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Geochemical discrimination of Pegmatites around Tafawa Balewa

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ABSTRACT

The geochemistry and mineralogy of the pegmatites around Tafawa Balewa were studied to evaluate their potential as a source of lithium and rare metals. These minerals have continued to play crucial roles in driving green technology, increasing their demand.

The pegmatites, which occurred in two (2) distinct locations, Gikil and Magalam, are generally silicious with moderate aluminium content. SiO_2 values range from 63.3 to 72.7, with an average of 68.7, while Al2O3 values range from 10.9 to 17.8, with an average of 14.6. The pegmatites show variations in their chemistry, notably in the composition of SiO2, Al2O3, and TiO_2, a reflection of the variation in their mineralogy. Variation diagrams of Rb vs Ba Vs Sr, K/Rb vs Rb and K/Rb vs Cs of the whole rock samples indicate that the pegmatite of Gikil is highly fractionated, bear strong rare metal affinity and variably enriched in Cs, Ta and Be and belong to the LCT- Tourmaline subtype class of rare metal pegmatites. They are significantly mineralised in LiO_2 (up to 2.4%), but low in Ta and Beryl. In contrast, those of Magalam are mainly primitive and barren of rare metals. Pegmatites from these two areas are granitic and show evidence of emanating from a similar melt source. The pegmatites of Gikil are post-orogenic, postdating the possibly syn-orogenic pegmatites of Magalam.

Keywords: Pegmatite, Lithium, Rare metal, Vein, Fractionation

INTRODUCTION

Lithium and rare earth metals are listed as critical metals, with lithium playing a crucial role in green technology leading to a rapid increase in supply, demand and general usage, such as in high-tech industries and battery technology (USGS, 2021). Granitic pegmatites have always attracted interest as an important source of these minerals and colourful gemstones (Oyebamiji et al, 2018).

Several researchers have described and characterised various pegmatite fields in Nigeria. Earlier studies concentrated on discriminating pegmatites into rare metal mineralised and barren ones to elucidate modes and the presence of rare metal mineralisation.

Current knowledge on Nigerian pegmatites shows that rare metal pegmatites occur (but are not confined) within some 600km long NE-SW trend belt stretching from Oke – Ogun in Oyo state to Wamba Local gover6nment, Nasarawa (Jacobson and Webb,1946, Matheis and Caen-Vachette, 1983, Kuster, 1990, Okunlola and Jimba, 2006, Okunlola and Akintola, 2008, Akintola and Adekeye, 2008, Akintola et al, 2012). Other rare metal pegmatite fields include the pegmatites around Obudu Hill in the Southeastern part of Nigeria (Ekwueme, 2004) and those of Kushaka – Birnin Gwari, (Garba, 2003) (Figure 1).

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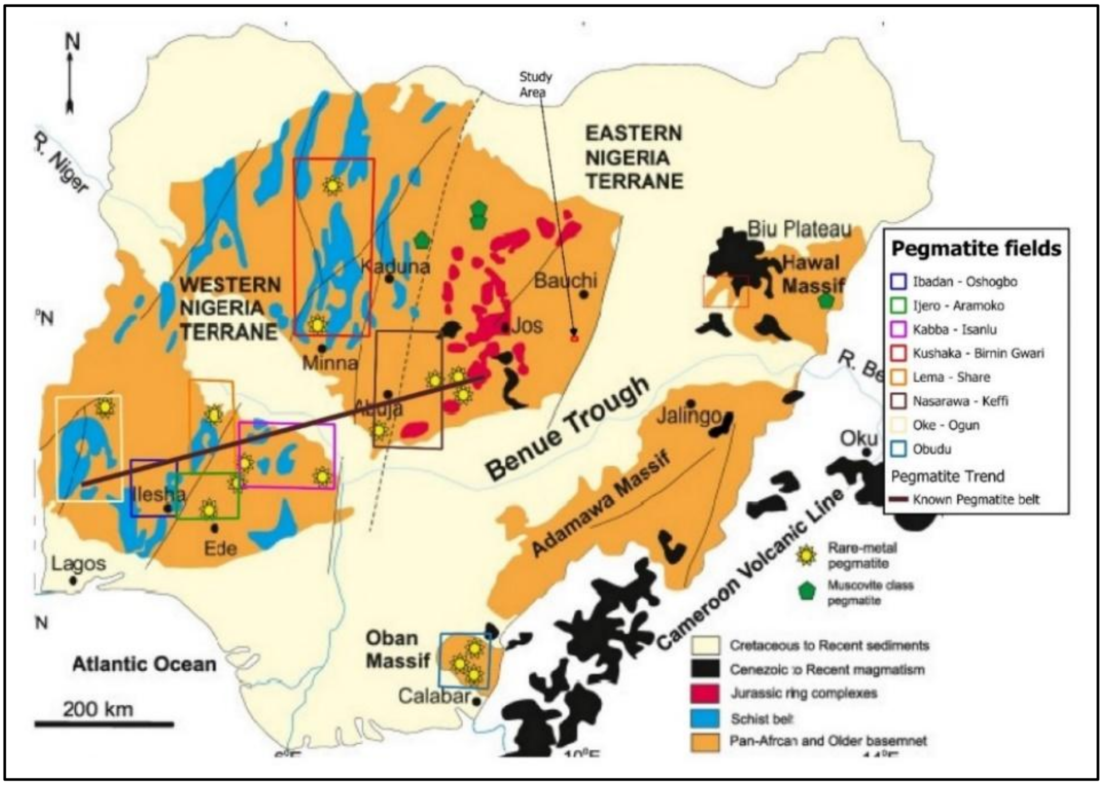

