

# **PS The Upper Mancos Shale in the San Juan Basin: Three Oil and Gas Plays, Conventional and Unconventional: Update**

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\*Adapted from poster presentation at 2018 AAPG Annual Convention & Exhibition, Salt Lake City, Utah, May 20-23, 2018. An earlier article on the same subject by the author is referenced, and linked, in the following page.

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## **Abstract**

The Mancos Shale (Upper Cretaceous) covers approximately 12,000 mi<sup>2</sup> in the San Juan Basin of northwestern New Mexico and southwestern Colorado. The Mancos is subdivided into two formations, the Upper Mancos Shale and the Lower Mancos Shale. The Upper Mancos is 900 to 1600 ft thick in the San Juan Basin. The Upper Mancos has been productive of oil and natural gas from sandstones and shales.

The Upper Mancos Shale contains three plays: the *Tocito marine bar play*, the *Naturally fractured Mancos shale play*, and the *Offshore Mancos shale play*. The *Tocito play* is a conventional oil play productive from sandstones in the lower part of the Upper Mancos. Reservoirs are northwest-southeast-trending shoestring sandstones on the southwestern flank of the basin.

The *Naturally fractured Mancos shale play* is located along the southeastern and northwestern flanks of the basin where Laramide tectonic uplift that formed the present-day basin outline initiated fracturing of the more brittle lithologies within the Upper Mancos. Open fractures formed prolific reservoirs produced by vertical wells.

The *Offshore Mancos shale play* is located northeast of, or paleo-offshore of, the Tocito marine bars. This is the modern unconventional play. The play extends north from the Tocito marine bars into the basin axis. Reservoir intervals are organic-rich marine shales with laminations and very thin beds of very fine-grained sandstones. Percentage and thickness of sandstone beds decrease to the northeast with increasing distance from the paleoshoreline. Recent exploration is within the Mancos C zone, which constitutes the lowermost 75 to 470 ft of the Upper Mancos Shale. The Mancos C thickens to the northeast.

Upper Mancos shales are both source rocks and reservoirs in the *Offshore Mancos shale play*. Along the southwestern flank of the basin, shales within the Mancos C are thermally immature. Peak oil generation in the Mancos C was attained along a trend just northeast of the Tocito marine bar reservoirs. The dry gas window is present in the deeper northern part of the basin. TOC of Mancos C shales ranges from 0.5 to

3.2%, averaging 1.8%. Kerogens are a mixture of oil-prone, gas-prone, and inertinitic types, with oil-prone types dominant. Production has been marginally economic oil and gas from scattered historic vertical wells. Most recent exploratory wells have been drilled horizontally with production exceeding that attained in vertical wells by an average factor of 9.4.

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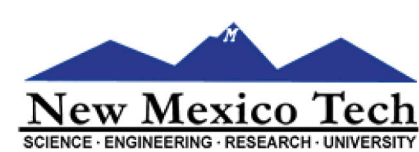
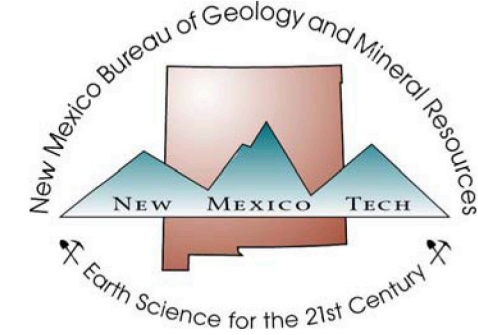
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# The Upper Mancos Shale in the San Juan Basin: Three oil & gas plays, conventional and unconventional: Update

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## ABSTRACT

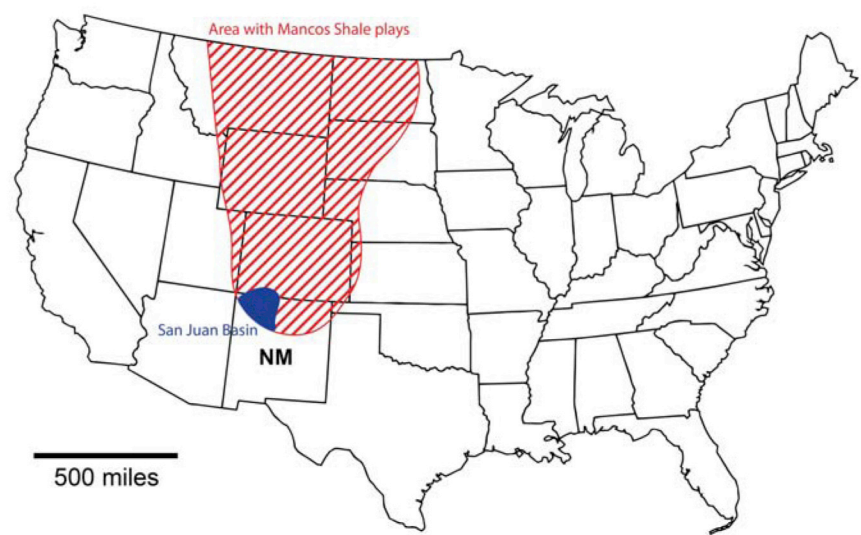
The Mancos Shale (Upper Cretaceous) covers approximately 12,000 mi<sup>2</sup> in the San Juan Basin of northwestern New Mexico and southwestern Colorado. The Mancos is subdivided into two formations, the Upper Mancos Shale and the Lower Mancos Shale. The Upper Mancos is 900 to 1,600 ft thick in the San Juan Basin. The Upper Mancos has been productive of oil and natural gas from sandstones and shales.

The Upper Mancos Shale contains three plays: the *Tocito marine bar play*, the *Naturally fractured Mancos shale play*, and the *Offshore Mancos shale play*. The *Tocito play* is a conventional oil play productive from sandstones in the lower part of the Upper Mancos. Reservoirs are northwest-southeast trending shoestring sandstones on the southwestern flank of the basin.

The *Naturally fractured Mancos shale play* is located along the southeastern and northwestern flanks of the basin where Laramide tectonic uplift that formed the present-day basin outline initiated fracturing of the more brittle lithologies within the Upper Mancos. Open fractures formed prolific reservoirs produced by vertical wells.

The *Offshore Mancos shale play* is located northeast of, or paleo-offshore of, the Tocito marine bars. This is the modern unconventional play. The play extends north from the Tocito marine bars into the basin axis. Reservoir intervals are organic-rich marine shales with laminations and very thin beds of very fine-grained sandstones. Percentage and thickness of sandstone beds decrease to the northeast with increasing distance from the paleoshoreline. Recent exploration is within the Mancos C zone, which constitutes the lowermost 75 to 470 ft of the Upper Mancos Shale. The Mancos C thickens to the northeast.

