COVENANT OIL FIELD, CENTRAL UTAH THRUST BELT



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Throne Member); the field averages 3000 barrels of oil and 12,600 bar- Throne dunes were smaller than Navajo dunes (widths up to 1650 feet) rels of water per day, respectively (Utah Division of Oil, Gas, and Mining, (Hartwick, 2010). Regional and Covenant core analyses of the mean dip of The Navajo/White Throne oil-filled reservoir covers about 960 acres. There 2017). The original oil in place is estimated at 100 million barrels; the es- dune foreset beds indicate paleocurrent and paleowind directions were timated recovery factor is 40 to 50% (Chidsey and others, 2007).

fault-propagation/fault-bend anticline, with nearly 800 feet of structural short-lived, and perhaps local marine incursions into the coastal dune drive mechanism is a strong water drive; water saturation is 38%. closure and a 450-foot oil column (Strickland and others, 2005; Chidsey field. These units appear as high gamma-ray zones and contain Bajocianand others, 2007). The structure formed above a series of splay thrusts age (Middle Jurassic) marine palynomorphs (dinoflagellate cysts) in the Cores from the Navajo Sandstone and Temple Cap Formation from Covin a passive roof duplex along the Gunnison thrust and west of a frontal covenant core. The uppermost Esplin Point Member documents a rise in enant field display a variety of eolian desert to coastal lithofacies (dune, triangle zone within the Jurassic Arapien Shale. The Navajo Sandstone, sea level and a return to coastal sabkha, tidal flat, and minor faults which, in Temple Cap Formation, Twin Creek Limestone and are repeated due to an conditions that continued with deposition of the Twin Creek Limestone combination, create reservoir heterogeneity. They also provide the peteast-dipping back-thrust detachment within the structure. The produc- above. The Temple Cap is separated from the underlying Navajo by the tive reservoirs are on the hanging wall of the back thrust. The Navajo and J-1 unconformity (Pipiringos and O'Sullivan, 1978). At Covenant field, all duction practices in the field. A thorough understanding of all the com-Temple Cap reservoirs are effectively sealed by mudstone and evaporite three members are present based on core and geophysical log analysis ponents that created Covenant field may lead to additional large oil and in the overlying Twin Creek Limestone and Arapien Shale. The Covenant (Sprinkel and others, 2009) (they are also present at Providence field but gas discoveries in this vast, under-explored region. The 2008 discovery oil is likely derived from a Carboniferous source within the central Utah non productive). thrust belt (Wavrek and others, 2005, 2007, 2010; Chidsey and others,

In Early (Pliensbachian/Toarcian) Jurassic time, Utah had an arid climate about 200 feet thick. These units are characterized by thick, large-scale, and lay 15° north of the equator (Hintze and Kowallis, 2009). The Nava- trough, planar, or wedge-planar cross-beds (35 to 40°) commonly recogjo Sandstone and age-equivalent rocks were deposited in an extensive nized as classical eolian dune features; contorted bedding, wind ripples, dune field (eolian environment) which extended from Wyoming to Ari- and small-scale cross-beds are also common (Sanderson, 1974; Dalrymzona. Dunes were large to small, straight-crested to sinuous, coalescing, ple and Morris, 2007). Massive, homogenous beds with no distinct seditransverse barchanoid ridges (Picard, 1975). Oases were present in the mentary structures or laminations are also recognized in the Navajo and form of springs or lakes due to the water table being close to the surface were probably formed by water-saturated sand (Sanderson, 1974). for long period of time. Some interdunes were erosional (deflation) areas Biek and others, 2010).

stone and Temple Cap Formation (White conditions of a coastal dune field (Blakey, 1994; Peterson, 1994). White the Temple Cap has lithofacies similar to the Sinawava. The Covenant field trap is an elongate, symmetric, northeast-trending lomitic limestone beds within the White Throne which suggest relatively ers, 2007); permeabilities from the core data are upwards of 100 mD. The

> The productive part of the Navajo Sandstone at Covenant field is about 240 feet thick; the White Throne Member of the Temple Cap Formation is

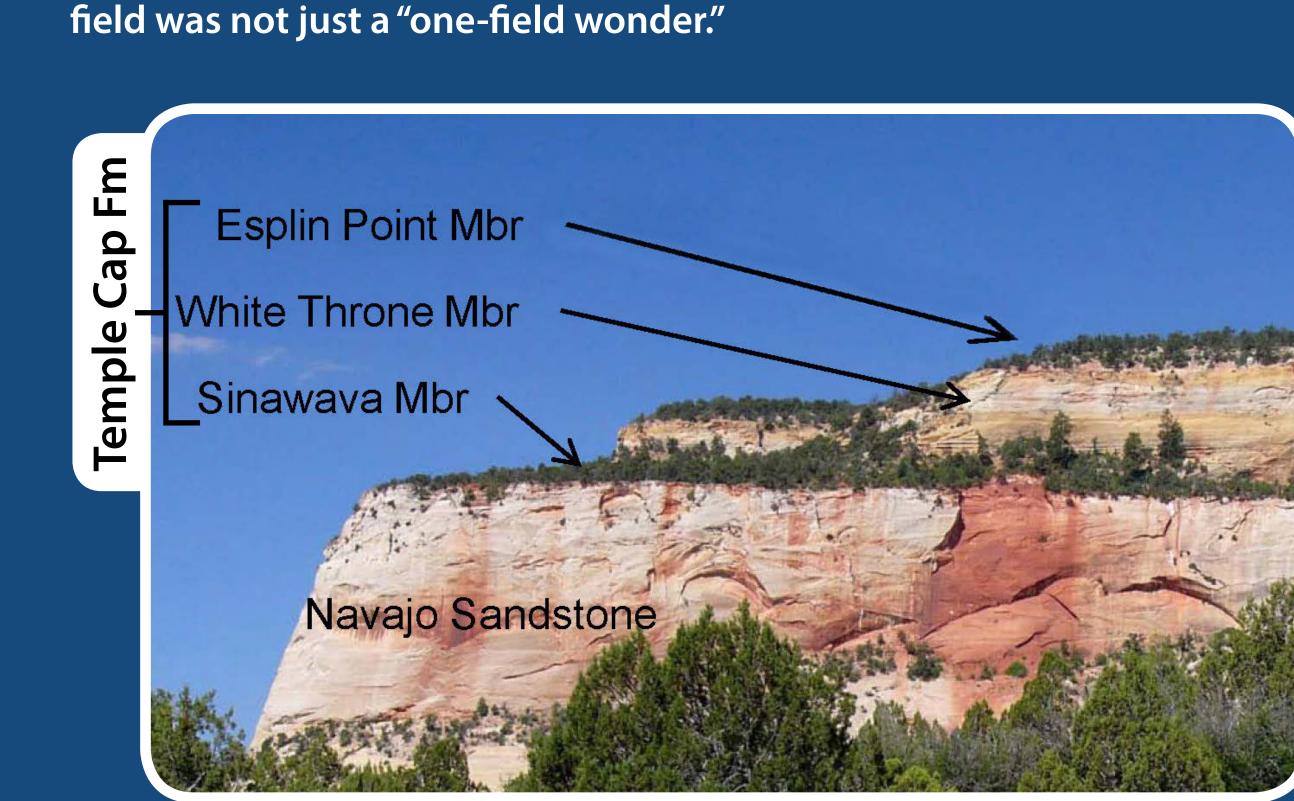
associated with running water, such as a wadi or desert wash. Regional In general, the Navajo Sandstone and White Throne Member consist of analyses of the mean dip of dune foreset beds indicate paleocurrent and very well to well-sorted, very fine to medium-grained (1/16 mm to ½ mm), paleowind directions were dominantly from the north and northwest (Ko-subangular to subrounded, light-yellow-gray sand or silt grains cementcurek and Dott, 1983; Peterson, 1988). Research on the geochronology ed by carbonate cement. However, some intervals show a bimodal grainof detrital zircon grains in the Navajo/Nugget suggests that most of the size distribution representing silty laminae between sand beds. The typisand was eroded from the ancestral Appalachian Mountains, transport- cal sandstone is 97% white or clear quartz grains (usually frosted) with ed to the west by a continental-scale river system to the western shore of some quartz overgrowths, illite, and varying amounts of K-feldspar. Feld-North America during the Jurassic, and was then blown southward into spar is more common in the Navajo than White Rim further indicating a the east gate of Zion National Park. This outcrop serves as an excellent the dune field (Dickinson and Gehrels, 2003, 2010; Rahl and others, 2003; slight variation in depositional environment (Hartwick, 2010). Glauco- analog to the Covenant field reservoir in the central Utah thrust belt. nite near the base of the White Throne suggests a transition to marginal

marine conditions.

