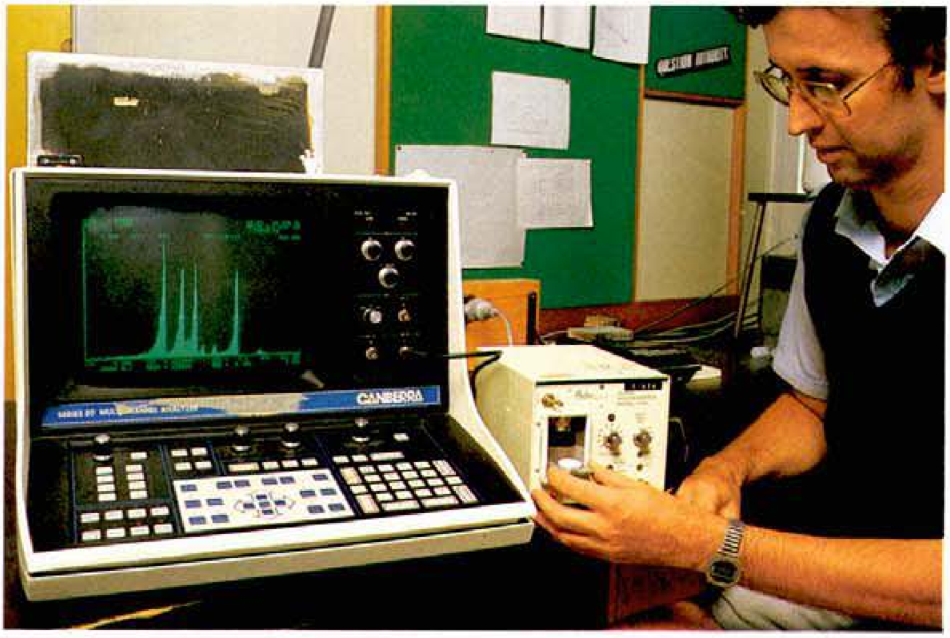
Seeking out the source of radium in groundwater

One of the potential problems in mining uranium is that highly radioactive radium can be leached out of tailings dams. However, you can't necessarily blame a nearby uranium mine if you find water containing high levels of radium.



Dr Bruce Dickson of the CSIRO Division of Mineral Physics has measured the radioactivity of more than 500 samples of groundwater from 16 locations throughout Australia, and found that some of them contain radium at levels up to ten times higher than the water in uranium tailings dams.

Other samples contained very high quantities of dissolved uranium (without a correspondingly high level of radium), yet there was no nearby uranium deposit.

The accompanying graph summarizes the results of Dr Dickson's measurements on many bore-water samples. You can see that a large number of points lie above the recommended maximum level of radioactivity for drinking water set by the Australian Water Resources Council (10 picocuries per litre). Most of these points belong to samples that are brackish or highly saline, so there's no danger that the water would be used for drinking.

However, some fresh-water samples showed radioactivity levels of some concern. Most of these came from uranium-rich regions, but a few originated from mineral springs in areas where no uranium concentrations have been identified.

Measuring the radioactivity of a groundwater sample.

Indeed, some years ago Dr Dickson found radioactivity levels in excess of 40 picocuries per litre in bottles of a popular brand of natural mineral water, and the product was withdrawn from the market. All the other bottled mineral waters that he measured were safe.

(This incident happened because the company bottled water straight from the spring. If the water is aerated first, a sediment containing ferric hydroxide forms, and this compound is a natural scavenger of radium. Aeration also removes any highly radioactive radon gas. Most bottled mineral waters available now are aerated and filtered first, so processing removes even slight traces of radium.)

Prospecting

Dr Dickson has been attempting to understand these variations in groundwater radioactivity, and to use this understanding to help uranium prospectors locate new deposits.

The key to determining the origin of a water's radioactivity, Dr Dickson finds, is to measure the relative levels of all four naturally occurring radium isotopes, as well as the uranium concentration.

The isotopes are radium-226 (half-life of 1600 years) and radium-223 (11 days), which derive from the radioactive decay of uranium-238 and uranium-235 respectively, and radium-228 (6 years) and radium-224 (4 days), which come from the decay of thorium.

