Geologic Review of the Oil and Gas Potential in the Southern Portion of Chama Basin, North-Central New Mexico: Eastern Rio Arriba County

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ABSTRACT

The objective of this review is to determine the geologic potential for oil and gas occurrence in the southern portion of the Chama Basin specifically in the area where 16 parcels, approximately 13,300 acres, are proposed for leasing by the BLM. The study area is geologically divided into two areas, the southern and northern Chama Basin as the potential occurrence of oil and gas in each is different and they are geologically dissimilar. The southern synclinal area contains some north and northeast mapped faults, while the northern area contains the Archuleta Anticlinorium area where there are numerous northwest and north trending faults and accompanying structures. The southern synclinal area has inadequate exploration well development (only 11), while the northern area with 132 wells reflects the higher level of prospective optimism. Of the 132 wells drilled since 1915, 12 wells have reported production.

Oil and gas traps could occur on the west side of Chama syncline in two different ways: (1) oil could fill fractures in Mancos source rock at points of maximum flexure at the bottom of syncline or (2) where reservoir rocks (Dakota, Morrison and Entrada) are curved upward becoming east dipping against a sealing fault. This conventional play occurs where permeable sands are turned upward by Milagro thrust faulting forming traps which becomes oil filled by thermal cracking of kerogen from within the Chama Basin and are sealed by offsetting impermeable Mancos shale or crystalline basement rock. On the east side of the Chama syncline oil could be contained within natural fractures in west dipping Mancos and Niobrara and also in porous reservoir rocks (Dakota, Morrison and Entrada), which are bent upward becoming west dipping against a sealing fault. Oil filled fractures in source rock reservoirs could also occur in the center of Chama syncline or any small structural feature or folded structure not currently identified by drilling or surface expression in Niobrara or Mancos intervals. It is uncertain if the Southern Chama Basin including the area of potential leasing has ever been thermally mature enough to generate hydrocarbons by either or both sufficient depth of burial or adjacent heat sources. This research found no published geochemical measurements available for the Chama Basin or Archuleta Anticlinorium

The south Chama Basin study area has low potential for oil and gas occurrences because all eleven of the oil and gas test wells there are dryholes with no oil or gas shows and there is a question as to whether any of the potential source rocks (i.e., Mancos and Graneros shale and Todilto limestone) intervals are thermally mature. There is the potential for deeper Pennsylvanian age source rock, but there are few well tests and the potential for oil and gas from these rocks has limited data and is therefore unknown. In addition, the Greenhorn Limestone through Burro Canyon, which includes the Graneros and Dakota, have been tested where present in the south Chama Basin by a large number and areal extent of uranium exploration drill-holes. The presumption is that when these test wells were drilled in the 1970's any significant oil and gas shows would have been reported. In addition, the shallow depth to these intervals provides minimal sealing from leakage of hydrocarbons to the surface.

A rating of moderate for the potential occurrence of oil and gas is recommended for the north study area as it contains a favorable geologic environment for the generation of hydrocarbons similar to the San Juan Sag described by Gries et al (1997) and the geologic processes necessary for development of structural features have provided the trapping mechanism. The north study area and the Approach Prospect are in an area rated as having moderate potential for the occurrence of hydrocarbons as the El Poso Ranch field wells did have minor amounts of production from fractured Greenhorn Limestone, indicating either the presence of mature source rock on western edge of Chama Basin and or hydrocarbons having migrated from known mature rocks of San Juan Basin. There has also been numerous oil shows from test wells in the Mancos shale in the vicinity of Gramps, Chromo and Navajo oil fields in Colorado.

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Geologic Review of the Oil & Gas Potential in the Southern Portion of the Chama Basin, North-Central New Mexico: Eastern Rio Arriba County

OBJECTIVE and STUDY AREA

The objective of this review is to determine the geologic potential for oil and gas occurrence in the southern portion of the Chama Basin, specifically in the area where 16 parcels, approximately 13,300 acres, are proposed for leasing by the BLM (exhibit 1). This review includes adjacent US Forrest Service lands that have also been nominated for leasing in the Canjilon area. The proposed leasing action is restricted to just Federal minerals located beneath BLM, US Forest Service and fee surface lands within the southern Chama Basin.

The study area is geologically divided into two areas, the southern and northern Chama Basin, as the potential occurrence of oil and gas in each is different and they are geologically dissimilar. The southern Chama Basin or Chama syncline is geometrically defined as a large block containing 20 townships (roughly 24 miles east to west) by 22 miles south to north precisely described from 24N to 27N and from 2E to 5E. The northern Chama Basin contains portions of Archuleta Anticlinorium and is geometrically defined as a large block containing 25 townships precisely described from 28N to 32N and from 1E to 5E (exhibit 2). However, because the northern Chama Basin is mostly contained within the Tierra Amarilla land grant and is fee lands, the area is not all under public land survey system and has only been partly surveyed into the system.

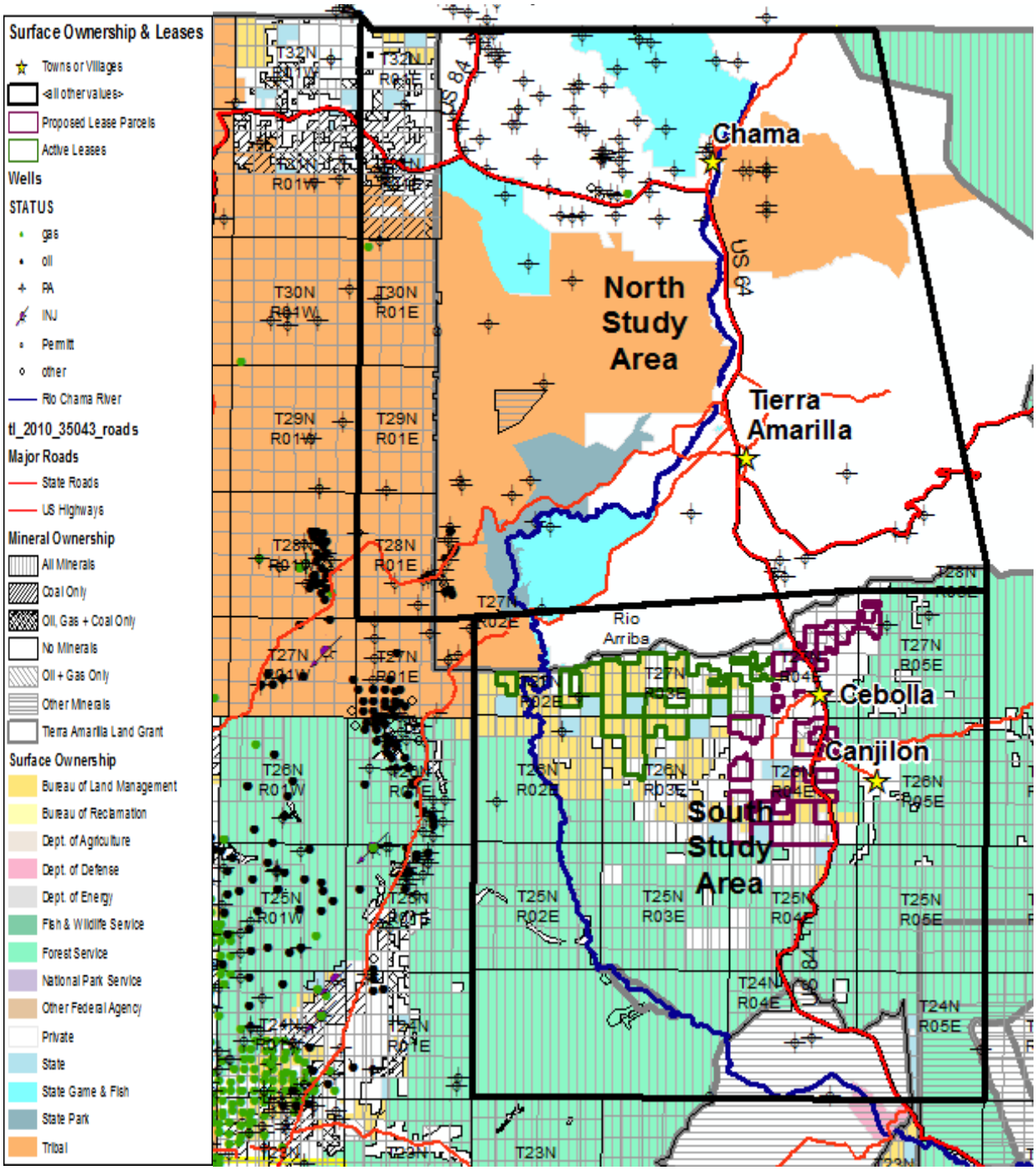
CHAMA BASIN

The southern Chama Basin is located in north central New Mexico and is centered approximately 35 miles south of the Colorado/New Mexico state line. The Chama Basin is within the eastern margin of the geologically stable Colorado Plateau but close to the western boundary of the Rio Grande rift (Shoemaker, 1979).

The Chama Basin is bounded on the west by the sedimentary rocks of the San Juan basin and on the east by the crystalline block faulted, Brazos uplift (or Tusas Mountains). On the south the basin is close to the western boundary of the Rio Grande rift and the widespread Jemez volcanic outpourings (Smith et al, 1961). To the north into Colorado lies the extensive San Juan Volcanic field and the almost entirely concealed sedimentary basin named the San Juan Sag (Gries et al, 1997) (exhibit 3).

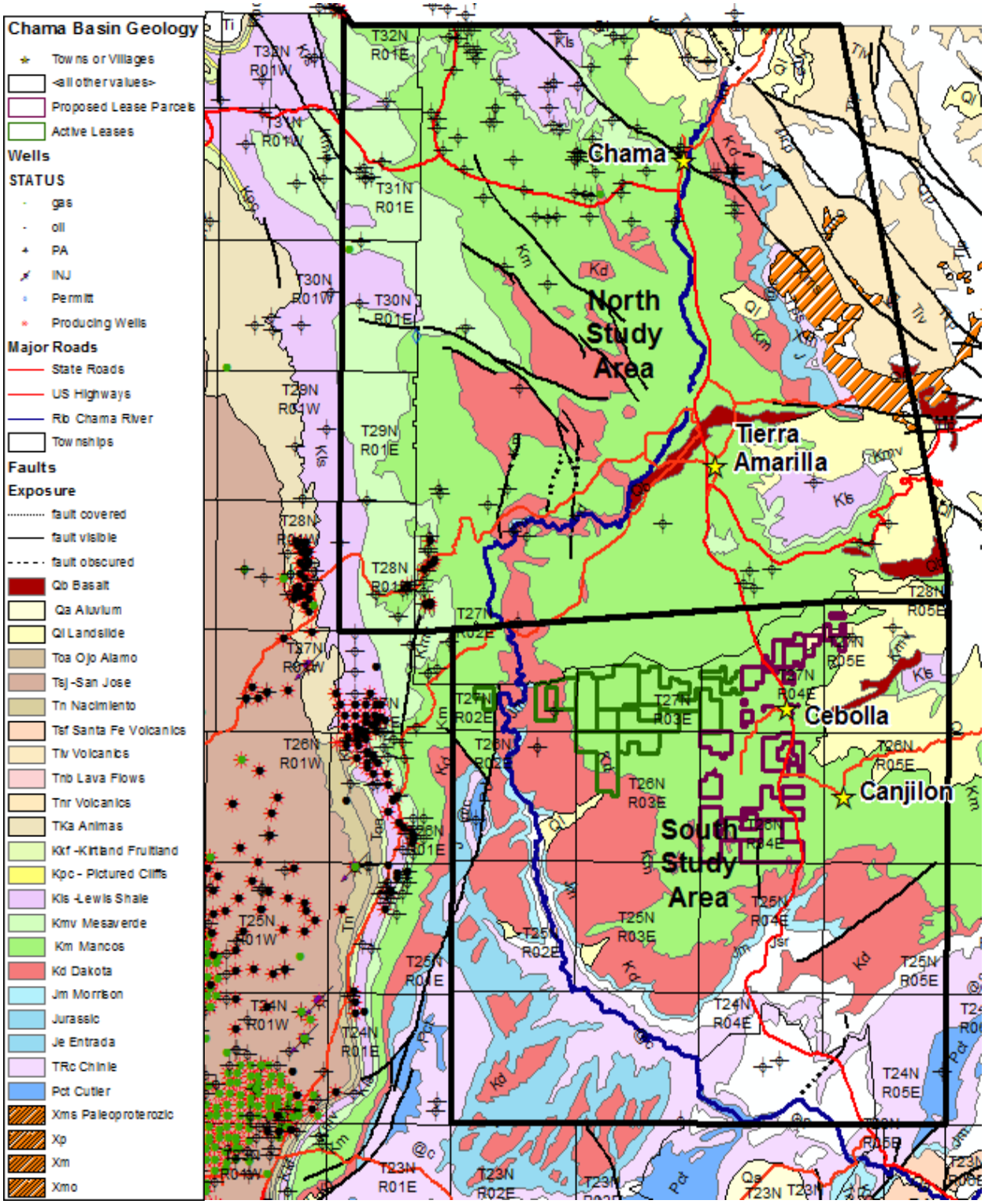
STRUCTURE

The structural feature here identified as the Chama Basin has been generally referred to as a basin, but some have further described it as an embayment, platform, and syncline (Kelly, 1950; Muehlberger et al, 1960; Landis et al, 1974). The Chama Basin has been called a platform by Muehlberger (1960), which separates the San Juan Basin on the west from the Brazos Uplift on the east, and an embayment or basin by Kelly (1950). Muehlberger (1960) further describes the Chama platform as lying between the Archuleta Anticlinorium on the west and the Brazos uplift on the east. The Chama Basin has been labelled by Budding et al (1961) as a shallow basinal structure merging to the west/northwest with the much larger San Juan Basin. Although the Chama Basin has the configuration of a shallow syncline, it is structurally considerably higher than the San Juan Basin (Baltz, 1967).



NORTH and SOUTH STUDY AREAS

Exhibit 1. Ownership Map of showing location of 16 parcels in red proposed for leasing near the villages of Cebolla and Canjilon. Also identified are the North and South Chama Basin Study Areas boundaries with the surface and mineral ownership colored and lined.



GEOLOGIC MAP with WELLS & FAULTS

Exhibit 2. Geologic Map of showing location of 16 parcels proposed for leasing near the villages of Cebolla and Canjilon. Also identified are the North and South Chama Basin Study Areas boundaries. Note extent of green colored Mancos Km and red Dakota Kd formations.

