

**HETEROGENEOUS SHALLOW-SHELF CARBONATE
BUILDUPS IN THE PARADOX BASIN,
UTAH AND COLORADO: TARGETS FOR INCREASED
OIL PRODUCTION AND RESERVES USING
HORIZONTAL DRILLING TECHNIQUES**
(Contract No. DE-2600BC15128)

**DELIVERABLE 1.3.1
GEOPHYSICAL WELL LOG/CORE
DESCRIPTIONS, CHEROKEE AND BUG
FIELDS, SAN JUAN COUNTY, UTAH, AND
LITTLE UTE AND SLEEPING UTE FIELDS,
MONTEZUMA COUNTY, COLORADO**

Submitted by

Utah Geological Survey
Salt Lake City, Utah 84114
December 2003



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INTRODUCTION

Over 400 million barrels (64 million m³) of oil have been produced from the shallow-shelf carbonate reservoirs in the Pennsylvanian (Desmoinesian) Paradox Formation in the Paradox Basin, Utah and Colorado. With the exception of the giant Greater Aneth field, the other 100 plus oil fields in the basin typically contain 2 to 10 million barrels (0.3-1.6 million m³) of original oil in place. Most of these fields are characterized by high initial production rates followed by a very short productive life (primary), and hence premature abandonment. Only 15 to 25 percent of the original oil in place is recoverable during primary production from conventional vertical wells.

An extensive and successful horizontal drilling program has been conducted in the giant Greater Aneth field. However, to date, only two horizontal wells have been drilled in small Ismay and Desert Creek fields. The results from these wells were disappointing due to poor understanding of the carbonate facies and diagenetic fabrics that create reservoir heterogeneity. These small fields, and similar fields in the basin, are at high risk of premature abandonment. At least 200 million barrels (31.8 million m³) of oil will be left behind in these small fields because current development practices leave compartments of the heterogeneous reservoirs undrained. Through proper geological evaluation of the reservoirs, production may be increased by 20 to 50 percent through the drilling of low-cost single or multilateral horizontal legs from existing vertical development wells. In addition, horizontal drilling from existing wells minimizes surface disturbances and costs for field development, particularly in the environmentally sensitive areas of southeastern Utah and southwestern Colorado.

GEOLOGIC SETTING

The Paradox Basin is located mainly in southeastern Utah and southwestern Colorado with a small portion in northeastern Arizona and the northwestern most corner of New Mexico (figure 1). The Paradox Basin is an elongate, northwest-southeast trending evaporitic basin that predominately developed during the Pennsylvanian (Desmoinesian), about 330 to 310 million years ago (Ma). During the Pennsylvanian, a pattern of basins and fault-bounded uplifts developed from Utah to Oklahoma as a result of the collision of South America, Africa, and southeastern North America (Kluth and Coney, 1981; Kluth, 1986), or from a smaller scale collision of a microcontinent with south-central North America (Harry and Mickus, 1998). One result of this tectonic event was the uplift of the Ancestral Rockies in the western United States. The Uncompahgre Highlands in eastern Utah and western Colorado initially formed as the westernmost range of the Ancestral Rockies during this ancient mountain-building period. The Uncompahgre Highlands (uplift) is bounded along the southwestern flank by a large basement-involved, high-angle reverse fault identified from geophysical seismic surveys and exploration drilling. As the highlands rose, an accompanying depression, or foreland basin, formed to the southwest — the Paradox Basin. Rapid subsidence, particularly during the Pennsylvanian and then continuing into the Permian, accommodated large volumes of evaporitic and marine sediments that intertongue with non-marine arkosic material shed from the highland area to the northeast (Hintze, 1993). The Paradox Basin is surrounded by other uplifts and basins that formed during the Late Cretaceous-early Tertiary Laramide orogeny (figure 1).

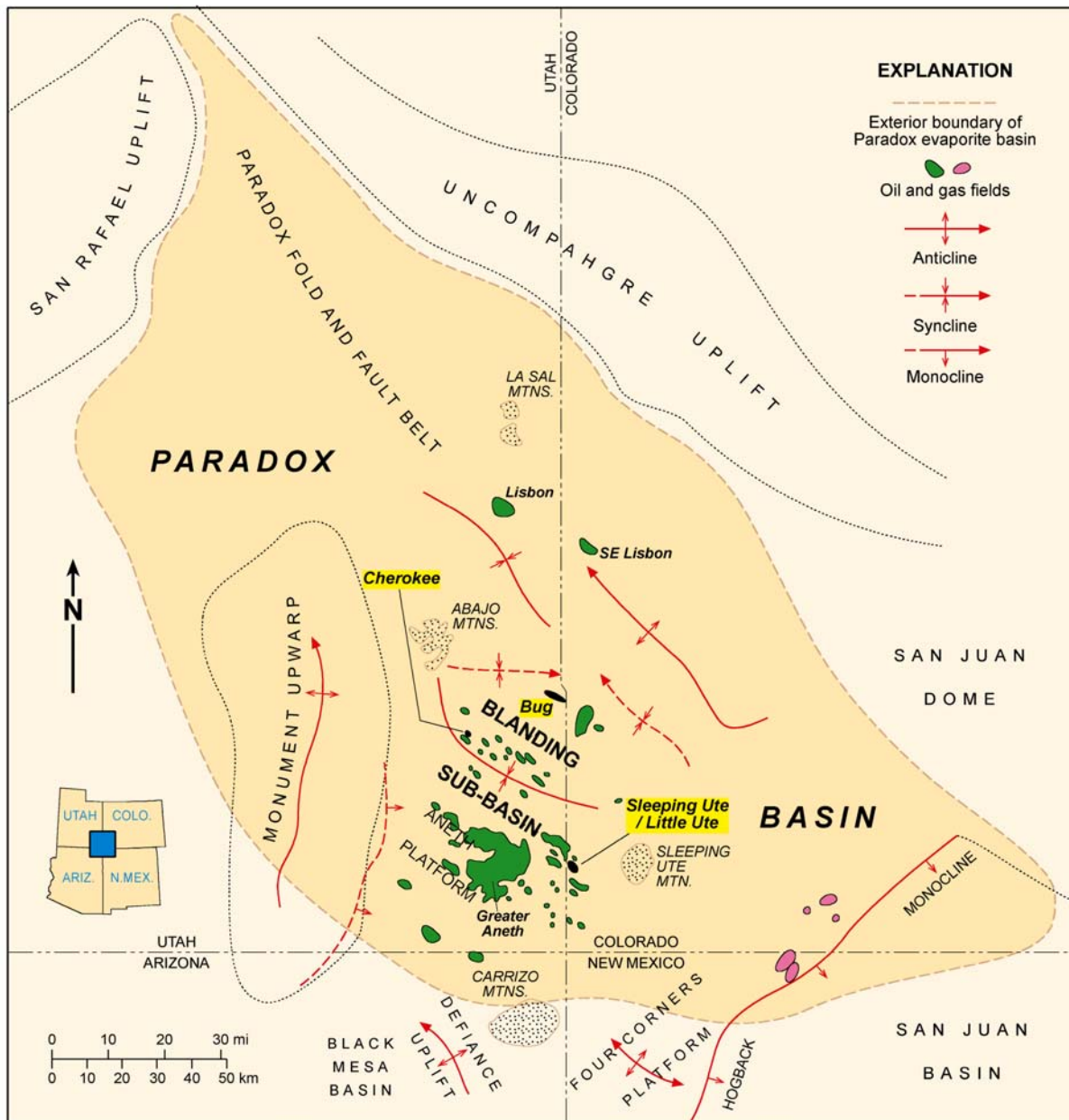


Figure 1. Location map of the Paradox Basin, Utah, Colorado, Arizona, and New Mexico showing producing oil and gas fields, the Paradox fold and fault belt, and Blanding sub-basin as well as surrounding Laramide basins and uplifts (modified from Harr, 1996).

