Structural Geology & Resources 2022
16 October 2022

Mineral systems as chemical reactors with no mathematics

Bruce Hobbs and Alison Ord

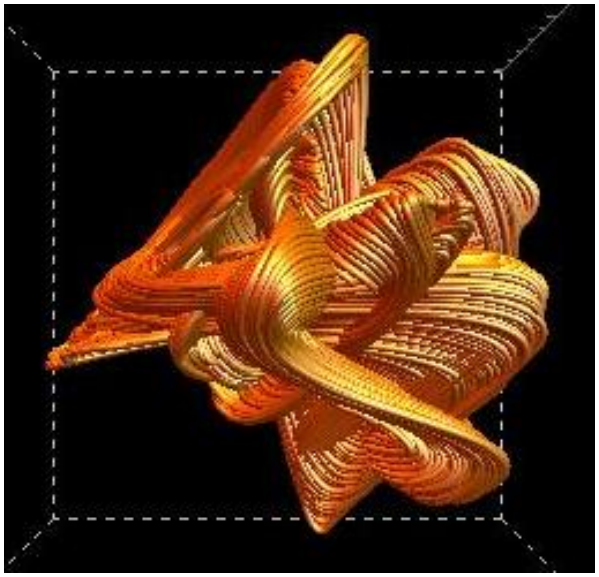
Session 6. **14:15 – 15:00**

Other examples.

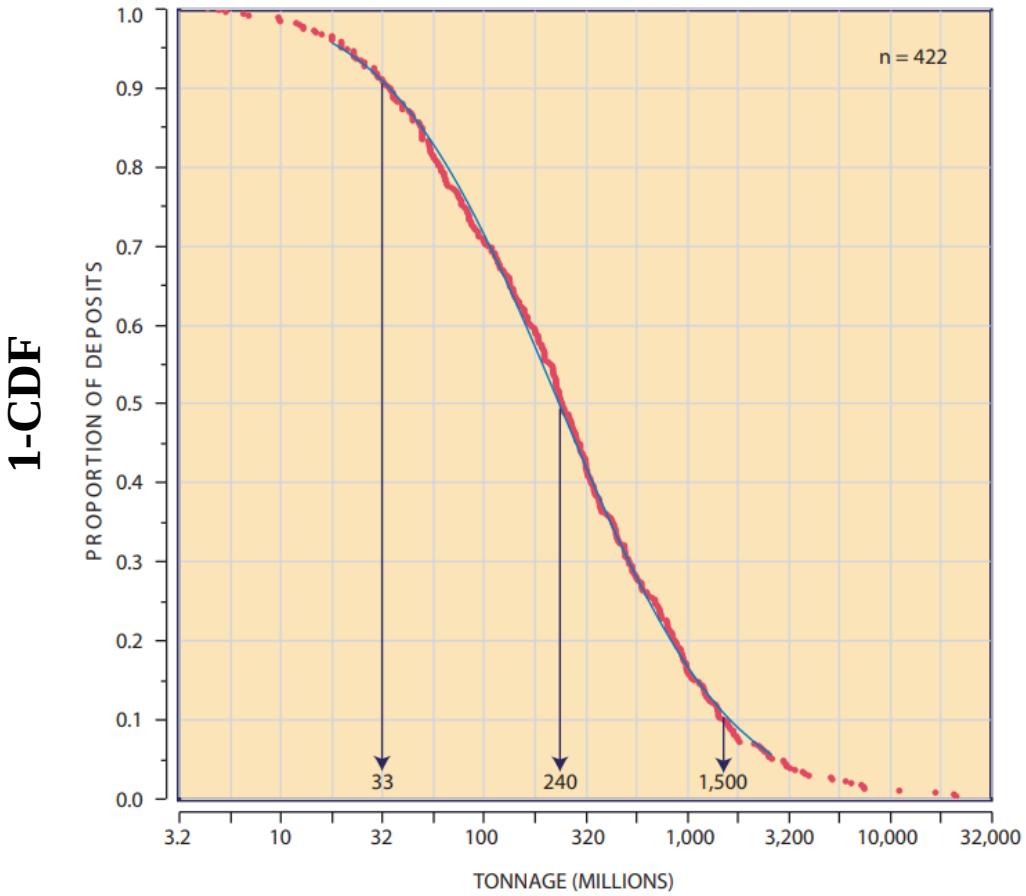
Cu Pb Zn

Regional distributions

Fingerprint for a mineralising system



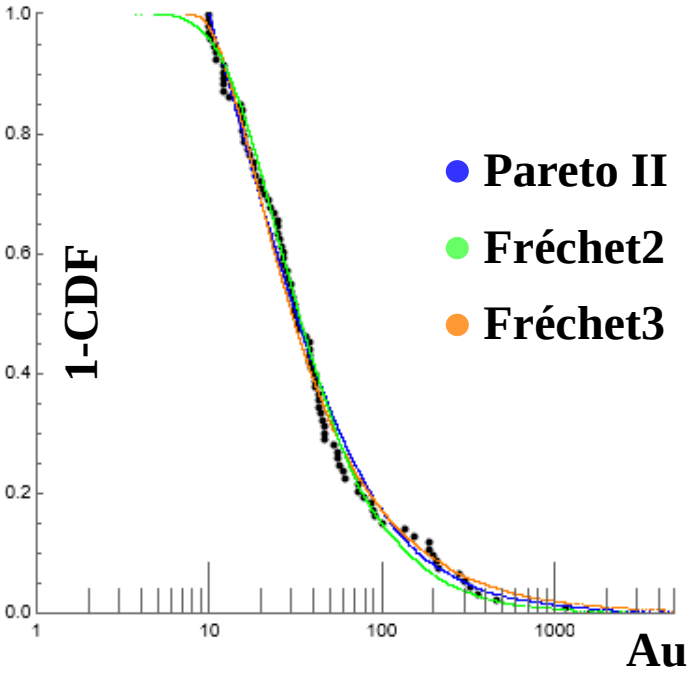
What probability distributions do we observe in mineralised systems?

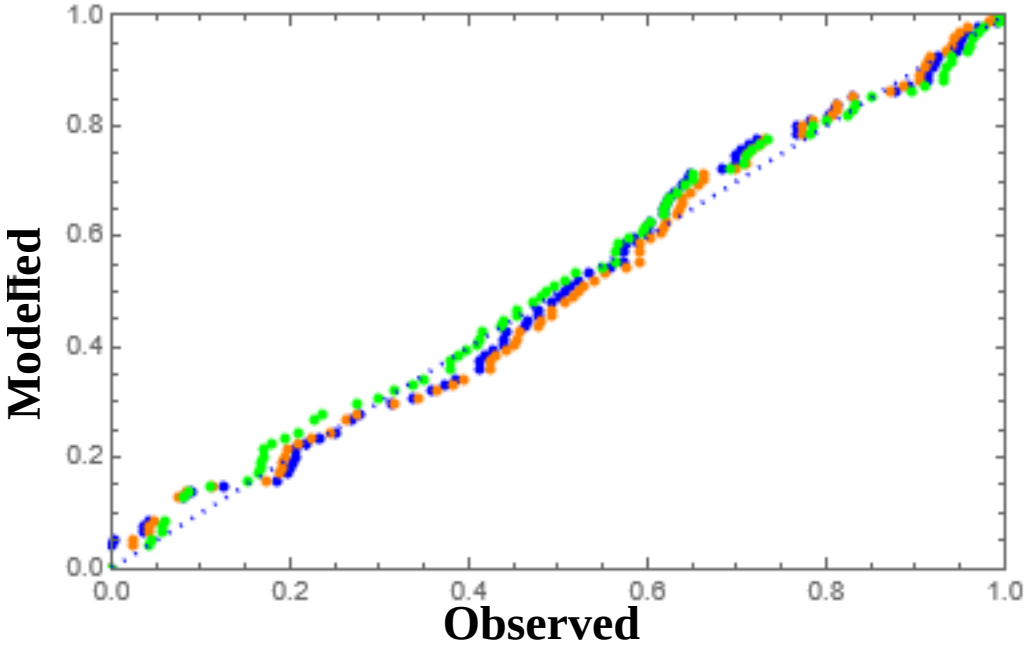


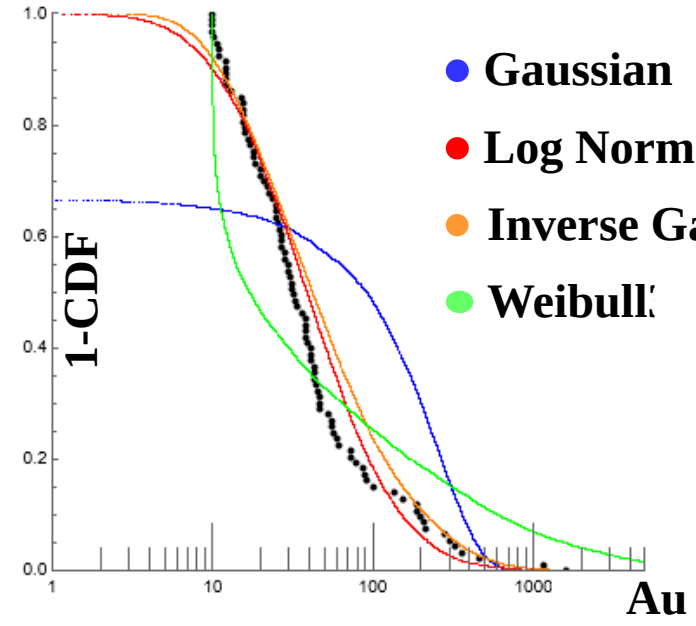
Fit is log-normal

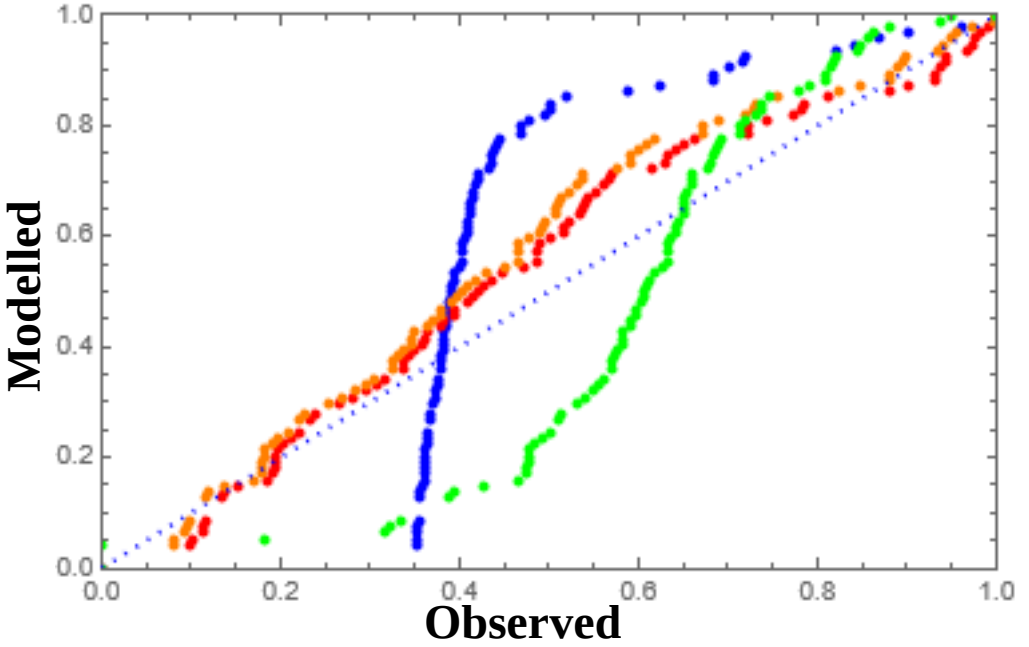
Tonnage model for all porphyry copper deposits

From Singer, Berger and Moring, 2008.


