Inferring Likely Fluid Movement from Outcrops – The Range of Interpretations*

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Abstract

One issue in reservoir development is the predictability of reservoir performance given the limited available data. It would be beneficial if we could view an outcrop and infer the likely dynamic behaviour in an analogous reservoir. In viewing outcrops therefore, we need to understand the complex interplay of how specific fluids interrogate the various heterogeneities; this can lead to a variety of interpretations. Previous work has shown that a variety of interpretations are available when viewing the same seismic section – this study proceeds along similar lines in the case of a rock outcrop. Within field simulation can enhance our ability to identify the key geological aspects affecting fluid flow.

Thirty-five Reservoir Engineers and Geoscientists, from different companies, were asked to view the outcrop at Tullig Point in south west Ireland. The outcrop is interpreted as a distributary channel or mouth bar succession that can be viewed both panoramically, from a neighbouring promontory, and also in detail through field glasses; thus, enabling geological interpretation. The group was divided into 7 teams; each team estimated the horizontal and vertical permeability. A 2-D grid was superimposed over a photograph of the outcrop, pseudo-logs of an injector and a producer well, and the fluid properties of the resident oil, gas as well as the water that was to be injected into the reservoir section. Each team interpreted the geology and estimated values for each node of the grid; these values were then used to simulate the recovery of oil, gas, and water-cut development using a black-oil simulator. The seven sets of results could then be compared and the performance pegged to the estimated permeability and hence back to the observations at the outcrop.

The simulation ran for one year and the recovered cumulative oil varied 3-fold (38 Mbbls to120 Mbbls), the time to 80% water cut ranging from 12 days to 131 days. The span of predicted performance was thought surprising, since the data set was possibly richer than is usual in the evaluation of reservoir performance for real reservoirs. It was concluded that both the geology and the fluid movement needed to be taken into account when considering the outcrop. Understanding how small variations in rock properties can profoundly influence fluid movement is enhanced with simulation allowing the prediction of the impact that the observed rock heterogeneities have on dynamic performance.

References Cited

Garland, C.R., P. Haughton, R.F. King, and T.P. Moulds, 1999, Capturing Reservoir Heterogeneity in a Sand-Rich Submarine Fan, Miller Field: Geological Society, London, Petroleum Geology Conference Series, v. 5, p. 1199-1208.

Smith P.J., and C.E. Brown, 1984, The Interpretation of Tracer Test Response from Heterogeneous Reservoirs: SPE Annual Technical Conference and Exhibition, 16-19 September, Houston, Texas, SPE 13262-MS, 19 p.

van Oort, B., 1988, Lesson Learnt in North Sea Oil Field Developments: Journal of Canadian Petroleum Technology, v. 27/6, Document PETSOC-88-06-11, 11 p.

Inferring Likely Fluid Movement from Outcrops – The Range of Interpretations

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Andy Woods (BPI Institute, Cambridge University)

Outline

- **Predictability**
- **Outcrop Grid Exercise**
- **Issues concerning using outcrop data**
- **Digitizing outcrops**
- **Describing the flow impact**

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Reservoir Performance Predictability

- Predicting reservoir performance accurately is important for development & management.
- If we can't predict accurately before production begins
  - ➢ We can't develop economically marginal fields
- If we can't predict accurately after production has started
  - ➢ We can't optimise recovery plan effectively
- Could viewing outcrops and inferring the likely dynamic behaviour in analogous reservoirs improve predictability?

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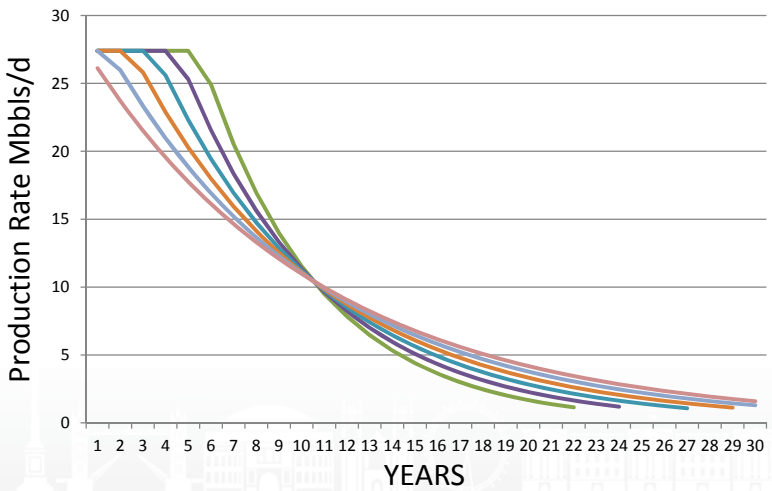
Impact of plateau length



For example in a 100 MMbbls field.

