

*Genetic significance of trace elements in certain rocks of  
Singhbhum, India*

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*Summary.* The distribution of trace elements is studied in different acid and basic rocks, adjacent to the copper lodes in the Mosaboni mines, Singhbhum, and adjoining the thrust zone, as well as of areas far away from the mineralized zones. Specific differences in composition and trace constituents in these rocks especially as regards S, Cu, Ni, and Co, suggest that the relationship of the Singhbhum granite with the soda granite is most unlikely, and that there is a connection between the soda granite and the sulphide ore-fluid; a genetic relationship of sulphide mineralization with the epidiorite is doubtful. The possibility of the existence of a common source for the Chotanagpur granite and the Singhbhum granite is inferred.

ACCORDING to Dunn and Dey (1942) the Iron-Ore Series north of the Copper-Belt thrust zone of Singhbhum consists of a lower stage, the Chaibasa Stage, and an upper stage, the Iron-Ore Stage, but only the Iron-Ore Stage was developed south of the main thrust (fig. 1). The Iron-Ore Stage was followed by the Dalma lavas and soda granite and granophyre in the north of the major thrust zone (having medium- to high-grade metamorphic facies) and by the Dhanjori quartzite-conglomerate, the Dhanjori lavas, the Singhbhum granite, the soda granite, granophyre, and biotite granite in the south (having low-grade metamorphic facies)—all the rocks belonging to one major orogenic belt. Sarkar and Saha (1963) recognized two distinct orogenic belts in the Singhbhum region; the older belt includes the Iron-Ore Series rocks and the Singhbhum granite lying south of the Copper-Belt thrust zone, while the Iron-Ore Series rocks to the north of the thrust zone belong to a younger orogenic belt. Further, they considered the soda granite-granophyre along the thrust zone as representing the closing stage of the younger orogenic period.

Concerning the source of sulphide mineralization in the Copper-Belt thrust zone of Singhbhum various possibilities have been considered by geologists. Stoehr (1870) and Maclaren (1904) suggested a relationship of the mineralization to (the intrusive phase of) the Dalma traps.

Dunn (1934, 1937) suggested that 'the Dalma lavas have no immediate genetic connection with the copper lodes, and the entire genetic derivation of these veins from soda granite intrusions is the only explanation'. The relation of the soda granite-granophyre to the Singhbhum granite was not clearly defined by Dunn (1937), but he visualized that either the soda granite ('formed under the influence of solutions rich in soda') represents merely a phase of the greater granite magma or is a separate intrusion. Later Dunn and Dey (1942) considered the soda granite-granophyre to be slightly younger than the Singhbhum granite.

Sulphide ores occur in the soda granite as well as in other types of country rocks (mica schist, quartz schist, chlorite schist, biotite schist, hornblende schist, epidiorite, and epidiorite schist) in the Singhbhum Copper-Belt. The country rocks adjoining parts of the lodes show evidence of sericitization, biotitization, and chloritization. According to Dunn and Dey (1942) the mica schist of the thrust zone at Mosaboni is stratigraphically older than the adjacent Dhanjori epidiorite. Banerji and Talapatra (1966), and Saha *et al.* (1965) suggested an origin of the soda granite by metasomatic transformation of the pre-existing mica schist.

#### *Description of rocks*

Dunn and Dey (1942) considered that the Singhbhum granite is older than the soda granite, but that clear evidence of their genetic relationship is lacking; they were not definite about the correlation of the Chotanagpur granite with the Singhbhum granite. The Dalma lavas and the Dhanjori lavas are probably contemporaneous, and this phase of volcanic activity is older than the Singhbhum granite and the soda granite phases.

