

# Contributions to Geochemical Prospecting for Minerals 1953-58

---

G E O L O G I C A L   S U R V E Y   B U L L E T I N   1000

*This volume was printed as  
separate chapters A-H*



QE 75  
B9  
no. 1000

**UNITED STATES DEPARTMENT OF THE INTERIOR**

**FRED A. SEATON, *Secretary***

**GEOLOGICAL SURVEY**

**Thomas B. Nolan, *Director***

## CONTENTS

---

[The letters in parentheses preceding the titles designate separately published chapters]

	Page
(A) Geochemical prospecting abstracts through June 1952, by John W. Harbaugh.....	1
(B) Geochemical prospecting investigations in the Nyebe lead-zinc district, Nigeria, by H. E. Hawkes.....	51
(C) A Paleozoic geochemical anomaly near Jerome, Ariz., by Lyman C. Huff.....	105
(D) Geochemical relations of zinc-bearing peat to the Lockport dolomite, Orleans County, N. Y., by Helen L. Cannon.....	119
(E) Geochemical studies in the southwestern Wisconsin zinc-lead area, by Vance C. Kennedy.....	187
(F) Principles of geochemical prospecting, by H. E. Hawkes.....	225
(G) Geochemical prospecting abstracts, July 1952-December 1954, by Jane Ebner Erikson.....	357
(H) Geochemical prospecting studies in the Bullwhacker mine area, Eureka district, Nevada, by Alfred T. Miesch and Thomas B. Nolan...	397

# Geochemical Prospecting Abstracts Through June 1952

---

GEOLOGICAL SURVEY BULLETIN 1000-A



Gift of the Department of the Interior  
March 3, 1849



o

8

1

# CONTRIBUTIONS TO GEOCHEMICAL PROSPECTING FOR MINERALS

## GEOCHEMICAL PROSPECTING ABSTRACTS THROUGH JUNE 1952

---

By JOHN W. HARBAUGH

---

### INTRODUCTION

This collection of abstracts is intended to include all published references available as of July 1, 1952, on geochemical methods of prospecting for minerals. References on general geochemistry or geochemical prospecting for petroleum are not included; references on alteration halos related to mineral deposits are included only where data on dispersed ore metals are presented. Papers on analytical methods are included where they deal directly with problems in geochemical prospecting. Reviews and summaries containing no original data are included with a brief annotation in place of an abstract.

The source of the abstract is given in italics at the end of the abstract. Some of them have been prepared by the compiler (*J. W. H.*), and some by H. E. Hawkes (*H. E. H.*). Arthur P. Pierce (*A. P. P.*) has prepared the abstracts of the majority of the Russian references. In many of the items the source was the author's abstract, or one of the standard abstract series, in which case the source is given. Several papers are included by title only, where for one reason or another it was not possible to prepare abstracts.

### ABSTRACTS

1. Ahrens, L. H., and Liebenberg, W. R. Tin and indium in mica as determined spectrochemically: *Am. Mineralogist*, vol. 35, pp. 571-578, 1950.

Spectrochemical analysis of 61 mica specimens shows a content of  $\text{SnO}_2$  varying from 5 to 5,000 ppm. Experimental evidence indicates that in specimens enriched in tin some of the tin is present as included cassiterite and some is located within the lattice structure of the mica. Micas from pegmatites near tin veins in the Usakos-Karibib-Omaruru area in southwest Africa are unusually rich in tin, whereas micas from similar pegmatites in the Uranoop River area, Namaqualand, where no tin mineralization is known, are unusually low in tin.

The author suggests that it may be possible to evaluate the likelihood of tin mineralization in an area by analyzing pegmatitic micas for tin.—*H. E. H.*

2. Almond, Hy, and Bloom, Harold. A semimicro method for the determination of cobalt in soils and rocks; a field test using the chromograph: U. S. Geol. Survey Circ. 125, 6 pp., 1951.

A chromatographic method for the quantitative estimation of cobalt in soils and rocks is described. A 0.1 g sample is fused with potassium bisulfate and the fusion product extracted with 5 ml of citrate solution. A 0.2 ml aliquot of the sample solution is mixed with 0.1 ml of 2-nitroso-1-naphthol solution in the chromograph and the reddish brown cobalt nitroso-naphtholate that precipitates on the filter paper is compared with that of a standard series. Cobalt contents from 10 to 400 ppm in soil or rock can be determined to within  $\pm 40$  percent of the figure obtained spectrophotometrically in the laboratory.—*Authors' abstract.*

3. Almond, Hy, and Morris, H. T. Geochemical techniques as applied in recent investigations in the Tintic District, Utah: *Econ. Geology*, vol. 46, pp. 608-625, 1951.

Field techniques for the rapid extraction and estimation of copper, lead, and zinc from altered rock are described, together with their application in the Tintic district, Utah. Either sulfuric acid or an acetic acid-ammonium acetate reagent is feasible as an extractant; but of these two, sulfuric acid is preferred.

Data obtained by partial extraction methods show that zinc and lead are concentrated in altered extrusive rocks 350 to 500 feet above a horizontal, pipelike ore body in limestone, where the extrusive rocks are cut by a fracture zone related to a strong premineral cross fault. Such concentrations are absent in altered but unbrecciated igneous rocks above the continuation of the same ore body in an unfaulted area.

In many places, premineral alteration diminished the original heavy metal content of the igneous rocks, and in unfractured extrusive rocks the hydrothermally leached rock yields a negative anomaly even though the rock lies only a short distance above ore.—*Authors' abstract.*

4. Andreev, B. A. Application of geophysical methods for prospecting chromite deposits [in Russian]: *Central Geol. and Prosp. Inst., Trans.* no. 100, 34 pp., 1937.

The testing of a new method called the "spectrometric survey" is recommended. This method consists of determining the concentration of ore components in the "aureoles in dissemination" by means of spectroanalysis; a sharp increase of concentration of chromite was determined in the residual layer directly over the main ore body.—*W. Ayvaboglou*, in *Geophysical Abstracts*, No. 4373.

5. Andreev, B. A. Results of the application of geophysical methods in the investigation of a corundum deposit [in Russian]: *Vses. Nauch.-Issled. Geol. Inst., Materaly Geofizika*, Sb. 11, pp. 58-75, 1947.

A detailed and comparative description is given of the results of magnetic, gravimetric, electrical resistivity, geochemical, and fluorescence analysis surveys of the Borli corundum deposit, central Kazakhstan. Four samples of surface debris, two directly over the corundum deposit, one 30 meters and one 50 meters from the deposit, were quantitatively analyzed for the major components. Only titanium and sulfate showed any correlation with the location of the corundum deposit. The titanium and sulfate are thought to be related respectively to rutile,

and pyrite is associated with the corundum. The author concludes that the gravimetric and fluorescence surveys gave the most direct indication of the position of the corundum. The success of the fluorescence survey is due to the dispersion by weathering of grains of corundum, showing a pronounced gray-blue to blue fluorescence.—A. P. P.

6. Anonymous. Geochemical prospecting—investigations in Australia: Chem. Eng. and Min. Rev., vol. 41, no. 2, pp. 43–44, 1948.

A brief discussion of geochemical prospecting principles and methods.

7. Babička, J., Komárek, J., and Němec, B. Gold in animal bodies: Acad. tchèque sci. Bull. internat., vol. 45, pp. 131–137, 1945.

The gold content of the antlers of roebuck browsing in a Czechoslovakian gold-bearing district was found to be higher than antlers of roebuck in unmineralized terrane. The gold content of a species of insect (cockshafer) showed a similar relationship.—H. E. H.

8. Beath, O. A., Hagner, A. F., and Gilbert, C. S. Some rocks and soils of high selenium content: Wyoming Geol. Survey Bull. 36, pp. 1–23, 1946.

The occurrence, in the western United States, of rocks and soils of high selenium content is reviewed. The phosphatic rock of the Phosphoria formation in western Wyoming, and the vanadium-uranium ores of the Salt Wash member of the Morrison formation are unusually rich in selenium. It is suggested that studies of the distribution of certain species of plants that grow preferentially in soils rich in selenium might be useful in prospecting for selenium-bearing ores.—H. E. H.

9. Billings, W. D. Vegetation and plant growth as affected by chemically altered rocks in the western Great Basin: Ecology, vol. 31, pp. 62–74, 1950.

*Pinus ponderosa*, *P. jeffreyi*, and certain montane herbaceous plants were found growing some distance to the east of the Sierra Nevada in the semi-arid sagebrush or pinyon-juniper zones. In every case, these stands were confined to volcanic rocks which had been hydrothermally altered with resultant accelerated chemical weathering. Sagebrush and its associates will not normally grow in soils developed from the altered rocks.

Analyses show that these soils are quite acid and very deficient in exchangeable bases, phosphorus, and nitrogen as compared to soils developed from unaltered rocks of the same type. Tobacco and tomato plants did not grow in the soil when given only distilled water or nutrient solutions lacking in phosphorus or nitrogen but matured and flowered when these elements were added. It is concluded that the pine stands are relicts which have remained because of the inability of sagebrush zone dominants to invade these mineral-deficient soils.—Author's abstract.

10. Bobrowski, Wladislaw, and Piechota, Aleksander. Influence of the substratum on the occurrence of heavy metals in the bark of contemporary pines on the Triassic of southwestern Poland [in Polish with English summary]: Panstwowa Sluzba Geol., Panstwowy Inst. Geol. [Serv. geol. Pologne, Inst. geol. Pologne] Biul. 58, pp. 6–12, 1949.

The bark of pines in areas of lead-zinc mineralization had a rusty tarnish, and analyses of the cleaned bark showed appreciable contents of zinc and lead.—Michael Fleischer, in Chem. Abs., vol. 45, col. 7479.



11. Buck, L. J. Association of plants and minerals: Jour. New York Bot. Garden, vol. 50, pp. 265-269, 1949.

This paper presents a popular discussion of the association of certain plants with mineral deposits. A list of plants reported to prefer an environment especially rich in certain metallic elements is given. The author describes the discovery of a deposit of chromite in Cuba by a native who noticed the association of chromite with the luxuriant growth of a certain shrub. In Venezuela a terrestrial orchid, believed to be *Epidendrum O'Brienianum*, has been helpful in determining the extent of an iron ore body.—J. W. H.

12. Buck, L. J. Shrub aids in determining extent of orebody: Garden Jour. [New York Botanical Garden], p. 22, Jan.-Feb. 1951.

A study of the distribution of a shrub, *Clusia rosea*, has helped to determine the extent of the newly discovered Cerro Bolivar iron ore deposit in Venezuela. *Clusia rosea* grows from 20 to 50 feet high and is characterized by horizontal branches and white to pink flowers. The close association of this shrub with iron ore and the fact that it can be recognized in aerial surveys have helped in determining the extent of the ore bodies.

The author further emphasizes the study of vegetation as an aid in geological work by quoting the following statement of D. J. J. Marais, of Johannesburg, South Africa:

The association of plants with certain strata is of course a well-known fact and we were often able to distinguish between various stratigraphic horizons in northern Rhodesia by virtue of the bush type growing on the different rock types. The differences in vegetation usually show up very well on aerial photographs and certain distinctive textures of vegetation can be observed; for example, on granite the trees appear to follow crisscrossing lines, probably joints. On the Archean schists, the texture is a wiggly line type. On arkoses and other coarse clastics, the tree growth is usually considerably more vigorous than on shales. The dolomites generally have their own typical vegetation. Being able to recognize the various rock types by the indigenous vegetation typical of each is of considerable assistance where outcrops are extremely rare.—J. W. H.

13. Campbell, J. Geo-spectrographic methods for finding mother lodes of placer deposits: Min. Jour., vol. 24, no. 24, p. 5, Phoenix 1941.

Spectrographic analyses of placer gravels may help in establishing the source of the placer minerals. For example, analyses for tin may help in tracing cassiterite placers. If gravel from the mouth of a stream contains significant amounts of metals, further analyses are made of samples collected systematically upstream. Tributaries which supply placer minerals are readily distinguished from tributaries which do not. In this manner the ultimate source, or mother lode, of the placer minerals may be discovered.—J. W. H.

14. Chisholm, E. O. A simple chemical method of tracing mineralization through light non-residual overburden: Canadian Inst. Min. Metallurgy Bull., vol. 43, pp. 64-68, 1950.

A simple method of analyzing soil material by shaking it in water and then determining the heavy metal content of the water with dithizone has yielded excellent results near Kenora, Ontario. With this method a mineralized zone containing zinc, copper, lead, and gold was traced under a layer of dense glacial

clay as much as 5 feet thick. Readily measurable amounts of heavy metals (largely zinc) were found in sand and clay sampled a few inches above the mineralized bedrock, but little zinc was found in samples obtained a foot or more above bedrock. Samples collected close to bedrock at 10-foot intervals along traverses 200 feet apart revealed an anomaly that corresponded with the mineralized zone as outlined by trenching and geologic mapping.

This mineralized zone lies near the shore of the Lake of the Woods. Samples of water collected near the shore were analyzed to determine whether anomalous amounts of heavy metals were present in the lake water. Readily detectable amounts of heavy metals were found within 5 feet of the shore near mineralized zones, but the heavy metal content dropped rapidly more than 5 feet from the shore. The amounts of metal in the water were negligible where no mineralized zones occurred near the shore.

Both the water extracts of soil and the samples of lake water were analyzed using an adaptation of Huff's field test for heavy metals in water. (See abs. 40.) The reagents used were prepared to Huff's specifications. Lake water, collected well away from shore, was a satisfactory substitute for distilled water.

The soils were analyzed as follows: The glacial overburden was penetrated to obtain a sample as close to bedrock as possible. Fifteen cc of the sample was placed in a 50 ml glass-stoppered, wide-mouth bottle. Twenty ml of metal-free water was added and shaken for exactly one minute. The mixture was allowed to settle for 30 seconds. Ten ml of the water (now muddy) was poured off into a 30 ml pyrex test tube. Three ml of 0.0016 percent solution of dithizone in carbon tetrachloride and 3 or 4 drops of ammonium hydroxide solution were added and the test tube corked and shaken for one minute. The muddy water and the carbon tetrachloride form a coarse emulsion. To separate the carbon tetrachloride from the water, the test tube was whirled on a 2-foot length of twine for half a minute. The intensity of the pink color produced in the carbon tetrachloride phase was a measure of the heavy metal extracted from the sample.

The water samples were analyzed as follows: Ten ml of water was poured into a 30 ml test tube and 5 drops of acetate buffer and 3 ml of 0.0016 percent dithizone-carbon tetrachloride solution were added. The tube was corked, shaken for one minute, and whirled centrifugally. The metal content was estimated from the mixed color of the carbon tetrachloride phase.—J. W. H.

15. Chisholm, E. O. Dithizone solution is sensitive field test for tracing copper, lead and zinc: *The Precambrian*, vol. 23, no. 1, pp. 38-39, 1950.

This is a review of the procedures given previously (abs. 14) for the estimation of heavy metals in natural waters and water extracts of soil samples.

16. Cooper, J. R., and Huff, L. C. Geological investigations and geochemical prospecting experiment at Johnson, Arizona: *Econ. Geology*, vol. 46, pp. 731-756, 1951.

Deposits of copper and zinc at Johnson, Arizona, occur in metamorphosed Paleozoic limestone near a quartz monzonite stock probably of late Cretaceous or early Tertiary age. The metallic mineralization was preceded by a stage of thermal metamorphism during which pure carbonate beds were recrystallized and impure carbonate beds were altered to garnet, diopside, and other contact-metamorphic silicates. Silicate formation, which involved loss of carbon dioxide, was accompanied by shrinkage that reached a maximum of 30 percent. In the following metallic mineralization, the metamorphic rock was replaced by copper and zinc sulfides associated with some chlorite and other relatively low

temperature gangue minerals. Nearly all the ore occurs as tabular masses and chimneys in particular beds in the Abrigo formation of Cambrian age.

The recently discovered Moore body is a lenticular mass in the Abrigo formation about 400 feet below the present surface. Faulted and fractured limestone and dolomite beds of the Escabrosa limestone (Mississippian) crop out above the ore body. Local copper stains, which are abundant in the district, and a greater-than-average amount of faulting are somewhat meager geological evidence for the presence of ore.

To determine if there was any geochemical evidence for the proximity of ore, outcrops of the Escabrosa limestone and part of the underlying Martin formation (Devonian), the fault zones, and soils were sampled both over the ore and in the adjoining area; and the samples were analyzed for traces of the ore metals [heavy metals].

The ore-metal content varies widely and is determined in part by stratigraphy and structure. Large areas abnormally high in ore metal are indicated by samples from the fault zones. Composite chip samples of the rock between the faults show small high areas within the high areas indicated by the fault-zone samples. One of the chip-sample anomalies is over the Moore ore body but displaced somewhat to one side of the center of the body. Two other anomalies are over unexplored ground some distance from the ore body. Soil samples collected on low ridges, where contamination is unlikely, show the same general anomalies as the rock samples.

A genetic relationship between the Moore ore body and the nearby geochemical anomaly is suggested by its proximity and by the presence in the anomaly area of fault zones which carry concentrations of ore metal and project toward the ore. Diamond drilling and further geochemical studies are suggested as possible means of checking the inferred relationship. At present, geochemical studies give promise of becoming a valuable adjunct of geology in prospecting the Johnson district and similar areas elsewhere.—*Authors' abstract.*

17. Coteló Neiva, J. M. Prospeção geoquímica [Geochemical prospecting]: Estudos, notas, e trabalho serv. fomento mineiro [Portugal]; vol. 5. pp. 91-98, 1949.

Techniques of prospecting by water analysis are reviewed, and possible applications of this method to exploration in Portugal are discussed.

18. Delavault, R. E., and Irish, R. I. Emploie de la dithizone en solution ammoniacale [Use of dithizone in ammoniacal solution]: Acad. sci. Paris Comptes rendus, vol. 229, p. 1079, 1949.

The sensitivity of the dithizone determination of copper and zinc in natural waters is increased by using sodium lauryl-sulfonate as an emulsifier. This permits the dispersion of the immiscible organic phase (xylene) as an emulsion. Freshly prepared ammoniacal dithizone is used to form copper and zinc dithizonates that readily color the dispersed droplets of xylene. By shaking 1 ml of emulsified xylene with 200 ml of water, very small quantities of copper and zinc are detectable. As little as 1 microgram of copper per liter of water may be measured (one part per billion). The test for zinc is twice as sensitive.—*J. W. H.*

19. Dorn, Paul. Pflanzen als Anzeichen für Erzlagerstätten [Plants as indicators of ore deposits]: Der Biologe, vol. 6, pp. 11-13, Munich, 1937.