Figure 1: Geological map of Nigeria showing the various pegmatite fields (after Garba, 2003).

The study area is located at the eastern boundary of the Northern basement complex along the trend line of the earlier defined NW-SE pegmatite belt. It straddles Tafawa Balewa NE and SE, sheet 170. Geographically, it straddles the Tafawa Balewa local government area of Bauchi state and the western boundary of the Kanam local government area of Plateau state, covering an area of about 47 km^2, the vast majority of that being in Tafawa Balewa (Figure 2). It is bounded by the corner coordinates in Table 1 below.

Table 1: Corner coordinates of the study area.

S/N	Longitude (Minna Datum)	Latitude (Minna Datum)
a	9° 47' 20"	9° 46' 30"
b	9° 51' 57"	9° 46' 30"
c	9° 47' 20"	9° 43' 30"
d	9° 51' 57"	9° 43' 30"

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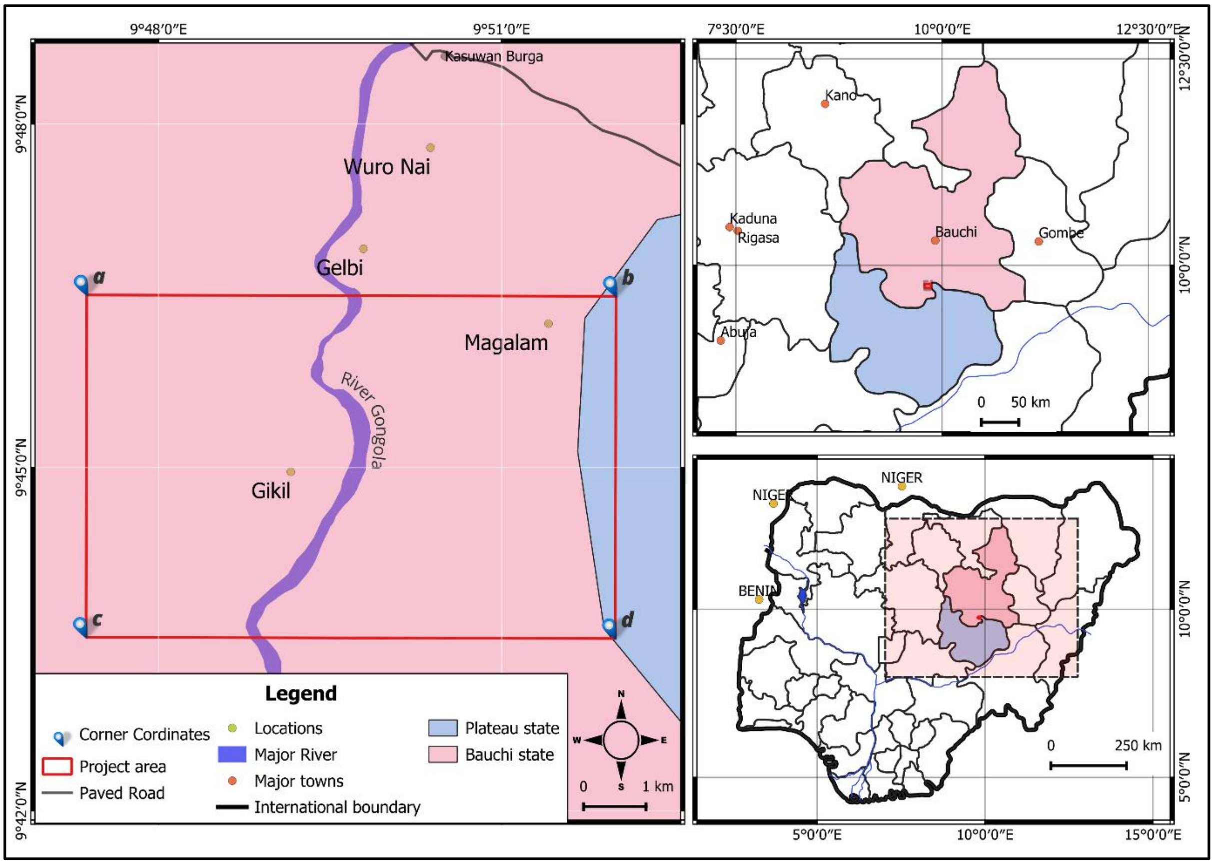

Figure 2: Location of study area.

