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GEOCHEMICAL EXPLORATION FOR HIDDEN
ORE DEPOSITS

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Geochemistry may be defined as the science which deals with the chemistry of the earth as a whole, and of its component parts. It is a broad field of science concerned with the abundance of the elements and with the laws which govern their distribution.

Geochemical prospecting is the art of applying the laws and data of geochemistry to the discovery of mineral deposits and is a relatively new additional tool of the geologist and mining engineer. Geochemical prospecting includes the systematic sampling, mapping and chemical analysis of water, soil,¹ rock, or vegetation, and the interpretation of data obtained.

We, as a nation, are faced with an increasing demand for minerals and with increasing difficulty in finding new supplies, a situation which faces other countries to some degree. Nearly all exposed outcroppings of mineral deposits in this country are known. To locate new supplies we must depend in the future on finding mineral deposits which are hidden from view, either by a soil mantle or by both loose debris and overlying barren rock. To accomplish this we will need to depend upon increased application of known techniques and development of new techniques for mineral exploration.

Geophysical methods are one of the principal means used in the search for hidden ore deposits. Such methods depend upon measuring certain physical attributes of the ore such as gravity, magnetism, electrical characteristics, radioactivity, etc. But these methods are indirect and are often affected by other phenomena, nor can they locate all types of mineral deposits.

Neither geophysics nor geochemistry locate ore but are tools which enable us to "*narrow the target area*" for more intensive and more expensive investigations. That is they pin-point favorable areas and eliminate large barren areas from our consideration so that we can concentrate our attention on the areas most likely to contain an economic mineral deposit. Whereas geophysical methods are based on physical properties and tell us something is present which gives rise to physical phenomena, geochemical methods are based on chemical properties and indicate something of the chemical nature of the covered area. Results of both techniques must be interpreted in conjunction with careful and detailed geologic studies.

GEOCHEMICAL METHODS

History: Geochemical prospecting had its early development in Russia and Scandinavia in the 1930's. The analytic procedures were cumbersome and not used on a large scale until shortly before World

War II. After the war the United States Geological Survey became interested in the technique and began a program to develop fast accurate analytical techniques for water, soil, plants and rock. The U. S. G. S. and others have devised procedures sensitive enough to distinguish as little as .002 parts per million of Zn in water, or as little as .2 p.p.m. of Ag in soils. Excellent procedures are now available for many metals.

The Basic Premises: An ore deposit is a unique concentration of metal ions which may represent a concentration or increase of several hundred times the normal abundance of the metal. Thus a 4% zinc orebody represents a concentration of about 300 times the normal content of zinc in the earth's crust.

The basic assumption is that during the formation of orebodies the adjoining rocks also increased in metal content to some degree. There were leakages from the main ore channels, and also the spent ore fluids deposited the last vestiges of metal as they permeated further into country rock. This leads to the following important general concept.

Surrounding the orebody itself is an envelope of material whose metal content is intermediate between that of the ore and of the country rock. This zone of higher than normal metal content is a geochemical anomaly (i.e. not normal) or "dispersion halo".

The presence of a zone of higher than normal metal content is indicative of the possible presence of a nearby ore deposit.

Halos of Dispersion: Two distinct types of dispersion patterns or halos occur in association with ore deposits. One is the genetic or primary type related to the ore-forming process itself. The other, a secondary dispersion pattern, is a result of weathering processes that cause the breakdown and scattering of the ore minerals in the products of soil disintegration—the soil, stream sediment or dissolved salts.

Primary Dispersion (Genetic): Genetic dispersion implies the distribution of elements (and their minerals) in the rock around an orebody in various three dimensional patterns, by processes related to the ore forming process. One would expect the content of diagnostic ions to be highest close to the ore and to decrease with distance from the orebody. This is found to be the case, the metal content decreasing outward on a hyperbolic curve.

In many cases the size of a primary halo may not be much larger than the ore deposit and so is of rather limited value. Sometimes however the halo is extensive and provides a large target area.