Many plants grow preferentially in soils containing unusual quantities of metals. *Viola calaminaria* Lej is called the calamine violet because of its re-

striction to calamine deposits in Europe. *Thlaspi calaminare* Lej, *T. cepae-folium* Koch, and *Viola lutea* Sur. are likewise associated with zinc districts. As high as 21.3 percent zinc oxide has been reported in the ash of *Thlaspi calaminare* L. The presence of *Ruta graveoleus* L., *R. latifolia* Mart., *Matricaria americana* L., and *Senecio brasiliensis* Less. growing together has been reported to be an indication of zinc deposits in the region of Ouro Preto, Brazil.

*Amorpha canescens* Nutt. is reported to be an indicator of lead-rich soils in the United States. *Sempervivum soboliferum* Sims prefers mine dumps containing traces of tin in the old tin mining regions of the Saxon Erzgebirge. *Trientalis europaea* L. grows abundantly and almost exclusively on these dumps. *Gnaphalium suaveoleus* Mart. and "Qualear Art" (Vochysiaceae) have been reported as tin indicators in the Brazilian tin districts.

Gold indicators reported from Brazil are *Crecropia laetivirens* Hub., *C. palmate* Willd., *C. lyratiloba*, *Alpina speciosa* Schum., *Typha latifolia* L., and *T. dominiguensis* Kunth. These contain gold in the ash. *Erigonum ovalifolium* is listed as a silver indicator which has led to the discovery of several silver deposits in Montana. *Polycarpha spirostyles* F. M. Muell., which contains copper in the ash, has been used successfully in finding copper deposits in North Australia and Queensland. *Alsine verna* L. and *Armeria vulgaris* are indicators of both copper and zinc in the Mansfield Kupferschiefer region of Germany. *Melichioferia nitida* and *Scoplophila liguta* similarly prefer copper rich soils but also grow on iron- and manganese-rich soils.

*Alsine setacea* is thought restricted to quicksilver deposits at Idria, Spain. *Convolvulus althaeoides* is a phosphorus indicator in Spain and has led to the discovery of phosphorite beds.

Scarcity or absence of vegetation may also indicate metallic ore deposits. The absence of vegetation on a norite reef in the Transvaal helped in the discovery of platinum.—J. W. H.

20. Feigelson, I. B. Geochemical indications for the presence of borates: Acad. sci. U. R. S. S. Comptes rendus, vol. 29, no. 8/9, pp. 592-595, 1940.

The following data is presented for the  $H_3BO_3$ : Br ratio in various brines:

The World ocean.....	0.95
The Ural-Emba region.....	2.03
Sources of Lake Inder.....	12.66
Subterranean waters of the Inder (eastern basin).....	*65.00
The Manguishlak peninsula.....	2.50
The Karabogas region.....	2.66
The Tchelkar region.....	2.46
The Ust-Urt plateau.....	.36
The Sarakamysh depression.....	2.00
The Khiva oasis.....	3.91
The Solikamsk-Berezniaki region.....	.25

\*Mean data.

The author concludes that where the  $H_3BO_3$ : Br ratio exceeds that for the ocean (0.95) there are good reasons for searching for borate. This relationship is explained on the assumption that both the borate and the bromine now occurring in saline waters are derived by the leaching of saline sediments. Bromine is one of the most soluble components of saline deposits and is used as a reference in determining the excess of borate in brine that has leached through such deposits. Thus, a high borate-bromine ratio in the brine is considered a favorable indication in prospecting for borax in saline sediment.—H. E. H.

21. Fersman, A. E. Geochemical and mineralogical methods of prospecting for useful minerals, Chap. IV, Special methods of prospecting [in Russian]: Akad. Nauk SSSR, Izd. pp. 164-238, 1939. English translation by Hartsock, Lydia, and Pierce, A. P., U. S. Geol. Survey Circ. 127, 1952.

The author reviews the characteristics of primary and secondary dispersion halos and presents in detail the techniques used in mapping them, including heavy mineral studies, spectrographic methods, the use of ultraviolet lamps, thermal, redox, pH, geophysical, and radiometric techniques.—H. E. H.

22. Flerov, B. L. The application of stannometric surveys to prospecting for primary tin deposits [in Russian]: Redkie Metally, no. 1, pp. 31-39, 1935.

The stannometric survey method, involving the systematic determination of the cassiterite content of heavy-mineral concentrates of surficial materials, is recommended for use in prospecting for primary tin deposits in areas of poor exposures.

The heavy minerals in the sample are concentrated by panning, and the cassiterite content of the panned concentrate is determined. Results for the alluvial materials are expressed in terms of ranges, as follows: (1) Greater than 500 g/m<sup>2</sup>, (2) 100-500 g/m<sup>2</sup>, (3) 10-100 g/m<sup>2</sup> (4) trace, and (5) absent. For residual soils the results are expressed in milligrams per standard sample weight.

The exploration procedure starts with widely spaced samples (300-500 meters) of the alluvial materials in major drainage patterns. When a promising area is found, lines of closely spaced samples are run in the residual soils along the slopes adjacent to the stream. Several illustrations of hypothetical stannometric surveys are given.—A. P. P.

23. Flerov, B. L. On methods of prospecting for primary deposits of tin [in Russian]: Sovetskaya geologiya, vol. 8, no. 19, pp. 63-81, 1938.

The author discusses the general procedure of prospecting for primary deposits of tin by means of systematic quantitative mineral analyses for detrital cassiterite. Topics discussed are: The selection of favorable localities for prospecting, the geological conditions necessary for the transportation and deposition of cassiterite in alluvium, the interpretation of results obtained in stream prospecting, methods of tracing cassiterite from the alluvium to its source deposit, and methods of outlining primary ore bodies of tin by means of their dispersion halos. Several idealized illustrations are given of dispersion halos in the vicinity of tin-bearing veins.—A. P. P.

24. Fowler, G. M. Geochemical prospecting in the Mississippi Valley [abstract]: Min. Cong. Jour., vol. 36, no. 12, p. 69, 1950.

Through the years, various methods have been employed to try to find new ore bodies. Exploration for ore bodies has been carried on in the Mississippi Valley by drilling on one-fourth to one-half mile centers at a cost of \$5,000 per square mile. Less costly methods would greatly extend the area that could be economically prospected.

Tri-State ore bodies are confined to small centers of intense structural deformation within an area of 2,000 miles. Soil analysis was first tried in areas already known from drilling and geophysical survey data. When the results of geophysical and geochemical methods were found to check fairly closely, the geochemical method was used in unknown areas.

One small ore body of about 50,000 tons was found by this method. Geochemical prospecting results eliminated many square miles that apparently contained only small and scattered ore bodies. Also, this method located and helped in defining faults, shear zones, and other evidence of premineral deformation that are now concealed by surface soils which are from a few inches to 10 ft. or more in thickness. The results were shown by the use of contours based on the relative amounts of the several trace elements that were present.

In the period from 1940 to the end of October 1941, some 11,741 separate samples were taken and analyzed. On the basis of this work, it was found that lead, gallium, nickel, cobalt, and tin gave the best results. It cost between 75 and 80 cents per sample at the time; now the cost would probably be about \$1.00 a sample. The geochemical method costs from \$200 to \$500 per square mile as compared with costs of \$2,000 to \$5,000 per square mile when drilling methods are used.—*Author's abstract.*

25. Fraser, H. J., and Wilson, H. D. B. Application of the spectroscope to ore finding [abstract]: *Geol. Soc. America Bull.*, vol. 52, p. 1948, 1941.

Development of the quantitative spectrographic technique has made available a new tool of possible use in the localization of ore bodies within a mineralized zone. (See abs. 148.) Vein quartz, free from any megascopic impurities, may show 20 elements or more present in quantitatively measurable amounts. A number of these elements may show significant variations between areas of economic mineralization and barren parts of the vein or silicified wall rock. From a study of these variations it is possible, under certain conditions, to predict whether one is approaching or going away from an ore body.—*Authors' abstract.*

26. Fulton, R. B. Prospecting for zinc using semiquantitative chemical analyses of soils: *Econ. Geology*, vol. 45, pp. 654-670, 1950.

One thousand five hundred samples of soil were collected and analyzed for zinc as a prospecting experiment at Austinville, Virginia. A sampling depth of 2.1-2.4 feet was selected on the basis of experiments showing that variations in the zinc content of soil from sample hole to sample hole were least erratic at depths greater than two feet. Sampling was done (1) on grids with samples spaced 100 feet apart, or (2) along parallel traverses 500 feet apart with samples collected at 100- or 200-foot intervals. Analyses were made by digesting one gram of pulverized soil with potassium acid sulfate and determining the zinc content with dithizone. The results show that abnormal amounts of zinc in soil can be correlated with zinc mineralization in the underlying bedrock. This correlation is evident in spite of the fact that much of the soil at Austinville has apparently been derived from river alluvium. Soil containing 1,000 ppm or more zinc appears, for the most part, to be associated with ore. Soil containing abnormal amounts of zinc commonly occurs along the trace of faults or spread over the intersections of faults.

The author concludes that determination of zinc in soils will be useful in prospecting for zinc deposits and an aid in tracing extensions of known ore bodies.—*J. W. H.*

27. Gilbert, R. E. Geochemical prospecting in the Park City district: *Min. Cong. Jour.*, vol. 37, no. 9, pp. 58-61, 1951.

Since June 1949, the New Park Mining Co. has used soil analysis in prospecting in the Park City district, Utah. As a result of this work, the author concludes that geochemical prospecting

\* \* \* shows promise of indicating zinc mineralization where the mineralization has been exposed to erosion, and where the covering soil is residual, even though its depth may be as great as 20 feet. In areas of abundant and long persistent vegetation, it appears that samples or topsoil will yield results as satisfactory as samples taken at a depth of several feet.

The author describes in detail his techniques of surveying, sampling, analysis, and plotting of data.

Sampling is done on a geometrical pattern; any area that contains abnormal amounts of heavy metals is resampled at intermediate points. In known ore-bearing areas, lines 100 feet apart are sampled every 50 feet, yielding a pattern that can be checked by sampling between the lines. Ten to twenty grams of soil are collected after humus has been removed. The total heavy metal content is colorimetrically determined by the dithizone method with the aid of a homemade photometer to estimate colors. Analytical data are plotted on cross-section paper and contoured. A three-man crew can collect and analyze about 45 samples a day.—J. W. H.

28. Goloubinoff, Vsevolad. Sur la prospection géochimique différentielle des gîte minéraux [On differential geochemical prospecting for mineral deposits]: Acad. sci. Paris Comptes rendus, vol. 204, pp. 1075-1077, 1937.

The Earth's crust contains on the average 20 ppm tin and 0.1 ppm gold. Igneous rocks genetically related to deposits of a given element may be expected to contain a higher proportion of that element than average. The author has found aplite associated with tin deposits in Perak, Malaya, that contains 2,500 ppm tin, whereas amphibole granite in the vicinity contains only 50 ppm and syenite 10 ppm. A granulite from Laos contains 500 ppm and a pegmatite from Haut Tonkin 100 ppm tin. Similarly, rocks in gold-bearing districts have a higher than average gold content. A micronorite from Haut Tonkin is eight times higher than average, a pegmatite from Annam 25 times, and a diabase from the Belgian Congo and a norite from French Guinea are 10 times higher.—H. E. H.

29. Graf, D. L., and Kerr, P. F. Trace-element studies, Santa Rita, New Mexico: Geol. Soc. America Bull., vol. 61, pp. 1023-1952, 1950.

Emission spectrography has been used to study distribution of trace elements in Paleozoic limestones surrounding Pb-Zn ore bodies near Santa Rita, N. Mex., and subsequent transportation of these traces into overlying Tertiary beds. Analyses are given for Pb, Zn, Cu, Ag, and V, important ore metals, and Mn and Al, prominent in pre-ore silication.

Pb highs from Tertiary fault zones may be correlated with ore bodies in pre-Tertiary rocks, but Zn has been leached unless considerable gouge is present. Pb and Zn highs from a remote part of the Tertiary area encourage further exploration.

A zoning of traces occurs in Tertiary montmorillonite zones bordering the ore-localizing Groundhog fault. Near a producing mine, Ag was deposited for 20 feet from the fault, and Pb for 40 feet. Most Zn highs are in a 60-foot zone, but a few extend as much as 250 feet.

In limestone aureoles of the ore bodies, trace-element distribution is controlled by small fractures, and penetration into massive wall-rock is negligible. Zn highs occur close to ore bodies, and Pb highs farther away. The shape of the Pb gradient seems controlled largely by temperature, and the relative im-

portance of pre-ore silication and ore-deposition may be important here.—*Authors' abstract.*

30. Harbaugh, J. W. Biogeochemical investigations in the Tri-State district: Econ. Geology, vol. 45, pp. 548-567, 1950.

An investigation was made to determine if variations in heavy metal content of vegetation could be used in prospecting for zinc-lead ore bodies in the Tri-State district. Twigs of blackjack oak (*Quercus marilandica*) were sampled on a grid extending over known ore bodies and barren ground. Determinations were made for zinc (dithizone method), copper (potassium-ethyl-xanthate method), and lead, nickel, silver, cobalt, and tin (spectrographic method). The areal distribution of zinc in these samples shows some correlation with the location of ore bodies, whereas the other metals show negligible correlation. The average zinc content of samples collected within 300 feet of known ore bodies in this grid is 67 percent greater than that of similar oak twig samples collected in barren areas some miles distant.

Samples of 24 species of trees, collected above mineralized zones in various places in the Tri-State district, showed an average zinc content 38 percent greater in leaves and 25 percent greater in twigs than similar samples from barren areas; samples of 16 species of grasses and herbaceous plants, gathered above mineralized zones, showed an average zinc content 30 percent greater than similar samples from barren areas.

It is concluded that determination of zinc in large numbers of plant samples may be of aid in prospecting in the Tri-State district.—J. W. H.

31. Hargraves, A. J. Geochemical sampling at Wallaroo-Moonta: South Australia Dept. Mines, Mining Review for half year ending June 30, 1948, no. 88, pp. 64-70, 1949.

A detailed description is given of soil sampling techniques used in the Wallaroo-Moonta geochemical prospecting investigations. (See abs. 104.) To obtain soil samples at depths of 10 feet, it was usually necessary to penetrate hard limestone (travertine or caliche) as well as unconsolidated materials. This required the use of augers of three different diameters, a jack hammer, and hand steel.

The soil profile usually consisted of the following materials: (1) Surface soil; (2) limy clay soil; (3) limestone (travertine or caliche) in various degrees of consolidation; (4) marls and clays; (5) decomposing bedrock.

The sampling procedure was more or less standardized. The ground around the hole was cleared of grass. With a 2 $\frac{3}{8}$ -inch auger a vertical hole was bored to the limestone, or to a depth of 3 feet. Small amounts of copper-free water were added to the hole so that the cuttings would adhere to the auger and could be recovered. A 2-inch steel-casing was set in the hole to prevent crumbly surface soil from falling into the hole as it was deepened. When the casing reached the top of the limestone, the hole was deepened with a jack hammer. As the drill steel turned inside the 2-inch casing, the unmoistened cuttings were blown out and collected in canvas wrapped around the casing and steel. When the limestone had been penetrated, a 1 $\frac{1}{4}$ -inch casing was inserted in the hole through the 2-inch casing and projecting a few inches above its upper end. Where limestone was not present, a 1 $\frac{5}{8}$ -inch auger was used instead of the jackhammer.

When a change in the soil material was encountered, the 1 $\frac{1}{4}$ -inch casing was inserted through the 2-inch casing in the same manner as described above. A 1 $\frac{1}{8}$ -inch auger was used inside the double casing to extend the hole to bedrock, or to a depth of 10 feet, whichever was shallower.



The author states,

In the event the ground became harder, additional pressure on the auger was obtained by use of a handle held down by one or two men, and working through a ball-thrust race on to the auger rods, while the brace is turned by another man. When this pressure was insufficient to cut a sample, yet the ground did not appear to be solid rock, the hole was deepened by hand steel and the cuttings recovered by auger.

The augers and drill steels were cleaned after each sample. Special precautions were taken to avoid salting due to surface dump material and wind-blown particles. Iron sheets were erected on the windward side if there was danger of tailings being blown into the hole.—*J. W. H.*

32. Hawkes, H. E. Research on geochemical prospecting by the Geological Survey [abstract]: *Econ. Geology*, vol. 42, p. 414, 1947.

The aims of geochemical prospecting research by the U. S. Geological Survey are described.

33. Hawkes, H. E. Geochemical prospecting for ores: a progress report: *Econ. Geology*, vol. 44, pp. 706-712, 1949.

Methods of prospecting for mineral deposits by means of chemical studies of residual soil, alluvium, glacial moraine, vegetation, and natural water were first applied on a systematic scale in Scandinavia and Russia about 15 years ago. Since the war, work in this field has been undertaken by several independent groups in the United States and Canada, including the Geochemical Prospecting Unit of the U. S. Geological Survey.

Best results have been obtained by systematic analysis of zinc in residuum, ground water, and vegetation; copper and lead in gossan and residuum; tin in residuum and alluvium; molybdenum in residuum; and cobalt, nickel, and gold in vegetation. In addition, studies of plant ecologies and toxicity symptoms in vegetation in relation to metal-rich soil appear to be promising.

Rapid colorimetric and spectrographic tests for traces of metals in soil, water, and vegetation have been developed for use under field conditions.—*Author's abstract.*

34. Hawkes, H. E. Geochemical prospecting for ores: In "Applied Sedimentation, a Symposium", edited by P. D. Trask, John Wiley, pp. 537-555, 1950.

A review of prospecting methods based on systematic exploration for secondary dispersion patterns by chemical analysis of soils, vegetation and water. A bibliography containing 124 references is included.

35. Hawkes, H. E. What geochemistry is and what it can do: *Min. Cong. Jour.*, vol. 37, no. 9, pp. 55-58, 1951.

A review of the principles and current status of geochemical methods of prospecting for minerals.

36. Hawkes, H. E., and Lakin, H. W. Vestigial zinc in surface residuum associated with primary zinc ore in East Tennessee: *Econ. Geology*, vol. 44, pp. 286-295, 1949.

Samples of residual clay were collected on a grid at the Friends Station zinc deposit, near Jefferson City, Tenn. The samples were analyzed for zinc by a rapid semiquantitative field method. (See abs. 54.) The purpose was to dis-

cover whether zinc-rich areas occur in surface residuum derived from the weathering of calcareous rocks containing zinc minerals and to determine whether the rapid test could be used effectively under field conditions for outlining such zinc-rich areas if they were found.

The zinc deposits in the immediate vicinity of the sampled area form a system of tabular shoots conformable to the bedding, which dips about 14°. Drill data show that an average thickness of 45 feet of residual clay overlies bedrock. Four feet was found to be the optimum depth for sampling. Samples collected at the surface or at a depth of only 2 feet were usually lower in zinc content than at 4 feet, indicating a removal of zinc by processes of soil formation. Samples collected at a depth of six feet contained only slightly more zinc than at four feet and were more difficult to obtain.

