

as Zn, Mn, Ni and to some extent Ag may indicate that they have been transported hydromorphically and precipitated at places where the soil pH is high, leaving behind Co and Pb near the source, giving a superjacent anomaly because of their low mobility under acid conditions. At this juncture, care should be taken to distinguish between the anomalies related to the effect of pH, topography and hydromorphic process and those anomalies genetically related to mineralization, keeping in mind the scavenging property of secondary Fe- and Mn- oxides.

The correlation matrix of elements in the secondary environment indicates that Pb, Co, Fe, Mn, Ni, Br, and Zn are the prominent elements of secondary environment in Malanjkhanda area (Table 2).

Based on the discussion dealing with the distribution of elements, it can be concluded that Zn, Mn and Ni can be used as regional guides with Ag and Cd as local guides in this type of deposit. The water extractable halogens such as Cl, K and Br

along with the elemental ratio Br/Cl are good guides in soil geochemical survey. Their mobility causes the formation of larger halos, thus constituting a more easily detectable exploration target and therefore they are useful pathfinders for blind Cu ore in this area.

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Table 1: Mean standard deviation, background, ranges (ppm) and contrast of elements in soil samples

S.No.	Elements	X	σ	$X+\sigma$	$X+2\sigma$	Contrast	Range
1.	Cu	125	138	263	401	3.2	14.7 - 3822
2.	Pb	16.7	5.8	22.5	28.3	1.7	2.4 - 38.1
3.	Zn	24	8.3	32	40	1.7	11 - 50.1
4.	Cr	29.9	14.4	44.3	58.6	2.0	11 - 70.7
5.	Ni	20.8	7.8	28.7	36.5	1.7	3.8 - 40.5
6.	Co	25.6	20.5	46	66.5	2.6	0.33 - 109
7.	Cd	0.5	0.19	0.69	0.88	1.8	0.2 - 1
8.	Ag	2.09	2.9	5	7.9	3.8	0.04 - 22.8
9.	Fe	3.65	1.66	5.31	6.96	1.9	0.87 - 8.76
10.	Mn	3415	7664	11080	18744	5.5	17.5 - 18405
11.	I	0.55	0.33	0.88	1.2	2.2	0.2 - 1.6
12.	Br	2.5	1	3.5	4.5	1.8	1.6 - 9
13.	Cl	542	222	764	986	1.8	250 - 1950
14.	pH	5.7	0.48	6.2	6.67	1.2	2.95 - 6.5

Table 2: Correlation coefficient of different elements and pH calculated for soil samples of mineralized area

	Cu	Pb	Zn	Cr	Ni	Fe	Mn	Co	Cd	Ag	I	Br	Cl	pH
Cu	1.0000	.4856	.2371	.2589	.2049	.5491	.3120	.3305	.4153	.1710	.2996	.3081	.1403	.2843
Pb		1.0000	.5069	.4176	.7605	.8251	.8775	.8100	.7105	.1301	.5852	.3954	.3897	.6218
Zn			1.0000	.3761	.6769	.5584	.2532	.0915	.5993	.2541	.5246	.4561	.2749	.7094
Cr				1.0000	.3992	.5793	.1270	.1941	.4494	.2679	.4315	.7113	.4723	.4234
Ni					1.0000	.6653	.6133	.5103	.5395	.1022	.6181	.4137	.3296	.6872
Fe						1.0000	.5994	.5226	.7430	.3096	.6310	.5225	.4143	.6420
Mn							1.0000	.9397	.4450	-.0543	.3805	.1242	.2116	.3805
Co								1.0000	.3261	-.0632	.3375	.0684	.1833	.2826
Cd									1.0000	.1564	.5885	.6047	.4366	.6934
Ag										1.0000	.1010	.2425	.1493	.3497
I											1.0000	.3252	.2088	.7477
Br												1.0000	.8121	.4869
Cl													1.0000	.3373
pH														1.0000

secondary environment, it was observed that, more useful information can be gathered by using the Br/Cl ratio which shows a large enhanced anomalous trend and characteristic distribution pattern in the secondary environment around the ore deposit. Solovov and Garanin (1971) proposed that the ratios of elements can increase the zonality contrast around the ore deposit. Elemental ratio such as Br/Cl with an enlarged secondary halo has covered the entire mineralized area with a pointed anomaly trending from southeast to northwest (Fig.2. 1). This trend of mineralization in unexplored area has been emphasized by other important indicator elements such as Cu, Co, Ni, Cd, Ag and Mn in this zone. Therefore, the Br/Cl ratio can be used as a regional guide in this deposit.

