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Soil Anomalies Associated with a Cu-Ni Mineralization in the South Kawishiwi Area, Northern Lake County, Minnesota

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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Abstract

Geochemical sampling in the contact zone between the Giants Range Granite and the Duluth Gabbro Complex along the South Kawishiwi River indicates the presence of extensive soil anomalies associated with the known Cu-Ni-Co-Ag mineralization in the basal part of the Duluth Gabbro Complex. A close spatial relationship was found between the ore bodies and associated anomalies, despite the fact that the parent material of the sampled soils was glacial overburden that mantles the area to a depth of 0-50 feet. The <74 mesh fraction of B-horizon soils was found to be an effective sample type for geochemical exploration in this area. Trace metals are believed to be held primarily by the clay-size hydrated iron oxides and manganese oxide, which are somewhat enriched in the fine fraction of the B-horizon soils.

Introduction

Geochemical sampling in the South Kawishiwi area, northern Lake County, Minnesota, was undertaken in September, 1970. Outcrop, soil, water and stream-sediment samples were collected over a roughly 16 mi^2 (41.6 km^2) area lying along the south shore of the South Kawishiwi River. The sampled area is bounded on the northeast by Gabbro Lake and extends about 1 mile west of Birch Lake.

The area ranges in altitude from 1,420 to 1,520 feet, with bedrock knobs and generally north-trending ridges forming the higher areas. The areas between the ridges are occupied by wetlands, streams, and lakes. A moderately thin mantle of Patrician drift covers the area, ranging in thickness from 0 to 50 feet (0-17.0 m), but generally being 2 to 20 feet (0.7-7 m) thick. Direction of the last ice movement, as indicated by glacial striae, is generally S. 25° W. in the Gabbro Lake quadrangle and S. 35° W. in the Kangas Bay quadrangle. Soils in this area are a mixture of immature and shallow soils on the ridges, gray-brown podzolic soils on the lower slopes, and peat and muck in the lower areas. Despite this variety in soil types, the A and B horizons were easily identifiable in the first two soil types. The third soil type was not sampled.

Geology

The area sampled lies along and just to the south of the contact between the Giants Range Granite, to the northwest, and the Duluth Gabbro Complex, to the southeast, and is predominantly underlain by the latter (Green and others, 1966). As shown on the geologic map, the complex consists of various types of troctolites, anorthositic rocks, and gabbroic rocks. Inclusions of the Biwabic Iron formation and hornfels occur sporadically through the troctolitic rocks. A few samples were collected over a porphyritic hornblende adamellite belonging to the Giants Range Granite in the northeast corner of the sampled area.

The ore bodies, consisting of disseminated copper-nickel sulfides, occur within and near the base of the Duluth Gabbro Complex. The northeastern ore body occurs in secs. 24 and 25, T. 62 N., R. 11 W.; it is at least 0.6 mile (1.0 km) long and 0.3 mile (0.5 km) wide, with its long axis trending northeastward. The southwestern ore body is along the south shore of the South Kawishiwi River in sec. 32, T. 62 N., R. 11 W., and sec. 5, T. 61, N., R. 11 W.; it is less than 0.1 mile (0.2 km) wide, with its long axis trending northeast.

The grade of the ore is not known to the author. G. M. Schwartz (1952) indicated that values of as much as 1.02 percent copper and 0.21 percent nickel were encountered during some early drilling in this area in 1951. The highest values found by the writer were from two outcrops near the northeastern ore body. Both outcrops contained 3,000 ppm copper and 700 ppm nickel.

G. M. Schwartz, who investigated this area in some detail in 1952-54, notes the following as to the mode of occurrence of the sulfides:

"The sulfides occur disseminated in the silicates and as small interstitial masses. The disseminations are most numerous in the plagioclase but also occur in pyroxene and olivine. The larger areas of sulfide are frequently associated with biotite but each occurs without the other. The sulfides include chalcopyrite, cubanite, pentlandite, and pyrrhotite, and a minute amount of barite. There are a few tiny veinlets of sulfide but most of the sulfide grains are intergrown in the silicates in such a manner that their contemporaneous crystallization seems certain."

