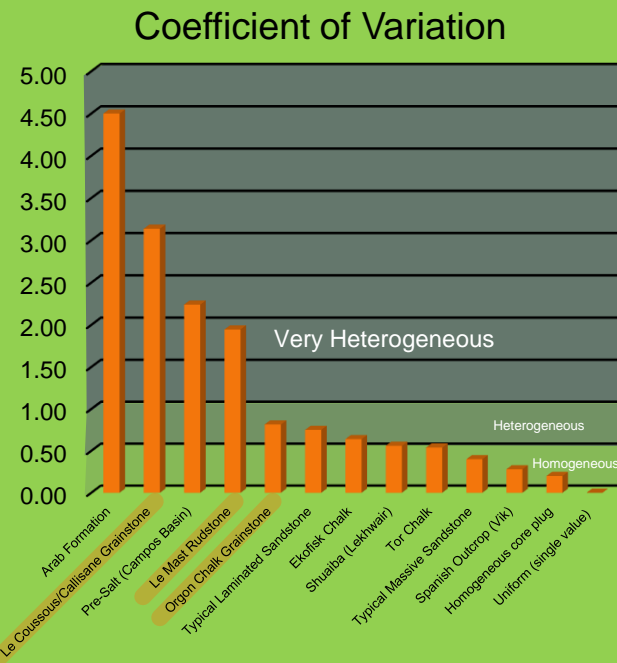


Carbonate Heterogeneity Provençale

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Heterogeneity in reservoirs is usually understood to mean permeability heterogeneity, although in carbonates, porosity can also sometimes also be considered heterogeneous

Heterogeneity can be defined by the **Coefficient of Variation (Cv)**
Cv is standard deviation divided by arithmetic average



Cv < 0.5 Homogeneous
0.5 < Cv < 1.0 Heterogeneous
Cv > 1.0 Very Heterogeneous

Heterogeneity Workflow - Lorenz Plots and PLT

- The Modified Lorenz Plot and can be compared with the Spinner Survey (PLT)
- NB: To do this you need to rotate the axes of LP (porosity feet – when porosity is quite uniform – corresponds to feet/depth)
- MLP shows same inflow zones as PLT** – then it is the **matrix** that is flowing (crossflow or commingled?)
- MLP shows no correspondence with PLT** - then the reservoir might well be **fractured**
- NB: Fracture property information is seldom captured in the core plugs which are basis for Lorenz Plots

Step 5

Heterogeneity Workflow – Coefficient of Variation

- Look at the carbonate interval (usually a bed)
- Does it look uniform? YES**
- Collect some data (25 samples)
- Calculate Cv for porosity and permeability
- The porosity Cv is usually <0.5
- If the permeability Cv is < 0.5
- Homogeneous confirmed**
- Relax and use any average for the properties

Step 1

- Look at the carbonate interval (usually a bed)
- Does it look uniform? NO**
- Collect some data (100 samples)
- Calculate Cv for porosity and permeability
- The porosity Cv is usually <0.5 (but might be slightly higher)
- In carbonates the permeability Cv is likely > 1.0 (if between 1 and 0 – heterogeneous)
- Very Homogeneous confirmed**
- You cannot relax – averages all different – so you need to do more analysis

Step 2

- Look at the carbonate interval (usually a bed)
- Permeability Cv > 1.00 (Porosity Cv may be greater than 0.5)
- You have a real sampling challenge.**
- If Cv is close to 1:0 calculate $10Cv^2$
- This will given number of samples to estimate average permeability within +/- 20%
- Or you can collect some more samples and establish average +/-20% and reasonable Cv
- If Cv >> 1 you probably need to switch to **carbonate sampling criteria** $4Cv^2$ to allow you to establish average +/-50% (Cv might not be great!)

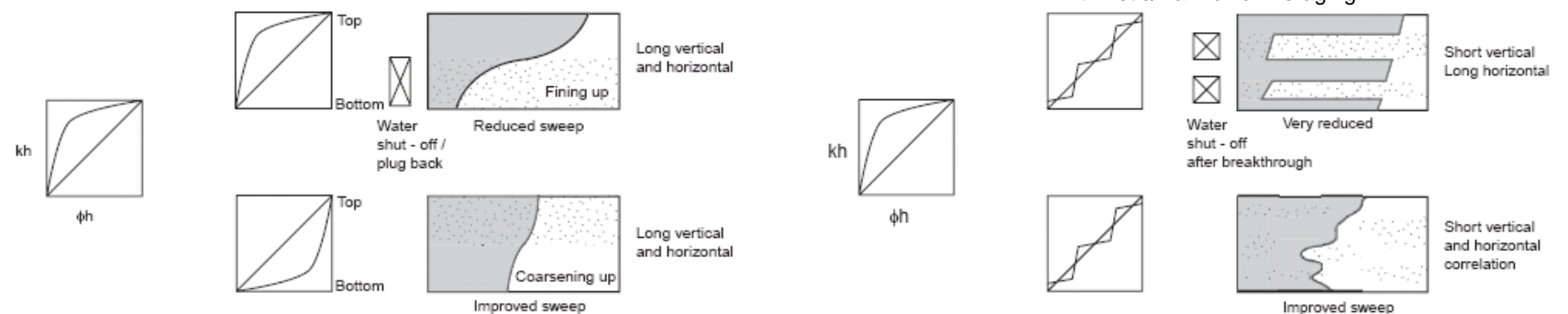
Step 3

Steps 1-3 allow you to get a handle on estimating average bulk permeabilities with some known degree of accuracy in carbonates

Steps 4-5 allow you to identify the spatial patterns in very heterogeneous carbonates and provide additional diagnostics (even whether the reservoir is fractured or not)

Heterogeneity Workflow – Lorenz Plots

- The Lorenz Plot and Modified Lorenz Plot are used together (NB: these are matrix property plots)



- Sometimes large scale natural ordering is seen – and sometimes there is small scale or no ordering**

NB: The semivariogram in the vertical direction can also help determine random vs ordered or repeating