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The Value of Core Description in Characterizing Coalbed Methane Reservoirs

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Core descriptions are generally undervalued in characterizing coalbed methane reservoirs. Many operators make only brief descriptions of the coals before placing them in desorption canisters. Once desorbed, the coals are crushed for laboratory analyses, eliminating the chance to describe them in the future.

Coal descriptions are valuable for a number of reasons. First, they can be used to help predict the relative productivity of different coal intervals. Parameters such as brightness, cleat spacing, and cleat-filling material can be related to gas content, storage capacity and permeability. Second, core descriptions are a valuable tool for integrating and quality checking measured parameters such as bulk density, ash content, and maceral composition. Third, when coal descriptions are combined with descriptions of interbedded rocks, they can be used to interpret the depositional environment. This has a direct bearing on the orientation, geometry, and continuity of the coal beds.

Coal core descriptions should capture numerous criteria, including coal lithotypes, cleat characteristics, and interbedded lithologies (Table 1). This normally requires a detailed examination of the core after desorption. A useful technique involves slabbing the core and crushing one-half of it for proximate analysis and isotherm measurements. The other half can be visually described, petrographically examined, and preserved for future analyses.

Coal core descriptions provide much more detail then density logs. Figure 1 shows a comparison between density log values sampled every 0.5 feet and a high-resolution CT density scan which measures variations in x-ray attenuation (x-ray density) in core. The CT scan shows several low density, vitrinite-rich coals in a cored interval dominated by higher-density, ash-rich coals. These thin coals would be captured in a core description. However, the bulk density log is unable to resolve them, and instead indicates that the interval becomes progressively more ash-rich with depth.

One of the key characteristics to capture in a core description is the brightness of the coal, which corresponds to the amount of vitrinite. Vitrinite-rich coals are typically well-cleated and permeable with a large gas storage potential. In an example from the San Juan Basin (Figure 2) core descriptions from seven wells show a progressive decrease in the amount of bright coals in a west to east direction (Figure 3). This trend is mimicked by the density log data, which shows a progressive decrease in the percentage of low density intervals from west to east (Figure 4). Most importantly, well test permeabilities in this example decrease from west to east, (Figure 5), indicating a link between the amount of bright, low-density coal and well productivity.

The coals in the San Juan Basin example are composed primarily of vitrinite and mineral matter. In other basins, the coals may contain a substantial amount of inertinite and exinite macerals. Density logs are not useful in distinguishing between maceral types because all three have a similar density. Figure 6 is a plot of bulk density vs. gas content for coal canister samples from the Hedong Coal Basin of China. The overall character of the plot shows that gas content increases as bulk density decreases, corresponding to a decrease in the percentage of mineral matter.

The wide range in gas values (90 to 260 scf/ton) below 1.50 g/cc can be related to a wide variation in maceral composition. Petrographic work shows that the higher gas contents are associated with more vitrinite-rich coals (Figure 7). In addition, the symbol legend on Figures 6 and 7 both indicate that lower density, more vitrinite-rich cores tend to be better cleated. This work suggests that brighter, better-cleated, more vitrinite-rich coal seams in the Hedong Basin have higher storage capacities, gas contents, and permeabilities. These conclusions are supported by well test permeabilities and well performance, which are greatest in Seam 8 (Figure 8).

Although many operators choose not to core the rock intervals between coal seams, there are many reasons to do so. Carbonaceous shales, sandstones, and carbonates can all be important sources of supplemental gas. Open fractures, as indicated by broken core with mineral crystals or bitumen on fracture faces, may be high-volume sources of water and gas production. The recognition of sequence boundaries and flooding surfaces are critical for establishing a useful correlation framework.

Figure 9 contains stratigraphic columns generated from core descriptions for the Taiyuan and Shanxi Formations in a Hedong Coal Basin well. The Taiyuan Formation in composed of thick, argillaceous, shallow marine limestones containing a large number of calcite-filled fractures. The absence of open-fracture indicators is consistent with low well test permeabilities in these carbonates. The coal seams interbedded with these limestones are thick, vitrinite-rich, and interpreted as back-barrier lagoonal coals.

