CERIUM ISOTOPES - NEW ASPECTS FOR KIMBERLITE GENESIS BY A NEW ISOTOPIC SYSTEM

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The radioactive decay of La-138 to Ce-138 with a halflife of 112×10^9y can be used for age determination but is especially interesting as an indicator for rare earth element fractionation, isotopic evolution and correlated geological processes (Tanaka, 1982).

The change of the valency from 3+ to 4+ by a temporary high oxygen fugacity is an outstanding feature of Ce (besides Eu) within the REE which may cause Ce anomalies. In meteorites and lunar rocks these anomalies reach 20% and more. Therefore the La-Ce system should be especially useful as an indicator of chemical processes involved in the genesis of crustal and mantle rocks.

We report here the first Ce isotopic data obtained for kimberlites. Three fresh South African kimberlites were analyzed for the radiogenic ratio Ce-138/Ce-142 (normalization ratio is Ce-136/Ce-142=0.01720) and compared with other terrestrial samples. The Jwaneng kimberlite (basaltic - Group I) has a significantly less radiogenic Ce-138/Ce-142 isotopic composition compared to the New Elands and Finsch kimberlites (micaceous - Group II) and to other terrestrial rocks. The measured differences for the isotopic composition of Ce between the two types of kimberlites reflect distinct mantle reservoirs with significant differences in Ce-138/Ce-142: the Group I kimberlite with Ce-138/Ce-142=0.02287955±44 clearly differs from the mean of the two Group II kimberlites which is Ce-138/Ce-142=0.0228261±12(2σ). The Group II kimberlites are identical within 1σ. In terms of ε-deviation from the chondritic uniform reservoir (BCR-1: Ce-138/Ce-142=0.0228166) this is $-9.2 \pm 1.9\varepsilon$ for Group I and $+4.2 \pm 0.5\varepsilon$ for Group II kimberlites, a total variation of $13.4 \pm 2.4\varepsilon$.

New Elands and Finsch, Group II, may be derived from an enriched source as initial Sr and Nd isotopic ratios and high time-averaged Rb/Sr and Sm/Nd indicate, whereas Jwaneng, Group I, should come from an undifferentiated to slightly depleted source relative to bulk earth (Smith, 1983). For Group II this seems to be consistent with the isotopic data of Ce though the slightly radiogenic ratio Ce-138/Ce-142 compared to bulk earth and a "normal" Pb-206/Pb-204 ratio close to the geochron are more likely derived from a bulk-earth-like source region. In contrast the higher Pb-206/Pb-204 ratio of the Group I corresponds to a much less radiogenic Ce. This indicates anomalous time-averaged Pb/U and La/Ce ratios in the sources of Group I kimberlites significantly lower than in bulk earth. The measured La/Ce ratio of Jwaneng normalized to the chondritic value is 1.55; most terrestrial La/Ce ratios are between 0.5 and 2.0 (Schier, 1983). The calculated La/Ce ratio of the Group I source derived from the chondritic evolution line is dependent on its age and the measured radiogenic Ce of this Group I kimberlite: for 4.5 b.y. the La/Ce ratio of the source would be 0.42 and becomes zero at the minimum source age of 2.6 b.y. The corresponding range of the Sm/Nd ratio is much smaller, varying from 1.04 at 4.5 b.y. to 1.06 at 2.6 b.y. These calculated source ratios of Group I, required to generate the present-day Ce-138/Ce-142 and Nd-143/Nd-144 ratios, are unlikely caused by normal differentiation processes. Melting curves combined with the La/Ce-Sm/Nd correlation line of source ratios as a function of time should give more information about the generation of this kimberlites´s source rock.

