

GEOLOGICAL SURVEY OF WYOMING

ALMOND AND FRONTIER TIGHT GAS SAND CROSS SECTIONS,
GREATER GREEN RIVER BASIN, WYOMING

by

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INTRODUCTION

ALMOND FORMATION

The Upper Cretaceous Almond and Frontier Formations in southeast Wyoming account for the majority of the tight gas sand production in Wyoming. These formations were selected as the subject of this study due to the blanket to near blanket geometry of their continental deltaic to barrier and offshore bar sands. Cross sections were constructed to illustrate these blanket or continuous sands within tight gas sand permit and application areas in the Greater Green River Basin. Detailed cross sections using porosity logs were constructed through densely drilled areas to show porosity variations, and, indirectly, permeability variations.

The "upper" Almond interval of the Almond Formation consists of fine to medium grained sandstones with sharp upper boundaries and gradational bases. Interbedded with the sandstones are shales, silty shales, and coal units. The cycles indicated by these rock sequences suggest barrier island, marsh-mudflat, and lagoonal-bay depositional environments for the "upper" Almond (Jacka, 1965). The primary depositional constraint on the "upper" Almond was the transgressive nature of the Lewis Seaway shoreline, combined with intermittent regressive phases. Intertonguing marine shales and barrier and shallow marine sandstones as well as vertical repetition of facies resulted from the above depositional constraints (Weimer, 1965). Delta systems served as dispersal centers for sediment derived from a source area immediately to the west. One delta system was located immediately to the north of the Great Divide and Washakie Basin area in north-central Wyoming and a second delta system to the south on the southern end of the Washakie Basin, immediately south of the Colorado-Wyoming state line (Weimer, 1970). The "upper" Almond shoreline facies migrates upward strati-

graphically in a westerly direction approaching the Rock Springs Uplift. Occurrence of the marginal marine "upper" Almond sequence appears to be restricted to the Great Divide and Washakie Basins and is not found west of the Rock Springs Uplift. The "upper" Almond is overlain by the Lewis Shale which represents the last major marine invasion of the Upper Cretaceous sea. It consists primarily of marine shales with some interbedded lenticular sands and blanket sands which represent prograding deltaic phases in the north and south. The "upper" Almond is underlain by "lower" Almond sediments which were formed in a fluvial type environment. They are characterized by relatively coarse channel sandstones interbedded with floodplain shales (Jacka, 1965).

Washakie and Great Divide Basin Area

Four electric log cross sections were constructed in the Great Divide and Washakie Basin area, designated A-A', B-B', C-C', and D-D' (Plate 1). Cross section A-A' (Plate 2) runs east-west through the Red Desert Basin; B-B' (Plate 3) runs east-west immediately south of the present Wamsutter Arch; C-C' (Plate 4) is also east-west crossing the Washakie Basin immediately north of the center; and D-D' (Plate 5) traverses mainly north-south across the Great Divide Basin, Wamsutter Arch, and Washakie Basin, tying in with A-A', B-B', and C-C'. Portions of electrical logs were selected to portray the upper Erickson Formation, all of the Almond Formation and the lower portion of the Lewis Shale, wherever possible. A bentonite unit above the top of the "upper" Almond in the Lewis Shale was selected as a datum. In most cases, the curve on the left of the electrical log is either gamma-ray or spontaneous potential and the curves on the right are resistivity, with a conductivity curve on the far right. The "upper" Almond was distinguished from the "lower" Almond by the blocky or coarsening upward pattern for sands on the spontaneous potential

or gamma-ray curve, characteristic of marginal marine or barrier bar sandstones. The "lower" Almond on the other hand is characterized by relatively thin sands and shales, with the sands usually exhibiting a fining upward log pattern consistent with fluvial type deposits.

Basically, the constructed cross sections agree with the observations of previous authors including Weimer (1965 and 1970) and Jacka (1965). The thickest portion of the "upper" Almond as demonstrated by the cross sections, coincides with the shoreline zone of Weimer, i.e., a concave to the east zone running from the northern delta system in central Wyoming to the delta system south of the Washakie Basin. An "upper" Almond thick is indicated on the eastern two-thirds of cross section A-A', as would be expected due to Weimer's postulated position of the northern delta system. This same thickened "upper" Almond sequence appears on the western quarter of the B-B' and C-C' cross sections representing the westerly portion of the shoreline zone between the two delta systems. The north-south cross section D-D' exhibits an "upper" Almond thickening on the northern quarter near the northern delta system and the edge of a thickening on the southern end, probably due to the close proximity of the postulated southern delta. These thickened areas exhibit stacked barrier bars or repeated facies as suggested by Weimer (1965). Some good examples of stacked bars include wells #3 and #4 of D-D' and well #4 in C-C'. It would appear that this stacking or repetition of facies seems to occur primarily near the delta systems. The thickened areas exhibit a range of thickness from approximately 120 feet to 275 feet, with an average of approximately 200 feet. The "upper" Almond appears to continue to the east of the above described thickened areas. However, it is considerably thinner and doesn't exhibit the repetition of facies noted in the thickened areas. The range of thickness for

"upper" Almond in these areas is zero to approximately 60 feet, as the "upper" Almond appears to be absent in some wells. As indicated in the literature, the east-west cross sections show the "upper" Almond climbing stratigraphically to the west. As a point of interest, lower Lewis marginal marine or barrier bar sand build-ups (see A-A', B-B', and C-C') indicate a shifting of the northern delta. The delta appears to have prograded eastward and sediments in early Lewis time were supplied from a northeasterly direction. In addition, the shoreline between the two deltas shifted westward as indicated by the increase in marine shale noted in the lower Lewis on the western ends of A-A', B-B', and C-C'.

Detailed cross sections using porosity logs were constructed through heavily drilled areas on B-B', C-C' and D-D' that exhibited "upper" Almond gas production. They are designated b-b' (Plate 6), c-c' (Plate 7), and d-d' (Plate 8) (see attached base map). The left curve on the log is gamma-ray and the curves on the right are compensated neutron and formation density (on the far right). In some cases sonic or density logs were substituted when no other porosity logs existed. As with the electric log sections, a bentonite unit was selected in the Lewis Shale to serve as the datum. The "upper" Almond is again picked based primarily on the gamma-ray or spontaneous potential characteristics exhibited by the electric log for the same well. Producing zones and compensated neutron-formation density curve crossovers are indicated. Generally, the crossover or "gas" effect has been suppressed by the low permeability of the sands, as exhibited by "upper" Almond producing wells in all three detailed cross sections. "Upper" Almond gas production, where information is available, occurs in the thinner portions of the unit. This is illustrated on the detailed porosity sections where the "upper" Almond ranges from 30 to 65 feet and averages 48 feet for the producing wells on d-d', ranges from 18 to 45 feet and averages 33 feet for producing wells

along b-b', and ranges from 18 to 22 feet and averages 20 feet for producing wells along c-c'. The traps appear to be stratigraphically controlled with some structural influence possible in the Wamsutter Arch area.

FRONTIER FORMATION

The basal Upper Cretaceous Frontier Formation represents a major regressive deposit with subordinate transgressive phases in the Greater Green River Basin. Alternating sand and shale sequences resulted from minor regressions and transgressions in the overall regressive sequence. The sandstones developed in the Frontier Formation have been informally referred to numerically as, "First" through "Fifth" Frontier. The "First" and "Second" Frontier sands, separated by a marine shale, are dominantly marginal marine and are relatively continuous and traceable, especially near the Frontier shoreline between the Moxa Arch and the Overthrust Belt (DeChadenes, 1975). The lower sands in the Frontier, i.e., "Third" through "Fifth" are dominantly fluvial and much less continuous. During Frontier time, a large prograding delta system stretched down across Wyoming from the northwest, with the thickest development coinciding roughly with the present location of the Wind River Mountains; a second delta system prograded toward southwest Wyoming from northeast Utah; and a third system prograded toward southeast Wyoming from northeast Colorado and western Nebraska (Barlow and Haun, 1966 and Goodell, 1962). In the Moxa Arch-La Barge area, smaller Frontier delta systems are indicated in the La Barge area and north and south of Kemmerer, Wyoming (Myers, 1977). The Frontier Formation is overlain by marine Hilliard Shale (Baxter Shale east of the Moxa Arch) and underlain by the marine Aspen Shale (Mowry Shale east of the Moxa Arch).