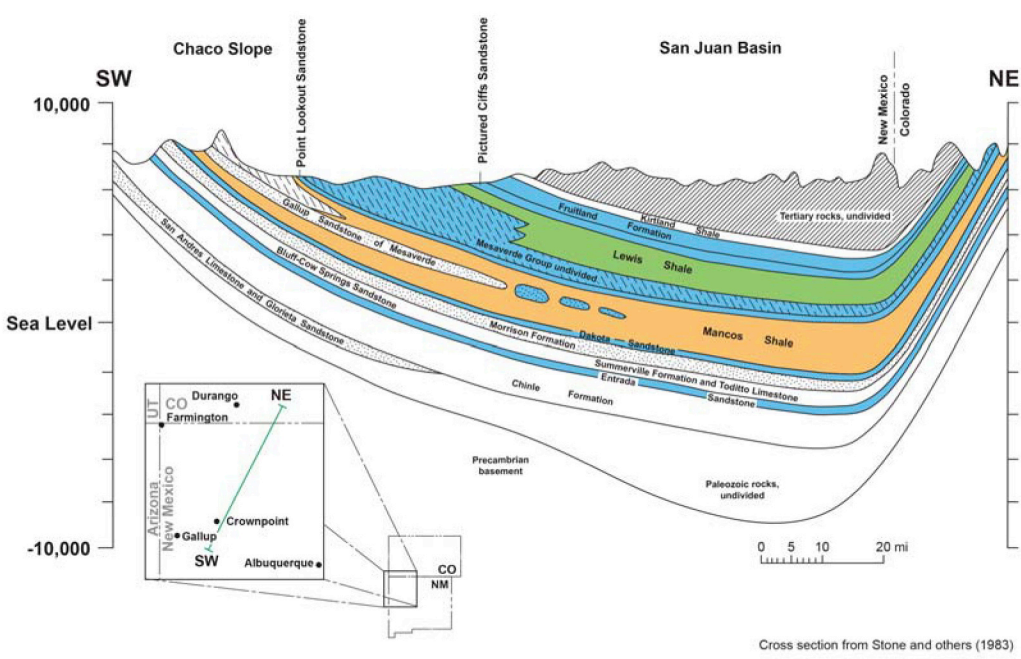
Upper Mancos shales are both source rocks and reservoirs in the *Offshore Mancos shale play*. Along the southwestern flank of the basin, shales within the Mancos C are thermally immature. Peak oil generation in the Mancos C was attained along a trend just northeast of the Tocito marine bar reservoirs. The dry gas window is present in the deeper northern part of the basin. TOC of Mancos C shales ranges from 0.5 to 3.2%, averaging 1.8%. Kerogens are a mixture of oil prone, gas prone, and inertinitic types with oil-prone types dominant. Production has been marginally economic oil and gas from scattered historic vertical wells. Most recent exploratory wells have been drilled horizontally with production exceeding that attained in vertical wells by an average factor of 9.4.



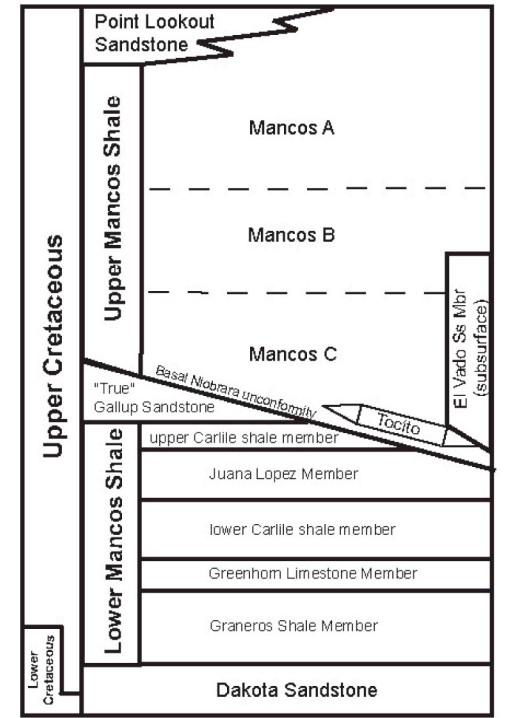
Area encompassing present and emerging Mancos Shale plays in the Rocky Mountain region with San Juan Basin indicated. See Sonnenberg (2011) for outlines of individual basins with Mancos Shale plays.



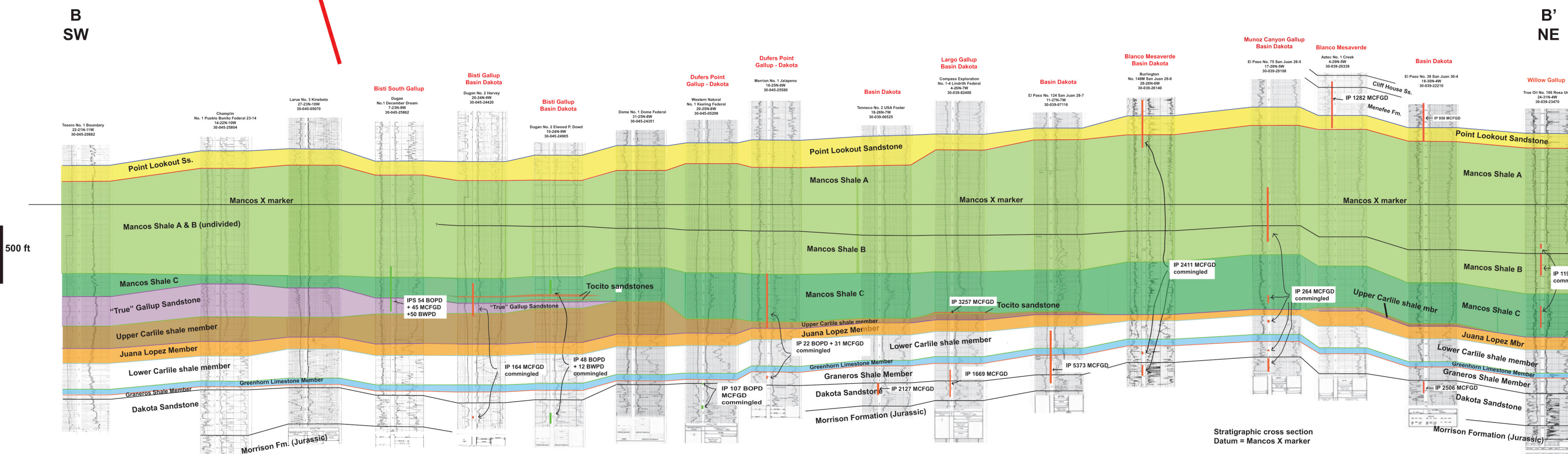
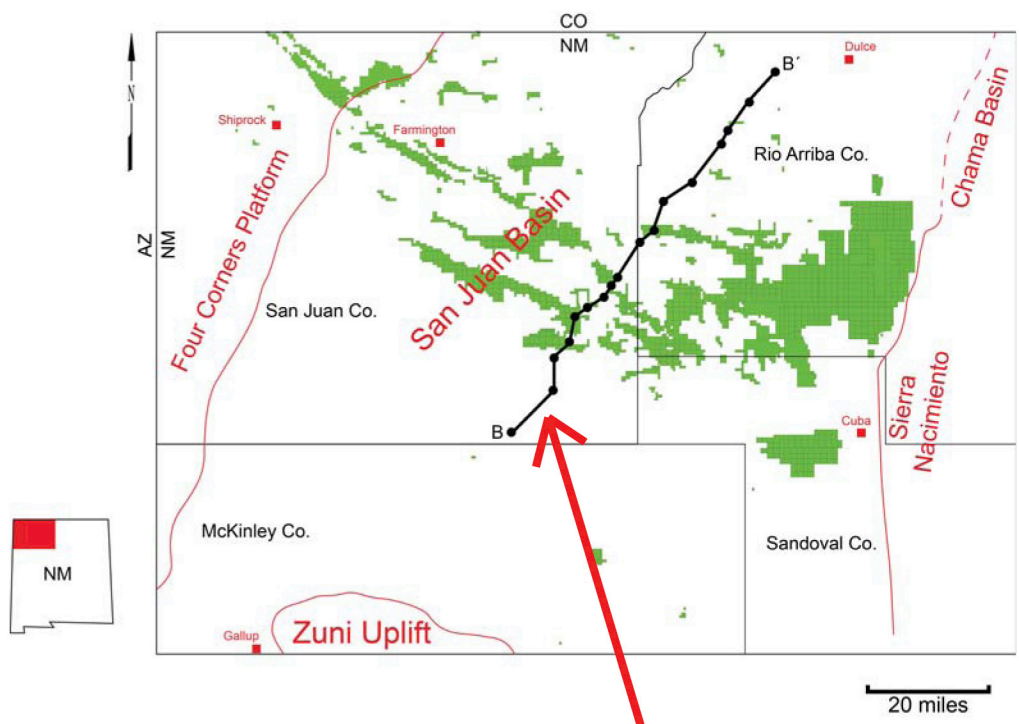
Tectonic map of San Juan Basin and adjacent areas. From Stone and others (1983).



