AAPG HEDBERG CONFERENCE
"MICROBIAL CARBONATE RESERVOIR CHARACTERIZATION"
June 4-8, 2012 – Houston, Texas

The Microbial-Dominated Slopes of Tengiz Field, Pricaspian Basin, Kazakhstan

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Tengiz field is an isolated carbonate buildup in the southeastern Pricaspian Basin, Kazakhstan, of Late Famennian to Early Bashkirian age. Platform backstepping through the Late Visean resulted in approximately 800 m (2625 ft) of relief above the Famennian platform, followed in the late Visean to Serpukhovian by up to 2 km (1.2 miles) of progradation of a microbially-dominated margin and slope. Tengiz Unit 1 (late Visean to Bashkirian) is the main producing reservoir interval.

Margin/slope facies were identified in core and from FMI logs, and include (from distal to proximal slope environments) mudstone, volcanic ash, platform-derived grainstone, coarse skeletal rudstone with boundstone clasts, massive boundstone breccia, and in-situ microbial boundstone ranging from upper slope to outer platform settings. These facies partly control non-matrix porosity distribution in the margin/slope as well as connectivity with the adjacent platform reservoir. Their spatial distribution and proportions are inferred from well data, seismic data, and outcrop analog concepts and can be viewed as occurring in accretionary and allochthonous sectors. The accretionary sector refers to the northern, northeastern, and southeastern portions of the buildup, where it is characterized by a conspicuous raised rim crest and a considerably wider progradational wedge (Figure 1). The allochthonous sector refers to the southwestern and northwestern parts of the buildup and is characterized by a lower, distally thickened apron that onlaps the Tournaisian and Visean platforms, which itself appears to be downlapped by a narrow progradational wedge (Figure 1). Periodic rim failure during both Serpukhovian and Bashkirian time resulted in a high degree of lateral facies discontinuity within the slope. Solution-enlarged fractures, large vugs, and lost circulation zones enhanced mainly during late diagenesis form a high-permeability, well-connected reservoir in the margin and slope.

