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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OPEN FILE REPORT
Colombia Investigations
(IR) CO-27

A GEOCHEMICAL STUDY OF THE RIO PANTANOS AREA

DEPARTMENT OF ANTIOQUIA, COLOMBIA
Preliminary report

by

Henry V. Alminas and Elwin L. Mosier
U. S. Geological Survey

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Prepared on behalf of the
Agency for International Development
U. S. Department of State and
the Government of Colombia

1972

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ABSTRACT

Geochemical sampling in the Western Cordillera has delineated an 18 km^2 area anomalous in copper, molybdenum, and silver. Highly anomalous metal contents are found in stream sediment, soil, and outcrop samples collected within this area. The area is underlain by intrusive granodiorite to quartz diorite that has porphyritic and granitoid phases. Most of the outcrop samples contain disseminated pyrite, chalcopyrite, and bornite.

A geochemical reconnaissance sampling program in the Western Cordillera, formulated by Andrés Jimeno V., Director, Instituto Nacional de Investigaciones Geológico-Mineras (INGEOMINAS), and Earl M. Irving, U. S. Geological Survey (USGS) Chief of Party in Colombia, was carried out from 1969 to 1971 by geologists of the INGEOMINAS office in Medellín. This work was part of a cooperative program of INGEOMINAS and the USGS sponsored by the Government of Colombia and the Agency for International Development, U. S. Department of State.

Seventeen generally east-trending traverses were completed across the Western Cordillera. These traverses, generally paralleling major drainages, cross the range at intervals of 10 to 30 km.

Samples consisting predominantly of sieved (<80) stream sediments and panned concentrates of stream sediments were collected at approximately one-half kilometer intervals along each traverse. The samples were analyzed by use of semiquantitative spectrographic methods in the INGEOMINAS chemical laboratories in Bogotá. At the time of the authors' arrival in Colombia (February 1972), only the sieved stream sediment samples had been analyzed.

Our main assignment in Colombia was the evaluation of existing geochemical data, the delineation of areas warranting further work, and the planning and initiation of geochemical exploration programs deemed applicable to these areas. The Río Pantanos area was one of several localities within the Western Cordillera selected for more detailed geochemical work because some of the sediment samples seemed to contain anomalous amounts of copper. These samples had been collected during a reconnaissance traverse in 1970 along the Río Pantanos by INGEOMINAS geologists Alfonso Calderon and Hector Castro.

Alminas began a detailed field investigation of the Río Pantanos area in the period March 15 to April 21, 1972, and was accompanied by Jaime Cruz B., Octavio Ramirez, and Alfonso Calderon of INGEOMINAS. A second field trip into the Río Pantanos area, from April 25 to May 8, 1972, was made by Alminas and INGEOMINAS geologists Octavio Ramirez, Alfonso Arias, Alfonso Calderon, and Hector Castro. Mosier made the spectrographic analyses of the geochemical samples.

GEOLOGIC AND GEOGRAPHIC SETTING

Western Cordillera

The Western Cordillera (Cordillera Occidental) is a north-northeast-trending range more or less parallel to the Pacific coast of Colombia and is 100 km inland (fig. 1). The range rises from near sea level to above 4600 meters and is within a region of extremely high rainfall (greater than 750 cm per year). As a result, most of the range, and especially the western slope, is covered by exceedingly heavy tropical forest. Owing to these factors and the resultant extremely poor access into the area, probably less geologic information is available about the Western Cordillera than about any other part of the Colombian Andes.

The available information was summarized by Earl M. Irving (written commun., December 23, 1971) who describes the range as being composed mainly of a thick eugeosynclinal sequence, strongly folded and faulted, of mafic volcanic rock having interbedded chert layers, thin-bedded shale, siltstone, and minor fine-grained sandstone, reportedly of flysch type. Some geologists have mentioned the presence of turbidites. Scant fossils indicate that the sequence is mainly Cretaceous in age. The sequence is cut by small stocks and at least one batholith, chiefly of quartz diorite, which are probably of middle Tertiary age, as indicated by radiometric ages determined on similar plutons elsewhere in the range.

Río Pantanos area

The Río Pantanos area is on the western slope and near the northern end of the Western Cordillera (fig. 1), in the Departamento de Antioquia, about 43 km southwest of Frontino, the nearest sizable town. The 20 km^2 area (pl. 1) sampled is bounded on the west by Alto Chajeradó, the north-west by Río Amparadó, the north and east by Quebrada Chontaduro, and on

Figure 1.-Index map showing the area sampled in the Cordillera Occidental, northwestern Antioquia.

the south by Río Pantanos. It is an area of subdued topography relative to the surrounding region. The main topographic feature is a narrow ridge abutting Alto Chajeradó to the west and trending east-northeast through the center of the low-lying area for about 10 km. This ridge cuts across the north-northwest-trending regional grain. Altitudes within the area range from 770 meters in the southern swamps along the Río Pantanos to 1,040 meters at the western top of the ridge. The entire area is covered with dense tropical rain forest.

As far as could be determined, the sampled area is within a single intrusive body ranging from granodiorite to quartz diorite in composition, and from porphyritic to granitic in texture. The areal extent of this intrusion is as yet unknown, but its boundaries may coincide with those of the low-lying area delineated by the Amparadó, Chontaduro, and Pantanos drainages. Alluvium in a stream entering the sampled area from the north contains gabbroic cobbles. Gabbroic cobbles, also found in the Amparadó drainage indicate the presence of mafic intrusives to the north and northwest. Some of these cobbles contain disseminated chalcopyrite and pyrite. Gabbroic debris was also found in the Río Pantanos alluvium, thus indicating gabbroic intrusives to the south or east.

Pyrite, chalcopyrite, and bornite are disseminated and form microveinlets in the outcrops throughout the ridge area. Most of the rock is sericitized, chloritized, kaolinized, and epidotized. At two locations the outcrops also show silicification.

The soil of the Río Pantanos area may be classified as weakly ferallitic (Millot, 1970). It is a yellow equatorial clay characteristically found overlying silicic parent rock in rain forest environments. The continuous saturation of the profile by ground water, because of the high annual rainfall, extremely short dry season, and dense shade forest, has inhibited development of surface encrustations of iron-oxide cemented soil. Little variation in color or coarseness was noted in the Río Pantanos soils, either areally or with depth. The humic layer is extremely thin. The A-horizon (top layer, ranging from 20-40 cm in thickness) is only very slightly darker than the B-horizon (yellow to reddish yellow and varible in thickness). Both consist of slightly silty clay. In the ridge area the C-horizon is the same color, but has increasing amounts of coarser material downward and culminating at the decayed bedrock. In the low-lying area around the ridge, no variation in coarseness is found to a depth of 2.4 meters. In addition, a color change from yellow to gray is encountered at a depth of 1 to 2 meters.

SAMPLE TYPES AND ANALYTIC METHODS

Sample traverses in the Río Pantanos area were dictated by the extremely poor access within the area and the short time available for the work. As a result, traverses followed the existing limited trail system and the streams draining the area. Traverses along streams offered the additional advantage of being in areas of maximum rock exposure. Where necessary, as in the northern part of the area, new trails were cleared.

Four basic sample types were taken: outcrop, B-horizon soil, <80-mesh sieved stream sediment, and panned concentrates of stream sediments. In addition, several soil profiles to a 2.4 m depth were taken by hand auger, some stream water samples were collected for pH determinations, and a 32-foot core was recovered from sample location HVA-145 (pl. 1).

All samples in the Río Pantanos area were analyzed for 33 elements by the six-step semiquantitative spectrographic method (Grimes and Marranzino, 1968). These analyses were made in the INGEOMINAS chemical laboratories in Bogotá by E. L. Mosier, USGS, and by chemists A. Barratto and V. G. Garcia of INGEOMINAS, under Mosier's general supervision. A few selected outcrop samples and the core samples were analyzed for copper by atomic absorption spectrometric methods (Ward and others, 1969). Mercury was determined on 154 <80-mesh, B-horizon soils by large-volume, atomic absorption techniques (Vaughn, 1967). Selected outcrop and <10-mesh sieved stream sediment samples were checked in the field for cold-acid-extractable copper by the Canney and Hawkins method (Canney and Hawkins, 1958). Soil and water pH were measured in the field with an Orion specific ion meter model 404. Furthermore, laboratory measurement of soil pH were made of a slurry consisting of 1 part soil (25 gm) and 2 parts water (50 ml) of known pH.

Outcrop samples

Outcrop samples (pl. 1) were taken wherever available in the low-lying parts of the Río Pantanos area. Along the ridge, where outcrops are more continuous, samples were taken at no less than 50-meter intervals.

Parts of selected rock samples were hand ground and analyzed for cold-acid-extractable copper in the field. Laboratory study of rock samples included determination of rock type and degree and type of alteration and mineralization. Some samples were selected for thin sectioning and a reference split of each rock sample was retained in the Medellín INGEOMINAS office. The remainder of the sample was sent to Bogotá where it was crushed and then ground to <150 mesh in a Braun vertical grinder prior to semiquantitative spectrographic analysis.

Soil samples

Soil samples (pl. 2) were collected at 293 locations in the Río Pantanos area. Profiles to a 2.4-meter depth were taken by hand auger at 17 of these locations. The standard soil sample, however, was taken in the B-horizon at a 50- to 70-cm depth. Soil samples were generally collected at 100- to 200-meter intervals along drainage and trail traverses. Along the drainage traverses, soil samples were collected within 10 meters of the stream sediment sample locations.