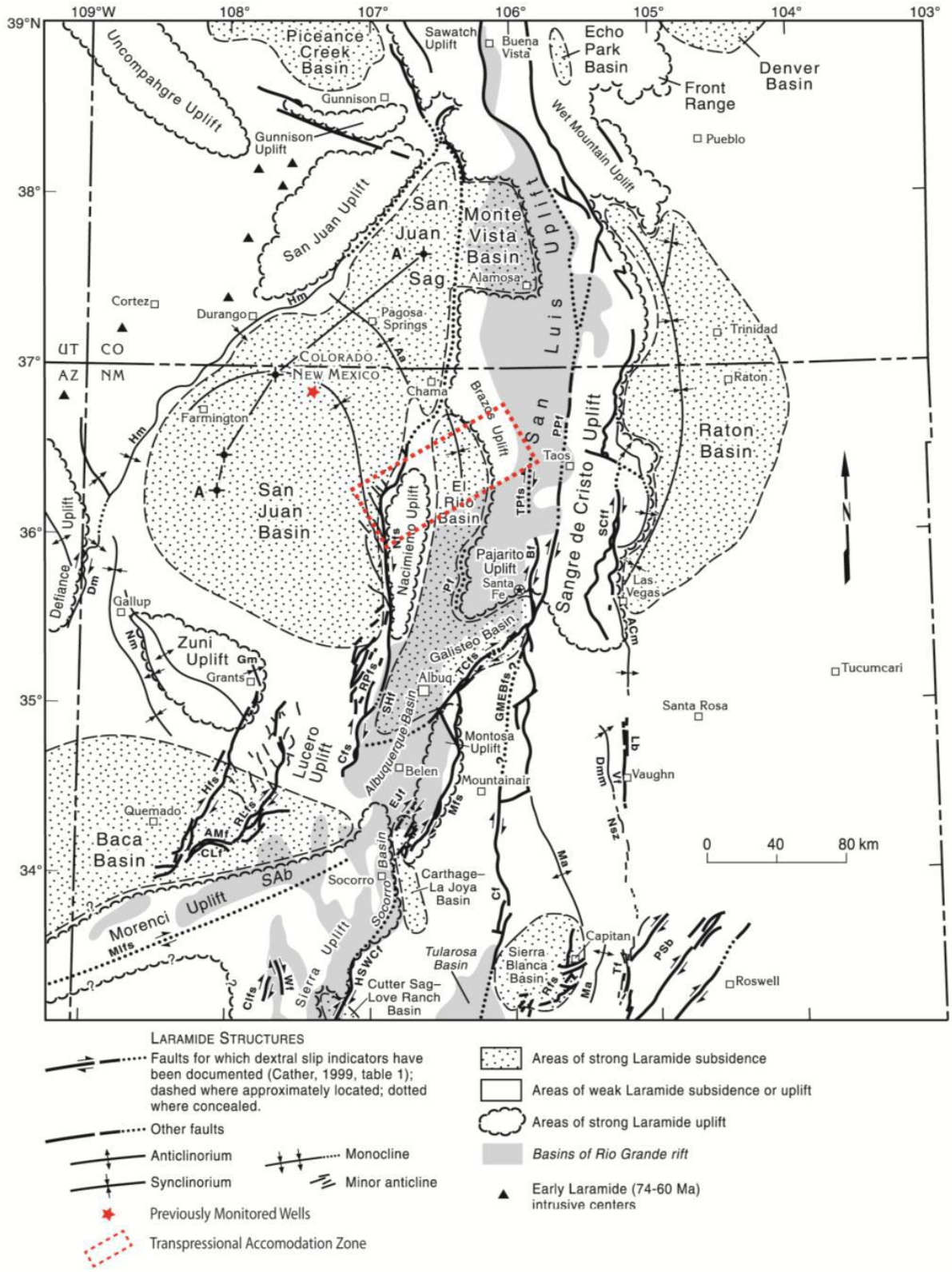


Exhibit 3: Structural map identifying features of north-central New Mexico showing Laramide-age uplifts, basins and faults (Modified after Cather, 2003).

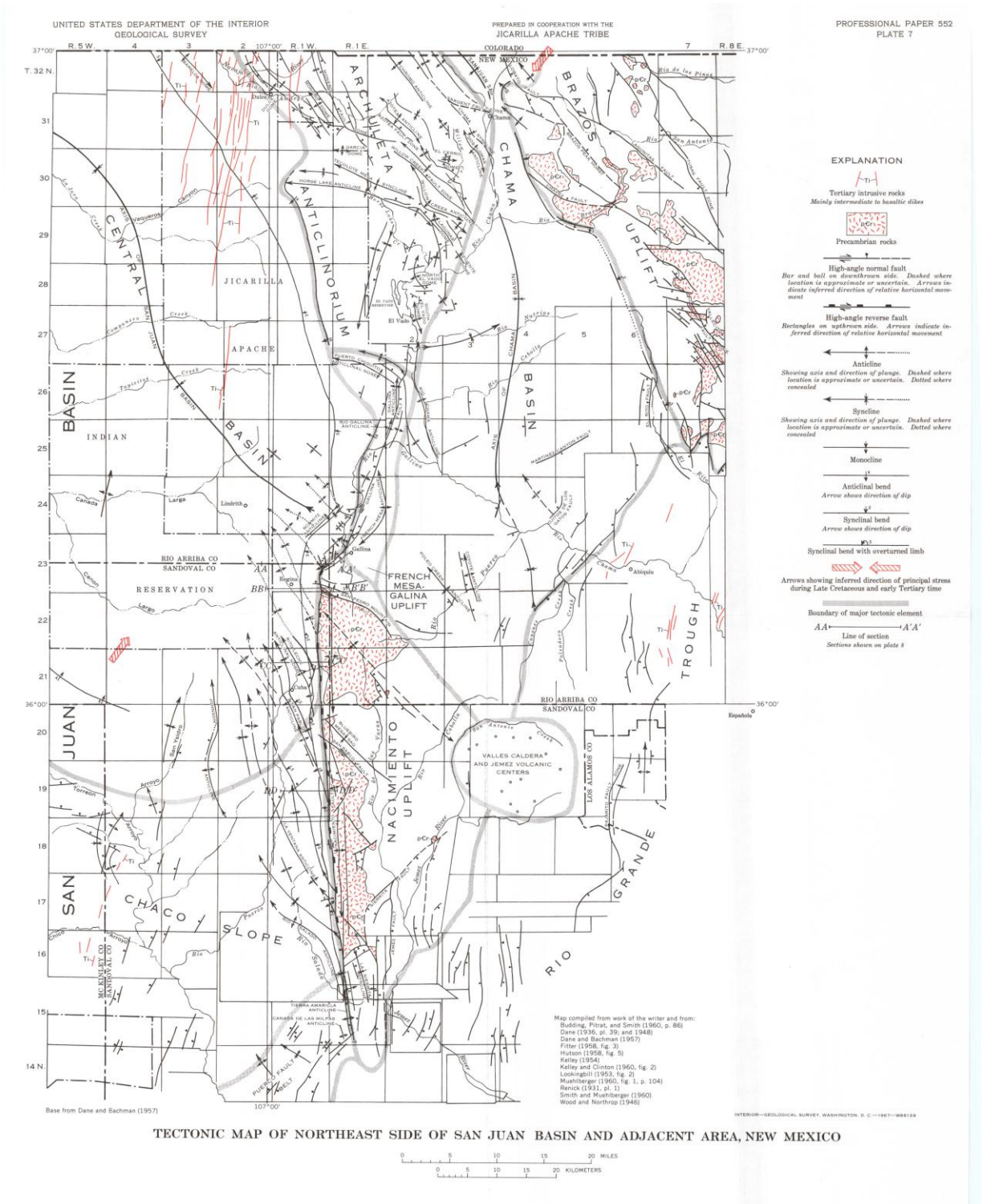


Exhibit 4: Structural Map identifying features of north-central New Mexico showing Laramide-age Brazos uplift, Chama and San Juan Basins, and boundaries of major tectonic elements (Baltz, 1967). Located northwest of the Chama Basin are several mostly northwest trending but some with north trending anticlines, synclines and faults of the Archuleta Anticlinorium.

Baltz (1967) describes the Archuleta Anticlinorium as probably originating as an intra-basinal arch in a large late Cretaceous structural and sedimentary basin. Two of the principle features, the Horse Lake and Willow Creek anticlines, suggest that the southeastern part of the anticlinorium originated as a broad elongate dome that was up-warped and then deformed into an anticlinorium by northeast oriented Laramide compressional forces (see red arrows on Exhibit 4).

Past Exploration

As Robert A. Bieberman (1960) has pointed out in his paper "Exploration for Oil and Gas in the Chama Basin" the search started in southern Colorado south of Pagosa Springs on the Little Blanco River as early as 1901 with the drilling of a well by B. T. Smith which produced a small quantity of oil. This early focus was related to an oil seep on the Navajo River and near the structurally visible Chromo anticline which is located just north of the Colorado/New Mexico state line.

Gramps Field

Located adjacent to the study area and just across the state line, the first major discovery in the area was made in 1935 with a well drilled to the Dakota sandstone on the Price anticline 3.5 miles north of the oil seep on the Navajo River. The well was completed as the discovery for the Price Gramps Field and it is unknown what this well ultimately produced but records indicate that from its start and through July of 1996 the Price Gramps Field total production was over 6.8 million barrels of oil (bo) (see field production graph below cumulative oil and water (IHS,2014)). It is because of this kind of total oil volumes that the search for other areas with similar geologic characteristics in a nearby setting is being pursued.

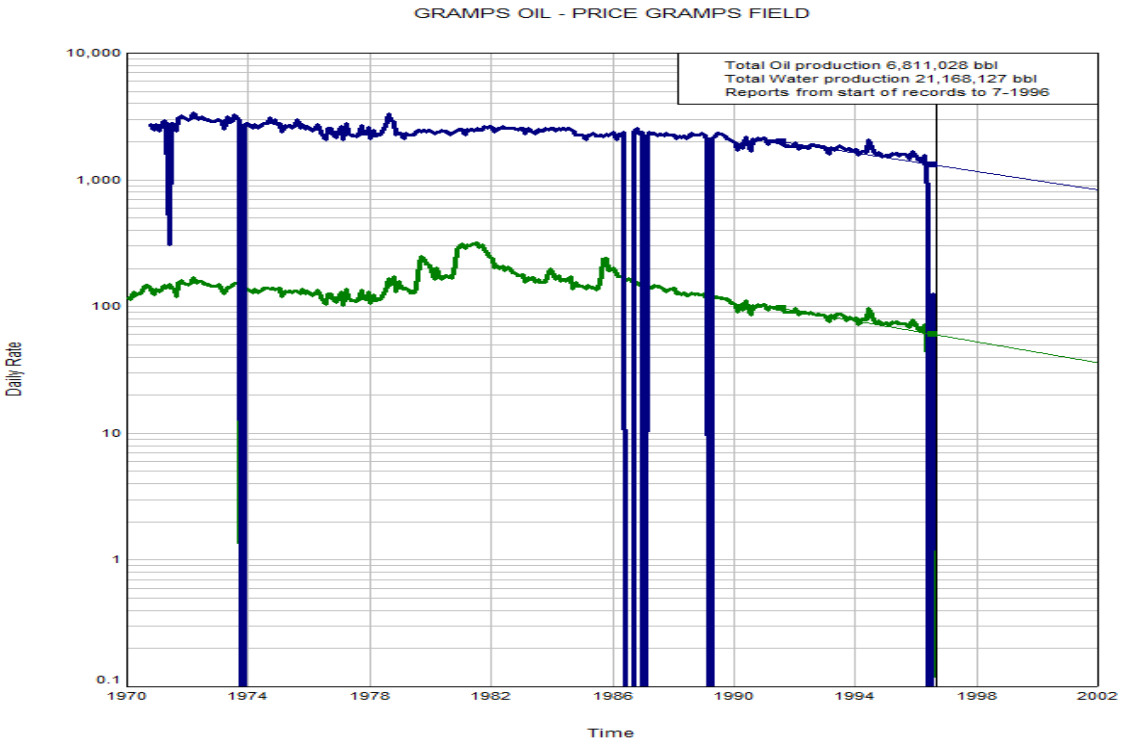


Exhibit 5: Above is a Rate versus Time Decline Graph for Price Gramps oil Field with cumulative production of 6.8 million barrels oil from it discovery to July of 1996.

Chromo Field

In 1947 the next significant oil discovery in the area took place just north of the state line in Colorado on the Chromo anticline which is easily accessible because US highway 85 passes through this boldly visible structure in the Navajo River Valley. Although several test wells have penetrated deeper formations in the Chromo Field, it only produces oil from the lower 1,000 ft. of the Mancos shale, an interval described as the El Vado member of the Mancos (Osterhoudt, 1978, and Wengerd and Gill, 1952).

The Chromo Field is small in size being contained within 140 acres on the southwest flank of the much larger Chromo anticline, which is about 11 miles long and 4 to 5 miles wide. The depth of oil in the Chromo field is from 400-700 ft. and from fractures in the Mancos shale as the deeper Dakota has been tested and is water wet (Bieberman, 1960). Bieberman further documents that 21 test wells had been drilled between the discovery of Gramps field in 1935 and the discovery of Chromo Field in 1947 and all of them were dry. This research will attempt to take Bieberman's efforts at describing the oil and gas potential of the Chama Basin forward to the present.

Modern Age of Chama Basin Exploration

For the purpose of defining the potential for oil and gas development of the Chama Basin, the area will be divided into two separate and distinct areas. In Baltz's USGS paper (1967), a tectonic map (exhibit 4) details the difference between the southern part of the Chama Basin and the northern part, by the amount of structural features present.

The southern synclinal area contains some north and northeast mapped faults, while the northern area named the Archuleta Anticlinorium area contains numerous northwest and north trending faults and accompanying structures. The southern synclinal has inadequate exploration well development (only 11) and while the northern area with 132 wells reflects the higher level of prospective optimism. Of the 132 wells drilled since 1915, 12 wells have reported production.

The following well data, specifically the well count along with formations penetrated and total depth, comes primarily from IHS Energy's well and production data bases with the use of PETRA software but also other sources such as Go-Tech production data and NMOCD online website were used. PETRA software was also used to construct four cross sections A-A', B-B', C-C' and D-D'.

Southern Chama Basin Wells

The southern Chama Basin or Chama Syncline is geometrically defined as a large block containing 20 townships precisely described from 24N to 28N and from 2E to 5E. Within this area there have been only 11 wells drilled with 9 of them drilled early on from 1943 to 1962 (see table 1 below). The southern portion of the Chama Basin is also the area that contains the 16 parcels proposed for leasing.

Well Name	#	Spud Date	Location	Footage	Prod Status	Statu s	Form At TD	TD	Operator Name	API#	Well Logs Available
Nutrius Prospect	1	10/11/2011	27N 2E 35	500 FNL 335 FEL	dryhole	D&A	Chinle	3800	Blue Dolphin Pro LLC	3003931018	Yes
Cebolla water well	2	2/5/2001	27N 4E 13 NW/4	2640 FNL 2640 FWL	water	Prod	Todilto	2450	Cebolla water conser	water well	Yes
Onoin Mountain	2	11/12/1962	27N 5E 10 C NE NW	660 FNL 1980 FWL	dryhole	D&A	Mancos	1250	Bayless Robert L LLC	3003907151	No
Onoin Mountain	1	10/18/1961	27N 5E 8 NE SW	1980 FSL 2110 FWL	dryhole	D&A	Dakota	1651	Bayless Robert L LLC	3003982358	No
Ghost	2	12/1/1959	24N 4E 22 SW NW	1980 FNL 810 FWL	dryhole	D&A	Unknown	800	Storms Jim	3003905408	No
Ghost	1	8/1/1959	24N 4E 22 C NE NE	660 FNL 660 FEL	dryhole	D&A	Unknown	2380	Storms Jim	3003905426	No
Salazar P	1	10/19/1955	23N 3E 1 SE	1980 FSL 660 FEL	dryhole	D&A	Unknown	1731	Watson J T	3003905155	No
Pack	1	10/29/1954	24N 4E 35 NE SW SE	830 FSL 1340 FEL	dryhole	D&A	Granite	4205	Watson J T	3003905215	No
Silver	1	12/5/1952	26N 2E 20 SE SW SW	330 FSL 990 FWL	dryhole	D&A	Unknown	2675	Hall E A	3003906355	No
Morton	1	2/17/1952	24N 5E 24 NE NE SE	2310 FSL 330 FEL	dryhole	D&A	Granite	2160	Lowry ETAL	3003905002	No
El Vado	1	8/24/1943	27N 2E 3 SE SW SW	330 FSL 990 FWL	dryhole	D&A	Unknown	2009	Phillips Petrlm CO	3003960065	No

Table 1: A total of 11 test wells were drilled in southern Chama Basin with none producing (IHS, 2014).