Moxa Arch Area

In the Moxa Arch area, four electric log cross sections were constructed, designated A-A', B-B', C-C', and D-D' (Plate 1). Cross section A-A' runs east-west immediately north of the Big Piney-La Barge area, B-B' runs east-west immediately south of the Big Piney-La Barge area, C-C' is also east-west crossing the Moxa Arch just east of Kemmerer, Wyoming (Plate 9). Cross section D-D' (Plate 10) traversed essentially north-south, skirting the east side of the Big Piney-La Barge area and following the Moxa Arch to the south. Portions of electric logs were selected to illustrate the underlying Aspen Shale, the Frontier Formation and the lower portion of the overlying Hilliard Shale, wherever possible. A bentonite unit between the "First" and "Second" Frontier sands was selected as a datum. In most cases, the curve on the left of the electric log is either gamma-ray or spontaneous potential and the curves on the right are resistivity, with a conductivity curve on the far right. The contact between the Hilliard and the Frontier was determined as the top of the "First" Frontier sandstone in the vicinity of the Big Piney-La Barge area where the "First" Frontier is present. Immediately to the south, where the "First" Frontier pinches out, the top of the Frontier is picked as a bentonite zone at the base of a marine shale and just above the "Second" Frontier. For the purpose of these cross sections, the "Second" through "Fifth" sandstones are lumped into the "Second" Frontier. The base of the Frontier is picked as a bentonite zone below the relatively well developed sandstone unit which was considered Frontier. The contact between the Frontier and Aspen is basically gradational. Examination of the cross sections A-A', B-B', C-C', and D-D' indicates basic agreement with the observations of previous workers such as

De Chadenedes (1975) and Myers (1977). The "First" Frontier (see A-A' and north portion of D-D') is restricted to the Big Piney-La Barge area, corresponding to the northern delta location for the "First" Frontier according to Myers (1977). Electric log character indicates coarsening upward sands as would be expected for delta front bar type deposits. A stacking or facies repetition is noted in wells #5 and #6 on the north end of D-D'. This stacking is absent moving away from the postulated delta location as indicated in the eastern wells on A-A' and well #7, #8, and #9 of D-D'. The thickening in well #1 of D-D' may indicate the presence of another delta system to the north. "First" Frontier thicknesses as indicated on A-A' and D-D' range from a thin of 35 feet to the east to a thick of 175 feet near the delta. In the case of the "Second" Frontier, log character indicates a predominately fluvial regime (fining upward, thin sands) for the lower sands and a delta plain, distributary channel, and barrier type regime for the upper sands, as suggested by De Chadenedes (1975). The upper sand units are continuous and traceable while the lower sands are not, as shown on the middle portions of B-B' and C-C'. Examination of B-B' and C-C' indicates a thickening in the delta plain and barrier bar sands of the upper "Second" Frontier coinciding with the "Second" Frontier shoreline and location of sediment sources south of Kemmerer and in the Big Piney-La Barge area as postulated by Myers (1977). Thin coals or coaly shales are indicated in the upper part of the "Second" Frontier in B-B' and C-C', usually at the top of coarsening upward bar type sand indicating an upper delta plain type setting. The cross sections, as would be expected, indicate a thinning in the Frontier to the east and south, moving away from the sediment sources. "Second" Frontier thicknesses range from about 400 feet

to the north (A-A') near the northern sediment source, to 830 feet near the southern sediment source (see well #1 on C-C'), to a thin of 270 feet on the south end of D-D'. A thinning in the "Second" Frontier is also indicated on the north end of D-D'.

Detailed cross sections using porosity logs were constructed through heavily drilled areas on B-B' and D-D' that exhibited Frontier production. They are designated b-b', d-d' and dd-dd' (see Plate 1). The left curve on the log is gamma-ray and the near curve on the right is compensated neutron and the far right curve is formation density. In some cases sonic or density logs were substituted when no other porosity logs existed. The Frontier top and bottom is picked from accompanying electric logs using the criteria discussed above. Producing zones and compensated neutron-formation density curve crossovers are indicated. As opposed to the suppressed effect noted for the "upper " Almond discussed earlier, the crossover or "gas" effect for producing zones in the "Second" Frontier, with a few exceptions, appears to be relatively normal as shown on b-b' (Plate 11), d-d' (Plate 12), and dd-dd' (Plate 13). Also, in contrast to the "upper" Almond, production appears to come from the thicker, well developed sands, as demonstrated by the electric log cross sections and porosity cross sections. The traps are basically stratigraphic with some structural influence, especially in the La Barge area.

Rock Springs Uplift Area

Two electric log cross sections were constructed in the north Rock Springs Uplift area, designated A-A' and B-B' (Plate 1). Cross section A-A' runs essentially north-south and B-B' runs east-west, on the north nose of the rock Springs Uplift (Plate 14). Portions of electrical logs were selected to portray the Frontier Formation, the underlying Mowry Shale and the lower portion of the overlying Baxter Shale. A bentonite unit above the top of the

Frontier Formation in the lower Baxter Shale was selected as the datum. The top of the Frontier was determined as the abrupt change from barrier bar sand to marine Baxter Shale. The lower contact between Frontier and Mowry Shale was put at the transition from siliceous Mowry Shale to the base of the first coarsening upward barrier bar type sequence identified as Frontier. The Frontier Formation is broken up into "First", "Second", and "Third" Frontier sands according to operators' jargon. However, this sequence is probably equal to the "Second" Frontier of the cross sections on the Moxa Arch. The curve on the left of the electric log is either gamma-ray or spontaneous potential and the curves on the right are resistivity with conductivity on the far right. Examination of cross sections A-A' and B-B' indicates a southerly spur of the major delta system referred to by Barlow and Haun (1966) and Goodell (1962). Excellent examples of barrier and delta front sands and delta plain sands are exhibited on both A-A' and B-B'. Cross section A-A' indicates a dominant barrier bar type deposit in what is referred to as "First" Frontier, especially on the southern half. The lower part of the sequence seems to be trending toward delta plain deposits. The portion of the Frontier termed "Second" and "Third" Frontier in A-A' appears to indicate more of a delta front and delta plain deposit. Cross section B-B' represents deposition further away from the source, as for the most part the sands are less well developed. However, the "First" Frontier still appears to be a barrier bar type deposit which disappears to the east. The "Second" and "Third" Frontier sands are mainly delta plain with some delta front bars. The overall thickness of the Frontier varies from about 550 feet on A-A' and the western end of B-B' to 370 feet on the eastern end of B-B' where the upper part of the Frontier is absent. Production is

limited to the "Second" and "Third" Frontier sands, usually where these delta plain and delta front sands are best developed. The traps are stratigraphically controlled with some structural influence relative to the Rock Springs Uplift.

East Washakie Basin Area

Two electric log cross sections were constructed in the east Washakie Basin area, designated A-A' and B-B' (see Plate 1). Cross section A-A' runs northwest-southeast through the area and B-B' runs north-northeast to south (Plate 15). Portions of electrical logs were selected to portray the Frontier Formation, the overlying Mowry Shale and upper portion of the Dakota Sandstone. A bentonite was selected at the base of the Carlile Shale as the datum. The top of the Frontier Formation was determined as the change from the marine Carlile Shale to a silty zone above the "Second" Frontier. The lower contact with the Mowry is represented by a characteristic break between a silty zone in the Frontier and the siliceous shale identified as Mowry. Once again the sand referred to as the "Second" Frontier is roughly equivalent to the zone labelled as "Second" Frontier on the Moxa Arch cross sections.

The curve on the left of the electric log is either spontaneous potential or gamma-ray and the curves on the right are resistivity with conductivity on the far right. The coarsening upward character of the "Second" Frontier sand on A-A' and B-B' indicates barrier bar type deposit, probably at a considerable distance from the sediment source. The sequence above and below the "Second" Frontier represents mostly marine conditions. The sands noted in wells #1 and #2 of B-B' immediately above the "Second" Frontier are possibly distributary channel deposits closer to the probable sediment source to the northeast. The "Second" Frontier sand and overall Frontier sequence maintain a fairly constant thickness, about 40 feet and 450 feet respectively. The trap is structural-stratigraphic.

