

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CORE DESCRIPTION AND RELATED DATA FROM ATLANTIC RICHFIELD COMPANY
CORE HOLE 2B FEDERAL DRILLED IN EOCENE GREEN RIVER FORMATION,
PICEANCE CREEK BASIN, NORTHWESTERN COLORADO

By

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Core Description and Related Data from Atlantic Richfield Company
Core Hole 2B Federal Drilled in Eocene Green River Formation
of Piceance Creek Basin, Northwestern Colorado

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INTRODUCTION

In 1968 the Department of Interior offered three selected tracts of oil-shale land in the Piceance Creek basin of northwest Colorado for leasing in a test program to determine the prospects for development of oil shale by private industry. Three bids were received for the tracts but the bids were judged to be inadequate by the Secretary of the Interior and the program was terminated. Further study of federal oil-shale lands by government and industry, and the oil embargo of 1973, brought about a successful leasing program. Surprisingly high bids were received for Federal tracts C-a and C-b (Colorado) and U-a and U-b (Utah) and these tracts were leased to industry in 1974 under provisions of the prototype oil-shale leasing program.

The Atlantic Richfield Company (now Arco Oil and Gas Company) Core Hole 2B Federal (fig. 1) was drilled to evaluate oil shale deposits on one of the three tracts of land selected by the Department of Interior in 1968. The well is in section 10, (1,715 ft from east line, 2,261 ft from north line) T. 3S., R. 96 W., Rio Blanco County and is about 1 mile east of Federal Oil Shale Lease Tract C-b leased to industry in 1974. The ground elevation of the drill hole is 7,250 ft MSL. The well was drilled by the Carmack Drilling Company using a 6 3/4 inch diamond core barrel and was started October 10, 1968 and completed November 2, 1968. This report describes some of the data gathered during the course of the drilling program to aid future investigations of the oil shale resources of northwest Colorado.

The surface geology of the drill site is shown on a geologic map of the Jessup Gulch 7.5 minute quadrangle by Duncan (1976). The location of the Atlantic Richfield Company core hole is inadvertently mislocated on Duncan's map but is shown correctly on figure 1 of this report. The Uinta Formation (fig. 2) is at the surface at the drill site. The core hole drilled into about 800 ft of the Uinta Formation and then penetrated into the Black Sulphur Tongue of the Green River Formation. The Black Sulphur Tongue is exposed in the NE ¼ of section 10 just above the level of Piceance Creek. Other subdivisions of the stratigraphic sequence penetrated by the drill hole are marked on the bulk density and Fischer assay logs that accompany this report.

The core hole was rotary-drilled from the surface to a depth of 1,084 ft, then cored to a total depth of 3,100 ft. Core point is approximately in the middle of the Thirteenmile Creek Tongue of the Green River Formation (fig. 2). The base of the cored sequence is in the L-O oil-shale zone of the Garden Gulch Member of the Green River Formation. The cored section is 2,016 ft thick and represents essentially the entire vertical sequence of oil shale in this part of the basin.

The core is archived and stored with the Core Research Center of the Geological Survey, Denver, Colorado. Fischer assays of the core, made on nominal 2-ft lengths of core, were done by the Colorado School of Mines

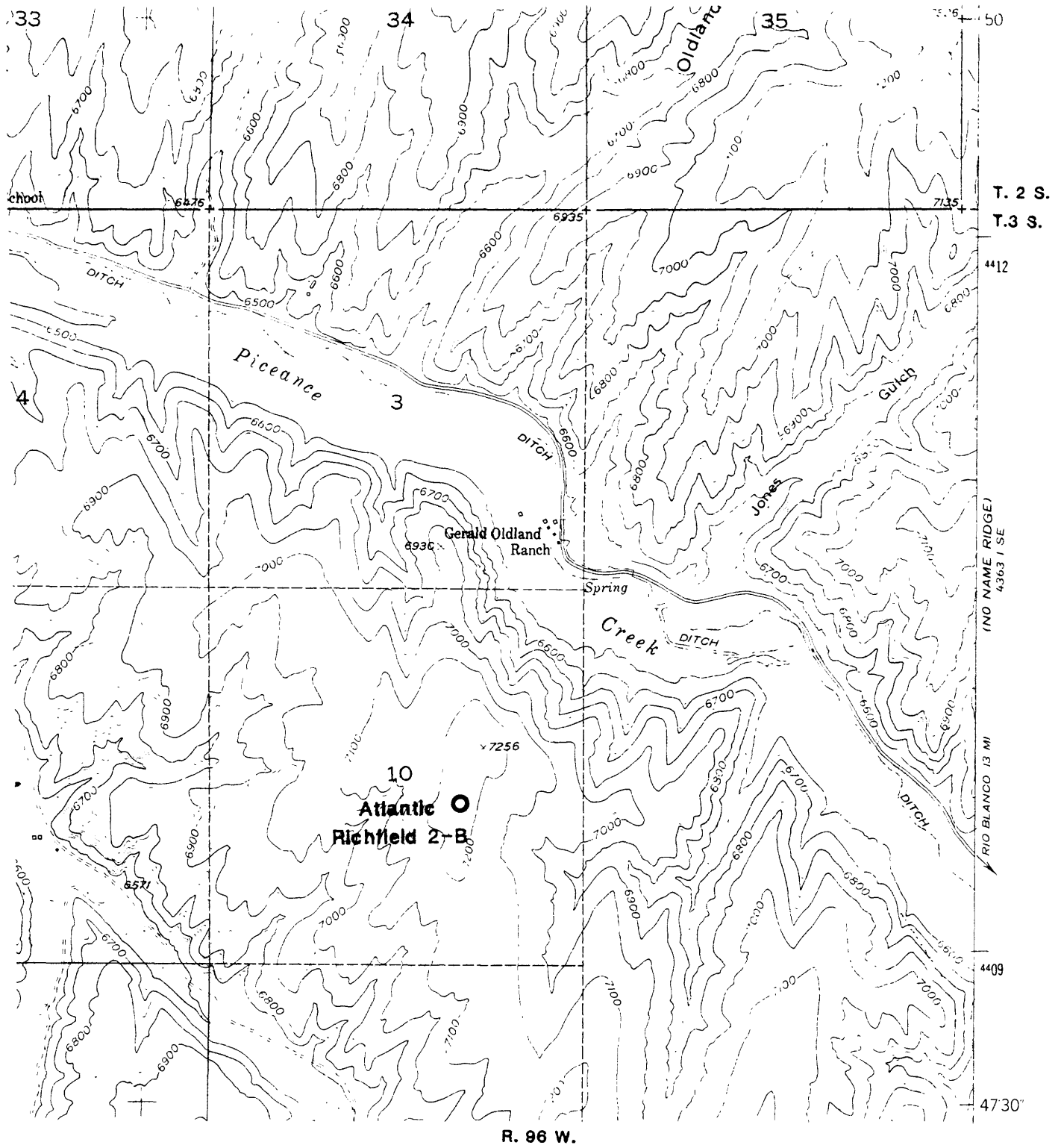


Figure 1.--Location of Atlantic Richfield Company Core Hole 2B Federal. Base from U.S. Geological Survey Jessup Gulch quadrangle, 1952, scale 1:24,000.

Research Foundation, Golden, Colo. in 1968. Sample splits from the assays were not saved.

The core description is contained in Appendix A. In the core description, a solid black vitreous hydrocarbon is noted occurring as lenses as much as 1/8 inch thick, as inclusions in oil shale as much as 1 inch across and as thin coats on fractures that cut the core at angles to bedding planes. The black hydrocarbon, which has not been analyzed, is generally referred to as gilsonite(?) or gilsonite because of its resemblance to the solid hydrocarbon of that name found in the Green River Formation in Utah (Carman and Bayes, 1961, p. 28-29). The solid hydrocarbon in the core strikingly resembles a black hydrocarbon present at the surface in nearby areas of the Piceance Creek basin, which on analyses is found to be unlike any previously described hydrocarbon (O'Sullivan and Ging, 1987). Chemical analysis of the solid black hydrocarbon described in the core may show that it is not gilsonite.

In addition to the Fischer assay, lithologic core description and partial geophysical log shown in this report, supplemental information can be found on other logs run in core hole 2B Federal. These include sonic, gamma-gamma density, neutron porosity, induction-electric and gamma ray logs which were run between depths of 266 and 3,100 ft.