1-CDF
Au
Pareto II
Fréchet2
Fréchet3

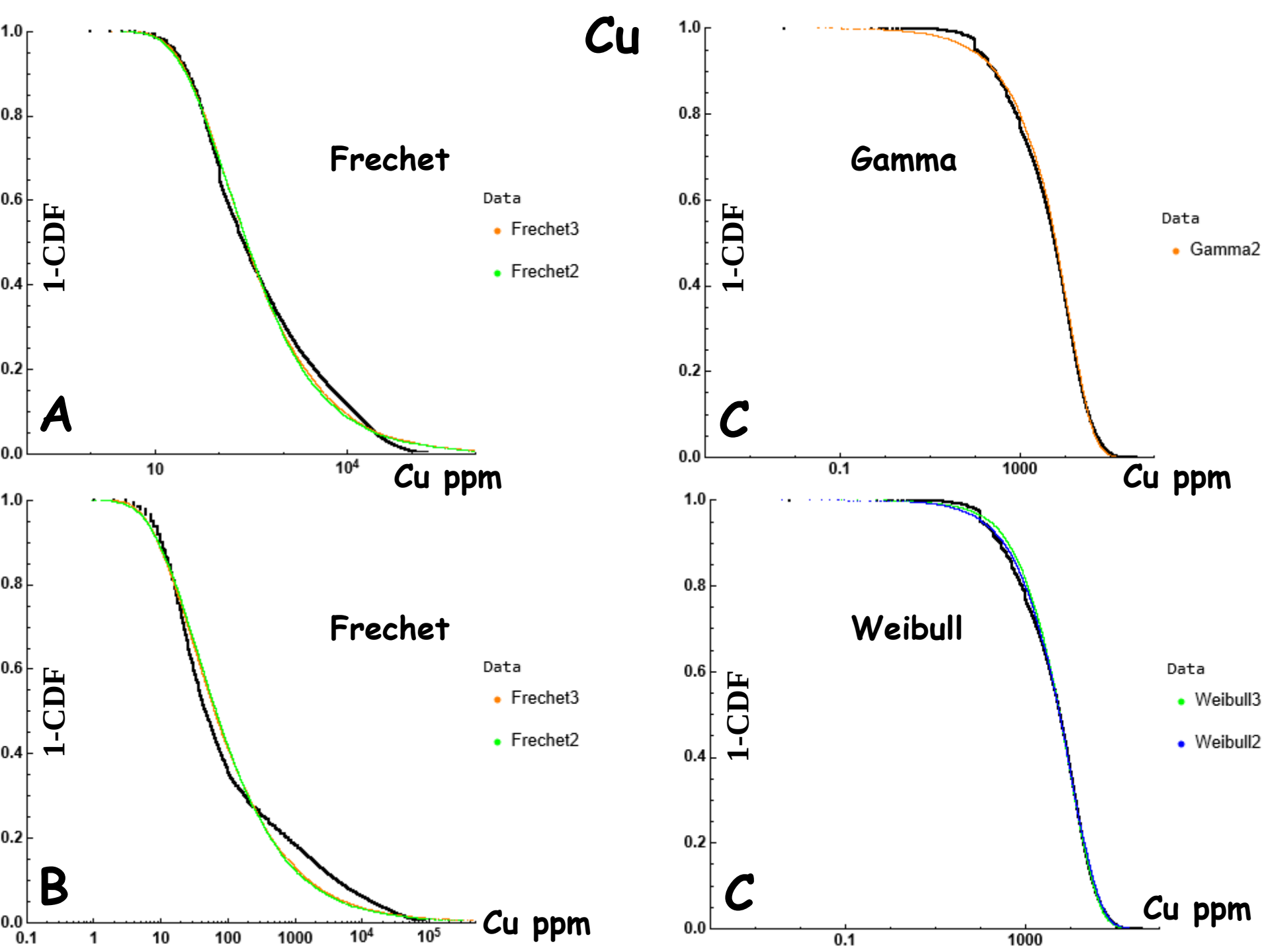

Modelled
Observed

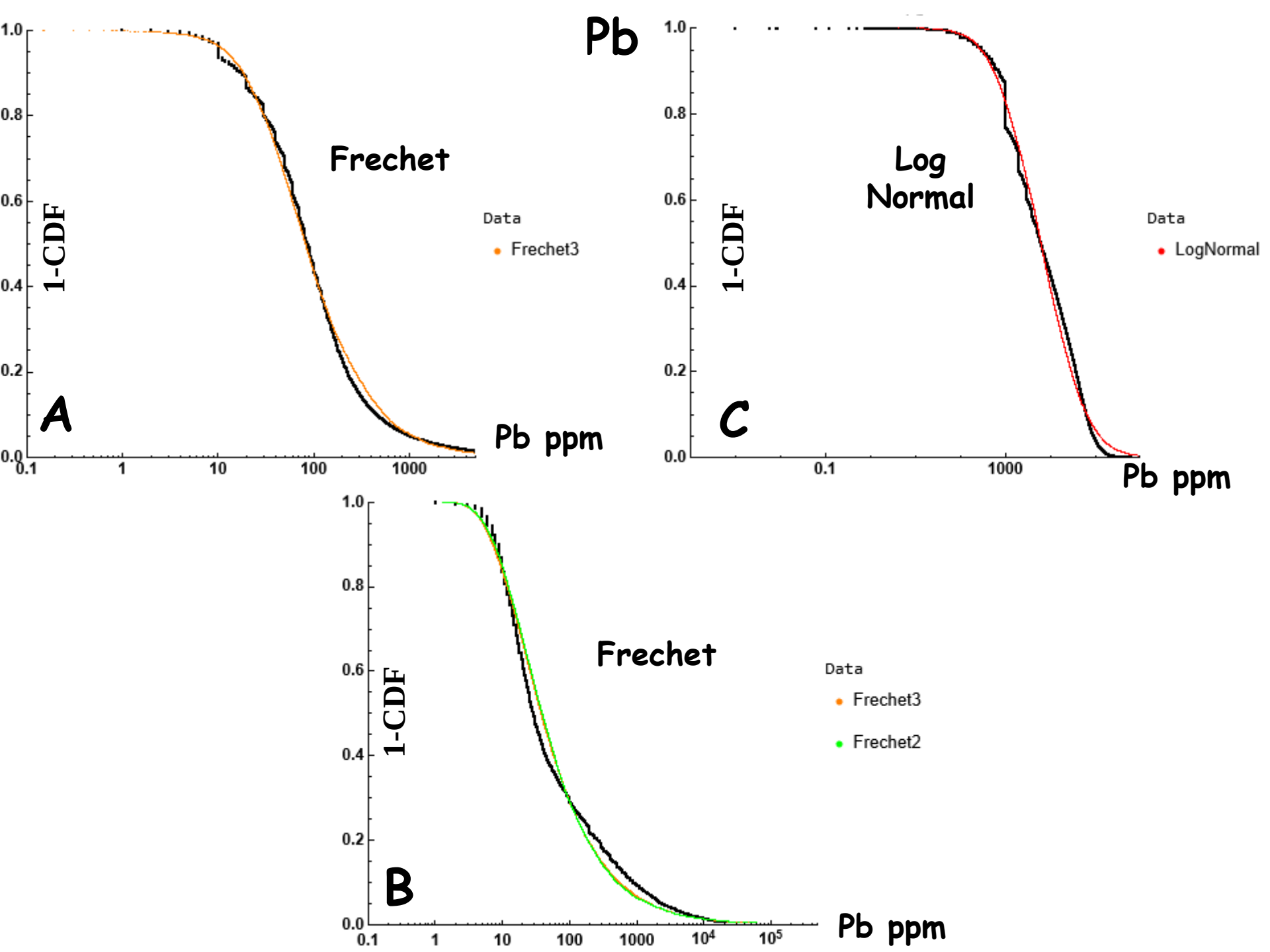

1-CDF
Au
Gaussian
Log Normal
Inverse Gaussian
Weibull

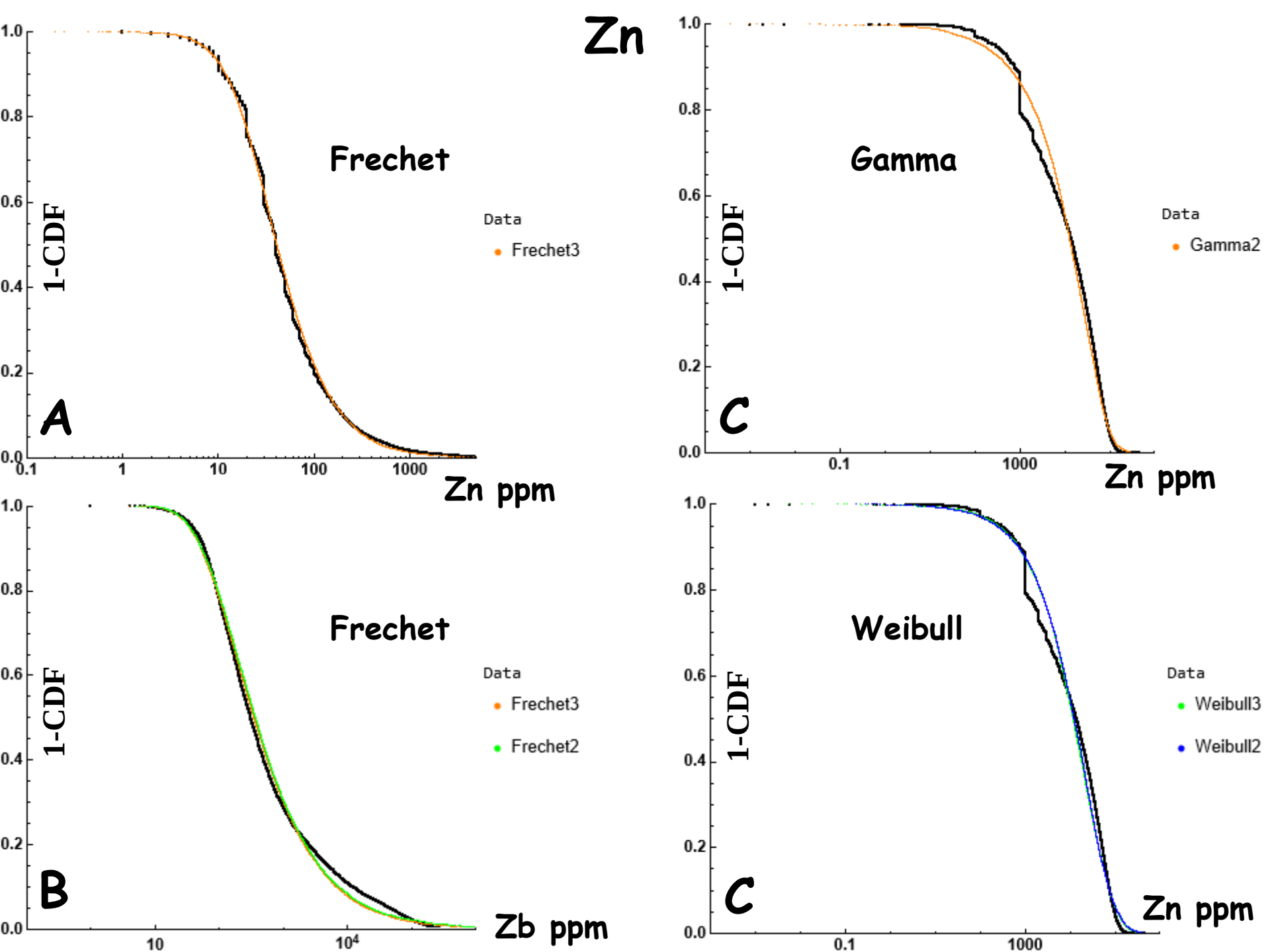

Modelled
Observed

Cu Pb Zn

from 3 systems
A, B and C

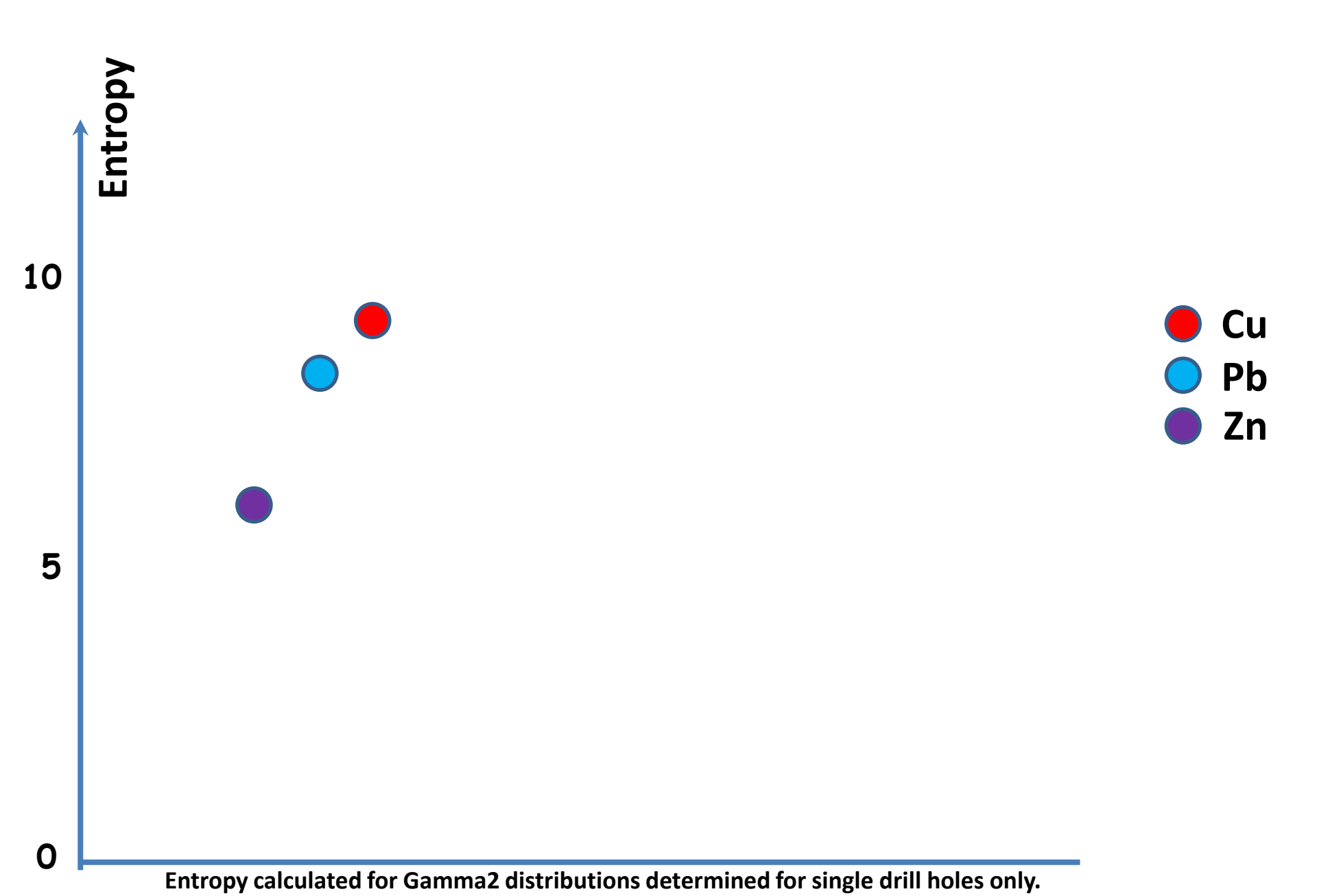

Cu
Frechet
1-CDF
A
Data
Frechet3
Frechet2
Cu ppm
Gamma
C
Gamma2
B
Weibull
Weibull3
Weibull2

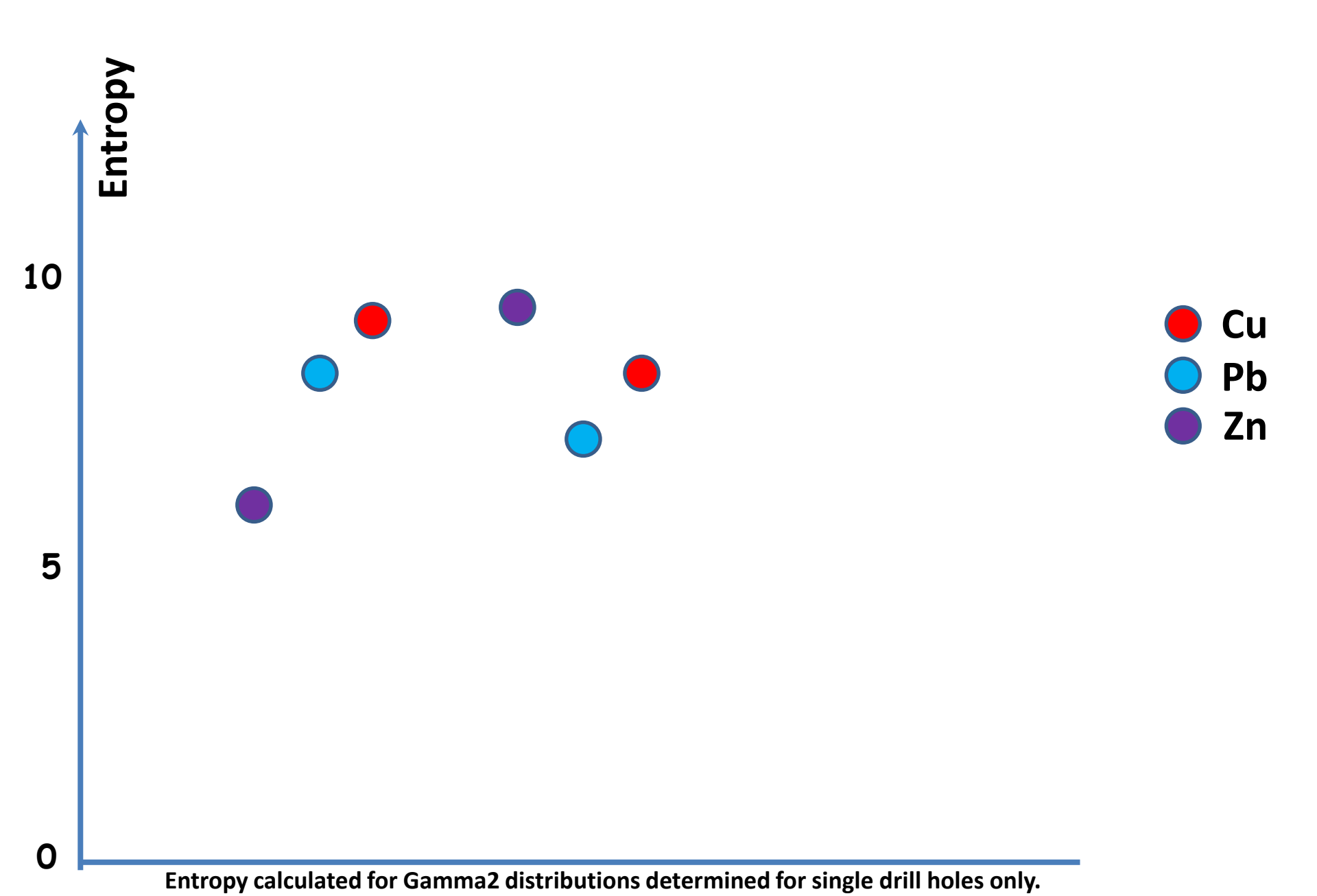

Pb
Frechet
1-CDF
A
Pb ppm
Data
Frechet3
Log
Normal
C
LogNormal
B
Frechet2
0.0
