U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OIL AND GAS RESOURCES OF U.S. NAVAL OIL SHALE RESERVES 1 AND 3, COLORADO, AND RESERVE 2, UTAH

by

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Open-File Report 94-427

Prepared for the U.S. Department of Energy
Contract No. DE-AT21-93-MC30141

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MS 940, Federal Center
Denver, CO 80225-0046

1994

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U.S. Geological Survey, Lakewood, Colorado

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EXECUTIVE SUMMARY

The U.S. Geological Survey recognizes several major plays for nonassociated gas in strata that underlie Naval Oil Shale Reserves 1 and 3, Colorado, and Reserve 2, Utah. All of the plays are for nonassociated gas. For purposes of this study, plays without gas/water contacts are separated from those with such contacts. Continuous-saturation accumulations are essentially single fields, so large in areal extent and so heterogeneous that their development cannot be properly modeled as field growth. Fields developed in gas-saturated plays are not restricted to structural traps and they are developed in any structural position where permeability conduits occur such as that provided by natural open fractures. Other fields in the region of the Reserves have gas/water contacts and the rocks are water-bearing away from structural culmination's.

Hydrocarbons hypothesized to underlie Reserves 1 and 3, Colorado were assigned to five major plays for nonassociated gas. The are: Cretaceous Mesaverde Gas-Saturated 2007; Wasatch Formation Gas-Saturated 2008; The Mancos & Associated Rocks 2021P; Cretaceous Dakota Group & Jurassic Morrison Fm 2011P; and the Paleozoic strata 2005P. Hydrocarbons that underlie Reserve 2, Utah were assigned to: Eastern Wasatch Gas-Saturated 2015; the Western extension of the Wasatch Formation 2016; Wasatch Formation Transitional 2017; the Basin Flank Mesaverde Group 2018; The Mesaverde Group Transitional 2019; Cretaceous Dakota Group & Jurassic Morrison Fm 2011U; and Paleozoic strata 2021U.

The plays can be assigned to two groups. Group I plays (2007, 2008, 2021P, 2011P, 2005, 2015, 2016, 2018, 2011U and 2021U) are those in which gas/water contacts are rare to absent and the strata are gas saturated. Group II plays (2019, 2017) contain reservoirs in which both gas-saturated strata and rocks with gas/water contacts seem to coexist.

The quantitative results of this assessment study are presented in Table 1.

INTRODUCTION

U.S. Naval Oil Shale Reserves 1 and 3 are located near the southeast margin of the Piceance basin, Colorado. Reserve 2 is located in the south-central part of Uinta Basin, Utah. The Reserves are underlain by petroliferous rocks of several ages that have yielded oil and/or gas in nearby fields (Figs. 1 and 2)

The combined Uinta-Piceance (UP) basin is a structural and topographic basin that trends east-southeast in northeastern Utah and northwestern Colorado and roughly parallels the Uinta Mountains to the north. It is an asymmetrical structural trough filled by as much as 5,000 m (17,000 ft) of Cretaceous Maastrichtian and Paleogene sedimentary rocks. The total sedimentary-rock section reaches a thickness of greater than 30,000 ft over much of the area with Cretaceous and Tertiary strata locally comprising more than 2/3 of that thickness.

PETROLEUM GEOLOGY

Oil and gas compositions indicate that at least three petroleum systems occur within the greater Uinta-Piceance basin. The nonassociated gas fields produce mostly from Mesozoic reservoir rocks with some gas migrating into the overlying Tertiary strata. Most of this gas is thought to originate from the underlying Cretaceous Mancos Formation and (or) Mesaverde Group, and it is interpreted to be part of one or more gas systems. The second petroleum system is represented by the relatively high sulfur oil in the Ashley Valley and Rangely oil fields. This oil probably originated from the Phosphoria Formation source rock sometime in late Mesozoic time. In the third system, production from the Green River Petroleum system is largely restricted to the Uinta Basin in northeastern

Table 1. Resources (potential additions to reserves) of Nonassociated Gas In Naval Oil Shale Reserves.

Mean	Std Dev	F95	F75	F50	F25	F05	EUR/well (mean)	Comment
Naval Oil Shale Reserve 1, Colorado								
Play 2007 Mesaverde								
Gas in billions of cubic feet								
670	203	393	524	641	783	1044	1.88	80 acre spacing
321	119	167	236	301	383	542	1.88	160 acre spacing
Play 2008 Wasatch Formation			Revised 4/20/94					
Gas in billions of cubic feet								
144.8	44.5	84.4	113	138.4	169.6	227	0.7	
Play 2005P Paleozoic Strata Gas								
Gas in billions of cubic feet								
0.48	0.472	0	0.19	0.37	0.64	1.35	0.2	
Play 2011P Dakota & Morrison Gas saturated								
Gas in billions of cubic feet								
47.46	18.33	23.98	34.43	44.28	56.94	81.76	0.28	
Play 2021P Mancos & Assoc. Gas Saturated								
Gas in billions of cubic feet								
3.4	1.68	1.4	2.22	3.04	4.18	6.6	0.2	
Naval Oil Shale Reserve 3, Colorado								
Play 2007 Mesaverde Gas Saturated								
Gas in billions of cubic feet								
315	97	184	246	302	369	493	1.88	80 acre spacing
198	123	66	114	168	247	430	1.88	160 acre spacing
Play 2008 Wasatch Formation								
Gas in billions of cubic feet								
63.1	24.3	31.96	45.84	58.9	75.67	108.5	0.7	
Play 2005P Paleozoic Strata Gas								
Gas in billions of cubic feet								
0.23	0.31	0	0	0.15	0.33	0.8	0.2	
Play 2011P Dakota & Morrison Gas saturated								
Gas in billions of cubic feet								
22.76	9.23	11.1	16.21	21.09	27.44	40.08	0.2	
Play 2021P Mancos & Assoc. Gas Saturated								
Gas in billions of cubic feet								
1.63	0.98	0.55	0.96	1.39	2.04	3.5	0.2	

Table 1. Continued.

Mean	Std Dev	F95	F75	F50	F25	F05	EUR/well (mean)	Comment
Naval Oil Shale Reserve 2, Utah								
Play 2011U: The Cretaceous Dakota Grp., Jurassic Morrison Fm., & Assoc. Strata								
Gas in billions of cubic feet								
159.971	60.821	81.698	116.7	149.52	191.58	273.67	0.79	
Play 2015: Wasatch Gas-Saturated East								
Gas in billions of cubic feet								
193	120.02	63.94	111.34	163.82	240.95	419.77	1.4	160 acre spacing
367	112	214	287	351	429	574	1.4	80 acre spacing
734	223	431	575	702	858	1145	1.4	40 acre spacing
Play 2016: Wasatch Gas-Saturated West								
Gas in billions of cubic feet								
17.43	12.01	5.12	9.43	14.37	21.89	40.09	1.35	
Play 2017: Wasatch Gas-Water Transitional								
Gas in billions of cubic feet								
119.18	74.6	39.23	68.54	101.02	148.88	260.14	0.74	
Play 2018: Mesaverde Basin Flank Gas-Saturated								
Gas in billions of cubic feet								
32.26	13.37	15.47	22.78	29.8	39	57.44	0.75	
Play 2019: Mesaverde Gas-Water Transitional								
Gas in billions of cubic feet								
78.91	49.51	25.88	45.31	66.83	98.66	172.73	0.59	
Play 2021U: Mancos-Ferron-Frontier Gas-Saturated								
Gas in billions of cubic feet								
1.64	1.03	0.53	0.94	1.39	2.05	3.61	0.02	

Utah. The Green River Formation contains the source rocks as well as most of the reservoir and seal rocks (some in Wasatch Formation) in this prolific petroleum system, and levels of maturity have been sufficient to generate exceptionally large volumes of paraffinic high pour-point oil and wet gas. Currently, economically viable oil in the Uinta Basin is recovered from the subsurface where the oil is above pour point temperatures and is moveable, and where strata are especially porous and permeable.

Reserve 1

Reserve 1 lies along the north margin of Reserve 3 in the Piceance basin, Colorado. Although no gas has been recovered from Reserve 1, reservoirs in the adjacent Reserve 3 yields gas from Upper Cretaceous reservoirs of the Mesaverde Group. The Paleocene and Eocene Wasatch Formation yields gas nearby but reservoir quality in this unit is frequently greater than that of underlying Cretaceous reservoirs. However, reservoir distribution and other problems seem to limit production from the Wasatch.

Currently, gas in the Tertiary and Cretaceous strata is extracted from fields without gas/water contacts and the section is believed to be gas saturated due to the concurrent and continuing generation of gas from Cretaceous source rocks. The zone of continuous gas-saturated Cretaceous strata can be approximated by

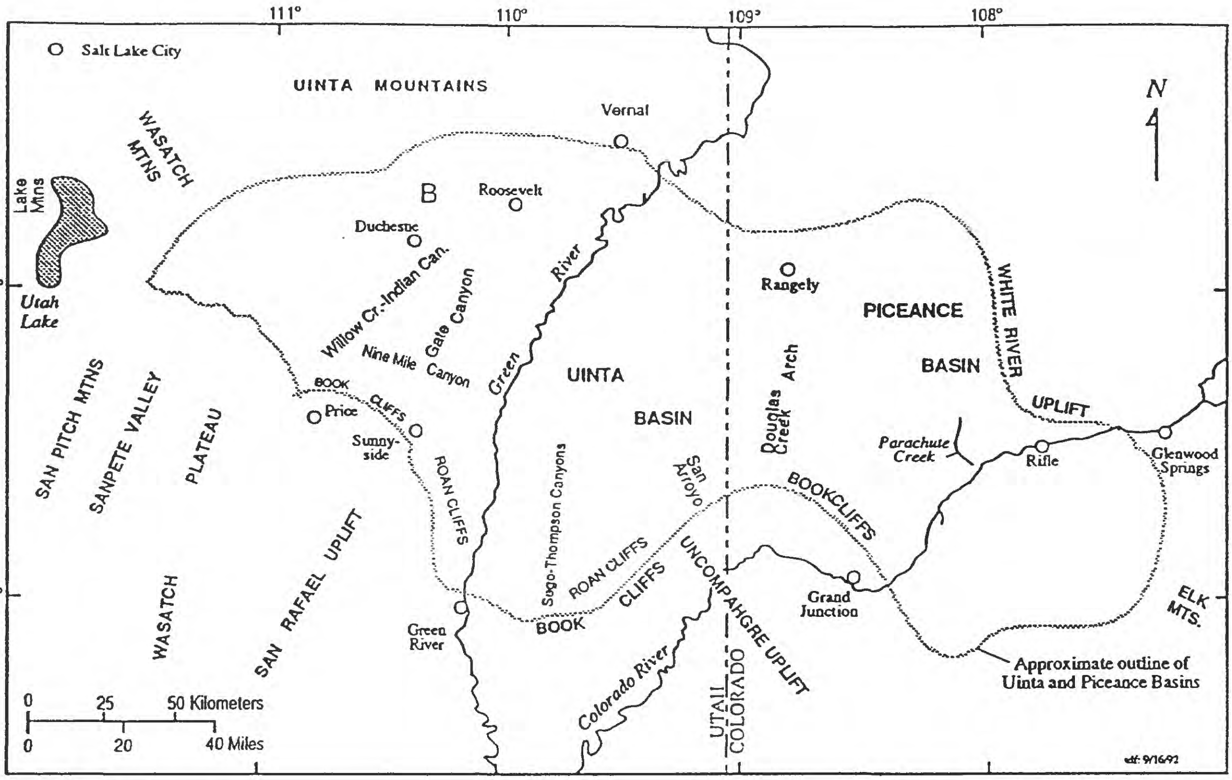


Figure 1a :

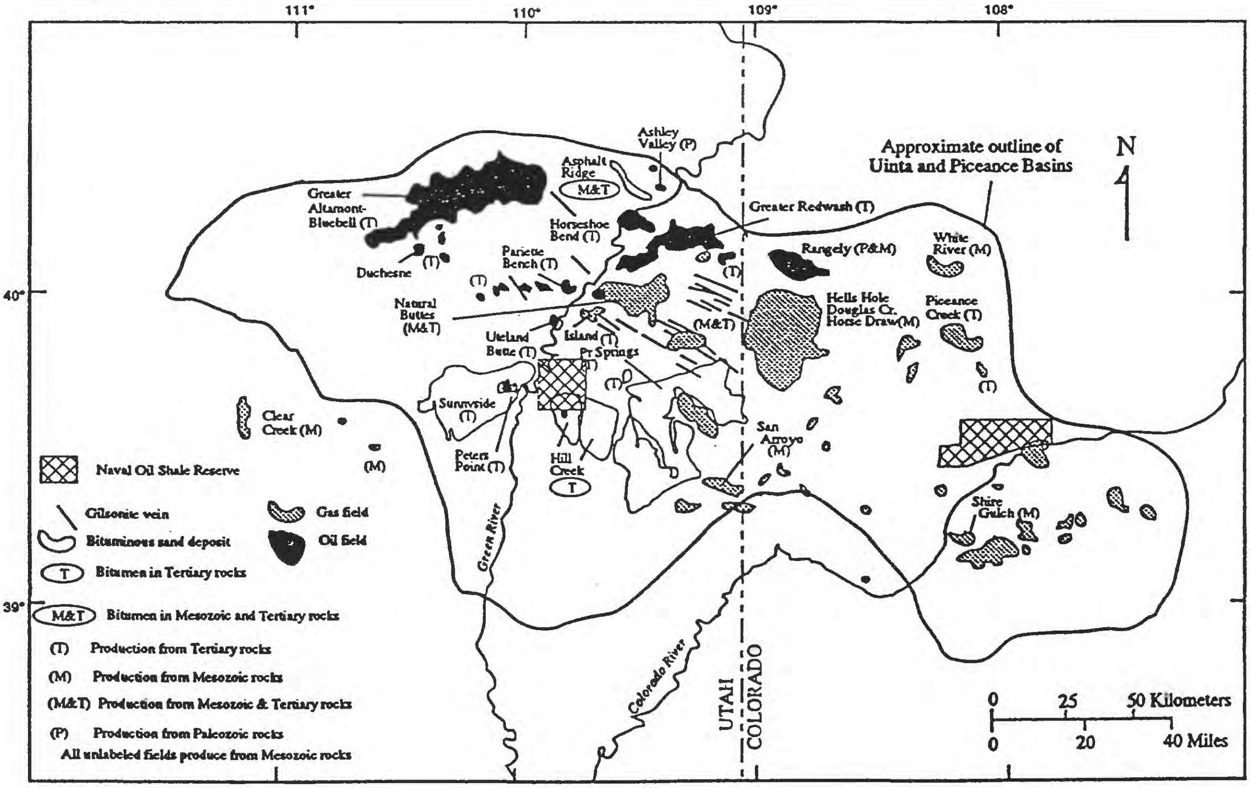


Fig. 1b:

Figure 1. Index map of the Uinta and Piceance basins showing: 1a, principal place names and names of bounding geologic features; and 1b, area of principal hydrocarbon accumulations in sedimentary rocks. Bitumen-bearing sandstones are abundant in surface exposures in regions between areas shown as tar sands.

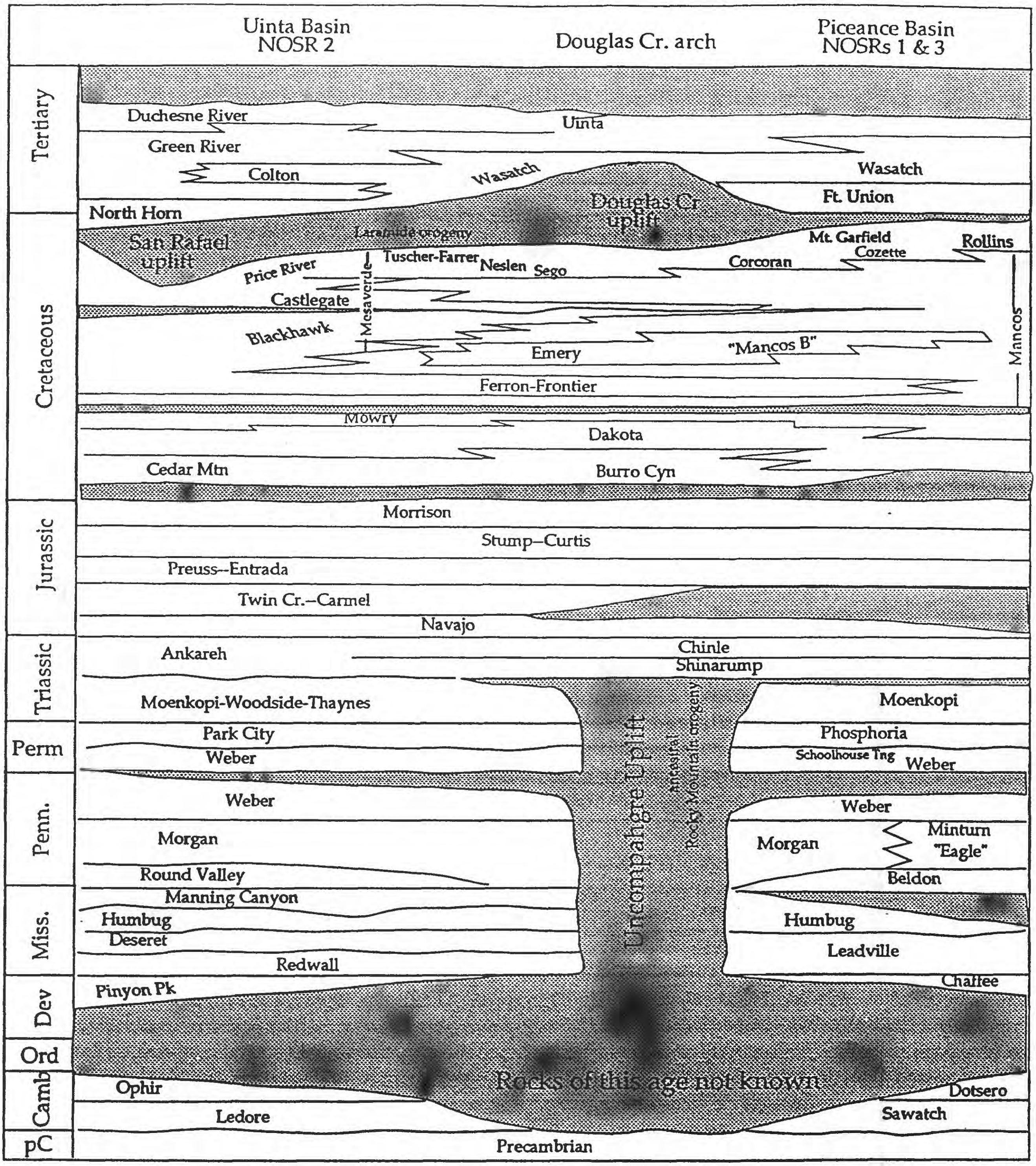
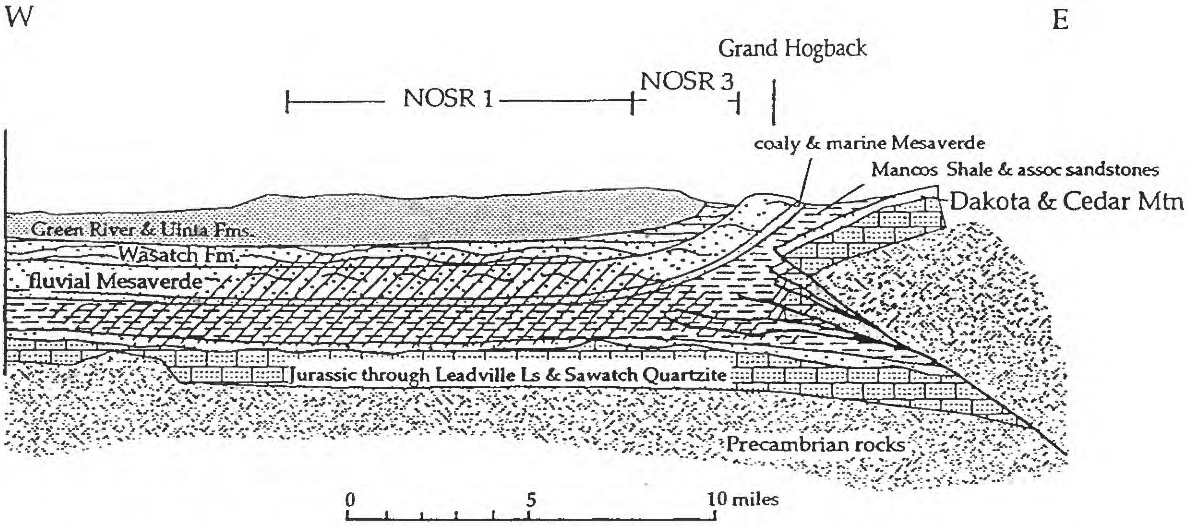


Figure 2. Chronostratigraphic diagram extending from area of Naval Oil Shale Reserve (NOSR) 2, Uinta Basin, Utah to Naval Oil Shale Reserves 1 & 3, Piceance basin, Colorado. Stratigraphic names are those frequently applied by industry to the strata.

mapping the surface projection of the trace of the boundary between those rocks at the Cameo coal level that have reached temperatures approximated by the vitrinite reflectance value of R_o 1.1. In this basin, that value delineates the area where gas is being generated from source rocks in such volume and at such a rate that it drives free water from the rock column and continuously saturates the section with gas. Gas-saturated Cretaceous strata are widespread in the basin. The region of Wasatch Formation reservoirs without gas/water contacts is much smaller than that for Upper Cretaceous strata and probably extends over much of the region of NOSRs 1 and 3 but not much farther north.



Preliminary diagrammatic W-E cross section at the latitude of Naval Oil Shale Reserves 1 & 3 and that extends from western edge of Piceance basin east through NOSRs 1 & 3 to the Grand Hogback. Constructed from surface and seismic information. Probable rollover on NOSR 1 is not shown. No vertical exaggeration. Diagonal lines indicate subsurface zone where gas/water contacts are believed to be rare or absent and section is saturated with gas. In this zone, limits of gas-bearing strata are not defined by structural traps.

Figure 3.

Reserve 3

U.S. Naval Oil Shale Reserve 3 is located near the southeast margin of the Piceance basin, Colorado. Reserve 3 yields gas from Late Cretaceous-age reservoirs of the Mesaverde Group whose values of matrix permeability, exclusive of fracture permeability, are commonly below 0.1 md *in situ* to gas. In addition, porosity of reservoirs is commonly less than 10%. The Paleocene and Eocene Wasatch Formation yields gas but reservoir quality in this unit is frequently greater than that of underlying Cretaceous reservoirs.

Currently, gas in the Tertiary and Cretaceous strata is extracted from fields without gas/water contacts and the section is believed to be gas saturated due to concurrent and continuing generation of gas from Cretaceous source rocks. The zone of continuous gas-saturated Cretaceous strata can be approximated by mapping the trace of the surface projection of the boundary between those rocks at the Cameo coal level that have reached temperatures approximated by the vitrinite reflectance value of Ro 1.1. In this basin, that value delineates the area of maximum generation of gas from source rocks in such volume that it is being expelled from the strata into Mesaverde and lower Wasatch beds at such a rate that it drives free water from the rock column and continuously saturates the section with gas. The region of Wasatch Formation reservoirs without gas/water contacts is much smaller than that for Upper Cretaceous strata and probably extends over much of the region of NOSRs 1 and 3.

Gas in strata without water/hydrocarbon contacts is commonly included in the estimates of unconventional gas. For the most part, successful production of unconventional natural gas in the Piceance basin is most successful where the strata are fractured naturally and where the rocks have fluid-pressure gradients more than 0.5 psi/ft.

Reserve 2

Reserve 2 lies southeast of the greater Natural Buttes gas field. Natural Buttes field produces associated and nonassociated gas from sandstone reservoirs of the Upper Cretaceous Mesaverde Group and the Paleocene and Eocene Wasatch Formation (Figs. 4 & 5). Unlike the production at Reserve 3 in Colorado, most gas in the Uinta Basin is produced from the Tertiary Wasatch (including Colton and North Horn Formations) Formation or temporally equivalent beds in the Green River Formation. Production from the Mesaverde Group is very limited.

Most of the gas currently being produced from Wasatch and Mesaverde reservoirs in the southeast Uinta Basin is extracted from fields without gas/water contacts and the section is believed to be gas saturated due to concurrent and continuing generation of gas from Cretaceous source rocks. The gases from the Mesaverde Group and much from the overlying Wasatch are almost identical in chemical and isotopic composition yet they occur over a depth interval of 3,500 to 9,3 00 ft. Studies by us indicate that most of this gas was is being generated at temperatures

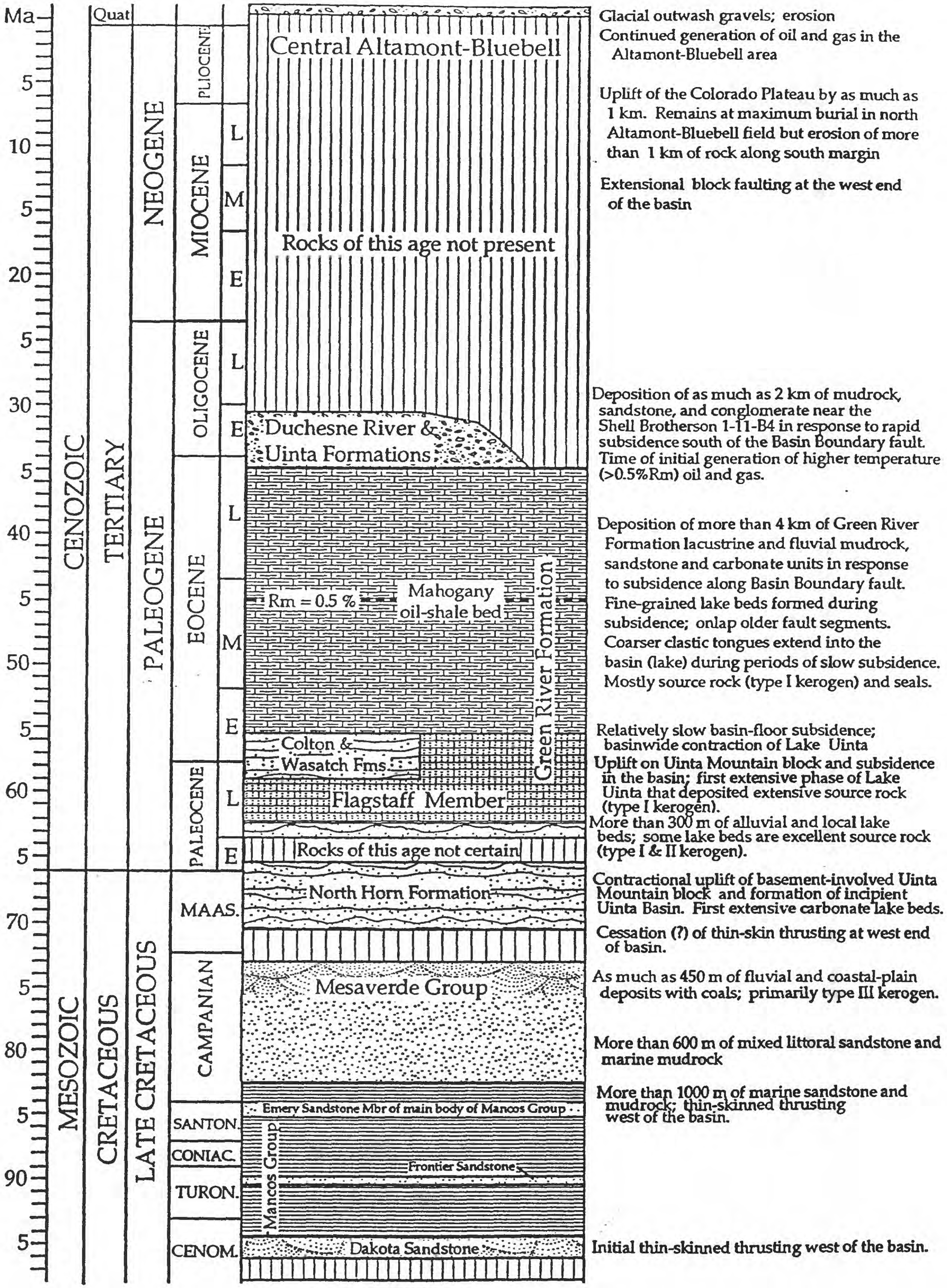


Figure 4. Diagram showing geologic column and a summary of geologic events for the area of the central part of the greater Altamont-Bluebell field, Uinta Basin, Utah and Colorado. Cretaceous strata are those thought to underlie the region of Naval Oil Shale Reserve (NOSR) 2.

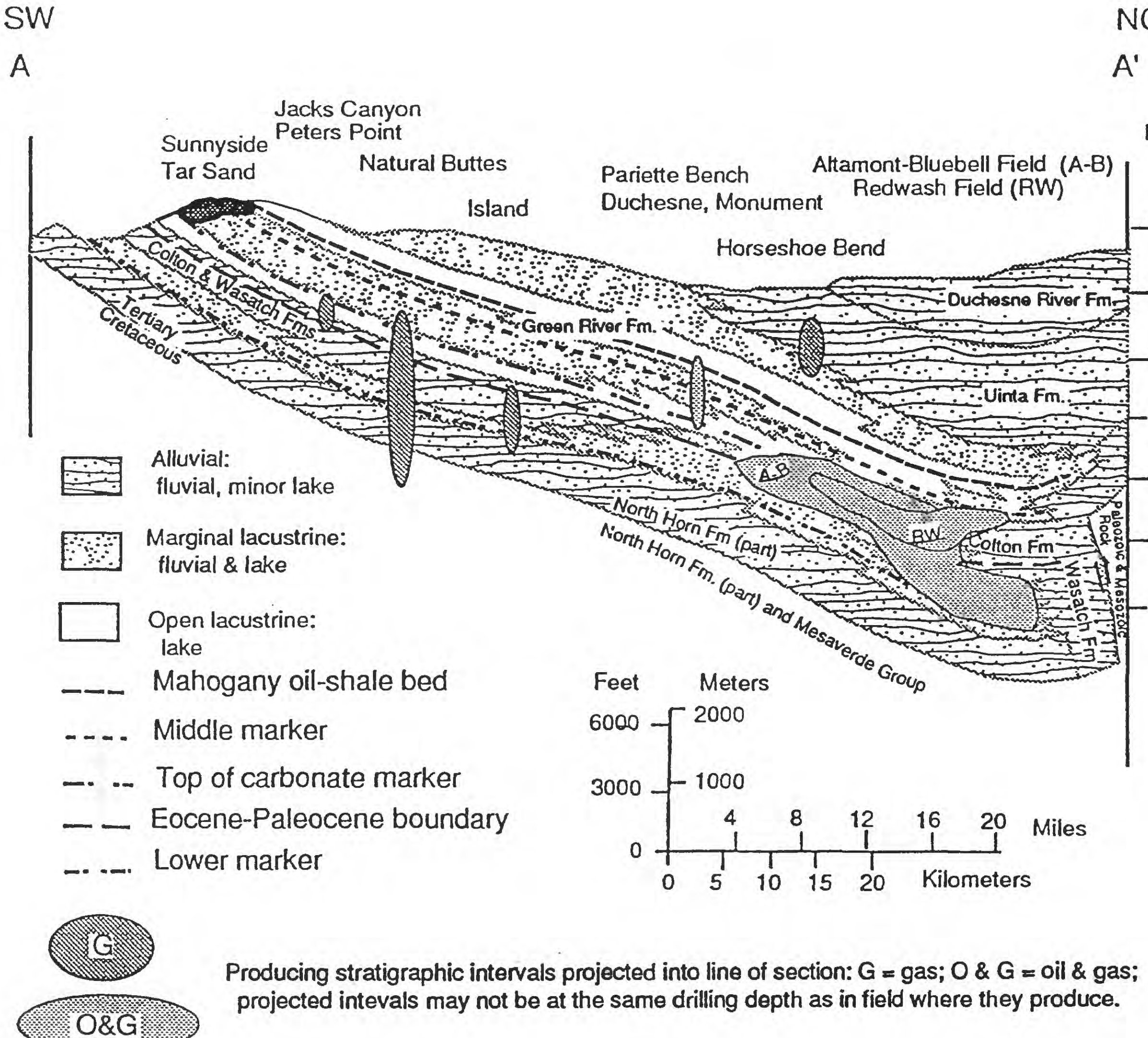


Figure 5. Cross section A-A' which extends from outcrops on the southwest flank of the Uinta Basin, through Duchesne and Altamont-Bluebell oil fields, to the north-central part of the basin (modified from Fouch, 1975). Section shows producing intervals for many of the basin's fields projected into the line of section. Stratigraphic markers are those commonly assigned to the units and follow the usage of Fouch, (1975), Fouch (1976), Ryder and others (1976), and Fouch(1981). Stratigraphic names projected into the line of section are those commonly assigned to the units and follow the usage of Fouch (1976), Ryder and others (1976), Bryant (1991), and Bryant and others (1989).

approximated by vitrinite reflectance values (R_o) in the range of 1.1 to 1.5 percent. These studies also indicate that the generation of gas under Natural Buttes is probably taking place in the lower part of the Mesaverde Group. These strata are characterized by this level of maturity in the Natural Buttes area and this zone of maturation apparently extends to the northwest margin of Reserve 2 (Fig. NOSR 2-6).

The extent of existing production in the Uinta Basin, when compared to our maps of productive lithofacies, suggest areas of future production. We expect that future drilling and production will link many small oil fields on the south flank of the basin, such as Pariette Bench, to the greater Altamont-Bluebell and Red Wash fields. This linkage will form a region of continuous production that extends from the northeast end of the Altamont-Bluebell complex east to Red Wash and southwest and west to rejoin the southwest tip of the Altamont-Bluebell complex. More than 750 mbo are expected to be produced from this area.

Petroleum-bearing Tertiary strata have been identified in drill holes distributed over much of the central and eastern parts of the Uinta Basin, and bituminous sandstones (tar sands or natural bitumen) are exposed along the basin's southern margin in the Roan Cliffs of NOSR 2. In addition, Tertiary oil reservoirs have yielded oil, east, south, and west of the Reserve. However, much of this oil-bearing section can be expected to be penetrated under NOSR 2 at depths above 5,000 ft drilling depths. These depths are frequently associated with insufficient temperature to heat the *in situ* oil above approximately 95° F and transform the hydrocarbon into moveable liquid.

Geologic Framework

Paleogeographic maps and cross sections characterize and portray the primary sedimentologic and stratigraphic composition of the region's hydrocarbon-bearing strata. Most information on the stratigraphic, structural and sedimentologic composition of the regions rocks presented herein is done so with illustrations so that the temporal and spacial components of the geologic system can be quickly realized.

Paleozoic Strata

Paleozoic strata of interest to this study involve a regionally extensive complex of reservoir quality eolian and associated sandstone, and carbonate beds that is bounded on the west and north by nonreservoir marine rocks, and on the east and southeast by the nonreservoir redbed lithologies, or by uplifted Precambrian rocks. Figures J1, J2, and J3 are paleogeographic maps that portray the spatial and temporal distribution of key lithologies.

Cretaceous and Tertiary Strata

Most reservoirs in existing fields are within lenticular fluvial sandstones that occur within two major sedimentary systems. Figure 6 illustrates these two systems in a chronostratigraphic cross section that extends from exposures in central Utah to those along the Book and Roan Cliffs that mark the southern edge of the Uinta Basin. Figure 7 illustrates many of these same strata between Price Canyon and the Natural Buttes gas field. In the first sedimentary system, Upper Cretaceous impermeable fluvial rock reservoirs occur within the Blackhawk, Castlegate, Sego, Neslen, Farrer, Tuscher, and Price River Formations which are assigned to the Mesaverde Group. A second sedimentary system consists of Tertiary rocks that occur in the Maastrichtian to lower Eocene North Horn Formation, and in the Paleocene and Eocene Wasatch and Colton Formations. Locally, fluvial sandstones of the Eocene part of the Green River Formation are tight-gas reservoirs but many operators frequently group the fluvial Green River reservoirs with those of the Wasatch Formation when applying stratigraphic terminology.

Upper Cretaceous Mesaverde Group and Associated Rocks

Paleogeographic maps and cross sections characterize and portray the primary sedimentologic and stratigraphic composition of the basin's hydrocarbon-bearing strata. Figures FR1-FR9 are paleogeographic maps that correspond to periods of Cretaceous time. The figures collectively indicate the stratigraphic and sedimentologic composition of rocks of this age in the basin. The maps and section also display stratigraphic names frequently applied to these strata.

Paleocene and Eocene Wasatch Formation and Associated Rocks

The cyclic nature of the Tertiary units and the interbedding of mixed lake and alluvial rocks (Green River Formation) with red colored alluvial strata (Wasatch, Colton, and Ft. Union, and North Horn Formations) has resulted in some confusion in the application of stratigraphic names. Most formational names applied in the basin are representative of lithologic and depositional facies. As a result, several facies and formations can be preserved within a thin stratigraphic interval.

Figure FR 10-FR12 illustrate the paleogeographic distribution of depositional facies for three periods of geologic time in the Paleogene. The maps also display stratigraphic names frequently applied to these rocks.

Reservoir Properties

Overall descriptions and reservoir properties for the current hydrocarbon plays adjacent to, as well as the anticipated plays in the NOSR areas, are provided by Chidsey (1993a, b), Hemborg, (1993), Tremain (1993), and Noe (1993a, b).

Reservoir properties for anticipated hydrocarbon plays on the NOSR properties are not expected to vary significantly from those listed above.

Reservoir properties, where available, for fields immediately adjacent to the NOSR areas, are presented in Table 2. Where no data have been published, estimates have been made from well logs of selected wells. Preliminary data analysis of these wells supported the data ranges provided in Table 2.

One caution on the use of well-log derived values in these areas. Core data are not commonly available in these fields and estimates derived from well-logs are subject to error, particularly in the Tertiary and Cretaceous sandstones of the Piceance and Uinta basins where the presence of high percentages of clay minerals (e.g., up to 40 percent in the Rulison field (Martinez and Duey, 1982)) adversely affect well-log response (Kukal, et. al, 1983; Hartmann and MacMillan, 1992; Shade and Hansen, 1992). Kukal, et al. (1983) provide a comprehensive discussion of these sources of error. In short, density logs provide

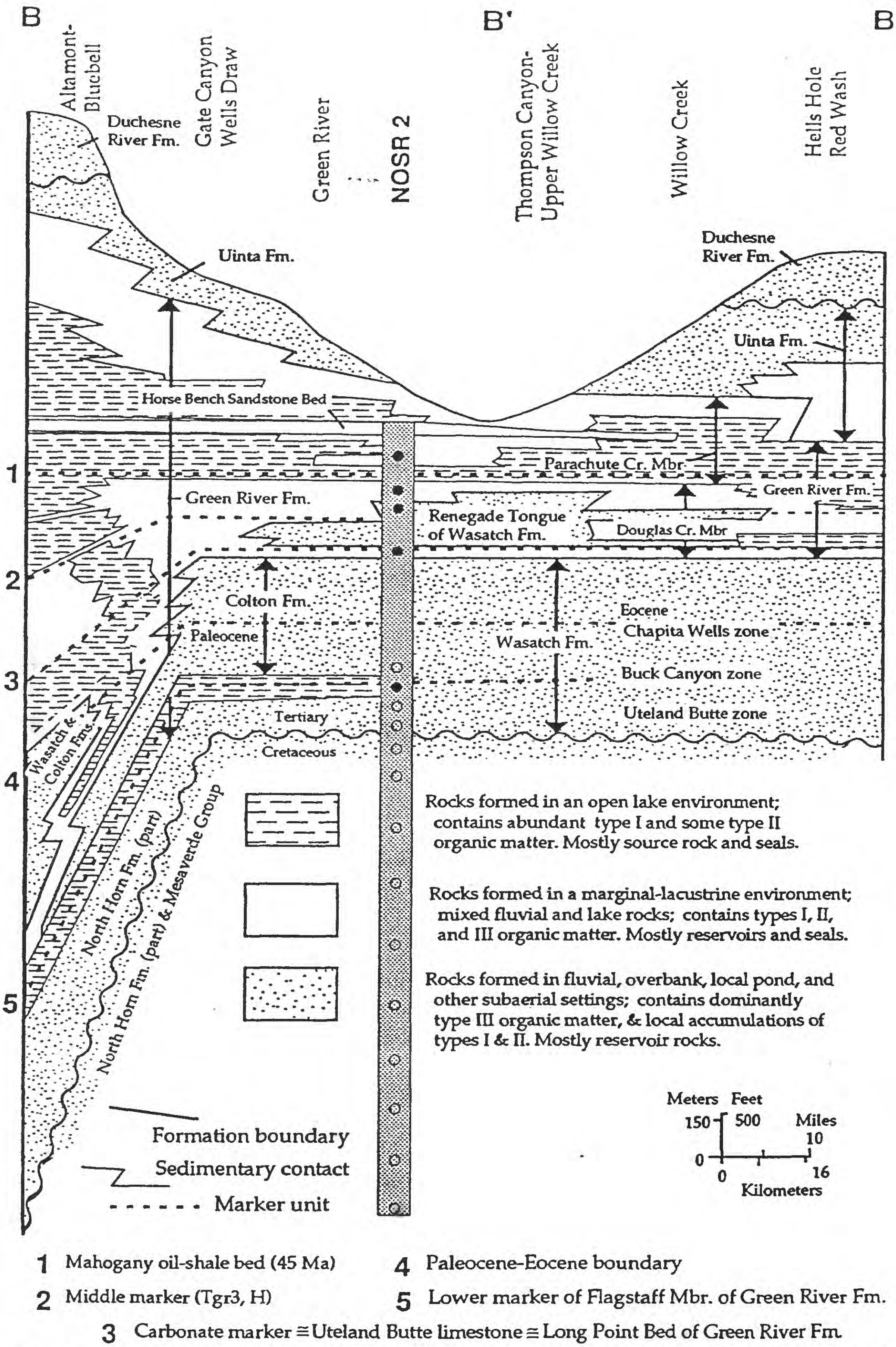


Figure 2-6. Stratigraphic diagram B-B′ that extends east from the Altamont-Bluebell oil field to the Red Wash and Hells Hole areas of the east end of the basin by way of Gate Canyon and Thompson Canyon of the basin's south flank. A hypothetical well on Naval Oil Shale Reserve (NOSR) 2 is illustrated to demonstrate the nature and locations of hydrocarbon species anticipated. Black dots indicate oil, open circles indicate gas. The Chapita Wells, Buck Canyon, and Uteland Butte zones are local names for gas-producing intervals in the Wasatch Formation of the central and eastern part of the basin. The Uteland Butte limestone is a local name for units that approximate the lower marker of the Green River Formation. Tgr3 is the Shell Oil Company name for the middle marker of the Green River Formation; H is the name for the middle marker commonly used by the Chevron Oil and other companies that operate in the eastern part of the basin. The Dark Canyon sequence is the siliceous pebble conglomerate at Dark Canyon of Fouch and Cashion (1979), and the Dark Canyon sequence of the Wasatch Formation of Franczyk et al (1992).

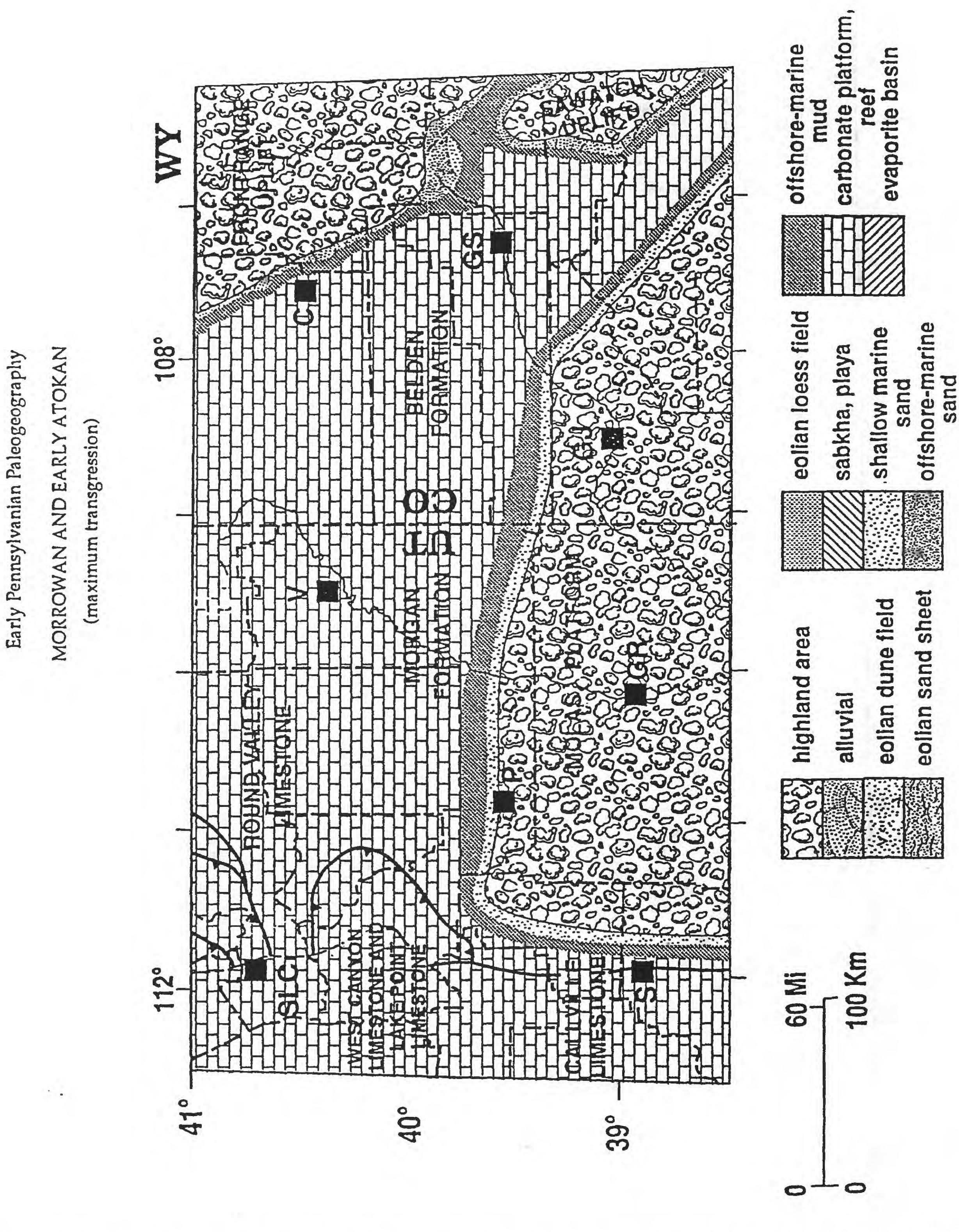


Figure J1. Paleogeographic map showing Early Pennsylvanian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from S.Y. Johnson *et al.*, 1992.

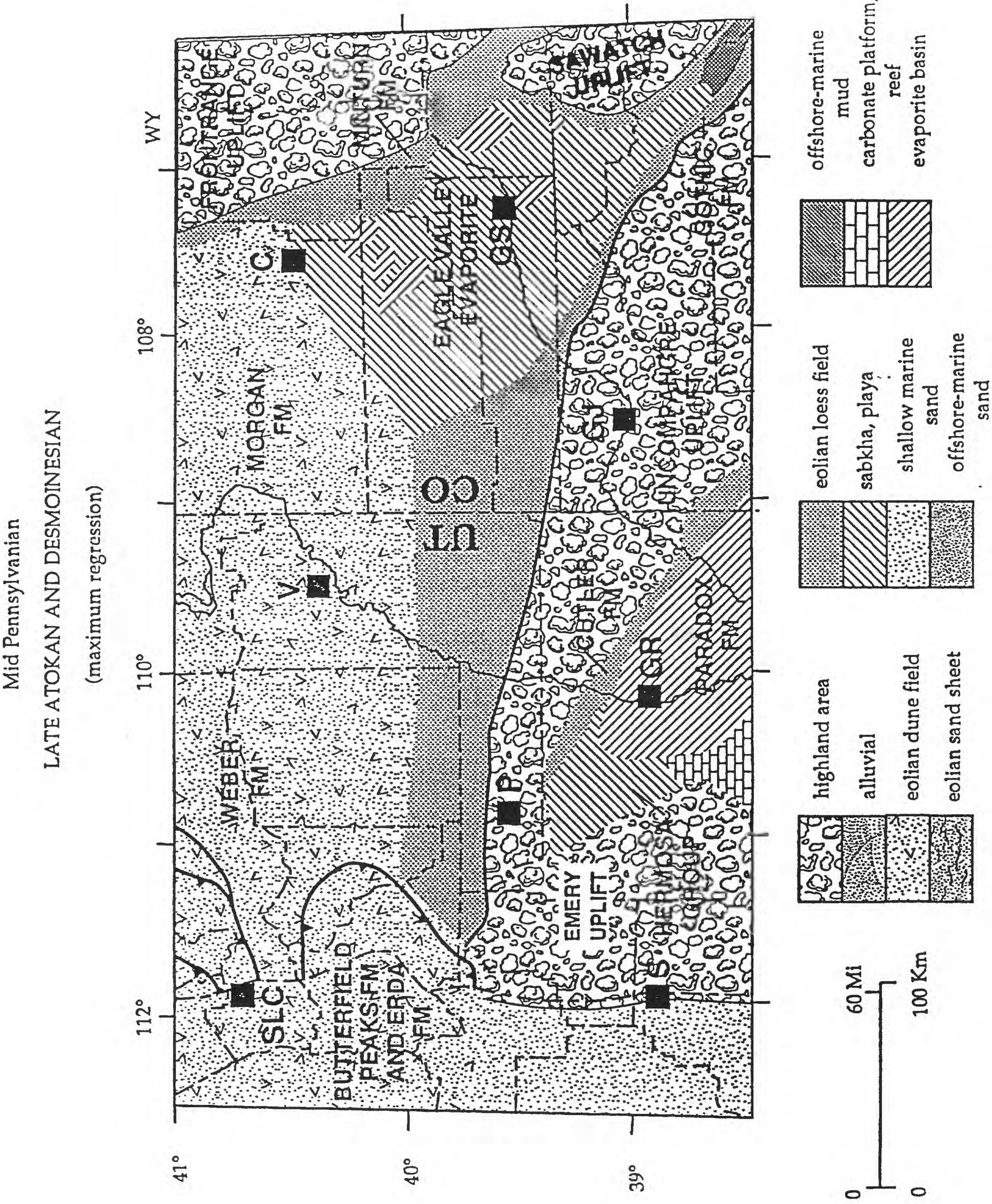


Figure J2. Paleogeographic map showing Middle Pennsylvanian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from S.Y. Johnson *et al.*, 1992.

Table P1. Regional reservoir properties of strata that underlie NOSR areas (Robertson and Broadhead, 1993)

Play	Porosity %	Permeability md	Well spacing acres
Green River Formation	15	——	160/320
Wasatch Formation			
Uinta Basin	13	0.1	40
Piceance basin	7-15	0.16-1.0	160
Mesaverde Group	12	0.1	40/160
Mancos "B"	11	0.1	160
Dakota Sandstone	13	0.1	320/640

the most reliable porosity values but these are generally higher than core values and may be in error by up to 4 porosity units, even after correction; the presence of large volumes of authigenic clays drastically reduces permeability and this, in turn, leads to variable invasion profiles and reduced resistivity and SP values. All this results in the high formation water saturations (Sw), ranging from 40-60 percent in core measurements and well-log calculations, common in these low-permeability sandstones.

Green River Formation

Oil and gas are produced from basal ostracodal limestones in the River Bend Unit (T. 10 S., R. 18 E., Uintah County) of the Greater Natural Buttes field. Production is limited to this area and is not expected to be significant at NOSR 2.

Wasatch Formation

The Wasatch, a designated tight reservoir, is productive in a number of fields around NOSR 1-3 and NOSR 2. Major fields are the Greater Natural Buttes (Uinta Basin) and Grand Valley (Piceance basin). Thickness of individual sandstone reservoirs is <100 ft and multiple reservoirs are the norm. The "G" sand, the primary target in the Grand Valley field, has an average net pay of 31 ft.

Wasatch reservoirs expected on the NOSRs will have multiple pay zones, each generally less than <75 ft gross and net pay <30 ft. Porosity is expected to average 9-12 percent and permeability <0.1 md.

Examination of well-log and completion data in the Grand Valley and Rulison fields, adjacent to NOSR 2, indicates that an empirical set of well-log cutoff values is used by operators to define commercial pay in sandstones of the Wasatch and Mesaverde intervals. These values are "clean" sandstone gamma-ray values ranging from <90 API, and in most wells <55-60 API, resistivity >30-40 ohm-m, and presence of gas effect, i.e., neutron-density log crossover.

Mesaverde Group

Primary production in the Piceance basin is from the upper fluvial (Williams Fork Formation) and coastal intervals and middle paludal, Cameo coal, interval. The lower marine interval (Iles Formation, consisting of Rollins, Cozette, and Corcoran Sandstones (NOSR 1-3); the Castlegate Sandstone (NOSR 2), despite the presence of gas effect on logs (neutron-density crossover) may not be productive (Reinecke et al., 1991) and is a secondary target in many wells in the Piceance basin.

Thicknesses of individual reservoirs anticipated in the fluvial interval will be erratic and generally <100 ft, net pay is highly variable and averages 260 ft in the Grand Valley field. Net pay in individual wells adjacent to NOSR 1-3 and NOSR 2 may exceed 500-600 ft. Mesaverde reservoirs anticipated in the NOSR areas will be overpressured, have porosities of 7-14 percent, and in-situ permeability <0.1 md. A well-developed Cameo coal interval capable of significant coalbed methane production, is likely in the NOSR 3. Expected net coal (beds exceeding 4 ft) is 50-70 ft.

Mancos "B"

Although this interval is productive in fields northwest of NOSR 1-3 and east of NOSR 2, no production Mancos "B" (Emery Sandstone, part) is reported in fields adjacent to either, and this play is not expected to be significant in the NOSRs. Properties of productive reservoirs are 7-11 percent porosity, <0.1 md permeability and net pay averaging 30-250 ft (Noe, 1993a).

Dakota Sandstone

The Dakota Sandstone-Cedar Mountain-Morrison interval is productive in fields around NOSR 2. Net pay averages 20-30 ft, porosity 10-15 percent, and permeability of 0.1 md. Similar reservoirs can be anticipated in NOSR 2.

In the immediate vicinity of NOSR 1-3, only two wells penetrated the Dakota (Arco et al., 1 North Rifle Unit, T. 4 S., R. 93 W., sec. 31, top at 13,400 ft, and Barrett Arco 1-27 Deep Test No. 1, T. 6 S., R. 97 W., sec. 27, top at 17,100). The Barrett Arco 1-27 had gas shows (neutron-density crossover) in thin (<10 ft) sandstone members, however, testing indicated that the interval is non-productive. The depth to the Dakota Sandstone combined with disappointing results

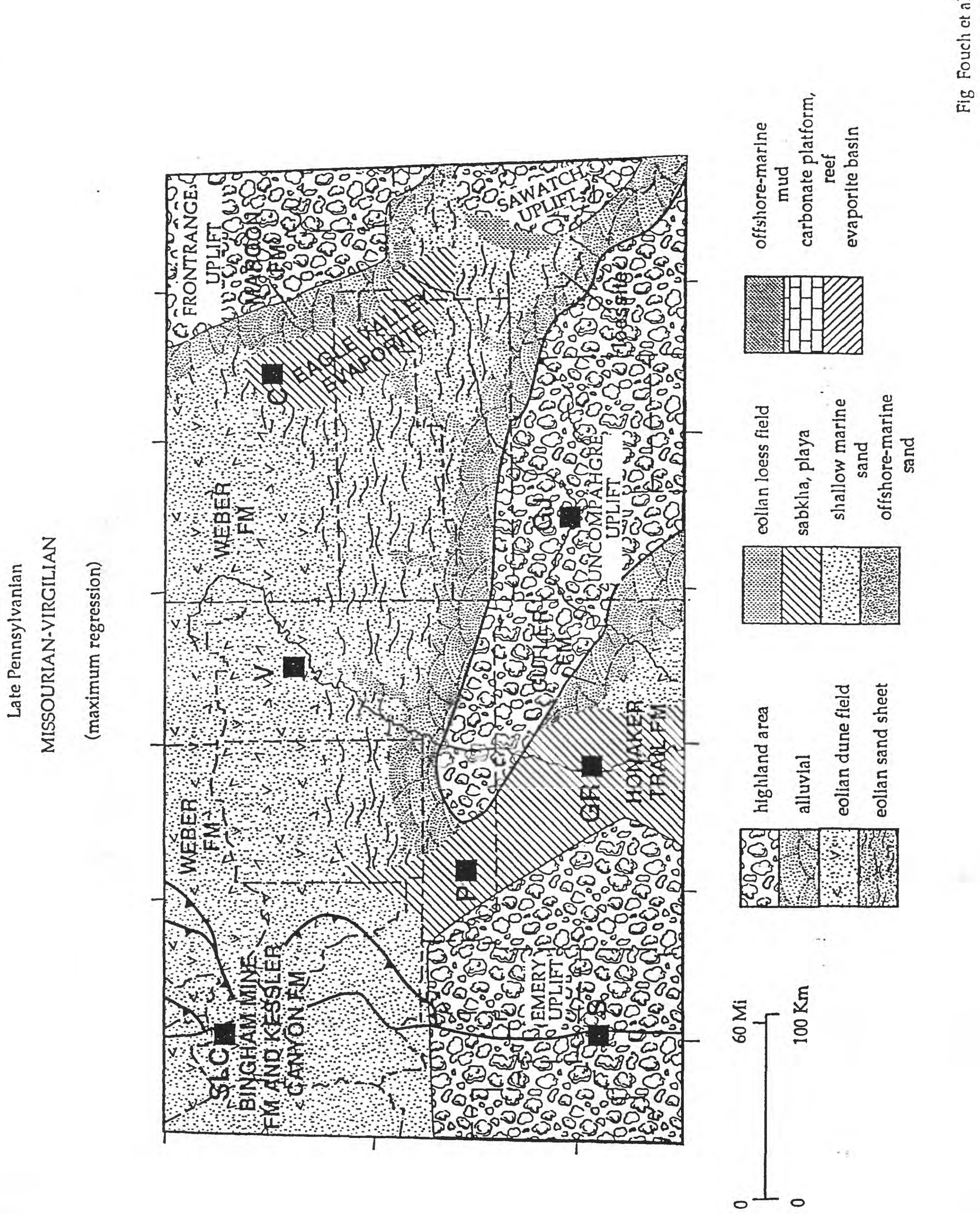
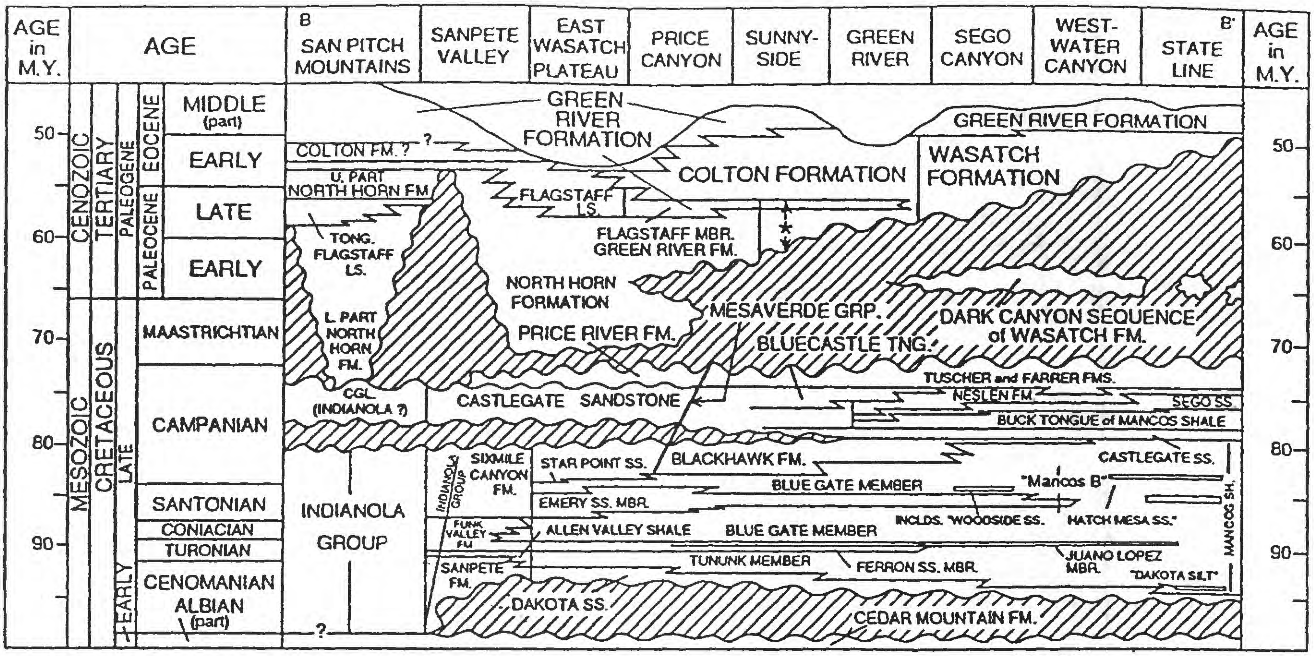


Figure J3. Paleogeographic map showing Late Pennsylvanian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from S.Y. Johnson *et al.*, 1992.



* : Flagstaff Member and North Horn Formation undivided

Figure 6. Albian to Middle Eocene chronostratigraphic diagram along cross section line illustrating nomenclature and temporal relations of major strata from the Sanpete Valley of central Utah to the Book Cliffs of eastern Utah via the southern part of the Uinta Basin, Utah (modified from Fouch and others, 1983, and Franczyk and others, 1989; Fouch and others, in press). Vertical line through strata indicates a change in stratigraphic nomenclature. Quote marks indicates an informal name applied locally to stratigraphic unit.

of production tests suggest that this will not be a significant play in NOSR 1-3.

Thermal History Of Organic Matter

Rm Map at Base of the Mesaverde Group.

Figure 8 is an R_m map at the base of the Mesaverde Group in the Uinta Basin, Utah. The map shows a general trend of increasing maturity from south to north. This trend generally follows the structural configuration on the base of the Mesaverde which indicates that maturity was set prior to (at maximum burial) or during early stages of structural movement. In some areas, however, the R_m lines cut across structure indicating that maturity continued during or for some time after structural movement. It is likely that toward the deepest part of the basin, maturation at the base of the Mesaverde continued to increase during or after uplift and erosion that began 10 Ma (Miocene). On the flanks of the basin, however, maturity patterns may have been achieved prior to uplift.

Four R_m lines and three zones of hydrocarbon generation are shown. The 0.65 percent R_m line is for reference, and shows the maturity of the base of the Mesaverde around the edge of the basin. The areas of the basin which have not achieved a maturity of 0.75 percent, not mature enough for significant gas generation, are shown by the light stipple pattern. The 0.75 percent R_m line indicates the onset of significant gas generation from type III kerogen at the base of the Mesaverde. The area between 0.75 percent and 1.10 percent R_m (darker stipple) is where one would expect to begin encountering gas generation and accumulation in Mesaverde reservoirs. The area north of 1.10 percent R_m (darkest pattern) is the zone of maximum gas generation and expulsion. The upper limit of gas generation in the northern and deepest, undrilled part of the basin is unknown at this time. The 1.50 percent R_m line is for reference only.

The base of the Mesaverde is greater than 0.75 percent R_m over a large area of the Uinta Basin. Except for the margins of the basin, where subsidence and burial depths were less, gas was probably being generated as Tertiary sediments were being deposited, in Paleocene or early Eocene time, and this generation continued until at least 10 Ma when uplift and erosion began in part of the basin accompanied by a regional cooling. In the deepest part of the basin, where the effect of uplift and erosion are not as great, if temperatures were still high enough, and kerogen was available (not "cooked out"), gas generation may have continued after 10 Ma and may be continuing today. It is likely that this gas was trapped in "tight reservoirs" throughout the generation history of the Mesaverde, and the pods of high fluid pressures (>0.5 psi) found in the basin today may mark the areas of active generation.

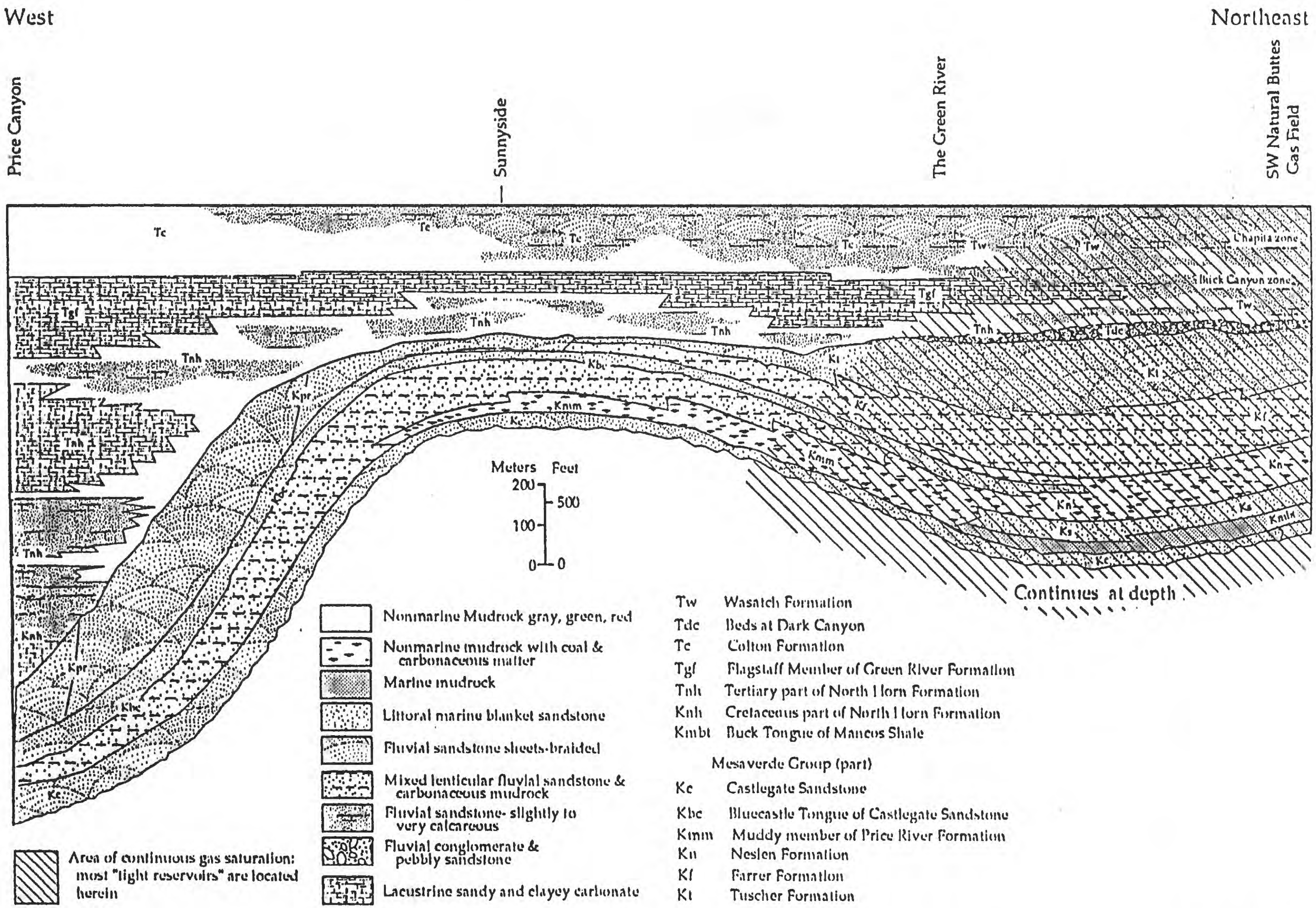


Figure 7. Stratigraphic cross section of upper Campanian through lowest Eocene rocks extending from Price Canyon to Sego-Thompson Canyons showing lithofacies and interpreted depositional environments (from Fouch and others, 1983). Rocks displayed on the right half of this section are the gas-bearing units in the eastern part of the Uinta Basin and the lithologic section is similar in composition to that penetrated in the gas fields of the eastern and central part of the basin, and it is like that anticipated to underlie NOSR 2. The gas-bearing lower Campanian Blackhawk Formation underlies the Castlegate Sandstone over much of the region but is not shown on the diagram. Tertiary rocks of the left half of the diagram are similar to part of the oil-bearing section in the Altamont-Bluebell area of the north-central Uinta Basin.

Table 2. Reservoir data for fields adjacent to NOSR 1-3 and NOSR 2.

Field/Reservoirs	Location	Prod.	Net Pay ft	Porosity %	Perm md	Sw %	Spacing acres	Pressure (drilling-mud density)	Reference
NOSR 1 - 3									
Grand Valley	T. 6-7 S. R. 94-96 W.	gas				40 av	160-210		Reinecke et al., 1991
Wasatch ("G" sand)		gas	<75 31 av	9-18 (log) av 14	—	—	—	normal	
Mesaverde		gas	260	10-12 log 7-9 core	<0.1	—	—	over	
Cameo Coals		gas	50-70	—	0.02-0.2	—	—	over	
Dakota		gas	30	6-20 (log)	—	—	—	normal	
Rulison	T. 6-7 S. R 93-94 W.						320/640		Martinez and Duey, 1982
Wasatch		gas	70 av	6.5 (core)	<0.1-.2	28-70	—	normal	
Mesaverde		gas	400 av	8-16 (log)	<0.1	30-100	—	over	CER, 1984; Finley, 1984; Kukal, 1987, 1989, 1990
NOSR 2									
Agency Draw	T. 12-13S . R. 20 E.						NA		
Mesaverde		gas	200-600	6-22 (log) 15.5 av	NA	NA	—	normal	
Dakota		gas	50-60	7-14	NA	NA	—	normal	
Flatrock	T. 14S R. 20 E.						NA		
Wasatch		oil?/gas		6-16 (log) 10-12 av	NA	NA	—	normal	
Greater Natural Buttes	T. 8-10 S. R. 19-23 E.						see below		Osmond, 1992 Shade and Hansen, 1992 Cole, 1993
Green River		oil/gas	<30/sand (1-4 sands) 110-360	8-18 (log/core)	NA	45-50	—	normal	
Wasatch		gas	40-52/sand (3-9) 30-140 net 67 av	8-18 (log/core) 10-14 Av	<0.1	35-85 45 av	40 outsideo unit	normal	
Mesaverde		gas	<80/sand	8-18 (log/core) 8-12 av	<0.1	50	NA	over	

Table 2. Continued.

