Under the patronage of His Royal Highness Prince Khalifa bin Salman Al Khalifa Prime Minister of the Kingdom of Bahrain

GEO 2014

Conference: 9 - 12 March 2014
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Bahrain International Exhibition and Convention Centre

11th Middle East Geosciences Conference and Exhibition

"Grain Size Geostatistics Enhance Reservoir Characterisation "

Robert Duller (University of Liverpool)
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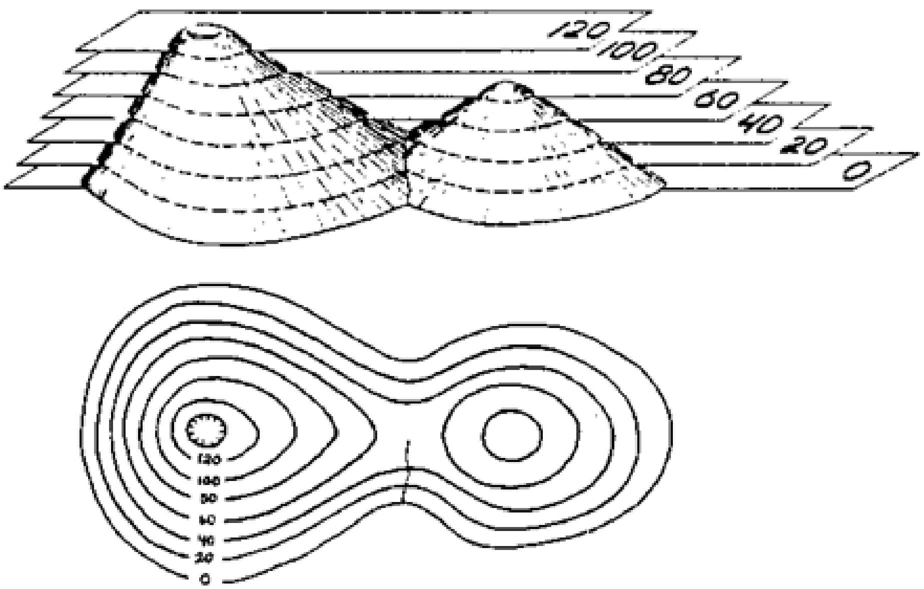
UNIVERSITY OF LIVERPOOL

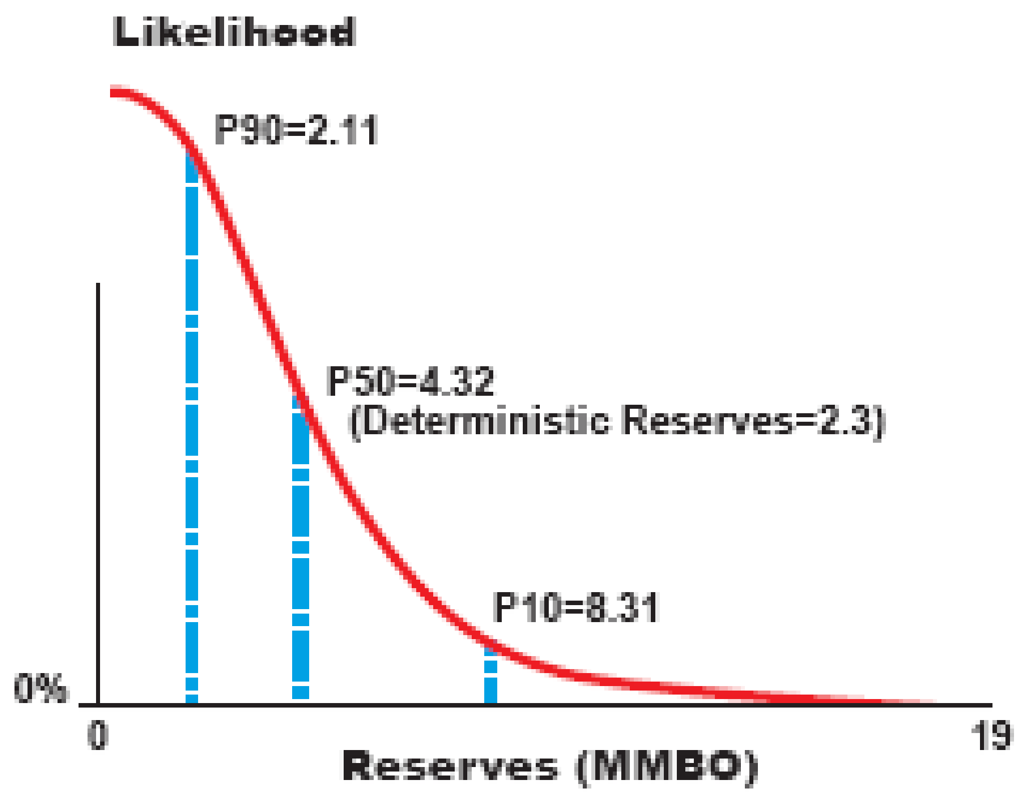
PETROG

Advances in modelling introduce new opportunities, but often also uncover previously unnoticed problems.

When rock volumes were estimated from planimetry:

