COVENANT OIL FIELD, CENTRAL UTAH THRUST BELT: POSSIBLE HARBINGER OF FUTURE DISCOVERIES

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REFERENCES

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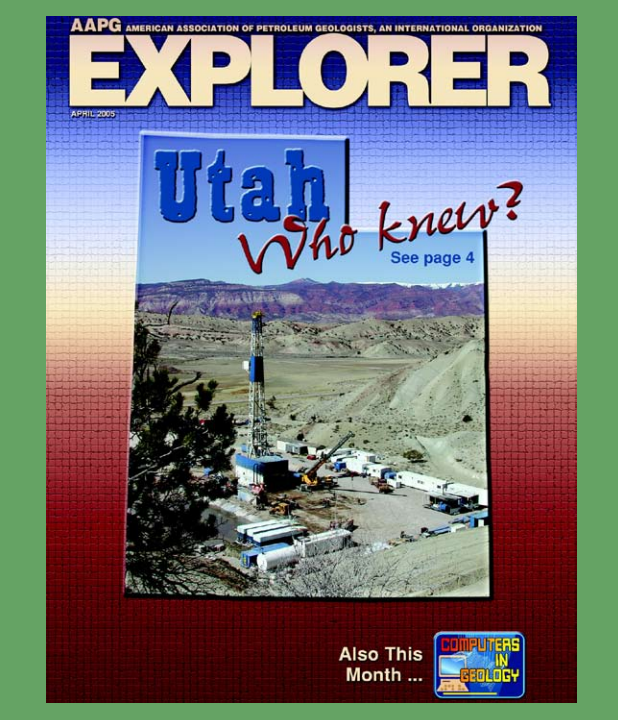
Field cores were described by L.F. Krystinik, geologic consultant. Jake DeHamer, WGO, interpreted core petrophysical data. The poster design was by Liz Paton of the UGS. James Parker, Liz Paton, Sharon Wakefield, and Cheryl Gustin of the UGS prepared the figures; Brad Wolverton of the UGS Core Research Center assisted with core photography.



SUMMARY

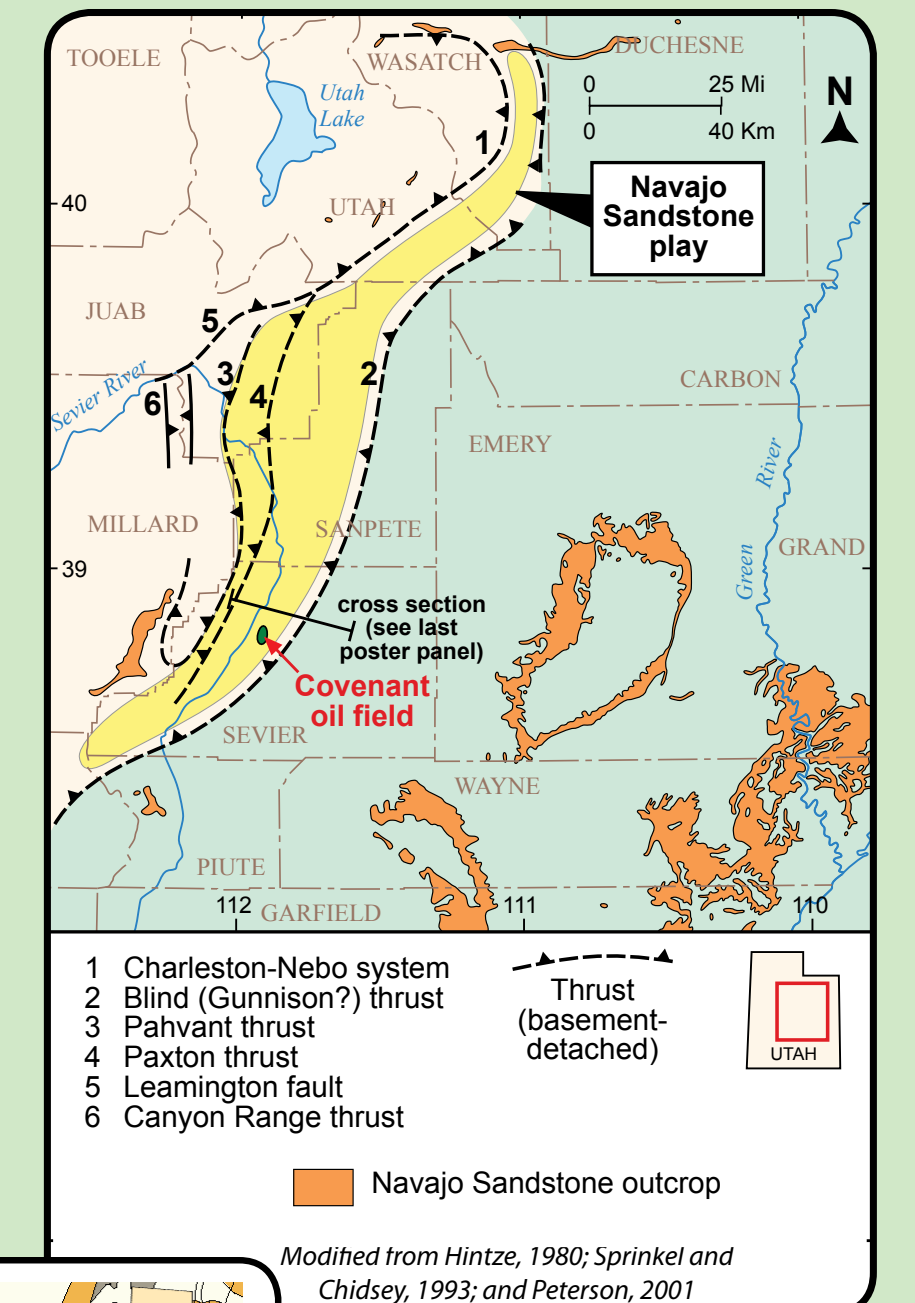
The central Utah thrust belt, or "Hingeline," has seen cycles of petroleum exploration for the past 50 years because explorationists viewed the geology as a natural extension of productive thrust belt-style structures in northern Utah and southwestern Wyoming. Early unsuccessful efforts tested anticlines identified from surface mapping and seismic reflection data. The lack of a Cretaceous source seemingly was to blame for these failures. The 2004 discovery of Covenant oil field proved that this region contains the right components (trap, reservoir, seal, source, and migration history) for large accumulations of oil. To date, 10 producing wells and one dry hole have been drilled from two surface pads. Covenant has produced over 3 million bbls of oil and no gas; the field averages 5500 BOPD from the Jurassic Navajo Sandstone. The OOIP is estimated at 100 million bbls; the estimated recovery factor is 40%.

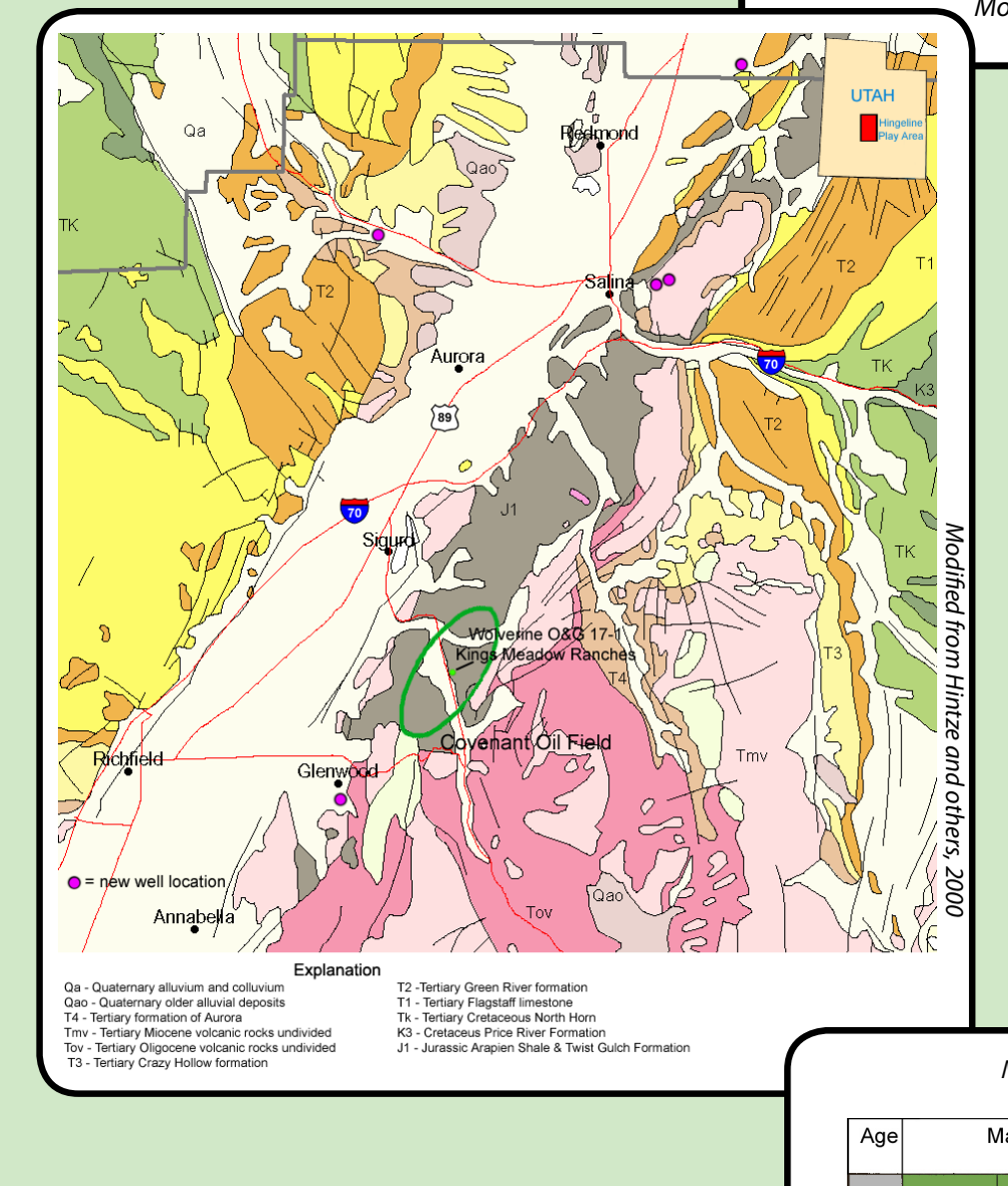
The Covenant trap is an elongate, symmetric, northeast-trending, fault-propagation anticline formed during the Sevier orogeny (Late Jurassic-early Tertiary), with nearly 800 ft (240 m) of structural closure. The structure formed above a series of splay thrusts in a passive roof duplex along the "blind" Gunnison-Salina thrust and west of a frontal triangle zone within the Jurassic Arapien Shale. The Jurassic Twin Creek Limestone and Navajo Sandstone are repeated due to an east-dipping back thrust detachment within the structure. This back- thrust forms a hanging wall cutoff along the west flank and north-plunging nose of the fold. Only the first Navajo (and possibly the Twin Creek) is productive. The eolian Navajo Sandstone reservoir is effectively sealed by mudstone and evaporites in the overlying Jurassic Twin Creek Limestone and Arapien Shale. Oil analysis indicates a probable Mississippian source – oil derived and migrated from rocks within the Hingeline region.

