Development History and Reservoir Characterization of the "Would Have Limestone": A Leonardian Toe-of-Slope Debris Flow Complex

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The Would Have Field was discovered when LCS reentered the Cobra Guitar #1 (a 1996 Fusselman test) in Feb., 2001. The 5,700' reentry was based on log analysis and an interpretation that the original DST was inconclusive with respect to reservoir fluids. CrownQuest acquired the field in 2003 from LCS at which time aggressive development was initiated. Waterflood operations commenced in May, 2004 on the Guitar Consolidated lease on the western side of the field. Whiting Oil and Gas acquired the property October, 2004 and has essentially completed delineating this 2000 acre field. Waterflood implementation, conformance work, and realignment is still in progress under the Guitar Consolidated lease to the west, and a "Would Have East Unit" was approved in the second quarter of 2006, with water injection scheduled to start in late 2006 with four initial water injection wells. Without factoring in ongoing waterflood optimization, EUR projections are in the range of 68 MBOE per well. There are 58 wells, 5 of which produce solely from the "Dillard Limestone" which immediately overlies the Would Have Limestone.

Two whole cores, numerous rotary sidewall cores, and subsurface mapping including both 2d and 3d seismic all suggest that the Would Have Limestone producing interval is a deepwater, toe-of-slope debris flow complex situated approx 12 mi from its coeval shelf margin to the east and accumulated in a long-term depositional low. While informally termed "Lower Clearfork", the Leonardian Would Have detrital and surrounding basinal facies could be more appropriately termed "Bone Spring" (invoking Delaware Basin nomenclature…) and may be time-equivalent to Lowermost San Andres rather than the Clearfork. While the overall Would Have Limestone can be imaged seismically, the package includes a much thicker upper Would Have Limestone composed of dense, black hemipelagic lime mudstone with multiple sparse skeletal-spiculitic wackestone intercalations (cm-scale) and no effective matrix porosity. The upper interval is, however, prone to fracturing, lost circulation, and consequent intriguing invasion profiles on resistivity logs. This widespread upper unit is interpreted as a toe-of-slope to lowermost slope "apron" that drapes the underlying "pay-prone" interval.

The lower Would Have Limestone has a much sparser aerial distribution and is the "pay-prone" interval composed of skeletal lime packstone-grainstone representing multiple, amalgamated sediment gravity flow events. Diverse upper slope through outer-shelf derived fauna include crinoids, brachiopods, fusulinids (Leonardian), and peloids, with subordinate green algae and ooids. No basal erosion is indicated and the composite "pay prone" interval had convex-upward relief after deposition. The "pay-prone" interval is an important mapping unit. Although thick (>5') debris flow accumulation is a prerequisite for pay development, it does not guarantee net effective pay because of the important role of secondary porosity (skeletal MO and VU). The "pay-prone" interval is characterized by anomalously clean GR<18api and shows a remarkably linear east to west trend 1 mi. wide by 3.5 miles in dip direction. The pay averages 14 feet thick with about 9.3% average porosity

and 14% average water saturation. No evidence of compartmentalization has been seen in the field. Similar, but much narrower producing trends exist within one mile to the north (Chaney Field) and south (Would Have South). Each mappable trend is a debris flow complex, possibly all emanating from a single slope-bypass conduit. The limits of Would Have Field are defined by an abrupt "pay-prone" pinchout updip to the east, more gradual change to non-amalgamated debris flows along depositional and structural strike to the north and south, and deterioration of reservoir quality and gradual onset of water production downdip to the west. An additional debris flow unit, informally termed the Dillard Limestone, produces locally but is much patchier and more limited in aerial extent.

The overall waterflooding pattern is being realigned from a 9-spot to an east-west oriented line-drive to counteract premature breakthrough along an easterly-westerly permeability trend coincident with present day N55E maximum horizontal compressive stress. The fracture-prone upper Would Have Limestone and to a lesser extent the underlying shale have proved to be conduits for water breakthrough. The dense upper limestone was commonly completed early in the field's life due to its occasionally attractive invasion profile. Additional conformance measures are currently being pursued, primarily polymer treatments with some mechanical methods in the injection wells. Mechanical workovers to shut-off out-of-zone perforations (above the "pay-prone") in some producing wells may be considered in the future.