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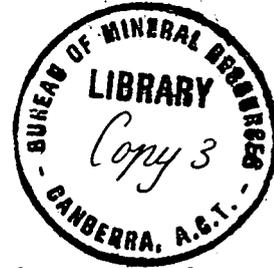
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Recent Research in Geochemical
Prospecting in Australia

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RECENT RESEARCH IN GEOCHEMICAL PROSPECTING IN AUSTRALIA

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Introduction and Acknowledgements

In Australia in recent years the use of geochemistry as a prospecting tool has been extremely widespread until at the present time it constitutes an essential part of almost every exploration effort. Many companies maintain their own laboratories but most prospecting organisations send their samples for determination to one of the many custom geochemical laboratories that have sprung up in response to the demand.

Research in geochemical prospecting has been done mainly to improve the effectiveness and interpretation of the field results, and to improve the analytical procedures or develop new ones.

The many companies and individuals who have contributed information for this review paper are acknowledged in the Proceeding of the 3rd International Geochemical Prospecting Symposium, held in Toronto from 16th-18th April 1970, which will be published later this year.

The research relevant to geochemical prospecting that has been carried out in Australia during the past two years can be classified under four general headings:-

1. Chemical methods and analytical techniques.
2. Improvements in field procedures.
3. Identification of significant geochemical associations.
4. Comprehensive studies of problems or of ore deposits.

Chemical methods and analytical techniques

Experimental work carried out in the Bureau of Mineral Resources (Beever, 1970) on the effectiveness of cold extraction of Cu, Pb and Zn by solvents such as cold ammonium citrate has shown that the amount of metals dissolved is affected by sediment size, by the ability of the

extractant to form complexes with the metals concerned, and by the mineral composition of the sample (secondary minerals being more susceptible to attack than sulphides). Drying the sample affects the results slightly and significantly increases the time taken to reach equilibrium. Results obtained by cold extraction methods, because of variability in percentage extraction, are generally less reliable than those obtained by 'total' analyses.

Although atomic absorption spectrophotometry remains the principal method used in geochemical analyses, because it is quick, cheap and has low detection limits for the more interesting base metals, several laboratories have developed X-ray fluorescence as a major method of determining both principal and minor constituents of geological materials, but particularly for such elements as Sn, Gb, Ta, Zn, etc. in trace quantities.

The CSIRO Division of Applied Mineralogy (Hudson, 1969) has developed a procedure to determine seventeen trace elements (Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Nb, Mo, and Pb) in quantities down to 10 ppm with an accuracy better than 20%. A single scattered background radiation measurement is used to determine element background and allow for matrix variation and the whole analysis can be completed within 20 minutes.

The same laboratory (Davis, et al, 1969) has developed a method of separating and determining tellurium in rocks in trace quantities down to 0.01 ppm. The method involves the use of synthetic pyrite prepared from precipitated sulphur and dried ferrous sulphate - natural pyrite contains too much tellurium. Tellurium is evolved by heating up to 15 grams of rock with up to 18% synthetic pyrite in a stream of pure nitrogen at 800°C. The sublimate containing sulphur and tellurium is dissolved and tellurium determined by atomic absorption.

Australian Selection Ltd. is carrying out research to develop a sensitive and rapid instrumental analysis technique to determine selenium and the platinum group metals.

At the Department of Analytical Chemistry, University of New South Wales, research is being conducted on the use of atomic fluorescence methods to analyse vegetation samples without prior ashing.

An infra-red spectrophotometer has been used by Planet Management and Research Ltd. for quantitative and semi-quantitative mineral analyses, and has proved particularly useful for fine grained material such as alteration zones.

A modification of the Shapiro test was used by Mines Exploration Ltd. (Russell - pers. comm.) for rapid field determination of phosphate rock samples. Concentrated ammonium vanado - molybdate solution and standard powdered phosphate rock samples containing 2, 5, 10, 20 and 30 percent P_2O_5 were accurately prepared in the laboratory and taken into the field. Fixed quantities of any field samples which showed a positive reaction to qualitative testing were dissolved in a fixed volume of diluted ammonium vanado - molybdate solution in a test tube and the colour compared with that of standard solutions prepared at the same time from equivalent amounts of standard powders and reagent. This enabled six grade intervals to be determined. Variations in accuracy of field testing are caused by changes in the reactivity of the apatite and the associated gangue and by the presence of iron oxides which also produce a yellow colour in acid solution.

Improvements in field techniques

Studies in some areas have demonstrated extensive leaching of Cu, Ni, Zn, Mo, from the near-surface part of the profile. Because of this and because in so many places transported soils bear little

relationship to the underlying rock, surface geochemical sampling may give quite misleading results and extensive use is made of various types of auger, mostly power driven, to obtain samples near the base of the soil profile or in the weathered rock, which gives a more reliable indication of element distribution in the underlying formation.

