OIL AND GAS FIELD STUDIES

UTAH GEOLOGICAL SURVEY

UTAH GEOLOGICAL SURVEY
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Department of Natural Resources

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Open-File Report 430

OIL AND GAS FIELD STUDIES (re-released 6/04), CD (80 p., 29 plates)

compiled by Craig D. Morgan ((OG16-23, C84, OFR-307 & 232))

These are older publications (1991-2001) with data that are still current because, although these fields have not seen significant activity, they are in basins with active drilling. With increased drilling interest in Utah, the reports are being released in a new form so the data may be of more use. They are published as pdf files (Acrobat Reader is included on the CD) and may easily be viewed and printed.

The Duchesne, Bridgeland, and Humpback studies were part of a Department of Energy-funded study lead by Terratek with UGS as a subcontractor. The area was part of the DOE/Green River study by the UGS which issued a series of CD publications.

The Cisco Dome, PR Springs, Harley Dome, Cisco Townsite, and Agate publications were prepared by Craig Morgan and Roger Bon as evaluation work for School and Institutional Trust Lands Administration (SITLA) in northern Grand County. There is an increased interest in the Uintah/Grand County border area.

Cane Creek anticline and Cane Creek play area were reports published in response to horizontal drilling activity in the Paradox Basin and interest in the Cane Creek Shale of the Paradox Formation.

Salt Wash Field was an evaluation for SITLA. Only one well was drilled in the field since the study, but it produced from the Leadville and has current interest.

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Reports Included in this Publication

Note: The copies in this publication are low resolution. If higher resolution is needed please see the individual reports, linked below.

Duchesne oil field, T. 4 S., R. 4 and 5 W., UBM, Duchesne County, Utah by C.D. Morgan, 2 plates, 1997; Oil and Gas Field Study 16 https://doi.org/10.34191/OG-16

Bridgeland and South Myton Bench oil fields, T. 4 S., R. 2 and 3 W., UBM, Duchesne County, Utah by C.D. Morgan, 2 plates, 1997; Oil and Gas Field Study 17 https://doi.org/10.34191/OG-17

Humpback secondary-recovery (water-flood) unit, T. 8 S., R. 17 E., Salt Lake Base Line, Uintah County, Utah by C.D. Morgan, 2 plates, 1997; Oil and Gas Field Study 18 https://doi.org/10.34191/OG-18

Petroleum geology of the Cisco Dome area, Grand County, Utah, by Craig D. Morgan, 4 plates, 6/99; Oil and Gas Field Study 19 https://doi.org/10.34191/OG-19

Gas fields in the PR Springs area, Grand County, Utah, by Craig D. Morgan, 2 plates, 6/99; Oil and Gas Field Study 20 https://doi.org/10.34191/OG-20

Petroleum geology of the Harley Dome field, Grand County, Utah, by Roger L. Bon, 2 plates, 6/99; Oil and Gas Field Study 21 https://doi.org/10.34191/OG-21

Petroleum geology of the Cisco Townsite and Cisco Wash areas, Grand County, Utah, by Craig D. Morgan, 2 plates, 11/99; Oil and Gas Field Study 22 https://doi.org/10.34191/OG-22

Petroleum geology of the Agate, Danish Wash, Sage, and Seiber Nose Reservoirs in the Greater Cisco Field, Grand County, Utah, by Craig D. Morgan, 2 plates, 12/01;
Oil and Gas Field Study 23 https://doi.org/10.34191/OG-23

Geological considerations for oil and gas drilling on State potash leases at Cane Creek anticline, Grand and San Juan Counties, Utah, by C.D. Morgan, W.A. Yonkee, and B.T. Tripp, 1991, 24 p.;
Circular 84 https://doi.org/10.34191/C-84

"Cane Creek" exploration play area, Emery, Grand, and San Juan Counties, Utah, by C.D. Morgan, 15 p., 9 pl., 1:140,000, March 1992; Open-File Report 232 https://doi.org/10.34191/OFR-232

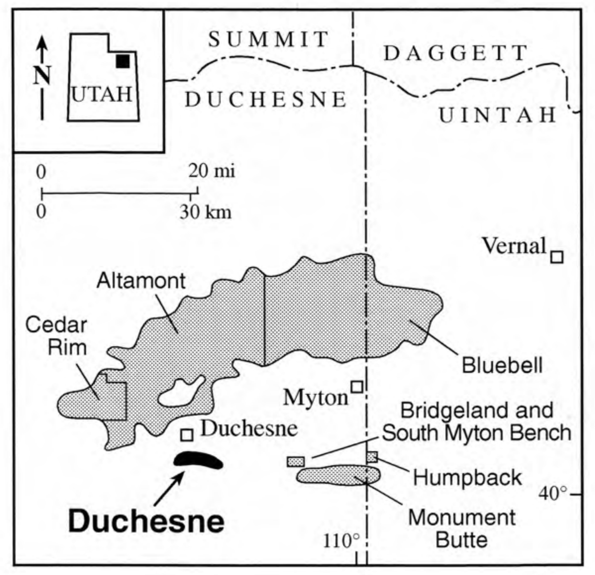
Exploring for new oil in old fields, Salt Wash Field: a case study, by C.D. Morgan, 41 p., 2 pl., 1994; Open-File Report 307 https://doi.org/10.34191/OFR-307

DUCHESNE OIL FIELD
T. 4 S., R. 4 AND 5 W., UBM
DUCHESNE COUNTY, UTAH

by

Craig Morgan

1997



Oil and Gas Field Study 16
UTAH GEOLOGICAL SURVEY
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INTRODUCTION

The Duchesne field, discovered in 1951, is located in T. 4 S., R. 4 and 5 W., Uinta Base Line and Meridian (figure 1). Hydrocarbon production is from the Tertiary Green River and Wasatch Formations (figure 2). The Green River reservoir sandstones were deposited in fluvial-deltaic, interdeltaic, to shallow-lacustrine environments. The Wasatch reservoir sandstones are fluvial-channel deposits.

TerraTek Incorporated is conducting a study in the Duchesne - Monument Butte area titled *Advanced Fracture Modeling in the Uinta Basin (Utah) for Optimized Primary and Secondary Recovery.* The Utah Geological Survey, under a subcontract to TerraTek Inc., compiled and mapped basic oil-well data from the Duchesne, South Myton Bench, and Bridgeland fields, as well as the Humpback Unit. The data will be used by TerraTek Inc. in developing their geologic characterization of the area. The Duchesne field was chosen for study because the Duchesne fault zone trends east-west through the field and is the major focus of the TerraTek Inc. study.

HYDROCARBON PRODUCTION

Cumulative production from the Duchesne field and neighboring wells (28-1 and 3-13) as of September 30, 1996 was 1,623.6 thousand barrels of oil equivalent (MBOE) (227,304 MT).

The upper Green River Formation (Evacuation Creek and Parachute Creek Members) production is from a minimum of 1,334 and a maximum of 3,595 feet (406.9-1,096.5 m) drill depth. The upper Green River cumulative production is 210.6 MBOE (29,484 MT) (table 1), which is 13 percent of the total production from the Duchesne field area. Production from the upper Green River is dominantly oil with little to no associated gas. Two wells (1-21D and 1-22D) produce minor amounts of gas and no oil.

The lower Green River Formation (Garden Gulch, Douglas Creek, and Castle Peak Members) production is from a minimum of 5,380 and a maximum of 6,964 feet (1,604.9- 2,124.0 m) drill depth. The lower Green River cumulative production is 474.1 MBOE (66,374 MT) (table 2), which is 29 percent of the total production from the Duchesne field area. Production from the lower Green River is dominantly gas. The average gas-to-oil ratio (GOR) of lower Green River production based on the initial-potential (IP) tests is 17,135 CFG (cubic feet of gas)/BO (66.83 m^3/MT). The average GOR based on the lower Green River cumulative production is 47,305 CFG/BO (184.49 m^3/MT); this does not include the 1-3D and number 1 (section 9) wells which have no reported gas production.

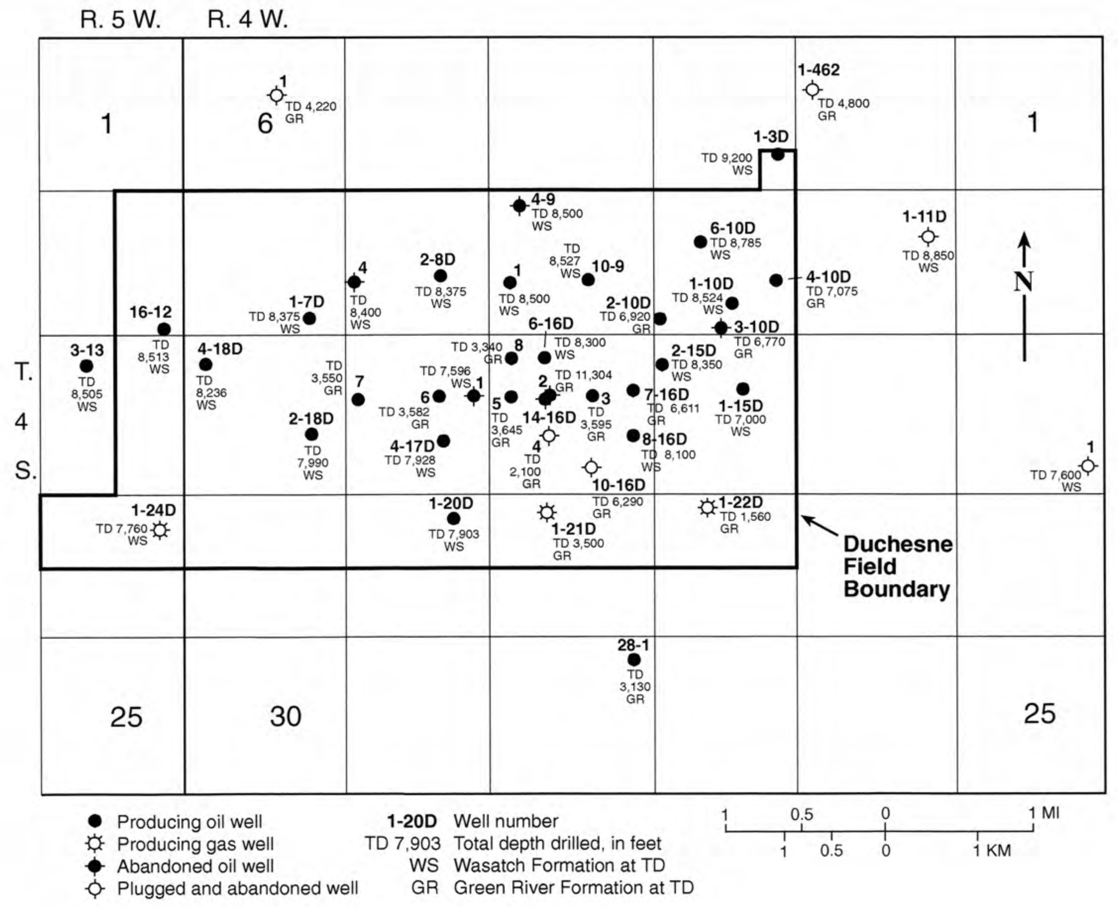


Figure 1. Well location map of the Duchesne field area.

The Wasatch Formation production is from a minimum of 7,126 to a maximum of 8,500 feet (2,173.4-2,592.5 m) drill depth. The Wasatch cumulative production is 875.8 MBOE (122,612 MT) (table 3), which is 54 percent of the total production from the Duchesne field area. Production from the Wasatch is dominantly oil with associated gas. The average GOR of the Wasatch production based on the IP tests is 614 CFG/BO (2.39 m^3/MT). The average GOR based on the Wasatch cumulative production (excluding the number 2 [section 16] and number 1 [section 17] wells which have no gas production reported) is 1,115 CFG/BO (4.35 m^3/MT).

Four wells are perforated in the Wasatch and lower Green River Formations from a minimum of 5,895 to a maximum of 8,107 feet (1,797.9-2,472.6 m) drill depth. The hydrocarbons produced from the Wasatch and lower Green River are commingled in these wells. The cumulative commingled production is 25.3 MBOE (3,542 MT) (table 4), which is 4 percent of the total production from the Duchesne field area. Production from these wells is dominantly oil with associated gas. The average GOR based on the IP tests is 2,145 CFG/BO (8.37 m^3/MT). The average GOR based on the cumulative production (excluding the 4-9 and 3-13 wells which have no gas production reported) is 8,862 CFG/BO (34.56 m3/MT).

STRUCTURE

A structure contour map of the top of the Douglas Creek Member of the Green River Formation was constructed using tops picked from geophysical well logs. The structural dip is about 500 feet/mile (245.4 m/km) northeast into the Uinta Basin (figure 3). Ray and others (1956) mapped numerous east-west-trending normal faults in the area collectively referred to as the Duchesne fault zone (figure 4). Ballou (1993) describes the reservoirs in the Duchesne field as fracture-enhanced stratigraphic traps. Faulting was not identified in the correlations of the geophysical well logs at the Douglas Creek horizon. I have not attempted to correlate the upper Green River or overlying Uinta Formation.

STRATIGRAPHY AND DEVELOPMENT OF THE LOWER GREEN RIVER RESERVOIRS

The lower Green River Formation is the objective of the numerous water-flood units developed in the Monument Butte area (T. 8-9 S., R. 16-19 E., Salt Lake Base Line) about 10 miles (1.6 km) east to southeast of the Duchesne field. Many of the Douglas Creek stratigraphic intervals that are being flooded in the Monument Butte area are productive in the Duchesne field. The stratigraphic intervals are grouped into the lower Douglas Creek (G-5 through G-7) and the upper Douglas Creek (R-1 through R-5 and G-1 through G-4) (figure 5). Most wells are perforated and produce from more than one interval. Therefore, the contribution that any one interval makes to production cannot be determined.

Lower Douglas Creek

The lower Green River G-5 interval (also referred to as the Extra Gold sandstone by Coors Energy, a former operator in the field), is the most commonly perforated interval in the Duchesne field area. The G-5 interval is perforated in nine of the 11 wells that produce from the lower Green River (figure 6). The G-6 interval is perforated in two wells both in T. 4 S., R. 5 W.

Upper Douglas Creek

The R-2 interval is perforated in three wells in the Duchesne field area (figure 7). Two wells (the number 1 [section 9] and 6-10D wells) are perforated in the G-1 interval, and one well is perforated in the G-3 (1-20D) and G-4 (6-10D) interval. The R-5 interval which commonly produces in the Monument Butte area (known as the "C Sandstone") is not productive in the Duchesne field area.

Table 1. Cumulative production from the upper Green River Formation by well, as of September 30, 1996 (Utah Division of Oil, Gas and Mining records).

Well	Section (T4S,R4W)	Oil (MBO)	Gas (MMCFG)	Total Hydrocarbons (MBOE)
1-15D	15	1.7	13.3	3.9
3	16	74.4	3.6	75.0
5	16	41.2	0	41.2
8	16	13.5	0	13.5
6	17	42.3	0	42.3
7	17	24.6	8.1	26.0
1-21D	21	0	0.6	0.1
1-22D	22	0	1.7	0.3
28-1	28	8.3	0	8.3
TOTAL		**206.0**	**27.3**	**210.6**

MBO = thousand barrels of oil
MMCFG = million (thousand-thousand) cubic feet of gas
MBOE = thousand barrels of oil equivalent (6 MCFG = 1 BO)

Table 2. Cumulative production from the lower Green River Formation by well, as of September 30, 1996 (Utah Division of Oil, Gas and Mining records).

Well	Section (T4S,R4W)	Oil (MBO)	Gas (MMCFG)	Total Hydrocarbons (MBOE)
1-3D	3	1.8	0	1.8
1	9	0.2	0	0.2
2-10D	10	2.6	131.4	24.5
3-10D	10	0.8	178.2	30.5
4-10D	10	4.5	65.8	15.4
2-15D	15	44.9	529.7	133.2
6-16D	16	54.2	128.9	75.7
7-16D	16	5.7	288.7	53.8
8-16D	16	9.8	475.6	89.1
4-18D	18	28.1	78.2	41.1
1-20D	20	3.1	32.5	8.5
1-24D	24 (R5W)	0.1	1.4	0.3
TOTAL		**155.8**	**1,910.4**	**474.1**

MBO = thousand barrels of oil
MMCFG = million (thousand-thousand) cubic feet of gas
MBOE = thousand barrels of oil equivalent (6 MCFG = 1 BO)

Table 3. Cumulative production from the Wasatch Formation by well, as of September 30, 1996 (Utah Division of Oil, Gas and Mining records).

Well	Section (T4S,R4W)	Oil (MBO)	Gas (MMCFG)	Total Hydrocarbons (MBOE)
1-7D	7	43.8	35.7	49.7
4	8	28.7	59.9	38.6
2-8D	8	64.9	59.4	74.8
1	9	293.8	146.2	318.2
10-9	9	44.3	53.8	53.2
2	16	82.8	0	82.8
1	17	99.9	0	99.9
4-17D	17	39.5	39.9	46.2
4-18D	18	15.6	28.2	20.3
16-12	12 (R5W)	84.2	47.9	92.1
TOTAL		**797.5**	**471.0**	**875.8**

MBO = thousand barrels of oil
MMCFG = million (thousand-thousand) cubic feet of gas
MBOE = thousand barrels of oil equivalent (6 MCFG = 1 BO)

Table 4. Cumulative production from wells with the Wasatch and Green River Formation production commingled, as of September 30, 1996 (Utah Division of Oil, Gas and Mining records).

Well	Section (T4S,R4W)	Oil (MBO)	Gas (MMCFG)	Total Hydrocarbons (MBOE)
4-9	9	1.1	0.5	1.2
1-10D	10	5.6	41.6	12.5
6-10D	10	1.7	17.5	4.6
3-13	13 (R5W)	6.4	3.5	7.0
TOTAL		**14.8**	**63.1**	**25.3**

MBO = thousand barrels of oil
MMCFG = million (thousand-thousand) cubic feet of gas
MBOE = thousand barrels of oil equivalent (6 MCFG = 1 BO)

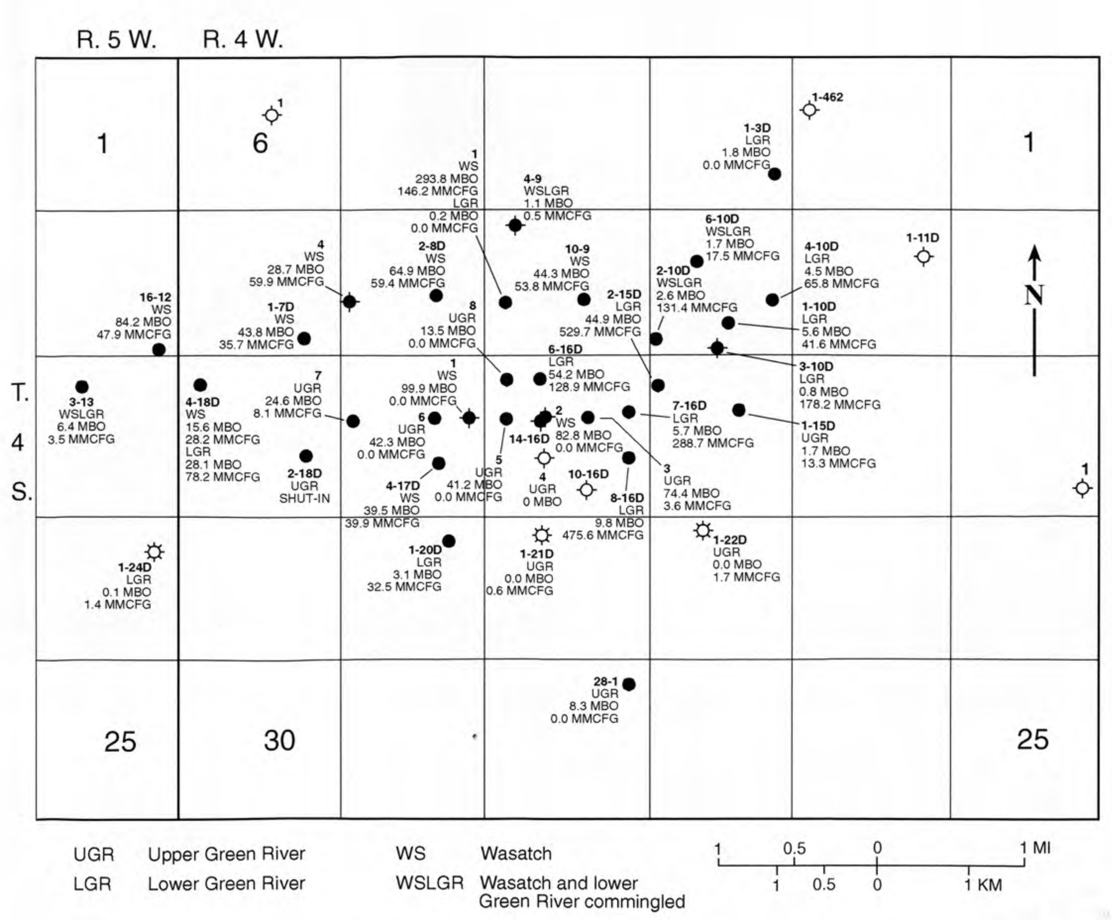


Figure 2. Cumulative hydrocarbon production in thousands of barrels of oil (MBO) and million cubic feet of gas (MMCFG) as of September 30, 1996.

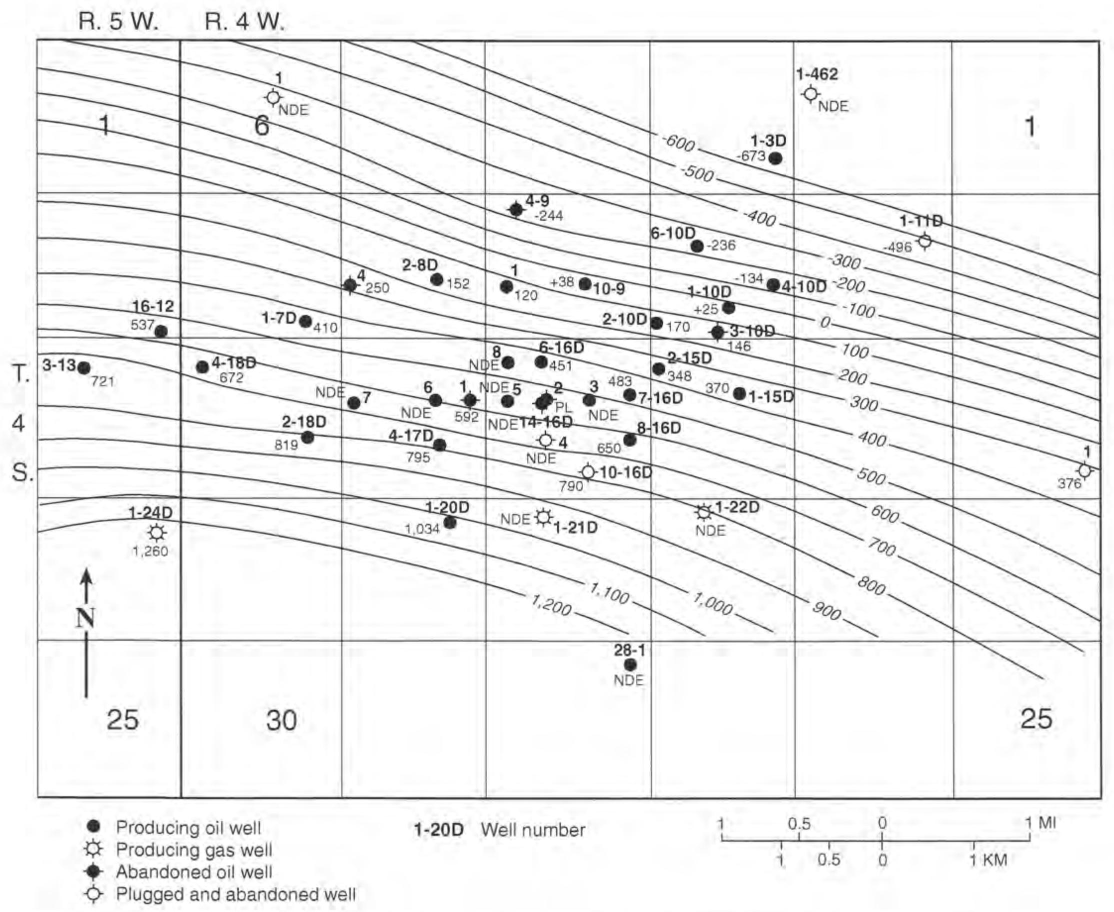


Figure 3. Structure contour map of the top of the Douglas Creek Member of the Green River Formation. Contour interval is 100 feet; datum is sea level.

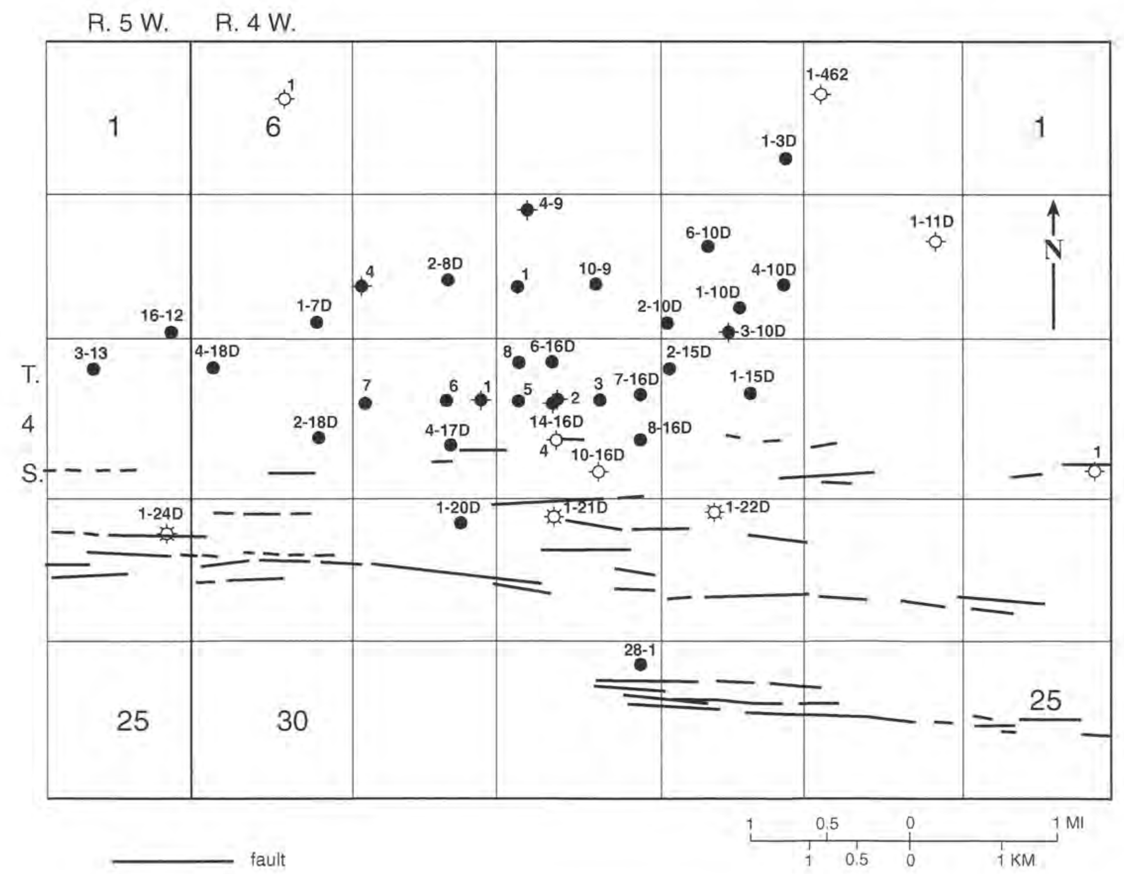


Figure 4. Surface traces of faults in the Duchsene field area, from Ray and others (1956).

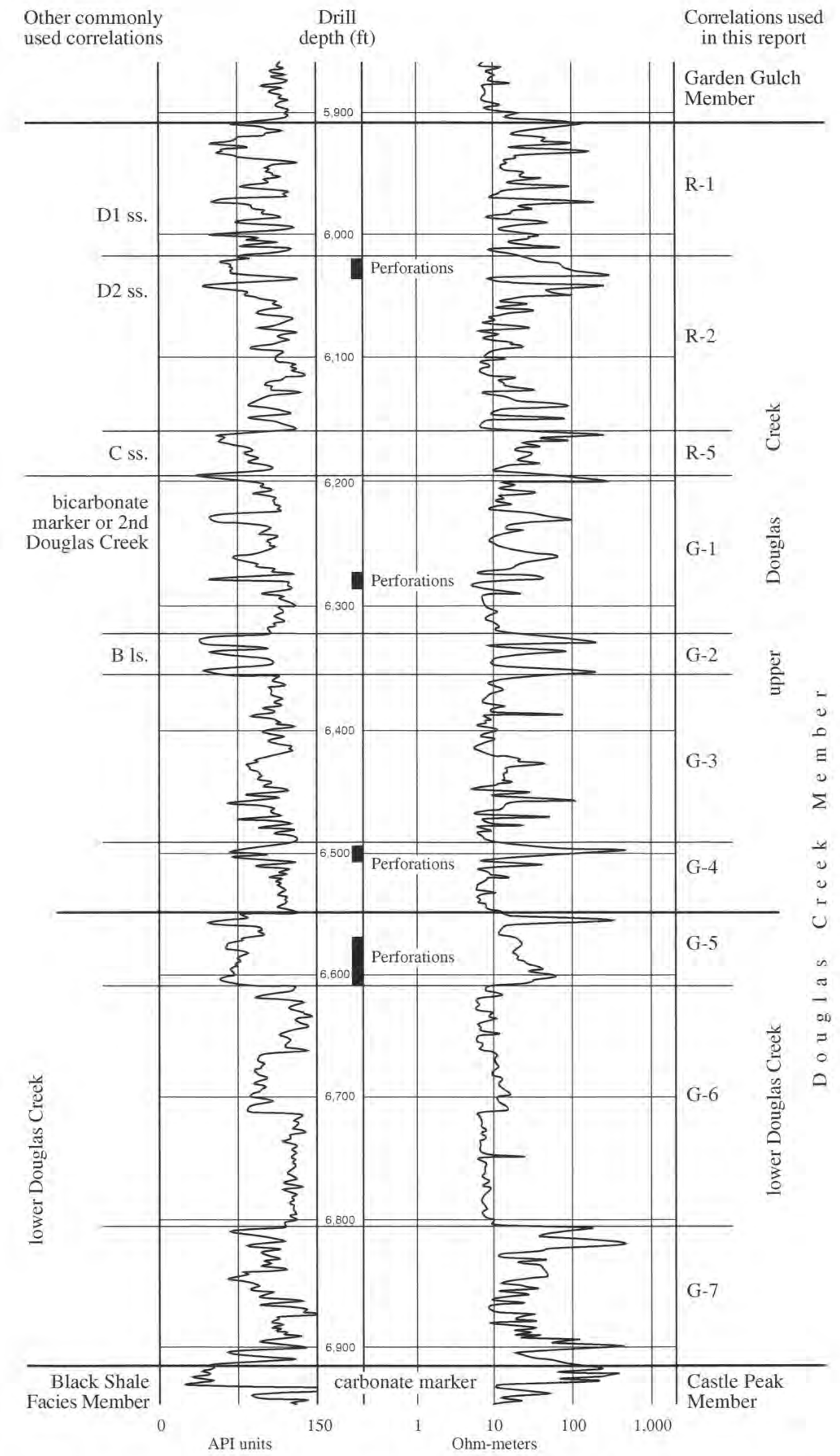


Figure 5. Gamma-ray and resistivity log section from the 6-10D well showing correlations used in this report. Interval definitions R-1 through R-5, and G-1 through G-7, modified from Balcron Oil Division (DOGM Hearing, Cause 238-1).

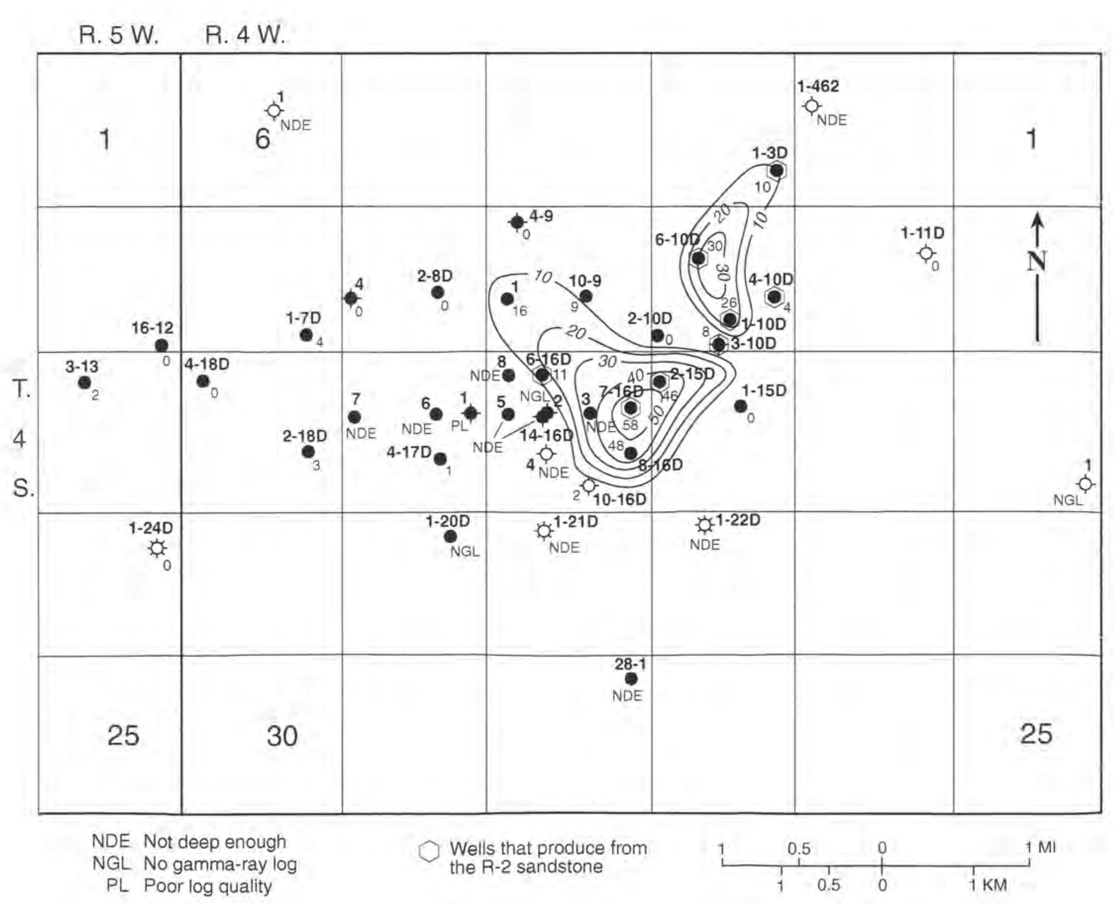


Figure 6. Sandstone isolith map of the G-5 interval. Sandstone bed is defined as less than 75 API gamma-ray units. Contour interval is 10 feet.

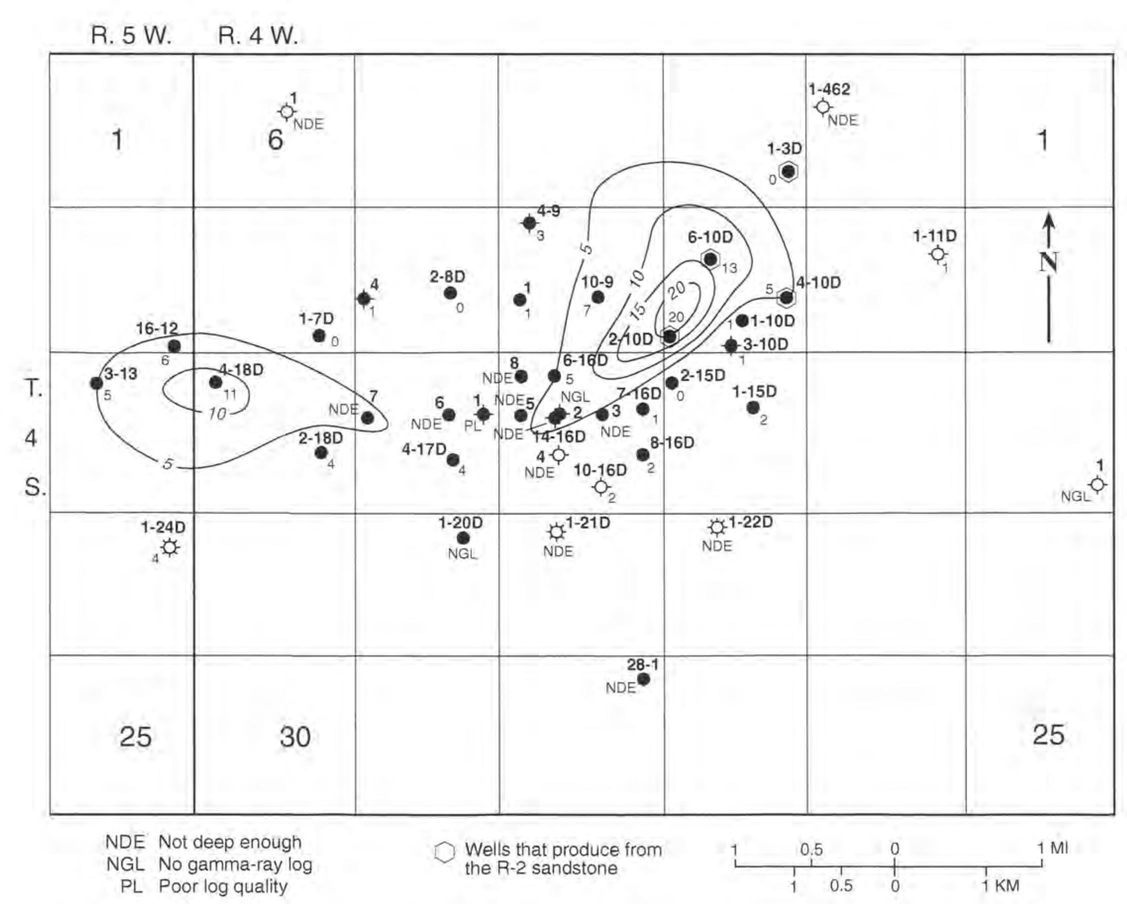


Figure 7. Sandstone isolith map of the R-2 interval. Sandstone bed is defined as less than 75 API gamma-ray units. Contour interval is 5 feet.

ACKNOWLEDGMENTS

This study was partially funded through a subcontract (no. 33332) with TerraTek Incorporated, Salt Lake City, Utah. TerraTek Inc. is the Principal Investigator of a study titled *Advanced Fracture Modeling in the Uinta Basin (Utah) for Optimized Primary and Secondary Recovery* funded in part by the National Petroleum Technology Office, U.S. Department of Energy, Bartlesville, Oklahoma, contract number G4S51729.

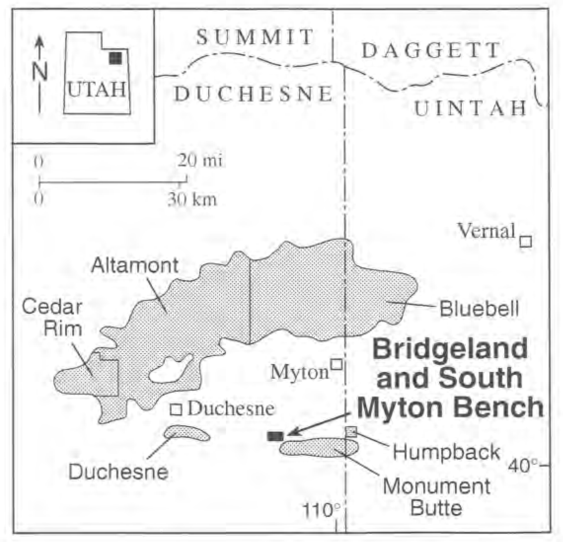
REFERENCES

Ballou, R.L., 1993, Duchesne, *in* Hill, B.G., and Bereskin, S.R., editors, Oil and gas fields of Utah: Utah Geological Association Publication 22, unpaginated.

Ray, R.G., Kent, B.H., and Dane, C.H., 1956, Stratigraphy and photogeology of the southwestern part of the Uinta Basin, Duchesne and Uintah Counties, Utah: U.S. Geological Survey Oil and Gas Investigations Map OM-171, scale 1:63,360.

BRIDGELAND AND SOUTH MYTON BENCH OIL FIELDS, T. 4 S., R. 2 AND 3 W., UBM DUCHESNE COUNTY, UTAH

by
Craig D. Morgan
1997



Oil and Gas Field Study 17
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INTRODUCTION

Bridgeland (abandoned) and South Myton Bench (active) fields are located in T. 4 S., R. 2 and 3 W., Uinta Base Line and Meridian, Duchesne County (figure 1). Hydrocarbons were produced from the Tertiary Wasatch and Green River Formations at Bridgeland field but only the Green River Formation is productive at South Myton Bench field. The Green River reservoir sandstones were deposited in fluvial-deltaic, interdeltaic, to shallow-lacustrine environments. The Wasatch reservoir sandstones are fluvial-channel deposits.

Analysis of geophysical well logs from Bridgeland and South Myton Bench fields identified several beds in the lower Green River Formation (Garden Gulch, Douglas Creek, and Castle Peak Members) that may still have hydrocarbon potential. The upper Green River and Wasatch Formation potential was not investigated.

TerraTek Incorporated is conducting a study in the Duchesne - Monument Butte area titled *Advanced Fracture Modeling in the Unita Basin (Utah) for Optimized Primary and Secondary Recovery*. The Utah Geological Survey, under a subcontract to TerraTek Inc., compiled and mapped basic oil-well data from the Duchesne, South Myton Bench, and Bridgeland fields, as well as the Humpback Unit. The data will be used by TerraTek Inc. in developing their geologic characterization of the area. The Bridgeland and South Myton Bench fields are east of, and on trend with, the Duchesne fault zone, a major focus of the TerraTek Inc. study. The Bridgeland and South Myton Bench fields are located about midway between the Duchesne fault zone and Humpback Unit where Balcron Oil Division will be collecting core in cooperation with TerraTek Inc.

HYDROCARBON PRODUCTION

Bridgeland field was first placed into production in 1983 and was abandoned in August 1989. A total of 75,358 barrels of oil ([BO] 10,550.1 MT) and 30,717 thousand cubic feet of gas ([MCFG] 869,810 m^3) were produced from Bridgeland field. South Myton Bench field was first placed into production in 1984. As of November 1996, there were two active wells in the South Myton Bench field that produced intermittently. A total of 62,078 BO (8,690.9 MT) and 189,871 MCFG (5,376,580 m^3) have been produced from South Myton Bench field. All production data in this report are from the records of the Utah Division of Oil, Gas and Mining.

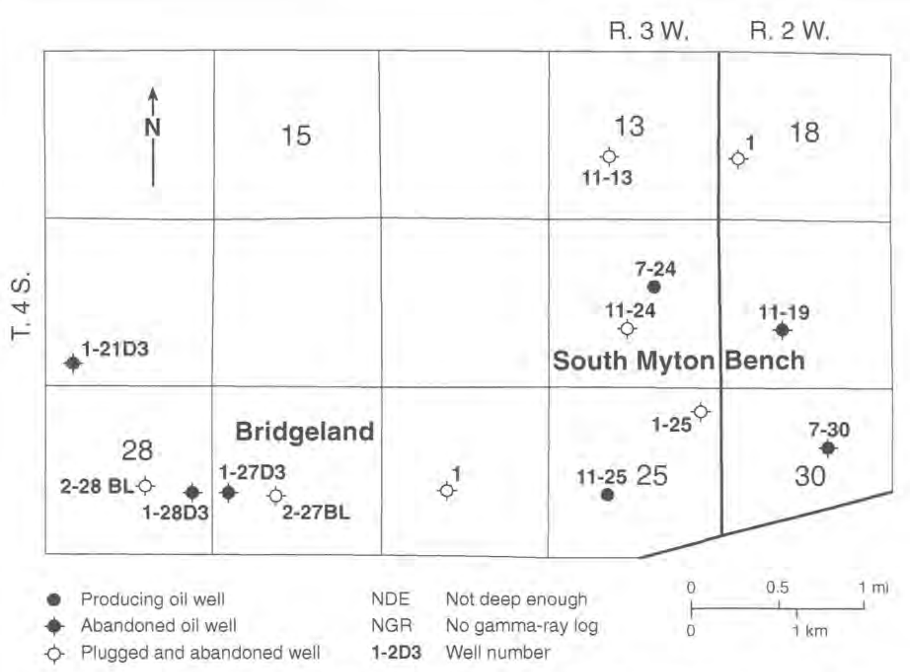

Figure 1. Bridgeland and South Myton Bench fields, Duchesne County, Utah.

STRUCTURE

A structure contour map of the top of the Douglas Creek Member of the Green River Formation was constructed using tops picked from geophysical well logs. The structural dip is about 400 feet/mile (196.3 m/km) northeast into the Uinta Basin (figure 2). Faulting was not identified in the correlations of the well logs at the Douglas Creek horizon. The highly complex, heterogeneous character of the Green River Formation makes it very difficult to identify faults that have displacements of a few feet to a few tens of feet.

Oleson (1986) interpreted a fault below the "C" marker (about 200 feet [61 m] below the top of the Douglas Creek Member) in the number 1 well (section 18) and 11-13 well. Oleson determined that about 50 feet (15 m) of section was displaced by a normal fault, trending east to west with the downthrown side to the north. Although there is no surface faulting in the area, Olsen felt that the fault was related to the Duchesne fault zone.

Ballou (1993) states that the 1-27D3 was drilled to investigate the possibility of fractured reservoirs on trend with the east-west-trending Duchesne fault zone, in the Bridgeland field. The operator did not report encountering any faults in this well.

BRIDGELAND FIELD DEVELOPMENT HISTORY

The Bridgeland field was discovered in 1982 with the completion of the 1-28D3 well in the Green River Formation. The completion of the 1-27D3 in 1984 established production from the deeper Wasatch Formation. The 1-27D3 well was later recompleted in the upper Green River. Most of the hydrocarbons produced at Bridgeland field have come from the upper Green River (table 1).

Table 1. Cumulative hydrocarbon production from Bridgeland field.

Well	Formation	Oil Produced (BO)	Gas Produced (MCFG)
1-27D3	upper Green River	195	864
1-28D3	upper Green River	55,126	9,189
1-21D3	lower Green River	9,114	13,467
1-27D3	Wasatch	10,603	6,357

SOUTH MYTON BENCH FIELD DEVELOPMENT HISTORY

South Myton Bench field was discovered in 1983 with the completion of the 11-25 well in the Green River Formation. There are currently two active wells that produce intermittently and two abandoned oil wells. The hydrocarbons produced at South Myton Bench field have come from the lower Green River. The 7-30 well was completed in both the upper and lower Green River but never produced (table 2).

Table 2. Cumulative hydrocarbon production from South Myton Bench field, as of November 30, 1996.

Well	Formation	Oil Produced (BO)	Gas Produced (MCFG)	Status
7-30	upper and lower Green River	0	0	abandoned
11-19	lower Green River	6,043	21,903	abandoned
7-24	lower Green River	53,434	159,911	active[1]
11-25	lower Green River	2,621	8,057	active[2]

[1]November 1996 monthly production: 4 days, 0 BO, 80 MCFG
[2]November 1996 monthly production: 1 day, 5 BO, 0 MCFG

LOWER GREEN RIVER POTENTIAL

Hydrocarbons have been produced from the lower Green River Formation at Bridgeland and South Myton Bench fields. The lower Green River is the objective of the numerous water-flood units developed in the Monument Butte area (T. 8 and 9 S., R. 16 through 19 E., SLBM) located two miles south of South Myton Bench. Based on correlation and analysis of geophysical well logs the Bridgeland and South Myton Bench area may contain additional potential for exploitation of hydrocarbons from the lower Green River. In the following discussion bed boundaries were defined using a 75 API unit gamma-ray cut-off; density porosity was calculated using a matrix density of 2.68 grams/cubic centimeters. The following sandstones are believed to have areas with hydrocarbon potential that have not been exploited, based on 40-acre (16.2 ha) well spacing.

Upper Y-2 Sandstone

The upper Y-2 sandstone was perforated in the 7-30 well but was never produced. In the 11-19 well the upper Y-2 sandstone is at a drill depth of 4,847 feet (1,478.3 m), is 16 feet (4.9 m) thick with a maximum density porosity of 16 percent, and more than 200 ohm-meters resistivity (figure 3). The upper Y-2 sandstone is 12 feet (3.7 m) thick in the 11-24 well (figure 4) with density porosity of 12 to 18 percent. Using a minimum 6-foot (1.8-m) thickness, the upper Y-2 sandstone has hydrocarbon potential in the SE1/4 section 24 (T. 4 S., R. 3 W.), E1/2 section 20 (not shown), S1/2 section 19, and N1/2 section 30 (T. 4 S., R. 2 W.).

Lower Y-2 Sandstone

The lower Y-2 sandstone was perforated in the 7-30 well but was never produced. In the 11-19 well the lower Y-2 sandstone is at a drill depth of 4,881 feet (1,488.7 m), is 8 feet (2.4 m) thick with a maximum density porosity of 20 percent, and more than 40 ohm-meters resistivity (figure 3). The lower Y-2 sandstone is 6 feet (4.9 m) thick in the 11-24 and 7-30 wells (figure 5). In the 11-24 well the lower Y-2 sandstone has 13 to 14 percent density porosity and 150 ohm-meters resistivity. Porosity of the lower Y-2 sandstone in the 7-30 well cannot be determined due to rugose hole conditions. Using a minimum 6-foot (1.8-m) thickness, the lower Y-2 sandstone has hydrocarbon potential in the SE1/4 section 24 (T. 4 S., R. 3 W.), SW1/4 section 19, and NW1/4NE1/4 section 30 (T. 4 S., R. 2 W.).

Y-6 Sandstone

The Y-6 sandstone bed was perforated in the 11-19 well. Based on the geophysical well logs and comparison with similar beds in the Monument Butte area it is surprising that the 11-19 well didn't produce a greater volume of hydrocarbons. In the 11-19 well the Y-6 sandstone is at a drill depth of 5,263 feet (1,605.2 m), is 9 feet (2.7 m) thick with a maximum density porosity of 15 percent, and has resistivity from 150 to more than 200 ohm-meters (figure 3). In the 1-25 well the Y-6 sandstone is 16 feet (4.9 m) thick (figure 6) with a maximum density porosity of 7 percent, and 70 ohm-meters resistivity. Using a minimum 6-foot (1.8-m) thickness, the Y-6 sandstone has hydrocarbon potential in the SE1/4 section 24 and NE1/4 section 25 (T. 4 S., R. 3 W.), SW1/4 section 19 and NW1/4 section 30 (T. 4 S., R. 2 W.). The hydrocarbon potential of the Y-6 sandstone may be limited by the small areal distribution and low porosity of the bed.

R-1 Sandstone

The R-1 and several beds in the Castle Peak Member of the Green River Formation are perforated in the 11-25 well. In the 11-19 well the R-1 sandstone is at a drill depth of 5,411 feet (1,650.4 m), is 8 feet (2.4 m) thick, with a maximum density porosity of 13 percent, and 70 to more than 100 ohm-meters resistivity (figure 3). In the 11-24 and 1-25 wells, porosity of the R-1 sandstone is generally less than 10 percent. In the 1-27D3 well, the R-1 sandstone is 14 feet (4.3 m) thick (figure 7) with density porosity of 12 to 16 percent, and 35 to 50 ohm-meters resistivity. The R-1 sandstone may be a poor objective in the South Myton Bench field due to low porosity, but has hydrocarbon potential in the Bridgeland field area (sections 27 and 28, T. 4 S., R. 3 W.).

R-5 Sandstone

The R-5 and other sandstone beds are perforated in the 7-30 and the 1-21D3 wells. In the 11-19 well the R-5 sandstone is at a drill depth of 5,564 feet (1,697.0 m), is 13 feet (3.9 m) thick with a maximum density porosity of 13 percent, and 125 to more than 200 ohm-meters resistivity (figure 3). Although the R-5 sandstone is more than 6 feet (1.8 m) thick in the 11-24, 1-25, and 1-27D3 wells (figure 8), density porosity is generally less than 10 percent. Therefore, the hydrocarbon potential of the R-5 sandstone may be limited to section 19 (T. 4 S., R. 2 W.), although additional drilling could find good porosity in the SE1/4 section 24 (T. 4 S., R. 3 W.) along the trend of the bed.

G-4 Sandstone

The G-4 and B-1 sandstone beds are perforated in the 7-24 well. In the 7-24 well the G-4 sandstone is at a drill depth of 5,982 feet (1,824.5 m), is 20 feet (6.1 m) thick with density porosity of 18 percent, and 90 to 150 ohm-meters resistivity (figure 9). Although the G-4 sandstone is more than 6 feet (1.8 m) thick in the 11-19, 7-30, and 1-27D3 wells (figure 10), density porosity is generally less than 10 percent. In the 1-21D3 well the G-4 sandstone is 9 feet (2.7 m) thick with density porosity of 10 to 16 percent, and 30 ohm-meters resistivity. Porosity in the G-4 sandstone appears to be developed only in portions of the bed. Therefore, the hydrocarbon potential of the G-4 sandstone cannot be determined until additional drilling occurs in the area.

B-1 Sandstone

In the 7-24 well the B-1 sandstone is at a drill depth of 6,411 feet (1,955.4 m), is 50 feet (15.3 m) thick with density porosity of 12 percent (over 34 feet [10.4 m]) and 25 to 70 ohm-meters resistivity (figure 9). In the 11-24 well the B-1 sandstone is 13 feet (3.9 m) thick (figure 11); a 9-foot (2.7-m) section of the B-1 has 10 percent or more density porosity with a maximum of 13 percent, and 32 ohm-meters resistivity. The B-1 sandstone appears to be a very limited reservoir.

CONCLUSIONS

Preliminary analysis of geophysical well logs and isochore mapping of potential reservoir beds show that good hydrocarbon potential exists in the Bridgeland and South Myton Bench area. The analysis did not include permeability data or oil-saturation calculations. The lower Green River is the objective of the many water-flood units being actively developed in the Monument Butte area two miles (3.2 km) to the south. Several beds in the lower Green River Formation have porosity and shows of hydrocarbons but have not been fully exploited in the Bridgeland and South Myton Bench area. The Bridgeland and South Myton Bench area has good potential for development drilling and eventually water flooding of the lower Green River.

South Myton Bench Field
Ute Tribal 11-19
T. 4 S., R. 2 W., section 19
KB 5,496 ft

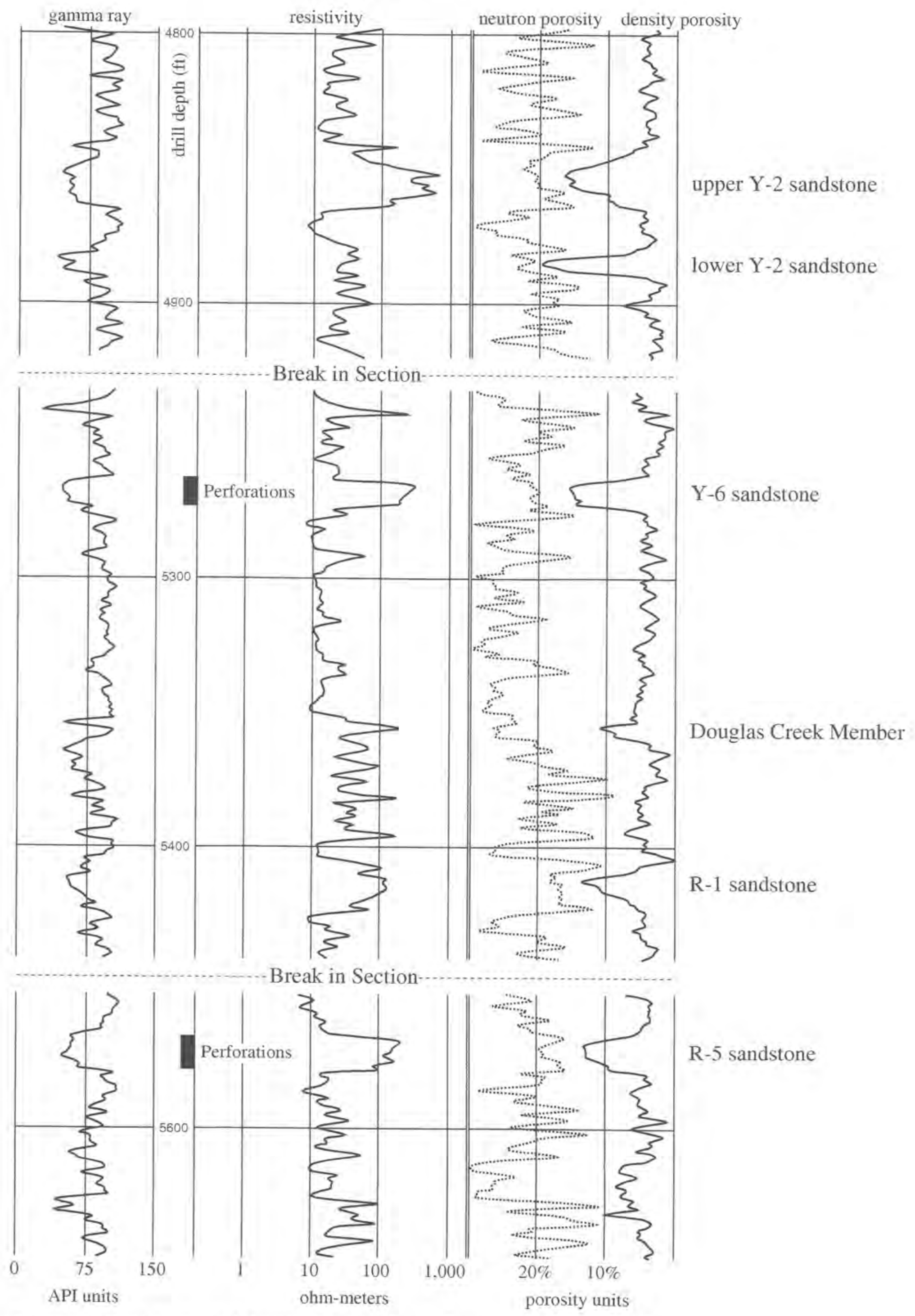

Figure 3. Resistivity and density/neutron logs of proven and potential reservoir beds in the 11-19 well.

South Myton Bench Field
Ute Tribal 7-24
T. 4 S., R. 3 W., section 24
KB 5,545 ft

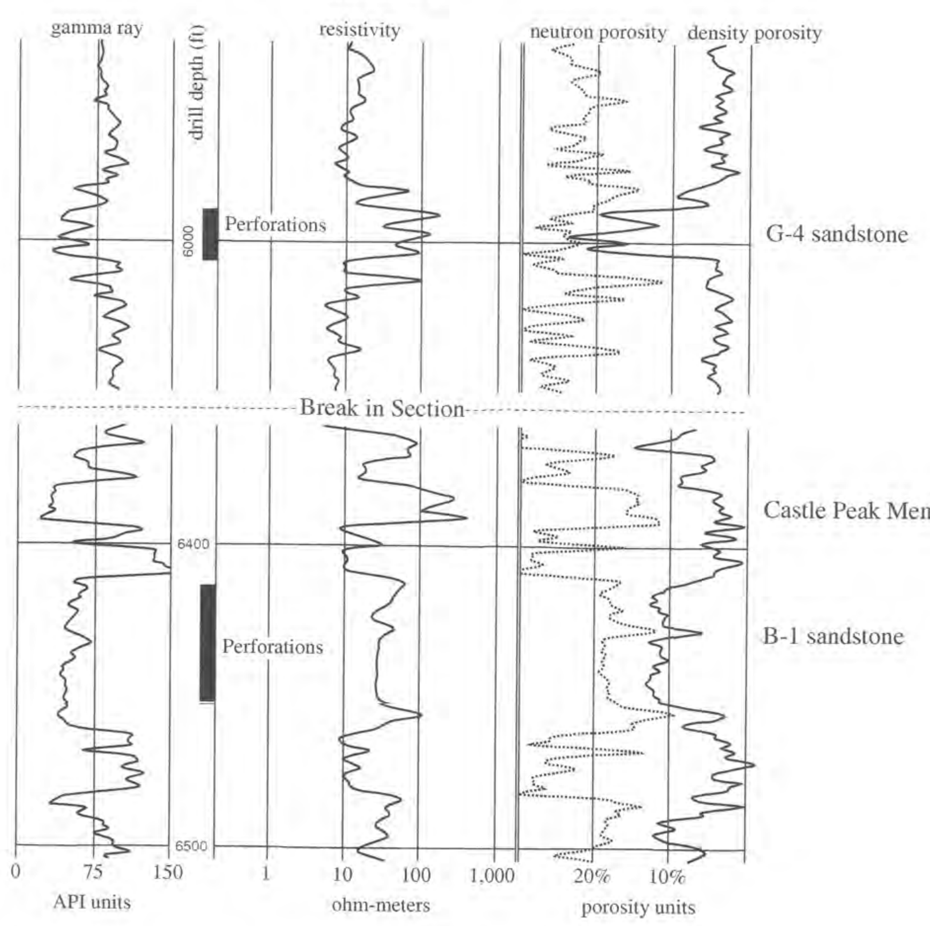

Figure 9. Resistivity and density/neutron logs of the reservoir beds in the 7-24 well.

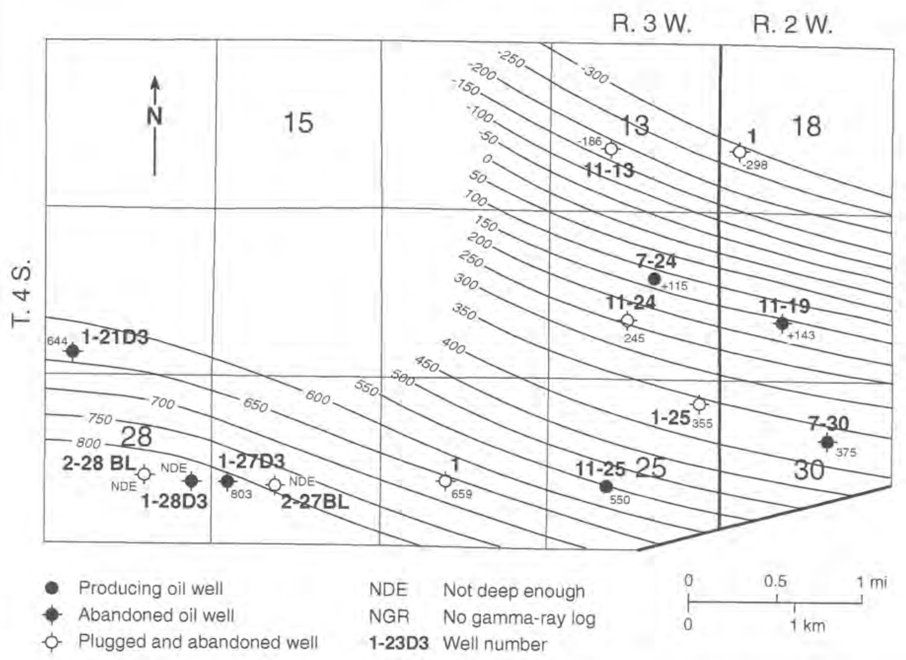

Figure 2. Structure of the top of the Douglas Creek Member of the Green River Formation. Contour interval is 50 feet; datum is sea level.

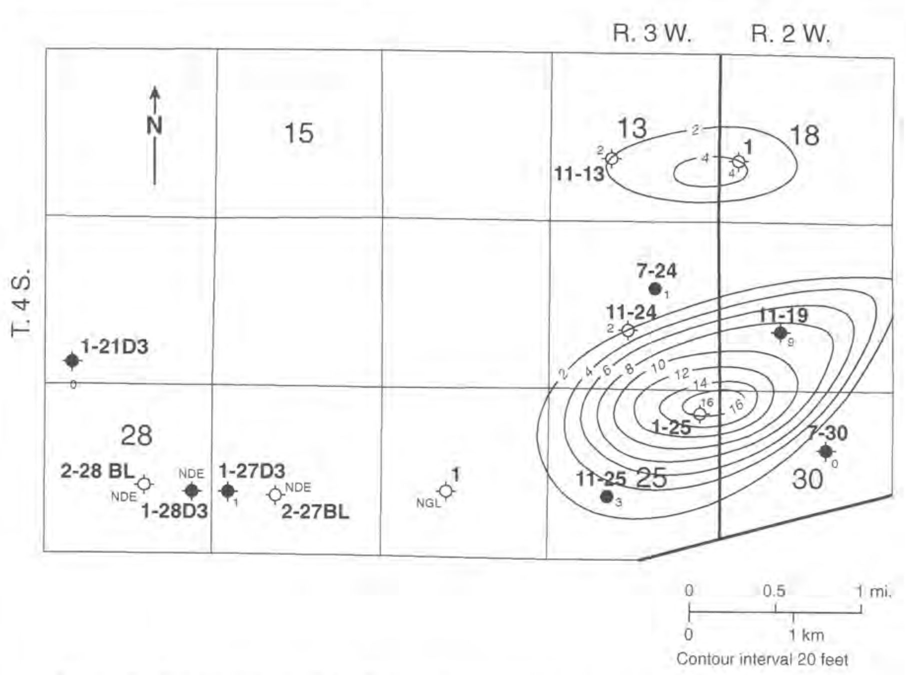

Figure 6. Isochore map of the Y-6 sandstone. Contour interval is 2 feet.

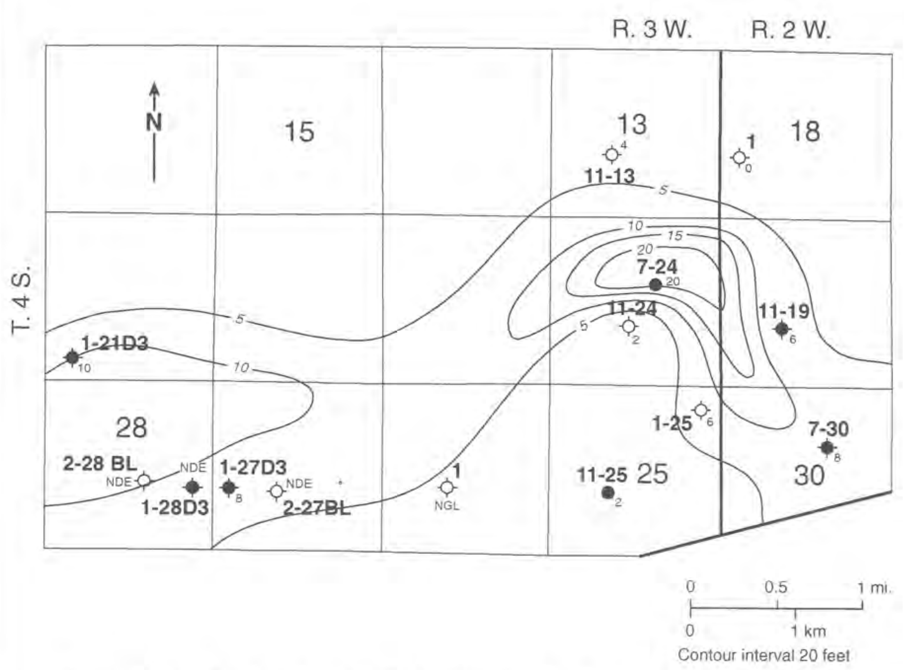

Figure 10. Isochore map of the G-4 sandstone. Contour interval is 5 feet.

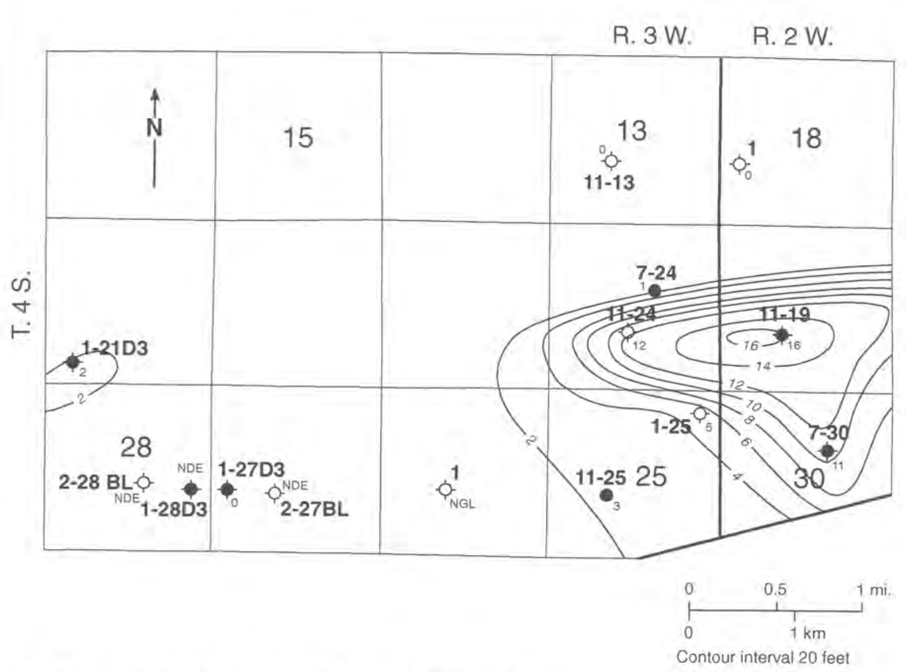

Figure 4. Isochore map of the upper Y-2 sandstone. Contour interval 2 feet.

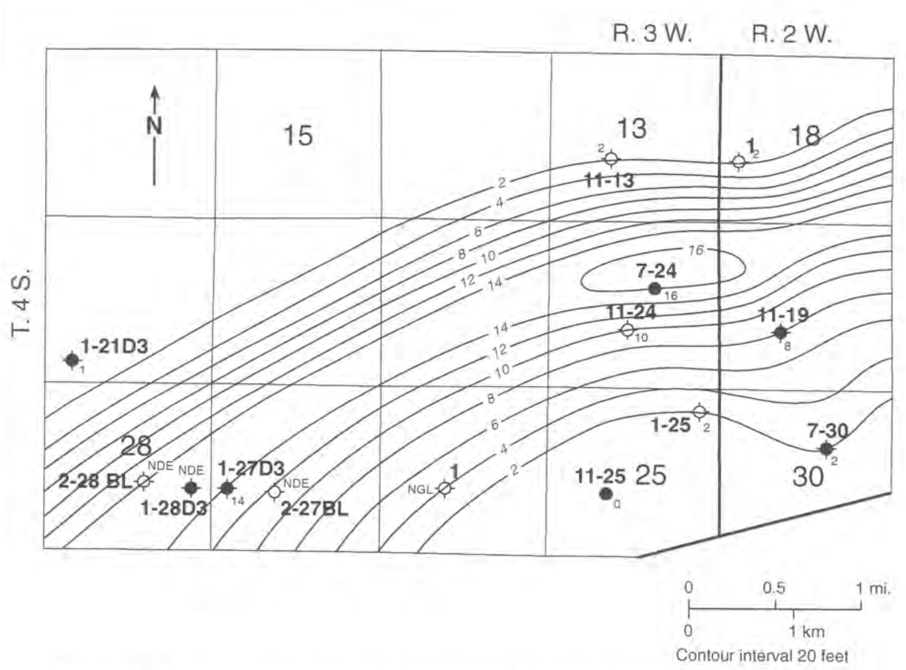

Figure 7. Isochore map of the R-1 sandstone. Contour interval is 2 feet.

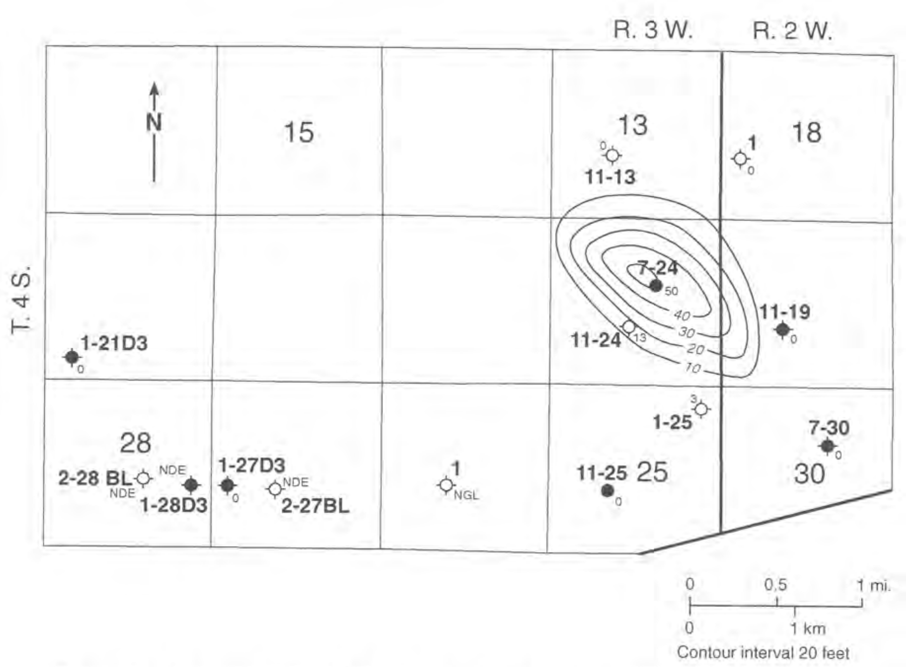

Figure 11. Isochore map of the B-1 sandstone. Contour interval is 10 feet.

