Evaluation of Chemical Flooding in the Minnelusa Formation, Powder River Basin, Wyoming*

Geoffrey Thyne[1], Vladimir Alvarado[2] and Glen Murrell[1]

Search and Discovery Article #50239 (2010)
Posted February 26, 2010

* Adapted from an oral presentation at AAPG Annual Convention and Exhibition, Denver, Colorado, USA, June 7-10, 2009.

[1]Enhanced Oil Recovery Institute, University of Wyoming, Laramie, WY (gthyne@uwyo.edu)
[2]Department of Chemical and Petroleum Engineering, University of Wyoming, Laramie, WY

Abstract

The choice of EOR techniques should be based on knowledge of prior efforts in similar settings. The Minnelusa Formation of Wyoming offers such an opportunity. The formation is a prolific producer with over 607 million barrels of oil cumulative to date from approximately 100 Minnelusa fields located in the Powder River basin. These fields are relatively small, eolian sandstone deposits with similar porosity and permeability, but have a wide range of production by field. About half of these fields have been subjected to some form of enhanced oil recovery, primarily with polymer floods. While some of these fields followed the traditional EOR sequence of primary, secondary and tertiary treatment, there were many cases where application of polymer was coincident with start of waterflooding. An evaluation of the effectiveness of all phases of recovery was performed using production data. The metric used was the incremental production after treatment where incremental was limited to that oil produced in addition to normal production activities. This metric provides the basis for estimating potential income to pay for the treatment. Almost all cases of water or chemical flooding produced positive results in terms of increased oil production.

Based on the incremental production metric, in-field drilling produced 50% incremental production, standard waterflooding, also positive for most cases, reached a maximum of 300% incremental production. Traditional post-waterflood application of polymer also showed mostly positive results with the best response generating more than 400% incremental production. However, application of polymer concurrent with the start of waterflooding produced the best results with incremental production as high as 1500%. These high values are partially related to low primary production potential, but other factors also play a role. The much larger range in chemical flood response was not strongly related to geological factors. Specific factors such as net pay, size and age of the field, ndepth/temperature, number of wells, cumulative production, oil gravity and formation water chemistry played some role in controlling the degree of success, but the most important variable was how soon the polymer was applied after field production was started. Application of chemical treatment in the first five years of the field produced significantly better results.

Selected References

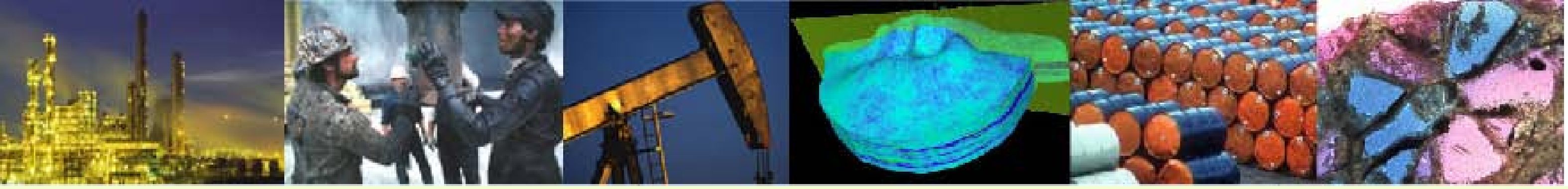
James, S.W., 1989, Diagenetic history and reservoir characteristics of a deep Minnelusa reservoir, Hawk Point field, Powder River Basin, Wyoming, *in* E.B. Coalson, (ed.), Rocky Mountain reservoirs—1989: Rocky Mountain Association of Geologists, p. 81–96.

Markert, J.C. and Z. Al-Shaieb, 1984, Diagenesis and evolution of secondary porosity in upper Minnelusa sandstones, Powder River basin, Wyoming: AAPG Memoir, v. 37, p. 367-389.

Reyes, B. and K. Murray, 2009, Implementation of a Geographical Information System (GIS) for the Enhanced Oil Recovery Institute (Eori), Laramie, Wyoming**:** AAPG Search and Discovery Article #90090, AAPG Annual Convention and Exhibition, Denver, Colorado, June 7-10, 2009. Web accessed 11 December 2009.
http://www.searchanddiscovery.net/abstracts/html/2009/annual/abstracts/reyes.htm

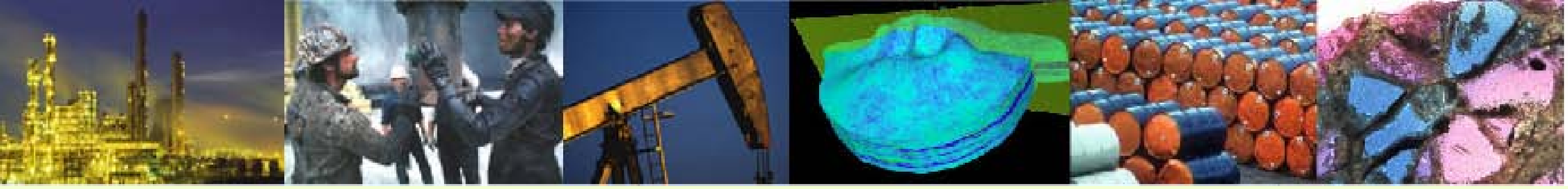
Shier, D.E., 1986, (author) Classification of oil traps and effective mapping; Upper Minnelusa Formation: Rocky Mountain Section SEPM, 1 volume, irregular pagination.

Shier, D.E., 1986, Microcomputer aids subsurface mapping: Geobyte, v. 1/3, p. 74-78.



Evaluation of Chemical Flooding in the Minnelusa Formation, Powder River Basin, Wyoming

Geoffrey Thyne, Vladimir Alvarado and Glen Murrell
Enhanced Oil Recovery Institute
University of Wyoming



