Barium-rich alkali feldspar in basanite from central Kachchh, northwestern India

Alkali feldspar with barium (Ba) is often present in alkaline, potassic, ultrapotassic, lamprophyre and alkaline silicic volcanic rocks (refs 1–3, and references therein). It provides valuable information regarding the behaviour of Ba during crystallization of magma and its characterization. Here we report the occurrence of Ba-rich alkali feldspar (hyalophane) rim around plagioclase from basanite (Kumari Dungar, Figure 1) intrusive into the Mesozoic Bhuj sandstone in the central part of the Kachchh, northwestern Deccan Traps (NWDT), Gujarat, India.

Petrographic characters of basanite show porphyritic texture (Figure 2 *a*), consisting of olivine, clinopyroxenes, plagioclase, Ba-rich alkali feldspar, spinel and nepheline (in order of decreasing abundance) with occasional biotite and analcime. Olivine (core = $Fo_{81}Fa_{19}$; rim = $Fo_{72}Fa_{28}$) is the main phenocryst phase; larger grain shows fracture with embayed margins (Figure 2 *a*), indicating xenocrystic nature and often contains Cr-spinel [$100 \times Cr/(Cr + Al) = 20$ and $100 \times Mg/(Mg + Fe) = 32$] inclusion. Clinopyroxenes are Ti-rich diopside (TiO_2 = 2–4.5 wt%) and mostly occur as microphenocryst as well as in groundmass. Ba-rich alkali feldspar (BaO = 2–6 wt%, K_2O = 7.5–9 wt%, Na_2O = 3.5–4 wt%; Table 1) occurs as thin rims mantling plagioclase (Ab_{24} An_{75}; Figure 2 *b*) and as microlites in groundmass, and contains 4–12 mol% celsian with $Ab_{33–38}$ $An_{3–9}$ $Or_{52–57}$ (Table 1). It also shows decrease in Ba content from 5.85 to 0.20 wt% (points 5–7 in Figure 2 *b*; Table 1) from the inner to outer part of the rim along with an increase in Or content from 46 to 61.83 mol%. Similar feature has also been observed for points 3 and 4. Such zoning pattern possibly indicates the crystal melt distribution for Ba with decrease in its content in the residual liquid as crystallization progresses.

The whole-rock geochemistry indicates silica under saturated (SiO_2 – 40%), alkaline ($Na_2O + K_2O$ – 4%), magnesian (MgO – 10%) character of basanite with high values of TiO_2 (>2%), Ni (389 ppm) and Cr (564 ppm), and very high values of Ba (595 ppm) and Sr (595 ppm). The chondrite normalized[4] rare earth element (REE) pattern (Figure 3 *a*) shows enrichment of LREE over HREE (La_N/Yb_N = 19) with positive Eu anomaly indicating plagioclase accumulation. The primitive mantle[4] normalized incompatible trace element pattern (Figure 3 *b*) indicates enrichment in large ion lithophile elements (LILE) and high field strength elements characterized by positive peaks of Th and Nb. The positive anomaly of

Table 1. Representative electron microprobe analysis of feldspar, clinopyroxene and nepheline from basanite plug, Kachchh, northwestern Deccan Trap, Gujarat, India

	Feldspar									Nepheline	Clinopyroxene	
Point no.	1/1.	2/1.	3/1.	4/1.	5/1.	6/1.	7/1.	8/1.	9/1.	10/1.		11/1.
SiO_2	60.22	61.11	58.88	62.48	59.04	63.38	62.77	60.25	48.02	49.80	SiO_2	46.54
TiO_2	0.23	0.14	0.34	0.13	0.29	0.17	0.04	0.88	0.00	0.11	TiO_2	2.27
Al_2O_3	19.90	20.87	20.62	19.99	21.26	20.17	19.53	19.83	31.94	31.13	Al_2O_3	7.01
FeO	0.15	0.05	0.26	0.17	0.09	0.21	0.11	0.07	0.52	0.43	Cr_2O_3	0.74
CaO	0.51	0.69	0.55	0.68	1.01	1.45	0.76	1.70	14.84	0.39	FeO	5.72
Na_2O	3.50	3.69	3.46	3.73	4.02	4.99	3.74	3.64	2.64	15.94	MgO	13.47
K_2O	8.98	8.67	8.39	9.32	7.48	8.15	10.33	8.63	0.25	2.70	CaO	23.38
BaO	5.19	5.51	6.03	2.34	5.85	0.29	0.20	2.24	0.08	0.00	Na_2O	0.34
Total	98.68	100.73	98.54	98.85	99.03	98.81	97.47	97.24	98.29	100.49	Total	99.46
	No. of oxygen atoms = 32									No. of oxygen atoms = 32	No. of oxygen atoms = 06	
Si	11.48	11.41	11.31	11.63	11.23	11.62	11.73	11.43	8.96	9.22	Si	1.73
Ti	0.03	0.02	0.05	0.02	0.04	0.02	0.01	0.13	0.00	0.01	Ti	0.06
Al	4.47	4.59	4.67	4.39	4.77	4.36	4.30	4.43	7.02	6.79	Al	0.31
Fe^{2+}	0.02	0.01	0.04	0.03	0.01	0.03	0.02	0.01	0.08	0.07	Cr	0.02
Ca	0.10	0.14	0.11	0.14	0.21	0.28	0.15	0.35	2.97	0.08	Fe(ii)	0.18
Na	1.30	1.33	1.29	1.35	1.48	1.77	1.35	1.34	0.95	5.72	Mg	0.75
K	2.18	2.07	2.06	2.21	1.82	1.90	2.46	2.09	0.06	0.64	Ca	0.93
Ba	0.39	0.40	0.45	0.17	0.44	0.02	0.01	0.17	0.01	0	Na	0.02
Total	19.99	19.97	19.98	19.93	19.99	20.02	20.03	19.94	20.04	22.53	Total	4.00
An	2.60	3.51	2.91	3.51	5.22	7.13	3.81	8.79	74.45	–	Wo	50.20
Ab	32.63	33.86	32.92	34.84	37.62	44.52	34.00	33.95	23.94	–	En	40.24
Or	55.01	52.41	52.57	57.23	46.09	47.82	61.83	53.04	1.46	–	Fs	9.55
Cs	9.77	10.22	11.60	4.42	11.06	0.52	0.36	4.23	0.15	–	–	–