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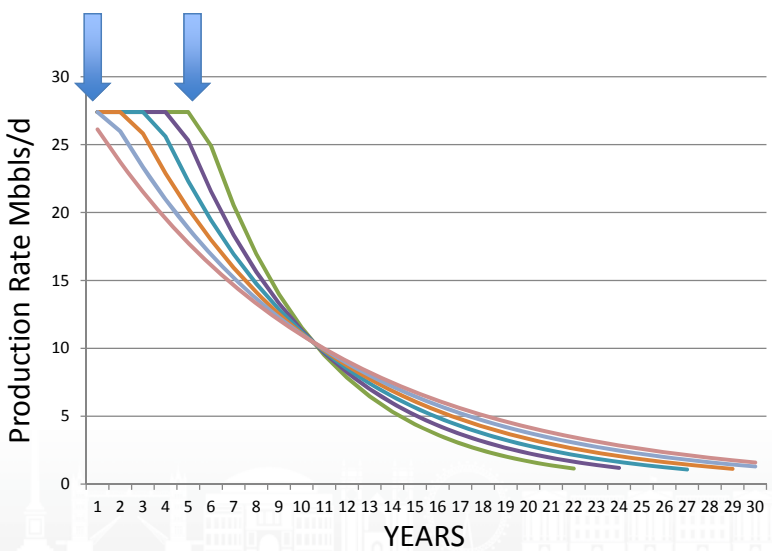
Impact of plateau length

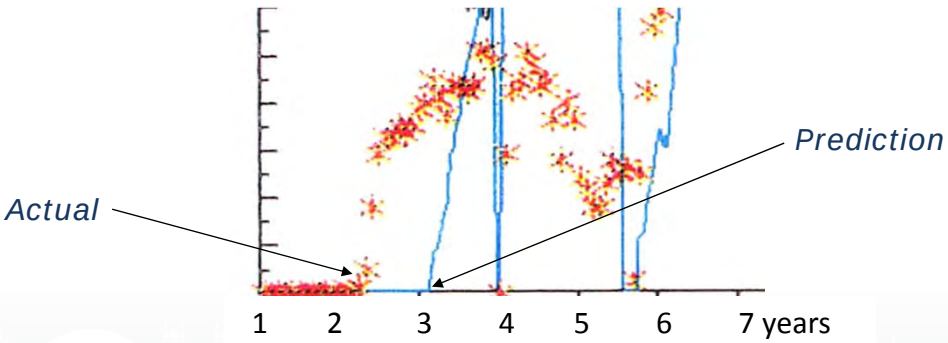


For example in a 100 MMbbls field
The reduction in plateau time results in a 15% reduction in value.

⟹ predicting the onset of water production in an oil field is therefore crucial.

Water cut prediction

Water breakthrough is very difficult to predict…



… breakthrough a year before prediction!

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Grid Exercise

Geologists have traditionally viewed outcrops to understand the depositional character, the 3 dimensional architecture and understand the potential of an analogous reservoir.

Tullig Point - S.W. Ireland – interpreted as a distributary channel sand-body.

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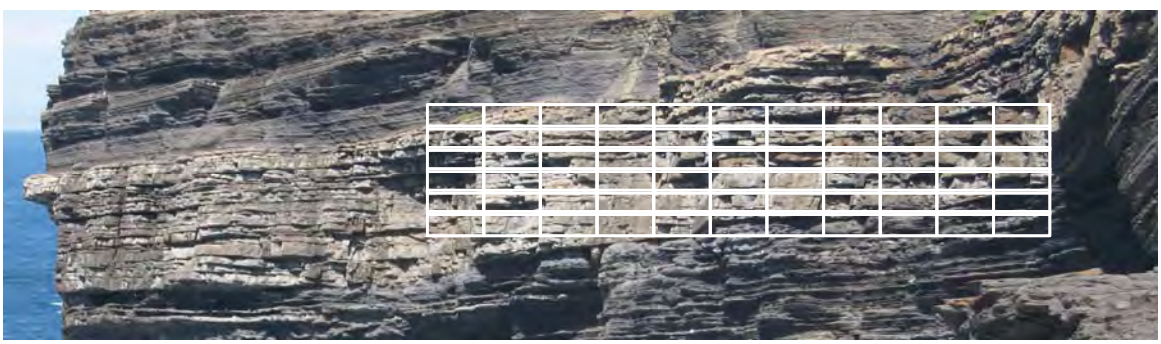
Grid Exercise

From a parallel promontory 7 groups of mostly engineers view the outcrop



With pseudo well and core data each group were asked to estimate K_h and K_v for each node in this grid – using their judgement, engineering knowledge and their understanding of fluid flow.

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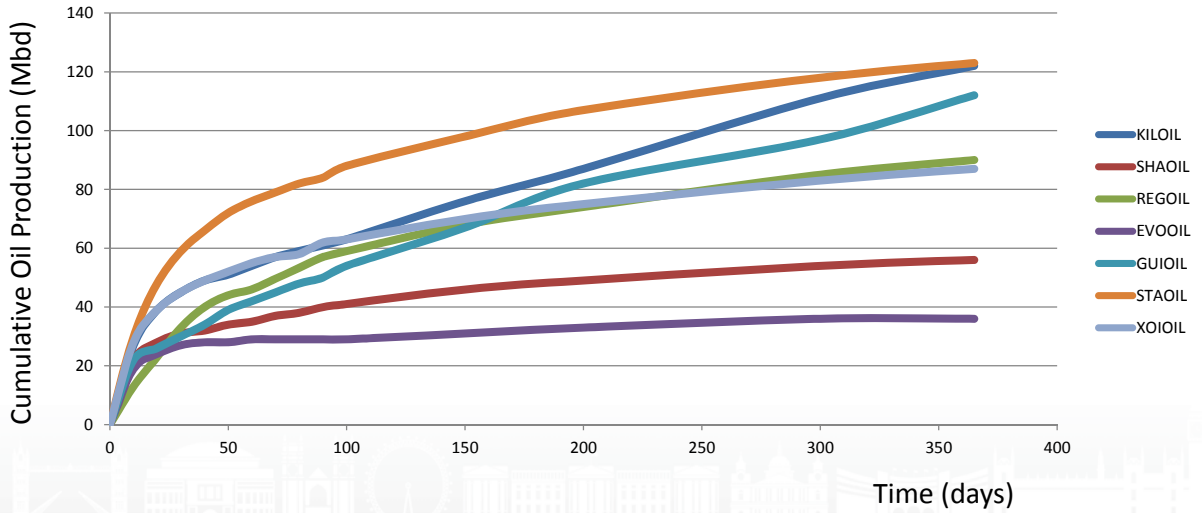
Predictions from 7 groups