The overlying Shanxi Formation contains thinner coals of poorer quality. These coals are interbedded with low permeability (< 0.1 md) distributary channel and crevasse splay sandstones. The sharp, scoured bases of the channel sandstones indicate that these are likely to erode underlying coalbeds, creating lateral discontinuities. This is substantiated by cross-sections indicating that Shanxi Formation coal seams are less continuous than the deeper lagoonal coals of the Taiyuan Formation (Figure 10). As a result, the Shanxi coals will require more wells and a closer well spacing than the Taiyuan coals.

External character
- Thickness
- Appearance (massive, fibrous, friable, sucrosic, fresh, weathered, oxidized)
- Sheared (distorted or disturbed cleating, numerous slickensides)
- Cannel (smooth, shiny, massive, conchoidal fracture, dense)
- Bony (compact with a high ash content)

Lithotypes present and approximate percentage of each
- Vitrain (black with brilliant, vitreous luster)
- Clarain (semi-bright with silky luster)
- Durain (gray-brown with a dull luster)
- Fusain (charcoal appearance)

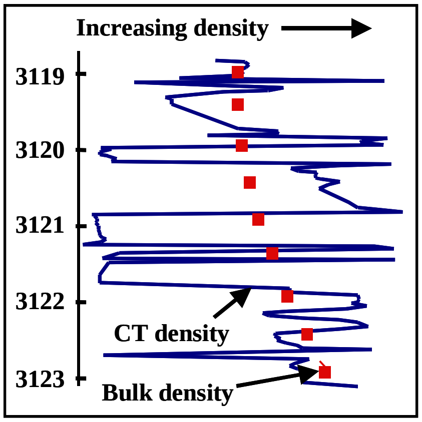
Brightness and banding
- Bright (less than 10% dull laminae)
- Bright banded (10-40% dull laminae)
- Banded (dull and bright laminae in subequal proportions)
- Dull banded (10-40% bright laminae)
- Dull (less than 10% bright laminae)
- Band character (continuous, discontinuous, lens-shaped)
- Band thickness: Thin (0.5-2mm), medium (2-5mm), thick (5-50mm), v thick (> 50mm)

Cleating
- Development: poorly to well-developed, continuous to discontinuous, incipient
- Distribution: regular or irregularly distributed, face cleats only or face + butt cleats
- Characteristics: cleat spacing, height, curvature, orientation relative to bedding
- Characteristics of other fractures, faults, or joints
- Strike and dip of cleats and other fractures if core is oriented
- Orientation of other fractures relative to cleats (normal, oblique, sub-parallel)
- Presence of stylolites or slickensides

Accessories
- Lenses or partings of mudstone, siltstone, sandstone, or carbonate within the coal seam
- Minerals: Mica, pyrite, limonite, siderite, gypsum, sulfur, calcite
- Distribution of minerals (disseminated, nodules, lenses, cleat lining or filling)
- Plant material: Wood, stems, rooting, plant impression fossils, comminuted plant material

Adjacent lithologies and contacts
- Contacts between coals and adjacent lithologies (sharp, scoured, gradational)
- Presence of seat earths beneath the coals
- Tonsteins : Color, mineralogy, log response (excellent chronostratigraphic horizons)
- Paleosols (burrowing, rooting, blocky fracture, oxidation)
- Detailed descriptions of rocks between the coal seams