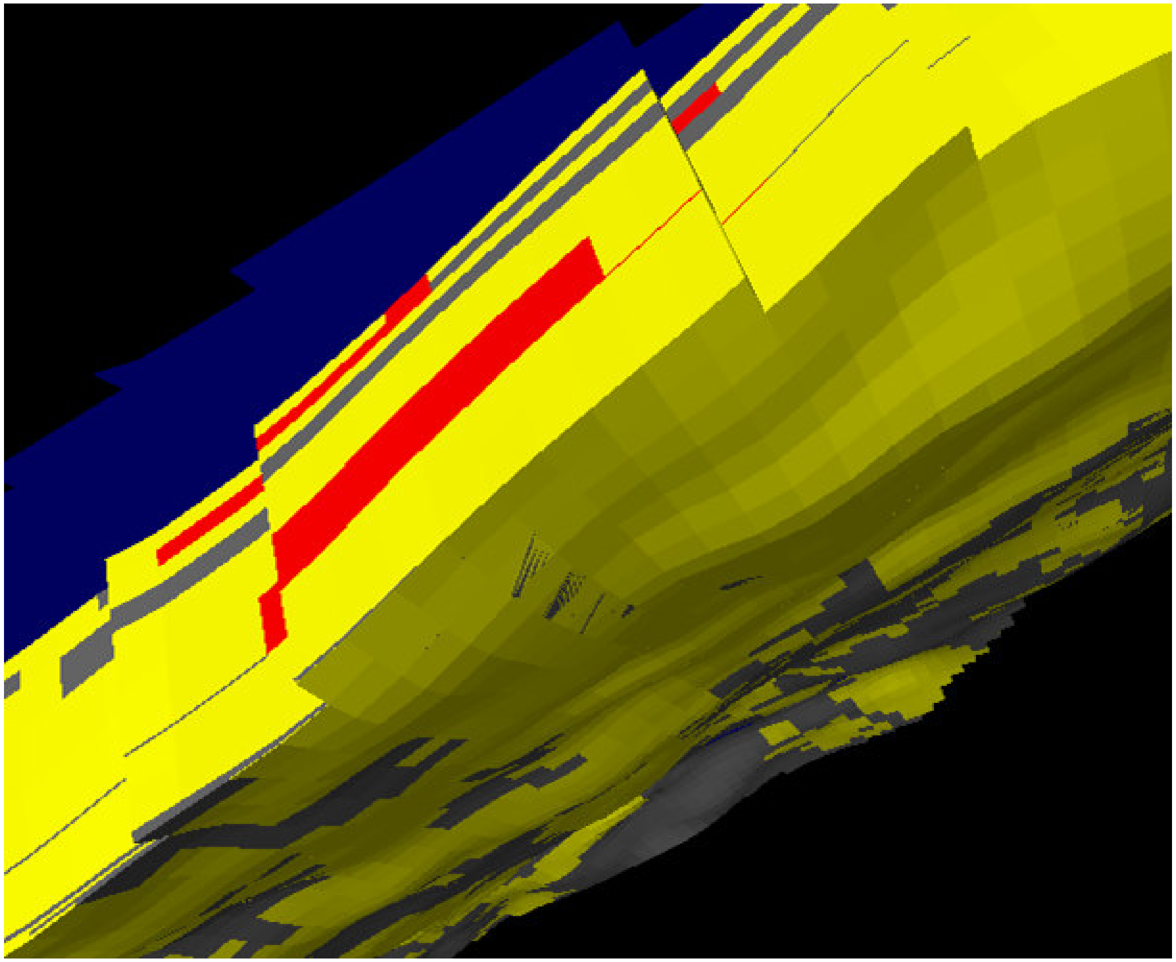


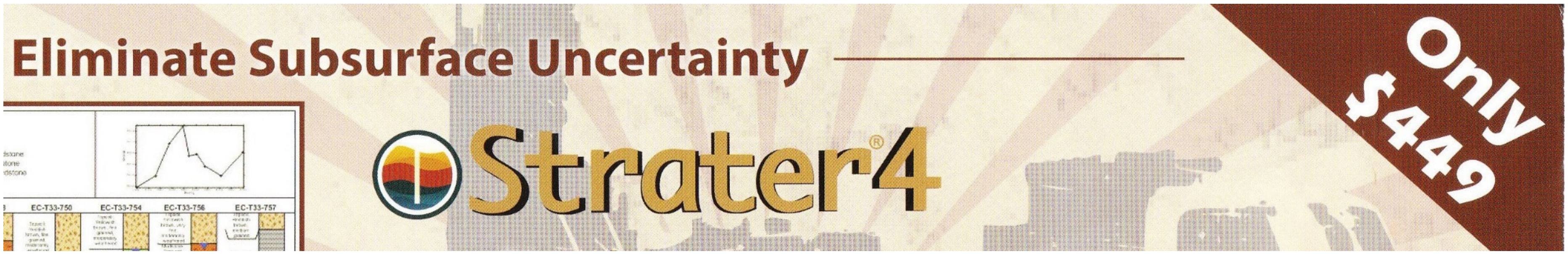
... and reserves calculated from single values of porosity and saturation:



When volumes were estimated from planimetry, and reserves calculated from single values of porosity and saturation, the variability of the GRV arising from surface uncertainty, and the variability of porosity and saturation across the reservoir, simply didn't enter into consideration.

Newer software allows parameters to vary across the reservoir, and geostatistics models variance directly

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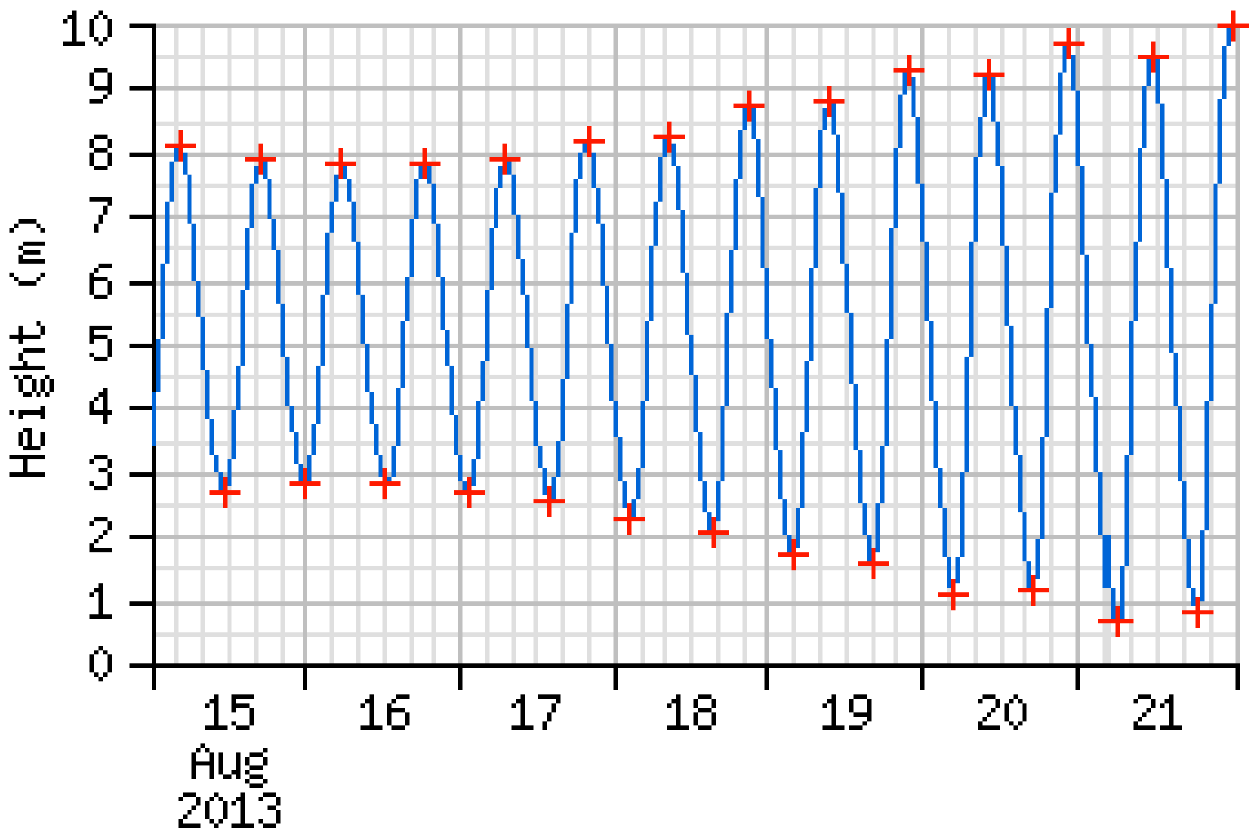
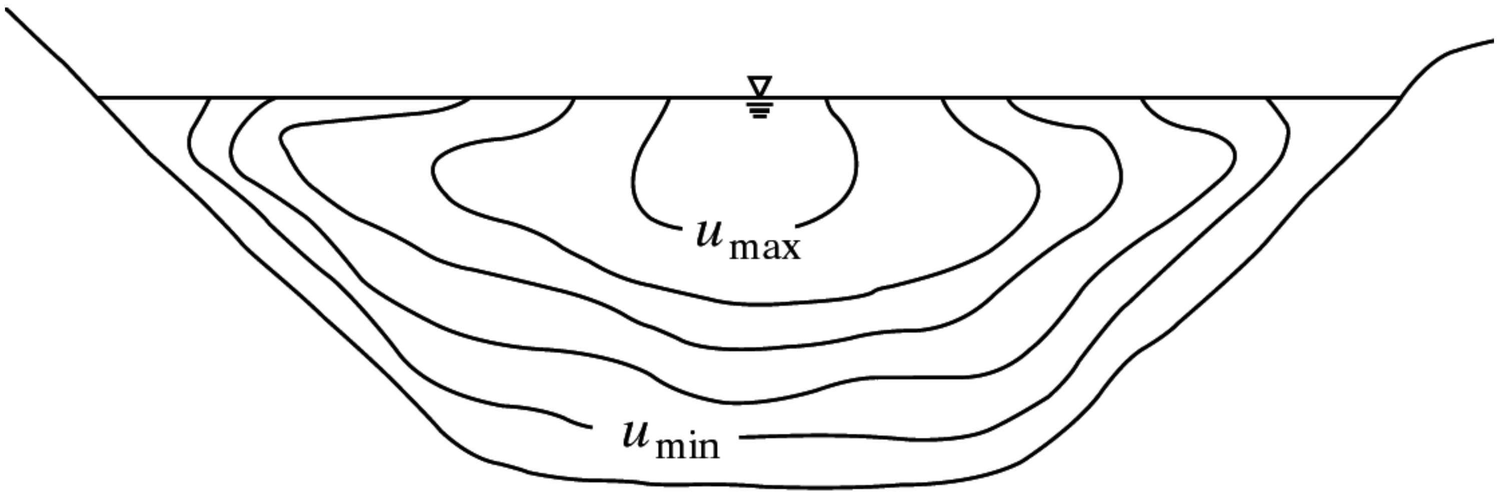
Uncertainty cannot always be eliminated:



