Tools and techniques in radiometric exploration

All areas of geophysical exploration are becoming increasingly dependent on electronic instruments in the search for minerals and energy sources. Radioactive minerals in particular are in great demand. Here’s a run-down on the instruments used and how they are employed.

Malcolm J. Plunkett

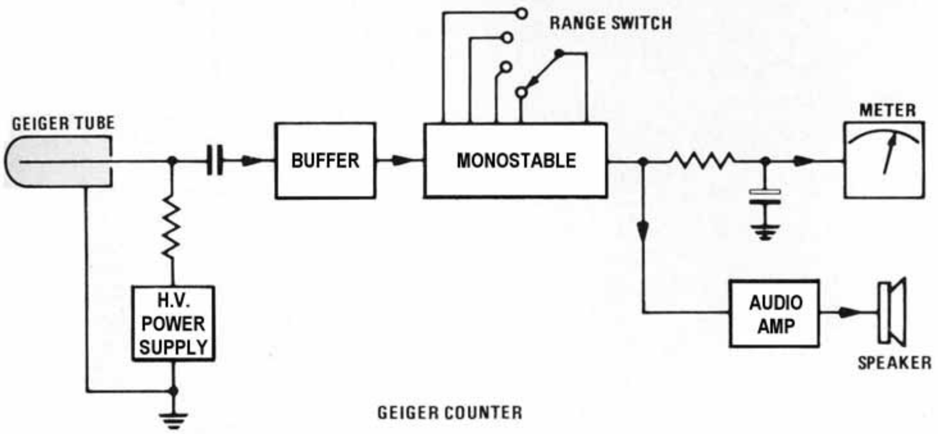
URANIUM EXPLORATION started in earnest after the second world war when every man and his dog was selling up and heading for the bush with geiger counter in hand. At that time, the major deposits were discovered purely by surface indications of radioactivity. However, that era is virtually at an end, and future finds are more likely to be below the surface or in inaccessible areas. The Roxby Downs deposits in South Australia for example are over 300 metres below the surface.

It has been necessary therefore to refine existing prospecting techniques, develop new ones, and improve the sensitivity and discrimination of all instruments in radiometric measurement techniques in common use, and to give some insight into the various methods of radiometric surveying. As mentioned before, Geiger counters were the major instrument in use in early uranium exploration and while other detectors are now available, the Geiger counter still has a place in preliminary exploration and radiation monitoring. A Geiger tube consists of a hollow metallic cylinder with a centrally- located wire inside. The whole system is either sealed in a glass cylinder or the outer metal tube is used as the sealed chamber with appropriate end insulation. The cylinder is evacuated and filled with a gas such as helium, argon or neon, plus a small percentage of an organic or halogen gas as a quenching agent.

A high voltage is applied between the central wire and the outer tube, so that when a gamma ray enters it, the gas filling ionises and causes a discharge. The discharge is quickly quenched or extinguished by the quenching agent, resulting in a relatively large current pulse through the tube that can be easily measured. The gamma rays must be stopped completely for a discharge to occur, which results in a very low conversion efficiency for Geiger tubes of only 1%, as only one in each hundred rays is completely stopped. This insensitivity can be useful however, as the Geiger counter can be used in areas of very high radioactivity without the count rate becoming excessive.