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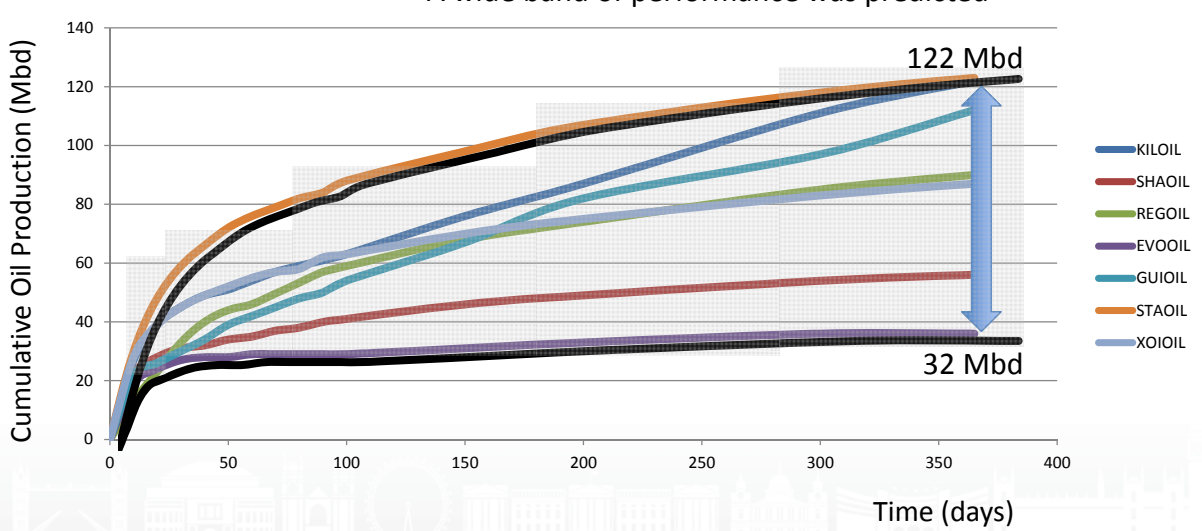
Predictions from 7 groups

A wide band of performance was predicted



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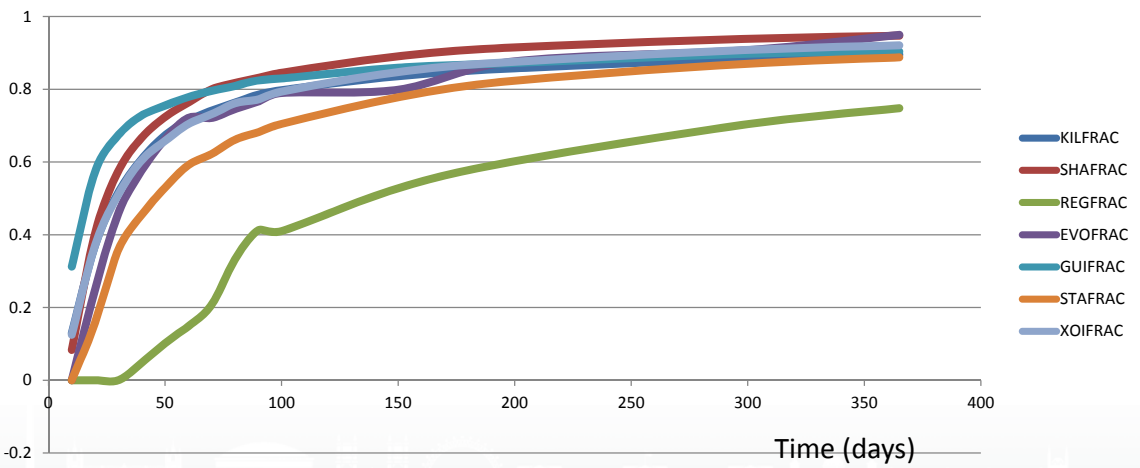
Water Oil Ratio (WOR) Curves



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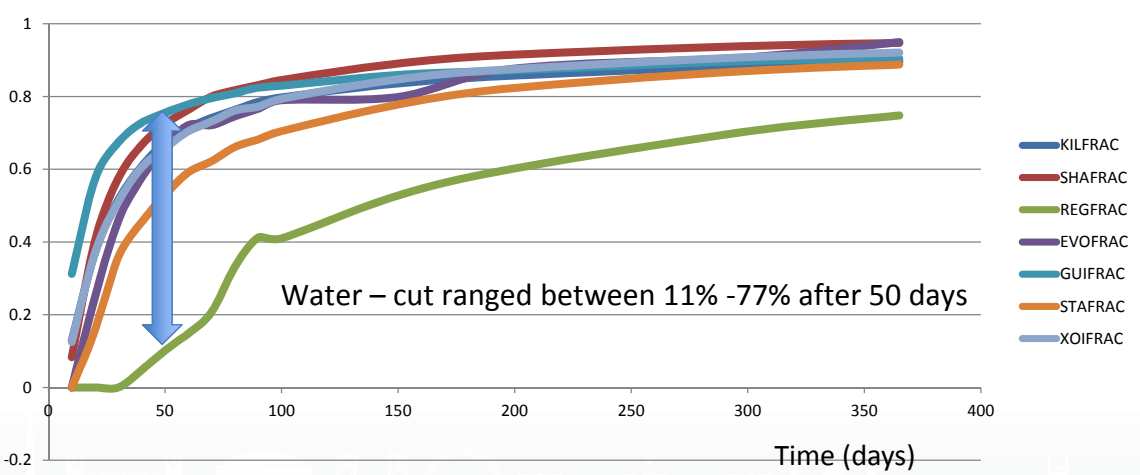

