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CARBONATITES : OCCURRENCES, CHARACTERISTICS AND THEIR ECONOMIC SIGNIFICANCE

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ABSTRACT Carbonatites are rare igneous rocks having more than 50% of carbonate minerals. The mineralogy of the carbonatites is highly variable and contains calcite, dolomite, ankerite, natrolite, sodalite, apatite, magnetite, barite, fluorite, mica etc. in variable proportion. Geochemically the carbonatites also have very wide variation in major, trace and REE composition. There are only 330 known carbonatite occurrences in the world including one active volcano. India also has the carbonatite occurrences. So far about 20 major and 11 minor carbonatite occurrences have been reported from India. Due to the complex mineralogical and chemical composition, the carbonatites are one of the valuable sources for many important minerals especially REE, niobium, igneous phosphate, strontianite, fluorite, apatite, uranium etc.

KEYWORDS : Carbonatite, Indian occurrences, Economic aspects

INTRODUCTION:

Carbonatites are defined as igneous rocks which contain more than 50% of carbonate minerals and less than 10 % SiO_2 (Streckisen, 1980; Woolley and Kempe, 1989). Most of the carbonatites are shallow intrusive bodies associated with alkaline or hyper alkaline igneous rocks. On the basis of major elements and REE, the carbonatites are divided into different categories :

Class	Chemical Characteristic
Calcio-carbonatite	CaO/(CaO+FeO+MgO > 0.80
Dolomite carbonatite	(Ca,Mg)-rich
Ferro-carbonatite	(FeO + MnO) > MgO
Magnesio-carbonatite	MgO > (FeO + MnO)
Rare earth carbonatite	RE_2O_3 > 1% wt
Natro-carbonatite	(Na_2O + K_2O) > (CaO+MgO+FeO)

The normal sequence of cationic abundances in the carbonatite is - Ca > Mg > Fe > (Na + K). The mineralogy of the carbonatites is highly variable. The mineral composition includes calcite, dolomite, ankerite, natrolite, sodalite, apatite, magnetite, barite, fluorite, mica etc. The presence of these minerals is variable from rock to rock. Approximately 60 % of intrusive carbonatites worldwide are predominantly calcitic; most of the remaining 40 % comprise members of the dolomite-ankerite series. Photo 1 and 2 shows the samples of Dolomitic and Ferro-carbonatites from Newania area, Rajasthan.

Geochemically the carbonatites have very wide variation in major, trace and REE composition. Table 1 gives the chemical range of carbonatites (After Gold, 1966).

Table 1 : Chemical composition of Carbonatites

Major Elements	Percentage range	Trace elements & REE	Concentration range in PPM
SiO_2	0.58 – 25.20	V	15 – 200
TiO_2	0.10 – 1.75	Li	5 – 55
Al_2O_3	0.10 – 5.72	Nb	50 – 1000
Fe_2O_3	0.29 – 12.81	Y	10 – 130
MnO	0.14 – 1.58	Ce - La	30 – 5300
MgO	0.31 – 12.75	Sr	600 – 7500
CaO	14.10 – 50.83	Pb	9 – 150
Na_2O	0.14 – 29.56	Ba	90 – 2900
K_2O	0.04 – 7.14	Zr	120 – 1200
P_2O_5	0.95 – 3.32		
CO_2	8.75 – 37.57		
H_2O+	1.15 – 3.45		

Three main theories have been suggested for the origin of carbonatites: (1) Residual melts of fractionated carbonated nephelinite or melilitite (Gittins 1989; Gittins and Jago 1998), (2) Immiscible melt fractions of CO_2-saturated silicate melts (Freestone and Hamilton 1980; Brooker and Hamilton 1990; Dawson 1998; Brooker and Kjarsgaard 2011) and (3) Primary mantle melts generated through partial melting of CO2-bearing peridotite (Wallace and Green 1988; Harmer et al. 1998; Ying et al. 2004).

WORLD OCCURRENCES OF CARBONATITES:

There are only 330 known carbonatite occurrences in the world, distributed almost in all the continents. There is only one active volcano of carbonatite known as Oldoinyo Lengai volcano in Tanzania (Photo 4). The countries where the carbonatites have been reported are: Angola, Australia, Bolivia, Brazil, Burundi, Canada, China, Congo, Finland, Germany, Greenland, India, Kenya, Kyrgyzstan, Magnolia, Namibia, Norway, Pakistan, Russia, South Africa, Spain, Tazakistan, Tanzania, Ukraine, UAE, USA, Vietnam, Zambia and Zimbabwe.

Photo 1 : Dolomitic carbonatite (Newania, Rajasthan)

Photo 2 : Ferro – carbonatite (Newania, Rajasthan)

Photo 3 : Apatite in carbonatites (Newania, Rajasthan)

Photo 4 : Oldoinyo Lengai volcano in Tanzania, the world's only carbonatite volcano.

