

THE CARBONATITES OF AMBA DONGAR, GUJARAT, INDIA

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The geology, petrography and major and trace element geochemistry of Amba Dongar carbonatites are described. The ring structure of Amba Dongar carbonatite-alkalic complex has a central core of basalt collared by carbonatite breccia which in turn is surrounded by a sovite rim. Ankeritic carbonatite occurs as disjointed plugs intruding sovite and also as small dikes in surrounding sovite, fenites and basalts. Sideritic carbonatite forms thin veins in ankeritic carbonatite. Plugs of nephelinite and phonolitic nephelinite form the outermost ring of the complex. The complex is intrusive into Bagh sandstone-Deccan Traps sequence (Cretaceous-Eocene) and is situated in the rift zone of Narmada valley. The trace element contents reveal certain characteristic features such as pronounced enrichment in Ce + La ($> 3.0\%$) in ankeritic carbonatite and high values of Th, Ba and P. Fenitization of surrounding Bagh sandstone shows two distinct trends: 1. earlier soda fenitization (orthoclase-albite-aegirine rock) and 2. potash fenitization leading to the development of pure feldspar rocks. The paper describes briefly the fenitization of nephelinites for the first time.

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Introduction

The Amba Dongar carbonatite-alkalic complex is a classic example of ring structure with an innermost ring of carbonatite breccia rimmed by sovite while ankeritic carbonatite forms plugs intruding the sovite. The central depression is occupied by intrusive tholeiitic basalt which came towards the end of carbonatite activity invading the original core of carbonatite breccia, the remnants of which are, in places, seen as xenoliths within the former. Carbonatite breccia also forms a discontinuous outer rim to sovite. Plugs of nephelinite and phonolitic nephelinite mark the outer limit of the ring structure. The complex is a part of the Chhota Udaipur carbonatite-alkalic district which covers an area of about 1200 km² and includes three major complexes: 1. The Amba Dongar car-

bonatite-alkalic ring complex, 2. the carbonatite-alkalic complex of Panwad-Kawant and 3. the large (11 km) carbonatite breccia sill at Siriwasan. The dating done so far gives three very different ages; 37.5 ± 2.5 ma (Deans and Powell 1968), 61 ± 2 ma and 76 ± 2 ma (Deans et al, 1973). Precise dating is still awaited.

Pronounced effects of fenitization on surrounding sandstone were described earlier by Deans et al. (1972, 1973) and Sukheswala and Viladkar (in press). The basic rocks (pre-carbonatite basalts and dolerite dikes) have also undergone CO₂ and alkali fenitization (Sukheswala et al., in press). Recent work shows that nephelinites associated with and enveloped in sovite have been affected by the fenitizing fluids from the carbonatite magma.

Large reserves of fluorite deposits, estimated by the Geological Survey of India as

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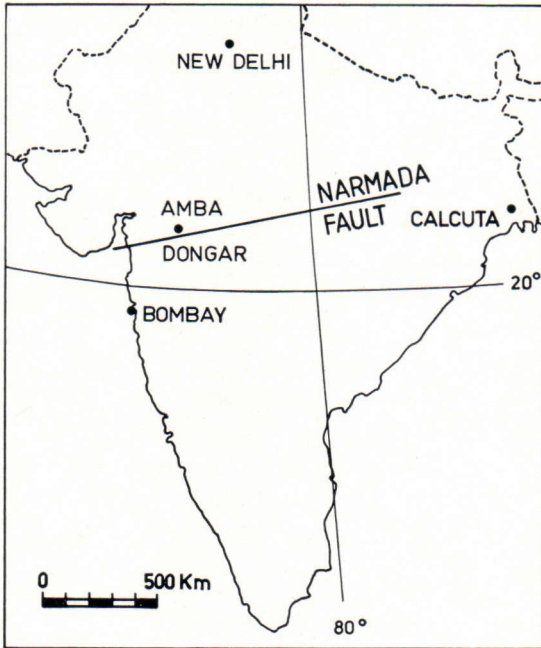


Fig. 1. Map of India, showing the site of Amba Dongar and the Narmada-Son lineament.

11 600 000 tons averaging 30 per cent CaF_2 , are associated with the carbonatites and are presently mined by the Gujarat Mineral Development Corporation. Fluorite veins and replacement deposits occur both in sovite and ankeritic carbonatites. Minerals associated with fluorite are barite, galena, pyrite, chalcopyrite and dickite.

The earlier published work on the complex includes the papers by Sukheswala and Udas (1963, 64, 67), Deans and Powell (1968), Sethna (1971) and Deans et al. (1972, 73).

