Implication of Mafic Magmatism in an Intracontinental Rift Setting: A Case Study from the Paleoproterozoic Dhanjori Formation, Singhbhum Crustal Province, India

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ABSTRACT

We present major, trace, rare earth element, and selected high-field-strength element ratios (Nb/Th, Zr/Nb, Nb/Y, and Zr/Y) of the Paleoproterozoic Dhanjori volcanic and volcaniclastic rocks of the Singhbhum crustal province, eastern India. The geochemical characteristics of the upper Dhanjori volcanic rocks indicate that these are basaltic komatiites. Our geochemical data, in combination with the sedimentological and stratigraphic characteristics of the interbanded metasedimentary rocks clearly indicate an intracontinental rift setting for Dhanjori volcanism and sedimentation.

Introduction

The Paleoproterozoic (2100 Ma; Sm-Nd age from upper Dhanjori volcanic rocks; Roy et al. 2002*b*) Dhanjori Formation, eastern India (figs. 1, 2), represents metamorphosed clastic sedimentary rocks interbedded with mostly mafic volcanic and volcaniclastic rocks. Earlier researchers claim that part of the Dhanjori volcanic and volcaniclastic rocks are komatiitic (Viswanathan and Sankaranan 1973; Gupta et al. 1980, 1985; Sarkar et al. 1992). Since komatiites can be genetically related to mantle plumes (Campbell et al. 1989; Campbell and Griffiths 1990; Griffiths and Campbell 1991; Condie 2003, 2005; Eriksson et al. 2004 and references therein), researchers speculated that the Dhanjori volcanism was possibly a consequence of mantle plume uplift (Eriksson et al. 1999; Mazumder et al. 2000; Roy et al. 2002*b*; Mazumder and Sarkar 2004). Bose (2000) suggested that the Dhanjori lavas are not komatiitic as they are lacking in diagnostic major and trace element chemistry. Here we present the major, trace, and rare earth element (REE) characteristics of the Dhanjori volcanic and volcaniclastic rocks and discuss their possible origin and implications.

Regional Geology

The Dhanjori Formation covers an 800-km^2 area and crops out along an east-west-striking, broadly curvilinear belt extending from Singpura in the southeast to Narwapahar in the northwest (fig. 1; Gupta et al. 1985; Gupta and Basu 2000; Mazumder 2005). The Dhanjori Formation comprises siliciclastic sedimentary rocks interlayered with mafic volcanic and volcaniclastic rocks (rarely felsic; Gupta and Basu 2000), deformed and metamorphosed to greenschist facies (Dunn and Dey 1942; Iyenger and Alwar 1965; Saha 1994; Gupta and Basu 2000; Mazumder and Sarkar 2004; Mazumder 2005). It is flanked by the ~1.6-Ga (Krishna Rao et al. 1979; Sengupta and Mukhopadhaya 2000) Singhbhum Shear Zone (SSZ) to its north and northeast and Iron Ore Group of rocks to its northwest (not shown in fig. 1; for details, see Saha 1994). The Dhanjori Formation directly overlies the Archaean granite basement and, in turn, is overlain by mica schist-quartzite assemblages of the shallow to deep marine Chaibasa Formation (Bose et al. 1997; Mazumder and Arima 2004; Mazumder 2005; figs. 1,

Manuscript received October 3, 2008; accepted March 17, 2009.

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[The Journal of Geology, 2009, volume 117, p. 455–466] 0022-1376/2009/11704-0008$15.00. DOI: 10.1086/599197