Cores from the Navajo Sandstone display a variety of eolian lithofacies (dune, interdune, lake/playa, fluvial/wadi), fracturing, and minor faults which, in combination, create reservoir heterogeneity. Reservoir sandstone is 97% frosted quartz grains (bimodal grain size), with some quartz overgrowths and illite. The net reservoir thickness is 424 ft (129 m) over a 960 acres (390 ha) area. Porosity averages 12%; permeability is ≤100 mD. The drive mechanism is a strong water drive; water saturation is 38%. A thorough understanding of all the components that created Covenant field will determine whether it is a harbinger of additional, large oil discoveries in this vast, under-explored region.

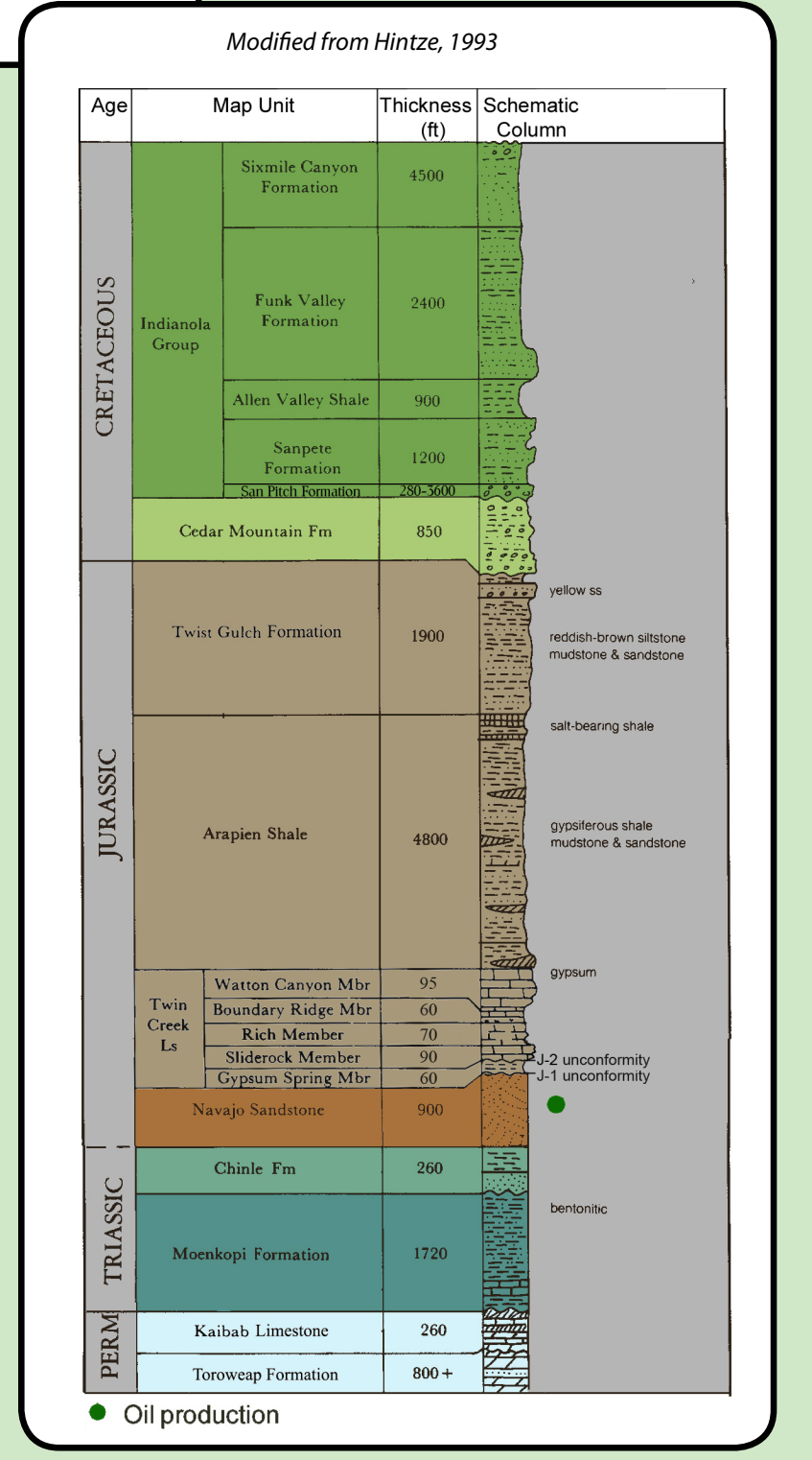
Location of Covenant Oil Field, Uplifts, and Selected Thrust Systems in the Central Utah Thrust Belt

Numbers and sawteeth are on the hanging wall of the corresponding thrust system. Colored (light orange) area shows present and potential extent of the Navajo Sandstone Hingeline play in the central Utah thrust belt.