Table 1: Summary of critical components to capture in coal description work



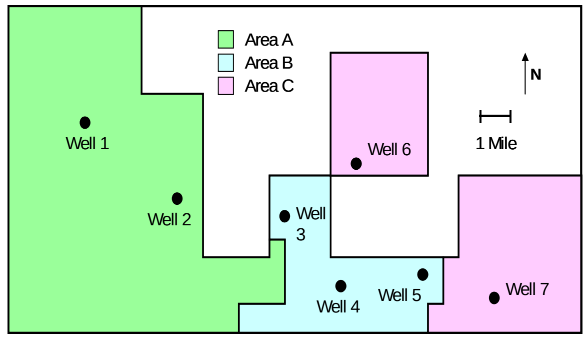
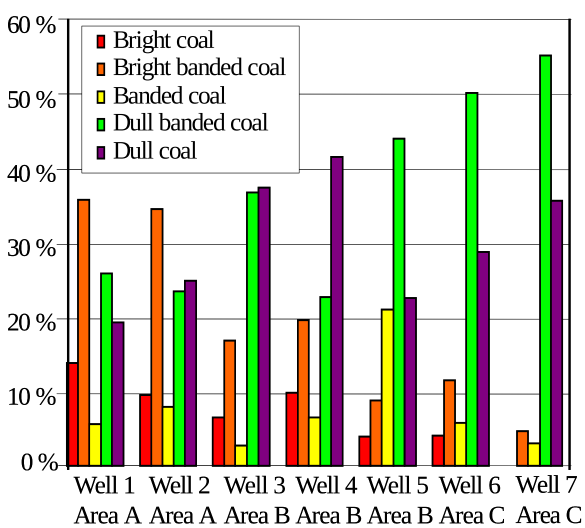
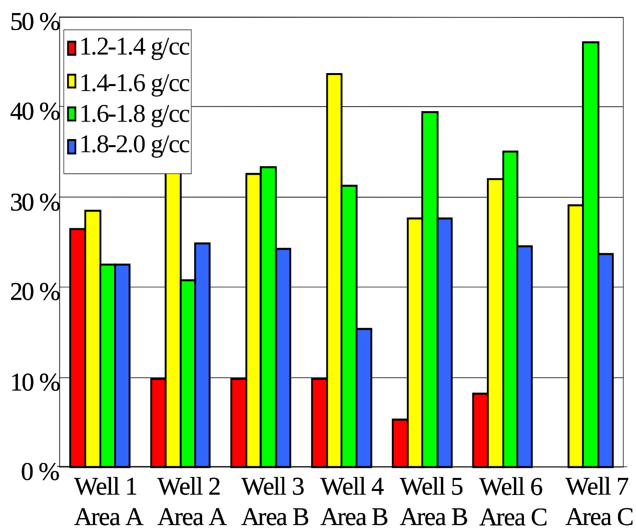
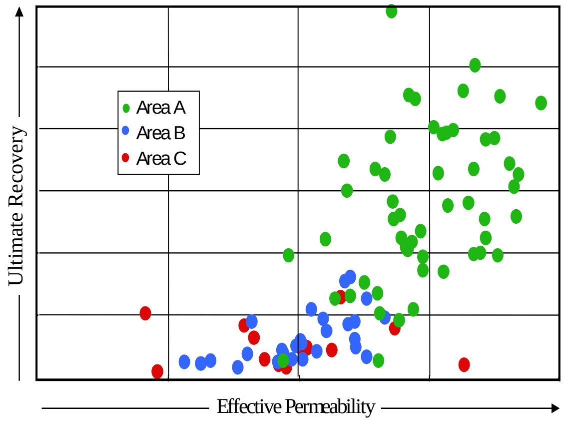


Figure 1 (left): Comparison plot showing a high-resolution CT density scan of a coal core interval and its corresponding bulk density log values. The density log fails to resolve thin, low-density, well-cleated, bright coals. **Figure 2 (right)** is a location map of a San Juan Basin lease showing the position of the wells displayed in Figures 3 and 4.





<u>Figures 3 and 4</u>: Two graphs summarizing core and log data from seven wells in the Fruitland Coal, San Juan Basin. The graph on the left shows a progressive eastward decrease in the percentage of brighter coals based on the core description in each well. The graph on the right shows a progressive eastward decrease in the percentage of low-density coal in these same wells. Both the core and logs indicate that the eastern coals contain more mineral matter, resulting in duller, more poorly-cleated, gas-poor coals.



