

MAJOR ELEMENT SYSTEMATICS OF ALKALINE VOLCANIC AND LAMPROPHYRIC ROCKS – TOWARD A GEOCHEMICAL AND PETROGENETIC CLASSIFICATION SCHEME FOR THE POTENTIALLY DIAMONDIFEROUS ALKALINE ROCKS.

Taylor, W.R. and Rock, N.M.S.

Key Centre for Strategic Mineral Deposits, Department of Geology, University of Western Australia, Nedlands, W.A., 6009, Australia.

Understanding the petrogenesis of the alkaline volcanic and lamprophyric rocks has frequently been clouded by nomenclatural problems arising from their mineralogical and compositional diversity. Lamprophyric rocks of essentially identical bulk chemical composition, for example, may have very different phenocryst and groundmass mineralogies due to differences in their low pressure crystallization and degassing histories. These problems have tended to obscure petrogenetic relationships and have led to contentious type-locality or mineralogically-based classification schemes. Major and trace element whole-rock geochemistry provides information essential for correct rock classification and in practice, some combination of mineralogy and petrochemistry is required to classify lamprophyric rocks. While many useful discriminant diagrams are available for assessing mineral chemistry, rock geochemical classifications have received less attention. In this study our aim is to remedy this situation by extending the geochemically-oriented classification scheme of Foley et al. (1987) for ultrapotassic rocks to include the continuum of sodic to potassic alkaline rocks. Our approach differs from that of Foley et al. in that: (1) chemical analyses included in our database have been restricted to relatively primitive compositions to cover rocks most likely to be of direct mantle derivation i.e. to include the potentially diamondiferous rocks; and (2) more rigorous statistical procedures (multigroup discriminant analysis) have been applied to confirm the validity of assigned groups.

The database, which contains more than 1800 major and trace element analyses of alkaline volcanic and lamprophyric rocks, was assembled by combining the relevant parts of the LAMPDA database of Rock (1990) and ultrapotassic rock database of Foley et al. (1987) with a significant number of new analyses from the literature. The database, which originally contained >3000 analyses, was screened to eliminate non-primitive and altered compositions. Analyses that met the following criteria were retained: (1) $\text{FeO}^*/\text{MgO} < 1.25$; (2) $\text{Al}_2\text{O}_3 < 15\text{wt}\%$; (3) $\text{MgO} > 5 \text{ wt}\%$; (4) LOI (exclusive of CO_2 for some rock types) $< 12\text{wt}\%$. Using $\text{CaO-Al}_2\text{O}_3$, $\text{TiO}_2\text{-K}_2\text{O}$, and $\text{SiO}_2\text{-MgO}$ bivariate diagrams, major element (10 oxide) compositions were assigned to one of six geochemical groupings. The first four groups correspond broadly to Groups I-IV of Foley et al. (1987): Group I (lamproites), Group II (kamafugites), Group III (shoshonites), Group IV (transitional lamproites). The new groups are: Group V (kimberlites) and Group VI (basanites, nephelinites and melilitites). Further within-group subdivisions were made on the basis of compositional similarity. As also shown by Foley et al. (1987) for the ultrapotassic rocks, the $\text{CaO-Al}_2\text{O}_3$ plot effects maximum separation of the groups although considerable overlap exists. The $\text{CaO-Al}_2\text{O}_3$ plot is additionally useful in a petrogenetic sense since the fields occupied by Groups I-VI can be correlated with differences in the chemical nature of their mantle source regions, depths of origin and activity of volatile species such as CO_2 . Based on experimental evidence, the low CaO contents of Group I and some Group V rocks imply depleted, CO_2 and clinopyroxene-poor, phlogopite-bearing peridotite sources whereas more fertile garnet lherzolitic to pyroxenitic sources are implied for Groups II and VI. Experimental and xenolith studies show that rocks of highest pressure origin will be found in Groups I, II and V and rocks outside these

groups should probably be regarded as having low diamond-bearing potential. Group III (shoshonitic) rocks are typically found in convergent continental margin tectonic settings and their origin is most probably related to subduction zone processes - an environment not normally regarded as conducive to diamond stability at depth.

Because no one simple oxide plot can fully separate the various groups and their subdivisions, multigroup discriminant analysis using the SYSTAT® package was applied to confirm the validity of the assignments. High percentages (>90% and mostly >95%) of inter-group correct classifications were achieved, confirming the statistical validity of our six-fold classification scheme. Within-group correct classifications were also high, and mostly exceeded 85%. Figures 1 and 2 show graphically the results of 10-oxide multigroup discriminant analysis for kimberlites and related rocks i.e. the rocks most likely to contain diamond (Group V, II and olivine lamproites from Group I) and for lamproites and related rocks (Groups I and IV). In both figures, factors (1) and (2) include a large component of CaO and Al_2O_3 , respectively, so that they resemble bivariate CaO- Al_2O_3 plots, however, only multidimensional treatment can achieve optimal separation into groups and sub-groups.

