1798670 Grain Size Geostatistics Enhance Reservoir Characterisation

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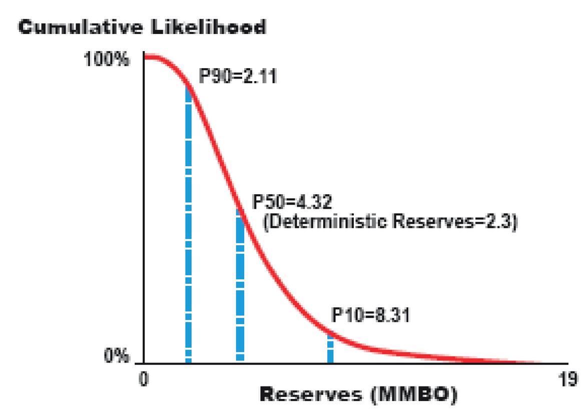
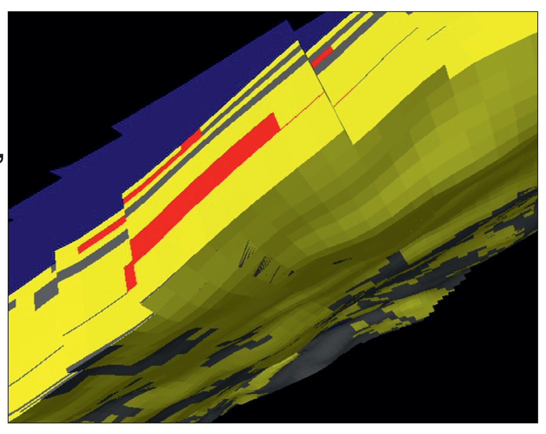
1 THE ASSUMPTION IN GEOSTATISTICAL MODELS

Each step forward exposes previously unrealised opportunities, or problems, depending on point of view. When gross rock volumes were calculated using simple planimetry, and hydrocarbon pore volume (HCPV) estimated using a single representative value for each of porosity and saturation, variation was not well understood. If HCPV can only be estimated this coarsely, then the Monte Carlo estimate of reserves is similarly restricted in its prediction of variance (right):





Now that we have tools such as Petrel able to model variation in the parameters themselves, we can use geostatistics to more accurately model the expected variance in volumes based on models of the variation in the parameters affecting volume.

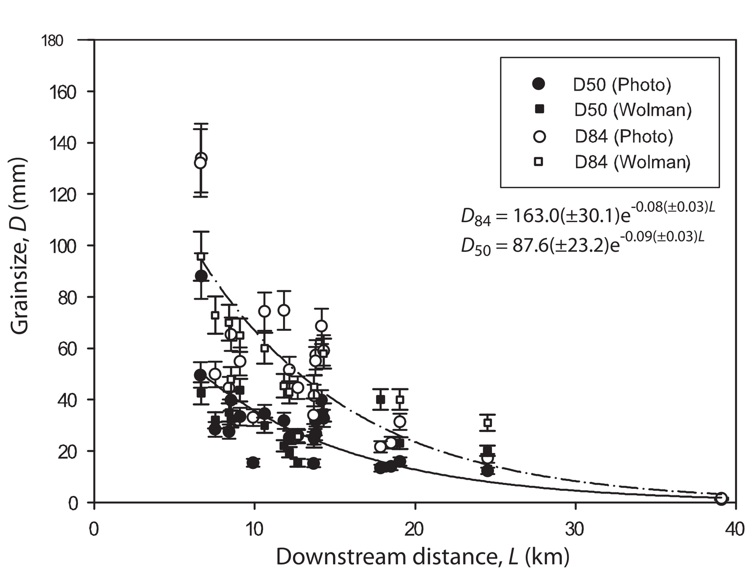
Here we look at grain size, as being an underlying, primary geological parameter which influences, in different ways, many of the parameters used in modelling volumetrics.

2 THE WAY FORWARD

Geostatistics models variance directly, and assumes that there are no trends in the data. In other words, the geologist is expected to model the trends directly, geologically, and let the geostatistics model the variation. However, geologists model values (of porosity, saturation, etc.) not variance; how do we know if there is a trend in the variance? If we haven't checked this, the whole basis for geostatiistics can be invalid. Decisions on geostatistical models are invariably taken on the basis of looking at one aspect of the data, its value, and hoping it is representative of a different aspect, its variance, where the word "hoping" is used advisedly, because until now very little thought has been given to this problem / opportunity.

