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MULTIELEMENT STUDY IN THE DRAINAGE SEDIMENTS OF A PART OF LESSER HIMALAYA, CENTRAL NEPAL

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सारांश

यस अभिलेखमा चितवन र धादिंग जिल्ला भित्र पर्ने ६६० वर्ग कि. मि. क्षेत्रमा खोलाको बालुवाको नमुनाहरूमा बिभिन्न खनिज तत्वहरूको बिवरण र यिनको अन्तर सम्बन्ध सम्बन्धि अध्ययनको वर्णन गरिएकोछ। तत्वहरूको आपसी सम्बन्धको अध्ययन गर्दा तामा, शीसा र जस्ता, आरसेनिक, एण्टीमोनी र बिस्मथको सम्बन्ध सकारात्मक पाइएको छ। तर एण्टीमोनी र बिस्मथको संबन्ध भने ठीक विपरीत पाइएको छ, जस्मा बिस्मथ ग्रेनाइट भन्ने चट्टानमा बढीमात्रामा अवस्थित भएको र एण्टीमोनी सो चट्टानमा नगण्य मात्रामा रहेको तथ्य यसबाट थाहा भएको छ। आरसेनिक धातुको तामा, शिसा र जस्ता संग निकटतम सम्बन्ध भएको हुंदा यो तत्व उपरोक्त आधारभूत धातुहरूको खोजी कार्यमा मार्ग सुचक को रूपमा प्रयोग गर्न सकिने संभावना देखिएको छ।

प्रकृतिमा धातुहरूको द्वितियक फैलावट मा वातावरण अनुरूप फलाम, मेंगानीज र निकेल हाईड्रोक्साइडले तामा र जस्ता जस्तो घुलित अवस्थामा बढी टाढा सम्म जान सक्ने धातुहरूको फैलावटमा महत्वपूर्ण भूमिका खेलेको हुन्छ जसले गर्दा खोला नालाको बालुवामा रासायनिक विश्लेषणले देखाएको धातुको संकेत अर्थात असाधारण मात्रा वास्तवीक धातुको प्रतिबिम्ब हो या माथिका अन्य कारणबाट बन्न आएको हो छुट्याउन अति आवश्यक पर्छ। यस कारण द्वितियक हाईड्रोक्साइडको तामा, जस्ता एनोमलीहरूमा प्रभाब हेर्न र पोटासीयमको टिन र शीसा मा प्रभाव हेर्न उक्त तत्वहरू संगै रिग्रेसन बिश्लेषण गरिएको छ। यस अध्ययनबाट केवल फलामको मात्र तामाको एनोमलीमा आवश्यक मात्रामा असर परेको तथ्य पत्ता लागेको छ जुन तत्वको फलाम संगै प्राथमिक अवस्थामा (कोहेरेन्स) चाल्कपाइराइट माफिक खनिजहरू मा भएको हुनाले नै हुन गएको बिश्वास गरिएको छ। खोलाको बालुवामा पाइएको भूरसायनिक संगठन ले प्राथमिक बातावरणको प्रतिबिम्ब गरेको छ र सतही अवस्थामा द्वितीयक प्रक्रयाले धेरै कम मात्रामा परिवर्तन गरेको पाइएको छ।

ABSTRACT

Distribution of different elements from 183 regional stream sediment samples representing 600 Km^2 of Chitwan–Dhading Districts (Toposheet 72A/14) has been described. The study of inter–element relationships demonstrated positive correlation among Cu, Pb & Zn. Arsenic, Sb & Bi correlations are found to be positive except that Bi & Sb exhibit antipathetic relation, the former showing affinity towards granite in contrast to the latter, which was virtually absent in anomalous amount over granites. A close association of As with Cu, Pb & Zn anomalies suggest that As could be used as a pathfinder for basemetal mineralization.

Regression analysis was used to study the effect of secondary hydroxides of Fe, Mn & Ni on Cu & Zn dispersion, and that of K on Sn & Pb dispersion. The only significant variance explained was Fe on regression of Cu, which was attributed to primary coherene of Cu with Fe probably in chalcopyrite or mafic minerals. The geochemical associations found in stream sediments reflect primary environment and secondary processes in surficial condition modify these very little.

