Assessment of Transport Properties Using High Resolution CT and NMR: An Example from the Central Tengiz Platform Reservoir, Pricaspian Basin, Kazakhstan*

By

Jeroen A.M. Kenter[1], Olga Vizika[2], Elisabeth Rosenberg[2], P.M. (Mitch) Harris[3], Mark Skalinski[4], and Matthew Buoniconti[3]

Search and Discovery Article #20049 (2008)
Posted May 20, 2008

*Adapted from oral presentation at AAPG Annual Convention, Long Beach, California, April 1-4, 2007

[1]Chevron Energy Technology Company, Voorburg, Netherlands (jeroenkenter@chevron.com)
[2]Institut Français du Pétrole, 1 et 4, avenue de Bois-Préau, 92852 Rueil-Malmaison Cedex, France
[3]Chevron Energy Technology Company, San Ramon, California, U.S.A. (MitchHarris@chevron.com)
[4]TengizChevroil, Atyrau, Kazakhstan

Abstract

The central platform in the Tengiz buildup contains a succession of cyclic shallow water deposits ranging from Famennian to Bashkirian in age. The upper Visean, Serpukhovian, and Bashkirian form the main hydrocarbon-bearing interval and contain cyclic, depositional cycles ranging from dm- to m-scale to 10's of meters in thickness. The distribution of reservoir rock types in the central platform is determined by a combination of primary depositional and burial diagenetic modification and includes spatial variations of both porosity enhancing (corrosion) as well as porosity filling (reducing) effects.

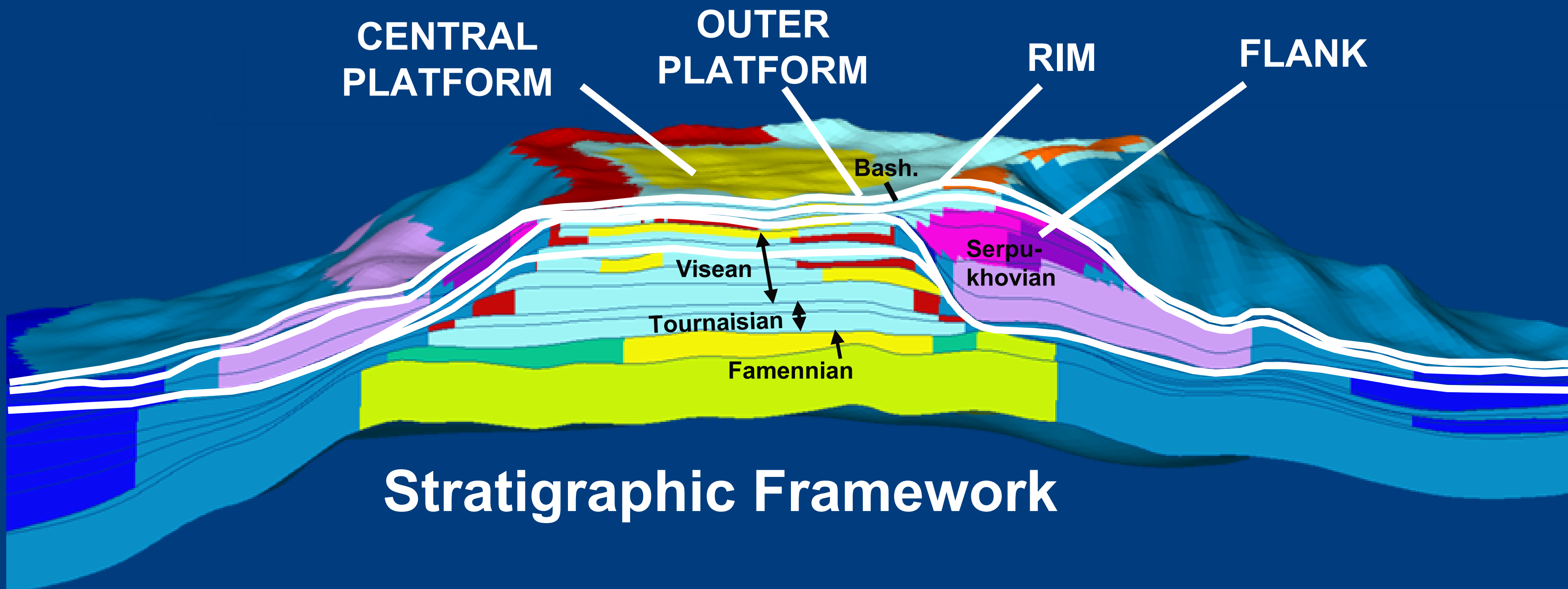
A pilot study using a combination of pore network modeling of the petrophysical properties from high resolution (~1 micron) CT microscanner imagery of several selected plug samples resulted in spatial pore and pore-throat size distributions, level and type of pore interconnectivity as expressed by the aspect ratio as well as the coordination numbers (number of pore throats per pore). Porosity, permeability, capillary pressure, and formation factors were estimated from CT and NMR analyses and show a close match with those derived from analytical measurements. Most strikingly, the CT imagery allowed the extraction of the 3D distribution of pore type and connectivity as well as cement types, information essential to reservoir quality assessment but very difficult to reconstruct using the classic petrographic approach.

High resolution CT and NMR imagery of key reservoir intervals provide reliable data on rock properties and, more importantly, they fill the essential link between petrophysics and geology at the scale of even small pore types (~1-3 microns) and pore filling cements.

ASSESSMENT OF TRANSPORT PROPERTIES USING HIGH RESOLUTION CT AND NMR: AN EXAMPLE FROM THE CENTRAL TENGIZ PLATFORM RESERVOIR, PRICASPIAN BASIN, KAZAKHSTAN

Jeroen Kenter[1], Olga Vizika[2], Elisabeth Rosenberg[2], P.M. (Mitch) Harris[3], Mark Skalinski[4], Jean Hsieh[3], Tony Dickson[5], and Matthew Buoniconti[3]

[1] Chevron Energy Technology Company, Voorburg, Netherlands Chevron ETC, San Ramon; [2]Institut Français du Pétrole, 1 et 4, avenue de Bois-Préau, 92852 Rueil-Malmaison Cedex, France, [3]Chevron Energy Technology Company, San Ramon, California, U.S.A., [4]TengizChevroil, Atyrau, Kazakhstan, [5]Cambridge University, UK



Stratigraphic Framework

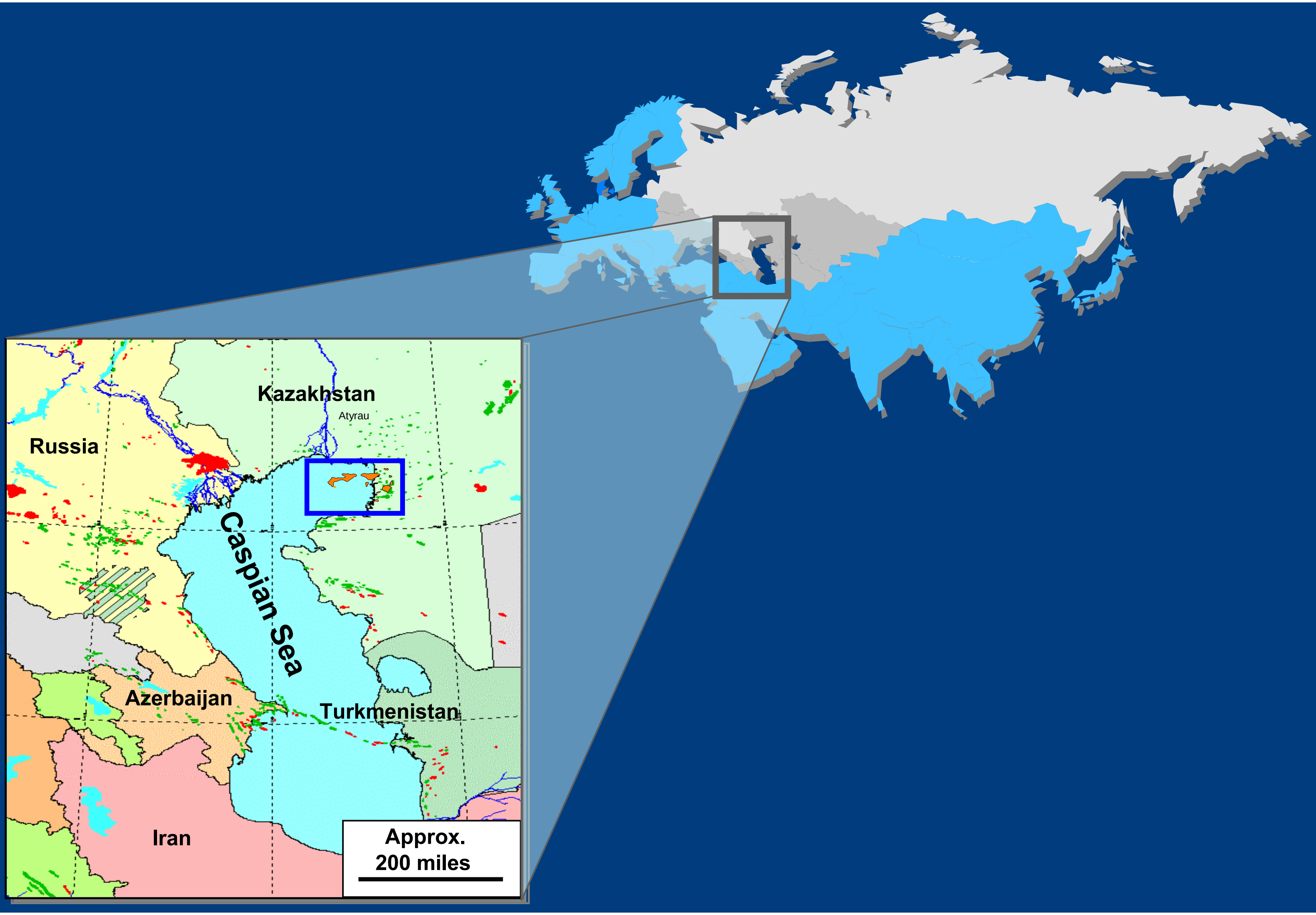
Outline

- Rationale
- Regional setting and history Tengiz Field
- Depositional Rock Types and Cyclicity
- Reservoir Quality and Diagenetic Modification
- Pore Network Modeling (PNM) and Nuclear Magnetic Resonance (NMR): effective transport properties
- Spatial reservoir quality prediction through integration PNM, diagenesis and petrophysics