Structural characteristics

The complex is situated within the rift zone of Narmada river trending ENE, which lies about 9 kms to the south of the complex (Fig. 1), and has a sympathetic fault system in the north of the complex. The main structural feature of the complex is updoming of the Bagh sandstone-limestone and overlying

basalts. As a result the Bagh sandstones around the sovite ring dike show radial outward dips of high angles (Fig. 2). The tectonic effects of the complex can well be observed up to the periphery of 5 km as the sandstone outcrops and basalts in the surrounding region are highly disturbed, faulted and show slumping. During updoming multitudes of fractures and joints created in the surrounding sandstone acted as channeways for the fenitizing solutions. Radial to the dome run several valleys and geological mapping reveals the faulted nature of some of the major valleys. Post-carbonatite fault movements were mainly responsible for the formation of steep vertical scarps exposing sovite and carbonatite breccia. Of particular interest is a vertical scarp of 80 m in the eastern part of the sovite ring dike. The sovite outcrop in this section shows major slumping (Fig. 3). A network of alvikite dikes is seen at the base of this scarp. Most of the fault valleys are occupied by thick travertine deposits.

The sovite and fenites exhibit intense fracturing and micro-faulting. The thin dikes of alvikite and ankeritic carbonatite show displacements. In fluorite mines, sections of sovite exposed during mining operations reveal fracturing and abundant brecciation. These fracture planes served as channels for ankeritic melts, resulting in criss-cross veining, and also for hydrothermal solutions carrying fluorine and abundant silica.

Carbonatites

Seven units of carbonatites are discernible in the complex:

1. Carbonatite breccia forming an inner and outer rim to sovite and also occurring as separate plugs in surrounding sandstone and basalt.
2. Sovite forming a large ring dike and isolated plugs in surrounding sandstone.

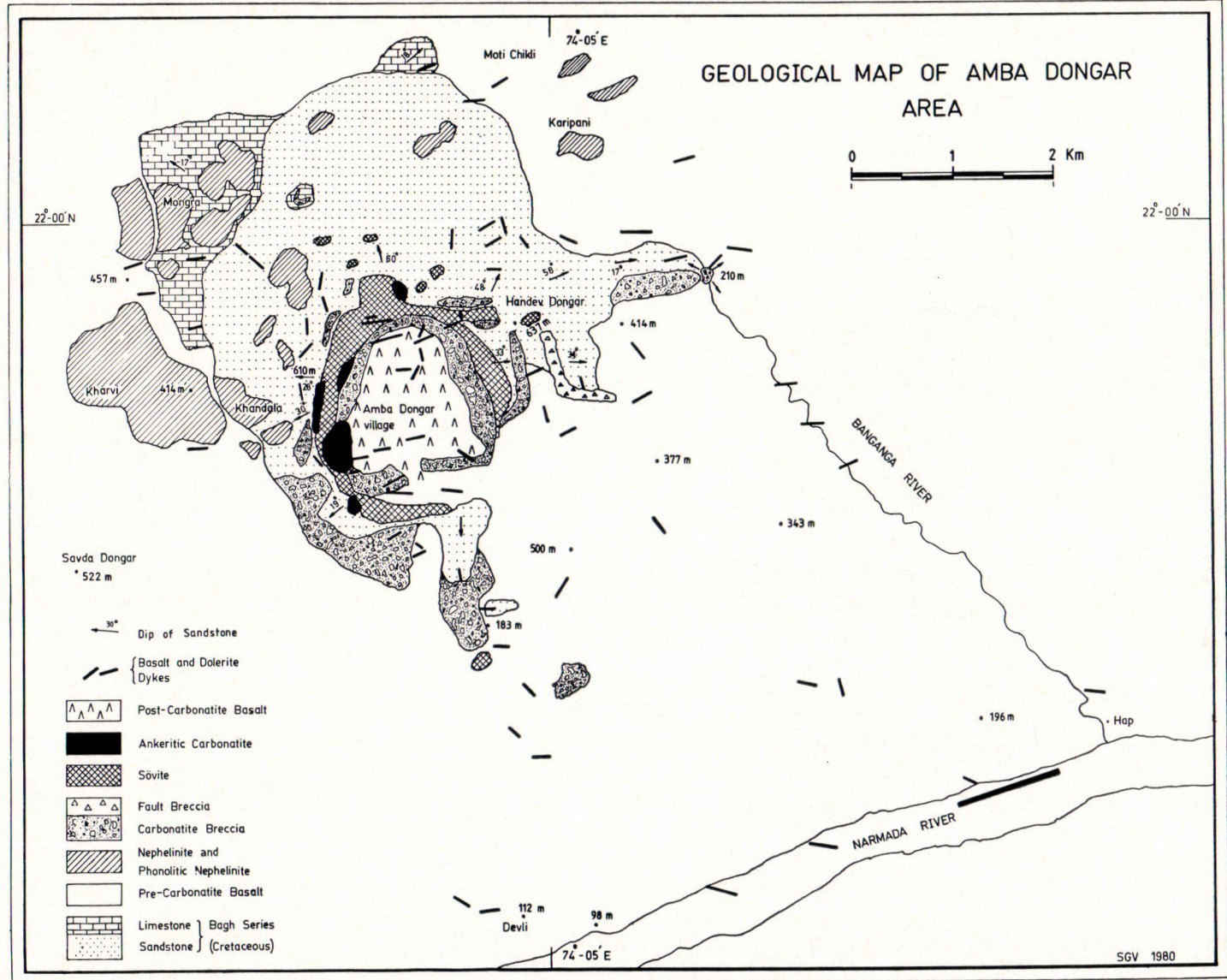


Fig. 2. Geological map of Amba Dongar area.