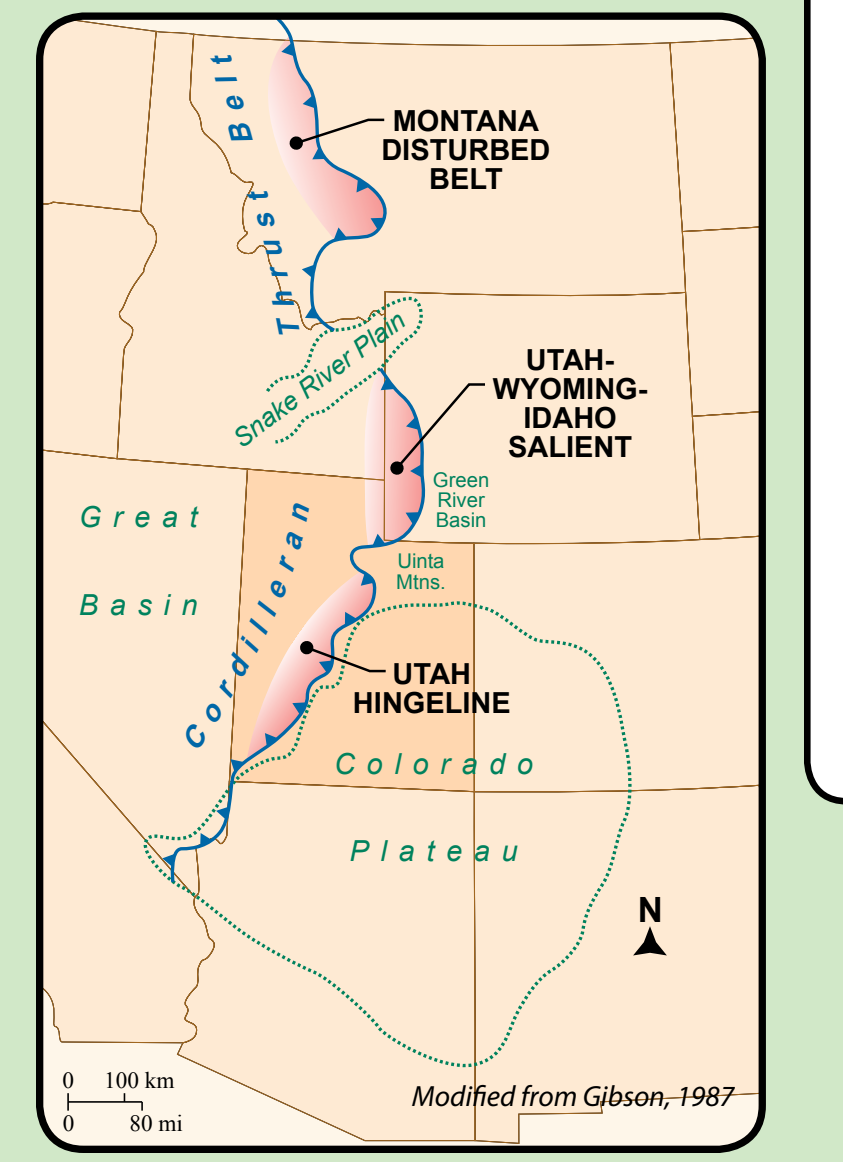


Surface Geology, Covenant Field Area, Sevier County, Utah

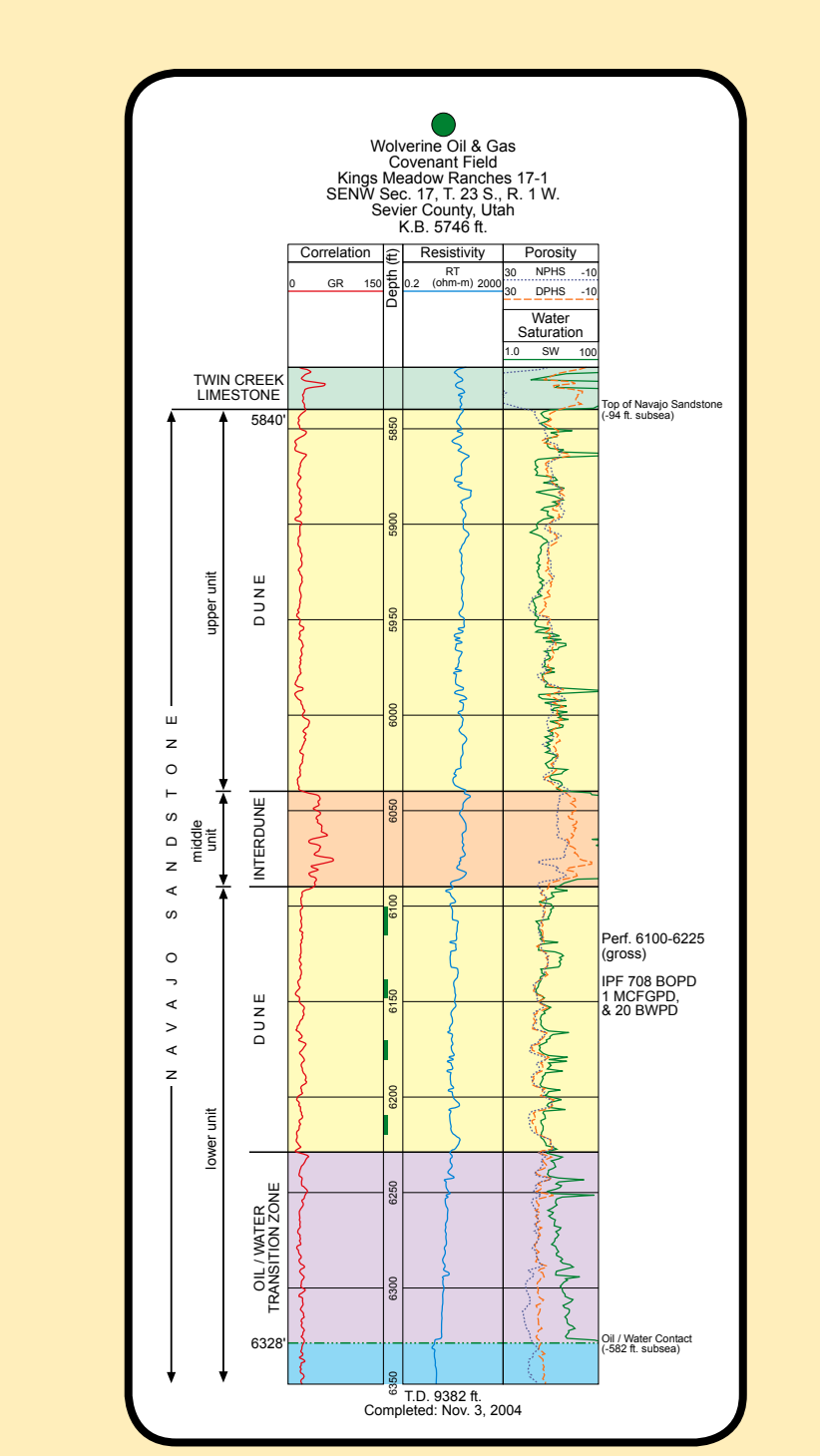


Stratigraphic Column, Central Utah Thrust Belt

Location of the Cordilleran Thrust Belt including the Montana "Disturbed" Belt, Utah-Wyoming-Idaho Salient, and Utah "Hingeline"



GENERAL FIELD OVERVIEW



Typical Geophysical Well Log of the Jurassic Navajo Sandstone, Kings Meadow Ranches No. 17-1 Discovery Well, Covenant Field

Discovery Well

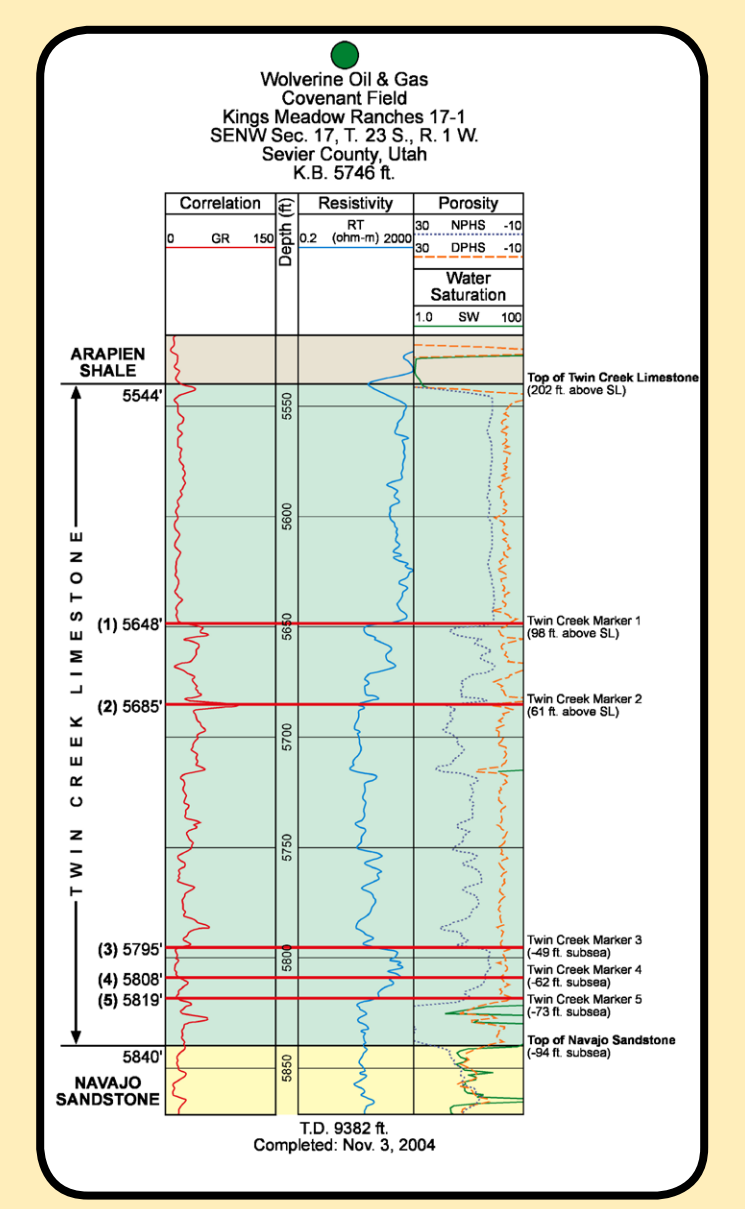
- Wolverine Gas & Oil Corp. Kings Meadow Ranches No. 17-1 (SENW Sec. 17, T. 23 S., R. 1 W., Sevier Co., Utah
- T.D. – 9382 ft
- Completed – November 3, 2004
- Producing Reservoir – Jurassic Navajo Sandstone
- IPF – 708 BOPD, 1 MCFGPD, 20 BWPD

Production & Reserves

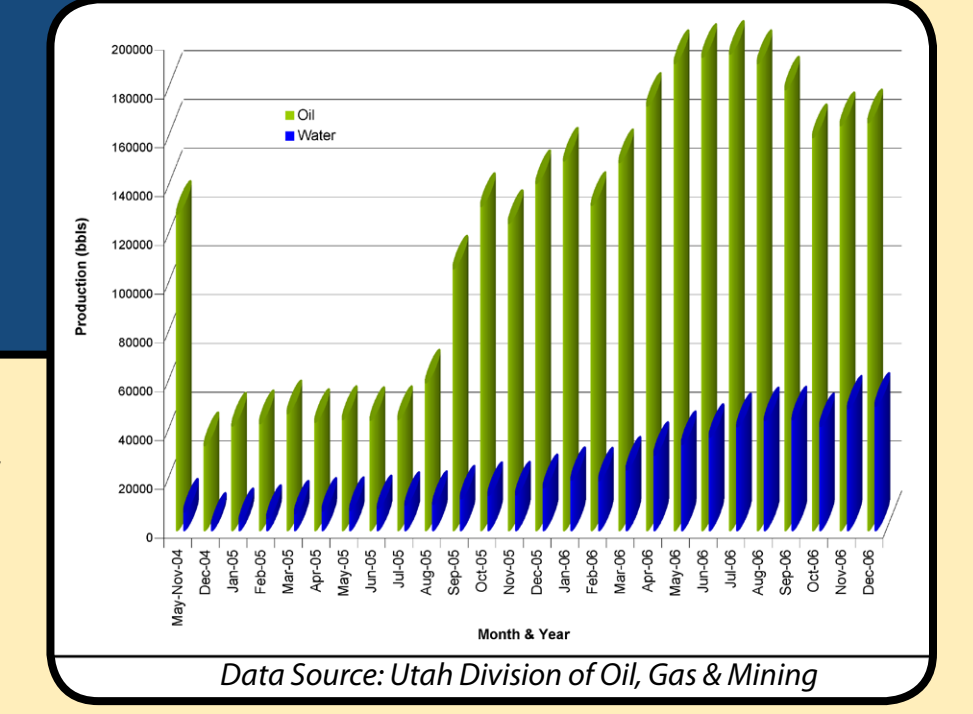
- Producing Wells – 10
- Dry Holes – 1
- Abandoned Producers – none
- Monthly Production (November 2006) – 166,036 BO & 49,810 BW
- Cumulative Production (as of December 1, 2006) – 2,938,869 BO & 527,076 BW
- OOIP – 100 million bbls
- Estimated Recovery Factor – 40%

Reservoir Data

- Productive Area – 960 acres
- Gross Pay – 487 ft
- Net Pay – 424 ft
- Net to Gross – 0.87
- Hydrocarbon Column – 450 ft
- Average Porosity – 12%
- Permeability – up to 300 mD
- Water Saturation – 38%
- Water Resistivity – 0.279 ohm-m @ 77°F, 26,035 TDS
- BHT – 188°F
- Type of Drive – strong water drive
- Initial Reservoir Pressure – 2630 psi



