PETROPHYSICAL ANALYSIS AND GEOGRAPHIC INFORMATION SYSTEM FOR SAN JUAN BASIN TIGHT GAS RESERVOIRS

Robert Lee, Program Manger

Martha Cather, Principal Investigator

Robert Balch, Co-Principal Investigator

Thomas Engler, Co-Principal Investigator

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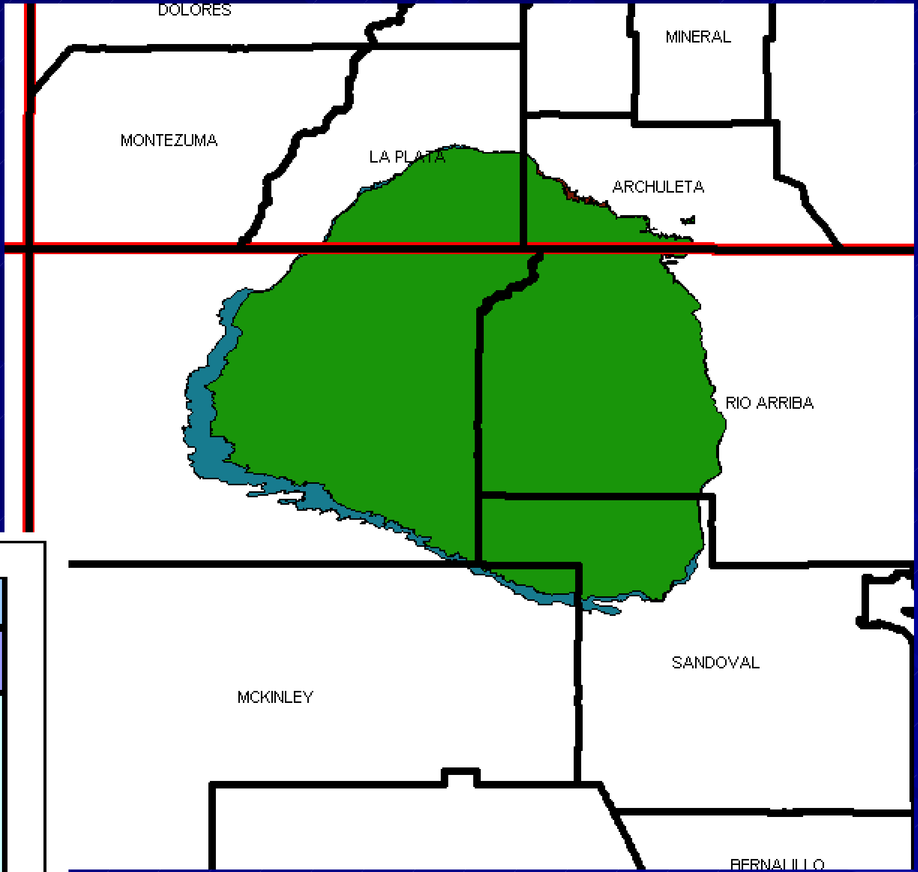
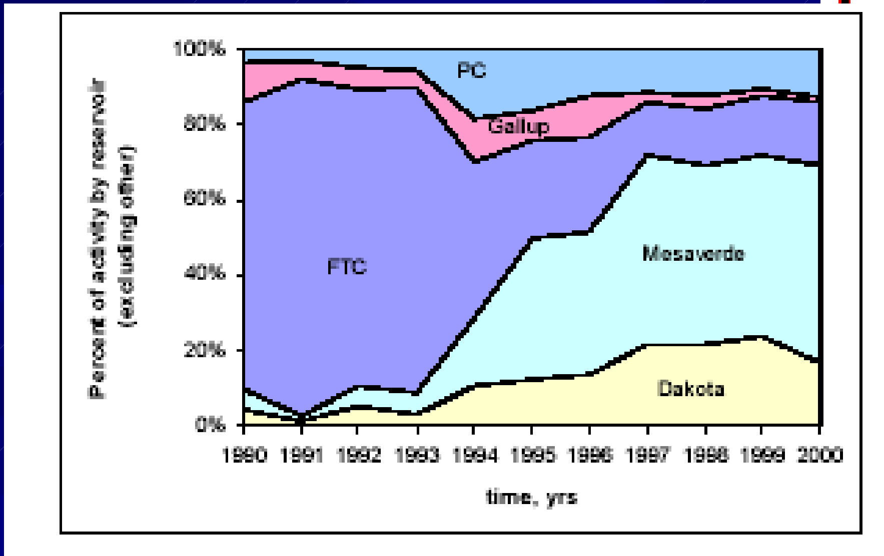
Introduction – San Juan Basin