The Nutrias Prospect #1 well was drilled by Blue Dolphin LLC in 2011 as a dryhole with no shows of hydrocarbons. This test well provides the most information on potential for oil and gas development in the southern Chama Basin because of its location and the use of modern petrophysical well logging services. The well was drilled and well logs ran to a total depth of 3800 ft.to test the Entrada sandstone, which in this area is 300 ft. thick and known to be productive in the southern San Juan Basin on the Chaco Slope. The closest oil production to this test well is from the Mancos shale in the East Puerto Chiquito Field located approximately 7 miles to the southwest on the west dipping monoclinal structure, which forms the eastern edge of the San Juan Basin. There is also minor oil production from nine wells from the Greenhorn member of the Mancos formation approximately 10 miles to the northwest on the El Poso Ranch, but none of these wells ever had individual cumulative production over 550 bo. In a personal conversation with Richard Dolecek (Dolecek, 2013), consulting geologist for Blue Dolphin, the operator of the lease said the Nutrius Prospect #1 was “The driest well he has ever seen!”

Included on this list with oil and gas test wells is the Cebolla Mutual Domestic water well drilled into the Todilto formation in 2001 to a total depth of 2610 ft. but plugged back and perforated into the water producing Burro Canyon from 1,800 to 1,850 ft. and Brushy Basin member of the Morrison formation from 1,914 to 1,924 ft. and from 1,942 to 1,951 ft. (See cross section B-B’ C-C’ and D-D’ noting red rectangles identifying water producing intervals that were perforated.) The Cebolla water well is defined as a good well, both in water quantity with an estimated production rate of 100 gpm and quality having a PH close to neutral and having low alkalinity, total dissolved solids and hardness (Souder, Miller & Associates, 2001). Souder, Miller & Associates further describes through step tests and productions tests that the primary aquifer, the Burro Canyon, is leaky confined and has a transmissivity between 10-100 ft^2/day (Souder, Miller and Associates, 2000). This type of water production describes the Burro Canyon/Brushy Basin reservoir of large lateral extent, being roughly 30 by 40 miles and extending northward from outcrops along the southern edge of the basin and around the west side of the basin with dramatic outcrops in the Ghost Ranch area and Chama River gorge. The recharge area is present along the structurally higher east side of the basin, in the Brazos uplift or Tusas mountains.

The Onion Mountain #1 and #2 were rank wildcat wells drilled by R.L. Bayless, a later well-known San Juan Basin operator from Farmington, NM, in 1962 with the intent of testing the Mancos/Dakota. The

Onion #1 well was drilled to total depth of 1,651 ft. and recorded the top of the Dakota at 1,622 ft. The Onion #2 well was drilled to total depth of 1,200 ft. where the bit was left stuck in the swelling clays of the Mancos shale. Both of the wells were then plugged and abandoned and 3 ft. dry-hole markers were placed in the holes. These wells reported no shows of hydrocarbons and were not logged with petro-physical tools, so no comparison could be made.

The remaining seven wells on the above list were drilled prior to December 1959 and are located south of the Dakota/Burro Canyon/Entrada escarpment and so would only evaluate older Pennsylvanian/ Permian strata. The seven dry hole tests have no well logs and very little other information (IHS, 2014).

Northern Chama Basin Wells

The northern Chama Basin (NM portion only) encompasses a portion of the Archuleta Anticlinorium and several other northwest trending structural features and their associated faults such as Horse Lake, Willow Creek, Azotea, Chromo Anticlines as well as the North El Vado Dome.

The northern Chama Basin is geometrically defined as a large block containing 16 townships precisely described from 29N to 32N and from 2E to 5E (exhibits 1 & 2). Within this area there have been 132 wells drilled with 12 of them having reported oil production as is noted by the presence of a capital P in the status column (see table 2 below).

Table 2. Total of 132 test wells were drilled in Northern Chama Basin Study Area (IHS, 2014).

Well Name	Well #	Spud Date	Location	Footage	Prod Status	Final Status	Formation At TD	TD	Operator Name	UWI or API#	Log TD
GOMEZ CELSO	3	2007-06-16	32N 1E 25 SE NE NW	845 FNL 2110 FWL		D&A	ENTRADA	2754	LONE WOLF NEW MEXICO	30039299890000	2767
GOODING	2	2007-06-15	32N 2E 30 NW SE SE	1960 FSL 2540 FEL		D&A	ENTRADA	2107	LONE WOLF NEW MEXICO	30039299900000	2118
GOMEZ CELSO	2	2006-06-15	32N 2E 31 SE NE NE	1300 FNL 200 FEL		D&A	ENTRADA	2213	LONE WOLF NEW MEXICO	30039297550000	2002
GOODING	1	2006-03-08	32N 2E 29 NW SW SW	1100 FSL 300 FWL		D&A	ENTRADA	2084	LONE WOLF NEW MEXICO	30039297540000	2084
EL POSO	4	2005-11-28	28N 1E 14 NW NE NW	530 FNL 1765 FWL	P	OIL	GRANEROS	1709	BLUE DOLPHIN PRO LLC	30039295860000	
EL POSO	7	2005-11-21	28N 1E 26 SW SW NW	2130 FNL 620 FWL	P	OIL	GRANEROS	1883	BLUE DOLPHIN PRO LLC	30039295870000	
EL POSO	3	2005-11-20	28N 1E 11 SE SE SW	480 FSL 2105 FWL	P	OIL	GRANEROS	1731	BLUE DOLPHIN PRO LLC	30039295880000	
GOMEZ CELSO	1	2005-10-15	32N 2E 19 SE SE SW	600 FSL 2600 FWL		D&A	DAKOTA	1447	LONE WOLF NEW MEXICO	30039295380000	
EL POSO	5	2005-10-03	28N 1E 23 NE NW NW	550 FNL 955 FWL	P	OIL	GRANEROS	1805	BLUE DOLPHIN PRO LLC	30039295850000	
EL POSO	6	2005-09-25	28N 1E 22 W2 SE SE	660 FSL 970 FEL	P	OIL	GRANEROS	1995	BLUE DOLPHIN PRO LLC	30039295820000	
EL POSO	1	2005-03-14	28N 2E 8 SE	2000 FSL 1450 FEL		D&A	ENTRADA	1564	BLUE DOLPHIN PRO LLC	30039292060000	NL
EL PASO	2	2004-10-28	29N 1E 35 NE SE NE	1500 FNL 450 FEL		D&A	DAKOTA	1194	BLUE DOLPHIN PRO LLC	30039292050000	
FANT R	1	2000-05-18	31N 2E 24 NE SW SE	990 FSL 1650 FEL		D&A	MORRISON	987	INTER-CONT ENERGY	30039264360000	
GARCIA	1R	1998-12-07	31N 2E 24 SE NE SE	1800 FSL 350 FEL		D&A	DAKOTA	506	THOMAS O&G CO	30039259290000	
GARCIA	4	1998-10-10	31N 2E 24 SE SE	1200 FSL 925 FEL		D&AW	DAKOTA	1010	PUFF TOM	30039255870001	
GARCIA	1	1998-07-08	31N 2E 24	1800 FSL 300 FEL		J&AW	DAKOTA	460	PUFF TOM	30039251290001	
SUNTEX	3	1997-09-15	28N 1E 14 NW SE NW	1858 FNL 1800 FWL		D&A	DAKOTA	1660	CHUZA OPERATING	30039232760000	
SUNTEX	2	1997-09-12	28N 1E 22 E2 SE SE	660 FSL 365 FEL		D&A	DAKOTA	1974	CHUZA OPERATING	30039230700000	
GONZALES 18	1	1997-08-03	31N 2E 18 C SW SW	660 FSL 660 FWL		D&A	MANCOS	1380	SPUR OIL CO INC	30039238050000	940
GONZALES	1	1997-08-01	31N 1E 13 SE NE SE	1650 FSL 330 FEL		D&A	DAKOTA	1445	SPUR OIL CO INC	30039240810000	
GARCIA RANCH	4	1996-09-01	31N 2E 24 SE SE	1200 FSL 925 FEL		D&A	MORRISON	1010	DURKEE E F & ASSOC	30039255870000	1017
GONZALES	1	1996-08-14	32N 2E 30 SE SE	350 FSL 1090 FEL		D&A	ENTRADA	2606	THOMPSON ENGR & PROD	30039255850000	
Quinlan Ranch	Q4-1	1994-08-08	31N 3E 19 NW SW	2475 FSL 495 FWL		D&A	MORRISON	771	DEKA EXPL INC	30039252850000	771
Quinlan Ranch	Q2-2	1994-08-03	31N 2E 1 SE SE NE	3100 FSL 330 FEL		D&A	GREENHORN	2469	DEKA EXPL INC	30039251890000	2460
Quinlan Ranch	Q2-1	1994-08-01	32N 2E 23 SE NE	1700 FNL 340 FEL		D&A	MORRISON	2450	DEKA EXPL INC	30039251920000	2410
PHOENIX	1		27N 1E 28 SW SE	240 FSL 1680 FWL		D&A	ENTRADA	3871	AMERICAN HUNTER	3003925357	3871
JOE GARCIA	1	1993-08-29	31N 2E 13 SW SW NW	2970 FSL 350 FWL		D&A-O	DAKOTA	980	SANTA FE SOUTHERN CO	30039252900000	
GONZALES 2A	3	1993-05-06	31N 1E 2 SE SW NE	2310 FNL 1830 FEL		D&A	GRANITE	2232	OEXCO INCORPORATED	30039252150000	2226
GARCIA	A-1	1992-11-19	31N 2E 24	1800 FSL 300 FEL		D&A	DAKOTA	500	DEKA EXPL INC	30039251290000	
GARCIA A-2	2	1992-09-08	31N 2E 24 SE SE NE	2200 FNL 500 FEL		D&A-O	MORRISON	968	DEKA EXPL INC	30039251900000	965
RIO CHAMA	2	1990-09-24	30N 3E 2 NE NW SE	2150 FSL 1525 FEL		D&A	UNKNOWN	362	HEYSE OIL INC	30039246220000	
Quinlin 29	1	1990-07-09	32N 3E 29 NW NE			D&AW	ENTRADA	3865	SPUR OIL CO INC	30039221350001	
RIO CHAMA	1	1989-01-20	30N 3E 2 NE NW SE	2200 FSL 1525 FEL		D&A	UNKNOWN	660	HEYSE OIL INC	30039243430000	

