Airphoto reference	*Reg'd No.*	*Acid insol. %*	*Organic C %*
Digby Peaks 01/0010	74710001	7.80	.32
Digby Peaks 01/0010	74710003	4.55	.09
Digby Peaks 01/0010	74710005	6.40	.06
Digby Peaks 04/0048	74710162	2.45	.09
Digby Peaks 04/0048	74710179	3.50	.05
Digby Peaks 03/0066	74711048	7.20	.03
Digby Peaks 03/0066	74711050	5.65	.03
Digby Peaks 02/0119	74711063	8.70	.04
Toko 13/0022	74711157	6.4	.05
Toko 13/0022	74711158	7.6	.05
Neeyamba Hills 08/0020	74711410	20.2	.05
RC05/0076	74712040	4.30	.03
Digby Peaks 02/0107	74712116	5.50	.05
LK06/0766	74712342	86.7	.07
Glenormiston 11/0262	74712347	83.40	.07
Abudda Lakes 07/0150	74712466	84.80	.10
Mount Whelan 07/0122	74712497	87.50	.10
Neeyamba Hills 12/0032	74712552	7.30	.03
Glenormiston 12/0016	74712591	3.00	.03

Table 2. An example of hypothesis testing (original as computer printout).

Given in Table 3 is an example of using the system to aid in the production of written reports. Certain specific information on the file has been expressed in the format in which it would be directly incorporated into a report or BMR Record.

GEO/K103—Black Mountain 2 m from base section Shergold 1975
Chatsworth Limestone
A layer 7.5-15 cm thick of light purplish to olive grey, coarse-grained bituminous biosparite (shelly calcarenite), grain supported, with fine sparite settling out on upper surfaces of trilobite and pelmatozoan fragments. This limestone appears to be well washed and contains little mud, and there are few signs of the continued abrasion of fragments.
Fauna: *Pseudagnostus clarki patulus, Pseudagnostus elix, Pseudagnostus* sp. A.; *Caznaia squamosa, Euloma (plecteuloma) strix, Hapsidocare chydaeum, Koldinioidia* cf. *cylindrica, Sigmakainella primaeva, Wuhuia* cf. *Wuhuia dryope.*

GEO/K106—Black Mountain 51 m from base section Shergold 1975
Chatsworth Limestone
A 15 cm layer of very coarse biosparite (shelly calcarenite), grain supported, containing infiltered sand and silt grade sediment, and trilobite and pelmatozoan fragments showing few signs of continued abrasion.
Fauna: *Pseudagnostus clarki patulus, Pseudagnostus* sp. B, *Pseudagnostus coronatus; Caznaia squamosa, Ceronocare* sp., *Euloma (Plecteuloma) strix, Hapsidocare chydaeum, Koldinioidia* cf. *cylindrica, Mendosina* sp., *Pagodia (Pagodia)* sp., *Sigmakainella primaeva.*

GEO/K107—Black Mountain 68 m from base Shergold 1975
Chatsworth Limestone
A layer 7.5 cm thick splitting into two leaves and increasing in thickness to 15 cm, of light to medium grey biopelsparite containing abundant fine peloids, and trilobite fragments with geopetal structures.
Fauna: *Pseudagnostus clarki patulus; Caznaia squamosa, Caznaia sectatrix, Atopasaphus stenocanthus, Koldinioidia* cf. *cylindrica, Prosaukia* sp. A.

Table 3. An example illustrating the application for report writing (original as computer printout).

Selection and formatting of geochemical data as input for various statistical analysis programs has been much simplified by using the system. Procedures have been established for obtaining relatively simplistic plots from the system, using library programs. Further development of the system will probably be in this area.

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Can rank-size 'laws' be used for undiscovered petroleum and mineral assessments?

E. J. Riesz

A number of empirical laws which state that a simple relationship exists between the size and ranking of objects have been used in assessing undiscovered petroleum and minerals resources. The most well known of these, the log-log and log-linear laws, are described and compared with log-normally distributed statistics which I have assumed give a good description of sizes of petroleum and mineral deposits.

The log-log law, which states that the log of size of a mineral deposit plots as a straight line against the log of the rank of the deposit sizes, was found to give a fair fit for the bigger deposit sizes, but the smaller sizes would be over-estimated. The log-linear law which states that the log of size of a deposit plots as a straight line against the rank of the deposit sizes was found to give a poor fit for both the big and small sizes.

The log-log law may be useful for assessing undiscovered resources where geological analogues exist and the largest deposit can be assessed by other means.