Outcrop Grid Exercise - Summary

- Predicting reservoir performance from viewing outcrops can lead to a wide variety of interpretations.
- Can we train ourselves to see what is important in the outcrop to fluid flow?
- Can we describe the flow impact of the rock outcrop adequately to improve our predictive models?
- Where could it go wrong?

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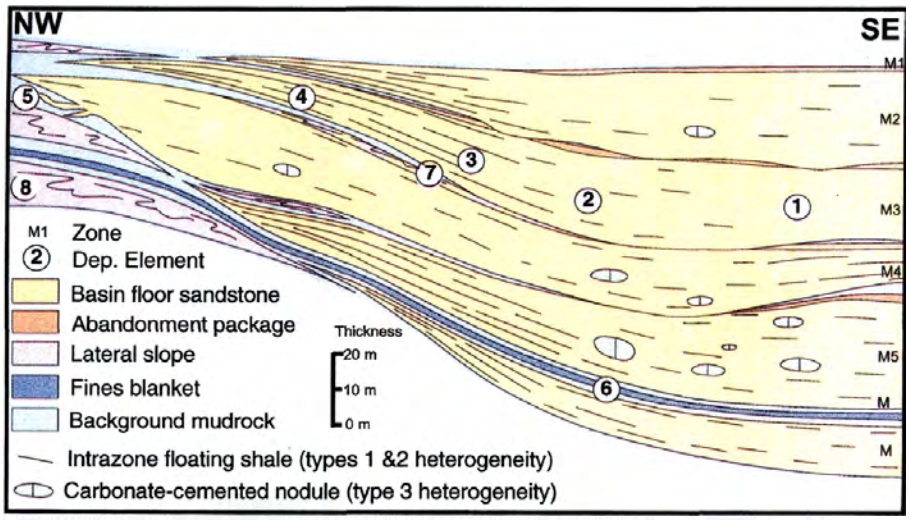
Where can it all go wrong?

1. Sometimes small features matter…



1999- GARLAND et al **Capturing reservoir heterogeneity in a sand-rich submarine fan, Miller Field**

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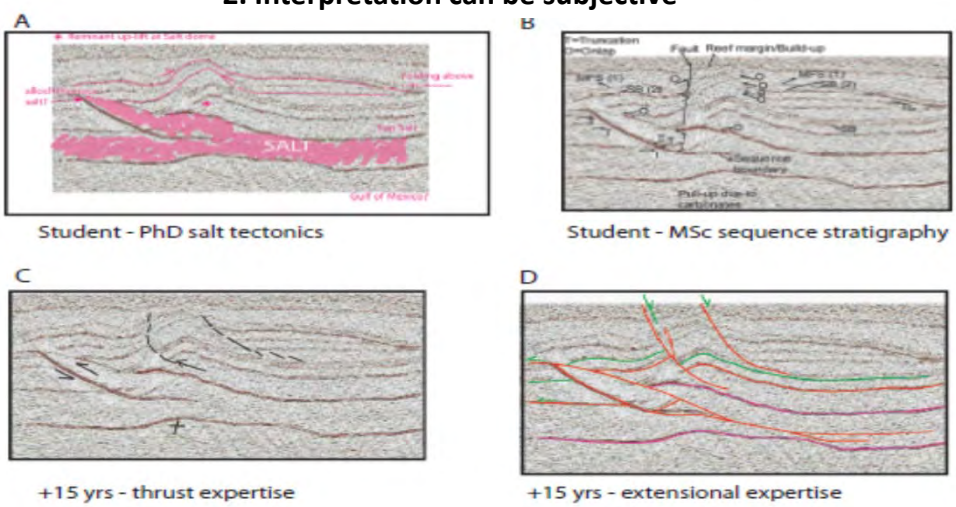
Where can it all go wrong?

2. Interpretation can be subjective

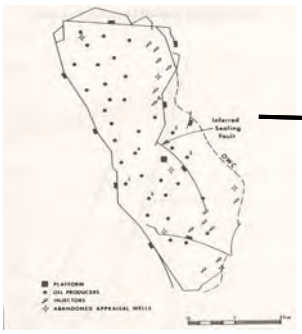


Bond et al, 2007

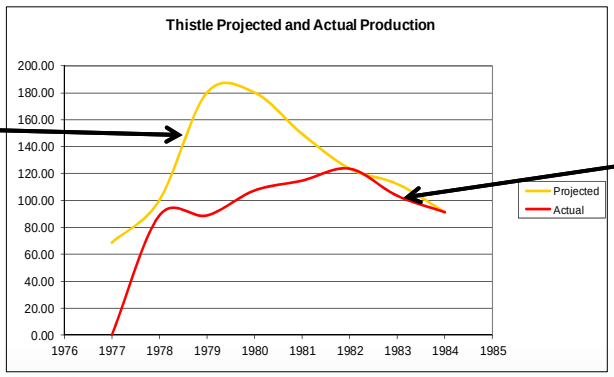
Where can it all go wrong?

