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Research Paper

PRELIMINARY GEOCHEMISTRY OF TOPAZ OCCURRENCE IN A-TYPE GRANITES AROUND MASSANGE AREA, CENTRAL NIGERIA

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The Massange Topaz is a gem mineral with chemical composition of Al_2SiO_4 $(F,OH)_2$ and is found as alluvial deposits within the Sha-Kaleri A-type Granite Complex (SAGC) in central Nigeria. A total of sixteen (16) samples were collected and analyzed for major oxides (SiO_2, Al_2O_3, Fe_2O_3, CaO, P_2O_5, K_2O, Na_2O, TiO_2 and MgO), major elements (F, Cu and Zn) and trace elements (Rb, Zr, Br, Cr, Ba and Sr) to determine variety in elemental constitution of the gems and rocks. Massange topaz is rich in fluorine and alumina. The fluorine in its composition is a determinant factor on its formation because it is a necessary ingredient in hydrothermal fluid for the formation of topaz. This paper will focus on why the topaz deposits in the study area are concealed in the subsurface and why the mineralizing fluid crystallized to topaz leaving out other gem types. Also, the authors will attempt to describe the rock units that host the mineralization of the topaz and the elements that led to the resultant gem properties. This research work also considers the enhancement of gemstones for better value in a bid to make them more appreciable in Nigeria.

Keywords: Geochemistry, Topaz, Granites, Gemmology, Massange

INTRODUCTION

Topaz has a chemical composition of $Al_2SiO_4(F,OH)_2$. The fluorine in its composition is a determinant factor on its formation reason being that fluorine is a necessary ingredient in hydrothermal fluid for the formation of the gem topaz. This occurs only in few geologic environments. Topaz occurs as an accessory mineral in some granites and associated hydrothermally altered rocks, as well as in the pegmatites, rhyolites and other aluminous rocks. The crystallographic, optical and chemical properties of topaz can vary with chemical composition which reflects the petrogenesis of the rocks in which the individual crystals formed (Christiansen *et al.*, 1983). Correlation be tween physical properties and OH:F ratio of topaz have been discussed by Chaudhry and Howie (1970) and Ribbe and Rosenberg (1971) and Deer *et al.* (1986).

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The substitution of the larger OH for F influences an increase in the cell dimension, refractive indices and results in a decrease in density. Rosenberg (1967 and 1969) considered also that the composition of topaz may be a sensitive indicator of environmental conditions; topaz that exhibit low OH/F ratios are reportedly found in cavities in rhyolites whilst those with higher ratios occur in pegmatites and greisens. They are recovered from the pegmatites and cavities or "gem pockets" in biotite granites. They are known to be associated with highly acid igneous rocks probably deposited by the action of hot floriferous gases after solidification of the magma (Webster, 1962; and Abaa, 1991).

The study area is along the south eastern part of the SAGC located in Wamba Local Government Area of Nassarawa State, Central Nigeria (Figure 1). The research was carried out on a scale of 1:12,500 and covers an estimated areal extent of approximately 87 Km^2. The area lies within the bounds of latitudes 09°08'30" N and 09°04'00" N and longitudes 008°42'30" and 008°45'30" E.

METHODOLOGY

A total of sixteen (16) samples were selected for geochemical analysis, these samples comprised of six (6) topaz crystals as shown in Figure 2 and ten (10) biotite granites. The rocks and gem samples were collected from granitic rock outcrops and mine pits from alluvial sands near river banks. A total of four open mine pits were dug between one to four metres.

