more silica-rich than the one the olivine crystal is in equilibrium with. Microcrystals of clinopyroxenes were observed surrounding the periphery of the orthopyroxenes (reaction rim). This suggests that the orthopyroxenes were formed from greater depth first before the clinopyroxenes which is typical of a solid solution enstatite and ferrosilite series.

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1. Introduction

The Jos Plateau is situated in central Nigeria bounded by Latitudes 9°00' and 10°00'N and Longitudes 8°30' and 9°30'E. The basement complex rocks of the Lower Paleozoic to Precambrian ages underlie about half of its entire landmass. These rocks comprise of gneiss-migmatites basement rocks, the Pan-African Granites (Older Granites) and the predominant Jurassic non-orogenic alkaline Younger Granites (Turner, 1976). Basaltic volcanism on the Jos Plateau was represented by scattered volcanic cones, domes and thin lava flows which are typically alkaline olivine basalts (Kogbe, 1989; Wright, 1985). This volcanism was reported to have begun from the early Tertiary and continued up to the Quaternary period (Hossain et al., 1986; Ugodulunwa and Schoeneich, 1994; Turner, 1983). The occurrence of these basaltic volcanoes on the Jos Plateau have been linked to the widespread Cenozoic volcanism that overlies directly the Pan-African Basement and in some places the Younger Granite bodies (Mackay et al., 1949; Wright, 1976 and 1985). Recent studies on the basalts of the Jos Plateau classified them as intraplate alkaline basalts composed essentially of phenocrysts of olivine, pyroxenes and plagioclases embedded in a fine-grained groundmass (Irving and Price, 1981; Lar and Tsalha, 2005; Lekmang, 2018; Mohammed et al., 2014).

The earliest eruptions of these basaltic lavas mixed with sediments/gravels are termed as fluviovolcanic series (Mackay et al., 1949; Wright, 1985). Fresh basalts which occur as giant volcanic or small cones and thin valley infilling lava flows on the Jos Plateau are seen in the field of study. These fresh basalts according to Mackay et al., 1949 and Wright, 1985, postdated the fluviovolcanic series and were referred to as younger or newer basalts.

Recent dating by Mohammed, et al., (2014), using Ar–Ar method on the basaltic rocks from the composite volcanoes of Kassa and the Panyam volcanic lines, gave ages spanning from 1.3 Ma to 2.5 Ma and 5 Ma to 7 Ma respectively. This clearly confirms successive episodes of eruptions associated with volcanic activities on the Jos

Plateau and not as suggested by pioneer workers such as: Mackay et al., 1949; Macleod et al., 1971; Wright, 1985, whose categorization was based on the intensity of weathering of the volcanoes. The time of emplacement of the Jos Plateau basalts is therefore contemporaneous (CGG, 2014; Mohammed et al., 2014). Similar basaltic rocks of Quaternary ages (6 Ma and 4.8 Ma) at Annobon Island have also been found to be synchronous along the Cameroon line (Njonfang et al., 2011; Guiraud and Maurin, 1992; Moreau et al., 1987). However, in the field, the two main basalts; “Older” and “Newer” exhibit similar mineralogical compositions composing of olivine and pyroxenes phenocrysts without any distinction.

The Kerang twin (Kerang I and II) volcanoes are essentially composed of basaltic rocks with associated lava flows covering a total area of 40 square kilometers. And is bounded between Latitudes 9°20'02" and 9°22'05"N and Longitude 9°08'02" and 9°14'02"E, part of Pankshin Sheet 190 (NW). The magma which was basaltic in nature, extruded the basement complex rocks (Fig. 1). The Kerang I volcano is a very big single crater and single eruption volcano located just 1 km away from the giant Kerang II volcano and about 2.5 km from the Amshel volcano and third in the series of the Panyam Volcanic Line. The diameter of the crater is about 400 m with a peak flank as high as 1456 m above sea level (Table 1). The volcanic pile from top to bottom consists of ash and breccias interbedded with ash, scoria, pumice, and boulders of basalts at the middle; while pumice, scoria, boulders of fragmented basalts and lava flows, pyroclastic materials (basalts, granitics, and lava flows) of various sizes are found at the bottom of the hill. Away from the hill are the lava flows filling the valleys and river channels. The cone is fairly weathered with deep gullies measuring about 1.84m – 2.56m. The fragments of the basement rocks form part of the pyroclastic materials at the base of this volcano indicating that the basement was shattered violently.

The Kerang II volcano is the most distinctive and picturesque volcano of the Panyam volcanic line located south of the Kerang I volcano. It has a

peak height of 1510m above sea level and the second-largest volcano on the Jos Plateau compared to the Jiblik volcano which has a flank peak height of 1670m above level (Table 1). The Kerang II volcano has three steep-sided craters indicative of three successive eruptions. The smallest crater has a diameter of 305m wide; the medium has diameter width of 600m, while the largest crater has a diameter width of 1km without water. The volcanic pile of the Kerang II volcano is composed of ash at the top; scoria,

breccias interbedded with ash and fragmented boulders of basaltic rocks at the middle. The bottom of the hill is composed of fragmented basalts and lava flow, boulders, pumice, welded scoria and pyroclastic materials (granitic, basalts and lava flow) of various sizes. The purpose of this study is to present a comprehensive petrographic analysis of the basaltic rocks of Kerang twin volcanoes.

