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A note on the calcite-dolomite exsolution in the carbonatite magma of Amba Dongar diatreme, Gujarat, India

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ABSTRACT

The sub-volcanic carbonatite-alkalic diatreme at Amba Dongar sövite is voluminous in the form of a ring dike and isolated plugs, followed by plugs, dikes and numerous veins of ankeritic carbonatite. Dolomitic carbonatite is not exposed anywhere, however, minute streaks of this occur along with bands in banded sövite exposures. Electron microprobe analytical data on some of the thin sections of sövites from the ring dike exsolution between calcite and dolomite is examined and this exsolution phenomena found in some sövite sample of Amba Dongar complex is discussed.

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1. Introduction

In the Amba Donga complex, sövite is the predominant type of carbonatite that is composed of calcite, apatite, barite, magnetite, phlogopite, aegirine-augite, and REE-minerals such as monazite, bastnäsite, parasite and synchysite. Sövite exhibits a diversity of grain sizes in different parts of the ring dike. Near the contact of sövite with the inner rim of carbonatite breccia and away from this contact to the outer rim of sövite ring dike the grain-size variation is imminent. For the first few meters, the sövite outcrops are coarse-grained, which subsequently become medium grained and towards the outermost part of the ring dike, the grain size becomes extremely fine-grained in contact with Bagh sandstone (Viladkar, 1981).

2. Petrography and BSE images

More than 50 thin sections of various sövite samples from different parts of the ring dike were examined by petrological microscope with focus on the carbonate mineralogy. In thin sections large variation in grain size was observed. This led to mainly three textural types: coarse, medium and porphyritic carbonatites. In the porphyritic type calcite rhombohedra are set in fine-grained groundmass consisting of anhedral calcite.

The exsolution phenomenon is observed during the electron microprobe analysis of thin sections and relevant BSE images are presented here (Fig. 1–5). The existence of exsolution texture between calcite and dolomite is clearly observed during the analytical work. Large numbers of BSE images were taken and few are selected to discuss this phenomena in following sections.

Some BSE images give clear indication on the relationship between calcite and dolomite and the exsolution phenomena (Fig. 1–5). The exsolution texture, in general, indicates that originally calcite and dolomite were at equilibrium, and subsequently, both minerals got exsolved in subsolidus state from a homogeneous carbonatite magma.

Out of the large number of analyses only the representative analyses of calcite, dolomite and strontianite are given in Table 1. In following figures the analyzed carbonate numbers correspond to the numbers in Table 1.

Compositions of analyzed carbonates the samples 1203 and 1223 are plotted in the phase system

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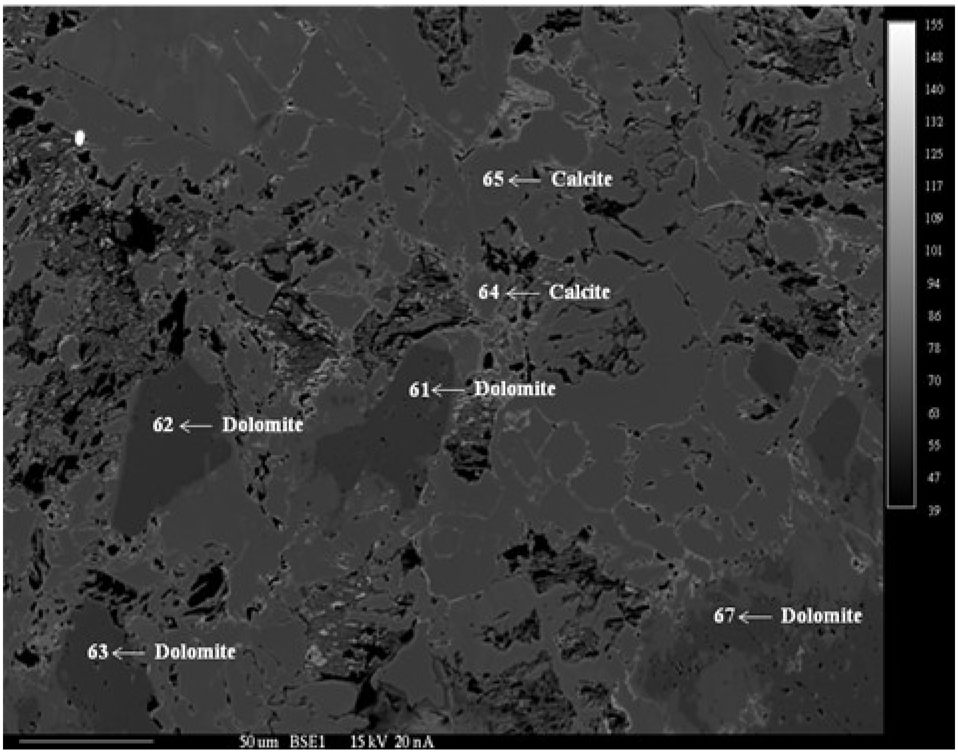

