Reassessment of the grades of the Adelaide model logging pits

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International efforts made in the early 1980s to cross-calibrate the grades of model pits used in the calibration of total-count gamma-ray logging tools for uranium were never applied to bring the Australian, Canadian and USA pits into agreement. Recent studies on calibration revealed problems with the Australian pits and data from the 1980 studies has been re-evaluated to give new grades for the Adelaide pits of 0.210, 0.983, 0.051 and 0.18 eU₃O₈% for pits AM1, 2, 3 and 7, respectively. These changes ensure the four pits are in relative agreement with logging results and gamma-ray transport modelling. The absolute grade is more difficult to assign definitely but indications are that AM1, through being twice sampled by coring and analysis, is more likely to be correct than pits whose grades are solely based on analysis of poorly handled samples. The changes in the grades actually have little effect on the grades in U deposits determined using the Adelaide model pits for calibration as the error with AM2 acted as a compensation for the Z-effect in that pit.

Keywords: assigned grades, calibration, gamma-ray, logging, model pits, uranium.

Introduction

Total-count logging probes are used by uranium (U) miners and explorers to assist with ore estimates. The theory of the operation of such probes was established in the 1960s (Dodd and Eschliman, 1971). The relationship between the U grade in a thick zone in a model pit to the count-rate in a field drillhole, for U contents below a few percent, as given by George (1982b) is

$$G_d = K F_m F_z F_w F_c F_d r$$ (1)

where $G_d =$ dry grade commonly expressed as weight-percent eU₃O₈,

$K =$ a constant of proportionality, determined at a calibration facility,

$F_m =$ Moisture Factor to correct for differences in formation water (100 – % water in calibration model)/(100 – % water in formation),

$F_z =$ Z-effect¹ Factor to correct for the presence of U itself, which is a function also of $R_z$,

$F_w =$ Water Factor for differences in the fluid between test-pit and field drillhole,

$F_c =$ Casing Factor to correct for hole rod or casing material,

$F_d =$ Dead-time Factor, also a function of $r$, and

$r =$ Observed count-rate.

As indicated by the factor $K$, the existence of a set of model pits in which to perform calibration is essential for the quantitative use of gamma-ray logging. In Australia such a set of pits was constructed in the late 1970s in Adelaide and is now maintained and run by S.A. Department for Water. The design of the AM2 pit is shown in Figure 1. There are four pits suitable for calibration of total count tools as detailed in Table 1.

The assigned grades in Table 1 are based on laboratory analyses (Wenk and Dickson, 1981). In the early 1980s, questions were raised about the grades in these pits not being correct and two groups, one from Canada (Bristow et al., 1982) and one from the USA (George, 1982b), brought probes to Adelaide and cross-calibrated the Adelaide pits against their own. These results were presented at an OECD/NEA meeting in Paris in 1982 and published in the conference proceedings. But for unknown reasons there was no resolution to the conflicts that were apparent in the different grade estimates.

Fig. 1. Design of the AM2 pit at Adelaide.

¹The Z-effect refers to the increasing adsorption of low-energy gamma-rays (<600 keV) due to the increased photoelectric adsorption of higher Z elements, such as U itself.
More recently, studies using Monte-Carlo gamma-ray transport codes to derive correction factors for different logging scenarios revealed that a determination of \( F_z \) from data collected in the AM pits did not give consistent values. This identified a need to revisit the data of the cross-calibration studies to determine if a consistent set of grades could be assigned to these pits.

### The George (1982) Study

In 1981, Dr D.C. George of Bendix Field Engineering Corporation undertook an international cross-calibration of total-count logging pits in Australia and the USA. His methodology essentially used equation (2) recast as the ratio of total-count logging pits in Australia and the USA. His Corporation undertook an international cross-calibration of the holes dry so no other corrections were necessary but the formation moisture, \( F_m \), correction was included.

A report was initially issued (George, 1982a) in which the grades of the AM pits did not give consistent values. This identified a need to revisit the data of the cross-calibration studies to determine if a consistent set of grades could be assigned to these pits.

A final adjustment or not?

Efforts continued in the USA after the 1982 conference to standardise their model pit collection and a year later George et al. (1983) reported results from a cross-calibration involving 45 pits. The results and full details of the pits are given in Leino et al. (1984). This work adjusted the grade of N3 to 654±23 pCi/g(Ra\(^{226}\)), which equates to 0.231 ± 0.008%eU\(^3\)O\(_8\) and implies that the grades of the Australian AM pits have to be increased by another 6.0%.