High and low water times and heights at Liverpool (Gladstone Lock)

There is uncertainty in any fluvial system, even though we know the equations of motion:

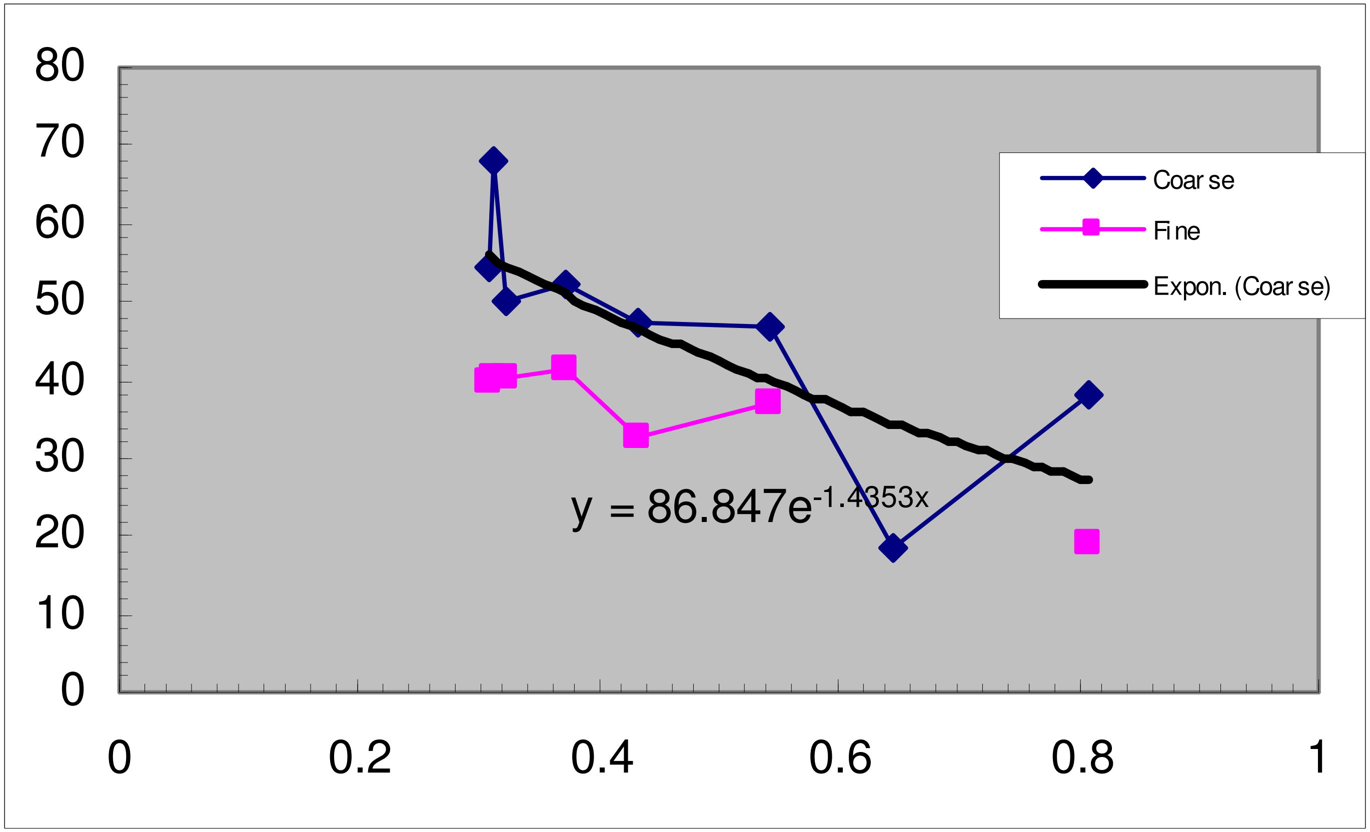


Geostatistics models variance directly.

Reservoir characterisation requires many proxies: one parameter standing in for another.

Correlation is generally used to show that values are correlated.

This is fine, provided we are modelling values. What does it say if we are modelling variances?


80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
Coar se
Fi ne
Expon. (Coar se)
y = 86.847e-1.4353x

(constant) mean of x

(constant) mean of z

$$x_0^{ck} = \mu_x + \sum_{i=1}^{n} w_i \left(x_i - \mu_x \right) + \sum_{j=1}^{m} v_i \left(z_j - \mu_z \right)$$