Well Name	Well #	Spud Date	Location	Footage	Prod Status	Final Status	Formation At TD	TD	Operator Name	UWI or Apl #	Log TD
HILL RANCH	1	1987-12-23	31N 3E 28 C SW SW	660 FSL 660 FWL		D&A	ENTRADA	1223	CAMBERM & ASSOC O&G	30039241820000	
SUNTEX	1	1987-12-01	28N 1E 26 NW SW NW	1824 FNL 570 FWL		TA	DAKOTA	2000	SUNTEX ENERGY CORP	30039230710000	
SUNTEX	4	1987-03-20	28N 1E 23 SW NE NW	935 FNL 1650 FWL		D&A	DAKOTA	1769	SUNTEX ENERGY CORP	30039232770000	
SAMANTHA	1	1986-10-26	28N 1E 26 SE NW SW	1580 FSL 1202 FWL	P	OIL	GREENHORN	1730	ALANA OIL & GAS CORP	30039234420000	
SAMANTHA	2	1986-10-21	28N 1E 26 NE NE SW	1985 FSL 2290 FWL	P	OIL	GREENHORN	1788	ALANA OIL & GAS CORP	30039234440000	
SAMANTHA	3	1986-09-14	28N 1E 26 NE SE SW	1105 FSL 2490 FWL	P	OIL	GREENHORN	1778	ALANA OIL & GAS CORP	30039234460000	
Quinlan Ranch	1	1986-08-14	32N 2E 23 NE SW SE	1200 FSL 1700 FEL		D&A	DAKOTA	2430	S & L RESOURCES INC	30039240580000	
El Poso Ranch	7	1985-05-28	28N 1E 14 NW SW SE	990 FSL 2310 FEL	P	OIL	GREENHORN	1464	TEXAS ROSE PET INC	30039236730000	
El Poso Ranch	3	1984-12-23	28N 1E 11 NE SE SW	967 FSL 2148 FWL	P	OIL	GREENHORN	1710	TEXAS ROSE PET INC	30039236690000	
El Poso Ranch	1	1984-12-18	28N 1E 14 SE NW SE	1824 FSL 1778 FEL	P	OIL	GREENHORN	1630	TEXAS ROSE PET INC	30039236700000	
El Poso Ranch	2	1984-12-04	28N 1E 14 SE SE SW	618 FSL 2418 FWL	P	OIL	GREENHORN	1710	TEXAS ROSE PET INC	30039236720000	
MADDOX W A	5	1983-09-05	28N 1E 11 NE NE SW	2004 FSL 2310 FWL		D&A	UNKNOWN	40	SUNTEX ENERGY CORP	30039232750000	
MADDOX W A	6	1983-09-05	28N 1E 23 C NW SW	1980 FSL 660 FWL		D&A	UNKNOWN	82	SUNTEX ENERGY CORP	30039232780000	
El Poso Ranch	1	1983-08-09	28N 1E 26 SE NW SW	1590 FSL 1202 FWL		D&A	ENTRADA	3034	SANDI PRODUCTION INC	30039227850000	3034
Chama Butte	1	1980-07-20	32N 3E 29 NW NE			D&A	ENTRADA	3865	HANSON OIL CORP	30039221350000	
ESQUIBEL	1	1977-01-04	28N 4E 28 NE NE SW	2250 FSL 2094 FWL		D&A-O	ENTRADA	2676	COQUINA OIL CORP	30039213080000	2675
LA CORINA	36	1976-09-14	30N 1E 6 SE SE NW	2300 FNL 2150 FWL		GAS	DAKOTA	2455	DUGAN PROD CORP	30039211550000	
VALDEZ	1	1975-11-16	31N 1E 20 SE NW NW	850 FNL 870 FWL		D&AW	MORRISON	1850	DUGAN PROD CORP	30039204910001	1856
TURKEY NEST	1	1974-10-20	31N 1E 18 SE SE SE	400 FSL 600 FEL		D&A	DAKOTA	1890	DUGAN PROD CORP	30039209030000	
LA CORINA	35	1974-07-04	30N 1E 6 NE NE NE	330 FNL 330 FEL		D&A	P CAMBRIAN	4558	DUGAN PROD CORP	30039209040000	
VALDEZ	1	1972-04-29	31N 1E 20 SE NW NW	850 FNL 870 FWL		D&A	DAKOTA	1510	DUGAN PROD CORP	30039204910000	
QUINLAN	1	1966-10-12	31N 3E 16	1650 FSL 1000 FEL		D&A	UNKNOWN	265	CHAMA DRILLING CO	30039182340000	
SANCHEZ	1	1966-05-19	31N 2E 21	2200 FSL 500 FEL		D&A	DAKOTA	551	RISING KEITH L	30039182310000	
JIC 29-1	1-32	1964-10-11	29N 1E 32 SE SW	660 FSL 2010 FWL		D&A	GALLUP /SD/	1535	BELCO PET NRTH AMER	30039074690000	1535
Andres Trust	4	1963-12-16	28N 5E 20 NE			D&A	GALLUP /SD/	1504	ATLANTIC REFG CO	30039181910000	
RAYOS	1	1963-12-13	28N 1E 29 SE NE	1650 FNL 990 FEL		D&A-O	DAKOTA	2270	FOUTZ J L	30039072340000	
Andrus Trust	1	1963-11-13	28N 5E 15 SW SW NW	2195 FNL 580 FWL		D&A	JUANA LOPEZ	1118	ATLANTIC REFG CO	30039074210000	
Andrus Trust	2	1963-11-09	28N 5E 21 NW SE NW	1741 FNL 1650 FWL		D&A	JUANA LOPEZ	1336	ATLANTIC REFG CO	30039822710000	
BENNETT FOUTZ	1	1963-10-09	30N 1E 18 SE SE	790 FSL 330 FEL		D&A	NIOBRARA	2805	BENNETT & FOUTZ	30039078290000	
Pound Ranch	14	1963-09-27	28N 1E 14 SW NE NW	740 FNL 1850 FWL		D&A	DAKOTA	1788	TAMANACO OIL CORP	30039823780000	
SARGENT	1-9	1962-12-15	31N 3E 20	1800 FSL 2150 FEL		D&A	UNKNOWN	1320	DYSART STELLA ESTATE	30039181970000	
WHIGHAM	1	1962-11-26	28N 1E 7 SW SW	330 FSL 330 FWL		TAW	GREENHORN	3370	FOUTZ&BURSUM CONS CO	30039073720001	3370
SARGENT	3	1962-08-22	31N 2E 32 SW	2380 FSL 1980 FWL		D&A-OG	MORRISON	1212	GREAT AM OIL CO INC	30039181930000	
SARGENT	3	1962-08-22	31N 3E 19 NW NE SW	2380 FSL 1980 FWL		TA-OG	DAKOTA	1212	GREAT AMERICAN O&G	30039600110000	
EL Poso Rch H	1-35	1962-08-04	29N 1E 35 NE SE	2045 FSL 355 FEL		D&A	DAKOTA	1226	BENSON-MONTIN-GREER	30039050160000	1226
EL Poso Rch N	11	1962-07-27	28N 1E 11 SE SW	680 FSL 2080 FWL		TA-O	GALLUP /SD/	1452	TAMANACO OIL CORP	30039050060000	1452
Botterill Core	1-4	1962-07-04	32N 3E 24 SW	300 FNL 2000 FEL		D&A	DAKOTA	1430	UNION OIL	30039181880000	
Botterill Core	1-14	1962-07-04	31N 3E 4			D&A	DAKOTA	1430	UNION OIL CO OF CAL	30039601060000	
WHIGHAM	1	1961-10-25	28N 1E 7 SW SW	330 FSL 330 FWL		D&A	GREENHORN	3370	BAYLESS ROBERT L LLC	30039073720000	3370
Puerta Grande	1	1961-10-02	28N 1E 27 C NW NW	660 FNL 660 FWL		D&A-OG	DAKOTA	1572	E P R O C ASSOCIATES	30039072490000	1572
Pond Ranch-B	27	1961-08-29	28N 1E 27 NW NE	330 FNL 1501 FEL		D&A-OG	DAKOTA	1927	TAMANACO OIL CORP	30039050080000	1927
John Sargent	1	1960-12-12	31N 2E 4 NE SE SE	880 FSL 380 FEL		D&A-G	ENTRADA	1215	CARRACO OIL	30039503100000	
SARGENT	1	1960-12-12	31N 3E 19	660 FSL 1580 FEL		TA	ENTRADA	1214	CARRACO OIL	30039601080000	
Sargent John est	2	1960-10-31	31N 3E 18 NE SW SE	830 FSL 1800 FEL		D&A	MORRISON	1076	GREAT AM OIL CO INC	30039181950000	
John Sargent est	2	1960-10-31	31N 3E 19 NE SW SE	830 FSL 1800 FEL		D&A	MORRISON	1076	GREAT AM OIL CO INC	30039601050000	
POND RANCH-D	26	1960-07-25	28N 1E 26 C NW NW	660 FNL 660 FWL		D&A-O	BURRO CANYON	2068	TAMANACO OIL CORP	30039050070000	
SPILL BROS	1	1959-10-30	28N 4E 33 NW NW	560 FNL 760 FWL		D&A	ENTRADA	2660	HAMILTON JOHN INVEST	30039050130000	2660
2 SARGENT	2	1959-10-22	32N 3E 8	475 FNL 321 FEL		D&A	ENTRADA	3004	RHINE PETROLEUM	30039050460000	
SARGENT	1	1959-10-01	32N 3E 16 NE NW	1000 FNL 2000 FWL		TA	UNKNOWN	3034	RHINE PET INDUSTRY	30039600990000	
Edwards Sargent	1	1959-09-20	32N 3E 33 NE NW	1000 FNL 2000 FWL		D&A-O	UNKNOWN	3034	RHINE PETROLEUM	30039600060000	
GONZALES	2	1958-11-05	31N 1E 11 NE SE SE	990 FSL 330 FEL		D&A	MORRISON	998	SHARPLES OIL CRP THE	30039050270000	
GONZALES	1	1958-10-10	31N 1E 2 C NE NW	660 FNL 1980 FWL		D&A-G	MORRISON	1085	SHARPLES OIL CRP THE	30039050250000	1105
PENN BLDG	1	1957-09-09	28N 4E 33 NW	2310 FNL 330 FWL		TA	UNKNOWN	1330	HAMILTON INVEST INC	30039600890000	
Chama LC	1	1957-08-03	31N 4E 29 SW NE	1980 FNL 1980 FEL		D&AW		2025	VAUGH G H	30039050390001	
Chama LC	1	1956-10-21	31N 4E 29 SW NE	1980 FNL 1980 FEL		D&A	MORRISON	650	VAUGHN G H PROD CO	30039050390000	
Chama LC	3	1951-07-15	31N 4E 30 NW SE NE			D&A	DAKOTA	715	LARRAZOLA O A JR	30039050410000	
Chama L C	1	1950-08-21	30N 4E 5 S2 NW NE			D&A	UNKNOWN	360	LARRAZOLA O A JR	30039050240000	
Chama L C	3	1950-08-21	31N 4E 29 NE	2040 FNL 1980 FEL		D&A-O	MORRISON	360	LARROZOLA O A JR	30039182300000	
Chama L C	1	1950-01-11	31N 4E 32 C SW SE			D&A	MORRISON	485	LARRAZOLA O A JR	30039050420000	
Chama L C	1	1949-12-20	31N 4E 29 NE	660 FNL 1980 FEL		D&A	MORRISON	585	LARAZOLA O A	30039182290000	
E D SARGENT	1	1949-07-12	29N 2E 15 NE SW NW			D&A	ENTRADA	1195	SOUTHWEST EXPL INC	30039050170000	
JICARILLA	1	1948-11-10	28N 1E 33 NE SE NE			D&A-O	P CAMBRIAN	5987	DERBY REFG CO	30039071730000	
MARTINEZ	1	1948-10-12	28N 3E 14 SE SW NW			D&A-O	ENTRADA	1902	SOUTHWEST EXPL INC	30039050110000	
PENN BLDG CO	1-B	1948-09-07	28N 4E 33 C SW NE	1980 FNL 1980 FEL		D&A	MORRISON	1889	SOUTHWEST EXPL INC	30039050150000	
PENN BLDG CO	1	1948-08-13	28N 2E 22 NW NW NE			D&A-O	GRANITE	2460	SOUTHWEST EXPL INC	30039050100000	
SARGENT	2	1945-12-30	31N 3E 23 SE NE NE			J&A	UNKNOWN	816	RHODES R S	30039050380000	
Sargent John hs	2	1945-12-16	31N 3E 23 SE NE NE	990 FNL 330 FEL		D&A	UNKNOWN	816	RHODES R S	30039182370000	
WIRT	1	1944-12-17	31N 2E 21 NW SE SE			D&A	UNKNOWN	705	TRAVIS LOUIS R	30039050360000	
SARGENT	1	1944-12-14	31N 3E 23 SW SE NE			D&A	TODILTO	880	RHODES R S	30039050370000	

Well Name	Well #	Spud Date	Location	Footage	Prod Status	Final Status	Formation At TD	TD	Operator Name	UWI or API#	Log TD
Sargent John	1	1944-11-29	31N 3E 19 NE	2225 FNL 737 FEL		D&A	ENTRADA	880	RHODES R S	30039182360000	
FEE	1	1942-11-01	30N 2E 3 SE SE NE			D&A	UNKNOWN	1200	WILLIAMS	30039050200000	
WIRT	1	1938-11-16	30N 2E 2			D&A	UNKNOWN	453	OIL CITY PETRLM INC	30039050180000	
ESQUIBEL	1	1938-10-06	28N 4E 1			D&A	DAKOTA	1920	CONTINENTAL OIL CO	30039050120000	
ESQUIBEL	1	1938-10-06	28N 4E 27 C	2640 FNL 2640 FEL		D&A	UNKNOWN	1920	CONTINENTAL OIL CO	30039600010000	
GONZALES M	1	1938-09-05	32N 2E 19	990 FNL 330 FWL		D&A	DAKOTA	1022	AXELIND OIL COMPANY	30039181870000	
GONZALES	6	1938-08-25	32N 1E 13 NW NW SW	2310 FSL 330 FWL		D&A	DAKOTA	1022	AXELIND OIL COMPANY	30039050430000	
Tierra Amarilla	1	1934-09-27	28N 2E 16 C SE SE			D&A	UNKNOWN	600	PAN STATES OIL	30039050090000	600
Mosota LND Co	1	1933-10-30	28N 2E 4 SW SE			D&A	UNKNOWN	347	PAN STATES CORP	30039182350000	
CHAMA	4	1931-07-15	31N 4E 30 NW SW NE			D&A	DAKOTA	702	LARAZOLA O A ETAL	30039050400000	
AZOTEA	1	1928-12-31	31N 2E 2 C NW NW			D&A	UNKNOWN	930	AZOTEA OIL COMPANY	30039050280000	
MARTINEZ	1	1928-12-28	30N 2E 16 SE NE SW			D&A	UNKNOWN	2030	WILLOW CREEK SYND	30039050210000	
AZOTEA	3	1928-12-28	31N 2E 8 SE SE NE			D&A	UNKNOWN	757	AZOTEA OIL COMPANY	30039050320000	
FEE	1	1928-06-30	31N 2E 17 C NE NE			D&A	UNKNOWN	2300	AZOTEA OIL COMPANY	30039050350000	
AZOTEA	2	1927-11-26	31N 2E 2 C NE			D&A	UNKNOWN	1965	AZOTEA OIL COMPANY	30039050300000	
UNKNOWN	2	1927-09-15	31N 2E 2			D&A	MANCOS	510	AZOTEA OIL COMPANY	30039182380000	
FEE	2	1927-07-15	31N 2E 17 C NW NE			D&A	UNKNOWN	510	AZOTEA OIL COMPANY	30039050340000	
VALDEZ	1	1927-01-03	31N 1E 20 C NE NW			D&A	UNKNOWN	1472	ACHE PAUL S	30039182590000	
CHROMO	1	1926-10-30	30N 2E 2 SE SE NE			D&A			WILLIAMS	30039050190000	
GARCIA	1	1926-10-03	31N 1E 17 SW NW SW			D&A-O	DAKOTA	1472	ACHE PAUL S	30039079660000	
GONZALES	1	1926-05-29	31N 1E 2 C SW SE			D&A	UNKNOWN	1008	OWENS ALBUQURQUE OIL	30039050260000	
Azotea str	1	1926-05-29	31N 2E 8 SE SE NE			D&A	UNKNOWN	1008	OWENS ALBUQURQUE OIL	30039601070000	
GOVT	1	1925-12-31	31N 2E 2 C NE			D&A	UNKNOWN	1800	PRAIRIE OIL & GAS CO	30039050290000	
UNKNOWN	1	1925-01-01	31N 2E 14 C NE			D&A	DAKOTA	1215	P OIL & GAS	30039181940000	
GOVT	1	1924-11-12	32N 1E 33 C W2			D&A	UNKNOWN	725	BARNES	30039079870000	
CHROMO	1	1923-12-30	32N 2E 18 C NW			D&A	UNKNOWN	567	CROWLEY PETROLEUM	30039050440000	
GONZALES	1	1922-12-30	32N 2E 30 NW SW NW			D&A	DAKOTA	1508	PRAIRIE OIL & GAS CO	30039050450000	
LOONEY	1	1920-12-21	30N 2E 31 NW NW SE			D&A	UNKNOWN	1783	CALIFORNIA CO THE	30039050230000	
TIERRA AMARILLA	1	1920-12-20	30N 2E 23			D&A	UNKNOWN	2054	WILLIAMS ET AL	30039050220000	
FEE	1	1915-09-30	31N 2E 11 SW SW NE			D&A	UNKNOWN	478	OIL CITY PETRLM INC	30039050330000	
MEATING	0	1801-01-01	31N 1E 17	1970 FNL 440 FEL		D&A	UNKNOWN	1427	ACHE PAUL S	30039182580000	

Table 2: A total of 132 test wells were drilled in Northern Chama Basin Study Area (IHS, 2014).

El Poso Field

The 12 wells listed below in table 3 are the only wells to report production from the study area. Because their reported cumulative volumes are so low it is obvious that they do not pay for their drilling or operation cost as the best well, the El Poso Ranch #10 produced a cumulative 547 bo from an unknown start date to Sept. of 1997. The 12 wells in this small field (1 mile wide by 3.5 miles long) all produced from the Greenhorn interval and have all been plugged and abandoned after a long period of being shut-in and idle (NMOCD website 2014).

The significance of these low volume wells is that they are the closest oil producers to the proposed lease area, which is centered near the Village of Cebolla approximately 18 miles to the east and five miles south. Of further importance is that the El Poso wells could be analogous to a prospect identified as the Approach Prospect (discussed further in this review), but never developed because of Rio Arriba County's environmental concerns and unknown reasons of the lessee of these private (fee) Tierra Amarilla Land Grant leases.

These once producing wells are located on the western edge of the Chama Basin, while the proposed lease parcels are located near the basin axis in the center of the south Chama Basin. The oil produced from the Greenhorn limestone in these El Poso wells is most likely sourced from below from the Graneros shale or from above in the Mancos shale. A third possible source is from those same intervals but from the San Juan Basin, which is structurally lower and known to be thermally mature, spilling

across the Nacimiento fault or hinge line and up-dip and into the higher western edge of the Chama Basin.