Field/Reservoirs	Location	Prod.	Net Pay ft	Porosity %	Perm md	Sw %	Spacing acres	Pressure (drilling-mud density)	Reference
Jacks Canyon							NA		
Wasatch		gas	34	10-18 (log)	NA	—	—	normal	
Dakota		gas	NA	6-14(log)	NA	—	—	normal	
Peter's Point	T. 12 S. R. 16-17 E.						NA		
Wasatch		gas	16-24	14-19 (log)	NA	NA	—	normal	
Pine Springs	T. 14 S. R. 22 E.						320		Osmond, 1993
Wasatch		gas	16	8-22 (log?) 15 av	<0.1	NA	320	normal	
Dakota/Morrison		gas	20	12-18 Dakota 10-13 Morrison	NA	10	320	NA	
Seep Ridge	T. 13 S. R 22 E.								Osmond, 1993
Dakota/Morrison		gas	25/11	10-15 (log?)	NA	37	320	normal	
Stone Cabin	T. 12 S. R. 15 E.								Langenwalter, 1993
Wasatch		gas	24	8-10 (log?)	2-3 md	40	160	normal	
Mesaverde		gas	26?	8-16 (log?)	NA	NA	—	over	

NA - Not available

Notes:
1. For fields where no published data were available, porosities and net pay were estimated from density logs from selected wells. Net pay was defined by neutron-density crossover.
2. Porosity values derived from well-log data may overestimate true (core) porosity by 1-4 p.u.

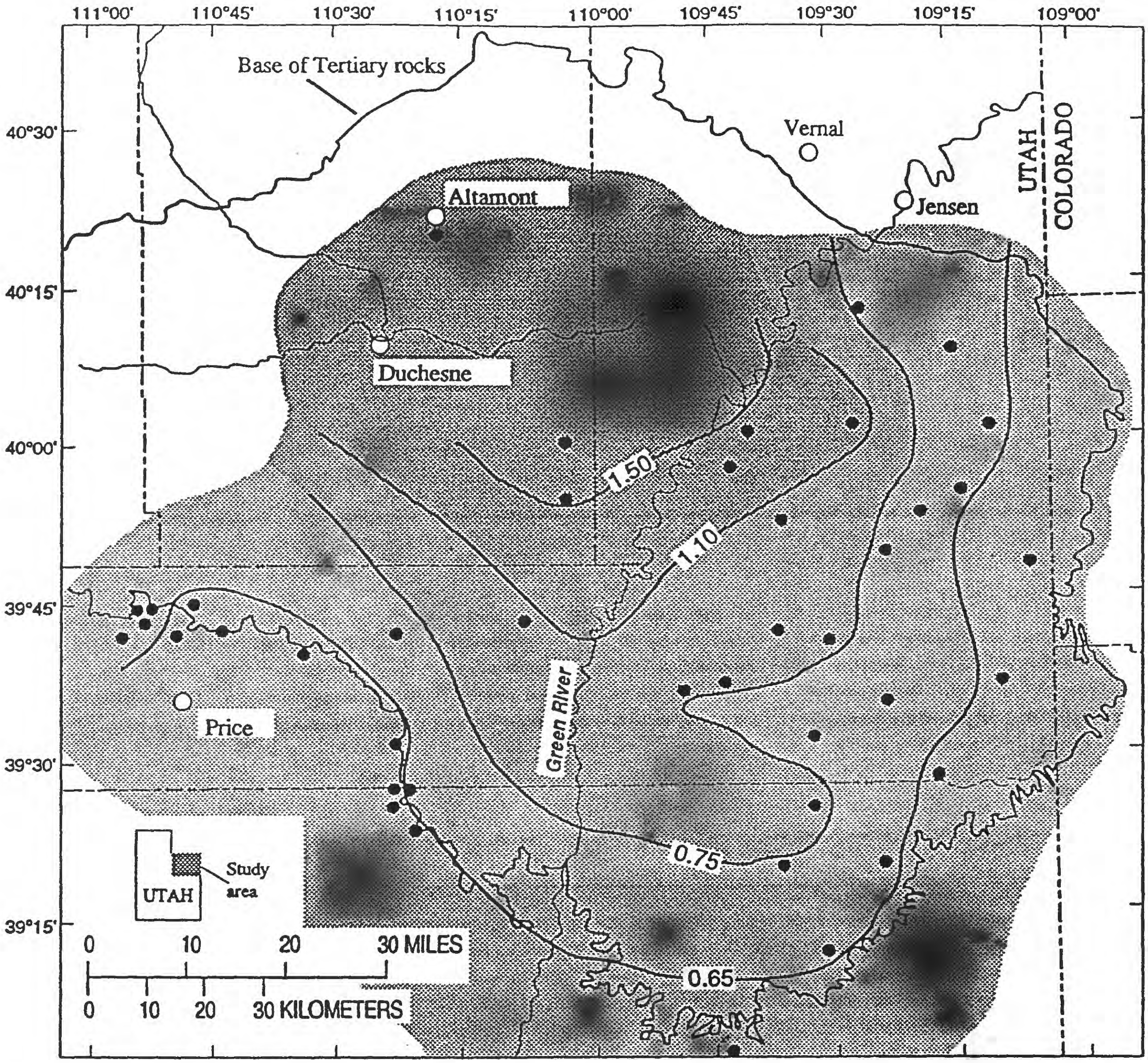


Figure 8. Vitrinite reflectance (R_m) map showing thermal maturity on the base of the Mesaverde Group, Uinta Basin, Utah. The map indicates areas of no gas generation (light stipple pattern), onset of significant gas generation (0.75 percent R_m line, and darker stipple pattern), and maximum gas generation and expulsion (1.10 percent R_m line and darkest pattern).

It is very important to note that the line described by the surface projection of the vitrinite reflectance value (R_o) > 1.10 at the base of the Mesaverde in the Uinta and Piceance basins indicates that the Tertiary and Cretaceous stratigraphic section below 3,000 ft± separates those fields with hydrocarbon contacts from those without. For strata and areas whose R_o < 1.10, the fields will have hydrocarbon/water contacts.

We have measured R_o values for strata over much of the Uinta and Piceance Creek basins and through much of the buried stratigraphic section as a basis for prediction. In both basins a key component of assignment of hydrocarbons was their position relative to the line described by the surface projection of the vitrinite reflectance value (Ro) > 1.10 at the base of the Mesaverde.

Seismic Data Evaluation

There is little or no drilling in either the NOSR 1 and 3 or NOSR 2 area that penetrates the entire sedimentary section. Modern multichannel seismic reflection data is the only source of information that, in this case, can image all of the geologic section with the potential to generate and trap hydrocarbons. Much of the well information in and around the NOSR's penetrates only the Wasatch and Mesaverde intervals,

Figure FR1. Paleogeographic map showing early Late Cretaceous paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Cretaceous: Early Cenomanian

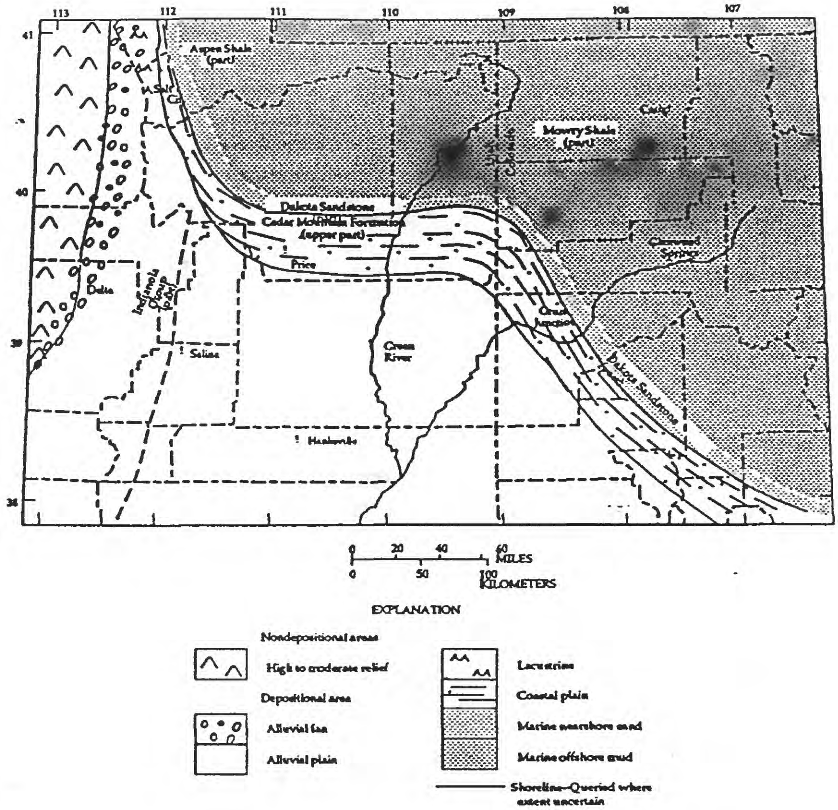
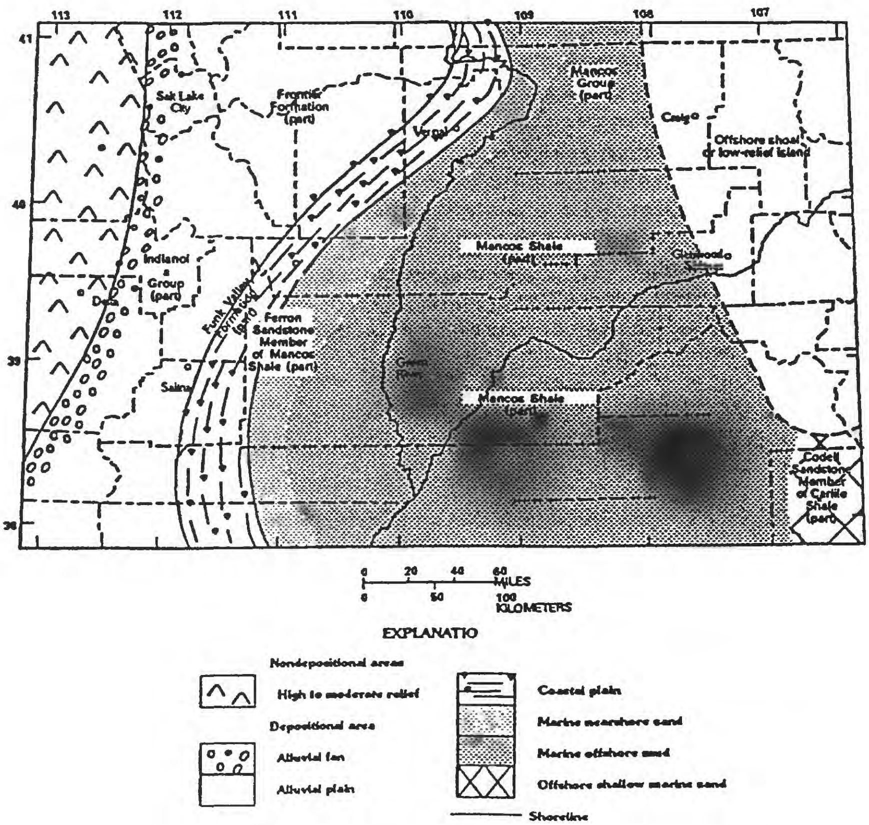


Figure FR2. Paleogeographic map showing mid Cretaceous Turonian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Mid Cretaceous: Turonian



Cretaceous: Late Santonian: Emery-Mancos B time

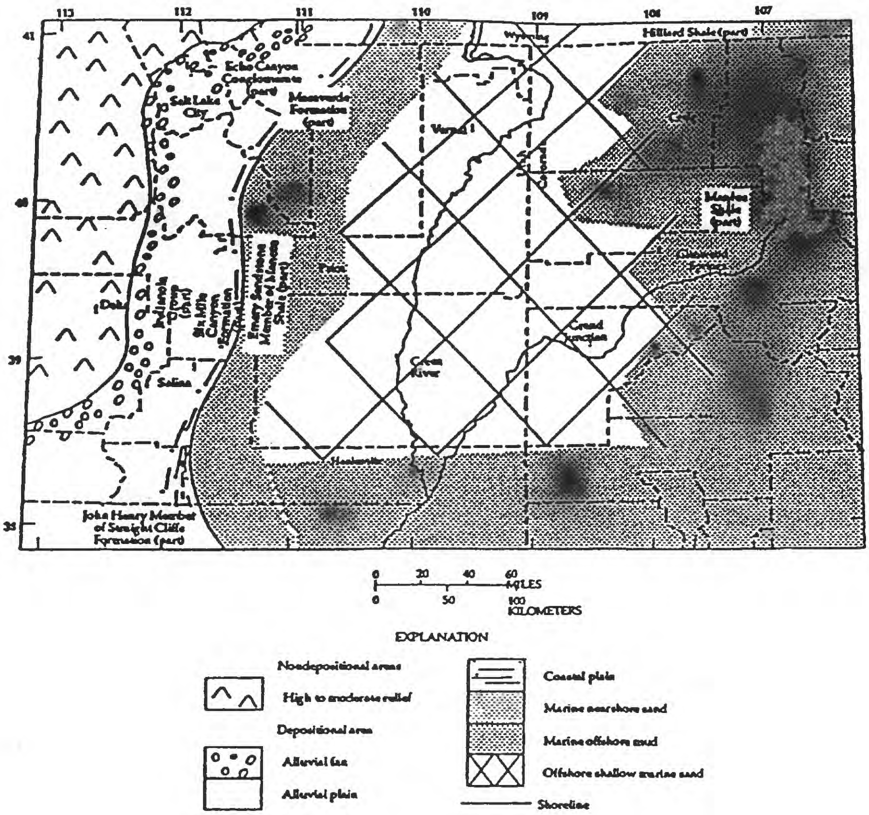


Figure FR3. Paleogeographic map showing Late Cretaceous late Santonian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Cretaceous Late Early Campanian Blackhawk Time

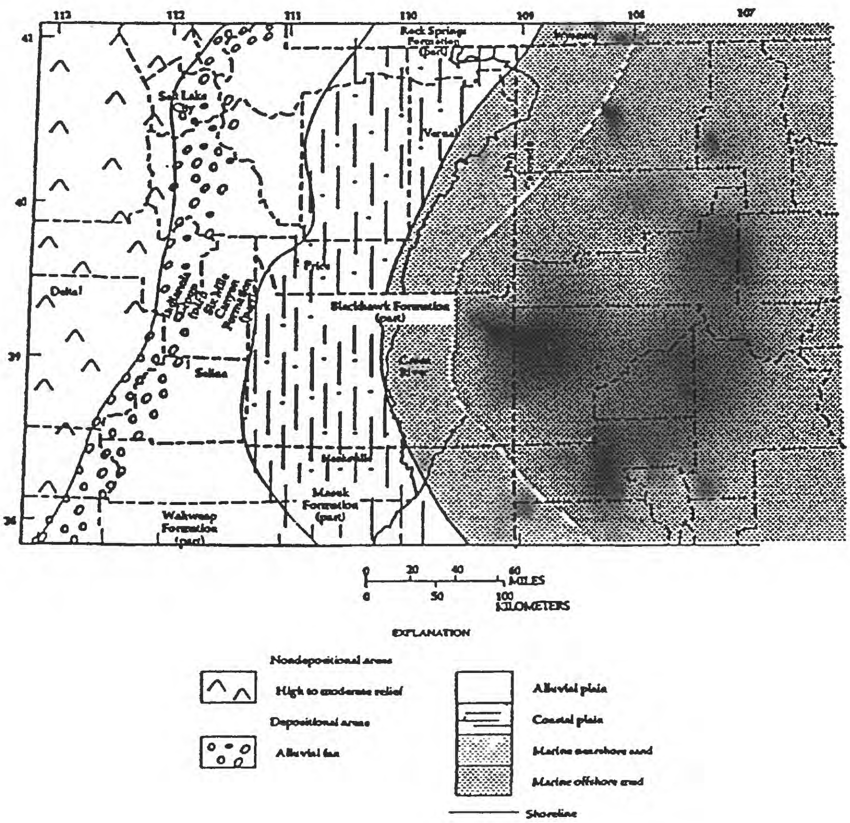


Figure FR4. Paleogeographic map showing Late Cretaceous early Campanian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Figure FR5. Paleogeographic map showing Late Cretaceous mid Campanian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Cretaceous early mid Campanian Castlegate Time

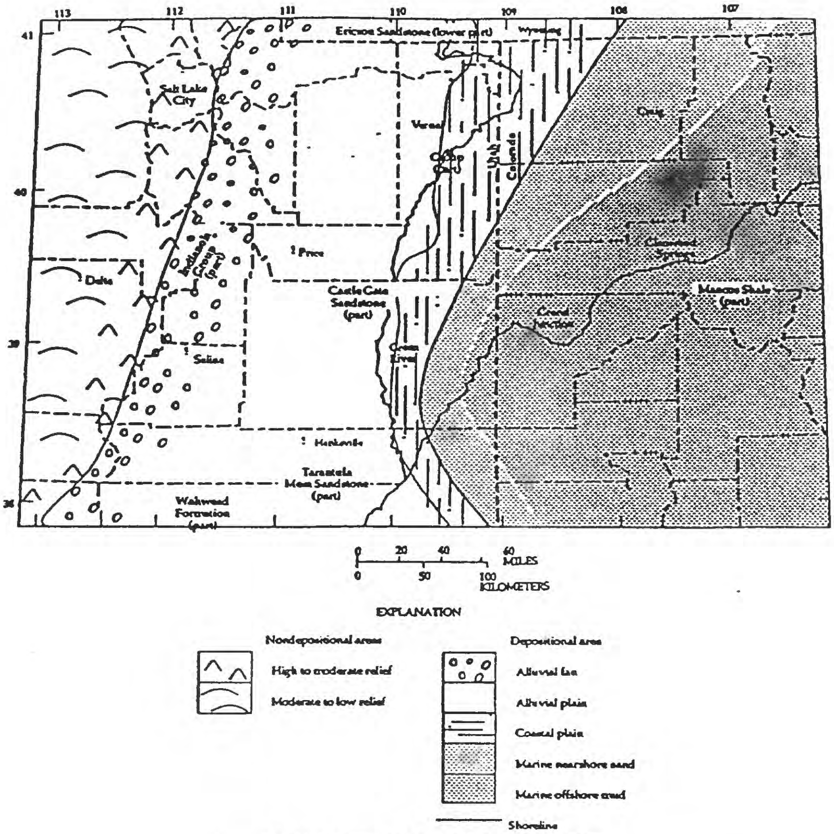
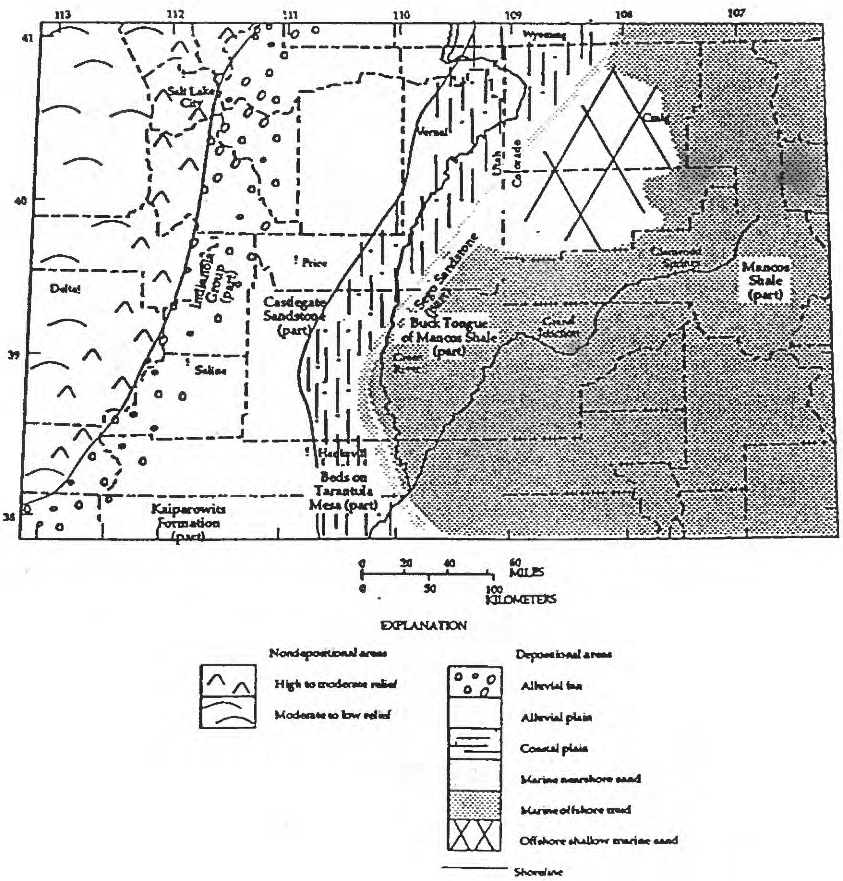


Figure FR6. Paleogeographic map showing Late Cretaceous mid Campanian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Cretaceous mid Campanian Sego Time



Cretaceous early late Campanian Rollins-Mt Garfied Time

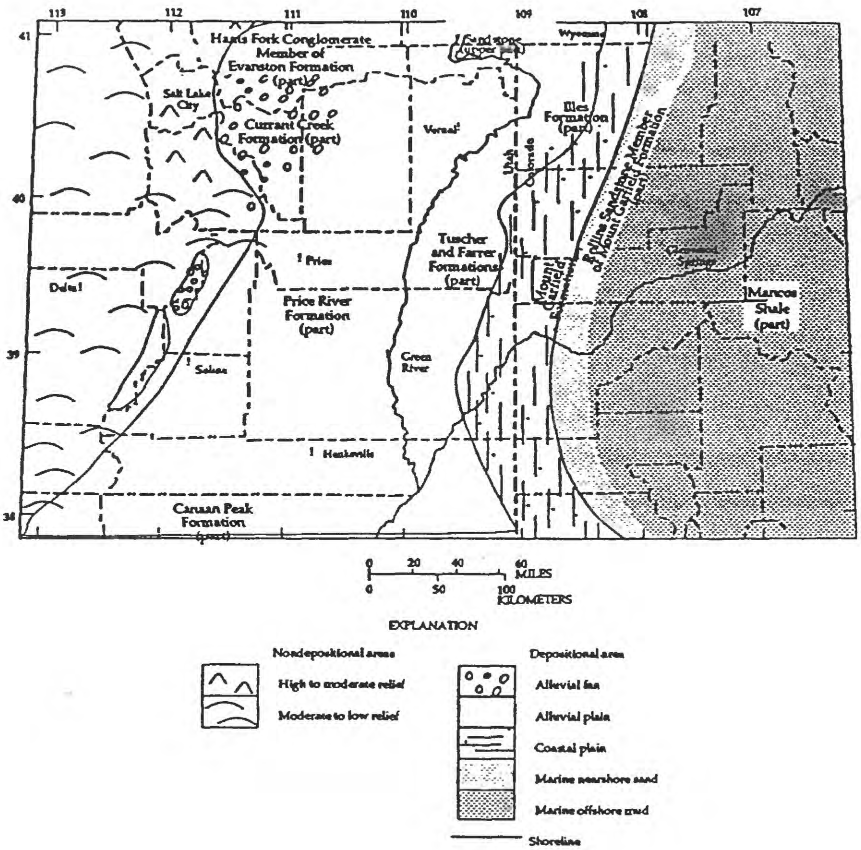


Figure FR7. Paleogeographic map showing Late Cretaceous early late Campanian paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Cretaceous late Campanian-early Maastrichtian Hunter Canyon-Twentymile

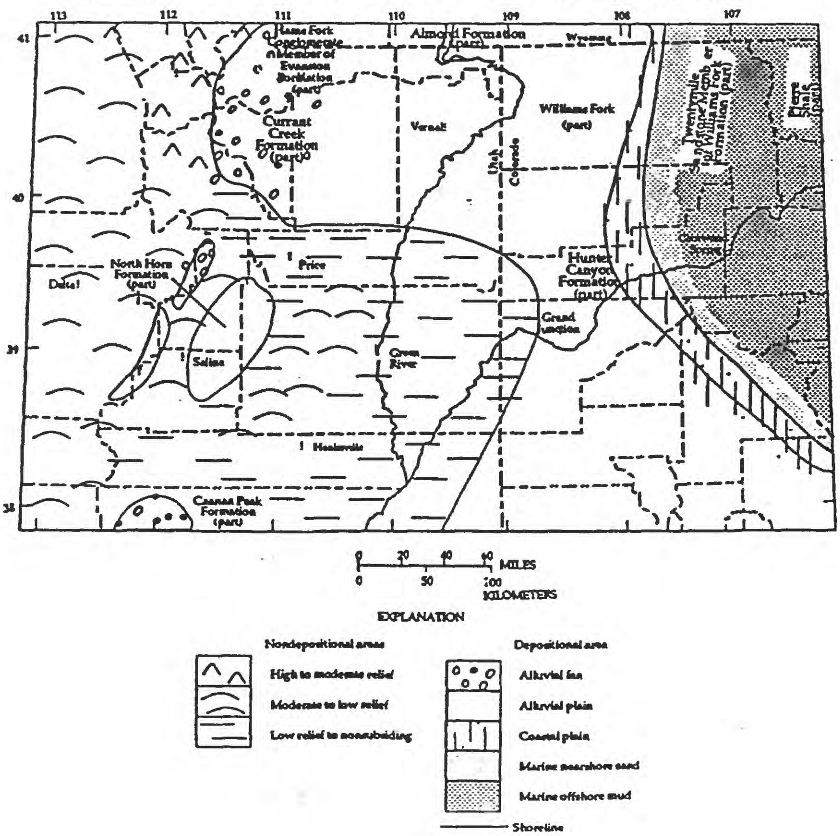


Figure FR8. Paleogeographic map showing Late Cretaceous late Campanian-early Maastrichtian Hunter Canyon—Twentymile paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Figure FR9. Paleogeographic map showing Late Cretaceous late Campanian-early Maastrichtian North Horn-Williams Fork paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Cretaceous late Campanian-early Maastrichtian North Horn-Williams Fork

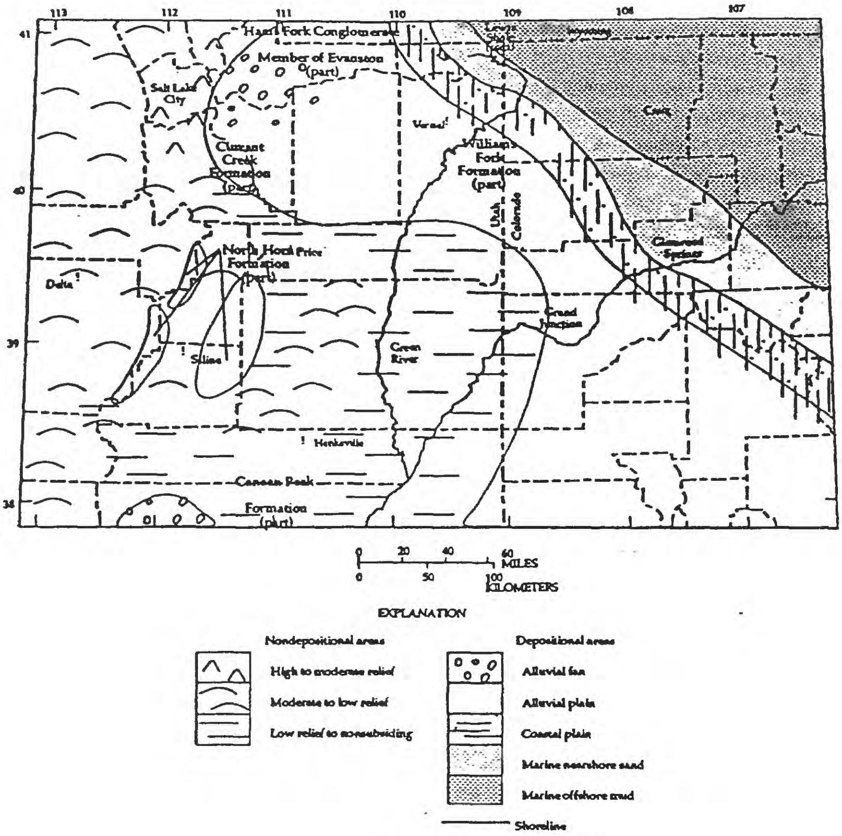
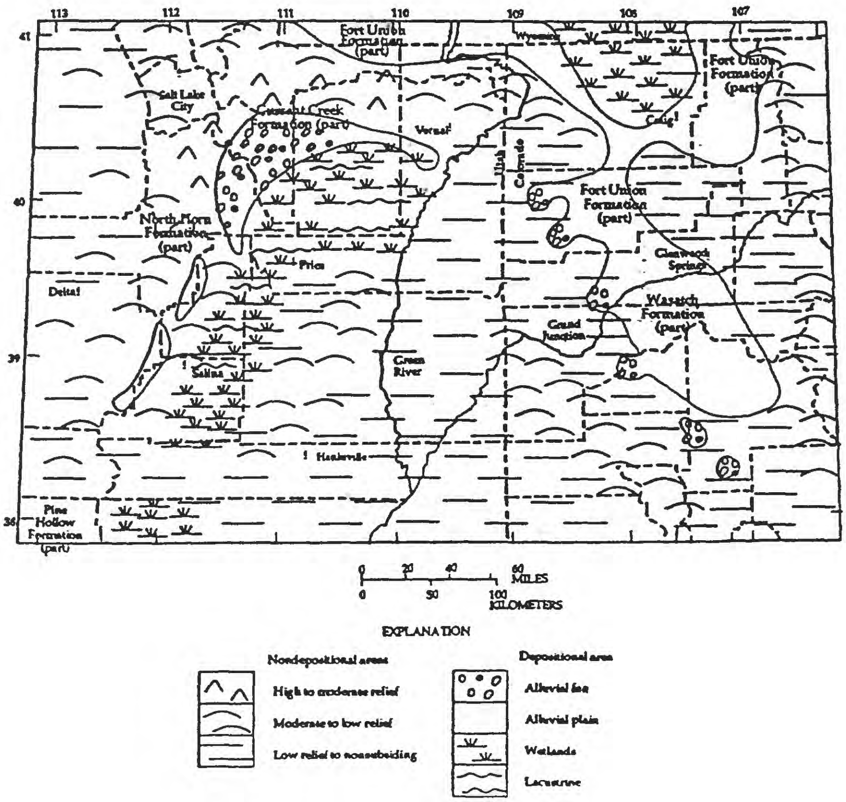


Figure FR10. Paleogeographic map showing mid Paleocene North Horn-Ft Union paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Mid Paleocene North Horn-Ft. Union



Middle Eocene

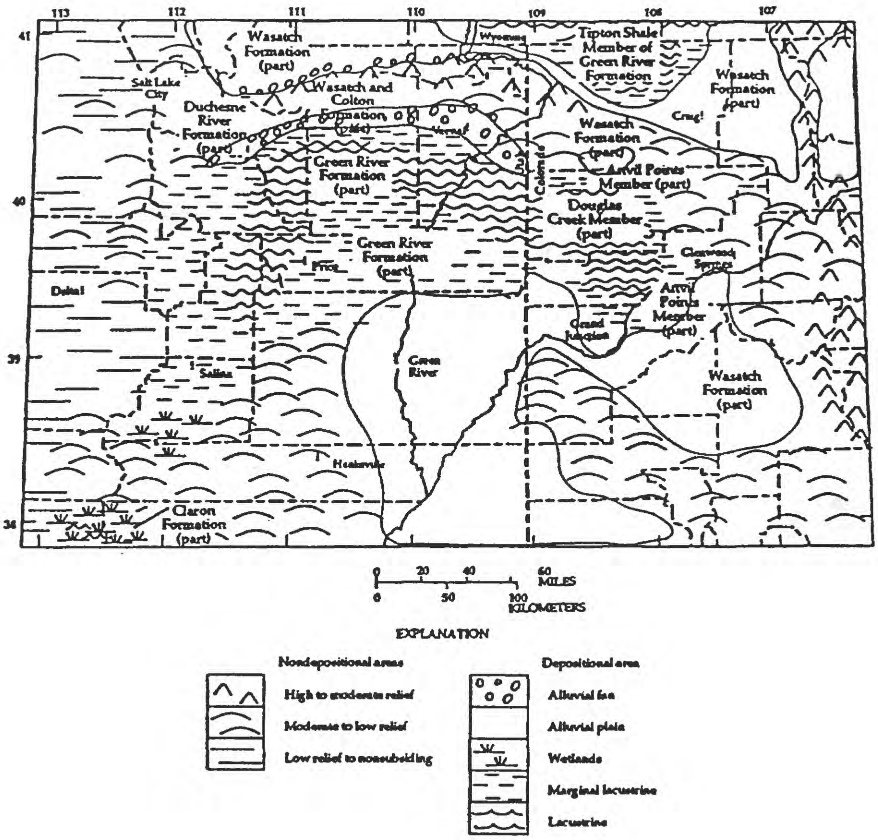


Figure FR11. Paleogeographic map showing middle Eocene paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

Late Middle Eocene

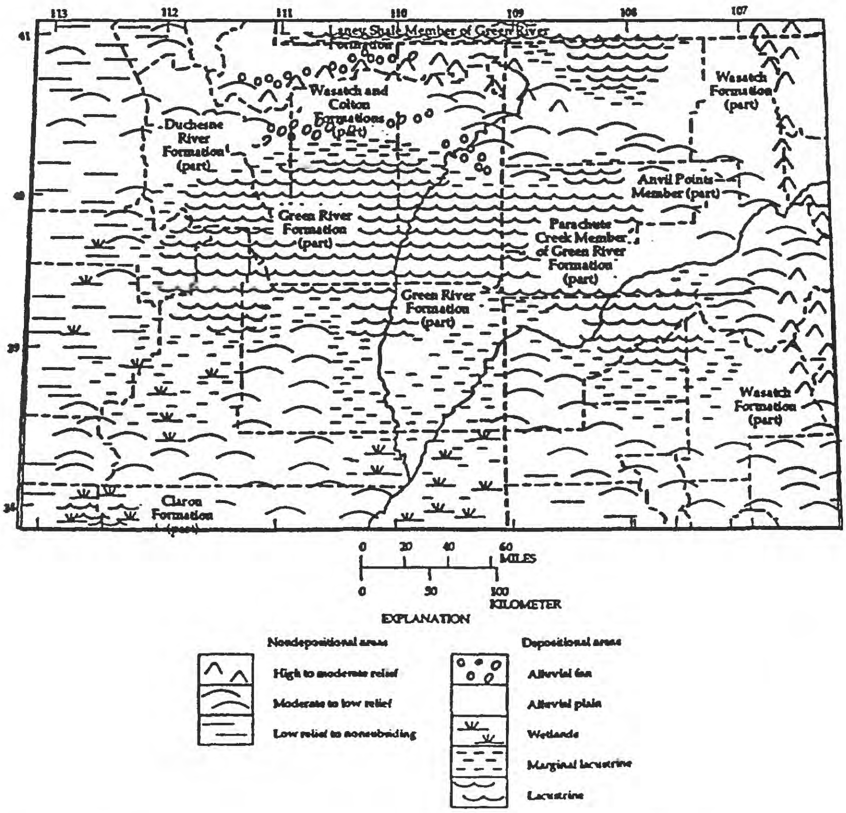


Figure FR12. Paleogeographic map showing late early to early middle Eocene paleogeography in the Uinta and Piceance basins. Stratigraphic and lithologic components under Naval Oil Shale Reserves can be inferred from these data. Modified from Franczyk *et al.*, 1992.

therefore, seismic reflection data is the only tool available which can examine the structural characteristics under these shallow horizons and provide the information needed to extrapolate structural trends into areas where there is no drilling data. This becomes increasingly more important when evaluating NOSR's 1 and 3 and especially NOSR 2, since NOSR 2 has not been tested by the drill at all.

NOSR 1 and 3

Two very long seismic lines from Grant-Norpac Inc. provided the primary source of structural information for this area. Two other shorter seismic lines from Seis-Port Exploration and Celsius Energy also provided much needed information along the northern and southern margins of the project area respectively. Figure T3 shows that Grant-Norpac line CPB-1 runs diagonally across NOSR 1 and 3 beginning in the northwest corner and ending in the southeast, well across the Colorado River. Figure T3 also shows that Grant Norpac line CPB-3 begins in the northeast corner of the study area at Parker Ridge, proceeds across the NOSR 1 and 3 project area, and ends in the southwest well past Parachute Creek. No exact location data was available for either the Seis-Port Exploration line or the Celsius Energy line. Generally, the Seis-Port Exploration line runs almost due west-east, cutting across the most northern edge of NOSR 1. The Celsius Energy line looks to closely follow Interstate highway 70 and the Colorado River just to the south of NOSR 3.

Digital field data were available for both of the Grant-Norpac lines. No digital information was available for the Seis-Port Exploration or the Celsius Energy lines. Original processing for the Grant-Norpac lines was determined to be excellent and produced seismic sections that were very interpretable through the entire sedimentary section from the surface to acoustic basement. The Seis-Port Exploration line, although interpretable, was not of the same quality as the Grant-Norpac lines. An oversized page copy and interpretation of the Celsius Energy line was acquired from a report by Waechter and Johnson, 1986. Utilization of all of this data provided enough deep multichannel seismic reflection data to construct a general subsurface structural picture for the NOSR 1 and 3 project area.

Interpretation of the Grant-Norpac and the Seis-Port Exploration lines was achieved by correlating subsurface information from several deep boreholes in the area with the seismic data. Two wells played an important part in the interpretation. The first well was the Arco North Rifle No. 1 which is located along Grant-Norpac line CPB-3 just off the northeast boundary of NOSR 3 in the Government Creek area. The Arco North Rifle No. 1 well bottomed in the Cretaceous Dakota Formation at a depth of approximately 5,253.5 meters (17,170 ft) as measured from the wells kelly bushing. The other well which provided good subsurface information was the Barrett Resources No. 1-27 Arco Deep well located just to the south of Grant-Norpac line CPB-3 in the vicinity of Parachute Creek. This well bottomed in Precambrian granite at a total depth of about 4,734 meters (15,531 ft) as measured from the kelly bushing. Several other shallower wells were used to verify geologic tops interpreted on the Grant-Norpac data but these wells probed only the upper part of the section and did not penetrate much below the Mesaverde Corcoran sandstones. Data from many wells which penetrated the Wasatch and upper Mesaverde formations in the southern part of NOSR 3 were available but their locations were to far away from the seismic lines to make reliable correlations. Among the more useful wells used were the Calco Sheaffer No. 1, Arco Exxon No. 1-36, DOE MWX wells, Northwest Exploration Clough No. 2, and the Barrett Resources No. A-2 Crystal Creek.

Synthetic seismograms were generated from the sonic, density, or resistivity logs for the wells mentioned above. These synthetic seismograms were then matched with the seismic data at the appropriate locations along the seismic lines and the key geologic tops determined in the wells were then correlated with their corresponding seismic reflectors. Figure T1 shows the synthetic seismogram constructed from the sonic and density logs for the Barrett Resources No. 1-27 Arco Deep well. Geologic formation tops marked on the synthetic seismogram were provided courtesy of Barrett Resources. Figure T2 shows how the synthetic seismogram fits into the Grant-Norpac seismic data on line CPB-3. Good correlation was achieved with the seismic data at several levels by adjusting the frequency content and wave shape of the wavelet convolved with the reflectivity series generated from the well log data. Interval velocity data produced from the acoustic logs for the Barrett Resources No. 1-27 Arco Deep well contributed to the time-to-depth conversions of the Grant-Norpac lines. The interval velocities calculated from the Barrett Resources No. 1-27 Arco Deep well were:

Geologic Interval	Interval Velocity (m/s)	Interval Velocity (ft/s)
Surface - Wasatch	3,300	10,825
Wasatch - Mesaverde	3,515	11,535
Mesaverde - Cameo	4,503	14,775
Cameo - Mancos	4,595	15,075
Mancos - Dakota	4,170	13,680
Dakota - Permo-Penn	5,070	16,635
Permo-Penn - acoustic basement	4,973	16,315

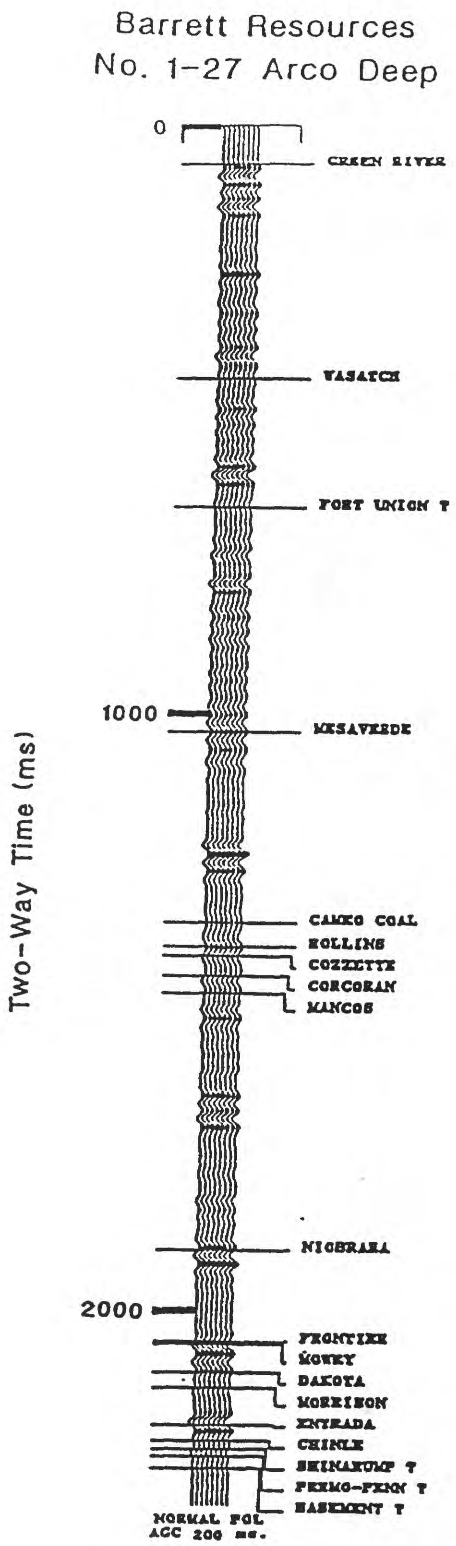


Figure T1. Synthetic seismogram produced using well log data from the Barrett Resources No. 1-27 Arco Deep well.

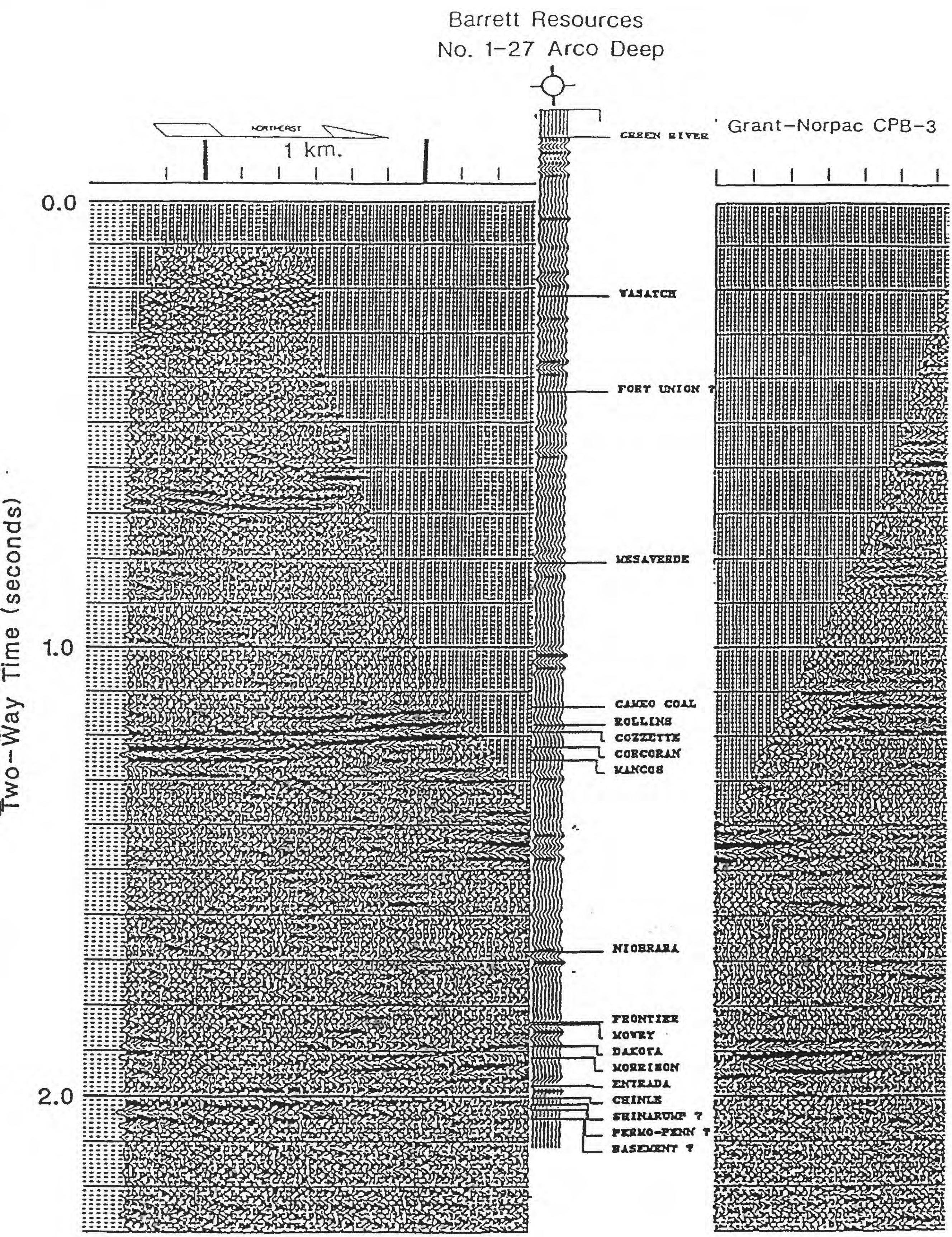


Figure T2. Synthetic seismogram produced from the Barrett Resources No. 1-27 Arco Deep well inserted into Grant-Norpac seismic line CPB-3. The synthetic seismogram is used to correlate geologic horizons with seismic reflectors in the NOSR 1 and 3 project area.

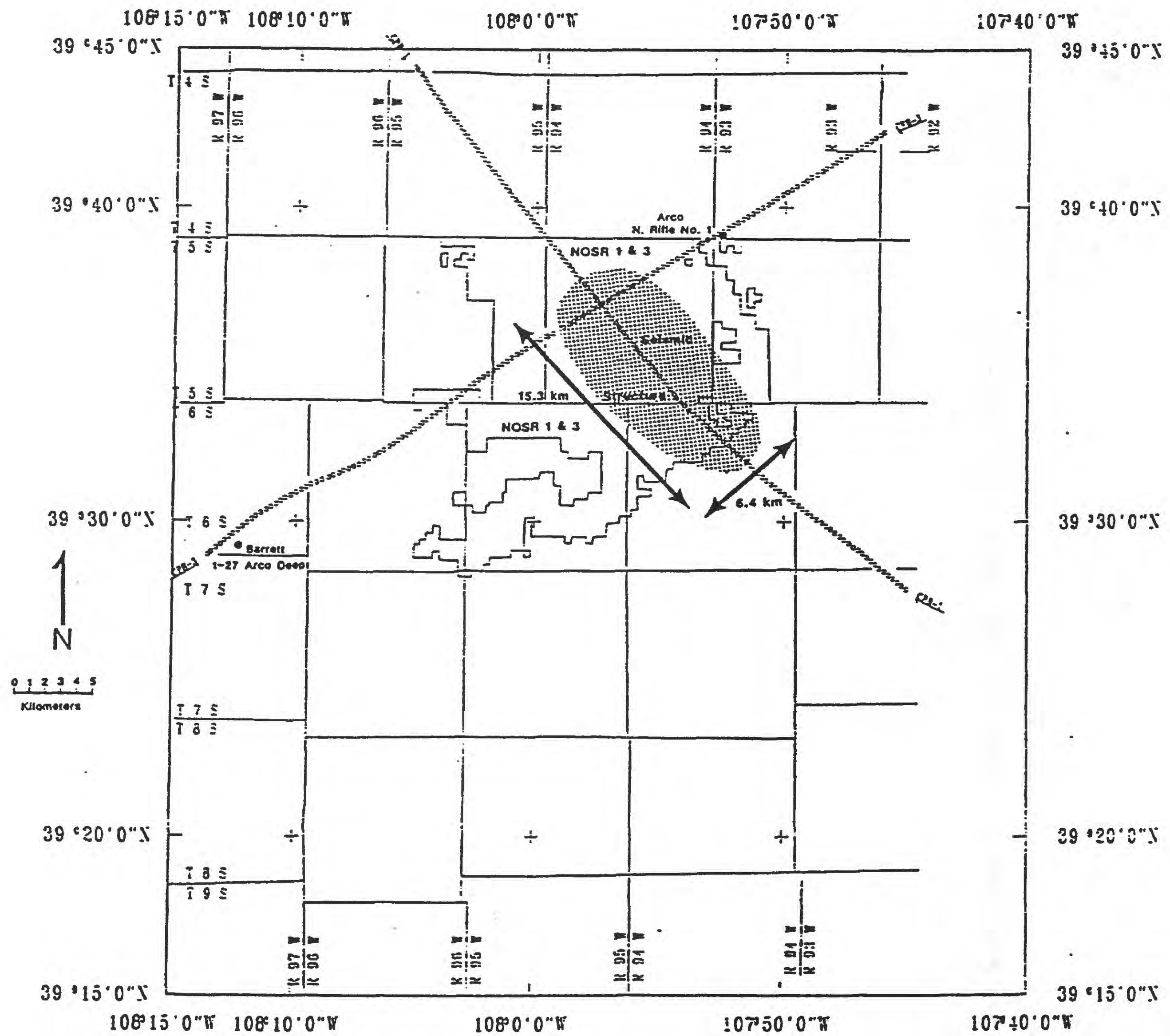


Figure T3. Map of the NOSR 1 and 3 project area showing the extent of the structural high derived from seismic data as defined at the Cretaceous Dakota Fm. level.

Several important structural features were discovered using the non-depth converted seismic data from Grant-Norpac. First was a suspected closed structural high at all levels from the surface through the Mississippian Leadville Formation in the NOSR 1 and 3 project area. Figure T3 is a map showing the possible surface extent of the structural closure as mapped at the Cretaceous Dakota level. A second important feature determined from the seismic data and well tops from the Barrett Resources No. 1-27 Arco Deep well was a large normal fault with over 1,525 meters (5,000 ft) of throw. This fault is interpreted as the Garmesa fault which is attributed to the ancestral Uncompahgre uplift. Lastly, the structure produced by thrust faulting associated with the Grand Hogback can be seen at the far northeastern end of Grant-Norpac line CPB-3. The Arco North Rifle No. 1 well may have penetrated the far western edge of this structure, just off the northeastern boundary of NOSR 3. Seismic reflectors from the surface through the Mancos zone turn sharply upward in the NOSR 3 area along line CPB-3 in response to the effects of the Grand Hogback structure. Other than deep faulting in rocks of Mississippian age and older the most important structural feature for hydrocarbon trapping as determined from the seismic data is the structural high as depicted in figure T3.

Since the project did have digital field data for the portion of Grant-Norpac line CPB-3 which crossed the NOSR 1 and 3 area reprocessing of the data was undertaken to confirm the structural anomaly and to try and obtain better results for a possible stratigraphic interpretation of the productive lower Mesaverde sequence. Figure T4 is a small scale copy of the reprocessed section with key geologic horizons labeled These horizons were determined from correlation with well information along the line as described above. Figures T5a and T5b are the same line displayed at a larger scale. Upon closer inspection the reader will notice that the structural closure is still present beneath the NOSR 1 area. Closure exists at all levels from the Mississippian Leadville Formation, on up through the section, and well into the Green River Formation above the Wasatch level. The reprocessing confirms that structural closure still exists in seismic time but is somewhat smaller in area and amount of closure then that evident from the original Grant-Norpac processing. Figure T6 is a portion of the reprocessed data which has been converted from two-way seismic travel time to depth. Figure T7 is a plot of the velocity model used in the conversion process. The vertical scale in figure T6 represents depth below the seismic datum in thousands of feet. The seismic datum is at 2,529.9 meters (8,300 ft) above sea level. The key geologic horizons as interpreted on figure T4 have been transferred and re-labeled on figure T6. Note that in figure T6 even after depth conversion the structural high is still present and in certain places exhibits over 30 meters (100 ft) of closure.

Much of the hydrocarbon production from the NOSR 3 area is from gas charges sands of Tertiary Wasatch and Mesaverde age. A possible stratigraphic interpretation for a portion of the reprocessed data from the lower Mesaverde section is presented in figure T8. This portion of the lower Mesaverde section represents layers which includes the Cameo coals and Rollins, Cozzette, and Corcoran sands. The upper figure, T8a, is a copy of the un-interpretaed reprocessed seismic data covering the interval from the top of the Cameo to the top of the Mancos layers. The lower portion, figure T8b, displays a possible interpretation of the data in this interval. Note the general complex character of the data in this interval. This may be caused by the depositional environment active during lower Mesaverde time and may indicate that a fluvial system sands which thin and thicken laterally across the NOSR 1 and 3 area. Changes in reflection amplitude most likely is caused by the inability of the seismic wave to separately resolve or image the tops and bottoms of the individual lithologic units. In some cases where the layer thickness does seem to image the lithologic boundary's properly a change in reflection amplitude may indicate local porosity in the sand layers or lenses. In any case the interpretation of individual sand bodies in this interval is difficult.

NOSR 2

Unlike NOSR 1 and 3 there was an abundance of seismic data available in the NOSR 2 project area. Originally there were nine seismic lines available which were actually located within the NOSR 2 boundary. During the project an additional four seismic lines were procured which were located just east of NOSR 2 in an area where drilling had taken place. The new lines were used to correlate drill hole data with seismic reflectors. These new lines intercepted the older data allowing us to extrapolate the well information into the NOSR 2 seismic data. The older data was shot by TRW and processed by Seismograph Service Corp. TRW line 1 runs from north to south along the eastern edge of NOSR 2. TRW lines 2 through 5 are located primarily in the southern part of NOSR 2. TRW line 6 run from west to east beginning along the middle of the western edge of NOSR 2 and proceeds southeast into NOSR 2. TRW lines 7 and 8 run primarily from north to south starting roughly in the

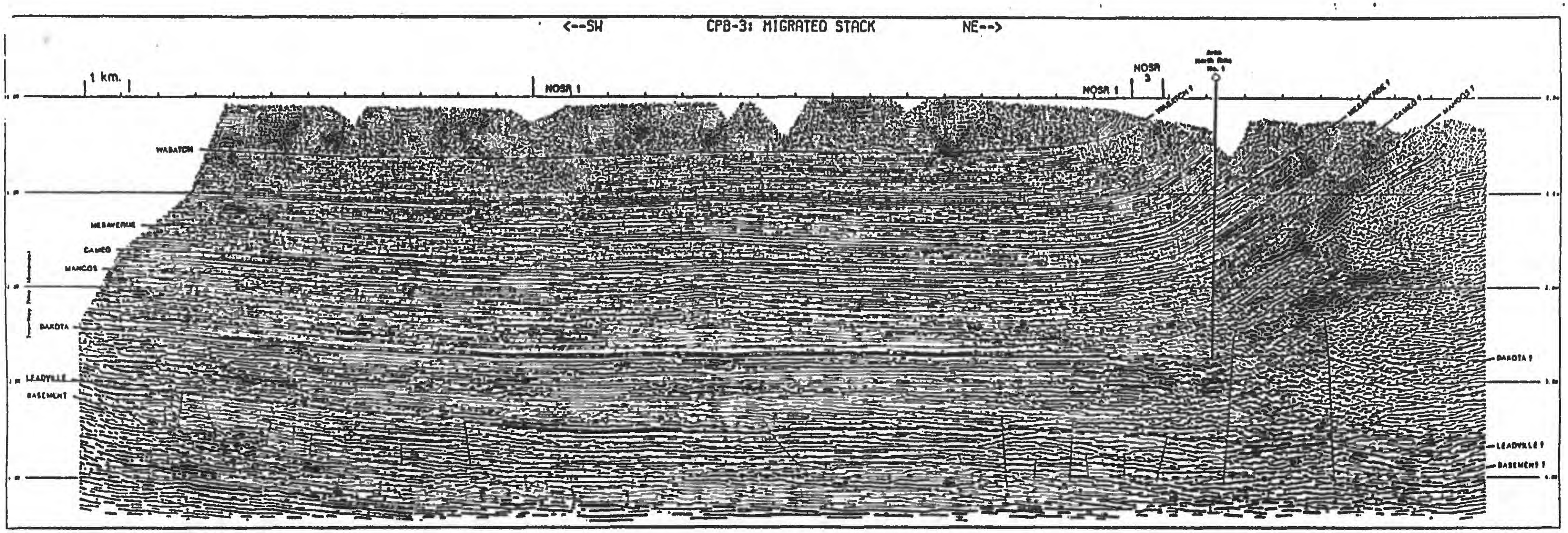


Figure T4. Reprocessed Grant-Norpac seismic line CPB-3 showing the location of the ARCO north Rifle No. 1 well and key geologic tops as determined from correlation with the Barrett Resources No. 1-27 ARCO Deep well.

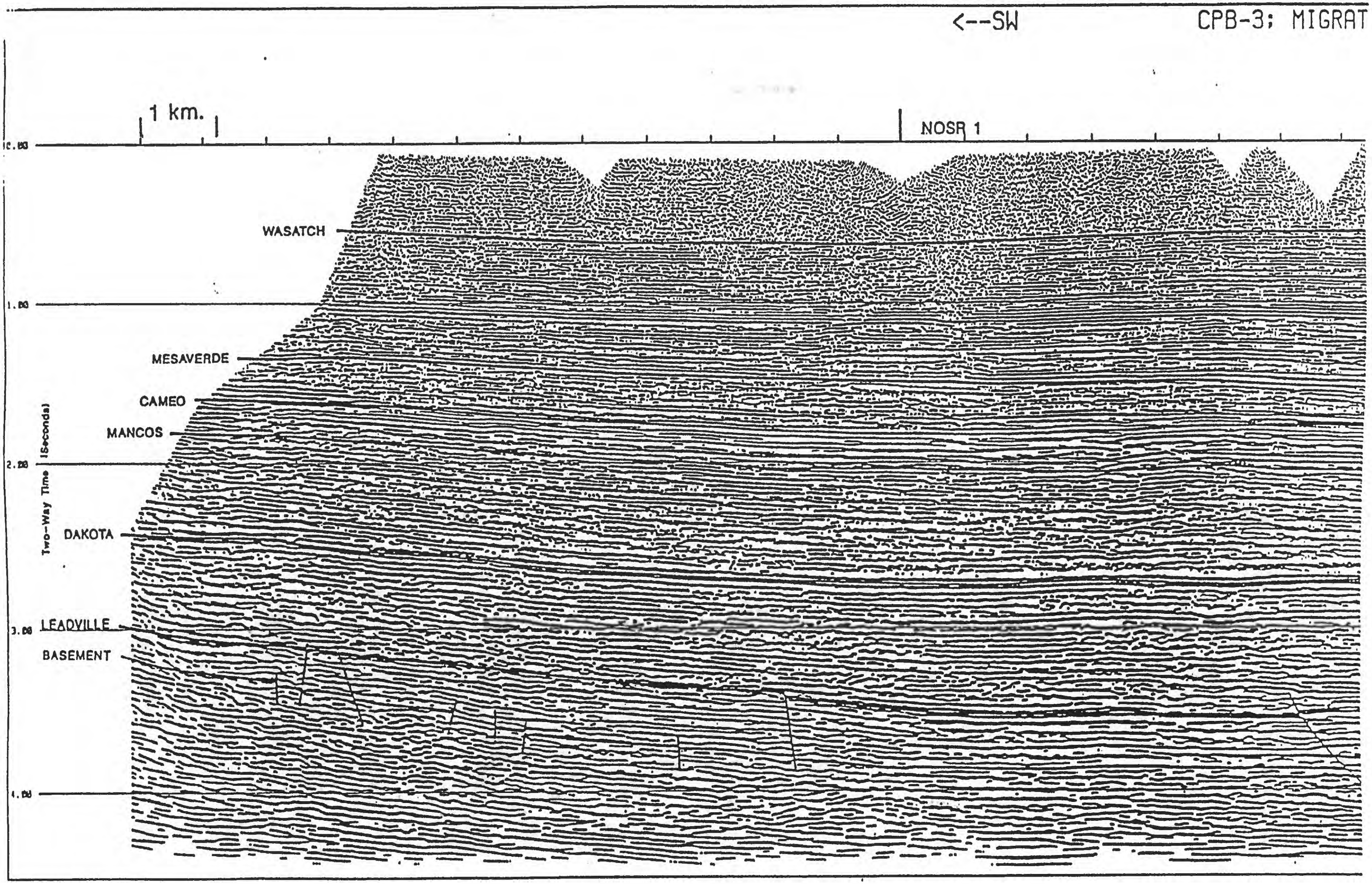


Figure T5a. Portion of the reprocessed Grant-Norpac seismic line CPB-3 (see figure T4).

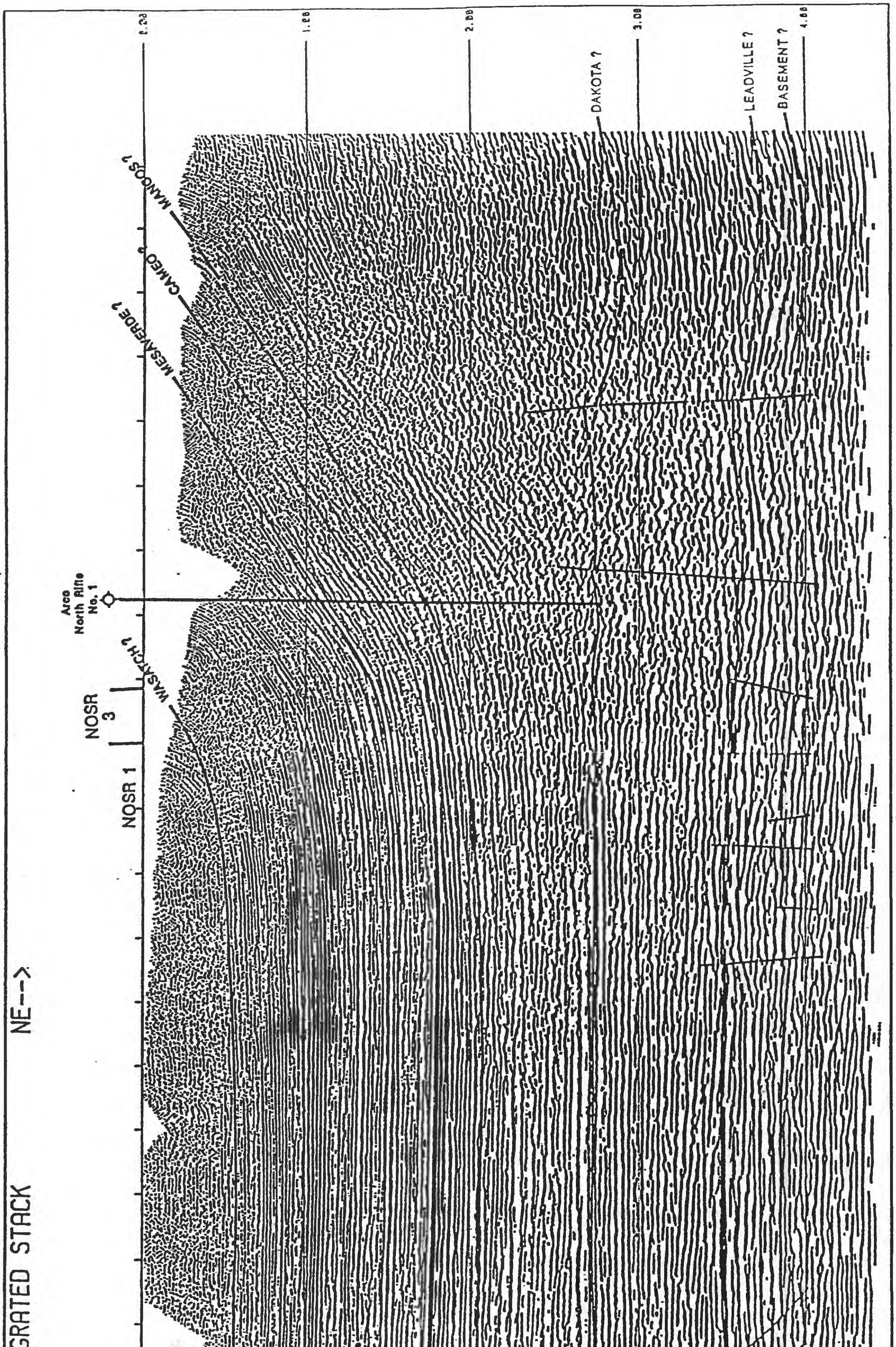


Figure T5b. Portion of the reprocessed Grant-Norpac seismic line CPB-3 (see figure T4).

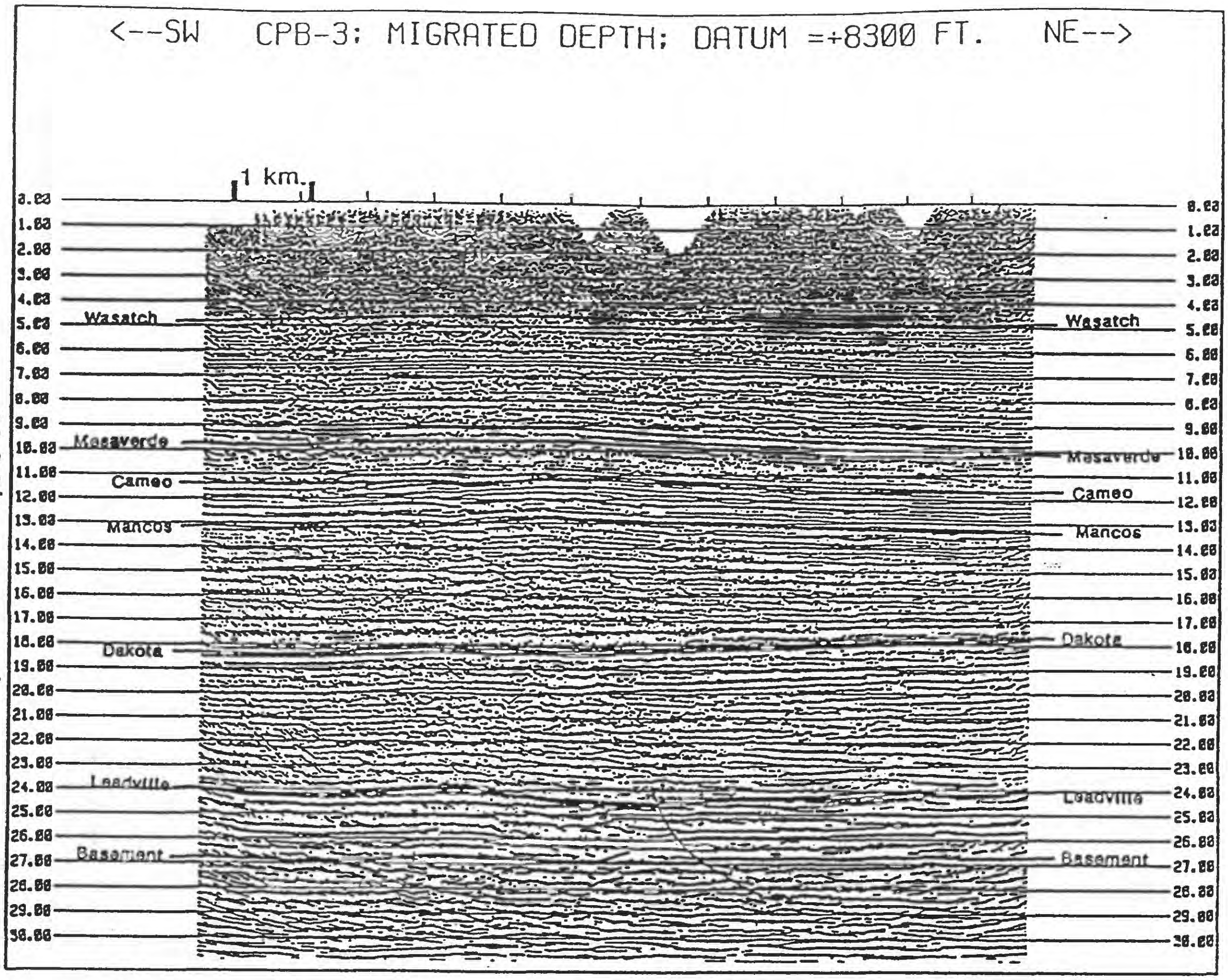


Figure T6. Depth converted reprocessed Grant-Norpac seismic line CPB-3 over the structural high.

middle of the northern edge of NOSR 2. TRW line 7 reaches almost to the middle of the NOSR 2 area. Another older line, Union line 2, begins about a third of the way in from the middle western edge of NOSR 2 and proceeds south before turning southeast and ending at the middle of the southern border of NOSR 2. All of these lines seem to follow either drainage or surface roads. The four new lines, designated ADC, are located outside of the eastern border of NOSR 2 in the Agency Draw area. The ADC lines were shot by CGG for Champlin Petroleum. ADC lines 1, 2, and 4 all tie with the TRW data set and in fact much of ADC line 1 follows the same track as TRW line 4. Figure Tinsert shows the location of the ADC, TRW and Union seismic lines. No reproducible copies of Union line 2 were available so it has not been included as an illustration.

