High-resolution core-log integration: Approaching the centimeter scale

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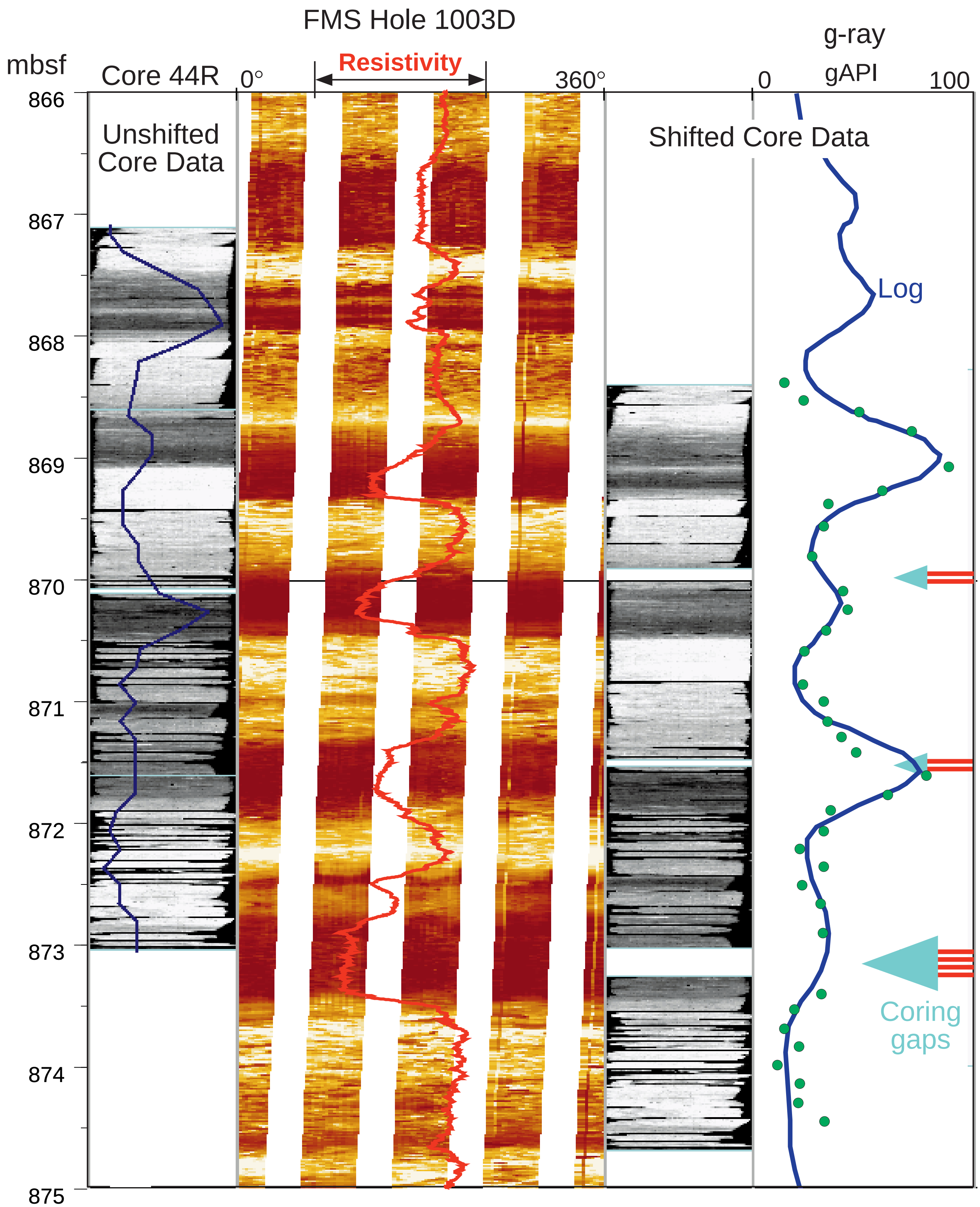
Geophysical well logs and cores are routinely acquired in nearly all ODP holes. While cores provide unique information on the biological, physical and chemical characteristics of the rocks drilled, well logs can provide unique data on the in-situ physical and chemical properties of the formation. Combining the two data sets can significantly augment the characterization of a drill site, because the in-situ measurements are acquired continuously at a high sampling frequency (typically 6 in., but as low as 0.1 in. depending on the measurement). To take full advantage of the complementary data sets it is necessary to precisely depth-match core and log measurements.

These middle Miocene carbonates from the Great Bahama Bank display cyclic alternation of light and dark sediment layers. The light intervals (higher electrical resistivity) represent well cemented carbonates primarily of shallow water origin. The dark intervals (lower resistivity) represent less lithified, intensely burrowed sediments with abundant planktonic foraminifers and minor amounts of organic carbon and clay (5–7%). The cyclic sedimentation is a result of changes in sea-level and associated changes in productivity of shallow water carbonates on the Great Bahama Bank and occurs at a periodicity of about 20,000 years.

The illustration is an example of precise core-depth matching using two different visual correlation techniques: 1) scanned core photographs versus Formation MicroScanner (FMS) micro-resistivity images of the borehole wall, and 2) natural gamma-ray profiles measured on core versus downhole gamma-ray. The image correlation is based on different types of measurements, i.e., borehole wall resistivity measured in the FMS log versus light reflectance measured in the core photograph. The excellent correlation in these carbonates indicates that electrical resistivity (a measure of fluid content and porosity) and color are intrinsically related. The gamma-ray data correlation is based on the same physical measurement (natural radioactivity) and although they are of lower vertical resolution, they help eliminate uncertainties in the correlation.

The high-resolution core-log depth matching techniques offer great potential for a number of studies. Core tops often are located at a position lower than that assumed during core curation, indicating that the drilling process washes sediment out before it enters the core barrel. In formations where soft and hard sediment layers alternate such as in these carbonates, the softer material (darker layers) often is not fully recovered, leading to gaps within the core. This precise positioning of core pieces is critical for the determination of sedimentation rates, for the interpretation of depositional history and for the correlation with other data such as adjacent drill holes or seismic reflection profiles. Core-log integration studies can benefit from the availability of the very high vertical resolution of the FMS log (~1 cm). The red curve superposed on the borehole image is the average resistivity measured by the 64 buttons of the FMS tool. The fine detail provided by this log can be used as a proxy for sedimentary cycle analyses, even where sedimentation rates are very low, or to investigate sub-Milankovitch periodicities. In addition, integration and calibration of the high-resolution resistivity curve against other logs and core measurements can provide detailed information on the physical properties of the formation that could not be obtained by standard methods of drilling and core analysis.



Example of high-resolution depth-matching of core data with respect to well logs of the middle Miocene carbonates from the Great Bahama Bank (ODP Leg 166). A high degree of accuracy can be achieved in the depth matching by using both images (core and FMS) and logs (gamma ray). On the left an image of the core and natural gamma-ray measurements are shown at their original, curatorial depths. The FMS image for that interval is shown in the second panel, together with the average value of the 64 FMS-button resistivity (red curve). The FMS resistivity is calibrated with respect to another resistivity curve (spherically-focussed log), and the scale ranges from 0.75 to 3 Ohm-m. The third panel shows the shifted core images, with the corresponding gamma-ray measurements (green dots) shown on the fourth panel together with the downhole gamma-ray log (HNGS, blue curve). This example demonstrates coring gaps between the recovered pieces, particularly within the darker, low resistivity/high gamma-ray intervals.