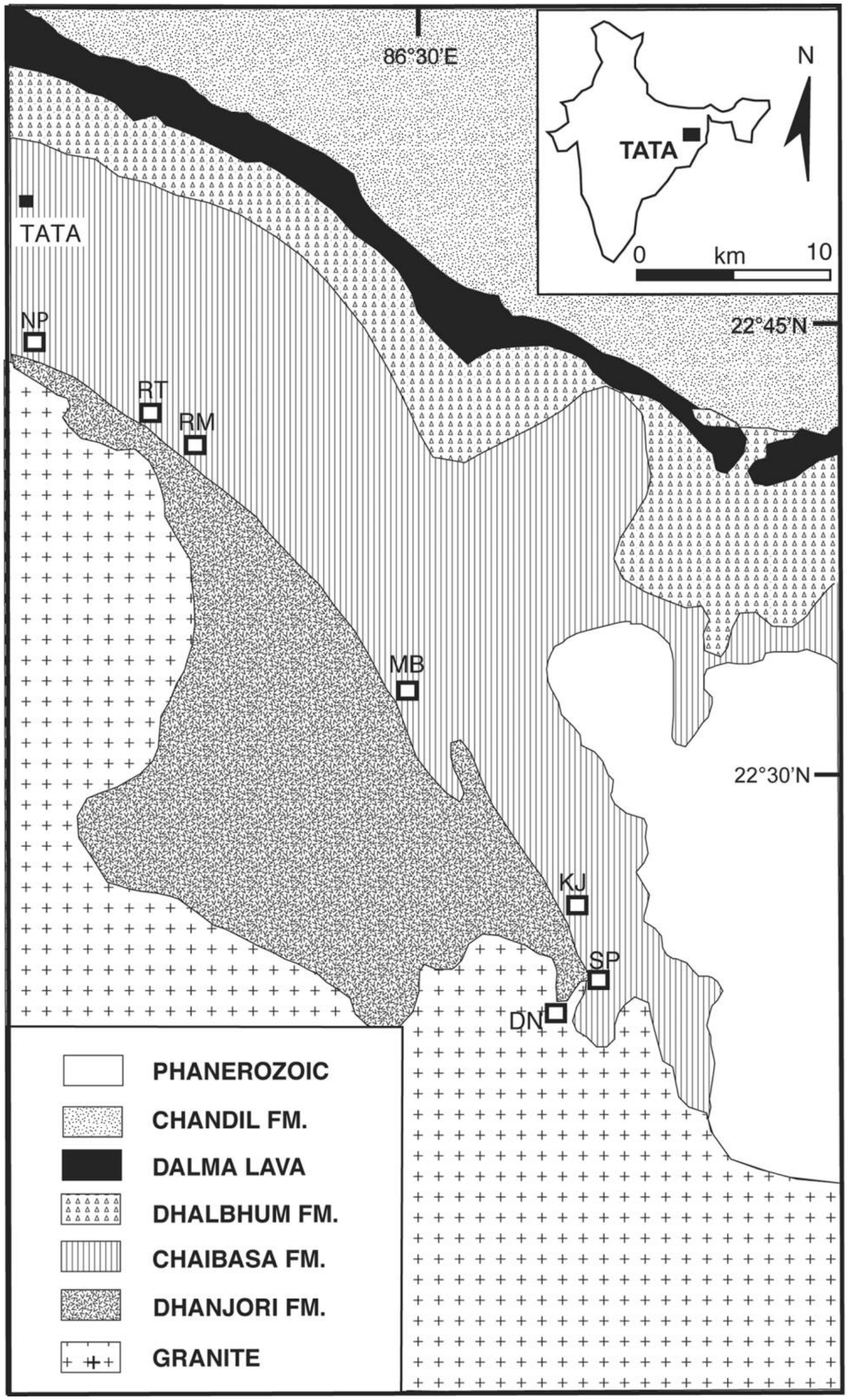

Figure 1. Simplified geological map showing the disposition of the Dhanjori Formation and its bounding litho-units (modified after Saha 1994). Study locations: *NP* = Narwa Pahar, *RT* = Rukmini Temple (Jadugoda), *RM* = Rakha Mines, *MB* = Mosaboni, *KJ* = Khejurdari, *SP* = Singpura, *DN* = Dongadaha.

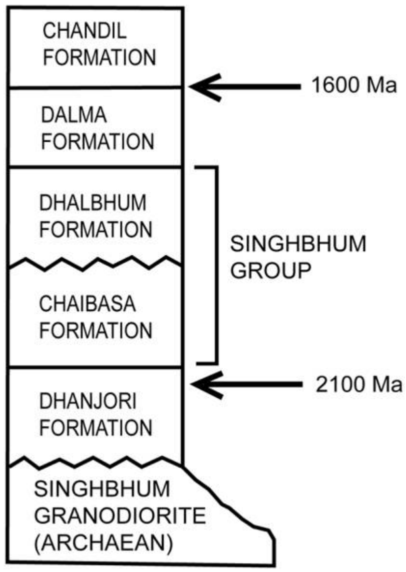

Figure 2. Proterozoic stratigraphic succession of the Singhbhum crustal province, eastern India (modified after Mazumder 2005; age data after Roy et al. 2002*a*, 2002*b*).

2). The contact between the Dhanjori and the Chaibasa formations is marked by a clast-supported sheet conglomerate and/or pebbly sandstone interpreted as transgressive lag deposit by Bose et al. (1997) and Mazumder (2005; his fig. 8*a*). No direct age data is available from the Chaibasa and Dhalbhum formations, but the minimum age of the Dalma lava that conformably overlies the Dhalbhum Formation (cf. Bhattacharya and Bhattacharya 1970) of the Singhbhum Group is 1.6 Ga (Roy et al. 2002*a*; fig. 2).

Dhanjori Volcanic and Volcaniclastic Rocks

The Dhanjori volcanic rocks include mafic lava flows. These are mostly massive but show excellent flow banding (fig. 3*a*) and vesicular structures. These rocks are composed of actinolite, hornblende, relict pyroxenes, and olivines, along with epidotes and chlorites. Occasionally olivine pseudomorphs are present in the fine-grained plagioclase and augite groundmass. The volcaniclastic facies is represented by tuff and agglomerate and generally occurs immediately above or in close lateral contact with the volcanic rocks (fig. 4). Clasts (interpreted as bombs; cf. Mazumder and Sarkar 2004; fig. 3*b*) are mostly angular, irregular in shape, and poorly sorted. The tuffs and agglomerates are mafic to ultramafic (rarely acidic; see Singh 1998; Gupta and Basu 2000) in composition. Vitric tuffs in the central part of the study area are overlain by basaltic lava flows (fig. 4). Thickness of individual agglomerate bands is up to 3.5 m.

Sampling and Analytical Procedures. The rock samples were collected from the Bhagabandi sector, south of Mosabani, and the Jobla-Kulamara sector, south of Rakha Mines (see figs. 1, 4). All rock samples are from the Upper Dhanjori Member (fig. 4). We analyzed 28 samples for the major and trace elements and 12 out of those 28 samples for selected trace elements and REEs (tables 1, 2). Interested readers may consult Mazumder and Sarkar (2004) for sedimentological and stratigraphic characteristics of the Dhanjori Formation.

Major element analyses were carried out with x-ray fluorescence (Rigaku RIX-3000) at the National Institute of Polar Research, Tokyo. The analytical procedure followed the methods by Motoyoshi and Shiraishi (1995) and Motoyoshi et al. (1996). The