INTRODUCTION

The conventional geochemical prospecting technique is based on the systematic sampling of the entire drainage system at regular distance and subsequent analyses for the ore metals and associated elements with a view to detecting anomalous dispersion trains related to discrete mineral deposits. The study of inter–relatians of multielements help in determining geochemical associations and also behaviour of elements during their redistribution in the surficial environment. Regression analysis in many cases has been successful in discreminating significant from nonsignificant anomalies (Rose *et al.*, 1970; Chatupa *et al.*, 1972).

AREA DESCRIPTION

The investigation area (Fig. 1) is dominantly a part of the Mahabharat Range separated from the Siwaliks in south by Main Boundary Thrust (MBT). Topography is generally steep, deeply, dissected by Manahari drainage system in the south and Malekhu in northern part. Altitude in the area varies from 305 to 2262 m. Many of the streams including most ot the secondary tributaries are perenial but tertiary tributaries tend to be torrential. Much of the area is covered by dense vegetation.

The geology has been described by Stocklin & Bhattarai (1977, 1980,) [Fig. 3] and consists, from south to north, of Neogene molasse sediments (Siwalik), dark slates (Benighat) with carbonates (Jhiku), yellowish grey limestone (Malekhu), green phyllite (Robang) with quartzites (Dunga) and metagabbro (granodiorite) of Upper

Nawakot Group, garnet--mica--schist (Raduwa), crystalline marble (Bhainsedoban), biotite schist and quartzite (Kalitar), fine grained biotite schist (Kulekhani) and crystalline marble (Markhu) of Bhimphedi Group and fine clastic sediments (Tistung) of Phulchoki Group. Two granite bodies have intruded biotites schist and quartzite of Kathmandu Complex. The Main Boundary Thrust (MBT) separates Siwaliks (Si) from upper Nawakot Group and Mahabharat Thrust (MT) separates Upper Nawakot Group from Bhimphedi Group. Numerous post-intrusive transverse faults occur in the area. The two important areas investigated by Mineral Exploration Project (up to drilling stage) are Labang-Khairang for lead and zinc and Devrali for copper.

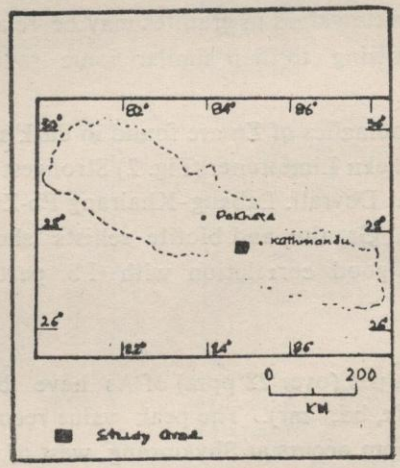


Fig 1. Location Map.

ANALYSIS

Stream Sediment samples collected at mean density of one sample per 3 sq. km. were analysed for 31 elements of which 15 elements are discussed in this paper. Direct Reading Inductively Coupled Plasma Spectrometry capable of simultaneous multielement determination (Thompson *et al.*, 1978) was employed in analysing samples at Imperial College of London. Strong total attack method (mixture of Conc. HNO_3, $HClO_4$ & HF) was used in the sample digestion.

Distribution of Individual Elements

Copper: Nine anomalous values of Cu (over 67 ppm equivalent to 95th

percentile occur over Benighat Slate which generally contain high Cu background as well as erratic values associated with graphitic material (Fig 2.). The highest 208 ppm corresponds with Cu mineralization at Devrali (Fig.3). Few weak anomalies (over 48 ppm) occur in streams draining Bhainsedobhan. Marble and Kalitar Schist. Two anomalies at NW margin are correlated with Cu & Fe showings in Raduwa schists. Granite is marked by relatively low Cu values.