The analyses show that the normal zinc content of soil at Friends Station is about 0.03 percent. This is high compared to most soils, where the zinc content rarely exceeds 0.01 percent and may be the effect of widely disseminated sphalerite in the parent limestone. In places zinc concentrations of 0.08 and 0.10+ percent were found, representing a tenfold excess of zinc over that occurring in normal soils. A principal zinc-rich area, revealed by sampling, is interpreted as the decomposed remnant of the updip extension of the present ore body. The authors conclude that the rapid test for zinc in soil will be helpful in prospecting for zinc deposits.—*J. W. H.*

37. Hayashi, S., Sekine, S., and Kishi, H. Chemical prospecting by natural water in Kitogazawa mine, Tochigi Prefecture [in Japanese]: Jour. Geol. Soc. Japan, vol. 57, no. 670, 1951.

(Not reviewed)

38. Hedström, Helmar, and Nordström, Allan. Malmletningsteknikens nuvarande ståndpunkt [New aspects of ore prospecting]: Meddel. Jernkontorets Gruvbyrå [Uppsala], vol. 39, pp. 1-10, 1945.

A discussion of prospecting by spectrographic analysis of plant ash is included in this review of new exploration techniques. Graphs show an abnormally high chromium content in certain shrubs growing over a chromite deposit in Greece. The authors describe the difficulty of using plant analysis in prospecting where there is a mantle of glacial drift. Plants growing over a drift-covered zinc-lead deposit in Sweden were not found to contain abnormal amounts of zinc, copper, or silver.—*J. W. H.*

39. Hills, E. S. The metalliferous geochemical zones of Australia: Econ. Geology, vol. 42, pp. 478-491, 1947.

Spot maps showing recorded occurrences of minerals containing certain elements as essential or important constituents have been prepared, in an attempt to discover and delimit the main metallogenetic provinces of Australia. Correlation with geological events is clear in a broad way, and it is shown that in Paleozoic and later times there has been a progressive shift in the location of successively developed ore-zones from west to east in eastern Australia.—*Author's abstract.*

40. Huff, L. C. A sensitive field test for heavy metals in water: Econ. Geology, vol. 43, pp. 675-684, 1948.

A semiquantitative colorimetric analytical method using dithizone to detect traces of heavy metals in natural water is described. Although reagents of

exceptional purity are required, only simple equipment is needed and the test can be made in a few minutes in the field. A combined mixed color and monochrome technique makes the test suitable for a wide range of concentrations. The test is very sensitive; as little as 0.01 part per million of either copper, lead, zinc or any combination of the three metals can be detected readily.

The dithizone test permits rapid field identification of drainage elements which contain significant concentrations of heavy metals. An example is given showing how the test can be used to trace the heavy metal content of a drainage system back to its source. It is possible that, under favorable conditions, the field test may facilitate prospecting by detecting metals discharged by the weathering of hidden ore bodies. However, until the method receives further investigation, it would be premature to predict its value.—*Author's abstract.*

41. Huff, L. C. A sensitive field test for detecting heavy metals in soil or sediment: *Econ. Geology*, vol. 46, pp. 524-540, 1951.

A semiquantitative colorimetric analytical method using nitric acid for digestion and dithizone for the determination is embodied in a simple test to detect the presence of copper, lead, zinc, and other nonferrous ore metals in soil or sediment. For the most part, only simple chemical equipment is necessary and tests can be made conveniently in a makeshift field laboratory. The test is adequately sensitive to obtain a slight positive test from the small traces of ore metals present in ordinary soils and sediments and can easily detect the larger quantities present in soils or sediments derived from ore deposits. It is hoped that the test will prove useful in prospecting for ore deposits by geochemical methods.—*Author's abstract.*

42. Jakosky, J. J., Dreyer, R. M., and Wilson, C. H. Geophysical investigations in the Tri-State zinc and lead mining district: *Kansas Geol. Survey Bull.* 44, pp. 51-77, 1942.

A series of geophysical and geochemical prospecting experiments were made in the western part of the Tri-State district. Soil and rock samples were analyzed to determine whether their heavy metal content could be correlated with subsurface zinc-lead ore bodies. The ore bodies of the Tri-State district occur in limestone, which, in the western part of the district, is overlain by a maximum of 200 feet of shale. The soil samples were collected at a depth of three feet on grids or along traverses. Manganese, lead, vanadium, gallium, molybdenum, titanium, nickel, and cobalt were determined by arcing 0.1 gram of pulverized sample in a grating spectrograph. Results show that the distribution of these metals in soil bears little or no relation either to ore mineralization or to subsurface structural conditions. Rather, the distribution appears to be caused by drainage features or due to soil or lithological conditions unrelated to mineralization.

The rock samples were obtained from drill holes, half of which encountered mineralization and half did not. Samples of shale collected above mineralized limestone did not contain larger amounts of metals than did shale samples collected above barren limestone. The authors conclude that they were unable to find a method of geochemical prospecting applicable to problems in the Tri-State district.—*J. W. H.*

43. Jerome, S. E. Special field applications of a confirmatory test for lead: *Econ. Geology*, vol. 45, pp. 358-362, 1950.

Five percent solutions of acetic acid and potassium iodide, applied in a number of ways, are useful in detecting cerussite and anglesite occurring under a

variety of conditions. This test aids in recognizing ores containing these minerals and may be used to guide their sampling, exploration, development, mining, and milling. It has the advantages of rapid, large scale coverage; ease of application in field and laboratory; simplicity of solutions and equipment; immediate, specific, and visible results; only reasonable care required to prevent either contamination or deterioration of solutions; and practically no interference of other elements or compounds normally encountered in the field.

Calibration of potassium iodide test results and visual detection of cerussite can be facilitated by treatment with 10 percent sodium sulfide solution. *Author's summary.*

44. Keller, W. D. Higher alumina content of oak leaves and twigs growing over clay pits: *Econ. Geology*, vol. 44, pp. 451-54, 1949.

Qualitative spectrographic analysis indicates that the leaves and twigs of oak and hickory growing over high-alumina clay deposits in Missouri are richer in alumina than normal.—*H. E. H.*

45. Kennedy, V. C. Mineralization surrounding ore in the southwestern Wisconsin lead-zinc district: Unpublished thesis, Pennsylvania State College, 1949.

Small amounts of iron and zinc, in excess of that normally present in non-mineralized rock, were found above and to the side of ore bodies in the southwestern Wisconsin lead-zinc district. Analyses of churn drill cuttings showed that greater than normal amounts of iron and zinc occurred in limestone and dolomite country rock, sometimes more than 100 feet from ore bodies. Samples from twelve churn drill holes were analyzed. Four of these holes passed through ore bodies, seven holes passed near, but not through ore bodies, and one hole was drilled in barren ground about five miles from the nearest known ore. Although most of the holes were about 300 feet deep, in all but one hole samples representing at least the first 135 feet above the ore bearing horizons were analyzed. The cuttings were grouped so that each sample represented either 10-, 15-, or 20-foot sections from the hole. The cuttings were dried, crushed, and sieved. A partial extraction of iron and zinc was made by digesting the samples with 2N nitric acid in test tubes placed in boiling water. Zinc was colorimetrically determined with dithizone; iron was colorimetrically determined with tiron (disodium-1,2 dihydroxy-benzene-3,5 disulfonate).

The results show that the iron and zinc content of the country rock is highly variable. The cuttings from the barren hole drilled five miles from the nearest known ore had an average zinc content of 0.002 percent and an average iron content of 0.25 percent. The cuttings above the ore bearing horizon from holes passing through or near ore bodies contained much more iron and zinc than the barren hole. The cuttings from the four holes passing through ore bodies showed a high zinc content more than 50 feet above the ore and a high iron content extending 100 or more feet above the ore. The cuttings from one hole contained abnormal quantities of zinc and iron for more than 138 feet vertically from the nearest known ore.

The author concludes that cuttings containing more than 0.02 percent zinc or 0.7 percent iron in the country rock, as determined by the author's method, may be considered anomalous and could indicate the presence of mineralization in the vicinity. The author suggests that, because of these mineralization halos, soil analysis possibly may be useful in prospecting for ore bodies lying as deep as a hundred feet beneath the surface.—*J. W. H.*

46. Kimura, Kenjiro; and Fujiwara, Shizuo. Geochemical prospecting for metallic ore deposits [in Japanese with English summary]: Jour. Geography [Tokyo], vol. 60, pp. 9-19, 1951.

(Not reviewed)

47. Kimura, Kenjiro; Fujiwara, Shizuo; and Morinaga, Kenichi. Chemical prospecting. III. Chemical studies on the natural waters of the Hitachi Mine district [in Japanese]: Jour. Chem. Soc. Japan, Pure Chem. Sect., vol. 71, pp. 464-467, 1950.

To find some relations between the distribution of the chemical constituents of brook waters and the location of ore bodies, the contents of sulfate, iron, etc., of the water samples which were collected from the brooks that passed the area of the Hitachi Mine were determined. The waters which passed the area where the working ore deposits were present contained more than 20 or 30 mg./l. of sulfate ion, while the waters which passed no ore deposit did not show the presence of sulfate. Thus, in this district, the brook waters which contain 5 to 10 mg./l. sulfate ion can be often traced back to a suspected ore body. The results obtained have been compared with those obtained by the electrical method of prospecting.—K. Yamasaki, Chem. Abs., vol. 45, col. 6130g.

48. Kimura, Kenjiro; Fujiwara, Shizuo; and Morinaga, Kenichi. Chemical prospecting in Hosokura Mine district [in Japanese]: Jour. Chem. Soc. Japan, Pure Chem. Sect., vol. 72, pp. 398-402, 1951.

Chemical analyses of river water, pit waters, and soils in the Hosokura Mine districts, Miyagi Prefecture, are carried out. The sulfate ion is only detectable in river waters of the propylitic andesite zone, where the sulfide ores can be found. Soils of tuffic quartz-andesitic and propylitic origins can be distinguished from each other by the analysis of aqueous extracts of soils.—K. Yamasaki, in Chem. Abs., vol. 46, col. 863b.

49. Kimura, Kenjiro; Fujiwara, Shizuo; and Yasuda, Yashio. Chemical prospecting. IV. Chemical prospecting at the southern part of the Sado gold mine. The distribution of minute amounts of silver and copper in rocks [in Japanese]: Jour. Chem. Soc. Japan, Pure Chem. Sect., vol. 71, pp. 467-471, 1950.

Samples of rocks which showed strongest alteration were collected from the southern part of the Sado Mine and the contents of silver and copper were determined. Rocks collected in the vicinity of the main ore deposits showed high contents, while those collected near copper ore deposits considerable copper and silver was not detected in them. The distribution of these elements in rocks was influenced considerably by the location of ore veins, even if they were very small ones. Thus, the rocks which showed high contents of copper and silver can be traced back to small ore veins and then to a main ore body. The rocks from several places of this region contained neither silver nor copper, though they showed very strong alteration. The alteration seems to be barren and no ore deposit is expected in these places.—K. Yamasaki, in Chem. Abs., vol. 45, col. 6130i.

50. Kingman, Owen. Geochemical techniques and results at Ducktown: Min. Cong. Jour., vol. 37, no. 10, pp. 62-65, 1951.

Geochemical work at Ducktown, Tenn., indicates that rock analysis may be used to detect mineralization channels. Ore minerals at Ducktown are pyr-

rhodite, pyrite, chalcopyrite, sphalerite, and magnetite. About 3,000 rock samples were collected near four ore bodies. The samples were pulverized and leached with sodium hydroxide and acetic acid, and the copper and zinc content was determined with dithizone. Results of analyses were plotted to show relation to ore or to magnetic anomalies. Although drilling has shown that some of the results are contrary to expectations, the author concludes that geochemical work may contribute to finding ore.—J. W. H.

51. Konovalov, E. P. On the hydrochemical method of prospecting for gold [in Russian]: *Sovetskaya Geologiya* no. 2, pp. 114–117, 1941.

Quantitative chemical analysis of river and stream waters has proved to be unsuccessful as a method of prospecting for surface deposits of gold. Analyses of the waters of the Sutar River Basin revealed a range of from 0.006 to 0.1 milligrams of gold per ton. In the lower part of the basin the concentration changed from zero at the surface of the river waters to 0.01 mg/ton to 0.02 mg/ton with increasing depth. In the waters of the tributaries, concentration varied and reached a maximum of 0.10 mg/ton. Also, samples taken along a traverse across the river at different distances from the banks and at different depths varied greatly. Samples taken at the same spot but at different times showed large variations.—A. P. P.

52. Kreiter, V. M. Search and prospecting for useful minerals [in Russian], *Gosudarstvennoe izdatel'stvo geologicheskoi literatury*, pp. 284–289, Moscow-Leningrad, 1940.

The writer describes the procedure and methods of analysis used in surveying the ore zones of copper and lead deposits, giving an example of each type of survey. A survey made for copper at the Kal'makyr porphyry copper deposit is described and illustrated. Weathered material from outcrops of both disseminated copper ore and country rock were systematically sampled and analyzed for copper. The data were plotted on geologic maps and lines of equal copper content drawn. A cuprometric map of the Kal'makyr copper deposit is given as an example. (See abs. 151.) Flame test and colorimetric methods proved successful in making field determinations of the percentage of copper in the samples. A study of limonite structures was used as a further criteria in mapping the ore zones. A survey for lead at the Tary-ekan polymetallic deposit was made by systematically sampling weathered and altered rock along profile lines crossing the deposit. The lead content was determined by estimating the amount of precipitate formed in the reaction of lead with potassium iodide and nitric acid. The resulting plumbometric map of the Tary-ekan deposit is given.—A. P. P.

53. Lakin, H. W., Almond, Hy, and Ward, F. N. Compilation of field methods used in geochemical prospecting by the U. S. Geological Survey: U. S. Geol. Survey Circ. 161, 1952.

Simple field methods are given for the determination of trace quantities of heavy metals in water; heavy metals, zinc, copper, lead, nickel, cobalt, tungsten, molybdenum, and silver in soils; and zinc, nickel, and molybdenum in plants. These tests are designed to give positive tests for background material and results within 30 to 50 percent of the correct value for materials containing abnormal amounts of the element. One person can perform 30 to 40 analyses per 8-hour day. The following topics are discussed: analytical properties of colorimetric reagents used in the field methods; toxicity of certain reagents and

the proper mode of handling these reagents; and special apparatus developed to simplify the techniques of trace analysis.—*Authors' abstract.*

54. Lakin, H. W., Stevens, R. E., and Almond, Hy. Field method for the determination of zinc in soils: *Econ. Geology*, vol. 44, pp. 296-306, 1949.

A method is described for the field estimation of total zinc in soils. A small sample of soil is fused with potassium bisulfate, the fused mass dissolved in water, buffered at pH 4 to 5.5 with acetate buffer, and sodium thiosulfate added to form complex ions with metals that might cause interference. Measured increments of the sample solution are added to a carbon-tetrachloride-dithizone solution, with vigorous shaking after each addition, until a standard color is obtained in the organic phase. Under favorable conditions up to sixty determinations per day can be made by one man. Comparisons of data obtained by the field method with accurate laboratory analyses of the same samples indicate that the method is sufficiently reliable for reconnaissance surveys.—*Authors' abstract.*

55. Landergren, Sture. Om spektralanalytiska metoder och deras användning vid malmundersökningar och malmprospektering. [On spectroanalysis and its application in investigating and prospecting for ore deposits]: *Teknisk Tidskrift Bergvetenskap*, vol. 69, pp. 65-68, 73-78, 1939.

Not reviewed.

56. Leach, Paul. Simple chemical tests to aid prospectors: *Eng. and Min. Jour.*, vol. 148, no. 10, pp. 78-79, 1947.

Some of the early research work of the U. S. Geological Survey on geochemical prospecting is reviewed. Results of brief geochemical tests on stream water near Butte, Mont., are presented, showing the persistence of copper, zinc and iron in stream water many miles from their source. Water in a small stream just below the mines at Butte contained 60 to 80 ppm copper, 400 ppm zinc, and 80 ppm iron. In the same drainage basin, 32 miles downstream from Butte, the water of Deer Lodge River was found to contain 0.05 ppm copper, 3 ppm zinc, and 0.8 ppm iron.—*J. W. H.*

57. Lidgley, Ernest. Some indications of ore deposits: *Australasian Inst. Min. Eng. Proc.*, vol. 4, pp. 110-122, 1897.

In addition to a summary of personal observations on geologic features that serve as ore control, the author presents a list (pp. 116-117) of indicator plants for deposits of iron, lead, zinc, silver, limestone, and phosphate.—*H. E. H.*

58. Lovering, T. S. Structure of East Tintic District modified: *Min. Cong. Jour.*, vol. 37, no. 9, pp. 61, 84, 1951.

In the East Tintic district, Utah, drilling based in part on geochemical evidence proved the presence of carbonate rock with associated mineralized jasperoid, underlying about 2,000 feet of lava, although previous evidence indicated the presence only of inhospitable quartzite. Thus the area thought to be favorable for commercial replacement ore has been greatly enlarged.—*H. E. H.*

59. Lovering, T. S., Huff, L. C., and Almond, Hy. Dispersion of copper from the San Manuel copper deposit, Pinal County, Arizona. *Econ. Geology*, vol. 45, pp. 493-514, 1950.

At San Manuel, near Tucson, Arizona, recent churn drilling has blocked out large reserves of low-grade "porphyry copper" ore. This virgin deposit has a

small outcrop and seems ideally suited for a geochemical study of the dispersion pattern produced by weathering in a desert climate. Samples of soils, alluvium, ground water, and vegetation were analyzed for copper. To avoid grinding, to accentuate differences in copper concentration, and to decrease sampling error, sampling was confined to the silt and clay fraction of the soil and alluvium. A sensitive field test for copper, using hydrochloric acid for a digestant and dithizone for copper determination, proved both quick and reliable.

The results of the study show that at present little copper from the ore body dissolves in the ground water or runoff, and also that very little is taken up by plants growing on the ore outcrop. For this reason, prospecting for similar deposits by the sampling and analysis of ground water or vegetation is unlikely to be fruitful. A study of plant ecology, however, shows that certain plant species grow preferentially on outcrops of copper ore and may be useful as indicators of ore.

Chrysocolla along joints carries most of the copper in the oxidized zone. The chrysocolla is slowly disintegrated mechanically as the rock weathers and enters the fine fraction of the soil. Slope wash and soil creep carry the copper along with the other soil materials into the nearby washes, where they are incorporated in the alluvium and swept downstream during floods. Abrasion probably continues to concentrate the copper in the fines, but the net change downstream is a decrease in copper content caused by dilution.

As copper can now be readily determined by chemical analysis in the field, analysis of soil and alluvium seems to be one of the best geochemical methods of prospecting for copper in a desert environment. Wherever appreciable copper is found in alluvium or soils, upstream or upslope sampling can be used to trace the copper back to its source.—*Authors' abstract.*

60. Lovering, T. S., Sokoloff, V. P., and Morris, H. T. Heavy metals in altered rock over blind ore bodies, East Tintic district, Utah: *Econ. Geology*, vol. 43, pp. 384-399, 1948.