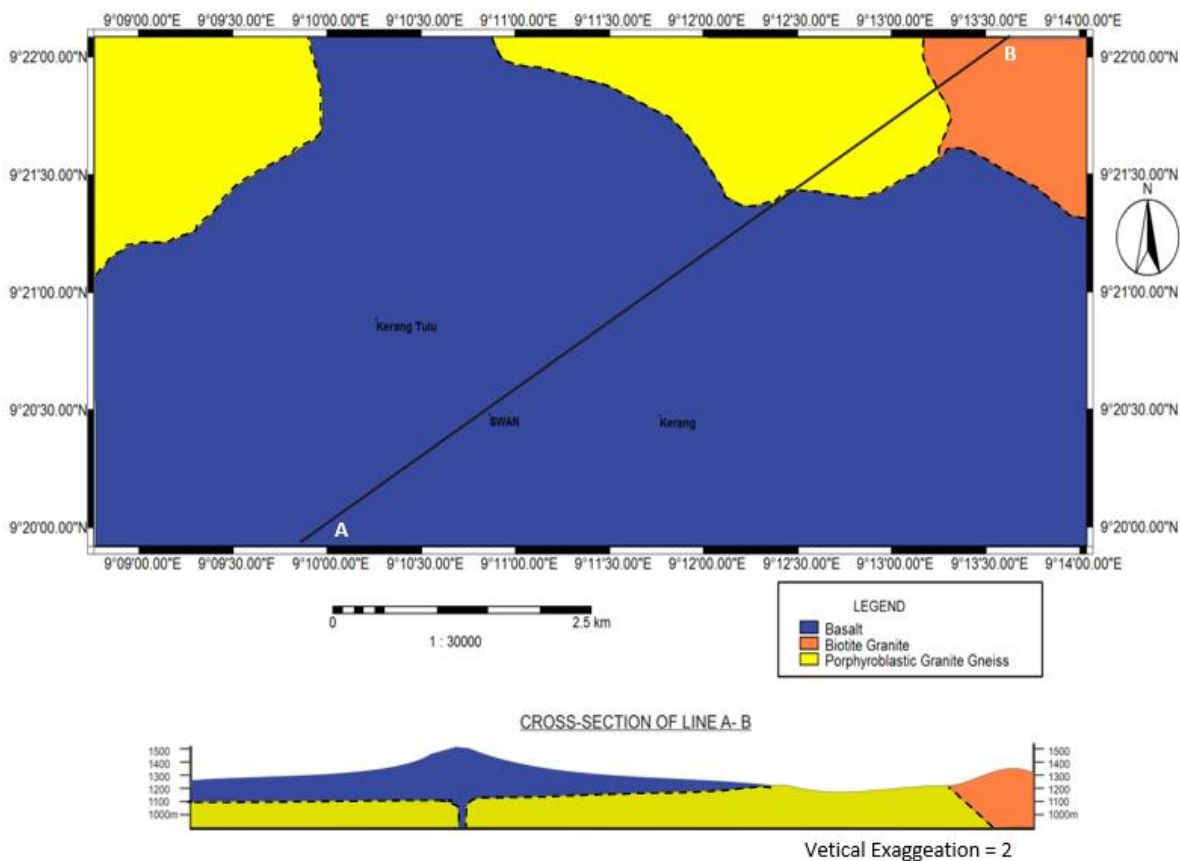


Figure 1. Geological map of the study area.

2. Methodology

A careful and systematic mapping of the Kerang twin volcanoes was carried out on a scale of 1:10,000. The traverse mapping method was

used. Outcrops in the field were located and unaltered samples were collected along an N–S and E–W grid across the volcanic edifices. Their physical characteristics features such as: surface weathering, morphology, outcrop patterns, and extent of the vegetation cover were determined and tabulated (Table 1). Fifteen representative

samples of the basaltic rocks were carefully selected and analyzed for petrographic studies in the Petrology Laboratory of the Department of Geology, University of Jos, Jos, Nigeria using a high magnifying petrological microscope.

3. Results and discussion

3.1 Results

The summarized field description of the Kerang twin volcanic hills is given in table 1. In hand specimen, the rocks were massive and aphanitic with most of them having large crystals of olivine and pyroxenes embedded in fine-grained groundmass. A complete megascopic description of the rock samples is presented in table 2.

Result of their microscopic study showed similar mineralogical compositions composing of clinopyroxene, titanite, orthopyroxene, olivine, and labradorite (An_{79-53}) as major mineral constituent of the rocks with opaque minerals (mostly ilmenite and/or magnetite) as accessory minerals (Figs. 2-6). A minute amount of

secondary minerals (sericite & smectite) was also observed.