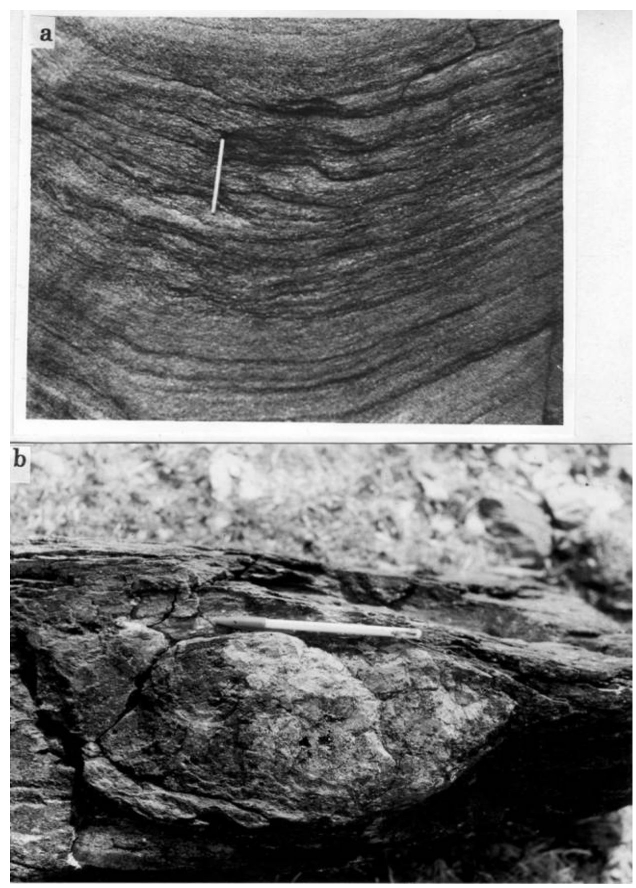

Figure 3. *a*, Flow banding within Dhanjori basalt, Bhagabandi, south of Mosaboni. *b*, Large bomb within Dhanjori volcaniclastic deposit (pen length 13 cm), Sargachira, south of Mosaboni.

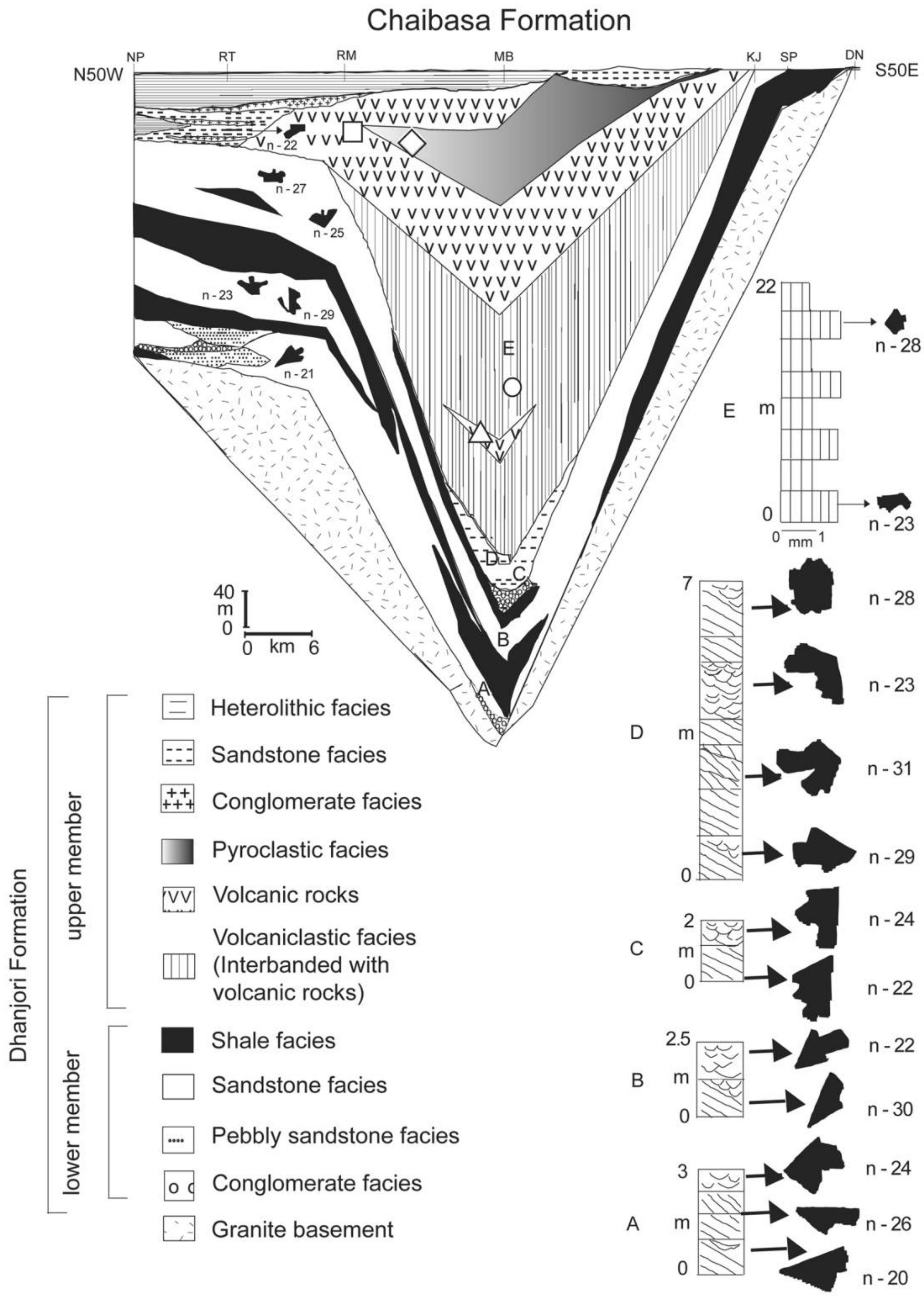

Figure 4. Panel diagram showing lateral and vertical lithofacies transitions during Dhanjori sedimentation. Spatial and temporal changes in paleocurrent directions have been shown. Study locations are marked in figure 1 (modified after Mazumder and Sarkar 2004). Note sample positions in the volcano-sedimentary sequence: *triangle* = Dhanjori volcanic rocks from the Bhagabandi sector, south of Mosaboni; *circle* = Dhanjori volcaniclastic rocks, Sargachira, south of Mosaboni; *square* = Dhanjori volcanic rocks from the Jobla-Kulamara sector, south of Rakha Mines; *rhomb* = Dhanjori volcaniclastic rocks from the Jobla-Kulamara sector, south of Rakha Mines. Interested readers may consult Mazumder and Sarkar (2004) for sedimentological and stratigraphic characteristics of the Dhanjori Formation.