Fig. 1. Exsolved dolomite in the Sample 1223.

Table 1. Selected carbonate analyses from Amba Dongar carbonatites.

Sample No. 1223												
	FeO	MnO	MgO	CaO	SrO	BaO	$FeCO_3$	$MnCO_3$	$MgCO_3$	$CaCO_3$	$SrCO_3$	Total
4	0.26	1.27	21.50	28.77	0.80	0.08	0.00	2.00	50.00	48.00	1.00	101.00
5	0.50	0.50	0.30	55.00	0.77	0.16	1.00	1.00	0.00	97.00	1.00	100.00
3	0.00	0.00	0.00	5.68	59.35	0.05	0.00	0.00	0.00	15.00	85.00	100.00
6	0.07	0.30	20.38	27.11	1.14	0.04	0.00	0.00	48.00	50.00	1.00	99.00
7	0.03	1.40	0.17	53.52	0.40	0.11	0.00	2.00	0.00	97.00	0.00	99.00
9	0.00	0.52	21.34	30.46	1.21	0.00	0.00	1.00	49.00	50.00	1.00	101.00
10	0.26	1.83	19.80	29.74	1.03	0.10	0.00	2.00	46.00	50.00	1.00	99.00
11	0.60	2.20	21.18	29.05	1.07	0.00	1.00	3.00	48.00	47.00	1.00	100.00
Sample No. 1203												
	FeO	MnO	MgO	CaO	SrO	BaO	$FeCO_3$	$MnCO_3$	$MgCO_3$	$CaCO_3$	$SrCO_3$	Total
1	0.09	1.75	20.17	29.24	0.65	0.02	0.00	2.00	47.00	49.00	1.00	99.00
2	0.29	0.49	12.50	39.91	1.45	0.15	0.00	1.00	30.00	68.00	1.00	100.00
3	0.47	0.60	21.49	29.49	1.40	0.13	1.00	1.00	49.00	48.00	1.00	100.00
5	3.87	3.92	41.82	0.63	0.22	0.02	5.00	5.00	89.00	1.00	0.00	100.00
5	0.61	0.36	33.89	12.03	0.49	0.03	1.00	0.00	78.00	20.00	0.00	99.00
6	0.45	1.28	35.71	10.83	0.52	0.00	1.00	2.00	80.00	17.00	0.00	100.00
7	0.35	2.35	19.17	29.39	0.81	0.30	0.00	3.00	45.00	50.00	1.00	99.00
8	0.26	0.90	19.50	30.90	0.45	0.04	0.00	1.00	46.00	52.00	0.00	99.00

$CaCO_3$-$MgCO_3$-$FeCO_3$ (Fig. 6 and 7, after Anovitz and Essene, 1987) and only representative analyses are given in Table 1. In Amba Dongar, both FeO and MnO contents of dolomite and calcite (1203 and 1223) are very low. Higher concentration of Fe and Mn in calcite and dolomite are known from the carbonatites worldwide. Yang and Le Bas (2004) stated that the FeO content of calcite could affect the calcite-dolomite geothermometry, while Gittins (1979) advocated that the Mg diffusion can also affect this geothermometry.