3 FIELD INVESTIGATION OF AN ANCIENT SYSTEM

A number of workers have demonstrated that the mean and standard deviation of grain size distributions, measured in the field, are linked. The coefficient of variation, Cv (Cv = std.dev./mean) is observed to be approximately constant [Paola and Wilcock, 1992; Paola and Seal, 1995; Duller et al., 2010], as presented **below**. This would be enough to satisfy the requirements of geostatistics, but this relationship is yet to be rigorously tested and substantiated. This provides a clear impetus for further work in this area.



Above:Time-averaged grain size data from a single 'time-surface' within the Montsor Fan succession, Spanish Pyrenees. Below: Coefficient of variation for each sample plotted as a function of distance. In both figures, *n* = 100 per data point. [Duller et al., "From grain size to tectonics", Journal Geophysical Research - Earth Surface]

A statistical test for significance (Ch-squared test) shows that the coefficient of variation is effectively constant within a single grain size range. The question is whether this relationship can be expected to hold more generaly and if so under what restrictions of environment, for example.

Coefficient of Variation for data:

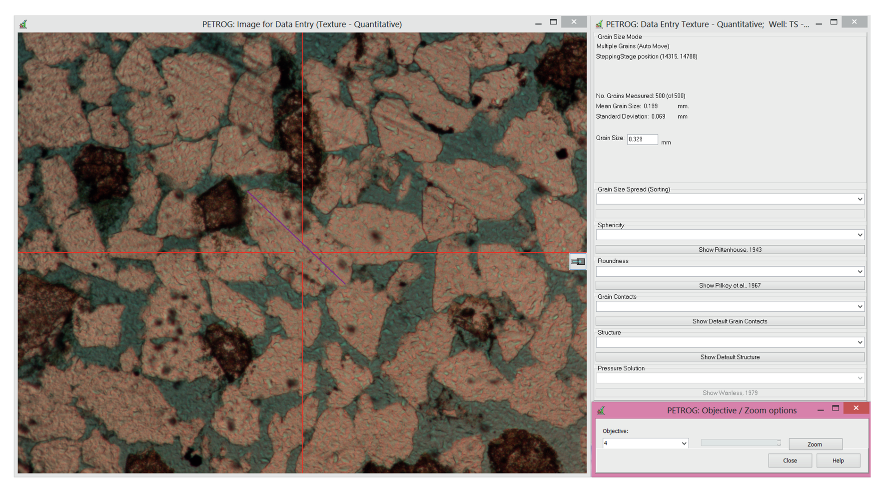
Distance downstream:	A	B	C	D
1361.37	0.753	0.945	0.834	0.912
1381.09	0.824	0.894	1.043	1.048
1425.88	0.836	0.872	0.838	0.882
1641	0.841	0.897	0.854	0.868
1905.47	0.792	0.840	0.707	0.723
2396.77	0.995	0.976	0.966	1.000
2848.13	0.831	0.795	0.442	0.795
3261.62	0.740	0.902	0.763	0.813
3576.06	0.910	0.941	0.920	1.030
χ^2	0.059	0.028	0.295	0.111
P()	0.99	0.99	0.99	0.99

To investigate this, we took samples from Brent cores and looked at the variance arising from sampling; or, more specifically, how the mean, standard deviation and coefficient of variation converge to a stable value, which we subsequently look at to see whether it is representative of the physical property of interest, i.e. grain size.

4 DATASET & METHODOLGY

PETROG point counting software and SteppingStage was used to undertake two-dimensional grain size analysis of clastic sedimentary rocks under thin section. Representative samples for initial grain size analysis using PETROG were selected from the Ness Formation, Brent Group, Thistle Field, North Sea [10330 ft; Well 211/18a-33(18)] - channelized fluvial sandstones. Two thin sections were selected from this depth to quantitatively assess the possible textural variance introduced by sedimentary process: thin section A (TSA) and thin section B (TSB).