3.1.1. Clinopyroxene

The clinopyroxenes are pale green in colour and exhibit weak pleochroism. The crystals are euhedral to subhedral in shape. They show perfect cleavages and exhibit moderately curved fractures and relief. They have an inclined extinction angle of between 49° and 53° . In some of the samples, their edges show dark brown rims indicating interaction with other minerals or alteration (Figs. 2a-h). The sub-ophitic texture exhibited by the clinopyroxenes could be an interaction with plagioclase crystals. The crystals also occur as bunch of crystals and together with other crystals give the rocks a glomerocryst texture (Figs. 2a-h). In one of the samples (Fig. 2g-h), the crystals of the clinopyroxene and olivine are intimately interlocked in each other. This interpenetrative pattern (intergrowth texture), is typical feature of a mutual relationship between two different minerals.

Table 1. Summary of physical characteristics of the Kerang twin volcanoes.

PHYSICAL FEATURES	DUSTIN (Kerang I) VOLCANO	KERANG (Kerang II) VOLCANO
Height above sea level (asl)	1460m	1510m
Longitude/Latitude	E09°11'42" / N09°21'05"	E09°11'29" / N09°20'25"
Number of craters	Single crater	Three craters
Types of rocks	Basalts with olivine phenocrysts in groundmass	Basalts with olivine phenocrysts in groundmass
Pyroclastic materials	Bombs, blocks, breccias, tuffs, ash	Bombs, breccias, tuffs, ash
Diameter of the crater	210m–300m	Average of 600m
Width of collapsed flank	225m	350-400m
Degree of weathering	Weathered	Weathered
Vegetative cover	Dry, sparse	Dry, sparse
Structural features	Cracks and joints (in basalts)	Cracks and joints (in basalts)
Directions of collapsed flank	NW-SE	NW-SE
Types of outcrops	Cinder cone volcano	Composite Volcano
Pattern of outcrop	Steep sided with single vent	Steep sided with three clustered vents
Classification(type)	Cinder	Composite

Table 2. Megascopic Description of the Kerang twin Volcanoes based on location and textures.

	SAMPLEID	LOCATION	DESCRIPTION	TEXTURE
Kerang 1	LICD 12A, 12B	Top	Phenocrysts of orthopyroxenes, clusters of clinopyroxenes imbedded in glassy matrix	Aphyritic texture
	LICD 3, 4, 5 & 6	Middle	Microphenocrysts of pyroxenes of olivine are visible Titan augite, microphenocrysts of clinopyroxenes, lenticular labradorites and opaque minerals & clustered clinoproxenes	Coarse grained porphyritic
	LICD 13,19, 22 & 31	Bottom	Large crystals of olivine, titan augite, microphenocrysts of clinopyroxenes	Porphyritic texture
	LICD 20	Lava Flow	Olivine crystals with infillings of calcite and groundmass of volcanic glass	Aphyritic texture
Kerang II	LICK 2, 4, 6 & 8	Top	Phenocrysts of clustered clinopyroxenes and broken tabular labradorites, Phenocryst of orthopyroxenes with fine grained matrix	Porphyritic texture
	LICK 10, 13, 14 & 17	Middle	Phenocrysts of titan augite, orthopyroxene, olivine in groundmass of labradorites and opaque minerals	Porphyritic texture
	LICK 22, 27, 28	Bottom	Phenocrysts of titan augite, clinopyroxenes and microphenocrysts of olivines	Porphyritic texture
	LICK 5, 19, & 24	Lava Flow	Cracked crystals of clinopyroxenes in filled with analcite, broken crystals of orthopyroxenes and microphenocrysts of olivine and opaque minerals in volcanic glass matrix	Aphyritic texture