INDIAN OCCURRENCES OF CARBONATITES:

Carbonatite occurrences were unknown in India until 1963, when the first description of the Amba Dongar complex was published by Sukheswala and Udas (1963). Subsequent to Amba Dongar discovery, many other carbonatite occurrences were reported from different parts of the Indian sub-continent. So far about 20 major and 11 minor carbonatite occurrences have been reported from India by various workers. The major occurrences includes : (1) Amba Dongar - Siriwasan (Gujarat) (2) Newania (Rajasthan) (3) Sevathur (Tamil Nadu) (4) Samalpatti (Tamil Nadu) (5) Pakkanadu (Tamil Nadu) (6) Hogenakal (Tamil Nadu) (7) Chelima (Andhra Pradesh) (8) Elchuru (Andhra Pradesh) (9) Kunavaram (Andhra Prades) (10) Mundwara

(Rajasthan) (11) Sarnu-Dhandali (Rajasthan) (12) Sung valley (Meghalaya) (13) Munnar (Kerala) (14) Khambammettu (Tamil Nadu) (15) Swangkre (Meghalaya) (16) Kollengal (Karnataka) (17) Bora, Visakhapatanam (Andhra Pradesh) (18) Samchampi (Assam) (19) Kuthni-Beldhi (West Bangal) and (20) Dei-Kharwad-Chhaktaleo (Gujarat). Figure 1 shows the location of few of important carbonatite occurrences in India. These carbonatites are having their association with major fracture zones and CFB provinces like Deccan traps, Rajmahal traps and Sylhet traps (Ray and Ramesh, 2006).

Based on detailed geophysical and structural geology investigations, carbonatite complexes of India are located in and are associated with six major tectonic settings. These include: (1) Eastern Ghat mobile belt (2) Narmada rift zone (3) Aravalli rift zone (4) Assam-Meghalaya plateau (5) Western Ghat faults and (6) Cuddapah-Godavari rifts. Out of these the Narmada and Trans-Aravalli rifts and the Meghalaya plateau are of late Mesozoic and Tertiary (100 to 40 million years), whereas those related to the Eastern Ghat, Cuddaph, and Aravalli rifts and the Western Ghat Faults are middle and late Proterozoic age. The oldest carbonatite complex is of Hogenakal ~2000 Ma (Natarajan et al., 1994), and the youngest is perhaps the Amba Dongar complex which seems to have emplaced during the late stages of Deccan volcanism ~65 Ma (Courtillot et al., 1988).

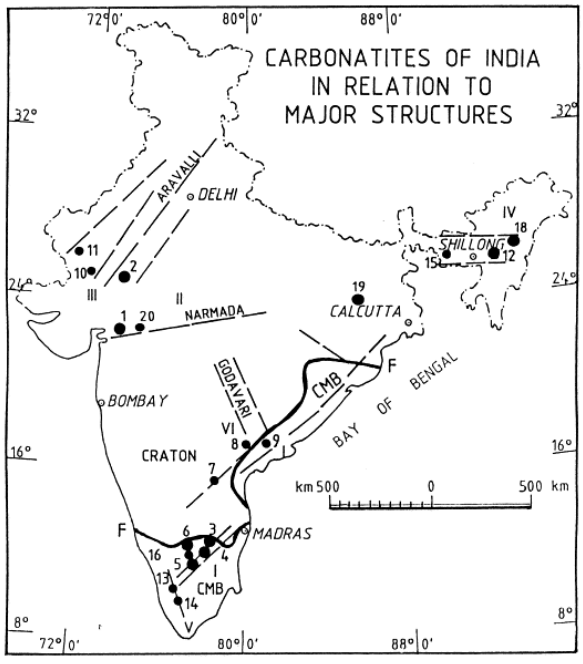

Fig. 1. Location of important carbonatite deposits in India. 1. Ambadongar - Siriwasan-Nakal; 2, Newania; 3, Sevattur; 4, Samalpatti Complex; 5, Pakkanadu-Mulakkadu; 6, Hogenakal; 7, Chelima; 8, Elchuru; 9, Kunavaram; 10, Mer-Mundwara; 11, Sarnu-Dandeli; 12, Sung Valley; 13, Munnar; 14, Khambammettu; 15, Swangkre; 16, Kollegal; 17, Borra; 18, Samchampi; 19, Kutni-Beldih; 20, Dei-Kharwad-Chhaktaleo areas. Note: Larger solid dots refer to complexes studied in detail (Krishnamurthy et, al., 2000).

ECONOMIC SIGNIFICANCE:

Due to the complex mineralogical and chemical composition, the carbonatites are one of the valuable sources for many important minerals. Carbonatites contain the highest concentration of REE of any igneous rock, and are therefore, good target of REE exploration. They are the sole source of Niobium (Nb), principal source of REEs, largest source of igneous phosphate and subordinate source of Strontianite. Carbonatites have been considered to host the majority of the world's niobium, with up to 10% of the western world's niobium once sourced from Niobec mine in the Oka carbonatite, Quebec (Scales 1989). The studies on carbonatite deposits have revealed that the carbonatite complexes are commonly enriched in carbon, fluorine, phosphorus, manganese, strontium, niobium, barium, and the REE, especially the lighter lanthanides, and many cases there is also enrichment of vanadium, copper, zinc, molybdenum, lead, thorium and uranium (Richardson and Birkett 1996; Hornig-Kjarsgaard 1998). Recent study based on their temporal and spatial association and genetic setting with hydrocarbon deposits considered them indicator for the exploration of hydrocarbons/gas hydrate deposits (Ramaswamy et al., 2009).

