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Indicator plants as guide to mineralisation in parts of Sikkim-Darjeeling Himalaya, India

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ABSTRACT

Systematic geobotanical and biogeochemical studies have not been attempted in any of the basemental prospects in the eastern Himalaya. The conventional geochemical soil and bedrock sampling in this rugged terrain has been proved to be abortive due to steep surface gradient, soil creep, landslide and excessive precipitation. As a supplement to conventional geochemical prospecting, an orientation survey on the population and growth habits of plants may help in the selection of plant species for prospecting. The chemical analyses of systematically sampled plants may possibly lead to the identification of indicator plants which are likely to act as direct guide to mineralisation in the substrate. With these ideas in view, the Pb-Zn-Cu deposit of the Bhotang mine near Rangpo, Sikkim and Pb-Zn-Cu mineralised zone of Malkhola Block, Gorubathan in Darjeeling district, West Bengal have been selected for such studies so as to find out the possible correlation of the elemental concentrations in the substrate and plants growing over them and subsequently delineating the indicator plants for certain elements. The presence and distribution pattern of such indicator plants in adjoining areas or elsewhere may help to detect zones of mineralisation which may not have any surface expression.

The polymetallic Pb-Zn-Cu deposit of the Bhotang mine, Rangpo, Sikkim the mineralisation occurs in the form of veins, disseminations, patches and lenses in chlorite schist and phyllite. Five zones of mineralisation have been delineated from southwest to northeast and it has been observed that the chalcopyrite-rich zone increases towards the southwestern direction and galena predominates over the other sulphides in the northeastern part.

The leaves, twigs and roots of different plant species occurring in the hill above the Bhotang mine have been systematically sampled and analysed for basementals and associated trace elements. The ashes of several plant species, viz. *Dioscorea batatas, Eupatorium odoratum, Lantana camara, Pteris longifolia, Adiantum* sp., grass with hard internode, grass without hard internode and locally known Koirala (Family: *Verbenaceae*) show anomalous concentrations of Pb, Zn and Cu and other trace elements. A rare variety of plant, locally known as Koirala (Family: *Verbenaceae*) grown on the hanging wall side of the lode and *Pityrogramma* sp., an extremelyrare variety of fern, have yielded very high values of Cu Pb and Zn which designates them as possible indicator plants for basemetal mineralisation in this terrain.

The study has thus indicated that *Koirala* and *pytyrogramma* sp. In Rangpo area, and *Plumbago zeylanica* and *Micana scandens* in Gorubathan area, Darjeeling hold good promise as local indicator plants for identifying zones of basemental mineralisation.

INTRODUCTION

The copper-zinc-lead sulphide deposit at the Bhotang Hill, Rangpo, Sikkim and the lead-zinc mineralisation at Gorubathan, Darjeeling district, West Bengal are the two most intensively explored localities in the eastern Himalaya. The polymetallic deposit at Rangpo is being mined by the Sikkim Mining Corporation and is the only source of basementals in Sikkim. The mine is located on the southern flank of the Bhotang Hill with prolific growth of Sub-Himalayan vegetation. The Tista River and its tributary, Rangpo Chu flow along the foot of the hill. In Gorubathan area, out of the four

separate occurrences, the Malkhola Block is the most important constituting bulk of ore reserve.

Several copper occurrences were earlier reported from Sikkim. Subsequently, detailed exploration of the Rangpo deposit was conducted by the Indian Bureau of Mines and Geological Survey of India to assess the potentiality and feasibility of mining the polymetallic ore (Mukherjee and Rao, 1974). Ghosh (1968, 1978) carried out detailed quantitative analysis of ore body zoning and study of mercury in rocks and sulphide ores of Bhotang mine. Recently, the nature of mineralisation and controls of ore localisation at the Bhotang mine has been described (Singh, 1991).

In parts of eastern Himalaya, the soil geochemical surveys have not produced consistent results even over the zones of mineralisation. This erratic situation is largely due to steep surface gradient, soil creep, landslides and excessive precipitation in the Himalayan terrain.