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APPENDIX A

LIST OF GREATER GREEN RIVER BASIN OIL AND GAS FIELDS TO ACCOMPANY PLATE 1

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formations*</u>
f 1	12N., 91-93W.	West Side Canal	Tfu, K1, Kfh, Kle, Kf
2	12N., 93W.	Smith Ranch	Tw, Tfu, K1, Kle
3	12N., 93-95W.	State Line	Tw, Tfu
4	12N., 95W.	Little Snake	Tw
5	12N., 96W.	Cherokee Ridge	Tfu
6	12N., 96W.	Round Table	Tfu
7	12N., 96W.	Powder Springs	Tfu
8	12N., 99-100W.	Hiawatha, East	Tw, Tfu
a 9	12-13N., 100-101W.	Canyon Creek	Tfu, K1, Kalu, Kall, Ke
f 10	12N., 103W.	Middle Mountain	Kf, Kall, Ke
11	12N., 107W.	Buster Basin	Kn
12	13N., 89W.	Savery	Kmv, Kc
13	13N., 89-90W.	Sierra Madre	Ksh
a 14	13N., 90W.	Dixon	Kalu, Kall
15	13N., 91-92W.	Baggs, South	Tw, Tfu, K1, Kle, Kall
16	13N., 94W.	Cedar Breaks	Kmv
17	13N., 94W.	McPherson Springs	Kle
18	13-14N., 95W.	Triton	Kle
f 19	13N., 99-100W.	Kinney	Tw, Kall, Kf, Kcv
20	13N., 99W.	Pioneer	Tw, Kall, Jn
21	13-14N., 100W.	Trail	Ke, Kr
22	13N., 103W.	Vermillion Creek	Kmv
23	13-15N., 112-113W.	Butcher Knife Springs	Kd, Pm
f 24	13N., 114W.	Hickey Mountain	Kf
25	14N., 91W.	Browning	Jm, Pt
a 26	14N., 91-92W.	Robbers Gulch	Kle, Kalu, Kall
a 27	14N., 92-93W.	Blue Gap	Kalu, Kall

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formations*</u>
a 28	14N., 92W.	Unnamed	Kalu, Kall
a 29	14N., 92W.	Unnamed	Kalu, Kall
a 30	14N., 96W.	Haystack	Kalu, Kall
31	14N., 97W.	Twin Fork	Tfu, Kle
a 32	14N., 100W.	Unnamed	Kalu?, Kall?
f 33	14N., 102W.	Potter Mountain	Kr, Kba, Kf
f 34	14N., 103W.	Salt Wells	Kf, Kcv
f 35	15N., 91W.	Cherokee Creek	Kmv, Kf, Kd
a 36	15N., 92-93W.	Mexican Flats	Kle, Kalu, Kmv
a 37	15N., 94W.	Windmill Draw	Kalu
38	15N., 95W.	N.T.	Kal
39	15N., 97W.	Adobe Town	Tfu, Kl
40	15N., 99W.	Smokey	Kle, Kmv
f 41	15N., 103W.	Joyce Draw	Kf, Kcv
42	15N., 104W.	Little Worm Creek	Kcv, Jm
f 43	15N., 104W.	Pretty Water Creek	Kf, Pp
44	15N., 111 W.	Leo	Kh, Kf
f 45	15N., 113W.	Big Dry Creek	Kf
46	16N., 90W.	Deep Creek	Kmv, Kmd
f 47	16N., 90W.	Browns Hill	Kf
f 48	16N., 91W.	Deep Gulch	Kmv, Ks, Kf
f 49	16N., 91-92W.	Cow Creek	Kc, Kf, Kd, Jn
a 50	16-17N., 93W.	Barrel Springs	Kalu, Kall, Ke, Kr, Kmv
51	16N., 94W.	Red	Kall
52	16N., 94W.	Unnamed	Kall
53	16N., 94-95W.	Shallow Creek	Kl
54	16N., 95W.	Salazar	Kall, Ke
a 55	16N., 97-98W.	Iron Pipe	Kle, Kalu, Kmv, Ke
56	16N., 98W.	Alkaline Creek	Kle, Kall
a,f 57	16N., 99W.	Unnamed	Kalu, Kf
58	16-17N., 99W.	Bitter Creek	Kfh, Kl, Pw
f 59	16-17N., 100-101W.	Brady	Kbl, Kf, Kd, Jn, Pw
f 60	16-17N., 104W.	Baxter Basin, South	Kf, Kd

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formations*</u>
f 61	16-17N., 112-113W.	Church Buttes	Kf, Kd, Pm
62	16N., 113W.	Unnamed	Kd
a 63	17N., 92W.	Baldy Butte	Kalu, Kall
a 64	17N., 93W.	Unnamed	Kalu, Kall
a 65	17N., 93-94W.	Coal Gulch	Kalu, Kall, Kmv
66	17N., 94W.	Unnamed	Kmv
a 67	17-18N., 94-95W.	Wildrose	Kalu, Kall, Kmv
a 68	17N., 95W.	Emigrant Trail	Kalu, Kall, Kmv
69	17N., 96W.	Unnamed	Kl
70	17N., 96W.	Unnamed	Kal
71	17N., 96W.	Unnamed	Kl, Kfh, Kle
72	17N., 96W.	Unnamed	Kall
73	17-18N., 96W.	Hansen Draw	Kall, Kr
74	17N., 97W.	Laney Wash	Kl
a 75	17N., 98-99W.	Higgins	Kalu, Kall, Pw
a 76	17-18N., 99-100W.	Sand Butte	Kalu
a 77	17N., 99-100W.	Antelope	Kalu, Kall, Ke
78	17N., 100W.	Brady, North	Jn, Pw
a 79	17N., 100W.	Unnamed	Kalu
f 80	17-18N., 102W.	Camel Rock	Kf, Kd
f 81	17N., 103W.	Unnamed	Kf
82	17N., 108W.	Massacre Hills	Kr
a 83	18-19N., 91-92W.	Creston	Kalu, Kall, Ke
84	18N., 92W.	Unnamed	Kmv
a 85	18-19N., 92-93W.	Standard Draw	Kalu, Kall
86	18N., 94W.	Unnamed	Kmv
a 87	18N., 94W.	Unnamed	Kalu
a 88	18-19N., 94-95W.	Red Lakes	Kalu, Kall, Ke, Kmv
89	18N., 95W.	Unnamed	Ke
90	18N., 96W.	Wells Bluff	Kmv, Ke
a 91	18N., 97-98W.	Delaney Rim	Kle, Kalu, Kall
a 92	18-19N., 97-98W.	Table Rock	Tw, Kle, Kalu, Kall, Jn, Pw, Mm

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formations*</u>
a 93	18N., 98W.	Table Rock, SW	Kle, Kalu, Kall, Jn, Pw
94	18N., 98W.	Neff	Kall
95	18N., 98-99W.	Stage Stop	Kl, Kle, Kall
a 96	18-19N., 98-99W.	Monel	Kalu
a 97	18-19N., 99-100W.	Patrick Draw, West	Kle, Kalu
a 98	18N., 100W.	Unnamed	Kalu
99	18N., 101W.	Golden Wall	Kcv
100	18N., 102W.	Chimney Rock	Kbl
f 101	18N., 103W.	Unnamed	Kf, Kd
f 102	18-19N., 103-104W.	Baxter Basin, Middle	Kf, Kd
f 103	18N., 104W.	Six Mile Springs	Kf
f 104	18N., 111 W.	Pipeline Crossing	Kf
f 105	18N., 111 W.	Unnamed	Kf
f 106	18-19N., 112-113W.	Bruff	Kf, Kd, Pm
f 107	18N., 113W.	Verne	Kf
108	19N., 88W.	Rim	Pp
f 109	19-20N., 88W.	Hatfield	Kf
f 110	19N., 89W.	Espy	Kn, Kf, Pt
a 111	19N., 90W.	Creston, SE	Kalu
112	19N., 90W.	Sugar Creek	Kf, Kmd, Pt
113	19N., 91W.	Fillmore	Kle, Ke
114	19-20N., 91-92W.	Unnamed	Kal
115	19N., 92W.	Unnamed	?
a 116	19-20N., 92-93W.	Echo Springs	Kalu, Kmv
117	19N., 94W.	Tierney	Kmv
118	19N., 95W.	Desert Flats	Kal
119	19N., 95W.	Unnamed	Kall
120	19N., 96W.	Shell Creek	Kal
121	19N., 97W.	Tipton	Kall
a 122	19N., 97W.	Robin	Kalu, Kall
a 123	19-20N., 98W.	Arch	Kalu, Kall, Kmv
a 124	19-20N., 98-99W.	Patrick Draw	Kfh, Kle, Kalu, Kall, Kmv
a 125	19N., 99W.	Unnamed	Kalu

