Bima Journal of Science and Technology, Vol. 7 (1) Mar, 2023 ISSN: 2536-6041

DOI: 10.56892/bima.v7i01.392

STRUCTURAL AND LITHOLOGICAL CONTROLS OF PEGMATITE MINERALIZATION IN IKARA NORTHWESTERN NIGERIA

*YUNUSA, A., and IBRAHIM, A. A.

Department of Geology, Ahmadu Bello University Zaria

Corresponding Author: adamuyunusa@abu.edu.ng

ABSTRACT

Structural and lithological control of mineralization in the pegmatite of parts of Ikara was studied using field and petrographic studies of the area together with lineaments and structural analysis to determine the controls of mineralization in the area by remote sensing and field measurements. The area is composed of gneisses, schist, quartzite, and granites as major rock types. NE-SW trending joints define the structural trends of the area which is consistent with the regional orientation of the Pan-African deformation. Mineralized pegmatite in the area occurs within the granites, while the unmineralized pegmatites occur in the gneisses and quartzites. The pegmatites in the study area are long and narrow bodies and have no sign of interaction with the enclosing granites except at contact, which ranges from very sharp to gradational. Structural features indicate that pegmatite mineralization in the study area is structurally controlled within dykes, fractures and veins probably associated with the Late Pan-African Orogeny. Gem minerals in the study area occur in pockets within the pegmatite as epigenetic mineralization and beryl constitutes the most important economic mineral. Accessory phases are beryl, amethyst, tantalite and tourmaline.

Keywords: Pegmatites, Fractures, Mineralization, Ikara, Basement Complex

INTRODUCTION

Pegmatites are widespread throughout the basement complex of Nigeria. In the past, the search for mineralized pegmatites in Nigeria was concentrated within the NE-SW regions Jacobson and Webb, (1946). However, recent studies of (Olatunji and Jimoh, 2016), (Abdullahi *et al.* 2017), (Yunusa and Ibrahim 2019), (Chukwu, 2022) and references therein have contributed to the better understanding of Southwestern and Northern Nigeria pegmatite bodies.

According to (Garba, 2003), there are numerous occurrences of semi-precious beryl, aquamarine and tourmaline in the Nigerian Pan-African basement associated with both barren and rare metal pegmatites. (Abdulhamid, 2017) reported that mineralized pegmatite in Badafi (extension of the study area) are enriched in beryl. The mineralized pegmatite strikes NNW-SSE and NE-SW directions. Furthermore, Ekwueme (2003), Garba (2003), Akintola and Adekeye (2008) reported that Pan-African pegmatite in Nigeria form two structural trends in the NE-SW and NW-SE belts that intersect at the Jos Plateau.

Garba, (2002) and Okunlola, (2005) noted that rich concentrate of rare-metal bearing pegmatites in the late Precambrian terrain of Nigeria are concentrated close to major transcurrent faults, for example the Kalangai, the Ifewara and the Anka fault systems have southern extension up to the Okene-Ogun areas in the southwest. Deformational episodes producing tight to isoclinal folds mainly controlled the mineralized pegmatites in most of the rare-pegmatite fields in Nigeria and these isoclinal folds are linked also to major transcurrent faults (Garba, 2002).

Bima Journal of Science and Technology, Vol. 7 (1) Mar, 2023 ISSN: 2536-6041

DOI: 10.56892/bima.v7i01.392

Hydrothermal mineral deposits are formed due to the association between processes such as structural, hydrological, thermal and geochemical processes (Zhang *et al.* 2008). Structural processes characterize a critical control on mineralization (Zhang *et al.* 2011). Therefore, evaluating structural elements controlling mineralization in an area will lead to the determination of exploration targets and the discovery of ore bodies (Dugdale, 2009; Liu *et al.* 2010).

