

## 27. *Geochemical Studies on the Carbonated Apatite Glimmerites from Damodar Valley, India*

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Lamprophyres containing "leucite", have been reported to occur as dykes or sills, intruding into the Gondwana formations in and around Damodar Valley (Ghose, 1949; Banerjee, 1953), and the districts have been considered classical localities of leucite-bearing rocks in India (Chatterjee, 1974). Recently we made detailed studies on the geochemistry of these rocks, using the following rock samples:

S: from a drill core at Sudamdih, Dhanbad district, Bihar;

M-1, M-2, M-3: from drill cores at Mohanpur and

P: from a dyke at Poidih, both Burdwan district, West Bengal.

All these localities, included in Damodar Valley, are situated about 250–270 km NW of Calcutta.

Microscopically all the samples are characterized by variable proportions of phenocrystic phlogopite and apatite, and microphenocrystic ankerite and chromian spinel in the groundmass composed of phlogopite, apatite, ankerite, rutile, pyrite and devitrified glass. In addition priderite microphenocrysts occur rarely in Mohanpur rocks as accessory mineral. Phlogopite is always the most important constituent, whereas modal percentage of apatite is 8–30%, ankerite 8–18%, and spinel <5%. A thorough scan with the electron beams failed to show the presence of any leucite in all the samples. Thus the rocks from these localities in Damodar Valley are not leucite-bearing as previously considered.

Bulk rock analyses obtained by using standard XRF technique (Table I) show remarkable features of these rocks; i.e., extremely low SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> contents, and high P<sub>2</sub>O<sub>5</sub>, TiO<sub>2</sub>, and K<sub>2</sub>O contents. They are also high in some minor and trace elements such as Ce, Y, La (La > Y), Nd, Rb, Sr, Ba, and Zr (Table II), all of which are higher almost by one order than those of the average basalts (Frey *et al.*, 1978; Masuda and Aoki, 1979).

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Table I. Chemical analyses of carbonated apatite glimmerites

	S	M-1	M-2	M-3	P
SiO <sub>2</sub>	32.37	35.29	35.70	34.11	30.31
TiO <sub>2</sub>	9.32	4.25	5.94	6.56	7.33
Al <sub>2</sub> O <sub>3</sub>	9.84	5.54	5.99	9.08	6.61
Fe <sub>2</sub> O <sub>3</sub> *	8.68	11.20	11.22	10.44	11.51
MnO	0.12	0.286	0.137	0.145	0.17
MgO	8.09	8.31	10.05	6.10	11.20
CaO	8.26	7.18	5.85	11.55	11.76
Na <sub>2</sub> O	0.13	0.11	0.08	0.21	0.12
K <sub>2</sub> O	7.09	3.42	4.69	4.90	2.82
Cr <sub>2</sub> O <sub>3</sub>	0.053	0.045	0.062	0.078	0.12
BaO	0.487	0.506	0.280	0.933	0.495
P <sub>2</sub> O <sub>5</sub>	2.93	6.32	2.42	5.18	3.53
SO <sub>3</sub>	0.17	0.31	0.48	0.45	1.47
Ig. Loss	11.78	14.77	15.61	8.75	11.59
Minor & trace elements	0.86	1.502	0.823	1.171	1.070
Total	100.18	99.039	99.332	99.657	100.105

Table II. Analyses of minor and trace elements of carbonated apatite glimmerites (ppm)

	S	M-1	M-2	M-3	P	Average basalts
Sc	27	31	20	33	29	23
Co	83	49	49	44	62	49
Ni	336	425	298	127	519	101
Cr	181	154	212	267	411	—
Cu	104	54	50	73	100	51
Zn	160	146	150	122	98	136
Ga	30	27	20	32	26	—
Rb	151	130	129	90	113	24
Sr	2431	7227	2723	5730	3032	417
Ba	4383	4554	2520	8397	4455	364
Ce	891	1675	643	925	1142	95
Zr	845	1090	1362	824	1697	204
Y	79	137	66	86	80	39
La	495	1020	384	557	687	41
Nd	413	823	320	448	503	48
Th	46	58	32	30	66	6
Pb	47	118	46	62	61	—