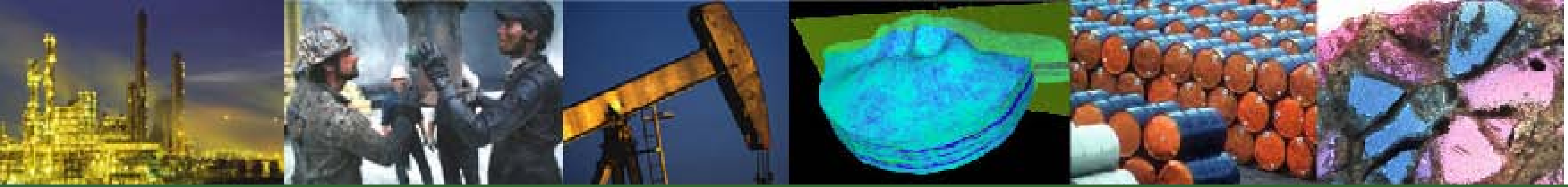
Acknowledgements

Contributions to this work by the EORI staff

Eolian Deposition - Jim Steidtmann

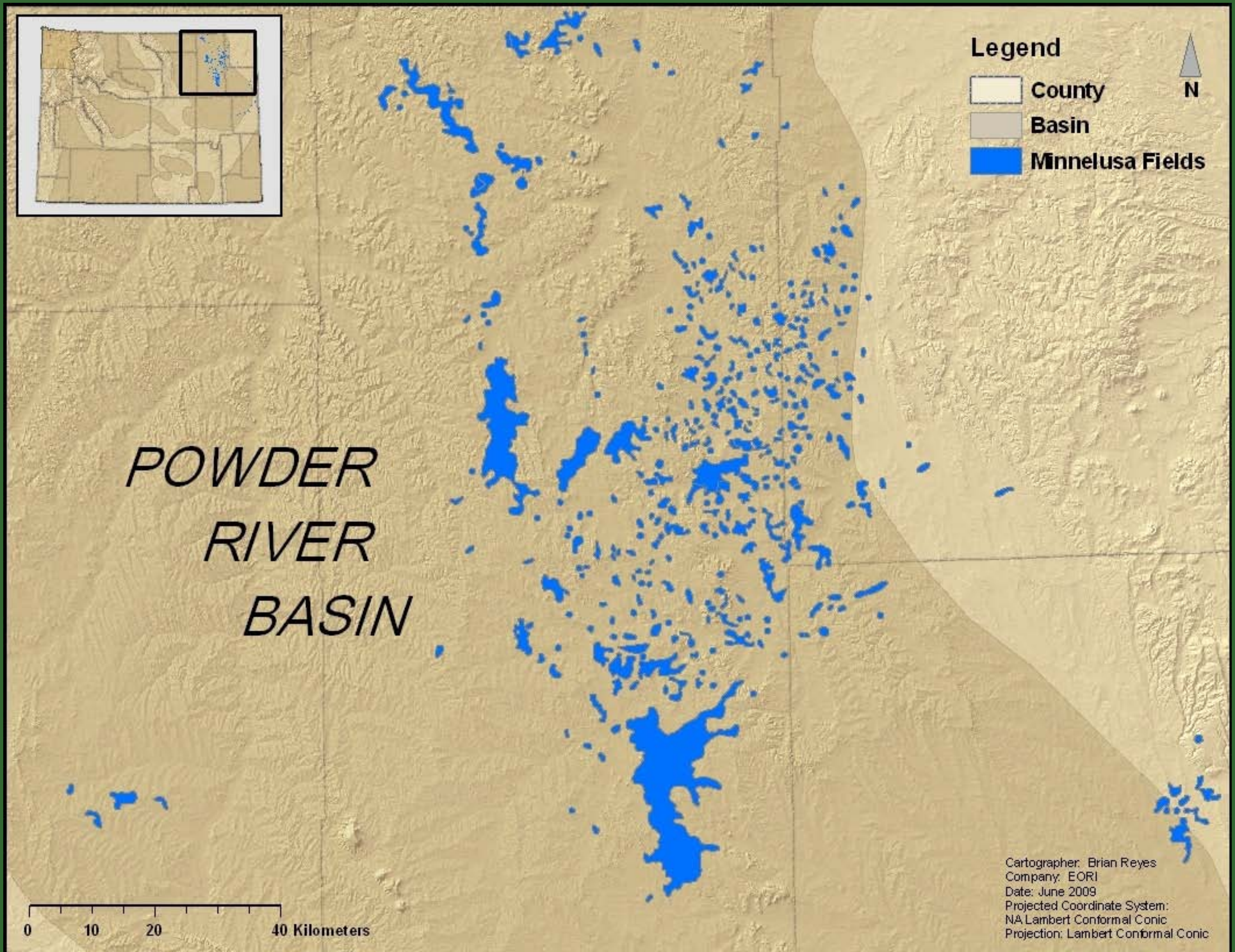
Maps - Brian Reyes

Strat and Photomicrographs – Pegui Yin

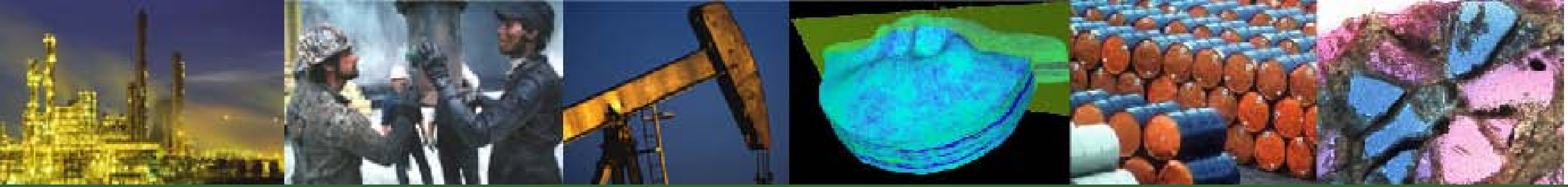


Minnelusa fields are found in Powder River Basin

Isolated units along former shoreline

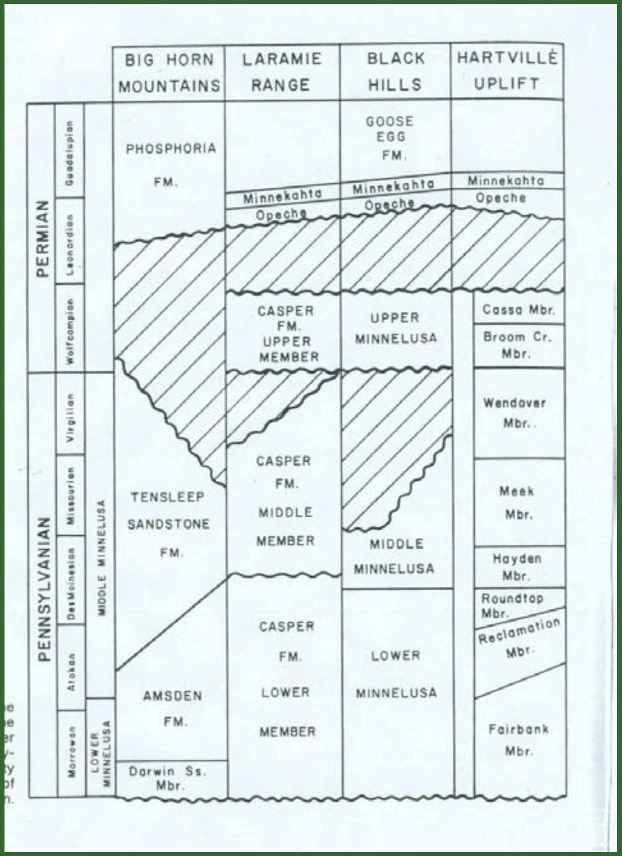


Reyes 2009



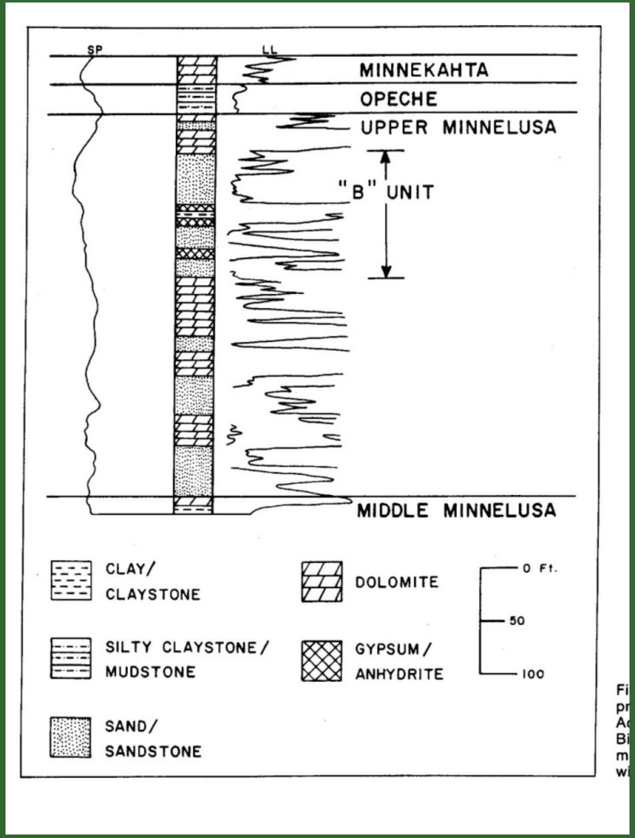
Minnelusa is Penn.-Permian in age
Equivalent to Tensleep (eolian system)

Minnelusa Stratigraphy

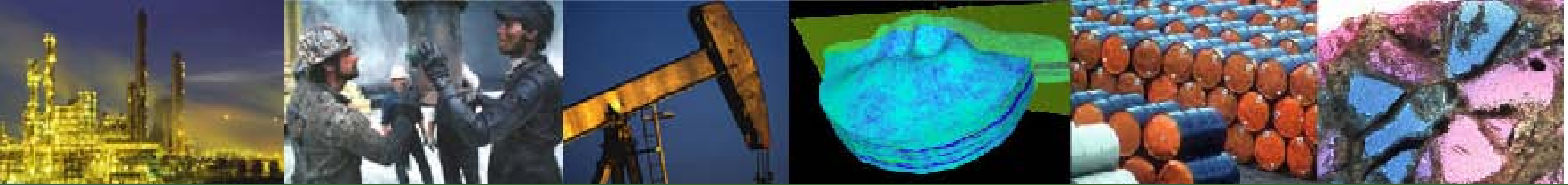


Markert and Al-Shaieb 1984

Minnelusa is a eolian dune system with inter-bedded dolomite layers



James 1989

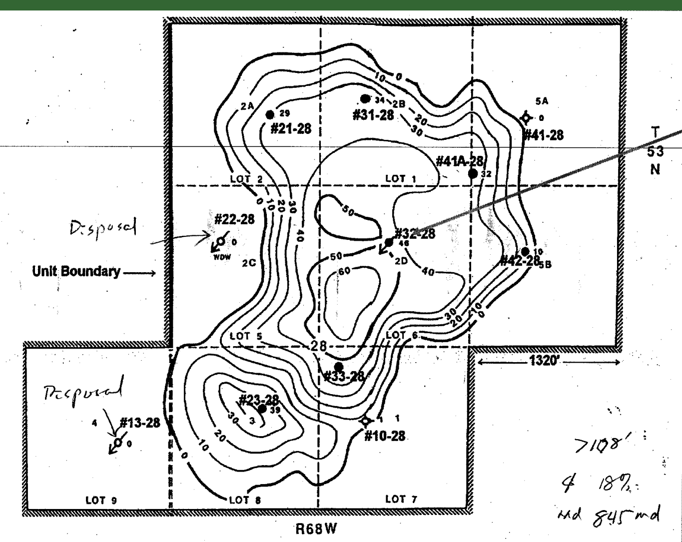


Reservoirs

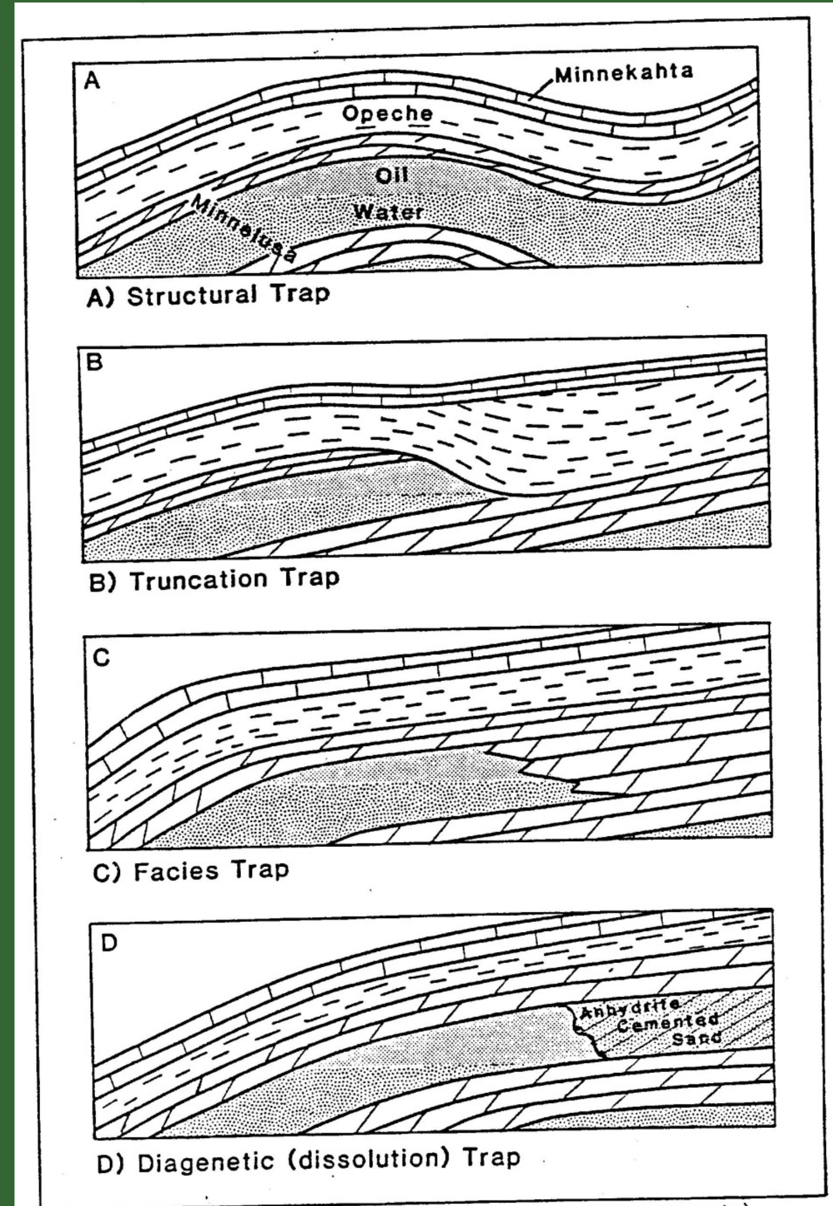
Generally small (<15 wells) with under 10 MMBO OOIP

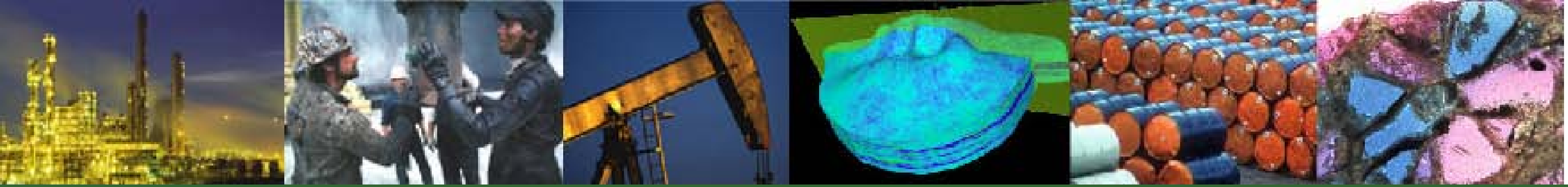
Minnelusa trapping is generally stratigraphic in nature