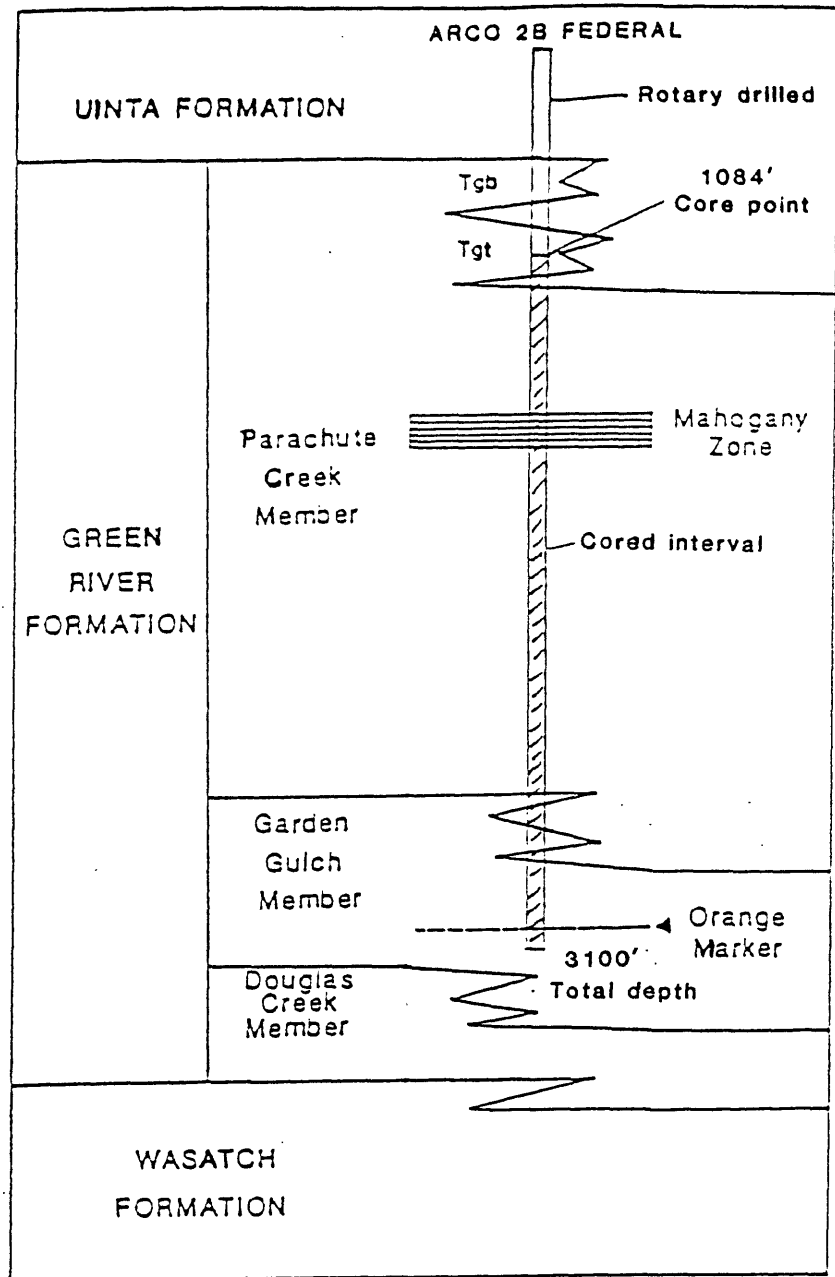
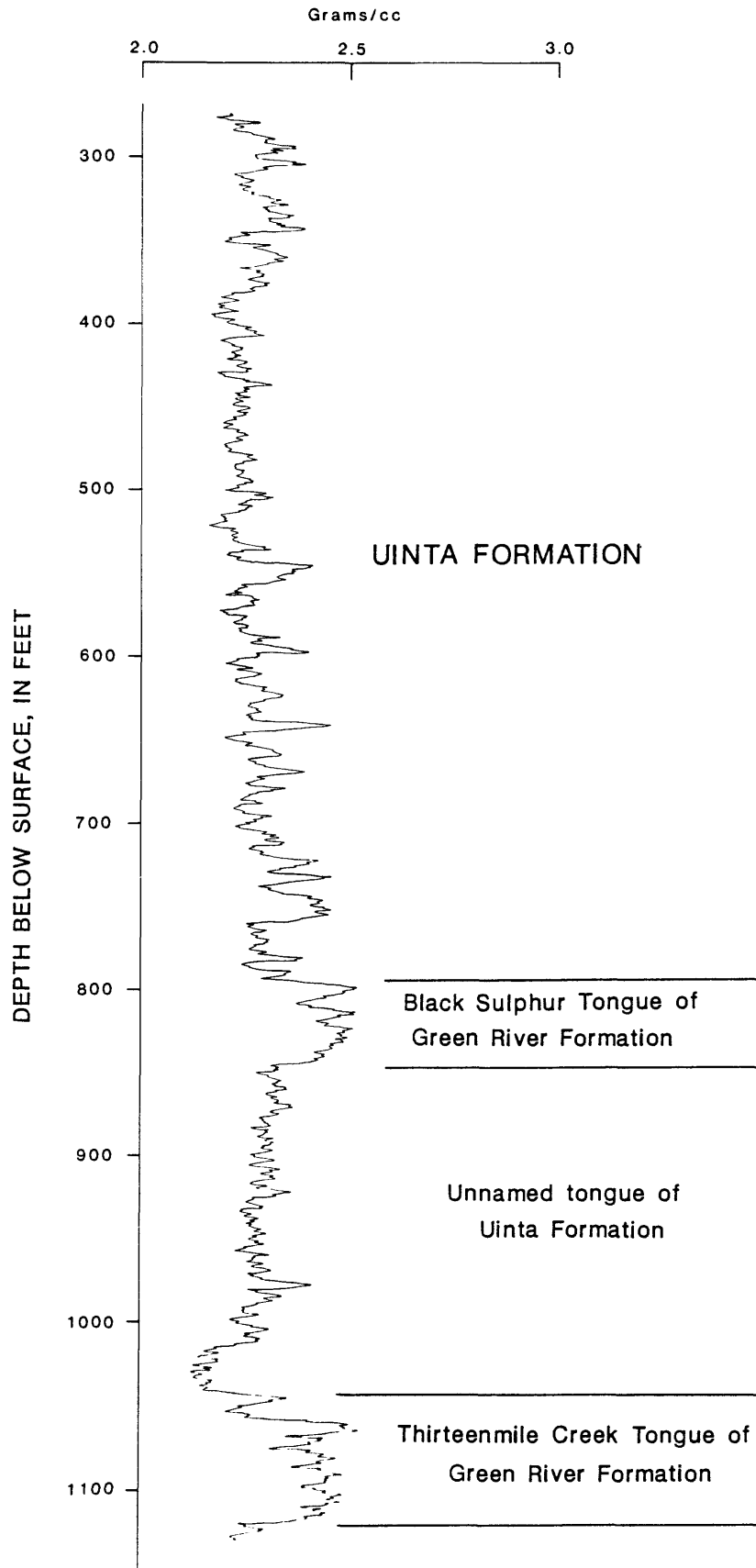
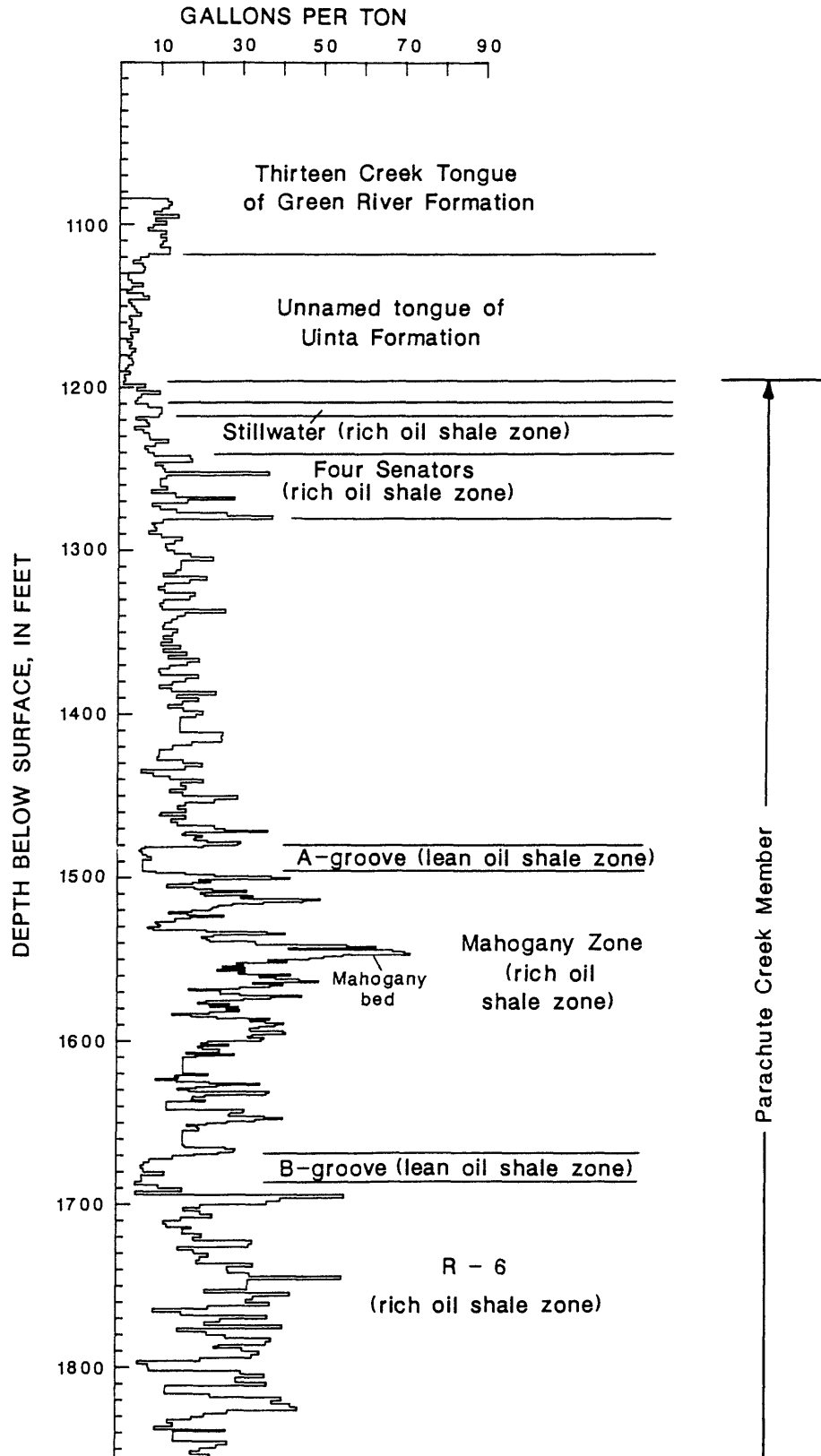