Systematic geobotanical and biogeochemical investigations have not been carried out earlier in such occurrences. An orientation survey on the population and growth habits of plants and analyses of different organs of plant samples were undertaken to study the capability of vegetation in identifying the regional geochemical patterns related to polymetallic sulphide mineralisation in Rangpo, Sikkim and Gorubathan, West Bengal (Sen and Pattnaik, 1989). The present study is aimed at finding out the possible correlation of the elemental concentrations in the substrate and different organs of the plants growing over them. Certain plants have been identified in both the areas which by virtue of their significant elemental concentration and rarity could be effectively used as indicator plants for basementals in similar geological environment elsewhere in the Himalayan terrain to locate ore localisation.

GEOLOGICAL SETUP

This part of eastern Himalaya is constituted of Precambrian metasedimentary seqence of alternating pelitic and psammitic rocks belonging to the Daling Group which consists of phyllites, black shales, slaty shales, garnetiferous chlorite schist, talc schist and quartzite with metabasics. The Daling Group of Darjeeling-Sikkim Himalaya is tectonostratigraphically located below the high grade gneissic rocks, limited by the sheared belt of mylonitic granite gneiss (Acharyya, 1989). The Lingtse Gneiss, associated with the Daling Group, has yielded a whole rock Rb-Sr age of 2034±21 Ma.

The Bhotang Mine, Rangpo occupies the southern part of a large F_2 fold which appears to be a doubly plunging antiformal structure (Fig. 1). Three folding deformations have been recorded in the rocks of the area. The earlier schistosity (S_1), axial planar to F_1 folds is subparallel to bedding (S_0) and forms the most penetrative structural element in the rocks. The F_2 folds have moderate to steep plunge to the north and south. The F_3 folds which produce an axial plane crenulation cleavage (S_3) is superimposed on earlier F_2 folds. The Pb-Zn-Cu mineralisation occurs in Rangpo, Sikkim in the form of veins, disseminations, patches and lenses in chlorite schist and phyllite. In the ore zones the minerals consist of pyrrhotite, chalcopyrite, sphalerite, galena, pyrite, arsenopyrite, magnetite, marcasite, chalcocite, cobaltite, tetrahedrite-tennantite and few grains of native silver (Ghosh, 1978; Singh, 1991). Five zones of mineralisation have been delineated from southwest to northeast and it has been observed that the copper-rich zone increases towards the southwesterly direction and lead and zinc predominate in the northeastern part of the Rangpo deposit (Mukherjee and Rao, 1974). The ore body has been proved over a vertical height of about 275 m, the average width of the ore body being about 5 m. chlorite schist and metabasics form the footwall and the central part of the lode with massive replacement and dissemination types of mineralisation. The hanging wall portion shows ore filling along the foliation planes in talc schists. The mineralised zone trends in a NE-SW direction from the eastern bank of Tista river near Main adit and is shifted towards west by an arcuate fault and is also affected by another NW-SE trending fault as a result the ore zone appears to be two sub-parallel lodes (Fig. 2).

The lead-zinc ore bodies of Gorubathan are hosted by the Daling Group. The predominant lithounits of this formation are quartz-sericite schist/ phyllite, sericite quartzite and quartz-magnetite

