Diagenetic Processes and Their Impact from the Petrophysical Properties in Kashagan Carbonate Platform Reservoir (Carboniferous, Kazakhstan)*

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Abstract

The Kashagan (offshore Kazakhstan) huge isolated carbonate platform developed from Visean to Bashkirian in the Precaspian Basin; the sedimentation is organized in shallowing upward cycles marked at the top by subaerial exposure surfaces. This diagenetic study, based on about 2000 samples from 1600 m of cores from 11 wells, integrated sedimentology, petrography, fluid inclusion, stable isotopes and trace elements data and reconstructed the pore-system evolution in the margin and in the platform interior.

The early diagenesis includes marine cement fringes followed by meteoric dissolution and cementation. The meteoric diagenesis, related to cyclic subaerial exposure surfaces, more evident in the Bashkirian sequence, is still detectable in the older sequences by petrographic and geochemical signature. The main karst surfaces, correlated along the whole platform, are evidenced by non-luminescent cements, root traces, sharp $\delta^{13}C$ depletion, and fresh or brackish fluid inclusion calcites.

In the inner platform, the porosity follows a cyclic pattern due to interaction of different factors: the fresh water dissolution more intense and preserved in the middle part of the cycle, cementation in the cycle top and compaction processes that destroyed the porosity at the cycle top and base. The diagenetic processes and resulting porosity pattern are more complex in the platform margin areas because the sedimentary cyclicity is less defined, and because of the stronger overprint of burial diagenesis.

The burial late diagenesis in the inner platform is represented by some calcite cementation that not altered deeply the porosity network. In the margins, burial exotic fluid diagenesis is detected. These fluids were able to enter the rim through slope and margin

facies and karst/flank margin fracture network; they caused dissolution, cementation and local dolomitization. The exotic fluid cementation is characterised by distinct petrographic and geochemical features: bright luminescence, high Mn content, depleted $\delta^{18}O$, high Th and low salinity fluid inclusions. Due to this diagenetic overprint, the platform margin is characterized by a heterogeneous porosity with larger pores and fractures but with lower matrix porosity values.

The understanding of the links between the sedimentological setting, the different diagenetic events and the pore system modifications allowed to construct several semi-quantitative reservoir quality maps that are used as a base for reservoir modelling.

Denver 2009

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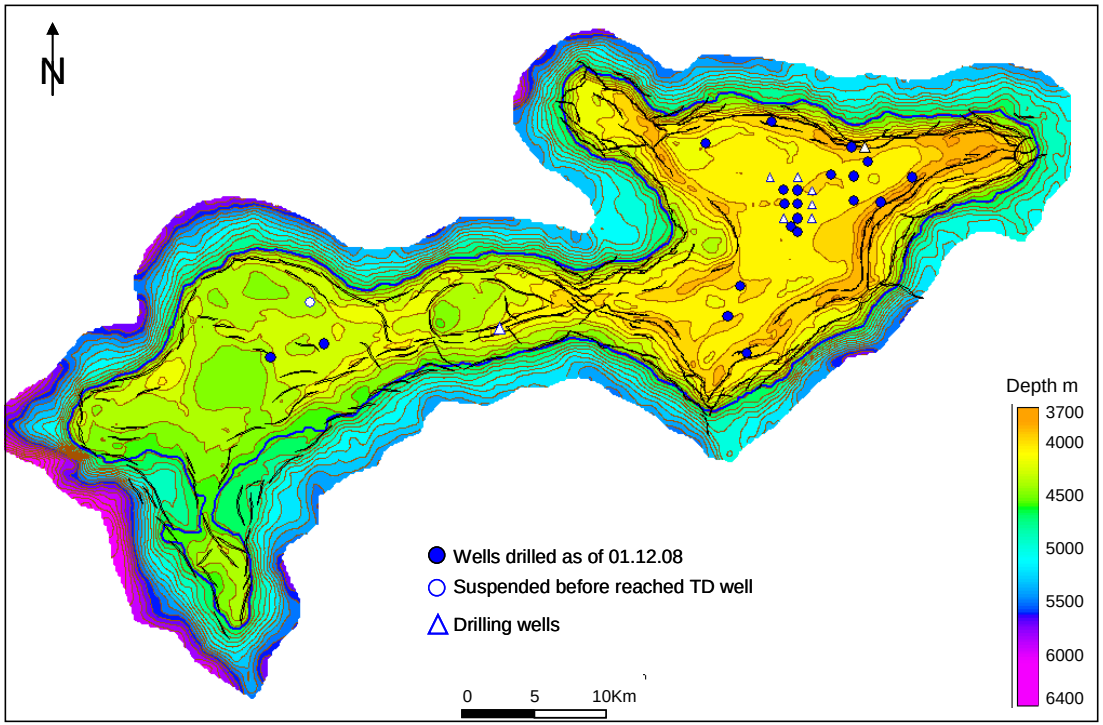
AAPG - Denver, 8 June 2009

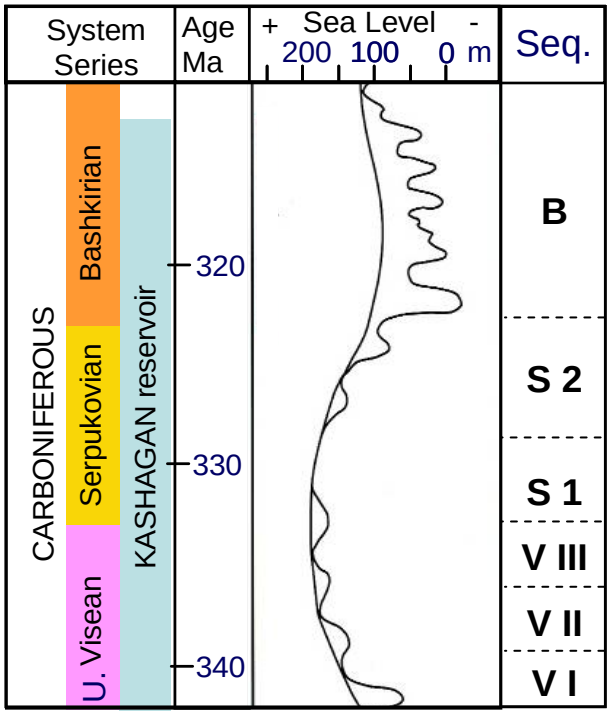
Outline

1. Geological Setting
2. Near Surface Diagenesis
3. Burial Diagenesis
4. Conclusions

Location map

Kashagan Reservoir

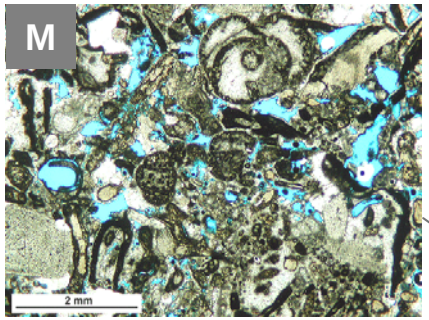


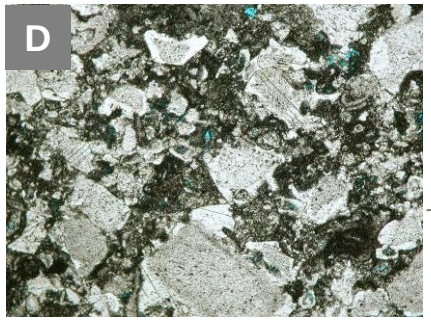


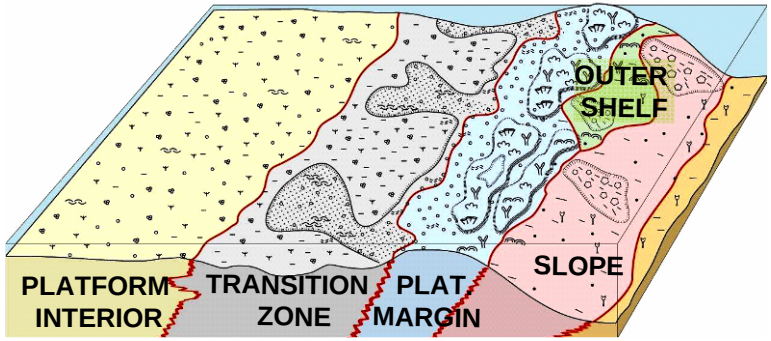
- **Reservoir Age: Carboniferous (Upper Visean, Serpukhovian and Bashkirian)**
- Reservoir average depth: ~ 4300 m
- Reservoir average thickness: ~380 m
- Dimension: 80km * 35 km
- **12 exploration and appraisal wells**
- **11 development wells**
- **2000 m of continuous cores**

