THE DETERMINATION OF GOLD IN VEGETATION
AND ITS APPLICATION TO SPECIFIC
PROBLEMS IN BIOGEOCHEMISTRY

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ABSTRACT

Studies were carried out to devise a method for determining nanogram quantities of gold in vegetation.

The samples (0.5g) were digested with fuming nitric acid over a water bath. After addition of hydrochloric acid, the gold was extracted into a small volume (1 ml) of methylisobutyl ketone (MIBK). The organic layer was back-extracted with distilled water to remove iron interference and gold in the MIBK was determined by an electrothermal atomization technique with graphite furnace atomic absorption spectrometry.

The optimum instrumental conditions for drying, ashing and atomization of gold were as follows: drying, 4.5V, 20 secs; ashing 6V, 20 secs; atomization 8V, 4 secs. A furnace cooling time of 50 sec. was allowed to attain high precision of signal heights.

Tests on the efficiency of the method developed, showed high precision, good accuracy with the limit of detection of 1 ng/g. Recovery studies on the known amounts of gold added to vegetation, showed an average recovery of 99.4%. On the basis of these results, the method developed and outlined can be used on a routine basis for analysis of vegetation, soils and rocks.

Biogeochemical and geochemical studies were carried out at 4 areas having different geological, topographical and climatic conditions. These were: Waihi, New Zealand, Seruwila in Sri Lanka, the Serbomacedonian massif in Northern Greece, and Yathkyed Lake in Arctic Canada. At each of these study areas, different plant species were collected and analyzed together with the soil for biogeochemical studies.

Investigations were carried out to determine whether the concentration of gold in plants could be used to predict the concentration of this element in the soil and also whether any other elements present could be used as a pathfinder for gold.

The results of biogeochemistry showed good correlation existing between gold in plant and gold in soil provided the gold concentration in the substrate was sufficiently high. Arsenic was found to be a possible pathfinder element for gold, particularly when the latter is present with chalcophile elements.

The range of plant species analyzed in this study suggest that gold uptake is not restricted to any particular plant species or to plants with deep rooting system provided the substrate is auriferous.

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1.1 Introduction

The term biogeochemistry was first used in 1917 by the Russian scientist Vernadsky, who defined it broadly as the study of the relationship between living material and the geological environment. Biogeochemical prospecting, as known today, originated from this concept. It deals with prospecting for minerals by chemical analysis of plant samples collected from suspected areas of mineralization. The success of this technique relies on the assumption that an anomalous concentration of a metal in the substrate, presumably caused by the presence of the ore, will result in an anomalous concentration of that element in the vegetation growing upon it.

Pioneering work on biogeochemical prospecting began 50 years ago when Tkalich (1938) discovered that an arsenopyrite ore deposit in Siberia could be delineated by the iron content of the vegetation growing upon it. In 1939 Brundin showed that the abnormally high content of vanadium in the leaves of trees in a part of Sweden and tungsten in the leaves of some trees in Cornwall, England could be attributed to the high level of these metals in the soil. However, it was not until the late 1940's that Warren et al. (1947) initiated biogeochemical prospecting as a viable exploration technique.

Biogeochemical methods based on trace element levels in vegetation have received some attention, however their potential use in prospecting has not been fully investigated. The major reason for this is probably that analysis of soils and drainage sediments has proven so effective in prospecting that there has been very little incentive to develop other methods.

A recent survey showed that biogeochemical techniques using perennial plants with deep rooting systems are among the most economical methods of prospecting. A good example is the finding of juniper roots more than 60 m from the surface in the uranium mines in the Colorado Plateau. It is not only the root system but other factors such as the pH of the soil, drainage and perhaps also the region from which plants take up their moisture, which have to be taken into account.