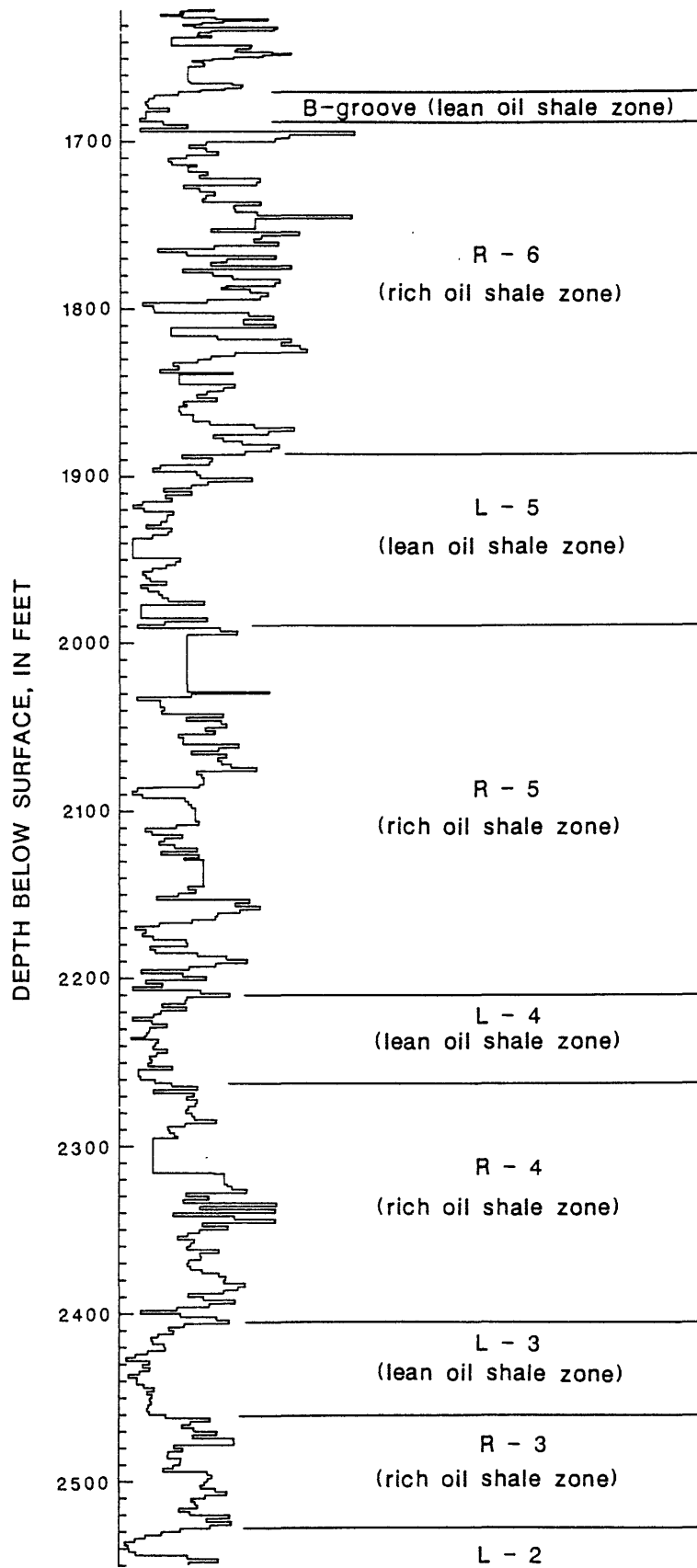
Figure 2.--Schematic section of Green River and associated Formations, all of Eocene age, near Atlantic Richfield Company 2B Federal. Only selected tongues, members and oil-shale zones are shown. Tongues of Green River Formation: Tgb--Black Sulphur tongue; Tgt--Thirteenmile Creek Tongue. Orange marker is a conspicuous deviation on the geophysical response line of mechanical logs that denotes a widespread stratigraphic marker horizon in the Piceance Creek basin.

ATLANTIC RICHFIELD COMPANY
Core Hole 2B Federal
BULK DENSITY

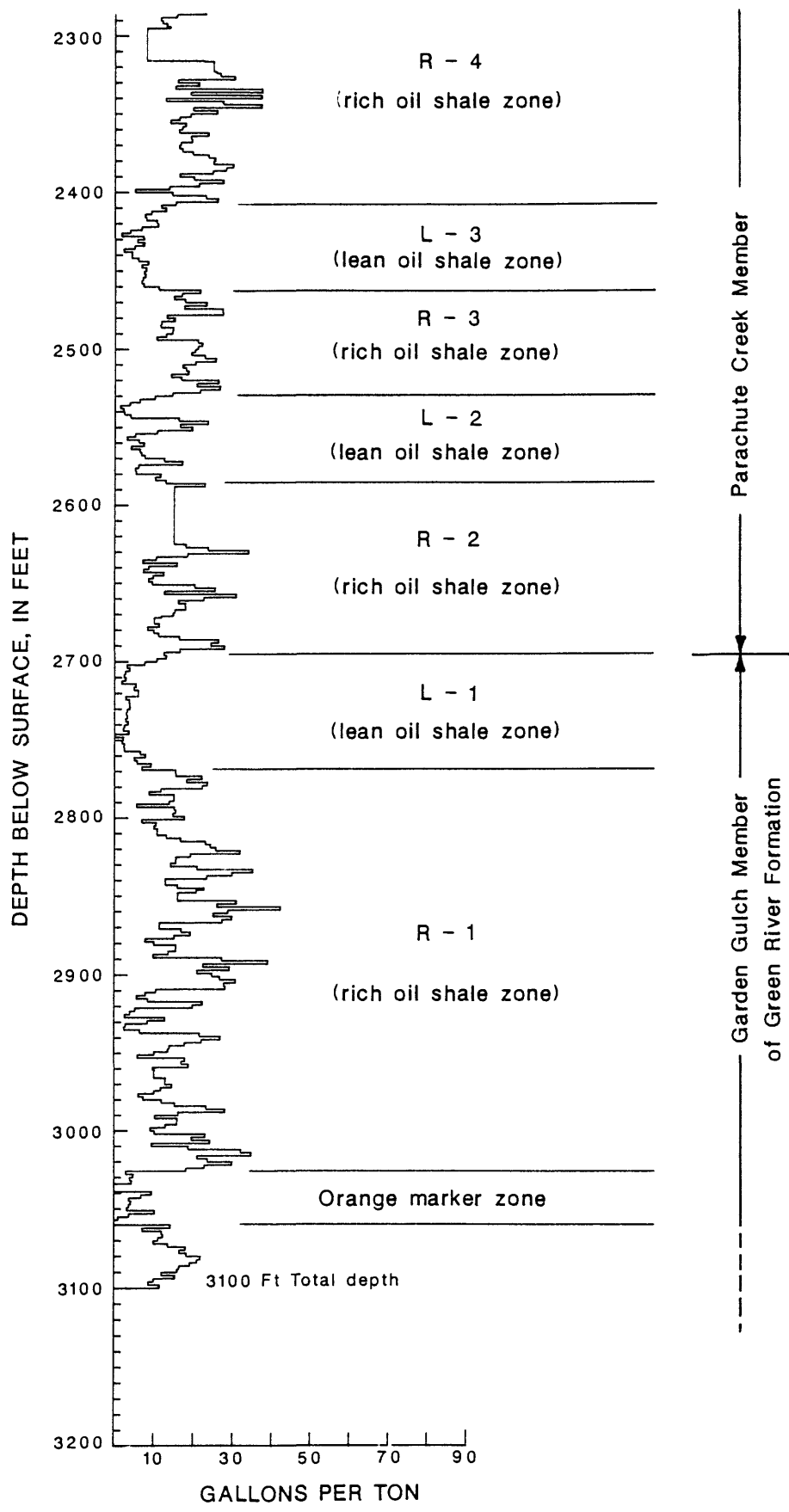


Fischer assay log of Atlantic Richfield Company
 Core hole 2B Federal
 (Fischer assays by Colorado School of Mines
 Research Foundation, Golden, Colo.)





Parachute Creek Member of Green River Formation



REFERENCES

- Carman, E.P., and Bayes, F.S., 1961, Occurrence, properties, and uses of some natural bitumens: U.S. Bureau of Mines Information Circular 7997, 42 p.
- Duncan, D.C., 1976, Preliminary geologic map of Jessup Gulch quadrangle, Rio Blanco County, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-756, scale 1:24,000.
- O'Sullivan, R.B., and Ging, T.G., 1987, Preliminary report on solid bitumens in Eocene rocks of Piceance Creek basin, northwestern Colorado: U.S. Geological Survey Open-File Report 87-478, 13 p.

APPENDIX A

Description of Core of Atlantic Richfield Company
Core Hole 2B Federal

Abbreviations used in core description

| | | |
|--------|---|-------------|
| calc | - | calcareous |
| dk | - | dark |
| est | - | estimated |
| F | - | fine |
| irr | - | irregular |
| lamin- | - | laminated |
| lt | - | light |
| mod | - | moderate |
| msg | - | missing |
| ss | - | sandstone |
| xtal | - | crystal |
| xtln | - | crystalline |
| V | - | very |

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco-Federal 2B PAGE 1 OF _____
 LOCATION Sec. 10, T. 3 S., R. 96 W., Rio Blanco Co., Colorado ELEVATION 7250 Gl. TOTAL DEPTH _____
 DATE BEGUN 10/10/68 DATE COMPLETED 10/31/68 DRILLER Carmack LOGGED BY W.B. Cashion and R.B. O'Sullivan
 CASING: _____ REMARKS: Colors described with core wet

| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION | Drill hole |
|--------|--------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| 1084.0 | 1084.5 | 0.5 | Oil shale, brown to gray, varved, graded fair | |
| 84.5 | 84.6 | 0.1 | Tuff, tan, calc, irr top and base | |
| 84.6 | 93.3 | 8.7 | Oil shale, brown to dk gray, varved, grade mod | |
| 93.3 | 93.35 | 0.05 | Tuff, tan extremely irr | |
| 93.35 | 94.3 | 0.95 | Interbedded marlstone and tuff, abundant contorted bed | |
| 94.3 | 96.3 | 2.0 | Oil shale, dk brown to dk gray, grade mod, abundant thin numerous beds of tuff, contorted bedding, many dikes | |
| 96.3 | 10.1 | 13.8 | Oil shale, tan to dk gray, grade fair to mod, contorted bedding, numerous tuff beds (est. 40%), lower 5' contains less contorted beds than above, 1/8" siltstone at base, dk brown, spotted white, very even top and bottom. | core msg 1113.4-1114.0 |
| 1110.1 | 1117.1 | 7.0 | Oil shale, tan to dk brown, grade fair to mod, slightly less than above, contains numerous tuff laminae, some irr bedding, tuff bed - top at 1112.1 (1/8" thick) - tuff dk brown spotted white, even top and slightly irr base | |
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CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco, Federal 2B LOCATION _____ PAGE 3 OF _____
 DATE BEGUN _____ DATE COMPLETED _____ DRILLER _____ ELEVATION _____ TOTAL DEPTH _____
 CASING _____ LOGGED BY _____ REMARKS: _____

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1202.6 | 1206.0 | 3.4 | Oil shale, gray to dk brown, varved, silty, grade mod, unit contains several V thin tuff beds, 1" tuff at 0.1' above base, grade decreases downward - lower 2' grade fair |
| 06.0 | 07.6 | 1.6 | Siltstone, lt gray, contorted bedding, contains lenses of organic matter |
| 07.6 | 08.0 | 0.4 | Oil shale, tan to dk brown, grade fair |
| 08.0 | 12.5 | 4.5 | Siltstone, gray to tan, tuffaceous, contains several thin evenly bedded tuffs between 1208.5 - 1209.4, most of sequence is contorted and contains irr dikes |
| 12.5 | 12.6 | 0.1 | Oil shale, tan to brown, grade fair |
| 12.6 | 12.9 | 0.3 | Siltstone, lt gray, contains thin oil shale laminae |
| 1212.2 | 1214.0 | 1.1 | Oil shale, dk brown to dk gray, contains thin tuff lenses, irr bedding grade rich |
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Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco-Federal 2B PAGE 4 OF 4
 LOCATION _____ TOTAL DEPTH _____
 DATE BEGUN _____ DATE COMPLETED _____ DRILLER _____ ELEVATION _____ LOGGED BY _____
 CASING _____ REMARKS: _____