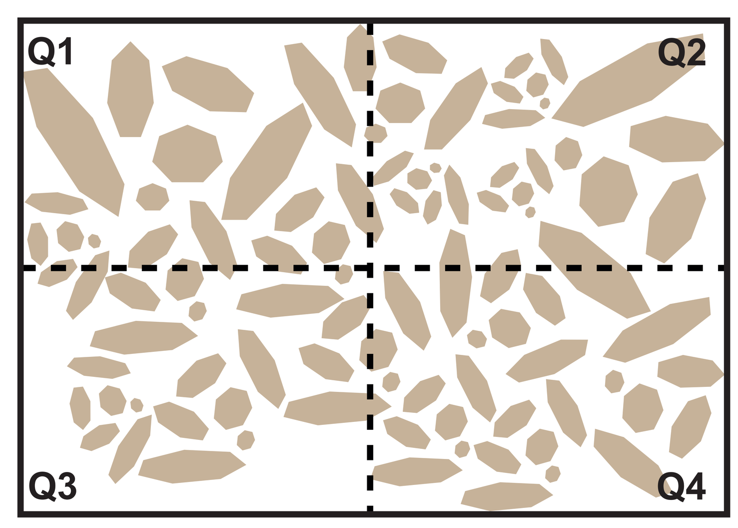
PETROG WORKFLOW



Step 1. PETROG evenly distributes points across the area of interest in a grid system
Step 2. If a grain occupies the area located in the centre of the field of view (displayed by the crosshairs) then its grain size is measured.
Step 3. For the purposes of this experiment, grain size is defined as major axis length only.
Step 4. Each grain is therefore measured through a single click at either end of the major axis of the grain.
Step 5. PETROG then moves the field of view along to the next point in the grid and the process is repeated until 500 points have been collected.

5 EVALUATING SCALES OF GRAIN SIZE VARIABILITY

To assess textural variability in each thin section, grain size counts were completed for a maximum area of interest (n = 500), and then for quadrants of this area (each quad, n = 500).

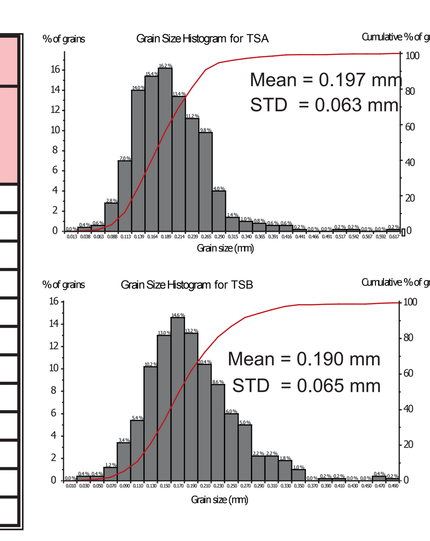


Step 1: Define maximum area of interest as defined by solid outline (26 x 17 mm)
Step 2: Use PETROG coordinate system to define quadrants (Q1-Q4) within this area (13 x 8.5 mm).
Step 3: Implement PETROG workflow (above). Maintain maximum area of interest for each thin section.
Step 4: Plot data and perform statistical assessment using PETROG

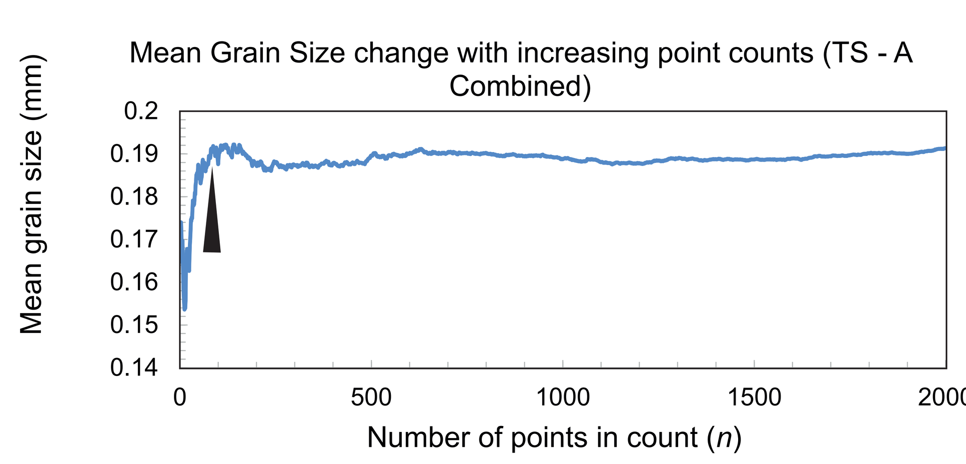
Our methodology lets us assess: 1) resampling or random vaiation by comparing quadrants; 2) localised spatial differences in each thin section by comparing quadrants with the full area analysis; and 3) spatial variability in the same rock unit, by comparing samples.

