THE CARBON ISOTOPIC COMPOSITION OF CARBONATITES, KIMBERLITES, AND DIAMONDS

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The carbon and oxygen isotopic composition of carbonates from
14 carbonatite complexes and 11 kimberlites have been measured,
and additional occurrences from Canada, East Africa, Greenland,
and Australia are being processed.

While there is some overlap in carbon and oxygen isotopic
composition of carbonate species, e.g., dolomite (rauhaugites),
ankerite and siderite (rodbergites), are enriched in C^{13} by about
2.2, 2.0, and 3.5‰ respectively with respect to calcite (sovites).
Other intrinsic variable are indicated in carbonatite processes by
the range in mean carbon isotopic composition of some well known
carbonatites (Table 1), and the spatial and temporal relationships
with the rift valleys in the East African carbonatites (Table 2).
Likewise there is a spread in isotopic composition of seven
Canadian carbonatites from $\partial C^{13} = -2.4‰, \partial O^{18} = 10.7‰$ for St. Andre,
Quebec to $\partial C^{13} = -7‰, \partial O^{18} = 7‰$ for Lackner Lake, Ontario.

The clustering of values of certain carbonatite complexes in
$\partial C^{13} - \partial O^{18}$ space (Figure 1), separates into groups of (a) deep-
seated or hyperbyssal carbonatites with restricted fields, and (b) a
near surface "volcanic-subvolcanic association" carbonatite with
much greater fields. The larger oxygen isotopic composition
range extending towards higher O^{18} contents for carbonatites of
shallower levels may be due to: (1) a loss of isotopically light-water
during pressure reduction at the time of emplacement: (2) an
equilibration of some of the carbonates with magmatic carbonatite
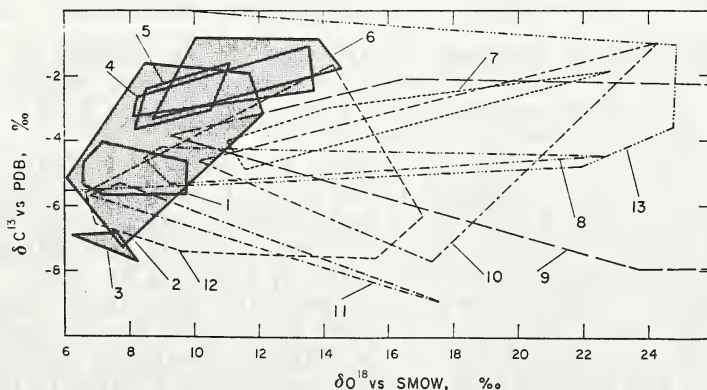waters to low temperatures; (3) an influx of meteoritic water. In

Fig. 1. The carbon and oxygen isotopic composition ranges of carbonatite com-
plexes.

1. Oka; 2. Alnö; 3. Laacher See; 4. Sukulu Hill; 5. Tororo Hill; 6. St.
André; 7. Homa Mountain; 8. Albany Forks; 9. Ruri; 10. Rangwa; 11. Magnet
Cove; 12. Kaiserstuhl; 13. Mbeya.

The Oka field is restricted to multiple readings only.

Table 1. The carbon isotopic composition of selected carbonatites

Location	Mean δC^{13}	Rock type	Source
1. Complexes for which a large number of analyses have been carried out.			
St. Honoré	−4·7	all rocks	This work
Oka	−5·0	all rocks	DEINES (1970a)
2. Complexes for which few isotopic composition analyses are available, showing, a restricted carbon and oxygen isotopic composition range			
St. André	−2·6	rauhaugites	This work
Tororo	−2·7	sövites	This work
Sukulu	−2·7	sövites	This work
Mbeya	−3·4	sövites, rauhaugites	SUWA et al. (1969)
Alnö	−5·5	sövites	TAYLOR et al. (1967), BAERTSCHI (1957) ECKERMANN et al. (1952)
Magnet Cove	−5·5	sövites	CONWAY and TAYLOR (1969), This work
Oldoinyo Lengai	−5·8	natro-carbonate lava	DENAEYER (1970), VINOGRADOV et al (1970) O'NEIL (1971)
Kaiserstuhl	−6·2	sövites	GONFIANTINI and TONGIORGI (1964)
Laacher See	−7·1	sövites	TAYLOR et al. (1967)
3. Complexes for which only carbon isotopic composition measurements have been reported (four analyses and more)			
Chadobets	−3·4	ankerite sövite	BAGDASAROV et al. (1969)
Potvornyy	−5·2	sövites	VINOGRADOV et al. (1967)
Ozerny	−5·6	sövites	VINOGRADOV et al. (1967)
Kerimasi	−5·8	sövites	VINOGRADOV et al. (1970)
Sanskiy	−6·3	sövites	VINOGRADOV et al. (1967)
4. Individual analyses of carbonatite carbonates with oxygen isotopic compositions between 6 and 8‰ vs SMOW			
Spitzkop	−5·3	sövite	BAERTSCHI (1957)
Cripple Creek	−5·4	olivine syenite	TAYLOR et al. (1967)
Iron Hill	−5·6	sövite, rauhaugite	TAYLOR et al. (1967), BAERTSCHI (1957)
Lueshe	−5·9	sövite	DENAEYER (1970)
Nemegosenda Lake	−6·5	sövite	This work
Lackner Lake	−7·0	sövite	This work

the latter case any isotope exchange would have to be limited to below 250°C, because at higher temperatures an exchange with ordinary surface or ground waters ($\delta O^{18} <$ 0‰) would lead to a depletion in O^{18} in the carbonate below 6‰.