Southwest-northeast structural cross section through the San Juan Basin with Mancos Shale highlighted in orange. Modified from Stone and others (1983).



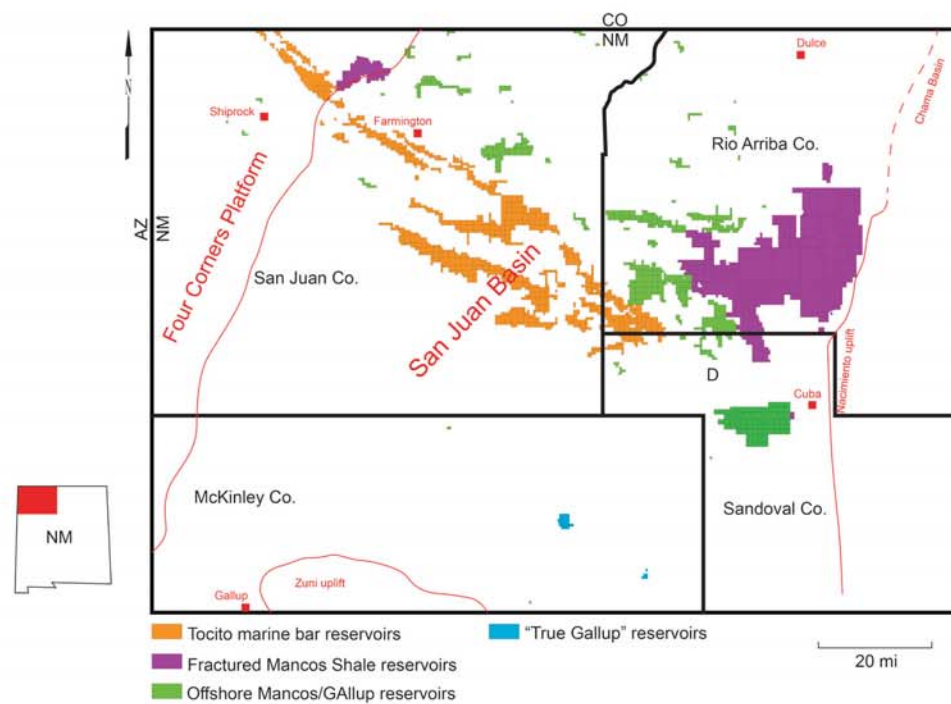
Stratigraphic column of Mancos Shale in San Juan Basin. From Broadhead (2015).



Southwest-northeast stratigraphic cross section through the Mancos Shale. Datum is the Mancos X marker, a prominent resistivity log marker in the Mancos A. Location map shows the location of the cross section and the oil pools that are productive from the Mancos Shale.



# The Three Mancos Plays



Productive reservoirs in the Upper Mancos Shale can be grouped into three plays on the basis of reservoir lithology, internal Mancos stratigraphy, and the extent of natural fracturing of the reservoir.

1. Tocito marine bar play
2. Naturally fractured Mancos shale play
3. Offshore Mancos Shale play

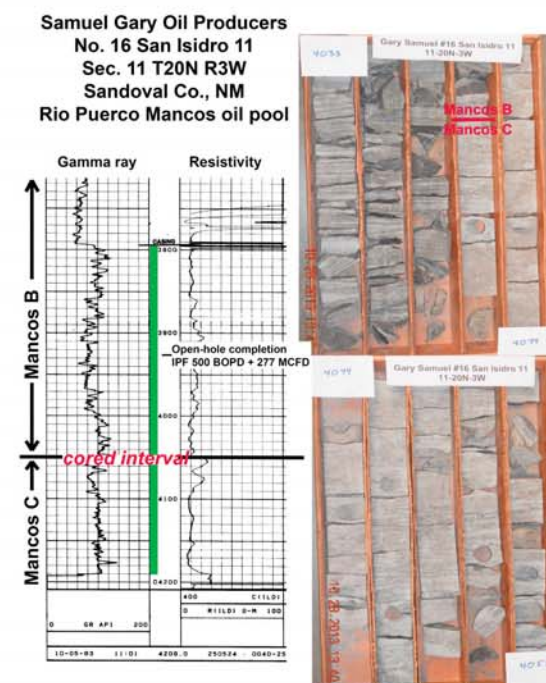
The **Tocito marine bar play** consists of northwest-southeast-trending sandstone reservoirs in the lower part of the Mancos C unit. The marine bars were deposited off shore of, and parallel to, the Late Cretaceous shoreline. The elongate linear nature of these sandstone bodies are mimicked by the shape of the oil pools that they form. This is a conventional play and most of the reservoirs were developed in the 1950's with vertical wells.

The **Naturally fractured Mancos Shale play** is present along the southeastern and northwestern flanks of the basin. In these areas Laramide tectonic uplift that formed the present-day basin outline steeply turned Cretaceous strata upward on the basin flanks and acted to initiate fracturing of the more brittle lithologies within the Upper Mancos Shale. The more brittle strata contain dolomitic siltstones and fine-grained sandstones interbedded with unfractured marine shales (London, 1972; Greer and Ellis, 1991). These sediments were deposited further offshore (northeast) than the sandstones of the Tocito marine bar play. This is a conventional play developed with vertical wells. Most reservoirs were discovered in the 1950's and 1960's. production in the major reservoirs is by gravity drainage.

