

TABLE 1. Products of uranium decay with potential as uranium ore indicators

Isotope	Half life	Comments
^{238}U	$4.5 \times 10^9 \text{ y}$	Mobile in oxidizing groundwaters
^{234}U	$2.5 \times 10^5 \text{ y}$	Increased concentrations in water resulting from α -recoil
^{230}Th	$8.0 \times 10^4 \text{ y}$	Least mobile element, indicative of original U location
^{226}Ra	1620 y	Mobile in deep groundwaters, less so in surface
^{222}Rn	3.8 d	Inert gas; diffusion distance limited by short half-life
^{214}Pb , ^{214}Bi	$\sim 30 \text{ m}$	95% gamma emission of U ores from these isotopes
^{210}Pb	20 y	Gives 100 y integration of radon flux
^{206}Pb	stable	Long time scale integrator of radon flux
^4He	stable	Helium produced by alpha decay. Inert, light gas

school of thought maintaining that radon is capable of diffusing in detectable quantities over hundreds of metres. Some impressive results have been published to substantiate these claims from surveys made using the track-etch method (Greigich and Fisher, 1976). Other studies on surface radon emanation (Gableman, 1977) have found examples of massive spurts of gas which cannot be correlated with the emanation potential of the soil and were interpreted as irregular injections from greater depths. A model of subterrestrial fluid convection has also been proposed to account for spurts of radon (Mongro-Campero and Fleischer, 1977). On the other hand geochemical evidence suggests that radon diffusion in dry rocks is small and, if radon is carried by ground-water movement, then those waters will carry the longer-lived ^{226}Ra or ^{238}U as well. Deposition of ^{226}Ra and ^{238}U closer to the surface will then give rise to the surface radon anomalies. The possibility of such movements suggests that geochemical analyses for leachable uranium of ^{226}Ra should also be made of samples taken from beneath the immediate soil horizon.

Thus much remains to be learnt about radon and helium sources and migration below the ground. However, with the increasing number of techniques being proposed and evaluated for their measurement, and the increasingly detailed approach to those evaluations, the relative merits of the methods and their relevance in uranium exploration will become clear. With the present momentum of exploration need, this should occur in the near future.

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PRACTICAL GAMMA SCINTILLOMETRY TOTAL COUNT VERSUS SPECTROMETRY

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The purpose of this paper is to illustrate the relative sensitivities of total count and multichannel spectrometry in uranium exploration.

The spectra of Uranium and Thorium are examined and a comparison made between logarithmic and linear plotting. This emphasises the relatively small number of counts recorded in the 1.76 MeV "uranium" peak and 2.62 "thorium" peak compared with total count. The preponderance of Bismuth 214 peaks in the spectrum is discussed and the lack of any outstanding peaks of other daughter products. Reference is made to work carried out by Mero on the use of lower energy emissions from other daughter products with indication of uranium assaying and determination of equilibrium. The use of simultaneous total count, gamma and beta from prepared samples in uranium assaying is described following work of Eicoltz and Daly & Urquart. This method also indicates the state of equilibrium. The energy spectrum of Thorium is compared with the Uranium Spectrum and the dissimilarities discussed.

The efficiency of sodium iodide as a gamma detector is examined and curves of absorption efficiency have been plotted.

ed for selected energy levels and crystal thicknesses. These illustrate the greater efficiency of this detector at low energy levels. This is further emphasised by the plot of crystal thickness against energy level for various efficiencies. These results indicate that a thickness of 100 mm (4 inches) has an efficiency of 80% for the 1.76 MeV peak while a thickness of 50 mm (2 inches) has only a 50% efficiency. Corresponding efficiencies for 0.5 MeV are 95% and 80%.

Combining crystal efficiency with the spectra for uranium and thorium which are normally taken with large crystal volumes illustrates the need for very large crystals for the 1.76 and 2.62 MeV uranium and thorium channels.