MATERIALS AND METHODS

Seven (7) whole rock samples and 1 soil sample were collected around exposed pegmatite swarms without any planned bias for the various zones within the pegmatites. Rock samples are not widely distributed as their collection was based on the availability of pegmatite exposures (Figure 3).

All samples were prepared for geochemical analysis by drying, crushing to 70% passing 2mm mesh size, and splitting 500g sub-sample before pulverising to 85% passing 75µm. These samples were analysed for 47 elements including Li, Cs, Sn, Ti and Ta using multi-element, 0.15g, sodium peroxide fusion, ICP-AES (per-700) and peroxide fusion, REEs and Refractory, ICP-ES/MS Finish (Per-700R) at the MS Analytical laboratory, Langley, BC, CANADA. The major elements were presented in weight per cent (%) while the trace elements are in parts per million (ppm).

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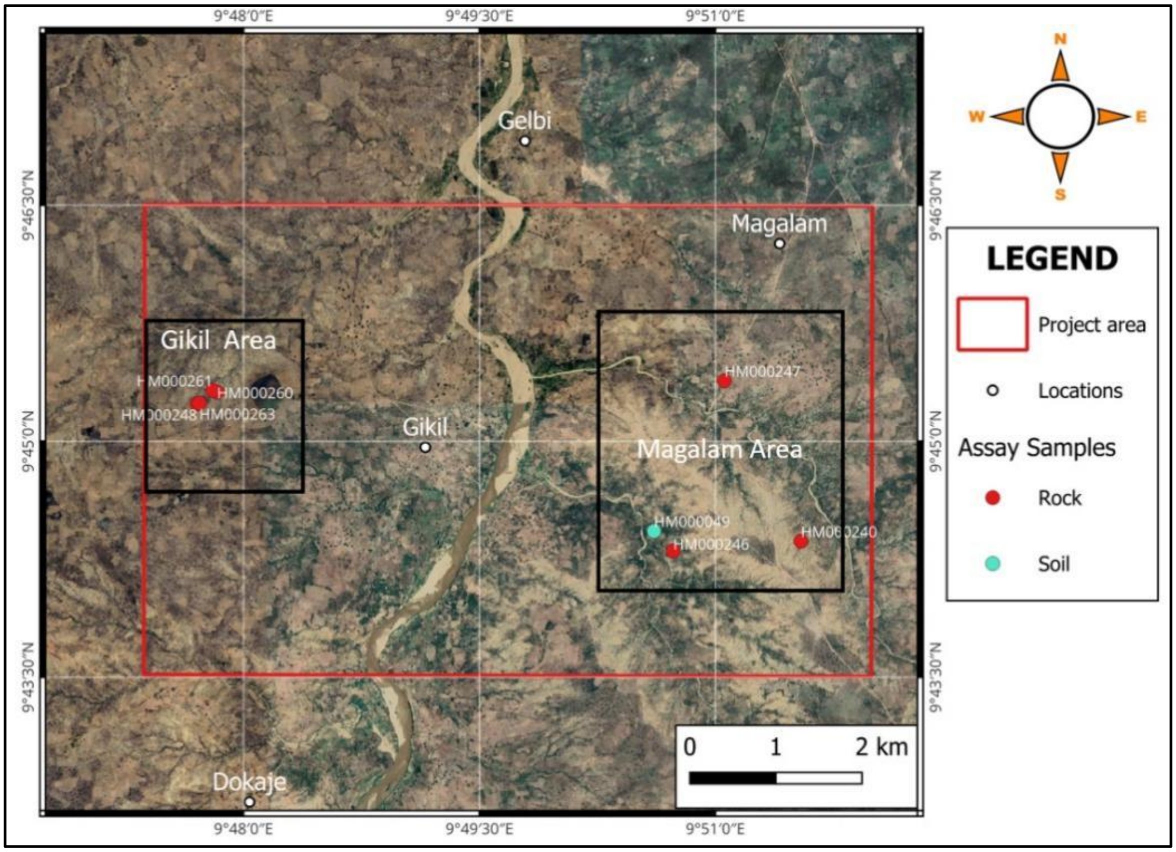

Figure 3: Sample distribution.

RESULT AND DISCUSSION

Geochemistry of the Pegmatites

Geochemical analysis shows variations in the chemical compositions of the pegmatites from Gikil and Magalam, reflecting their mineralogical and evolutionary differences.

The Magalam pegmatites are slightly more enriched in SiO_2 than the Tourmaline-bearing Gikil pegmatite, with a mean value of 70.55 and 66.86%, respectively. They are, however, relatively lower in Al_2O_3 than the Gikil pegmatite, with mean values of 13.15 and 16.13, respectively (Figure 4). The Magalam pegmatites which are associated with Rutile are more enriched in TiO_2 (Mean value of 0.22%) compared to the Gikil pegmatites (mean value of 0.02%). The Rutile-bearing Magalam pegmatites show more enrichment in Fe_2O_3, K_2O and CaO (Figure 3).