G. M. Schwartz and J. M. Harris (1952) made a further statement of interest to this report:

"The majority of the sulfide-bearing rocks were deeply weathered and generally occurred in outcrops that were low, inconspicuous and often situated in low ground, along water courses or causing a swampy area. Often these outcrops were so much weathered as to make the classification of the variety of the gabbro difficult. This leads to the speculation that perhaps the topography may reflect, in a negative way, the presence of sulfides. It is probable that weathering and erosion, both pre- and postglacial, proceeded more rapidly where the sulfides were more abundant."

Materials sampled

Soils were the main sample medium in this investigation. Samples from both A- and B-horizon soils were collected at each of the 97 sample localities.

The A horizon was sampled immediately below the turf at about a 4-in (10-cm) depth. This is a fine, organic-rich material containing few rock fragments and ranging in color from black through brown to dark red.

The B horizon was generally sampled at a depth of 1 to 1.5 feet (30-45 cm). This material is substantially coarser than that in the A horizon, contains a higher proportion of rock fragments, and generally is characterized by a pronounced "grittiness." The organic content is substantially lower than that of the A horizon, and the iron-oxide content is somewhat higher. Colors generally range from yellow through red to light brown.

The lower portion of this horizon is essentially comprised of clay and coarse rock fragments, and has a yellow-olive color. This zone, at a 2-to-3-foot (60-90 cm) depth, represents the tradition from B horizon to its parent material--glacial drift.

Samples of outcrops, taken within a distance of 20 feet of a soil sample location, were collected wherever available along the soil sample traverse lines. Outcrops were sampled at 54 of the 97 sample locations.

Stream water and stream sediment samples were collected at 10 selected sites within background and anomalous parts of the sampled area. The resulting data, however, were nonindicative, and these two sample media will not be dealt with further in this report.

Sample preparation

Most of the A- and B-horizon soil samples were oven-dried to speed preparation. Selected samples were air-dried for subsequent mercury determinations. The dried samples were sieved through a 74 mesh (0.249 mm opening) screen. All the <74 mesh samples and selected >74 mesh samples were then ground in a Braun vertical grinder. In addition, 5-gram splits of the <74 mesh B-horizon samples were leached for five minutes with 1.5 N oxalic acid, filtered, and the filtrate evaporated to dryness. The resultant leachate was then hand ground in a mortar and pestle.

Outcrop samples were crushed and ground to <150 mesh.

The water samples were prepared at collection site. Preparation consisted of filtration of 100 ml of water through a 0.45 μ millipore membrane filter, measurement of pH and acidification with HNO_3. Stream sediment samples were oven dried, sieved through a 74 mesh screen, and ground in a Braun vertical grinder.

Analytical techniques

All rock, soil, stream-sediment, and leachate samples were analyzed by semiquantitiative spectrographic methods (Ward and others, 1963). Water samples were analyzed by atomic absorption methods (Fishman and others, 1966). All analyses were performed by the Field Services Section of the Exploration Research Branch. Analysts: D. J. Grimes, R. W. Leinz, K. J. Curry, R. L. Miller, J. G. Frisken, A. L. Meier, J. Reynolds, C. L. Whittington, R. Babcock, and R. T. Hopkins, Jr.

Results

Spectrographically determined Cu, Ni, Co, and Ag contents of the <74 mesh, B horizon soil samples from the area are plotted on plates 1 through 4. The corresponding histograms are shown in figures 1 through 4. The degree of Ni/Cu, Co/Cu, and Ag/Cu correlation, in this sample medium, can be seen in figures 5 through 7. Scatter diagrams showing copper content relationships of outcrop to B horizon soil, A horizon to B horizon, and the >74 mesh fraction to the <74 mesh fraction within the B horizon are shown in figures 8 through 10, respectively.