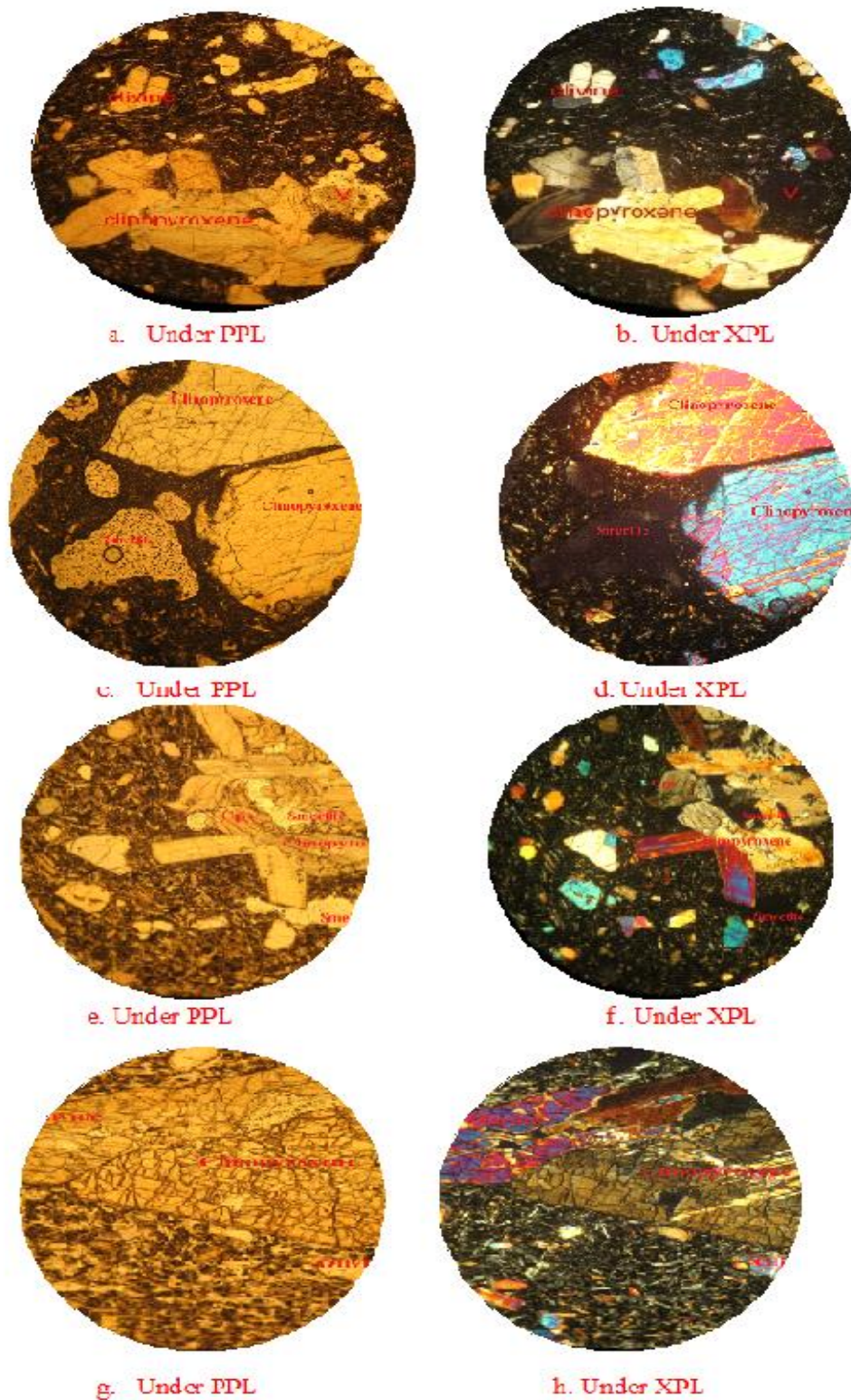


Figure 2a-h: Photomicrograph of large phenocryst clusters of zoned clinopyroxene (a-b), large individual crystals (c-d), intertwined clusters infilled with smectite (e-f), and a mutual interlocked grain of olivine & clinopyroxene (g-h) and labradorite (X40), in fine groundmass.

3.1.2. Titanaugite

The titanaugites occur as a very large crystal (approximately 2–4 mm) with sharp straight edges exhibiting moderate to strong brown color. This could be as a result of slow cooling of large magma body at depth. Their crystals are euhedral to subhedral in shape and show hourglass-

shaped zoning which is a common feature in alkali-rich basaltic rocks (Fig. 3a-f). Their crystals show perfect cleavages, moderate relief, and inclined extinction angles. One of the samples (Fig. 3c-d), has a xenocryst of olivine. This suggests that the enclosed olivine crystal was a member of an early formed crystal fraction.