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1214.0 | 1224.6 | 10.6 | Marlstone, brown to dk gray, V silty, grade lean to fair, lower 2" better grade, contains abundant tuff beds and intrusions, some contorted beds, lower part is varved |
| 24.6 | 26.7 | 2.1 | Tuff, lt gray to tan, even top & base, calc, contorted bedding, thin lenses of oil shale as much as 1/8" thick, speckled in part (analcite?) |
| 26.7 | 31.8 | 5.1 | Oil shale, brown to dk gray, mostly laminated, rare contorted bedding and micro-dikes, grade fair to mod |
| 31.8 | 34.2 | 2.4 | Oil shale, dk brown to dk gray, laminated, numerous tuff beds less than 1/8" thick, grade rich |
| 34.2 | 43.0 | 8.8 | Oil shale, brown to dk gray, mostly laminated, rare contorted bedding; two 1/2" tuffs between 1238.6 - 1238.8 - even tops & bases, brown to gray, several thin tuffs less than 1/8" thick, grade fair to mod |
| 43.0 | 46.3 | 3.3 | Oil shale, dk gray - dk brown, lamin., contains thin lenses of tuff less than 1/8" thick, grade rich |
| 1246.3 | 1251.5 | 5.2 | Oil shale, brown to gray, varved, thin lenses of tuff less than 1/4" thick, grade fair to mod |

Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco-Federal 2B PAGE 5 OF
 LOCATION _____ ELEVATION _____ TOTAL DEPTH _____
 DATE BEGUN _____ DRILLER _____ LOGGED BY _____
 DATE COMPLETED _____ REMARKS: _____
 CASING _____

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|------------------------------------------------------------------------------------------------------|
| 1251.5 | 1253.6 | 2.1 | Oil shale, dk brown & dk gray, varved, rare contorted bed, grade rich |
| 53.6 | 54.0 | 0.4 | Core msg |
| 54.0 | 54.8 | 0.8 | Oil shale, brown to dk gray, varved, grade mod |
| 54.8 | 61.0 | 6.2 | Core msg |
| 61.0 | 63.3 | 2.3 | Oil shale, brown to dk gray, varved, grade mod |
| 63.3 | 66.3 | 3.0 | Oil shale, tan to dk brown, varved, contains several thin irr tuffs less than 1/4" thick, grade fair |
| 66.3 | 69.0 | 2.7 | Oil shale, dk brown to dk gray, varved, grade rich |
| 69.0 | 78.1 | 9.1 | Oil shale, brown to dk brown, varved, few thin tuff beds less than 1/4" thick, grade mod |
| 78.1 | 81.0 | 2.9 | Oil shale, dk brown to dk gray, varved, few thin irr tuffs less than 1/4" thick, grade rich |
| 1281.0 | 1283.2 | 2.2 | Oil shale, gray to brown, varved, grade mod |

Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco Federal 2B PAGE 6 OF
 LOCATION ELEVATION TOTAL DEPTH
 DATE BEGUN DATE COMPLETED DRILLER , LOGGED BY
 CASING REMARKS:

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1283.2 | 1284.0 | 0.8 | Core msg |
| 84.0 | 85.7 | 1.7 | Oil shale, brown to dk gray, varved, grade mod |
| 85.7 | 86.0 | 0.3 | Core msg |
| 86.0 | 89.5 | 3.5 | Oil shale, brown to dk gray, varved, grade mod to rich. Contains 0.1' irr tuff at 1288.3 - 1288.4 |
| 89.5 | 95.6 | 6.1 | Oil shale, dk brown to dk gray, varved, grade rich. Two 1/2" irr tuff beds at 1293.6 and 1293.8 |
| 95.6 | 1303.7 | 8.1 | Oil shale, brown to dk gray, varved, grade mod, tuffs about 1/2" thick w/irr tops and bases with tops at 1295.8, 1296.7, 1297.0, 1298.1, 1300.9. Tuffs 0.1' thick, irr bedding, with tops at 1295.9, 1298.3, 1299.4 |
| 03.7 | 06.0 | 2.3 | Oil shale, dk brown to dk gray, irr bed, predominate, some varves, grade mod |
| 06.0 | 12.0 | 6.0 | Core msg? |
| 1312.0 | 1314.7 | 2.7 | Oil shale, dk brown to dk gray, varved, grade mod. Few thin irr tuff beds less than 1/2" thick |
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Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco Federal 2B
 LOCATION _____
 DATE BEGUN _____ DATE COMPLETED _____ DRILLER _____ ELEVATION _____ LOGGED BY _____
 CASING _____ TOTAL DEPTH _____
 REMARKS: _____

Drill hole

| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1314.7 | 1316.3 | 1.6 | Oil shale, tan to dk brown, varved, grade lean. Lower 1' is partially leached, contains vugs filled with solid hydrocarbon |
| 16.3 | 19.2 | 2.9 | Oil shale, dk brown to dk gray, irr bedding, contains lenses of tuff, V irr bedding, grade rich |
| 19.2 | 22.6 | 3.4 | Oil shale, dk brown to dk gray, varved, grade mod |
| 22.6 | 22.9 | 0.3 | Tuff and oil shale interbedded, oil shale dk gray, grade mod. Interval from top down is as follows: 1/2" tuff, 1/2" oil shale, 1/2" tuff, 1/4" oil shale, 2" tuff, V irr bed |
| 22.9 | 24.4 | 1.5 | Oil shale, brown to dk gray, varved, grade mod. Tuffs, irr bedding, tops at 1323.2' (1/4" thick), and 1323.6' (1" thick) |
| 24.4 | 26.9 | 2.5 | Oil shale, dk brown to dk gray, varved, grade rich |
| 26.9 | 27.2 | 0.3 | Tuff and interbedded oil shale, V irr bedding. Oil shale is dk brown to dk gray, grade mod. Tuffs are brown. Interval from top down is as follows: 1/4" tuff, 1/4" oil shale, 1/4" tuff, 1/2" oil shale, 2-1/2" tuff |
| 1337.2 | 1331.1 | 3.9 | Oil shale, dk brown to dk gray, varved, grade mod, irr tuffs 1/2" thick tops at 29.3' and 30.3' |

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco Federal 2B LOCATION _____ DATE COMPLETED _____ DRILLER _____ ELEVATION _____ LOGGED BY _____
 PAGE 8 OF _____ TOTAL DEPTH _____
 DATE BEGUN _____ REMARKS: _____
 CASING _____

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1331.1 | 1331.5 | 0.4 | Tuff, brown, contorted, irr top and base |
| 31.5 | 35.5 | 4.0 | Oil shale, brown to dk gray, conspicuously banded lt brown, varved, grade fair, Tuff bed 1/2" thick, top at 1335.1 w/irr top and base |
| 35.5 | 37.7 | 2.2 | Oil shale, dk gray and dk brown, varved, grade rich |
| 37.7 | 65.0 | 27.3 | Oil shale, dk gray to dk brown, varved, grade fair. Tuffs, brown, irr tops and bases, tops at 1338.9' (1/2" thick); 1339.2' (1" thick); 1339.5 (1" thick); 1339.7 (1-1/4" thick); 1339.9 (1" thick) 1340.9 (1/2" thick); 1341.4 (1/2" thick); (all tuffs are contorted); 1352.8 (1" thick); 1356.3 (1/2" thick) 1361.2 (1/4" thick); 1362.5 (1/2" thick); 1362.8 (1/2" thick); 1363.0 (1/2" thick); 1363.2 (1-1/2" thick in this case w/ even top and base) |
| 65.0 | 66.0 | 1.0 | Core msg |
| 66.0 | 76.8 | 10.8 | Oil shale, brown to dk gray; varved; grade fair, core badly broken between 1366 and 1370, tuff at 1367.6 (1/2" thick) irr top & base, contorted, tuff at 1372.3 (1/2" thick) contorted; 1376.5 (1" thick) |
| 1376.8 | 1382.0 | 5.2 | Oil shale, dk brown to dk gray, varved, grade mod |

Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco Federal 2B LOCATION Arco Federal 2B DATE COMPLETED DRILLER ELEVATION LOGGED BY
 DATE BEGUN DATE COMPLETED DRILLER ELEVATION LOGGED BY
 CASING REMARKS:

PAGE 9 OF
 TOTAL DEPTH

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION | Drill hole |
|--------|--------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| 1382.0 | 1384.3 | 2.3 | Oil shale, brown to dk gray, varved, grade fair | |
| 84.3 | 88.4 | 4.1 | Oil shale, dk brown to dk gray, varved; grade mod, core badly broken between 1386 and 1388 | |
| 88.4 | 91.0 | 2.6 | Interbedded oil shale and irr, tuff, contains .2' vuggy zone 1' below top; "Wavy Bed"? | |
| 91.0 | 1401.7 | 10.7 | Oil shale, dk brown to dk gray, varved; grade mod, contains lenses of tuff less than 1/4" thick, the tuffs are numerous, brown, | |
| 1401.7 | 11.0 | 9.3 | Core msg | |
| 11.0 | 18.0 | 7.0 | Oil shale, dk brown to dk gray, varved, irr, grade mod to rich, contains tuffaceous? lenses up to 1/2" thick, core from 1414-1418 badly broken | core msg |
| 18.0 | 38.6 | 20.6 | Oil shale, gray to dk brown, varved, some irr beds, grade fair, tuff- top at 1421 (1"thick) w/ irr top and base, xtal cavity bed from 1428.3 to 1428.5 (nahcolite?) | 1421.6-1424.0 |
| 38.6 | 50.0 | 11.4 | Oil shale, brown to dk gray, varved, grade fair, | |
| 1450.0 | 1452.6 | 2.6 | Oil shale, dk brown to dk gray, varved, grade rich, few thin irr, tuff beds less than 1/4" thick | |

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco-Federal 2B PAGE 10 OF
 LOCATION ELEVATION TOTAL DEPTH
 DATE BEGUN DATE COMPLETED DRILLER LOGGED BY
 CASING REMARKS:

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION | |
|--------|--------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| 1452.6 | 1469.3 | 16.7 | Oil shale, dk brown to dk gray, varved, grade fair, tuff, grayish brown, top at 1465.4 (1/4" thick) | core msg 1460-1461.2 |
| 69.3 | 72.0 | 2.7 | Oil shale, dk gray to dk brown, varved, some irr laminae, grade rich | |
| 72.0 | 77.7 | 5.7 | Oil shale, brown to dk gray, varved, mainly regular but some irr varves, upper part grade mod, lower 1' grade fair | |
| 77.7 | 80.0 | 2.3 | Oil shale, gray to almost black, varved, some irr varves, grade rich | |
| 80.0 | 98.0 | 18.0 | Oil shale, tan to dk brown, varved, grade lean, core from 1480.8 to 1489.0 badly broken, many pieces of core are stained a dead white, probably from nahcolite | core msg 1489.0-1496.0 |
| 98.0 | 1500.6 | 2.6 | Oil shale, med gray to almost black, some varving but most layers lenticular, contains numerous thin (less than 1/8" thick) tufts in lower 1', grade rich | |
| 1500.6 | 1504.0 | 3.4 | Oil shale, brown to dk gray, varved, grade fair, tuff - top at 1502.3 (1-1/2" thick), contains laminae of organic material, tuff contorted | |
| 1504.0 | 1505.5 | 1.5 | Oil shale, tan to dk brown, numerous tuff laminae less than 1/8" thick | |
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Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco Federal 2B PAGE 11 OF _____
 LOCATION _____ ELEVATION _____ TOTAL DEPTH _____
 DATE BEGUN _____ DRILLER _____ LOGGED BY _____
 DATE COMPLETED _____ REMARKS: _____
 CASING _____

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|-----------------------------------------------------------------------------------|
| 1505.5 | 1509.5 | 4.0 | Oil shale, dk brown to almost black, irr varving, grade rich, contains numerous |
| | | | lt gray tuff laminae, tuff as follows - tops at 1506.8' (1-1/2" thick); |
| | | | 1507.3' (1" thick); and 1/2" tuff at base of interval, False Marker? |
| | | | |
| 09.5 | 12.0 | 2.5 | Oil shale, brown to dk gray, varved, grade mod |
| | | | |
| 12.0 | 14.2 | 2.2 | Oil shale, dk brown to almost black, varved, grade rich, contains numerous tuff |
| | | | laminae, tuff top at 1513.1 (1/2" thick) irr, interval contains some pyrite |
| | | | nodules |
| | | | |
| 14.2 | 18.0 | 3.8 | Oil shale, gray to dk brown, varved and contorted, grade fair to mod, contains |
| | | | thin zones about 2" thick of tuff intrusions, irr tuff - top at 1517.5 (1" thick) |
| | | | |
| 18.0 | 27.0 | 9.0 | Oil shale, brown to dk gray, varved, grade fair, .3' vuggy zone at top |
| | | | |
| 27.0 | 27.5 | 0.5 | Tuff, blue gray, fine grained in upper part, tan coarser grained and contorted |
| | | | in lower part, top is even, base slightly irr (Mahogany Marker?) |
| | | | |
| 27.5 | 32.5 | 5.0 | Oil shale, brown to dk gray, varved, grade fair, 1" irr tuff at base |
| | | | |
| 32.5 | 35.0 | 2.5 | Oil shale, dk brown to almost black, varved, grade rich to very rich |
| | | | |
| 1535.0 | 1538.3 | 3.3 | Oil shale, dk gray to dk brown, varved, some beds irr, grade mod |
| | | | |

Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco-Federal 2B PAGE 12 OF
 LOCATION ELEVATION TOTAL DEPTH
 DATE BEGUN DATE COMPLETED DRILLER LOGGED BY
 CASING REMARKS:

| FROM | TO | THICKNESS | LITHOLOGIC DESCRIPTION | core msg |
|--------|--------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| 1538.3 | 1554.3 | 16.0 | Oil shale, dk brown to dk gray, varved, some beds irr, grade rich, conspicuous pyritic zone from 1538.4 - 1538.7, interval contains numerous thin, tan tuff beds, a concentration of tuff beds between 1545 and 1546.4, a zone of intruded tuffs between 1551.8 and 1552.1, Mahogany bed 1544 | 1550.6-1551 |
| 1554.3 | 1559.0 | 4.7 | Oil shale, brown to dk gray, varved, w/some irr bedding, grade mod | |
| 59.0 | 67.3 | 8.3 | Oil shale, tan to dk gray, bedding mostly contorted, grade rich, numerous tuff intrusions | |
| 67.3 | 72.3 | 5.0 | Oil shale, tan to dk gray, varved, grade mod, some thin tuff lenses less than 1/4" thick | |
| 72.3 | 76.0 | 3.7 | Oil shale, gray to dk gray, contorted, varved, grade rich, contains numerous irr lenses of tuff less than 1/4" thick | |
| 76.0 | 78.8 | 2.8 | Oil shale, gray to dk brown, varved, grade fair | |
| 78.8 | 82.5 | 3.7 | Oil shale, dk gray to almost black, varved, grade rich, wavy and contorted bedding, tuffaceous?, xtal cavity at 1579.8 (0.1' thick), gillsonite lenses at 1581.3' (1/8" thick) | |
| 82.5 | 98.0 | 15.5 | Oil shale, gray to dk gray, varved, grade mod to rich, contains numerous tuff lenses and thin beds less than 1/4" thick, much of core badly broken, contains several thin wiggly and punky zones | |
| 1598.0 | 1604.0 | 6.0 | Oil shale, tan, varved, grade lean, core badly broken | core msg 1600-1601 |

Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco-Federal 2B LOCATION _____ DATE COMPLETED _____ DRILLER _____ ELEVATION _____ TOTAL DEPTH _____
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| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1604.0 | 1610.0 | 6.0 | Oil shale, dk brown to dk gray, core badly broken, grade mod |
| 10.0 | 20.0 | 10.0 | Core msg |
| 20.0 | 20.8 | 0.8 | Oil shale, lt to dk gray, varved, grade mod, punky, vuggy zone (0.3') at base, core badly broken |
| 20.8 | 31.4 | 10.6 | Oil shale, lt to dk gray, varved, grade fair, punky, vuggy zones, tops at 1626.2 (0.2' thick) and 1628.0 (0.1' thick) both zones contain pyrite, core badly broken |
| 31.4 | 32.5 | 1.1 | Oil shale, dk gray to almost black, grade rich |
| 32.5 | 35.3 | 2.8 | Oil shale, tan to dk gray, varved, grade fair |
| 35.3 | 36.3 | 1.0 | Oil shale, lt gray, punky, vuggy, porous, grade lean. Lower 1/2 is badly broken |
| 36.3 | 37.0 | 0.7 | Oil shale, tan to dk gray, varved, grade mod |
| 37.0 | 44.0 | 7.0 | Core msg |
| 44.0 | 45.3 | 1.3 | Oil shale, tan to lt gray, vuggy, punky, porous, grade lean, core badly broken |
| 1645.3 | 1647.4 | 2.1 | Oil shale, lt to dk gray, varved, grade mod |

Drill hole

CORE LOG

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DRILL HOLE Arco-Federal 2B LOCATION _____ PAGE 14 OF _____
 DATE BEGUN _____ DATE COMPLETED _____ DRILLER _____ ELEVATION _____ TOTAL DEPTH _____
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| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1647.4 | 1649.5 | 2.1 | Oil shale, lt gray, vuggy, punky, porous, grade lean, core badly broken |
| 49.5 | 51.3 | 1.8 | Oil shale, tan and lt gray, varved, grade lean, silty |
| 51.3 | 54.0 | 2.7 | Marlstone, tan, silty, vuggy, badly broken, evidently 2 feet of core missing although there is no record of it |
| 54.0 | 55.2 | 1.2 | Oil shale, lt to med gray, varved, grade mod, lower 0.5' contains many oblate-shaped, white xtl'n pods (1/8"-1/4" diameter) |
| 55.2 | 55.6 | 0.4 | Oil shale, tan to lt gray, vuggy, punky, porous, grade lean, several bladed xtal cavities, probably weathered-out nahcolite, silty, contains some white oblate xtl'n pods |
| 55.6 | 67.0 | 11.4 | Oil shale, tan to lt gray, silty, grade lean, numerous tuff intrusions as much as 1/4" thick, numerous oblate white xtl'n pods (there is 1.2 ft of core representing this interval. Cannot determine which part is missing) |
| 167.0 | 1682.0 | 15.0 | Oil shale, tan and lt gray, some varving, grade fair to lean, 0.4' punky, vuggy zone at top and one at 1667.7' (0.1' thick) and one at 1668.0' (0.4' thick). conspicuous zone of white xtl'n pods at 1668.6' (2.6" thick). Core badly broken. Lower 1/2' contains zone of white xtl'n pods |

Drill hole

CORE LOG

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| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION | core msg |
|--------|--------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1682.0 | 1691.7 | 9.7 | Marlstone, lt gray, varved, pyritic. Lower 3 ft contains white xtn pods and lenses. Lower 3 ft is vuggy with vugs containing white carbonate and specks of pyrite. Some thin zones of lean oil shale in lower 3 ft | 1684-1686 |
| 91.7 | 1700.6 | 8.9 | Oil shale, brown to dk gray, varved, grade rich, vuggy, punky, porous zone top at 96.0 (0.5' thick) | |
| 1700.6 | 01.3 | 0.7 | Tuff, lt tan, interbedded with oil shale, top very irr, base even. Interval is as follows from top: 0.15' tuff, 0.03' oil shale (lean), 0.25' tuff, 0.19' oil shale (grade mod), 0.08' tuff | |
| 01.3 | 15.0 | 13.7 | Oil shale, tan to dk gray, varved, grade fair, vuggy, punky porous zone top at 1710.0 (1.0' thick). Lower 2.0' is lean oil shale. Core badly broken | |
| 15.0 | 18.0 | 3.0 | Core msg | |
| 18.0 | 22.4 | 4.4 | Oil shale, tan to lt gray, varved, grade lean, vuggy, punky, porous zones at 1719.2 (0.3' thick) 1720.3 (0.1' thick) | |
| 22.4 | 23.1 | 0.7 | Oil shale, dk gray to almost black, varved, grade rich | |
| 23.1 | 26.0 | 2.9 | Oil shale, lt to dk gray, varved, grade mod. Core badly broken | |
| 1726.0 | 1728.0 | 2.0 | Oil shale, tan to lt gray, varved, grade fair. Core badly broken | |