3. We can miss important features altogether

Before Production



Major Faults only



After Production

A lot more Faulting seen on later seismic

1988 - B. van Oort Lesson learnt in North Sea Developments

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Digitized Outcrops

AAPG Short v2.mp4

With drone technology and digitizing algorithms the detailed geometries of the flow units can be estimated and then used to improve reservoir performance predictions.

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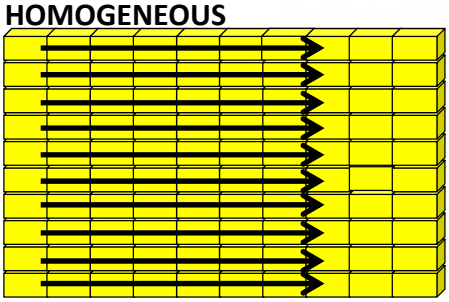
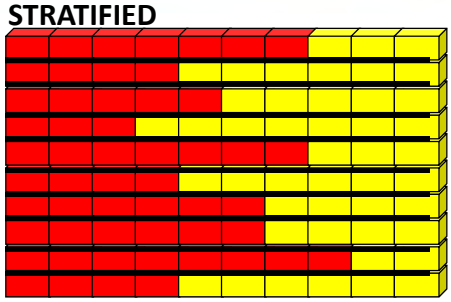
Describing - Reservoir Heterogeneity

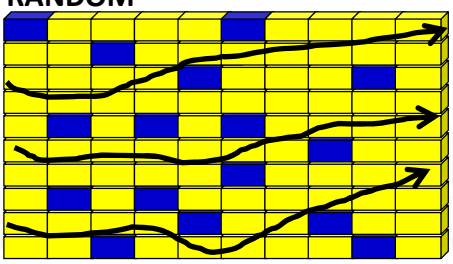
HOMOGENEOUS



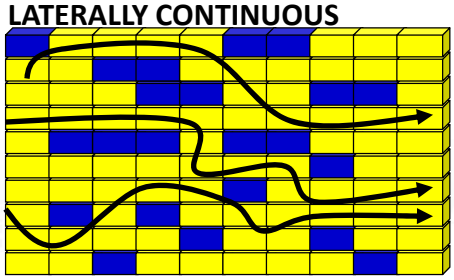
STRATIFIED



RANDOM



LATERALLY CONTINUOUS



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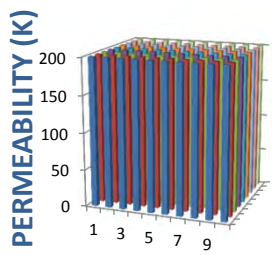
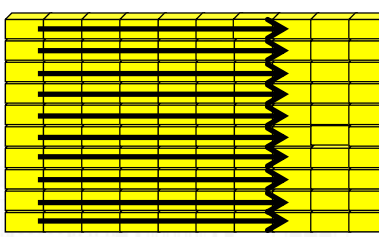
Homogeneous

Kilbaha Bay

2m

Sandstones deposited by turbidity currents in a deep-water channel.





Dispersion of the flood front caused only by rel perms effects

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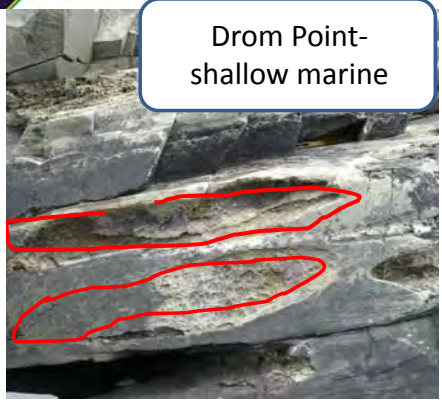
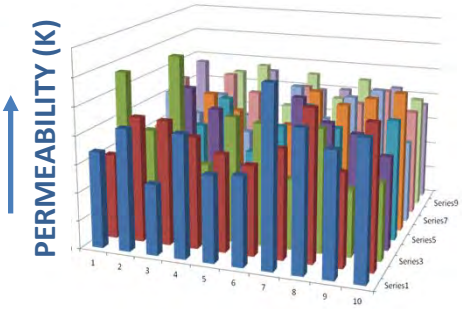
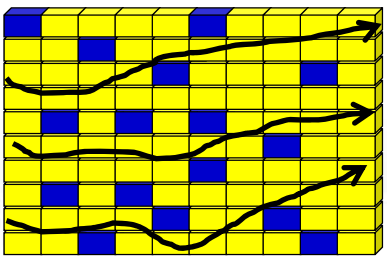
Random heterogeneity

Drom Point- shallow marine





Hummocky cross stratified sandstones in a shallow marine shore-face setting influenced by storm waves.