By considering the relative abundance of each isotope and of dissolved uranium, Dr Dickson can make a good assessment of whether a groundwater has recently acquired its radioactivity from a nearby uranium deposit or has spent a long time in contact with 'country' rock of low radioactivity.

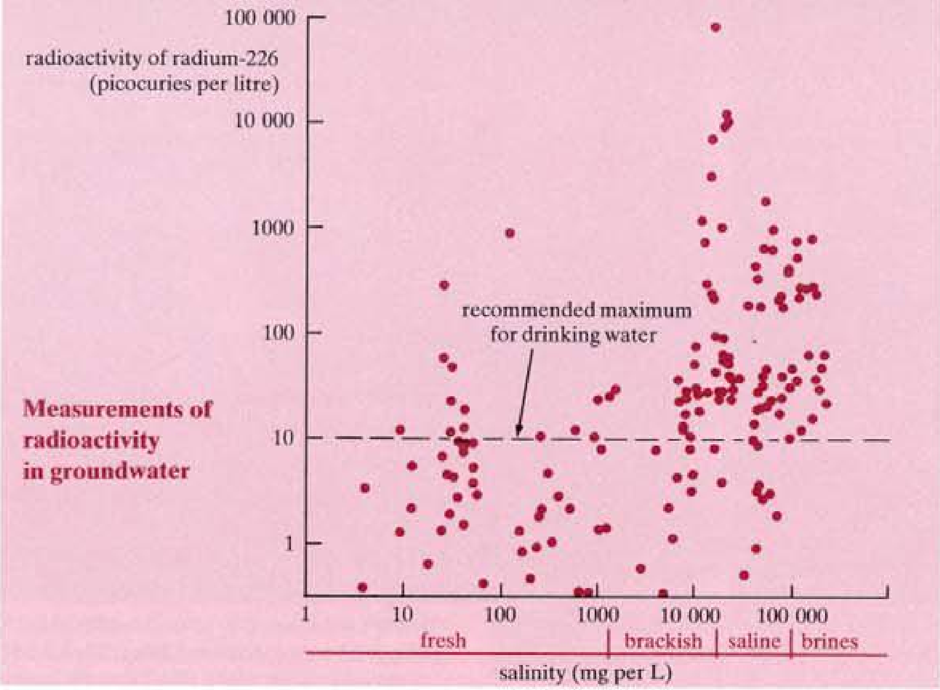
It is important to recognize that saline or acidic waters are very effective at leaching radium from rocks. All rocks contain small quantities of uranium and thorium, ranging from 0·5 parts per million (p.p.m.) in sandstones to 100 p.p.m. in some granites and shales. Laboratory studies show that sodium chloride solutions of strengths often found in Australia (above 30 g per L) can quickly leach radium into solution from natural rocks, provided the rock is porous or highly fractured. After saline water has worked on them for a long time it may carry quantities of radium equivalent to that borne by relatively fresh water after contacting uranium ore bodies with 3000 p.p.m. uranium.

Flow of these waters can carry the radium away from the source rocks and, if it comes to the surface, radioactive 'hot spots' can be formed. These 'anomalies' are commonly found on the margins of salt lakes (which have high salinity) or in tropical swamps (that have high acidity).

Leakage from a tailings dam can be distinguished from water having a naturally high radium concentration.

Examples of the first have been found near Lake Tyrell in Victoria, on the Eyre Peninsula in South Australia, and near Northam in Western Australia. In the last instance, the acidic saline water carrying the radioactivity came to the surface after the land was cleared for agriculture.

Examples of the second sort of anomaly occur in areas of high rainfall where radium from springs and seepages becomes trapped in acidic sediments, rich in organic matter.



The highest radioactivity readings came from salty groundwaters. However, some fresh groundwaters also exceeded the recommended maximum for drinking water.

Although the amount of radium in the water may be low, it accumulates in the sediments over long periods, and can lead to radium activities 100 to 1000 times greater than the natural content of the sediments. Dr Dickson has seen such cases from Australia's 'Top End', and from near Sydney.

Disappointment

Anomalies of both kinds have, in a number of instances, turned the excitement engendered by a fast-clicking Geiger counter to disappointment when drilling proved fruitless. To save mining companies such needless expense, Dr Dickson's analysis scheme can be used to distinguish radium accumulated from uranium-rich rocks from radium leached from country rock.

