# Petrochemistry of magmatic rocks in the Irumide belt: indications on the evolution and tectonic setting of the belt.

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## ABSTRACT

The Irumide belt in Zambia, consists of a northeast trending late Mesoproterozoic terrane of granites and granite gneisses, overlain by the Muva Supergroup sequence of quartzites and metapelites. The Irumide belt is in concealed thrust contact with the Palaeoproterozoic Bangweulu Block to the North, and has an overprinted, and therefore ill-defined contact with the Neoproterozoic Mozambique belt to the South. The belt is truncated to the southwest by the Neoproterozoic Zambezi belt, and to the northeast by the Ubendian shear zones, which were reactivated in Neoproterozoic times.

A number of volcanic units have been recognised as conformable layers within the Muva Supergroup. These consist mostly of andesitic lavas and rhyolitic tuffs, and have been folded together with the metasediments. A U-Pb Sensitive High-Resolution Ion Microprobe (SHRIMP) age has been obtained on magmatic zircons from one tuff, and indicates a crystallisation age of 1880 Ma (De Waele et al., 2001). In the Ibangwe Hill locality in the Central Irumide belt, an extensive fault-bounded terrane is underlain by a mixture of basaltic pillow-lavas, metapelites, quartzites and rhyolitic tuffs of the Ibangwe Group (Mosley and Marten, 1979). Owing to the fault bounded setting, and the fact that no age has yet been obtained on these volcanics, their relationship with the Muva Supergroup is uncertain.

Granitoids make up about 60% of the belt’s rock volume, and consist mainly of foliated, and often porphyritic biotite granites. Although contact relationships, occurrence or absence of xenoliths and differing structural fabrics have been used to discriminate the granitoids into pre- syn- and post- tectonic suites, their bulk geochemical composition remains remarkably similar throughout the belt. The majority of granitoids classify as peraluminous and alkaline. Only the Luswa suite in the NE portion of the belt shows distinct fractionated I-type affinities. Tectonic discrimination diagrams indicate a within plate and/or volcanic arc setting for the Irumide granitoids. The volcanics include both basaltic and rhyolitic end members, and define a tholeiitic trend. Trace element geochemistry indicates a predominant within plate character for the Irumide volcanics.

This paper presents geochemical data obtained from a total of 25 granitoids and 24 volcanic rocks from across the Irumide belt, and attempts to discriminate and interpret the different magmatic suites in the belt.

## GRANITOIDS

Granites in the Irumide belt may be distinguished into an older suite of syntectonic leucocratic biotite granites, and a younger porphyritic granite suite, which contains abundant xenoliths, and rafts of metasediments (Mapani, 1992). High-grade paragneisses and migmatites occur in the southwestern and internal portions of the belt, where metamorphic conditions locally attained granulite facies (Fig. 1).