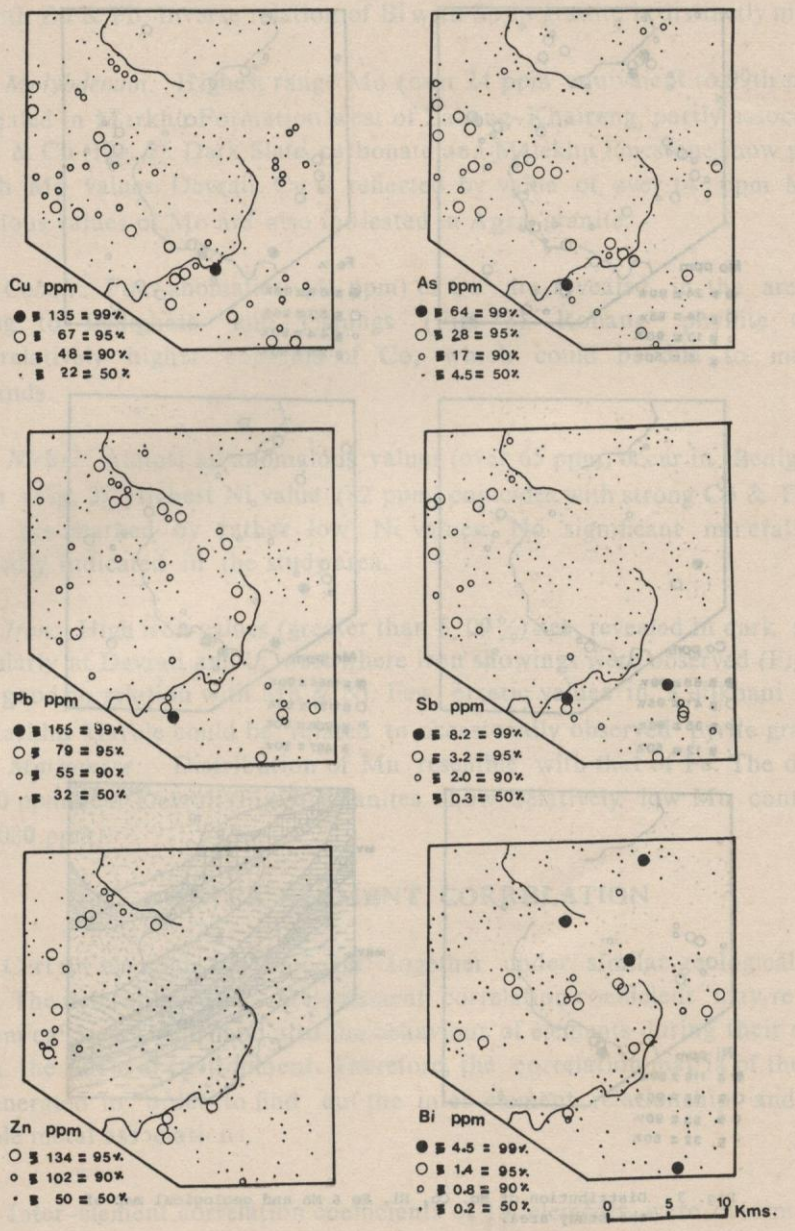
Lead: Anomalous concentration (over 79 ppm) of Pb is confined to Markhu Marble in Labang-Khairang area and in Benighat Slate & Dunga quarzite (Fig. 2). The peak value 180 ppm occurs at Devrali associated with copper mineralization. To the east of Devrali, four values of over 95th percentile correspond with dark slate with carbonate. Two erratic values in granites may be related to primary association of Pb with K–feldspar owing to their similar ionic radii.

Zinc: Most of the anomalies of Zn are found in dark slate & carbonate (bg & jk) Markhu Marble and Maleku Limestone. (Fig. 2) Strongest values 280 ppm is associated with high Cu & Zn at Devrali. Labang–Khairang Pb-Zn mineralization is expressed by over 134 ppm Zn. Granite and biotite schists show markedly lowZn concentration. Zn exhibits good correlation with Pb particulary at higher level of concentration.

Arsenic: High values (over 28 ppm) of As have been found generally associated with carbonates (jk, bd, mr). The peak value recordcd at 96 ppm supported by one value of 50 ppm occurs at Shyamrang, west of Deverali, second highest value 76 ppm is coincident with granite at Goldhunga (Fig. 2). Arsenic background is found over 15 ppm in Benighat Slate, and over 10 ppm in marble. Garnet–biolite schist and granite are marked by less than 10 ppm As.