fter over 50 years of exploration in the In Middle (Bajocian) Jurassic time, Temple Cap Formation was deposited The Sinawava Member of the Temple Cap Formation is a more heterocentral Utah thrust belt, the 2004 discov- when a shallow seaway spread south-central and geneous, 50-foot-thick section. This unit is characterized by low-angle ery of Covenant oil field proved that the southwestern Utah (Blakey, 1994; Peterson, 1994; Hintze and Kowallis, to horizontal laminae or distorted bedding consisting of redbrown, very 2009; Biek and others, 2010). The Temple Cap is divided into the three fine to fine-grained, thin, poorly sorted sandstone to mudstone, limenembers: the Sinawava (basal), White Throne, and Esplin Point (Sprin- stone, and gypsum (Sprinkel and others, 2009). Horizontal stratification kel and others, 2009, 2011; Biek and others, 2010; Doelling and others, often contains silty laminae between beds. These beds may also display ccumulations of oil. Covenant 2013). The Sinawava Member represents a brief change from eolian des-ripples or channel characteristics (scour) suggesting tidal flow or floodas produced over 24 million barrels of oil ert conditions to coastal sabkha and tidal flat environments. Wind-blown ing events. Again, the presence of glauconite in sandstone indicates masand dunes of the White Throne Member signify a return to eolian dune rine to marginal marine conditions. The Esplin Point Member capping

> dominantly from the northeast (Peterson, 1988; Hartwick, 2010). The close each reservoir. The average porosity for the Navajo Sandstone and White proximity to the coast is indicated by a few thin interbedded marine do- Throne Member is 12% (Strickland and others, 2005; Chidsey and oth-

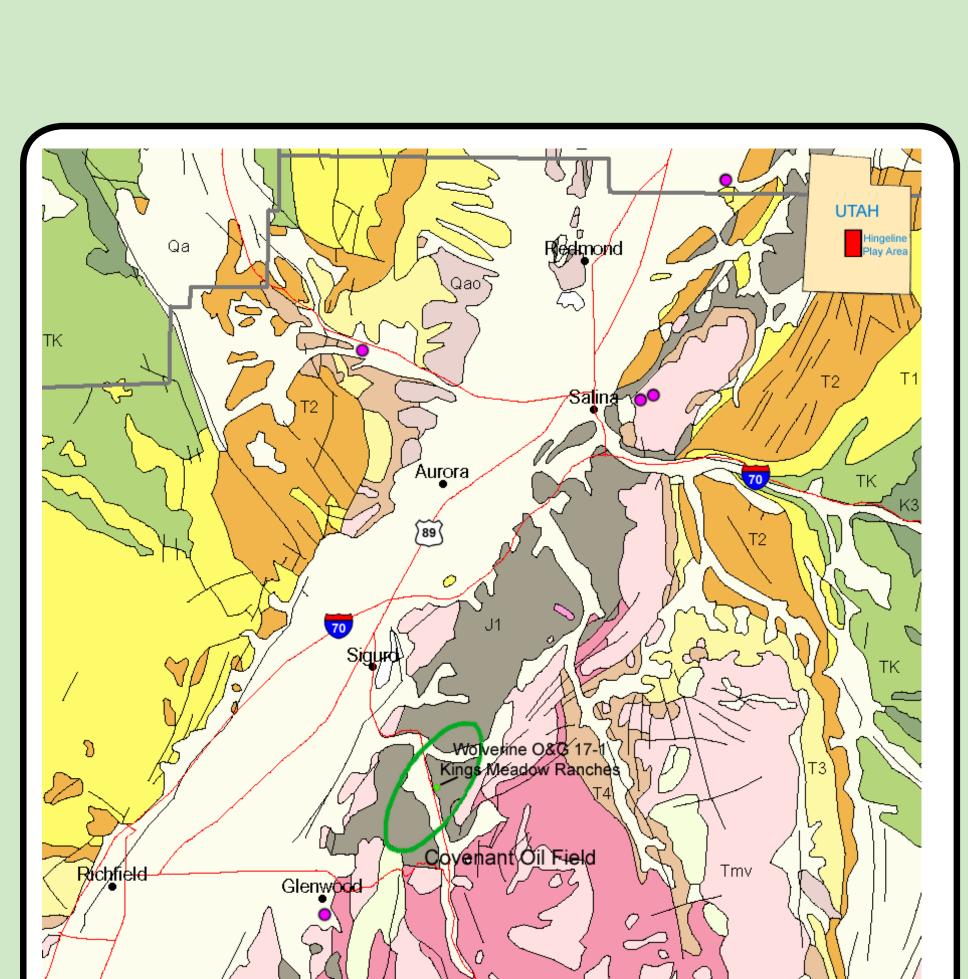
> > of Providence field 20 miles to the northeast confirmed that Covenant



REGIONAL SETTING

Field, Uplifts, and Selected Thrust Systems in the **Central Utah Thrust Belt**

Numbers and sawteeth are on the



Nugget Sandstone

Ankareh Formation

Modified from Hintze, 1980; Sprinkel and Chidsey, 1993; and Peterson, 2001

detached)

Surface Geology, **Covenant Field Area, Sevier County, Utah**

Correlation of the Lower and Middle Jurassic Section in Central Utah

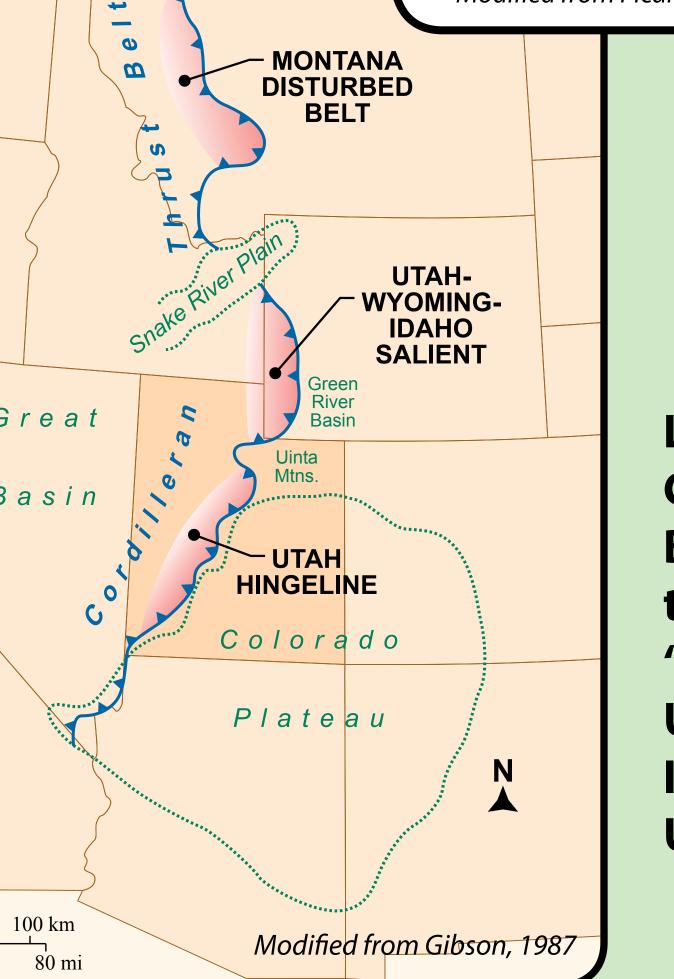
Paxton thrust

Leamington fault

Canyon Range thrust

Navajo Sandstone outcrop

northwest is shown



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

Undivided Cambrian

Stratigraphic Column,

Central Utah Thrust Belt

dolomite, limestone

Oil and gas production

From Sprinkel and others, 2009

Map Unit

Sixmile Canyon 4500

salt core from Redmond quarry in the Arapien north of the town of Salina

Kssp Cretaceous Sanpete & San Pitch Formations PEu Precambrian undivided

- Discovery Well 1 W., Sevier Co., Utah • T.D. – 9382 ft
- IPF 708 BOPD, 1

Production & Reserves

- (May 2017) 3009 BO & 12,613 BW
- 24,009,694 BO & 32,807,283 BW Pour Point – 2.2°F OOIP – 100 million bbls
- **Estimated Recovery Factor – 40%**