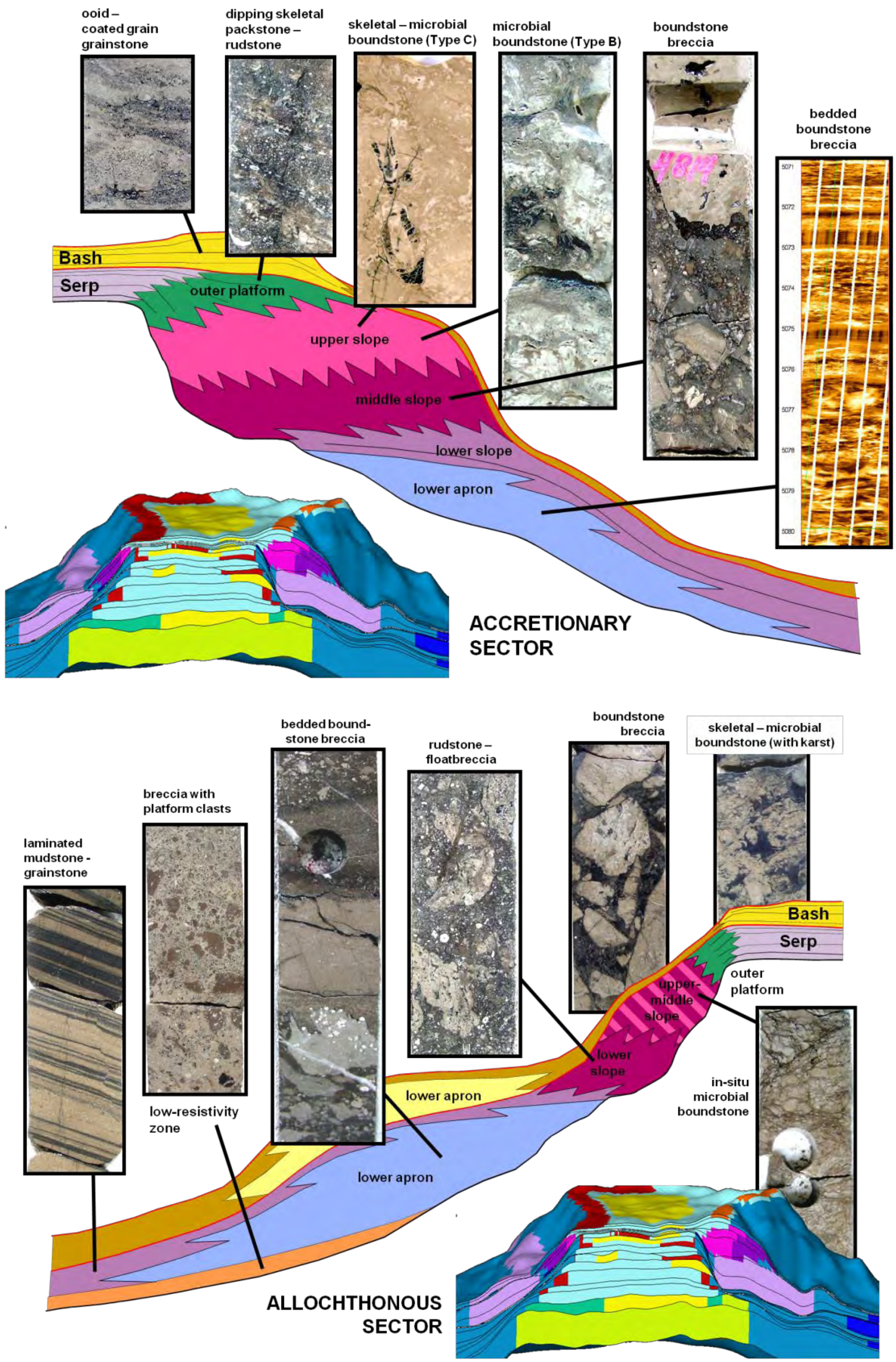

Figure 1. Schematic cross sections for accretionary (top) and allochthonous (bottom) sectors of the Tengiz margin and slope, modified from Collins *et al.* (2006). Cross sections show margin/slope profile and depositional regions. Core photographs and FMI log illustrate representative rock types.

Tengiz cores and FMI logs suggest that the in-situ boundstone interval is perhaps 150–200 m (492–656 ft) thick. In-situ microbial boundstones are light colored in core, with textures that include relatively featureless micritic to peloidal fabrics (type A) or irregular laminar fabrics and amalgamated semiconcentric laminar masses (type B). A third boundstone type (type C), characterized by massive to peloidal fabric with common skeletal grains (bryozoans, algae, forams, ostracods, pelecypods, crinoids, corals, and sponges), represents the transition between upper-slope and outer-platform facies. Small- to medium-size fenestrae filled with banded cements are commonly abundant, and larger cement lined cavities filled with internal sediment or skeletal accumulations are observed. Boundaries between microbial masses are sometimes formed by networks of elongate cavities that are also frequently cement filled. Breccias consisting of irregularly shaped to subangular boundstone clasts with stylolitic (welded breccia) or fracture (mosaic breccia) contacts are found in the Tengiz middle to upper slope. The matrix consists mainly of several generations of calcite cement, secondary microbial encrustations, microbial cement, and minor amounts of platform-derived skeletal sediment, thin-bedded marly volcanics, or argillaceous carbonate. Very little open primary pore space is observed in these breccias.

The middle and lower slope consists of mainly detrital facies, including sedimentary boundstone breccias; coarse skeletal rudstones; fine-grained breccias; massive or poorly bedded allochthonous grainstones; and thin-bedded to laminated grainstones, packstones, wackestones, mudstones, argillaceous carbonates, volcanic ashes, and cherts. Clast size and packing varies in the breccias, with textures ranging from matrix-supported float breccia to welded breccia with stylolite-bounded clasts. Clast sizes range from less than 1 cm (0.4 in.) to several meters. The matrix contains variable amounts of bioclastic debris, fine-grained carbonate, argillaceous mudstone, and volcanic ash. The most visible skeletal components are large crinoids and brachiopod shell fragments similar to outer-platform facies. Relationships between clast size, clast packing, matrix grain size, and matrix composition have not been fully evaluated, but they appear to be poorly correlated. Clasts are dominantly upper-slope microbial boundstone fragments, although platform-derived clasts and reworked slope clasts are increasingly observed in breccias near the base of the section. Some detrital breccias are massive and unbedded over very thick intervals, whereas others are layered and contain intervals of bedded, grainy periplatform facies.

Our studies of the Tengiz high-relief margin and slope suggest that: 1) the microbial-boundstone production extends to ~300 m (985 ft) water depth, 2) the detrital lower slope consists mostly of matrix-free cemented rudstone sourced by the slope boundstone with subordinate platform top derived material, 3) carbonate production on the slope is controlled by environmental parameters (temperature, nutrients, oxygenation), that may be directly or indirectly related to water depth, but the microbial boundstone response to relative sea-level changes differs from modern reefs, 4) carbonate growth is not seriously reduced during sea-level falls because it can continue downslope, 5) progradation can take place at high rates despite the lack of platform top shedding(slope vs. highstand shedding), and 6) concepts of leeward progradational vs. windward aggradational margins do not directly apply.

Paleozoic high-relief platforms with microbial boundstone-dominated margins and slopes, like Tengiz and similar reservoirs throughout the Pricaspian Basin, seem to have developed in mesotrophic, starved and restricted basins with oxygen-depleted bottom waters. These types of conditions would generally not be considered suitable for robust boundstone development.