Rationale

- Tengiz platform reservoir quality is controlled by diagenetic modification of a cyclic depositional system
- Complex and multiple stages of diagenetic modification
- Reservoir quality = primary depositional texture + "mostly" diagenesis
- Pore typing difficult and non-quantitative using classic petrographic methods
- Identification and mapping of diagenetic events and their genesis allows spatial modeling
- Pore Network Modeling (PNM) links spatial diagenetic overprint, petrophysics and effective transport properties

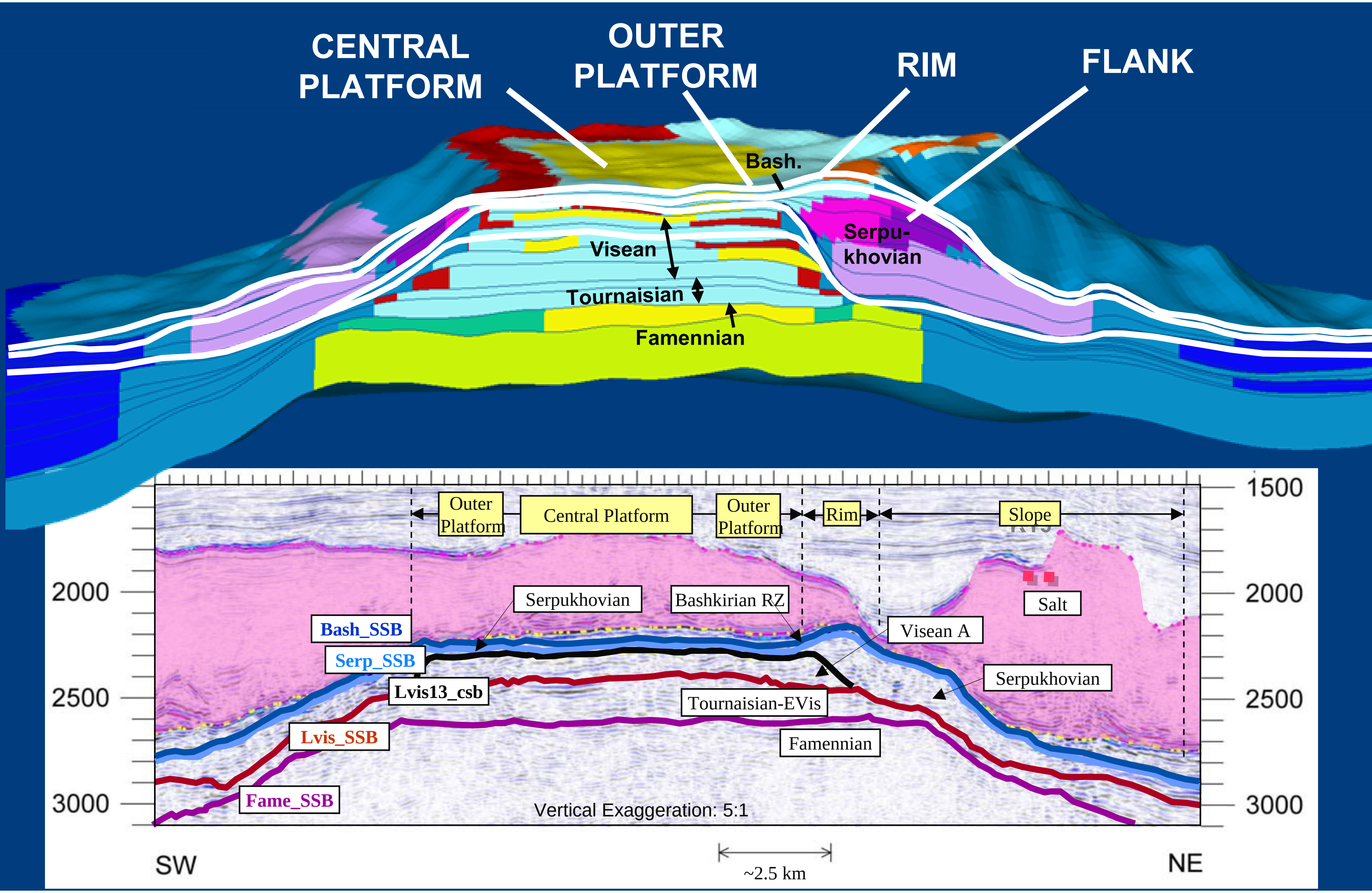
Regional Setting – Caspian Sea



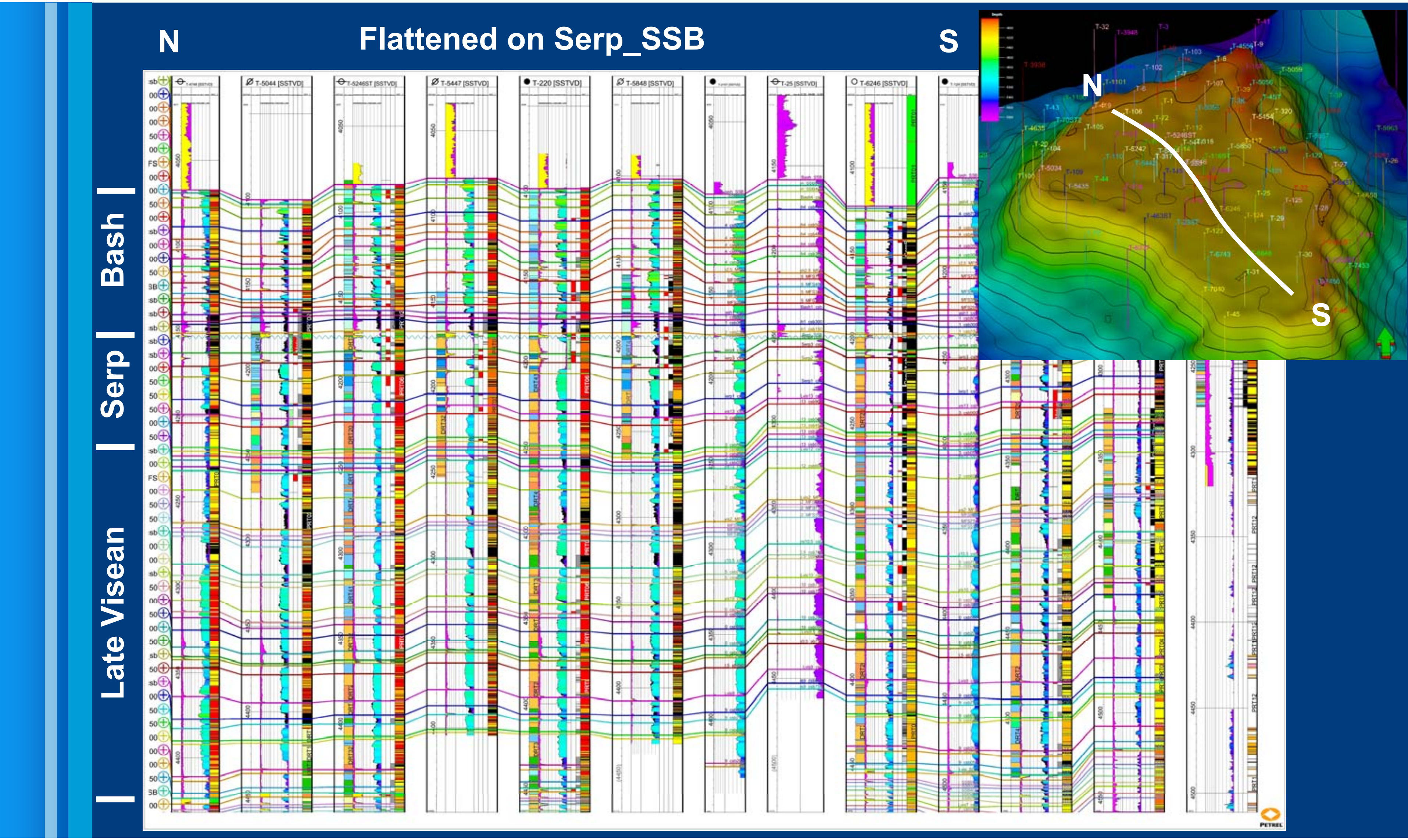
Tengiz Field – Background

- Produces oil from an isolated Devonian-Carboniferous carbonate platform (aerial extent of >110 km2)
- “Giant” - one of the world's 10 largest oil fields with 6-13.5 billion barrels of reserves
- More than 115 wells
- Highest rate wells in the platform margin and slope in fractured carbonates with low (<6%) matrix porosity; platform wells higher porosity (up to 18%), but matrix permeability is typically low (<10 md)