For the Group I, II and V rocks (Fig. 1) it is clear that chemical variation on the basis of major oxides is gradational between groups and subgroups, e.g. gradation exists between micaceous kimberlites and olivine lamproites; and between calcic kimberlites, carbonatitic kimberlites and aillikites. Some Group II rocks have been shown to host traces of diamond and those Group II compositions taken to be of highest pressure origin, e.g. those plotting near the Group I boundary, are of particular interest as further rock-types that might be candidates for hosting economic quantities of diamond. The discriminant plot for lamproites and transitional lamproites (Fig. 2) shows that the different lamproite sub-groups tend to cluster, emphasizing distinct, largely regionally controlled, compositional differences. Minor overlap is evident between Mediterranean-type lamproites and the cocite sub-group, and between Holsteinsborg-type lamproites and New South Wales-type leucitites. An important feature of the diagram is the separation of lamproites and transitional lamproites into two types either side of the dashed line in Fig. 2. The line divides high- TiO_2 compositions, to the left, from low- TiO_2 composition to the right. This division has important petrogenetic significance, since rocks in the low- TiO_2 group are largely associated with continental margin collisional belts where there has been some previous record of subduction, whereas rocks in the high TiO_2 group are found in continental intra-plate settings. The diamond potential of a province containing high TiO_2 lamproites (e.g. the West Kimberley region, N.W. Australia) appears to be significantly greater than a province containing low- TiO_2 lamproites such as the southern Mediterranean region. It is worth noting that the low- TiO_2 "olivine lamproites" of the Aldan Shield do not classify within Group I, and they are probably picritic variants of Group IV or Group III (shoshonitic) rocks. The very few calcic lamproite (madupite) compositions that meet the criteria for relatively primitive melts, plot in a separate field in Fig. 2. This field also includes the kalsilite-bearing lavas from San Venzano and Cuppaello which have closest bulk compositional affinity with calcic lamproites, rather than with kamafugites with which they have previously been placed on mineralogical grounds.

References

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- Rock, N.M.S. (1990) *Lamprophyres*. Blackie & Sons Ltd, Glasgow.

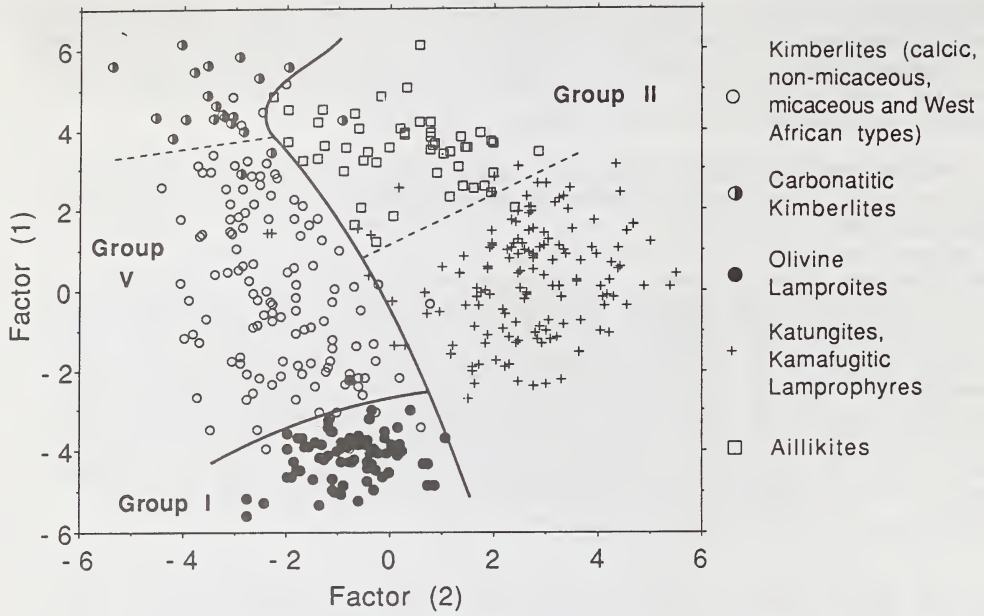


Fig.1 Discriminant analysis factor plot for Group V rocks (kimberlites), olivine lamproites from Group I, and Group II rocks (kamafugites).

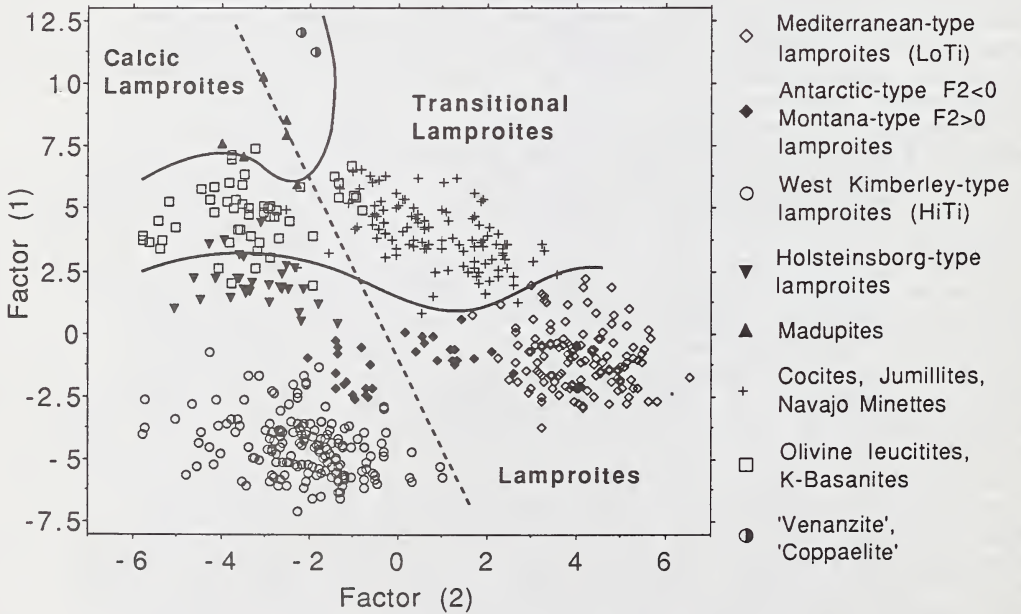


Fig. 2 Discriminant analysis factor plot for Group I rocks (lamproites, excluding olivine lamproites) and Group IV rocks (transitional lamproites). Dotted line separates high-TiO₂ (left) from low-TiO₂ (right) compositions.