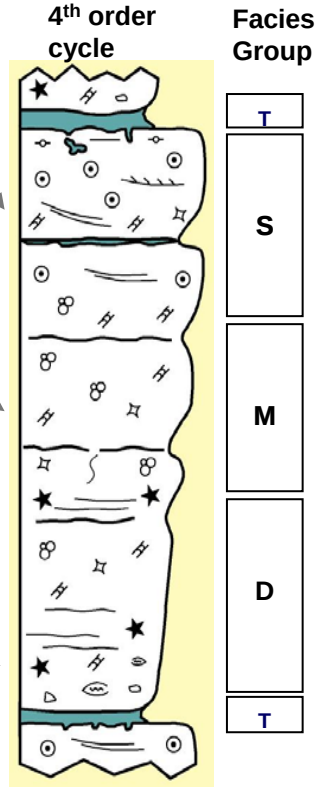
Sedimentological setting

Platform Interior

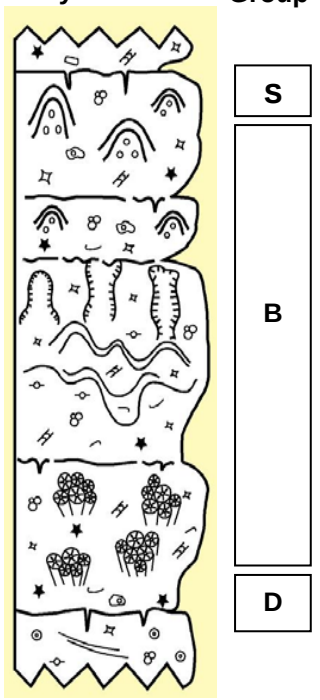


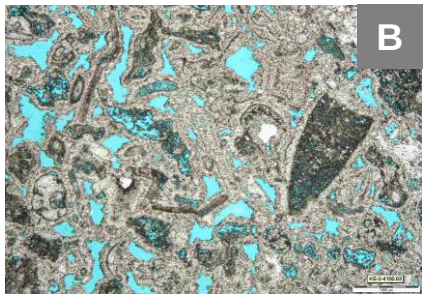


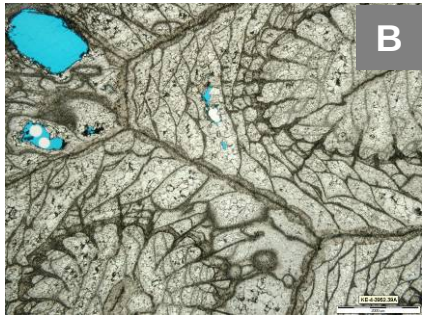


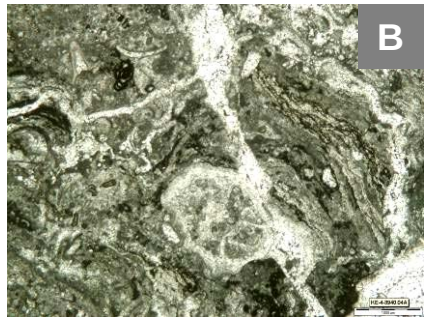


Platform Margin





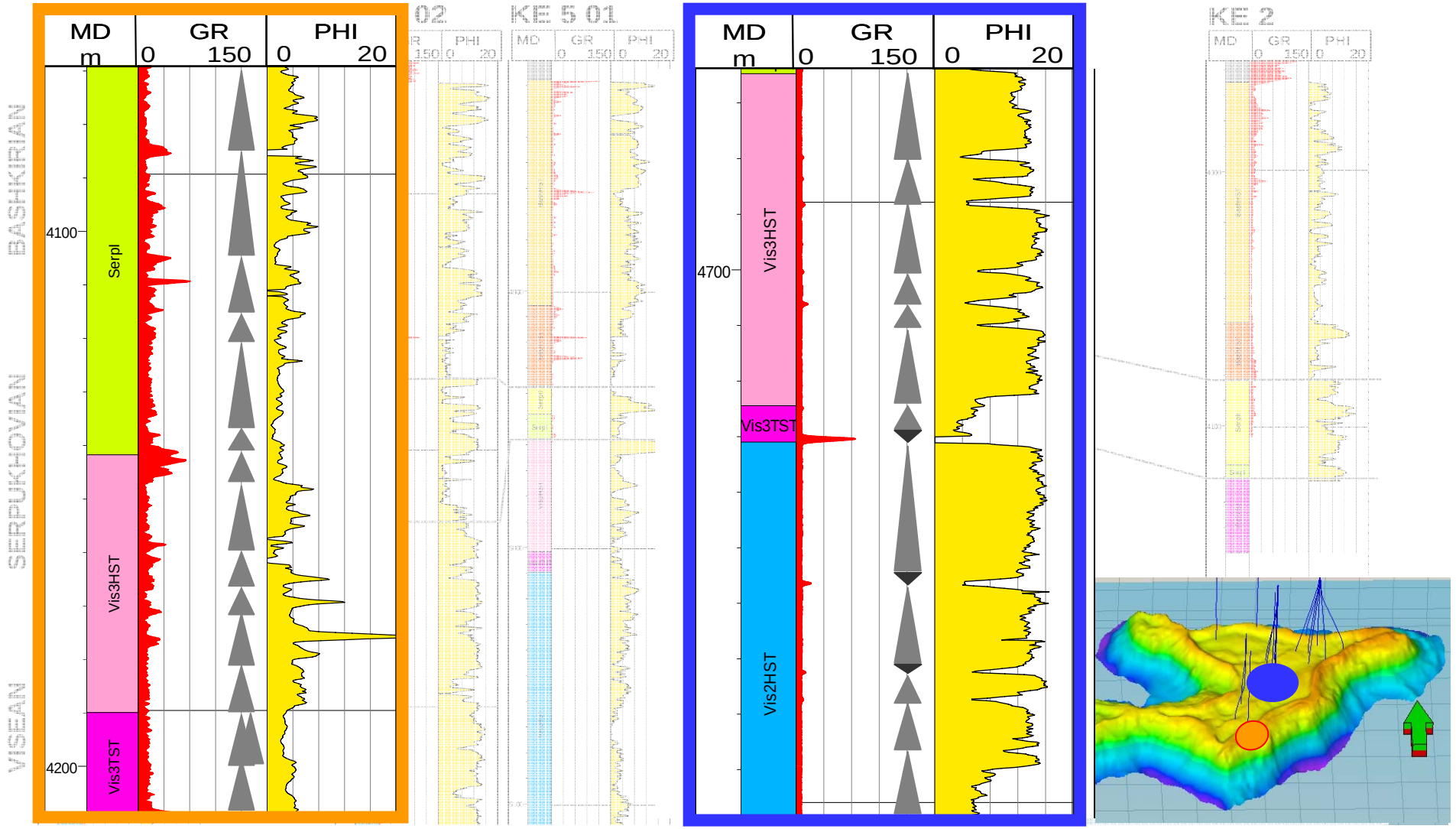




Sedimentation is organized in 4th order cycles capped by subaerial exposure and marked by green shale laminae.

The 4th order cycles are less defined in the platform margin where the bioconstructed facies prevail.

