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Optimising subsurface characterisation from core and logs: applications for the deep-sea frontier

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Downhole logging measurements provide data from strata beneath the seafloor and are the only continuous source of in situ information about the physical and chemical properties of rocks (or sediments), including fluids in the pore space. Routinely measured during industry and scientific (ODP/IODP) drilling, log data complements core observations and measurements (e.g. lithology, mineralogy, fabric, chemical and physical properties) and when integrated can be used to address key geological questions. Integration of core and log data are effective in understanding how the underlying geology controls the petrophysical properties, the spatial and temporal relationships in palaeoclimate studies and the nature of fluid flow within the Earth's crust, and estimating the abundance and distribution of hydrates beneath the sea-floor.

Using examples from hydrocarbon reservoir sandstones, detailed core-based sedimentological facies schemes compared with wireline log data demonstrate links between sedimentological facies and groupings based on petrophysical characteristics including neutron and density responses. In active tectonic settings, e.g. within an accretionary prism, characterizing physical properties and identifying boundaries contributes to understanding their recent movement. Analysing logging-while-drilling data (IODP Expedition 314) using a statistical approach (iterative nonhierarchical cluster analysis; INCA) accurately defines lithological and structural boundaries, enabling a quantitative definition of sediments from the slope and from within the accretionary prism. Core-calibrated interpretations of log responses enable extrapolation of sedimentological interpretations to poor core recovery zones or to holes where coring did not take place.

In palaeoclimate studies, accurate depths to recovered core are essential for providing a robust framework for dating key events, and this is crucial where core recovery is incomplete or recovered core may have expanded non-linearly. Core-log comparison can establish a true depth framework, for example the visual correlation of core and with high resolution optical and acoustic images of the borehole wall in ancient coral reefs, provides the spatial relationship for age dates used to establish the course of postglacial sea-level rise (IODP Expedition 310).

Carbonate hydrocarbon reservoirs are complex because intrinsic heterogeneities occur at many scales of observation and measurement. Heterogeneity in carbonates can be attributed to variable lithology, chemistry/mineralogy, pore types, pore connectivity, and sedimentary facies. Intrinsic complexities can be related to geological processes controlling carbonate deposition and changes during subsequent diagenesis. 'Heterogeneity' is rarely defined or numerically quantified but statistical heterogeneity measures derived from wireline log data show a strong relationship to underlying geological heterogeneities in carbonate facies, clay content and porosity, and these zones of heterogeneity show strong correlation to fluid flow zones. This numerical heterogeneity can be related to reservoir quality indicators and geology.

The physical and chemical processes involved in hydrate formation are key to unlocking the role hydrates play in sea-floor stability, climate, and future energy supply. This huge methane reservoir is in constant flux, absorbing gas from below, releasing gas above, and continually equilibrating to changes in pressure, temperature and geochemical regimes. Implications of this vast and dynamic, methane reservoir on the global carbon cycle, long-term climate, seafloor stability, and global economics and energy policy, are only now being widely investigated. Evaluating hydrate accumulation can be undertaken from core and log data, and tied to seismic reflection data. Hydrate distribution is characterised from downhole images and tied back to core measurements (ODP Expedition 204).

These industry and academic studies demonstrate how integrating geological and petrophysical data, from both core and downhole data, can have a significant impact on our understanding, and how techniques developed in industry can be used to support exploration of the deep-sea frontier.