The Paradox Basin can generally be divided into two areas: the Paradox fold and fault belt in the north, and the Blanding sub-basin in the south-southwest (figure 1). Most oil production comes from the Blanding sub-basin. The source of the oil is several black, organic-rich shales within the Paradox Formation (Hite and others, 1984; Nuccio and Condon, 1996). The relatively undeformed Blanding sub-basin developed on a shallow-marine shelf which locally contained algal-mound and other carbonate buildups in a subtropical climate.

The two main producing zones of the Paradox Formation are informally named the Ismay and the Desert Creek (figure 2). The Ismay zone is dominantly limestone comprising equant buildups of phylloid-algal material with locally variable small-scale subfacies (figure 3A) and capped by anhydrite. The Ismay produces oil from fields in the southern Blanding sub-basin (figure 4). The Desert Creek zone is dominantly dolomite comprising regional nearshore shoreline trends with highly aligned, linear facies tracts (figure 3B). The Desert Creek produces oil in fields in the central Blanding sub-basin (figure 4). Both the Ismay and Desert Creek buildups generally trend northwest-southeast. Various facies changes and extensive diagenesis have created complex reservoir heterogeneity within these two diverse zones.

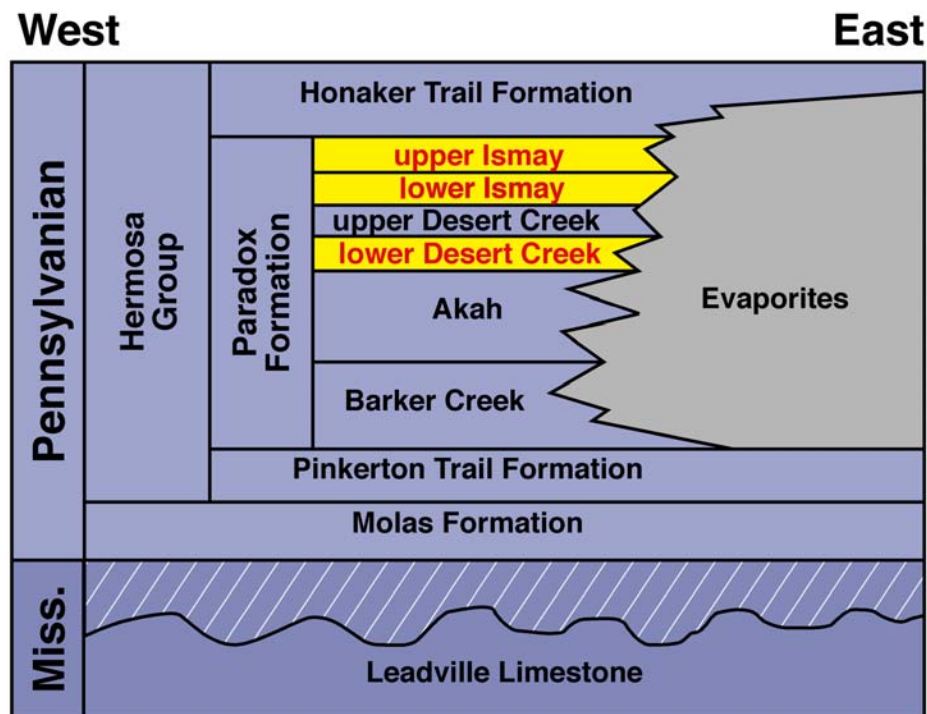


Figure 2. Pennsylvanian stratigraphy of the southern Paradox Basin including informal zones of the Paradox Formation; the Ismay and Desert Creek zones productive in the case-study fields described in this report are highlighted.

CASE-STUDY FIELDS

Two Utah fields were selected for local-scale evaluation and geological characterization: Cherokee in the Ismay trend and Bug in the Desert Creek trend (figure 4). Two Colorado fields are also selected for evaluation: Little Ute and Sleeping Ute in the Ismay trend (figure 4). This evaluation included data collection, plots of petrophysical data (core-plug porosity and permeability), and core descriptions of these fields as summarized in this report.

This geological characterization focused on reservoir heterogeneity, quality, and lateral continuity, as well as possible compartmentalization within the fields. From these evaluations, untested or under-produced compartments can be identified as targets for horizontal drilling. The models resulting from the geological and reservoir characterization of these fields can be applied to similar fields in the basin (and other basins as well) where data might be limited.

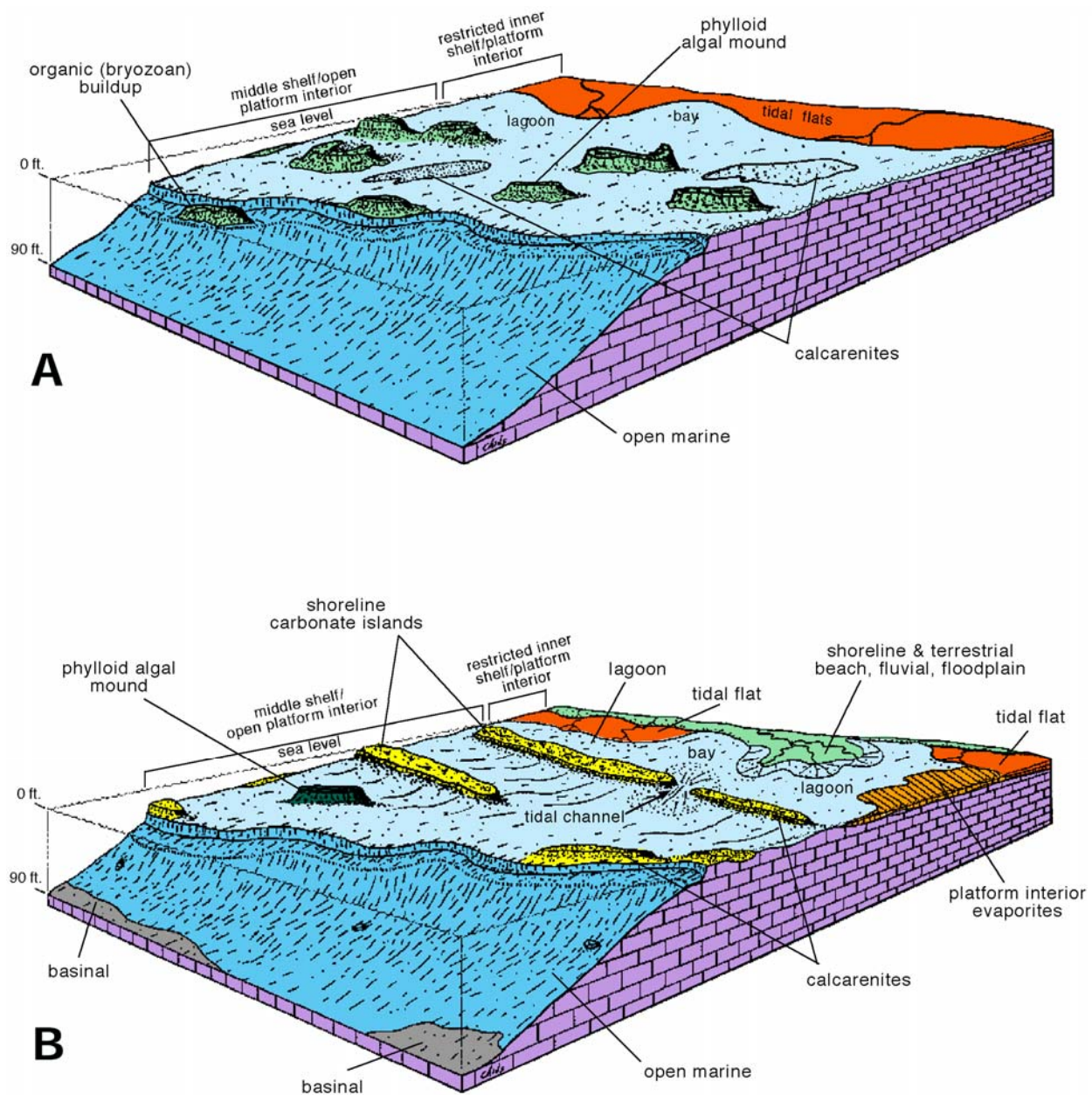


Figure 3. Block diagrams displaying major depositional facies, as determined from core, for the Ismay (A) and Desert Creek (B) zones, Pennsylvanian Paradox Formation, Utah and Colorado.