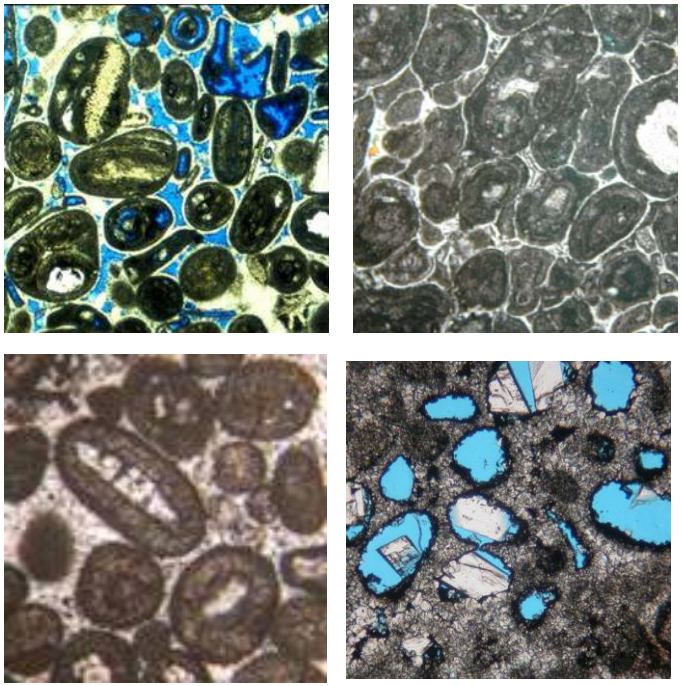
Porosity patterns

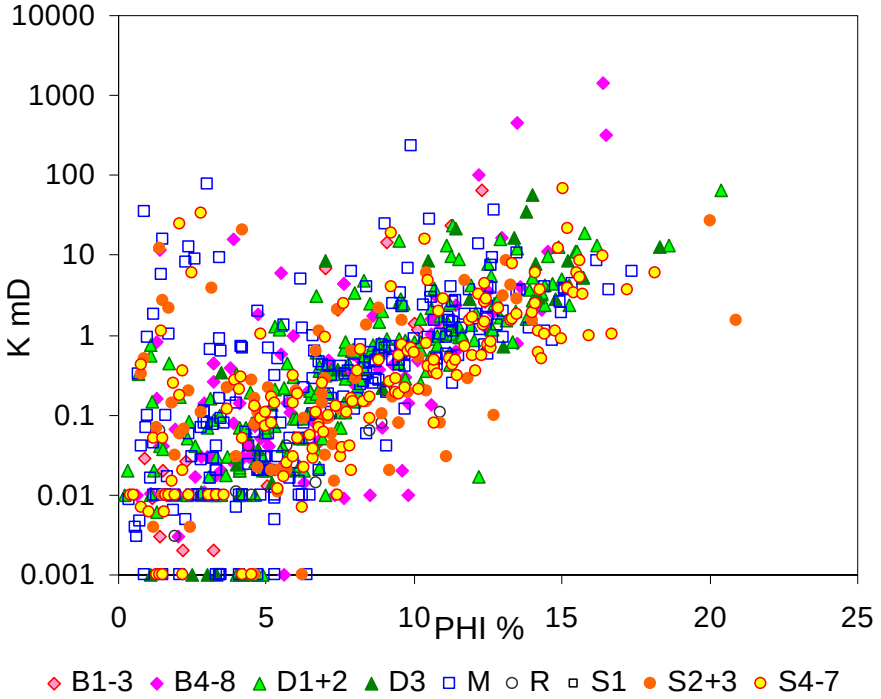


Platform Margin = lower porosity + higher heterogeneity

Platform Interior = Porosity cyclicity, + tight layers

Facies and petrophysics





➢ SAME DEPOSITIONAL FACIES BUT DIFFERENT POROSITIES

➢ SAME POROSITY AND PERMEABILITY RANGES IN DIFFERENT DEPOSITIONAL FACIES

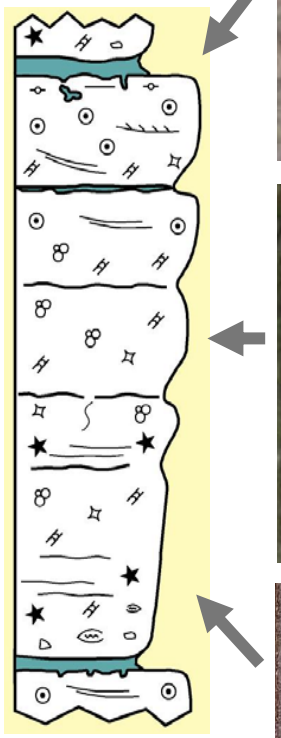
THE DIAGENESIS OVERPRINTED THE PRIMARY PORE SYSTEM

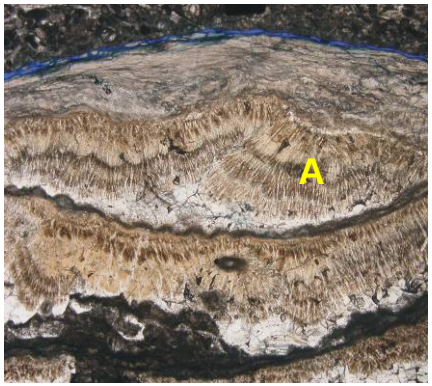
Understanding the geological controls on the diagenetic evolution allows to distribute the diagenetic processes and resulting petrophysical properties

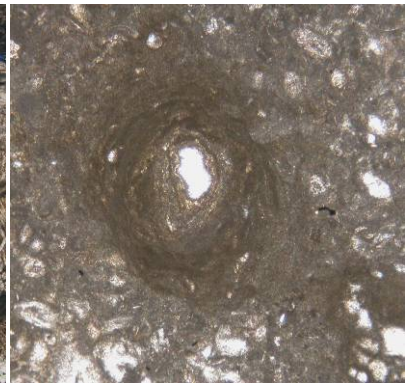
Outline

1. Geological Setting
2. Near Surface Diagenesis
3. Burial Diagenesis
4. Conclusions

Near Surface Diagenesis – Platform Interior



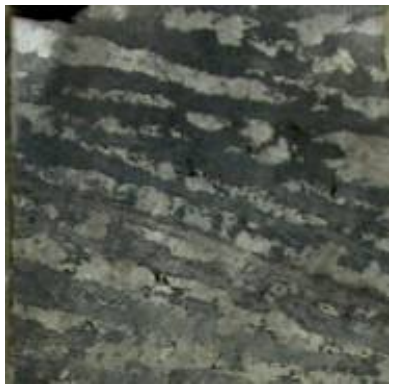


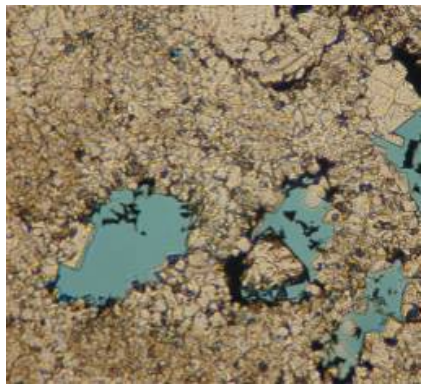


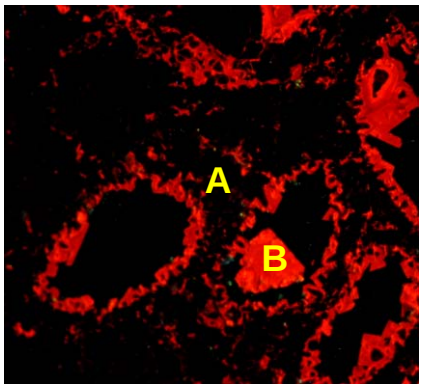
Cycle Top

- Green Argillite
- Pendant cements
- Compaction

TIGHT



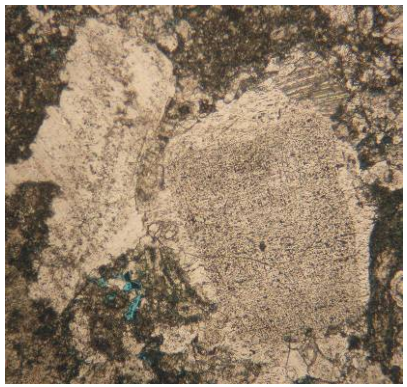


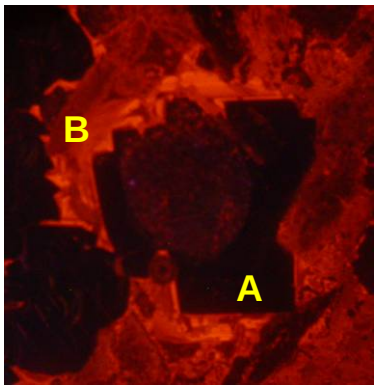


Cycle centre

- Grainstones
- Dissolution (mold)
- IP Preservation
- Partial cementation

POROUS





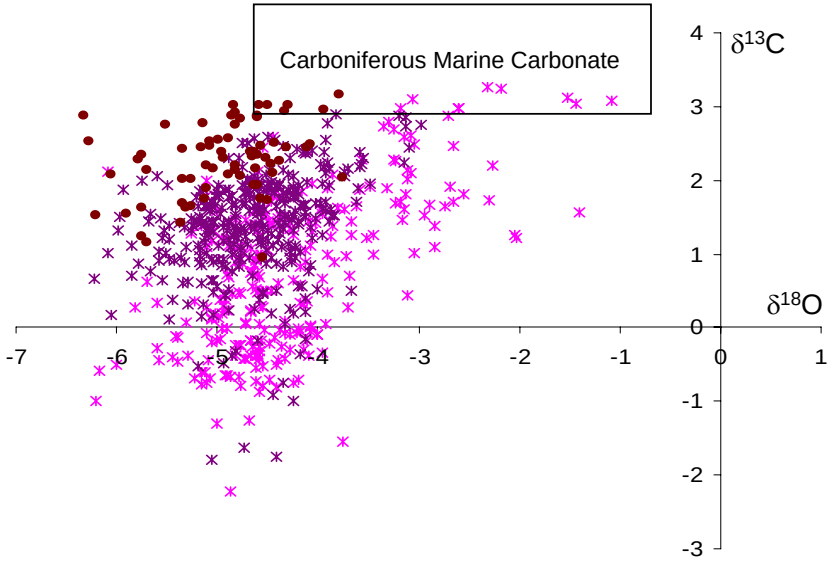
Cycle Bottom

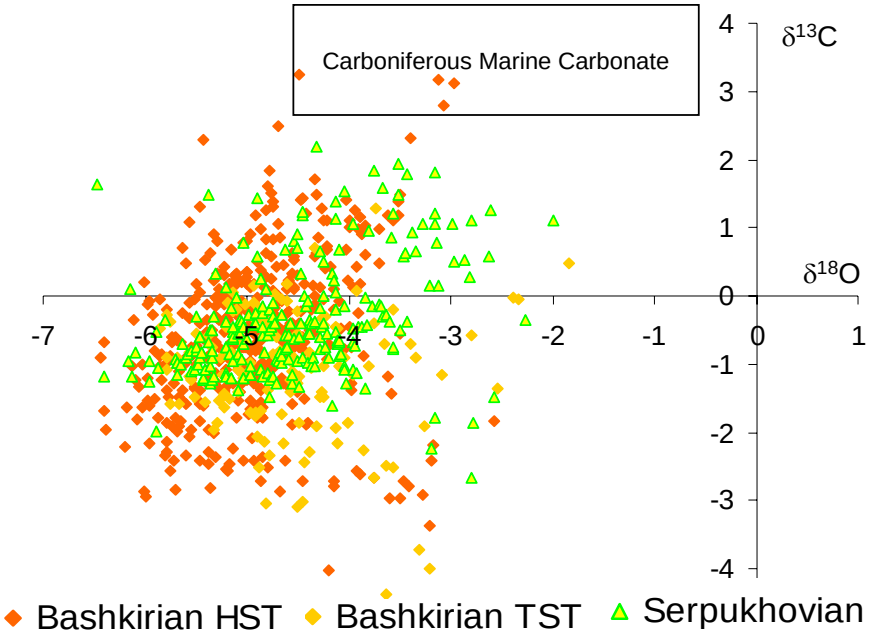
- Packstone/wackestone
- Compaction
- Cementation