- In 2003, ~29,000 wells produced 1,007,782,512 mcf gas
- SJB produced ~70% of gas in NM.





Statement of Problem

- San Juan gas plays have long production histories; much data has been collected and subsequently is at risk of being lost or forgotten.
- Mergers and sales jeopardize the existence & availability of data.
- Lack of time and/or expertise within companies makes it difficult to identify the data and then utilize it for better reservoir understanding.
- Improved access to data will enable more efficient targeting of areas best suited for down-spacing.
- Old data must be made available in more useful digital formats.
  - Modern users expect better performance from data and tools.
- We need to tie models and data back to logs for improved calculation of reservoir parameters
- Operators need better reservoir characterization.

Solution to Problem

The PRRC and NMBGMR have accumulated a large data resource for the San Juan Basin. We will use this data to address the problems.

Most Data ⟷ Least Data

Well Data – many wells

- Various well files
- Production data
- Logs
- Cores
- Cuttings

General data

- GIS Layers
- Reports, theses
- Bibliographies

Specialized core analysis data for ~200 wells

- Foot-by-foot permeability data
- Oil and water saturations
- Perforation intervals
- Formation tops picked from multiple sources
- Basic completion data
- Analysis interpretations
- Driller's logs & core descriptions

A few wells:

- Permeability – k_{90}, k_v, k
- Porosity
- Grain density
- Water chemistry Pre- and post-stimulation flow rates
- Core and cuttings
- Source rock data
- Produced water chemical analyses

Methodology

Five core tasks:

- Data Collection
- Data Integration
- Data Analysis
- Creation of User Interface
- Technology Transfer

Methodology – Data Collection (1 of 2)

Data collection

- Inventory available data for location, importance, and completeness
- Determine necessary data types to meet project goals
- Physically collect data
- Perform any necessary processing to make data more compatible with user needs.

Data Assessment

- Assess known data sets for accuracy and completeness
- Examine for data integrity to discover gaps, errors, or inadequacies

Methodology – Data Collection (2 of 2)

Digital Data Conversion

- Scanned production data must be converted to text format.
- Some digital well log images will be converted to LAS files for use in various log analysis programs.

Acquisition and Conversion of Non-digital Data

- Scan & digitize some paper logs
- Some data from paper forms must be hand-entered into digital databases
- Abstract petrophysical data from literature and other sources.

Methodology – Data Integration (1 of 2)

Data Cleaning

Data is first collected into temporary databases for cleaning

- Find and correct discrepancies and duplications in data (approximate string matching)
- Find and fill in missing values
- Identify and correct or delete outlying values (spatial outlier analysis

Data Reduction

Some data may require reduction to a representative sample using such methods as:

- Clustering
- Data aggregation
- Dimensionality reduction
- Data compression
- Generalization

Methodology – Data Integration (1 of 2)

Creation of Primary Database

- After the data is indexed, cleaned and subjected to any necessary preprocessing, a final database will be created.
- The database platform will be in both SQL Server (for use via Internet) and Microsoft Access (for stand-alone use).

Methodology – Data Analysis

Aggregation and organization of regional data for tight gas reservoirs in the San Juan basin provides a unique opportunity to make vertical and spatial correlations to both fill in missing data and to generate useful new data types using various correlation tools that can be mapped regionally as GIS layers.