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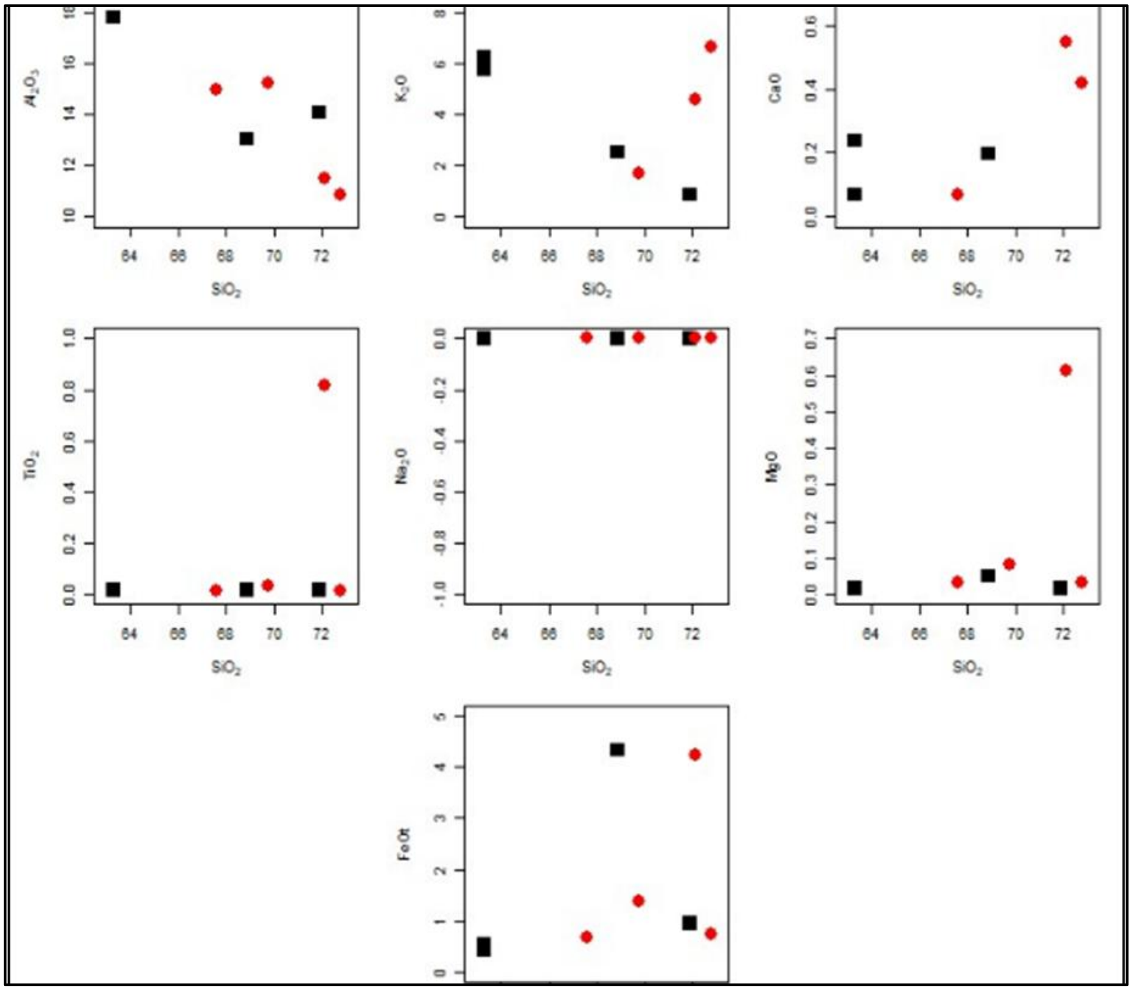

Figure 4: Multiple plots of SiO2 vs Al2O3, K2O, TiO2, Na2O, MgO, P2O5, FeO.

The high content of these major oxides in the pegmatites of the study area can be attributed to the presence of grossularite garnet and or fe-rich tourmaline (Olatunji and Jimoh 2017). The pegmatites all have Aluminium Saturation Indices (ASI) greater than 1. i.e A/CNK > 1.1 and A/NK > 1.1, This is an indication of the peraluminous nature of the pegmatites and it is backed by a plot A/CNK vs A/NK (Figure 5). (Cerny, 1991a; London, 2005).

The peraluminous pegmatites are often an LCT family of pegmatites and are associated with S-type granites based on Cerny et al. (2012) and Cerny (1982) classification scheme. These peraluminous rocks may have been derived from sub-aluminous magma by factional crystallisation as hypothesised for Gikil, or by partial melting of upper crustal rocks, as in many pegmatites around Magalam (Turpin et al., 1990).