The samples of the Chotanagpur granite, the Singhbhum granite, the soda granite, and the epidiorite from different areas of the Singhbhum and Ranchi districts (fig. 1 and table I) were selected from the collections made by J. A. Dunn, A. K. Dey, P. R. Sengupta, and S. K. Bose of the Geological Survey of India; the soda granite and the epidiorite adjoining the thrust zone at Mosaboni and also adjacent to the sulphide ores within the mines were also studied. Considering the general geology of the area (Dunn, 1937; Dunn and Dey, 1942) and the field information of the rock samples, recorded by Dunn in his progress reports and diaries (during 1924-32, available in the Geological Survey of India), each rock sample may be assumed to represent average material for the particular lithologic type, and hence the trace constituents of the

TABLE I. Description of rocks

No.*	Type of rock	Locality
48/494 (D†)	Epidiorite, Dalma lavas	N. of Phulberia; 22° 55' N., 86° 38' E.
33/777 (D†)	Epidiorite agglomerate, Dalma lavas	$\frac{1}{2}$ mile SE. of Silaghati; 22° 56' N., 85° 42' E. $\frac{3}{4}$ mile SSW. of Mankidih; 22° 59' N., 85° 36' E.
33/755 (D)		
44/971 (D†)	Epidiorite, Dhanjori lavas	N. of Kharudihi; 22° 30' N., 86° 18' E. 1 mile NW. of Kalajhor; 22° 31' N., 86° 24 $\frac{1}{2}$ ' E. $\frac{1}{2}$ mile NW. of Jublatola; 22° 38' N., 86° 21' E. 1 mile WSW. of Surda; 22° 33' N., 86° 26' E. $\frac{3}{4}$ mile SW. of Purnapani; 22° 34' N., 86° 26' E.
44/986 (D)		
44/987 (D†)		
DV-28 (S)		
DV-35 (S)		
18/1 (B)	Epidiorite-schist, Dhanjori lavas	$\ddagger$ $\S$
18/2 (B)		
45/103 (D†)	Soda-granite	$\parallel$ $\nabla$ Mosaboni mine; 22° 31' N., $**$ 86° 27 $\frac{1}{2}$ ' E. $\dagger\dagger$
45/151 (D†)		
21/20 (S)		
20/38 (S)		
18/3 (B)	Sheared soda-granite and chlorite-schist	$\dagger\dagger$ $\S\S$
18/4 (B)		
45/932 (D†)	Singhbhum granite	S. of Sasagora; 22° 28' N., 86° 11' E. NNW. of Raipur; 22° 36' N., 86° 12' E. 3 miles S. of Gura; 22° 45' N., 86° 4' E.
40/633 (D†)		
45/090 (D)		
48/516 (D†)	Chotanagpur granite	E. of Punda; 22° 59' N., 86° 40' E.
34/870 (D)	Chotanagpur granite-gneiss	E. of Gopla; 22° 56' N., 85° 9' E.

\* The letters after the numbers refer to collections: (D) J. A. Dunn; (S) P. R. Sengupta; (B) S. K. Bose. (D†) indicates rock samples described by Dunn and Dey (1942) as representative of the particular lithologic type.

† Level 18, cross-cut W. to pilot shaft at 125-135 ft (10 samples) on N.-side wall; about 2000 ft vertical depth.

§ Level 18, cross-cut W. to pilot shaft at 265-275 ft (10 samples) on N.-side wall; about 2000 ft vertical depth.

∥ W. lode, level 3, 485 ft S.

∇ W. lode, level 5.

\*\* 2000 ft N. drive, level 21.

†† 1800 ft N. drive, level 20.

‡‡ Level 18, drive NW. lode at 190-200 ft (10 samples) on footwall side; about 2000 ft vertical depth.

§§ Level 18, drive NW. lode at 200-210 ft (10 samples) on footwall side; about 2000 ft vertical depth.

particular sample may be considered as representative. Point-count modal analyses of seventeen specimens of the epidiorite, the Singhbhum granite, the Chotanagpur granite, and the soda granite (table II) were made; the chemical analyses of some of the specimens were published by Dunn and Dey (1942, pp. 363, 396, 403, 408, 414; tables 9, 15, 17,

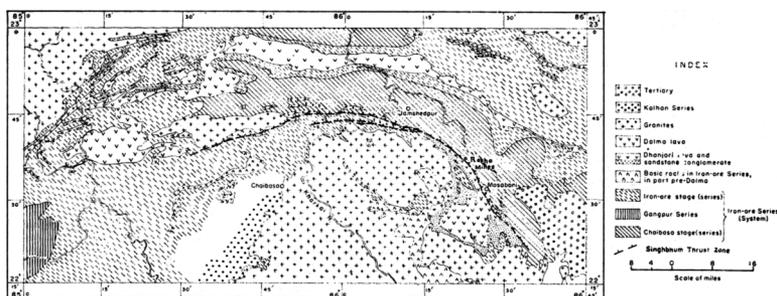


FIG. 1. Stratigraphic units in Singhbhum and adjacent areas (after Dunn and Dey, 1942, plate 40).

