Sedimentary Facies and Reservoir Characteristics of the Nugget Sandstone (Jurassic), Painter Reservoir Field, Uinta County, Wyoming[1]

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Painter Reservoir Field is one of a number of fields producing from the Jurassic Nugget Sandstone in the Thrust Belt Province of southwest Wyoming and northeast Utah. The field is an asymmetric anticlinal structure located on the hanging wall near the leading edge of the Absaroka Thrust Plate. Original oil in-place (OIP) is estimated to be 138,000,000 barrels. Painter Reservoir Field has produced over 30,000,000 BO since its discovery in 1977.

The Nugget Sandstone is a stratigraphically complex and heterogeneous unit deposited primarily by eolian processes in an extensive sand sea. Dune and interdune/sand sheet facies have been identified during studies of over 5,000 ft (1,500 m) of core from 13 Painter Reservoir wells. The dune foreset facies is the best reservoir rock and consists of dipping avalanche and wind-ripple strata. The interdune facies has the poorest reservoir quality and consists of flat-lying wind-ripple strata, with zones of bioturbation and wavy lamination. The dune facies comprises approximately 75% of the cores examined, and the interdune facies approximately 25%. A high degree of heterogeneity results from variations in grain size, sorting, mineralogy, and thickness between cross strata. Porosity ranges from 1.5 to 21.5%. Air permeability measured on core plugs ranges from hundredths to thousands of millidarcies.

Nugget reservoir characteristics are strongly influenced by depositional environment. Porosity and permeability variations between facies and their arrangement in stacked vertical sequences result in stratigraphic layering of the reservoir. Consistent Nugget dune orientations result in directional permeability trends. The maximum permeability direction is parallel to dune slipfaces, which trend northwest to southeast. However, facies discontinuity, fracturing, and faulting offset permeability trends in parts of the field. The stratigraphic layering and directional permeability of the Nugget Sandstone are reflected in Painter Reservoir field history.

INTRODUCTION

Painter Reservoir Field is located in the Fossil Basin of southwest Wyoming, and is one of a series of fields on the hanging wall of the Absaroka Thrust Plate in the Thrust Belt Province (Fig. 1). Hydrocarbon production is from the Jurassic Nugget Sandstone, the principal reservoir for several fields located along the trend. The hydrocarbons were generated in Cretaceous source rocks in the footwall of the Absaroka Thrust (Warner, 1980). The Painter structure was first mapped with geophysical data and was confirmed in 1977 by the drilling of the discovery well, PRU 22-6A. Painter Reservoir Field is operated by Chevron USA with other working interests owned by Amoco Production Company and Union Pacific Resources. The field was developed on 40-acre (16 ha) spacing. Nitrogen and produced hydrocarbon gas were injected to balance withdrawals and to maintain reservoir pressure, until a tertiary recovery program was initiated in January, 1983. The tertiary program utilized nitrogen injection to increase reservoir pressure, and to cause miscible displacement of oil by gas-cap fluids. Initial response to the program was good; production peaked in 1983 at 14,000 BOPD. However, reservoir pressure was reduced in 1987 due to premature nitrogen breakthrough and increasing gas/oil ratios (GOR's). The current pressure-maintenance program once again utilizes nitrogen and produced hydrocarbon gas.

STRUCTURE

Painter Reservoir Field is trapped by a northeast-trending, doubly-plunging, asymmetric anticline located on the hanging wall near the leading edge of

FIELD DATA:	Painter Reservoir Field
Producing Interval:	Nugget Sandstone
Geographic Location:	Uinta County, Wyoming
Present Tectonic Setting:	Utah–Wyoming Thrust Belt
Depositional Setting:	Eolian sand sea just east of a shallow sea (Kocurek and Dott, 1983)
Age of Reservoir:	Jurassic
Lithology of Reservoir:	Very fine to coarse-grained, moderately to well-sorted quartz arenite to subarkosic arenite
Diagenesis:	Compaction; quartz, dolomite, and calcite cements; grain-coating and pore-bridging illite; fracturing
Porosity Types:	Intergranular, rare secondary porosity
Porosity:	1) dune maximum 21.5%, average 13.6%, 2) interdune/sand sheet maximum 18.0, average 9.7%
Permeability:	1) dune maximum 1,450 md, arithmetic average 16.5 md; 2) interdune/sand sheet maximum 120 md, arithmetic average 1.5 md
Fractures:	Abundant fractures
Nature of Trap:	Structural
Entrapping Facies:	Gypsum Springs anhydrite member of Twin Creek Limestone
Source Rocks:	Subthrust Cretaceous shales
Timing of Hydrocarbon Migration:	Eocene or later (60 Ma or less)
Discovered:	1977
Reservoir Depth:	9,500–10,200 ft (2,850–3,060 m)
Reservoir Thickness:	850–950 ft (255–285 m)
IP (discovery well):	410 BOPD, 859 MCFGPD
Areal Extent:	About 1,700 acres (688 ha); 3.5 by 1 mi (5.6 by 1.6 km)
Original Reservoir Pressure:	4,130 psi
Cumulative Production (1/89):	30,900,000 BO, 274 BCFG
Estimated Oil in Place:	138,000,000 BO, 502 BCFG
Oil Gravity:	45–58° API
Minimum Water Saturation:	Dune 10%, interdune/sand sheet 14%

the Absaroka Thrust (Figs. 2 and 3). The structure has a gently dipping west flank, with a relatively undisturbed stratigraphic section. The east flank is structurally more complicated; wells generally penetrate numerous imbricate splays of the Bridger Hill Thrust and steeply dipping or overturned Nugget Sandstone. The structure has approximately 1,150 ft (345 m) of closure above the oil–water contact.

STRATIGRAPHY

The Nugget Sandstone overlies red beds of the Triassic Ankareh Formation and is unconformably overlain by marine limestones, anhydrites, and shales of the Middle Jurassic Twin Creek Formation (Fig. 4; Jordan, 1965; Picard, 1975; Fox, 1979). The Gypsum Springs Anhydrite, the lowermost member of the Twin Creek, serves as the top seal for the Nugget reservoir. The Twin Creek interval is overlain by clastic rocks of the Stump and Preuss formations. Salt beds up to 200 ft (60 m) thick are common in the lowermost Preuss Formation and serve as a detachment surface for the Bridger Hill Thrust. The nonmarine Lower Cretaceous Gannett and Bear River units unconformably overlie the Stump interval and are, in turn, separated from the Cretaceous–Paleocene Evanston Formation by an angular unconformity (Lamb, 1980). The Tertiary (Eocene) Wasatch Formation is present at the surface and is separated from the Evanston Formation by another unconformity (Lamb, 1980; Frank, et al., 1982). Although the Nugget Sandstone is currently the only productive unit in the field, oil and/or gas shows have been encountered in the Thaynes Formation, various Twin Creek members, and the lowermost Ephraim Conglomerate Member of the Gannett Formation.