Presence of strontianite is conspicuous in many thin sections of sövite. In general, strontium content of carbonatites in Amba Dongar is high and varies between 0.40 to 1.21% in sample 1223 and between 0.22 and 1.45% in sample 1203. Buckley and Woolley (1990) who worked on the carbonates of the magnesite-siderite series from four African carbonatite complexes and Newania, India reported much lower Sr values in dolomite from Lueshe, Kangankunde, Chipman Lake and Newania carbonatites. While Zaistev (1996) reported unusually high

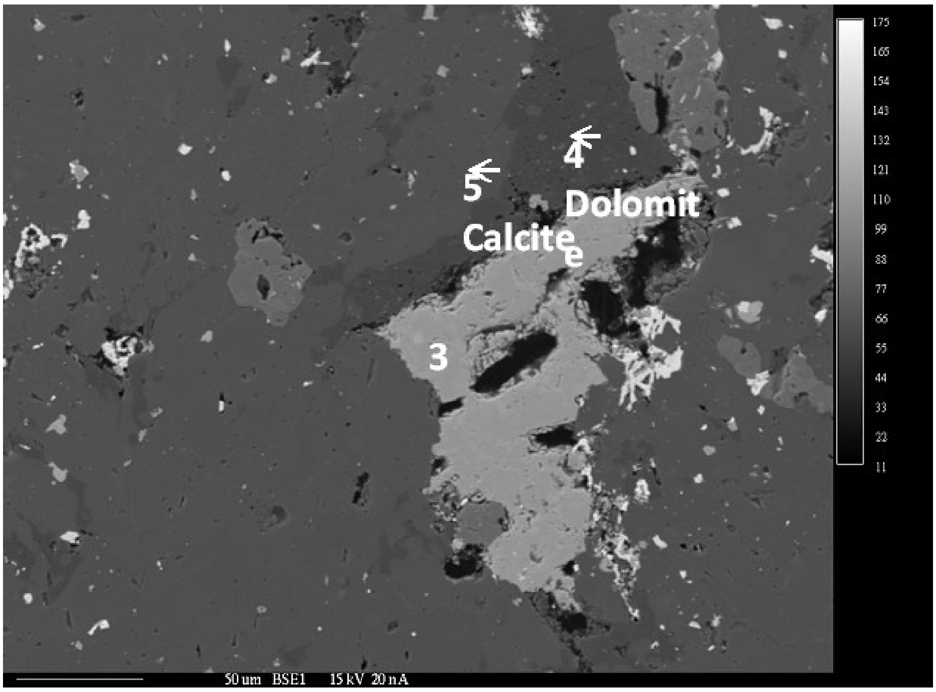

Fig. 2. Numbers 3, 4 and 5 (sample 1223) correspond to analyses numbers in Table 1.

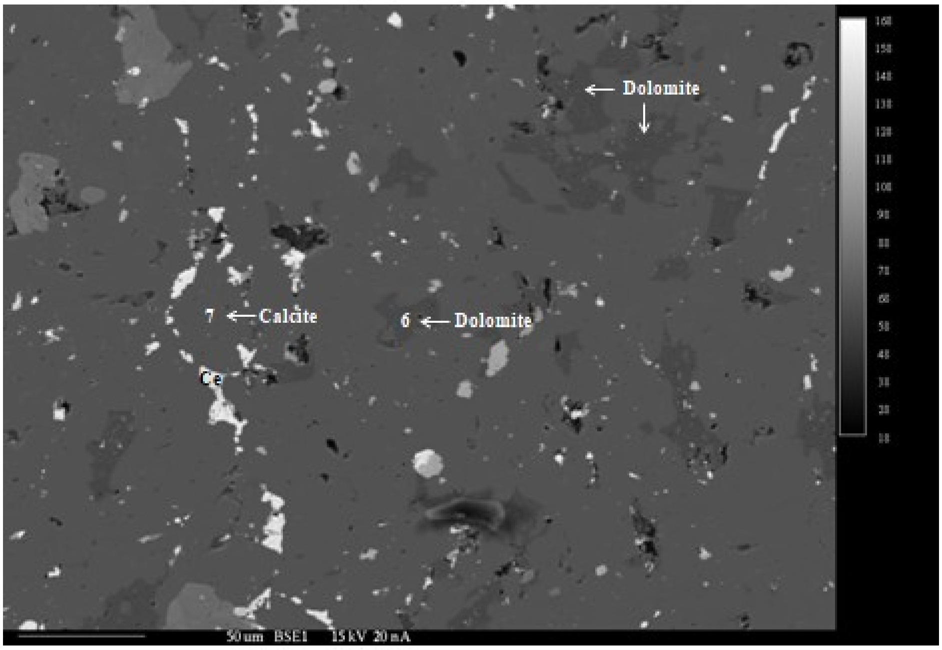

Fig. 3. Strontianite (bright spots) around some calcite grains (1203).