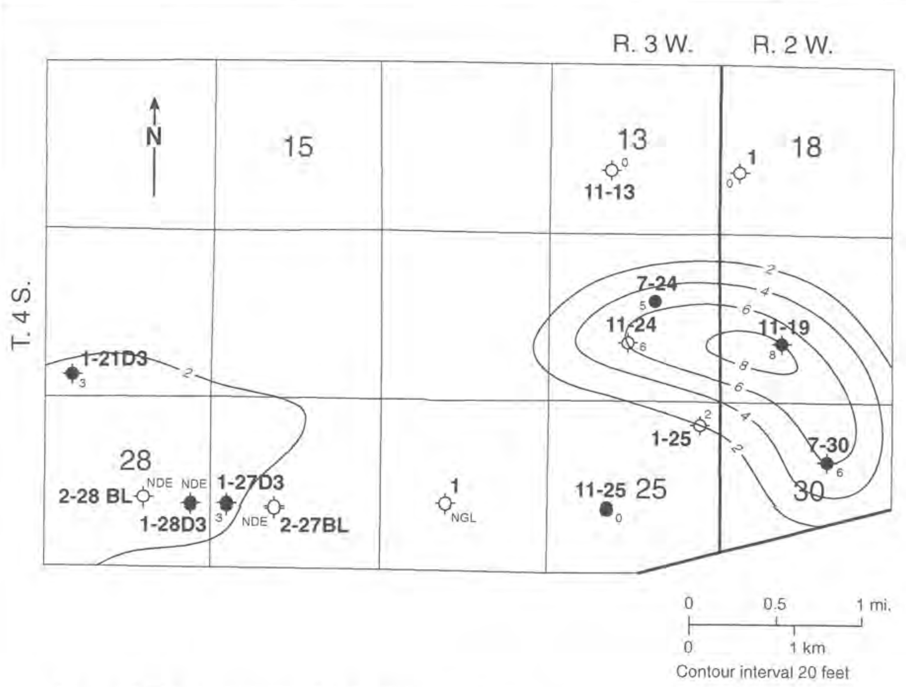

Figure 5. Isochore map of the lower Y-2 sandstone. Contour interval 2 feet.

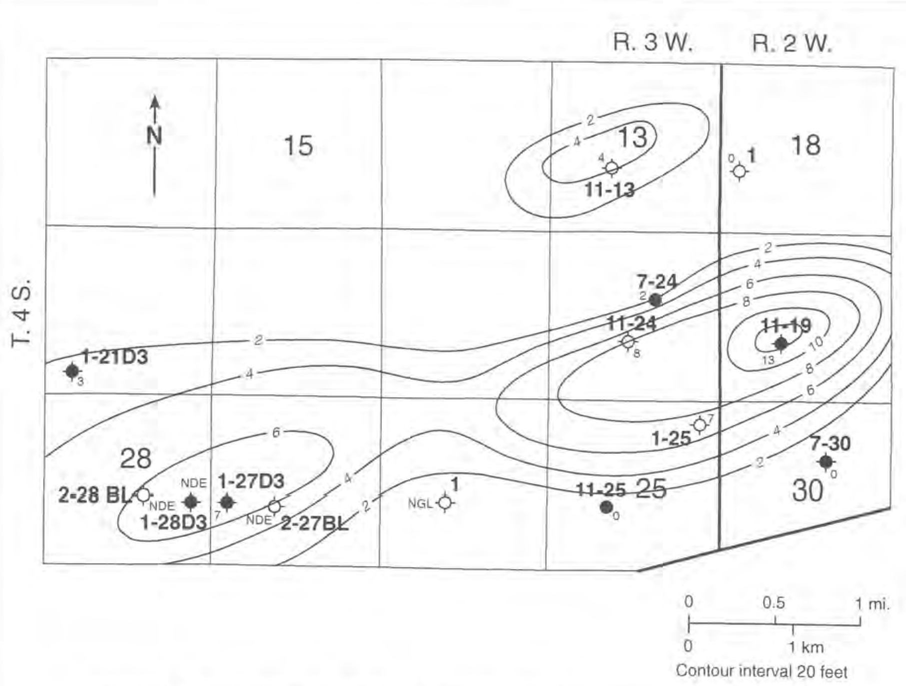

Figure 8. Isochore map of the R-5 sandstone. Contour interval is 2 feet.

ACKNOWLEDGMENTS

This study was partially funded through a subcontract (no. 33332) with TerraTek Incorporated, Salt Lake City, Utah. TerraTek Inc. is the Principal Investigator of a study entitled *Advanced Fracture Modeling in the Uinta Basin (Utah) for Optimized Primary and Secondary Recovery*, funded in part by the National Petroleum Technology Office, U.S. Department of Energy, Bartlesville, Oklahoma, contract G4S51729.

Robert L. Ballou, Uinta Oil and Gas, Roosevelt, Utah, provided some well data and helpful suggestions.

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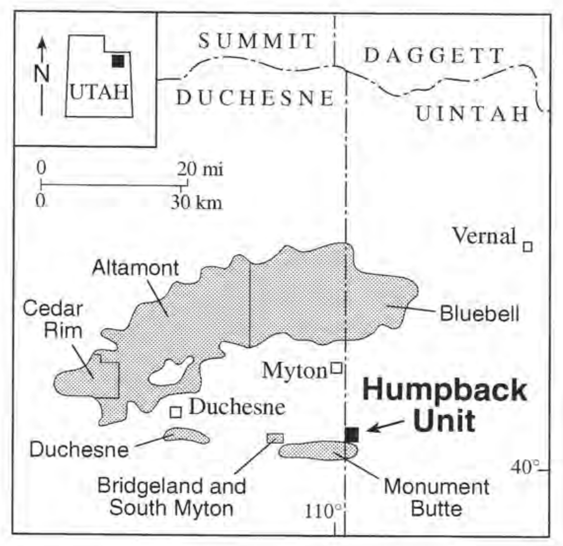
Ballou, R.L., 1993, Bridgeland, *in* Hill, B.G., and Bereskin, S.R., editors, Oil and gas fields of Utah: Utah Geological Association Publication 22, unpaginated

Oleson, N.E., 1986, Petroleum geology of the Eocene Lower Green River Formation, Duchesne and Uintah Counties, Utah: Waco, Baylor University, M.S. thesis, 173 p.

HUMPBACK SECONDARY-RECOVERY (WATER-FLOOD) UNIT T. 8 S., R. 17 E., SALT LAKE BASE LINE UINTAH COUNTY, UTAH

by
Craig D. Morgan
1997



Oil and Gas Field Study 18
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

INTRODUCTION

Equitable Resources Energy Company, Balcron Oil Division, proposed the Humpback Unit (figure 1) before the Board of the Utah Division of Oil, Gas and Mining for the purpose of secondary oil recovery from the Green River Formation (Cause 238-1). The water-flood objectives in the Humpback Unit are fluvial-deltaic lacustrine sandstone beds deposited within deltaic cycles or intervals, that make up the Garden Gulch, Douglas Creek, and Castle Peak Members of the Tertiary Green River Formation. As of December 31, 1996, the Humpback Unit has been approved but secondary recovery had not commenced.

TerraTek Incorporated is conducting a study in the Duchesne - Monument Butte area entitled *Advanced Fracture Modeling in the Unita Basin (Utah) for Optimized Primary and Secondary Recovery*. The Utah Geological Survey under a subcontract to TerraTek Inc., compiled and mapped basic oil-well data from the Duchesne, South Myton, Bridgeland fields, and Humpback Unit. The data will be used by TerraTek Inc., in developing their geologic characterization of the Duchesne - Monument Butte area. The Humpback Unit was chosen for study because Balcron Oil Division intends to drill and core a well in the unit as part of the TerraTek study.

STRUCTURE

In the Humpback Unit the top of the Douglas Creek Member dips dominantly north to northeast into the Uinta Basin (figure 2). The dip is about 125 feet/mile (61.3 m/km). A subtle north-plunging anticline is present in the western half of the unit. Hydrocarbon entrapment is stratigraphically controlled and production does not appear to be enhanced by the subtle anticline.

DOUGLAS CREEK MEMBER: R-5 INTERVAL

Balcron Oil Division proposes to water flood numerous sandstone beds in the Garden Gulch, Douglas Creek, and Castle Peak Members of the Green River Formation. The R-5 interval (Lomax "C Sandstone") of the Douglas Creek Member is productive in more wells in the Humpback Unit than any other interval and is typical of the fluvial-deltaic deposits that are productive in the unit; therefore, the R-5 was selected for detailed mapping.

The isochore map of the R-5 interval (figure 3) shows a general thickening from south to north into the basin, and thinning both east and west away from the Humpback Unit. The R-5 interval can be subdivided into an upper R-5 and lower R-5 (figure 4). The lower R-5 is interpreted as a prograding distributary-mouth bar. The upper R-5 is interpreted to be a distributary channel and associated overbank deposit.

Lower R-5 Interval

Mapping of the lower R-5 interval (figure 5) shows south to north thickening into the basin. The east to west trend of the lower R-5 interval parallels the shoreline of Lake Uinta during R-5 deposition. The unit becomes more lenticular to the south (landward). Isochore mapping of porous (12 percent of more density porosity) lower R-5 sandstone shows two areas of buildup (figure 6). The isolated buildups indicate the lower R-5 interval is a limited and poor quality (thin and low porosity) reservoir.

Upper R-5 Interval

The isochore map of the upper R-5 interval shows a lenticular north-to-south trending body that thins rapidly east and west of the Humpback Unit (figure 7). The upper R-5 interval is interpreted as a distributary channel that flowed northward into Lake Uinta feeding the underlying distributary-mouth bar (lower R-5 interval). Isochore mapping of porous upper R-5 sandstone (figure 8) shows a trend that closely follows the thickness trend of the overall interval (figure 7). The thickest buildup of porous sandstone appears to be in the center of the channel as defined by the upper R-5 interval isochore map (figure 7). The thicker and more laterally continuous buildup of porous sandstone indicates the upper R-5 sandstone is a better quality reservoir than the lower R-5 sandstone.

DEPOSITION OF SHALE OVERLYING THE R-5 INTERVAL

An isochore map of the shale directly overlying the R-5 interval shows an east to west trend, parallel to the shoreline, increasing in thickness from south to north (figure 9). The contours trend east to west, paralleling the shoreline. The shale increases in thickness south to north. The shale is interpreted to be a transgressive deposit representing rise in relative lake level and drowning of the R-5 delta. Localized southward thickening of the shale overlying the upper R-5 channel may be due to the channel not being filled with clastic material before the lake transgressed. If the upper portion of the channel was filled with mud then the channel sandstone reservoir should be isolated laterally from any associated clastic overbank deposits.

PRODUCTION AND ESTIMATED RECOVERY

According to Balcron Oil Division (Cause 238-1) existing wells in the Humpback Unit have produced 388,938 barrels of oil ([BO] 7,623.2 MT) and 649,471 thousand cubic feet of gas ([MCFG] 18,391,070 m^3) as of October 1, 1996. Remaining primary reserves are estimated to be 577,344 BO (80,828.2 MT) which yields an ultimate primary recovery of 966,282 BO (135,279.5 MT). The plan of development for 1997 calls for recompletion of three wells and drilling three new wells. Balcron estimates the primary recovery resulting from the recompletions and drilling will be an additional 223,919 BO (31,348.7 MT), bringing the ultimate primary recovery from the Humpback Unit to 1,190,201 BO (166,628.1 MT), a recovery factor of 3.123 percent (Balcron Oil Division, Cause 238-1). Many of the wells in the Humpback Unit will be converted to water-injection wells (figure 10). Using a 1:1 primary to secondary recovery ratio, the ultimate (primary and secondary) recovery is estimated to be 2,351,514 BO (329,211.9 MT) and 4,865,167 MCFG (137,766,930 m^3) for a recovery factor of 6.41 percent (Balcron Oil Division, Cause 238-1).

ACKNOWLEDGMENTS

This study was partially funded through a subcontract (no. 33332) with TerraTek Incorporated, Salt Lake City, Utah. TerraTek Inc., is the Principal Investigator of the study entitled Advanced Fracture Modeling in the Uinta Basin (Utah) for Optimized Primary and Secondary Recovery funded by the National Petroleum Technology Office, U.S. Department of Energy, Bartlesville, Oklahoma, contract G4S51729.

Kevin Reinschmidt, Ballard Petroleum in Billings, Montana (formerly with Equitable Resources, Balcron Oil Division), provided some well data and helpful suggestions.

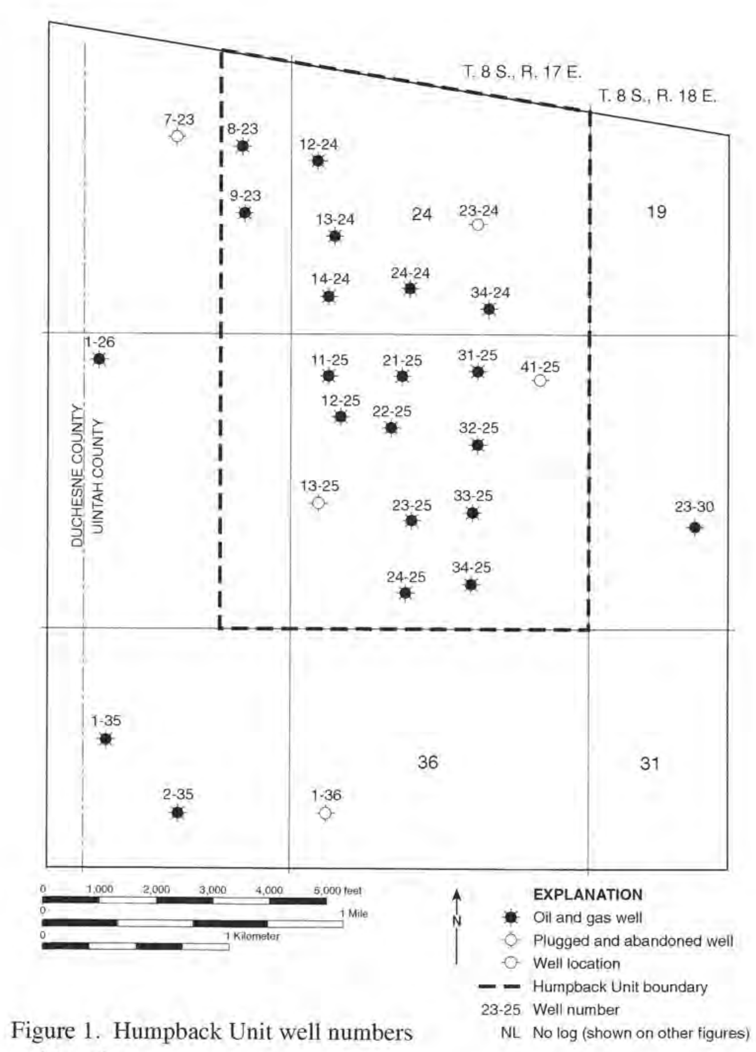


Figure 1. Humpback Unit well numbers and locations.

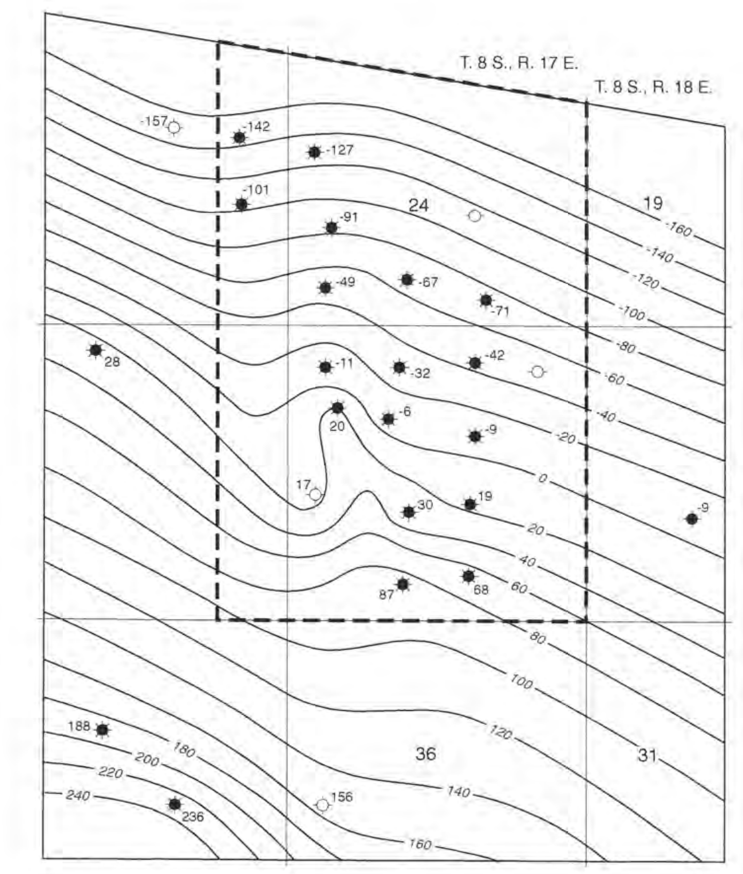


Figure 2. Structure contour map of the top of the Douglas Creek Member of the Tertiary Green River Formation. Contour interval is 20 feet, sea level elevation.

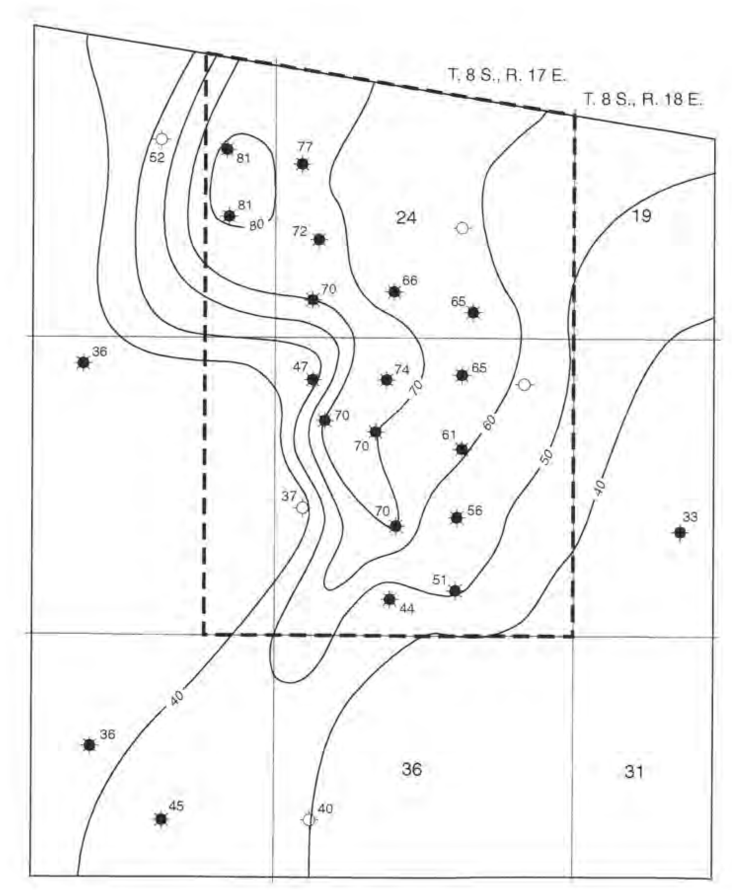


Figure 3. Isochore map of the R-5 interval of the Douglas Creek Member of the Tertiary Green River Formation. Contour interval is 10 feet.

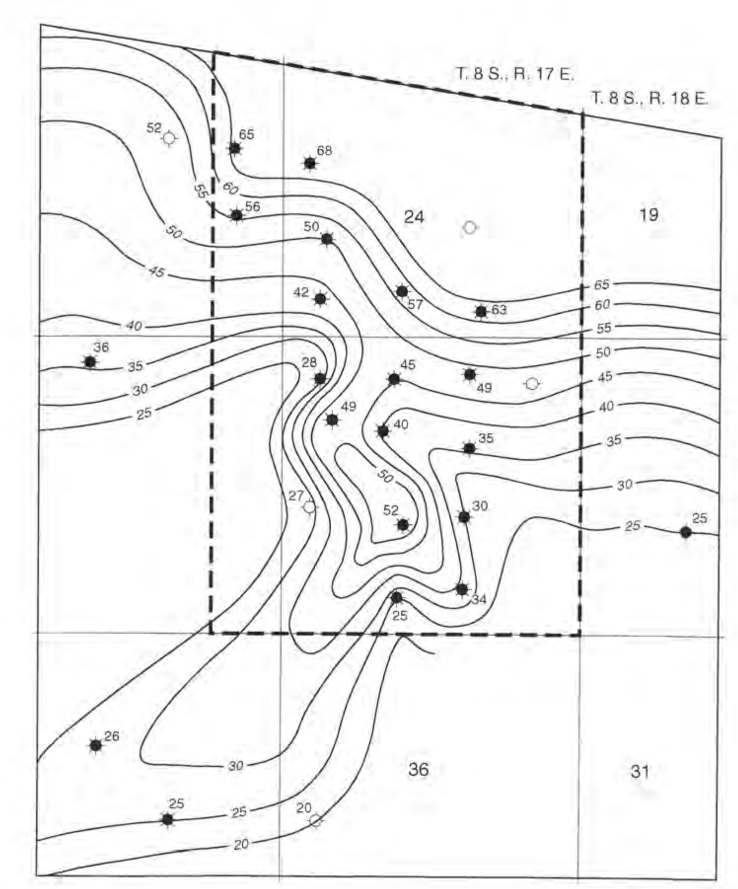
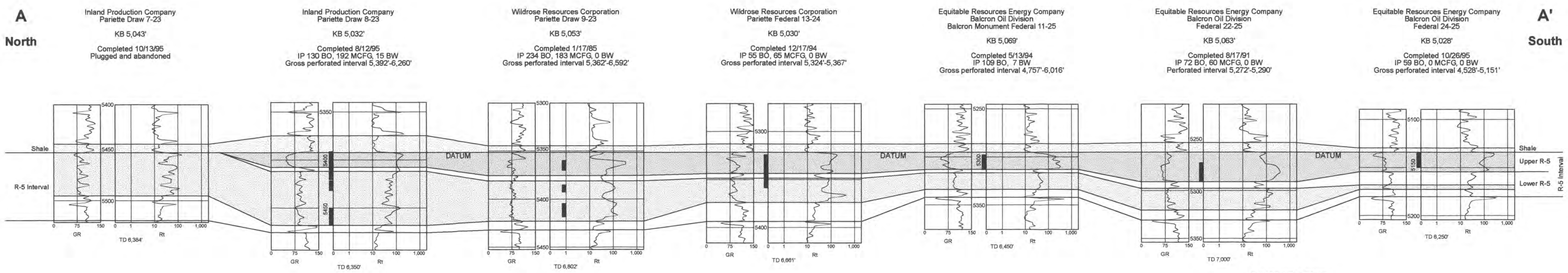
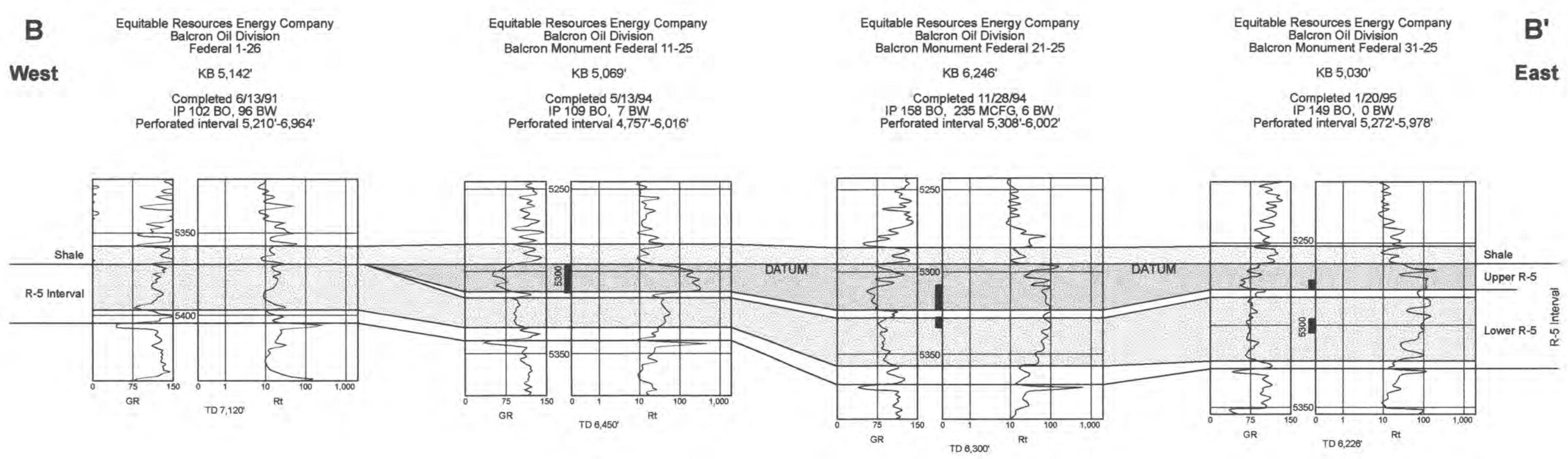
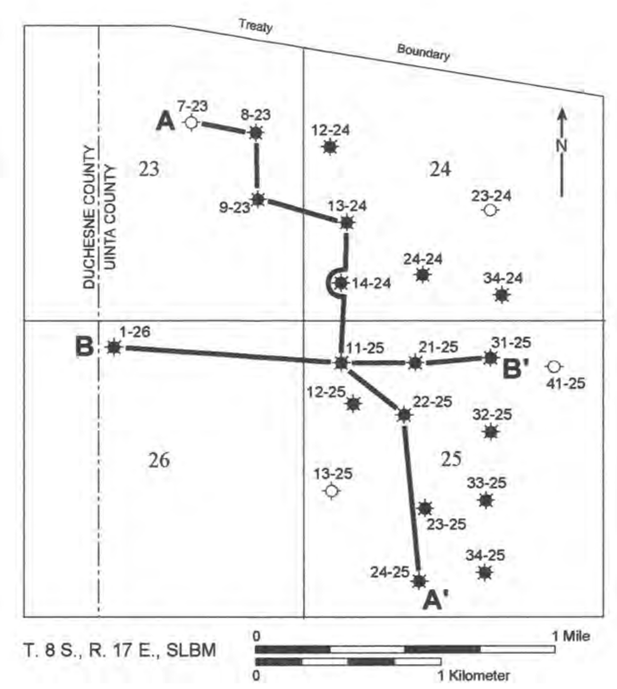


Figure 5. Isochore map of the lower R-5 interval of the Douglas Creek Member of the Tertiary Green River Formation.
Contour interval is 5 feet.







CROSS SECTIONS EXPLANATION

- BO Barrels of oil
- BW Barrels of water
- GR Gamma ray (API units)
- IP Initial potential (daily rate)
- KB Kelly bushing elevation
- MCFG Thousand cubic feet of gas
- Rt Resistivity (ohms)
- TD Total depth
- Shale
- Sandstone
- Siltstone
- Perforation

INSET MAP EXPLANATION

- Oil and gas well
- Plugged and abandoned well
- Well location
- 23-25 Well number

Figure 4.
STRATIGRAPHIC CROSS SECTIONS
R-5 Interval of the Green River Formation

Datum is top of R-5 interval.
Distance between well logs not to scale on cross sections.

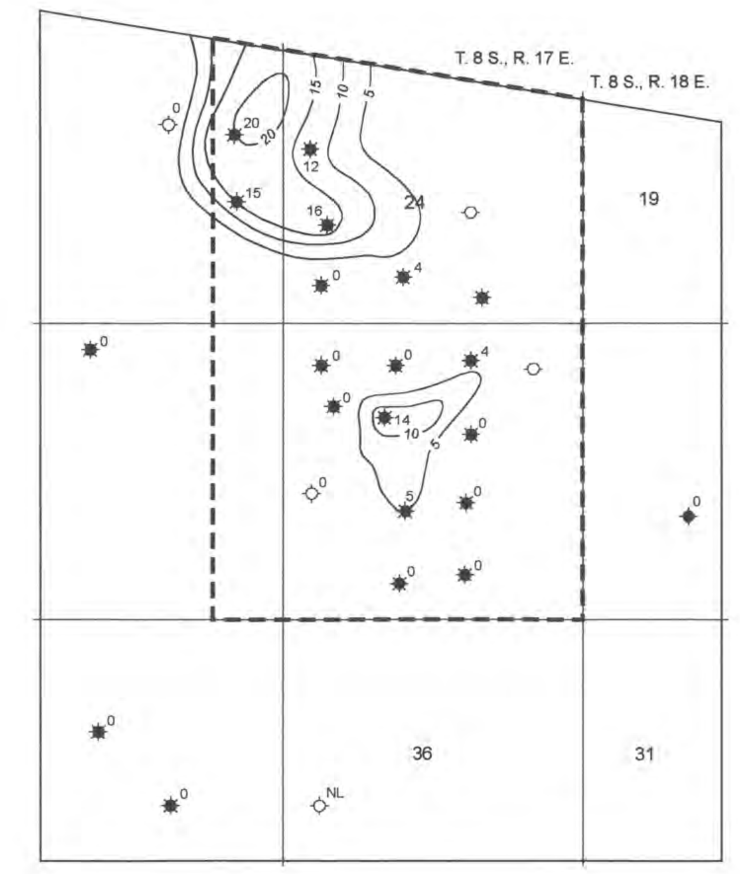


Figure 6. Isochore map of porous (12 percent or more density porosity) lower R-5 interval. Density porosity calculated using a matrix density of 2.68 grams per cubic centimeter (gm/cc). Contour interval is 5 feet.

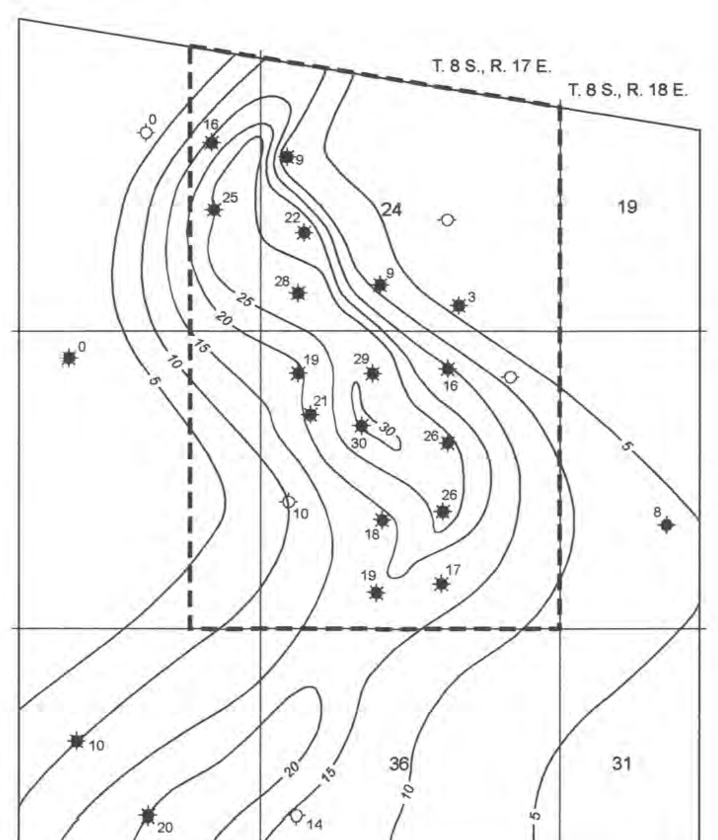


Figure 7. Isochore map of upper R-5 interval. Contour interval is 5 feet.

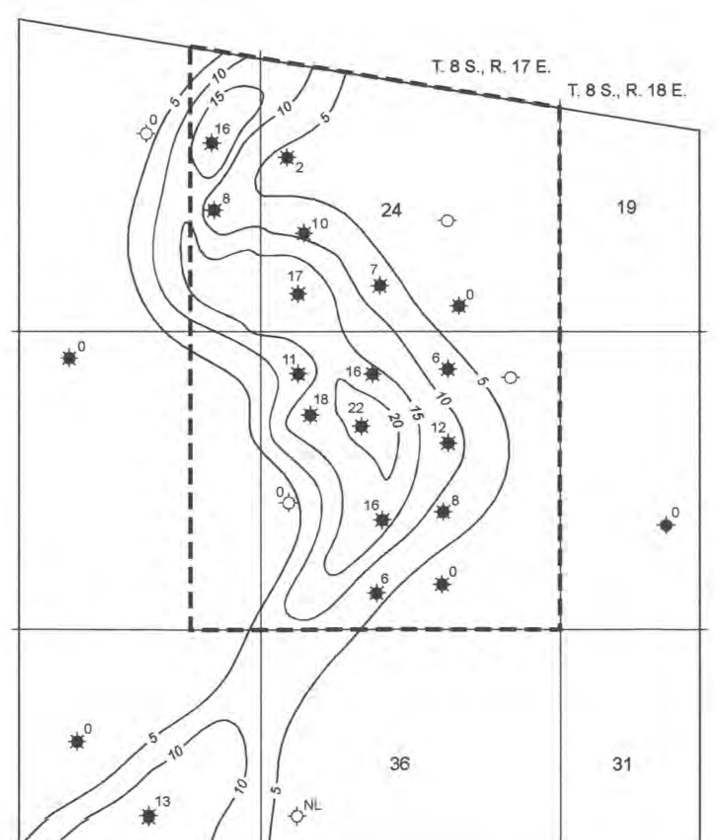


Figure 8. Isochore map of porous (12 percent or more density porosity) upper R-5 sandstone. Sandstone defined by the gamma-ray log reading of 75 API units or less. Density porosity calculated using a matrix density of 2.68 gm/cm. Contour interval is 5 feet.

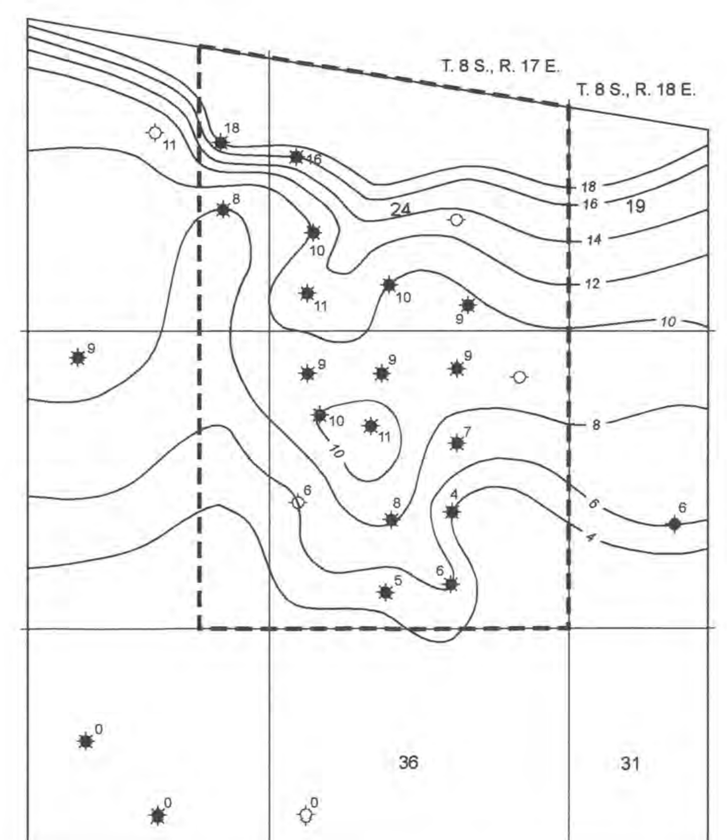
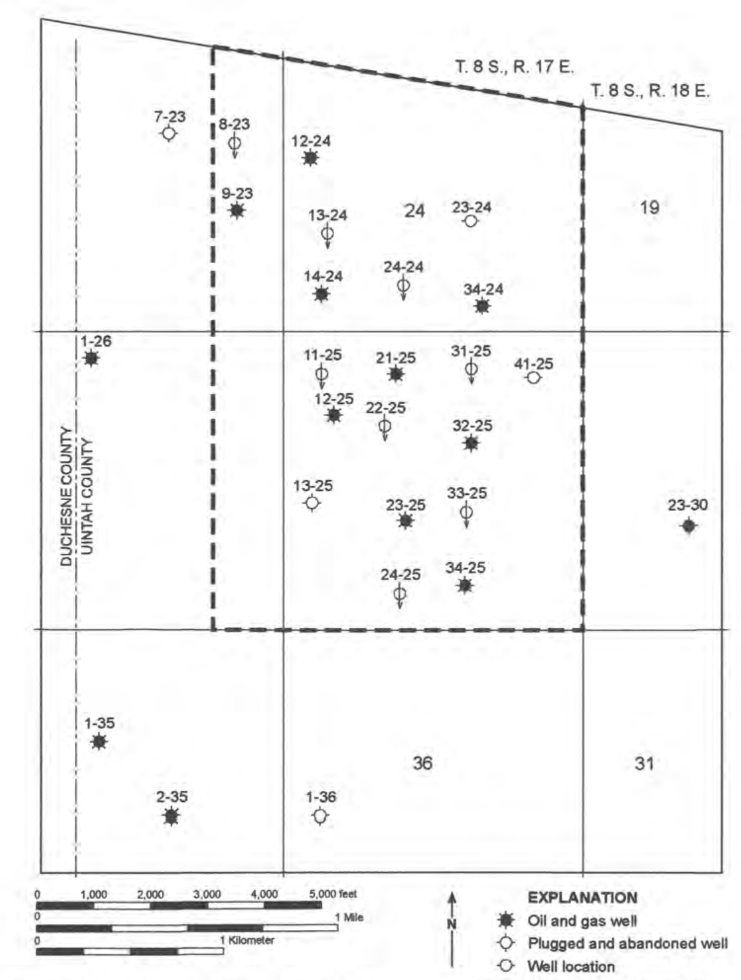


Figure 9. Isochore map of shale bed overlying R-5 interval. Contour interval is 2 feet.



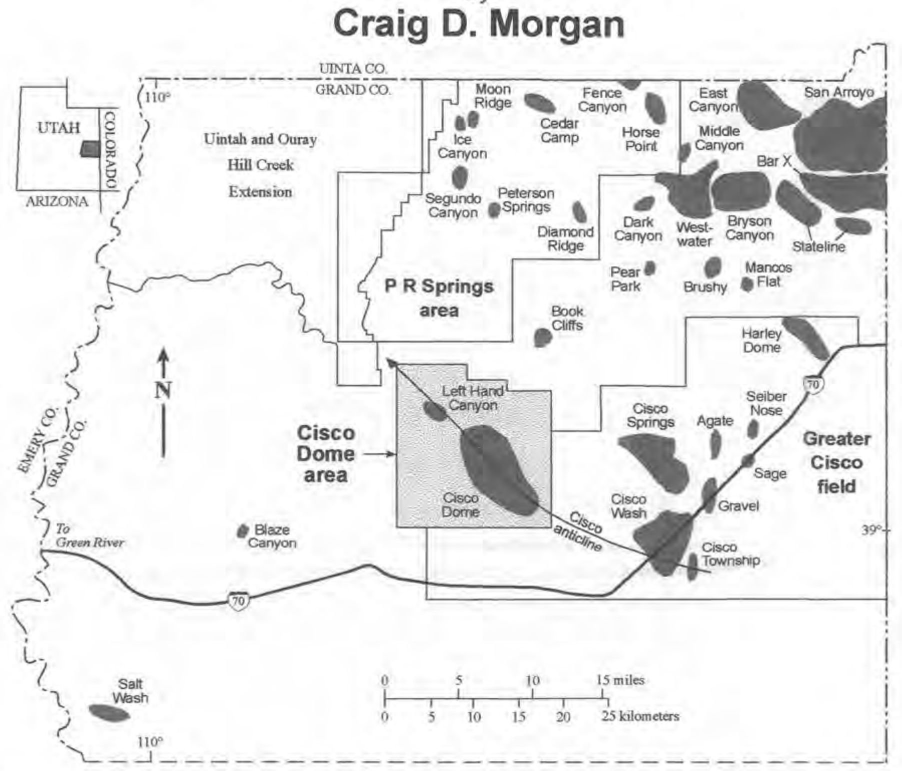
EXPLANATION

- Oil and gas well
- Plugged and abandoned well
- Well location
- Humpback Unit boundary
- 23-25 Well number
- NL No log (shown on other figures)
- Proposed injection well

Figure 10. Proposed injection pattern. From Balcron Oil Division, Cause 238-1, figure 4.

PETROLEUM GEOLOGY OF THE CISCO DOME AREA, GRAND COUNTY, UTAH

by
Craig D. Morgan



Oil and Gas Fields Study 19 June 1999
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

INTRODUCTION

Cisco Dome is a Laramide-age asymmetrical, doubly plunging anticline in T. 19 - 20 S., R. 21 - 22 E., Salt Lake Base Line and Meridian, Grand County, Utah. Cretaceous Mancos Shale is exposed over most of the Dome with Tertiary-age Wasatch Formation exposed on the northern flanks of the structure. The Cisco Dome and Left Hand Canyon fields are located in the Cisco Dome area (index map above).

Hydrocarbons are produced from Cretaceous- and Jurassic-age sandstones in structural and combination stratigraphic/structural traps. Most of the production is from the Jurassic Morrison, and Cretaceous Cedar Mountain and Dakota Formations, and minor production is from the Jurassic Entrada Sandstone and Cretaceous Mancos Shale. Cisco Dome was considered a separate oil and gas field (figure 1) until 1978 when it was included in the larger Greater Cisco field (index map above), but in this report "Cisco Dome field" will be used. Northwest of Cisco Dome field is the Left Hand Canyon field (figure 1) which is not included in the Greater Cisco field.

This report is part of a study of the petroleum geology of the Cretaceous Dakota Sandstone of north Grand County. The study will be used to improve our knowledge of the geology, hydrocarbon production, and hydrocarbon potential of the Dakota and is intended to help determine the value of lands in the area managed by the Utah School and Institutional Trust Lands Administration.

STRUCTURE

Cisco Dome lies along the northwest flank of the ancestral Uncompahgre Highland and is a separate closure along the northwest-trending Cisco anticline. There is 600 feet (200 m) of closure at Cisco Dome mapped on the top of the Cretaceous Dakota Sandstone (figure 2). The structure is asymmetrical with a steeper, faulted south flank. Additional faults cut across the north flank of the structure.

The No. 1 well (SE1/4NE1/4 section 23, T. 20 S., R. 21 E.) (figure 1) was drilled on the crest of Cisco Dome in 1944 by Continental Oil Company to a depth of 4,747 feet (1,447.8 m). The well encountered Triassic Chinle Formation overlying Precambrian granite.

DEVELOPMENT AND PRODUCTION HISTORY

Utah Oil Refining Company discovered Cisco Dome field in 1925 with the completion of a gas well at a depth of about 2,000 feet (610 m) in the Dakota Sandstone (Quigley, 1961). By the end of 1929, eleven gas wells and six dry holes had been completed. Gas from Cisco Dome was used by a carbon black plant from 1927 to 1931 when the federal government issued a proclamation forbidding further exploitation of natural gas for carbon black. The wells were shut in and only one well was produced for local use at a farm from 1937 through 1954. Activity at Cisco Dome resumed in 1954 and eight wells were drilled during the following five years but remained shut in until 1972.

More than 16 billion cubic feet of gas (BCFG) (448 million m^3) and 850,000 barrels of oil (BO) (119,000 MT) have been produced at Cisco Dome field as of December 31, 1996. Production from Cisco Dome field has been primarily gas but over 500,000 BO (70,000 MT) have been produced from the Cedar Mountain Formation in the Calf Canyon unit in the north portion of the field. Two wells on the crest of the structure have produced over 20,000 BO (2,800 MT) from the Entrada Sandstone.

The production history of Cisco Dome field is not well documented. Older records are often incomplete and of questionable accuracy. Production, particularly abandoned production at the time of field or unit name changes, is not always carried over to the new field or unit name in the records. Table 1 shows the cumulative production, current status, and producing horizon, by well. The table undoubtly is incomplete and contains some inaccurate numbers due to the poor records but is still a useful representation of the production history of the field. The producing horizons reported are based on my well-log correlations and may not always agree with what the operator reports.

Cisco Dome field produced 8,400 BO (1,176 MT) and 283,064 thousand cubic feet of gas (MCFG) (7,925,792 m^3) in 1996. Figure 3 is a graph of the annual production from the Cisco Dome field. The sum of the annual production is 38 percent less oil and 14 percent less gas than the sum of the cumulative production from individual wells (table 1). Corrections (additions) to the cumulative production of a well are not shown in the annual record, therefore the higher values derived from table 1 are considered a more accurate record of the cumulative production from Cisco Dome field. Reporting and record keeping have improved and the annual production shown in figure 3 since 1984 should be accurate.

Anschutz Corporation discovered Left Hand Canyon field in 1972 with the completion of the 1-773 well (section 29, T. 19 S., R. 20 E.) at a drill depth of 4,750 feet (1,448.8 m) in the Jurassic Entrada Sandstone. The well produced a little more than 20,000 BO (2,800 MT) and was abandoned in 1978. The 30-5 well (section 30, T. 19 S., R. 20 E.) is completed as a gas well in the Dakota Sandstone but has never produced. The 29-13 well (section 29, T. 19 S., R. 20 E.) is completed in the Dakota and has produced 41,088 BO (5,752.3 MT) and 469,954 MCFG (13,158,712 m^3) as of December 31, 1996. Left Hand Canyon field produced 34,987 BO (4,898.2 MT) and 7,052 MCFG (197,456 m^3) from one well (29-13) in 1996.

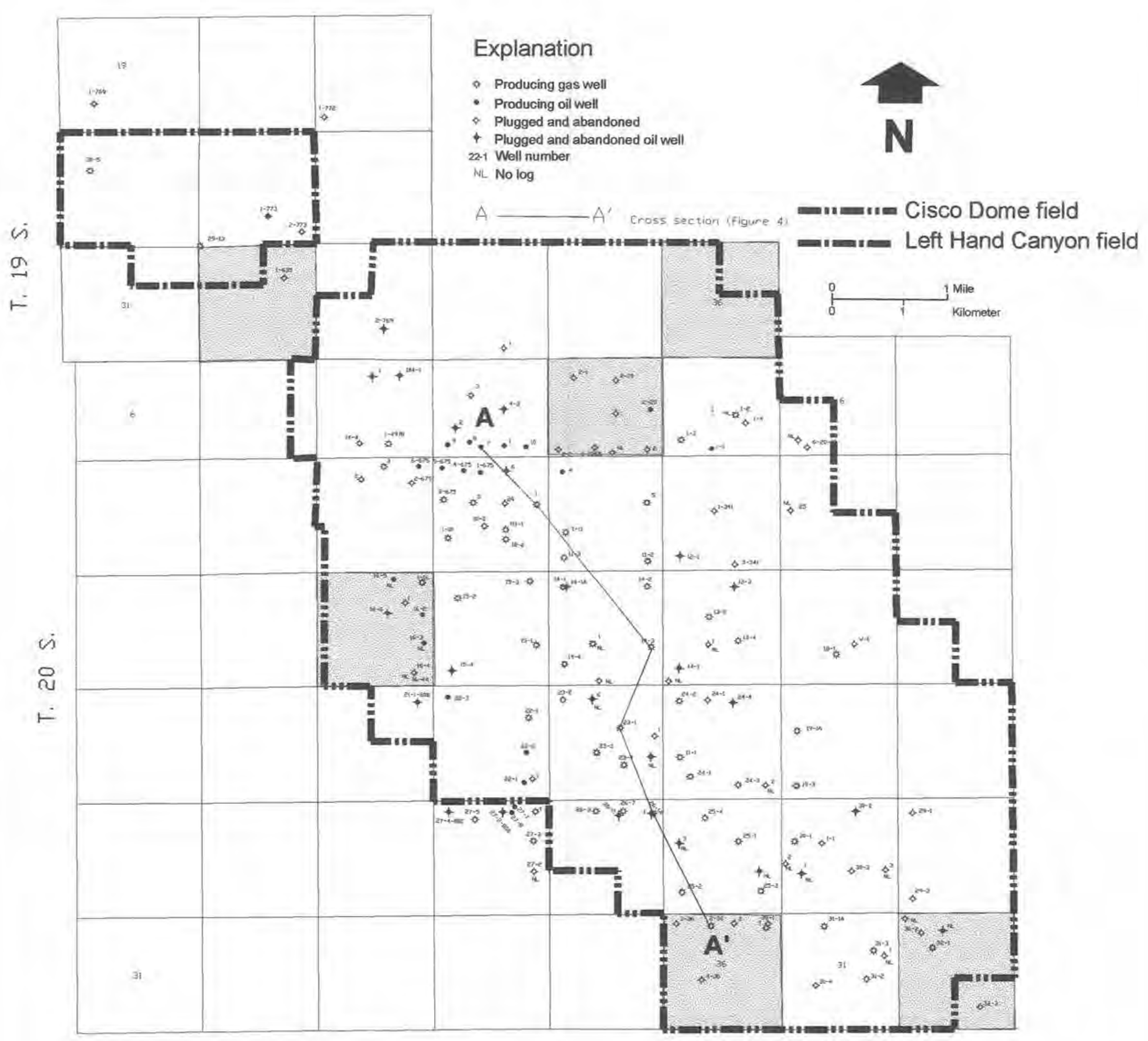


Figure 1. Location map of the Cisco Dome area showing boundaries of Left Hand Canyon and the original Cisco Dome fields. Shaded sections are lands managed by the Utah School and Institutional Trust Lands Administration. Cross section A - A' is shown in figure 4.

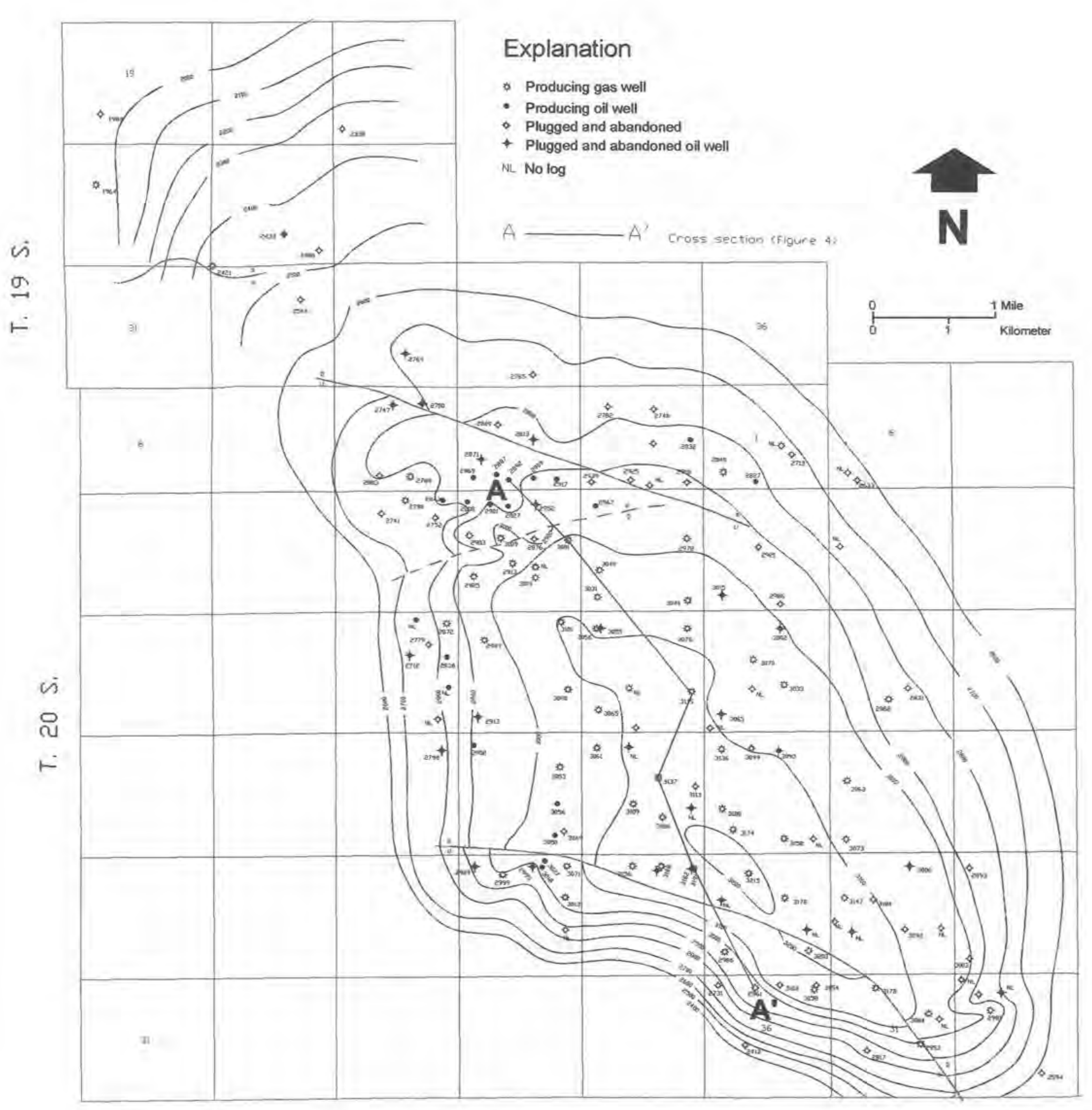


Figure 2. Structure contour map of the top of the Dakota Sandstone. Contour interval is 100 feet. Datum is mean sea level.

STRATIGRAPHY OF THE PRODUCING RESERVOIRS

Hydrocarbon production at Cisco Dome is from Jurassic- and Cretaceous-age sandstone, chiefly the Jurassic Morrison and Cretaceous Cedar Mountain and Dakota Formations (figure 4). A small amount of hydrocarbon has been produced from the Jurassic Entrada Sandstone and Cretaceous Mancos Shale. The Morrison, Cedar Mountain, and Dakota are separated by unconformities typically at the base of channels incised into the underlying formation. The reported producing horizons in table 1 and the following discussions are based on geophysical well-log correlations. These formation contacts are difficult to identify so the picks in this study may not agree with picks made by the well operators or other workers.

Entrada Sandstone

The Entrada Sandstone is an eolian deposit which occurs at a drill depth ranging from 4,750 feet (1,448.8 m) at Left Hand Canyon to 2,822 feet (860.7 m) on the crest of Cisco Dome. The Entrada reservoir is typically a porous, blanket-type sandstone productive from structural traps. The structurally highest penetration at the top of the Dakota Formation is the 25-4 well (NE1/4NW1/4 section 25, T. 20 S., R. 21 E.). The 25-4 well was completed in the Entrada in 1981 and produced 664 BO (92.9 MT) before it was recompleted in the Morrison Formation in 1985. The 25-2 well (SW1/4SW1/4 section 25, T. 20 S., R. 21 E.) is 229 feet (69.8 m) lower than the 25-4 well at the top of the Dakota but is 8 feet (2.4 m) higher at the top of the Entrada and has produced 20,487 BO (2,868.2 MT) from the Entrada as of December 31, 1996. The Federal 1-773 well (SW1/4SE1/4 section 29, T. 19 S., R. 20 E.) in Left Hand Canyon field was completed in 1972 and produced 20,003 BO (2,800 MT) from the Entrada before it was plugged and abandoned in 1978.

Morrison Formation

The Morrison Formation is a continental deposit of interbedded channel sandstone, variegated shale, and a few thin limestone beds, ranging from 350 to 698 feet (106.8-212.9 m) in drilled thickness in the Cisco Dome area. Gas and some oil have been produced from sandstone in both the Salt Wash and overlying Brushy Basin Members. Traps are formed where the channels cross the structural axis, or where bends in the channels create an updip pinch-out of the sandstone bed along the flank of the structure.

Cedar Mountain Formation

The Cedar Mountain Formation is a fluvial-lacustrine deposit of interbedded sandstone, siltstone, and some pale green shale, ranging from 49 to 158 feet (14.9-48.2 m) in drilled thickness in the Cisco Dome area. Some gas and most of the oil produced at Cisco Dome is from the Cedar Mountain. Most of the production is from the Buckhorn Conglomerate Member which forms the basal portion of the formation. Traps are formed similar to those in the Morrison Formation.

Dakota Sandstone

The Dakota Sandstone is a fluvial to littoral-marine deposit of sandstone and shale ranging from 56 to 180 feet (17.1-54.9 m) in drilled thickness in the Cisco Dome area. Gas and a minor amount of oil are produced primarily from one to three sandstone beds. Sandstone beds in the Dakota are labeled (in ascending order) Kd B, Kd A, and Kd Z in this report in keeping with the terminology used in Morgan (1998). Kd B and Kd A are incised fluvial channel deposits that trend west to east across Cisco Dome (figures 5 and 6). Based on well log correlations Kd Z does not appear to be incised and may be a tidal channel or nearshore bar deposit (figure 7). Traps are formed similar to those in the Cedar Mountain and Morrison Formations.

Mancos Shale

The Mancos Shale is a shallow marine deposit of mostly shale and some siltstone and thin sandstone and is exposed on the surface throughout most of the Cisco Dome area. Minor amounts of gas and oil are produced from the siltstone and sandstone intervals. Three wells have a combined production of about 1,500 BO (210 MT) and 37,000 MCFG (1,036,000 m^3) from stratigraphic traps formed by variation in porosity or possibly fracture density in the reservoir.

CALF CANYON WATER-FLOOD UNIT

Calf Canyon Water-flood unit encompasses parts of sections 3, 4, 9, 10, and 11, T. 20 S., R. 21 E., on the north end of the Cisco Dome field. Oil was discovered at Calf Canyon in 1977 in the Buckhorn Conglomerate Member of the Cedar Mountain Formation. Almost 600,000 barrels (80,000 MT) of 36.5^{o} API gravity oil had been produced (as of Dec. 31, 1996) at an average depth of 3,000 feet (915 m). At Calf Canyon the Buckhorn trends west to east about perpendicular to the structural axis, then turns southeast in section 11 where gas has been produced from the sandstone updip from the oil production (figure 8). Reservoir properties of the Buckhorn are shown in table 2. Secondary recovery (water flooding) was started at Calf Canyon in 1992 and was expected to last for about 22 years, but the water flood does not appear to have had an effect on the annual production from the unit as of December 31, 1996 (figure 9).

SUMMARY AND FUTURE POTENTIAL

More than 16 BCFG (448 million m^3) and 800,000 BO (112,000 MT) have been produced from the Cisco Dome field at depths ranging from about 2,000 to 3,000 feet (600-900 m). Most production has been from combination stratigraphic/structural traps in the fluvial channel sandstone beds of the Morrison, Cedar Mountain, and Dakota Formations.

A minor amount of production has come from the Entrada Sandstone and Mancos Shale. Hydrocarbon accumulations in these reservoirs at Cisco Dome field appear to be very limited and do not offer much potential for future exploration. Additional potential may still exist in many of the productive beds in the Morrison, Cedar Mountain, and Dakota Formations. Also, there are many fluvial channel sandstone beds in the Morrison that are not currently productive but may be good exploration targets. Calf Canyon unit is an example of how one sandstone bed can contain a large volume of oil at a shallow depth.

ACKNOWLEDGMENTS

Funding for this study was provided by the Utah School and Institutional Trust Lands Administration.

Table 1. Cumulative oil, gas, and water production from wells in the Cisco Dome field as of December 31,1996. NA is data not available. Data sources: Stowe (1979) and Utah Division of Oil, Gas and Mining.

Township and Range	Section Well Number	Producing Formation (Member or Bed)	Formation at TD	Completion Date	Oil BO	Gas MCFG	Water BW	Status	API# 43-019-
T. 20 S., R. 21. E.	NWSE 1 1-2	Morrison	Curtis	1/82	0	0	0	shut in	30603
	SESW 1 1-1	Morrison (SW)	Curtis	11/79	47,493	95,576	0	shut in	30566
	SWSW 1 1-3	Morrison (BB)	Unknown	6/83	0	0	0	shut in	31037
	NESE 2 2-20	Morrison (BB)	Curtis	8/82	565	0	662	shut in	30699
	SWNE 3 4-3	Morrison (SW)	Morrison	5/82	132	0	0	PA	30807
	SESE 3 10	Cedar Mountain	Entrada	11/85	22,954	17,003	1,130	POW	31203
	SWSE 3 1	Cedar Mountain	Salt Wash	2/77	109,729	20,475	5,321	POW	30298
	SESESW 3 7	Cedar Mountain	Morrison	11/84	110,383	27,309	3,739	POW	31168
	SESW 3 8	Cedar Mountain	Salt Wash	9/85	32,766	5,625	1,270	Recompleted	31197
	SESW 3 8	Dakota	Morrison	1/94	1,314	23,467	43	PGW	31197
	SWSW 3 11	Cedar Mountain	Entrada	11/85	19,824	6,330	797	Injection	31209
	NWSW 3 2	Dakota (A) Morrison (BB)	Entrada	7/78	0	0	0	PA	30366
	NWNE 4 104-1	Dakota (A,B)	Entrada	7/78	0	43,641	N/A	PA	30375
	NENW 4 1	Morrison (BB)	Morrison	3/72	0	0	0	PA	30078
	SWSE 4 1-4970	Cedar Mountain	Entrada	1/79	811	390,048	50	shut in	30449
	NWNE 9 3	Morrison (BB,SW)	Salt Wash	4/75	3	12,244	10	shut in	30222
	NENE 9 6-675	Cedar Mountain	Morrison	12/85	5,361	2,763	591	shut in	31208
	NENW 9 2	Morrison (BB)	Entrada	5/72	Unknown	NA	NA	PA	30083
	NWNE 10 6	Dakota (A,B) Cedar Mountain Morrison (SW)	Entrada	7/78	Unknown	NA	NA	PA	30391
	SENE 10 1	Cedar Mountain	Morrison	12/83	6,311	549,267	396	PGW	30986
	SWNE 10 2A	Dakota Morrison (SW)	Summerville	11/78	496	548,021	398	PA	30471
	NWNWSE 10 III-1	Cedar Mountain	Morrison	6/58	0	431,904	0	shut in	15108
	SWNWSE 10 10-2	Morrison (BB)	Unknown	4/85	0	189	0	shut in	30168
	NESW 10 10-2	Morrison (BB)	Morrison	12/85	1,306	0	0	shut in	31210
	NWSW 10 1-10	Dakota (A,B)	Entrada	10/79	0	81,352	0	shut in	30484
	SENW 10 3	Morrison	Morrison	10/81	138,842	419,117	280	PGW	30836
	SWNW 10 3-675	Cedar Mountain	Morrison	10/83	0	13,314	0	shut in	31094
	NENW 10 1-675	Morrison (BB)	Morrison	4/78	182,932	47,423	1,255	POW	30376
	NWNW 10 4-675	Cedar Mountain	Morrison	6/85	47,043	31,416	6,481	POW	31187
	NWNWNW 10 5-675	Morrison	Morrison	9/85	14,507	10,691	159	POW	31199
	SENE 11 5	Dakota (A,B) Cedar Mountain	Entrada	6/78	23	13,316	147	shut in	30393
	SESE 11 11-2	Cedar Mountain	Summerville	1/81	0	285,953	0	shut in	30882
	SWSW 11 11-3	Cedar Mountain Morrison (BB)	Summerville	1/82	0	485,132	0	PGW	30884
	NWSW 11 II-1	Cedar Mountain	Morrison	5/79	0	1,824,532	72,241	PGW	30485
	NWNW 11 4	Cedar Mountain	Not Reported	7/78	41,949	0	458	shut in	30392
	SWSW 12 12-1	Morrison (BB)	Not Reported	5/82	0	0	0	shut in	30932
	NWNE 13 13-3	Morrison (SW)	Entrada	4/82	31	0	455	shut in	30883
	NWSE 13 13-4	Morrison (BB)	Summerville	6/82	0	12,893	0	shut in	30885
T. 20 S., R. 21. E.	SWSW 13 13-1	Morrison (BB)	Entrada	10/77	258	380	716	shut in	30348
	SENW 13 13-2	Morrison (BB)	Not Reported	10/80	0	625,899	0	PGW	30673
	NENE 14 14-2	Dakota (Z,A)	Entrada	5/79	0	160,185	5,048	PGW	30487
	NESE 14 14-3	Dakota (A)	Salt Wash	10/79	6,542	245,979	264	PGW	30488
	NESW 14 1	Dakota	Dakota	4/28	0	655,761	0	shut in	15119
	SWSW 14 14-4	Morrison (BB)	Entrada	5/82	0	263,206	0	PGW	30878
	NWNW 14 14-1	Dakota (Z,A,B)	Morrison	6/78	144	470,332	27,810	PGW	30403
	NWNW 14 14-1A	Cedar Mountain Morrison (BB,SW)	Entrada	5/79	0	1,853	0	shut in	30436
	NENE 15 15-3	Morrison (BB)	Morrison	7/80	0	205,863	9,046	PGW	30637
	NESE 15 15-1	Dakota (Z,A,B)	Entrada	8/80	747	0	163	shut in	30585
	SWSW 15 15-4	Dakota (B)	Entrada	5/82	0	0	0	shut in	30887
	NWNW 15 15-2	Dakota (B)	Morrison	3/81	0	345,451	0	shut in	30636
	NENE 16 1-16	Morrison(BB,SW)	Summerville	12/79	210	0	0	shut in	30546
	SENE 16 16-2	Dakota(Z)	Summerville	7/80	402	0	0	shut in	30590
	SWNE 16 16-6	Morrison	Unknown	5/81	0	0	0	shut in	30765
	NWNE 16 16-5	Morrison	Unknown	12/81	0	0	0	shut in	30722
	NESE 16 16-3	Dakota	Unknown	12/81	0	0	0	shut in	30675
	NENE 21 21-1-80B	Morrison (SW)	Salt Wash	5/81	17	0	0	PA	30644
	SENE 22 22-1	Morrison (BB)	Entrada	8/80	0	618,303	0	PGW	30625
	NESE 22 22-2	Morrison (BB)	Entrada	11/80	9,836	199,274	0	PGW	30644
	SESE 22 22-1	Morrison (BB)	Salt Wash	11/80	18,222	740	375	POW	30684
	NWNW 22 22-3	Mancos	Entrada	12/85	1,509	3,932	0	shut in	30665
	SWNE 23 23-1	Dakota (Z)	Entrada	6/78	2,302	546,032	31	PGW	30355
	NWSE 23 23-4	Morrison (BB)	Entrada	6/81	0	94,534	0	PGW	30760
	NESW 23 23-3	Morrison (BB)	Morrison	8/80	0	519,741	0	PGW	30588
	NENW 23 6	Dakota	Dakota	11/28	Unknown	NA	NA	PA	10275
	NWNW 23 23-2	Dakota	Morrison	5/80	5,006	84,018	101	PGW	30586
	SWSE 24 24-3	Dakota (A)	Entrada	12/79	19	115,030	0	PGW	30432
	NESWSW 24 24-1	Dakota	Unknown	6/84	0	0	0	shut in	31010
	NWSW 24 11-1	Morrison (BB)	Base Salt	9/57	0	466,150	0	shut in	15107
	NWNW 24 24-2	Dakota (A,B) Cedar Mountain	Entrada	10/79	0	105,842	0	PGW	30530
	SWNE 25 25-1	Cedar Mountain	Entrada	5/78	0	873,368	0	PGW	30359
	NESE 25	Dakota	Morrison	9/26	Unknown	NA	NA	PA	05260
	SESE 25 25-3	Morrison (BB)	Salt Wash	12/79	0	118,844	0	PGW	30575
	SWSW 25 25-2	Entrada	Entrada	4/80	20,487	0	2,913	POW	30587
	NENW 25 25-4	Entrada	Entrada	6/81	664	0	0	Recompleted	30743
	NENW 25 25-4	Morrison (BB)	Entrada	5/85	0	194,941	0	PGW	30743
	SWNW 25 3	Morrison	Morrison	?/27	Unknown	NA	NA	PA	10272
	NENE 26 1	Dakota (Z,A,B)	Morrison	?/28	Unknown	NA	NA	PA	10274
T. 20 S., R. 21. E.	NENE 26 26-1A	Dakota (Z,B)	Salt Wash	11/79	0	148,616	2,772	PGW	30477
	NWNE 26 26-2	Morrison	Unknown	Unknown	Unknown	NA	0	PA	
	NWNE 26 26-7	Dakota (B)	Morrison	7/85	0	0	0	shut in	31139
	NWNE 26 26-3	Mancos	Entrada	1/90	0	16,948	0	PGW	30582
	NENE 27 1	Dakota (A,B) Morrison (BB)	Cedar Mountain	12/79	0	265,647	0	shut in	30513
	NENE 27 1(Mancos)	Mancos	Cedar Mountain	Unknown	0	19,139	0	PGW	30513
	SENE 27 27-3	Dakota (B)	Salt Wash	5/82	3	1,127	0	shut in	30643
	NWNE 27 2707	Morrison (SW)	Morrison	8/83	558	40	114	shut in	31068
	NWNE 27 27-8	Dakota (Z,A,B) Morrison (BB,SW)	Morrison	11/84	1,126	0	1,441	shut in	31165
	NWNE 27 27-8	Mancos	Morrison	1/85	0	19,132	0	PGW	31165
	NENW 27 27-5	Mancos	Entrada	4/87	0	14,287	0	PGW	30715
	NWNW 27 27-4-80C	Morrison (SW)	Salt Wash	8/82	Unknown	NA	NA	PA	30695
	NENE 36 1	Dakota (Z,A,B) Cedar Mountain	Morrison	7/55	4	121,621	5	shut in	15106
T. 20 S., R. 22 E.	SESW 18 18-1	Dakota (A)	Entrada	11/83	0	4,602	0	shut in	30875
	SWSW 19 19-3	Dakota (A)	Morrison	3/77	275	307	0	shut in	30302
	SWNW 19 19-1A	Dakota (Z,A)	Entrada	3/84	0	143	0	shut in	20896
	NWNE 30 30-2	Mancos	Entrada	10/79	0	0	0	PA	30492
	NWSW 30 1	Dakota	Kayenta	4/25	Unknown	NA	NA	PA	11390
	SWNW 30 30-1	Dakota (Z)	Entrada	7/78	0	70,198	0	shut in	30429
	SENE 31 31-3	Dakota (B)	Entrada	6/78	0	88,146	0	shut in	30428
	NESE 31 31-2	Dakota (AB) Cedar Mountain Morrison (BB)	Entrada	6/82	0	4,530	0	shut in	30876
	NENW 31 31-1A	Dakota (Z,A)	Morrison	4/77	0	77,637	0	PGW	30308
	NENW 32	Dakota	Dakota	9/28	Unknown	NA	NA	PA	11246
	SENW 32 32-1	Morrison (SW)	Entrada	10/77	0	96,335	0	PGW	30347
	Original 16 Wells	Dakota Cedar Mountain Morrison	Variable	10/20s	Unknown	NA	NA	PA	NA
T. 19 S., R. 21 E.	NWSE 33 2-769	Cedar Mountain	Entrada	5/78	134	0	3,838	PA	30431
Totals					853,240	16,406,062	150,579		

Dakota (Z,A,B): sandstone beds in the Dakota Sandstone, see figure 4.
Morrison (BB): Brushy Basin Member of the Morrison Formation
Morrison (SW): Salt Wash Member of the Morrison Formation
BO: Barrels of oil
MCFG: Thousand cubic feet of gas
BW: Barrels of water
API #: American Petroleum Institute well index number; first five numbers given in heading.
PA: Plugged and abandoned
POW: Plugged oil well
PGW: Plugged gas well
TD: Total Depth

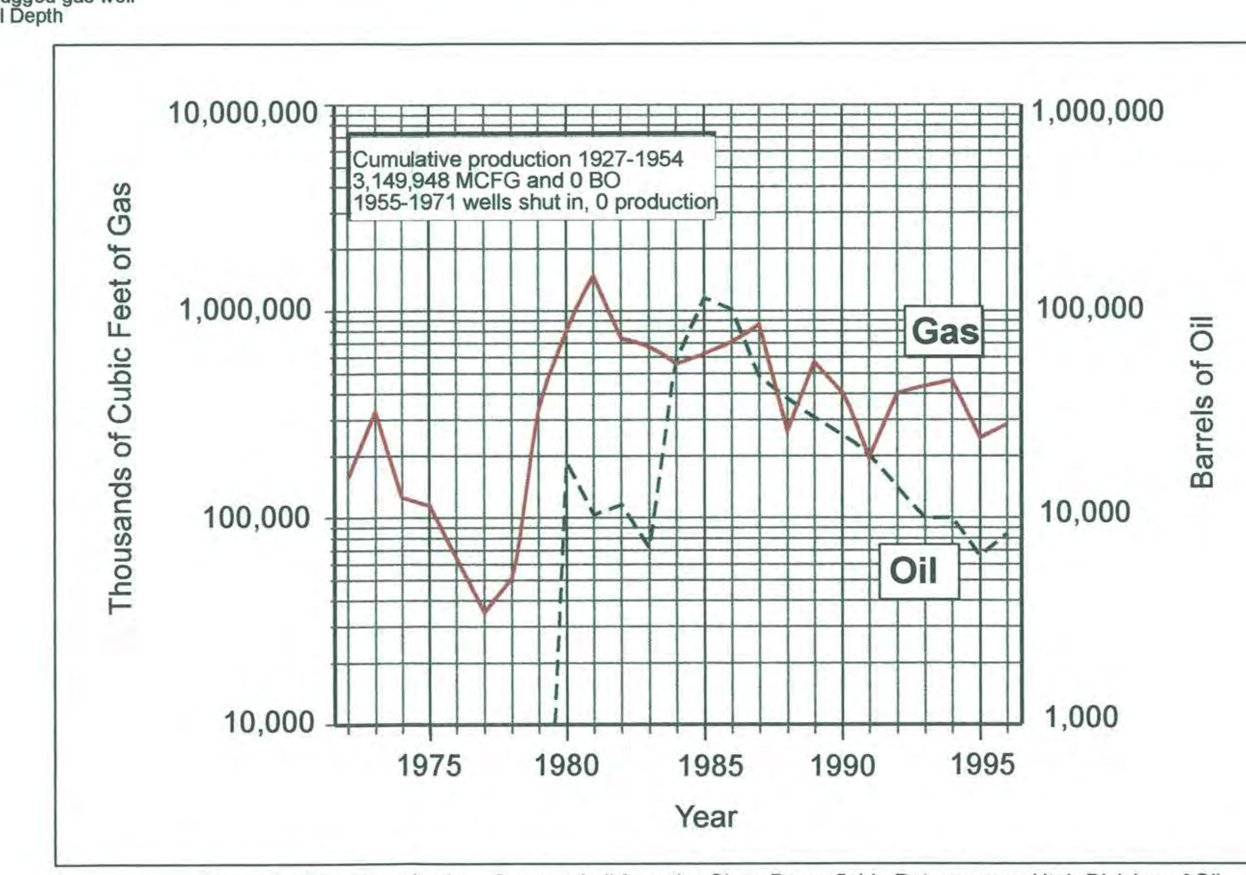


Figure 3. Annual production of gas and oil from the Cisco Dome field. Data source: Utah Division of Oil, Gas and Mining records.