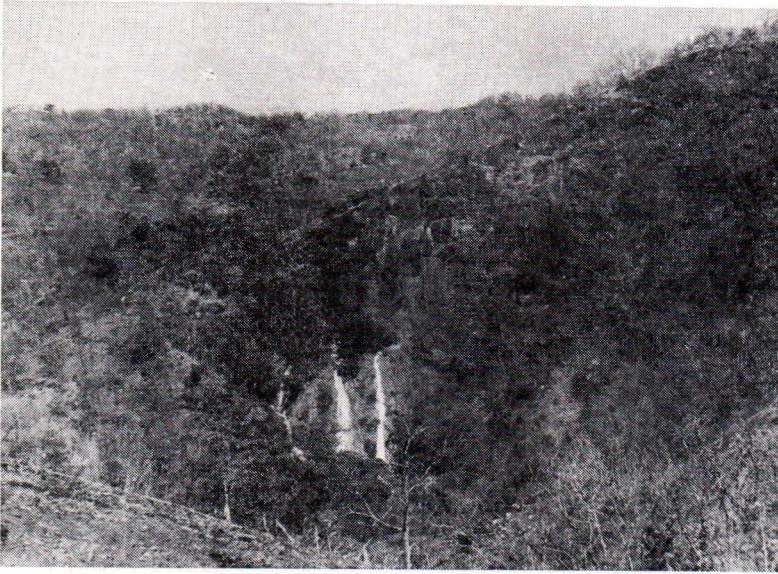


Fig. 3. Vertical scarp in the eastern part of sovite ring dyke. At the base of the scarp is a network of alvikites.

3. Ankeritic carbonatite occurring as plugs within sovite and veins in sandstone, basalt, fenite and sovite.
4. Sideritic carbonatite invading ankeritic carbonatite.
5. Alvikite invading sovite, fenite, carbonatite breccia and sandstone.
6. Silicified carbonatite.
7. Pegmatitic carbonatite invading sovite.

1. Carbonatite breccia

The carbonatite activity in Amba Dongar began with the emplacement of a plug of carbonatite breccia of about 1.5 km in diameter which, towards the end of carbonatite activity, was intruded by multiple injections of basalts and is now seen only as a major rim around the central core of basalt. Besides this innermost rim carbonatite breccia also forms a discontinuous outer rim to sovite and circular and oblong-shaped outcrops in the surrounding Bagh sandstone and basalt. Major outcrops of this rock are seen in the valleys as steep escarpments of about 200 metres. Huge boulders measuring 10 m × 6 m are quite common. The rounded to subangular

fragments in breccia show great variation in size from a few cm up to 1 m × 1/2 m. Sovite constitutes the major proportion of the rounded fragments, the others include metamorphics, sandstone, basalt, and nephelinite all set in a calcitic or ankeritic matrix.

Xenocrystal quartz, probably from the metamorphics, is abundant and is partly converted to orthoclase. Differential weathering of the enclosed fragments gives the rock an appearance simulating vesicular rock, because the sovite fragments being weathered easily are removed and rims of harder matrix stand out prominently. Very often rounded fragments of sovite are liberated from the matrix and are dispersed in the soil. The carbonatite breccia has been intruded by alvikite, ankeritic carbonatite and a number of dolerite dikes.

2. Sovite

Sovite forms a large ring dike of variable width that reaches its maximum width in the northern part of the Amba Dongar village, where mining operations for fluorite are in progress. Topographically sovites are

at higher elevations forming a chain of hills around the central depression. From its contact with carbonatite breccia the first few feet of the outcrop comprises coarse sovite passing into medium-grained sovite, which is observed only in the western part of the ring dike. Vertical banding is conspicuous in some parts of the ring dike, accentuated by the presence of apatite, barite, and martite while sometimes it is marked by the presence of orthoclase and some streaks of aegirine-feldspar rock. Frequently jasper veins are seen standing out prominently on weathered surfaces. Faces cut open during mining operations in the northern part of the ring dike provide excellent illustrations of minor structural disturbances such as faulting and fracturing. In some portions a very peculiar type of structure was noticed. The rock becomes highly 'vesicular' and light in nature. During silicification of sovite this light rock was also silicified but it still retained its original form, which now resembles a 'honey comb' structure.