Previous studies (Garba, 2003; Abdulhamid, 2017; Yunusa and Ibrahim, 2019) in the area were based on characterizing the pegmatite on the basis of geological mapping, geochemistry, petrology and mineralogy. Data on the structural relationship of the pegmatite bodies are largely scanty. However, understanding the structural elements of the host rock is necessary in the study of pegmatites (Dill, 2018). Such information can provide insights about the controls of the mineralization process during the final stages of magmatic activity. Therefore, this work focused on the structural attributes of the rocks with a view to determine the controls for the emplacement of the pegmatite bodies in Ikara, Northwestern Nigeria (Figure 1).

Geology and Pegmatite Occurrence of the Study Area

The study area consists of gneiss, schist, quartzite and granite as major rock units. The gneiss occurs as low lying to moderately rising outcrops of N-S trends and are marked by foliation. They also occur along river channels. Schist occurs as flat-topped hilly ridge with N-S to NE-SW trend. The schist is also poorly exposed along road excavation and river channels. Quartzite occur as linear ridges trending NE-SW. Quartzite boulders occur at high topography and extends for hundreds of meters. Granites occur as oval shaped bodies and are mostly oriented in NNE-SSW trend and occupy about 65% of the study area.

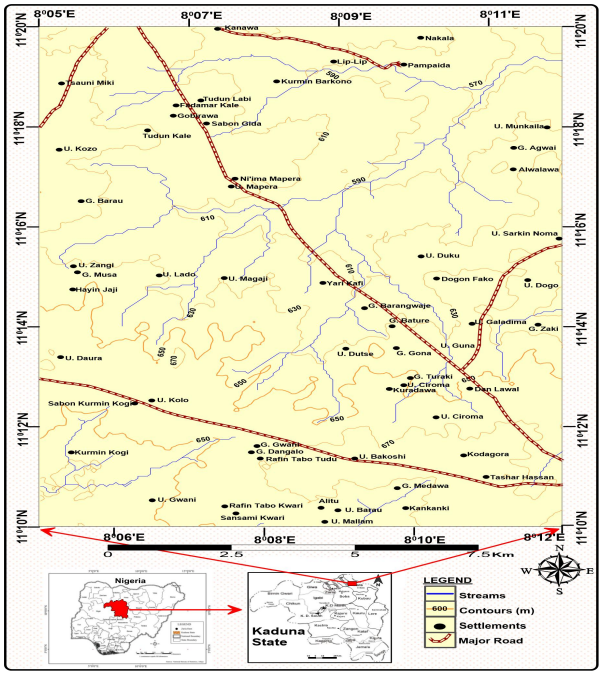

Figure 1: Location map of the study area showing drainage, major roads and settlements

Gem minerals in the study area occur in pockets within the pegmatites. Artisanal miners in the area knows that each pegmatite is unique with its own set of pocket indicators. Certain mineralogical aspects of the pegmatite serve to indicate the presence of pocket bearing pegmatite; such as the presence of mica within the pegmatite. The presence of dominant white mica (muscovite) in a pegmatite indicates shallow pocket of gemstones while pinkish mica (muscovite) dominance indicates deep pocket of gemstones. Changes in mineralogy either as distinct mineral species or chemical changes within a specific crystal may indicate a nearby presence of economically important cavity of gemstones.

Mining in the study area is done by pick and shovel from the surface and later followed

Bima Journal of Science and Technology, Vol. 7 (1) Mar, 2023 ISSN: 2536-6041

DOI: 10.56892/bima.v7i01.392

with explosives into the pegmatite as the pegmatite widens with depth. The dominant colours of the beryl from the area are pale green, bluish green and pale yellowish green. In pegmatites of parts of Ikara, beryl constitutes the most important economic mineral and is the main mineral mined. The artisanal mining performed in the year 2011 by Rich Quarry Nigeria Limited in Dogon Fako extracted about 25 tonnes of amethyst.

MATERIALS AND METHODS

A detailed and systematic field mapping of the study area was carried out on a scale of 1:50,000 covering an area of about 240 km^2 with particular interest to pegmatites and fractures in comparison to other structures. The geology and structures of the area were mapped systematically and a geological map was produced and digitized using ArcGIS 10 software. Equipment used for this study include: Global Positioning System, Compass Clinometer and a measuring tape. The attitude of structures was measured using Bruton compass clinometer and presented using rosette diagram. The dimension of pegmatites was also measured using a measuring tape. All the readings collected were plotted on rosette diagram using GeoRose 0.5.1 software. Lineaments for the study area were extracted using manual digitizing technique from Landsat ETM+ imagery and their dominant direction determined through rose diagram.