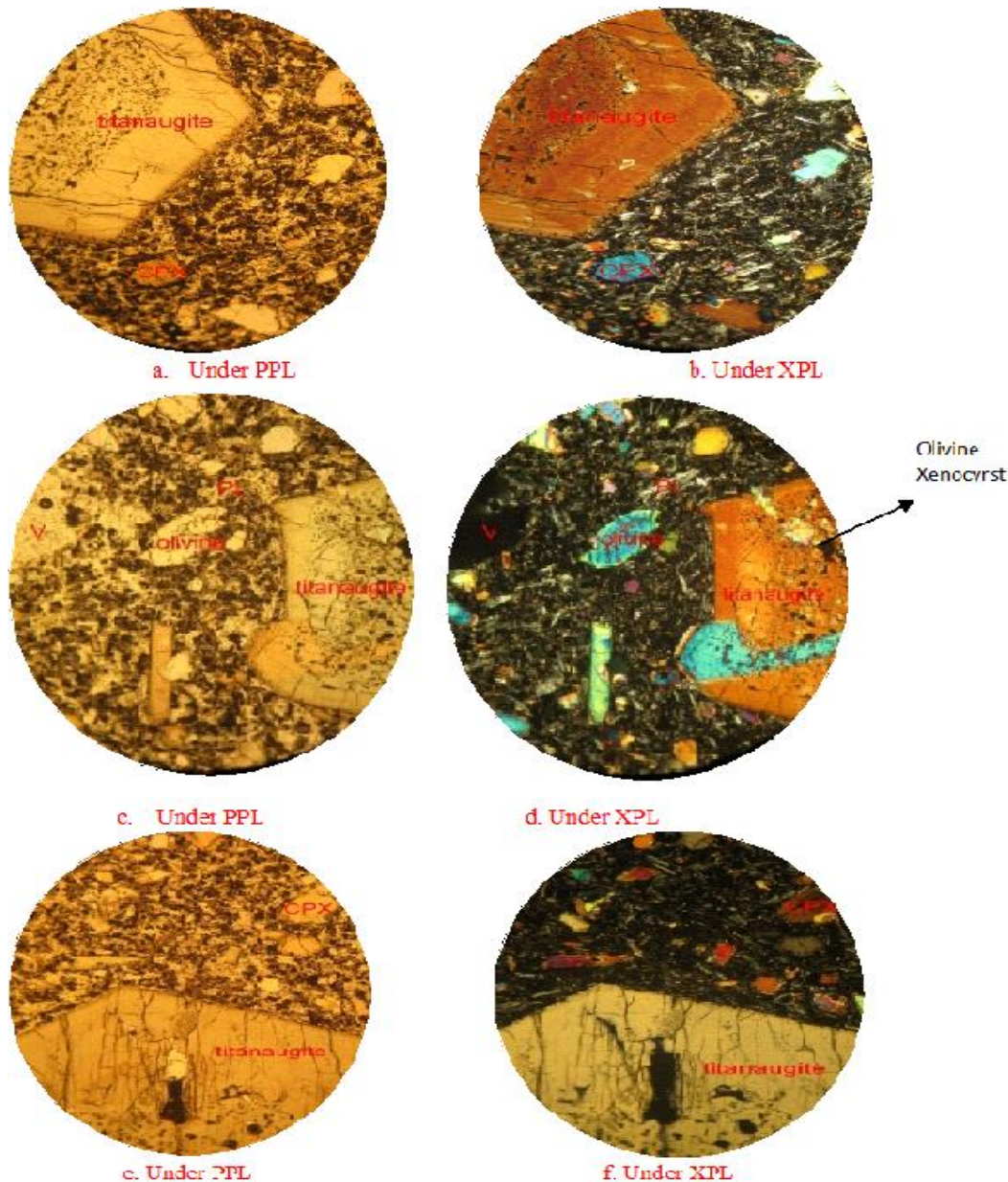


Figure 3 (a-f). Photomicrograph of Kerang twin basaltic rock with large zoned crystal of titanaugite with sharp edges, xenocryst of olivine (c-d), and microphenocrysts of clinopyroxenes embedded in fine-grained matrix of labradorite (whitish speck) laths (X40).

3.1.3. Olivine

The large olivine crystals of the Kerang twin volcanoes are subhedral to anhedral in shape and lack cleavages, but commonly characterized by their network pattern of fractures (Fig. 4a-f). They appear grayish-green to pale yellow in color, with glassy luster, moderate relief, and exhibit pleochroism. And appear as embedded grain within the matrix of the samples. In figure 4 (a-b), a large olivine crystal is surrounded by radially oriented fibrous clinopyroxene crystals. Such a relationship where a crystal of one mineral is surrounded by other minerals, produces what is

termed as reaction rim or reaction corona. This is as a result of reaction between the olivine crystal and the magma which is presumably more silica-rich than the one the olivine crystal was in equilibrium with (in this case clinopyroxene). So also, in figure 2 (g-h) large crystal of olivine and clinopyroxene are intimately interlocked with each other. Such an interpenetrative pattern exhibited by these crystals is typical of mutual relationship that could exist between two different minerals. The olivine crystal in figure 4 (c-d), seems to be altered to serpentine (serpentinization/iddingsite).