Pinch out into Opeche Shale



Johnson 1985

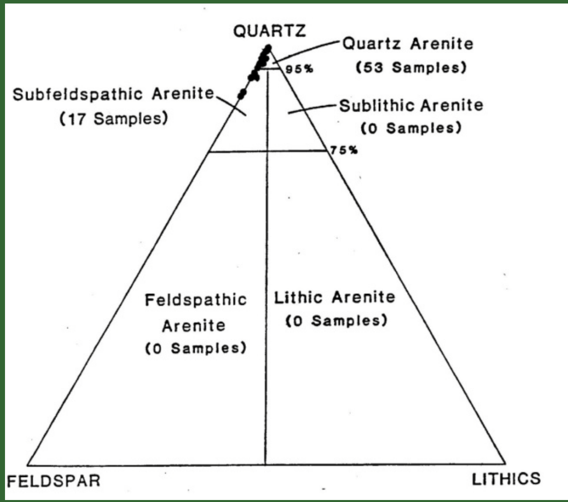




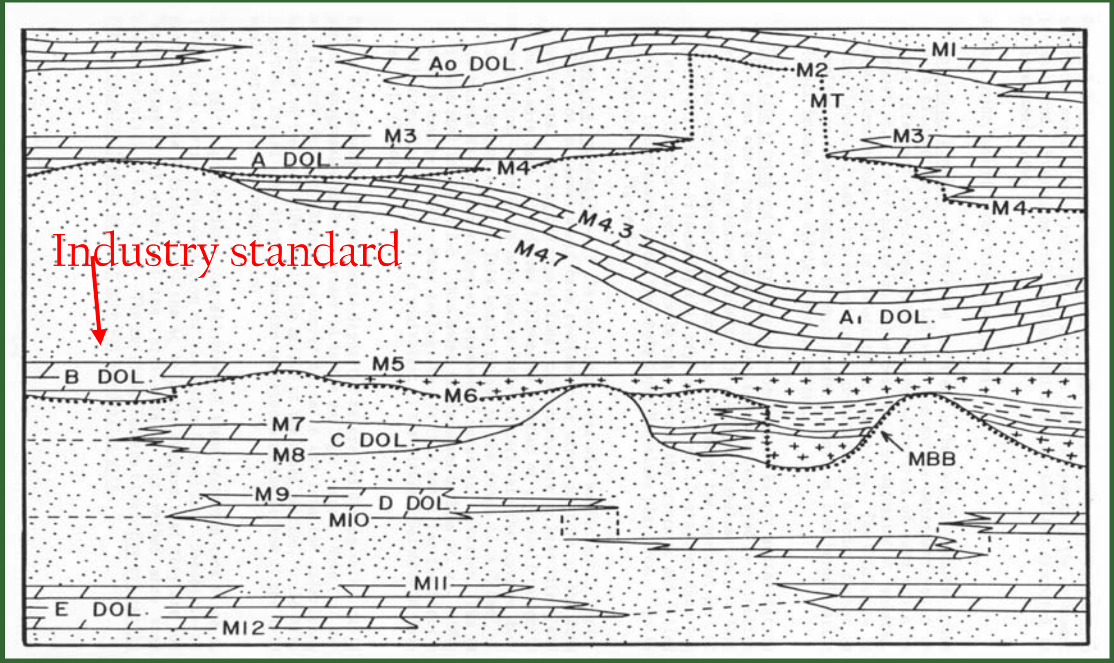
Lithology and sedimentary structures

Minnelusa is fine to very fine grained
Moderately to well-sorted
70% detrital, 23% cements
Quartz Arenite
Anhydrite and Dolomite cements

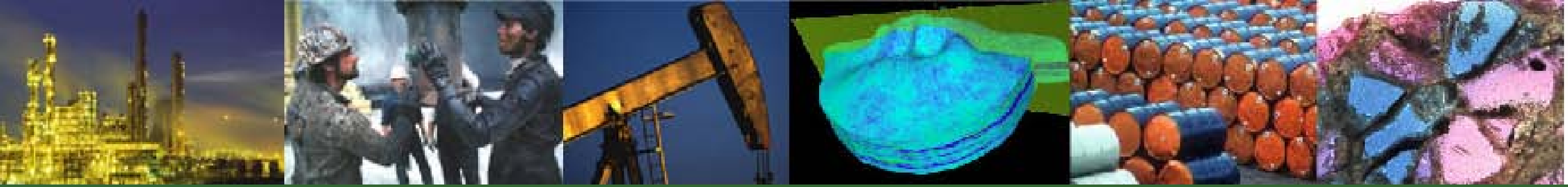
Shier, 1986



Johnson 1985

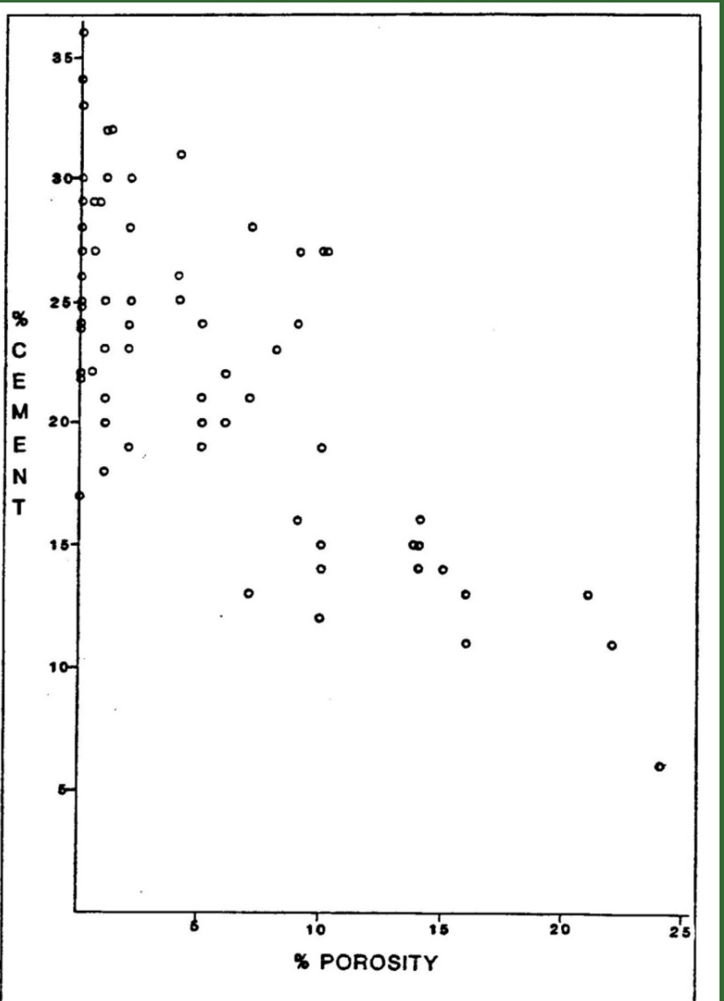


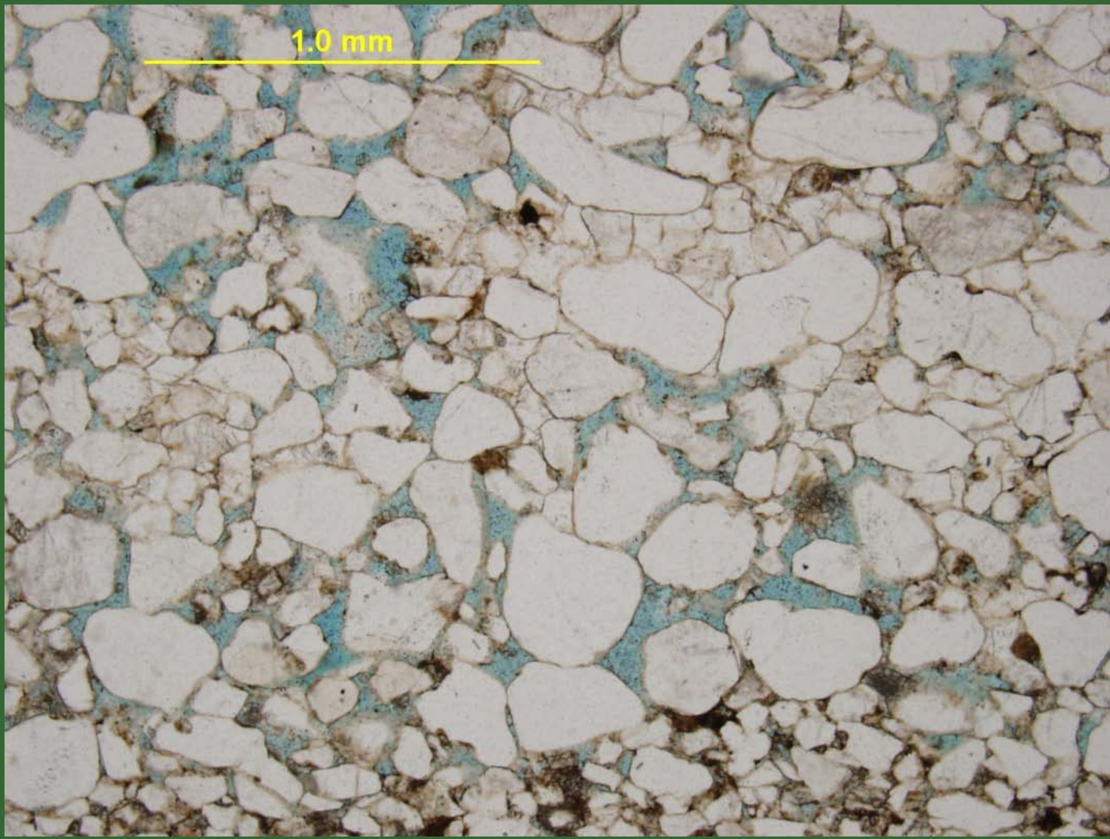
Cross-bedded sandstone
Dolomitic sandstone
Sandy dolostone
Dolostone



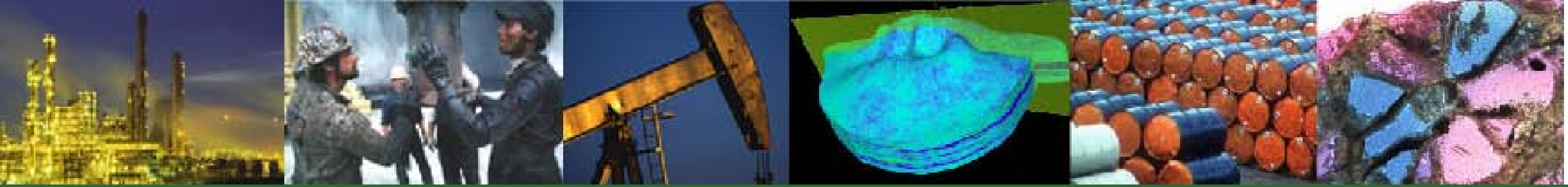
Anhydrite and Dolomite cements control porosity (inverse relationship)

Anhydrite Dissolution



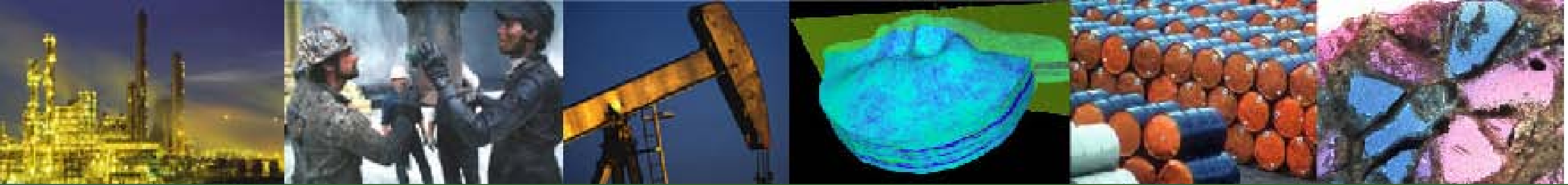


Johnson 1985



Why the Minnelusa?