Standard chemical tests and spectroscopic analyses of altered Tertiary lavas that occur above blind ore bodies in the East Tintic district, Utah, have failed to show any evidence of the mineralization in the underlying dolomites. A new technique involving dithizone was used in the field to test ammonium acetate extracts of crushed samples of the lava for soluble heavy metals, with significant results. Concentrations of heavy metals, believed to be chiefly zinc, with some lead and rarely copper (?), were found in pyritized rhyolite above and up-rake from known blind ore bodies, and were lacking in similarly altered rhyolite underlain by barren rocks. An incompletely prospected area of pyritic alteration shows a definite pattern of positive tests and seems worthy of further exploration. The theory and practice of the dithizone method as used in the field is described briefly.—*Authors' abstract.*

61. Lundberg, Hans. Future of geophysics in connection with plant life: *California Min. Jour.*, vol. 9, no. 9, p. 5, 1940.

The analysis of plant ash as an aid in prospecting is briefly discussed.

62. Lundberg, Hans. The future of geophysics in the light of new developments: *Canadian Min. Jour.*, vol. 61, pp. 225-6, 1940.

The analysis of plant ash as an aid in prospecting is briefly discussed.



63. Lundberg, Hans. New techniques in geoexploration: Mining and Metallurgy, vol. 22, pp. 257-258, 1941.

New ideas and developments in geophysical and geobotanical methods of mineral exploration are briefly reviewed. Gold can be detected spectrochemically in distilled water that has been shaken with a few grains of placer gold for 60 or 70 hours. Tin can be similarly detected in water after shaking for eight hours with cassiterite. Sampling and analysis of vegetation in Canada and Newfoundland have indicated the presence of ore beneath 30 to 40 feet of glacial material.—H. E. H.

64. Lundberg, Hans. On the history of geophysical exploration: Canadian Inst. Min. Metallurgy Bull., vol. 41, pp. 171-185, 1948.

The history of geophysical and geochemical methods of exploration for minerals is reviewed. Data collected by Dr. Brundin (see abs. 115) where the tin content of heather collected on profiles across Cornish tin-tungsten veins show a strong correlation with the position of underlying ore. Data are reproduced from the work of Hedström and Nordström (see abs. 38), showing increased uptake of chromium in plants growing in three to four feet of residual soil over a chromite deposit in Greece. Original data collected by the author show increased lead content of the leaves of *Acer saccharum* over a lead deposit in Canada.—H. E. H.

65. Lungwitz, E. E. Der geologische Zusammenhang von Vegetation und Goldlagerstätten [The geologic relationship of vegetation and gold deposits]: Zeitschr. prakt. Geologie, vol. 8, pp. 71-74, 1900.

(Not reviewed)

66. Maliuga, D. P. On soils and plants as prospecting indicators for metals [in Russian]: Izv. Akad. Nauk. SSSR, Ser. Geol., no. 3, pp. 135-138, 1947.

Some earlier work on the composition of plants and soils as related to geology is reviewed, and original data are presented on the increased cobalt and nickel content of plants and soils in the vicinity of mineral deposits in the Urals.

The normal cobalt content of soil is about 10 ppm, and the normal nickel content is 40 ppm; thus, the ratio of cobalt to nickel is 1:4. In the A<sub>1</sub> horizon of a podsollic soil above the Ufaiei nickel deposit, the cobalt content was found to be 12 ppm, or about the same as in normal soil; and the nickel content was 130 ppm, or about three times normal. However, cobalt and nickel were found to have greatly enriched all horizons of chernozem soils above two shallow nickel deposits in the South Urals. Cobalt was found in amounts ranging from 84 to 850 ppm, or 8.4 to 85 times greater than normal. Nickel enrichment was even more, ranging from 1,300 to 6,900 ppm, or 32 to 170 times greater than normal. The ratio of cobalt to nickel ranged from 1:8 to 1:30 over the cobalt-nickel deposits, indicating that nickel has enriched more than cobalt. Cobalt and nickel have enriched most in the uppermost 5 to 10 cm. of the latter soil. Their concentration decreases with depth through the B<sub>1</sub> horizon.

Plants are also enriched in cobalt and nickel near certain nickel deposits. *Stipa Capillata* L., was found to contain 2.2 ppm cobalt and 8.7 ppm nickel where growing on a normal chernozem soil. A sample of this grass growing in a chernozem soil over a cobalt-nickel deposit contained 280 ppm cobalt and 6,400 ppm nickel. This is 127 times above normal for cobalt and 735 times above normal for nickel. Thus, plants are also relatively more enriched with nickel than cobalt.

A pine, *Pinus sylvestris* L., contained 6.5 ppm cobalt and 36 ppm nickel where growing on a normal podsollic soil. This pine growing in a podsollic soil over a cobalt-nickel deposit contained 45 ppm cobalt, about 7 times normal, and 620 ppm nickel, which is 20-times normal.

The author concludes that enrichment of cobalt and nickel in soils and plants provides an effective prospecting indicator for deposits of these metals.—*J. W. H.*

67. Maliuga, D. P. Soils and plants as indicators in prospecting for metals [in Russian]: *Priroda*, vol. 36, no. 6, pp. 13-17, 1947.

This paper is identical with previous paper by Maliuga. (See abs. 66.)

68. Maliuga, D. P. Experimental use of soil-flora method of exploration in Transural steppe provinces [in Russian]: *Doklady Akad. Nauk SSSR*, vol. 76, pp. 231-233, 1951.

(Not reviewed.)

69. Micholić, Stanko. A geochemical method of prospecting ore deposits: *Internat. Geol. Cong., "Report of the Eighteenth Session,"* pt. 2, pp. 86-87, 1950.

It has been shown elsewhere (Miholić, S., *Ore deposits and geologic age: Econ. Geology*, vol. 42, pp. 713-720, 1947) that there is a certain parallelism between the geologic age of a system of joints and faults and the mineral deposits connected with them. In order to determine the age of such a system, the age of igneous rocks formed simultaneously is determined by a radioactive method. Besides the classical method based on the determination of uranium, thorium and lead, a much quicker and more convenient method based on the radioactive transformation of rubidium into strontium can also be used. When the age of the system is thus determined, the determination of heavy metals (other than iron and manganese) in mineral and thermal waters of the region gives an additional hint. The method has been applied with success in 1940 while prospecting for copper in Northwestern Croatia.—*Author's abstract.*

70. Millman, A. P. Geochemical prospecting by the field analysis of surface waters: *Mine and Quarry Eng.*, vol. 16, pp. 145-148, 1950.

A review of the general principles of ore prospecting by analysis of surface waters.

71. Ozerov, I. M. The stannometric survey as a prospecting method [in Russian]: *Razvedka Nedr.*, no. 24, pp. 52-56, 1937.

The author describes the experience of his field party in the exploration and development of tin deposits in the North Kirgiz region. A portable field spectroscope was used for quantitative analyses for tin in samples of alluvial materials. A method of determining the concentration of tin by means of the order of appearance of its spectral lines is described in detail.—*A. P. P.*

72. Prokofiev, V. Summary of the report "The feasibility of spectroanalyses of rare and minor metals in rocks and ores, and the practicality of constructing the apparatus" [in Russian]: *Prob. Sov. Geol.*, vol. 6, p. 740, 1936.

Members of the Government Optical Institute (U. S. S. R.) obtained successful results in performing quantitative spectroanalytical determinations for tin while

in the field during the summer of 1935. This method is being considered for use in the search for other metals. Analytical methods are presently being developed by the Institute for the determination of tungsten, bismuth and beryllium, which are often associated with tin. It is possible to determine an element quantitatively either by comparison of intensities of the spectral lines or if the element, such as tin, possesses many lines of differing intensity, by the order of appearance of the lines.—A. P. P.

73. Raeburn, C., and Milner, H. B. Alluvial prospecting, 478 pp., Thos. Murby and Co., London, 1927.

The theory and practice of exploration for placer deposits are exhaustively reviewed, with particular emphasis on nonprecious heavy minerals. The classification, lithology, provenance, and mechanics of formation of alluvial deposits; the equipment and procedures used in sampling; and methods of heavy mineral identification are discussed at length. Although this treatise is aimed at exploration for placer deposits, many of the principles and techniques discussed are pertinent to problems of prospecting for primary ores by mineralogical and chemical analysis of stream sediments. For example, in the chapter on provenance, the authors discuss various heavy mineral assemblages that are characteristically derived from certain types of parent rock.

The behavior of the various heavy minerals in stream transport as determined by hardness or cleavability is considered. For example, relatively soft minerals, such as wolframite, tend to be pulverized and to enter the fines rather than the heavy fraction of stream sediment. The soft minerals rarely form economic placer deposits. Colloidal clay may carry fine gold, so that gold is more mobile in muddy streams than in clear streams. Flaky minerals such as platinum tend to travel farther than equidimensional minerals such as cassiterite.—H. E. H.

74. Rankama, K. K. On the use of the trace elements in some problems of practical geology; Soc. géol. Finlande Comptes rendus, vol. 14, p. 92-106, 1940.

The nickel content of the ash of the birch leaves from two nickel mining districts in Finland was investigated by spectrographic analysis. At Makola, where 3 to 4 meters of peat and glacial materials overlie the bedrock, samples were collected on a grid pattern. The NiO content of the ashed samples ranged from 200 ppm to less than 10 ppm with, in general, the highest values near the ore body. The possibilities of the use of minor elements in prospecting are discussed.—L. C. Huff.

75. Rankama, K. K. Über eine neue Prospektionsmethode [On a new method of prospecting]: Geologischen Rundschau, vol. 32, pp. 575-578, 1941.

An outline of the principles of spectrographic analysis of plant ash as a prospecting method.

76. Rankama, K. K. *Kemia malmintutkimuksen apuna: geokemialliset ja radioaktiiviset menetelmät prospektauksessa* [Chemistry as an aid in the search for ore; geochemical and radioactive methods of prospecting]: Kemian Koskusliiton Eripainoksia, vol. 27, no. 4, pp. 3-11, 1945.

(Not reviewed.)

77. Rankama, K. K. Some recent trends in prospecting: chemical, biogeochemical, and geobotanical methods: Mining and Metallurgy, vol. 28, pp. 282-284, 1947.

The development (exclusive of Russia) of prospecting methods based on chemical and biological studies of plants, soils, and water is reviewed.

78. Ratsbaum, E. A. Method of increasing the precision of results of spectral determinations for tin in field exploration [in Russian]: Razvedka Nedr., no. 8-9, pp. 50-52, 1938.

The precision of semiquantitative spectrographic determinations for tin in prospecting work may be increased by using cobalt as an internal standard.—*H. E. H.*

79. Ratsbaum, E. A. Field spectroanalytical laboratory for servicing prospecting parties [in Russian]: Razvedka Nedr., vol. 10, no. 1, pp. 38-41, 1939. Translated by V. P. Sokoloff, "Selected Russian papers on geochemical prospecting for ores", U. S. Geol. Survey, pp. 1-6, Feb. 1950.

The author presents a complete list of equipment necessary to outfit a mobile field spectrographic laboratory mounted in a truck. The list is based on the author's experience with mobile laboratories in the Turkestan Expedition in 1936.

80. Reiche, Parry. A survey of weathering processes and products: Univ. of New Mexico Pub. in Geology, no. 3, 95 pp. 1950.

The author presents a comprehensive summary of modern concepts of the physical, chemical, and biological factors involved in weathering, with 88 references.

81. Reichen, L. E. Geochemical field method for the determination of nickel in plants: Anal. Chem., vol. 23, pp. 727-729, 1951.

Fresh leaves or vegetation are ashed directly over an open flame in platinum dishes. Ten milligrams of ash are taken up in hydrochloric acid, buffered with sodium citrate, the pH is adjusted to 8.8 with ammonium hydroxide in a total volume of 2 ml, and the solution is filtered through a filter stick. A confined spot is made with a chromograph in reagent paper impregnated with dimethylglyoxime using 0.2 ml of this solution. The test spots are then compared with standard spots.

The test is intended mainly for concentrations from 0.02 to 0.5 percent nickel in the ash of a plant; however, the difference between 0.003 and 0.010 percent was detected by increasing the weight of the ash analyzed and holding the volume constant. Results of analyses of plants for nickel by this field test agreed within 30 percent or less of the true nickel content. This is satisfactory for reconnaissance field work in biogeochemical prospecting.

All of the apparatus is portable, and none of the reagents are hazardous to transport—so that a field laboratory can be set up at any base of operations. The direct method of ashing takes only a few minutes as compared with the hours required by wet-digestion or dry ashing in a furnace. The rapid ashing combined with the confined spot, which takes about 3 minutes to make, makes it possible to analyze a minimum of 30 samples a day.—*Author's abstract.*

82. Reichen, L. E., and Lakin, H. W. Field method for the determination of zinc in plants: U. S. Geol. Survey Circ. 41, 1949.

A field method for estimating zinc in fresh plant leaves is described whereby samples are collected with a leaf punch and ashed directly over a flame, the zinc in the ash then being determined with dithizone. Results obtained by the field method compare favorable with those obtained by the more precise laboratory method. Forty or more samples can be tested for zinc in a day.—*Authors' abstract.*

83. Reichen, L. E., and Ward, F. N. Field method for the determination of molybdenum in plants: U. S. Geol. Survey Circ. 124, 4 pp., 1951.

Fresh plant material is ashed directly by heating in nickel or platinum dishes over a flame. An acid solution of 25 milligrams of ash is treated with stannous chloride and potassium thiocyanate. The amber-colored molybdenum thiocyanate complex ion is extracted with isopropyl ether, and the intensity of the color of the ether layer over a sample solution is compared with the ether layer over standard molybdenum solutions treated similarly. Field determinations can be made quickly and the method requires no special equipment. As little as 0.25 microgram or 0.001 percent molybdenum can be determined in plant ash.—*Authors' abstract.*

84. Riley, L. B. Ore body zoning: Econ. Geology, vol. 31, pp. 170-184, 1936.

Ten samples of rock were collected along a mine crosscut in a partially oxidized silver-lead ore body at Sierra Mojada, Mexico. The line of samples extended through the ore body and into barren and only slightly altered wallrock on both sides. The samples were treated with hydrochloric acid, and a series of rapid microchemical tests were made on the elements extracted by the acid. The minerals that were not dissolved by the acid were examined microscopically. Distribution patterns, or halos, systematically related to the distance from the walls of the ore were found for euhedral quartz, "microsilica," aluminum silicate, gypsum, carbon dioxide, zinc, arsenic, and lead. Some of these features are thought to be primary and some the result of dispersion during oxidation of the deposit. The author recommends similar studies of mineralogical and chemical halos around ore deposits as a method of exploration.—*H. E. H.*

85. Roberts, E. E. Geochemical and geobotanical prospecting for barium and copper; Unpublished Ph. D. thesis, Stanford University, 1949.

The major purpose of this investigation has been to develop geochemical and geobotanical methods of prospecting for barite deposits. Either soil or plant leaves, and in some instances both, were collected at five barite deposits in California and Nevada. These were analyzed spectrographically and found to contain barium in highly variable amounts. Variation in the barium content of plants was shown to be definitely related to variation in the barium content of soil. Soil contained from less than 0.01 percent barium to about 10 percent; the ash of leaves contained from 0.01 percent to about 5 percent. The highest concentrations of barium were usually found nearest known barite veins. The ash of leaves generally contained several times as much barium as the soil on which the plant grew. These data show that dispersion halos of barium can be detected by analyzing either soil or plants.

A common disadvantage of plant analysis was the irregular distribution of the plant species to be sampled. This made collection of plant samples at uniform intervals difficult. The difficulty was overcome, however, by sampling

a second species to fill in the gaps. The barium content of one species was converted into terms of the other with a conversion factor, determined by analyzing samples of the two species obtained where they were growing close together. In this way the barium content of two species could be plotted as if only one species had been sampled. For example, interior live oak and whiteleaf manzanita were sampled at one barite deposit, and Douglas fir and whiteleaf manzanita at another deposit. By expressing the barium content of the oak and fir samples in terms of whiteleaf manzanita, the results were plotted as if only whiteleaf manzanita had been sampled.

The soil samples were obtained at depths ranging from the surface down to 24 inches. At one barite deposit, samples were taken at two intervals—surface to 12 inches and 12 to 24 inches beneath the surface. Most of the samples from the top interval were found to contain slightly more barium than those from the lower interval.

A study of 50 soil samples showed no correlation between the pH of the soil and its barium content. However, there is probably a rough correlation between annual rainfall and barium content of soil, for the highest content appears to be associated with areas where the rainfall is least.

An improvement in soil analysis technique was made by eliminating the grinding and splitting of samples. As an experiment, three soil samples were screened into two fractions, one to minus 1.65 mm and the other to minus 0.07 mm. The minus 1.65 mm fraction was ground in a mortar and split, but the minus 0.07 mm fraction received no further preparation. Analyses showed that the barium contents of both fractions were closely related, but the smaller fraction contained more barium than the larger fraction. Thus, grinding and splitting appear to be unnecessary, and screening to minus 0.07 mm is sufficient.

The author concludes that both soil and plant analysis should be useful in prospecting for barite deposits. Soil analysis appears to be simpler, however, because ashing is eliminated.

Copper in soil and tree leaves was investigated in a brief reconnaissance in Michigan's Keweenaw Peninsula copper country. Soil samples were collected about a mile apart and 18 inches deep along two traverses running perpendicular to the strike of the rocks. Spectrographic analyses showed the copper content to be greatest in samples collected over the copper-bearing series, which locally contains native copper. The copper-bearing series crops out within a belt several miles wide but is largely covered by glacial drift. Soil samples collected over adjacent barren sandstone formations contained considerably less copper. The copper content of quaking aspen leaves showed a correlation with the copper content of the soil on which they grew. The author recommends that further studies on geochemical prospecting for copper be undertaken.—J. W. H.

86. Robinson, W. O., Lakin, H. W., and Reichen, L. A. The zinc content of plants of the Friedensville zinc slime ponds in relation to biogeochemical prospecting: *Econ. Geology*, vol. 42, pp. 572-582, 1947.

The zinc content of thirty different kinds of plants growing on slime ponds containing on the average 12.5 per cent zinc were determined by the dithizone method. The zinc content ranged from 39 p. p. m. in the fruit of the false solomon's seal (*Smilacina racemosa*) to 5,400 in the horsetail (*Equisetum arvense*). This latter plant varied considerably in zinc at different places on the slime ponds. The zinc contents of the aspen (*Populus grandidentata*), ragweed (*Ambrosia artemisiifolia*), and horsetail grown on normal soils are compared to those on the slime ponds and it is recommended that the poplar and ragweed be studied further as indicators of zinc ore bodies.—Authors' abstract.

87. Rokhlin, M. I. Use of the stannometric survey in the Arctic under permanent frost conditions [in Russian]: *Prob. Arktiki*, no. 4, pp. 61-90, 1938.