Digital field data for all of the TRW lines were available for re-processing. The digital data for Union line 2 along with several very old Continental Oil Company lines were not available. The paper copy of Union line 2 was used in the evaluation , but due to the poor quality of the Continental lines and a lack of exact surface locations for these lines they were of little use in the study. Information from the Continental lines were only used as a reference to the type of structures that might be present within NOSR 2. Procurement of the ADC data included digital field information and these lines were processed to improve the final results and provide better correlation with the TRW data set. Re-processing and re-display of the TRW data produced more interpretable seismic sections. Processed data in digital form allowed us to re-display the ADC data at the same vertical and horizontal scales as the TRW data, thereby facilitating correlation of the ADC data with the TRW data.

Several key wells in the area in and around the ADC data set were used to correlate geologic horizons with seismic reflectors. The most important well was the Celeron Agency Draw No. 16-3 which bottomed in Mississippian age rocks at a total depth of about 4,694 meters (15,400 ft) as measured form the kelly bushing. This is the deepest well in the area and it projects nicely into ADC line 4. Another well, the

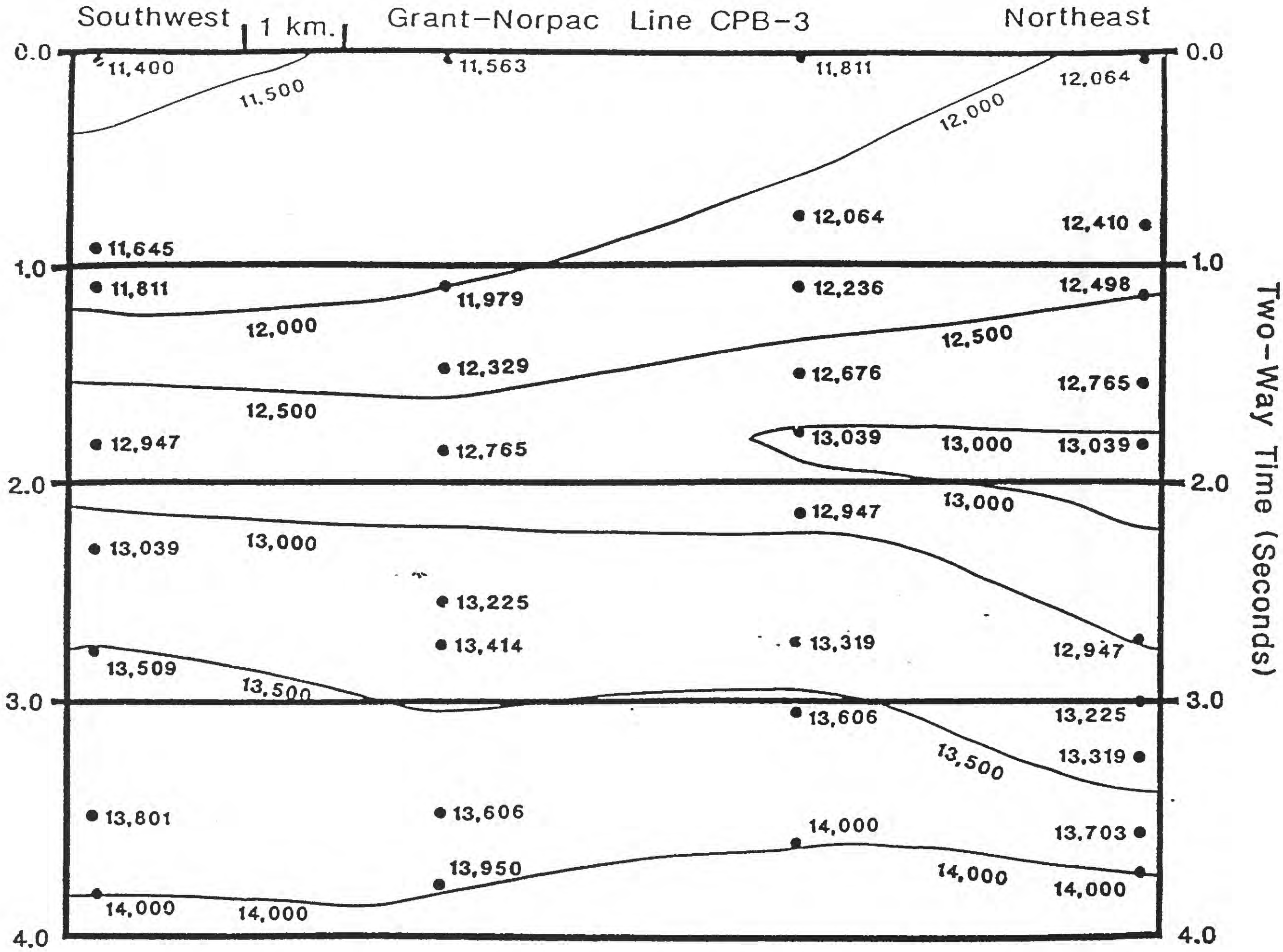


Figure T7. Velocity model used to convert from two-way travel time to depth the reprocessed portion of the Grant-Norpac seismic line CPB-3 presented in figure T6.

Texaco Skyline Government Agency Draw No. 1, is located just off the end of ADC line 2 and can also be projected into ADC line 5. This well penetrated to a total depth of about 3,737 meters (12,260 ft) as measured from the kelly bushing and bottomed in the Jurassic Entrada Formation. Several other shallower wells provided good information for locating the Wasatch, Mesaverde, Sego/Castlegate, and Mancos horizons on the seismic data. These wells include the Del Rio Resources Agency Draw No. 23-1, Del Rio Resources Agency Draw No. 1-1A, and the Sinclair Uintah Oil No. 1. Other wells were available but they are located at a significant distance from the seismic data and therefore projecting them into the seismic lines is risky.

Synthetic seismograms were generated from the borehole log data for the Celeron, Texaco, Del Rio Resources and Sinclair wells. These synthetic seismograms were then inserted into the ADC seismic data at projected locations and key geologic horizon markers were then correlated with seismic reflectors. The interpreted seismic horizons were then loop tied to confirm there proper position before extrapolating their information into the TRW and Union lines. After all of the data had been interpreted the horizons picked at all of the seismic line intersections were examined to make sure that all horizons tied properly. Figure T9 shows the correlation of the Celeron wells synthetic seismogram with seismic data from ADC line 4. Interval velocity data from the Celeron well was used to perform time-to-depth conversions for the key geologic horizons. These horizons included the tops of Wasatch, Mesaverde, Sego/Castlegate, Mancos, Dakota, Entrada, Mississippian, and acoustic basement. Interval velocities determined from the Celeron well were:

Geologic Interval	Interval Velocity (m/s)	Interval Velocity (ft/s)
Surface - Green River	3,640	11,975
Green River - Wasatch	3,735	12,255
Wasatch - Mesaverde	4,213	13,822
Mesaverde - Sego/Castlegate	4,398	14,430
Sego/Castlegate - Mancos	4,347	14,260
Mancos - Dakota	4,115	13,500
Entrada - Mississippian	4,943	16,217
Mississippian - acoustic basement	5,984	19,635

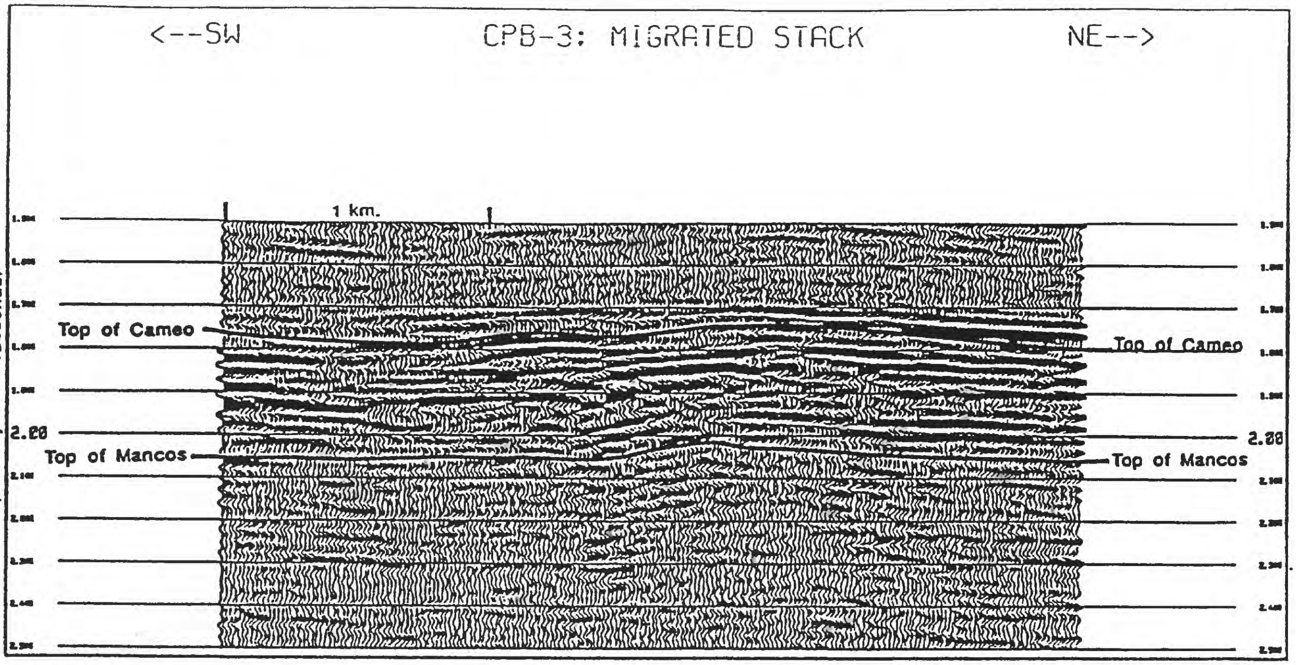


Figure T8a. Portion of the reprocessed Grant-Norpac seismic line CPB-3 showing the reflection character through the lower Mesaverde Fm. interval.

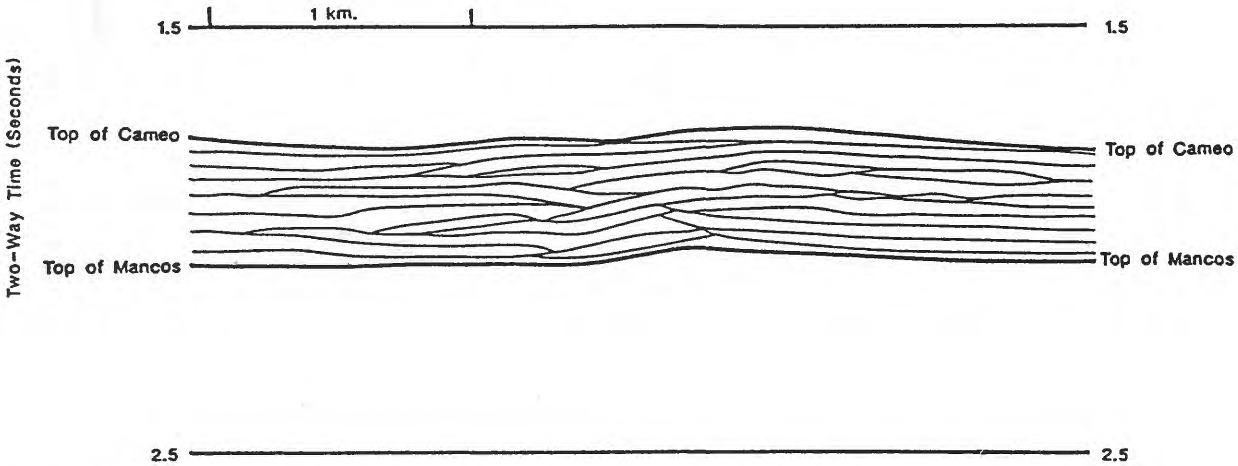


Figure T8b. The same portion of data presented in figure T8a illustrating a possible interpretation for the lower Mesaverde interval.

The Celeron well was used in this determination because it penetrated most of the sedimentary section and produced the best match between the synthetic seismogram and the surface seismic data.

One important structure located in the southeastern corner of NOSR 2 was evident on the seismic data. This apparent closed structural high is located in the Tabyago Springs area and is therefore known as Tabyago Dome. According to the seismic data this structure has an axis which runs approximately from northwest to southeast and is cut by many deep seated faults. Figure T10 is a portion of seismic line TRW-2 showing the complex nature of the Tabyago Dome structure. No apparent closed structures are seen on the seismic lines covering the western and northern edges of NOSR 2. Data is sparse or not present in the heart of NOSR 2 so locating structures similar to Tabyago Dome is difficult at best. A complete subsurface structural analysis of NOSR 2 would require additional seismic information in areas not presently covered by either the TRW or Union data.

HYDROCARBON PLAYS FOR ASSESSMENT

Hydrocarbon-bearing Phanerozoic strata have been identified in drill holes distributed over much of the eastern and north-central parts of Utah and northwest Colorado. The hydrocarbon accumulations in

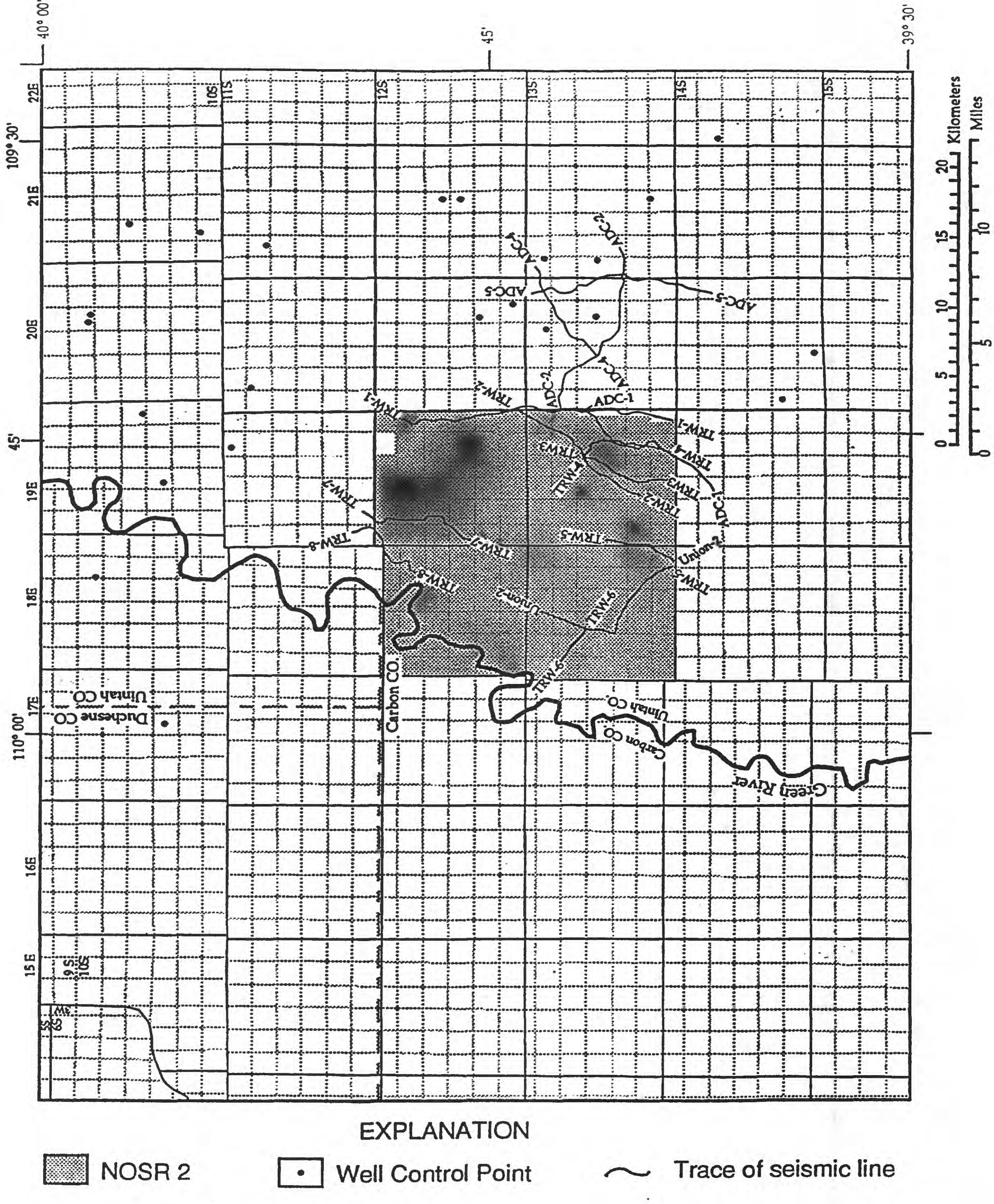


Figure Tinsert.

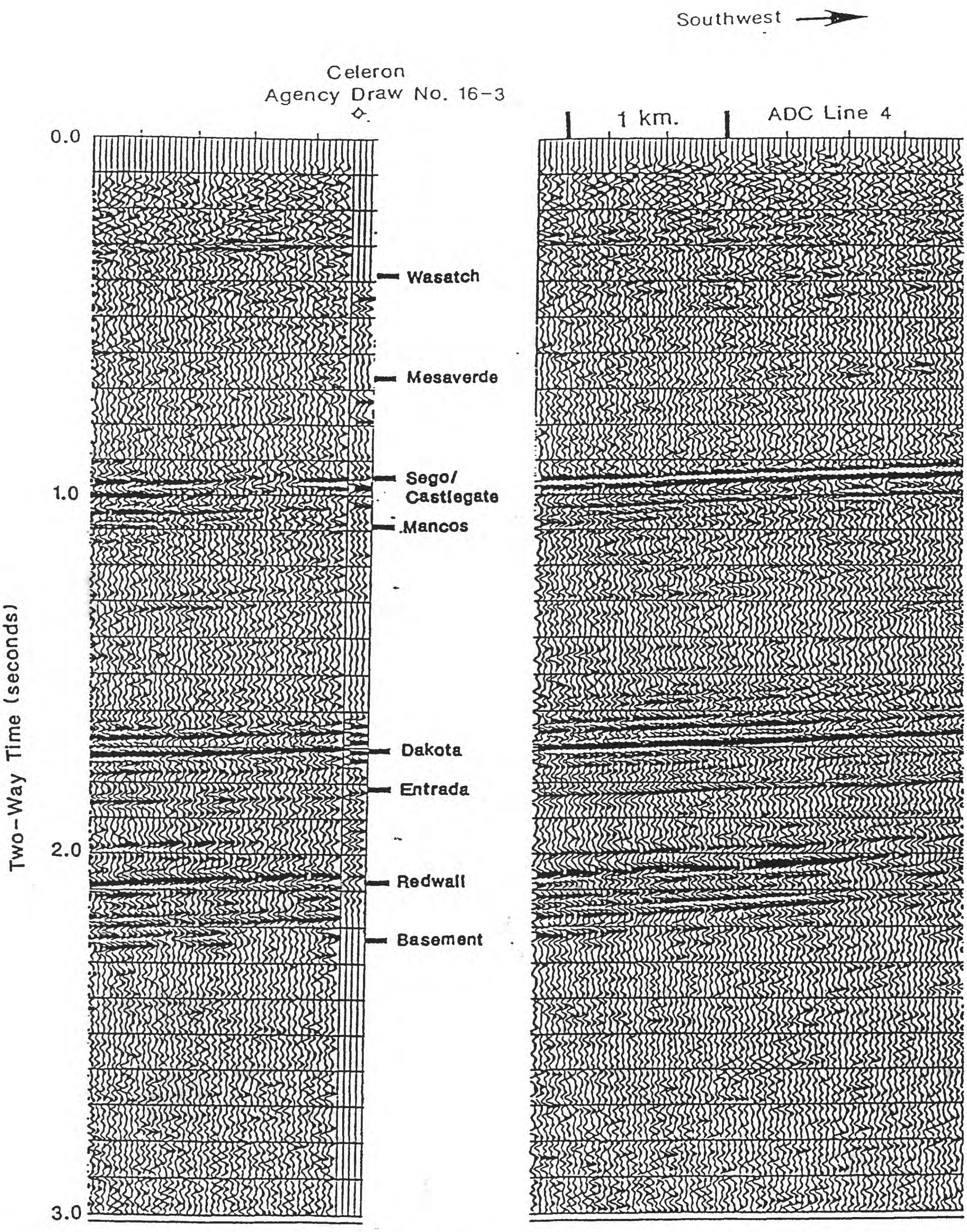


Figure T9. Synthetic seismogram produced from the NOSR 2 Celeron Agency Draw No. 16-3 well log data. The synthetic seismogram has been inserted into a portion of reprocessed seismic line ADC-4 and shows the correlation between geologic horizons and seismic reflectors in the NOSR 2 project area.

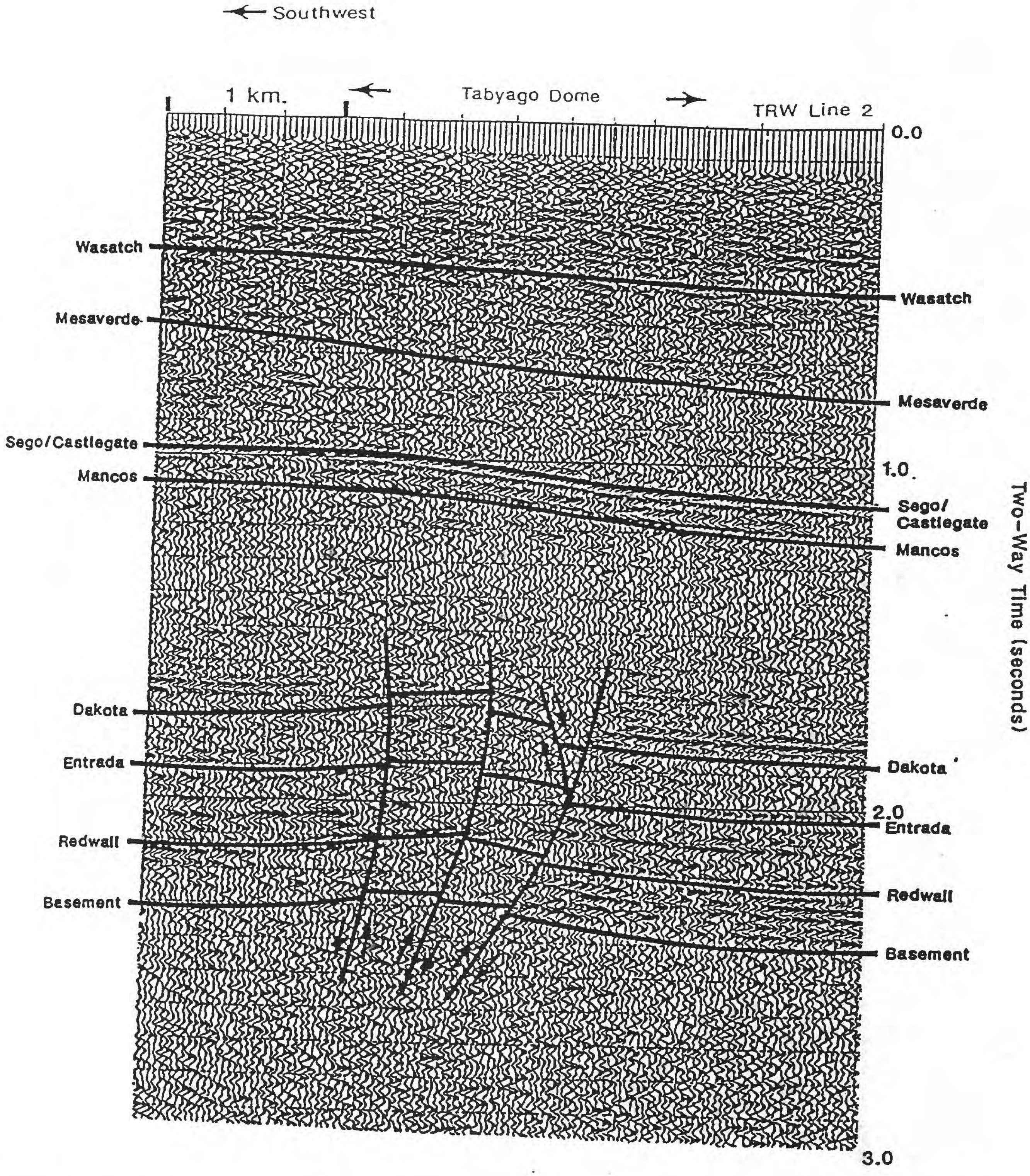
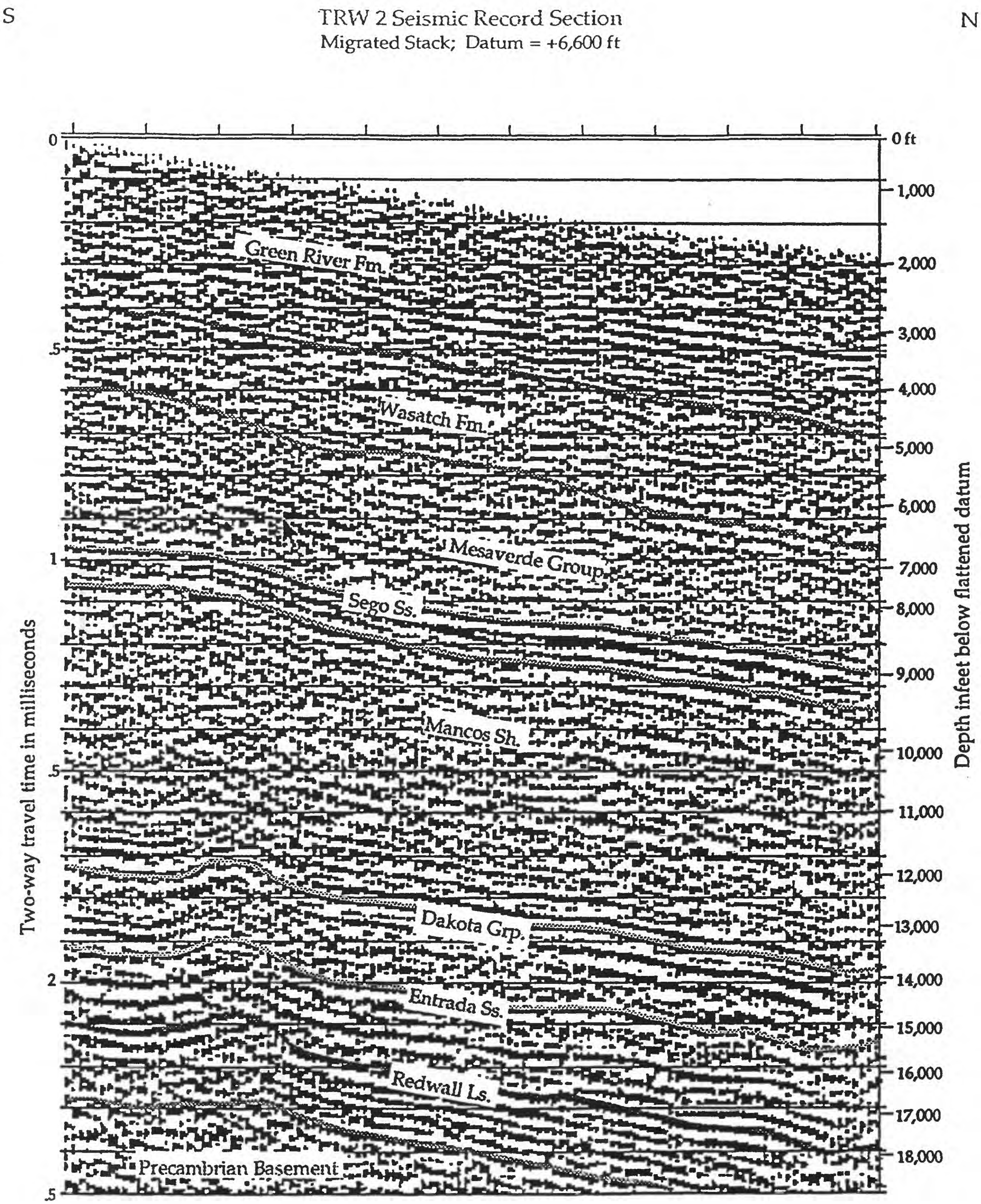
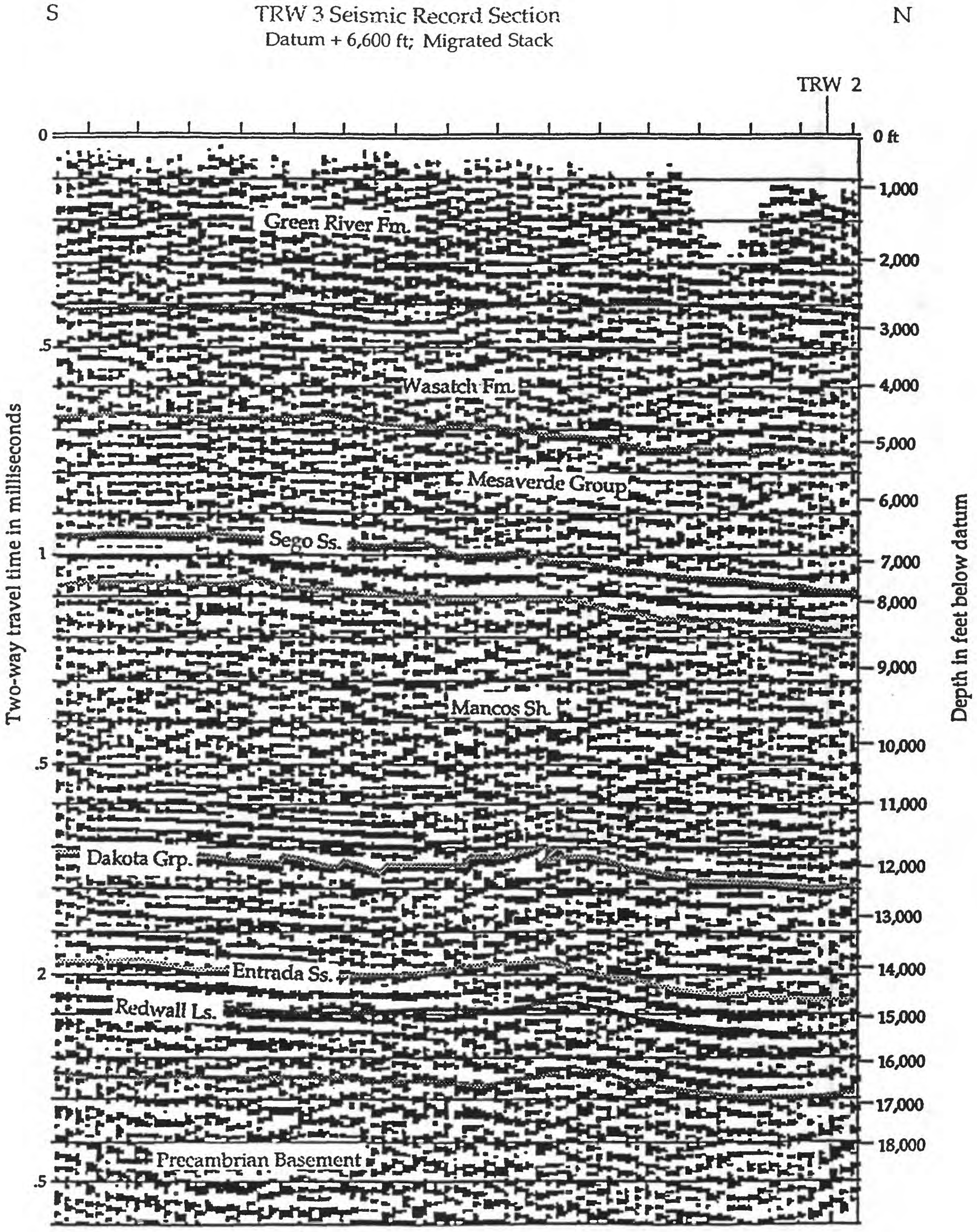
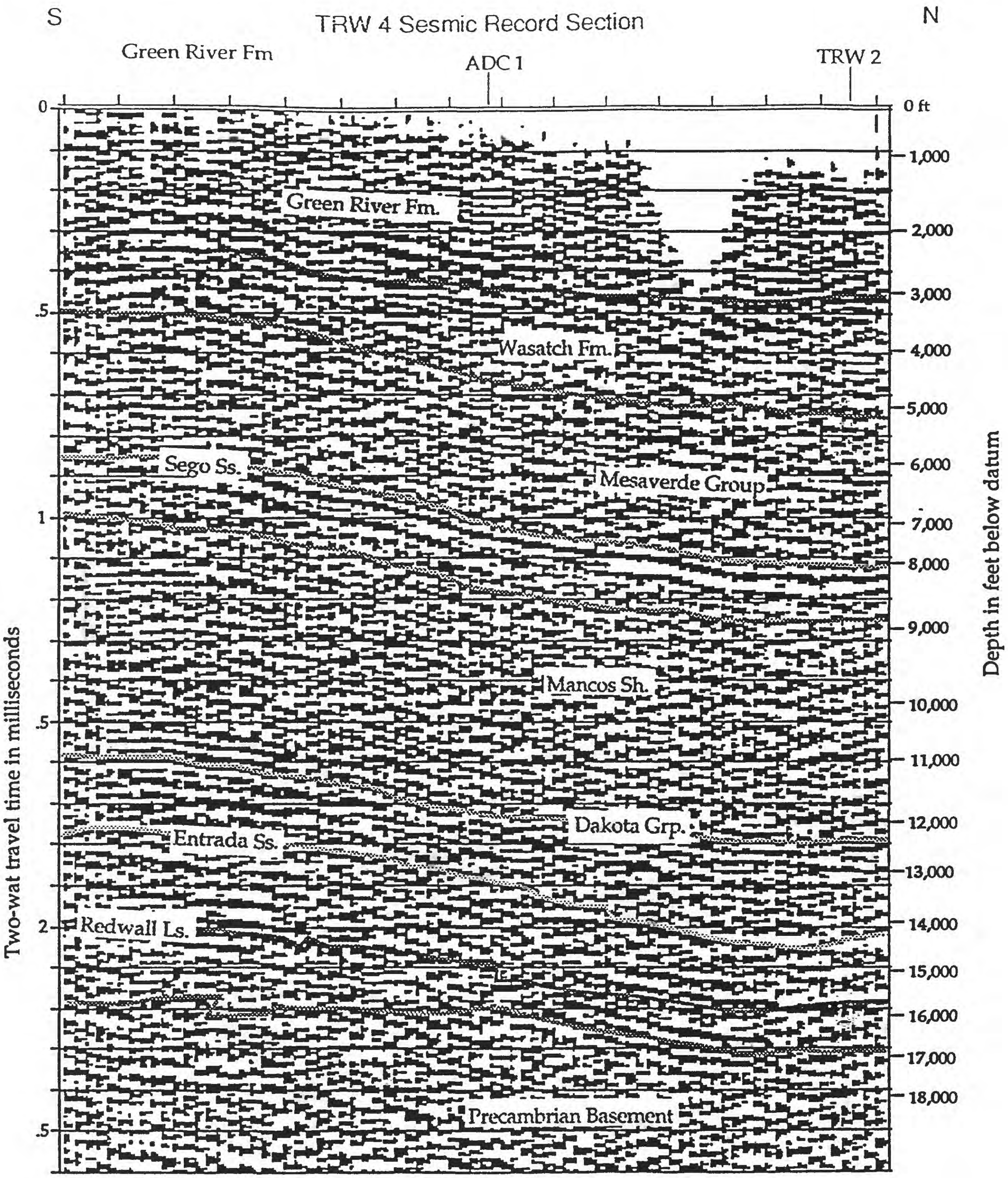
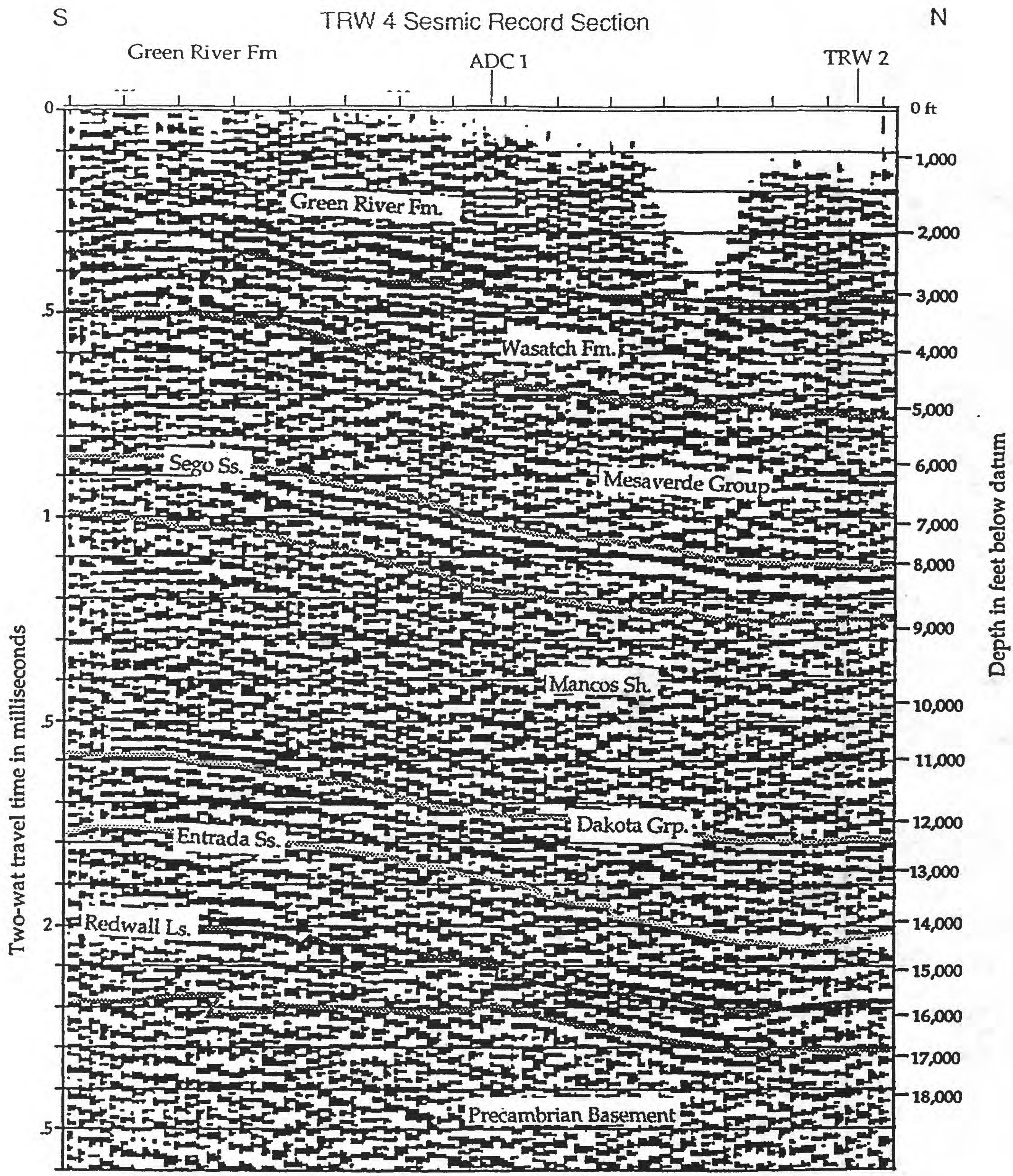


Figure T10. Portion of reprocessed TRW seismic line 2 illustrating the structural complexity of the Tabyago Dome feature in the NOSR 2 project area.


S
TRW 2 Seismic Record Section
Migrated Stack; Datum = +6,600 ft
N
Two-way travel time in milliseconds
0
.5
1
.5
2
.5
0 ft
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
Depth infeet below flattened datum
Green River Fm.
Wasatch Fm.
Mesaverde Group
Sego Ss.
Mancos Sh.
Dakota Grp.
Entrada Ss.
Redwall Ls.
Precambrian Basement

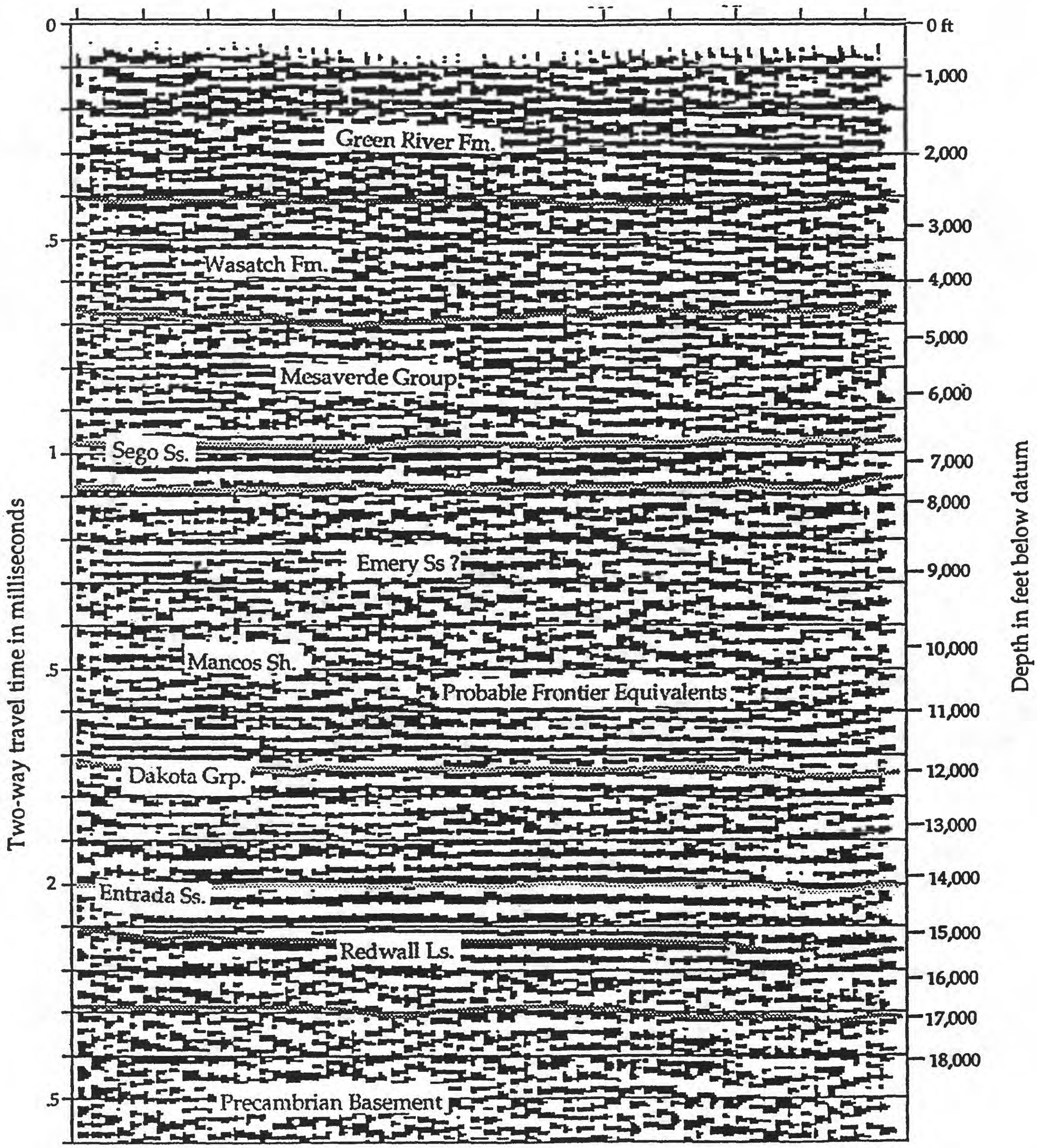

S
TRW 3 Seismic Record Section
Datum + 6,600 ft; Migrated Stack
N
TRW 2
0
.5
1
.5
2
.5
Two-way travel time in milliseconds
0 ft
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
Depth in feet below datum
Green River Fm.
Wasatch Fm.
Mesaverde Group
Sego Ss.
Mancos Sh.
Dakota Grp.
Entrada Ss.
Redwall Ls.
Precambrian Basement


S
TRW 4 Sesmic Record Section
N
Green River Fm
ADC 1
TRW 2
0
.5
1
.5
2
.5
Two-wat travel time in milliseconds
0 ft
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
Depth in feet below datum
Green River Fm.
Wasatch Fm.
Sego Ss.
Mesaverde Group
Mancos Sh.
Dakota Grp.
Entrada Ss.
Redwall Ls.
Precambrian Basement


S
TRW 4 Sesmic Record Section
N
Green River Fm
ADC 1
TRW 2
0 ft
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
Depth in feet below datum
0
.5
1
.5
2
.5
Two-wat travel time in milliseconds
Green River Fm.
Wasatch Fm.
Sego Ss.
Mesaverde Group
Mancos Sh.
Dakota Grp.
Entrada Ss.
Redwall Ls.
Precambrian Basement

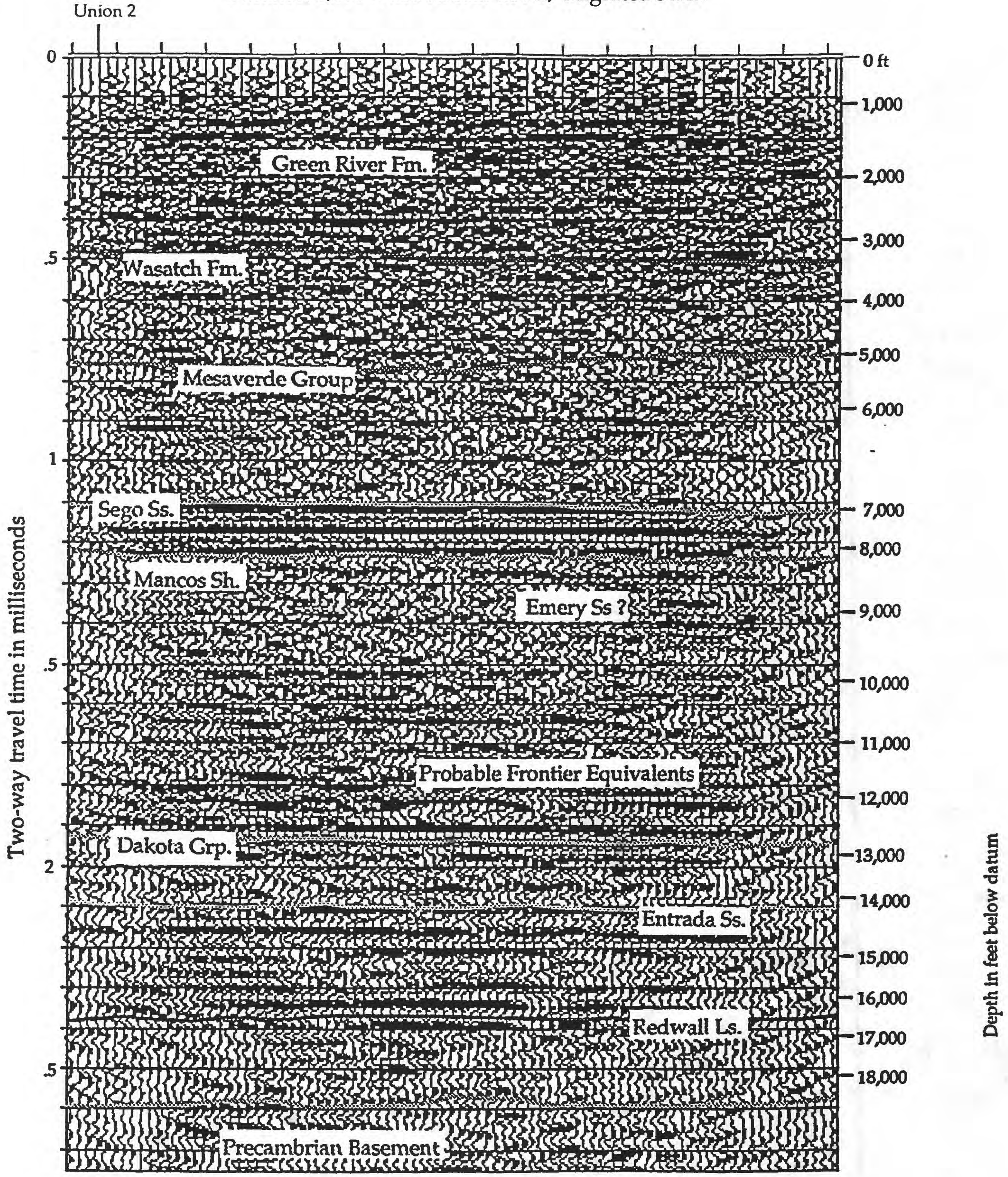
S TRW 5 Seismic Record Section N

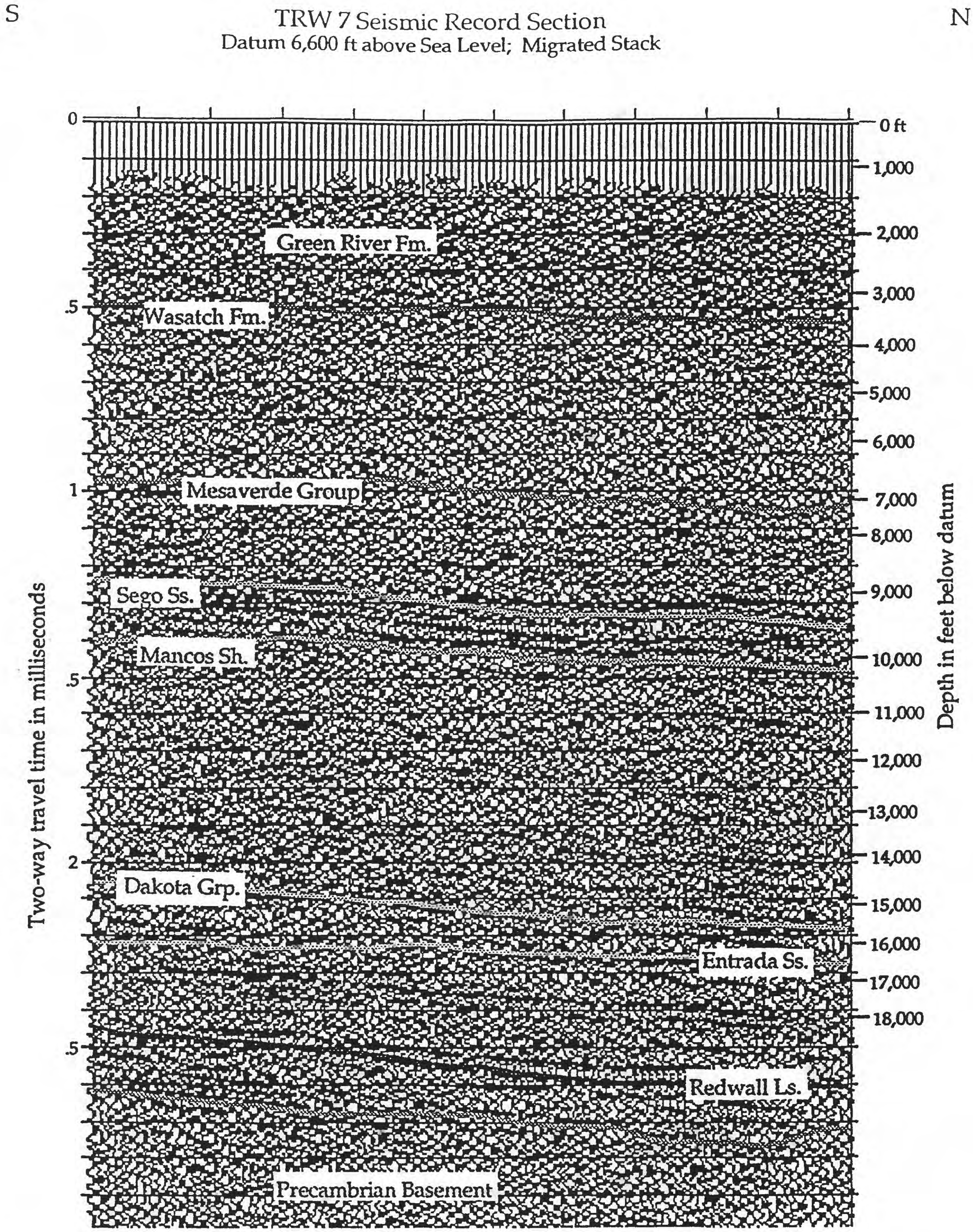
Datum + 6,600 ft, Migrated Stack

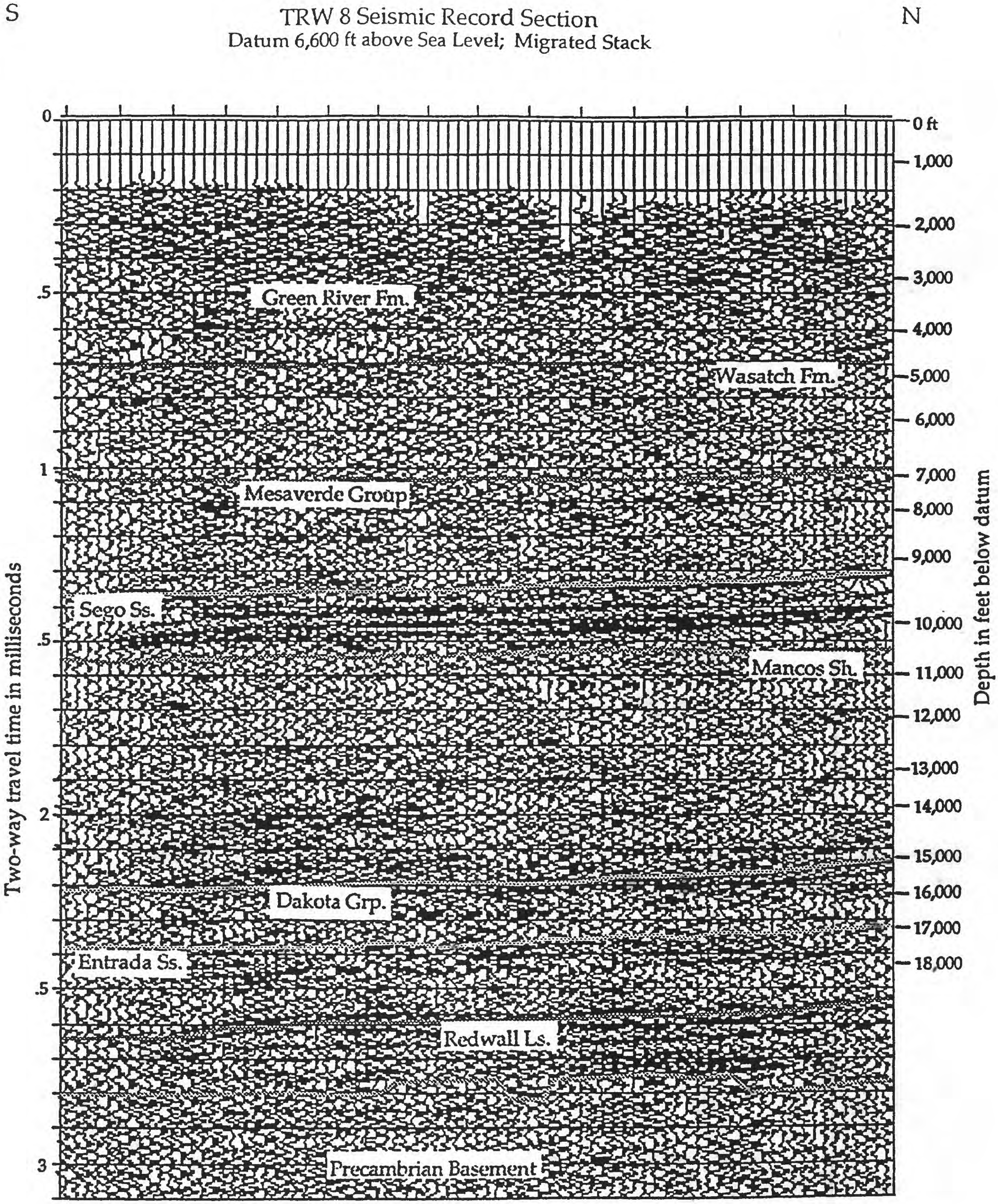


SE TRW 6 Seismic Record Section NW

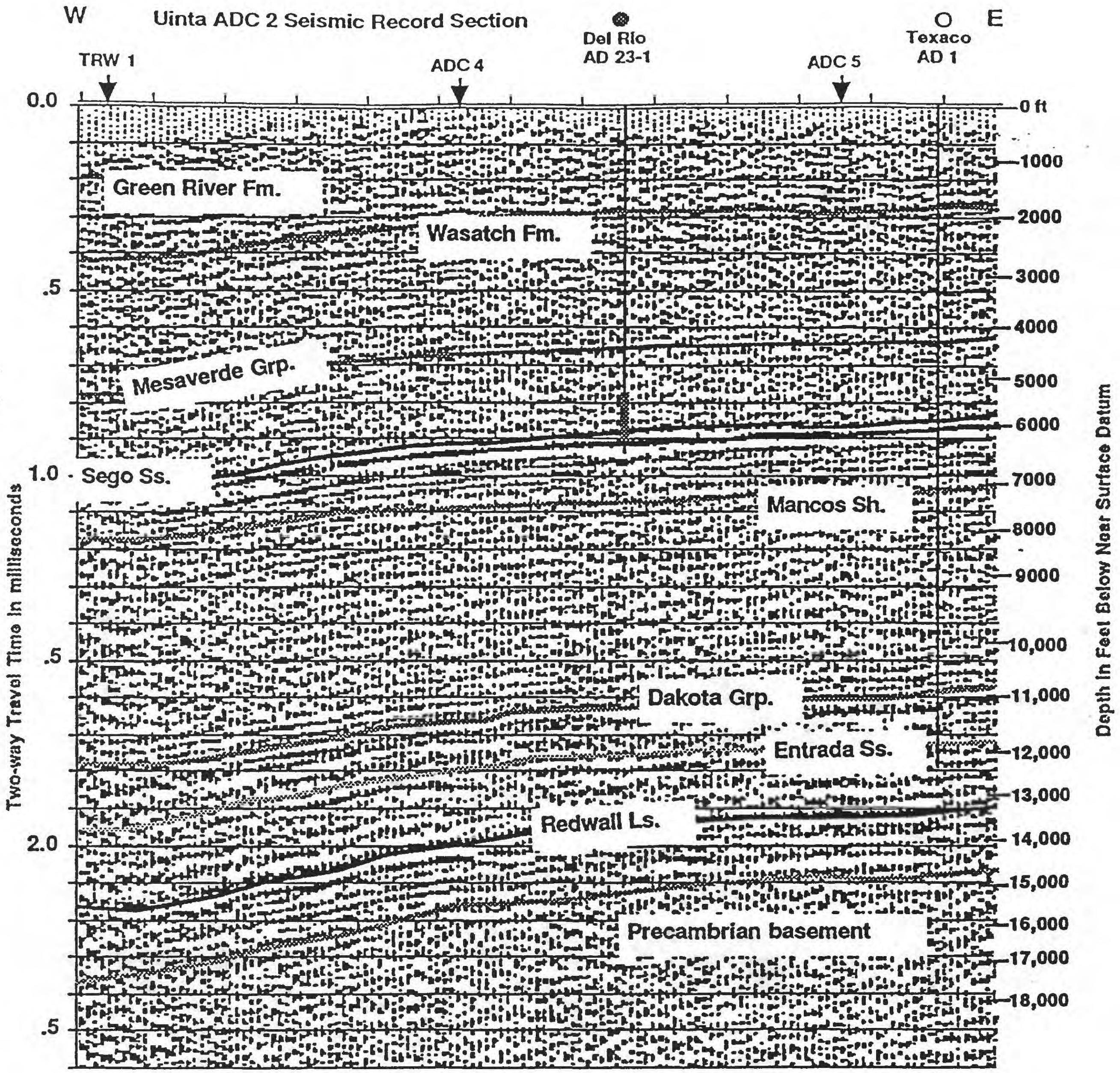
Datum is 6,600 ft above Seal Level; Migrated Stack




S
TRW 7 Seismic Record Section
Datum 6,600 ft above Sea Level; Migrated Stack
N
0
.5
1
.5
2
.5
Two-way travel time in milliseconds
0 ft
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
Depth in feet below datum
Green River Fm.
Wasatch Fm.
Mesaverde Group
Sego Ss.
Mancos Sh.
Dakota Grp.
Entrada Ss.
Redwall Ls.
Precambrian Basement



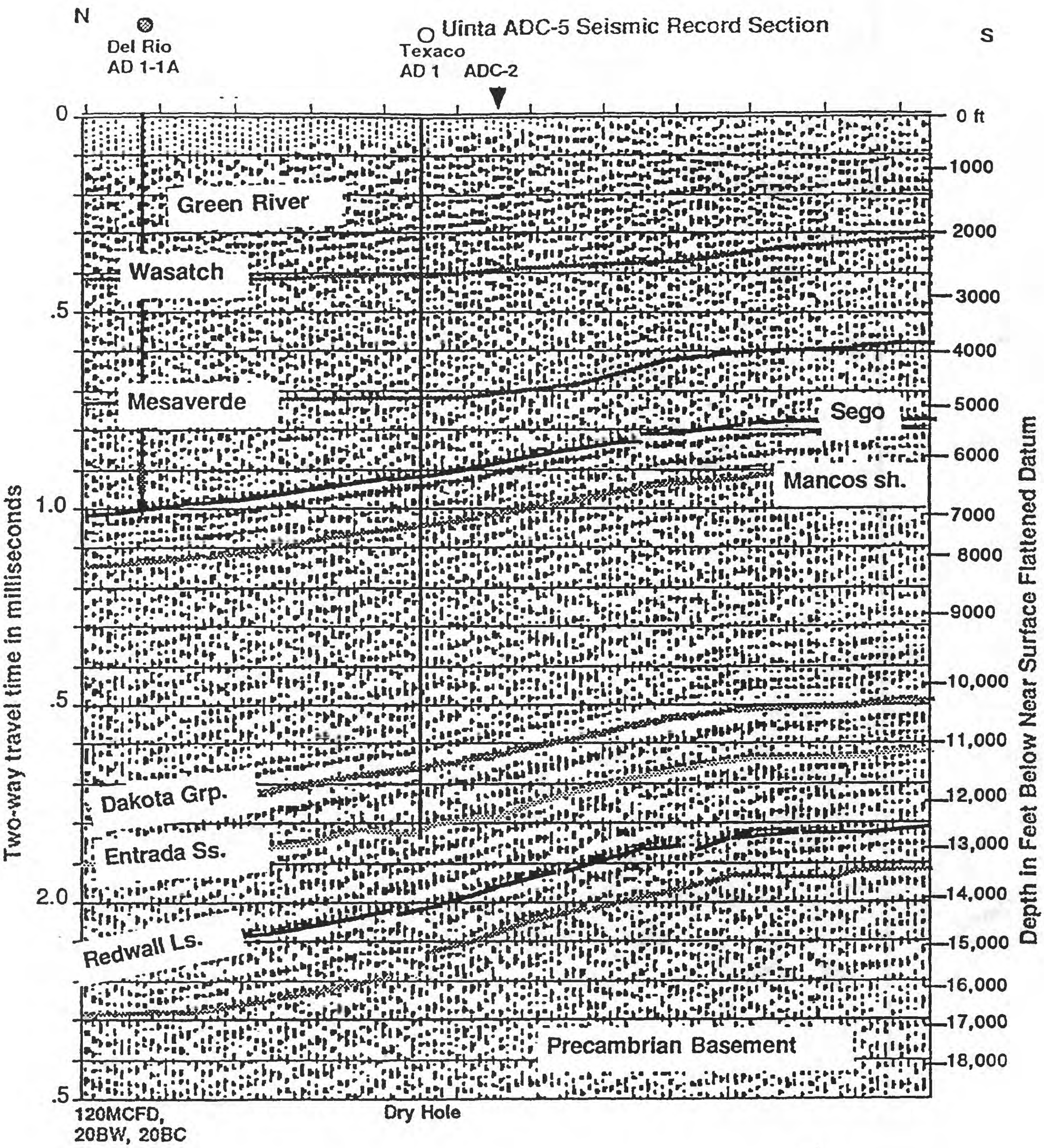
S
TRW 8 Seismic Record Section
Datum 6,600 ft above Sea Level; Migrated Stack
N
0
.5
1
.5
2
.5
3
Two-way travel time in milliseconds
0 ft
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
Depth in feet below datum
Green River Fm.
Wasatch Fm.
Mesaverde Group
Sego Ss.
Mancos Sh.
Dakota Grp.
Entrada Ss.
Redwall Ls.
Precambrian Basement



the region can be grouped into geologically-based *plays*, that is, hydrocarbon accumulations with common characteristics. The play has as its essence the notion that variance in stratal or rock properties, generally factors involving petroleum source, reservoir, and trapping units, has served to isolate accumulations to restricted areas. If conditions are favorable for discovery and exploitation, the accumulations may become fields. In other words, groups of fields and undiscovered hypothesized accumulations with similar geologic and engineering (production) characteristics constitute a play. These common characteristics or factors establish a basis for understanding such that their presence can be predicted in undrilled and otherwise unexplored areas, and so that the amount of oil and gas resources in the undrilled areas can be estimated.

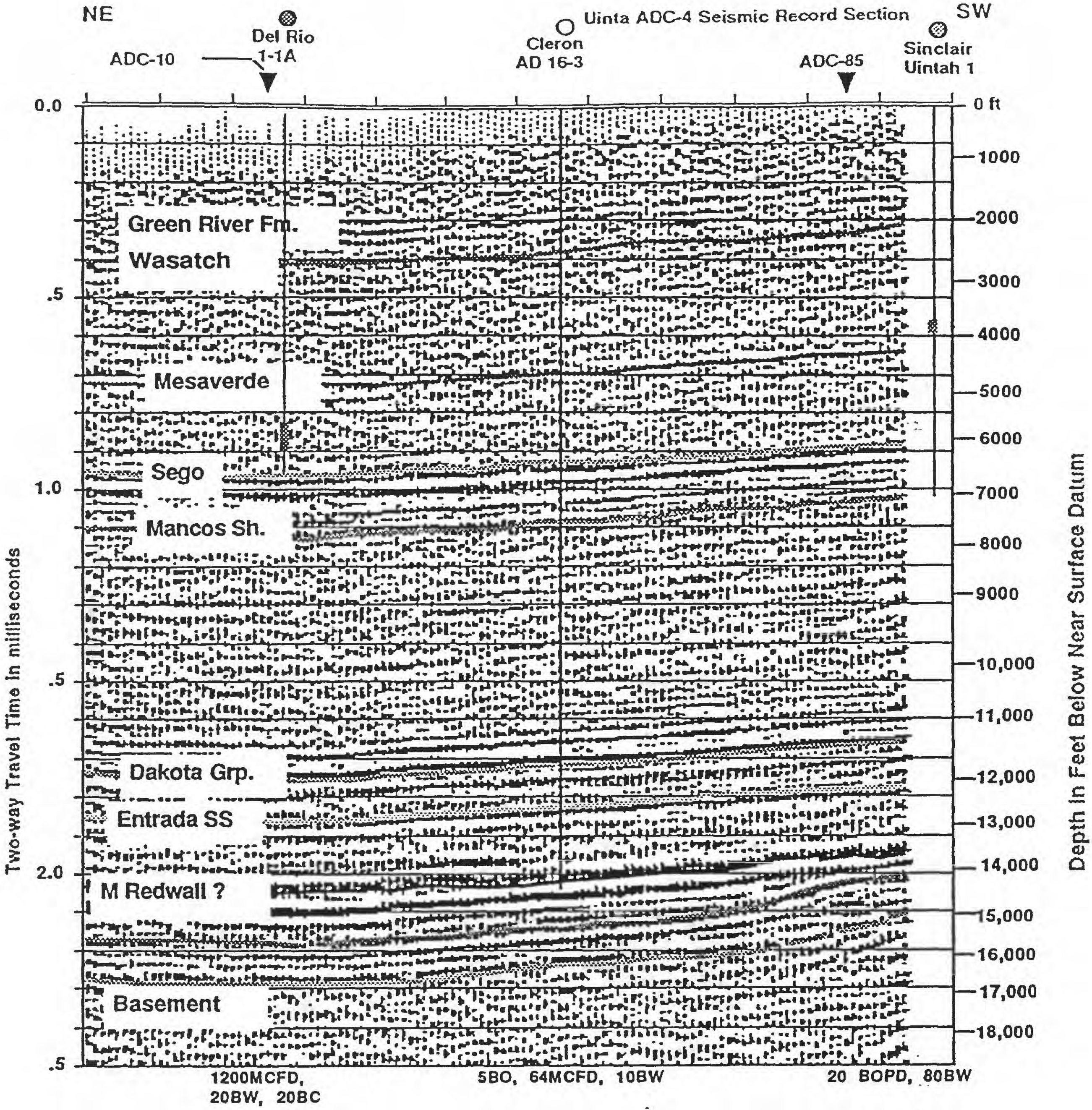
The discussion of the definition of plays and their stratigraphic , sedimentologic, and structural components is dependent upon data presented above. The reader's attention is particularly called to the paleogeographic maps and cross sections. Lithofacies and depositional facies illustrated in these figures were used by us to characterize the composition of strata in the hydrocarbon-bearing terranes and to serve as a basis for delineating play boundaries and their projections to the subsurface of sparsely or undrilled areas.