Table 1. Whole-Rock Compositions of Volcanic and Volcaniclastic Rocks of the Upper Dhanjori Member: Jobla-Kulamara Sector

	Jobla-Kulamara sector, south of Rakha Mines														
	Volcanics sample									Volcaniclastic sample					
Rock type	R6C	R6B	R6/D	R6D/1	R6F	R7	R8	DV	UDV1	RM1	RM2	RM3	UDPHY1	UDVC1	UDVC2
X-ray fluorescence (wt%):															
SiO_2	55.32	56.08	54.34	54.77	55.91	60.37	52.78	54.44	55.9	55.81	56.11	56.43	47.27	56.01	54.7
TiO_2	.75	.77	.64	.65	.77	.49	.72	.76	.75	.28	.36	.36	.74	.34	.24
Al_2O_3	8.2	8.22	6.3	6.37	8.19	9.66	7.77	9.3	8.04	6.09	5.37	5.43	33.2	5.83	6.94
	13.1	13.28	14.85	14.19	13.3	12.13	13.74	12.21	12.33	11.21	10.91	10.98	2.08	10.47	11.06
MnO	.15	.16	.2	.2	.16	.12	.14	.19	.15	.17	.17	.18	0	.13	.14
MgO	9.54	9.51	10.7	10.85	9.08	6.17	10.62	9.15	9.54	19.89	19.75	20.05	.78	19.88	20.29
CaO	9.25	9.13	10.56	10.59	9.06	10.1	10.68	9.18	9.2	4.24	4.57	4.59	.23	5.38	4.79
Na_2O	3.06	2.93	1.92	1.97	2.9	.74	2.3	2.94	2.96	.89	.85	.86	.81	.16	.14
K_2O	.35	.41	.19	.19	.34	.18	.21	.6	.39	.59	.59	.6	10.41	.03	.03
P_2O_5	.08	.09	.07	.07	.09	.12	.08	.1	.09	.03	.03	.03	.17	.03	.02
Total	99.8	100.58	99.77	99.85	99.8	100.08	99.04	98.87	99.35	99.2	98.71	99.51	95.69	98.26	98.35
Mg#	.59	.59	.59	.6	.57	.5	.6	.6	.61	.78	.78	.78	.43	.79	.78
ICP-MS (ppm):															
V	140		127		140					116	115		281	123	
Cr	947		1270		962					1770	1750		304	1830	
Co	61		69		61					79	78		2	68	
Ni	242		290		257					485	483		...	502	
Cu	67		135		72					46	42		...	40	
Zn	72		81		71					82	87		...	34	
Ga	14		11		14					9	9		63	7	
Ge	1.6		1.4		1.6					1.5	1.7		2.4	1.4	
Rb	18		3		17					34	34		367	2	
Sr	100		38		89					32	31		51	6	
Y	22.6		17.8		23.9					9.6	9.2		49.6	9.1	
Zr	125		85		128					46	43		227	46	
Nb	5.4		4		5.5					2.2	2.2		14.7	2.7	
Sb	.5		.3		.3					.2	.4		2.3	.8	
Cs	.3		...		.3					1.7	1.8		2.1	...	
Ba	22		7		23					58	58		514	17	
La	20.5		9.07		19.6					8	7.9		16.5	6.51	
Ce	40.4		21.6		42.8					14.4	14.4		31	15.5	
Pr	4.71		2.19		4.62					1.68	1.72		2.99	1.71	
Nd	18.9		9.44		18.5					6.41	6.3		10.2	6.22	
Sm	4.73		2.69		4.58					1.4	1.43		2.05	1.49	
Eu	1.38		1.07		1.33					.389	.394		.717	.329	
Gd	4.46		2.99		4.43					1.37	1.41		2.87	1.36	
Tb	.77		.56		.77					.25	.26		.81	.26	
Dy	4.25		3.45		4.33					1.54	1.53		6.23	1.49	
Ho	.81		.67		.84					.32	.32		1.47	.3	
Er	2.46		1.94		2.53					1.04	1.05		5.3	.98	
Tm	.361		.263		.362					.171	.165		.848	.155	
Yb	2.09		1.5		2.11					.98	1.02		5.26	.96	
Lu	.287		.196		.297					.144	.147		.765	.137	
Hf	3.3		2.3		3.3					1.2	1.2		6.6	1.2	
Ta	.33		.25		.32					.17	.15		1.26	.18	
W	.8		1.2		.5					1.7	...		24.6	1.4	
Tl	.12		.09		.1					.29	.34		1.41	...	
Bi	.8		1		1.4					1.4	2.1		.7	.4	
Th	3.11		2.33		3.17					1.26	1.3		19.3	1.1	
U	.52		.41		.47					.38	.39		4.56	.33	
Nb/Th	1.7		1.7		1.7					1.8	1.7		.8	2.5	
Zr/Nb	23.2		21.2		23.3					20.4	20.1		15.4	16.9	
Zr/Y	5.5		4.8		5.3					4.8	4.7		4.6	5.1	
Nb/Y	.2		.2		.2					.2	.2		.3	.3	
DNb	−.31		−.21		−.3					−.2	−.18		−.06	−.14	
Ce/Ce*	.96		1.14		1.05					.92	.91		1.03	1.09	

REEs and selected trace elements (Nb, Hf, Ta, W, Tl, Bi, Ga, Ge, Sn, Sb, Cs, Th, and U) were analyzed at Activation Laboratories (Ancaster, Ontario) using instrumental neutron activation techniques and inductively coupled plasma-mass spectrometry (ICP-MS). The analytical procedure followed the methods of Hoffman (1992). Detail procedure and analytical standards are available at http://www.actlab.com/.