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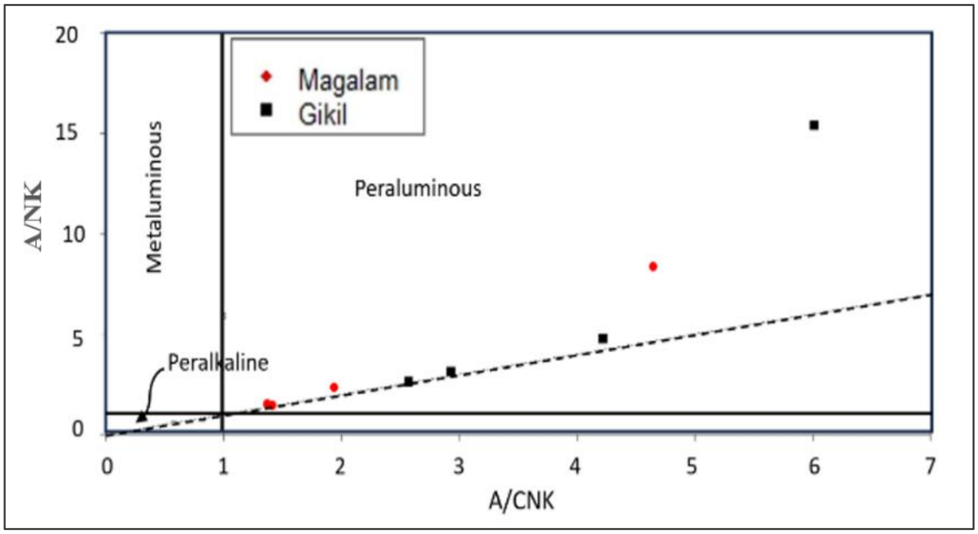

Figure 5: Aluminium Saturation Indices (after Shand, 1943).

Mineralisation Potential of the Pegmatites

The degree of fractionation of the pegmatites was measured using Rb Vs Sr Vs Ba ternary plot. Following Čern´y *et al.* (2005a), the pegmatites of Gikil mostly showed the highest level of fractionation, an indication of a complex type of rare metal pegmatite. This contrasts those of Magalam that are primitive (unfractionated) and therefore plots as anomalous granites (Figure 6).

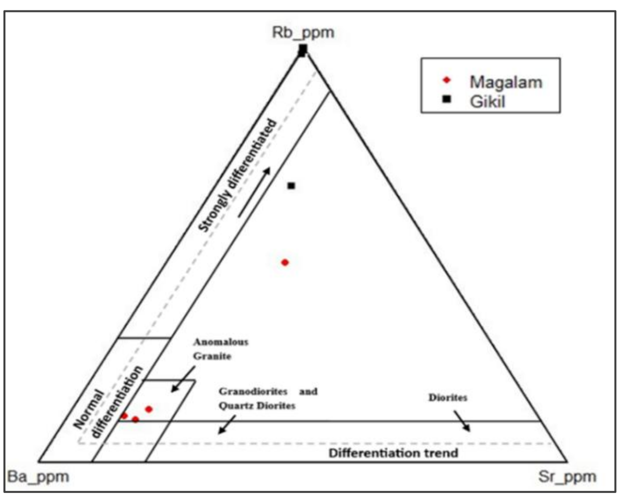

Figure 6: Ternary plot showing the level of differentiation of the various samples (after Maniar and Piccoli 1989).

The K/Rb vs Rb plot of the whole rock samples indicate strong rare metal bearing affinity around Gikil. These pegmatites are enriched in Li, Cs, be and Ta (Figure 7 and 8) with the most significant results comprised of a lithium point anomaly up to 2.4% LiO_2. In contrast, those of Magalam are dominantly barren and not differentiated.

Plots of Ta vs Cs+Rb and Ta vs Ga were used to confirm the potential for Ta mineralisation (Figure 9 and 10). Though weak, the Gikil pegmatite is mineralised in Tantalum according to Beus (1966) and Gordiyenko (1971).

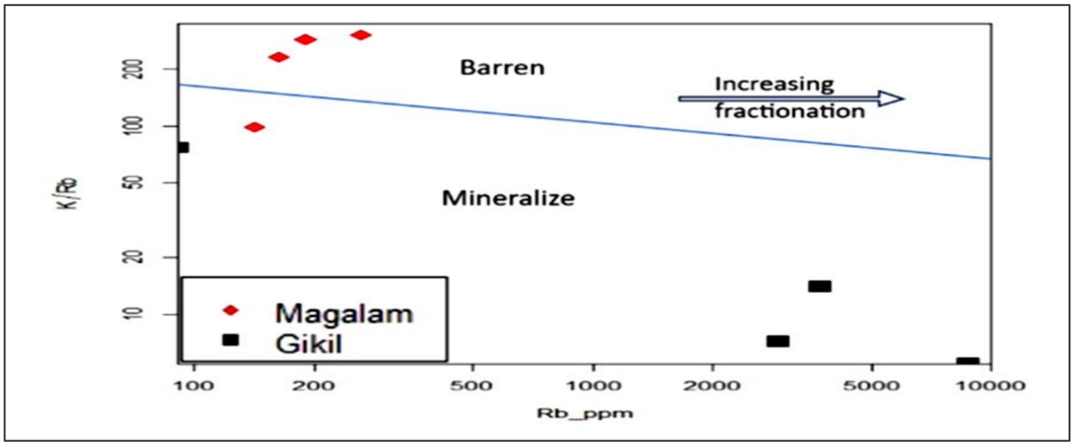

Figure 7: plots discriminating barren from rare metal mineralised pegmatite (after Straurov et al., 1966).