RESULTS AND DISCUSSION

Lineaments extracted from the Landsat ETM+ imagery is shown in (Figure 2) and their dominant direction determined through rose diagram (Figure 3).

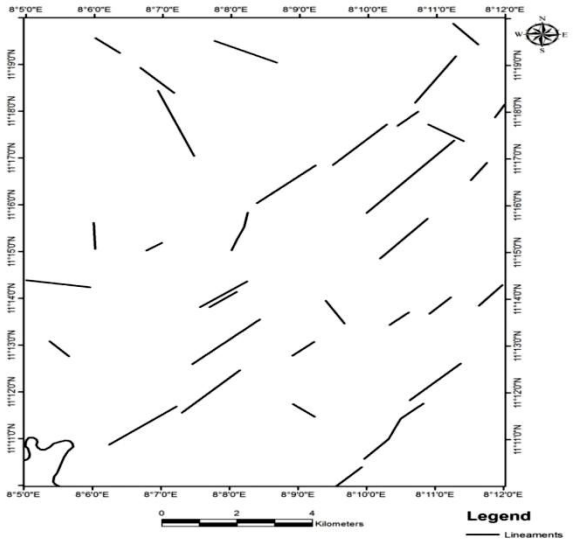

Figure 2: Lineament map showing the trends of the lineaments in the study area with dorminant NE-SW direction

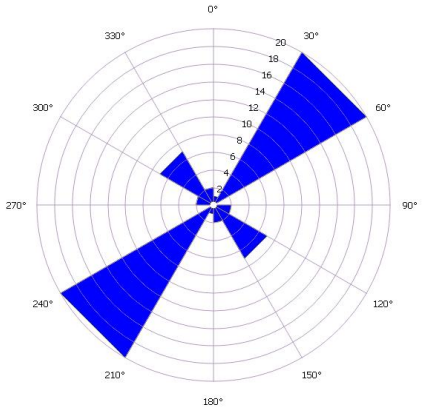

Figure 3: Rose plot showing the trends of the lineaments in the study area

These lineaments show a major NE-SW and a minor NW-SE trend with very few of the lineaments intersecting each other. Some of the lineaments mapped on the Landsat imagery examined on the ground consisted in part of linear segments of drainage (Fig. 4).

Bima Journal of Science and Technology, Vol. 7 (1) Mar, 2023 ISSN: 2536-6041

DOI: 10.56892/bima.v7i01.392

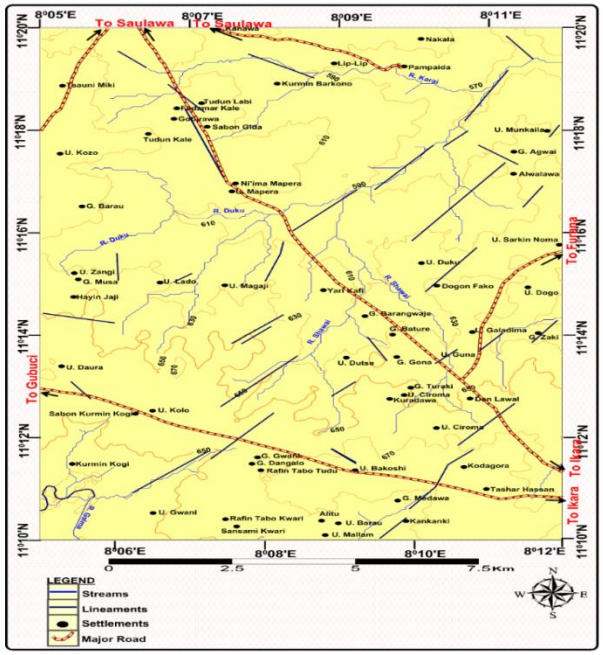

Figure 4: Lineament map superimposed on drainage map of the study area showing the relation of lineaments with drainage pattern.