Results. The Dhanjori volcanic and volcaniclastic rocks have Ce/Ce* ratios between 0.99 and 1.1 (tables 1, 2), suggesting negligible mobility of light REEs (LREEs) in these rocks (cf. Polat et al. 2002). Our analyses revealed that the Dhanjori volcanic and volcaniclastic rocks have SiO_2 and MgO content of 46%–56% and 9%–12%, respectively (tables 1, 2). Spinifex texture is lacking. A few highly altered ultramafic volcaniclastic rocks samples have

Table 2. Whole-Rock Compositions of Volcanic and Volcaniclastic Rocks of the Upper Dhanjori Member: Bhagabandi Sector

Rock type	Bhagabandi sector, south of Mosaboni												
	Volcanics sample											Volcaniclastic sample	
	LDV	LDV1	LDV2	LDV3	LDV4	LDV5	LDV6	LDV7	LDV12	LDV13	LDV16	LDVC3	LDVC1
X-ray fluorescence (wt%):													
SiO_2	52.12	53.8	52.35	52.36	54.95	50.96	46.55	49.08	54.89	53.16	52.14	69.7	62.02
TiO_2	.74	.72	.74	.78	.79	.88	.88	.95	.71	.83	.82	.26	.33
Al_2O_3	10.58	9.1	10.19	11.74	8.71	10.01	10.65	9.69	8.81	9.4	11.25	7.45	9.88
	13.94	12.48	13.27	12.11	11.32	14.27	14.9	15.03	12.14	12.65	13.02	6.39	7.9
MnO	.2	.2	.19	.18	.19	.21	.22	.22	.2	.21	.2	.1	.12
MgO	10.88	10.66	10.73	9.25	9.76	12.17	11.99	12.41	9.32	9.8	10.39	7.3	8.57
CaO	8.59	9.35	8.72	8.32	10.38	8.51	8.92	8.98	9.13	9.53	8.55	6.43	7.49
Na_2O	2.79	2.71	2.82	3.36	2.84	2.27	1.97	1.85	2.9	2.62	3.02	1.26	1.59
K_2O	.26	.42	.2	.64	.41	.25	.29	.1	.67	.76	.54	.97	1.26
P_2O_5	.1	.1	.09	.04	.09	.12	.13	.12	.09	.08	.06	.04	.07
Total	100.2	99.54	99.3	98.78	99.44	99.65	96.5	98.43	98.86	99.04	99.99	99.9	99.23
Mg#	.61	.63	.62	.6	.63	.63	.61	.62	.6	.61	.61	.69	.68
ICP-MS (ppm):													
V		182				181	193			178	157		
Cr		1160				1240	1280			1150	1180		
Co		65				66	75			70	65		
Ni		300				302	341			345	291		
Cu		47				91	115			196	75		
Zn		110				99	128			122	112		
Ga		15				13	15			16	17		
Ge		1.6				1.3	1.5			1.5	1.3		
Rb		8				5	5			18	12		
Sr		113				61	129			217	60		
Y		19				20.7	23.9			20.2	17.9		
Zr		91				106	106			106	102		
Nb		5				5.4	5.1			5.3	5.1		
Sb		...				...	...			...	–		
Cs		...				...	...			.1	.1		
Ba		89				66	66			355	109		
La		13.7				12.7	13.5			13	8.98		
Ce		27.4				27.8	29.1			26.9	21.1		
Pr		3.04				3.16	3.41			3.06	2.58		
Nd		12.4				13.4	14.4			12.8	10.7		
Sm		3.18				3.52	3.92			3.48	3.05		
Eu		1.21				.954	1.37			1.25	.942		
Gd		3.29				3.59	4.14			3.52	3.15		
Tb		.57				.64	.71			.61	.56		
Dy		3.31				3.71	4.19			3.68	3.27		
Ho		.67				.75	.85			.74	.67		
Er		2				2.2	2.53			2.13	2.02		
Tm		.281				.322	.339			.307	.291		
Yb		1.72				1.89	2.1			1.92	1.75		
Lu		.243				.265	.299			.26	.256		
Hf		2.5				2.7	2.7			2.6	2.5		
Ta		.23				.29	.27			.27	.27		
W		...				1.1	...			1.8	...		
Tl		.16				.08	.12			.23	.17		
Bi		.4				.3	.3			.6	.3		
Th		1.06				1.15	1.25			1.11	1.08		
U		.2				.23	.25			.21	.22		
Nb/Th		4.7				4.6	4.1			4.8	4.7		
Zr/Nb		18.3				19.8	20.7			20	19.9		
Zr/Y		4.8				5.1	4.4			5.2	5.7		
Nb/Y		.3				.3	.2			.3	.3		
DNb		−.15				−.21	−.17			−.22	−.25		
Ce/Ce*		1				1.03	1.01			1	1.03		

MgO content around 20% (table1). The Dhanjori volcanic rocks are basaltic komatiite (fig. 5; Parman and Grove 2004). In the Jensen plot (Jensen 1976), however, all the Dhanjori volcanic rocks plot in the komatiitic basalt field (fig. 6). Malviya et al. (2006) reported similar basaltic komatiitic from the Bundelkhand cratonic province. Compared with the rocks reported by Malviya et al. (2006), the Dhanjori volcanic rocks have relatively low Al_2O_3. Although the Dhanjori volcanics plot in the komatiitic basalt field in the Jensen (1976) diagram, in the absence of spinifex texture, petrologists would refer to these volcanics simply as "high-Mg basalts" (N. Arndt and W. Altermann, pers. comm., 2006).

The Dhanjori volcanics from the stratigraphically older level (Bhagabandi sector, south of Mosaboni; figs. 1, 4) have restricted REE concentrations.