The Nugget Sandstone is areally extensive and was deposited primarily by eolian processes in a coastal to inland sand sea or erg (Hunter, 1981; Kocurek and Dott, 1983; Lindquist 1983, 1988). It extends from south-central and southwestern Wyoming to southeastern Idaho and northern Utah, increasing in thickness from less than 100 ft to over 2,000 ft (30–600 m) from east to west (Jordan, 1965). Nugget rocks are stratigraphically equivalent to the Navajo Sandstone of Colorado, Utah, and Arizona, and to the Aztec Sandstone of southern Nevada (Jordan, 1965; Doelger, 1981; Marzolf, 1982; Kocurek and Dott, 1983). The Nugget type section is located near Nugget Station on the Oregon Shortline Railroad 15 mi (24 km) west of Kemmerer, Wyoming (Veatch, 1907). The section is poorly exposed and small, as are most Nugget Sandstone outcrops in southwestern Wyoming near the producing trend. The best outcrops of sandstones comparable to those at Painter Reservoir Field Navajo sandstone are found along the south flank of the Uinta Mountains.

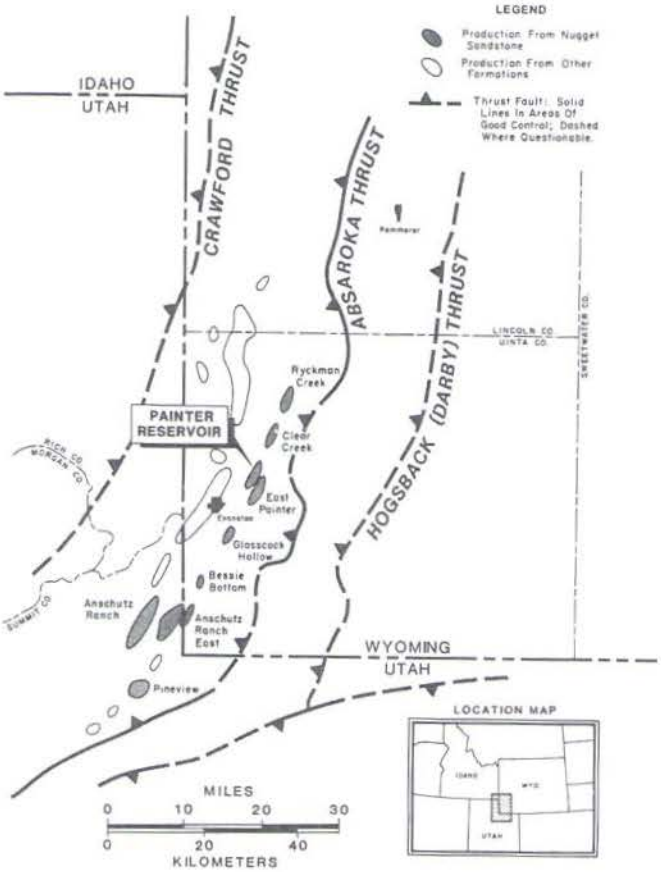


Figure 1. Location map of southwest Wyoming showing Thrust Belt fields and trends of major thrust faults (after Royse and Warner, 1987; reprinted with permission of the AAPG).

SEDIMENTARY FACIES

The Nugget Sandstone in Painter Reservoir Field is very fine to coarse grained, moderately to well sorted, and ranges in composition from quartz arenite to subarkosic arenite. Dune and interdune/sand sheet facies similar to those described by Lindquist (1983, 1988) have been identified during studies of over 5,000 ft (1,500 m) of core from 13 Painter Reservoir wells and are described in the following sections. These facies are the product of complex eolian processes occurring in a large sand sea.

Dune Facies

Dune deposits are the most abundant rock type, comprising 75% of the Nugget core examined. The facies is characterized by dipping (up to 25°), laminated to thin-bedded strata ranging in thickness from less than 0.1 in. (0.25 cm) to over 1.0 in. (2.5 cm) (Fig. 5). Individual dunes range in thickness from less than one ft (0.3 m) to almost 50 ft (15 m), and consist of either one set of cross strata formed by the migration of a simple dune, or of multiple cosets formed by the migration of superimposed dunes. Burrow traces locally disrupt stratification of dune deposits in the lower half of the formation.

Cross-strata provide clues to the origin of Nugget dunes. Thicker strata (typically thicker than 0.4 in., or 1.0 cm) are interpreted as grainflow deposits of avalanches on the slipfaces of migrating dunes. Thinner laminae (typically thinner than 0.4 in. or 1.0 cm), are interpreted as translatent strata (Hunter, 1977) formed by the migration of wind ripples across the dune slipfaces. Grainfall deposits have not been identified in cores, possibly due to their poor preservation potential in large dunes; they tend to form in the upper slipface regions, which commonly avalanche and are beveled (Hunter, 1981).

The "avalanche subfacies" consists primarily of avalanche strata, although interbedded wind-ripple laminae usually are present (Fig. 5, Plate 1A). It is the most abundant subfacies, comprising 45% of the Nugget core examined. Bedding is either distinct or indistinct. Flame structures and fadeout laminae are present. Dunesets composed primarily of avalanche strata are thickest and most common in the upper two-thirds of the Nugget Sandstone. Avalanche strata make the best Nugget reservoir. This is due to coarser grain sizes, better sorting, and thicker bedding, which lend better transmissibility to the rocks (Fig. 6).

The "mixed" subfacies, or dune deposits consisting of repetitive interbeds of thin avalanche deposits and wind-ripple laminae, comprises 30% of the Nugget cores. Dunes composed of mixed strata are thickest and most common in the lower half of the Nugget section. Both foreset and toeset deposits are present in this subfacies, but are difficult to differentiate in core. Toeset deposits can be recognized in some sequences by a gradual upward increase in bedding angle, from horizontal interdune laminae below to steeper dipping dune foreset beds above (Fig. 5). Toesets are characterized by concave-upward strata, and by almost tangential contacts with underlying interdune laminae. Characteristic "toeing out" or pinching out of strata also is present in some sequences. Mixed-subfacies dunes have poorer reservoir properties than do avalanche-subfacies dunes. Porosity and permeability are lower, and horizontal/vertical permeability ratios higher, in this subfacies than in the avalanche subfacies (Figs. 6 and 7) because of the greater abundance of finer-grained, poorer-sorted, and thinner wind-ripple strata.

Interdune/Sand Sheet Facies

The interdune/sand sheet facies comprises 25% of the core examined. Individual units range in thickness from less than one ft (0.3 m) to over 30 ft (10 m). The facies is thicker and more common in the lower half of the Nugget. Two subfacies are recognized. The "dry" interdune subfacies comprises 20% of cores examined. It is characterized by moderate sorting and horizontal lamination typically less than 0.4 in. (1 cm) thick (Fig. 5, Plate 1B). Preserved ripple forms can be identified locally. These rocks are interpreted as translatent strata formed by the migration of wind ripples across a relatively dry interdune or sand sheet environment. Reservoir quality is poorer in the dry interdune/sand sheet subfacies than in the dune facies (Figs. 6 and 7) due to finer grain sizes, poorer sorting, and thinner strata; higher hori-