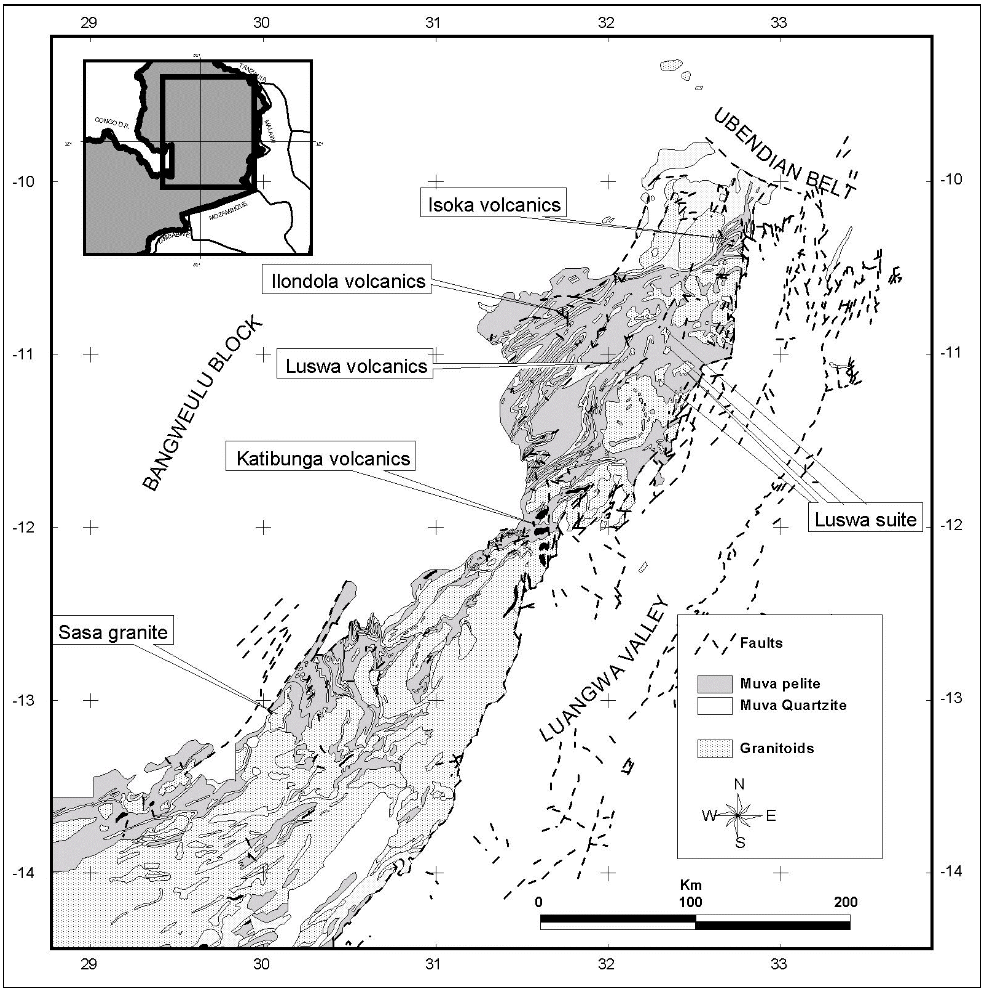

**Figure 1:** Simplified geological map of the Irumide belt, showing location of volcanics and granite suites described in the text.

The major element geochemistry of the granites indicates a silica content between 65-76% $SiO_2$ and an Agpaitic Index ($AI=(Na_2O + K_2O)/Al_2O_3$) ranging from 0.42 to 0.72 in accordance with the absence of alkali pyroxenes or amphiboles in the granitoids. The Aluminium Saturation Index ($ASI=(Al_2O_3/(CaO + Na_2O + K_2O))$) is greater than one for all granites which gives them normative corundum and classifies them as peraluminous (Fig. 2).