Discussion and Geochemical Implications

The secondary dispersion patterns of Cu, Co and Pb in Malanjkhanda follow a similar trend of enrichment in the vicinity of quartz vein, forming oval halos near the quartz exposure. This may indicate their genetic relation to sulphide ore and suggest other important pathfinder elements whose anomaly spread is wide enough to be detected at a reasonable distance. Anomalous contents of the indicator elements such as Cu, Co, Cd, Ag, Mn and Ni are detected in N35W of quartz vein along 6th and 7th traverses, possibly indicating the extension of sulphide mineralization in this zone. The higher mobility of elements such

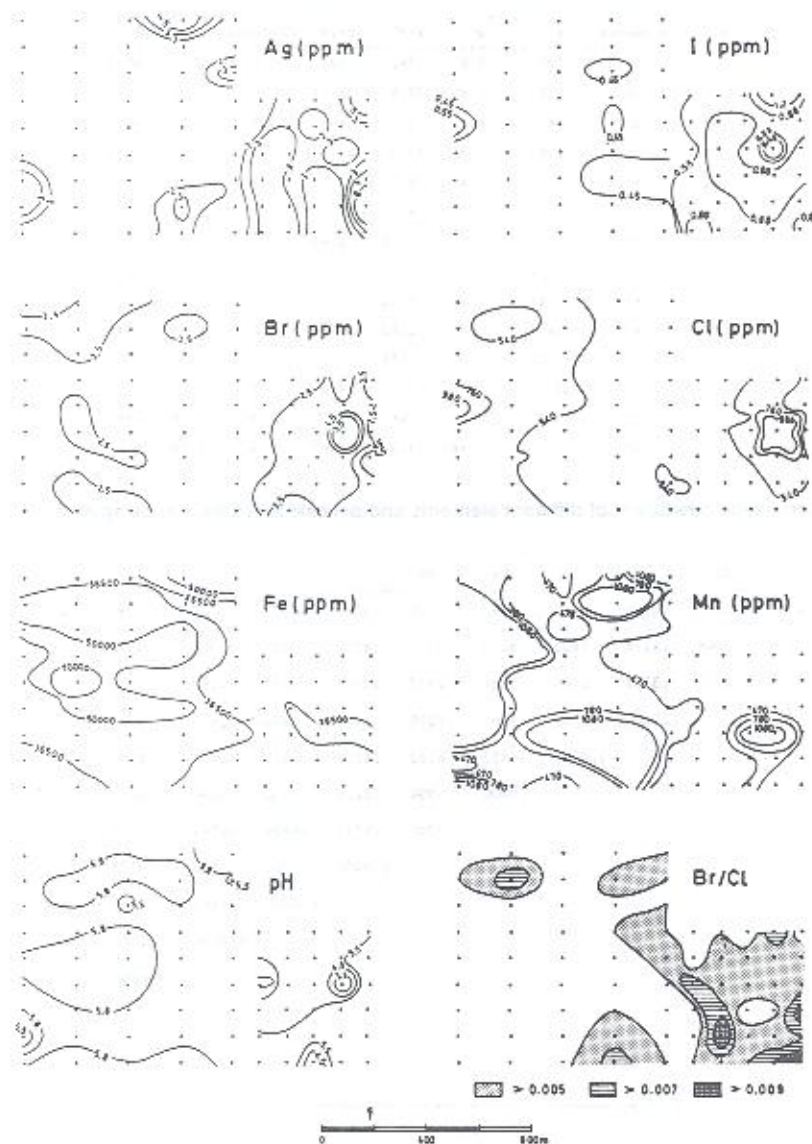


FIG:2.1 Geochemical contours showing distribution pattern of different elements in soil samples of Malanjkhanda Copper deposit (M.P. - INDIA)

above results and indicates the importance of elements such as Ni, Zn, Mn and emphasizes their preference in search of mineralization in secondary environments.