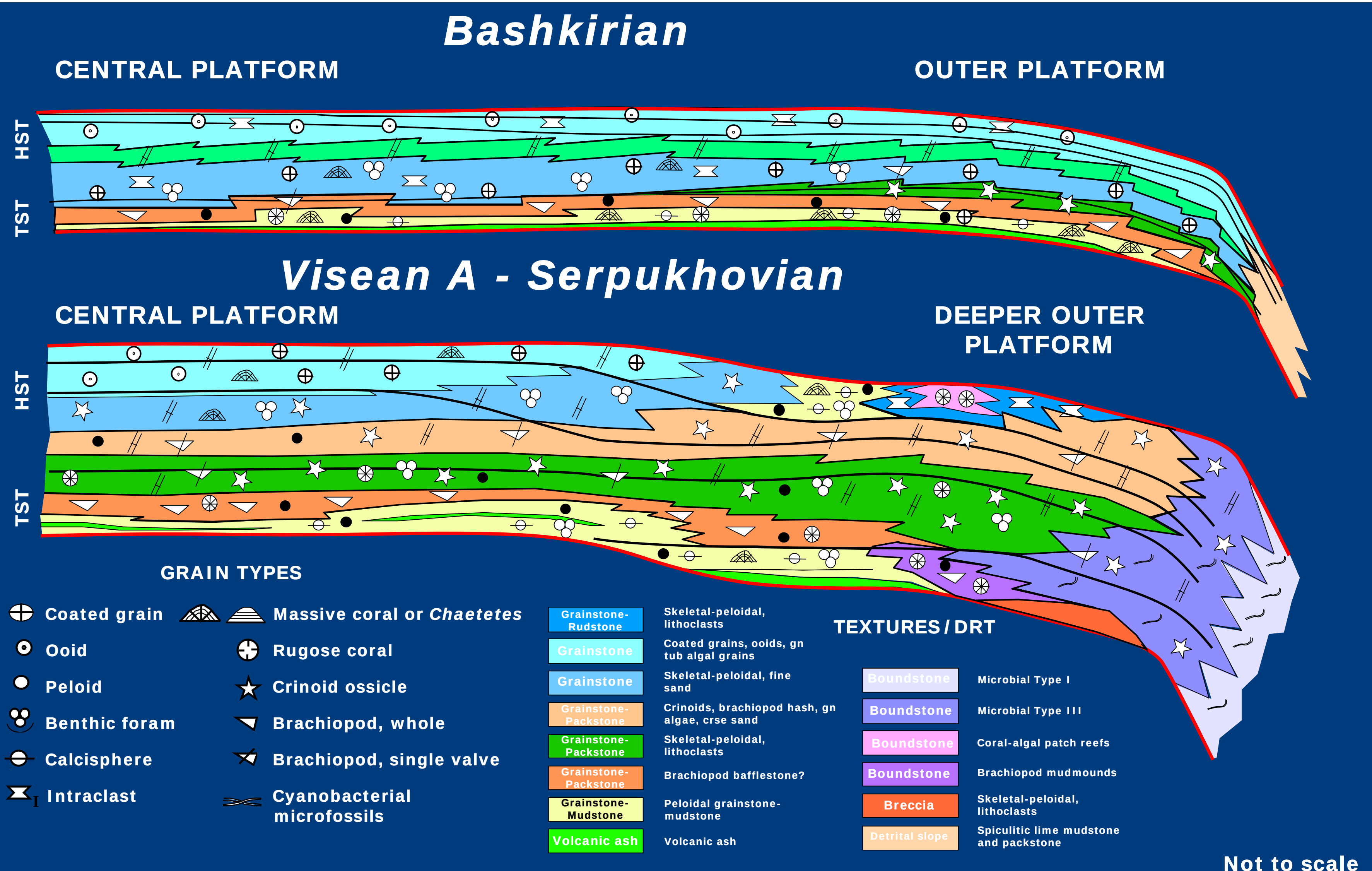
General Environments of Deposition



Cyclic depositional system: 2nd order TST / HST plus 4th and 5 / 6th order



Simplified Depositional Models



Depositional Rock Types and Cyclicity

Late Visean and Serpukhovian:

- Highly cyclic arrangement of complete grainy porous shoaling cycles with basal thin and tight lagoonal intervals
- Significant diagenetic overprint
- Predictable facies and reservoir quality

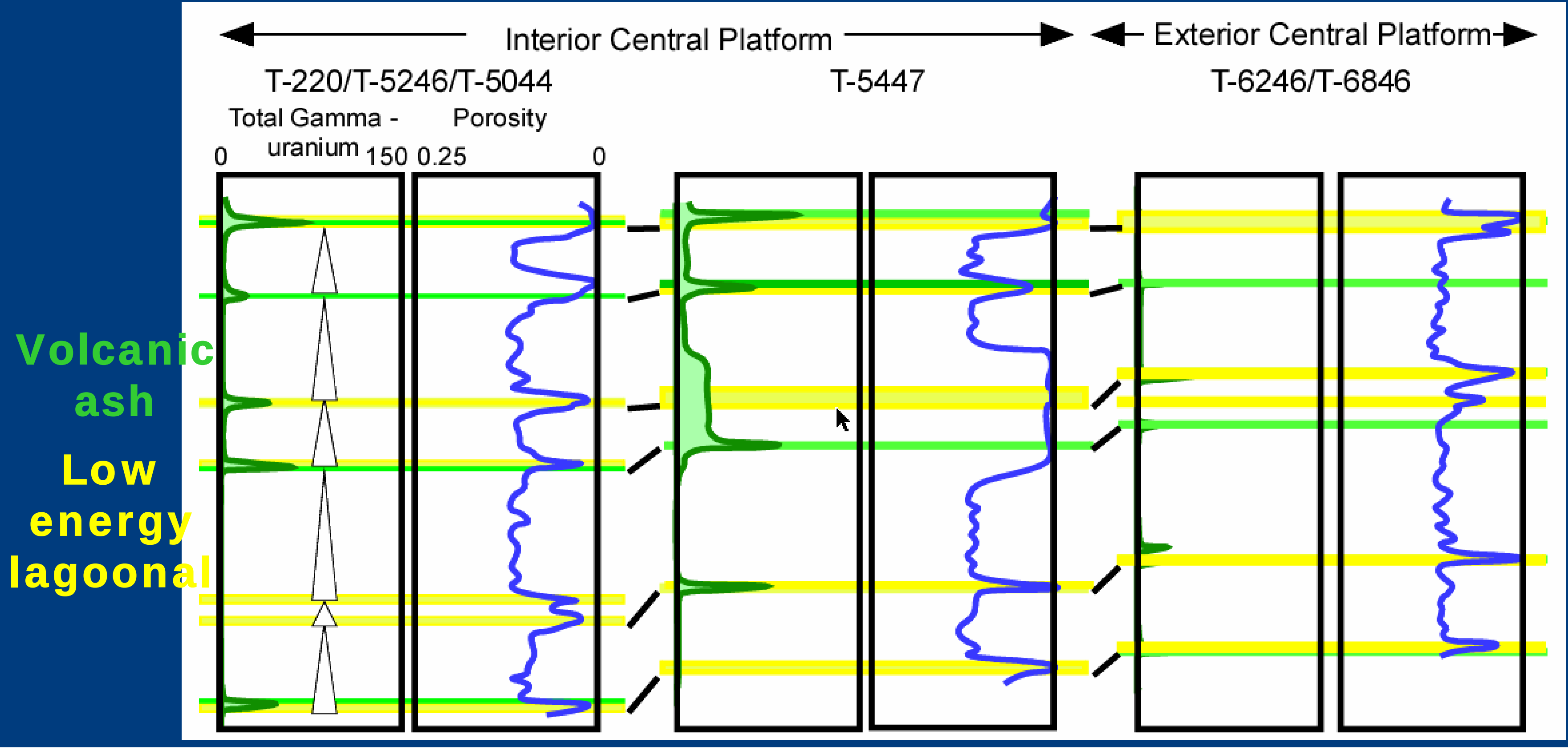
Bashkirian:

- High energy facies with thin lagoonal/ash intervals
- Significant early diagenetic overprint (compaction and corrosion)
- Relatively predictable lateral facies BUT poorly predictable reservoir quality

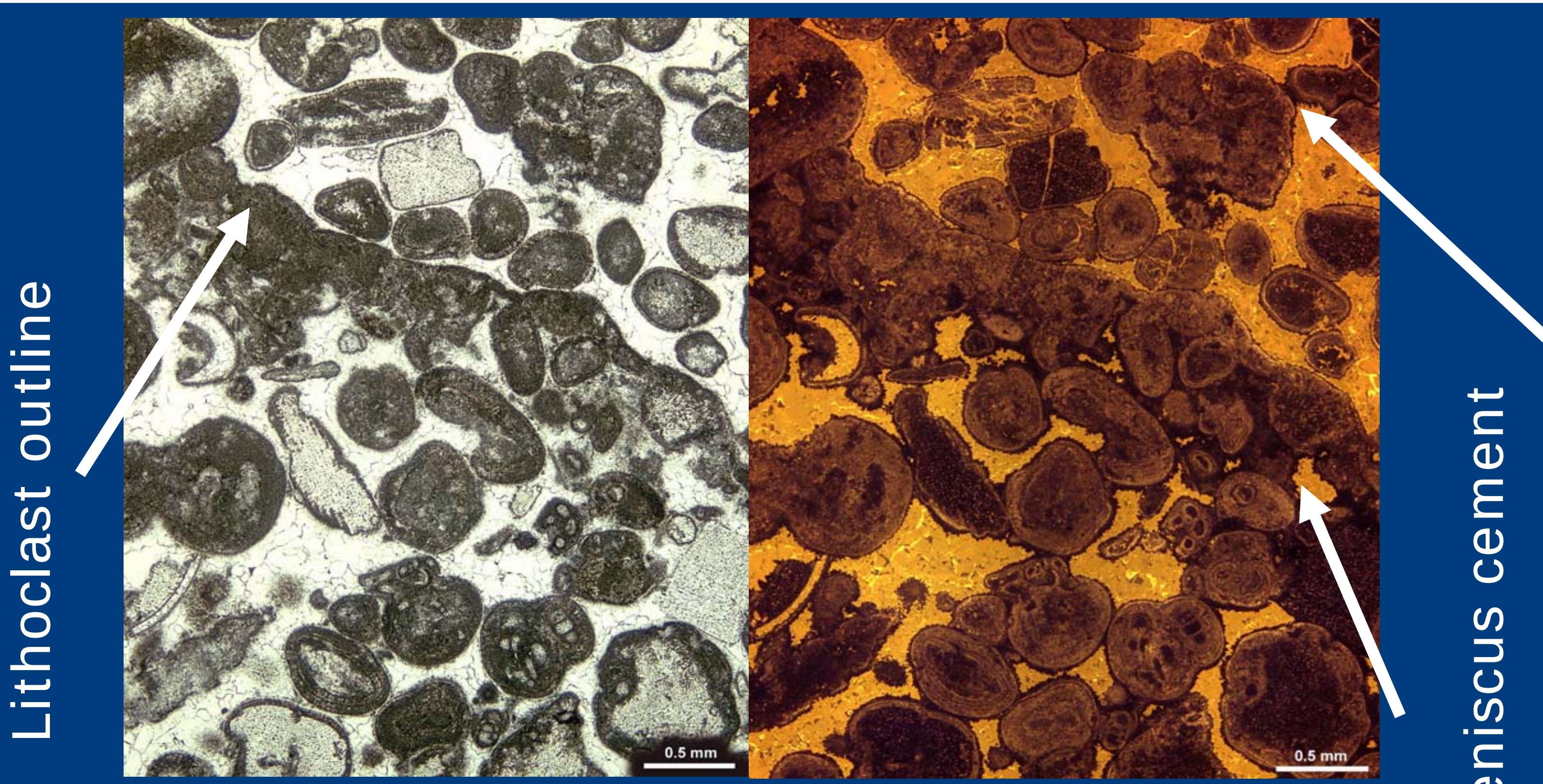
Diagenetic Modification and Reservoir Quality – Early Burial