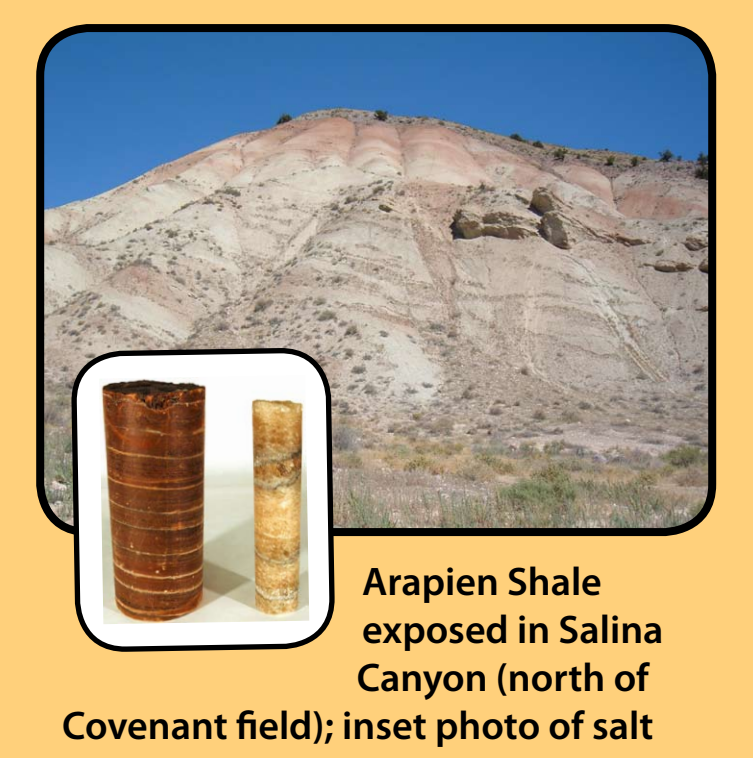
Typical Geophysical Well Log of the Jurassic Twin Creek, Kings Meadow Ranches No. 17-1 Discovery Well, Covenant Field



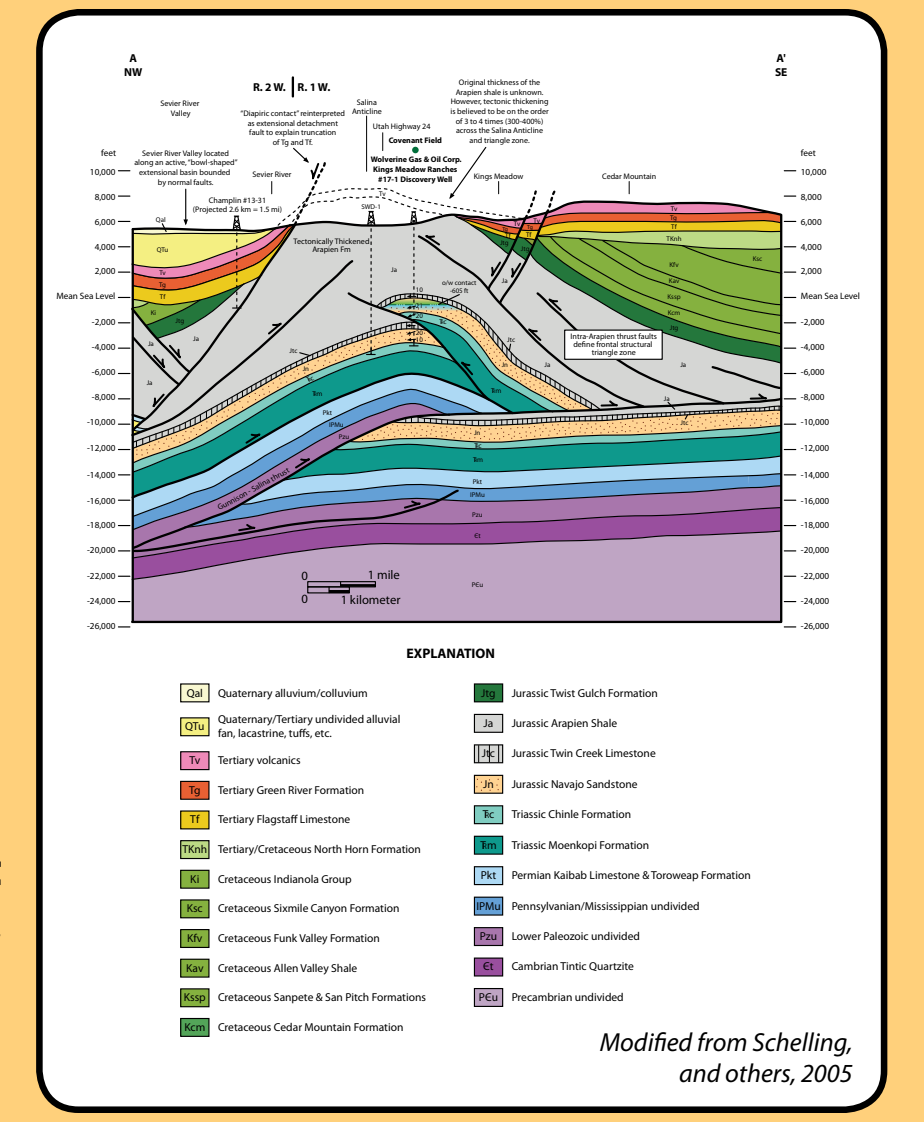
Historical Monthly Oil & Water Production, Covenant Field

STRUCTURAL GEOLOGY

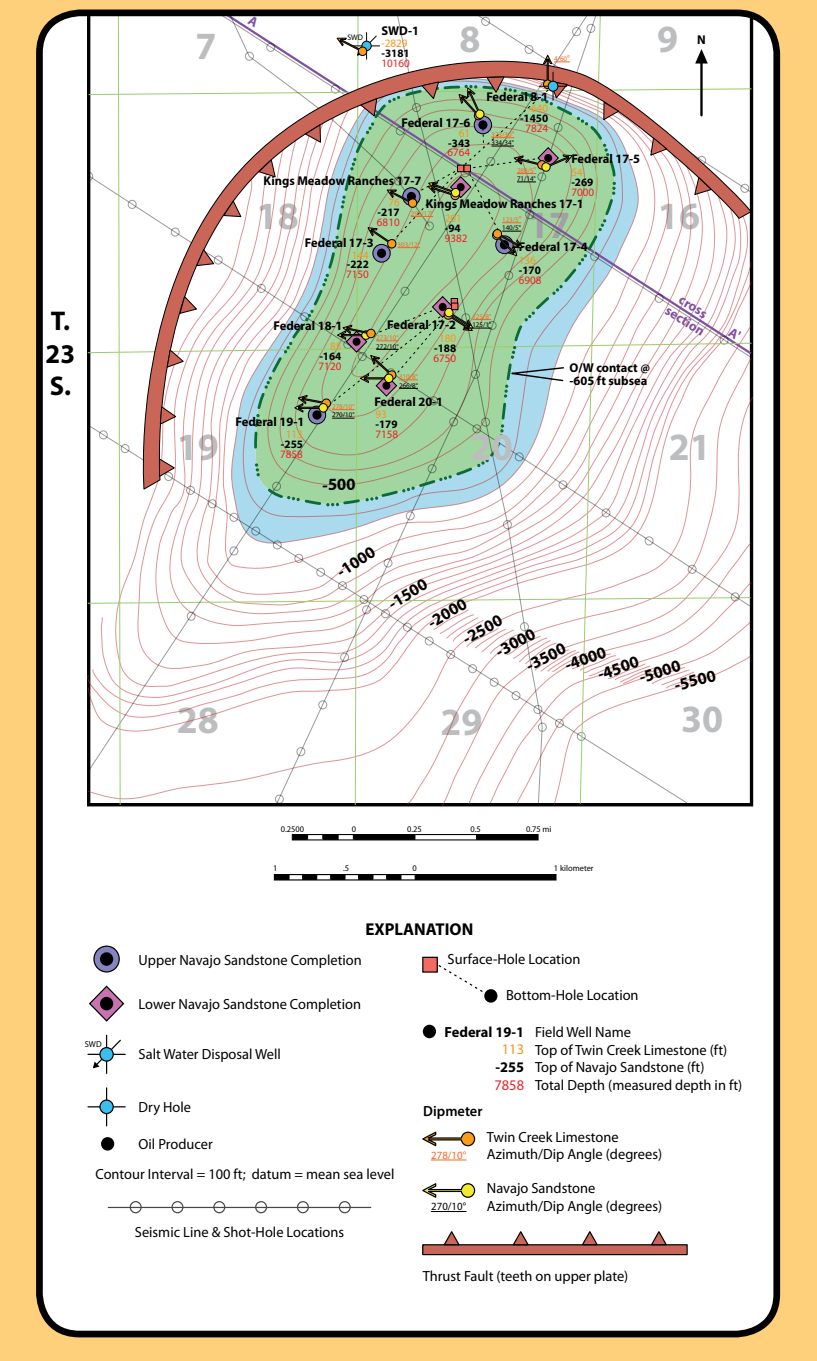
Reservoir Seal: Jurassic Arapien Shale



Arapien Shale exposed in Salina Canyon (north of Covenant field); inset photo of salt core from Redmond quarry in the Arapien north of the town of Salina



Northwest-Southeast Structural Cross Section, Covenant Field



Structural Contour Map, Top of Navajo Sandstone, Covenant Field

COVENANT FIELD RESERVOIR: EOLIAN JURASSIC NAVAJO SANDSTONE

Navajo Sandstone Lithofacies Recognized in Core from the Federal No. 17-3 Well

T – Thick: dune deposits containing the large-scale, trough, planar, or wedge-planar cross-beds (35 to 40°) commonly recognized as classical eolian dune features. Very well to well-sorted, dune and avalanche deposits. Sand layers greater than 0.5 cm thick in core. The brink to the toe of the dune slipface consists of thin, graded, tabular grainfall laminae (rarely preserved in the core) and thick, subgraded, avalanche laminae. The "thick" classification is correlated to avalanche deposits. Porosity ranging from 5 to 15%, and permeabilties typically from 7 to 300 mD.

