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RESEARCH ARTICLE

# PETROGRAPHY AND MICROTEXTURAL CHARACTERISTICS OF GRANODIORITE FROM WASIMI, SOUTHWESTERN NIGERIA

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**ABSTRACT**

Rock samples of granodiorite from Wasimi were studied in detail to determine the minerals, mineral associations and the different micro-texture present in order to unravel the processes that were involved during the cooling of the magma. The following minerals were observed; plagioclase feldspars, K-feldspars, biotite, pyroxene, amphiboles, with zircon and sphene as accessory minerals. The pyroxene are engulfed in amphiboles and have reaction rims. Pyroxene occur as inclusions in plagioclase feldspars. Amphiboles are poikilitic with inclusions of quartz. Symplectic texture exits between the following minerals; plagioclase and K-feldspar, biotite and quartz, plagioclase and amphibole. The plagioclase feldspars have fractured and bent twin lamellae. Crystals of plagioclase feldspars are zoned and also exhibit both Carlsbad and albite form of twinning. It can be said that there was an initial slow cooling of the magma which was responsible for the large crystals of feldspars which was later followed by rapid cooling as the magma rises close to the surface which gave rise to zoned plagioclase feldspars and indication of high level intrusive.

**KEYWORDS**

Micro-textures, plagioclase, twinning, reaction rims, intrusive, poikilitic.

## 1. INTRODUCTION

Granodiorite is an intrusive rock, intermediate in composition between diorite and granite. The granodiorite of Wasimi is coarse-grained light coloured rock with dark spots which occur as low-lying outcrops and as boulders (Figure 1). The study area is located in Osun State, Nigeria which is part of the Precambrian Basement Complex. Samples from locations 1 & 2 in the centre of the town are charnockitic, occurring mostly as boulders while samples from locations 3 to 9 are granodioritic rocks (Figure 2). This study focuses on the textural relationship between the different minerals with more emphasis on the feldspars. The study of microtextures has contributed to the understanding of geological and geochemical magmatic processes (Lee and Parsons, 1997; Dini et al., 2004; Sable et al., 2006). These microtextures are sources of information on crystal growth *T*, cooling rates, and isochemical and non-isochemical replacement reactions which are in a way associated with late magmatic or externally derived aqueous fluids (Parsons et al., 2015). There are reported cases of microtextures in feldspar that have shown great complexity (Parsons et al., 2013; Parsons et al., 2015). Alkali feldspars can be said to rank with minerals such as quartz and plagioclase as the most common mineral in the earth's crust (Young, 1981). Microtextures in alkali feldspar has been greatly studied by several authors (Yuguchi and Nishiyama, 2007; Yuguchi et al., 2011a, 2011b; Balić-Žunić et al., 2013). This study aim to use petrography to identify the various mineral present, determine the order of crystallization of the minerals and use the microtextures to interpret the processes that occurred during the cooling of the magma.

## 2. MATERIALS AND METHODS

Thin section of the rocks was made at the labouratory of the Department of Geology, Obafemi Awolowo University.

**Figure 1:** Field Photograph of granodiorite at Wasimi

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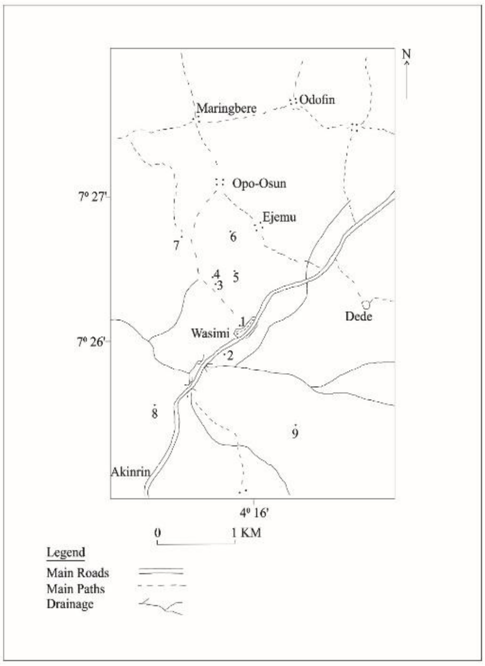


**Figure 2:** Map showing the location points of the samples (modified after Federal Survey Nigeria, 1966)

The detailed study of these thin sections was carried out at the Department of Geosciences, University of Lagos. Twenty thin sections were prepared from ten samples. Photomicrographs were taken to represent minerals, micro-textures and microstructures observed under the microscope.

## 3. Results

### 3.1 Petrography

Pyroxene are subhedral to anhedral and occur as inclusions in amphibole (Figures 3 - 10). Crystals of pyroxene have reaction rims of amphiboles (Figures 5 & 6). The amphiboles are greenish irregular in shape and in some cases like sieves (Figures 3, 6, 7, 9 & 10). Amphiboles is poikilitic with inclusions of quartz (Figure 11). Biotite are anhedral in shape, having between a needle-like to radiating form (Figures 12 - 15). There is a symplectic texture between biotite & plagioclase, and also between biotite & quartz (Figure 16 & 17). Some biotite crystals have inclusions of K-feldspar (Figure 18) and sphene. Plagioclase occur as phenocrysts in matrix of pyroxene, amphibole, biotite, and quartz (Figure 19).