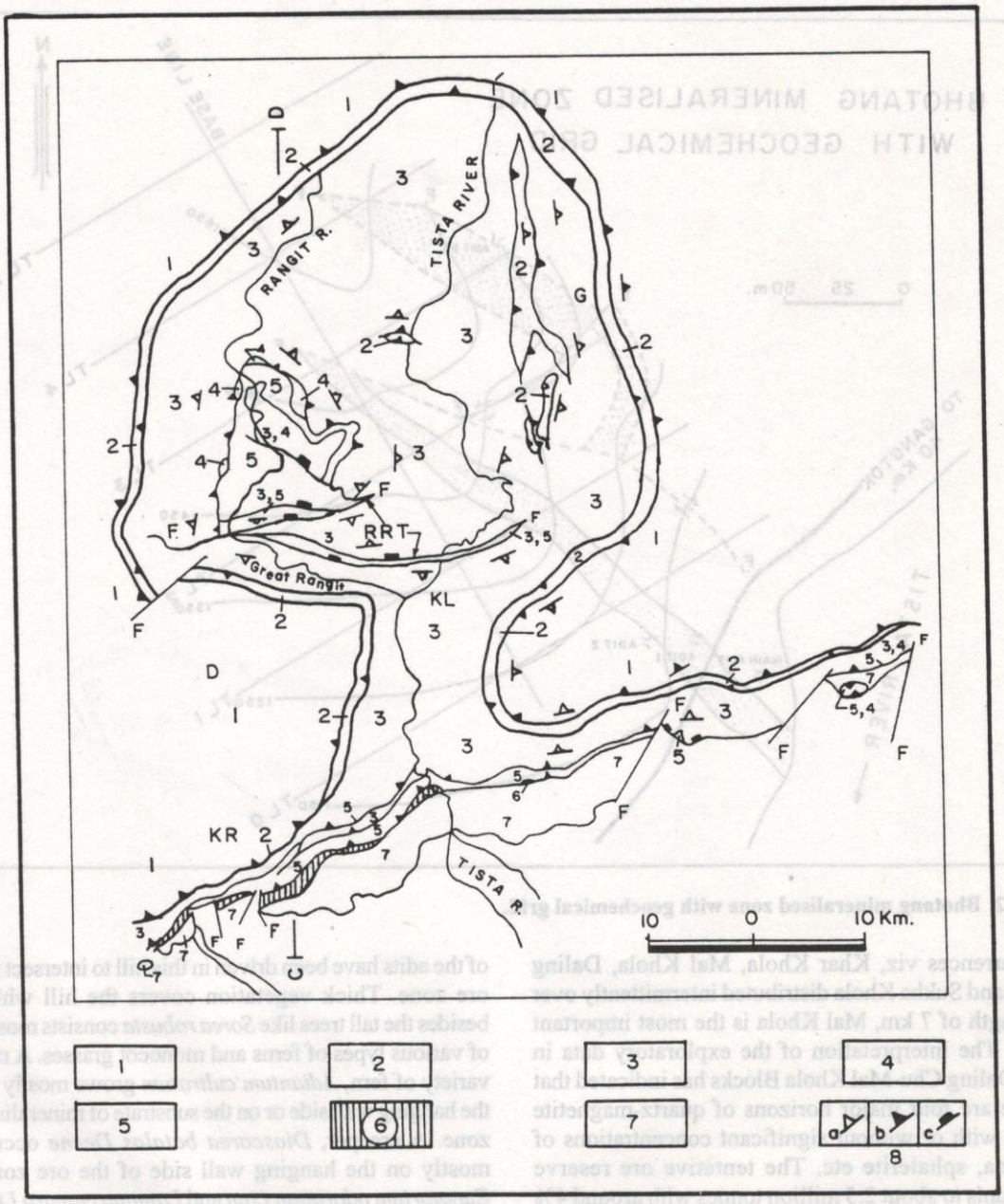

Fig. 1: Geological map of part of Darjeeling-Sikkim Himalaya (after Acharyya and Ray, 1989).

rocks. Epidiorites, chlorite-schist, graphitic carbon phyllites are other associated rock types of the Daling Group. The epidiorite-green bed assemblage which appears to be bedded flows is associated with stratiform syngenetic quartz-magnetite beds with polymetallic (Pb-Zn-Cu) sulphides (Acharyya, 1989). Fine laminated alternations of metalliferous and chlorite-sericitic volcanogenic beds indicate exhalative chemogenic precipitation (Ray, 1975; 1976). The ore minerals constitute magnetite, galena, sphalerite, pyrite, chalcopyrite adn pyrrhotite. In Gorubathan, out of four basemental