Antimony: The main features of Sb results are the high values over 2 ppm in Benighat Formation and low (less than 0.5 ppm) contents over granites (Fig.2). Carbonates and biotite–schists reveal most of the values around 1 ppm. The best anomaly in the area in Shyamrang represented by peak value 13 ppm supported by two values of over 3.25 ppm (i.e. 95 th percentile) and positively correlated with As& Bi. Few strong anomalous values also occur in Markhu Formation at Khanikhola, west of Labang.

Bismuth: High Bi values (over 0.8 ppm) are coincident with granite margin. Other rocks reveal values around 0.10 ppm, although Benighat Slate tend to show little higher. Strongly amomalous contents of Bi (over 3.25 ppm) are distributed



Fiq. 2 Distribution of Cu, Pb, Zn, As, Sb & Bi in stream sediments.

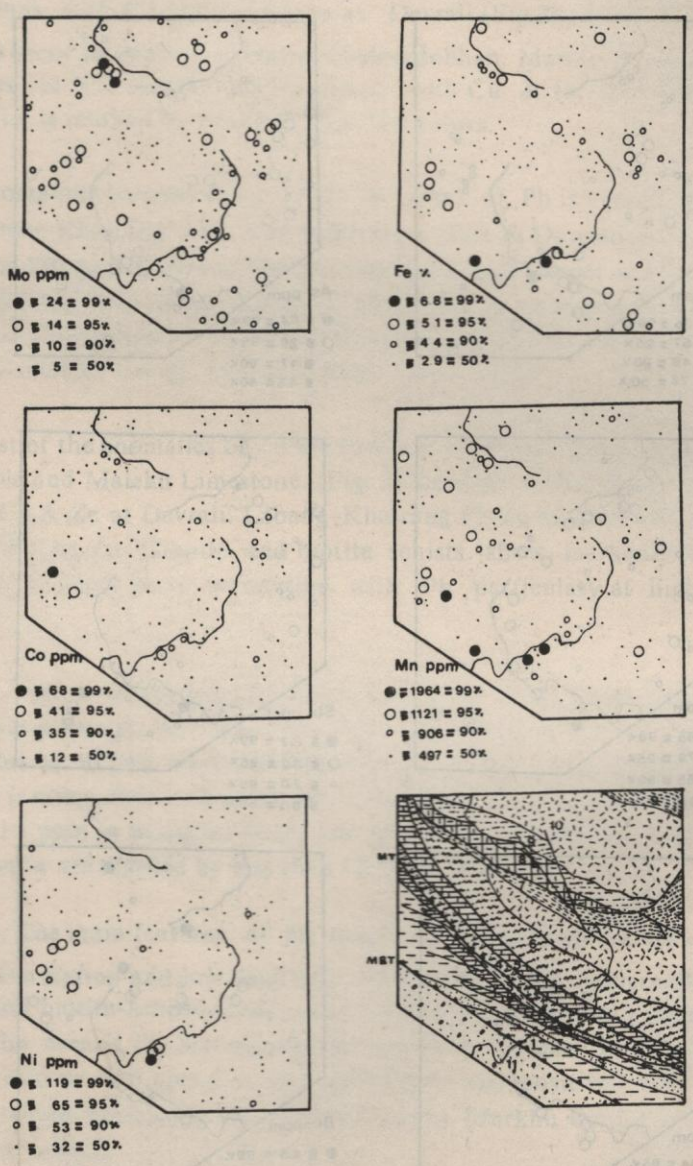


Fig. 3 Distribution of Mo, Co, Ni, Fe & Mn and geological map of the study area.

Legend to geological map : 1. Benighat Slate with Jhiku carbonate. 2. Malekhu Limestone. 3. Robang Phyllite with Dunga quartzite. 4. Raduwa Formation. 5. Bhainsedobhan Marble. 6. Kalitar Formation. 7. Kulikhani Formation. 8. Markhu Formation 9. Tistung Formation. 10. Granite. 11. Siwaliks. D. Devrali Cu. L. Labang Pb - Zn.

in and close to the granite bodies indicating spotty mineralization during later phase of crystallization (Fig. 2). Bismuth over Benighat Slate exhibits good association with Zn & Pb. Inverse relation of Bi with Sb in granite is distinctly marked.