0.2
0.4
0.6
0.8
1.0
0.1
1
10
100
1000
10^4
10^5

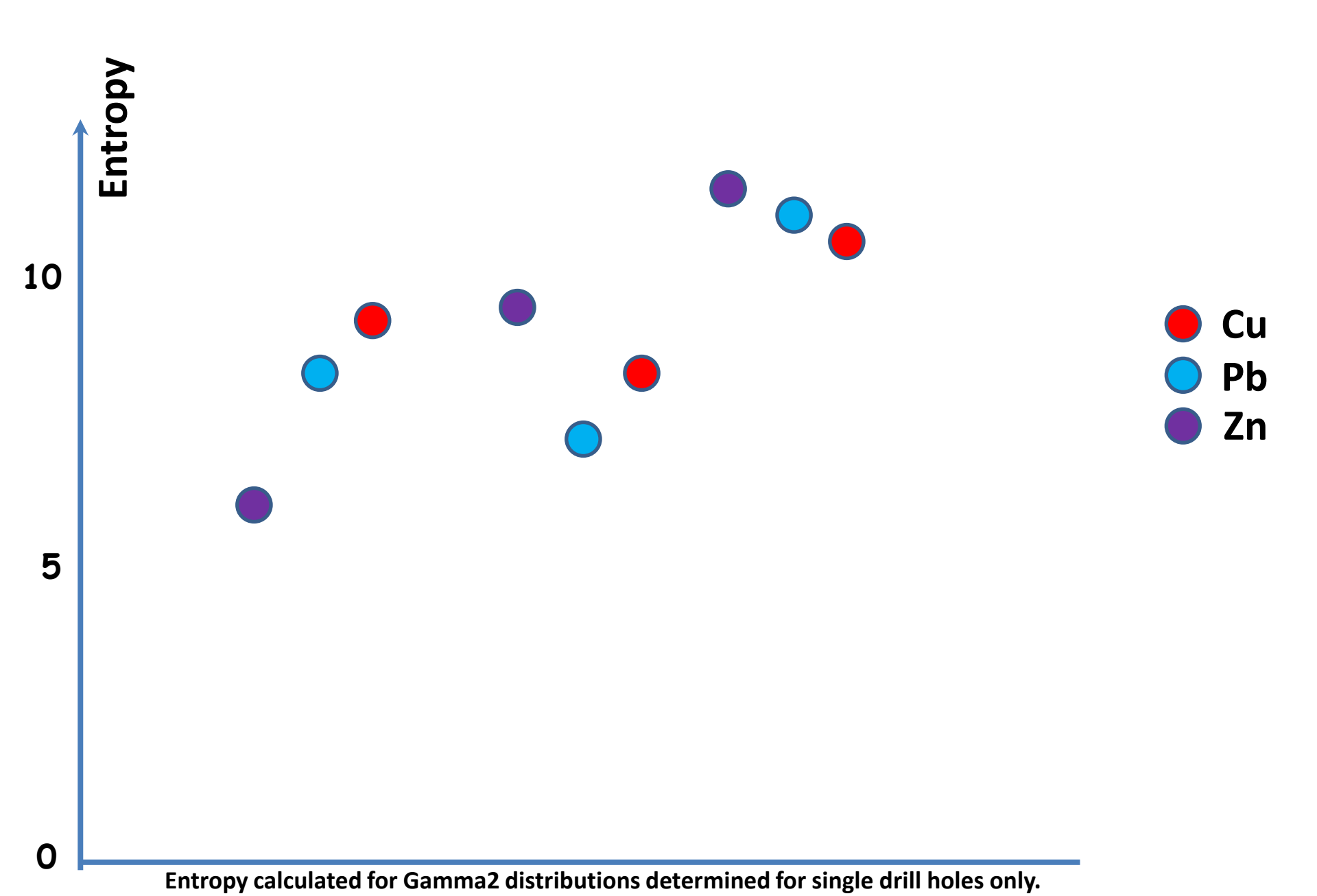

Zn
Frechet
1-CDF
A
Data
Frechet3
Zn ppm
Gamma
C
Gamma2
Zn ppm
Frechet
B
Frechet3
Frechet2
Zb ppm
Weibull
C
Weibull3
Weibull2
Zn ppm

Entropy calculated based on a Gamma distribution for data from a Cu, Pb, Zn deposit

	shape	scale	entropy
Zn	0.55	253.69	5.90
Pb	0.21	12616.60	8.07
Cu	0.27	18693.40	9.03

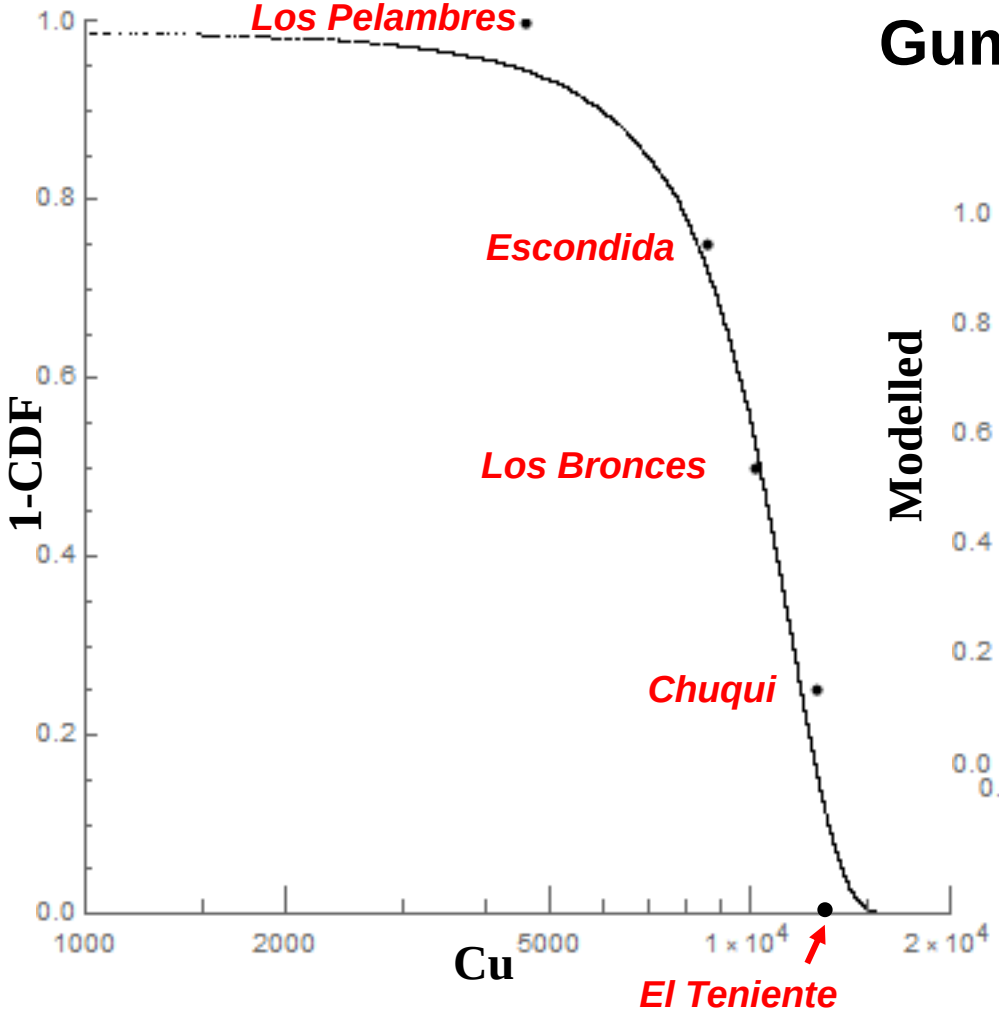

Entropy
10
5
0
Cu
Pb
Zn
Entropy calculated for Gamma2 distributions determined for single drill holes only.

