The Gamma-logging Calibration Facility at the Australian Mineral Development Laboratories

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Abstract

A facility for the calibration of down-hole radiometric logging instruments has been constructed at the Australian Mineral Development Laboratories in South Australia. Three calibration models of a borehole passing through a zone of homogeneous uranium ore have been completed and are available to users. The radiometric grades determined for the models are 0.209%, 0.920% and 0.054% equivalent U_3O_8.

Introduction

Gamma-logging is widely used in exploration and in estimation of *in situ* reserves of radioactive elements such as uranium. The calibration of gamma-logging probes is based on correlating a measured gamma-ray count-rate from a detector against a known radiometric uranium grade specified as equivalent U_3O_8 (denoted eU_3O_8). Currently the best means of obtaining the calibration is to construct a model of a borehole passing through a zone of uranium ore of known grade (International Atomic Energy Agency, IAEA, 1976). The ore zone, made from mixed uranium ore and concrete, can be made homogeneous and be constructed with its radius and half-thickness greater than the dimension needed to give an effective infinite medium at the radiation energy emitted by the ore. To fulfil the need for a facility in Australia to calibrate gamma-logging equipment, the South Australian Department of Mines and Energy commissioned the Australian Mineral Development Laboratories (AMDEL) to construct three concrete models (called test-pits).

These test-pits were constructed at AMDEL's Frewville site in South Australia and are now available for use by industry.

Construction

The test-pits were designed to meet the IAEA recommendations so that they would be suitable for use as an Australian primary calibration facility. Knowledge of the construction of calibration boreholes at Grand Junction (Knapp & Bush 1976) and at Ottawa (Killeen 1978) was of assistance during the design stages.

Instead of using a pipe as a former around which concrete was poured (a procedure which seemed more difficult to perform successfully) a central core was drilled for the borehole. As a result of this drilling, the core was available for the analysis of the test-pits, instead of relying only on tub samples.

Improvements were made to the design of the test-pits after the first one was built. For example, the thickness of the upper barren zone was increased from 1.0 m to 1.6 m so that probes could remain in the borehole at the top of a run.

Each test-pit contains three zones: a simulated ore zone sandwiched between an upper and a lower barren zone. The diameter of the pits is 1.22 m and at the axis of the ore zone the radius approximates an infinite thickness for the 1.764 MeV gamma-rays emitted by uranium ore. The thickness of the ore zone in the three test-pits varies from 1.41 to 1.45 m. The central boreholes, 108 mm diameter, were made by diamond-drilling through the three zones and into the barren concrete extension below. Each borehole was drilled 1° off vertical to ensure that probes lowered into it would remain in contact with the wall.

The concrete used was selected from local materials having low uranium, thorium and potassium concentrations. The uranium content of the ore zone was arranged by mixing in known weights of a 10% U_3O_8 ore crushed to −1 mm. This ore was a remainder of a sample earlier sent to AMDEL for metallurgical studies, and was made available by kind favour of Queensland Mines Ltd.

Samples

The core obtained from diamond-drilling the test-pits was split into two halves and sectioned into approximately 100 mm lengths for analysis. The samples of one-half of the core were crushed, pulverized and dried at 110°C for 16 hours. The results reported here are on a dry-weight basis.

Analysis

Independent analyses have been made by AMDEL and by the Division of Mineral Physics of the Commonwealth Scientific and Industrial Research Organization (CSIRO) for the uranium and radiometric grades of the test-pits. Final results agree well between the two sets except for the chemical uranium content of the high-grade test-pit.

Radiometric uranium (eU_3O_8) analyses were carried out using the sealed-can method (Scott & Dodd 1960).

To convert from gamma-ray count-rate to eU_3O_8 requires a standard calibration sample which is prepared in the same manner as the samples being measured. For the results reported here, CSIRO used a pitchblende sample prepared by Sill (Sill & Hindman 1974), and AMDEL used a Canada Centre for Mineral and Energy Technology (CANMET) BL-5 sample (Faye et al. 1979). With both standards, uranium and its daughter radionuclides are stated to be in secular equilibrium.