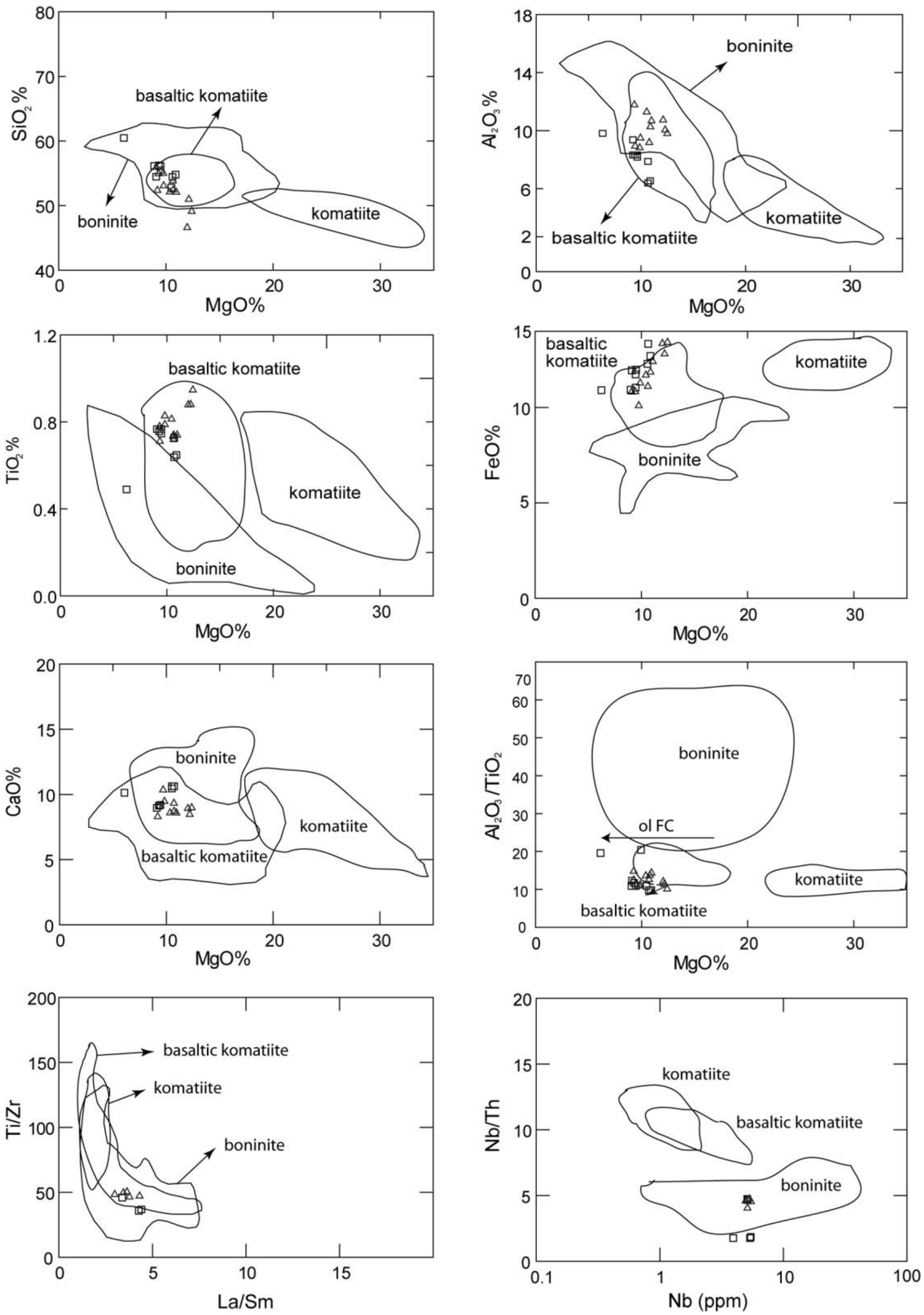

Figure 5. Various major and trace element variation diagrams (basaltic komatiite after Parman and Grove 2004; boninite after Upadhaya 1982); *triangles* = Dhanjori volcanic rocks from the Bhagabandi sector, south of Mosaboni; *squares* = Dhanjori volcanic rocks from the Jobla-Kulamara sector, south of Rakha Mines. Note that all data plot in the basaltic komatiite and basalt field.

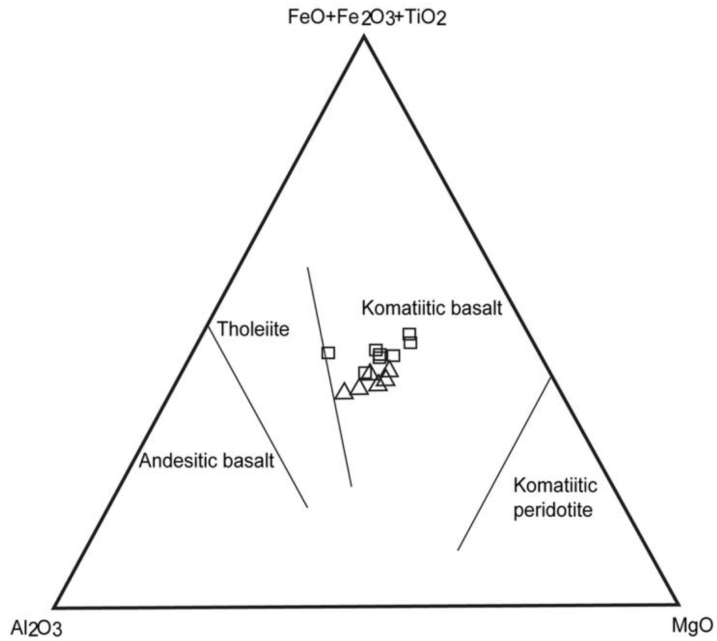

Figure 6. Plot of Dhanjori volcanic rocks in the Jensen (1976) diagram.

They show substantial enrichment of all the REEs versus chondritic values (fig. 7*a*) and also show a LREE enrichment (slight slope from left to right), as would be expected from rocks derived by partial melting of the mantle (Rollinson 1993). There is little or no indication of an Eu anomaly (fig. 7*a*; tables 1, 2). In comparison with these volcanic rocks, the stratigraphically younger volcanic rocks (Jobla-Kulamara sector, south of Rakha Mines; figs. 1, 4) show a much greater range in REE abundances and patterns, probably reflecting variable magmatic sources and/or dilution by sediment (fig. 7*b*). Several appear to have a slight negative Eu anomaly characteristic of more evolved igneous rocks. The rock sample UDPHY1 (a schistose, fine-grained, mafic volcaniclastic rock) appears somewhat unusual in that its heavy REE (HREE) concentrations are highest of the lot (fig. 7*b*), due to the presence of heavy minerals (garnet) enriched in the HREEs.