- Total production to date over 607 MMBO
- 100+ operational fields with only Minnelusa production
- Geologically "uniform" and relatively simple
- About 30 fields have been treated with some form of chemical flooding, mostly polymer
- Provides basis to develop screening criteria



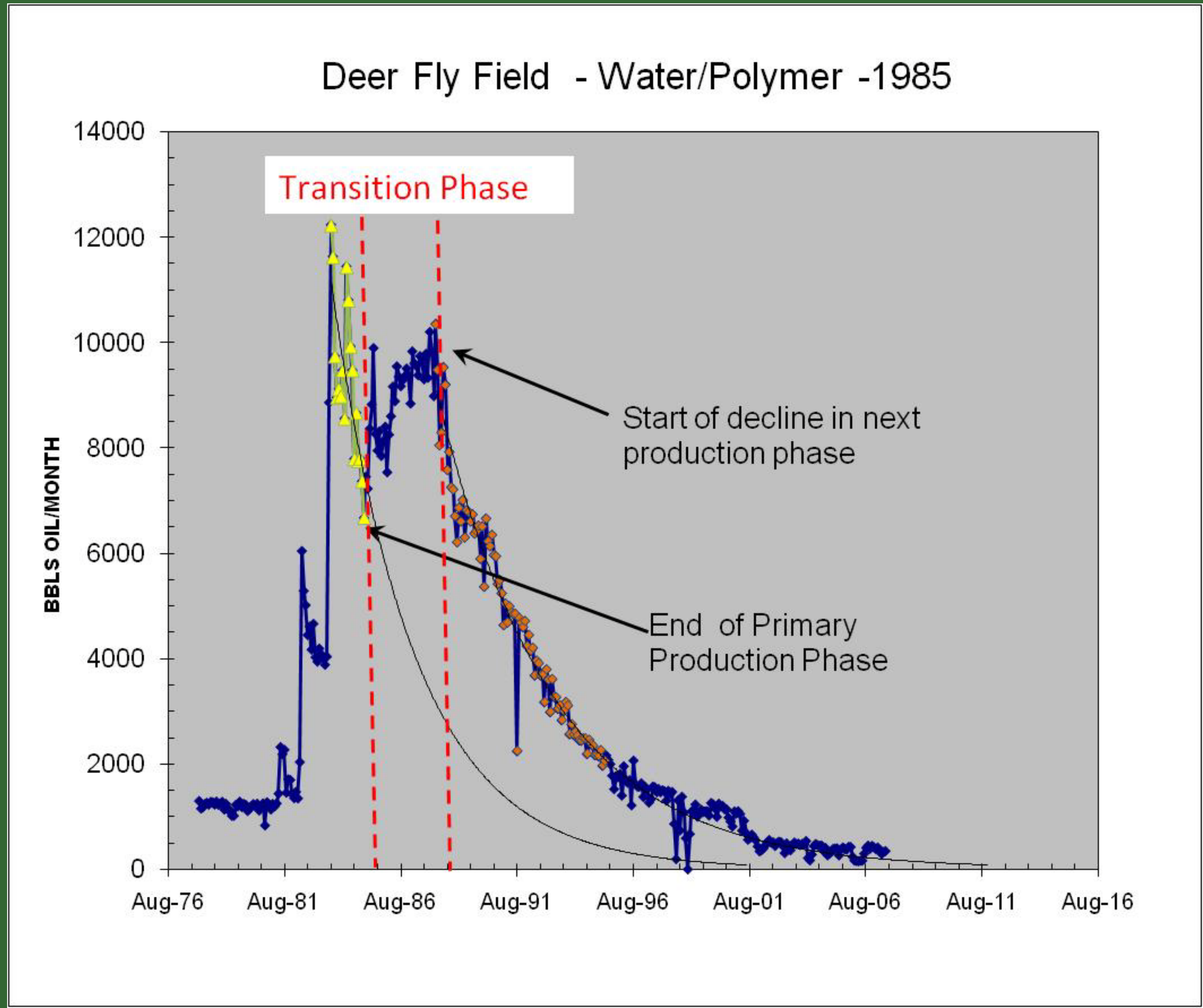
Production Analysis

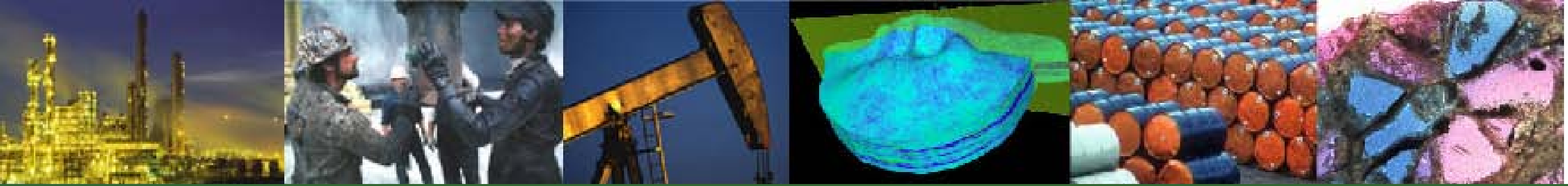
OOIP from volumetric calculation

Assume exponential declines to calc. EUR

Transitional phase assigned to successive phase production

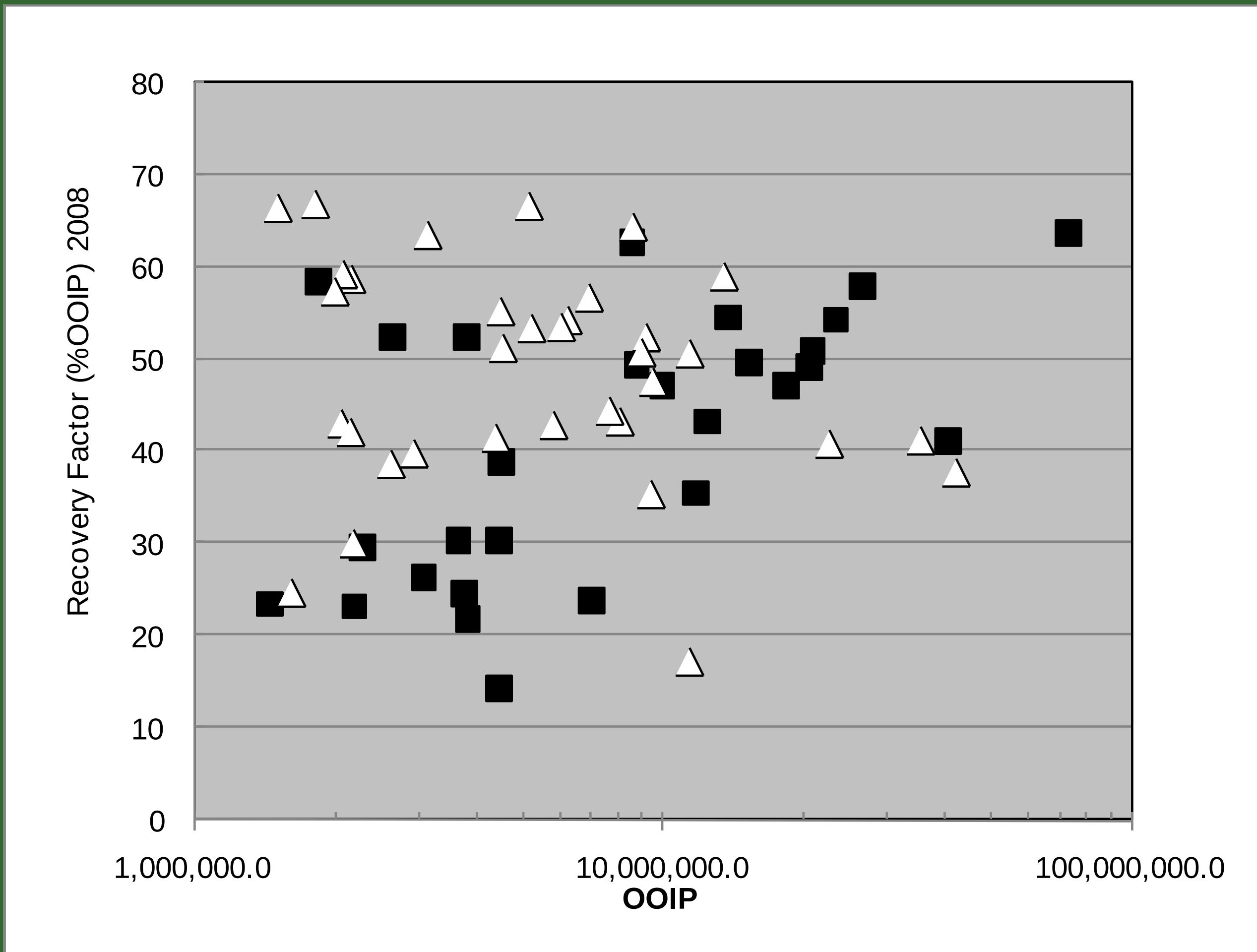
Each phase recovery factor calculated as %OOIP