1

Early burial diagenesis: differential porosity reduction in 1) grainy (cemented) vs muddy (crushed) rock types, 2) tightening near cycle boundaries, 3) in dispersed ash intervals

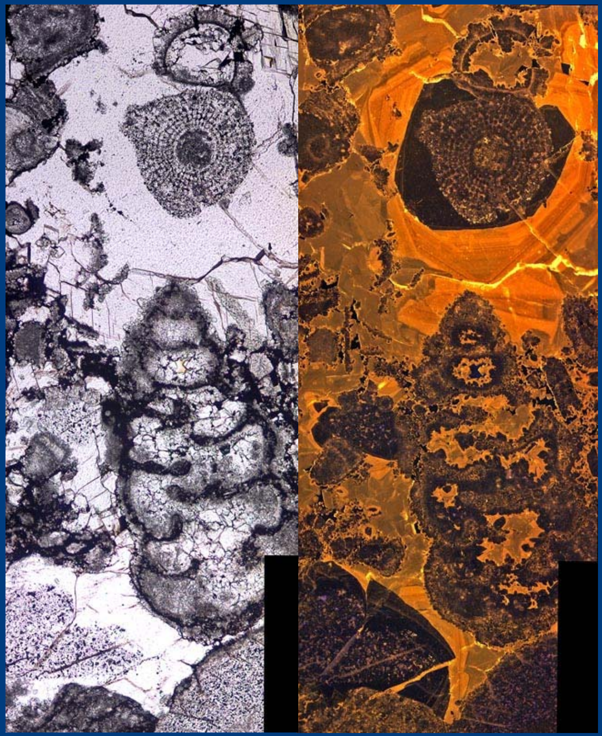


Phase 1: Non-luminescent meteoric cement

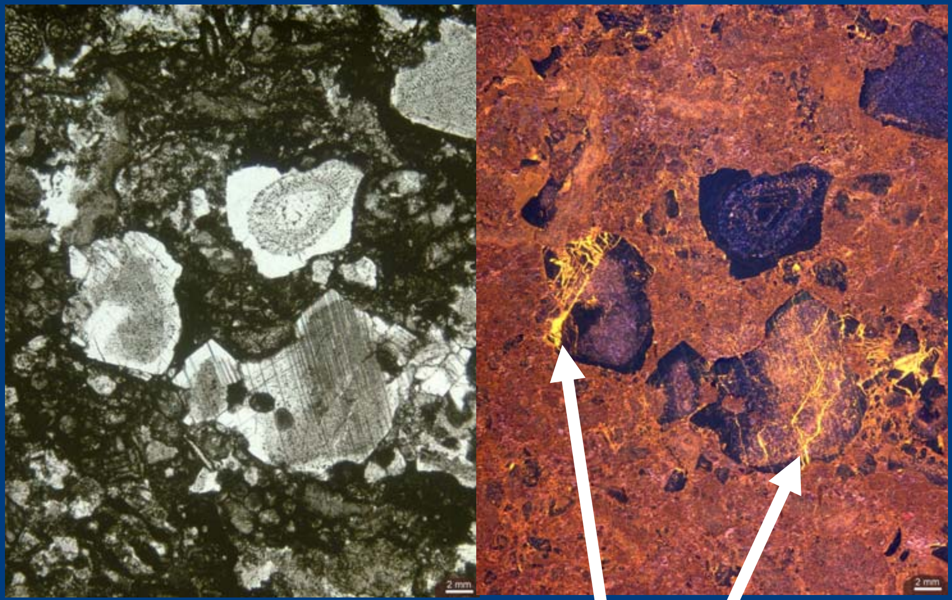


Marginal cementation by syntaxial fringe cement: meteoric meniscus and pendant cement in both lithoclasts and matrix

Phase 1: Non-luminescent syntaxial cements filling interparticle porosity

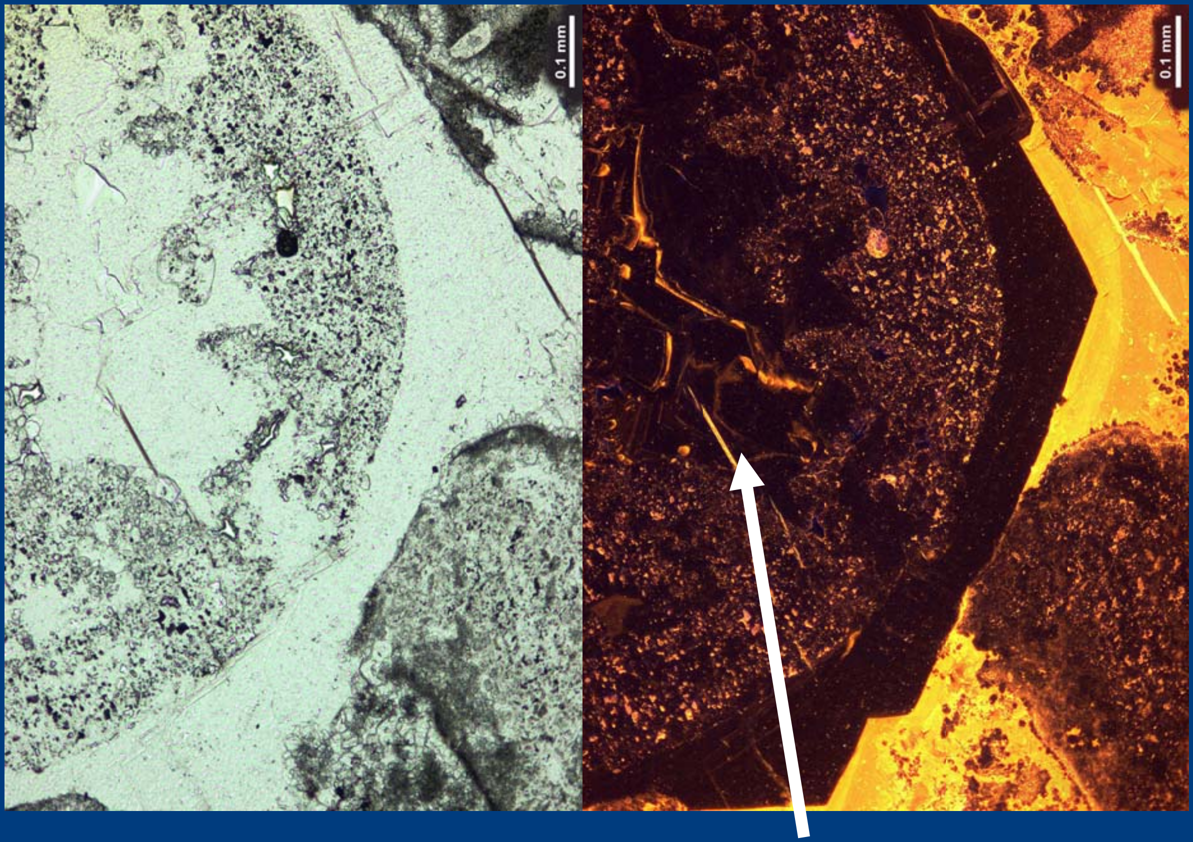


Early syntaxial calcite fractured but healed (non-luminescent) and cementing grainstones and preserving porosity



Absence of such early syntaxial calcite leaves framework ductile and leads to crushing of fabric and reduction of porosity in packstones-wackestones