The writer discusses the problems of prospecting for tin in the primary rocks, residual and alluvial deposits, and beach sands of Arctic regions. Examples are given of the results of surveys made over a quartz-tourmaline-cassiterite deposit and over a sulfide-cassiterite deposit. A spectrographic field laboratory was used to determine the concentration of tin in samples of residual material overlying the deposits.

A theoretical derivation of the size, distribution, and sorting properties of cassiterite in alluvial sands is made, and a profile showing the observed concentrations of tin in the different size fractions of a marine placer deposit is given.—A. P. P.

88. Rosenqvist, Anna M. Geokjemisk og geobotanisk malmleting xiv. Et forsøk på å anvende hydrofile laver til geobotanisk malmleting. Kjemisk analyse av Cu i vannprøver. [Geochemical and geobotanical ore prospecting—14, Is it possible to use hydrophilic lichens as an indicator of ore poisoning by Cu in natural waters?]: *K. norske vidensk. selsk., Forh.* vol. 22, no. 20, pp. 82-87, 1950.

The variability of the growth of hydrophilic lichens in relation to the copper contents of the waters is investigated. The copper content of 24 samples from the Røros area has been determined. No correlation was found between the lichen-flora and the copper contents of the water. To judge from the present material the hydrophilic lichens do not seem to have a sufficient sensitivity of copper by the concentrations found.—*Author's abstract.*

89. Rosenqvist, A. M., and Vogt, Thorolf. Geokjemisk og geobotanisk malmleting V. Betemmelse av kobber i vannprøver analysemetoden. [Geochemical and geobotanical ore prospecting—5, determination of copper in natural waters, the analytical method]: *K. norske vidensk. selsk., Forh.*, vol. 15, no. 22, pp. 83-86, 1943.

A description is given of the method of Hahn and Leimbach for the determination of very small quantities of copper. The copper acts catalytically on the reduction of Fe (III) with  $\text{Na}_2\text{S}_2\text{O}_4$ , rhodanine being used as indicator. The standard solutions employed are listed, and the data of a numerical example are tabulated and plotted in a curve for adjustment. This method was used on natural waters in the Røros district in the summer of 1941 as a technique for chemical ore prospecting.—*Authors' English abstract.*

90. Safronov, A. P. and Sergeev, E. A. New geophysical methods for prospecting and surveying mineral deposits based upon the study for dispersion halos [in Russian]: *Razvedka Nedr.*, no. 18, pp. 24-25, 1936.

Recent studies have led to new methods of prospecting based upon the physical and chemical properties of the dispersion halo, zone of dispersed metals or elements usually associated with mineral deposits.

A method of determining anions, such as sulfate and chloride, in the soil by measuring the potential developed on specially designed electrodes has been developed for prospecting for sulfide deposits. This method, known as the electrode potential method, has been used with success at the Baurdu polymetallic deposit. A spectrochemical method for tin was instrumental in the discovery of a new tin vein at Khapcheranga. Drop analysis methods for boron were used successfully in exploration for borates in the Inder district.

All of these methods are in a stage of further development. Quantitative spectrochemical methods for tungsten, molybdenum, boron, and chromium, and polarographic methods for chromium, lead, zinc, and nickel are being developed.—*A. P. P.*

91. Salmi, Martti. Turpeiden hivenaineista [Trace elements in peat]: Geol. Tutkimuslartos. Geotek. julkaisu, no. 51, 20 pp. 1950.

Sixty-three samples of peat, representing forty-nine peat bogs in Finland and one in Norway, were analyzed spectrochemically for copper, zinc, cadmium, tin, lead, manganese, cobalt, and nickel. Of these fifty peat bogs, three occur in mineralized areas: copper and zinc are known to exist in the bedrock in the neighborhood of the Kivisuo bog, and in the black schist beneath the Viirusuo bog; the bog of Jakobsbakken adjoins a copper-nickel-lead deposit. So far as is now known, all of the other bogs are over unmineralized ground, and the data from them may be used for comparison with the bogs in the mineralized areas. The author's data may be summarized as follows:

Bog	Number of samples	Median content expressed as percent of ash							
		Cu	Zn	Cd	Sn	Pb	Mn	Co	Ni
Kivisuo.....	3	0.1	0.3	0.0003	<0.001	0.06	0.1	0.006	0.01
Viirusuo.....	6	.06	.1	<.0003	<.001	.003	.1	.006	.01
Jakobsbakken.....	3	.1			.003	.01	.01	.01	.1
All others.....	51	.03	<.03	<.0003	<.001	.003	.1	.003	.01

The author concludes that 0.1 percent copper and 0.6 percent zinc in peat ash indicates rock mineralized respectively with copper and zinc. In the Jakobsbakken bog, 0.03 to 0.1 percent nickel could be regarded as an indication of nickel-bearing ore.—*H. E. H.*

92. Saukov, A. A. Geochemistry of mercury [in Russian]: Akad. Nauk. SSSR, Inst. Geol. Nauk Trudy, vol. 78, Mineral-Geokhim, ser. no. 17, 129 pp., 1946.

This is a comprehensive treatise on the geochemistry of mercury, including a chapter on primary and secondary dispersion halos of mercury and their relation to cinnabar deposits. During hydrothermal deposition, mercury and its sulfides, in the gaseous state, may penetrate country rock and produce halos extending hundreds or even a few thousand meters beyond the ore deposits.

Twenty-three samples of shale and sandstone collected along a 3,100 meter traverse crossing the Khpek mercury deposit, Latankhor district, were found to contain from 0.09 and 0.12 ppm Hg at the ends of the traverse, to a maximum of 17.6 ppm. The average of all samples is 8.3 ppm, well above the 0.077 ppm value for the average of the Earth's crust. The width of the zone of mercury-rich rocks is about 2,000 meters. The data suggest that shale commonly contains somewhat more mercury than sandstone from the same locality. A 3,500 meter traverse across the Khpek deposit also shows abnormally high mercury content in shales and sandstones adjoining the vein over a width of about 1,000 meters. Twenty samples of shale and marl collected along two traverses, each over 2,000 meters long, across the Kazardikam deposit, Dagestan, contained an average of over one ppm mercury, but did not show a well-defined pattern related to the known ore.

Mineral specimens collected from various types of ore deposits were analyzed spectrographically for mercury. Barite from Khaidarkhan contained 20 ppm



Hg and barite from Ashata 10.4 ppm. Barite from the Tiua-Muiun uranium deposit, Central Asia, is also considerably enriched in mercury. Calcite and stibnite specimens were also found to be rich in mercury.

Cinnabar occurring in alluvial placers is mentioned as an example of secondary dispersion of mercury.

The author concludes that rapid field methods of analysis for mercury would be of considerable value to the field geologist in mapping mercury-bearing districts.—*H. E. H.*

93. Schmitt, Harrison. Outcrops of ore shoots: *Econ. Geology*, vol. 34, pp. 654-673, 1939.

The original surface features that led to the discovery of ore bodies in nine districts in the Southwestern United States and northern Mexico are described. Evidence of hydrothermal leakage of base metals has been observed in channelways extending upward from two sulfide deposits in the Hanover district, N. Mex. In the Parral district, Chihuahua, the author finds (p. 667) that

\* \* \* all of the ore shoots are expressed at the outcrop by some silver (by assay), even if blind. In searching for ore shoots a good procedure is to cut samples across the outcrop of the vein at regular intervals, \* \* \* and sink a prospect hole where the assays are highest, even though the silver content is below that of ore grade.

One small ore body was found by this method. In general, where the channelways are open, the ore shoots and their associated leakage halos pitch steeply, whereas in manto deposits in flat-lying limestones horizontal flow may predominate. Leakage is commonly evidenced at the surface by low-grade gossans, thin seams of high-grade gossans or cappings, and residual gangue minerals. In places, a diagnostic "alteration jacket" of secondary silicate minerals or dispersed base-metal sulfides may be associated with blind ore deposits.—*H. E. H.*

94. Sergeyev, Ye. A. Application of drop analysis in prospecting for mineral deposits [in Russian]: *Razvedka Nedr*, no. 12, pp. 27-29, 1936.

The search for methods which may be used in prospecting for concealed borate deposits has led to the development of a semiquantitative colorimetric test for borate ions suitable for use in the field. This method utilizes the reaction of boric acid with quinalizarin to give a blue reaction product. An example of results obtained over a borate deposit in the Inder region is given.—*A. P. P.*

95. Sergeyev, Ye. A. Geochemical method of prospecting for ore deposits [in Russian]: *Materialy Vsesoiuznogo Nauchno-Issledovatel'skogo Geologicheskogo Instituta, Geofizika, sbornik* 9-10, pp. 3-55, 1941. [Translated by V. P. Sokoloff, "Selected Russian papers on geochemical prospecting for ores," *U. S. Geol. Survey*, pp. 15-87, Feb. 1950.]

This paper is a comprehensive summary up to 1940 of Russian work on soil analysis as a method of prospecting for ore deposits. The author discusses the origin of and methods for detecting mechanical, saline, and complex types of dispersion halos. Details of field procedure, equipment, and techniques for the chemical and spectrographic determination of heavy metals in soil samples are given. The results of twenty experimental field projects using geochemical methods are described, and mineral discoveries attributable to soil analysis are listed.—*J. W. H.*

96. Sergeyev, Ye. A. Water analysis as a means of prospecting for metallic ore deposits [in Russian]: *Razvedka Nedr.*, vol. 12, no. 2, pp. 51-55, 1946. Translated by H. E. Hawkes, "Selected Russian papers on geochemical prospecting for ores", U. S. Geol. Survey, pp. 7-12, Feb. 1950.]

In 1941 field experiments were made in the Altai Mountains, Siberia, to determine whether analyses of stream water would be useful in prospecting for ore deposits. Analyses of water sampled at successive points from mouth to headwaters of streams in two mineralized areas showed that heavy metals derived from the leaching of sulfide bodies could be readily traced in the streams. The author concludes that application of this method is favored where the ore bodies are undergoing active oxidation, where the soluble products of oxidation are discharged into the surface drainage, and where the drainage system is well developed.—J. W. H.

97. Sergeyev, Ye. A. A new luminoscope for field use [in Russian]: *Razvedka Nedr.*, vol. 12, no. 5, pp. 41-42, 1946. [Translated by V. P. Sokoloff, "Selected Russian papers on geochemical prospecting for ores," U. S. Geol. Survey, pp. 13-14, Feb. 1950.]

A luminoscope for field use has been developed in Russia for detecting dispersion halos containing fragments of fluorescent minerals. The instrument consists of a light-proof cylinder, the upper end of which is equipped with a quartz-mercury ultraviolet lamp and a magnifying eyepiece. The open lower end of the apparatus is placed over the test area of ground that has been stripped of humus to expose any fluorescent minerals that may be present. A hand-cranked generator supplies current. Minute amounts of many fluorescent minerals can be observed; for example, in laboratory experiments less than 0.05 percent of scheelite in fragmented rock material was definitely detectable.—J. W. H.

98. Sergeyev, Ye. A., and Solovov, A. P. The ionic method of geophysical prospecting [in Russian]: *Materialy, Tsentral'nyi Nauchno-Issledovatel'skii Geologo-Razvedochnyi Institut, Geofizika*, no. 3, pp. 1-10, 1937. [Translated and abstracted by H. E. Hawkes, "Selected Russian papers on geochemical prospecting for ores," U. S. Geol. Survey, pp. 89-96, 1950.]

Sulfate ion and sulfuric acid concentrations in soil moisture may be determined in the field by measuring the spontaneous potential generated on an electrode inserted into the ground. A lead electrode coated with lead sulfate is used to determine sulfate ion concentration; a platinum electrode coated with lead peroxide is used to determine sulfuric acid concentration. The physical theory of the method and the construction of the apparatus are discussed. On the basis of field experiments in Russia, the authors recommend the method as a means of prospecting for oxidizing sulfide deposits.—J. W. H.

99. Sigov, A. P. Prospecting by heavy mineral studies [in Russian]: *Ural Sci. Res. Inst. of Geol. Prospecting and Econ. Mineralogy*, Trans. no. 4, 64 pp., 1939.

Techniques are described in detail for mapping, sampling, and mineralogical determinations of alluvial material as a method of prospecting for both placer and lode deposits of tin, tungsten, mercury, molybdenum, zirconium, tantalum, niobium, thorium, and rare earths.—H. E. H.

100. Sofronov, N. I. On the "aureoles of dissemination" in mineral deposits and their use in prospecting [in Russian, with English summary]: *Prob. Sov. Geol.*, vol. 6, pp. 302-323, 1936.

The author reviews the known facts of alterations of primary deposits in the zone of weathering. He comes to the conclusion that the outcrops of the deposits are regularly connected with zones of accumulation of talus or products of disintegration resting more or less in place, rich in characteristic or useful elements of the deposit in different phases.

For these zones the author proposes the name "aureoles of dissemination" ("dispersion halos"), and divides them according to the state of the contained characteristic or useful element into "salt", "mechanical", and "gaseous" aureoles. In the "salt aureoles", the characteristic or useful element is present in liquid state (as easily soluble salt), in mechanical aureoles in the shape of steady minerals, and in gaseous ones in the form of gas.

The author recommends a wide use in prospecting of the aureoles of dissemination as a feature indicating the presence of different deposits. In many cases they can be used in geological surveying.

The search for aureoles is carried out by means of an original method which is called the physico-chemical method of prospecting. It is based upon a testing of surface formations on a large scale by means of the exact and quick methods of physico-chemical analysis.

For the search of salt aureoles of dissemination it is recommended to use selective electrodes and a polarographical analysis on the base of an electroanalysis; spectro-metallometrical surveys for mechanical aureoles, etc.

In order to corroborate his conclusions about the use of the methods recommended the author quotes several examples from the work carried out successfully in 1935 by the geophysical department of the Central Scientific Geological and Prospecting Institute on very different deposits (polymetallic, borate, tin, deposits).—*Author's English abstract.*

101. Sofronov, N. I. and Solovov, A. P. Summary of reports, "Problems of spectroanalysis in survey work," and "Results of the application of spectroanalysis in prospecting for tin-bearing veins" [in Russian]: *Prob. Sov. Geol.*, vol. 6, pp. 739-740, 1936.

In 1935 a geophysical party of the Government Optical Institute used a portable Schmidt-Khynch prism spectrograph for quantitative tin analysis while prospecting in Khapcheranga. Satisfactory results were obtained for tin on samples of ore, drill cores, and alluvial materials. All the analyses were performed in a field laboratory. In two and a half months, over 2,500 spectrographic tin determinations were made as compared with 1,160 by conventional methods in the preceding five years. The spectrographic data led to the discovery of a new tin vein.—*J. W. H.*

102. Sokoloff, V. P. Chemical prospecting for ore [abstract]: *Geophysics*, vol. 13, p. 505, 1948.

A brief review of prospecting methods by analysis of soils, plants, and water for traces of lead, zinc, and copper.

103. Sokoloff, V. P. Geochemical prospecting for ore: *Mines Mag.*, vol. 38, pp. 21-24, 1948.

The principles of prospecting for ores by analysis of stream water, soil, and vegetation are discussed, with examples from the author's work. The dis-

tribution of heavy metals in surface waters of part of the Kokomo district, Colo., is illustrated graphically. Studies of glacial soil at Kokomo show a greater content of lead and zinc in soil over ore than in soil over barren rock, and greater in surface soil as compared with the subsoil. Studies at the Lucky Strike mine, at Kokomo, suggest that as a result of the glacial history the lead-zinc halo spreads uphill from the ore body rather than downhill. At Gold Hill, N. C., residual soil over a sulfide ore body shows a leaching of zinc throughout the profile, as contrasted with an accumulation of lead throughout the profile, especially in the subsoil. Copper at the Gold Hill locality tends to increase with depth, and shows a leaching effect intermediate between lead and zinc. The use of indicator and accumulator plants in prospecting are discussed. Abnormalities in plants resulting from unusually high amounts of certain metals in the soil are illustrated by an example from the Kokomo area where chlorosis, or yellowing of the leaves, of willows was found to occur over soil containing about one percent zinc.—H. E. H.

104. Sokoloff, V. P. Geochemical reconnaissance in the Wallaroo mining district: South Australia Dept. Mines, Mining Review, no. 88, pp. 32-64, 1949.

A geochemical prospecting reconnaissance was made in the Wallaroo-Moonta copper mining district of South Australia. Large scale soil sampling revealed that anomalous amounts of extractable copper in soil could be correlated with copper deposits in depth. At one place the physical character of the soil materials and the soil profile appear to reflect the presence of an ore body. The Wallaroo-Moonta mining district is well suited for geochemical prospecting investigations. Rock outcrops are scarce; the soil is thick, and the topography is flat. Soil samples were obtained from auger holes spaced 50 to 300 feet apart on 23 traverses. The traverses were run over both known ore bodies and unexplored ground. A total of 1,280 samples were obtained from 326 auger holes.

The soils of the Wallaroo-Moonta district are not over 20 feet thick and in places are less than 10 feet thick. The topsoil is underlain by a layer of travertine (caliche), which in turn is underlain by sandy clay, silty loam, and other unconsolidated materials. The bedrock is pre-Cambrian. The surface is mantled with tailings in places, but the more or less impermeable travertine appears to protect the underlying layers from contamination.

Soil samples were collected at a depth of ten feet, or immediately above bedrock, whichever was shallower. A new sample was begun at each change in the type of soil material. Only the samples obtained beneath the layer of travertine were analyzed for copper; the remaining samples were merely visually inspected. The travertine was drilled with a pneumatic jack hammer, and the unconsolidated materials were removed with augers. (See abs. 31.) Special care was taken to avoid contamination of samples. Tailings, if present, were removed from the surface at the sampling site, and every sample was examined for evidence of contamination.

After collection the samples were dried over a flame and crushed on an iron plate with a roller. Ten grams were treated with 0.25 N sulfuric or hydrochloric acid and the pH of the solution was adjusted to about 2.5. Copper was determined by shaking a portion of the sample solution with a solution of dithizone in carbon tetrachloride and estimating the copper content by the mixed color method according to an arbitrary scale.

The author concludes that there is an association between unusually high amounts of extractable copper in the lower part of the soil profile and known copper ore bodies in depth. The soil profile also appears to be modified over

or near certain ore bodies in the following manner: (1) There is a thinning or absence of the travertine layer, (2) the lower part of the travertine is reddish if it is present, and (3) a yellow sand-silt-clay mixture is present in the lower part of the soil profile. Study of the physical characteristics of the soil (texture, color, consistency, presence of concretions, and thickness) may be of considerable help in prospecting for copper deposits, especially if they are interpreted in conjunction with the geochemical data.—*J. W. H.*

105. Sokoloff, V. P. Geochemical prospecting methods: West Australian Min. and Commercial Rev., vol. 13, no. 12, p. 16, Feb. 1949.

The detection of dispersion halos by analysis of soils, plants and water is briefly discussed.