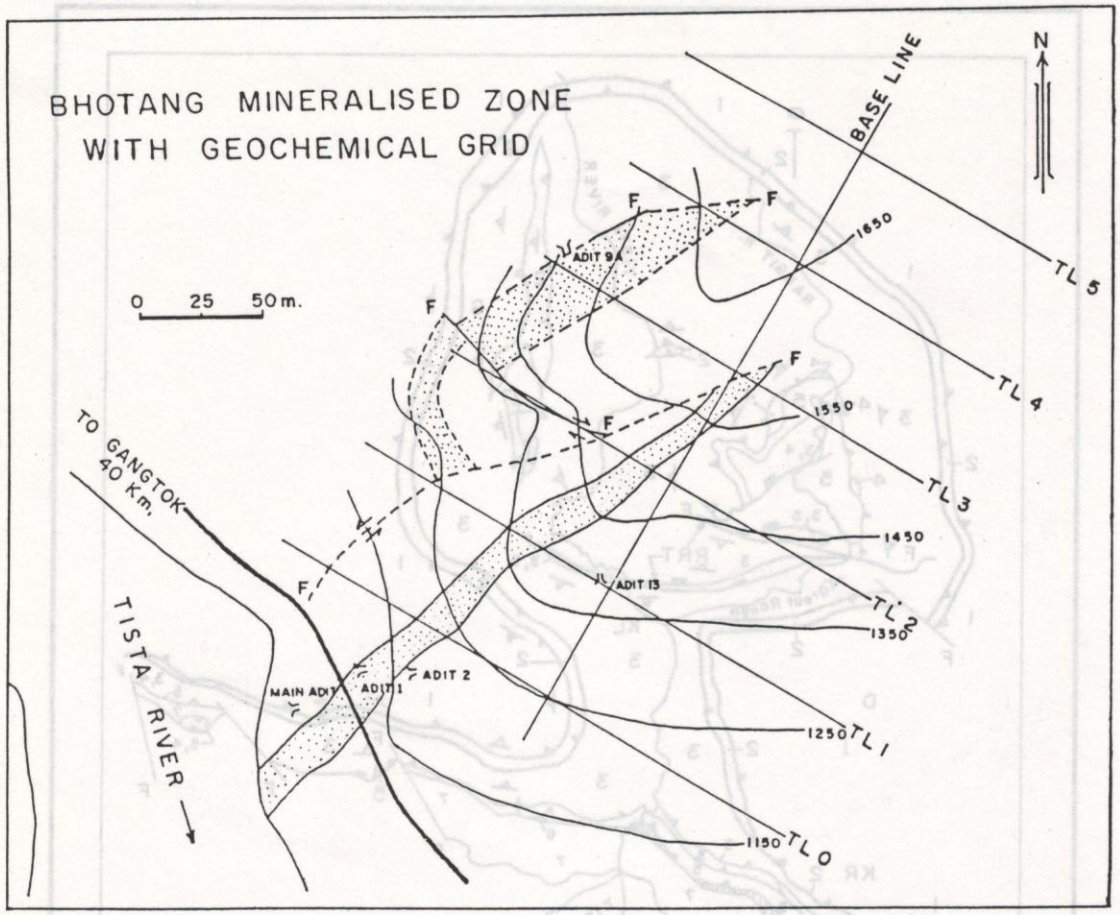

Fig. 2: Bhotang mineralised zone with geochemical grid.

occurrences viz, Khar Khola, Mal Khola, Daling Chu and Sukha Khola distributed intermittently over a length of 7 km, Mal Khola is the most important one. The interpretation of the exploratory data in the Daling Chu-Mal Khola Blocks has indicated that there are four major horizons of quartz-magnetite rock with or without significant concentrations of galena, sphalerite etc. The tentative ore reserve amounts to about 2.5 million tonnes with around 4% Pb and 4% Zn. The other important constituent coper is 1,400 gms/tonne (Saha, 1978).