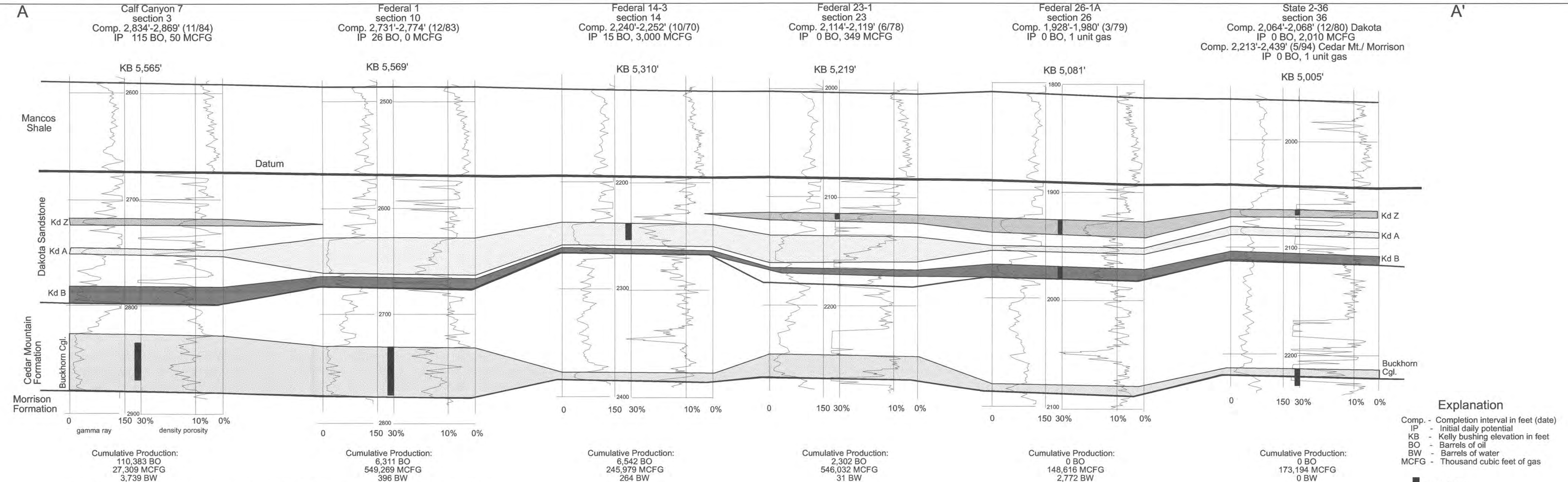


Figure 4. North to south gamma-ray and density porosity logs, and stratigraphic cross section from the top of the Coon Springs Sandstone of the Mancos Shale to the top of the Morrison Formation. Gamma ray in API units, density porosity in percent, log depths in feet.

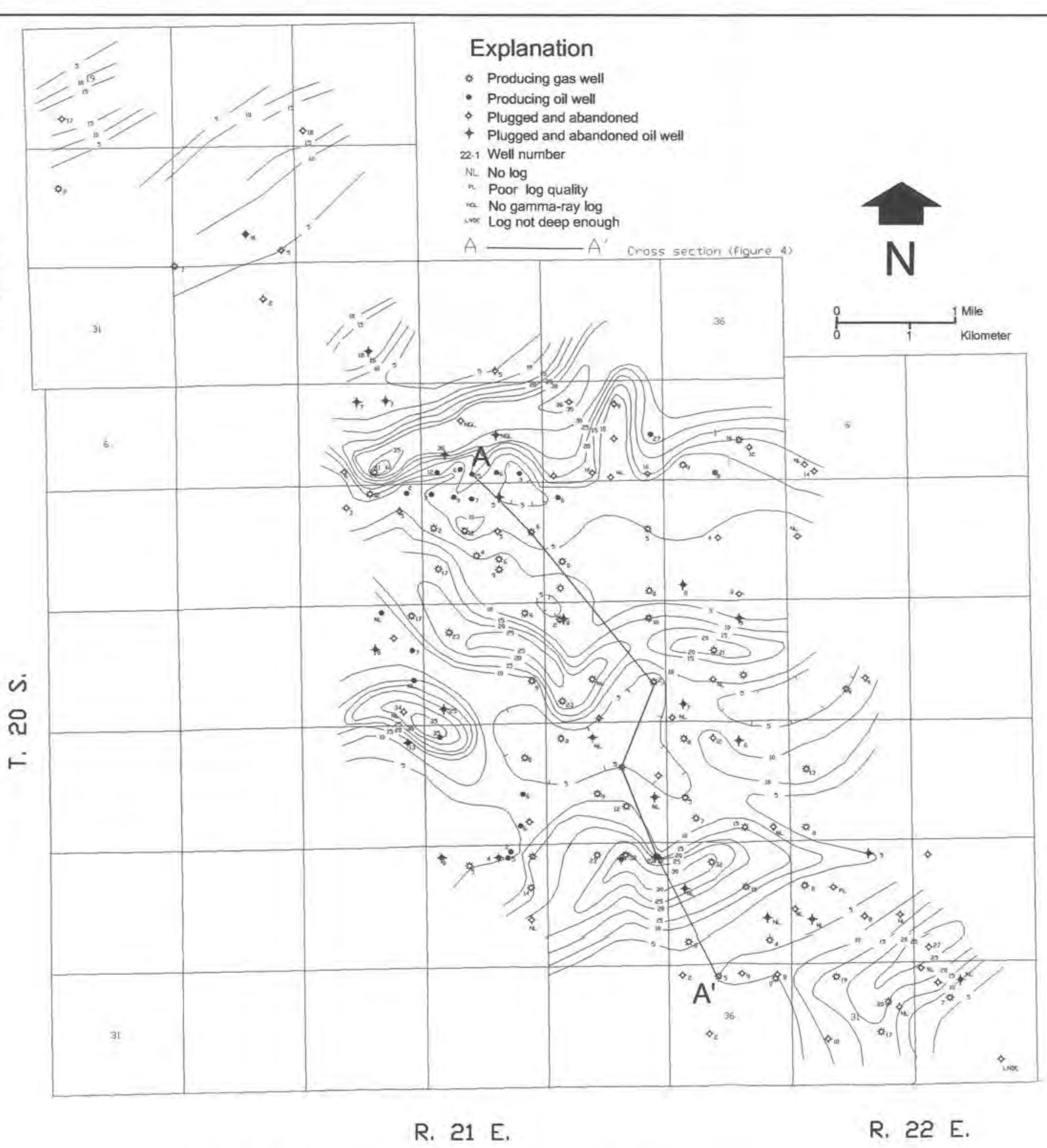


Figure 5. Isochore map of the Kd B bed. Contour interval is 5 feet.

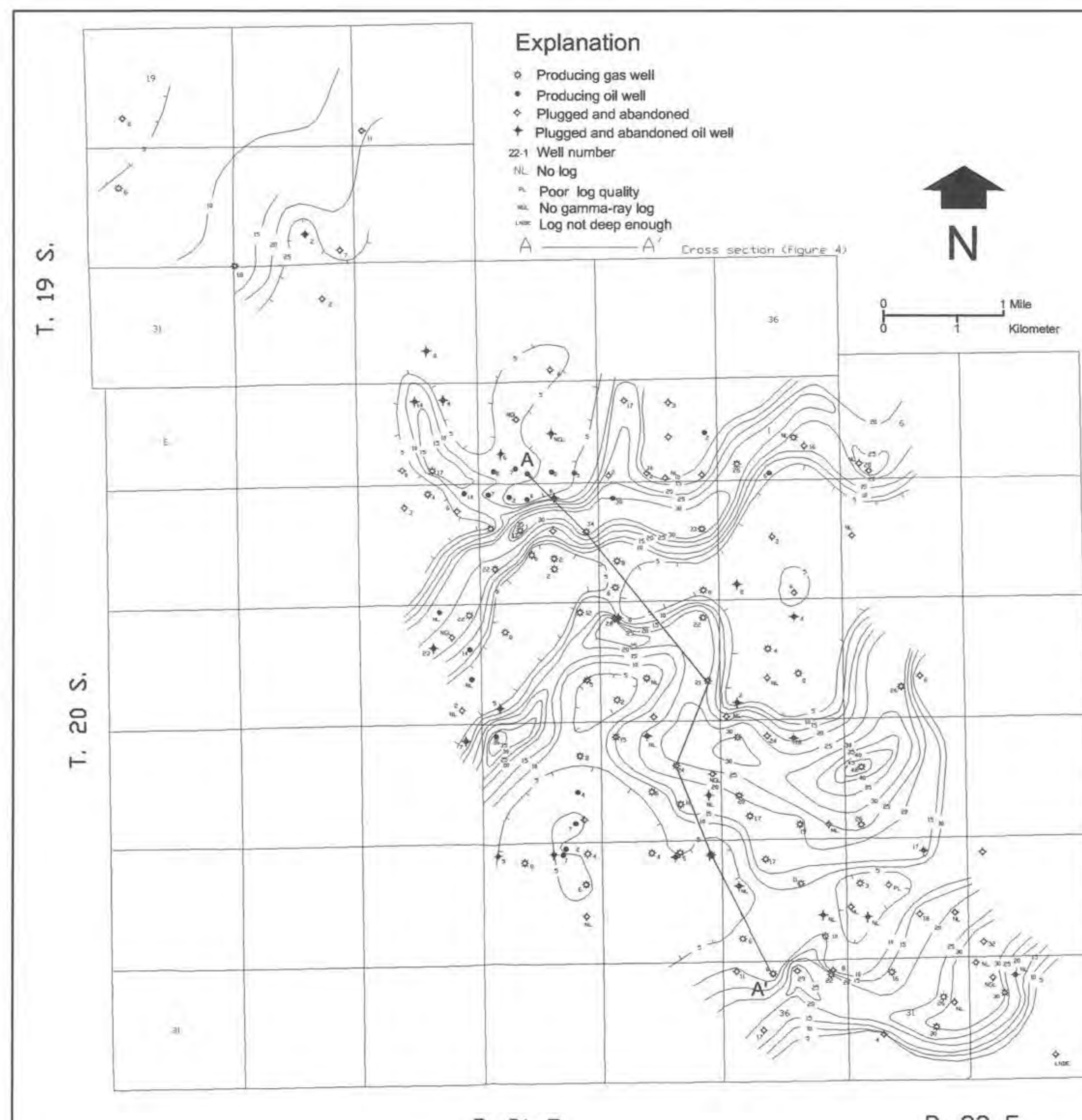


Figure 6. Isochore map of the Kd A bed. Contour interval is 5 feet.

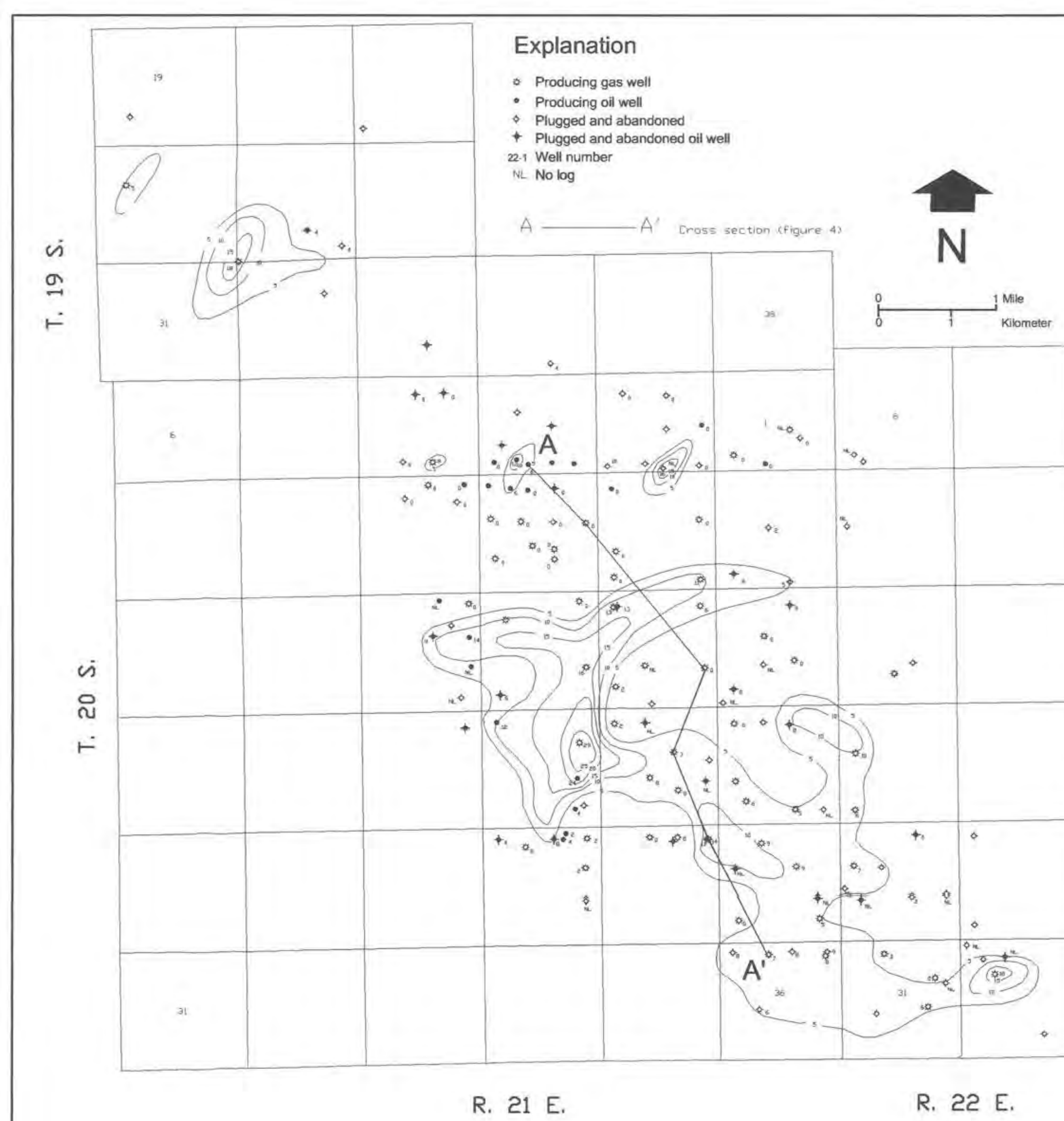


Figure 7. Isochore map of the Kd Z bed. Contour interval is 5 feet.

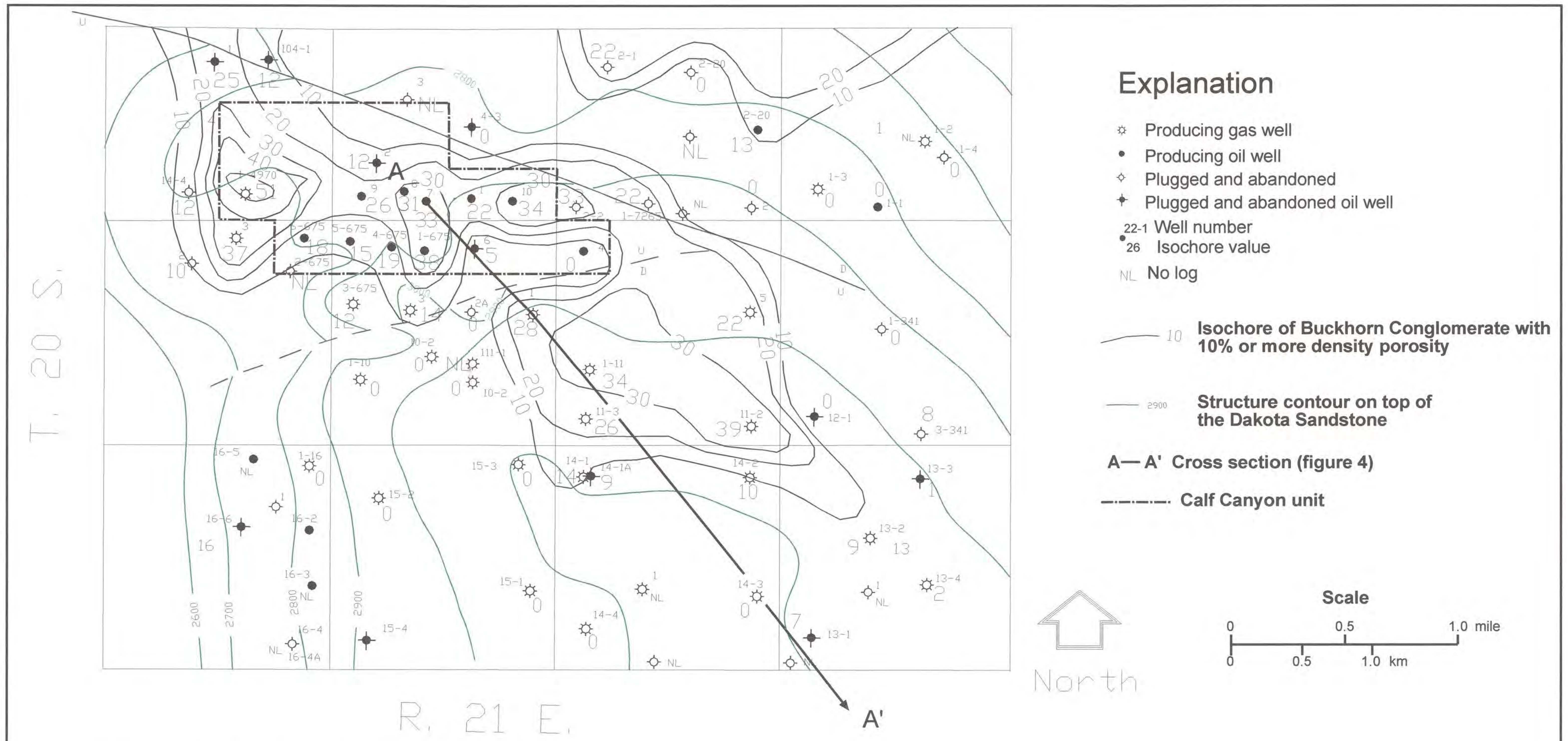


Figure 8. Isochore map of the Buckhorn Conglomerate Member of the Cedar Mountain Formation with 10% or more density porosity, and structure contour map of the top of the Dakota Sandstone, in the vicinity of the Calf Canyon Water-flood unit. Isochore interval is 10 feet. Structure contour is 100 feet, datum is mean sea level.

Table 2. Reservoir properties of the Buckhorn Conglomerate Member of the Cedar Mountain Formation at Calf Canyon unit. Data source, Board of the Utah Division of Oil, Gas and Mining hearing file, Cause 102-75.

Number of producers	8 (40 acre spacing)
Number of injectors	1 (Calf Canyon 11, SWSW section 3)
Average well depth	3,000 feet
Primary producing mechanism	solution gas drive
Oil reservoir area	640 acres
Average pay thickness	19.41 feet
Reservoir pore volume	2,179 acre-feet
Average porosity and permeability	15.6% and 5 md
Average connate water saturation	44.8%
Original bottom-hole pressure and temperature	900 psi and 120 °F
Original oil in place (OOIP)	4,441,049 BO
Estimated primary recovery (percent of OOIP)	592,816 BO (13.3%)
Estimated secondary recovery (percent of OOIP)	325,596 BO (7.33%)
Estimated ultimate recovery (percent of OOIP)	918,412 BO (20.68%)

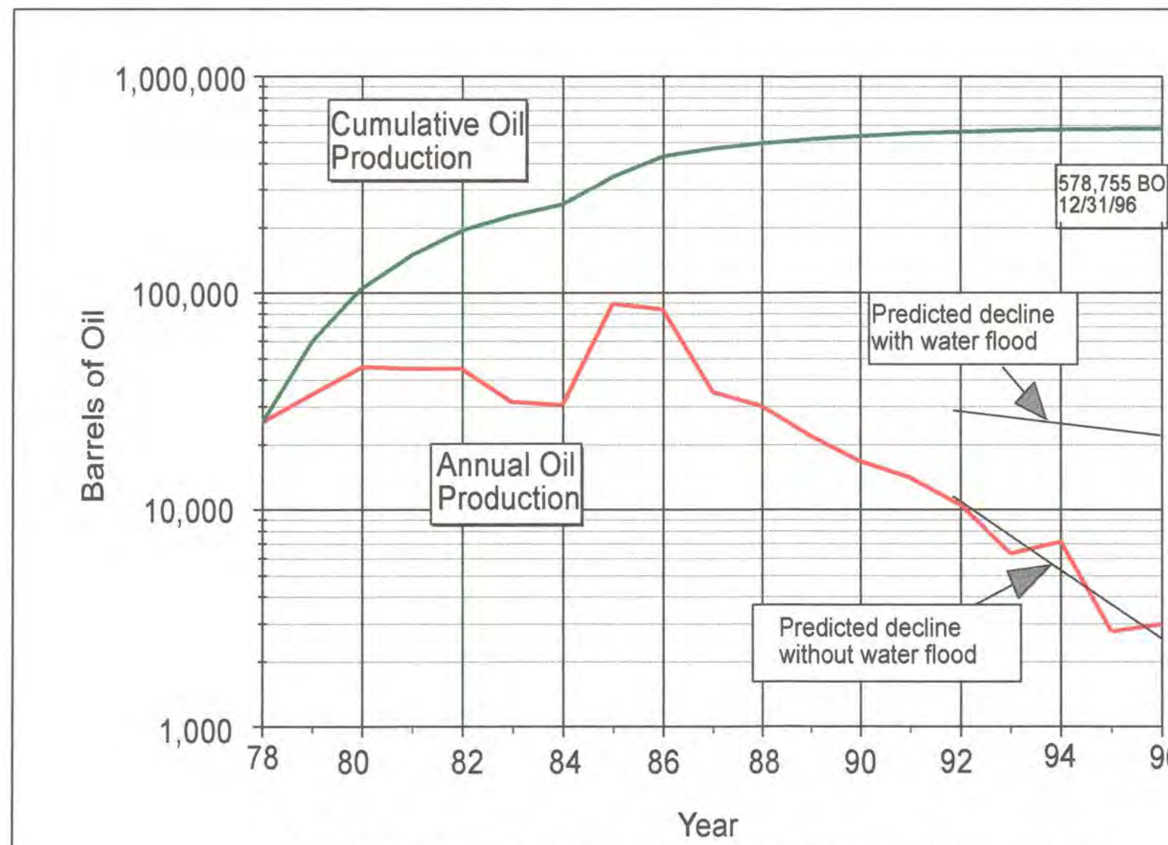


Figure 9. Annual and cumulative oil production from the Calf Canyon unit. Predicted decline curves are from Utah Board of Oil, Gas and Mining hearing file, Cause 102-75. Production data from the Utah Division of Oil, Gas and Mining records.

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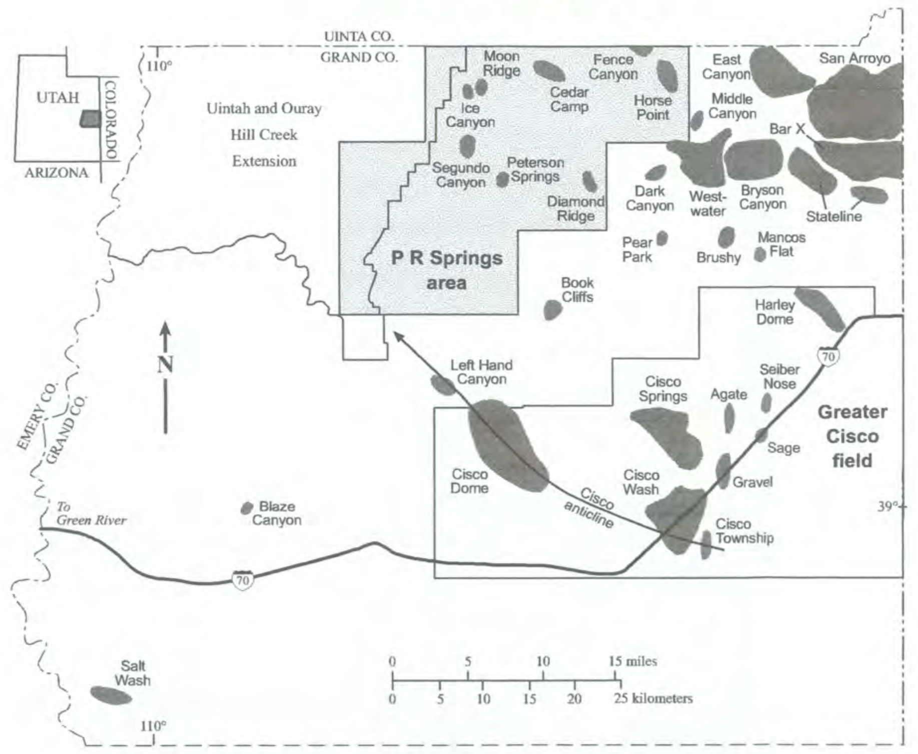
GAS FIELDS IN THE PR SPRINGS AREA GRAND COUNTY, UTAH

by
Craig D. Morgan



Oil and Gas Fields Study 20 June, 1999
UTAH GEOLOGICAL SURVEY
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INTRODUCTION

The PR Springs study is part of a Utah Geological Survey (UGS) investigation of hydrocarbon production and potential of the Cretaceous-age Dakota and Cedar Mountain Formations in northern Grand County, Utah. The Dakota and Cedar Mountain are the primary producing reservoirs in northern Grand County where the Utah School and Institutional Trust Lands Administration (SITLA) has extensive land holdings. The UGS investigation is intended to provide basic geologic data that can be used to determine the value of the SITLA property and to identify and facilitate development of additional hydrocarbon potential. The PR Springs area consists of nearly 200,000 acres (80,900 ha) mostly owned by SITLA. The area is situated along the southern Book Cliffs with surface outcrops of Tertiary Wasatch and Green River Formations.

There are numerous small gas fields in the PR Springs area with production from Cretaceous and Jurassic-age (Morrison and Entrada) reservoirs (figure 1). Thirty-five hydrocarbon test wells have been drilled in the area, mostly in the north, for an average density of one well per 8 square miles (20.7 km^2). Only two wells have been drilled in the southwest portion of the area (T. 17 S., R. 20 E., and T. 18 S., R. 20-21 E., Salt Lake Base Line and Meridian) for an average density of one well per 54 square miles (139.9 km^2). The deepest well was drilled by the Anschutz Corporation (State 411-2 [section 23, T. 18 S., R. 20 E.]) to a depth of 10,789 feet (3,290.6 m) in Precambrian granite.

STRUCTURE

The PR Springs area lies along the northwest flank of the ancestral Uncompahgre Highland. Deep tests in the area have encountered Triassic Chinle Formation overlying Precambrian granite. Structural dip in the PR Springs area is generally to the northwest at about 170 feet per mile (32.4 m/km), into the Uinta Basin. Most hydrocarbon production is located along subtle west- to northwest-plunging anticlines (figure 2). Faults have not been mapped in the area on the surface. Peterson (1973) mapped a southeast- to northwest-trending subsurface fault associated with the Horse Point - Fence Canyon anticline at the Dakota silt (Coon Springs Sandstone) horizon. The Peterson Spring well (section 14, T. 17 S., R. 21 E.) encountered a fault in the Tununk Shale Member of the Mancos Shale.

OIL AND GAS FIELDS

Most of the gas wells in the PR Springs area produce from sandstone beds in the Cedar Mountain and Dakota Formations (table 1 and figure 1). The productive beds are lenticular fluvial channel deposits. The Dakota Formation is overlain by the Coon Springs Sandstone, a regressive-marine, upward-coarsening deposit in the Tununk Shale Member of the Mancos Shale. The isochore map of the interval from the top of the Coon Springs to the top of the Dakota shows a southeast to northwest depositional trend (figure 3). In the PR Springs area two sandstone beds can be correlated in the Dakota, and are referred to as Kd A (upper bed) and Kd B (lower bed) in this report (figure 4). Isochore maps of Kd A and Kd B indicate an overall southwest to northeast depositional trend, perpendicular to the depositional trend of the overlying Coon Springs (figures 5 and 6).

Fence Canyon field is described by Osmond (1993) and Peterson (1973). Stowe (1979) describes Diamond Ridge, Fence Canyon, Horse Point, Moon Ridge, and Segundo Canyon fields.

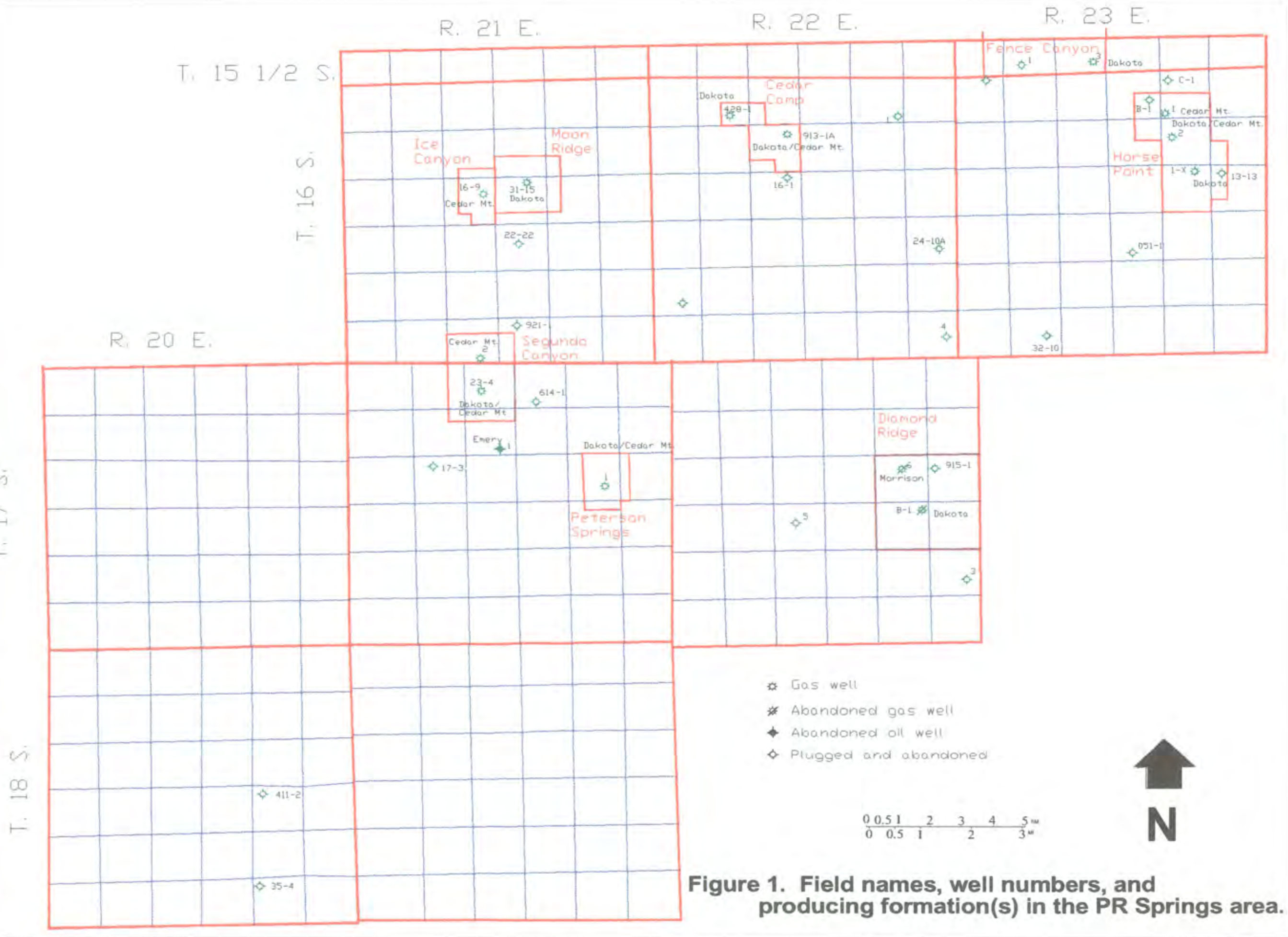

Figure 1. Field names, well numbers, and producing formation(s) in the PR Springs area.

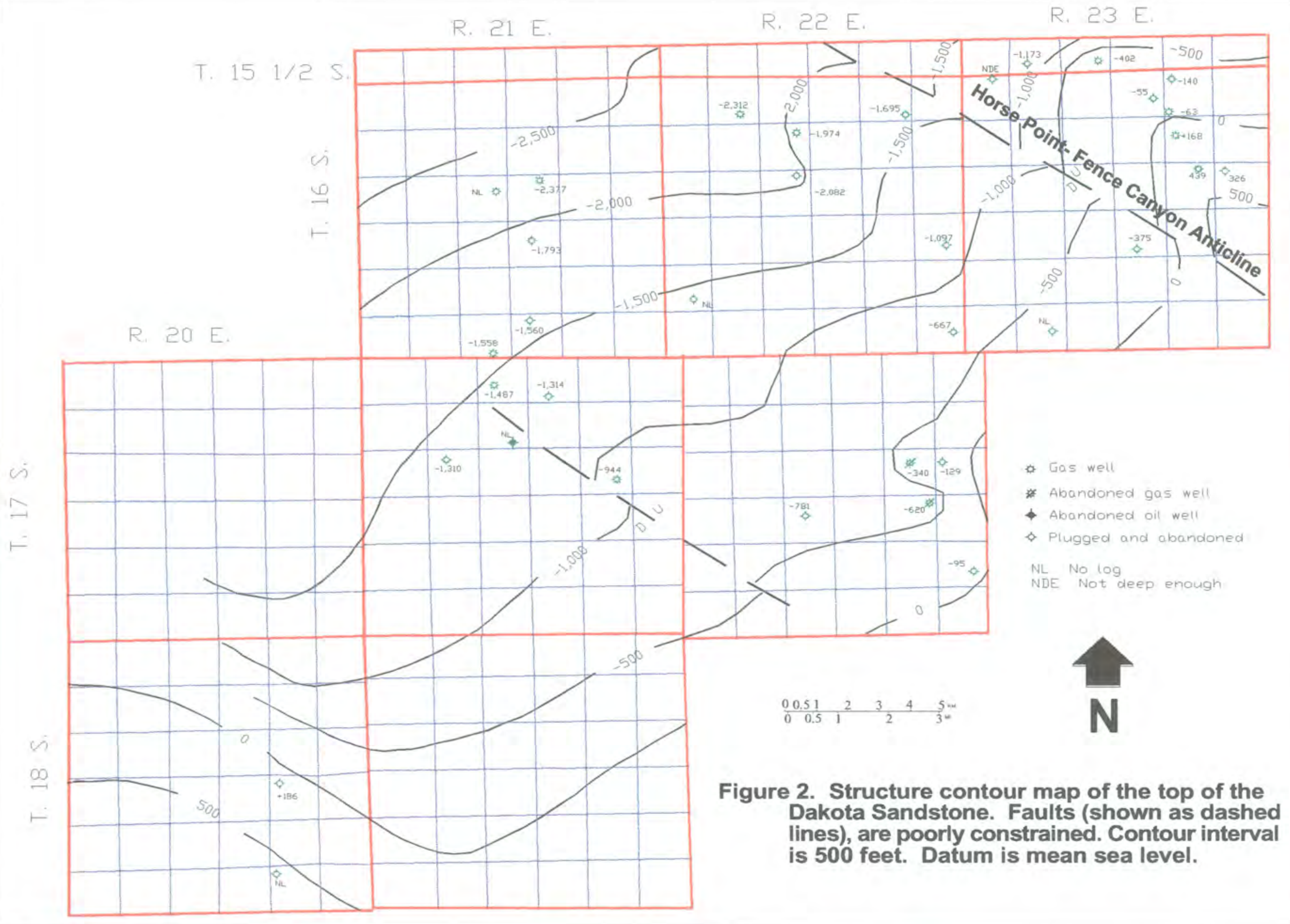

Figure 2. Structure contour map of the top of the Dakota Sandstone. Faults (shown as dashed lines), are poorly constrained. Contour interval is 500 feet. Datum is mean sea level.

Table 1. Hydrocarbon production from the PR Springs area as of December 31, 1996. Data from the Utah Division of Oil, Gas and Mining. Production given in barrels of oil (BO) and thousand cubic feet of gas (MCFG).

Field Name and Date of Discovery	Well Number	Formation at Total Depth	Reservoir(s)	Cumulative Production	Monthly Production (Dec. 1996)
Cedar Camp 1988	428-1	Morrison	Dakota	0 BO 9,473 MCFG	shut in
	913-1A	Morrison	Dakota/ Cedar Mountain	59 BO 320,239 MCFG	0 BO 1,150 MCFG
Diamond Ridge 1960	6	Morrison	Morrison	0 BO 261,455 MCFG	plugged and abandoned
	B-1	Morrison	Dakota	0 BO 205,024 MCFG	plugged and abandoned
Fence Canyon 1960	3	Entrada	Dakota	1,809 BO 853,963 MCFG	66 BO 6,753 MCFG
Horse Point 1961	1	Morrison	Cedar Mountain	0 BO 437,030 MCFG	0 BO 3,627 MCFG
	2	Cedar Mountain	Dakota/ Cedar Mountain	75 BO 77,582 MCFG	0 BO 3,910 MCFG
	1-X	Entrada	Dakota	0 BO 2,721,355 MCFG	0 BO 10,349 MCFG
Ice Canyon 1988	16-9	Entrada	Cedar Mountain	78 BO 882,611 MCFG	0 BO 3,692 MCFG
Moon Ridge 1962	31-15	Morrison	Dakota	0 BO 1,873,926 MCFG	0 BO 2,951 MCFG
Peterson Springs 1983	1	Entrada	Dakota/ Cedar Mountain	0 BO 275,551 MCFG	0 BO 1,057 MCFG
Segundo Canyon 1962	2	Morrison	Cedar Mountain	0 BO 1,870,111 MCFG	0 BO 5,360 MCFG
	23-4	Morrison	Dakota/ Cedar Mountain	0 BO 169,149 MCFG	0 BO 1,173 MCFG
originally part of Segundo Canyon	1 (Section 9)	Morrison	Emery(Mancos)	704 BO 888 MCFG	plugged and abandoned
TOTALS	14 wells 10 active			2,725 BO 9,958,357 MCFG	66 BO 40,022 MCFG

HYDROCARBON SHOWS

Geophysical well logs and/or mud logs indicate shows of hydrocarbons in some wells that were not exploited. The wells were completed in other beds or the shows were not considered sufficient to warrant a completion attempt.

Two wells were drilled in the Bogart Canyon area (sections 23 and 35, T. 18 S., R. 20 E.) and both had encouraging shows in the Dakota Sandstone. The State 411-2 well drilled in section 23 encountered 9 to 13 percent density porosity with density/neutron crossover (gas effect). The Bogart Canyon 35-4 well was not logged with geophysical tools because of drill pipe stuck in the hole. The Dakota was not tested in either well probably because they had only minor increases of gas in the drilling mud.

North of the Horse Point field the Little Berry State C-1 well (section 2, T. 16 S., R. 23 E.) encountered 14 and 19 percent density porosity (both beds had density/neutron crossover) in the Kd A and Kd B, respectively. The Cedar Mountain Formation in the C-1 well has 14 percent density porosity with some density/neutron crossover. The well was air drilled. A 10-foot (3.0 m) flare lasting less than two minutes was reported while drilling the Kd A; no shows were encountered while drilling the Kd B. A 16- to 30-foot (4.9- 9.2 m) flare was reported while drilling the Cedar Mountain, which was open-hole tested for a rate of 120 thousand cubic feet of gas per day (MCFG/D [3,397.9 m^3 /D]), but a completion attempt of the Cedar Mountain yielded an uneconomical rate.

The Diamond Ridge 4 well (section 36, T. 16 S., R. 22 E.) encountered 21 feet (6.4 m) of Kd A (a porosity log was not run). The Dakota Sandstone was air drilled and gas was reported while drilling the Kd A, but the flare quickly died. The Cedar Mountain Formation flowed at a rate of 430 MCFG/D (12,175.8 m^3 /D) while drilling, but was reported as non-economical during production testing.

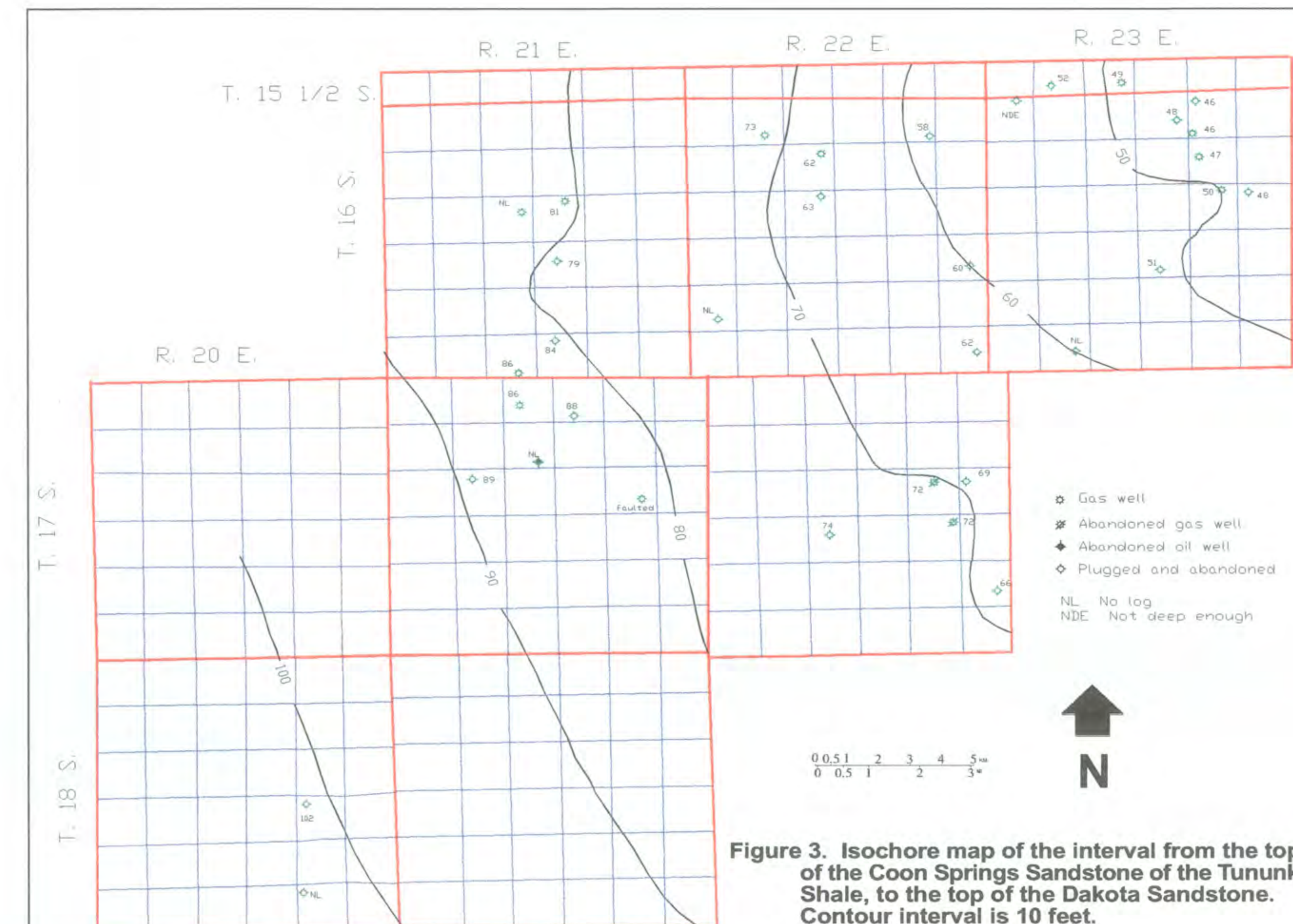

Figure 3. Isochore map of the interval from the top of the Coon Springs Sandstone of the Tununk Shale, to the top of the Dakota Sandstone. Contour interval is 10 feet.

COALBED METHANE

The coal-bearing Neslen Formation of the Cretaceous Mesaverde Group is found at depths ranging from 2,000 to 5,000 feet (610 to 1,524 m) deep in the PR Springs area. Coal beds in the Neslen Formation have not been tested for methane gas in the PR Springs area. Sample and density logs usually were not run over the shallow coal-bearing interval in most of the oil and gas drill holes. Therefore, the number of beds and coal thickness can only be determined in a few of the wells. The gas content of the coals is unknown.

Most of the individual coal beds are less than 2 feet (0.6 m) thick. The thickest individual bed identified in a well was 8 feet thick (2.4 m) (figures 7 and 8). A total of 4 to 15 feet (1.2 - 4.6 m) of coal can be expected in most of the PR Springs area (figure 9).

SUMMARY

Most of the hydrocarbon production in the PR Springs area is gas from southwest- to northeast-trending channel sandstone beds in the Dakota and Cedar Mountain Formations. Current production is from small isolated fields located along the structural axis of subtle plunging anticlines. The area is sparsely drilled and has good exploration potential for stratigraphic traps in the highly lenticular channel sandstone beds.

SHEET 2 of 2

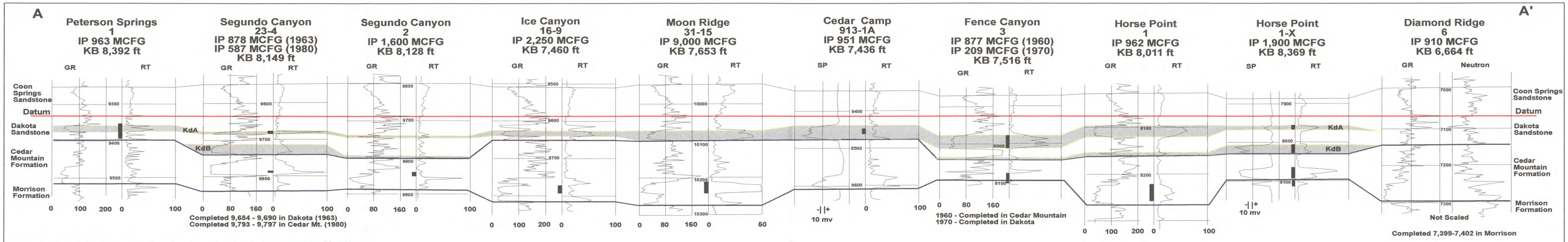

Figure 4. Stratigraphic cross section of the Coon Springs Sandstone of the Mancos Shale, Dakota and Cedar Mountain Formations. Location of cross section shown in figures 5 and 6. Datum is the top of the Dakota.

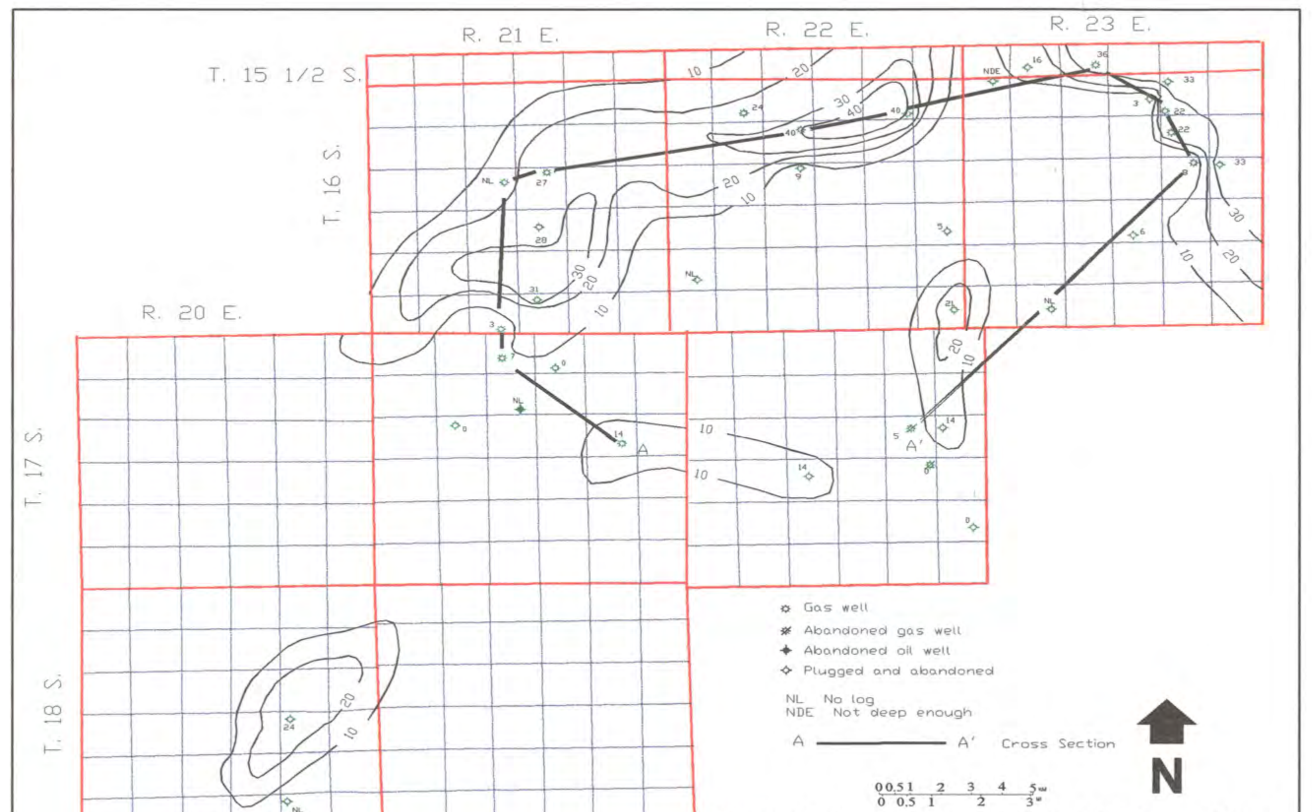

Figure 5. Isochore map of the Kd A sandstone bed in the Dakota Sandstone. Contour interval is 10 feet.

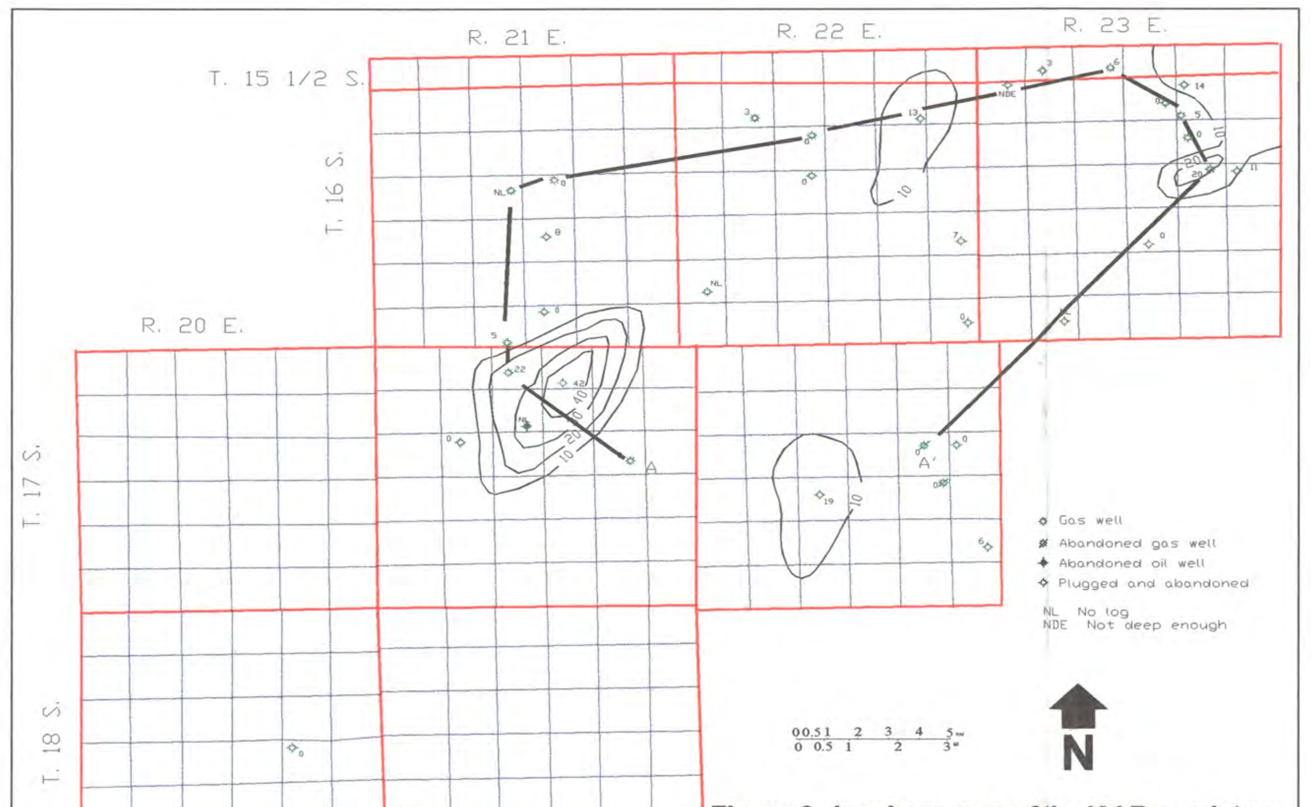

Figure 6. Isochore map of the Kd B sandstone bed in the Dakota Sandstone. Contour interval is 10 feet.

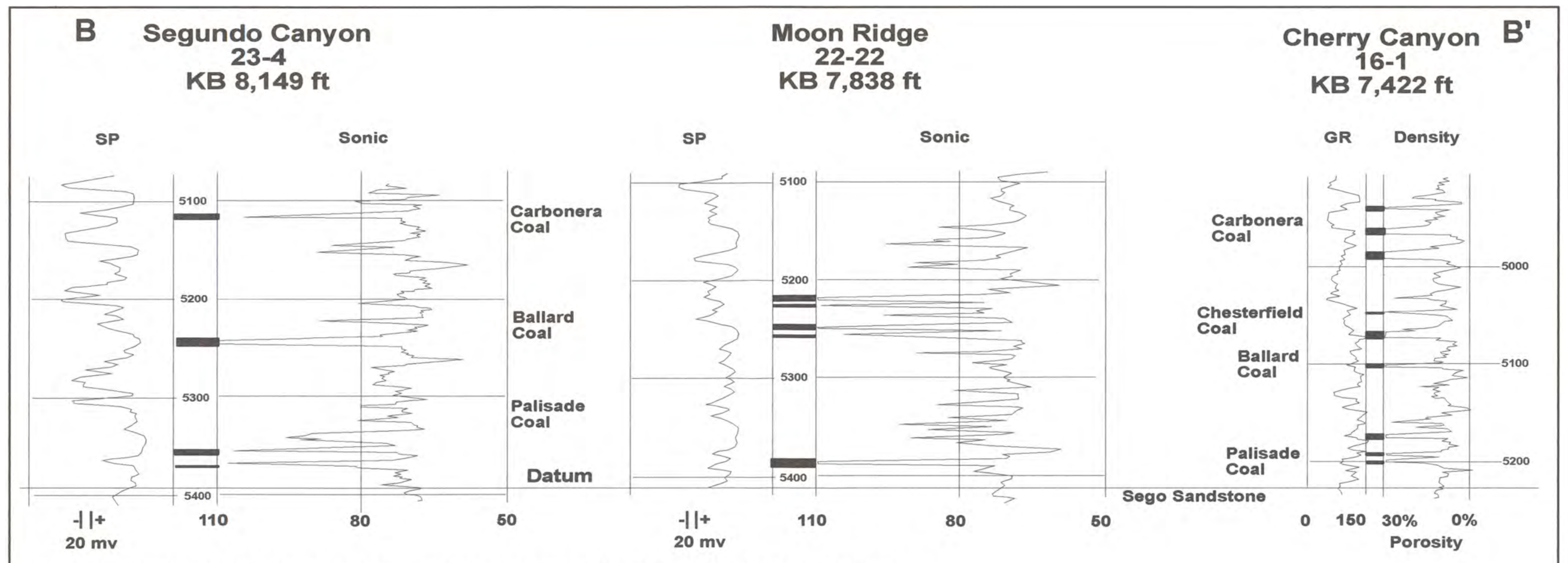

Figure 7. Stratigraphic cross section of coal-bearing section in the Neslen Formation of the Mesaverde Group. Location of cross section shown in figures 8 and 9.

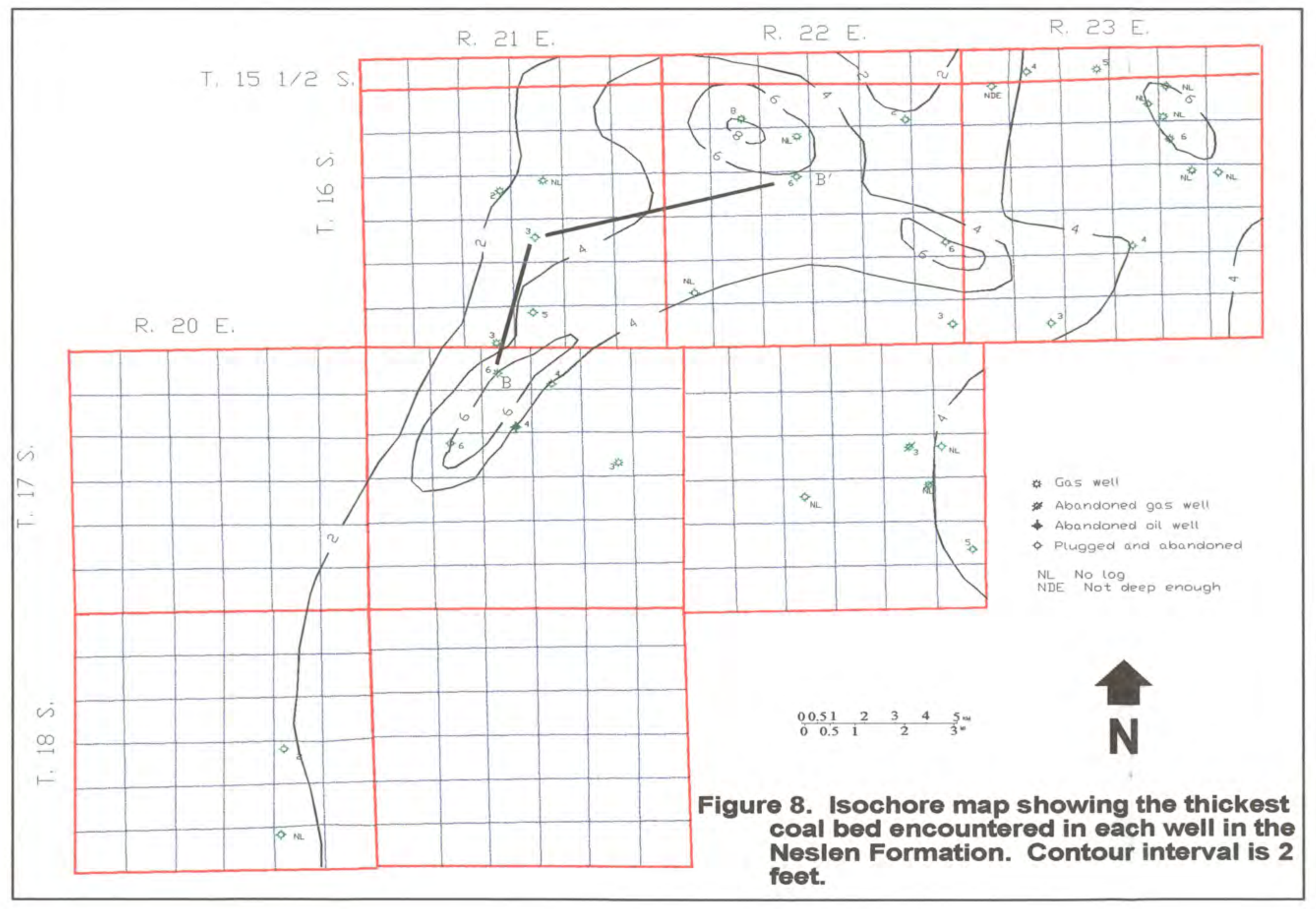

Figure 8. Isochore map showing the thickest coal bed encountered in each well in the Neslen Formation. Contour interval is 2 feet.

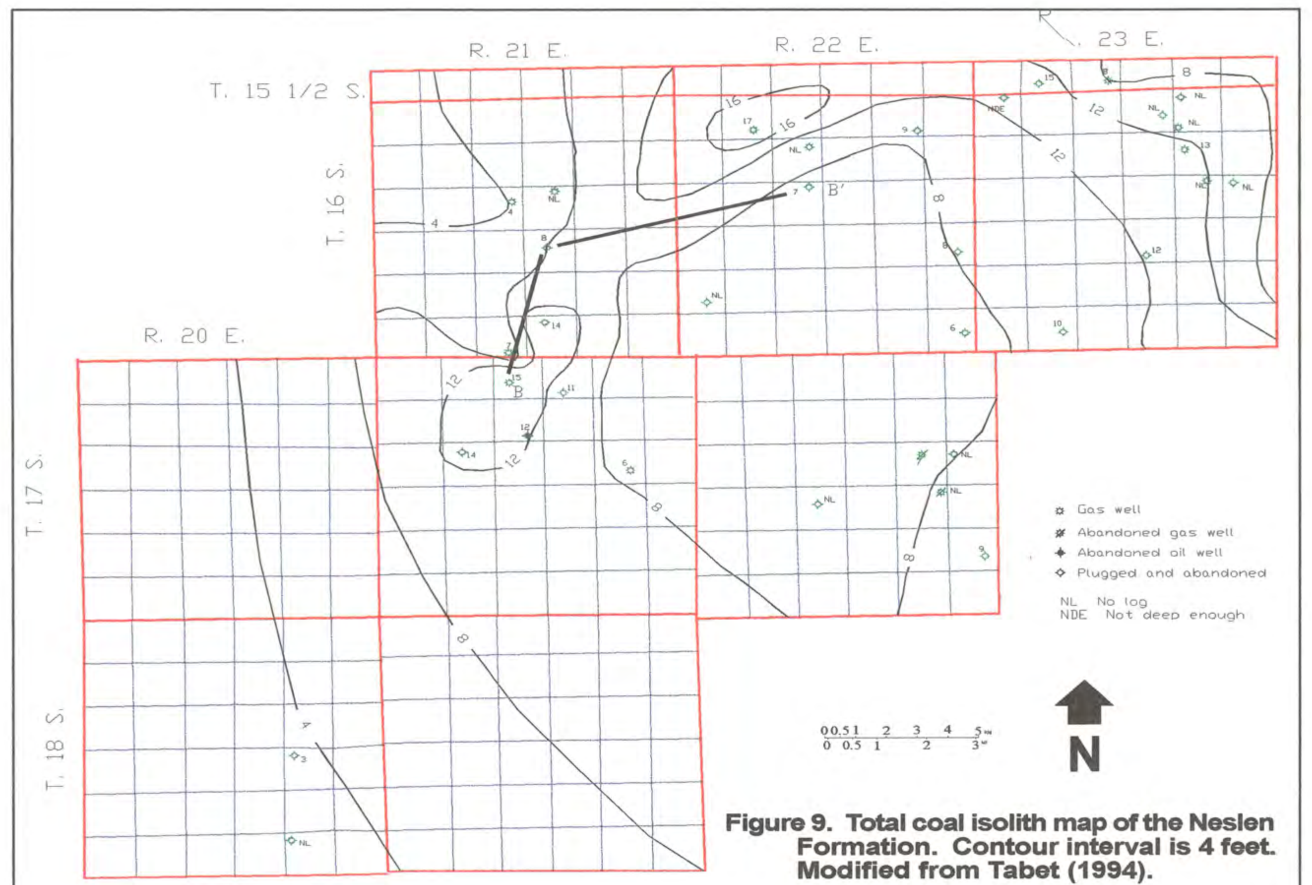

Figure 9. Total coal isolith map of the Neslen Formation. Contour interval is 4 feet. Modified from Tabet (1994).

ACKNOWLEDGMENTS

This report was funded as part of a larger study of the Cretaceous Dakota Sandstone, northern Grand County, by the School and Institutional Trust Lands Administration. David E. Tabet, Utah Geological Survey, assisted with the coal data.

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Stowe, C.H., 1979, Utah's oil and gas industry, past, present and future: Salt Lake City, University of Utah, Utah Engineering Experiment Station report. 1,628 p.

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Cross Section Explanation

ft - feet
GR - Gamma ray in API units
IP - Initial daily potential
KB - Kelly bushing elevation in feet
MCFG - Thousand cubic feet of gas
MV - Millivolt
RT - Resistivity in ohm-meters
Sonic - Travel time in microseconds per foot
SP - Spontaneous potential in millivolts

Log Depths in Feet

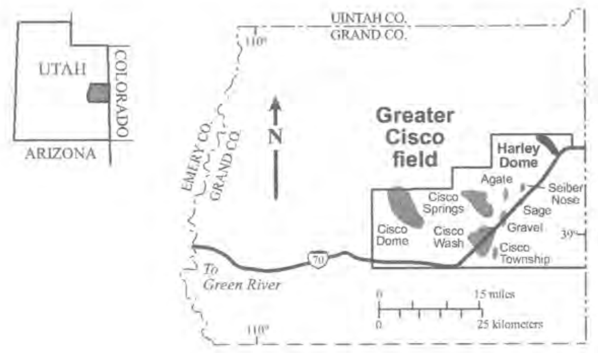
Perforation

Coal Bed

SHEET 1 OF 2
UGS OG-21

PETROLEUM GEOLOGY OF THE HARLEY DOME FIELD, GRAND COUNTY, UTAH

by
ROGER L. BON
Utah Geological Survey



Oil and Gas Field Study 21
Cartography by Jim Parker
1999
STATE OF UTAH
Department of Natural Resources
UTAH GEOLOGICAL SURVEY

INTRODUCTION

This report is part of a study of the petroleum geology of the Cretaceous Dakota Sandstone of northern Grand County. This study was designed to provide information on the geology, hydrocarbon production, and hydrocarbon potential of the Dakota Sandstone and is intended to help determine the value of lands in the area managed by the Utah School and Institutional Trust Lands Administration.

Harley Dome field, containing about 4,920 acres (1,991 ha), is located in Townships 18 and 19 South, Ranges 24 and 25 East, Salt Lake Base Line and Meridian, Grand County, Utah. Harley Dome field is the easternmost of several small, shallow (production generally less than 5,000 feet [1,524 m] deep) oil and gas fields (primarily gas) comprising the Greater Cisco field (figure 1). Natural gas accumulations are found in the Cretaceous Dakota Sandstone, and Jurassic Morrison Formation and Entrada Sandstone. Concentrations of carbon dioxide (CO_2) and helium (He) are present in both the Morrison and Entrada.

The discovery well, Home Oil Company No. 1, was completed in the middle part of the Morrison Formation and was noted to contain "high" concentrations of He and CO_2. The discovery well was drilled in 1925; in 1931 the well was deepened and a recompletion was attempted in the lower part of the formation but was unsuccessful. Several other wells drilled nearby also encountered He and CO_2. Harley Dome field was set aside as a helium reserve by the U.S. government in 1933; that designation was rescinded in 1964. Harley Dome was further drilled in the mid-1950s, early and late 1960s, and mid-1970s. The Harley Govt. No.1 is the only well with reported production (table 1), although several wells were completed and tested. The last well was drilled in Harley Dome field in 1994. Utah Division of Oil, Gas and Mining well records show one shut-in well and one temporarily abandoned well as of June 30, 1999. Well records indicate that the temporarily abandoned well has been plugged but a report has not been filed by the operator. The Harley Dome field was combined with 12 other small oil and gas fields to form the Greater Cisco field in 1978. Total reported gas production from the Harley Dome field is 159 thousand cubic feet of gas (MCFG) (4,452 m^3) with no reported oil or water production.

STRUCTURE

Harley Dome is located on the southern flank of the Uinta Basin and west of Douglas Creek arch. Harley Dome field encompasses most of Harley Dome, a broad, northwest-trending asymmetric fold flanked by the Bryson Wash syncline to the east and the Danish Flat syncline to the west. Strata dip up to 20 degrees on the eastern flank of the dome and up to 8 degrees on the western flank. The dome exhibits about 100 feet (30 m) of closure based on the mapped top of the Dakota Sandstone. Harley Dome and other structures within the Greater Cisco field are part of a broad band of structural features that formed as a result of the late Paleozoic Uncompahgre uplift to the southeast and the Laramide orogenic formation of the Uinta Basin to the northwest. No faults have been mapped or reported in drill records within Harley Dome field. The deepest stratigraphic test in the field, the A. Lansdale Govt. No. 13 well, encountered Precambrian granite at about 1,800 feet (549 m). Willis (1994) reported that Early to Middle Proterozoic high-grade metamorphic and intrusive igneous basement rocks underlie the Harley Dome quadrangle and are unconformably overlain by about 1,700 feet (518 m) of Triassic to Early Cretaceous strata.

DEVELOPMENT AND PRODUCTION HISTORY

Development History

Due to incomplete records of the earliest drilled wells, it was not possible to compile a complete well history for the field. Home Oil Company drilled the discovery well (Home Oil Company No. 1), section 4, T. 19 S., R. 25 E., in Harley Dome field in 1925. Open-flow estimates of 125 MCFG (3,500 m^3) and 4,000 MCFG (112,000 m^3) were reported from intervals in the Morrison Formation at drill depths of 488 to 518 feet (149-158 m) and 538 to 584 feet (164-178 m), respectively. The lower interval was noted to contain a high concentration of an "odorless" gas. The well was completed and shut in. An offset well (Federal No. 2) was drilled by Home Oil Company in 1926. That well open-flow tested 250 MCFG (7,000 m^3) (non-helium-bearing) from the Morrison (564 to 591 feet [172-180 m]) and 5,000 MCFG (140,000 m^3) of "odorless" gas from the Entrada (860 to 945 feet [262-288 m]). The well was re-entered in 1931 to test for commercial quantities of CO_2 but was unsuccessful. The Federal No. 2 well was finally plugged and abandoned in 1944.

The Harley Dome field was declared a Federal helium reserve in 1933. That status was revoked in 1964 after further evaluation of the field (Willis, 1994). The first non-helium-bearing natural gas well, Federal No. B-1, section 29, T. 18 S., R. 25 E., was drilled in 1955 and completed in the Dakota A bed at a drill depth of 599 to 632 feet (183-193 m). The well tested at the rate of 50 thousand cubic feet of gas per day (MCFGPD) (1,400 m^3) before acid treatment and 60 MCFGPD (1,680 m^3) following a 500-barrel acid treatment. The well was plugged and abandoned.