- **Methods of Data analysis include:**
  - Parameter Analysis
  - Pay Zone Definition
  - Spatial Analysis

Methodology – Pay Zone Definition

Pay Zone Definition

- Well data will be analyzed to develop vertical correlations of petrophysical properties.
- Well logs corresponding to the core analysis database will be digitized and calibrated using the core data.
- Performance indicators will be extracted from the database and used to develop a set of criteria from the perforated pay zones.
- These criteria will be extended to identify potential bypassed pay zones in a given well.

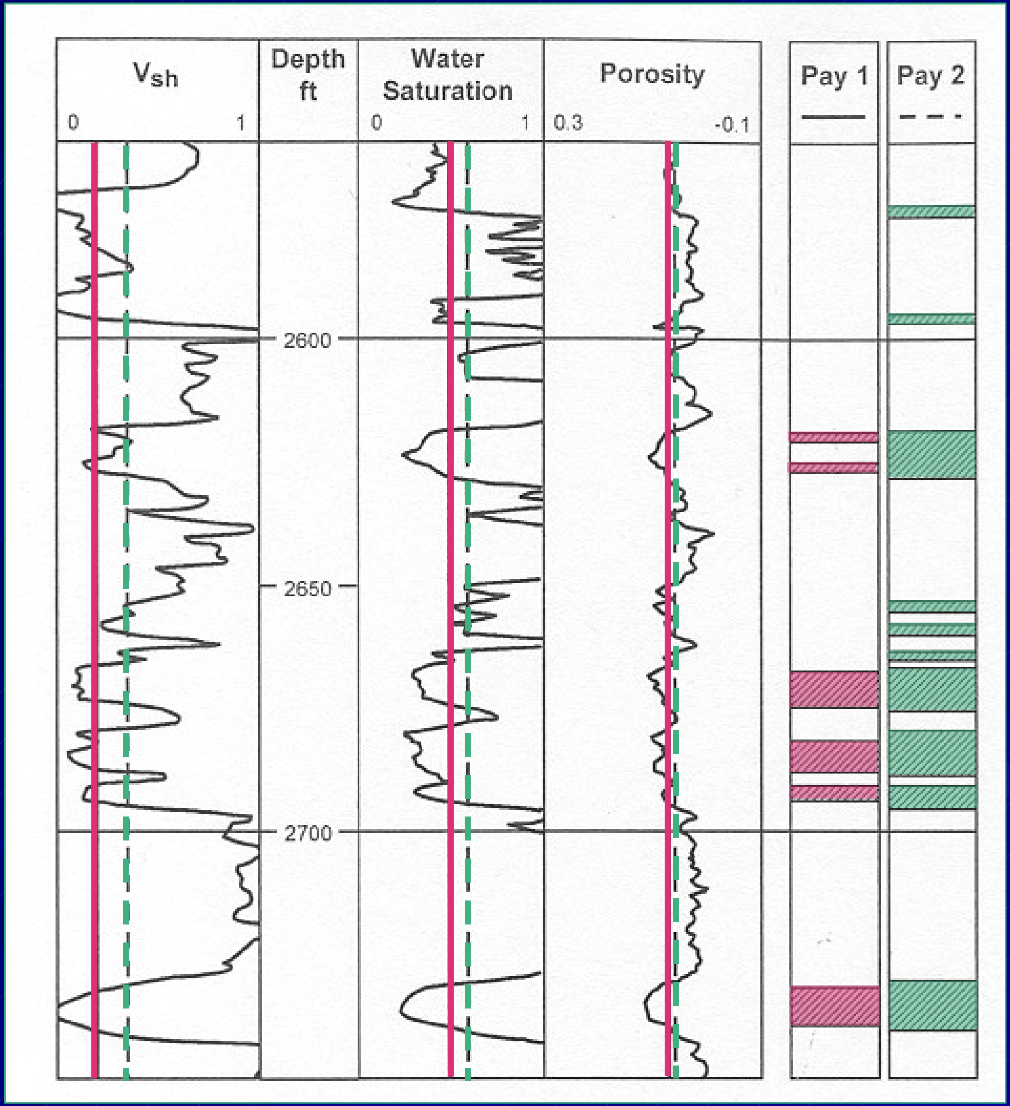
Methodology – Pay Zone Definition

How do we identify or distinguish net pay in a well ?