There are inclusions of pyroxene within phenocrysts of plagioclase feldspar (Figure 20). Symplectic texture exits between plagioclase & K-feldspar (Figures 21 - 27), plagioclase & quartz (Figure 27). There is a deformation of the twin lamellae of some plagioclase crystals with bent twin lamellae (Figure 28). Plagioclase crystals show evidence of fracturing (Figure 29). Phenocrysts of some plagioclase are zoned (Figures 30 - 35), with some having a dendritic core (Figure 30). There is an antiperthite structure in the plagioclase (Figure 36). The K-feldspar occur as subhedral phenocrysts. Quartz crystals are small in sizes compared to the other minerals and more concentrated around plagioclase and K-feldspars (Figures 31 - 37).

## 4. Discussion

Phenocrysts of plagioclase feldspars are embedded in matrix of pyroxene, amphibole biotite and quartz. Pyroxene was the first mineral to crystallize followed by early crystallization of plagioclase feldspars, amphibole, biotite and quartz, with K-feldspar coming last, based on the mineral-mineral assemblage.

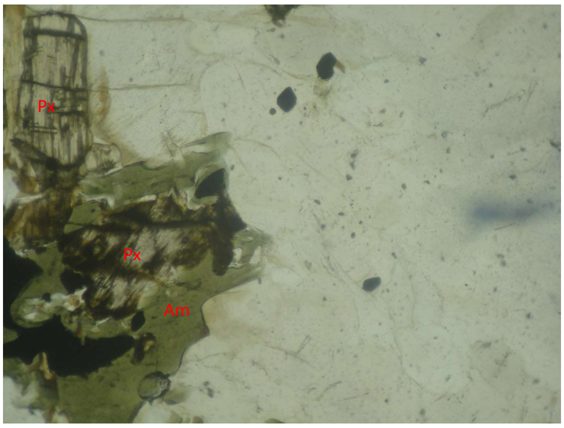


**Figure 3:** Photomicrograph showing pyroxene (Px) mantled by amphibole (Am). PPL

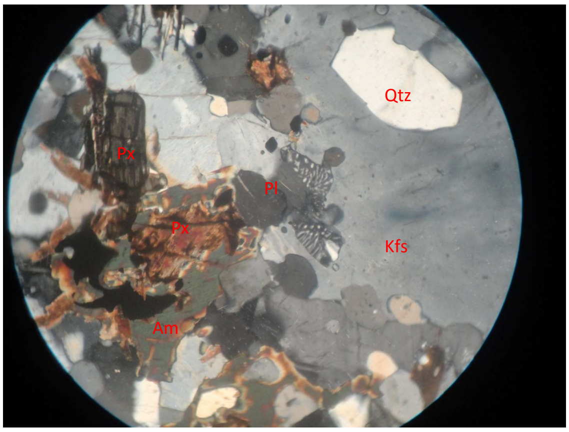


**Figure 4:** A photomicrograph showing symplectic texture between plagioclase (Pl) & K-feldspars (Kfs). The K-feldspars has inclusions of quartz. XPL