Phase 1: Non-luminescent cement filling dissolution pits in crinoids



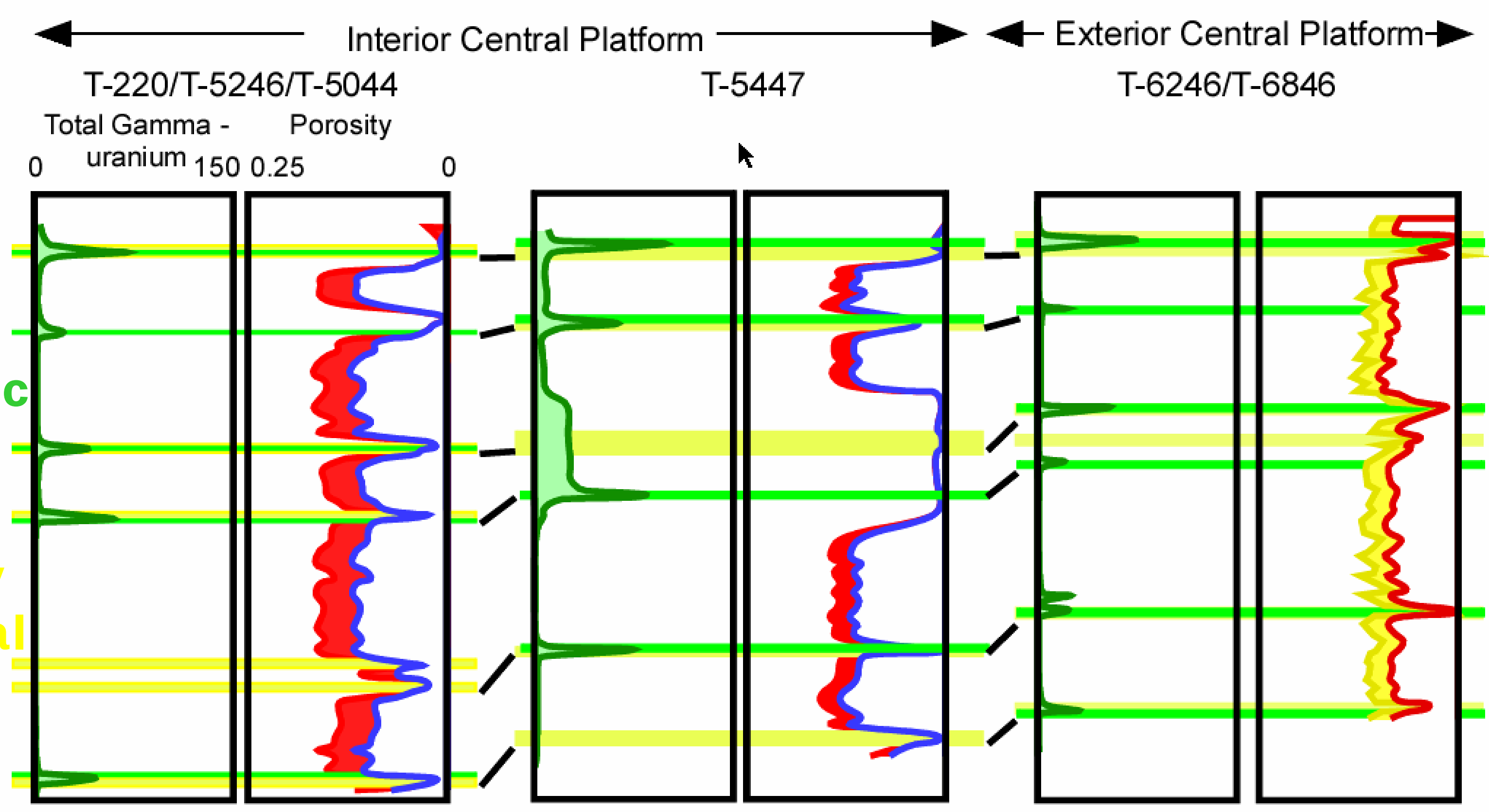
Centripetally filling of crinoid dissolution cavities by non-luminescent calcite cement

Diagenetic Modification and Reservoir Quality – Late (Deep) burial 1

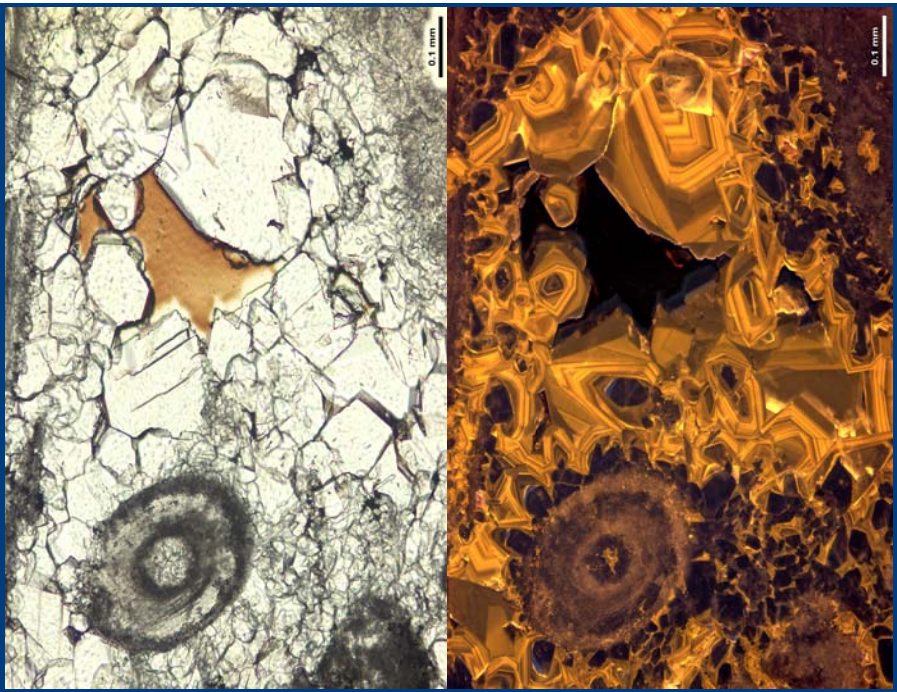
2 **Late (deep) burial diagenesis**: corrosion and differential cementation across platform

Volcanic ash

Low energy lagoonal

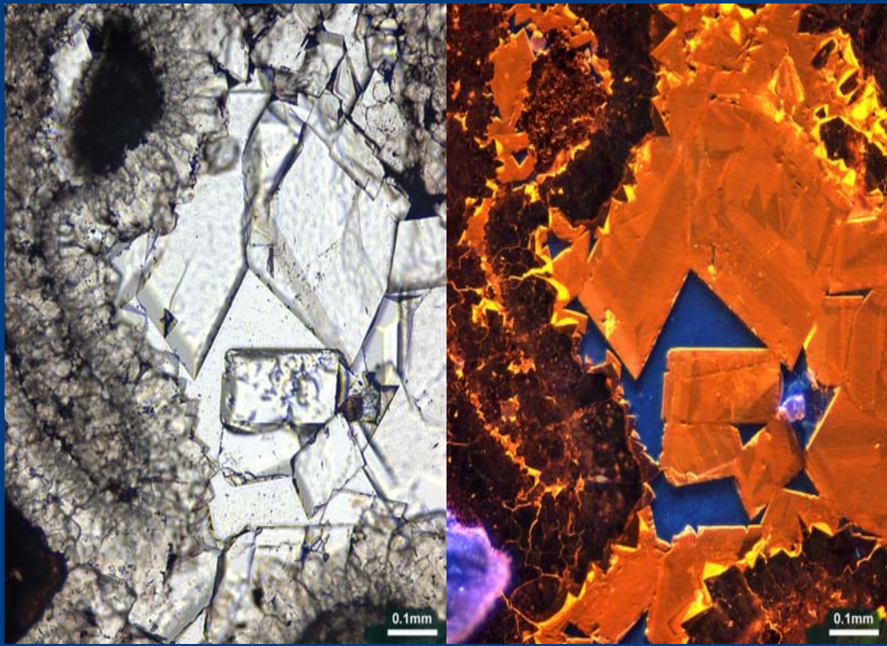


Stage 2: Orange luminescent scalenohedral cement filling most of remaining pore space



Strikingly zoned scalenohedral calcite cement filling pores

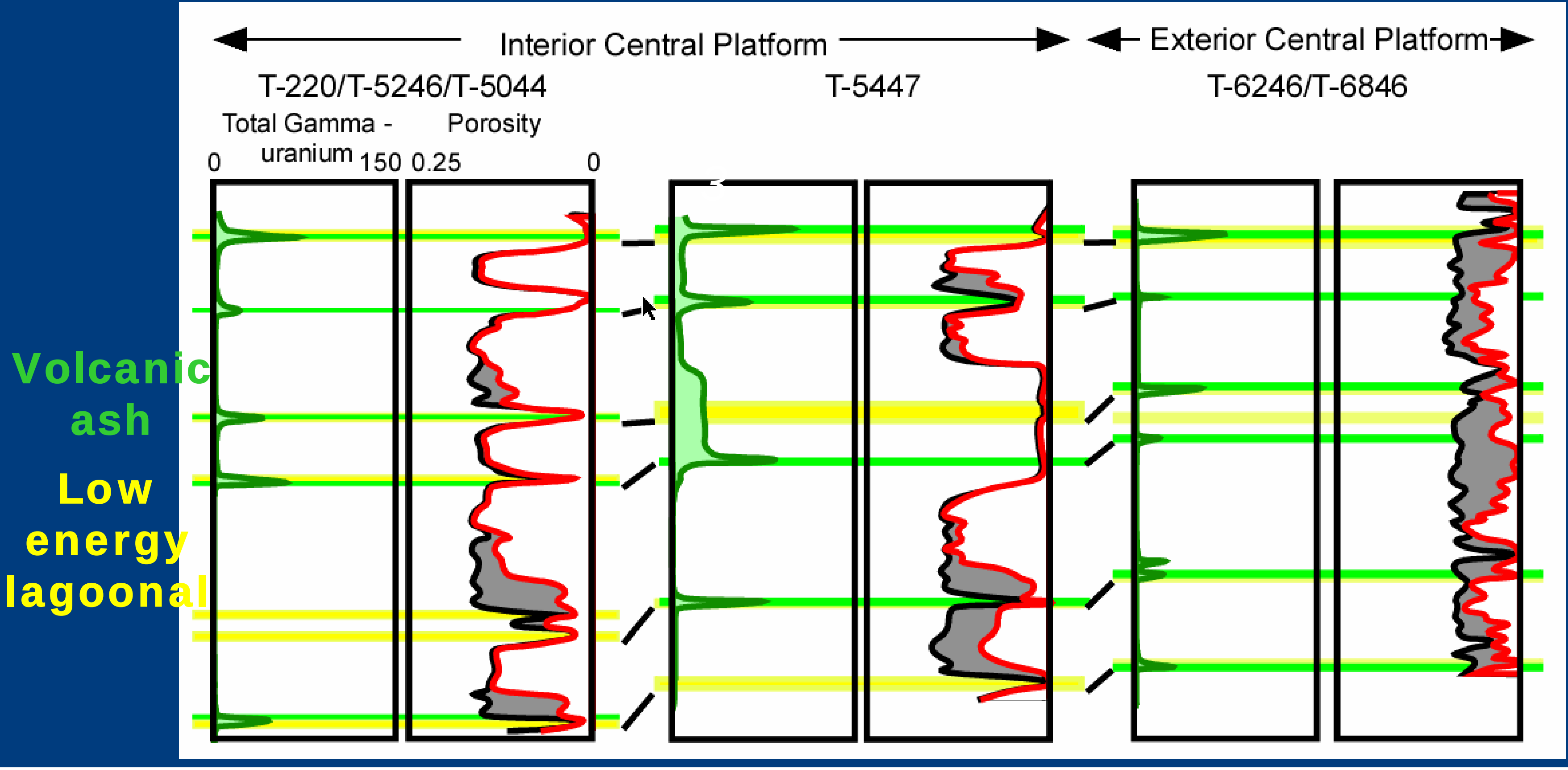
Rhombohedral calcite cement filling pores