The larger the K variation The larger the dispersion

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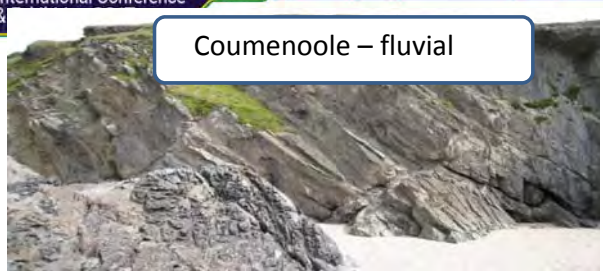
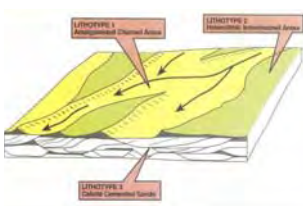
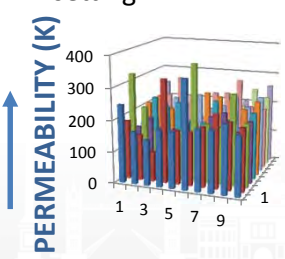
Laterally continuous heterogeneity

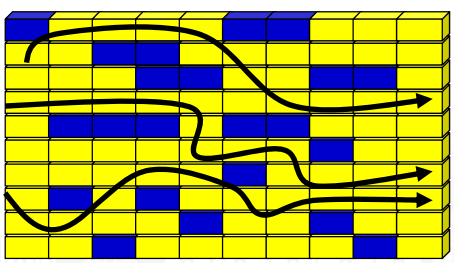
Coumenoole – fluvial





Sandstones deposited as bars in a braided river setting.





Cross-section is heterogeneous but not entirely random there is a predominant length scale length of variability **λ**

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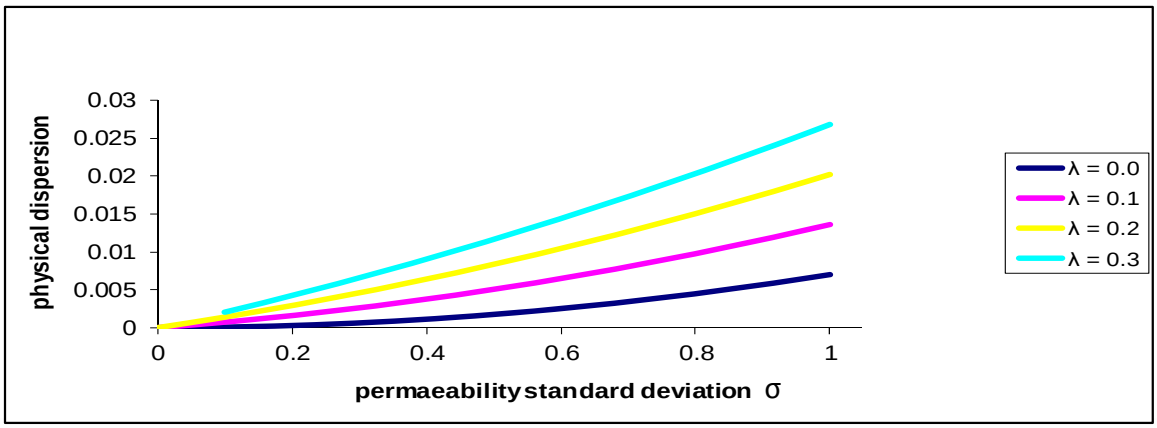
Laterally continuous heterogeneity



Smith & Brown, 1984 "… tracer response from heterogeneous reservoirs…"

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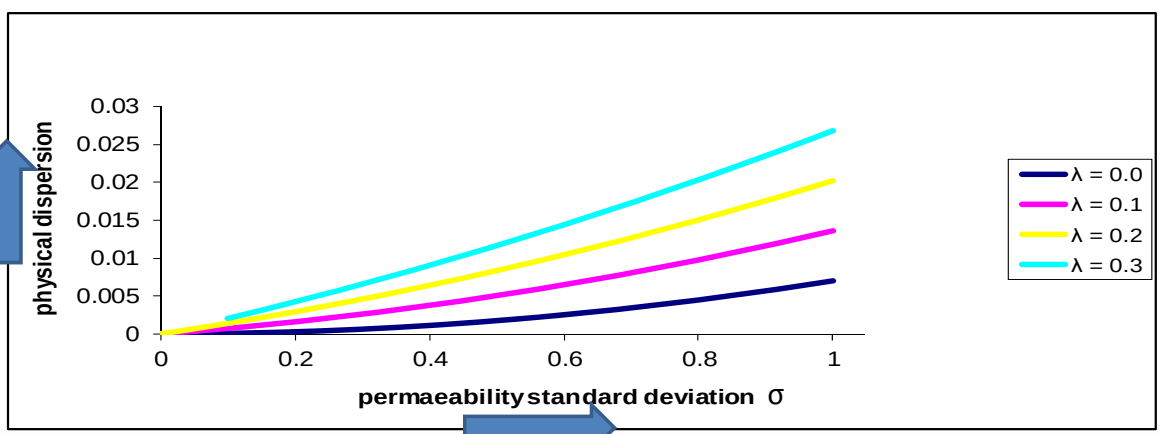
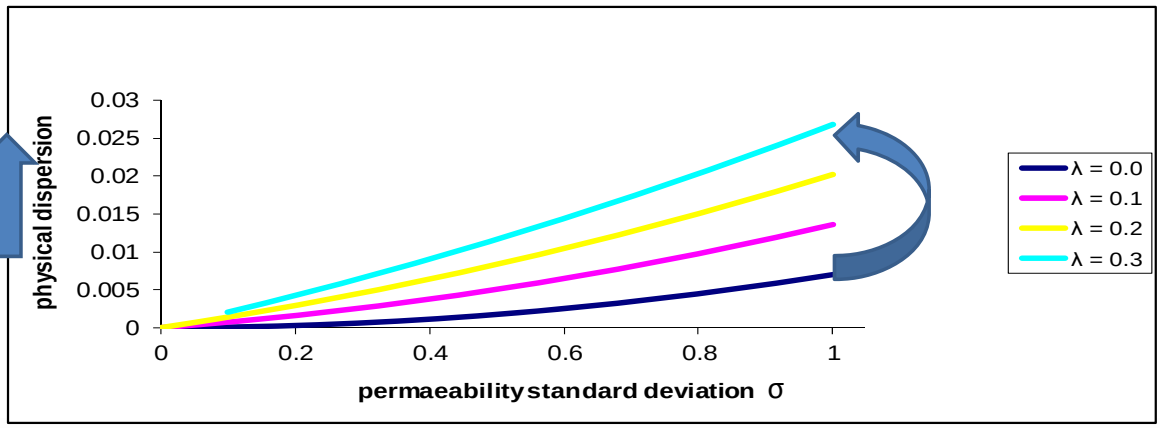
Laterally continuous heterogeneity