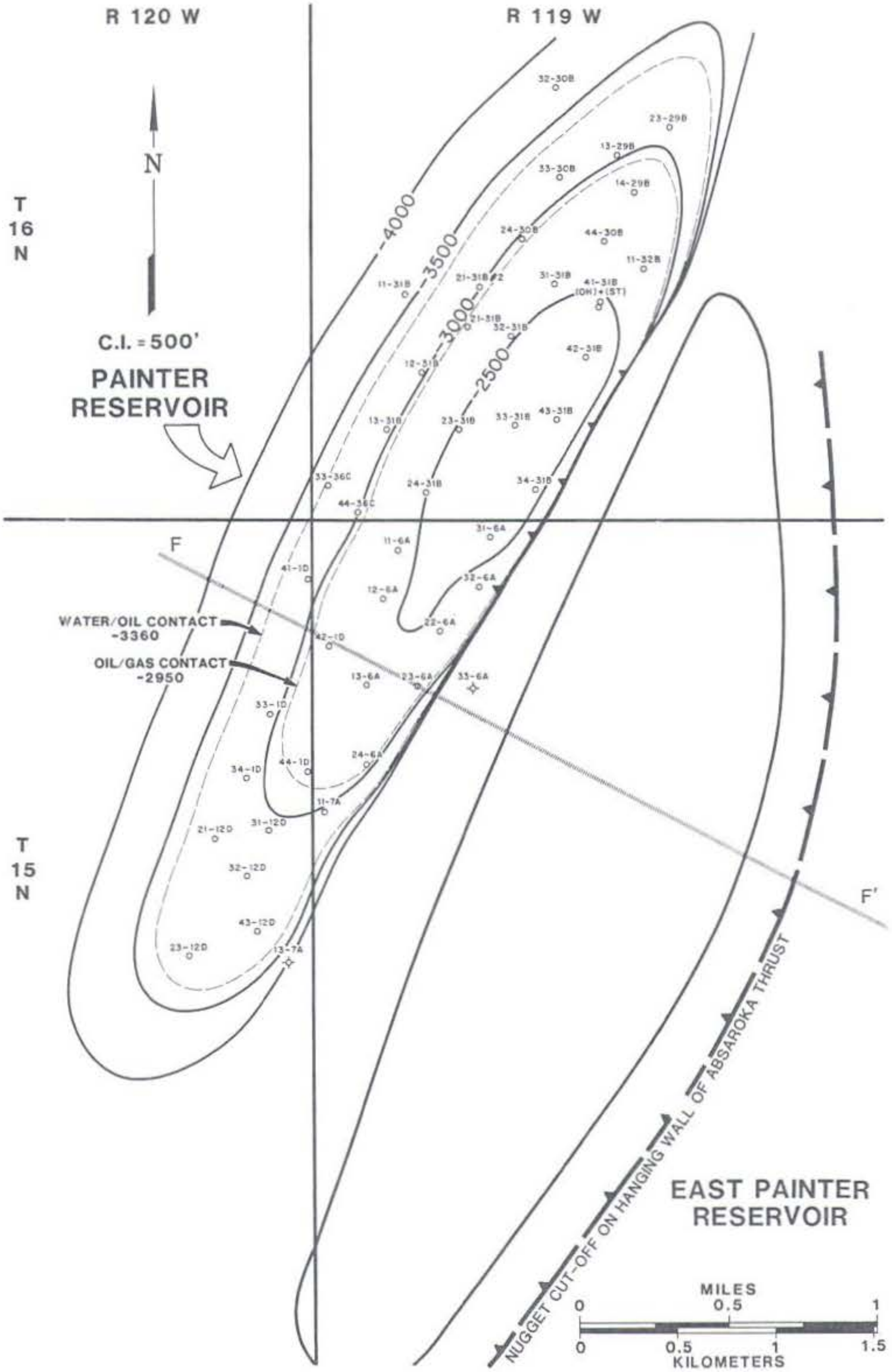


Figure 2. Structure contour map on the top of the Nugget Sandstone, Painter Reservoir Field. Datum is sea level. The location of East Painter Reservoir Field is outlined.

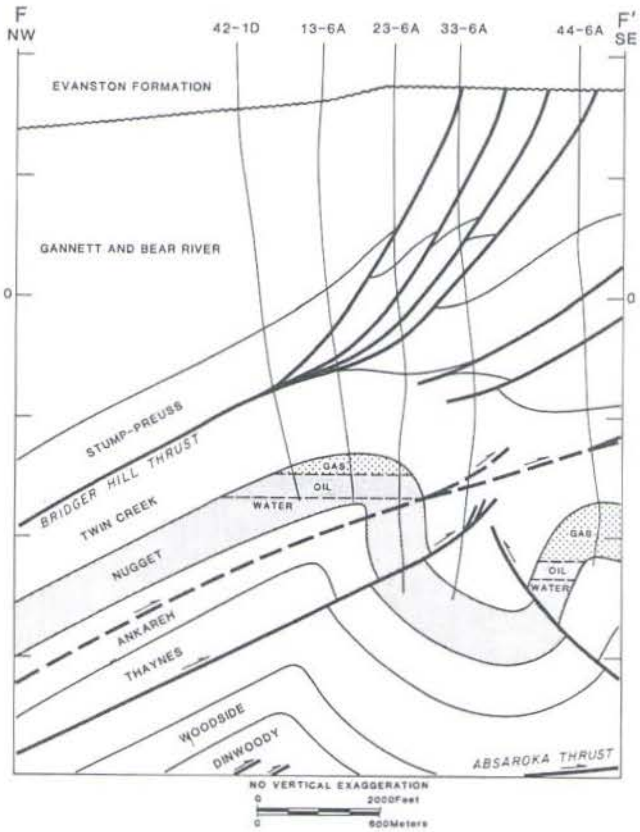


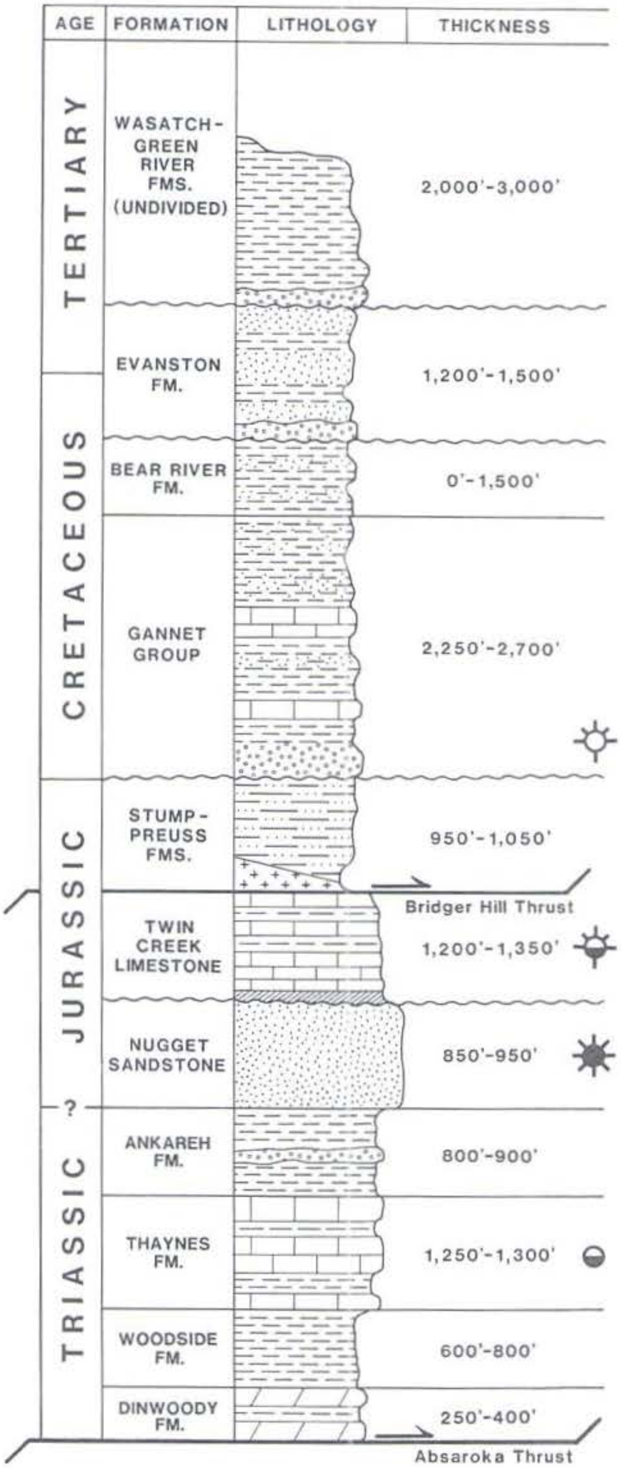
Figure 3. Northwest-southeast cross section F-F' across Painter Reservoir Field, interpreted by T. A. Heffner, 1984, and revised by R.L. O'Neill, 1988. Line of section is shown in Figure 2.

