Propagating RRT to the Log Domain

Energetic discussions were held which can be grouped under 6 major headings.

Definition of RRT

In order to focus the discussions we broadly define RRT in our context as a grouping of rocks in terms of their petrophysical properties of porosity, permeability, capillary pressure response and relative permeability. Since we are functioning in the log domain, only such grouping is considered as can be distinguished from log responses. However, in order to assist the geologist in mapping the RRT across the reservoir, the groupings must be related to the geological processes. This may not always be feasible or unique, but an attempt must be made.

Do logs represent RRT?

In this section the discussion focuses on whether log signature variations are representative of RRT changes. Logs were grouped into two categories – standard (or conventional) and non-standard (or advanced).

Standard logs that provide insight to RRT in carbonates are:

a) GR and Spectral GR. If the latter is available the CGR (=SGR – U) should be preferred
b) SP – this was not believed to add insight to RRT in carbonate reservoirs
c) Neutron-Density
d) PEF – provided it is not affected by barite
e) Compressional Sonic – provides insight to secondary porosity
f) Resistivity – when used as activity curves highlights vuggy intervals
g) Dipmeter – activity curves provide insight to vuggy or heterogeneous intervals

Non-standard logs that can be used for input to RRT are:

a) Borehole Images – electrical or acoustic
b) NMR
c) Capture or Inelastic Spectroscopy
d) Dielectric logs
e) Production logs

Input to Carbonate RRT from specific logs or log suites

Standard logs can be used in carbonates for simple rock typing.

a) They provide reasonably good evaluation of mineralogy, except if dispersed anhydrite, clay or siderite is present

b) Total porosity is simple to evaluate if no complex minerals are present, but they provide no insight to pore types. This is essential for RRT in carbonates
c) A secondary porosity index (SPI) can be obtained by comparing neutron-density to sonic porosity. SPI = PHI_nd – PHI_sonic
d) While tar mats can be identified, quantification of bitumen volume is not possible
e) Vertical resolution is usually not better than 2 ft
    a. This is a problem in laminated reservoirs
    b. And in the presence of Super-K streaks
f) Due to high typical logging speeds, the measurement precision may be poor
g) Combining several standard logs in a pattern recognition algorithm (PCA, Neural Network, MDHistograms, etc.) is a good way to achieve better grouping for RRT

Non-Standard logs provide the best input to carbonate RRT

a) These logs usually have very good vertical and azimuthal resolution. This is important to capture the heterogeneity present in many carbonate reservoirs
b) NMR, borehole image and acoustic logs provide input to pore types or partitions. These pore types have been shown to be related to the Dunham rock fabric classification
c) Good permeability estimation is possible from porosity partitions. However, it is recommended to use core data, formation tester or production log based permeability to calibrate/validate the estimate from the partitions.
d) Borehole images can be very effective in capturing vertical and azimuthal heterogeneity in carbonate reservoirs and recent work shows this can be used to generate more representative Pc and Kr curves. This should help RRT estimation.

Core-Log Integration

Use of core data is essential to guide log-derived RRT. Cores provide important characterization of the rock matrix. Typical core plug measurements do not capture the effect of fractures. It is very important to carefully QC the core analysis in terms of sample preparation and measurement protocols and results. Else the core data might become misleading. Sometimes the best rock type is the vuggiest and there is very poor to no recovery on core. This must be recognized in order to avoid bias in the core calibration.

Since pore typing from logs is an important input to RRT, these must be calibrated/validated with core. Simple RCA and K-phi plots are not useful. We need MICP and Thin Sections for this.

FRF measurements on core provide Archie cementation exponent, which can provide valuable insight to RRT.

Core NMR is very useful to calibrate/validate log NMR interpretations; however, in carbonates it is very important that the lab NMR measurement is performed at reservoir conditions. This is because of a strong temperature effect on the NMR properties. NMR measurement on the fluids is also helpful to improve the interpretation.

Acceptable accuracy of RRT estimates

It is important to recognize that 100% accuracy is not deliverable from log-derived RRT. So what is acceptable accuracy? The group pointed out that it is more important to identify the best RRT since this will impact the reservoir performance the most. However, we need to keep the storage in mind. Poorer rock types may contribute more to storage. The Stratified Modified Lorenz plot is very useful for this.

If the estimate is off by one rock type (in terms of rock quality), this is acceptable.

Some pointed out that it is equally important to identify the worst rock types in terms of impact on reservoir management decisions.

It was generally felt that less than 50% - 60% match to core was unacceptable. The exact threshold will depend on the level of heterogeneity in the reservoir.

Use of Dynamic Data

Finally, it is very important to relate the RRT to the dynamic data and to use the dynamic data (production data) to validate/calibrate the estimates from logs. There were several good talks in the technical sessions which showed the link between the RRT and the dynamic performance of the field.

Take away points:

a) Log-based RRT crucial for reservoir simulation and management
b) Advanced logs – NMR, image, acoustics – essential for proper RRT in carbonates
c) Important to relate to core for proper calibration
d) Field dynamic data – production tests and history – should be related to RRT