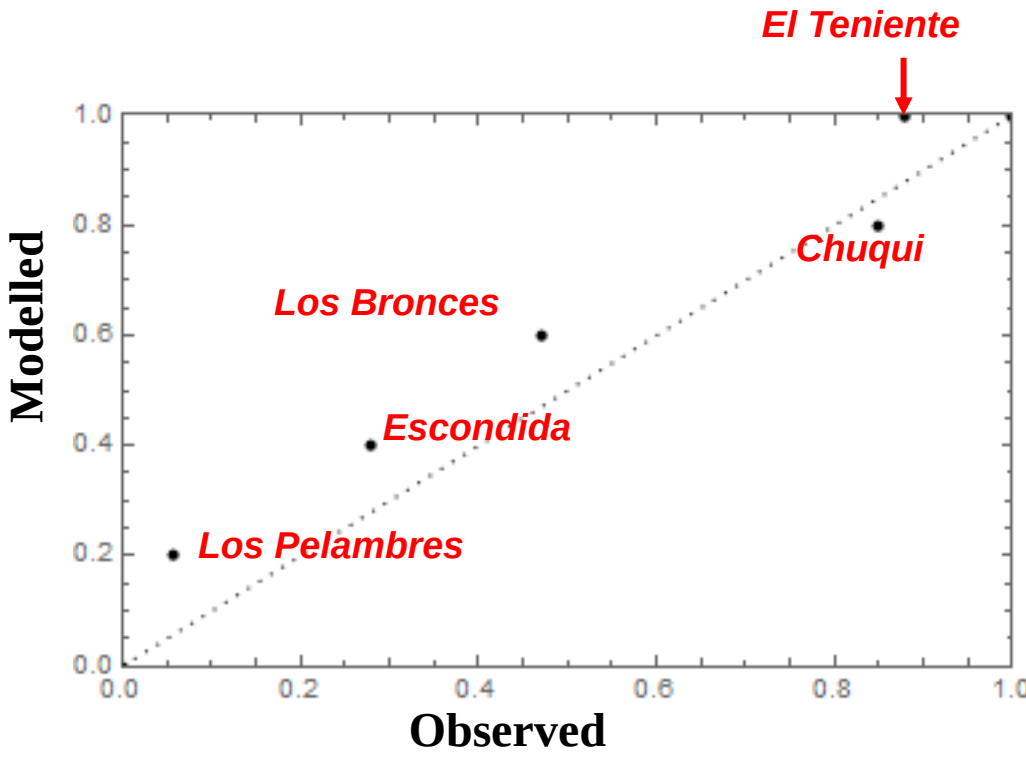

Entropy
10
5
0
Cu
Pb
Zn
Entropy calculated for Gamma2 distributions determined for single drill holes only.


Entropy
10
5
0
Cu
Pb
Zn
Entropy calculated for Gamma2 distributions determined for single drill holes only.