Besides the major rim of the central complex there are isolated plugs of sovite outside the ring within sandstone.

Sovite has caught up various xenoliths which vary in size from 2 cm to 10 m. or even more sometimes. The largest xenolith (finitized sandstone) exposed during mining measures 200 m × 40 m. All the xenoliths are finitized.

3. *Ankeritic carbonatite*

Circular and oblong plugs of ankeritic carbonatite intrude sovite with a sharp contact which is clearly visible even on weathered ground, since the ankeritic carbonatite forms dark brown soil rich in iron oxide. Where the rock is rich in manganese the soil cap is black in colour. Weathering appears to be more effective in the valleys where the outcrops of ankeritic carbonatite are mantled by

dark brown to black soil. The ankeritic carbonatite has caught up the xenoliths of sovite and fenites. In places the potash fenites are so much shattered and veined by ankeritic carbonatite that only the patches of feldspar (pink) are seen surrounded by ankeritic material. All the outcrops of ankeritic carbonatite are highly radioactive.

4. *Sideritic carbonatite*

These veins, black in colour, are restricted to exposures of the ankeritic carbonatite plug southwest of Amba Dongar village. The average thickness of the veins is about 4 cm and they run for only short distances.

5. *Alvikite*

Numerous dikelets of calcitic carbonatite ranging in width from 3 cm to 15 cm are noticed in sovite, fenite, carbonatite breccia and sandstone. In some dikelets calcite crystals along the margin show lineation. Even along thin dikes effects of finitization on the surrounding sandstone are noticed. A network of alvikites invades sovite and carbonatite breccia at the base of the steep escarpment in the eastern part of the ring dike. The dikelets are quite thin but swell out in some places. The entire area is intensely disturbed by minor doming of surrounding rocks. The details of this interesting area have not yet been reported mainly due to the inaccessibility of the area, the abundance of snakes and the presence of hostile tribals.

From the field evidence collected so far it can be assumed that there are probably two phases of alvikite intrusions.

6. *Silicified carbonatite*

This is the most common rock type associated with fluorite mineralization. Towards the end of the carbonatite activity hydrothermal solutions rich in fluorine and silica

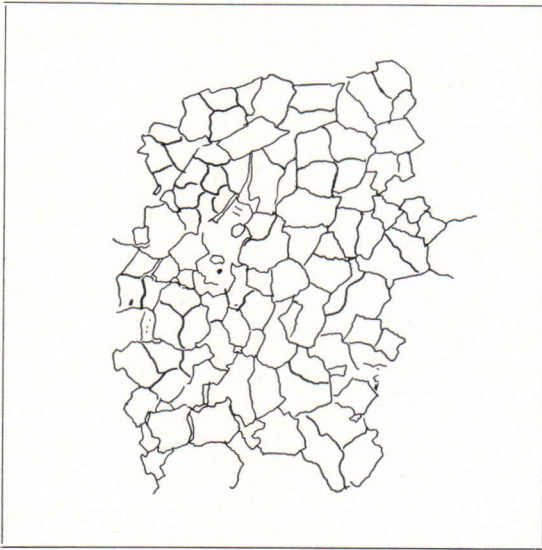


Fig. 4 a

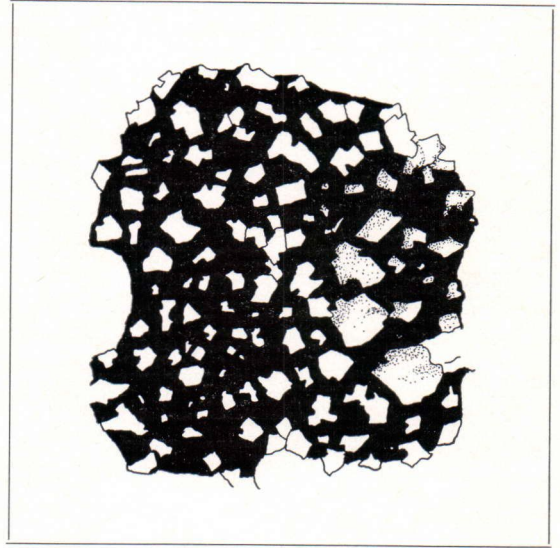


Fig. 4 c

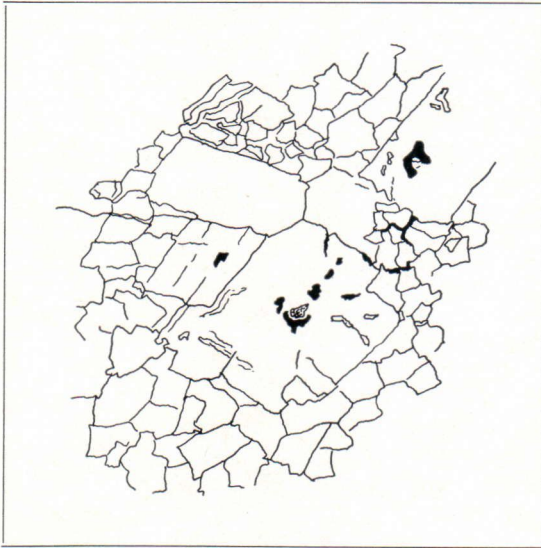


Fig. 4 b

Fig. 4. Different types of textures seen in sovite (traced from photomicrographs)