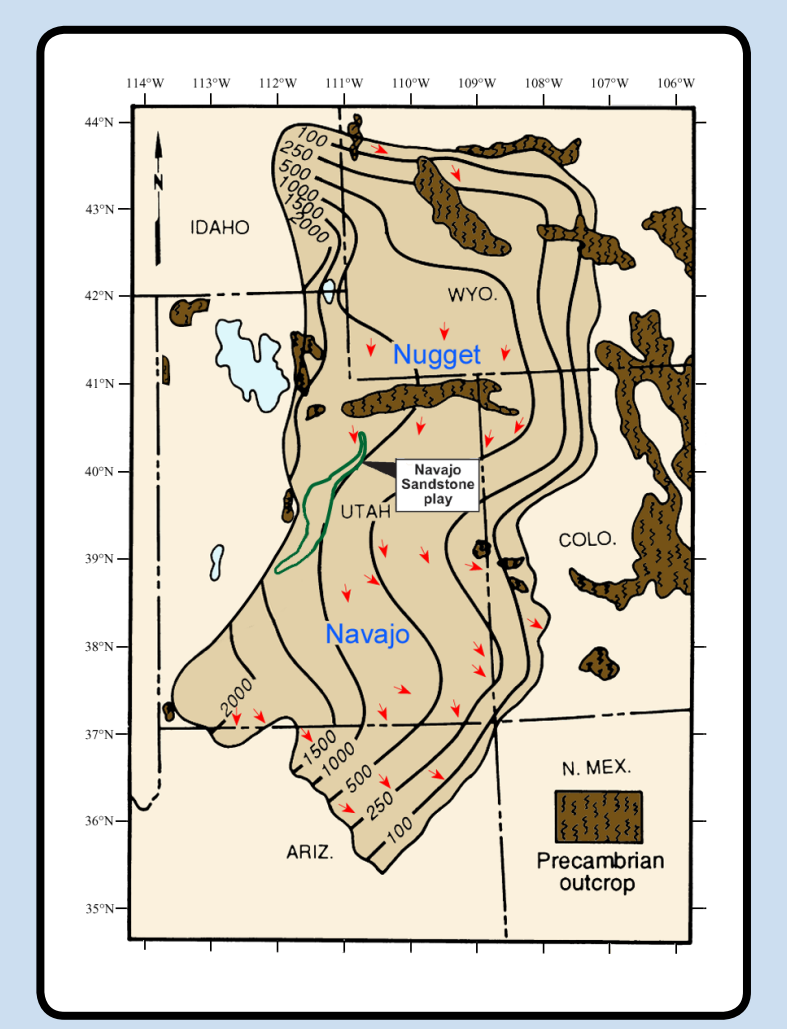
TC – Thin Continuous: sand layer continuously bedded, trough, planar, or wedge-planar cross-beds less inclined than the thick lithofacies (20 to 35°), and less than 0.5 cm thick in core. Moderately well to poorly sorted with more clay cementation than the "TD" lithofacies. The TC lithofacies can occur within the thick and Thin Discontinuous lithofacies making the TC lithofacies a transitional phase. All porosities are under 10% and permeabilites range from 1 to 30 mD.

TD – Thin Discontinuous: flat lying bedding less than 0.5 cm thick in core containing wind ripples, and some cross-bedding (0 to 20°). Moderately to poorly sorted with greater carbonate cement than TC layer. Thin discontinuous tightly packed, reworked ripple strata are representative of dune toe lithofacies. Low porosities and permeabilites are characteristic.

WBH – Interdunal: low-angle to horizontal laminae or distorted bedding consisting of very fine to fine-grained, thin, poorly sorted sandstone, siltstone, and shale dominated by carbonate cement. Beds may contain wind ripples or fluvial characteristics (scour). Very low porosities and permeabilities. Interdunal fluvial characteristics indicate sheet flow or flooding events in a fluvial/wadi while other deposits suggest wet, playa or lacustrine conditions.

M– Massive: homogenized sandstone layers showing no distinct sedimentary structures or laminations. This lithofacies probably formed by water-saturated sand.

FB – Fault Breccia: Breccia resulting from a fault and fracture zones running through the core of the Federal No. 17-3 well.

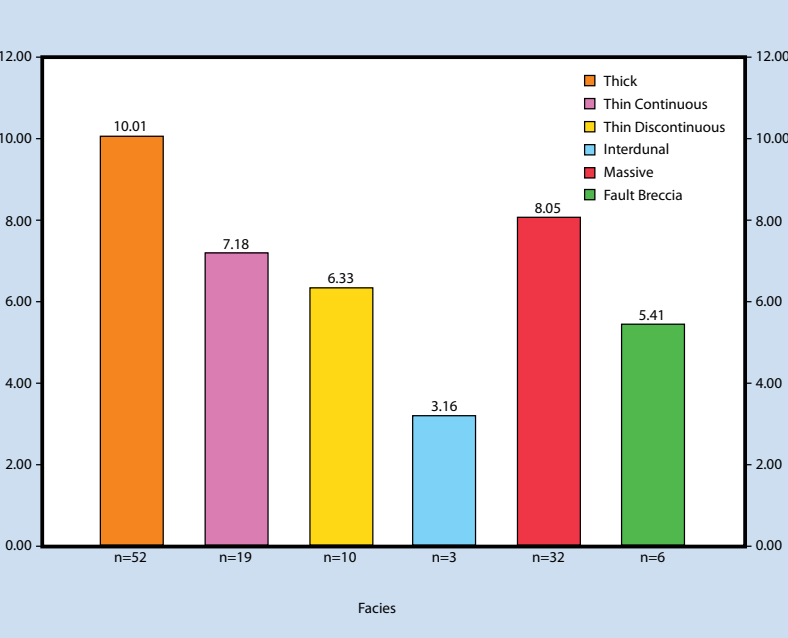


Regional Isopach Map of the Navajo/Nugget Sandstone

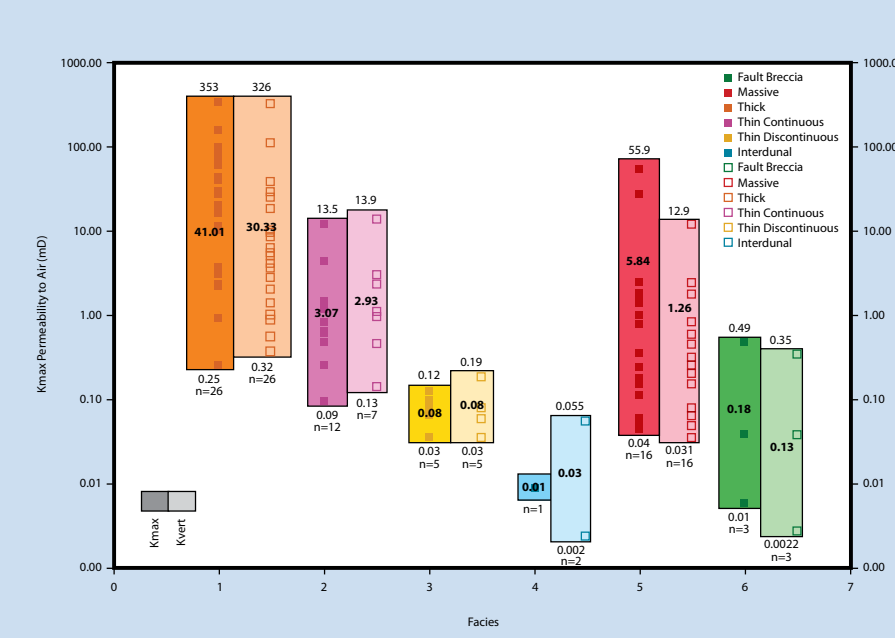
Paleowind generally from the north and northwest is shown by arrows. Contours are in feet.

Petrography

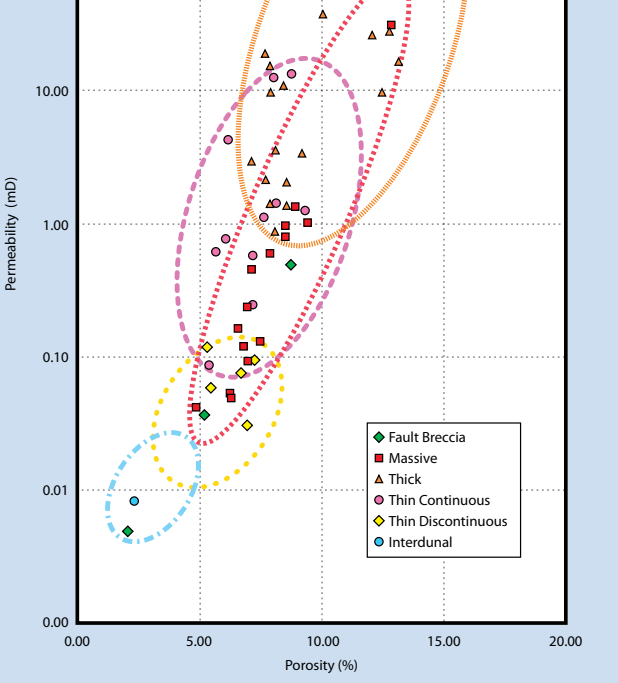
- Lithology – very fine- to medium-grained (1/16 mm to ½ mm), quartz sandstone; 97%, white or clear quartz grains with varying amounts of K-feldspar
- Sand Grains – subangular to subrounded, very well to well-sorted, usually frosted
- Pore Types – primary intergranular, fracture
- Grain Density – 2.651 g/cm³
- Diagenesis – minor overgrowths of quartz; some authigenic clay mineralization has occurred in the form of grain-coating, pore-bridging, and fibrous illite; some ferroan (?) dolomite and fractured, corroded K-feldspar are also present