Well Name	Well Num	Prod From	Prod To	Location	Footage	Cumulative Oil Bo	Producing Formation	Operator Name
EL POSO	3	Jan-06	Jun-10	28N 1E 11 SE SE SW	480 FSL 2105 FWL	306	GREENHORN	BLUE DOLPHIN PRO LLC
EL POSO	4	Jan-06	May-10	28N 1E 14 NW NE NW	530 FNL 1765 FWL	201	GREENHORN	BLUE DOLPHIN PRO LLC
EL POSO	5	Jan-06	Jun-10	28N 1E 23 NE NW NW	550 FNL 955 FWL	206	GREENHORN	BLUE DOLPHIN PRO LLC
EL POSO	6	Jan-06	Jun-10	28N 1E 22 W2 SE SE	660 FSL 970 FEL	259	GREENHORN	BLUE DOLPHIN PRO LLC
EL POSO	7	Jan-06	Jun-10	28N 1E 26 SW SW NW	2130 FNL 620 FWL	201	GREENHORN	BLUE DOLPHIN PRO LLC
SAMANTHA	1	Nov-87	Nov-87	28N 1E 26 SE NW SW	1580 FSL 1202 FWL	12	GREENHORN	SPUR OIL INC
SAMANTHA	2	Apr-85	Nov-87	28N 1E 26 NE NE SW	1985 FSL 2290 FWL	107	GREENHORN	SPUR OIL INC
SAMANTHA	3	Jul-85	Nov-87	28N 1E 26 NE SE SW	1105 FSL 2490 FWL	82	GREENHORN	SPUR OIL INC
EL POSO RANCH	7	Apr-85	Jul-85	28N 1E 14 SE NW SE	1824 FSL 1778 FEL	18	GREENHORN	CHUZA OPERATING
EL POSO RANCH	8	Apr-85	Jul-85	28N 1E 14 SE SE SW	618 FSL 2418 FWL	34	GREENHORN	PETROLEUM DEV CORP
EL POSO RANCH	9	Apr-85	Jul-85	28N 1E 11 NE SE SW	967 FSL 2148 FWL	18	GREENHORN	CHUZA OPERATING
EL POSO RANCH	10	Sep-97	Sep-97	28N 1E 14 NW SW SE	990 FSL 2310 FEL	547	GREENHORN	CHUZA OPERATING

Table 3: Listed above are 12 producing wells located in the Northern Chama Basin Study Area and their cumulative oil production in barrels of oil. All 12 of these producing wells have been plugged and abandoned (IHS Data, 2014).

Beck and Hallett (1997) interprets the placement of these wells as near the west dipping monoclinal flexure, the boundary between the San Juan Basin and the Archuleta Anticlinorium (see exhibits 6 and 7 and cross sections A-A' and B-B' below). The El Poso Field wells are all located along a mapped north-south trending syncline with possible sealing against or because of high angle normal faults to the west. Beck and Hallett propose three ages for potential hydrocarbon reservoirs: (1) Mancos, Greenhorn, and Dakota of Cretaceous, (2)Todilto and Entrada of Jurassic, and (3) unknown named formations of arkosic sandstone and limestone of Pennsylvanian age similar to Gallina Mountain.

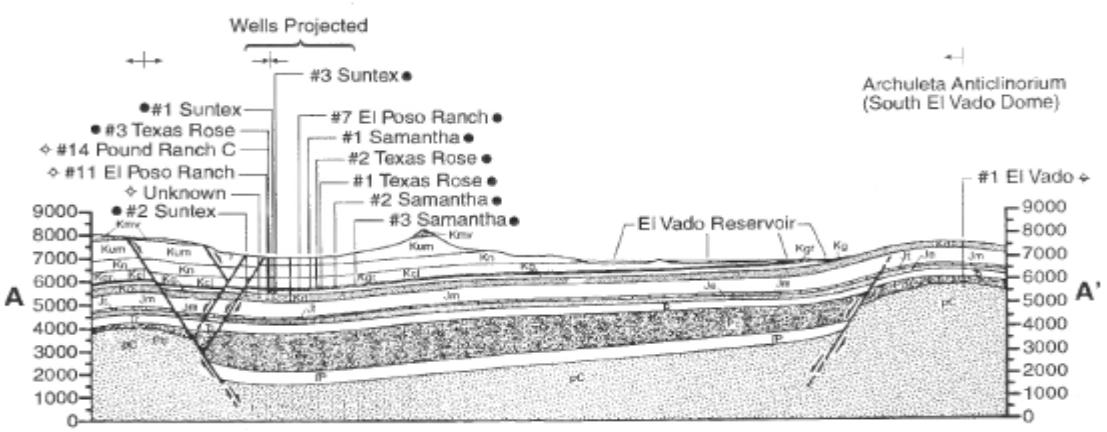


Exhibit 6. Structural location of El Poso wells producing from Greenhorn Limestone (Kgr) in broad syncline on west side of the Chama Basin. upper Mancos Kum, Niobrara Kn, Carlile shale Kcl, Graneros Kg, Dakota Kd, Jurassic Morrison Jm, Todilto Jt, Entrada Je, Triassic undifferentiated T, Permian Cutler Pc and Pennsylvanian undifferentiated P. Cross section A-A' west to east by (Beck and Hallett, 1997).

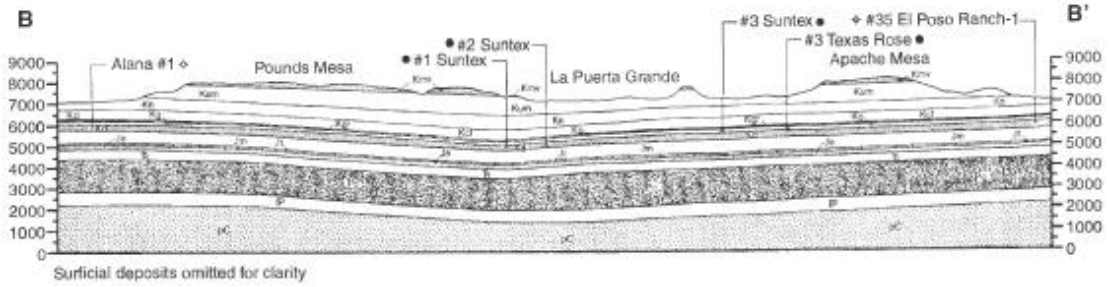


Exhibit 7. Cross section B-B' south to north by (Beck and Hallett, 1997). Pounds Mesa, La Puerto Grande and Apache Mesa are all located just outside of the Study Area on the western edge.

Simplified South Chama Basin Stratigraphic Column	Potentially Productive
Mesaverde Group	
Menefee sand shale & coals	
Point Lookout Sandstone	
Mancos Shale	Oil & Gas
Greenhorn Limestone (fractured)	Oil
Graneros member of the Mancos Shale	
Dakota Formation	Oil & Gas
Two wells Sandstone Tongue of Dakota	
Whitewater member of Mancos Shale	
Paguate Sandstone Tongue of Dakota	
Clay Mesa member of Mancos Shale	
Cubero Sandstone Tongue of Dakota	
Oak Canyon member of	
Encinal Canyon member	
~~ (Unconformity K2 between Lower and Upper Cretaceous)	
Burro Canyon Formation	Water, Oil & Gas
~~ (Unconformity K1 between Lower Cret. Burro Canyon and Upper Jur.	
Morrison Formation	
Brushy Basin member of Morrison	Water, Oil & Gas
Bluff sandstone	
Summerville formation	
Todilto Limestone Formation gypsum	
Entrada Sandstone	Water & Oil
Chinle Group	
Pennsylvanian undifferentiated	Oil & Gas

Exhibit 8: Simplified South Chama Basin Stratigraphic Column of rock which outcrop in the South Chama Basin Study Area. Those intervals which have been identified as being potentially productive for water, oil and gas are noted.

Stratigraphic Column Ghost Ranch Area

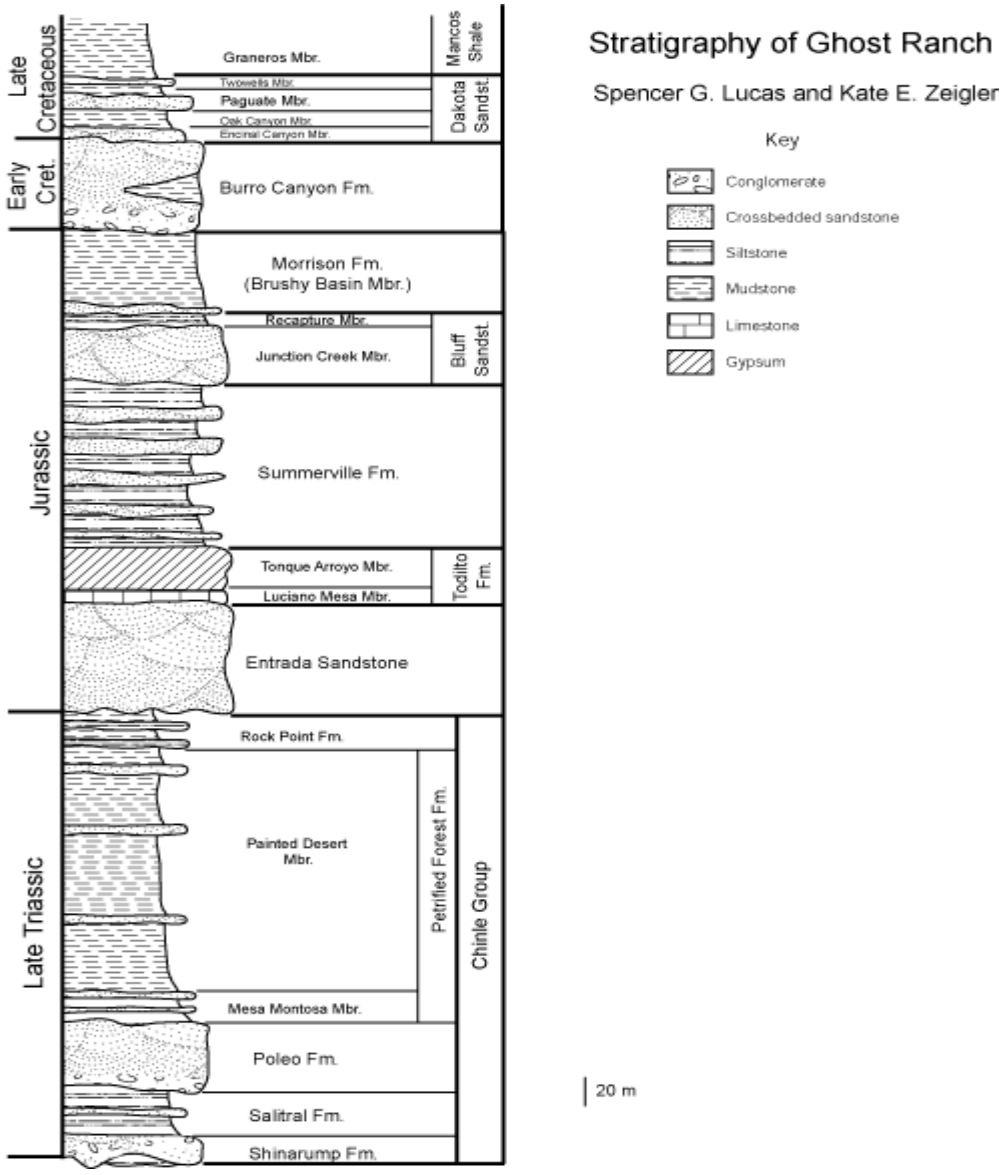


Exhibit 9: Stratigraphic nomenclature column for the Ghost Ranch area modified from the diagram inside the back cover of the 2005 New Mexico Geological Society guidebook by Lucas and Zeigler.

Four Cross Sections

Three west to east cross sections, A-A' , B-B' and C-C', and one north to south, D-D', were constructed using IHS well data and Petra Software version 3.1.9.4 in order to verify the lateral presence of potentially productive Mancos, Greenhorn, Dakota, Burro Canyon and Entrada Formations. Exhibit 10 is a Petra map showing the well locations of the four cross sections.

Cross section A-A' (exhibit 11) uses the Juana Lopez as a datum and correlates productive Greenhorn limestone in the El Poso #6 and #5 wells located on the western flank of the Chama Basin with two dryholes located 16 and 22 miles further east on the eastside of the Chama Basin. One of the dryholes,

the Esquibel #1, tested the Mancos, Greenhorn, Dakota, Burro Canyon and Entrada Formations with a show of hydrocarbon while the other dryhole, the Andrus Trust #2, tested just the Mancos shale interval with no shows of hydrocarbons. It is unknown what formation the show occurred in the Esquibel #1.

Cross section B-B' (exhibit 12) uses the top of the Greenhorn as a datum and correlates nonproductive Greenhorn, Dakota, Burro Canyon and Entrada Formations in the Phoenix #1 well located on the eastern flank of the San Juan Basin with one dryhole test and one water producing well located 18 and 22 miles further east on the eastside of the Chama Basin. The dryhole test, the Spill Brothers #1 tested the Mancos, Greenhorn, Dakota, Burro Canyon and Entrada Formations with no shows of hydrocarbons while the other well is the water producing Cebolla MDWC #2 which is the water well for the community of Cebolla. It produces potable water from perforations in the casing in the Burro Canyon and Brushy basin intervals.

Cross section C-C' (exhibit 13) uses the top of the Burro Canyon as a datum and correlates nonproductive Burro Canyon and Entrada Formations in the Phoenix #1 well located on the eastern flank of the San Juan Basin with one dryhole test and one water producing well, located 8 and 22 miles further east on the eastside of the Chama Basin. The dryhole test, the Nutrias Prospect #1, tested the Dakota at the surface and then penetrated the Burro Canyon, Brushy Basin and Entrada Formations with no shows of hydrocarbons, while the other well is the Cebolla MDWC #2, which is producing water from the Burro Canyon and Brushy Basin for the community of Cebolla. The objective of Nutrias Prospect #1 was to test the Entrada sand, which was over 300 ft. thick; however the well was plugged and abandoned with no shows of hydrocarbons.

Cross section D-D' (exhibit 14) trends north to south and spans a distance of over 30 miles down the apparent center of the Chama Basin. The cross section contains 4 wells and uses the base of the Greenhorn as a datum. The cross section correlates nonproductive Greenhorn, Dakota and Burro Canyon in the Celso Gomez #1 well located close to the Colorado-New Mexico state line with two other dryhole tests and the water producing Cebolla MDWC #2 water well. The Garcia A2 #2 is a dryhole, but tested the Dakota and Burro Canyon intervals with no sign of hydrocarbons. The Esquibel #1 tested the Greenhorn, Dakota, Burro Canyon and Entrada interval and was plugged and abandon as a dryhole, but it did have a show of hydrocarbon reported. All four wells in cross section D-D' correlate the Greenhorn, Dakota and Burro Canyon with the Cebolla MDWC water well.

Well Log Analysis

The IHS Petra database constructed for this study consists of 531 wells with some containing raster well log images (like those used in cross section A-A') obtained from the New Mexico Oil Conservation Division online database. Because of the limited numbers of wells and wells with well logs, the area of study had to be expanded mainly westward beyond the initial North South study areas of the Chama Basin to wells located on the monocline between the two basins. The older wells from the 1920's on to the 1960's and some 1970's wells just did not have well logs run.