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formations*</u>
a 126	19-20N., 99-100W.	Desert Springs, West	Kalu, Kall
127	19N., 100W.	Hallville	Kall
128	19N., 100W.	Red Hill	Kall
129	19N., 100W.	Unnamed	Kall
f 130	19N., 101W.	Unnamed	Kf?
f 131	19N., 101W.	Unnamed	Kf
f 132	19-20N., 101W.	Point of Rocks	Kmv, Kf
f 133	19-20N., 101W.	Shiprock	Kmv?, Kf
134	19N., 102W.	Bartlett	Jm
f 135	19N., 102W.	Black Butte Circle	Kf, Kd, Jm
f 136	19N., 103W.	Airport	Kf
137	19N., 103W.	Unnamed	Kd
138	19N., 103W.	Unnamed	Kla
139	19N., 103W.	Unnamed	Kd
f 140	19-21N., 103-104W.	Baxter Basin, North	Kf, Kd, Jm, Jn
f 141	19N., 106W.	Reiser Canyon	Kf
142	19N., 106W.	Unnamed	Kd
143	19N., 111 W.	Unnamed	Kd
f 144	19-20N., 112W.	Fabian Ditch	Kf
f 145	19-20N., 112-113W.	Wilson Ranch	Kf
146	20N., 91W.	Unnamed	Kall
147	20N., 93W.	Unnamed	Kall
150	20N., 94W.	Tierney, North	Kall
a 151	20-21N., 94-95W.	Wamsutter	Kle, Kalu, Kall
a 152	20N., 95W.	Unnamed	Kalu, Kall
153	20-21N., 99-100W.	Playa	Kle
f 154	20N., 101W.	Deadman Wash	Kf, Jm
155	20N., 101-102W.	Masterson	Kb1, Kd
f 156	20N., 101W.	Unnamed	Kf
f 157	20N., 101W.	Unnamed	Kf
f 158	20N., 102-103W.	Marianne	Kf, Kmd, Kd
f 159	20N., 105W.	Unnamed	Kf

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formation*</u>
f 160	20N., 111 W.	Wildhare	Kf
161	21N., 90W.	Mahoney Draw	Ke
162	21N., 91W.	Windy Hill	Ke or Kall
a 163	21N., 92S.	Monument Lake	Kalu, Ke
164	21N., 93W.	Unnamed	Kle, Kal
a 165	21N., 93W.	Five Mile Gulch	Kalu, Ke
a 166	21-22N., 94W.	Siberia Ridge	Kalu, Kall
167	21N., 97-98W.	Desert Springs	Kle, Kall
168	21N., 99W.	Ten Mile Draw	Kle, Kall
169	21N., 100W.	Roser	Kall
170	21N., 102W.	Unnamed	?
f 171	21-22N., 103-104W.	Crooked Canyon	Kf, Kd
172	21N., 110W.	White Feather	Kmv
f 173	21N., 111 W.	Seven Mile Gulch	Kf
f 174	21N., 111 W.	Unnamed	Kf
f 175	21N., 112W.	Whiskey Butte	Kf
f 176	21N., 112W.	Unnamed	Kf
f 177	21N., 113W.	Opal Bench	Kf
f 178	21N., 113W.	Unnamed	Kf
a 179	22N., 92W.	Unnamed	Kalu
180	22N., 93W.	Continental Divide	Tfu
a 181	22N., 93W.	Unnamed	Kalu, Kall
182	22N., 93W.	Unnamed	?
a 183	22N., 94W.	Unnamed	Kalu
a 184	22N., 94W.	Unnamed	Ke, Kalu
a 185	22N., 95W.	Stock Pond	Kalu, Kall
186	22N., 95W.	Unnamed	Kle
187	22N., 96W.	Red Desert	Kall
a 188	22N., 96-97W.	Sheep Camp, South	Kalu, Kall
189	22N., 97W.	Sheep Camp, North	Kall
190	22N., 99W.	Unnamed	?

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formation*</u>
f 191	22-23N., 103W.	Pine Canyon	Kf, Kcv
f 192	22N., 103W.	Leucite Hills	Kf, Kd, Jm
f 193	22N., 106W.	Megas	Kf
f 194	22N., 111W.	Unnamed	Kf
f 195	22N., 111W.	Unnamed	Kf
f 196	22-23N., 111-112W.	Storm Shelter	Kf
f 197	22N., 112W.	Opal	Kf
f 198	22N., 112-113W.	Blackjack	Kf
f 199	22-23N., 112W.	Shute Creek	Kf
200	23N., 88W.	Cole Springs Draw	Js
f 201	23-24N., 88W.	Bell Springs	Kf, Kd, Js
202	23N., 94W.	Sentinel Ridge	Kall, Ke
203	23-24N., 94W.	Battle Springs	Kle, Kall, Ke
204	23N., 96W.	Gale	Ke
205	23N., 96W.	Great Divide	Kle
206	23-24N., 96-97W.	Hay Reservoir	Kle
207	23N., 97W.	Lost Creek	Kle
208	23N., 98W.	Mud Lake	Suspended
209	23N., 99W.	Sinkhole	Kle
f 210	23N., 102W.	Steamboat Mtn.	Kf
f 211	23-24N., 102-104W.	Nitchie Gulch	Kf, Kd
f 212	23N., 108W.	Sandy Bend	Kf
f 213	23N., 110W.	Unnamed	Kf
f 214	23N., 112W.	Emigrant Springs	Kf
215	24N., 87-88W.	Separation Flats	Kmd
216	24N., 91W.	Stewart Creek	Kle, Kmv
217	24N., 93W.	Stratton Draw	Kmv
a 218	24N., 96W.	Nickey	Kle, Kalu, Kall
a 219	24N., 96W.	Bush Lake	Kle, Kalu, Kall, Ke, Kr
220	24N., 101W.	Treasure	Kmd
221	24N., 102W.	Freighter Gap	Kmr
f 222	24N., 110W.	Horn Canyon	Kf

Number	Township & Range	Field Name	Producing Formation*
f 223	24N., 111W.	Mesa	Kf
f 224	24-25N., 111W.	Lincoln Road	Kf
	225 24N., 114W.	Craven Creek	Ta, Tfu, Kh
f 226	25N., 88W.	Sherard, South	Kf, Kmr, Kmd, Kcv, IPt
	227 25N., 88W.	Mahoney, South	Kd, Jn
	228 25-26N., 87-88W.	Mahoney Dome	Kd, Js, IPt
f 229	25N., 89W.	Lamont	Kf
f 230	25N., 89W.	Sherard, North	Kf
a 231	25N., 95W.	Unnamed	Kle, Kalu, Kall
	232 25N., 97W.	Bastard Butte	Kle
	233 25N., 97W.	Forbes	Ke
	234 25N., 98W.	Lost Valley	Kall, Ke, Kr, Kbl
	235 25N., 99W.	Unnamed	?
f 236	25N., 107W.	Simpson Gulch	Kf, Kmv
	237 25N., 108W.	Unnamed	Kmv?
f 238	25N., 109-110W.	Swan	Kf, Kd
f 239	25N., 111W.	Buckhorn Canyon	Kf
f 240	25-26N., 111-112W.	Fontenelle II	Kf
	241 26N., 89W.	Bailey Dome	Kla, Jn, Pt
	242 26N., 89-90W.	Wertz	Kf, Kmr, Kmd, Kcv, Js, Tc, IPt, IPa, Mm, Cf
	243 26N., 90W.	Lost Soldier	Kf, Kmr, Kmd, Kla, Jm, Js, Jn, IPt, Mm, Cf
	244 26N., 90W.	Twin Buttes	Kn
a 245	26N., 93W.	Osborne Draw	Kalu?, Kall
	246 26N., 96-97W.	Pickett Lake	Kle
	247 26N., 102W.	Buccaneer	Kmd
	248 26N., 112W.	Stead Canyon	Tfu
	249 26N., 112W.	Whelan	Tfu
	250 26-27N., 112W.	Labarge East	Ta
f 251	26-27N., 112W.	Spur Creek	Ta, Kf, Kbr
f 252	26-27N., 112-113W.	Green River Bend	Ta, Kmv, Kf, Kbr
f 253	26-27N., 113W.	Labarge	Ta, Kh, Kf, Kbr

