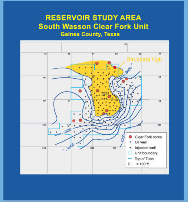
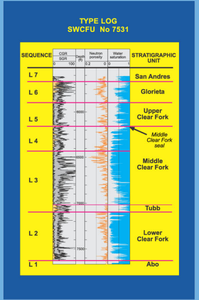
RESERVOIR GEOLOGY AND PETROPHYSICS

RESERVOIR SETTING



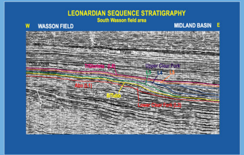
Structural setting of South Wasson Clear Fork field showing well and cored well control.



Key fieldwide log and reservoir issues.

1. The reservoir seal for the upper Clear Fork reservoir is at the top of the L4 sequence boundary.
2. The reservoir seal for the lower Clear Fork reservoir is at the top of the L2 sequence boundary (base of the Tubb).
3. Conventional gamma-ray logs are not accurate for correlation because of abundant and variable uranium.

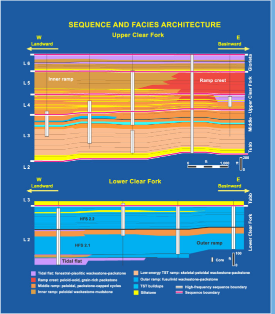
SEQUENCE STRATIGRAPHY AND CYCLICITY

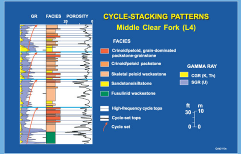


2-D seismic data document the occurrence of a major sea-level fall and basinward stepping during Leonardian sequence L 4. This event is documented in outcrop and the reservoir by abundant updip, silt-rich carbonates. The L4/L5 sequence boundary formed by this sea-level fall forms the reservoir top seal for the upper Clear Fork reservoir at South Wasson field. Similarly, the L2/L1 sequence boundary forms the top seal for the lower Clear Fork reservoir.

The South Wasson reservoir succession is consistent with the outcrop model. Notable similarities include

1. accommodation trends in lower Clear Fork high frequency sequences (HFS L 2.1 and L 2.2),
2. upper Clear Fork systems tracts and architecture,
3. facies and facies-stacking patterns, and
4. porosity trends.



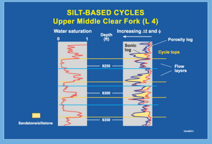


South Wasson Clear Fork cyclicity and facies stacking are also consistent with outcrop analogs. Key similarities include

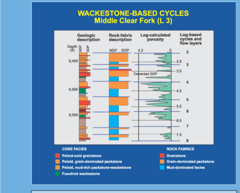
1. cycle thickness (average: 10 ft),
2. facies-stacking patterns,
3. cycle amalgamation in ramp crest, and
4. facies- and cycle-controlled porosity development (highest porosity in cycle tops).

Note again the lack of correlation between gamma-ray and carbonate facies or cyclicity.

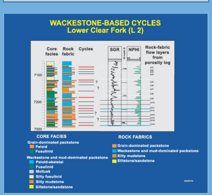
CALIBRATION OF CYCLES, ROCK FABRICS, AND POROSITY FOR FLOW-UNIT CORRELATION



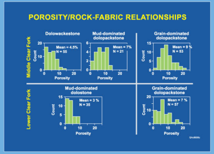
Siltstone-based cycles in the upper part of the middle Clear Fork are easily defined by acoustic and porosity logs. Flow layers are defined by more porous, grain-dominated dolostones at cycles tops and less porous, mud-dominated silty dolostones at cycle bases.



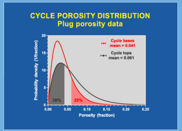
Critical to the calibration of cores to wireline porosity logs is the definition of rock fabrics using thin sections. The example above shows a good correspondence among facies, rock fabrics, porosity zones, and cycle tops. Where exceptions are encountered, as with the locally cemented grain-dominated packstone (above), correlations are carried from offsetting wells.



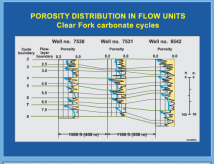
Correlations between facies, rock fabric, cyclicity, and porosity are equally good from the lower Clear Fork. Although porosity in the upper cycles is relatively continuous, porosity in the lower cycles is very discontinuous, and many cycle tops must be extended from picks in adjacent wells.