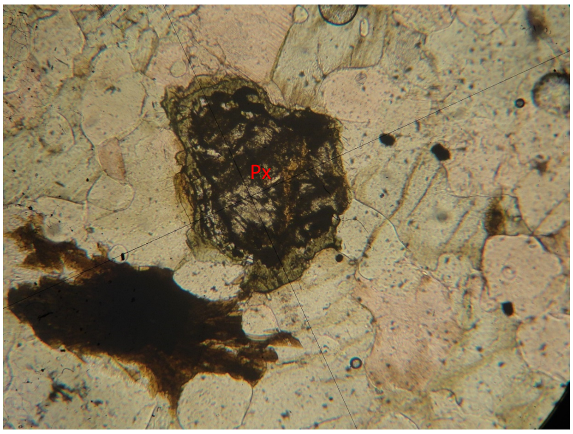


**Figure 5:** Photomicrograph of showing pyroxene (Px) with reaction rims. PPL

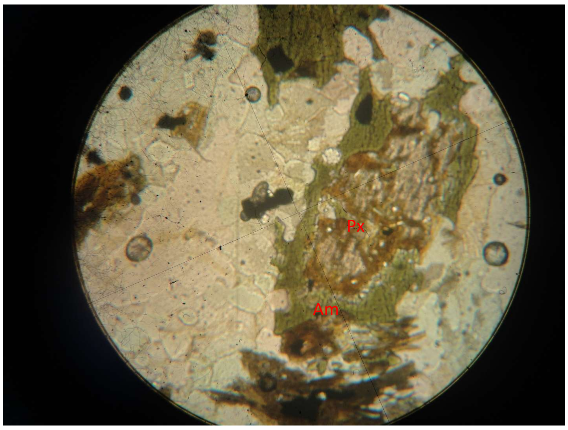


**Figure 6:** Photomicrograph of showing pyroxene (Px) with reaction rim of amphibole (Am). PPL

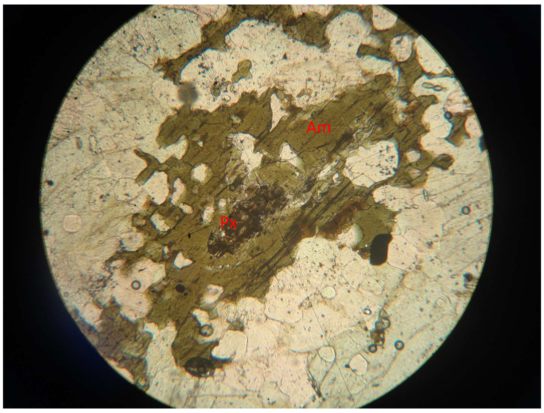


**Figure 7:** Photomicrograph showing inclusion of pyroxene (Px) in amphibole (Am). PPL

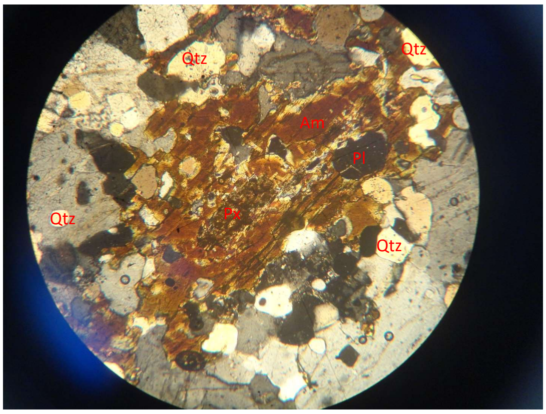


**Figure 8:** Photomicrograph showing inclusion of pyroxene (Px) and plagioclase (Pl) in amphibole (Am). XPL

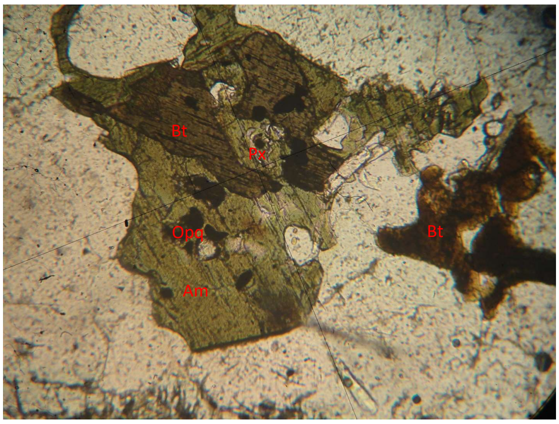


**Figure 9:** Photomicrograph showing resorbed pyroxene (Px) and opaque (Opq) mantled by amphibole which in turn is surrounded by biotite (Bt). PPL

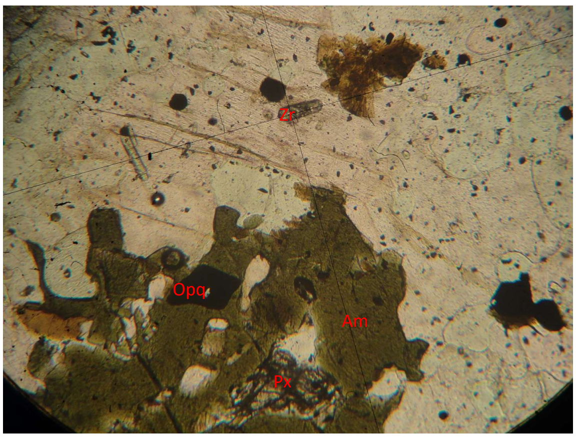


**Figure 10:** Photomicrograph showing inclusions of pyroxene (Px), opaque (Opq) in amphibole (Am). Zircon. PPL

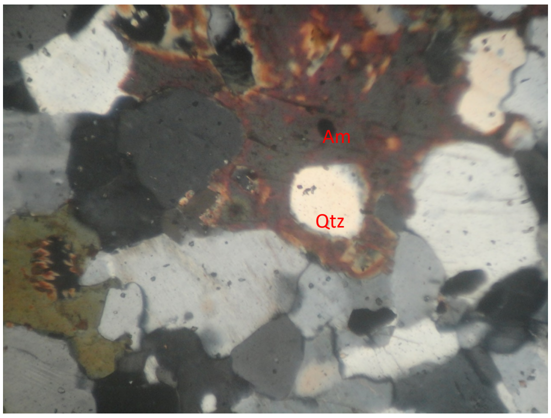


**Figure 11:** A photomicrograph showing quartz (Qtz) as inclusions in amphibole (Am). XPL

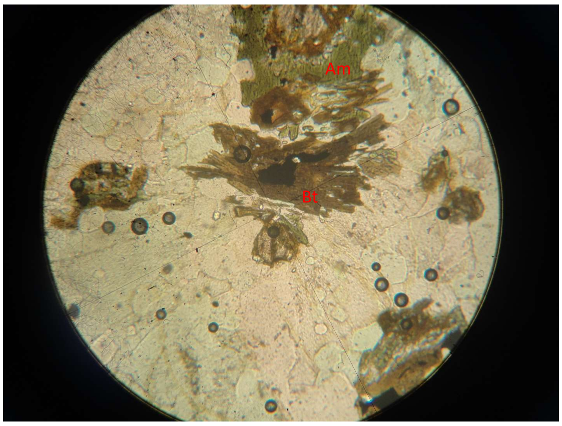


**Figure 12:** Photomicrograph showing anhedral form of biotite (Bt) with radiating form. PPL

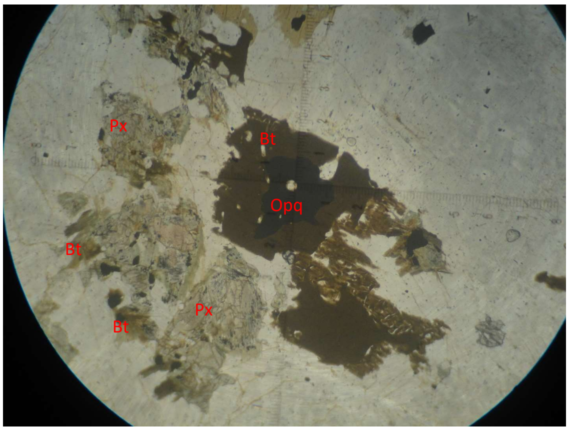


**Figure 13:** Photomicrograph showing inclusions of opaque (Opq) within biotite (Bt). Take note of the biotite/pyroxene boundaries. PPL