The **Offshore Mancos Shale play** is located northeast of the Tocito marine bar play. The Mancos in this area was deposited basinward (**further offshore**) than the Tocito marine bar reservoirs. Reservoir lithology is generally similar to what is found in the Naturally fractured Mancos Shale play, except that natural fractures, if present, are more widely disseminated and perhaps are not opened. In general, the percentage and thickness of sandstone beds decreases to the northeast with increasing distance from the paleoshoreline, but trends of sandstone thickness are not linear. This play has been traditionally developed with vertical wells. In the last 6 years this play has been revitalized with the advent of horizontal drilling although some wells in the play continue to be drilled vertically.

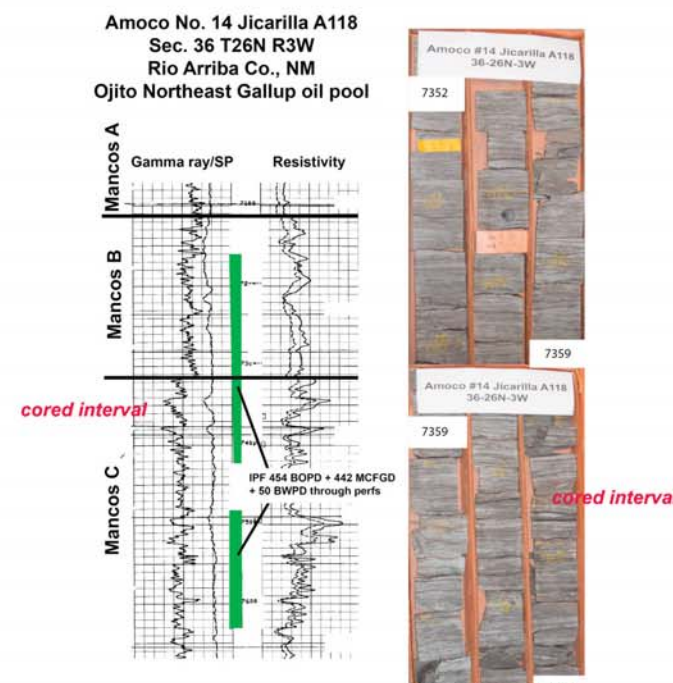
## Offshore Mancos Play

### Proximal facies



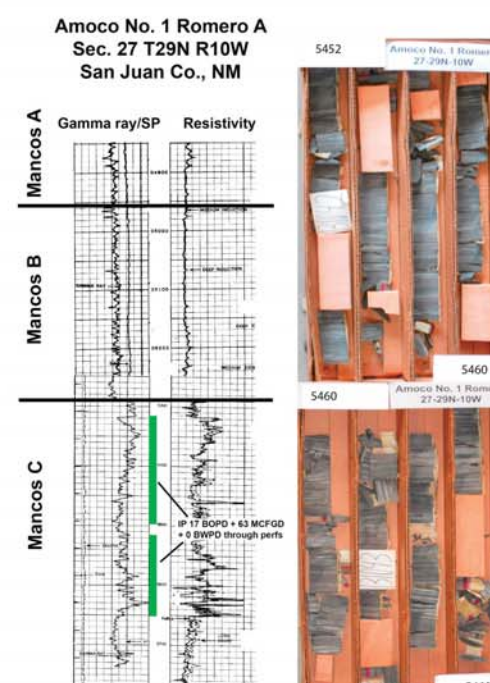
Proximal facies of the Mancos C. Sandstones in the proximal part of the Mancos C often form upward-fining sequences and reservoirs are often intensely bioturbated and are finer grained than the Tocito marine bar reservoirs. The resulting oil pools do not have the well-defined shoestring shape of the Tocito marine bar reservoirs.

### Medial facies



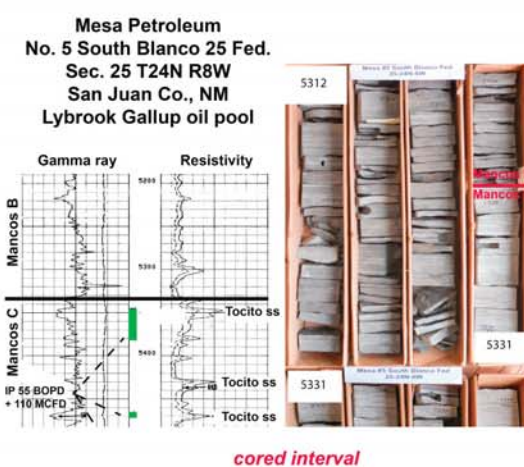
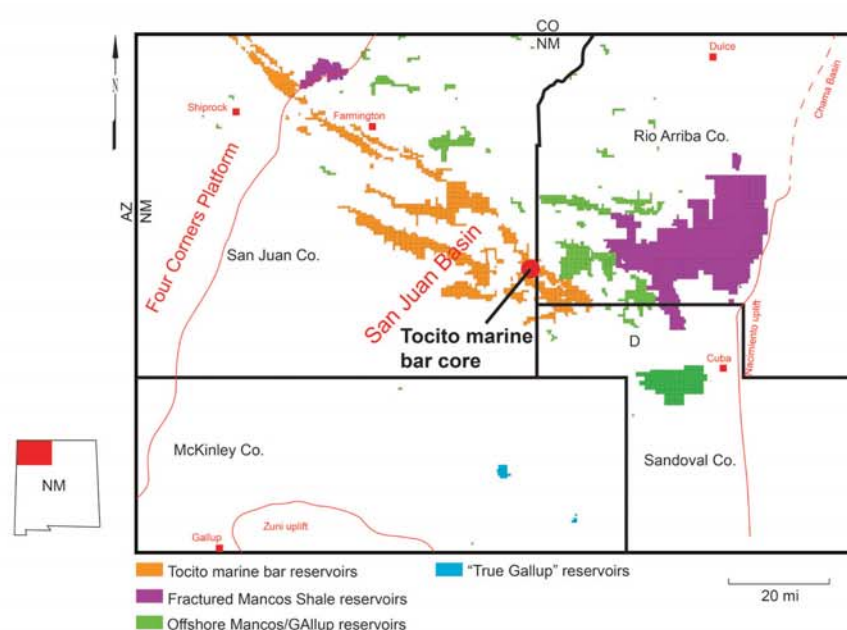
Medial facies of the Mancos C. Reservoir intervals are formed by shales with laminations and thin beds of very fine-grained sandstones and siltstones. Log signatures suggest upward-fining sandstone bodies, but the reservoir zones are dominantly shale. Vertical wells produce large volumes of oil only where natural fractures occur. The shales are not as densely fractured as on the upturned basin margins.