We have calculated the ΔNb values of the Dhanjori rocks following the methodology prescribed by Fitton et al. (1997). Our samples have negative ΔNb values and thus plot below the ΔNb line in the plot of Nb/Y versus Zr/Y (fig. 8*a*). The Dhanjori basalts and volcaniclastic rocks have low Nb/Th ratios (up to 4.7) and a moderate Zr/Nb values (15–23; tables 1, 2; fig. 8*b*).

Discussions

Mazumder et al. (2000) computed pre-2.0-Ga crustal thicknesses from Rb-Sr distribution in volcanic rocks and plutons and silica-normalized K_2O content of calc-alkaline rocks in Indian crustal provinces following methodologies recommended by Condie and Potts (1969) and Condie (1973). During the emplacement of the Singhbhum granite (phase III of Saha [1994], onto which the Dhanjori volcano-sedimentary succession was deposited), the crust in the Singhbhum crustal province was ~48 km thick (Mazumder et al. 2000; Bhattacharya and Shalivahan 2002; Shalivahan and Bhattacharya 2002) at ca. 3100 Ma (Saha 1994). Cooling down of the vast volume of Singhbhum granite might have induced an isostatic readjustment. The associated extensional regime and deep-seated fractures controlled the formation of the Dhanjori basin (Roy et al. 2002*b*; Mazumder and Sarkar 2004; Mazumder 2005).

The Dhanjori Formation is entirely terrestrial and dominantly fluvial (Mazumder and Sarkar 2004; Mazumder 2005). There are coarser-grained remnants of an alluvial fan complex at the base of the formation, whereas the rest of the unit is almost entirely represented by fining-upward fluvial cycles (Mazumder and Sarkar 2004). Unlike the lower

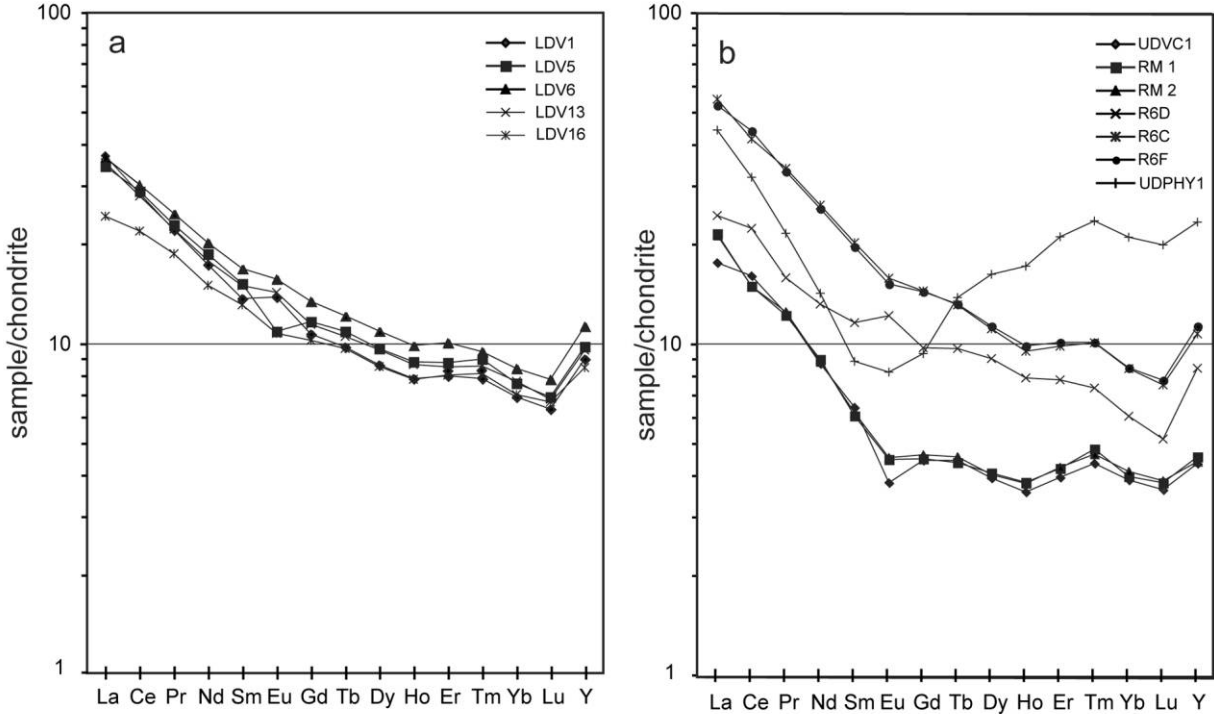

Figure 7. Rare earth element plot of Dhanjori volcanic rocks from the Bhagabandi sector, south of Mosaboni (*a*), and the Jobla-Kulamara sector, south of Rakha Mines (*b*); normalization after Taylor and McLennan (1985).

member, the upper member of the Dhanjori Formation does not include any sheet flood and sieve deposits and is characterized merely by mass flow and channel deposits. This clearly suggests steepening of the depositional surface (cf. Mazumder and Sarkar 2004; Mazumder 2005). The significant change in bed dip coinciding with sharp diversion in fluvial current direction between the two members indicates basin tilting (see Mazumder and Sarkar 2004). The change from a broadly northeasterly paleoslope toward the southwest also coincides with the commencement of the volcanic phase. Although the older member maintains a roughly uniform thickness laterally, the younger member is, in contrast, vastly thicker at the central part of the study area, where the volcanic eruptions evidently took place (fig. 4). The central part apparently subsided differentially as a consequence of volcanic eruptions. The inferred isolated lacustrine deposit in the upper member plausibly owes its origin to damming of a river by volcanics (cf. Mazumder and Sarkar 2004).