An accuracy of ±2% is estimated for the radiometric analyses. A comparison of the mean results for the test-pits is given in Table 1. Agreement between the sets is good; i.e. ±1.1%, ±0.8% and ±2.7% relative to the mean of each set for test-pits 1, 2 and 3 respectively.

TABLE 1

Mean Radiometric Uranium Analyses (ppm eU_3O_8)

Test-Pit no.	No. of samples	CSIRO	AMDEL	Average
1	14	2112	2067	2090
2	14	9273	9131	9202
3	14	553	524	538

Variations to the eU_3O_8 analyses of the core samples along the boreholes are shown in Fig. 1. The mean results have standard deviations of ±3.0%, ±1.9% and ±4.6% for test-pits 1, 2 and 3 respectively.

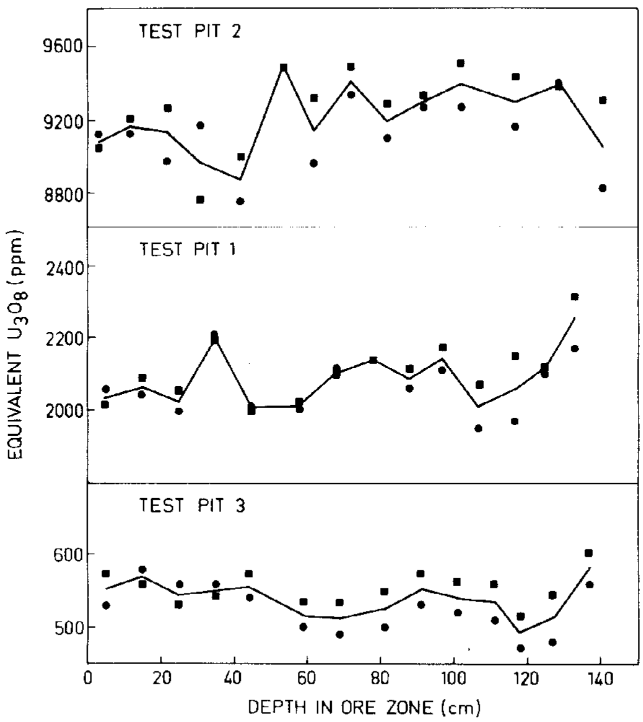

FIGURE 1

Variations of the dry-weight eU_3O_8 analyses of the core samples through the ore zones of the three test-pits obtained by AMDEL (•) and CSIRO (▪).
The solid line joins the mean of each sample.

TABLE 2

Mean Uranium Analyses (ppm U_3O_8)

Test-pit no.	CSIRO	AMDEL	Average	Equilibrium factor
1	1774	1812	1793	0.86
2	7980	8452	8216	0.89
3	466	468	467	0.87

The chemical uranium content in each sample was also determined, as shown in Table 2. The results labelled 'CSIRO' were carried out by the Physics Division, Australian Atomic Energy Commission, Lucas Heights, N.S.W. using the delayed-fission neutron-analysis technique (Wall 1978). The AMDEL results were obtained by X-ray fluorescence analysis. An accuracy of ±3% is obtained by each method. The mean results for test-pits 1 and 3 agree to within ±1.1% and ±0.2% respectively, but for the high-grade ore in test-pit 2 the mean results differ from the average by ±2.9%. The equilibrium factor (equal to the ratio of U_3O_8 to eU_3O_8) is also shown, derived from the average analyses. Since the test-pits were prepared from the same ore the equilibrium factor for the three pits should be identical. The factors obtained for the three test-pits are in good agreement.

The thorium and potassium contents of the cores from the ore and barren zones were determined by X-ray fluorescence and atomic absorption spectrometry, respectively, at AMDEL. The mean values of thorium and potassium concentration of the core samples are given in Table 3. There are only small variations between the three test-pits and the levels are sufficiently low to contribute less than 0.5% to the observed count rate in the low-grade pit.

Specific gravities of the core samples were also determined on the core soon after drilling and after drying at 110°C for 16 hours. These results are given in Table 3.