Hydrocarbons hypothesized to underlie Reserves 1 and 3, Colorado were assigned to five major plays for nonassociated gas (Fig—play maps). They are: Cretaceous Mesaverde Gas-Saturated 2007; Wasatch Formation Gas-Saturated 2008; The



Mancos & Associated Rocks 2021P; Cretaceous Dakota Group & Jurassic Morrison Fm 2011P; and the Paleozoic strata play 2005P. Hydrocarbons that underlie Reserve 2, Utah were assigned to: Eastern Wasatch Gas-Saturated 2015; the western extension of the Wasatch Formation play 2016; Wasatch Formation Transitional 2017; the Basin Flank Mesaverde Group 2018; the Mesaverde Group Transitional 2019; Cretaceous Dakota Group & Jurassic Morrison Fm 2011U; and Paleozoic strata play 2021U. If warranted, these plays could in turn be subdivided (i.e., Cameo, Corcoran, Mt. Garfield, Cozzette, Mt. Garfield, Iles, Dakota-Jurassic, Ferron-Frontier, Sego, Castlegate, Blackhawk, Neslen, Morrison, Weber, Leadville/Morgan, Emery, Mancos B, etc.).

For this study, gas plays without gas/water contacts were separated from those with such contacts. Fields developed in "gas-saturated" plays are not restricted to structural highs and they are developed in any structural position where permeability conducts such as natural open fractures occur.



NOSR 1 and 3 Plays

Cretaceous Mesaverde Gas-Saturated 2007 (Play Figure). This play consists of mixed stratigraphic and structural accumulations of gas in sandstone reservoirs of the Upper Cretaceous Mesaverde Group. Reconstructions of the burial history of the strata and measures of vitrinite reflectance (Ro), indicate that gas is currently being generated from source rocks within the Upper Cretaceous section.

We believe that the rapid and ongoing generation of gas has led to the strata's high fluid-pressure gradients, and that gradients more than 0.5 psi/ft can be expected in unexplored units. Porosity for units below 10,000 ft is commonly less than 10% and may be as low as 6 to 8%. Many of these reservoirs will be characterized by values of matrix permeability below 0.1 md *in situ* to gas.

The composition of source rocks in the Upper Cretaceous (Type III organic matter—high oxygen to hydrogen ratio) units is such that most hydrocarbons generated from them are gas. In addition, the gas generating section appears to be continuously saturated and relatively free of water/gas contacts. These relations suggest that the regional extent of the gas-saturated zone will be much larger than that established by current drilling, and that it will underlie most of Reserves 3 and 1.

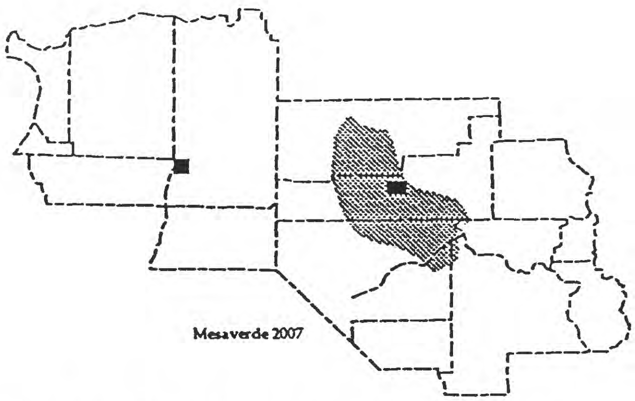


Figure 2007. Map showing shaded area of the Cretaceous Mesaverde Gas Saturated play 2007 in northwest Colorado. The entire area of Naval Oil Shale Reserves 1 & 3 is within the play boundary.

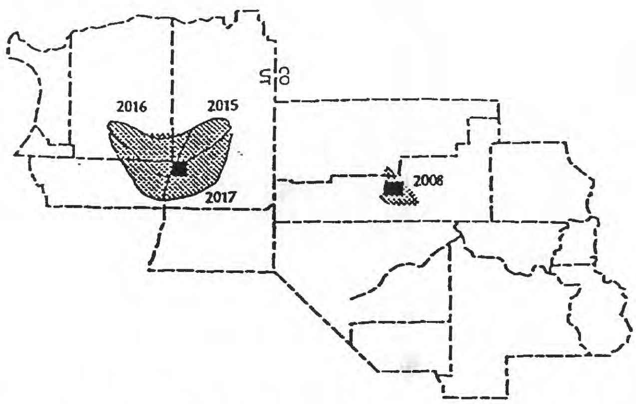


Figure 2008. Map showing shaded area of the Tertiary Wasatch Formation Gas Saturated play 2008 in northwest Colorado. The entire area of Naval Oil Shale Reserves 1 & 3 is within the play boundary. Map also shows the Wasatch Formation Gas Saturated plays 2016 and 2015, and the Wasatch Formation Gas-Water Transitional play 2017 in northeast Utah. Naval Oil Shale Reserve 2 is underlain in part by the Utah Wasatch plays.

Wasatch Formation Gas-Saturated Play 2008 (Figure). The Tertiary Wasatch play consists of structural and stratigraphic accumulations of gas trapped in Paleocene and Eocene sandstone reservoirs of the Wasatch Formation. Most of the gas in the play has migrated vertically from source Type III (woody-herbaceous) rocks in the underlying Cretaceous section.

Gas/water contacts are rare to absent in the area of Reserve 3 and reservoirs yield gas, some condensate and a little water. Local values of porosity can exceed 18% though lower values are most common. For the most part, values of matrix porosity and permeability are comparable to those of reservoirs in some conventional fields.

The Mancos & Associated Rocks Play 2021P. This play includes gas in the Mancos B (Emery Sandstone part? equivalent), and in temporal equivalents of the Frontier and Ferron Sandstones and associated units. These strata are very fined grained where developed in the Piceance basin and their presence as viable reservoirs under Reserves 1 and 3 is not certain (Fig. FR3).

Measures of rock properties in the Cretaceous section in existing fields indicate that for equivalent depths, lithofacies, and levels of maturity, reservoir properties are greater in the Piceance basin than in the Uinta.

The Cretaceous Dakota Group, Cedar Mountain, Burro Canyon, and Jurassic Morrison Formation Play 2011P (Figure): This play involves fine to coarse grained fluvial, shallow marine, and eolian sandstones that underlie Reserves 3 and 1. Rock ages range from lower Upper Cretaceous to Lower Cretaceous and Jurassic. The plays lies at drilling depths near and below 15,000 ft and porosity and permeability values are expected to be near and below 10% and 0.1 md respectively. Because of the relatively high Ro vitrinite value of the base of the overlying Mesaverde section near Reserve 3, the stable hydrocarbon species will be gas. Herbaceous type III organic matter is present in the Dakota Group and may serve as a local source of thermal gas for the play (Fig. FR1).

Paleozoic strata play 2005 (Figure): The regional Paleozoic play involves a regionally extensive complex of reservoir quality eolian and associated sandstone, and carbonate beds that is bounded on the west and north by nonreservoir marine rocks, and on the east and southeast by the nonreservoir redbed lithologies, or by uplifted Precambrian rocks. For purposes of this study, structures associated with salt in the Paleozoic section are grouped with this play as are traps in Mississippian-age potential carbonate reservoir rocks.

Over much of the region, reservoir rocks in Play 2005U contain oil in the subsurface and are stained by it on surface exposures. Existing fields in the regional play involve stratigraphic pinchouts and traps draped across structures in the Paleozoic rocks. The play includes Rangely field, the largest oil field in the Rocky Mountain region; stratigraphically and temporally equivalent beds contain several billion barrels of oil in place at the Tar Sand Triangle in the northern part of the Paradox basin of eastern Utah.

The largest known accumulations in the play are of oil, but vitrinite reflectance values (much greater than $R_o > 1.1$) for most strata of this play in the area of

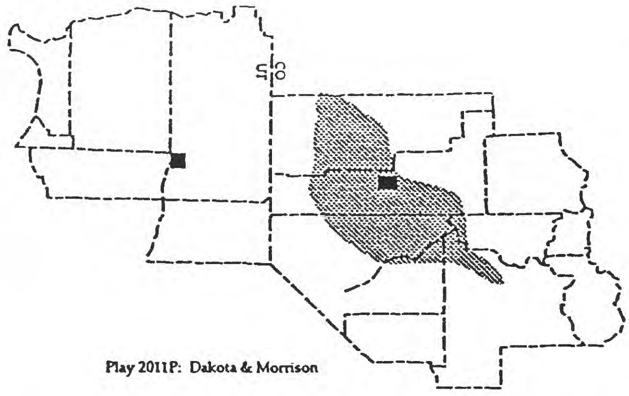


Figure 2011P. Map showing shaded area of the Cretaceous Dakota Group-Jurassic Morrison Formation Gas Saturated play 2021P in northeast Utah. The entire area of Naval Oil Shale Reserves 1 and 3 are within the play boundary.

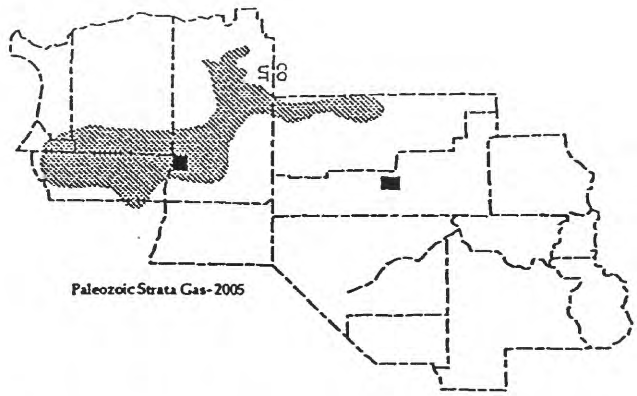


Figure 2005. Map showing shaded area of the Paleozoic clastic and carbonate play 2005. The entire area of Naval Oil Shale Reserves 2 is within the play boundary but important elements of the play are absent under Reserves 1 and 3.

NOSRs 1 and 3, and the anticipated deep drilling depths required to reach the play under the NOSRs, suggest that the stable hydrocarbon species will be gas if present.

Inspection of the paleogeographic maps presented previously in this paper indicate that the optimum components of the play do not underlie the area of NOSRs 1 and 3 (Figs. J1-J3). For this reason we do not include the NOSRs in the primary area of the play. However, for completeness, we have evaluated the play extension using data from wells outside the area of the viable play (see Appendix C).

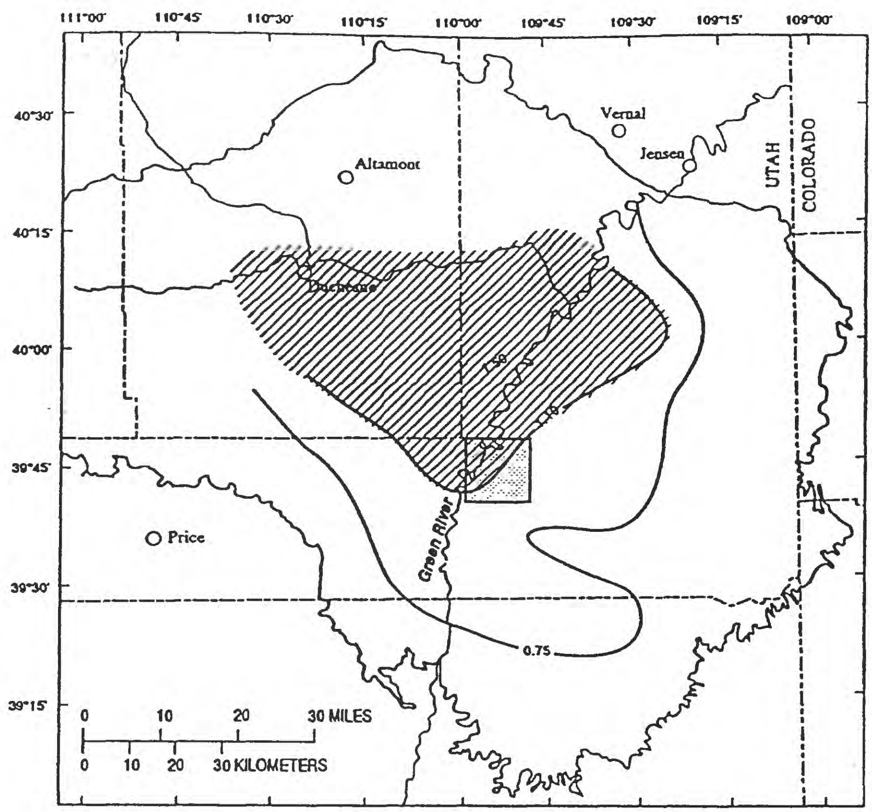
NOSR 2 Plays

Hydrocarbons that underlie Reserve 2, Utah were assigned to: Eastern Wasatch Gas-Saturated 2015; the western extension of the Wasatch Formation play 2016; Wasatch Formation Transitional 2017; the Basin Flank Mesaverde Group 2018; , The Mesaverde Group Transitional 2019; Cretaceous Dakota Group & Jurassic Morrison Fm 2011U; and Paleozoic strata play 2021U.

Eastern Wasatch Gas-Saturated Play 2015, Play 2016, and Play 2017 (see fig. 2007): This play includes Paleogene fluvial and lacustrine strata commonly assigned to the Wasatch or Colton Formations in the southeast part of the Uinta Basin, Utah.

Of particular note is the absence or gas/water contacts from within the area of primary production at the Natural Buttes field. A key component of assignment of hydrocarbons to plays was their position relative to the line described by the surface projection of the vitrinite reflectance value (Ro) > 1.10 at the base of the Mesaverde. The line serves to separate the Wasatch Formation into domains in which a region where free water seems to coexists with zones of continuous gas saturation (Play 2017) from those believed to be characterized be continuos-gas saturation (Plays 2015 and 2016). The large Natural Buttes gas field serves as the core of play 2015 and it is developed above the area where gas is being generated in the underlying Mesaverde Group and rising directly to be trapped in reservoirs of the Wasatch Formation. As a result, source, reservoir rocks, and trap are in close proximity and drilling success is relatively high. Play 2016 is that region of continuous gas saturation where source and reservoir rocks are separated by an northwest thickening wedge of lower Tertiary strata and the resultant drilling success is not as high as that for play 2015.

Basin Flank Mesaverde Group Play 2018; The Mesaverde Group Transitional Play 2019 (Figure:) The plays consists of mixed stratigraphic and structural accumulations of gas in sandstone reservoirs of the Upper Cretaceous Mesaverde Group. Reconstructions of the burial history of the strata and measures of vitrinite reflectance (Ro), indicate that gas is currently being generated from source rocks within the Upper Cretaceous section. Of particular note is the absence or gas/water contacts from within the area of primary production from the Mesaverde at the Natural Buttes field. A key component of assignment of hydrocarbons to plays was their position relative to the line described by the surface projection of the vitrinite reflectance value (Ro) > 1.10 at the base of the Mesaverde. The line serves to separate the Mesaverde into domains in which a region where free water seems to coexists with zones of continuous gas



NOSR 2 Play No. 2018: Cretaceous Mesaverde Gas Saturated

Play Area: Mesaverde Group reservoirs at drilling depths near and less than15,000ft. Mesaverde Group strata include the Rim Rock, Castlegate, and Sego Sandstones, and the Blackhawk, Tuscher, Farrer, Price River, and Neslen Formations. Contains gas-saturated strata.

Naval Oil Shale Reserve (NOSR) 2

1.10

Level of vitrinite reflectance (measure of thermal maturity) on basal Mesaverde

Figure 2018. Map showing shaded area of the Cretaceous Mesaverde Gas Saturated play 2018 in northeast Utah. The play includes the northwest part of Naval Oil Shale Reserve 2.

saturation (Play 2019) from those believed to be characterized be continuous-gas saturation (Play 2018).

We believe that the rapid and ongoing generation of gas has led to the strata's high fluid-pressure gradients, and that gradients more than 0.5 psi/ft can be expected in unexplored units. Porosity for units below 10,000 ft is commonly below 10% and may be as low as 6 to 8%. Many of these reservoirs will be characterized by values of matrix permeability less than 0.1 md *in situ* to gas.

The composition of source rocks in the Upper Cretaceous (Type III organic matter—high oxygen to hydrogen ratio) units is such that most hydrocarbons generated from them are gas. In addition, the gas generating section appears to be continuously saturated and relatively free of water/gas contacts (Play 2018). These relations suggest that the regional extent of the gas-saturated zone will be much larger than that established by current drilling, and that it will underlie at least the northwest margin of Reserve 2.

The Mancos & Associated Rocks Play 2021U (Figure:) This play includes gas in the Mancos B (Emery Sandstone part? equivalent), Frontier and Ferron Sandstones and associated units. These strata are very fined grained where exposed along the southern margin of the Uinta Basin near Woodside, Westwater, and Wellington. However, seismic reflection data suggests that they may underlie Reserve 2. The expected hydrocarbon species in these reservoirs is gas because of the thermal state of rocks at

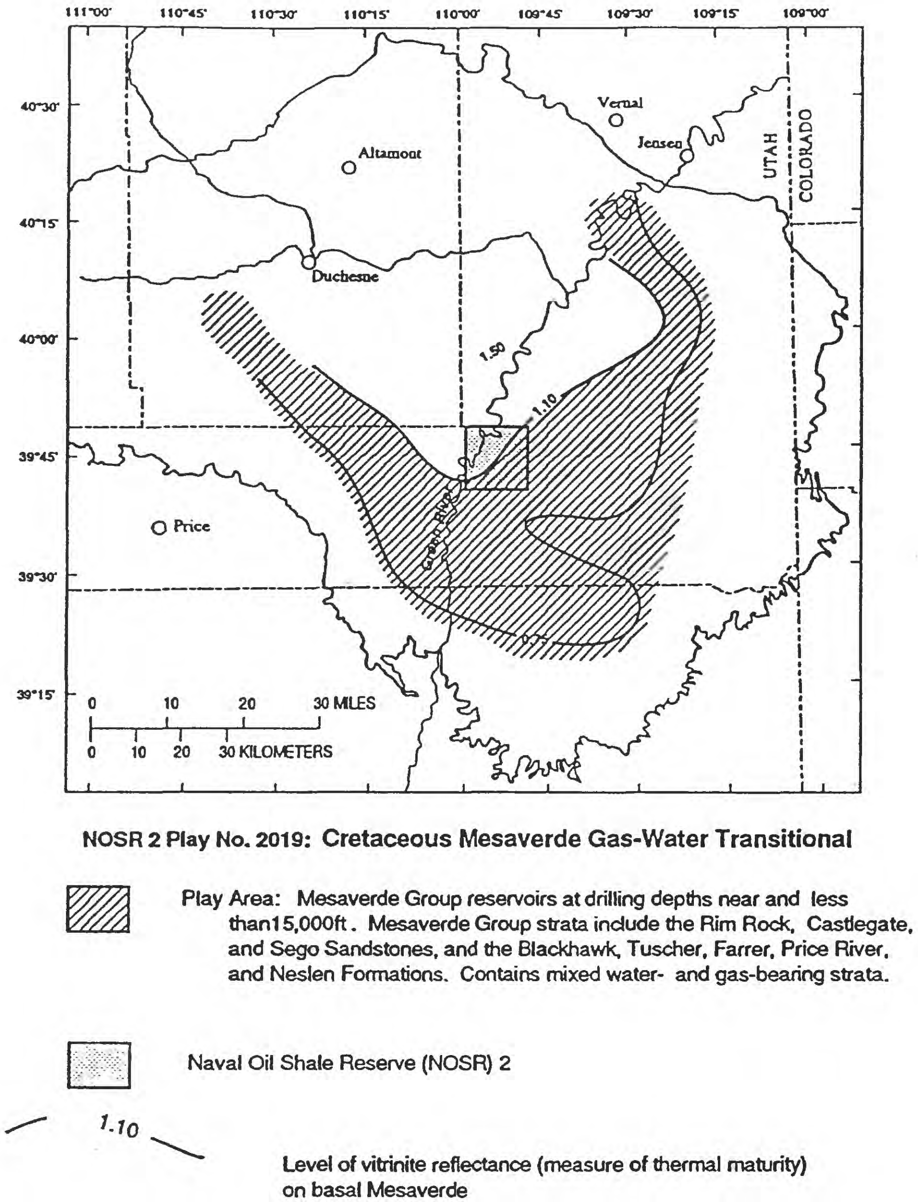


Figure 2019. Map showing shaded area of the Cretaceous Mesaverde Gas-Water Transitional play 2018 in northeast Utah. The play includes the southeast 2/3 rds of Naval Oil Shale Reserve 2.

comparable and shallower drilling depths in Natural Buttes wells. In addition, the Mancos Shale in this region contains abundant Type III organic matter, a common source of gas.

Cretaceous Dakota Group & Jurassic Morrison Fm 2011U (Figure:) This plays involves fine to coarse grained fluvial, shallow, marine, and eolian sandstones that underlie Reserves 2 (see seismic record sections) and are exposed south of the Book Cliffs. The rocks range in age from lower Upper Cretaceous to Lower Cretaceous and Jurassic.

Inspection of borehole logs from fields in the play area indicate that porosity and permeability values are expected to be near and below 10% and 0.1 md respectively. However, local pods of higher porosity are apparently preserved such as at the Seep Ridge gas field southeast of NOSR 2. Because of the relatively high Ro Vitrinite value of the base of the overlying Mesaverde section near Reserve 2, the stable hydrocarbon species will be gas. Herbaceous type III organic matter is present in the Dakota Group and may serve as a local source of thermal gas for the play.

Paleozoic strata (see Fig. 2005:) Stratigraphic reconstructions by S.Y. Johnson et al. (1992) indicate that Reserve 2 is largely underlain by fluvial redbed lithologies and sparse carbonates (Figs. J1-J3). In addition, data derived from production tests in the region are scarce and where present, do not indicate that viable reservoirs have been detected. However, seismic record sections (see figures) indicate that some Paleozoic strata underlie the region of NOSR 2 at the northwest margin of the ancestral Uncompahgre

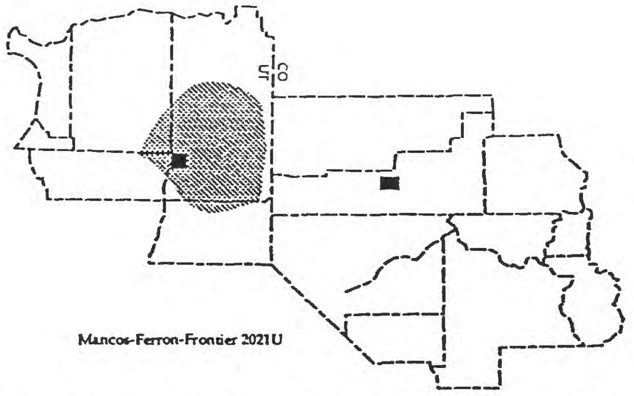


Figure 2021U. Map showing shaded area of the Cretaceous Mancos B-Emery sandstone Member of the Mancos Shale Gas Saturated play 2021. Play also includes Ferron and Frontier Sandstones and associated units. The entire area of Naval Oil Shale Reserves 1 & 3 is within the play boundary. Naval Oil Shale Reserve 2 is underlain by the play.

uplift. Elsewhere, the primary Paleozoic play in the region involves a regionally extensive complex of reservoir quality eolian and associated sandstone, and carbonate beds that is bounded on the west and north by nonreservoir marine rocks, and on the east and southeast by the nonreservoir redbed lithologies, or by the absence of the section over uplifted Precambrian rocks. It is important to note that the primary reservoir rock in that system, The Weber Sandstone, does not appear to be well developed, if at all, in the NOSR 2 area.

STATEMENT OF PROBLEM

The hydrocarbon accumulations addressed in this section are defined as "continuous-type" gas or oil accumulations, not significantly affected by hydrodynamic influences, for which assessment methodologies based on sizes and numbers of fields are not appropriate. We describe here the protocol that we used to assess potential additions to gas and oil reserves from continuous-type accumulations of the study areas.

Continuous-type accumulations are essentially single fields, so large in areal extent and so heterogeneous that their development cannot be properly modeled as field growth. Many assessment methodologies, such as that which will be used by the U.S. Geological Survey for conventional plays of their 1995 National Assessment, are inappropriate for continuous-type accumulations because such accumulations cannot be represented as groups of discrete, countable units (fields) delineated by down-dip hydrocarbon-water contacts.

Nature Of Continuous-Type Accumulations

Our definition of a continuous-type unconventional hydrocarbon accumulation is based on the observed setting and inferred dynamics of the accumulation; the definition does not incorporate criteria that are commonly associated with other types of unconventional accumulations such as low API gravity, low matrix permeability (tight), or special regulatory status. For example, tight-gas production may or may not be from a continuous-type accumulation that requires the special resource-assessment methodology described here.

The geologic setting typical of continuous-type accumulations is illustrated in Figure S1. Common geologic characteristics of a continuous-type accumulation include occurrence downdip from water-saturated rocks, lack of obvious trap and seal, crosscutting of lithologic boundaries, large areal extent, relatively low matrix permeability, abnormal pressure (high or low), and close association with source rocks. The boundary between a continuous-type accumulation and up-dip, water-saturated rocks (Fig. S1) may be transitional rather than abrupt.

Aspects of hydrocarbon production common to a continuous-type accumulation include large in-place hydrocarbon volume, low recovery factor, low water production, very few truly dry holes, and a heterogeneous "hit or miss" character for production rates and ultimate recoveries of wells. Unlike undiscovered accumulations in discrete structural and stratigraphic traps, the locations of continuous-type accumulations are often known.

Terminology

The assessment of continuous-type hydrocarbon accumulations is based on play analysis. In play analysis, an assessment area is partitioned into geologic plays and the plays are analyzed individually.

Selected definitions of particular importance to the assessment of continuous-type accumulations are presented here. These definitions should be viewed more as explanations than as inflexible technical rules.

Cell. A subdivision of a play with an area or size (acres, or mi^{2}acres/640) equal to the typical spacing expected for wells of the play. Virtually all cells in a continuous-type accumulation are capable of producing some hydrocarbons. For purposes of this discussion, a productive cell is one that contains at least one well for which production from the play is formally reported. A play with no productive cells is a hypothetical play. A nonproductive cell is one that contains one or more wells that evaluated the play, none of which was productive in the play. An untested cell is one that has not been evaluated by a well. The number of untested cells in a play equals the total number of cells minus the number of cells (productive plus nonproductive) that have been evaluated.

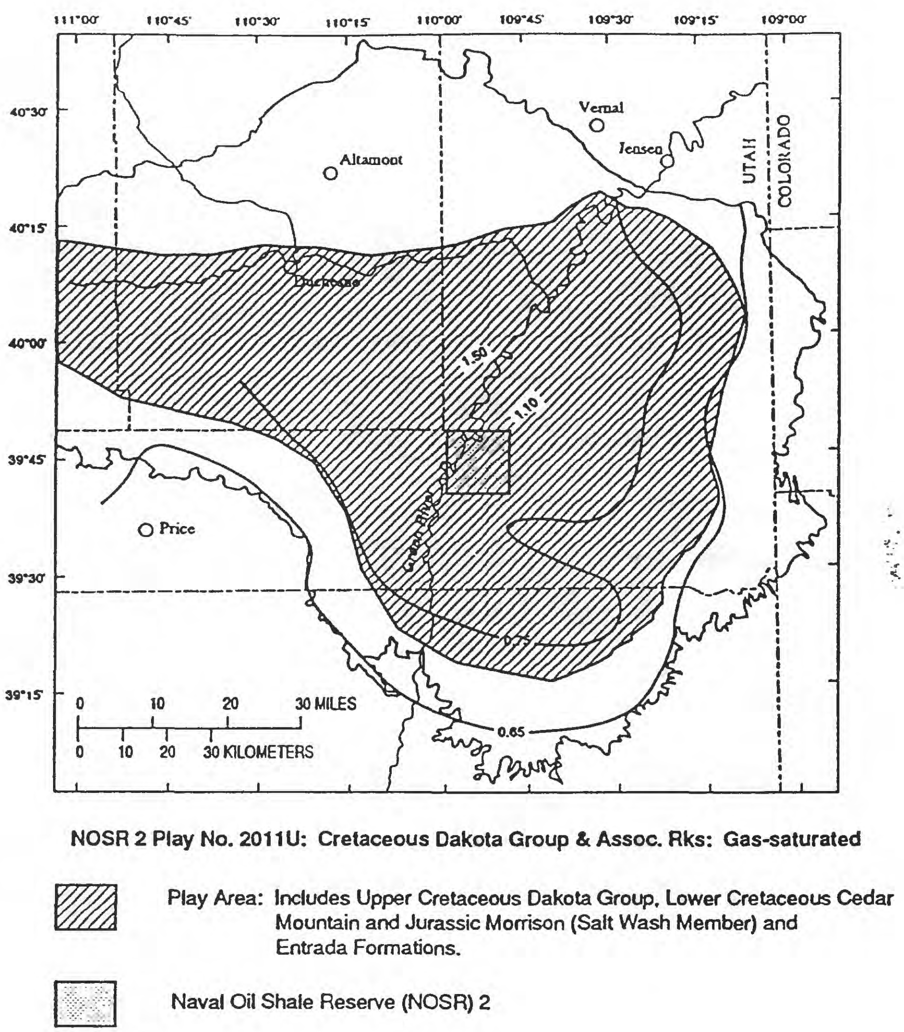


Figure 2011U. Map showing area of the Cretaceous Dakota Group-Jurassic Morrison Formation Gas Saturated play 2011U in northeast Utah. The entire area of Naval Oil Shale Reserve 2 is within the play boundary.

Success ratio. The fraction (0-1.0) of untested cells in a play expected to be productive. The combination of success ratio and number of untested cells yields the number of productive, untested cells in a play.

Estimated ultimate recovery (EUR) probability distribution for productive, untested cells. A distribution that serves as a reference model for production from the productive, untested cells of a play. The EUR data of the distribution (barrels of oil or millions of cubic feet of gas) should be representative of productive cells yet to be drilled, rather than established production.

Play probability. The probability (0-1.0) that untested cells of a play are capable of producing at least one million barrels of oil or six billion cubic feet of non-associated gas. These minimum production thresholds are the same as those that will be used by the U.S. Geological Survey for conventional plays (discrete accumulations) of their 1995 National Assessment.

Procedure

Overview

The procedure outlined by the flow diagram of Figure S2 is straightforward in concept. A continuous-type accumulation is subdivided into plays, and geologic risk (play probability) is assigned to each play. A play is regarded as a collection of hydrocarbon-containing cells. The number of untested cells in a play and the fraction of untested cells expected to be productive (success ratio) are estimated. The combination of success ratio and number of untested cells yields the number of productive, untested cells in a play. Existing production is used as a reference model for potential production from productive cells yet to be drilled.

Represent Continuous-Type Accumulations by Plays

For the case of a continuous-type accumulation, the first step of the assessment (Fig. S2) is to represent the

SKETCH OF CONTINUOUS-TYPE ACCUMULATION

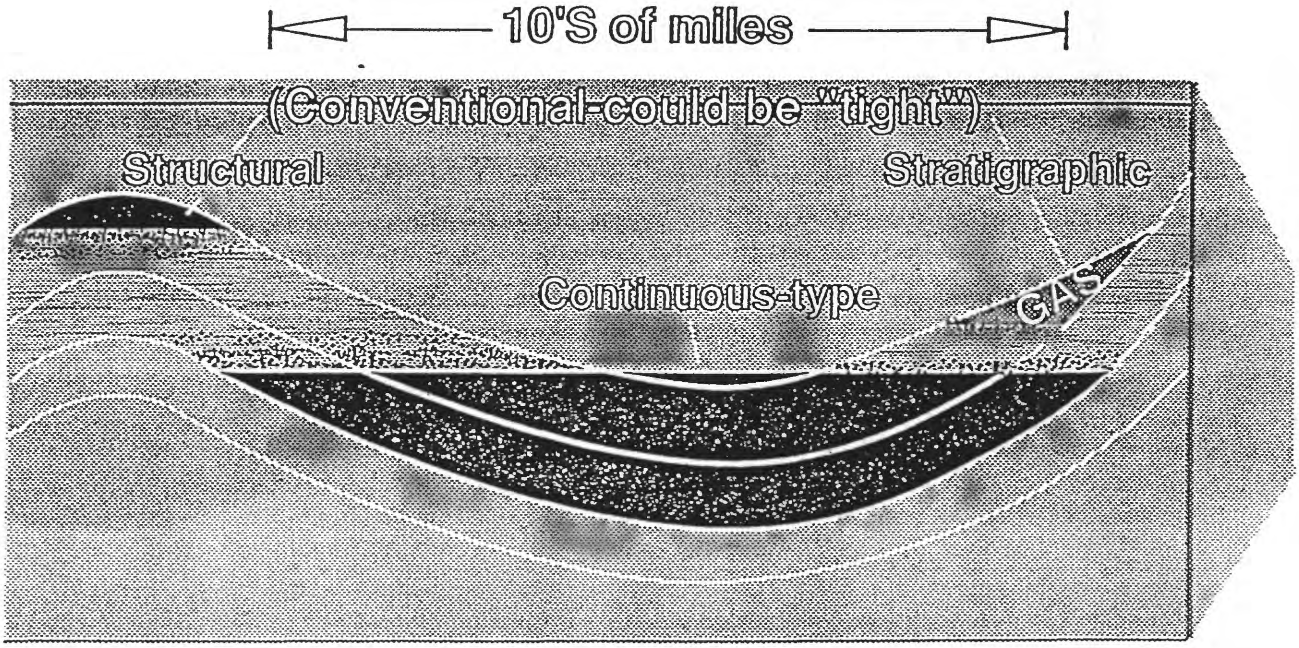


Figure S1. Geologic setting of continuous-type gas or oil accumulations relative to discrete accumulations in structural or stratigraphic traps.

accumulation by a play or plays sufficiently homogeneous so that each play can be reasonably characterized by a single play probability, cell size, success ratio, and EUR probability distribution for productive, untested cells. Play boundaries must be concisely drawn because the assessment depends strongly on the area of the play. Each play is identified as either a gas play or an oil play. A gas to oil ratio of 20,000 cubic feet of gas per barrel of oil separates gas plays from oil plays.

Assign Risk to Play

A play probability is estimated for each play. Lower play probability equates to a greater geologic risk that untested cells are not capable of producing the minimum threshold volume; a play probability of 1.0 reflects geologic certainty that the minimum production threshold can be met. The computational model (described in the following section) incorporates the play probability as a weighting factor in calculating unconditional play potential.

The possibility exists that a play is so speculative that an effort at quantitative assessment could not be defended. For such cases, we have adopted the convention that a continuous-type play will not be assessed if the play probability is less than 0.11.

After assigning risk to a play, the assessment process can be regarded as proceeding along two parallel flow paths. The right branch of Figure S2 addresses the number of productive, untested cells in a play, and the left branch addresses the production expected from those cells.

Estimate Number of Untested Cells in Play

For purposes of resource assessment, it is convenient to envision the hydrocarbons of a continuous-type accumulation as residing in cells. A play is then regarded as a collection of cells of area or size equal to the typical spacing expected for wells of the play (Fig. S3). The total number of cells in a play equals the area of the play (mi^2) divided by the cell size (mi^2).

A cell is characterized as either evaluated or untested (Fig. S3). An evaluated cell is either productive or nonproductive. The number of untested cells in a play equals the total number of cells minus the productive and nonproductive cells.

Uncertainties in defining; play boundaries, number of evaluated cells, and cell sizes lead to measurement error in the number of untested cells. This measurement error is expressed by estimating the minimum possible number and maximum possible number of untested cells in the play. For cases where

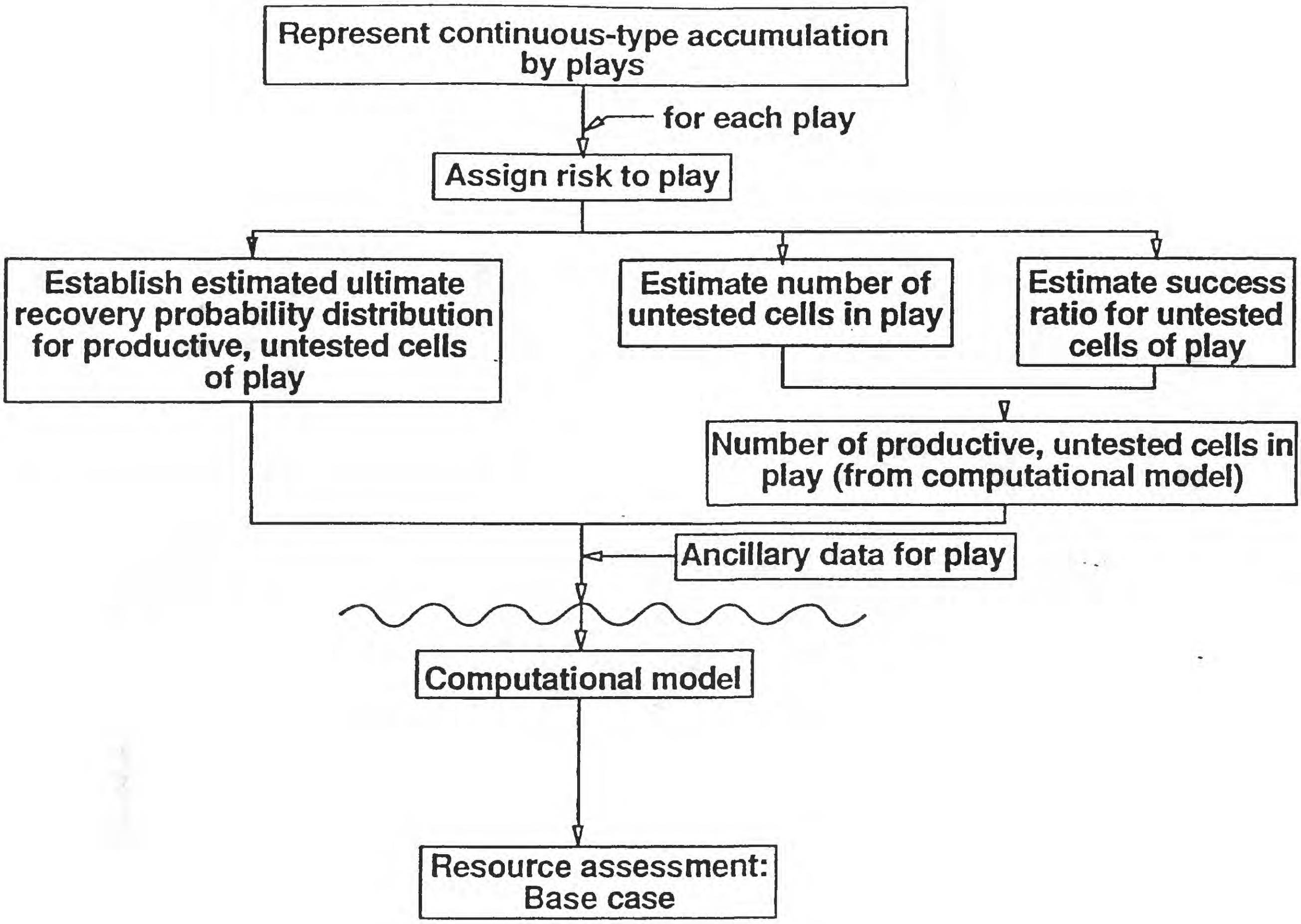


Figure S2. Flow diagram emphasizing geologically based portion of protocol (above wavy line) used to assess continuous-type gas and oil accumulations. The computational model is described in a separate section.

measurement error in the number of untested cells is significant, provision is made in the computational model to treat the number of untested cells as a probability distribution.

Estimate Success Ratio for Untested Cells of Play

One approach to estimating success ratio is to extrapolate results of existing drilling in a play to the untested cells of the same play. Success ratio is then the number of productive cells divided by the number of cells evaluated (productive plus nonproductive).

If existing drilling results are not typical of the play as a whole, or the play is insufficiently drilled to establish a realistic success ratio, or the play has no productive cells (a hypothetical play), success ratio can be based upon drilling results from an analog play or upon concepts regarding geologic factors controlling production.

Success ratio is treated in the computational model as a single-valued parameter. As shown schematically in Figure S2 the combination of success ratio and number of untested cells yields the number of productive, untested cells expected for a play. However, the computational model provides no insight as to which untested cells are expected to be productive.

Establish Estimated Ultimate Recovery (EUR) Probability Distribution for Productive, Untested Cells of Play

The initial step in generating this EUR probability distribution is to select a group of wells that form a sample set representative of the productive, untested cells of the play. Wells from an analog play can be used if necessary.

The next step is to calculate EUR values for these wells (see section on acquisition and analysis of production data). Because the EUR probability distribution provides a reference model for productive, untested cells of the play, production data that are thought to be atypical of the productive, untested cells are not used. The assumption that the EUR probability distribution replicates future production from productive, untested cells is unlikely to be valid if the EUR values display a pronounced time or spatial dependence.

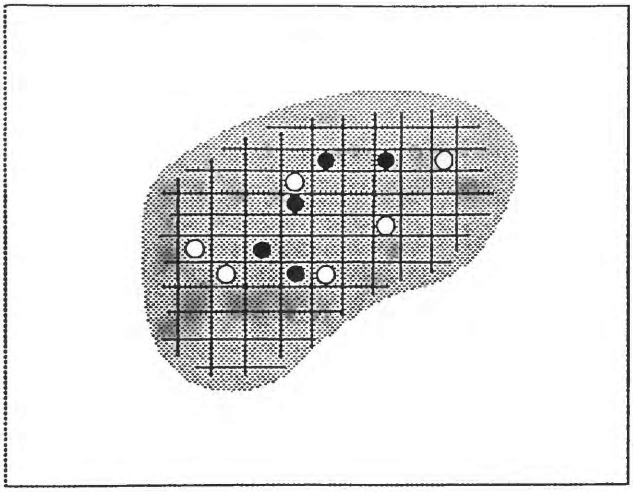


Figure S3. Sketch depicting a continuous-type play as a collection of cells of area equal to typical spacing expected for wells of the play. Circles represent cells that have been evaluated by wells; evaluated cells are either productive (solid circles) or nonproductive (open circles). Remaining cells are untested.

If a fully developed EUR probability distribution analogous to Figure S4 can be generated, seven fractiles (the 100th, 95th, 75th, 50th, 25th, 5th, and 0th probabilities) are supplied to the computational model. The 100th, 50th, and 0th fractiles represent the minimum, median, and maximum EUR's of the distribution, respectively. In cases of poorer data, where details of the EUR probability distribution are uncertain, three fractiles (the 100th, 50th, and 0th probabilities) are supplied to the computational model and a log-normal probability distribution is assumed. In most cases, the minimum EUR is taken as zero, for which the probability is 100% that a productive cell's EUR will be higher.

At this point in the assessment procedure, the fundamental geologically based elements of the assessment are established. The computational model calculates the base-case assessment (Fig. S2) by combining the play probability, number of untested cells, success ratio, and EUR probability distribution.

Ancillary Data for Play

In order to assess co-products in a play (gas in an oil play or oil and condensate in a gas play) and to provide background data for a play, selected ancillary data are assembled. These data are: 1) the ratio of total gas to oil (cubic feet of gas per barrel of oil) for an oil play, or the ratio of oil and natural-gas liquids to total gas (barrels of liquid per million cubic feet of gas) for a gas play; 2) the minimum, maximum, and median depths (ft) of untested cells; 3) the fraction (0-1.0) of untested cells expected to be evaluated by wells originally targeted for the play, for a deeper horizon, and for a shallower horizon; 4) the API gravity (degrees) of oil and condensate in the play; 5) the fraction (0-1.0) of the play that carries a "tight" Federal Energy Regulatory Commission (FERC) designation; and 6) the fraction (0-1.0) of the play that may be off-limits to drilling in the foreseeable future for reasons such as wilderness or park designations, environmental restrictions, Native American concerns, physical inaccessibility, etc.

Operational Aspects

The information and attributes required for the assessment of continuous-type accumulations are supplied by earth scientists who are experts regarding the area under consideration. These regional experts complete a form for each play, which is the source of the input data required for the computational model and also provides selected ancillary information. Completed data forms are included in this report in Appendix A.

To bridge the gap between the data form and the expanded explanation of the assessment model presented here, and to promote procedural uniformity among plays, a succinct outline that provides guidelines for completing the data form is supplied to each regional expert.

In overview, experienced earth scientists supply the data required by the assessment model, and computer routines programmed to implement the assessment model execute the resource calculations. This arrangement combines the expertise of geologists, geophysicists, and petroleum engineers with the computer's facility for manipulation of numbers.

Remarks

A comprehensive assessment of the nonassociated gas resources of the Naval Oil Shale Reserves must consider unconventional hydrocarbon accumulations. To this end, we identify a category of unconventional accumulation that we call a continuous-type accumulation, and describe a model for assessing potential reserve additions from this type of oil or gas accumulation.

Our assessment model relies on existing production to characterize reserve additions expected from undrilled portions of continuous-type plays. The paradigm that in-place hydrocarbon volume is the foundation for unconventional-resource assessment is not endorsed. A consequence of using production histories from existing wells is that we do

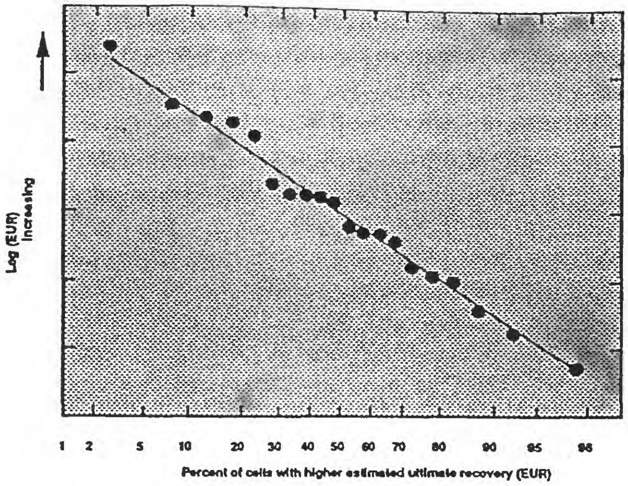


Figure S4. Illustration using hypothetical data of estimated ultimate recovery (EUR) probability distribution for productive, untested cells of a continuous-type play. Horizontal axis is that of arithmetic probability paper.

not rely upon projections of secondary parameters such as porosity, permeability, water saturation, and net pay. The integrated effect of all these factors is reflected in a well's production data.

Our assessment model projects past and present production patterns into the future. Therefore, the "base-case" assessment (Fig. S2) implicitly incorporates a continuation of historical technologic and economic trends. Although beyond the scope of the present work, it would be possible to modify the base-case assessment to reflect perceptions of future economic and technologic change.

PROBABILISTIC METHODOLOGY FOR ASSESSMENT OF PETROLEUM RESOURCES FROM CONTINUOUS-TYPE ACCUMULATIONS

A geostochastic system called UNCLE (unconventional energy) was developed for the assessment of oil and gas resources from continuous-type accumulations. UNCLE is an efficient appraisal system for petroleum play analysis that uses a geologic probability model and an analytic probabilistic methodology.

In play analysis, geologic plays are defined within a petroleum assessment area, and the individual plays are analyzed. The individual play estimates of oil and gas are aggregated, respectively, to estimate the petroleum potential of the entire assessment area. Therefore, UNCLE is comprised of two separate probabilistic methodologies: one for play analysis and another for play aggregation.

The geologic model for a play consisting of a continuous-type accumulation is basically a number-size model in which the number and sizes of volumes of oil and gas from a continuous-type accumulation are modeled (J.W. Schmoker, oral communication, 1994).

The probabilistic methodologies that were developed to solve the play analysis model and the play aggregation problem are analytic methodologies derived from probability theory as opposed to Monte Carlo simulation. Resource estimates of undiscovered, recoverable unconventional oil and gas resources are calculated and expressed in terms of probability distributions.

There are many steps necessary to be able to go from the geologic probability model to the resource estimates. The complete quantitative procedure requires the following steps:

1. The geologic probability model defines an extremely complex probability problem.
2. The probability problem is essentially characterized by a data form.
3. The data form is solved by developing a probabilistic methodology.
4. The probabilistic methodology is based on analytic probability theory.
5. The analytic probability theory is used to derive numerous mathematical equations.
6. The mathematical equations are the basis for designing computer algorithms.
7. The computer algorithms are needed to write large, complicated computer programs.
8. The computer programs are run to perform the data processing.
9. The data processing results in the generation of the resource estimates.
10. The resource estimates are produced in the form of tables or graphs.

This report is an explanation of the probabilistic methodology developed by the author, a mathematical statistician, to go from the geologic probability model to the petroleum resource estimates. The computer programs were written by Richard H. Balay, a computer scientist.

Geologic Probability Model

A geologic model for the quantity of undiscovered petroleum resources in a play involves uncertainty because of the incomplete or fragmentary geologic information generally available. The geologic probability model defines an extremely complex probability problem. The basic information required by the geologic probability model is put on a data form. The data form is filled out by the geologist who is assessing the play.

The geologic probability model consists of the following geologic and probabilistic descriptions and assumptions:

1. The play type is oil or gas.
2. The play probability is the probability that untested cells of a play are capable of producing at least a specified minimum quantity of resources, i.e., the play is favorable.
3. The number of untested cells in the play is a discrete random variable that is characterized by three estimated values: median value, minimum value, and maximum value, which are also the fractiles F_{50}, F_{100}, and F_0, respectively, where, for example, F_{50} denotes the value where the probability of exceeding it is 0.50. Four more fractiles F_{95}, F_{75}, F_{25}, and F_5 are calculated assuming a constructed probability distribution that is bell-shaped symmetric if F_{50} is equal to the midpoint of F_{100} and F_0, positively skewed if F_{50} is to the left of the midpoint, and negatively skewed if F_{50} is to the right of the midpoint.
4. The success ratio is the proportion of untested cells expected to be productive.
5. The estimated ultimate recovery (EUR) well size represents the production from productive untested cells. The EUR is a continuous random variable that is characterized by three estimated values: median value (F_{50}), minimum value (F_{100}), and maximum value (F_0); or by seven estimated fractiles: F_{100}, F_{95}, F_{75}, F_{50}, F_{25}, F_5, and F_0. In the case of only three given fractiles, the four remaining fractiles are calculated assuming a log normal distribution.
6. If an oil play, the expected ratio of total gas to oil (GOR) is estimated.
7. If a gas play, the expected ratio of oil and natural gas liquids to total gas is estimated.
8. The depth of the untested cells is a continuous random variable that is characterized by three estimated values: median value, minimum value, and maximum value. The depth is not used in any of the calculations.
9. A subplay model is an option to estimate resources in a fraction of the play from estimates of the entire play.
10. An available economic model truncates distributions of the EUR using a minimum economic cut-off value.

Probability judgments concerning the play parameters and random variables are made by experts familiar with the geology of the area of interest. The experts review all available data relevant to the appraisal, identify the major plays within the assessment area (e.g., basin or province), and then assess each identified play. All of the geologic data required by this model for a play are entered on an oil and gas appraisal data form. Information from the data form is entered into computer data files as the input for a computer program based upon an analytic method.

Probabilistic Methodology

Play Analysis—UNCLE

The analytic method was developed by the application of many laws of expectation and variance in conditional probability theory. It systematically tracks through the geologic probability model, computes all of the means and variances of the appropriate random variables, and calculates all of the probabilities of occurrence. In arriving at probability fractiles, the lognormal distribution is used as a model for the play resource distribution (Crovelli, 1984). Oil, nonassociated gas, associated-dissolved gas, gas, and liquids in nonassociated gas are possible resources assessed depending upon whether the type of play is oil or gas. A simplified flowchart for the method is presented in Figure C1.

The basic steps of the analytic method of play analysis (UNCLE) are:

1. Select the play.
2. Select the play type: oil or gas. For illustrative purposes, suppose the play type is oil.
3. Compute the mean and variance of the estimated ultimate recovery (EUR) well size of oil using the estimated seven fractiles and assuming a uniform distribution between fractiles, that is, a piecewise uniform probability density function (as is done in the case of a simulation method).
4. Compute the mean and variance of the number of untested cells from the estimated seven fractiles, assuming a uniform distribution between fractiles (as is also the case in a simulation method).

5. Compute the mean and variance of the number of productive, untested cells by applying the success ratio of oil to the mean and variance of the number of untested cells.
6. Compute the mean and variance of the conditional (A) play potential for oil—the quantity of oil in the play, given the play is favorable. These values are determined from the probability theory of the expectation and variance of a random (number of productive, untested cells) of random variables (estimated ultimate recovery well sizes).
7. Compute the conditional play probability of oil—the probability that a favorable play has at least one productive, untested cell. This probability is a function of the success ratio of oil and the number of untested cells distribution.
8. Compute the mean and variance of the conditional (B) play potential for oil—the quantity of oil in the play, given the play is favorable and there is at least one productive, untested cell within the play. These values are determined by applying the conditional play probability of oil to the mean and variance of the conditional (A) play potential for oil.
9. Compute the unconditional play probability of oil—the probability that the play has at least one productive, untested cell. This probability is the product of the conditional play probability of oil and the play probability.
10. Compute the mean and variance of the unconditional play potential for oil—the quantity of oil in the play. These values are determined by applying the unconditional play probability of oil to the mean and variance of the conditional (B) play potential for oil.
11. Model the probability distribution of the conditional (B) play potential for oil by using the lognormal distribution with mean and variance from step 8. Calculate various lognormal fractiles.
12. Compute various fractiles of the conditional (A) play potential for oil by a transformation to appropriate lognormal fractiles of the conditional (B) play potential for oil using the conditional play probability of oil.
13. Compute various fractiles of the unconditional play potential for oil by a transformation to appropriate lognormal fractiles of the conditional (B) play potential for oil using the unconditional play probability of oil.
14. Process associated-dissolved gas as a second resource to be assessed. Repeat steps 3 through 13, substituting associated-dissolved gas for oil, with two basic modifications as follows. The estimated ultimate recovery (EUR) well size of oil is multiplied by the gas-oil ratio. The success ratio of associated-dissolved gas is the same as the success ratio of oil.
15. Suppose nonassociated gas is the resource to be assessed, i.e., the play type is gas. Repeat steps 3 through 13, substituting nonassociated gas for oil and using the estimated ultimate recovery (EUR) well size of nonassociated gas and the success ratio of nonassociated gas.
16. Process liquids in nonassociated gas as a second resource to be assessed. Repeat steps 3 through 13, substituting liquids in nonassociated gas for oil, with two basic modifications as follows. The estimated ultimate recovery (EUR) well size of nonassociated gas is multiplied by the expected ratio of liquids to nonassociated gas. The success ratio of liquids in nonassociated gas is the same as the success ratio of nonassociated gas or zero if the liquids ratio is zero.

Play Aggregation—UNCLE-AG

A separate probabilistic methodology was developed to estimate the aggregation of a set of plays. The resource estimates of the individual plays from play analysis using the UNCLE program are aggregated using an analytic probability method. Oil, nonassociated gas, associated-dissolved gas, gas, and liquids in nonassociated gas resources are each aggregated in turn. UNCLE-AG is also able to aggregate a set of plays under a dependency assumption. A simplified flowchart of play aggregation is presented in Figure C2.

The basic steps of the analytic method of play aggregation are:

1. Select plays to aggregate.
2. Process oil as the first resource to be aggregated.
3. Compute the mean, variance and fractiles of the unconditional aggregate potential for oil in the polar case of complete independence—the quantity of oil in the assessment area of the aggregated plays under independence.
    (a) Determine the mean and variance by adding all the individual play means and variances of the unconditional play potential for oil, respectively.

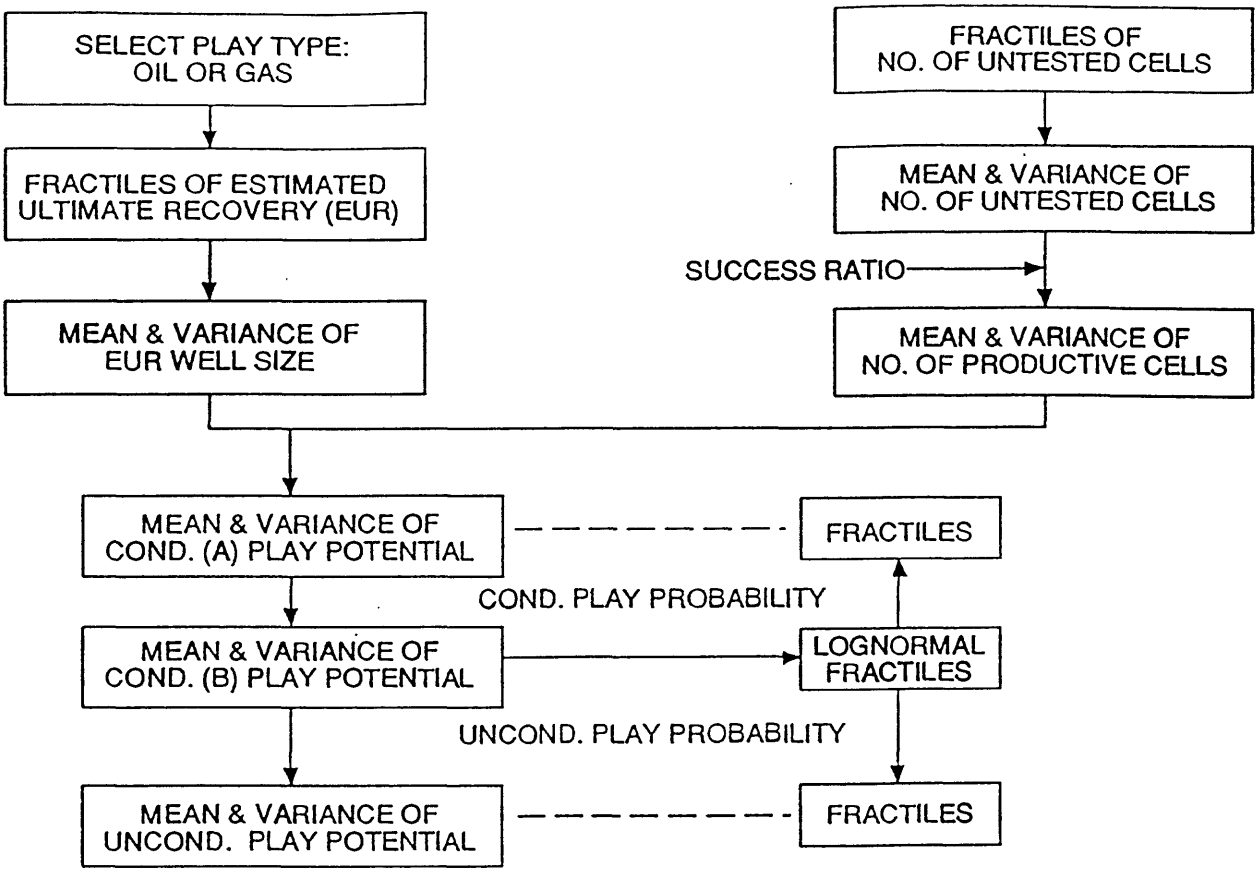


Figure C1. Flowchart for analytic method of play analysis (UNCLE).

(b) Calculate the unconditional aggregate probability of oil—the probability that the assessment area has at least one play with oil—from the individual unconditional play probabilities of oil under the assumption of independence.

(c) Compute the mean and variance of the conditional aggregate potential for oil—the quantity of oil in the assessment area, given the assessment area has at least one play with oil. These are determined by applying the unconditional aggregate probability of oil to the mean and variance of the unconditional aggregate potential for oil.

(d) Model the probability distribution of the conditional aggregate potential for oil by using the lognormal distribution with mean and variance from (c).

(e) Compute various fractiles of the unconditional aggregate potential for oil by a transformation to appropriate lognormal fractiles of the conditional aggregate potential for oil using the unconditional aggregate probability for oil.

4. Compute the mean, variance and fractiles of the unconditional aggregate potential for oil in the polar case of perfect positive correlation—the quantity of oil in the assessment area of the aggregated plays under perfect correlation.

   (a) Determine the mean and standard deviation by adding all the individual play means and standard deviations of the unconditional play potential for oil, respectively.

   (b) Calculate the unconditional aggregate probability of oil—the probability that the assessment area has at least one play with oil—from the individual unconditional play probabilities of oil under the assumption of perfect positive correlation.

   (c) Compute various fractiles of the unconditional aggregate potential for oil by adding all the individual play fractiles of the unconditional play potential for oil, respectively.

5. Compute the mean, variance and fractiles of the unconditional aggregate potential for oil in the case of interpolation between the polar case of complete independence ($d = 0$) and the polar case of perfect positive correlation ($d = 1$)—the quantity of oil in the assessment area of the aggregated plays under a degree of dependency, d ($0 \leq d \leq 1$). Interpolate the mean, standard deviation, fractiles, and unconditional aggregate probability of oil between the two polar cases of steps 3 and 4.
6. Compute the mean, variance and fractiles of the conditional aggregate potential for oil in the case of interpolation—the quantity of oil in the assessment area, given the assessment area has at least one play with oil.
   (a) Determine the mean and variance of the conditional aggregate potential for oil by applying the interpolated unconditional aggregate probability of oil to the interpolated mean and variance of the unconditional aggregate potential for oil.
   (b) Model the probability distribution of the conditional aggregate potential for oil by using the lognormal distribution with mean and variance from (a). Calculate various lognormal fractiles.
7. Process nonassociated gas as the second resource to be aggregated. Repeat steps 3 through 6 using play-analysis estimates of nonassociated gas—namely, the individual play means, variances and fractiles of the unconditional play potential for nonassociated gas, as well as the individual unconditional play probabilities of nonassociated gas.
8. Process associated-dissolved gas as the third resource to be aggregated. Repeat steps 3 through 6 using play-analysis estimates of associated-dissolved gas—namely, the individual play means, variances and fractiles of the unconditional play potential for associated-dissolved gas, as well as the individual unconditional play probabilities of associated-dissolved gas.
9. Process gas as the fourth resource to be aggregated. Repeat steps 3 through 6 using play-analysis estimates of gas—namely, the individual play means, variances and fractiles of the unconditional play potential for gas, as well as the individual unconditional play probabilities of gas.
10. Process liquids in nonassociated gas as the fifth resource to be aggregated. Repeat steps 3 through 6 using play-analysis estimates of liquids in nonassociated gas—namely, the individual play means, variances and fractiles of the unconditional play potential for liquids in nonassociated gas, as well as the individual unconditional play probabilities of liquids in nonassociated gas.

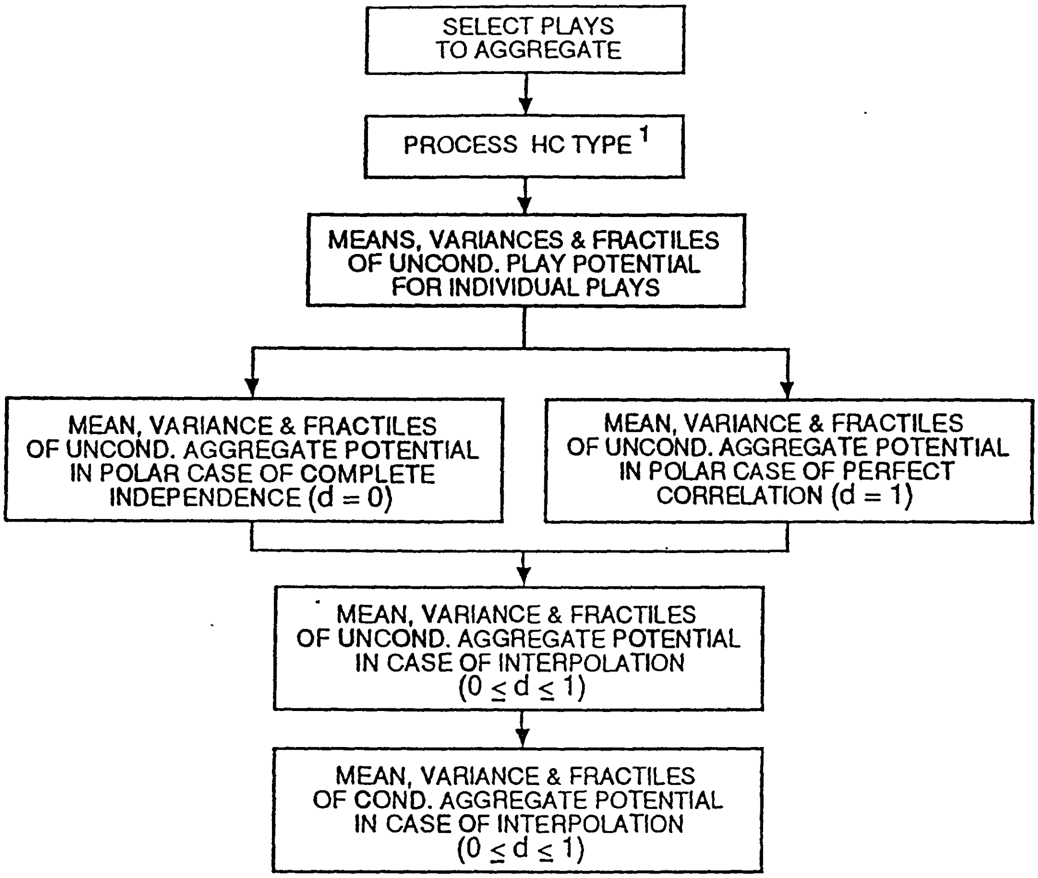
Relation Between UNCLE and UNCLE-AG

UNCLE-AG is related to UNCLE as follows. UNCLE not only generates a file of resource estimates for an individual play but also outputs a second file of results that consists of the unconditional play probability, cutoff, mean, standard deviation and fractiles of the unconditional play potential for each of the seven resources. The second file is needed for an aggregation of plays and forms an input file for UNCLE-AG. Therefore, after UNCLE is run on each play in a set of plays, any subset of plays can be aggregated by running UNCLE-AG on the corresponding subset of aggregation input files. UNCLE-AG not only generates a file of resource estimates for an aggregation of plays but also outputs a second file of results needed for an aggregation of aggregations, which forms yet another input file for UNCLE-AG. Hence, after UNCLE-AG is run on each aggregation in a set of aggregations, any subset of aggregations can be aggregated at once. Compared to the simulation method, the application of UNCLE-AG can result in tremendous savings of time and cost, especially when analyzing many aggregations involving hundreds of plays.

ACQUISITION AND ANALYSIS OF PRODUCTION DATA

Data for the calculation of estimated ultimate recovery (EUR) for wells within a specified play are obtained from the Petroleum Information Corporation data base. Due to the absence of reservoir pressure data and reservoir fluid pressure-volume-temperature (PVT) analyses, plots of pressure versus cumulative gas produced (P\Z plots) for gas reservoir EUR determination cannot be generated. Therefore, an estimate of the ultimate recovery relies upon the production history and a decline curve analysis (DCA).

The wells selected to generate the EUR distribution must represent the range of productivities within the area. Production histories of insufficient duration (less than 30 months) or inconsistent behavior are excluded from the analysis due to the increased uncertainty imposed by the DCA approach. Inactive wells are included because these types of wells will be encountered in the drilling of the untested cells. A history of downtime was generally not included in forecasting the future productivity of the well.



[1] OIL, NONASSOCIATED GAS, ASSOCIATED-DISSOLVED GAS, GAS, AND LIQUIDS IN NONASSOCIATED GAS RESOURCES ARE EACH AGGREGATED IN TURN.

Figure C2. Flowchart for analytic method of play aggregation (UNCLE-AG).

This use of DCA assumes, in part, that there are no backpressure effects, gas flow into the wellbore is radial, the wells are producing in a stage of depletion and that the cumulative effects that have altered production in the past will continue to do so in the future. Segmented exponential declines are used to represent historical and forecasted production. A maximum producing life of 35 years or an economic limit of 10 MCFD is imposed. If the production rate is high at the end of the 35 year limit, a constant decline rate during the last five years of production forces productivity to the economic limit of 10 MCFD. Figure B1 is an illustration of the use of DCA for a Wasatch producer located in T 10 S and R 19 E of the Uinta Basin, Utah.

The calculated EUR's for the specified play are arranged in descending order and are plotted on semi-log probability paper (Fig. B2). This represents the EUR distribution of the untested cells of the play.

CLOSING COMMENTS

It is important to remember that many of the steps involved in this study required the assignment of strata to plays and that assumptions be made in the assessment of these plays. These assignments and assumptions could be varied from that used herein. For example our definition of a play requires that the geologist group hydrocarbon accumulations in the region into geologically-based *plays*, that is, hydrocarbon accumulations with common characteristics. This grouping requires that we draw boundaries between plays and project those boundaries to unexplored areas using some combination of geologic parameters that can be associated with production in the plays and that can be measured in unexplored areas. For this study we have chosen to draw boundaries and measure production indices using conservation limits. However these conservative limits may serve to lower the relative resources in a play.