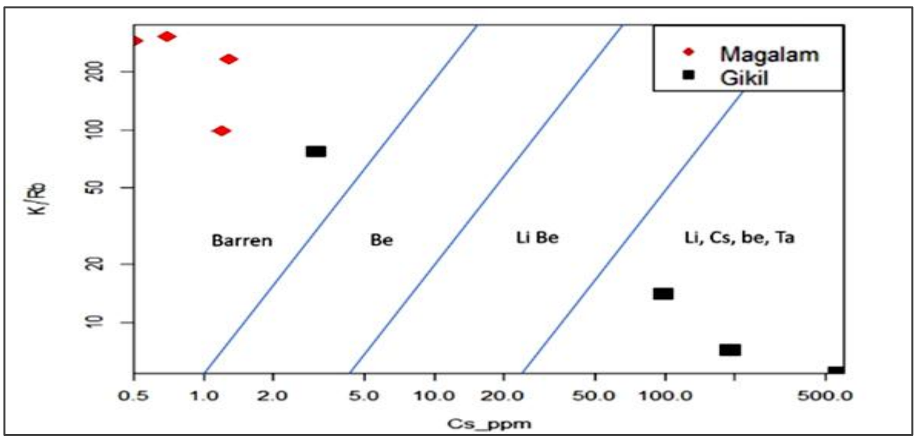

Figure 8: plots discriminating barren from rare metal mineralised pegmatite (after Straurov et al., 1966).

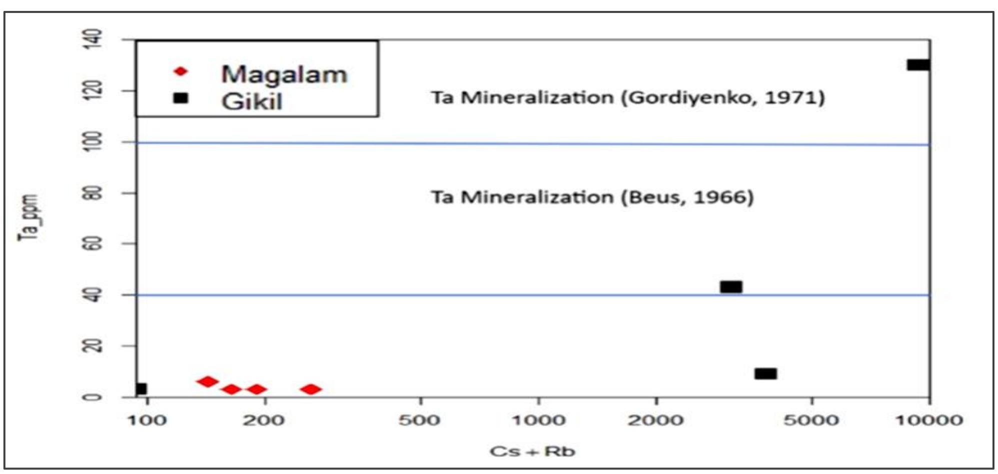

Figure 9: Graph of Ta against Cs+Rb for pegmatite samples from the Gikil and Magalam area (After Gaupp et.al, 1984).

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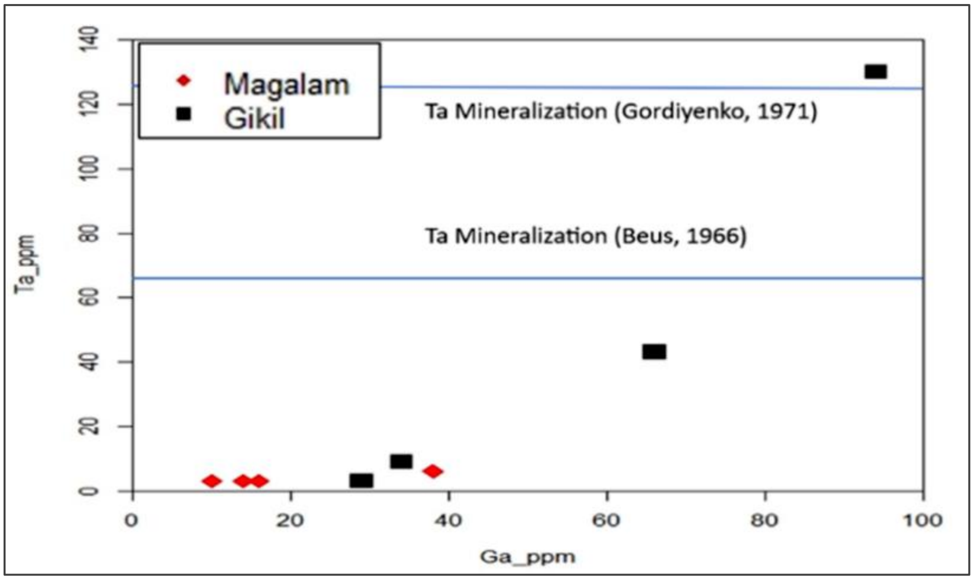

