A REVIEW OF RADIOMETRIC DATING METHODS APPLICABLE TO KIMBERLITES AND RELATED ROCKS

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INTRODUCTION

Because of the compositional diversity of kimberlites, no simple dating method can be applied to all occurrences. Furthermore, the altered nature of many kimberlites, at least as far as surface exposures are concerned, diminishes the usefulness of some methods. Dating of diatreme facies (as opposed to hypabyssal facies) kimberlites may also present difficulties because of the presence of contaminants of crustal derivation that may not be isotopically reset during eruptive events.

Rb-Sr METHODS

Phlogopite mica is present in many kimberlites and notably in Group II types. In general two distinct types of mica are present, viz. fine grained groundmass phlogopite and coarser grained phenocrysts and/or xenocrysts. The latter two mica types (here considered together as macrocrysts) are easier to date by virtue of their larger size and higher Rb-Sr ratios. Mineral separation and cleaning is considerably less difficult compared to groundmass mica, and the macrocrysts tend to contain much lower common Sr and consequently more radiogenic Sr. Commonly, a model age from one analysis of macrocrystic mica is sufficient to constrain the emplacement age.

Refinement of the Rb-Sr dating technique in the Bernard Price Institute Isotope Laboratory has led to successful dating of many previously undated kimberlites and related rocks. This has been achieved in part by the development of a mild acid-leaching procedure which significantly reduces the common Sr component originating from carbonates that commonly invade and adhere to mica platelets. Detailed leaching tests on a full range of fresh to altered mica from one locality have shown that the leaching does not remove significant amounts of Rb or radiogenic Sr (Fig. 1) even in the case of moderately altered micas. However isochron representation of Rb-Sr mica data may represent mixing lines (between hypothetically pure mica and carbonate - Allsopp and Barrett, 1975). Consequently the analysis of low-Rb components such as fresh whole rock or primary minerals such as clinopyroxene is advantageous (Smith et al., 1985). The dating of 1 mg samples, with ages as young as 20 m.y., is feasible by the Rb-Sr method. A problem with some kimberlites, that is not alleviated by leaching, is the presence of minor amounts of crustal biotite. At New Elands, biotite is present in the kimberlite and has not been isotopically reset, resulting in anomalously old ages if not completely removed from analysed samples (Smith et al., 1985).

K-Ar METHODS

K-Ar dating of kimberlite whole rocks and micas is also quite feasible, though Ar loss may be a serious problem, especially with altered samples (Fitch and Miller, 1983). The $^{40}Ar/^{39}Ar$ (Smith et al., 1985; Allsopp and Roddick, 1984) provides a method of monitoring Ar-loss. Laser heating Ar-Ar techniques may also have important implications for mica dating, particularly in respect of small sample sizes (see Sutter and Hartung, 1984). Anomalously old mica xenocrysts may present problems to both K-Ar and Rb-Sr dating, though are considered important insofar as mantle studies are concerned.

U-Pb METHODS

Zircon is rare or absent in most kimberlites, but where present is useful material for dating by the conventional U-Pb method. (Davis, 1977; Pidgeon, unpubl. data). Very low U and Pb abundances present problems to conventional U-Pb techniques. The U content of kimberlite zircons is particularly low (<10 ppm) and consequently reasonably large sample sizes, exceptionally high precision, and low blank levels are pre-requisites for the application of this method. The $^{238}U-^{206}Pb$ ages have generally been regarded as the most reliable, but difficulties arise in that such ages may reflect Pb-loss; the concordia approach is thus preferred but in view of blank considerations substantial sample qualities are required. Some published $^{238}U-^{206}Pb$ ages for kimberlites may be unreliable on account of the above considerations. In general U-Pb zircon ages show good agreement with age data obtained by other techniques though some results obtained by Davis may be about 5% too high.

Kimberlitic zircons have been dated by means of the ANU Ion probe, SHRIMP (Bristow, 1986; Kinny et al., this conference). The low U contents present problems to automatic peak selection but, given careful monitoring and sufficient counting times, good results may be obtained.

Perovskite is a common groundmass component of most kimberlites and related rocks. Separation of this commonly very fine grained mineral is, however, difficult. Almost pure perovskite separates can be obtained by dissolution of kimberlite in HF, followed by magnetic separation of perovskite from other insoluble heavy minerals. This procedure is not deleterious to the reliability of the results provided that the perovskite is fresh, with euhedral to rounded morphology. Perovskite characterized by anhedral, skeletal morphology (commonly with "atoll" structures) apparently do not give reliable results. Th-Pb ages on perovskites are also feasible and provide an additional check on data reliability.

FISSION TRACK METHODS

The fission track method has been applied successfully to both kimberlitic zircons (Naeser and McCallum, 1977; Haggerty et al., 1983) and apatites. Kimberlitic zircon tend to be strongly refractory and etching of tracks is much more difficult than is the case with crustal zircons. Also the low U abundance of these zircons results in fewer tracks to count and hence poorer precision. To some extent this is overcome by the large size of kimberlitic zircons which allows analyses of a greater number of samples from a single grain. In the case of apatites, ages have been obtained from both primary matrix apatite and from apatite obtained from xenoliths contained in intrusions. The ages of apatite in xenoliths are reset and though only limited data are thus far available the method appears to have wide application (see Naeser, 1971; Gleadow and Edwards, 1978). An advantage of this method is that alteration does not have particularly adverse effects, and samples from surface exposures may be used. A disadvantage is that fission tracks may be annealed, particularly in apatites, by subsequent thermal events adjacent to or affecting the kimberlite or related rock intrusions. Consequently fission track ages may not necessarily represent true emplacement ages and must be interpreted with caution.

CONCLUSION

Emplacement ages of kimberlites and related alkalic rock types may be determined by a wide variety of techniques, though in terms of routine procedures Rb-Sr mica dating is probably the most commonly used technique; zircons are a rare component of most kimberlites and separation of perovskite in sufficient amounts for U-Pb analysis is exceedingly difficult. Mild-acid leaching procedures have been shown to greatly improve the success of Rb-Sr mica dating, even on altered samples. Finally it should be emphasized that careful petrographic inspection of any mineral or specimen considered for dating is essential.

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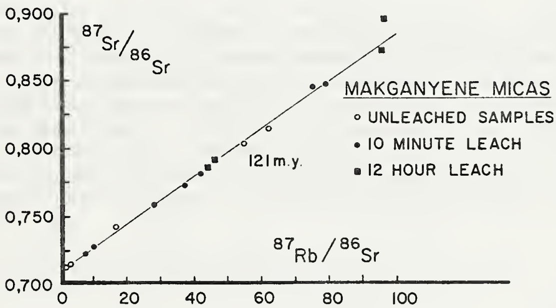

FIGURE 1