Deconvolution of Gamma-ray Logs by Optimum Error Distribution

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Key words: gamma-ray, logging, interpretation, deconvolution, error distribution

1. Introduction

The quantitative interpretation of gamma-ray logs from uraniferous zones has usually been performed using a technique almost twenty years old, known as the iterative approach (Scott 1963). More recently, Conaway and Killeen (1978) showed, based on theoretical studies of eastern European workers (e.g. Suppe & Khaikovich 1960), that an inverse filter could be derived which, when convolved with the recorded log, could remove the effects of the logger's impulse response and so obtain the true radiometric assay profile in the drill hole. This technique, which is much more efficient in terms of computation time than the earlier iterative approach, is known as the inverse filter technique.

The present paper introduces a new technique for the deconvolution of gamma-ray logs. This new technique is about equally as efficient as the inverse filter method in deconvolving a recorded log. However, it does have an advantage in that no theoretical assumptions are made about the nature of the gamma-ray impulse response of the logger. Rather, the deconvolution operator is determined experimentally in artificial test pits or directly in field drill holes.

2. Deconvolution by Optimum Error Distribution

Mereu (1976) described a technique for deriving the weights of a wave-shaping filter F, which, when convolved with a given input signal, produced a desired output signal. The algorithm for computing the weights of the filter is:

$$F = G * S,$$

where

S = the cross-correlation function of the input signal W and the desired output signal D,

G = $F_1 * F_2 * F_3 *, \ldots F_N$
= a symmetric filter which is derived from the auto-correlation function R of the input signal as follows:

F_1 = R with signs of alternate terms changed,

F_2 = $R * F_1$ with signs of alternate non-zero terms changed,

F_N = $R * F_1 * F_2, \ldots, F_{N-1}$ with signs of alternate non-zero terms changed.

Mereu's filter is similar to the more familiar Wiener filter (e.g. Robinson 1967) except that errors in the latter are distributed across the filter, whereas those of the former can be moved away from the area of interest and so an error free, or more correctly, an 'optimum error distribution' filter is produced. Mereu (1978) subsequently followed his theoretical work by publishing a Fortran computer program listing to compute the weights of F.

The problem now is to obtain data experimentally which can be used to determine F by the optimum error distribution algorithm.

3. Artificial Test Pit Data

Artificial test pits have been built by the Australian Mineral Development Laboratories at their Frewville site in South Australia (Wenk & Dickson 1981; see also Milton 1982, this issue). Figure 1 shows a schematic section of the pits. Their dimensions and grades of mineralisation are listed in Table 1. The ore zones are thick enough to be considered to be infinitely thick (International Atomic Energy Agency 1976). Pit 2 was logged carefully with a digitally-recording logger, and the resulting curve was differentiated each 0.05 m and 0.10 m in a fashion similar to that used by Scott (1963) to determine the anomaly produced by bodies of unit thickness. For a body of thickness 0.05 m, the computed anomaly each 0.05 m, expressed as a percentage of that observed opposite the centre of the body, is {1.1, 1.8, 3.3, 6.7, 12.2, 21.1, 36.1, 66.1, 100.0, 66.1, 36.1, 21.1, 12.2, 6.7, 3.3, 1.8, 1.1}. For the body of thickness 0.10 m, the corresponding anomaly each 0.10 m is {1.1, 3.3, 12.2, 36.1, 100.0, 36.1, 12.2, 3.3, 1.1}. These series represent the given wavelets W. The desired wavelets in each case have unit value at the centre of the sequence and zeros elsewhere.

These sequences W and S have been given as input to the computer program and the outputs are shown in Fig. 2. Also shown in Fig. 2 are the inverse filter weights as determined by Conaway & Killeen (1978). Note that the two filters are almost identical for 10 cm sampling intervals, but for 5 cm sampling there are more non-zero coefficients in the optimum error distribution filter than in the inverse filter. Consequently, the two filters are of equal efficiency as measured in terms of computer time for 10 cm sample intervals. For 5 cm sampling, the new filter is slower than the inverse filter technique.