TABLE II. Modal analyses

<i>Granites</i>	34/870	40/633	45/090	45/103	45/151	21/20	20/38	18/3*	18/4*
Quartz	26.5	33.2	35.4	34.6	33.6	27.8	31.4	43.5	42.0
Plagioclase	23.2	46.3†	13.7	43.3	49.3	49.0	41.2	9.7	10.3
K-feldspars (perthitic)	40.4	3.8	49.8	—	—	—	—	—	—
Biotite	9.5	—	0.2	7.8	8.2	4.5	9.2	13.6	14.3
Muscovite	—	—	0.1	—	—	3.2	6.8	2.0	1.5
Chlorite	—	3.2	—	12.3	6.3	11.3	5.3	27.6	28.3
Hornblende	—	9.8	—	—	—	—	—	—	—
Epidote-Zoisite	—	2.0	—	—	—	0.8	2.8	—	—
Apatite	0.2	—	—	—	—	0.2	0.7	0.8	0.6
Sphene	—	1.5	—	—	—	—	—	—	—
Opaque ores‡	0.2	0.2	0.8	2.0	2.6	3.2	2.6	2.8	3.0
<i>Epidiorites</i>	44/986	33/777	33/755	44/971	DV-28	DV-35	18/1*	18/2*	
Amphibole	56.5	44.6	52.2	59.6§	67.5	65.3	11.8	12.2	
Plagioclase	13.2	17.5	16.3	13.8	12.3	17.7	12.7	13.8	
Epidote-Zoisite	17.8	12.8	13.6	9.7	4.7	4.3	8.5	8.0	
Chlorite	5.3	21.7	12.7	10.4	2.3	2.5	5.2	5.5	
Quartz	3.4	1.4	2.5	1.7	9.2	5.4	19.0	18.7	
Biotite	—	—	—	—	1.5	2.8	37.5	37.0	
Muscovite	—	—	—	—	—	—	tr.	tr.	
Apatite	—	—	—	—	—	—	1.3	1.0	
Opaque ores‡	3.8	2.0	2.7	4.8	2.5	2.0	4.0	3.8	

\* Average data of 10 samples.

† Saussuritized and sericitized (40/633 is a hornblende granodiorite).

‡ Oxide minerals mainly. § Actinolite mainly. || Hornblende mainly.

19, 22). The modal analyses showed more opaque minerals in the specimens of the soda granite and the epidiorite as compared to other granites. The possibility of the presence of some grains of sulphides in each specimen of the soda granite and the epidiorite was thoroughly checked by X-ray study (powder method) of the separated fractions; no sulphide mineral was detected in any of these specimens.

*Spectrum analysis of rocks*

A fully representative portion weighing about 20 g was carefully selected from each specimen of rock, and homogeneous material was obtained by crushing the separated rock to -75-mesh size; from this about 2 g was powdered to -200-mesh size. An accurately weighed 4 mg of this powder was thoroughly mixed with 4 mg of Specpure carbon powder and packed in the bore (1.2 mm diam., 6 mm deep, wall thickness 0.5 mm) of a Specpure carbon electrode. The 'direct-current cathode layer method' (Strock, 1936) was developed with an arrangement of two lenses and a circular diaphragm of 4 mm diameter for focusing about 5 mm of the cathode layer arc and also for controlling the fluctuating arc during volatilization (Mukherjee, 1948). Continuous exposure of 80 sec. in four steps (20 sec. each at 6, 9, 7, and 10 A) was given for minimizing the effect of differential volatilization of elements. The spectrogram was taken by the Hilger large quartz and glass spectrograph, and a uniform condition for processing was maintained. The standards were prepared from Specpure compounds using pure quartz as the matrix material, and the percentages were calculated by interpolation of the standard curves of concentration-density after background corrections. Suitable spectrum lines of the elements were selected considering both position and intensity (Strock, 1936), and the relative intensities as densities with background corrections were measured by the Hilger non-recording microphotometer.