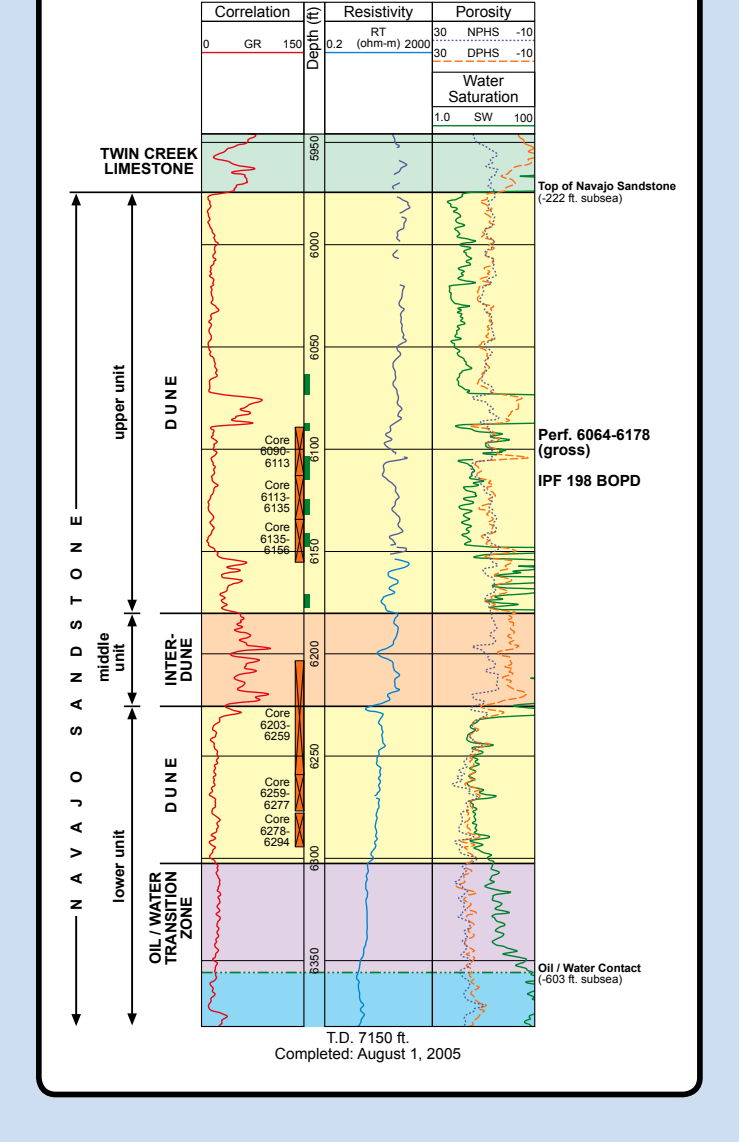
Average Porosity for Upper Navajo Lithofacies



Permeability for Upper Navajo Lithofacies

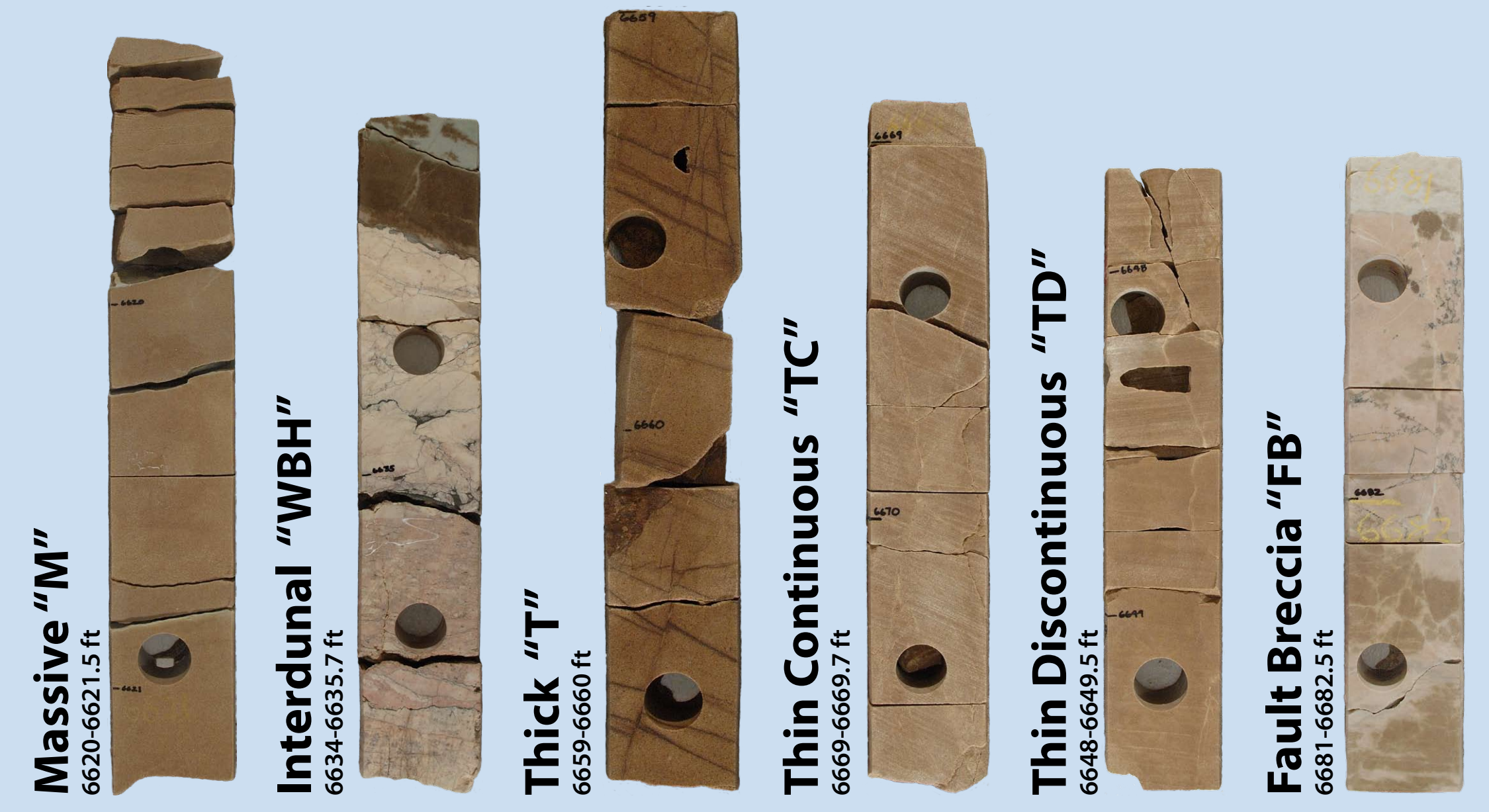


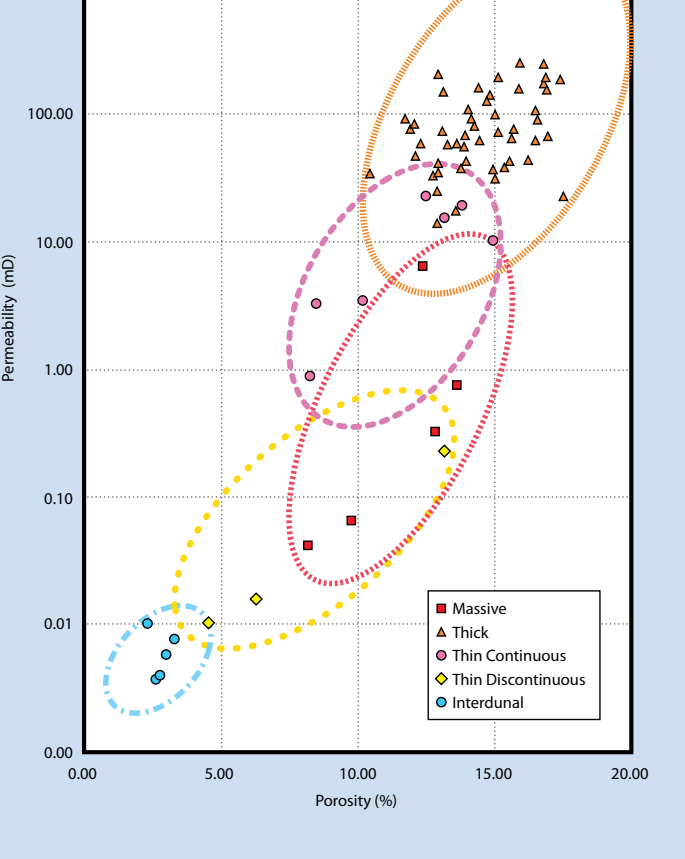
Permeability vs. Porosity Cross Plot by Lithofacies, Upper Navajo Lithofacies



Typical Geophysical Well Log of the Cored Section of Jurassic Navajo Sandstone, Federal No. 17-3 Well