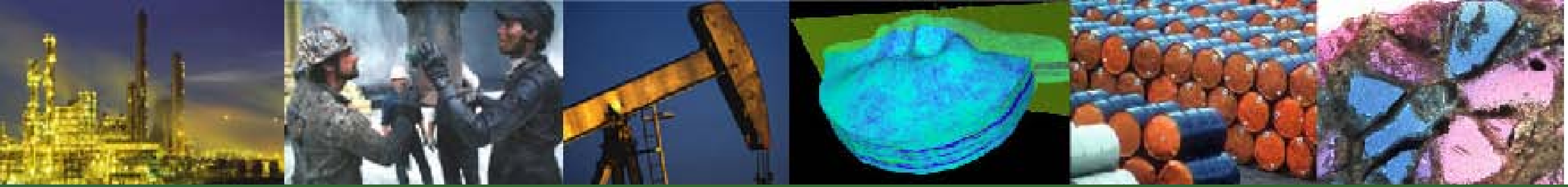




OOIP vs. Recovery Factor

Triangles are chemical floods, squares are water flood only



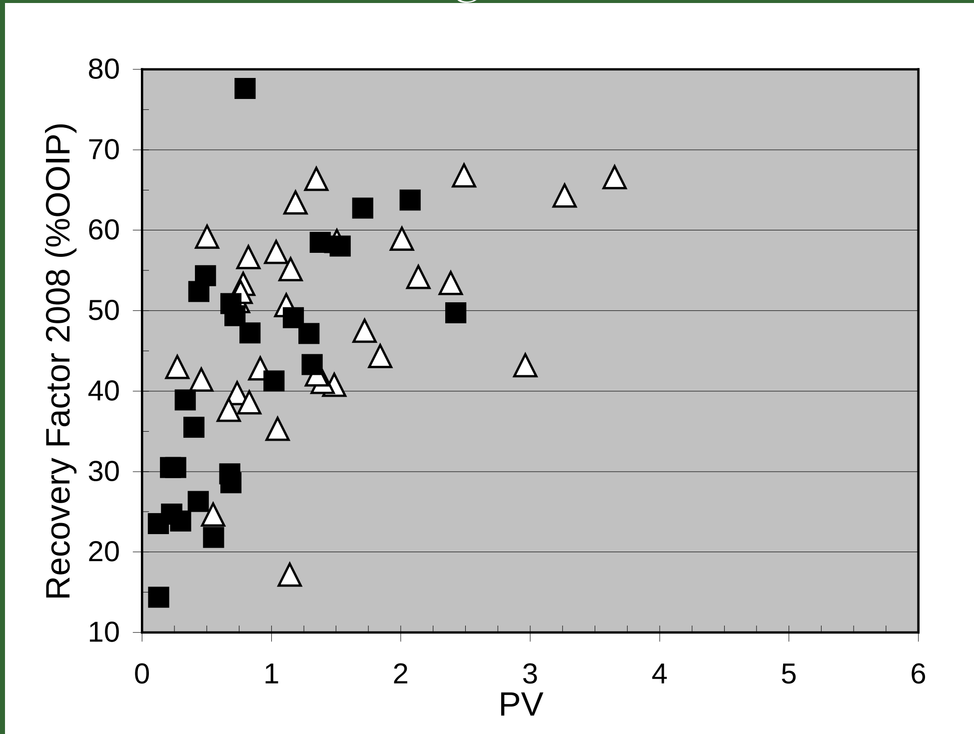


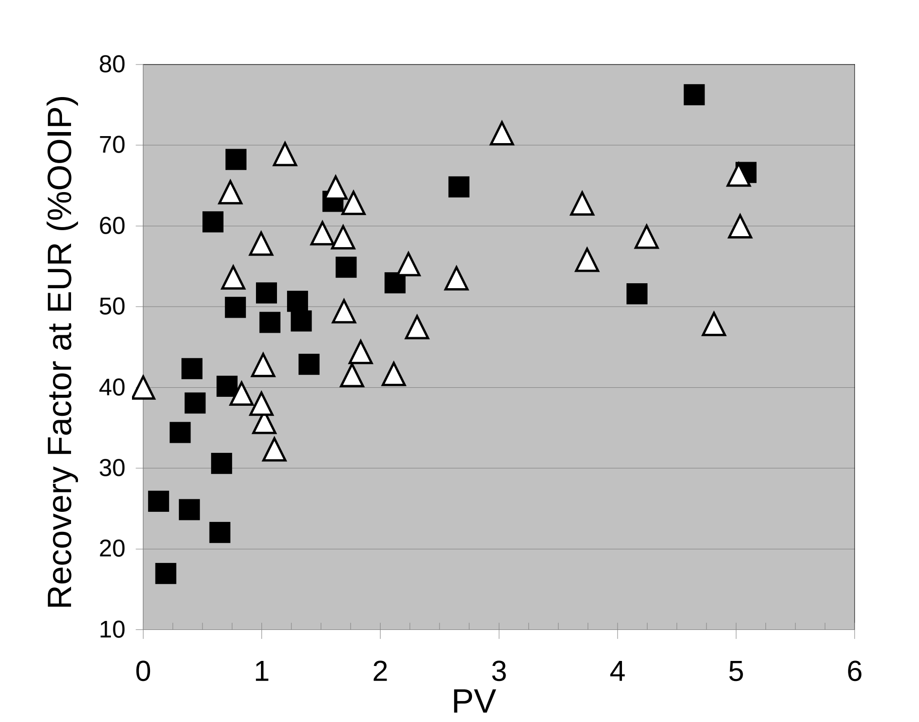
Recovery Factor and Flooding Volumes

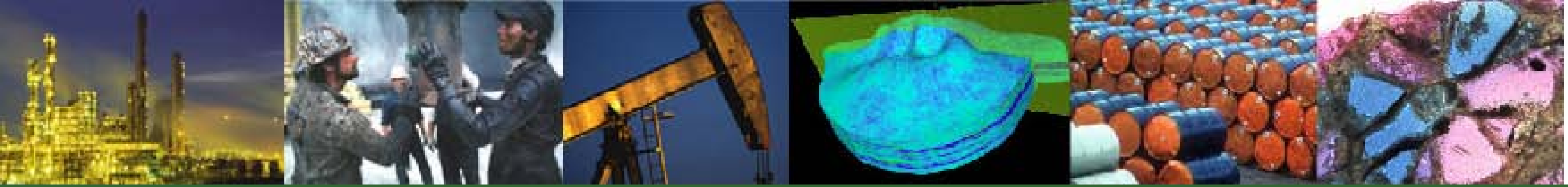
Normalize flooding history

EUR = estimated ultimate recovery

Triangles are chemical floods, squares are water flood only

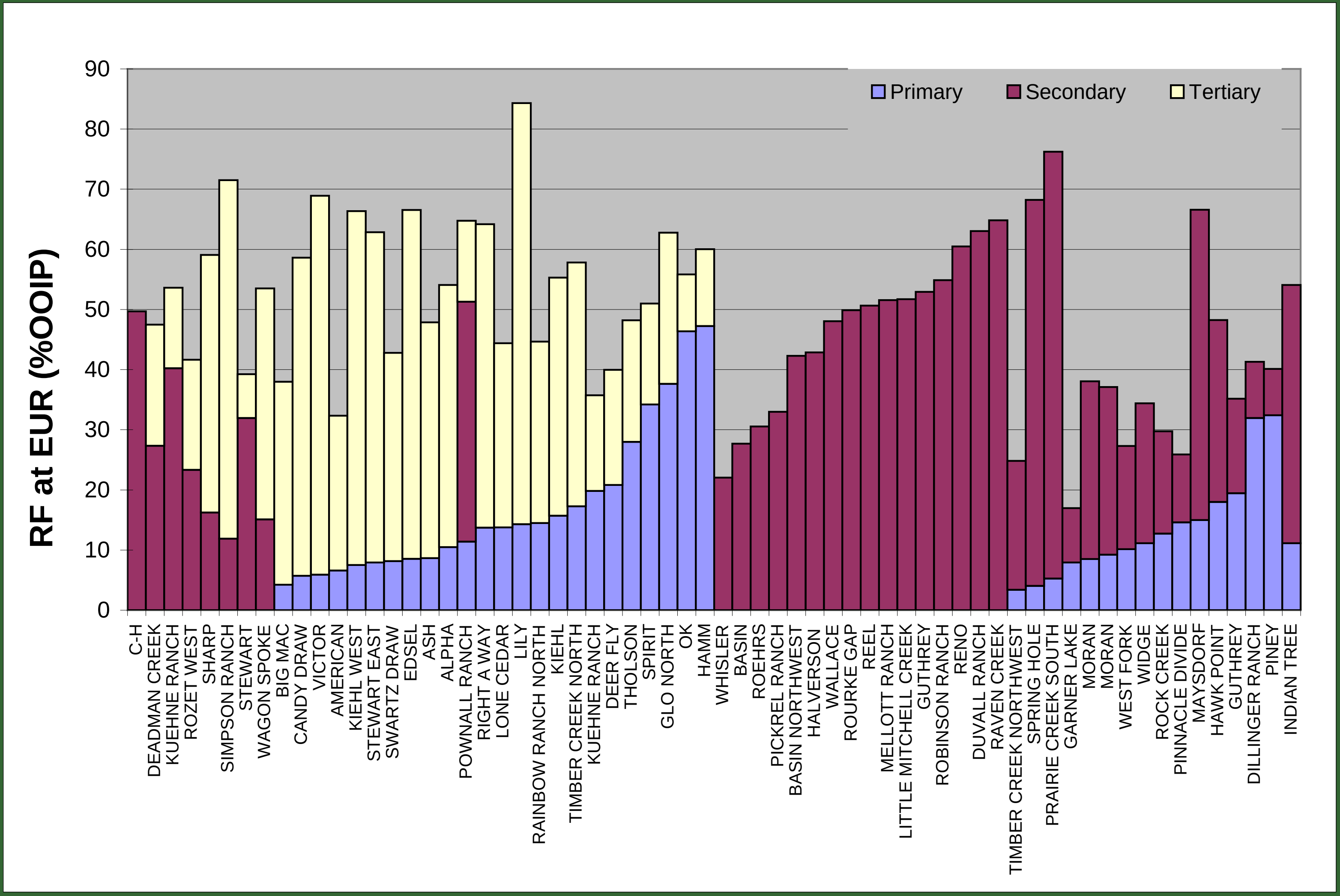




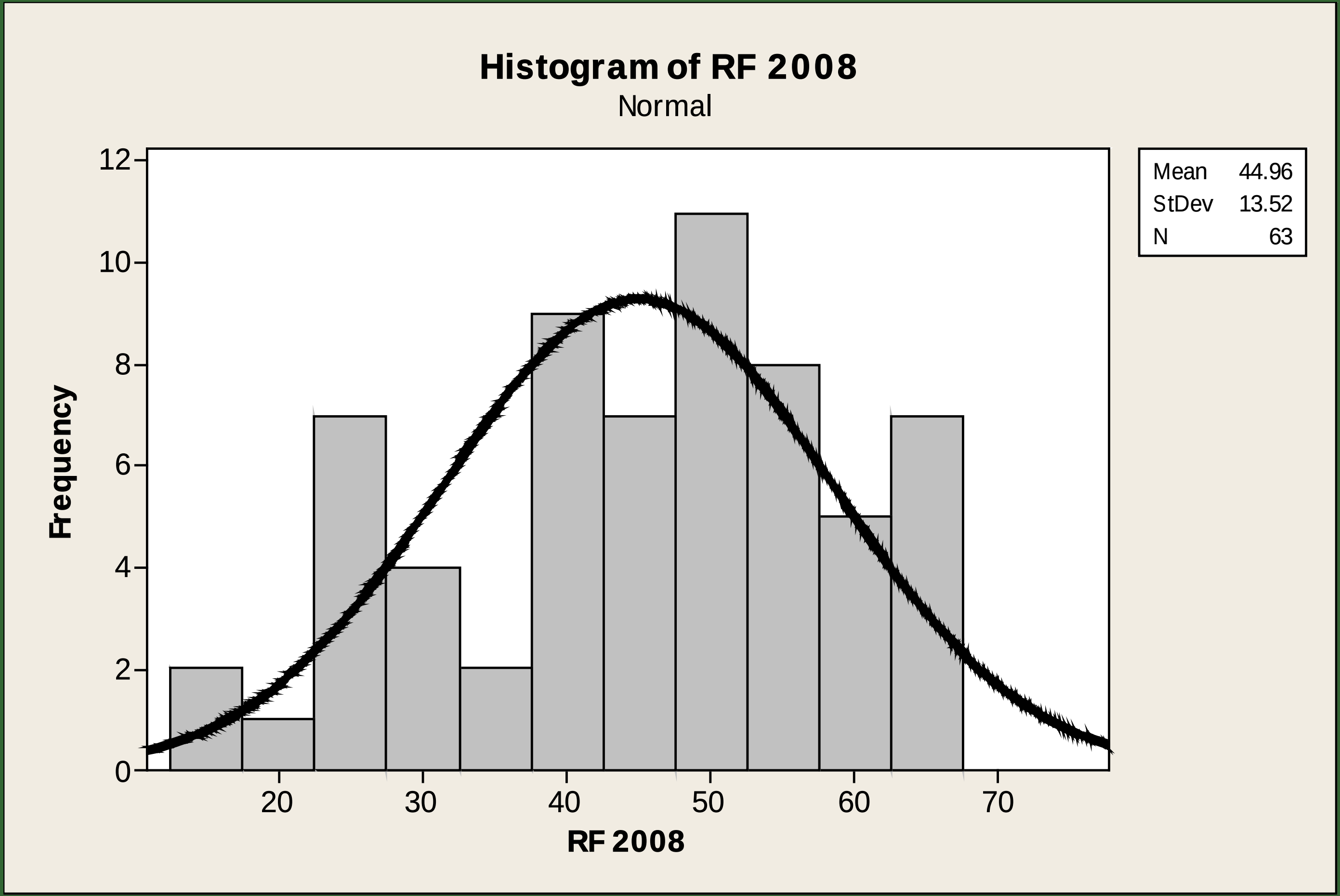


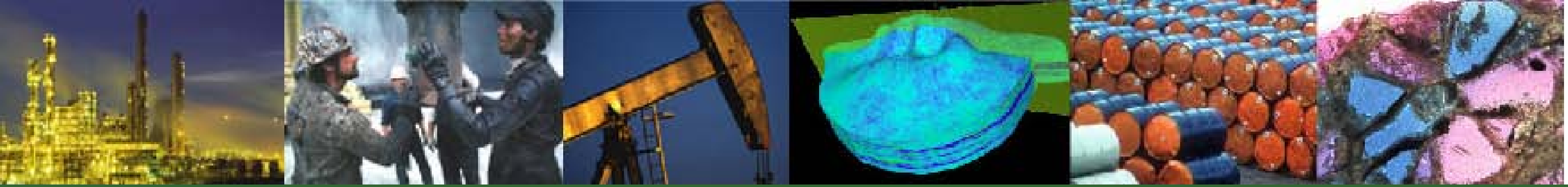
Production Analysis

Each phase expressed as Recovery Factor (% OOIP)