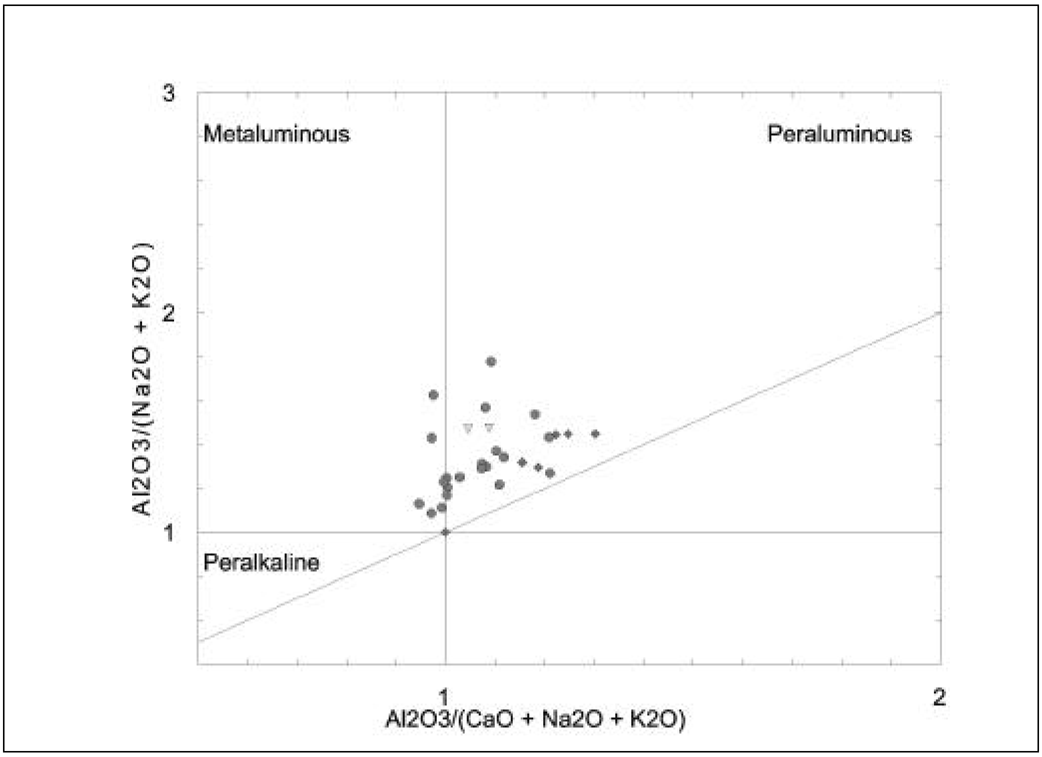

**Figure 2:** Classification of Irumide granitoids after Maniar and Piccoli (Maniar and Piccoli, 1989). (Inverted triangles: Sasa Granite; circles: alkaline and porphyritic granites; diamonds: Luswa Suite.)

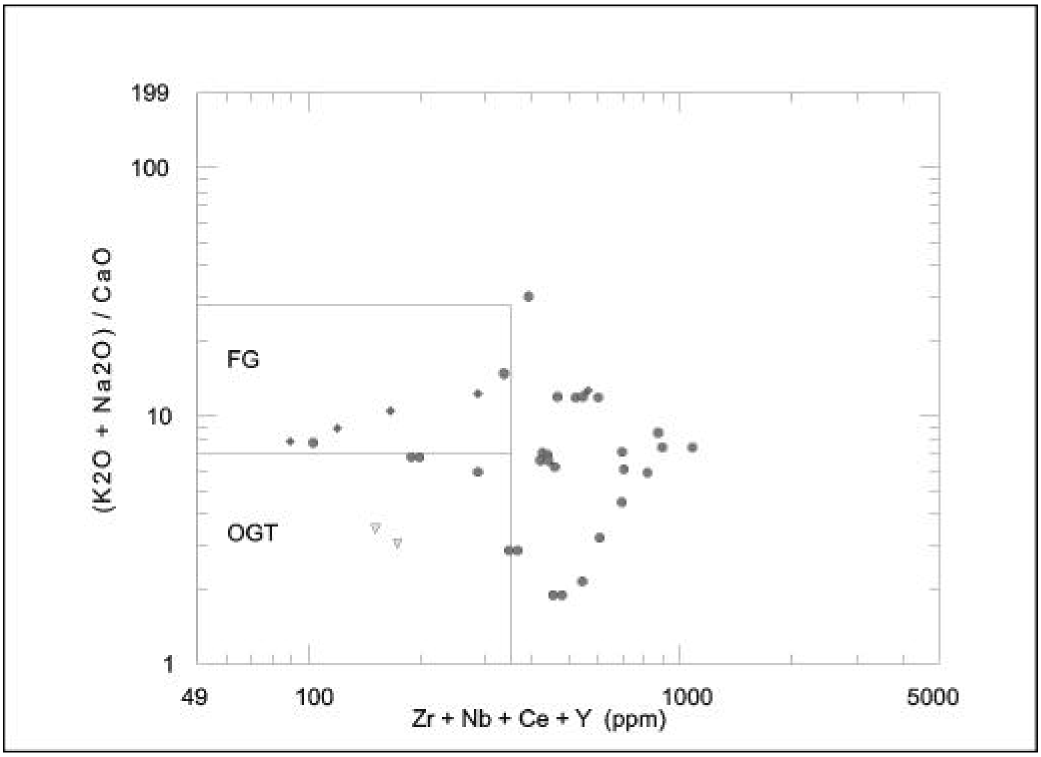

**Figure 3:** Classification of Irumide granitoids after Whalen et al. (Whalen et al., 1987). (Inverted triangles: Sasa Granite; circles: alkaline and porphyritic granites; diamonds: Luswa)

On a multivariate plot proposed by Whalen et al. (Whalen et al., 1987), the Irumide granitoids are classified as predominantly A-type. Only the Sasa Granite plots in the Orogenic Granite field, while most members of the Luswa suite display fractionated characteristics (Fig. 3).

The majority of the granites have high $K_2O/Na_2O$. A discrimination diagram proposed by Le Maitre (Le Maitre, 1989) using modal compositions shows most plutons to lie within granodiorite (4), monzo-granite (3b) and a few in tonalite (5) field (Figure 4). The tectonic discrimination diagrams proposed by Pearce et al. ((Pearce et al., 1984), using highly immobile Y and Nb, discriminate the different Irumide granitoids into three main fields (Figure 5). The Sasa granite clearly plots in the field classifying it as either Volcanic Arc or Syn-Orogenic affinity. The Alkaline and porphyritic granitoids plot either in Within Plate or Volcanic Arc/Syn-Orogenic fields. The Luswa suite seems to have significantly lower Nb contents than the alkaline and porphyritic granites confirming their fractionated I-type character.