GEOBOTANICAL AND BIOGEO-CHEMICAL INVESTIGATIONS

The Bhotang hill near Rangpo, Sikkim rises rather steeply towards north from the river bed of Tista. Some of the adits have been driven in this hill to intersect the ore zone. Thick vegetation covers the hill which besides the tall trees like *Sorea robusta* consists mostly of various types of ferns and monocot grasses. A rare variety of fern, *Adiantum cultratum* grows mostly on the hanging wall side or on the substrate of mineralised zone. A creeper, *Dioscorea batalas Decne* occurs mostly on the hanging wall side of the ore zone. *Eupatorium odoratum Linn* and *Lantana camara Linn* have more or less similar distribution pattern as that of the creeper. Another type of *Verbenaecae* (Koirala) is a very rare plant of 1-2 m height with thick stem of about 3-4 cm in diameter. A grass characterised by long-bladded leaves and hard internode has grown profusely over the abandoned Adit No. 13 close to the mineralised zone. *Pityrogramma* sp. is an extremely rare type of fern which occurs at one station only.

Above the underground workings of Bhotang Mine on the hill slope traverse lines were laid at an interval of 50m across the NE-SW trending ore one. Plant, soil and bedrock samples, wherever possible, were collected from stations at 25m interval. Samples of different organs, viz, leaves twigs and roots of various plant species and bark of tall trees like *Shorea robusta* and grasses were collected at each sample point, wherever present. Leaves and twigs of 2-3 years old of each species were usually sampled. The different types of fern, viz, *Adiantum cultratum*, *Pityrogramma* sp., *Pteris longifolia* were usually sampled as a whole as these plants have too small leaves and thin, tender stems to be sampled separately. To avoid the possible contaminating effects of mud splatter from heavy rains and mine debris the leaves and twigs of plants were collected usually about 1m above the ground.

The sampling of plants at Gorubathan was restricted to two selected sectors covering (a) Exposures II, III, IV and (b) Exposures V in the Mal Khola Block.

The plant samples each weighing 200-300 gm thus collected were thoroughly washed in running stream water and air-dried. 15 gm of dried samples were taken and ashed in an electric muffle furnace at 450°C for 4-5 hours. In most cases 15 gm of the dried plant samples yielded 1.5-2 gm of ash. After dissolution of plant ash the samples were analysed by Emission Spectrographic Method at Central Chemical Laboratory G.S.I., Calcutta.

Wherever possible, the bed rock and soil samples were collected along with the plant samples. The humus soil was usually taken but soil samples from each sample point could not be drawn because of the transported and unstable nature of the soil in the hill slope.

MORPHOLOCICAL AND MUTATIONAL CHANGES

The morphological changes in plants and evidence of disease are considered useful aids in geobotanical prospecting and have been used as field guides since the eighteenth century (Brooks, 1972). Mottling or chlorosis or 'yellowing' of leaves, nearly always indicative of iron deficiency, was observed in most of the plants growing over the mineralised substrate. The stimulatory and antagonistic effects of various pairs of elements on their absorption by plants show that high copper or zinc levels in the substrate of the Bhotang hill and Mal Khola Block have depressed iron uptake and produced chlorosis in the vegetation. Chlorosis is also a symptom of manganese deficiency (Brooks, 1972). In fact, manganese is depleted in the plant ash of both Rangpo and Gorubathan area, the average value being 800 ppm and 425 ppm respectively. Besides chlorosis in most of the vegetation, the leaves of *Pteris longifolia Linn* have developed reddish and yellowish colours and also black spots. The leaf margins of the fern, *Adiantum cultratum* have turned violet and pink at places. The leaves of *Gleichenia flexuosa* close to the mineralised zone have become bleached and turned reddish or pink.

RESULTS OF BIOGEOCHEMICAL SURVEYS

Rangpo Area

The mean concentrations and range of values of certain elements in the ash of different organs of the plant species growing over the Bhotang Mine, Rangpo and in background area, Mansang are tabulated (Table 1). The analytical data have shown that the chemistry of certain organs of plants has several coherent multi-element patterns associated with the polymetallic deposit. Five of the thirteen varieties of plants sampled show high elemental concentrations which very well corroborate with the geochemical pattern of the mineralised substrate.