Work on the relative concentrations of elements in the different size fractions of stream sediments has shown that the fraction which contains the highest metal values may be different under different climatic, geological and terrain conditions, and that while the -80 mesh fraction is usually satisfactory, fractions as coarse as -20 +40 give better results in certain circumstances. Accordingly some companies adopt the practice of commencing the stream sediment sampling programme of an area by making analyses of the different size fractions of key samples.

Much experimentation has been done with line and hole spacing for geochemical grids for both reconnaissance and detailed investigations. Optimum spacing differs according to conditions but lines 400 feet apart with holes 100 or 200 feet apart along the lines is one commonly used. In the nickel search areas many companies analyse only for copper and nickel, copper/nickel ratio being particularly significant.

In New Guinea, where terrain is rugged, vegetation cover thick, outcrop sparse, and gossans virtually non-existent, the geochemical method of prospecting has indeed been a boon to the explorer. There is plenty of water, so the most effective method is to take sediment samples from the streams, using each small tributary as a means of sampling its catchment for anomalous metal values. The main difficulty is access, and helicopters

are extensively used. To facilitate coverage, one company, C.R.A. Explorations Ltd., used a modified tuna-fishing vessel, the 'Craestar' of approximately 200 tons, 97 feet long, cruising speed $9\frac{1}{2}$ knots, as a mobile helicopter base. On board is a self-contained, air-conditioned laboratory using an atomic absorption spectrophotometer and bottled compressed air for analysis of geochemical samples. With this combination of laboratory and sampling team, C.R.A. were able to sample 15,000 square miles of New Britain, New Ireland, and part of mainland New Guinea in six months.

Geochemistry is associated with other exploration methods in various ways. In the nickel search areas some combination of detailed geological mapping, surface prospecting, airborne and ground magnetic surveys, geochemical methods and induced polarization surveys is applied. Under certain conditions of deep transported, skeletal or 'mixed' soils ground geophysics (a combination of magnetic and induced polarization methods) has been used as a reconnaissance tool ahead of deep augering for geochemical samples (Dono an, Gentle and Kappelle 1969).

Some companies are making increased use of mineralogical studies of rocks, especially from drill cores, to aid in the interpretation of geochemical and geophysical anomalies.

A method of scrape-sampling of diamond drill cores has been developed for obtaining a rapid indication of trace element distributions in diamond drill cores, and is now used as a routine procedure in investigations by the Bureau of Mineral Resources in the Rum Jungle area. It consists of scraping sufficient material from the outside of the core to obtain one representative sample for every tray of core (about 20 feet), which is then analysed by emission spectrography for about 30

elements, including Cu, Pb, Zn, Sn, Cd, Bi, Ag, Au, Ga, Ge, As, Sb, Co, Ni, Cr, V, W, Mo, Mn, Ta, Nb, Be, Th, Pt and Os. The method is considered to have three main advantages, in that it may indicate mineralization which might otherwise be overlooked, e.g. very fine-grained disseminated sulphide occurrences in black slates; it may indicate minor elements associated with known mineralization, e.g. Cd associated with Zn, or Mo associated with Cu, for which detailed assays may be warranted; and even in drill holes which have failed to intersect major mineralisation, the trace element distributions may help to elucidate the structural controls of minor anomalous zones, e.g. whether a surface geochemical anomaly is related to primary mineralisation controlled by bedding, faults or some other geological features.

Identification of significant geochemical association

Because so much exploration for nickel is being done in the Western Australian Shield area, where exposures are poor and geochemical methods are very widely used, many companies have made investigations of trace element distribution and associations in the rocks and soils of the area, aimed at increasing knowledge of geochemical dispersion processes. Studies carried out by J. Barry (1969) of C.R.A. Exploration Pty. Ltd. resulted in the following observations. The soils of the area have a low clay and silt content and there is not much variation in the trace element content of the various size fractions. However, soils derived from ultrabasic rocks-peridotites etc. - are generally impoverished and those from amphibolites enriched in metal content compared with their parent rocks. The table below illustrates the threshold content of Ni, Co, Cr, and Cu in both soil and rock.

| <u>Rock Type</u> | <u>Soil</u> | | | | <u>Rock</u> | | | |
|-------------------------------|-------------|-----|------|-----|-------------|-----|------|-----|
| | Ni. | Co. | Cr. | Cu. | Ni. | Co. | Cr. | Cu. |
| Amphibolite | 120 | 38 | 670 | 588 | 180 | 25 | 450 | 170 |
| Peridotite | 700 | 54 | 1300 | 94 | 2800 | 110 | 2200 | 95 |
| Country rock (schist etc.) | 670 | 44 | 1600 | 34 | 780 | 74 | 2850 | 70 |

Anomalous copper concentrations are associated with nickel derived from sulphide mineralization, as compared to that accumulated in the laterite capping over nickeliferous rocks. Laterites contain a higher percentage of chromium than do nickeliferous limonites (200-700 ppm) or cupriferous limonites (less than 150 ppm).