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formation*</u>
f 254	26-28N., 113-114W.	Hogsback	Kf, Kmd, Kd, Jn
255	27N., 89W.	Bunker Hill	Ksh, Ks
256	27N., 93W.	Antelope Springs, East	Tw
f 257	27N., 95W.	Bison Basin	Kf, Jm
258	27N., 95W.	Girrard	Kmd, Kd
259	27N., 95W.	Trail Ridge	Kd
260	27N., 103W.	Pacific Creek	Kmv
261	27N., 108W.	Unnamed	Tfu
262	27N., 110W.	Green River Bluffs	Tfu
263	27N., 110W.	Unnamed	?
264	27N., 110W.	Unnamed	?
f 265	27N., 111W.	Bird Canyon	Kf, Kbr
266	27N., 111W.	Russ	Ta
f 267	27N., 112W.	Figure Four Canyon	Kf
f 268	27N., 113W.	Birch Creek	Ta, Kmv, Kf, Kbr
f 269	27N., 113W.	Labarge North	Ta, Kmv, Kf
f 270	27-28N., 113W.	Saddle Ridge	Ta, Kmv, Kf
f 271	27-28N., 114W.	Dry Piney	Kf, Kbr, Jn
272	28N., 92W.	Golden Goose	Kd
273	28N., 92W.	Kirk	Kcv, Pp
274	28N., 92W.	Sheep Creek	Pp
f 275	28N., 92-93W.	Crooks Gap	Kf, Kmd, Kd, Kla, Jm
f 276	28N., 93W.	Happy Springs	Kf, Kmd, Kd, Kla, Pp
277	28N., 93W.	Jade Ridge	Kmd, Kd
278	28N., 108W.	Jonah	Tfu
f 279	28N., 109W.	Cutlass	Kf
f 280	28N., 111W.	Unnamed	Kf
281	28N., 112W.	McDonald Draw, Middle	Ta
282	28N., 112W.	McDonald Draw, South	Ta
283	28-29N., 112W.	McDonald Draw, North	Ta
f 284	28-29N., 112-113W.	Chimney Butte	Tw, Tfu, Kmv, Kf
285	28-29N., 113W.	Big Piney	Tw, Ta, Kmv
f 286	28-29N., 113-114W.	Tip Top	Tw, Kf, Jn

<u>Number</u>	<u>Township & Range</u>	<u>Field Name</u>	<u>Producing Formation*</u>
f 287	28N., 114W.	Pine Grove	Kf
f 288	28N., 115W.	Hoback III	Kf, Kbr
289	29N., 112W.	Long Island	Ta, Kmv
290	29N., 112W.	Miller Ranch	Ta, Kmv
291	30-33N., 108-109W.	Pinedale	Tfu, Kl, Kmv
292	30N., 112W.	Star Corral, East	Ta
293	30N., 113W.	Deer Hill	Ta
294	30N., 113W.	Middle Piney Creek	Tfu
295	30N., 113W.	Ruben	Ta
296	30N., 113W.	Star Corral	Ta
297	30N., 114W.	Unnamed	Mm
298	31N., 113W.	Goat Hill	Tw
f 299	31N., 114W.	Bald Mountain	Kf
300	32N., 114W.	Mickelson Creek	Kmv
301	33N., 114W.	Ote Creek	Tfu
302	33N., 114W.	Unnamed	Kmv
f 303	35N., 115W.	Lookout Mountain	Kf

* Fields producing from Almond Formation "upper" and/or "lower" of the Mesaverde Group are represented by Kalu and Kall respectively. Kal represents Almond Formation undifferentiated. Kmv may be used to represent undifferentiated formations within the Mesaverde Group.

f Field produces from Frontier Formation

a Field produces from "upper" Almond Formation

FORMATION SYMBOL INDEX

Tertiary

Tw -- Wasatch fm.
Tfu -- Fort Union fm.
Ta -- Almy fm.

Cretaceous

Kl -- Lance fm.
Kfh -- Fox Hills ss.
Kle -- Lewis shale
Kmv -- Mesaverde fm.
Kal -- Almond fm.
Kalu -- Almond fm., "upper"
Kall -- Almond fm., "lower"
Ke -- Erickson fm.
Kr -- Rock Springs fm.
Kbl -- Blair fm.
Kh -- Hilliard sh.
Kba -- Baxter sh.
Kc -- Cody sh.
Ks -- Steele sh.
Ksh -- Shannon ss.
Kn -- Niobrara sh.
Kf -- Frontier fm.
Kmr -- Mowry sh.
Kmd -- Muddy ss.
Kbr -- Bear River fm.
Kcv -- Cloverly group
Kd -- Dakota ss.
Kla -- Lakota cgl.

Jurassic

Jm -- Morrison fm.
Js -- Sundance fm.
Jn -- Nugget ss.

Triassic

Tc -- Chugwater fm.

Permian

Pp -- Phosphoria fm.

Pennsylvanian

Pw -- Weber fm.
Pm -- Morgan fm.
Pt -- Tensleep ss.
Pa -- Amsden fm.

Mississippian

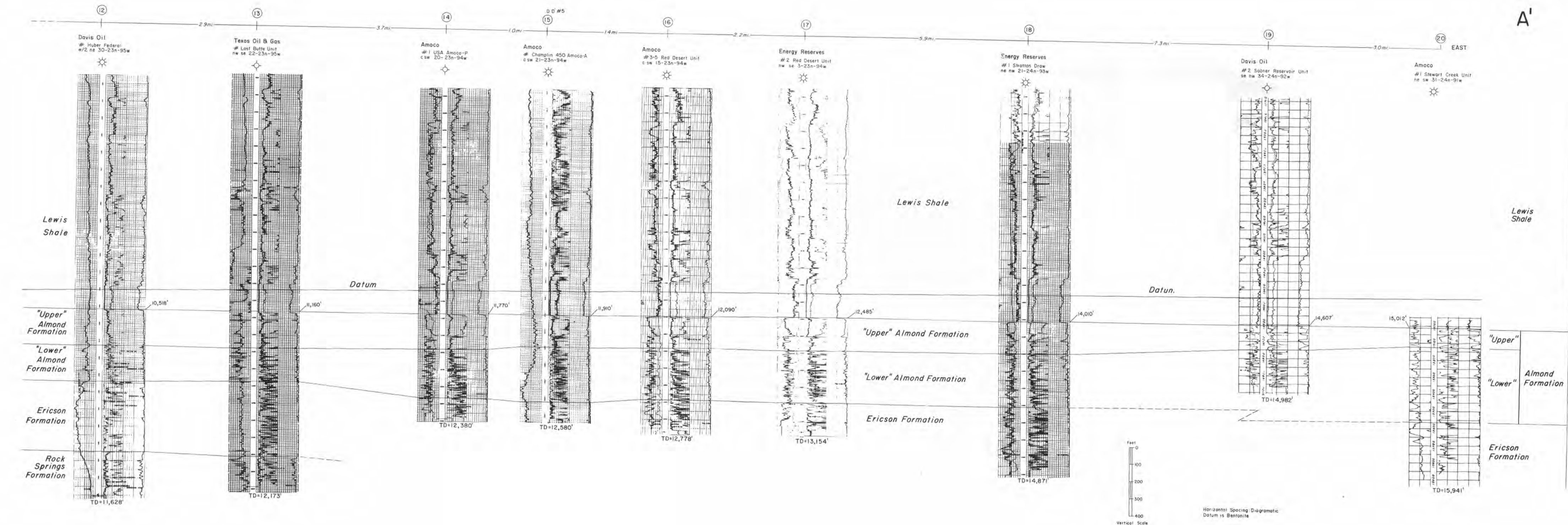
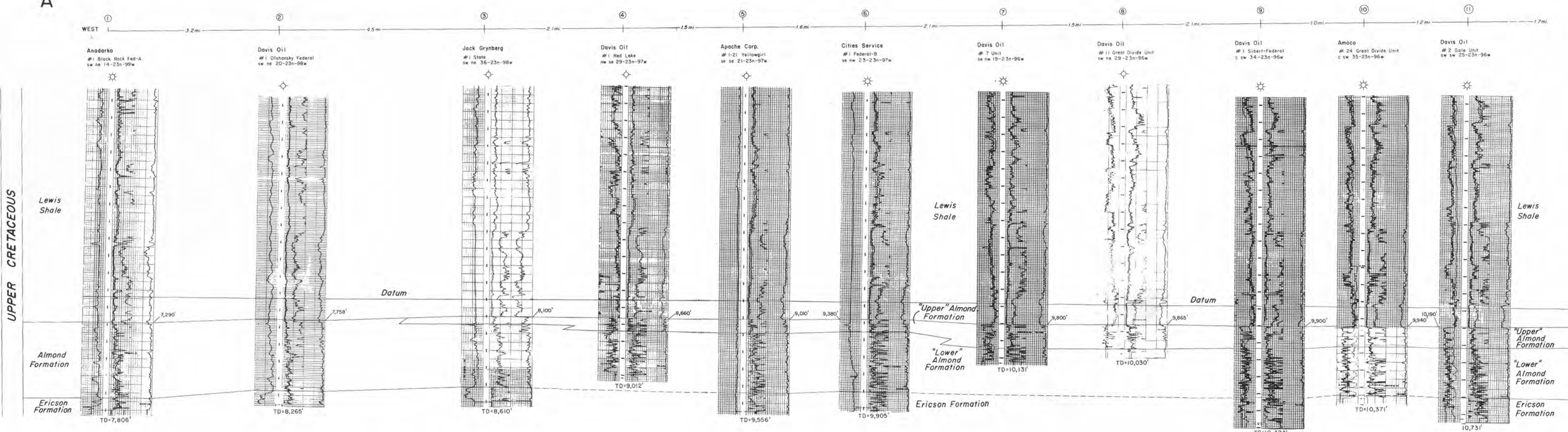
Mm -- Madison ls.