It is difficult to assess the true effectiveness of biogeochemical prospecting because the method is seldom used by itself; nevertheless, there are documented cases where biogeochemistry has proved to be successful. Cannon (1960, 1964) used biogeochemistry to identify uranium deposits and more recently Dunn (1981) from the analysis of twigs of Picea mariane, identified uranium deposits in northern Saskatchewan beneath an overburden of 150 m of sandstone. Dunn found that the analysis of the soil did not accurately indicate the extent of the uranium deposit as the concentration of uranium in the soil was only between 1 to 3 µg/g compared with the concentration of 154 µg/g in the twigs of Picea mariane. Brooks (1983) provides a table detailing more examples of successful applications of biogeochemical prospecting.

1.2 Gold in Vegetation

Gold has long been known to be a microconstituent of many plants and animals including man. The Czechoslovakian alchemist, Paterson Hain James is said to have found gold in Hungarian grapes in the early Eighteenth century but it was not until much later that Lungwitz (1900) suggested that the gold content of vegetation might indicate mineralization in the substrate. Today there are several records of uptake of gold by vegetation dating back to Berg (1928) and Bertrand (1932) who were perhaps the two earliest workers on the accumulation of gold in vegetation and animals.

The plant, Equisetum species has been analyzed by a number of workers (Nemec et al. 1936, Warren and Delavault 1950, Razin and Rozhkov 1966, Cannon et al. 1968 and Brooks et al. 1981b). While Nemec et al. (1936) found an extraordinarily high value of 610 µg/g in the ash of Equisetum palustre, the results of the other workers only ranged from 0.17-0.40 µg/g of ash. Since then it has been shown that the method used by Nemec et al. was not specific for gold but had interference from arsenic giving Equisetum a much higher gold content.

A review of gold levels in about 100 different plant species as compiled by Jones (1970), shows that the maximum concentration is 36 ng/g with the mean of 7 ng/g. These results show that the gold concentration of vegetation is greater than the concentration in the earth's crust which is about 4 ng/g (Mason and Moore, 1982). More recently Boyle (1979) presented a review on the biogeochemistry of gold and its deposits. Apart from Boyle, Brooks (1981b, 1982, and 1983) is the only other worker to have critically reviewed biogeochemical prospecting for gold. Erdman and Olson (1985) have compiled a comprehensive bibliography outlining fifty years of research into the use of plant analysis in prospecting for gold and other precious metals.

1.3 Biogeochemical Prospecting for Gold

The gold content of most plants normally ranges from 0.005 to 0.10 μg/g in the ash. When vegetation is to be used for prospecting for gold, the amount of gold in the plant material must be sufficiently high for analysis by the analytical procedure chosen. Unlike many other elements (such as nickel which plants can hyperaccumulate to the extent of 10 percent nickel in dry material - Jaffré et al., 1976) gold does not seem to be accumulated to any sufficient level by any plant species. Also because it is not known which plants can be used specifically to indicate gold deposits, emphasis has been placed on seasonal variations in the gold content of plants and its content in various organs of the plants. Schiller et al. (1973) noted marked seasonal variations in the gold content of plants, the maximum concentration being present during springtime. Dunn (1984) also found that maximum concentration of gold in alder twigs growing on the Southern La Range Belt, Saskatchewan was in spring (June).

With respect to the content of gold in the various organs of plants, Khotamov et al. (1966) state that the largest amounts of gold are concentrated in the above-ground portions of plants particularly the leaves. Warren and Barakso (1982) showed that young growth tends to have a higher gold content than old organs. Dunn (1984) concludes from a study in Saskatchewan, that the highest gold concentration occurs in the bark, followed by twigs, trunk and lastly needles.

The main obstacle to the use of biogeochemical methods for prospecting for gold lies with the analytical problems involved in determining this element at the very low concentrations (ng/g) normally found in vegetation. Unfortunately until recently, the only practical method of determining gold in vegetation was by the highly-expensive neutron activation analysis method. There is clearly a need for an inexpensive, quick and a reliable method for analysis of gold, and the development of such a method is the main purpose of this thesis. A further aim was to determine whether biogeochemical prospecting could be used for detecting gold mineralization.