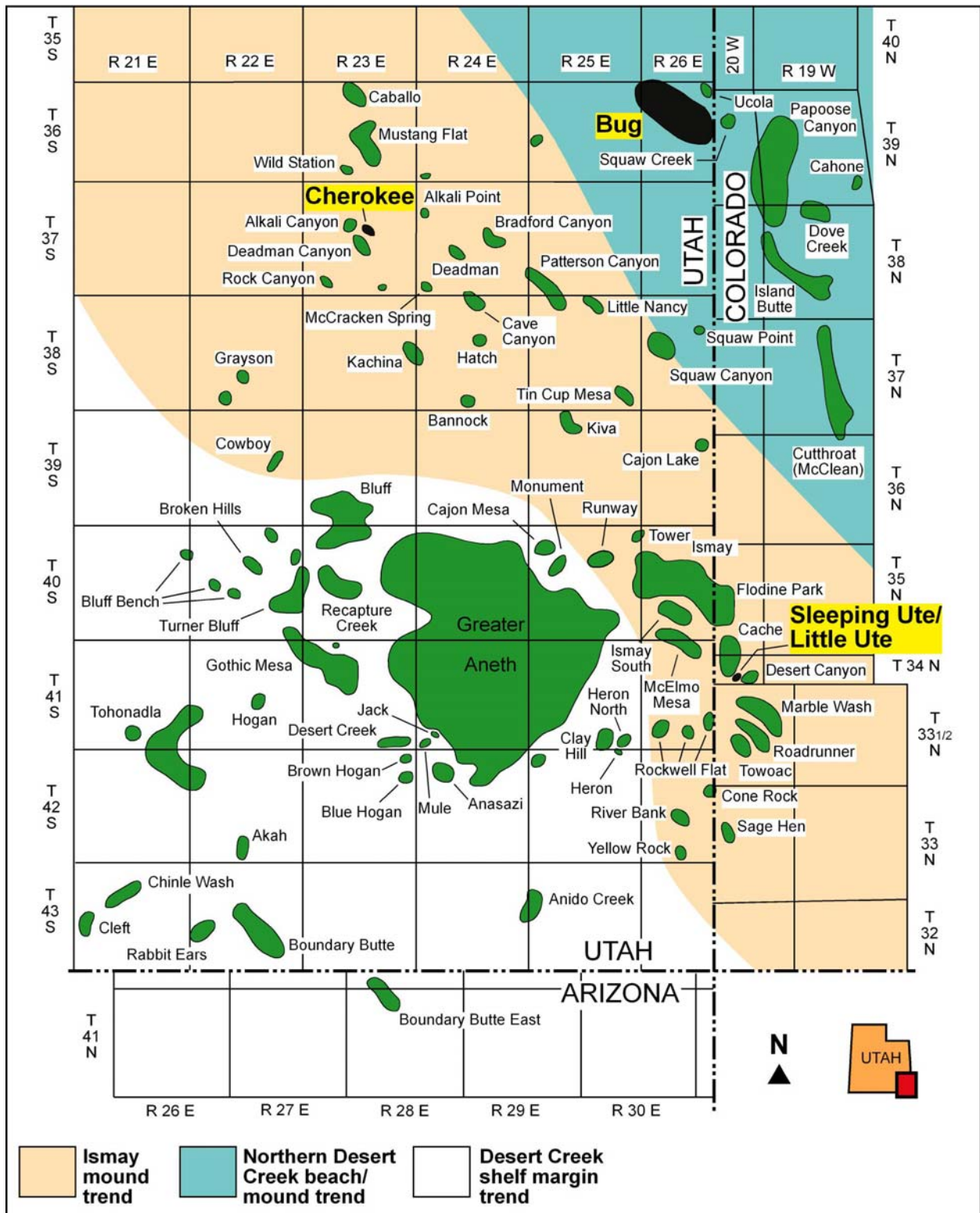


Figure 4. Map showing the project study area and fields (case-study fields in black) within the Ismay and Desert Creek producing trends in the Blanding sub-basin, Utah and Colorado.

Cherokee Field

Cherokee field (figure 4) is a phylloid-algal buildup capped by anhydrite that produces from porous algal limestone and dolomite in the upper Ismay zone. The net reservoir thickness is 27 feet (8.2 m), which extends over a 320-acre (130 ha) area. Porosity averages 12 percent with 8 millidarcies (md) of permeability in vuggy and intercrystalline pore systems. Water saturation is 38.1 percent (Crawley-Stewart and Riley, 1993).

Cherokee field was discovered in 1987 with the completion of the Meridian Oil Company Cherokee Federal 11-14, NE1/4NW1/4 section 14, T. 37 S., R. 23 E., Salt Lake Base Line and Meridian (SLBL&M); initial potential flow (IPF) was 53 barrels of oil per day (BOPD) (8.4 m³), 990 thousand cubic feet of gas per day (MCFGPD) (28 MCMPD), and 26 barrels of water (4.1 m³). There are currently four producing (or shut-in) wells and two dry holes in the field. The well spacing is 80 acres (32 ha). The present field reservoir pressure is estimated at 150 pounds per square inch (psi) (1,034 Kpa). Cumulative production as of June 1, 2003, was 182,071 barrels of oil (28,949 m³), 3.65 billion cubic feet of gas (BCFG) (0.1 BCMG), and 3,358 barrels of water (534 m³) (Utah Division of Oil, Gas and Mining, 2003). The original estimated primary recovery is 172,000 barrels of oil (27,348 m³) and 3.28 BCFG (0.09 BCMG) (Crawley-Stewart and Riley, 1993). The fact that both these estimates have been surpassed suggests significant additional reserves could remain.

Bug Field

Bug field (figure 4) is an elongate, northwest-trending carbonate buildup in the lower Desert Creek zone. The producing units vary from porous dolomitized bafflestone to packstone and wackestone. The trapping mechanism is an updip porosity pinchout. The net reservoir thickness is 15 feet (4.6 m) over a 2,600-acre (1,052 ha) area. Porosity averages 11 percent in moldic, vuggy, and intercrystalline networks. Permeability averages 25 to 30 md, but ranges from less than 1 to 500 md. Water saturation is 32 percent (Martin, 1983; Oline, 1996).

Bug field was discovered in 1980 with the completion of the Wexpro Bug No. 1, NE1/SE1/4 section 12, T. 36 S., R. 25 E., SLBL&M, for an IPF of 608 BOPD (96.7 m³), 1,128 MCFGPD (32 MCMPD), and 180 barrels of water (28.6 m³). There are currently eight producing (or shut-in) wells, five abandoned producers, and two dry holes in the field. The well spacing is 160 acres (65 ha). The present reservoir field pressure is 3,550 psi (24,477 Kpa). Cumulative production as of June 1, 2003, was 1,622,2020 barrels of oil (257,901 m³), 4.47 BCFG (0.13 BCMG), and 3,181,448 barrels of water (505,850 m³) (Utah Division of Oil, Gas and Mining, 2003). Estimated primary recovery is 1,600,000 bbls (254,400 m³) of oil and 4 BCFG (0.1 BCMG) (Oline, 1996). Again, since the original reserve estimates have been surpassed and the field is still producing, significant additional reserves likely remain.