Sr values from Khibina carbonates. In Amba Dongar, carbonatite melt concentration of Sr seems to be high and reaches up to 4% in apatite and 1.21% in carbonatite (Viladkar, 1981).

Carbonate compositions show large spread from calcite end member to dolomite but do not cross over to $MgCO_3$. This is evident in the ternary diagram of sample 1203 while such continuous spread is absent in sample 1223 (Fig. 7). In Amba Dongar, during the fractionation of carbonatite magma, calciocarbonatite has evolved to ankeritic carbonatite (Viladkar, 2012).

Though the dominant carbonate in sövite is calcite, inclusions of dolomite are seen in various samples of the sövite ring dike.

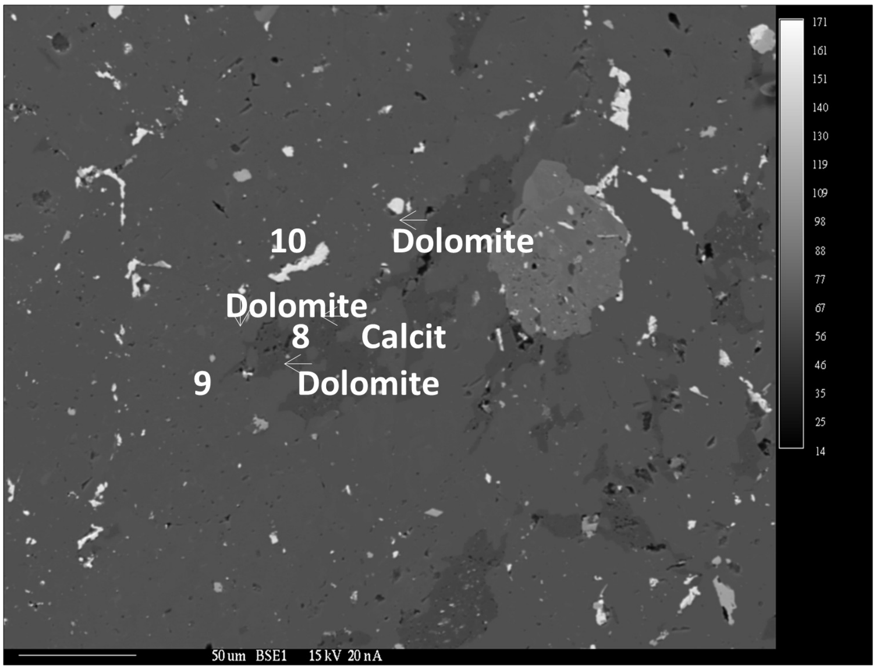

Fig. 4. Number 9 and 10 correspond to analyses number 9 and 10 in Table 1. Bright spots are of strontianite.