Molybdenum: Highest range Mo (over 24 ppm equivalent to 99th percentile) is revealed in Markhu Formation west of Labang-Khairang, partly associated with Pb, Zn & Cu (Fig. 3). Dark Slate, carbonate and Malekhu limestone show particularly high Mo values. Devrali Cu is reflected by value of over 14 ppm Mo. These anomalous values of Mo are also indicated in Agra granite.

Cobalt: Four anomalies (41 ppm) of Co are revealed in the area corresponding to Benighats and Tistungs (Fig. 3). Robang phyllite tends to show relatively higher contents of Co, which could be due to metagabbro interbands.

Nickel: Almost all anomalous values (over 65 ppm) occur in Benighat Formation (Fig, 3). Highest Ni value (82 ppm) coincides with strong Co & Fe. Granite bodies are marked by rather low Ni values. No significant mineralization is apparently indicated in the study area.

Iron: High iron values (greater than 5. 09%) are revealed in dark slates (bg) particularly at Devrali and in west where iron showings were observed (Fig. 3). Iron shows good correlation with Mn & Ni. Few erratic values in Kulikhani Quartzite and Markhu Marble could be related to occasionally observed pyrite grains.

Manganese: Distribution of Mn resemble with that of Fe. The data peak at 2100 ppm near Devrali (Fig.3). Granites show relatively low Mn contents (less than 1000 ppm).

INTER-ELEMENT CORRELATION

Certain elements tend to occur together under similar geological environments. The determination of inter-element correlation coefficient may reveal these geochemical associations and also the behaviour of elements during their redistribution in the surficial environment. Therefore, the correlation matrix of the elements was generated in order to find out the inter-element relationship and establish possible metal associations.

Inter-element correlation coefficients of 15 elements were determined using Minitab and resulting correlation matrix is given in Table 1, the lower left half contains the actual values and the upper right half indicates the significance of coefficients at 95 and 99 percents (Nichol, 1968; Armour Braon & Nichol, 1970).

Table 1. Correlation matrix

As	Bi	Co	Cu	Fe	K	Li	Mn	Mo	Ni	Pb	Sb	Sn	W	Zn
As 1	+		++	++						++	++			
Bi .14	1									++				++
Co	1	1	++	++			++	++	++			+		+
Cu .34	.28	.38	1	++		— —	++	++	++	+		++	++	++
Fe .58	.12	.56	.61	1		— —	++	++	++	+	++	++	++	++
K		.07	.13	.13	1					—	++	++	++	
Li		—.08	—.22	—.32	.50	1			++			++	++	
Mn		.42	.44	.44	.14	.06	1		++			++	++	++
Mo		.40	.33	.38	.07	·07	.21	1					++	
Ni		.58	.62	.71	.07	.22	.39	.32	1			++		++
Pb .18	.22	—.72	.15	—.05	—.15	.01	.07	.09	.10	1	++			++
Sb .20	.08		.21	.42						.29	1			
Sn		.39	.34	.35	.27	.26	.24	.37	.35	—.01		1	++	
W		.06	.06	.28	,20	—.03	.07	.29	.06	—.13		.27	1	
Zn .21	.32	.18	.18	.15	—.09	—.04	.10	.31	.34	.49	·38	.12	.13	1

++ or — — above 99/ singnificance level — Significant

\+ or — above 95/ significance level — Probably significant

r (99/, 183) = 0.186

r (95/, 183) = 0.142

From the table, it is apparent that the elements Co, Cu, Fe, Ni & Mn reveal very strong sympathetic correlation with each other (over 3 times 99 percent significance level). The strong correlation of Pb & Zn suggests their close association probably during the mineralization. Potassium, Li, Sn, & W exhibit close correlation which may imply their association in granites; these elements show inverse relation with Fe, Co & Ni.

