AFES Seminar
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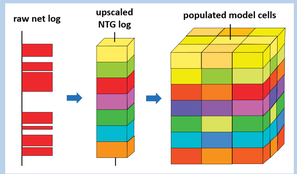
What do geomodellers do with net logs?

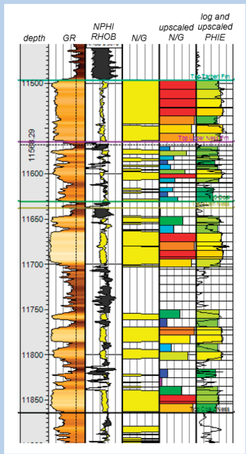
Claire.Imrie@lr.org
Moira.Belka@lr.org

Lloyd's Register

In 3D geocellular models, the Net to Gross ratio (NTG) defines the proportion of rock (represented as a grid cell) that is able to contain hydrocarbons and flow.

- In a basic scenario:
  - The geomodeller builds a 3D model containing a number of grid cells relating to the size and resolution of the model
  - The petrophysicist's net log is upscaled to the grid cells that the well passes through
  - The geomodeller then populates the model with NTG and other properties between the wells
- However, what geomodellers do with net logs depends on:
  - Geology of the reservoir: complexity/heterogeneity/architecture
  - How NTG is defined (which parameter cut offs are used, or by facies)
  - Fluid type – which may influence how the geology is captured and what the net reservoir cut offs are
  - Whether there are facies logs
  - Purpose of the model (see box below)
  - And finally, the best practices of the company or preferences of the geologist/ geomodeller and reservoir engineer

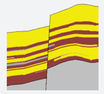




Geomodel purposes include:

Visualisation

- Model is used for sense checks, geological interpretation and comfort
- **NTG** distribution for visualisation of reservoir juxta-position across faults may be useful



- Sometimes there will be no need for **NTG**

Volumetrics

- **NTG** usually required as part of the STOIIP calculation (portion of reservoir that can contain flowing hydrocarbons)

STOIIP = GRV x NTG x net porosity x (1-Sw) x (1/Bo)

GIIP = GRV x NTG x net porosity x (1-Sw) x (1/Bg)

- Vary **NTG** as part of uncertainty analysis

Dynamic Simulation

- **NTG** distribution is usually preferred to represent what flows in the reservoir
- **NTG** modelling has the additional benefit of removing low permeability cells, which can increase the run time of dynamic simulations

Well Planning

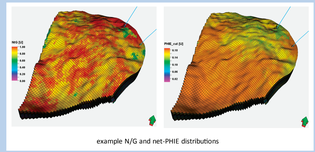
- Not likely to require **NTG** specifically for this, but may use a **NTG** distribution (e.g. based on seismic attributes) to indicate better net reservoir areas

Other
(eg. EOR, gas storage)

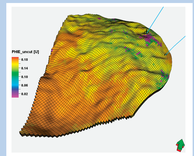
- **NTG** distribution will be necessary in EOR models to represent all features that influence fluid flow, such as flow barriers and thief zones
- This may require increased model resolution in the zone(s) of interest

Options for **treatment of the net log** (within or without a facies model) include:

1 **Model NTG, with net porosity and permeability**
- Remove (undefine) non-net parts of porosity and permeability from the wells logs, then upscale and model NTG, net-PHIE and net-perm
- NTG can be modelled like facies (discrete) or co-simulated (continuous) with porosity or permeability depending on the geological interpretation
- Pros: No low perms in model. Cons: 'hardwires' the cut-offs from the start of the modelling process which makes them harder to vary later on


example N/G and net-PHIE distributions

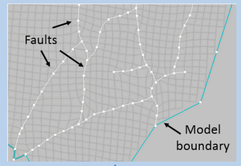
2 **Model gross porosity and permeability; then apply the NTG cut-off to the modelled grid cells:**
- Dependent on the geological architecture and what is actually contributing to 'net' vs 'non-net' rock (i.e. facies/diagenesis)
- Will generally suffice for volumetric range calculations and uncertainty analysis
- Pros: Volumetric sensitivity to cut-offs easily evaluated. Cons: Can place flow barriers randomly within the model, which cannot ever contribute to flow/pressure support (reservoir initially deemed non-net may flow at reduced pressure, although this may be more relevant for gas than oil)

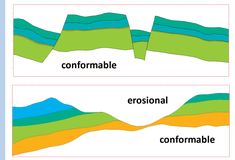

example PHIE distribution with N/G cut-off applied after modelling

3 **Do not use the Net Log at all: model gross properties only (porosity, permeability and Sw)**
- Could be the preferred option, especially if the model has sufficient vertical resolution, or the reservoir is homogeneous, or fluid is gas
- Pros: no need for NTG or cut-offs. Cons: all hydrocarbons included in volumetric calculations, therefore STOIIP/GIIP may be optimistic