Division of Oil, Gas and Mining records show a total of 21 wells including re-entries have been drilled in the Harley Dome field to date (July 1999). Ten wells were plugged and abandoned immediately following testing or were not tested. Of the 11 remaining wells, nine were eventually plugged and abandoned after years of being shut in, and two wells remain shut in or are temporarily abandoned.

Production History

The only well having a record of production is the Harley Govt. No. 1 which was drilled in 1960. The well was completed in the Dakota Sandstone C bed (930 to 942 feet [283-287 m]) and flow tested 830 to 890 MCFGPD (23,240-24,920 m^3) before being shut in. During July 1993, the well was opened and produced for two days before being shut in again. The well has a reported cumulative production of 159 MCFG (4,452 m^3). Several other wells were tested for commercial gas production. The most productive gas test was from the Lansdale Govt. No. 12-X well (originally Ute Royalty Federal No. 1) which flowed an estimated 3,050 MCFGPD (85,400 m^3) from two intervals, 1,051 to 1,058 feet (320-322 m) and 1,069 to 1,078 feet (326-329 m) in the Morrison Formation before the well was completed.

STRATIGRAPHY OF PRODUCING RESERVOIRS

Natural gas accumulations in the Harley Dome field are found in sandstone reservoirs in the Cretaceous Dakota and Jurassic Morrison and Entrada Formations. A generalized stratigraphic section for the Harley Dome area is shown in figure 2. The Dakota, Morrison, and Entrada are separated by unconformities created by erosional scours and channels cut into the base of the underlying formations. The underlying formations (Cedar Mountain, Summerville, and Kayenta, respectively) are present but exhibit erosional surfaces, in addition to local scouring, and are not productive in this field. Traps are formed where the channel sandstone beds cross the structural axis or bends in the channel create an updip pinch-out of the bed along the flank of the structure (Morgan, 1999).

Entrada Sandstone

The Entrada Sandstone is an eolian deposit composed of very fine- to coarse-grained sandstone with large-scale cross beds and lesser amounts of siltstone near its base. Hydrocarbons have accumulated in structural traps in the more porous beds (Morgan, 1999). The Entrada ranges in thickness from 250 feet to 293 feet (76-89 m) and is at depths ranging from 836 feet to 1,873 feet (255-571 m). Only two wells penetrate the full thickness of the Entrada, making it difficult to determine the true thickness over the extent of the Harley Dome field. Several wells that penetrated the Entrada encountered water-saturated sandstone and drilling was terminated.

Table 1. Cumulative gas production from wells in the Harley Dome field as of July 1, 1999. Data sources: Stowe (1979), and Utah Division of Oil, Gas and Mining well records (1999).

Township and Range	Section/Operator Well Number	API # 43-019-	Formation at TD	Total Depth (ft)	Completion Date	Gas (MCFG)	Perforation Record/ Formation/Gas Test	Status
T18S R25E	NWSW 29 Texota Oil & Gas Federal #B-1	11280	Entrada	1,534	12/10/55	0	Perf @ 599'-606'/Dakota B bed/50 MCFG, 25 BW	PA
	NESW 29 A. Lansdale Govt. #3	20249	Entrada	1,392	07/14/67	0		PA
	SWNE 30 Belco Petroleum Harley Govt. #1	15046	Morrison	1,233	04/16/60	159	Perf @ 820' - 880'/Dakota A bed, 990' -1,000' / Morrison/891 MCFGPD	SI
	SWSE 30 A. Lansdale Federal #11	30478	Summerville	1,534	11/29/78	0	Perf @ 830' - 848'/Dakota B bed/180 MCFGPD, 3 BW	PA
	NWNE 31 Ute Royalty Govt. #1	20411	Morrison	1,122	09/12/55	0	Perf @1,067'-1,077'/Morrison/1,760 MCFGPD (interval 1,051' -1,058' &1,069' -1,078' tested @ 3,050 MCFGPD)	PA
	NWNE 31 A. Lansdale Govt. #12-X	11484	Morrison	1,494	07/14/77	0	Re-entry of Ute Royalty #1. Perf @ 940' - 946'/Dakota B bed/50 MCFGPD	PA
	SWNE 32 W. Broadhead State #32-1	30651	Morrison	805	07/10/80	0		PA
	NWNW 33 Tilton & Wilson Govt. #1	11576	Entrada	1,197	05/23/55	0		PA
	SWNW 33 A. Lansdale Govt. #6	30005	Entrada	1,200	02/29/68	0		PA
	NWSE 33 A. Lansdale Govt. #2	30006	Entrada	1,100	11/20/69	0		PA
	SWSE 33 A. Lansdale Govt. #1	20247	Entrada	944	12/18/67	0		TA
T19S R25E	NWNW 3 A. Lansdale Govt. #3-30-A	30260	Entrada	1,200	08/19/75	0		PA
	NWSW 3 A. Lansdale Govt. #4	30003	Entrada	1,000	06/13/68	0		PA
	SENE 4 A. Lansdale Govt. #13	30008	Proterozoic	1,815	06/04/68	0	Perf @ 804' - 878'/Morrison-Entrada/10,400 MCFGPD (helium), 890' - 946' /Entrada/120 MCFGPD (helium)	PA
	NENE 4 Fallgren & Weightman Home Oil Co. #1	11513	Morrison	1,000	05/28/31	0	Perf @ 488' - 518' /Morrison/125 MCFGPD, 538' - 584' /Morrison/4,000 MCFGPD (helium & CO_2)	PA
	SENE 4 Fallgren & Weightman Federal #2	11514	Wingate	1,675	07/10/31	0	Perf @ 564' - 591'/Morrison/250 MCFG, 860' -945' /Entrada/5,000 MCFG (helium & CO_2 open-flow estimates)	PA
	NWSE 4 A. Lansdale Govt. #9	30007	Entrada	1,200	04/03/68	0		PA
	NENW 6 Franklin Adams Federal #6-1	30650	Entrada	2,066	06/29/80	0		PA
	NENW 10 A. Lansdale Govt. #5	30004	Entrada	1,170	05/02/68	0		PA

Explanation: TD-total depth, PA-plugged and abandoned, TA-temporarily abandoned, SI-shut in, Perf-perforation interval, MCFG-thousand cubic feet of gas, MCFGPD-thousand cubic feet of gas per day.

GAS ANALYSIS

The following analyses are from samples taken from the Belco Petroleum Harley Govt. No. 1 (section 30, T. 18 S., R. 25 E.) and the Lansdale Govt. No. 13 (section 4, T. 19 S., R. 25 E.) wells.

Table 2. Gas analysis data from selected wells in the Harley Dome field, Grand County, Utah. Analytical data taken from Stowe (1979) and Utah Division of Oil, Gas and Mining well records (1999).

Well:	Harley Govt. #1	Lansdale Govt. #13	Lansdale Govt. #13
Formation:	Dakota	Morrison-Entrada	Morrison
Depth: (ft)	930	890-946	635
Components: (nearest 0.1% volume)			
Oxygen	ND	0.0	0.0
Nitrogen	ND	83.8	81.3
Methane	84.2	8.5	14.8
Ethane	0.7	0.3	0.5
Higher fractions	0.3	0.1	0.2
Hydrogen sulfide	0.0	0.0	0.0
Carbon dioxide	0.5	0.8	0.4
Helium	<0.1	6.5	2.8
BTU/FT^3	877	NA	163

NA-not available, ND-not detected

Figure 1. Location of the Harley Dome field in northern Grand County, Utah and well locations. Cross sections A-A' and B-B' are shown in figures 5 and 6, respectively.

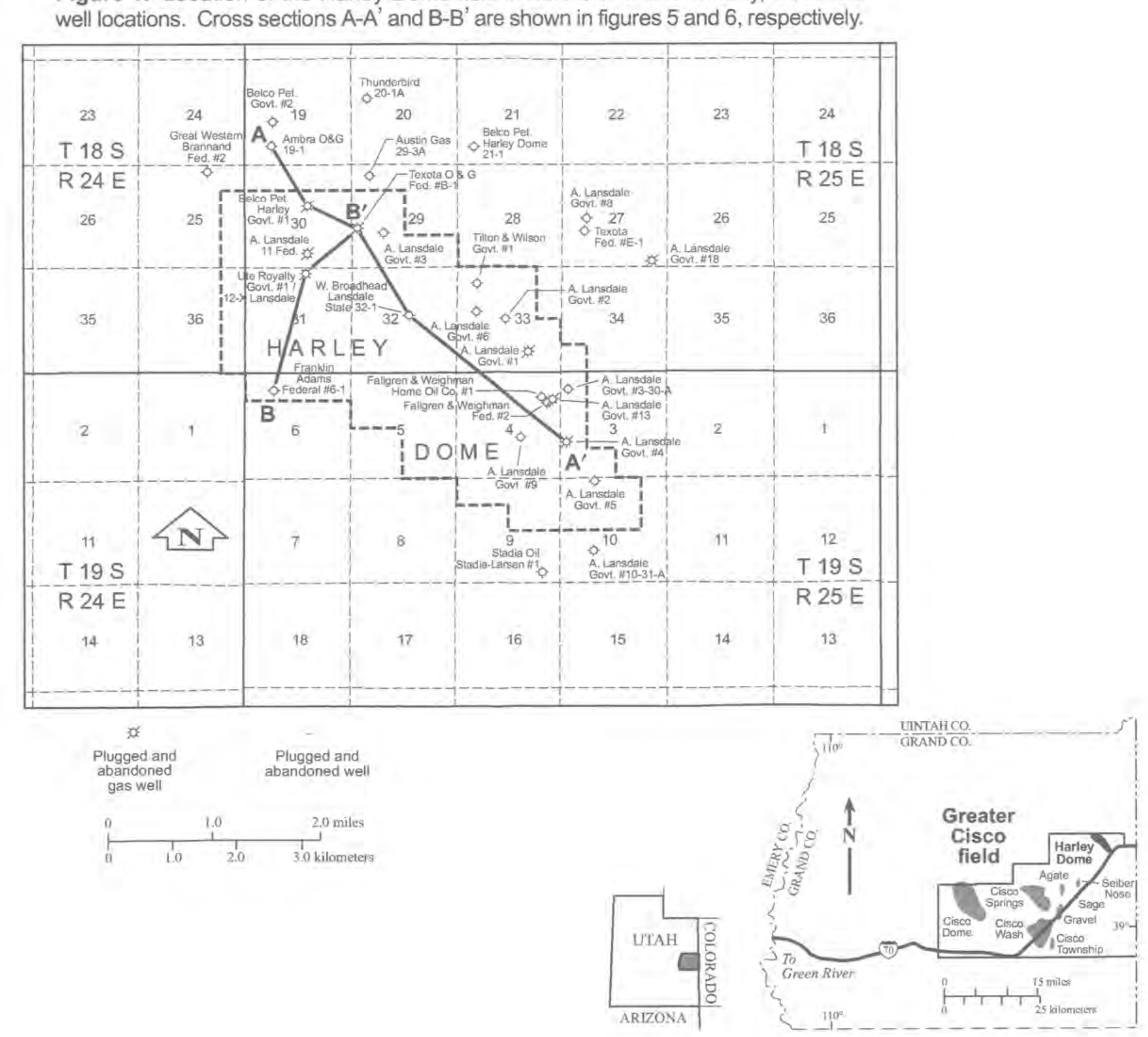


Figure 2. Generalized stratigraphic section of Harley Dome quadrangle (from Willis, 1994).

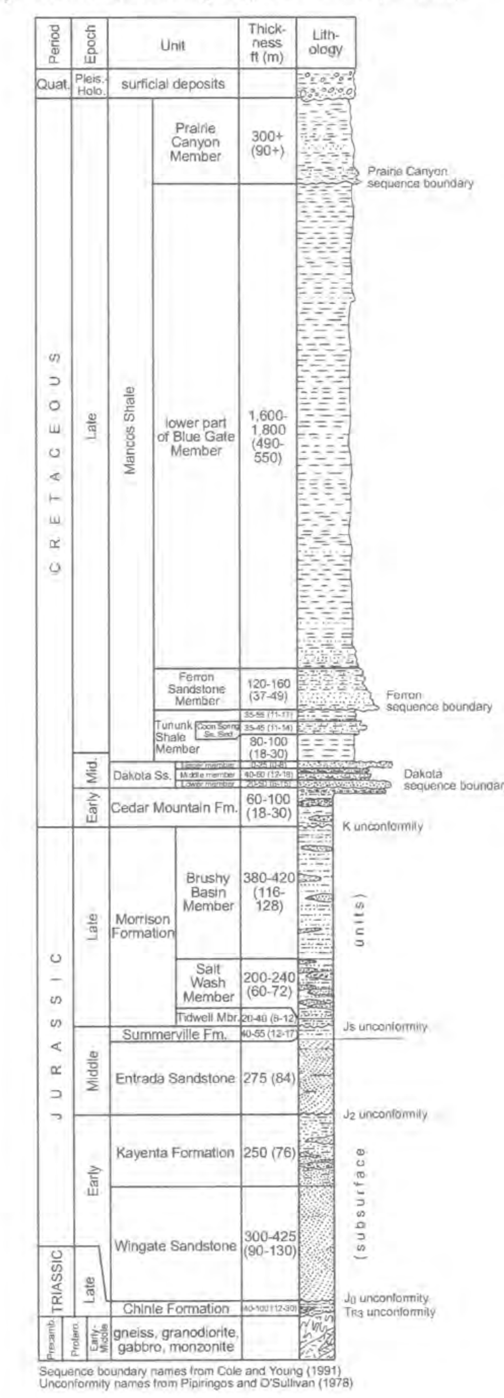


Figure 3. Isopach map of the combined thickness of the Morrison and Summerville Formations. Values taken from geophysical logs and drill logs. Contour interval is 20 feet.

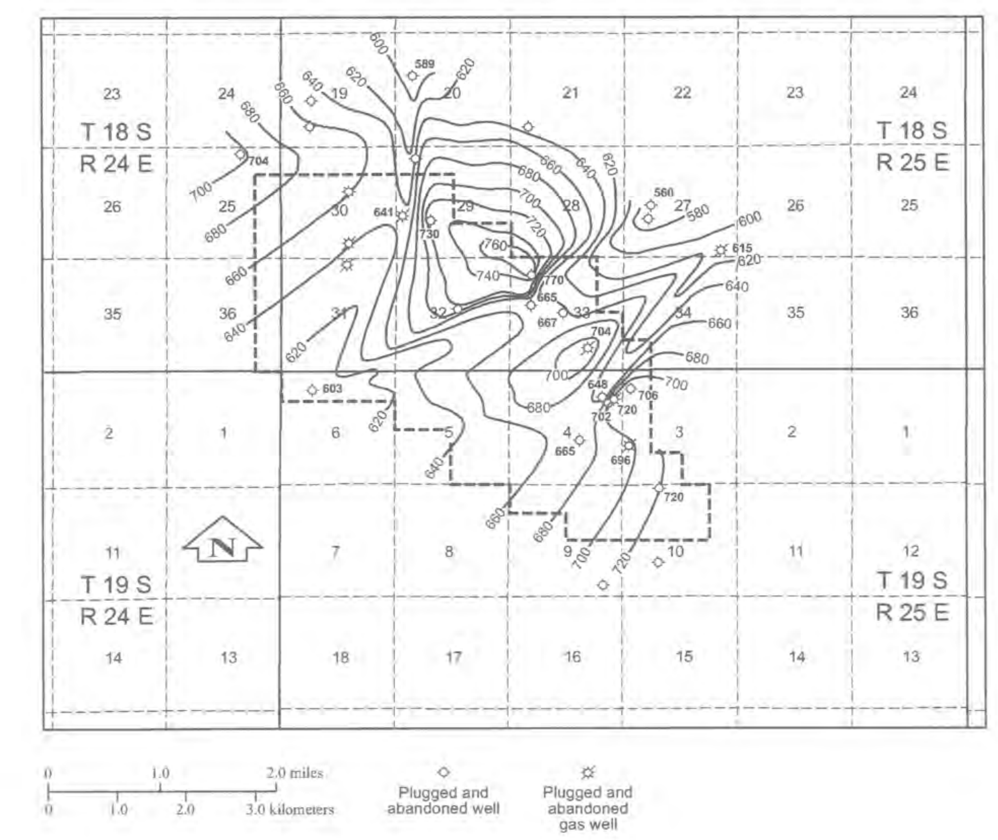
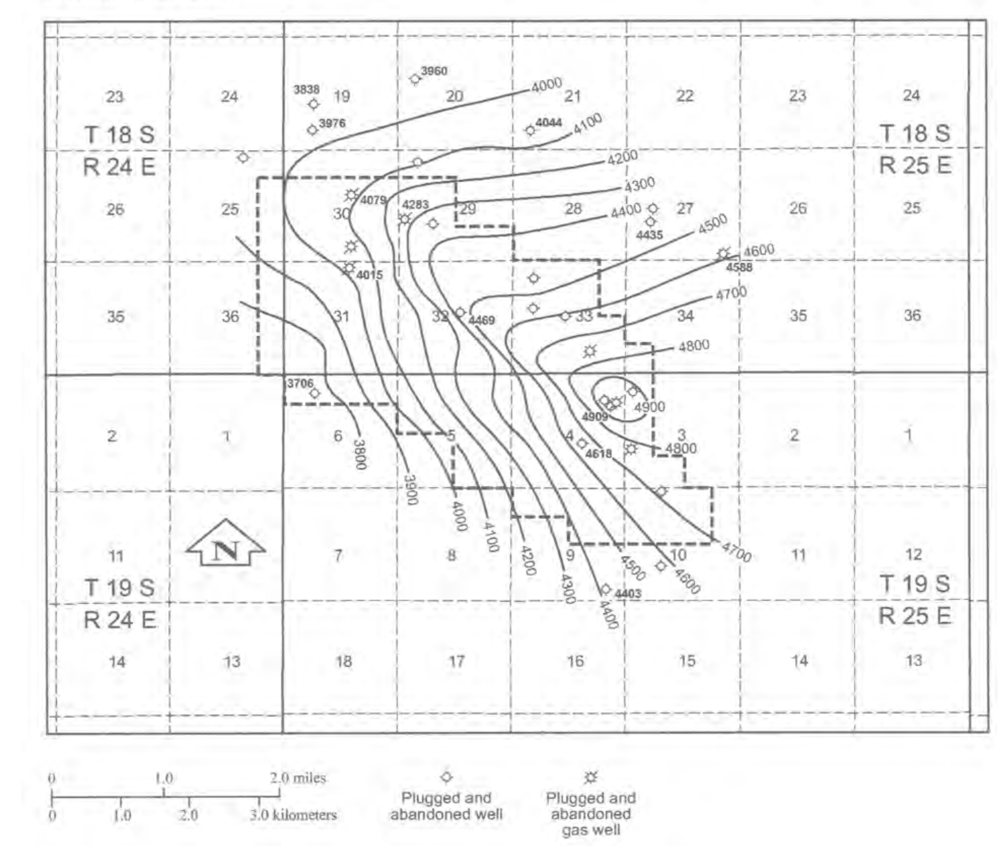


Figure 4. Structure contour map of the top of the Dakota Sandstone. Values shown for all wells with geophysical logs and selected drill logs. Contour interval is 100 feet, datum is mean sea level.



Morrison Formation

The Morrison Formation is a continental deposit of channel sandstone, variegated shale, and thin limestone beds (Morgan, 1999). In the Harley Dome field the formation ranges in thickness from 495 feet to 665 feet (151-203 m) at depths ranging from 132 feet to 1,270 feet (40-387 m). The Morrison consists of three members: the Tidwell (lowest member), Salt Wash (middle member), and Brushy Basin (upper member). In the Harley Dome field the Tidwell Member is often thin or not present. Reported thicknesses for the Morrison often include the underlying Summerville Formation, which ranges from 40 to 55 feet (12-17 m) in thickness (Willis, 1994). The mapped interval (figure 3) shows the combined thickness of the Morrison and Summerville Formations.

Dakota Sandstone

The Dakota Sandstone comprises a sequence of fluvial sandstone, littoral mudstone, carbonaceous shale, coal, and conglomerate deposits that represent the last terrestrial deposition prior to transgression of the Mancos sea. The Dakota is exposed near the center of Harley Dome but, where covered, ranges in thickness from 117 feet to 144 feet (36-44 m). The structure on top of the Dakota is shown in figure 4. The Dakota forms a broad structural dome that exhibits about 100 feet (30 m) of closure near the eastern boundary of the field. Gas production in the Dakota is from one to three beds labeled in descending order as Kd A, Kd B, and Kd C. The extent of these beds is shown in figures 5 and 6; figure 5 shows the extent of the beds in a northwest-trending cross-section line, A-A', along the crest of Harley Dome, and figure 6 shows the extent of the beds in a northeast-trending cross-section line, B-B'. The location of lines A-A' and B-B' are shown in figure 1.

The Kd A bed is 53 to 126 feet (16-38 m) below the top of the Dakota Sandstone and ranges from 9 to 56 feet (3-17 m) thick, averaging about 27 feet (8 m) thick (figure 7). The Kd B bed, where present, is 10 to 42 feet (3-13 m) below the Kd A bed and ranges from 4 to 36 feet (1-11 m) in thickness, averaging about 14 feet (4 m) thick (figure 8). The Kd C bed is present sporadically and is not mappable across Harley Dome field. Where present, it is 33 to 60 feet (10-18 m) below the Kd B bed and ranges from 6 to 21 feet (2-6 m) in thickness, averaging about 13 feet (4 m) thick. The Kd C bed locally has downcut or channeled into the upper part of the Cedar Mountain Formation. Most geophysical well logs do not distinguish the underlying Cedar Mountain (which ranges from 60 to 100 feet [18-30 m] in thickness) from the Dakota and, as a result, the reported thickness of the Dakota often includes the Cedar Mountain. Due to the scarcity of true Dakota thickness data from geophysical and drill logs, the mapped interval (figure 9) includes the combined thickness of the Dakota and Cedar Mountain Formations.

Figure 5. Northwest to southeast well log stratigraphic cross section from top of Dakota Sandstone to total depth of well. No horizontal scale. See figure 1 for location of line.

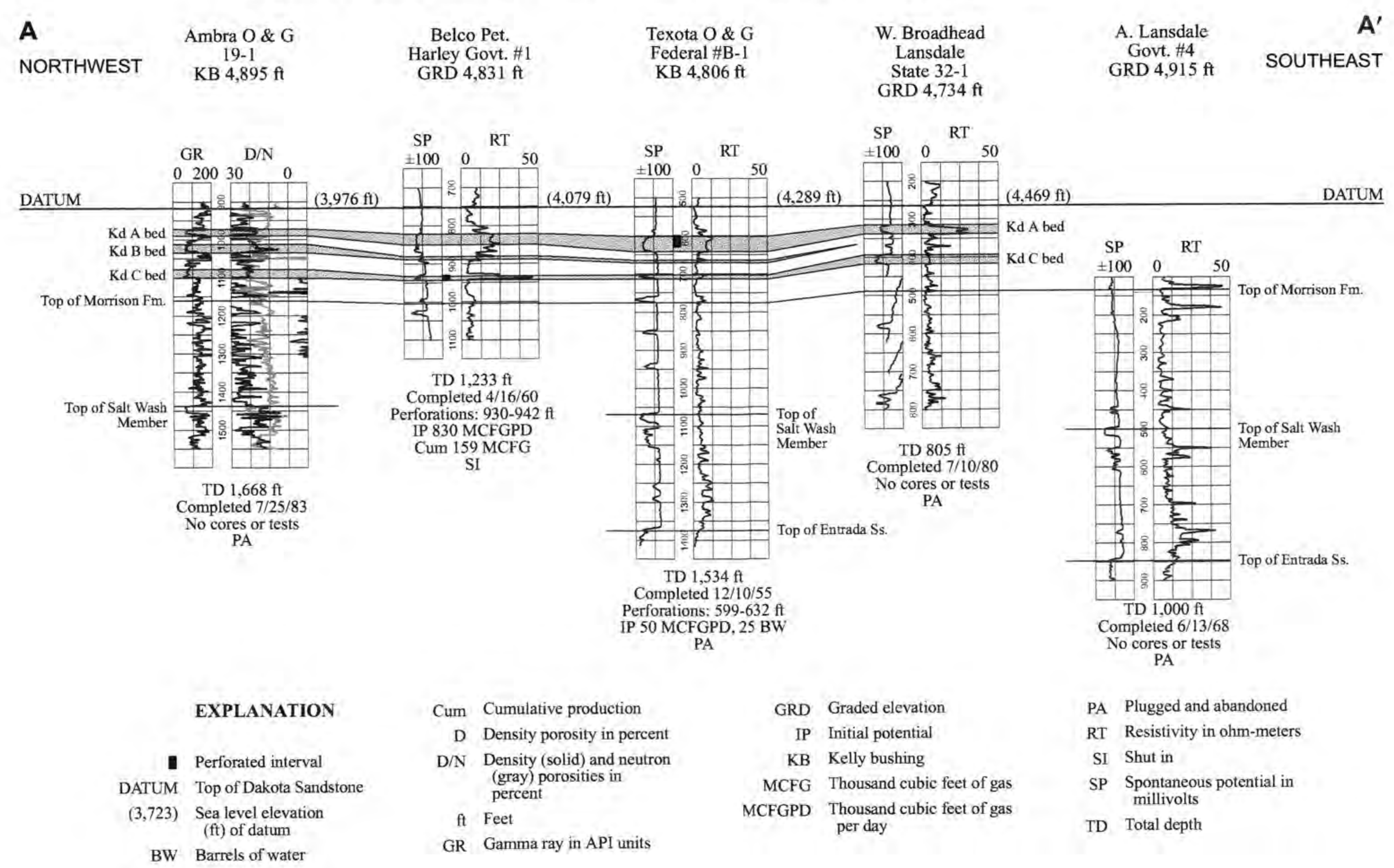


Figure 6. Southwest to northeast well log stratigraphic cross section from top of Dakota Sandstone to total depth of well. No horizontal scale. See figure 1 for location of line.

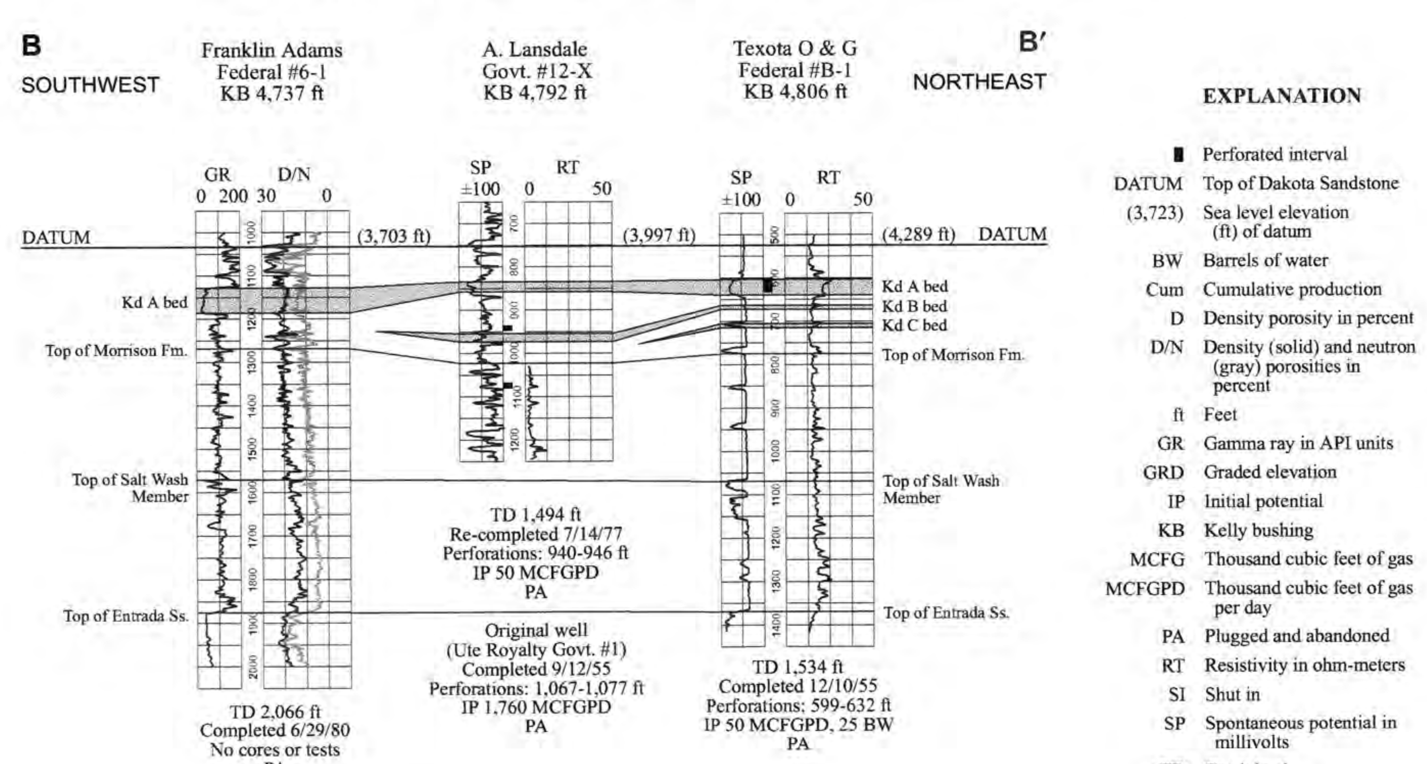


Figure 7. Isopach map of the Kd A bed of the Dakota Sandstone. Values shown for wells with geophysical logs. Contour interval is 10 feet.

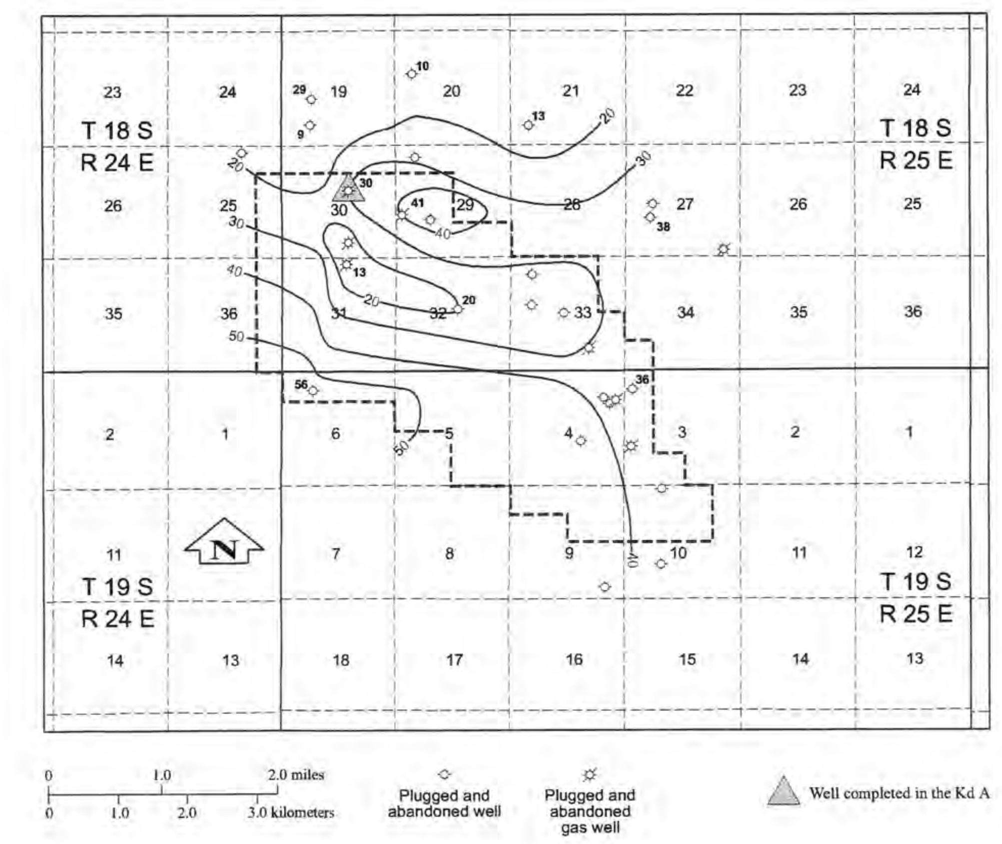


Figure 8. Isopach map of the Kd B bed of the Dakota Sandstone. Values shown for wells with geophysical logs. Contour interval is 10 feet.

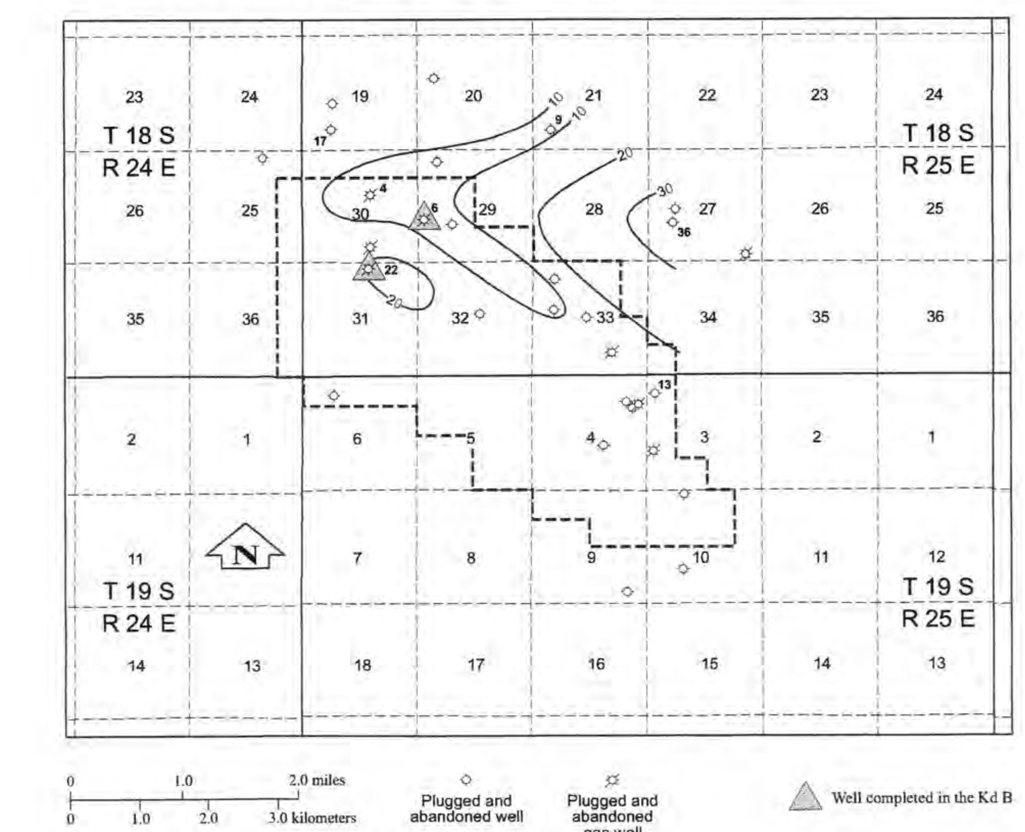
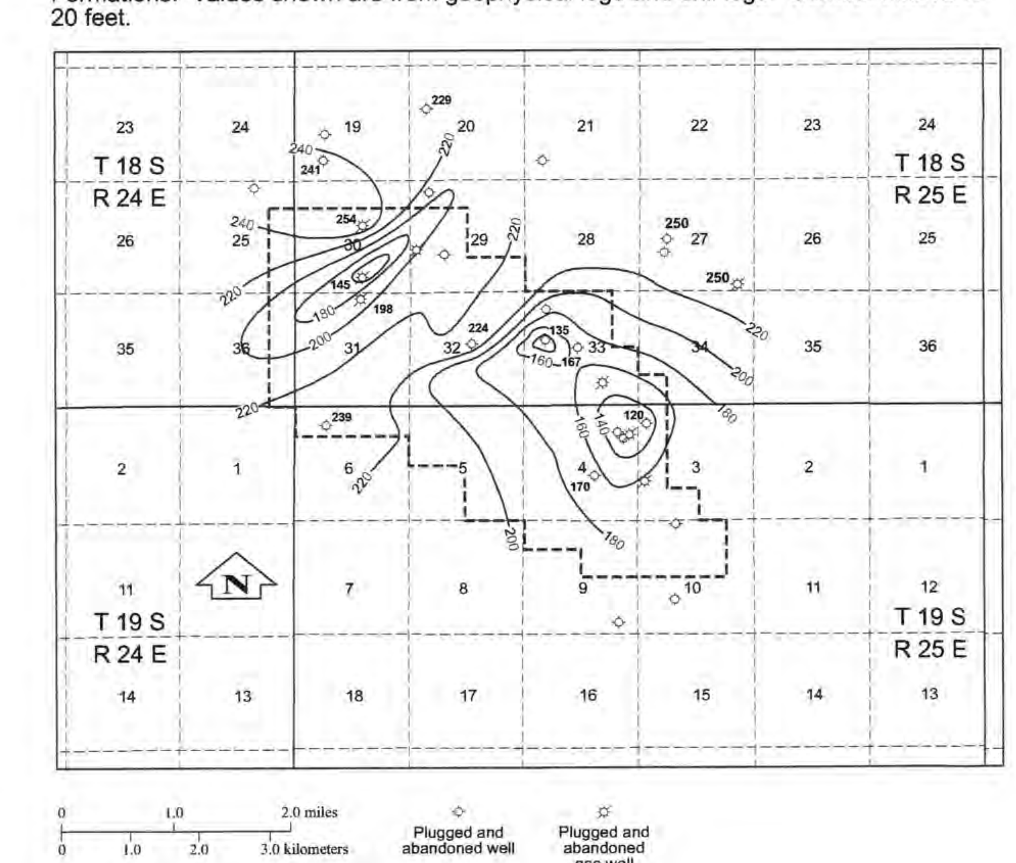


Figure 9. Isopach map of the combined thickness of the Dakota and Cedar Mountain Formations. Values shown are from geophysical logs and drill logs. Contour interval is 20 feet.



Mancos Shale

The Mancos Shale is the uppermost geologic unit in the field. The Mancos consists of thick shale, siltstone, mudstone, and sandstone that were deposited in a Late Cretaceous seaway. The upper portion of the formation has been eroded leaving about 1,000 feet (305 m) of the lower part of the formation present within a portion of the Harley Dome field. This lower interval includes the Ferron Sandstone and Tununk Shale Members. The Tununk is further divided into an upper and lower part separated by the Coon Springs sandstone bed which has been productive in other parts of the Greater Cisco field but is not productive in the Harley Dome field.

SUMMARY AND FUTURE POTENTIAL

There has been little commercial production of natural gas (159 MCF [4,452 m^3]), and no CO_2 or He recovered from the Harley Dome field from discovery (1925) through July 1, 1999. The last well drilled in the field was in 1994. Harley Dome field was combined with several other small fields to form the Greater Cisco field in 1978. Due to the absence of stratigraphic traps and low structural closure of Harley Dome, it appears that the field has relatively low potential for hydrocarbon production. Additional potential may be found in beds in the Entrada, Morrison, and Dakota Formations in nearby areas that are more structurally complex. Some potential exists for the development of CO_2 and He as both gases were found in abundance in several wells and the field was, at one time, set aside as a federal helium reserve.

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SHEET 1 OF 2
UGS OG-22

PETROLEUM GEOLOGY OF THE CISCO TOWNSITE AND CISCO WASH AREAS, GRAND COUNTY, UTAH

by

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Utah Geological Survey

Oil and Gas Fields Study 22
Cartography by Jim Parker
1999

STATE OF UTAH
Department of Natural Resources
UTAH GEOLOGICAL SURVEY

INTRODUCTION

Cisco Townsite and Cisco Wash lie along the Laramide-age Cisco anticline in T. 21 S., R. 23 and 24 E., Salt Lake Base Line and Meridian, Grand County, Utah (figures 1 and 2). Cisco Townsite is an abandoned railroad town. Weathered Cretaceous Mancos Shale is exposed over most of the area with Cretaceous Dakota, Cedar Mountain, and Jurassic Morrison Formations exposed in the southeast portion of the study area.

Hydrocarbons are produced from Cretaceous- and Jurassic-age sandstone in combination stratigraphic-structural traps. Most of the production is from the Morrison with lesser amounts from the Cedar Mountain and Dakota Formations. Production in the area was designated by the Utah Division of Oil, Gas and Mining as Cisco Wash Field except section 24, T. 21 S., R. 23 E., which was designated Cisco Townsite Field. I was unable to find a current map or description of the boundaries of the Cisco Wash field. In 1978 the area was included in the Greater Cisco field.

This report is part of a study of the petroleum geology of the Cretaceous Dakota Sandstone of northern Grand County. The study improves our understanding of the geology, hydrocarbon production, and future development potential of the Dakota and can help determine the value of lands managed by the Utah School and Institutional Trust Lands Administration.

STRUCTURE

The Cisco Townsite and Cisco Wash area lies along the northwest-plunging Cisco anticline, which is a subsidiary fold on the northwest-plunging ancestral Uncompahgre uplift. The top of the Dakota Sandstone has about 50 feet (15 m) of mapped closure in the Cisco Townsite area (figure 3). A few minor faults have been mapped in the area by Doelling (1993).

The Federal 1 well (SE¼NW¼ section 13, T. 21 S., R. 23 E.), one of the deepest stratigraphic tests in the area, was drilled in 1954 near the crest of the Cisco anticline to a depth of 2,826 feet (861.4 m) by L. M. Lockhart Oil Company. At total depth, the well encountered Triassic Chinle Formation overlying Precambrian granite.

DEVELOPMENT AND PRODUCTION HISTORY

The Cisco Townsite field was discovered by D. & N. Mining Company in 1954 with the completion of the Murray 2 well (Block 8, section 24, T. 21 S., R. 23 E.). The well was completed in the Morrison Formation flowing 27 barrels of oil per day (BOPD) (3.8 MTPD) (Hendel, 1961) from a depth of 558 to 610 feet (170.1-185.9 m). The Cisco Wash field was discovered by A. Lansdale in 1962 with the completion of the Lansdale 3 well (SW¼NE¼ section 3, T. 21 S., R. 23 E.). The well was completed in the Dakota Formation flowing 300 thousand cubic feet of gas per day (MCFGPD) (8,490 m^3/d) from a depth of 1,082 to 1,312 feet (329.8-399.9 m). Although the Murray 2 and Lansdale 3 are the official discovery wells for the area, some hydrocarbon production was reported as early as 1921 (Stowe, 1979). The Arizona-Utah No. 2 well tested 500 MCFGPD (14,160 m^3/d) (depth not reported) and the Cisco Oil Refining Company completed a well (unclear which one) that produced up to 10 BOPD (1.4 MTPD) from a depth of 550 feet (167.6 m) in the Morrison Formation.

Most wells were completed natural (no artificial stimulation), and many were completed open hole (no casing). A few wells were treated with 1,000 gallons of acid and one well was given a sand-oil fracture treatment (volumes not reported). The wells that were stimulated produced only small volumes of oil or gas and do not appear to have been improved by the treatment. Fifty-three of the 63 active wells are currently shut in because it is uneconomical to lay a gas line to the well or the low daily rate of production is not enough to pay for the operating costs of the well.

More than 200,000 BO (28,000 MT) and 1.5 billion cubic feet of gas (BCFG) (42 million m^3) have been produced from 39 wells in the Cisco Townsite and Cisco Wash fields from 1968 through mid-1998 (table 1). Early records are poor and some production may not have been reported to the State or may have been attributed to the wrong well. In 1997, annual production came from eight wells totaling 2,455 BO (343.7 MT) and 10,436 MCFG (295,550 m^3). Oil and gas analyses for the area are shown in table 2.

STRATIGRAPHY OF THE PRODUCING RESERVOIRS

Hydrocarbon production in the Cisco Townsite and Cisco Wash area is from sandstone beds in the Jurassic Morrison and Cretaceous Cedar Mountain and Dakota Formations (figures 4 and 5). A small amount of hydrocarbons has been produced from the Jurassic Entrada Sandstone in Grand County, but in the Cisco Townsite and Cisco Wash area the Entrada is water bearing. Some wells have reported oil staining in drill cuttings from the Entrada. The Morrison, Cedar Mountain, and Dakota are separated by unconformities that typically are found at the base of channels incised into the underlying formation. Traps are formed where the channel sandstone beds cross the structural axis of the Cisco anticline or where bends in the channels create an updip pinch out of the beds along the flank of the structure. The producing horizons reported in table 1 and the following discussions of those units are based on geophysical well-log correlations. Identifying these formation contacts is difficult and my interpretation may differ from picks made by the well operator or other workers.

Morrison Formation

The Morrison Formation is a continental and lacustrine deposit of interbedded channel sandstone, variegated shale, and some thin limestone, ranging from 498 to 660 feet (151.8-201.2 m) of drilled thickness. It has a maximum drilled depth of 1,650 feet (502.9 m) in the Cisco Townsite and Cisco Wash area. More than 200,000 BO (28,000 MT) and 1.3 BCFG (36.8 million m^3) have been produced from sandstone beds in both the Salt Wash and Brushy Basin Members of the Morrison.

Cedar Mountain Formation

The Cedar Mountain Formation is a fluvial-lacustrine deposit of interbedded sandstone, siltstone, and some pale-green shale, ranging from 34 to 223 feet (10.4-67.9 m) of drilled thickness. It has a maximum drilled depth of 1,552 feet (473.0 m) in the Cisco Townsite and Cisco Wash area. More than 3,000 BO (420 MT) and 130 MCFG (3,680 m^3) have been produced from sandstone beds, mostly from the basal Buckhorn Conglomerate of the Cedar Mountain.

Dakota Sandstone

The Dakota Sandstone is a fluvial to littoral marine deposit of sandstone and shale ranging from 58 to 155 feet (17.7-47.2 m) of drilled thickness. It has a maximum drilled depth of 1,418 feet (432.2 m) in the Cisco Townsite and Cisco Wash area. More than 9,000 BO (1,260 MT) and 48 MCFG (1,360 m^3) have been produced from two sandstone beds, the Kd B and Kd A. These two sandstone beds are incised fluvial channel deposits that generally trend northward in the Cisco Townsite and Cisco Wash area (figures 6 and 7).

SUMMARY AND FUTURE POTENTIAL

More than 200,000 BO (28,000 MT) and 1.5 BCFG (42 million m^3) have been produced from the Cisco Townsite and Cisco Wash area at depths typically ranging from 200 to 1,500 feet (60-460 m). Production is from combination stratigraphic-structural traps found in the fluvial sandstone beds of the Morrison, Cedar Mountain, and Dakota Formations. The majority of the production is from the Morrison Formation.

Most of the wells in the Cisco Townsite and Cisco Wash area have produced small volumes of hydrocarbons. Only one well produced over 100,000 BO (14,000 MT) and four wells have produced more than 100,000 MCFG (2.8 million m^3). Undiscovered hydrocarbons probably still exist in the area because the lenticular nature of the channel sandstone reservoirs can provide many small stratigraphic traps. Any new discoveries will probably be single-well accumulations. As a result, the area may still attract independent operators but probably does not have sufficient potential for larger companies.

Table 1. Cumulative oil and gas production from active wells in the Cisco Townsite and Cisco Wash area as of June 30, 1998. Oil in barrels (bbl) and gas in thousand cubic feet (MCF). Data source Utah Division of Oil, Gas and Mining. Abbreviations: Entrada Sandstone (Je), Morrison Formation (Jm), Salt Wash Member (Jmsw), Brushy Basin Member (Jmbb), Cedar Mountain Formation (Kcm), Dakota Sandstone (Kd), Dakota bed A (Kd A), completion (Comp.), not reported (NR), no log (NL), producing oil well (POW), producing gas well (PGW), temporarily abandoned (TA). Some wells were not completed but they were never properly plugged; as a result they are listed as shut in (SI). Some shut-in wells were completed but have never produced.

T. 21 S., R. 23 E.

Section	Well Name & Number	Comp. Date	Cumulative Oil (bbl)	Cumulative Gas (MCF)	Producing Reservoir	Status	Formation at Total Depth	API Number 43-019-
SESW 1	WK 1-13	12/81	5,169	0	Jmsw	SI	Jm	30420
SESW 1	CP 1-4	2/81	10,734	0	Kd - NL	POW	Jm	30671
SESW 1	CP 1-5	12/81	0	15,854	Kd A	SI	Jm	30674
SWNE 1	WK 1-14	2/77	375	2,482	Jmbb	SI	Jm	30299
SWNW 1	WK 3	12/80	0	0	Kd A	SI	Kcm	30267
SWSE 1	WK 2	3/76	0	9,077	Jmbb	SI	Jm	30270
SWSW 1	WK 1	4/78	708	0	Jmbb	SI	Jm	30266
NWNE 2	Escondito 1	8/80	0	46,843	Jm	SI	Jm	30561
NWNW 2	Crest 2-8	12/76	0	0	Jmsw	SI	Jm	30316
NWSW 2	Wiegand 2-1	1/74	106	0	Kcm	POW	Jm	30081
SENW 2	Pioneer 1	4/81	0	355	Jmsw	SI	Jm	30791
SESE 2	Wiegand 2-3	9/83	24	0	Kd - NL	SI	Kd	31096
SESW 2	Grindstaff 9	4/74	0	3,833	Kd - NL	SI	Kd	30195
SESW 2	Wiegand 2-2	9/73	341	0	Kcm	POW	Jm	30181
SWNW 2	Crest State 1-B	5/74	0	0	TA	SI	Jm	30198
SWNE 3	Lansdale 3	11/62	0	0	Kd-Jm	SI	Jm	15597
NWNE 4	JV 8A	6/79	0	24,981	Kd A	SI	Kd	20416
SWSW 4	JV 4-1	4/85	0	1,371	Jmsw - NL	SI	Jm	31025
NWNW 5	Vukasovich 10	5/73	0	89,401	Jm	SI	Jm	30141
NENE 9	Drossos 9-1	6/82	50	90	Jmsw	POW	Jm	30921
NESE 9	MPD 9-2	3/86	0	1,454	Kd-Jm	SI	Jm	31216
NWSE 9	MPD 9-2B	12/88	0	153	Kd A	SI	Jm	31281
NWSE 9	MPD 9-2B	12/88	0	153	Kd A	SI	Jm	31281
SENE 9	9-2A	10/85	0	1,826	Jmsw	SI	Jm	31201
SENW 9	Federal 9-3	12/97	0	0	TA	SI	Jm	31258
NWNW 10	Vukasovich 5	12/75	0	33,499	Jmsw	SI	Jm	30127
NWSW 10	MPD 10-2C	12/88	2,856	101,414	Jmbb - NL	POW	Jm	31276
SWNE 10	Lansdale 2	4/87	176	0	Jmbb	SI	Je	15596
SWNE 10	Lansdale 6	2/65	0	0	Jmbb	SI	Jm	15598
SWSE 10	Federal 1	4/79	2,391	42	Jmsw	SI	Je	30475
NWSE 11	Adak 11-1A	11/75	153,569	18,937	Jmbb	POW	Jm	30259
SESW 11	Othf 7-11	8/77	0	304,390	Jmsw	SI	Jm	30358
SWNW 11	Lansdale-Vukasovich 22	7/73	0	0	Jm	SI	Jm	30159
NWNE 12	Tomlinson 1	6/83	0	5,583	Jmbb	PGW	Jm	30964
SWSW 13	Golden 1	NR	0	0	NL	SI	Jm	10383
SWNE 14	Adak 14-1	1/78	13	0	Jmsw	SI	Jm	30396
SWSE 14	Nuggett 14-4	10/78	1,906	0	Jmsw	POW	Je	30423
SWSW 14	Nuggett 14-22	9/79	0	0	TA - NL	SI	NR	30539
NWNE 15	Petro 15-5	7/80	0	28,967	Kcm	PGW	Jm	30611
SENE 15	Petro 15-3	12/79	0	4,494	Jmsw	SI	Jm	30523
SENW 15	MPD 15-2	8/89	0	7,108	Kcm	SI	Kcm	31277
SENE 16	FZ 16-2A	11/87	0	0	Jmsw	SI	Jm	31247
SESW 16	16-1	1/84	0	0	Kd	SI	Kd	30913
SENW 22	Drossos 22-1	6/82	19,118	714,356	Jm	SI	Jm	30914
SENW 22	FZ 22-1 OS	5/88	8,017	0	Jmbb	POW	Jm	31262
SENW 22	FZ 22-3	11/89	0	0	TA - NL	SI	NR	31284
NENE 23	Paulson 23-2	2/76	0	21,562	Jmsw	SI	Jm	30261
NENW 23	Petro-X 23-1	10/79	0	0	Jmsw	SI	Jm	30558
NESW 24	Whyte State 2	12/62	0	0	TA - NL	SI	Jm	16263
NWNE 24	Gibralter 1	5/83	200	0	Jmsw	SI	Jm	31033
SENE 24	Vanover 2	11/83	0	0	Kcm	SI	Kcm	31105
SWNW 24	Whyte State 5	10/62	0	0	Jm	SI	Jm	16264
NENE 25	Whyte State 1	1/68	0	0	Jmbb	SI	Jm	20271
NENE 25	Whyte State 2	3/68	80	0	Kd	SI	Jm	20296
NWSE 26	State 1	9/54	0	0	TA - NL	SI	Jm	15600
SESE 26	State Losey 1	10/54	0	0	TA - NL	SI	NR	11539
NENW 33	State 1	9/76	0	0	TA - NL	SI	NR	30311
Total 56 active wells			205,833	1,438,072		10 producing and 46 shut-in wells		

T. 21 S., R. 24 E.

Section	Well Name & Number	Comp. Date	Cumulative Oil (bbl)	Cumulative Gas (MCF)	Producing Reservoir	Status	Formation at Total Depth	API Number 43-019-
NWNW 6	Federal 6-3	10/89	0	100,766	Kcm	SI	Kcm	31292
SWNW 6	Federal 6-1	7/89	0	0	Kd	SI	Kd	31285
SENW 7	Federal 7-6	3/92	0	9,496	Jmbb	SI	Jm	31298
NWSW 8	Federal 8-3	3/85	0	136	Jmsw	SI	Je	31067
NENW 17	Federal 17-1	9/84	0	0	Jmbb	SI	Jm	30997
SENE 18	BPB 18-2	11/92	0	0	TA - NL	SI	Jm	31248
NESE 29	State 1	12/74	0	0	TA - NL	SI	Jm	30100
Total 7 active wells			0	110,398		All wells shut-in		
Grand Total (T. 23-24 E.) 63 active wells			205,833	1,548,470		10 producing and 53 shut-in wells		

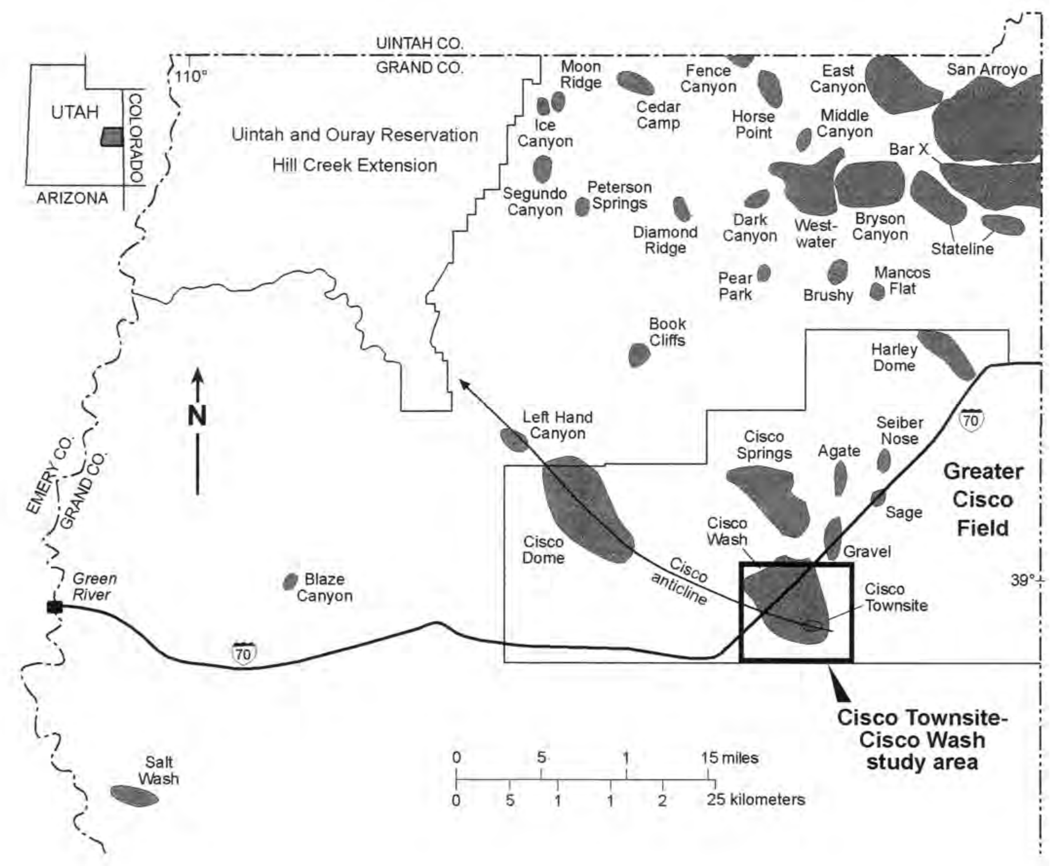

Figure 1. Location of oil and gas fields (shaded and labeled) in northern Grand County, and the Cisco Townsite and Cisco Wash study area within the Greater Cisco field.

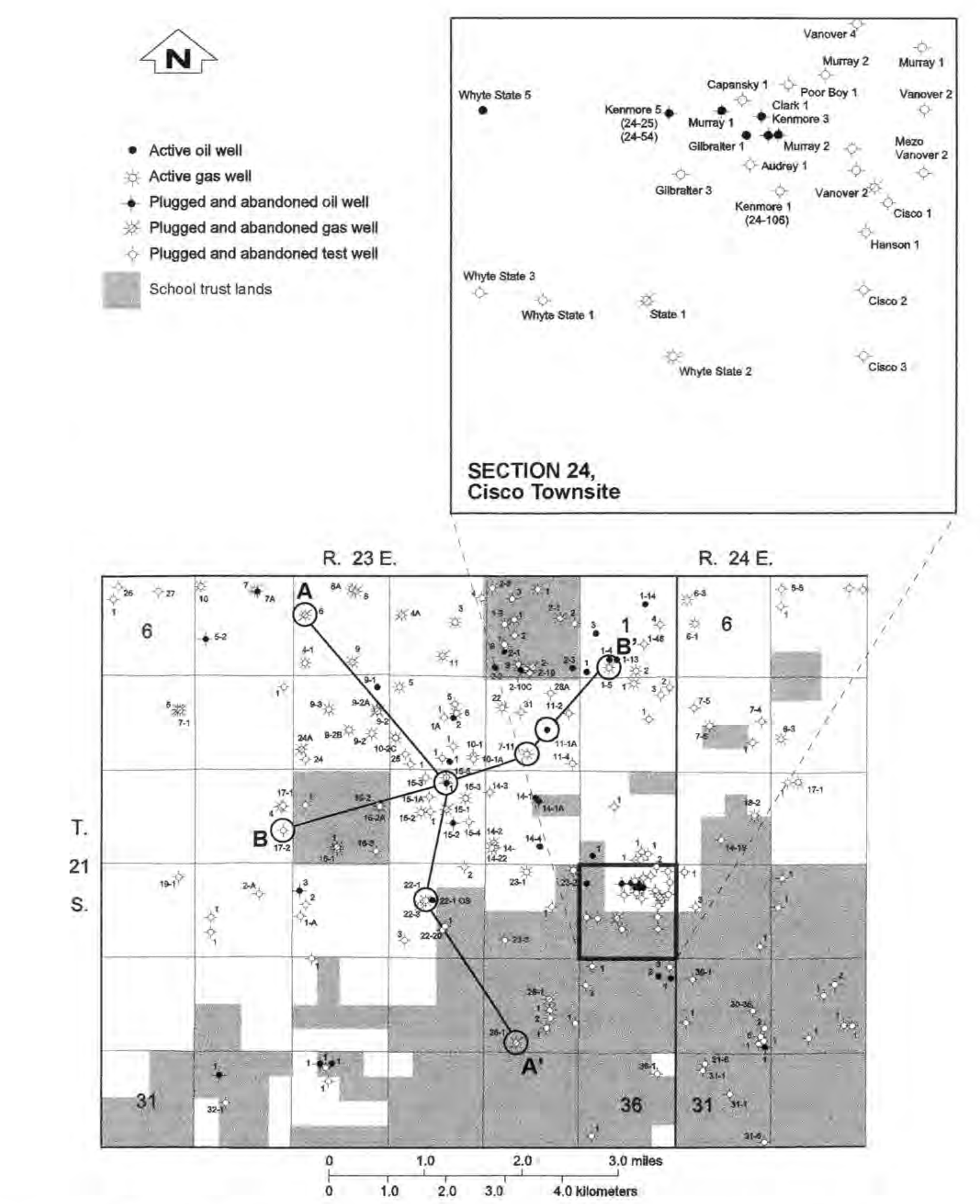

Figure 2. Location and well number of oil and gas wells in the Cisco Townsite and Cisco Wash area. Cross section A-A' and B-B' are figures 4 and 5, respectively.

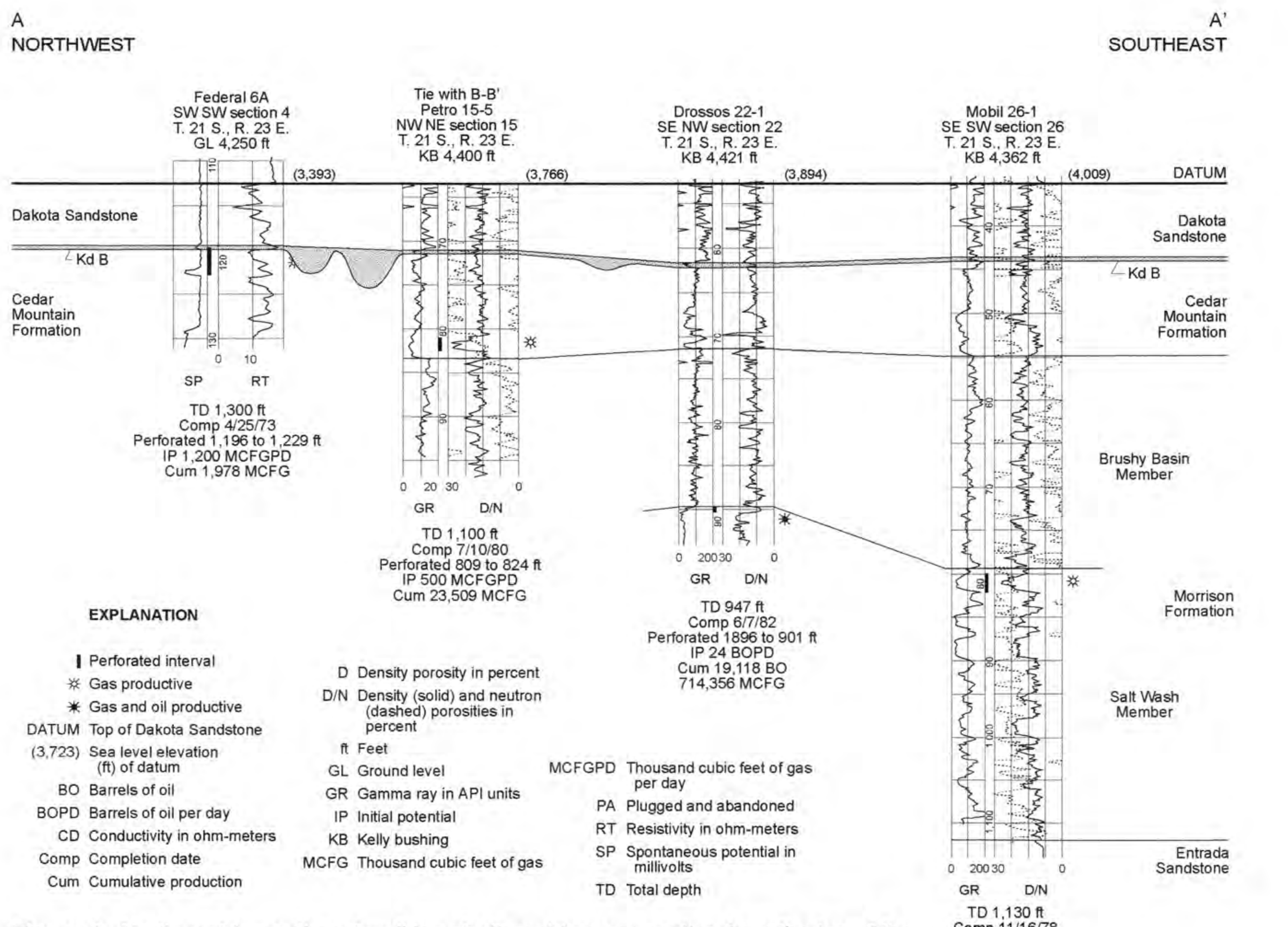

Figure 4. Northwest-to-southeast well log stratigraphic cross section from the top of the Dakota Sandstone to total depth of the well. No horizontal scale; see figure 2 for location of line.

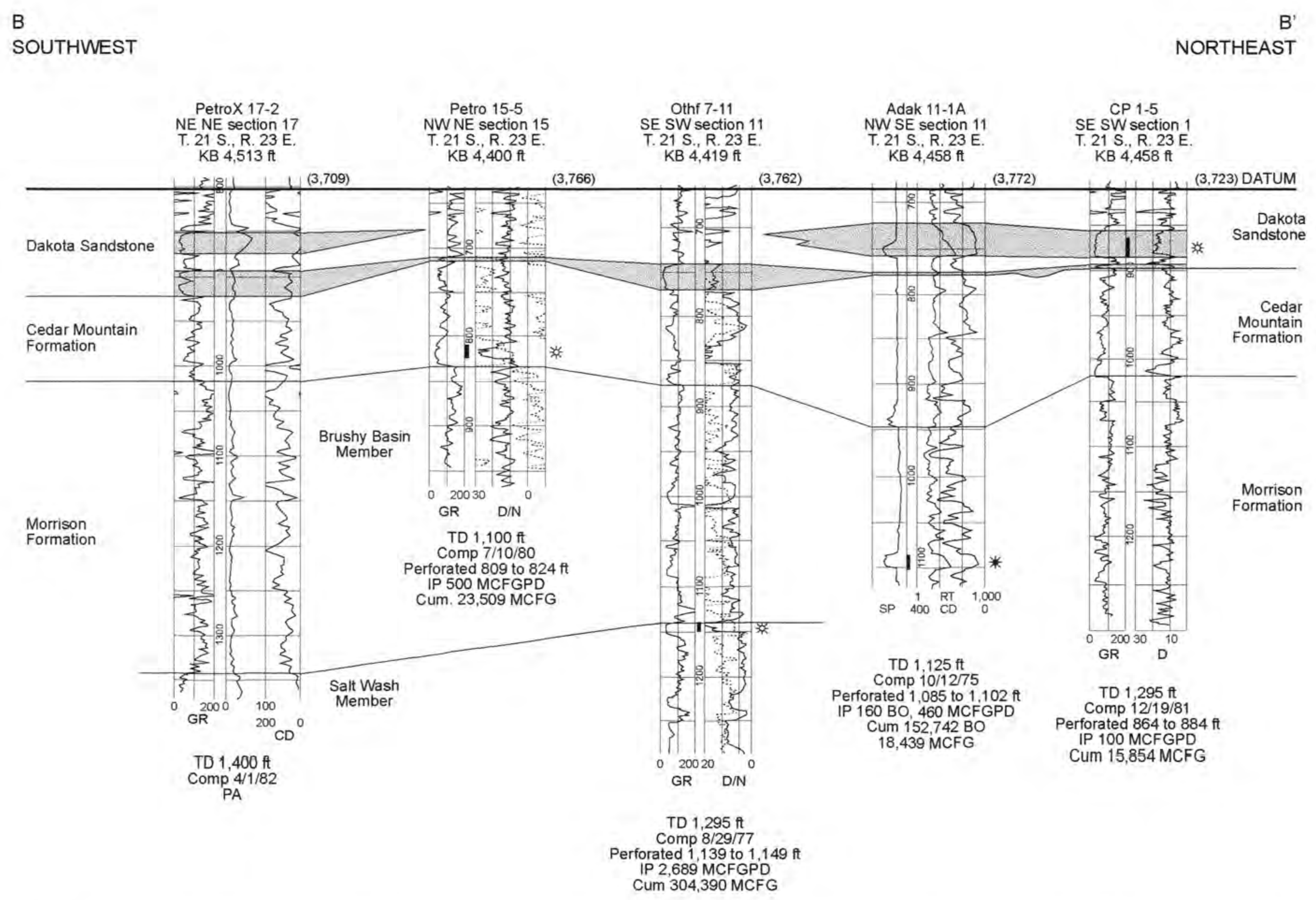

Figure 5. Southwest-to-northeast well log stratigraphic cross section from the top of the Dakota Sandstone to total depth of the well. No horizontal scale; see figure 2 for location of line and figure 4 for explanation of symbols and abbreviations.

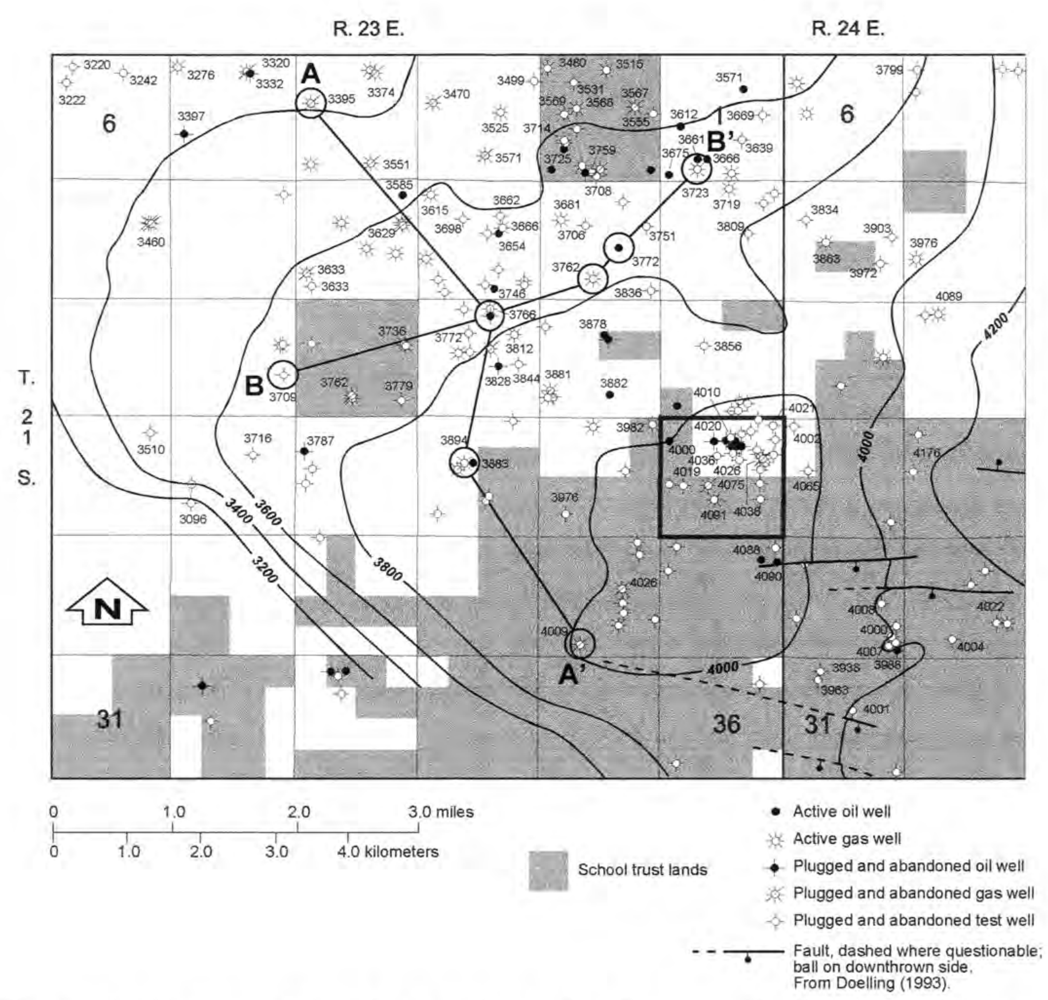

Figure 3. Structure contour map of the top of the Dakota Sandstone. Values shown for all wells with geophysical logs. Contour interval is 200 feet. Datum is mean sea level.

Table 2. Oil and gas analyses from the Cisco Wash area. From Stowe (1979).