Introduction

Simple relationships between the size of a mineral or petroleum deposit within a province and its rank relative to other deposits within the province have been used to assess undiscovered resources. The most well known of these is Zipf's Law, which states the biggest value is twice as big as number two, three times as big as number three and so on, was formulated by Zipf (1949) for use in modelling aspects of human behaviour. More recently this law and variants of it have been used in methods of assessing undiscovered mineral resources. Rowlands & Sampey (1977) used Zipf's Law to estimate the undiscovered gold resources of the Western Australian shield, and predicted that large undiscovered gold resources exist in the area.

Zipf's law is a special case of a more general empirical relationship, which states that the log of size (of deposit in the case of minerals) plots as a straight line against the log of the rank of the individual objects (deposit sizes). Zipf's law is the special case where the slope of the line is 45 degrees. I will refer to this generalised relationship as the 'log-log law'. Ivanhoe (1976) has used the law to develop a method to estimate the remaining undiscovered petroleum resources in partially explored areas.

Jeffries (1975) has used a different empirical relationship, that the log of size plots as a straight line against the rank of the individual deposit, to compare the oil fields of the Gippsland Basin, and the Lower Texas Gulf coast, USA. I will refer to this relationship as the 'log-linear law'.

Kaufman & others (1975) have concluded that petroleum field sizes are well described by a log-normal distribution. Krige (1978) shows how a de Wijsian model of mineral concentration will produce a log-normal distribution of ore grades. I have thus come to the conclusion that undiscovered petroleum or mineral deposit sizes do fit a log-normal distribution. Therefore, I have tried to discover what, if any, relationship exists between either the log-log or log-linear laws and the log-normal distribution to determine if they have any validity for undiscovered resource assessment.

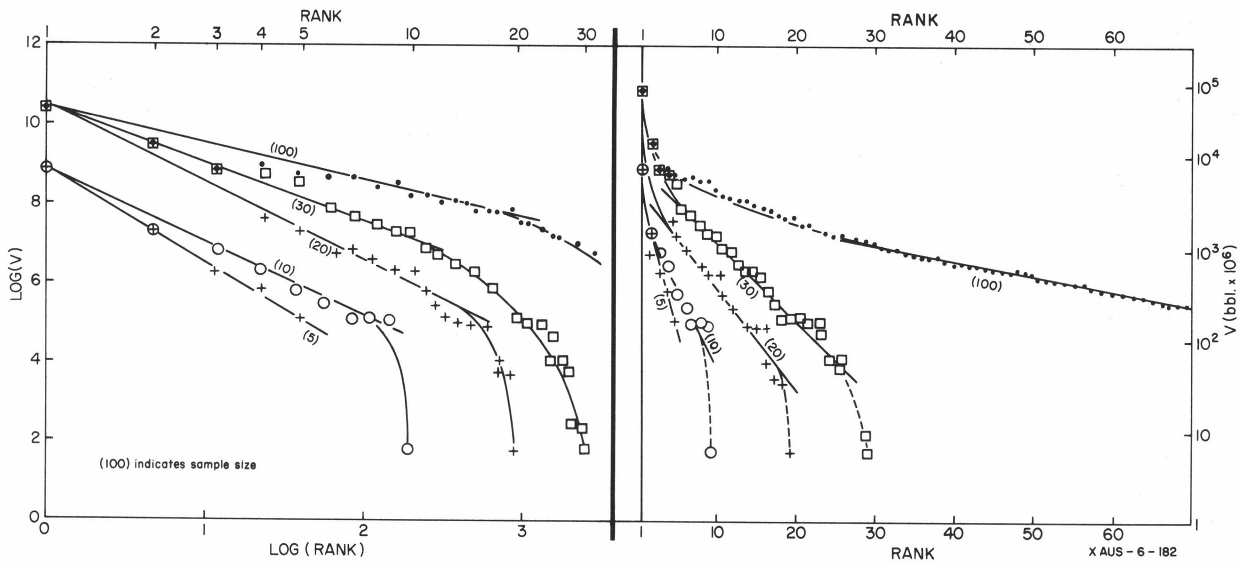


Fig. 1. Fit of log-normal data to empirical laws.

Log-normal fit to empirical laws

I chose a log-normal distribution with a logarithmic standard deviation (σ) of 1.7, similar to that used by Kaufman & others (1975, p. 131) to describe the major Alberta Oil field-size distribution, to produce statistics to test the laws.

The log-normal distribution used was truncated at both ends, with values less than one thousandth or greater than twenty times the size of the mean value of exp ($\mu + \frac{1}{2}\sigma^2$) ignored because of computational restraints. The effect on the values chosen was slight, as the chance that values from a small sample would be selected from these ends is very small.

Samples of between 5 and 100 values were chosen at random, using Monte Carlo simulation and plotted according to both the laws (Fig. 1). For the largest number of samples (100) the computational restraints referred to above affected the size of the biggest value selected; in most cases the minimum value selected by the computer was also constrained. In the measurement of actual deposit sizes very small sizes tend to be either undetected or ignored because of their lack of economic significance, so the effect of the minimum constraint should not be important.