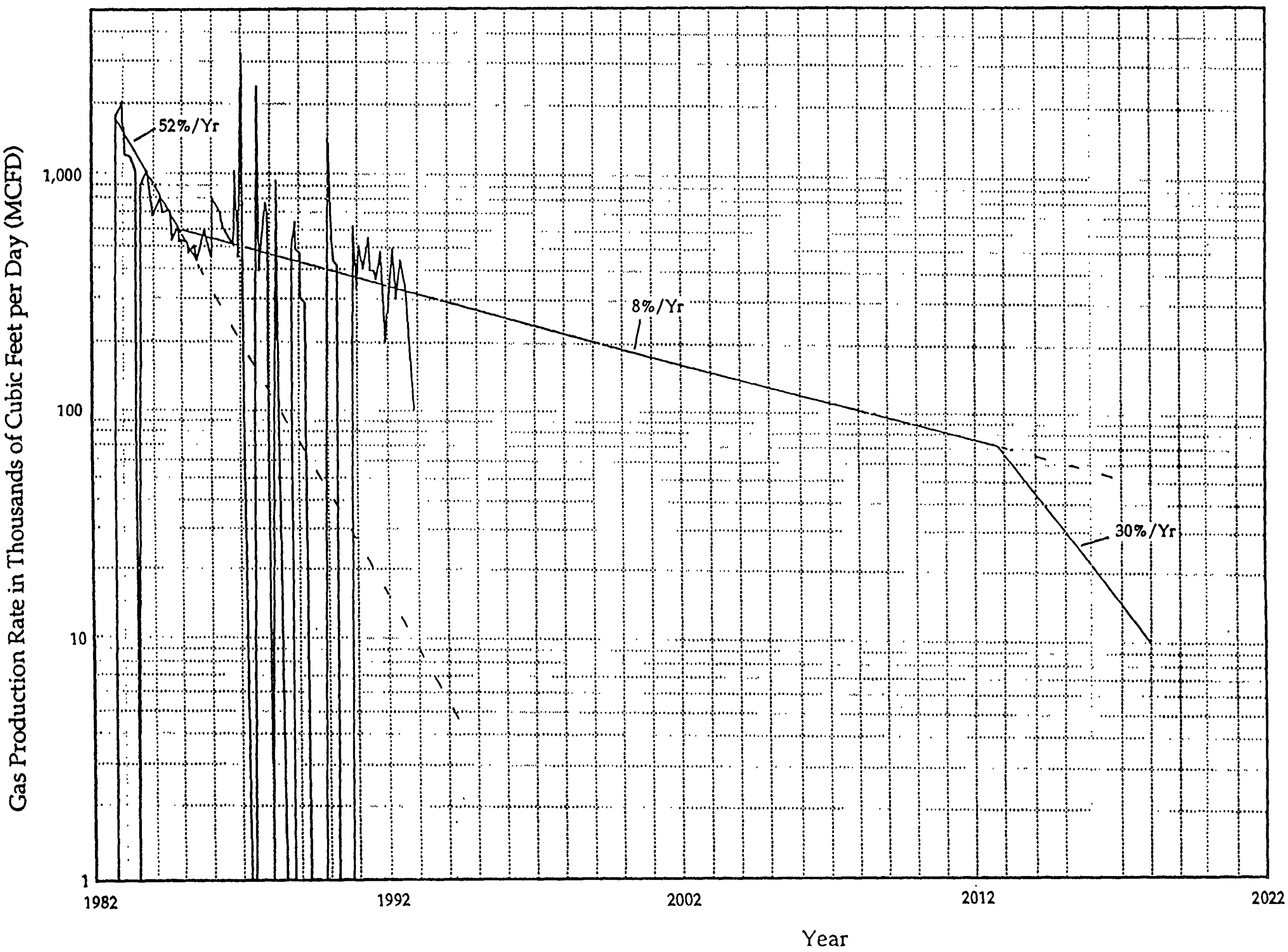


Figure B1. This is an actual production rate curve (thousands of cubic feet per day versus year) for a Wasatch producer located in the Uinta Basin, Utah. The straight solid lines show the exponential segments of the decline curve analysis (DCA) of the well. The area under the solid lines is the estimated ultimate recovery (EUR). The dashed lines are extrapolations of straight line segments of the initial and succeeding decline rates. To impose a 35 year well life, a constant decline rate is forecasted in year 30 to force the productivity to an economic limit of 10 MCFD in year 35.

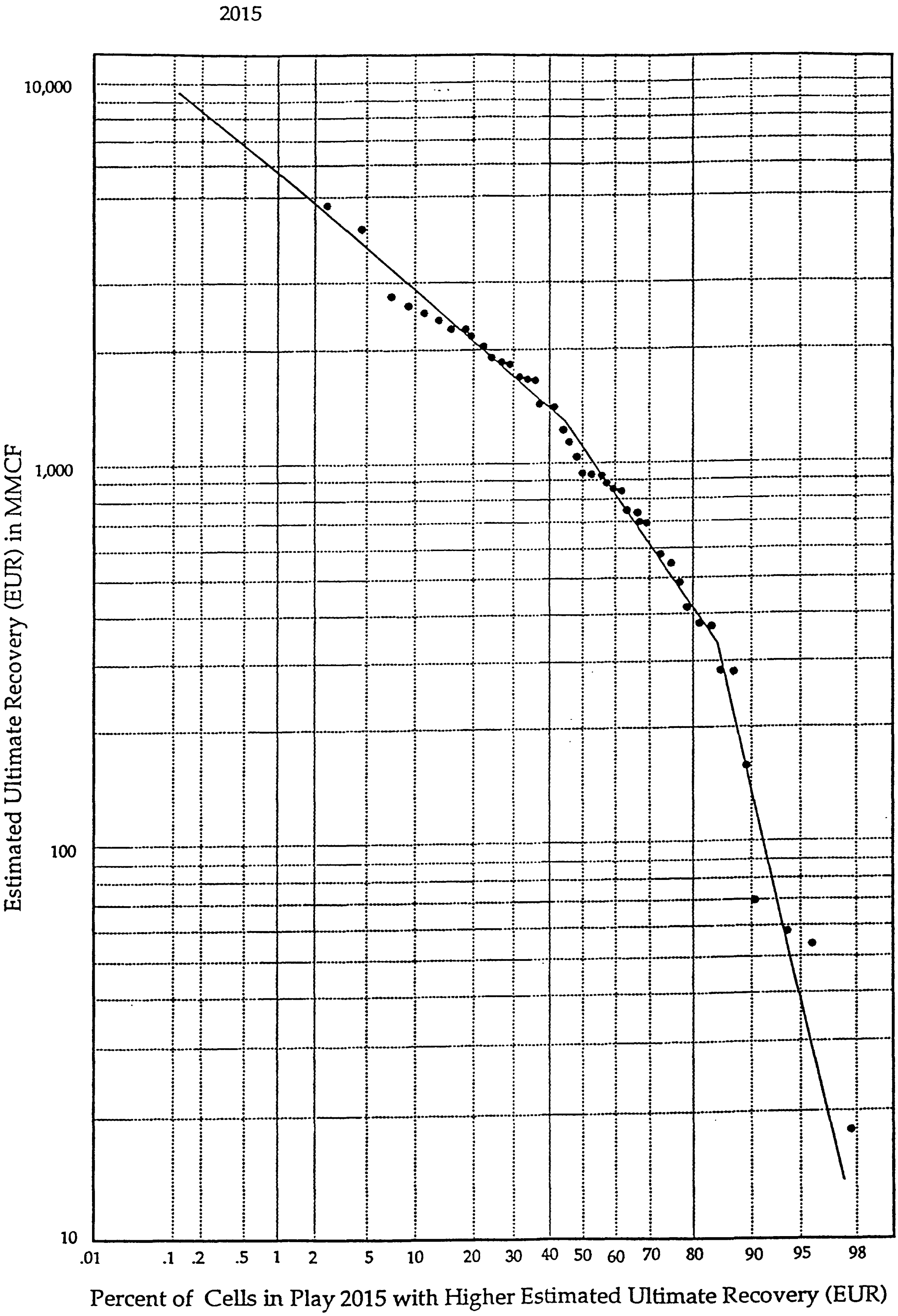


Figure B2. This is the estimated ultimate recovery (EUR) distribution of a 45 well sample set representing the untested cells in a Wasatch, Uinta Basin play. The log of the EUR in millions of cubic feet is plotted against an arithmetic probability scale. The EUR calculated for the well in figure 13 represents one point on this distribution.

In this report we have used a vitrinite reflectance value (R_o) of 1.1% as a threshold measure to draw a line between plays characterized among gas-saturated and transitional plays. For purposes of illustration and calculation, these boundaries are regarded as sharp lines even though we know that the boundaries between plays, and therefore calculated production indices, are probably gradational throughout the area of the play. Indices used to approximate play characteristics (i.e. cell success ration, EUR distribution) are probably commonly gradational from play to play. For example, one could select a value between R_o 0.75% and 1.10% to distinguish among gas-saturated and transitional plays. In this study use of a lower threshold value of Ro to separate plays would have the effect of increasing the area of potential higher resources because it would serve to increase the area characterized by gas-saturated rocks. However, the use of a lower value of Ro would probably also serve to lower the cell success ration and EUR distribution for the play because it would result in the inclusion of an increased number of wells that produce water and that have lower values of ultimate recovery.

We have used past performance (i.e., cell success ratio, EUR distribution) as our primary indicator of the capacity of the strata to yield gas in the future. The EUR distribution for a play is correct for that spacing determined to be correct for the accumulation, i.e., wells recover all gas but do not drain gas in communication with another. However, in this analysis we found that spacing for play varied from area to area and only through a history of extensive drilling and production has an appropriate spacing been defined. Our EUR analysis for plays made use of data from wells that were drilled over a number of years and to fill a variety of spacing requirements. Due to the limitations of the study we did not attempt to determine separate EUR distributions for each spacing although to do so would have provided a refined basis for assessment.

For the most part, plays (or segments thereof) analyzed as a part of this study have a history of production dating back as much as 25 years. The record of production from these plays includes not only gas produced from zones completed during early periods of the fields (wells) development but also a continued addition of gas from zones or pays that were not initially discovered or connected to the wellbore and were behind-the-pipe during the formative years of production. Behind-the-pipe reserves are those determined by operators to represent discovered reserves that could be produced economically when and if they are connected to the well bore. Their recognition is based upon geophysical and petrophysical measures of secondary parameters believed by the operator to be indicators of gas that could be produced economically. Normal development of a play results in the production from both initial reserves and the addition of "behind the pipe" reserves from subsequently completed zones, and the EUR distribution for the play reflects this growth.

The U.S. Department of Energy has determined that the record of existing production from the Mesaverde Group in the area of Naval Oil Shale Reserves 1 and 3 does not reflect a history of addition of behind-the-pipe reserves because of the short history of production from this play (2007). Therefore, in this study we use a EUR distribution and cell success ratio for the Mesaverde Play 2007 that was determined by FD Services for the Department of Energy (see Appendix A). Their distribution consists of an EUR distribution determined by adding Mesaverde (including the Cameo Coal) behind-the-pipe reserves to the EUR determined solely from existing production records for the play. This addition of behind-the-pipe reserves has the effect of increasing the production values along the entire EUR distribution.

ACKNOWLEDGMENTS

We would like to take the opportunity to express our gratitude to the many individuals who contributed to the success of this endeavor. The U.S. Geological Survey, at the request of the Gary Latham of the U.S. Department of Energy Office of Naval Petroleum & Oil Shale Reserves, was asked to characterize the petroleum geology of the Naval Oil Shale Reserves in Utah and Colorado, and to assess their oil and gas resources. This report was prepared for the U.S. Department of Energy Office of Naval Petroleum & Oil Shale Reserves who cofunded much of this research in conjunction with the U.S. Geological Survey's Evolution of Sedimentary Basins, and Onshore Oil and Gas Programs. We are especially indebted to Lorraine LaFreniere and Ralph Schulte and other members of FD Services who provided the EUR distribution and cell success ratio used in the analysis of the Mesaverde Group (play 2007) and Wasatch Formation (play 2008) at Reserves 1 and 3. In addition, formation tops, and other geologic data in the Piceance basin made available by LaFreniere were used in our analyses and the construction of maps of various types. LaFreniere shared her considerable expertise with us and the report benefited greatly from it. We also wish to acknowledge the assistance of Richard Mast and Lois Williams of the USGS in the determination of cell success ratios for each play, and Charles Spencer of the USGS for his help in identifying key petroleum plays and drawing their boundaries. Finally, we thank, Gary Latham, Ray Williams, Joe Rochelle and their staffs at the U.S. Department of Energy for providing valuable information, and encouragement, support, and thoughtful guidance throughout the course of the study.

REFERENCES

Boardman, C.R., and C.F. Knutson, 1980, Reservoir characteristics in Uinta basin gas wells, U.S. Department of Energy Report DOE/ET/11399-1,89 p., 26 tables, 36 figures.

Boardman, C.R., and C.F. Knutson, 1981, Uinta basin lenticular sandstone reservoir characteristics, SPE/DOE Paper 9849, SPE/DOE Low Permeability Symposium, p. 217-222.

Chidsey, T.C., Jr., 1993b, UN-3, Wasatch Formation, *in* Robertson, J.M., and Broadhead, R.F., project coordinators, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 87-88.

Chidsey, T.C., Jr., 1993a, UN-2, Green River Formation, *in* Robertson, J.M., and Broadhead, R.F., project coordinators, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 85-86.

Cole, W.A., 1993, Natural Buttes field, *in* Hill, B.G., and Bereskin, S.R., eds., Oil and Gas field of Utah: Utah Geological Association Publication No. 22, 3 p.

Coruh, C. and Costain, J.K., 1983, Noise attenuation by Vibroseis whitening (VSW) processing, Geophysics, v. 48, p. 543-554.

Crovelli, R.A., 1984, Procedures for petroleum resource assessment used by the U.S. Geological Survey—statistical and probabilistic methodology; *in* Masters, C.D., ed., Petroleum resource assessment: International Union of Geological Sciences, pub. no. 17, p. 24-38.

Crovelli, R.A., 1987, Probability theory versus simulation of petroleum potential in play analysis, *in* Albin, S.L., and Harris, C.M., eds., Statistical and computational issues in probability modeling, Part 1: Annals of Operations Research, v. 8, p. 363-381.

Crovelli, R.A., 1988a, Multi-model approach to petroleum resource appraisal using analytic methodologies for probabilistic systems: Journal of Mathematical Geology, v. 20, no. 8, p. 955-972.

Crovelli, R.A., 1988b, U.S. Geological Survey assessment methodology for estimation of undiscovered petroleum resources in play analysis of the Arctic National Wildlife Refuge, *in* Chung, C.F., Fabbri, A.G., and Sinding-Larsen, R., eds., Quantitative Analysis of Mineral and Energy Resources: Dordrecht, Holland, D. Reidel Publishing, NATO ASI Series C: Mathematical and Physical Sciences, v. 223, p. 145-160.

Crovelli, R.A., and Balay, R.H., 1986, FASP, An analytic resource appraisal program for petroleum play analysis: Computers and Geosciences, v. 12, no. 4B, p. 423-475.

Crovelli, R.A., and Balay, R.H., 1988, A microcomputer program for oil and gas resource appraisal: Computer Oriented Geological Society, COGS Computer Contributions, v. 4, no. 3, p. 108-122.

Crovelli, R.A., and Balay, R.H., 1990a, FASPU English and metric version—Analytic petroleum resource appraisal microcomputer programs for play analysis using a reservoir-engineering model: U.S. Geological Survey Open-File Report 90-509-A, Documentation (paper copy) 25 p.; Open-File Report 90-509-B, Executable program (5.25" diskette).

Crovelli, R.A., and Balay, R.H., 1990b, PROBDIST: Probability distributions for modeling and simulation in the absence of data: U.S. Geological Survey Open-File Report 90-446-A, Documentation (paper copy) 51 p.; Open-File Report 90-446-B, Executable program (5.25" diskette).

Crovelli, R.A., and Balay, R.H., 1992, APRAS—Analytic petroleum resource appraisal system—Microcomputer programs for play analysis using a field-size model: U.S. Geological Survey Open-File Report 92-21-A, Documentation (paper copy) 28 p.; Open-File Report 92-21-B , Executable program (5.25" diskette).

Crovelli, R.A., and Balay, R.H., 1993, LOGRAF—Lognormal graph for resource assessment forecast: U.S. Geological Survey Open-File Report 92-679-A, Documentation (paper copy) 30 p.; Open-File Report 92-679-B, Executable program (5.25" diskette).

Finley, R.J., 1984, Geology and engineering characteristics of selected low-permeability sandstones—a national survey: Texas Bureau of Economic Geology, Report of Investigations No. 138, p. 146-166.

Fouch, T. D., Wandrey, C. J., Pitman, J. K., Nuccio, V. F., Schmoker, J. W., Rice, D. D., Johnson, R. C., and Dolton, G. L., 1992, Natural gas accumulations in low permeability Tertiary and" Cretaceous (Maastrichtian-Campanian) rock, Uinta Basin, Utah: U.S. Department of Energy Formal Publication DOE/MC/20422-3051 DE92001132) 81 p.

Fouch, T.D., Nuccio, V.F., Anders, D.E., Rice, D.D., Pitman, J.K., and Mast, R.F., [in press], The Green

River Petroleum System, Uinta Basin, Utah, USA, *in* Magoon, L.B., and Dow, W.C., eds., The Petroleum System—From Source to Trap: American Association of Petroleum Geologists Memoir 60, Chapter 25, 28 MS pages, 17 figures, 2 tables.

Fouch, T.D., Nuccio, V.F., Osmond, J.C., MacMillan, L., Cashion, W.B., and Wandrey, C.J., 1992b, Oil and Gas in uppermost Cretaceous and Tertiary rock, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., eds., Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado, Utah Geological Association Guidebook 20: Salt Lake City, Utah, U.S.A., Utah Geological Association, p. 9-47.

Fouch, T.D., Wandrey, C.J., Pitman, J.K., Nuccio, V.F., Schmoker, J.W., Rice, D.D., Johnson, R.C., and Dolton, G., L., 1992c, Natural gas accumulations in low-permeability Tertiary and Cretaceous (Maastrichtian-Campanian) rock, Uinta Basin, Utah: U.S. Department of Energy Report DOE/MC/20422-3051 (DE92001132), 81 p.

Franczyk, K. J., Fouch, T. D., Johnson, R. C., and Molenaar, C. M., 1992, Cretaceous and Tertiary paleogeographic reconstructions for the Uinta-Piceance study area: U.S. Geological Survey Bulletin 1787-Q, 37 p.

Franczyk, K.J., Pitman, J.K., Cashion, W.B., Dyni, J.R., Fouch, T.D., Johnson, R.C., Chan, M.A., Donnell, J.R., Lawton, T.F., and Remy, R.R., 1989, Evolution of resource-rich foreland and intermontane basins in eastern Utah and western Colorado, 28th International Geologic Congress Field Trip Guidebook T-324, p. 53 p.

Hartmann, D.J., and MacMillan, L., 1992, Petrophysics of the Wasatch Formation and Mesaverde Group, Natural Buttes producing area, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., ed., Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado, Utah Geological Association Guidebook 21: Salt Lake City, Utah U.S.A., Utah Geological Association, p. 175-192.

Hartmann, D.J., and MacMillan, L., 1992, Petrophysics of the Wasatch Formation and Mesaverde Group, Natural Buttes producing area, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., eds., Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado: Utah Geological Association, Guidebook 20, p. 175-192.

Hemborg, H.T., 1993, PC-1, Wasatch Formation and Douglas Creek Member of the Green River Formation, *in* Robertson, J.M., and Broadhead, R.F., project coordinators, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, 96 p.

Hodges, L.T., and Knutson, C.F., 1981, Tight gas sandstone channel continuity and directivity, Upper Cretaceous Lance and Paleocene, Greater Green River Basin, Wyoming, *in* Proceedings of the 1981 SPE/DOE Symposium on Low Permeability Gas Reservoirs: Society of Petroleum Engineers and U.S. Department of Energy, SPE/DOE paper 9844, p. 165-176.

Johnson R.C., and Rice, D.D., 1990, Occurrence and Geochemistry of natural gases, Piceance basin, northwest Colorado: American Association of Petroleum Geologists Bulletin, v. 74, p. 805-829.

Johnson R.C., Nuccio Vito F., 1993, Surface Vitrinite Reflectance, Study of the Uinta and Piceance Basins and Adjacent Areas, Eastern Utah and Western Colorado- Implications for the Development of Laramide Basins and Uplifts: U.S. Geological Survey Bulletin 1787, 35 p.

Johnson, R.C., and Nuccio, V.F., 1986, Structural and thermal history of the Piceance Creek basin, western Colorado, in relation to hydrocarbon occurrence in the Mesaverde Group, *in* Spencer, C.W., and Mast, R.F., eds., Geology of tight gas reservoirs: American Association of Petroleum Geologists Studies in Geology No. 24, p. 165-205.

Johnson, R.C., and Nuccio, V.F., in press, A surface vitrinite reflectance study of the Uinta-Piceance basin area, western Colorado and eastern Utah and its implications for the development of Laramide basins and uplifts: U.S. Geological Survey Bulletin, 48 p., 24 figures, 1 plate.

Johnson, R.C., Crovelli, R.A., Spencer, C.W., and Mast, R.F., 1987, An assessment of gas resources in low-permeability sandstones of the Upper Cretaceous Mesaverde Group, Piceance basin, Colorado: U.S. Geological Survey Open-File Report 87-357, 165 p.

Johnson, R.C., 1987, Geològic history and hydrocarbon potential of Late Cretaceous-age, low-permeability reservoirs, Piceance basin, western Colorado; DOE/MC/20422-2337 (DE87006476), n. Distribution Category UC-132, 97 p.

Johnson, S.Y., Chan, M.A., and Konopka, E.A., 1992, Pennsylvanian and Early Permian Paleogeography of the Uinta-Piceance Basin Region, northwestern Colorado and Northeaster Utah, *in* U.S. Geological Survey Bulletin 1787-CC, p. CC1-CC35.

Keighin, C.W., and Fouch, T.D., 1981, Depositional environments and diagenesis of some nonmarine Upper Cretaceous reservoir rocks, Uinta basin, Utah, *in* Ethridge, F.G., and Flores, R.M., eds., Recent and Ancient Nonmarine Depositional Environments: Models for Exploration: Society of Economic Paleontologists and Mineralogists Special Publication No. 31, p. 109-125.

Knutson, C.F., and L. T. Hodges, 1981, Development of techniques for optimizing selection and completion of western tight gas sands, comparison of core, geophysical log, and outcrop information, phase III report, U.S. Department of Energy Report DOE/BC10005-3, p. 54 p., 14 figs, 7 plates.

Knutson, C.T., Hodges, L.T., and Righter, S.B., 1981, Permeability, petrography and small scale structural element analysis of Upper Cretaceous channel sandstone from the Rock Springs Uplift and Wind River Basin, Wyoming, *in* Proceedings of the 1981 SPE/DOE Symposium on Low Permeability Gas Reservoirs: Society of Petroleum Engineers and U.S. Department of Energy, v. SPE/DOE paper 9874, p. 427-436.

Kukal, G.C., 1987, Log analysis, chapter 4, *in* Multiwell Experiment final report—part 1, the Marine interval of the Mesaverde Formation: Sandia National Laboratory, Report SAND87-0327, 62 p.

Kukal, G.C., 1988, Log analysis, chapter 4, *in* Multiwell Experiment final report—part 2, the Paludal interval of the Mesaverde Formation: Sandia National Laboratory, Report SAND88-1008, 93 p.

Kukal, G.C., 1989, Log analysis, chapter 4, *in* Multiwell Experiment final report—part 3, the Coastal interval of the Mesaverde Formation: Sandia National Laboratory, Report SAND88-3284, 96 p.

Kukal, G.C., 1990, Log analysis, chapter 4, *in* Multiwell Experiment final report—part 4, the Fluvial interval of the Mesaverde Formation: Sandia National Laboratory, Report SAND89-2612A, volume A, 173 p.

Kukal, G.C., Biddison, C.L., Hill, R.E., Monson, E.R., and Simons, K.E., 1983, Critical problems hindering accurate log interpretation of tight gas reservoirs, SPE-11620, *in* 1983 SPE/DOE symposium on low permeability, proceedings: Society of Petroleum Engineers, p. 181-190.

Langenwalter, R.J., 1993, Stone Cabin field, *in* Hill, B.G., and Bereskin, S.R., eds., Oil and Gas field of Utah: Utah Geological Association Publication No. 22, 1 p.

MacMillan, L., 1992, A heuristic method for reserve analysis in the greater Natural Buttes producing area, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., ed., Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Guidebook 20: Salt Lake City, Utah U.S.A., Utah Geological Association, p. 165-174

Martinez, C., and Duey, H., 1982, Rulison field, *in* Oil and gas fields of Colorado, Nebraska, and adjacent areas: Rocky Mountain Association of Geologists, Denver, p. 442-449.

Noe, D.C., 1993a, PC-3, Mancos marine sandstones, *in* Robertson, J.M., and Broadhead, R.F., project coordinators, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 99-100.

Noe, D.C., 1993b, PC-4, Dakota Sandstone, Cedar Mountain Formation, and Morrison Formation, *in* Robertson, J.M., and Broadhead, R.F., project coordinators, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 101-102.

Nuccio, V.F., and Fouch, T.D., 1992, Thermal maturity of the Mesaverde Group, Uinta Basin, Utah: *in* Magoon, L.B., ed., The Petroleum System—Status of Research and Methods 1992: U.S. Geological Survey Bulletin 2007, p. 70-78.

Nuccio, V.F., and Johnson, R.C., 1986, Thermal maturity map of the Lower part of the Upper Cretaceous Mesaverde Group, Uinta Basin, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1842, one plate.

Nuccio, V.F., and Johnson, R.C., 1988, Surface vitrinite reflectance map of the Uinta, Piceance, and Eagle basins area, Utah and Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-2008-B, 21 p., one plate.

Nuccio, V.F., Schmoker, J.W., and Fouch, T.D., 1992, Thermal maturity, porosity, and lithofacies relationship applied to gas generation and production in Tertiary and Cretaceous low-permeability (tight) sandstones, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., eds., Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Guidebook 20: Salt Lake, City, Utah, U.S.A., Utah Geological Association, p. 77-94.

Osmond, J.C., 1992, Greater Natural Buttes gas field, Uintah County, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., eds., Hydrocarbon and mineral resources of the Unita Basin, Utah and Colorado: Utah Geological Association, Guidebook 20, p. 143-163.

Osmond, J.C., 1993, Pine Springs field, *in* Hill, B.G., and Bereskin, S.R., eds., Oil and Gas field of Utah: Utah Geological Association Publication No. 22, 3 p.

Osmond, J.C., 1993, Seep Ridge field, *in* Hill, B.G., and Bereskin, S.R., eds., Oil and Gas field of Utah: Utah Geological Association Publication No. 22, 2 p.

Pantea Michael P., 1993, Preliminary Geologic Map of the East, Evacuation Creek Quadrangle, Garfield and Rio Blanco Counties, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-2220 scale 1:24,000.

Pantea Michael P., Scott, Richard W. Jr., 1986, Preliminary Geologic, Map of the Flat Rock Mesa Quadrangle, Uintah County Utah, Colorado: U.S.

Geological Survey Miscellaneous Field Studies Map MF-1866 scale 1:24,000.

Pitman, J.K., Anders, D.E., Fouch, T.D., and Nichols, D.J., 1986, Hydrocarbon potential of nonmarine Upper Cretaceous and Lower Tertiary rocks, eastern Uinta basin, Utah, *in* Spencer, C.W., and Mast, R.F., eds., Geology of Tight Gas Reservoirs: American Association of Petroleum Geologists Studies in Geology No. 24, p. 235-252.

Pitman, J.K., Fouch, T.D., and Goldhaber, M.B., 1982, Depositional setting and diagenetic evolution of some Tertiary unconventional reservoir rocks, Uinta basin, Utah: American Association of Petroleum Geologists Bulletin, v. 66, no. 10, p. 1581-1596.

Pitman, J.K., Franczyk, K.J., and Anders, D.E., 1987, Marine and nonmarine gas-bearing rocks in Upper Cretaceous Blackhawk and Neslen Formations, eastern Uinta Basin, Utah: Sedimentology, diagenesis, and source rock potential: American Association of Petroleum Geologists Bulletin, v. 71, no. 1, p. 76-94.

Pitman, J.K., Franczyk, K.J., and Anders, D.E., 1988, Diagenesis and burial history of nonmarine Upper Cretaceous rocks in the central Uinta basin, Utah: U.S. Geological Survey Bulletin 1787-D, 24 p.

Reinecke, K.M., Rice, D.D., and Johnson, R.C., 1991, Characteristics and development of fluvial sandstone and coalbed reservoirs of upper Cretaceous Mesaverde Group, Grand Valley field, Colorado, *in* Schwochow, S.D., Murray, D.K., and Fahy, M.F., eds., Coalbed methane of western North America: Rocky Mountain Association of Geologists, Denver, p. 209-225.

Rice, D.D., Fouch, T.D., and Johnson, R.C., 1992, Influence of source rock type, thermal maturity, and migration on composition and distribution of natural gases, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., eds., Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Guidebook 20: Salt Lake City, Utah, U.S.A., Utah Geological Association, p. 95-110

Robertson, J.M., and Broadhead, R.F., project coordinators, 1993, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau Mines and Mineral Resources, 208 p.

Rowley Peter D., Hansen, Wallace R., Tweto, Ogden, Carrara, Paul E., Geologic Map of the Vernal 1x2 degree Quadrangle, Colorado, Utah, and Wyoming, 1985, U.S. Geological Survey Miscellaneous Investigations Series Map I-1526 scale 1:250,000.

Schmoker, J.W., Nuccio, V.F., and Pitman, J.K., 1992, Porosity trends in predominantly nonmarine sandstones of the Upper Cretaceous Mesaverde Group, Uinta and Piceance basins, Utah and Colorado, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., eds., Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Guidebook 21: Salt Lake, City, Utah, U.S.A., Utah Geological Association, p. 111-122.

Shade, M.E., and Hansen, D.K.T., 1992, Drilled sidewall cores aid in interpretation of the Tertiary Wasatch Formation, Natural Buttes field, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., eds., Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado: Utah Geological Association, Guidebook 20, p. 193-217.

Spencer, C.W., and Wilson, R.J., 1988, Petroleum geology and principal exploration plays in the Uinta-Piceance-Eagle basins province, Utah and Colorado, U.S. Geological Survey Open-File Report 88-450, 35 p.

Spencer, Charles W., 1987, Hydrocarbon generation as a mechanism for overpressuring in Rocky Mountain region: American Association of Petroleum Geologists Bulletin, v. 71, n. 4, p. 368-388.

Stokes, W. Madsen James H. Jr., 1963, Geologic Map of Utah Northeast Symposium, p. 51-64

Tremain, C.M., 1993, PC-2, Mesaverde Group, *in* Robertson, J.M., and Broadhead, R.F., project coordinators, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 97-98.

Tweto, Ogden, 1979, Geologic Map of Colorado, U.S. Geological Survey", scale 1:500,000.

Verbeek, Earl R., and Grout, Marilyn A., 1993, Geometry and Structural Evolution of Gilsonite Dikes in the Eastern Uinta Basin, Utah: U.S. Geological Survey Bulletin 1787-HH, 42 p.

Waechter, N.B., and Johnson, W.E., 1986, Pennsylvanian-Permian paleostructure and stratigraphy as interpreted from seismic data in the Piceance basin, northwest Colorado, *in* Stone, D.S., ed., New interpretations of northwest Colorado geology: Rocky Mountin Association of Geologists, p. 51-64.

Weiss, Malcolm P., Witkind, Irving J., Cashion, William B., 1990, Geologic Map of the Price 30'x60' Quadrangle, Carbon, Duchesne, Uintah, Utah, and Wasatch Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1981 scale 1:100,000.

Wesley, J.B., Wandrey, C.J., and Fouch, T.D., 1993, Principal drill stem test database (UBDST) and documentation: analysis of Uinta Basin, Utah gas-bearing Cretaceous and Tertiary strata: U. S. Geological Survey Open-file Report 93-193, 19 p., 1 -3 1/2 inch diskette.

APPENDIX A

PLAY MAPS, EUR DISTRIBUTIONS AND DATA SHEETS, AND INPUT DATA FOR ANALYSIS. PLAY MAPS ARE APPROXIMATE. SEE PLATES FOR CORRECT PLAY OUTLINES IN AREA OF NAVAL OIL SHALE RESERVES.

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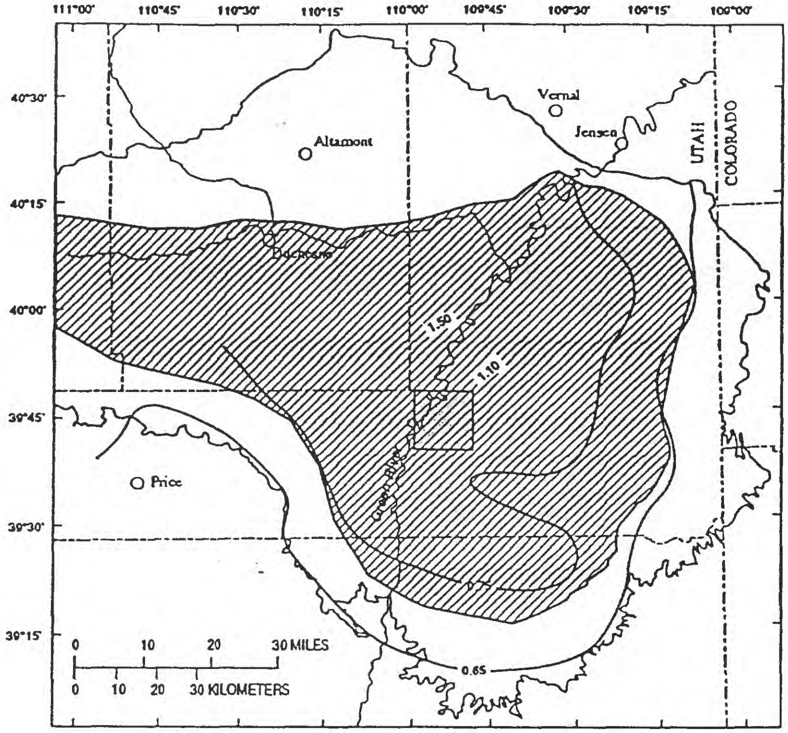
NOSR 2 Play 2011U



NOSR 2 Play No. 2011U: Cretaceous Dakota Group & Assoc. Rks: Gas-saturated

Play Area: Includes Upper Cretaceous Dakota Group, Lower Cretaceous Cedar Mountain and Jurassic Morrison (Salt Wash Member) and Entrada Formations.

Naval Oil Shale Reserve (NOSR) 2

USGS-DOE NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta

Date: 3/28/94 Play Name, No.: Cretaceous Dakota & Jurassic Ss Gas Staurated: 2011U

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: - Oil or X Gas (I C) X Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (80-640) acres; _____ mi² (acres/640)

Area of NOSR 2 (III A2): 141 mi2 Total no. of cells (III A3): __

No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0

No. of untested cells in NOSR (III D): 564 50th fractile

Minimum possible number of untested cells (III E1): 141 100th fractile

Maximum possible number of untested cells (III E2): 1128 0th fractile

(.53)

Success ratio (0-1.0) (IV): .35

EUR probability distribution (V*):

	Minimum			Median			Max*
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(1.6)	(40)	290	(980)	(2700)	6000

NOSR 2

Play Number & Name: **Play 2011U - Dakota, Morrison & Assoc.**

Source for Well Data: Petroleum Information : cumulative production to July of 1993

Comments:
Pressure data is unavailable.
Plot of EUR vs. Initial Production Date does not support a learning curve.
EUR calculations reflect current spacing.

Screen Data:
Dakota, Morrison, Cedar Mtn., Salt Wash or Entrada Formations
Wells located within the designated play area
Initial production date < 1992
Active or inactive status

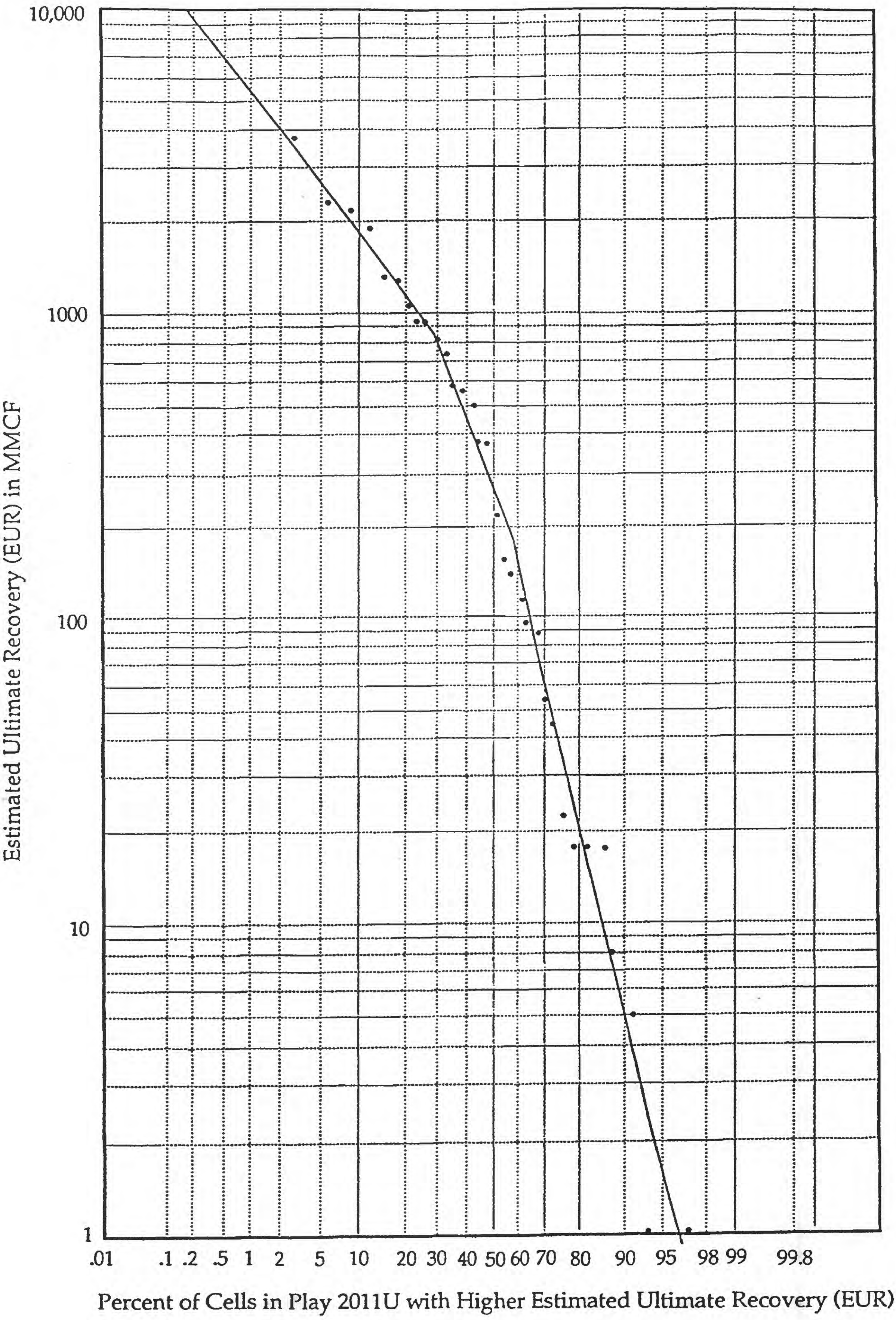
Total number of wells that meet screening criteria: 39

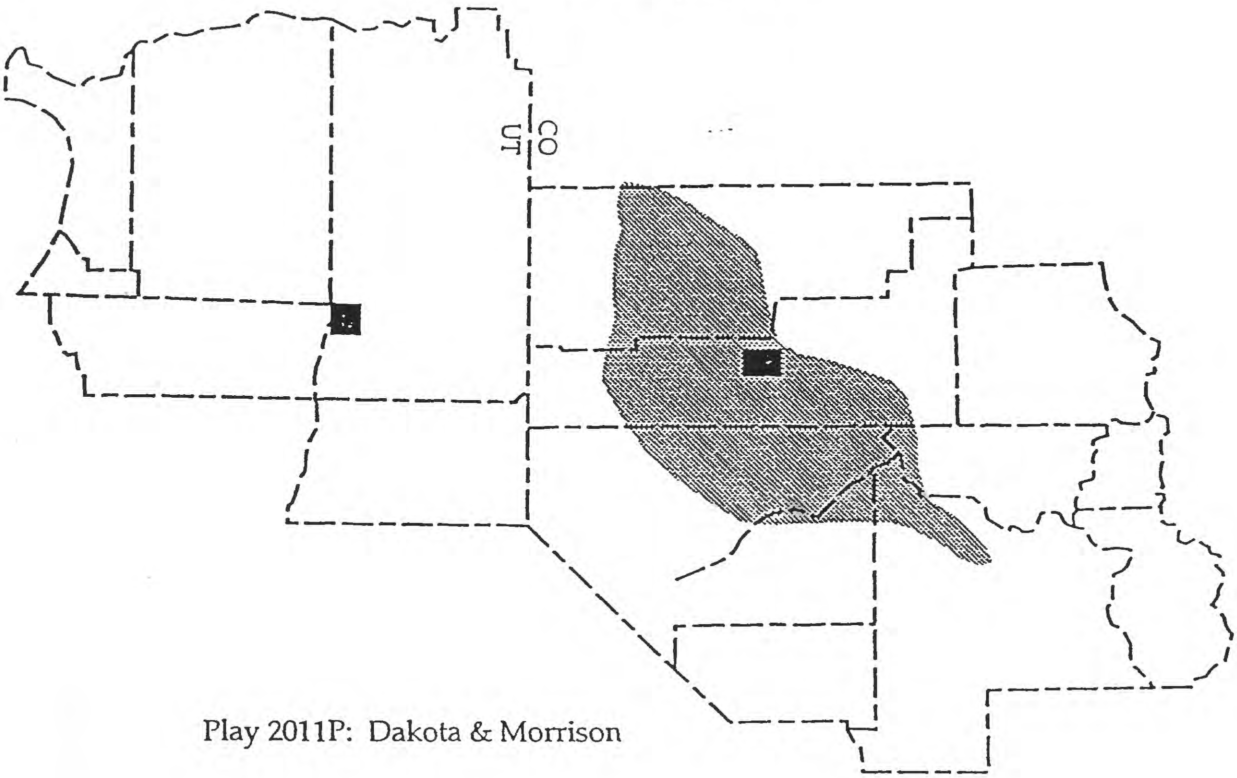
Total number of wells used in the EUR Distribution: 32

Calculation of EUR:
Decline Curve Analysis (DCA)
Assumptions:
No back pressure effects, radial flow, producing in the depletion stage, cumulative effects of factors altering production in the history of the well = cumulative effects in the future, etc.
Segmented exponential declines are used.
Life of a well is assumed to be 35 years maximum or will produce until an economic limit of 10 MCFD is reached. If necessary, a constant decline rate is imposed during the last five years to force the production rate to the economic limit of 10 MCFD in year 35.
Inactive wells remain idle.
Downtime is assumed negligible in the future.

EUR Probability Distribution:

Fractile	EUR (MMCF)
0	6000
5	2700
25	980
50	290
75	40
95	1.6
100	0


10,000
1000
100
10
1
Estimated Ultimate Recovery (EUR) in MMCF
.01
.1
.2
.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
Percent of Cells in Play 2011U with Higher Estimated Ultimate Recovery (EUR)



Play 2011P: Dakota & Morrison

USGS-DOE NOSR 1 ASSESSMENT

DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Piceance

Date: 3/26/94 Play Name, No.: Dakota Grp & Jurassic Tight Gas, 2011P

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-80) acres; ______ mi^2 (acres/640)

Area of NOSR 1 37,500 acres (III A2): Total no. of cells (III A3): 234

No. of productive cells in NOSR (III B): 0 No. of nonproductive cells in NOSR (III C): 0

No. of untested cells (III D): 234 50th fractile

Minimum possible number of untested cells (III E1): 59 100th fractile

Maximum possible number of untested cells (III E2): 472 0th fractile

Success ratio for entire play(0-1.0) (IV): 0.7

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(2)	(30)	60	(265)	(1200)	2000

NOSR 1 & 3

Play Number & Name:	**Play 2011P, Dakota & Assoc.**
Source for Well Data:	Petroleum Information : cumulative production to July of 1993
Comments:	Pressure data is unavailable. Plot of EUR vs. Initial Production Date does not support a learning curve. EUR calculations reflect current spacing.
Screen Data:	Piceance Basin Dakota or Entrada Formations Fields - Calf Canyon, Mesagar, Hunters Canyon, Cameo, Bronco Flats Initial production date < 1990 Active or inactive status

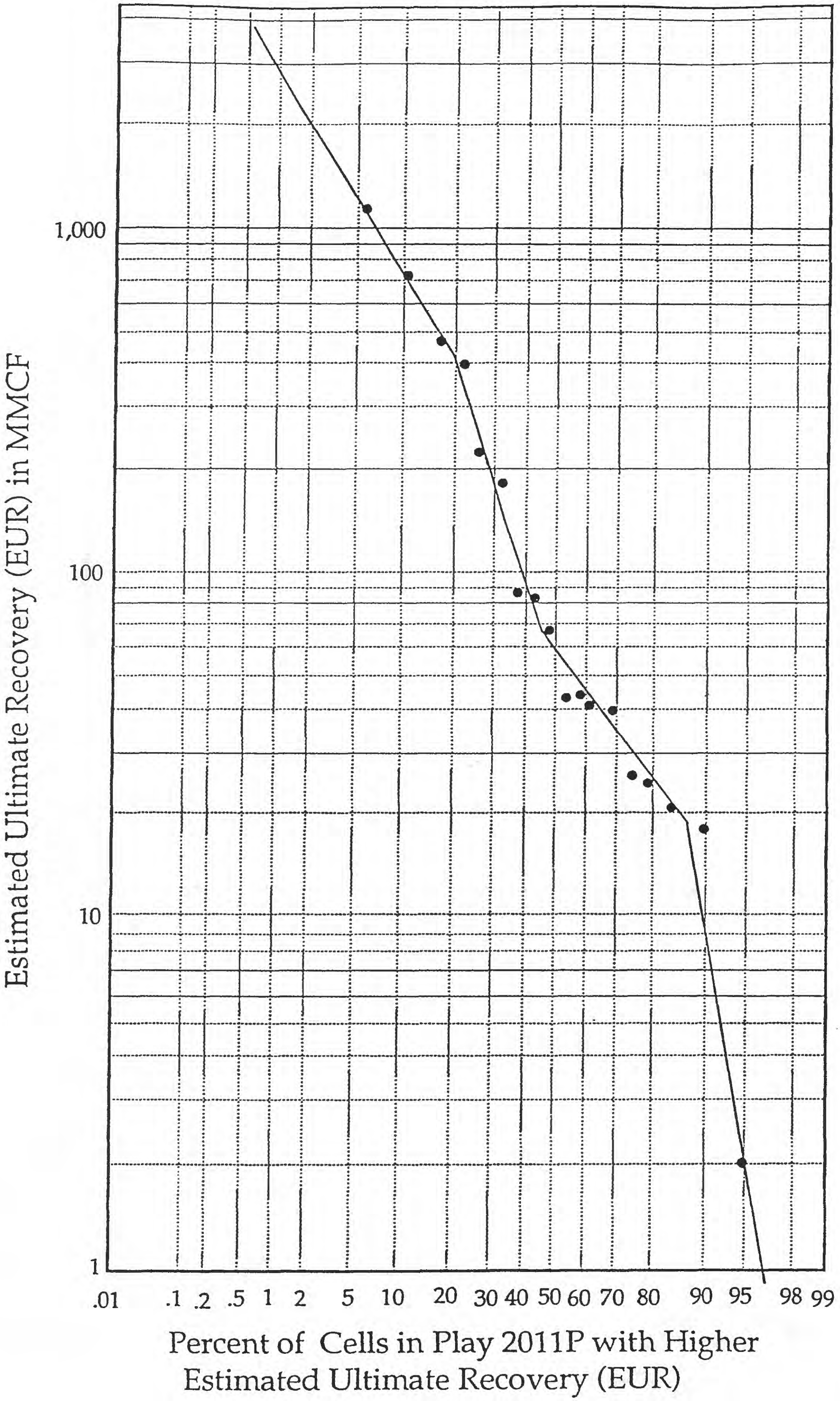
Total number of wells that meet screening criteria: 18

Total number of wells used in the EUR Distribution: 17

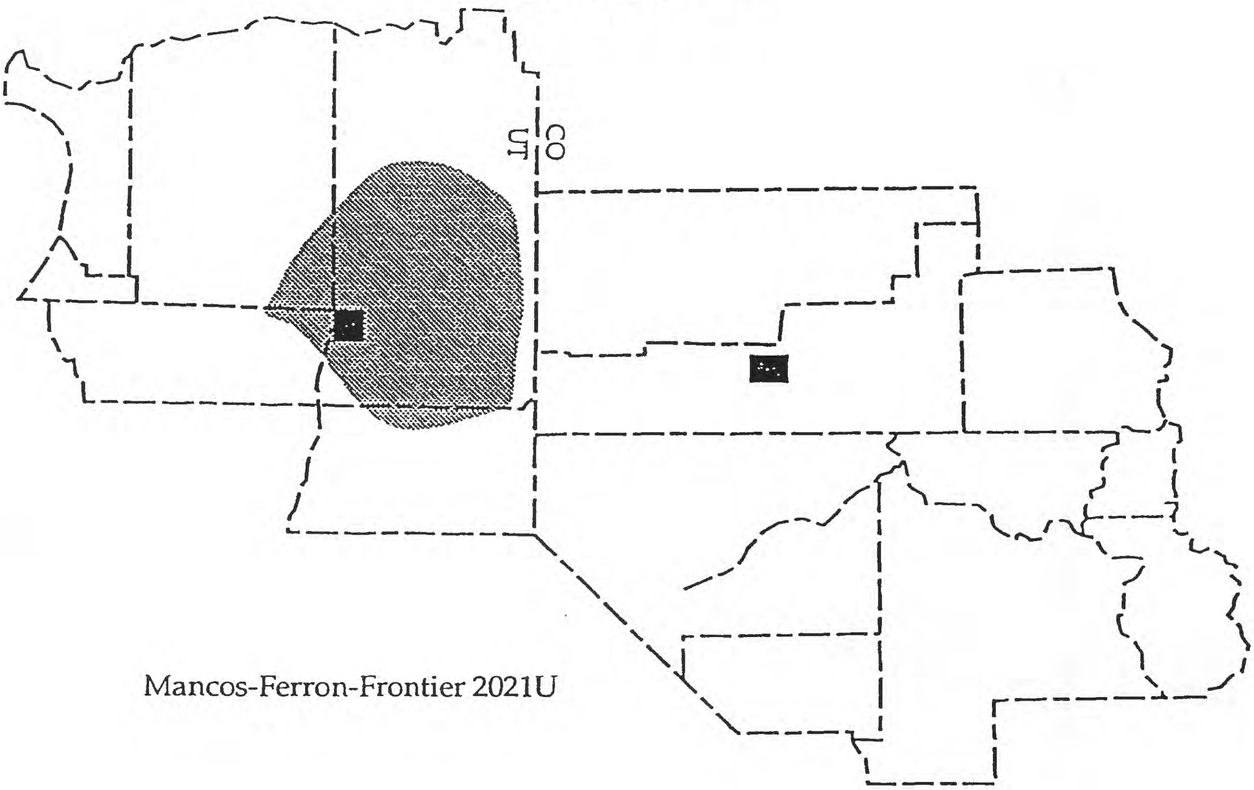
Calculation of EUR:	Decline Curve Analysis (DCA) Assumptions: No back pressure effects, radial flow, producing in the depletion stage, cumulative effects of factors altering production in the history of the well = cumulative effects in the future, etc. Segmented exponential declines are used. Life of a well is assumed to be 35 years maximum or will produce until an economic limit of 10 MCFD is reached. If necessary, a constant decline rate is imposed during the last five years toforce the production rate to the economic limit of 10 MCFD in year 35. Inactive wells remain idle. Downtime is assumed negligible in the future.

EUR Probability Distribution:

Fractile	EUR (MMCF)
0	2000
5	1200
25	265
50	60
75	30
95	2
100	0


Estimated Ultimate Recovery (EUR) in MMCF
1,000
100
10
1
.01
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99
Percent of Cells in Play 2011P with Higher Estimated Ultimate Recovery (EUR)

NOSR 2 Play 2021U



Mancos-Ferron-Frontier 2021U

USGS-DOE NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta

Date: 3/28/94 Play Name, No.: Mancos & Assoc Gas Saturated 2021U
(codes in parenthesis, such as IV B, refer to the procedure outline)
Play Type: - Oil or X Gas (I C) X Confirmed or __ Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-40) acres; ______ mi² (acres/640)
Area of NOSR 2 (III A2): 141 mi2 Total no. of cells (III A3): __
No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0
No. of untested cells (III D): 565 50th fractile
Minimum possible number of untested cells (III E1): 141 100th fractile
Maximum possible number of untested cells (III E2): 2256 0th fractile

Success ratio in entire play (0-1.0) (IV): .14
EUR probability distribution (V*):

Minimum				Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(1)	(3)	7	(19)	(48)	100

NOSR 2

Play Number & Name: **Play 2021U - Mancos & Assoc.**

Source for Well Data: Petroleum Information : cumulative production to July of 1993

Comments: Pressure data is unavailable. Plot of EUR vs. Initial Production Date does not support a learning curve. EUR calculations reflect current spacing.

Screen Data:

Mancos Formation
Wells located within the designated play area
Initial production date < 1990
Active or inactive status

Total number of wells that meet screening criteria: 7

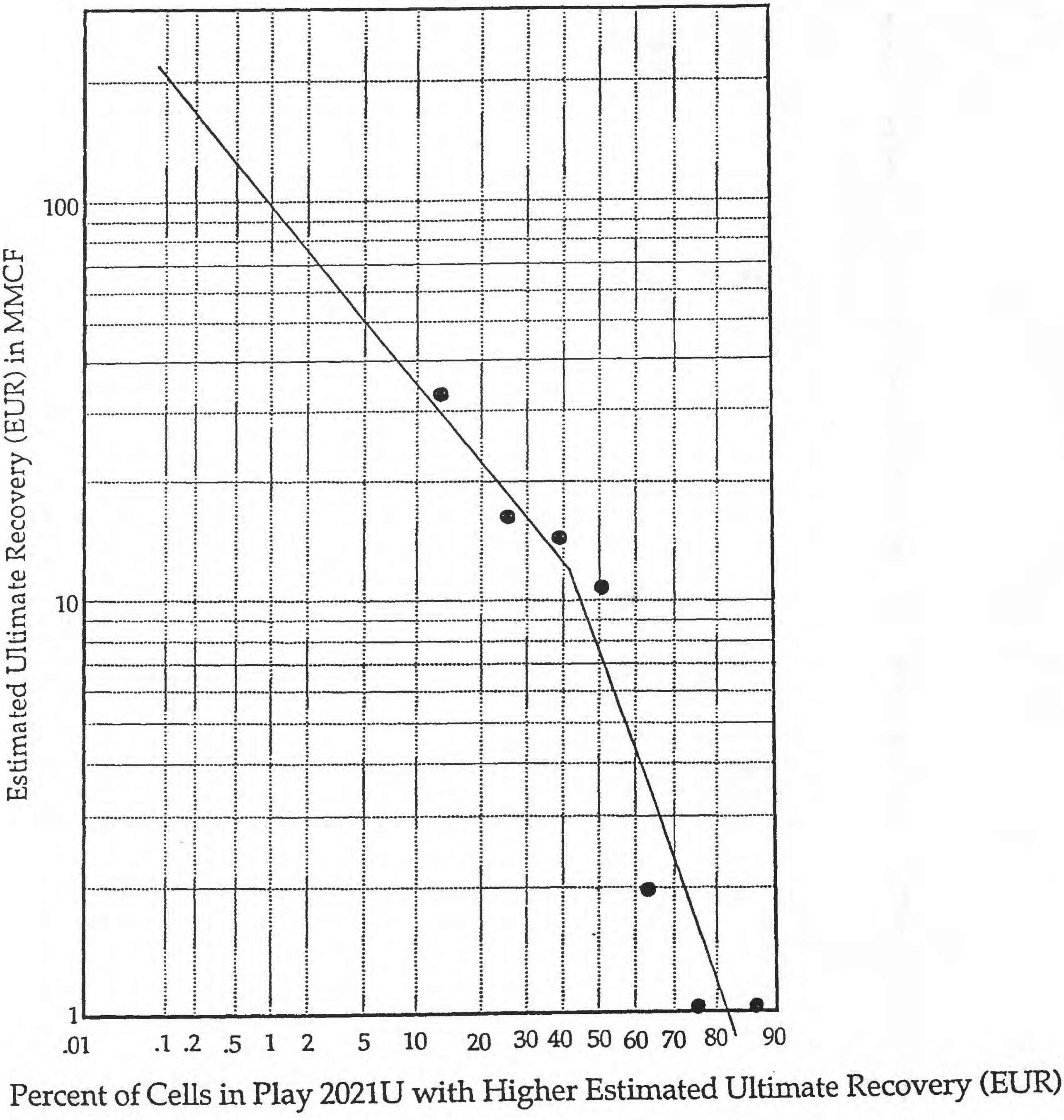
Total number of wells used in the EUR Distribution: 7

Calculation of EUR:

Decline Curve Analysis (DCA)
Assumptions:
No back pressure effects, radial flow, producing in the depletion stage, cumulative effects of factors altering production in the history of the well = cumulative effects in the future, etc.
Segmented exponential declines are used.
Life of a well is assumed to be 35 years maximum or will produce until an economic limit of 10 MCFD is reached. If necessary, a constant decline rate is imposed during the last five years to force the production rate to the economic limit of 10 MCFD in year 35.
Inactive wells remain idle.
Downtime is assumed negligible in the future.

EUR Probability Distribution:

Fractile	EUR (MMCF)
0	100
5	48
25	19
50	7
75	3
95	1
100	0


Estimated Ultimate Recovery (EUR) in MMCF
100
10
1
.01
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90
Percent of Cells in Play 2021U with Higher Estimated Ultimate Recovery (EUR)

NOSR 1 & 3 Play 2021P

No Map Available

USGS-DOE NOSR 1 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Piceance

Date: 3/26/94 Play Name, No.: Mancos + Gas-Saturated, 2021P

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-80) acres; ______ mi² (acres/640)

Area of NOSR 1 37,500 acres (III A2): Total no. of cells (III A3): 234

No. of productive cells in NOSR(III B): 0 No. of nonproductive cells in NOSR (III C): 0

No. of untested cells (III D): 234 50th fractile

Minimum possible number of untested cells (III E1): 59 100th fractile

Maximum possible number of untested cells (III E2): 472 0th fractile

Success ratio from play (0-1.0) (IV): .07

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(2.6)	(27)	140	(290)	(600)	800

NOSR 1 & 3

Play Number & Name: Play 2021P, Mancos & Assoc. Rocks

Source for Well Data: Petroleum Information : cumulative production to July of 1993

Comments:
Pressure data is unavailable.
Plot of EUR vs. Initial Production Date does not support a learning curve.
EUR calculations reflect current spacing.

Screen Data:
Piceance Basin
Mancos Formations
Wells located in the designated play area
Initial production date < 1990
Active or inactive status

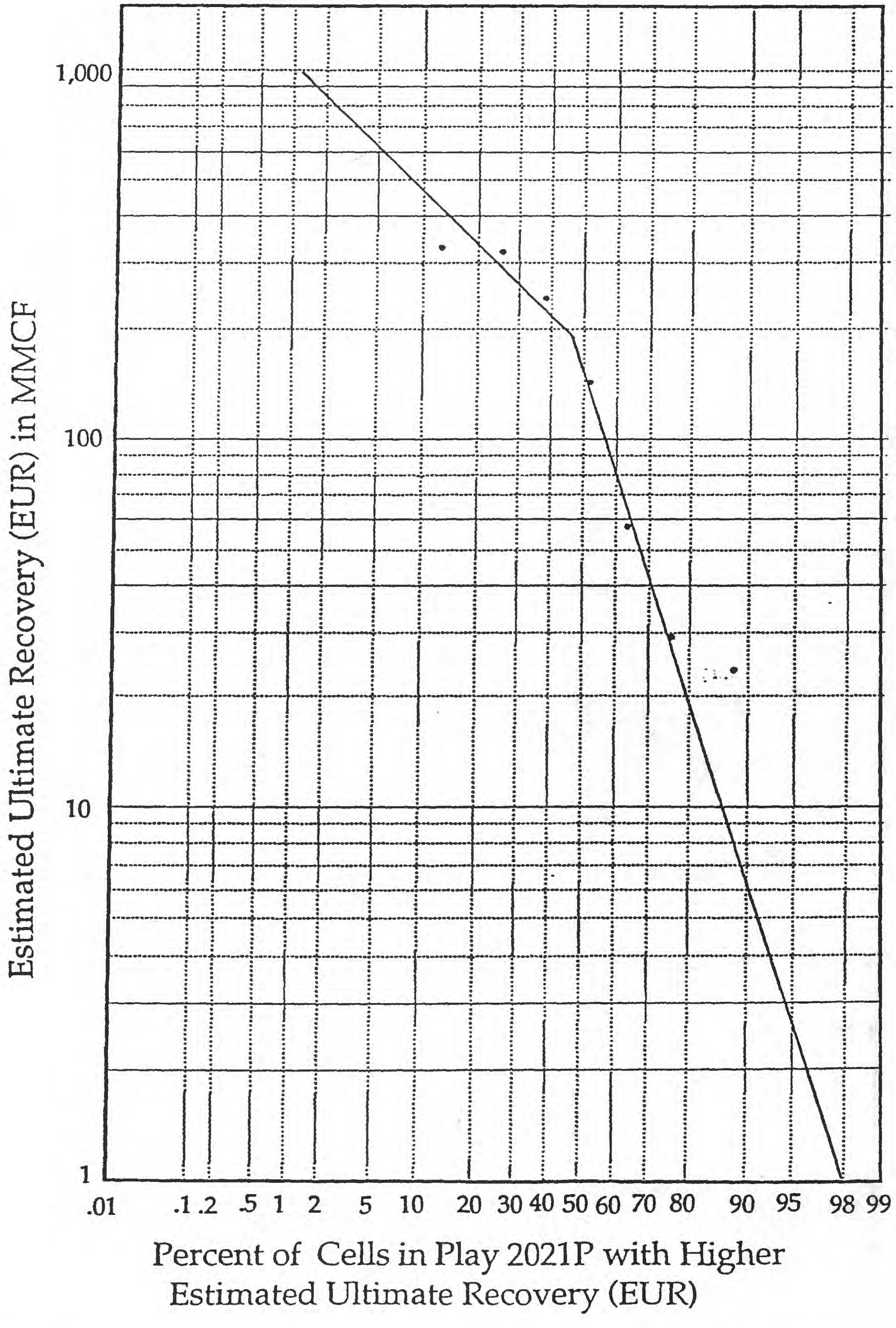
Total number of wells that meet screening criteria: 7

Total number of wells used in the EUR Distribution: 7

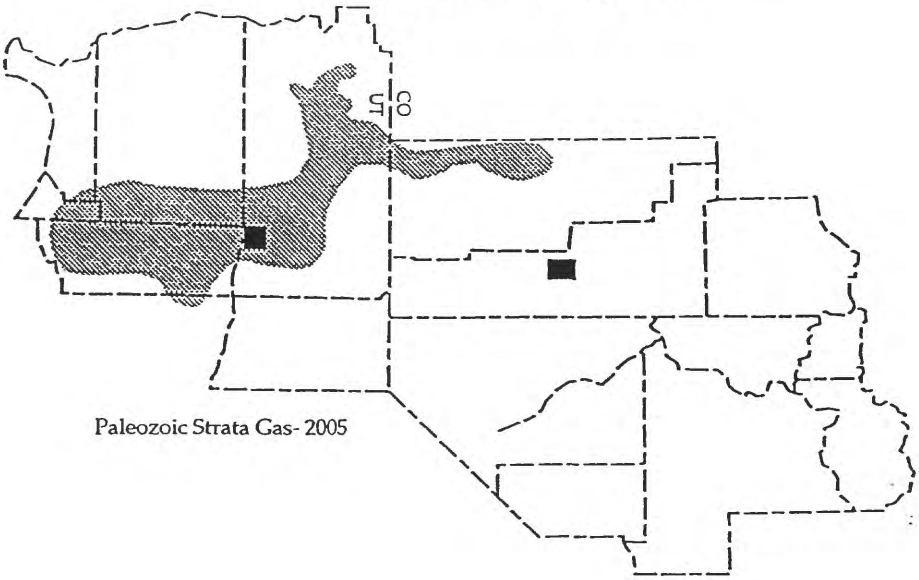
Calculation of EUR:
Decline Curve Analysis (DCA)
Assumptions:
No back pressure effects, radial flow, producing in the depletion stage, cumulative effects of factors altering production in the history of the well = cumulative effects in the future, etc.
Segmented exponential declines are used.
Life of a well is assumed to be 35 years maximum or will produce until an economic limit of 10 MCFD is reached. If necessary, a constant decline rate is imposed during the last five years to force the production rate to the economic limit of 10 MCFD in year 35.
Inactive wells remain idle.
Downtime is assumed negligible in the future.

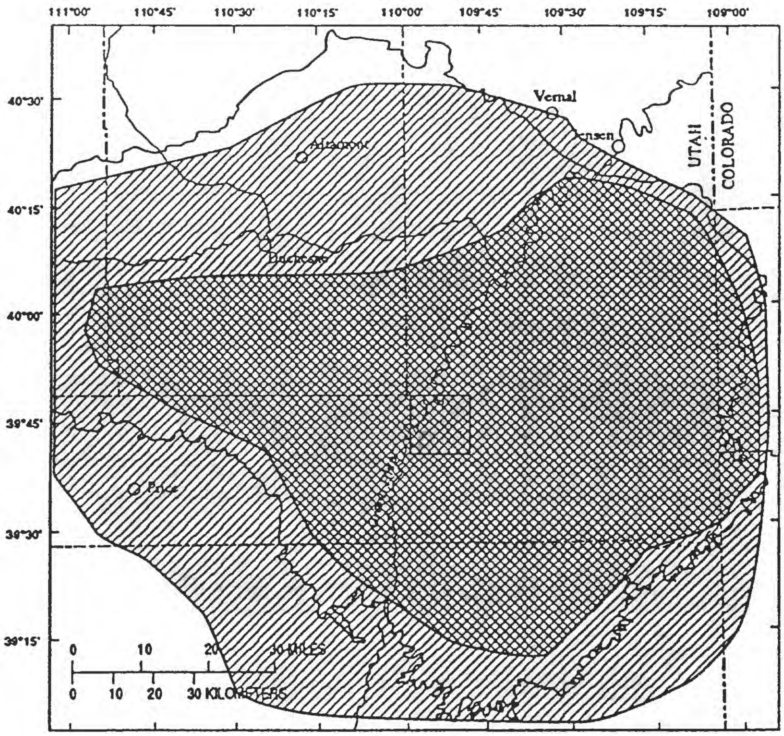
EUR Probability Distribution:

Fractile	EUR (MMCF)
0	800
5	600
25	290
50	140
75	27
95	2.6
100	0



NOSR 1 & 3 , NOSR 2 Play 2005





NOSR 2 Play No. 2005: Paleozoic Siliciclastic & carbonate Rocks : Gas-saturated

Play Area: Includes Pennsylvanian & Permian sandstones such as the White Rim, Coconino, Weber and associated units and carbonate strata including the Permian Kaibab & Mississipian Redwall Limestone (Madison, Leadville).

Area most like anticipated traps, etc. at NOSR 2: Wells from this area are emphasized. Wells south of Book Cliffs may contain water contacts and some structures may involve salt tectonics. Carbonate portion of play may contain water contacts.

Naval Oil Shale Reserve (NOSR) 2

USGS-DOE NOSR 1 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Piceance

Date: 3/26/94 Play Name, No.: Paleozoic Gas, 2005P

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-80) acres; ______ mi^2 (acres/640)

Area of NOSR 1 37,500 acres (III A2): Total no. of cells (III A3): 234

No. of productive cells in NOSR (III B): 0 No. of nonproductive cells in NOSR (III C): 0

No. of untested cells (III D): 234 50th fractile

Minimum possible number of untested cells (III E1): 59 100th fractile

Maximum possible number of untested cells (III E2): 472 0th fractile

Success ratio for entire play(0-1.0) (IV): 0.01

Used Mancos EUR Distribution because of anticipated extreme impermeable nature of reservoirs

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(2.6)	(27)	140	(290)	(600)	800

USGS-DOE NOSR 3 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Piceance

Date: 3/26/94 Play Name, No.: Paleozoic Gas, 2005P

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-80) acres; ______ mi^2 (acres/640)

Area of NOSR 3 18,040 acres (III A2): Total no. of cells (III A3): 113

No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0

No. of untested cells (III D): 113 50th fractile

Minimum possible number of untested cells (III E1): 28 100th fractile

Maximum possible number of untested cells (III E2): 226 0th fractile

Success ratio for entire play(0-1.0) (IV): 0.01

Used Mancos EUR Distribution because of anticipated extreme impermeable nature of reservoirs

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(2.6)	(27)	140	(290)	(600)	800

USGS-DOE NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta

Date: 2/25/94 Play Name, No.: Paleozoic Strata: 2005U

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: - Oil or X Gas (I C) X Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): .05 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (80-640) acres; ______ mi^2 (acres/640)

Area of NOSR 2 (III A2): 141 mi2 Total no. of cells (III A3): __

No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0

No. of untested cells (III D): 564 50th fractile

Minimum possible number of untested cells (III E1): 141 100th fractile

Maximum possible number of untested cells (III E2): 1128 0th fractile

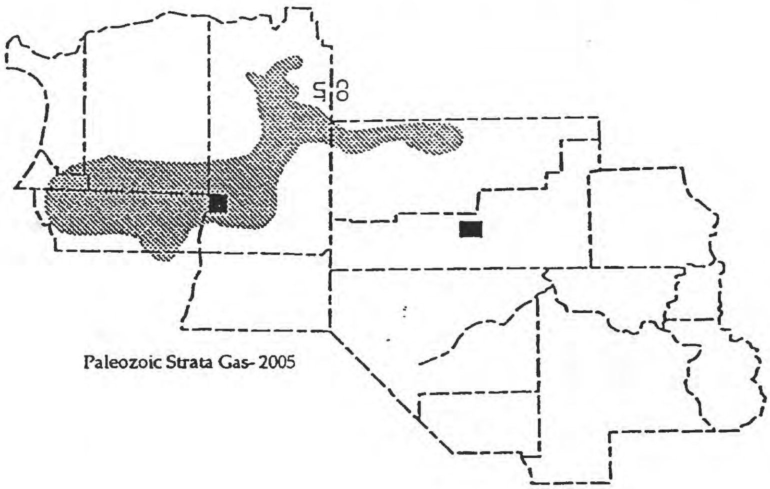
(0.0)

Success ratio (0-1.0) (IV): _____

EUR probability distribution (V*):

	Minimum	Median	Max				
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	____	(__)	(__)	___	(__)	(__)	_

Not assessed because of low play probability and lack of wells to generate EUR distribution



Paleozoic Strata Gas- 2005

NOSR 2

Play Number & Name: Play 2005: Not Viable and Not Assessed: Paleozoic

Source for Well Data: Petroleum Information : cumulative production to July of 1993

Comments: One well in production data base. Produced 1 month (1/76).

