Geochemical features of rare metal pegmatites in Nassarawa area, central Nigeria

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Abstract

Mineralized pegmatites in Nassarawa area, have been studied in order to evaluate their geochemical features and economic potential. The pegmatites consist of microcline-microperthite, quartz, muscovite, minor plagioclase and accessory minerals. Some samples show replacement of microcline by albite and formation of gilberite. Samples of the pegmatites and their eluvials were also sampled and analyzed, for major, minor and trace elements. Indicator elements such as Li, K, Rb, Cs, Nb, Ta, Sn and Ga have higher abundances in pegmatites and muscovite than in K-feldspars and albite. Compared with the K-feldspars, albite is depleted in Rb, Cs, F, G and Ga but enriched in the ore elements Nb, Ta, and Sn.

Rb and Cs show high positive correlation coefficient of 0.911 and 0.805 respectively for K-feldspar and muscovite. The correlation coefficient of Rb and Cs for albite, is also positively high, with a value of 0.848. K/Rb versus Cs shows high negative correlation coefficients of -0.928 and -0.816, correspondingly for K-feldspar and muscovite, as characteristic of mineralized pegmatites.

Contrasts between samples of the pegmatites and albite on one hand and K-feldspar and muscovite on the other, are essentially reflected by the element indicators, Rb, Cs and K. Consequently, Rb, Cs and K contents of K-feldspar and muscovite can be used as reliable exploration aids for rare-metal pegmatites.

Introduction

Two distinct and economically important types of Sn-Nb-Ta mineralizations occur in Nigeria. The older suite is related to Pan-African (ca.600Ma) pegmatites. These mineralized pegmatites are concentrated in a broad belt stretching for about 400km of a distance from the Wamba area in central Nigeria to Ago-Iwoye area in southwestern Nigeria (Jacobson and Webb, 1946; Wright, 1970; Kinnaird, 1984, and Kuster, 1990). However, Ekwueme and Matheris (1995) have also identified mineralized pegmatites in the Precambrian basement of southeastern Nigeria. Based on field relationship, the pegmatites in which mineralization is closely associated with late albitionization have been genetically linked in Nassarawa area. Some of the rare metal mineralized fields occur in proximity to areas previously known for hydrothermal gold mineralization (Garba, 2002). The rare-metal pegmatite fields, which are all closely associated with NE-SW and NNE-SSW regional fault systems are enriched to varying degrees in late-stage polyphase mineralization.

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Contrasts between samples of the pegmatites and albite on one hand and K-feldspar and muscovite on the other, are essentially reflected by the element indicators, Rb, Cs and K. Consequently, Rb, Cs and K contents of K-feldspar and muscovite can be used as reliable exploration aids for rare-metal pegmatites.

Analytical procedure

Samples were analyzed for major, minor and trace elements using Philips 1404 automatic XRF spectrophotometer in the Applied Geochemistry Laboratory of the Technical University, Berlin (TUB). The micas and some silicates were analyzed for lithium (Li) and magnesium (Mg) following the leaching of the pulverized samples with 20ml 10% HCl, and fusion with NaOH at 500°C. Dissolution followed in dilute HCl (distilled water + 20ml of 10% HCl) and the solution was heated in a sand bath at 100°C to obtain a clear solution. Samples were later analyzed for lithium using atomic absorption spectrophotometer while their magnesium contents were determined using Perkin-Elmer ICP/6000, at the Applied Geochemistry Laboratory of the Technical University, Berlin. Trace element contents and rare earth elements of the pegmatites, the mica and feldspar were determined in the Geologie Forschungs Zentrum Postdam, using an ELAN 5000A quadrupole ICP mass spectrometer. Lognormal transformations of the data were subjected to bivariate correlation analysis using SPSS software.

Geological setting and petrography

Nigeria lies within the Pan-African reactivation mobile belt east of the West African craton. Pegmatites are widely
distributed within the Nigerian basement complex rocks with a marked concentration of the mineralized pegmatites occurring in a broad belt extending from Ago-Iwoye area in the southwest to Bauchi area in the northeast (Fig. 1). This Pan-African belt continues southwest into northeast Brazil where analogous mineralized rare metal pegmatites also occur (Schuling, 1967).

