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The Petrogenetic Emplacement of Imori Complex, a Mesozoic Alkaline Granite North Central Nigeria: As a Case Study for Emplacement of Some Isolated Minor Intrusions within the Nigerian Ring-Complexes and Elsewhere

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Abstract:

Migratory trend of emplacement of the Mesozoic alkaline ring-complexes of Nigeria has been reported and is believed to be related to the general N-S trend of the complexes. It is also believed that these N-S trends of the lineament of incipient rifts controlled the disposition of the individual complexes. The minor alkaline granitic rocks of the Imori Complex were emplaced in line with the migratory N-S trend. It is located directly south of the larger Kudara Complex as a cupola, formed by southward migration of remnant magma in an arcuate manner from probably the Kudara magma chamber to form the Imori Complex with a narrow stretch of basement rocks separating the two complexes. This emplacement was aided by: an initial gas build-up in the ascending magma which probably led to up-doming of the overlying basement rocks, sealing up of previous orifices and conduits by igneous rocks with consequent to renewed magmatic activity in the magma chamber, or the surface cauldron subsidence or collapse of the central block and consequent caldera formation adding its load pressure on the magma chamber which would aid the fluidization process by expelling portion of the magma.

Keywords: Emplacement, apophyses, arcuately, ascension, caldera

1. Introduction

The ring-complexes of Nigeria and Niger Republics constitute a mega-province, which is one of the best studied examples of mid-plate magmatism in the world. The Imori Complex is part of the cycles of intrusive rocks of the Mesozoic alkaline complexes in the Nigerian province. It is one of the ring-complexes that form the western edge of the Jos Plateau (Bowden and Kinnaird, 1984). The structural aspects of the Imori Complex differ from those of a typical ring-complex as described from other ring-complexes in the province (Jacobson et al., 1958, MacLeod et al., 1971, Bowden and Turner 1974 and Ike, 1983). The Imori Complex lacks ring-dyke, cauldron subsidence structures and it is a minor intrusion. The Complex lies south of the Kudara Complex (Fig. 1) covering a surface area of about 30km² and it is oval in shape. The Complex has been incised by streams and consequently development of shallow gorges on the southern part. The Complex consists of five rock units namely; the basement rock, rhyolite, biotite granite, arfvedsonite granite and a monodoleritic dyke (Fig. 2).

Figure 1: Mesozoic Alkaline Ring Complexes in Nigeria after Kinnaird 1985)
Arrow Indicates the Imori Complex. Insert Map of Africa Showing the Location of the Mesozoic Alkaline Complexes (After Bowden Et Al., 1987)

Figure 2: Geological Map of Imori Complex

Fractures (joints, faults and lineaments) were the main structural elements delineated on the granitic outcrops. The orientation of the joint sets is dominantly NW-SE direction. In the eastern part of the Complex, some of these joints have been filled with silicious (quartz) material. The faults in the area are dextral strike slip faults with NW-SE orientation. The major drainage system in the area is structurally controlled by this fault.

The objectives of this paper are to provide the petrogenetic model of emplacement for the Imori Complex as a case study for the emplacement of some of the isolated minor intrusions within the Nigerian ring-complexes province and elsewhere. In addition, it also provided the first geological map of the Imori Complex (Fig 2).

2. Petrography

2.1. Dolerite Dyke

A minor dolerite dyke occurs between the alkaline granites towards the eastern part of the Complex (Fig. 2). It is dark-gray in colour and slightly denser than rhyolite of approximately equal size. This minor outcrop of dolerite is assumed to be a chilled contact dyke in view of its size rather than being formed from a separate mafic magma. In thin section anhedra of augite is seen to partially envelope, euhedral laths of plagioclase. The large size of the augite crystal arises from their inability to nucleate as efficiently as plagioclase (Figure 3).

2.2. The Rhyolite

The minor isolated rhyolite dyke in the south-eastern periphery is flattened and intrusive into basement rock. In the northeast, another outcrop of rhyolite which is generally brownish in colour also intruded the basement rock. Under the microscope, the constituent minerals of the rhyolite are equigranular and are composed of quartz and alkali-rich feldspar. Rounded phenocryst of quartz is seen on the slide, they are resorbed as quartz xenocryst in the form of an enclave (Figure 4). Small sprays of both opaque minerals and amphibole occur as intergrowths with the feldspar thus conferring a crude spherulitic texture in the groundmass.

2.3. Biotite Granite

The biotite granite is the most widespread rock unit and occurs dominantly in the southern part of the Imori Complex. This rock constitutes about two-third of the rocks of the Complex. Generally, the biotite granite is light brown in colour and is composed of feldspar, quartz and biotite. The feldspars are the most abundant minerals in the rock and are generally responsible for the overall colour of the rock.

Under the microscope, the biotite granite is composed of quartz, orthoclase, microcline, biotite and plagioclase in the form of narrower albite exsolution lamellae (perthite). The common accessory mineral in this rock is hematite. Quartz crystal appears in the interstitial of perthitic crystals and is colourless to light yellow in colour in XPL. The mafic mineral, biotite occurs as tabular anhedra plate in small sheaf-like clusters. The biotite pleochroism is brown to green, which aid its identification.