- Productive Area 960 acres
- Net to Gross 0.87 Hydrocarbon Column – 450 ft

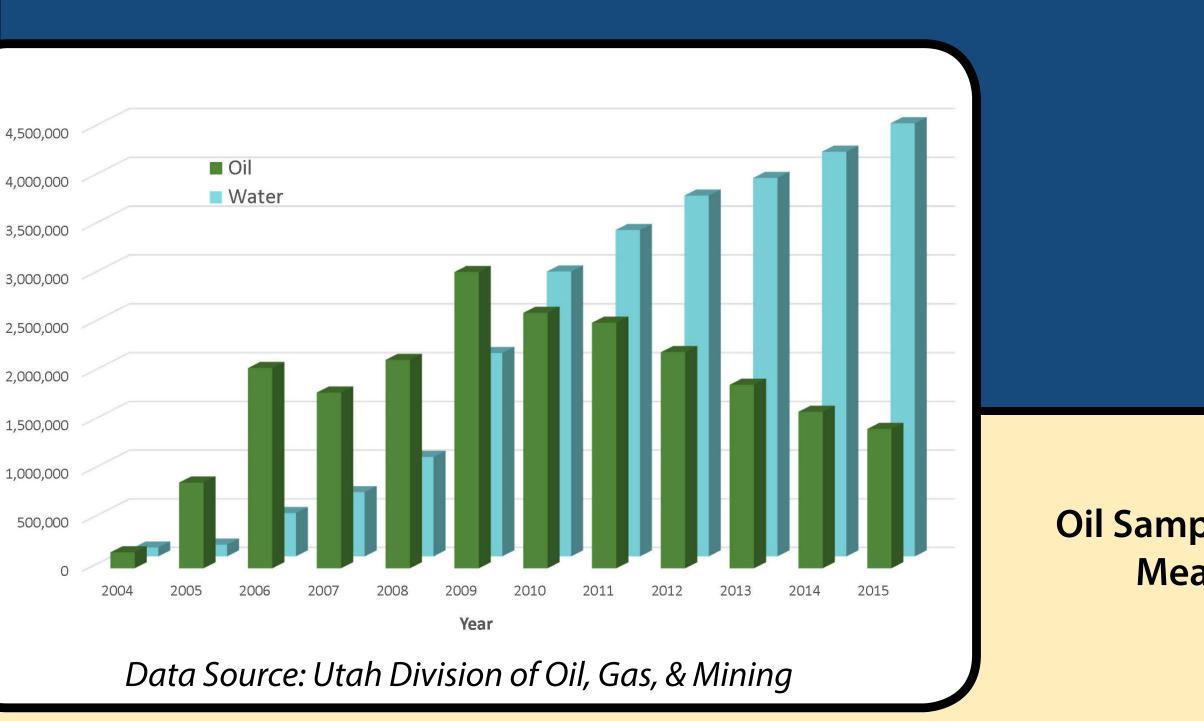
GENERAL FIELD OVERVIEW

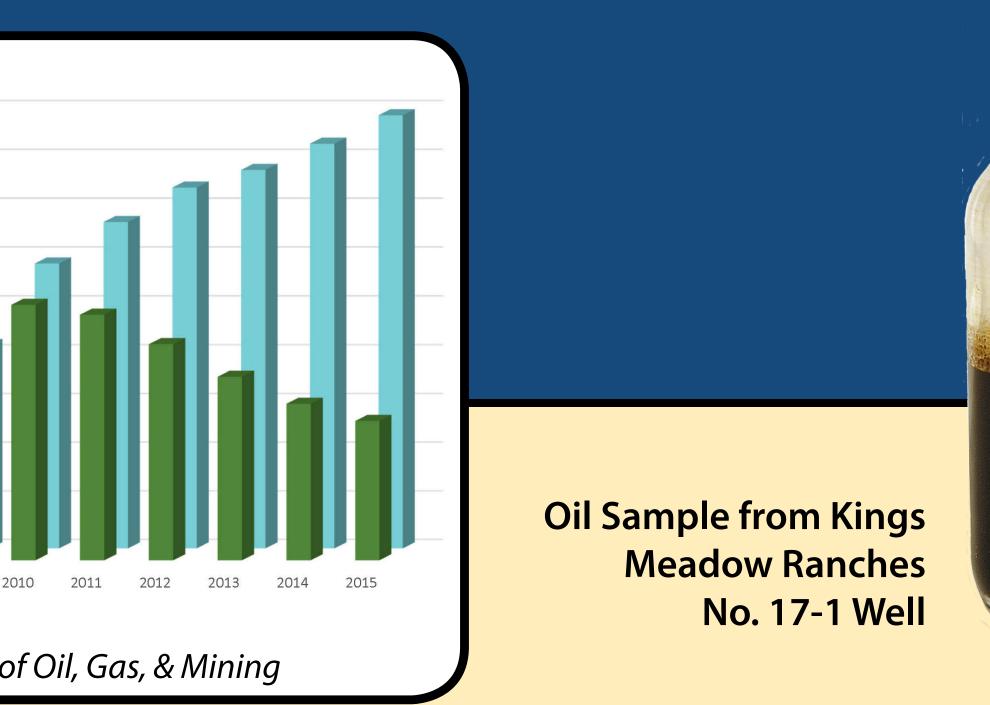
- Permeability up to 300 mD Water Saturation – 38%
- Water Resistivity 0.279 ohm-m @ 77°F,
 - Type of Drive strong water drive
 - Initial Reservoir Pressure 2630 psi