primary (well) data at location i

co-kriging weights

secondary (seismic) data at location j

$m >> n$ *(i.e. we assume there is more secondary data than primary)*

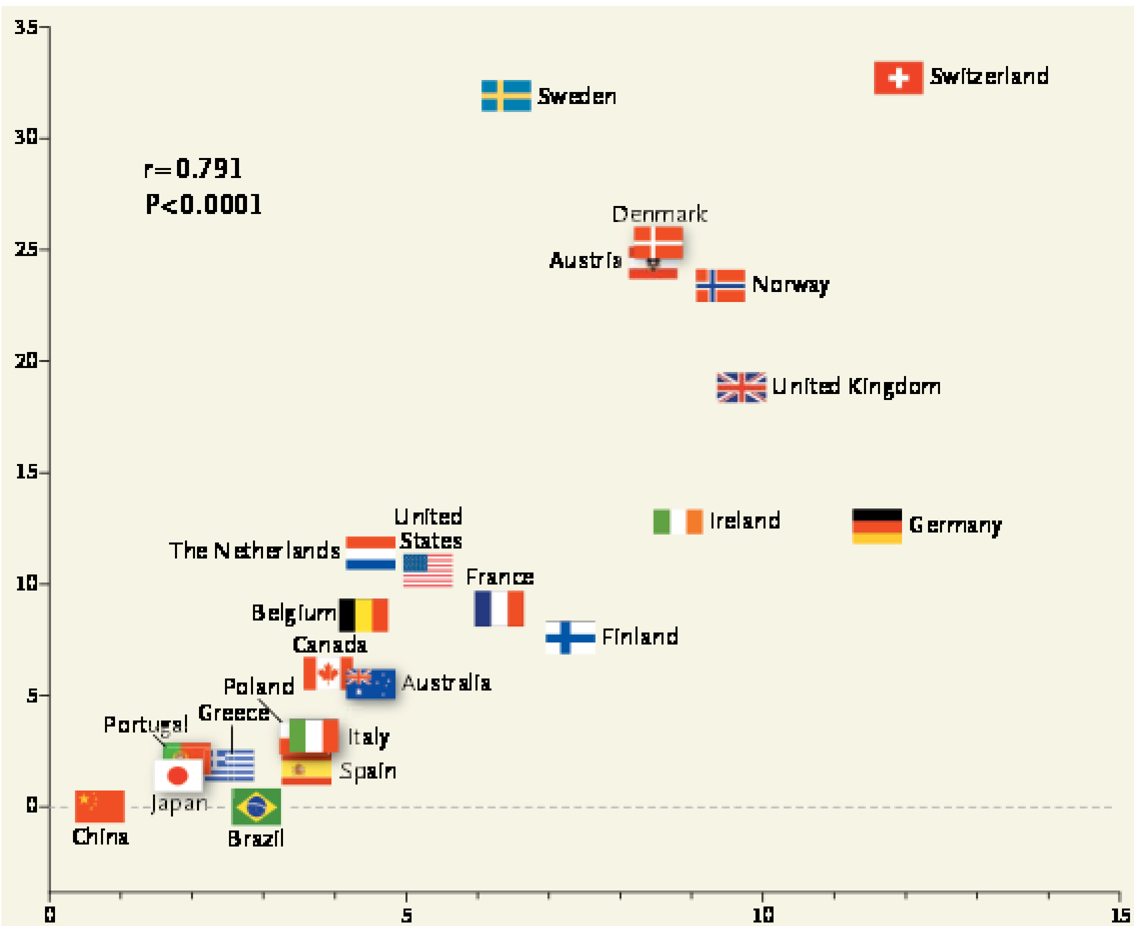
On what basis do we choose a secondary variable?

Preferably, one that is highly correlated.

If it is highly correlated, then we have a reasonable expectation that the variance in the secondary variable is a good proxy for the variance in the primary variable.

Horizontal axis: Chocolate consumption per 1000 population

Vertical axis: Number of Nobel laureates from that country



r (corr.coeff.) = 0.79

If Sweden is treated as an outlier, corr. coeff. increases to 0.86

(*Why might Sweden be an outlier*?)

The NEW ENGLAND JOURNAL of MEDICINE

OCCASIONAL NOTES

Chocolate Consumption, Cognitive Function, and Nobel Laureates

Franz H. Messerli, M.D.

Along with the usual caveats on correlation (causality, false positives), here we additionally have to consider what it is that is being correlated and how a significant correlation will be applied.

Choosing a secondary variable:

If it is highly correlated, then we have a reasonable expectation that the variance in the secondary variable is a good proxy for the variance in the primary variable.

Implicit, unstated assumption:

"correlation of means =>
correlation of variances"

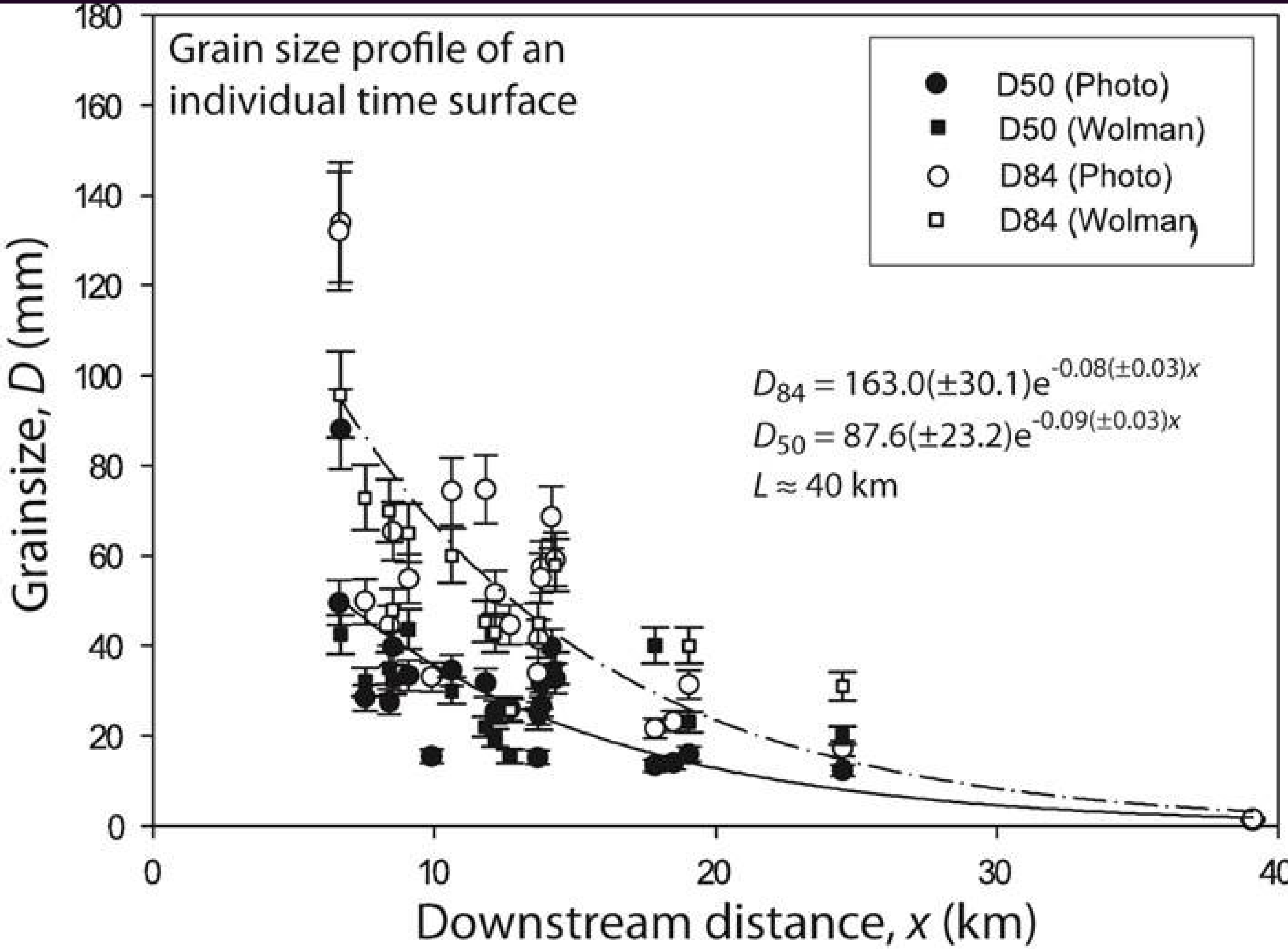
Is this justifiable?

(and how can we check?)

This question is fundamental to the characterisation of reservoirs through geostatistical modelling, yet it has not been formally addressed.

So we set out to address this question.

We chose grain size as the primary variable for our investigation.