The resulting lineament map shows that the strike of economically important structures is parallel and controlled by NE-SW trending lineaments in the study area. The rose diagram shows the directional frequency of the mapped lineaments over the study area. The geological map of the study area was produced based on field data and the images produced from the LandsatETM+.

Mineralization was found to be frequently associated with granites, indicating that lithological controls for mineralization were also identified as demonstrated by an active artisanal mining (Fig. 5).

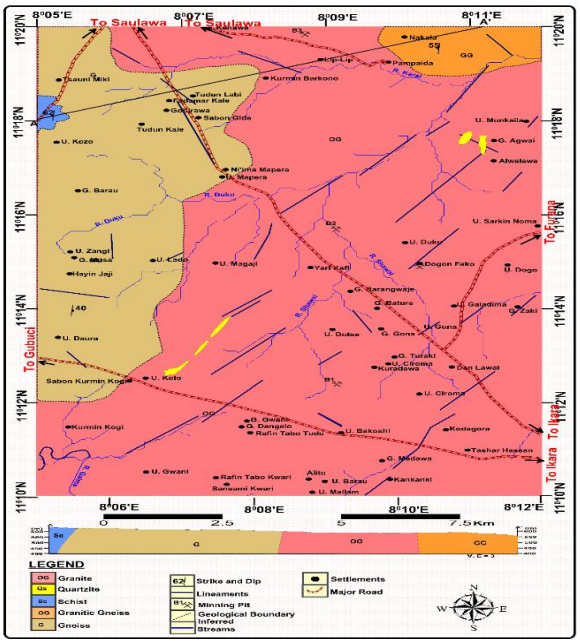

Figure 5: Geological map of Ikara area (Adapted from Yunusa & Ibrahim 2019)

Relationship between mineralization and structures

There is no sign of interaction between the pegmatite and the enclosing granites except at contact. The pegmatite consists of discrete dykes that forms a NE-SW trending bodies and is composed of large crystals of quartz and K-feldpar. They also occur as dyke swarms particularly along the margins of the plutons. They are small bodies, majority of them being less than two meters. Major accessory phases are amethyst, beryl, tantalite and tourmaline. Muscovite is the most abundant mica occurring in the pegmatite of the study area while biotite is few. Pegmatite within the vicinity of the mining site is weathered. These pegmatite bodies dip vertically to sub-horizontally and strikes mainly in the NE-SW direction intruding into the granites. It is worthy to note that mineralized pegmatite within the granites are zoned.

Bima Journal of Science and Technology, Vol. 7 (1) Mar, 2023 ISSN: 2536-6041

DOI: 10.56892/bima.v7i01.392

The mining site was opened by miners using drills, pickaxes, digger, tunnel and shovel. The technique for finding gemstones in the study area is at artisanal level, miners dig along the strike of the pegmatite to get luck. The technique for finding and recovering gemstones have changed today, the most widely used gemstone exploration techniques are ground penetrating radar and trace element analysis. The trace element analyses involve seeking signature elements as clues to where gems may lie while ground penetrating radar provides subsurface mapping of potential gem bearing pockets or vugs.

Mining activities in the area until now are artisanal (Plate I and II).