But should this change be applied? The difficulty in accepting the grades of the USA and Canadian pits as correct is that their grades are based on samples taken at the time of construction. In both cases very non-standard methods compared with concrete-industry standards were used. For the USA, 1.9 L samples were placed in ice-cream cartons and allowed to air dry. George et al. (1983) recognised that this was not an optimum procedure and stated ‘if additional samples are collected (say by coring), or if additional information becomes available on the present unknowns (the difference, if any, between the concrete in the samples … and the concrete in-situ in the models), then the assignments could change’. As this quote indentifies, the sampling technique used by the USA could give biased results as the concrete in the sample containers was not cured properly and may contain far less water of crystallisation than a properly cured concrete, as in the pits. This sampling methodology could have introduced a systematic error with all the results being high.

### Table 1. Data for Adelaide pits AM1, AM2, AM3 and AM7

<table>
<thead>
<tr>
<th>Ore-zone</th>
<th>AM1</th>
<th>AM2</th>
<th>AM3</th>
<th>AM7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (m)</td>
<td>1.22</td>
<td>1.22</td>
<td>1.22</td>
<td>2.16</td>
</tr>
<tr>
<td>Ore-zone thickness (m)</td>
<td>1.41</td>
<td>1.43</td>
<td>1.43</td>
<td>1.68</td>
</tr>
<tr>
<td>Porosity %</td>
<td>17</td>
<td>19</td>
<td>18</td>
<td>23.4</td>
</tr>
<tr>
<td>Wet density (g.c(_m)^{-3})</td>
<td>2.31</td>
<td>2.33</td>
<td>2.35</td>
<td>2.21</td>
</tr>
</tbody>
</table>

Table 2. Recalculation of AM grade using data and methodology outlined in George (1982b) where \( R_{oc} \) is dead-time and Z-effect corrected count-rate

<table>
<thead>
<tr>
<th>Ore-zone</th>
<th>AM1</th>
<th>AM2</th>
<th>AM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counts</td>
<td>24088</td>
<td>25612</td>
<td>118957</td>
</tr>
<tr>
<td>( F_z )</td>
<td>1.050</td>
<td>1.054</td>
<td>1.250</td>
</tr>
<tr>
<td>( R )</td>
<td>22926.6</td>
<td>24303.0</td>
<td>95152.9</td>
</tr>
<tr>
<td>Moisture %</td>
<td>13.2</td>
<td>7.4</td>
<td>8.1</td>
</tr>
<tr>
<td>( R_{oc} )</td>
<td>27751.2</td>
<td>27464.6</td>
<td>129649.5</td>
</tr>
<tr>
<td>Grade</td>
<td>0.218</td>
<td>0.217</td>
<td>1.016</td>
</tr>
</tbody>
</table>

Actually has little or no effect on calculated in situ grades because the low value for AM2 relative to both AM1 and AM3 acts as a self-correction for the Z-effect (as shown below).
Values of $F_Z$ for AM2 were determined by modelling for four of the detectors. The modelled values (Table 3) are dependent on the setting in the detectors of a low-energy threshold, which is set to prevent noise from the detector entering the electronics. This setting is generally low but unknown and the values shown are calculated with estimates of the thresholds. The agreement of the $F_Z$ values between those calculated using the new grade value and modelled for AM2 gives a degree of confidence that the new grade values are relatively correct. Unfortunately this analysis only applies to the relative grades because the $F_Z$ calculation involves a ratio of grades and cannot be used to justify the absolute values of the grades. For the moment our confidence in these grade reassignments must rest on the good agreement of the AM1 grades of the two sets of cored samples.

Grade for pit AM7

Pit AM7 is larger in diameter than pits AM1–AM3 and accommodates five drillholes of sizes BQ, NQ, PQ, HQ and 108 mm (same as AM1–AM3) to enable water factor corrections to be determined. The grade of this pit is assigned 0.17%$U_3O_8$. This grade requires adjusting in line with the other pits.

Some logging data made available for this study (Table 4) was used to calculate the grade of AM7 with the assumption that $F_Z$ and formation moisture for AM1 and AM7 were the same and using the moisture data in Table 1. This gave a new grade value of 0.18%$U_3O_8$ (Table 4). Further work is recommended to refine this value, which should include modelling to take into account the larger diameter but lower density of the U-zone in this pit, relative to the other three.

Conclusion

The grades for the total count calibration pits in Adelaide should be changed to 0.210, 0.983, 0.051 and 0.018 e$U_3O_8$% for pits AM1, 2, 3 and 7, respectively. This change ensures the four pits are in relative agreement with logging results and gamma-ray transport modelling. The absolute grades are more difficult to confirm but indications are that through being twice sampled by coring and analysis, AM1 is more likely to be correct than those pits whose grades are solely based on analysis of poorly handled samples. The recommended changes in the grades actually have little effect on the grades in U deposits determined using the Adelaide model pits for calibration as the error with AM2 compensated the Z-effect in that pit. These changes leave the Australian pits some 6% lower than the USA and Canadian pits and there is clearly a need to determine a method to analyse the true grades of these concrete pits before this issue can be finally resolved.

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References