Airborne surveying is briefly discussed and reference made to sources of detailed information. Ground total count work is discussed and relative merits of integral and differential spectrometry illustrated. For maximum sensitivity with small crystals work should be limited to total count. Spectrometry requires a minimum of 50 mm crystal thickness and larger sizes are an advantage. Field assaying is outlined and the calibration of scintillometers and spectrometers discussed. Borehole logging with total count and spectrometric ratemeters is described with particular reference to crystal thicknesses and volumes. Continuous logging and static readings are compared with illustrations and statistics compared. Restrictions on logging speeds are illustrated. Mention is made of radiometric standardization pits at Australian Mineral Laboratories and extension to inhole assaying discussed.

HELIUM ISOTOPES IN ENERGY EXPLORATION

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1. Introduction

Sources of energy are becoming a more important component of the minerals industry, both for national use and for export income. There are few opportunities to integrate concepts of metal mining into the energy environment. However, we believe that the implications that can be drawn from observation of the natural variation of helium isotope abundances can be useful in the exploration for oil and gas reservoirs for concealed uranium deposits.

2. Concept

Tracing the dispersion of highly mobile "pathfinder" elements is a well-developed concept in mineral exploration especially applicable to the search for base metal deposits. Radon is commonly used to infer the presence of uranium mineralization; its association is clearly recognized as ^{238}U is its only progenitor. Similarly helium is a suitable indicative element because one of its isotopes, ^4He , is generated by the α -decay of uranium and its α -emitting daughters.

In oil and gas exploration, a comparable strategy calls for the identification of an associative element which is functionally relatable to hydrocarbon trap mechanisms and which undergoes a spatial dispersion capable of detection at the surface. In recent years, helium has been proposed as a suitable element.

It will be shown in the following discussion, that helium isotope determination is capable of yielding much more valuable information than measurements of total (elemental) helium.

3. Discussion

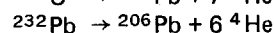
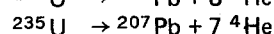
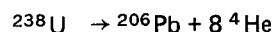
An isotopic approach to exploration is suggested on the basis that (i) helium has two naturally occurring stable isotopes whose ratio is known to vary over at least 5 orders of magnitude and (ii) known reactions are sufficient to explain these natural isotopic abundance variations.

Three major contributions to the helium inventory are readily identifiable.

- (i) A primordial component included during planetary formation.
- (ii) A ^4He radiogenic component due to natural α -decay integrated over the life of the earth.
- (iii) A ^3He radiogenic component from the β -decay of tritium originating in atmospheric and geologic sources.

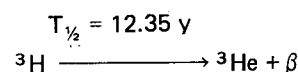
The ^4He radiogenic component is principally due to uranium and thorium decay.

The relevant reactions are

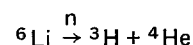


For a crustal average of 4 ppm U and 12 ppm Th, the present crustal generating capacity of ^4He is $8.2 \times 10^{-13} \text{ cm}^3/\text{g/y}$. Assuming the age of the crust is $4.5 \times 10^9 \text{ y}$ and that no appreciable amount of U or Th has been added or removed, the production of ^4He at the time of formation of the crust was $31 \times 10^{-13} \text{ cm}^3/\text{g/y}$. Using an average annual production rate of $\sim 20 \times 10^{-13} \text{ cm}^3/\text{g/y}$ over the period $4.5 \times 10^9 \text{ y}$, one calculates that a gram of average crustal material should contain $9 \times 10^{-3} \text{ cm}^3$ of ^4He . In fact, the observed figure is 10-30% of this amount, the remainder having been lost from lattice locations, by diffusion into pore space or fissures and ultimately by degassing into the atmosphere.

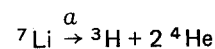
In the case of ^3He , the parent source is principally the reaction



Tritium is generated in the crust by the reactions



and



and in the atmosphere by