Soils were found to be the most effective sample media in the South Kawishiwi area, delineating anomalies of the greatest intensity and areal extent. Despite the glacial cover in this area, which ranges from 0 to 50 feet (0-17.0 m) in thickness, the soil anomalies showed a close spatial relationship to the ore bodies. Figure 8 indicates that some, though rather local, glacial transport occurred.

A high correlation (0.81) was found between the copper contents of the >74 mesh and <74 mesh fractions of B horizon soils. Copper contents of the finer fraction were found to be consistently higher, however, in both the background and anomalous samples, indicating that a trace metal enrichment has occurred in the fine fraction relative to its parent material.

A and B horizon copper contents show an even higher correlation (0.96), although the B horizon has consistently higher copper contents, especially in the anomalous samples (fig. 10). Evidently a certain amount of A horizon trace metal leaching and B horizon enrichment has occurred.

A copper content comparison of <74 mesh, B horizon soils and the therefrom derived oxalic acid leachates (fig. 11) shows a correlation coefficient of .82 and a strong trace metal concentration in the iron and manganese oxide-rich leachates. A plot of the leachate copper contents is shown in plate 5.

Figure 12 shows a comparison of copper contents in <74 mesh B horizon soils, as determined by spectrographic and cold extractable methods. The latter method generally extracts between 1 and 10 percent of the total copper. As a result, copper was not detected in 45 percent of the samples. In the remainder of the samples, the copper content correlation coefficienr for the two analytical methods is 0.64. As might be expected, cold extractable copper anomalies (pl. 6) are areally restricted and centered immediately over the most strongly mineralized parts of the area.

Thus, it is evident that the major portion of trace metals in the South Kawishiwi area soils are associated with the clay-size hydrated iron oxides and manganese oxide rather than with the clay itself. As a result, the most intense and areally extensive anomalies are found in the finer fraction of the B horizon, which is enriched in these two oxides.

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Figure 1. Frequency distribution of spectrographically determined Cu contents of 97 B-horizon <74 mesh soil samples.

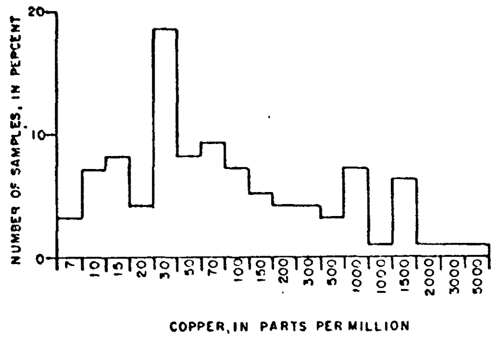


Figure 2. Frequency distribution of spectrographically determined Ni contents of 97 B-horizon <74 mesh soil samples.

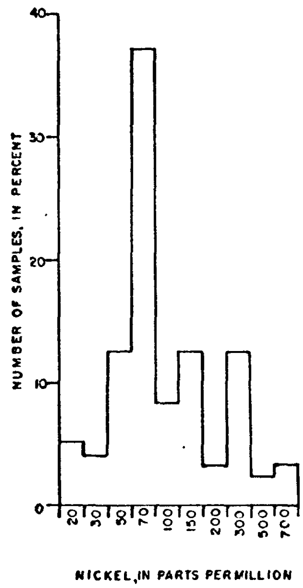


Figure 3. Frequency distribution of spectrographically determined Co contents of 97 B-horizon <74 mesh soil samples.

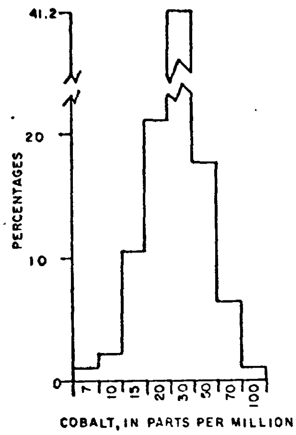
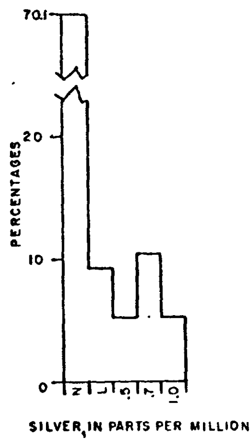


Figure 4. Frequency distribution of spectrographically determined Ag contents of 97 B-horizon <74 mesh soil samples. L indicates Ag present but below lowest standard. N indicates Ag was not detected.