Figure 1: Location Maps of the Study Area

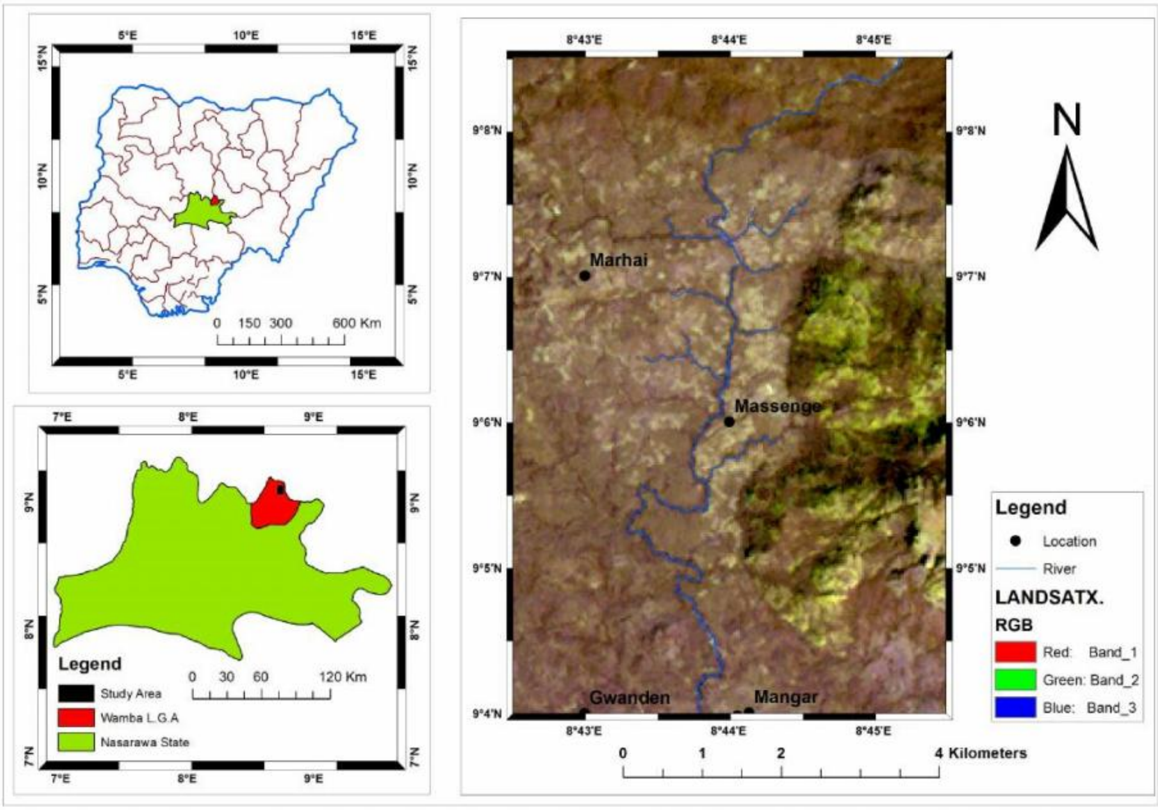


Figure 2: Clear Crystals of Topaz from the Study Area

The samples were pulverized and analysed for major oxides (SiO_2, Al_2O_3, Fe_2O_3, CaO, P_2O_5, K_2O, Na_2O, TiO_2 and MgO), major elements (F, Cu and Zn) and trace elements (Rb, Zr, Br, Cr, Ba and Sr) using Atomic Absorption Spectrophotometer (AAS). Data were rounded off suitably according to the value of standard deviation from measurements in triplicate.

Gemological tests were carried out at the lapidary in Top Gems Prolific Nigeria Limited. Luminescence tests were done in complete darkness, using a Raytech LS-7 long and short wave UV source. Specific gravity was determined by the hydrostatic method. Pleochroic and dichroic characters were observed using a calcite dichroscope with a rotating eyepiece, the Chelsea filter reaction was determined in conjunction with an optical lens.

The results of the analysis were presented as data, and documented as correlation plots to characterize granites analysed and suggest with significant reasons various models that justifes the occurrence of the economically significant topaz gem in the study area dominated by the biotite granites of the study area.

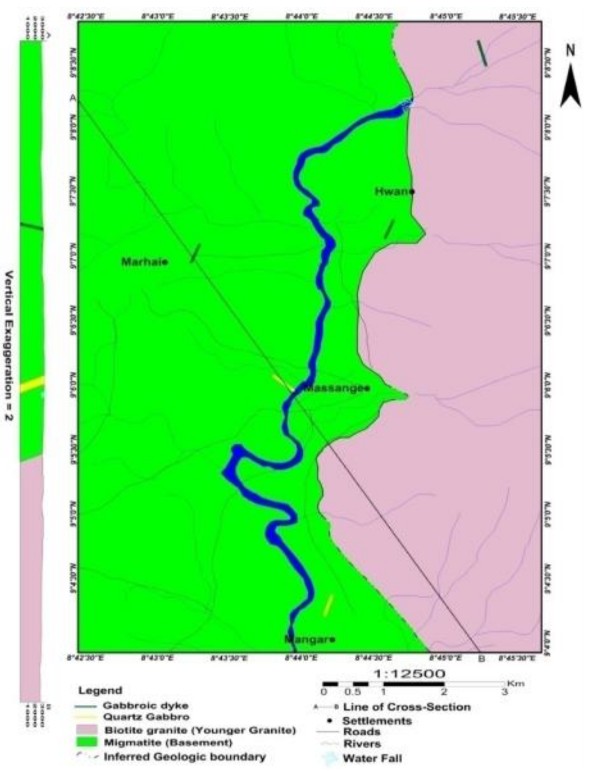
GEOLOGICAL SETTING

The Sha-Kaleri Younger Granite Complex occupies an area nearly 375 square kilometers in the south western region of Jos Plateau. The complex is the third largest after Jos Bukuru and Sara-Fier complex in the Nigerian Younger Granite province.