Selected soils were analyzed for cold-acid-extractable copper in the field. Upon return to the laboratory in Medellín, pH determinations were made on 154 soil samples. Subsequently the samples were dried and sent to the INGEOMINAS laboratories in Bogotá for preparation and analysis. Here, the soils were passed through an 80-mesh screen and the fine fraction was analyzed by a semiquantitative spectrographic method.

Sieved stream sediments

Sieved stream sediment samples (pl. 3) were collected at 326 locations in the Río Pantanos area. They were taken in all well established streams crossing trail traverse lines, from the main stream, and from all significant tributaries at some distance above the confluence with the main streams. In drainages having few tributaries, main stream samples were taken at 100- to 200-meter intervals. Samples were collected from the active part of the stream channel and wet sieved on location through a 10-mesh screen. Subsequently the samples were dried and passed through an 80-mesh screen. The $<$80-mesh fraction was then analyzed spectrographically.

Stream sediment panned concentrates

Panned concentrates of stream sediments (pl. 4) were collected at 213 locations at major stream/trail intersections and at approximately 500-meter intervals along drainage traverses. The heavy fraction obtained by panning at the sample site was wrapped in plain bond typing paper and allowed to dry. In the laboratory at Bogotá magnetite was removed from the concentrate with a hard magnet, and the remainder of the sample was passed through bromoform. The mineralogic assemblage of the bromoform heavy fraction was routinely checked under a binocular microscope. Subsequently this material, and a few of the magnetite separates, were analyzed spectrographically.

GEOCHEMICAL DATA

The three metals (copper, molybdenum, silver) known to be present in anomalous amounts in the Río Pantanos area (figs. 2 and 3) are discussed in detail in the following sections of this report. Zinc (fig. 4) is believed to be marginal in amount, and forms a weak and erratic fringe zone in the Río Pantanos anomaly. Gold was detected in the panned concentrates of stream sediments at two locations (HVA120=20 ppm; OR5124=30 ppm). It should be kept in mind that the limit of detection for gold is high (10 ppm) in the semiquantitative spectrographic analytic method. The silver content of bedrock samples probably can be used as an approximate index of the gold content.

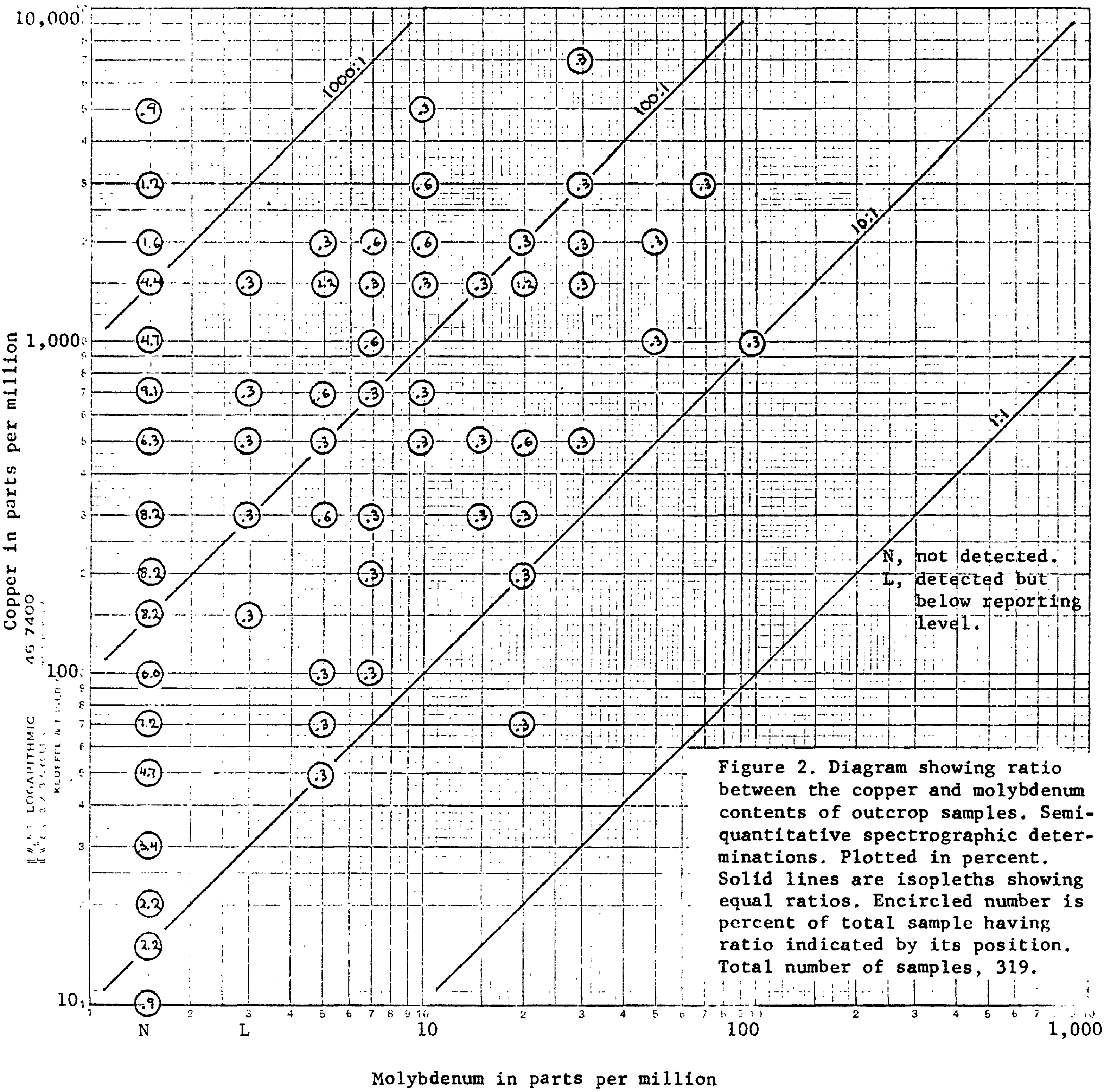


Figure 2. Diagram showing ratio between the copper and molybdenum contents of outcrop samples. Semi-quantitative spectrographic determinations. Plotted in percent. Solid lines are isopleths showing equal ratios. Encircled number is percent of total sample having ratio indicated by its position. Total number of samples, 319.

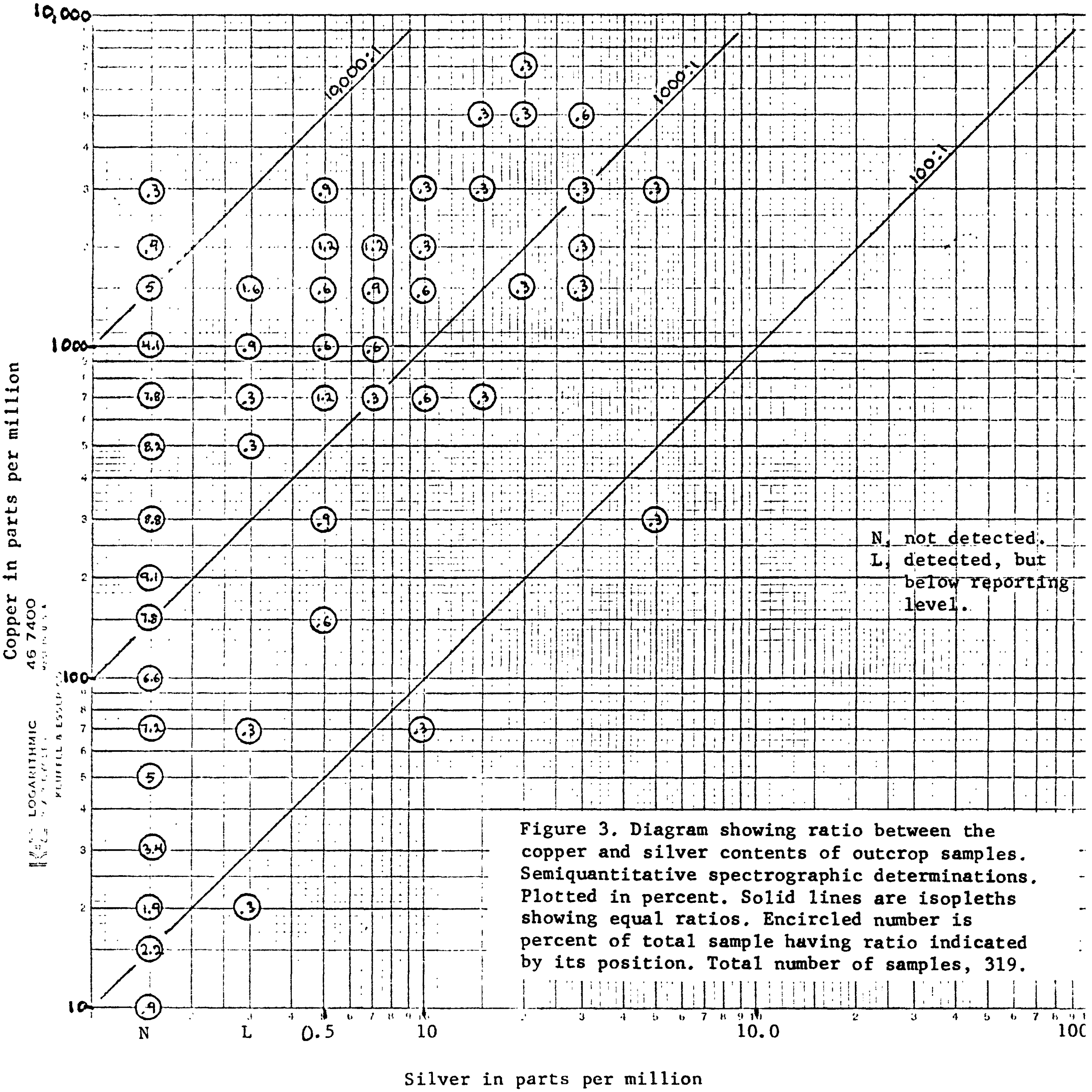


Figure 3. Diagram showing ratio between the copper and silver contents of outcrop samples. Semiquantitative spectrographic determinations. Plotted in percent. Solid lines are isopleths showing equal ratios. Encircled number is percent of total sample having ratio indicated by its position. Total number of samples, 319.