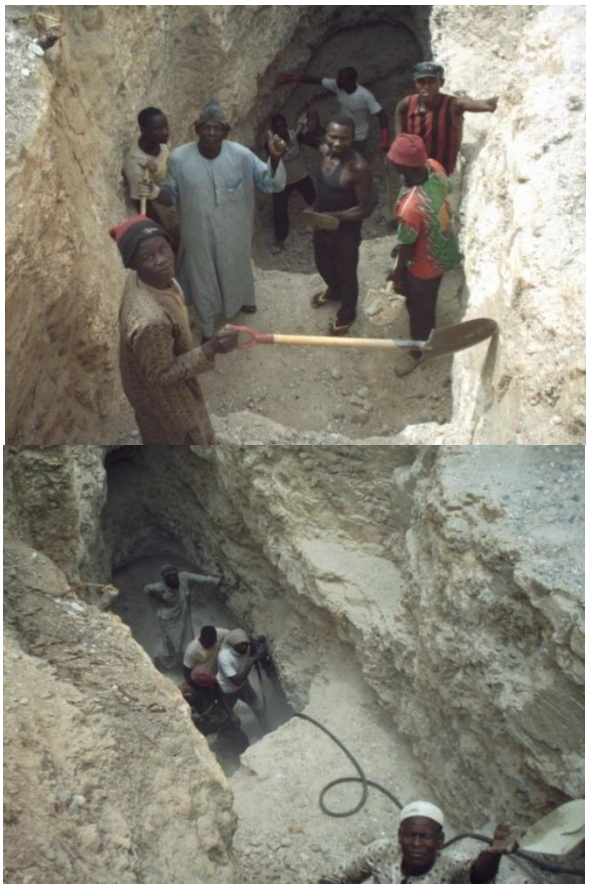

Plate: a) Active artisanal mining pit for beryl, SW of Kuradawa, **b)** Active artisanal mining pit for aquaberyl, NW of Lip-Lip

Fracture Analysis of the Basement Rocks

Fractures can be defined as a planar or sub planar discontinuity which forms due to an external or internal stress (Fossen, 2010). They are usually found in brittle structures as their rock body accommodates the stress or deformation in showing the marks when they lost cohesion through fracture characteristics (George *et al.* 2012). Tectonic fractures commonly form in rock when the tensile strength of the rock is exceeded; they are therefore, important structures for constraining the deformational history of the rocks.

In this study, multiple fracture orientations were measured on outcrops and reported in azimuth. High fracture density is observed in the granites compared to the gneisses because of their ductile nature. All the fractures (joint) values for both granite and gneiss were measured and plotted on a rosette diagram (Fig. 6 and Fig. 7).

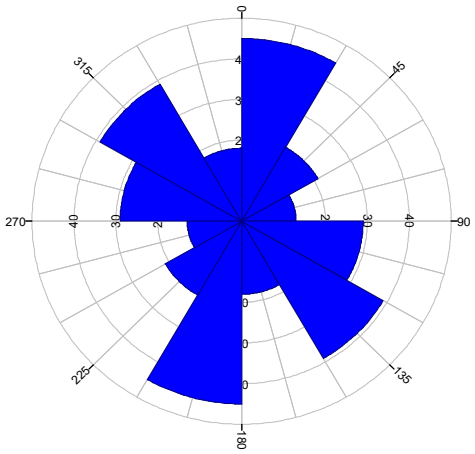

Figure 6: Rose diagram plot of the orientation of joints on granites

DOI: 10.56892/bima.v7i01.392

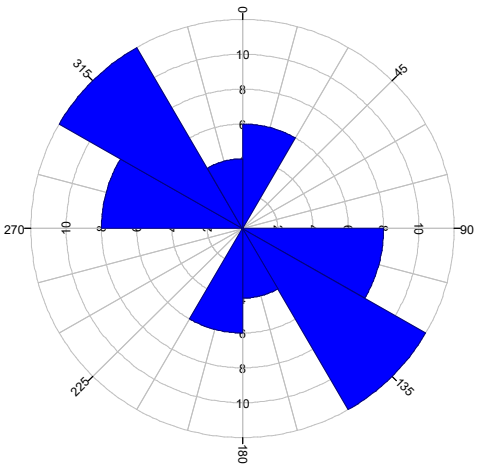

Figure 7: Rose diagram plot of the orientation of joints on gneisses

The trends of the pegmatite were also measured and plotted on the rosette diagram (Fig. 8).