Since the matrix composition of the standard was different from that of the rock sample considerable error should be expected due to the complex matrix of the rock. The percentage of accuracy for most of the elements was determined as  $\pm 30\%$  in the composition range 0.1 ppm to 10 ppm and as  $\pm 20\%$  in the composition range 10 ppm to 1000 ppm. For checking the accuracy of determination of the trace elements spectrograms of the two standard rocks G-1 and W-1 (Fairbairn, 1951) were taken along with each sample; the determined values for most of the elements in G-1 and W-1 were found to be within  $\pm 25\%$  of the average data reported by Fleischer and Stevens (1962).

The average data of trace elements in the Skaergaard differentiates of East Greenland (Wager and Mitchell, 1951), Caledonian plutonic rocks of Scotland (Nockolds and Mitchell, 1948), and other igneous rocks (Goldschmidt, Tröger, Strock, Noll, Engelhardt, Sandell and Goldich; Wager and Mitchell, 1951) have been considered in explaining the distribution of trace elements in the Singhbhum rocks (tables III and IV). The trace constituents of the diabase W-1 are compared with those of the epidioritic rocks without any implication regarding the effect of metamorphism on the variations of trace constituents.

*Genetic significance*

Selective enrichment of certain trace elements at different stages during fractionation was observed by Wager and Mitchell (1951) in

TABLE III. Trace constituents of granitic rocks (in parts per million)

	Chotanagpur granite		Singhbhum granite		Soda granite		Granite schist		Acid rocks†	C-rocks (acid)§	
	48/516	34/870	45/592	40/633	45/590	45/103	45/151	21/20			20/38
Ag	0.5	0.7	0.6	0.8	1	1.2	0.7	1.4	0.6	1.3	1.2
As	0.2	0.3	0.4	0.6	0.5	0.3	0.4	0.3	0.5	0.6	0.5
B	4	6	5	8	7	6	7	9	8	6	7
Ba	850	980	870	760	830	560	640	730	620	650	630
Be	2	3	6	4	5	8	7	8	6	7	5
Bi	0.1	0.2	0.3	0.2	0.3	0.5	0.3	0.2	0.4	0.3	0.2
Cd	3	4	6	8	5	30	27	25	22	32	28
Cr	12	15	18	27	23	35	33	26	30	22	18
Cu	13	16	27	23	20	52	46	48	50	53	55
Ga	16	18	25	20	23	22	24	17	15	18	16
Ge	0.4	0.5	0.8	0.6	0.7	1	1.2	0.7	0.6	1	0.8
I	23	26	33	28	30	36	33	28	30	34	36
Li	970	680	750	570	620	470	520	380	420	550	520
Mn	1.2	1.5	1	0.8	0.7	1.2	1	0.8	0.9	1.8	1.6
Ni	2	3	20	16	23	78	70	73	65	86	92
P	830	580	370	520	470	350	950	620	570	530	480
Pb	47	60	45	53	73	25	23	32	26	18	22
Rb	93	87	78	85	73	63	70	67	65	78	73
Sr	380	430	520	550	470	930	880	1050	960	1200	1100
Sb	0.3	0.5	0.2	0.4	0.3	0.1	0.2	0.1	0.1	<0.1	<0.1
Se	3	2	3	4	2	9	12	10	11	8	9
Sn	3	4	3.5	2.5	4	2	2.5	3	1.5	2.5	2
Sr	320	280	300	250	280	200	180	210	170	180	160
Tl	4100	3800	4300	4500	3800	3900	3700	3800	4100	3600	3800
V	35	28	55	43	52	45	33	46	37	65	70
Zn	28	35	40	45	37	48	43	30	37	45	48
Zr	150	170	210	170	200	220	240	170	200	220	240

\* Average data of 10 samples, collected from the same type of rock at different points within a distance of 10' from level 18 (table I).

† Chemical analysis of sulphur and phosphorus by Dr. B. Das Sarma, Senior Chemist, G.S.I.

‡ Average data for acid rocks (Wager and Mitchell, 1951) from Goldschmidt (G), Tröger (T), Noll (N), Stroock (S), Engelhardt (E), Sandell and Goldich (SG); data for granite G-1 from Felscher and Stevens (FS), 1962.