Because of the presence of variable amounts of uranium, the gamma-ray log is useless for detailed correlation. Only porosity, acoustic, and resistivity logs are usable for rock-fabric correlation. Silt-rich zones can be identified by porosity-acoustic overlays and by resistivity logs. Carbonate rock fabrics, however, are definable only with porosity logs. Both outcrop and subsurface data (above) demonstrate that higher porosity tends to be developed in grain-dominated fabrics. This relationship is used to correlate carbonate cycle tops.



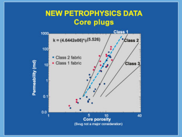
Statistical analys of porosity in cycle tops and bases (upper and lower rock-fabric flow layers) show that the mean porosity of cycle tops is greater than that of cycle bases at the 95% confidence level. Nevertheless, there is a 38-percent chance that a value less than 4 percent will be in a cycle top and a 20-percent chance that a porosity greater than 6 percent will be in a cycle base.



Using porosity as an proxy for facies and rock fabric, cycle tops are picked on logs at the change from higher porosity, cycle-top, grain-dominated dolopackstone to low- porosity, cycle-base, mud-dominated dolostones. Flow-layer boundaries are picked at the change from low to high porosity (from mud- to grain-dominated dolostones).

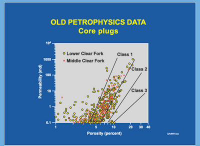
A SINGLE PERMEABILITY TRANSFORM CHARACTERIZES THE ENTIRE RESERVOIR

CLASS 1 PETROPHYSICS FOR CLASS 1 AND CLASS 2 FABRICS

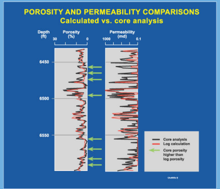


Carefully measured porosity and permeability data indicate class 1 petrophysics for most rocks, even though many possess class 2 rock fabrics. Note that no data fall in the < 3-percent porosity range-supporting the conclusions that the old data in this range are in error (see below).

LOW-POROSITY, HIGH-PERMEABILITY DATA ARE SAMPLING AND MEASUREMENT ERRORS



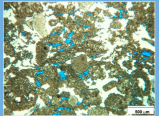
Original porosity and permeability core data also show that most rocks exhibit class 1 petrophysics. Note that the data in the <3-percent porosity range are probably artifacts of poor sample cleaning and analysis.



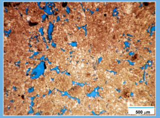
Comparison of core- and log-calculated permeability shows good agreement. Where values deviate, core porosity tends to be higher than the log porosity, which results in log-calculated permeability being slightly understated.

CLASS 1 ROCK FABRICS THAT EXHIBIT CLASS 1 PETROPHYSICS

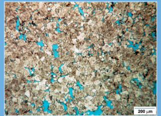
Dolograinstones, large crystalline dolostones, and coarse-grained, grain-dominated dolopackstones



Dolograinstone that plots in class 1 field. White areas are anhydrite.
Porosity = 7.1%; permeability = 1.6 md.



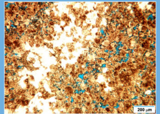
Large-grain, grain-dominated, dolopackstone that plots in class 1 field.
Porosity = 10.3%; permeability = 60 md.



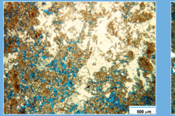
Large crystalline dolowackestone that plots in class 1 field.
Porosity = 11.7%; permeability = 33.6 md.

CLASS 2 ROCK FABRICS THAT EXHIBIT CLASS 1 PETROPHYSICS

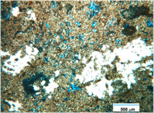
Grain-dominated dolopackstones and medium crystalline dolowackestones with patchy anhydrite



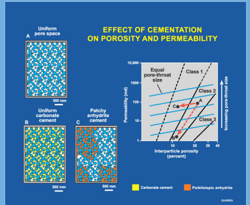
Medium crystalline, grain-dominated dolopackstone that plots in class 1 field. White areas are anhydrite.
Porosity = 6.9%; permeability = 2.1 md.



Medium crystalline, grain-dominated dolopackstone that plots in class 1 field. White areas are anhydrite.
Porosity = 13.5%; permeability = 11.



Medium crystalline, dolowackestone that plots in class 1 field. White areas are anhydrite.
Porosity = 12.6%; permeability = 4.8 md.



Cementation can affect rock fabrics in two ways.

1. Carbonate cements tend to occlude pore space uniformly, thus not affecting rock fabric class (pathway A-B).
2. Anhydrite cement tends to form poikilotopic patches that occlude pore space only locally. This occlusion reduces porosity significantly but causes only a minor decrease in pore-throat size. Therefore, a class 2 rock fabric containing poikilotopic anhydrite will actually behave as a class 1 rock fabric (pathway A-C).