Distributions for regional endowment

Chile copper Top 5 deposits
Gumbel distribution



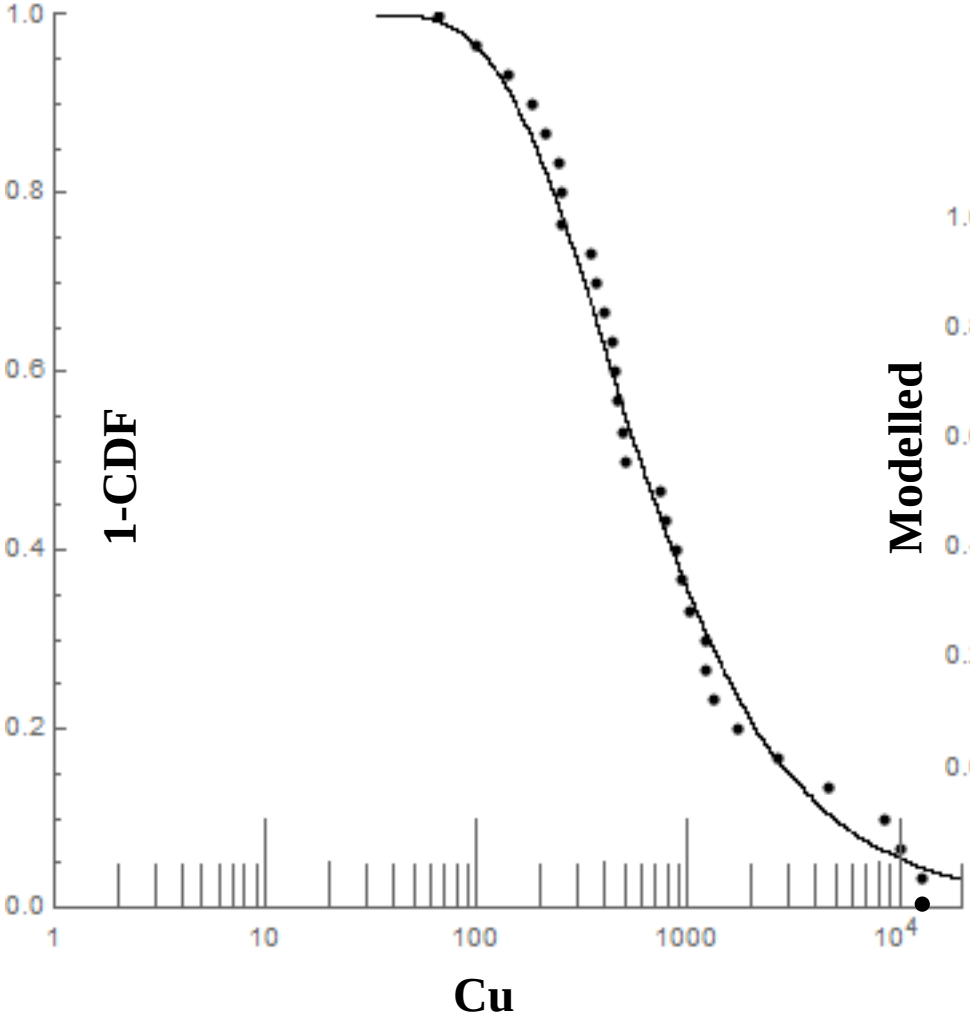


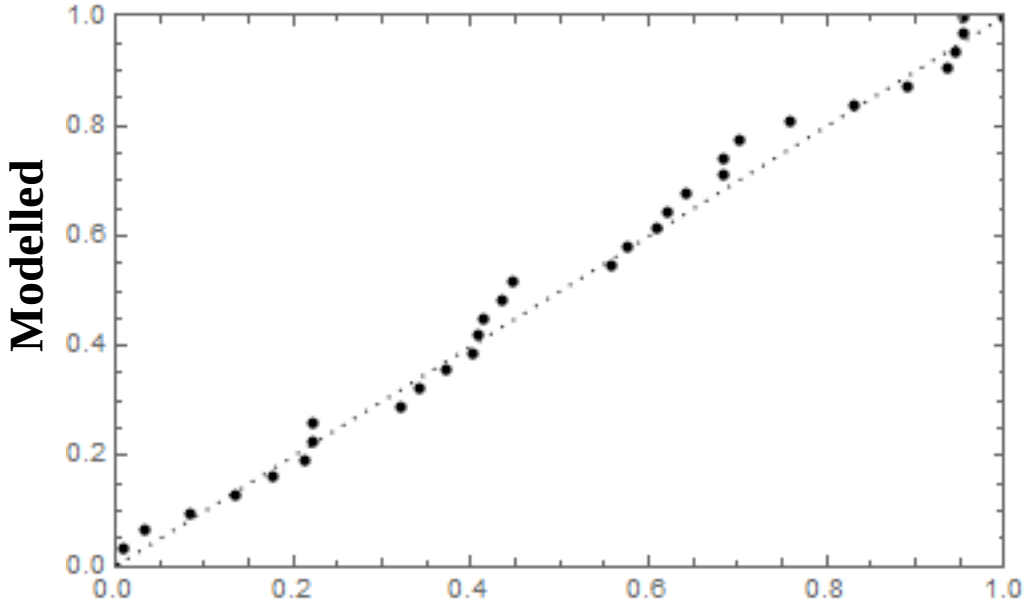
Power law → Weibull → Gumbel

Power law → Fréchet → Gumbel

Hierarchal evolution as systems grow

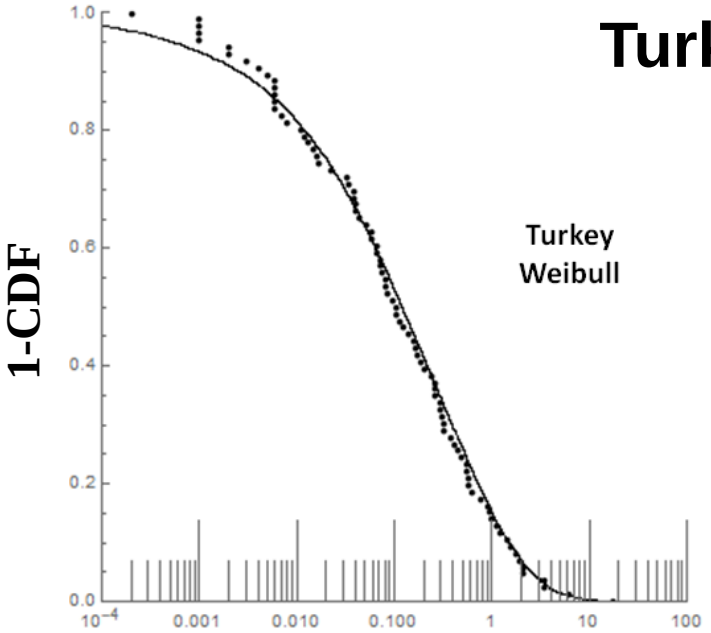
Chile porphyry copper
Fréchet

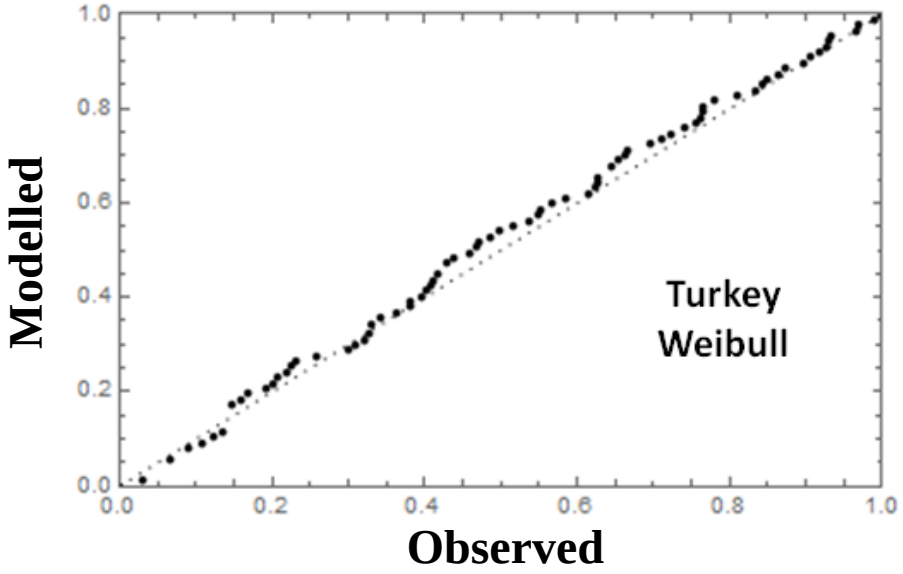




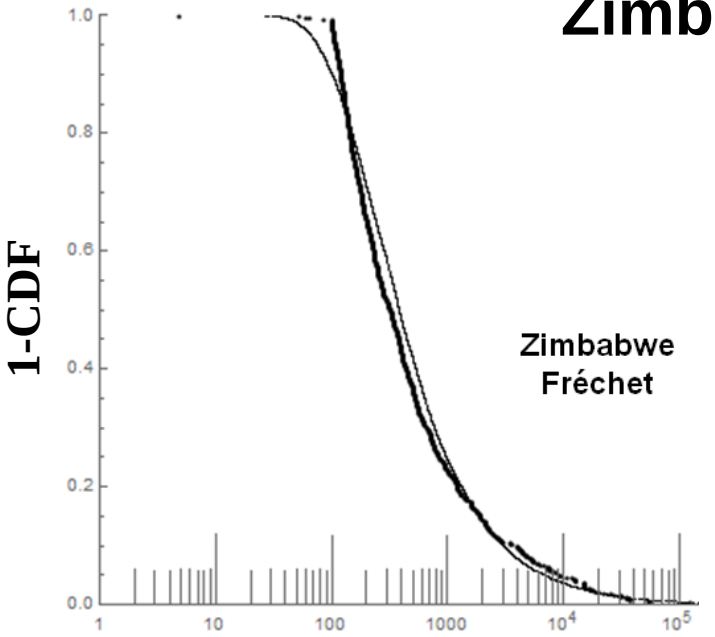
Data from Singer, USGS Report

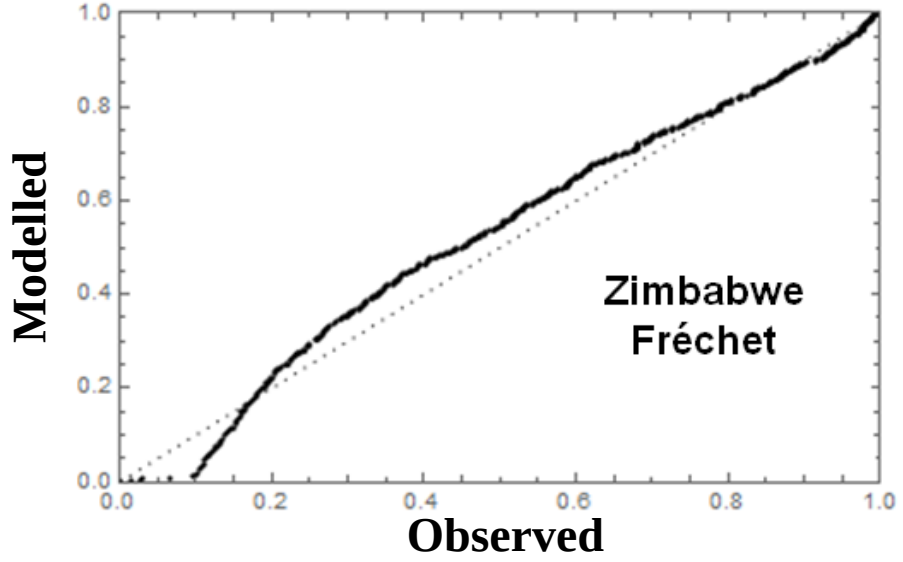
Turkey



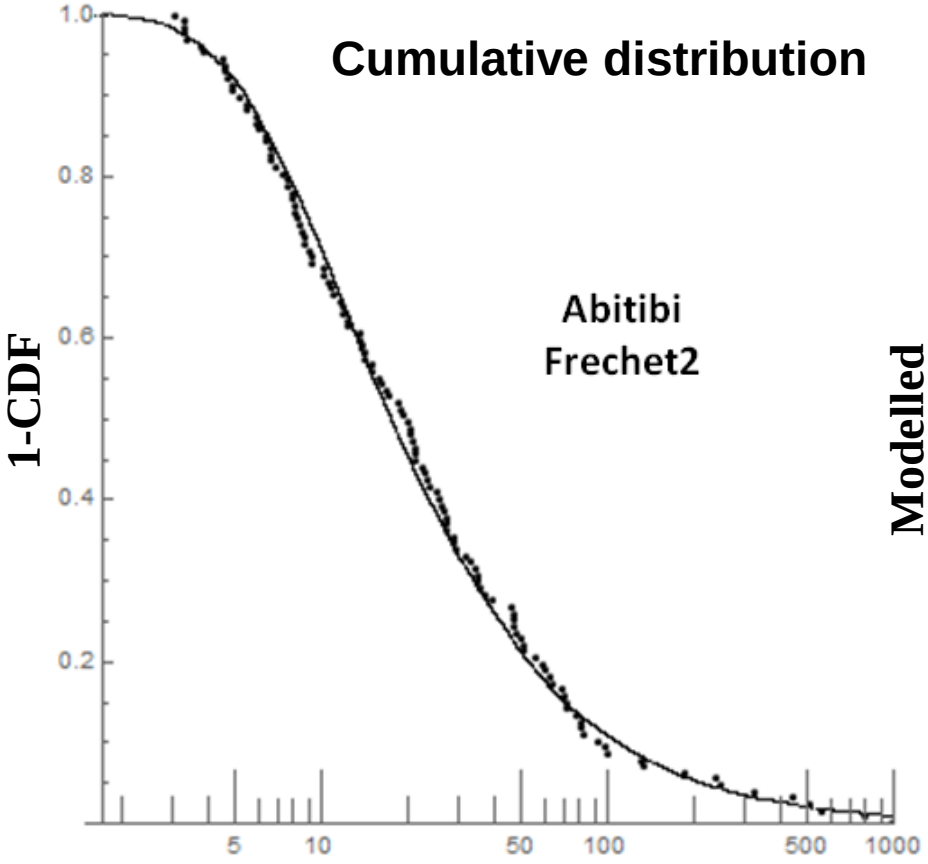


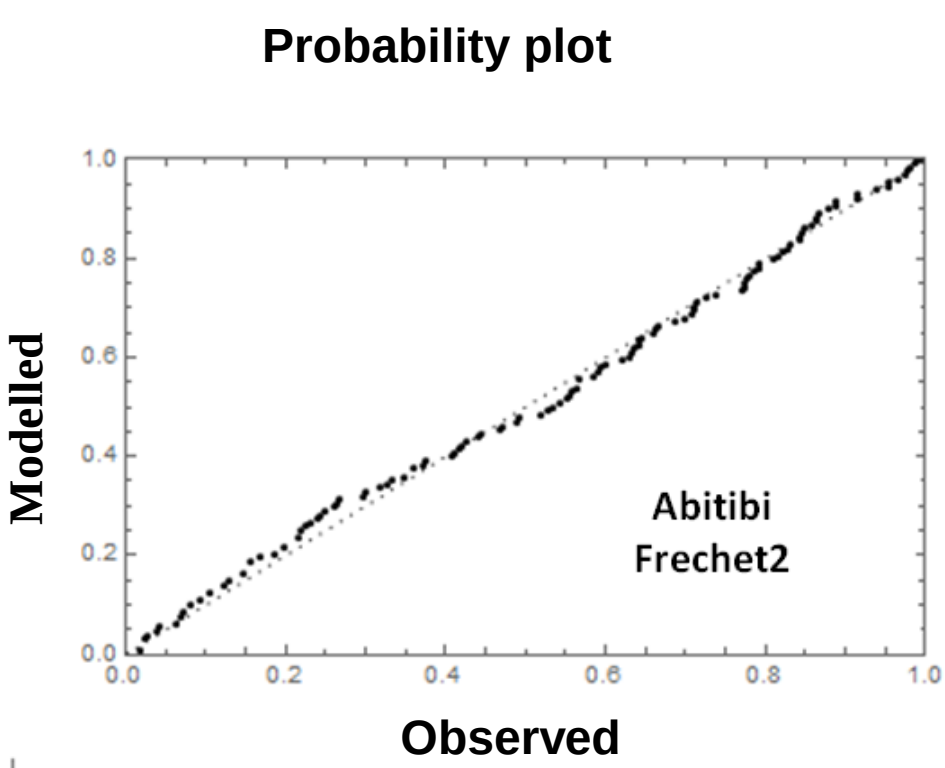
Zimbabwe



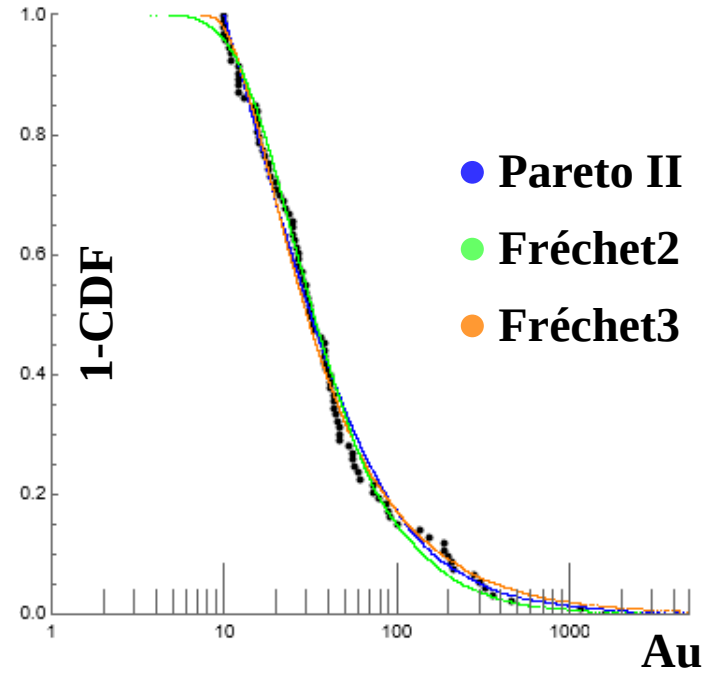


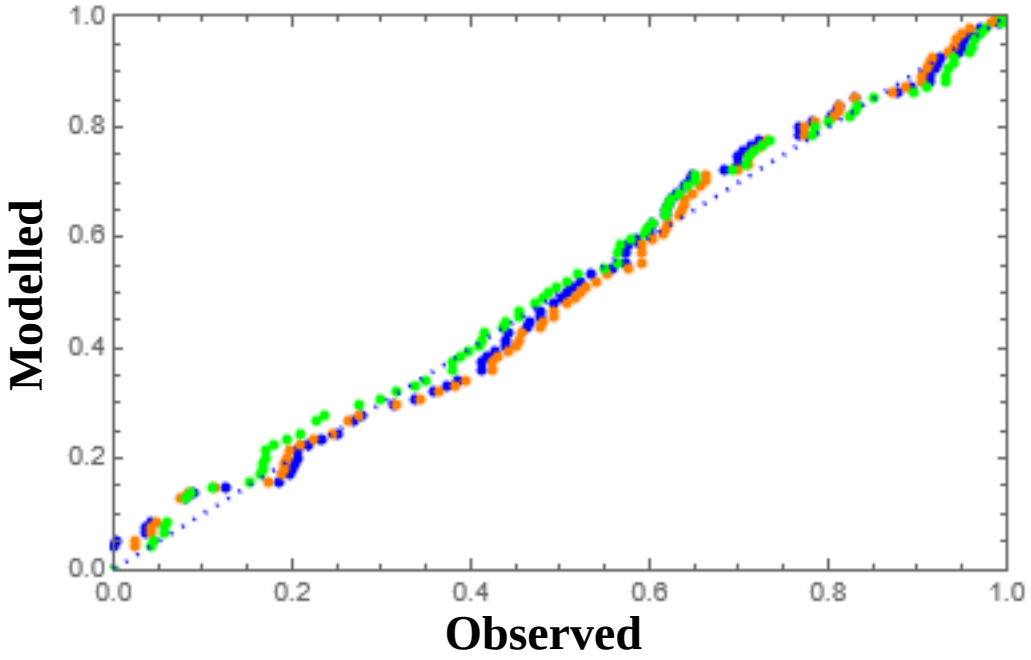
Abitibi


Cumulative distribution
1-CDF
1.0
0.8
0.6
0.4
0.2
5
10
50
100
500
1000
Abitibi
Frechet2

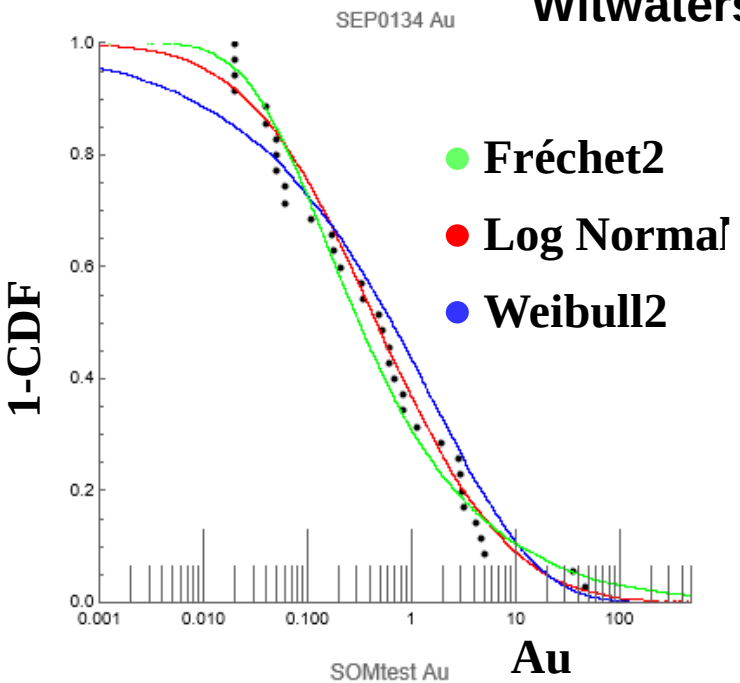

Probability plot
Modelled
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Abitibi
Frechet2
Observed