The creeper, *Dioscorea batatas Decne* yields anomalous values of Pb, Zn and Cu in the ash of leaf, twig and root samples but the ash of the roots contains the highest average concentrations of 730 ppm Pb, 2170 ppm Zn and 280 ppm Cu. The distribution of metal values in space in different organs of *Discorea batatas Decne* broadly corresponds to the different zones of Pb-Zn-Cu mineralisation as established by earlier workers (Mukherjee and Rao, 1974). The Zn/Cu values in the roots of the plant gradually decreases from northeast to southwest corroborating the increase in copper percentage towards the southwestern part of the mineralised zone (Mukherjee and Rao, 1974).

Table 1: Concentration ranges with mean values in parentheses of some elements in the ash of leaves, twigs and roots of certain plant and grass samples (in ppm) from Bhotang Mine area, Rangpo and at a background side near Mansong (* denotes no. of samples).

Element	Dioscorea batatas			Eupatorium odoratum			Lantana camara		
	Leaves	Twigs	Roots	Leaves	Twigs	Roots	Leaves	Twigs	Roots
		*22			*17			*15	
Cu	90-300	40-240	60-1200	110-500	30-240	130-3200	10-300	140-300	170-400
	(170)	(130)	(280)	(230)	(100)	(210)	(190)	(225)	(250)
Pb	20-1000	20-1000	40-1200	10-500	20-1000	80-1000	60-1000	40-700	30-1000
	(330)	(400)	(730)	(90)	(310)	(680)	(410)	(270)	(575)
Zn	640-4000	430-2960	620-4800	650-3700	330-4000	1180-4000	320-2960	460-3020	640-3020
	(1450)	(1230)	(2170)	(1540)	(1230)	(2410)	(820)	(1320)	(2015)
Mn	350-1000	150-800	200-1000	200-1000	30-1000	250-4000	20-1000	350-1000	30-1000
	(930)	(340)	(530)	(700)	(340)	(760)	(430)	(950)	(895)
Ni	10-40	10-20	10-30	10-30	5-10	10-60	2-9	5-15	2-12
	(12)	(13)	(14)	(15)	(7)	(16)	(2.5)	(6)	(3.5)
Cr	20-400	20-400	20-300	20-250	20-310	40-300	20-250	30-300	30-300
	(180)	(130)	(110)	(130)	(120)	(130)	(145)	(125)	(90)
Ba	40-1000	30-1000	30-1000	30-700	30-800	40-1000	30-700	30-800	40-1000
	(470)	(290)	(320)	(380)	(390)	(475)	(190)	(215)	(270)
Ag	1-3	1-2	1-10	1-5	1-4	1-8	--	1	--
	(1.4)	(1.3)	(3.6)	(1.8)	(2.7)	(2.8)		(1)	
Mo	10-40	--	10-40		20-40	15-100	--	--	40-100
	(26)		(23)	(20)	(30)	(45)			(70)
				Background area					
Cu	50	20	60	10	40	60	50	10	100
Pb	10	20	30	20	30	50	10	10	40
Zn	200	150	125	10	60	40	150	170	200

	Grass with hard internode	Pteris longifolia	Adiantum cultratum	"Koirala" (Verbenaceae)			Pityrogramma sp.	Grass without hard stem
	*10	*6	*6	*3			*1	*11
				Leaves	Twigs	Roots		
Cu	65-300	80-160	160-500	180-350	160-260	--	150	60-350
	(180)	(110)	(280)	(265)	(220)			(170)
Pb	40-1600	30-1000	40-700	900-		--	900	30-1000
	(895)	(370)	(240)	1000	(1000)			(440)
Zn	1210-4200	675-4000	1155-2180	(950)	980-4000	--	4000	30-1000
	(2900)	(1730)	(1530)		(2680)			(2750)
Mn	200-1000	300-400	300-700	(4000)	800-1000	--	400	500-1000
	(710)	(330)	(450)		(800)			(950)
Ni	15-30	10-30	6		10-200	--	30	10-30
	(18)	(14)		25-30	(130)			(14)
Cr	40-300	30-160	20-250	(28)	90-250	--	150	20-200
	(135)	(100)	(165)	110-150	(150)			(110)
Ba	30-1000	40-400	50-800	(130)	670	--	1000	100-1000
	(320)	(150)	(330)	1000				(510)
Ag	1-4	1-2	1-8		--	--	--	1-3
	(2.1)	(1.4)	(4)	--				(2)
Mo	10-20	--	--		40	--	--	10-20
	(15)			--				(15)