We conclude that the spread in carbon and oxygen isotopic composition in carbonatite complexes is due not only to the carbonate species present, but also is a function of geographic locality and depth of emplacement. By analysing rocks only with like minerals and taking the mean of a large population of samples, and by applying an "emplacement level" filter to include only those analyses lying in the range δO^{18} = 6 to 8‰ (the range for feldspars from ultramafic rocks, which by analogy should be the range for primary, high temperature carbonates) we believe we are looking at geographic variations related to the source material. Table 1 represents a compilation of filtered results, with a mean carbon isotopic composition of -5.1‰, and a standard deviation of ± 1.4‰, vs PDB,

Because diamonds, kimberlite carbonates and carbonatites are thought to derive their carbon from similar depths, we can ponder the question of how uniform the isotopic composition of carbon might be in the mantle. A review of the available data on the carbon isotopic

Table 2. Spatial and temporal isotopic composition relationships
of carbon in East African carbonatites

Approximate age relation	Location				
	W. Rift	Lake Victoria	Lake Malawi (Nyasa)	Lake Chilwa	E. Rift
Recent					−5·9
Rift volcanism	−5·7 to −7·9				−5·8 to −7·4
Mt. Elgon volcanism		−2·4			
Kavirondo rift volcanism		−3·3 to −4·4			
Tororo intrusions		−2·7 to −2·9			
Mbeya carbonatite			−3·4		
Chilwa intrusive series, Cretaceous				−2·3 to −3·2	

composition ranges of carbonatite and kimberlite carbonates shows that they are similar and overlap that of diamonds except for the anomalously light (∂C^{13} = -27.8 to -28.4) carbonados. The mean for 22 selected carbonatite complexes (-5.1‰, s = + 1.4‰ vs PDB) is indistinguishable from that of 13 kimberlite pipes ($\bar{}$-4.7‰, S = + 1.2‰) as well as that of 60 individual diamond analyses (-5.8‰, $\bar{s}$ = ± 1.8 ‰). The oxygen isotopic compositions of kimberlite carbonates (10.5 to 15.5‰), however, are enriched in O^{18} by several permil with respect to those of carbonates from the subvolcanic type of carbonatite.

The data suggest that not all carbonatite, kimberlite (1.6 to 9.0 ‰) and diamond occurrences have the same average carbon isotopic composition and that significant difference exist between them. The available diamond analyses are plotted in Figure 2 and compared with those of the kimberlite carbonates. Diamonds from the Kimberley pipes are enriched in C^{13} (mean ∂C^{13} = -2.9) with respect to the Zairian pipes of Tshaba (-6.6), and Disele (-6.8) and the Mir pipe (-7.5) in Siberia.

If the filtered analyses of sovites of subvolcanic carbonatites are adequate to represent the carbon isotopic composition of the total carbon in a carbonatite, and that no major losses of carbon have occurred in the formation of carbonatites, one is led to the conclusion that the carbon isotopic composition of the original carbonatite magmas differed. This might be due either to isotopic inhomogeneities in the source of the carbonatite carbon, or to isotope effects in the derivation of the carbonatite magma from its ultimate source. In this connection it would be interesting to study the carbon isotopic composition difference between diamonds and carbonate in kimberlites, because such isotope effects should be different for reduced and oxidized forms of carbon. Theoretical computations suggest that even at $1000^{\circ}C$ considerable isotopic composition differences should exist between diamond, carbon dioxide and carbonate. At this temperature diamond would be expected to be 4.4‰ lighter and calcium carbonate about 2‰ lighter than carbon dioxide, so that diamond would be depleted in C^{13} about 2‰ compared to calcite at isotopic equilibrium. A general
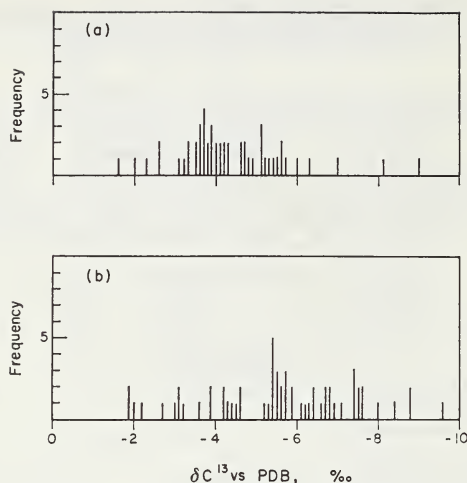
Fig. 2 The carbon isotopic composition of carbonates from kimberlites (A), and of diamonds (B).

shift of the diamond carbon isotopic compositions towards lower C^{13} concentrations is not apparent (see Fig. 2) from the present data, although the number of available analyses may be too small to show this effect. Analyses of both carbon-bearing phases from the Mir Pipe shows essentially the same isotopic composition for carbonate and diamond.

If carbonatite or kimberlite carbonates as well as diamonds represent samples of carbon, the isotopic composition of this carbon can be bracketed only within the limits of -2 to $-8^{\circ}/oo$. The overall average C^{13} content of such carbon might be close to the average of the three sample types studied here, which is $-5.2^{\circ}/oo$. However, the selection of this or any other value within the above given range as a criterion for deep-seated carbon sources cannot be justified, because the source of kimberlite, carbonatite and diamond carbon may not be uniform isotopically.