Diagenetic Modification and Reservoir Quality – Late (Deep) Burial 2

3

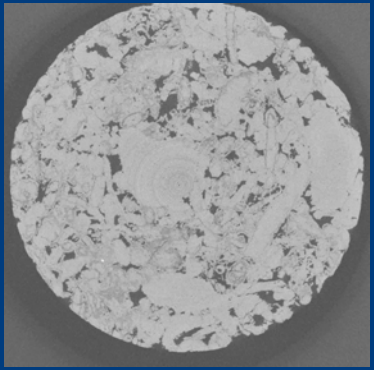
Late (deep) burial diagenesis: differential deposition of bitumen "cement" across platform in matrix, (micro and macro)pores, vugs, fractures, etc.



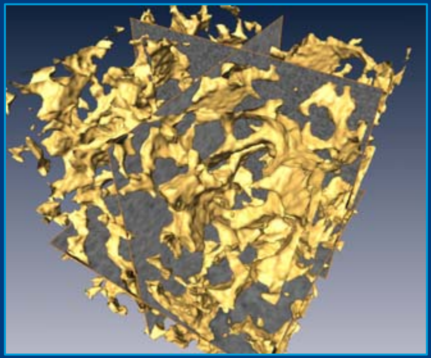
Pore Network Modeling (PNM) using CT imagery (CMT)

- X-Ray Microtomography (CMT): characterisation of the pore space at the micron scale
- Extraction of pore image in order to fit realistic and representative structures of pore networks
- Calculation of transport properties by Pore Network Modeling satisfying comparison between experiments (dual Phi/K)

High resolution CT imaging: process

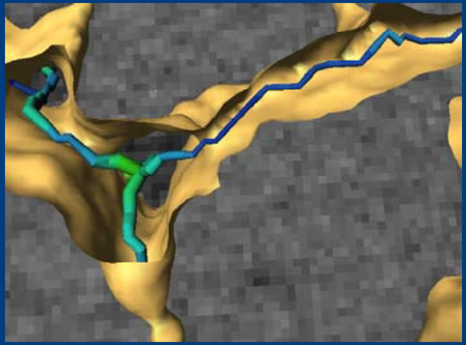


High resolution CMT grey scale image of 5 to 38 mm core plug

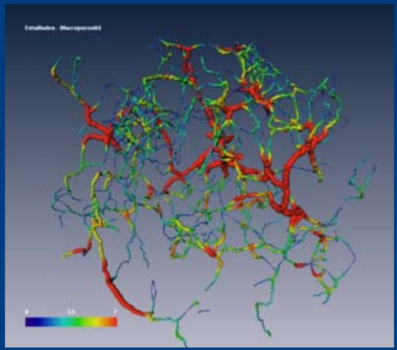


Pore volumes following thresholding

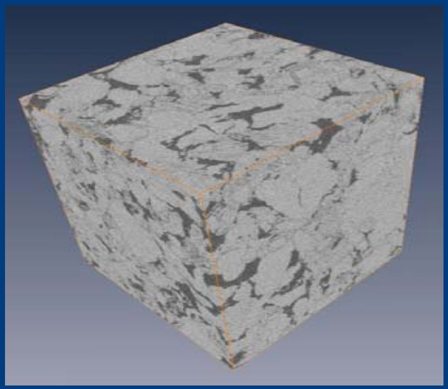
Pore throats mapped as function of diameter



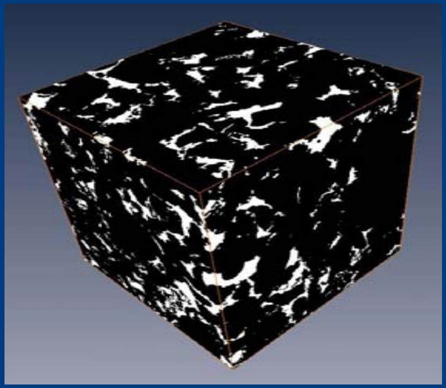
Final 3D pore network mesh as input for calculation of transport properties

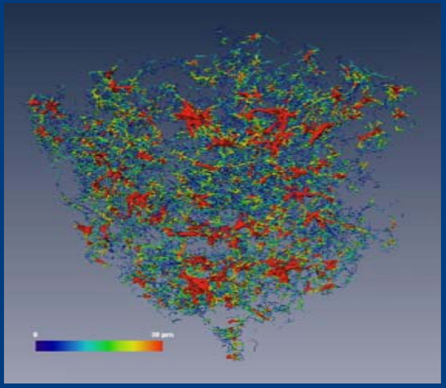


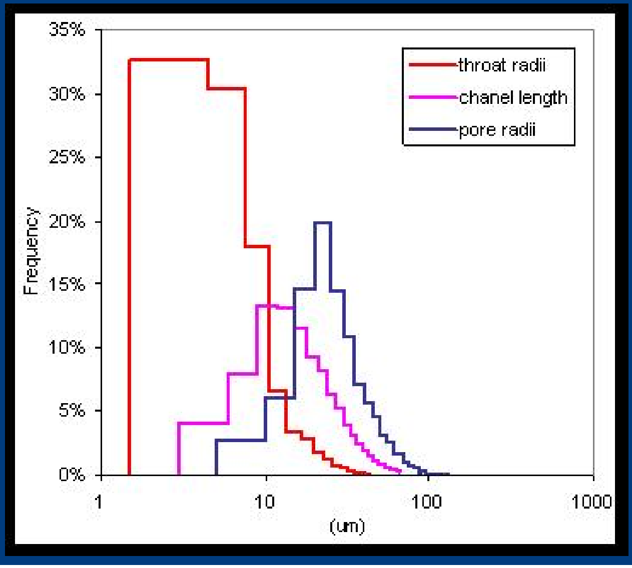
High resolution CT imaging: example



Plug 372 T-5246 ~372 4152.84 m; well-sorted skeletal grainstone (SPG) showing BP, MP and cement lining pores

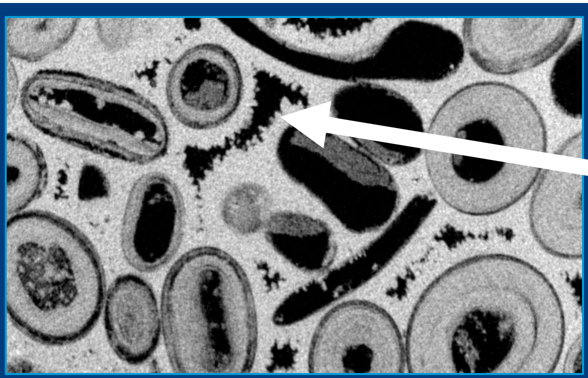


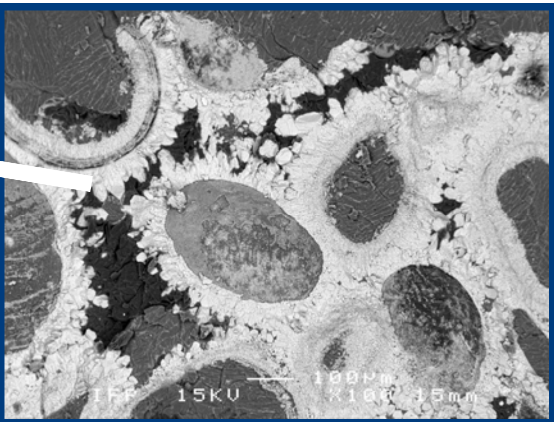




Representative volume analyses of pore parameters and microporosity cut off at 2 um