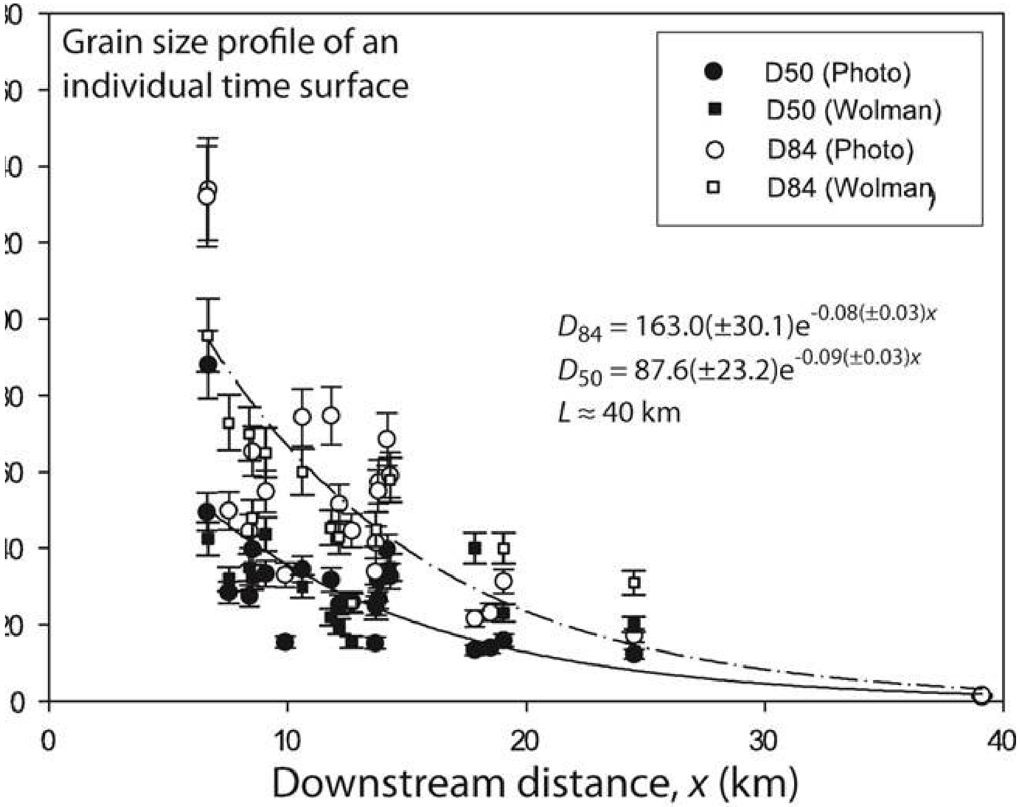


Time-averaged grain size data from a single 'time-surface', Montsor Fan succession, Spanish Pyrenees. [Duller et al., "From grain size to tectonics", J. Geophys. Res.]

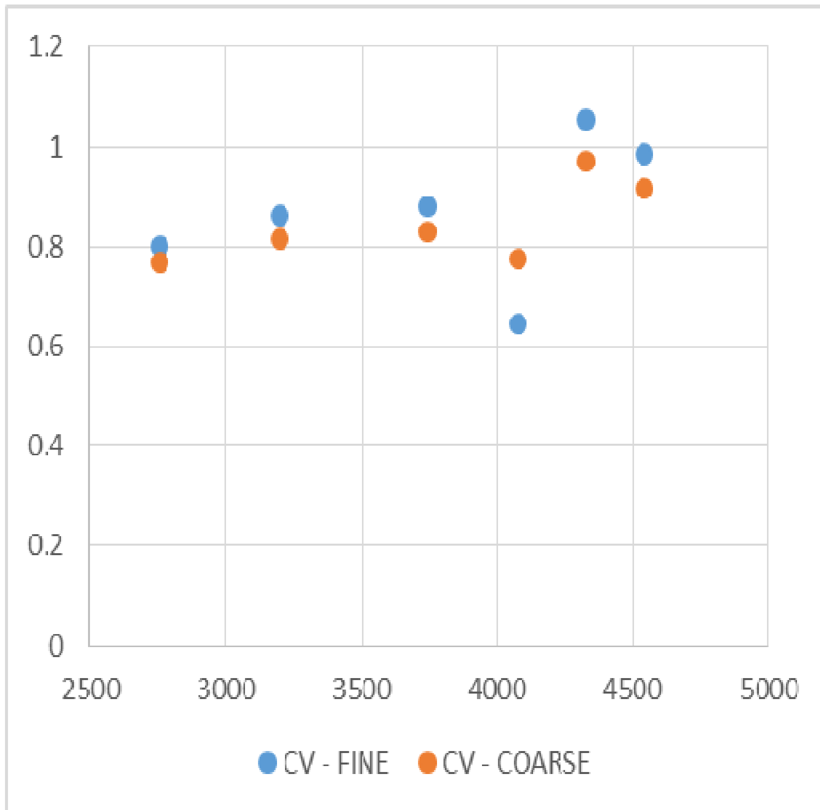
Question: Does the mean vary in synchronicity with variance?

If so, then coefficient of variation (defined as ratio of standard deviation to mean) should have a predictable pattern

Mean and variance



Coefficient of variation



Coefficient of Variation for 4 sets each of 100 samples of grain size data

Distance downstream				
	0.753	0.945	0.834	0.912
	0.824	0.894	1.043	1.048
	0.836	0.872	0.838	0.882
	0.841	0.897	0.854	0.868
	0.792	0.840	0.707	0.723
	0.995	0.976	0.966	1.000
	0.831	0.795	0.442	0.795
	0.740	0.902	0.763	0.813
	0.910	0.941	0.920	1.030
χ^2	0.059	0.028	0.295	0.111

Summary so far:

Geostatistics models variation.

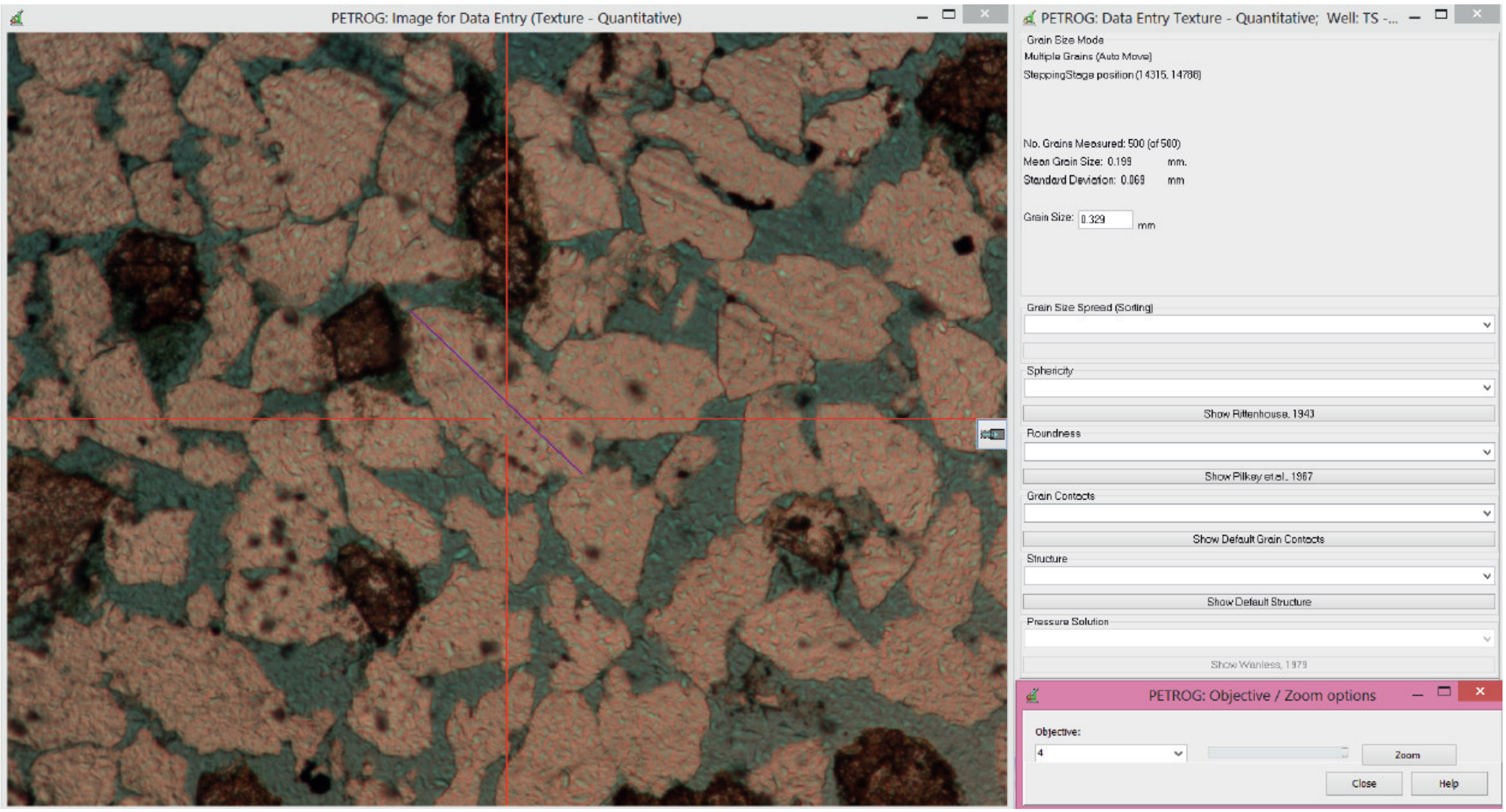
Can we use proxies for variation?

