Table 1. Lower Muschelkalk Facies

Facies	Mineralogy, Texture and Color	Bedding Style	Physical Sedimentary Structures	Biogenic Sedimentary Structures*	Grain size and Sorting	Components, Frequency, and Occurrence	Thickness	Porosity and Permeability	Interpretation
Facies 1 Pedogenic dolomarlstone	Clayey, slightly silty, occasionally dedolomitized, green, red, or purple marlstone	Mottled, brecciated, laminated, or structureless	Caliche-like fabrics, relict millimeter-thick graded laminae, oscillation and wave ripples	Mottled, rhizobrecciated fabrics, poorly developed soil horizons	Clay to coarse calcisiltite, poorly sorted	Very irregualr to subrounded clasts in various states of disintegration and dissolution	Few centimeter-, decimeter- to meter-thick intervals	phi = 13–20% k = 0.04–0.9 md microporosity, occasional millimeter-sized separate vugs	Incipient soil formation in a low-energy coastal-plain environment and transgressive reworking of pedogenic deposits
Facies 2 Gray bituminous lime marlstone	Medium to dark gray bituminous lime marlstones	Centimeter-thick platy to flasery or nodular	Scour surfaces, centimeter-thick graded laminae	Bi 2-4, vertical or oblique traces penetrating a few centimeters deep; occasional *Rhizocorallium*	Calcilutite, variable amounts of clay, and calicarenitic	Abundant phytoclasts and marine acritarchs, unidentifiable fine-grained bioclastic detrius	Decimeter- to few decimeter- or meter-thick intervals	No poroperm plug data available	Suspension deposits reworked by bioturbation and occasional storms in an open-marine environment
Facies 3 Algal-laminated mudstone	Yellowish to greenish gray dolomitic lime or dolomudstone with variable clay content	Even, millimeter-thick platy to wavy, weakly disturbed to contorted, and crinkly	Decimeter-deep tepeeing desiccation cracks, millimeter-thick graded laminae, erosive bases, millimeter-sized calcite nodules, rare oscillation ripples	Crinkly and even algal lamination, bi 0-2, millimeter-sized *Planolites*-type, vertebrate tracks	Clay, calcilutite to calcisiltite, rare fine calcarenite	Laminae of peloids, calcispheres, fine-grained, unidentifiable bio-detritus, phosphatic particles, detrital quartz silt	Decimeter- to few decimeter-thick beds	phi = 4–24% k = 0.04–33 md intercrystalline and some separate vug porosity	Restricted, low-energy peritidal environment extensively colonized by microbial mats and influenced by occasional storms
Facies 4 Bioturbated lime mudstone	Weakly dolomitic lime mudstone with variable clay content and green-gray or yellowish color	Disturbed even bedding, flasery to nodular	(relict) graded laminae, centimeter-deep synaresis cracks	Bi 3-6, (a) millimeter- to centimeter-scale horizontal *Planolites*-type, (b) centimeter-scale vertical *Rhizocorallium* and *Teichichnus*	Clay to calcisiltite	Rare and dispersed shells (ostracods and gastropods), fecal pellets in clusters, quartz silt, holothurian ossicles	Decimeter- to few decimeter- or meter-thick intervals	phi = 6–17% k = 0.01–2 md intercrystalline porosity	Medium-energy subtidal deposits modified in variable degrees and fashion by bioturbation
Facies 5 Graded laminated lime mudstone	Relatively clean, (dolomitic) lime mudstones of gray-greenish color	Evenly bedded, millimeter-to centimeter-thick platy, weakly disturbed	Centimeter-to millimeter-thick graded laminae, erosive bases, tool marks, load casts, low-angle and ripple-cross lamination	Bi 0-2, millimeter-to centimeter-scale ichnofossils, penetrating laminae from the top	Calcilutite to calcisiltite or fine calcarenite	Peloids, shells (bivalves, ostracods and gastropods), calcispheres, quartz silt, phosphatic grains at the base of laminae	Decimeter- to few decimeter-thick beds or meter-thick intervals	phi = 7–15% k = 0.01–0.8 md intercrystalline porosity	Open-marine subtidal sediments frequently reworked by storms and weakly modified by bioturbation