TIGHT

Main Near surface diagenesis cements = Calcite group A (non luminescent) - Calcite group B (bright orange)

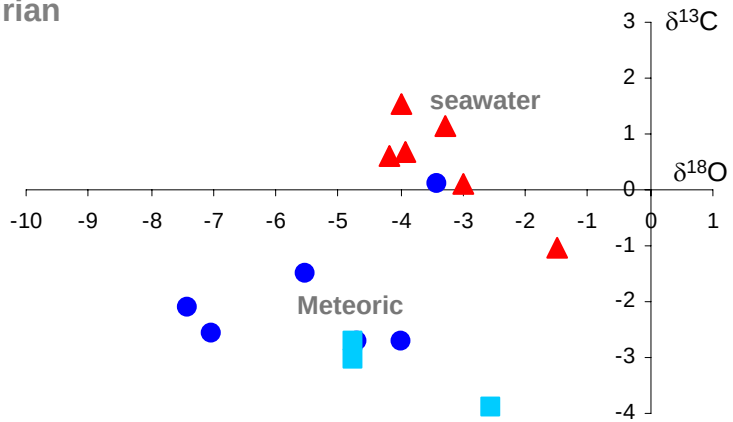
Stable isotopes





Increasing meteoric overprint from Visean to Bashkirian

Microdrilled samples of calcite cements



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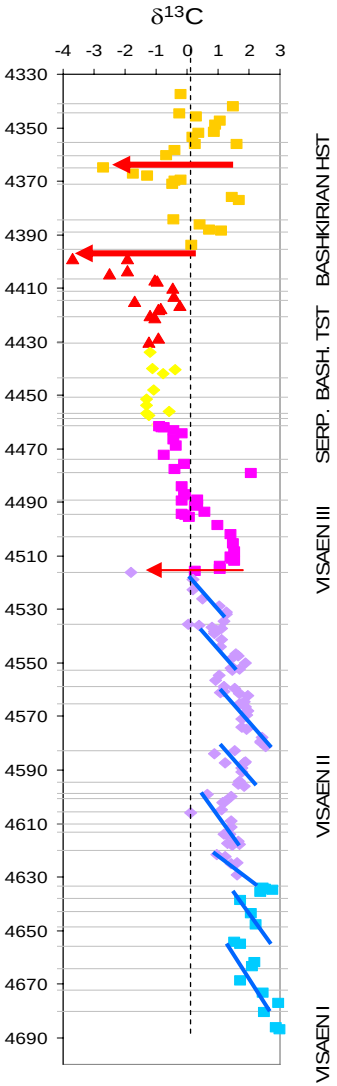
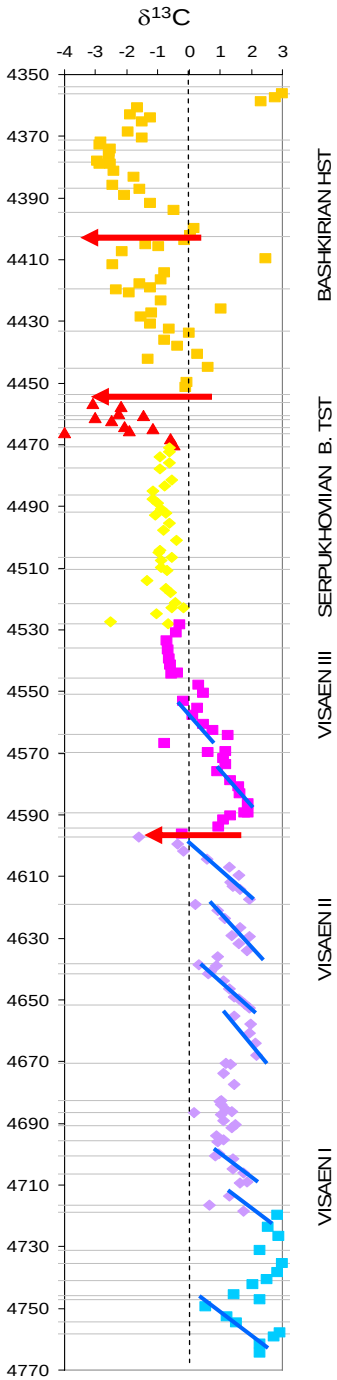
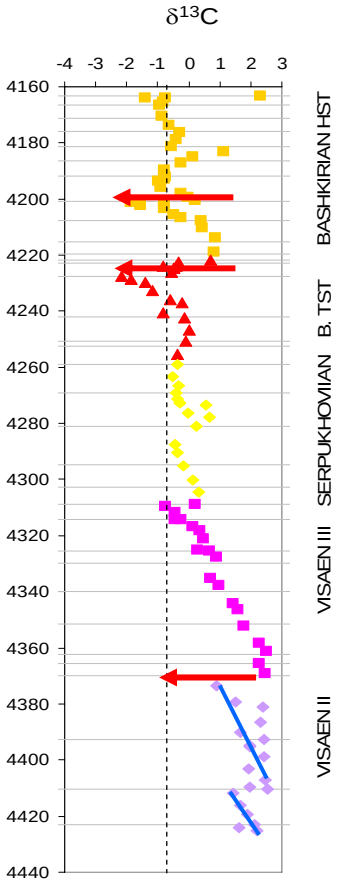
$\delta^{13}C$ Vertical Distribution

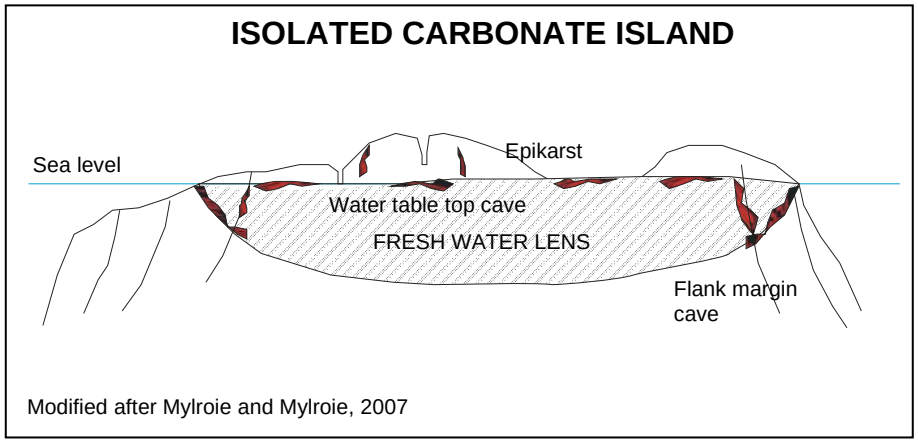


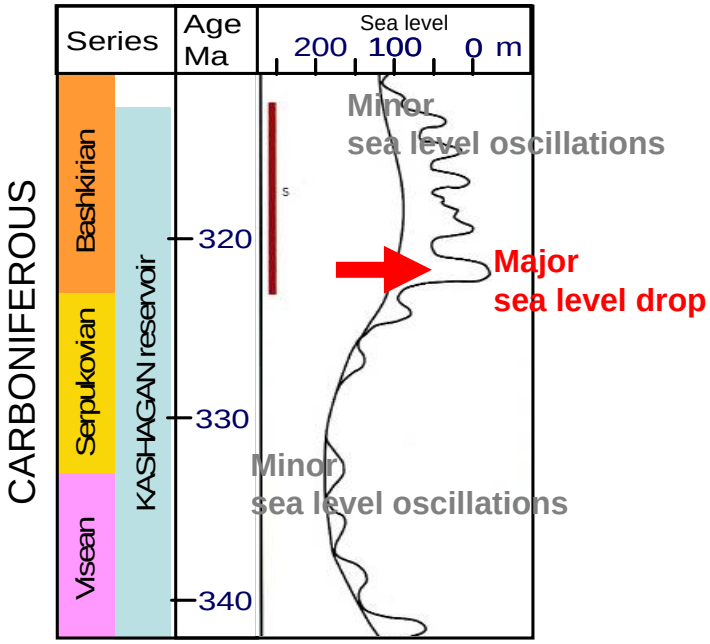




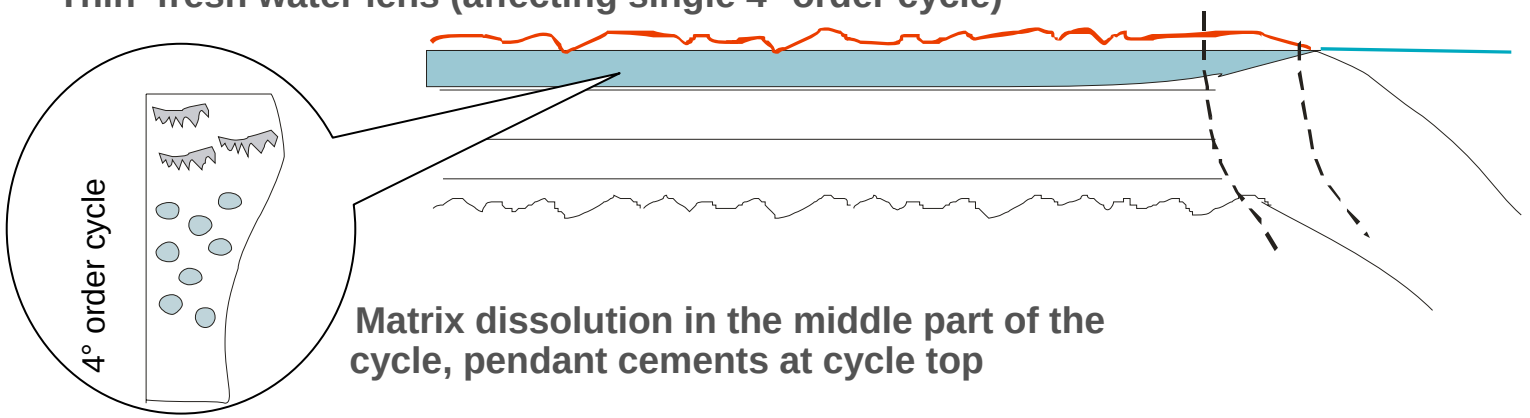
- Overall increased depletion upsection
- Strong depletion events mark 3rd order and some 4th order cycle tops
- 4th order cycles pattern preserved in the carbon signature

