2003 GCSSEPM Foundation Ed Picou Fellowship Grant for Graduate Studies in the Earth Sciences Recipient

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Integrated reservoir characterization and 3-D diagenetic modeling of the Cotton Valley sandstones, East Texas Basin, USA.

Problem: The United States is dependent upon oil imports to fulfill a major share of its crude oil requirements. The United States`s industries and economy are vulnerable to oil supply disruptions. Natural gas could substitute for a significant fraction of the oil and coal consumed today. The Cotton Valley sandstones, which are the target of this study, are considered as the major gas reservoirs/reserves in Arkansas, Louisiana, and East Texas. The Cotton Valley sandstones are "tight gas sandstones that they have low porosity and permeability as a result of compaction plus extensive cementation by quartz.

My work is an attempt to understand, quantify, model, and predict diagenetic processes and how they affect reservoir quality. Prediction is desired on two levels: (1) before drilling when geologists need to evaluate the probability that a sandstone target in a given regional setting and at a given depth will have attractive reservoir properties; and (2) when a target reservoir has been located and identified by drilling, and geologists need to be able to specify what heterogeneity may present in the untested parts of the reservoir.

Project Goal: Determine the factors controlling the reservoir quality of the Cotton Valley sandstones in some gas fields in East Texas Basin by integrating a wide spectrum of techniques and data, with special attention to the importance of silica released by dissolution at grain contacts and stylolites as a source of quartz cement; also, to determine the diagenetic and thermal history of the Cotton Valley sandstones, including sources and sinks of all diagenetic phases, and determine what factors control the distribution of the producing sandstones.

This information will be used to enhance predictions of where to find the best porosity and permeability in the Cotton Valley sandstones and similar sandstones when developing producing hydrocarbon fields. The approach is to integrate rocks, well logs, petrography, isotope geochemistry, ichnofossils and petrophysics to interpret the digenetic history.

Procedures: (1) Conduct a sequence startigraphic framework of the Cotton Valley sandstones by using 300 well logs combined with 4180 feet of core data to determine the reservoir architecture in representative gas fields in East Texas Basin. These fields include Woodlawn, Blocker, and Waskom in Harrison County; Carthage in Panola County; and Oak Hill and Dirgin in Rusk County. By integrating well logs and core data, the major depositional sequences and system tracts will be identified. In each sequence and system tract, the various reservoir units will be classified into different types of litho/biofacies.
(2) In each facies I will assess the importance of pressure solution of quartz cement at grain contacts and stylolites versus silica released from shales as a source of silica for quartz cement. I will also evaluate the relative importance of burial history, mineral composition, grain size and sorting, and proximity of shale beds as factors influencing the amount of quartz cement. Other diagenetic events that influence reservoir quality will also be evaluated.

(3) Construct a model for the depositional environment of the Cotton Valley sandstones by integrating core and well data and creating net sand, isopach, gross sand and log facies maps and cross sections. Study of the cores includes lithofacies, primary sedimentary structures, trace fossils, facies relations, textures, compositions and vertical grain-size change.

(4) Examine the relationship between reservoir facies and architecture interpreted from sequence stratigraphy, depositional environment and the distribution of various diagenetic phases, and consider the control of depositional environment on diagenesis and reservoir quality.

(5) Assess and predict porosity and permeability of sandstones as hydrocarbon reservoirs in a prospect area by using a forward numerical model.

Work Accomplished: I have described 4180 feet of conventional cores in 15 cored wells in representative gas fields in East Texas Basin. Thin sections for petrographic analysis have been made of 120 samples. I have established the sequence stratigraphic framework of the Cotton Valley sandstones by correlating 60 well logs and establishing five dip and strike oriented stratigraphic cross-sections. I have defined six main third order sequences and in each sequence identified the **HST**, **TST**, and **LST** (if present). Unconformity surfaces and system tracts from well logs are integrated with core data and the exact location of the surfaces are identified. Net sand maps for the **HST** and **TST** are completed. At present, I am writing the sequence stratigraphy part of the study.

Selected shale samples have been analyzed for organic carbon pyrolysis data, LECO organic carbon and total sulfur, Rock Eval II pyrolysis, kerogin microscopy, and vitrinite reflectance. I have obtained petrochemical and production data for some wells, and I am still seeking the data for the rest. I have calculated the porosity from neutron and density logs for some wells. I have compared the actual porosity from core with the calculated porosity from logs and the visual porosity from thin-sections for similar facies in various system tracts.