Average Porosity – 12%

Oil Characteristics

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





Production, Covenant Field

Reservoir Seal: Jurassic Arapien Shale

Typical Geophysical Well Log

Sandstone and Temple Cap

Formation, Kings Meadow

Ranches No. 17-1 Discovery

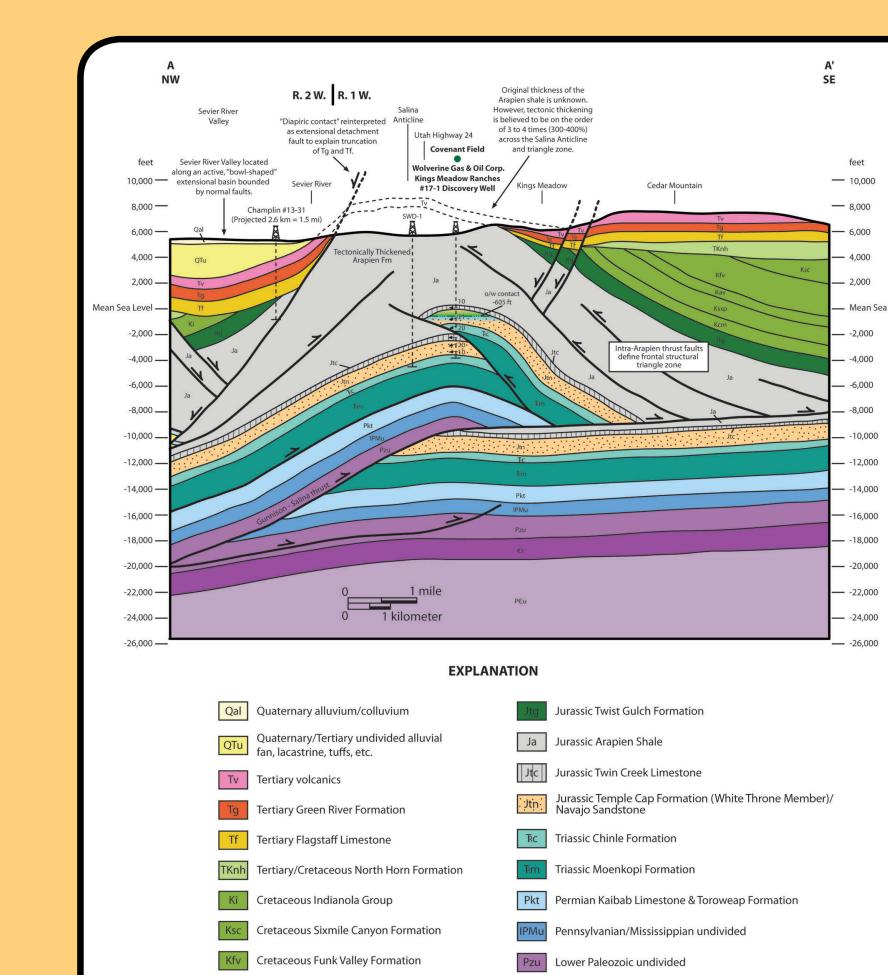
Historical Monthly Oil & Water

of the Jurassic Navajo

Well, Covenant Field



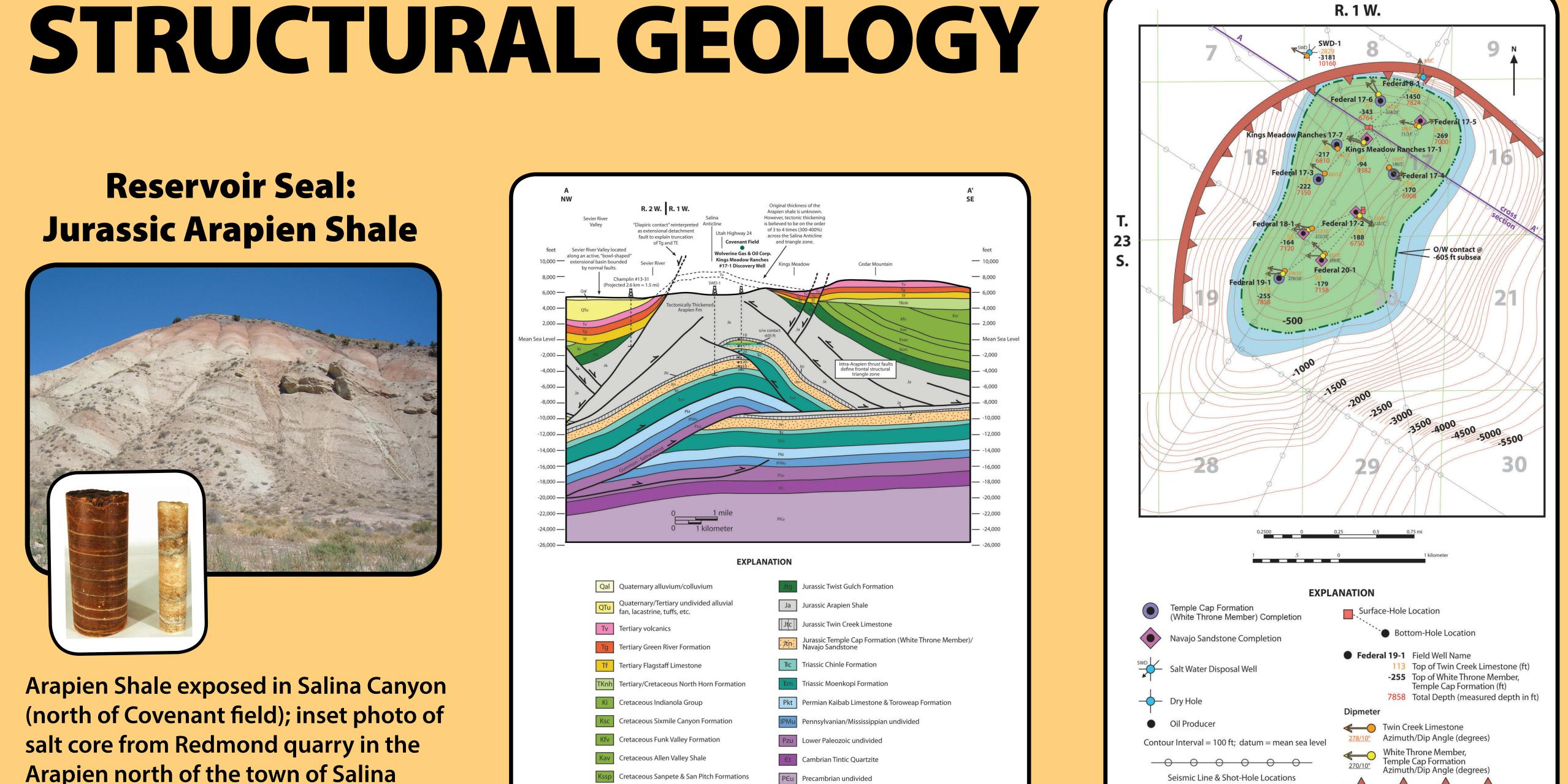
Arapien Shale exposed in Salina Canyon (north of Covenant field); inset photo of



Northwest-Southeast Structural Cross Section, Covenant Field

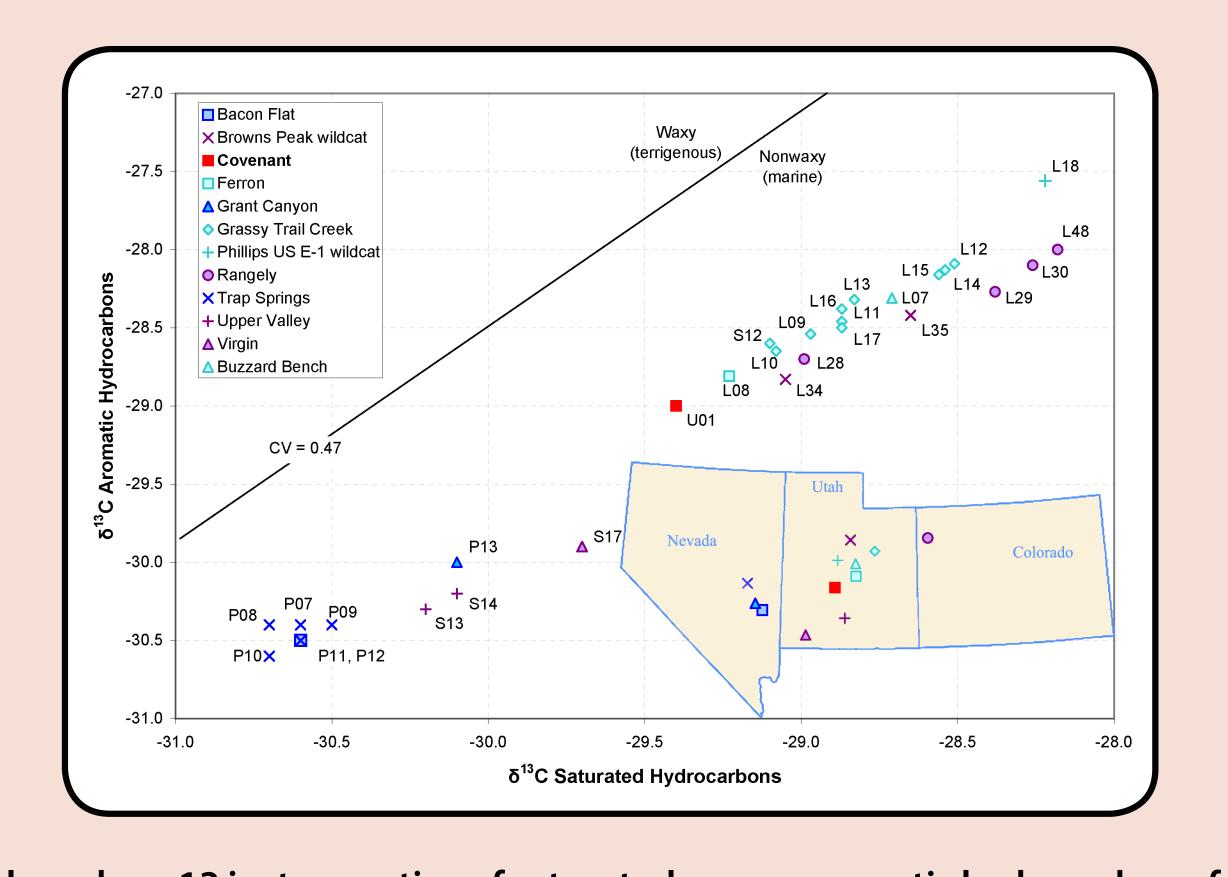
Cretaceous Cedar Mountain Formation

Modified from Schelling and others, 2005

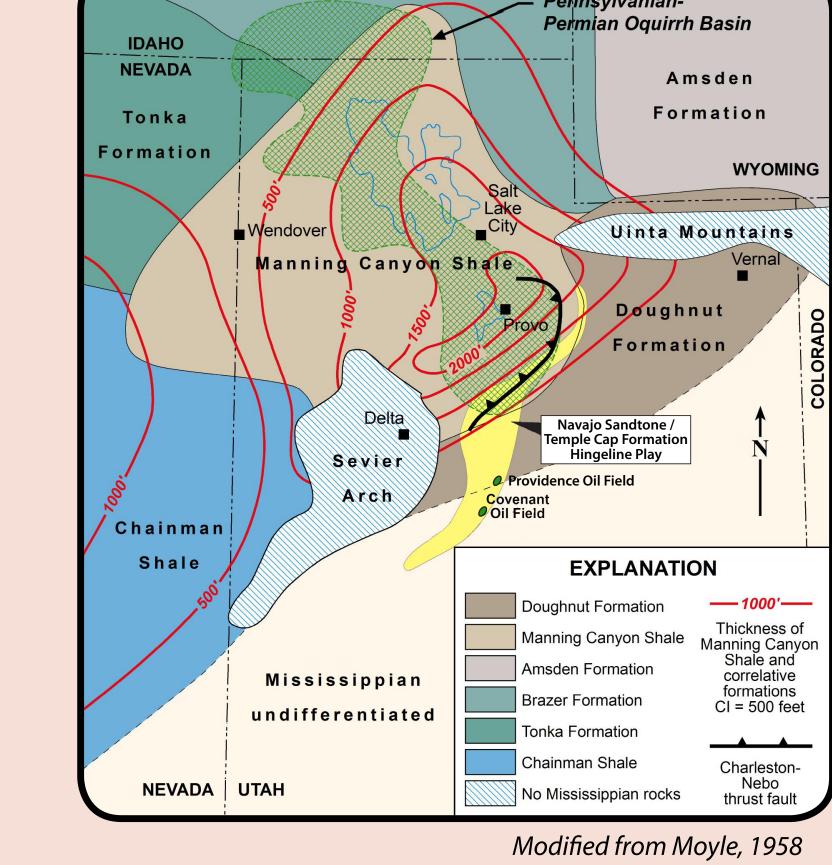


Structural Contour Map, Top of White Throne Member of the Temple **Cap Formation, Covenant Field**