Chemical tests of rock samples from tunnels, surface exposures or drill holes may indicate a halo which encourages further search.

Secondary Dispersion: Secondary patterns of dispersion include the distribution of elements in the weathered products of rock disintegration. Metal ions present in the parent rock will be scattered in the material overlying and subjacent to the rock. Those minerals which

are resistant and relatively insoluble will tend to remain near the source, whereas the less resistant and more soluble components will be distributed more widely by ground and surface waters. Modifying the above simple concept is the physical effect of transport (glacial, fluvial, or gravitational) and the reprecipitation of the soluble elements by reaction or absorption.

Successful prospecting of weathering products is dependent on the existence of a diagnostic variation of ion content which is suggestive of a hidden ore deposit.

PATTERNS OF DISTRIBUTION

The geometric form of the geochemical pattern is largely controlled by the geologic processes which have acted during its formation.

One of the most common types is the *dispersion halo*, a more or less symmetrical surface zone centered about the orebody, containing anomalously high quantities of ore elements as compared to the quantities present in the surrounding area. This development is a result of lateral migration of elements from the orebody into the soil and the soil waters and the vegetation growing in the soil. Such halos are usually much larger than the mineralized zone and provide a broad target. They may overlie the ore or may have been offset to some extent by the action of soil creep, glaciers, or circulating ground waters.

A second pattern type is the *dispersion fan* in which the erosional products converge toward the source. Fan forms may be a result of glacial action, fanning out in the direction of ice movement, of downslope soil creep, or of ground waters migrating downslope and depositing trace elements.

A third type is the *dispersion train*. Here the weathering products of a mineralized zone enter the surface drainage as sediment or dissolved salts. The pattern of dispersion is then controlled by the linear drainage pattern of the stream.

ANALYTIC METHODS

The methods used most extensively and successfully are spectrographic, various colorimetric techniques and spot tests.

Spectrographic Analysis: Spectrographic methods require skilled operators and expensive equipment but do permit the determination of several elements from the one spectrogram and the speedy analyses of a large number of samples. Russian and Swedish geologists have used this method extensively and have developed portable truck mounted units. The U. S. G. S. also has a portable unit.

Quantitative estimations of the trace metals are made by visual comparison of the unknown spectrogram with standard spectrograms. The sensitivity varies for different metals but is less than the sensitivity of chemical methods for some important elements.

Colorimetric Analysis: Colorimetric methods of analysis for heavy

metals offer the greatest advantages because of their simplicity and the portability of the equipment. The basis of the methods is to have or place the metal to be tested in a soluble form and then add a reagent to convert the metal into a colored product. The intensity of the colored product as compared to standards is a measure of the metal concentration in the sample.

Non-specific tests for total heavy metals or for certain groups of metal ions are very useful for reconnaissance testing of an area. Specific tests for particular elements can also be made. These may be used alone or in conjunction with non-specific tests.

Spot Tests: Spot tests are based on the same principle as colorimetric analysis. The difference is that for spot tests a fixed amount of test solution is brought into contact with a fixed area of reagent paper. The intensity of the colored spot produced on the paper is a measure of the concentration of the heavy metal. The main advantages of spot tests are the permanent record secured and the ease of estimation.

FIELD TESTS

The analytical methods used in geochemical prospecting do not need to supply the accuracy required in a chemical laboratory because the difference in metal content between anomalous and normal material is often several hundred per cent. T. S. Lovering (1955), director of the geochemical section of the U. S. G. S. has stated the proposition very aptly, "A fair degree of precision—reproducibility of results—rather than a highly quantitative accuracy is the end sought in applied geochemical prospecting." While a high degree of accuracy is rarely necessary, speed is nearly always a paramount requirement.

A satisfactory field test should meet four requirements. It should be:

1. Sensitive enough to detect significant variations in metal content of the samples.
2. Fast enough so the field man can decide—while still in the area—whether additional samples are required.
3. Economic, so that large areas can be tested.
4. Amenable to the use of simple and portable equipment.