Permeability variability **σ** ↑

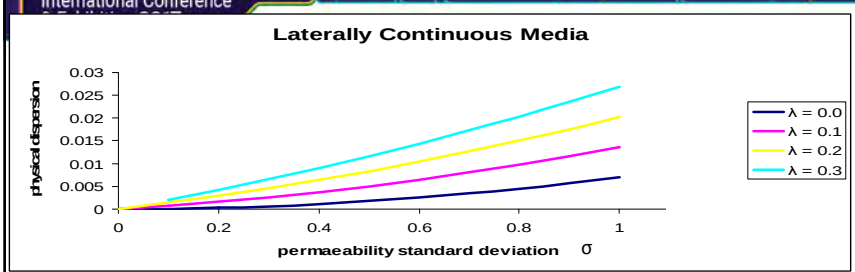
- MORE HETEROGENEITY
- MORE DISPERSION

Laterally continuous heterogeneity

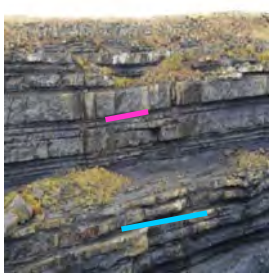


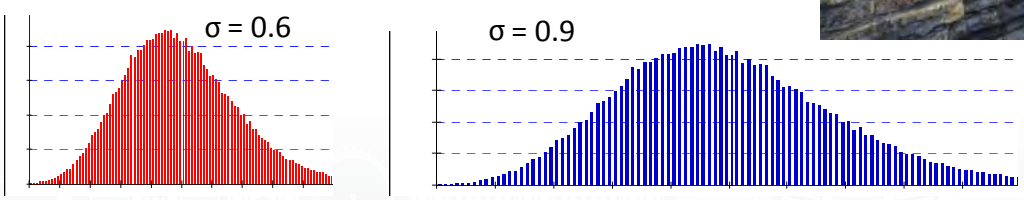
Scale length of variability **λ**↑ – THE MORE LATERAL CONTINUITY
– THE MORE DISPERSION

Integrating the data



Field Outcrop





Permeability Variability

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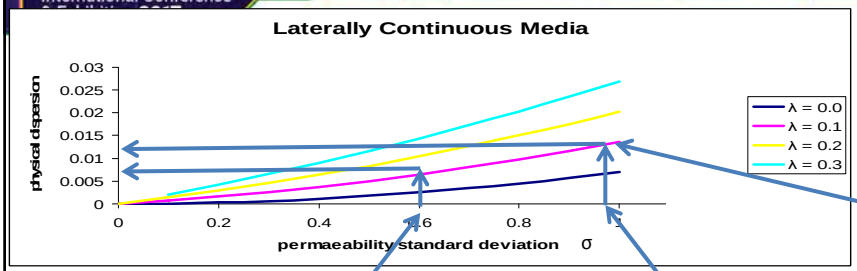
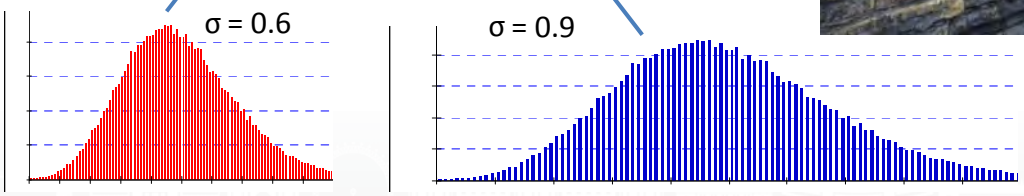
Integrating the data



Field Outcrop



Permeability Variability

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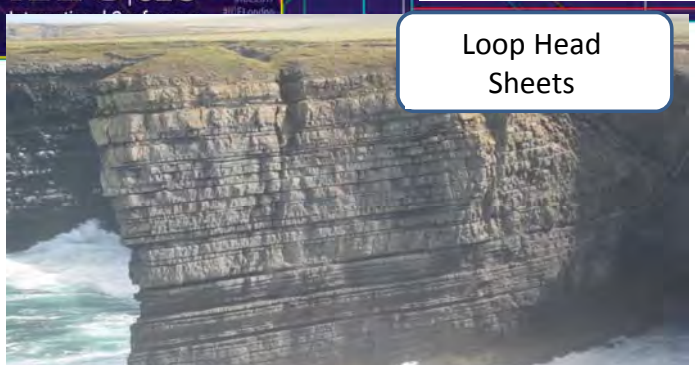
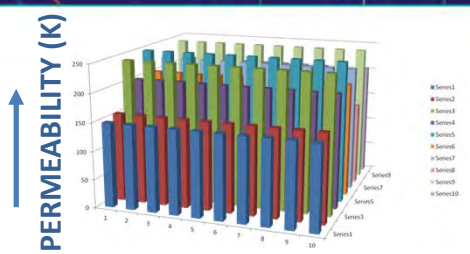
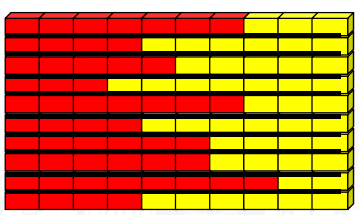
Stratified beds