The use of cold water soluble Cl, Br and I as geochemical guides in the prospecting of base metal in Malanjkhanda seems to give encouraging results. These elements are more mobile with larger halos than Cu and other elements in the secondary environment. It is believed that the hydrothermal fluids which form

Cu ore bodies contain significant concentration of the halogens particularly Cl which forms chloride complexes with the ore forming elements and hence facilitates their transportation. In this case while mineralizing fluids deposited the metal the halogens might have been trapped in the secondary environment thereby forming their halos around the ore body. Probably some part of the halogens remained in the fluid in the gangue and ore minerals. In addition to the higher mobility of Cl and Br in the



these samples are easily and thoroughly extractable by hot HNO_3 , rather than aqua regia and combination of Nitric/Perchloric acids. However, in the case of Mn, aqua regia showed better results, probably due to the presence of HCl which extracts Mn and Fe more effectively. Hence, one gram of -80 fraction of each soil sample was treated with 5ml conc. HNO_3 and boiled for three hours, cooled overnight and diluted with 10ml. of distilled water. The clear solution was decanted and analyzed by A A S (Perkin Elmer model 307) for Cu, Pb, Zn, Cr, Ni, Co, Cd, Ag, Fe, Mn, pH and halogens. I, Br, were analyzed using the ion specific electrode and Cl was estimated by titration method (Hess, 1971). Duplicate analysis of some of the samples were carried out to find out the variation in the different batches, homogeneity and reproductivity of anomalies from a single site. Precision was given more emphasis than accuracy to avoid the creation of spurious anomalies and unrecognized weak anomalies. Twelve reagent blanks and three international standard samples (GXR- 2, GXR- 5, GXR- 6) were repeatedly analyzed along with the different batches to estimate the precision in each of the extractions. Apart from the above precautions, care was taken to avoid instrument drift, systematic errors and contamination of samples.

Results

The geochemical contours are shown in Figures 2 and 2.1. As is apparent from perusal of Fig.2, the elemental contours of Cu show a broad parallelism as well as inwardly increasing concentration in strike direction with a maximum in the southeast and above background values in the northwest. The boundary of background value is slightly wider than 500m. Pb concentration is more pronounced on the hanging wall rather than the footwall. In the mineralized zone, the distribution pattern of Pb in soil closely follows that of Cu and Zn. Pb is well correlated with Fe and such affiliation of Pb with Fe and Mn is confirmed from the conclusions of Antropova (1969), Norish (1975), Tidbal (1976), Schintzer and Kernodorff (1981), Dunlop et al (1983), who studied the partitioning of base metals with Fe- and Mn- oxides and concluded that Pb is associated with Fe oxides. Groundwater from higher levels in the south to the lower levels in the southeast of the main quartz vein is considered to have partly leached Zn from the reef which was then precipitated in the lower southeastern part of the area. Therefore, Zn dispersion is controlled by the topography of the area while Zn is hydromorphically dispersed in the adjoining area and an increase in the pH ensured precipitation of the Zn and minimized dispersion in the southern part of deposit. This was