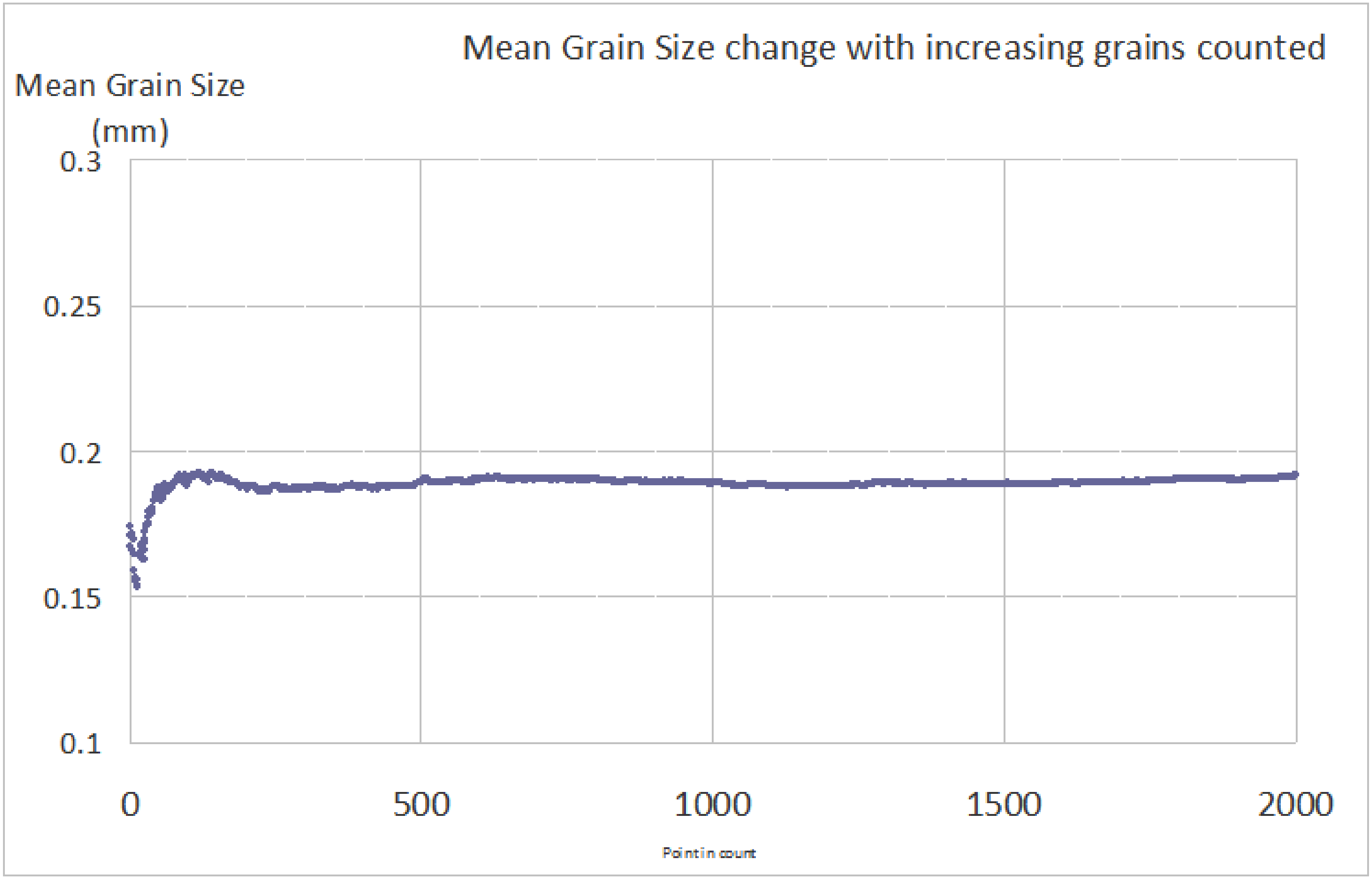
Yes, if values and variances are related – which they do appear to be, in these few cases.