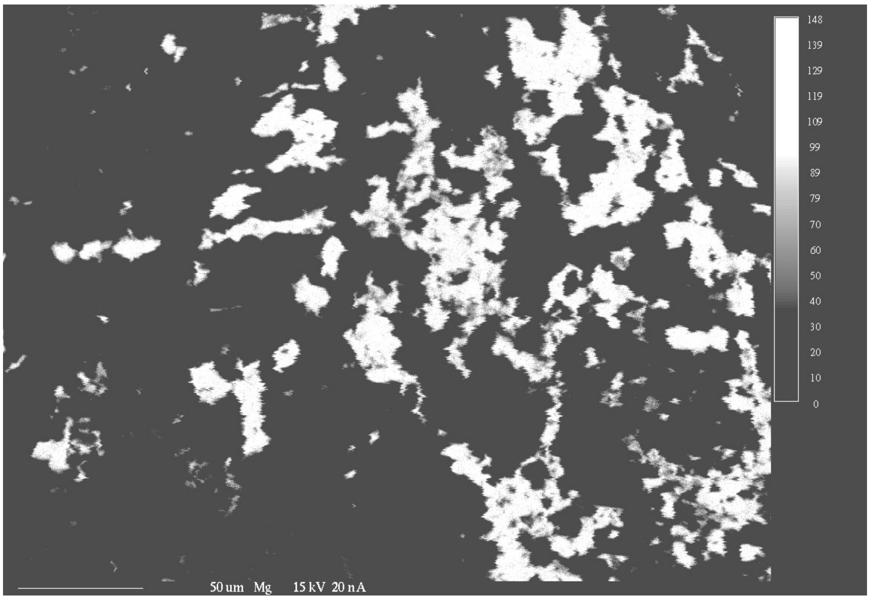

Fig. 5. Relation between strontianite (bright) and calcite in sample 1203.

Table 2. Analyses of periclase from sovites of Amba Dongar.

FeO	MnO	MgO	CaO	SrO	BaO	Total
0.41	0.54	98.85	0.13	0.00	0.05	99.98
10.90	2.64	85.99	0.45	0.00	0.00	99.98
0.80	1.60	96.25	1.33	0.00	0.00	99.98
1.41	0.78	97.40	0.39	0.00	0.01	99.98
3.25	1.80	94.57	0.39	0.00	0.11	100.12

3. Discussion

Electron microprobe analyses of carbonate phases suggest that in the Amba Dongar area, the carbonatite magma at the time of emplacement was not pure $CaCO_3$ but had good amount of Mg in the carbonatite melt. Viladkar and Wimmenauer (1992) reported presence of periclase in some samples of sövites from Amba Dongar carbonatite. Presence of periclase (Table 2; periclase chemistry) indicates that the original melt was Mg-rich. It also suggests that the magnesian component was present in sufficient amount during crystallization of the carbonatite magma. Harmer and Gittins (1997) argued that ‘due to the incongruent melting of dolomite, calcite will

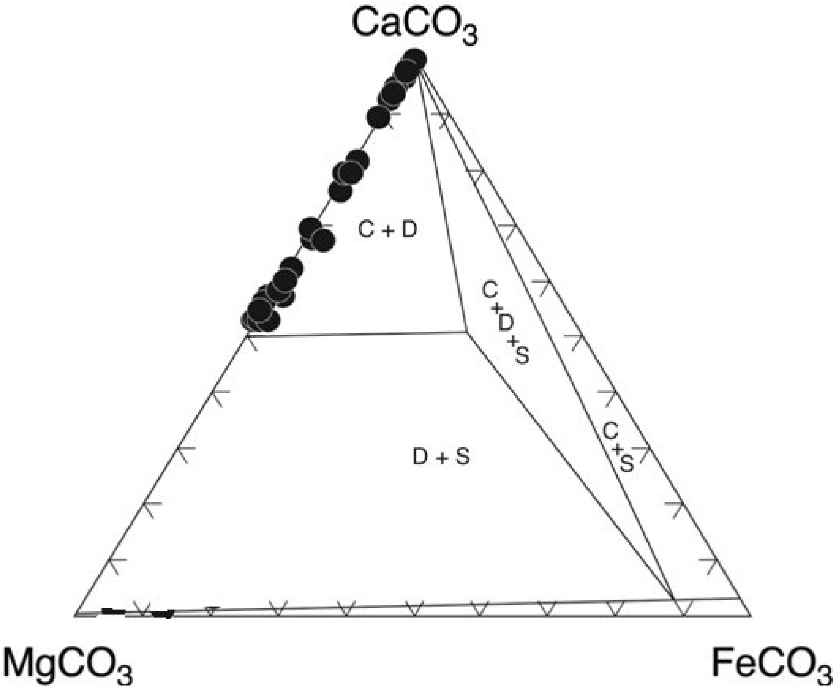

Fig. 6. Compositions of carbonates from sample 1203 (After Anovitz and Essene, 1987).