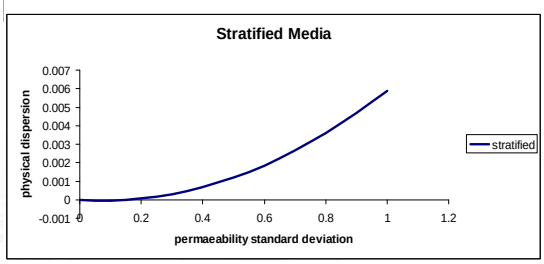


Loop Head Sheets



Sandstones deposited by turbidity currents in a distal fan lobe setting.





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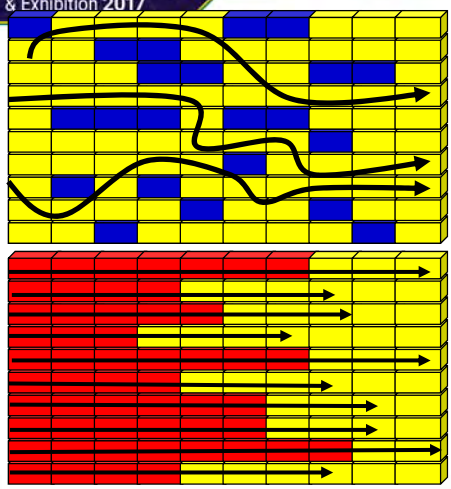
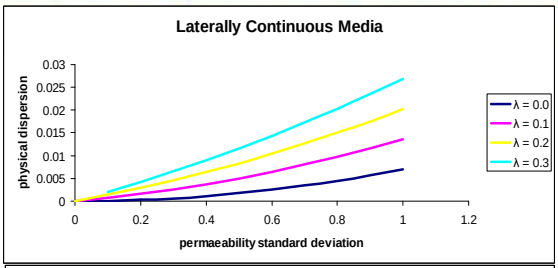
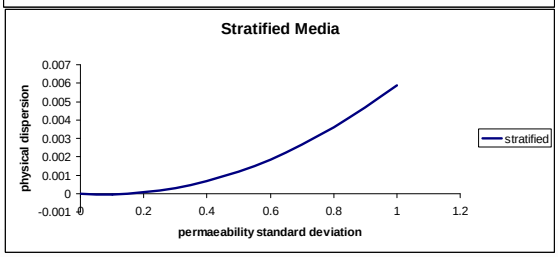
Equivalent Stratified Model







A stratified model that gives the same dispersion as a laterally continuous one and hence avoids Monte Carlo repetitive simulations

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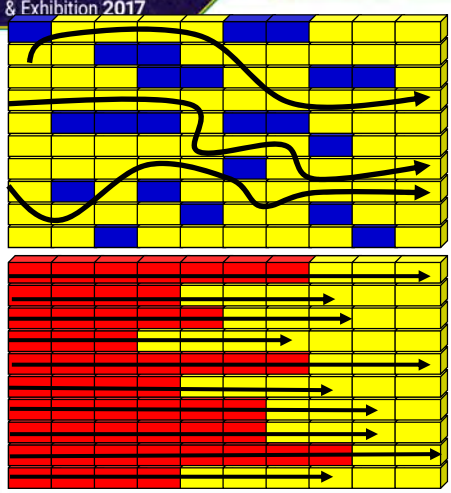
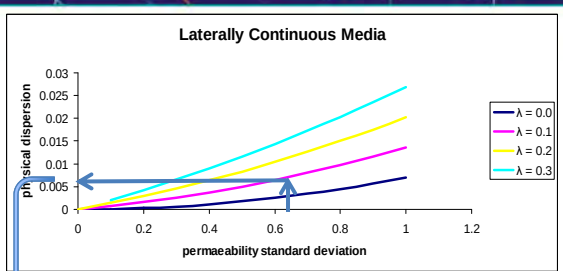
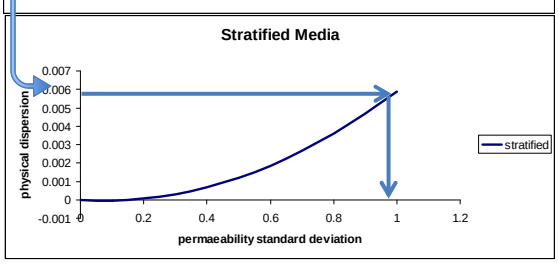
Equivalent Stratified Model







A stratified model that gives the same dispersion as a laterally continuous one and hence avoids Monte Carlo repetitive simulations

Conclusions

- Reservoir Prediction is important, particularly in periods of sustained low oil price.
- When viewing outcrops the complex interplay of how fluids interrogate the heterogeneities needs to be understood.
- Possibly outcrop mapping could improve performance prediction.
- A richer language to describe rock outcrops is needed.