The Pb/Zn value in the plant also increase gradually towards southwest upto Adit No. 13. Similar spatial variations of Pb/Zn and Zn/Cu ratios are indicated by the metal values in the ash of the roots of *Eupatorium odoratum Linn*. The ash of the leaves and roots of this plant species are enriched in Cu (mean 230 ppm) and Zn (mean 2646 ppm) respectively. The maximum mean concentration of Cu (280 ppm) in plant ash has been recorded in fern, *Adiantum cultratum*. The mean lead and zinc values recorded in the fern are 240 ppm and 1530 ppm respectively. A long bladed grass with hard internode which has prolific growth over the mineralised substrate has yielded maximum concentrations of Pb (895 ppm) and Zn (2900 ppm) and fairly high value of Cu (180 ppm). The localisation of this type of grass over the mineralised substrate and its scanty growth outside it characterise it as a conspicuous plant species which can be used as a local indicator plant. A rare vriety of plant, belonging to the family *Verbenaceae*, locally known as 'Koirala', has grown on the hanging wall side of the ore zone and yields very high mean values of Cu (265 ppm), Pb (950 ppm) and Zn (4000 ppm) in the ash of the leaves. The rarity of this plant and its abnormal high metal values designate this *Verbenaceae* as a local indicator plant. Besides these, *Pityrogramma* sp., a very rare variety of fern, has yielded high values of Cu (150 ppm), Pb (900 ppm) and Zn (4000 ppm) which characterises it as a significant indicator plant of basemental mineralisation in this Sub-Himalayan terrain.

Gorubathan Area

The average concentrations of selected elements in the ash of the plant species of Gorubathan, Darjeeling district, West Bengal are given in Table 2. In the two sectors of Mal Khola Block, 15 plant species were sampled. In the Sector I, covering explsures II, III and IV, of the nine plant species sampled the following plants recorded moderately hgh average concentrations of basementals. The leaves of *Micana scandens, Eupatorium odoratum Linn* and twigs of *Plumbago zeylanica* have yielded 120 to 138 ppm of Cu. The leaves of *Micana scandens* and twigs of *Phologocanthus thyrsyflorus* and *Plumbago zeylanica* have recorded 1290-1868 ppm of Zn. In the ash of the twigs of *Schima wallichii* and *Plumbago zeylanica* 170-200 ppm of Pb has been recorded. In Sector II, comprising exposure V, the twigs of *Blumea balsamifera* have yielded the maximum concentration of 120 ppm Cu. The plant species, *Polyalthia simiarus, Blumea balsamifera* and *Brassaiopsis hainla* have indicated high Zn values ranging from 880 to 2060 ppm. The maximum average enrichment of Pb (421 ppm) has been noticed in the twigs of *Bambosa ramosissima*. The analytical results of a few bed rock samples collected from the area have yielded low and insignificant values.

Among the plant species samples in both Rangpo and Gorubathan areas, two species, *Dioscorea batatas* and *Eupatorium adoratum* have been found to be quite abundant in both the occurrences. The level of concentrations of Pb, Zn and Cu in these plants at Rangpo is higher than that of the Gorubathan area which may be attributed to contrasted lithology, variation in the degree of mineralisation and development of soil profile.

CONCLUSIONS

The Sub-Himalayan flora of the Bhotang Mine area, Rangpo, Sikkim and Mal Khola Block area, Gorubathan, west Bengal have indicated anomalous concentrations of lead, zinc and copper. The plants showing higher uptake of base mentals in Rangpo area are the organs of *Eupatorium odoratum Linn, Dioscorea batatas Decne,* a *verbenaceae* locally known as 'Koirala', *Pityrogramma* sp., *Lantana camara Linn, Pteris longifolia Linn, Adiantum cultratum* and in Gorubathan area different organs of *Micana scandens, Eupatorium odoratum, Plumbago zeylanica, Phologocanthus thyrsyflorus, Schima wallichii* and *Jumbosa ramosissima* have yielded significant base mental concentrations.