Most of the values selected visually fit the log-log law well, with the exception of the smaller sizes, which (as mentioned above), tend to be insignificant in practice. The bulk of the data fit the log-linear law reasonably well, but high values tend above the line, and low values below. Both laws fit small samples reasonably well.

Sarhan & Greenberg (1962) have computed means and standard deviations for each of up to 20 samples chosen from a normal distribution. The expected values with ranges of plus and minus one standard deviation can be plotted on a logarithmic scale to give results consistent with Figure 1 (G. Hill, CSIRO, personal communication, April 1978).

Probability distributions to fit empirical 'laws'

I have derived continuous frequency distributions, from which, randomly selected values give a good visual fit to the log-log and log-linear laws respectively.

Log-Log law

The frequency distribution is given by:

$$f(v) = \begin{cases} K_2 V^{-1-K_1}, & Z_1 > \log V > Z_N \\ O & , \log V > Z_1,\ Z_N > \log V \end{cases}$$

(derived in following section) where:

K_1 determines the ratio of field sizes ($K_1 = 1$ for Zipf's Law),

K_2 is the normalising constant,

$Z_1 = \log$ (maximum field size), $Z_N = \log$ (minimum field size),

V is field size.

Thirty values were chosen at random from the distribution and plotted according to both empirical laws (Fig. 2). The data only gives a good visual fit to the log-log law. 0.5 was chosen for K_1 which gave a variance close to that used for the log-normal distribution in the previous section.

Log-linear law

The frequency distribution is given by:

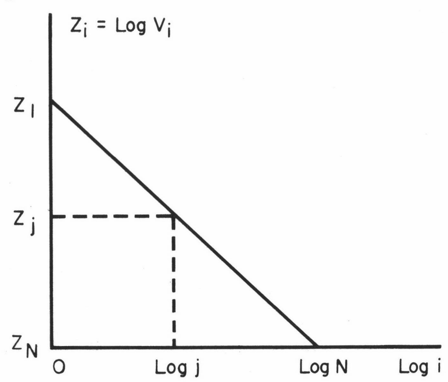
$$f(v) = \begin{cases} K_2/V, & Z_1 \geqslant \log V \geqslant Z_N \\ O & , \log V > Z_1,\ Z_N > \log V \end{cases}$$

(derived in following section) where the terms have the same meaning as in A.

Thirty sample values were chosen at random as above, and plotted according to both laws (Fig. 2). In this case, the reverse was true, the data only give a good visual fit to the log-linear law.

Mathematical formulation

Log-log law



$$\log j = \frac{Zj \quad Z_1}{Z_2 \quad Z_1} \times \log 2$$

$$= \frac{Z_1 \quad Z_j}{m} \quad \text{where } m = \frac{-\log (V_2/V_1)}{\log 2}$$

$$\therefore j = e^{Z_1/m} \times e^{-Zj/m}$$

$$\text{Prob. } \{Z \leqslant Zj\} = \frac{N-j}{N-1}$$

$$= \frac{e^{Z_1/m}\, e^{-Z_N/m} - e^{Z_1/m}\, e^{-Zj/m}}{e^{Z_1/m}\, e^{-Z_N/m} - 1}$$

$$= \frac{e^{-Z_N/m} - e^{-Zj/m}}{e^{-Z_N/m} - e^{-Z_1/m}}$$

Assume the probability distribution is continuous (i.e., values of V between the discrete ones Vi are allowable)

i.e. Cumulative distribution

$$F_1(Z) = \frac{e^{-Z/m} - e^{-Z_N/m}}{e^{-Z_1/m} \quad e^{-Z_N/m}} \qquad (Z_1 \geqslant Z \geqslant Zn)$$

$\therefore$ Frequency distribution

$$f_1(Z) = \frac{-1}{m} \; \frac{e^{-Z/m}}{e^{-Z/_1m} - e^{-Z_N/m}} \quad (\text{obtained by } \frac{d}{dZ})$$

$$\text{i.e. } f(V) = \text{constant} \times V^{-1-1/m} \quad (\text{by substitution})$$

$$= \frac{V^{-1-1/m}}{m\,(V_N{}^{-1/m} - V_1{}^{-1/m})}$$

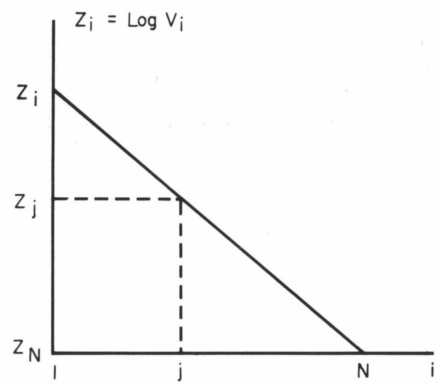
$$= K_2 V^{-1-K_1} \qquad (Z_1 \geqslant \log V \geqslant Z_N)$$