### Distal facies



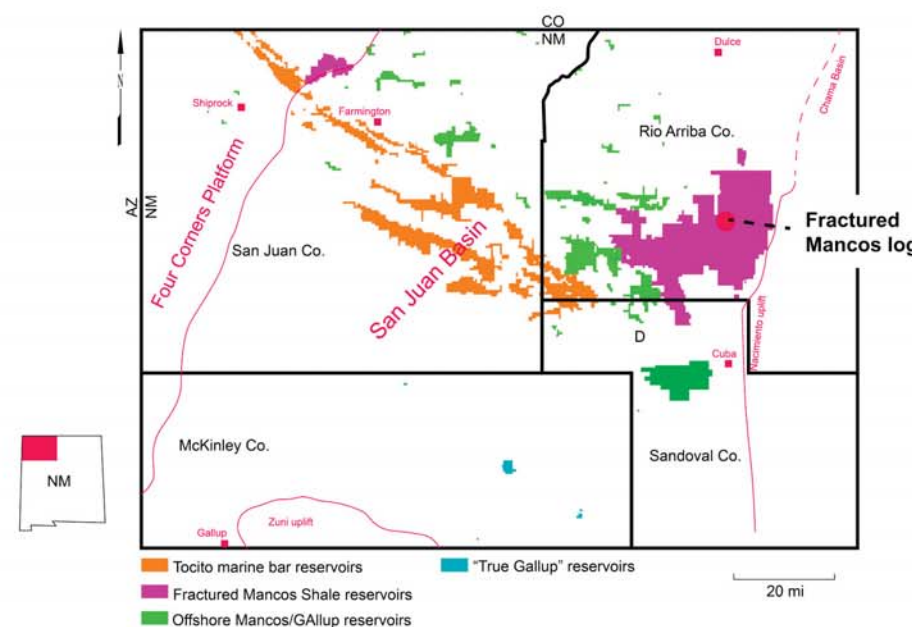
Distal facies of the Mancos C. The distal Mancos C consists mostly of dark-gray, organic-rich marine shales with only minor laminations of siltstones and very fine-grained sandstones. This facies is most effective as a reservoir in the deeper northern part of the basin where it is within the thermogenic gas window.

## Tocito Marine Bar Play

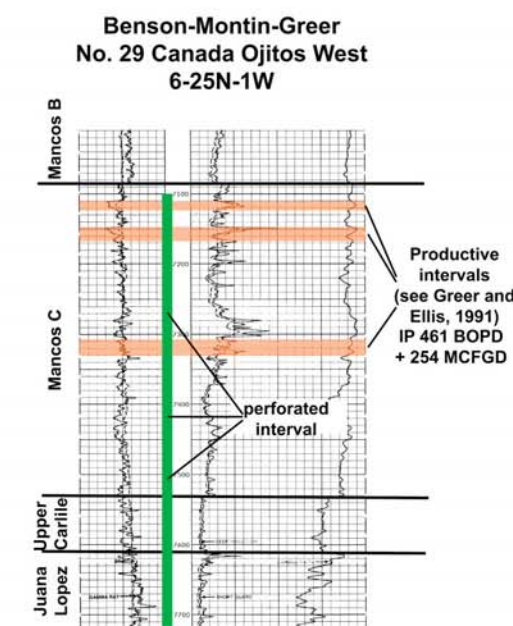


This core through the Tocito marine bar reservoir in the Lybrook "Gallup" oil pool exhibits the fine-to medium-grained sandstones with only minor shale laminae that form the reservoirs. Traps are stratigraphic and the shoestring sandstone bodies are encased in Mancos shales.

## Naturally Fractured Mancos Shale Play



Location of log, shown at right, from Puerto Chiquito Mancos oil pool. This reservoir is heavily fractured and many wells produced large volumes of oil from the Mancos C



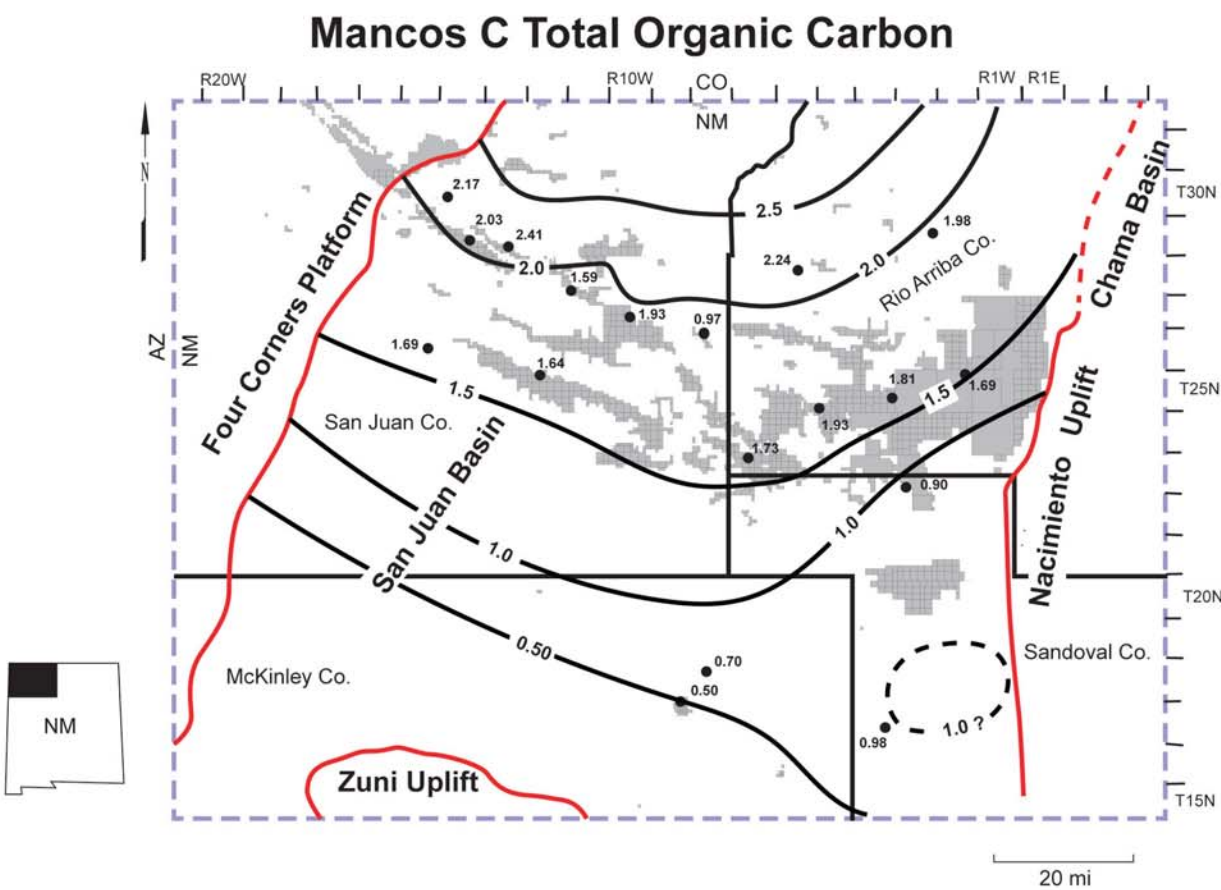
This well log from a productive well in the Puerto Chiquito West oil pool indicates the perforated interval in the well and the primary productive intervals (shown in orange). The reservoirs are formed fractured shales and interlaminated siltstones with seals formed by unfractured nonsilty shales (see Greer and Ellis, 1991).