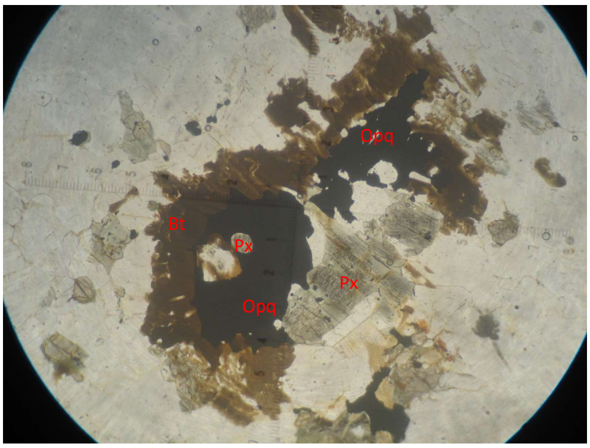


**Figure 14:** Photomicrograph showing pyroxene (Px) as inclusions within opaque surrounded by biotite (Bt). PPL

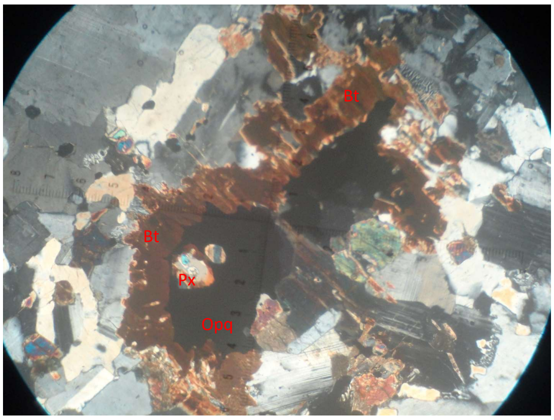


**Figure 15:** Inclusions of pyroxene within opaque (Opq) which is surrounded by biotite (Bt). XPL

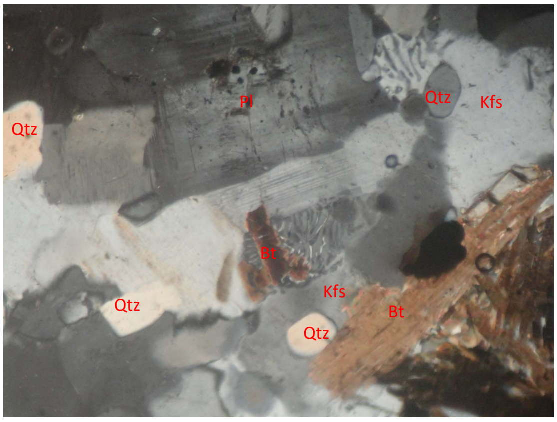


**Figure 16:** Photomicrograph showing symplectic texture (wormy-like) between plagioclase (Pl) & biotite (Bt) and K-feldspar (Kfs), also between plagioclase and quartz (Qtz). XPL

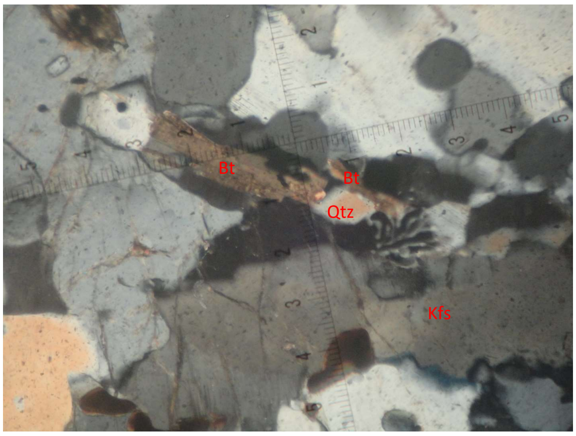


**Figure 17:** Photomicrograph showing symplectic texture (wormy-like) between biotite (Bt) and quartz (Qtz). XPL

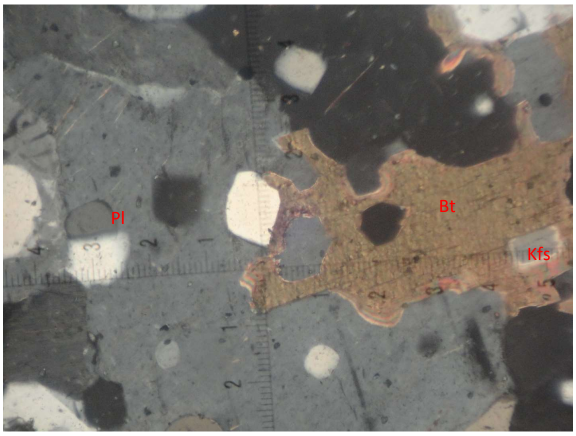


**Figure 18:** Photomicrograph showing biotite (Bt) with inclusions of K-feldspars (Kfs). XPL

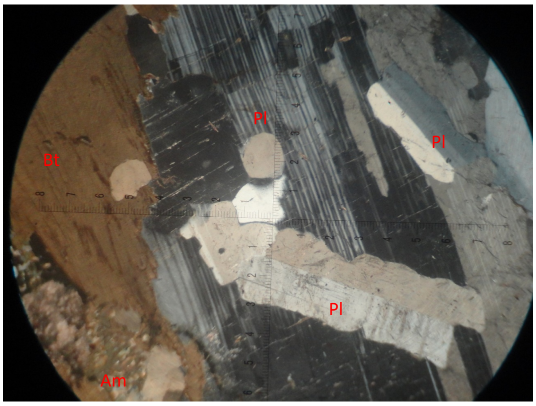


**Figure 19:** Photomicrograph showing plagioclase feldspars (Pl) overlapping each other and occurring as phenocrysts. XPL