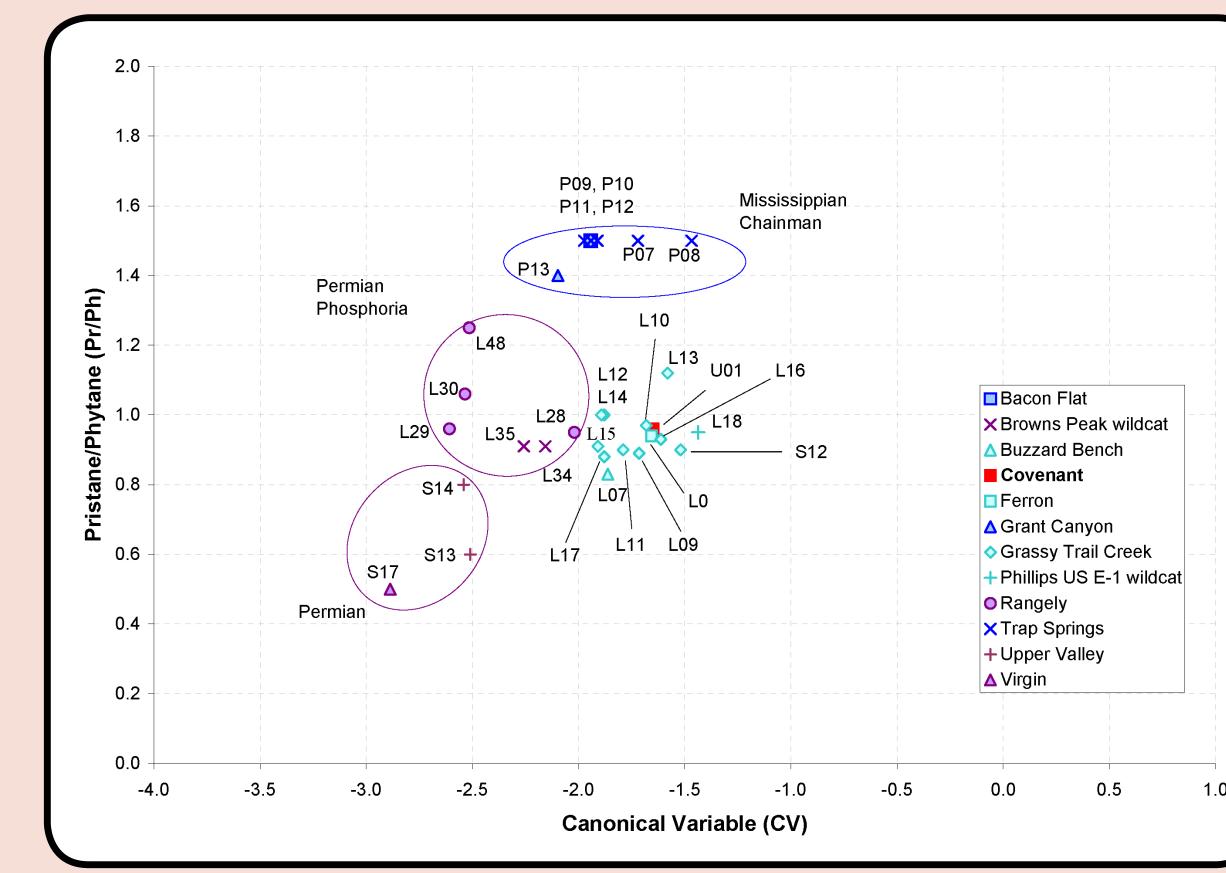
HYDROCARBON SOURCE



Stable carbon-13 isotope ratios of saturated versus aromatic hydrocarbons from the Covenant field oil and other key oils from Utah, Colorado, and Nevada (see inset for field locations). 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. The line labeled CV = 0.47 (CV = canonicalvariable, Sofer, 1984) divides waxy (terrigenous) and nonwaxy (marine) sources, and shows that oils in this region are derived from marine sources. Data sources: Sprinkel and others, 1997; Lillis and others, 2003; Baseline DGSI, 2005.



Location and Thickness of the Manning **Canyon Shale & Correlative Formations**



Canonical variable (CV) versus pristane/phytane values from the Covenant field oil and other key oils from Utah, Colorado, and Nevada (see figure above for field locations). The plot suggests the Covenant field oil is not likely derived from the Mississippian Chainman Shale, a major source of oil in Nevada, or the Permian Phosphoria Formation, a source of oil in Wyoming, northwestern Colorado, and northeastern Utah. This does not preclude the source of oil in the Covenant field from being a local Carboniferous organic-rich source bed. Correlation presented here is based on this plot only; other geochemical parameters should be used to fully evaluate the correlation of oils.

COVENANT FIELD RESERVOIRS: JURASSIC NAVAJO SANDSTONE & TEMPLE CAP FORMATION

Navajo Sandstone / **Temple Cap Formation** Lithofacies Recognized in **Core from the Federal** No. 17-3 Well

sists of thin, graded, tabular grainfall lami-

TC - Thin Continuous: sand layer conuously bedded, trough, planar, or wedgeplanar 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.

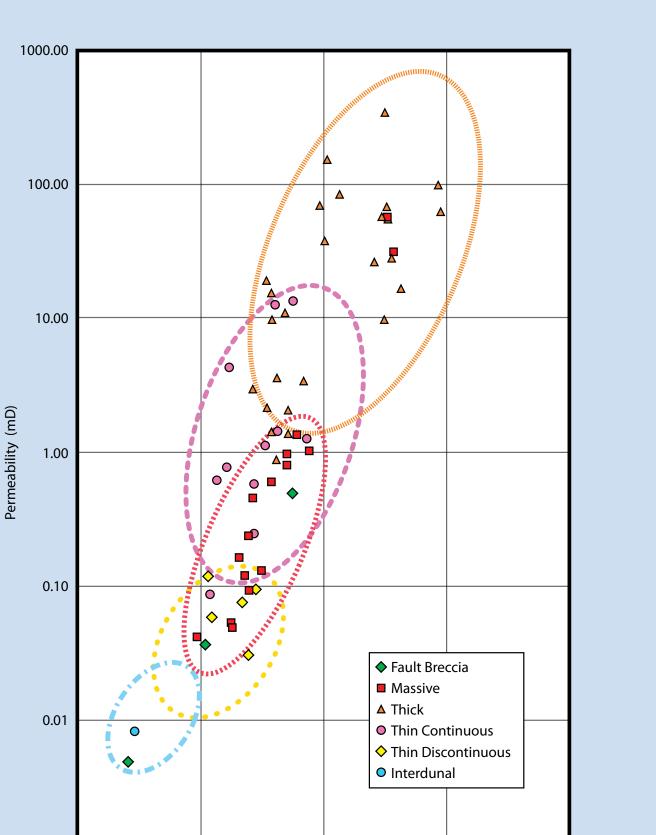
strata are representative of dune toe litho-

WBH – Interdunal to Coastal Sabkha / Tidal Flat to Marine: 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.