Apply a set of sequential cutoffs based on:

- *Rule of thumb?*
- *Statistical correlation?*
- *other?*

Example of Net-pay identification using two different sets of cutoffs



From Pekot, et al., SPE 57440, Oct 1999

Pay 1

V_{sh} < 20%

ϕ > 7 %

S_w < 50%

Pay 2

V_{sh} < 35%

ϕ > 6 %

S_w < 60%

Methodology – Parameter Analysis

- The most important correlation is the relationship between permeability and porosity as a function of lithology or rock type
- The second most important correlation is to determine values of in-situ stress in each rock layer above, within, and below the pay zones

Methodology – Parameter Analysis

Parametric study

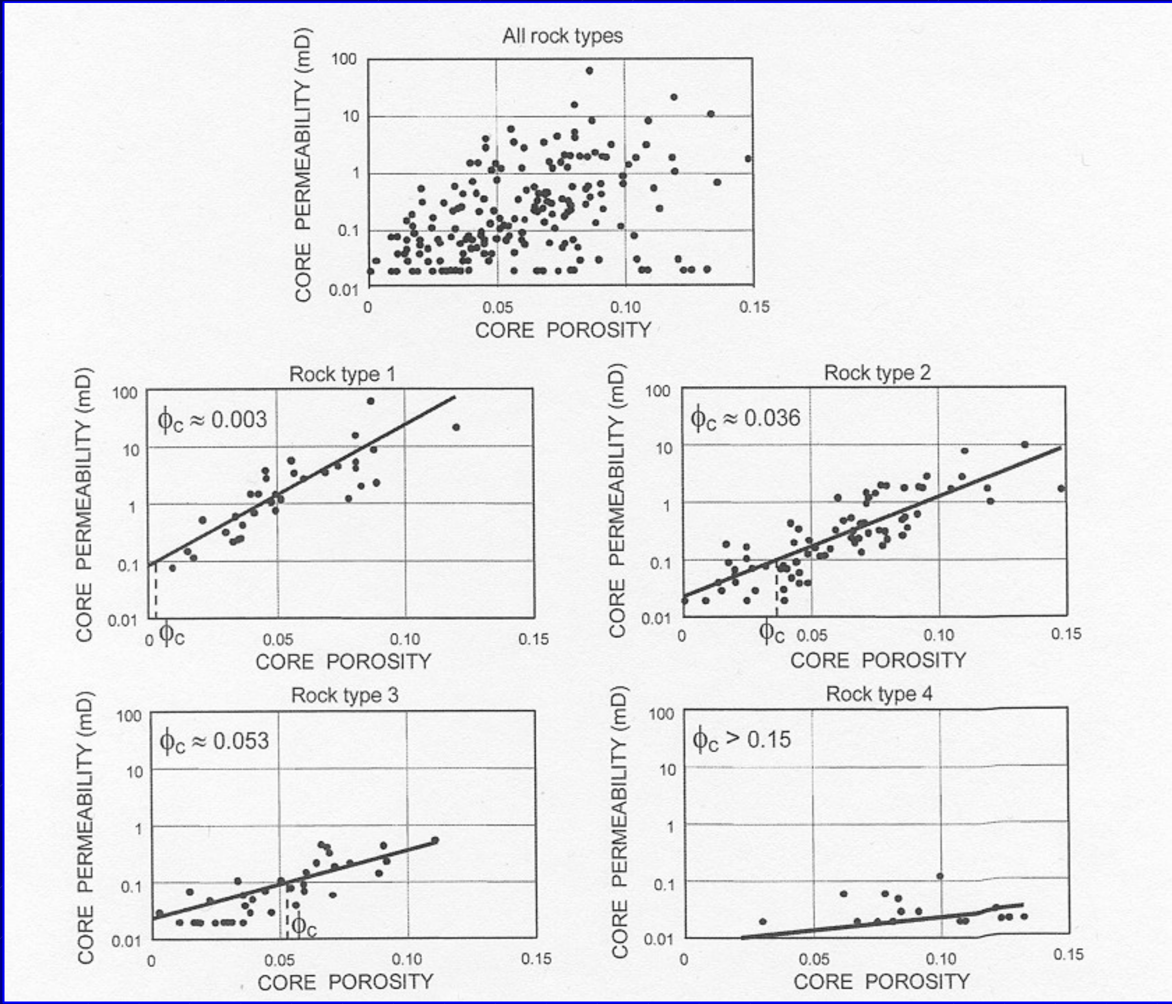
Porosity

- *Impact of grain density*
- *Impact of pore geometry exponent, m*
- *porosity vs permeability relationship*
- *other?*

Can we distinguish rock types?

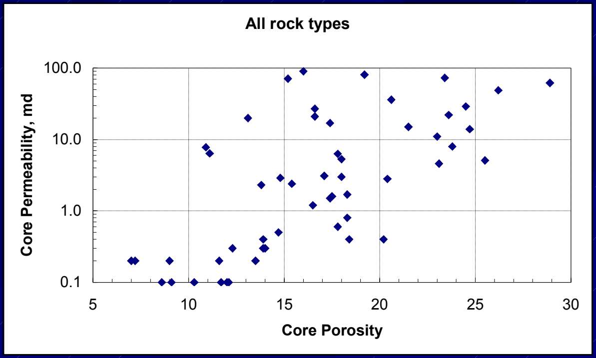
Methodology – Parameter analysis

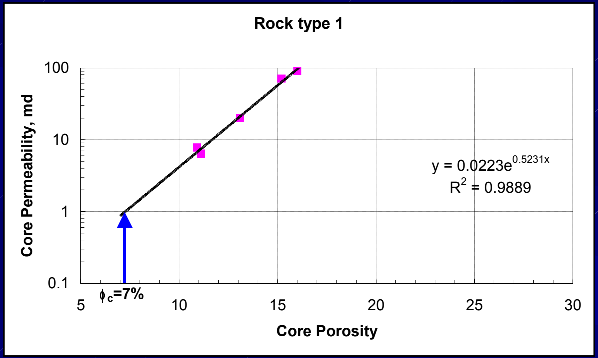
Porosity vs Permeability relationships for four rock types

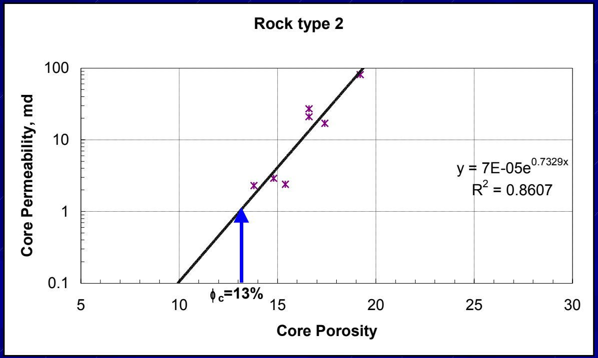


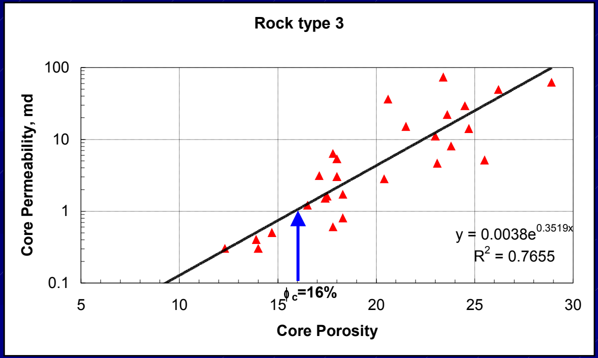
From Worthington & Cosentino, SPEREE, Aug 2005