zontal permeabilities in rocks of this subfacies are associated with thicker laminae and coarser grain sizes. The horizontal/vertical permeability ratio is highest in this subfacies because of the thin and texturally variable strata.

The "damp" interdune subfacies composes 5% of cores examined. It is identified by burrowed, mottled, wavy, and/or contorted wind-ripple laminae (Plate 1C). These structures are inferred to result from a damp environment, as moisture in the sediment tends to stimulate organic activity and to reduce the competency of the sand (Ahlbrandt and Fryberger, 1981; Kocurek, 1981). The damp interdune facies is most common in the lower half of the Nugget Sandstone. Rocks of damp-interdune origin have the poorest reservoir properties of any Nugget facies (Figs. 6 and 7), because of the tendency for finer grains to become trapped in a moist environment (Ahlbrandt and Fryberger, 1981). The ratio of horizontal to vertical permeability is lowest in this facies because of bioturbation.

DIAGENETIC AND TECTONIC FEATURES

Diagenetic features seen in the Nugget Sandstone at Painter Reservoir Field include compaction, pressure solution, quartz overgrowths, poikilotopic carbonate cements (Plate 1D), molds after quartz and feldspar, and grain-coating and pore-bridging illite. Tec-



AGE	FORMATION	LITHOLOGY	THICKNESS
TERTIARY	WASATCH-GREEN RIVER FMS. (UNDIVIDED)		2,000'-3,000'
	EVANSTON FM.		1,200'-1,500'
CRETACEOUS	BEAR RIVER FM.		0'-1,500'
	GANNET GROUP		2,250'-2,700'
JURASSIC	STUMP-PREUSS FMS.		950'-1,050'
	TWIN CREEK LIMESTONE		Bridger Hill Thrust 1,200'-1,350'
	NUGGET SANDSTONE		850'-950'
?			
TRIASSIC	ANKAREH FM.		800'-900'
	THAYNES FM.		1,250'-1,300'
	WOODSIDE FM.		600'-800'
	DINWOODY FM.		250'-400'

Figure 4. Schematic columnar section of Painter Reservoir Field. Productive and "show" zones in the field indicated by symbols at right of column.

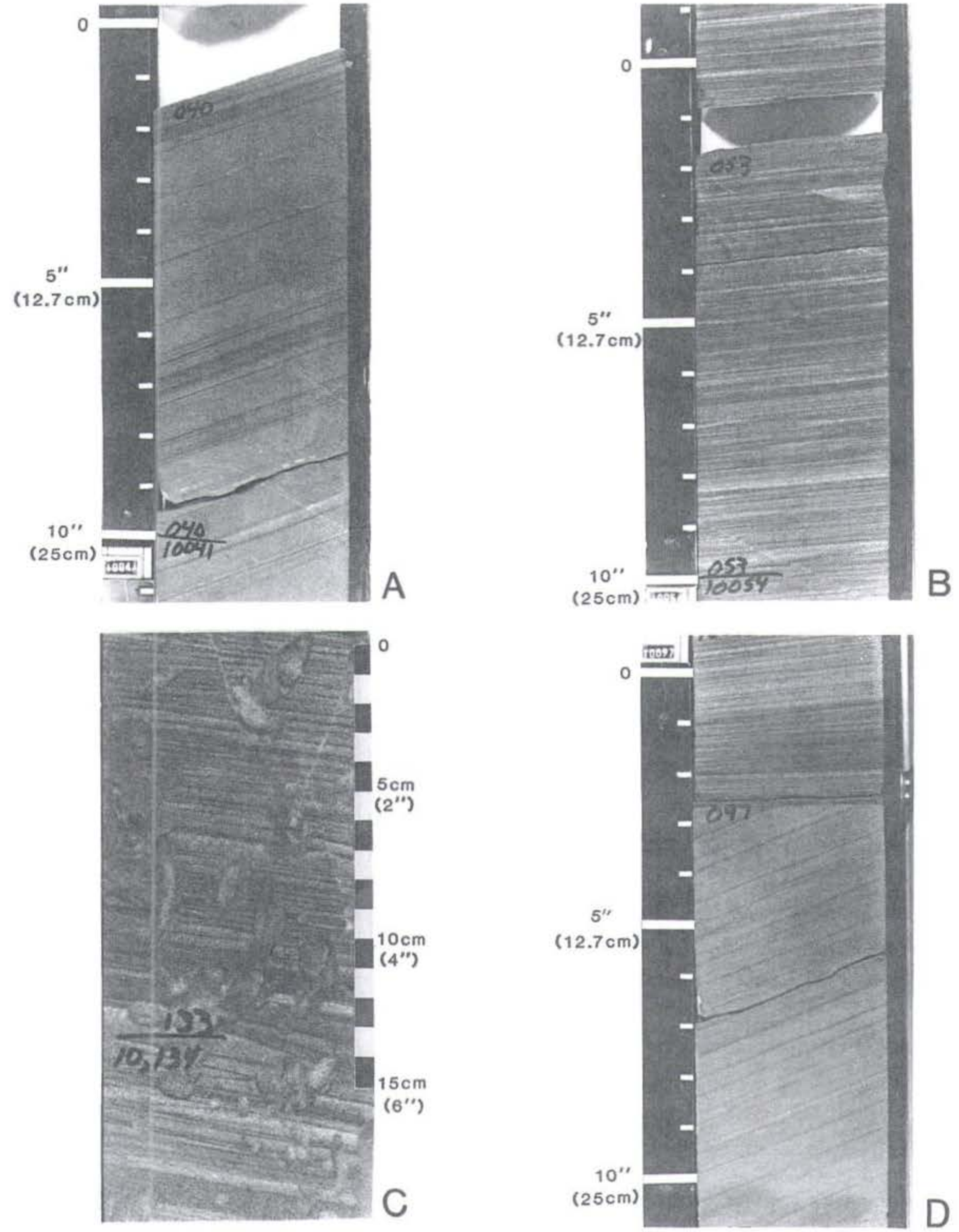


Figure 5. Cores of major Nugget reservoir facies.

A. Dune facies composed primarily of avalanche strata, with interbedded wind-ripple strata. PRU 31-31B, 10,040 ft (3,060 m).

B. Dry interdune/sand sheet subfacies composed of flat-lying wind-ripple translatent strata. PRU 31-31B, 10,053 ft (3,064 m).