The study of correlation matrix has enabled us to establish following associations of elements in the investigation area.

Fe – Ni – Co – Cu – Mo – Mn
Pb – Zn – Cu – Sb – As – Bi
Sn – W – K
Li – K – Sn

Regression Analysis

In the study area, some of the highest values of Cu & Zn associate with high contents of Fe & Mn & Ni and Pb & Sn with strong K values. Fe & Mn normally have scanning effect on Cu & Zn in secondary environment. Therefore, in order to investigate such effect and also the behaviour of these elements in surficial environment, Cu was regressed against Fe, Mn & Ni; Zn was regressed on Fe & Mn Similarly, Pb & Sn were regressed on K. Results of the regression are summarized in Table 2.

Table 2. Summarized regression results

Elements	Total % variance accounted for	Variable with proportion of variance % contributed in regression
Cu	48.8	Fe (91.5), Mn (5), Ni (3.5)
Zn	2.5	Fe (94.3), Mn (5.7)
Pb	4.3	K
Sn	7.5	K

The regression equations accounted for 48.8%, 2.5%, 4.5%, & 7.5% of total variations in the means of dependent variables Cu, Zn, Pb & Sn respectively. Out of 48.8% of total variance accounted for in the regression of Cu on Fe, Mn & Ni, over 45% is explained by Fe alone. In contrast, Mn & Ni appear to be insignifi-

cant predicters. Furthermore, in some areas Fe & Mn have failed to explain significant proportion of variance in the regression of Zn. This means that Zn distribution is not evidently affected by Fe & Mn concentration despite its similar behaviour to that of Cu in surficial environment. The prevalent field conditions such as rugged topography, rapid erosion, moderately high rainfall and neutral pH mitigate chemical dispersion and promote clastic dispersion of metals in drainages. Therefore, the high variance of Cu distribution explained by Fe content is attributable to primary coherence that could be in chalcopyrite or in mafic minerals.

The regression of dependent variable Sn & Pb against independent variable K has accounted for poor proportion of variance (7.5% and 4.3%). This implies that K has no significance in distribution of Pb & Sn concentrations. In other words, Pb & Sn anomalies are independent of K and may be related to mineralization.

DISCUSSION AND CONCLUSION

The relatively high concentration of many of the elements over Benighat Formation could possibly be due to carbonaceous and pyritiferous nature of the bedrock. Clustering of anomalous values of Cu, As, Sb, Bi, Zn, Pb & Mo in and around Devrali may suggest complex mineralization associated with Robang phyllite, Benighat Slate & Jhiku carbonate. Lead and Zinc values supported by Mo are particularly high in Markhu-marble, most probably related to Labang–Khairang Pb–Zn mineralization. In general, Pb, Zn, Sb and partly Cu, As & Bi reveal positive intercorrelation.

The element association may (though not necessarily) give some indication about the type of mineralization. The close association of As, Sb & Bi with Cu, Pb & Zn may suggest low temperature and shallow depth hydrothermal mineralization. The virtual absence of anomalous Sb in the vicinity of granites (probably high temperature zone) might be attributable to the fact that during crystallization from the hydrothermal fluids, Bi crystallizes first followed by As & Sb (Rankama & Sahama, 1956). Similarly the association of Sn, W and Mo anomalies in the vicinity of granite bodies may indicate the occurrence of Sn–W contact metamorphic deposits.

The determination of inter-element correlation coefficients on the data of study area demonstrated probable association of elements. The area, as is highly rugged mountaineous terrain, is at a stage of rapid erosion. Consequently mechanical dispersion (clastic) is predominant in producing inconsistent anomalous

trains in the drainages. The groups of elements established on the basis of correlation coefficients apparently reflect primary association.

The regression analysis revealed that there is little effect of Fe on the dispersion of Cu in contrast to virtually no effect on Zn dispersion in the same environment. Manganese and Ni do not contribute significant variance in the regression for both Cu & Zn. This may imply that the area apparently lacks favourable conditions for scavenging of Cu & Zn ions by hydrous oxides of Fe & Mn. The variance of Cu accounted for by Fe in regression probably indicate primary coherence with iron.

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