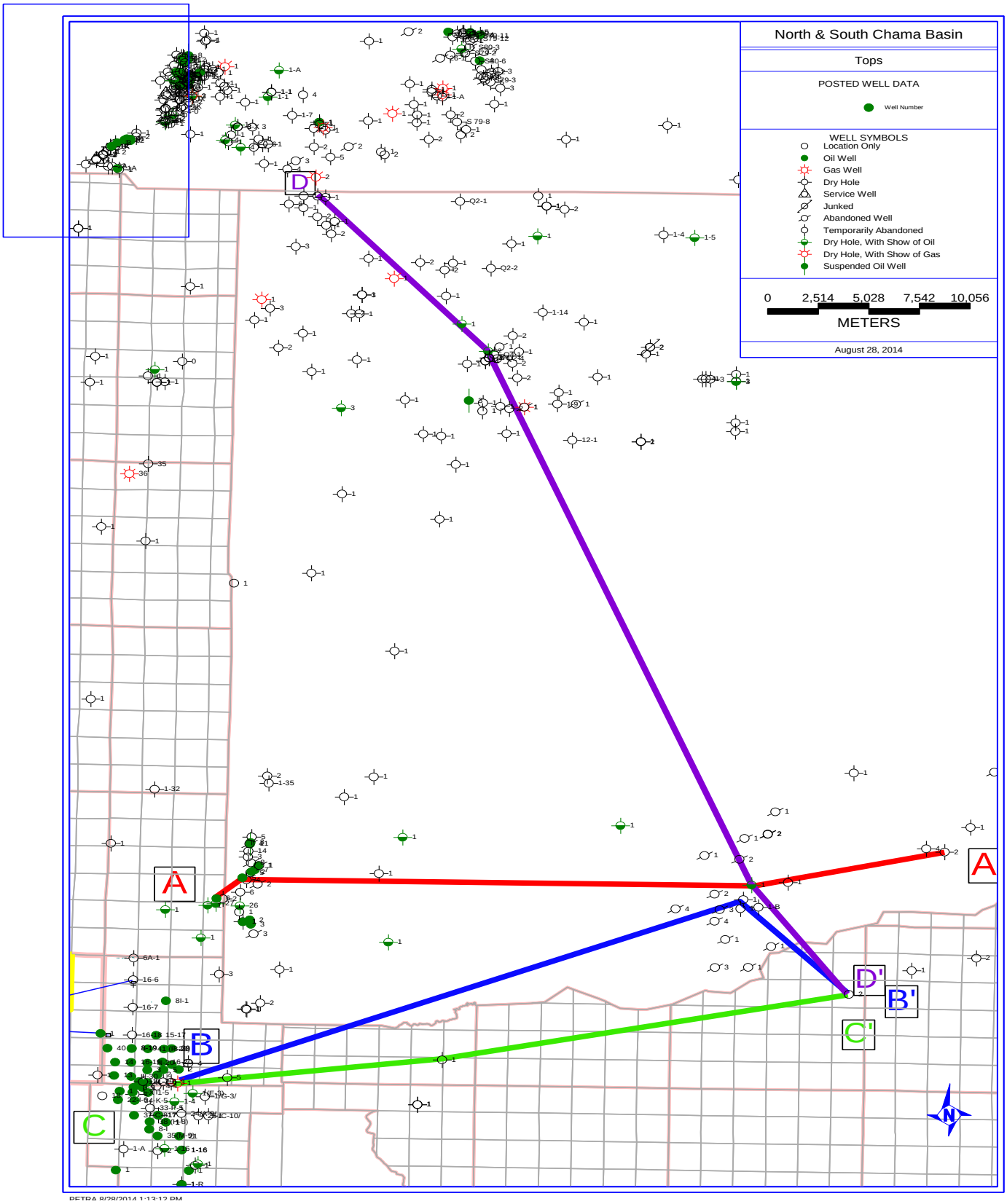


Exhibit 10. Petra Map shows locations of four cross sections A-A', B-B', C-C' and D-D'

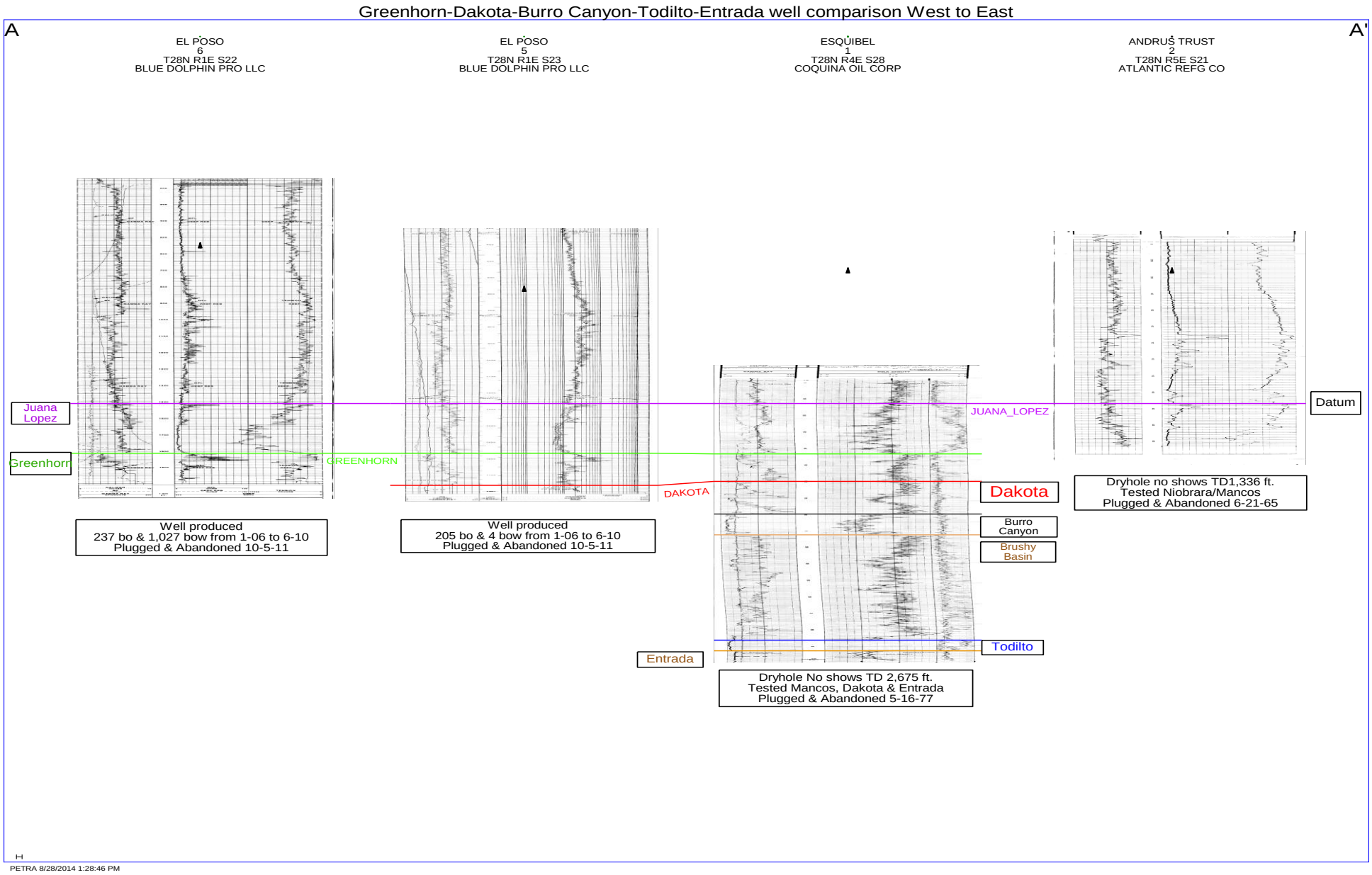


Exhibit 11. Cross section A-A’ contains four wells El Poso#6, El Poso #5, Esquibel #1 and Andrus Trust #2.

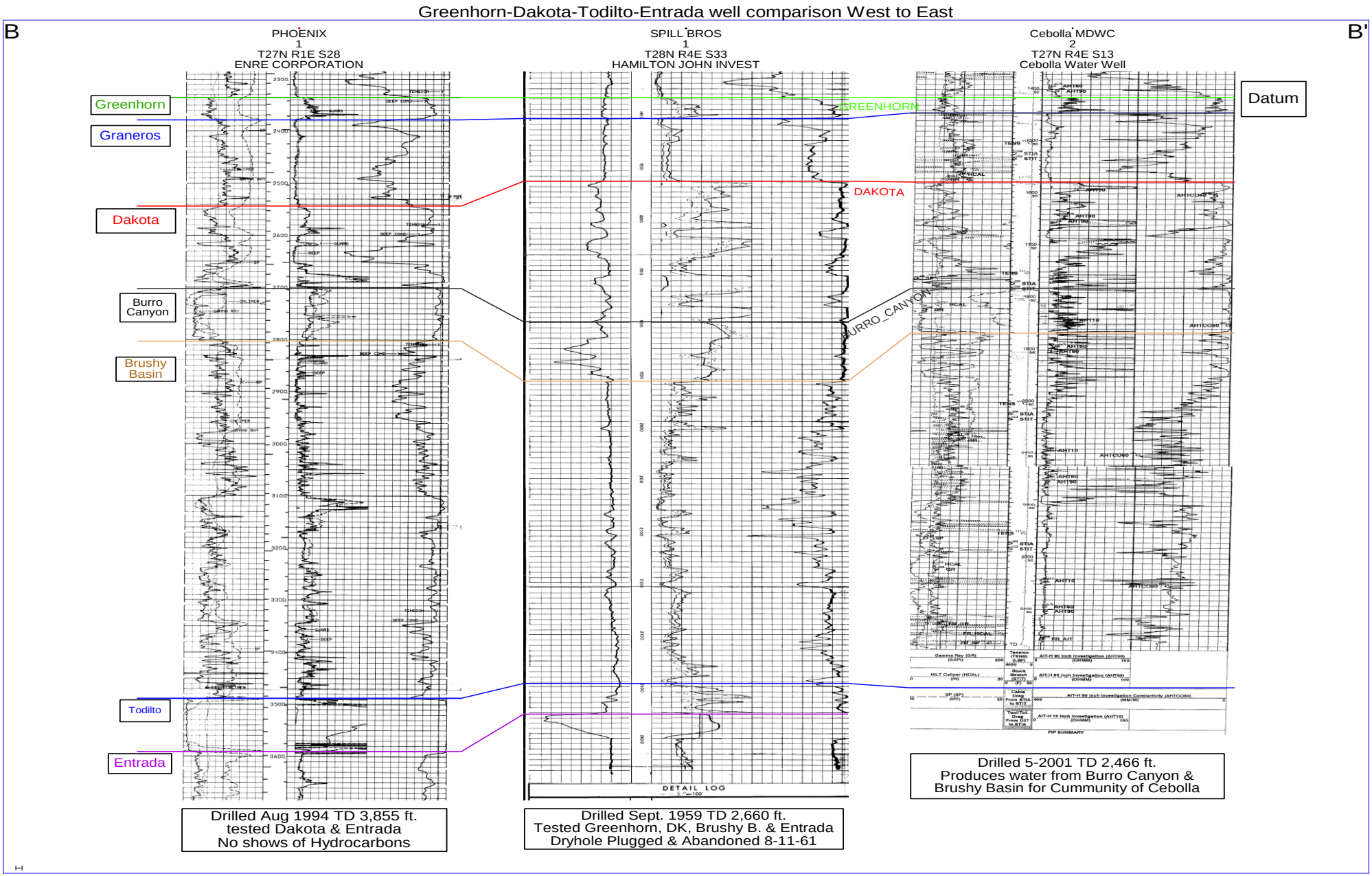
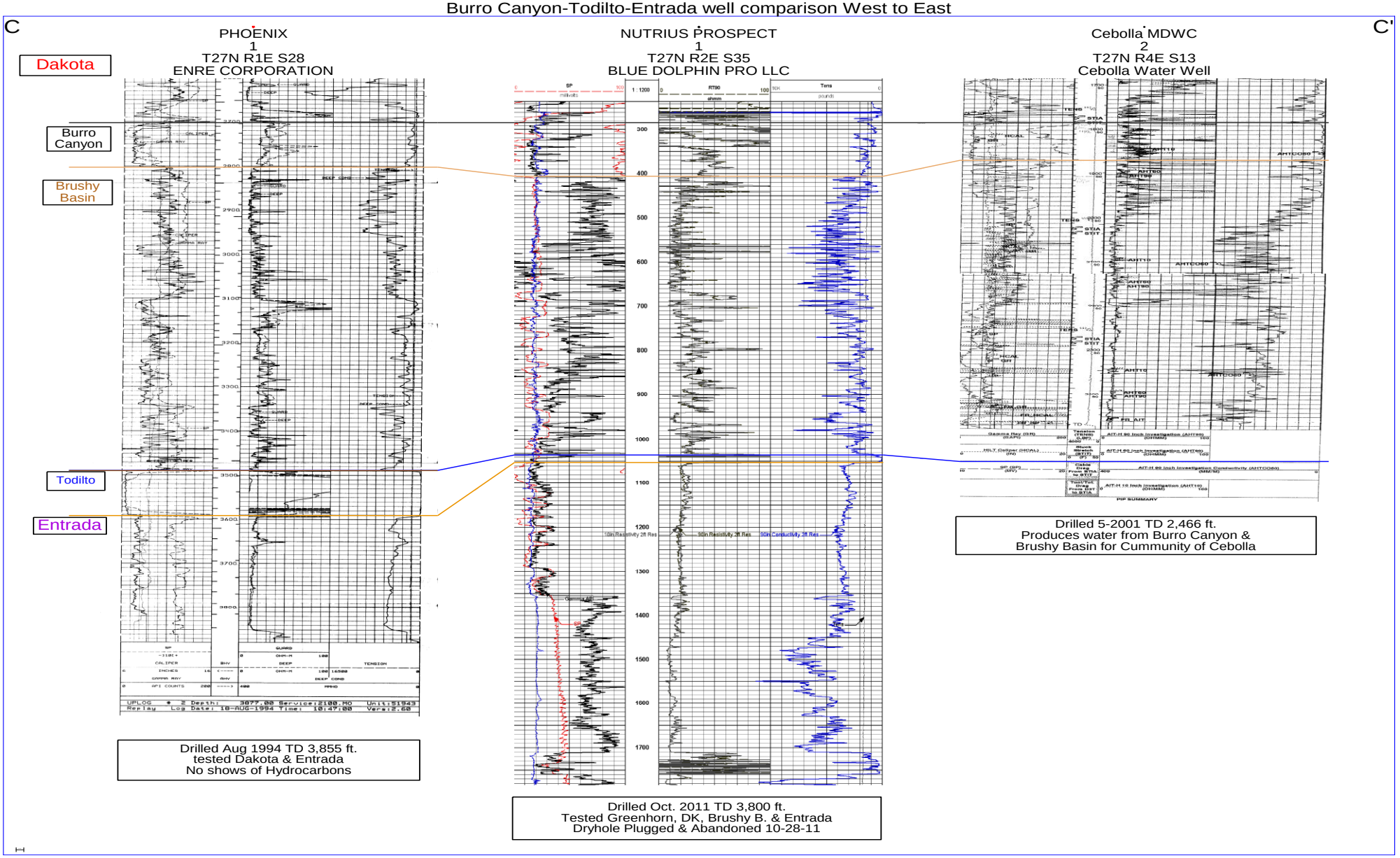


Exhibit 12. Cross section B-B’ contains three wells Phoenix #1, Spill Bros #1, 6, and Cebolla MDWC #2

Burro Canyon-Todilto-Entrada well comparison West to East



PETRA 8/28/2014 2:17:33 PM (Phoenix#1_Nutrius Prospect#1_CebollaWater Well.CSP)

Exhibit 13. Cross section C-C' contains three wells Phoenix #1, Nutrius Prospect #1, and Cebolla MDWC #2