Near Surface Diagenesis – Minor Subaerial exposure events



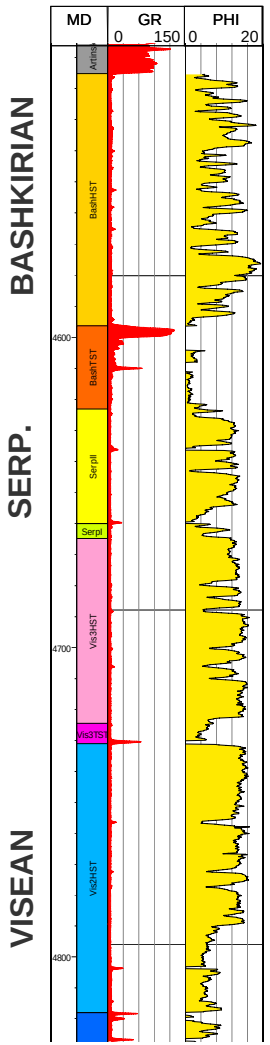


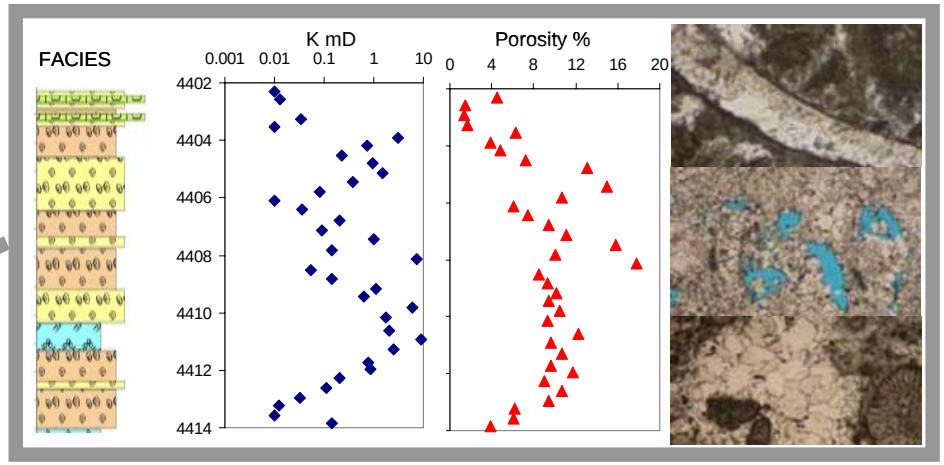
Thin fresh water lens (affecting single 4° order cycle)



Matrix dissolution in the middle part of the cycle, pendant cements at cycle top

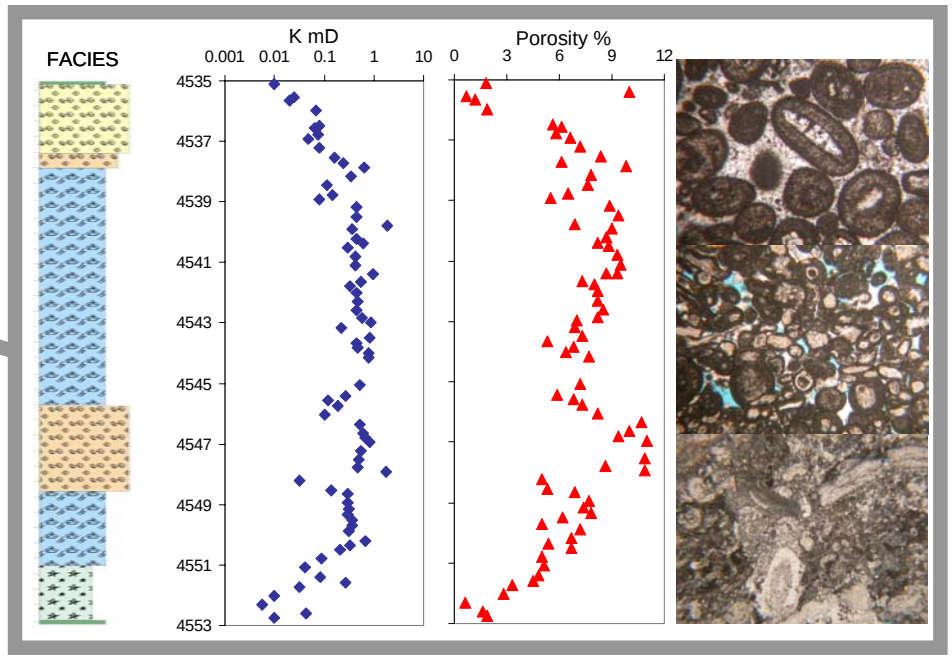
Porosity Cyclic patterns in Platform Interior





Bashkirian Cycle

- Thin Bash-Serp Cycles
- Bell-shaped porosity
- Porosity moldic and preserved interparticle



Visean Cycle

- Thick Visean Cycles
- Box-like porosity
- Porosity mainly preserved inteparticle

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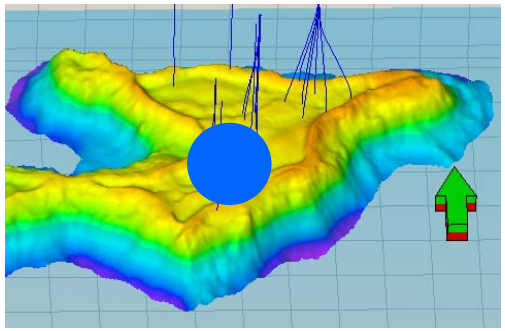
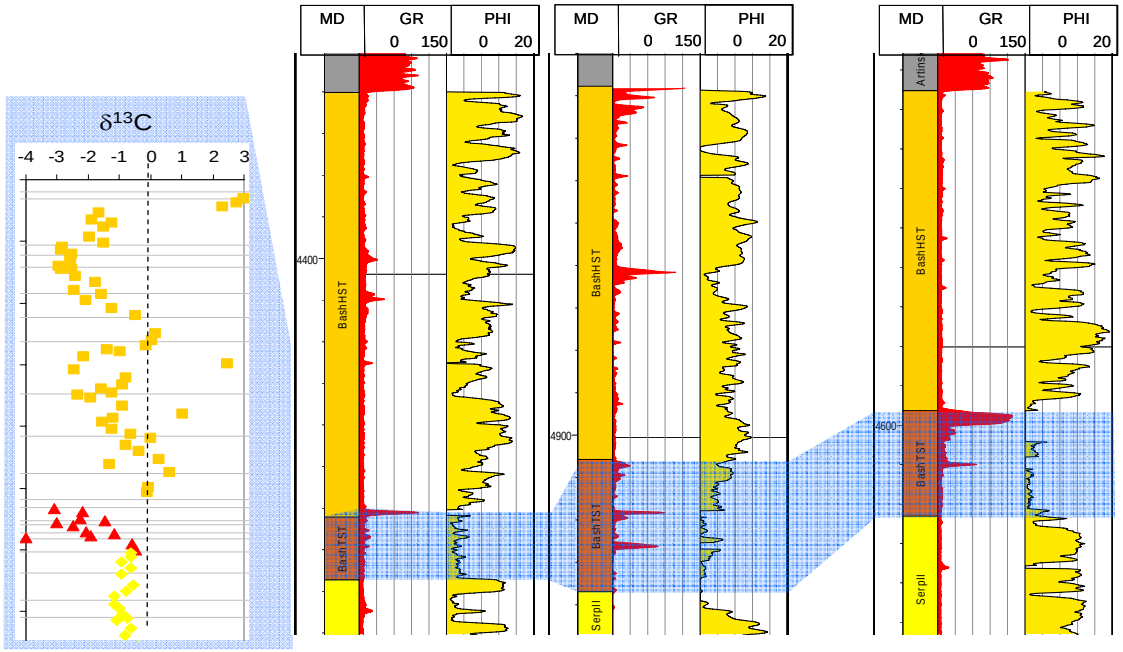
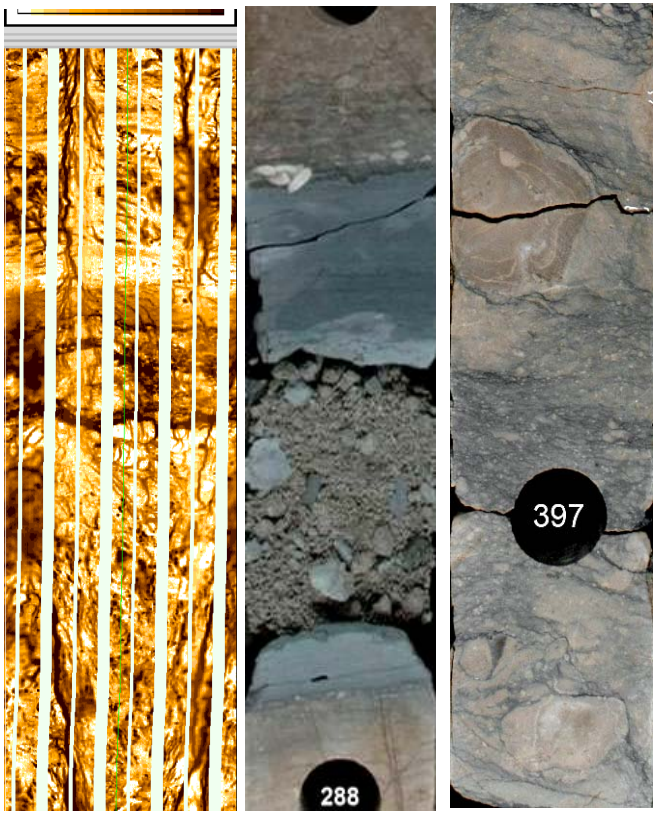
Major Subaerial Exposure Events - Platform Interior