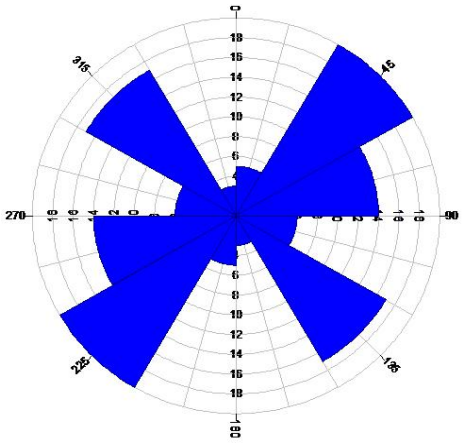

Figure 8: Rose diagram plot of the orientation of pegmatite veins/dyke in the study area (Adapted from Yunusa & Ibrahim 2019)

Extensional fractures (Joints) characterized in the crystalline basement rocks of the area shows that the orientation of the strike of the fractures are dominantly in the NNE-SSW direction on the granites while dominant on NW-SE direction on the gneisses. The most prominent strike directions for the pegmatite dyke are: NE-SW, NW-SE and ENE-WSW while minor set occur in the NNE-SSW and WNW-ESE. The trend of the granites generally agrees with the geologic and lithologic relationships of the Pan-African suites and indicates that the Pan-African orogeny played a major role in the structural evolution of the rock (Garba, 2003). This is also consistent with the structural features mapped by Abdulhamid (2017) for badafi pegmatites. The trends of the gneisses are indicative of pre-Pan-African orogeny (This work).

The rosette diagram plotted shows that the general trend of the pegmatite and joints of the granites are almost in the same direction; this implies that the tectonic forces that led to the fracturing of the outcrop were more pronounced in the NE-SW direction. Therefore, lineaments of NE-SW trends within the granite will help in proceeding further for exploration which is also in line with the works of (Wright, 1976) who suggested that such trends have connections with oceanic fracture zones and may harbor mineralization. The mineralization extends along strike and not along intersection of trends. The major trend on the pegmatites within the granites is consistent with the views of Ekwueme (2003), Garba (2003), Akintola and Adekeye (2008) on enrichment for exotic minerals. Some ENE-WSW pegmatite trends are interpreted as being initiated upon emplacement under the influence of prevailing regional stress regime.

CONCLUSION

Structural studies on the rock units revealed that mineralization in the study area is structurally controlled by the dykes, fractures and veins which provide the structural conduits for the epigenetic mineralization. Lithological controls for mineralization were also recognized with mineralization commonly associated with the granites.

DOI: 10.56892/bima.v7i01.392

Lineament analysis shows that the trends of lineament have significant control on pegmatite emplacement. Therefore, the lithological and structural studies carried out in the area have demonstrated the relationship between structures and mineralization and lithology and makes it possible to delineate prospective areas.

Studies on the Precambrian pegmatites of the area which intruded the basement complex rocks of Northwestern Nigeria revealed that the pegmatite trends are consistent with the well-known trends of pegmatites within the Northwestern Nigeria Basement Complex and owes its orientation to pre-existing fractures. The ENE-WSW oriented pegmatites could represent initiation upon emplacement.

Acknowledgement

The authors wish to thank the anonymous reviewers and the editor for their suggestions and constructive comments which significally contribute to improve the manuscript. The authors also wish to express profound gratitude to the village head of dogon faqo who provided accommodation during the field work exercise.

REFERENCES

Abdulhamid, N. T. (2017). Geology, Geochemistry and Structural Controls of Badafi Pegmatite Field, Parts of Sheets 80 (Kabo SW, SE) and Sheet 103 (Ikara NW, NE), Northwestern Nigeria (*Unpublished MSc. Thesis*). A hmadu Bello University, Zaria.

Abdullahi, A. M, Haruna, A., Usman, A., and Arabi, A. S. (2017). X-Ray Fluorescence Base Investigation of the Gwon Gwon Pegmatite Field Wamba, Northcentral, Nigeria. *Journal of Geosciences and Geomatics, Journal of Geosciences and Geomatics*,5(1), 37–45.

Akintola, O. F., and Adekeye, J. I. D. (2008). Mineralization controls and Petrogenesis of the Rare Metal Pegmatites of Nasarawa Area, Central Nigeria. *Earth Sciences Research Journal*, 12(1), 44–61.

Chukwu, A. (2022). Geochemical characterization of mineralized pegmatites around Wowyen areas, Akwanga, Northcentral Nigeria. Advances in geological and geotechnical engineering research 4(1)

Danbatta, U.A. (1991). Geological Investigation of the Southwestern Portion of the Zuru Schist Belt, NW Nigeria. *Unpublished M.Sc thesis*, Ahmadu Bello University Zaria, pp. 146-150.