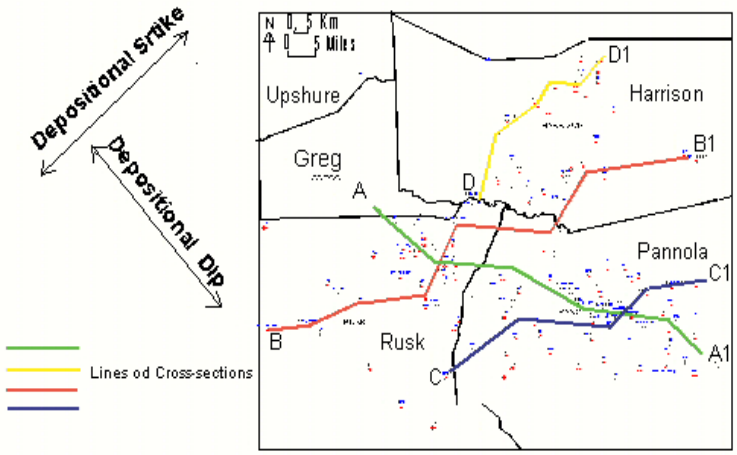
Work Needed: I will study in detail the difference in reservoir properties between the two major producing facies in the Cotton Valley sandstones, which are channel mouth

bar and the shoreface. I will identify in detail the different types of ichnofossils in the cores and use with primary sedimentary structures to define the depositional environment for every facies. I need to establish and quantify the diagenetic history of the Cotton Valley sandstones by using data from petrography, **SEM**, **XRD**, conventional and scanned cathodoluminesence, fluid inclusions in authigenic quartz and carbonates, stable isotope geochemistry, and vitrinite reflectance.

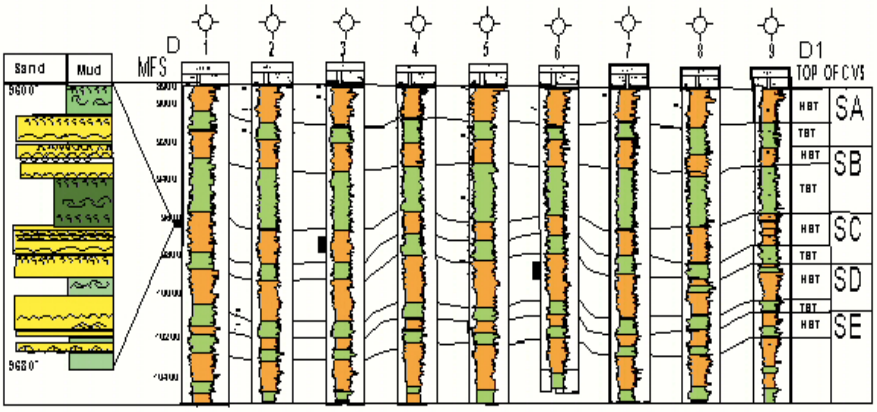
The relation of stylolite abundance and intensity relative to depth and amount of quartz cement needed to be evaluated, as well as the amount of silica lost at grain contacts using scanned cathodoluminesence and the overlap quartz concept. I will integrate sandstone and shale diagenesis with burial depth and thermal history, and fluid evolution and migration. Touchstone, a commercially available application, will be used to evaluate the forward modeling prediction of reservoir quality.

Why this work is important? This study will produce 3-D modeling of various diagenetic events that control the Cotton Valley sandstone reservoir quality. Matching these models with reservoir architecture will help to answer important questions useful to new drilling and development. Consequently, this will decrease the risk factor in petroleum exploration. Compaction and cementation are the main processes that control reservoir quality in sandstones. This study will constrain and quantify the variables that control quartz cement, and provide quantitative data on the importance of pressure solution at grain contact and stylolites as a source of quartz cement. The data will also provide a case study to test the reliability of Touchstone, a commercially reservoir quality predictor for quartzose sandstones.

Duration of investigation: I will complete the needed work by the end of fall 2004.



Location Map of study area



Schematic representation of NE-SW stratigraphic cross-section (**not to scale**) on the top of CVS, with core to log integration for well No. 1. SA: sequence A. HST: high stand system tract TST: transgressive system tract. MFS: maximum flooding surface.

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Estimated expenses to complete the work

In order to establish porosity and permeability data for all lithofacies and environments, I will send 30 core samples to Core Lab to measure porosity, kh (horizontal permeability), and kv (vertical permeability).

Title of Category	No. of samples	Unit cost	$US
Helium porosity	25	65/sample	1625
Kh	25	65/sample	1625
Kv	25	65/sample	1625
Total	25		**4,875**