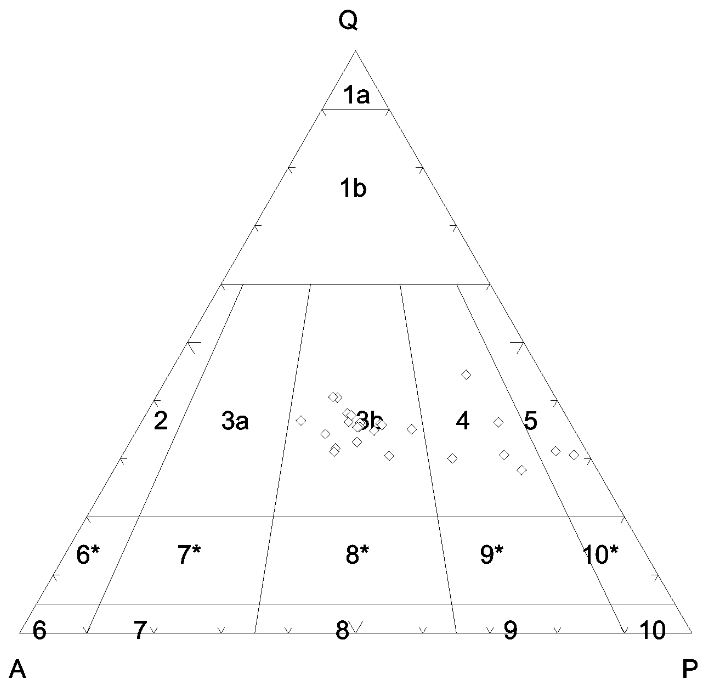

**Figure 4:** Discrimination diagram after Le Maitre (Le Maitre, 1989) using modal compositions

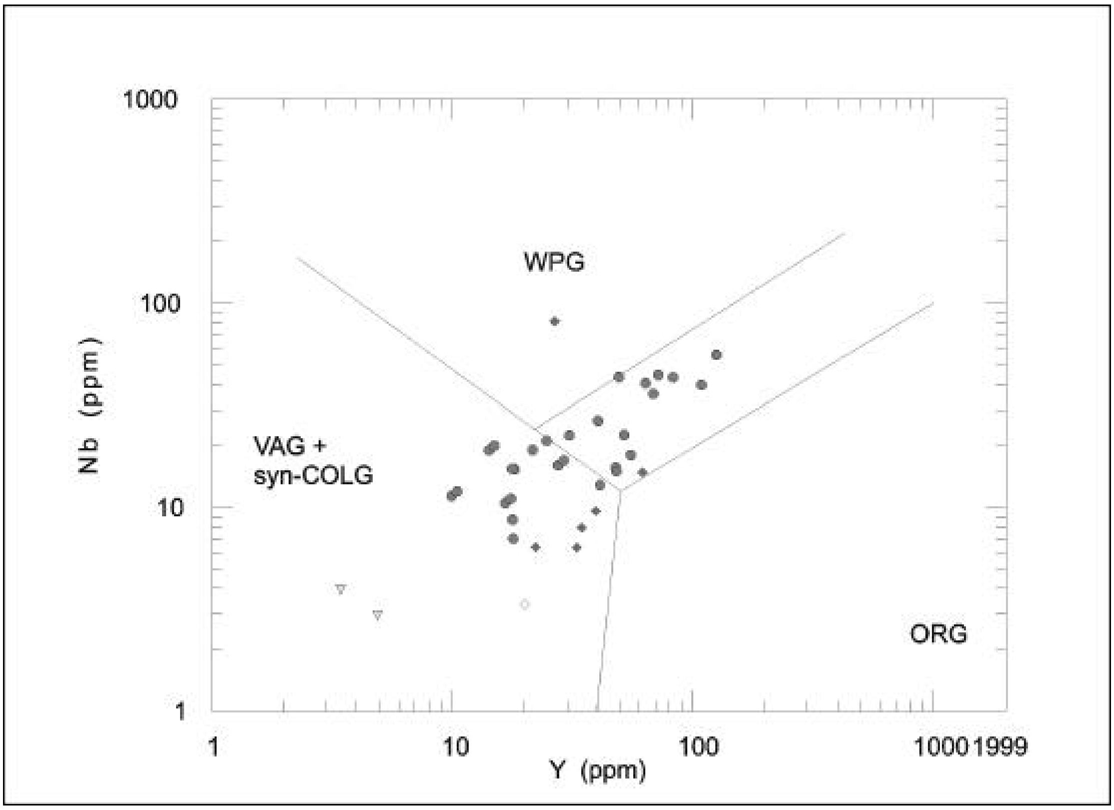

**Figure 5:** Tectonic discrimination diagram after Pearce et al. (Pearce et al., 1984). (Inverted triangles: Sasa Granite; circles: alkaline and porphyritic granites; diamonds: Luswa suite)

Trace element characteristics are dominated by enrichment in High Field Strength (HFS) elements. Based on REE plots, the granitoids can be subdivided into three main groups. The Sasa granite, which has calc-alkaline characteristics, plots with a uniformly, and moderately sloped REE pattern (Fig. 6a). Characteristic is the absence of a negative Eu-anomaly, indicating that either no fractionation of feldspars took place during formation of the Sasa pluton, or depletion due to fractionation was balanced by progressive enrichment through a participating lower crustal source. The porphyritic granitoids and common syn- late tectonic granites, which have distinct alkaline characteristics, plot with progressively depleted LREE and relatively flat HREE pattern (Fig. 6b). A suite of granites from the Central Irumide belt (Luswa Granites) plot with a very moderate slope in LREE, and no HREE depletion (Figure 6c). This indicates that no residual phases were fractionated from the melt.