Example workflow: building a geocellular model for volumetrics and dynamic simulation
Ultimately, the model should aim to capture the level of heterogeneity required for dynamic simulations

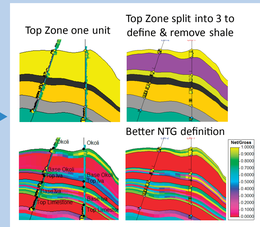
Model set up and framing
- **Collection and QC of data** (horizons, faults, well logs, fluid contacts, etc)
- **Analysis** of reports, literature and data to develop understanding of reservoir geology and vertical/lateral heterogeneity, and define conceptual geological model
- **Creation of net logs** from cut-offs and corresponding 'cut' PHIE and perm logs
- **Framing session** with team (modelling requirements and treatment of uncertainty)



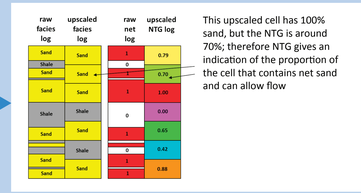


X-section view showing options for modelling horizons

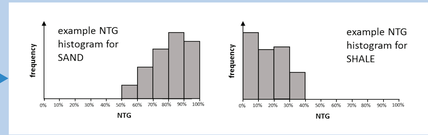
Structural modelling
- **The model grid is built** using top and base reservoir surfaces and incorporating faults
- **Internal zonation** can be done to further (vertically) subdivide the model
  - Zones can be useful for creating laterally continuously non-net features (flow barriers)
  - Defined using additional seismic surfaces and/or well correlation of facies or net logs
  - Different facies modelling approaches can be applied in different zones



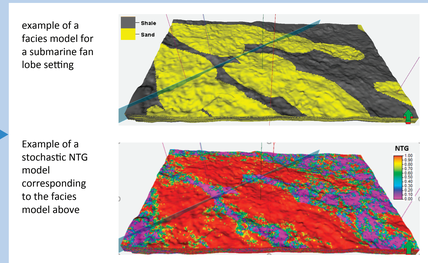
Layering and upscaling
- **Define the vertical resolution of the model** by inserting a number of layers within each zone (the more layers, the finer the vertical resolution)
  - The optimal vertical resolution depends on the vertical heterogeneity and it's importance with respect to the reservoir fluids to be simulated – can be assessed using variograms
  - We generally need to find a compromise between detail and simulation run time
- **Well logs are upscaled** to the penetrated grid cells
  - Arithmetically for NTG, net PHIE and net (horizontal) permeability
  - Using the 'most of' option for facies



Data analysis
- **The raw and upscaled well logs are analysed** for each model zone to provide:
  - Facies proportions and trends for each zone
  - Trends and distributions/histograms of NTG, net PHIE and net perm for each zone (and facies)
  - Geostatistical parameters describing lateral and vertical continuity for each zone (and facies)



Facies and property modelling
- **A facies model may be built** for predicting reservoir quality between the wells
  - Examples of depositional models that can control reservoir quality include estuarine settings, submarine fans, marine transgression, etc
- **The model is then populated with petrophysical properties** including NTG, net PHIE and net permeability
  - Stochastically or by interpolation for each zone/facies, guided by the data analysis
- **A saturation-height function is applied** to calculate initial water saturation



Volumetrics, uncertainty analysis and creating simulation grids
- **HIIP volumes are calculated**
- **Volumetric ranges** can be derived using multiple deterministic models or through a Monte Carlo analysis, or through a combination of both
  - Uncertainty in NTG can be derived from uncertainty in the cut-off values, and from the proportion of net sand in the reservoir
- **The model is adapted or upscaled (if necessary) to create a grid for dynamic simulation**

What do we want from petrophysicists?
- Discussion between the Petrophysicist, Geologist and Reservoir Engineer regarding cut-offs and representation/capture of NTG in the wells, static and dynamic models
- NTG log and how it is derived and a range of cut-offs or net logs for uncertainty analyses

Do we need to model 3D NTG?
- NTG: is it an out of date, traditional concept?
- NTG can be difficult to model in 3D in a meaningful way
- Should 3D NTG match petrophysical well averages? No (wells are unlikely to be completely representative of the reservoir and may be drilled in sweet spots)
- Could it be argued that STOIIP can include everything? The simulation model can define what will flow/is recoverable (however, RE's may prefer not to have low permeability/high Sw cells in the simulation grid)
- As with many aspects of reservoir geology, there is no one strategy to NTG modelling