THE STATISTICAL CLASSIFICATION OF KIMBERLITE GARNET BY DIVISIVE CLUSTER ANALYSIS AND MULTIPLE DISCRIMINANT ANALYSIS

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Garnet concentrates from eight Somerset Island kimberlites have been classified into statistically significant, compositionally coherant groups of garnet using TWINSPAN , a divisive cluster analysis technique and multiple discriminant analysis (MDA). This scheme for classifying garnet from kimberlite and associated ultrabasic xenoliths is a preferred alternative to agglomerative cluster analysis and non-statistical cluster fusion used by Dawson and Stephens (1976) and Danchin and Wyatt (1979), as it embodies a purely statistical approach. The sample base used in this classification scheme included only garnet in kimberlite concentrate and is believed to be random and representative at the present level of erosion as each intrusion is relatively petrographically simple. On average each population tested was comprised of 225 samples. Mitchell (1978,1979), Dawson (1980) and Jago (1982) concluded that the diverse sample base of other schemes has led to some confusion and misclassification of new samples, (especially Group 1 and Cr-poor Group 9 garnet) and to considerable compositional overlap between discrete groups of garnet characteristic of one kimberlite or kimberlite province with those in another.

TWINSPAN computes the classification by repeated dichotomization (division) of the sample population (Fig. 1) through reciprocal averaging (Hill 1973), a gradient scaling technique. This method classifies both samples and variables, ultimately generating groups of like samples with a characteristic suite of variables. The sample/variable classification is given in an ordered two-way table. The example illustrated in Fig. 2 shows that each cluster is characterized by a suite of variables which are ordered (5) to (1) according to their relative contribution to the characterization of one group compared to the other.

Multiple discriminant analysis (MDA) (Pearce 1974) was chosen to test the statistical significance of the fusion of garnet clusters as it can monitor simultaneously the changes in several variables in an statistical analysis and order the variables according to their ability to contribute to the variation between test groups. Although MDA can not be used directly as a classification tool, the method outlined by Klecka (1975) can 1)determine at what level of statistical significance a prior classifcation of data into two or more subsets falls, 2) the role of each variable contributing to the statistical analysis, 3) into which subset a misclassified case belongs and 4) the rate or percent overall correct case classification of existing subsets.

The principal advantage of TWINSPAN is the linear dependence of computer time to the amount of data analysed, in contrast to other methods in which time requirements rise to the second or third higher order of the number of samples. In addition, TWINSPAN does not store zero values of the data matrix, nor does it produce or store a secondary matrix of sample similarities. Although the method may generate any number of clusters, the statistically optimum number of clusters generated is not determined by TWINSPAN but by multiple discriminant analysis. This is favoured over Danchin and Wyatt's (1979) scheme, as their centroid method of calculation is prone to reversals and the combination of statistically non-similar clusters and Dawson and Stephens' (1976) scheme, which used the rate of change in the number of clusters generated to determine the optimum number of clusters. Both methods ultimately used petrogenetic similarity as a final criteria although this can be highly subjective as it is based upon an a priori knowledge of sample paragenesis.

Our two-level classification scheme illustrated in Fig. 1 initially generates, from a random population of garnet and raw oxide data (TiO_2, Al_2O_3, Cr_2O_3, FeO, MgO, CaO), 'X' clusters of garnet. Using MDA, these are combined at a minimum 95% confidence level and 90% correct case classification to form 'Y', statistically significant, compositionally coherant groups of clusters. This is termed the 'Primary Aggregation Level' (PAL). Each of the 'Y' groups is then disaggregated at the 'Primary Disaggregation Level'(PDL) and the constituent clusters processed by MDA to determine, if within each, there exist 'Z' statistically significant, compositionally coherant subgroups of clusters. Each of the 'Z' subgroups is then tested for compositional variation trends using correlation analysis. Garnet in individual subgroups can then be plotted on multivariate diagrams