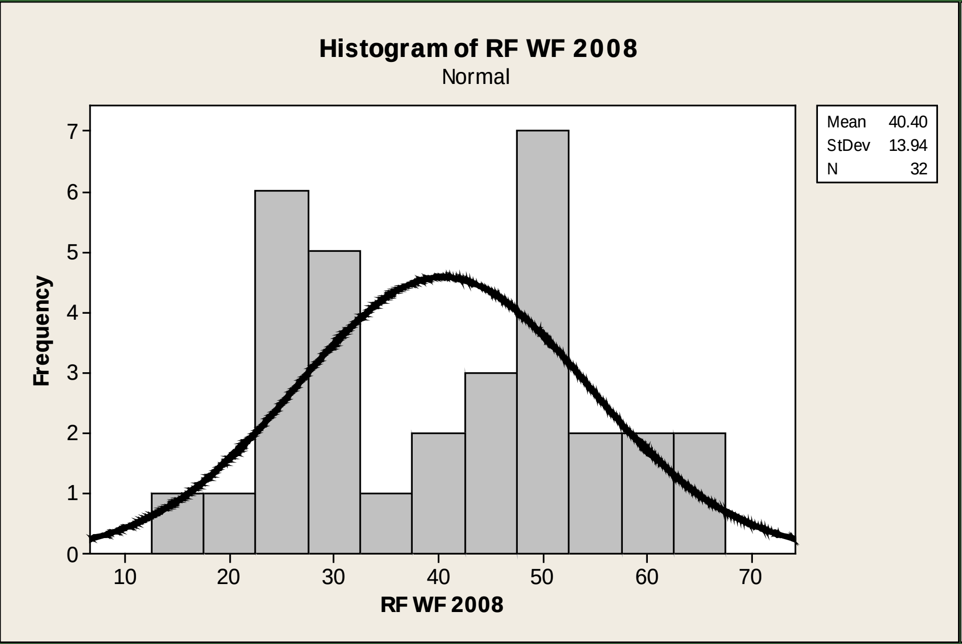


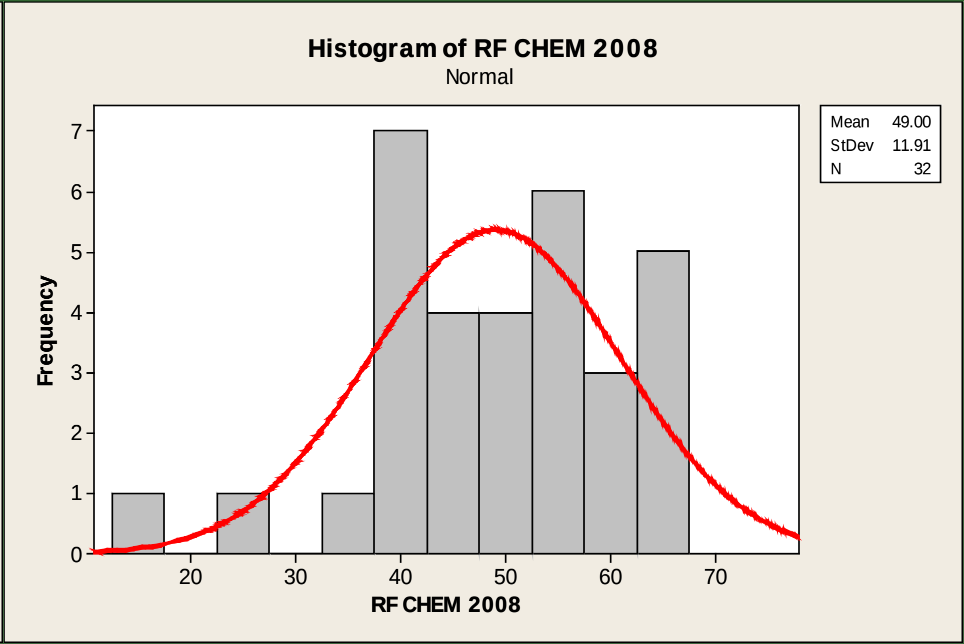
Distribution of Secondary and Tertiary Recovery Factors

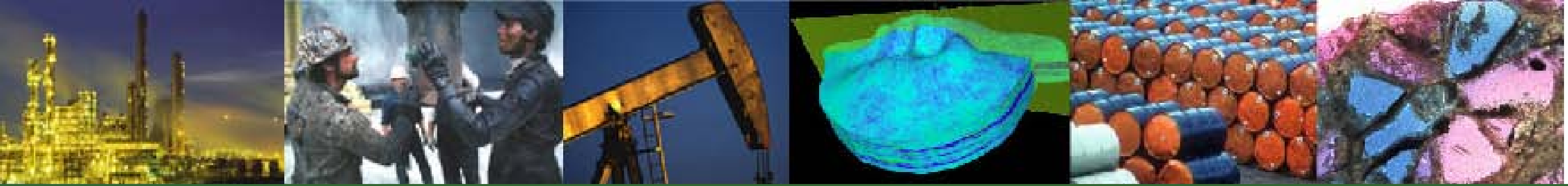




Distribution of WF and Chem. Flood Recovery Factor

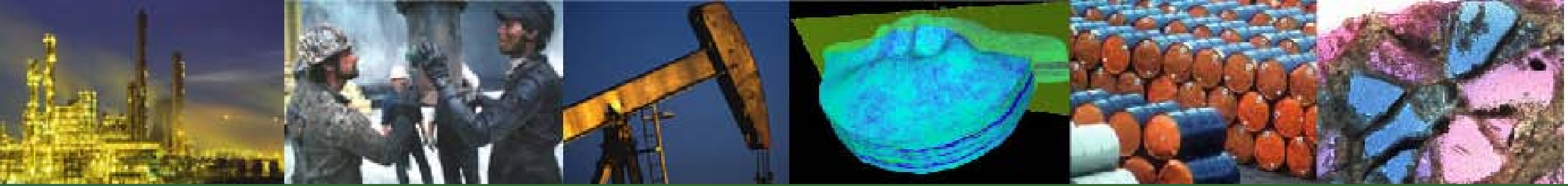






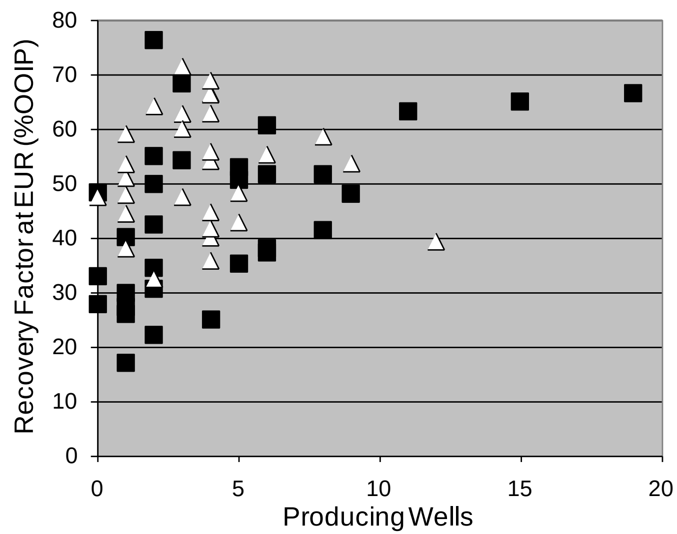
Parameters Evaluated to Explain Range of Recovery Factors

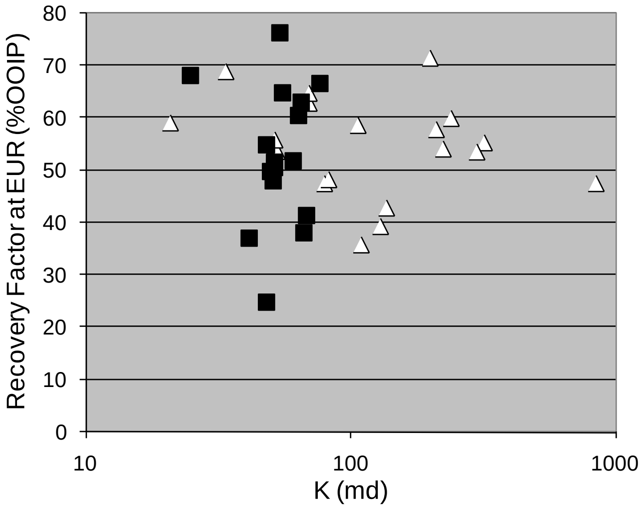
Number of Wells, Permeability, Porosity, Reservoir Salinity, Well Spacing, Pore Volumes Flooded, Oil Saturation, Duration of Flooding, Oil Density (API), Depth, Time between Discovery and EOR