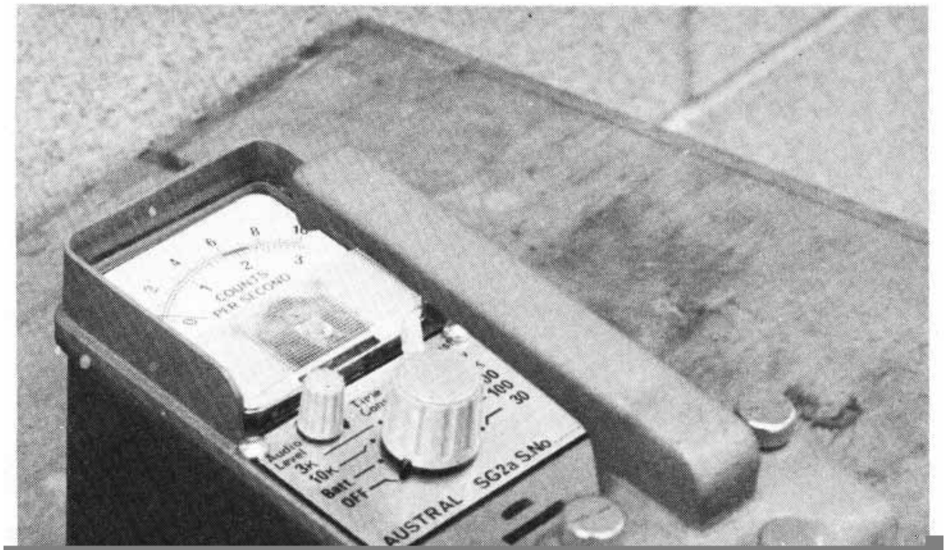
The Geiger counter circuitry shown m the accompanying block diagram is quite simple using a monostable to give a constant width to the pulses, which are averaged over several seconds so that the count rate is proportional to the average dc level. The range switch can change the monostable width, or the meter resistor, or both, to get the correct division ratios. To maintain accuracy with this system, it is important to keep a constant pulse height and stable pulse width. Although the high voltage supply can be very low powered, it is important to keep the output voltage stabilised and within the admissible operating voltage range (known as the counting.plateau).

Block diagram of a typical commercial Geiger counter. The monostable has provision for selecting preset pulse widths (‘RANGE’) for differing count rates, depending on the level of radioactivity being measured. The monostable output is differentiated by a CR network and drives a meter calibrated in counts per second.



Scintillation counters

Scintillation detectors are the basis for almost all modern radiometric exploration instruments. As with the Geiger tube, the principal of operation is quite simple. However, the method by which the electrical pulses are produced is completely different. The detector assembly consists of a scintillation crystal which is optically coupled to a photomultiplier tube. The crystal is usually made of thallium-activated sodium iodide which has the property of emitting a small flash of light (scintillation), when a gamma ray is stopped in it. The photomultiplier tube is a light



amplifier which gives out an accurate, amplified reproduction of the light flash in the crystal, in the form of a short electrical pulse (approx. 2 us).

The great advantage of this rather indirect method of detection is in its efficiency, which approaches one hundred percent. Special protection is needed for scintillation crystals and photomultiplier tubes, which results in an instrument which is less rugged, more expensive, but far more sensitive than a Geiger counter. The circuitry of a simple scintillation counter is very similar to a Geiger counter, but usually with extra ranges for the higher count rates.

Radiometric ground surveying

In the search for unknown uranium deposits the ground is traversed on a regular grid, noting the readings at set intervals. The chance of finding an outcrop on the surface is very low, so it is important to note any change in the normal background radiation level, as even a metre or so of soil may have a considerable masking effect. If an area of high radioactivity is located, it would be very premature to stake a claim at this stage. Firstly, the material may be thorium, potassium, or uranium or a combination of them. These can be distinguished from each other because the radiation they produce has characteristic energy levels, resulting in different height pulses from the photo- multiplier tube. By counting only three narrow ranges of pulse heights, the ratio of the three radioactive elements can be determined.