Facies 6 Skeletal peloidal lime pack-/grainstone	Clean, medium to dark gray lime packstones and (rare) grainstones	Continuous sheets, pinching and swelling	Graded centimeter-thick laminae, erosive bases, tool marks, pot and gutter casts	Bi 0-1, rare, poorly defined traces from the top of individual laminae	Poorly sorted calcisiltite to calcirudite	Disintegrated and abraded brachiopod and bivalve shells, crinoids, intraclasts, and detrital quartz	Centimeter- to few centimeter-thick beds to (few) decimeter-thick	No representative poroperm plug data available	High-energy open-marine (amalgamated) tempestite facies
Facies 7 Intraclastic packstone	Relatively clean dolo- or lime packstones of variable color (clast-dependent)	Discontinuous patchy sheets	Erosive bases, normal grading, horizontally aligned or imbricated intraclasts	*Trypanites*-borings on intraclasts	Very poorly sorted coarse calcirudite to calcilutite	Subangular to rounded intraclasts, often iron-stained and bored, glauconitic, bivalve shells	Centimeter-to decimeter-thick beds	No representative poroperm plug data available	Short-lived, but very high-energy tempestite deposits

*Bi = bioturbation index (Reineck, 1967).

dolomarlstones (facies 1) at the base are succeeded by (marly) bioturbated or graded laminated lime mudstones (facies 4 and 5) and the potential reservoir facies of algal-laminated dolomudstones (facies 3) with desiccation cracks at the top (Figures 7, 8). Translated into reservoir properties, the (marly) baffles at the base, tight limestones in the middle, and (commonly) porous dolomites at the top are easily recognized with wire-line logs (Figure 8). Depending on paleogeographic and paleotectonic location, predictable variations of this motif are observed. In more seaward sections, for example, cycle-capping dolomites, if present, are only thinly developed. Instead, algal laminites are present as limestones devoid of reservoir potential.

Subtle but systematic variations in the facies composition observed in stacks of four to six small-scale cycles reflect the superimposed trends defining medium-scale cycles. The Lower Muschelkalk is interpreted to consist of four medium-scale cycles. Typically, the thickest reservoir-prone algal-laminated dolomudstones are found in the initial transgressive deposits and the maximum regressive deposits of medium-scale cycles (Figure 8). The cumulative thickness of reservoir-prone algal-laminated dolomudstones (facies 3) is not similar within each of the medium-scale cycles. Instead, medium-scale cycles with low cumulative thickness of algal dolomudstones (1 and 3) alternate with high cumulative thickness (2 and 4). Based on this observation, the four medium-scale cycles are grouped into two intermediate cycles. During each of the intermediate cycle regressions, the cumulative thickness of algal dolomudstones is clearly higher (Figure 8).

The overall large-scale, transgressive-regressive cycle constituting the entire Lower Muschelkalk is poorly depicted by gamma-ray logs. In cores and outcrops, however, the succession around peak transgression is reflected by several decimeter-thick, grain-rich, brachiopod-bearing marker beds (Terbratelbänke) documenting the most open-marine conditions (Aigner et al., 1998). Similar to the small-scale (marly) baffle-tight porous pattern, the basal parts of the large-scale cycle are noticeably marlier and commonly devoid of reservoir potential (Figure 8).

The punctuated but predictable occurrences of stacks of reservoir-prone dolomudstones reflect the superimposed trends of the small-, medium-, and intermediate-scale as well as the large-scale cycle. This fourfold hierarchy directly controls the vertical stacking of reservoir-prone, tight, and (marly) baffling facies. The high-resolution sequence-stratigraphic framework is thus of key importance for the stratigraphic correlation.