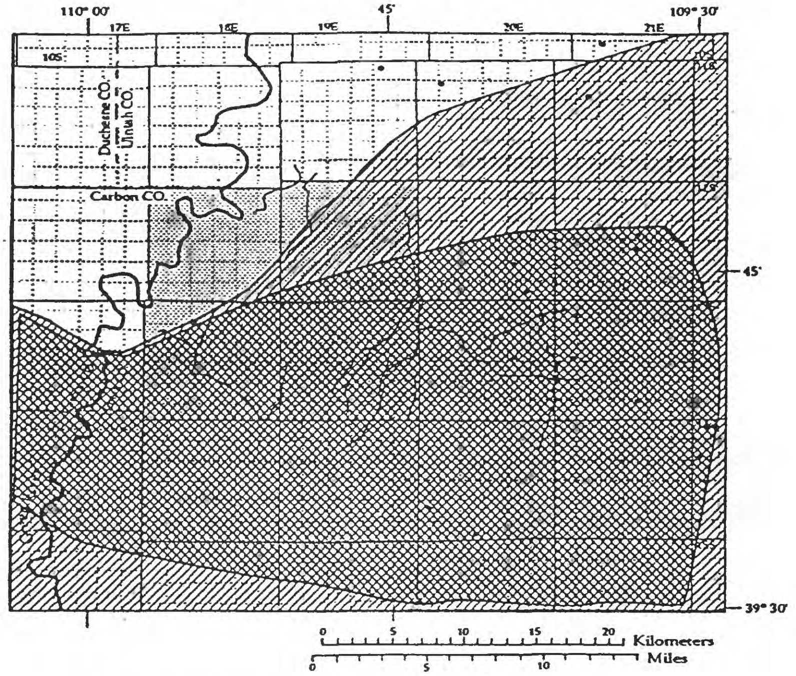
Screen Data: Designated area of play Formations - White Rim, Coconino, Weber, Kaibab, Redwall, Madison, Leadville
Active or inactive status

Total number of wells that meet screening criteria: 1

Total number of wells used in the EUR Distribution: 0

Insufficient data to generate an EUR Distribution.

NOSR 2 Play 2017



NOSR 2 Play No. 2017 Wasatch Formation: gas/water contacts

Play Area– Wasatch Production (includes Uteland Butte, Chapita, & Buck Canyon zones) from this area

Area most like that anticipated at SE 2/3 of NOSR 2; EUR analysis emphasizes this area

Naval Oil Shale Reserve (NOSR) 2

USGS-DOE NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta

Date: 3/26/94 Play Name, No.: Wasatch Gas /Water Contacts, 2017
(codes in parenthesis, such as IV B, refer to the procedure outline)
Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

---

368 records at cell size of 160 acres = cells tested—most successful near sat gas so degraded for other area
Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-40) acres; ______ mi^2 (acres/640)
Area of NOSR 2 (III A2): 99 mi^2 Total no. of cells (III A3): __
No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0
No. of untested cells (III D): 396 50th fractile
Minimum possible number of untested cells (III E1): 99 100th fractile
Maximum possible number of untested cells (III E2): 1584 0th fractile
(.44)

Success ratio (0-1.0) (IV): .3
EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(11)	(90)	300	(1000)	(2550)	4000

Play Number & Name: Wasatch with Gas/Water Contacts 2017

Notes: Divided area into 21 segments; spanning the drilling history, 40% of wells in each area were randomly selected for analysis; inactive wells included. Repetitive downtime is not in forecast.

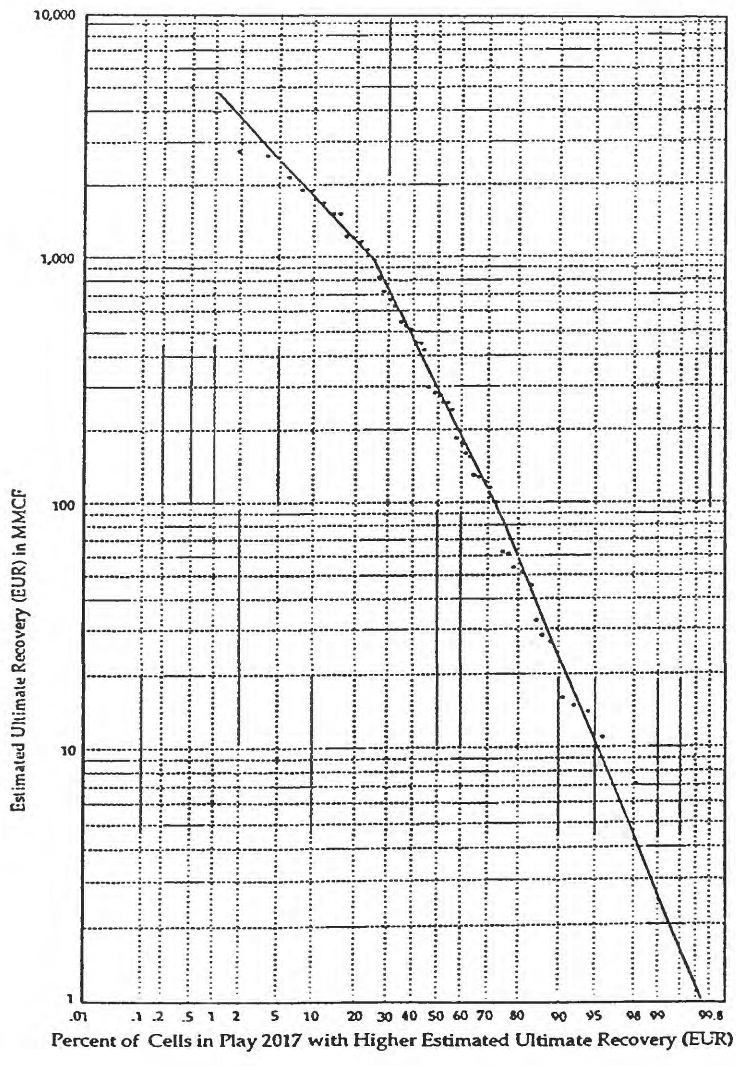
Total number of wells that meet screening criteria: 131

Total wells used in EUR Distribution: 51 (40%)

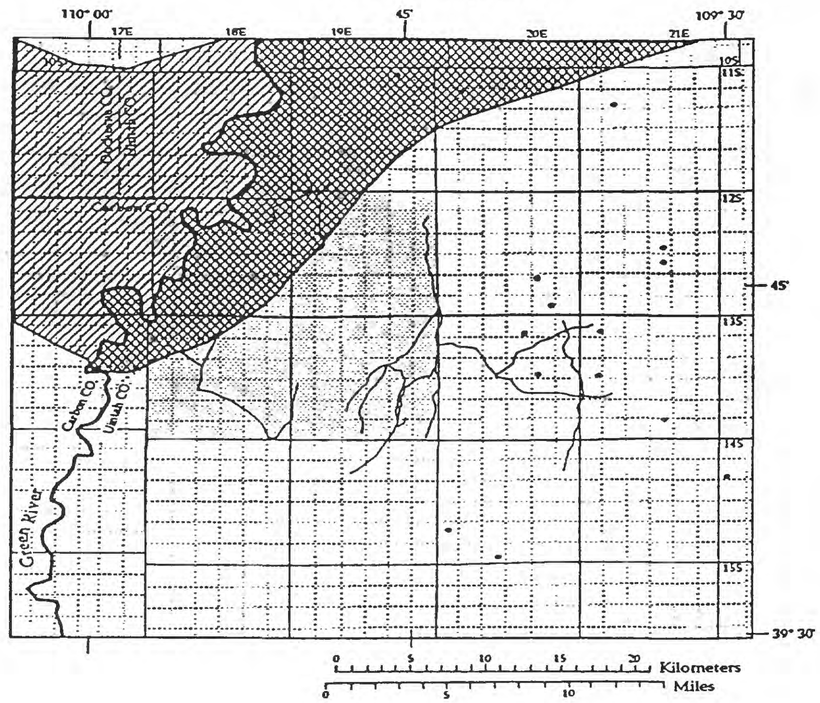
Calculation of EUR: See play 2015.

EUR probability distribution:

Fractile %	EUR (MMCF)
0	4000
5	2550
25	1000
50	300
75	90
95	11
100	0



NOSR 2 Play 2016



NOSR 2 Play 2015 and 2016: Wasatch Formation: gas-saturated

Play Area 2015– Wasatch Formation Production (includes Uteland Butte, Chapita, and Buck Canyon zones) from this area

Play Area 2016– Wasatch Formation Production (includes Uteland Butte, Chapita, and Buck Canyon zones) from this area

Naval Oil Shale Reserve (NOSR) 2

USGS-DOE NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta
Date: 3/26/94 Play Name, No.: Wasatch Gas Saturated Extension, 2016
(codes in parenthesis, such as IV B, refer to the procedure outline)
Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

---

30 records = cells tested at 160 acres per cell
Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-40) acres; ____ mi2 (acres/640)
Area of NOSR 2 (III A2): 8 mi^2 Total no. of cells (III A3): 32
No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0
No. of untested cells (III D): 32 50th fractile
Minimum possible number of untested cells (III E1): 8 100th fractile
Maximum possible number of untested cells (III E2): 128 0th fractile

Success ratio of Play in NOSR 2 area (0-1.0) (IV): .3
EUR probability distribution for entire play 2016 (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(230)	(670)	1080	(2050)	(2650)	4500

Play Number & Name: Wasatch Formation Gas Saturated West 2016

Notes: See play 2015

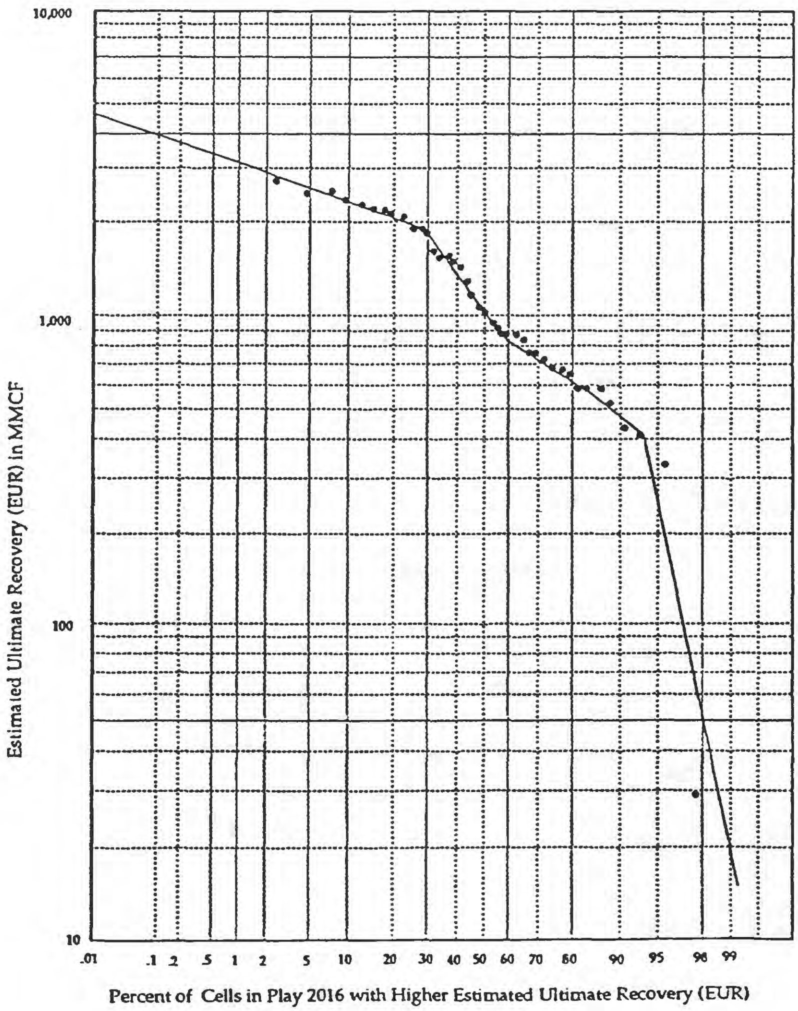
Total number of wells that meet screening criteria: One well in play area in the PI database. Analog production area is T10S, R. 19E, the westernmost Wasatch production from Play 2015, east of the Green River. Fifty wells meet criteria.

Total number of wells used in the EUR Distribution: 41 (erratic production history and excessive downtime prevented DCA of some wells)

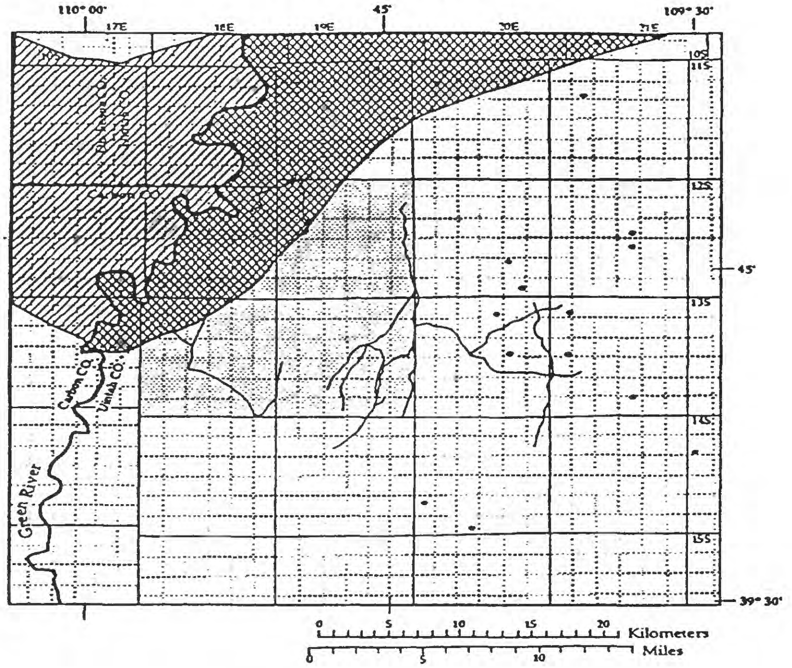
Calculation of EUR: see play 2015.

EUR probability distribution:

Fractile %	EUR (MMCF)
0	4500
5	2650
25	2050
50	1080
75	670
95	230
100	0



NOSR 2 Play 2015



NOSR 2 Play 2015 and 2016: Wasatch Formation: gas-saturated

Play Area 2015-- Wasatch Formation Production (includes Uteland Butte, Chapita, and Buck Canyon zones) from this area

Play Area 2016-- Wasatch Formation Production (includes Uteland Butte, Chapita, and Buck Canyon zones) from this area

Naval Oil Shale Reserve (NOSR) 2

NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta

Date: 3/26/94 Play Name, No.: Wasatch Gas-Saturated Main, 2015

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-40) acres; ______ mi^2 (acres/640)

Area of NOSR 2 (III A2): 34 mi2 Total no. of cells (III A3): 136

No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0

No. of untested cells (III D): 136 50th fractile

Minimum possible number of untested cells (III E1): 34 100th fractile

Maximum possible number of untested cells (III E2): 544 0th fractile

(.88)

Success ratio of play in NOSR 2 area (0-1.0) (IV): .75

EUR probability distribution (V*) from entire area of Play 2015:

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(32)	(520)	1100	(1900)	(3300)	6500

NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta

Date: 4/19/94 Play Name, No.: Wasatch Gas-Saturated Main, 2015
(codes in parenthesis, such as IV B, refer to the procedure outline)
Play Type: -__Oil or X Gas (I C) X Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 40 (80-20) acres; ______ mi^2 (acres/640)
Area of NOSR 2 (III A2): 34 mi^2 Total no. of cells (III A3): 544
No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0
No. of untested cells (III D): 544 50th fractile
Minimum possible number of untested cells (III E1): 272 100th fractile
Maximum possible number of untested cells (III E2): 1088 0th fractile
Success ratio of entire play in at 40 acre spacing (0-1.0) (IV): .9
EUR probability distribution (V*) from entire area of Play 2015:

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(32)	(520)	1100	(1900)	(3300)	6500

NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta

Date: 3/26/94 Play Name, No.: Wasatch Gas-Saturated Main, 2015
(codes in parenthesis, such as IV B, refer to the procedure outline)
Play Type: -__Oil or X Gas (I C) X Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)
Cells (III) Cell Size (III A1): 80 (160-40) acres; ______ mi^2 (acres/640)
Area of NOSR 2 (III A2): 34 mi2 Total no. of cells (III A3): 272
No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0
No. of untested cells (III D): 272 50th fractile
Minimum possible number of untested cells (III E1): 136 100th fractile
Maximum possible number of untested cells (III E2): 544 0th fractile
Success ratio of entire play 2 area (0-1.0) (IV): .9
EUR probability distribution (V*) from entire area of Play 2015:

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(32)	(520)	1100	(1900)	(3300)	6500

Play Number & Name:	Wasatch Formation Gas Saturated East 2015
Source for well data:	Petroleum Information: Cumulative production data until July 1993
Notes:	No pressure data available. Plot of EUR vs. Production date indicated no learning curve over time. EUR calculations reflect current spacing
Screen Data:	Wasatch Formation > 3,000 ft depth to top of perforations < 1991 production start date, drilling history 1976-1990 Wells were selected at random taking into account above Inactive wells included

Total number of wells that meet screening criteria: 226

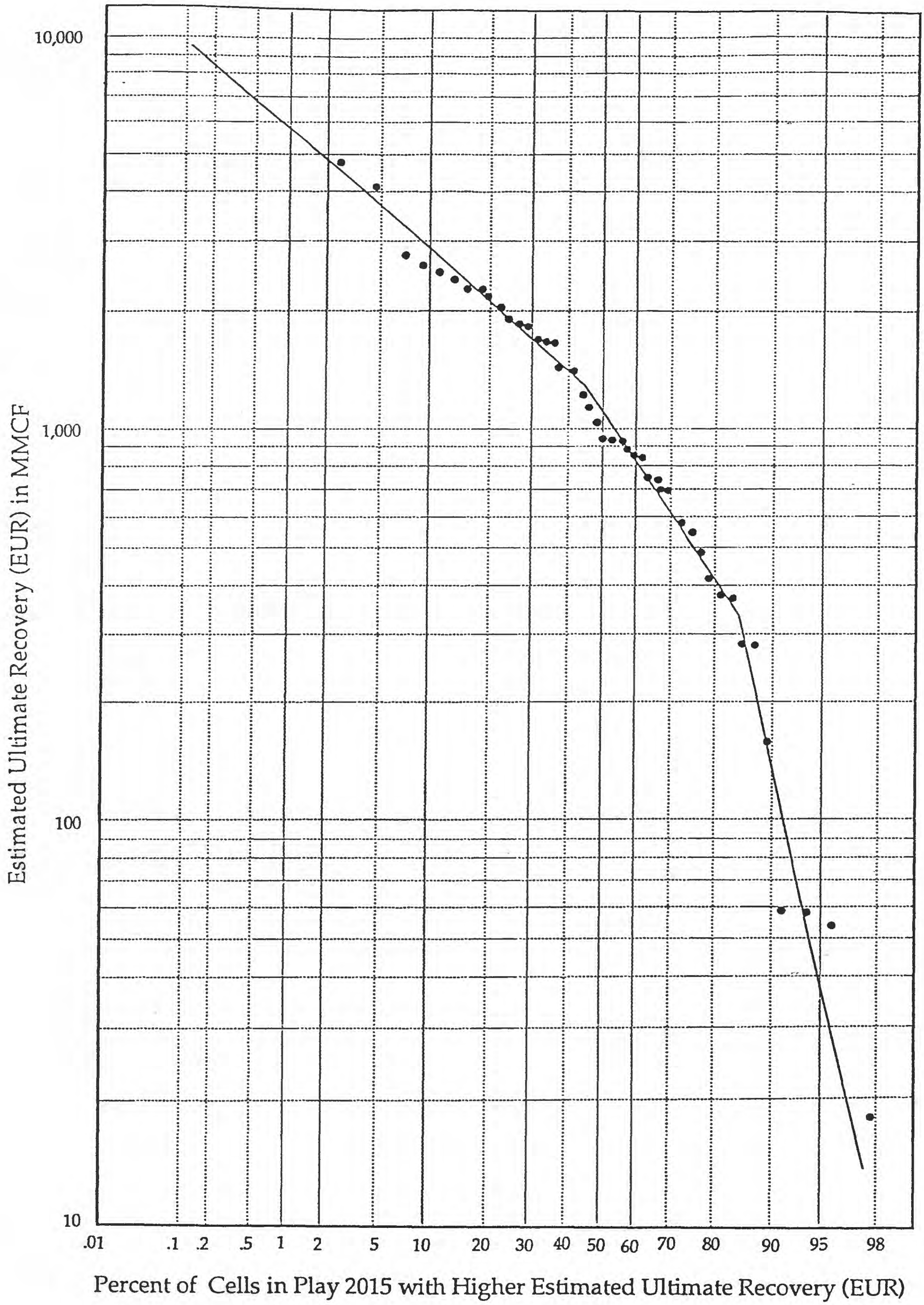
Total number of wells used in EUR distribution: 45 (20%)

Calculation of EUR: Decline curve analysis (DCA)

Assumptions:
No backpressure effects, radial flow, producing in depletion stage, cumulative effects o factors altering production in history = cumulative effects in future, etc.,
Segmented exponential declines are used.
Life of a well is assumed to be 35 years maximum or will produce until an economic limit of 10 MCFD is reached. If necessary, a constant decline rate is imposed during the last five years to force the production rate to the economic limit of 10 MCFD in year 35.
Inactive wells do no resume production in this analysis.
A consistent history of downtime for a given well was reflected in the production forecast for that well (play 2015 only).

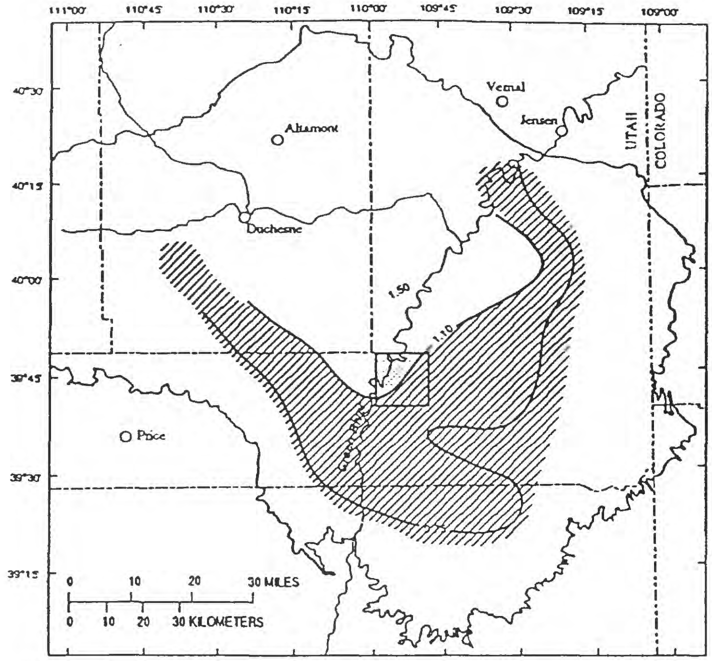
EUR probability distribution:

Fractile %	EUR (MMCF)
0	6500
5	3300
25	1900
50	1100
75	520
95	32
100	0



10,000
1,000
100
10
Estimated Ultimate Recovery (EUR) in MMCF
.01
.1
.2
.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
Percent of Cells in Play 2015 with Higher Estimated Ultimate Recovery (EUR)

NOSR 2 Play 2019



NOSR 2 Play No. 2019: Cretaceous Mesaverde Gas-Water Transitional

Play Area: Mesaverde Group reservoirs at drilling depths near and less than15,000ft . Mesaverde Group strata include the Rim Rock, Castlegate, and Sego Sandstones, and the Blackhawk, Tuscher, Farrer, Price River, and Neslen Formations. Contains mixed water- and gas-bearing strata.

Naval Oil Shale Reserve (NOSR) 2

1.10 Level of vitrinite reflectance (measure of termal maturity) on basal Mesaverde

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USGS-DOE NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist:__Tom Fouch__________ Province Name, No.:__Uinta____

Date:__3/28/94____ Play Name, No.:_Mesaverde Gas-Water Transitional, 2019__

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

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160 records at 1t 160 acre spacing = 160 cells tested

Play Probability (0-1.0) (II A):__1____ Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1):_160 (640-40)___acres; ______ mi^2 (acres/640)

Area of NOSR 2 (III A2): _99_mi^2 Total no. of cells (III A3): __

No. of productive cells (III B): __0_ No. of nonproductive cells (III C): _0_

No. of untested cells (III D): _396_ 50th fractile

Minimum possible number of untested cells (III E1): _99_100th fractile

Maximum possible number of untested cells (III E2): _1584_ 0th fractile

Success ratio (0-1.0) (IV): __.25__

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	__0_	(_1_)	(_25_)	_380_	(_750_)	(_1950_)	_3000

Play Number & Name: MESAVERDE GAS/WATER TRANSITIONAL2019

Notes: See notes for play 2015.

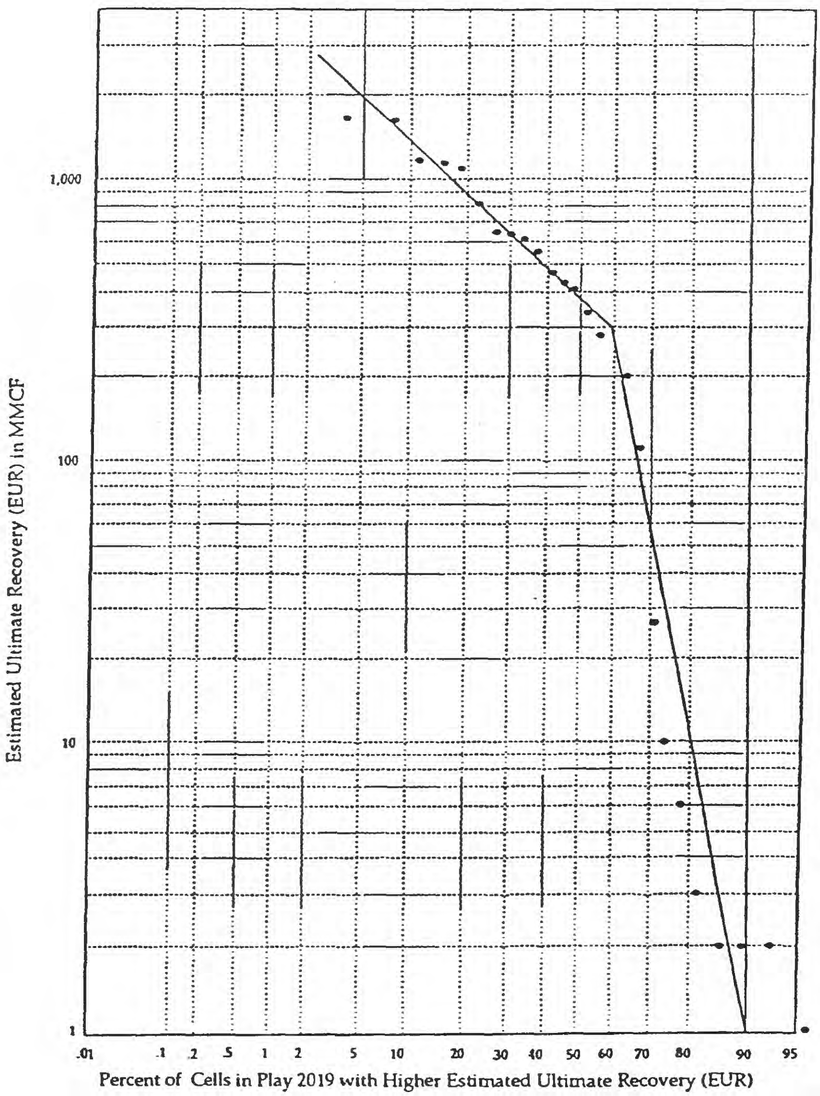
Total number of wells that meet screening criteria: 30

Total number of wells used in the EUR Distribution: 25

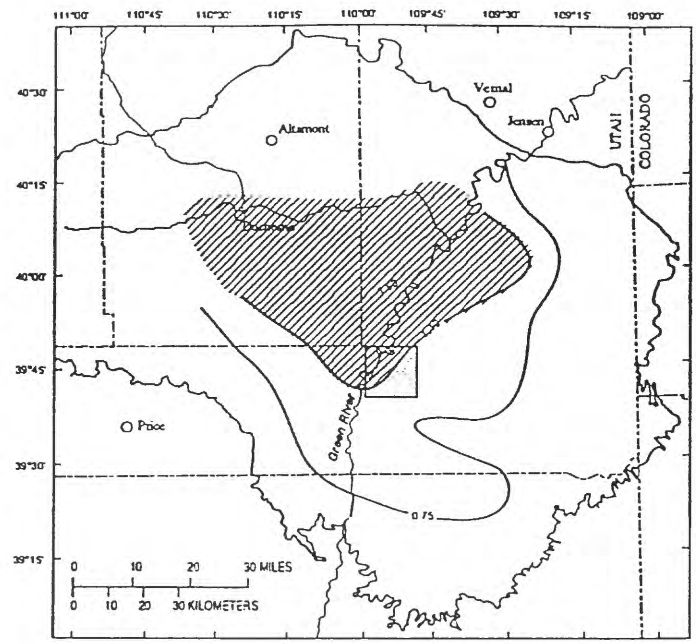
Calculation of EUR: **See play 2015.**

EUR probability distribution:

Fractile %	EUR (MMCF)
0	3000
5	1950
25	750
50	380
75	25
95	0
100	0



NOSR 2 Play 2018



NOSR 2 Play No. 2018: Cretaceous Mesaverde Gas Saturated

Play Area: Mesaverde Group reservoirs at drilling depths near and less than15,000ft . Mesaverde Group strata include the Rim Rock, Castlegate, and Sego Sandstones, and the Blackhawk, Tuscher, Farrer, Price River, and Neslen Formations. Contains gas-saturated strata.

Naval Oil Shale Reserve (NOSR) 2

1.10

Level of vitrinite reflectance (measure of termal maturity) on basal Mesaverde

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USGS-DOE NOSR 2 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta

Date: 3/27/94 Play Name, No.: Basin Flank Mesaverde Gas Saturated < 15,000, 2018

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or X Gas (I C) X Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-80) acres; ____ mi² (acres/640)

Area of NOSR 2 (III A2): 42 mi² Total no. of cells (III A3): ___

No. of productive cells (III B): 0 No. of nonproductive cells (III C): 0

No. of untested cells (III D): 168 50th fractile

Minimum possible number of untested cells (III E1): 42 100th fractile

Maximum possible number of untested cells (III E2): 336 0th fractile

(.22)

Success ratio for entire play (0-1.0) (IV): .25

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(1.0)	(100)	480	(1200)	(2100)	3000

Play Number & Name: MESAVERDE BASIN FLANK 2018

Notes: See play 2015

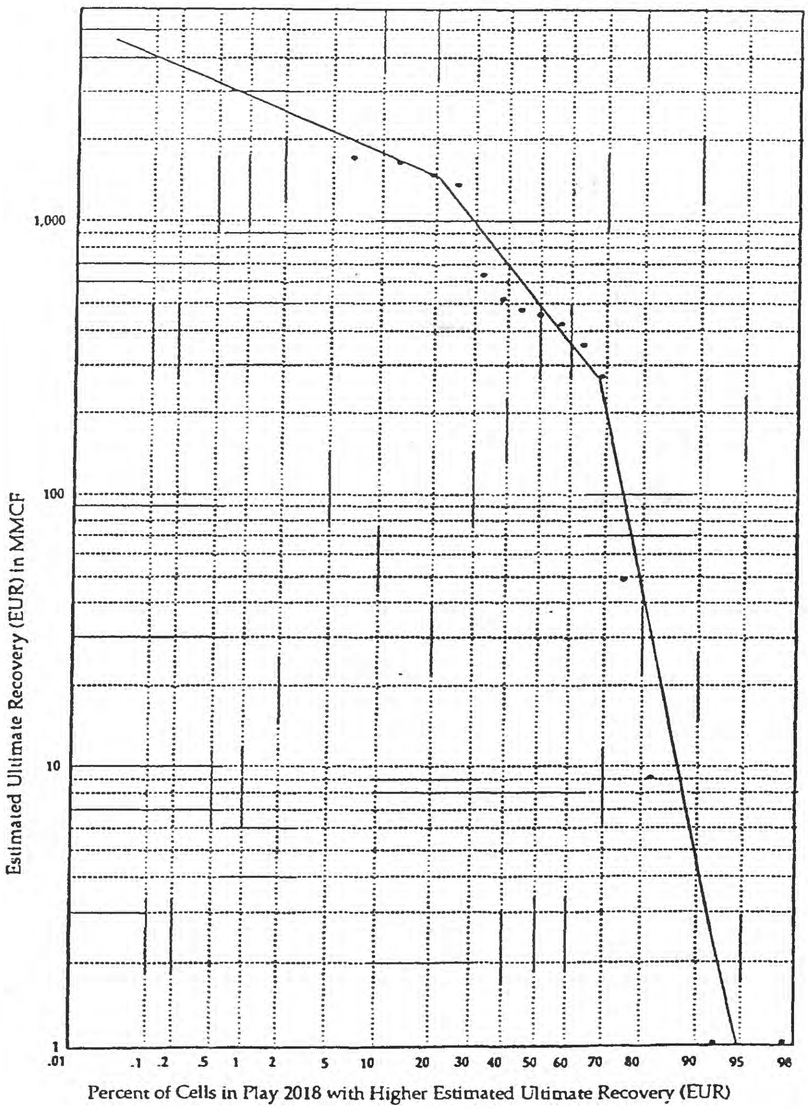
Total number of wells that meet screening criteria: 16

Total number of wells used in the EUR Distribution: 15

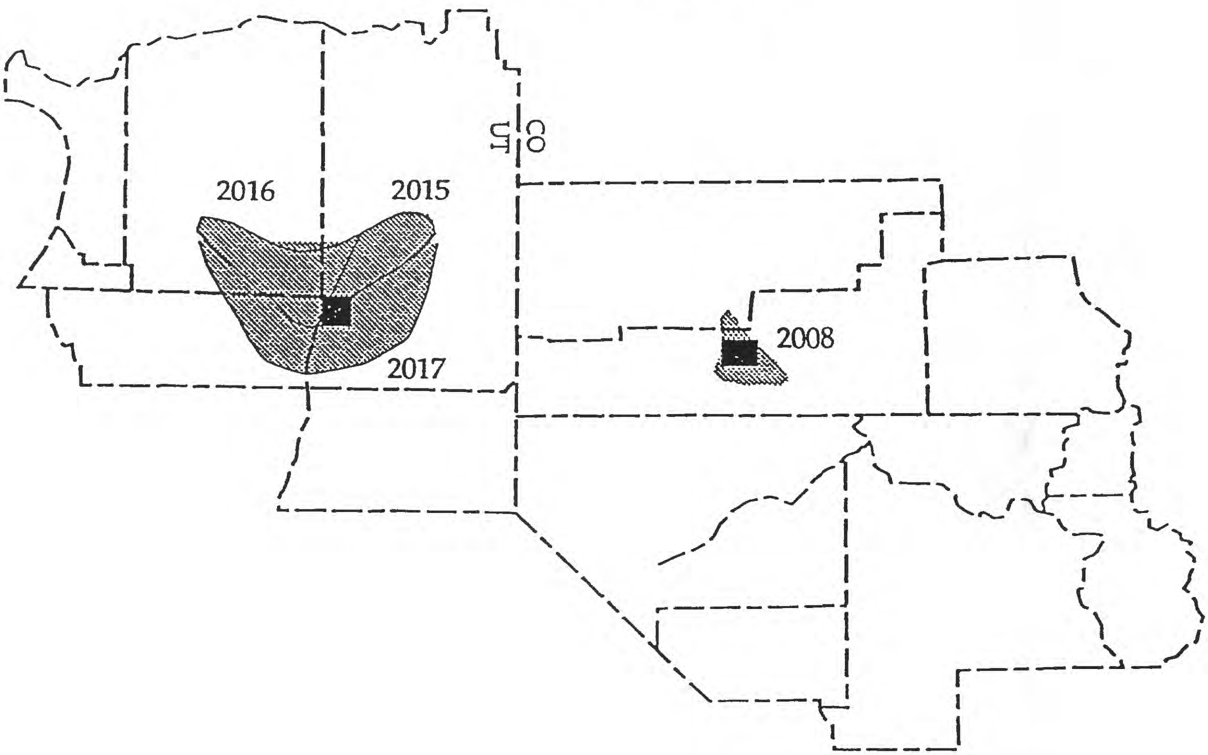
Calculation of EUR: See discussion for play 2015.

EUR probability distribution:

Fractile %	EUR (MMCF)
0	3000
5	2100
25	1200
50	480
75	100
95	0
100	0



NOSR 1 & 3 Play 2008



USGS-DOE NOSR 1 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Piceance

Date: 3/26/94 Play Name, No.: Wasatch Gas-Saturated, 2008
(codes in parenthesis, such as IV B, refer to the procedure outline)
Play Type: -__Oil or X Gas (I C) X Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (320-80) acres; ______ mi^2 (acres/640)
Area of NOSR 1 37,500 acres (III A2): Total no. of cells (III A3): 234
No. of productive cells in NOSR 1 (III B): 0 No. of nonproductive cells in NOSR (III C): 0
No. of untested cells (III D): 234 50th fractile
Minimum possible number of untested cells (III E1): 117 100th fractile
Maximum possible number of untested cells (III E2): 472 0th fractile

Success ratio of entire play to be used on NOSR 1(0-1.0) (IV): .83
EUR probability distribution (V*):

	Minimum	Median	Max				
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(8)	(220)	580	(1050)	(1600)	2600

EUR Distribution and Cell success ratio developed by FD Services for Grand Valley, Parachute, and Rulison fields

USGS-DOE NOSR 3 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Piceance

Date: 3/26/94 Play Name, No.: Wasatch Gas-Saturated, 2008

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-80) acres; ______ mi^2 (acres/640)

Area of NOSR 3 18,040 acres (III A2): Total no. of cells (III A3): 113

No. of productive cells (III B): 6 No. of nonproductive cells (III C): 1

No. of untested cells (III D): 106 50th fractile

Minimum possible number of untested cells (III E1): 26 100th fractile

Maximum possible number of untested cells (III E2): 217 0th fractile

Success ratio (0-1.0) (IV): .83

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(8)	(220)	580	(1050)	(1600)	2600

EUR Distribution and cell success ratio developed by FD Services for Grand Valley, Parachute, and Rulison fields

NOSR 1 & 3

Play Number & Name: Play 2008, Wasatch Gas Saturated

Source for Well Data: Petroleum Information : cumulative production to July of 1993

Comments: Pressure data is unavailable.
Plot of EUR vs. Initial Production Date does not support a learning curve.
EUR calculations reflect current spacing.

Screen Data: Wasatch Formation
Rulison and Parachute Fields
Initial production date < 1990
Active or inactive status

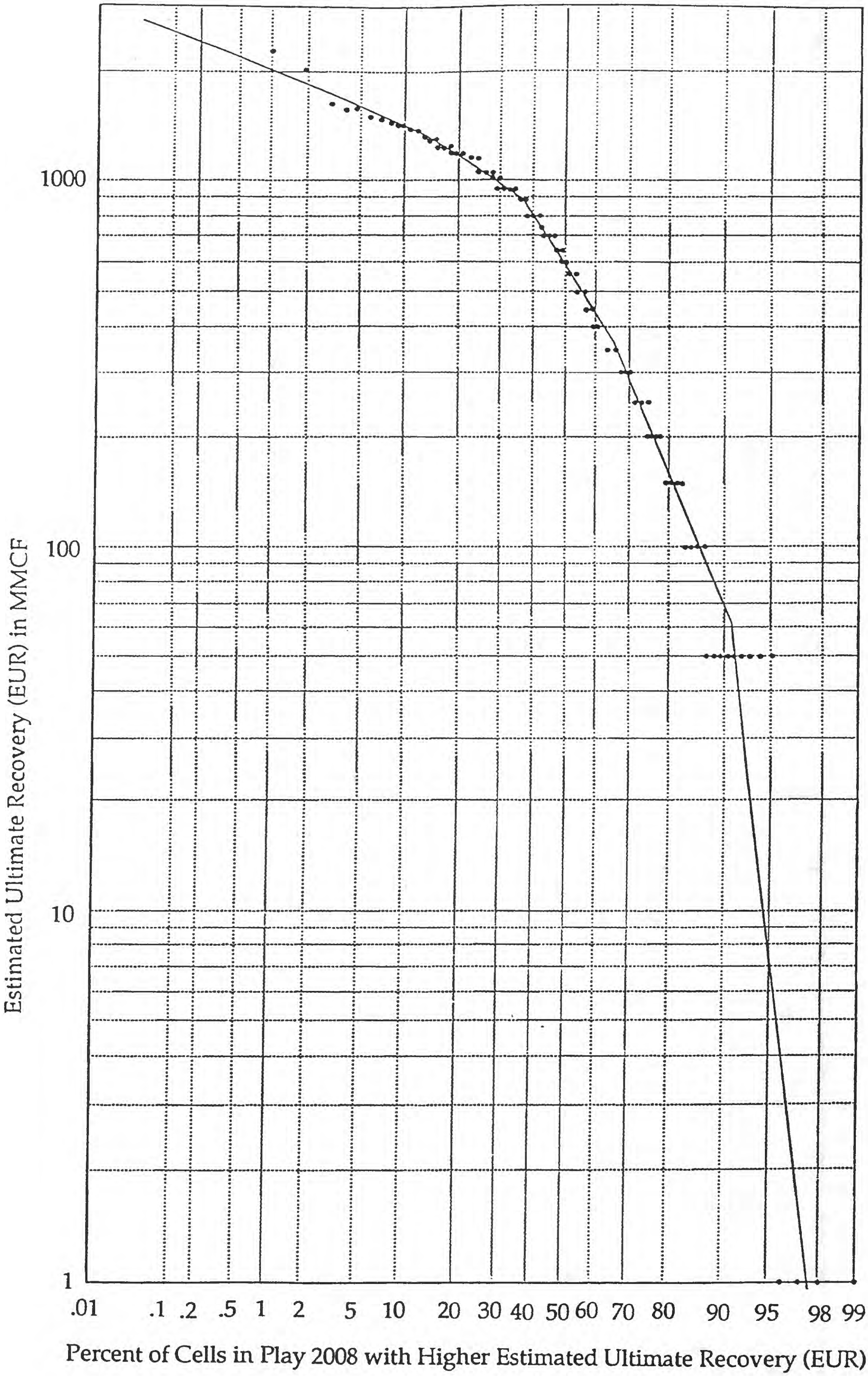
Total number of wells that meet screening criteria: 30

Total number of wells used in the EUR Distribution: 24 (Rulison Field only)

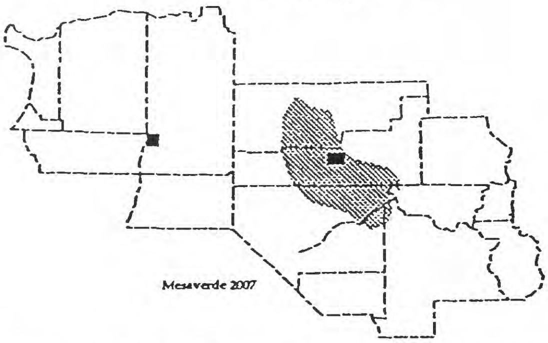
Calculation of EUR: Decline Curve Analysis (DCA)
Assumptions:
No back pressure effects, radial flow, producing in the depletion stage, cumulative effects of factors altering production in the history of the well = cumulative effects in the future,etc.
Segmented exponential declines are used.
Life of a well is assumed to be 35 years maximum or will produce until an economic limit of 10 MCFD is reached. If necessary, a constant decline rate is imposed during the last five years to force the production rate to the economic limit of 10 MCFD in year 35.
Inactive wells remain idle.
Downtime is assumed negligible in the future.

EUR Probability Distribution:

Fractile	EUR (MMCF)
0	2200
5	1400
25	720
50	380
75	95
95	14
100	0


Estimated Ultimate Recovery (EUR) in MMCF
1000
100
10
1
.01
.1
.2
.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent of Cells in Play 2008 with Higher Estimated Ultimate Recovery (EUR)

NOSR 1 & 3 Play 2007



USGS-DOE NOSR 1 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Piceance

Date: 4/20/94 Play Name, No.: Mesaverde Gas-Saturated, 2007

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 80 (160-40) acres; ______ mi^2 (acres/640)

Area of NOSR 1: 37,500 (III A2): Total no. of cells (III A3): 469

No. of productive cells in play (III B): 0 No. of nonproductive cells in play (III C): __

No. of untested cells in NOSR 1 (III D): 469 50th fractile

Minimum possible number of untested cells in NOSR 1 (III E1): 234 100th fractile

Maximum possible number of untested cells in NOSR 1 (III E2): 938 0th fractile

Success ratio of (play) (0-1.0) (IV): .71

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(700)	(1250)	1700	(2700)	3000	(4000)

EUR Distribution and Cell success ratio developed by FD Services for Grand Valley, Parachute, and Rulison fields. Includes "behind-the-pipe gas" and gas from the Cameo Coal sequence.

USGS-DOE NOSR 1 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Piceance

Date: 4/20/94 Play Name, No.: Mesaverde Gas-Saturated, 2007

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-40) acres; ______ mi^2 (acres/640)

Area of NOSR 1 37,500 acres (III A2): Total no. of cells (III A3): 234 at 160 spacing

No. of productive cells in play (III B): 354 No. of nonproductive cells in play (III C): 142

No. of untested cells in NOSR 1 (III D): 234 50th fractile

Minimum possible number of untested cells in NOSR 1 (III E1): 59 100th fractile

Maximum possible number of untested cells in NOSR 1 (III E2): 472 0th fractile

Success ratio of (play) (0-1.0) (IV): .71

EUR probability distribution (V*):

	Minimum	Median	Max				
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(700)	(1250)	1700	(2700)	3000	(4000)

EUR Distribution and Cell success ratio developed by FD Services for Grand Valley, Parachute, and Rulison fields. Includes "behind-the-pipe gas" and gas from the Cameo Coal sequence.

USGS-DOE NOSR 3 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta-Piceance

Date: 3/26/94 Play Name, No.: Mesaverde Gas-Saturated, 2007

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

160 records at 1t 160 acre spacing = 160 cells tested

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 80 (160-40) acres; ______ mi² (acres/640)

Area of NOSR 3 18,040 acres (III A2): Total no. of cells (III A3): _225

No. of productive cells in play (III B): 3 No. of nonproductive cells in play(III C): 1

No. of untested cells (III D): 221 50th fractile

Minimum possible number of untested cells (III E1): 111 100th fractile

Maximum possible number of untested cells (III E2): 443 0th fractile

Success ratio of play (0-1.0) (IV): .71

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th)	0th
EUR (BO or MMCF)	0	(700)	(1250)	1700	(2700)	3000	(4000)

EUR Distribution and Cell success ratio developed by FD Services for Grand Valley, Parachute, and Rulison fields. Includes "behind-the-pipe gas" and gas from the Cameo Coal sequence.

17720 acres untested

USGS-DOE NOSR 3 ASSESSMENT
DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: Tom Fouch Province Name, No.: Uinta-Piceance

Date: 3/26/94 Play Name, No.: Mesaverde Gas-Saturated, 2007

(codes in parenthesis, such as IV B, refer to the procedure outline)

Play Type: -__Oil or _X_Gas (I C) _X_Confirmed or __Hypothetical (IV A)

160 records at 1t 160 acre spacing = 160 cells tested

Play Probability (0-1.0) (II A): 1 Stop here if play does not exceed 0.10 (II B)

Cells (III) Cell Size (III A1): 160 (640-40) acres; ______ mi² (acres/640)

Area of NOSR 3 18,040 acres (III A2): Total no. of cells (III A3): 113 @ 160 acres

No. of productive cells in play (III B): 354 No. of nonproductive cells in play(III C): 142

No. of untested cells (III D): 110 50th fractile

Minimum possible number of untested cells (III E1): 27 100th fractile

Maximum possible number of untested cells (III E2): 440 0th fractile

Success ratio of (play) (0-1.0) (IV): .71

EUR probability distribution (V*):

	Minimum			Median			Max
Fractile:	100th	(95th)	(75th)	50th	(25th)	(5th	0th
EUR (BO or MMCF)	0	(700)	(1250)	1700	(2700)	3000	(4000)

EUR Distribution and Cell success ratio developed by FD Services for Grand Valley, Parachute, and Rulison fields. Includes "behind-the-pipe gas" and gas from the Cameo Coal sequence.

NOSR 1 & 3

Play Number & Name: **Play 2007, Mesaverde**

Source for Well Data: Petroleum Information : cumulative production to July of 1993

Comments: Pressure data is unavailable.
Plot of EUR vs. Initial Production Date does not support a learning curve.
EUR calculations reflect current spacing.

Screen Data: Piceance Basin
Mesaverde Formation
Fields - Grand Valley, Rulison, Parachute, Coon Hollow, Sheep Creek, Logan Wash, Buzzard Creek, Hells Gulch, Sulphur Creek, Debeque, Divide Creek, Mam Creek, Plateau
Initial production date < 1989
Active or inactive status

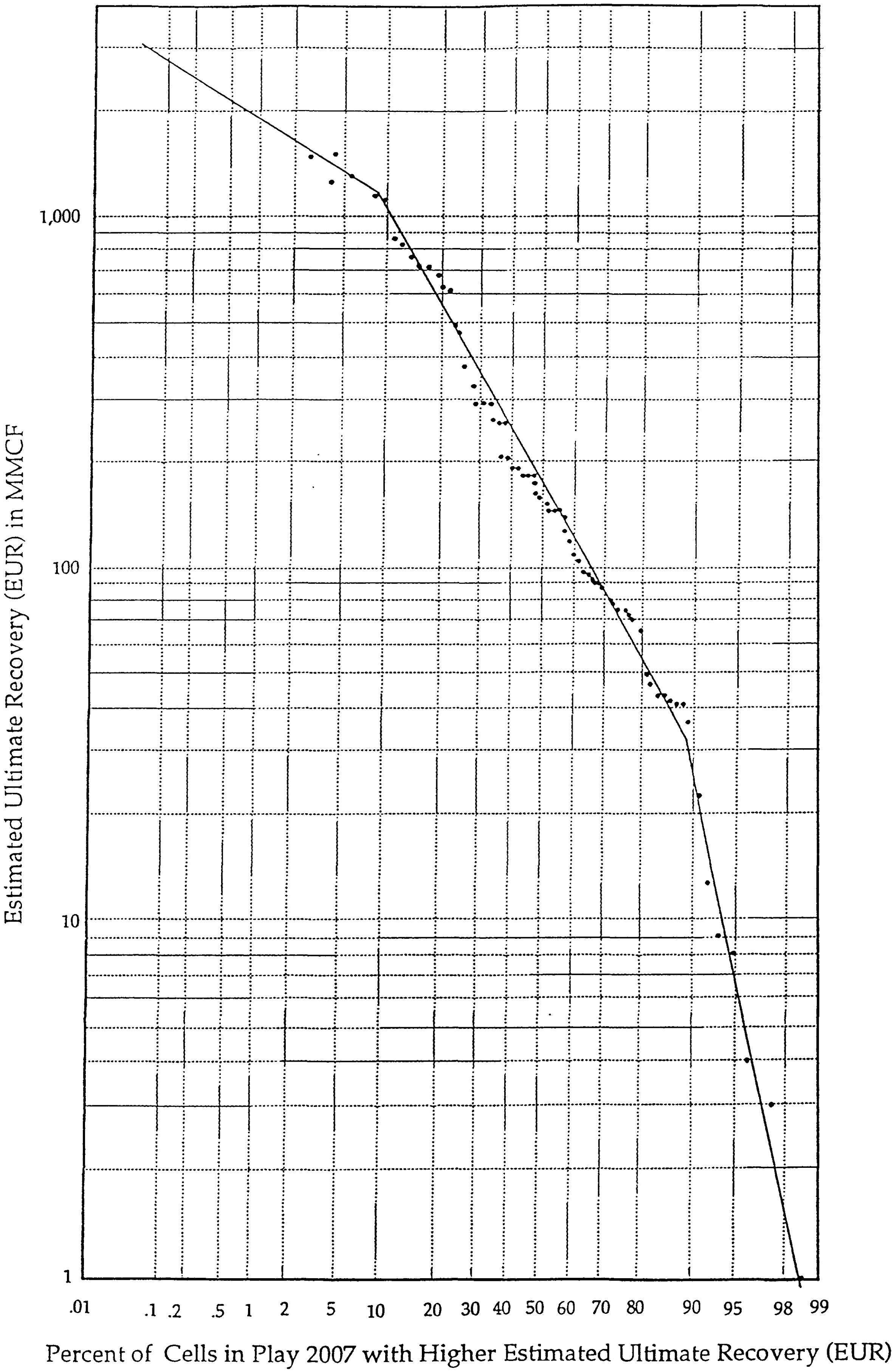
Total number of wells that meet screening criteria: 87

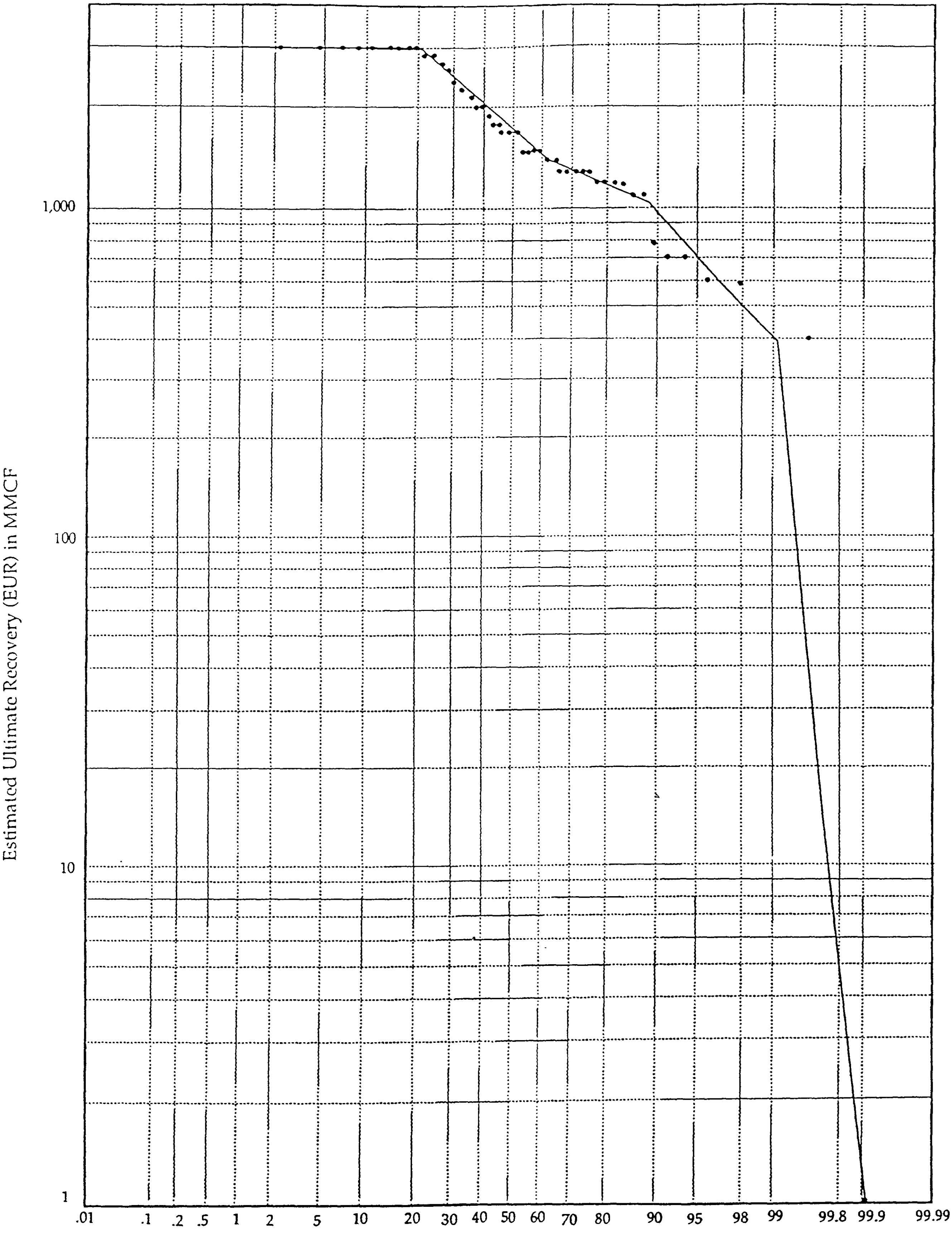
Total number of wells used in the EUR Distribution: 74

Calculation of EUR: Decline Curve Analysis (DCA)
Assumptions:
No back pressure effects, radial flow, producing in the depletion stage, cumulative effects of factors altering production in the history of the well = cumulative effects in the future, etc.
Segmented exponential declines are used.
Life of a well is assumed to be 35 years maximum or will produce until an economic limit of 10 MCFD is reached. If necessary, a constant decline rate is imposed during the last five years to force the production rate to the economic limit of 10 MCFD in year 35.
Inactive wells remain idle.
Downtime is assumed negligible in the future.

EUR Probability Distribution:

Fractile	EUR (MMCF)
0	2000
5	1350
25	440
50	170
75	70
95	7
100	0


Estimated Ultimate Recovery (EUR) in MMCF
1,000
100
10
1
.01
.1
.2
.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Percent of Cells in Play 2007 with Higher Estimated Ultimate Recovery (EUR)



Percent of Cells in Play 2007 (Mesaverde) with Higher Estimated Ultimate Recovery (EUR);
(includes behind pipe reserves & gas in the Cameo Coal)

APPENDIX B

SEISMIC DATA ACQUISITION AND REPROCESSING

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SEISMIC DATA ACQUISITION AND REPROCESSING

Recording Parameters

Two data sets were recorded on and adjacent to NOSR-2. One data set is composed of 8 lines (designated TRW-1 through TRW-8), originally recorded for TRW corporation in 1981 and owned by the Dept. of Energy with full publication rights. The other data set is composed of 4 lines (designated ADC-1, 2, 4, and 5), originally recorded for Champlin Oil in 1979 and purchased by the Dept. of Energy, with limited publication rights (see below).

The ADC data set has, in general, better signal to noise ratio and is somewhat easier to interpret than the TRW data set. This enhanced data quality of the ADC lines is most likely due to their being recorded with twice the number of recording channels and a 3000' greater source-receiver offset than that of the TRW lines. Table JM 1gives a summary of the main recording parameters for each data set.

Data Set:	TRW	ADC
# of Recording Channels:	48	96
Energy Source:	Vibroseis	Vibroseis
Geophone Spacing:	220 ft.	220 ft.
Source Spacing:	440 ft.	440 ft.
Nominal Fold:	12	24
Sweep Frequencies:	58-12 HZ	56-14 HZ
Sweep Length:	14 s	16 s
Near/Far Offset:	660/8,360 ft.	990/11,330 ft.
Correlated Record Length:	5 s	4 s
Recording Instrument:	DFS III	SERCEL

Table JM 1: Recording parameters for the seismic lines.

Data Processing

All of the lines were reprocessed using a standard processing sequence that included spiking deconvolution, surface-consistent residual statics analysis, and wave-equation migration (applied after stacking). Where necessary, crooked line geometry was applied in areas where the recording line deviated significantly from a straight line. The TRW data set was prewhitened before cross correlation (Coruh and Costain, 1983). Processing parameters were kept as consistent as possible and were tied at line intersections to facilitate the interpretation.

Prior to migration, the data were shifted to a horizontal datum of +6,600 ft. above sea level and the ADC lines were shifted to a horizontal datum of +6000 ft. above sea level. The velocity used for both datum shifts was 10,000 ft/sec.; thus, there is a 120 ms bulk shift between datums of the two data sets. The velocities used for migration were determined as follows: each stacked section was migrated a number of times, each time using a different, time- and space- invariant velocity function (called constant velocity migration, or CVM). A migration velocity model that varied in space and time was then constructed from the CVM's and the data were migrated using that model.

USGS/DOE Publication Rights

These ADC seismic lines are proprietary industry profiles, purchased by the U.S. Department of Energy with limited publication rights. These data were purchased from Union Pacific Resources Company, through Geodata Corporation. The data may be shown in page size illustrations without shotpoints.

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APPENDIX C

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RESOURCE ASSESSMENT OF THE NAVAL OIL SHALE RESERVES #1 AND #3 CONVENTIONAL PENNSYLVANIAN-PERMIAN PLAY - A RATIONALE

W.C. Butler

GENERAL STATEMENT

This hypothetical hydrocarbon play in the Pennsylvanian-Permian stratigraphic section is highly speculative; strata of this age are essentially unexplored by drilling in this part of the Piceance basin. Hydrocarbon-water contacts are assumed in this play, i.e., if the reservoirs were gas saturated, this method of assessment would not be appropriate. The NOSR 1 & 3 area is outside the play area but is assesed here because of the interest in the potential under the Reserves. This assessment combines both Naval Oil Shale Reserves #1 (37,550 acres) and #3 (18,040 acres) because of their common boundary, overall relatively small areas, and splintered arrangement, i.e., small parcels of each NOSR are juxtaposed to each other. However, if necessary at a later time, NOSR #3 may be considered a cluster of the total assessed acreage with resources allocated only to it.

Non-associated gas is the stable hydrocarbon species expected in the area. It was assessed using the engineering-model FASPU (Fast Appraisal System for Petroleum - Universal version) computer program (Crovelli and Balay, 1986, 1988, 1990). This assessment program was made available to scientists and engineers of the Department of Energy (Washington, D.C. and Casper, WY.) during meetings with the U.S. Geological Survey in 1993. Although the reservoirs will be tight, it is because individual potential traps with gas-water contacts, if present, can be approximately delineated, that the area is assessed using this conventional assessment method.

All input data to the FASPU program are presented in the computer printouts (exhibit A). The estimated undiscovered recoverable resources are listed in the same attached printout (figure FB-1) under the unconditional play probability category. Because the targets in this area are so deep, the estimated resources calculated by this model cannot be defined as economically recoverable at this time. However, an assessment using conventional methodology is important and should be done in order to compare with other unconventional (continuous gas saturation "bubbles") assessment methodologies presented in this report. Secondly, it is done in order to anticipate future questions about the potential Upper Paleozoic resource base which is very significant in the northern Piceance basin.

In addition to the conventional-type hydrocarbon accumulation model, another assumption is made that the structure of the potential Upper Paleozoic reservoirs reflects the present-day basement structure. Precambrian basement blocks (horsts, grabens, and half-grabens) owe their origin to pre-existing zones of weakness established during Precambrian time. These blocks were rearranged during Late Paleozoic tectonism creating the Ancestral Rockies, and then overprinted by the Late Mesozoic to Early Cenozoic Laramide orogeny.

The nearest production from reservoirs of this age is 35-40 miles to the northwest and north (Douglas Creek, Wilson Creek, and Thornburg fields). However, the primary reservoir rocks in these fields are not well developed or preserved under NOSR 1 and 3. Although the marginal play probability (presence of charge, source rock, migration, timing, reservoir rock, seals, and trapping) is fairly low, the conditional play probability that at least one accumulation (drillable prospect) of minimum size exists is somewhat lower. The success ratio of finding Pennsylvanian-Permian production elsewhere in the Piceance basin was estimated in order to provide a reasonable play probability to apply to the overall assessment. This however, was not really representative of the NOSR area because of the lack of testing (statistical sampling) of the section by drilling, and because of the extreme drilling depths at NOSRs #1 and #3. A north-south strip of oil-saturated outcrops, plus drilling shows (oil swabbed from borehole), have been reported in the White River uplift area within just a few miles northeast of NOSR #3 on the east side of the Grand Hogback fault. Although the structural framework changes over a short distance from the uplift to the NOSR area, these hydrocarbon occurrences suggests that petroleum could be "in the system" fairly close to the assessment area.

General Stratigraphic Framework

The overall Pennsylvanian-Permian stratigraphic section at NOSRs 1&3 consists of marginal-marine blanket redbed sandstones shed north-northeastward off the rising Uncompahgre Mountains. These arkosic to subarkosic units are about 3,000 to more than 4,000 feet thick, increasing in a general east-northeast direction. The redbed parts of the section generally are not good quality reservoirs. Most of the upper part of the stratigraphic section includes the continental Weber(?)-Maroon Formations about 1,000 to 2,000 feet thick from west to east, respectively. The Weber Formation is generally a light-colored to gray, clean well-sorted eolian sandstone providing excellent reservoir qualities. An important consideration is that the quality of Pennsylvanian-Permian reservoirs generally deteriorates from the Colorado-Utah border eastward to the Eagle basin. At Rangely field, the largest known oil accumulation in the U.S. Rockies, 50 miles northwest of NOSR #1, the ultimate oil recovery is expected to be over 955 million barrels from depths of 5,200-6,600 feet. Production is from the "Schoolhouse Member" or tongue of the Weber Formation which is a diagenetic facies of the Maroon Formation. The latter is a predominately red poorly-sorted arkosic clastic unit of shaly sandstone to sandy shale and limey mudstone totaling about 400-1200 feet thick. The marine Morgan Formation may be in part a temporal equivalent to the Maroon Formation; it disconformably underlies the Maroon Formation and may interfinger into the assessment area. This disconformity may have significance in locally trapping hydrocarbons in this play.

Subjacent to, and interbedded with, the Maroon Formation is the Minturn Formation of 1,000-2,000 feet of impure poorly-sorted clastic strata and lesser carbonate strata. These carbonates may also serve as potential reservoirs and have better porosity than the tight sandstones. Gypsum lenses of the Eagle Valley Formation, an evaporite facies of the Maroon and Minturn Formations, may extend westward into the assessment area.

Potential source rocks may include the Belden Shale, a limy shale up to 400 feet thick, if present, near the base of the Pennsylvanian section. Other potential source rocks, if present, may include the Park City-Phosphoria Formations, as much as 200 ft thick near the top of this play reservoir. The source of petroleum at Rangely, whether the Belden Shale or the Park City-Phosphoria Formations, is questionable and debated among geologists who work the Piceance basin.

This play is based on the premise that the Maroon Fm.-Minturn Formations and possibly Weber reservoirs do indeed exist in the NOSR 1&3 area at depths between 15,000 and 20,000 feet. Long-range migration of petroleum is not required to fill potential traps. Thermal dry gas is the principal hydrocarbon species that would be chemically stable at these depths. As such, drilling for the Upper Paleozoic targets may not be economically feasible in the deeper parts of the Piceance basin; if the probability for discovering oil was higher, the targets would be more attractive for exploration. Thickness of the primary pay zone is projected to be about >150 feet; porosity is estimated to be fairly tight at below 10 percent, probably averaging 5-6 percent.

General Structural Framework

Thickness of the Phanerozoic strata in the NOSR part of the Piceance basin is, based on seismic data, believed to be as much as 5,000 feet thicker than depicted on previous regional maps, such as in Mallory (1972), Tweto (1983), and Spencer and Wilson (1988). Seismic data also help define areas of drillable prospects within the play outline. The play is primarily a structural play, although a stratigraphic component may be developed. Various models of fault-and-fold geometry can fit our existing data, and thus we present one example only. Data for the regional basement surface structure was taken from unpublished work by Ogden Tweto, U.S. Geological Survey. This surface was modified using seismic lines processed and interpreted for this study. In this conventional resource model, the faults must be assumed to be sealed in the lowest part of the basin. Paleozoic structure was interpreted from 4 seismic lines in the assessment area: 1) Grant NORPAC Tensor #1 and #3, 2) Seis-Port Explorations, Inc., and 3) Celsius Energy Corporation (I-70 line from Rifle to Parachute). See Waechter and Johnson (1986, plate 2) for their interpretation of seismic line #4.

To invoke only stratigraphic trapping (possible along the upthrown side of the basement blocks, but at a lesser degree of certainty) would make the play too speculative to consider. Disconformities and porosity-permeability pinchout traps are possible where redbeds (seals) interfinger with cleaner sands, but structure seems to be a necessary ingredient for most of the other Piceance basin accumulations similar to this play.