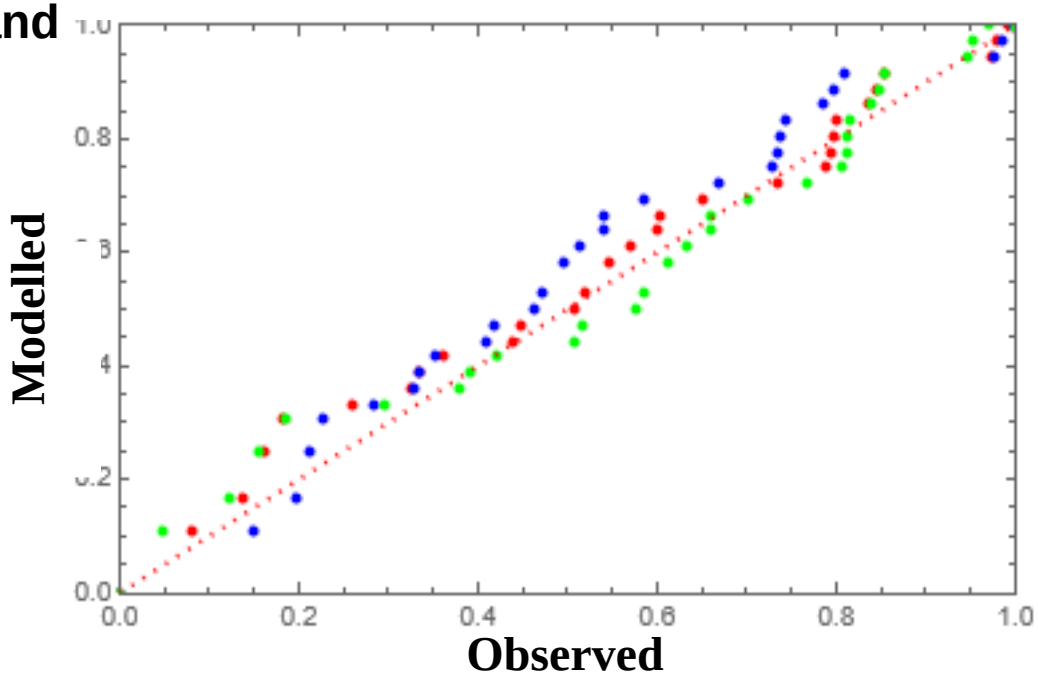
Au tonnage West Africa

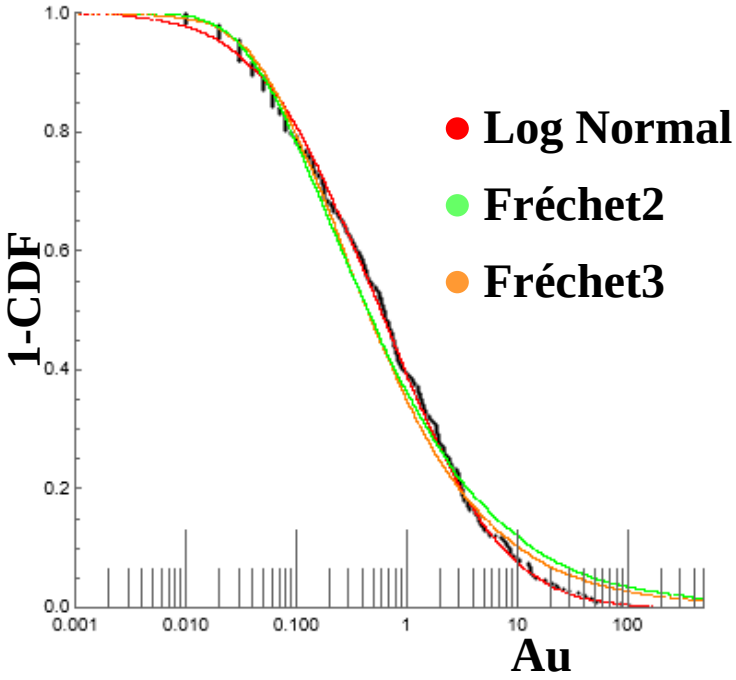


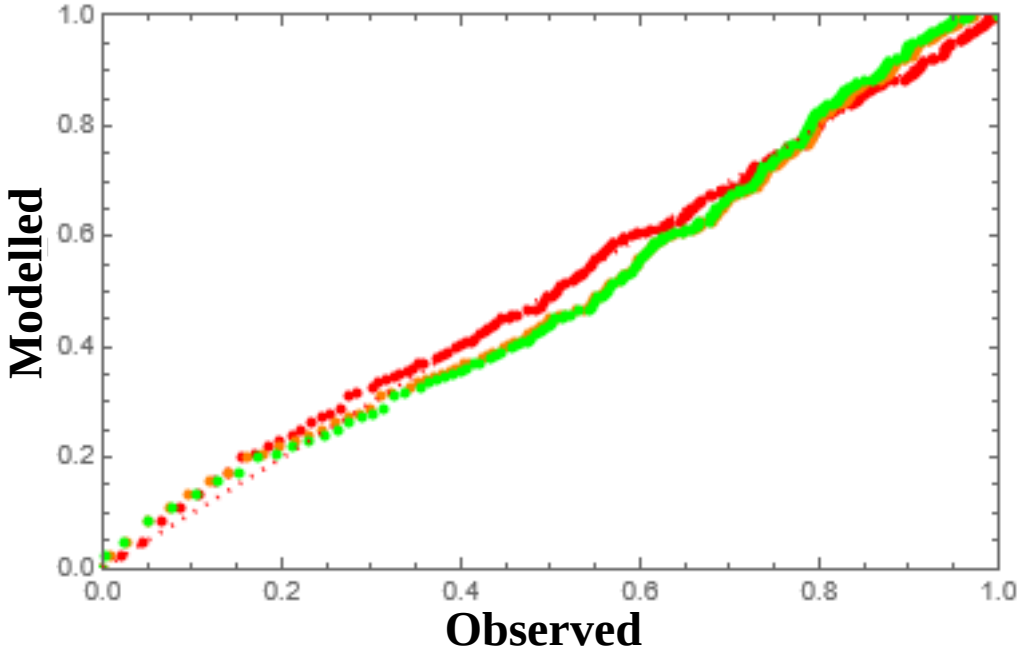


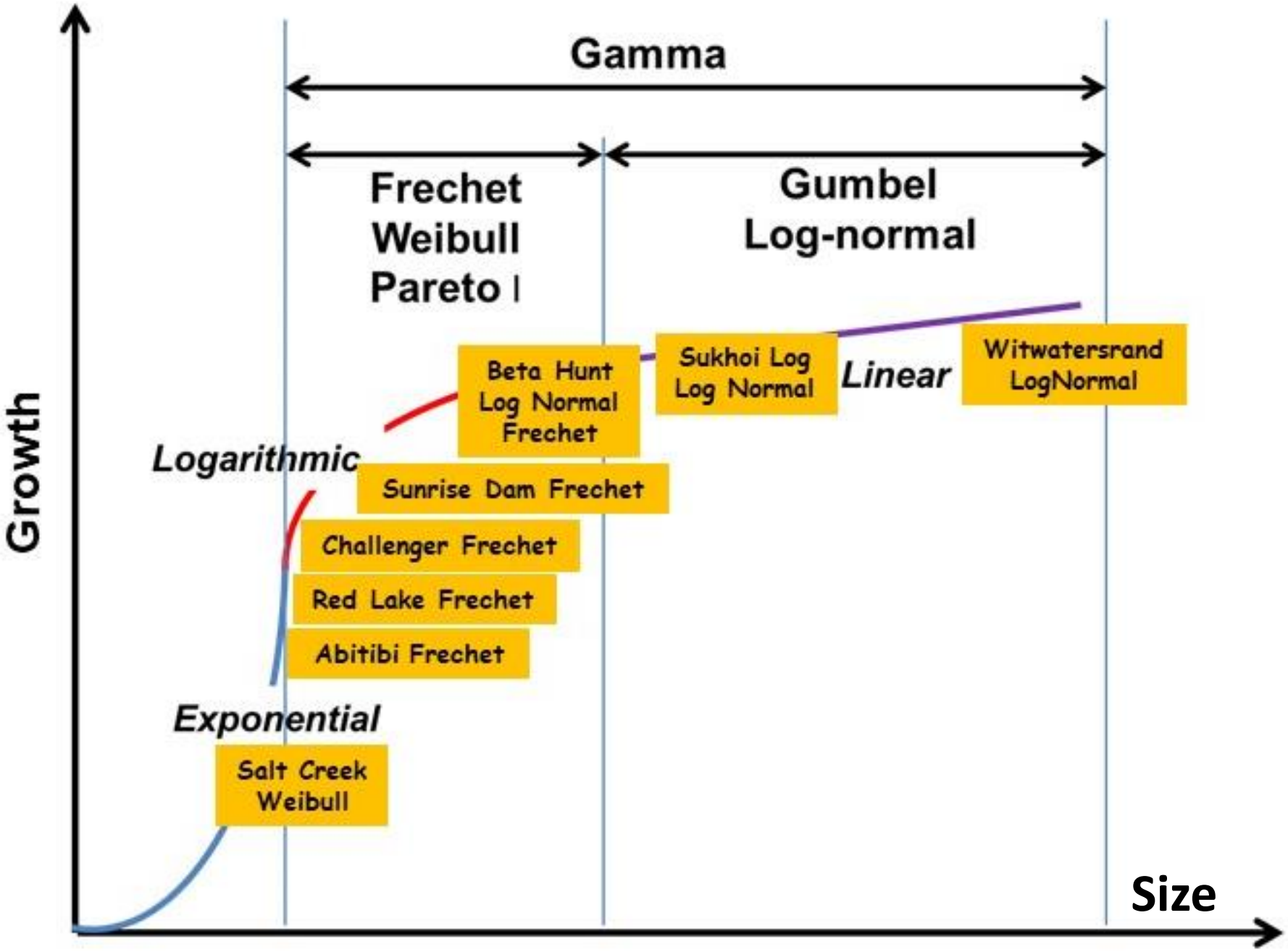
Witwatersrand

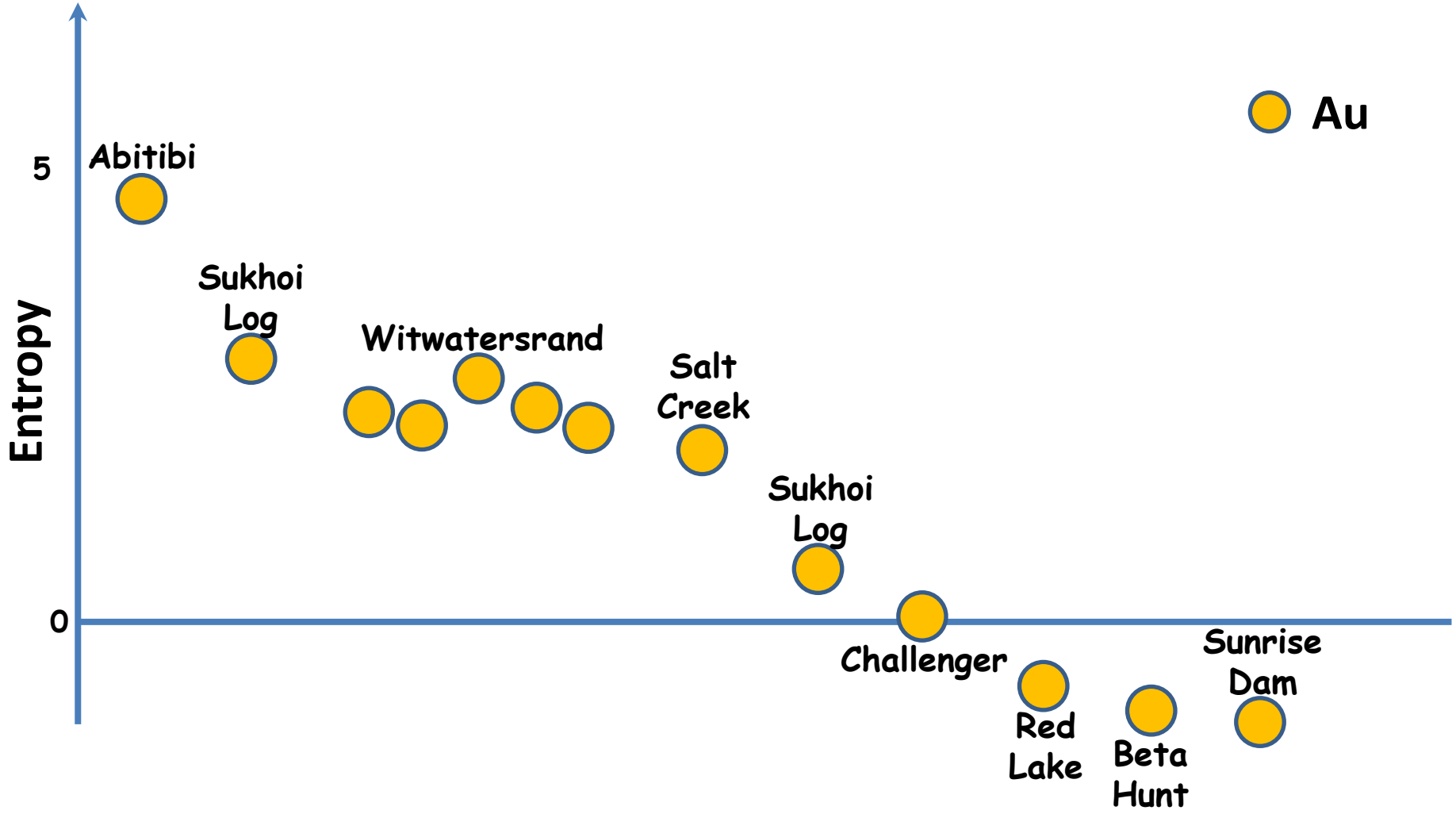




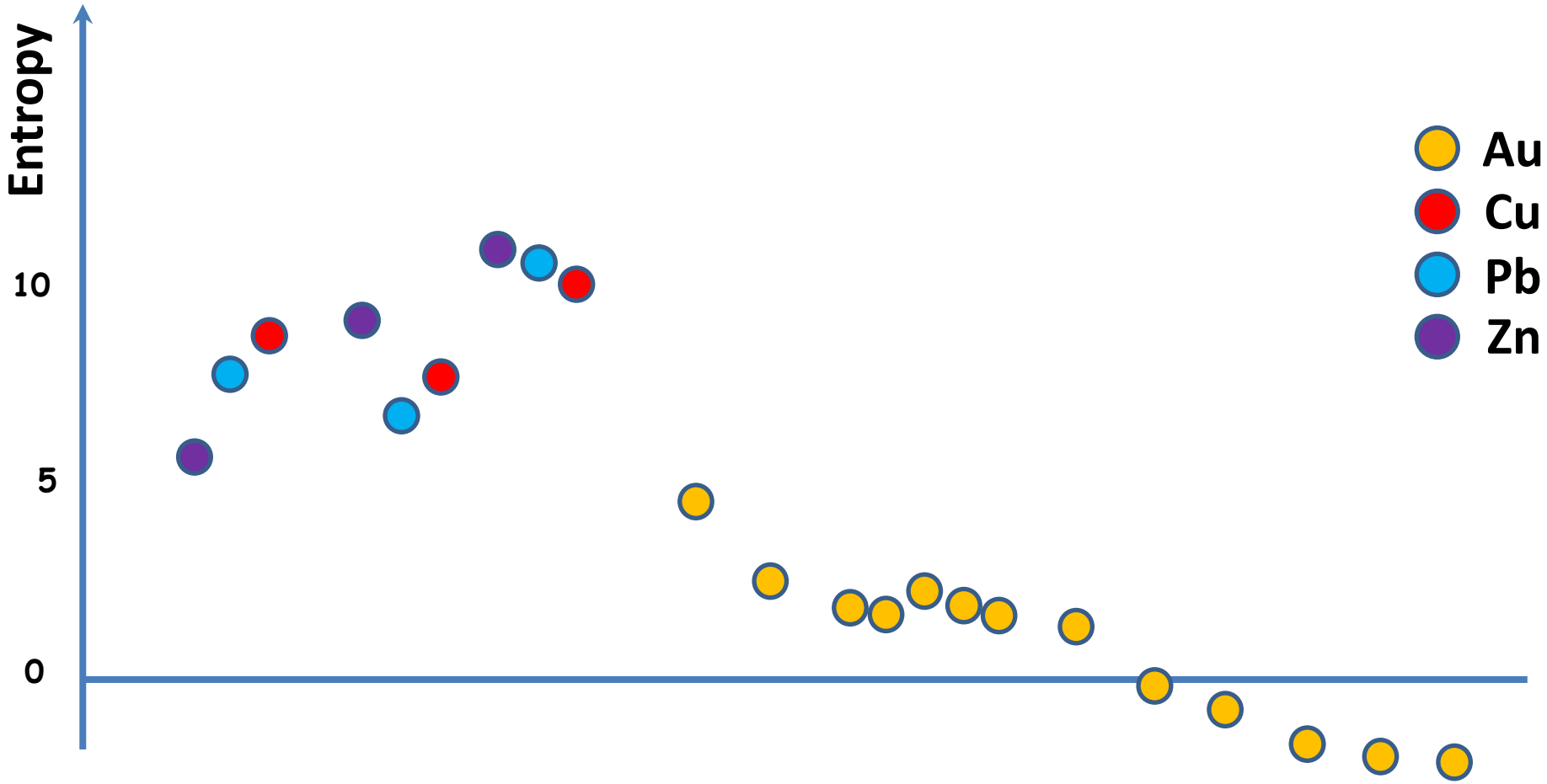


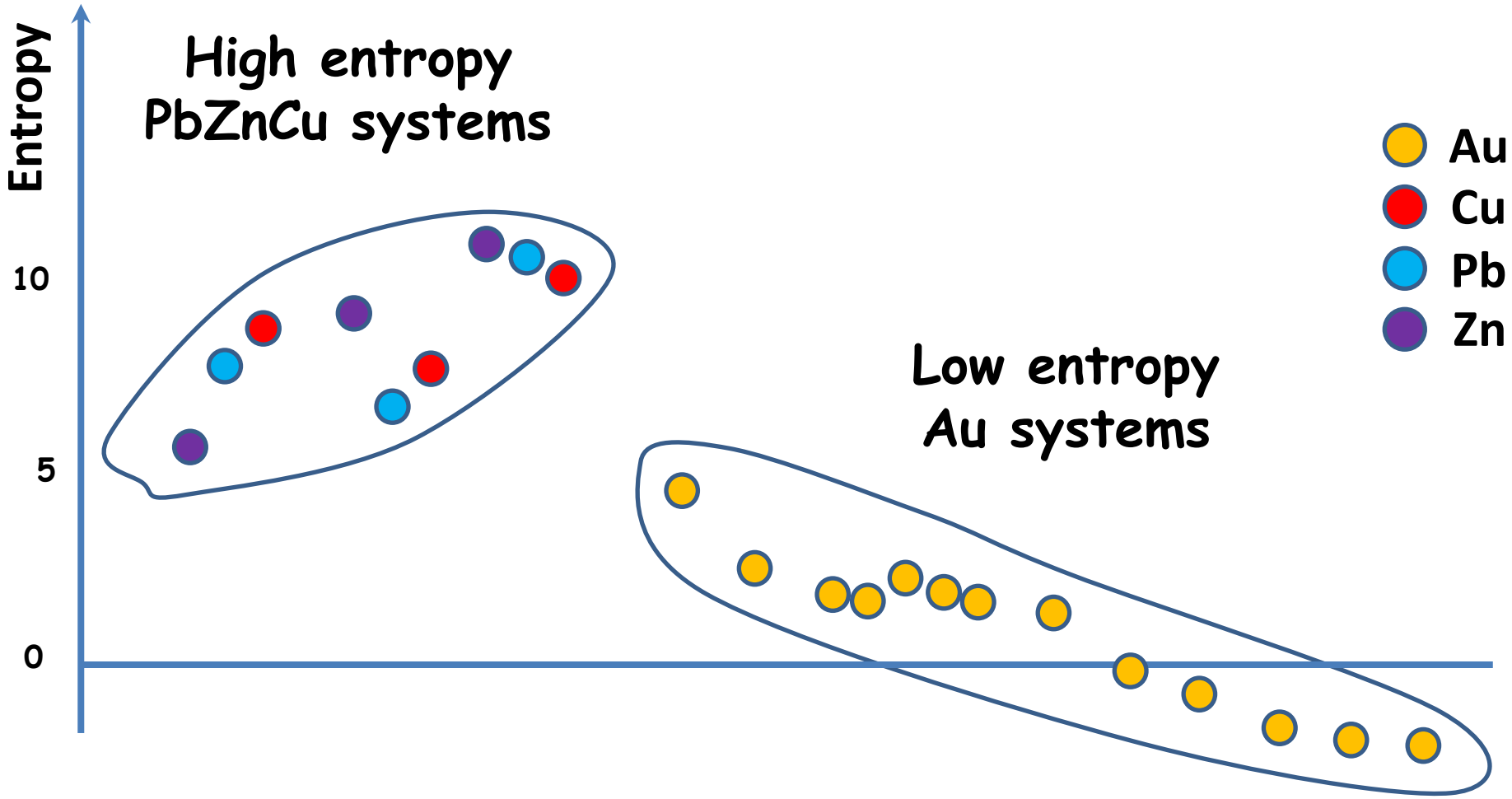