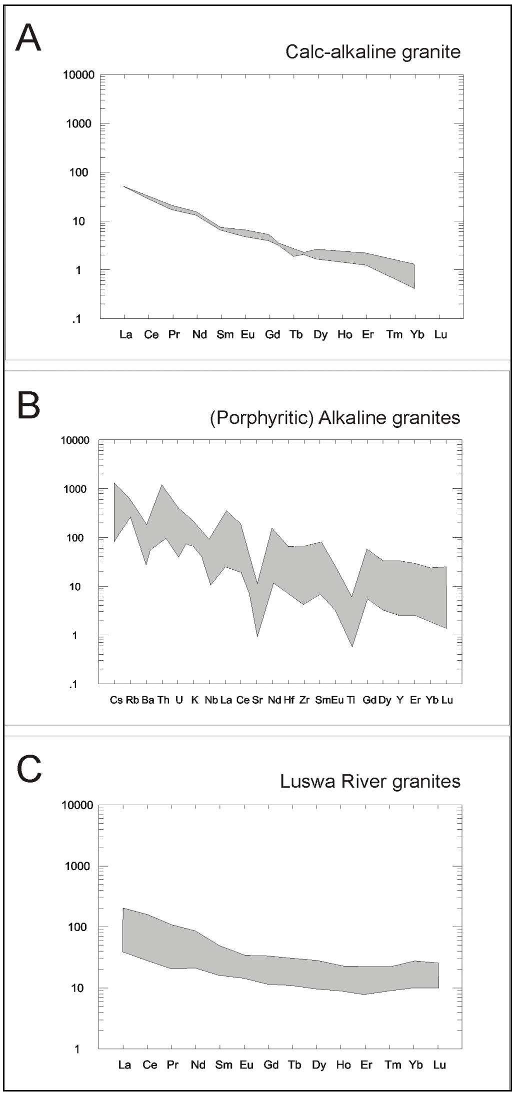

**Figure 6**: (a) REE diagrams (normalised to chonditic reservoir, values after Sun (Sun and McDonough, 1989)) (a) Sasa foliated granite; (b) alkaline and porphyritic granites; (c) Luswa suite

## VOLCANICS

Volcanics have been described only from the northeastern part of the belt (Fig. 1) where they have been sampled from four different localities. The metarhyolites and rhyolitic tuffs occur as narrow layers within the Muva metasediments, and have been subsequently folded together with them during Irumide compressional tectonics. Magmatic zircons from the Luswa rhyolite, which defines a narrow layer of felsic tuff, and is cross-cut by a grey granite in the north of the Luswa River area, have been dated using SHRIMP, and yield an eruption age of 1880 ± 12 Ma. The grey granite cutting it has an emplacement age, determined using SHRIMP, of 1009 ± 12 Ma. The Ilondola Mission, and Isoka occurrences correlate well with the Luswa rhyolite, and can be taken at first estimation to be of equivalent age, and thus to be co-genetic. The Katibunga volcanics however, occur in a fault bounded basin in the south of the Katibunga Mission area (figure 1), and cannot be directly correlated with the Luswa occurrence. The Katibunga volcanics have been interpreted by Mosley et al. (Mosley and Marten, 1979) to form part of the base of the Muva sequence.

