

## Geology and Development of the Bone Spring formation In Loving County and adjacent areas: Part 2 Avalon Shale.

John Worrall<sup>1,2</sup> and Chad Krankawsky<sup>1</sup>

<sup>1</sup>Bold Energy, II

<sup>2</sup>Manzano Energy Partners

The "Avalon Shale" or "Leonard Shale" is an informal term applied to the shale and siltstone lying in between the between the top of the Bone Spring formation and the top of the First Bone Spring sandstone, an interval typically 950 feet thick in Loving County. This interval can be further loosely subdivided into three units, the uppermost Bone Spring limestone, the Upper Avalon Shale and the Lower Avalon Shale. Production occurs where logs indicate high gamma ray (>75u), porosity logs show 16-18% porosity with little separation between the curves on a limestone matrix, and the resistivity is greater than 20 ohm-m, typically 60-100 ohm-m. Mudlog shows are common in the form of gas, especially in drilling breaks, with samples often showing dry cut throughout. Maps show the Avalon section can have up to 600 feet of potential reservoir within the 950 foot interval. Often there is a tight interval in the middle, leading to the designation of an "Upper and Lower" although the stratigraphic depth of that tight interval varies widely across the basin.

Historically, due to abundant mudlog shows, the Avalon interval has been tried in numerous vertical completions with only a couple of commercial completions. In 1991, the first horizontal Avalon attempt by Strata Production (the Yeso Hills #1) was a "technical success" in finding gas in the matrix, but a financial dry hole due to water from abundant fractures. Strata took 100 ft of core from the "Upper" Avalon. Core data from the Strata well shows the Avalon is a very dark gray shaly siltstone, (2) emitted excellent mud log shows coming from the rock matrix, (3) has good total organic carbon (5-6%), (4) has low permeability, generally <.1 md; (5) contains significant CO<sub>2</sub> (14%) in the dry gas, and (6) has a true porosity much lower than log porosity. In January, 2009 Chesapeake drilled the first recent lateral in the Avalon, the PLU Pierce Canyon 17 #1H in Sec.17- T2SS-R30E to kick off this new play. This well showed a high liquids content and has produced 57 MBO and 724 MMCFG in 2 years. A traverse of subsequently drilled pilot logs from Avalon laterals across the state line from west to east, shows numerous interesting trends: (1) depth to the top of the Upper Avalon pay interval increases from 4500 ft in T26S-R25E to 9400 feet in the Haley area of Loving County; (2) the net (>12% density) shale section can be up to 600 feet thick generally coincident with the thickest (deepest) Bone Spring deposits; (3) there is no apparent systematic division stratigraphically. separating the "Upper" and "Lower" shale; (4) oil production and liquids content increases dramatically eastward (i.e. GORs are lower to the east) with a maximum known gas liquids content of 6.1 gallons liquid per MCF tested in the Anadarko Bullhead 55-1- 41#1H in Loving County; (6) known CO<sub>2</sub> content in the produced gas ranges from 6 to 14% with no systematic trend; and (7) the direction of drilling induced fractures rotates from NE-SW in T26SR25E towards almost E-W in Lea County.

Mapping of the Avalon Shale in Loving County shows the net pay is up to 600 feet thick. In western Loving County, the Upper Avalon generally appears more shaly, e.g. it shows higher gamma ray (>100 units) than the Lower Avalon which appears more silty (GR<80 units). Logs and mudlog shows suggest both are potentially productive across most of Loving County.

All three of the Bone Spring objectives have potential to each produce in excess of 250 MBOE per well. Hence stacking of these reservoirs provides excellent reserve and multi pay potential.

Horizontal well completions to date have predominantly consisted of the Perf and Plug method to provided zonal isolation between hydraulic fracture stages. The typical hydraulic fracture stimulation treatment consists of 7 to 10 fracture stages with approximately 2 to 3 MMLB of 20/40 mesh Brady or Ottawa sand proppant. Hydraulic fracture fluids generally consist of slickwater pads followed by 100 mesh sand slugs to provided leak off control. A 10 - 20 ppg linear gel is generally pumped with a sand slurry concentration of 1 - 3 ppg, and in some cases a 20 - 30 ppg cross-linked gel is used. Recently two wells operated by Mewbourne Oil Company (Red Hill West 8-1H and Red Hills West 22-1H) in New Mexico have been completed using open hole mechanically set packers. To the best of the author's knowledge these two wells represent the only Avalon Shale wells which have been fracture stimulated using a completion method different from the Perf and Plug method to date. Initial production results from these two wells will be compared and contrasted to offset Avalon Shale completions. Through the course of this presentation it is the author's intent to show that completion methodology is a critical aspect into making the Avalon Shale a commercial success.

Production results to date within the Avalon Shale play have shown very encouraging initial production rates with reported first 30 day average production rates of 800 - 1000 BOEPD (6:1 conversion ratio). While these initial production rates are very encouraging; sustained high production rates past 6 months have yet to be achieved within the play to date. Initial annual decline rates for both condensate and gas within the Avalon Shale have been modeled as having as high as a 99.9% annual decline with hyperbolic exponents ranging from 0.5 to 1.3. Using the modeled decline rates, the industries current purported recoverable resource estimates of 350 to 500 MBOE per well are not achievable with the current completion methodology to date. It is the author's belief that as the industry experiments more with different completion methodologies; commercial success will be achieved in the not too distant future.