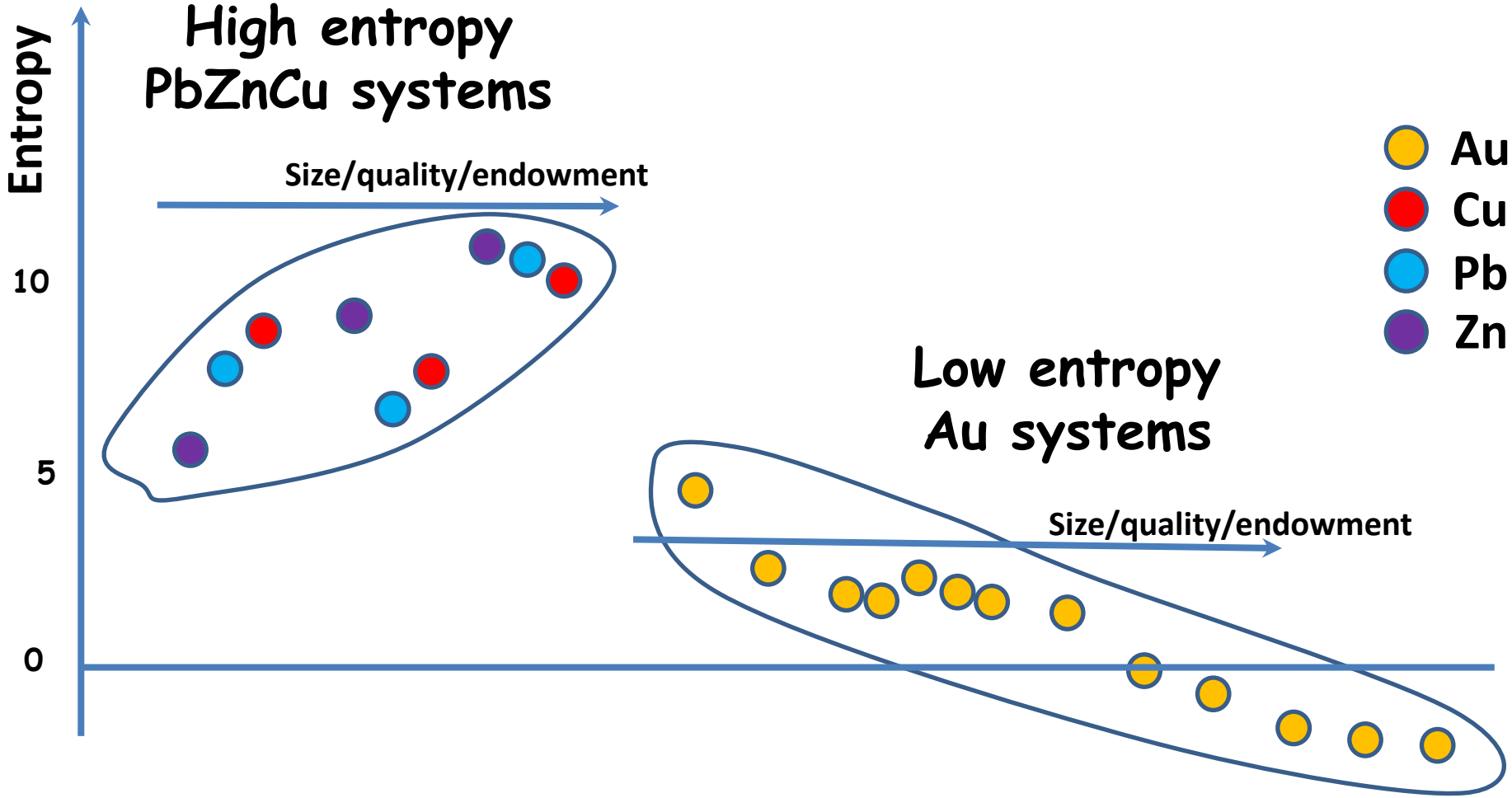

Gamma
Frechet
Weibull
Pareto I
Gumbel
Log-normal
Growth
Size
Logarithmic
Linear
Exponential
Beta Hunt
Log Normal
Frechet
Sukhoi Log
Log Normal
Witwatersrand
LogNormal
Sunrise Dam Frechet
Challenger Frechet
Red Lake Frechet
Abitibi Frechet
Salt Creek
Weibull



Entropy calculated for best-fit distribution for each system.