Environmentally, his approach is also useful in allowing a leakage from a tailings dam to be distinguished from water having a naturally high radium concentration. Such knowledge would prevent a repetition of the incident in 1982, when groundwater at the foot of the Ranger tailings dam was found to be rising above the natural ground surface. Initially, this was thought to be a leak, but the radium isotopic pattern was found to be uncharacteristic of the tailings water. Subsequently, it turned out that groundwater was seeping through fracture zones in the basement rock.

Dr Dickson's scheme is shown as a scoring system in the accompanying box. It readily shows the lack of usefulness, as a pointer for exploration, of the dissolved uranium figure by itself, which only contributes at most 1 of a maximum score of 8. Similarly, the radium-226 figure by itself isn't significant, and even if the two figures are both high, this only contributes another point to the score. The most important factors are considered to be the amounts, relative to radium-226, of radium-223 and radium-228.

The scheme's construction is empirical, although we can justify parts of it on theoretical grounds. For example, radium-228 is a decay product of thorium, and hence a relative abundance of this isotope points away from the likelihood of finding a nearby uranium source. Initially, it was expected that significant levels of radium-223 (with a half-life of only 11 days) would indicate a nearby uranium source, but in fact that's not the case. Low levels of radium-223 (compared with the long-lived radium-226) are more likely when near a uranium enrichment.

However, the scheme works well, as measurements taken near known uranium deposits have shown. To date it has given results in agreement with assessments from other methods for a wide variety of different groundwaters, even when concentrations of salt, uranium, and radium isotopes vary over a large range.

Dr Dickson is now looking at methods of using natural radioactivity as a tracer of groundwater movement. He has developed a model that describes how the isotopic composition of uranium and radium in an aquifer changes over time. He hopes to use the model to determine the rate of transport of these elements in particular aquifers (a figure that can otherwise be difficult to establish), and even possibly determine the flow rate of the water itself.

Andrew Bell

Any prospect of uranium?

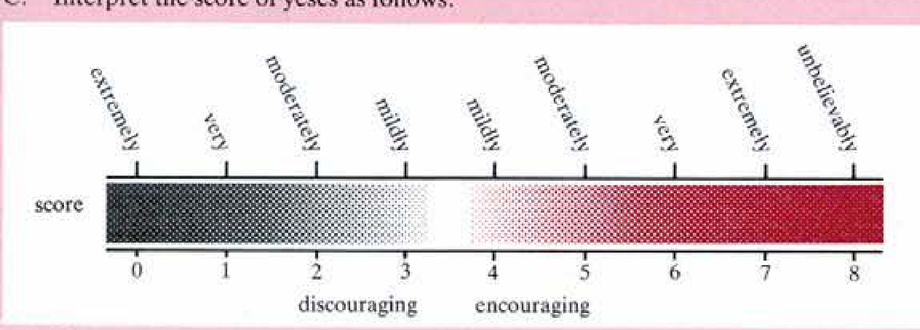
Dr Dickson has drawn up a scheme, based on the analysis of a groundwater sample, that indicates your chances of finding uranium nearby.

A. Analyse your groundwater sample.

B. Answer the following questions and count the number of 'yes' replies.

1. Is the uranium concentration greater than 10 micrograms per litre?
2. Is the figure for radium-226 radioactivity (pCi per L) greater than that for the concentration of uranium (μg per L)?
3. Is the radioactivity of radium-224 less than half that of radium-226?
4. Is the radioactivity of radium-226 greater than 11 times that of radium-223? If it is greater than 43 times count two yeses.
5. Is the radioactivity of radium-226 greater than twice that of radium-228 (one yes), greater than 10 times (count two yeses), or greater than 100 times (count three yeses)?

C. Interpret the score of yeses as follows:



D. If the result is encouraging, undertake further prospecting!

More about the topic

Radium isotopic measurements in the search for uranium in palaeodrainage channels. B.L. Dickson, R.L. Meakins, and A.M. Giblin. *Journal of Geochemical Exploration*, 1984, **22**, 363–6.

Radium isotopes in saline seepages, south-western Yilgarn, Western Australia. B.L. Dickson. *Geochimica et Cosmochimica Acta*, 1985, **49** (in press).