106. Sokoloff, V. P. Sampling and testing of soil and rock for copper, lead, and zinc in geochemical reconnaissance: Mines Mag., vol. 40, no. 11, pp. 15-22, 1950.

Procedures used by the author for collection and preparation of samples of soil and rock in geochemical prospecting are described. Detailed instructions and a list of reagents and equipment for dithizone determination of copper, zinc, and lead are given.

107. Sokoloff, V. P. Geochemical prospecting methods bring results in Australia: Min. World, pp. 26-28, April 1950.

A brief account of geochemical prospecting for gold in western Australia is presented. (See abs. 108.)

108. Sokoloff, V. P. Dispersion of gold in rock and soil: Chem. Eng. and Min. Rev., vol. 43, no. 1, pp. 7-10, 1950.

The author reviews results of a study of the distribution of traces of gold in rocks and soils in the vicinity of gold-bearing orebodies in Western Australia. Drill cores analyzed for traces of gold showed a distribution of "gold-positive bands," suggesting diffusion of gold into the walls of the lode channels. These bands are interpreted as the trace analogues of economic lodes, localized by microstructures in the country rock. Sampling and analysis of mature residual soils showed a correlation between gold anomalies in the soil and known lodes. In an experimental reconnaissance, several gold anomalies and a buried body of gold-bearing rock were discovered. The author points out that caution must be used in interpreting geochemical anomalies in soil because of uncertainty as to whether they reflect a large underlying deposit or are merely the remnants of a deposit that has been largely eroded.—*H. E. H.*

109. Sokoloff, V. P. Geochemical exploration for copper in the Wallaroo mining district, South Australia: Geoch. et Cosmoch. Acta., vol. 1, pp. 284-298, 1951.

A systematic examination of the polymorphic soil mantle in the Wallaroo Mining District, South Australia, resulted in a discovery of three copper anomalies in the lower soil horizons. The exploratory borings of these anomalies established a sub-economic chalcopryite mineralization at several hundred feet depth. The outcome of the project so far may be described as a technical success (the copper ore was found) but a commercial failure (less than 0.5% chalcopryite in the ore).—*Author's abstract.*

110. Sokoloff, V. P. Exploration for copper in Wallaroo mining district, South Australia: *Chem. Eng. and Min. Rev.*, vol. 43, pp. 331-341, 1951.

The author's experimental geochemical prospecting study at Wallaroo is reviewed. (See abs. 104.) Subsequent drilling of three of the copper anomalies in soil reported in the author's previous paper showed disseminated chalcopyrite in the underlying rock. Inasmuch as the maximum copper content was one percent, the results were considered a technical success but a commercial failure.—*H. E. H.*

111. Starr, C. C. Leaf samples as an aid to prospecting for zinc: *Western Miner*, vol. 22, no. 1, p. 43, 1949.

Ten samples of alder leaves and 11 samples of surface water were collected on the property of the Western Exploration Co., Ltd., Silverton, B. C. The zinc content of the alder leaves ranged from 139 to 1,111 ppm expressed on an ash basis; the water analyses show an average of about 0.3 ppm and reaches a maximum of 0.75 ppm zinc. The location of the samples with respect to the known veins is shown on a sketch. The author concludes that plant sampling may be useful in prospecting, but that water samples are of doubtful value.—*H. E. H.*

112. Stevens, R. E., and Lakin, H. W. The chromograph, a new analytical tool for laboratory and field use: *U. S. Geol. Survey Circ.* 63, 11 pp., 1949.

The chromograph, a new device for making confined spot tests on reagent papers, is described. The device is used to confine colored precipitates to a definite area on a strip of reagent paper fed through the apparatus, and to control automatically the rate of flow of test solution through the confined spot. After a spot test is completed, the sample number may be written on the paper, and the paper pulled through the apparatus to bring into position a spot on an unused portion of the reagent paper for the next test. The strips of paper containing the spots serve as semipermanent records of tests performed. The rate of flow of test solution through the reagent paper is controlled by the pull of a column of water and/or the filtrate from previous tests, and by a capillary tip which decreases the rate to less than that permitted by the paper alone.

Procedures for chromographic determination of nickel with dimethylglyoxime reagent paper and of copper with rubeanic acid reagent paper are described.

The device is readily adaptable to determinations in the field, as it is small, of light weight, and not easily damaged. Field kits containing chromographs are described. The chromograph has been used successfully in the field for locating nickel- and copper-bearing formations by testing samples of the overlying soils.—*Authors' abstract.*

113. Stoll, W. C. The presence of beryllium and associated chemical elements in the wallrocks of some New England pegmatites: *Econ. Geology*, vol. 40, pp. 136-141, 1945.

Samples of mica-schist and mica-gneiss wall rocks of some New England pegmatites were found, by spectrographic analysis, to contain lithium, beryllium, zinc, tin, lead, columbium, molybdenum, and cerium in extremely low concentration. The highest concentration of beryllium obtained was 0.0021 percent Be. It is thought likely that these elements were added to the wall rocks by solutions emanating from nearby channels of circulation of pegmatitic liquors during the time of emplacement of the pegmatite bodies. At least part of the added chemical elements found lodging as minor elements within common, rock-form-

ing minerals, possibly as a result of recrystallization of these minerals in the presence of the introduced solutions.—*Author's abstract.*

114. Sundberg, Karl. Moderna malmletningsmetoder [Modern methods of mineral exploration]: Jernkontorets Annaler, vol. 121, pp. 455-528, Uppsala, 1937.

New methods of prospecting, including geochemical techniques (pp. 456-460), are reviewed.

115. Swedish Prospecting Co. P. M. angående vår goekemiska prospekteringsmetod [Concerning our geochemical prospecting method]: 11 pp. Malmö, Sweden, Feb. 1939.

An advertising brochure on spectrographic analysis of plant ash as a prospecting method. Maps and charts show the relative amounts of tin, tungsten, lead, and zinc in plants growing near deposits of these metals in Cornwall and Wales.—*J. W. H.*

116. Takashiro and Fujiwara. Geochemical prospecting of metallic ore deposits [in Japanese]: Jour. Geol. Soc. Japan, vol. 57, no. 670, 1951.

(Not reviewed)

117. Tikhomirov, N. I., and Miller, S. D. On a physico-chemical method of prospecting for molybdenum in the semi-desert climate of the northern Lake Balkhash area [in Russian]: Razvedka Nedr., no. 2, pp. 34-39, 1946. [Translated by H. E. Hawkés, "Selected Russian papers on geochemical prospecting for ores," U. S. Geol. Survey, pp. 97-103, 1950.]

Weathered rock material was analyzed at the Kounrad molybdenite-wolframite deposits of the northern Lake Balkhash area, Soviet Central Asia. A mantle of granitic rubble and sandy clay, 10 to 80 cm. thick, overlies the mineralized veins. Samples of this material were collected at intervals of 0.5 to 5 meters along traverses perpendicular to the veins. Semiquantitative spectrographic analyses show that there is an extremely well-defined halo of dispersed molybdenum. Furthermore, there is a correspondence between the width and molybdenum content of the halo, and the thickness of the vein. Tungsten also forms dispersion halos, but they are less distinctive.—*J. W. H.*

118. Tkalic, S. M. Investigation of vegetation as a guide in prospecting [in Russian]: Vest. Dal'nevostoch. Filiala Akad. Nauk [Vladivostok], no. 32 (5), pp. 3-25, 1938.

The author discusses plant life and plant ecology as related to the chemical composition and geologic structure of the substratum. Tables are given showing the approximate concentrations of many of the elements in soils, rocks, ores, dispersion halos, and in several plant species.

Controlled experiments were carried out to determine the ability of plants to absorb different elements. Plants artificially nourished by solutions of copper sulfate, iron sulfate, and sodium chloride were analyzed quantitatively. Other experiments were carried out upon plants grown in prepared soils containing copper, zinc, and iron sulfide minerals. Also, analyses were made of plants growing in the vicinity of known ore bodies. An example is given of a successful survey for iron in leaves of *Calamagrostis* (beach grass) growing in the area of the Unashin arsenopyrite deposit.

Microchemical, colorimetric, and spectrochemical methods of analysis were used to obtain quantitative determinations of metals in plants. Semiquan-

titative determinations for copper were made by microchemical methods in the field.—A. P. P.

119. Vogt, J. H. L. Nickel in igneous rocks: *Econ. Geology*, vol. 18, pp. 307-353, 1923.

The tenor of nickel in the sulfide minerals of nickeliferous pyrrhotite ores is apparently related to the nickel content of the genetically associated basic igneous rocks and their constituent ferromagnesian minerals.—H. E. H.

120. Vogt, Thorolf. "Kjemisk" og "botanisk" malmleting ved Røros ["Chemical" and "botanical" prospecting in the Røros area]: *K. norske vidensk. selsk., Forh.*, vol. 12, pp. 81-84, 1939.

Stream waters draining sulfide deposits of the Røros district contain easily detectable amounts of the sulfate ion. Testing for sulfate ion in natural waters or in aqueous soil extract, using barium chloride, may be useful in prospecting for sulfide deposits. Hydrochloric acid may be added to the water to expel carbon dioxide. Reagents for testing for copper (ferric thiocyanate and sodium thiosulfate), zinc (in the absence of ferric compounds: ammonium mercuric thiocyanate), and nickel (diphenylglyoxime) are mentioned as testing reagents in the field.—*Revised author's abstract.*

121. Vogt, Thorolf. Geokjemisk og geobotanisk malmleting II. *Viscaria alpina* (L.) G. Don som "kisplante" [Geochemical and geobotanical ore prospecting—2, *Viscaria alpina* (L.) G. Don as a pyrite plant]: *K. norske vidensk. selsk. Forh.*, vol. 15, no. 2, pp. 5-8, 1942.

The occurrence of *Viscaria alpina* (L.) G. Don on different rocks, particularly on serpentine, dunite, and outcrops of cupriferous pyrite deposits, in Norway is discussed. It is presumed at present that the thriving of the plant at these ore deposits is principally due to its enduring large contents of copper, etc., in the soil, the plant being thus left without competitors.—*Author's abstract.*

122. Vogt, Thorolf. Geokjemisk og geobotanisk malmleting III. Litt om planteveksten ved Rørosmalmene [Geochemical and geobotanical ore prospecting—3, Some notes on the vegetation at the ore deposits of Røros]: *K. norske vidensk. selsk. Forh.*, vol. 15, no. 6, pp. 21-24, 1942.

As stated in a previous communication (II), *Viscaria alpina* (L.) G. Don in the Røros area, is reported only from serpentine and cupriferous sulfide deposits. *Melandrium dioicum* (L.) Schinz and Thell., found profusely at some ore deposits, also stands the ore-poisoned soil very well. Further, the following plants are growing on more or less ore-poisoned soil: *Equisetum arvense* L., *Equisetum palustre* L., *Equisetum limosum* L., *Juncus trifidus* L., *Agrostis canina* L., *Agrostis borealis* Hn., *Deschampsia flexuosa* (L.) Trin., *Eriophorum vaginatum* L., *Eriophorum polystachyum* L., *Carex rostrata* Stokes, *Salix reticulata* L., *Salix herbacea* L., *Salix glauca* L., *Salix arbuscula* L., *Betula odorata* Bechst. coll., *Betula nana* L., and the moss *Oligotrichum hercynicum* (Hedw.) Lam.—*Author's abstract.*

123. Vogt, Thorolf. Geokjemisk og geobotanisk malmleting VII. Sporelementer i myrmalm og sjømalm, [Geochemical and geobotanical ore prospecting—7, Trace elements in bog and lake ores]: *K. norske vidensk. selsk. Forh.*, vol. 15, pp. 91-94, 1942.

X-ray spectrograms show that zinc, copper, nickel, cobalt, and calcium are co-precipitated with manganese hydroxides in bogs and lakes. Analysis of bog



and lake ore may be useful in determining the types of ore deposits to be expected within the drainage basin.—*J. W. H.*

124. Vogt, Thorolf, and Bergh, H. Geokjemisk og geobotanisk, malmleting, X. Bestemmelse av kobber i jordprøver. [Geochemical and geobotanical prospecting—10, Determination of copper in soil]: K. norske vidensk. selsk. Forh., vol. 19, pp. 76–79, 1946.

Soil humus can bind comparatively large quantities of copper and other heavy metals. This is due to the adsorption or chemisorption of heavy metal cations to humic acids, forming metal humates. A grid of 134 samples of humus-rich glacial soil, collected near the southern Lossius copper deposit near Røros, reveals copper isograds that outline a fan of glacial dispersion. The copper content of soil within the fan varies from 500 to 7,000 ppm, as compared with 20 ppm in normal soil.—*J. W. H.*

125. Vogt, Thorolf, and Bergh, H. Geokjemisk og geobotanisk malmleting, XII. Bestemmelse av jern og mangan i jordprøver. [Geochemical and geobotanical ore prospecting—12, Iron and manganese in soil]: K. norske vidensk. selsk. Forh., vol. 20, no. 27, pp. 106–111, 1948.

Iron, manganese, and humus content were determined in 72 samples of glacial soil collected on a grid near the southern Lossius sulfide deposit near Røros. Iron content ranges from 100 to 45,000 ppm, while manganese ranges from 1 to 3,500 ppm. Humus content ranges from about 5 to 80 percent in the soil. The areal distribution of iron and manganese are similar, but the distribution of humus content shows little relation to that of iron and manganese. The authors conclude that determination of iron and manganese in soil may be useful in prospecting for deposits containing iron sulfide.—*J. W. H.*

126. Vogt, Thorolf, and Bergh, H. Geokjemisk og geobotanisk malmleting, XI. Sink og bly i jordprøver. [Geochemical and geobotanical ore prospecting—11, Zinc and lead in soil]: K. norske vidensk. selsk. Forh., vol. 20, no. 26, pp. 100–105, 1948.

The results of 134 determinations of zinc and lead made in 1942 and 1943 on soil from the outcrop of the southern Lossius sulphide deposits near Røros are published. The contents of zinc varies from 4 to 7,500 mg Zn per kg waterfree soil. As the zinc contents in normal soil may be about 100 (50–200) mg per kg. the concentration factor near the ore deposits lies about 5 to 50.

The contents of lead are 0 to 440 mg Pb per kg waterfree soil. The concentration factor may be of the same order as for zinc (and copper). The present method seems to be very useful for geochemical work on deposits containing Cu, Zn, Pb, and probably also for other heavy metals.—*Authors' abstract.*

127. Vogt, Thorolf, and Braadlie, O. Geokjemisk og geobotanisk malmleting, IV. Plantevekst og jordbuunn ved Rørosmalmene. [Geochemical and geobotanical ore prospecting—4, Vegetation and soil at the ore deposits of Røros]: K. norske vidensk. selsk. Forh., vol. 15, no. 7, pp. 25–28, 1943.

Some analyses of ore-poisoned soil from Røros are presented in a table. The soil samples are mostly taken near the roots of different plant species growing scattered on the poisoned soil, and also from the ground with normal vegetation in the immediate neighborhood. The weathering ore is composed of pyrrhotite, chalcopyrite, some sphalerite, etc. The decisive poison agent in the soil probably was the copper, possibly also  $\text{FeSO}_4$ . The plant species, arranged according to the copper content in the soil, are tabulated.—*Authors' abstract.*

128. Vogt, Thorolf, Braadlie, O., and Bergh, H. Geokjemisk og geobotanisk malmleting IX. Bestemmelse Cu, Zn, Pb, Mn, og Fe i planter fra Rørosfeltet. [Geochemical and geobotanical ore prospecting—9, Determination of copper, zinc, lead, manganese, and iron in plants from the Røros district]: K. norske vidensk. selsk. Forh., vol. 16, pp. 55–58, 1943.

The copper, zinc, lead, manganese, and iron contents of eight samples of plants growing over the Nyberget copper deposit are compared with that of four plant samples from normal soil. The content of these metals in different plant parts is highly variable and shows no consistent correlation with the location of the copper deposit. On an ash basis, the Cu content of the samples ranges from 43 to 13,600 ppm, the zinc from 4,200 to 39,400 ppm, the lead from 11 to 270 ppm, the manganese from 36 to 1,140 ppm, and the iron from 98 to 530 ppm. The authors conclude that the determination of copper and zinc in plants does not seem to be useful as a prospecting method in the areas studied.—J. W. H.

129. Vogt, Thorolf, and Bugge, Jens. Geokjemisk og geobotanisk malmleting VIII. Bestemmelse av kobber i planter fra Rørosfeltet ved kvantitativ røntgenanalyse. [Geochemical and geobotanical ore prospecting—8, Determination of copper in plants from the Røros district by quantitative X-ray analysis]: K. norske vidensk. selsk. Forh., vol. 16, no. 14, pp. 51–54, 1943.

X-ray spectrographic analyses of ash of 12 plant samples show that the leaves and twigs of dwarf birch (*Betula nana* L.) and willow (*Salix glauca* L.) contain more than twice as much copper where growing on copper-rich soil than on normal soil. The leaves contain more copper than the twigs, and the birch contains more than the willow. This indicates that the same parts of the same species must be collected for comparative results. The authors conclude that the method does not seem to be useful in prospecting for copper in the area studied.—J. W. H.

130. Vogt, T., and Rosenqvist, A. M. Geokjemisk og geobotanisk malmleting VI. Bestemmelse av kobber i vannprøver fra Rørosfeltet. [Geochemical and geobotanical ore prospecting—6, Determination of copper in natural waters from the Røros district]: K. norske vidensk. selsk. Forh., vol. 15, no. 23, pp. 87–90, 1943.

Copper was determined in surface waters in the Røros district as an experiment in prospecting for copper deposits. Four water samples containing 2 to 3.2 ppm copper came from a stream draining a mine, and six samples containing 0.05 to 0.185 ppm apparently received their copper from hidden ore. Fifty-seven samples containing a maximum of 0.044 ppm are believed to represent normal waters, the copper presumably coming from decaying plant material and soil.—J. W. H.

131. Thyssen, Stephan von. Geochemische und pflanzenbiologische Zusammenhänge in Lichte der angewandten Geophysik [Geochemical and botanical relationships in the light of applied geophysics]: Beitr. angew. Geophysik, vol. 10, pp. 35–84, 1942.

Certain plants enrich themselves in some of the metals that are present in small amounts in rocks and soils. Metals not toxic to plants are absorbed through the roots and concentrated largely in leaves and bark. Toxic elements, however, tend to be concentrated in the roots as a result of the plant's effort to reject them. The degree of concentration for each element can be expressed

as the "enrichment factor" (content in biosphere/content in lithosphere). The enrichment factor for each element rises with the atomic weights shown in the individual vertical rows of the periodic chart of the elements (copper-silver-gold for example), where as it remains essentially constant in the horizontal rows (sodium-magnesium-aluminum-silicon for example). Zinc, boron, strontium, beryllium, gold, copper, and lead have high enrichment factors, which range from 100 to 1,000 in some plants. On the other hand, molybdenum, iron, titanium, and aluminum have enrichment factors less than one.