Drill hole

CORE LOG

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| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1728.0 | 1732.9 | 4.9 | Oil shale, lt to dk gray, varved, grade lean to fair. Core badly broken |
| | | | 1728.0' - 1729.2'. Well developed pyrite cubes at 1729.0' |
| 32.9 | 45.8 | 12.9 | Oil shale, lt to dk gray, upper 3.0' grade lean. Lower part - grade fair. Several vuggy, punky porous zones. Numerous thin tuff intrusions and beds. Contains leached zones, solution cavities and brecciated zones resulting from leaching of nahcolite(?). Lower 8' bedding is more regular. Lowermost 2p' badly broken |
| 45.8 | 52.0 | 6.2 | Core msg |
| 52.0 | 52.5 | 0.5 | Oil shale, lt to dk gray, varved, grade fair. Core badly broken |
| 52.5 | 54.6 | 2.1 | Oil shale, tan to lt gray, varved except upper 1.2' where bedding is very contorted, grade fair. Some tuff intrusions in lower 0.6' |
| 54.6 | 55.0 | 0.4 | Oil shale, dk brown to almost black, varved, grade rich |
| 55.0 | 59.2 | 4.2 | Oil shale, tan to dk gray, varved, grade fair |
| 59.2 | 62.7 | 3.5 | Oil shale, gray to almost black, varved, grade rich |
| 1762.7 | 1764.0 | 1.3 | Siltstone, tan, dolomitic, core badly broken |

U. S. GEOLOGICAL SURVEY

CORE LOG

DRILL HOLE Arco-Federal 2B PAGE 17 OF
 LOCATION TOTAL DEPTH
 DATE BEGUN DATE COMPLETED DRILLER ELEVATION , LOGGED BY
 CASING REMARKS:

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1764.0 | 1768.1 | 4.1 | Oil shale, lt tan to lt gray, varved, grade lean, several tuffs as follows: 1765.0' (1/8"), 1765.15' (1/8"), 1766.7' (1/2"), 1766.85' (3/8"). Several solution cavities in lower 2 feet. 1766.0' to 1766.5' core badly broken |
| 68.1 | 70.8 | 2.7 | Oil shale, gray to almost black, varved, grade rich |
| 70.8 | 70.9 | 0.1 | Tuff, intrusion, tannish gray |
| 70.9 | 81.1 | 10.2 | Oil shale, lt to dk gray, varved, grade mod |
| 81.1 | 82.2 | 1.1 | Oil shale, lt to dk gray, vuggy, punky, porous, grade fair |
| 82.2 | 90.0 | 7.8 | Oil shale, brown to gray, varved, grade lean. Vuggy, punky, porous zone at 1788.6' (0.2'). Lower 1.5' badly broken |
| 90.0 | 92.9 | 2.9 | Oil shale, lt to dk gray, grade rich |
| 92.9 | 98.0 | 5.1 | Oil shale, tan to dk gray, varved, grade mod |
| 1798.0 | 1801.0 | 3.0 | Siltstone, tuffaceous, tan to lt gray, varved with many conspicuous dk gray laminae. Upper 1/2 ft and lower 1 ft badly broken |

Drill hole

core msg
1796'-1797'

CORE LOG

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| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1801.0 | 1801.3 | 0.3 | Oil shale, lt to dk gray, varved, grade mod. Contains several solution cavities as much as 3/8" in diameter |
| 01.3 | 01.7 | 0.4 | Siltstone, tuffaceous, very lt gray, varved with a few dk gray laminae |
| 01.7 | 02.0 | 0.3 | Oil shale, dk gray, grade mod. Core badly broken contains solution cavities |
| 02.0 | 02.3 | 0.3 | Siltstone, tuffaceous V lt gray |
| 02.3 | 03.6 | 1.3 | Oil shale, lt to dk gray, varved, grade mod |
| 03.6 | 04.0 | 0.4 | Siltstone, tuffaceous, V lt gray (there is 0.1' of this in core box but assume it extends to 1804.0') |
| 04.0 | 10.9 | 6.9 | Oil shale, lt to dk gray, varved, grade mod, tuff, top at 1804.2' (1/2" thick) sl irr top and base. From 1810' to 1811' core badly broken, lower 1/2 of interval of better grade than upper part. Upper half 2 or 3 thin (2"-3" thick) Units of lean grade |
| 1810.9 | 1816.0 | 5.1 | Core msg |
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Drill hole

CORE LOG

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DRILL HOLE Arco-Federal 2B PAGE 20 OF
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| FROM | TO | THICKNESS | LITHOLOGIC DESCRIPTION |
|--------|--------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1870.0 | 1875.4 | 5.4 | Oil shale, brown to med gray, laminated, grade fair, contains at least 3 vuggy zones, each about 0.3' thick, contains tuff? 1874.1 to 1874.4', irr bedded |
| 75.4 | 86.5 | 11.1 | Oil shale, tan to gray-brown, laminated, lower part varved, grade fair, lower 2' contains some irr bedding, some thin (less than 1/2" thick) punky, vuggy zones. Leached zone top at 1878.8' (4" thick) |
| 86.5 | 98.0 | 11.5 | Marlstone, lt to med gray, varved and laminated, grade lean, contains small amount of organic matter, contains small vugs filled with calcite, and abundant particles and lenses of pyrite, punky and porous throughout interval, contains siltstone bed - top at 1895.0' (0.2' thick), much of interval speckled white |
| 98.0 | 1900.0 | 2.0 | Oil shale, tan to dk brown, varved, grade fair, contains vugs filled w/calcite, lower part is irr bedded |
| 00.0 | 6.1 | 6.1 | Oil shale, dk gray, laminated, grade mod, contains abundant thin (less than 1/16" thick) lenticular (1/4" long) white to lt gray oblate material (probably calcite) contains tuff? top at 1903.9 (0.3' thick), tuff is vuggy, punky and porous. |
| 1906.1 | 1908.7 | 2.6 | Marlstone, lt to med gray, varved and laminated, grade lean, contains small vugs filled with calcite, abundant particles and lenses of pyrite, punky and porous zones throughout, much of interval speckled white, Core badly broken |

Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

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 REMARKS: _____

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1908.7 | 1910.7 | 2.0 | Oil shale, tan to brownish-gray, laminated, some irr bedding, grade fair, contains thin (as much as 1/4" thick) tuff intrusions that extends through 6" of core, contains some vuggy cavities as much as 1" across |
| 10.7 | 12.7 | 2.0 | Oil shale, tan to dk gray, varved, grade fair, prominent banding tan and dk gray from 1912.0' to 1912.3', may be tuffaceous. Tuff, brown, at base of interval (1" thick) irr top and base |
| 12.7 | 14.7 | 2.0 | Oil shale, tan to dk gray, varved, grade lean, speckled white, contains small vugs (less than 1/8" across) throughout. Core badly broken |
| 14.7 | 20.6 | 5.9 | Marlstone, lt gray, tuffaceous, grade V lean, contains numerous pyrite xtals, some bedding planes contain blebs of an amber resinous material |
| 20.6 | 27.6 | 7.0 | Oil shale, tan to med gray, laminated, some contorted bedding, grade lean, contains 2 vuggy zones less than 2" thick, contains abundant lt gray lenses along bedding planes (less than 1/4" long), silty. Tuff, tan 0.2' thick at base w/irr top and base |
| 1927.6 | 1974.0 | 46.4 | Marlstone, lt to med gray, varved, grade lean, vuggy (less than 1/16" across) throughout, small particles and lenses of pyrite, tuffaceous, core badly broken, contains some beds of oil shale, grade fair, less than 1' thick, tops at 1931.6', 1934.0', 1952.0', at 1960' to 1964' interval somewhat shaly, at 1952.4' to 1954.0' contains contorted bedding and micro faults |

Drill hole

CORE LOG

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| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION | core msg |
|--------|--------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| 1974.0 | 1988.3 | 14.3 | Oil shale, tan to dk gray, partly varved, partly laminated, grade lean, some conspicuous tan and dk gray banding, contains thin zones of small vugs (vugs 1/16" across) | 1977'-1985' |
| 88.3 | 91.2 | 2.9 | Brecciated zone, core badly broken, tuffaceous, micaceous, limy, silty, chunks of marlstone up to 1/2" across set in a V f grain matrix, interval is V porous | |
| 91.2 | 95.0 | 3.8 | Oil shale, tan to dk gray, varved, grade fair | |
| 95.0 | 2029 | 34.0 | Core msg - only 10' recovered between 1885' and 2029' assumed they recovered 1985' - 1995' | |
| 29.0 | 31.5 | 2.5 | Oil shale, tan to grayish-brown, laminated, grade fair, contains several irr tuff beds as much as 1/2" thick. Most conspicuous tuff at base of unit | |
| 31.5 | 40.0 | 8.5 | Oil shale, gray to brown, partly laminated and partly varved, grade lean, lower part vuggy | |
| 40.0 | 45.0 | 5.0 | Oil shale, tan to grayish-brown, laminated, grade mod, few small vugs less than 1/2" across, tuff intrusion 1" thick w/top at 2042.4' | |
| 2045.0 | 2050.0 | 5.0 | Oil shale, tan to grayish brown, laminated, some irr bedding, grade fair to mod, vuggy | |

Drill hole

CORE LOG

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DRILL HOLE Arco-Federal 2B PAGE 23 OF
 LOCATION _____ ELEVATION _____ TOTAL DEPTH _____
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| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2050.0 | 2051.7 | 1.7 | Oil shale, lt to dk brown, laminated, grade lean, tuffaceous, vuggy, punky, porous |
| 51.7 | 58.2 | 6.5 | Oil shale, tan to med gray, varved, grade fair, tuffaceous, several thin vuggy, punky zones less than 1" thick |
| 58.2 | 63.3 | 5.1 | Oil shale, brown, grade lean, extremely vuggy, w/vugs as much as 1" across, vugs filled w/a V lt gray botryoidal mineral (quartz) |
| 63.3 | 85.5 | 22.2 | Oil shale, brown to lt gray, varved, grade mod, at 2067.0 is a thin (1/16" thick) black, vitreous, soft (hardness less than 5) band. Several tuff intrusions between 2066.5-2066.9, as much as 1/8" thick. At 2069.0 there is tuff (1/2" thick) with few coarse grains. Zone of V lt gray tuffs between 2076.0-2077.2. Tuffs are as much as 1/2" thick, irr tops and bases. Tuff, lt gray, top at 2078.25, 1/2" thick, fine to med grained, irr top and base. Top and base of tuff is replaced by pyrite (1/16" thick) |
| 2085.5 | 2092.2 | 6.7 | Oil shale, lt gray, laminated, grade lean. Unit is sandy and silty. At 2091.0 core /contains several circular (as much as 1/2" across) patches of a white mineral that apparently swells when wet (montmorillonite?). Lower 2' of core is badly broken |