TWINSPAN in conjunction with MDA typically generated groups of garnets which lie along three major compositional variation trends, generally comprising six sub-groups. Figures 3, 4 and 5 illustrate an example of our method applied to Nord, one of eight test populations. Solid lines on these figures depict sub-group boundaries defined by a large number of data points, while dashed lines define boundaries which are constrained by relatively few points. Trend 1 garnets are characterized by relatively Ca- and Cr-poor (av. CaO=4.91, av. Cr_2O_3=1.16 wt.%) and Ti-rich compositions and are divided at 'PDL' into relatively Mg-rich, Ti-poor (Trend 1A) and Mg-poor, Ti-rich (Trend 1B) subgroups. Both in general demonstrate a moderate to strong negative correlation between Fe+Ti and Mg at relatively constant CaO. Possible source parageneses include dunite, Cr-poor garnet lherzolite, websterite, pyroxenite and mono- and poly-mineralic macrocrysts. Trend 2 garnets lie along a parallel compositional variation trend to Trend 1 but, in comparison are Ca- and Cr-rich (av. CaO=5.13, av. Cr_2O_3=3.83 wt.%) and may contain up to 1.48 wt.% TiO_2. The compositional variation trend of Trend 2A is similar to Trend 1 in contrast to Trend 2B which exhibits little correlatable variation in major and minor elements and may plot within a relatively restricted compositional range on the Ca-rich side of Trend 2A. Source parageneses include Dawson and Stephens' (1976) Group 11 garnets, Cr-rich macrocrysts, harzburgite and granular and porphyroclastic garnet +/- chromite lherzolite, the latter group dominating. However, lherzolitic garnet is not separated naturally into two groups which are compositionally similar to Trends 2A and 2B suggesting that some other source may be important. Although Nord does not demonstrate the relationship, Trend 3 is composed of Mg-Ti-rich, Ca-poor (Trend 3A) and Mg-Ti-poor, Ca-rich (Trend 3B) subgroups. Overall, it is characterized by the highest Cao and Cr_2O_3 contents (av. CaO=6.09, av. Cr_2O_3=6.87 wt.%) of all groups whilst major and minor elements deomonstrate a positive correlation between Mg and Ti and Ca and Cr and a negative correlation between Mg+Ti and Ca. Trend 3, in contrast to its orientation depicted on Fig. 3, may be orientated subparallel to Trends 1 and 2. Trend 3 garnets are compositinally most similar to Dawson and Stephens' (1976) Groups 10 and 11 macrocrysts, but may include rare Cr-rich lherzolite, harzburgite and Cr-poor knorrigitic garnets.

Trend 1 garnet using Dawson and Stephens' (1976) classification is dominated by Group 1 macrocrysts. Ti-rich compositions characteristic of Trend 1B on average contain a higher proportion of rare Group 2 macrocrysts and a significant component of Cr-poor Group 9 garnet. Trend 2A is dominated by Cr-poor Group 9 and lesser Cr-rich Group 9 garnet while Cr-rich Group 9 characterizes Trend 2B. Trends 3A and 3B are dominated by Ti-poor, Cr-rich Group 9 garnets although Trend 3B may also contain a significant component of relatively Ti-rich Group 11 garnets.

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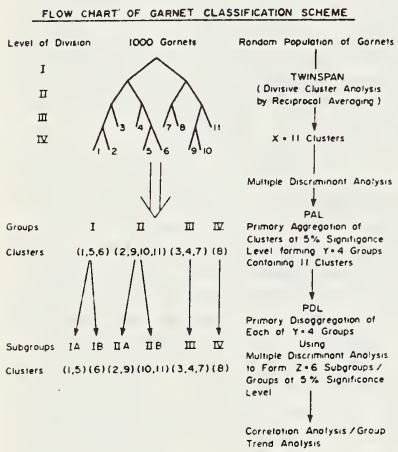

Figure 1

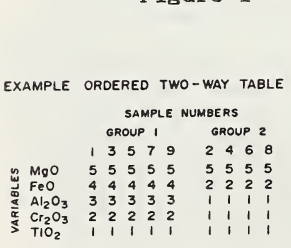

Figure 2

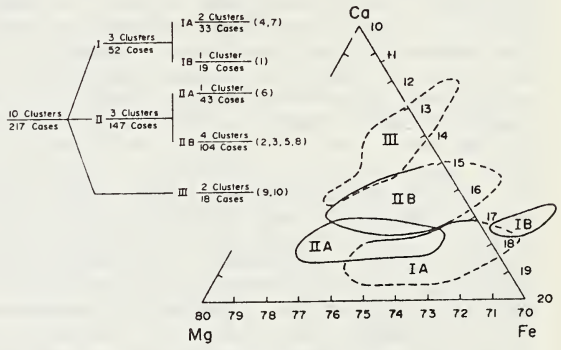

Figure 3

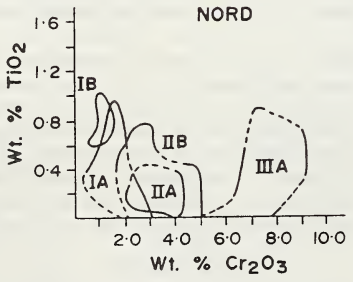

Figure 4

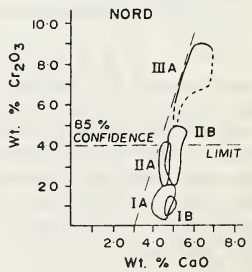

Figure 5