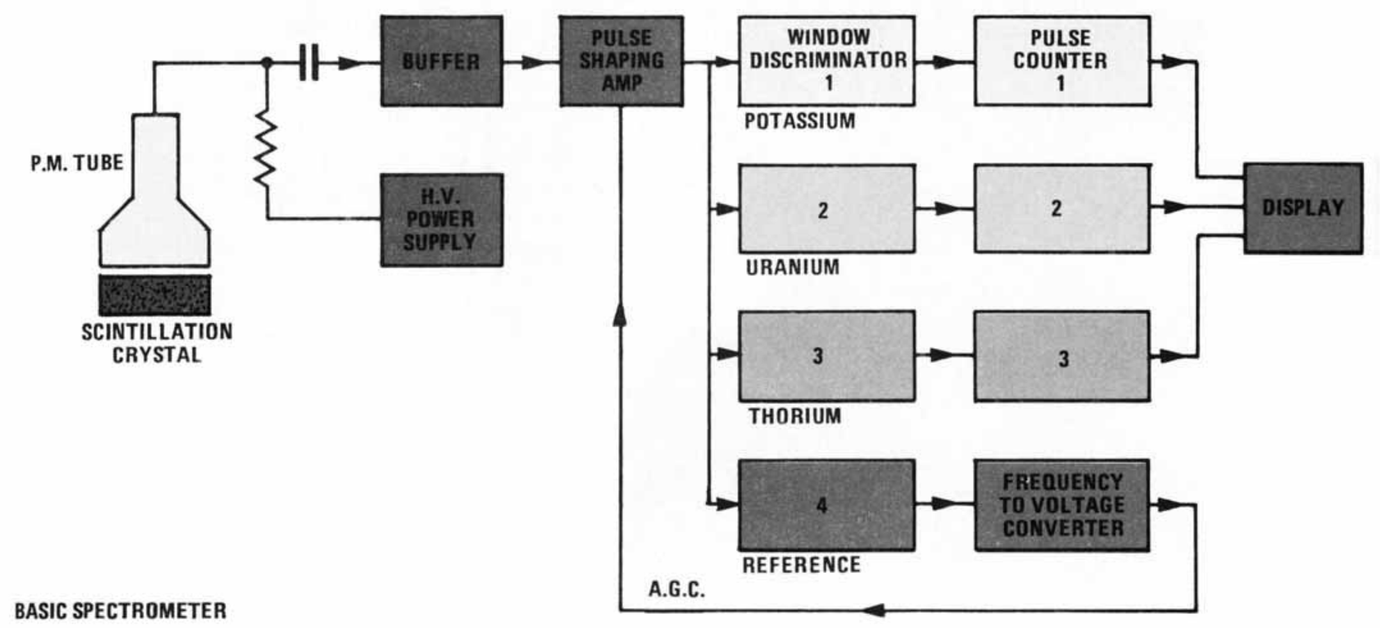
This is known as pulse height spectrometry and is beyond the capabilities of a simple scintillation counter and impossible with a Geiger counter. The scintillation crystal used in spectrometers must be large to obtain good results, and the circuitry must be highly stable and temperature compensated. A fourth channel is sometimes used to monitor the pulses from a small quantity of radioactive material which is doped into the crystal, to allow automatic temperature compensation.

A problem encountered with all radiation measuring instruments is that the emissions are random, requiring the circuitry to be ready to accept pulses separated by only a few microseconds when the average time between pulses may be 100 milliseconds. It is clear then that a simple monostable system would not be suitable, and pulse height spectrometers must employ sophisticated pulse shaping and counting circuits to

THE BASICS

Uranium exploration is based on the measurement of naturally occurring radioactive elements. All igneous and sedimentary rocks contain variable amounts of the three main naturally occurring radioactive elements, uranium, thorium, and potassium. The average concentration of these elements is only 0.1 - 10 parts per million, while uranium ore may have a concentration of several percent.

An element is considered to be radioactive when the atoms of which it is made disintegrate spontaneously, causing it to decay and form new elements known as daughter products. As it decays, it may emit several types of radiation, however the one of interest to us is gamma radiation. Gamma rays have no mass, no charge, and can be regarded as highly penetrating electromagnetic radiation. The measuring device must therefore have a detector for converting these gamma rays into electrical pulses which can be counted for a fixed time period, or averaged as in a car tachometer.



BASIC SPECTROMETER

minimise these problems.

Even spectrometers cannot always determine the usefulness of a deposit, as leaching and weathering can remove the original uranium, leaving only the radioactive daughter products behind.

In conclusion, it can be seen that finding naturally occurring radioactive material is relatively simple, but finding out exactly what you have found is considerably more difficult!