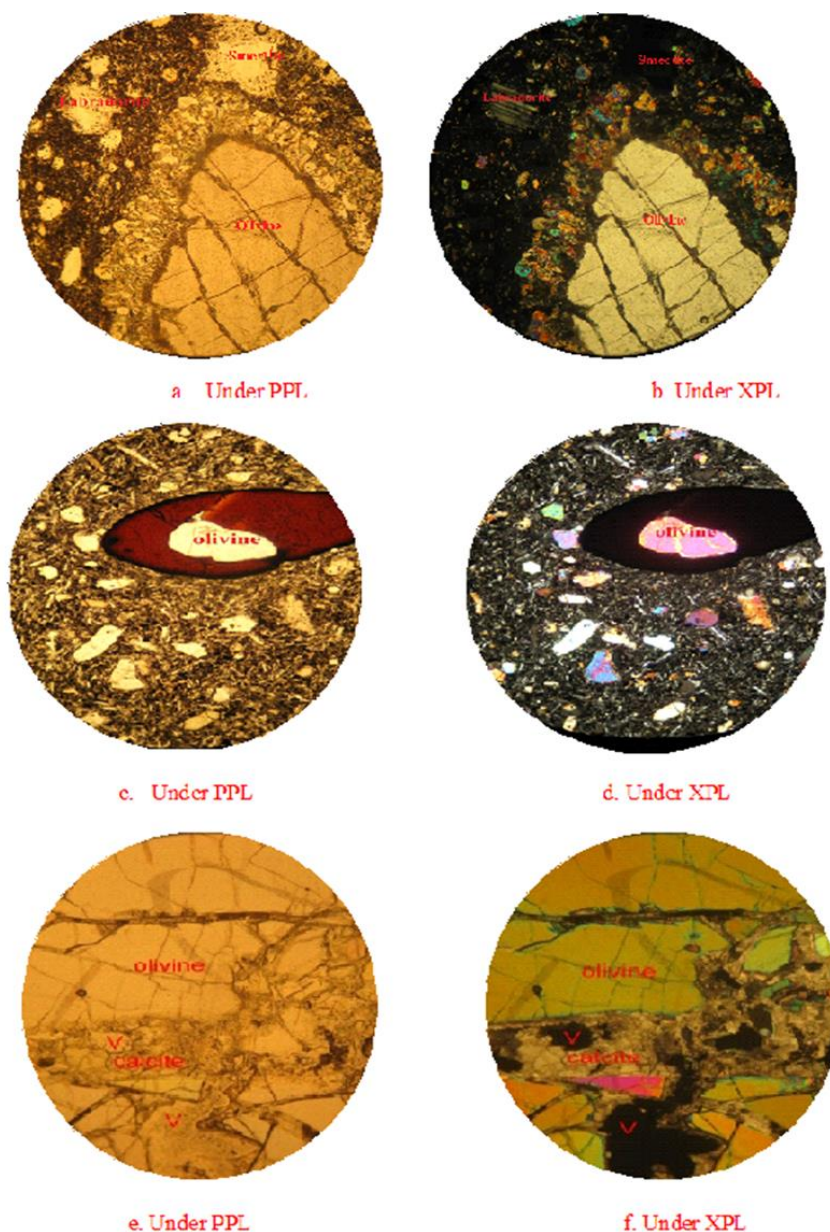


Figure 4 (a-f). Photomicrograph of large phenocryst of olivine (a-b), from the Kerang twin basaltic rocks surrounded by rim of clinopyroxene crystals (reaction rim) and microphenocrysts of labradorite (An79–54), depicting typical corona texture and evidence of recrystallization of constituent minerals; a transformed crystal (c-d) to serpentine (iddingsite), and a cracked crystal (e-f) within-filling of calcite and smectite (v) embedded in fine-grained matrix of labradorite laths (X40).

3.1.4. Orthopyroxene

The orthopyroxene phenocrysts (2–5 mm) are colorless and has a parallel extinction angle. They are euhedral to subhedral in shape and have inclusion of opaque (dark) minerals (magnetite and ilmenite) in some samples (Fig. 5a-f). Some of the orthopyroxene crystals have slightly curved edges surrounded by weak alignment of

clinopyroxene crystals along their edges and show brown rim of radially oriented fibrous blue and brown clinopyroxene crystals (Fig. 5a-b). The large sizes of these orthopyroxene crystals are evidence of slow cooling of magma at depth. While the reaction rims could be as a result of the reaction between early formed crystals with the melt of changing composition.