The presence of such elements as arsenic, mercury, selenium, platinum and cobalt have been investigated (Marshall pers. comm.) as pathfinders to the occurrence of nickel sulphides but without conspicuous success, and the copper/nickel association is the most reliable indicator for sulphide mineralization.

In the Tennant Creek area systematic sampling of the outcropping ironstones has shown that most of them contain 30 ppm Cu, compared to background values of 5 to 10 ppm in the surrounding unmineralised sediments, but in those ironstones associated with major sulphide lodes, which usually also contain anomalous cobalt and bismuth, the copper content may rise to several hundred ppm.

CSIRO Division of Applied Mineralogy (Hudson, in prep.) has been investigating the occurrence of alteration haloes around orebodies in the 'greenstone' belt of Western Australia. In one such investigation, selected diamond drill cores from Western Mining Corporation's nickel mine at Kambalda are being examined. These cores pass from the Ni-Fe-S ore of the Lunnun Shoot into a footwall sequence of basaltic rocks. The extent and nature of

any halo around the orebody is being assessed in terms of textural, mineralogical and chemical variation in the footwall rocks. Seventeen minor elements (Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Nb, Mo and Pb) have been selected for semi-quantitative chemical study by a rapid X-ray fluorescence technique.

It is proposed to extend this investigation to a broader study of the effect on wall rocks of ores differing in composition and genesis, using the electron probe microscope to study the migration of materials from the ore zone, especially by identifying indicator elements in grain boundaries and cracks.

In both Western Australia and Victoria many of the gold deposits are associated with anomalous quantities of arsenic (James and Mazzucchelli, 1969). Studies of this association have demonstrated differences in the arsenic dispersion patterns between replacement lode-type mineralization (e.g. Fimiston, (Kalgoorlie), and Agnew, Western Australia) and quartz vein-type mineralization (Norseman, Western Australia, and many of the Victorian gold mines) (Mazzucchelli, pers. comm.).

It has been shown that in the former type there is usually a very close, sometimes linear, relationship between the concentrations of arsenic and gold in the orebodies, as well as a primary dispersion halo in the wall-rocks. In the latter both gold and arsenic appear to be erratic in distribution in the quartz itself, but strong and consistent arsenic anomalies occur in the wall-rocks. At Norseman, all the major known gold-quartz orebodies are associated with strongly anomalous arsenic in the wall rocks. However, the distribution of arsenic along the controlling structures is so extensive that the primary arsenic target is a very large one and considerable detailed drilling

must be carried out within the arsenic anomaly to find gold ore-shoots.

These studies have led to the recognition of the usefulness of the arsenic-gold association in the reconnaissance phase of gold exploration and it has been used with success to locate gold mineralisation indicated by arsenic anomalies found by soil sampling programmes.

Similarly in New Guinea where gold is in places associated with arsenic, lead, and zinc the content of these metals in stream sediment samples has been used as a possible indicator for gold, as well as for the base metals themselves. Other similar relationships have been investigated in certain areas in the hope of identifying pathfinder elements for use in geochemical prospecting.

At Rum Jungle in the Northern Territory, W.F. Ridley of the Geological Survey of Queensland has been carrying out, in conjunction with the Bureau of Mineral Resources, a geobotanical survey of the Woodcutters area, where a lead-zinc deposit was found by the Bureau of Mineral Resources in 1966. Samples of wood, bark and leaves of various trees throughout the area have been taken at the beginning and end of the wet season, and trace element analyses for Cu, Pb, Zn, Ni, have been completed of 470 samples. The objectives are to determine whether there is any correlation between the metal content of the vegetation and the geochemical anomalies in the soil and weathered bedrock, and with the known mineralization; whether any types of vegetation in the area preferentially concentrate any of the metals; and whether there is any correlation between metal content of the vegetation and the ground water level, which is practically at the surface at the end of the wet season, and may be at a depth of 50 feet or more by the end of the dry. Results so far indicate that although some differences exist in the metal content of the trees on the mineralised and on the unmineralised areas,

these differences are less pronounced than those in the soil.