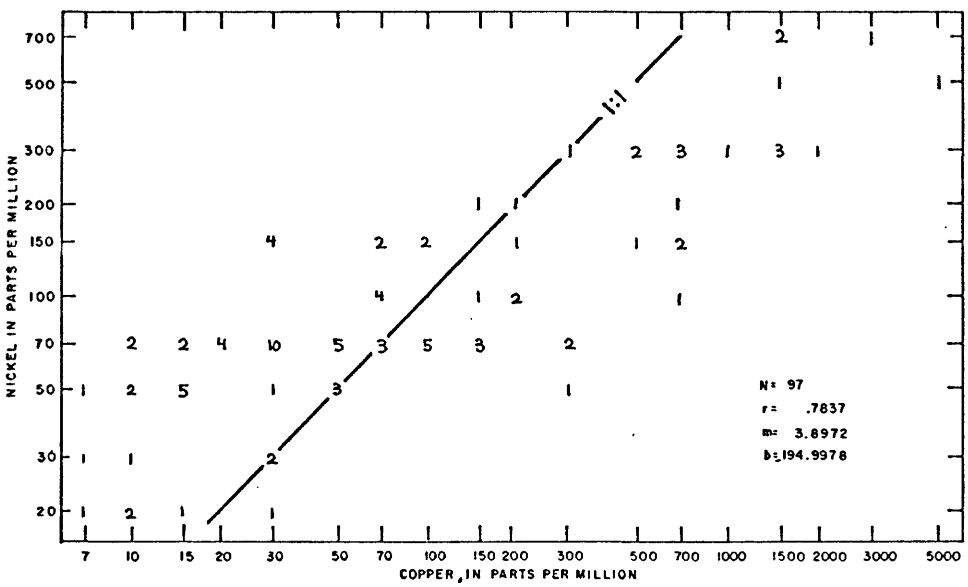


Figure 5. Scatter diagram showing the spectrographically determined Ni-Cu content relationship in 97 <74 mesh B-horizon soil samples. Numbers indicate the number of samples falling within a given Ni-Cu content class.

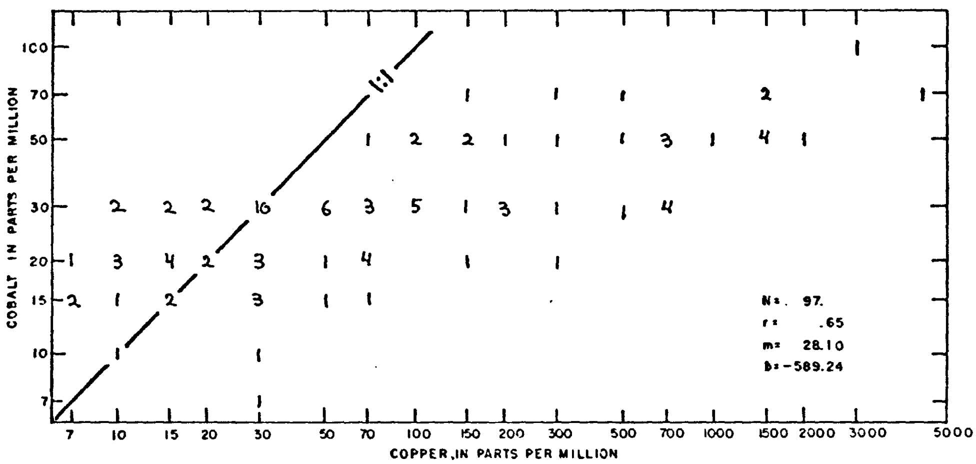


Figure 6. Scatter diagram showing the spectrographically determined Co-Cu content relationship in 97 <74 mesh B-horizon soil samples. Numbers indicate the number of samples falling within a given Co-Cu content class.