Little Ute and Sleeping Ute Fields

Little Ute and Sleeping Ute fields are located in Montezuma County, Colorado (sections 3, 10, and 11, T. 34 N., R. 20 W. (figure 4). The producing reservoirs consist of phylloid-algal buildups in the Ismay zone flanked by bryozoan mounds and mound flank debris. These porous mounds, capped by impermeable anhydritic dolomite, produce primarily from porous phylloid-

algal limestones, some of which have been dolomitized. The net reservoir thickness is 30 feet (9.1 m), which extends over approximately 640 acres (260 ha). Porosity ranges from 4 to 20 percent with 1 to 98 millidarcies (md) of permeability in vuggy and intercrystalline pore systems.

The first well drilled in the Little Ute/ Sleeping Ute study area was a dry hole, completed in 1959. The Calvert Drilling Company Desert Canyon No. 1 was drilled in the SW/4 of section 10, T. 34 N., R. 20 W., to a total depth of 5,938 feet (1,810 m) to the Gothic shale as a test of the Ismay and Desert Creek zones of the Paradox Formation. The well was plugged and abandoned on September 29, 1959, after a drill-stem test and four cores were taken in the Ismay and Desert Creek. The results of the drill-stem test, taken over the interval of 5,697 to 5,840 feet (1,736-1,780 m), were discouraging in that there was a very weak blow of air to the surface that died in 5 minutes and only 55 feet (17 m) of drilling mud was recovered. Somewhat more encouraging were the cores taken from 5,675 to 5,739 feet (1,730-1,749 m), 5,729 to 5,782 feet (1,746-1,762 m), 5,782 to 5,820 feet (1,762-1,774 m), and 5,880 to 5,938 feet (1,792-1,819 m). Over that entire interval, there were favorable reports of petroliferous odor, visible vuggy and intercrystalline porosity, and bleeding oil.

There are currently three producing wells and three dry holes in the Little Ute and Sleeping Ute study area proper. Well spacing is 80 acres (32 ha). The net reservoir thickness is 20 feet (6 m) over a 240-acre (97 ha) area. Porosity averages 15 percent and permeability is 0.01 to 2 md. Water saturation is 50 percent (Ghazal, 1978). Cumulative production from these three wells, plus the Desert Canyon No. 3 well that defined the Desert Canyon field, exceeds 325,000 barrels (51,675 m³) of oil and 750 million cubic feet (21 million m³) of gas.

FIELD DATA COLLECTION AND CORE DESCRIPTIONS

Reservoir data, cores and cuttings, geophysical logs, various reservoir maps, and other information from the project fields and regional exploratory wells were collected by the Utah Geological Survey (UGS) and Colorado Geological Survey (CGS). Well locations, production data, completion tests, basic core analysis, formation tops, porosity and permeability data, and other data were compiled and entered in a database developed by the UGS. This database, INTEGRAL, is a geologic-information database that links a diverse set of geologic data to records using MS AccessTM. The database is designed so that geological information, such as lithology, petrophysical analyses, or depositional environment, can be exported to software programs to produce strip logs, lithofacies maps, various graphs, statistical models, and other types of presentations.

All available conventional cores from the case-study fields (table 1) were photographed (see compact disk) and described (figures 5 through 16). Special emphasis was placed on identifying the flow unit's bounding surfaces and depositional environments. The core descriptions follow the guidelines of Bebout and Loucks (1984) which include: (1) basic porosity types; (2) mineral composition in percentage; (3) nature of contacts; (4) carbonate structures; (5) carbonate textures in percentage; (6) carbonate fabrics; (7) grain size (dolomite); (8) fractures; (9) color; (10) fossils; (11) cement; and (12) depositional environment. Carbonate fabrics were determined according to Dunham's (1962) and Embry and Klovan's (1971) classification schemes.

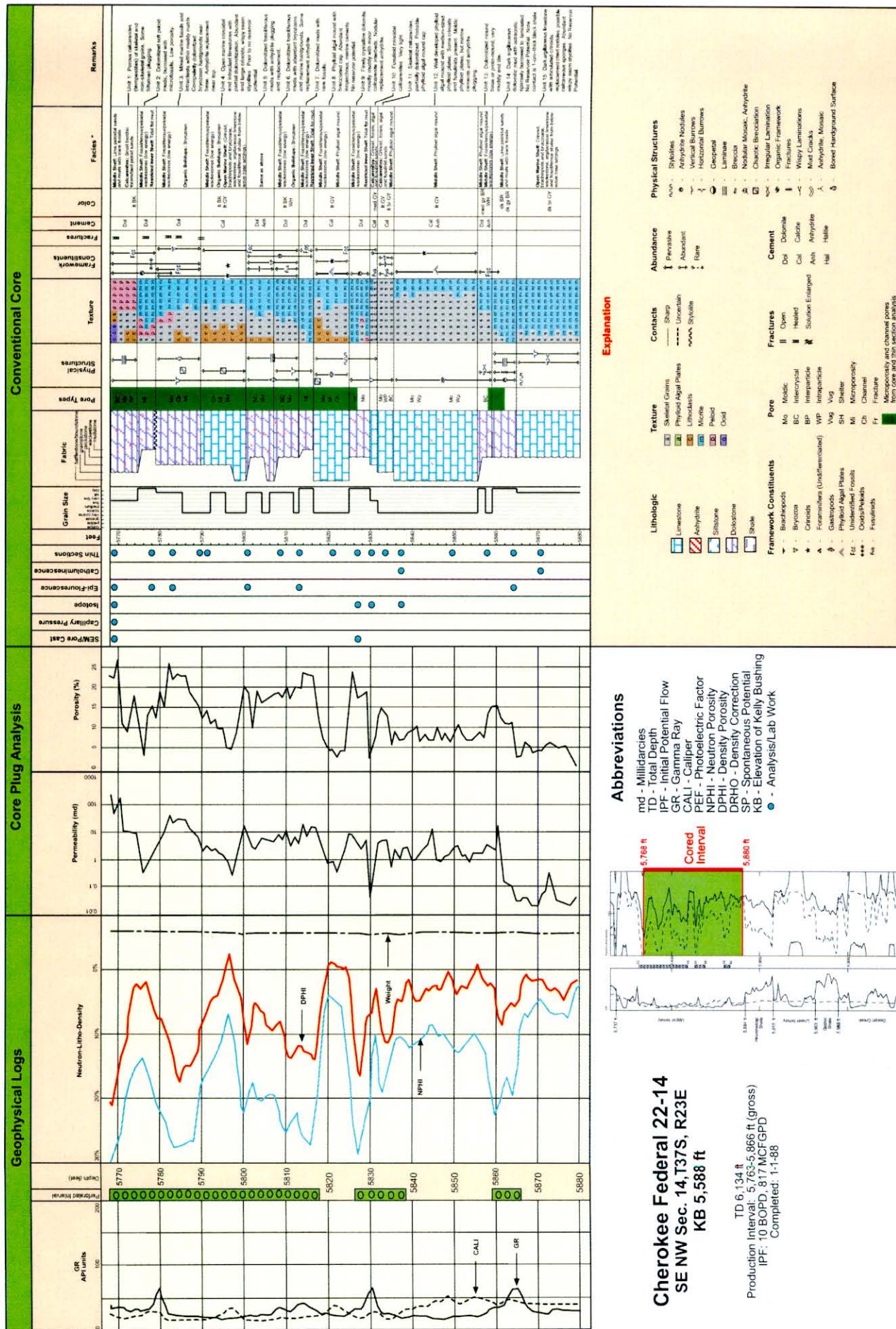


Figure 5. Cherokee Federal 22-14 geophysical well log, porosity/permeability plot, and core description (upper Ismay zone).