In a diagram proposed by Winchester et al. (Winchester and Floyd, 1977) the Luswa, Ilondola and Isoka volcanics are classified as rhyodacitic to rhyolitic composition, while all but two samples of the Katibunga volcanics plot in the (Sub)alkaline basalt, trachite and nephelinite fields (Fig. 7a). In the Total Alkalies versus Silica (TAS) diagram of Le Maitre (Le Maitre, 1989), the Katibunga volcanics plot as basalts (B) and basaltic andesites (O1)(Fig. 7b). Two of the Katibunga samples have elevated $SiO_2$ content and plot as dacites. The Luswa, Ilondola and Isoka volcanics are quite felsic and plot as either dacites or rhyolites. Irvine and Baragar (Irvine and Baragar, 1971) used the TAS diagram to distinguish alkaline and subalkaline volcanics (Fig. 7b). All but one of the volcanics plot with subalkaline affinities, possibly reflecting mobilisation of alkalies during Irumide metamorphism.

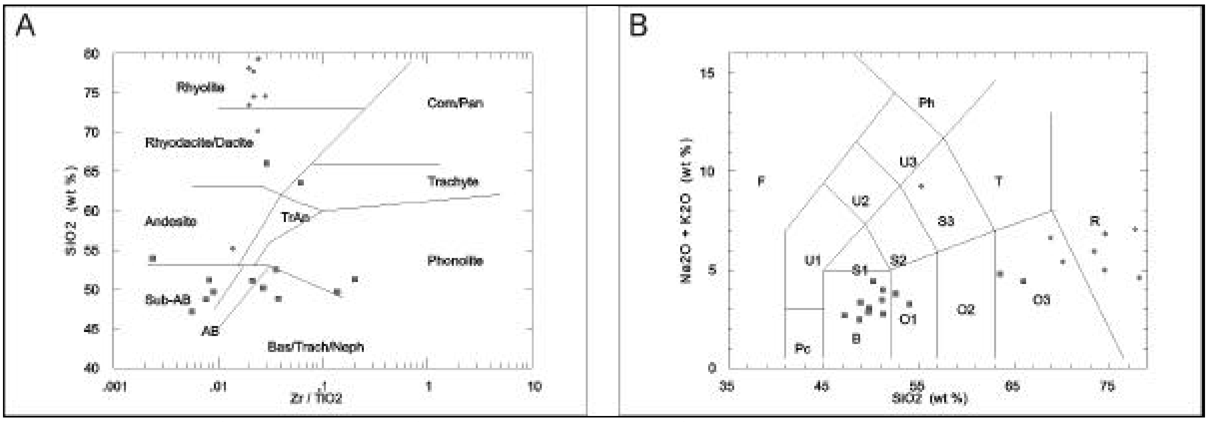

**Figure 7:** (a) Classification diagram of the Irumide volcanics after Winchester et al. (Winchester and Floyd, 1977), (b) classification of Irumide volcanics after Le Maitre (Le Maitre, 1989). Dashed line after Irvine and Barager (Irvine and Baragar, 1971) separates subalkaline (below) from alkaline volcanics (above). Squares: Katibunga volcanics, diamonds: Luswa, Ilondola and Isoka volcanics.

Tectonic discrimination is attempted based on contents of Zr, Y and Nb. A triangular plot proposed by Meschede (Meschede, 1986) does not allow distinction of tectonic setting, as the Katibunga basalts plot across all proposed fields. Excluding Nb content in the discrimination diagram proposed by (Pearce and Norry, 1979)(Fig. 8b) indicates that the Katibunga basalts are of predominant within plate character. The erratic behaviour displayed by Nb possibly reflect analytical problems associated with the ionisation-dissolution problems reported for Nb in ICP-MS analysis.