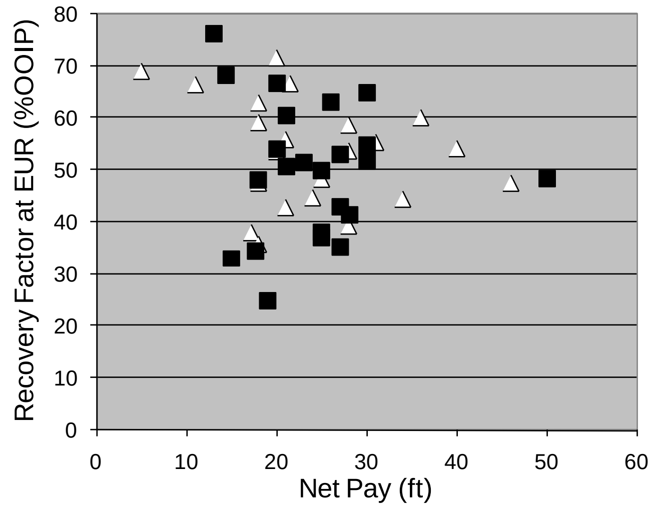


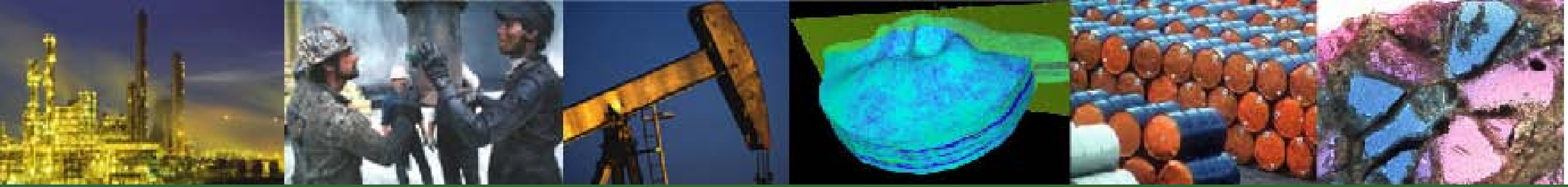
Petrophysical and Production Controls

Triangles are chemical floods, squares are water flood only

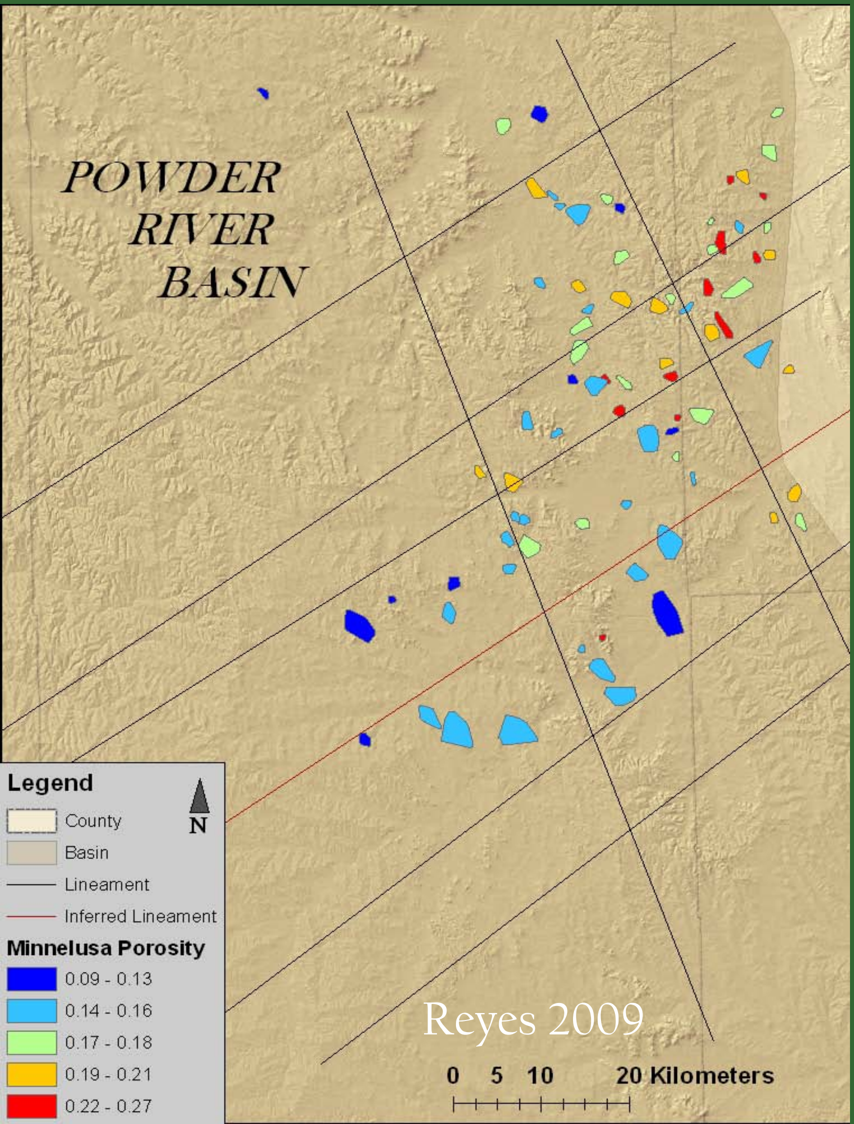


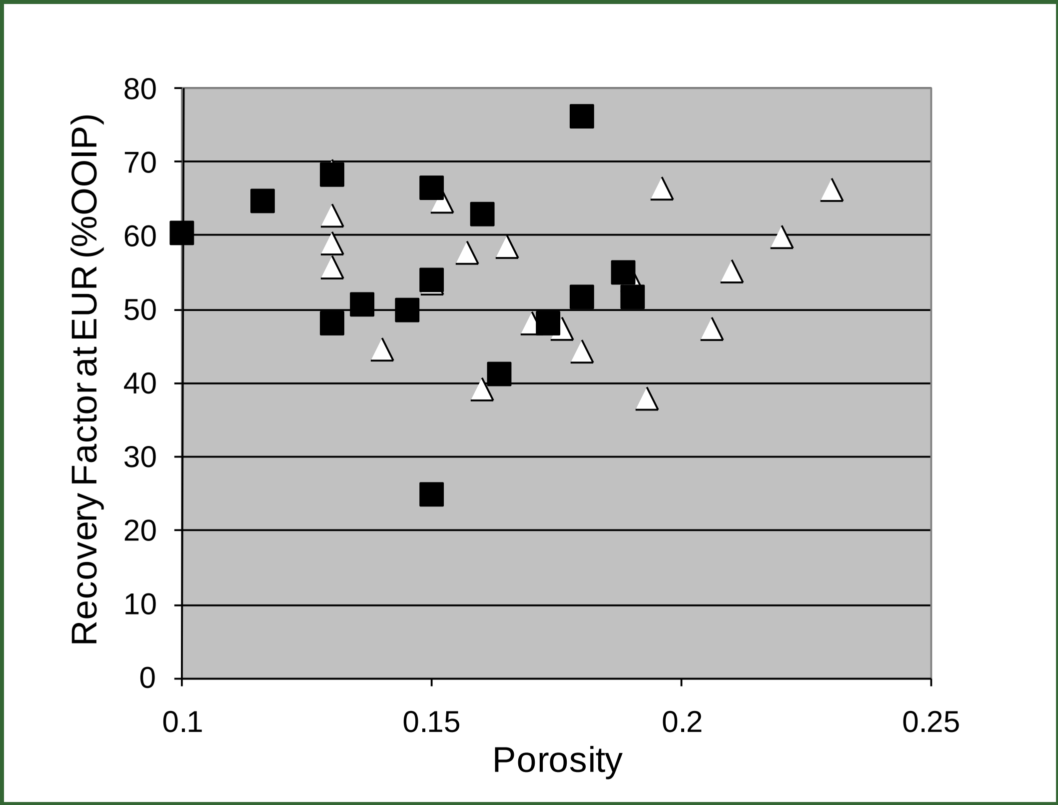




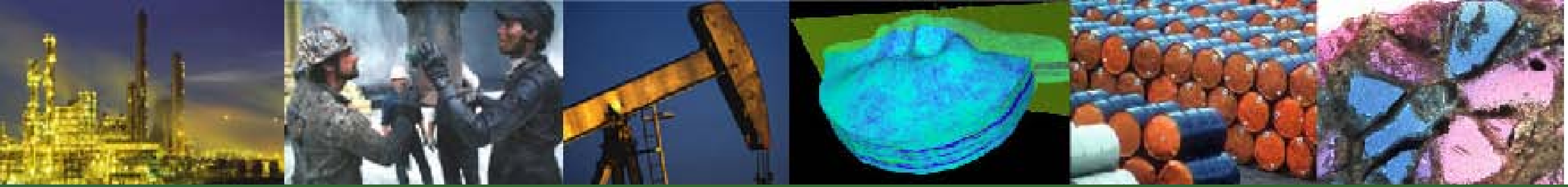


Regional Porosity Trend

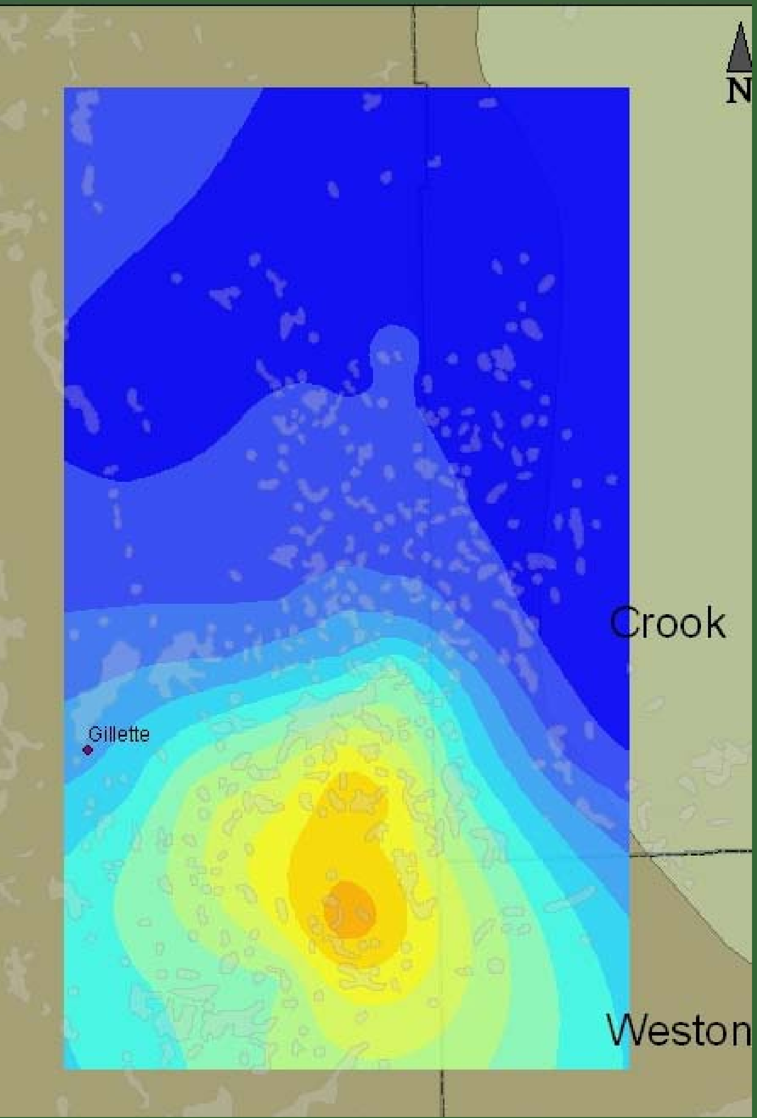


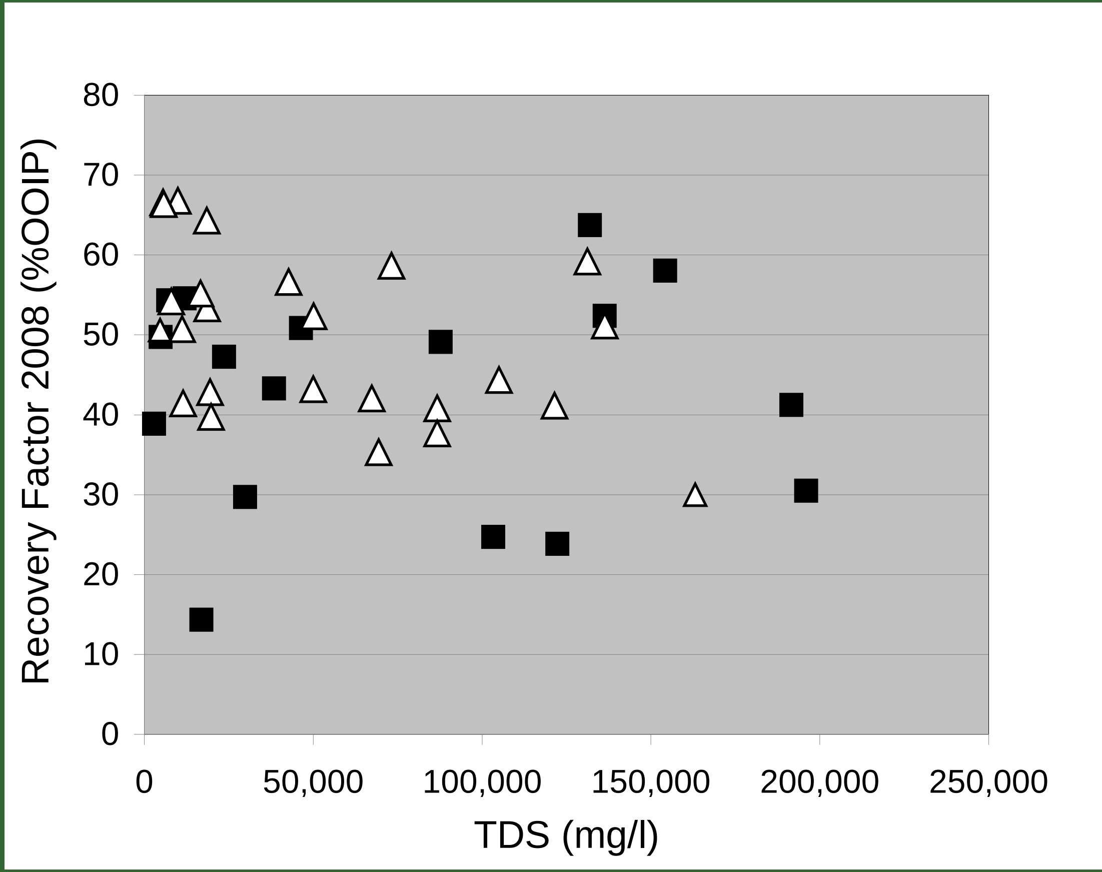


Triangles are chemical floods, squares are water flood only

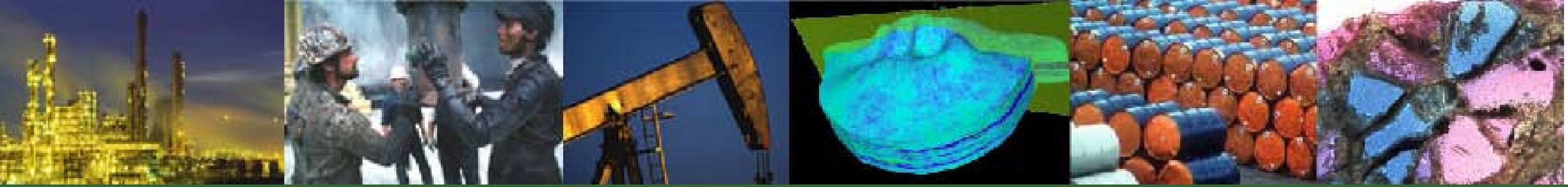


Regional Water Salinity Trend

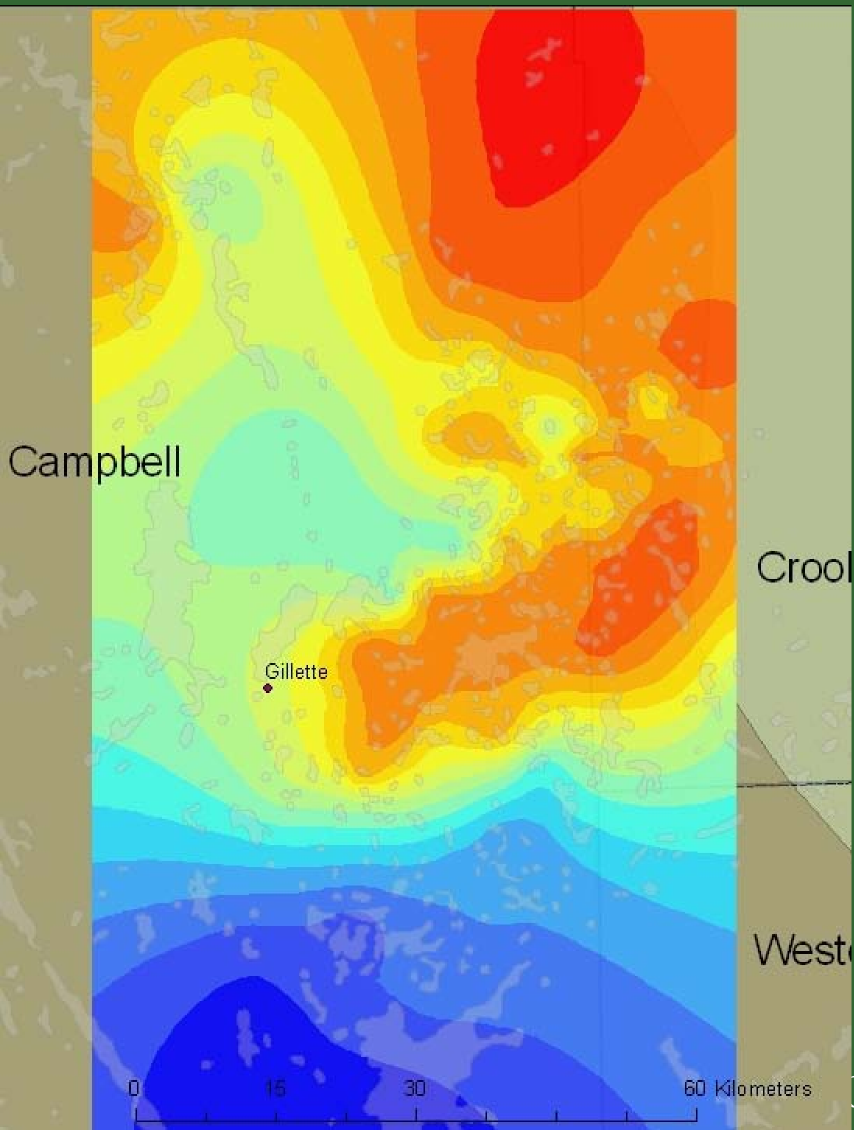


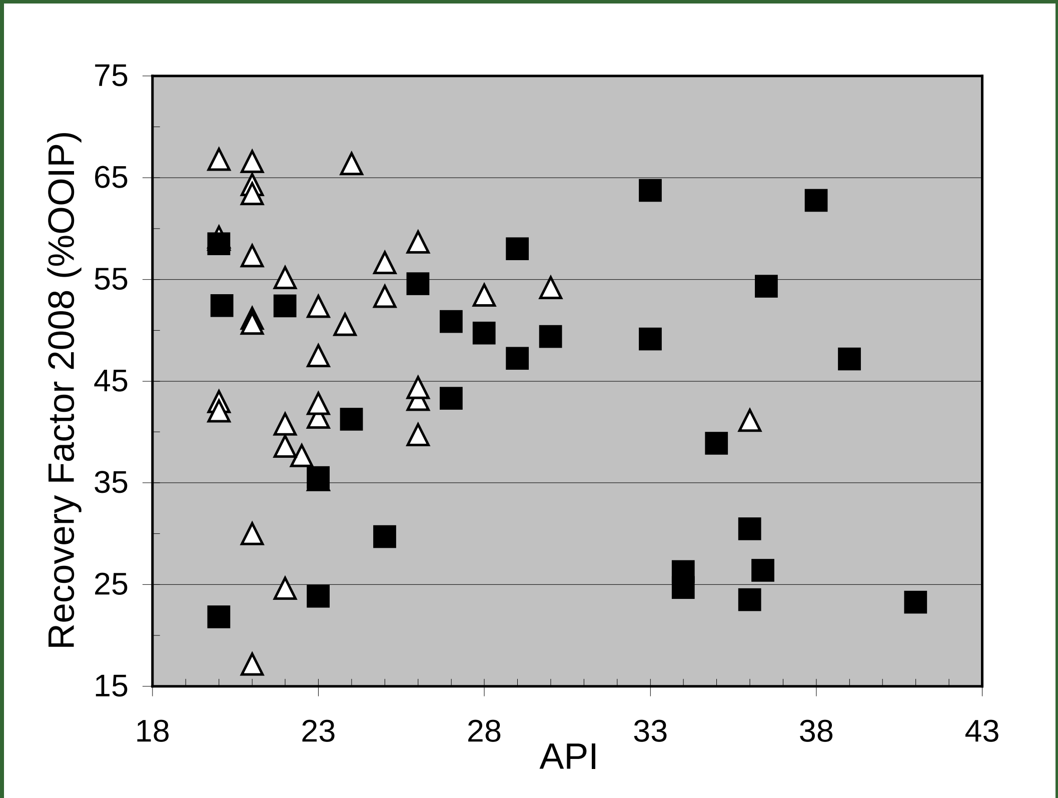