The pegmatites range in dimensions from a few metres to over a kilometre in length while the width varies from a few centimeters to ten meters and more (Fig. 2). Dykes with strike lengths between 300 and 700 metres are quite common. Although the majority of the pegmatites occur in the form of regular, tabular dykes with fairly constant dips and strikes, many of the richly mineralized pegmatites occur as sill-like bodies with pronounced pinch and swell structures. The swellings are generally loci of intense albitization and mineralization. There is a tendency towards the arrangement of the pegmatites in sub-parallel groups akin to an en-echelon emplacement and in some cases, there are two or more intersecting sets of dykes. Majority of the pegmatites generally crosscut the foliations of the host schists and gneisses. The pegmatites are characterized by well-developed graphic intergrowths of quartz and feldspar.

The simple, barren quartz-feldspar (with minor mica) pegmatites occur close to the granites while the complex mineralized pegmatites are found far away in the host schists. The barren pegmatites are composed essentially of quartz, microcline-microperthite, minor plagioclase and minor mica. The minor plagioclase appears to be replacing the perthite with sericite as by-product. Garnet, magnetite and tourmaline are the accessory minerals.

The mineralized pegmatites are composed of microcline-microperthite, quartz, albite, muscovite, minor plagioclase and accessory minerals. They display textural and mineralogical zonation parallel to the walls of the intrusion. The zonation is accentuated by the quartz-mica margins of

Fig. 1. Generalized geological map of Nigeria showing the pegmatite zone and the study area (modified after Odeyemi et al., 1999)

Fig. 2. Geological map of Nassarawa tantalite fields
the dykes due to the alternation of bands of coarse-pegmatite and lenses of fine-grained albite (cleavelandite). These pegmatites show a pervasive albitization. In some samples, sub-parallel microcracks filled with albites and sericite occur within perthite crystals. Such cracks provided the channel ways by which the soda-rich late stage mineralizing fluids deposited the ores of Nb-Ta-Sn-Be.

Albite is found mainly in the albite-rich aplitic zones of the footwalls and in small amounts in all zones of the pegmatites. Secondary albite occur close to the quartz core of the mineralized pegmatites, while fine-grained albite and platy cleavelandite, both primary in origin, occur mostly in paragenesis with K-feldspar, primary muscovite and phosphate minerals. However, it is difficult to distinguish primary albite from the metasomatically formed secondary albite. K-feldspar crystallized in nearly all zones of the pegmatite. However, from the middle to the inner zones, especially close to the quartz cores of the mineralized pegmatites, replacement of microcline by albite is complete, giving rise to the formation of secondary fine-grained muscovite-gilberite.

**Results**

The results of chemical analyses of samples of the pegmatites, albite, K-feldspar and muscovite are shown in Table 1. The ranges and mean contents (ppm) of some geochemical indicators and ore elements are also shown in Table 2. In Table 2, it is observed that albite has the highest concentration of F of 11,637ppm followed by muscovites (4751ppm), while it was not detected in pegmatites and K-feldspar. Muscovite has also the highest average Ga content of 159ppm while K-feldspar is the least value of 19ppm. Muscovite are the most enriched in Nb (158ppm) while K-feldspar are the least enriched, with 11ppm. Muscovite also has the highest concentration of 352ppm Sn, while K-feldspar has the least value of 34ppm. The pegmatites contain the highest Ta content of 107ppm, while K-feldspar has the least value of 22ppm. K-feldspar contains the highest average Rb value of 6,504ppm followed by muscovite (5302ppm) while the least value of 601ppm occurs in the pegmatites. Cs content in the K-feldspar is the highest at 3489ppm, while the pegmatites contain the least value of 123ppm. K-feldspar also has the highest average value of 107,796ppm for K and albite has the least value of 13,906ppm. Compared with the K-feldspar, albite is depleted in Rb, Cs, F and Ga but enriched in the ore elements Nb, Ta and Sn. Also considering the indicator elements Rb, Cs and K, K-feldspar and muscovite are more enriched than the albites and pegmatites.