C. Damp interdune subfacies, with burrows disrupting bedding. PRU 42-31B, 10,133 ft (3,089 m).

D. A typical facies sequence. Dipping foreset strata are truncated and overlain by relatively flat-lying wind ripple strata of a dune toeset. PRU 31-31B, 10,097 ft (3,078 m).

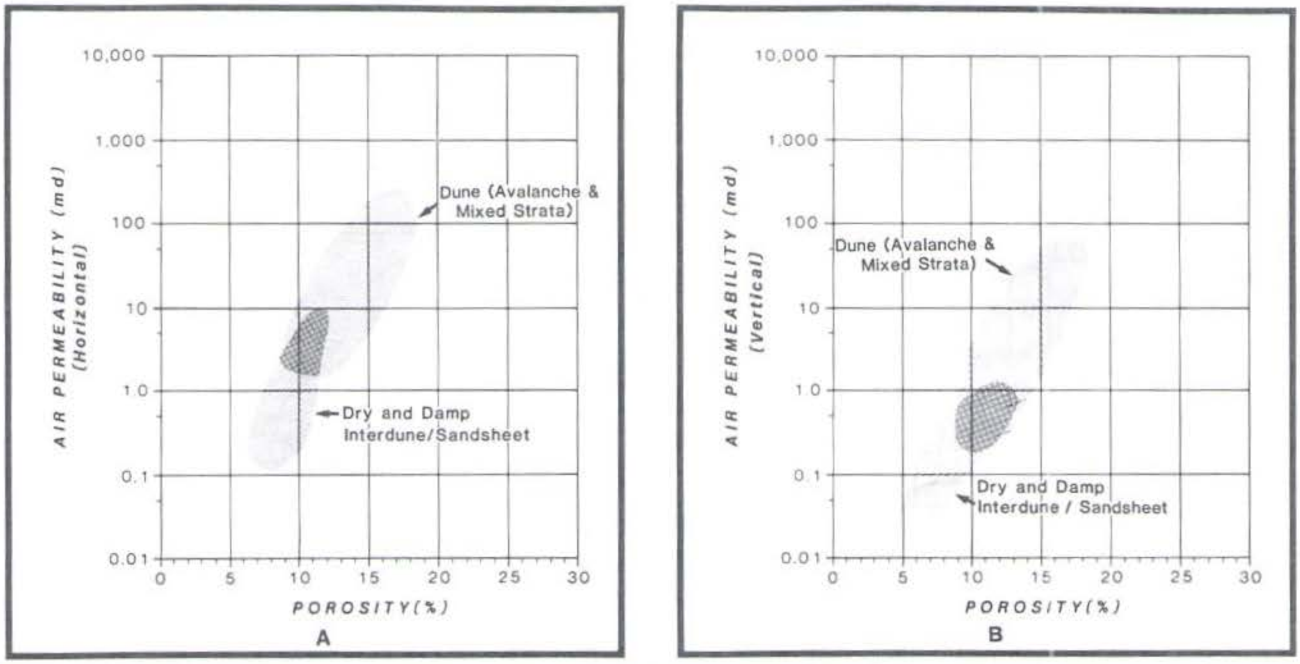


Figure 6. Porosities and air permeabilities measured on core plugs from major reservoir facies, Nugget Sandstone. Horizontal permeabilities (A) are markedly greater than vertical permeabilities (B) for any given porosity. Cores from wells PRU 31-31B and 42-31B.

tonic features include both open and closed fractures. Although these features affect the reservoir, productive characteristics are controlled principally by depositional processes.

Diagenetic processes most responsible for reduction in reservoir quality are compaction and illite formation. Compaction has reduced both porosity and permeability, particularly in finer-grained and more poorly sorted strata (Plate 1B; Fox, 1979). Illite is ubiquitous, coating grains, bridging pores, and reducing permeability (Fig. 8), especially in the finer-grained strata. The presence of pore-bridging illite does not reduce porosity as much as it does permeability, which causes scatter of data on plots of porosity versus permeability (Fig. 6).

Linear or anastomosing, high-angle fractures are abundant in the Nugget Sandstone and significantly affect the reservoir. They typically are filled with finely ground quartz gouge and cemented by quartz (Plate 1D). The gouge is created by limited movement, typically less than two in. (5 cm), along the fracture. As in East Painter Field (Lindquist, 1983), permeability measured in fractured and non-fractured core plugs in Painter Field indicates that fractures reduce horizontal permeability and may redirect fluid flow through the dune facies. However, permeability in the interdune/sand sheet facies generally is not reduced by the presence of gouge-filled fractures. Open fractures are observed less commonly in core than are closed fractures, possibly because core is lost more often from rocks in which the fractures are not cemented. Therefore, the importance of open fractures in the reservoir is difficult to quantify.

PALEOGEOGRAPHY

The Nugget stratigraphic sequence at Painter Reservoir is similar to that described at Anschutz Ranch East Field (Lindquist, 1988). Porosity tends to increase upward, reflecting the gradual buildup and migration of eolian sediments in an extensive sand sea or erg (Fig. 9). Core studies confirm Lindquist's interpretation that the depositional environment in the lower third of the Nugget was one of small, isolated dunes surrounded by extensive low-relief interdune areas and sand sheets. The depositional environment in the upper two-thirds of the Nugget in Painter Field was characterized by large dunes and dune complexes in a vast sand sea. Sediment supply and aridity increased through time during Nugget Sandstone deposition. Structural complications make measurement of Nugget stratigraphic thickness difficult; however, restorations indicate that the formation is between 850 and 950 ft (255-285 m) thick in Painter Field

STRATIGRAPHIC FACTORS IN RESERVOIR BEHAVIOR

Stratigraphic Layering

Nugget stratigraphy is characterized by stacked facies sequences, which are fairly well defined in cores and on wireline logs (Lindquist 1983, 1988). The marked difference in porosity and permeability between facies results in stratigraphic layering of the reservoir that directs fluid flow. Effects of stratigraphic layering in the Nugget reservoir have been observed in producing wells (Fig. 10). For instance, the PRU

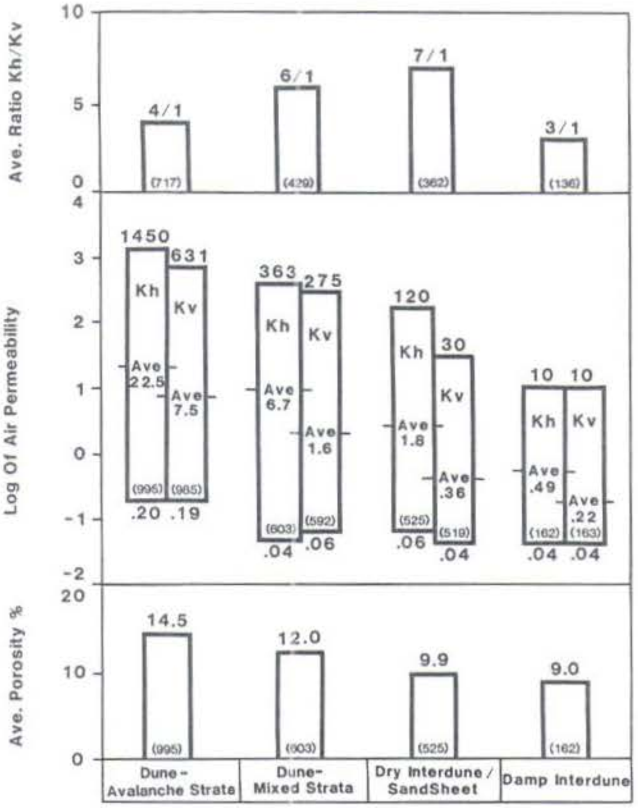


Figure 7. Arithmetic averages of porosity, permeability, and horizontal/vertical permeability ratios, by facies. Permeability ranges also are shown. Permeabilities are measured in millidarcies. The number of samples (n) used for calculation is shown. Measurements were made on core plugs from same wells as in Figure 6.