2.4. Arfvedsonite Granite

The arfvedsonite granite is the second major rock unit of the Imori Complex. It is the dominant rock in the north east of the Complex. It has the most imposing topography with highest peak being greater than 800m above sea levels. The predominant joint set on the arfvedsonite granites are oriented in NW-SE direction. Majority of the joints are filled with quartz as veins. The quartz veins are generally few centimetres wide and there is no any evidence of mineralization in them.

In hand-specimen the arfvedsonite granite is creamy white in colour as a result of its abundant orthoclase feldspar content. The minerals of the rock are feldspars, quartz, arfvedsonite and biotite. The arfvedsonite occurs as needle-like crystals which are randomly distributed throughout the rock. The rock is generally fine-grain.

Under the microscope, arfvedsonite is recognized by its pleochroic blue green absorption colour. It occurs as anhedra to subhedra grain and as interstitial acicular (needle like) crystals. Quartz occurs as aggregate, filling interstitial spaces among early paragenetic minerals. The feldspar is perthitic alkali feldspar. It is the most abundant mineral constituent in the rock (Figure 5).

Figure 3: Photomicrograph of Medium-Grained Dolerite Depicting Subophitic Texture of Columnar Plagioclase Crystals in Augite
Aug= Augite, Pla=Plagioclase, Opq= Opaque Mineral

Figure 4: Photomicrograph of the Light Grey Rhyolite with Quartz Xenocryst in Fined-Grained Groundmass Mainly of Alkali Feldspar. Qtz= Quartz Xenocryst with Glass Rim Round It
Sphtic Txt= Spherulitic Texture. A= XPL, B=PPL

Figure 5: Photomicrograph Biotite Granite
The Albite Exsolution Lamellae Are Seen in Larger Orthoclase and Microcline as Perthite
Bio= Biotite, Orth= Orthoclase, Mcr= Microcline, Hem= Hematite, Qtz= Quartz, A= XPL, B= PLL

Figure 6: Photomicrograph of Arfvedsonite Granite with Elongate Crystal of Arfvedsonite
Associating with Quartz and Feldspar
Arf= Arfvedsonite, Pth= Perthite, Orth= Orthoclase,
Mcr= Microcline, Qtz= Quartz A= XPL= Cross Polarised Light. B= PPL= Plane Polarised Light

3. Background Information

3.1. The Birth of the Concept

The Nigerian Mesozoic ring-complexes have attracted the attention of Earth scientist since the pioneer work of Falconer (1911), who recognises them as discordant, high level magmatic rocks. Magmatic rocks also known as igneous rocks form by cooling and solidification of magma that originated at deep sources within the lithosphere, ascended to shallow depths and finally emplacement occurs at a particular position within the crust as intrusive / plutonic rocks or on the surface of the crust as extrusive rocks.

Several authors have explained various ways through which igneous rocks originated and were emplaced. Classical examples are the Tibchi ring structure, in Nigeria (Ike, 1983), Great Tonalite Sill plutons of Alaska USA (Ingram and Hutton 1994), Ljugaren Lopolith granite Central Sweden (Cruden, 1998), the Coastal batholiths of Peru (Haerderlen and Atherton 2002), and the Glencoe ring intrusion of Scotland (Kokelaar and Moore 2006).

Migratory trend of emplacement of the Mesozoic alkaline ring-complexes of Nigeria has been reported by Bowden et al., (1976), Karche et al., (1976), Turner and Bowden, (1979) and Rahaman et al., (1984) and is believed to be related to the general north-south trend of the complexes. (Black and Girod, 1970) stated that the most spectacular arrangement of locations for the Mesozoic alkaline complexes was controlled by structural weakness in the lithosphere. Tectonic activity within and along plate margins may lead to fragmentation of the plates (Atherton and Ghani 2002). The general N-S lineament of incipient rifts controlled the disposition of the individual complexes in Nigeria province Ajakaiye (1984), Gandu et al., (1986) and Anifowose (2004).

3.2. A Case Study and Model for the Emplacement of the Nigerian Ring-Complexes

Ike, (1983) presented a five-stage classical model as a case study for the emplacement of the Nigerian Mesozoic alkaline complexes (Fig.3).