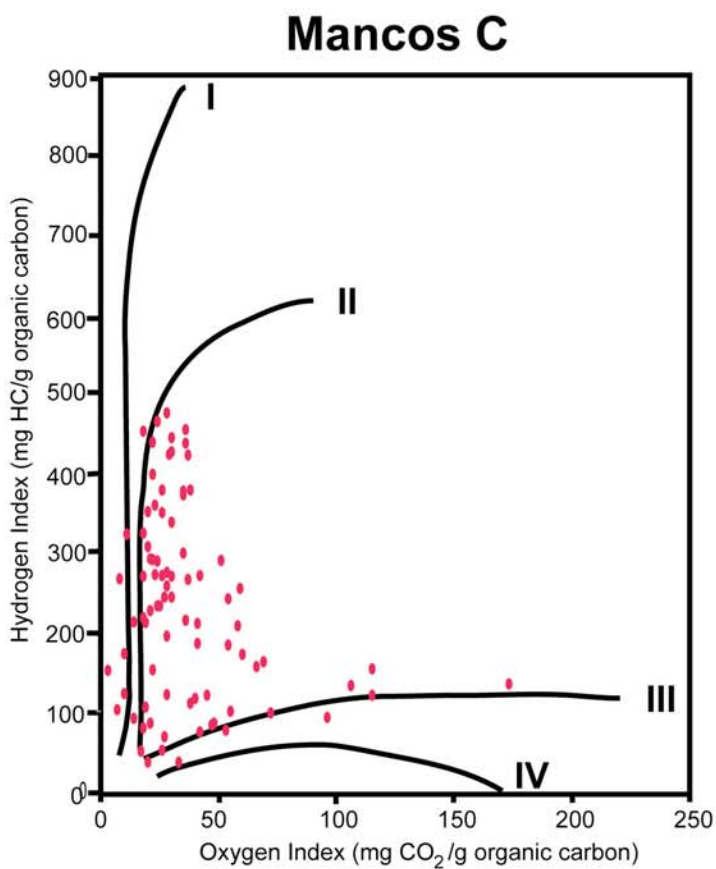
# Upper Mancos Petroleum Source Rocks

The Mancos C does not contain the highest TOC levels, but kerogens are dominantly oil prone, unlike the Mancos A, Mancos B, upper Carlile shale, lower Carlile shale, and the Greenhorn.

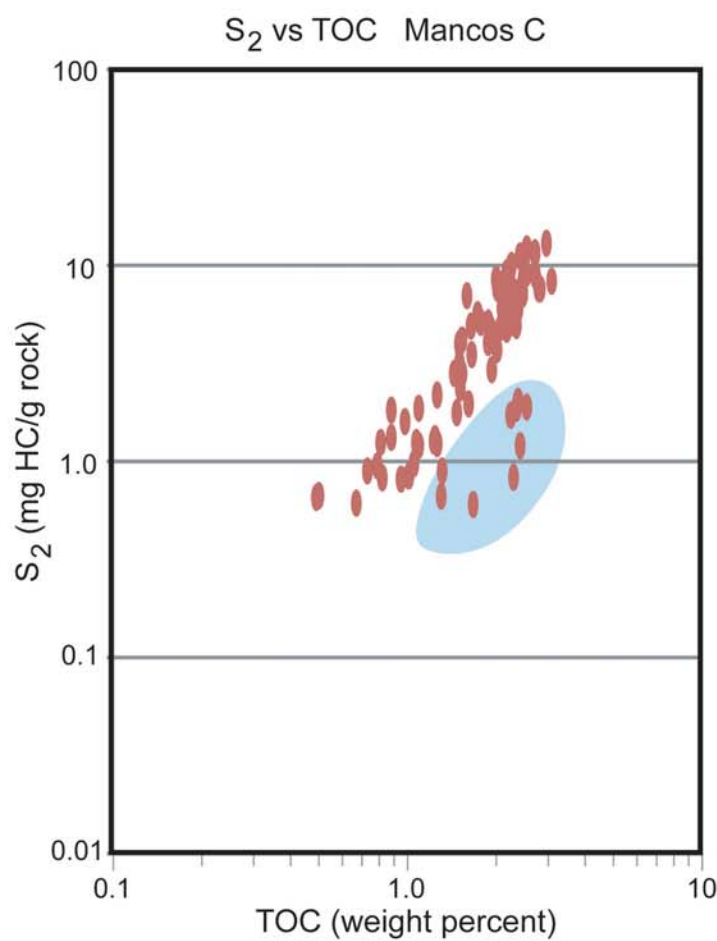
STRATIGRAPHIC UNIT	TOC (average per well)	KEROGEN TYPES	No. of SAMPLES
Mancos A	1.8%	gas prone dominant oil prone inertinite	24
Mancos B	2.0%	oil prone gas prone inertinite	27
Mancos C	1.6%	oil prone dominant gas prone inertinite	122
upper Carlile shale	2.0%	oil prone gas prone inertinite	15
Juana Lopez Member	2.0%	oil prone dominant	13
lower Carlile shale	1.4%	oil prone gas prone	22
Greenhorn Limestone	1.1%	oil prone gas prone inertinite	3
Graneros Shale Member	2.5%	oil prone dominant	2