Figure 1. Panoramic view of volcanic plug (Kumari Dungar, 23°17′51.3″N, 69°27′15.6″E), Kachchh northwestern Deccan Traps (NWDT), Gujarat.

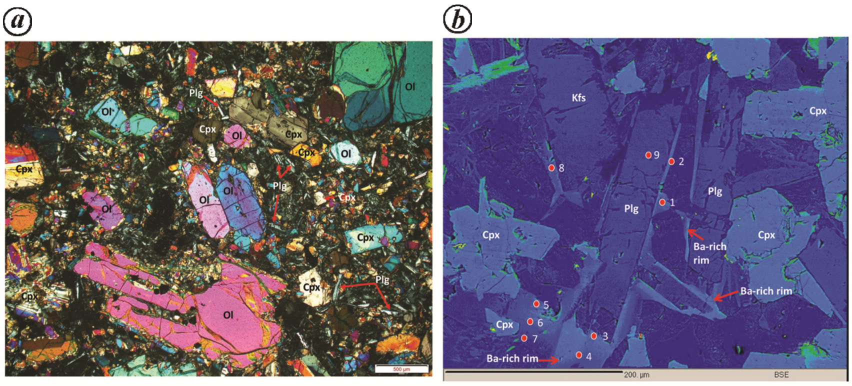

Figure 2. ***a***, Photomicrograph showing mineral constituents of basanite. Ol, Olivine; Cpx, Clinopyroxene and Plg, Plagioclase. Note: Olivine with embayed margin. ***b***, Backscattered electron image of basanite showing Ba-rich rim mantling plagioclase with false colour. Plg, Plagioclase; Kfs, K-feldspar and Cpx, Clinopyroxene. Note: Red colour filled circles with numbers indicate electron probe analysis point.

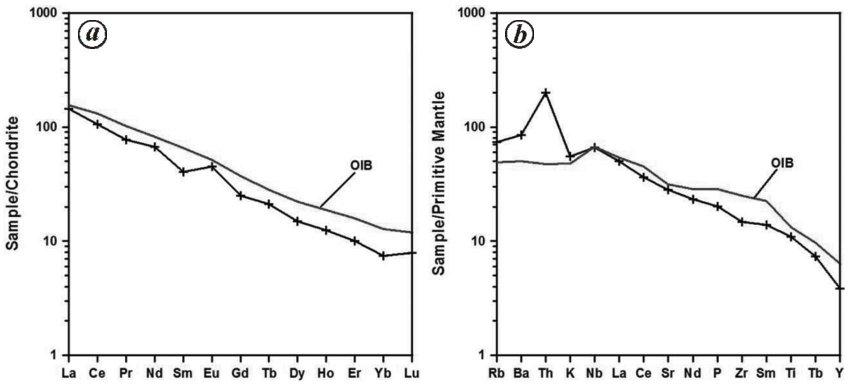

Figure 3. (***a***) Chondrite[4] normalized REE and (***b***) primitive mantle[4] normalized multi-element diagram of basanite plug in Kachchh, NWDT, Gujarat.

Th points to the role of the crustal component during emplacement of basanite plug.

The growth of Ba-rich alkali feldspar (hyalophane) over existing plagioclase grains indicates that plagioclase served as a nucleation site. The precipitation of hyalophane mantle around plagioclase is due to gradual enrichment of incompatible Ba in the residual melt due to crystallization of Ba-free phases (olivine and clinopyroxene) during the early stage of crystallization. The zoning pattern in the Ba-rich mantle (more Ba close to the grains) suggests depletion of the element with growth of the mantle. The initial enrichment of Ba in the melt is due to metasomatic activity in the source region to an extent so as to precipitate hyalophane during the later stage of crystallization. It is obvious that introduction of such metasomatic fluids would result in enrichment of LILE/LREE content, which is manifested in REE and incompatible trace element patterns of basanite (low La/Nb = 0.7; Figure 3) of the study area, and shows similarity with ocean island basalt (OIB) type source[4] in this regard.

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