In general, we desire a method that can be applied in the field or in a temporary field headquarters so that the geologist guiding the program can use current data in his day to day planning.

Water Tests: Hydrogeochemical prospecting by sampling stream water, or ground water, is similar in principle to alluvial prospecting. Both follow the trail of anomalously high concentrations of metals upstream to locate the source of the contamination. When positive color tests are found in a stream the geologist or prospector proceeds upstream testing the water from time to time, and any entering tributaries, until he locates the area which is supplying soluble metal ions to the water. This area is then subjected to more intensive investiga-

tions, such as detailed soil sampling, geophysical or drill tests, to outline the favorable zone in more detail.

Soil Testing: The less-mobile metals tend to build up in the soil over or downslope from a mineral deposit, whereas the more mobile elements will be dispersed to a greater extent and develop a broader anomaly.

Anomalies occur in residual soils which have formed in place through chemical weathering. The metal ions may be residual in character and only the more mobile elements have migrated to any degree by movement of ground waters and soil creep. Materials of glacial origin will contain metals which are present largely because of mechanical erosion. However, we do know that added to this may be more metals from the subjacent deposit which have entered the mantle material at a later stage. This superimposed halo apparently develops by diffusion and by movement of ground waters.

The samples are taken at a depth sufficient to be below the mixed surface layer in fairly homogeneous material. In glaciated areas a depth of one foot or so is usually sufficient, in residual soils greater depth may be necessary to reach below the leached "A" soil horizon. A sample of only a few grams is as representative as a larger one, it is then screened and the fine soil fraction used for testing. The finer soil fractions of less than 80 mesh (0.175 mm. max. size) usually contain most of the heavy metals.

The above description is over-simplified, actually the problem of where and how to sample can be quite complex.

Biogeochemistry—Accumulator Plants: Many plants have the ability to concentrate certain elements from the soil, thus emphasizing an anomaly which may be present. These plants are called accumulator plants. Solutions in the soil dissolve certain compounds in a ratio which depends on the solubility of the elements. The root systems act as effective sampling devices that can pick up elements from the deeper soil layers or even bed rock. The soil solutions then enter the plants and the elements may be concentrated in the young parts of the plant especially the young twigs and leaves. Samples of the twigs or leaves from a plant type are taken in a systematic manner, the samples ashed and tested. The results are plotted and contoured, and the anomaly, if present, outlined.

Sometimes the plants native to an area do not concentrate the metal we hope to find, but may have the ability to concentrate an associated element. Detection of abnormal amounts of such an *indicator* element may indicate the presence of the associated economic metal.

A general disadvantage of biogeochemical prospecting is that different species of plants under similar conditions concentrate such widely different amounts of metals that much preliminary work is necessary in order to select a species for sampling. Furthermore, the amounts of metal vary widely in different parts of any one plant.

Indicator plants are those that may be especially abundant in soil

containing certain trace elements and essentially absent where these elements are in very low concentrations. For example selenium and uranium are associated in many places in the western states. Certain plants need selenium, whereas others cannot tolerate much of it. Thus "loco weed" and other varieties of *Astragalus* grow only on soils containing selenium. Plotting the areas where such plants are abundant outlines zones which are worth investigating for uranium. Investigation of plant distribution or plant abnormalities related to trace elements in soil is a geobotanical method rather than geochemical.

CONCLUSION

Geochemical prospecting provides the geologist with a powerful new tool in the search for hidden ore deposits. It is a tool with many possibilities but also with limitations, whose full potential can only be attained through close association with geologic studies.

Dr. Williams of the new Geochemical Prospecting Research Center, London, has expressed a philosophy which should guide our thinking at the present stage of development of geochemical application. "Geochemical prospecting is still in its infancy and should not be hailed as a prodigy offering a panacea for the perplexities of mineral exploration. Its healthy development calls for the aid of disinterested fundamental research in the field and in the laboratory, even though its ultimate paramount aim is to discover virgin mineral deposits. It is an additional handmaiden to geology, certainly not a substitute for it, and the interpretation of geochemical anomalies is essentially a geological problem."

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