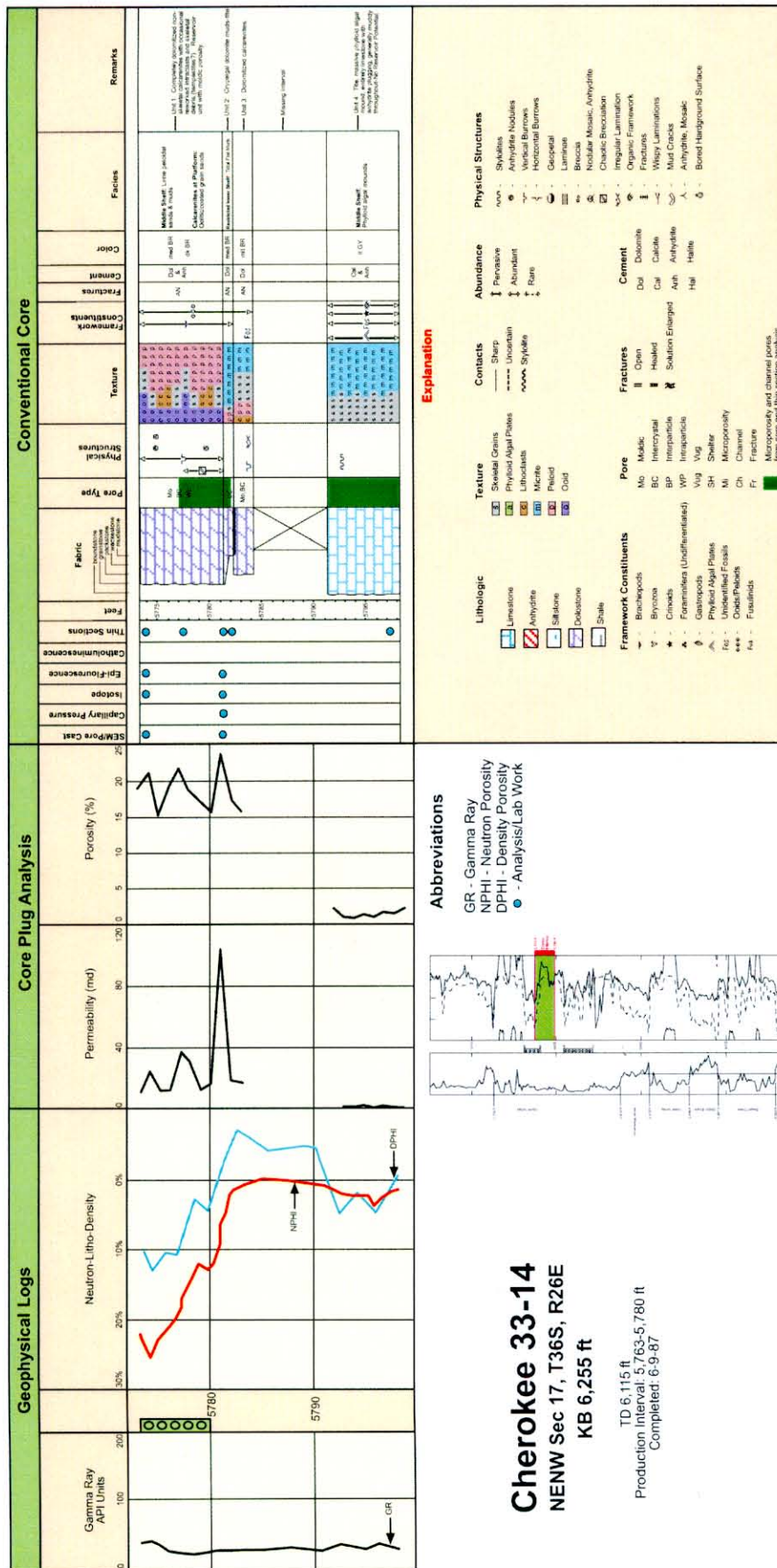


Figure 6. Cherokee Federal 33-14 geophysical well log, porosity/permeability plot, and core description (upper Ismay zone).

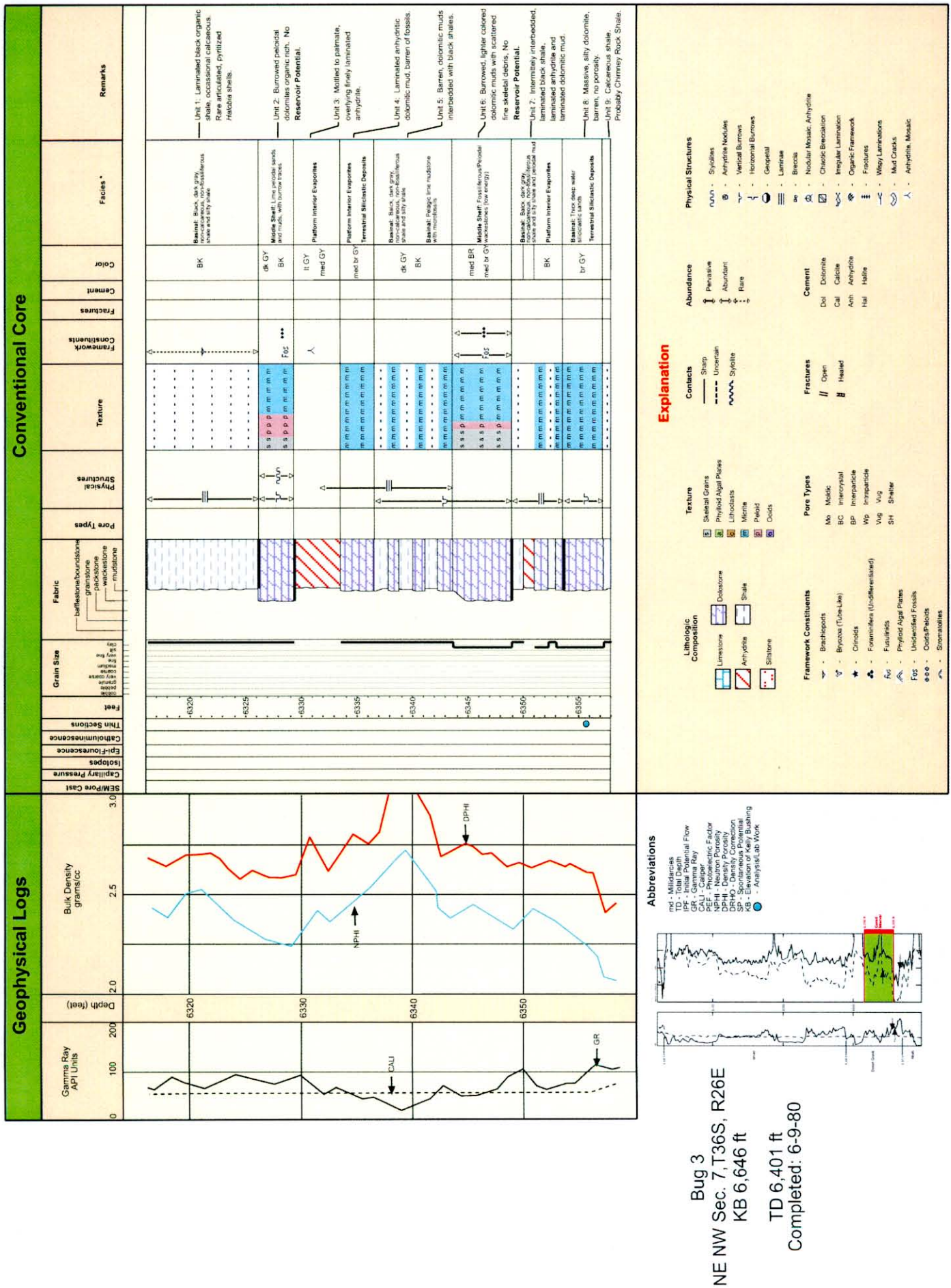


Figure 8. Bug 3 geophysical well log, porosity/permeability plot, and core description (Desert Creek).