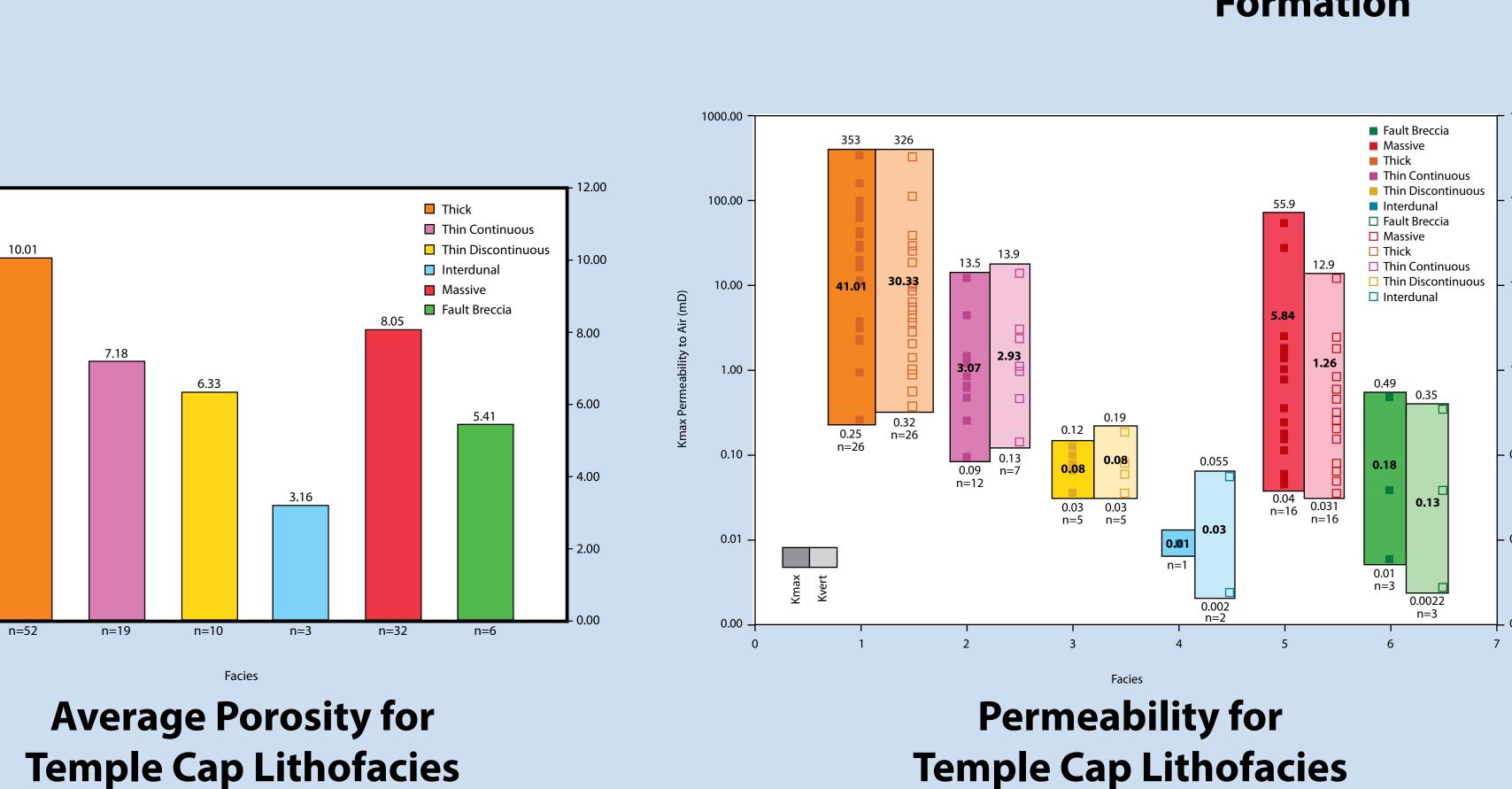
FB - Fault Breccia: Breccia resulting from core of the Federal No. 17-3 well.

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-
- Pore Types primary intergranular, fracture
- 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 in White Throne Member



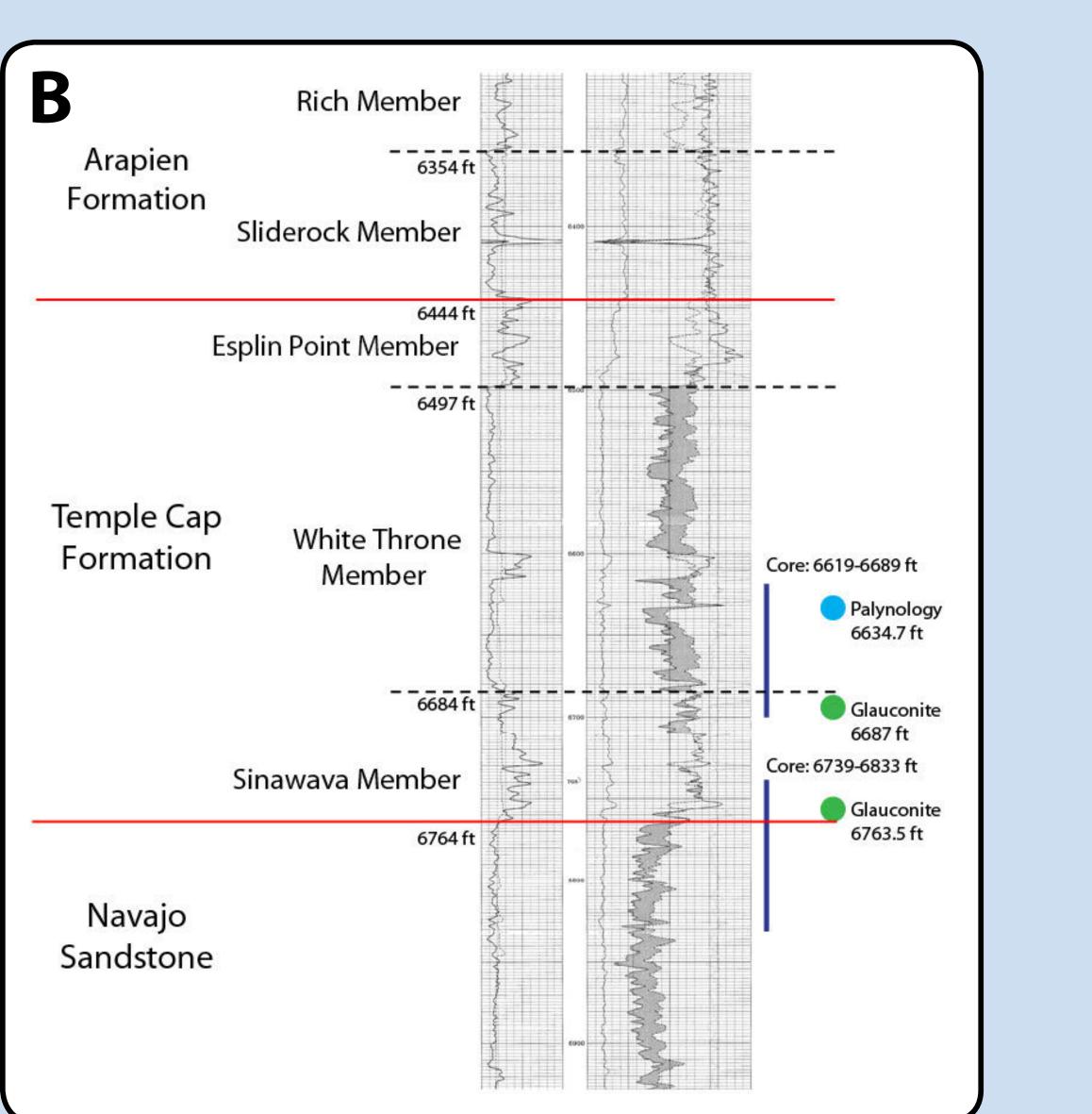
Permeability vs. **Porosity Cross Plot by** Lithofacies, Temple Cap





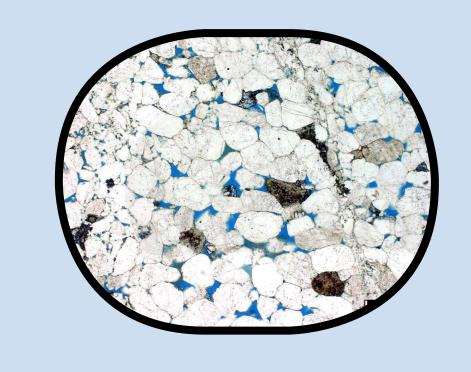
the White Throne Member of the Temple Cap Formation, Federal No. 17-3 well, 6634.7 feet.