The study area is characterized by three major lithologic units; this comprises the migmatites of the Basement Complex, biotite granites of the Younger Granite Complex and dykes of gabbro and quartz gabbros that cross cuts the migmatites at distinct locations (Figure 3).

The migmatite show a discrete leucocratic

Figure 3: Geologic Map of the Study Area



component characterized by a crystalloblastic texture showing a concordant alternation of palaeosome and neosome. The biotite granite can be described to have a coarse to medium grained texture, grey colouration with phaneritic crystals of quartz, feldspars and predominantly biotite.

The dominant structural trends of Joints show N-S for migmatite, NNW-SSE for biotite Granite, E-W for quartz gabbro and NE-SW for the pure gabbro respectively. Quite a good number of dykes, specifically gabbroic dykes of quartz and pure compositions were observed in the study area, with majority of them occurring within the Basement Complex. They range in width between 1.2 and 3.1 meters. Granitic net veins observed within the confines of the area are leucocratic intrusions, with visible crystallinity being phaneritic and essentially granitic in composition. The foliations observed were predominantly in the central and western half of the study area which hosts the migmatites of the Basement Complex.

RESULTS AND DISCUSSION

Geochemistry

The main chemical characteristics of the biotite granites in the study area are their high concentrations of SiO_2 (>71 wt%), low contents of MgO (<1.48 wt%), TiO_2 (<0.62 wt%), P_2O_5 (<0.07 wt%), Ba (<0.11 wt%) and Sr (<0.03 wt%). The analysed granites are highly fractionated as indicated from the high SiO_2 (range from 71.0 to 74.7 wt%). They also have high Fe_2O_3 and alkalis, low concentrations of Al_2O_3, CaO, TiO_2 and MgO (Table 1). Decrease of MgO and TiO_2 contents suggests fractionation of mafic minerals along with feldspars (Katzir *et al.*, 2007). There is a slight excess of K_2O relative to Na_2O in granite with Na_2O/K_2O ratio < 1 (Table 1).

The major oxides measured in the topaz samples analysed include SiO_2, Al_2O_3, FeO, Fe_2O_3, CaO, TiO_2, MgO and P_2O_5 (Table 1). Measured SiO_2 concentrations ranged from 31.45 wt% to 32.99 wt%, CaO concentration ranged from 0.02 wt% to 0.15 wt%, Al_2O_3 ranged from 55.05 to 56.40 wt% while FeO_{tot} ranged from 0.27 wt% to 0.36 wt%. Most of the compositional variability observed in the topaz samples involved SiO_2, Al_2O_3 and F with lesser involvements of CaO, FeO_{tot}, TiO_2, P_2O_5, MgO and the alkalis.

The close range of percentage content of the major oxides SiO_2, Al_2O_3 and F (17.05 wt% to 20.7 wt%) shows that all six (6) topaz samples have similar geological background and source of mineralizing fluid (Tables 1 and 2).

Variations in SiO_2, Al_2O_3 and F do not seem to be responsible for any difference in the physical properties of topaz because all six (6) samples

Table 1: Major Oxides in Topaz (TPZ) and Representative Samples of Biotite Granites (BG) from the Study Area

Sample	SiO_2	Al_2O_3	CaO	TiO_2	MgO	P_2O_5	Na_2O	K_2O	FeO_{tot}	Na_2O/K_2O	Al_2O_3/Na_2O+K_2O+CaO
TPZ1	32.99	56.12	0.02	0.01	0.01	-	-	-	0.27	-	-
TPZ2	31.95	55.8	0.13	0.01	0.07	-	-	-	0.36	-	-
TPZ3	31.45	56.4	0.03	0.01	0.17	-	-	-	0.32	-	-
TPZ4	32.8	55.05	0.12	0.01	0.13	-	-	-	0.28	-	-
TPZ5	31.92	56.26	0.02	0.01	0.03	-	-	-	0.27	-	-
TPZ6	31.9	55.75	0.15	0.01	0.05	-	-	-	0.36	-	-
BG1	74.7	12.79	0.67	0.22	0.13	0.03	3.84	5.55	2.05	0.69	9.55
BG2	74.5	12.43	2.42	0.37	1.02	0.06	3.84	1.49	2.69	2.57718	7.14698
BG3	72	14.66	1.39	0.18	0.31	0.07	3.62	6.29	1.06	0.57552	11.72972
BG4	73.9	13.23	0.37	0.2	0.12	0.02	3.58	6.12	1.92	0.58497	10.18553
BG5	71	14.4	2.76	0.54	1.48	0.06	3.33	2	3.63	1.665	9.08432
BG6	74	12.87	0.74	0.22	0.14	0.03	3.79	5.69	2.32	0.66608	9.82578
BG7	71.7	13.75	1.86	0.32	0.39	0.06	2.91	4.62	2.79	0.62987	11.20509
BG8	74.3	12.68	0.78	0.24	0.15	0.03	3.68	5.41	2.33	0.68022	9.63565
BG9	73.43	11.78	1.29	0.38	0.03	0.06	3.47	4.22	3.71	0.82227	8.90481
BG10	73.09	12.01	1.66	0.62	0.62	0.07	3.58	4.09	3.18	0.87531	9.10475