- a. fine-grained
- b. porphyritic
- c. fragmental

were responsible for replacing sovite towards its outer rim. The outcrops of such rocks are non-uniform in width.

7. Pegmatitic sovite

These are very coarse-grained rocks, with calcite crystals averaging 1.5 to 2 cm, in-

vading sovite. The thickness of such veins varies from 1 cm to 8 cm and they stand out prominently, as calcite crystals are conspicuous due to their milky white colour.

Petrography

Sovite

In a hand specimen, the texture of sovite varies from coarse-grained to extremely fine-grained and resembles marble. In thin sections the variation in grain size leads to textures from coarse-grained to fine porphyritic (Fig. 4). In porphyritic varieties earlier formed calcite rhombohedra are set in a matrix of anhedral calcite grains. In coarse-grained sovite large calcite crystals (1.5 mm) invariably show fused crystal mar-

gins. Sometimes the large phenocrysts of calcite are rimmed by hematitic material while in some rocks oxidized ankerite and iron oxide form the base for anhedral calcite crystals. Inclusions of iron oxide are often arranged along the cleavage planes or they line the crystal margins. Fine-grained sovite (calcite: 0.15 mm) normally shows mosaic texture and calcite grains are devoid of cleavage.

Sovite is composed essentially of calcite, which is non-fluorescent with abundant inclusions of fine material brown in colour. Accessory minerals are: apatite, fluorite, barite, ankerite, phlogopite, pyrochlore, magnetite and bastnaesite (rare).

Apatite (0.75 to 1.0 mm) occurs in three crystal habits: ovoid grains, prismatic needles and hexagonal stubby crystals (Fig. 5). It is often replaced on rims by calcite and has inclusions of magnetite. Fluid inclusions, seen at high magnification, are often rounded or oblong. Some rocks show a notable concentration of apatite in the form of clusters and streaks.

Barite is another ubiquitous mineral along with apatite, having crystallized at early magmatic and late hydrothermal stages. Early magmatic grains (0.34 to 1.1 mm) are often corroded or replaced by calcite. Sometimes the concentration of barite is high enough to warrant the rock being called barite-sovite. Hydrothermal barite is associated with fluorite veins.

Magnetite (0.3 to 0.47 mm), often martitized, is skeletal, octahedral and corroded by calcite. Ilmenite is sporadic.

Phlogopite forms small flakes and sometimes occurs in segregated patches. It shows pleochroism from colourless (X) to brownish yellow (Z).

Pyrochlore occurs as small crystals (0.07 to 0.17 mm), cubes (0.12 to 0.35 mm) or rounded grains, cinnamon or yellow in colour, having a dark core and light margins (Fig. 6). Some-

times pyrochlore has developed along the crystal margins of calcite while occasionally it clusters around magnetite grains. The majority of the grains show embayment by calcite.

Bastnaesite is extremely rare and occurs as radiating needles.

Some examples of the mineral composition of sovite are given in Table 1.

Alvikites

These are medium- to fine-grained rocks, some of them showing tabular texture. The common accessory mineral is apatite which in some rocks occurs as accicular needles. Pyrochlore is rare, while magnetite occurs in good proportion in some specimens.

Ankeritic carbonatite

These are dark brown coloured, medium- to fine-grained rocks with high radioactivity. Sometimes, due to high magnetite content, they are heavy, resembling iron ore. The rocks are mainly composed of ankerite, which in majority of cases is oxidized to hematite while still preserving the original form of ankerite. Apatite and monazite are seen in minor amounts, while barite and fluorite occur in high proportions. Thorite was no-

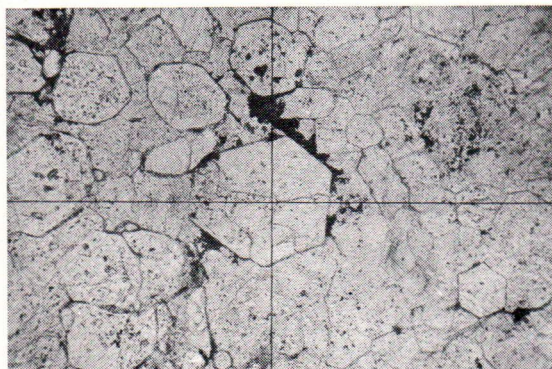


Fig. 5. Apatite in sovite showing different crystal habits (plane polarized light. x160)