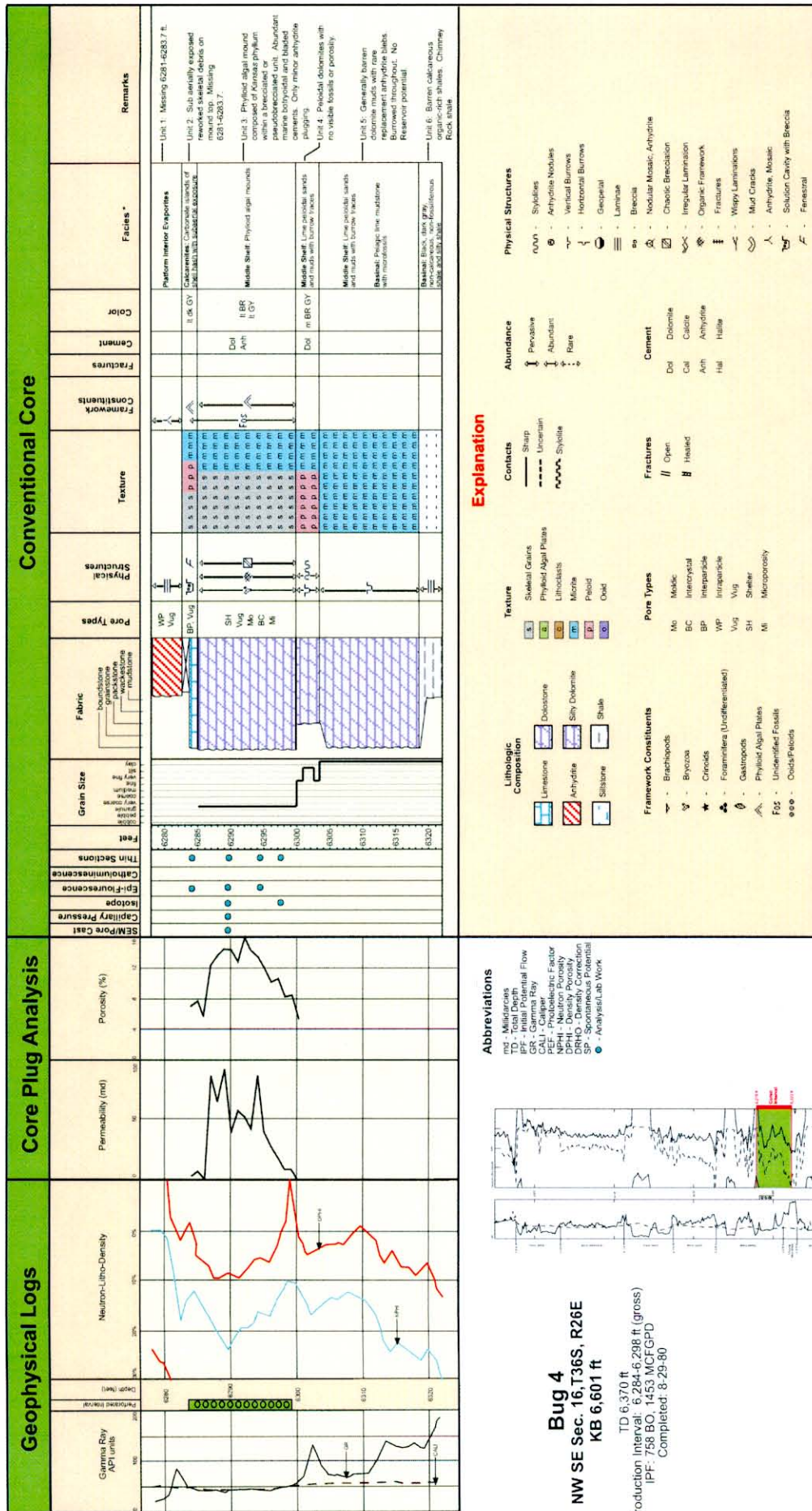


Figure 9. Bug 4 geophysical well log, porosity/permeability plot, and core description (Desert Creek).

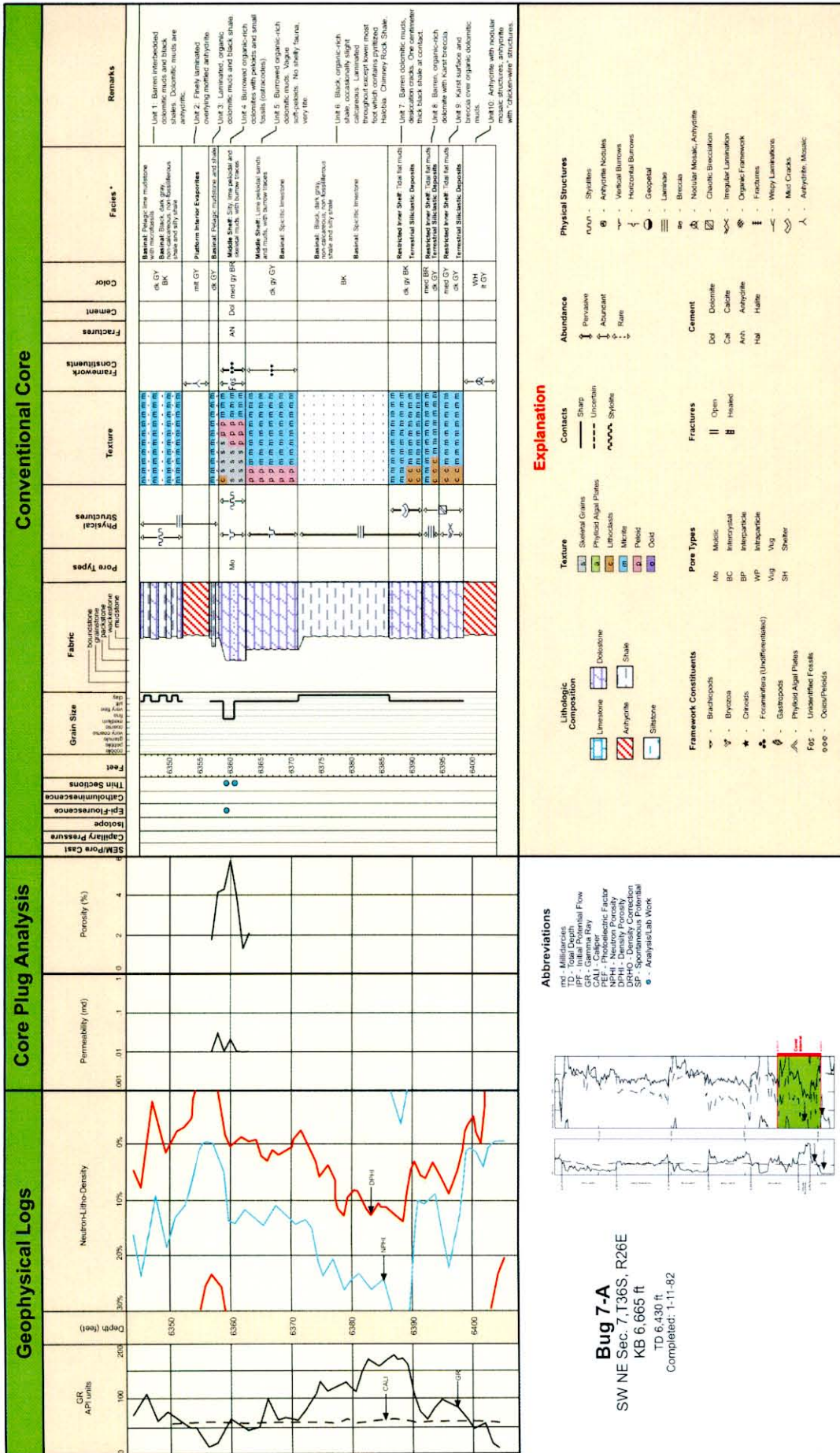


Figure 10. Bug 7-A geophysical well log, porosity/permeability plot, and core description (Desert Creek).