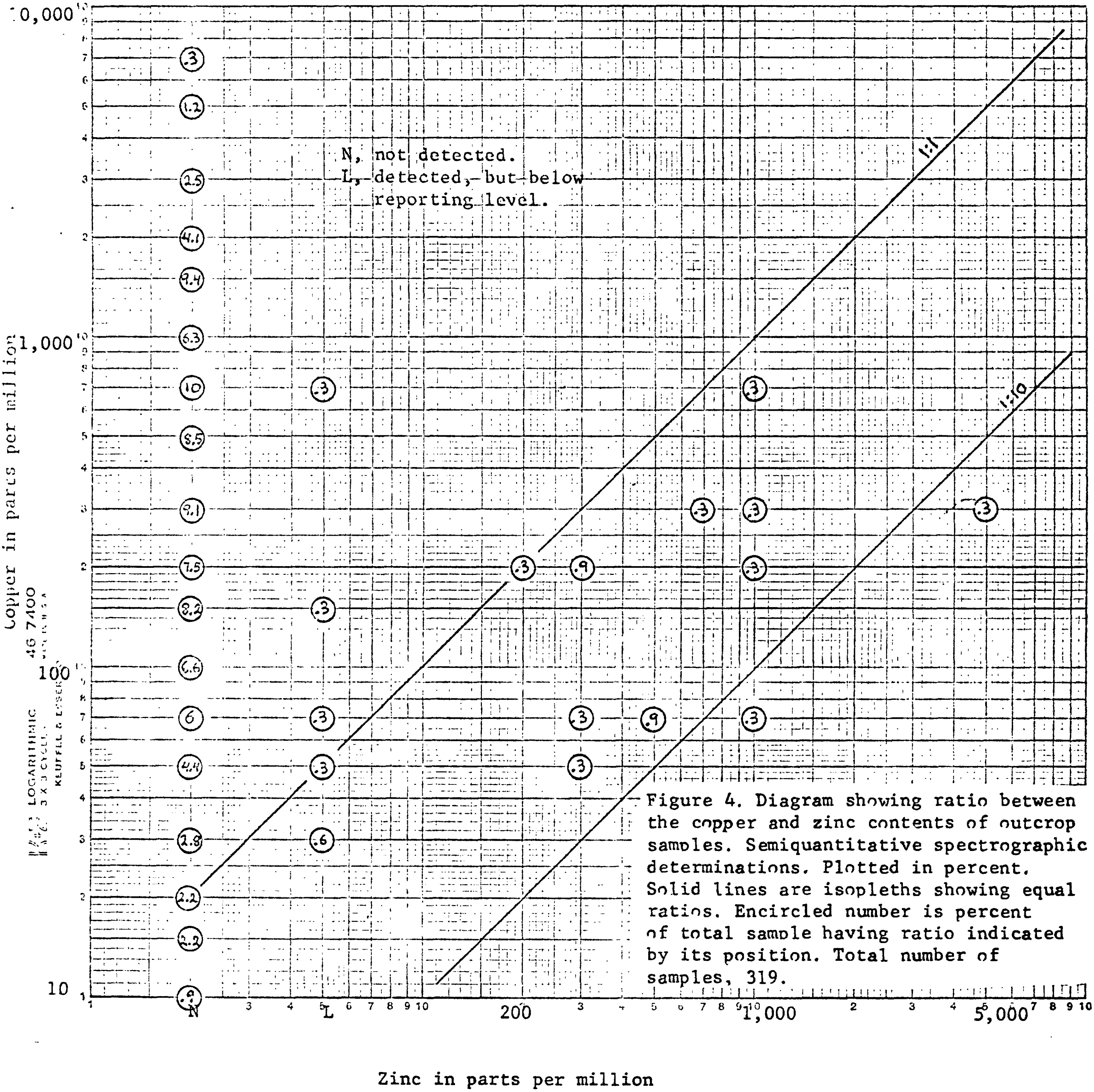


Figure 4. Diagram showing ratio between the copper and zinc contents of outcrop samples. Semiquantitative spectrographic determinations. Plotted in percent. Solid lines are isopleths showing equal ratios. Encircled number is percent of total sample having ratio indicated by its position. Total number of samples, 319.

Copper

Outcrop samples

Copper contents of the Río Pantanos outcrop samples range from 5 to 15,000 ppm, the widest range in copper values shown by any of the four types of surficial sample from the area. A comparison of copper contents of the four are shown in figures 5 and 6. A percent frequency distribution of the values (fig. 6) shows a multimodal distribution with modes occurring at the 70, 300, 700, and 1,500 ppm classes. Copper values of 100 ppm or greater, 77.5 percent of the total, are considered anomalous. The selection of anomalous levels is interpretive, being based on the rock type, copper percentage frequency distributions, and the copper/molybdenum/silver association diagrams (figs. 2 and 3).

Spatially, the highest outcrop copper values delineate a 1- to 1.5-km wide belt-like zone trending easterly through the center of the area sampled (pl. 1). This belt coincides with the previously mentioned central ridge. The northern and southern boundaries of the belt, between Quebrada Palma to the east and Quebrada El Lano to the west, are artificial as no outcrops could be found in these low-lying and generally swampy areas. However, outcrops farther south, along the Río Pantanos and in the southwestern corner of the sampled area, show copper values in the background range. An outcrop of quartz diorite porphyry, found about 1 km north of the ridge, contains 300 ppm copper. The highest copper values were found in rocks near the western end of the belt.