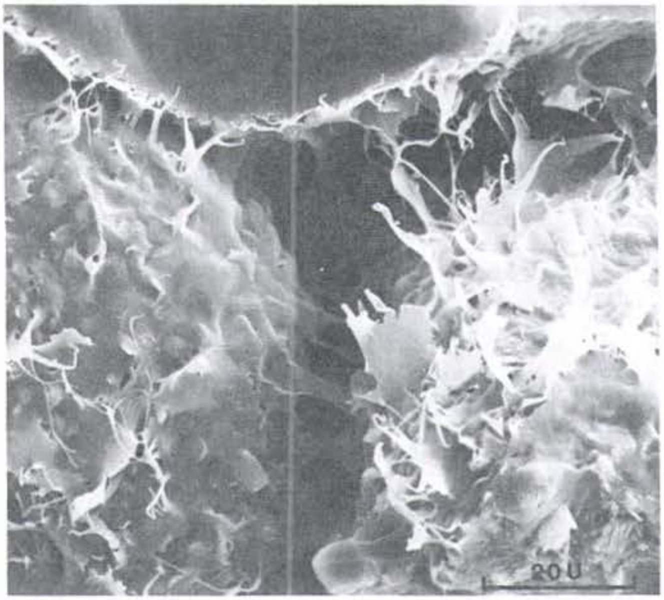


Figure 8. SEM image of grain-coating and pore-bridging illite. Magnification 1,000x. PRU 21-12D, 10,359 ft (3,157.4 m).

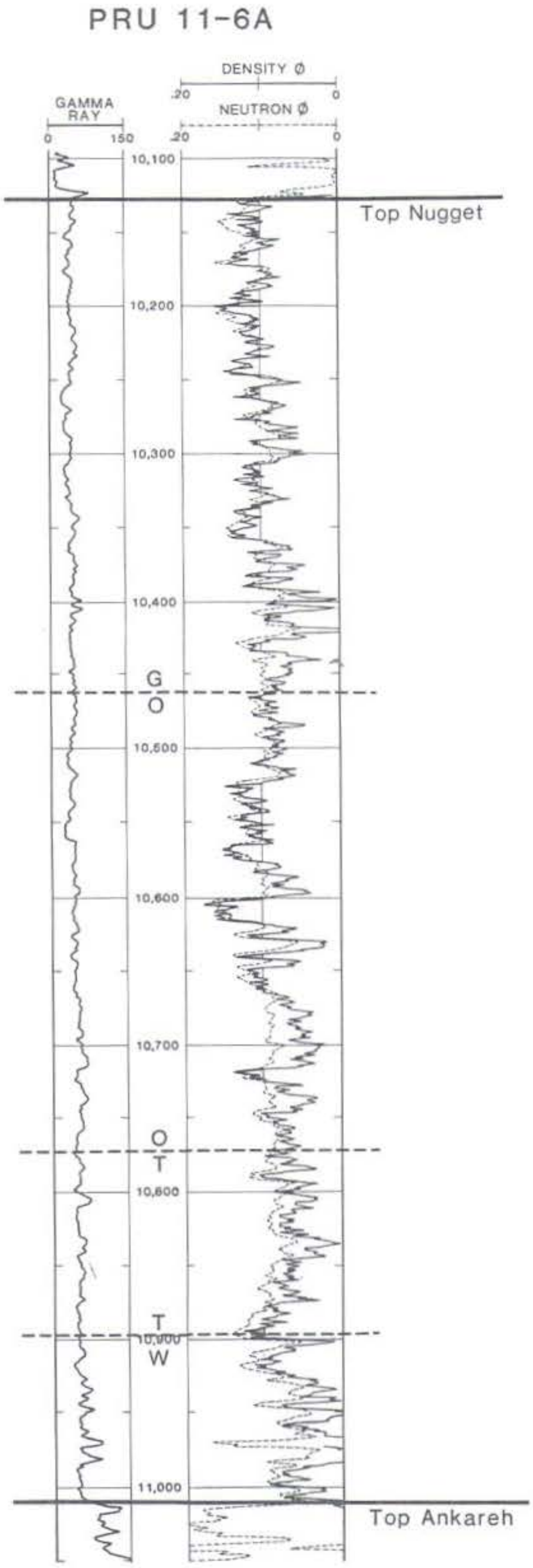


Figure 9. Compensated neutron/formation density log with gamma ray, showing the upward increase in Nugget Sandstone porosity. (100 ft = 30.5 m)