§ Average data for Caledonian plutonic rocks (acid) as reported by Wager and Mitchell (1951) from the values obtained by Nockolds and Mitchell (1948).

TABLE IV. Trace constituents of epidioritic rocks (in parts per million)

	Epidiorite						Epidiorite schist		Basic rocks†	C-rocks (Basalts)§			
	48/494	33/777	33/755	44/971	44/987	44/986	DV-28	DV-35			18/1*	18/2*	
Ag	0.1	0.3	0.2	0.3	0.1	0.2	0.1	0.2	<0.1	<0.1	<0.1	FS	—
As	0.6	0.5	0.7	0.6	0.4	0.7	0.8	0.7	0.5	0.6	0.6	2 FS	—
B	12	14	13	15	10	12	8	9	8	10	8	17 FS	—
Ba	63	55	77	85	67	65	55	53	57	65	57	70 E	150
Be	3	5	4	5	4	6	5	3	4	3	4	3 FS	—
Cd	0.4	0.5	0.6	0.2	0.4	0.6	0.7	0.5	0.6	0.4	0.4	0.3 FS	—
Co	27	23	25	27	30	35	33	23	27	30	27	100 G	70
Cr	93	70	98	73	80	85	87	75	95	90	95	500 G	300
Cu	53	43	45	48	50	58	45	53	60	55	60	150 SG	—
Ga	12	13	7	15	10	8	12	9	8	10	8	8 G	17
Ge	1.3	1	0.8	1.7	1	1.5	1.2	1	0.9	0.8	0.8	1.6 FS	—
Li	27	20	23	25	30	35	33	27	22	18	22	10 S	30
Mn	1970	1160	1120	1380	3250	1830	1250	1180	1270	1320	1320	1500 T	1100
Mo	0.5	0.4	0.5	0.7	0.6	0.5	0.3	0.4	0.7	0.5	0.5	10 FS	—
Ni	65	83	47	63	57	53	50	55	58	63	63	200 G	200
Pt	930	370	300	270	520	330	250	270	530	480	480	1500 T	1000
Pb	10	25	10	12	13	15	9	12	5	7	5	8 FS	—
Rb	17	12	13	15	12	15	10	13	10	9	10	22 FS	—
Sr	930	900	700	830	870	980	750	800	870	830	870	2000 T	—
Sb	0.4	0.3	0.4	0.6	0.3	0.4	0.5	0.7	0.6	0.5	0.6	1 FS	—
Sc	30	27	33	43	33	35	27	25	28	26	26	23 G	20
Sn	0.7	0.8	0.6	0.5	0.7	1	0.5	0.6	1.2	1.5	1.5	3 FS	—
Sr	110	95	150	100	150	130	95	170	110	98	110	180 N	1000
Tl	9800	6300	6300	6100	5000	7200	7000	6500	5800	6100	6100	10,000 T	5000
V	250	230	170	200	230	270	170	150	210	280	280	250 T	150
Zn	70	67	75	63	67	78	83	75	78	73	78	82 FS	—
Zr	87	73	120	80	75	110	93	120	97	110	97	100 FS	60

\* Average data of 10 samples, collected from the same type of rock at different points within a distance of 10' from level 18 (table I).

† Chemical analysis of sulphur and phosphorus by Dr. B. Das Sarma, Senior Chemist, G.S.I.

‡ Average data for basic rocks; ref. footnote to table III.

§ Average data for Caledonian plutonic rocks (basic); ref. footnote to table III.

successive Skaergaard differentiates: Cr, Ni, Co were concentrated in early rocks (ultrabasic and basic) with very little or none in later (acid) fractions, Cu, S, P, V, Sc, Mn, Sr were concentrated in the middle or late middle stages (basic and intermediate), and Ba, Zr, Li, Ga were concentrated in the latest granite fraction (acid), although the variations of Co, Sr, Ga were small throughout the series. However, the average data for hypersthene-olivine gabbro (basic) of the Skaergaard differentiates show lower concentrations of S (450-500 ppm), Cu (67 ppm), Ni (120 ppm), Co (48 ppm), Cr (230 ppm), and P (260 ppm) than the average data for basic rocks reported by Goldschmidt and others (table IV).

