Assessing the nickel exploration potential of the Norseman to Wiluna greenstone belt using the Zipf Law

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TALK CONTENT

• Background on the Zipf’s probability distribution
• Early applications to mineral exploration
• Terrane maturity, known and residual mineral endowment
• The Norseman to Wiluna greenstone belt case study
• General conclusions about its applicability
ZIP’S PROBABILITY DISTRIBUTION

The Zipf’s probability distribution is an exponential discrete equivalent of the continuous Pareto distribution:

\[ Y = cr^{-k} \]

Where:
- \( Y \) is the size of the deposit of rank \( r \),
- \( c \) is a scaling factor equal to the size of rank 1 deposit
- \( k \) is a constant approximately equal to 1 in stable mature systems
ZIP’S PROBABILITY DISTRIBUTION

Theoretical Zipf’s Distribution
Natural scale plot

Theoretical Zipf’s Distribution
Log-log scale plot
EMPIRICAL EVIDENCE OF ZIPF’S POWER LAW

Named after American linguist George Kingsley Zipf (1902–1950), who observed that the frequency of words appears to abide by it.

Subsequently a wide variety of natural and human phenomena seemed to follow this power-law, at least in their upper, large events tail.

Potential application to the size of mineral and petroleum deposits was later foreshadowed by Folisbee and by Rowlands and Sampey in 1977.

The idea was met with scepticism and essentially forgotten until reconsidered by CET.
CET’S RESEARCH ON ZIPF’S POWER LAW

Conference papers, mainly by P. Guj and T. C. McCuaig on the applicability of the Zipf’s Law to Au and Ni exploration in the Yilgarn leading to publication of:


Research consultancies for:

• Barrick for gold in the Marymia greenstone belt,
• Nickel West in the Norseman-Wiluna Belt, and
• Geological Survey of NSW for tin in the Wagga-Omeo Belt
MINERAL ENDOWMENT AND EXPLORATION MATURITY

- ORIGINAL MINERAL ENDOWMENT
- ERODED MINERALISATION
- PRE-EXPLORATION ENDOWMENT
- KNOWN ENDOWMENT DISCOVERIES
- RESIDUAL ENDOWMENT

TERRANE MATURITY
MINERAL DISCOVERY

• Is a form of sampling without replacement from a finite population of undiscovered mineral deposits, i.e. from the pre-exploration mineral endowment

• is not random sampling as large deposits with bigger footprints are generally found earlier in the exploration history

• This is helpful in the estimation of the original mineral endowment as the Zipf’s distribution is a function of the size of the largest, rank deposit in the terrane
THE BIGGEST DEPOSITS ARE FOUND EARLY-ON IN THE EXPLORATION HISTORY OF A TERRANE

Discovery date and Pre-Mined Resource for deposits found in the Kambalda Nickel Camp: 1966-2011 – MinEx Consulting, 2012
NORSEMAN TO WILUNA GREENSTONE BELT (NWGB) NICKEL SULPHIDE DEPOSITS

• 94 nickel sulphide deposits in total in the NWGB
  • 17 deposits in 10 komatiitic dunite bodies
  • 77 deposits in 37 peridotite groups (‘channels’)  

Including

• 39 deposits in Kambalda domain peridotite channels
NWGB LOCATION OF NICKEL SULPHIDES DEPOSITS
LOCATION OF MINERALISED KOMATIITIC LAVA FLOWS IN THE KAMBALDA NICKEL CAMP
MT KEITH IS THE LARGEST NICKEL DEPOSIT IN THE NWGB

• Zipf’s distribution is a function of the size of the largest rank 1 deposit in the terrane

• Size must include historical production plus currently delineated resources, plus inferred resources and/or reasonable exploration potential

• In theory, for outcropping orebodies some allowance could also be made for their eroded components

• In our study Mt. Keith was considered to contain 4.17 Mt of nickel metal
LOG-LOG PLOT OF ZIPF-GENERATED AND KNOWN Ni DEPOSITS SIZES in the NWGB

- The largest 5 deposits match those theoretically generated by the Zipf’s curve
- Known deposits ranking above 5 deviate below the Zipf’s curve-predicted residual endowment
- The gap closes up progressively with exploration maturity
USING ZIPF’S LAW TO PREDICT THE RESIDUAL ENDOWMENT in the NWGB

The gaps, between known and Zipt-predicted endowments, which amount to 14.8 Mt of nickel metal, may represent either:

• New deposits yet to be discovered, or
• Possible future growth in the resources of known deposits following better delineation drilling.

Either way the gap will be reduced with on-going exploration.
FACTORS AFFECTING THE SHAPE OF THE ZIPF’S CURVE

- Hypothetical Mt. Keith resources
- Current Mt. Keith resources
- Effect of erosion
- Effect of incomplete delineation of largest deposit
- Effect of incomplete deposit delineation

The diagram illustrates the contained Ni metal t * '000 against the rank of ore body, comparing current Ni ore bodies and Zipf predicted ore bodies.
KAMBALDA IS A MATURE TERRANE

Total residual endowment of 0.4Mt Ni most likely represents extensions of current orebodies.
STATISTICAL REALITY CHECKS

Probability-log plot of sizes of Ni deposits in the “natural” and “residual” endowments

Statistical validity
Using petroleum exploration reality check criteria:
• P90/P10 be 20 to 120
• Swanson mean be between P17 and P83
• Variance lies between 0.81 & 3.50

Interpretation
Given a discovery there is:
• 50 % chance that it is equal or smaller than the median value (26,600 t Ni), and
• 90% chance that it is equal or smaller than 160,000 t Ni.
GENERALISED CONCLUSIONS

Zipf’s analysis may provide an indication of the:
• Amount of metal still to be discovered in an exploration terrane, and of
• The likely number and size of the undiscovered orebodies

But it will not provide any indication of where within the exploration terrane they may be located which may be addressed using other techniques such as those researched by:
• A. Mamuse, e.g. spacial centrographic and analyses and
• A. Porwal, e.g. GIS-based prospectivity analysis using weight-of-evidence and logistic regression models.