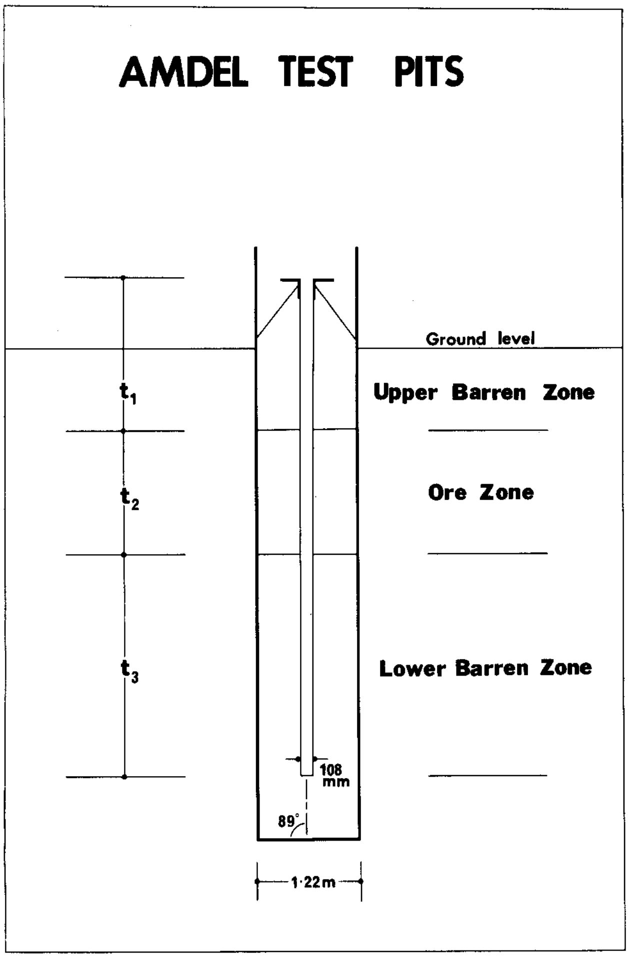

FIGURE 1

Generalised cross section, AMDEL test pits. The values of the parameters are shown in Table 1.

TABLE 1

AMDEL TEST PITS

Parameter	Pit 1		Pit 2		Pit 3	
t_1 (m)	1.04		1.61		1.83	
t_2 (m)	1.41		1.45		1.43	
t_3 (m)	3.45		3.04		2.84	
	Ore	Barren	Ore	Barren	Ore	Barren
eU_3O_8 (%)	0.20	–	0.920	–	0.054	–
U_3O_8' (%)	0.179	5 ppm	0.822	2 ppm	0.047	3 ppm
U_3O_8/eU_3O_8	0.86		0.89		0.87	
ThO_2 (ppm)	10	6	5	3	4	3
K (%)	0.76	0.51	0.76	0.54	0.55	0.53
Specific gravity (dry)	2.14	2.22	2.14	2.18	2.17	2.19
Specific gravity (wet)	2.31	2.35	2.34	2.35	2.35	2.36
Porosity (%)	17	13	19	17	18	17

4. Example

Figure 3 shows part of a log recorded each 0.10 m in DDH S1/166 at the Ranger One uranium orebody in the Northern Territory of Australia. Also shown in this figure is the deconvolved log. The inverse filter method of interpretation produced a total grade-thickness product of 0.0053 m% eU_3O_8 between 70.0 m and 71.5 m, while the technique of deconvolution by optimum error distribution indicated an identical total grade-thickness product over the same interval.