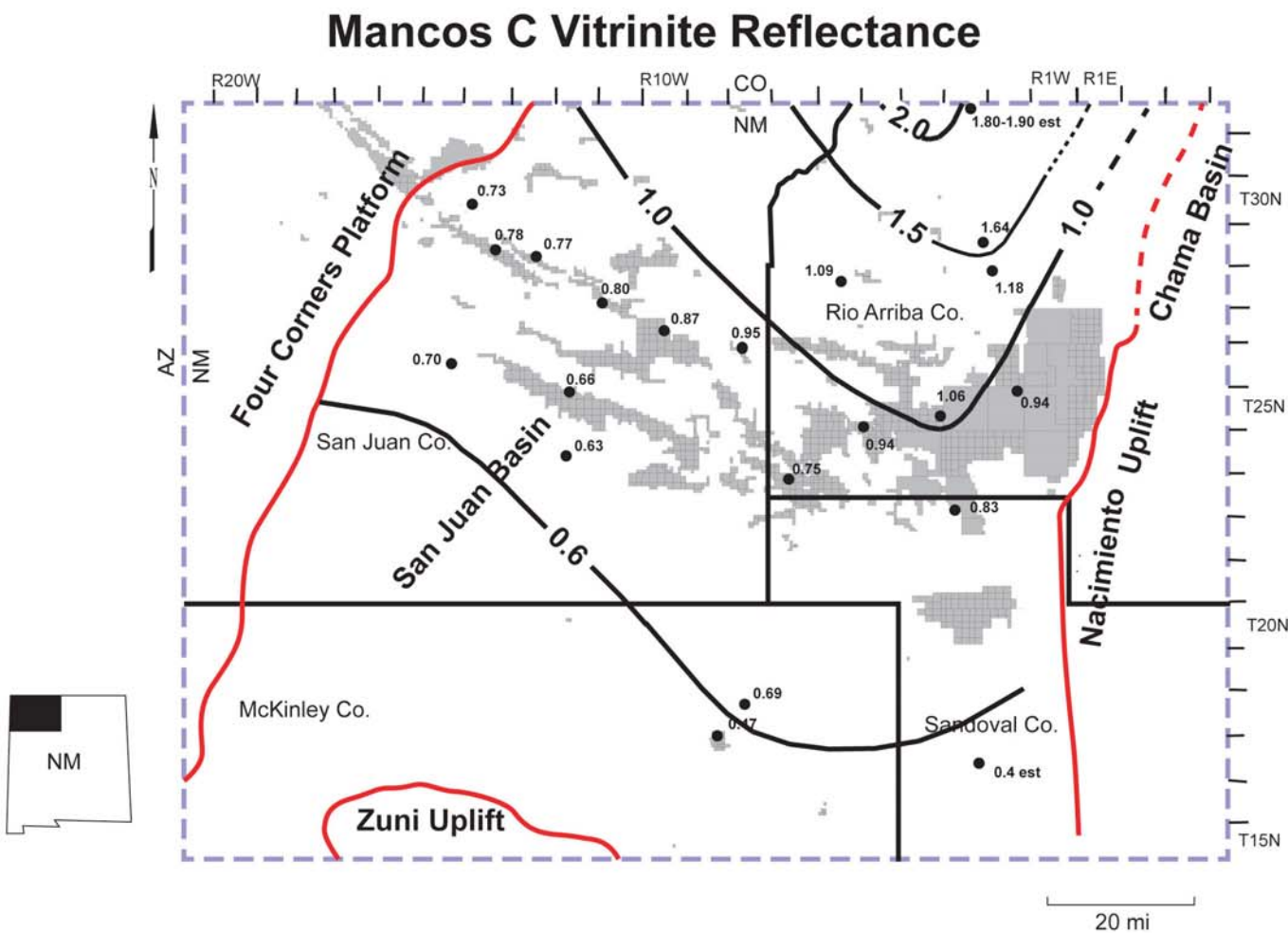
Total organic carbon (TOC) of the Mancos C shales. TOC is between 1 and 2% throughout most of the established productive areas and increases to the north, basinward.



Pseudo-Van Krevelen diagram derived from Rock-Eval data for Mancos C shales in the San Juan Basin. Type II kerogens predominate in most samples.

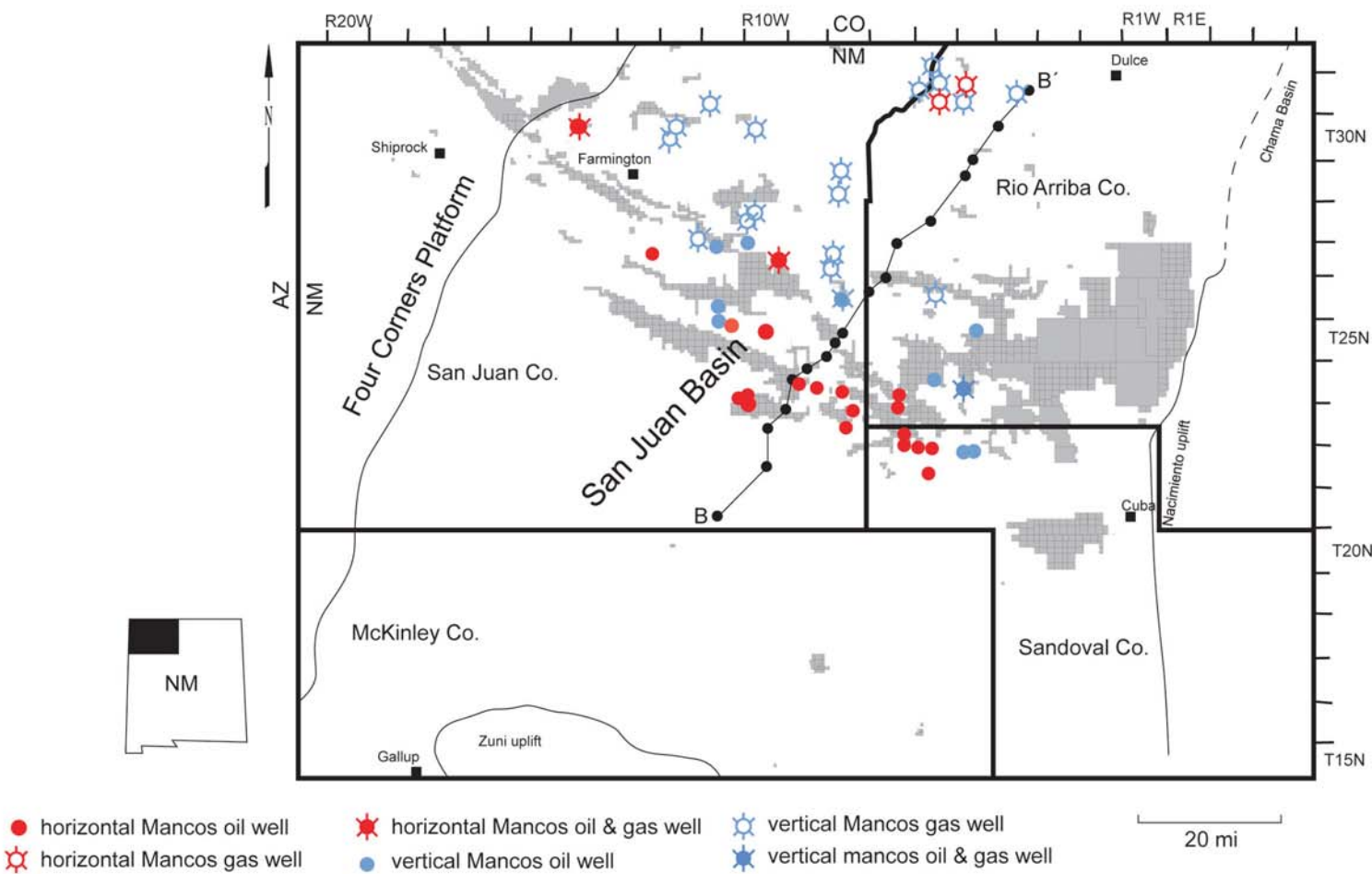


Plot of Rock-Eval S2 vs. Total Organic Carbon (TOC) for Mancos C shales. The samples in the blue region are from the deeper, northern, more thermally mature parts of the basin.