also proved by higher background and low standard deviation which indicates that, Zn was mobilized and taken out of the mineralized area (Table.1). The distribution pattern of Cr, Ni and Co shows that the behavior of Cr is a function of the pH and a reflection of its geochemical similarity with Fe, bounded mostly in limonite at the surface while Ni in soils of Malanjkhanda was leached out from mineralized area on either side of the quartz vein, mobilized, migrated and accumulated in the southeast and northwest of the investigated area (Fig. 2). In the present area, where the limonite content is high, it is indisputable that Fe- and Mn - oxides along with clay minerals are responsible for the fixation of Co in soils. This fact is reflected in their correlation constant, particularly in the mineralized area with a correlation factor of $r=0.9397$ (Table 2). Hence, the oval anomaly zone of Co was formed near the quartz vein which is inherited from parent material. Similarly, the distribution pattern of Cd, Cu and their close coherence reveals the association of Cd with sulphide mineralization. The accumulation of Ag is more pronounced along the topographic slope due to hydromorphic process toward east and southeast, but the same southeast- northwest anomalous trend of mineralization is clearly discernible (Fig. 2). The main reason for higher concentration of Ag in mineralized area is due to the genetic relation of Ag with Cu and release of Ag during weathering and precipitation in alkaline reduction potential and in a medium enriched in "S" compounds and this could be the reason for the formation of enlarged halos of Ag near the quartz vein. Ag with a high contrast of 3.8 and standard deviation higher than the background value reveals its higher mobilization during the weathering with a peculiar large secondary halo spreading over 400m area, enveloping the zone of mineralization. A few isolated anomalous zones of Ag are noticed in the barren area but the most pronounced anomalous zone lies in the NW, along the 6th and 7th traverses which repeatedly indicate the presence of sulphide mineralization in that region.

In spite of differences in concentration of Mn in both the areas more attention is paid to the distribution pattern and continuation trend of Mn from the zone of exposed mineralization to the southwestern part of the investigated area. Four anomaly aureoles are present with the most pronounced zone, being in the immediate vicinity of the northwest of the quartz vein (Fig.2.1). In this case, the most prominent geochemical interference and interaction is observed in the strong affinity of Mn- oxides for Co, with correlation factor $r=0.9397$ (Table 2), and other elements such as Ni, Pb and Fe. This affinity is noticed all over the area but the degree of relation is stronger in the vicinity of quartz vein. Variation of elements with respect to the quartz vein, confirm the