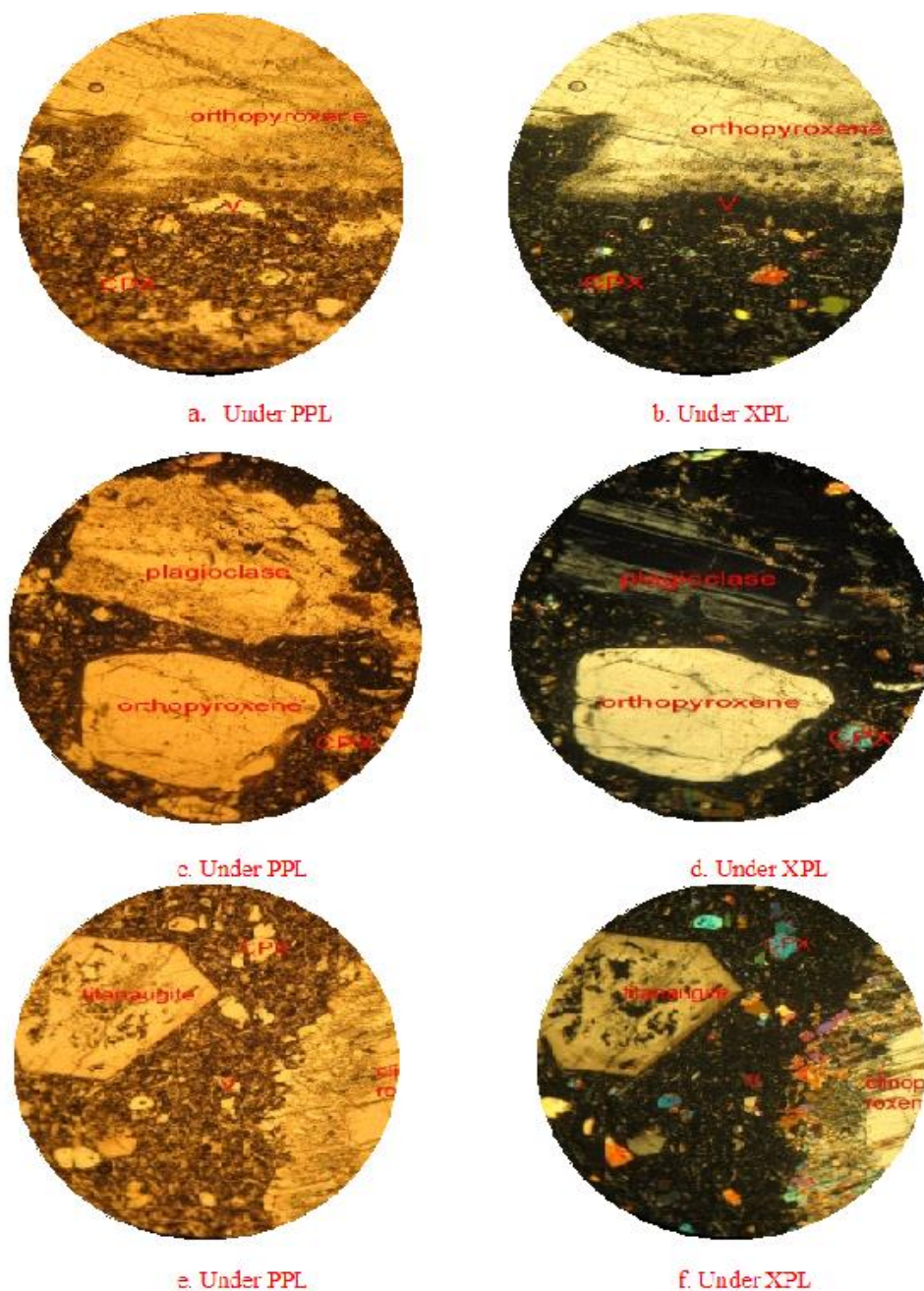


Figure 5 (a-f). Photomicrograph of rocks from Kerang twin volcanoes showing large phenocryst of orthopyroxene with chilled margin (reaction rim) (a-d) and microphenocryst of titanite (e-f) crystal embedded in a finer groundmass (X40).

3.1.5. Plagioclase

The plagioclase appears to fall in the composition range An_{79–52}. Minor zoning was observed in some of the large crystals and resorption margins (Fig. 6a-d). They are distinguished by their contrasting shades of black and white band (twinning). They are tabular and lenticular in shape without colors. Their crystals are randomly distributed and form the dominant phase in the

groundmass. Phenocrysts and microphenocrysts of labradorite were observed in most of the samples (Figs. 4 & 5). They mostly occur as individual laths in groundmass and are intimately intergrown with stubby clinopyroxene prisms to form glomeroporphyritic clots. Both the clinopyroxenes and plagioclases (labradorites) microphenocrysts appear to have sharper and better-formed crystal outlines.