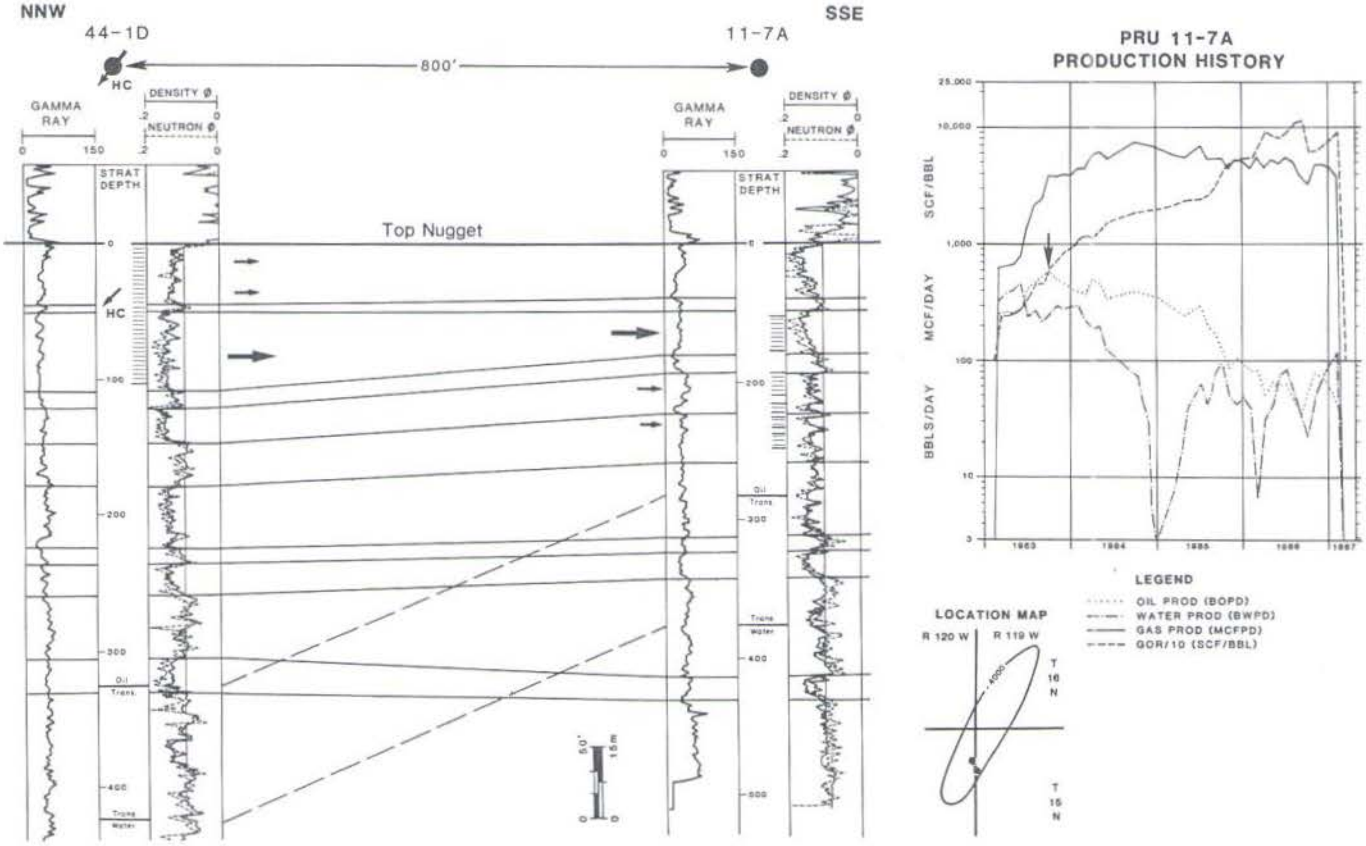


Figure 10. Stratigraphic cross section between PRU 44-1D and PRU 11-7A, illustrating the effects of stratigraphic layering on reservoir behavior. Logs display true stratigraphic thickness and are hung on the top of the Nugget. Most of the gas injected into the PRU 44-1D was entering the Nugget reservoir at the stratigraphic horizon shown by a heavy arrow; most of the gas produced from the PRU 11-7A was out of the correlative zone (also shown by a heavy arrow). See text for detailed discussion.

44-1D was converted from oil production to hydrocarbon-gas injection in February, 1983. One month after the conversion, the PRU 11-7A, which had previously been shut in due to high water cuts, was put back on production at a rate of 270 BOPD and 350 BWPD, with a GOR of 2,500 CFG/BO. Within seven months, oil production had increased to over 600 BOPD with a GOR of 6,500 CFG/BO. However, by January of 1987, oil production had fallen to 60 BOPD with a GOR of almost 80,000 CFG/BO, the highest in the field. Production logs indicated that almost half of the gas injected into the PRU 44-1D was entering a porous zone near the top of the reservoir and channelling to the PRU 11-7A well through the same zone. Thus, the injection zone in the PRU 44-1D well and the uppermost perforated zone in the PRU 11-7A appear to be in direct stratigraphic communication. The PRU 11-7A well was subsequently shut in. This type of behavior is common in Painter Field, but typically is more subtle than this example. Lateral discontinuity of facies, variable dune geometry, and the possible presence of faults and fractures in the Nugget Sandstone make prediction of these occurrences, and their magnitude, difficult.

Gas production also increased in the deeper producing intervals of the PRU 11-7A while gas was being injected into the PRU 44-1D well, despite apparent stratigraphic separation from the injection interval. Thus, the interdune deposits in the upper Nugget between these two wells are not barriers to flow, but they do tend to direct flow through more-permeable dune facies. Where pressure gradients are small, flow is controlled primarily by permeability layering. Where pressure gradients are large, vertical flow across the lower-permeability interdune facies can be significant, as between the perforated stratigraphic layers in the PRU 11-7A. Large pressure differentials also occur between injection and production perforations in dual injection/production wells.

Directional Permeability

Depositional attitudes of Nugget cross strata at Painter Reservoir have been determined from dipmeter logs, after rotation to remove structural dip components (Fig. 11). Data from several wells indicate dip azimuths between 215° and 225°. This southwesterly trend coincides well with other regional dip azimuths reported in the literature on the Nugget and Navajo formations (Jordan, 1965; Picard, 1975;

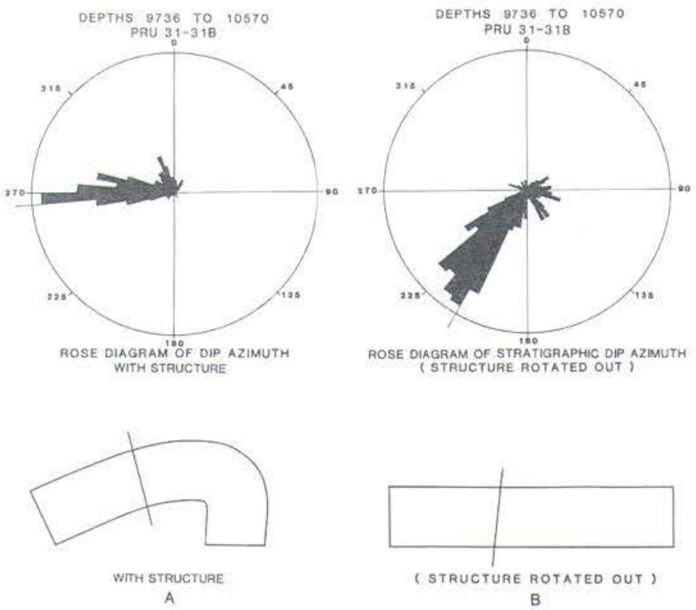


Figure 11. Present Nugget structural dip azimuth (A), and Nugget stratigraphic dip azimuth, with structural attitude rotated out (B). Note the unimodal distribution of laminae.

Doelger, 1981; Kocurek and Dott, 1983; Lindquist, 1983). The unimodality of the trend suggests that Nugget dunes were predominantly straight-crested transverse, barchanoid, or oblique dunes (Hunter, 1981; McKee, 1979; Lindquist, 1983, 1988). Wider scatter of rotated dip data in some wells indicate that an incorrect structural dip was used or that other Nugget dune morphologies are present, although minor.

The consistent depositional dip orientations and the straight-crested dune morphologies inferred for the Nugget at Painter Reservoir suggest that directional permeability should exist. Based on the geometry of modern transverse dunes, the maximum permeability should be parallel to the internal stratification and dune axis, because this is the direction in which fluids can travel the farthest before encountering flow-inhibiting boundaries (Fig. 12A). In the Nugget, the direction of maximum permeability should be northwest-southeast.

This permeability anisotropy is supported by production history in the field, particularly during pressurization of the gas cap from 1983 to 1985. During this period, nitrogen and hydrocarbon-gas injection rates were increased in the gas cap to elevate field pressure and to cause miscible displacement of the oil in the oil "leg". Pressure response and subsequent gas breakthrough occurred more rapidly along northwest-southeast trends, rather than longitudinally up and down the field (Fig. 13A). The trend is parallel to the inferred dune axes and maximum-permeability direction.