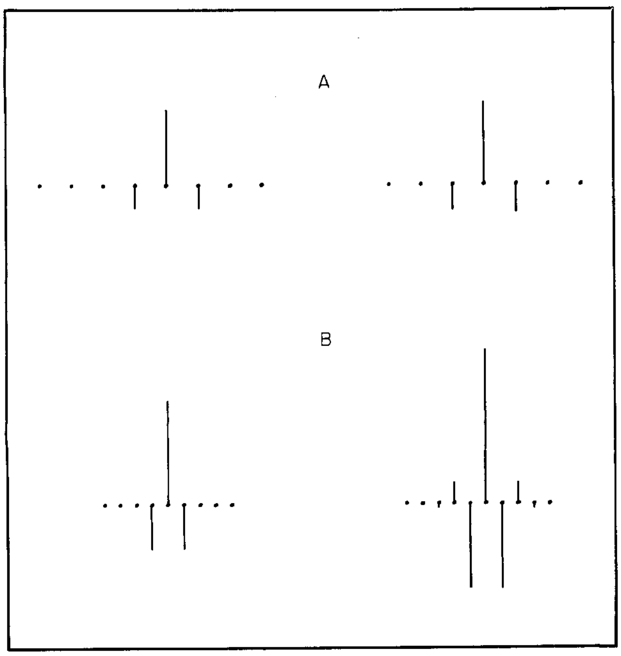

FIGURE 2

(A) – Inverse filter (left) and optimum error distribution deconvolution (right) filter coefficients for a sampling of 10 cm.
(B) – Inverse filter (left) and optimum error distribution deconvolution (right) filter coefficients for a sampling interval of 5 cm.

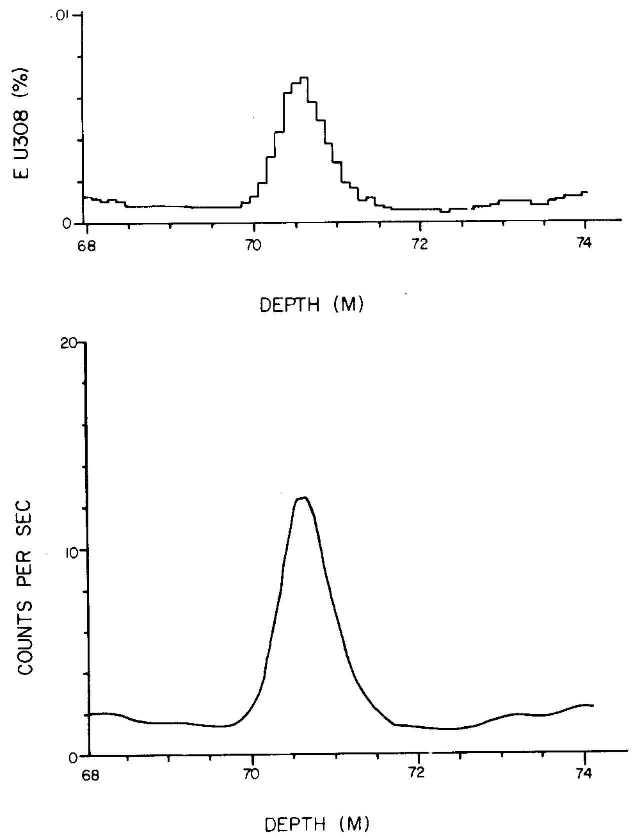

FIGURE 3

Part of gamma-ray log from DDH S1/166 at Ranger One (below), and inversion solution computed by optimum error distribution deconvolution (above).

5. Discussion

This study has shown that an alternative, entirely experimentally-oriented deconvolution operator can be obtained for recovering the true radiometric assay profile from a recorded gamma-ray log. It is as efficient as the inverse filter approach for logs recorded each 0.10 m in a drill hole, though marginally slower for logs recorded each 0.05 m. Its advantage over the inverse filter method is that no theoretical assumptions about the nature of the gamma-ray impulse response are made. Providing good calibration facilities are available, the new system automatically accounts for the finite length of a scintillation crystal detector, and the ratemeter time constant distortion which is inherent in logs recorded using analogue chart recorders. However, it does have disadvantages in that it is highly system and procedure-oriented. The deconvolution filter is unique to each type of logger, and new filters are required for each new logging speed and sample interval chosen for a given logging unit.

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(Received 22 August 1981)