CHAPTER X Stable Isotopes in the Carbonatites

X.1 Introduction:
Isotope geochemical studies, in recent years, are considered most important in the petrogenetic interpretation of igneous rocks. The stable isotopes are regarded as the consequence of mass fractionation in chemical reactions. In general, mass fractionation effects are comparatively small, except for the lighter elements, O, H, C and S.
It is observed that rocks of the continental crust have very different stable isotope compositions from those of the mantle, and thus, isotopic studies can provide important constraints on the extent of crustal contamination in lavas or magmas. Although stable isotopes may become fractionated by crystal-liquid differentiation processes, yet the magnitude of these effects is small compared to the difference in isotopic composition between crustal and mantle reservoirs (Wilson, 1989). Therefore, Oxygen isotope studies are extensively used in petrology.

Oxygen has three stable isotopes, $^{16}$O, $^{17}$O and $^{18}$O. Its isotopic composition in a sample is generally reported in terms of a parameter $\delta^{18}O$, which is the difference between the $^{18}O / ^{16}O$ ratio of the sample and that of a Standard called SMOW (Standard Mean Ocean Water).
Crystal-liquid fractionation processes during partial melting and subsequent fractional crystallization may potentially cause variations in the oxygen isotope composition of magmas. (Kyser et al. 1982). However, at magmatic temperatures the mass fractionation of oxygen isotopes is much less pronounced than at atmospheric temperatures and consequently, the effects are only small (Faure, 1986). Thus, broadly speaking, primitive basaltic magmas should have oxygen isotopic compositions which directly reflect those of their mantle source. Based on the above considerations, the stable isotopic studies of the carbonatites, of the Samchampi Alkaline Complex of the Karbi Hills have been made to gain some informations of the conditions of formations of the carbonatites.

The carbonatites (both calcio and magnesio carbonatites) of the Samchampi-Samteran Alkaline Complex were analysed for stable isotopes, particularly for Carbon and Oxygen at Physical Research Laboratory, Ahmedabad. The results are given below.

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Sample No</th>
<th>$\delta^{13}$C (‰) PDB</th>
<th>$\delta^{18}$O (‰) PDB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1/93</td>
<td>-3.68</td>
<td>-22.62</td>
</tr>
<tr>
<td>2</td>
<td>71</td>
<td>-3.84</td>
<td>-22.94</td>
</tr>
<tr>
<td>3</td>
<td>165</td>
<td>-2.96</td>
<td>-22.88</td>
</tr>
<tr>
<td>4</td>
<td>177</td>
<td>-3.68</td>
<td>-23.12</td>
</tr>
<tr>
<td>5</td>
<td>179</td>
<td>-3.50</td>
<td>-23.10</td>
</tr>
</tbody>
</table>
The isotopic composition is generally expressed in delta (δ) notation as per mil deviations (‰) from a reference sample. The reference samples are Standard Mean Ocean Water (SMOW) for δ\(^{18}\)O : δ\(^{16}\)O; Pee Dee Belemnite (PDB) for δ\(^{13}\)C : δ\(^{12}\)C; and Canyon Diablo Trilite (CDT) for δ\(^{34}\)S : δ\(^{32}\)S. The oxygen isotope results for the carbonatites of the area are given in PDB which can suitably be converted into SMOW by using the formula:

\[ \delta^{18}O_{\text{SMOW}} = 1.03088 \times \delta^{18}O_{\text{PDB}} + 30.86 \]

By using this conversion the δ\(^{18}\)O PDB (‰) became

\[
\begin{align*}
1 & = 7.54 \\
2 & = 7.21 \\
3 & = 7.27 \\
4 & = 7.02 \\
5 & = 7.04
\end{align*}
\]

The isotope variation in the carbonatite may be attributed due to (a) isotopic composition variation in source magma (b) resulting from fractionation process during carbonatite evolution and (c) due to post magmatic alteration (Deines, 1989).

X.2. Oxygen

The oxygen isotopic composition of the carbonatites of the area is fairly uniform. The δ\(^{18}\)O SMOW values of the carbonatites fall within the world δ\(^{18}\)O ‰ for carbonatites between 5 ‰ and 25 ‰. The mean oxygen isotope values in
Chondrites, Achondrites, ultramafic xenoliths in basalts are given below.

Chondrite = 5.3 ‰
Achondrite = 4.5 ‰

Grand mean for = 4.9 ‰
all stony meteorite

Ultramafic xenolith from basalt and kimberlite = 5 ‰ and 7 ‰+ 0.4 ‰

Unaltered basalt = 6.1 ‰

Data from meteorites, mafics and ultramafic xenolith and basalt indicate that O isotope composition of the mantle lie between 5 ‰. and 6 ‰., although the existence of mantle reservoir of isotopic composition outside this range has also been considered (Kyser et al. 1982; Kyser, 1988; Taylor and Sheppard, 1986).

The mantle silicate had average $\delta^{18}O$ values between 5 ‰. and 6 ‰. and carbonate melt fractionated $\delta^{18}O$ to the same degree as calcite, the $\delta^{18}O$ values of carbonate melts lie between 7 ‰. and 8 ‰. (Deines, 1989). The oxygen isotope values for the carbonatites fall very much within these values.

X.3 Carbon

The $\delta^{13}C$ in carbonatites range from -2.96 ‰ to 3.84 ‰. PDB. Deines and Gold (1973) reported $\delta^{13}C$ values of -2.8 ‰ for the carbonatites of East Africa which exactly matched with the carbon isotope values of Samchampi. Pineau et al. (}
1976) suggested -4 ‰ PDB as the starting composition of δ13 C.

In comparison to this primitive δ13 C composition the δ13 C values of the Samchampi carbonatites show a marginal enrichment (-2.8 ‰ to -3 ‰). Pineau et al calculated the path of Raleigh fractionation at 700 °C in a closed system. The slope of the path was determined by H2O/CO2 mole ratio. The most pristine isotope composition for Samchampi calcio-carbonatite corresponds to δ18 O = +7.02 and δ13 C = -3.68. However, when compared with the pristine sovite of Mundwara and Barmer (Sarkar and Bhattacharya, 1992) the δ13 C values of Samchampi carbonatite show enrichment in carbon. This marginal enrichment is attributed to the fractional crystallization process.

Assuming the mantle silicate have 18 O value 5.7 ‰ and that the mode of carbonatitic carbonate at 7.5 ‰ represents isotopic equilibrium temperature lies between 1100 °C and 1200 °C (Deines, 1989).

As suggested by Pineau et al. (1976) and keeping in view the carbon enrichment, it is inferred from Raleigh fractionation trend the carbonatite of the Samchampi are mantle derived and formed from fractionation of liquid charged with CO2 and H2O.
The large range in $\delta^{18}O$ is accompanied by only minor changes in $\delta^{13}C$. The extreme $\delta^{18}O$ values can be attributed to secondary processes in which $\delta^{13}C$ and $\delta^{18}O$ may or may not be correlated. (After deines, P.-1989).

Fig. 10.

O smow vs $\delta^{18}C$ PDB plots of carbonatites.

& Samchampi.