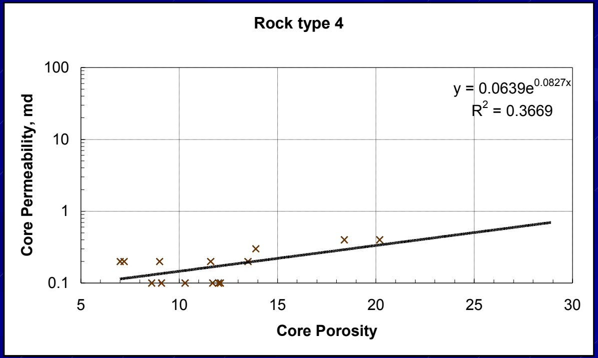
Porosity vs Permeability relationships for four rock types











San Andres Carbonate, West Texas Example

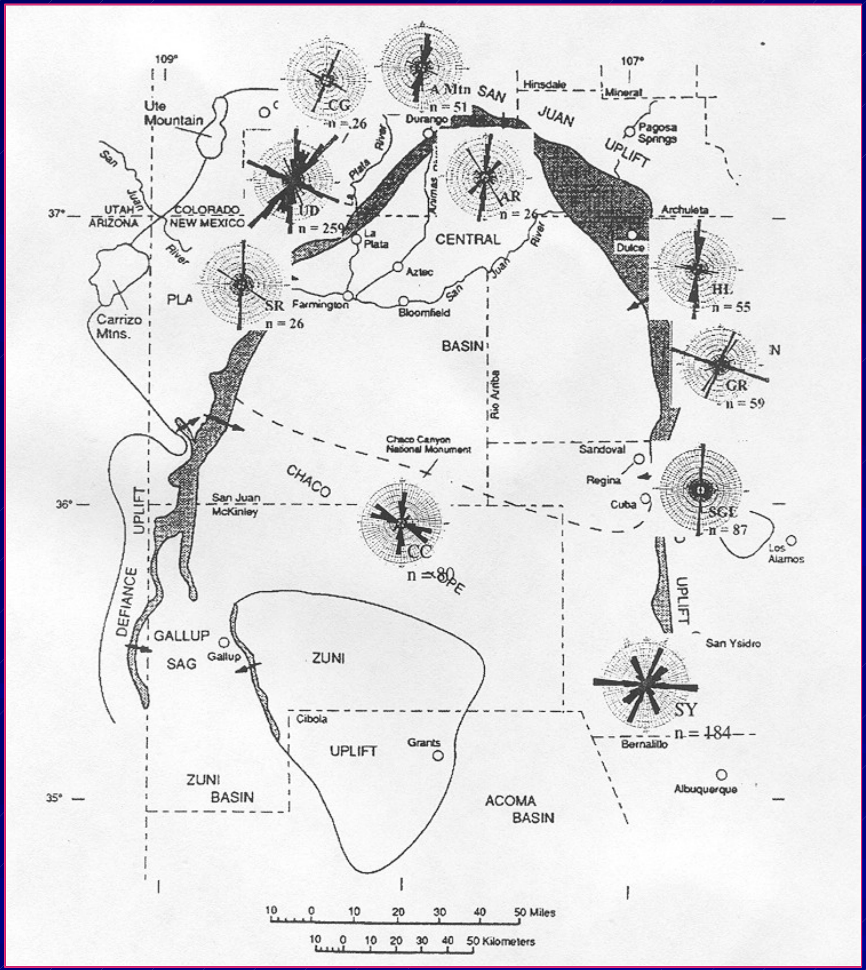
Methodology – Spatial Analysis

Spatial Analysis

- Individual well analyses will be combined to develop a spatial map of the variability for given properties.
  - For example, the variability in permeability anisotropy will be investigated and compared to the generic 10:1 ratio currently used throughout the basin.
- Some data will be geographically clustered. It would be of more use if regional estimates could be made.
- Geographically limited or sparse data can be correlated across large areas, by interpolating and/or extrapolating data.
  - One example: the generation of mappable pseudo-core porosity using wire line logs utilizing limited core data and a non-linear regression analysis
  - Other possible values to regress include regional primary fracture orientation, production indicators, permeability, and water chemistry values.

Methodology – Spatial Analysis

Does a spatial variation exist in some of these properties?



After Lorenz & Cooper, 200x

<u>Example:</u>
Rule of thumb is $k_{max}/k_{min} \approx 10:1$ for Mesaverde

Original source?