appear to be colourless and stubby. However, the fact remains that these oxides and F are basic requirements for topaz crystallization in a favourable environment. The absence of the alkalis is a requirement for topaz mineralization in an environment.

Fluorine, F plays an important role in several processes occurring in magmas and associated fluids. Fluorine reduces viscosity and increases ion diffusivity in silicate melts (Dingwell *et al.*, 1985; and Giordano *et al.*, 2004). Fluorine has also shown to have a major influence on the activity coefficients of trace elements in magmas by increasing the solubility of Zr, Ti and other high field strength elements (Keppler, 1993). High concentrations of F (>17 wt%) in topaz samples analysed presents us with a likely magmatic (primary) origin.

FeO_{tot}, TiO_2, Zn, Cr, Br, Rb were found to remain fairly constant in all the samples analysed.

Chondrite-normalized spider diagram after Thompson (1982) in Figure 4 shows the granites are enriched in Ba, P, Ti and very much depleted in Sr while K, P and Ti concentrations exhibit the highest peaks. A binary plot of SiO_2 against F (Figure 5) revealed a negative correlation between silica and fluorine, indicating that topaz crystallized within an environment high in F with low concentrations of SiO_2. A ternary plot of Al_2O_3 – FeOtot – MgO (Figure 6) showed that all the topaz samples from Massange plot in the alumina zone, indicating that they are alumina-rich and

Table 2: Major and Trace Elements in Topaz (TPZ) and Biotite Granite (BG)

Sample	F	Cu	Zn	Rb	Zr	Br	Cr	Ba	Sr
TPZ1	17.05	0.05	0.02	0.07	0.08	0.07	0.1	-	-
TPZ2	17.24	0.06	0.02	0.06	0.08	0.06	0.12	-	-
TPZ3	20.01	0.04	0.02	0.06	0.06	0.16	0.11	-	-
TPZ4	18.2	0.08	0.02	0.07	0.04	0.06	0.11	-	-
TPZ5	20.37	0.04	0.05	0.07	0.04	0.06	0.11	-	-
TPZ6	17.25	0.06	0.5	0.06	0.06	0.05	0.15	-	-
BG1	-	-	-	-	-	-	-	0.04	0.002
BG2	-	-	-	-	-	-	-	0.05	0.017
BG3	-	-	-	-	-	-	-	0.11	0.002
BG4	-	-	-	-	-	-	-	0.03	0.004
BG5	-	-	-	-	-	-	-	0.06	0.031
BG6	-	-	-	-	-	-	-	0.04	0.004
BG7	-	-	-	-	-	-	-	0.1	0.015
BG8	-	-	-	-	-	-	-	0.04	0.002
BG9	-	-	-	-	-	-	-	-	-
BG10	-	-	-	-	-	-	-	-	-

Table 3: Gemological Properties of Massange Topaz Crystals

Sample	Carat Weight	Cut	Clarity	Colour	Hardness	Streak
1	4cts	Rough	IF	Transparent	8	White
2	5cts	Rough	SI	Transparent	8	White
3	2cts	Rough	VVS	Transparent	8	White
4	3cts	Rough	VVS	Transparent	8	White
5	2cts	Rough	SI	Transparent	8	White
6	2cts	Rough	SI	Transparent	8	White

Note: Where: IF Clarity (internally flawless) – Loupe clean. VVS Clarity (very very slight inclusions) – Almost loupe clean. SI Clarity (Slightly included) – inclusions are noticeable and can be seen with the naked eye.

were formed in a peraluminous provenance and within high to weakly acidic environments. This is further supported by the ternary plot of SiO_2 – FeO – CaO (Figure 7) where all the samples plot at the SiO_2 dominant field.