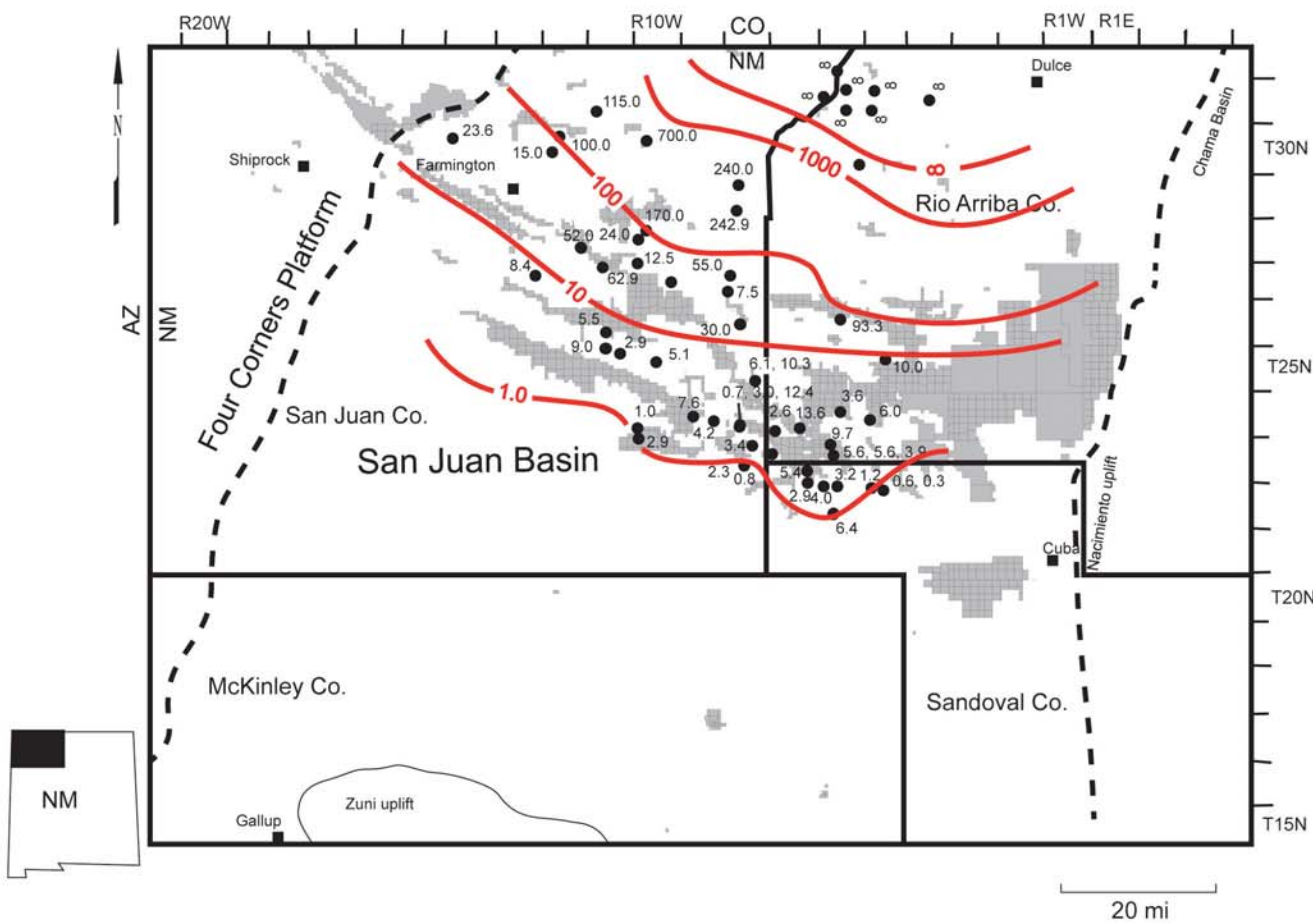


Vitrinite reflectance contours of the Mancos C unit in the San Juan Basin.

# Production and Gas Window



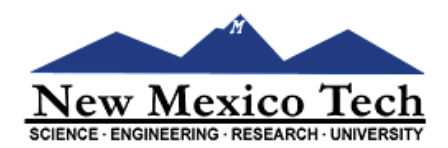
Selected recent Mancos exploratory well. Horizontal wells in red. Vertical wells in blue. Most horizontal wells have a lateral reach of approximately one mile. Gas-productive shale is located to the north and oil-productive shale is located to the south. Average oil production from the oil wells during the first 12 months is 48 MBO (ranging from 8 to 164 MBO) for horizontal wells and 5.1 MBO (ranging from 0.2 to 12 MBO) for vertical wells, rendering the average horizontal well 9.4 times more productive than the average vertical well. All horizontal wells were completed in the Mancos C and most vertical wells were completed in the Mancos C in addition to other units in both Lower Mancos Shale and the Upper Mancos Shale.



Gas-oil ratio of produced fluids for the first 12 months of production from the Mancos exploration wells shown in the figure at the left. The GOR increases to the north as a function of increasing thermal maturity.



# Summary points



1. The Mancos Shale in the San Juan Basin is subdivided into two formations separated by an unconformity, the Lower Mancos Shale and the Upper Mancos Shale.
2. Most historical production and current/recent exploration are in the Mancos C unit of the Upper Mancos Shale. The term "Gallup" is often loosely, and incorrectly, applied to the Mancos C.
3. There are three oil & gas plays in the Upper Mancos/ Mancos C: a) *Tocito marine bar play*, b) *Naturally fractured Mancos shale play*, and c) *Offshore Mancos shale play*. The three plays form a continuum.
4. The Tocito marine bar play is a conventional oil play productive from sandstones in the lower part of the Mancos C. Reservoirs are northwest-southeast-trending shoestring sandstones on the southern flank of the basin.
5. The Naturally fractured Mancos shale play is a conventional oil play located along the northwestern and southeastern flanks of the basin. In these areas, Laramide tectonic uplift turned Upper Cretaceous strata upward and initiated fracturing of siltstones and sandstones in the Mancos C.
6. The Offshore Mancos shale play is located northeast of, or paleo-offshore of, the Tocito marine bars. This is the modern, active unconventional play in the San Juan Basin. Target strata are in the Mancos C unit.
7. The Offshore Mancos shale play extends northeastward from the Tocito marine bars into the deep axial part of the San Juan Basin.
8. From the oil window in the southern part of the basin the play crosses into the wet gas window and finally into the dry gas window in the northern part of the basin.
9. In the southern, oil part of the Offshore Mancos shale play, reservoir intervals are organic-rich marine shales with laminations and very thin beds of very fine-grained sandstones. Percentage and thickness of sandstones decrease toward the northeast with increasing distance from the paleoshoreline.
10. Kerogens are dominantly oil-prone in the Mancos C, with TOC increasing to the northeast.
11. In current/recent exploratory efforts, horizontal wells are more 9.4 times more productive than vertical wells.

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