Cambrian

Cf -- Flathead ss.

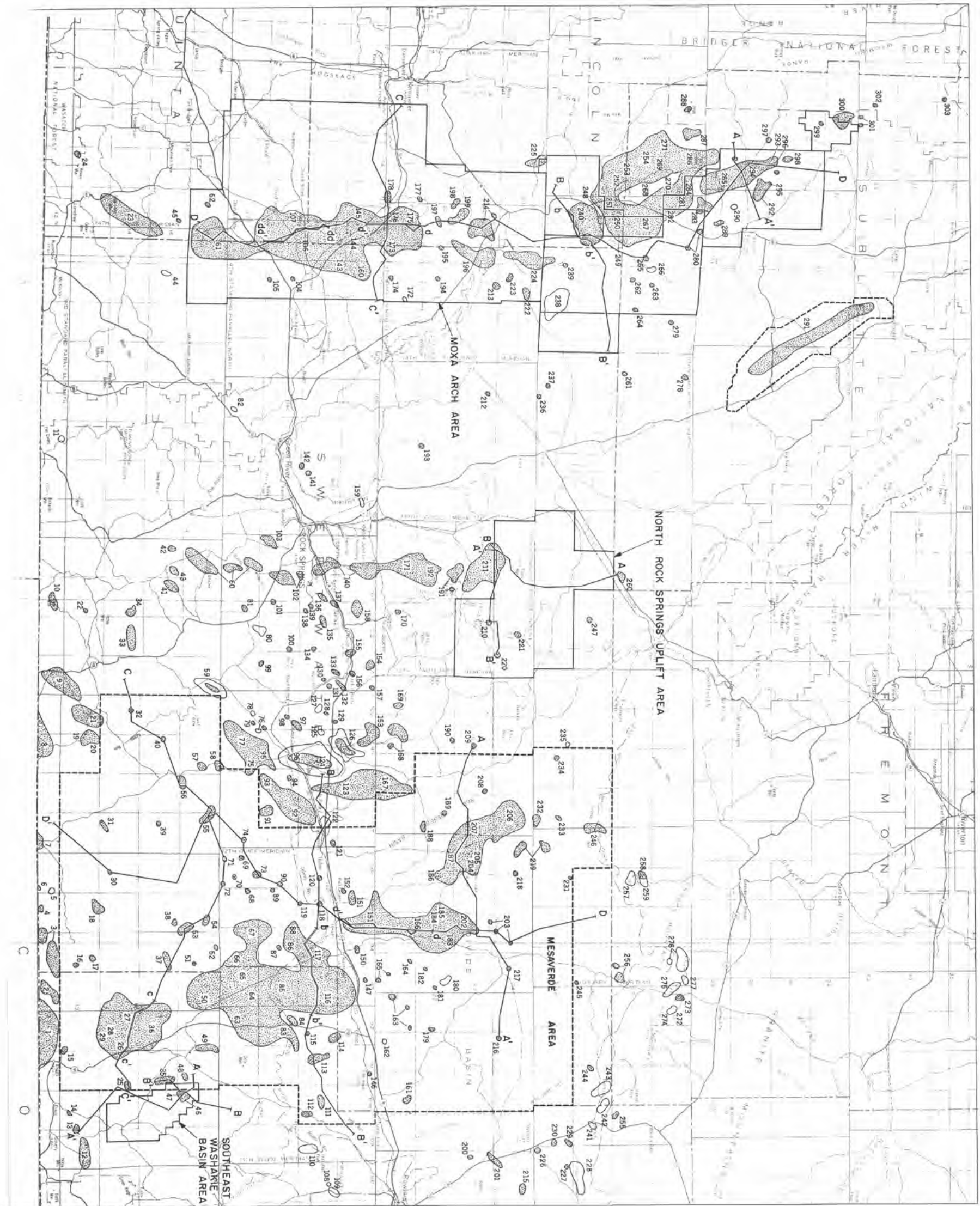
A

UPPER CRETACEOUS



A'

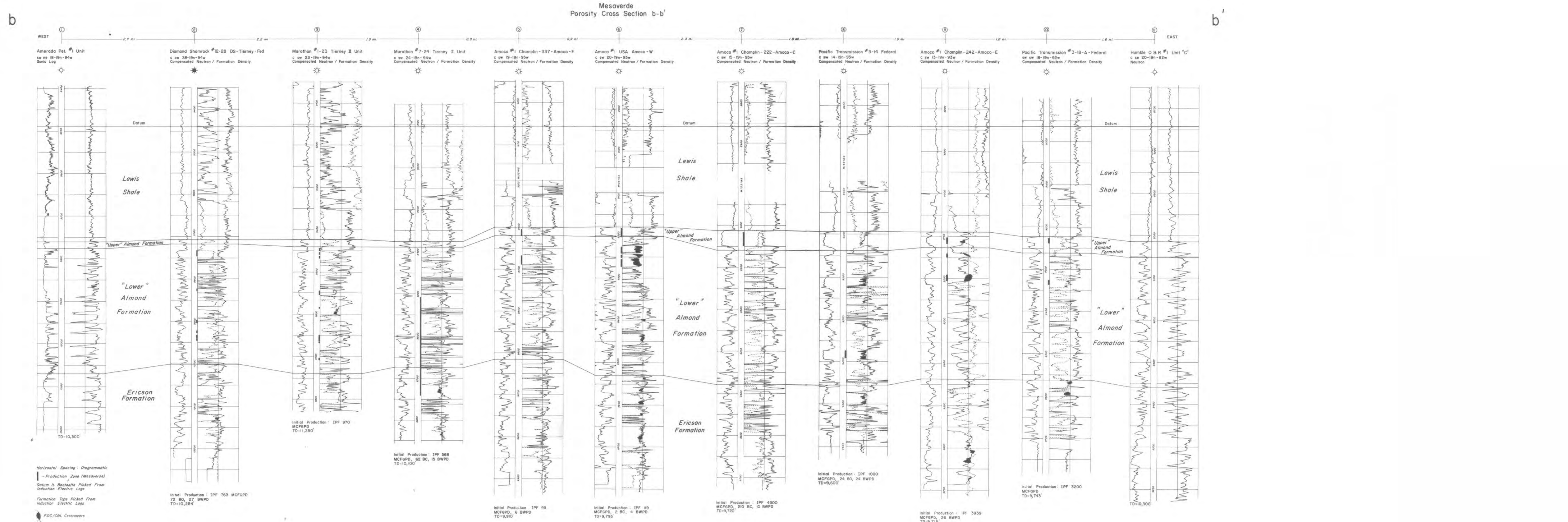
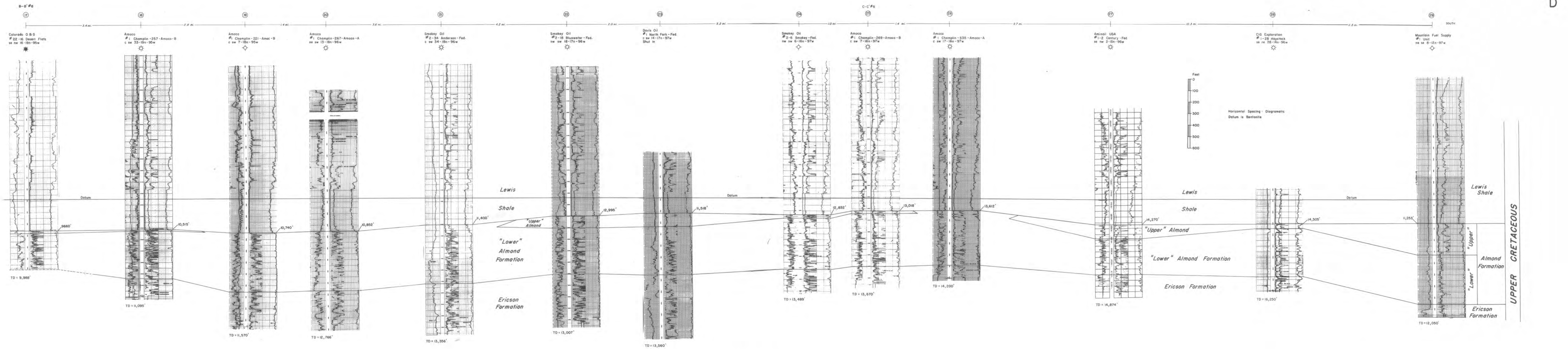
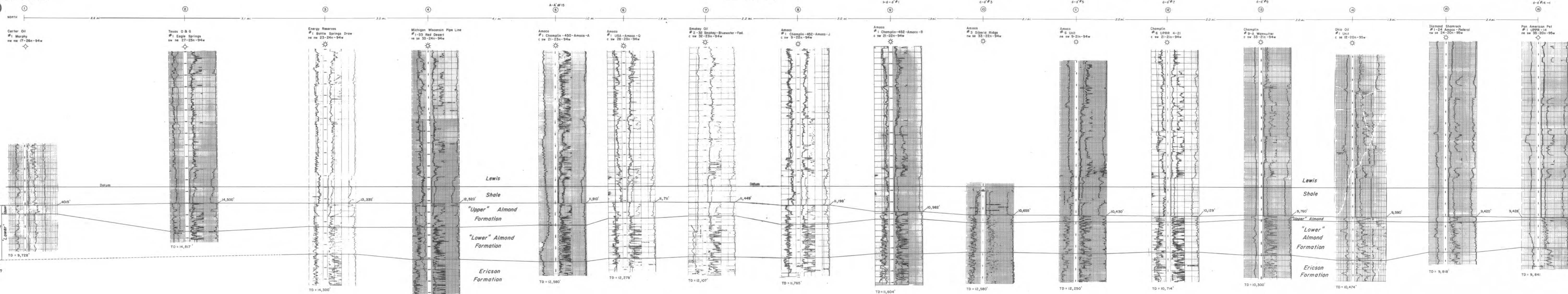
UPPER CRETACEOUS