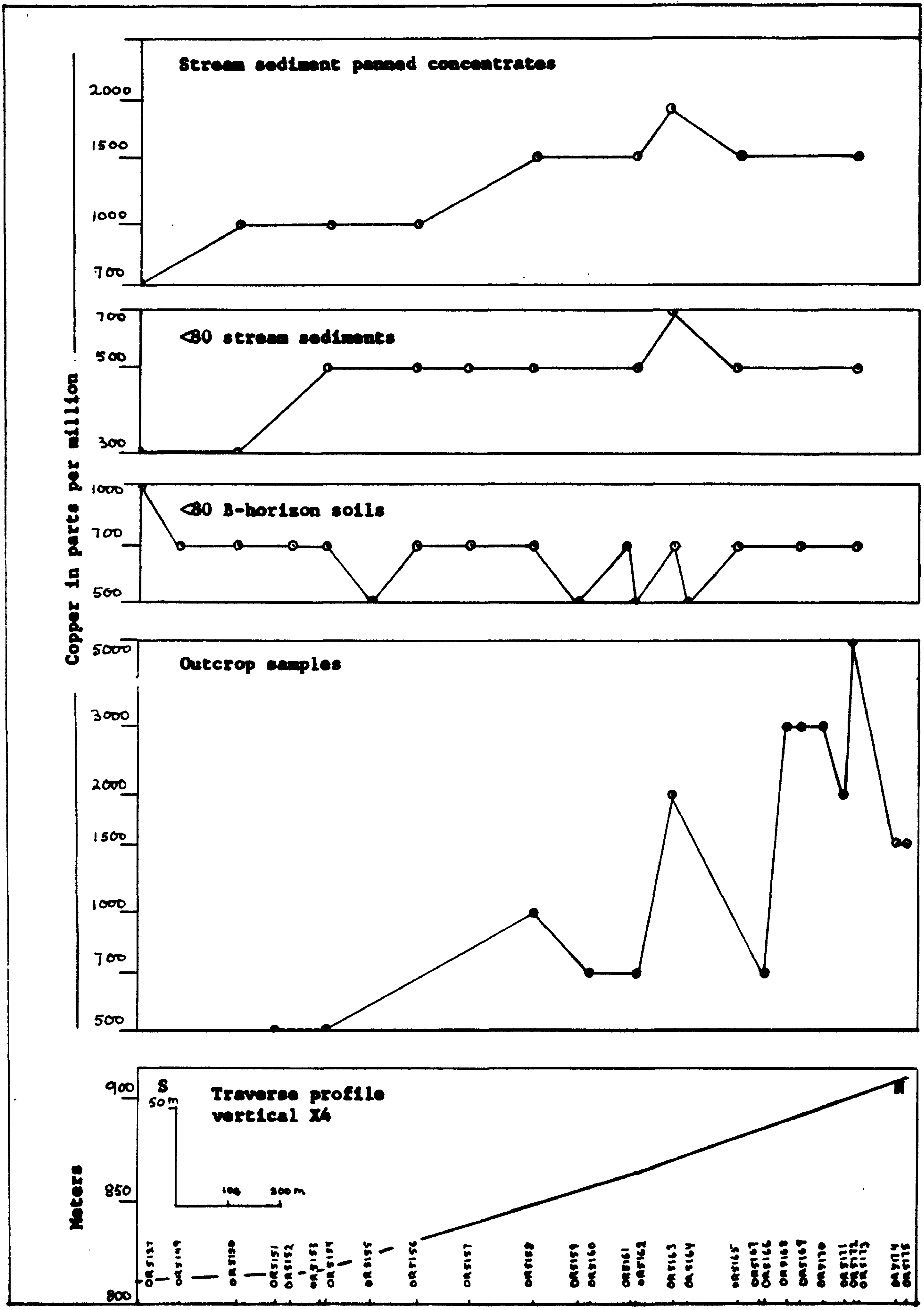
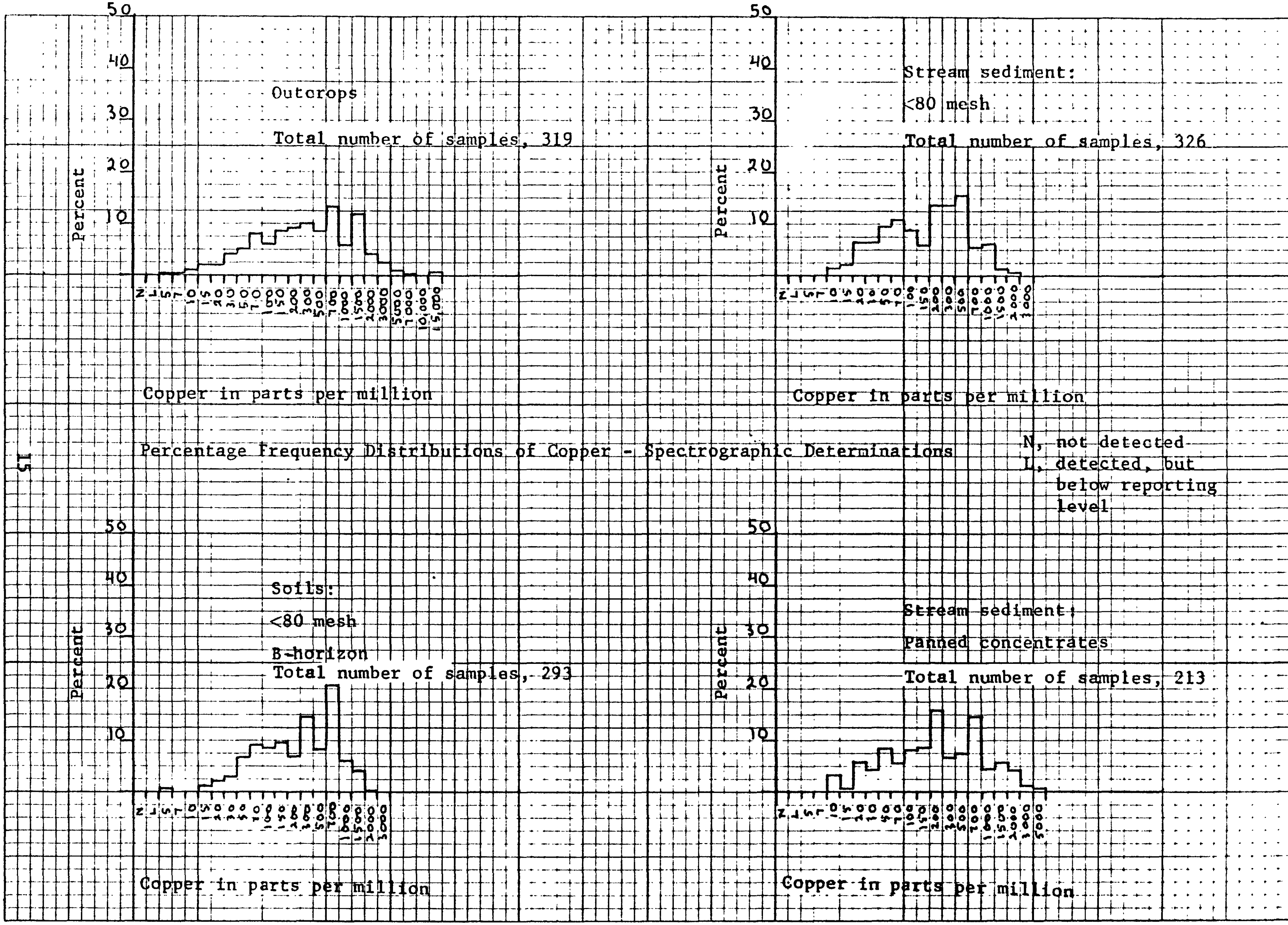


Figure 5. Comparison of copper content in samples along drainage traverse OR 5127.



Percentage Frequency Distributions of Copper - Spectrographic Determinations

Core samples

Table 1 shows the copper and silver content of a 32-foot core as determined by the atomic absorption and by the semiquantitative spectrographic method. Molybdenum was below the detection limit (5 ppm) throughout the length of the core. Abundant malachite was visible in the core to a depth of 16 feet. Disseminated pyrite, chalcopyrite, bornite, and chalcocite were noted in the 16- to 32-foot interval (O. Ramirez, written commun., June 19, 1972).

Soil samples

The range of copper values in B-horizon soil samples is substantially narrower (5-2,000 ppm) than that in outcrop samples. This sample type also exhibits a multimodal copper value distribution with modes in the 70, 150, 300, and 700 ppm classes (fig. 6); 77 percent of the copper values equal or exceed 100 ppm and are considered anomalous. As can be seen in figure 7, soil copper content was found to be somewhat lower but generally representative of the copper content of the underlying bedrock. Anomalous copper values in soil are in a 2½- to 3-km wide east-trending belt (pl. 2). As may be noted from a comparison of plates 1 and 2, this anomaly shows a greater areal extent and lower intensity than that delineated on the basis of outcrop sample data. Also, whereas the highest copper values in the outcrops occurred within well defined zones on the northern and southern slopes of the ridge, in the soils these zones have intermediate values (500-700 ppm). The highest copper values in the soils are found in the low-lying east-central portion of the area sampled northwest of Quebrada Palma.

Table 1.--Copper and silver contents of diamond drill core from sample location HVA-145

Depth (ft)	Copper (ppm) atomic absorption	Copper (ppm) semiquantitative spectrographic	Silver (ppm) semiquantitative spectrographic
0-2	4,250	2,000	1.0
2-4	3,510	2,000	1.5
4-6	3,900	3,000	1.0
6-8	22,000	20,000	2.0
8-10	13,250	10,000	1.5
10-12	13,800	15,000	1.0
12-14	11,760	10,000	1.0
14-16	7,010	5,000	<.5
16-18	5,750	3,000	0.7
18-20	7,300	5,000	1.0
20-22	869	1,000	N
22-24	2,670	2,000	0.5
24-26	14,000	7,000	5.0
26-28	5,870	3,000	1.5
28-30	6,900	3,000	2.0
30-32	5,740	5,000	3.0
Average	8,036	6,000	1.5