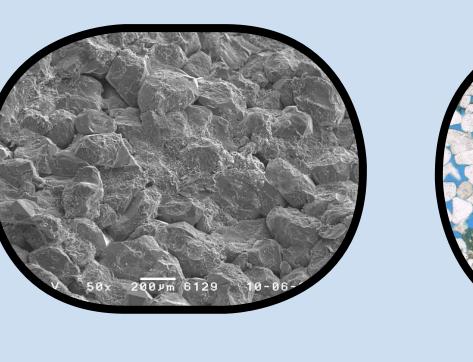
Courtesy of Gerald Waanders,

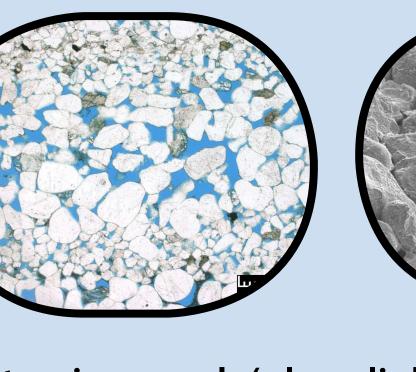


True Vertical Depth (A) and Measured Depth (B) Geophysical Well Log of the Cored Section of Jurassic Navajo Sandstone and Temple Cap Formation,

Representative Photomicrographs and SEM Images



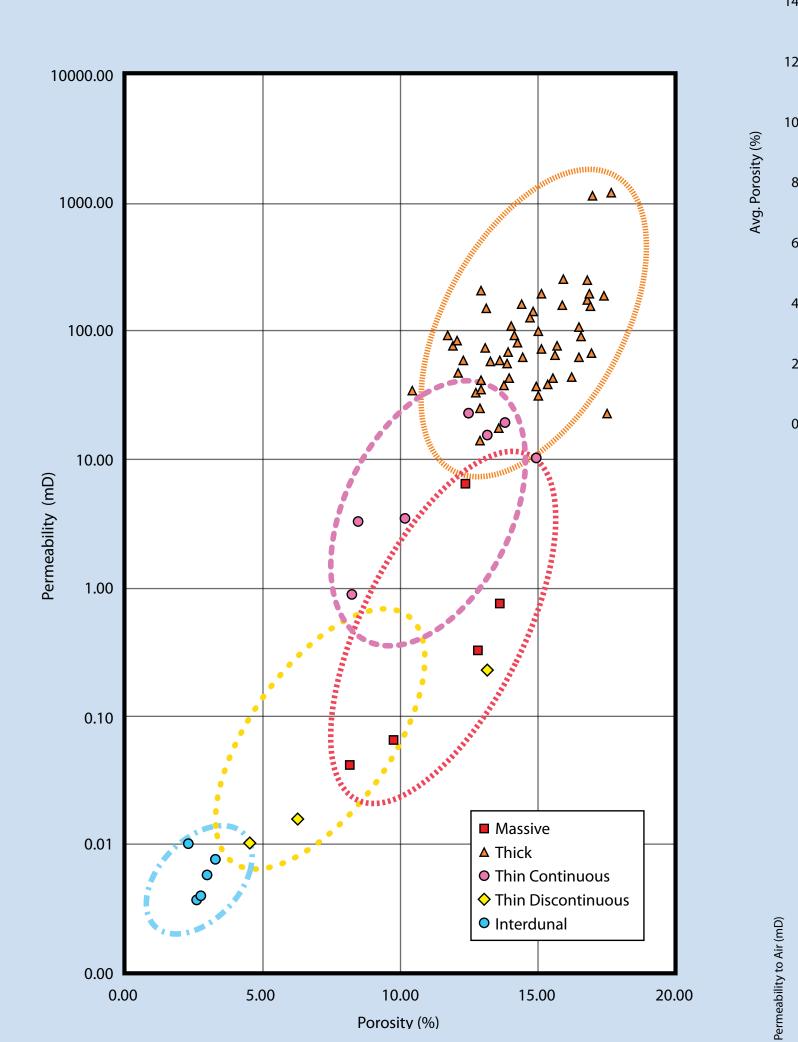




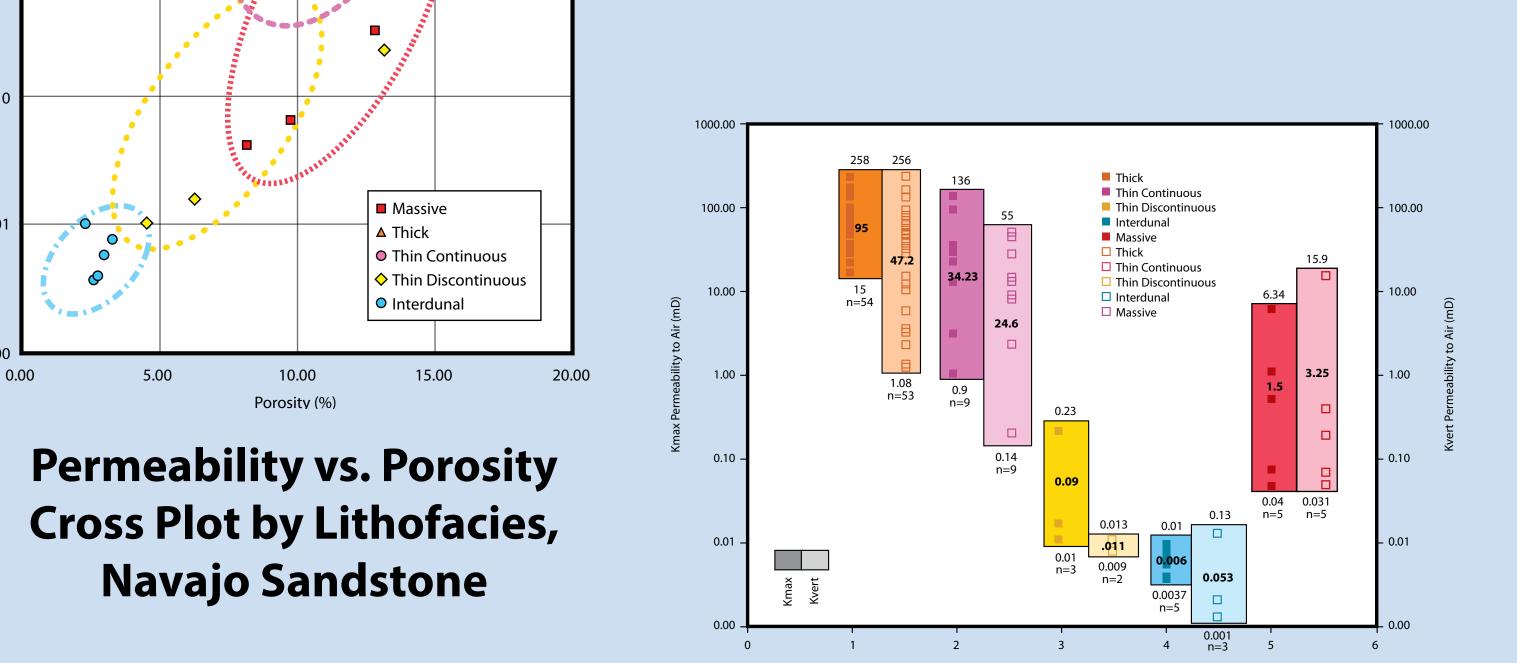
graph is intergranular porosity. Federal No. 17-3 ity = 149 mD

