Stratigraphy Principles for Rock Facies Interpretation Analysis

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Introduction

Facies analysis interprets the characteristics of sedimentary rocks in order to reconstruct depositional environments and predict how those environments change in space and time. A facies may be defined by lithology, grain size, sedimentary structures, fossils, color, mineral composition, geophysical-log response, or a combination of attributes. Facies become most informative when they are studied as associations rather than isolated rock labels (Miall, 1997).

The original analysis focuses on Walther’s law and cross-plots from the Sawan 1, Sawan 7, and Sawan 8 wells. A stronger interpretation must distinguish lithology from fluid response, explain the limits of log-based classification, and avoid assuming that every low-resistivity interval is clean reservoir sand. Well logs should be calibrated with core, cuttings, tests, and regional geology.

Facies and Depositional Environment

A sedimentary facies records conditions at the time of deposition and the effects of later alteration. Grain-supported sandstone with cross-bedding may indicate migrating dunes or channels; laminated mudstone may represent lower-energy water; fossils and bioturbation may reveal salinity, oxygen, and substrate conditions. The same lithology can form in different environments, so interpretation requires multiple lines of evidence.

Facies associations group units that occur together within a depositional system. Channel sandstone, levee siltstone, and floodplain mudstone may form a fluvial association. Shoreface sand, offshore-transition heterolithics, and marine mudstone may form a coastal association. The relationships among facies provide greater confidence than one measurement alone.

Walther’s Law of Facies

Walther’s law states that facies occurring in conformable vertical succession were deposited in environments that were laterally adjacent. As a shoreline migrates, a location may receive deposits from environments that previously existed beside one another. A vertical sequence can therefore preserve a lateral environmental transition.

The law applies only where deposition is reasonably continuous. An unconformity, erosion surface, or major hiatus may place facies together that were not adjacent. The original wording that vertical and horizontal successions “remain the same” is misleading. Walther’s law concerns the relationship between lateral environments and conformable vertical facies, not identical repetition.

Transgression and Regression

Transgression occurs when the shoreline moves landward, commonly because accommodation increases faster than sediment supply. At a fixed location, deeper-water facies may overlie shallower-water facies, producing a retrogradational or deepening-upward pattern. Regression occurs when the shoreline moves basinward because sediment supply exceeds the creation of accommodation, producing shallowing-upward or progradational patterns.

Sea-level change is important, but tectonic subsidence, compaction, sediment supply, climate, and basin geometry also control shoreline movement. Regression does not always require a fall in global sea level, and transgression does not guarantee a simple uniform increase in water depth.

A sharp grain-size change may reflect flooding, erosion, channel incision, or diagenesis. The interpretation should identify surfaces and stacking patterns rather than infer sea-level movement from one bed boundary.

Sequence-Stratigraphic Surfaces

Sequence stratigraphy organizes strata using unconformities, correlative conformities, flooding surfaces, and maximum-flooding intervals. These surfaces help correlate wells and separate changes caused by depositional migration from breaks in the record (Catuneanu, 2006).

A sequence boundary may record erosion or nondeposition associated with relative sea-level fall. A flooding surface marks an abrupt shift toward deeper-water deposition. A maximum-flooding surface represents the greatest landward extent of the sea in a sequence and is often associated with condensed fine-grained deposits. Surface identification should integrate logs, seismic data, core, fossils, and regional relationships.

Well Logs Used in Facies Interpretation

Gamma Ray

Gamma-ray logs measure natural radioactivity. Shale commonly has higher gamma-ray response because clay minerals and organic-rich material may contain potassium, uranium, and thorium. Clean sandstone often has lower response, but exceptions are common. Feldspathic, micaceous, glauconitic, or uranium-rich sand can show high gamma ray, while some carbonates and shales may be relatively low.

Density

Bulk-density logs respond to electron density and are used to estimate porosity when matrix and fluid density are known. Low density may indicate higher porosity, gas, coal, or a different matrix. Borehole washout and mudcake can distort the reading.

Neutron Porosity

Neutron tools respond primarily to hydrogen. In water-filled clean formations they provide a porosity estimate. Shale-bound water can create apparently high porosity, and gas can create a density-neutron crossover.

Resistivity

Resistivity depends on pore fluid, saturation, porosity, clay, salinity, temperature, and invasion. Hydrocarbon-bearing clean formations often have higher resistivity than water-bearing intervals, but low-resistivity pay is possible in shaly, thin-bedded, or conductive-mineral systems. Resistivity should never be treated as a direct lithology measurement.

Cross-Plots

A cross-plot places two or more log measurements against one another to reveal clusters, trends, and outliers. Density-neutron plots can help distinguish sandstone, limestone, dolomite, shale, and gas effects. Gamma-ray–porosity plots can show how effective porosity changes with shale content. Resistivity–porosity plots may help evaluate saturation when supported by formation-water information.