Applicable throughout basin?

Methodology – User Interfaces

A simple and intuitive UI is key to project acceptance by industry. Users should be able to query, view and export data and GIS layers and access key data offline.

Internet Data Availability:

- The information base will be a SQL Server georeferenced database.
  - A web-based data query interface similar to those used at the PRRC for other web-based data products.
  - Downloadable shape files for key data will be available for users who wish to import files into their own GIS software.
  - Certain important data tables will also be made available as comma-separated-value (.csv) text files.

Stand-Alone CD-ROM

- Key data tables will be converted to a Microsoft® Access data database so users can have an off-line version of the data.
- Some GIS shapefiles and a simple GIS viewer (eg., Arc Explorer) will be included in the stand-alone version.

Methodology – Technology Transfer

Technology transfer is a critical project component. Active efforts will be made to inform industry of project plans and results, and to solicit their input.

Technology Transfer Plan

- Kickoff meeting in Farmington, NM on Feb. 16, 2006.
- Presentation on project at Four-Corners Oil and Gas show in May 2006.
- Prominent display of project information on GO-TECH web site (3,000,000 hits last year).
- Tech transfer workshops in Farmington and Denver near project conclusion.
- Professional trade journal articles, the PTTC national newsletter, and the PRRC's regional newsletter.
- Efforts to ensure high visibility in web search engines such as Google, Yahoo, and Alta Vista,
- Peer reviewed papers and presentations will give exposure of the work through Sci-search, GeoRef, and Petroleum Abstracts.

Relationship to Solicitation Goals

There is strong synergy between Solicitation and Project goals

Solicitation Goals

- The collection, analysis, and improved availability of critical information, such as water chemistries, velocity data, core analysis, and other petrophysical information.

Project Objectives

- Project will create an accessible and functional archive of a wide variety of data pertinent to the Mesaverde Group and Dakota Sandstone of the San Juan Basin.

Relationship to Solicitation Goals

Solicitation Goals

- Improving recognition and characterization of zone-specific production potential from well logs

Project Objectives

- Tie petrophysical data to old logs or cased-hole logs.
- Perform spatial analysis of permeability ratios.
- Improve time depth correlations through regional mapping of sonic logs.
- Analyze water data for potential commingled production compatibility issues, scale problems, and to estimate water resistivities for determining formation water saturation.