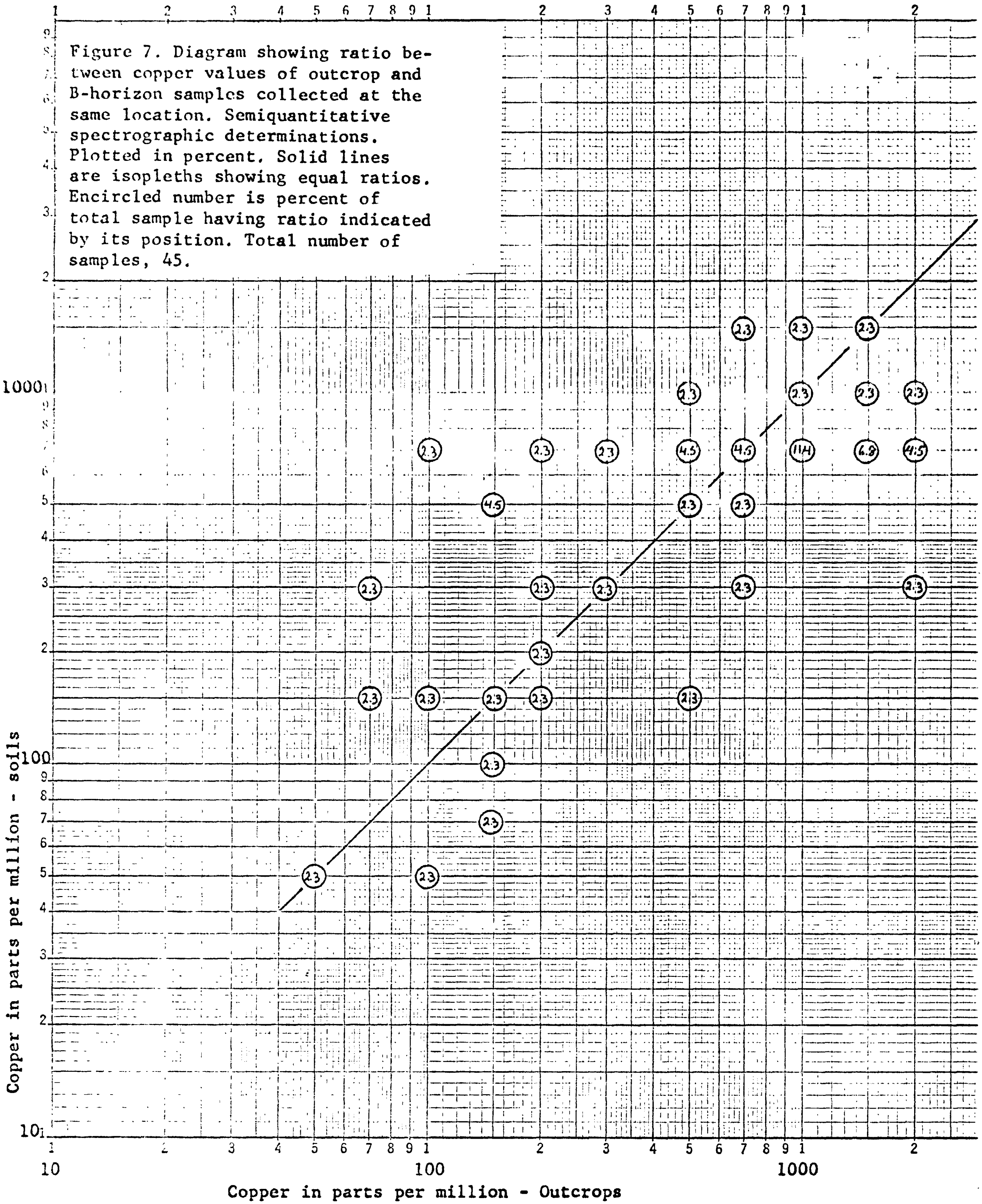


Figure 7. Diagram showing ratio between copper values of outcrop and B-horizon samples collected at the same location. Semiquantitative spectrographic determinations. Plotted in percent. Solid lines are isopleths showing equal ratios. Encircled number is percent of total sample having ratio indicated by its position. Total number of samples, 45.

Sieved stream sediments

Copper values in the <80 mesh sieved stream sediment samples range from 10 to 2,000 ppm. A histogram of these values (fig. 6) shows a multimodal distribution with modes at the 70, 500, and 1,000 ppm classes. About 63 percent of the values equal or exceed 100 ppm, and thus, of the four sample types tested, these exhibit the lowest proportion of anomalous copper values. The copper values in the sieved stream sediment samples show a similar areal distribution to those of the soil samples (compare pls. 2 and 3).

Panned concentrates of stream sediment

Panned concentrates of stream sediments from the Río Pantanos area show a 10 to 5,000 ppm copper content range. A percentage frequency distribution (fig. 6) shows modes at the 50, 200, 700, and 1,500 ppm classes; 73 percent of the values equal or exceed 100 ppm and are considered anomalous. The areal distribution of the concentrate copper values (pl. 4) greatly resembles that of the outcrop samples.

<u>Molybdenum</u>

Outcrop samples

Molybdenum, detected in 20 percent of the outcrop samples, ranges from <5 to 300 ppm. A histogram of molybdenum values (fig. 8) shows a multmodal distribution with an 80 percent mode at the "not-detected" class, a 5 percent mode at the 5 ppm class, and a 3 percent mode at the 20 ppm class. Detectable molybdenum is considered to be anomalous for all sample types collected within the area. No molybdenum was detected in any outcrop samples containing less than 50 ppm copper. Molybdenum-bearing outcrop samples occur in the same belt-like zone (pl. 5) as the samples having high copper contents.

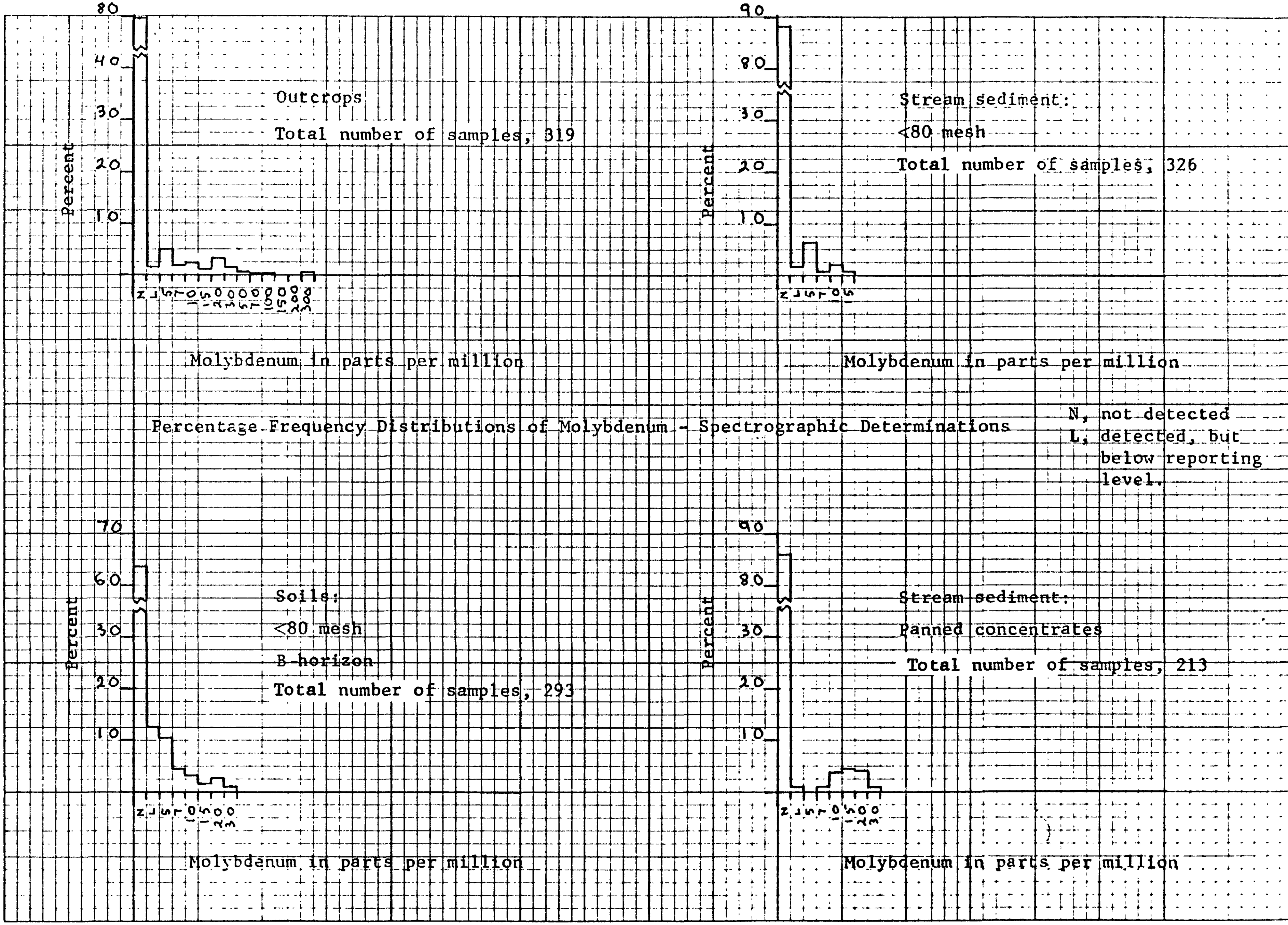

Outcrops
Total number of samples, 319
Percent
Molybdenum in parts per million
Stream sediment:
<80 mesh
Total number of samples, 326
Percent
Molybdenum in parts per million
Percentage Frequency Distributions of Molybdenum - Spectrographic Determinations
N, not detected
L, detected, but below reporting level.
Soils:
<80 mesh
B horizon
Total number of samples, 293
Percent
Molybdenum in parts per million
Stream sediment:
Panned concentrates
Total number of samples, 213
Percent
Molybdenum in parts per million

Figure 8

Soil samples

Molybdenum was detected in 36.5 percent of the analyzed B-horizon soils, in amounts ranging from <5 to 30 ppm, a substantially narrower range than that for the outcrop samples (fig. 8). The B-horizon soil molybdenum values give some indication of the central copper belt, but the highest values in soil and outcrop samples, however, are within a 1 km^2 area just northeast of Quebrada Palma. This is a relatively low lying (800-860 m) area somewhat south of the copper belt. The two outcrop samples having the highest molybdenum content (100 to 300 ppm) determined for the Río Pantanos area, were collected here. This is also the area of highest soil copper content.

Sieved stream sediments

Of the four sample types tested in the Río Pantanos area, sieved stream sediment samples show the lowest proportion of anomalous molybdenum values. Molybdenum was detected in only 12 percent of these samples, and ranged between <5 and 15 ppm. Minor modes occur at the 5 and 10 ppm classes (fig. 8). The great majority of the molybdenum-bearing samples come from two drainages just north of Quebrada El Lano. The rest came from a narrow belt just south and west of the soil molybdenum anomaly at Quebrada Palma.