Entropy
10
5
0
Au
Cu
Pb
Zn


Entropy
10
5
0
High entropy
PbZnCu systems
Low entropy
Au systems
Au
Cu
Pb
Zn



Entropy increases with size for PbZnCu as opposed to Au, for which entropy decreases with size.

Could this represent different growth mechanisms?

Growth for Au and replacement for PbZnCu?

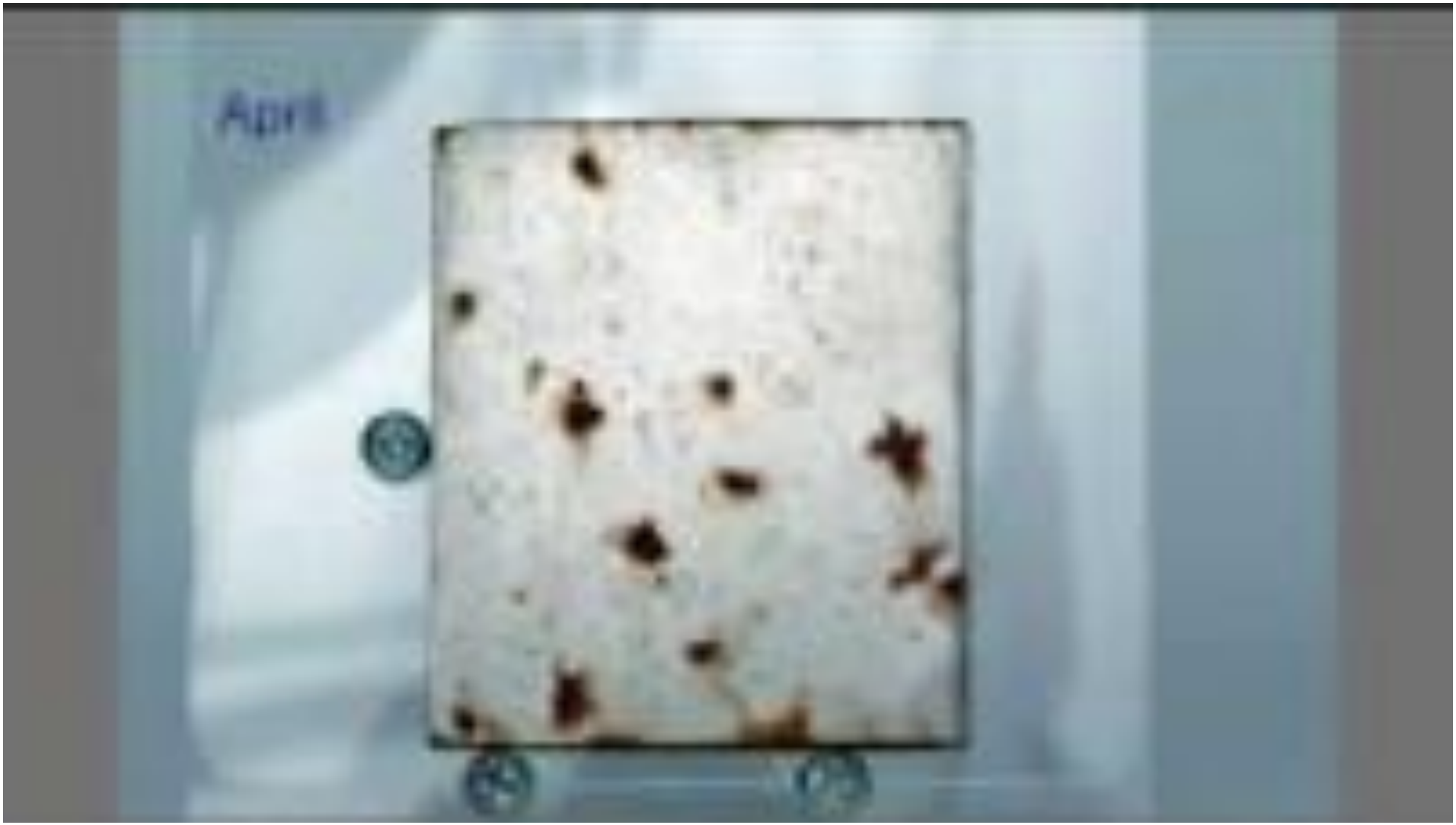
Consider two growth laws

Logistic

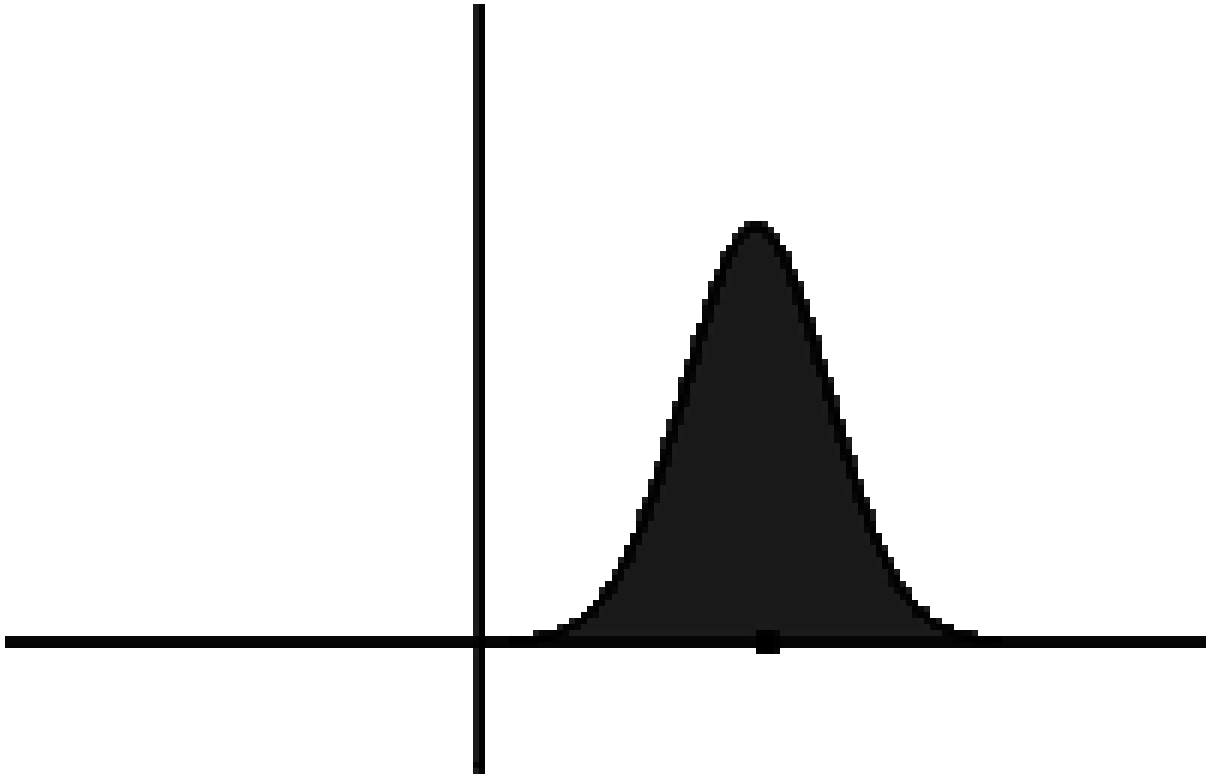
Fokker-Planck

Logistic growth – the growth rate gets smaller and smaller as the size approaches a maximum imposed my limited resources in the environment – produces an S-shaped curve

Fokker-Planck – equivalent to the advection-diffusion equation

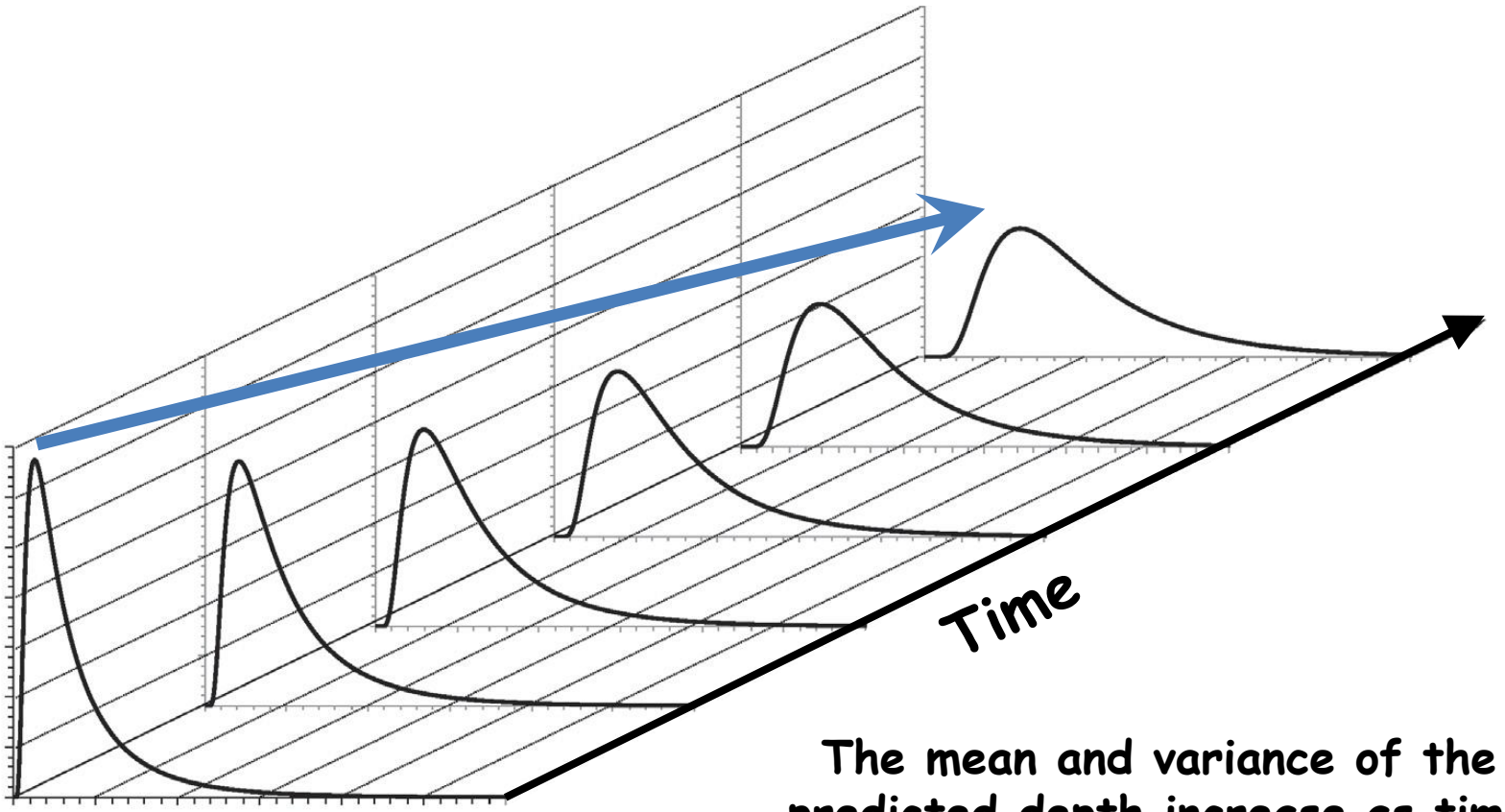

April

A solution to the one-dimensional Fokker - Planck equation, with both the drift and the diffusion term.



The initial condition is a Dirac delta function in x=1, and the distribution drifts to x=0.

Evolution of the probability distribution with time for a replacement process.



The mean and variance of the predicted depth increase as time increases, which is expected.