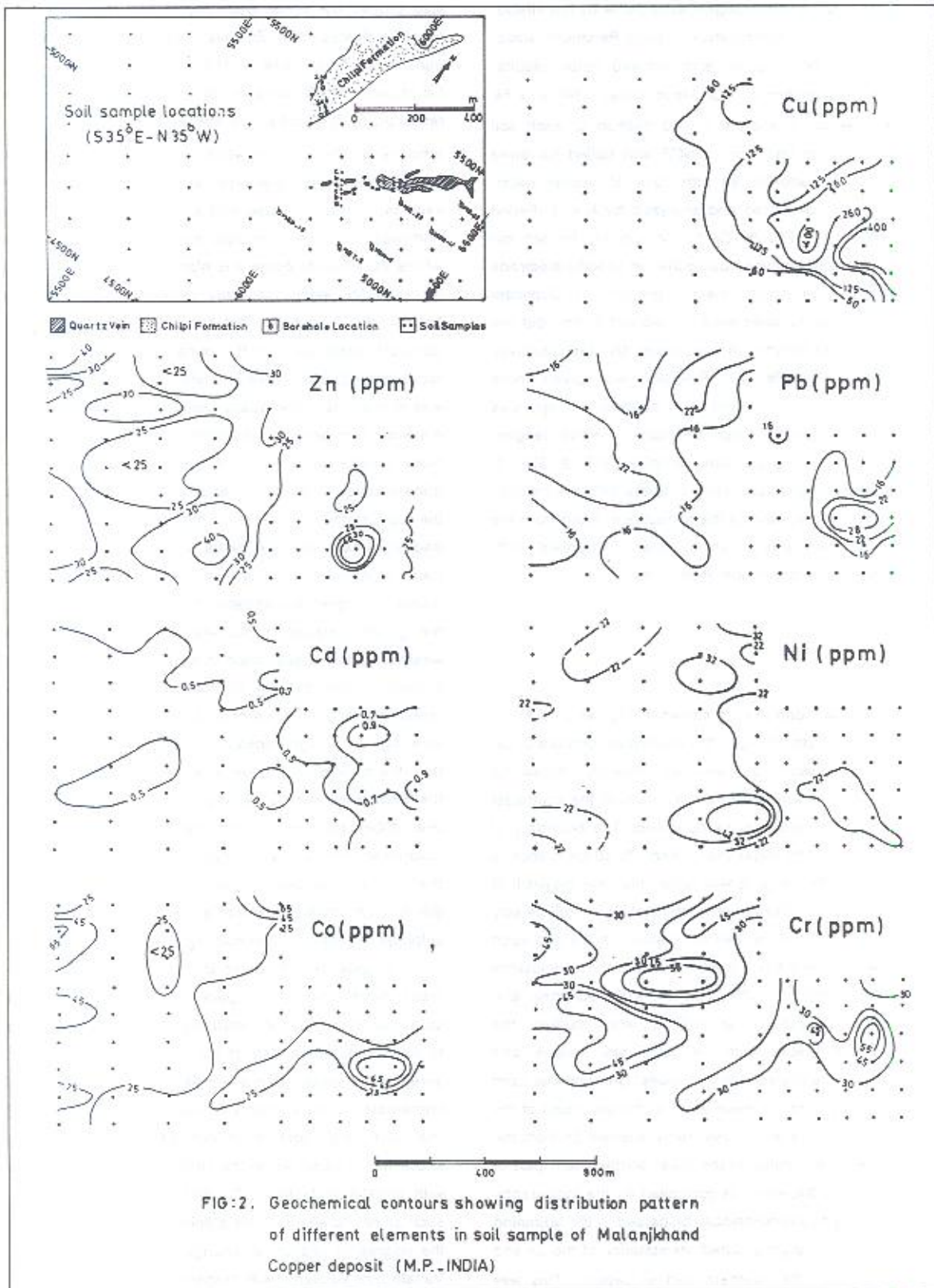
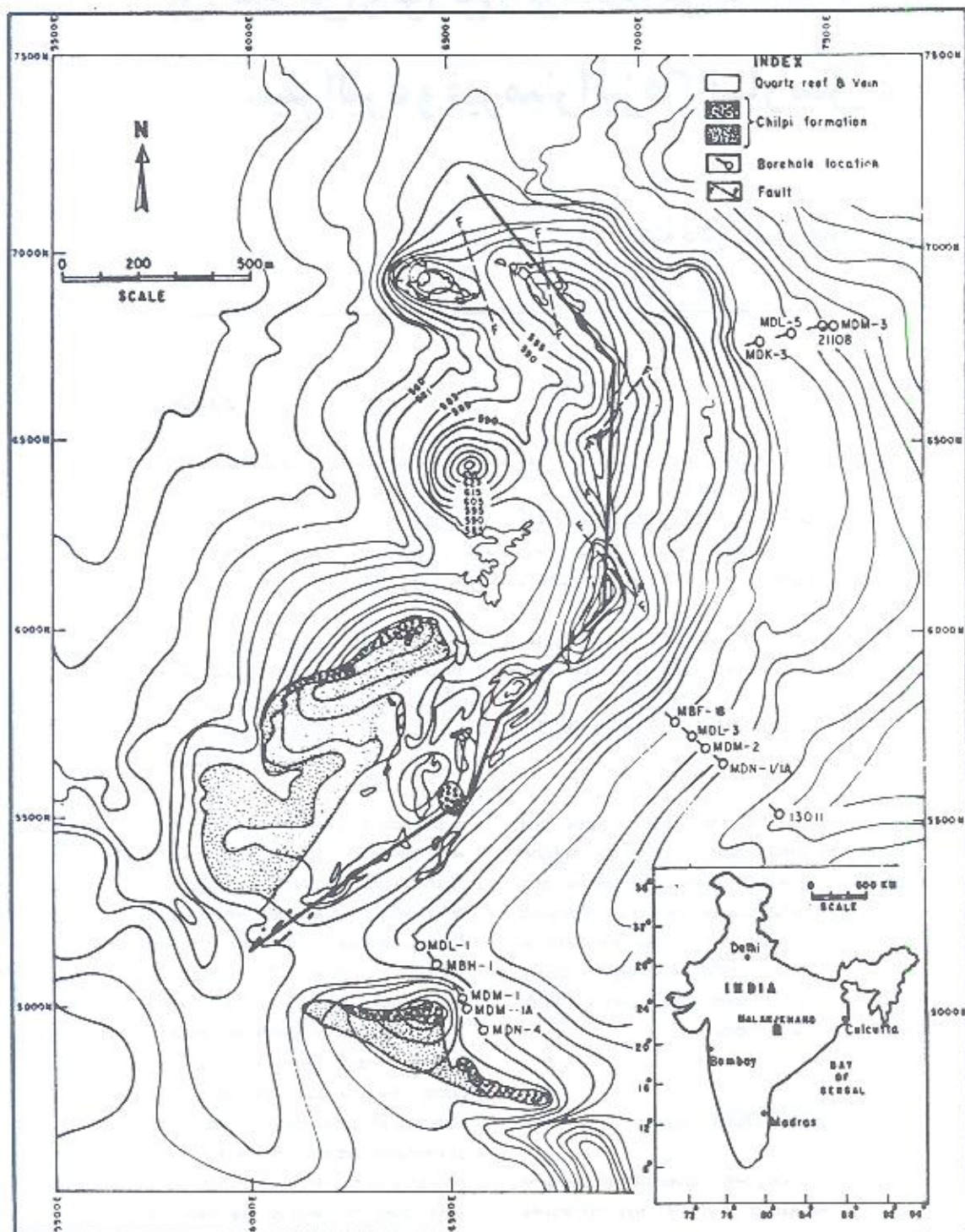