Triangles are chemical floods, squares are water flood only



Regional API Trend



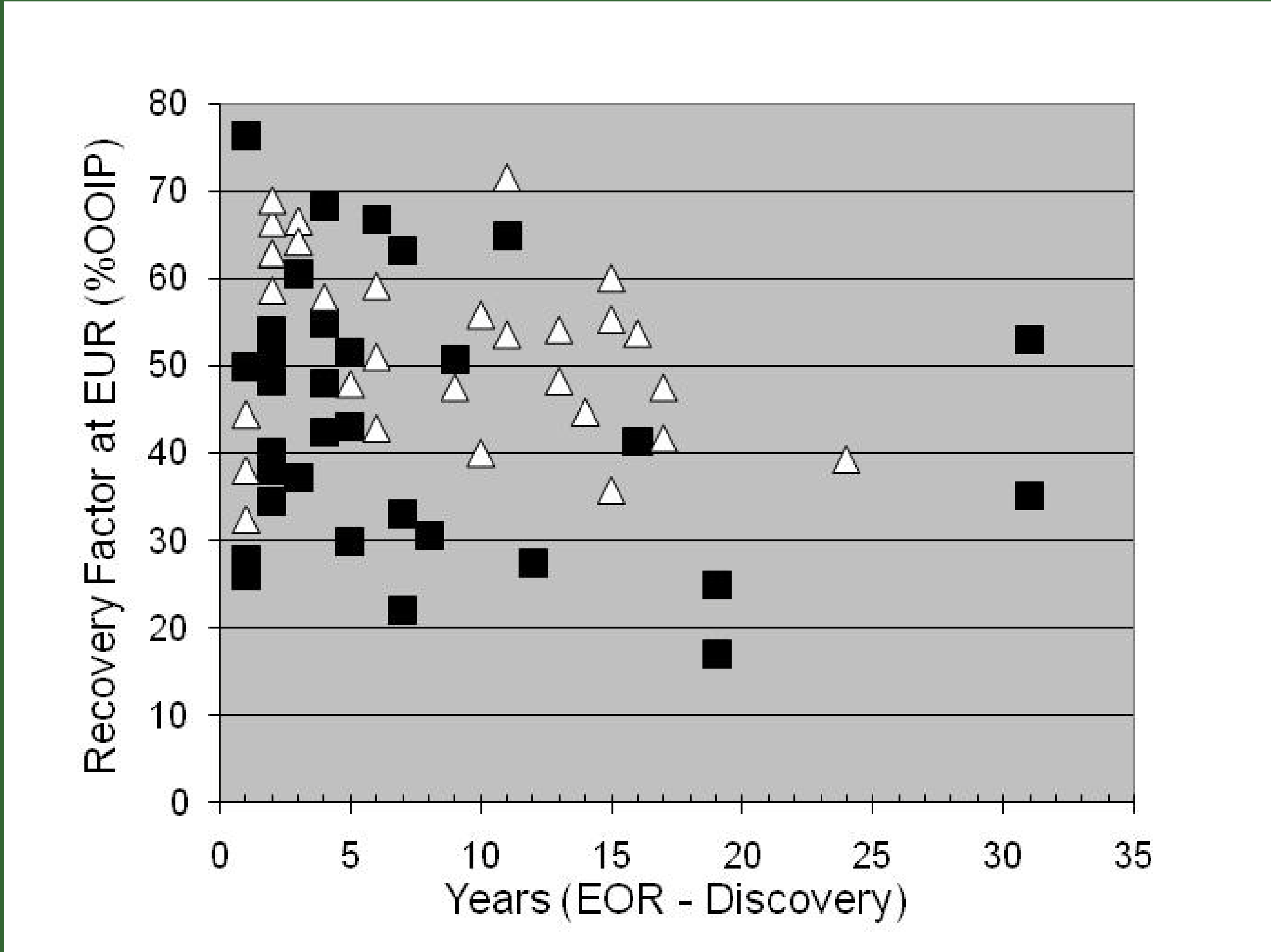


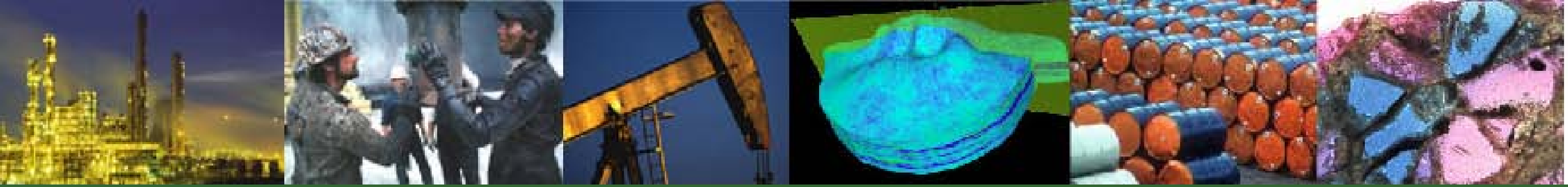
009

Triangles are chemical floods, squares are water flood only

How Soon EOR Started

Triangles are chemical floods, squares are water flood only





CONCLUSIONS

- Chemical flooding improves recovery by an average of 9% OOIP compared to waterflooding.
- Chemical flooding produces more oil sooner.
- The sooner you start EOR the more you get.
- Further work will focus on determining if completion interval, work over history, etc. are important factors for increased recovery.