Figure 10: Graph of Ta against Ga for pegmatite samples from Gikil and Magalam area (After Gaupp et.al, 1984).

Tectonic Environment of Emplacement of Pegmatite

Total Alkali Saturation (TAS) plot of the samples showed that they are predominantly granitic in composition (Figure 11). The tectonic environment of emplacement of the pegmatite as discriminated using Pearce et al. (1984) diagrams showed that all the pegmatites from Gikil had signatures of Within Plate Granite (WPG), hence post-orogenic. Those of Magalam seem to be of a hybrid source, sharing the properties of Within Plate Granite (WPG) and Syn Collisional Granites (SCG) and crustal thickening (Figure 12).

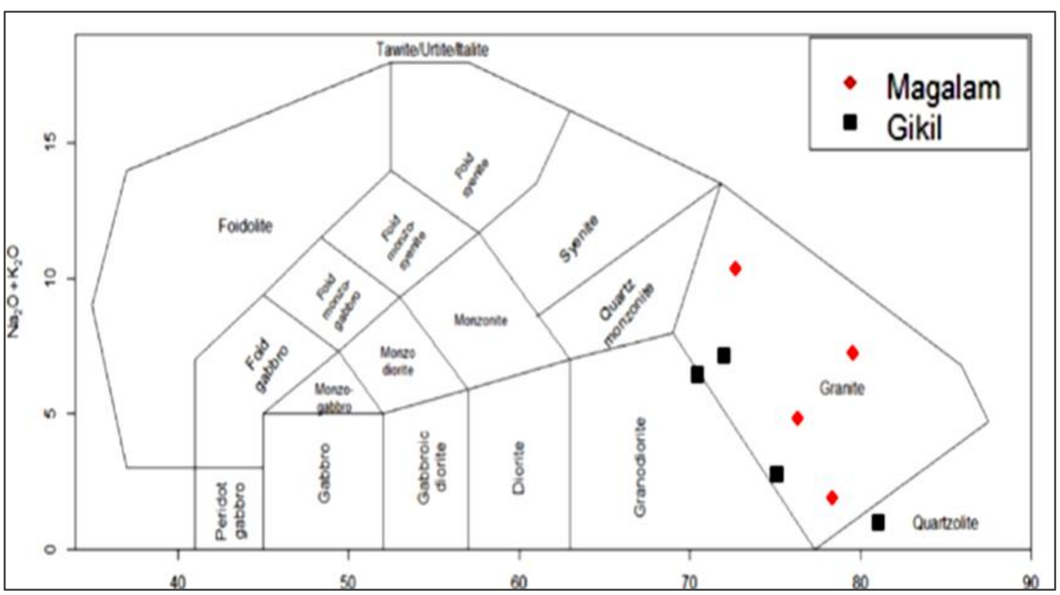

Figure 11: Total alkali vs. silica (TAS) diagram (Middlemost, 1994).

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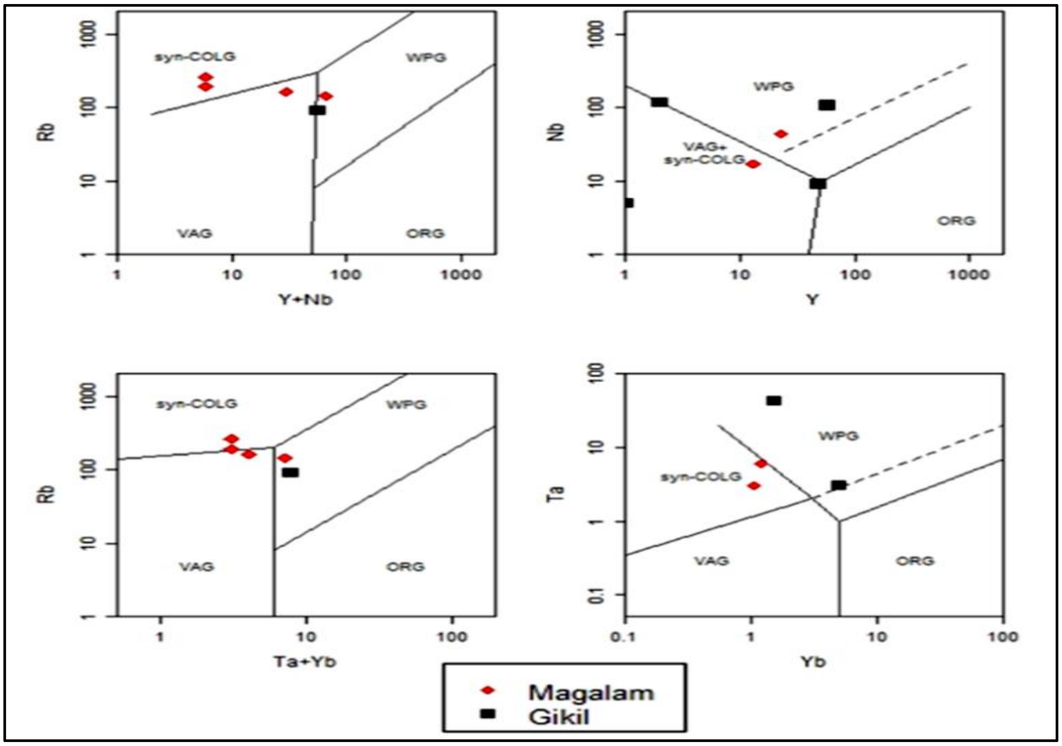

