The optimal method for the estimation of the mean of a lognormal distribution model is to use Sichel's t estimator. The spreadsheet-type table shows the detailed calculation for the mean and standard deviation of the logarithms, where g_i represents the sample value and y_i the natural logarithm of (g_i + ¯¤). For Sichel's estimation, we need:

$$\text{¹¤} = \frac{1}{n} \sum \log_e(g_i + \text{¯¤}) \qquad V = \frac{1}{n} \sum (\log_e(g_i + \text{¯¤}) - \text{¹¤})^2$$

g_i	$y_i = \log_e(g_i + 580.35)$	$(y_i - \bar{y})^2$
13.0	6.3858	0.625847
26.4	6.4081	0.591011
96.0	6.5167	0.435836
196.6	6.6554	0.271976
454.0	6.9415	0.055395
535.8	7.0176	0.025360
548.1	7.0286	0.021990
618.7	7.0893	0.007675
653.1	7.1176	0.003519

g_i	$y_i = \log_e(g_i + 580.35)$	$(y_i - \bar{y})^2$
794.0	7.2257	0.002386
1004.2	7.3681	0.036545
1111.6	7.4336	0.065919
1139.7	7.4501	0.074649
1371.2	7.5764	0.159592
1931.6	7.8288	0.425007
2262.8	7.9527	0.601832
2433.9	8.0111	0.695918
3215.0	8.2415	1.133464
Sums:	130.2487	5.1709

From the summations at the bottom of the table, we find that: ¹¤ = 7.2360 and V = 0.2873. Using the procedure recommended by Sichel, the t estimator for the average grade would be:

$$t = \exp(\text{¹¤})\,°_n(V)$$

where $°_n(V)$ is obtained from standard tables of Sichel's correction factor (Table 7).

$°_n(V)$	15	20	18
0.2	1.104	1.105	
0.3	1.160	1.161	
0.2873	1.1529	1.1539	1.1535

$ª_p(V;n)$	15	20	18
0.2	0.869	0.885	
0.3	0.841	0.86	
0.2873	0.8446	0.8632	0.8557

Interpolating between rows and columns in Table 7, we obtain $°_n(V)$=1.1265. Substituting in the equation above, gives:

$$t = e^{7.2360} \times 1.1535 = 1388.5789 \times 1.1535 = 1601.8161$$

That is, our 'best' estimator for the mean of the lognormal model is $t = 1601.8161$.

To find a lower 90% confidence level, we must again turn to tables — in this case, Table 8(c). Interpolating between columns and rows for V =0.2874 and 18 samples, we obtain $ª_{0.10}$=0.8655. To obtain a lower 90% confidence level we multiply this by t:

$$1601.8161 \times 0.8557 = 1370.62$$

Finally we subtract the additive constant from the t estimator and from any confidence levels calculated:

$$\tau^* = t - \beta^* = 1601.8161 - 580.35 = 1021.34 \text{ cmg/t}$$

That is, our best estimate of the average is 1021.34 cmg/t with a lower 90% confidence level of

$$1370.62 - 580.35 = 790.27 \text{ cmg/t}$$

Grade/Tonnage Calculations: For the payability calculations we need to estimate the logarithmic mean and standard deviation, μ^* and σ^*. Since we have the original sample data:

$$\begin{aligned}(\sigma^*)^2 &= \frac{n}{n-1}V = \frac{18}{17} \times 0.2874 = 0.3042 \\ \sigma^* &= 0.5515 \\ \mu^* &= \bar{y} = 7.2360\end{aligned}$$

To calculate the proportion of the deposit which is above the pay limit or 'cutoff', we use the Standard Normal tables, Table 1. Since that distribution has a mean of zero and a standard deviation, we must standardise our cutoff value:

$$\begin{aligned}x_c &= \frac{\log_e(\text{cutoff} + \beta^*) - \mu^*}{\sigma^*} \\ P &= 1 - \Phi(x)\end{aligned}$$

The average value of the proportion above cutoff — for a three parameter lognormal — is found by:

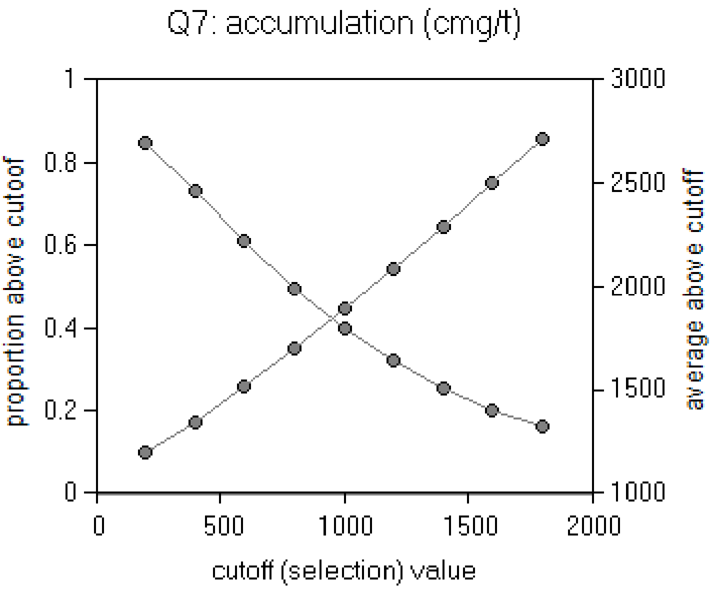
$$\tau^*_c = \frac{P'}{P}(\tau^* + \beta^*) - \beta^*$$

where P' is the proportion of a Standard Normal distribution above:

$$\begin{aligned}x_q &= x_c - \sigma^* \\ P' &= 1 - \Phi(x')\end{aligned}$$

Q7: grade/tonnage calculations for 3 parameter lognormal model

cutoff	x	P	x'	P'	τ^*_c
200	-1.0449	0.8479	-1.5964	0.9426	1200.25
400	-0.6312	0.7304	-1.1827	0.8779	1344.88
600	-0.2946	0.6092	-0.8461	0.7962	1513.00
800	-0.0108	0.4974	-0.5623	0.7070	1696.21
1000	0.2346	0.4006	-0.3170	0.6177	1889.33
1200	0.4506	0.3199	-0.1009	0.5332	2089.14
1400	0.6437	0.2543	0.0921	0.4563	2293.61
1600	0.8181	0.2018	0.2666	0.3882	2501.39
1800	0.9772	0.1600	0.4257	0.3288	2711.59



8. **The following accumulation values were obtained from borehole intersections during the project evaluation stage of a new gold mine.**

247	292	483	25	1232
167	67	1285	335	61
2001	346	1579	453	31
54	1262	225	5836	3
68	2532	31	915	811
626	281			

Answer: When the data are plotted on a logarithmic scale, it is clear that it is not log-normal. The downturn in the low values — or deviation from the expected straight line — is indicative of a three parameter lognormal. The second graph shows a probability graph using an additive constant (β) of just over 28.13 cmg/t.

The optimal method for the estimation of the mean of a lognormal distribution model is to use Sichel's *t* estimator. The spreadsheet-type table shows the detailed calculation for the mean and standard deviation of the logarithms, where g_i represents the sample value and y_i the natural logarithm of $(g_i + \beta)$. For Sichel's estimation, we need:

$$\mu = \frac{1}{n} \sum \log_e(g_i + \beta) \qquad V = \frac{1}{n} \sum (\log_e(g_i + \beta) - \mu)^2$$