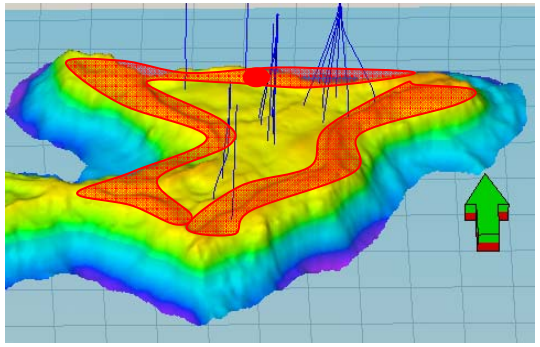
BASHKIRIAN KARST
Major subaerial exposure event
Low porosity
4th order cycles are destroyed

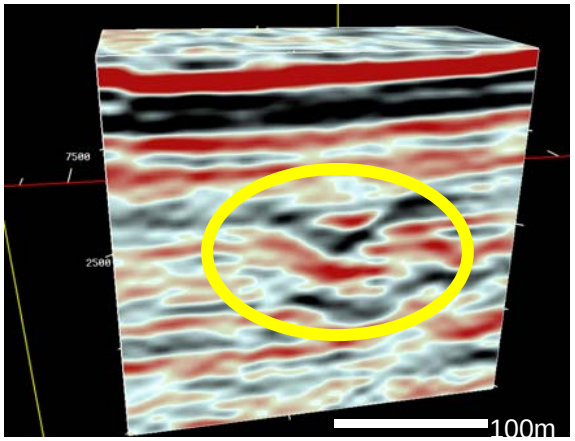




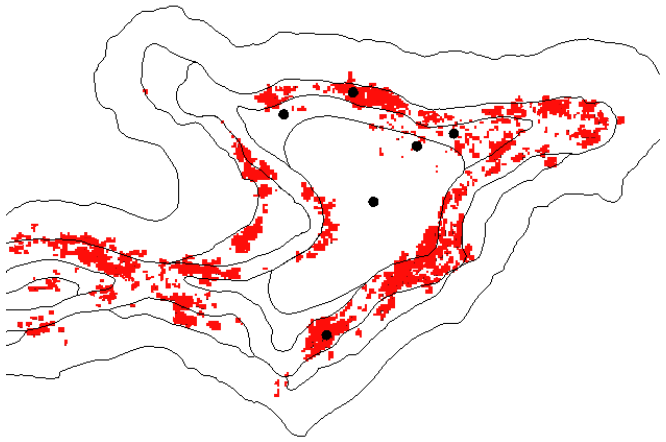
- Tight collapse breccia with argillite infilling

Major Subaerial Exposure Events – Platform Margin





- V structure body at Top Upper Visean

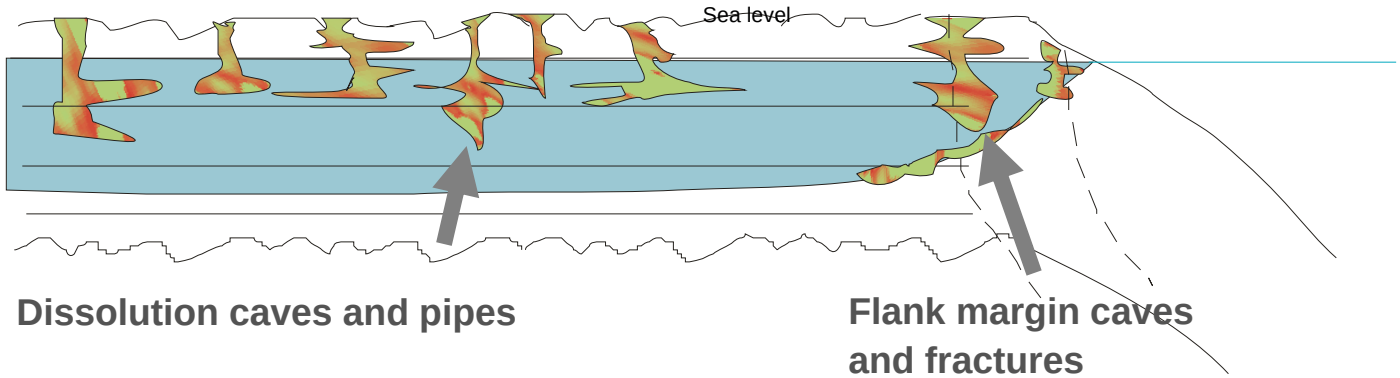


- Fractures with argillite infilling
- Large dissolution vugs
- Lost circulation zones

- Seismic “geobodies” correspond to lost circulation zones

Near Surface Diagenesis - Major Subaerial Exposure

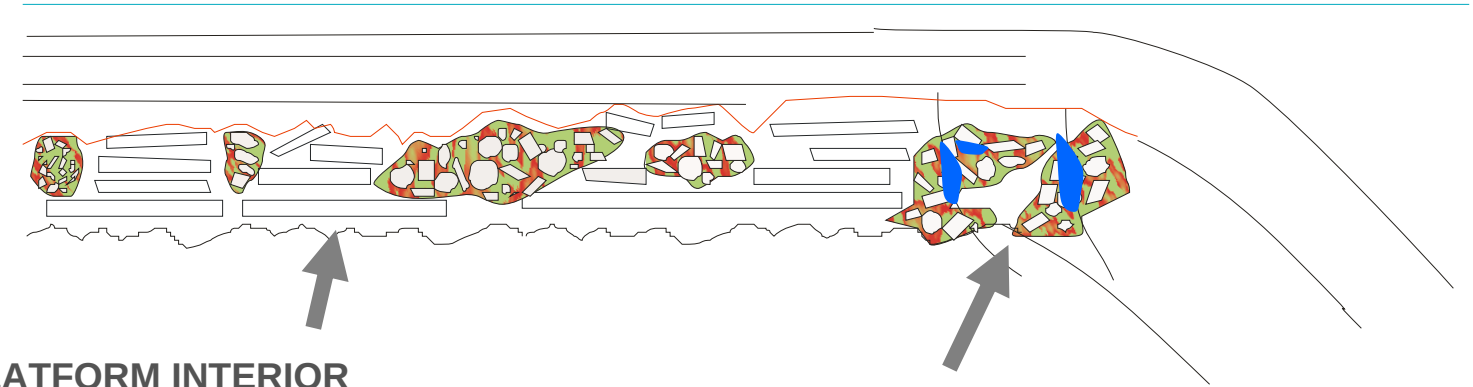
1) Thick fresh water lens (affecting several 4th order cycles)



Dissolution caves and pipes

Flank margin caves and fractures

2) Burial and compaction phase



PLATFORM INTERIOR
Collapse breccia with argillite matrix

PLATFORM MARGIN
Partial preservation of flank margin caves and fracture system

Outline

1. Geological Setting
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3. Burial Diagenesis
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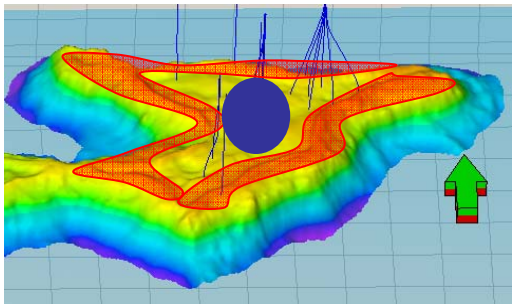
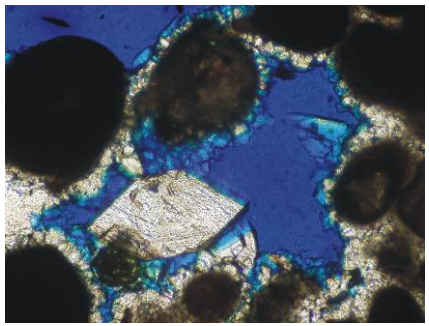
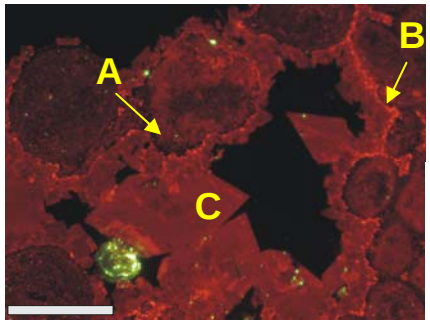
Burial Diagenesis