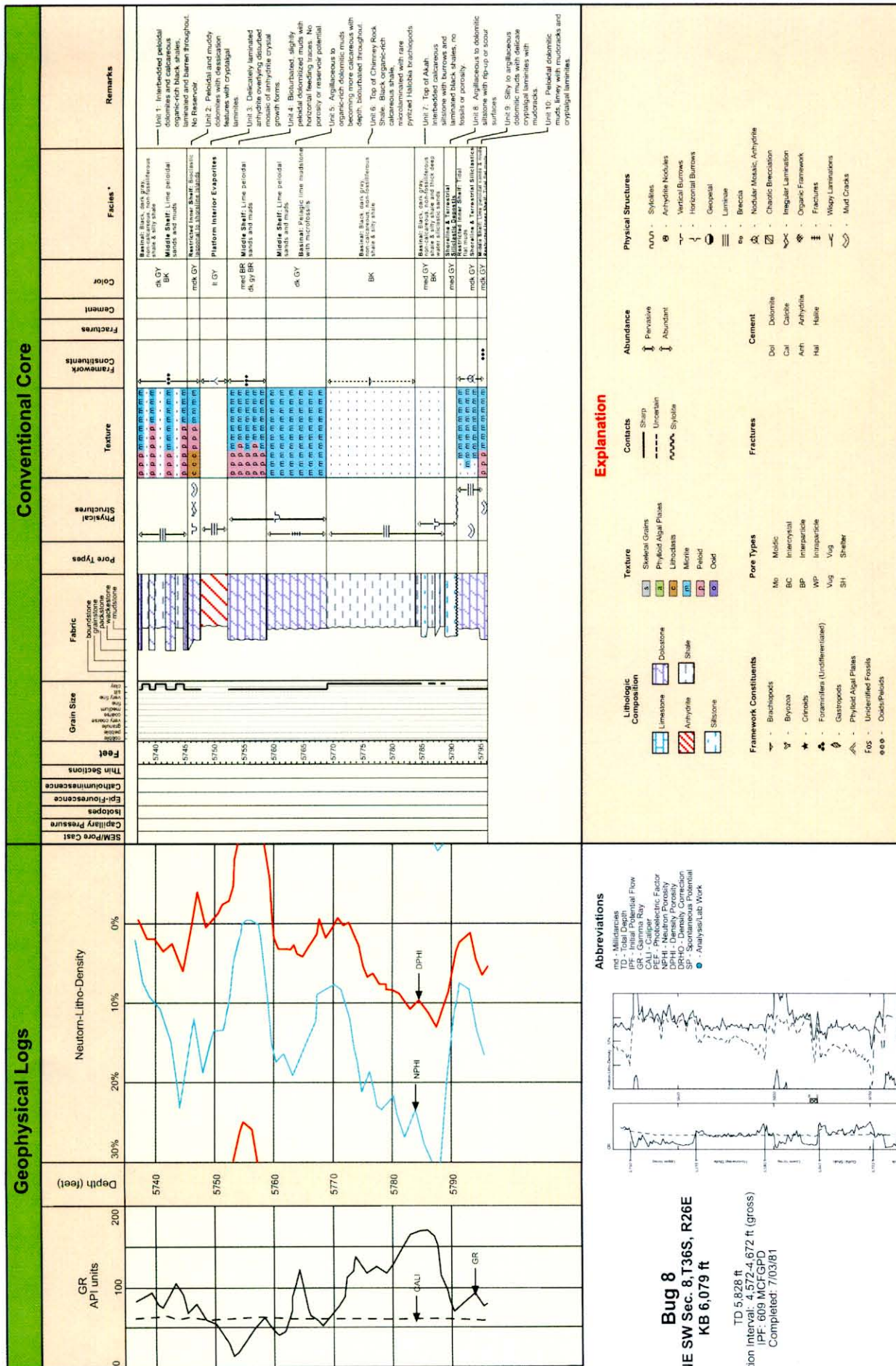
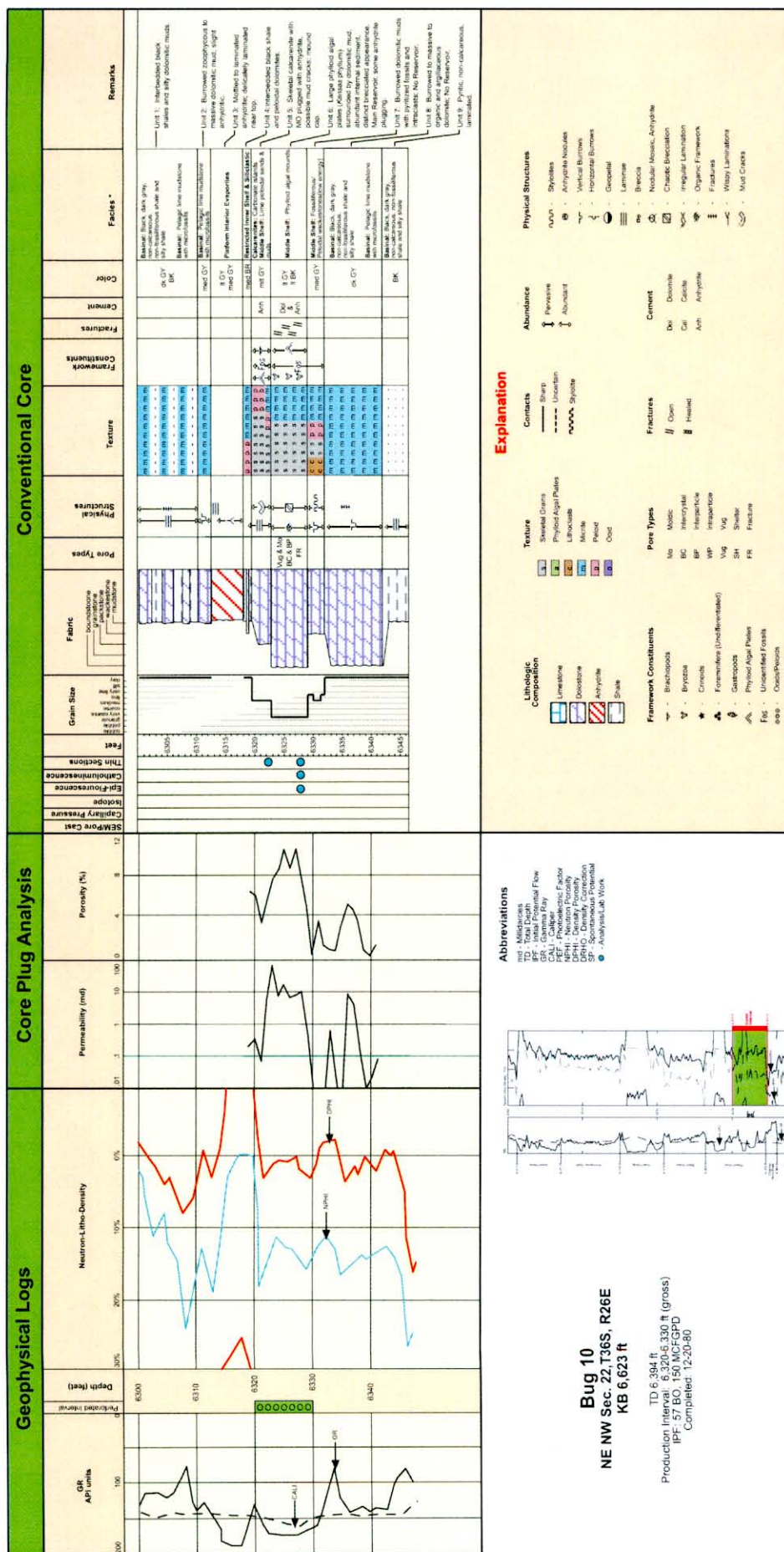