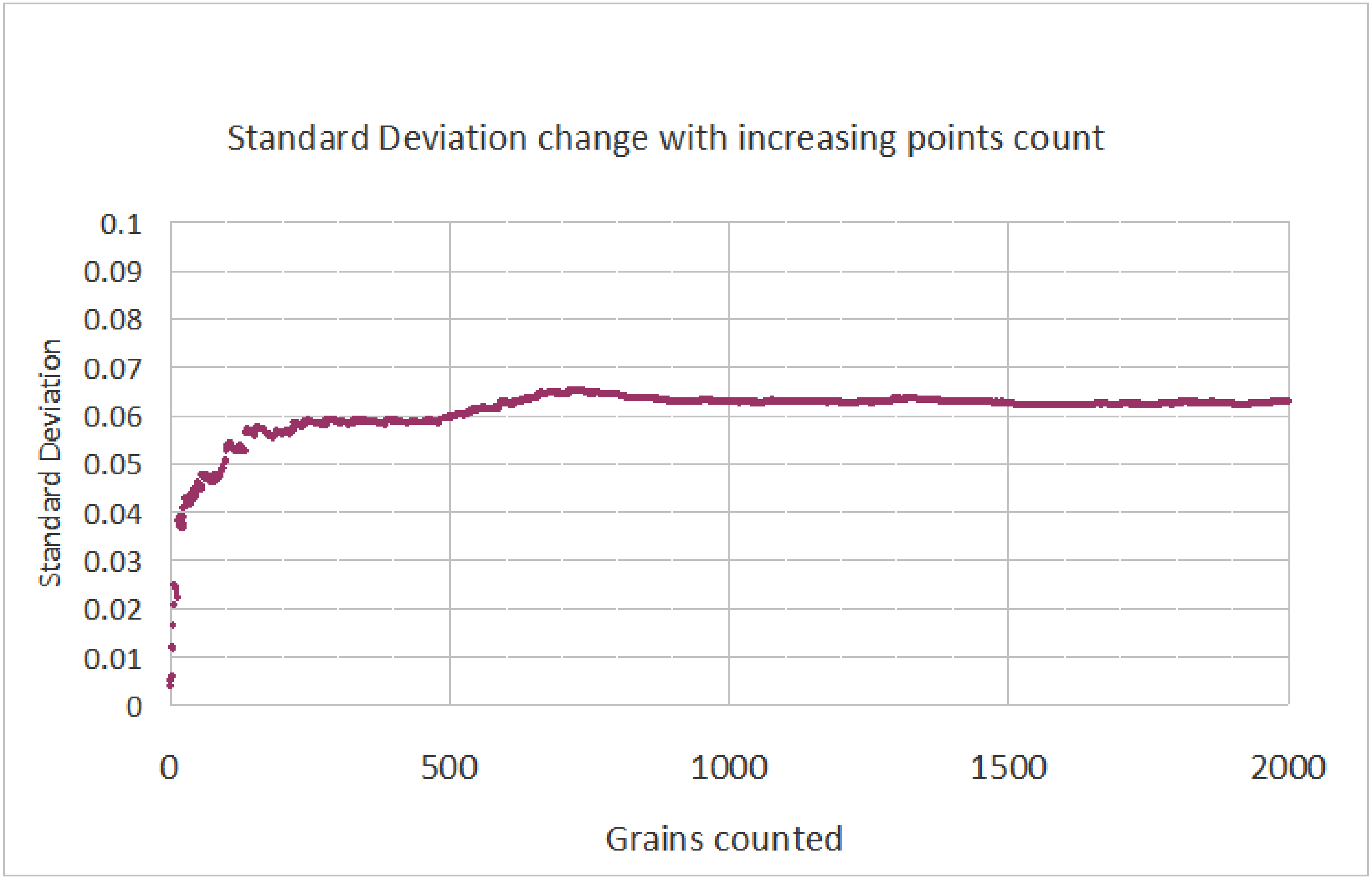
Still to look at:

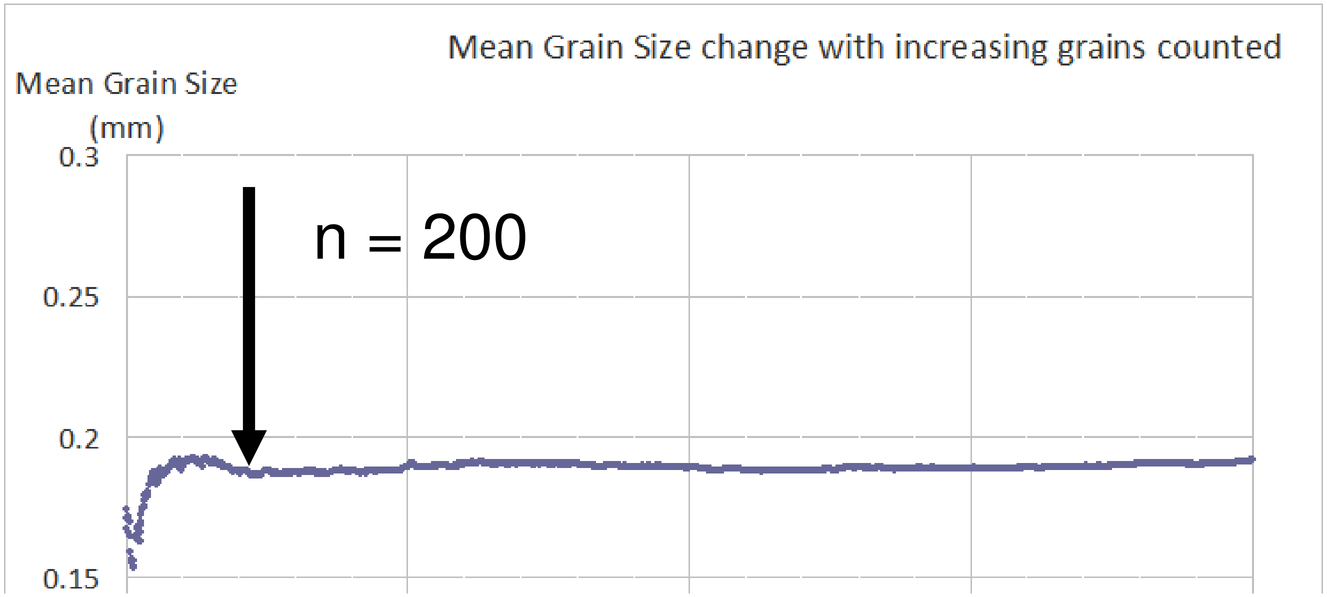
Is it a universal law, a consequence of the geology, or does it just happen by chance in some cases?

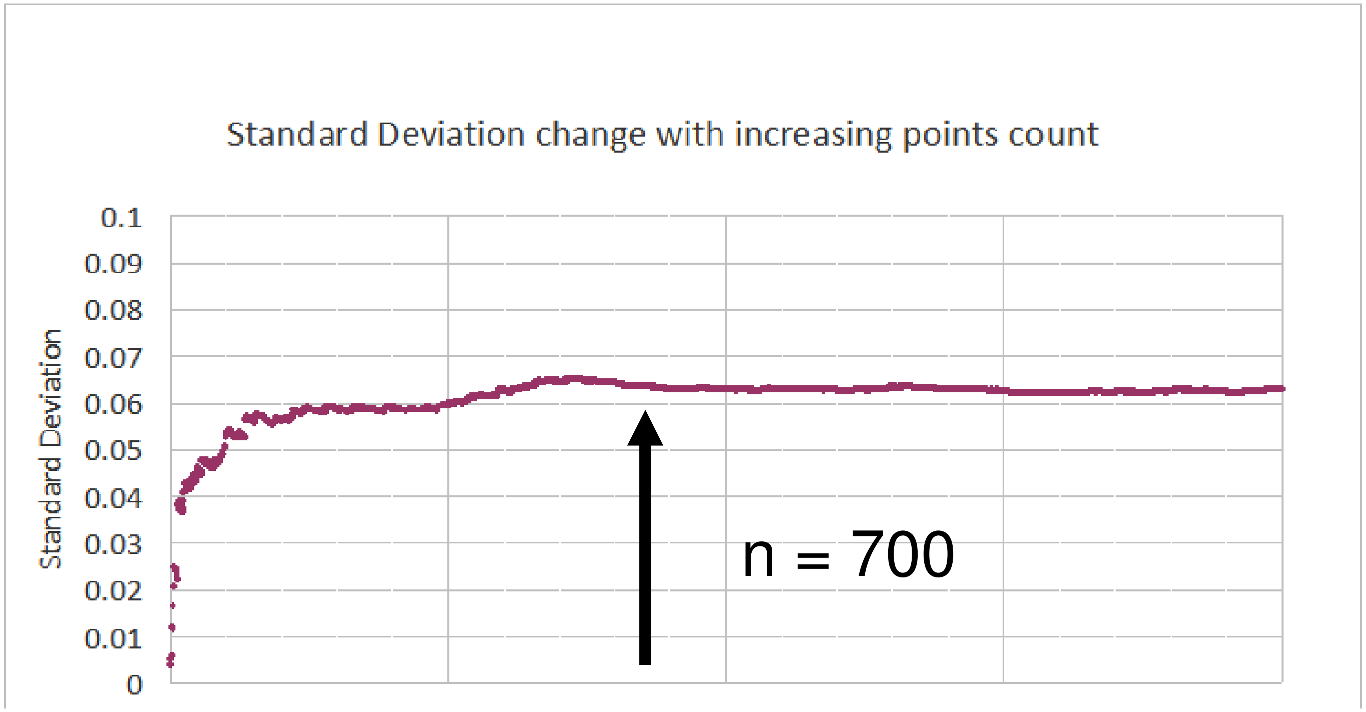
Further analysis: Brent Formation, UK North Sea