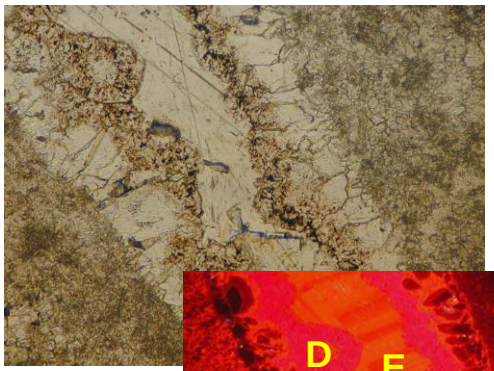


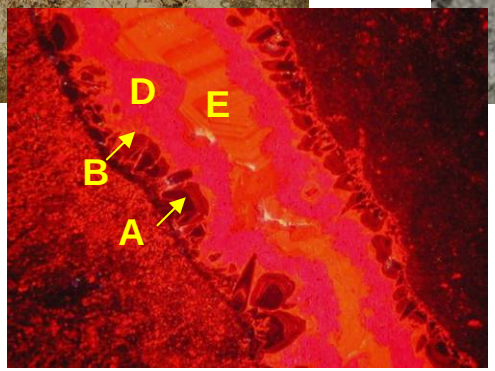


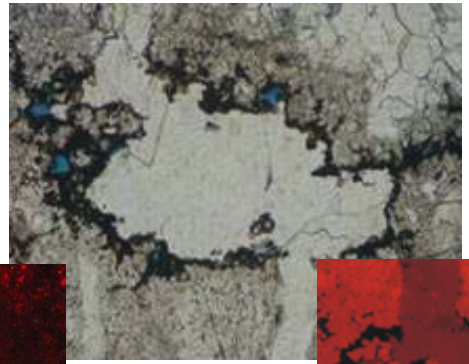
Platform Interior

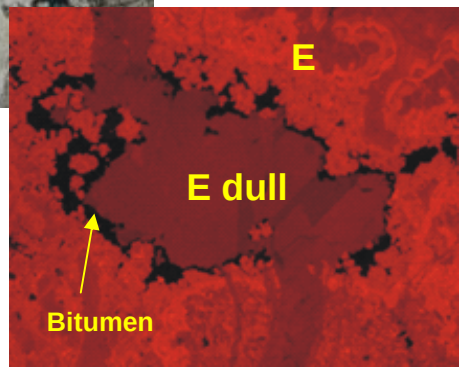
- Minor cementation by red dull calcite C

DEPOSITIONAL CYCLES PRESERVED
LAYERED RESERVOIR







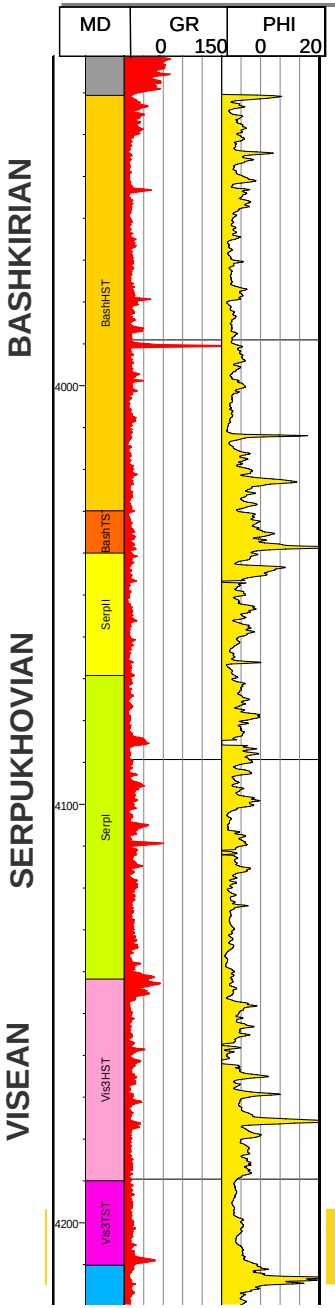


Platform Margin

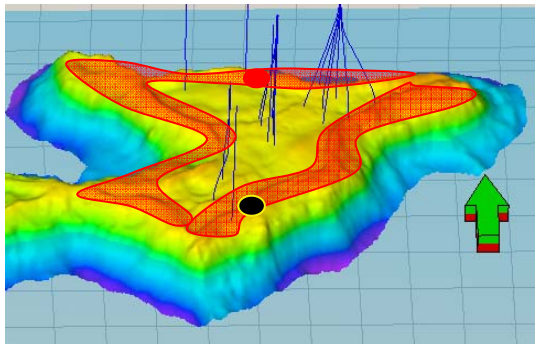
- Fracturing
- Dolomite D cementation
- Calcite E cementation
- Bitumen emplacement
- Calcite E dull cementation

CEMENTATION

Burial Diagenesis - Platform Margin

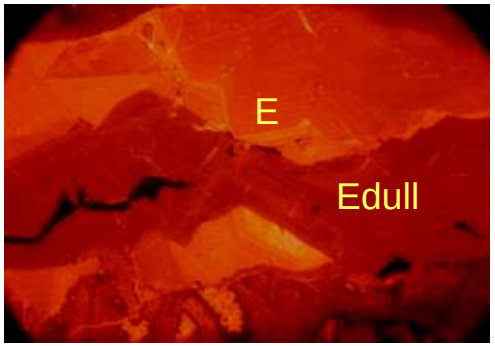


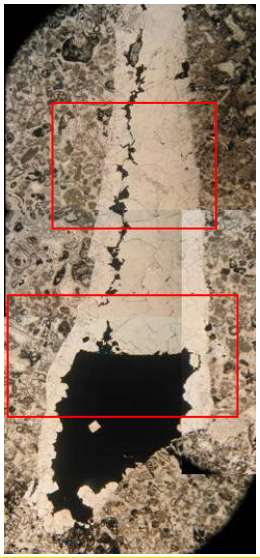
- 4th order cyclic porosity loss
- Low porosity
- Relatively High Fracturation

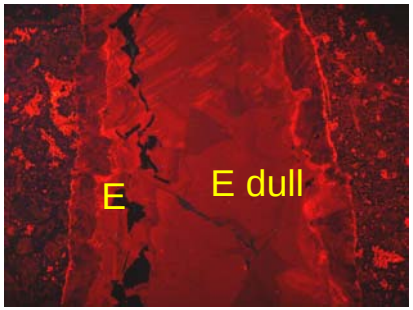


Cemented fractures

Open fractures







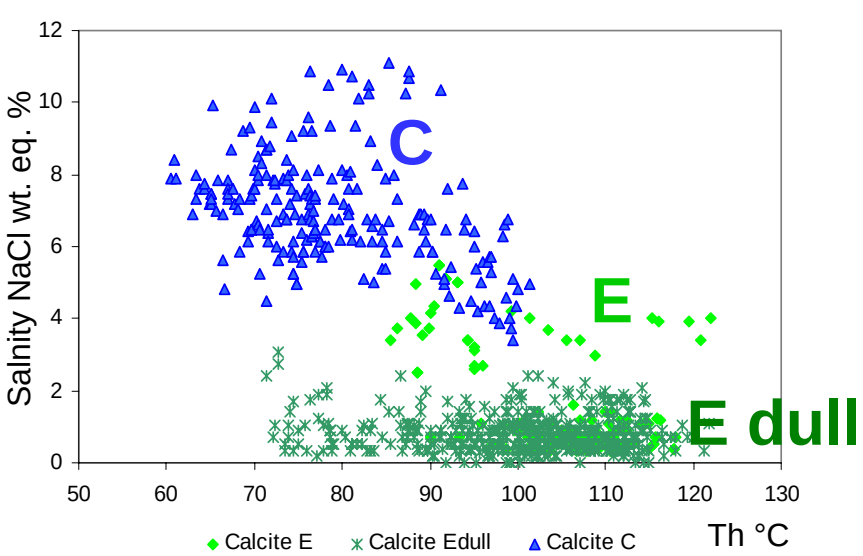
Burial cements – Geochemistry

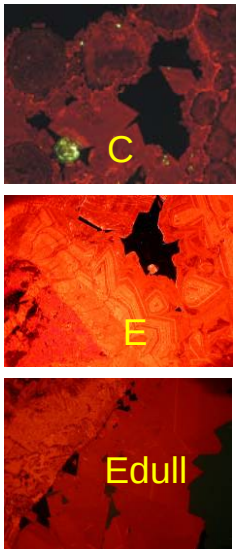
Fluid Inclusion data trend

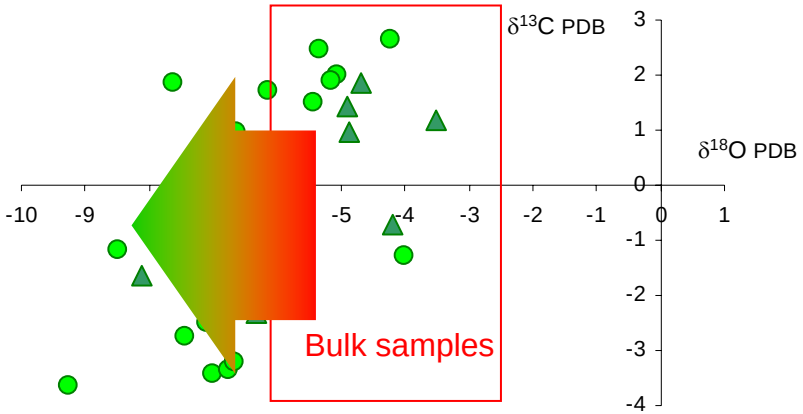
- Increase in temperature
- Decrease in salinity

The Th of the calcite E dull dull exceeds the present BHT

- Hydrothermal Fluids?