FIG. 1 GEOLOGICAL CONTOUR MAP OF MALANJKHAND COPPER DEPOSIT (M.P) (After H.C.L 1986)



پراکندگی و توزیع ژئوشیمیایی عناصر در خاک‌های مینرالیزه و غیرمینرالیزه کانسار مس مالانجکند

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چکیده

تحقیقات همه جانبه و مطالعات گسترده عناصر همراه با استفاده از هاله‌های ثانویه و روند پراکندگی و توزیع عناصر نادر و هالوژنها با مشخص شدن پارامترهای آپتیمال و ارزش‌یابی بهینه بر روی خاک‌های دوباره‌نشته‌های مس دوران آرکش در اطراف کانسار مس مالانجکند هندوستان مورد بررسی قرار گرفت. تجزیه‌شیمیایی عناصر Al , Mn , Fe , Ag , Cd , Co , Ni , Cr , Zn , Pb , Cu و Br در توده معدنی جهت ارزش‌یابی کاربرد آن‌ها در این کانسار، انجام شده و نتیجه آزمایش‌ها نشان می‌دهد که تجزیه‌شیمیایی صرفاً براساس کمیت فلز در خاک برای مشخص کردن علائم و راهنماهای مهم و وجود آنومالی‌های با ارزش در راستای کانی‌سازی موجود مفید نمی‌باشد.

طی این بررسی‌ها مشاهده گردید که بعضی از عناصر با تحرک بیشتر مانند Zn , Cu و Ni عناصر راهنمای منطقه‌ای بوده و دیگر عناصر از قبیل Ag , Cd و Br/Cl در پی‌جویی و کشف آنومالی‌های مربوط به این کانسار و همچنین در تعیین گستره منطقه و ردیابی ریشه توده معدنی بسیار مفید واقع گردیده‌اند.

جدول ضرایب انطباق عناصر دلالت براین دارد که Pb , Zn , Ni , Co , Fe , Mn و Br عناصر راهنما و مشخصه محیط ثانویه در منطقه مالانجکند می‌باشند.