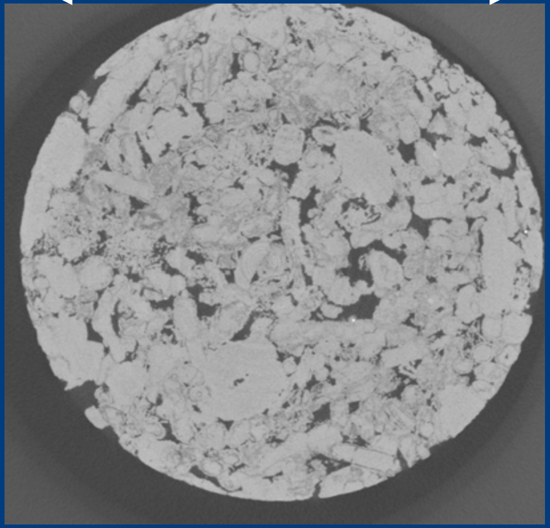
CMT versus petrography

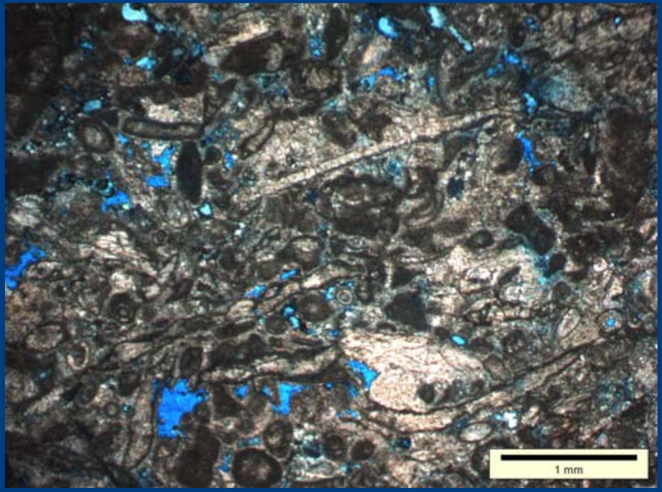




CMT image (left) resolving cement; SEM image for comparison (right)

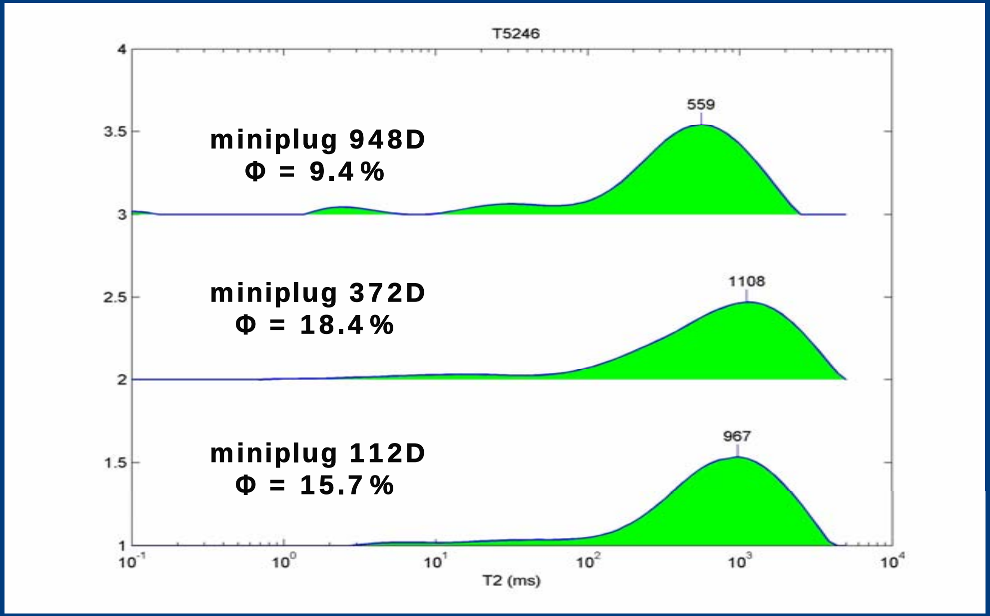
5 mm diameter and 25 mm length





CMT image and photomicrograph of plug 372: significant limitations petrography for quantitative assessment pore type distribution

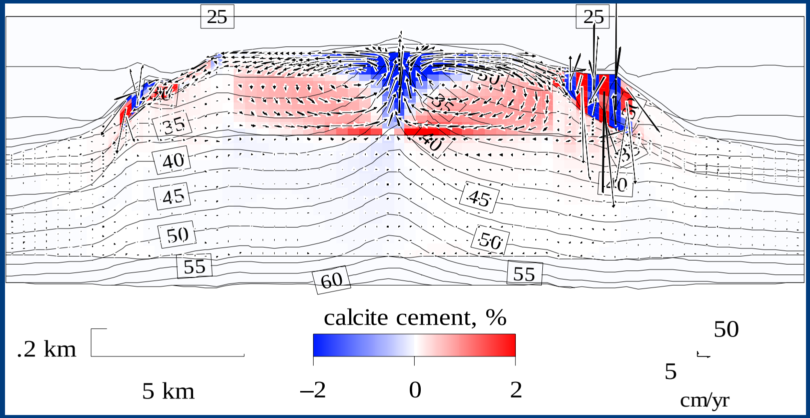
Nuclear Magnetic Resonance (NMR) for effective pore size distributions

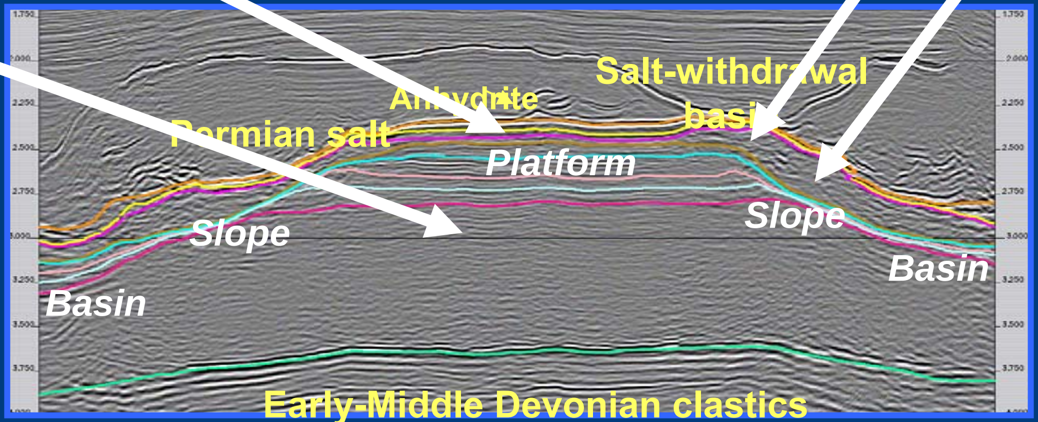


- T2 curves show effective porosity at different scale pores; here microporosity and connected larger pores
- CT and NMR imagery fill the essential link between petrophysics and geology at the scale of even small pore types (~1-3 microns) and pore filling cements

Diagenetic analogs: Reactive Transport Modeling (RTM)

RTM models suggest burial free convection cells generating sweet spots in platform center and cementation in outer platform; no diagenetic analogs (yet) from outcrop





Burial dissolution in the central platform

Limited burial diagenetic modification of the Devonian

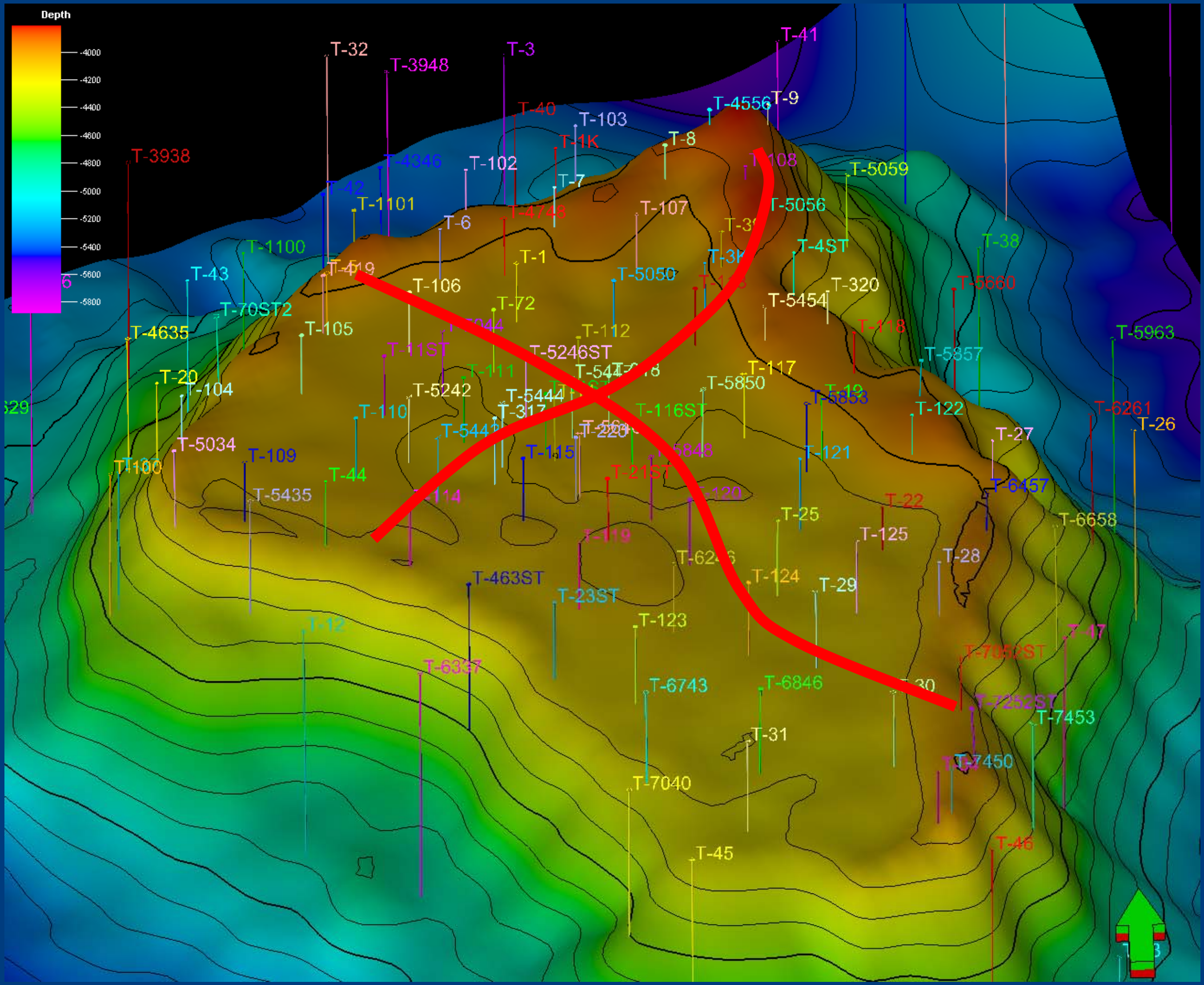
Limited potential for seawater dolomitization