These are:

- Pre-caldera volcanism through a central volcano (stage 1)
- The formation of the peripheral ring-fracture (stage 2)
- Fluidization along the ring-fracture as agent for surface cauldron subsidence and intra-caldera volcanism (stage 3)
- A quiescent ring-dyke intrusion sequel to waning of fluidization (stage 4)
- The central granite intrusion (stage 5)

Figure 7: Model for the Emplacement of the Nigerian Mesozoic Alkaline Ring-Complexes (Ike, 1983)

- Stage 1: The earliest igneous activity was violent and eruptive, with mainly pyroclastic products and culminated in a central shield volcano built on an up-domed terrain.
- Stage 2: At a critical stage in the early volcanic era, a master cone-fracture, inward-dipping at depth and steepening to towards the ground surface.
- Stage 3: The beginning of fluidization along the ring-fracture and commencement of surface subsidence of the central block and overlying volcanic edifice were essentially contemporaneous. The fluidized quartz porphyries were feeders to intra-calderal ignimbrites.
- Stage 4: The granitic porphyry magma moving behind the fluidized quartz was essentially degassed, and its was quiescent and fracture-controlled
- Stage 5: The central granite stock ended the cycles and was emplaced by piecemeal stopping

The model of Ike, (1983) aligned itself with the structural evolution of the Kudaru Complex except for the lack of evidence of intra-caldera or post-subsidence volcanism. However, the minor intrusion of the Imori Complex which is assumed to be apophyses of the Kudaru Complex lack the evidence of the peripheral ring-fracture as master cone and there is no surface cauldron subsidence observed. This is suggestive that its emplacement was as a result of shallow centripetal dipping cupola similar to that of the Mada Complex (Abba, 1985).

A cupola is an isolated upward – projecting body of intrusive rock that lies near a larger body; both bodies are presumed to unite or be joined at depth (Dictionary of Geology and Mineralogy 2003).

According to Ike, (1983) stage 3 - fluidization along the ring-fracture is an agent for surface cauldron subsidence and intra-caldera volcanism. This stage gave rise to the collapse of the central block and consequent caldera formation began as soon as magma evacuation started. The subsided central block added its load pressure on the magma chamber which would aid the fluidization process by expelling portions of the magma; this gave rise to the post surface subsidence volcanism while the product of fluidization are the crystal-rich ignimbrites which formed the intra – caldera unit Ike, (1983).

Evidence of these crystal-rich ignimbrites is observed in some complexes, e.g., Ririwai (Jacobson et al. 1958), Banke (Jacobson and Macleod 1977), Ningi-Burra (Turner and Bowden 1979) and Tibchi (Ike, 1979). However, no evidence of intra-caldera volcanism was observed anywhere in the Kudaru Complex (Bain 1934) and (Adamu 1980). Adamu (1980) was of the opinion that the lack of evidence of post-caldera eruption in the Kudaru Complex was as a result of non-eruption because it is believed that magma which should have been used in the renewed volcanism may have migrated to another site to form an entirely new complex. This is most probably the case with Imori Complex, as an apophysis or cupola of its larger Kudaru Complex.

3.3. Magma Migration and Its Emplacement Mechanism- A Model for the Imori Complex

The evolved granitic magma that forms the Imori granite suites is presumed to have ascended the crust arcutely southward from the primary Kudaru magma chamber by means of dyke system (Fig. 4). Dyke emplacement provides not only for upwards transport of magma possibly feeding surface fissure ascension but may also transport magma over considerable lateral distances too (Ernst et al., 1995). This arcutely migrating magma by means of upward stopping was aided by the collapse of the central block of the Kudura Complex which provided an effective increase of geostatic pressure over the hydrostatic pressure of the rising magma – (a zone of weakness above the magma chamber and its preferred pathway) (Walker 1975). This upwelling propagation of magma-filled dyke was intersected at shallow depth with a freely slipping horizontal or fracture – resistant horizon at which point the magma spread out laterally as a thin sill. Given sustained magma pressure, this sill probably inflates vertically to form up doming of the roof. This voluminous tabular intrusion was limited only by the continued supply of magma as the case with the Imori Complex.

From (Fig.4), it is seen that the splitting of the parent magma from the primary Kudaru magma chamber, the split magma migrated southwardly in line with the general migration pattern of the ring-complexes in Nigeria to produce the minor intrusion of the Imori Complex Joro, (2017).

Figure 8: Idealized Schematic Cross Section Illustrating the Evolution Model for the Minor intrusion of Imori Alkali Granites Dyke-Sill Complex (Joro 2017)

A small portion of the magma probably extruded first to form the rhyolitic rocks. However, the larger portion of the magma crystallized at shallow depth to form the fine to medium grained composite alkaline granite intrusion of the Imori Complex. Over several million years ago, this near surface intrusive rocks has been exposed to its present level as seen today by the processes of weathering, mass wasting and erosion as illustrated in (Fig. 5)

Figure 9: Erosional Remnants of Downward Projecting Roof of Imori Complex

4. Summary

The minor alkaline suites of the Imori Complex originated and evolved from the differentiated magma of the Kudaru magma chamber. The magma migrated arcuately southwards and was emplaced as an apophyses or cupola of the larger Kudaru Complex. It is possible that other arcuately migrated magma from the same Kudaru magma chamber are yet to be exposed by the present level of erosion. Out of the over fifty intrusive complexes, some of the minor ones such as the Forum Complex, Fan Complex, Sharwai Complex, Shona Complex, Tuff Complex, Ningishi Complex, fit into this petrogenetic model. In addition, this model can be used to explain the emplacement of some intrusive arms as cupola even among the larger ring-complexes in the Nigerian province and elsewhere in the world.

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