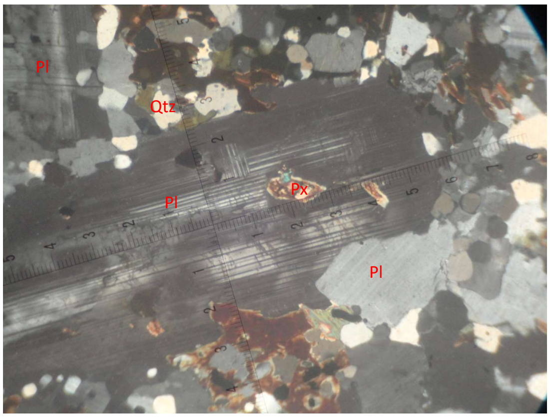


**Figure 20:** A photomicrograph showing inclusions of pyroxene (Px) in plagioclase feldspar (Pl). XPL

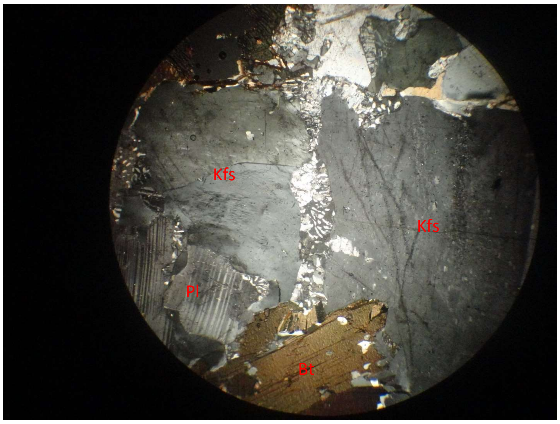


**Figure 21:** Photomicrograph showing symplectic texture (wormy-like) between plagioclase (Pl) and K-feldspar (Kfs). Tiny white vermicules occurring in myrmekite; it is a rim myrmekite. XPL

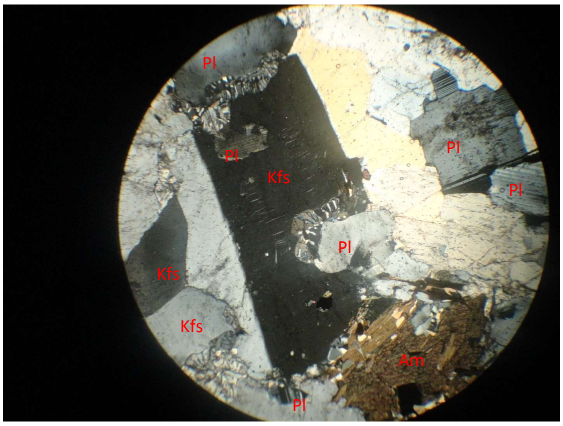


**Figure 22:** Photomicrograph showing myrmekitic texture between plagioclase (Pl) and K-feldspar (Kfs). Perthitic texture can be observed. The lamellae of the plagioclase (Pl) are disappearing away. XPL

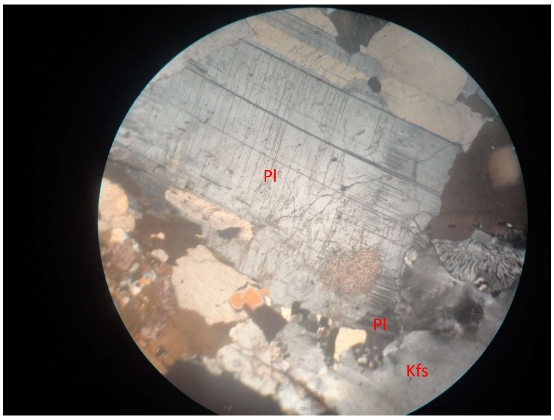


**Figure 23:** Photomicrograph of large albite-twinned crystal of plagioclase. Myrmekite occur between the boundary of K-feldspar (Kfs) and plagioclase (Pl). XPL

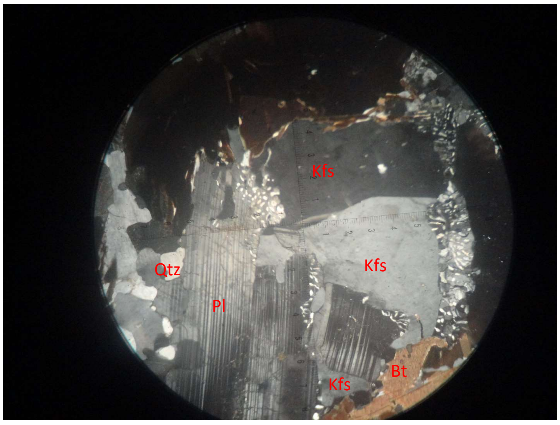


**Figure 24:** Photomicrograph showing myrmekite at the boundary of plagioclase (Pl) and K-feldspar (Kfs). Plagioclase embayed in K-feldspar. XPL