$$\text{Where } K_1 = +{}^1/_m$$

$$= \frac{\log 2}{\log V_1/V_2}$$

$$K_2 = -K_1 (V_1{}^{-K_1} - V_N{}^{-K_1})^{-1}$$

Log-linear law



$$j = \frac{Zj + Z^2 - 2Z_1}{Z_2 - Z_1}$$

$$\text{Prob. } \{Z \leqslant Zj\} = \frac{N-j}{N-1}$$

$$= \frac{Zj - Zn}{Z1 - Zn}$$

As for the log-log law, assume the cumulative probability distribution is continuous.

$$\text{i.e. } F_1(Z) = \frac{Z - Zn}{Z_1 - Zn} \qquad (Z_1 \geqslant Z \geqslant Zn)$$

$$\therefore f_1(Z) = \frac{\text{constant}}{Z_1 - Zn} \qquad (\frac{d}{dZ})$$

$$\therefore f(V) = \frac{\text{constant}}{V} \quad (Z_1 \geqslant \log V \geqslant Zn) \quad (\text{by substitution})$$

$$= (\log V_1/V_N)^{-1} \times V^{-1} \quad (\text{normalising condition})$$

Conclusions

If the assumption that undiscovered mineral deposits (oil fields or ore bodies) are log-normally distributed is correct, then neither of the so-called laws (log-log or log-linear) are strictly correct.

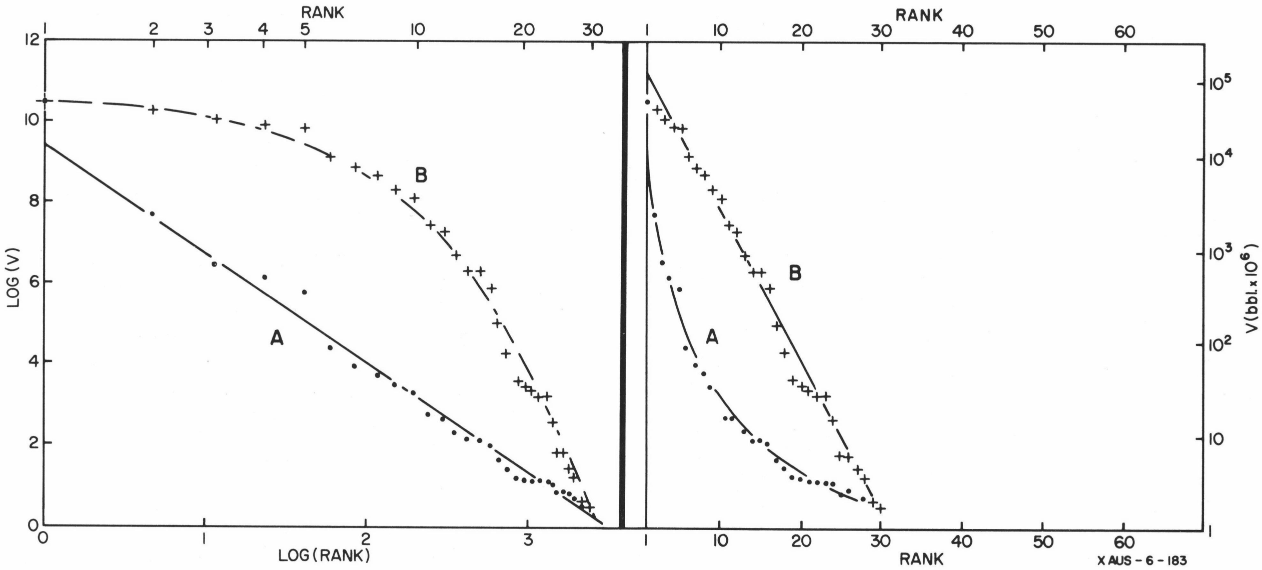


Figure 2. A—log-log distribution, B—log-linear distribution.

The log-log law appears the more valid and therefore the more useful of the two laws, as the larger (and usually the only economically significant) log-normal statistics do appear to fit this law reasonably well. Smaller values would be overestimated if this law were used, and perhaps the only way of determining if the undiscovered portion of the fields or ore bodies in an area fall into this category is to compare the discovered field (or ore body) sizes with those from a similar well-known geologically analagous area.

The log-linear law is less useful as both large and small field (or ore body) sizes are poorly estimated.

Acknowledgement

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