Core Photos of Lithofacies in Upper Navajo of the Federal No. 17-3 Well



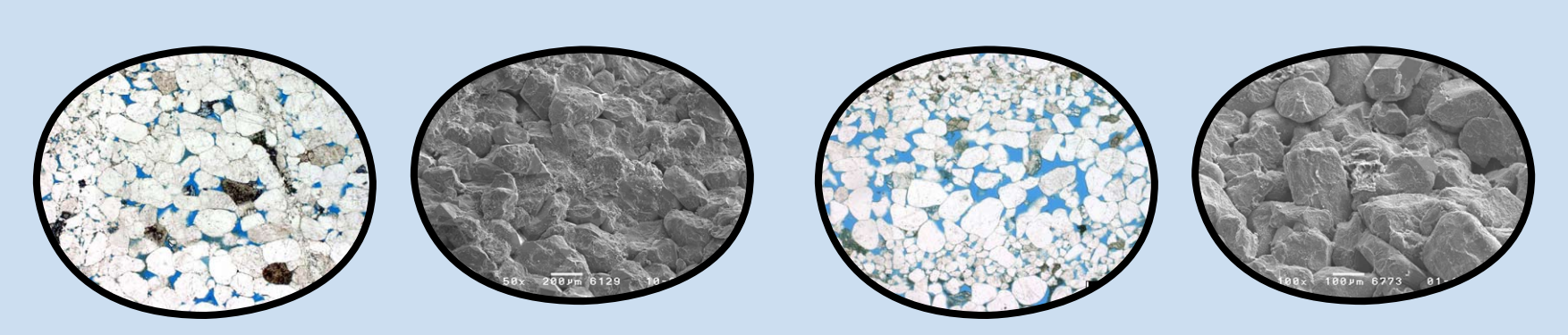


Permeability vs. Porosity Cross Plot by Lithofacies, Lower Navajo

Modern Analog –Little Sahara Dune Field, West-Central Utah

Outcrop Analog – Jurassic Navajo Sandstone, San Rafael Swell, East-Central Utah

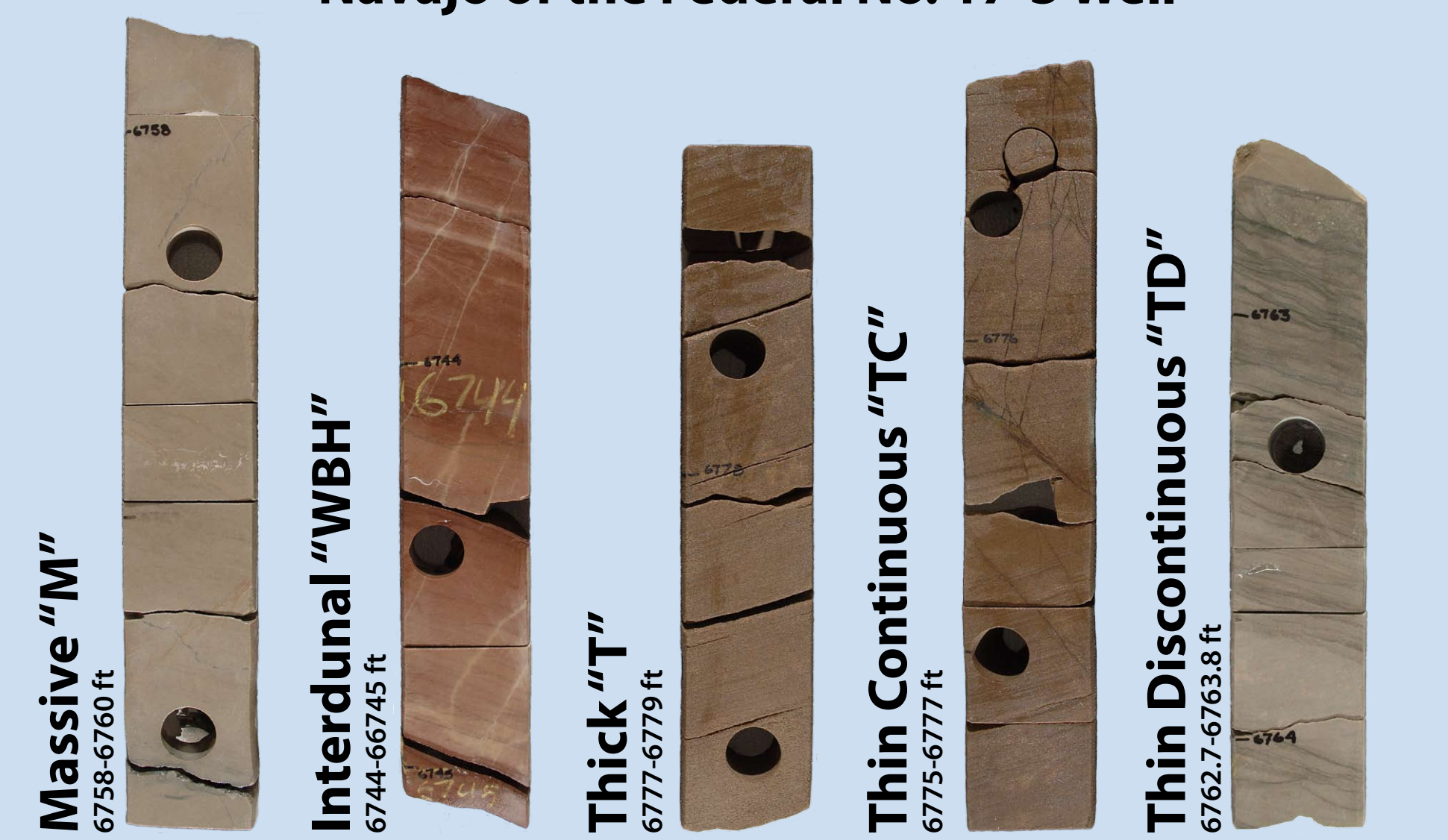
Representative Photomicrographs and SEM Images

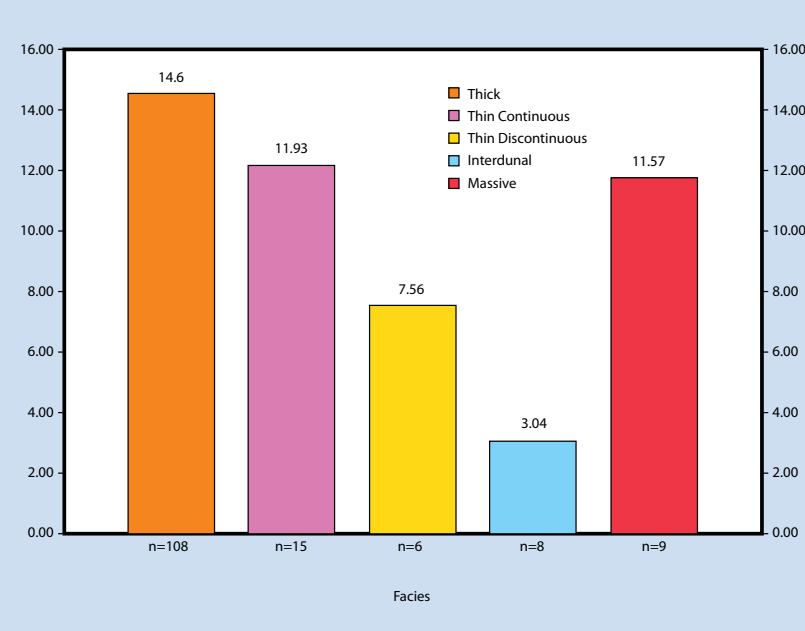


Photomicrograph (plane light) and SEM image from the upper unit of the Navajo Sandstone showing typical well-sorted, subangular to subrounded quartz sand and silt. Note a few fractured and corroded K-feldspar grains are present. Blue space on photomicrograph is intergranular porosity. Federal No. 17-2 well, 6129 ft, porosity = 8.1%, permeability = 17.9 mD

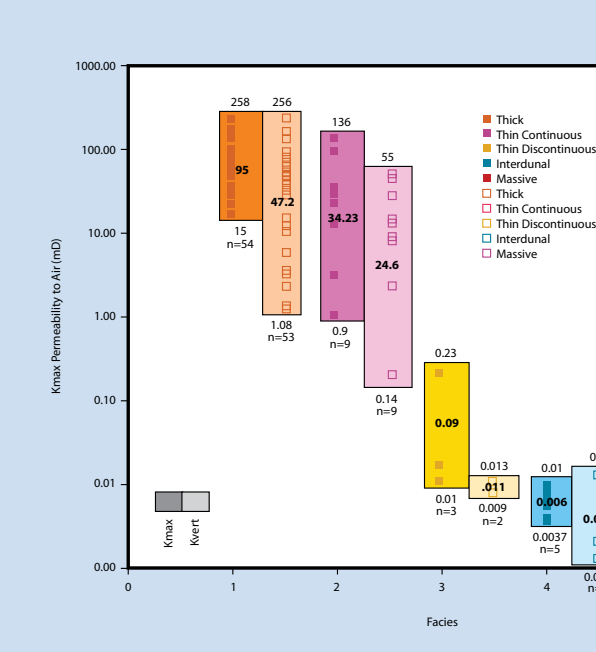
Photomicrograph (plane light) and SEM image from the lower unit of the Navajo Sandstone showing bimodal distribution of subangular to subrounded quartz sand and silt. Blue space on photomicrograph is intergranular porosity. Federal No. 17-3 well, 6773 ft, porosity = 14.8%, permeability = 149 mD

Core Photos of Lithofacies in Lower Navajo of the Federal No. 17-3 Well





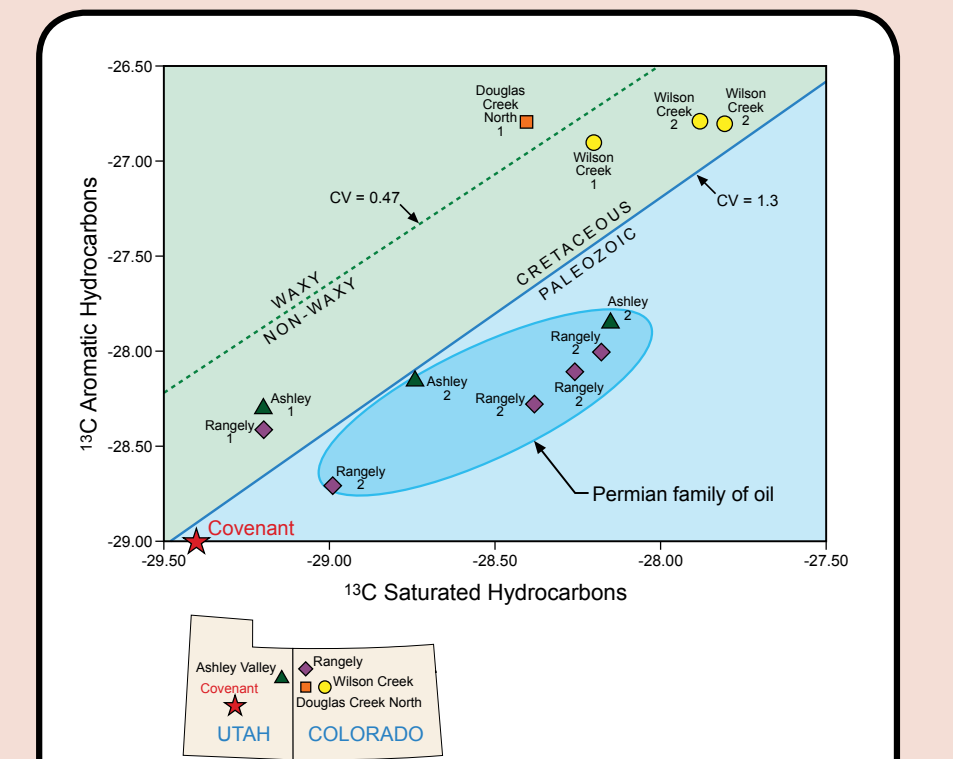
Average Porosity for Lower Navajo Lithofacies