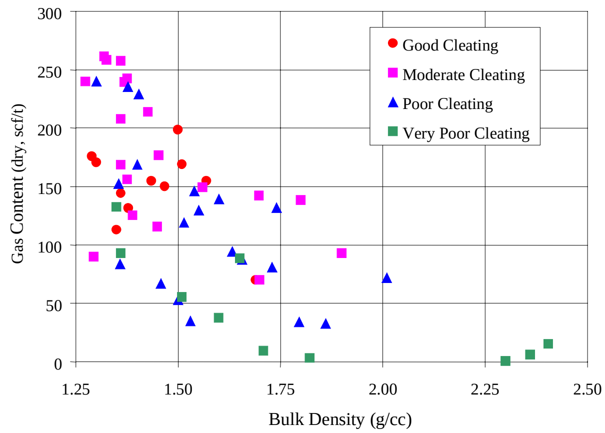
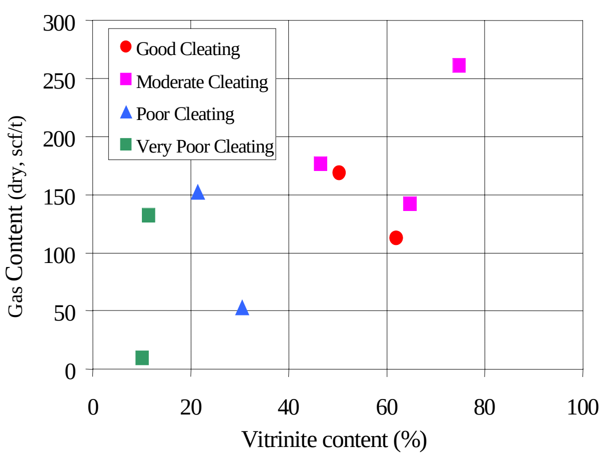


Figure 5 (left): Graph of effective permeability from well tests vs. ultimate recovery from well production in a Fruitland coal lease, San Juan Basin. The location of Areas A, B, and C are shown in Figure 2. Permeability and production rates increase in a westward direction, coinciding with decreases in coal density and the appearance of brighter, more well-cleated coals in the core. **Figure 6 (right)** is a graph of bulk density vs. gas content for canister samples from the Hedong Coal Basin, China. Overall, the plot shows that as bulk density decreases (due to decreasing mineral matter), gas content increases. The large scatter in the gas content data at low densities can be related to variations in maceral content.



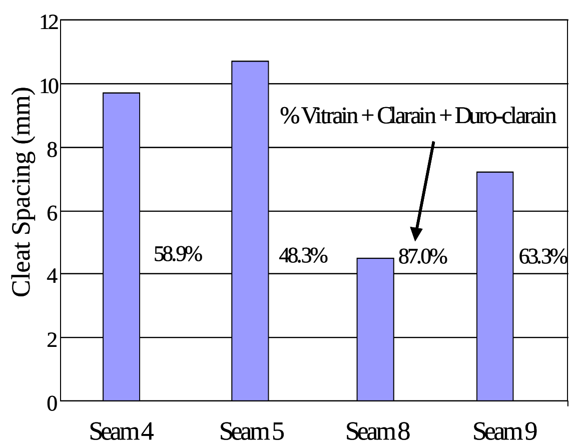


Figure 7 (left): Graph of vitrinite content vs. gas content for coal canister samples from the Hedong Coal Basin, China. The graph shows that both gas content and degree of cleating increase with increasing vitrinite content. **Figure 8 (right)** Graph showing cleat spacing by seam based on petrographic analyses of 16 canister and mine samples from the Hedong Coal Basin, China. Seam 8, which has the most closely-spaced cleats, also has the highest percentage of brighter coals.