Oil Analysis section 24, T. 21 S., R. 23 E. Morrison Formation at 565 feet		Gas Analysis section 30, T. 20 S., R. 24 E. Cedar Mountain Formation at 842 feet	
API Gravity	33.8°	Methane	82.1%
Pour Point	below 5°F	Ethane	2.5%
Viscosity	48 seconds @ 100°F	Higher fractions	1.4%
Color	brownish black	Carbon dioxide	trace
Sulfur	1.07%	Helium	0.7%
Nitrogen	0.07%	Heat value	922 BTU/ft^3

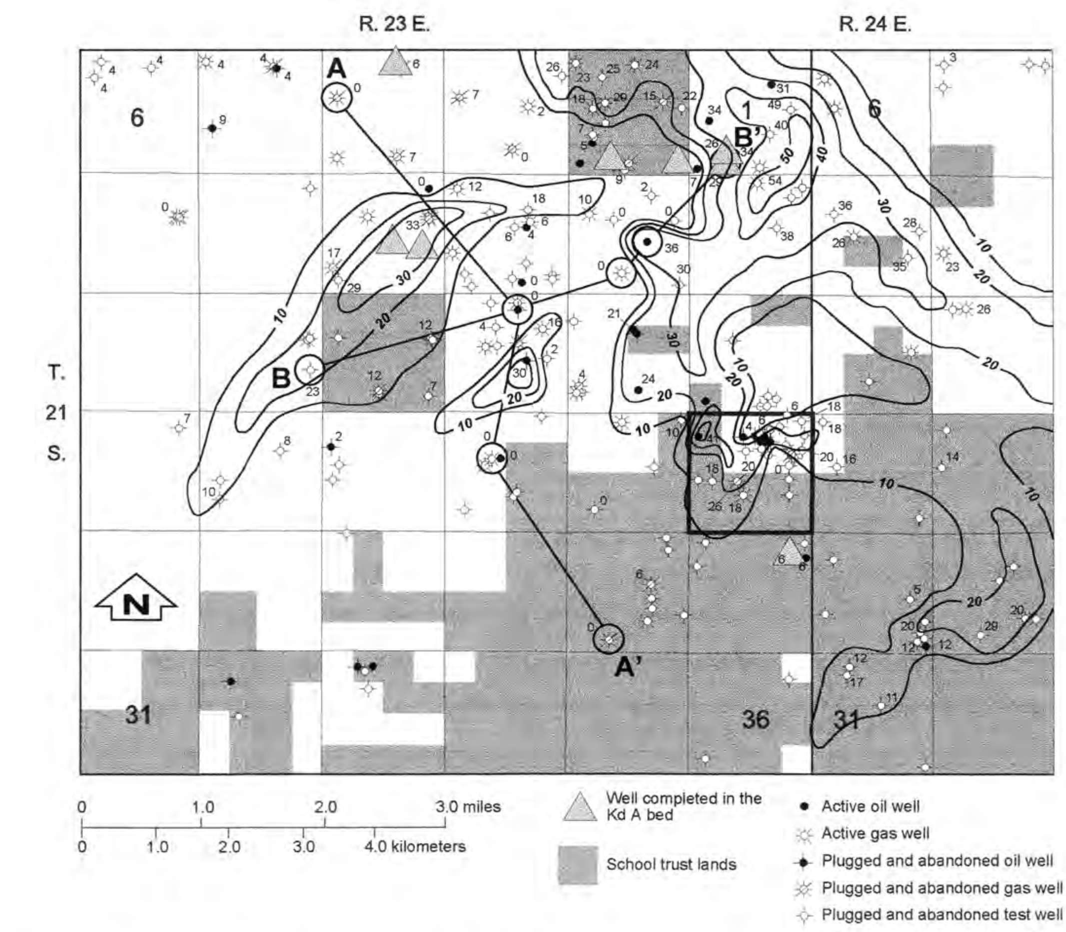

Figure 6. Isochore map of the Kd A bed of the Dakota Sandstone. Values shown for all wells with geophysical logs. Contour interval is 10 feet.

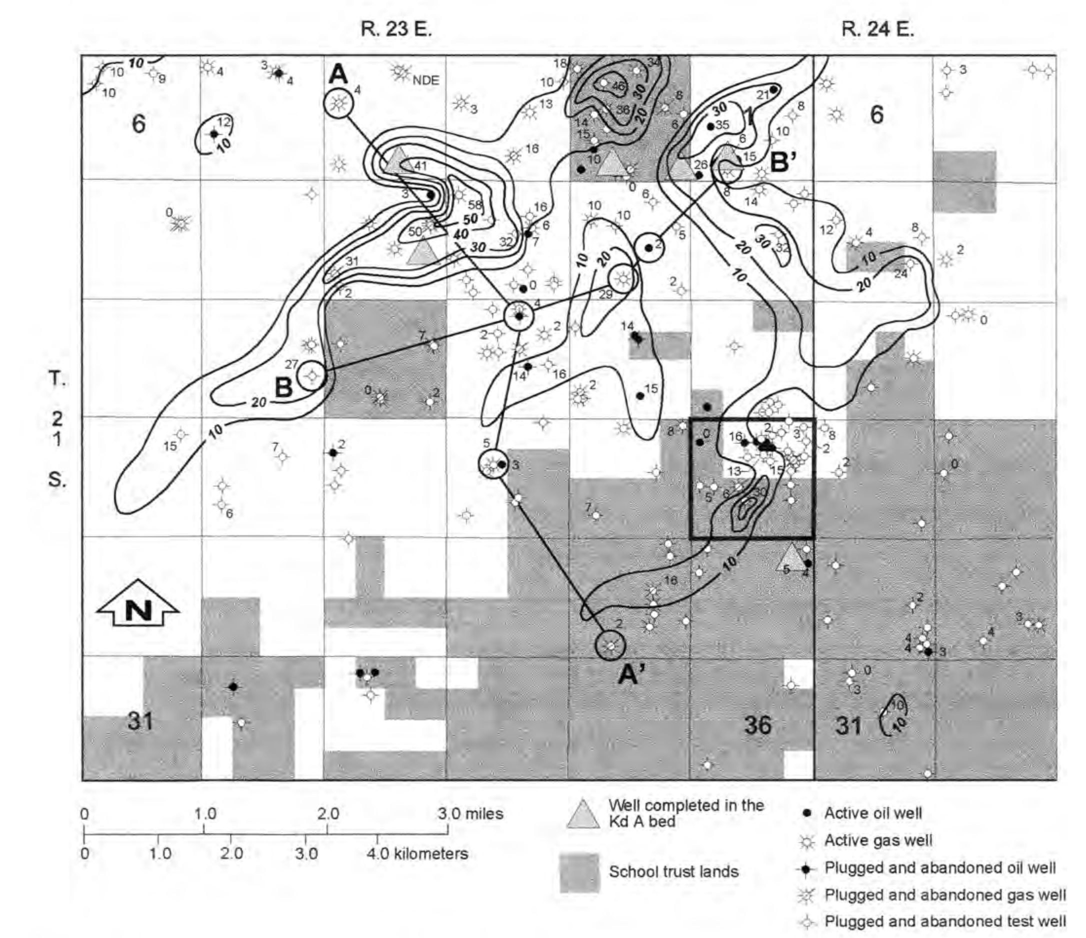

Figure 7. Isochore map of the Kd B bed of the Dakota Sandstone. Values shown for all wells with geophysical logs. Contour interval is 10 feet.

ACKNOWLEDGMENTS

This report was funded as part of a larger study of the Cretaceous Dakota Sandstone, northern Grand County, by the Utah School and Institutional Trust Lands Administration.

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PETROLEUM GEOLOGY OF THE AGATE, DANISH WASH, SAGE, AND SEIBER NOSE RESERVOIRS IN THE GREATER CISCO FIELD, GRAND COUNTY, UTAH

by
Craig D. Morgan

Oil and Gas Field Study 23 December 2001
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

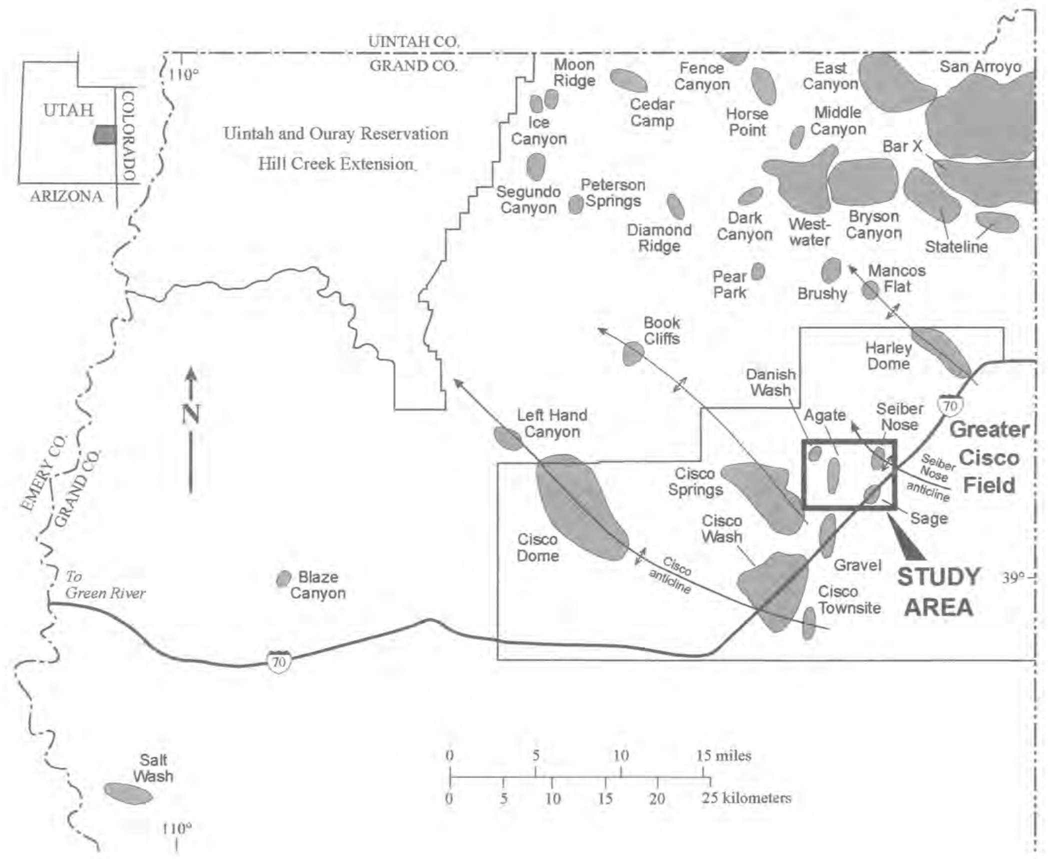

Figure 1. Location of oil and gas fields (shaded and labeled) in northern Grand County and the Agate, Danish Wash, Sage, and Seiber Nose reservoirs within the Greater Cisco field.

INTRODUCTION

Agate, Danish Wash, Sage, and Seiber Nose reservoirs (figures 1 and 2), collectively referred to as the Agate area in this report, lie along the plunge and the flank of the Laramide-age Seiber Nose anticline in T. 19 and 20 S., R. 24 E., Salt Lake Base Line and Meridian, Grand County, Utah (figure 3). Weathered Cretaceous Mancos Shale is exposed over most of the area with Cretaceous Dakota Sandstone exposed in the southeast portion of the study area (Willis and others, 1996).

Hydrocarbons are produced from Cretaceous- and Jurassic-age sandstone reservoirs that have combination stratigraphic-structural traps. Most of the production is from the Morrison Formation with lesser amounts from the Cedar Mountain and Dakota Formations (figure 4 and table 1). Production in the area was designated by the Utah Division of Oil, Gas and Mining as Agate field, Danish Wash field, Sage field, and Seiber Nose field until 1978, when the area was included in the Greater Cisco field.

This report is part of a study of the petroleum geology of the Cretaceous Dakota Sandstone of northern Grand County. The study improves our understanding of the geology, hydrocarbon production, and future development potential of the Dakota and can help determine the resource value of property in the area including those lands managed by the Utah School and Institutional Trust Lands Administration whose funding helps support this study.

STRUCTURE

The Seiber Nose oil accumulation lies along the northwest-plunging Seiber Nose structure, which is a subsidiary fold on the northwest-plunging ancestral Uncompahgre uplift. Willis and others (1996) mapped the surface structure as a monocline draped over northwest-trending, high-angle basement faults. Well-log data show minor folds at the Dakota level throughout most of the area (figure 3). There are no faults mapped in the area.

The Megadon Enterprises Hays 1-6 well (NE1/4NE1/4 section 6, T. 20 S., R. 24 E.), one of the deepest stratigraphic tests in the area, was drilled in 1982 to a depth of 2,523 feet (769.0 m) in the Jurassic Entrada Sandstone. The stratigraphically deepest tests in the Greater Cisco field have encountered Triassic Chinle Formation overlying Precambrian granite (Bon, 1999; Morgan, 1999a, 1999b; Doelling, 2001).

STRATIGRAPHY OF THE PRODUCING RESERVOIRS

Hydrocarbon production in the Agate area is from sandstone beds in the Jurassic Morrison and Cretaceous Cedar Mountain and Dakota Formations (figures 5 and 6). A small amount of hydrocarbons has been produced from the Jurassic Entrada Sandstone in Grand County, but in the Agate area the Entrada is water bearing. The Morrison, Cedar Mountain, and Dakota are separated by unconformities that typically are found at the base of channels incised into the underlying formation. Hydrocarbon traps are formed where the channel sandstone beds cross the structural axis of the Seiber Nose, or where bends in the channels create an updip pinch-out of the beds along the flank of the structure (figure 7). The producing horizons reported in table 2 and the following discussions of those units are based on geophysical well-log correlations. Identifying these formation contacts is difficult and my interpretation may differ from picks made by the well operator or other workers.

Morrison Formation

The Morrison Formation is a continental and lacustrine deposit of interbedded channel sandstone, variegated shale, and some thin limestone, ranging from 498 to 660 feet (151.8-201.2 m) of drilled thickness. It has a maximum drilled depth of 2,258 feet (688.2 m) in the Agate area. More than 160,000 barrels of oil (BO) (4,044.9 m^3) and 300,000 thousand cubic feet of gas (MCFG) (8.5 million m^3) have been produced from sandstone beds in both the Salt Wash and Brushy Basin Members of the Morrison. No attempt was made to identify the Tidwell Member, as mapped by Willis and others (1996), on well logs and therefore it is included in the basal part of the Morrison in the Salt Wash Member.

Cedar Mountain Formation

The Cedar Mountain Formation is a fluvial-lacustrine deposit of interbedded sandstone, siltstone, and some pale-green shale, ranging from 34 to 223 feet (10.4-67.9 m) of drilled thickness. It has a maximum drilled depth of 2,140 feet (652.3 m) in the Agate area. More than 400 BO (64 m^3) and 40,000 MCFG (1.1 million m^3) have been produced from sandstone beds in the Cedar Mountain.

Dakota Sandstone

The Dakota Sandstone is a fluvial to littoral marine deposit of sandstone and shale ranging from 58 to 155 feet (17.7-47.2 m) of drilled thickness. It has a maximum drilled depth of 2,022 feet (616.3 m) in the Agate area. More than 86,000 MCFG (2,436,000 m^3) has been produced from the Dakota Sandstone, but no oil. The sandstone beds (Kd A and Kd B) in the Dakota are incised fluvial-channel deposits that generally trend north to northeast in the Agate area (figures 8 and 9). Willis and others (1996) divide the Dakota into three parts: (1) a lower conglomerate sandstone interval, (2) a middle carbonaceous shale, coal, and sandstone interval, and (3) an upper sandstone interval.

DEVELOPMENT AND PRODUCTION HISTORY

The Agate, Danish Wash, Sage, and Seiber Nose fields were discovered between 1955 and 1966; initial discoveries were in the Dakota Sandstone and Morrison Formation (table 2). The gravity of the oil produced from the Agate area ranges from 34^0 to 40^0 API (table 3). The heating value of the gas produced from the Agate area ranges from 958 to 1,013 British thermal units (table 4). Development drilling after the initial discoveries established production from the Cretaceous Cedar Mountain Formation. The most productive oil well is the Eppie 4 (table 1) in the Agate field which has produced 75,899 BO (12,067.9 m^3) from a sandstone bed in the Brushy Basin Member of the Morrison Formation. The most productive gas well is the Capansky-Phillips 8-1 (table 1) in an unnamed field that produced 204,767 MCFG from a sandstone bed in the Brushy Basin Member.

More than 160,000 BO (25,000 m^3) and nearly 0.5 billion cubic feet of gas (BCFG) (14 million m^3) have been produced from 18 wells in the Agate area through April 30, 2001 (table 1). Records are poor and some production may not have been reported to the State or may have been attributed to the wrong well. In 2000, annual production came from six wells totaling 2,214 BO (352.0 m^3) and 3,426 MCFG (97,020 m^3).

SUMMARY AND FUTURE POTENTIAL

More than 160,000 BO (25,000 m^3) and 450,000 MCFG (12.7 million m^3) have been produced from the Agate area at depths typically ranging from 1,000 to 2,000 feet (300-600 m). Production is from combination stratigraphic-structural traps found in the fluvial sandstone beds of the Morrison, Cedar Mountain, and Dakota Formations. The majority of the production is from the Morrison Formation.

Most of the wells in the Agate area produce at a low daily rate resulting in a small volume of hydrocarbon being produced over the life of the well. The best oil wells produce a total of 40,000 to 76,000 BO (6,000 - 12,000 m^3) and the best gas wells produce a total of 100,000 to 200,000 MCFG (2.8 - 5.7 million m^3). Undiscovered hydrocarbons probably still exist in the area because the lenticular nature of the channel sandstone reservoirs can provide many small stratigraphic traps. Any new discoveries will probably be small accumulations similar in production potential to previous wells. As a result, the area may still attract small independent operators, but probably does not have sufficient potential for larger companies.

ACKNOWLEDGMENTS

This report was funded as part of a larger study of the Cretaceous Dakota Sandstone, northern Grand County, by the Utah School and Institutional Trust Lands Administration.

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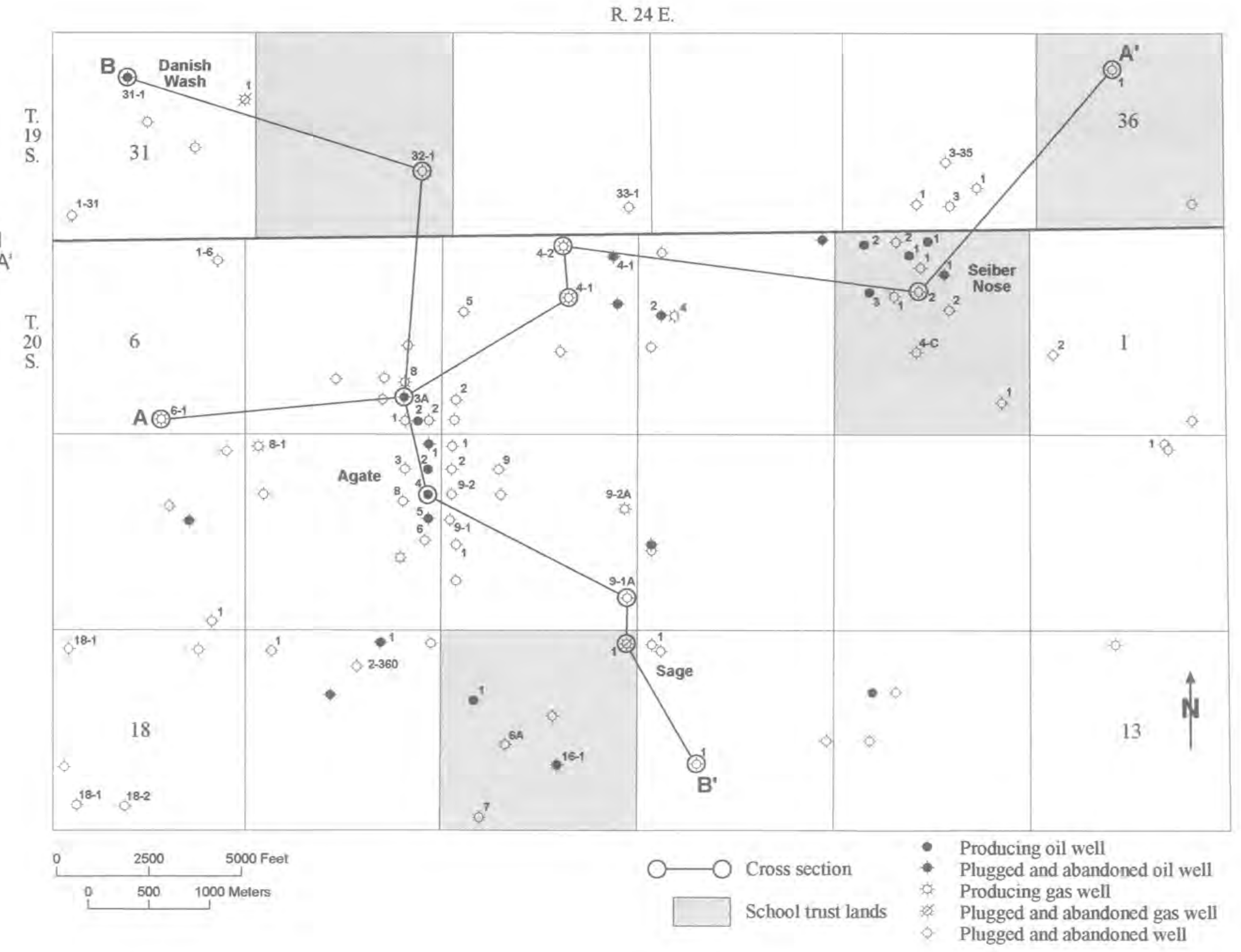

Figure 2. Location and well number of oil and gas wells in the Agate area. Cross section A-A' and B-B' are figures 5 and 6, respectively.

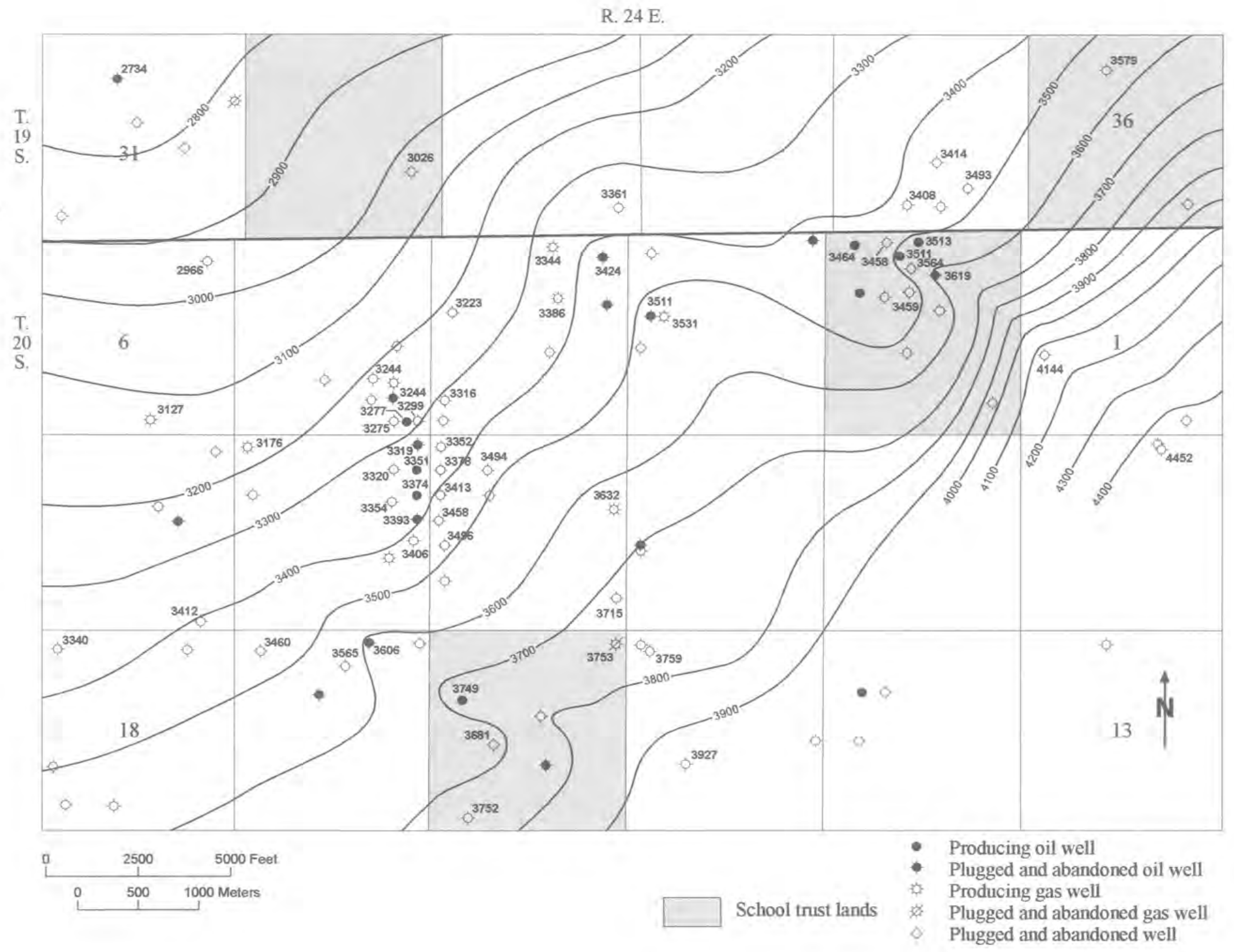

Figure 3. Structure contour map on the top of the Dakota Sandstone in the Agate area. Values shown for all wells with geophysical logs. Contour interval is 100 feet. Datum is sea level elevation.

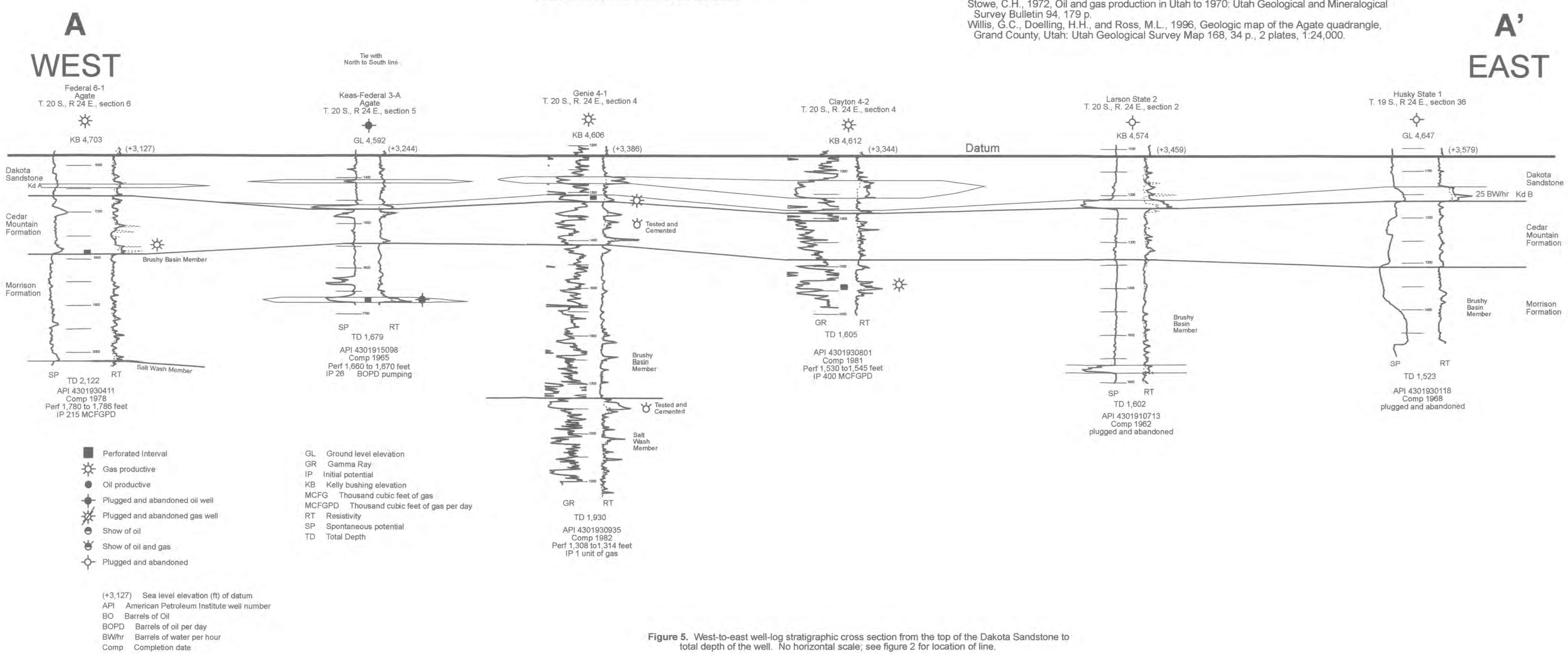

Figure 5. West-to-east well-log stratigraphic cross section from the top of the Dakota Sandstone to total depth of the well. No horizontal scale; see figure 2 for location of line.

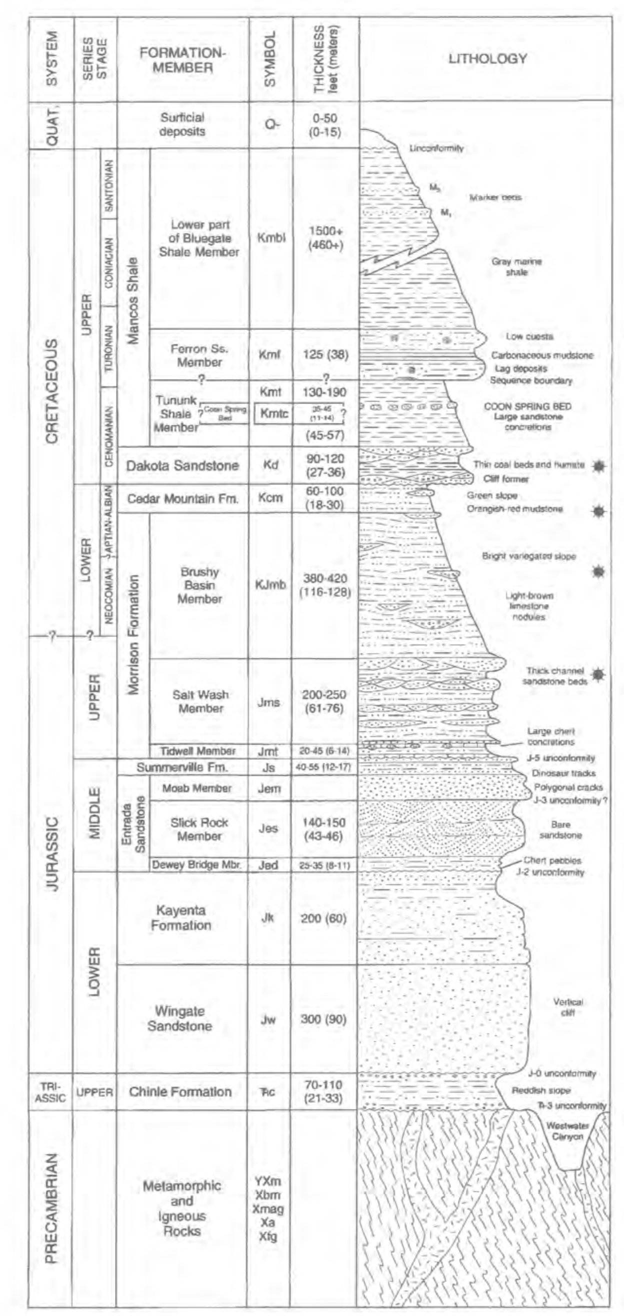

Figure 4. Lithologic column for the Agate quadrangle (modified from Willis and others, 1996).
● Oil and gas reservoir

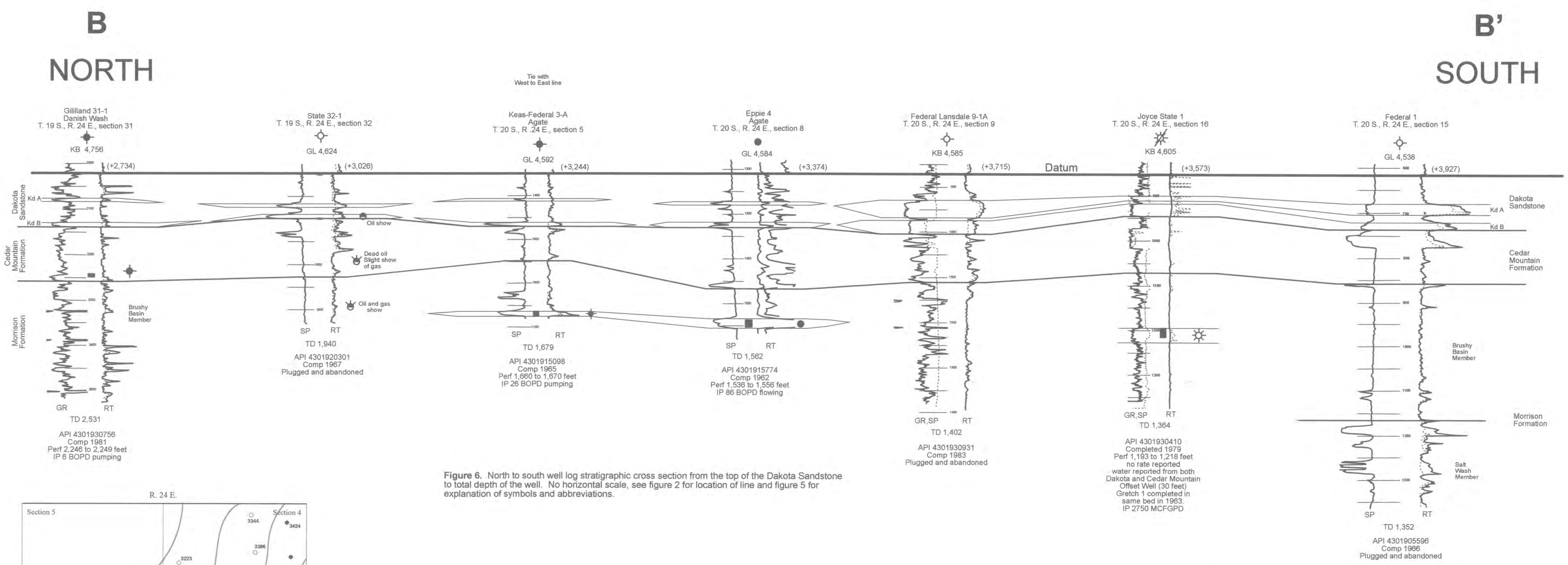

Figure 6. North to south well log stratigraphic cross section from the top of the Dakota Sandstone to total depth of the well. No horizontal scale, see figure 2 for location of line and figure 5 for explanation of symbols and abbreviations.

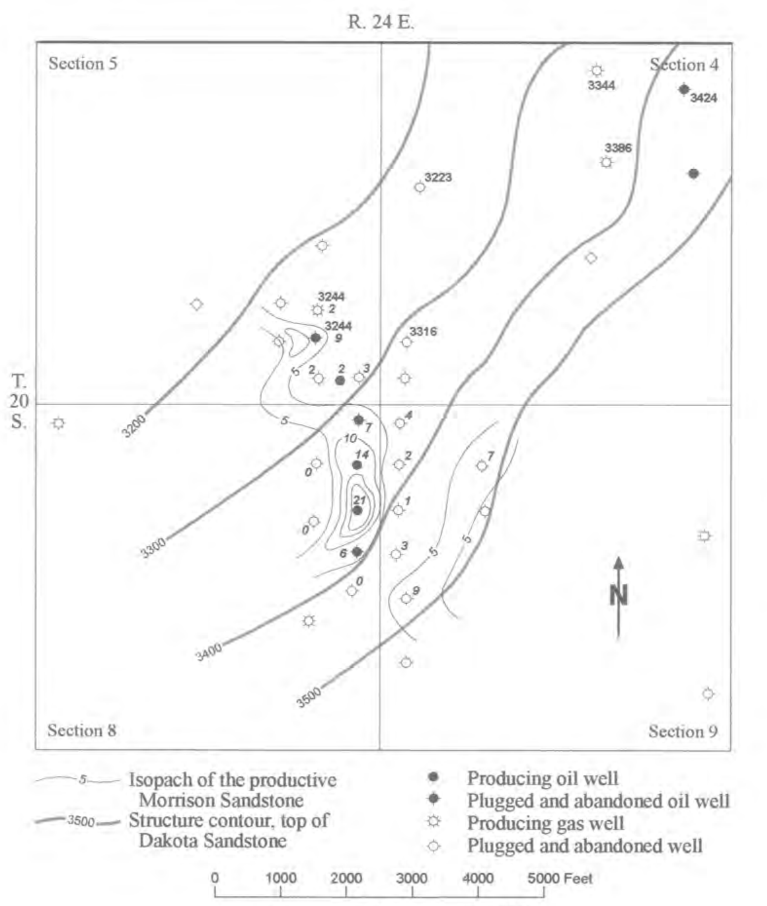

Figure 7. Structure contour and sandstone isochore map of the Agate reservoir. Structure contour interval is 100 feet (mean sea level datum), and isochore contour interval is 5 feet.

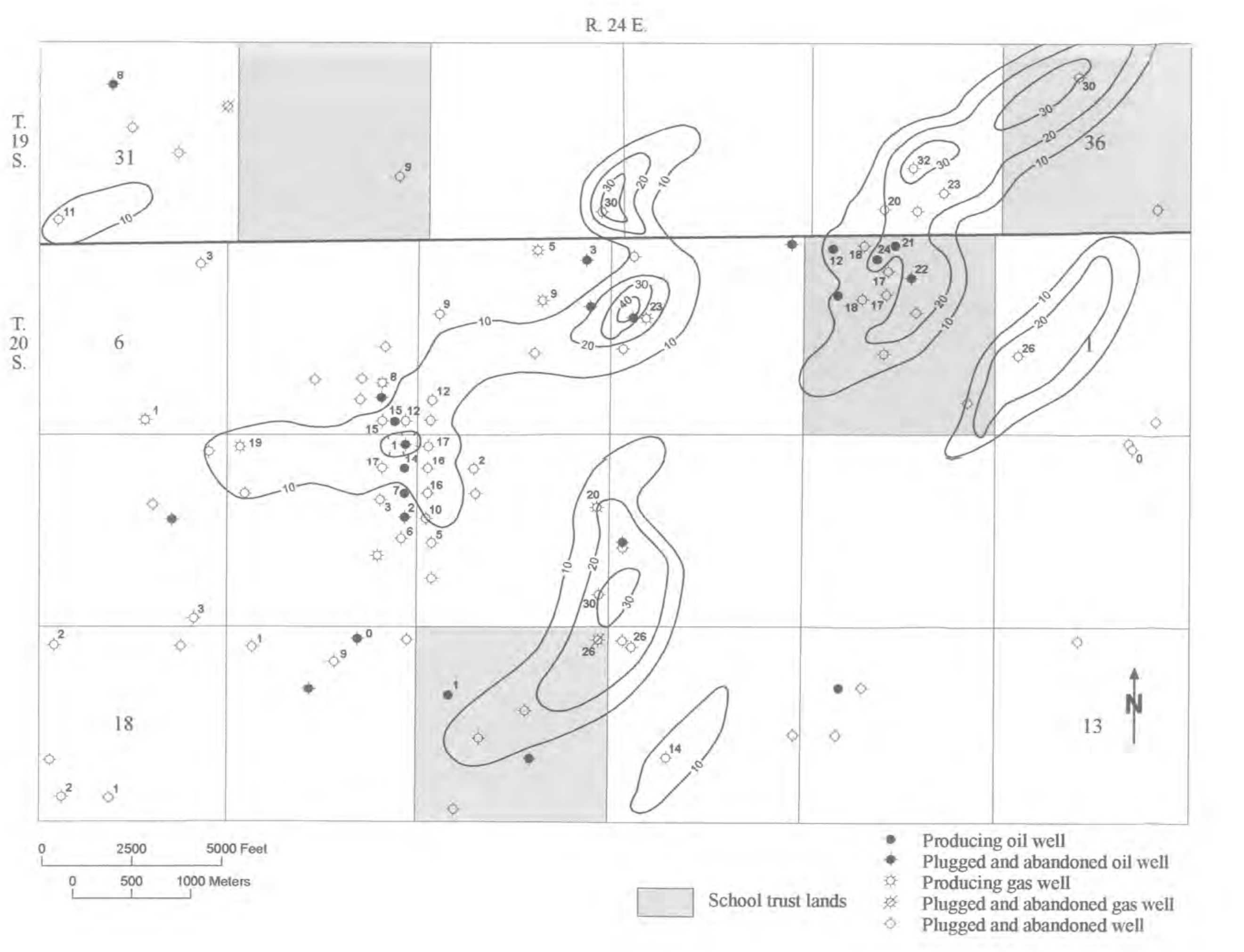

Figure 8. Isochore map of the A bed of the Dakota Sandstone (Kd A). Values shown for all wells with geophysical logs. Contour interval is 10 feet.

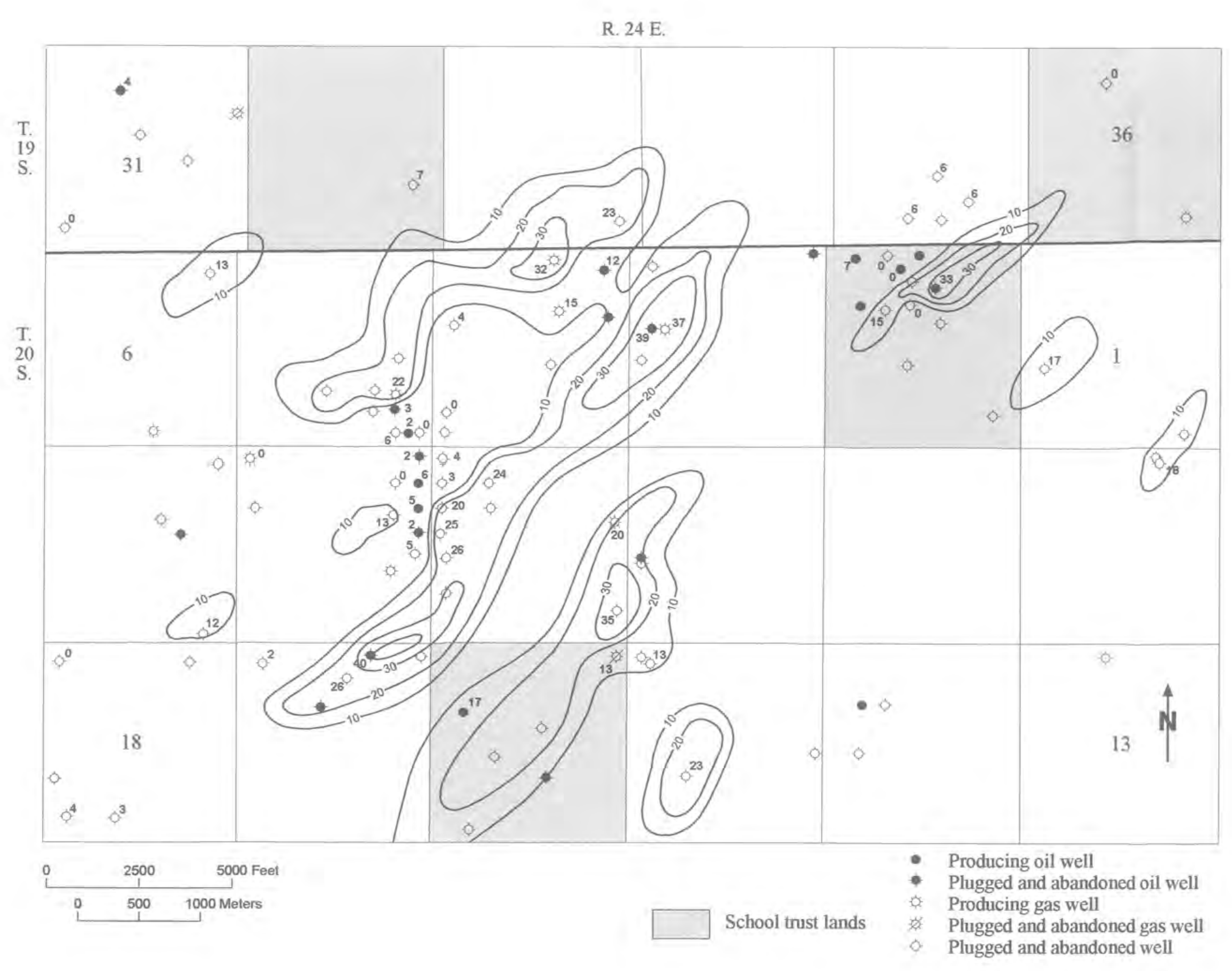

Figure 9. Isochore map of the B bed of the Dakota Sandstone (Kd B). Values shown for all wells with geophysical logs. Contour interval is 10 feet.

Table 1. Cumulative oil and gas production from all wells in the Agate, Danish Wash, Sage, and Sieber Nose fields and neighboring wells as of April 30, 2001. Completion (Comp.), oil in barrels (bbl), and gas in thousand cubic feet (MCF). Producing reservoirs and formations at total depth are: Entrada Sandstone (Je), Morrison Formation (Jm), Salt Wash Member (Jmsw), Brushy Basin Member (Jmbb), Cedar Mountain Formation (Kcm), Dakota Sandstone (Kd), Dakota bed A (Kd A), Dakota bed B (Kd B), Not reported (NR), No log (NL) (data taken from the well record). Status: Producing oil well (POW), producing gas well (PGW), plugged and abandoned oil well (PAO), plugged and abandoned gas well (PAG). Some wells were completed but have never been produced or were never plugged. Some older wells may have production that is not reported in the current records. Data source: Utah Division of Oil, Gas and Mining.

Section	Well Name & Number	Comp. Date	Cumulative Oil (bbl)	Cumulative Gas (MCF)	Producing Reservoir	Status	Formation at Total Depth	API Number 43-019-
T. 20 S., R. 24 E.								
NENW 2	Larsen State 1	1955	26,539	0	Jm	POW	Jm	15317
NWNW 2	State 2	1978	386	0	Jm	POW	Jmsw	30366
SWNE 2	Duchess State 1-A	1970	331	0	Kcm	POW	Kcm	30065
NENW 2	Promontory Seiber State 1	1964	90	0	Jm	POW	Jmbb	15318
SWNW 2	State 3	NR	0	0	Kd	PAO	NL	11369
SWNW 3	Patsantaras Pete 2	1982	0	0	Jmbb	POW	Jm	30899
SWNW 3	Patsantaras Pete 4	1982	0	0	Jmbb	PGW	NL	30916
SENE 4	Government 4-2A	1991	0	5,793	Jm	PAG	Jm	31312
NWNE 4	Clayton 4-2	1981	86	101,453	Kcm	PAG	Jm	30801
NENE 4	Staley 4-1	1991	0	0	Jm	PAG	Jm	31311
SWNE 4	Genie 4-1	1982	0	15,098	Kd	PAG	Jmsw	30935
SESE 5	Keas 8	1984	0	0	Kcm	PGW	Jm	31113
SESE 5	Keas 2	1966	119	0	Jmbb	POW	Jm	15097
SESE 5	Keas 3-A	1965	15,729	0	Jmbb	PAO	Jm	15098
SWSE 6	Bowers 1-6	1978	0	41,890	Kcm	PGW	Jmsw	30411
SWNE 7	Bowers 1-7	1978	NR	NR	Kcm	PAG	Jmsw	30417
SENE 8	Eppie 5	1962	NR	NR	Jm	PAO	Jmbb	15775
NENE 8	Eppie 1	1961	NR	NR	Jmbb	PAO	Jm	15772
NWNW 8	Capansky-Phillips 8-1	1964	0	204,767	Jmbb	PGW	Jm	15100
NESE 8	Eppie 7	1968	0	0	Kd	PGW	Jmbb	30014
SENE 8	Eppie 4	1962	75,899	9,672	Jmbb	POW	Jm	15774
NWSW 8	Broadhead 8-3	1985	0	0	Jmsw	PAG	Jmsw	31067
NENE 8	Eppie 2	1961	42,459	870	Jmbb	POW	Jmbb	15773
SENE 9	Lansdale 9-2A	1984	0	0	Kd	PGW	Jmsw	31150
NWSW 10	Federal 5	1963	NR	NR	Jmbb	PAG	Jmbb	16259
SWNW 14	Broadhead 1	1966	185	0	Kd	POW	NL	20092
SWNW 16	1 JDP Speedy State	2000	280	1,504	Jmsw	POW	Jm	31370
NENE 16	Joyce State 1	1979	0	564	Jmsw	PAO	Jmsw	30410
NENE 16	Gretchen	1963	NR	NR	Jmbb	PAG	Je	16260
NWSE 16	Damon State 16-1	1982	0	135	Kd	PAG	Jm	30668
NWNE 17	Agate 1	1969	NR	NR	Jm	PAO	Jm	30023
SENW 17	Livestock 1	1978	NR	NR	Jm	PAO	Jm	30278
T. 19 S., R. 24 E.								
SENE 31	Grossman 1	1955	0	70,866	Kd	PAG	Kd	15014
TOTAL 33 WELLS, 18 with reported production			162,103	452,612				

Table 2. Discovery data for the Agate, Danish Wash, Sage, and Seiber Nose fields.

	AGATE	DANISH WASH	SAGE	SEIBER NOSE
Discovered by	Raphael Pumpelly	Smith and Moore	Walter Broadhead	Carter Oil
Well name	Fee 1	Government 1	Federal 1	Larson State 1
Discovery date	1961	1955	1966	1955
Well location	NE1/4NE1/4 section 8, T. 20 S., R. 24 E.	SE1/4NE1/4 section 31, T. 19 S., R. 24 E.	SW1/4NW1/4 section 14, T. 20 S., R. 24 E.	NE1/4NW1/4 section 2, T. 20 S., R. 24 E.
Producing interval (feet)	Morrison 1,579 to 1,596	Dakota 1,954 to 1,984	Dakota 390 to 400	Morrison 1,430 to 1,439
Initial production rate	50 BOPD flowing	1,470 MCFGPD	2 BOPD pumping	126 BOPD flowing
Reference	Peterson (1972)	Quigley (1961a)	DOGM	Quigley (1961b)

BOPD = barrels of oil per day
MCFGPD = thousand cubic feet of gas per day
DOGM = Utah Division of Oil, Gas and Mining unpublished data

Table 3. Analyses of oil samples from the Morrison Formation.

	Morrison Formation	Morrison Formation	Morrison Formation
	section 8, T. 20 S., R. 24 E.	section 5, T. 20 S., R. 24 E.	section 2, T. 20 S., R. 24 E.
	Eppie 1 Agate Field	Keas 3-A Agate Field	unknown Seiber Nose Field
API gravity	40.4	38.1	34.8
Pour point (°F)	below 5	below 5	30
Color	Greenish black	Brownish green	Brownish black
Viscosity (at 100 °F)	38 seconds	40.2 seconds	44 seconds
Sulfur (%)	0.61	0.82	0.96
Nitrogen (%)	0.034	NR	0.055
Reference	Peterson (1972)	Stowe (1972)	Stowe (1972)

NR = not reported

Table 4. Analyses of gas samples from the Morrison and Dakota Formations.

	Morrison Formation	Dakota Sandstone
	sec. 8, T. 20 S., R. 24 E.	sec. 31, T. 19 S., R. 24 E.
	Capansky-Phillips 8-1 Unnamed field	Grossman 1 Danish Wash
Heating value (BTU)	958	1013
Methane (%)	88.7	NR
Ethane (%)	1.0	NR
Propane (%)	0.7	NR
Nitrogen (%)	8.4	NR
Helium (%)	0.5	NR
Reference	Peterson (1972)	Stowe (1972)

BTU = British thermal units
NR = not reported

PETROLEUM GEOLOGY OF THE AGATE, DANISH WASH, SAGE, AND SEIBER NOSE RESERVOIRS IN THE GREATER CISCO FIELD, GRAND COUNTY, UTAH

by
Craig D. Morgan

GEOLOGICAL CONSIDERATIONS FOR OIL AND GAS DRILLING ON STATE POTASH LEASES AT CANE CREEK ANTICLINE, GRAND AND SAN JUAN COUNTIES, UTAH

by
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Utah Geological Survey

CIRCULAR 84 **DECEMBER 1991**
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

COVER PHOTOGRAPH - *The Cane Creek anticline, a view to the northwest from Kane Springs Canyon. The Permian Cutler Group is the oldest unit exposed in the photograph. (Photo: Craig D. Morgan, Utah Geological Survey, 1991).*

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GEOLOGICAL CONSIDERATIONS FOR OIL AND GAS DRILLING ON STATE POTASH LEASES AT CANE CREEK ANTICLINE, GRAND AND SAN JUAN COUNTIES, UTAH

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GEOLOGICAL CONSIDERATIONS FOR OIL AND GAS DRILLING ON STATE POTASH LEASES AT CANE CREEK ANTICLINE, GRAND AND SAN JUAN COUNTIES, UTAH

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ABSTRACT

The recent success of the Kane Springs Federal 27-1 well in the abandoned Bartlett Flat field has stimulated petroleum industry interest in leasing and drilling land in the Moab area in southern Grand and adjacent San Juan Counties. The well, completed using new horizontal drilling techniques, produces from the "Cane Creek" zone of the Pennsylvanian Paradox Formation and it is thought that other lands in the area are equally promising particularly using horizontal drilling techniques.

Lands that have petroleum potential include leases that encompass and surround the potash solution mine of Moab Salt Company located in sec. 23-27 and 35-36, T. 26 S., R. 20 E. There is concern that oil and gas drilling could cause contamination of the potash mine and reserves, and/or alter fluid flow in the potash mine thus affecting potash production.

The Utah Division of State Lands and Forestry asked the Utah Geological Survey to advise them on how close to the potash mine should oil and gas leasing be allowed based upon geological considerations. The Utah Geological Survey concluded that there are insufficient geologic and engineering data available, particularly on the extent and continuity of faults (fluid pathways), to make recommendations with a specific statistical certainty, but the following three options are offered for consideration.

1. Do not issue oil/gas leases where active potash leases exist.
2. Issue restricted oil/gas leases that do not allow surface or subsurface occupancy (to salt 10) over active potash leases.
3. Issue oil/gas leases with a number of precautionary stipulations including a buffer zone around the potash mine workings.

INTRODUCTION

The successful completion of the Kane Springs Federal 27-1 well in Grand County by Columbia Gas Development Corporation (figure 1) sparked strong interest in oil and gas leasing in the Moab area. This includes lands that had been withdrawn from oil and gas leasing for potash development (figure 2). The State Land Board lifted the order withdrawing oil and gas leasing on state potash leases in the Moab area in August 1991 (appendix D). Allowing oil and gas leasing on the lands would help the Board meet their fiduciary responsibility to maximize profits from state lands for the school trust fund. A potential impact of oil and gas exploration and production in this area is interference with the Moab Salt Company's potash solution mine (figures 2 and 3). Provisions for oil and gas leasing remain to be determined and must address potential impacts of oil and gas development on the potash mine and reserves.

This report briefly summarizes available geological and geohydrological data pertaining to oil and gas activities in the Moab area. Potential contamination of the potash and modification of fluid circulation within the potash mine depend on: 1) the permeability of rock matrix and fractures in the area, 2) local fluid pressures and gradients, and 3) location of drill holes and their casing design. Future studies of structural geology, geohydrology, reservoir engineering, and geophysics may be needed to adequately understand this geologically complex area. Possible options for oil and gas development are given, but specific recommendations may require future site-specific studies and guidance from experts.

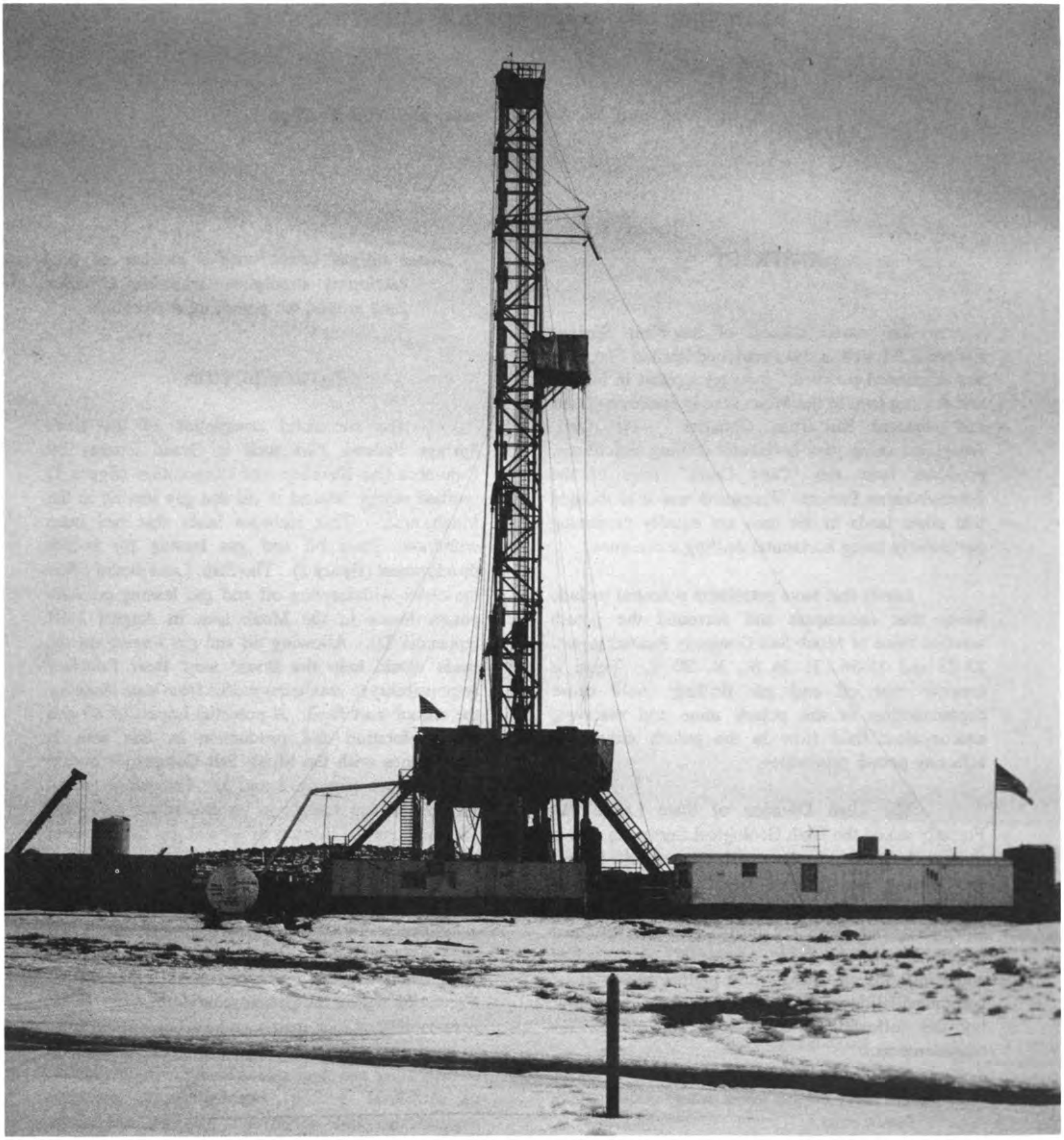


Figure 1. *Columbia Gas Development Corp. horizontal well, Kane Springs Federal 27-1, (NW 1/4 SE 1/4 sec. 27, T. 25 S., R. 19 E). The well is completed flowing 914 bbl of oil and 290 mcf of gas per day from the "Cane Creek" zone of the Paradox Formation. The well has revived production from the abandoned Bartlett Flat field. In the foreground is the drill hole marker of the Pure Oil Big Flat 5, a vertical well completed in the "Cane Creek" zone. This well was abandoned in 1965 after producing less than 40,000 bbl of oil. (Photo: Craig D. Morgan, Utah Geological Survey, 1991).*

Figure 2. Moab Salt Company potash plant in 1963, immediately after its construction (photo courtesy of the Utah Historical Society).

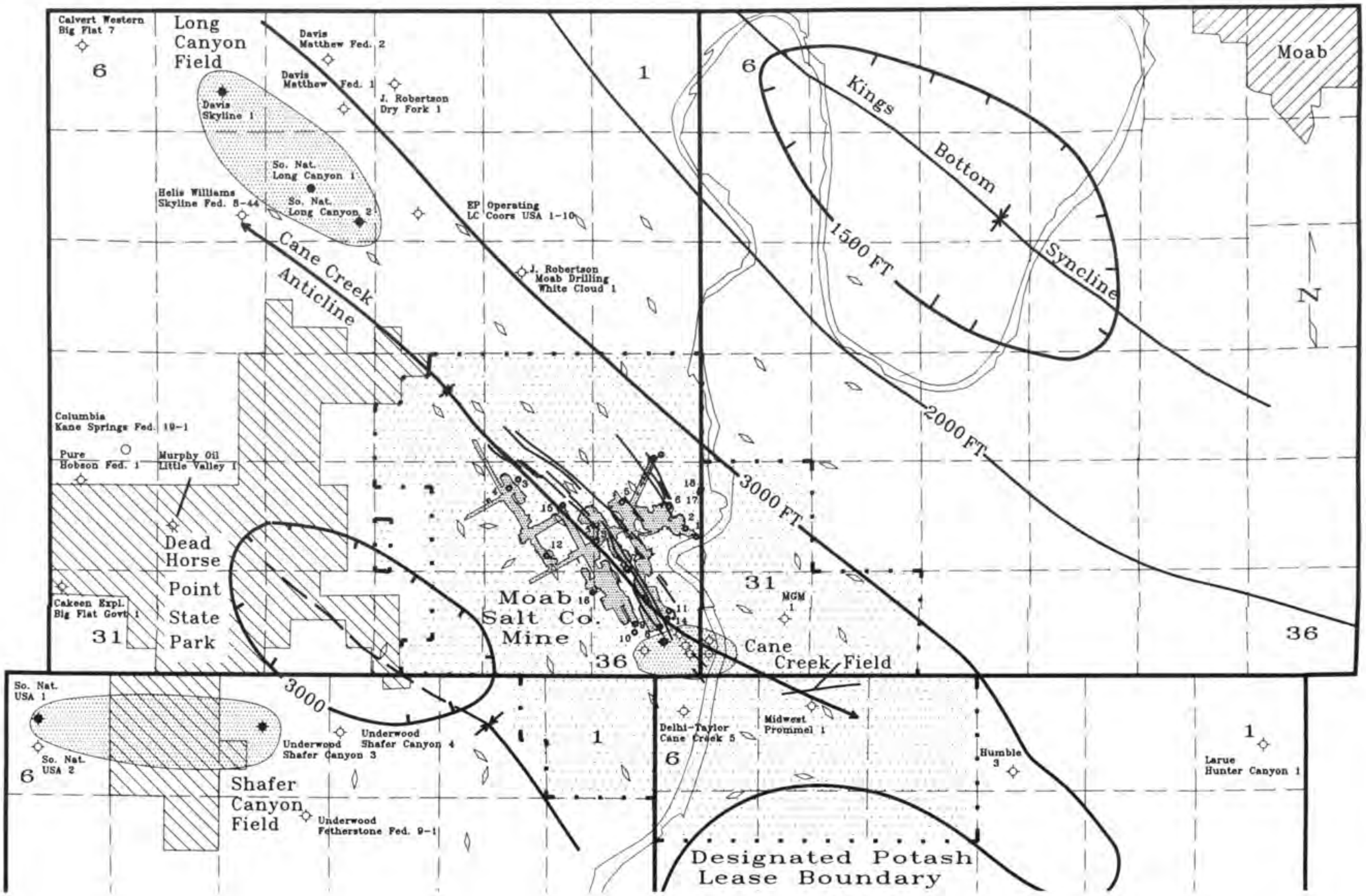
HISTORICAL DEVELOPMENT OF THE MOAB AREA

The Moab area has a long history of petroleum and potash exploration and production, much of it centered on the Pennsylvanian Paradox Formation. Oil and gas exploration began in 1925 with the discovery of the Cane Creek field. The Midwest Exploration and Utah Southern No. 1 Shafer well (sec. 31, T. 26 S., R. 21 E.) encountered oil at 2,028 feet (618 m) in the Paradox Formation. The well was later deepened to 4,986 feet (1,520 m), encountering numerous additional oil and gas shows (Smith, 1978a). A total of five more wells were drilled in the immediate vicinity during the period of 1928 to 1958, each had shows of oil in the Paradox Formation. Cumulative production, however, was slight, totalling 1,887 bbl of oil and 25,000 mcf gas.

By 1962, three additional fields had been discovered in the Moab area which produced oil and gas from fractured zones in the Paradox Formation. They are the Bartlett Flat, Long Canyon, and Shafer Canyon fields. The Lion Mesa field was discovered in 1980 (appendix B).

In 1956, exploration indicated a significant potash resource in the Paradox Formation on the Cane Creek anticline (Smith, 1978a). In 1960, 9,445 acres (3822.4 h) of land on the Cane Creek anticline were withdrawn from oil and gas leasing to encourage potash mining (Smith, 1978a). In 1964, Texas Gulf Sulfur Inc. (now Moab Salt Company) began underground room-and-pillar mining of the potash. In 1970, problems with explosive gas pockets, high mine temperatures, and a contorted ore zone dictated a change to solution mining of the original workings (Phillips, 1975). Current potash production is roughly 100,000 tons (90,718,480 kg) per year. Moab Salt Company began marketing the byproduct halite a few years ago and currently produces roughly 200,000 tons (181,436,960 kg) per year (R. York, Moab Salt Company, personal communication, 1991).

In April, 1991, Columbia Gas Development Corporation successfully completed the Kane Springs Federal 27-1 horizontal well in the Bartlett Flat field (sec. 27, T. 25 S., R. 19 E., 8 miles (13 km) northwest of the potash mine. The 27-1 well is completed flowing 914 bbl of oil and 290 mcf of gas per day from the "Cane Creek" zone of the Paradox Formation. Cumulative production for the Bartlett Flat field, which had been abandoned in 1965, was only 39,393 bbl of oil. The successful application of new horizontal drilling technology has revived


Calvert Western Big Flat 7
Long Canyon Field
Davis Matthew Fed. 2
Davis Matthew Fed. 1
J. Robertson Dry Fork 1
Davis Skyline 1
So. Nat. Long Canyon 1
So. Nat. Long Canyon 2
Helis Williams Skyline Fed. 8-44
EP Operating LC Coors USA 1-10
J. Robertson Moab Drilling White Cloud 1
Cane Creek Anticline
Kings Bottom Syncline
1500 FT
2000 FT
3000 FT
Moab
Columbia Kane Springs Fed. 19-1
Pure Hobson Fed. 1
Murphy Oil Little Valley 1
Dead Horse Point State Park
Cakeen Expl. Big Flat Govt 1
Moab Salt Co. Mine
MGM 1
Cane Creek Field
So. Nat. USA 1
So. Nat. USA 2
Underwood Shafer Canyon 3
Underwood Shafer Canyon 4
Shafer Canyon Field
Underwood Fetherstone Fed. 9-1
Delhi-Taylor Cane Creek 5
Midwest Prommel 1
Humble 3
Larue Hunter Canyon 1
Designated Potash Lease Boundary
3000
N
6
1
31
36

T.26 S.

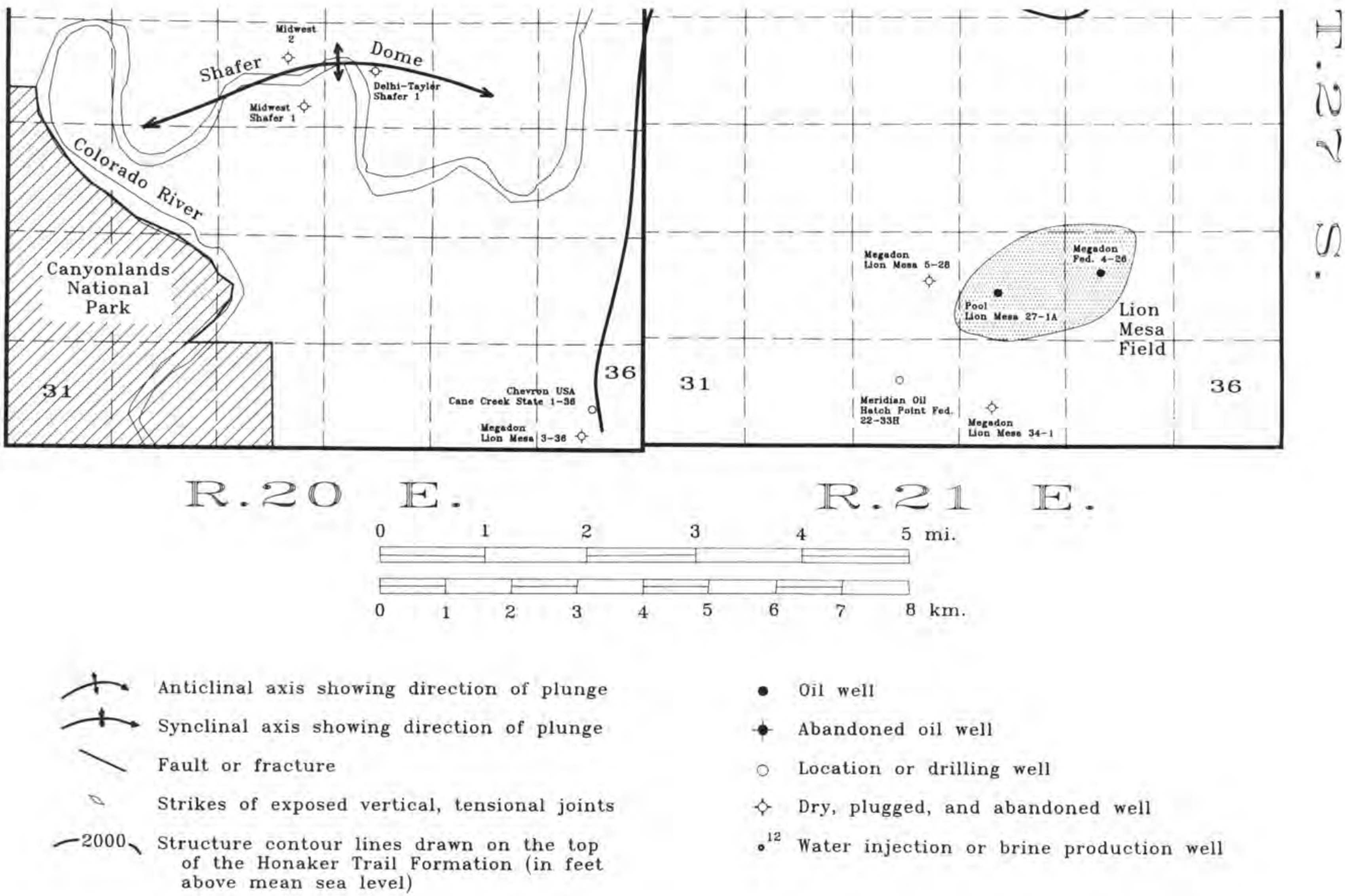


Figure 3. Moab Salt Company mine and vicinity, Grand and San Juan Counties, Utah. Surface faults and fractures in the mine area are from Huntoon (1985). Structure contour lines on top of the Honaker Trail Formation are from Doelling (1981), contour interval is 1000 feet (305 m). Strikes of exposed vertical extensional joints are from Huntoon (1985).

interest in oil and gas exploration throughout the region. The long-standing withdrawal of land in the Moab area from oil and gas leasing suddenly became an issue with oil companies, Moab Salt Company, and with state and local governments.

CURRENT STATUS AND FUTURE ACTIVITIES

In August 1991, the State Land Board lifted the order (appendix D) withdrawing oil and gas leasing on state potash leases in the Moab area. Increasing the acreage available for oil and gas exploration obviously improves the probability of additional hydrocarbons being discovered in the area. Moab Salt Company, however, maintains that oil and gas exploration could jeopardize their current operation and future plans to develop a deeper salt horizon. The actual acreage made available for oil and gas leasing and any restrictions attached will be determined by the Division of State Lands and Forestry.

Moab Salt Company plans to eventually mine the potash resources of salt 9 approximately 1,000 feet (305 m) below the current mine in salt 5 [the rhythmically bedded salt layers of the Paradox basin were designated as units 1 through 29, in descending order, by Hite (1960)]. They plan to rehabilitate and deepen the shaft originally used for the mining of salt 5. Development of salt 9 will follow the same pattern used for salt 5; potash and halite will be mined by room-and-pillar methods to expose enough surface area for later conversion to solution mining. Moab Salt Company projects a remaining mine life of 30 years (R. York, Moab Salt Company, personal communication, 1991).

GEOLOGY

Geological Setting

The Cane Creek anticline is one of a series of northwest-trending, salt-cored anticlines that make up the fold and fault belt of the north and northeast part of the Paradox basin (Kelley, 1958). The anticlines formed by salt diapirism and regional warping over a protracted period of time (figure 4).