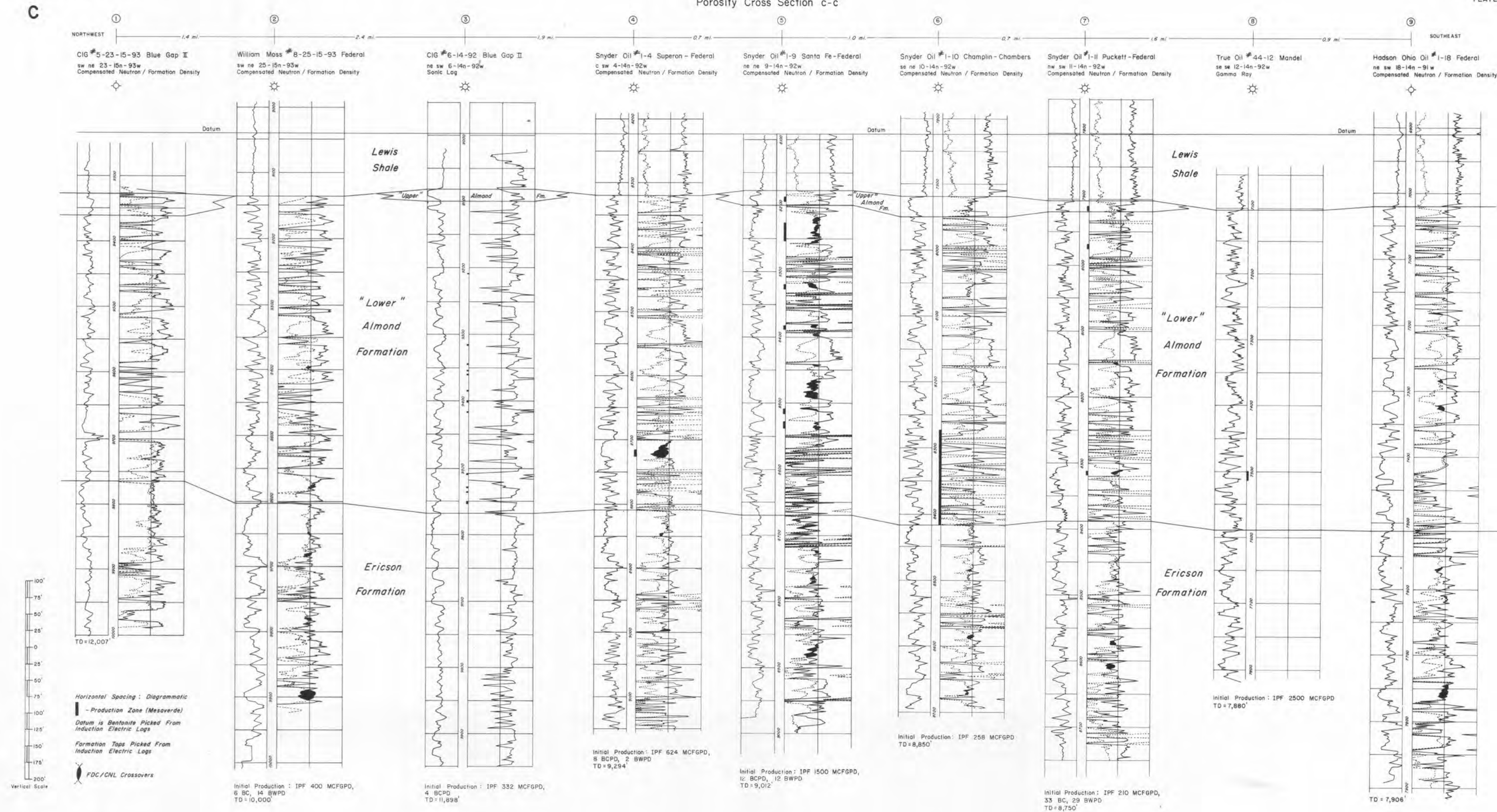
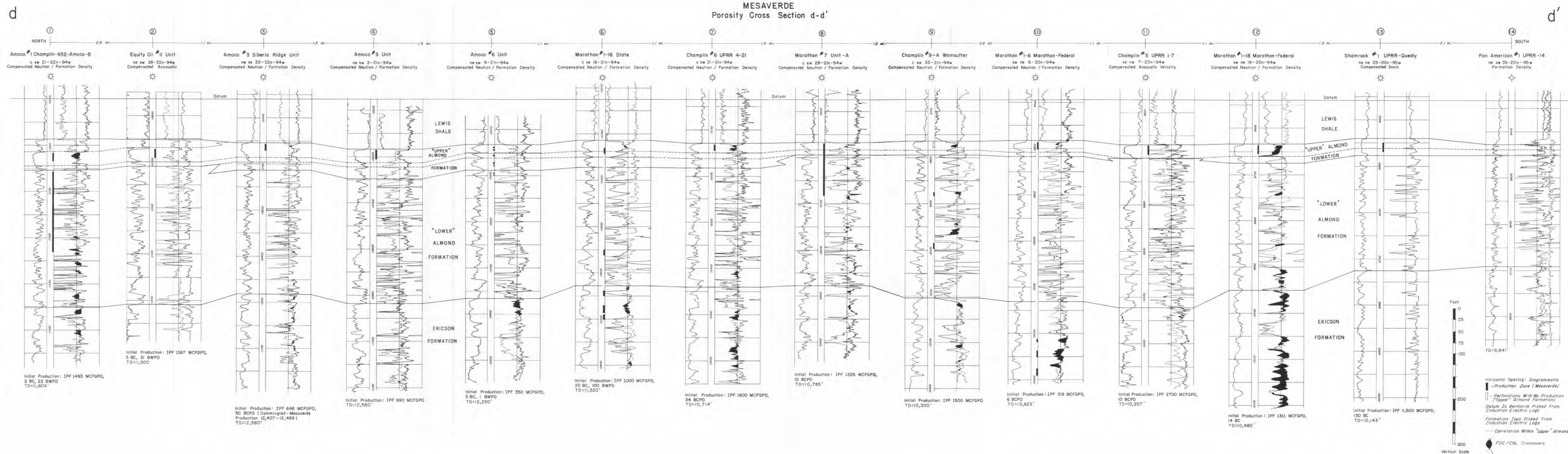


- LEGEND
- Mesa Verde Tight Gas Sand Pools and Application Areas
 - Greater Tight Gas Sand Pools and Application Areas
 - Oil Fields
 - Gas Fields
 - Oil and Gas Fields
 - E-Leg Cross Section Line
 - Dashed Line Section Line