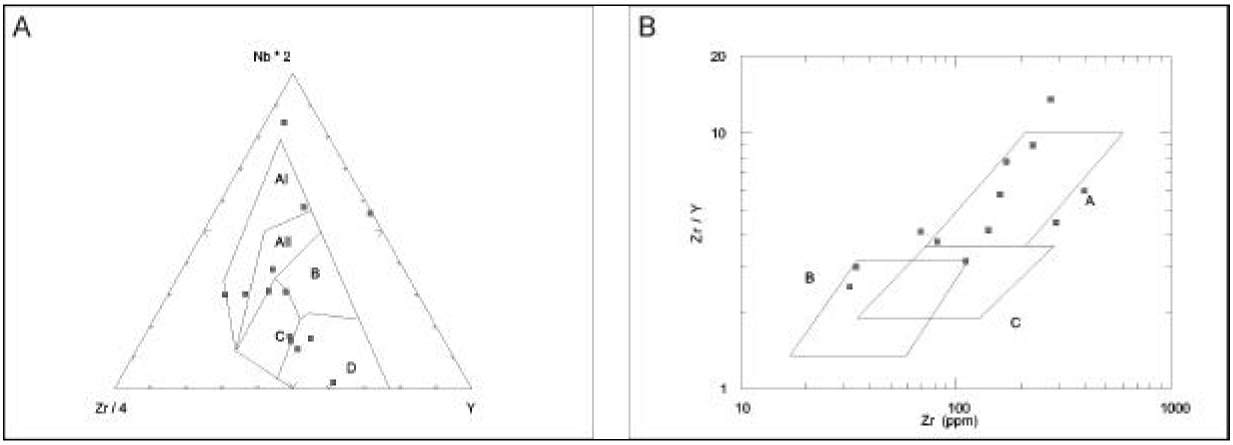

**Figure 8:** Tectonic discrimination diagrams of the Katibunga basalts after Meschede (Meschede, 1986)(a) and Pearce and Norry (Pearce and Norry, 1979)(b).

The multielement and REE geochemistry of the Irumide volcanics is quite similar for both acid and basic end-members. The Luswa, Ilondola and Isoka rhyolites plot with a relative flat slope (normalised to Primitive Mantle after Sun et al. (Sun and McDonough, 1989)) at about 50-100 times MORB values (Fig. 9). Moderate Nb, Sr, and Ti anomalies may reflect a small amount of fractionation or substantial participation of enriched lower crust. The Katibunga volcanics display a much wider range of REE content, and show much more pronounced negative anomalies in Ba, Nb, Sr, Zr and Ti (Figure 9). Assuming that the Katibunga volcanics and various rhyolites in the belt form part of the same volcanic suite that intruded the Muva supergroup at around 1800 Ma, we can infer relationships using MgO, FeO (total) and Na2O + K2O composition in a triangular diagram as proposed by Irvine and Baragar (Irvine and Baragar, 1971)(Fig. 10). The diagram indicates that the Irumide volcanism may display a tholeitic trend with characteristic Fe-enrichment, although insufficient intermediate volcanics have been incorporated into the dataset.