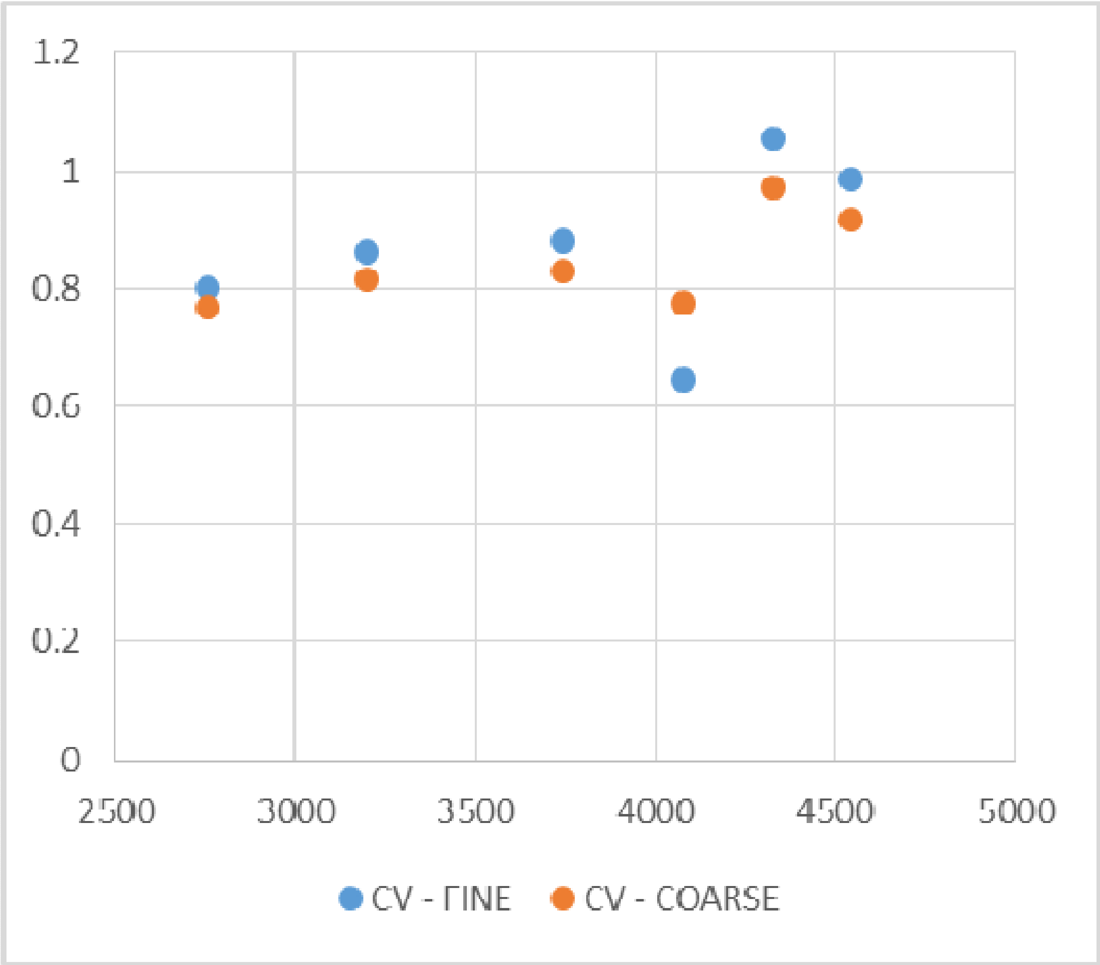

Mean Grain Size change with increasing grains counted
Mean Grain Size (mm)
0.3
0.25
0.2
0.15
0.1
0
500
1000
1500
2000
Point in count


Standard Deviation change with increasing points count
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Standard Deviation
0
500
1000
1500
2000
Grains counted


Mean Grain Size change with increasing grains counted
Mean Grain Size
(mm)
0.3
0.25
0.2
0.15
n = 200


Standard Deviation change with increasing points count
Standard Deviation
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
n = 700

Coefficient of variation: 100 grains



..... maybe 100 grains is not enough.

Summary and Conclusions

“correlation of means => correlation of variances” may be acceptable in some cases, but data collection methodology needs to change

Summary and Conclusions

Take care: assumptions are being made, when building models, that have not yet been justified through experimental work.

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If there is a trend:

9.5 15.9 18.0

9.0 11.0 13.6 16.4 22.0 21.0

10.5 14.1 19.0

…why do we need to remove it?

	9.5		15.9		18.0	
9.0	11.0	13.6	16.4	22.0	21.0	
	10.5		14.1		19.0	
Local mean	10.0		15.0		20.0	
Local s.d.	0.9		1.4		1.8	
c.v..	11.0		11.0		11.0	

Trend: Why do we need to remove it?

		9.5			15.9			18.0	
	9.0	?	11.0	13.6	?	16.4	22.0	?	21.0
		10.5			14.1			19.0	
Local mean		10.0			15.0			20.0	
Local s.d.		0.9			1.4			1.8	
c.v.		11.0			11.0			11.0	

If we were only interested in values, then the calculation would cope:

		9.5		12.7		15.9				18.0	
	9.0	10	11.0		13.6	15	16.4		22.0	20	21.0
		10.5				14.1		16.6		19.0	
Local mean			10.0			15.0				20.0	
Local s.d			0.9			1.4				1.8	
c.v.			11.0			11.0				11.0	

But if we are modelling variance, then we would need to re-calculate the semivariogram locally to honour the input variance:

		9.5		X_4		15.9				18.0	
	9.0	X_3	11.0		13.6	X_5	16.4		22.0	X_1	21.0
		10.5				14.1		X_2		19.0	
Local mean			10.0			15.0				20.0	
Local s.d.			1.4			1.4				1.4	

…because using a single semivariogram would increase the low variances and decrease the high.

But if we are modelling variance, then we would need to re-calculate the semivariogram locally to honour the input variance:

		9.5		X_4		15.9				18.0	
	9.0	X_3	11.0		13.6	X_5	16.4		22.0	X_1	21.0
		10.5				14.1		X_2		19.0	
Local mean			10.0			15.0				20.0	
Local s.d.			1.4			1.4				1.4	

'Second order stationarity' is the assumption that one variogram can be used throughout (i.e. that variance is dependent only on separation distance, not on position)

Does the data display a trend?
If so, should we remove it because:

a) the data are non-stationary (violate the second order stationarity condition, that variance is dependent only on separation distance, not on position);

b) a trend is determinism, i.e. there is a predictable part to the data, so the data are not purely stochastic, and hence any prediction of the variance will be biased;

c) otherwise we would need a ‘power’ semivariogram, and Petrel doesn’t provide this choice;

d) all of the above.