Determination of metals with a high enrichment factor is recommended in biogeochemical prospecting for metals. It is pointed out, however, that the amount of metal taken up by a plant is greatly affected by the pH of the soil. Success in biogeochemical prospecting requires that variations in the metal content of plants be greater than that brought about by normal differences in soil pH.

The author recommends that biogeochemical prospecting investigations be made by analyzing healthy plant specimens of the same species and of the same size and stage of maturity.—J. W. H.

132. Ward, F. N. A field method for the determination of tungsten in soils: U. S. Geol. Survey Circ. 119, 4 pp., 1951.

The thiocyanate-stannous chloride method for the determination of small quantities of tungsten has been modified for use on soils in geochemical processing. A 0.25 g sample of soil is fused with a modified carbonate flux in a Pyrex test tube, extracted with water, and an aliquot of the aqueous extract is treated with stannous chloride and potassium thiocyanate in moderately concentrated hydrochloric acid. The tungsten thiocyanate complex ion, formed rapidly at a temperature of 90°C to 100°C, is extracted with a small volume of isopropyl ether, and tungsten determinations are made by comparing the yellowish-green color of the ether layer over a sample solution with that over a standard solution treated similarly. With a suitable aliquot, the field method can be used on soils containing 10 to 800 ppm of tungsten.—*Author's abstract.*

133. Ward, F. N. Determination of molybdenum in soils and rocks: Anal. Chem. vol. 23, pp. 788-791, 1951.

Molybdenum determinations have been made on soils and rocks using a 0.1-gram sample by a modified application of the thiocyanate-stannous chloride method. The finely powdered sample is fused in a test tube with a 1 to 1 mixture of sodium carbonate and potassium nitrate. The fused mass is extracted with hot water and filtered. An aliquot of the filtrate is transferred to a similar test tube, and neutralized, and the following reagents are successively added with shaking after each addition: sodium tartrate, concentrated hydrochloric acid, potassium thiocyanate, stannous chloride, and isopropyl ether. The latter, being almost immiscible with water, remains on top, and the brown colored thiocyanate complex of quinquevalent molybdenum collects in this phase. The determination is made in the same test tube by comparing the brown color of the organic layer produced by the sample with that given by a standard molybdenum solution.

The time required for each determination and the quantities of reagents used have been decreased proportionally with the size of the sample resulting in a rapid method with sufficient accuracy for exploratory and routine work. In an ordinary working day of 8 hours 25 to 30 determinations can be completed.

The useful range of the suggested procedure is from 0.1 to 32 ppm of molybdenum, but the upper limit may be extended without a great sacrifice in accuracy.

Finally, a small case will accomodate all the necessary chemicals and equipment, making possible the acquisition of useful geochemical data at temporary locations.—*Author's abstract.*

134. Warren, H. V., and Delavault, R. E. Biogeochemical investigations in British Columbia: *Geophysics*, vol. 13, pp. 609-624, 1948.

Different parts of various trees were analyzed for copper and zinc to determine which part or parts would be most useful in biogeochemical prospecting. Analyses of wood and bark have yielded erratic results; cones are too frequently absent from trees desirable for sampling, and leaves or needles may contain significant quantities of copper and zinc but are difficult to ash. The use of branches with needles or leaves attached is partially satisfactory, but dirt retained in the joints between leaves or needles and twigs may cause contamination. Young twigs are considered best because they ash readily, are easy to collect, and are less likely to be contaminated. Furthermore, deciduous trees, which apparently take up greater amounts of zinc than conifers, may be sampled in winter if twigs are collected.—*J. W. H.*

135. Warren, H. V., and Delavault, R. E. Further studies in biogeochemistry: *Geol. Soc. America Bull.*, vol. 60, pp. 531-560, 1949.

Several methods for the determination of traces of copper and zinc are presented; the authors conclude that the dithizone method is best. Samples of trees growing near the Britannia and Sullivan mines, British Columbia, were analyzed to provide data on the copper and zinc content that might be expected in trees adjacent to and some at a distance from buried ore bodies. Results suggest that the ratio of these metals is of more importance in biogeochemical prospecting than their absolute amount. The normal copper to zinc ratio is in the range of 0.10 to 0.15; a copper to zinc ratio greater than 0.15 in areas of igneous or metamorphic rock suggests the presence of abnormal amounts of copper. In areas of zinc concentration, the ratio, expressed as zinc to copper, will rise from about 10 to 100, or even to 500 at places devoid of copper mineralization.

Spectrographic analyses revealed that trees growing near the Sullivan mine contain more manganese and boron than samples from trees located elsewhere. This appears to be important inasmuch as boron and manganese are associated with the Sullivan ore deposit.—*J. W. H.*

136. Warren, H. V., and Delavault, R. E. Gold and silver content of some trees and horsetails in British Columbia: *Geol. Soc. America Bull.*, vol. 61, pp. 123-128, 1950.

An area known to contain many gold-bearing veinlets, and in which many prospect pits and trenches had been dug, was selected for this investigation. Overburden usually ranging from 4 to 8 feet in depth, and in part composed of glacial clay, wherever panned near bedrock revealed the presence of gold. The amount of gold yielded by panning surface material was in most cases negligible.

Samples from five species of trees were carefully taken in a manner that appeared to eliminate danger of physical salting. Four collections of horsetails were also made from near-by ground which was, however, known to contain much more modest quantities of gold.

Careful analyses (fire assays) revealed gold in every sample but one. Control samples from non-gold-bearing areas with similar climate in no instances provided weighable quantities of gold.

Silver was found in most plants including those growing in areas where there was no evidence of silver mineralization.—*Authors' abstract.*

137. Warren, E. H., and Delavault, R. E. A history of biogeochemical investigations in British Columbia: Canadian Min. and Met. Bull., vol. 43, no. 458, pp. 344-350, 1950.

This is a chronological account of research on biogeochemical prospecting in British Columbia by Warren and his associates.—*J. W. H.*

138. Warren, H. V., Delavault, R. E., and Irish, R. I. Biogeochemical researches on copper in British Columbia: Trans. Royal Soc. Canada, vol. 43, pp. 119-137, 1949.

Twigs of sagebrush and of seven species of trees common in British Columbia were analyzed for copper and zinc by the dithizone method. The twigs were sampled (1) in areas mineralized with copper (positive areas), and (2) in unmineralized areas (negative areas). The copper content and the copper to zinc ratio observed in the negative areas are taken as normal; the samples from positive areas frequently showed a copper content and copper to zinc ratio higher than normal.

For each species the following estimates are made of the limits that appear to separate normal from abnormal copper content and copper to zinc ratio. Where either the copper content or the copper to zinc ratio is above this limit, the presence of copper mineralization may be suspected. Copper is expressed on a dry-weight basis.

Species	ppm copper (dry-weight basis)	Copper: zinc ratio
Douglas fir ( <i>Pseudotsuga taxifolia</i> )----	10	0.25
Lodgepole pine ( <i>Pinus contorta</i> )-----	10	.25
Engelmann spruce ( <i>Picea engelmanni</i> )--	12	.20
Dwarf and Rocky Mountain juniper ( <i>Juniperus communis</i> and <i>J. scopu-</i> <i>lorum</i> )-----	8	.40
Poplar ( <i>Populus tremuloides</i> )-----	10	.20
Red alder ( <i>Alnus rubra</i> )-----	10	.40
Sagebrush ( <i>Artemisia tridentata</i> )-----	24	1.0

—*J. W. H.*

139. Warren, H. V., Delavault, R. E., and Irish, R. I. Improved dithizone field test for heavy metals in water [abstract]: Geol. Soc. America Bull., vol. 61, no. 12, pt. 2, p. 1533, 1950.

In many areas of the Pacific Northwest heavy runoff from rain, melting snow, and ice fields causes extreme dilution of the heavy-metal content of natural waters.

Field work has shown that in many areas it is practical to apply geochemical methods in the search for copper and zinc only if it is feasible to detect as little as 0.001 parts per million of these metals in natural waters.

A modification of the dithizone methods has been developed. (See abs. 18.) This modified method is simple, as accurate as is necessary for field work, and can readily detect heavy metals in concentrations as low as 0.001 p. p. m. Under favorable conditions an experienced field man can detect even lower concentrations.—*Authors' abstract.*

140. Warren, H. V., Delavault, R. E., and Irish, R. I. Further biogeochemical data from the San Manuel copper deposit, Pinal County, Arizona: *Geol. Soc. America Bull.*, vol. 62, pp. 919-930, 1951.

Analyses of certain species of plants collected over and near the oxidized outcrop of the San Manuel copper deposit show a higher copper content and higher copper: zinc ratio than was found in similar plants from unmineralized areas. Many samples representing different parts of the same individual plants were analyzed, but no well-defined trend in the localization of copper and zinc is apparent. The following are averages, irrespective of the plant parts sampled, computed from the authors' tables:

	Number of samples	ppm of dry plant		Ratio Cu: Zn
		Cu	Zn	
California poppy:				
Over ore.....	2	32	59	0. 54
Over barren ground.....	2	12	108	. 11
Palo Verde:				
Over ore.....	2	11	17	. 65
Over barren ground.....	9	6	22	. 27
Creosote bush:				
Over ore.....	4	32	23	1. 4
Near ore.....	26	26	28	. 93
Over barren ground.....	31	12	29	. 41
Scrub oak:				
Over ore.....	4	37	31	1. 2
Over barren ground.....	4	7	20	. 35

Saguaro and ocotillo cactus were also sampled with inconclusive results. The authors conclude that biogeochemical methods should not be overlooked as a potential prospecting tool even in areas where soil testing has been shown to be effective. (See abs. 59.)—H. E. H.

141. Warren, H. V., Delavault, R. E., and Irish, R. I. Preliminary studies on the biogeochemistry of iron and manganese: *Econ. Geology*, vol. 47, pp. 131-145, 1952.

Twig and leaf samples, collected for copper and zinc as part of the authors' experimental work on biogeochemical prospecting, were also analyzed for iron and manganese. Iron was estimated colorimetrically with dipyrldyl, and manganese was estimated with formaldoxime. The data show that, under comparable conditions, the iron content of alder (av. 40 ppm dry weight) is nearly twice that of other associated plants (av. 20 ppm dry weight). The data also show that the manganese content of hemlock is highest (av. 50 ppm dry weight) and that of cottonwood least (av. 25 ppm dry weight). There is a marked variation in the iron and manganese content, which appears to depend on the plant organ sampled. However, many more analyses are necessary before it will be possible to generalize on these relations. Other things being equal, the ratio of iron to manganese is higher in dry climates than in humid climates. Comparable samples of 16 species collected over granodiorite and over conglomerate show a generally higher content of iron and manganese in samples from over the conglomerate than in those from over the granite.

At the Sullivan mine the iron, manganese, and zinc contents of plants growing over the deposits are higher than normal. The data suggest that, in the Sullivan area, it would be more profitable to concentrate biogeochemical studies on zinc. However, biogeochemical anomalies in iron and manganese might be useful in

prospecting for deposits where iron or manganese were abundant and where the metal being sought was present in only minor quantities, such as for some epithermal gold or silver deposits.—H. E. H.

142. Warren, H. V., Delavault, R. E., and Irish, R. I. Biogeochemical investigations in the Pacific Northwest: Geol. Soc. America Bull., vol. 63, pp. 435-484, 1952.

Comparative data are presented on the copper, zinc, and ash content of buds, leaves or needles, and stems of Douglas fir, lodgepole pine, yellow pine, white-bark pine, Engelmann spruce, Sitka spruce, white spruce, western red cedar, Rocky Mountain juniper, dwarf juniper, hemlock, Rocky Mountain fir, alpine fir, balsam fir, willow, aspen, cottonwood, scrub birch, mountain birch, silver birch, Sitka alder, syringa, choke cherry, saskatoon, mountain maple, devil's club, broom bush, and sagebrush. Less complete data on many other species of plants native to British Columbia are discussed.

The analytical methods are essentially those described by Warren and Delavault (See abs. 135.) Experience has shown that a precision for copper of 2 to 5 percent may be expected if enough copper is present in the sample. The weight of sample to be used in an analysis should be such that the sample will contain a minimum of 5 micrograms of copper, or 2 micrograms of zinc. Most ashing was done in an automatically controlled electric oven at 620° C. After treatment with HCl, any appreciable amount of residual charred material in the ash is filtered off. Estimation of copper and zinc was made by dithizone.

Consideration of both significance of data and ease of sampling and ashing leads to the conclusion that stems of one full year's growth of gymnosperms, particularly Douglas firs and pines, provide the most useful samples in biogeochemical prospecting. With gymnosperms it is necessary to confine sampling only to the same genus in any given problem, as different species within a genus appear to give comparable results. Gymnosperms can be identified in winter as well as summer, and the year-old stems do not vary significantly with time of year. Using Douglas fir stems, the authors consider as anomalous anything over 9 ppm (dry weight) for copper, 60 ppm (dry weight) for zinc and anything outside the limits 0.07 to 0.23 for the Cu : Zn ratio.

Although angiosperms have not been investigated as thoroughly as the gymnosperms, several genera, particularly the birches and possibly also maples, willows, and devil's club, show considerable promise. The principal drawback is the difficulty in identifying the species of angiosperms in the absence of flowers or fruit, particularly during the winter.

In general, the normal metal content of vegetation was found to range considerably from area to area because of climate, physiography, and underlying rock types. Within a given environment, the authors consider variations of more than 100 percent above normal for copper and more than 50 percent above normal for zinc as "probably anomalous." Examples are given from the data of field surveys.

Common errors in biogeochemical prospecting work are: (1) Failing to consider the dilution effect in plants growing along river banks and lake shores, (2) collecting orientation samples over mine dumps or conspicuous ore outcrops, where experience has shown erratic variations in copper and zinc content, (3) failing to take account of the effect of variations in the pH of the soil, (4) failing to determine a reliable value for the normal lead and zinc content in a given area.—H. E. H.

143. Warren, H. V., and Howatson, C. H. Biogeochemical prospecting for copper and zinc: Geol. Soc. America Bull., vol. 58, pp. 803-820, 1947.

Copper and zinc were determined in the ash of leaves, twigs, bark, wood, and cones of a variety of trees. The samples, collected in five copper or zinc mining camps in British Columbia, have been separated into two classes: (a) Those collected in "positive" areas containing known ore deposits and (b) those collected in nearby "negative" areas where sufficient mining or exploration has assured the absence of ore deposits.

Results show that the samples collected in copper-bearing areas contain considerably more copper than samples from negative areas. Similarly, samples obtained in zinc-bearing areas contain more zinc than samples from negative areas. The authors conclude that analysis of vegetation may be helpful in prospecting for copper and zinc.—J. W. H.

144. Webb, J. S., and Millman, A. P. Heavy metals in natural waters as a guide to ore; a preliminary investigation in West Africa: Inst. Min. Metallurgy Bull., no. 518, pp. 3-16, 1950.

The dithizone field test evolved by the U. S. Geological Survey (see abs. 40) was used by the writers to estimate the heavy metal content of natural waters in areas of lead-zinc mineralization in Nigeria, West Africa. The test, of which details are given, is rapid and simple in operation.

It was found that springs issuing from the lodes contained relatively high concentrations of heavy metals. The addition of these natural lode waters to the main drainage system caused significant increases in the metal content of the stream waters; the magnitude of these increments being subject to considerable diurnal variation during the rainy season.

The results of this preliminary reconnaissance indicate that dithizone testing of natural waters, including streams, springs and pools, should be given a thorough trial. This geochemical method shows promise of becoming a useful supplement to geological prospecting in the Nigerian lead-zinc belt and elsewhere.—*Authors' abstract.*

145. Webb, J. S., and Millman, A. P. Heavy metals in vegetation as a guide to ore; a biogeochemical reconnaissance in West Africa: Inst. Min. Metallurgy Trans., vol. 60, pp. 473-504, 1951. Discussion at Oct. 1951 general meeting of Institute: Trans. vol. 61, pp. 105-118, 1952.

The concentrations of Pb, Zn and Ag in twigs and leaves of savannah trees in the Nigerian lead-zinc belt increase in proximity to mineralization. Using a spectrographic technique, Pb is found to give pronounced geochemical anomalies many times wider than the lodes. Although Ag is erratic, this element has a limited value as a "pathfinder", while the status of Zn as an index element is lowered to some extent by the relatively poor spectrographic sensitivity of this element.

The normal concentration of Pb, Ag, and Zn in dried twigs of several species of trees when growing in unmineralized areas, is essentially constant at approximately 1, 0.05, and <100 ppm respectively. The ratios between peak and background values in positive areas range between 7-270 to 1 for Pb, 4-6 to 1 for Ag, and up to at least 20 to 1 for Zn. Comparable anomalies were detected in leaves. Some of the factors controlling the nature, width and magnitude of the geochemical anomalies are considered.

In addition to the positive results obtained near lodes which have been more or less disturbed by shallow open-casting, the anomalies detected over essentially



virgin mineralizations suggest that the systematic determination of the heavy metal content of twigs might, in favourable circumstances, provide useful information concerning the location of hidden (sub-outcropping) veins. Further orientation work is required, including a comparison with the methods of systematic soil analysis.—*Authors' abstract.*

146. White, C. H. Organisms as guides to copper ore, *Mining Mag.*, vol. 40, pp. 26-27, 1929.

It was formerly thought that study of the habits of a group of African birds, the plantain eaters (*Musophogidae*), might help to locate outcrops of copper ore. The red pigment of their wing feathers contains 7 percent copper, and it was inferred that these birds obtained copper when they picked up gravel for their craws from copper outcrops. Inasmuch as these birds inhabit all of Africa south of the Sahara, the author maintains that observation of them would not be helpful in prospecting.—*J. W. H.*

147. White, W. H. Plant anomalies related to some British Columbia ore deposits: *Canadian Inst. Min. Metallurgy Bull.*, no. 459, pp. 368-371, 1950.

Twigs of fir or pine trees from three lead-zinc areas and one copper area in British Columbia were analyzed with a dithizone field test. Zinc alone was determined in samples from the zinc-lead areas. The results show a good correlation between location of the veins and high zinc content of the twigs. The zinc content was found to range from 24 to 364 ppm of twig material. Fifty ppm was considered to be the boundary between normal and anomalous zinc content in one of the areas and 100 ppm as the boundary in the other two. In the copper area analyses were made for both copper and zinc. Here, samples with a ratio of copper to zinc of 0.30 or more correlate moderately well with the location of the copper deposit. The distribution of copper alone, however, shows poor correlation, and zinc shows no correlation.