Panned concentrates of stream sediment

Detectable molybdenum was found in 14 percent of the panned concentrates of stream sediments. The range of values, <5 to 30 ppm, is the same as that of the soil samples, although the percentage frequency distribution (fig. 8) differs markedly from those of the other three sample types. The majority of these molybdenum-bearing samples are from Quebrada El Lano. The remainder are distributed sporadically through the central copper belt and in the anomalous area near Quebrada Palma.

Silver

Silver, detected in only 20 percent of the Río Pantanos outcrop samples, ranged between 0.5 and 7 ppm. Detectable silver (at 0.5 ppm) is considered anomalous for all sample types tested. The percent frequency distribution of silver (fig. 9) in bedrock is similar to that of molybdenum, and the areal distribution shows a marked similarity to that of molybdenum in bedrock. Silver was detected in 1 percent of the sieved stream sediment samples (fig. 9) and 3 percent of the soils (fig. 9). Panned concentrates of stream sediments showed both the highest proportion (21 percent of samples having detectable silver contents and the highest silver values (fig. 9) found in any of the four sample types.

Mercury

No evidence of a mercury halo associated with the Río Pantanos mineralization was found. In the 154 B-horizon soil samples analyzed, mercury ranged between <0.06 and 0.55 ppm (fig. 10). Twenty-four soil profiles to a 2.4-m depth taken throughout the area show that soil-mercury content drops sharply with depth of sample. It is believed that the relatively "high" mercury content of the shallow soil samples may be due to interference caused by the expectedly higher proportion of organic material in this soil horizon relative to the deeper ones.

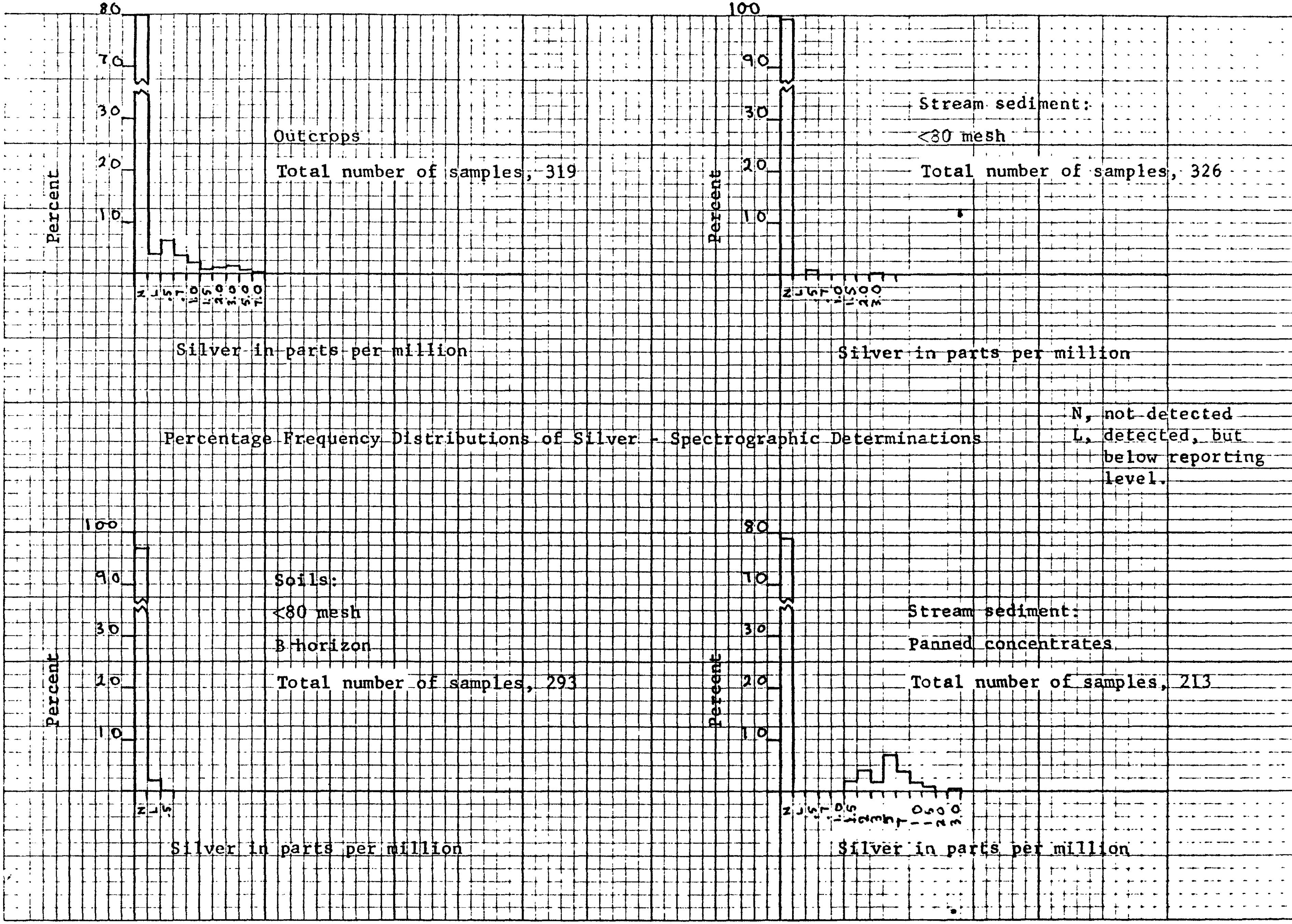

Outcrops
Total number of samples, 319
Percent
Silver in parts per million
Stream sediment:
<80 mesh
Total number of samples, 326
Percent
Silver in parts per million
Percentage Frequency Distributions of Silver - Spectrographic Determinations
N, not detected
L, detected, but below reporting level.
Soils:
<80 mesh
B horizon
Total number of samples, 293
Percent
Silver in parts per million
Stream sediment:
Panned concentrates
Total number of samples, 213
Percent
Silver in parts per million

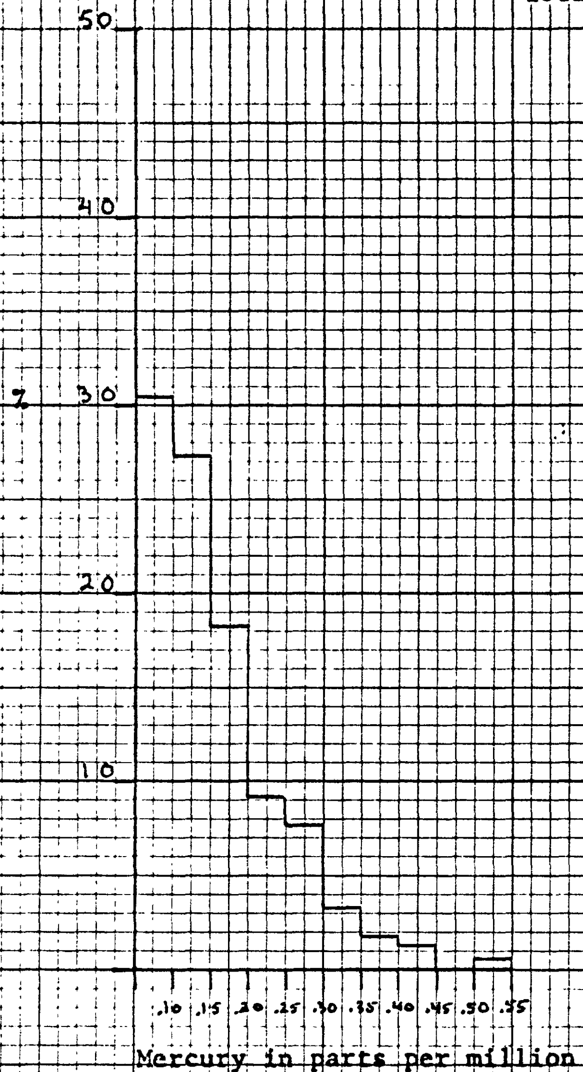
Figure 9

Figure 10

Percent Frequency Distribution Of Mercury

Soils: B-horizon
<80 mesh

Total number of samples, 154



Cold-acid-extractable copper

Cold-acid-extractable copper values show a similar range (<1 to approximately 240 ppm) in outcrop, B-horizon soil, and <80 sieved stream sediment samples (fig. 11). The greatest percentage of high values is in outcrop samples, is less in stream sediments, and least in soils. Ratios of total copper to cold-acid-extractable copper in <10 mesh stream sediments range from 50/1 to 2/1 (fig. 12), with the ratio decreasing as the total copper content increases. Areal distribution of cold-acid-extractable copper in sieved stream sediments is similar to that of total copper in panned concentrates of stream sediments.

LEACHING

The degree of leaching must be taken into consideration in the interpretation of the Río Pantanos geochemical data for the extreme climatic conditions in this area ensure intense and rapid weathering. The combination of extremely high rainfall and relief, on the other hand, ensures high run-off rates and resultant rapid erosion. Leaching, which is influenced by rainfall and relief, is quite variable even within the relatively narrow boundaries of the sampled area.