The CSIRO Division of Applied Mineralogy has embarked upon a project to study the use of tourmalines as ore indicators. To test the validity of the assumption the tourmalines which are genetically related to hydrothermal orebodies containing V, Cr, Mn, Co, Ni, Cu, or Zn should contain anomalous amounts of these elements, tourmalines have been collected from as many different environments as possible and analysed. Tourmaline is regarded as a particularly suitable mineral for this type of research because of its high chemical and mechanical stability, causing it to be preserved in deeply leached soils, laterite profiles and stream sediments (Hudson, in prep).

Comprehensive studies of problems or of ore deposits

A study of a large number of samples provided by Mount Isa Mines Ltd., mainly from drill cores, was made in the Bureau of Mineral Resources (Smith and Walker, in prep.). The samples were representative of the sedimentary formations adjacent to the orebodies, the greenstones, and other locally occurring basic igneous rocks.

The absence of primary element dispersion around the stratiform Pb-Zn-Ag orebodies confirms the now very widely held belief that these are syngenetic ores formed with the sediments. In contrast the pattern of element distribution shown by samples around the 1100 Cu orebody, together with the mode of occurrence of the orebody, indicate that this orebody is in part at least epigenetic and that much of the Cu in these silica dolomite bodies is derived from the underlying greenstones. Attempts to characterize each of the sedimentary formations chemically were not entirely successful. Little overall difference was found in the composition

of each unit, although wide variations occurred within them. The ranges of Ca are the most distinctive, although they overlap. It may be possible to define the upper limit of the Urquhart Shale, in which the orebodies occur, by a break in the pattern of Ca values between it and the overlying Group 2 Shales.

Another project on which the Bureau of Mineral Resources is engaged is a study of the elemental composition - trace and major - of Australian granites. A large number of samples have been obtained and these are being systematically analysed by X-ray fluorescent spectrometer and direct reading optical spectrograph for Si, Al, Fe, Mn, Mg, Ca, Na, K, P, Ti, Sc, V, Cr, Ni, Cu, Zn, Ga, Rb, Sn, Y, Zr, Nb, Sn, Cs, Ba, La, Ce, Pb, Th, U, Co and possibly Be, Ge, Mo, Tl, Li, W, Nd, Sb and As. Petrological studies of the samples are being carried out at the same time.

Work has been sporadic due to staff changes but analyses of approximately 200 samples from North Queensland, the first area to be studied, have been completed. It is hoped that it will be possible to correlate the results of the analyses with such features as age, petrology, tectonic environment, and associated mineralization to help to define metalliferous provinces and delineate favourable areas for the occurrence of additional mineral deposits, particularly of gold, copper, tin and wolfram.

Another study undertaken by the Bureau of Mineral Resources that has a bearing on geochemical prospecting is an investigation of the dispersion of metals in stream waters from a known source in the Canberra area, namely the abandoned mine and tailings dumps at Captains Flat near the head of the Molonglo River.

The study covers three periods:-

(i) Before 1962 when water pumped from the workings and treatment plant discharged abnormal quantities of Fe, Al, Mg, Cu, Pb, Zn, and SO_4 ions into the river;

(ii) 1962 to December 1966, when the mine ceased operations but mine waters continued to overflow into the river.

(iii) Since December 1966, when the mine was sealed, and discharge of metal ions was confined to that leached from tailings dumps and also from slimes spread over part of the upper reaches of the river by a previous tailings dump collapse.

During the pre-1962 period pH of river water rose progressively from 3 immediately below the mine to over 7 at 45 km. downstream. Fe precipitated rapidly in the first 500 m, then more slowly, together with Al and Cu, as pH rose to 5 over the next 13 km, by which time precipitation of these three metals was complete.

Sediment at the 13 km point consisted mainly of iron and aluminium oxides and silica, with Cu, Pb, and Zn ranging from 1000 to 5000 ppm.

Zinc persisted in the waters as far downstream as Lake Burley Griffin, a distance of 70 km.

In the period 1962-66 zinc content of the river water progressively decreased from 1000 ppm immediately below the mine to 0.72 ppm at 67 km. downstream; after the mine was sealed in 1966 the corresponding figures for zinc content are 19 and 0.27 respectively.

Two mechanisms have operated for the removal of base metal ions from solution: sorption and/or co-precipitation under mildly acid conditions during hydrolysis, in the upper reaches of the river; and separation of basic salts, either carbonate or sulphate, and deposition with the silt and clay, in the neutral reaches of the river.

Some companies have been processing and plotting geochemical data by computer, and various programmes have been developed for this purpose. A new company, Scientific Computer Systems, has been set up to provide computing services with special accent on the application of computers to the mining industry.

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