Dill, H.G. (2018). Geology and Chemistry of Variscan-type Pegmatite Systems (SE Germany) with Special Reference to Structural and Chemical Pattern Recognition of Felsic Mobile Components in the Crust. *Ore Geology Reviews*, 92: 205-239.

Dugdale, L. J., 2009. Adding value to Exploration—Reducing Time and Cost to Discovery in Western Victoria. *Geoscience Australia Record*, 9, 39–44.

Ekwueme, B. N. (2003). Petrogenesis of Schists in Southeast Lokoja, Central Nigeria. *Global Journal of Geological Sciences*, 1(1), 29–42.

Fajobi, A. (1999). Potential of Nigeria's Gemstone. *'The Guardian'* Thursday August 5, 1999. 36, 37.

Fossen, H. (2010). Structural Geology (1st edition). Cambridge; New York: *Cambridge University Press* 29.

Garba, I. (2002). Late Pan-African Tectonics and Origin of Gold Mineralization and Rare Metal Pegmatites in the Kushaka Schist Belt, Northwestern Nigeria.

DOI: 10.56892/bima.v7i01.392

Journal of Mining and Geology, 38(1), 1–12.

Garba, I. (2003). Geochemical Discrimination of Newly Discovered Rare-Metal Bearing and Barren Pegmatites in the Pan-African (600 ± 150 Ma) Basement of Northern Nigeria. *Applied Earth Science*, 112(3), 287–292.

George, H. D., Stephen, J., and Charles, F. K. (2012). Structural Geology of Rocks and Regions, 3rd Edition.

Groat, L. A., and Laurs, B. M. (2009). Gem Formation, Production, and Exploration: Why Gem Deposits Are Rare and What is Being Done to Find Them. *Elements*, 5(3), 153 158.

Ike, E. C. (1988). Late-Stage Geological Phenomena in the Zaria Basement Granites. Geological Survey of Nigeria. *Nigerian Publishers*.

Jacobson, R., and Webb, J. S. (1946). The Pegmatites of Central Nigeria. *Geological Survey of Nigeria Bulletin,*17*:* 40-61.

Liu, L. M., Zhao, Y. L and Zhao, C., (2010). Coupled Geodynamics in the formation of Cu Skarn Deposits in the Tongling-AnqingDistrict, China: Computational Modeling and Implications for Exploration. *Journal of Geochemical Exploration*, 106, 146 155.

Okunlola, O. (2005). Metallogeny of Tantalum-Niobium Mineralization of Precambrian Pegmatites of Nigeria. (137), 38–50.

Olatunji, A. S., and Jimoh, O. R. (2016). Geochemical Study of Tourmalines from Some Parts of Southwestern Nigeria. *International Research Journal of Geology and Mining*, 6(1), 009–0027.

Wright, J. B. (1976). Fracture Systems in Nigeria and Initiation of Fracture Zones in the South Atlantic. *Tectonophysics*, 34, 143–147.

Yunusa, A. and Ibrahim, A.A. (2019): Beryl Mineralization and the Evolution of Pegmatites of Ikara NW Nigeria. *African Journal of Earth and Environmental Sciences*. Maiden Edition, 35-48.

Zhang, Y., Robinson, J and Schaubs, P. M., (2011). Numerical modeling of structural controls on fluid flow and mineralization. *Geoscience Frontiers*, 2 (3), 449–461.

Zhang, Y., Schaubs, P. M., Zhao, C., Ord, A., Hobbs, B. E and Barnicoat, A., (2008). Fault Related Dilation, Permeability Enhancement, Fluid Flow and Mineral Precipitation patterns: numerical models. In: C. A. Wibberley, W. Kurz, J. Imber, R. E. Holdsworth, C. Collettini (Eds.) The Internal Structure of Fault Zones: Implications for Mechanical and Fluid-Flow Properties, *Geological Society, London, Special Publications*, 299, 239–255.