Sedimentary rocks in the area of the Cane Creek anticline (figure 5) include: a lower sequence of Devonian to Mississippian carbonate rocks and minor sandstone; a middle sequence of mixed carbonate rocks and evaporates which includes the Pennsylvanian Paradox Formation; an upper sequence of Pennsylvanian and Permian sandstone, siltstone, and carbonate rocks of the Honaker Trail Formation and Cutler Group; and an uppermost sequence of Triassic to Jurassic siltstone and sandstone. The Paradox Formation is of particular interest because it contains economic potash deposits and oil and gas potential. Oil has also been produced from the Mississippian Leadville Dolomite in the general area.

The Paradox basin was an area of subsidence and accumulation of thick salt deposits in the Paradox Formation during Pennsylvanian time (about 300 million years ago). The Paradox Formation consists of evaporates, mostly halite with lesser amounts of potassium-salts, cyclically interbedded with shale and carbonate units. The formation was deposited in a subsiding basin where the flow of seawater was periodically restricted. When the basin was restricted, evaporation of seawater resulted in precipitation of gypsum, halite, sylvite, and carnallite, forming extensive evaporite deposits. Eventually salt deposition ceased in the basin and a more typical suite of marine carbonate and clastic rocks was deposited. But during this period of deposition, long-term, rhythmic changes in climate and sea level resulted in 29 salt beds being deposited (Hite, 1960, 1968). All 29 salt beds are not present everywhere in the basin. Moab Salt Company produces potash and halite from salt 5, and parts of the mine are open up to salt 3 (figure 6). "Clastic zones" which are actually composed of shale, carbonate, anhydrite, and siltstone separate the salt units and represent periods of less restricted seawater flow into the basin. The shales contain significant quantities of organic carbon from the remains of marine microorganisms. Thick, fractured shale zones, including the "Gothic," "Chimney Rock," and "Cane Creek" zones, are attractive oil and gas prospects with horizontal drilling.

The thick salt section strongly influenced the structure of younger, overlying rocks. The low-density salt tended to rise, bulging the overlying, denser strata into elongate, salt-cored anticlines (Elston and Shoemaker, 1962). Overlying rocks were fractured and locally extended by minor faults along crests of the anticlines in the fold and fault belt of the Paradox basin (figure 4). Salt sections are greatly thickened and occur at shallower depths along anticline crests compared to surrounding areas. The Moab Salt Company potash mine is positioned on the crest of the Cane Creek anticline to take advantage of the shallow, thick salt. Other significant structural elements occurring in this part of the Paradox basin include a set of prominent northwest- striking, steeply dipping faults such as the Moab fault and a less prominent set of northeast-trending lineaments and faults (Hite, 1975). Many of these surface features probably terminate above or within the salt beds of the Paradox Formation.

Geological Considerations for Oil and Gas Drilling

Fluids in the potash mine do not currently (1991) appear to be in communication with hydrocarbon-bearing units, but oil and gas activity may create fluid pathways. Determining adequate measures to protect the salt resource is difficult due to the geologic complexity of the area. The extent of potential fluid communication between the potash mine and oil and gas wells would be partially controlled by rock and fracture permeability and local fluid pressure gradients. Specific knowledge, however, is limited on characteristics of faulting and fracturing at depth, local fluid flow patterns, local flow behavior of the salt, and the exact extent of the

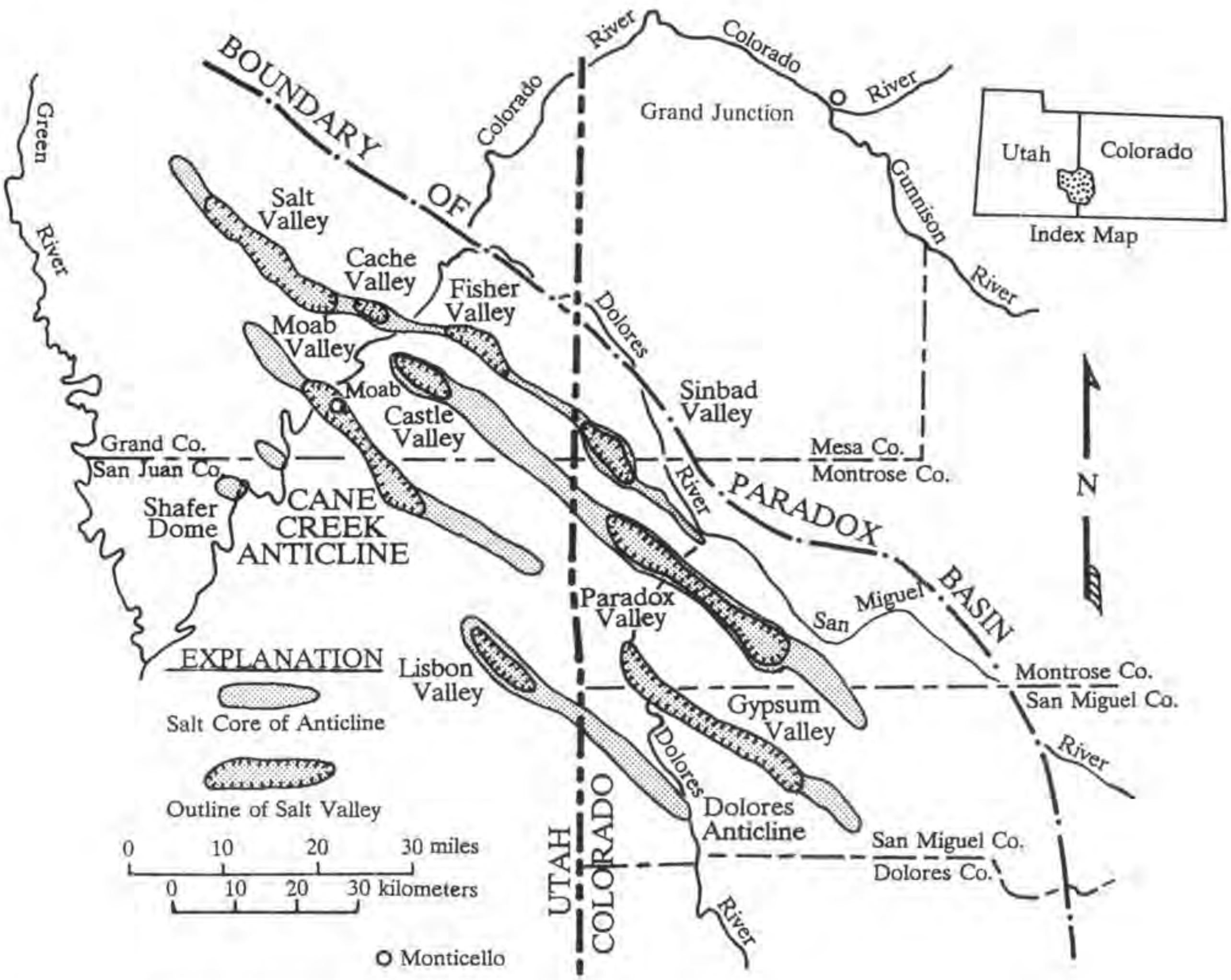


Figure 4. Salt anticlines of the Paradox basin, modified from Elston and Shoemaker (1962).

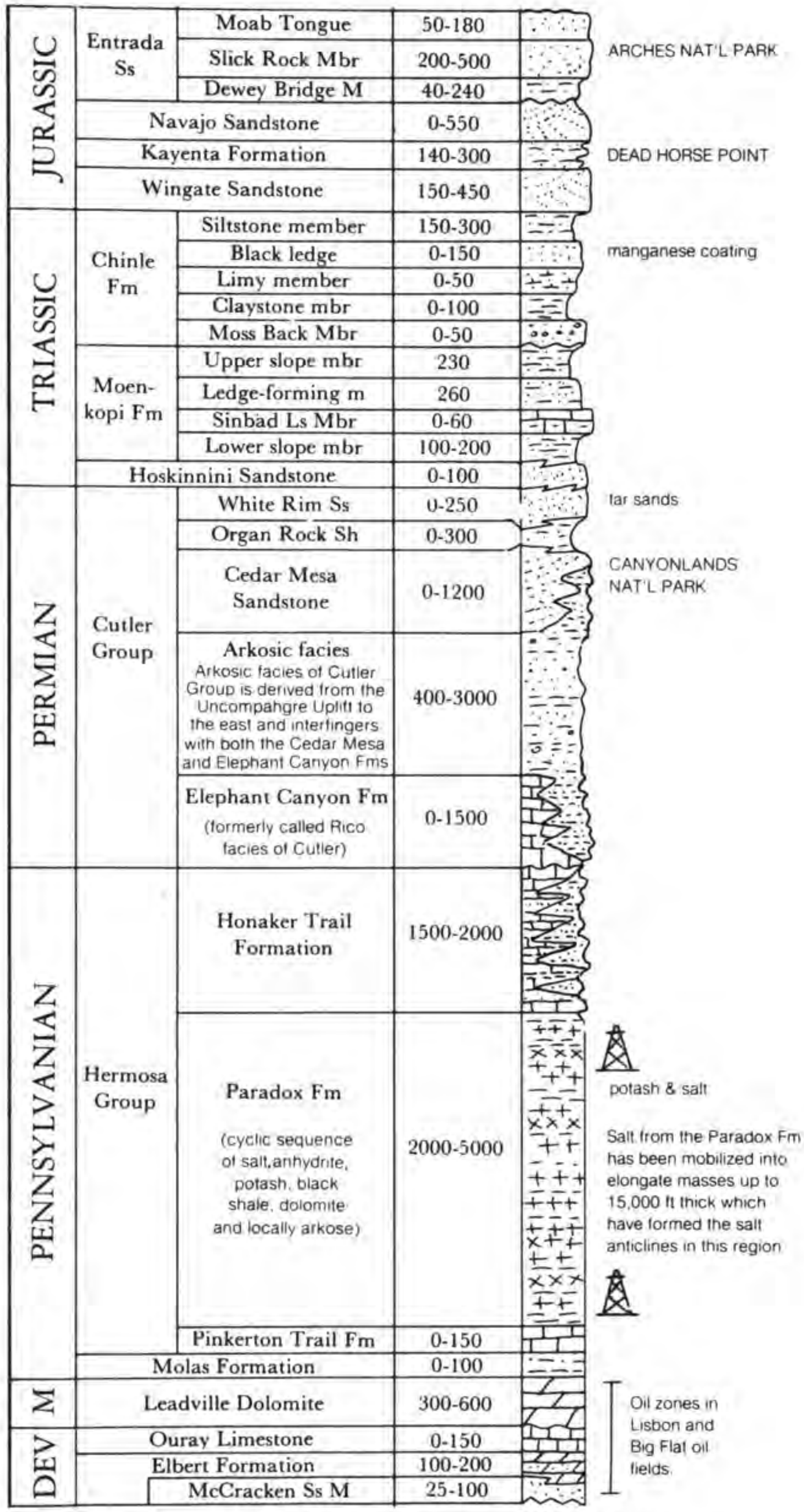


Figure 5. Stratigraphy of the Moab - Cane Creek anticline region (from Hintze, 1988).

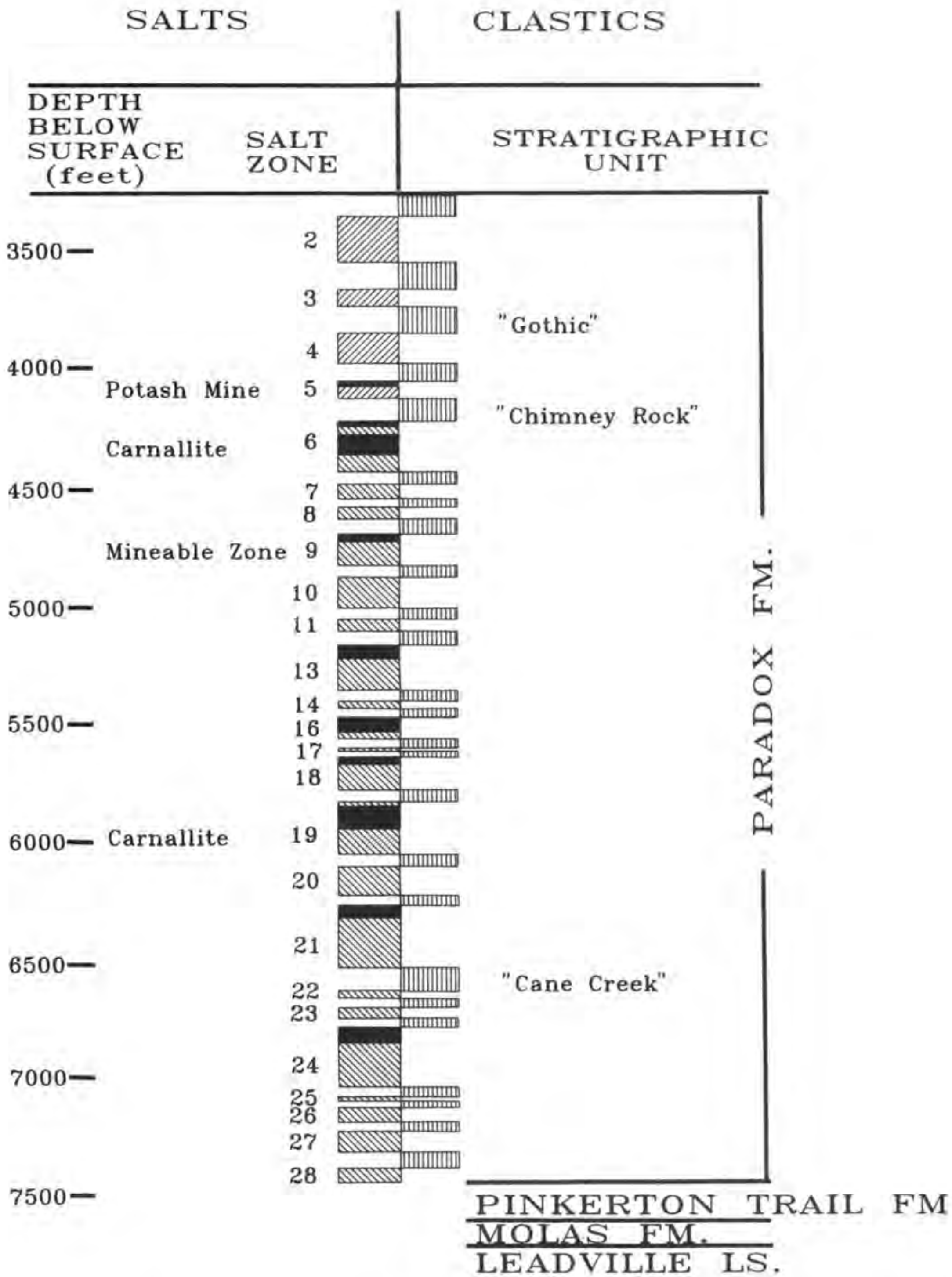


Figure 6. *Detailed salt stratigraphy of the Paradox Formation in the Cane Creek anticline area, Moab Drilling Company (Government Whitecloud No. 1) well, sec. 14, T. 26 S., R. 20 E., (modified from Hite and others, 1972). Halite units are indicated by a diagonal hatched pattern, shaly units by a vertical hatched pattern, and potash by solid black. Salt units are not always distinguishable in each well; salty units 1, 12, and 15 were not recognized at this well.*

solution cavity at the Moab Salt Company mine. Techniques to obtain needed data may be expensive, difficult to implement, and lack adequate resolution to reveal geological details at depth.

The rate of potential fluid flow between an oil and gas well and the potash mine would be proportional to rock permeability and to gradients in fluid pressure. Salt and shale, the dominant rock types in the Paradox Formation, have extremely low permeabilities (unfractured). Permeabilities of core samples taken from drill hole GD-1 at Gibson Dome, (located 25 miles [40 km] south of the Cane Creek anticline) range from less than 10^{-4} millidarcies for halite to a maximum of about 10^{-2} millidarcies for shale and carbonate rocks in clastic sequences in the Paradox Formation (table 1). Most samples from the Cutler Group and Honaker Trail Formation in the same core have permeabilities ranging from 10^{-4} to 10^{-2} millidarcies, but permeabilities can be as high as $\sim 10^{2}$ millidarcies.

Huntoon (1979) indicated that faults, joints, and bedding-plane partings may substantially increase the permeability of rocks in the Cane Creek area. Bulk permeabilities for fractured rock, estimated from drill-stem tests in the area, are mostly between 10^{-2} and 10^{2} millidarcies (table 1). Permeability for jointed shale and carbonate rocks from the "Cane Creek" zone (in the 27-1 well) is calculated at 39 millidarcies (Columbia Gas Development, 1991), which is about four orders of magnitude greater than the estimated permeability for unfractured shale in the area.

Effects of faulting on permeability and fluid flow can be even greater, as illustrated by the accidental flooding of the potash mine in 1970. The salt company planned to drill several water-injection wells into the underground workings and convert to solution mining. The first injection well drilled along the crest of the Cane Creek anticline probably intersected a fault system above the Paradox Formation that is connected to an aquifer (Huntoon,

Table 1. Summary of estimated permeabilities.

Location	Formation	Matrix Permeability (md)	Bulk Permeability (md)
Well GD-1[1]	Cutler Group	mostly 10^{-4} to 10^{1} maximum of 90	10^{-3} to 30
Cane Creek anticline[2]	Cutler Group/Honaker Trail Fm. - faulted	---	$\sim 10^{4}$
Well GD-1[1]	Honaker Trail Fm.	mostly $\sim 10^{-4}$ maximum of 20	10^{-2} to 1
Well GD-1[1]	Paradox Fm. - halite	$< 10^{-4}$ to $3x10^{-4}$	---
	Paradox Fm. - clastics	$2x10^{-4}$ to 4x10-2	$2x10^{-2}$ to 7
Kane Springs Federal 27-1 Well[3]	Paradox Fm. - "Cane Creek" zone	---	39
Well GD-1[1]	Leadville Dol.	$4x10^{-3}$ to 2	1 to 30
Lisbon field[4]	Leadville Dol.	---	average 20, (variable)

Note: Permeability listed in millidarcies (md), 1 md = 10^{-6} cm/s. Data sources for table: (1) Thackston and others (1984), (2) Huntoon (1986), (3) Columbia Gas Development (1991), and (4) Clark (1978).

1986). Continued drilling of the well into the mine allowed communication between the fault system and the mine. The resulting massive infiltration of 800 million gallons (3.0 x 10^6 m^3) of water, at a rate of 39,700 gpm (2.5 m^2/s), completely filled the underground workings in a period of two weeks. Huntoon (1986) later estimated a minimum transmissivity of 4 x 10^5 gal/day/ft (4,969 m^2/d) for an aquifer 1,000 feet (305 m) thick, which corresponds to an average permeability of $\sim 10^4$ millidarcies for the faulted rocks overlying the Paradox Formation.

Characteristics of fault and fracture networks in the area, including fracture orientation, size, spacing, connectivity, and hydraulic conductivity of individual faults, have a major control on fluid flow. Mapping by Huntoon (1985) and Doelling, Yonkee, and Hand (in prep.) delineates the nature of surface faults and joints. A set of northwest-striking faults is spatially limited to the region of the anticline. Some faults display bleached zones recording significant permeability and flow of reducing fluids within the fault system. The depth of these faults is uncertain, but they probably terminate above the Paradox Formation (Huntoon, 1985). A dominant set of subvertical joints strikes to the northwest (figure 7) and spacing between joints ranges from 1 to 10 feet (0.3 to 3 m) over most of the Cane Creek anticline. A secondary set of subvertical joints strikes to the northeast and spacing between fractures is generally greater than 10 feet (3 m). Minor joint sets are locally developed.

Faults at depth can form major conduits for fluid communication between oil and gas wells and the potash mine, and fluid flow is highly sensitive to changes in properties of fault and fracture networks. The location, orientation, and physical properties of faults at depth are poorly constrained throughout most of the Moab area. Huntoon (1985) described a series of gently dipping, north-northwesterly striking faults with minor reverse slip within salt and clastic units in parts of the potash mine. Microearthquakes correlated with pumpdowns of the mine indicated slip along minor (<300 feet [100 m] long) steeply dipping, northwest- and northeast-striking faults at depths less than 0.6 mile (1 km) (Wong and others, 1987). Most local magnitudes are less than 1.0 (Richter magnitude) and estimated stress drops are less than 1 bar. The physical properties of fractures and faults at depth may also change due to changes in stress, changes in fluid pressure, and fracture healing.

Gradients in fluid pressure also control rates of fluid flow. The seepage velocity (average linear velocity), V, of fluid is given by $V = Kdh/dl\ \Theta$ where K is hydraulic conductivity, which is proportional to permeability, dh/dl is the hydraulic gradient , and Θ is the rock porosity. The regional horizontal hydraulic gradient in the Cutler Group and upper Honaker Trail Formation is about 0.013, reflecting gentle topographic slopes toward the Colorado River (Woodward-Clyde, 1982). Gradients in the Paradox Formation and underlying rocks are probably variable, reflecting localized overpressuring. Fluid pressures in these lower rocks may vary from about hydrostatic to 100 to 200 bars in excess of hydrostatic pressure (table 2). Blowouts in wells have also been reported from the Cane Creek and Shafer Canyon fields, reflecting overpressuring in clastic zones in the Paradox Formation. Fluids in the potash mine are at or less than hydrostatic pressure, but future drilling in the area could penetrate overpressured zones.

Times required to transport fluids an average distance of 0.6 mile (1 km), using ranges in permeability and hydraulic gradient, are given in table 3. Transport time is highly variable. It can be short for areas of high hydraulic conductivity and permeability, such as faulted and overpressured areas.

The extent and location of salt dissolution in the potash mine workings is uncertain. Moab Salt Company estimates that dissolution of salt has extended about 20 feet (6 m) into the walls of the old underground workings. Phillips (1975), however, indicates that dissolution is expected to be uneven. Preferred orientations of fractures in salt or adjacent clastics, variations in abundances of halite and potassium salts, and differential fluid flow could all favor heterogeneous salt dissolution.

Flowage of salt adjacent to drill holes may increase stresses leading to failure of well casing. Rates and directions of salt flowage are difficult to predict and depend on subtle changes in temperature, in-situ stress, lithology, and fluid characteristics.

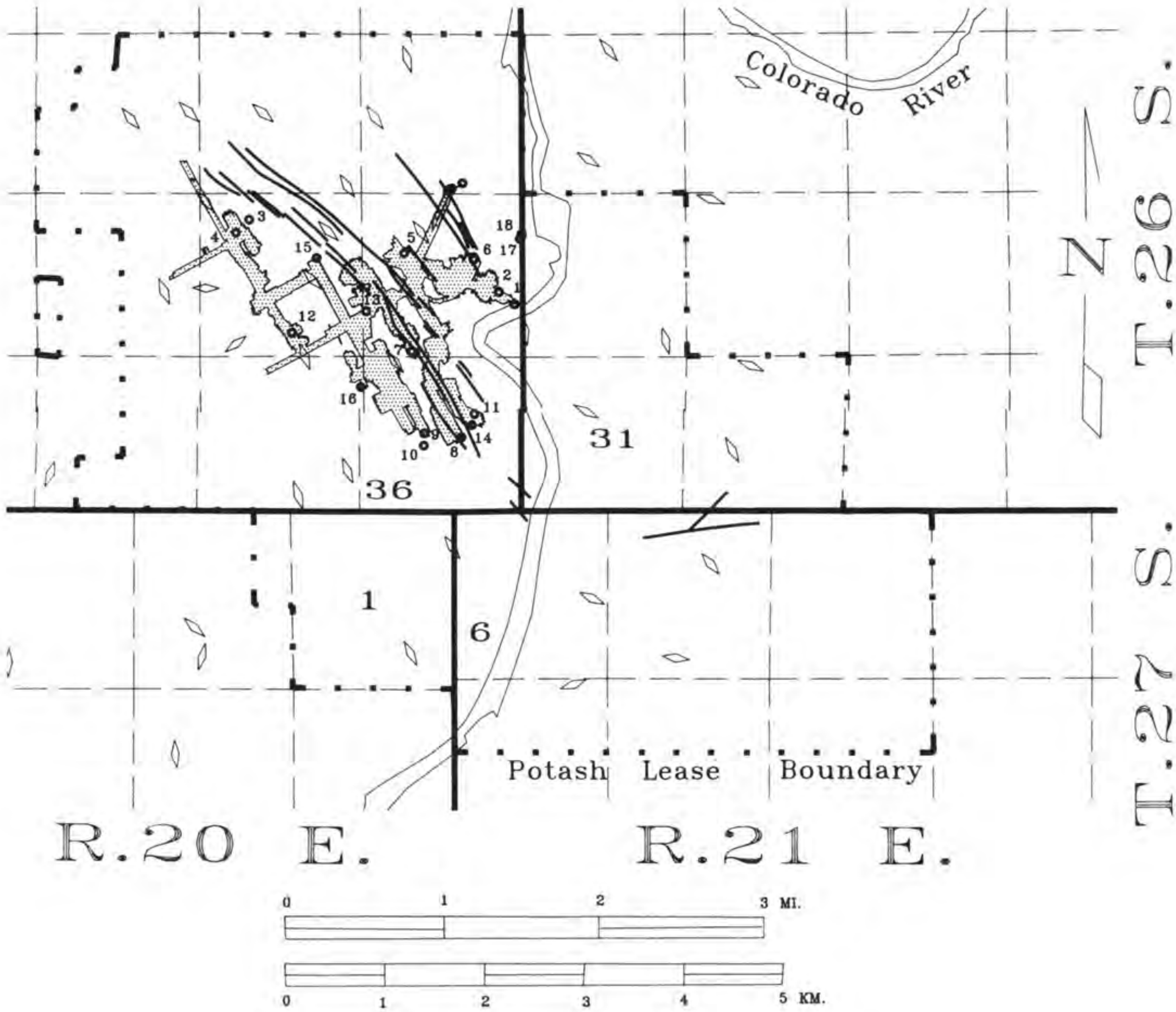


Figure 7. Moab Salt Company subsurface mine workings, brine wells, and local surface faults and fractures; brine wells appear as numbered circles, average strikes of fractures are shown as oriented diamonds (modified from Huntoon, 1985).

Table 2. Summary of fluid pressures.

Location	Formation	Depth (ft)	Fluid Pressure(bars)	Excess Pressure(bars)
Long Canyon field[2]	Paradox Fm. "Cane Creek" zone	7054	345	130
Kane Springs 27-1 Well[3]	Paradox Fm. "Cane Creek" zone	7251	424	204
Bartlett Flat field[4]	Leadville Dol.	7645	386	156
Lisbon field[1]	Leadville Dol.	7776	192	0

Note: Excess pressure also indicated by blowouts reported from intervals in the Paradox Fm. in the Cane Creek field (Smith, 1978a) and in the Shafer Canyon field (Smith, 1978d). Data sources for table: (1) Clark (1978), (2) Smith (1978b), (3) Columbia Gas Development (1991), (4) Smith (1978c).

Table 3. Approximate times for fluid transport.

Hydraulic conductivity (cm/s) / **Permeability (md)**	$K = 10^{-2}$ / $k = 10^4$	$K = 10^{-4}$ / $k = 10^2$	$K = 10^{-6}$ / $k = 1$
Hydraulic Gradient			
dh/dl = 1.0	1.2 days	.3 year	30 years
dh/dl = 0.1	12 days	3 years	300 years
dh/dl = 0.01	120 days	30 years	3000 years

Note: The average distance (d) that a fluid travels is given by d = vt, where v is velocity and t is time. Calculated for porosity (Θ) = 0.01 and distance (d) = 1000 m; using the relationship, time = $d\Theta/K(dh/dl)$. For Cutler Group and Upper Honaker Trail Formation dh/dl = .0103 and k = 20 md (Woodward-Clyde Consultants, 1982).

POTENTIAL IMPACTS OF OIL AND GAS DEVELOPMENT ON POTASH MINING

Oil and gas activity near the Moab Salt Company mine has the potential to affect the present potash and halite production, and future potash reserves. Possible contamination of fluids in the mine, or possible modification of the fluid-flow system in the mine due to oil and gas activity should be considered in development of the area. Potential impacts could occur during drilling or production and are partly related to fluid flow along fracture networks, drill holes, and between overpressured and normal to underpressured horizons. Some of the potential impacts are listed here.

During Oil and Gas Drilling

1. Loss of drilling fluids from the well bore into fractured clastic and adjacent potash zones could locally contaminate potash resources.

2. Drilling into pre-existing fracture systems that are in communication with the mine may cause accidental modification of fluid circulation into or out of the potash mine.

3. Weighted drilling fluid could hydrofracture the salt and adjacent clastics, creating possible pathways for fluid circulation into or out of the potash mine.

4. A drill hole may encounter a high-pressure zone in the lower Paradox Formation resulting in a blowout and potential flow of oil or brines into lower pressure zones in or around salts 5 or 9. Such a drill hole could be shut-in for days or weeks.

During Oil and Gas Production

1. Fracture stimulation, using fluid and sand injection to improve hydrocarbon recovery, could result in communication between the potash and crude oil by fracture propagation.

2. Corrosion and resulting failure of cement and well casings by salt and brines could result in crude oil contamination of the potash zones and/or mine.

3. Salt flowage may collapse oil well casings and could result in contamination of the potash zones and the mine.

4. Microseismicity in the area may produce fractures, increasing permeability and allowing interaction with an oil and gas well not presently in communication with the mine. The small-magnitude earthquakes in the area present a limited hazard of direct damage to oil well casing and potential release of hydrocarbons.

OPTIONS FOR ISSUING OIL AND GAS LEASES IN POTASH AREAS

Several options for leasing and future development are presented below. Specific recommendations are not made due to the limited amount of geologic and engineering data available.

1. Do not issue oil and gas leases on active potash leases. This option would assure Moab Salt Company that their operations and future ore reserves are not at risk due to oil and gas activity.

2. Issue restricted oil and gas leases where active potash leases exist.

   A. Issue restricted oil and gas leases that do not allow occupancy of the surface or subsurface. Issuing oil and gas leases without allowing occupancy allows an operator to drill adjacent to the border of the potash lease and include the restricted lease in a participating or spaced area. Without the restricted lease, it is necessary to drill farther from the potash lease to prevent drainage of hydrocarbons from beneath it.

   B. Issue restricted oil and gas leases that do not allow occupancy from the surface down through salt 10. This would prevent drilling through potash 5 and 9 within the potash lease area, but would allow directional drilling for deeper oil zones under it.

3. Issue oil and gas leases and allow drilling on potash leases with precautionary stipulations (in addition to the standard Utah Division of Oil, Gas and Mining regulations - appendix B) such as:

   A. Prohibit drilling within a critical vertical and horizontal distance (a buffer zone) of the potash workings.

   B. Site drilling locations to avoid possible interaction with known faults.

   C. Restrict fracture stimulation within a buffer zone.

   D. Require casing and cement to withstand the pressure and corrosive effects of the salt.

   E. Drill to salt 10 then pressure test the salt section above salt 10 before proceeding.

   F. Drill into or through salt 10 and set casing before proceeding.

   G. Require two strings of casing to be set through salt 10.

Specific well locations would be considered on a case-by-case basis (this is standard procedure for all locations now) and concerns by Moab Salt Company could be addressed at that time.

Concluding Remarks

The Utah Geological Survey feels that option 3 provides the best opportunity to maximize return on state potash lands. Implementing all or part of the precautionary stipulations in addition to the standard Utah Division of Oil, Gas and Mining regulations on a case-by-case basis should allow for adequate protection of potash development in the area. The Utah Geological Survey does not feel there are sufficient data to recommend a specific buffer zone between oil and gas drilling and the potash mine. Geological and engineering data and analyses by specialists may be helpful in deciding on a buffer zone. Horizontal and vertical buffer zones need to be considered. Data from Moab Salt Company on the location, trend, and fluid flow through fractures noted during underground mining may provide part of the answer. Seismic, rock mechanic, reservoir engineering, and geohydrologic data from the oil industry may also be needed.

ACKNOWLEDGMENTS

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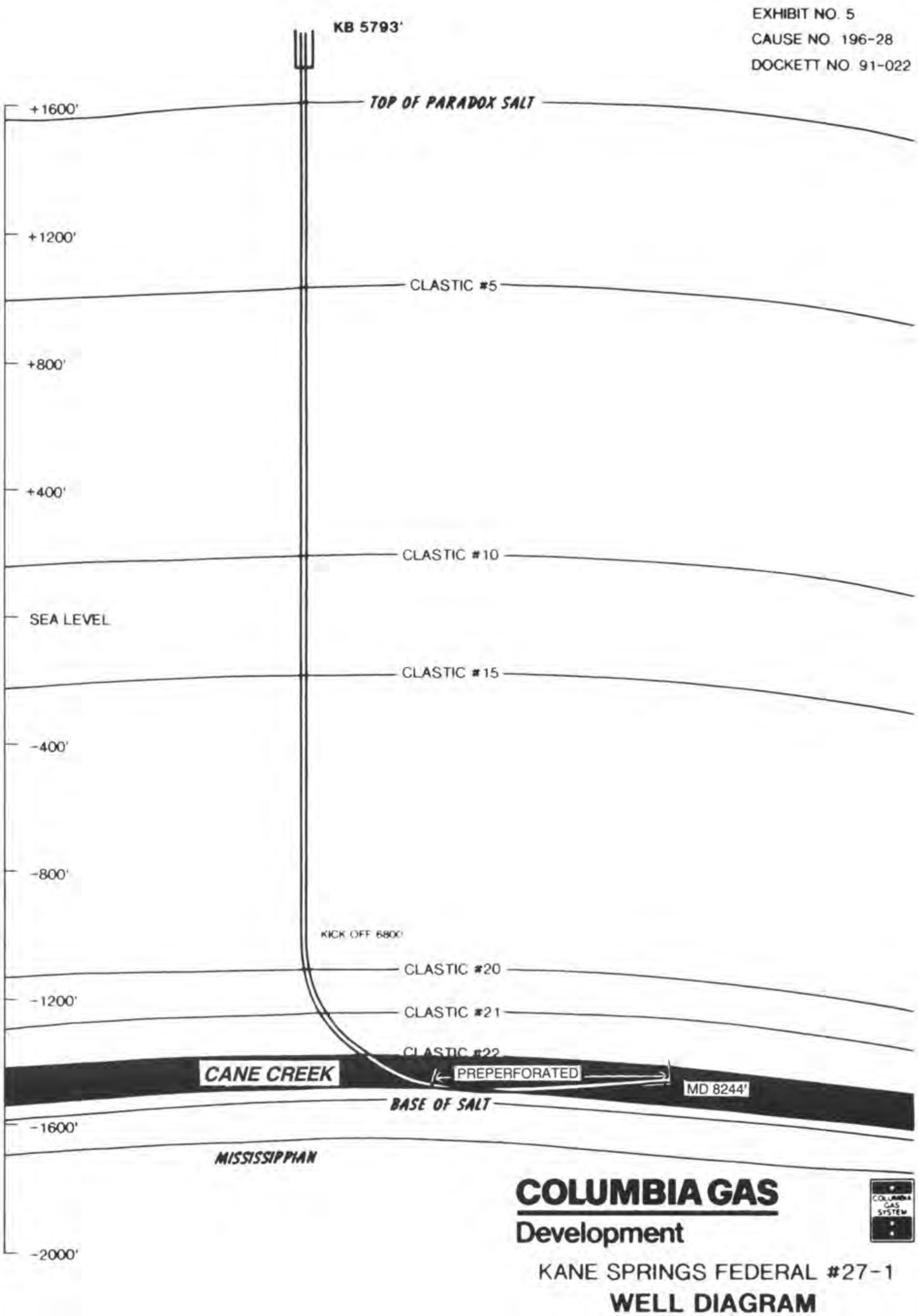
APPENDIX A

EXHIBITS SUBMITTED BY COLUMBIA GAS DEVELOPMENT FOR THE HEARING BEFORE THE BOARD OF THE UTAH DIVISION OF OIL, GAS, AND MINING

IN THE MATTER OF THE REQUEST OF COLUMBIA GAS DEVELOPMENT CORPORATION TO FLARE OR VENT GAS FROM THE KANE SPRINGS FEDERAL NO. 27-1 WELL LOCATED IN SECTION 27, T. 25 S., R. 19 E., SLM, GRAND COUNTY, UTAH; REQUEST FOR EXCEPTION TO RULE R615-3-20

CAUSE NO. 196-28, DOCKET NO. 91-022.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CAUSE NO. 196-28
DOCKETT NO. 91-022
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TOP OF PARADOX SALT
+1600'
+1200'
CLASTIC #5
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+400'
CLASTIC #10
SEA LEVEL
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-400'
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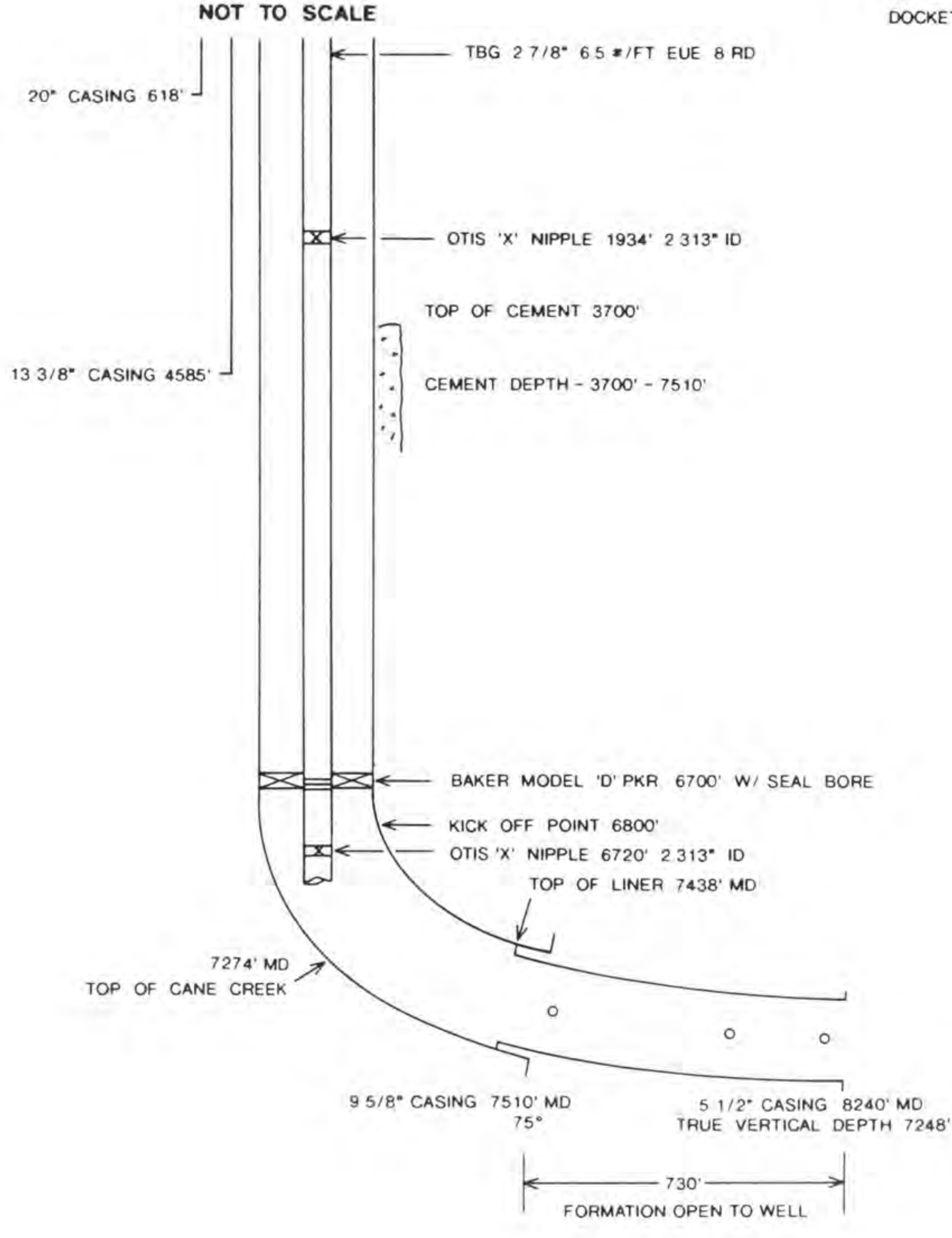
KICK OFF 6800'
CLASTIC #20
-1200'
CLASTIC #21
CLASTIC #22
CANE CREEK
PREPERFORATED
MD 8244'
BASE OF SALT
-1600'
MISSISSIPPIAN
-2000'
COLUMBIA GAS
Development
KANE SPRINGS FEDERAL #27-1
WELL DIAGRAM

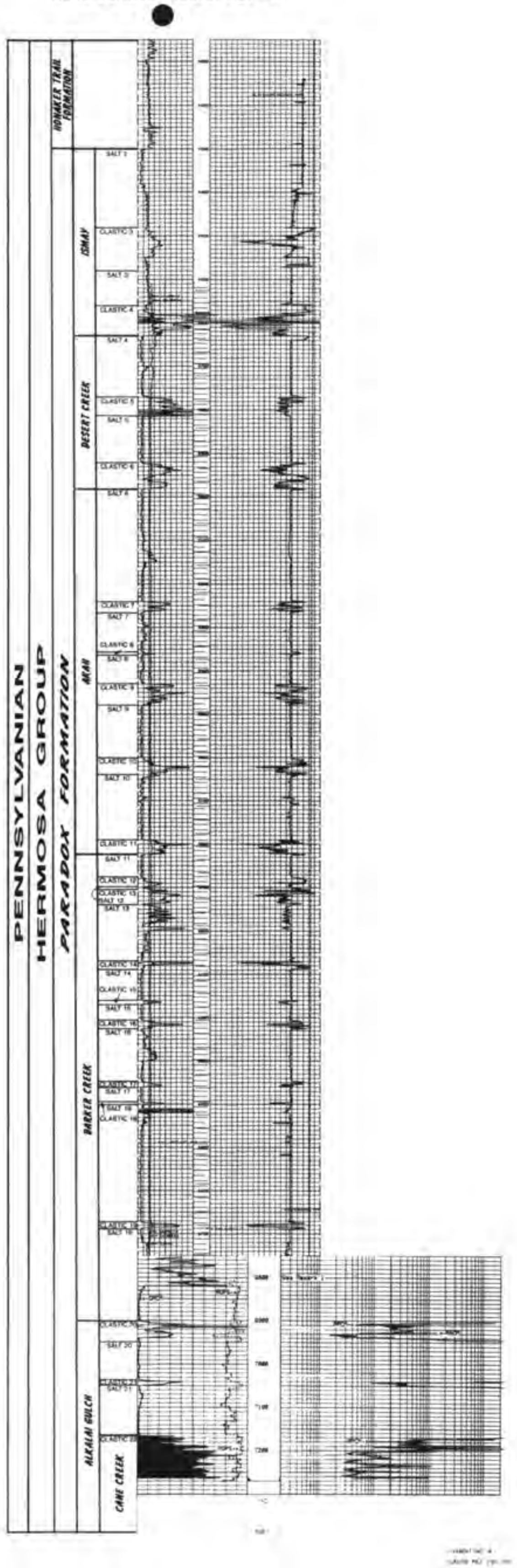
EXHIBIT NO 6
CAUSE NO 196-28
DOCKETT NO 91-022



COLUMBIA GAS
Development

KANE SPRINGS FEDERAL #27-1
WELL DIAGRAM

C.G.D.C.
Kane Springs Federal #27-1



APPENDIX B

DRILLING SUMMARY FOR THE COLUMBIA GAS DEVELOPMENT CORPORATION KANE SPRINGS FEDERAL 27-1 HORIZONTAL WELL AND A SUMMARY OF THE OIL AND GAS FIELDS OF THE AREA PRODUCING FROM THE PARADOX FORMATION

KANE SPRINGS FEDERAL 27-1 WELL

Surface Location:	SE1/4 NW1/4 SE1/4, sec. 27, T. 25 S., R. 19 E. (800 fsl, 1930 fel) Grand County, Utah Drilled in the abandoned Bartlett Flat field
Bottom Hole Location:	200 fnl, 1350 fel
Drilling History:	Spudded: 12/31/90 est., TD reached: 3/15/91, Completed: 4/1/91 est.
Initial Potential:	914 bbl oil, 290 mcf gas/day (10/64 in choke at 3,460 psi)
One Hour Test:	2,302 bbl oil, 627 mcf gas/day, 14/64 in choke
Producing Interval:	"Cane Creek" zone of the Paradox Formation.
Total Depth:	8,244 ft (2,512.8 m) mechanical depth (MD), 7,248 ft (2,209.2 m) true vertical depth (TVD)
Horizontal Leg:	966 ft (294.4 m) est. with 730 ft (222.5 m) preperforated liner.

OIL FIELDS IN THE AREA OF THE CANE CREEK ANTICLINE

Bartlett Flat Field:	Discovery date: 1961 Discovery well: Pure Oil Big Flat 5 Productive zone: "Cane Creek" zone of the Paradox Formation Date abandoned: 1965 Cumulative prod.: 39,393 bbl oil, 22,051 mcf gas Bottom-hole pressure: 5,600 psig (pounds per square inch) at 7,250 ft (2209.8 m), .77 psig/ft
Cane Creek Field:	Discovery date: 1925 Discovery well: Midwest Exploration - Utah Southern #1 Shafer Productive zone: Paradox Formation Date abandoned: 1958 Cumulative prod.: 1,887 bbl oil, 25,000 mcf gas (?)
Long Canyon Field:	Discovery date: 1962 Discovery well: Southern Natural Gas Long Canyon 1 Productive zone: "Cane Creek" zone of the Paradox Formation Cumulative prod.: 927,972 bbl oil (Dec. 1990), 993,315 mcf gas, 112,131 bbl water Bottom hole pressure: 5,000 psig at 7,075 ft (2,156.5 m), 0.71 psig/ft. approx.

Lion Mesa field:

Discovery date: 1980
Discovery well: Megadon Energy Lion Mesa 27-1A Federal
Productive zone: "Cane Creek" zone of the Paradox Formation
Cumulative prod.: 1,596 bbl oil (Dec. 1990), 0 mcf gas, 8 bbl water
Bottom-hole pressure: 3,500 psig at 7,706 ft (2,348.8 m), .45 psig/ft

Shafer Canyon Field:

Discovery date: 1962
Discovery well: Southern Natural Gas USA 1
Productive zone: "Cane Creek" zone of the Paradox Formation
Date abandoned: 1967
Cumulative Prod.: 67,556 bbl of oil, 63,807 mcf gas, 1408 bbl water

Data sources: Columbia Gas Development, Kane Springs Unit, 1991: Quigley, 1978: Smith, 1978a,b,c,d: Stowe, 1972: Utah Division of Oil, Gas and Mining, records.

APPENDIX C

UTAH OIL AND GAS CONSERVATION GENERAL RULE R615-3-28 (DESIGNATED POTASH AREAS, UTAH DIVISION OF OIL, GAS, AND MINING)

1. In any area designated as a potash area, either by the board, the Division of State Lands and Forestry or an appropriate federal agency, all wells shall be drilled, cased, cemented, and plugged in accordance with the rules and orders of the board. The following minimum requirements and definitions shall also apply to the drilling, logging, casing, and plugging operations within the Salt Section to protect against migration of oil, gas, or water into or within any formation or zone containing potash. As used in this rule, Salt Section shall mean the Paradox Salt Section of Pennsylvanian Age.

2. Any drilling media used through the Salt Section shall be such that sodium chloride is not soluble in the media at normal temperatures.

3. Gamma ray-neutron, gamma ray-sonic or other appropriate logs shall be run promptly through the Salt Section. One field copy of the log through the Salt Section shall be submitted to the division within ten days, or upon the request of the division, whichever is the earlier.

4. A directional survey shall be run from a point at least 20 feet below the Salt Section to the surface. The survey shall be filed with the division prior to completion or plugging and abandonment of the well. " In addition to the requirements of the R615-3-8, any casing set into or through the Salt Section shall be cemented solidly through the Salt Section above the casing shoe.

5. In addition to the requirements of the R615-3-8, any casing set into or through the Salt Section shall be cemented solidly through the Salt Section above the casing shoe.

6. Any cement used in setting casing or in plugging which comes in contact with the Salt Section shall be of such chemical composition as to avoid dissolution of the Salt Section and to provide weight, strength, and physical properties sufficient to protect uphole formations and prevent blowouts or uncontrolled flows.

7. If a well is dry, cement plugs at least 200 feet in length shall be placed across the top and the base of the Salt Section, across any oil, gas or water show, and across any potash zone. Plugs shall not be required inside a properly cemented casing string. The division shall approve the location of the plugs after examining the appropriate logs, drilling and testing records for the well. No well shall be temporarily abandoned with open hole in the Salt Section.

8. The division may inspect the drilling operations at all times, including any mining operations that may affect any drilling or producing well bores. A potash owner, if contributing by agreement to the logging and directional survey costs of a well, may inspect the well for compliance with this rule.

9. Before commencing drilling operations for oil or gas on any land within designated potash area, the operator shall furnish by registered mail, a copy of the APD, together with the plat or map required under R615-3-4, to all potash owners and lessees whose interests are within a radius of 2,640 feet of the proposed well.

10. After proper notice and hearing, the board may modify this rule for a particular well or area by requiring that greater or lesser precautions be taken to prevent the escape of oil, gas, or water from one stratum into another. The board may also expand or contract from the designated potash areas.

APPENDIX D

STATE LAND BOARD RULE R632-20-38 AMENDING OR RESCINDING LEGISLATIVE WITHDRAWAL OF LANDS FOR POTASH WITHDRAWAL (10/01/91)

1. **AUTHORITY**
This rule is adopted pursuant to Section 65A-1-2 to implement Section 65A-6-15 permitting amendment or rescission of the withdrawal of potash lands from oil and gas leasing.

2. **POLICY**
The Board finds that oil and gas potential in the withdrawn area may be significant and that the withdrawal should be lifted upon terms and stipulations which address the significant conflicts with other mineral and surface uses and to accommodate multiple use of the land without jeopardy to the trust interests in mineral development.

3. **REQUIREMENTS AND PROCEDURES**
The withdrawal of land from oil and gas leasing imposed by Section 65A-6-13-14, shall be modified or rescinded and lands made available for oil, gas, and hydrocarbon leasing by the division subject to and upon the issuance of a written finding of the following conditions:

(a.) The modification or rescission of the withdrawal shall be determined to be in the best interest of the school and institutional trust beneficiaries and determined after consultation with the Division of Oil, Gas, and Mining and the Utah Geological Survey, to be susceptible of prudent resource development.

(b.) The lands that are subject to modification or rescission shall be identified by legal description in the record.

(c.) Notice of the proposed action shall have been given to all lessees of the affected lands and opportunity shall have been provided for public comment on the proposed action.

(d.) In offering lands for lease, the division shall make disclosure of possible development conflicts with other mineral development and multiple uses and may provide, consistent with trust obligations, for terms and stipulations as may be appropriate to accommodate prudent multiple mineral development of the lands and to accommodate protection of the wildlife, recreation, and park values.

4. The lands that become available for leasing as a result of a modification or rescission of the withdrawal shall not be leased except at the discretion of the division and in a manner consistent with the conditions of the modification or rescission and in a manner determined to take advantage of the market conditions.

"CANE CREEK" EXPLORATION PLAY AREA, EMERY, GRAND, AND SAN JUAN COUNTIES

by

Craig D. Morgan
Utah Geological Survey

OPEN-FILE REPORT 232 **MARCH 1992**
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah

Craig D. Morgan
Utah Geological Survey

This open-file report is a series of maps and cross sections to aid in evaluating the oil and gas exploration potential of the Pennsylvanian Paradox Formation, with special emphasis on the "Cane Creek" shale zone. The mapped area covers T. 24 - 26 S., R. 17 - 21 E., Emery and Grand Counties, and T. 26 - 30 S., R. 19 - 24 E., San Juan County. The scale of the maps is 1:500,000. The cross sections have a vertical scale of 1 inch equals 400 feet, and a horizontal scale of 1 inch equals approximately 7,000 feet. Table 1 lists the wells that are used as data points for the mapping.

During Pennsylvanian time the Paradox Formation was deposited in a large, continually subsiding basin. The basin subsided along a series of northwest-trending faults. The nearly equal rates of subsidence and sedimentation produced a thick sequence (greater than 6,000 feet) of cyclic carbonate, black organic-rich shale, and evaporite units deposited in a marginal marine to sabkha environment. The Paradox Formation consists of a maximum of 29 recognized cycles of evaporation and precipitation. These cycles were assigned numerical values by Hite (1960), starting with cycle 1 at, or near, the top of the formation and cycle 29 at, or near, the base. A typical cycle consists of a lower clastic zone, overlain by a generally thick (100+ feet) upper evaporite zone of anhydrite, halite, and occasionally potassium and magnesium salts. The clastic zone consists of organic-rich black shale and carbonate rocks (mostly dolomite) with thin interbedded anhydrite. The top of each cycle is an irregular surface thought to represent dissolution of salt by less saline normal seawater. The shale zones are often fractured and contain hydrocarbons. The "Cane Creek" is the thickest shale zone, and oil and gas have been produced from it for many years.

THE MAPS ARE:

MAP A: INDEX MAP

The index map shows state and national parks, major rivers, oil and gas fields, the outline of federal units, and the locations of proposed "Cane Creek" test wells. The locations of all drill holes that penetrated the Paradox Formation are shown with total depth drilled and formation at total depth.

MAP B: STRUCTURE CONTOUR MAP; Top Of The Paradox Formation

Structure contours are drawn on top of the Paradox Formation, which is defined as the top of the shale unit overlying cycle 2, or cycle 1 when present. The contour interval is 500 feet. All control wells are shown with the elevation of the top of the Paradox Formation as picked from geophysical logs.

MAP C: STRUCTURE CONTOUR MAP; Base Of The Lowest Salt, Paradox Formation

Structure contours are drawn on the base of the lowest salt in the Paradox Formation, equivalent to the saline facies or middle unit of the Paradox Formation (Hite, 1960). The contour interval is 500 feet. All control wells are shown with the elevation of the base of the lowest salt as picked from geophysical logs.

MAP D: THICKNESS MAP; Top Of Highest Salt To Base Of Lowest Salt, Paradox Formation

Values for the thickness contour map were determined from geophysical logs of drilled holes, and extend from the top of the first salt encountered to the base of the last salt. The mapped interval is equivalent to the saline facies of Hite (1960). The contour interval is 1,000 feet.

MAP E: THICKNESS MAP; "Cane Creek" Shale Of The Paradox Formation

Values for the thickness contour map were determined from geophysical logs of drilled holes, and include the entire "Cane Creek" interval. The "Cane Creek" interval consists of carbonate mudstone, organic-rich shale, siltstone, and interbedded anhydrite occurring in the basal portion of cycle 21. The contour interval is 20 feet.

MAP F: MAP OF NORTHWEST-TRENDING SURFACE STRUCTURES

This map displays the northwest axial trend of major anticlines and synclines, faults, and vertical to near-vertical joints and fractures. The data were compiled from published surface geologic maps, (Bates, 1955a,b&c; Detterman, 1955a&b; Doelling and others, 1991; Hinrichs and others, 1971a&b; Huntoon and others, 1982; Platt, 1955; Sable, 1955a&b, 1956; Smith and others, 1968-1969; and Tolbert, 1956).

MAP G: MAP OF NORTHEAST-TRENDING SURFACE STRUCTURES

This map displays the northeast axial trend of major anticlines and synclines, faults, and vertical to near-vertical joints and fractures. The data were compiled from published surface geologic maps, (Bates, 1955a,b&c; Detterman, 1955a&b; Doelling and others, 1991; Hinrichs and others, 1971a&b; Huntoon and others, 1982; Platt, 1955; Sable, 1955a&b, 1956; Smith and others, 1968-1969; and Tolbert, 1956).

MAP H: OIL AND GAS SHOWS; Paradox Formation

Oil and gas shows from any cycle in the Paradox Formation are plotted with the corresponding cycle number of Hite (1960). Production and shows from the "Cane Creek Shale" are prominently displayed. A show is defined as a recovery of oil and/or flow of gas during an open-hole or production test and any reported blowout. Sample shows are not displayed on this map.

CROSS SECTIONS:

CROSS SECTION A - A'

Cross section A-A' is a west to east line using geophysical logs from Sunburst 1 and Big Flat 1 (Big Flat field), to Skyline 8-44 and Long Canyon 1 (Long Canyon field). The vertical section is from the top of cycle 19 of the Paradox Formation through the top 50-100 feet of Leadville Limestone. The cross-section datum is the top of the "Cane Creek Shale."

CROSS SECTION B - B'

Cross section B-B' is a northwest to southeast line using geophysical logs from Bartlett Flat, Big Flat, Shafer Canyon, Lion Mesa, and Wilson Canyon fields. The vertical section is from the top of cycle 19 of the Paradox Formation through the top 50-100 feet of Leadville Limestone. The cross section datum is the top of the "Cane Creek Shale."

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Table 1. Listing of wells shown on the maps in Open File Report 232. Ls=Limestone, Dolo=Dolomite and Qtz=Quartzite.

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T24S R17E Sec 1	Federal 1	Shell Oil	9,143	Leadville Ls
T24S R17E Sec 26	Ten Mile 1-26	Megadon Energy	8,615	Leadville Ls
T24S R18E Sec 27	Federal 1-27	Ladd Petroleum	9,443	Leadville Ls
T24S R19E Sec 22	Klondike 2	Mountain Fuel Supply	7,830	Paradox
T24S R20E Sec 11	State 12-11	Tiger Oil	12,357	Elbert
T24S R20E Sec 16	Salt Valley 1	Ladd Petroleum	11,330	Elbert
T24S R20E Sec 36	State 1	Union Oil	7,534	Paradox
T25S R17E Sec 20	Bowknot 43-20	Superior Oil	7,225	Lynch Dolo
T25S R18E Sec 10	Federal 1	McRae Oil & Gas	8,784	Leadville Ls
T25S R18E Sec 10	Kane Sprgs 10-1	Columbia Gas	Location	Paradox
T25S R18E Sec 20	Federal 1-20	Shell Oil	7,856	Leadville Ls
T25S R18E Sec 20	Green Rvr 20-1	Chevron USA	Location	Paradox
T25S R18E Sec 21	Federal 1-21	Shell Oil	6,875	Paradox
T25S R18E Sec 21	Shenandoah - Bowknow 1	Reads & Stevens	6,915	Paradox

Table 1

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T25S R18E Sec 30	Federal - Bowknot 1	Federal Oil	7,574	Leadville Ls
T25S R18E Sec 35	Shell - Quintana - Fed	Shell Oil	8,140	Leadville Ls
T25S R19E Sec 6	Long Canyon 1-6	Coors Energy	Location	Paradox
T25S R19E Sec 11	Long Canyon 1-11	Coors Energy	Location	Paradox
T25S R19E Sec 26	Big Rock - Bartlett 1	General Crude Oil	8,875	Leadville Ls
T25S R19E Sec 27	Big Flat 6	Calvert Western Expl.	7,322	Paradox
T25S R19E Sec 27	Big Flat 5	Pure Oil	7,243	Paradox
T25S R19E Sec 27	Husky 1	Supron Energy	7,729	Leadville Ls
T25S R19E Sec 27	Kane Sprgs 27-1	Columbia Gas	7,248	Paradox
T25S R19E Sec 28	Kane Sprgs 28-1	Columbia Gas	Location	Paradox
T25S R19E Sec 36	Kane Sprgs 36-1	Columbia Gas	Location	Paradox
T25S R20E Sec 9	Moab 16-9	Chandler & Assoc.	9,968	Ouray Ls
T25S R20E Sec 13	West Moab 1-13	Coors Energy	Location	Paradox
T25S R20E Sec 23	Gold Bar 2	Davis Oil	9,683	Ouray Ls

Table 1

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T25S R20E Sec 29	Gold Bar 1	Davis Oil	8,286	Paradox
T25S R21E Sec 18	Utah 2	Delhi Oil	9,424	Paradox
T25S R21E Sec 18	Arches 1	Samson Resources	8,005	Paradox
T26S R17E Sec 5	Bowknot 14-5	Superior Oil	6,498	Leadville Ls
T26S R17E Sec 17	Pool 1	Davis Oil	6,969	Leadville Ls
T26S R17E Sec 20	Federal 2-20	Megadon Energy	6,836	Leadville Ls
T26S R18E Sec 4	Minerals 1-4	Jack Grynberg & Assoc.	7,696	Leadville Ls
T26S R18E Sec 7	Govt Mineral Point 1	Pure Oil	7,282	Ouray Ls
T26S R19E Sec 3	Mineral Canyon 1-3	Ensearch Expl.	8,184	Leadville Ls
T26S R19E Sec 4	Mineral Canyon 33-4 H	Meridian Oil	Location	Paradox
T26S R19E Sec 11	Big Flat 74-11	Tidewater Oil	8,389	Elbert
T26S R19E Sec 11	1	Ruby Glen	8,213	Ouray Ls
T26S R19E Sec 11	Ruby 1	King Oil	7,860	Leadville Ls

Table 1

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T26S R19E Sec 14	Big Flat 1	Pure Oil	7,954	Ouray Ls
T26S R19E Sec 14	Big Flat 2	Pure Oil	7,812	Leadville Ls
T26S R19E Sec 14	USA - Sunburst	Energy Reserves	8,262	Leadville Ls
T26S R19E Sec 14	Mineral Canyon 1-14	Ensearch Expl	8,163	Elbert
T26S R19E Sec 14	Kane Sprgs 14-1	Columbia Gas	Location	Paradox
T26S R19E Sec 20	Kane Sprgs 20-1	Columbia Gas	Location	Paradox
T26S R19E Sec 23	Big Flat 3	Pure Oil	8,600	Lynch Dolo
T26S R19E Sec 23	Big Flat 4	Pure Oil	6,721	Paradox
T26S R20E Sec 4	Matthew 2	Davis Oil	7,253	Paradox
T26S R20E Sec 4	Matthew 1	Davis Oil	6,946	Paradox
T26S R20E Sec 5	Skyline 1	Davis Oil	7,670	Paradox
T26S R20E Sec 6	Big Flat 7	Calvert Western Expl.	7,797	Paradox
T26S R20E Sec 8	Skyline 8-44	Helis William Estate	8,082	Ouray Ls
T26S R20E Sec 9	Long Canyon 1	Southern Natural Gas	8,134	Lynch Dolo

Table 1

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T26S R20E Sec 9	Long Canyon 2	Southern Natural Gas	7,791	Leadville Ls
T26S R20E Sec 10	LC Coors 1-10	EP Operating	8,550	Lynch Dolo ?
T26S R20E Sec 14	White Cloud 1	Jay Robertson	8,044	Leadville Ls
T26S R20E Sec 19	Kane Sprgs 19-1	Columbia Gas	Location	Paradox
T26S R20E Sec 25	Shafer 1-A	Utah Southern Oil	4,107	Paradox
T26S R20E Sec 29	Little Valley 1	Murphy Oil	8,600	Lynch Dolo
T26S R20E Sec 30	Hobson 1	Pure Oil	6,674	Paradox
T26S R20E Sec 31	Big Flat 1	Cakeen Expl.	7,669	Leadville Ls
T26S R20E Sec 36	MGM 2	Modoc Inc	7,462	Paradox
T26S R20E Sec 36	Federal 1-X	Texas Gulf	8,005	Elbert
T26S R20E Sec 36	Cane Creek 1	MGM Pet.	7,452	Paradox
T27S R19E Sec 3	Ornsby 1	British American Oil	8,065	Leadville Ls
T27S R19E Sec 27	Grays Pasture 1	Rosen Oil	7,645	Leadville Ls
T27S R20E Sec 3	Shafer Canyon 4	Rip Underwood	6,200	Paradox

Table 1

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T27S R20E Sec 4	Shafer Canyon 3	Rip Underwood	6,199	Paradox
T27S R20E Sec 6	USA 1	Southern Natural Gas	5,990	Paradox
T27S R20E Sec 6	USA 2	Southern Natural Gas	7,134	Lynch Dolo
T27S R20E Sec 9	Fetherstone 9-1	Rip Underwood	6,116	Paradox
T27S R20E Sec 15	Shafer 1	Delhi - Taylor	4,156	Paradox
T27S R20E Sec 16	Shafer 1	Midwest Expl.	5,863	Leadville Ls
T27S R20E Sec 36	Lion Mesa 3-36A	Megadon Energy	7,705	Leadville Ls
T27S R20E Sec 36	Cane Creek State 1-36	Chevron USA	Location	Paradox
T27S R21E Sec 1	Hunters Canyon 1	La Rue Jr.	6,698	Elbert
T27S R21E Sec 3	Unit 3	Humble Oil	6,354	Leadville Ls
T27S R21E Sec 26	Lion Mesa 4-26	Megadon Energy	7,800	Leadville Ls
T27S R21E Sec 27	Lion Mesa 27-1A	Pool Energy	8,100	Leadville Ls
T27S R21E Sec 28	Lion Mesa 5-28	Megadon Energy	7,858	Leadville Ls
T27S R21E Sec 33	Hatch Point 22-33H	Meridian Oil	Location	Paradox

Table 1

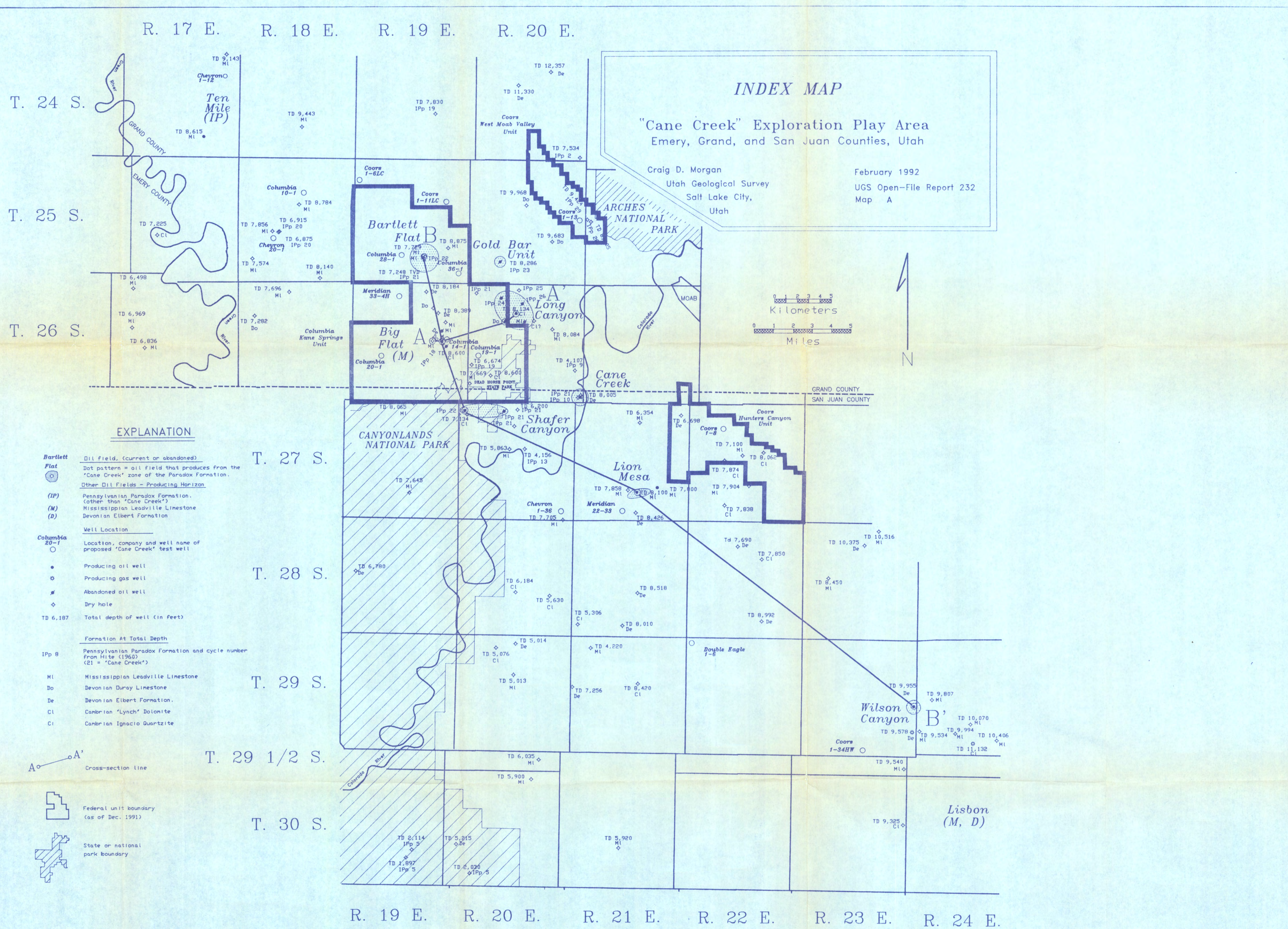
LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T27S R21E Sec 34	Lion Mesa 34-1	Megadon Energy	8,426	Elbert
T27S R22E Sec 8	Hunters Canyon 1-8	Coors Energy	Location	Paradox
T27S R22E Sec 15	Putnam 1	La Rue Jr.	8,062	Lynch Dolo
T27S R22E Sec 16	Hunters Canyon 1	May Petroleum	7,100	Leadville Ls
T27S R22E Sec 17	Unit 1	Humble Oil	7,874	Lynch Dolo
T27S R22E Sec 27	Bridger Jack	La Rue Jr.	7,904	Leadville Ls
T27S R22E Sec 32	Behind Rocks 1	Chevron Oil	7,838	Lynch Dolo
T28S R19E Sec 18	Murphy Range 1	Shell Oil	7,193	Elbert
T28S R20E Sec 22	Lockhart 1	Gulf Oil	6,184	Lynch Dolo
T28S R20E Sec 23	USA-Lockhart 1	Pan American Pet.	5,630	Lynch Dolo
T28S R21E Sec 22	Hatch Mesa 1	Richfield Oil	8,518	Elbert
T28S R21E Sec 31	Charles 1	Pan American Pet.	5,306	Ignacio Qtz
T28S R21E Sec 33	Hatch 1	Kimbark Oper.	8,010	Elbert
T28S R22E Sec 9	Red Rock 1	Gulf Oil	7,690	Elbert

Table 1

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T28S R22E Sec 10	Flat Iron Mesa 1	Pure Oil	7,850	Lynch Dolo
T28S R22E Sec 34	Govt B-1	Cities Service	8,992	Elbert
T28S R23E Sec 2	Muleshoe 1	California Oil	10,516	Leadville Ls
T28S R23E Sec 10	Muleshoe 1	Westcoast O&G	10,375	Elbert
T28S R23E Sec 17	Lundell 1	British American Oil	8,450	Leadville Ls
T29S R20E Sec 3	Lockhart 1-3	Flying Diamond	5,014	Elbert
T29S R20E Sec 4	Rustler Dome 1	Carter Oil	5,076	Lynch Dolo
T29S R20E Sec 15	USA-Rustler Dome 1	Kadane & Sons	5,013	Leadville Ls
T29S R21E Sec 5	Rector 1	Damson Oil	4,220	Leadville Ls
T29S R21E Sec 15	Federal 6-15	Husky Oil	8,420	Lynch Dolo
T29S R21E Sec 18	Horsehead 1	Pure Oil	7,256	Elbert
T29S R22E Sec 6	1-6	Double Eagle	Location	Paradox
T29S R23E Sec 24	Chevron - Fed 1	Gulf Oil	9,955	Elbert
T29S R23E Sec 25	Husky - Fed 15-25	Husky Oil	9,578	Elbert

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T29S R23E Sec 34	1-34 HW	Coors Energy	Location	Paradox
T29S R24E Sec 19	La Sal 1	Pure Oil	9,807	Leadville Ls
T29S R24E Sec 28	Big Indian - B 1	Pure Oil	10,070	Leadville Ls
T29S R24E Sec 29	Big Indian 5	Pure Oil	9,994	Leadville Ls
T29S R24E Sec 30	Federal 13-30	Husky Oil	9,534	Leadville Ls
T29S R24E Sec 33	USA-Big Indian 1	Pure Oil	11,132	Ignacio Qtz
T29S R24E Sec 35	La Sal 1	Pennzoil	10,406	Leadville Ls
T29 1/2S R20E Sec 35	Gibson 1	Reynolds Mining	6,035	Leadville Ls
T29 1/2S R23E Sec 36	Gulf - State 1	Kimbark Oper.	9,540	Leadville Ls
T30S R19E Sec 26	Beef Basin 4	Trident	1,897	Paradox
T30S R19E Sec 26	Beef Basin 3	Trident	2,114	Paradox
T30S R20E Sec 2	Gibson Dome 1-2	Belco Pet.	5,900	Leadville Ls
T30S R20E Sec 19	USA-Lost Canyon 1	Pure Oil	5,215	Elbert

LOCATION	WELL NAME	ORIGINAL OPERATOR	TOTAL DEPTH (FT.)	FORMATION AT TOTAL DEPTH
T30S R20E Sec 32	Beef Basin 5	Trident	2,030	Paradox
T30S R21E Sec 21	Gibson Dome 1	Woodward & Clyde	5,920	Leadville Ls
T30S R23E Sec 13	Federal 1	Apache	9,325	Lynch Dolo