Major oxides were used to obtain cross plots to determine their compatibility or relationships. Figure 8 shows the plots of MgO, FeO_{tot}, Na_2O, TiO_2, CaO, K_2O against SiO_2 respectively.

Figure 4: Chondrite-Normalized Spider Diagram After Thompson (1982)

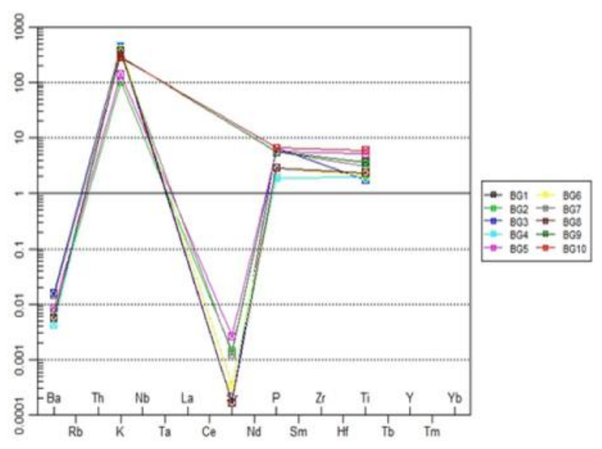


Figure 5: Silica vs Flourine Plot Illustrating Negative Correlation

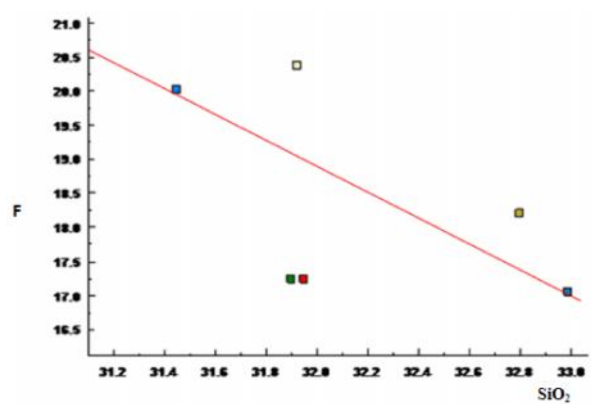


Figure 6: A Ternary Plot of Al_2O_3 - FeO_{tot} - MgO

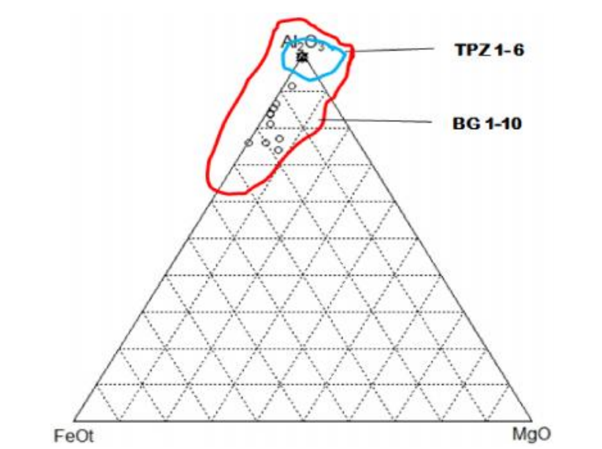
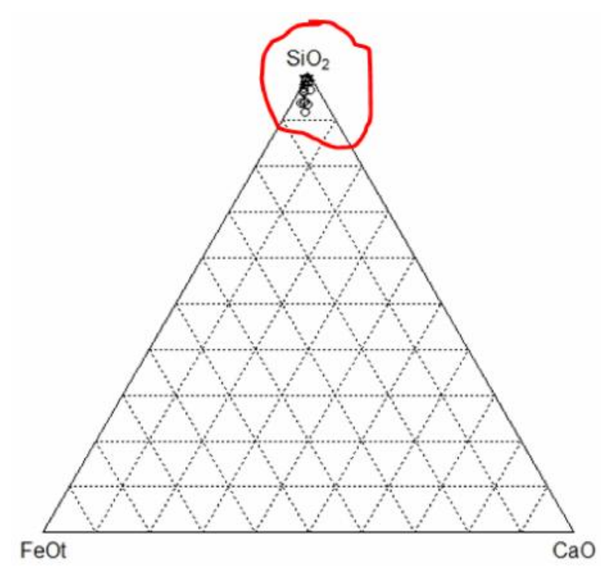
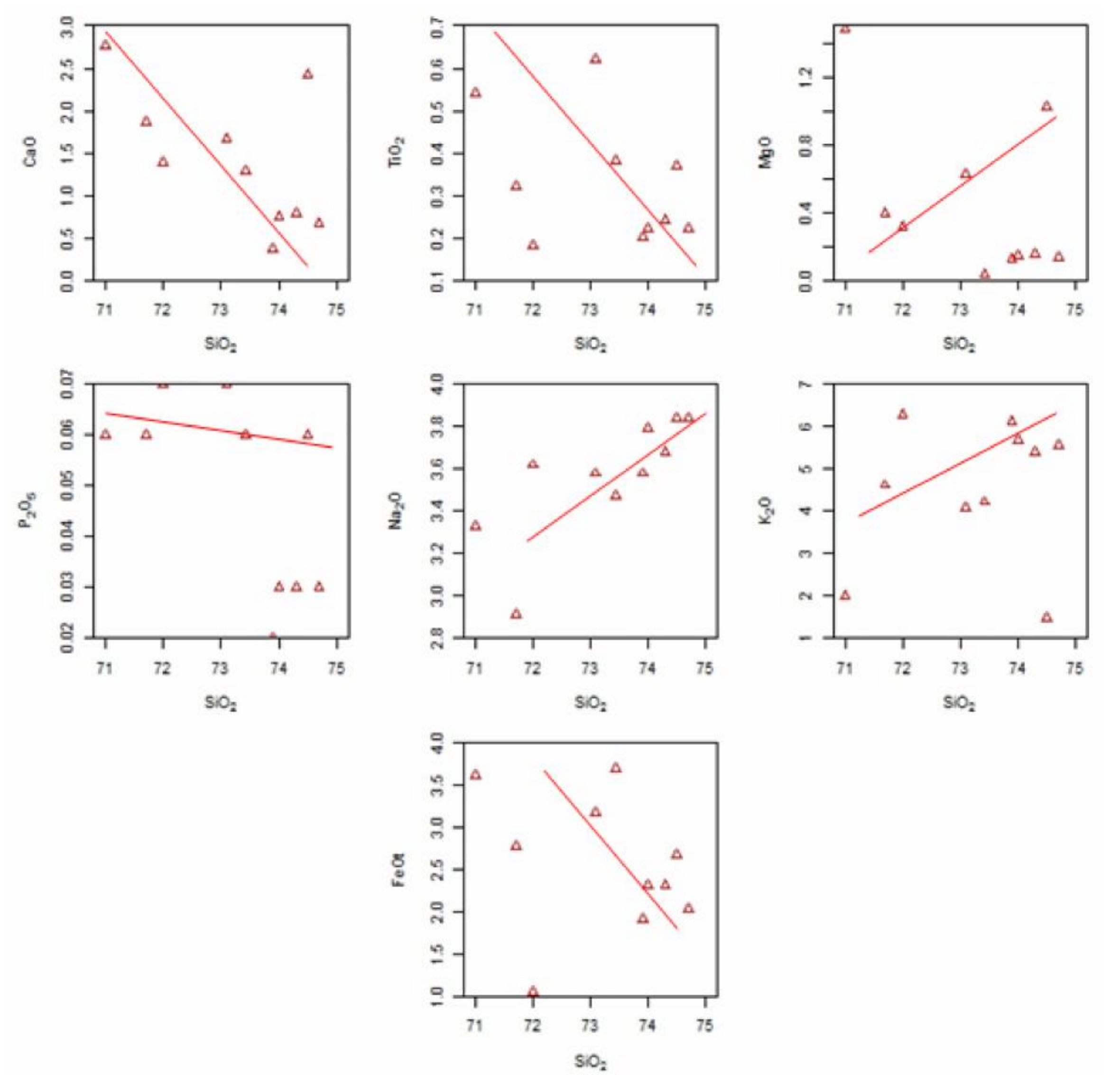


Figure 7: Ternary Plot of SiO_2 - FeO - CaO



The geochemical data displaying the ratios of Na_2O/K_2O and Al_2O_3/Na_2O+K_2O+CaO for the various samples shown in Table 1 shows that the ratio of Na_2O/K_2O is low (ranges from 0.57 to 2.58 wt%). The composition of Al_2O_3 is greater than the alkali Na_2O+K_2O+CaO in all the rock samples by values ranging between 7.14 to 11.3 wt%. This implies that the rocks are peraluminous. Rocks that are characterized by low Mg, Ca and Fe as well as low ratio of Na_2O/K_2O are termed fertile and peraluminous (Cerny *et al.*, 1981; and Longstaff, 1982). From values of Al_2O_3/Na_2O+K_2O+CaO ratio, it can be deduced that Na_2O+K_2O+CaO/Al_2O_3 ratio is less than unity and according to Pearce *et al.* (1984), such a ratio confirms the per aluminous character of the rock. However, Chappell and White (1974) have established that diagnostic minerals in strongly peraluminous granites can be cordierite, muscovite, garnet or an Al_2SiO_5 polymorph. In view of this, topaz which is a polymorph of Al_2SiO_5 is likely to be an included phase in the biotite granites. An AFM diagram using the alkalis (Na_2O+K_2O), FeO_{tot} and MgO