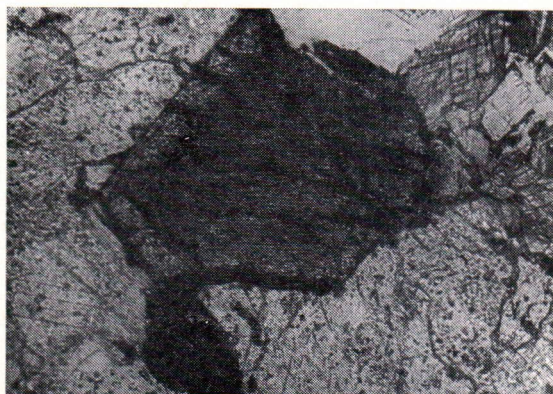


Fig. 6. Pyrochlore in sovite (plane polarized light x270)

ticed in one thin section only. The veins of ankeritic carbonatite in sovite are ochreous red in colour and normally without accessory minerals.

Sideritic carbonatite

These are dark brown to black coloured rocks and sometimes opaque in thin sections. High manganese is characteristic but no manganese mineral could be identified.

A large quantity of iron oxide, cherry red in colour, occurs as fracture filling material in fluorite mineralized zones. The origin of this material is not yet understood but it does not seem to be a product of weathering. Fluorite crystals are normally found embedded in such pockets.

Chemistry

The detailed geochemistry of different carbonatite units is under study. The major and trace elements (Tables 2 and 3) in sovite (ring dike) and ankeritic carbonatite (plugs) are discussed below.

Amba Dongar sovites are characterised by a low content of Mg, and the small amount that is present is accommodated in the calcite lattice. No exsolved lamellae of dolomite were detected in any sovite on staining. The crystallization differentiation is well observed in Amba Dongar carbonatites with the order of crystallization: sovite — ankeritic carbonatite — sideritic carbonatite indicating an increase in pressure during differentiation. The absence of the dolomite phase and the large proportion of ankeritic carbonatite could be due to the initial high iron content of the melt.

Both iron and manganese show abundances increasing from early sovite to youngest sideritic carbonatite. Cobalt (2 ppm to 39 ppm), nickel (1 ppm to 6 ppm) and chromium (7 ppm to 33 ppm) are present only in ankeritic carbonatite and totally absent from sovite. Phosphorus is rather unevenly distributed and the highest concentrations reached in both sovite and ankeritic carbonatite are more than 3 per cent.

Barium is abundant and exceeds strontium. Barite in Amba Dongar carbonatites shows

Table 1. Mineral composition of sovite in volume %.

Sp. Nos.	185	193	203	152	121	128	149	198	187
Calcite	74.3	78.5	85.0 *	80.0	66.0	76.0	83.0	79.3	67.0
Barite	4.5	—	7.5	7.0	9.0	1.6	1.0	1.4	6.7
Apatite	5.4	15.3	6.6	12.0	13.0	—	tr.	13.0	9.0
Phlogopite	9.0	—	—	—	—	—	—	—	3.0
Hematite	4.4	—	—	1.0	1.0	18.0	10.0	4.4	3.6
Magnetite	2.5	4.6	—	—	11.0	—	6.0	1.3	8.8
Pyrochlore	—	1.6	—	—	—	4.4	0.3	0.6	1.7
Fluorite	—	—	1.0	—	—	—	—	—	—

* contains 12.0% phenocrysts of calcite

All are surface samples from different parts of ring dike.

Table 2. Major element analyses of carbonatites.

Sp. No.	1	2	3	4	5	6	7	8	9	10	11
SiO ₂	1.84	2.00	3.94	41.88	0.36	13.13	1.20	40.02	n.a.	n.a.	n.a.
TiO ₂	0.20	0.19	0.29	0.38	0.80	0.28	0.70	0.10	0.20	0.20	1.20
Al ₂ O ₃	1.77	1.25	2.79	6.00	n.d.	n.d.	n.d.	0.43	n.a.	n.a.	n.a.
Fe ₂ O ₃	2.86	2.35	3.47	8.18	19.71	10.20	17.15	9.72	10.75	8.47	45.00
FeO	0.16	0.28	0.64	1.40	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
MnO	0.47	0.15	0.35	0.31	4.50	2.46	0.67	1.58	1.92	1.14	5.00
MgO	2.25	2.00	3.75	3.48	7.50	1.25	1.25	4.60	6.72	12.48	7.50
CaO	49.68	50.03	46.15	16.90	35.61	38.85	43.40	22.50	37.75	35.03	15.41
Na ₂ O	0.16	0.10	0.14	6.00	0.15	1.18	0.23	0.11	n.d.	n.d.	n.d.
K ₂ O	0.04	0.08	0.70	2.75	0.04	0.02	0.03	0.06	n.d.	n.d.	n.d.
P ₂ O ₅	1.14	1.70	0.71	1.00	1.88	0.39	0.09	tr.	0.20	0.31	0.68
CO ₂	39.00	39.60	36.20	9.00	28.16	32.06	35.10	20.00	38.00	36.50	23.50
H ₂ O ±	1.08	1.24	1.12	1.75	1.40	0.78	0.44	1.50	2.70	2.40	
Total	100.65	100.97	100.25	99.03	100.11	99.60	100.26	100.62	98.22	96.53	97.09