Greenhorn-Dakota-Todilto well comparison North to South

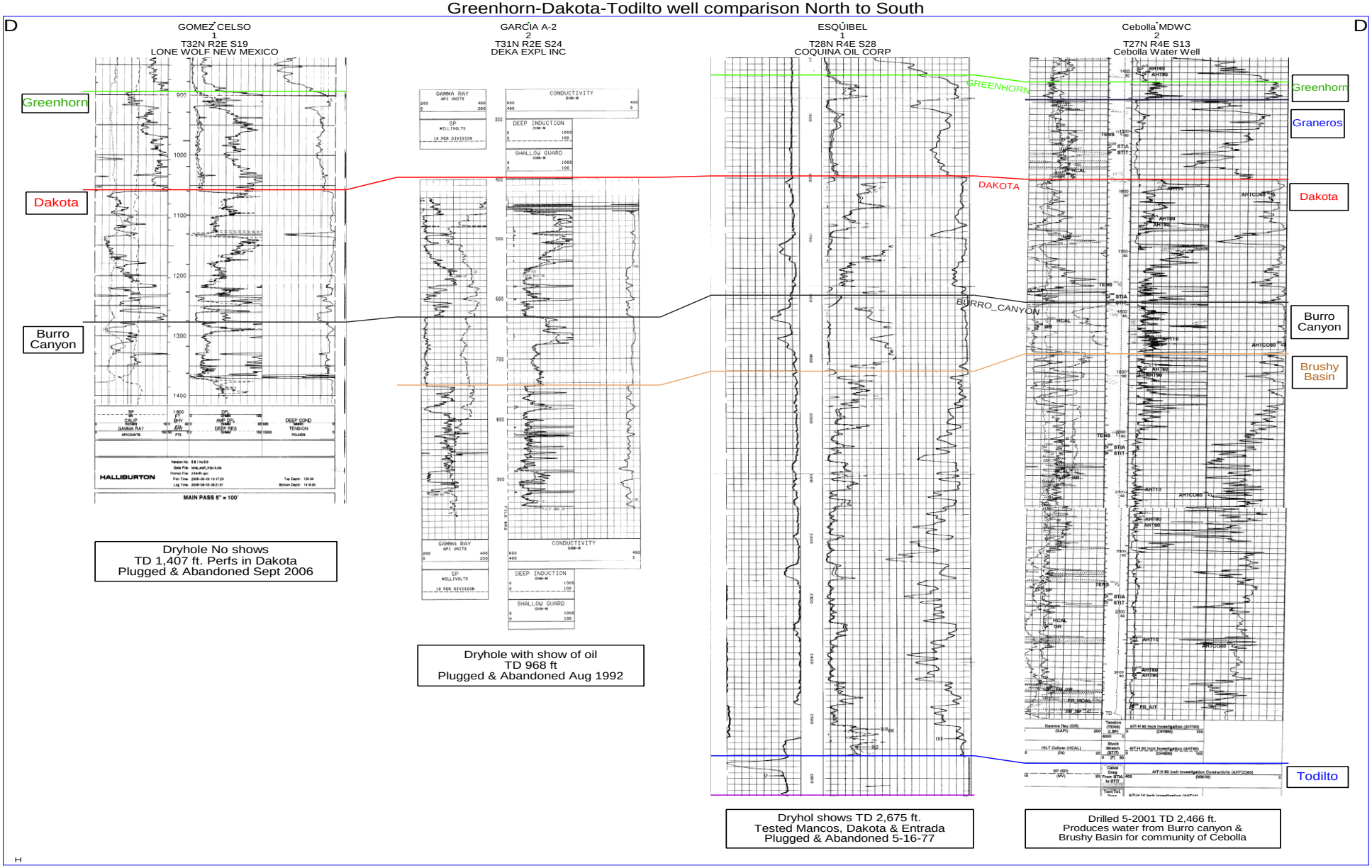


Exhibit 14. Cross section D-D' contains four wells Celso Gomez #1, Garcia A-2#1 and Cebolla MDWC #2

Approach Operating LLC

In November of 2009 Approach Operating submitted a total of 16 applications to drill exploratory test wells to New Mexico Oil Conservation Division (NMOCD) proposing to test the Mancos, Greenhorn and Dakota intervals. These test wells were to be drilled on the southern end of the Tierra Amarilla Land Grant and just north of the proposed BLM leases (see exhibits 1 & 2 and also exhibit 14, Grey's structure "Top of Greenhorn Limestone" map, with purple line identifying boundary of Approach's drilling prospect). The planned total depth of these wells was approximately 2,000 ft. The NMOCD also established the Tierra Amarilla Mancos Oil Pool, which designated 40 acre spacing and required a closed loop drilling mud systems to protect surface aquifer from potential spills (NMOCD 2014). All of the proposed applications to drill expired and no test wells were ever drilled as mainly Rio Arriba County and a group of local citizens intervened by expressing their concerns about the environment, water and their way of rural life being impacted. Approach Operating's area of exploration interest is the very southern boundary of the Tierra Amarilla Land Grant and the southern portion of the North Study Area.

Grey's Structure Top of Greenhorn Map and Conceptual Cross Section SW to NE

David Grey, a geologist/geophysicist has provided both a structure map, "Top of the Greenhorn Limestone," exhibit 15, and a SW-NE cross-section labeled "Conceptual Cross Section Illustrating the Plays in the Tierra Amarilla and their Relationship to Analog Fields" exhibit 16. Grey's data comes from IHS well data and uses Petra software (Grey, 2013). The conceptual cross section SW to NE was constructed by unknown software.

Grey's structure map (exhibit 15) and cross section (exhibit 16) are useful for interpreting potential oil and gas prospects and identifying structural features of the Chama Basin. The primary structural feature which divides the San Juan Basin from the uplifted and structurally elevated Chama Basin is a series of north trending en echelon faults called the Nacmiento/Gallina faults (Baltz, 1967) and (Arthur, 2013). The Nacmiento/Gallina fault system exhibits a right lateral expression and is documented with two ages of movement an older compressional style with vertical displacement in the pre-Jurassic sediments and a younger right lateral movement in the Jurassic that initiated strike-slip movement (Baltz, 1967; Cather, 2003; and Cather, 2006). Greys cross section labels the Gallina fault system of Baltz (1967) and Cather (2004) as the Puerto Chiquito Fault, which this author believes are the same or of the same en echelon type system that separates the two basins.

Two brown lines on Grey's structure map (exhibit 15) has identified two parallel and prominent thrust faults with apparent forces originating from the southwest, which are named Gramps and Milagro. Further evidence of these southwest directed thrusting is found in Cather's description (Cather, 2004) of proprietary industry seismic data described by Taylor and Huffman (1998) suggesting that "the Archuleta Anticlinorium is at least locally underlain by southwest-directed thrust faults." The two thrust fault traces widen from approximately 3 mile apart to approximately 8 miles as they arch toward the southeast and then particularly the Milagro thrust becomes south trending and terminates near the west flowing Nutrias River and the location of the 16 parcels proposed for BLM leasing. In conversations with Grey, this is because of a lack of wells drilled in this southern Chama Basin, and its presence further south is speculated. If the Milagro fault extends further south, it could help to form a seal and trap mechanism for hydrocarbons.

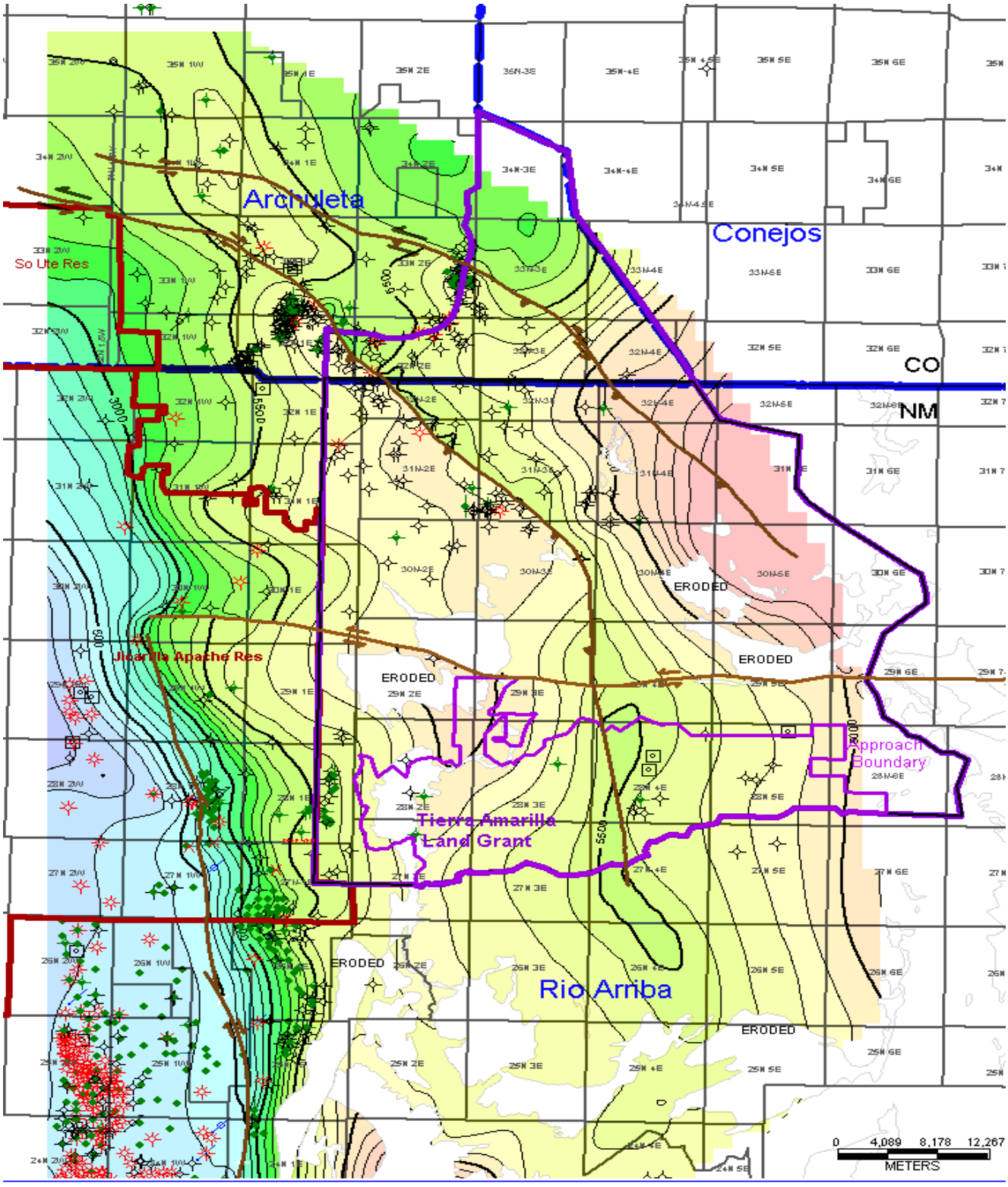


Exhibit 15. Structure map of Chama Basin Top of Greenhorn Limestone by David (Grey, 2013) outlined in dark purple is Tierra Amarilla Land Grant in lighter purple is area of Approach's Prospect. Contour intervals are 500 ft.

Grey's structural interpretation map (exhibit 15) identifies several white areas labeled (ERODED) for eroded Greenhorn where the outcropping Greenhorn Limestone is either thinly present or is eroded away at outcropping. The 500 ft. contour interval lines are broken and offset by both the Gramps and Milagro thrust faults and by another unnamed west trending slip fault identified with a brown line that is undocumented except here.

Potential Hydrocarbon Traps in South Chama Basin

Some of the potential hydrocarbon traps or plays are identified in the cross-section and described below (note areas of green shading on cross-section SW-NE exhibit 16 as potential hydrocarbon traps):

- Oil and gas traps could occur on the west side of Chama syncline in two different ways, (1) oil could fill fractures in source rock, both the upper and lower Mancos Km and Niobrara Kn, at points of maximum flexure at the bottom of syncline, or (2) where reservoir rocks (Dakota Kd, Morrison Jm and Entrada Je) are curved upward becoming east dipping against a sealing fault. This conventional play occurs where permeable sands are bent upward by Milagro thrust faulting forming traps that become oil filled by thermal cracking of kerogen from within the Chama Basin and are sealed by offsetting impermeable Mancos shale Km or crystalline basement rock.
- On the east side of the Chama syncline oil could be contained within natural fractures in west dipping Mancos and Niobrara and also in porous reservoir rocks (Dakota Kd, Morrison Jm and Entrada Je), which are bent upward becoming west dipping against a sealing fault.
- Oil filled fractures in source rock reservoirs could occur in the center of the Chama syncline or any small structural feature or folded structure not currently identified by drilling or surface expression in Niobrara Kn or Mancos Km intervals.
- Conventional traps could be formed on the west side of the Chama syncline within the Archuleta Anticlinorium area by the Milagro thrust fault, forming dome-like or anticlinal structures in Dakota Kd, Morrison Jm or Entrada Je, trapping hydrocarbons. In comparison the El Poso wells produced from Greenhorn limestone in a faulted syncline (Beck and Hallett, 1997).
- Similar shallow oil accumulation to Chromo Field in Colorado which produced with 300-700 ft. of surface cover from fractured rock intervals of Sanostee, Tocito sand and Limestone zones located off flank of an anticline where oil filled fractures produced from brittle rocks (Osterhoudt, 1978).
- Horst, up-thrown blocks or Graben, down-thrown blocks create offsetting hydrocarbon traps by placing porous sands like the Entrada offset by impermeable shale.