Starting from a chondritic reservoir for melting calculations, and provided that the La/Ce-Sm/Nd correlation line for the generation of the source represents all possible La/Ce and Sm/Nd ratios of the endproducts of melting as a function of time, it is apparent that a batch melting process cannot generate the source of the Group I kimberlite at any time, either as the residuum or as the melt. No batch melting curve, either for the liquid or the solid, intersects the La/Ce-Sm/Nd correlation line (see Fig.1). Agreement was found for continuous melting calculations (Langmuir, 1977) which showed that the possible range of Group I source ratios La/Ce and Sm/Nd result from a liquid (enriched in LREE) rather than the residue. It was postulated previously

(Wyllie, 1975) that fractional fusion can produce kimberlitic magmas. A corresponding calculation was performed as a 3% continuous melting of a chondritic source with total removal of the melt. The resulting liquid has the required La/Ce and Sm/Nd ratios 2.7 b.y. ago to generate the present-day Ce-138/Ce-142 and Nd-143/Nd-144 ratios, and could therefore serve as a 2.7 b.y. old source for cretaceous southern African kimberlites.

A second and much discussed event of melting of this original source occured 90 m.y. ago (Smith, 1983) which again changed the La/Ce and Sm/Nd source ratios by enrichment of the LREE in the resulting liquid. The measured La/Ce and Sm/Nd ratios of the kimberlite represent the ratios in this liquid (Kramers, 1981). The radiogenic isotopic ratios of Ce and Nd are long-time-fractionated and should therefore reflect an original source feature of kimberlites.

REFERENCES

TANAKA T. and MASUDA A. 1982. The La-Ce geochronometer: a new dating method. **Nature** 300, 515-518.

SMITH C.B. 1983. Pb,Sr and Nd isotopic evidence for sources in southern African Cretaceous kimberlites. **Nature** 304, 51-54.

SCHIER D. 1983. Entwicklung eines Ionenaustausch-Trennverfahrens und massenspektrometrische Isotopiebestimmung des Cers (Seltene Erden) als Grundlage einer neuen radiometrischen Altersbestimmung, **Diplomarbeit (unpubl.)** . MPI für Chemie, Mainz, 72.

LANGMUIR C.H. et al 1977. Petrogenesis of basalts from the Famous Area mid-atlantic-ridge. **Earth and Planetary Science Letters** 36, 133-156.

WYLLIE P.J. and HUANG W.-L. 1975. Peridotite, kimberlite, and carbonatite explained in the system CaO-MgO-SiO_2-CO_2. **Geology** 3, 621-624.

KRAMERS J.D. et al. 1981. Can Kimberlites be generated from an ordinary mantle ? **Nature** 291, 53-56.

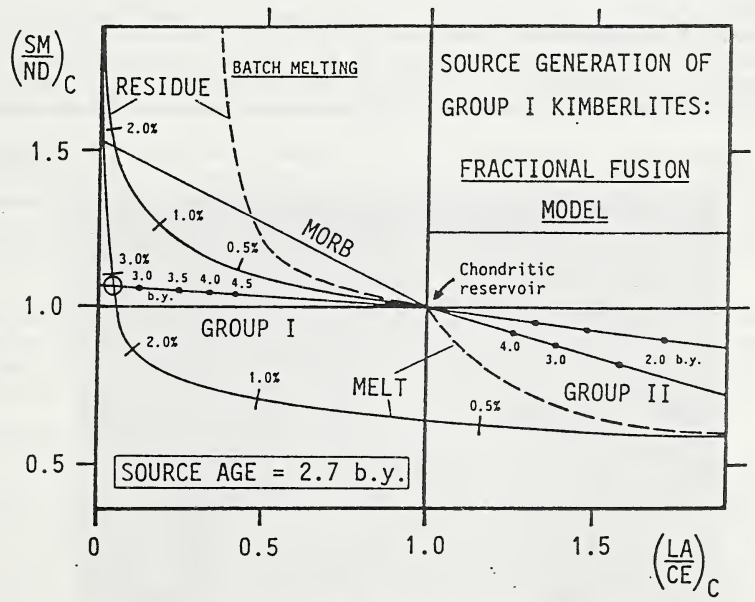

Figure 1.