A review of the analytical results of the ash of the plant samples has indicated that few plant species are anomalously enriched in lead, zonc and copper and can suitably be used as indicator plants for base mental mineralisation. The extremely rare variety of fern, *Pityrogramma* sp., and the *verbenaceae*, (Koirala) in Bhotang Mine area, Rangpo and *Plumbago zeylanica* and *Micana scandens* in Gorubathan area, Darjeeling hold very good promise as local indicator plants for identifying zones of base mental mineralisation.

Table 2: Average concentration (ppm) of selected elements in ash of plants of Gorubathan area. W. Plant - Whole plant (leaf + twig + flower + root), No. in parentheses indicates no. of samples, X - element not detected).

SN	Type of Plant	Organ	No. of Samples	Average Concentration					
				Cu	Zn	Pb	Mn	Ba	Sr
01.	*Micana scandens*	W. Plant	80 (30)	110	1120	40	714	340	260
		Leaves	40 (23)	121	1292	27	810	340	268
		Twigs	27 (13)	87	896	65	587	395	200
02.	*Bauhinio racemosus*	W. Plant	58 (30)	43	463	44	543	546	392
		Leaves	35 (21)	40	383	45	558	546	386
		Twigs	19 (9)	61	734	43	562	558	293
03.	*Schima wallichii*	W. Plant	76 (51)	60	286	103	894	688	252
		Leaves	35 (26)	55	248	45	937	582	164
		Twigs	24 (19)	108	405	201	914	739	352
04.	*Eupatorium odoratum Linn*	W. Plant	47 (23)	123	913	70	801	292	206
		Leaves	27 (17)	138	904	22	740	296	174
		Twigs	7 (3)	53	1027	40	800	382	214
05.	Phologacanthus thyrsyflorus	W. Plant	34 (20)	35	1059	227	670	489	350
		Leaves	17 (10)	10	992	125	641	490	381
		Twigs	17 (10)	64	1224	227	599	531	281
06.	Boehmoria platyphylla	W. Plant	63 (32)	37	443	52	566	429	300
		Leaves	31 (17)	27	323	20	643	445	242
		Twigs	30 (15)	45	627	76	497	444	351
07.	Morinda citrifolia	W. Plant	30 (19)	54	981	82	900	345	429
		Leaves	15 (7)	40	843	34	953	245	410
		Twigs	15	60	943	110	820	366	444
08.	Discorea batatas Decne	W. Plant	23 (20)	60	1010	119	906	294	218
		Leaves	15 (13)	57	845	119	906	227	240
		Twigs	8 (7)	42	780	202	837	351	296
09.	Plumbago zeylanica	W. Plant	51 (35)	87	1020	112	736	282	166
		Leaves	23 (18)	62	565	50	774	214	138
		Twigs	16 (12)	128	1868	172	687	381	192
10.	Eugenia jambosa	W. Plant	21 (14)	52	492	86	770	167	80
		Leaves	16 (10)	49	327	30	705	100	38
		Twigs	4 (3)	71	1035	239	1000	442	252
11.	Polyathia simiarus	W. Plant	40	60	553	X	559	164	357
		Leaves	23	36	383	X	611	133	225
		Twigs	13	96	878	X	533	181	546
12.	Blumea balsamifera	W. Plant	53	108	1036	X	675	212	425
		Leaves	27	94	890	X	779	197	421
		Twigs	26	120	1110	X	598	188	417
13.	Sarcosperma arboreum	W. Plant	22	68	580	X	283	224	377
		Leaves	15	53	360	X	281	152	326
		Twigs	7	101	560	X	288	377	485
14.	Jambosa ramosissima	W. Plant	27 (16)	41	593	271	279	179	308
		Leaves	15 (8)	36	389	117	308	124	266
		Twigs	11 (8)	62	952	421	255	257	410
15.	Brassa hainla	W. Plant	13	25	1069	X	373	270	468
		Leaves	7	26	2062	X	425	172	292
		Twigs	6	26	652	X	312	385	693

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