Figure 11. Bug 8 geophysical well log, porosity/permeability plot, and core description (Desert Creek).



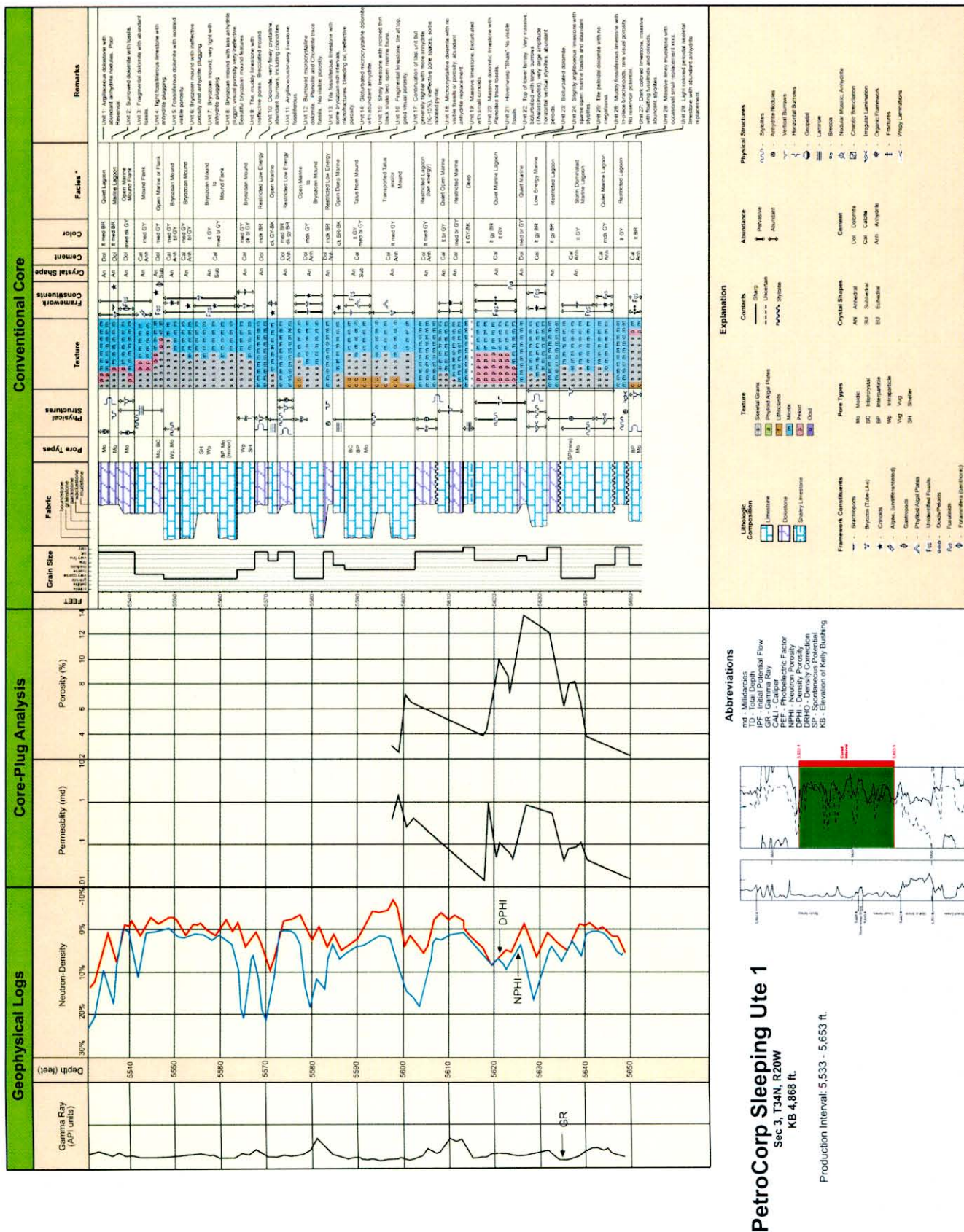


Figure 16. Sleeping Ute 1 geophysical well log, porosity/permeability plot, and core description (Ismay).

Table 1. List of well conventional slabbed core examined and described from project fields in the Paradox Basin of Utah and Colorado.

Well	Location	API No.	Cored Interval (ft)	Field	Stratigraphic Zone	Repository
Cherokee 22-14	14-37S-23E, UT	43-037-31367	5768-5880	Cherokee	Ismay	UGS
Cherokee 33-14	14-37S-23E, UT	43-037-31316	5770-5799	Cherokee	Ismay	UGS
May-Bug 2	7-36S-26E, UT	43-037-30543	6290-6333	Bug	Desert Creek	UGS
Bug 3	7-36S-26E, UT	43-037-30544	6316-6358	Bug	Desert Creek	UGS
Bug 4	16-36S-26E, UT	43-037-30542	6278-6322	Bug	Desert Creek	UGS
Bug 7A	7-36S-26E, UT	43-037-30730	6345-6400	Bug	Desert Creek	UGS
Bug 8	8-36S-26E, UT	43-037-30589	5737-5796.1	Bug	Desert Creek	UGS
Bug 10	22-36S-26E, UT	43-037-30591	6300-6346.5	Bug	Desert Creek	UGS
Bug 13	17-36S-26E, UT	43-037-30610	5913-5951.3	Bug	Desert Creek	UGS
Bug 16	17-36S-26E, UT	43-037-30607	6278-6333	Bug	Desert Creek	UGS
Little Ute 1	11-34N-20W, CO	05-083-06553	5836-5955.3	Little Ute	Ismay	TOS
Sleeping Ute 1	3-34N-20W, CO	05-083-06540	5533-5653	Sleeping Ute	Ismay	TOS

* UGS = Utah Geological Survey, Salt Lake City, Utah; TOS = Triple O Slabbing, Denver, Colorado

Geological characterization on a local scale focused on reservoir heterogeneity, quality, and lateral continuity as well as possible compartmentalization within case-study fields. This utilized representative core and modern geophysical well logs to characterize and initially grade various intervals in the fields for horizontal drilling suitability.

The typical vertical sequence or cycle of lithofacies from the case-study fields, as determined from conventional core, was tied to its corresponding log response (figures 5 through 16). These sequences graphically include: (1) carbonate fabric, pore type, physical structures, texture, framework grain, and facies described from core; (2) plotted porosity and permeability analysis from core plugs; and (3) gamma-ray and neutron-density curves from geophysical well logs. The graphs can be used for identifying reservoir and non-reservoir rock, determining potential units suitable for horizontal drilling projects, and comparing field to non-field areas.

ACKNOWLEDGMENTS

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