Average Porosity for

Navajo Lithofacies

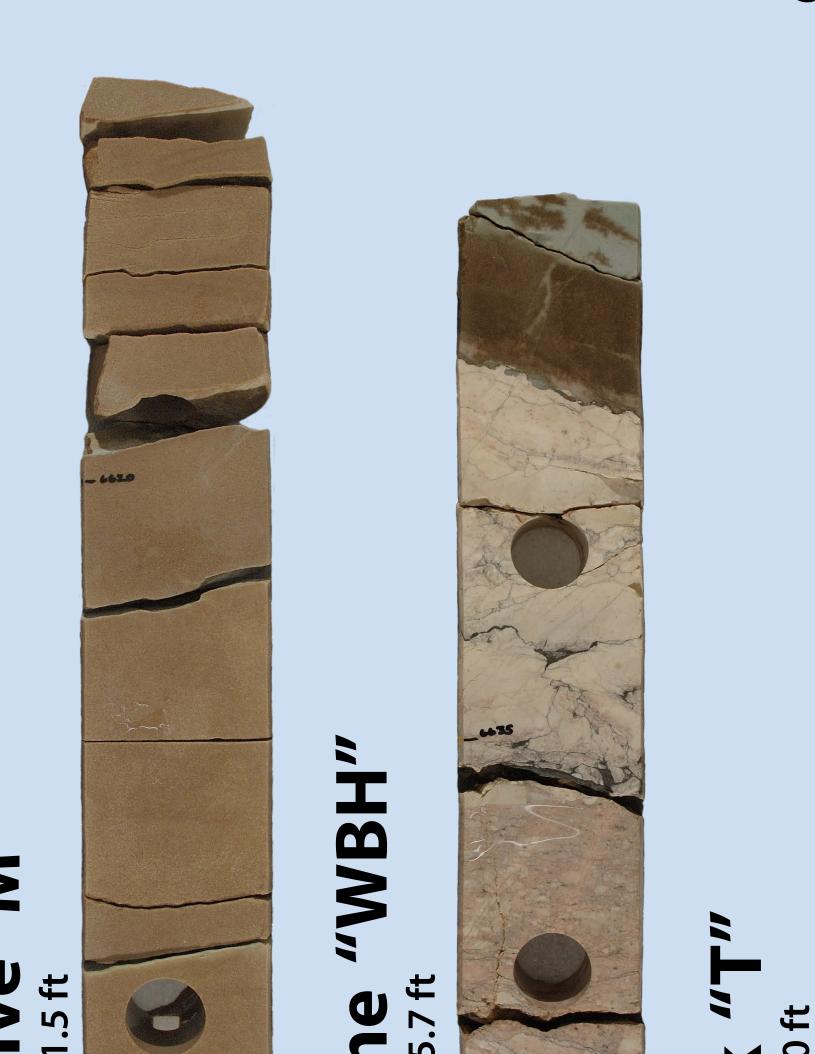


well, 6129 ft, porosity = 8.1%, permeability =



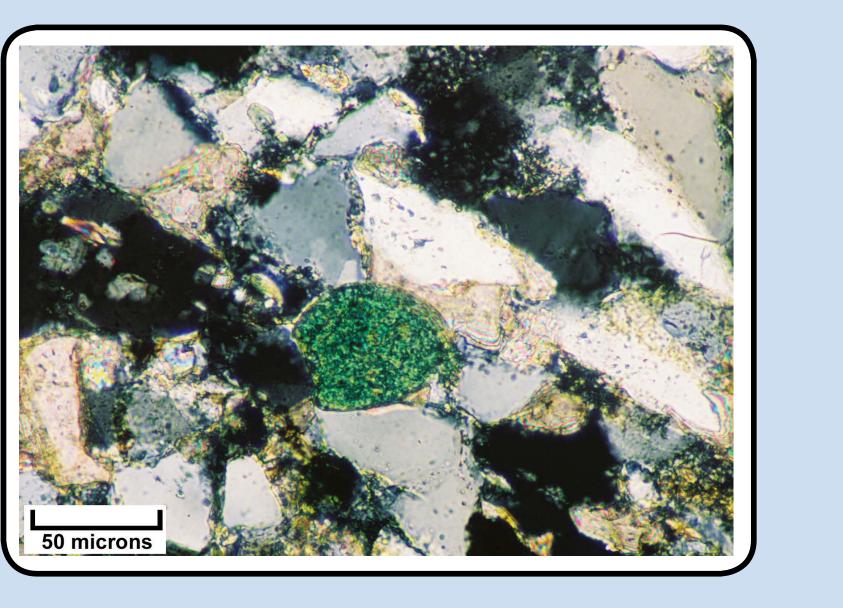
Permeability for **Navajo Lithofacies**

Core Photos of Lithofacies in Temple Cap Formation of the Federal No. 17-3 Well





Thin 6648-664



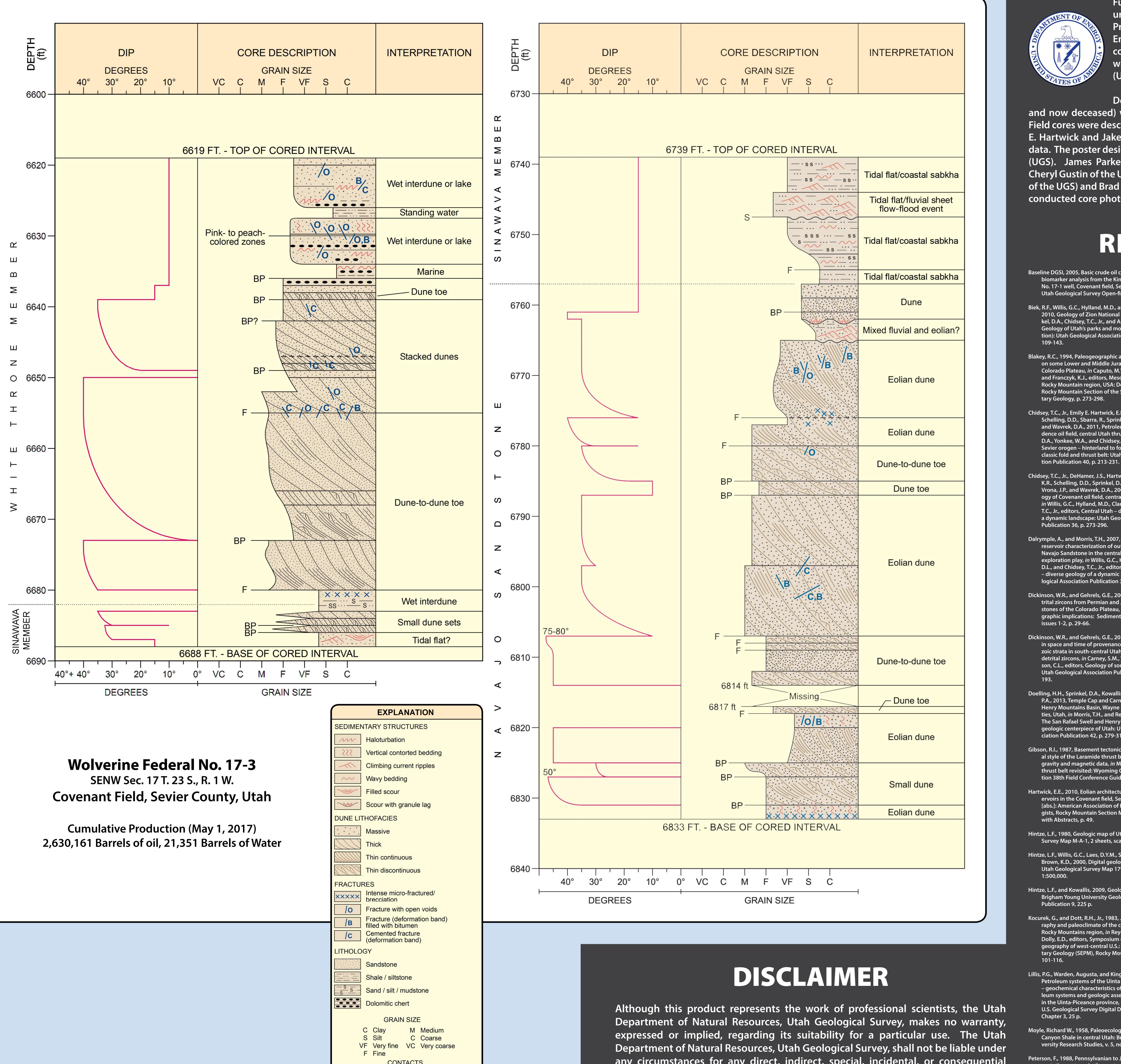
Photomicrograph (crossed nicols) of a single glauconite grain (green) within a matrix base of the White Throne Member of the Temple Cap Formation, Federal No. 17-3 well

> Courtesy of David E. Eby, Eby Petrography & Consulting, Inc.

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



Core Description



any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

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REFERENCES

tion of Geologists Open-file Report, 54 p.

tion of Petroleum Geologists Guidebook, p. 109-12

Geological Survey Professional Paper 1035-A, 29

Sandstone, Utah: Geology, v. 31, no. 9, p. 761-76

Sprinkel, D.A., Castaño, J.R., and Roth, G.W., 1997, Emerg

Pipiringos, G.N., and O'Sullivan, R.B., 1978, Principal ur

Rahl, J.M., Reiners, P.W., Campbell, I.H., Nicolescu, S., and

Geology Studies, v. 21, pt. 1, p. 215-246.

Biek, R.F., Willis, G.C., Hylland, M.D., and Doelling, H.H

Rocky Mountain region, USA: Denver, Colorado,

Chidsey, T.C., Jr., Emily E. Hartwick, E.E., Johnson, K.R.,

K.R., Schelling, D.D., Sprinkel, D.A., Strickland, D.K.

Schelling, D.D., Strickland, D., Johnson, K.R., Vrona, J.P. D.L., and Chidsey, T.C., Jr., editors, 2007, Central Utah

graphic implications: Sedimentary Geology, v. 16

Hintze, L.F., and Kowallis, 2009, Geologic history of Utah:

Rocky Mountains region, in Reynolds, M.W., and eography of west-central U.S.: Society for Sedimen

Lillis, P.G., Warden, Augusta, and King, J.D., 2003, in the Uinta-Piceance province, Utah and Colorado

eolian deposits of the western interior of the United

States: Sedimentary Geology, v. 56, p. 207-260.

Rocky Mountain Section Meeting, Official Program Kocurek, G., editor, Late Paleozoic and Mesozoic

November 2017

boniferous versus Permian petroleum systems in

Wavrek, D.A., Schelling, D.D., Sbarra, R., Vrona, J.P., and