INDEX MAP
"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah
Craig D. Morgan
Utah Geological Survey
Salt Lake City, Utah
February 1992
UGS Open-File Report 232
Map A
R. 17 E.
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R. 20 E.
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T. 26 S.
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Ten Mile (IP)
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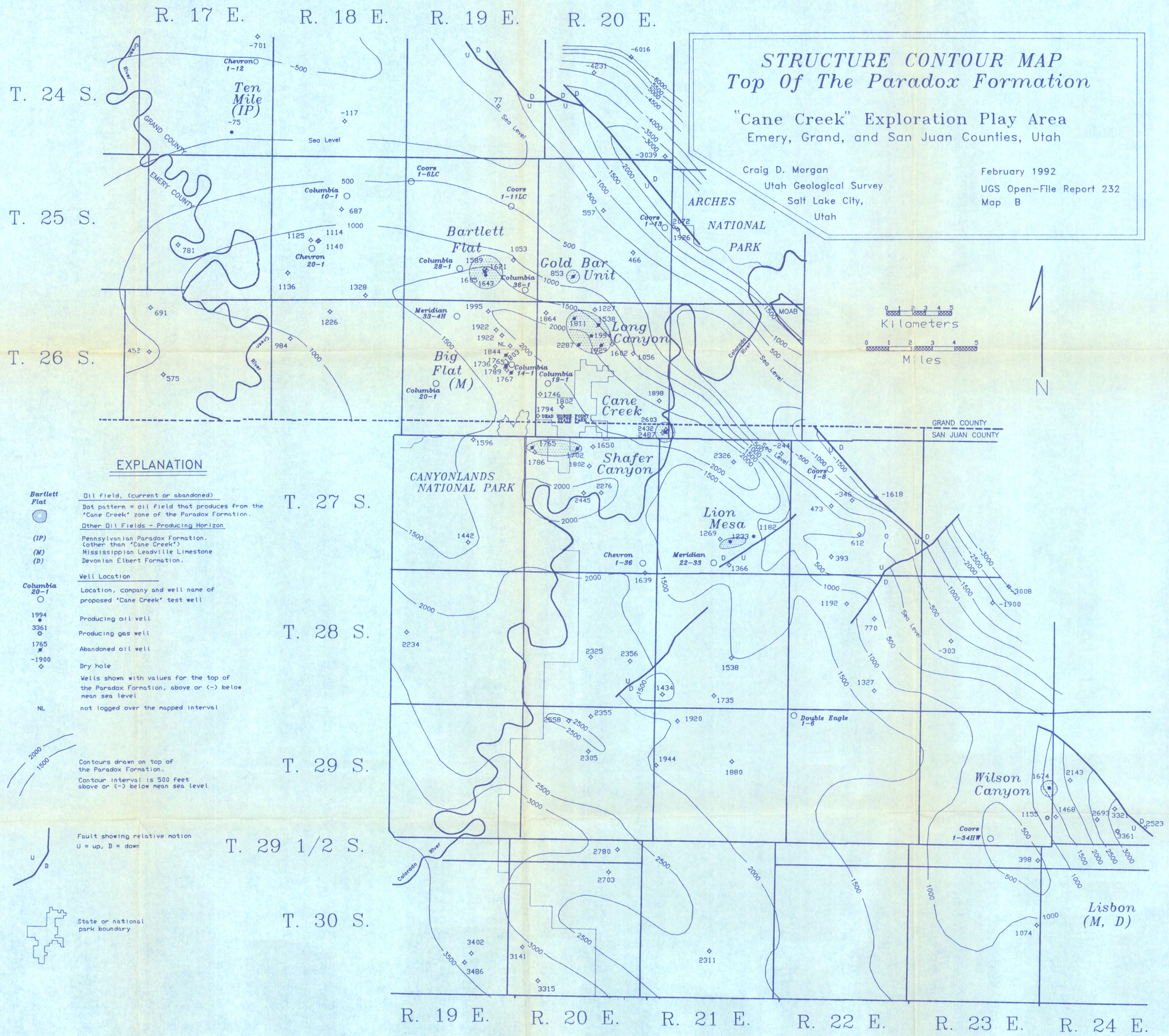
Gold Bar Unit
Long Canyon
Big Flat (M)
Cane Creek
Shafer Canyon
Lion Mesa
Wilson Canyon
Lisbon (M, D)
ARCHES NATIONAL PARK
CANYONLANDS NATIONAL PARK
DEAD HORSE POINT STATE PARK
MOAB
GRAND COUNTY
EMERY COUNTY
SAN JUAN COUNTY
Green River
Colorado River
Coors West Moab Valley Unit
Columbia Kane Springs Unit
Coors Hunters Canyon Unit
Double Eagle 1-6
Kilometers
Miles
N
A
A'
B
B'
EXPLANATION
Oil field, (current or abandoned)
Dot pattern = oil field that produces from the "Cane Creek" zone of the Paradox Formation.
Other Oil Fields - Producing Horizon
(IP) Pennsylvanian Paradox Formation. (other than "Cane Creek")
(M) Mississippian Leadville Limestone
(D) Devonian Elbert Formation
Well Location
Columbia 20-1 Location, company and well name of proposed "Cane Creek" test well
Producing oil well
Producing gas well
Abandoned oil well
Dry hole
TD 6,187 Total depth of well (in feet)
Formation At Total Depth
IPp 8 Pennsylvanian Paradox Formation and cycle number from Hite (1960) (21 = "Cane Creek")
Ml Mississippian Leadville Limestone
Do Devonian Ouray Limestone
De Devonian Elbert Formation.
Cl Cambrian "Lynch" Dolomite
Ci Cambrian Ignacio Quartzite
Cross-section line
Federal unit boundary (as of Dec. 1991)
State or national park boundary

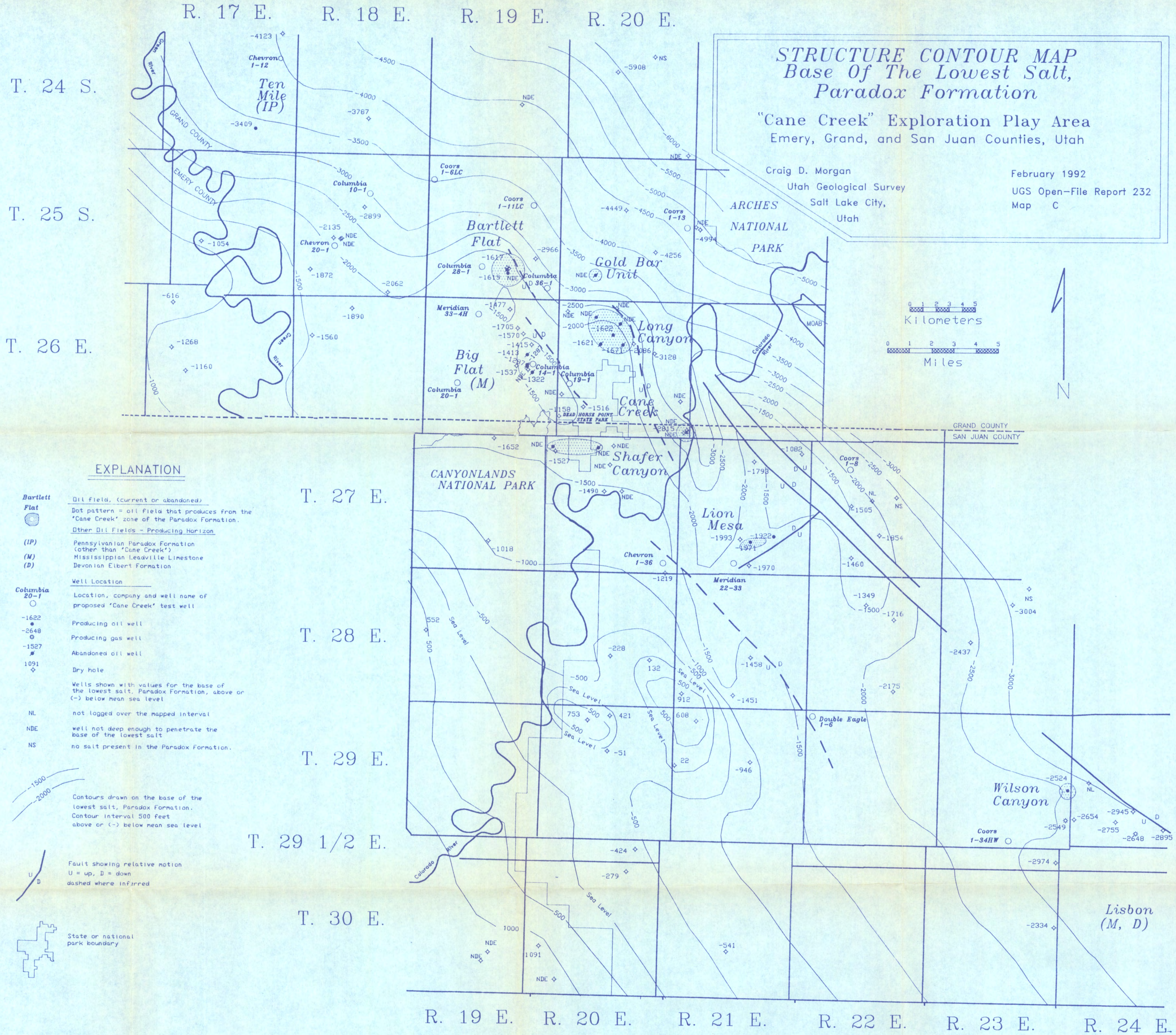
STRUCTURE CONTOUR MAP
Top Of The Paradox Formation

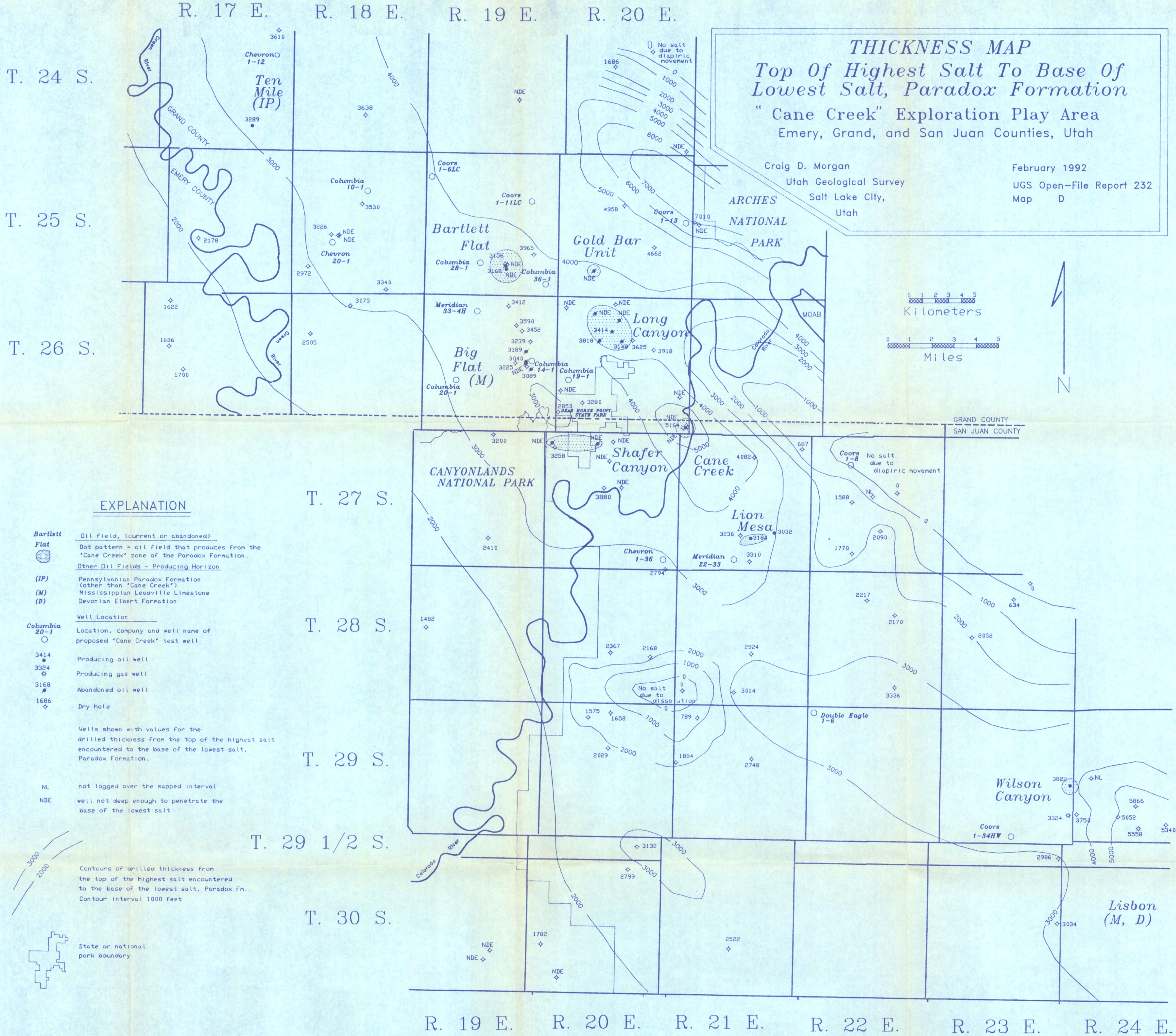
"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah

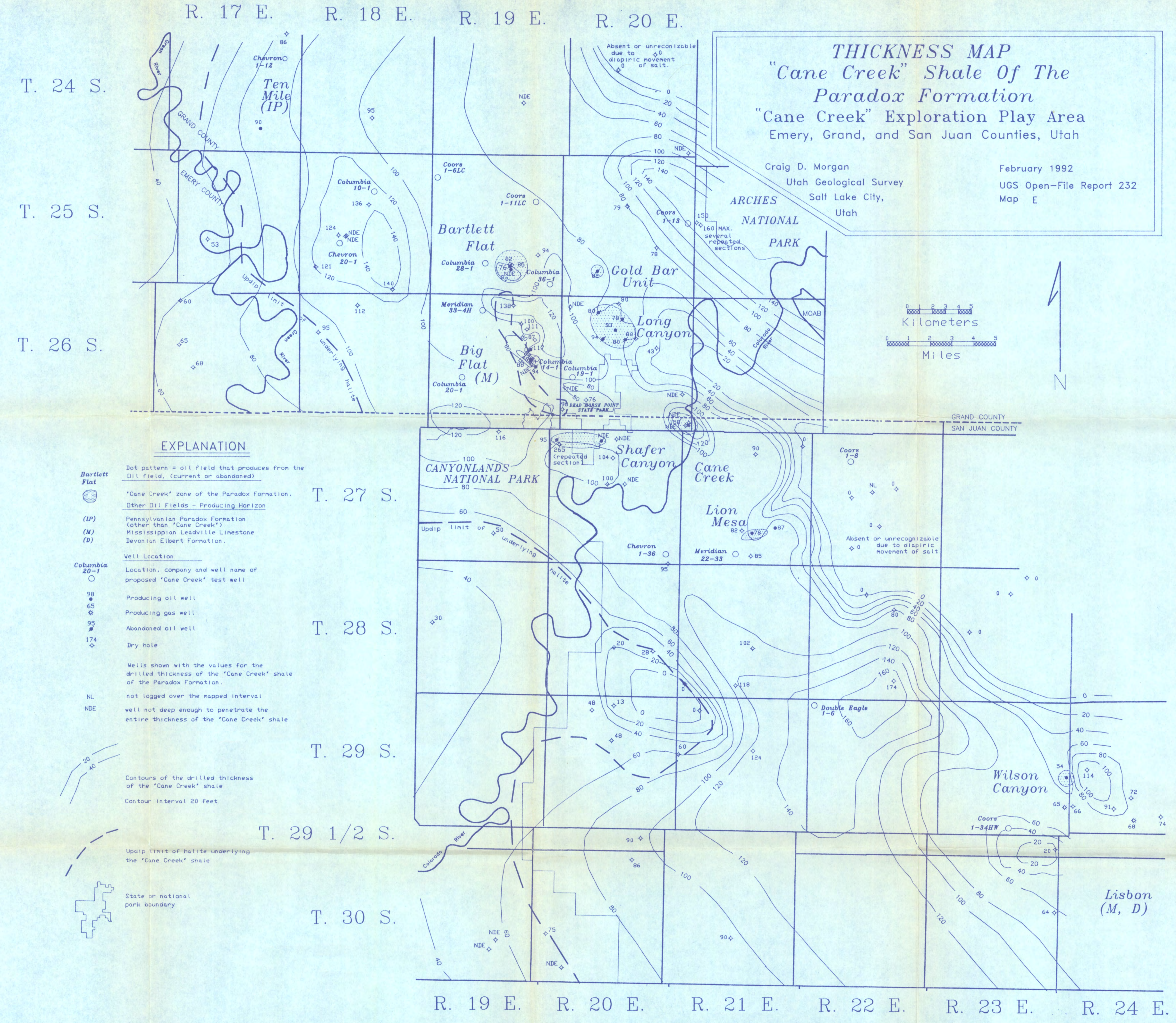
Craig D. Morgan
Utah Geological Survey
Salt Lake City,
Utah

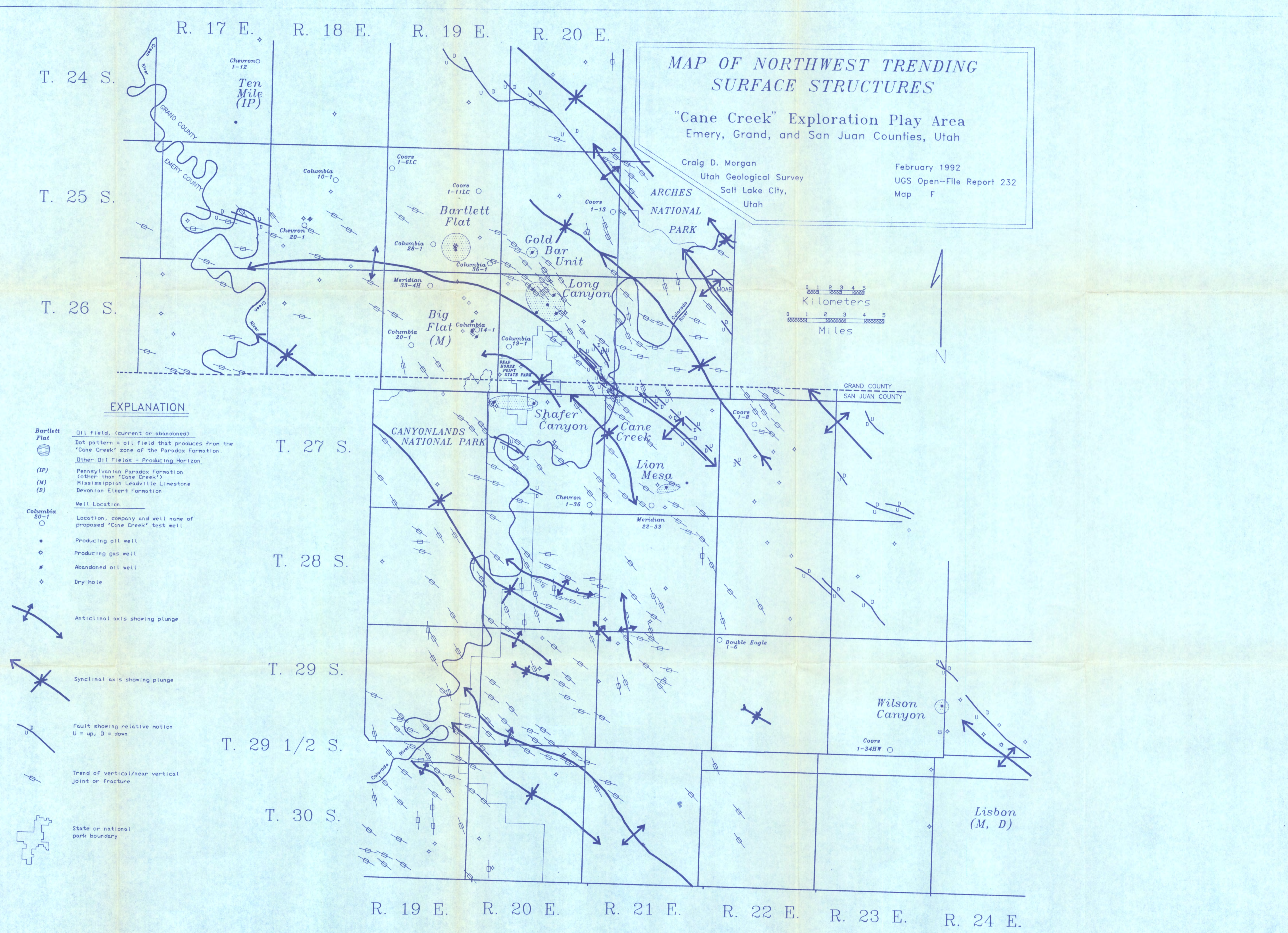
February 1992
UGS Open-File Report 232
Map B

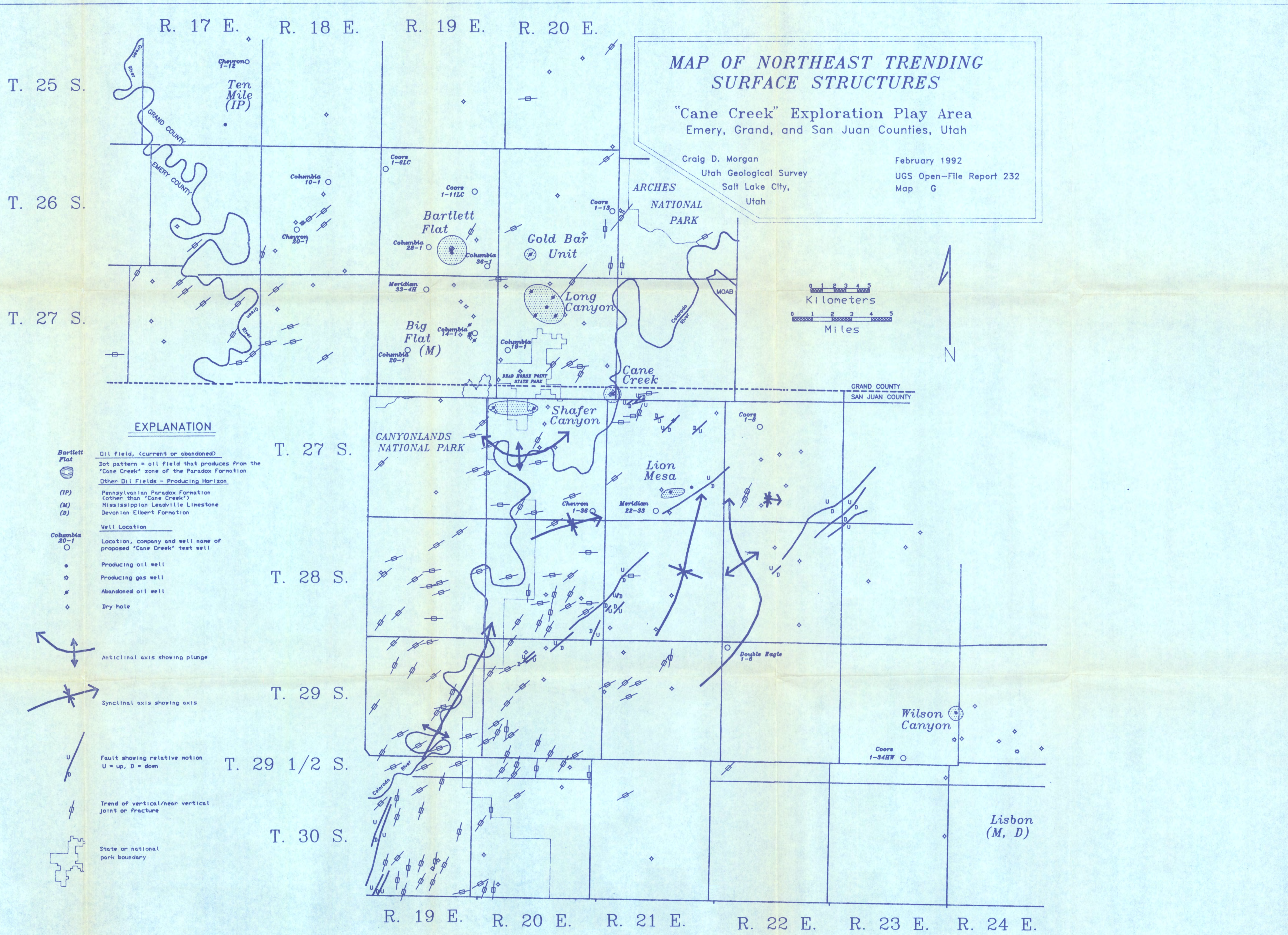



STRUCTURE CONTOUR MAP
Base Of The Lowest Salt,
Paradox Formation
"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah
Craig D. Morgan
Utah Geological Survey
Salt Lake City,
Utah
February 1992
UGS Open-File Report 232
Map C
EXPLANATION
Bartlett Flat
Oil field, (current or abandoned)
Dot pattern = oil field that produces from the "Cane Creek" zone of the Paradox Formation.
Other Oil Fields - Producing Horizon
(IP) Pennsylvanian Paradox Formation (other than "Cane Creek")
(M) Mississippian Leadville Limestone
(D) Devonian Elbert Formation
Columbia 20-1
Well Location
Location, company and well name of proposed "Cane Creek" test well
-1622 Producing oil well
-2648 Producing gas well
-1527 Abandoned oil well
1091 Dry hole
Wells shown with values for the base of the lowest salt, Paradox Formation, above or (-) below mean sea level
NL not logged over the mapped interval
NDE well not deep enough to penetrate the base of the lowest salt
NS no salt present in the Paradox Formation.
-1500
-2000
Contours drawn on the base of the lowest salt, Paradox Formation. Contour interval 500 feet above or (-) below mean sea level
Fault showing relative motion U = up, D = down dashed where inferred
State or national park boundary
Kilometers
Miles
N
R. 17 E.
R. 18 E.
R. 19 E.
R. 20 E.
T. 24 S.
T. 25 S.
T. 26 E.
T. 27 E.
T. 28 E.
T. 29 E.
T. 29 1/2 E.
T. 30 E.
R. 19 E.
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
Ten Mile (IP)
Bartlett Flat
Gold Bar Unit
Long Canyon
Big Flat (M)
Cane Creek
Shafer Canyon
Lion Mesa
Wilson Canyon
Lisbon (M, D)
ARCHES NATIONAL PARK
CANYONLANDS NATIONAL PARK
GRAND COUNTY
SAN JUAN COUNTY
EMERY COUNTY
Green River
Colorado River
MOAB
Chevron 1-12
Columbia 10-1
Chevron 20-1
Coors 1-6LC
Coors 1-11LC
Coors 1-13
Columbia 28-1
Columbia 36-1
Meridian 33-4H
Columbia 14-1
Columbia 19-1
Columbia 20-1
Coors 1-8
Chevron 1-36
Meridian 22-33
Double Eagle 1-6
Coors 1-34HW


THICKNESS MAP
Top Of Highest Salt To Base Of Lowest Salt, Paradox Formation
"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah
Craig D. Morgan
Utah Geological Survey
Salt Lake City, Utah
February 1992
UGS Open-File Report 232
Map D
R. 17 E.
R. 18 E.
R. 19 E.
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
T. 24 S.
T. 25 S.
T. 26 S.
T. 27 S.
T. 28 S.
T. 29 S.
T. 29 1/2 S.
T. 30 S.
Ten Mile (IP)
Bartlett Flat
Gold Bar Unit
Long Canyon
Big Flat (M)
Shafer Canyon
Cane Creek
Lion Mesa
Wilson Canyon
Lisbon (M, D)
ARCHES NATIONAL PARK
CANYONLANDS NATIONAL PARK
MOAB
GRAND COUNTY
SAN JUAN COUNTY
EMERY COUNTY
Green River
Colorado River
No salt due to diapiric movement
No salt due to dissolution
Kilometers
Miles
N
EXPLANATION
Bartlett Flat
Oil field, (current or abandoned)
Dot pattern = oil field that produces from the 'Cane Creek' zone of the Paradox Formation.
Other Oil Fields - Producing Horizon
(IP) Pennsylvanian Paradox Formation (other than 'Cane Creek')
(M) Mississippian Leadville Limestone
(D) Devonian Elbert Formation
Well Location
Columbia 20-1
Location, company and well name of proposed 'Cane Creek' test well
3414 Producing oil well
3324 Producing gas well
3168 Abandoned oil well
1686 Dry hole
Wells shown with values for the drilled thickness from the top of the highest salt encountered to the base of the lowest salt, Paradox Formation.
NL not logged over the mapped interval
NDE well not deep enough to penetrate the base of the lowest salt
Contours of drilled thickness from the top of the highest salt encountered to the base of the lowest salt, Paradox Fn. Contour interval 1000 feet
State or national park boundary

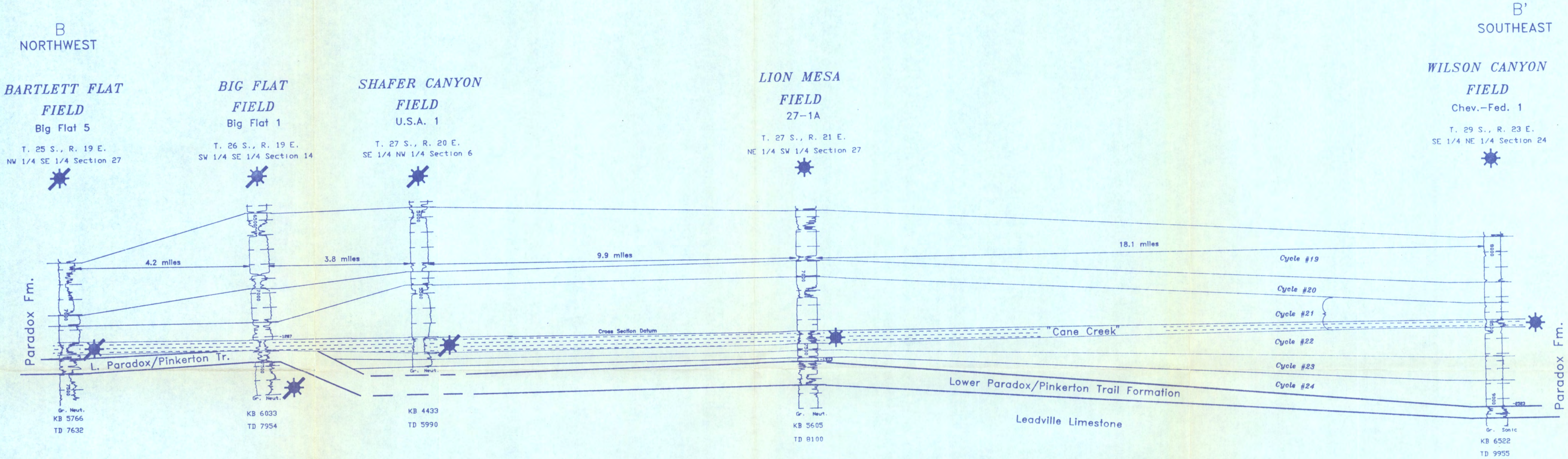

THICKNESS MAP
"Cane Creek" Shale Of The
Paradox Formation
"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah
Craig D. Morgan
Utah Geological Survey
Salt Lake City,
Utah
February 1992
UGS Open-File Report 232
Map E
Kilometers
Miles
N
R. 17 E.
R. 18 E.
R. 19 E.
R. 20 E.
T. 24 S.
T. 25 S.
T. 26 S.
T. 27 S.
T. 28 S.
T. 29 S.
T. 29 1/2 S.
T. 30 S.
R. 19 E.
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
Absent or unrecognizable due to diapiric movement of salt.
Ten Mile (IP)
GRAND COUNTY
EMERY COUNTY
Green River
Bartlett Flat
Big Flat (M)
Gold Bar Unit
Long Canyon
ARCHES NATIONAL PARK
MOAB
Colorado River
160 MAX. several repeated sections
DEAD HORSE POINT STATE PARK
GRAND COUNTY
SAN JUAN COUNTY
CANYONLANDS NATIONAL PARK
Shafer Canyon
(repeated section)
Cane Creek
Lion Mesa
Absent or unrecognizable due to diapiric movement of salt
Updip limit of underlying halite
Wilson Canyon
Lisbon (M, D)
Colorado River
EXPLANATION
Dot pattern = oil field that produces from the Oil Field, (current or abandoned)
'Cane Creek' zone of the Paradox Formation.
Other Oil Fields - Producing Horizon
(IP) Pennsylvanian Paradox Formation (other than 'Cane Creek')
(M) Mississippian Leadville Limestone
(D) Devonian Elbert Formation.
Well Location
Location, company and well name of proposed 'Cane Creek' test well
Producing oil well
Producing gas well
Abandoned oil well
Dry hole
Wells shown with the values for the drilled thickness of the 'Cane Creek' shale of the Paradox Formation.
NL not logged over the mapped interval
NDE well not deep enough to penetrate the entire thickness of the 'Cane Creek' shale
Contours of the drilled thickness of the 'Cane Creek' shale
Contour interval 20 feet
Updip limit of halite underlying the 'Cane Creek' shale
State or national park boundary


MAP OF NORTHWEST TRENDING SURFACE STRUCTURES
"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah
Craig D. Morgan
Utah Geological Survey
Salt Lake City, Utah
February 1992
UGS Open-File Report 232
Map F
Kilometers
Miles
N
R. 17 E.
R. 18 E.
R. 19 E.
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
T. 24 S.
T. 25 S.
T. 26 S.
T. 27 S.
T. 28 S.
T. 29 S.
T. 29 1/2 S.
T. 30 S.
GRAND COUNTY
EMERY COUNTY
SAN JUAN COUNTY
Green River
Colorado River
Ten Mile (IP)
Bartlett Flat
Gold Bar Unit
Long Canyon
Big Flat (M)
ARCHES NATIONAL PARK
MOAB
DEAD HORSE POINT STATE PARK
CANYONLANDS NATIONAL PARK
Shafer Canyon
Cane Creek
Lion Mesa
Wilson Canyon
Lisbon (M, D)
Chevron 1-12
Columbia 10-1
Chevron 20-1
Coors 1-6LC
Coors 1-11LC
Coors 1-13
Columbia 28-1
Columbia 36-1
Meridian 33-4H
Columbia 20-1
Columbia 14-1
Columbia 19-1
Coors 1-8
Chevron 1-36
Meridian 22-33
Double Eagle 1-6
Coors 1-34HW
EXPLANATION
Bartlett Flat
Oil field, (current or abandoned)
Dot pattern = oil field that produces from the 'Cane Creek' zone of the Paradox Formation.
Other Oil Fields - Producing Horizon
(IP) Pennsylvanian Paradox Formation (other than 'Cane Creek')
(M) Mississippian Leadville Limestone
(D) Devonian Elbert Formation
Well Location
Columbia 20-1
Location, company and well name of proposed 'Cane Creek' test well
Producing oil well
Producing gas well
Abandoned oil well
Dry hole
Anticlinal axis showing plunge
Synclinal axis showing plunge
Fault showing relative motion
U = up, D = down
Trend of vertical/near vertical joint or fracture
State or national park boundary



MAP OF NORTHEAST TRENDING SURFACE STRUCTURES
"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah
Craig D. Morgan
Utah Geological Survey
Salt Lake City, Utah
February 1992
UGS Open-File Report 232
Map G
R. 17 E.
R. 18 E.
R. 19 E.
R. 20 E.
T. 25 S.
T. 26 S.
T. 27 S.
Ten Mile (IP)
Chevron 1-12
Green River
GRAND COUNTY
EMERY COUNTY
Columbia 10-1
Chevron 20-1
Coors 1-6LC
Coors 1-11LC
Coors 1-13
Bartlett Flat
Columbia 28-1
Columbia 36-1
Gold Bar Unit
ARCHES NATIONAL PARK
Meridian 33-4H
Long Canyon
Big Flat (M)
Columbia 14-1
Columbia 18-1
Columbia 20-1
MOAB
Colorado River
Kilometers
Miles
N
Cane Creek
DEAD HORSE POINT STATE PARK
GRAND COUNTY
SAN JUAN COUNTY
Shafer Canyon
CANYONLANDS NATIONAL PARK
Coors 1-8
Lion Mesa
Chevron 1-36
Meridian 22-33
T. 27 S.
T. 28 S.
T. 29 S.
T. 29 1/2 S.
T. 30 S.
Double Eagle 1-6
Wilson Canyon
Coors 1-34HW
Lisbon (M, D)
R. 19 E.
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
EXPLANATION
Bartlett Flat
Oil field, (current or abandoned)
Dot pattern = oil field that produces from the 'Cane Creek' zone of the Paradox Formation
Other Oil Fields - Producing Horizon
(IP) Pennsylvanian Paradox Formation (other than 'Cane Creek')
(M) Mississippian Leadville Limestone
(D) Devonian Elbert Formation
Well Location
Columbia 20-1 Location, company and well name of proposed 'Cane Creek' test well
Producing oil well
Producing gas well
Abandoned oil well
Dry hole
Anticlinal axis showing plunge
Synclinal axis showing axis
Fault showing relative motion U = up, D = down
Trend of vertical/near vertical joint or fracture
State or national park boundary

OIL AND GAS SHOWS
Paradox Formation
"Cane Creek" Exploration Play Area
Emery, Grand, and San Juan Counties, Utah
Craig D. Morgan
Utah Geological Survey
Salt Lake City, Utah
February 1992
UGS Open-File Report 232
Map H
R. 17 E.
R. 18 E.
R. 19 E.
R. 20 E.
T. 24 S.
T. 25 S.
T. 26 S.
T. 27 S.
T. 28 S.
T. 29 S.
T. 29 1/2 S.
T. 30 S.
R. 19 E.
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
Kilometers
Miles
N
Green River
GRAND COUNTY
EMERY COUNTY
SAN JUAN COUNTY
Colorado River
MOAB
ARCHES NATIONAL PARK
CANYONLANDS NATIONAL PARK
Ten Mile (IP)
Bartlett Flat
Gold Bar Unit
Long Canyon
Big Flat (M)
Cane Creek
Shafer Canyon
Lion Mesa
Wilson Canyon
Lisbon (M, D)
Chevron 1-12
Columbia 10-1
Chevron 20-1
Coors 1-6LC
Coors 1-11LC
Columbia 28-1
Columbia 36-1
Meridian 33-4H
Columbia 20-1
Columbia 14-1
Columbia 19-1
Coors 1-13
"Cane Creek"
Coors 1-8
Chevron 1-36
Meridian 22-33
Double Eagle 1-6
Coors 1-34HW
EXPLANATION
Bartlett Flat
Oil field, (current or abandoned)
Dot pattern = oil field that produces from the 'Cane Creek' zone of the Paradox Formation
Other Oil Fields - Producing Horizon
(IP) Pennsylvanian Paradox Formation (other than 'Cane Creek')
(M) Mississippian Leadville Limestone
(D) Devonian Elbert Formation
Well Location
Columbia 20-1
Location, company and well name of proposed 'Cane Creek' test well
Producing oil well
Producing gas well
Abandoned oil well
Dry hole
Oil well producing from the 'Cane Creek' shale, Paradox Formation.
Abandoned oil well that produced from the 'Cane Creek' shale, Paradox Formation. Additional oil/gas shows in the Paradox Formation are indicated by the corresponding cycle number (Hite, 1960).
17,18
Well that has tested oil and/or gas from the Paradox Formation.
Shows indicated by corresponding cycle number (Hite, 1960).
'Cane Creek' is spelled out rather than referenced with a cycle number (21).
State or national park boundary



CROSS SECTION B – B'

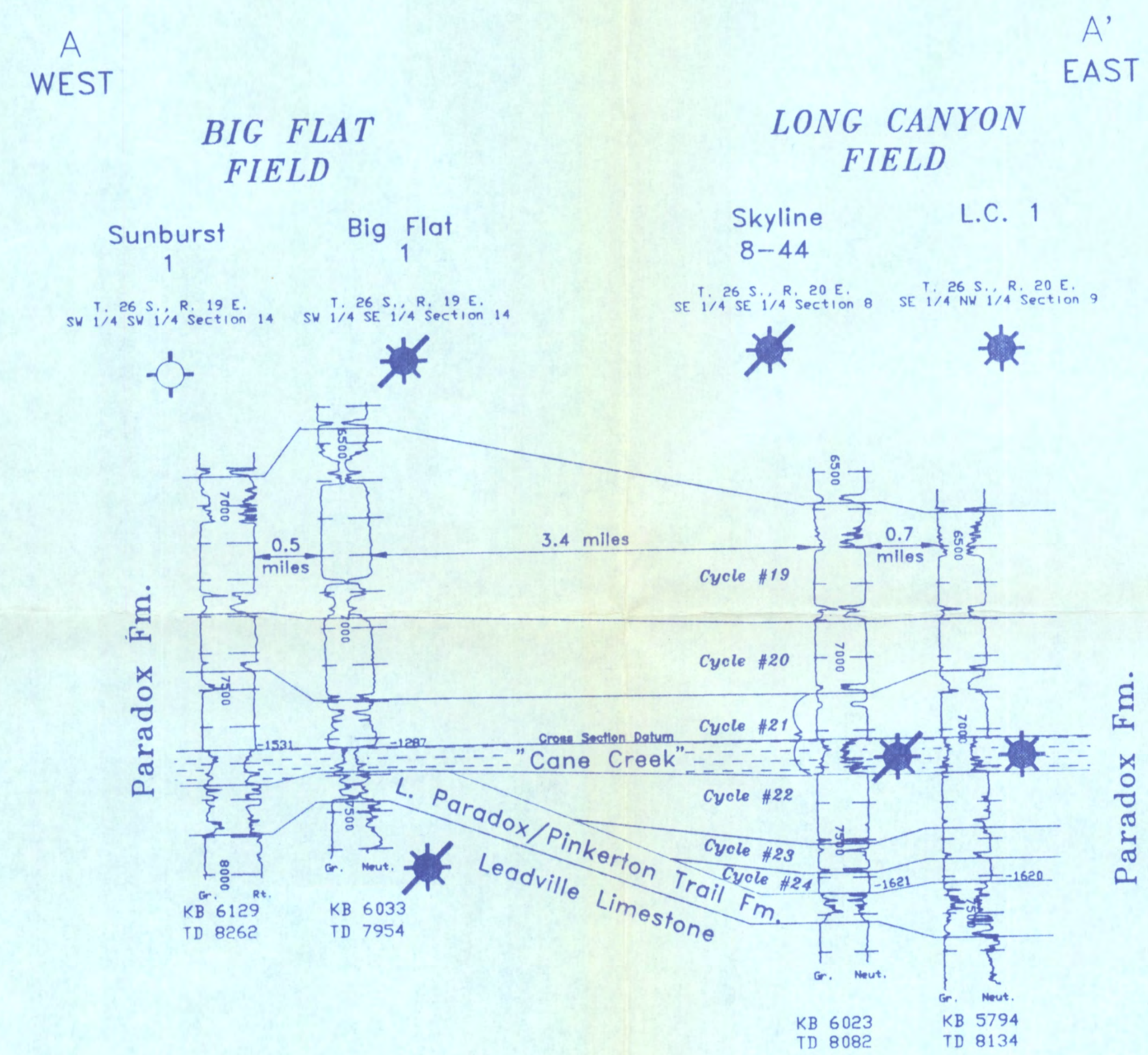
STRATIGRAPHIC CROSS SECTIONSS

"Cane Creek" Exploration Play Area

Emery, Grand, and San Juan Counties, Utah

Craig D. Morgan
Utah Geological Survey
Salt Lake City, Utah

February 1992
UGS Open-File Report 232



CROSS SECTION A – A'

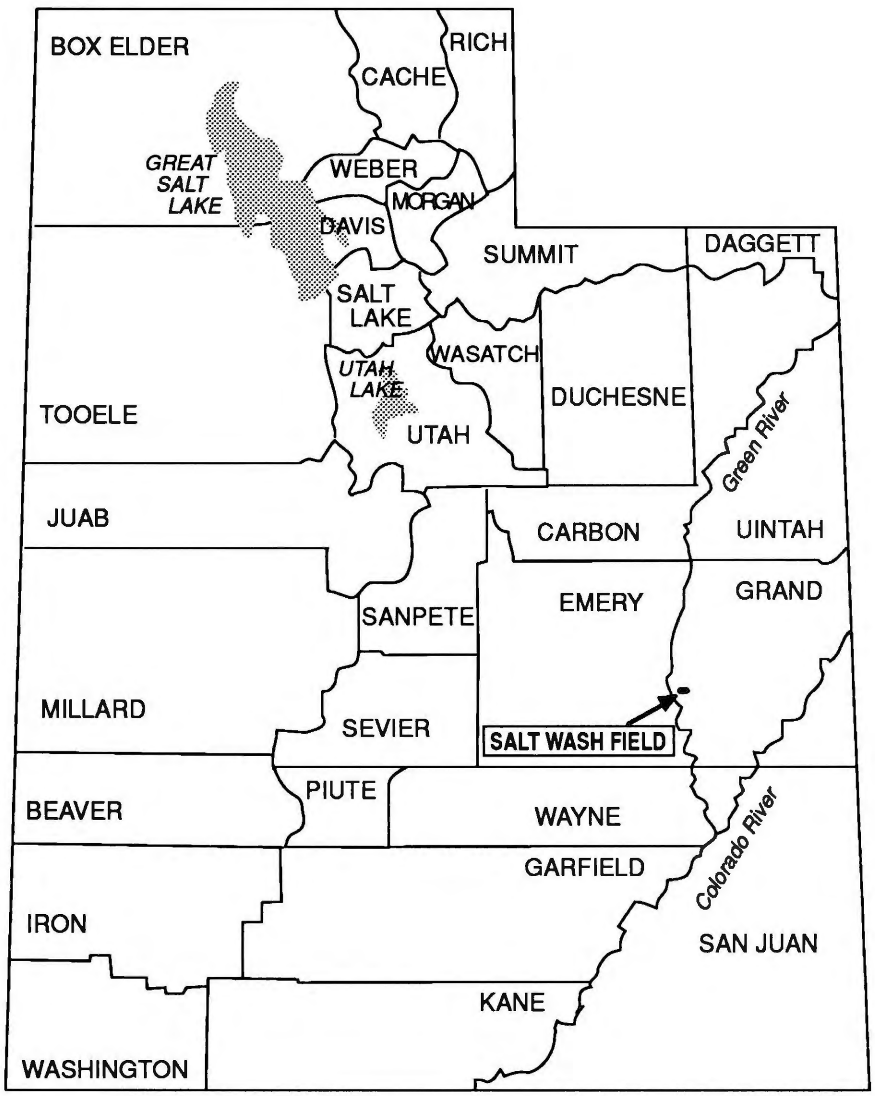
EXPLANATION

(symbol)	Producing oil and gas well
(symbol)	Abandoned oil and gas well
(symbol)	Dry hole
-1973	Subsea elevation on the base of the lowest Paradox Formation salt (Map C)
KB	Kelly bushing
TD	Total depth of the well
Gr.	Gamma ray log curve
Neut.	Neutron log curve
Sonic	Sonic log curve
Rt.	Resistivity log curve

Cycle numbers of Hite (1960)
See Index Map (Map A) for location of lines.

EXPORING FOR NEW OIL IN OLD FIELDS, SALT WASH FIELD: A CASE STUDY

by
Craig D. Morgan



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UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

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FIGURES

TABLES

PLATES (in pocket)

DISKETTE (in pocket)

The Utah Geological Survey Integral*gim database of wells drilled in the Salt Wash field area.

ABSTRACT

Over 1.4 million barrels (0.2 million m^3) of oil and 11 billion cubic feet (0.3 billion m^3) of gas have been produced from the Salt Wash field since its discovery in 1961. The field is an asymmetrical west-trending anticline productive from the Mississippian Leadville Limestone. Three to six million barrels (0.5 to 0.9 million m^3) of oil may still be recoverable from the Salt Wash field. A poor understanding of the reservoir heterogeneity combined with mechanical problems in the wells and unmarketable inert gases have resulted in the field being incompletely developed more than 30 years after its discovery.

The discovery well was completed in the lower Leadville Limestone. Cores from the well contain porous crystalline dolomite with abundant vertical fractures. The operators believed the Leadville was a single reservoir with a large gas cap and a thin, 15-foot (4.6-m) oil column. The wells were perforated just above the oil/water contact in an attempt to produce the oil ring. Vertical fractures provided pathways for water resulting in early abandonment of most of the wells. Recompletion was rarely attempted because the casing was collapsed in most wells by the thick salt section in the Pennsylvanian Paradox Formation overlying the Leadville.

Recompletions have resulted in oil production from what was originally believed to be gas cap in both the lower and upper Leadville. In the majority of the wells, casing collapse prevented recompletion in the higher porosity zones. As a result, the majority of the Leadville reservoir (lower and upper) may be virtually undrained.

The Cane Creek shale of the Paradox Formation drill-stem tested oil in one well but has never been exploited at Salt Wash field. An updip porosity pinchout in Cycle 1 of the Paradox

Formation creates an untested trap across the western plunge of the anticline.

Many Leadville prospects in the northern Paradox basin were abandoned after testing high volumes of inert gas and no oil, or producing small quantities of oil. Drill-stem tests of the upper Leadville at the Salt Wash field recovered gas and no oil. However, once perforated, over 300,000 barrels (47,700 m^3) of oil were produced from the interval in one well. Many of the Leadville tests that were plugged and abandoned may represent by-passed potential.

INTRODUCTION

The Salt Wash field is located in parts of section 7, 8, 15, 16, 17, and 18, T. 23 S., R. 17 E., Salt Lake Base Line, in the northern Paradox basin, Grand County, Utah (figures 1 and 2). The field is 10.5 miles (16.9 km) south of Interstate 70 and is accessible by improved county road.

The field was discovered by Pan American Petroleum Corporation (Amoco Production Company) in 1961 with the completion of the 1 Salt Wash well (figure 1) drilled to a total depth of 9,523 feet (2,902.6 m) in the Cambrian Lynch Dolomite. The well was completed flowing 115 barrels (18.3 m^3) of oil (BO) per day from perforations (8,693 to 8,707 feet [2,649.6 to 2,653.9 m]) in the Mississippian Leadville Limestone. Wells have also been drilled in the field by Shell Oil Company, Texaco Oil Company, Consolidated Oil and Gas Incorporated, Megadon

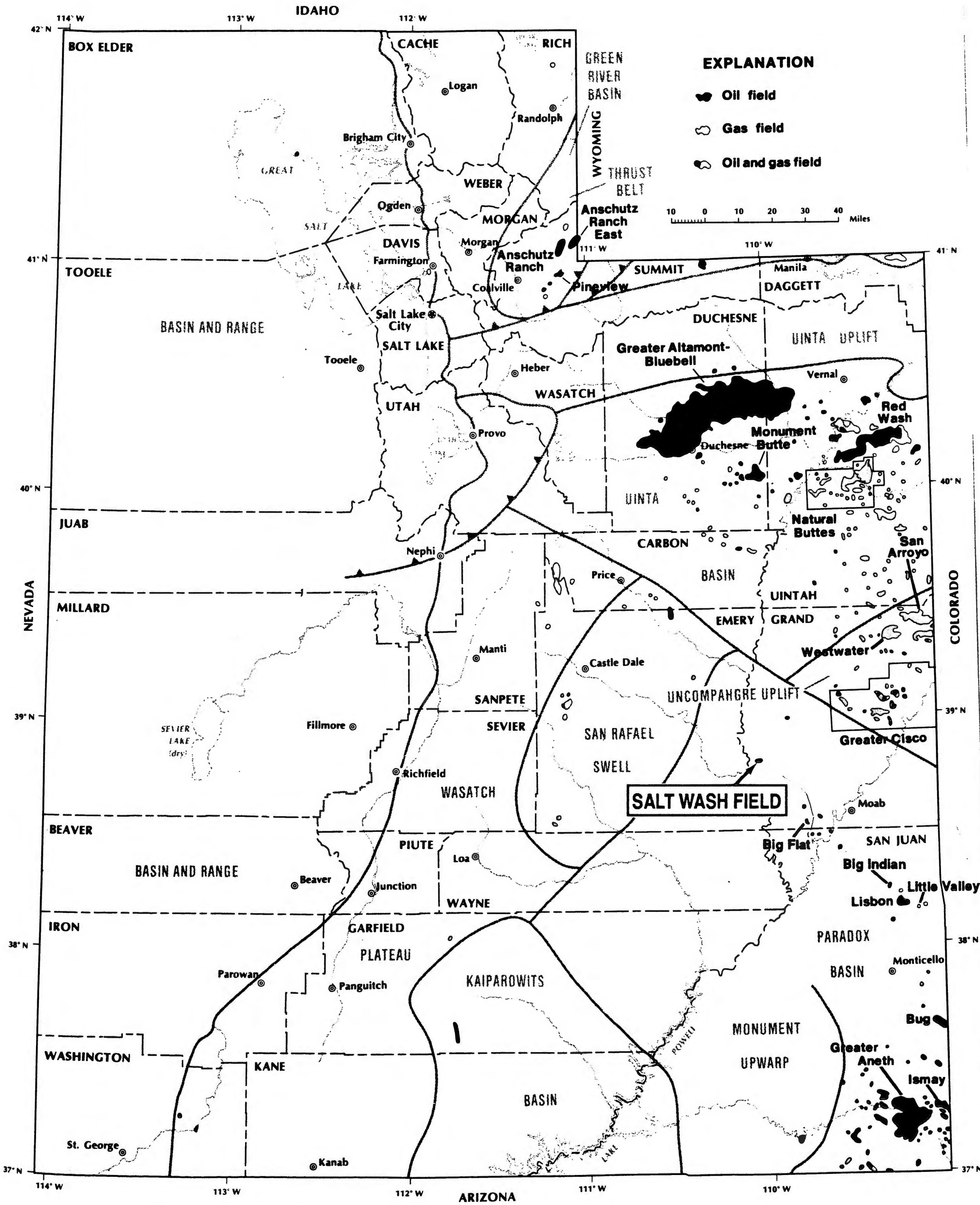

Figure 1. Oil and gas fields of Utah.

Energy Company, and SW Energy Company. Additional tests have been drilled in the area outside the field boundaries, by Reserve Oil and Gas Company, Belco Oil and Gas Company, and Willard Pease.

The Salt Wash field is an asymmetrical anticline with 300 to 600 feet (91.4 to 182.8 m) or more of closure on the top of the Leadville Limestone (figure 3). Cumulative production from the field is over 1.4 million barrels (0.2 million m^3) of oil (MMBO) and 11 billion cubic feet (0.3 billion m^3) of gas (BCFG) with an approximate average production of 1,000 BO (159 m^3) per month since 1977 (figure 4). Eleven wells have been completed as oil producers in the Salt Wash field. Eight wells were completed in the Leadville Limestone, two in the Devonian Elbert Formation, and one in the Pennsylvanian Paradox Formation. Most wells had a short production history due to high water production and collapsed casing. The majority of the production from the field has come from two wells, the 22-16 CF&I (<500,000 BO [79,500 m^3]) and 3 Govt. Smoot (<300,000 BO [47,700 m^3]) (figure 2).

The field currently (12/93) contains six active wells, but only the 3 Govt. Smoot produces on a regular basis. A short-radius horizontal leg was recently drilled in the upper Leadville Limestone in the 1-15 Federal well (figure 2). This well is currently shut-in and results of the drilling and completion attempt have not been released.

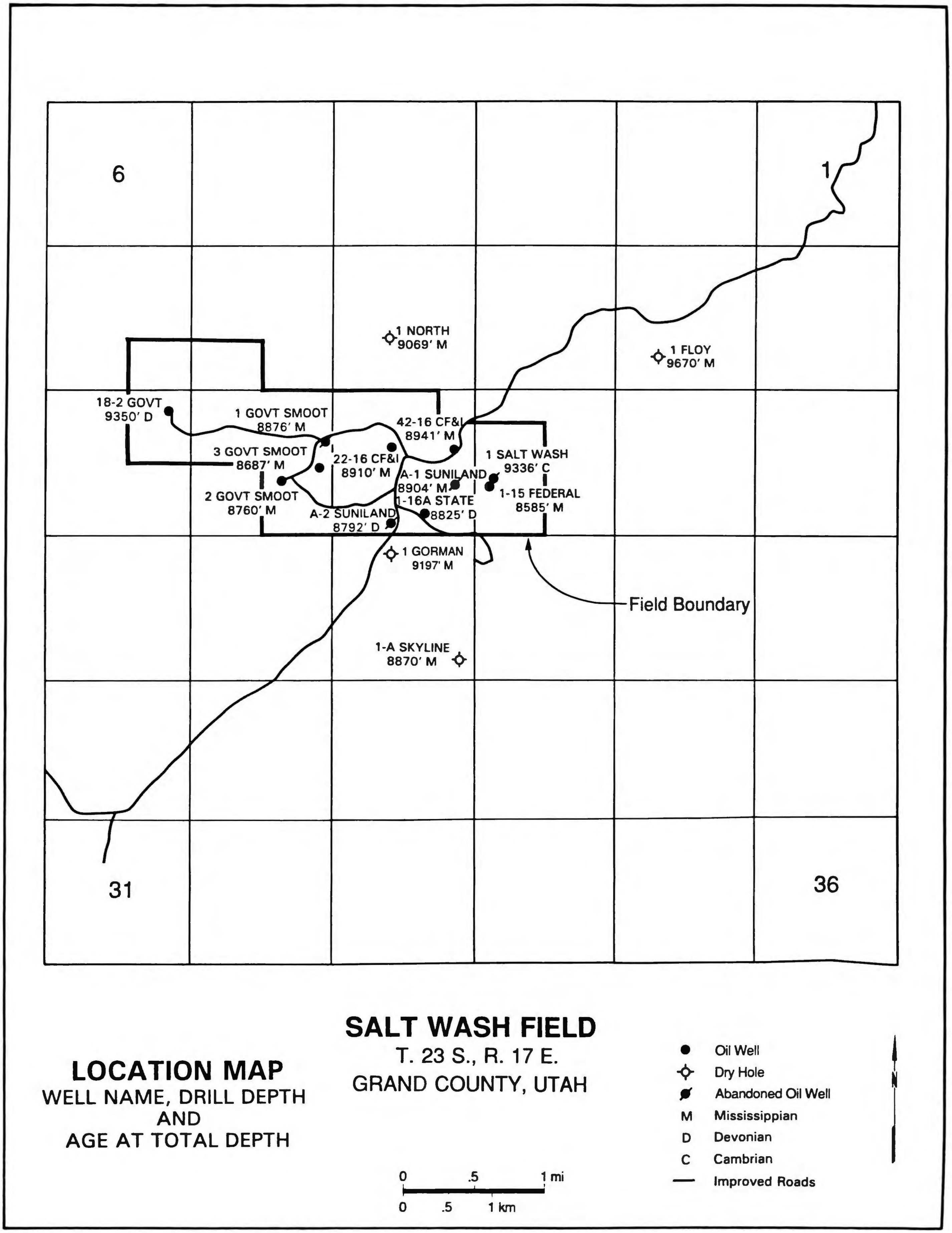

Figure 2. Drill hole location map of Salt Wash field.

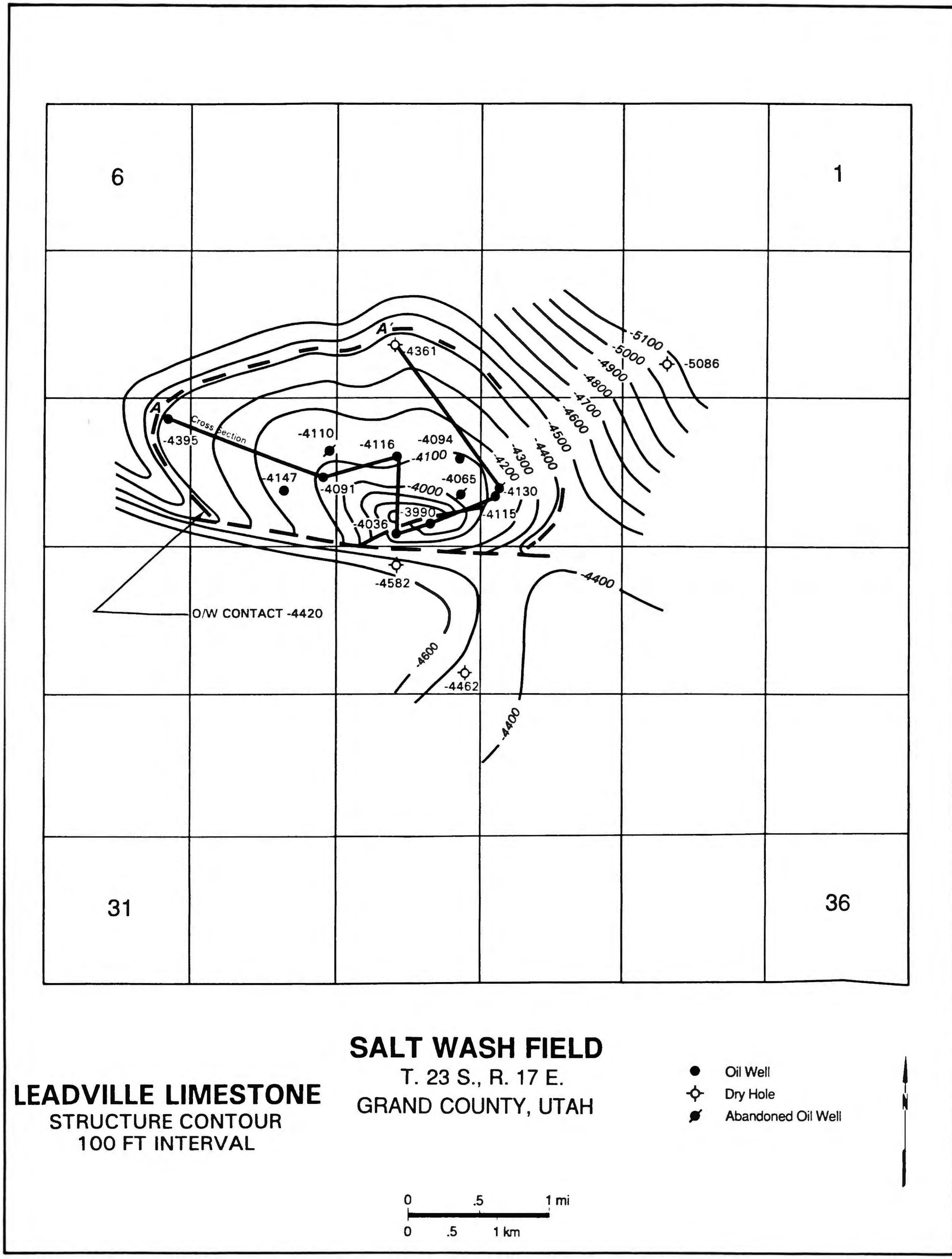

Figure 3. Top of upper Leadville Limestone structure contour map. Faults (dashed) are highly interpretative.

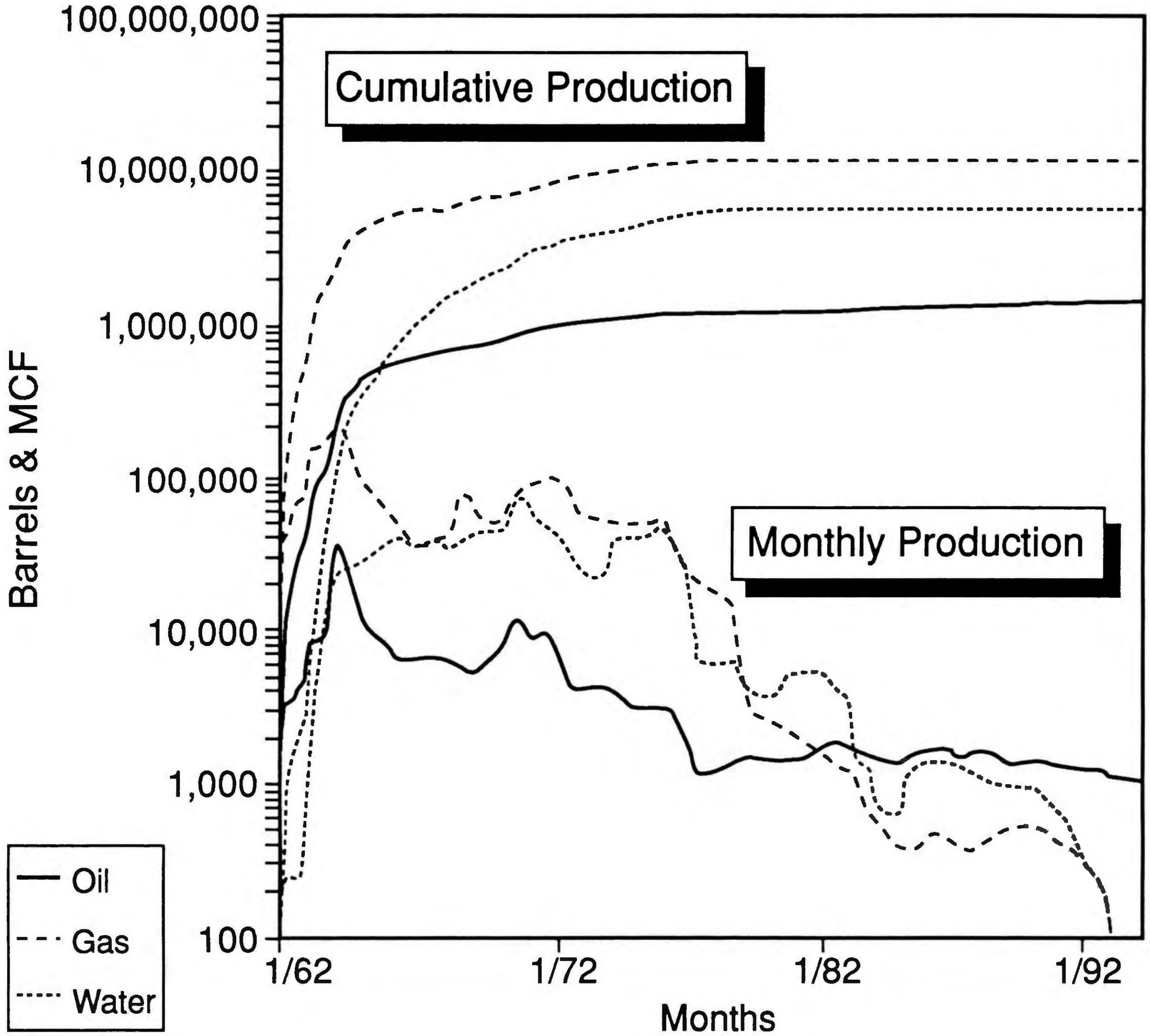

Figure 4. Generalized monthly and cumulative-production curves of the Salt Wash field. Over 1.4 million barrels (0.2 million m^3) of oil and 11 billion cubic feet (0.3 billion m^3) of gas have been produced from the field. The current production (12/31/93) is approximately 1,000 BO (159 m^3) per month, primarily from one well.

Previous Work

Peterson (1973) wrote the first published report on the Salt Wash field. Norton (1975), Clem and Brown (1984), and Smouse (1993) also wrote brief field summaries. Chidsey and Morgan (1993), and Morgan (1993) discuss the Salt Wash field in the Atlas of Major Rocky Mountain Gas Reservoirs (Robertson and Broadhead, 1993).

Purpose and Scope

A detailed study of the Salt Wash field was undertaken to develop a geologic model of a field that produces from the Leadville Limestone, that would aid and encourage more exploration in the Paradox basin. The Leadville Limestone was a major exploration target in the northern Paradox basin during the 1960s. During that time, the Lisbon (discovered in 1960), Salt Wash (1961), Big Indian (1961), Little Valley (1961), and Big Flat (1962) fields were discovered. Since 1962 there have not been any significant Leadville Limestone oil fields discovered and industry's interest in exploring for Leadville reservoirs in the northern Paradox basin has greatly decreased. A better understanding of the reservoir and its potential at Salt Wash field may help increase interest and improve exploration for new Leadville reservoirs in the Paradox basin.

This study uses well and field-history data, and well logs. Mud logs, sample descriptions, and core descriptions and analyses were used; drill cuttings and core were not examined by the author. The basic field-history and reservoir data were compiled for the "Atlas of Rocky Mountain Gas Reservoirs" (Robertson and Broadhead, 1993) funded by the Gas Research Institute. The field was investigated for its horizontal drilling potential in the Cane Creek shale (Pennsylvanian Paradox Formation) and Leadville Limestone as part of the "Increased Petroleum Production From Directed Horizontal Drilling in Utah" study (on-going). The horizontal drilling study is funded by the Utah Office of Energy and Resource Planning, who also provided some direct funding for the Salt Wash study.

REGIONAL GEOLOGY

The Salt Wash field is located in the northern Paradox basin of the Colorado Plateau physiographic province. The area was the site of shallow-shelf marine deposition but was occasionally emergent, from Cambrian through Pennsylvanian time. Faulting during the Late Mississippian to Early Pennsylvanian resulted in the development of the Paradox basin and individual structures within the basin, including the Salt Wash anticline. Marine evaporites and organic-rich shales were deposited in the basin during most of Pennsylvanian time. The sea transgressed over the area during the Late Pennsylvanian and shallow marine-shelf conditions returned. This was followed by clastic terrigenous deposition from Permian through Early Cretaceous time. Salt diapirism and large salt-cored anticlines (Moab and Cache Valleys, for example) formed primarily during Permian and Triassic time. Cretaceous marine and Tertiary alluvial deposits were eroded from the Salt Wash area during regional uplift of the Colorado Plateau, beginning in Miocene time.

STRATIGRAPHY AND PRODUCING FORMATIONS

The stratigraphic units exposed at the surface, at an average elevation of 4,400 feet (1,341.1 m), in the Salt Wash field area are the Jurassic Summerville and Curtis Formations, and Entrada Sandstone (figure 5). The deepest stratigraphic unit penetrated by drilling is the Cambrian Lynch Dolomite in the Pan American Petroleum (Amoco) 1 Salt Wash well (plate 1), which reached a total depth of 9,493 feet (2,983.5 m).

The majority of the production from the Salt Wash field is from the lower and upper Leadville Limestone. A minor amount of oil was produced from the Devonian Elbert Formation, from the A-2 Suniland and 1-16A State wells. The productive intervals in these two wells were originally correlated with the Leadville Limestone (rather than the Elbert Formation), and reported as such to the Utah Division of Oil, Gas and Mining. A minor amount of oil has been produced from the Paradox Formation in the 18-2 Govt. well.