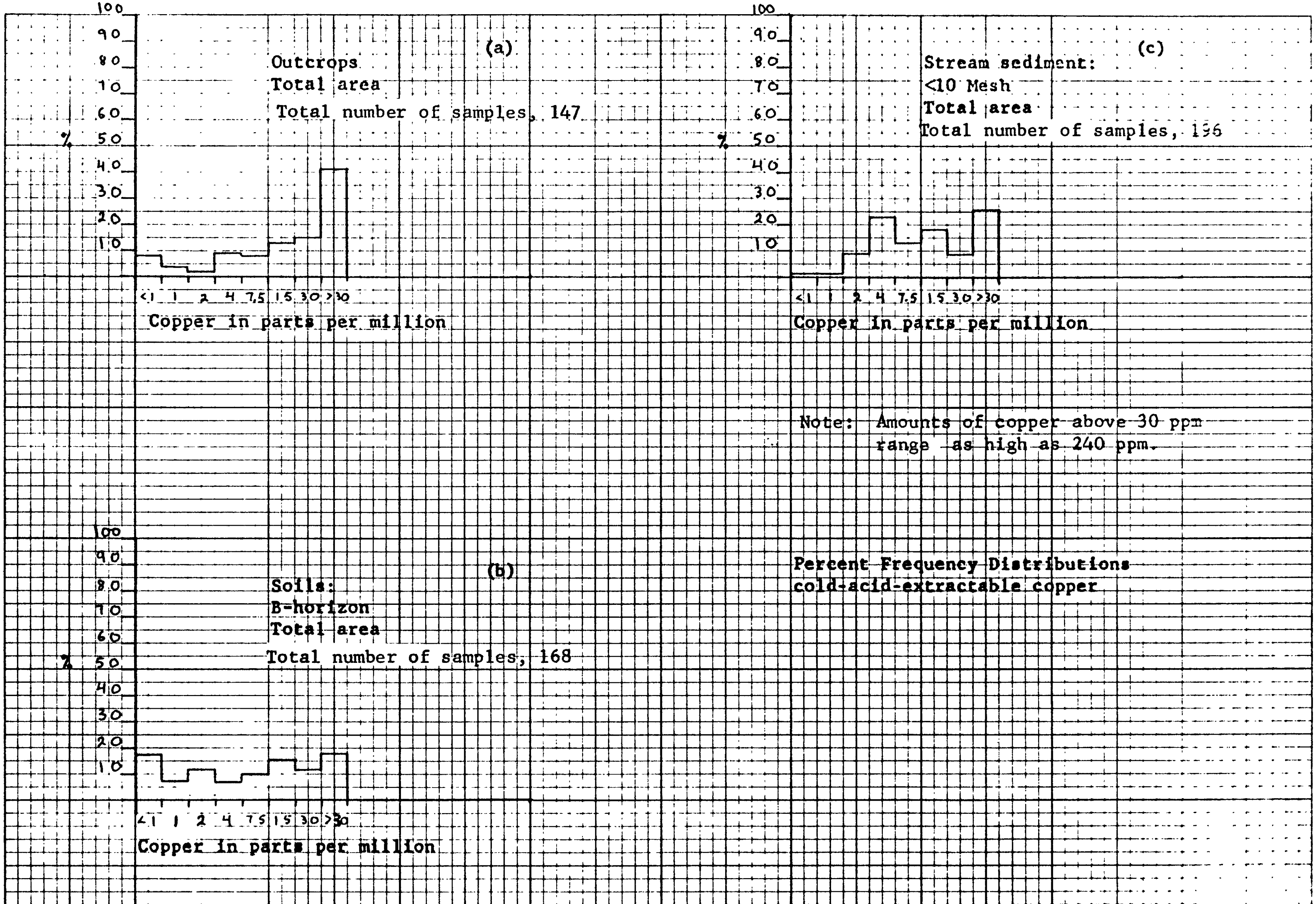

(a)
Outcrops
Total area
Total number of samples, 147
%
100
90
80
70
60
50
40
30
20
10
<1 1 2 4 7.5 15 30 >30
Copper in parts per million
(c)
Stream sediment:
<10 Mesh
Total area
Total number of samples, 196
Copper in parts per million
Note: Amounts of copper above 30 ppm range as high as 240 ppm.
(b)
Soils:
B-horizon
Total area
Total number of samples, 168
Copper in parts per million
Percent Frequency Distributions
cold-acid-extractable copper

Figure 11

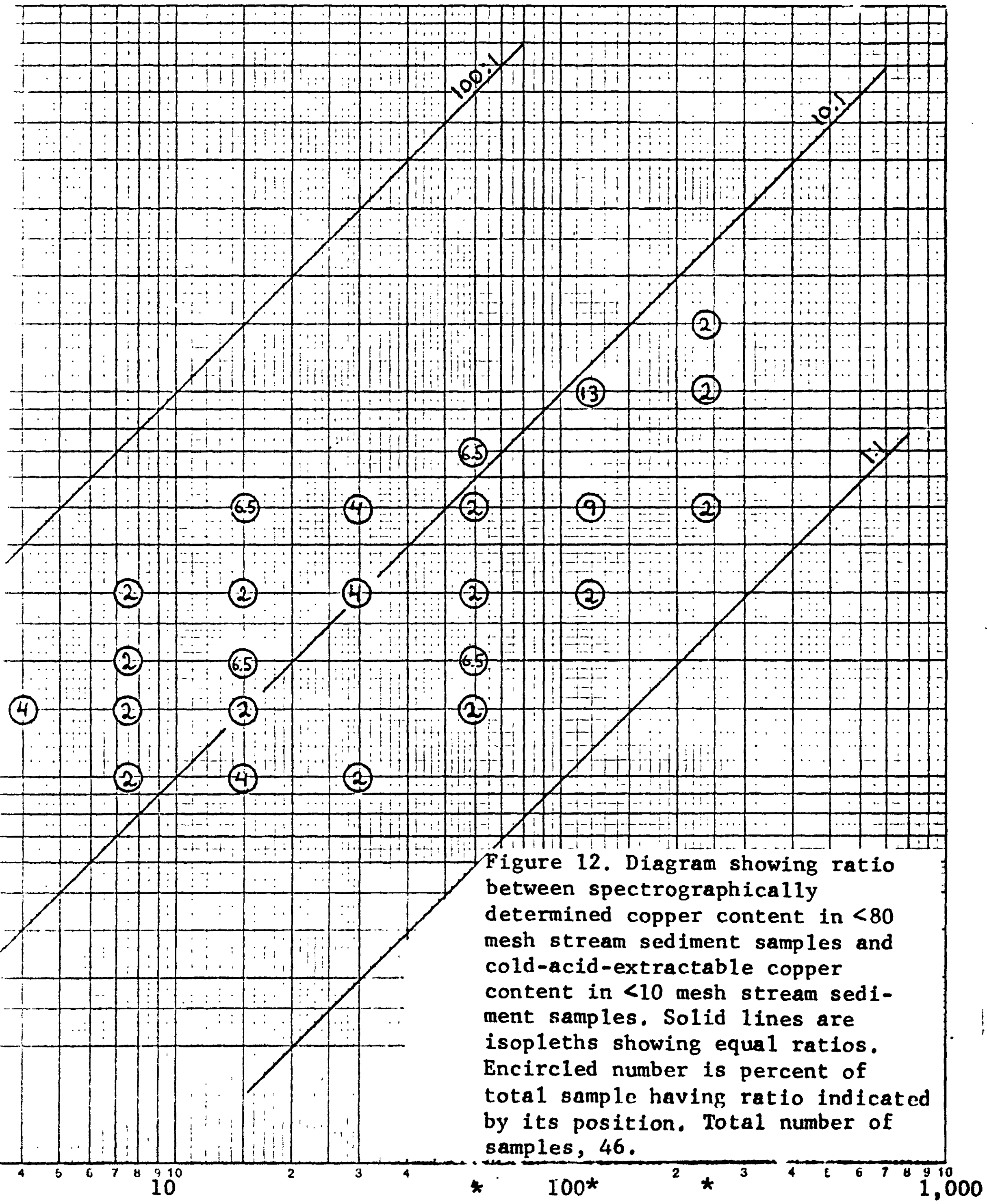


Figure 12. Diagram showing ratio between spectrographically determined copper content in <80 mesh stream sediment samples and cold-acid-extractable copper content in <10 mesh stream sediment samples. Solid lines are isopleths showing equal ratios. Encircled number is percent of total sample having ratio indicated by its position. Total number of samples, 46.

*Estimated cold acid extractable values.

cold-acid-extractable copper in parts per million

Three general "leaching zones" within this area may be defined:

1) Zone 1 is a narrow strip along the top of the central ridge of the Río Pantanos area, which generally lies above 950 meters. The ridge top is characterized by a continuous soil cover of relatively low relief. Leaching conditions must be considered maximal here because this zone has the lowest water table (below 0.5 m), permitting the greatest downward and lateral movement of water. The low relief keeps erosional rates low, thus permitting thorough leaching of the soil cover. In addition, this zone shows the lowest soil and water pH values (3.6 and 3.0 respectively), probably due to the sulfide-rich bedrock underlying it. The postulated high degree of leaching is borne out by the low (max. 200 ppm) copper values in soils collected from this zone despite the fact that outcrop samples collected at lower altitudes just to the north and south of the zone show high copper values.