Structural traps flank the northwest-trending Precambrian horsts (paleo-highs) as depicted on seismic line cross-sections. The displacement of the basement blocks is not simple; the data suggest that movement has been intermittent with different senses of adjustments (throw) throughout their long history. Movement along some of the bounding normal faults seems to be "up" at one end of the block and "down" at the other end, as in the analogous movement of piano keys. Rotation of these blocks probably occurred around both their northeast- and northwest-trending axes. The horsts may have either a reduced or a completely missing Pennsylvanian-Permian section due to erosion; drillable prospects are therefore limited to the flanks of these structures.

The primary high-angle basement faults trend almost due northwest and secondary faults trend northeast. The northeast-trending faults are undoubtedly longer on the map view than conceptually depicted, but their true extent is unknown at present. Faults seem to parallel the stream/river drainages, that is, they may be expressed in the geomorphology of the assessment area. If some of the faults dip as much as 70 degrees, which is shown by seismic data, then their ground surface offset/expression may be from 4,700 to 7,300 feet, generally increasing from southwest to northeast with the increasing depth to basement. This assumes the faults maintain their integrity and migrate upward and intersect the ground surface. Strata, however, may be draped over the faults exhibiting folds, or may be exhibited by a zone of fracturing rather than a single fault. Major fold structures at the Dakota Sandstone level trend about N39°-41°W south of the assessment area near Parachute and in the southwestern part of the NOSR area. Orientations for the five ground surface fracture directions are: 1) N39°-58°W, 2) N9°-11°E, 3) N20°-42°E, 4) N65°-76°E, and 5) N1°E-N13°W. In the general assessment area, the high-angle major basement fault, GarMesa, has an offset as much as 5,500 feet, and the low-angle Grand Hogback thrust shows a displacement of 15,000-16,000 feet. Only the faults with large displacements are readily apparent and mappable given the scarcity of subsurface information below the Cretaceous Dakota Sandstone.

Salt tectonics may also play a complicating role in the structural configuration of the Pennsylvanian and younger strata, particularly in the eastern part of the Colorado Naval Reserves. As additional subsurface information becomes available with additional drilling and seismic data, the accuracy of the present structural model will undoubtedly improve significantly. As noted above, there are several solutions that currently satisfy the gross basement structure data (modification is possible within limits), and we acknowledge that the model presented here is just one example until additional information becomes available.

Quantitative Assessment Of Undiscovered Recoverable Non-Associated Gas

Input values to the FASPU program for volume parameters, such as trap closures and reservoir thicknesses, are derived from the basement structure map (BP-#5). It is assumed, for this exercise, that structural closure in the basement might be reflected in the overlying Pennsylvanian-Permian strata. There are no boreholes that penetrate these potential reservoirs in the area of NOSRs #1 and #3. Closure is created by the faults that cut basement rock. A distribution of seven volume attributes, from fractile 100 to 0, was established by calculating the area that could be considered "available trap" from the following basement map elevations:

FRACTILE	STRUCTURE CONTOUR	ACRES OF TRAP PER ELEVATION INTERVAL	CUMULATIVE TRAP ACRES INTERVAL
F100	-15,000 to -14,000 FT	1,645	1,645
F95	-15,500 to -15,000 FT	1,766	3,411
F75	-15,750 to -15,500 FT	1,850	5,261
F50	-16,500 to -16,000 FT	800	6,061
F25	-17,000 to -16,500 FT	3,526	9,587
F5	-17,500 to -17,000 FT	7,002	16,589
F0	-18,250 to -17,500 FT	13,619	30,208

Results of undiscovered, technologically-recoverable, but not economic, resources from the FASPU Assessment program for this play are given below, as well as in EXHIBIT A. They are presented as five scenarios. Slight variations in play attributes, from conservative (pessimistic) to liberal (optimistic), were used to construct the scenarios. Overall values for the geologic variable included these ranges: reservoir thickness, 25-500 ft; porosity, 1-12%; trap fill, 5-75%; hydrocarbon saturation, 50-85%; and recovery factor, 8-15%. The reader can thus judge which scenario best fits his/her own prejudice, whether it is based on "hard data" or intuition. The exercise can be viewed as a Delphi assessment (by committee) with five experts giving their own range of input values. Fractile values indicate AT LEAST the amount shown. F50 is the median value.

Scenario #1: Unconditional Results Using Very Pessimistic Input Values.

FRACTILE	ESTIMATED NON-ASSOCIATED GAS BILLIONS OF CUBIC FEET	
F95	0	
F75	0	
F50 (most likely)	0	Mean = 0.356
F25	0	
F5	0	

The risk of drilling a dry hole is: 0.978
The yield factor at F50 is: 562,120 cubic feet per acre

Scenario #2: Unconditional Results Using Pessimistic Input Values.

FRACTILE	ESTIMATED NON-ASSOCIATED GAS BILLIONS OF CUBIC FEET	
F95	0	
F75	0	
F50 (most likely)	0	Mean = 1.637
F25	0	
F5	9.745 (1 chance in 20 this amount is present)	

The risk of drilling a dry hole is: 0.923
The yield factor at F50 is: 562,120 cubic feet per acre

Scenario #3: Unconditional Results Using Moderate Input Values.

FRACTILE	ESTIMATED NON-ASSOCIATED GAS BILLIONS OF CUBIC FEET	
F95	0	
F75	0	
F50 (most likely)	0	Mean = 4.385
F25	0	
F5	27.988	

The risk of drilling a dry hole is: 0.836
The yield factor at F50 is: 562,120 cubic feet per acre

Scenario #4: Unconditional Results Using Optimistic Input Values.

FRACTILE	ESTIMATED NON-ASSOCIATED GAS BILLIONS OF CUBIC FEET	
F95	0	
F75	0	
F50 (most likely)	0	Mean = 13.970
F25	0	
F5	79.985	

The risk of drilling a dry hole is: 0.814
The yield factor at F50 is: 646,660 cubic feet per acre

Scenario #5: Unconditional results using very optimistic input values.

FRACTILE	ESTIMATED NON-ASSOCIATED GAS BILLIONS OF CUBIC FEET	
F95	0	
F75	0	
F50 (most likely)	0	Mean = 17.137
F25	14.646	
F5	92.196	

The risk of drilling a dry hole is: 0.802
The yield factor at F50 is: 480,960 cubic feet per acre

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EXHIBIT A

FASPU - FAST APPRAISAL SYSTEM FOR PETROLEUM (UNIVERSAL)

COMPUTER PROGRAM

INPUT AND OUTPUT DATA

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EXHIBIT A1 - MOST PESSIMISTIC SCENARIO (#1)

FASP:UE 90.7 03/26/94 12:45:20 NOR13PLZC.DAT Run # 41

PLAY : PENNSYLVANIAN-PERMIAN CONVENTIONAL GAS PROJECT : NAVAL OIL SHALE RESERVES 1&3, PICEANCE BASIN, NW COLORADO

INPUT SUMMARY

Play Attribute Probabilities				Prospect Attribute Probabilities		
Charge: Hydrocarbon Source	Traps	~~Migration~~	Potential Res. Facies	Trapping Mechanism	Effective Porosity	Hydrocarbon Accumulation
0.500	0.500	1.000	0.600	0.600	0.600	0.400

Marginal Play Probability	Conditional Deposit Probability	Reservoir Lithology	Hydrocarbon Prob. Gas	Hydrocarbon Prob. Oil	Recovery Factors % Oil	Recovery Factors % Free Gas
0.150	0.144	1	1.000	0.000	0.00	8.00

Geologic Variables	F100	F95	F75	F50	F25	F05	F0
Closure (thousand acres)	1.64500	3.41100	5.26100	6.06100	9.58700	16.5890	30.2080
Thickness (feet)	25.0000	50.0000	100.000	150.000	200.000	300.000	500.000
Porosity (percent)	1.00000	3.00000	5.00000	6.00000	7.00000	9.00000	11.0000
Trap Fill (percent)	5.00000	15.0000	20.0000	25.0000	30.0000	45.0000	60.0000
Depth (thousand feet)	17.0000	18.5000	20.0000	23.5000	24.0000	25.0000	26.0000
HC Saturation (percent)	50.0000	55.0000	60.0000	65.0000	70.0000	75.0000	80.0000
Number of Prospects	1	1	1	1	1	1	1

GEOLOGIC VARIABLES and PROBABILITIES OF OCCURRENCE

	Mean	Std. Dev.
Closure	8.15237	4.94974
Thickness	161.875	86.8105
Porosity	6.00000	1.87972
Trap Fill	26.6250	9.93023
Depth	22.2875	2.30322
HC Saturation	65.0000	6.58231
Prospects	1.00000	0.0
Accumulations	0.14400	0.35109

"Dry Hole" Risk = 0.9784

Prob. (Depth <= 7500 feet) = -0.3167

RESOURCE	Oil	NA Gas	AD Gas	Gas
Cond. Prob. Prospect has	0.0000	0.1440	0.0000	0.1440
Cond. Play Prob.	0.0000	0.1440	0.0000	0.1440
Uncond. Play Prob.	0.0000	0.0216	0.0000	0.0216

Variable	Function	A	B	D(feet)	A	B	D(feet)	A	B	D(feet)	A	B
Pe (PSI)	Linear	0.4200000	14.700000									
T (Deg Rankine)	Linear	0.0200000	510.00000									
Rs (Thousand CuFt/BBL)	Linear	0.000	1.0000000									
Bo (no units)	Linear	0.000	1.0000000									
Z (no units)	Linear	0.000	1.0000000									

	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Millions of BBLs)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Billions of CuFt)							
Number of Accumulations	0.14400	0.35109	0	0	0	0	1
Accumulation Size	17.0568	19.7390	2.44777	5.98851	11.1522	20.7684	50.8101
Cond. Prospect Potential	2.45618	9.59001	0.0	0.0	0.0	0.0	16.0258
Cond. (B) Play Potential	17.0568	19.7390	2.44777	5.98851	11.1522	20.7684	50.8101
Cond. (A) Play Potential	2.45618	9.59001	0.0	0.0	0.0	0.0	16.0258
→ Uncond. Play Potential	0.36843	3.81634	0.0	0.0	0.0	0.0	0.0
ASSOCIATED-DISSOLVED GAS (Billions of CuFt)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAS (Billions of CuFt)							
Number of Accumulations	0.14400	0.35109	0	0	0	0	1
Accumulation Size	17.0568	19.7390	2.44777	5.98851	11.1522	20.7684	50.8101
Cond. Prospect Potential	2.45618	9.59001	0.0	0.0	0.0	0.0	16.0258
Cond. (B) Play Potential	17.0568	19.7390	2.44777	5.98851	11.1522	20.7684	50.8101
Cond. (A) Play Potential	2.45618	9.59001	0.0	0.0	0.0	0.0	16.0258
Uncond. Play Potential	0.36843	3.81634	0.0	0.0	0.0	0.0	0.0

YIELD FACTORS	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Thousand BBL / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Million CuFt / Acre-Ft)	0.60681	0.24672	0.29539	0.43177	0.56212	0.73183	1.06971
DISSOLVED GAS (Million CuFt / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXHIBIT A2 - PESSIMISTIC SCENARIO (#2)

FASP:UE 90.7 03/26/94 13:03:53 NOR13PLZC.DAT Run # 22

PLAY : PENNSYLVANIAN-PERMIAN CONVENTIONAL GAS PROJECT : NAVAL OIL SHALE RESERVES 1&3, PICEANCE BASIN, NW COLORADO

INPUT SUMMARY

Play Attribute Probabilities				Prospect Attribute Probabilities		
Charge: Hydrocarbon Source	Traps	~~Migration~~	Potential Res. Facies	Trapping Mechanism	Effective Porosity	Hydrocarbon Accumulation
0.600	0.700	1.000	0.750	0.750	0.650	0.500

Marginal Play Probability	Conditional Deposit Probability	Reservoir Lithology	Hydrocarbon Prob. Gas	Hydrocarbon Prob. Oil	Recovery Factors % Oil	Recovery Factors % Free Gas
0.315	0.244	1	1.000	0.000	0.00	10.00

Geologic Variables	F100	F95	F75	F50	F25	F05	F0
Closure (thousand acres)	1.64500	3.41100	5.26100	6.06100	9.58700	16.5890	30.2080
Thickness (feet)	25.0000	50.0000	100.000	150.000	200.000	300.000	500.000
Porosity (percent)	1.00000	3.00000	5.00000	6.00000	7.00000	9.00000	11.0000
Trap Fill (percent)	5.00000	15.0000	20.0000	25.0000	30.0000	45.0000	60.0000
Depth (thousand feet)	17.0000	18.5000	20.0000	23.5000	24.0000	25.0000	26.0000
HC Saturation (percent)	50.0000	55.0000	60.0000	65.0000	70.0000	75.0000	80.0000
Number of Prospects	1	1	1	1	1	1	1

GEOLOGIC VARIABLES and PROBABILITIES OF OCCURRENCE

	Mean	Std. Dev.
Closure	8.15237	4.94974
Thickness	161.875	86.8105
Porosity	6.00000	1.87972
Trap Fill	26.6250	9.93023
Depth	22.2875	2.30322
HC Saturation	65.0000	6.58281
Prospects	1.00000	0.0
Accumulations	0.24375	0.42934

"Dry Hole" Risk = 0.9232
Prob. (Depth <= 7500 feet) = -0.3167

RESOURCE	Oil	NA Gas	AD Gas	Gas
Cond. Prob. Prospect has	0.0000	0.2438	0.0000	0.2438
Cond. Play Prob.	0.0000	0.2438	0.0000	0.2438
Uncond. Play Prob.	0.0000	0.0768	0.0000	0.0768

Variable	Function	A	B	D(feet)	A	B	D(feet)	A	B	D(feet)	A	B
Pe (PSI)	Linear	0.4200000	14.700000									
T (Deg Rankine)	Linear	0.0200000	510.00000									
Rs (Thousand CuFt/BBL)	Linear	0.000	1.0000000									
Bo (no units)	Linear	0.000	1.0000000									
Z (no units)	Linear	0.000	1.0000000									

Depth Floor (feet) = 7500.00

	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Millions of BBLs)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Billions of CuFt)							
Number of Accumulations	0.24375	0.42934	0	0	0	0	1
Accumulation Size	21.3210	24.6738	3.05972	7.48564	13.9402	25.9604	63.5126
Cond. Prospect Potential	5.19699	15.2378	0.0	0.0	0.0	0.0	29.8301
Cond. (B) Play Potential	21.3210	24.6738	3.05972	7.48564	13.9402	25.9604	63.5126
Cond. (A) Play Potential	5.19699	15.2378	0.0	0.0	0.0	0.0	29.8301
→ Uncond. Play Potential	1.63705	8.88638	0.0	0.0	0.0	0.0	9.74537
ASSOCIATED-DISSOLVED GAS (Billions of CuFt)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAS (Billions of CuFt)							
Number of Accumulations	0.24375	0.42934	0	0	0	0	1
Accumulation Size	21.3210	24.6738	3.05972	7.48564	13.9402	25.9604	63.5126
Cond. Prospect Potential	5.19699	15.2378	0.0	0.0	0.0	0.0	29.8301
Cond. (B) Play Potential	21.3210	24.6738	3.05972	7.48564	13.9402	25.9604	63.5126
Cond. (A) Play Potential	5.19699	15.2378	0.0	0.0	0.0	0.0	29.8301
Uncond. Play Potential	1.63705	8.88638	0.0	0.0	0.0	0.0	9.74537

YIELD FACTORS	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Thousand BBL / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Million CuFt / Acre-Ft)	0.60681	0.24672	0.29539	0.43177	0.56212	0.73183	1.06971
DISSOLVED GAS (Million CuFt / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXHIBIT A3 - MODERATE SCENARIO (#3)

FASP:UE 90.7 03/26/94 13:16:34 NOR13PLZC.DAT Run # 31

PLAY : PENNSYLVANIAN-PERMIAN CONVENTIONAL GAS PROJECT : NAVAL OIL SHALE RESERVES 1&3, PICEANCE BASIN, NW COLORADO

INPUT SUMMARY

Play Attribute Probabilities				Prospect Attribute Probabilities		
Charge: Hydrocarbon Source	Traps	~~Migration~~	Potential Res. Facies	Trapping Mechanism	Effective Porosity	Hydrocarbon Accumulation
0.750	0.750	1.000	0.800	0.750	0.750	0.650

Marginal Play Probability	Conditional Deposit Probability	Reservoir Lithology	Hydrocarbon Prob. Gas	Hydrocarbon Prob. Oil	Recovery Factors % Oil	Recovery Factors % Free Gas
0.450	0.366	1	1.000	0.000	0.00	12.50

Geologic Variables	F100	F95	F75	F50	F25	F05	F0
Closure (thousand acres)	1.64500	3.41100	5.26100	6.06100	9.58700	16.5890	30.2080
Thickness (feet)	25.0000	50.0000	100.000	150.000	200.000	300.000	500.000
Porosity (percent)	1.00000	3.00000	5.00000	6.00000	7.00000	9.00000	11.0000
Trap Fill (percent)	5.00000	15.0000	20.0000	25.0000	30.0000	45.0000	60.0000
Depth (thousand feet)	17.0000	18.5000	20.0000	23.5000	24.0000	25.0000	26.0000
HC Saturation (percent)	50.0000	55.0000	60.0000	65.0000	70.0000	75.0000	80.0000
Number of Prospects	1	1	1	1	1	1	1

GEOLOGIC VARIABLES and PROBABILITIES OF OCCURRENCE

	Mean	Std. Dev.
Closure	8.15237	4.94974
Thickness	161.875	86.8105
Porosity	6.00000	1.87972
Trap Fill	26.6250	9.93023
Depth	22.2875	2.30322
HC Saturation	65.0000	6.58281
Prospects	1.00000	0.0
Accumulations	0.36563	0.48160

"Dry Hole" Risk = 0.8355

Prob. (Depth <= 7500 feet) = -0.3167

RESOURCE	Oil	NA Gas	AD Gas	Gas
Cond. Prob. Prospect has	0.0000	0.3656	0.0000	0.3656
Cond. Play Prob.	0.0000	0.3656	0.0000	0.3656
Uncond. Play Prob.	0.0000	0.1645	0.0000	0.1645

Variable	Function	A	B	D(feet)	A	B	D(feet)	A	B	D(feet)	A	B
Pe (PSI)	Linear	0.4200000	14.700000									
T (Deg Rankine)	Linear	0.0200000	510.00000									
Rs (Thousand CuFt/BBL)	Linear	0.000	1.0000000									
Bo (no units)	Linear	0.000	1.0000000									
Z (no units)	Linear	0.000	1.0000000									

Depth Floor (feet) = 7500.00

	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Millions of BBLs)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Billions of CuFt)							
Number of Accumulations	0.36563	0.48160	0	0	0	1	1
Accumulation Size	26.6512	30.8422	3.82465	9.35705	17.4253	32.4505	79.3907
Cond. Prospect Potential	9.74436	22.6394	0.0	0.0	0.0	11.2176	47.8433
Cond. (B) Play Potential	26.6512	30.8422	3.82465	9.35705	17.4253	32.4505	79.3907
Cond. (A) Play Potential	9.74436	22.6394	0.0	0.0	0.0	11.2176	47.8433
→ Uncond. Play Potential	4.38496	15.9420	0.0	0.0	0.0	0.0	27.9880
ASSOCIATED-DISSOLVED GAS (Billions of CuFt)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAS (Billions of CuFt)							
Number of Accumulations	0.36563	0.48160	0	0	0	1	1
Accumulation Size	26.6512	30.8422	3.82465	9.35705	17.4253	32.4505	79.3907
Cond. Prospect Potential	9.74436	22.6394	0.0	0.0	0.0	11.2176	47.8433
Cond. (B) Play Potential	26.6512	30.8422	3.82465	9.35705	17.4253	32.4505	79.3907
Cond. (A) Play Potential	9.74436	22.6394	0.0	0.0	0.0	11.2176	47.8433
Uncond. Play Potential	4.38496	15.9420	0.0	0.0	0.0	0.0	27.9880

YIELD FACTORS

OIL (Thousand BBL / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Million CuFt / Acre-Ft)	0.60681	0.24672	0.29539	0.43177	0.56212	0.73183	1.06971
DISSOLVED GAS (Million CuFt / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXHIBIT A4 - OPTIMISTIC SCENARIO (#4)

FASP:UE 90.7 03/26/94 14:14:01 NOR13PAL2.DAT Run # 61

PLAY : PENNSYLVANIAN-PERMIAN CONVENTIONAL NAG PROJECT : NAVAL OIL SHALE RESERVES 1&3, DEPT. OF ENERGY NPOSR OFFICE

INPUT SUMMARY

Play Attribute Probabilities				Prospect Attribute Probabilities		
Charge: Hydrocarbon Source	Traps	~~Migration~~	Potential Res. Facies	Trapping Mechanism	Effective Porosity	Hydrocarbon Accumulation
0.800	0.800	1.000	0.800	0.800	0.650	0.700

Marginal Play Probability	Conditional Deposit Probability	Reservoir Lithology	Hydrocarbon Prob. Gas	Hydrocarbon Prob. Oil	Recovery Factors % Oil	Recovery Factors % Free Gas
0.512	0.364	1	1.000	0.000	0.00	15.00

Geologic Variables	F100	F95	F75	F50	F25	F05	F0
Closure (thousand acres)	1.64500	3.41100	5.26100	6.06100	9.58700	16.5890	30.2080
Thickness (feet)	25.0000	50.0000	100.000	175.000	250.000	350.000	500.000
Porosity (percent)	1.00000	3.00000	5.00000	6.50000	8.00000	10.0000	12.5000
Trap Fill (percent)	5.00000	15.0000	25.0000	30.0000	35.0000	50.0000	75.0000
Depth (thousand feet)	17.0000	18.5000	20.0000	23.5000	24.0000	25.0000	26.0000
HC Saturation (percent)	50.0000	55.0000	65.0000	70.0000	75.0000	80.0000	85.0000
Number of Prospects	1	1	1	2	2	2	2

GEOLOGIC VARIABLES and PROBABILITIES OF OCCURRENCE

	Mean	Std. Dev.
Closure	8.15237	4.94974
Thickness	185.625	101.610
Porosity	6.51250	2.27849
Trap Fill	31.1250	11.6362
Depth	22.2875	2.30322
HC Saturation	69.2500	7.76343
Prospects	1.50000	0.50000
Accumulations	0.54600	0.61675

"Dry Hole" Risk = 0.8136

Prob. (Depth <= 7500 feet) = -0.3167

	RESOURCE Oil	NA Gas	AD Gas	Gas
Cond. Prob. Prospect has	0.0000	0.3640	0.0000	0.3640
Cond. Play Prob.	0.0000	0.4798	0.0000	0.4798
Uncond. Play Prob.	0.0000	0.2456	0.0000	0.2456

Variable	Function	A	B	D(feet)	A	B	D(feet)	A	B	D(feet)	A	B
Pe (PSI)	Linear	0.4200000	14.700000									
T (Deg Rankine)	Linear	0.0200000	510.00000									
Rs (Thousand CuFt/BBL)	Linear	0.000	1.0000000									
So (no units)	Linear	0.000	1.0000000									
Z (no units)	Linear	0.000	1.0000000									

Depth Floor (feet) = 7500.00

	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Millions of BBLs)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Billions of CuFt)							
Number of Accumulations	0.54600	0.61675	0	0	0	1	2
Accumulation Size	49.9710	59.6587	6.82162	17.0063	32.0873	60.5421	150.932
Cond. Prospect Potential	18.1894	43.2854	0.0	0.0	0.0	20.2989	89.7769
Cond. (B) Play Potential	56.8714	65.9381	8.13708	19.9300	37.1441	69.2266	169.555
Cond. (A) Play Potential	27.2842	53.7880	0.0	0.0	0.0	35.4077	118.906
→ Uncond. Play Potential	13.9695	40.8325	0.0	0.0	0.0	0.0	79.9847
ASSOCIATED-DISSOLVED GAS (Billions of CuFt)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAS (Billions of CuFt)							
Number of Accumulations	0.54600	0.61675	0	0	0	1	2
Accumulation Size	49.9710	59.6587	6.82162	17.0063	32.0873	60.5421	150.932
Cond. Prospect Potential	18.1894	43.2854	0.0	0.0	0.0	20.2989	89.7769
Cond. (B) Play Potential	56.8714	65.9381	8.13708	19.9300	37.1441	69.2266	169.555
Cond. (A) Play Potential	27.2842	53.7880	0.0	0.0	0.0	35.4077	118.906
Uncond. Play Potential	13.9695	40.8325	0.0	0.0	0.0	0.0	79.9847

YIELD FACTORS	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Thousand BBL / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Million CuFt / Acre-Ft)	0.70729	0.31337	0.32227	0.48603	0.64666	0.86038	1.29758
DISSOLVED GAS (Million CuFt / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

EXHIBIT A5 - MOST OPTIMISTIC SCENARIO (#5)

FASP:UE 90.7 03/25/94 17:53:31 NOR13PAL2.DAT Run # 52

PLAY : PENNSYLVANIAN-PERMIAN CONVENTIONAL NAG PROJECT : NAVAL OIL SHALE RESERVES 1&3, DEPT. OF ENERGY NPOSR OFFICE

INPUT SUMMARY

Play Attribute Probabilities				Prospect Attribute Probabilities		
Charge: Hydrocarbon Source	Traps	~~Migration~~	Potential Res. Facies	Trapping Mechanism	Effective Porosity	Hydrocarbon Accumulation
0.800	0.800	1.000	0.850	0.800	0.650	0.700

Marginal Play Probability	Conditional Deposit Probability	Reservoir Lithology	Hydrocarbon Prob. Gas	Hydrocarbon Prob. Oil	Recovery Factors % Oil	Recovery Factors % Free Gas
0.544	0.364	1	1.000	0.000	0.00	15.00

Geologic Variables	F100	F95	F75	F50	F25	F05	F0
Closure (thousand acres)	1.64500	3.41100	5.26100	6.06100	9.58700	16.5890	30.2080
Thickness (feet)	25.0000	50.0000	100.000	175.000	250.000	350.000	500.000
Porosity (percent)	1.00000	3.00000	5.00000	6.50000	8.00000	10.0000	12.5000
Trap Fill (percent)	5.00000	15.0000	25.0000	30.0000	35.0000	50.0000	75.0000
Depth (thousand feet)	17.0000	18.5000	20.0000	23.5000	24.0000	25.0000	26.0000
HC Saturation (percent)	50.0000	55.0000	65.0000	70.0000	75.0000	80.0000	85.0000
Number of Prospects	1	1	2	2	2	2	3

GEOLOGIC VARIABLES and PROBABILITIES OF OCCURRENCE

	Mean	Std. Dev.
Closure	8.15237	4.94974
Thickness	185.625	101.610
Porosity	6.51250	2.27849
Trap Fill	31.1250	11.6362
Depth	22.2875	2.30322
HC Saturation	69.2500	7.76343
Prospects	1.75000	0.43301
Accumulations	0.63700	0.65572

"Dry Hole" Risk = 0.8020

Prob. (Depth <= 7500 feet) = -0.3167

RESOURCE	Oil	NA Gas	AD Gas	Gas
Cond. Prob. Prospect has	0.0000	0.3640	0.0000	0.3640
Cond. Play Prob.	0.0000	0.5376	0.0000	0.5376
Uncond. Play Prob.	0.0000	0.2925	0.0000	0.2925

Variable	Function	A	B	D(feet)	A	B	D(feet)	A	B	D(feet)	A	B
Pe (PSI)	Linear	0.4200000	14.700000									
T (Deg Rankine)	Linear	0.0200000	520.00000									
Rs (Thousand CuFt/BBL)	Linear	0.000	1.0000000									
Bo (no units)	Linear	0.000	1.0000000									
Z (no units)	Linear	0.000	1.0000000									

Depth Floor (feet) = 7500.00

	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Millions of BBLs)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Billions of CuFt)							
Number of Accumulations	0.63700	0.65572	0	0	1	1	2
Accumulation Size	49.4538	59.0441	6.75049	16.8295	31.7544	59.9150	149.373
Cond. Prospect Potential	18.0012	42.8388	0.0	0.0	0.0	20.0880	88.8482
Cond. (B) Play Potential	58.5946	67.0751	8.55550	20.7945	38.5490	71.4624	173.692
Cond. (A) Play Potential	31.5021	57.2040	0.0	0.0	9.98275	41.7970	129.550
→ Uncond. Play Potential	17.1371	45.0145	0.0	0.0	0.0	14.6460	92.1963
ASSOCIATED-DISSOLVED GAS (Billions of CuFt)							
Number of Accumulations	0.0	0.0	0	0	0	0	0
Accumulation Size	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. Prospect Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (B) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cond. (A) Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncond Play Potential	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GAS (Billions of CuFt)							
Number of Accumulations	0.63700	0.65572	0	0	1	1	2
Accumulation Size	49.4538	59.0441	6.75049	16.8295	31.7544	59.9150	149.373
Cond. Prospect Potential	18.0012	42.8388	0.0	0.0	0.0	20.0880	88.8482
Cond. (B) Play Potential	58.5946	67.0751	8.55550	20.7945	38.5490	71.4624	173.692
Cond. (A) Play Potential	31.5021	57.2040	0.0	0.0	9.98275	41.7970	129.550
Uncond. Play Potential	17.1371	45.0145	0.0	0.0	0.0	14.6460	92.1963

YIELD FACTORS

	Mean	Std. Dev.	F95	F75	F50	F25	F05
OIL (Thousand BBL / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-ASSOCIATED GAS (Million CuFt / Acre-Ft)	0.69997	0.31018	0.31889	0.48096	0.63995	0.85149	1.28425
DISSOLVED GAS (Million CuFt / Acre-Ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX D

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SELECTED BIBLIOGRAPHY FOR UINTA-PICEANCE BASINS, UTAH AND COLORADO, NAVAL OIL SHALE RESERVES (NOSR) 1, 2, AND 3

A RESOURCE ASSESSMENT STUDY FOR THE DEPARTMENT OF ENERGY, NAVAL PETROLEUM AND OIL SHALE RESERVES OFFICE, WASHINGTON, D.C.

W.C. Butler
U.S. Geological Survey, Denver, CO.

N.B. These references focus on five areas: 1) the general geology of the study area (geochemistry, structure, stratigraphy, basin history, geophysics, etc., 2) the petroleum geology of nearby producing fields, including available databases, 3) the methodology of assessing reserves and undiscovered resources (with case studies), 4) the general principles of petroleum exploration, and 5) probability and statistics.

Abbott, W., 1957, Tertiary of the Uinta basin, *in* Guidebook: Intermountain Association of Petroleum Geologists, 8th Annual Field Conference, p. 102- 109.

Abbott, W.O., and Katich, P.J., 1956, Stratigraphy of the Book Cliffs in east- central Utah: Peterson, J.A., editor, Geology and economic deposits of east-central Utah: Intermountain Association of Petroleum Geologists, 7th Annual Field Conference.

Abrams, G.A., Grauch, V.J.S., and Bankey, V., 1990, Complete Bouguer gravity anomaly map of the Uinta and Piceance basins and vicinity, Utah and Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-20008-D, scale 1:500,000.

Adams, M.A., and Kirr, J.N., 1984, Geologic overview, coal deposits, and potential for methane recovery from coalbeds of the Uinta basin, Utah and Colorado, *in* Rightmire, C.T., Eddy, G.E., and Kirr, J.N., editors, Coalbed methane resources of the United States: American Association of Petroleum Geologists, Studies in Geology Series #17, p. 253-269.

Adelman, M.A., Houghton, J.C., Kaufman, G., and Zimmerman, M.B., 1983, Energy resources in an uncertain future: Cambridge, MA., Ballinger Publishing Company, 434 p.

Allen, P.A., and Collinson, J.D., 1986, Lakes, *in* Reading, H.G., editor, Sedimentary environments and facies, 2nd Edition: Boston, MA, Blackwell Scientific Publications, p. 63-94.

American Gas Association, 1973, Reserves of crude oil, natural gas liquids, and natural gas in the United States and Canada, and United States productive capacity as of December 31, 1972: AGA Committee on Natural Gas Reserves, Canadian Petroleum Association, and American Petroleum Institute, v. 27, p. 89-251.

American Gas Association, 1993, Natural gas exploration, drilling, reserves, and resources: A 1992 perspective: Arlington, VA., AGA Gas Supply and Statistics, April, catalog no. F20392.

American Petroleum Institute, 1976, Standard definitions for petroleum statistics: Washington, D.C., API Technical Report 1, 2nd edition, 40 p.

Amyx. J.W., Bass, D.M., and Whiting, R.L., 1960, Petroleum reservoir engineering: New York, NY., McGraw-Hill Book Company.

Anders, D.E., and Gerrild, P.M., 1984, Hydrocarbon generation in lacustrine rocks of Tertiary age, Uinta basin, Utah — Organic carbon, pyrolysis yield, and light hydrocarbons, *in* Woodward, J., Meissner, F.F., and Clayton, J.L., editors, Hydrocarbon source rocks of the greater Rocky Mountain region: Rocky Mountain Association of Geologists, Symposium, p. 513-529.

Anderson, D.W., and Picard, M.D., 1972, Stratigraphy of the Duchesne River Formation (Eocene-Oligocene?), northern Uinta basin, northeastern Utah: Utah Geological and Mineralogical Survey Bulletin 97, 29 p.

Arps, J.J., 1956, Estimation of primary oil reserves: New York, NY., American Institute of Mining Engineers Transactions, v. 207, p. 182-191.

Arrington, J.R., 1960, Size of crude reserves is key to evaluating exploration programs: Oil and Gas Journal, v. 58, n. 9, February 29th, p. 130-134.

Baars, D.L., 1962, Permian System of Colorado Plateau: American Association of Petroleum Geologists Bull., v. 46, p. 149-218.

Baars, D.L., 1970, Stratigraphic control of petroleum in White Rim Sandstone (Permian) in and near Canyonlands National Park, Utah: American Association of Petroleum Geologists Bull., v. 54, n. 5, p. 709-718.

Baars, D.L., 1975, Pre-Pennsylvanian reservoir rocks of the eastern Colorado Plateau and southern Rocky Mountains, *in* Bolyard, D.W., ed., Deep drilling frontiers in the central Rocky Mountains: Rocky Mountain Association of Geologists, Symposium, p. 71-74.

Baars, D.L., 1979, The Colorado Plateau aulocogen — Key to continental scale basement rifting, *in* Podwysocki, M.H., and Earle, J.L., eds., Proceedings of the Second International Conference on Basement Tectonics: Denver, CO., Basement Tectonics Committee, Inc., available from Utah Geological Association, Pub. 5, p. 157-164.

Baldwin, T.A., 1971, A program for developing subsurface values on the Navy Oil Shale Reserves in Utah and Colorado: Tetra Tech, Inc., Pasadena, CA., unpublished report, June, 1971, 66 p. less appendices.

Ball Associates, Ltd., 1965, Surface and shallow oil — Impregnated rocks and shallow oil fields in the United States: U.S. Bureau of Mines Monograph 12, published by the Interstate Oil Compact Commission, Oklahoma City, OK., 375 p.

Bally, A.W., 1987, Phanerozoic basin evolution in North America: Episodes, v. 10, n. 4, p. 248-253.

Barb, C.F., 1944, Hydrocarbons of the Uinta basin of Utah and Colorado: Golden, CO., Colorado School of Mines Quarterly, v. 39, n. 1, 115 p.

Barker, Colin, 1979, Organic geochemistry in petroleum exploration: American Association of Petroleum Geologists, Continuing Education Course Note Series #10, 159 p.

Barker, C.E., 1989, Rock-Eval analysis of sediments and ultimate analysis of coal, Mesaverde Group, Multiwell Experiment Site, Piceance basin, Colorado: U.S. Geological Survey Bull. 1886-N, 5 p.

Barss, D.L., 1978, The significance of petroleum resource estimates and their relation to exploration: Bulletin of Canadian Petroleum Geology, v. 26, n. 2, p. 275-291.

Bass, N.W., 1958, Pennsylvanian and Permian rocks in the southern half of the White River uplift, *in* Curtis, B.F., editor, Symposium on Pennsylvanian rocks of Colorado and adjacent areas: Rocky Mountain Association of Geologists, p. 91-94.

Bass, N.W., 1963, Composition of crude oils in northwestern Colorado and northeastern Utah suggests local sources: American Association of Petroleum Geologists Bulletin, v. 47, n. 12, p. 2039-2044.

Bass, N.W., 1964, Relationship of crude oils to depositional environment of source rocks in the Uinta basin, *in* Sabatka, E.F., ed., Guidebook to the geology and mineral resources of the Uintah basin — Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Field Conferrence, p. 201-206.

Bayer, K.C., 1983, Generalized structural, lithologic, and physiographic provinces in the fold and thrust belts of the United States: U.S. Geological Survey map, scale 1:2,500,000.

Bayley, R.W., and Muehlberger, W.R., 1968, Basement rock map of the United States: U.S. Geological Survey, scale 1:2,500,000.

Beck, A.E., 1981, Physical principles of exploration methods: New York, NY., John Wiley and Sons - A Halsted Press Book, 234 p.

Beebe, B.W., Murdy, R.J., and Rassinier, E.A., 1975, Potential Gas Committee and undiscovered supplies of natural gas in the United States, *in* Haun, J.D., ed., Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 91-96.

Berman, A.E., Poleschook, D., Jr., and Dimelow, T.E., 1980, Jurassic and Cretaceous systems of Colorado, *in* Kent, H.C., and Porter, K.W., editors, Colorado geology: Rocky Mountain Association of Geologists 1980 Symposium, p. 111-128.

Bissell, H.J., 1964, Lithology and petrography of the Weber Formation in Utah and Colorado, *in* Sabatka, E.F., editor, Guidebook to the geology and mineral resources of the Uinta basin: Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Annual Field Conference, p. 67-91.

Bloomfield, P., Deffeys, K.S., Watson, G.S., Benjamin, Y., and Stine, R.A., 1979, Volume and area of oilfields and their impact on order of discovery, Princeton, NJ., Department of Statistics, Resource estimation and validation project, prepared for the U.S. Department of Energy, contract no. 78-S-01-6540, 53 p.

Boardman, C.R., and Knutson, D.F., 1980, Reservoir characteristics in Uinta basin gas wells: U.S. Department of Energy Report DOE/ET11399-1, 89 p.

Boardman, C.R., and Knutson, D.F., 1981, Uinta basin lenticular sandstone reservoir characteristics, SPE/DOE Paper 9849, SPE/DOE Low Permeability Symposium, p. 217-222.

Bois, C., 1975, Petroleum-zone concept and the similarity analysis-contribution to resource appraisal: American Association of Petroleum Geologists, Studies in Geology #1, p. 87-90.

Bostick, N.H., and Freeman, V.L., 1984, Tests of vitrinite reflectance and paleotemperature models at the Multivell Experiment Site, Piceance Creek basin, Colorado, *in* Spencer, C.W., and Keighin, C.W., editors, Geologic studies in support of the U.S. Department of Energy Multiwell Experiment, Garfield County, Colorado: U.S. Geological Survey Open-File Report 84- 757, p. 110-120.

Bowker, K.A., and Jackson, W.D., 1989, The Weber Sandstone at Rangely Field, Colorado, *in* Coalson, E.B., editor, Petrogenesis and petrophysics of selected sandstone reservoirs of the Rocky Mountain region: Rocky Mountain Association of Geologists Guidebook, p. 65-80.

Brainerd, A.E., and Van Tuyl, F.M., 1954, A resume of petroleum exploration and exploration development in Colorado 1862-1954, *in* Jensen, F.S., Sharkey, H.H.R., and Turner, D.S., editors, Oil and gas fields of Colorado: Rocky Mountain Association of Geologists.

Branson, C.C., editor, 1962, Pennsylvanian system in the United States: American Association of Petroleum Geologists Symposium, 508 p.

Braunstein, J., editor, 1976, North American oil and gas fields: American Association of Petroleum Geologists Memoir 24.

Brill, K.G., 1944, Late Paleozoic stratigraphy, west-central and northwestern Colorado: American Association of Petroleum Geologists Bulletin, v. 55, p. 621-656.

Brown, C.A., Smagala, T.M., and Haefele, G.R., 1986, Southern Piceance basin model — Cozzette, Corcoran and Rollins Sandstones, *in* Spencer, C.W., and Mast, R.F., editors, 1986, Geology of tight gas reservoirs: American Association of Petroleum Geologists, Studies in Geology #24, p. 207-219.

Brown, K.W., 1984, Summary of oil and gas activities in Utah, 1982: Utah Geological and Mineral Survey, Division of Utah Department of Natural Resources, Circular 75, 56 p.

Brown, K.W., and Ritzma, H.R., 1980, Summary of oil and gas drilling and production in Utah 1978: Utah Geological and Mineral Survey, Division of Utah Department of Natural Resources, Circular 65, p. 86.

Brown, K.W., and Ritzma, H.R., 1982, Oil and gas fields and pipelines of Utah: Utah Geological and Mineral Survey, Map 61.

Bryant, B., 1992, Geologic and structure maps of the Salt Lake City 1°x2° quadrangle, Utah and Wyoming: U.S. Geological Survey Miscell. Invest. Series Map I-1997, scale 1:125,000.

Bunn, J.R., 1952, Petroleum possibilities in the Uinta basin (Colorado-Utah): Petroleum Engineering, v. 24, n. 3, p. 62, 64-68, 72-74.

Burchell, P.W., 1964, Historical development of oil and gas production in Utah's Uinta basin: Intermountain Association of Petroleum Geologists Guidebook, 13th Annual Field Conference, p. 181-185.

Burrus, Jean, editor, 1986, Thermal modeling in sedimentary basins: Carcans, France, First IFP Exploration Research Conference, June 3-7, 1985, Collection Colloques et Seminaires #44, 600 p.

Buss, W.R., 1951, Bibliography of Utah geology to December 31, 1950: Utah Geological and Mineralogical Survey Bulletin 40, 210 p.

Buss, W.R., and Goeltz, N., 1974, Bibliography of Utah geology from 1950 to 1970: Utah Geological and Mineralogical Survey Bulletin 103, 285 p.

Butler, W.C., 1993, A quantitative assessment of five stratigraphic hydrocarbon plays in the Cretaceous and Tertiary strata of Naval Oil Shale Reserve #3, Piceance basin, Garfield County, northwestern Colorado: U.S. Geological Survey Administrative Report for the U.S. Department of Energy, Office of Naval Petroleum and Oil Shale Reserves, 104 p.

Byrd, W.D., II, 1970, P.R. Spring oil-imgregnated sandstone deposit, Uintah and Grand Counties, Utah: Utah Geological and Mineralogical Survey Special Studies 31, 34 p.

Caldwell, R.H., and Heather, D.I., 1991, How to evaluate hard-to-evaluate reserves: Society of Petroleum Engineers, Journal of Petroleum Technology, August, p. 998-1005.

Calhoun, J.C., Jr., 1953, Fundamentals of reservoir engineering: Norman, OK., University of Oklahoma Press.

Cameron Engineers, Inc., 1977, Phase I report, oil and gas potential, Naval Oil Shale Reserve 2, Uintah County, Utah: Denver, CO., contract no. N00016-76-C-0048, job order no. 705, August, 1977, 13 p. less appendices.

Campbell, J.A., 1981, Summary of Paleozoic stratigraphy and history of western Colorado and eastern Utah, *in* Epis, R.C., and Callender, J.F., editors, Western Slope Colorado: New Mexico Geological Society, 32nd Field Conference Guidebook, p. 81-87.

Campbell, J.A., and Ritzma, H.R., 1979, Geology and petroleum resources of the major oil-impregnated sandstone deposits of Utah: Utah Geological and Mineralogical Survey Special Studies 50, 24 p.

Carmen, E.P., and Bayes, F.S., 1961, Occurrence, properties and uses of some natural bitumens: U.S. Bureau of Mines Information Circular 7997, 42 p.
Carter, L.M.H., editor, 1988, USGS research on energy resources — 1988, Program and abstracts: U.S. Geological Survey Circular 1025, V.E. McKelvey Forum on Mineral and Energy Resources, 70 p.
Carter, L.M.H., editor, 1992, USGS research on energy resources, 1992, Program and Abstracts: U.S. Geological Survey Circular 1074, V.E. McKelvey Forum on Mineral and Energy Resources, 89 p.
Carter, W.D., 1957, Disconformity between Lower and Upper Cretaceous in western Colorado and eastern Utah: Geological Society of America Bulletin, v. 68, n. 3, p. 307-314.
Case, J.E., Morin, R.L., and Dickerson, R.P., 1992, Map showing interpretation of geophysical anomalies of the northwestern Uncompahgre uplift and vicinity, Grand County, Utah, and Mesa County, Colorado: U.S. Geological Survey Geophysical Invest. Map GP-997, scale 1:125,000.
Cashion, W.B., 1959, Geology and oil-shale resources of Naval Oil-shale Reserve No. 2, Uintah and Carbon Counties, Utah: U.S. Geological Survey Bull. 1072-O, p. 753-793, scale 1:48,000.
Cashion, W.B., 1967, Geology and fuel resources of the Green River Formation, southeastern Uinta Basin, Utah and Colorado: U.S. Geological Survey Professional Paper 548, 48 p.
Cashion, W.B., 1972, Geology and fuel resources of the Green River Formation, southeastern Uinta basin, Utah and Colorado: U.S. Geological Survey Professional Paper 548, 48 p.
Cashion, W.B., 1973, Geologic and structure map of the Grand Junction quadrangle, Colorado and Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-736, scale 1:250,000.
Cashion, W.B., 1974, revision of nomenclature of the upper part of the Green River Formation, Piceance Creek basin, Colorado and eastern Uinta basin: U.S. Geological Survey Bulletin 1394-G, 9 p.
Cashion, W.B., and Donnell, J.R., 1972, Chart showing correlation of selected key units in the organic-rich sequence of the Green River Formation, Piceance Creek basin, Colorado, and Uinta basin, Utah: U.S. Geological Survey Oil and Gas Investigations Chart OC-65
Cashion, W.B., Kilburn, J.E., Barton, H.N., Kelley, K.D., Kulik, D.M., and McDonnell, J.R., Jr., 1990, Mineral resources of the Desolation Canyon, Turtle Canyon, and Floy Canyon Wilderness study areas, Carbon, Emery, and Grand Counties, Utah: U.S. Geological Survey Bull. 1753-B, 38 p., scale 1:100,000.
Chapman, R.E., 1976, Petroleum geology - A concise study: New York, NY., American Elsevier Publishing Company, Inc., 302 p.
Chatfield, J.E., 1965, Petroleum geology of the greater Red Wash area, Uintah County, Utah: Rocky Mountain Association of Geologists, The Mountain Geologist, v. 2, n. 3, p. 115-121.
Chatfield, J.E., 1972, Case history of Red Wash field, Uintah County, Utah, *in* King, R.E., editor, Stratigraphic oil and gas fields - Classification, exploration methods, and case histories: American Association of Petroleum Geologists Memoir 16, p. 342-353.
Chenoweth, P.A., editor, 1985, Oil and gas fields of the United States, 2nd edition: Tulsa, OK, PennWell Maps, PennWell Publishing Company, scale approximately 1 inch equals 56.7 miles.
Chidsey, T.C., Jr., editor, 1991, Geology of east-central Utah: Utah Geological Association Field Symposium, Publication 19, 389 p.
Choate, R., Jurich, D., and Saulnier, Jr., G.J., 1984, Geologic overview, coal deposits, and potential for methane recovery from coalbeds, Piceance basin, Colorado, *in* Rightmire, C.T., Eddy, G.E., and Kirr, J.N., editors, Coalbed methane resources of the United States: American Association of Petroleum Geologists, Studies in Geology #17, p. 223-251.
Clark, R.W., Jr., 1951, How to estimate crude oil reserves by decline trend method: Petroleum Engineer, September, p. B-7.
Claypool, G.E., Love, A.H., and Maughan, E.K., 1978, Organic geochemistry, incipient metamorphism, and oil migration in black shale members of Phosphoria Formation, western interior United States: American Association of Petroleum Geologists Bulletin, v. 62, p. 98-120.
Clem, K., 1985, Oil and gas production summary of the Uinta basin, *in* Picard, M.D., editor, Geology and energy resources, Uinta basin of Utah: Utah Geological Association Publication 12, p. 159-167.
Close, J.C., and Erwin, T.M., 1989, Significance and determination of gas content data as related to coalbed methane reservoir evaluation and production implications: Tuscaloosa, AL., talk presented at the 1989 Coalbed Methane Symposium, 1989, p. 37-55.
Cluff, R.M., and Barrows, M.H., 1982, Hydrocarbon generation and source rock evaluation (Origin of petroleum III): American Association of Petroleum Geologists Reprint Series No. 24.

Coalson, E.B., editor, 1989, Petrogenesis and petrophysics of selected sandstone reservoirs of the Rocky Mountain region: Rocky Mountain Association of Geologists Guidebook, 353 p.

Cohenour, R.E., 1983, Mineral appraisal of lands in the Fort Duchesne area, Uintah County, Utah: Utah Geological and Mineralogical Survey Report Investigations No. 8.

Cole, R.D., and Young, R.G., 1991, Facies characterization and architecture of a muddy shelf-sandstone complex: Mancos B interval of Upper Cretaceous Mancos Shale, northwest Colorado-northeast Utah, *in* Miall, A.D., and Tyler, N., editors, The three-dimensional facies architecture of terrigenous clastic sediments and its implications for hydrocarbon discovery and recovery: Society for Sedimentary Geology (SEPM), Concepts in sedimentology and paleontology, vol. 3, p. 277-287.

Colorado Geological Survey, 1983 (1991), Oil and gas fields of Colorado: CGS Map Series 26, revised after Scanlon, scale 1:500,000.

Colorado Oil and Gas Conservation Commission, 1989, Oil and gas statistics for the state of Colorado: Denver, CO., COGCC compilers, 577 p. excluding unpaginated addenda.

Conybeare, C.E.B., 1965, Hydrocarbon-generation potential and hydrocarbon-yield capacity of sedimentary basins: Bulletin of Canadian Petroleum Geology, v. 13, p. 509-528.

Cook, E., 1975, Undiscovered or undeveloped crude oil 'resources' and national energy strategies: American Association of Petroleum Geologists, Studies in Geology #1, p. 97-106.

Cooke, L.W., 1985, Estimates of undiscovered economically recoverable oil and gas resources for the Outer Continental Shelf as of July 1984: U.S. Minerals Management Service OCS Report MMS 85-0012, 45 p.

Cooles, G.P., Mackenzie, A.S., and Quigley, T.M., 1986, Calculation of petroleum masses generated and explelled from source rocks, *in* Leythaeuser, D., and Rullkotter, J., editors, Advances in organic geochemistry 1985: Organic Geochemistry, v. 10, p. 235-245.

Covington, R.E., 1964, Bituminous sandstones in the Uinta basin, *in* Sabatka, E.F., editor, Guidebook to the geology and mineral resources of the Uinta basin: Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Annual Field Conference, p 227-242.

Covington, R.E., 1965, Bituminous sands and viscous crude oils, *in* The First Intermountain Symposium of Fossil Hydrocarbons, proceedings: Brigham Young University, Salt Lake Center for Continuing Education, p. 364-374.

Covington, R.E., and McDonald, R.L., 1965, Stratigraphic and structural controls of bituminous sandstone deposits in Utah (abst.): American Association of Petroleum Geologists Bulletin, v. 49, n. 9, p. 1577.

Craze, R.C., and Buckley, S.E., 1945, A factual analysis of the effect of well spacing on oil recovery, *in* Drilling and production practices: American Petroleum Institute, p. 144-155.

Cronquist, Chapman, 1991, Reserves and probabilities — synergism or anachronism?: Society of Petroleum Engineers, Journal of Petroleum Technology, October, p. 1258-1264.

Crouse, P.C., 1989, Coal seam methane is one of the hotter current plays: World Oil, November, p. 47-50.

Crovelli, R.A., 1984a, Procedures for petroleum resource assessment used by the U.S. Geological Survey — Statistical and probabilistic methodology, *in* Masters, D.D., ed., Petroleum resource assessment: International Union of Geological Sciences, pub. no. 17, p. 24-38.

Crovelli, R.A., 1984b, U.S. Geological Survey probabilistic methodology for oil and gas resource appraisal of the United States: Journal of the International Association for Mathematical Geology, v. 16, n. 8, p. 797-808.

Crovelli, R.A., 1986, A comparison of analytical and simulation methods for petroleum play analysis and aggregation: U.S. Geological Survey Open-File Report 86-97, 21 p.

Crovelli, R.A., 1987, Probability theory versus simulation of petroleum potential in play analysis, *in* Albin, W.L., and Harris, C.M., editors, Statistical and computational issues in probability modeling, pt. 1: Annals of Operations Research, v. 8, p. 363-381.

Crovelli, R.A., 1993, Probability and statistics for petroleum resource assessment: U.S. Geological Survey, Open-File Report 93-582, 143 p.

Crovelli, R.A., and Balay, R.H., 1986, FASP, an analytical resource appraisal program for petroleum play analysis: Computers and Geoscienses, v. 12, n. 4B, p. 423-475.

Crovelli, R.A., and Balay, R.H., 1990, PROBDIST: Probability distributions for modeling and simulation in the absence of data: U.S. Geological Survey, Open-File Report 90-446-A, documentation 51 p., Open-File Report 90-446-B, executable program (5.25" diskette).

Crovelli, R.A., and Balay, R.H., 1992, LOGRAF: Lognormal graph for resource assessment forecast: U.S. Geological Survey, Open-File Report 92-679-A, documentation 30 p., Open-File Report 92-679-B, executable program (5.25" diskette).
Crysdale, B.L., and Schenk, C.J., 1988, Bitumen-bearing deposits of the United States: U.S. Geological Survey Bull. 1784, 45 p.
Curry, H.D., 1964, Oil-content correlations of Green River oil shales, Uinta and Piceance Creek basins, *in* Sabatka, E.F., ed., Guidebook to the geology and mineral resources of the Uintah basin — Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Field Conferrence, p.169-171.
Curtis, G.R., 1972, Petroleum-impregnated rocks and shallow oil fields, *in* Mallory, W.W., editor, Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, p. 293-296.
Dane, C.H., 1955, Stratigraphic and facies relationships of the upper part of the Green River Formation and the lower part of the Uinta Formation in Duchesne, Uintah and Wasatch Counties, Utah: U.S. Geological Survey Chart OC-52.
Data Resources, Incorporated, 1986, Energy Review, Autumn 1986: Lexington, MA., Data Resources, Inc., 213 p.
Davis, L.M., 1951, Characteristics, occurrence and uses of the solid bitumen of the Uinta basin, Utah: Compass, v. 29, n. 1, p. 32-39.
Demaison, G., and Murris, R.J., 1984, Petroleum geochemistry and basin evaluation: American Association of Petroleum Geologists Memoir 35, 426 p.
De Voto, R.H., 1980, Pennsylvanian stratigraphy and history of Colorado, *in* Kent, H.C., and Porter, K.W., editors, Colorado geology: Rocky Mountain Association of Geologists 1980 Symposium, p. 71-101.
De Voto, R.H., 1980, Mississippian stratigraphy and history of Colorado, *in* Kent, H.C., and Porter, K.W., editors, Colorado geology: Rocky Mountain Association of Geologists 1980 Symposium, p. 57-70.
De Voto, R.H., Bartleson, B.L., Schenk, C.J., and Waechter, N.B., 1986, Late Paleozoic stratigraphy and syndepositional tectonism, northwestern Colorado, *in* Stone, D.S., editor, New interpretations of northwest Colorado Geology: Rocky Mountain Association of Geologists Symposium, p. 37-49.
De Voto, R.H., and Peterson, J.A., editors, 1956, Geology and economic deposits of east-central Utah: Intermountain Association of Geologists, 7th Annual Field Conference, 334 p.
De Voto, R.H., and Preston, D.A., editors, 1961, A symposium of the oil and gas fields of Utah: Intermountain Association of Petroleum Geologists, 250 p.
De Voto, R.H., and Sabatka, E.F., editors, 1964, Geology and mineral resources of the Uinta basin, Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists Guidebook, 13th Annual Field Conference, 277 p.
De Voto, R.H., and Seal, O.G., Jr., editors, 1957, Geology of the Uinta basin (Utah): Intermountain Association of Petroleum Geologists Guidebook, 8th Annual Field Conference, 224 p.
Doelling, H.H., and Graham, R.L., 1972, Eastern and northern Utah coal fields: Utah Geological and Mineralogical Survey, Monograph Series No. 2.
Dolton, G.L., and 12 others, 1981, Estimates of undiscovered recoverable conventional resources of oil and gas in the United States: U.S. Geological Survey Circular 860, 87 p.
Donaldson, J.C., and MacMillan, Logan, 1980, Oil and gas — history of development and principal fields in Colorado, *in* Murray, D.K., ed., Colorado geology: Rocky Mountain Association of Petroleum Geologists, symposium, p. 175-189.
Donnell, J.R., 1958, The Weber Sandstone in the White River uplift, *in* Curtis, B.F., editor, Symposium on Pennsylvanian rocks of Colorado and adjacent areas: Rocky Mountain Association of Geologists, p. 95-98.
Donnell, J.R., 1961, Tertiary geology and oil-shale resources of the Piceance Creek basin between the Colorado and White Rivers, northwest Colorado: U.S. Geological Survey Bulletin 1082-L, p. 835-891.
Drew, L.J., 1974, Estimation of petroleum exploration success and the effects of resource base exhaustion via a simulation model: U.S. Geological Survey Bulletin 1328, 25 p.
Drew, L.J., 1990, Oil and gas forecasting - Reflections of a petroleum geologist: New York, NY., Oxford University Press, International Association for Mathematical Geology, Studies in Mathematical Geology No. 2, 252 p.
Drew, L.J., Attanasi, E.D., and Schuenemeyer, J.H., 1988, Observed oil and gas field size distributions: A consequence of the discovery process and prices of oil and gas: Mathematical Geology, v. 20, n. 8, p. 939-953.

Drew, L.J., and Schuenemeyer, J.H., 1993, The evolution and use of discovery process models at the U.S. Geological Survey: American Association of Petroleum Geologists Bull., v. 77, p. 467-478.

Drew, L.J., Schuenemeyer, J.H., and Root, D.H., 1980, Petroleum-resource appraisal and discovery rate forecasting in partially explored regions - An application to the Denver basin: U.S. Geological Survey Professional Paper 1138-A, 11 p.

Driese, S.G., and Dott, R.H., Jr., 1984, Model for sandstone-carbonate "cyclothems" based on the upper member of the Morgan Formation (Middle Pennsylvanian) of northern Utah and Colorado: American Association of Petroleum Geologists Bulletin, v. 68, p. 574-597.

Dunn, H.L., 1972, Oil and gas fields of the Piceance basin and Axial basin uplift, *in* Mallory, W.W., editor, Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, p. 278-280.

Dunn, H.L., 1974, Geology of petroleum in the Piceance Creek basin, northwestern Colorado, *in* Murray, D.K., ed., Guidebook to the energy resources of the Piceance Creek basin, Colorado: Rocky Mountain Association of Geologists, p. 217-223

Eardley, A.J., 1950, Guidebook to the geology of Utah, Petroleum geology of the Uintah basin: Utah Geological and Mineralogical Survey, Intermountain Association of Petroleum Geologists, 1st Field Conference, Number 5, 151 p.

Eardley, A.J., 1963, Structural evolution of Utah: Utah Geological and Mineralogical Survey Bulletin 54, p. 19-29.

Edsall, D.W., 1988, Additional geophysical work and exploratory wells required to delineate magnitude of pre-Tertiary hydrocarbon accumulations in existing stratigraphic traps at Naval Oil Shale Reserve No. 2, Utah: Final Report: unpublished report, August, 1988, 22 p.

Ethridge, F.G., and Flores, R.M., editors, 1981, Recent and ancient nonmarine depositional environments: Models for exploration: Society of Economic Paleontologists and Mineralogists, Special Publication No. 31, 349 p.

Eugster, H.P., and Surdam, R.C., 1973, Depositional environments of the Green River Formation of Wyoming: A preliminary report: Geological Society of America Bull., v. 84, p. 1115-1120.

Eugster, H.P., and Hardie, L.A., 1975, Sedimentation in an ancient playa-lake complex: The Wilkins Peak Member of the Green River Formation of Wyoming: Geological Society of America Bull., v. 86, p. 319-334.

Fassett, J.E., editor, 1988, Geology and coal-bed methane resource of the northern San Juan basin, Colorado and New Mexico: Rocky Mountain Association of Geologists, Symposium Guidebook, 351 p.

Fender, H.B., and Murray, D.K., 1978, Data accumulation of the coal beds of Colorado, final report: Colorado Geological Survey Open-File Report 78-2, 25 p.

Finley, R.J., 1985, Reservoir properties and gas productivity of the Corcoran and Cozzette tight sandstones, Colorado, *in* Low permeability reservoirs, 1985 SPE/DOE Joint Proceedings: Society of Petroleum Engineers of AIME and U.S. Department of Energy Symposium, May 19-22, 1985, 13852, p. 33-45.

Fisher, J.D., Erdmann, C.E., and Reeside, J.B., Jr., 1960, Cretaceous and Tertiary formations of the Book Cliffs Carbon, Emergy, and Grand Counties, Utah, and Garfield and Mesa Counties, Colorado: U.S. Geological Survey Prof. Paper 332, 80 p.

Fisher, W.L., Finley, R.J., Senc, S.J., Ruppel, S.C., White, G.W., Ayers, W.B., Jr., and Dutton, S.P., 1988, An assessment of the natural gas resource base of the United States: Austin, TX., Bureau of Economic Geology, p. 1-77.

Flores, R.M., and Kaplan, S.S., editors, 1985, Cenozoic paleogeography of the West-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Paleogeography Symposium #3.

Folsom, L.W., 1963, Economic aspects of Uinta basin gas development (summary), *in* Oil and gas possibilities of Utah, re-evaluated: Utah Geological and Mineralogical Survey Bulletin 54, p. 199-206.

Folsom, L.W., 1968, Economic aspects of Uinta basin gas developments, *in* Beebe, B.W., editor, Natural gases of North America Volume One, Natural gases in rocks of Cenozoic age: American Association of Petroleum Geologists Memoir 9, p. 199-208.

Fouch, T.D., 1975, Lithofacies and related hydrocarbon accumulations in Tertiary strata of the western and central Uinta basin, Utah, *in* Bolyard, D.W., editor, Symposium on deep drilling frontiers of the central Rocky Mountains: Rocky Mountain Association of Geologists, p. 163-174.

Fouch, T.D., 1981, Distribution of rock types, lithologic groups, and interpreted depositional environments for some Lower Tertiary and Upper Cretaceous rocks from outcrops at Willow Creek-Indian Canyon through the subsurface of Duchesne and Altamont oil fields, southwest to north-central parts of the Uinta basin, Utah: U.S. Geological Survey Oil and Gas Invest. Map, Chart OC-81, 2 sheets.

Fouch, T.D., Cashion, W.B., Ryder, R.T., and Campbell, J.H., 1976, Field guide to lacustrine and related nonmarine depositional environments in Tertiary rocks, Uinta basin, Utah, *in* Epis, R.C., and Weimer, R.J., editors, Studies in Colorado field geology, Colorado School of Mines, Professional Contributions of Colorado School of Mines Number 8, p. 358-385.

Fouch, T.D., Claypool, G.E., Hanley, J.H., and Tschudy, R.H., 1977, Newly recognized petroleum source-rock units in east-central Utah — Implications for detection of petroleum in nonmarine Units (abst.): American Association of Petroleum Geologists Bull., v. 61, n. 5, p. 785-786.

Fouch, T.D., Lawton, T.F., Nichols, D.J., Cashion, W.B., and Cobban, W.A., 1982, Chart showing preliminary correlation of major Albian to Middle Eocene rock units from the Sanpete Valley in central Utah to the Book Cliffs in eastern Utah, *in* D.L. Nielson, editor, Overthrust belt of Utah: Utah Geological Association, 1982 Symposium and Field Conference, Publication 10, p. 267-272.

Fouch, T.D., Lawton, T.F., Nichols, D.J., Cashion, W.B., and Cobban, W.A., 1983, Patterns and timing of synorogenic sedimentation in upper Cretaceous rocks of central and northeast Utah, *in* Reynolds, M.W., and Dolly, E.D., editors, Mesozoic paleogeography of the West-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Paleogeography Symposium 2, Denver, CO., p. 305-336.

Fouch, T.D., and Magathan, E.R., editors, 1980, Paleozoic paleogeography of the West-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Paleogeography Symposium #1, 431 p.

Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., editors, 1992, Hydrocarbon and mineral resources of the Uinta basin, Utah and Colorado: Utah Geological Association Guidebook 20, 1992 Field Symposium, 366 p.

Fouch, T.D., Nuccio, V.F., Osmond, J.C., MacMillan, Logan, Cashion, W.B., and Wandrey, C.J., 1992, Oil and gas in uppermost Cretaceous and Tertiary rock, Uinta basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., eds., Hydrocarbon and mineral resources of the Uinta basin, Utah and Colorado: Utah Geological Association Special Symposium, guidebook 20, p. 9-48.

Fouch, T.D., Nuccio, V.F., and Rice, D.D., 1992, Review of geologic controls on natural gas in Cretaceous and Tertiary tight-gas sandstone reservoirs, Uinta basin, Utah and Colorado: U.S. Department of Energy, DOE/METC- 92/6125, (DE92001278), p. 59-75.

Fouch, T.D., Wandrey, C.J., Pitman, J.K., Nuccio, V.F., Schmoker, J.W., Rice, D.D., and Wesley, J.B., 1991, Preliminary report on the characterization of Tertiary and Cretaceous low-permeability (tight) gas-bearing rocks in the Uinta basin, Utah, *in* Proceedings of the 1990 Natural Gas Research and Development Conference: U.S. Department of Energy report DOE/METC-91/ 6117, (DE91002035), p. 5-14.

Franczyk, K.J., 1991, Stratigraphic and time-stratigraphic cross sections of phanerozoic rocks along line C-C', Uinta and Piceance basin area, southern Uinta Mountains to northern Henry Mountains, Utah: U.S. Geological Survey Miscell. Invest. Map I-2184-C.

Franczyk, K.J., Fouch, T.D., Johnson, R.C., Molenaar, C.M., and Cobban, W.A., 1992, Cretaceous and Tertiary paleogeographic reconstructions for the Uinta-Piceance basin study area, Colorado and Utah: U.S. Geological Survey Bull. 1787-Q, 37 p.

Franczyk, K.J., Hanley, J.H., Pitman, J.K., and Nichols, D.J., 1991, Paleocene depositional systems in the western Roan Cliffs, Utah, *in* Chidsey, T.C., Jr., ed., Geology of east-central Utah: Utah Geological Association Field Symposium, Publication 19, p. 111-127.

Franczyk, K.J., and Pitman, J.K., leaders, 1989, Evolution of resource-rich foreland and intermontane basins in eastern Utah and western Colorado: American Geophysical Union Field Trip Guidebook T324, Salt Lake City, Utah, to Grand Junction, Colorado, July 20-24, 1989, 28th International Geological Congress, 53 p.

Franczyk, K.J., Pitman, J.K., and Nichols, D.J., 1990, Sedimentology, mineralogy, palynology, and depositional history of some uppermost Cretaceous and lowermost Tertiary rocks along the Utah Book and Roan Cliffs east of the Green River: U.S. Geological Survey Bulletin 1787-N, 27 p.

Freeman, V.L., 1979, Preliminary report on rank of deep coals in part of the southern Piceance Creek basin, Colorado: U.S. Geological Survey, Open- File Report 79-725, 10 p.

Freethey, G.W., and Cordy, G.E., 1991, Geohydrology of Mesozoic rocks in the upper Colorado River basin in Arizona, Colorado, New Mexico, Utah, and Wyoming, excluding the San Juan basin: U.S. Geological Survey Prof. Paper 1411-C, 118 p.

Frezon, S.E., Finn, T.M., and Lister, J.M., 1984, total thickness of sedimentary rocks in the conterminous United States: U.S. Geological Survey Open-File Report 83-0920, scale 1:5,000,000.

Fryberger, S.G., 1979, Eolian-fluviatile (continental) origin of ancient stratigraphic trap for petroleum in Weber Sandstone, Rangely Oil Field, Colorado: Rocky Mountain Association of Geologists, The Mountain Geologist, v. 16, p. 1-36.

Fryberger, S.G., and Koelmel, M.H., 1986, Rangely Field: Eolian system boundary trap in the Permo-Pennsylvanian Weber Sandstone of northwest Colorado, *in* Stone, D.S., editor, New Interpretations of northwest Colorado geology: Rocky Mountain Association of Petroleum Geologists Symposium, p. 123-149.

Gas Research Institute, 1993, Piceance basin Colorado, *in* GRI Quarterly Review of Methane from Coal Seams Technology, August, v. 11, n. 1, p. 23-27.

Geological Services of Tulsa, Inc., 1980, Geologic framework and potential structural control of methane in coal beds of southeastern Piceance Creek basin, Colorado: U.S. Department of Energy, Morgantown Energy Technology Center, prepared for TRW Energy Systems Group under TRW contract no. DE-AC-21-78MCO8089, 34 p.

Gere, W.C., Horton, G.W., Harstead, J.N., and Russell, D.F., 1963, Oil and natural gas, *in* Mineral and water resources of Utah: Utah Geological and Mineralogical Survey Bulletin 73, U.S. Geological Survey for U.S. Senate Committee on Interior and Insular Affairs, 88th Congress, 2nd Session, p. 51-60.

Gillespie, W.A., 1957, Ute Trail field - Uintah County, Utah, *in* Guidebook to the geology of the Uinta basin: Intermountain Association of Petroleum Geologists, 8th Annual Field Conference, p. 202-203.

Gillette, R., 1974, Oil and gas resources - Did USGS gush too high? Science, v. 185, n. 4146, p. 127-130.