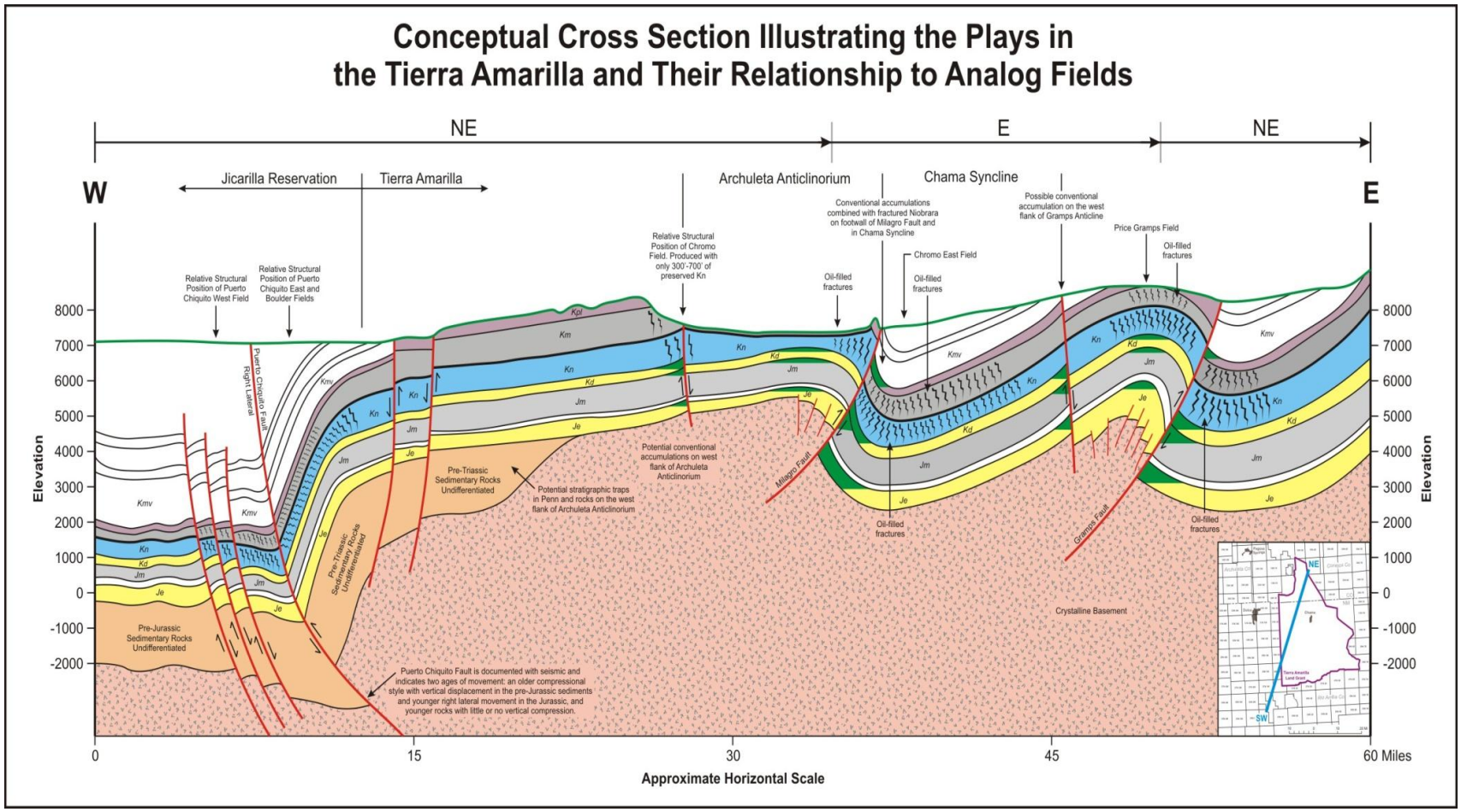


Exhibit 16. Conceptual Cross Section SW to NE across Chama Basin & Tierra Amarilla Land Grant Limestone by David (Grey, 2013)

Thermal Maturation of Source Rock

It is uncertain if the southern Chama Basin, including the area of potential leasing, has ever been thermally mature enough to generate hydrocarbons by either or both sufficient depth of burial or adjacent heat sources. In the Chama Basin the Mancos shale is volumetrically the most important source rock because of its well documented rich organic material in adjacent parts of Colorado and New Mexico (Ryder 1977). Oil production along with numerous oil shows from test wells in the Mancos shale in the vicinity of Gramps, Chromo and Navajo oil fields (IHS well data, 2014) suggests its thermal maturity in the northern portion of the study area. This research found no published geochemical measurements available for the Chama Basin or Archuleta Anticlinorium (NM Petroleum Source Rock Database, 2014).

Ryder (1977) believes the organic rich Mancos shale do not appear to have generated and expelled significant volumes of oil until they were blanketed by 1,500 to 2,000 m of volcanic rocks in the middle to late Oligocene time. Also, Gries et al (1997) places the oil generation of the nearby San Juan Sag to have occurred in a similar Oligocene to Miocene time. Ryder furthermore proposes a large proportion of the hydrocarbons if generated and expelled may have escaped into the overlying volcanic cover. This report adds that because of this later Cenozoic extensional faulting (Baltz, 1967) and lack of confining seals potentially no hydrocarbons were trapped. Additionally, erosion has cut the surface down to expose large areas of Mancos shale, Greenhorn limestone and Dakota sandstones over a wide area of the south Chama syncline (see exhibit 2 and exhibit 13).

Ryder, if correct in his middle to late Oligocene time of oil generation from Mancos shale in Chama Basin, places it significantly later (approximately 33-35 million years) than the San Juan Basin's middle to late Paleocene. Arthur (2013) further supports a late Paleocene age of 59 Ma for peak oil generation through basin modeling of San Juan Basin in his report on the oil and gas potential for West Puerto Chiquito field.

A review of data sites for chemical testing of Chama Basin wells, including NM Bureau of Geology and Minerals in Socorro, found no thermal maturity data. The NM Petroleum Source Rock Database (Broadhead et al, 1998), maintained by NM Bureau of Geology and Minerals, contains 135 wells, three of which were of interest because they appeared near the study area. The database was investigated to determine if it contained thermal maturation data, either TOC or vitrinite reflectance values for use in the Chama Basin's Mancos shale, Dakota or Morrison formations. All three wells, numbered 9, 10, and 11 in the data base, are located west of the Chama Basin in the eastern part of San Juan Basin and far from the area of leasing. A fourth well, numbered 122, located just across the Rio Arriba County line in Santa Fe County, is also out of Chama Basin and is too far south.

Because there is oil production from 12 El Poso Field wells located on the western edge of the Chama Basin, there is the possibility that oil may exist in other portions of the basin if the Mancos, Dakota and Morrison shale are thermally mature. There is also the possibility that the El Poso Field oil is sourced from older known mature San Juan Basin shale and not from Chama Basin.

Uranium Exploration Drill Holes

Another reason the potential for hydrocarbons in Burro Canyon Formation in the southern Chama Basin has been reduced to low is because of the large number and areal extent of uranium exploration drill-holes. Most likely, portable truck mounted rotary drill rigs using a combination of air, soap and light drilling muds would penetrate by plug chipping and coring potential intervals looking for uranium mineralization, but would also report hydrocarbons if present. It is estimated by Saucier (1974) that there are 2,000 uranium exploration drill holes in the south Chama Basin. Of importance is their location near the 16 tracts proposed for leasing. This is particularly true for the southern half of Township 26 N, Range 4 E, which is adjacent to the proposed leasing area and labeled "Assumed Mineralization" on exhibit 17 below. Most of the drill holes were bottomed in the Burro Canyon and their average drill depth was about 500 ft. (Saucier, 1974).

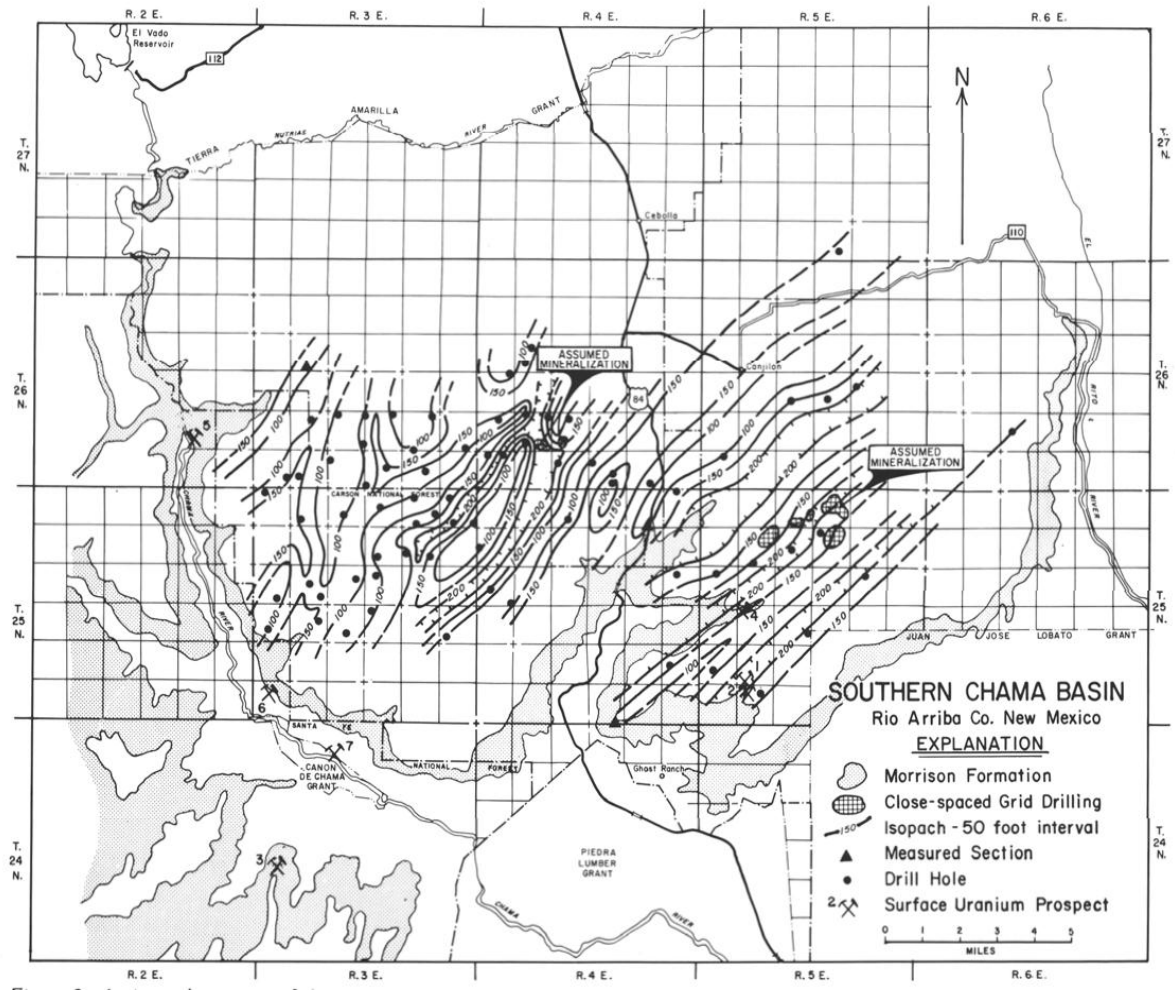


Exhibit 17. Isopach of Burro Canyon Formation in the southern Chama Basin from "Stratigraphy and Uranium Potential of the Burro Canyon Formation in Southern Chama Basin, New Mexico" (Saucier 1974), showing thickness of Burro Canyon formation from approximately 2,000 uranium prospect drill holes. Burro Canyon's depositional trend is to the northeast and it ranges from 80 to over 200 ft. thick over southern Chama Basin. The uranium mineralization is considered low grade with no significant production reported from any of these uranium prospects.

Potential for Occurrence of Oil and Gas

The oil and gas potential of the Chama Basin has always been associated or grouped with its adjacent and concurrent Laramide aged structural feature to the northwest, the Archuleta Anticlinorium of New Mexico and Colorado, even though the basin is a syncline and the Anticlinorium is a series of dome features (Ryder 1977). Oil production has only occurred from structural features associated with the Archuleta Anticlinorium area as no oil has been reported from the Chama syncline.

This review will describe the potential for oil and gas occurrence in the Chama Basin with emphasis on the possible discovery of oil and gas in or adjacent to the 16 proposed BLM leases located in the southern portion of the Chama Basin (see maps 1 & 2). The narrative has referenced prior published reviews and maps and has expanded on what can be inferred from well test data in the Chama Basin starting as early as 1920 and up to the most recent test in 2010, which was the Nutrias Prospect #1 drilled as a dry hole test of the Entrada formation.

The potential for occurrence of oil and gas will use guidance provided in BLM Manual 3031 – Energy and Mineral Resource Assessment. The manual sets standards for assessing, classifying, and reporting the potential for presence or occurrence, as opposed to the potential for development or extraction of mineral resources on lands managed by the BLM.

Definition of Oil and Gas Resource Potential

The potential occurrence of oil and gas is a prediction of the likelihood that an oil and gas resource will occur in a given area. The potential occurrence of a resource includes both exploitable and potentially exploitable occurrences, and does not evaluate whether the mineral resource can be developed economically. The four categories of mineral potential, as defined in BLM Manual 3031, are as follows:

- O (no potential) – the geologic environment, inferred geologic processes, and lack of mineral occurrences do not indicate potential for accumulation of mineral resources
- L (low potential) – the geologic environment and inferred geologic processes indicate low potential for accumulation of mineral resources
- M (moderate potential) – the geologic environment, inferred geologic processes, and reported mineral occurrences or valid geochemical/geophysical anomaly indicate moderate potential for accumulation of mineral resources
- H (high potential) – the geologic environment, inferred geologic processes, and reported mineral occurrences or valid geochemical/geophysical anomaly, and known mines or deposits [within the same type of geologic environment] indicate high potential for accumulation of mineral resources

In addition to those four categories, within each mineral potential category the potential must be supported according to a level of certainty regarding the available data. The level of certainty is a measure of confidence in the oil and gas data that was assessed. The levels of certainty are annotated in the narrative by use of the letter designations described below:

- A: the available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area
- B: the available data provide indirect evidence to support or refute the possible existence of mineral resources
- C: the available data provide direct evidence but are quantitatively minimal to support or refute the possible existence of mineral resources
- D: the available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources

Oil and Gas Moderate and High Potential

Moderate and High oil and gas potential is only allocated to areas that have the following characteristics, whereas Low potential will be given to areas that lack their presence:

- The known presence of thermally mature source rock or prospective pathways from organic rich rocks to sealed storage reservoirs exist.
- Source for hydrocarbons – e.g., an organic-rich shale or coal bed that has attained a level of thermal maturity through burial or other heating mechanism such that oil and/or gas could be generated. This type of data is generally obtained by testing core or drill cuttings samples being analyzed in a chemical laboratory.
- Reservoir-quality rock – sandstone, limestone, or fractured rock having interconnected porosity and permeability into which oil and/or gas may migrate from the source rock and be trapped.
- Trapping mechanism that prevents oil and/or gas from migrating out of the reservoir-quality rock; structural traps, stratigraphic traps, unconformities and faults are some common trapping mechanisms.
- Known deposits of oil and/or gas.

Low Potential South Chama Basin study area

Using the criteria discussed above, the South Chama Basin has *low* potential for oil and gas occurrences because all eleven of the oil and gas test wells there are dryholes with no oil or gas shows, and there is a question as to whether any of the potential source rocks (i.e., Mancos and Graneros shale and Todilto limestone intervals) are thermally mature (Table 4). There is the potential for deeper Pennsylvanian age rock, but there are few well tests and the potential for oil and gas from these rocks has limited data and is therefore unknown. In addition, the Greenhorn Limestone through Burro Canyon, which includes the Graneros and Dakota, has been tested where present in the South Chama Basin by a large number and areal of extent of uranium exploration drill-holes. The presumption is that when these test wells were drilled in the 1970's any significant oil and gas shows would have been reported. In addition, the shallow depth to these intervals provides minimal sealing from leakage of hydrocarbons to the surface.

Table 4: Rating System for Potential Hydrocarbon Occurrence in the South Chama Basin.

Mineral	Potential Occurrence	Level of Confidence
Oil & Natural Gas	Low	B

The available data supports a B level of confidence with indirect evidence and is quantitatively minimal as there are only 11 oil and gas test wells and they are all are dryholes with no oil or gas shows.

Moderate Potential North Chama Basin study area & Archuleta Anticlinorium

A rating of *moderate* for the potential occurrence of oil and gas is recommended for the north study area as it contains a favorable geologic environment for the generation of hydrocarbons similar to the San Juan Sag described by Gries et al (1997) and the geologic processes necessary for development of structural features have provided trapping mechanism (Table 5). The north study area and the Approach Prospect is in an area rated as having moderate potential for the occurrence of hydrocarbons as the El Poso Ranch field wells did have minor amounts of production from fractured Greenhorn Limestone, indicating either the presence of mature source rock on western edge of Chama Basin and or hydrocarbons having migrated from known mature rocks of San Juan Basin. There has also been numerous oil shows from test wells in the Mancos shale in the vicinity of Gramps, Chromo and Navajo oil fields in Colorado.

Table 5: Rating System for Potential Hydrocarbon Occurrence in the North Chama Basin

Mineral	Potential Occurrence	Level of Confidence
Oil & Natural Gas	Moderate	C

The available data supports a C level of confidence with direct evidence, but it is quantitatively minimal as there are only shows of hydrocarbons and minor amounts of cumulative production from the El Poso Field wells.

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