All analyses were carried out following the method of Shapiro and Brannock (1962).

Analyst: S. G. Viladkar

Location:

Sp. No. 1, 2, 3	sovite from ring dyke
4	xenolith of aegirine-phlogopite sovite within ring dyke of sovite
5	ankeritic carbonatite from plug, SW of Amba Dongar (ankerite is oxidized)
6, 7	sovite with oxidized ankeritic groundmass
8	silicified carbonatite
9, 10	ankeritic vein in sovite
11	sideritic carbonatite vein in ankeritic carbonatite plug southwest of Amba Dongar

a long range of crystallization from early magmatic to late hydrothermal. The large quantity of barite crystallizing in Amba Dongar carbonatites could be attributed to a high concentration of sulphur coupled with prevailing oxidizing conditions and low temperatures. Sethna and Viladkar (1977) have given the temperature of crystallization for Amba Dongar carbonatites as from 250° to 500°C. The concentration of strontium in sovite and ankeritic carbonatite varies from 1117 ppm to 3400 ppm (average 2394 ppm) and 1400 ppm to 5250 ppm (average 2723 ppm) respectively.

The niobium concentration in sovite and ankeritic carbonatite varies from 50 ppm to 1636 ppm. The highest concentration (1636 ppm) in sovite (sp. no. 192) is undoubtedly due to the abundant pyrochlore present in this rock.

Cerium and lanthanum show distinct enrichment from early sovite to late ankeritic carbonatite, which contains well over 3.0 %

Ce + La. Ce + La predominate over Y and the average ratios (Ce + La)/Y for sovite and ankeritic carbonatite are 43 and 104 respectively. The high concentration of Ce and La in ankeritic carbonatite may be due to the presence of monazite, while in sovite these elements are mainly dispersed in calcite (in sovite bastnaesite occurs in traces). Apart from Ce and La, five samples of carbonatites were analysed for Eu, which varies from 5 ppm to 50 ppm.

Fenitization

The details of fenitization of Bagh sandstone have already been described by Deans et al. (1972, 1973) and Sukheswala and Viladkar (in press). Two distinct trends of fenitization are seen in Amba Dongar: earlier soda fenitization, wherein the introduction of both Na and K (but Na > K) led to the formation of fenites rich in aegirine-augite aegirine, orthoclase and albite; later potash fenitiza-

Table 3. Trace element contents of Amba Dongar carbonatites in ppm.

Sp. No.	Ba	Sr	Zr	Nb	Zn	Ce	La	Y	Th	Mn	P
Sovite											
16	1500	4500	n.d.	270	n.a.	900	250	40	n.d.	1200	760
185	24300	3400	n.a.	350	n.a.	3600	2420	49	n.a.	2730	7100
295	18100	3000	n.a.	50	n.a.	2320	1240	70	n.a.	2200	6900
2	10100	2000	n.a.	250	n.a.	2700	800	130	n.a.	3700	4700
13	n.a.	1351	153	948	424	7329	6593	159	222	7300	7900
15	n.a.	2206	177	319	139	1185	130	122	118	3600	33600
19	n.a.	2708	155	554	98	516	80	45	77	2300	9300
60	n.a.	2825	140	271	234	1227	358	83	17	2300	31000
130	n.a.	1117	60	399	124	2891	1143	63	32	7200	5700
147	n.a.	2313	101	202	306	1934	552	107	195	9200	11300
149	n.a.	1932	101	47	131	1467	332	71	98	3700	12500
192	n.a.	1374	90	1636	100	1055	336	19	80	1400	14100
Ankeritic carbonatite											
3	n.a.	2105	509	86	1215	9550	3761	190	248	5000	13600
5	n.a.	1636	541	977	237	2000	385	200	249	5800	32500
6	n.a.	3190	159	244	44	453	121	24	3	1000	8500
646	8400	3100	n.a.	500	n.a.	13260	12000	n.a.	n.a.	2290	8700
11	n.a.	3100	n.a.	500	n.a.	22400	15100	190	n.a.	34900	4000
29	n.a.	5250	450	450	n.a.	13960	17900	90	n.a.	19100	170
448	8200	1400	n.a.	250	n.a.	870	740	34	n.a.	4180	n.a.
59	9000	2000	n.a.	570	n.a.	3000	1450	150	n.a.	5200	400
Carbonatite breccia											
49	n.a.	1369	69	141	233	1111	351	42	8	2200	7900
24	n.a.	2179	137	335	220	1293	415	120	89	4700	12400
25	n.a.	2383	128	212	222	1518	370	63	79	5100	9200
34	n.a.	2307	149	396	406	1991	1237	99	167	4800	7200