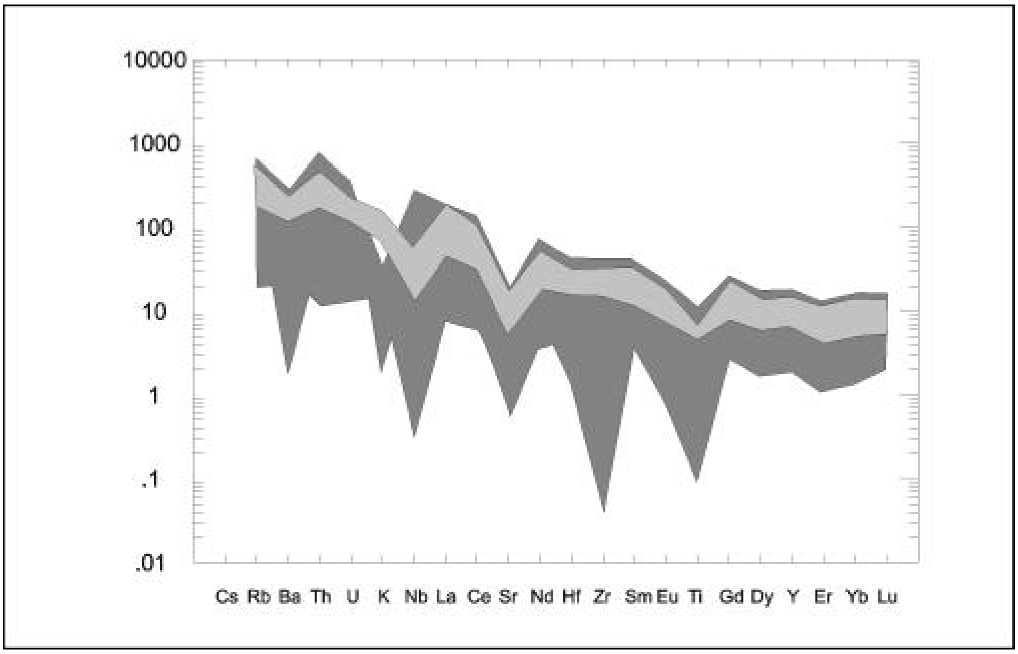

**Figure 9:** Multielement spidergram of the Irumide volcanics (normalised to Primary Mantle (Sun and McDonough, 1989)). Light grey indicates pattern of the Luswa, Ilondola and Isoka rhyolites, and dark grey indicates pattern of the Katibunga volcanics.

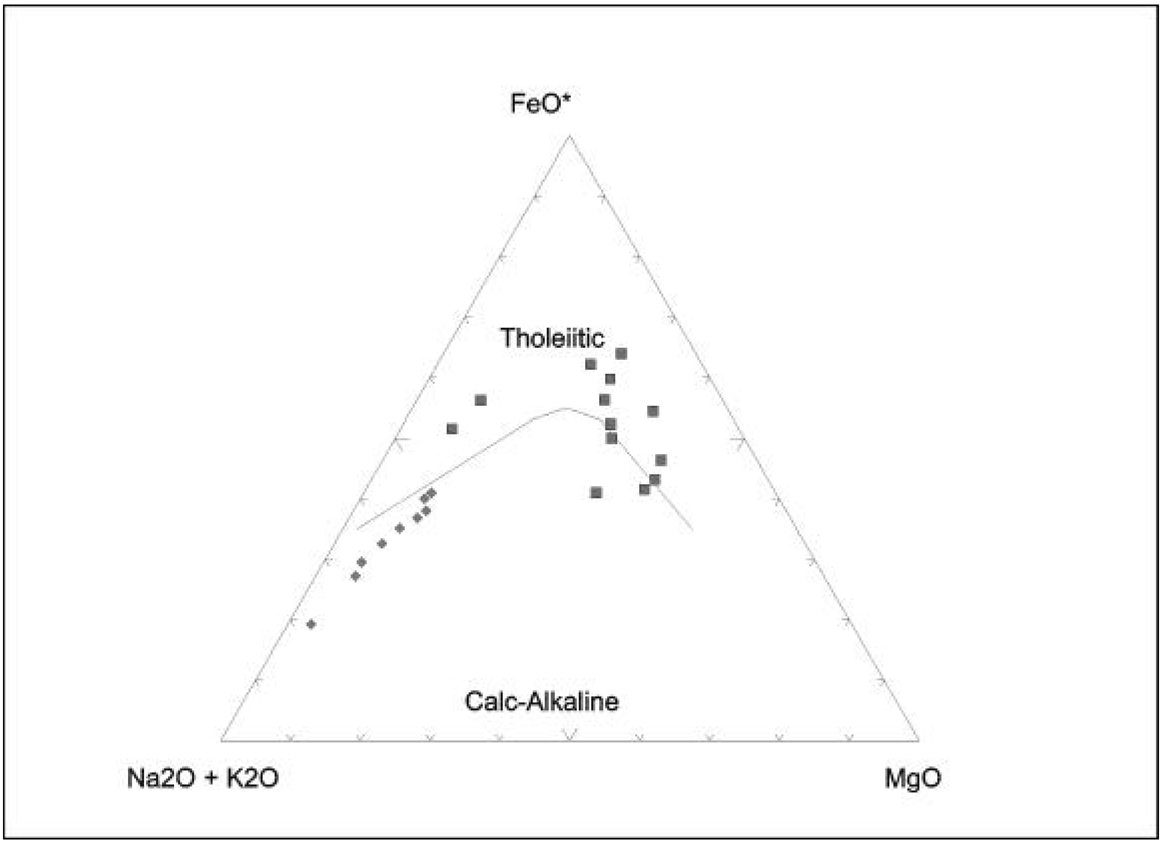

**Figure 10:** Triangular diagram plotting MgO, FeO (total) and ($Na_2O$ + $K_2O$) (AFM diagram) after Irvine and Baragar (Irvine and Baragar, 1971). Squares: Katibunga volcanics; diamonds: Luswa, Ilondola and Isoka volcanics.

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