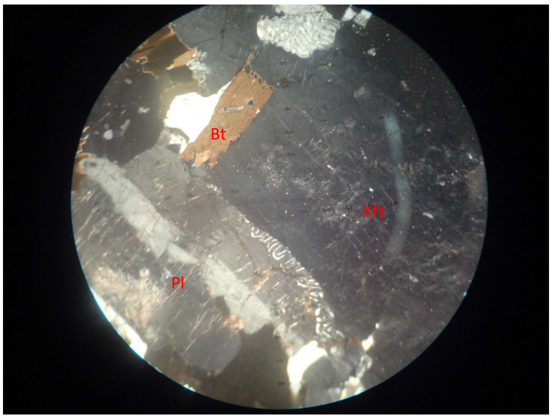


**Figure 25:** Photomicrograph showing string perthite in the plagioclase, with myrmekite (wormy-like) between plagioclase (Pl) and K-feldspar (Kfs). XPL

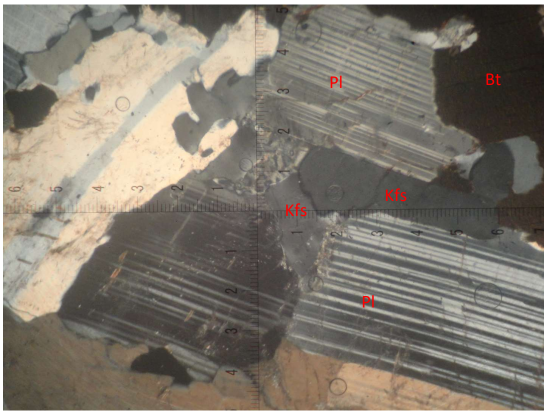


**Figure 26:** Photomicrograph showing myrmekitic texture at the boundary of plagioclase (Pl) and K-feldspars (Kfs). XPL

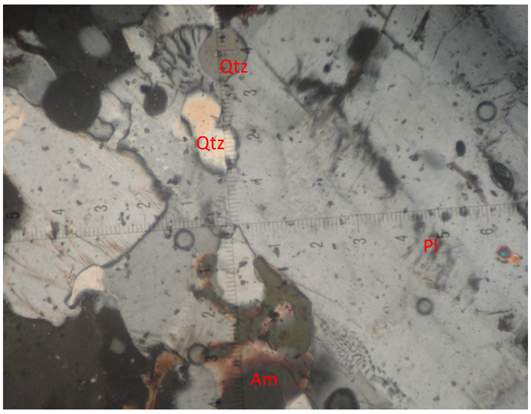


**Figure 27:** Symplectic texture between plagioclase and quartz, and between plagioclase and amphibole. XPL

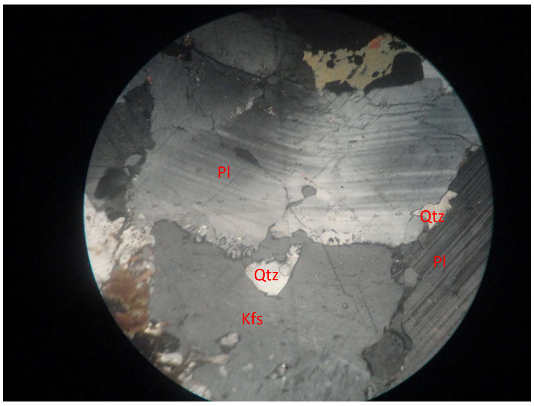


**Figure 28:** Photomicrograph showing myrmekite (wormy-like) at the boundary between plagioclase and K-feldspar. The plagioclase shows a deformed lamellae. XPL

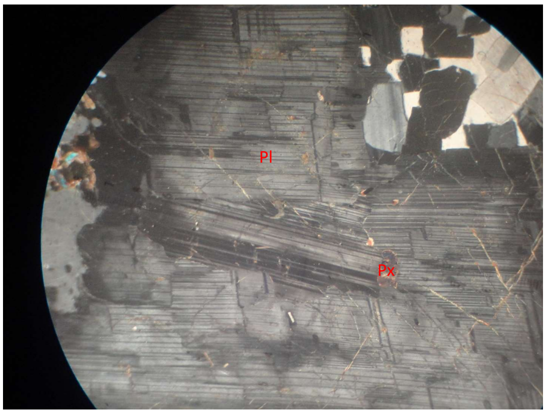


**Figure 29:** Photomicrograph showing fracture in the twin lamellae of plagioclase (Pl) and pyroxene (Px) has inclusions within the plagioclase. The fracture in the plagioclase is almost perpendicular to the long axis. XPL

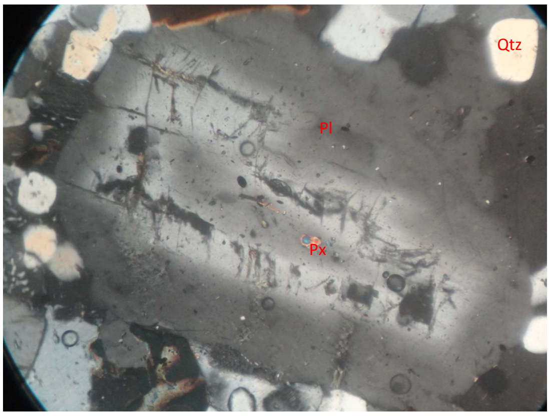


**Figure 30:** Photomicrograph showing a zoned plagioclase (Pl) with inclusion of pyroxene (Px) at the core. Take note of the dendritic nature in the core of the plagioclase. XPL