Figure 12: Graph of Rb against Y + Nb and Ta+Yb, Nb Against Y and Ta against Yb for samples from the Gikil and Magalam area (after Pearce et al., 1984).

ACN plot revealed that the pegmatites are peralkaline and associated with S-type granite which is most likely post-orogenic, derived by crustal melting or crust and mantle mixing.

The Precambrian pegmatite bodies occur mainly as dykes and veins suggesting they are emplaced in pre-existing fractures (fracture healing).

REE contents are generally more enriched in Gikil pegmatites than those of Magalam. The pegmatites show patterns of enriched light REE (LREE)- and depleted heavy REE (HREE), as shown from the chondrites normalised plot of the REE (Figure 13).

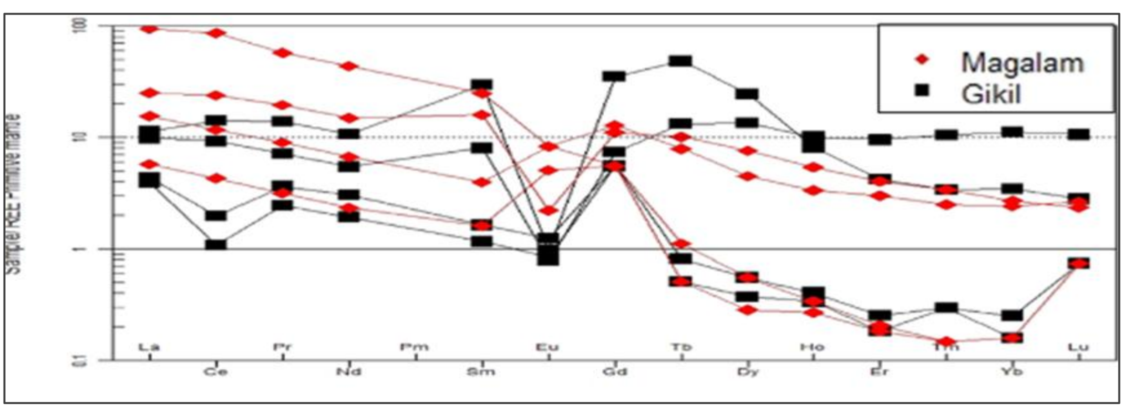

Figure 13: Chondrites-normalised REE patterns for the analysed pegmatites from Gikil and Magalam (McDonough et al. 1995).

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The patterns exhibit fractionated asymmetric concave-upward shapes, with strong negative Eu anomalies, an indication of granite-related pegmatites. These could have resulted from the high contents of garnet and the plagioclase feldspar in the pegmatites. Garnet will change REE patterns to LREE-enriched and HREE-depleted, whereas plagioclase feldspar will enrich all REE, but deplete Eu. The relative abundance of LREE as compared to HREE suggests that the study samples have originated and sourced from the upper continental crust material and not the mantle.

The similar shapes and patterns of the Gikil and Magalam pegmatites suggest that they have crystallised from the same source and through the same geological process. The chondrite plot also shows that each pegmatite varied in evolutionary trends.

CONCLUSION

The geochemistry of the pegmatite reflected the mineralogical composition of pegmatites within the study area. This includes enrichment in TiO_2 in rutile-bearing pegmatites of Magalam and Al_2O_3 content in spodumene-bearing pegmatites of Gikil. Gikil pegmatites, though highly fractionated, are yet to achieve the highest degree of fractionation reflected in weak mineralisation in Ta. They are complex-type pegmatites, rare-metal bearing and, in particular, LCT-Tourmaline subtype with enrichment in Li, Ta, and LREE. Magalam pegmatites are generally primitive and barren to rare metal but could be a significant host to rutile and related gemstones. Gikil pegmatites are post-orogenic while those of Magalam are probably orogenic. However, both pegmatites indicate a similar melt source.

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