n.a. not analyzed

n.d. not detected

tion was superimposed on earlier soda fenites and gave rise to pure potash fenites — orthoclase rocks — with relics of aegirine-augite and aegirine. Mild nephelinization has also been observed in one of the outcrops of fenite, occurring as xenoliths in sovite. The syenite-fenite from the marginal part of the outcrop shows typical igneous texture but the samples collected from the centre of the outcrop still show original sandstone features with development of aegirine-augite and albite.

The fenitization of nephelinites is briefly described here and the details will be given later elsewhere. The samples for such study were selected from the xenoliths of nephelinite in sovite which are exposed on road cuttings and in the mine adit, and also from the plugs of nephelinites situated not very far from sovite outcrops. The petrographic study shows that the nephelinites were affected by the fenitizing solutions from the

sovite magma. Nepheline is converted to fibrous hydromuscovite or is completely replaced by calcite retaining the original form. Orthoclase develops as poikilitic plates. Melanite shows partial replacement by sphene which is normally promoted along the cracks in melanite and sometimes is partially replaced by calcite. In places it shows sieve structure and bleaching of the originally dark colour. Aegirine-augite shows two changes: in some rocks it is replaced by wollastonite on the crystal margins, while in others phlogopite seems to have developed.

The effects of fenitization are more pronounced on xenoliths of nephelinites in sovite.

Travertine

Travertine forms thick deposits in all major valleys bordering the Amba Dongar dome. Chemically they are similar to car-

bonatites with elevated Na_2O . The concentrations of other elements are: Sr (2270 ppm), Ba (432 ppm) Nb (< 5 ppm), Ce (64 ppm), La (< 5 ppm). (work in progress).

Mode of emplacement

The carbonatite-alkalic complex of Amba Dongar is situated on the northwestern periphery of the Deccan Trap province, which is underlain by Bagh sediments and Dharwar metamorphics. The metamorphics are exposed in the northern periphery of the Chhota Udaipur carbonatite-alkalic district forming elongated hills striking NW-SE. The eroded and carved basins of the Pre-Cambrian metamorphics provided favourable places for the deposition of Bagh sediments during the Cretaceous period. Towards the late Cretaceous period the Baghs were covered by the stupendous activity of flood basalts designated in Indian geology as Deccan Traps. The lavas erupted mainly through fissures with sporadic central type eruptions.

The Amba Dongar complex is situated in the rift zone of Narmada valley which is regarded as an 'ancient plane of weakness' along which tectonic activities have occurred (West, 1962). According to Tandon and Choudhury (1970), epicentres of many earthquake shocks are aligned approximately parallel to the Narmada-Son lineament (Fig. 1). Mishra (1977) presumes the extension of this lineament to be to the Murray Ridge in the west and to the eastern syntaxial bend in the east connecting this structure with the worldwide rift system.

The Amba Dongar complex lies in a structurally disturbed zone. It is a typical sub-volcanic diatreme formed by the process of fluidization which was responsible for the emplacement of a plug of carbonatite breccia accompanied by the initial doming of the Baghs and Deccan basalts. In the second

phase of activity the roof of this volcano collapsed and the carbonatite melt was pushed up along a ring fault resulting in the emplacement of the sovite ring dike. Major doming occurred during this period. Sovite was then intruded by the later differentiate ankeritic carbonatite. The end of carbonatite activity is marked by the deposition of large fluorite deposits with associated quartz, galena, barite, pyrite and chalcopyrite.

Geological field work for the past few years has established that even after the emplacement of carbonatite the volcanic activity did not cease but from the same conduit multiple injections of basalt invaded the original core of carbonatite breccia leaving behind only a collar of it around the newly formed core of basalt. A number of dolerite dikes have been observed in 1 km periphery of this core.

It may be concluded that the Amba Dongar carbonatite-alkalic complex represents a typical high level sub-volcanic diatreme, which has preserved many of the original characteristics. Similar to Chitwa Island in Malawi (Garson, 1966), the differentiation of carbonatite is well documented in Amba Dongar by successive intrusions of sovite—ankeritic carbonatite — sideritic carbonatite. Carbonatites are rich in apatite and barite, and apatite forms segregated pools and streaks in sovite. Ankeritic carbonatites are exceptionally enriched in Ce and La.

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