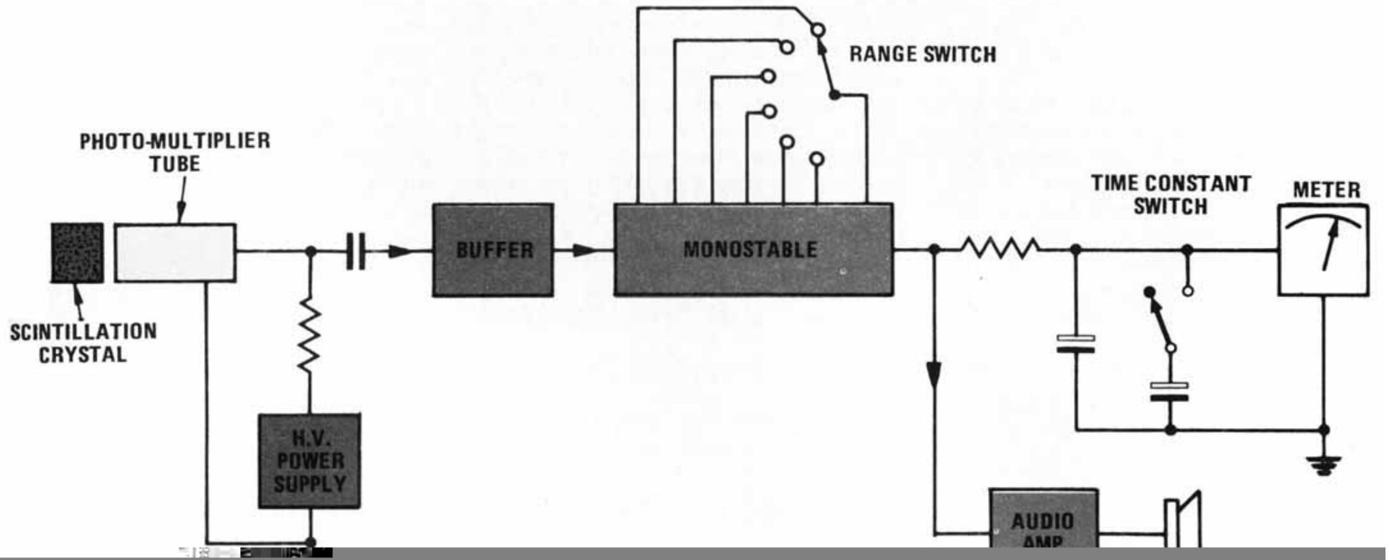
Airborne radiometric surveying

Airborne radiometric surveys have been carried out for many years but even using the latest airborne spectrometers, the results can only be used as a guide. The plane must fly on reylar grid lines recording the quantities of uranium, potassium and thorium, as well as the total radiation, on strip chart recorders or magnetic tape. The readings are used to produce radiometric contour maps on which the peaks indicate areas of high radioactivity, known as anomalies. However the size and intensity of the anomaly cannot directly determine the actual extent of the deposit, due mainly to the masking effect of any overlying material. Problems also arise with pockets of airborne natural radon gas, uneven terrain, cosmic radiation and temperature changes.

The results then, are mainly used to eliminate areas which have very few anomalies, and to give a starting point for follow up ground surveys, or borehole drilling.

Radiometric borehole logging

When boreholes are drilled to locate any type of deposit, it is a very costly procedure to recover core samples for



laboratory analysis, particularly if the exact depth of the seam is not known. The usual procedure is to lower a probe into the hole and measure the natural radioactivity, which is recorded on a strip chart recorder, relative to the depth of the probe. The probe contains a Geiger tube or more commonly, a scintillation detector, together with its high voltage power supply and a signal buffer. As the cable usually has only one insulated inner conductor and a high tensile steel braid, the pulses must be coupled on to the dc supply to the probe and then picked off across an inductor at the surface. The surface electronics consists of an accurate ratemeter with several selectable averaging time constants, to allow low count rates to be resolved accurately.

These probes are extremely important in uranium exploration as they can give the exact depth and thickness of the deposit and also a reasonably accurate figure for the grade of ore. However, radiometric borehole logging is quite often not used to locate uranium.

Because the scintillation detector is so sensitive, it can measure the minute amount of radioactive material present in various rocks, and while the count rate cannot directly identify the rock type, the boundaries between different beds can be sharply defined. This is a very useful measurement because the hole can be air or water filled and steel cased or uncased, without greatly affecting the results.

There are some problems however, as the probe must be watertight to depths of 1000 m or more and able to withstand the pressure at that depth. It must also be rugged and have a wide operating temperature range. This is an extremely harsh environment for sensitive electronic equipment, and careful design is essential.

Summary

Modern electronics and refined measurement techniques have greatly assisted uranium exploration and has led to radiometric borehole logging being accepted as a tool for exploration in general.

Spectrometer-type instruments have eliminated many errors in ground and airborne surveys and allow the field geologist using only a small portable instrument to gain enough information to decide if more detailed investigation is wpl.e24.6(e)-7r(x)24 Tc 0.0n-24.u(6(s)-1(w)30.