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The ranges and mean contents (ppm) of some geochemical indicators and ore elements are also shown in Table 2.
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Note: Pegmatities (1-6); ...Albite (7-12); ... K-feldspars (13-21); .... Muscovite (22-30)

Table 2. Range and average composition (ppm) of some indicator elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Pegmatites (6)</th>
<th>Albite (6)</th>
<th>K-feldspar (9)</th>
<th>Muscovite (9)</th>
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Note: average values in brackets.
From bivariate correlation analyses, Rb and Cs have high positive correlation coefficient of 0.911 and 0.805 for K-feldspar and muscovite respectively. The correlation coefficient of Rb and Cs for albite is also high and positive with a value of 0.848. K/Rb versus Cs has high negative correlation coefficient of -0.928 and -0.834 for K-feldspar and muscovite, respectively showing the characteristics of mineralized pegmatites. As observed from Fig 3, K/Rb has high negative correlation with Cs in albite. The same trend of high negative correlation is observed in K-feldspar (Fig 4) and muscovite (Fig 5). This K/Rb versus Cs relationship is characteristic of K-feldspar of rare-metal pegmatites and has been used along with K/Rb versus Cs in mica as reliable prospecting aids for rare metal pegmatites (Preinfalk et al, 2000).

Discussion and conclusions
Rare-metal bearing potentials of acid source rocks can be ascertained from geological and petrological ore-forming factors referred to as the “degree of specialization” (Tischendorf, 1977). Such metallogenetically specialized granitoids have been considered to be products of either extreme magmatic fractionation or substantial hydrothermal alteration. They are usually characterized by low levels of Fe, Mg, Ca, Ti, Ba, Sr, and Zr whereas Li, Rb, Cs, F, Be, Y and ore-forming elements Sn, Nb and Ta are enriched.

The major, minor and trace elements of the mineralized pegmatites of Nasarawa area are close to those of peraluminous Late-Pan African granites of the area. Magmatic fractionation in the primary mica and potassium feldspar of the pegmatites is marked by low Mg, Ti, Ba and Zr enhancement. The pegmatites are peraluminous and evolved towards increase in aluminum, phosphorus and thallium.
Element indicators identified for the degree of specialization can be used as pathfinders for exploration purposes. Matheis (1979) suggested that special attention should be given to petrogenetic indicators of rare-metal specialization elements such as Li, Rb, Cs and Be and ratios Mg/Li and K/Rb because they can be used as exploration aids for rare-metal pegmatites. In fact, geochemical indicators in feldspar and muscovite have been used in various attempts to identify rare-metal pegmatite mineralization potential (Gaupp et al., 1984). Contrasts between barren and mineralized pegmatites have been found to be quite significant for Rb and Cs (Adekeye and Akintola, 2005).

In the study area, there are rare-metal and a late hydrothermal enrichments of Ba and Sr along with albition in the mineralized pegmatites. Locally, Ta enrichment in the pegmatites is related to late metasomatic albitization of the pegmatites, while Sn enrichment is closely related to greizenization, that is, enrichment of F, Rb and Cs in muscovite. These phenomena are noticeable both within the pegmatites and their exocontacts in the host mica schist. Matheis (1979) had earlier shown that mineralized pegmatites in Ijero and Egbe areas of southwestern Nigeria are strongly depleted in Ba, Sr and Zr but highly enriched in Rb, Li, Be, Sn Na and Ta. Kuster (1990) also observed similar geochemical characteristics in mineralized pegmatites of Wamba area about 100kms northeast of Nasarawa area.

As shown in Table 2, muscovite and K-feldspar have the highest average contents of Cs, Rb and K. The correlations of their K/Rb versus Cs indicate the high potential for mineralization in Ta-Nb-Sn ores. Geochemical, as well as correlation analyses results agree with earlier observations of Beus (1968), Gordiyenko (1971), Cerny (1989, 1991b), and Preinfalk et al. (2000). These elements are therefore, good indicators for exploration. Moller and Morteani (1987) had earlier observed that in small amounts, albite occurs in all zones of rare-metal pegmatites but it is not easy to distinguish between primary and secondary metasomatic albite. This difficulty in separating primary and secondary feldspar of the pegmatites makes albite largely unstable for use as an indicator mineral for exploration.

All these observations indicate that the minerals of K-feldspar and muscovite give the best information on the mineralization potential of pegmatites. They are therefore, reliable as indicator minerals in exploration. Thus, the distribution of Rb, Cs, and K in muscovite and K-feldspar and their distinct geochemical evolutionary trends can serve as reliable aids in exploration for rare-metal pegmatites in this as well as other areas.

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