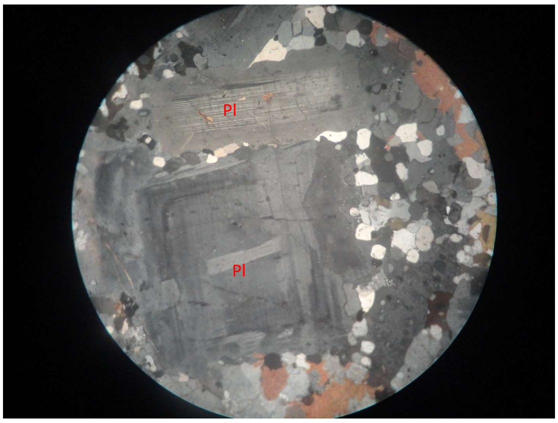


**Figure 31:** Photomicrograph showing zoning of plagioclase feldspar (Pl). XPL

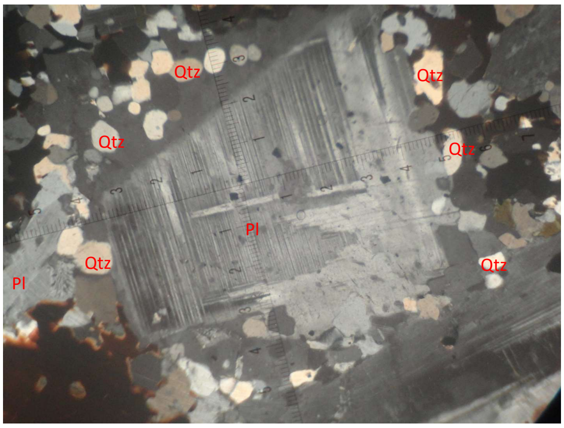


**Figure 32:** A photomicrograph showing a zoned plagioclase surrounded by subhedral crystals of quartz (Qtz). Symplectic texture (wormy-like) occur between plagioclase (Pl) and quartz (Qtz). XPL

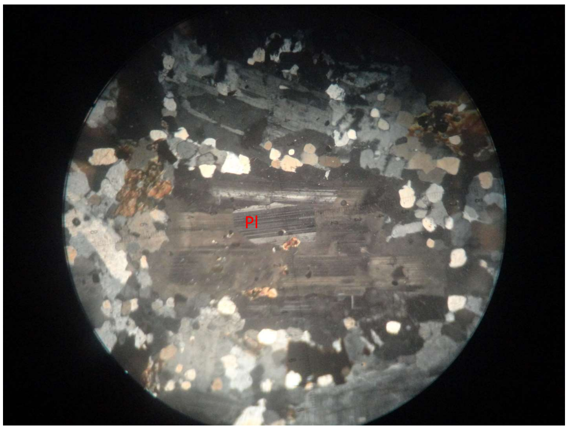


**Figure 33:** Photomicrograph showing zoning in plagioclase (Pl). Albite twinned plagioclase in the center. XPL

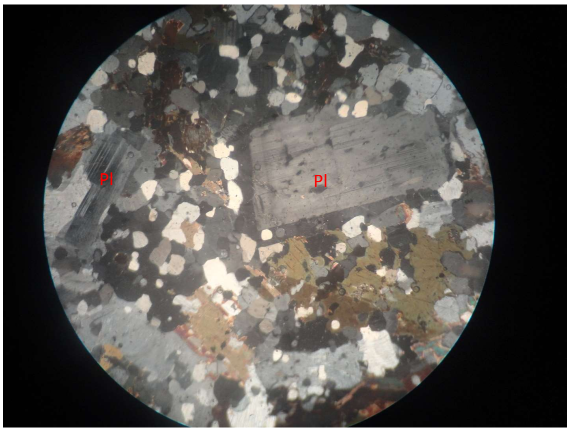


**Figure 34:** Photomicrograph showing zoning of plagioclase feldspar (Pl). XPL

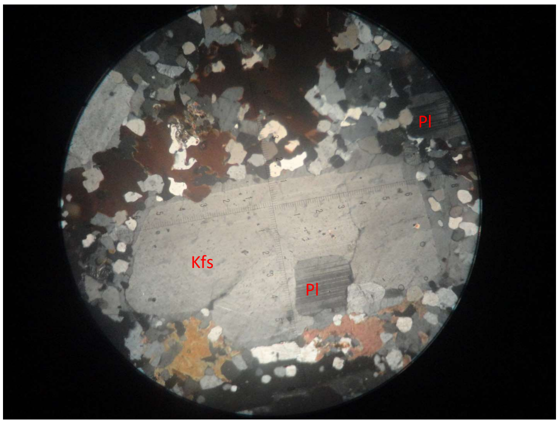


**Figure 35:** Photomicrograph showing zoning and perthitic structure in plagioclase (Pl). Plagioclase is surrounded by quartz. XPL