Drill hole

CORE LOG

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 REMARKS: _____

| FROM | TO | THICKNESS | LITHOLOGIC DESCRIPTION |
|--------|--------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2092.2 | 2095.3 | 3.1 | Oil shale, tan to dk gray, laminated, grade mod. Several cavities filled with black, soft, organic matter and minor amounts of fine grained pyrite. Cavities are as much as 1" across. Tops of cavities at 2092.4, 2094.4 and 2095.0 |
| 95.3 | 98.0 | 2.7 | Oil shale, tan to med gray, laminated, grade lean. Tuffs, tan, thickness difficult to determine due to broken core (less than .2'). Tops of tuffs are at about /2096.0, 2096.7, 2097.0 and 2097.5 |
| 98.0 | 2106.0 | 8.0 | Core msg |
| 2106.0 | 24.2 | 18.2 | Oil shale, tan to med gray, varved and irr bedding, grade lean. Unit contains numerous irr tuff beds as much as 1/4" thick. Cavity (1/4" thick) at 2108.5 filled with bladed material, probably result of leaching of nahcolite. Lower 13' contains several white circular inclusions containing soft material that swells when wet (montmorillonite?). Lower 13' is slightly porous. |
| 2124.2 | 2129.0 | 4.8 | Oil shale, tan to med gray, laminated, grade fair with exception of lower 1' which is mod grade. Several tuff beds, generally less than 1/8" thick throughout interval. Concentration of numerous very thin tuff beds (interval 0.2' thick), top at 2125.7 |
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Drill hole

CORE LOG

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| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2129.0 | 2145.0 | 16.0 | Core msg |
| 45.0 | 49.8 | 4.8 | Oil shale, lt to dk gray, laminated, grade mod. Upper 0.7' badly broken |
| 49.8 | 51.5 | 1.7 | Oil shale, lt to med gray, laminated, grade lean |
| 51.5 | 67.6 | 16.1 | Oil shale, lt to dk gray, laminated, grade mod |
| 67.6 | 79.0 | 11.4 | Oil shale, lt to med gray, laminated with some varving, grade fair. Specks and inclusions (as much as 1/4" across) of a black, vitreous mineral occur from 2169.8 to 2172.7. Very irr tuff intrusion at 2177.4 (1/2" thick) |
| 79.0 | 79.6 | 0.6 | Oil shale, lt to dk gray, varved, grade mod. Very irr tuff intrusion at base (as much as 1/2" thick) |
| 79.6 | 85.5 | 5.9 | Oil shale, tan to lt gray, varved and laminated, grade lean. Tufts, tan, tops at 2182.3 (1/4"), 2182.5 (3/4"), 2183.2 (1/2"), 2184.3 (1/4"), 2184.35 (1/8"), 2184.4 (3/8"), 2184.7 (1/4"), 2185.3 (1/4"), 2185.5 (1/4") |
| 2185.5 | 2194.0 | 8.5 | Oil shale, lt to dk gray, laminated, grade mod. Tufts, dk brown, tops at 2185.7 (1/2"), 2186.3' (1/4"), 2186.4 (1"), 2186.7 (1/4"), 2187.6 (1/4"). Nahcolite occurs in thin irr beds from 2189.7 to 2189.9. At 2186.9 there is cavity 1-1/2" across |

Drill hole

CORE LOG

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Drill hole

| FROM | TO | THICKNESS | LITHOLOGIC DESCRIPTION |
|--------|--------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2194.0 | 2196.8 | 2.8 | Oil shale, tan to lt gray, varved and laminated, grade lean. Tuffs, tops at 2196.3 (3/8"), 2196.4 (1-1/4") |
| 96.8 | 99.0 | 2.2 | Oil shale, lt to med gray, laminated, grade fair. Contains vuggy zone with tuff inclusions. Some vugs as much as 1-1/2" across. Top of vuggy zone 2197.9 (0.8' thick) |
| 99.0 | 2200.6 | 1.6 | Oil shale, lt to dk gray, grade rich |
| 2200.6 | 07.4 | 6.8 | Oil shale, tan to med gray, varved, grade lean. Lower 2' is vuggy, many vugs less than 1/4" across. Two vugs are 2" across. Vugs partially filled with what appears to be tuffaceous material. Lower .5' of core is broken |
| 07.4 | 20.7 | 13.3 | Oil shale, lt to dk gray, varved, grade fair |
| 20.7 | 23.0 | 2.3 | Oil shale, tan to lt gray, varved and laminated, grade lean. Slightly porous. From 2221.6 to 2222.6 there is a dike about 1/16" across. Some offsets. Dike is composed of white mineral with hardness less than 2.5, noncalcareous |
| 2223.0 | 2223.4 | 0.4 | Oil shale, lt to dk gray, varved, grade fair |

CORE LOG

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| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2223.4 | 2225.6 | 2.2 | Oil shale, tan to brown, laminated and varved, grade lean. Interval contains numerous thin (up 1/4") tuff beds. Tuffs contain black (carbonaceous?) material |
| 25.6 | 33.2 | 7.6 | Oil shale, lt to dk gray, varved, grade fair. Several thin (as much as 1/8") tuffaceous lenses that contain a soft black (Carbonaceous?) mineral. From 2230.0 to 2232.6 black vitreous hydrocarbon (gilsonite?) on fractures. |
| 33.2 | 41.2 | 8.0 | Oil shale, tan to med gray, varved, grade lean. Bladed. Xtals of nahcolite coat a vertical crack top at 2235.3 (.15' thick). Black vitreous hydrocarbon (gilsonite?) coats vertical crack at 2238.2 (.14' long). Inclusion (1" across) of black vitreous hydrocarbon (gilsonite?) at 2240.1 |
| 41.2 | 44.0 | 2.8 | Oil shale, lt to dk gray, varved, grade fair. Tuff top at 2241.9 (1" thick), irr top and base |
| 44.0 | 49.0 | 5.0 | Oil shale, ltr to dk gray, varved, grade lean. Interval somewhat porous |
| 49.0 | 52.2 | 3.2 | Oil shale, lt to dk gray, varved, grade fair |
| 52.2 | 54.3 | 2.1 | Oil shale, tan to lt gray, varved, grade lean. Black vitreous hydrocarbon coats vertical crack at 2252.4 (0.2' long) |
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| | | | |

Drill hole

CORE LOG

U. S. GEOLOGICAL SURVEY

DRILL HOLE Arco-Federal 2B LOCATION _____ DATE COMPLETED _____ DRILLER _____ ELEVATION _____ LOGGED BY _____
 PAGE 29 OF _____ TOTAL DEPTH _____
 DATE BEGUN _____ REMARKS: _____
 CASING _____

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2290.0 | 2292.0 | 2.0 | Oil shale, lt to med gray, varved, grade fair. Few thin tuff intrusions (as much as 1/4" thick). |
| 92.0 | 95.0 | 3.0 | Oil shale, tan to med gray, varved and laminated, grade lean. Conspicuous zone of pyrite stringers (0.4' thick), top at 2293.6 |
| 95.0 | 2316.0 | 21.0 | Core msg |
| 2316.0 | 16.5 | 0.5 | Oil shale, lt to dk gray, varved, grade fair to mod. Core somewhat broken |
| 16.5 | 23.0 | 6.5 | Core msg |
| 23.0 | 31.5 | 8.5 | Oil shale, lt to dk gray, varved, grade med. Black vitreous mineral (gilsonite?) forms inclusions (1/4" across) and coats fractures in a 0.5' interval, top at 2330.5 |
| 31.5 | 33.5 | 2.0 | Oil shale, med to dk gray, laminated, grade mod. Contains numerous thin layers (up to 3/16" thick) of very lt gray carbonate. Carbonate makes up 20-25% of core |
| 2333.5 | 2340.0 | 6.5 | Oil shale, med to dk gray, laminated, grade rich. Few very irr nahcolite inclusions (up to 1/2" across). Also small amount of pyrite |

Drill hole

CORE LOG

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 LOGGED BY _____

| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2340.0 | 2344.0 | 4.0 | Oil shale, lt to dk gray, varved, grade mod |
| 44.0 | 45.6 | 1.6 | Oil shale, tan, laminated, appears to be lean (assay 37 gal.). Interval includes several small tuff(?) inclusions (as much as 1/8" thick) |
| 45.6 | 55.4 | 9.8 | Oil shale, lt to dk gray, varved, grade mod. Numerous tuff intrusions and beds (as much as 1/3" thick). Tuff intrusion (3/16" thick), top 2351.7' has pyrite rims. Conspicuous pyrite stringers in series of zones, tops at 2345.6 (0.2' thick), 2347.8 (0.2' thick), 2348.7 (0.3' thick), 2349.3 (0.3' thick), 2351.2 (0.05' thick) |
| 55.4 | 63.8 | 8.4 | Oil shale, tan to dk gray, varved, grade fair. Unit contains numerous tuff beds and very irr tuff intrusions. Most as much as 1-1/2" |
| 63.8 | 64.7 | 0.9 | Oil shale, tan, irr bedded, grade lean |
| 64.7 | 73.7 | 9.0 | Oil shale, lt to dk gray, mostly laminated, some varying, grade fair. Conspicuous pyrite stringers in zone, top 2370.5 (.25' thick). Core is broken between 2370.8 and 2372.0' |
| 2373.7 | 2375.2 | 1.5 | Oil shale, tan to lt gray, laminated, grade lean |
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Drill hole