Dissolution beneath salt withdrawal basins

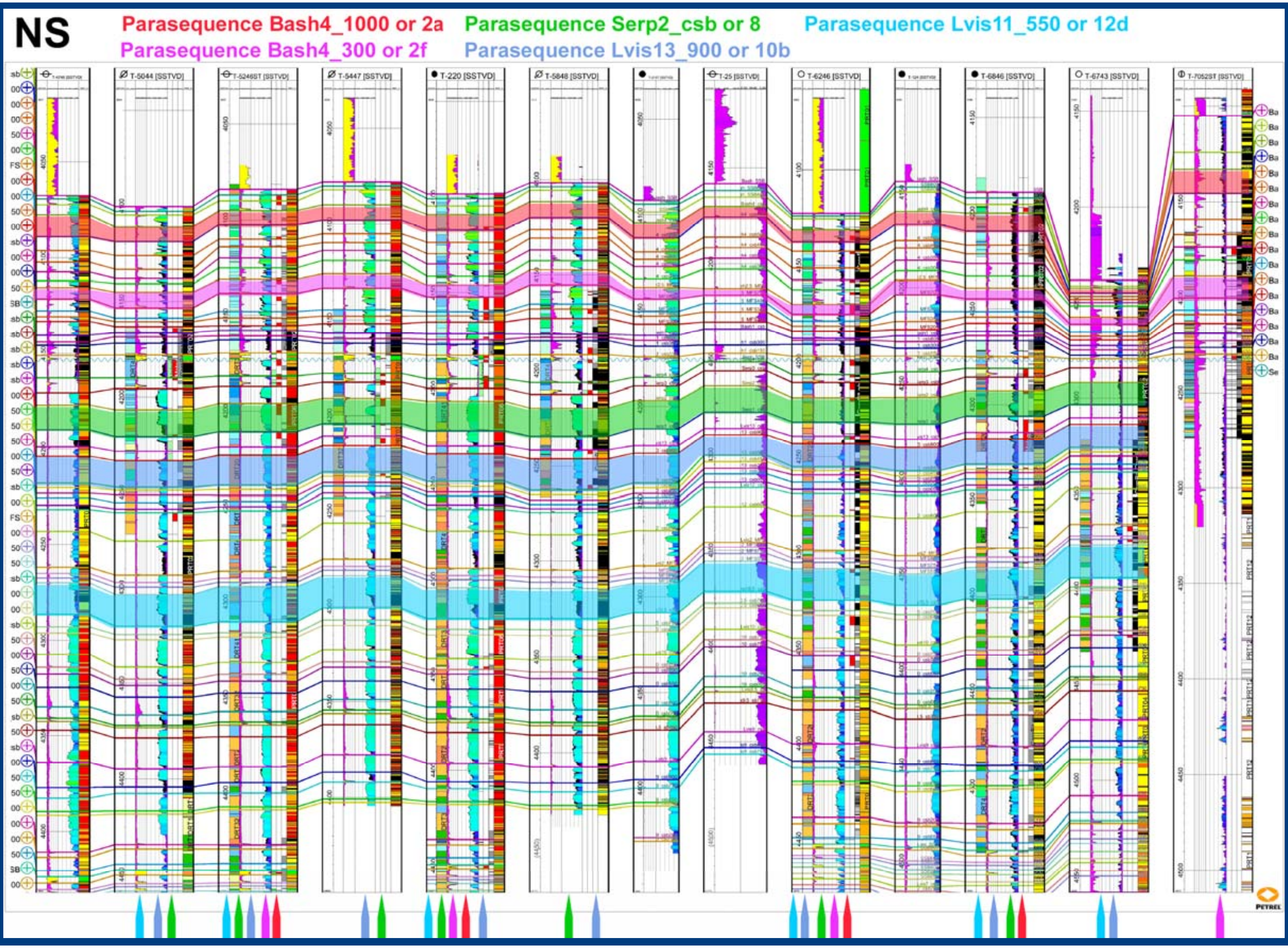
Alternating vertical dissolution and cementation in boundstone slope

Jones & Xiao, AAPG Bulletin, 2006, V. 90, p. 1251-1272

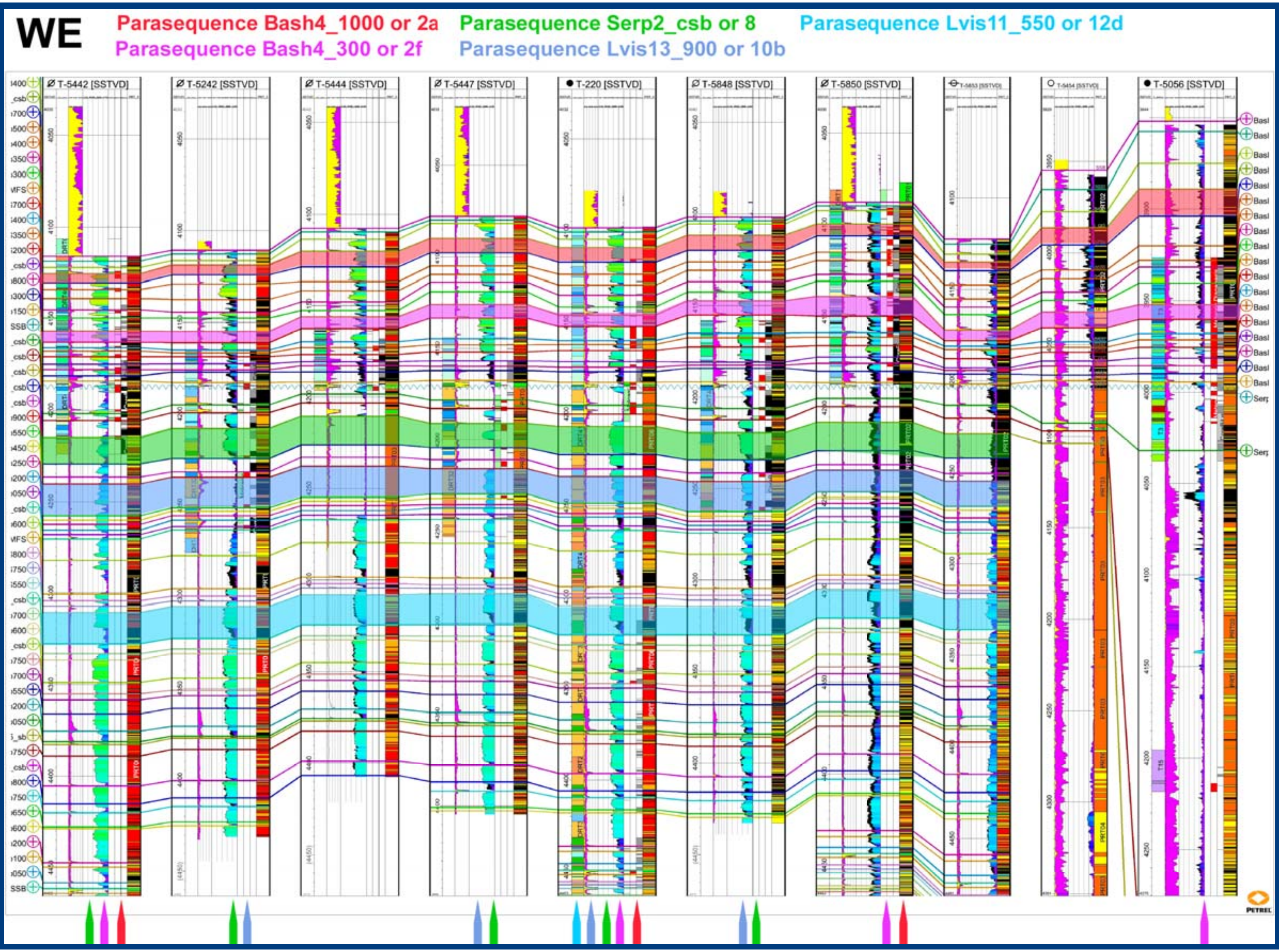
Integrated PNM / Diagenesis project: selection of depositional cycle



North-south well section



West-east well section



Summary and conclusions

- Tengiz platform Unit I reservoir quality controlled by multiple diagenetic phases overprinting a primary cyclic system
- Each of the diagenetic phases has specific spatially differential impact (porosity creation and occlusion)
- CTM/NMR imaging and PNM modeling produces reliable data on effective transport properties as well as quantitative pore type (and connection) distributions
- No outcrop or literature information on diagenetic analogs; RTM models available
- Spatial prediction of distribution of multiple diagenetic phases through focussing PNM, petrophysics and diagenetic studies (CL, stable isotopes) on one or more end member cycles across platform
- Issues are representative volumes, scaling, calibration, etc.
- Project in progress ......