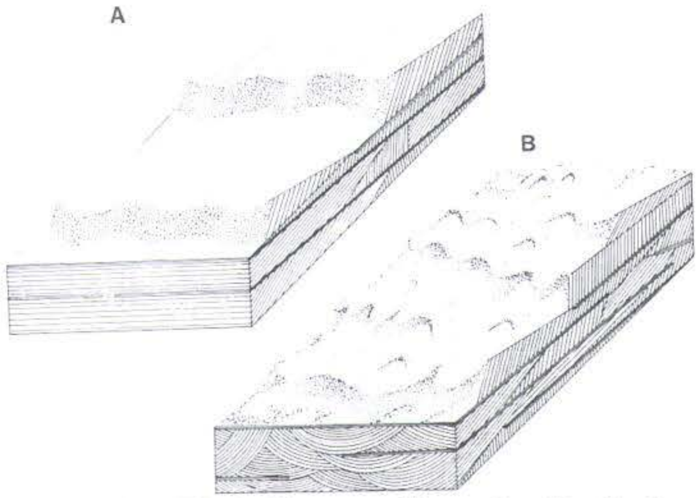


Figure 12. Block diagrams illustrating idealized Nugget Sandstone transverse/barchanoid dunes (A), the possible complexity of the depositional environment (B), and the resulting stratigraphic sequences. Transverse/barchanoid dune morphologies are inferred from unimodal depositional dip orientations (A). The direction of maximum permeability parallels dune axes, which are oriented predominantly in a southeast-northwest direction. However, directional permeability is influenced by relict dune geometry, which may be more complex than the idealized transverse/barchanoid dune geometry (B).

The field deviates from this trend on its northern end, possibly a result of geologic factors. First, downwind migration and lateral truncation of Nugget dunes have altered their original geometries, perhaps affecting permeability trends (Fig. 13B). Variation in the orientations of fractures and faults also can affect permeability trends. Thus, prediction of field-wide trends in directional permeability is difficult, given that the factors influencing these trends are hard to extrapolate beyond the borehole. Study of reservoir performance is essential in determining the significance and direction of permeability trends at any particular location in the field.

CONCLUSIONS

The Nugget Sandstone in Painter Reservoir Field is a stratigraphically heterogeneous reservoir. This heterogeneity is inherited primarily from eolian depositional processes. It is observed on many different scales in cores and field performance. Finer-scale heterogeneity results from variations in grain size, sorting, mineralogy, and bed thickness. Larger-scale heterogeneity results from porosity and permeability variations between dune and interdune facies, and from the geometry of these facies. Diagenetic and tectonic processes such as illite formation, fracturing, and faulting also affect reservoir properties.

Stratigraphic layering of the reservoir results from porosity and permeability variations between facies and their arrangement in stacked vertical sequences. Directional permeability resulting from consistent dune orientations and internal stratification is confirmed by field performance. The trend is altered in some locations by fracturing, faulting, and/or variations in dune geometries. Stratigraphic heterogeneity, combined with other complexities such as structure and hydro-

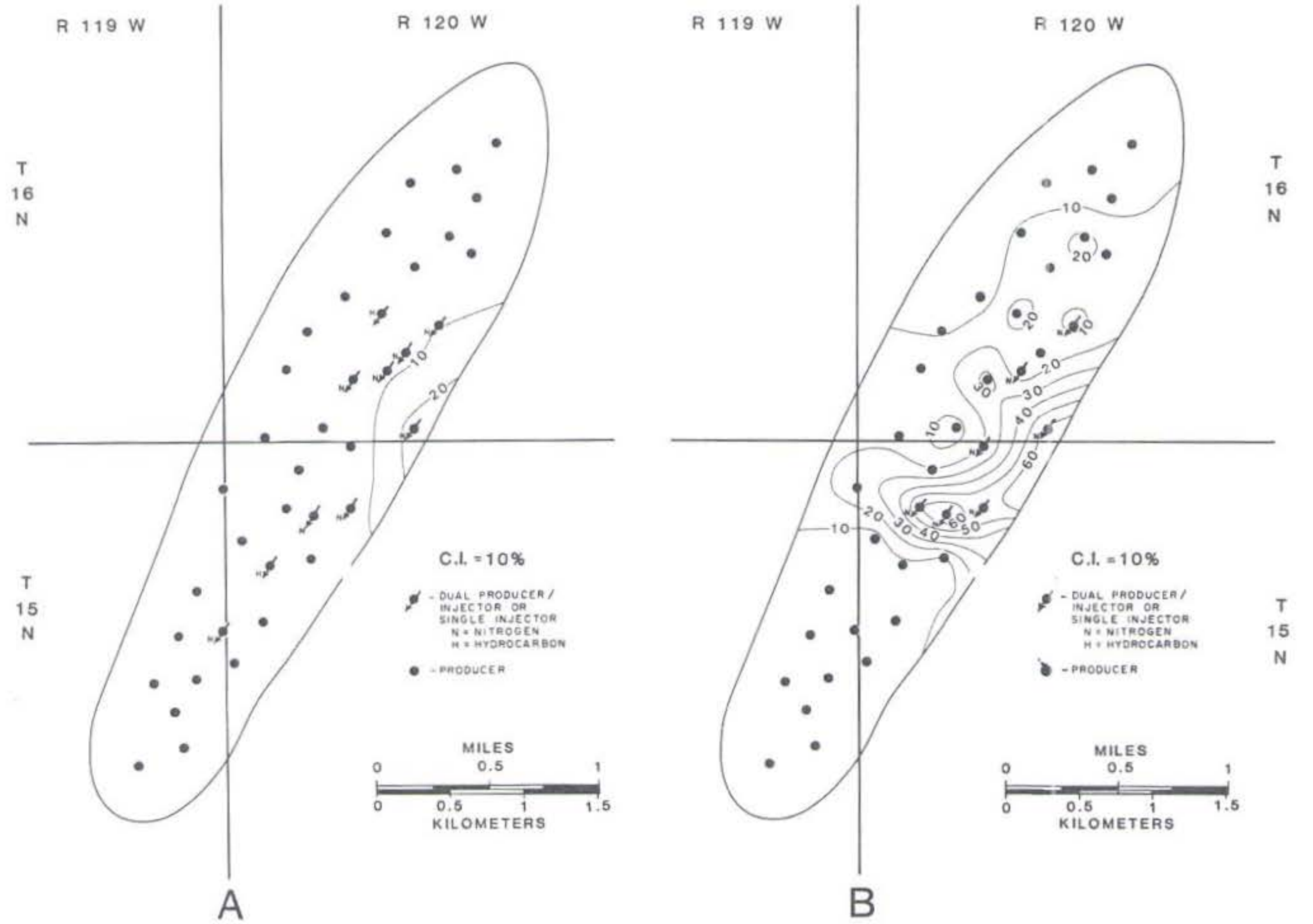


Figure 13. History of nitrogen migration during reservoir pressurization, shown by contours of produced nitrogen cuts. Wells near the crest and on the east flank of the field typically produce from the lower Nugget porosity zone; wells on the west flank and plunge ends typically produce from the upper Nugget zone. In January 1983, at the onset of reservoir pressurization, high nitrogen cuts in the central portion of the field were produced from the deep production perforations in the dual wells, and indicate vertical flow from the injection intervals to the production intervals (A). During January 1985, two years after the onset of reservoir pressurization, nitrogen production increased in a northwest-southeast trend in the central portion of the field. Note the deviation from this trend in the north plunge end (B).

carbon composition make exploitation of Painter Reservoir Field challenging.

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Authigenic chlorite forms a partial coating on a detrital framework grain. Surface sample of Point Lookout sandstone, La Plata Co., CO. Photo donated by Bill Keighin.