Permeability for Lower Navajo Lithofacies

OIL CHARACTERISTICS

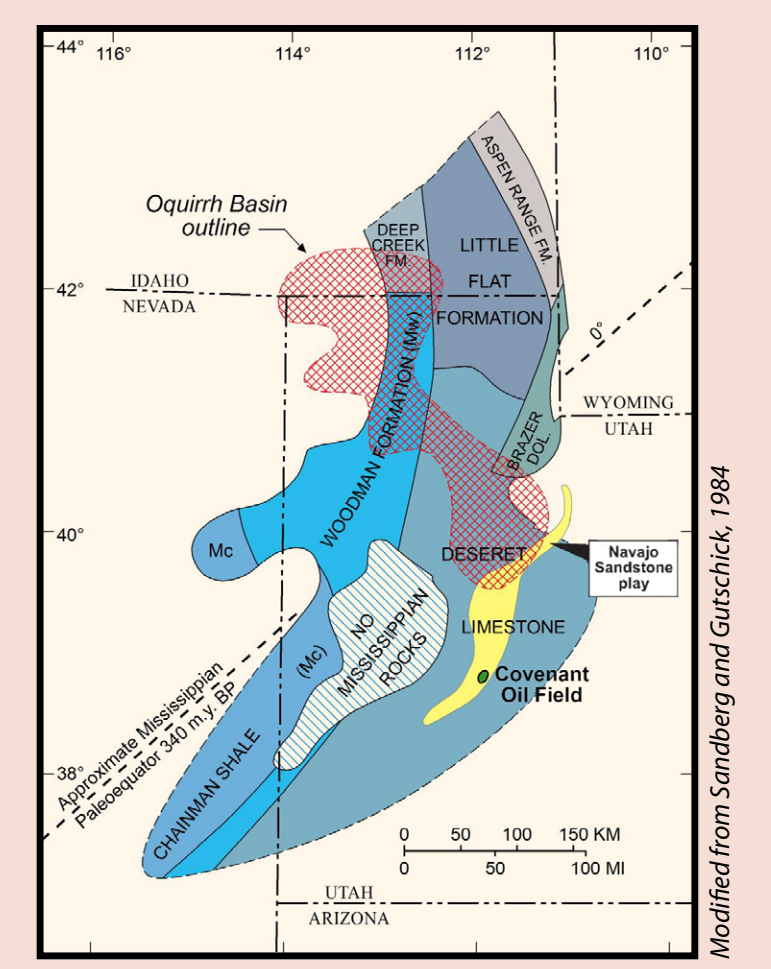
- Oil Gravity – 40.5° API
- Color – dark brown
- Viscosity – 4.0 centistokes @ 77°F
- Pour Point – 2.2°F
- Sulfur – 0.48%
- Nitrogen – 474 parts per million
- Stable Carbon-13 Isotopes – -29.4‰ (saturated) & -29.0‰ (aromatic) hydrocarbons
- Pristane/Phytane ratio – 0.96



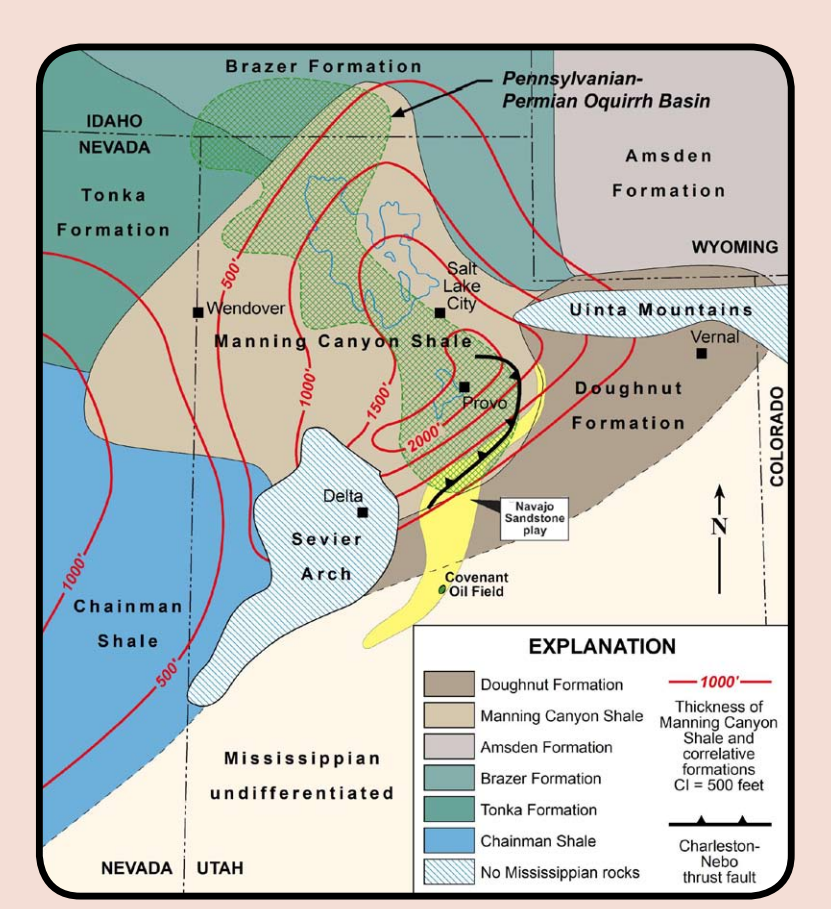
Stable Carbon-13 Isotope Ratios for Saturated vs. Aromatic Hydrocarbons from Covenant Field Oil & Cretaceous & Permian Oils

Units on both axes of the graph depict the carbon isotopes measured in the oil versus the Pee Dee Belemnite (PDB) standard in parts per thousand; a negative value implies the oil sample is depleted in the heavy isotope relative to the standard. Data sources: 1=Sprinkel and others, 1997; 2=Lillis and others, 2003; 3=Baseline DGSI, 2005. CV= Canonical value (Sofer, 1984.)

SOURCE ROCKS



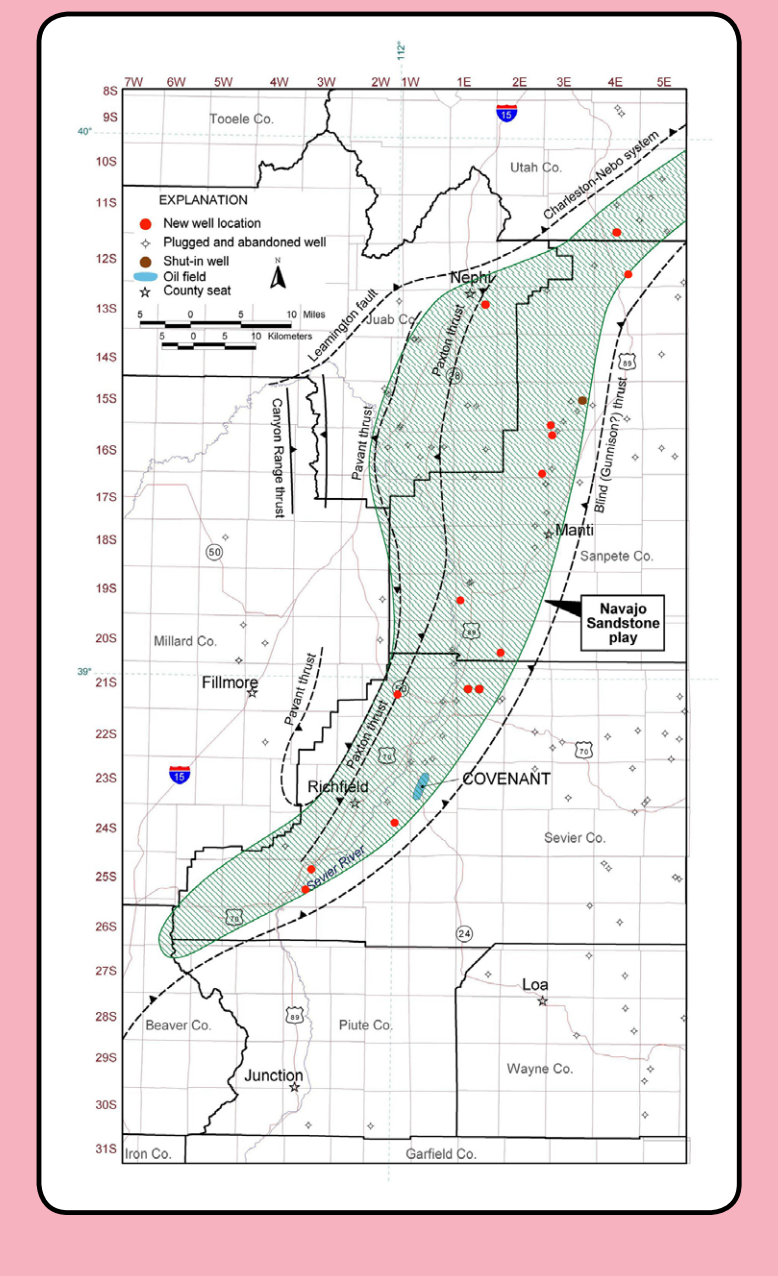
Location of the Mississippian Delle Phosphatic Member Present in the Deseret Limestone & Other Mississippian Formations



Location and Thickness of the Manning Canyon Shale & Correlative Formations

Oil Sample from Kings Meadow Ranches No. 17-1 Well

WHAT'S NEXT?



Potential Drilling Targets

Schematic east-west structural cross section through Sevier Valley, Utah