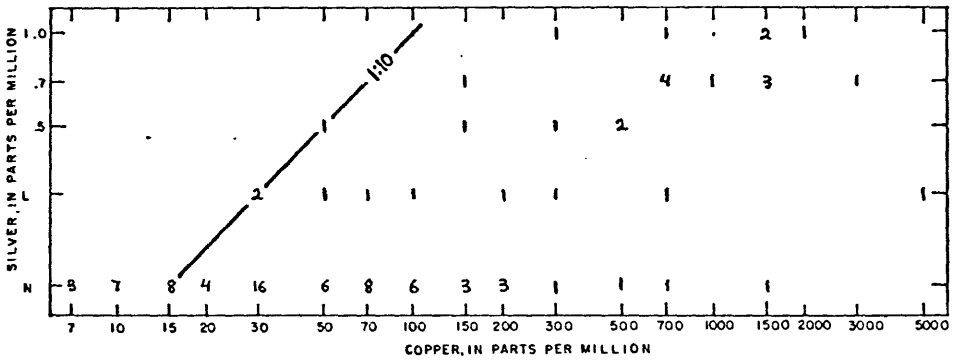


Figure 7. Scatter diagram showing the spectrographically determined Ag-Cu graphically determined Ag-Cu relationship in 97 <74 mesh B-horizon soil samples. Numbers indicate the number of samples falling within a given Ag-Cu content class. L indicates Ag present but below lowest standard. N indicates Ag was not detected.

