## GEOLOGY AND GEOCHEMISTRY





Tight rock analysis from the Hovenweep and Gothic shales belonging to the Jefferson State 4-1 well. Gas-filled porosity and permeability values are on the low end of the shale reservoir quality spectrum.												
Zone	Depth (feet)	As-Received Bulk Density (g/cm <sup>3</sup> )	As-Received Grain Density (g/cm <sup>3</sup> )	Dry Grain Density (g/cm <sup>3</sup> )	Porosity (% BV)	Water Saturation (% of PV)	Gas Saturation (% of PV)	Mobile Oil Saturation (% of PV)	Gas-Filled Porosity (% of BV)	Bound Hydrocarbon Saturation (% of BV)	Bound Clay Water (% of BV)	Pressure-Decay Permeability (md)
Hovenweep	5904.70	2.616	2.693	2.716	4.05	11.97	71.28	16.75	2.88	0.68	4.26	0.000070
	5929.70	2.624	2.676	2.691	2.69	12.48	71.91	15.60	1.94	0.56	4.44	0.000064
Gothic	6029.80	2.656	2.690	2.697	1.61	7.31	77.45	15.24	1.25	0.44	3.04	0.000057
	6030.60	2.624	2.698	2.706	3.16	4.61	87.71	7.68	2.77	0.55	4.08	0.000065

# THIN SECTIONS

### JEFFERSON STATE 4-1 WELL

Reflected ultra-violet light ifluorescent light with blue-violet filter) demonstrates a ity-only image, and most micropores appear orange in this view. This reflected light technique only demonstrates the presence of pores and has no validity in predicting their quantitative occurrence. From



top to bottom the approximate scale is 0.5 mm. 5930.8 feet.

#### MULE 31-K WELL

Plane-polarized view of dolostone interbed within Chimney Rock shale. Dolomite crystals are clearly bimodal; dark material represents pyrite and low carbonaceous material. From top to bottom the approximate scale is 1.0 mm. 6106 feet



rescent view of the image ne left illustrates presence of porosity in orange hues. I shades usually indicated From top to bottom the approximate scale is 1.0 mm. 6102 feet.

Closer view, under plane-

here, and the carbona

Cross-nicols view of upper Chimney Rock interval reveals mixed mineralogy, including very finely crystalline dolomite in mud matrix. From top to bottom the approximate scale is 1.0 mm. 6102 feet.

under plane-polarized light of Hovenweep nudstone quite typical of most mudstones in these Pennsylvanian deposits. Terrigenous clastics are white here, pyrite and carbonaceous material appear black, clays and

at this magnification. From top to bottom the

approximate scale is 2.3

mm. 5930.8 feet.



verview of dolomitic/calcareous mudstone that is characterized a wavy-laminated matrix primarily composed of clay minerals. Sil size crystals and concretions of calcite (ca) and dolomite (do) are dispersed in the matrix together with detrital silt (s). (Scale bar = 30 microns). 6102.4 feet.

## SCANNING ELECTRON MICROSCOPY—MULE 31-K WELL





Visible porosity in the dolostone is significantly reduced by authigenic cements including clays that fill most intercrystalline micropores between euhedral dolomite (+) and coat detrital quartz silt (q). (Scale bar = 2 microns). 6099 feet.



errigenous material, fossils, an clays. Mottled appearance ma be related to some bioturbation In this well, the Gothic i decidedly fractured, and in this view a subvertical fracture is posed of red-stained calcite genetic minerals. From top to tom the approximate scale is 1.0 mm. 6036.6 feet.



Epifluorescent view of dolostone interbed again illustrates presence of pores in orange. Routine core analysis of sample produced ~4% porosity here. From top to bottom the approximate scale is 1.0 mm.





Another closer view at same magnification showing authigenic cements such as silica (si) and flaky minerals including chlorite (ch filling intercrystalline cavities between dolomite rhombs (do). (Scale bar = 2 microns). 6099 feet.

Hoven

Lower



## GEOCHEMISTRY

Basic geochemical measurements from Jefferson State 4-1 well.											
	Depth	TOC	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Tmax		OI	S <sub>1</sub> /TOC	PI	Calculated Ro
	(feet)	(wt. %)	(mg/g)	(mg/g)	(mg/g)	(°F)	HI				
nay	5876.4	1.17	0.49	1.07	0.30	461	92	26	42	0.31	1.14
eep -	5903.3	1.77	1.90	2.50	0.45	444	141	25	108	0.43	0.83
	5930.4	1.39	1.49	2.12	0.56	442	152	40	107	0.41	0.80
nay -	6009.3	0.46	0.79	0.44	0.63	397	95	138	172	0.64	N/A
	6017.5	0.05	0.03	0.10	0.23	473	193	453	60	0.24	1.35
	6030.4	1.32	0.84	1.52	0.48	445	115	37	63	0.36	0.85
	6036.6	0.78	0.97	0.74	0.52	432	95	67	124	0.57	0.62

 $S_1$  is the amount of free hydrocarbons (gas and oil) in the sample (in milligrams of hydrocarbon per gram of rock). If  $S_1 > 1$  mg/g, it may be indicative of an oil show.

 $S_2$  is the amount of hydrocarbons generated through thermal cracking of nonvolatile organic matter.  $S_2$  is an indication of the quantity of hydrocarbons that the rock has the potential of producing should burial and maturation continue.  $S_3$  is the amount of  $CO_2$  (in milligrams  $CO_2$  per gram of rock) produced during pyrolysis of kerogen.  $S_3$  is an indication of the amount of oxygen in the kerogen. Tmax is the temperature at which the maximum release of hydrocarbons from cracking of kerogen occurs during pyrolysis (top of  $S_2$  peak). Tmax is an indication of the stage of maturation of the organic matter. HI is the hydrogen index (HI =  $[100 \times S_2]/TOC$ ). OI is the oxygen index (OI =  $[100 \times S_3]/TOC$ ). PI is the production index (PI =  $S_1/[S_1 + S_2]$ ).

Kerogen type determination from TOC and Rock-Eval pyrolysis data. Types I and II will generate oil, type III, gas; and type IV, little or no hydrocarbon.

## BIOTICS



somewhat rare fossils are accompanied by additional examples of brachiopods (inarticulat and articulate), ostracods, conodonts, and agglutinated foraminifera.