In the paragenetic sequence, magnetite-I comes first followed by pyrite-I. After the deformation of first phase, second phase of mineralization, magnetite-II, pyrite-II, sphalerite and chalcopyrite were deposited. The last ore minerals to be deposited are bornite, covellite and chalcocite mainly near the zone of oxidation. According to M. E. C 1979 chalcopyrite shows deformation twins. X- rays studies of chalcopyrite shows that there is no change in the cell volume with depth.

Sampling and Analytical Techniques

The residual soil is moderately well- developed in the area and soil profiles are preserved except at a few steep hill slopes and foot hills, (Saha 1982) where the soils are transported. It is difficult to distinguish between transported and "in situ" soil but it

is possible to infer the nature of the soil from their dissimilarity with the underlying bed rock and also from topography. In this study, the soil sampling area was divided into two parts: 1) zone of exposed mineralization, where soil samples were collected from the southern part of the deposit on either side of the main quartz reef along traverse (S35E - N35W) (Fig.2) 2) zone of unexplored area (without quartz exposure) where soil samples were collected in continuation of previous direction with a slight change in sample density. Overall, 75 soil samples were collected from 60cm. depth in both the areas. In addition, 12 samples were collected at close intervals near quartz reef to study the variation of elements and effect of the main lode on the distribution of trace elements as one approaches the quartz vein. All the soil samples were dried to remove the moisture and homogenized. The efficiency of different digesting reagents on the extraction of Cu, Pb, Zn, and Mn from soil samples revealed that, the sulphides in



Geochemical Dispersion in Mineralized and Unmineralized Soils near Malanjkhanda Copper Deposit (M.P.) India.

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Abstract

A multi element orientation study including the use of secondary halos and dispersion trains of trace elements and halogens was undertaken on the soils over an Archean copper deposit with the view of evaluating the optimal parameters. The analysis of Cu, Pb, Zn, Cr, Ni, Co, Cd, Ag, Fe, Mn, I, Br, Cl and pH in the ore body was taken up to evaluate their applicability to this deposit. The results of analysis indicate that simple bulk analysis of metal content in soil fail to reveal the presence of important copper anomalies along the trend of mineralization. It is observed that some mobile elements (Zn, Mn, Ni) are regional guides, and others such as Ag, Cd and the Br/Cl ratio are more useful in detecting anomalies related to this deposit and thereby the extension of the mining area.

The correlation matrix of elements indicate that Pb, Zn, Ni, Co, Fe, Mn, and Br are the prominent elements of secondary environment in the Malanjkhanda area.

Introduction

The Malanjkhanda copper deposit in Madhya Pradesh India is the largest Precambrian copper deposit of the world discovered to date (Fig 1). The study of soil mantle from geochemical point of view in Malanjkhanda is helpful in identifying the target zone for sulphide mineralization in this region. The formation of secondary halos based on the dispersion of elements is significantly larger than the primary halos and often considerably larger than the ore deposit itself. It is felt that a detailed soil geochemical survey can help in developing geochemical guides for prospecting similar deposits in that area.

Geological setting

The geological history of the area starts with the formation of granitic complex which was traversed by later quartz veins and

reefs (M.E.C, 1979). Emplacement of the reef was followed by deformation and the first phase of mineralization, resulting in the deposition of magnetite, pyrite and molybdenite. The existing mineralization was also deformed later by the major sulphide mineralization in which minor amount of sphalerite and abundant chalcopryrite were deposited. This phase of mineralization was subjected to a basic intrusive activity in the form of dyke. The Archean basement complex is overlain by a younger sedimentary sequence with a low metamorphic impress (representing the basal part of the Chilpighat Series) comprising conglomerate, arkosic grit, sandstone, quartzite and younger quartz veins (Fig. 1). The mineralization is mainly confined to quartz reefs and its offshoots with some dissemination in the granite. The deposit is considered to be a porphyry type (Sikka 1989, Md. Jafar 1991) of hydrothermal origin, 2.6 km long and with a maximum width of 0.5km. It trends N35E, dipping 60° east.