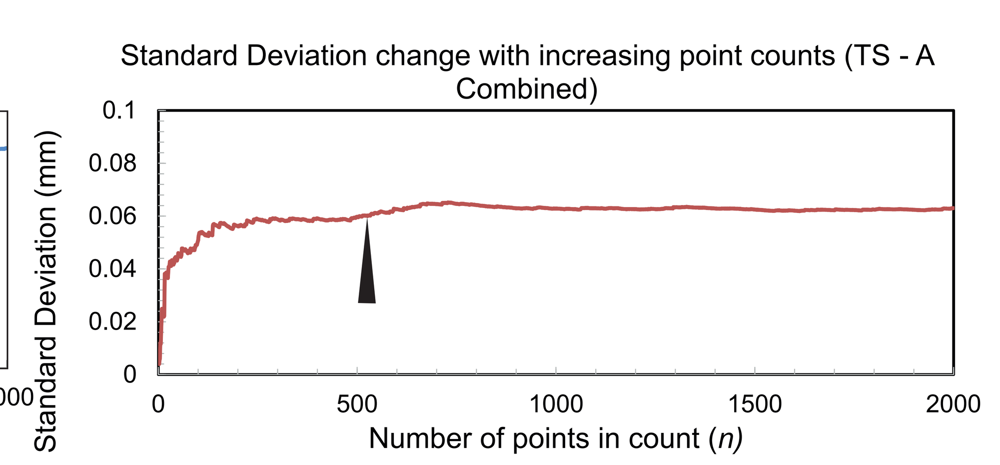
6 RESULTS: TRACKING STATIONARITY

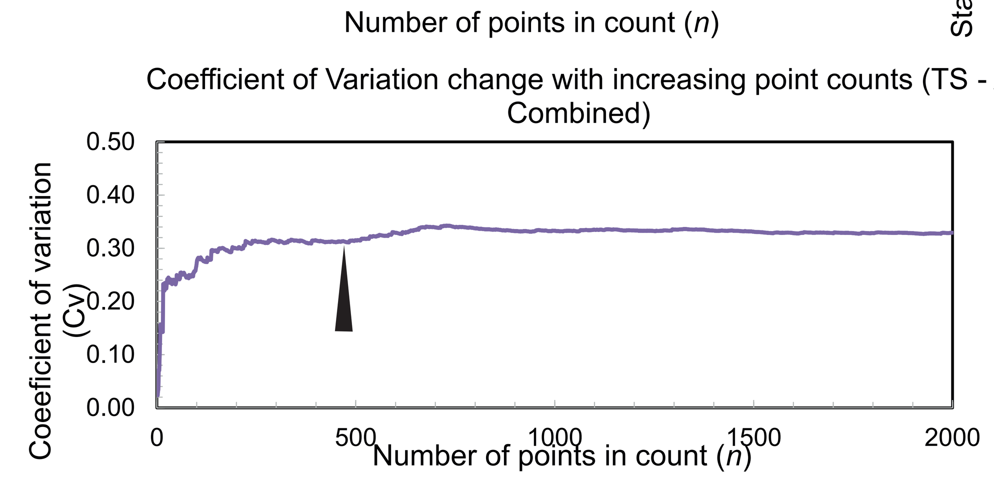
Dataset code	No. of Points in Count	Mean			Standard Dev.			Coefficient of Variation		
		Final Value	No. points to permanently <5%error	No. Points to permanently <1%error	Final Value	No. points to permanently <5%error	No. Points to permanently <1%error	Final Value	No. points to permanently <5%error	No. Points to permanently <1%error
TS - A (Full)	500	0.197	51	439	0.063	374	478	0.320	329	473
TS - A (Q1)	500	0.198	35	336	0.062	288	474	0.312	299	473
TS - A (Q2)	500	0.190	235	354	0.064	223	484	0.337	256	485
TS - A (Q3)	500	0.190	66	245	0.060	248	369	0.313	241	493
TS - A (Q4)	500	0.187	131	328	0.066	166	491	0.352	361	491
TS - A (Q's Combined)	2000	0.191	40	1701	0.063	512	1933	0.329	483	1464
TS - B (Full)	500	0.190	79	392	0.065	380	484	0.340	342	488
TS - B (Q1)	500	0.182	52	411	0.063	138	408	0.345	158	395
TS - B (Q2)	500	0.189	137	362	0.063	203	481	0.334	211	380
TS - B (Q3)	500	0.178	50	297	0.062	178	474	0.350	176	447
TS - B (Q4)	500	0.195	37	344	0.065	173	460	0.333	122	452
TS - B (Q's Combined)	2000	0.186	14	821	0.064	250	1461	0.342	190	1457



Data table summarising the results of the grain size analyses of TSA and TSB. Right: Grain size histogram (*n = 500*) for thin section A (TSA) and thin section B (TSB) performed by defining the major axis of each grain under the crosshairs throughout the a point count across the sample surface.







GENERAL RESULTS

- Mean stabilizes (<5% error of final value) at n> 50,
- Std./variance statbilizes (<5% error of final value) at n> 50,
- Value of CV stabilizes at n> 480

These initial results indicate that, within this environment, the assumption required by geostatistics (i.e. that variance does not display a trend) can be tested by looking at the data values, because the values and variances are related (ratio approximately constant). In geostatistical terms this means that first order stationarity implies second order stationarity; in geological terms it means we can meet Petrel's requirements by analysing the data values alone. The next necessary step is to justify the use of grain size as a valid proxy for reservoir quality.