Grace, J.D., Caldwell, R.H., and Heather, D.I., 1993, Comparative reserves definitions: U.S.A., Europe, and the Former Soviet Union: Society of Petroleum Engineers, Journal of Petroleum Technology, Sept., p. 866-872.

Gray, J., 1987, Reservoir engineering in coal seams, part I: The physical process of gas storage and movement in coal seams: Society of Petroleum Engineers, p. 28-40.

Grauch, V.J.S., and Plesha, J.L., 1989, Aeromagnetic maps of the Uinta and Piceance basins and vicinity, Utah and Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-2008-C, 2 sheets, scale 1:500,000.

Greethey, G.W., and Cordy, G.E., 1991, Geohydrology of Mesozoic rocks in the upper Colorado River basin in Arizona, Colorado, New Mexico, Utah, and Wyoming, excluding the San Juan Basin: U.S. Geological Survey Prof. Paper 1411-C, 118 p., scale 1:2,500,000.

Grossling, B.F., 1975, In search of a statistical probability model for petroleum-resource assessment: U.S. Geological Survey Circular 724, 18 p.

Grout, M.A., 1991, Cleat data for coal beds in the southern Piceance basin, northwestern Colorado: U.S. Geological Survey, Open-File Report 91- 363, 30 p.

Grout, M.A., Abrams, G.A., Tang, R.L., Hainsworth, T.J., and Verbeek, E.R., 1991, Late Laramide thrust-related and evaporite-domed anticlines in the southern Piceance basin, northeastern Colorado Plateau: American Association of Petroleum Geologists Bulletin, v. 75, n. 2, p. 205-218.

Grout, M.A., and Verbeek, E.R., 1983, Field studies of joints — Insufficiencies and solutions, with examples from the Piceance Creek basin, Colorado, *in* Gary, J.H., ed., 16th Oil Shale Symposium, proceedings: Golden, CO., Colorado School of Mines Press, p. 68-80.

Grout, M.A., and Verbeek, E.R., 1985, Fracture history of the Plateau Creek and adjacent Colorado River patterns at depth: U.S. Geological Survey, Open-File Report 85-744, 17 p.

Gwynn, J.W., 1971, Instrumental analysis of tars and their correlations in oil- impregnated sandstone beds, Uintah and Grand Counties, Utah: Utah Geological and Mineralogical Survey Special Studies 37, 64 p.

Hager, D., and Seeley, DeB.K., Jr., 1962, Uinta basin may prove a million acre reservoir: Oil and Gas Journal, v. 60, n. 13, p. 227-232.

Hail, W.J., Jr., 1977, Stewart Gulch Tongue — A new tongue of the Eocene Green River Formation, Piceance Creek Basin, Colorado: U.S. Geological Survey Bull. 1422-E, 8 p.

Hail, W.J., Jr., 1982, Preliminary geologic map of the Circle Dot Gulch quadrangle, Garfield County, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1293, scale 1:24,000.
Halbouty, M.T., 1970, Giant oil and gas fields in the United States, *in* Geology of giant petroleum fields: American Association of Petroleum Geology Memoir 14, p. 91-127.
Halbouty, M.T., and Moody, J.D., 1980, World ultimate reserves of crude oil: Proceedings of Tenth World Petroleum Congress, Bucharest, 1979, p. 291- 301.
Hale, L.A., and Van deGraff, F.R., 1964, Cretaceous stratigraphy and facies patterns - northeastern Utah and adjacent areas, *in* Sabatka, E.F., ed., Guidebook to the geology and mineral resources of the Uinta basin — Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Annual Field Conference, p. 115-138.
Hambleton, W.W., Davis, J.C., and Doveton, J.H., 1975, Estimating exploration potential, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 171-185.
Hansen, G.H., 1955, Drilling records for oil and gas in Utah: Utah Geological and Mineralogical Survey Bulletin 50.
Hansen, G.H., 1957, History of drilling operations in Utah's Uinta basin, *in* Seal, O.G., ed., Guidebook to the geology of the Uinta basin: Intermountain Association of Petroleum Geologists, 8th Annual Field Conference, p. 165-167.
Hansen, G.H., and Scoville, H.C., 1957, Guidebook to the geology of the Uinta basin: Intermountain Association of Petroleum Geologists, 8th Annual Field Conference.
Harbaugh, J.W., Doveton, J.H., and Davis, J.C., 1977, Probability methods in oil exploration: New York, NY., John Wiley and Sons, 269 p.
Harbaugh, J.W., and Ducastaing, M., 1981, Historical changes in oil-field populations as a method of forecasting field sizes of undiscovered populations: A comparison of Kansas, Wyoming, and California: Kansas Geological Survey, Subsurface Geology Series No. 5, 56 p.
Haun, J.D., 1962, Introduction to the geology of northwest Colorado, *in* Amuedo, C.L., and Mott, M.R., editors, Exploration for oil and gas in northwest Colorado: Rocky Mountain Association of Geologists, p. 7-14.
Haun, J.D., 1975, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology no. 1, 206 p.
Haun, J.D., and LeRoy, L.W., editors, 1958, Subsurface geology in petroleum exploration - A symposium: Golden, CO., Colorado School of Mines, Johnson Publishing Company, 887 p.
Hedberg, H.D., 1954, World oil prospects — From a geological viewpoint: American Association of Petroleum Geologists, v. 38, p. 1714-1724.
Hedberg, H.D., 1975, False precision in petroleum resource estimates, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 160.
Hendel, C.W., 1957, The Peters Point gas field, *in* Guidebook to the geology of the Uinta basin: Intermountain Association of Petroleum Geologists, 8th Annual Field Conference, p. 193-201.
Hendricks, T.A., 1965, Resources of oil, gas, and natural-gas liquids in the United States and the world: U.S. Geological Survey Circular 522, 20 p.
Heylmun, E.B., 1964, Shallow oil and gas possibilities in east and south- central Utah: Utah Geological and Mineralogical Survey Special Studies No. 8, 40 p.
Heylmun, E.B., 1965, Plain facts about oil and gas in Utah: Utah Geological and Mineralogical Survey, Circular 46, 14 p.
Hill, B.G., and Bereskin, S.R., editors, 1993, Oil and gas fields of Utah: Utah Geological Association Publication 22, unpaginated.
Hintze, L.F., 1964, Structural behavior of Utah, *in* Sabatka, E.F., editor, Guidebook to the geology and mineral resources of the Uinta basin: Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Annual Field Conference, p. 41-45.
Hintze, L.F., 1973, Geologic history of Utah: Brigham Young University, v. 20, part 3.
Hintze, L.F., 1975, Utah geological highway map: Brigham Young University, Dept. of Geology, Special Publication #3, scale 1:1,000,000, (with cross-sections, stratigraphic columns, and geologic history.)
Hintze, L.F., 1980, compiler, Geologic map of Utah: Utah Geological and Mineral Survey, scale 1:500,000.

Hintze, L.F., 1988, Geologic history of Utah - A field guide to Utah's rocks: Brigham Young University Geology Studies, Special Pub. 7, 204 p.
Hoffman, F.H., 1957, Possibilities of Weber stratigraphic traps, Rangely area, northwest Colorado: American Association of Petroleum Geologists Bulletin, v. 41, p. 894-905.
Horsfield, B., Yordy, K.L., and Crelling, J.C., 1988, Determining the petroleum-generating potential of coal using organic geochemistry and organic petrology, *in* Mattavelli, L., and Novelli, L., editors, Advances in organic geochemistry 1987: Organic Geochemistry, v. 13, p. 121-129.
Houghton, J.C., 1988, Use of the truncated shifted Pareto distribution in assessing size distribution of oil and gas fields: Mathematical Geology, v. 20, n. 8, p. 907-938.
Houghton, J.C., Dolton, G.L., Mast, R.F., Masters, C.D., and Root, D.H., 1993, U.S. Geological Survey estimation procedure for accumulation size distributions by play: American Association of Petroleum Geologists Bull., v. 77, p. 454-466.
Howell, D.G., editor, 1993, The future of energy gases: U.S. Geological Survey Professional Paper 1570, 890 p.
Hubbert, M.K., 1966, History of petroleum geology and its bearing upon present and future exploration: American Association of Petroleum Geologists Bulletin, v. 50, p. 2504-2518.
Hubbert, M.K., 1974, U.S. energy resources, a review as of 1972, pt. 1, *in* A national fuels and energy policy study: U.S. 93rd. Congress, 2nd. Session, Senate Committee on Interior and Insular Affairs, Committee Print, Serial Number 93-40 (92-75), 267 p.
Hunt, C.B., 1956, Cenozoic geology of the Colorado Plateau: U.S. Geological Survey Prof. Paper 279, 99 p.
Hunt, J.M., 1979, Petroleum geochemistry and geology: San Francisco, CA., W.H. Freeman and Company, 617 p.
Hunt, J.M., 1991, Generation of gas and oil from coal and other terrestrial organic matter: Organic Geochemistry, v. 17, p. 673-680.
Hunt, J.M., Stewart, F., and Dickey, P.A., 1954, Origin of hydrocarbons of Uinta basin, Utah: American Association of Petroleum Geologists Bulletin, v. 38, p. 1671-1698.
Hunter, R.L., and Mann, C.J., eds., 1992, Techniques for determining probabilities of geologic events and processes: New York, NY., Oxford University Press, International Association for Mathematical Geology Studies in Mathematical Geology, No. 4, 364 p.
ICF Resources, Inc., compiler, 1989, The coalbed methane resource and the mechanisms of gas production: Gas Research Institute Topical Report GRI-89/0266, 115 p.
ICF Resources, Inc., 1990, The United States coalbed methane resource: Quarterly Review of Methane from Coal Seams Technology, v. 7, n. 3, p. 10-28.
Irwin, C.D., chairman, 1977, Subsurface cross-sections of Colorado: Rocky Mountain Association of Geologists Special Publication No. 2, 39 p.
Jensen, F.S., Sharkey, H.H.R., and Turner, D.S., 1954, The oil and gas fields of Colorado - A symposium: Rocky Mountain Association of Geologists.
Jensen, F.S., 1972, Thickness of Phanerozoic rocks, *in* Mallory, W.W., editor, Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, p. 56.
Johnson, R.C., 1985, Early Cenozoic history of the Uinta and Piceance Creek basins, Utah and Colorado, with special reference to the development of Eocene Lake Uinta, *in* Flores, R.M., and Kaplan, S.S., editors, Cenozoic paleogeography of the West-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Paleogeography Symposium 3, p. 247-276.
Johnson, R.C., 1989a, Geologic history and hydrocarbon potential of Late Cretaceous-age, low permeability reservoirs, Piceance basin, western Colorado: U.S. Geological Survey Bull. 1787-E, 51 p.
Johnson, R.C., 1989b, Detailed cross sections correlating Upper Cretaceous and Lower Tertiary rocks between the Uinta basin of eastern Utah and western Colorado and the Piceance basin of western Colorado: U.S. Geological Survey Miscell. Invest. Series Map I-1974.
Johnson, R.C., Crovelli, R.A., Spencer, C.W., and Mast, R.F., 1987, An assessment of gas resources in low-permeability sandstones of the Upper Cretaceous Mesaverde Group, Piceance basin, Colorado: U.S. Geological Survey, Open-File Report 87-357, 165 p.
Johnson, R.C., and Keighin, C.W., 1981, Cretaceous and Tertiary history and resources of the Piceance Creek basin, western Colorado, *in* Epis, R.C. and Callender, J.E., editors, Western Slope Colorado: New Mexico Geological Society, 32nd Field Conference Guidebook, p. 199-210.

Johnson, R.C., and Nuccio, V.F., 1986, Structural and thermal history of the Piceance Creek basin, western Colorado, in relation to hydrocarbon occurrence in the Mesaverde Group, *in* Spencer, C.W., and Mast, R.F., editors, 1986, Geology of tight gas reservoirs: American Association of Petroleum Geologists, Studies in Geology #24, p. 165-205.
Johnson, R.C., and Rice, D.D., 1990, Occurrence and geochemistry of natural gases, Piceance basin, northwest Colorado: American Association of Petroleum Geologists Bull., v. 74, p. 805-829.
Johnson, S.Y., 1989, The Fryingpan Member of the Maroon Formation — A Lower Permian (?) basin-margin dune field in northwestern Colorado: U.S. Geological Survey Bull. 1787-I, 11 p.
Johnson, S.Y., 1992, Phanerozoic evolution of sedimentary basins in the Uinta-Piceance basin region, northwestern Colorado and northeastern Utah: U.S. Geological Survey Bulletin 1787-FF, 38 p.
Johnson, S.Y., and Johnson, R.C., 1991, Stratigraphic and time-stratigraphic cross sections of phanerozoic rocks along line A-A', Uinta and Piceance basin area-Eagle basin, Colorado, to eastern Basin and Range area, Utah: U.S. Geological Survey Miscell. Invest. Series Map I-2184-A.
Johnson, S.Y., and Johnson, R.C., 1991, Stratigraphic and time-stratigraphic cross sections of phanerozoic rocks along line B-B', Uinta and Piceance basin area, west-central Uinta basin, Utah to eastern Piceance basin, Colorado: U.S. Geological Survey Miscell. Invest. Map I-2184-B.
Jones, A.H., Bell, G.J., and Morales, R.H., 1987, Hydraulic fracture design rationale for the recovery of methane from coal seams: Gas Research Institute Report GRI-87/0016.
Jones, R.W., 1975, A quantitative geologic approach to prediction of petroleum resources, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 186-195.
Katz, B.J., Kelley, P.A., Royle, R.A., and Jorjorian, T., 1991, Hydrocarbon products of coals as revealed by pyrolysis-gas chromatography: Organic Geochemistry, v. 17, p. 711-722.
Kaufman, G.M., 1963, Statistical decision and related techniques in oil and gas exploration: Englewood Cliffs, NJ., Prentice-Hall, 307 p.
Kaufman, G.M., Balcer, Y., and Druyt, D., 1975, A probabilistic model of oil and gas discovery, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 113-142.
Kaufman, G.M., and Wang, J.W., 1980, Model mis-specification and the Princeton study of volume and area of oil fields and their impact on order of discovery: Cambridge, MA., Massachusetts Institute of Technology Energy Lab, Working Paper No. MIT-EL 80-003WP.
Kayser, R.B., 1966, Bituminous sandstone deposits Asphalt Ridge, Uintah County, Utah: Utah Geological and Mineralogical Survey Special Studies 19, 62 p.
Kellogg, H.E., 1977, Geology and petroleum of the Mancos B Formation, Douglas Creek arch area, Colorado and Utah, *in* Veal, H.K., editor, Exploration frontiers of the central and southern Rockies: Rocky Mountain Association of Geologists Symposium, p. 167-179.
Kelso, B.S., Goolsby, S.M., and Tremain, C.M., 1980, Deep coalbed methane potential of the San Juan River Coal Region, southwestern Colorado: Colorado Geological Survey Open-File Report 80-2, 56 p.
Kent, H.C, and Porter, K.W., editors, 1980, Colorado geology: Rocky Mountain Association of Geologists 1980 Symposium, 258 p.
Khavari-Khorasani, G., 1984, Free hydrocarbons in the Uinta basin: American Association of Petroleum Geologists Bulletin, v. 68, n. 9.
King, P.B., 1977, The evolution of North America (revised edition): Princeton, NJ., Princeton University Press, 197 p.
Kinney, D.M., 1951, Geology of the Uinta River and Brush Creek - Diamond Mountain areas, Duchesne and Uintah Counties, Utah: U.S. Geological Survey Oil and Gas Investigations Map OM-123.
Kinney, D.M., 1955, Geology of the Uinta River-Brush Creek area Duchesne and Uintah Counties, Utah: U.S. Geological Survey Bull. 1007, 185 p., scale 1:63,360.
Kitely, L.W., 1983, Paleogeography and eustatic-tectonic model of Late Campanian Cretaceous sedimentation, southwestern Wyoming and northwestern Colorado, *in* Reynolds, M.W., and Dolly, E.D., eds., Mesozoic paleogeography of the west-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, Symposium 2, Denver, CO., p. 273-303.
Klemme, H.D., 1971, Giants, supergiants, and their relation to basin types: Oil and Gas Journal, March 8th, p. 103-110.

Knutson, C.F., and Boardman, C.R., 1978, Continuity and permeability development in the tight gas sands of the eastern Uinta basin, Utah: U.S. Department of Energy Report NVO/0011-1.

Koelmel, M.H., 1986, Post-Mississippian paleotectonic, stratigraphic, and diagenetic history of the Weber Sandstone in the Rangely field area, Colorado, *in* Peterson, J.A., editor, Paleotectonics and sedimentation in the Rocky Mountain region: American Association of Petroleum Geologists Memoir 41, p. 383-409.

Krupa, M.P., and Spencer, C.W., 1989, U.S. Geological Survey publications on Western tight gas reservoirs: U.S. Geological Survey for U.S. Department of Energy, DOE/MC/20422-2677, (DE8900968), 133 p.

Lake, L.W., and Carroll, H.B., Jr., editors, 1986, Reservoir characterization: New York, NY., Academic Press, Inc., 659 p.

Larson, A.R., 1972, Developments in eastern and northwestern Colorado: American Association of Petroleum Geologists Bull., v. 56, n. 7, p. 1254-1259.

Larson, T.C., 1975, Geological considerations of the Weber Sandstone reservoir, Rangely Field, Colorado, *in* Bolyard, D.W., editor, Symposium on deep drilling frontiers of the Central Rocky Mountains: Rocky Mountain Association of Geologists, p. 275-279.

Law, B.E., 1984, Relationships of source-rock, thermal maturity, and overpressuring to gas generation and occurrence in low-permeability Upper Cretaceous and Lower Tertiary rocks, Greater Green River basin, Wyoming, Colorado, and Utah, *in* Woodward, J., Meissner, F.F., and Clayton, J.L., editors, Hydrocarbon source rocks of the greater Rocky Mountain region: Rocky Mountain Association of Geologists, Symposium, p. 469-490.

Law, B.E., and Johnson, R.C., 1989, Structural and stratigraphic framework of the Pinedale anticline, Wyoming, and the Multiwell Experiment Site, Colorado: U.S. Geological Survey Bull. 1886-B, 11 p.

Law, B.E., and Rice, D.D., editors, 1993, Hydrocarbons from coal: American Association of Petroleum Geologists Studies in Geology #38, 400 p.

Law, B.E., and Spencer, C.W., 1989, Geology of tight gas reservoirs in the Pinedale anticline area, Wyoming, and at the Multiwell Experiment Site, Colorado: U.S. Geological Survey Bull. 1886-A, 7 p.

Lee, M.W., 1989, Azimuthal vertical seismic profiles at the Multiwell Experiment Site, northwest Colorado: U.S. Geological Survey Bull. 1886-O, 16 p.

Lee, P.J., and Wang, P.C.C., 1983, Conditional analysis for petroleum resource evaluations: International Association Mathematical Geology Journal, v. 15, p. 349-361.

Lee, P.J., and Wang, P.C.C., 1985, Probabilistic formulation of a method for the evaluation of petroleum resources: International Association Mathematical Geology Journal, v. 17, p. 163-182.

Lee, W.T., 1923, Continuity of some oil-bearing sands of Colorado and Wyoming: U.S. Geological Survey Bull., 751-A.

Levorsen, A.I., 1967, Geology of petroleum, 2nd Edition: San Francisco, CA., W.H. Freeman and Company, 724 p.

Lewis, C.J., 1986, Are our oil and gas resource estimates realistic?, *in* Rice, D.D., editor, Oil and gas assessment - Methods and applications: American Association of Petroleum Geologists Studies in Geology No. 2, p. 195-202.

Leythaeuser, D., and Poelchau, H.S., 1991, Explusion of petroleum from type III kerogen source rocks in gaseous solution: Modeling of solubility fractionation, *in* England, W.A., and Fleet, A.J., editors, Geological Society Special Publication 59, p. 147-184.

Linstone, H.A., and Turoff, M., editors, 1975, The Delphi method - Techniques and applications: Reading, MA., Addison-Wesley Publishing Company, 620 p.

Logan, T.L., 1988, horizontal drainhole drilling techniques used for coal seam resource exploitation: Society of Petroleum Engineers Paper 18254.

Logan, T.L., 1993, Drilling techniques for coalbed methane, *in* Law, B.E., and Rice, D.D., editors, Hydrocarbons from coal: American Association of Petroleum Geologists Studies in Geology #38, p. 269-285.

Lorenz, J.C., 1985, Predictions of size and orientations of lenticular reservoirs in the Mesaverde Group, northwestern Colorado, *in* Low permeability reservoirs, 1985 SPE/DOE Joint Proceedings: Society of Petroleum Engineers of AIME and U.S. Department of Energy Symposium, May 19-22, 1985, 13851, p. 23-31.

Lorenz, J.C., 1989, Reservoir sedimentology of rocks of the Mesaverde Group, Multiwell Experiment Site and east-central Piceance basin, northwest Colorado: U.S. Geological Survey Bull. 1886-K, 24 p.

Lorenz, J.C., Warpinski, N.R., and Branagan, P.T., 1991, Subsurface characterization of Mesaverde reservoirs in Colorado: Geophysical and reservoir- engineering checks on predictive sedimentology, *in* Miall, A.D., and Tyler, N., editors, The three-dimensional facies architecture of terrigenous clastic sediments and its implications for hydrocarbon discovery and recovery: Society for Sedimentary Geology (SEPM), Concepts in sedimentology and paleontology, vol. 3, p. 57-79.

Lucas, P.T., and Drexler, J.M., 1976, Altamont-Bluebell — A major, naturally fractured stratigraphic trap, Uinta basin, Utah, *in* Braunstein, J., ed., North American oil and gas fields: Amer. Assoc. Petroleum Geologists Memoir 24, p.121-135.

Mackay, I.H., and North, F.K., 1975, Undiscovered oil reserves, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 76-86.

MacMillan, L., 1980, Oil and gas of Colorado: A conceptual view, *in* Kent, H.C., and Porter, K.W., editors, Colorado geology: Rocky Mountain Association of Geology 1980 Symposium, p. 191-197.

Magoon, L.B., editor, 1988, Petroleum systems of the United States: U.S. Geological Survey Bulletin 1870, 68 p.

Magoon, L.B., editor, 1992, The petroleum system — Status of research and methods, 1992: U.S. Geological Survey Bull. 2007, 98 p.

Mallory, W.W., editor, 1972, Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, 331 p.

Mallory, W.W., 1975a, Accelerated national oil and gas resource appraisal (ANOGRE), *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 23-30.

Mallory, W.W., 1975b, Middle and southern Rocky Mountains, northern Colorado Plateau, and eastern Great Basin region: U.S. Geological Survey Professional Paper 853, p. 265-278.

Malone, R.D., Shoemaker, H.D., and Byrer, C.W., editors, 1990, Proceedings of the Natural Gas Research and Development Contractors Review Meeting: Preliminary report on the characterization of Tertiary and Cretaceous low-permeability (tight) gas-bearing rocks in the Uinta basin, Utah: Morgantown, WV., U.S. Department of Energy, Office of Fossil Energy, November 14-15, 1990, 14 p.

Mankin, C.J., Chairman, 1991, Undiscovered oil and gas resources — An evaluation of the Department of the Interior's 1989 assessment procedures: Washington, D.C., National Research Council, Committee on Undiscovered Oil and Gas Resources, National Academy Press, 108 p. plus appendices.

Mantek, W.E., Chairman, 1989, Potential supply of natural gas in the United States (December 31, 1988): Golden, CO., Colorado School of Mines, Potential Gas Agency/Committee, April 1989, 160 p.

Marchant, L.C., Johnson, L.A., and Cupps, C.O., 1974, Properties of Utah tar sands - Threemile Canyon area, P.R. Spring deposit: U.S. Bureau of Mines Report of Investigations No. 7923, 14 p.

Marsh, G.R., 1971, How much oil are we really finding: Oil and Gas Journal, v. 69, n. 14, April 5, p. 100-104.

Mast, R.F., and Dingler, J., 1975, Estimates of inferred + indicated reserves for the United States, *in* Miller, B.M. and 8 others, Geological estimates of undiscovered recoverable oil and gas resources in the United States: U.S. Geological Survey Circular 725, p. 73-78.

Mast, R.F., and 9 others, 1989, Estimates of undiscovered conventional oil and gas resources in the United States — A part of the Nation's energy endowment: U.S. Geological Survey and Minerals Management Service, 44 p.

Matheron, G., 1963, Principles of geostatistics: Economic Geology, v. 58, p. 1246-1266.

McCulloch, C.M., 1977, Methane from coal, *in* Murray, D.K., editor, Geology of Rocky Mountain coal, Proceedings of 1976 Symposium: Colorado Geological Survey, Resource Series #1, p. 121-136.

McCulloch, C.M., Levine, J.R., Kissel, F.N., and Deul, M., 1975, Measuring the methane content of bituminous coalbeds: U.S. Bureau of Mines Report of Investigations 8043, 22 p.

McElhiney, J.E., Paul, G.W., Young, G.B.C., and McCartney, J.A., 1993, Reservoir engineering aspects of coalbed methane, *in* Law, B.E., and Rice, D.D., editors, Hydrocarbons from coal: American Association of Petroleum Geologists Studies in Geology #38, p. 361-372.

McEwen, R.B., Witmer, R.E., and Ramey, B.S., editors, 1983, Digital elevation models: U.S. Geological Survey, USGS Digital Cartographic Data Standards, National Mapping Program, Circular 895-B, 40 p.

McFall, K.S., Wicks, D.E., Kelso, B.S., and Brandenburg, C.F., 1988, An analysis of the coal-seam gas resource of the Piceance basin, Colorado: Society of Petroleum Engineers, Journal of Petroleum Technology, June, p. 740-748.

McFall, K.S., Wicks, D.E., Kuuskraa, V.A., and Sedwick, K.B., 1986, A geologic assessment of natural gas from coal seams in the Piceance basin Colorado: Gas Research Institute Topical Report GRI 87/0060, 75 p.

McKelvey, V.E., 1972, Mineral resource estimates and public policy: American Scientist, v. 60, p. 32-40.

McKelvey, V.E., 1975, Concepts of reserves and resources, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 11-14.

Mead, W.J., Sorensen, P.E., Jones, R.O., and Moseidjord, A., 1980, Competition and performance in OCS oil and gas lease sales and lease development, 1954- 1969: Final Report: U.S. Geological Survey, contract no. 14-08-0001- 18678, 109 p.

Megill, R.E., 1971, Exploration economics: Tulsa, OK., The Petroleum Publishing Company, 159 p.

Meisner, J., and Demirmen, F., 1980, The creaming method: A Bayesian procedure to forecast future oil and gas discoveries in mature exploration provinces: Journal Royal Statisticians Society, v. 143, 17 p.

Meissner, F.F., 1984, Cretaceous and Lower Tertiary coals as source for gas accumulation in the Rocky Mountain area, *in* Woodward, J., Meissner, F.F., and Clayton, J.L., editors, Hydrocarbon source rocks of the greater Rocky Mountain region: Rocky Mountain Association of Geologists Symposium, p. 401-432.

Meissner, F.F., Woodward, J., and Clayton, J.L., 1984, Stratigraphic relationships and distribution of source rocks in the greater Rocky Mountain region, *in* Woodward, J., Meissner, F.F., and Clayton, J.L., editors, Hydrocarbon source rocks of the greater Rocky Mountain region: Rocky Mountain Association of Geologists Symposium, p. 1-34.

Mercer, J.C., and others, 1985, Study of gas migration from Naval Oil Shale Reserve No. 3 to the Rulison Field: U.S. Department of Energy, Morgantown Energy Technology Center, research report DOE/METC-86/2020, December, 1985, 58 p.

Meyer, R.F., 1977, Petroleum resource data systems: International Association Mathematical Geology Journal, v. 9, p. 281-299.

Meyer, R.F., 1978, The volumetric method for petroleum resources estimation: International Association Mathematical Geology Journal, v. 10, p. 501- 518.

Meyer, R.F., editor, 1986, Shallow oil and gas resources - Proceedings of the First International Conference: Houston, TX., Gulf Publishing Company for The United Nations Institute for Training and Research, 686 p.

Molenaar, C.M., and Cobban, W.A., 1989, Middle Cretaceous stratigraphy on the south and east sides of the Uinta basin, northeastern Utah and northwestern Colorado: U.S. Geological Survey Bull. 1787-P, 34 p.

Molenaar, C.M., and Cobban, W.A., 1991, Middle Cretaceous stratigraphy on the south and east sides of the Uinta basin, northeastern Utah and northwestern Colorado: U.S. Geological Survey Bulletin 1787-P, 34 p.

Molenaar, C.M., and Cobban, W.A., 1991, Middle Cretaceous stratigraphy on the south side of the Uinta basin, east-central Utah, *in* Chidsey, T.C., Jr., ed., Geology of east-central Utah: Utah Geological Association Field Symposium, Publication 19, p. 29-43.

Molenaar, C.M., and Rice, D.D., 1988, Cretaceous rocks of the Western Interior basin, *in* Sloss, L.L., ed., Sedimentary cover — North American craton: U.S.: Geological Society of America, The geology of North America, vol. D-2, p. 77-82.

Moody, G.B., editor, 1961, Petroleum exploration handbook: New York, NY., McGraw-Hill Book Company.

Moore, C.A., 1972, Factors which may affect occurrence of gas in San Juan and Uinta basins, Rocky Mountains (abst.): American Association of Petroleum Geologists Bulletin, v. 56, n. 3, p. 640-641.

Moore, C.L., 1966, Limitations of statistical methods of predicting petroleum and natural gas reserves and avilability: Journal of Petroleum Technology, v. 18, n. 3.

Mott, M.R., and Amuedo, C.L., editors, 1962, Exploration for oil and gas in northwestern Colorado, Field Conference Guidebook: Rocky Mountain Association of Geologists, Denver, CO.

Murray, D.K., Fender, H.B., and Jones, D.C., 1977, Coal and methane gas in the southeastern part of the Piceance Creek basin, Colorado, *in* Veal, H.K., editor, Exploration frontiers of the central and southern rockies: Rocky Mountain Association of Geologists Symosium, p.379-405.

Murray, D.K., and Haun, J.D., 1974, Introduction to the geology of the Piceance Creek basin and vicinity, northwestern Colorado, *in* Guidebook to the energy resources of the Piceance Creek basin, Colorado: Rocky Mountain Association of Geologists, p. 29-39.

Murany, E.E., 1964, Wasatch Formation of the Uinta basin, *in* Sabatka, E.F., ed., Guidebook to the geology and mineral resources of the Uintah basin — Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Field Conferrence, p. 145-155.

Myal, F.R., Price, E.H., Hill, R.E., Kukal, G.C., Abadie, P.A., and Riecken, C.C., 1989, Geologic and production characteristics of the tight Mesaverde Group, Piceance basin, Colorado: U.S. Department of Energy report DOE/ MC/24120-2769, (DE90000415), 126 p.

Narr, W., and Currie, J.B., 1982, Origin of fracture porosity — Example from Altamont Field, Utah: American Association of Petroleum Geologists Bull., v. 66, p. 1231-1247.

National Petroleum Council, 1980, Unconventional gas sources: Washington, D.C., Tight gas reservoirs, v. 5, pt. 1, 222 p., and pt. 2., 767 p.; and executive summary, 3 p.

National Petroleum Council, 1992, The potential for natural gas in the United States — Sources and supply: Washington, D.C., NPC, 501 p.

National Research Council, 1988, Energy-related research in the U.S. Geological Survey: Washington, D.C., NRC Commission on Physical Sciences, Mathematics and Resources, National Academy Press, 95 p.

Nations, J.D., and Eaton, J.G., editors, 1991, Stratigraphy, depositional environments, and sedimentary tectonics of the western margin, Cretaceous Western Interior Seaway: Geological Society of America Special Paper 260, 216 p.

Nehring, R., with Van Driest, E.R., II, 1981, The discovery of significant oil and gas fields in the United States: The Rand Publication Series R-2654/ 1-USGS/DOE, v. 1, 236 p., v. 2, 477 p.

Newendorp, P.D., 1975, Decision analysis for petroleum exploration: Tulsa, OK., Petroleum Publishing Company, 668 p.

Nielson, D.L., editor, 1982, Overthrust belt of Utah: Utah Geological Association, Symposium and Field Conference, Publication 10, 335 p.

Nikols, D.J., and Rottenfusser, B.A., 1991, Coalbed methane — A Canadian resource for the 1990's, *in* Coalbed methane of Western North America: Rocky Mountain Association of Geologists Field Conference Guidebook, p. 249-253.

North, F.K., 1972, A sane look at U.S. gas resources: U.S. Federal Power Commission, National Gas Survey, v. 5, 1973, p. 113-156.

NRG Associates, Inc., 1986, The significant oil and gas fields of the United States (through December 31, 1983): available from Nehring Associates, Inc., Colorado Springs, CO. 80901.

NRG Associates, Inc., 1992, The significant oil and gas fields of the United States (through December 31, 1992): available from Nehring Associates, Inc., Colorado Springs, CO. 80901.

Nuccio, V.F., and Fouch, T.D., 1992, Thermal maturity of the Mesaverde Group, Uinta basin, Utah, *in* Magoon, L.B., editor, The petroleum system — Status of research and methods, 1992: U.S. Geological Survey Bull. 2007, p. 70- 78.

Nuccio, V.F., and Johnson, R.C., 1986, Thermal maturity map of the lower part of the Upper Cretaceous Mesaverde Group, Uinta basin, Utah: U.S. Geological Survey Miscell. Invest. Map MF-1842, scale 1:250,000.

Nuccio, V.F., and Johnson, R.C., 1988, Surface vitrinite reflectance map of the Uinta, Piceance, and Eagle basins area, Utah and Colorado: U.S. Geological Survey Miscell. Field Studies Map MF-20008-B, 21.

Nuccio, V.F., and Johnson, R.C., 1989a, Variations in vitrinite reflectance values for the Upper Cretaceous Mesaverde Formation, southeastern Piceance basin, northwestern Colorado — Implications for burial history and potential hydrocarbon generation: U.S. Geological Survey Bull. 1787-H, 10 p.

Nuccio, V.F., and Johnson, R.C., 1989b, Thermal history of selected coal beds in the upper Cretaceous Mesaverde Group and Tertiary Wasatch Formation, Multiwell Experiment Site, Colorado, in relation to hydrocarbon generation: U.S. Geological Survey Bull. 1886-L, 8 p.

Office of Technology Assessment, 1985, U.S. natural gas availability: Gas supply through the year 2000: Washington, D.C., U.S. Congress, OTA- E-245, February, 252 p.

Oil and Gas Journal, 1972, News: Utah oil field may rank among top 10 in the U.S.: O&GJ, October 23rd, p. 23-27-111-112.

Oil and Gas Journal, 1973, Technology: Here's how Shell solves Uinta basin problems: O&GJ, February 5th.

Osborn, G.D., 1973, Quaternary geology and geomorphology of the Uinta basin and the south flank of the Uinta Mountains, Utah: unpublished Ph.D. dissertation, Berkely, CA., University of California, 266 p.

Osmond, J.C., 1957, Brennan Bottom oil field, Uintah County, Utah, *in* Guidebook to the geology of the Uinta basin: Intermountain Association of Petroleum Geologists, 8th Annual Field Conference, p. 185-187.

Osmond, J.C., 1964, Tectonic history of the Uinta basin, Utah, *in* Sabatka, E.F., editor, Guidebook to the geology and mineral resources of the Uinta basin: Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Annual Field Conference, p. 47-58.

Osmond, J.C., 1965, Geologic history of the Uinta basin, Utah: American Association of Petroleum Geologists Bulletin, v. 49, n. 11, p. 1957-1973.

Osmond, J.C., Locke, R., Dille, A.C., Praetorious, W., and Wilkins, J.G., 1968, Natural gas in Uinta basin, Utah, *in* Beebe, B.W., editor, Natural gases of North America: American Association of Petroleum Geologists Symposium, Volume One, Memoir 9, p. 174-198.

Osmond, J.C., 1985, Reservoir sandstone patterns, Green River Formation, Duck Creek oil field, Uintah County, Utah: Utah Geological Association Publication 12, Geology and energy resources, Uinta basin of Utah, p. 187-192.

O'Sullivan, R.B., 1985, Preliminary geologic map of the Rio Blanco quadrangle, Rio Blanco and Garfield Counties, Colorado: U.S. Geological Survey Miscell. Field Studies Map MF-1816, scale 1:24,000.

O'Sullivan, R.B., 1986, Preliminary geologic map of the Anvil Points quadrangle, Garfield County, Colorado: U.S. Geological Survey Miscell. Field Studies Map MF-1882, scale 1:24,000.

O'Sullivan, R.B., and Hail, W.J., Jr., 1987, Preliminary geologic map of the Forked Gulch quadrangle, Garfield County, Colorado: U.S. Geological Survey Miscell. Field Studies Map MF-1953, scale 1:24,000.

O'Sullivan, R.B., Wahl-Pierce, F., and Arbelbide, S.J., 1981, Preliminary geologic map of the McCarthy Gulch quadrangle, Rio Blanco and Garfield Counties, Colorado: U.S. Geological Survey Miscell. Field Studies Map MF-860, scale 1:24:000.

Owen, A.E., and Whitney, G.W., 1956, San Arroyo-Bar X area, Grand County Utah and Mesa County, Colorado, *in* Peterson, J.S., editor, Geology and economic deposits of east-central Utah, p. 195-198.

Pakiser, L.C., and Mooney, W.D., editors, 1989, Geophysical framework of the continental United States: Geological Society of America Memoir 172, 826 p.

Palmer, I.D., Lambert, S.W., and Spitler, J.L., 1993, Coalbed methane well completions and stimulations, *in* Law, B.E., and Rice, D.D., editors, Hydrocarbons from coal: American Association of Petroleum Geologists Studies in Geology #38, p. 303-339.

Pawlewicz, J.J., Lickus, M.R., Law, B.E., Dickenson, W.W., and Barclay, C.S.V., 1986, Thermal maturity map showing subsurface elevation of 0.8 percent vitrinite reflectance in the greater Green River basin of Wyoming, Colorado, and Utah: U.S. Geological Survey Map MF-1890, scale 1:500,000.

Pelto, C.R., 1973, Forecasting ultimate oil recovery, *in* Symposium on petroleum economics and evaluation: Society of Petroleum Engineers, American Institute of Mining and Metallurgical Engineers, Dallas Section, SPE # 4261, p. 45-52.

Peterson, J.A., editor, 1986, Paleotectonics and sedimentation in the Rocky Mountain region, United States: American Association of Petroleum Geologists Memoir 41, 693 p.

Peterson, P.R., 1972, Pariette Bench field: Utah Geological and Mineralogical Survey, Oil and Gas Field Studies No. 1.

Peterson, P.R., 1973, Horseshoe Bend field: Utah Geological and Mineralogical Survey, Oil and Gas Field Studies No. 6.

Peterson, P.R., 1973, Castle Peak and Monument Butte fields: Utah Geological and Mineralogical Survey, Oil and Gas Field Studies No. 8.

Peterson, P.R., 1973, Cedar Rim area: Utah Geological and Mineralogical Survey, Oil and Gas Fields Studies No. 10.

Peterson, P.R., 1973, Flat Rock area: Utah Geological and Mineralogical Survey, Oil and Gas Fields Studies No. 11.

Peterson, P.R., 1973, Bluebell Field: Utah Geological and Mineralogical Survey, Oil and Gas Fields Studies No. 12.

Peterson, P.R., and Ritzma, H.R., 1974, Informational core-drilling in Utah's oil-impregnated sandstone deposits, southeast Uinta basin, Uintah County, Utah: Utah Geological and Mineralogical Survey Report of Investigations No. 88, in cooperation with the U.S. Bureau of Mines.
Peterson, V.E., 1957, Ashley Valley oil field, Uintah County, Utah: Intermountain Association of Petroleum Geologists Guidebook, 8th Annual Field Conference, p. 191-192.
Picard, M.D., 1956, Summary of Tertiary oil and gas fields in Utah and Colorado: American Association of Petroleum Geologists bulletin, v. 40, n. 12, p. 2956-2960.
Picard, M.D., 1957, Red Wash-Walker Hollow field, stratigraphic trap, eastern Uinta basin, Utah: American Association of Petroleum Geologists Bulletin, v. 41, n. 5, p. 923-936.
Picard, M.D., 1971, Petrologic criteria for recognition of lacustrine and fluvial sandstone, P.R. Spring oil-impregnated sandstone area, southeast Uinta basin, Utah: Utah Geological and Mineralogical Survey, Special Studies 36, 24 p.
Picard, M.D., editor, 1985, Geology and energy resources, Uinta basin of Utah: Utah Geological Association Guidebook, 338 p.
Picard, M.D., and High, L.R., Jr., 1970, Sedimentology of oil-impregnated, lacustrine and fluvial sandstone, P.R. Spring area, southeast Uinta basin, Utah: Utah Geological and Mineralogical Survey Special Studies 33, 32 p.
Picard, M.D., and High, Lee, R., Jr., 1968, Sedimentary cycles in the Green River Formation (Eocene), Uinta basin, Utah: Journal of Sedimentary Petrology, v. 38, n. 2, p. 378-383.
Picard, M.D., Thompson, W.D., and Williamson, C.R., 1973, Petrology, geochemistry, and stratigraphy of black shale facies of Green River Formation (Eocene), Uinta basin, Utah: Utah Geological and Mineralogical Survey Bulletin 100, 52 p.
Pirson, S.J., 1958, Reservoir engineering, 2nd Edition: New York, NY., McGraw- Hill Book Company, Chapter 2.
Pitman, J.K., Anders, D.E., Fouch, T.D., and Nichols, D.J., 1986, Hydrocarbon potential of nonmarine Upper Cretaceous and Lower Tertiary rocks, eastern Uinta basin, Utah, *in* Spencer, C.W., and Mast, R.F., editors, 1986, Geology of tight gas reservoirs: American Association of Petroleum Geologists, Studies in Geology #24, p. 235-252.
Pitman, J.K., Fouch, T.D., and Goldhaber, M.B., 1982, Depositional setting and diagenetic evolution of some Tertiary unconventional reservoir rocks, Uinta basin, Utah: American Association of Petroleum Geologists Bulletin, v. 66, n. 10, p. 1581-1596.
Pitman, J.K., Franczyk, K.J., and Anders, D.E., 1987, Marine and nonmarine gas- bearing rocks in Upper Cretaceous Blackhawk and Neslen Formations, eastern Uinta basin, Utah: American Association of Petroleum Geologists Bull., v. 71, p. 76-94.
Pitman, J.K., Spencer, C.W., and Pollastro, R.M., 1989, Petrography, mineralogy, and reservoir characteristics of the Upper Cretaceous Mesaverde Group in the east-central Piceance basin, Colorado: U.S. Geological Survey Bull. 1787-G, 31 p.
Pitman, J.K., and Sprunt, E.S., 1986, Origin and distribution of fractures in Lower Tertiary and Upper Cretaceous rocks, Piceance basin, Colorado, and their relation to the occurrence of hydrocarbons, *in* Spencer, C.W., and Mast, R.F., editors, 1986, Geology of tight gas reservoirs: American Association of Petroleum Geologists, Studies in Geology #24, p. 221-233.
Platt's Oilgram News, 1984, 300 TCF of undiscovered U.S. gas - Exxon: Platt's Oilgram News, v. 62, n. 82, April 27th, p. 2.
Pollard, J.H., 1977, A handbook of numerical and statistical techniques: Cambridge, Great Britain, Cambridge University Press, 349 p.
Porter, L., Jr., 1963, Stratigraphy and oil possibilities of the Green River Formation in the Uinta basin, Utah, *in* Oil and gas possibilities of Utah, re-evaluated: Utah Geological and Mineralogical Survey Bulletin 54, p. 193-198.
Porter, J.W., and McCrossan, R.G., 1975, Basin consanguinity in petroleum resource estimation, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 50-75.
Potential Gas Committee, 1987, Potential supply of natural gas in the United States (as of December 31, 1986): Golden, CO., Potential Gas Agency, Colorado School of Mines, 160 p.

Potter, C.J., Tang, R., and Hainsworth, T.J., 1989, Late Paleozoic structure of the southern part of the Uinta basin, Utah, from seismic reflection data: U.S. Geological Survey Bull. 1787-V, 10 p.

Preston, Don, editor, 1961, A symposium of the oil and gas fields of Utah: Intermountain Association of Petroleum Geologists, unpaginated.

Price, L.C., 1989, Primary petroleum migration from shales with oxygen-rich organic matter: Journal of Petroleum Geology, v. 12, p. 289-324.

Pruit, J.D., 1973, Developments in eastern and northwestern Colorado in 1972: American Association of Petroleum Geologists Bull., v. 57, n. 8, p. 1492- 1497.

Pruitt, R.G., Jr., 1961, The mineral resources of Uintah County, Utah: Utah Geological and Mineralogical Survey Bulletin 71, 101 p.

Quigley, M.D., 1965, Geologic history of Piceance Creek-Eagle basins: American Association of Petroleum Geologists Bull., v. 49, p. 1974-1996.

Radke, M., Willsch, H., and Teichmuller, M., 1990, Generation and distribution of aromatic hydrocarbons in coals of low rank: Organic Geochemistry, v. 15, p. 539-563.

Rascoe, B., Jr., and Baars, D.L., 1972, Permian System, *in* Mallory, W.W., editor, Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, p. 143-165.

Ray, R.G., Kent, B.H., and Dane, C.H., 1956, Stratigraphy and photogeology of the southwestern part of Uinta basin, Duchesne and Uintah Counties, Utah: U.S. Geological Survey, Oil and Gas Investigations Map, OM-171, 2 sheets, scale 1:63,360.

Remy, R.R., 1992, Stratigraphy of the Eocene part of the Green River Formation in the south-central part of the Uinta basin, Utah: U.S. Geological Survey Bull. 1787-BB, 79 p.

Rice, D.D., editor, 1986, Oil and gas assessment - Methods and applications: American Association of Petroleum Geologists, Studies in Geology no. 21, 267 p.

Rice, D.D., and Gautier, D.L., 1983, Patterns of sedimentation, diagenesis, and hydrocarbon accumulation in Cretaceous rocks of the Rocky Mountains: Society of Economic Paleontologists and Mineralogists, Lecture Notes for Short Course no. 11.

Rice, D.D., Law, B.E., and Clayton, J.L., 1993, Coalbed gas — An undeveloped resource, *in* Rice, D.D., editor, The future of energy gases: U.S. Geological Survey Professional Paper 1570, p. 389-404.

Richardson, F.H., Chairman, 1992, The potential for natural gas in the United States: Washington, D.C., National Petroleum Council, Committee on Natural Gas, v. II, 330 p. plus 13 appendices and glossary.

Rightmire, C.T., Eddy, G.E., and Kirr, J.N., 1984, Coalbed methane resources of the United States: American Association of Petroleum Geologists, Studies in Geology Series #17, 378 p.

Ritzma, H.R., 1967, Oil-impregnated sandstone deposits of Utah: Interstate Oil compact Commission bulletin, v. 9, n. 2, p. 87-98.

Ritzma, H.R., 1968, Preliminary location map - Oil-impregnated rock deposits of Utah: Utah Geological and Mineralogical Survey Map no. 25, scale about 1:1,000,000.

Ritzma, H.R., 1969, Tectonic resume, Uinta Mountains, *in* Geologic guidebook of the Uinta Mountains: Intermountain Association of Geologists, 16th Annual Field Conference, p. 57-63.

Ritzma, H.R., 1972, Petroleum and natural gas: The Uinta basin, *in* Mallory, W.W., editor, Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, p. 276-278.

Ritzma, H.R., compiler, 1973a, Publications on hydrocarbons by the Utah Geological and Mineral Survey, Circular 56.

Ritzma, H.R., 1973b, Utah's oil-impregnated sandstone deposits: A giant undeveloped resource (abst.): American Association of Petroleum Geologists Bulletin, v. 57, n. 5, p. 961-962.

Ritzma, H.R., 1973c, Oil-impregnated rock deposits of Utah: Utah Geological and Mineral Survey Map 33, 2 sheets.

Ritzma, H.R., and Oriel, S.S., editors, 1955, Guidebook to the geology of northwest Colorado: Intermountain Association of Petroleum Geologists, 6th Annual Field Conference, Salt Lake City, UT.

Roberts, P.K., 1964, Stratigraphy of the Green River Formation, Uinta basin, Utah: unpublished Ph.D. dissertation, University of Utah, 212 p.

Robertson, J.M., and Broadhead, R.F., project directors, 1993, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, published for a consortium of agencies including Gas Research Institute, Department of Energy, Colorado Geological Survey, Utah Geological Survey, and Geological Survey of Wyoming, 206 p.

Robinson, J.G., 1980, Determination of reserves and values and application of risk: Journal Canadian Petroleum Technology, November.

Robinston, J.E., 1982, Computer applications in petroleum geology: New York, NY., Hutchinson Ross Publishing Company, 164 p.

Roehler, H.W., 1992, Introduction to greater Green River basin geology, physiography, and history of investigations: U.S. Geological Survey Prof. Paper 1506-A, 14 p.

Root, D.H., and Mast, R.F., 1993, Future Growth of Known Oil and Gas Fields: American Association of Petroleum Geologists Bull., v. 77, p. 479-484.

Root, D.H., and Schuenemeyer, J.H., 1980, Petroleum resource appraisal and discovery-rate forecasting in partially explored regions — Mathematical foundations: U.S. Geological Survey Professional Paper 1138-B, 9 p.

Ross, R.J., Jr., and Tweto, O., 1980, Lower Paleozoic sediments and tectonics in Colorado, *in* Kent, H.C., and Porter, K.W., editors, Colorado geology: Rocky Mountain Association of Geologists 1980 Symposium, p. 47-56.

Ross, S., 1985, Introduction to probability models, 3rd edition: New York, NY., Academic Press, 502 p.

Rowley, P.D., Hansen, W.R., Tweto, O., and Carrara, P.E., 1985, Geologic map of the Vernal 1° x 2° quadrangle, Colorado, Utah, and Wyoming: U.S. Geological survey Miscell. Invest. Map I-1526, scale 1:250,000.

Rozendal, R.A., 1986, Conventional U.S. oil and gas remaining to be discovered: Estimates and methodology used by Shell Oil Company, *in* Rice, D.D., editor, Oil and gas assessment - Methods and applications: American Association of Petroleum Geologists Studies in Geology, No. 21 p. 151-158.

Rummerfield, B.J., and Morrisey, N.S., 1965, How to evaluate exploration prospects: World Oil, April, p. 126.

Ryan, J.M., 1965, National Academy of Sciences report on energy resources, discussion of the limitations of the logistic projections: American Association of Petroleum Geologists Bulletin, v. 49, n. 10.

Ryder, R.T., Fouch, T.D., and Elison, J.H., 1976, Early Tertiary sedimentation in the western Uinta basin, Utah: Geological Society of America Bull., v. 87, p.496-512.

Sabatka, E.F., editor, 1964, Guidebook to the geology and mineral resources of the Uinta basin: Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Annual Field Conference, 276 p.

Sanborn, A.F., 1971, Possible future petroleum of Uinta and Piceance basins and vicinity, northeast Utah and northwest Colorado, *in* Future petroleum provinces of the United States, their geology and potential, volume 1: American Association of Petroleum Geologists Memoir 15, p. 489-508.

Sanborn, A.F., 1977, Possible future petroleum of Uinta and Piceance basins and vicinity, northeast Utah and northwest Colorado, *in* Veal, H.K., editor, Exploration frontiers of the central and southern Rockies Symposium, p. 151-166.

Sanborn, A.F., 1981, Potential petroleum resources of northeastern Utah and northwestern Colorado, *in* Epis, R.C. and Callender, J.F., editors, Western Slope Colorado: New Mexico Geological Society, 32nd Annual Field Conference, p. 255-265.

Sanborn, A.F., and Goodwin, J.C., 1965, Green River Formation at Raven Ridge, Uintah County, Utah: Rocky Mountain Association of Geologists, The Mountain Geologist, v. 2, n. 3, p. 109-114.

Sandia National Laboratories, 1988, Multiwell Experiment final report: II. The paludal interval of the Mesaverde Formation: Albuquerque, NM., SNL and CER Corporation for the U.S. Department of Energy: SAND88-1008, contract DE-AC04-76DP00789, May, not consecutively paginated.

Sandia National Laboratories, 1990, Multiwell Experiment final report: IV. The fluvial interval of the Mesaverde Formation: Albuquerque, NM., SNL and CER Corportation for the U.S. Department of Energy: SAND 89-2612/A, contract DE-AC04-76DP00789, not consecutively paginated.

Sattler, A.R., Raible, C.J., and Gall, B.R., 1985, Integration of laboratory and field data for insight on the Multiwell Experiment paludal stimulation, *in* Low permeability reservoirs, 1985 SPE/DOE Joint Proceedings: Society of Petroleum Engineers of AIME and U.S. Department of Energy Symposium, May 19-22, 1985, 13891, p. 397-410.

Saunders, D.F., and Hicks, D.E., 1979, Regional geomorphic lineaments on satellite imagery — Their origin and applications, *in* Podwysocki, M.H., and Earle, J.L., eds., Proceedings of the Second International Conference on Basement Tectonics: Denver, CO., Basement Tectonics Committee, Inc., available from Utah Geological Association Pub. #5, p. 326-352.

Scanlon, A.H., 1983, Oil and gas fields map of Colorado: Colorado Geological Survey Map Series 22, scale 1:500,000.
Scheidt, G., and Littke, R., 1989, Comparative organic petrology of interlayered sandstones, siltstones, mudstones and coals in the Upper Carboniferous Ruhr basin, northwest Germany, and their thermal history and methane generation: Geol. Rundschau, v. 78, p. 375-390.
Schmoker, J.W., Coalson, E.B., and Brown, C.A., editors, 1992, Geological studies relevant to horizontal drilling: Examples from Western North America: Rocky Mountain Association of Geologists, 284 p.
Scholle, P.A., and Spearing, Darwin, editors, 1982, Sandstone depositional environments: American Association of Petroleum Geologists, 410 p.
Schuenemeyer, J.H., Bawiec, W.J., and Drew, L.J., 1980, Computational methods for a three-dimensional model of the petroleum-discovery process: Computers and Geoscience, v. 6, n. 4, p. 323-360.
Schuenemeyer, J.H., Drew, L.J., and Bawiec, W.J., 1980, A three-dimensional model to predict future oil discoveries in spatially connected multiple plays: International Association Mathematical Geology Journal, v. 12, n. 5, p. 459-472.
Schwade, I.T., 1967, Geologic quantification: Description-numbers-success ratio: American Association of Petroleum Geologists Bulletin, v. 51, p. 1225-1239.
Scott, R.W., Jr., in press, Structure contour map of the Precambrian surface in the Uinta-Piceance area, Utah and Colorado: U.S. Geological Survey Miscell. Invest. Series Map, contour interval 1,000 feet, scale 1:1,000,000.
Shannon, P.M., and Naylor, D., 1989, Petroleum basin studies: Boston, MA., Graham and Trotman, Inc., 206 p.
Smith, J.L., and Ward, G.L., 1981, Maximum likelihood estimate of the size distribution of North Sea oil fields: International Association Mathematical Geology Journal, v. 13, n. 5, p. 399-413.
Smith, M.R., and Brown, K.W., 1981, Utah mineral industry activity review and summary of oil and gas drilling and production 1980: Utah Geological and Mineral Survey, Division of Utah Department of Natural Resources and Energy, Circular 71, 31 p.
Soule, J.M., 1989, Precambrian to earliest Mississippian stratigraphy, geologic history, and paleogeography of northwestern Colorado and west- central Colorado: U.S. Geological Survey Bull. 1787-U, 35 p.
Spencer, C.W., 1987, Hydrocarbon generation as a mechanism for overpressuring in the Rocky Mountain region: American Association of Petroleum Geologists Bulletin, v. 71, n. 4, p. 368-388.
Spencer, C.W., 1989, Comparison of overpressuring at the Pinedale Anticline area, Wyoming, and the Multiwell Experiment Site, Colorado: U.S. Geological Survey Bull. 1886-C, 16 p.
Spencer, C.W., and Keighin, C.W., editors, 1984, Geologic studies in support of the U.S. Department of Energy Multiwell Experiment, Garfield County, Colorado: U.S. Geological Survey Open-File Report 84-757, 134 p.
Spencer, C.W., and Mast, R.F., editors, 1986, Geology of tight gas reservoirs: American Association of Petroleum Geologists, Studies in Geology #24, 299 p.
Spencer, C.W., and Wilson, R.J., 1988, Petroleum geology and principal exploration plays in the Uinta-Piceance-Eagle basins province, Utah and Colorado: U.S. Geological Survey Open-File Report 88-450-G, 35 p.
Stach, E., Mackowsky, M.Th., Teichmuller, M., Taylor, G.H., Chandra, D., and Teichmuller, R., 1982, Stach's textbook of coal petrology: Stuttgart, Gebruder Borntrager, 535 p.
Stearns, D.W., and Friedman, M., 1972, Reservoirs in fractured rock in stratigraphic oil and gas fields: American Association of Petroleum Geologists Memoir 16 and Society of Exploration Geophysicists Special Publication 10, p. 87.
Stokes, W.L., 1986, Geology of Utah: Utah Museum of Natural History and Utah Geological and Mineralogical Survey, Occasional Paper Number 6, 309 p.
Stone, D.S., 1975, A dynamic analysis of subsurface structure in northwestern Colorado, *in* Bolyard, D.W., ed., Deep drilling frontiers in the central Rocky Mountains: Rocky Mountain Association of Geologists, Symposium, p. 33-40.
Stone, D.S., 1977, Tectonic history of the Uncompahgre uplift, *in* Veal, H.K., editor, Exploration frontiers of the central and southern Rockies: Rocky Mountain Association of Geologists Symposium, p. 23-30.
Stone, D.S., editor, 1986, New interpretations of northwest Colorado geology: Rocky Mountain Association of Geologists Symposium, 308 p.
Stowe, C.H., 1972, Oil and gas production in Utah to 1970: Utah Geological and Mineralogical Survey Bulletin 94, 179 p.

Stowe, C.H., 1979, Utah's oil and gas industry: Past, present, and future: Salt Lake City, UT., University of Utah, Engineering Experiment Station.

Sweeney, J.J., Burnham, A.K., and Braun, R.L., 1987, A model of hydrocarbon generation from type I kerogen: Application to Uinta basin, Utah: American Association of Petroleum Geologists Bull., v. 71, p. 967-985.

Taylor, O.J., 1987, Oil shale, water resources, and valuable minerals of the Piceance basin, Colorado: The challenge and choices of development: U.S. Geological Survey Prof. Paper 1310, 143 p.

Terra Graphics, 1977, Oil and gas production map of the Western United States, Denver, CO, scale approximately 1:3,250,000.

Tetra Tech, Incorporated, 1979, Department of the Navy energy fact book: Arlington, VA., TTI, report TT-A-6054-79-403 for Office of Naval Research, 528 p.

Theobald, P.K., Schweinfurth, S.P., and Duncan, D.C., 1972, Energy resources of the United States: U.S. Geological Survey circular 650, 27 p.

Thomas, G.E., 1979, Lineament-block tectonics: North America-Cordilleran orogen, *in* Podwysocki, M.H., and Earle, J.L., eds., Proceedings of the Second International Conference on Basement Tectonics: Denver, CO., Basement Tectonics Committee, Inc., available from Utah Geological Association Pub. #5, p. 361-373.

Thompson, G.A., and Zoback, M.L., 1979, Regional geophysics of the Colorado Plateau: Tectonophysics, v. 61, p. 149-181.

Tissot, B.P., Deroo, G., and Hood, A., 1978, Geochemical study of the Uinta basin: Formation of petroleum from the Green River Formation: Chimica et Cosmochemica Acta, v. 42, p. 1469-1485.

Tissot, B.P., Pelet, R., and Ungerer, Ph., 1987, Thermal history of sedimentary basins, maturation indices, and kinetics of oil and gas generation: American Association of Petroleum Geologists Bulletin, v. 71, n. 12, p. 1445-1466.

Tissot, B.P., and Welte, D.H., 1978, Petroleum formation and occurrence: A new approach to oil and gas exploration: New York, NY., Springer-Verlag, 538 p.

Tissot, B.P., and Welte, D.H., 1984, Petroleum formation and occurrence, 2nd Edition: Berlin, Springer-Verlag Publishers, 699 p.

Tremain, C.M., 1984, Coalbed methane resources of Colorado: Colorado Geological Survey Map Series 19, scale 1:500,000.

Tremain, C.M., 1990, Coalbed methane development in Colorado, [as of] September 1990: Colorado Geological Survey Information Series 32, 35 p.

Tremain, C.M., Boreck, D.L., and Kelso, B.S., 1981, Methane in Cretaceous and Paleocene coals of western Colorado, *in* Epis, R.C., and Callender, J.F., editors, Western Slope Colorado: New Mexico Geological Society 32nd Field Conference Guidebook, p. 241-248.

Tweto, O., compiler, 1979, Geologic map of Colorado: U.S. Geological Survey and Geological Survey of Colorado, scale 1:500,000.

Tyler, R., Ambrose, W.A., Scott, A.R., and Kaiser, W.R., 1991, Coalbed methane potential of the greater Green River, Piceance, Powder River, and Raton basins: Gas Research Institute, Chicago, IL., prepared by Bureau of Economic Geology, Topical Report January-July 1991, 244 p.

United States Bureau of Mines and the United States Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

United States Department of Energy, 1980, Applied analysis model summaries - Analysis report: DOE Energy Information Administration, Office of Applied Analysis, December, 1980, DOE/EIA-0293, 169 p.

United States Department of Energy, 1982, Seismic evaluation of NOSR 2 - Naval Oil Shale Reserves management support and systems engineering project: McLean, Virginia, TRW under contract No. DE-AC01-78RA32012, DOE/RA/32012-T20, January, 1982, DOE Technical Information Center, 24 p.

United States Department of Energy, 1987a, U.S. crude oil, natural gas, and natural gas liquids reserves - 1986 annual report: DOE Energy Information Administration Report DOE/EIA-0216(86), Washington, D.C., 103 p.

United States Department of Energy, 1987b, Annual energy outlook 1986: DOE Energy Information Administration Report DOE/EIA-0383(86), Washington, D.C., 70 p.

United States Department of Energy, 1992, Geologic distributions of U.S. oil and Gas: DOE, Energy Information Administration, Office of Oil and Gas, DOE/EIA-0557, 137 p.

United States Geological Survey and the Minerals Management Service, 1988, National assessment of undiscovered conventional oil and gas resources: U.S. Geological Survey Working Paper, Open-File Report 88-373, 511 p.

Untermann, G.E., and Untermann, B.R., 1964, Geology of Uintah County: Utah Geological and Mineralogical Survey Bulletin 72, 112 p.

Utah Department of Natural Resources, 1990, Report of Utah oil and gas activity 1990: State of Utah, Division of Oil, Gas, and Mining, prepared by D. Staley, 25 p.

Utah Department of Natural Resources, 1992, September 1992 oil and gas production report: State of Utah, Division of Oil, Gas, and Mining, 248 p.

Utah Department of Natural Resources, 1993, September 1993 oil and gas production report: State of Utah, Division of Oil, Gas, and Mining, 249 p.

Utah Geological and Mineral Survey, 1983, Energy resources map of Utah: UGMS, Dept. of Natural Resources and Energy, scale 1:500,000.

Utah Geological Association, 1974, Energy resources of the Uinta basin, Utah: Utah Geological and Mineral Survey, UGA Annual Field Conference, Sept. 18-21, 1974, Pub. #4, 73 p.

Utah Geological Association, 1983, Energy resources and geologic overview of the Uinta basin, Utah: UGA Annual Field Conference, W.B. Cashion, Chairman, September 15-17, 1983, 73 p.

Utah Geological and Mineral Survery, 1983, Energy resources map of Utah: UGMS, Map 68, scale 1:500,000.

Verbeek, E.R., and Grout, M.A., 1983, Fracture history of the northern Piceance Creek basin, nowrthwestern Colorado, *in* Gary, J.H., ed., 16th Oil Shale Symposium, Proceedings: Golden, CO., Colorado School of Mines Press, p. 26-44.

Verbeek, E.R., and Grout, M.A., 1984a, Fracture studies in Cretaceous and Paleocene strata in and around the Piceance basin, Colorado — Preliminary results and their bearing on a fracture-coantrolled natural-gas reservoir at the MWX site: U.S. Geological Survey, Open-File Report 84-156, 30 p.

Verbeek, E.R., and Grout, M.A., 1984b, Prediction of subsurface fracture patterns from surface studies of joints — An example from the Piceance Creek basin, *in* Spencer, C.W., and Keighin, C.W., eds., Geologic studies in support of the U.S. Department of Energy Multiwell Experiment, Garfield County, Colorado: U.S. Geological Survey Open-File Report 84-757, p. 75- 86.

Vlissides, S.D., and Quirin, B.A., 1964, Oil and gas fields of the United States exclusive of Alaska and Hawaii: U.S. Geological Survey, scale 1:2,500,000.

Waechter, N.B., and Johnson, W.E., 1985, Seismic interpretation in the Piceance basin, northwest Colorado, *in* Gries, R.R., and Dyer, R.C., editors, Seismic exploration of the Rocky Mountain region: Rocky Mountain Association of Geologists and Denver Geophysical Society, p. 247-258.

Waechter, N.B., and Johnson, W.E., 1986, Pennsylvanian-Permian paleostructure and stratigraphy as interpreted from seismic data in the Piceance basin, northwest Colorado, *in* Stone, D.S., editor, New interpretations of northwest Colorado geology: Rocky Mountain Association of Geologists Symposium, p. 51-64.

Waples, D., 1982, Organic geochemistry for exploration geologists: Boston, MA., International Human Resources Development Corporation, 151 p.

Warner, M.M., 1966, Sedimentational analysis of the Duchesne River Formation, Uinta Basin, Utah: Geological Society of America Bulletin, v. 77, n. 9, p. 945-957.

Weeks, L.G., 1975, Potential petroleum resources — Classification, estimation, and status, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology No. 1, p. 31-49.

Wells, L.F., 1958, Petroleum occurrence in the Uinta basin (Utah-Colorado), *in* Weeks, L.G., editor, Habitat of oil - A symposium: American Association of Petroleum Geologists, p. 344-465.

Weimer, R.J., 1980, Recurrent movement on basement faults, a tectonic style for Colorado and adjacent areas, *in* Kent, H.C., and Porter, K.W., editors, Colorado geology: Rocky Mountain Association of Geologists, p. 23-35.

Weiss, M.P., Witkind, I.J., and Cashion, W.B., 1990, Geologic map of the Price 30'x 60' quadrangle, Carbon, Duchesne, Uintah, Utah, and Wasatch Counties, Utah: U.S. Geological Survey Miscell. Invest. Series Map I-1981, scale 1:100,000.

Wenger, W.L., and Morris, J.C., 1971, Utah crude oil - Characteristics of 67 samples: U.S. Bureau of Mines Report of Investigations 7532, 51 p.

Wesley, J.B., Wandrey, C.J., and Fouch, T.D., 1993, Principal drill stem test database (UBDST) and documentation: Analysis of Uinta Basin, Utah, gas- bearing Cretaceous and Tertiary strata: U.S. Geological Survey, Open-File Report 93-193, 18 p.
Whitaker, R.M., 1975, Upper Pennsylvanian and Permian strata of northeast Utah and northwest Colorado, *in* Bolyard, D.W., ed., Deep drilling frontiers in the central Rocky Mountains: Rocky Mountain Association of Geologists, Symposium, p. 75-85.
White, D.A., Garrett, R.W., Jr., Marsh, G.R., Baker, R.A., and Gehman, H.M., 1975, Assessing regional oil and gas potential, *in* Haun, J.D., editor, Methods of estimating the volume of undiscovered oil and gas resources: American Association of Petroleum Geologists, Studies in Geology, no. 1, p. 143-159.
White, D.A., and Gehman, H.M., 1979, Methods of estimating oil and gas resources: American Association of Petroleum Geologists Bulletin, v. 63, n. 2, p. 2183-2192.
Whiting, D.L., chairman, 1974, Energy resources of the Uinta basin, Utah: Utah Geological Association, Annual Field Conference Sept. 18-21, 1974, 73 p.
Wiley, D.R., 1967, Petrology of bituminous sandstones in the Green River Formation, southeastern Uinta basin: unpublished M.S. thesis, University of Utah, 95 p.
Wood, R.E., and Ritzma, H.R., 1972, Analysis of oil extracted from oil-impregnated sandstone deposits in Utah: Utah Geological and Mineralogical Survey Special Studies No. 39, 19 p.
Woodward, J., Meissner, F.F., and Clayton, J.L., editors, 1984, Hydrocarbon source rocks of the Greater Rocky Mountain region: Rocky Mountain Association of Geologists Symposium, 557 p.
World Oil, 1972, In Utah — Why Uinta basin drilling is costly and difficult, April, p. 65-68.
Yeend, W.E., and Donnell, J.R., 1960, Geologic map of the Rulison quadrangle, Garfield County, Colorado: U.S. Geological Survey Open-File Report, scale 1:24,000.
Young, R.G., 1955, Sedimentary facies and intertonguing in the Upper Cretaceous of the Book Cliffs, Utah-Colorado: Geological Society of America Bulletin, v. 66, n. 2, p. 177-201.
Young, R.G., 1957, Late Cretaceous cyclic deposits, Book Cliffs, eastern Utah: American Association of Petroleum Geologists Bulletin, v. 41, n. 8, p. p. 1760-1774.
Young, R.G., 1975, Lower Cretaceous rocks of northwestern Colorado and northeastern Utah, *in* Bolyard, D.W., ed., Deep drilling frontiers in the central Rocky Mountains: Rocky Mountain Association of Petroleum Geologists, Symposium, p. 141-147.
Zapp, A.D., 1962, Future petroleum producing capacity of the United States: U.S. Geological Survey Bulletin 1142-H, 36 p.