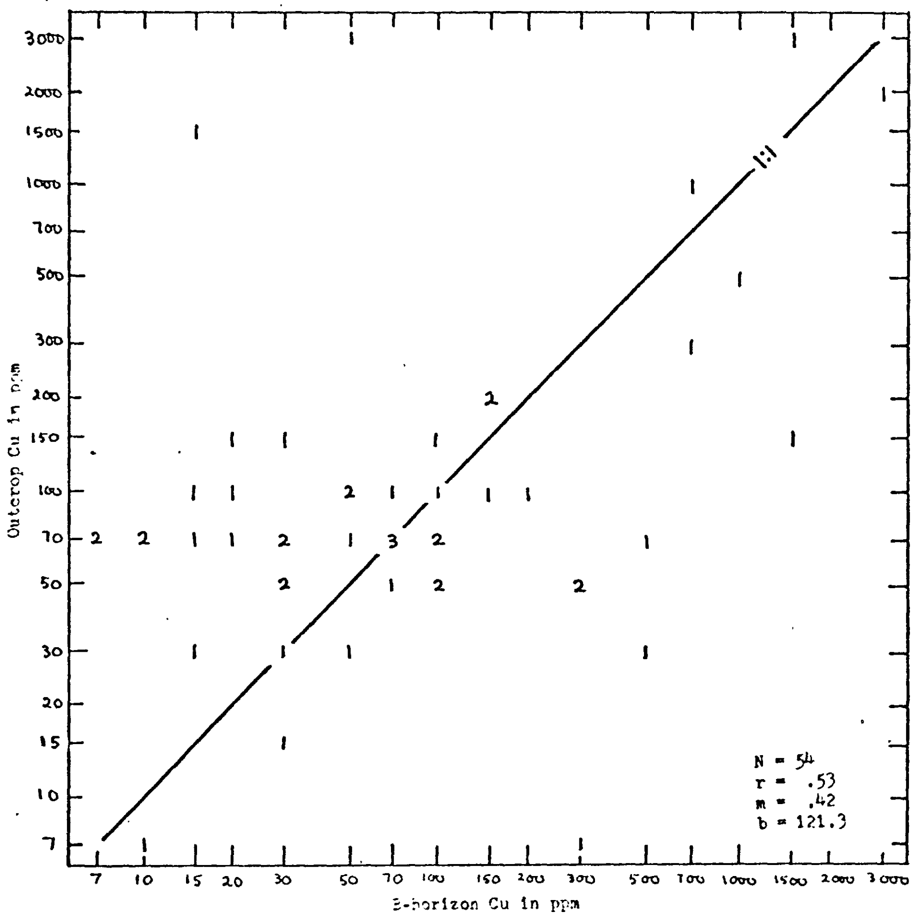


Figure 8. Scatter diagram showing the spectrographically determined Cu content relationship of 54 outcrop and <74 mesh B-horizon soil samples collected at the same localities.

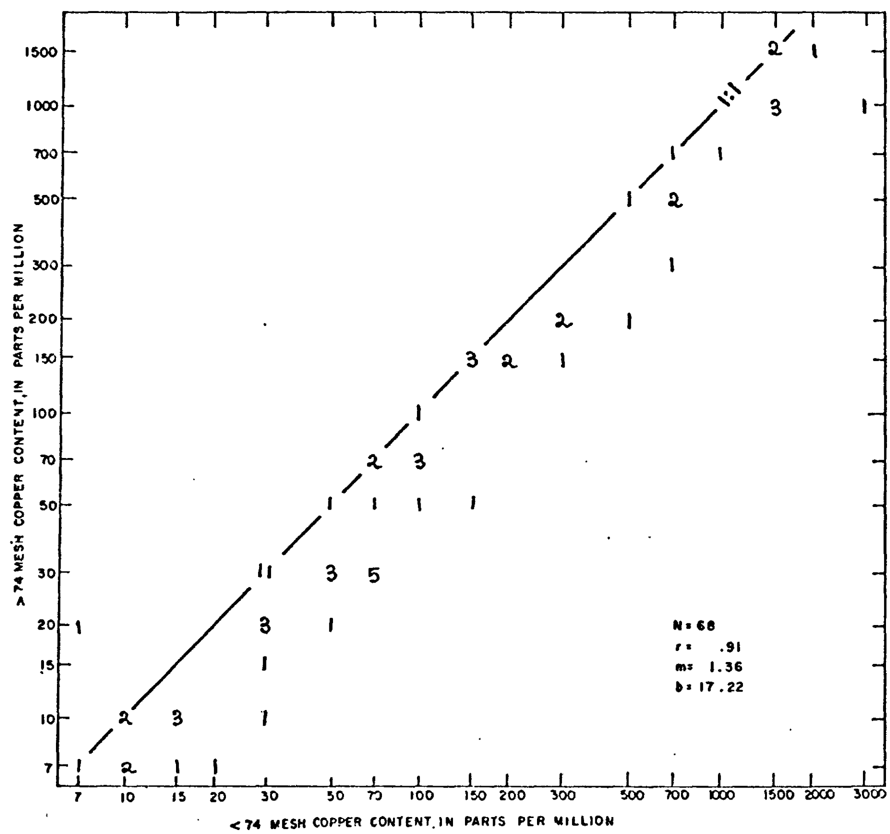


Figure 9. Scatter diagram showing the spectrographically determined Cu content relationship of >74 and <74 mesh fractions of 68 B-horizon soil samples.