Expected Project Impacts and Benefits

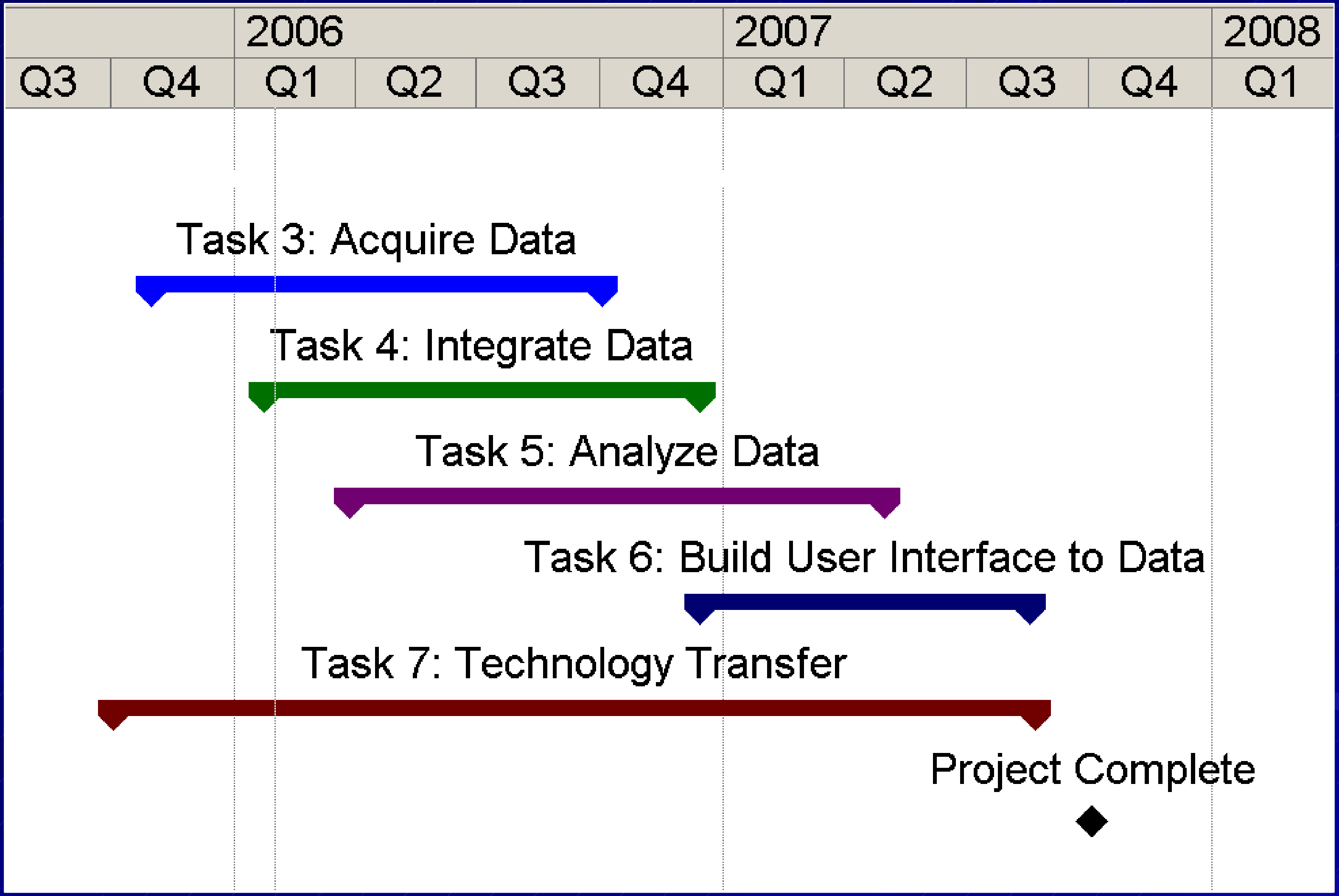
Impacts include:

- A significant increase in the accessibility of information about the San Juan Basin.
- Identification and quantification of bypassed pay zones both in existing wells and as infill well potential.
- A better understanding of regional permeability trends and ratios and their effects on well drainage will allow producers to make better decisions on placement of infill wells.
- Improved time-depth correlations.

Deliverables

- A web site that will contain:
  - Project description
  - Progress reports
  - Final User Interface and access to databases and additional files
- A CD containing a significant portion of the database, GIS shape files, and an ArcExplorer project to allow stand-alone map viewing
- Peer reviewed articles describing the system, interpretations and results of the study.

Project Schedule and Milestones



Project Team

- **Robert Lee, Project Manager.** Dr. Lee is Director of the PRRC/NM Tech, Director for the Southwest PTTC and part-time Professor of Petroleum and Chemical Engineering.
- **Martha Cather, PI:** Section head for the Industry Service and Outreach Group at the Petroleum Recovery Research Center as well as Coordinator for the Southwest Regional Lead Organization of the Petroleum Technology Transfer Council (PTTC).
- **Robert Balch, Co-PI:** Dr. Balch's primary responsibility on the proposed project is data mining and analysis. Dr. Balch is head of the REACT Group at PRRC.
- **Thomas Engler, Co-PI:** Dr. Engler is an Associate Professor of Petroleum Engineering and Chairman of the Department. His primary responsibility on this project is directing analysis of petrophysical data.
- **Tongjun Ruan, Research Scientist:** In addition to being a simulation expert, Dr. Ruan has developed expertise in web-based application software and soft computing methods using Java Technology for the REACT group's FEE Tool project.
- **Jenny Ma, Database Manager:** Ms. Ma has worked as Programmer/Analyst in the ISO group for several years and is currently database administrator at the PRRC. She has experience working in various database environments, such as SQL server, Oracle, DB2 and Dbase.