Clusters are not automatically facies. They are petrophysical classes that require geological interpretation. Polygon boundaries should be defined using calibration data rather than visual convenience. Depth trends, tool normalization, environmental corrections, and well-to-well differences must be considered before combining data (U.S. Geological Survey, n.d.).

Data Preparation in Interpretation Software

Before creating cross-plots in software such as Kingdom, the interpreter should verify log depth alignment, units, curve names, quality-control flags, and borehole conditions. Curves from different wells should be normalized when acquisition or geology causes systematic shifts.

The selected interval should correspond to the same stratigraphic unit. Plotting density, resistivity, and gamma ray across unrelated formations can create clusters caused by age or matrix rather than reservoir facies. Core descriptions, mud logs, pressure data, and tests should be linked to the plotted points where possible.

Sawan 1 Interpretation

The original study identifies sand and shale in the interval from approximately 3240 to 3365 meters using RHOB, LLD, and gamma ray. Low gamma ray may support a cleaner sandstone interpretation. Density may indicate porosity, and deep resistivity may contribute information about fluid saturation. However, the claim that low resistivity identifies sand is not generally valid. Clean water-bearing sand can be low resistivity, while hydrocarbon-bearing sand may be high resistivity.

The red polygon should therefore be described as a log-response cluster interpreted as sand after calibration. Shale-prone points with higher gamma ray may reflect greater clay content. The analysis should report the distribution and uncertainty rather than label every point categorically.

Sawan 7 Interpretation

The Sawan 7 interval from roughly 3265 to 3365 meters should be correlated with Sawan 1 using stratigraphic markers before comparing polygons. If the sand-prone cluster dominates, the interpreter should examine whether it forms one connected package or several thin beds separated by shale.

Thin beds can be blurred by tool resolution. Laminated sand and shale may produce intermediate gamma-ray and resistivity values. Net-to-gross estimates should account for cutoffs and uncertainty. A facies model that assumes homogeneous sand may overestimate connectivity.

Sawan 8 Interpretation

The selected Sawan 8 interval of approximately 3267 to 3350 meters also shows a proposed sand-dominated cluster. Differences from the other wells may reflect lateral facies change, structural position, compaction, fluid contacts, or log acquisition. The same polygon limits should not be transferred automatically without normalization.

If effective porosity decreases as gamma ray increases, the trend is consistent with greater shale volume and more bound water. The relationship should be tested statistically and compared with core porosity. Outliers may identify unusual mineralogy, poor hole conditions, or thin beds.

From Well Facies to a Depositional Model

Three wells provide vertical samples, not a complete map. The interpreter should correlate facies and surfaces, examine thickness trends, and integrate seismic geometry. Channel systems may create abrupt lateral changes, while shoreface systems may show more continuous belts. Depositional models guide interpretation but should not force the data into an expected pattern.

Walther's law can then connect vertical transitions with likely lateral adjacency, provided no major unconformity intervenes. For example, a conformable upward change from offshore mud to shoreface sand may represent shoreline progradation. A sharp erosional channel sand over offshore mud would require a different explanation.

Reservoir Quality

Depositional facies influence grain size, sorting, clay content, and initial porosity. Diagenesis later modifies reservoir quality through compaction, cementation, dissolution, and clay growth. Two sandstones deposited in the same environment may have different permeability after burial.

Reservoir evaluation should therefore separate facies from rock quality. Effective porosity, permeability, saturation, capillary pressure, and connectivity determine performance. Cross-plots are screening tools, not substitutes for core analysis and flow tests.

Uncertainty and Reproducibility

A defensible workflow records data sources, corrections, depth intervals, cutoffs, polygon rules, and calibration evidence. Results should include uncertainty ranges and alternative interpretations. Blindly relying on colors drawn around clusters makes the analysis difficult to reproduce.

Machine-learning classification can assist when labeled core data are available, but algorithms inherit errors in labels and may fail when applied to another field. Geological review remains necessary.

Conclusion

Stratigraphic facies interpretation combines rock characteristics, spatial relationships, well logs, core, and regional depositional models. Walther's law links conformable vertical facies with laterally adjacent environments, while sequence-stratigraphic surfaces identify breaks and shoreline stacking patterns. Gamma ray, density, neutron, and resistivity provide complementary evidence but are not unique indicators of lithology or fluid. In the Sawan wells, cross-plot clusters can support sand- and shale-prone interpretations only after quality control and calibration. The final objective is not merely to color points but to build a reproducible model of depositional environment, reservoir quality, and uncertainty (North American Commission on Stratigraphic Nomenclature, n.d.).

References

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