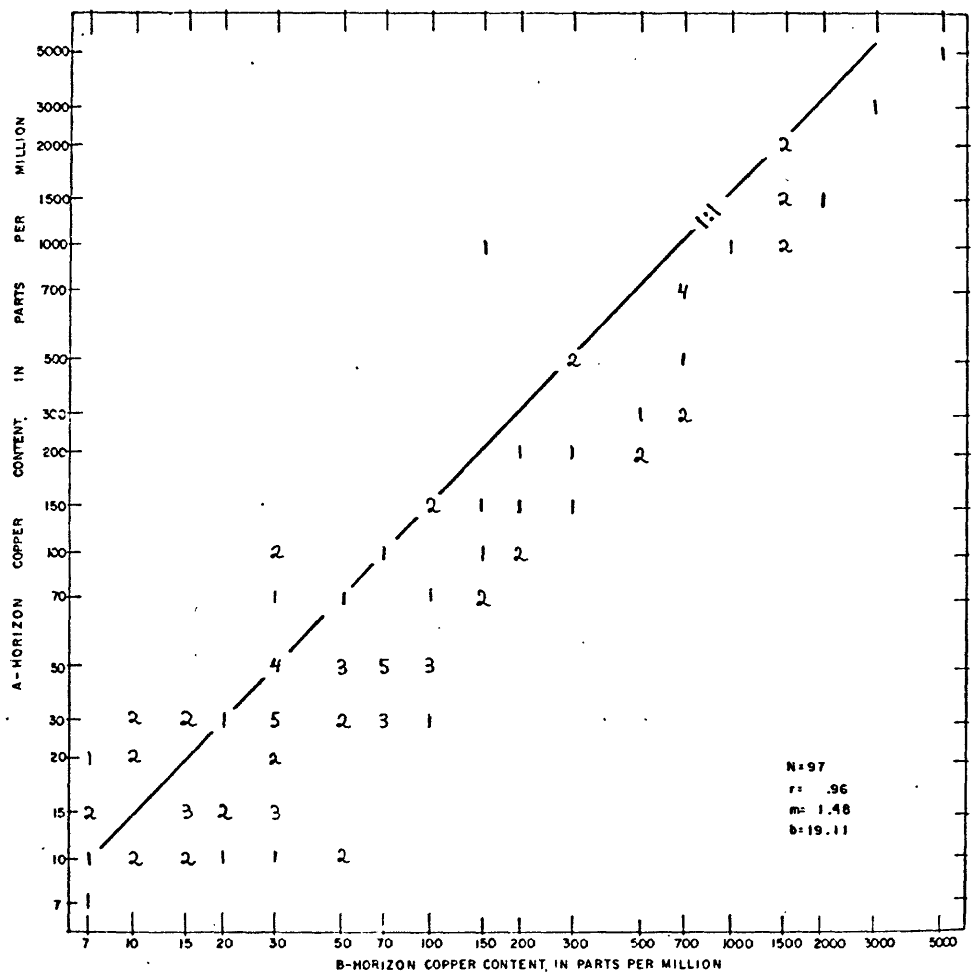


Figure 10. Scatter diagram showing the spectrographically determined Cu content relationship of 97 A- and B-horizon soil samples collected at the same localities.