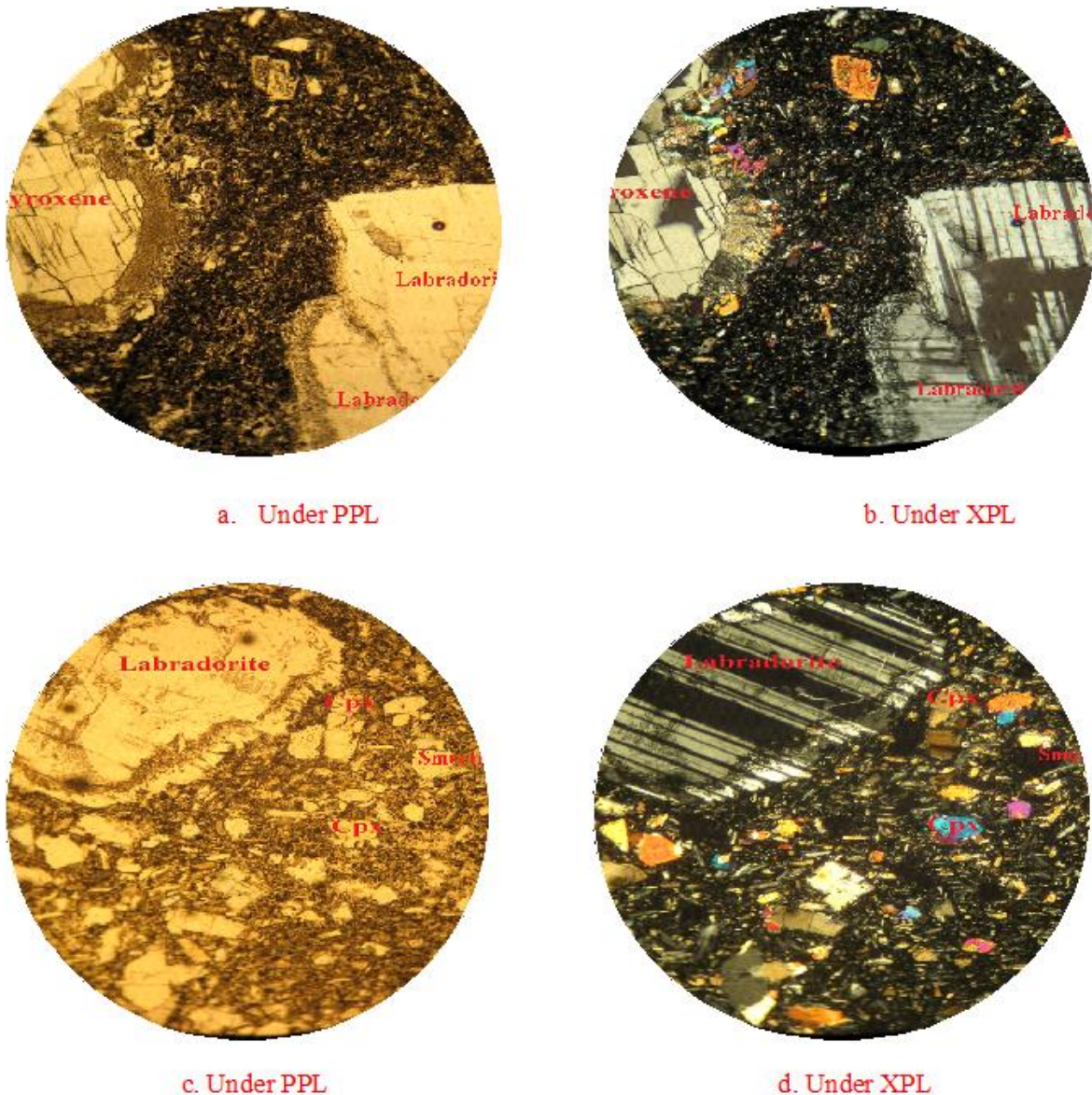


Figure 6 (a-d). Photomicrograph of large phenocrysts of orthopyroxene (4 mm in size) and labradorite (3–4 mm in size) (An_{63–52}) microphenocrysts with sharper edges and better-formed crystal outlines from the Kerang basaltic rocks embayed by resorption rim and surrounded by fine-grained crystals of the groundmass (X40).

3.1.6. Accessory minerals

Opaque and secondary minerals include ilmenite, magnetite and smectite, amongst others.

4. Discussion

Pioneer workers on the Jos Plateau volcanoes such as Mackay et al. (1949); Macleod et al. (1971); Kogbe, (1989) and Wright, (1985), have categorized the basalts of the Jos Plateau into two categories, namely, older and newer. This categorization was based on the intensity of weathering of the basalts. Those that are highly weathered and laterized are presumed to have been emplaced during the Tertiary and are therefore referred to as Older Basalts. By contrast, those with well-defined cones and less weathered, are believed to have been emplaced during the Quaternary, and are termed Newer Basalts. Field investigation revealed that the Kerang twin volcanoes are principally basalts emplaced within the pre-existing basement rocks.

Petrographic and mineralogical studies show that there is no distinction between the "Older" and "Newer" basalts as asserted by the earlier workers. This lack of clear difference between the Older/Newer, suggests that the basalts of the Kerang twin volcanoes are "Newer". They exhibit similar mineralogical compositions composing majorly of phenocrysts of clinopyroxenes, titanagites, olivines, orthopyroxenes and labradorites. They are texturally aphyritic and porphyritic in nature showing glomeroporphyritic clusters of phenocrysts, with opaque minerals (mostly ilmenite and/or magnetite) as accessory minerals similar to those of Biu Plateau volcanoes (Buchanan et al., 1971; Hossain, 1981; Lar and Saidu 2014). One of the olivine crystals (Figure 4a-f), exhibits overgrowth features.

This is as a result of reaction between the olivine crystal and the magma which is presumably more silica-rich than the one the olivine crystal is in equilibrium with (Mackenzie et al., 1984; Oyan et al., 2017). Orthopyroxenes are said to be pressure-oriented minerals (i.e., formed at great depth), so they crystallized first before clinopyroxenes in a solid solution enstatite and ferrosilite series. From these observations, it

could be implied that the orthopyroxene crystals were formed at great depth before their extrusion to the surface (Rollinson, 1993; Kerr et al., 2019). Also, the observed similarities in the compositions of the clinopyroxenes and plagioclases (labradorites) rims and microlites, suggest that the crystals were in equilibrium with the surrounding melt. This is being attested to by the inclusions of relicts of early-formed orthopyroxene and olivine (xenocryst) crystals in clinopyroxenes (Figs. 2, 3 & 6). This suggests that the minerals must have crystallized before being extruded. Furthermore, the occurrence of highly calcic labradorites in several of the samples, implies that labradorite and clots of clinopyroxenes crystallization occurred at relatively shallower depths shortly before eruption (Burrell, 2017; Mackenzie et al., 1984; Njome and De Wit, 2008).

5. CONCLUSION

Results obtained from the petrographic study of the Kerang twin basaltic rocks, suggest that they must have originated from a common source. The few larger resorbed magnesium-rich phenocrysts of olivine and orthopyroxene were undoubtedly not in equilibrium with the liquid in which they are now found, but evidently formed deeper in the eruption conduit under conditions of higher temperature and in a melt of lower silica content with a higher ratio of magnesia to iron. The basaltic rocks are composed majorly of phenocrysts of clinopyroxenes, titanagites, olivines, orthopyroxenes and labradorites embedded in finer groundmass and less commonly ilmenites and iron oxides as accessories minerals.

The assemblage of clinopyroxene-plagioclase-olivine on the other hand, does appear to be in equilibrium with the glass, which is in accord with the lower temperatures relative to high bulk silica content of the lavas extruded during this phase of their ascent.

The Kerang twin volcanoes are both mineralogically similar. Both contain abundant large phenocrysts of olivine, orthopyroxene and clinopyroxene as much as 3–5mm set in microcrystalline groundmass. Their petrographic

characteristics show that there is no distinction (petrographically) between the basaltic rocks earlier referred to as Older or Newer.

The basaltic rocks from the Kerang twin volcanoes display similar characteristics to those of the Biu Plateau volcanoes in terms of their textures and mineral compositions.

The rocks studied are strictly basalts and emplaced along the major N–S lineament in the host basement rocks.

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