The author draws the following conclusions from this study: (a) The tests for zinc or copper are inexpensive and quick; (b) the normal metal content of each species varies with the type of bedrock; (c) the increase from normal to anomalous metal content takes place within a short horizontal distance; (d) the width of the anomaly may range from 4 to 50 times the width of the ore deposit; (e) the size and intensity of the anomaly vary with the size of the deposit, but not necessarily with the grade or ore; (f) the ratio of copper to zinc is more important in investigation of copper deposits than either metal singly; (g) a "metal shadow" is cast by an ore deposit into the overburden, even though the overburden consists of transported material, such as glacial drift; (h) the "metal shadow" is stationary in position, uninfluenced by groundwater movement; (i) the maximum thickness of overburden through which a "metal shadow" may be cast is unknown, except that it exceeds 30 feet.—*J. W. H.*

148. Wilson, H. D. B. Geochemical studies of the epithermal deposits at Goldfield, Nevada: *Econ. Geology*, vol. 39, pp. 27-55, 1944.

Approximately fifty samples of vein material and wallrock from the ore deposits of Goldfield, Nev., were quantitatively analyzed by means of the spectrograph to determine whether the quantitative distribution of certain elements would give some clue to the loci of mineralization. It has been established that three elements, bismuth, silver, and tin, are genetically associated with gold values in the deeper veins. These elements are determinable even in very low grade vein material. Vertical zoning at Goldfield is evident with respect to tin,

less definite for bismuth and probably present among several of the accompanying elements.

Analyses of the wallrock show a great diversity in the change in distribution of the constituent elements during the process of mineralization and the accompanying alteration of the adjacent rocks. Some elements, such as manganese and magnesium, show a sharp quantitative change at the contact between highly altered and altered wallrock, while others, such as sodium and sometimes calcium, completely fail to show any change within this zone.

Going from the vein into the wallrock, little change is apparent in the manganese and magnesium content of the wallrock until the contact between the highly altered wallrock and less altered wallrock is reached. At this contact the amount of manganese and magnesium suddenly increases tremendously, then shows little additional change at a greater distance from the vein. On the other hand the leaching of sodium and sometimes calcium gradually decreases away from the vein with no marked boundary such as occurs with manganese and magnesium.

The wallrock of the Jumbo vein shows that magnesium, manganese, and calcium have been differentially leached over the entire distance investigated, but sodium is only leached for about forty feet from the vein and beyond that the highly altered wallrock contains almost the same amount of sodium as the fresh dacite.

Many other elements, such as boron, cobalt, copper, nickel, titanium, and zirconium, show no evident change due to wallrock alteration. Aluminum and vanadium show little evidence of change in the wallrock itself, but have been leached to a large degree in the highly silicified ledge of the Jumbo vein, which Ransome would consider the most extreme type of dacite alteration.

Cobalt showed an increase in the altered wallrock near the vein at the 225-foot level of the Clermont mine. The enrichment continued outward for thirty to forty feet from the vein.—*From author's abstract and summary.*

149. Wilson, M. E. Rock alteration at the Amulet mine, Noranda district, Quebec: *Econ. Geology*, vol. 30, pp. 478-492, 1935.

Pre-Cambrian rhyolite breccia, andesite lavas and dikes, and diorite associated with the sulfide ores at the Amulet mine have been altered to a rock showing an unusual spotted appearance on the weathered surface. This rock, called dalmatianite because of its spots, consists of cordierite, brown mica, gedrite, green spinel, quartz, chlorite, magnetite, pyrite, pyrrhotite, sphalerite, and chalcopyrite. Analysis of one specimen of dalmatianite shows 1.61 percent zinc. The author concludes that this alteration is the effect of the same hydrothermal emanations that formed the ore deposits.—*H. E. H.*

150. Zaidina, and Sergeyev. The work of the geophysical groups of TsNIGRI on spectral methods [in Russian]: *Razvedka Nedr.*, no. 7, pp. 55-57, 1938.

Development of quantitative spectrochemical methods for use in prospecting for metals was begun in the U. S. S. R. by the Central Geological and Prospecting Institute (TsNIGRI) in 1934. In 1935 the State Optical Institute (GOI) developed a successful method for making quantitative determinations of tin in rocks and ores. During 1935-36 research was begun upon the determination of molybdenum by means of an ultraviolet spectrograph. In 1936 methods for determining boron and nickel in rocks were worked out for field use. During

1937 methods for determining molybdenum, tungsten, and copper were tested in the field. In 1938 work was in progress on a method for determining chromium.—A. P. P.

151. Zenin, M. F. An experimental cuprimetric survey in Almalike [in Russian]: From "Geology of Central Asia," vol. 1, pp. 58-75, Tashkent, 1935.

The writer describes the methods employed in surveying the Kal'makyr porphyry copper deposit. Samples of rock from drill cores and the weathered ore outcrop were analyzed for copper and examined for cellular limonite structures. "Isocupric" contours were drawn to show the areal distribution of copper. (See abs. 52.)—A. P. P.

# INDEX

	Abstract
Accumulator plants. ( <i>See</i> Plants, accumulator.)	
Age, geochemical determination of	69
Alluvium. ( <i>See also</i> Placer deposits.)	
General	73, 99
Copper	59
Gold	73
Mercury	92, 99
Molybdenum	99
Niobium	99
Platinum	73
Rare earths	99
Tin	13, 22, 23, 71, 73, 87, 99, 101
Tungsten	73, 99
Zirconium	99
Alteration halos	
Distribution of minor elements	29, 49, 60, 148, 149
Indicator plants	9
Aluminum	
Plants, accumulator	44
Rocks	29
Analytical procedures. ( <i>See</i> Chemical analysis, Chromograph, Fire assay, Flame tests, Polarographic analysis, Spectrographic analysis, X-ray spectrographic analysis.)	
Animals	7, 146
Appraisal of prospects	52, 117, 151
Arizona	16, 59, 140
Arsenic	
Rocks	84
Australia	19, 31, 39, 104, 107, 108, 109, 110
Barium	
Plants, accumulator	85
Residual cover	85
Belgian Congo	28
Beryllium	
Rocks	113
Biogeochemical prospecting. ( <i>See</i> Plants, accumulator.)	
Bismuth	
Rocks	148
Bog and lake deposits	91, 123
Boron	
Plants, accumulator	135
Residual cover	94
Rocks	148
Water	20
Brazil	19
British Columbia	111, 134, 135, 136, 137, 138, 141, 142, 143, 147
British West Africa	144, 145

	Abstract
Bromine	
Water	20
Cadmium	
Bog deposits	91
California	85
Canada	63, 64
Cerium. ( <i>See</i> Rare Earths.)	
Chemical analysis, plants	
Copper	30, 118, 135, 142, 147
Iron	141
Manganese	141
Molybdenum	83
Nickel	81
Zinc	30, 82, 86, 135, 142, 147
Chemical analysis, soils and rocks	
Aluminum	84
Arsenic	84
Boron	90, 94
Copper	3, 50, 52, 59, 104, 106
Heavy metals	14, 15, 16, 27, 41, 60
Iron	45
Lead	3, 43, 52, 84, 106
Molybdenum	133
Tungsten	132
Zinc	3, 26, 36, 45, 50, 54, 84, 106
Chemical analysis, water	
Copper	18, 40, 89, 120, 139
Heavy metals	14, 15, 40, 144
Lead	40
Nickel	120
Sulfate	120
Zinc	18, 40, 120, 139
Chromium	
Plants, accumulator	38, 64
Plants, indicator	11
Residual cover	4
Chromograph	2, 112
Cobalt	
Bog deposits	91, 123
Plants, accumulator	30, 66
Residual cover	24, 42, 66
Rocks	42, 148
Colorado	103
Columbium. ( <i>See</i> Niobium.)	
Copper	
Alluvium	59
Birds	146
Bog deposits	91, 123
Glacial cover	85, 124
Plants, accumulator	30, 38, 59, 85, 128, 129, 134, 135, 138, 140, 142, 143, 147
Plants, indicator	19, 59, 88, 121, 122, 127
Residual cover	59, 85, 103, 104, 110
Rocks	3, 29, 49, 50, 52, 148, 149, 151
Water	40, 56, 59, 130

	Abstract		Abstract
Corundum.....	5	Japan.....	47, 48, 49
Cost of geochemical surveys.....	24, 27, 101	Jugoslavia.....	69
Cuba.....	11		
Czechoslovakia.....	7	Lead	
Dispersion halos, primary. ( <i>See</i> leakage halos, wall-rock halos.)		Bog deposits.....	91
Dispersion halos, secondary. ( <i>See</i> residual cover, transported cover, glacial cover, accumulator plants, indicator plants, plant symptoms.)		Glacial cover.....	103, 126
Dispersion trains. ( <i>See</i> alluvium, water, bog and lake deposits.)		Plants, accumulator.....	10, 30, 64, 115, 128, 145
		Plants, indicator.....	19, 57
		Plant symptoms.....	10
		Residual cover.....	24, 42, 103
		Rocks.....	3, 29, 42, 52, 84, 113
		Water.....	40
Electrochemical methods of analysis.....	90, 98	Leakage halos. ( <i>See also</i> Wall-rock halos.)	
Faults.....	26, 29, 69	General.....	25, 58
Finland.....	74, 91	Cobalt.....	42
Fire assay.....	136	Copper.....	3, 50
Flame tests for copper.....	52	Gallium.....	42
Fluorescent methods of mineral identification.....	5, 97	Heavy metals.....	16, 60, 93
French West Africa.....	28	Iron.....	45
		Lead.....	3, 29, 42
Gallium		Mercury.....	92
Residual cover.....	24, 42	Manganese.....	42
Rocks.....	42	Molybdenum.....	42
Genetic halos. ( <i>See</i> leakage halos, wall-rock halos.)		Nickel.....	42
Geochemical prospecting, general. ( <i>See</i> Reviews.)		Silver.....	93
Geochemical provinces		Titanium.....	42
General.....	39	Vanadium.....	42
Boron.....	20	Zinc.....	3, 29, 45, 50
Bromine.....	20	Lithium	
Gold.....	7, 28	Rocks.....	113
Nickel.....	119		
Tin.....	1, 28	Magnesium	
Germany.....	19	Rocks.....	148
Glacial cover.....	14, 85, 103, 124, 125, 126	Malaya.....	28
Gold		Manganese	
Alluvium.....	73	Bog deposits.....	91, 123
Animals.....	7	Glacial cover.....	125
Plants, accumulator.....	136	Plants, accumulator.....	128, 135, 141
Plants, indicator.....	19	Plants, indicator.....	19
Residual cover.....	108	Residual cover.....	42
Rocks.....	28, 108	Rocks.....	29, 42, 148
Water.....	51, 63		
Great Britain.....	64, 115	Mercury	
Greece.....	38, 64	Alluvium.....	92, 99
		Plants, indicator.....	19
Heavy metals		Rocks.....	92
Glacial cover.....	14	Mexico.....	84, 93
Residual cover.....	16, 27	Michigan.....	85
Rocks.....	16, 60, 93	Missouri.....	44
Water.....	14, 40, 96, 103, 144	Molybdenum	
Heavy mineral studies.....	22, 99	Alluvium.....	99
		Residual cover.....	42, 117
Indicator plants. ( <i>See</i> Plants, indicator.)		Rocks.....	42, 113
Indo-China.....	28	Montana.....	19, 56
Insects.....	7	New England.....	113
Iron		Newfoundland.....	63
Glacial cover.....	125	New Mexico.....	29, 93
Plants, accumulator.....	118, 128, 141	Nevada.....	9, 85, 148
Plants, indicator.....	11, 12, 19, 57	Nickel	
Rocks.....	45	Bog deposits.....	91, 123
Water.....	47, 56	Plants, accumulator.....	30, 66, 74
		Residual cover.....	24, 42, 66, 112
		Rocks.....	42, 119, 148
		Niobium	
		Alluvium.....	99
		Rocks.....	113

	Abstract		Abstract
North Carolina.....	103	Residual cover.....	
Norway.....	88, 89, 91, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130	Barium.....	85
Ontario.....	14	Boron.....	94
Peat. (See Bog and lake deposits.)		Chromium.....	4
Pennsylvania.....	86	Cobalt.....	24, 42, 66
Phosphorus, phosphates		Copper.....	59, 85, 103, 104, 110
Plants, indicator.....	19, 57	Corundum.....	5
Placer deposits (see also Alluvium).....	13, 22, 23, 71, 73, 87, 99, 101	Gallium.....	24, 42
Plants, accumulator.....		Gold.....	108
General.....	63	Heavy metals.....	16, 27
Aluminum.....	44	Lead.....	24, 42, 103
Barium.....	85	Manganese.....	42
Boron.....	135	Molybdenum.....	42, 117
Chromium.....	38, 64	Nickel.....	24, 42, 66, 112
Cobalt.....	30, 66	Sulfate.....	5
Copper.....	30, 38, 59, 85, 128, 129, 134, 135, 138, 140, 142, 143, 147	Tin.....	22, 23, 24, 87
Gold.....	136	Titanium.....	5, 42
Iron.....	118, 128, 141	Tungsten.....	97, 117
Lead.....	10, 30, 64, 115, 128, 145	Vanadium.....	42
Manganese.....	128, 135, 141	Zinc.....	26, 36, 103
Nickel.....	30, 66, 74	Reviews of geochemical prospecting	
Silver.....	30, 38, 136, 145	General.....	6, 21, 32, 33, 34, 35, 56, 64, 77, 95, 100, 102, 103, 105, 114
Tin.....	30, 64, 115	Alluvial prospecting.....	73, 99
Tungsten.....	115	Biogeochemical prospecting.....	11, 38, 61, 62, 63, 75, 131, 137
Zinc.....	10, 19, 30, 38, 86, 111, 115, 128, 134, 135, 138, 140, 142, 143, 145, 147	Water analysis.....	17, 70
Plants, indicator		Rhodesia.....	12
Alteration zones.....	9	Rocks	
Chromium.....	11	General.....	25, 84
Copper.....	19, 59, 88, 121, 122, 127	Aluminum.....	29
Gold.....	19	Arsenic.....	84
Iron.....	11, 12, 19, 57	Beryllium.....	113
Lead.....	19, 57	Bismuth.....	148
Manganese.....	19	Boron.....	148
Mercury.....	19	Cobalt.....	42, 148
pH.....	9	Copper.....	3, 29, 49, 50, 52, 148, 151
Platinum.....	19	Gallium.....	42
Rock types.....	12, 19, 57, 121, 122	Gold.....	28, 108
Selenium.....	8	Heavy metals.....	16, 60, 93
Silver.....	19, 57	Indicator plants for.....	12, 19, 57, 121, 122
Tin.....	19	Iron.....	45
Zinc.....	19, 57	Lead.....	3, 29, 42, 52, 84, 113
Plant symptoms		Lithium.....	113
Lead.....	10	Magnesium.....	148
Zinc.....	10, 103	Manganese.....	29, 42, 148
Platinum		Mercury.....	92
Alluvium.....	73	Molybdenum.....	42, 113
Plants, indicator.....	19	Nickel.....	42, 119, 148
Poland.....	10	Niobium.....	113
Polarographic analysis.....	90	Rare earths.....	113
Portugal.....	17	Silver.....	29, 49, 93, 148
Primary halos. (See Leakage halos, Wall-rock halos.)		Tin.....	1, 28, 101, 113, 148
Productivity of geochemical surveys.....	24, 27, 101	Titanium.....	42, 148
Quebec.....	149	Vanadium.....	29, 42, 148
Rare earths		Zinc.....	3, 29, 45, 50, 84, 113
Alluvium.....	99	Zirconium.....	148
Rocks.....	113	Sampling techniques.....	26, 27, 31, 106
		Secondary holos. (See residual cover, transported cover, glacial cover, accumulator plants, indicator plants, plant symptoms.)	
		Selenium	
		Plants, indicator.....	8

	Abstract		Abstract
Silver		Union of South Africa	1, 19
Plants, accumulator	30, 38, 136, 145	Vanadium	
Plants, indicator	19, 51	Residual cover	42
Rocks	29, 49, 93, 148	Rocks	29, 42, 148
Soil. (See residual cover, transplanted cover, glacial cover.)		Venezuela	11, 12
Spain	19	Virginia	26
Spectrographic analysis		Wall-rock halos	
General	25, 79	General	84
Aluminum	29, 44	Arsenic	84
Barium	85	Beryllium	113
Beryllium	113	Bismuth	148
Bismuth	148	Boron	148
Boron	90, 135, 148	Cobalt	148
Cadmium	91	Copper	49, 148
Chromium	4, 38, 90	Gold	108
Cobalt	30, 42, 91, 148	Lead	29, 84, 113
Copper	29, 38, 85, 91, 148	Lithium	113
Gallium	42	Manganese	148
Gold	63	Mercury	92
Lead	29, 30, 42, 91, 113, 115, 145	Molybdenum	113
Lithium	113	Nickel	148
Magnesium	148	Niobium	113
Manganese	29, 42, 91, 135, 148	Rare earths	113
Molybdenum	42, 90, 113, 117, 150	Silver	49, 148
Nickel	30, 42, 74, 91, 148	Tin	113, 148
Niobium	113	Titanium	148
Rare earths	113	Vanadium	148
Silver	29, 30, 38, 145, 148	Zinc	29, 45, 84, 113
Tin	1, 13, 30, 63, 71, 72, 78, 87, 90, 91, 101, 113, 115, 148, 150	Zirconium	148
Titanium	42, 148	Water	
Tungsten	90, 115, 117	Boron	20
Vanadium	29, 42, 148	Bromine	20
Zinc	29, 38, 91, 113, 115, 145	Copper	40, 56, 59, 130
Zirconium	148	Gold	52, 63
Sulfate		Heavy metals	14, 40, 96, 103, 144
Residual cover	5, 97	Iron	47, 57
Water	47, 48, 120	Lead	40
Sweden	38	Sulfate	47, 48, 120
Tennessee	36, 50	Tin	63
Tin		Zinc	40, 56, 111
Alluvium	13, 22, 23, 71, 73, 87, 99, 101	Weathering, review	80
Bog deposits	91	Wisconsin	45
Plants, accumulator	30, 64, 115	Wyoming	8
Residual cover	22, 23, 24, 87	X-ray spectrographic analysis	123, 129
Rocks	1, 101, 113, 148	Zinc	
Water	63	Bog deposits	91, 123
Titanium		Glacial cover	103, 126
Residual cover	5, 42	Plants, accumulator	10, 19, 30, 38, 86, 111, 115, 128, 134, 135, 138, 140, 142, 143, 145, 147.
Rocks	42, 148	Plants, indicator	19, 57
Transported cover	14, 26, 85, 103, 124, 125, 126	Plant symptoms	10
Tri-State district	24, 30, 42	Residual cover	26, 36, 103
Tungsten		Rocks	3, 29, 45, 50, 84, 113, 149
Alluvium	73, 99	Transported cover	26
Plants, accumulator	115	Water	40, 56, 111
Residual cover	97, 117	Zirconium	
Utah	3, 27, 58, 60.	Alluvium	99
U. S. S. R.	4, 5, 20, 21, 22, 23, 51, 52, 66, 71, 72, 79, 87, 90, 92, 94, 95, 96, 97, 98, 99, 100, 101, 117, 118, 150	Rocks	148