Roy et al. (2002*b*) concluded that the Dhanjori basic/ultrabasic rocks were genetically connected to the mantle plume. These authors further speculated that the plume possibly originated at the crust-mantle boundary and rapidly pierced through the crust without any contamination (Roy et al. 2002*b*, p. 514). As pointed out by Condie (2005), basalts plotting below the ΔNb line come from either a shallow depleted mantle source or from subduction zones or they represent plume-derived basalts that were subsequently contaminated by continental crust and/or subcontinental lithosphere. All our data plot below the ΔNb line in the plot of Nb/Y versus Zr/Y ratios (fig. 8*a*). The interbedded, compositionally immature terrestrial (alluvial fan and fluvial) deposits (fig. 4) indicate that sedimentation and contemporary volcanism took place in a continental rift setting (Mazumder and Sarkar 2004; Mazumder 2005) and thus rule out the possibility of volcanism in a subduction-related arc setting (Alvi and Raza 1992). Interestingly, our data, when compared to the distribution of Proterozoic nonarc greenstone basalts on the Zr/Y–Nb/Y plot (Condie 2005, his fig. 9*b*), closely resembles that of 1920-m.yr.-old Havari basalts.

Significant prevolcanic uplift of the lithosphere is one of the expected consequences of mantle plume upwelling (Campbell and Griffiths 1990; Farnetani and Richards 1994). Such prevolcanic uplift would result in (1) progressive paleogeographic

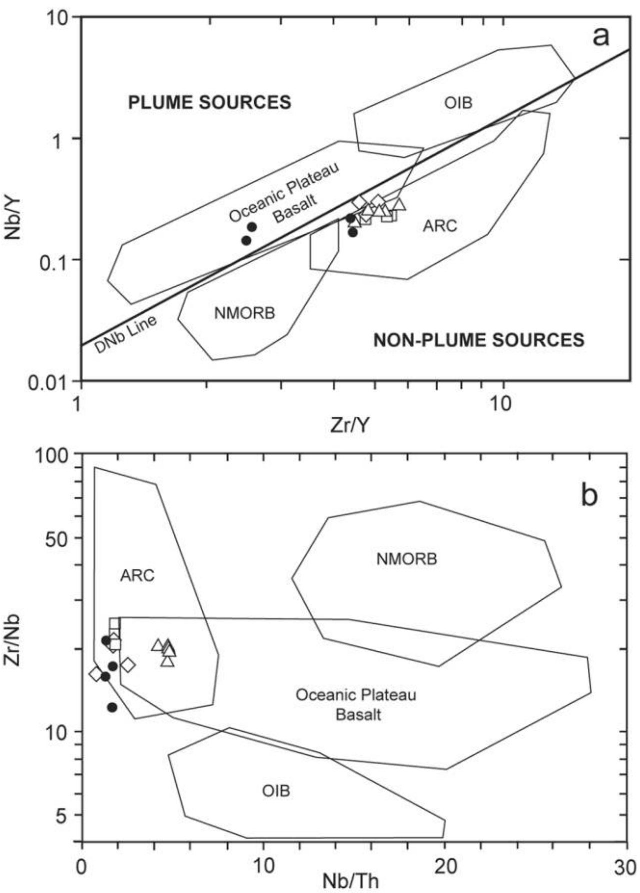

Figure 8. Nb/Y versus Zr/Y (*a*) and Nb/Th versus Zr/Nb (*b*) plots of Dhanjori volcanic and volcaniclastic rocks (after Condie 2005). Circles represent data from Roy et al. (2002*b*). See figure 5 legend for other symbols; see text for details.

shallowing and thinning of strata, (2) the abrupt appearance of erosional unconformities ("sequence boundaries" in sequence stratigraphic terminology; Posamentier and Vail 1988), and (3) radial sediment dispersal patterns. Additionally, various penecontemporaneous deformation structures are expected within underlying sediments that have suffered uplift irrespective of paleogeographic setting. This is because mass-flow processes would have operated because of large changes in paleoslope (cf. Rainbird 1993). The two members of the Dhanjori Formation display different paleocurrent trends related to fluvial response to basin tilting (fig. 4; Mazumder and Sarkar 2004). The basin tilting is definitely related to the rising magma, but the sediment dispersal pattern is not radial (cf. Cox 1989; Kent 1991). Although mass flow deposits are present within the upper member of the Dhanjori Formation, no penecontemporaneous deformation structures are found within the metasedimentary rocks close to the sediment-lava contact. Although all rifts are associated with some type of mantle uplift, our geochemical data coupled with sedimentological and stratigraphic data do not support plume-induced mantle uplift during Dhanjori sedimentation. The Dhanjori basin developed along the margin of the 3.1-billion-yr-old Singhbhum Granodiorite batholith. Confinement of the volcanic and volcaniclastic rocks within the upper member implies that initiation of rifting was not a consequence of convective upwelling in the mantle. Interbedded volcanics and volcaniclastics in different stratigraphic levels within the Upper Dhanjori Member therefore indicate episodic volcanic eruption during sedimentation.

ACKNOWLEDGMENTS

Financial support for this research came from the Japan Society for the Promotion of Science (JSPS). R. Mazumder is grateful to Y. Motoyoshi, K. Shiraishi, and K. Seno, National Institute of Polar Research, Tokyo, for helpful suggestions during x-ray fluorescence analysis and to the director of the Indian Statistical Institute, Kolkata, for his financial support (funding from Plan Rev. Budget 2007–2008) to complete this work. He is also grateful to G. M. Young, J. Chiarenzelli, G. Foulger, W. Altermann, N. Arndt, J. J. Mahoney, and H. C. Sheth for their unofficial comments, support, and encouragement. We are grateful to R. Rainbird and four anonymous official journal reviewers for their critical and constructive comments on an earlier version of the article.

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