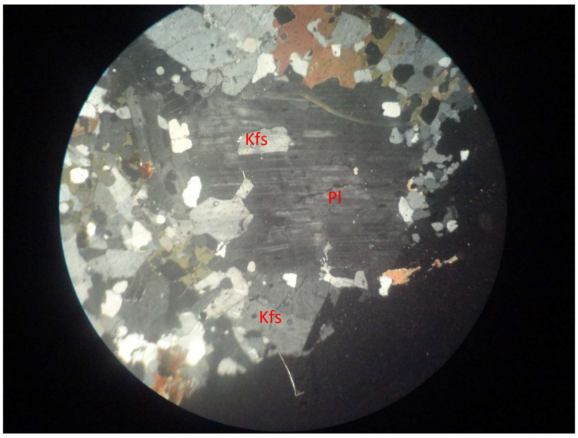


**Figure 36:** Photomicrograph showing antiperthite structure in granodiorite. XPL

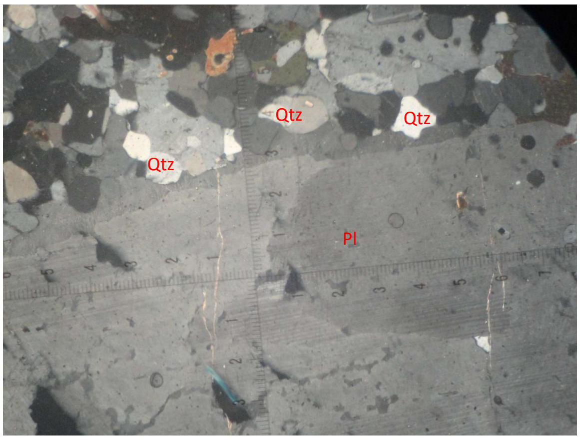


**Figure 37:** Photomicrograph showing sympletic texture between plagioclase (Pl) and quartz (Qtz). XPL

The relationship between pyroxene and amphibole can be represented as; Opx + Plagioclase 1 = Amphibole + Plagioclase 2. The orthopyroxene reacts with the K-rich melt to give biotite and quartz: Opx + $K^+$ (melt) = Biotite + Quartz. This reaction can be said to be responsible for the formation of symplectite between biotite and quartz. Plagioclase show fractured surfaces which are almost perpendicular to the long axis. The contact between many crystals of feldspars with each other in a purely accidental way could be as a result of uncoordinated growth (Smith, 1974). Carlsbad-albite twinning present in the studied rock is usually characteristic of igneous rocks (Turner, 1951; Dowty et al., 1974). Deformation lamellae has been described as planar features which do not obey any twin law (Borg and Heard, 1970).

Plastic strain in plagioclase, in which the lamellae are bent, have been identified over the years (Carter, 1971; Hanmer, 1982; Olsen and Kohlstedt, 1985). Deformation of twin lamellae in plagioclase could be due to stresses from the interference growth of the various crystals or

associated fracture pattern which is parallel to the said twinning (Seifert, 1965). Plagioclase crystals can be said to have undergone deformation due to the presence of fractures and bent lamellae, which are evidences of deformation (Figures 28 & 29). This form of deformation is sometimes a precursor to myrmekite formation (Collins and Collins, 2013). The replacement of plagioclase by K-feldspar can be proposed for the myrmekitic texture (Bhattacharyya, 1971; Byerly and Vogel, 1973; Beasley, 1983). The fractures in this plagioclase allows fluid to enter and thus facilitate replacement (Shirey et al., 1980; Putnis et al., 2007).
The $K^+$ needed to form this secondary K-feldspar is readily available from biotite that are in close association with the two minerals, which do show evidence of deformation or alteration. There can be said to be a form of metasomatism between the K-feldspar and the plagioclase. Myrmekite exist between plagioclase and K-feldspar (Gerald and Harrison, 1993), adjacent to biotite and the boundaries amongst these three minerals appears irregular. It is a texture that is well developed in granodiorite (Philips, 1974; Hibbard, 1979). In the plagioclases of the myrmekitic texture, the twin lamellae are fading away. The minerals K-feldspar and plagioclase appeared disturbed and reset by late stage hydrothermal actions (XuemingYang et al., 2002). Hubbard in a study on charnockitic rocks in South-West Nigeria observed that myrmekite originated from exsolution processes parallel to and contemporaneous with perthitization (Hubbard, 1966).

Perthitic texture is observed in the K-feldspar, and some string-perthite variety with whitish strands are present. The abundance of perthitic texture is an indication that the feldspar was formed at a high temperature which has cooled slowing thus resulting in unmixing (Kroll et al., 1991). Recently, perthitic alkali feldspars has been linked to the formation of myrmekites (Abart *et al.,* 2014). The crystals of plagioclase feldspar are zoned and zoned phenocrysts of plagioclase have been extensively used to track magma processes such as magma mixing and crustal contamination (Davidson and Tepley, 1997; Shcherbakov et al., 2011). Zoning in plagioclase has been found to be controlled by the 'An' content, which in turn is controlled by the values of temperature, pressure and fluid (Hattori and Sato, 1996; Pletchov and Gerya, 1998; Putirka, 2005). Zoning in plagioclase could be a reflection of disequilibrium of the crystals with the melt during rapid cooling, this is an indication of cyclical changes during crystallization (Shelly, 1966; Haase et al., 1980; Loomis, 1982; Blundy and Shimizu, 1991).

The history of evolution of the magma is recorded in the zoning of the plagioclase, and this can due to crystallization of magma at shallow levels (Loomis and Welber, 1982; Hattori and Sato, 1996; Landi et al., 2004; Ginibre et al., 2007; Ruprecht and Wörner, 2007; Ustunisik et al., 2014). Dendritic nature of some of the zoned plagioclase may be due to rapid undercooling (Lofgren, 1974a; Fenn, 1977; Swason, 1977; Hibbard, 1981). The complex micro-fabric of this rock can be due to magma mixing and the influx of fluid (Friese et al., 2012). Variations recorded in the rock textures can be attributed to mirror the changes in the pressure and temperature of crystallization (Breiter et al., 2005). The presence of large crystals of the K-feldspars might be due to their difficulty to nucleate. The presence of sphene is an indication of high volatility of the magma.

## 5. Conclusion

The significance of perthitic texture is an indication that feldspar formed at high temperature which had cooled slowly. The myrmekitic texture can be said to have formed by the replacement of plagioclase feldspar by K-feldspar. Zoning of plagioclase is due to disequilibrium due to rapid cooling and indication that it is a high-level intrusive rock. Deformation of the twin lamellae and the appearance of myrmekite can be attributed to the stresses developed during the final stages of crystallization.

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