Representative EPMA analyses of rock-forming minerals; phlogopite (hydroxy-titanophlogopite), apatite (fluor-apatite), ankerite (dolomitic ankerite:  $(\text{CaCO}_3)_{52\pm 3}(\text{MgCO}_3)_{36\pm 3}(\text{FeCO}_3)_{12\pm 3}$ ), chromian spinel, priderite, K-feldspar, and rutile, are given in Table III. Compared to priderites from West Kimberley and Leucite Hills (Car-

Table III. Microprobe analyses of rock-forming minerals of carbonated apatite glimmerites

	1	2	3	4	5	6	7
SiO <sub>2</sub>	37.94	0.00	0.00	0.00	62.91	0.00	0.00
TiO <sub>2</sub>	8.41	0.33	0.03	79.27	0.51	8.83	97.30
Al <sub>2</sub> O <sub>3</sub>	10.11	0.20	0.02	0.10	16.82	4.25	0.06
FeO*	8.07	0.30	5.45	8.94	1.23	37.19	0.73
MnO	0.08	0.00	0.02	0.04	0.05	0.78	0.06
MgO	18.41	0.40	17.07	0.13	0.74	8.91	0.00
CaO	0.00	54.63	26.44	0.19	0.48	0.72	0.09
Na <sub>2</sub> O	0.15	0.03	0.00	0.14	0.13	0.02	0.02
K <sub>2</sub> O	9.87	0.21	0.01	8.10	14.16	0.00	0.06
Cr <sub>2</sub> O <sub>3</sub>	n.d.	n.d.	n.d.	0.22	0.02	37.09	0.09
NiO	n.d.	n.d.	n.d.	0.09	0.10	0.06	0.08
BaO	n.d.	n.d.	n.d.	1.10	1.13	0.00	0.00
F	0.25	5.01	0.00	n.d.	n.d.	n.d.	n.d.
Cl	0.08	0.02	0.02	n.d.	n.d.	n.d.	n.d.
P <sub>2</sub> O <sub>5</sub>	0.47	36.91	0.02	n.d.	n.d.	n.d.	n.d.
Total	93.84	98.04	98.32**	98.32	98.28	97.85	98.49

\*Total iron as FeO. 1: Phlogopite from M-2. 2: Apatite from S. 3: Ankerite from M-1. \*\*Total contains CO<sub>2</sub> 49.24%. 4: Priderite from M-3. 5: K-feldspar from P. 6: Chromian Spinel from P. 7: Rutile from M-3.

michael, 1967), those from Mohanpur rocks are much lower in BaO and FeO.

From these mineral assemblages and bulk compositions, the rocks under investigation can not be termed lamprophyres, such as kersantite, minette, or camptonite (Nockolds *et al.*, 1978), but should belong to the "glimmerites" described first by Larsen and Pardee (1929), and later by Holmes (1937), which consist mostly of various micas and some minor constituents. Since the rocks are high in apatite and ankerite, they may be designated as "carbonated apatite glimmerites".

Quenching experiments on four rock samples under atmospheric pressure and NNO buffer conditions showed that the primary phases, liquidi, and solidi are as follows:

S: Leucite, 1305 and 1185°C,  
M-1: Leucite, 1245 and 1150°C,  
M-2: Olivine, 1250 and 1150°C,  
M-3: Leucite, 1242 and 1150°C,  
P: Olivine, 1235 and 1100°C.

The phases below solidi are the same in all the samples; i.e., leucite, olivine, clinopyroxene, rutile and Fe-oxides. It is to be noted that leucite always appears in these experiments, in spite of the absence

of modal leucite. Experimental studies at variable pressures on synthetic leucite-bearing melts (Gupta *et al.*, 1976), and natural leucite-bearing tephrites and basanites from East Eifel, Germany (Gupta and Yagi, 1980) indicate that leucite should not crystallize from potassium-rich magmas at pressures above 3 kbar. Although the quenching experiments under atmospheric pressure suggest that the apatite glimmerites could be potentially leucite-bearing, the fact that leucite is not present in these rocks suggests that the crystallization of the glimmerites from a highly potassic silica-undersaturated magma took place under  $P_{\text{fluid}} \simeq P_{\text{total}} > 3$  kbar, and the fluid was composed chiefly of H<sub>2</sub>O and CO<sub>2</sub>. Comparison of the chemistry of the chromian spinels found in these rocks with those studied under variable  $f_{\text{O}_2}$ -T conditions (Muan *et al.*, 1972; Sato, 1972) indicates that the parent magma crystallized under oxygen fugacities defined by NNO and FMQ buffers.

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