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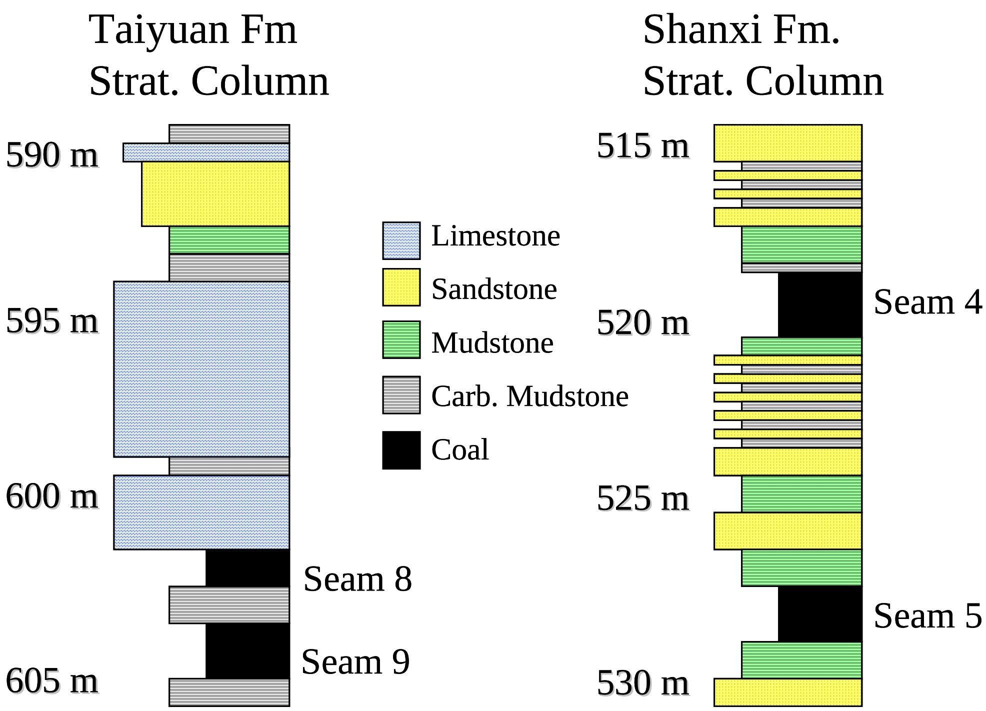

Figure 9: Stratigraphic columns built from core descriptions of the Taiyuan and Shanxi Formations, Hedong Coal Basin, China. Seams 8 and 9 formed in a low-energy lagoonal setting whereas Seams 4 and 5 were deposited in a higher-energy deltaic environment.

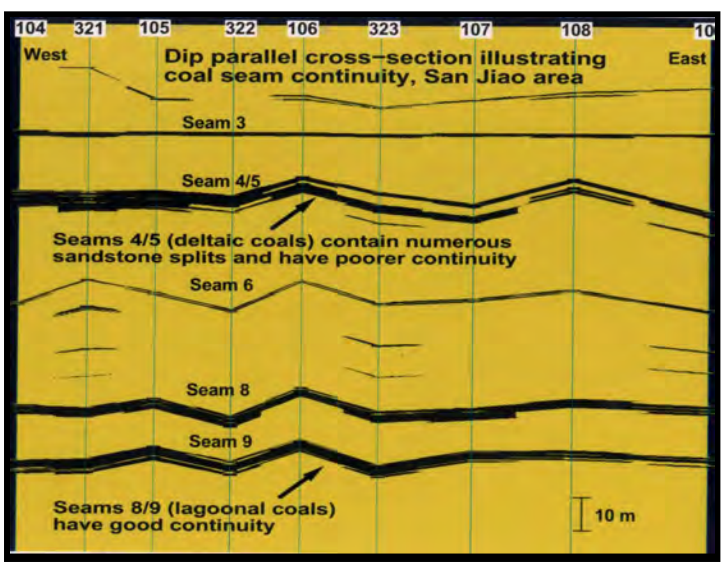

Figure 10: Dip-parallel cross-section constructed from mining corehole data in the Hedong Coal Basin, China. The cross-section shows that coal seams 4 and 5 are cut by numerous sandstone splits due to their deltaic origin. Lagoonal coal seams 8 and 9 are much more continuous.