GREATER GREEN RIVER BASIN
OIL AND GAS FIELDS

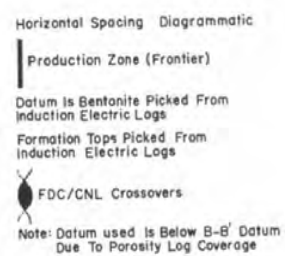




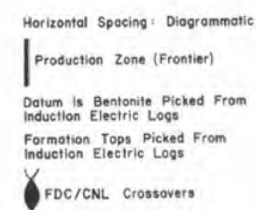
MESAVERDE
Porosity Cross Section d-d'



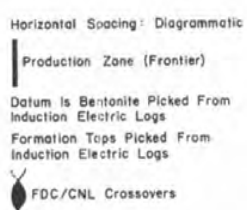
b



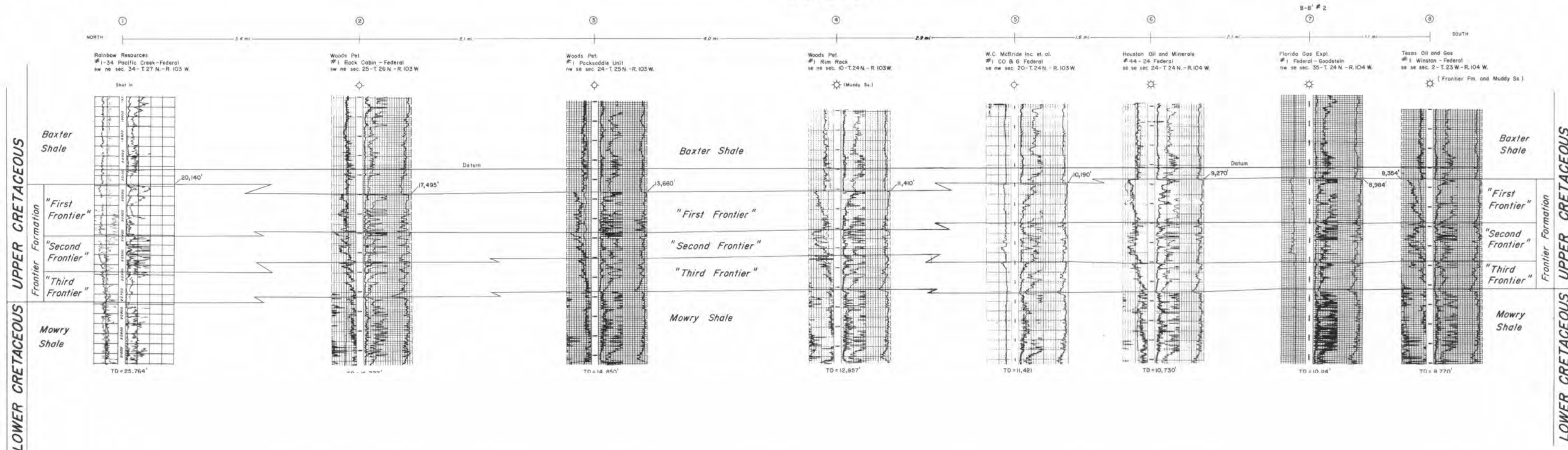
d



dd



North Rock Springs Uplift
Frontier Cross Sections
A-A' and B-B'

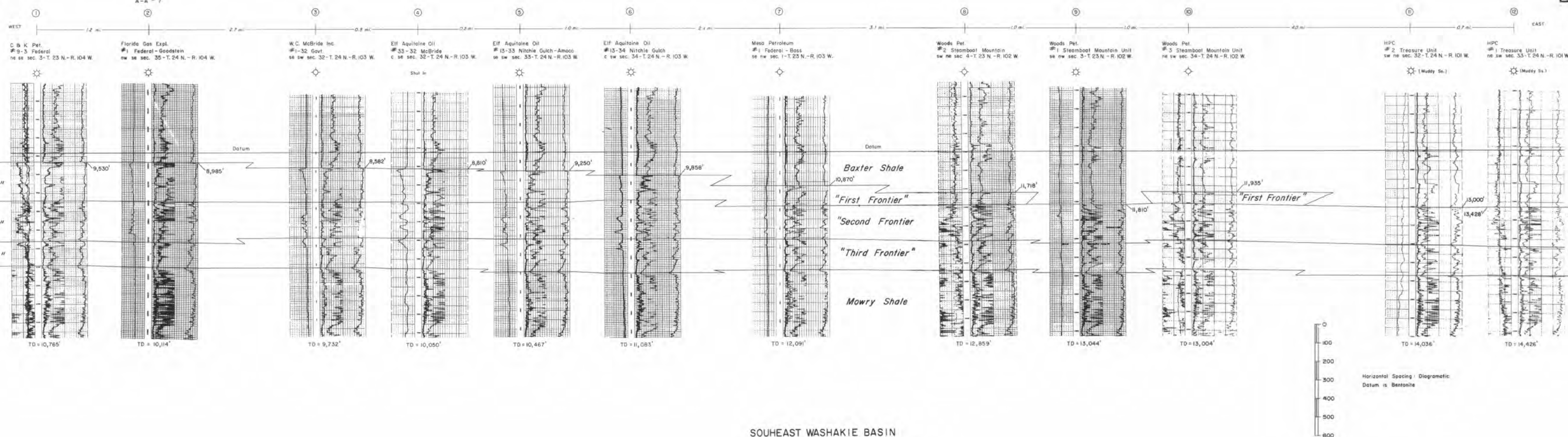


B

B'

UPPER CRETACEOUS
FRONTIER FORMATION
"First Frontier"
"Second Frontier"
"Third Frontier"
Mowry Shale
LOWER CRETACEOUS

UPPER CRETACEOUS
FRONTIER FORMATION
"First Frontier"
"Second Frontier"
"Third Frontier"
Mowry Shale
LOWER CRETACEOUS



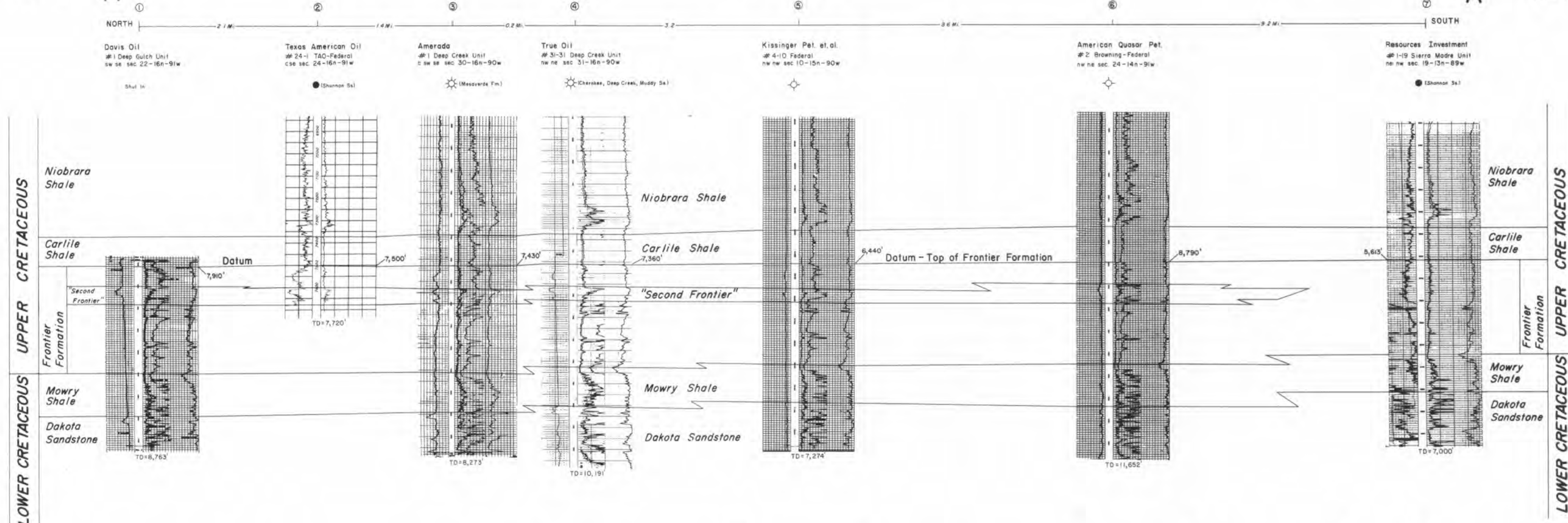
SOUTHEAST WASHAKIE BASIN
FRONTIER
Cross Sections A-A' and B-B'

GEOLOGICAL SURVEY OF WYOMING

A

A'

OPEN FILE REPORT 83-5
PLATE 15 OF 15



B

B'

Feet
0
100
200
300
400
500

Horizontal Spacing: Diagrammatic
Datum is Bentonite