2) Zone II includes the steeper parts of the northern and southern slopes of the central ridge between the altitudes of 800 and 950 m; is characterized by many outcrops and relatively shallow soils. This is the zone of least leaching, for it has the highest rate of mechanical erosion in the Río Pantanos. Therefore, it is in this zone that both the most numerous and the freshest outcrops are found. It is also the zone of highest copper values in bedrock samples, generally ranging between 1,000 and 5,000 ppm. Most outcrop samples also contain detectable molybdenum and silver. pH values in the soils average 4.9 (figs. 13 and 14). Soil copper values are intermediate, generally ranging between 500 and 1,500 ppm.

Figure 13

Zone - 2

Depth in meters	JC-112			JC-113			JC-114			OR-5194			OR-5195			OR-5196		
	Cu	Mo	pH	Cu	Mo	pH	Cu	Mo	pH	Cu	Mo	pH	Cu	Mo	pH	Cu	Mo	pH
.10	50	N	4.3	200	N	4.4	300	L	4.9									
.50	70	N	4.7	1000	N	4.9	700	5	5.2	150	N	4.9	150	N	4.7	200	N	4.6
													200	N	5.0			
100	150	N	4.9	700	N	5.0	1000	5	5.2	150	N	4.9				500	N	4.8
										200	N	5.0	150	N	4.8			
150	150	N	4.8	700	N	4.9	700	7	5.3									
										200	N	5.1	200	N	5.3	300	N	5.0
200										200	N	5.1	100	N	51	150	N	5.3
240	300	N	5.1	300	N	4.9	1000	N	5.2									

Copper and molybdenum in parts per million

Río Pantanos area soil profiles

Zone - 3

Depth in meters	JC-104			JC-107			JC-110			JC-125		
	Cu	Mo	pH	Cu	Mo	pH	Cu	Mo	pH	Cu	Mo	pH
.10	200	N	4.6									
.50	300	5	5.0	700	7	5.1	700	L	4.6	300	N	5.0
	300	5	5.0									
100				700	L	4.9						
							500	L	5.0			
										500	5	5.1
150												
				700	7	4.9						
200												
				700	L	4.8						
240				500	5	4.8	1000	N	4.9	300	N	5.8

Copper and molybdenum in parts per million

Figure 14

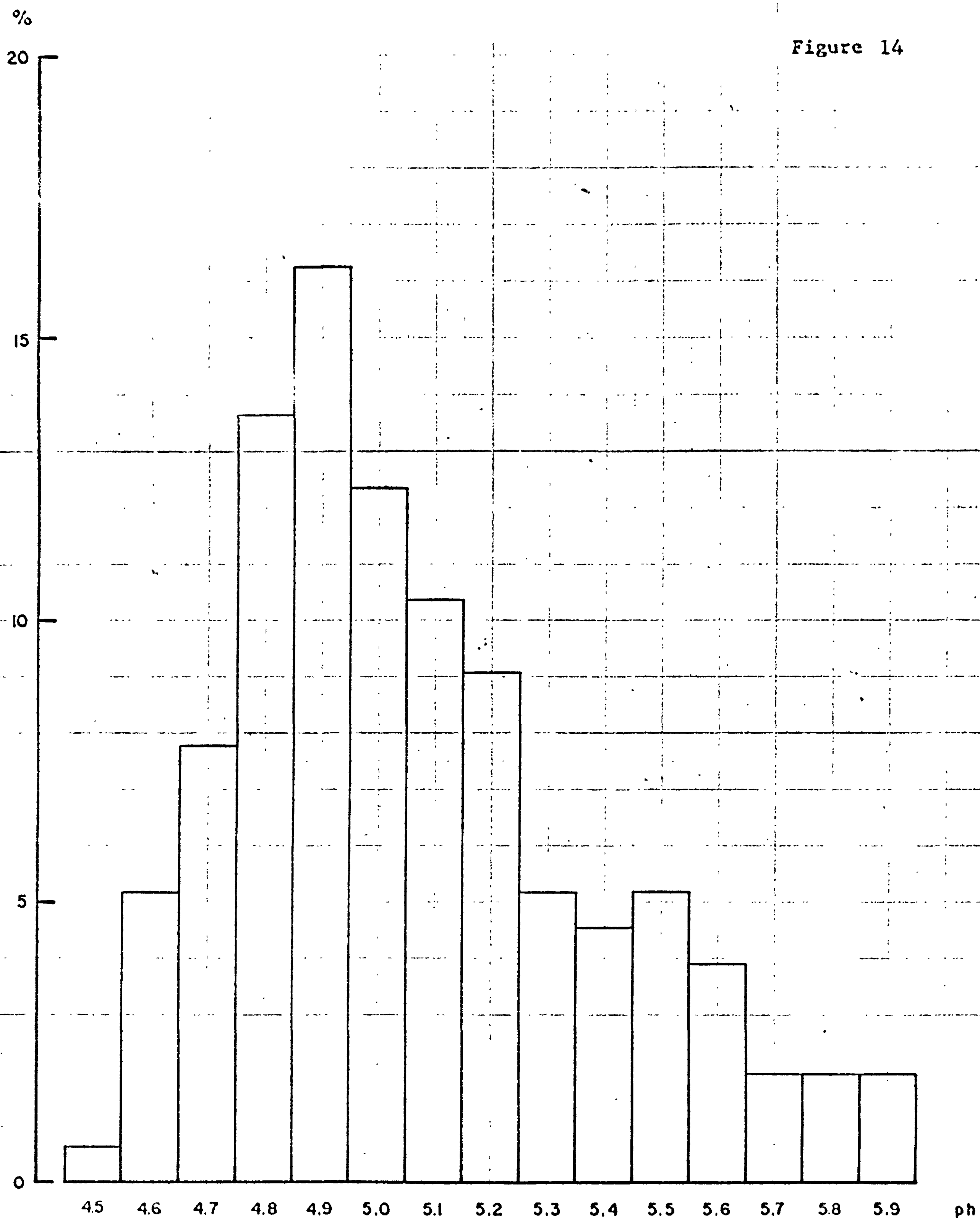


Figure 14. Percentage frequency distribution of pH values in B-horizon soils.

3) Zone III includes the low-lying parts of the Río Pantanos area to the north, east, and south of the central ridge. Altitudes range between 770 and 810 meters, and outcrops are sparse. The few outcrops present are intensely weathered, and in places, no more than saprolites. The nearly continuous soil cover is very deep, and the water table is at the surface. Soil pH varies between 4.9 and 5.9.

Depth profiles to 2.4 meters indicate that this zone consists of residual saprolite in some places and colluvial material, derived from the ridge, in others. Depth profiles also show some copper leaching in the topmost soil horizon.

Zone III soil data are the most difficult to interpret in that the soil may be residual or may have formed over transported colluvium. There is no rapid visual means of identifying soils from these respective sources. Also, despite the surface leaching, the copper content in the soils of this zone as a whole may be substantially enhanced by adsorption of ions, by clay, from the large quantities of water flowing through Zone III from the sulfide-rich ridge area.

CONCLUSION

Geochemical sampling north of the Río Pantanos in the Western Cordillera has delineated an 18 km^2 area highly anomalous in copper. The anomalous area is underlain by an altered and mineralized intrusive. which is granodioritic to quartz dioritic in composition and is in part porphyritic. Disseminated pyrite, chalcopyrite, and bornite are present in most outcrop samples. The size and characteristics of the area indicate the presence of a large disseminated copper deposit or deposits of potential commercial value.

Outcrop samples having the highest copper contents and associated molybdenum and silver define an east-trending zone 6 km long and 1 km wide. This zone is believed to represent the most favorable drilling target within the area sampled. A 32-foot drill core recovered from the western end of this zone shows an average copper content of 0.8 percent. Sieved stream sediment samples and panned concentrates of stream sediments indicate possible extensions of this zone to the east and to the northwest.

Soil samples containing highly anomalous amounts of copper and molybdenum define a 1 km^2 area northwest of Quebrada Palma. This area is also believed to merit exploration drilling.

This mineralized area was discovered by reconnaissance geochemical sampling, pointing up the fact that geochemical exploration techniques can be highly effective in tropical rain forest environments.

The Río Pantanos area is one of several "copper shows" found by reconnaissance geochemical sampling by INGEOMINAS in the Western Cordillera.

SUGGESTIONS FOR FUTURE WORK

A. Río Pantanos area

1) Complete geochemical sampling to delineate the anomalous region to the west, northwest, and east of the area sampled to date. The lead, zinc, and barium contents of samples taken from the outlying parts of the Río Pantanos area should be studied closely. Lead and zinc deposits are commonly associated with porphyry copper deposits.

2) Undertake diamond drilling:

   a) To determine the copper content of the unleached parts of the mineralized intrusive rock.

   b) To check for presence of an enrichment zone.

   c) To determine the distribution, grade, and quantity of copper ore.

   d) To determine the type and degree of mineralization of the bedrock underlying the low-lying swamp area around the central ridge.

3) Make a detailed geologic map of the area.

B, Western Cordillera

1) Undertake moderately detailed geochemical sampling of the Río Jiguamiandó area.

2) Re-analyze all of the Western Cordillera <80-mesh stream sediment samples with the exception of these originating in the Río Pantanos area.

3) Continue reconnaissance geochemical work in the Western Cordillera, giving priority to the area between Río Jiguamiandó and Río Pantanos.

4) Investigate the applicability of water sampling to reconnaissance geochemical exploration in this environment. A combination of pH and specific ion (SO_4^{-2}) determinations might prove highly successful.

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