Table 2 shows the important mineral deposits associated with the carbonatites in different countries.

Table 2 : Distribution of Important Economic Minerals within Carbonatites

S.No.	Name of Deposits	Resources/ Grade
1.	Aley property, British Columbia	20 MT - *0.7 %* Nb_2O_5 5 GT - 3-5 % P_2O_5
2.	Argor, Ontario	56.2 MT - 0.52% Nb_2O_5
3.	Lackner Lake, Ontario	111MT - 0.23% Nb_2O_5
4.	Nemegosend Lake, Ontario	18.1 MT - 0.47% Nb_2O_5
5.	Manitou Islands, Ontario	3.26 MT - 0.627% Nb_2O_5 0.032% U_3O_8
6.	St. Honore (Niobec), Quebec	9.6 MT - 0.66% Nb_2O_5
7.	Crevier- Lagorce townships, Quebec	15.2 MT- 0.189 % Nb_2O_5, 0.020% Ta_2O_5
8.	Oka Carbonatite, Quebec	112.7 MT - 0.44% Nb_2O_5 23.8 MT - 0.20-0.50% REOs
9.	Siilinjarvi, Finland	470 MT - 4% P_2O_5
10.	Kovdor, Kola Peninsula, Russia	700 MT - 6-7% P_2O_5
11.	Mountain Pass, California, U.S.A.	36.3 MT - 7.67 % REOs 20-25% $BaSO_4$
12.	Magnet Cove Complex, Arkansas, U.S.A.	11.7 MT - 0.0513% Nb 10.8 MT - 0.83% V 10 Mt - 2.0 % Ti
13.	Powderhorn Complex (Iron Hill), Colorado, U.S.A.	223 MT - 4.0% TiO_2
14.	Sarfartoq, Greenland	500 MT - 3.5 % P_2O_5 0.3 MT - 10% Nb_2O_5
15.	Qaqarssuk, Greenland	4.0 MT - 0.5% Nb_2O_5 3.4 MT - 3.5-6% P_2O_5
16.	Jacupiranga,Sao Paulo,Branzil	200 MT - 5.30 % P_2O_5
17.	Ipanema, Sao Paulo, Branzil	25 MT - 7.5 % P_2O_5
18.	Anitapolis, Santa Catarina, Branzil	186 MT - 4 % P_2O_5
19.	Tapira, Mines, Gerais, Branzil	114 MT - 1.2 % Nb_2O_5 241 MT - 8% P_2O_5
20.	Mato Preto, Parana State, Brazil	4.3 MT - 58 % CaF_2
21.	Palabora, South Africa	600 MT - 7% P_2O_5 286 MT - 0.69% Cu 2.16 MT - 0.5 % REOs
22.	Panda Hill (Mbeya),Tanzania	113 MT - 0.3 % Nb_2O_5
23.	Gakara-Karonge, Burundi	907 T REOs
24.	Okorusu, Namibia	7.9 MT - 50% CaF_2
25.	Kangankunde Hill, Malawi	269000 T REOs.
26.	Bayan Obe, Inner Mongolia, People's Republic of China	37 MT – 6% REOs 1 MT – 0.10% Nb
27.	Amba Dongar, India	11.6 MT - 30% CaF_2
28.	Kamthai ,Barmer (Rajasthan)	7.36 MT – 1.62 % REO_s

Apart from the workable deposit of fluorite at Amba Dungar (Gujarat) and REO at Kamthai (Barmer), minor occurrences of different minerals have also been reported from the Indian carbonatites. These include:

Apatite : Newania (Photo 3), Kutni-Beldih, Sevattur, Sung Valley, Amba Dungar, Siriwasan, Panwad Kawant, Meduaplli, Bora, Hogenadal, Jokipatti, Semalpatti

Fluorite : Panwad-Kanwant

Iron Deposits : Newania, Mundwara, Amba Dungar, Siriwasan, Panwad- (Magnetite and Hematite) Kawant, Bora, Sevattur, Sung Valley and Samchampi

Pyrochlore $(Na,Ca)_2 Nb_2O_6$: Sung Valley, Sevattur, Mundwara, Amba Dungar, Siriwasan, Panwad-Kawant, Jokipatti

Bastnasite (REE) CO_3F : Siriwasan

Barite : Ambadongar, Pakkanadu, Mundwara

Vermiculites	: Sevattur
Chalcopyrite	: Amba Dungar, Jokipatti
Galena	: Amba Dungar, Jokipatti
Zircon	: Arepalli, Jokipatti
Uranium and Thorium	: Siriwasan, Sevattur, Jokipatti, Semalpatti

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