TABLE 3

Analyses of Test-pits

Test-pit no. / Zone	1 ore	2 ore	3 ore	1, 2, 3 barren
Thickness of zone (m)	1.41	1.45	1.43	
eU_3O_8 (ppm)	2090	9200	540	–
U_3O_8 (ppm)	1790	8220	470	3
ThO_2 (ppm)	10	5	4	4
K (%)	0.76	0.76	0.55	0.55
Specific gravity, dry	2.14	2.14	2.17	2.19
Specific gravity, wet	2.31	2.34	2.35	2.35

Discussion

The analysis of the samples obtained by drilling the test-pits indicates that the ore zones as constructed are sufficiently homogeneous (to within ±5%) to be used as calibration models. This conclusion is borne out by many (mostly unpublished) test logging-runs (for example Alvey 1979).

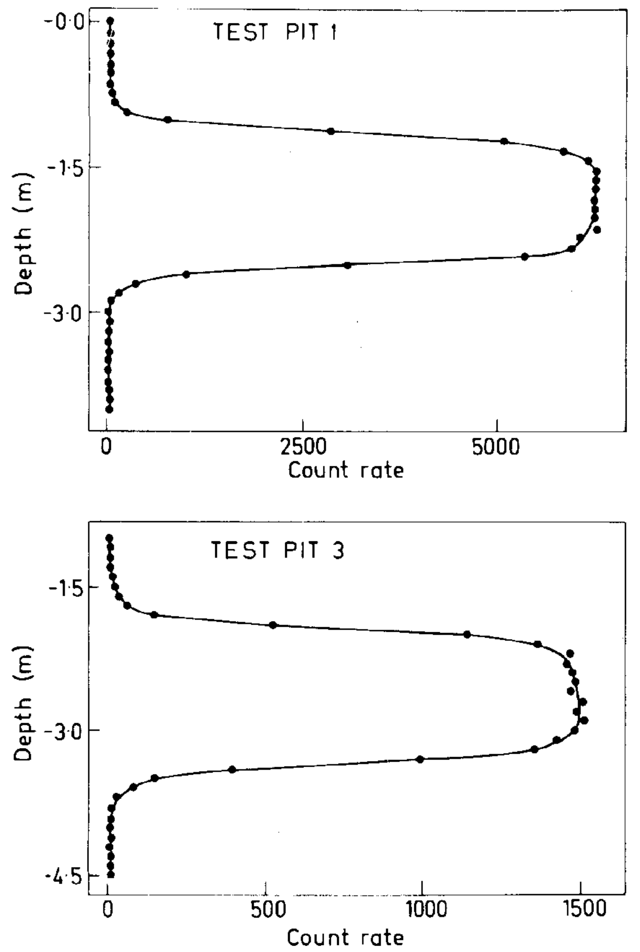

FIGURE 2

Gamma-ray logs of count-rate versus depth for test-pits 1 and 3. Units of count-rate are counts per second.

Figure 2 shows another set of results obtained using a SIROLOG probe (Eisler & Huppert 1979) with a 5 x 5 cm sodium iodide (thallium activated) scintillation crystal to log test-pits 1 and 3 at 5 cm intervals. The probe was stopped at each position to plot the full energy spectrum, and the counts for gamma-ray energy greater than 450 keV were recorded. The uniformity of the count-rate in the centre of the ore zones is evident.

The uranium grades given here for the test-pits are based on dried samples sealed to prevent radon loss, whereas the ore zones have a possible variable water content or could suffer radon loss. Such problems have been noted in other calibration facilities (Løvborg et al. 1978). Thus, such borehole models cannot be considered as absolutely static and their characteristics must be monitored over time. The present test-pits are being thus monitored to ensure that users can have confidence in them.

In addition to the pits described here, three more test-pits have been constructed and are currently being analysed. These are: a mixed thorium, uranium and potassium pit, an equivalent American Petroleum Institute (API) pit, and a limestone porosity pit. Details of these further pits will be available from AMDEL.

Procedures for Use

Information for use of calibration facilities is given in detail in a brochure available to users which may be obtained by contacting the Applied Technology Division, AMDEL. Included in this brochure are the test-pit dimensions and analyses, a detailed location map, the procedure to gain access to the calibration site and recommendations regarding the use of the test-pits.

Acknowledgments

The authors acknowledge the assistance of I. Thomas for the analyses made at AMDEL and J. T. Alvey (S.A. Department of Mines and Energy) for useful discussions.

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