Figure 8: Multiple Binary Plots of FeO_{tot}, Na_2O, TiO_2, CaO, K_2O, CaO and P_2O_5 Against SiO_2 Respectively



contents shows that the samples plot in the calc-alkaline fields (Figure 9). The calc-alkaline field shows that the magma from which the rock formed was enriched in silica and alkalis and originate from subduction related environments. High alkalis content with relative Fe-enrichment and silica suggest the plutonic generation of the magma from which they evolved. Further classification of the plutonic rocks using the parameters R1 and R2 after de la Roche *et al.* (1980) reveals a cluster of samples at the granite and alkali granite fields (Figure 10).

According to Miller (1985), melts that are peraluminous may form by melting of biotite-bearing metaluminous felsic rocks. It can therefore be inferred that the topaz deposits in the area may not have crystallized in veins or fractures of the SAGC because veins appear unmineralized and thin in the order of 2 mm-1 cm wide. They rather crystallized from

Figure 9: Ternary Plot in Terms of Alkalis (Na_2O+K_2O), FeO_{tot} and MgO Classifying Biotite Granites Under the Calc-alkaline Series (After Irvine and Baragar, 1971)

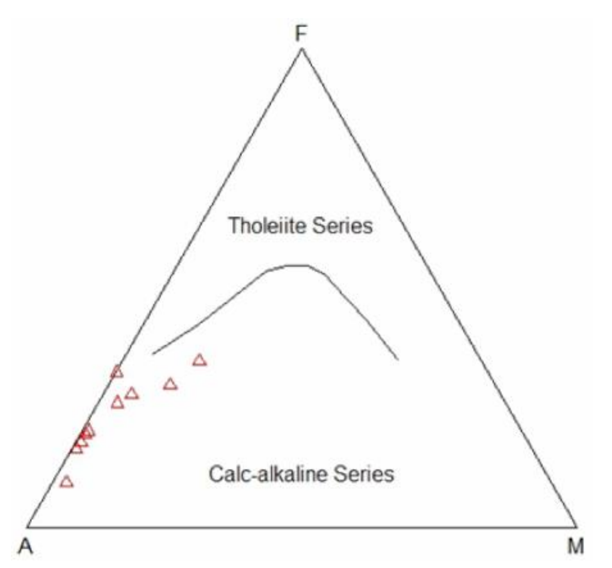
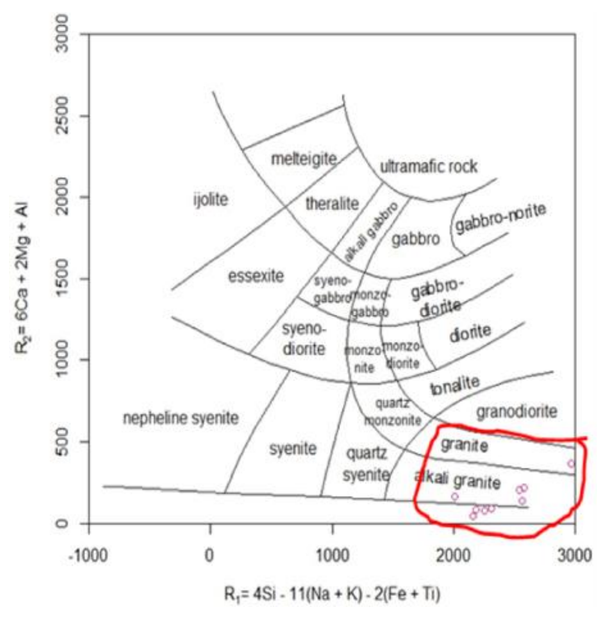


Figure 10: R1 and R2 Plots After de la Roche et al. (1980)



peraluminous melts generated from the melting of biotite-bearing felsic rocks. The Massange topaz, enriched in Large Ion Lithophile Element (LILE) were formed from granite-related fluids.

CONCLUSION

Field and laboratory studies of rock units from the study area reveals that the biotite granites have high SiO_2, low Na_2O/K_2O and are strongly peraluminous. The chemical composition of the topaz samples in the area are virtually dictated by the mineralizing fluid and the environment of depletion particularly the chemistry of the rock from which fluid was derived.