Compared to this general principle of selective enrichment the soda granite shows abnormal abundance of S, Cu, Ni, Co, whereas the Singhbhum granite shows comparable concentrations of S, Cu, Co, Ni (slightly higher), to those of average acid rock. Such high concentrations of S, Cu, Ni, Co as those in the soda granite are quite unlikely in any magmatic granite. Moreover, the soda granite has a higher concentration of Sc and lower concentration of Pb than the acid rock, whereas the Singhbhum granite has comparable concentrations of Sc and Pb to those of the acid rock. The soda granite and the Singhbhum granite show some common characteristics, having higher concentrations of Cr, V, Sr, Ba, Cd, Ag, lower concentrations of Mn, Li, Mo, Rb, and almost comparable concentrations of Sn, Ti, Ga, Zn, Ge, Be, Zr, P (Zr and P being slightly lower), to those of an average acid rock. Comparison of major and minor constituents of the Singhbhum granite and the soda granite (Dunn and Dey, 1942, chemical analyses, pp. 403, 414) shows that the soda granite is significantly deficient in Ca and poorer in K than the Singhbhum granite, but the percentage of Na is almost comparable; the soda granite is richer in albite compared to the Singhbhum granite and is generally free from perthitic orthoclase (table II), which is an important constituent of the Singhbhum granite (molecular norms, Sarkar and Saha, 1962; Banerji and Talapatra, 1966). Moreover, Sarkar and Saha (1963) showed from the Niggli values (based on the chemical analyses of a number of rock samples, published by Dunn and others) that the variations of  $c/fm$  and  $alk$  ratios when plotted against the respective  $si$  values are in distinctly separate series for the Singhbhum granite and soda granite. These specific differences in composition and trace constituents suggest that a relation of the Singhbhum granite to the soda granite is most unlikely, bearing in mind the metasomatic transformation origin of the soda granite (Banerji *et al.*, 1966). The

abundance of S, Cu, Ni, Co in the soda granite suggests an intimate relationship of the soda granite with the sulphide ore-fluid, although further evidence of a genetic connection is beyond the scope of the present study. The metasomatic transformation origin of the soda granite at the close of the Singhbhum orogeny (Sarkar and Saha, 1963) might be responsible for the introduction of sulphide ore-fluid to the system.

On the other hand, the epidioritic rocks are deficient in S, Cu, Ni, Co, Cr, and partly in Sr and P, having comparable concentrations of Mn, V, Ba, Sc, B, Ga, Li, Zn, Ge, Pb, Be, Cd, Rb, Zr, Ti to those of average basic rock. Considering the major and minor constituents (Dunn and Dey, 1942, chemical analyses, pp. 363, 396) and the mineral phases (table II) in these rocks, the abnormal poverty of S, Cu, Ni, Co in the epidiorite compared to any basic magmatic rock suggests that genetic relationship of the sulphide mineralization to the epidiorite is doubtful. The possibility of the sulphide ore-fluid being leached out from the parent basic magma (intrusive phase of the Dalma traps) at some stage is not supported by the over-all trace element distribution; though leaching of a sulphur ore-fluid from any basic magma will surely leave it impoverished in S, Cu, Ni, Co, it should affect other trace elements as well, whereas these epidioritic rocks have the ideal composition and trace constituents of typical basic rock apart from deficiencies in S, Cu, Ni, Co, Cr.<sup>1</sup>

The distribution of trace elements (table III) in the Singhbhum granite is comparable to that in the Chotanagpur granite. Considering the mineral phases (table II), the major and minor constituents (Dunn and Dey, 1942, chemical analyses, pp. 403, 408), and the trace constituents (table III) in the Singhbhum granite and the Chotanagpur granite, the possibility of the existence of a common source for the two granitizing fluids may be inferred. The most significant feature of the trace element distribution in the rocks of Singhbhum is that concentrations of S, Cu, Ni, Co are similar in both epidiorite and soda granite, but most other trace constituents differed in the manner usual for basic and acid rocks. The similarity in the selective concentrations of these elements in the two different types of rocks is unusual and reflects the conditions of emplacement and subsequent history of the intrusives.

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<sup>1</sup> Bhattacharjee *et al.* (1968) observed that Cu and Ni are always low in the Dhanjori epidiorite of the Rakha mines area.

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