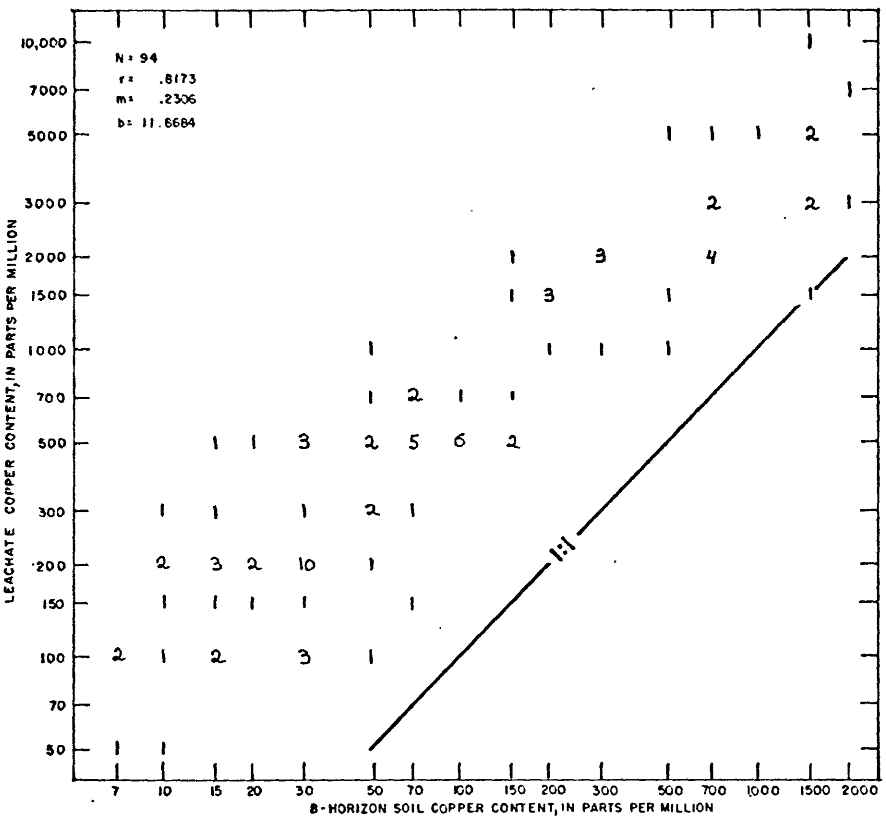


Figure 11. Scatter diagram showing the spectrographically determined Cu content relationship of 97 <74 mesh B-horizon soils and the corresponding oxalic acid leachates derived from them.

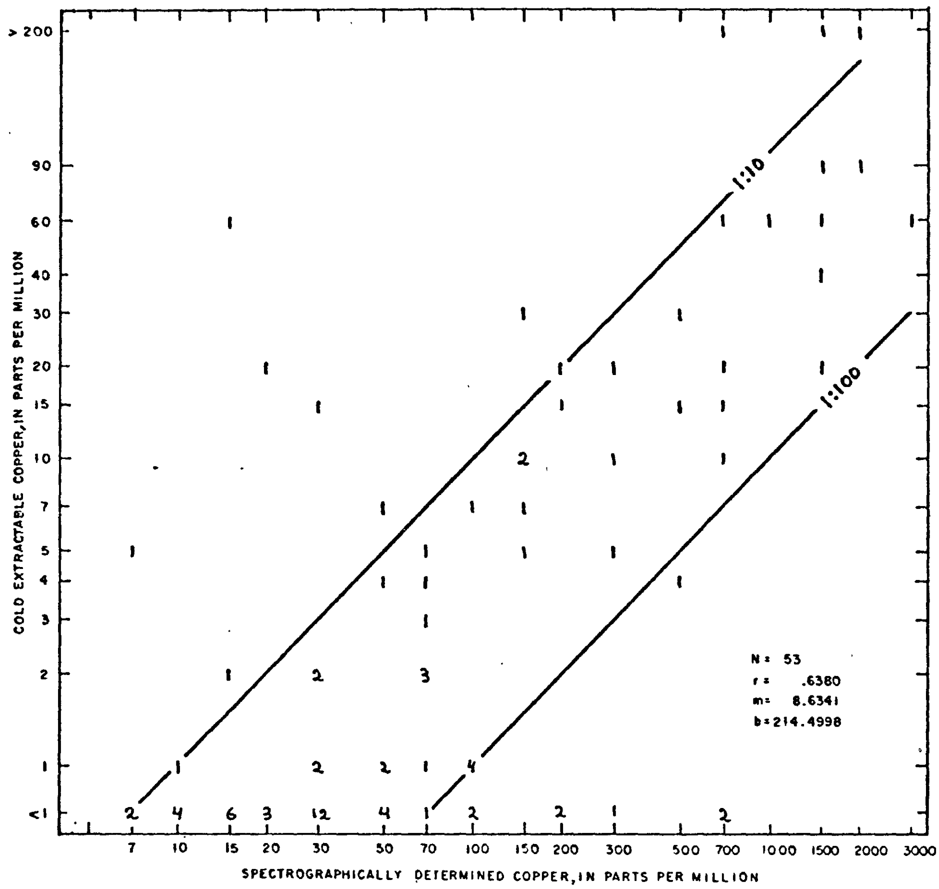


Figure 12. Scatter diagram showing the relationship of copper contents of 94 <74 mesh B-horizon soils as determined by cold extractable and semiquantitative spectrographic methods.