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 LOCATION _____ TOTAL DEPTH _____
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 REMARKS: _____

| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2375.2 | 2395.9 | 20.7 | Oil shale, lt to dk gray, varved, grade mod. Numerous smooth tuff intrusions (as much as 1/2" thick in upper 5'). Tuff, lt brown, at 2383.2 (0.1' thick) conspicuous pyrite stringers in zone 0.2' thick, top at 2383.5. Conspicuous zone of tuff beds and intrusions (1.8' thick), top at 2385.2 |
| 95.9 | 97.3 | 1.4 | Oil shale, tan to lt gray, laminated, grade lean |
| 97.3 | 2403.4 | 6.1 | Oil shale, dk gray, laminated, grade fair |
| 2403.4 | 09.4 | 6.0 | Oil shale, tan to dk gray, irr varved, grade fair. Contains numerous lt brown, calcareous, tuffaceous intrusions and beds. Some black vitreous hydrocarbon stains, vertical cracks in zone 0.1' thick, top at 2408.6 |
| 09.4 | 24.4 | 15.0 | Oil shale, lt to dk gray, varved, grade fair. Core breaks readily along bedding planes, suggesting that it is quite argillaceous |
| 2424.4 | 2470.4 | 46.0 | Oil shale, lt to med gray, grade lean. Vertical cracks filled with breccia consisting of very small (less than 1/16") bits of lt gray oil shale set in a dk brown to black matrix that is probably hydrocarbon. This zone is 0.5' thick and top is at 2430.6. Interval is argillaceous. Vertical irr. cracks filled partly with lt gray calcareous material and at places with dk brown to black hydrocarbon. Crack is less than 1/16" wide. One crack extends along core top at 2435.0. Another extends along core, top at 2438.6. Material in lower crack has been partially leached and walls consist of breccia from adjacent shale. Core is somewhat porous below 2434.6. Crack similar to those described above found at 2445.7. Extends 0.15' along core |

Drill hole

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| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | | Beginning at 2462.0 and extending 2470.0 assay results show grade to be fair to mod., although core has same appearance as that above which assays show to be lean. Conspicuous pyrite stringers, tops at 2464.0 (0.15' thick), 2468.1' (0.15' thick), 2469.4 (0.3' thick). |
| 2470.4 | 2493.3 | 22.9 | Oil shale, lt to dk gray, varved, grade fair to mod. Conspicuous pyrite stringers tops at 2474.6 (0.15' thick), 2475.5 (.05' thick), 2477.4 (0.3' thick), several conspicuous zones are very irregularly bedded |
| 93.3 | 2515.3 | 22.0 | Oil shale, lt to V dk gray, varved, grade mod. Several irr tuffaceous(?) beds as much as 1/2" thick. Conspicuous zone (1/2" thick) of pyrite stringers, top at 2494.5 |
| 2515.3 | 19.8 | 4.5 | Oil shale, tan to med gray, varved with some irr bedding, grade fair |
| 19.8 | 28.0 | 8.2 | Oil shale, lt gray to almost black, laminated, grade mod. Black vitreous mineral (gilsonite?) occurs in cracks (about 0.15' long) with tops at 2527.0 |
| 2528.0 | 2544.4 | 16.4 | Marlstone, tan to grayish brown, varved, some contorted bedding, grade lean, argillaceous, silty |
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Drill hole

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 DATE BEGUN _____ DATE COMPLETED _____ DRILLER _____ LOGGED BY _____
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| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION | DRILL HOLE |
|--------|--------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| 2544.4 | 2552.2 | 7.8 | Oil shale, tan to dk gray, laminated, grade fair to mod, breaks readily along bedding planes | |
| 52.2 | 73.4 | 21.2 | Oil shale, lt to dk gray, varved, some irr bedding, grade lean, numerous micro faults, tuffs even tops and bases, tops at 2556.4 (0.1' thick), 2556.5 (0.05' thick), 2557.4 (0.05' thick), and 2564.6 (0.1' thick). Unit also contains numerous tuffaceous(?) laminae, lower 5' is not as evenly bedded as upper part | core msg 2561-2564 |
| 73.4 | 88.0 | 14.6 | Oil shale, tan to dk brown, laminated and some varving, considerable disturbed bedding, grade lean, abundant tuffaceous(?) beds and laminae, unit contains bed of mod grade top at 2582.6 (0.2' thick), tan, noncalcareous, xtl mineral on fracture at 2576. Unit contains several stringers of fine grained pyrite. | |
| | | | Tan irr tuff, top at 2585.5 (1/2" thick). Oil shale of mod value at 2585.9 (0.7' thick) | |
| 88.0 | 2625.0 | 37.0 | Core msg | |
| 2625.0 | 27.9 | 2.9 | Oil shale, dk gray, laminated, grade mod | |
| 2627.9 | 2630.1 | 2.2 | Oil shale, tan to almost black, varved, some irr bedding, grade fair, numerous tuffaceous(?) beds and lenses | |

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| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2630.1 | 2650.4 | 20.3 | Oil shale, tan to dk gray, laminated with some varving, grade lean to fair, argillaceous(?) (core breaks easily along bedding planes). Tuff(?), tan, irr top at 2634.2 (0.1' thick) |
| 50.4 | 61.8 | 11.4 | Oil shale, tan to grayish brown, irr bedded, grade mod. Unit contains numerous tuffaceous(?) lenses. Tuff(?) tan, top at 2650.5 (1" thick) |
| 61.8 | 72.0 | 10.2 | Oil shale, dk brownish gray, laminated, grade fair. Tuff, lt brown, irr top at 2666.4' (1/4" thick). Tuffaceous? zone, tan even top and base, top at 2669.0' (0.2' thick), much of core badly broken |
| 72.0 | 76.0 | 4.0 | Core msg |
| 76.0 | 77.3 | 1.3 | Oil shale, tan to dk gray, partly varved and partly contorted bedding, grade fair |
| 2677.3 | 2685.5 | 8.2 | Oil shale, tan to dk gray, laminated, some varving, grade fair to mod. Core breaks readily along bedding planes. Contains numerous stringers and laminae of lt gray, calcareous, granular material generally less than 1/16" thick |
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Drill hole

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Drill hole

| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION |
|---------|---------|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2772.0 | 2784.0 | 12.0 | Oil shale, brown to brownish-gray, laminated, grade fair to mod. Contains banded tuffs and tuff zones, tops at 2772.1' (0.2' thick), 2772.6' (0.2' thick), |
| 2774.6' | 2782.7' | (0.2' thick) | 2783.1' (0.2' thick). Vertical fractures in tuff contain the white acicular mineral balls described above |
| 84.0 | 2813.0 | 29.0 | Oil shale, tan to brownish gray, laminated w/some varving, grade lean to fair. Tuffs and tuff zones, banded, tops at 2784.0' (0.4' thick), 2784.8' (0.2' thick), 2785.8' (0.1' thick), 2796.1' (0.2' thick), 2797.2' (0.1' thick), 2798.5' (0.4' thick). A few vertical fractures contain a soft brown hydrocarbon. Much of core breaks readily along bedding planes. Lower 8' is more argillaceous |
| 2813.0 | 24.3 | 11.3 | Oil shale, brown to dk gray, laminated, some varving, minor contorted bedding, grade mod to rich. Tuffs, tan, banded, tops at 2815.2' (0.1' thick), 2820.4' (0.1' thick) |
| 24.3 | 31.3 | 7.0 | Oil shale, dk gray, laminated, grade fair. From 2824.3' to 2831.3' interval contains coaly remains of plant materials along bedding planes. Core breaks readily along bedding planes |
| 2831.3 | 2840.6 | 9.3 | Oil shale, tan to dk gray, laminated, some varving, grade mod to rich. Contains tuff, tan, banded, tops at 2834.2' (0.2' thick), 2835.0' (0.2' thick), 2835.6' (0.1' thick), 2836.1' (0.05' thick), 2840.1 (0.2' thick) |
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REMARKS:

| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2958.5 | 2960.5 | 2.0 | Oil shale, brownish gray to dk gray, laminated, grade fair to lean. Core V |
| | | | badly broken |
| 60.5 | 66.0 | 5.5 | Core msg |
| 66.0 | 83.4 | 17.4 | Oil shale, lt gray to grayish brown, varved and laminated, grade fair. Interval argillaceous. Contains a few black rounded organic rich nodules up to 1/2" across. Tuffs tan, banded, tops at 2968.7' (0.05' thick), 2969.9 (0.05' thick). Core breaks readily along bedding planes. Lower 6' of core is badly broken |
| 81.4 | 88.8 | 5.4 | Oil shale, brown to dk gray, laminated, some irr bedding, grade mod. Minute lenses of tuffaceous(?) material along bedding planes. A bentonite(?) bed, yellowish brown, V irr, top at 2986.7' (1/4" thick) |
| 88.8 | 3002.0 | 13.2 | Oil shale, lt gray to grayish brown, varved, grade fair. Interval contains a zone of grade mod. from 2995.6' to 2996.9'. Core breaks readily along bedding planes. Lower 4' of core is badly broken |
| 3002.0 | 3009.0 | 7.0 | Oil shale, grayish brown to dk gray laminated, grade mod. Tuffs grayish-brown, banded, contorted, w/some oil staining. Tops at 3007.1' (1" thick) 3008.0' (2" thick), 3008.3' (2" thick) |

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| FROM | TO | THICK- NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3009.0 | 3011.2 | 2.2 | Oil shale, brownish-gray to med gray, varved, grade fair. Upper 1' is badly broken |
| 11.2 | 24.7 | 13.5 | Oil shale, brownish gray to V dk gray, laminated, some varving, grade mod. Lower part contains numerous med gray lenses that are slightly more calcareous than adjacent rock. Lenses are up to 1/2" thick |
| 24.7 | 57.0 | 32.3 | Claystone to marlstone, med gray, laminated in part, grade lean. Core badly broken. Tuff, grayish-brown, V irr bedding, top at 3039.4' (0.2' thick). A silty zone top at 3055.3' (0.8' thick approximately). Entire interval contains zones that are slightly calcareous. This interval is the "Orange Marker Zone" |
| 57.0 | 60.0 | 3.0 | Core msg |
| 60.0 | 80.0 | 20.0 | Oil shale, tan to dk brownish-gray, laminated, some varving, grade fair. Contains stringers and blebs (up to 1/8" across) of dk gray, carbonaceous material that contains specks of pyrite. Some fractures and bedding planes coated w/ a black, lustrous hydrocarbon (gilsonite?) |
| 3080.0 | 3086.0 | 6.0 | Oil shale, brown to dk grayish brown, laminated, grade mod. Contains thin lenses and blebs of a dk gray, carbonaceous material. Lenses are as much as 1/8" thick |
| 3086.0 | 3095.0 | 9.0 | Oil shale, grayish-brown to dk gray, laminated, grade fair. Contains irr fracture fillings of tuff? up to 1/8" thick |

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Drill hole

| FROM | TO | THICK-NESS | LITHOLOGIC DESCRIPTION |
|--------|--------|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3095.0 | 3100.0 | 5.0 | Oil shale, dk brownish-gray, some laminations, grade lean to fair. Interval argillaceous. Core breaks readily along bedding planes. Core badly broken |
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| | 3100 | | Total depth |
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