Geochemical reports have shown a constant presence of fluorine in some rock units and topaz samples. Considering the shallow depth at which topaz deposits were found to occur in abundance, it could be deduced that immense weathering of rock units must have generated the alluvium sands that served as overburden to the gem deposit at the subsurface. The fact that only the transparent colour variety of topaz is peculiar to the area, presents us with the fact that the topaz mineralization in the study area originated from the same mineralizing fluids void of impurities. The chemical composition of topaz could prove useful as a proximity indicator for a range of mineral deposit. Hence, would be useful in understanding Ore-forming processes, related depositional environments and the location of prospective exploration targets. For instance, Zr can be used as tracers for zirconium in their respective environments of crystallization.

REFERENCES

1. Abaa S I (1991), "Hydrothermal Fluids Responsible for the Formation of Precious Minerals in the Nigerian Younger Granite Province", *Mineralium Deposita*., Vol. 26, pp. 34-39.

2. Cerny P, Trueman D L, Zaehlke D V, Goad B E and Paul B J (1981), "Catlake-Winnipeg

River and the Wekusko Lake Pegmatite Fields, Manitoba", *Energy and Mines, Economic Geology,* Vol. 80, pp. 216-219.

3. Chappell B W and White A J R (1974), "Two Contrasting Granite Types", *Pacific Geology*, Vol. 8, pp. 173-174.
4. Chaudhry M N and Howie R A (1970), *Mineral, Mag*., Vol. 37, pp. 717-720.
5. Christiansen E H, Burt D M, Sheridan M F and Wilson R T (1983), "The Petrogenesis of Topaz Rhyolites from the Western United States Contributions to Mineralogy and Petrology", Vol. 83, pp. 16-30.
6. De la Roche H, Leterrier J, Grandclaude P and Marchal M (1980), "A Classification of Volcanic and Plutonic Rocks Using R1, R2-Diagrams and Major Element Analysis—Its Relationships with Current Nomenclature", *Chemical Geology,* Vol. 29, pp. 183-221.
7. Deer W A, Howie R A and Zussmam J (1986), *An Introduction to the Rock Forming Minerals*, 2nd Edition, p. 696, Longman Group Ltd., London.
8. Dingwell D B, Christopher I, Scarfe M and Cronin D J (1985), "The Effect of Fluorine on Viscosities in the System Na_2O-Al_2O_3-SiO_2: Implications for Phonolites, Trachytes and Rhyolites", *American Mineralogist*, Vol. 70, pp. 80-87.
9. Giordano D, Romano C, Dingwell D B, Poe D and Behrens H (2004), "The Combined Effects of Water and Fluorine on the Viscosity of Silicic Magmas", *Geochimica et Cosmochimica Acta,* Vol. 24, pp. 5159-5168.
10. Irvine T N and Baragar W R A (1971), "A Guide to the Chemical Classification of the Common Volcanic Rocks", *Journal of Petrology,* Vol. 17, pp. 589-637.
11. Katzir Y, Litvinosky B A, Jahn B M, Zanvilevich A N, Valley J W, Pelly I and Shimshilavilli E (2007), "Petrogenesis of A-Type Granites and Origin of Vertical Zoning in Katharina Pluton, Gebel Mousa (Mt. Moses) Area, Sinai, Egypt", Vol. 95, pp. 208-228, https://doi.org/10.1016/j.lithos.2006.07.013
12. Keppler H (1993), "Influence of Fluorine on the Enrichment of High Field Strength Trace Elements in Granitic Rocks", *Contributions to Mineralogy and Petrology*, Vol. 114, pp. 479-488.
13. Longstaffe F J (1982), "Stable Isotope in the Granite Pegmatite and Related Rocks", *Mineralogical Association of Canada, Short Course Handbook*, Vol. 6, pp. 373-404.
14. Miller C F (1985), "Are Strongly Peraluminous Magmas Derived from Pelitic Sedimentary Sources?", *Journal of Geology*, Vol. 93, pp. 673-689.
15. Pearce J A, Harris N B W and Tindle A G (1984), "Trace Element Discrimination Diagrams for the Tectonic Interpretation of Granitic Rocks", *Journal of Petrology*, Vol. 25, pp. 956-983.
16. Ribbe P H and Rosenberg P E (1971), "Optical and X-Ray Determinative Methods for Fluorine in Topaz", *American Mineralogist*, Vol. 56, pp. 1812-1821.
17. Thompson R N (1982), "Magmatism of the British Tertiary Volcanic Province", *Scottish Journal of Geology*, Vol. 18, pp. 50-107.
18. Webster R (1962), "Gems, Their Sources, Descriptions and Identification", pp. 74-90.

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