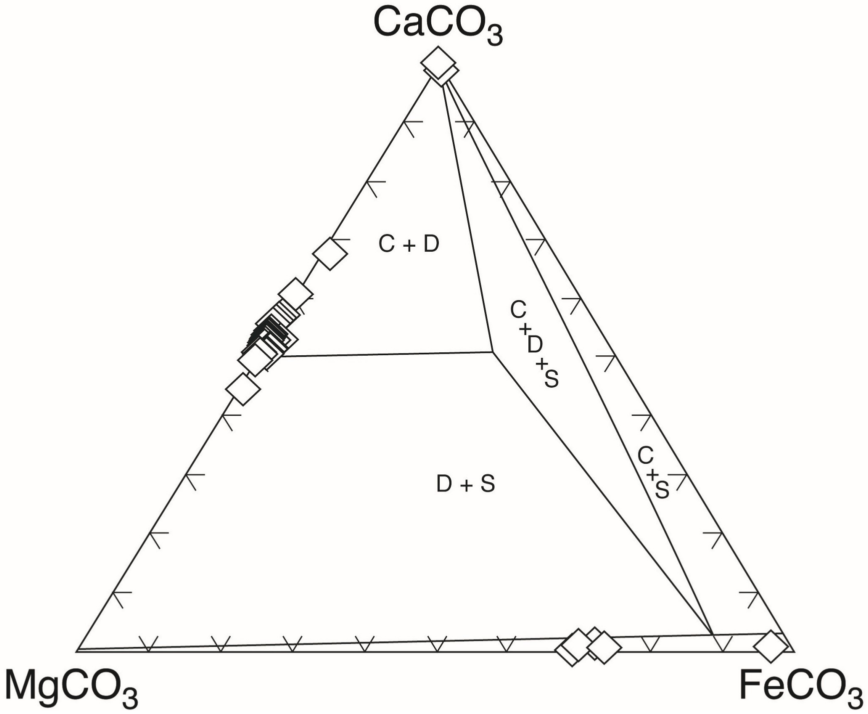

Fig. 7. Compositions of carbonates from sample 1223 (after Anovitz and Essene, 1987).

always be the liquidus phase in suitably-fluxed magnesian carbonatite (~dolomitic) melts'. Experimental data show that the 'dissociation temperature' of ~850 °C carries through into the melt phase as well. Under the equilibrium crystallization conditions, the early-formed calcites will react with the residual melt to form dolomite at the peritectic, which is analogous to the olivine--opx relationships in the tholeiitic melts. If the starting melt is not purely dolomitic (e.g., Dol60:Cc40), then even under equilibrium conditions, calcite will persist in the crystallized product and should appear texturally as the early phase (personal communication with Robin Harmer). It could be argued that if these carbonates have crystallized from previously homogeneous carbonate, then it is possible that the carbonate was magnesian in composition. This interpretation would be in keeping with the idea that many carbonatites were probably dolomitic or at least high magnesian, and produced calcite by crystallizing at pressures below the stability field of dolomite. Gittins et al. (2005) arrive at the same conclusion.

Viladkar and Wimmenauer (1992) mentioned that sometimes periclase in these samples have been converted to brucite. The brucite formation can take place in the presence of water. Since the beginning of carbonatite studies, it has been realized that the water is the most important fluid in carbonatite magma and presence of water can depress the melting temperature of calcite to 675 °C at 1 kb (Wyllie and Tuttle, 1960). Later studies on fluid inclusions in carbonatites demonstrated the presence of alkali-rich H_2O-CO_2 fluids (Rankin, 1975, 1977; Aspden, 1981; Samason et al., 1995). Treiman and Essene (1985) reported presence of periclase and brucite in carbonatite dike in Oka complex and concluded that the fluid phase in carbonatite was H_2O-rich. Gittins et al. (2005) contradicted this view and suggested that H_2O is not the only fluid phase in carbonatite magma which is responsible for lowering the melting temperature, but presence of F in carbonatite magma is more effective in lowering the melting temperature. Earlier experimental work of Keppler (2003) demonstrated the exceptionally high H_2O solubility in carbonatite magma. The present study indicates that the primary magma that formed the Amba Dongar carbonatite was calcitic, but with higher amount of dolomitic component. This conclusion is in coherence with the earlier studies, for e.g. Viladkar (2012) and references therein.

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Conflict of interest

The author declares no conflict of interest.

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