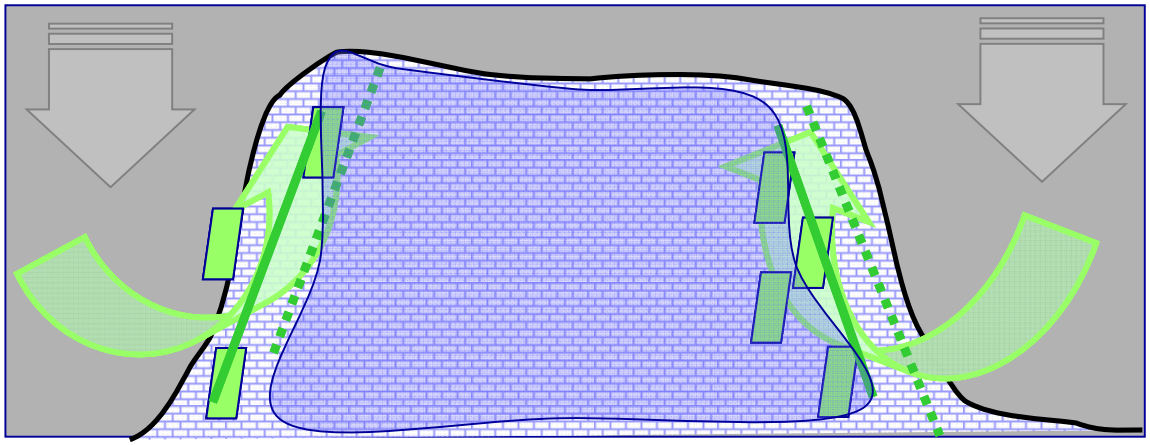
Oxygen more depleted than the host rock

E and E dull

- Late burial calcite in vugs
- Late burial calcite in fractures

Exotic Fluids

Geochemical and petrographic data suggest a progressive dilution of formation water with a higher T and lower salinity exotic fluid



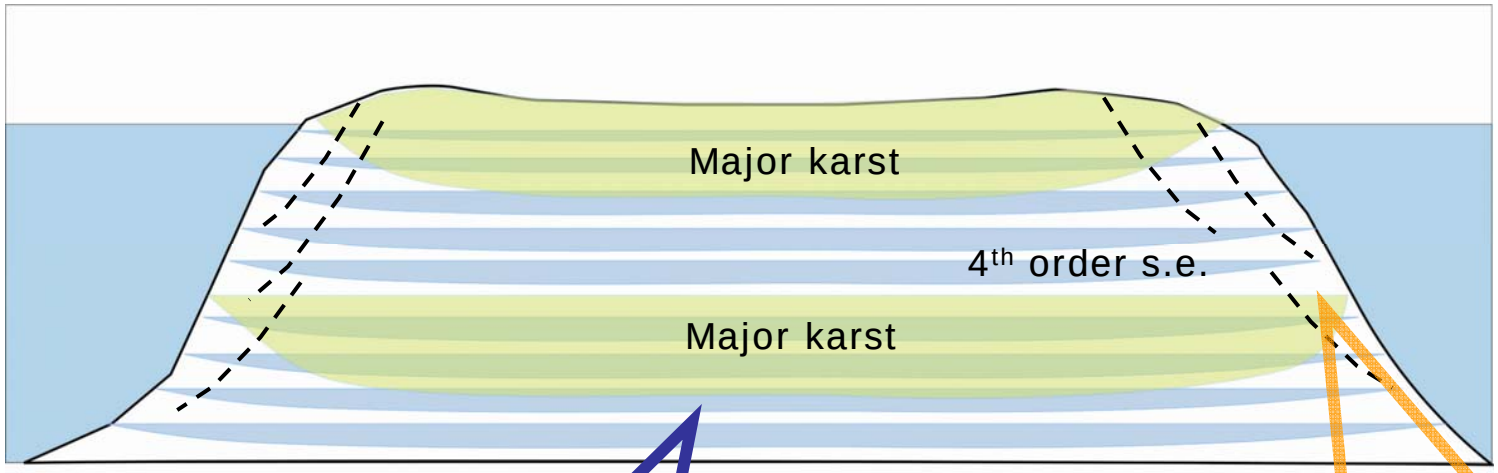
The exotic fluids could have entered the reservoir through the slope and the fractured Platform Margin.

The main effect in the reservoir is cementation of the matrix and increasing heterogeneity in the Platform Margin

Outline

1. Geological Setting
2. Near Surface Diagenesis
3. Burial Diagenesis
4. Conclusions

Near surface diagenesis effects on the reservoir properties



Platform Interior

- Porosity cyclicity linked to 4th order cycles capped by subaerial exposure
- Tight zones below major karst event

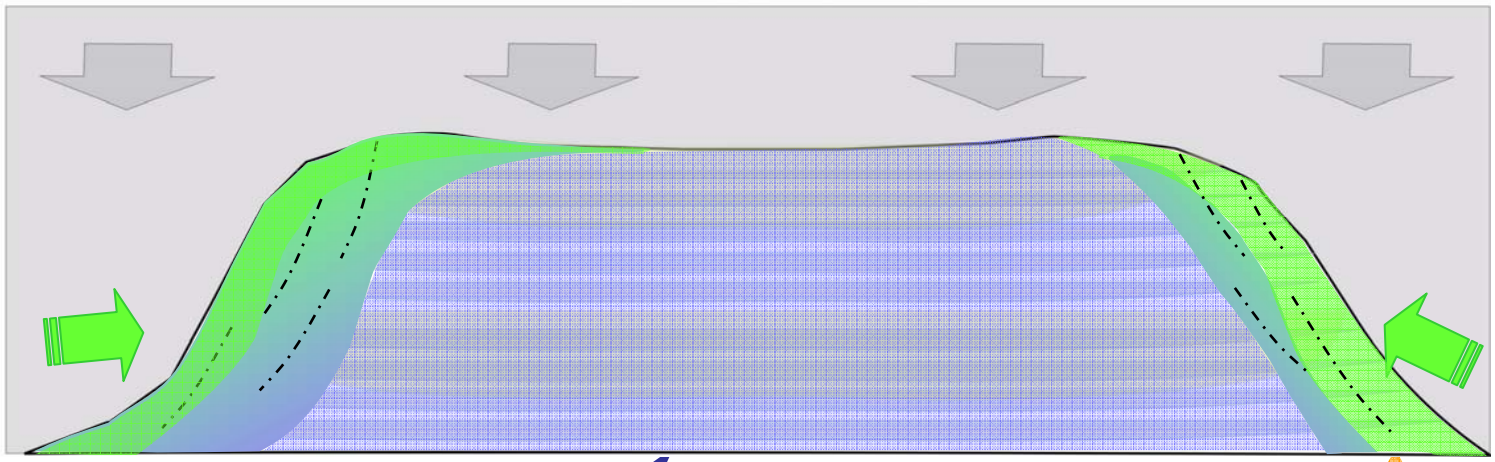
LAYERED RESERVOIR

Platform Margin

- Flank margin caves
- Dissolution enlarged fractures

HETEROGENEOUS RESERVOIR

Burial diagenesis effects on the reservoir properties



Platform Interior

- No strong late diagenetic overprint: Preservation of the porosity cyclicity

LAYERED RESERVOIR

Platform Margin

- Matrix cementation by exotic calcite and minor dolomite
- Dissolution along reactivated fractures

HETEROGENEOUS RESERVOIR
LOW POROSITY VARIABLE PERMEABILITY

Conclusions

In the carbonate system sedimentation and diagenesis interact to produce a complex pore system pattern

Detailed integrated diagenetic and sedimentological studies

- **help in the comprehension of the carbonate system evolution**
- **give an explanation about the distribution of the petrophysical properties in the subsurface**

These studies are useful to

- **better define and predict the reservoir quality within a reservoir or a prospect**

thanks

Thanks to AKCO and partners
for permission to present this study

ConocoPhillips
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Inpex
KMT
Shell
Total