Devonian Elbert Formation

The Elbert Formation unconformability overlies the Cambrian Lynch Dolomite and is unconformability overlain by the Devonian Ouray Limestone. The Elbert Formation is divided into the lower McCracken Sandstone Member and an upper limestone. In the 1 Salt Wash well, the McCracken Sandstone Member is 188 feet (57.3 m) thick and the upper limestone is 201 feet (61.3 m) thick. The upper limestone was productive in the A-2 Suniland and 1-16A State wells. Total production (12/31/93) from the two wells is 8,411 BO (1,337.3 m^3) and 90,563 MCFG (thousand cubic feet of gas) (2,564.7 m^3). The low volume of production

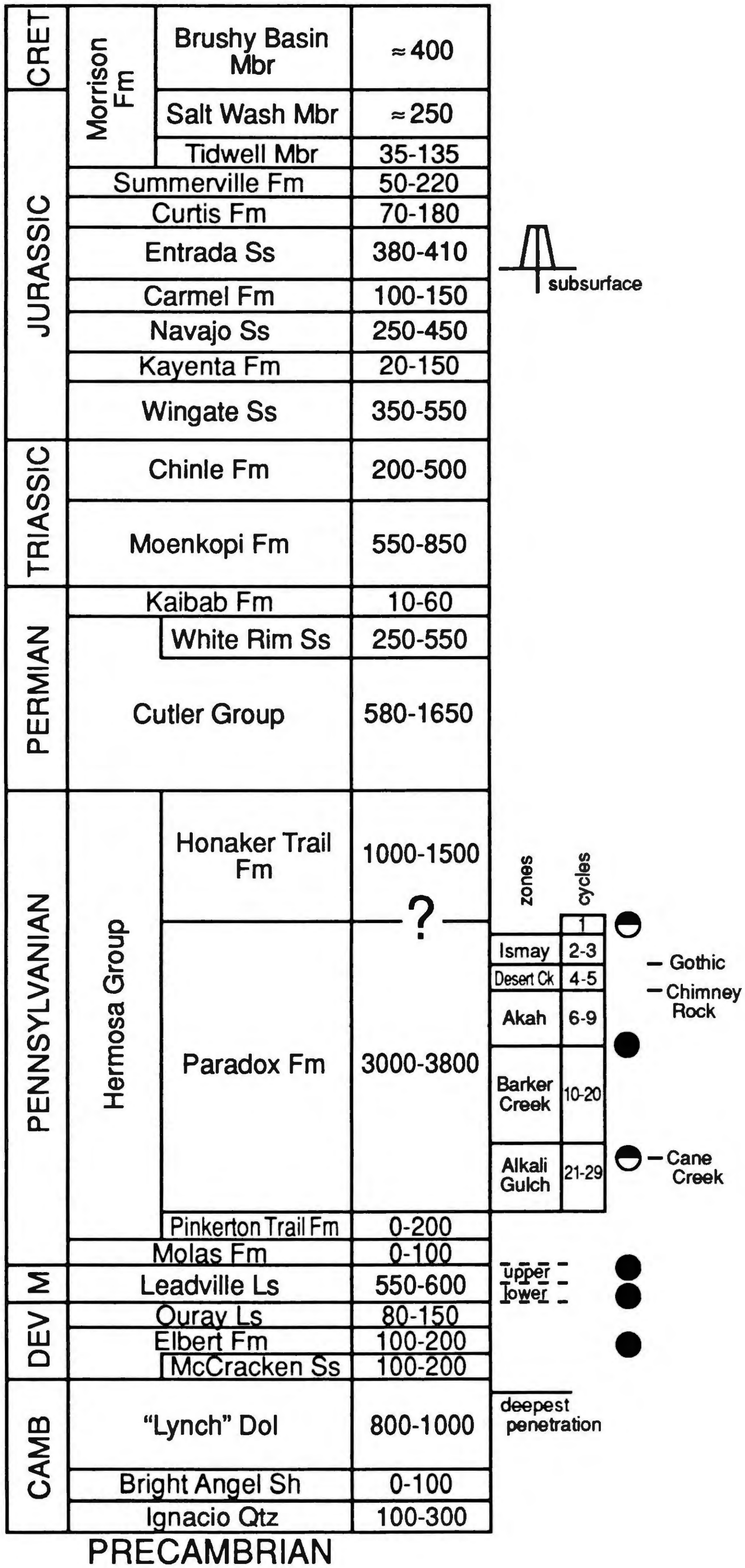

Figure 5. Stratigraphic column for the Salt Wash field area. Subsurface thicknesses determined from geophysical well logs except Cambrian, which is from Hintze, 1988. Surface thicknesses (in feet), from Doelling (verbal communication, 1994). Productive and potentially productive zones indicated with oil and show symbols, respectively.

and high water cut indicate the upper limestone reservoir has poor permeability and high water saturation. The McCracken Sandstone is a productive reservoir at Lisbon field (figure 1) but low resistivity values and a lack of drilling shows indicate the reservoir is wet in the wells drilled at Salt Wash field.

Mississippian Leadville Limestone

The Leadville Limestone unconformability overlies the Ouray Limestone and is unconformability overlain by the Pennsylvanian Molas or Pinkerton Trail Formation. The drilled thickness of the Leadville Limestone ranges from 566 feet (172.5 m) in the 1 Salt Wash well to 596 feet (181.7 m) in the 18-2 Govt. well. A large portion of the Leadville Limestone has been faulted out of the A-2 Suniland and 1-16A State wells. As a result the Leadville Limestone is only 196 feet (59.7 m) and 183 feet (55.8 m) thick in the A-2 and 1-16A wells respectively. The Leadville Limestone is informally divided into a lower and upper member (Baars, 1966). The lower Leadville Limestone is dolomitic with crystalline and vugular porosity. Structural closure of the Salt Wash anticline mapped on the top of the lower Leadville horizon is 300 to 700 feet (91.4 to 213.4 m) (figure 6). The lower Leadville Limestone reservoir is intermittently produced in the 2 Govt. Smoot well, and was produced in the 1 Salt Wash, 22-16 CF&I, 42-16 CF&I, and 1 and 3 Govt. Smoot wells. At Salt Wash field, over 1.1 MMBO (0.17 million m^3) and 8.5 BCFG (0.24 billion m^3) have been produced from the lower Leadville Limestone reservoir (12/31/93). The majority of this production is from the 22-16 CF&I well, where 0.6 million BO (0.09 million m^3) and 5.1 BCFG (0.14 billion m^3) was produced (figure 7).

The upper Leadville is limestone to dolomitic limestone with some thin (5 to 15 feet [1.5 to 4.6 m]) porous dolomite zones. The porosity may be in post-depositional, dolomitized vadose

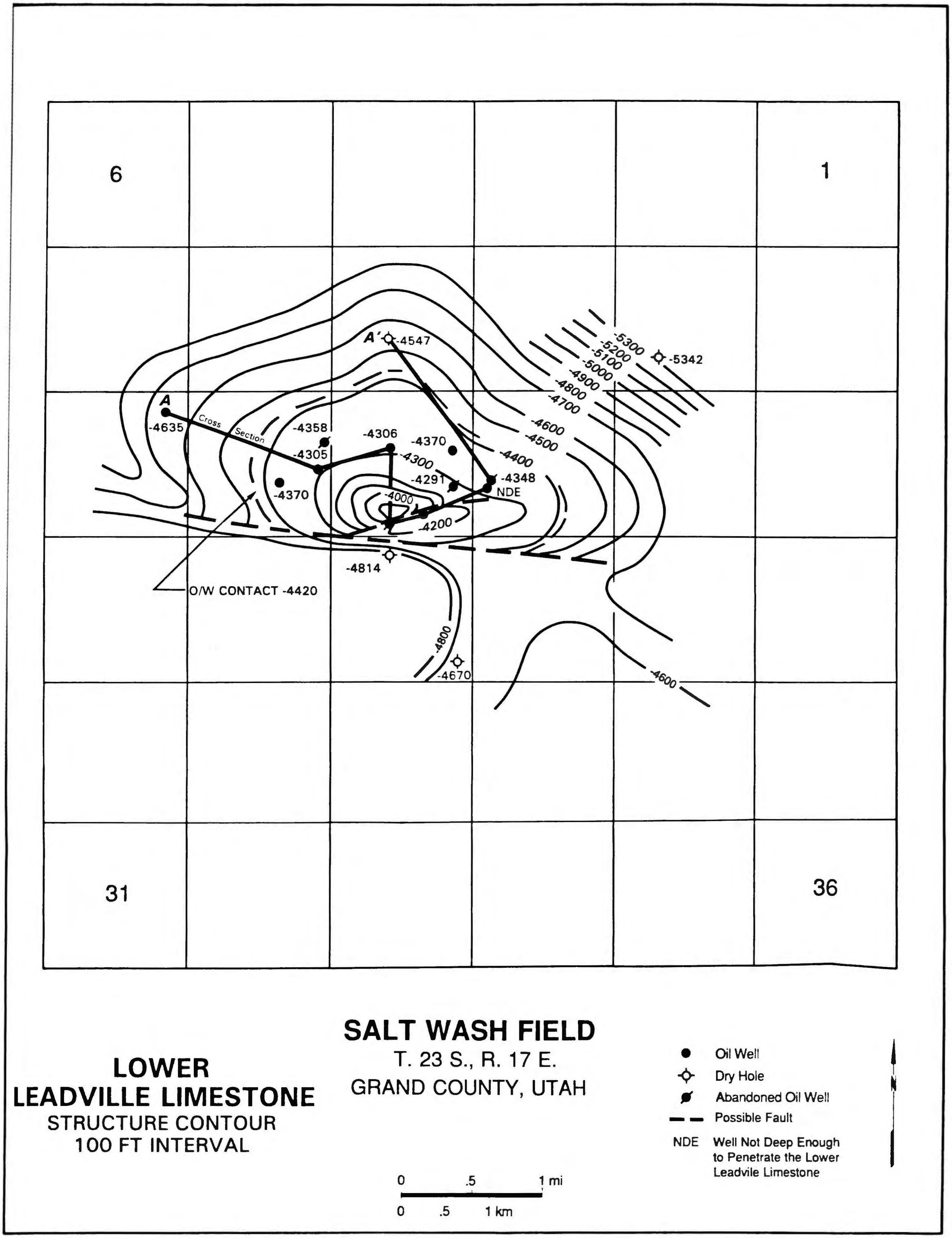

Figure 6. Top of the lower Leadville Limestone structure contour map. Faults (dashed) are highly interpretative.

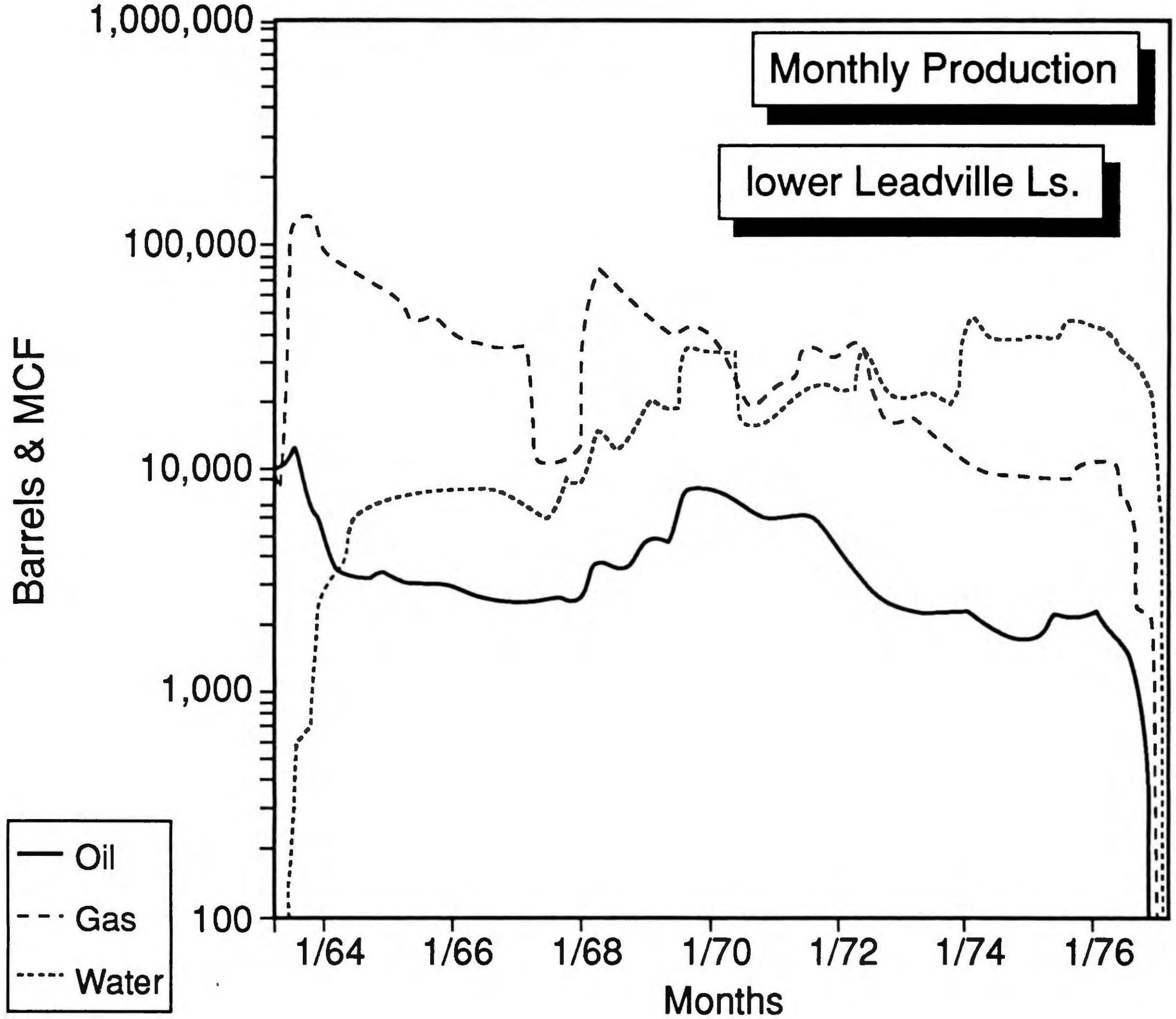

Figure 7. Generalized monthly production curves for the 22-16 CF&I well. Over 500,000 BO (79,500 m^3) were produced from this well in the lower Leadville Limestone.

zones. Zones with greater than 8 percent porosity occur in every well in the Salt Wash area except the 1-15 and 1 Salt Wash wells. Closure at the upper Leadville horizon is 300 to 600 feet (91.4 to 182.8 m) or more (figure 3).

The 42-16 CF&I well was recompleted in the upper Leadville Limestone reservoir in 1969. The upper and lower Leadville production was commingled. The monthly production rate increased but the casing partially collapsed a year later. The well was shut in from 1972 to 1982. From 1982 through 1991, the well was produced intermittently at an average rate of 10 to 12 BO (1.6 to 1.9 m^3) per day and has not been produced since May 1992. A bridge plug was set above the lower Leadville Limestone perforations in the 3 Govt. Smoot well and the upper Leadville Limestone was perforated. This well has produced over 300,000 BO (47,700 m^3) in 20 years and continues to flow at a relatively steady rate while the water and gas production decreased (figure 8). Cumulative production from the upper Leadville Limestone is 353,886 BO (56,267.9 m^3) and 3,133,468 MCFG (88,739.8 m^3) (11/30/93).

Completing wells in the lower Leadville reservoir is complicated by the potential for coning of the water directly below and in contact with the oil. Cores of the Leadville Limestone at Salt Wash field contain numerous vertical fractures creating high vertical permeability relative to horizontal permeability (often five to 10 times greater). As a result, wells like 1 Salt Wash, that were perforated directly above the oil/water contact began producing large quantities of water shortly after being placed in production (figure 9). Recompletion of these wells generally did not occur because the casing in the wellbore had collapsed (figure 10).

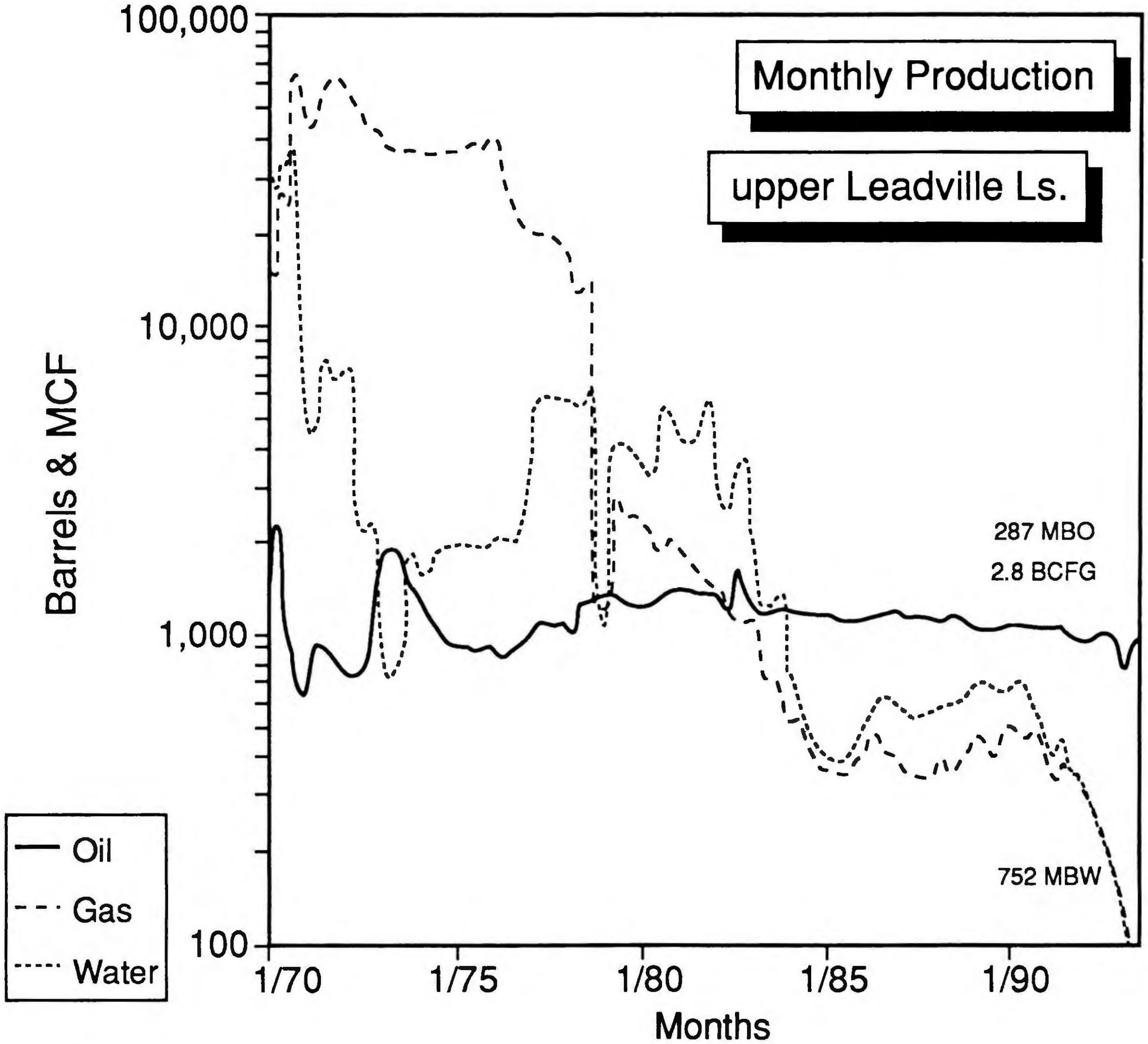

Figure 8. Generalized monthly production curves for the 3 Govt. Smoot well. Over 300,000 BO (47,700 m^3) has been produced from this well in the upper Leadville Limestone. The current production from this well is approximately 1,000 BO (159 m^3) per month. The oil rate has remained fairly constant over the years while the gas and water volumes decreased.

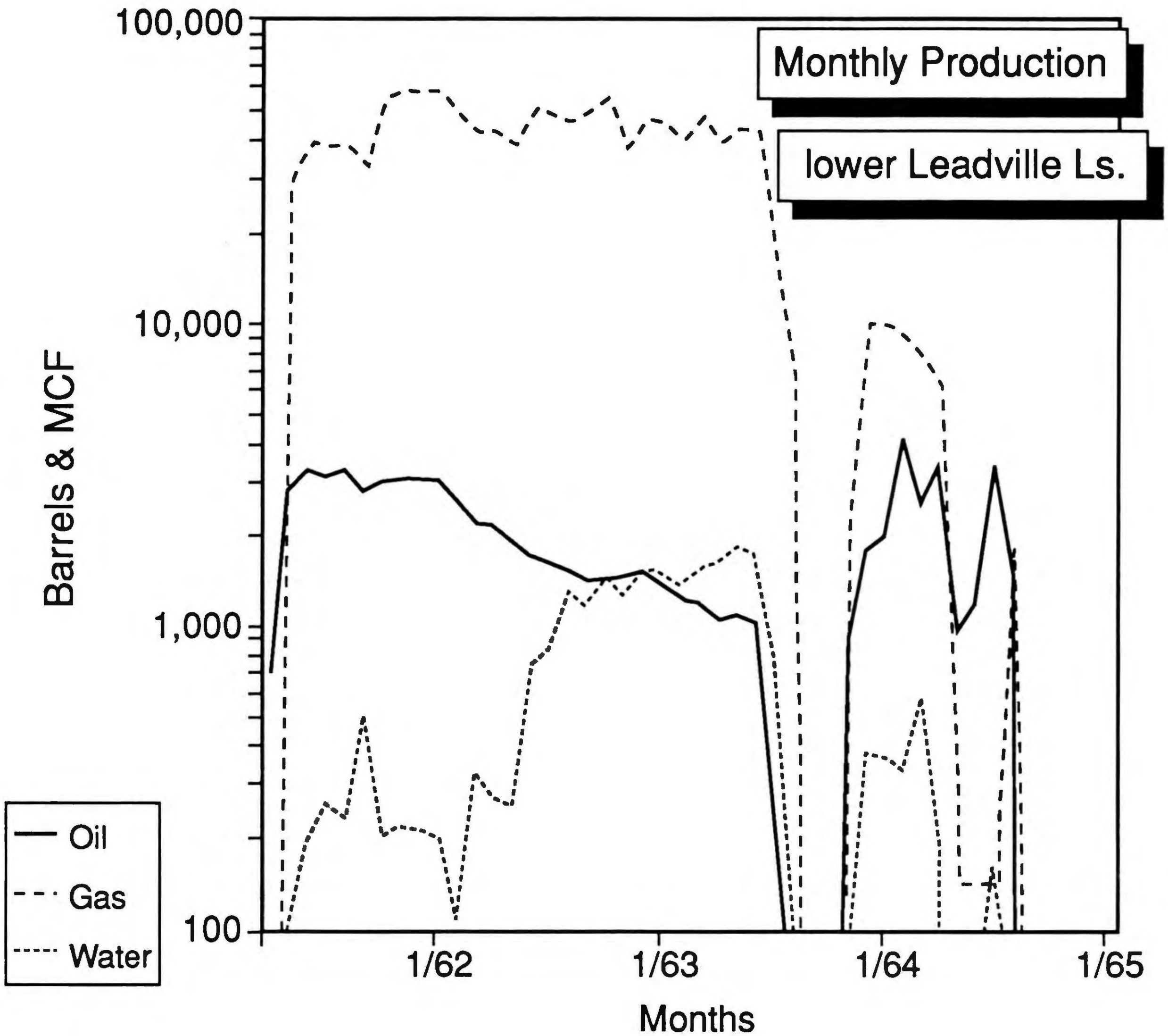

Figure 9. Generalized monthly production curves for the 1 Salt Wash well. Less than 57,000 BO (9,063 m^3) were produced from this well before the large water cut and collapse of the casing resulted in abandonment of the well. The large water cut, possibly due to coning, and casing collapse, were common problems in most of the wells.

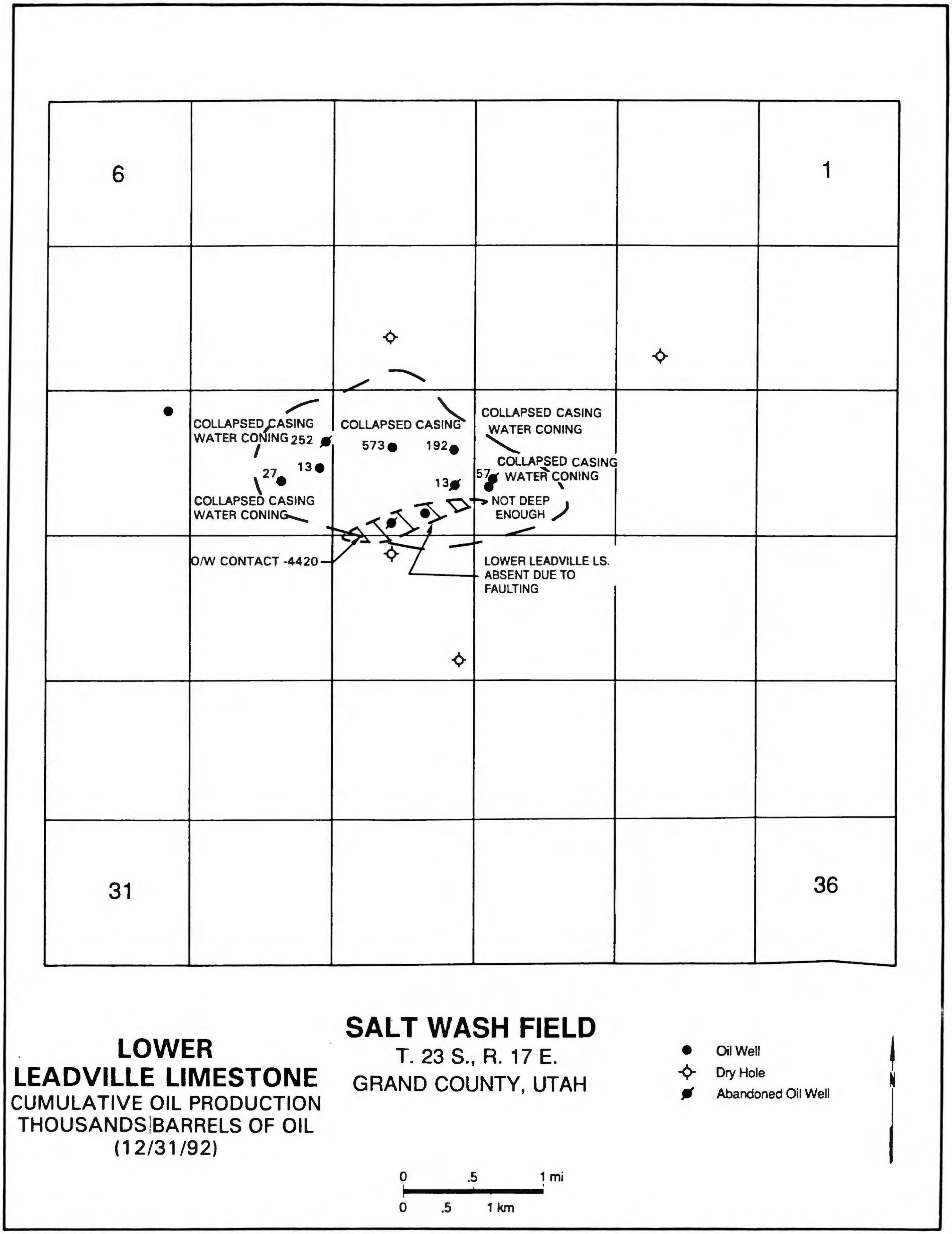

Figure 10. Status map of wells completed in the lower Leadville Limestone. Most wells were prematurely abandoned due to possible water coning and collapsed casing.

An additional problem can be the presence of water directly above the productive interval. The 1 Salt Wash well was tested at a rate of 533 MCFG (15,095 m^3) per day and recovered 858 feet (261.5 m) of highly gas-cut and mud-cut water from the upper Leadville overlying the productive lower Leadville reservoir. The 3 Smoot well was drill-stem tested from 8,630 to 8,687 feet (2,630.4 to 2,647.8 m). The test interval included the basal portion of the upper Leadville and upper portion of the lower Leadville. Gas, oil, and water flowed to surface (no gauge or volumes reported) during the test and the drill-pipe recovery was 4 BO (0.6 m^3) and nine barrels of water (BW) (1.4 m^3). The well was completed through perforations from 8,643 to 8,635 feet (2,634.4 to 2,631.9 m) in the upper portion of the lower Leadville. The initial potential of the well was gauged at 128 BO (20.4 m^3), 1,300 MCFG (36,816 m^3), and 1,050 BW (166.9 m^3) per day. In 14 months, 13,170 BO (2,094 m^3) and 310,256 BW (49,330 m^3) were produced from the well. The perforated interval is 104 feet (31.7 m) above the original oil/water contact. The high volume of water may be from a water-saturated zone at the top of the lower Leadville porosity. For water to be present at the top of the lower Leadville in this well, the reservoir must be more heterogenous than originally believed.

Pennsylvanian Paradox Formation

The Paradox Formation conformably overlies the Pinkerton Trail Formation and is conformably overlain by the Pennsylvanian Honaker Trail Formation. The Paradox Formation is part of the Hermosa Group, which consists of, in ascending order, the Pinkerton Trail, Paradox, and Honaker Trail Formations (figure 5). The Paradox is the only formation in the group that is productive in the Salt Wash field. The Paradox Formation was deposited in an evaporitic restricted basin. The formation is composed principally of salt beds, consisting of cyclically bedded halite and lesser amounts of anhydrite and potash with interbeds of dolomite, dolomitic siltstone, and organic-rich shales that were deposited during sea level high-stands. Hite (1960) numbered the salt cycles in descending order, 1 through 29. It is now common practice to consider a complete cycle as consisting of an interbed and overlying salt or equivalent carbonate unit. The cycles are informally grouped into zones; Ismay (cycles 2-3), Desert Creek (4-5), Akah (6-9), Barker Creek (10-20), and Alkali Gulch (21-29), (Hite and Cater, 1972; Reid and Berghorn, 1981).

The 18-2 Govt. well is perforated in interbeds 3-9, 11, 16-19. Production is intermittent and the total is 862 BO (137.1 m^3) and 629 MCFG (17.8 m^3). The Cane Creek shale (interbed 21) is productive in the Kane Springs unit 10 miles (16 km) south of the Salt Wash field. Horizontal drilling has proven to be the most successful method to exploit the fractured Cane Creek shale reservoir. The 1-16A State well recovered 600 feet (182.9 m) of oil during an open-hole drill-stem test of the Cane Creek shale (figure 11). Closure at the Cane Creek horizon is 200 feet (60.9 m^3) (figure 12). The Cane Creek shale is currently (3/1/94) not productive at the Salt Wash field.

In cycle 1 of the Paradox Formation, a facies change from porous dolomite (over 50 feet of 12 to 14 percent porosity) to anhydrite then to halite, occurs from west to east, across the western plunge of the Salt Wash anticline (figure 13 and plate 2). The updip pinchout of porosity in cycle 1 between 18-2 Govt. and the Govt. Smoot wells is a relatively shallow (5,500 feet [1,676.4 m]) untested trap similar to the Ismay and Desert Creek plays in the Greater Aneth area in southeast San Juan County.

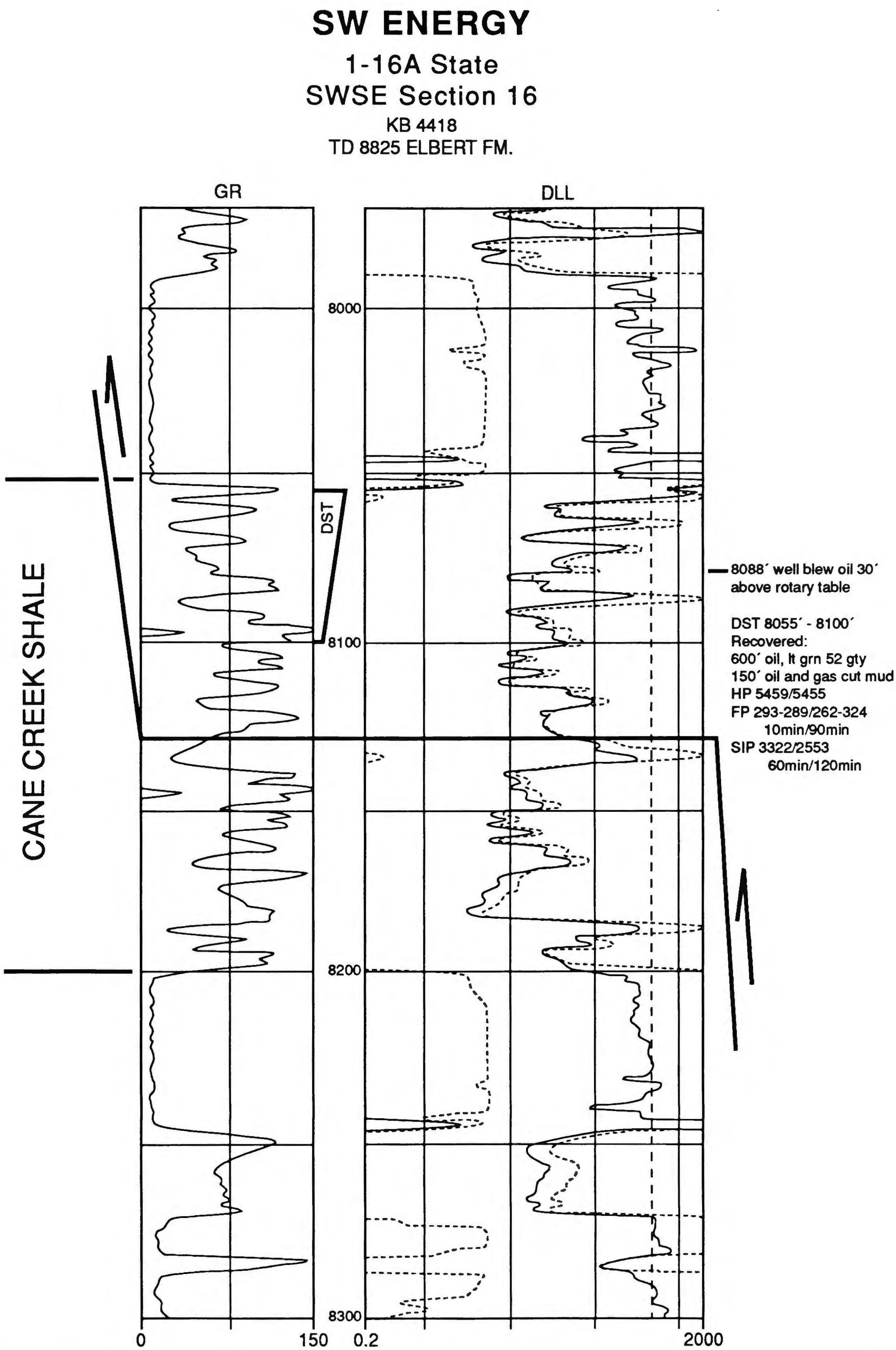

Figure 11. Geophysical log of the Cane Creek shale of the Paradox Formation in the 1-16A State well. A drill-stem test of the Cane Creek recovered 600 feet (182.9 m) of oil. The section is repeated by a reverse fault.

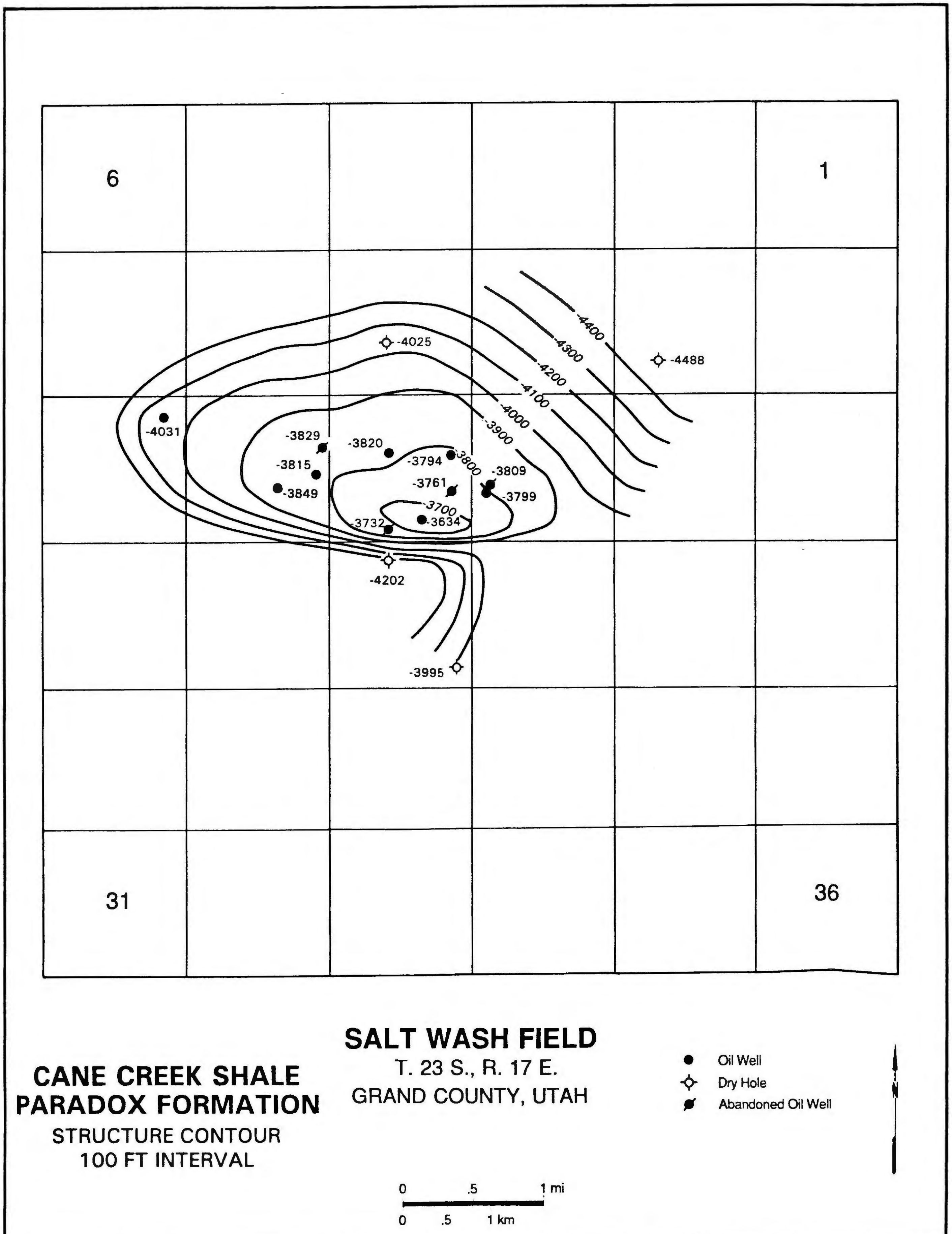

Figure 12. Top of the Cane Creek shale of the Paradox Formation structure contour map. The reverse fault causing approximately 75 feet of repeated section in the 1-16A well (figure 11) was not encountered in any other well. Therefore, the strike and extent of the fault is unknown and not shown on this map.

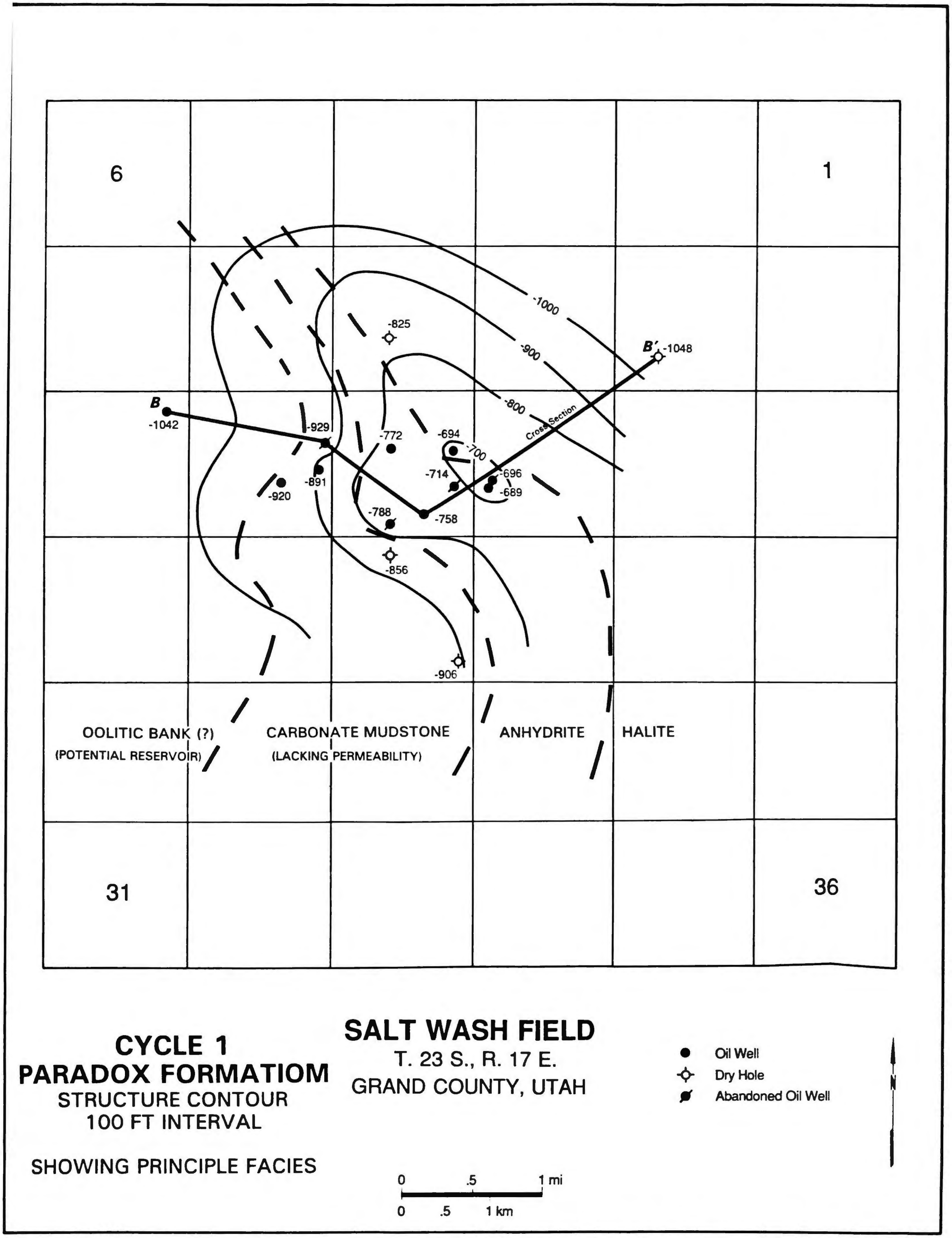

Figure 13. Top of cycle 1 of the Paradox Formation structure contour map. The principal facies of the cycle are shown. Note the updip pinchout of the porous oolitic bank(?) deposit creating a possible trap along the western plunge of the structure.

STRUCTURE

The Salt Wash field is an east-west asymmetrical anticlinal trap. The structure is associated with a high-angle east-west fault, down-to-the-south, that moved during Late Mississippian to Early Pennsylvanian time. Additional movement may have occurred on the fault during the Pennsylvanian and again in the Late Cretaceous to Early Tertiary. The fault has not been penetrated by any wells, but is visible on seismic profiles and may die out in the lower Paradox Formation (Ken Grove, Columbia Gas Development Corporation, and Robert Gray, Thistle Inc. Geophysical, verbal communication, 1994). A normal fault was penetrated by the A-2 Suniland and 1-16A State wells. As a result, the lower Leadville (over 300 feet (91.4 m) of section), is absent in these two wells. The A-2 Suniland and 1-16A State wells are the structurally-highest penetrations of Paleozoic-aged rocks in the field (figures 3 and 6). An additional 300 feet (91.4 m) of untested closure may be present on the upthrown side of the fault.

In the 1-16A State well, a reverse fault repeats the Cane Creek shale. A recumbent fold of cycle 19 was penetrated by the 22-16 CF&I well. I believe these are highly localized structures caused by salt movement during the Permian and Triassic.

The Ten Mile graben is located 2 miles (3.2 km) north of the Salt Wash field. The normal faults forming the graben are related to an underlying salt-cored anticline in the Paradox Formation. Beneath the salt-cored anticline, subsurface, high-angle faults displace Early and Pre-Pennsylvanian rock and die out upward in the Paradox Formation (Woodward-Clyde Consultants, 1984). The deeper faults place organic-rich shales against the Leadville Limestone, providing a migration pathway for hydrocarbons into the Leadville Limestone, downdip from the Salt Wash field.

OIL AND GAS COMPOSITION

The oil produced from the Leadville Limestone at the Salt Wash field is 50^0 API gravity, contains 0.23 percent sulfur, has a viscosity of 32 seconds at 100^0 F, and a pour point of 40^0 F. (Wenger and Morris, 1971). The oil and gas compositions are similar for both the upper and lower Leadville production. The gas has an average heating value of 442 BTU/ft^3, and a specific gravity of 1.015. The average composition of the gas produced from the Leadville Limestone at Salt Wash field is given in table 1.

Table 1. Average composition, in mole percent, of the gas produced from the Leadville Limestone at Salt Wash field. Data from Moore and Sigler (1987).

Methane (C_1) = 11.8	Butane (C_4) = 3.1	Nitrogen (N_2) = 71.9
Ethane (C_2) = 2.6	Isobutane (C_5) = 1.4	Carbon dioxide (CO_2) = 2.1
Propane (C_3) = 2.8	Higher fracs. (C_6+) = 0.7	Helium (He) = 1.4
		Hydrogen sulfide (H_2S) = 0.0

SOURCE AND MIGRATION OF HYDROCARBONS

Mass spectrometry and gas chromatography of the oil produced from the Leadville Limestone indicate that the source rock for hydrocarbons at Salt Wash field is the organic-rich shales in the Paradox Formation (Jim Palacas, U.S. Geological Survey, verbal communication, 1994). The Paradox Formation in the northern Paradox basin was not mature enough to generate oil until the Early Cretaceous or later (figure 14). The Salt Wash structural trap formed during the late Mississippian to early Pennsylvanian, long before the generation and migration of hydrocarbons.

The Paradox Formation is in fault contact with the Leadville Limestone at Ten Mile graben 2 miles (3.2 km) north of the field. The majority of the hydrocarbons may have been generated and migrated from the north and entered the Leadville Limestone at this location. The south-bounding fault between the A-2 Suniland and 1 Gorman wells (figures 2 and 6) may have been a migration pathway draining a much smaller source area.

The Paradox Formation interbeds, including the Cane Creek shale, are self-sourced fractured reservoirs. The most likely source of hydrocarbons for cycle 1 of the Paradox Formation is the organic-rich interbeds that over and underlie the reservoir.

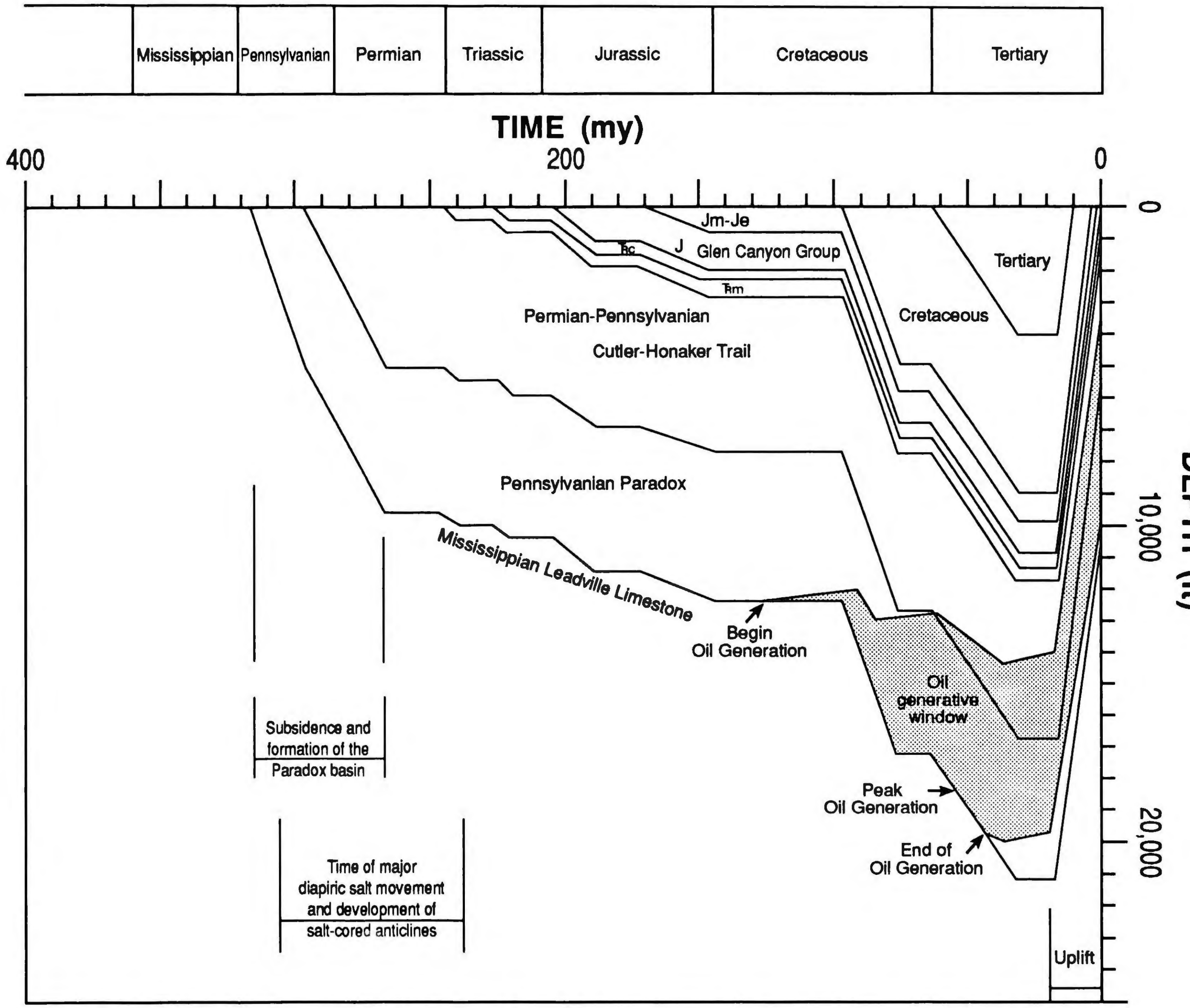

Figure 14. Burial history curve and Lopatin time-temperature interval (TTI) calculation for the 2 Gold Bar well (SW1/4 section 23, T. 25 S., R. 20 E.). A geothermal gradient of 44° F/mi (22° C/km) above the Paradox Formation, and 34° F/mi (13° C/km) through the Paradox was used (Sass and others, 1983). The 2 Gold Bar well is representative of the burial and thermal history of the Salt Wash field and northern Paradox basin. Oil generation in the Paradox Formation began in Early to Late Cretaceous time, well after the Salt Wash anticlinal trap had formed (Pennsylvanian time).

SOURCE AND MIGRATION OF INERT GASES

The inert gases (nitrogen, carbon dioxide, and helium) produced from the Leadville Limestone at the Salt Wash field may have come from a variety of sources. Nitrogen and carbon dioxide may have generated from Paleozoic rocks in the Uinta Basin, were they were deeply buried during the Late Cretaceous and Tertiary. Helium may have derived from basement rocks locally as well as migrated in from the north. The source of nitrogen and carbon dioxide in Leadville reservoirs in the Lisbon Valley and Blanding basin is from the south. There, volcanic intrusions provided the heat source for generation of nitrogen and carbon dioxide in the Blanding basin area approximately 40 million years ago.

Nitrogen in the subsurface can be generated in large volumes by the thermal alteration of dispersed organic nitrogen compounds in redbeds (Hunt, 1979). Carbon dioxide can be produced in large volumes by thermal decomposition of limestone. Impure limestones and water-wet dolomitized limestone begin generating carbon dioxide at temperatures as low as 167° F (75° C); maximum generation of carbon dioxide occur when subsurface temperatures approach 302° F (150° C) (Germann and Ayres, 1942; Kissin and Pakhomov, 1967; in Hunt, 1979). Both nitrogen and carbon dioxide can be generated from coal (Getz, 1977) but coal is considered an unlikely source for the inert gases found in the Paleozoic reservoirs of the northern Paradox basin. Helium is produced as a by-product of the alpha disintegration of naturally occurring radioactive elements. Helium can be produced from igneous, metamorphic, and sedimentary rocks depending upon their uranium and thorium contents (Hunt, 1979).

Because it is a smaller molecule, nitrogen commonly migrates farther distances than carbon dioxide. As a result, the percentage of nitrogen in reservoirs is higher, while the percentage of carbon dioxide is lower, farther from the source (Getz, 1977). A decrease in the carbon dioxide to nitrogen ratio occurs from north to south, from the Uinta basin into the northern Paradox basin. Paleozoic-aged reservoirs at Gordon Creek field (T. 14 S., R. 7 E.) and Farnham Dome field (T. 15 S., R. 11-12 E.), Carbon County, contain approximately 99 percent carbon dioxide. Woodside field (T. 19 S., R. 13 E.), Emery County, tested 32 percent carbon dioxide and 61 percent nitrogen (Morgan and Chidsey, 1991). Salt Wash (T. 23 S., R. 17 E.) and Big Flat (T. 26 S., R. 19 E.) fields, Grand County, produced gases containing over 70 percent nitrogen and only 2 to 3 percent carbon dioxide. In the southern portion of the Paradox basin of southeast Utah and southwest Colorado, the Leadville reservoirs contain 80 percent or more carbon dioxide (Picard, 1960). Northward, in Lisbon Valley, gases in the Leadville reservoirs are composed of approximately 26 percent carbon dioxide and 12 percent nitrogen. The Cane Creek anticline may be the divide between the two source areas.

REMAINING HYDROCARBON POTENTIAL

Lower Leadville Limestone

The porous dolomite in the lower Leadville is the most productive reservoir in the Salt Wash field. Over 1 MMBO (0.16 million m^3) have been produced from this reservoir and 1.0 to 1.4 million barrels (0.16 to 0.22 million m^3) of recoverable oil could still exist in the field. This estimate of remaining potential assumes the production from the 22-16 CF&I well is typical of the potential from the lower Leadville reservoir. This well had the longest trouble-free production history from 1963 till 1976, and produced over 500,000 BO (79,500 m^3). The 22-16 CF&I well has a gross productive interval of 114 feet (34.7 m), from the top of the lower Leadville porosity to the oil/water contact, at an elevation of -4420 feet (-1,347.2 m). A 31 BO/gross acre-foot (3,974 m^3 oil/gross h-m) recoverable, was calculated for the 22-16 CF&I well, assuming a 160-acre (64.8-h) drainage area. The BO/gross acre-foot was gridded for the Salt Wash field and an amount equal to the cumulative production for each well was removed from the gridded database within 160 acres (64.8 h) of the respective well.

The calculated range in quantity of recoverable oil (1.0 to 1.4 MMBO [0.16 to 0.22 million m^3]) is strongly effected by the minimum volume per 160 acres (64.8 h) that is assumed economically feasible to justify drilling. The recovery, number of wells drilled, and drainage area per well varies with the use of vertically or horizontally drilled wells. Horizontal wells can drain a much larger area and greatly reduce the amount of water coning compared to vertical wells (Chaperone, 1986).

These calculations are intended to demonstrate that a significant volume of oil may still potentially exist in the Salt Wash field. They are highly sensitive to the assumptions used. Therefore, the values given should be considered only as preliminary estimates.

Upper Leadville Limestone

The upper Leadville is the second most productive reservoir in the Salt Wash field. Nearly 300,000 BO (47,700 m^3) have been produced from this reservoir, which may still contain 1 to 2.4 million barrels (0.16 to 0.38 million m^3) of recoverable oil. The assumptions used in this estimation are: 1) the production from the 3 Govt. Smoot well is the average per-well potential, 2) the drainage area is 160 acres (64.8 h), and 3) the oil/water contact is -4,420 feet (-1,347.2 m) mean sea level.

The upper Leadville reservoir has only been exploited in the 42-16 CF&I and 3 Govt. Smoot wells. In the 42-16 CF&I well, was originally completed in the lower Leadville reservoir and produced from it for six years, and then the upper Leadville reservoir was perforated and that production commingled with the production from the lower Leadville. The additional perforations in the upper Leadville resulted in an increase in the monthly production rate of the well. The casing collapsed approximately one year after the upper Leadville was perforated. The short production history of this well, after the upper Leadville was put into production, is not adequate to determine the full potential of that reservoir.

The 3 Govt. Smoot well has produced nearly 300,000 BO (47,700 m^3) from the upper Leadville reservoir. The well has produced for over 23 years and continues to flow at an average rate of 1,000 BO (159 m^3) per month. The oil rate has remained fairly constant while the gas and water volumes have declined steadily during this time (figure 8). The decline in gas and water indicates the reservoir drive is gas expansion and gravity, with a very limited water drive.

Paradox Formation - Cane Creek Shale

The Cane Creek shale reservoir is currently not productive in the Salt Wash field. In the Kane Springs unit 10 miles (16 km) to the south, horizontal wells completed in the Cane Creek shale are estimated to have a potential in excess of 500,000 BO (79,500 m^3) per well (Grummon, 1993). The Salt Wash field has the potential for at least one, possibly two, horizontally drilled wells in the Cane Creek shale. In 1981, The 1-16A State well blew oil 30 feet (9.1 m) above the rotary table while drilling the Cane Creek shale. The operator gained control of the well and ran an open-hole drill-stem test. The drill-pipe recovery from the test was 600 feet (182.9 m) of oil and 150 feet (45.7 m) of oil and gas-cut mud (figure 12). The well was later completed in the deeper Devonian Elbert Formation.

Paradox Formation - Cycle 1

The cycle 1 reservoir is currently not productive in the Salt Wash field or any other fields in the northern Paradox basin. The reservoir has the potential for 1 million barrels (159,000 m^3) of recoverable oil. The assumptions used in this estimation are: (1) the potential productive area is at least 160 acres (64.8 h), (2) the drainage area is 40 acres (16.2 h), and (3) the average production will be 250,000 BO (39,750 m^3) per well. The productive area is based upon mapping using geophysical logs (figure 13). The drainage area and production is typical of many Ismay and Desert Creek wells. The exploratory play is the test of the updip pinchout of porosity from west to east across the western plunge of the anticline (figure 13 and plate 2).

SUMMARY

The Salt Wash field has been producing oil for over 30 years. The remaining potential may be greater than the total volume of oil produced from the field during all those years. Production problems (increased water production and casing collapse) led to the early abandonment of many of the wells. The lower Leadville was originally believed to be a single reservoir with a 15-foot (4.6-m) oil column and a large gas-cap. The upper Leadville reservoir was believed to be part of the gas-cap, lacking the potential to produce oil. Recompletion of a few of the wells has demonstrated that the oil/gas composition and the heterogeneity of the reservoir rock is far more complex than originally believed. A better understanding of reservoir heterogeneity can result in increased recovery from older fields, like Salt Wash field, and serve as a model for exploration and re-evaluation of dry holes that may have by-passed potential.

ACKNOWLEDGMENTS

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APPENDIX A

Wells drilled in T. 23 S., R. 17 E., of the Salt Lake Base Line, Grand County, Utah, that were used in this report and are in the Utah Geological Survey's Integral*gim database.

Original operator
Well name and number
Quarter, quarter, section
API number

Reserve Oil & Gas Company
Salt Wash North 1
NE1/4SW1/4 section 9
43-019-30282-0000

Belco Petroleum
Floy Unit 1
SE1/4SW1/4 section 11
43-019-10086-0000

Megadon Energy Corporation
Federal 1-15
NW1/4SW1/4 section 15
43-109-30752-0000

Pan American Petroleum Corp
Salt Wash 1
NW1/4SW1/4 section 15
43-019-10831-0000

Shell Oil Company
CF&I 22-16
SE1/4NW1/4 section 16
43-019-15819-0000

Shell Oil Company
CF&I 42-16
SE1/4NE1/4 section 16
43-019-15820-0000

Pan American Petroleum Corp
Suniland A-1
NE1/4SE1/4 section 16
43-019-10832-0000

Pan American Petroleum Corp
Suniland A-2
SE1/4SW1/4 section 16
43-019-10833-0000 (PAO)
43-019-10833-0001 (WDW)

Megadon Energy Corporation
State 1-16A
SW1/4SE1/4 section 16
43-019-30783-0000

Texaco Inc
Government Smoot 1
SE1/4NE1/4 section 17
43-019-16047-0000

Texaco Inc
Government Smoot 2
NW1/4SE1/4 section 17
43-019-16048-0000

Consolidated Oil & Gas, Inc
Government Smoot 3
NE1/4SE1/4 section 17
43-019-30044-0000

Wyoco Petroleum Corporation
Government Wyoco 18-2
NE1/4NE1/4 section 18
43-019-30679-0000

Wyoco Petroleum Corporation
Gorman Federal 1
NE1/4NW1/4 section 21
43-019-30658-0000

Pease Willard Oil & Gas Co
Skyline Federal 1-A
SE1/4SE1/4 section 21
43-019-30327-0000

APPENDIX A (continued)

Wells drilled in T. 23 S., R. 17 E., of the Salt Lake Base Line, Grand County, Utah, that were not used in this report because of the shallow drill depths (less than 2,000 feet) but are in the Utah Geological Survey's Integral*gim database.

S W Energy Corporation
Federal 27-2
NW1/4NW1/4 section 27
43-019-30829-0000

S W Energy Corporation
Government Smoot 21-3
SW1/4NE1/4 section 21
43-019-30746-0000

Megadon Enterprises Inc
State 1-16
SE1/4SE1/4 section 16
43-019-30681-0000

Denbe
Federal Rosenblatt 1
NE1/4NE1/4 section 20
43-019-10989-0000

APPENDIX B

Abbreviations and symbols used in this report.

API	American Petroleum Institute
BBLS	Barrels
BCFG	Billion cubic feet of gas
BHT	Bottom hole temperature
BO	Barrels of oil
BOPD	Barrels of oil per day
BTU	British Thermal Unit
BW	Barrels of water
C	Cambrian
C	Celsius
C_1	Methane
C_2	Ethane
C_3	Propane
C_4	Butane
C_5	Isobutane
C_{5+}	Fractions higher than C_5
Camb	Cambrian
Ck	Creek
CO_2	Carbon dioxide
Comp	Completed
Cond. CW	Condensate-cut water
Corp	Corporation
CF&I	Colorado Fuel and Iron
Cret	Cretaceous
D	Devonian
Dev	Devonian
DLL	Dual laterolog
DST	Drill-stem test
Dol	Dolomite
E.	East
F	Fahrenheit
Fm	Formation
FP	Flowing pressure
Ft	Feet
GCM	Gas-cut mud
GCM&MCW	Gas-cut mud and mud-cut water
GCO	Gas-cut oil
G&OCM	Gas and oil-cut mud
GO&W	Gas, oil, and water
Govt	Government
GR	Gamma ray
grn	Green
GTS	Gas-to-surface
gty	Gravity
h	Hectors
He	Helium
HGCM	Highly gas-cut mud
HGCW	Highly gas-cut water
HG&WCM	Highly gas and water-cut mud
HOCM	Highly oil-cut mud
HP	Hydrostatic pressure
H_2S	Hydrogen sulfide
IPF	Initial potential flowing
Inc	Incorporated
IPP	Initial potential pumping
J	Jurassic
Je	Jurassic Entrada Sandstone
Jm	Jurassic Morrison Formation
KB	Kelly bushing
km	Kilometer
Ls	Limestone
lt	Light
M	Mississippian
m	Meters
m^3	Cubic meters
Mbr	Member
MCFG	Thousand cubic feet of gas
MCW	Mud-cut water
mi	Miles
min	Minutes
MMBO	Million barrels of oil
MMCFG	Million cubic feet of gas
My	Million years
NE	Northeast
no.	Number
NW	Northwest
o/w	Oil-Water
p.	Page
Qtz	Quartzite
R.	Range
Rec.	Recovered
S.	South
SE	Southeast
Sh	Shale
SIP	Shut-in pressure
Ss	Sandstone
SW	Southwest
Sw	Water saturation
T.	Township
TD	Total depth
T_{Rc}	Triassic Chinle Formation
T_{Rm}	Triassic Moenkopi Formation
TSTM	To-small-to-measure
UO	Unit of oil
v.	Volume
W	Water
WCM	Water-cut mud
	Dry hole
●	Oil well
	Abandoned oil well
- -	Fault

APPENDIX C

INTEGRAL*gim
Geologic Information Manager
by Douglas A. Sprinkel

INSTALLING INTEGRAL*gim

System Requirements

The INTEGRAL*gim Geologic Information Manager includes the Salt Wash field data, INTEGRAL*gim application, and Paradox® Runtime. The Utah Geological Survey has a license to distribute Paradox Runtime for the purpose of running the INTEGRAL*gim application, which accesses the Salt Wash field data. Future reference INTEGRAL*gim implies Paradox Runtime and INTEGRAL*gim application.

INTEGRAL*gim may be used on a variety of stand-alone computers and local area network systems. A list of local area networks is available during the installation of Paradox Runtime. To run INTEGRAL*gim your computer must be at least a 100 % IBM-compatible with a hard disk and at least one floppy drive, protected mode capable 80286 or greater personal computer. Your computer must meet the following minimum requirements:

- DOS 3.0 or later, or OS/2 2.0 or later.
- 2MB (megabytes) RAM. 4MB or more (8MB is recommended) will significantly enhance performance and prevent errors during some operations.
- **9 MB of free disk space**. The Salt Wash field version of INTEGRAL*gim uses approximately 3MB of space and Paradox Runtime uses approximately 3MB of space. An additional 3MB of space is needed to for temporary tables created during some operations.
- INTEGRAL*gim will run on most color and monochrome monitors; however, some items displayed on monochrome or low-resolution color monitors may be difficult to read.

INTEGRAL*gim supports hardware and software options that enhance performance or allow the user to take advantage of all its capabilities. These options include the following:

- Microsoft Windows 3.0 or later.
- a bus or serial mouse (Microsoft, Logitech, IBM PS/2, or compatible).
- an 80 x 87 math coprocessor
- a dot-matrix printer (the beta test version only prints to a graphic capable dot-matrix printer).

System Files

INTEGRAL*gim requires that your computer have a CONFIG.SYS file residing in the root directory of the hard disk or on a start-up disk. The CONFIG.SYS file must at least contain two lines; FILES= 40 and BUFFERS = 40. In most cases, these lines are already present in the CONFIG.SYS file. An INTEGRAL.PIF file is located in the INTEGRAL subdirectory and may be used to configure INTEGRAL*gim for Windows.

INTEGRAL*gim Sublicense Agreement

The Utah Geological Survey is a registered user of Paradox Runtime and is licensed to distribute the Runtime program to run our INTEGRAL*gim application. Under our license, the Utah Geological Survey must sublicense you, the end user. Installing and using INTEGRAL*gim implies that you have read this sublicense agreement and agree to the following:

- Paradox Runtime is owned by Borland International, Inc. and may not be copied for redistribution.
- Limited support services are provided by the Utah Geological Survey. You should not look to Borland for any technical support.
- Borland International, Inc. and the Utah Geological Survey are not responsible for any damages resulting from using Paradox Runtime and INTEGRAL*gim application. These programs are provided to the end user without warranties or liabilities for any damages, actions based on its use, or quality.
- INTEGRAL*gim application may not be copied for redistribution; however, the data contained in INTEGRAL*gim are public domain and may be freely distributed outside of the INTEGRAL*gim application.

Installation Procedure

INTEGRAL*gim can be installed from DOS or from Microsoft Windows. Before you install INTEGRAL*gim, it is wise to make a backup copy of the program disks and store them in a safe place. INTEGRAL*gim consists of three disks. Disks 1 and 2 contain Paradox Runtime files and Disk 3 contains the INTEGRAL*gim application and data files. You must use the installation program on Disk 1 and not the DOS Copy command to properly install INTEGRAL*gim onto your hard disk because the program files on all three disks are compressed.

The installation procedure will create two subdirectories on your hard disk; PDOXRUN and SALTWASH. Paradox Runtime will be installed to the PDOXRUN subdirectory and INTEGRAL*gim will be installed to the SALTWASH subdirectory. SALTWASH.BAT will also be copied to the root directory on the C drive. For network installation, you will need to move the SALTWASH.BAT file from the root directory (C:\) to a mapped search drive that normally contains program .BAT files. Once the procedure starts, the user will be led through the installation with on screen instructions.

To install INTEGRAL*gim (Paradox Runtime and INTEGRAL*gim data files) from DOS (DOS prompt, C:\>):

1. Insert Disk 1 into a floppy drive.
2. Change to the floppy drive that contains Disk 1. If Disk 1 is in your B drive, type B: and press Enter. If Disk 1 is in your A drive, type A: and press Enter.
3. From the A:\> or B:\> prompt, type **li** and press Enter.
4. Read the Installation Instructions section below and follow the on screen instructions.

To install INTEGRAL*gim from Microsoft Windows:

1. Insert Disk 1 into a floppy drive
2. Click on File in the Program Manager.
3. Click on Run.
4. Enter **A:\li** (if Disk 1 is in the A drive) or **B:\li** (if Disk 1 is in the B drive) into the Run dialogue box.
5. Click on OK or press Enter
6. Read the Installation Instructions section below and follow the on screen instructions.

Installation Instructions

The installation procedure will start by installing the Paradox Runtime, the first program, using the Paradox Installation Utility. This part of the procedure will ask you a series of questions for setup information. In most cases you should **accept the default choices by pressing the function key [F2]**. If you do need to change a setting, simply follow the instructions given and then press F2. The last item in the Paradox Installation Utility is a reminder to register Paradox Runtime. You may ignore this because this copy of Runtime is registered to the Utah Geological Survey is registered, and the Utah Geological Survey has a license to distribute the program and sublicense the end user. **Make sure you read the sublicense agreement in the previous section.** The second program installed is INTEGRAL*gim and its data files.

Starting INTEGRAL*gim

The Salt Wash field version of INTEGRAL*gim can be started from the DOS prompt or from Microsoft Windows. To start INTEGRAL*gim from DOS, simple Type **SALTWASH**. To start INTEGRAL*gim from Windows, you must **create a new program item from the Program Manager** and include all of the information needed in the Program Item Properties dialogue box to start INTEGRAL*gim from Windows.

A
WEST
A′
NORTH
EAST:SOUTH
SW ENERGY
18-2 GOVT
NENE SECTION 18
KB 4219
TD 9350 ELBERT FM.
SW ENERGY
3 SMOOT
NESE SECTION 17
KB 4339
TD 8687 LEADVILLE LS.
R.P SMOOT
22-16 CF & I
SENW SECTION 16
KB 4490
TD 8906 LEADVILLE LS.
SW ENERGY
A-2 SUNNILAND
SESW SECTION 16
SALT WATER DISPOSAL
KB 4388
TD 8900 ELBERT FM.
SW ENERGY
1-16A STATE
SWSE SECTION 16
KB 4418
TD 8825 ELBERT FM.
MEGADON ENERGY
1-15 FEDERAL
NWSW SECTION 15
KB 4295
TD 8585 LEADVILLE LS.
PAN AMERICAN
1 SALT WASH
NWSW SECTION 15
KB 4283
TD 9533 LYNCH DOLOMITE
RESERVE OIL & GAS
1 SALT WASH NORTH
NESW SECTION 9
KB 4463
TD 9069 LEADVILLE LS.
PENNSYLVANIAN PINKERTON TRAIL AND MOLAS FORMATIONS
-4420
UPPER LEADVILLE LS. POROSITY ZONES (>8%)
UPPER
LOWER
MISSISSIPPIAN LEADVILLE LIMESTONE
DEVONIAN OURAY LIMESTONE
DEVONIAN ELBERT FORMATION
FAULT
OURAY LS.
ELBERT FM.
OPEN HOLE
McCRACKEN SS. MEMBER OF THE ELBERT FM.
UPPER LEADVILLE LS
LOWER LEADVILLE LS
ELBERT FM.
McCRACKEN SS. MEMBER OF THE ELBERT FM.
TRAVEL TIME
8% DOLOMITE POROSITY
POROSITY
MATRIX 2.71
GR
NEUTRON
2800 API UNITS
COMP. 8/17/82 PARADOX FM.
5736′- 8014′ (GROSS)
IPP 1 UO
CUMULATIVE PRODUCTION (12/31/92)
847 BO
629 MCFG
266 BW
ORIGINAL OPERATOR
CONSOLIDATED OIL & GAS
COMP. 12/18/69 LEADVILLE LS.
8643′- 8655′
IPF 128 BO
1300 MCFG
1050 BW
CUMULATIVE PRODUCTION
13,170 BO
398,248 MCFG
310,256 BW
RECOMPLETED 2/71
8474′- 8486′
IPF 26 BO
2,308 MCFG
173 BW
CUMULATIVE PRODUCTION
UPPER LEADVILLE LS. (12/31/92)
289,317 BO
3,475,908 MCFG
814,868 BW
ORIGINAL OPERATOR SHELL OIL
COMP. 3/23/63 LEADVILLE LS.
8900′- 8907′
IPF 1,215 BO
25 MCFG
0 BW
RECOMPLETED 1/18/68
8846′- 8847′ (8846′- 8907′ GROSS)
RECOMPLETED 2/71
8806′- 8810′ (8806′- 8907′ GROSS)
CUMULATIVE PRODUCTION (12/31/92)
572,646 BO
5,070,716 MCFG
2,702,367 BW
ORIGINAL OPERATOR
PAN AMERICAN
COMP. 12/23/63 ELBERT FM.?
8775′- 8781′ AND 8783′- 8792′
IPP 70 BO
47 BW
CUMULATIVE PRODUCTION
8,364 BO
90,363 MCFG
48,272 BW
DEEPENED 6/69 FOR SALT WATER INJECTION
ORIGINAL OPERATOR
MEGADON ENERGY
COMP. 9/17/81 ELBERT FM.?
8670′- 8690′ AND 8715′- 8750′
IPF 4 BO
400 BW
CUMULATIVE PRODUCTION (12/31/92)
47 BO
200 MCFG
0 BW
COMP. 6/30/81 LEADVILLE LS.
8500′- 8544′ AND 8555′- 8580′
IPF 300 BO
100 MCFG
200 BW
CUMULATIVE PRODUCTION (12/31/92)
24,593 BO
0 MCFG
14,448 BW
COMP. 5/28/61 LEADVILLE LS.
8693′- 8707′
IPF 115 BO
9 BW
CUMULATIVE PRODUCTION (PLUGGED 8/64)
56,989 BO
1,229,664 MCFG
43,835 BW
COMP. 6/21/76 D & A
PLATE 1
SALT WASH FIELD
T. 23 S., R. 17 E.
GRAND COUNTY, UTAH
UTAH GEOLOGICAL SURVEY
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B
WEST

PLATE 2
SALT WASH FIELD
T. 23 S., R. 17 E.
GRAND COUNTY, UTAH

B′
EAST

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