

# **The Chlorite-Bearing Reservoirs: Effects of the Main Petrographic Parameters on Reservoir Quality\***

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Search and Discovery Article #50178 (2009)

Posted April 27, 2009

\*Adapted from oral presentation at AAPG International Conference and Exhibition, Cape Town, South Africa, October 26-29, 2008.

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## **Abstract**

Fe-chlorite bearing sandstones are present in many basins of different age; owing to the presence of pore-lining/pore-filling Fe (and Mg)-chlorite they are a reservoir even in high depth/high temperature regimes. On the other side, the abundance and thickness of the coatings is a limiting factor for permeability; in order to predict the reservoir quality, it is thus important to understand the factors that influence the chlorite coatings growth.

As the chlorite-bearing reservoirs are deposited in specific settings, and namely in the transitional environments, where mixing between Fe-rich fresh waters and marine waters occurs, it is mandatory to sort out the effect of textural parameters (grain-size and sorting) and of grain composition on chlorite abundance. The grain composition is also affecting the type (Mg vs. Fe-Chlorite) and crystalline structure (platelets vs. filaments) of the chlorite that will form on grain surfaces.

Another parameter is the texture of the chlorite itself in the pore-space; the reservoir quality strongly changes with the proportion of pore-filling vs. pore-lining chlorite; moreover, the efficiency also depends on the relationship between grain-size and the thickness/type of chlorite coatings.

Moreover, as in many cases the burial and thermal histories seem to affect the chlorite distribution and thickness, we have also considered the effect of these two additional variables.

In order to answer these questions, a huge data-set, comprising many basins (North Africa, Santos, North Sea, Middle Indus, Nile delta) and stratigraphic age (Silurian, Jurassic, Cretaceous and Miocene) was used. On all samples quantitative petrography, pore network characterisation and X-Ray diffraction analyses were carried out.

Finally, an attempt to model the reservoir quality considering the concurrence of all the above mentioned parameters was performed.



# **The Chlorite-Bearing Reservoirs: Effects of the Main Petrographic Parameters on Reservoir Quality**

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Cape Town, 28 October 2008

A chlorite-bearing reservoir is a reservoir that shows, in a given geological situation, considerably better reservoir quality than a non-chlorite-bearing reservoir, due to the presence of a peculiar grain-coating mineral, the Fe-rich chlorite.

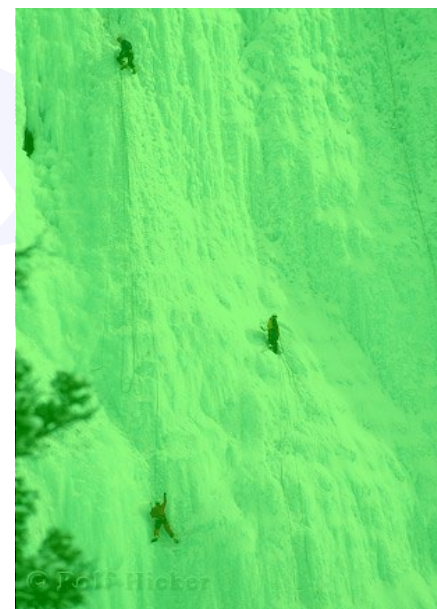


# The Chlorite-bearing Reservoirs

## 1 - Introduction



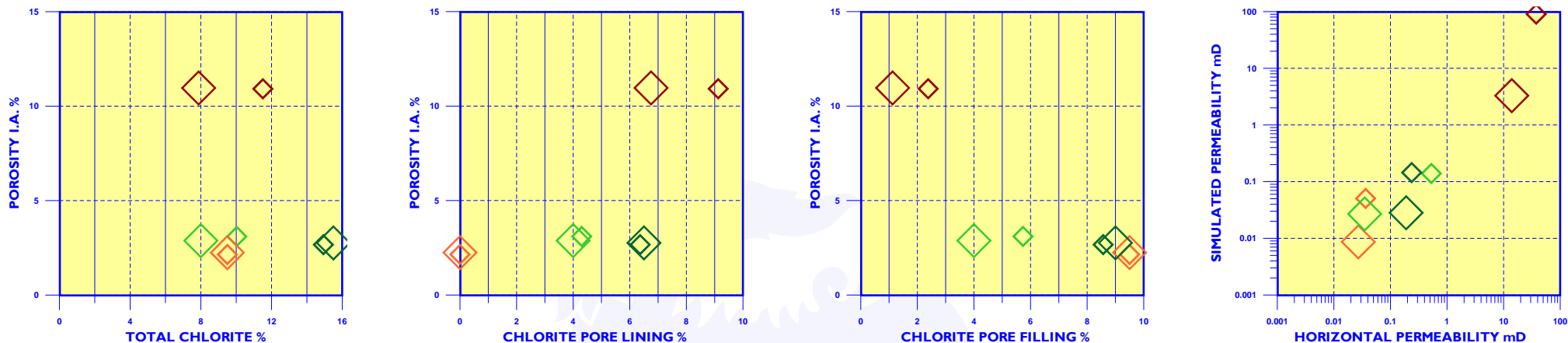
1. INTRODUCTION
2. WHAT WE KNOW ABOUT CHLORITE
3. CHLORITE AND RESERVOIR QUALITY
4. CASE STUDY 1 – SEDIMENTOLOGY AND GRAIN SIZE
5. CASE STUDY 2 – SEDIMENTOLOGY AND COMPOSITION
6. CASE STUDY 3 – COMPOSITION AND GRAIN-SIZE
7. A TOUCH OF MODELLING
8. CONCLUSIONS AND WAY FORWARD



# The Chlorite-bearing Reservoirs

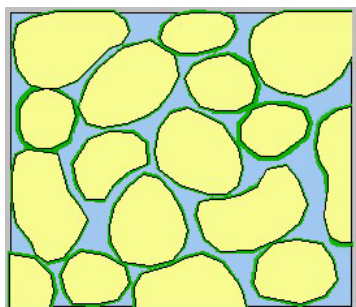
## 2 - What we know about chlorite

### THE IMPORTANCE OF BEING PORE-LINING

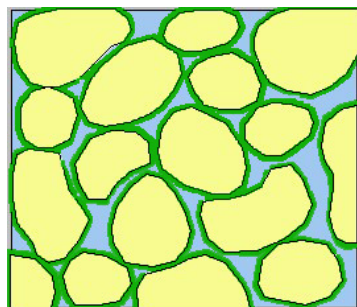


### A TOUCH OF MODELLING

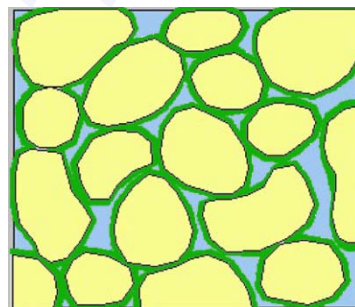
Decreasing efficiency, increasing micro-porosity



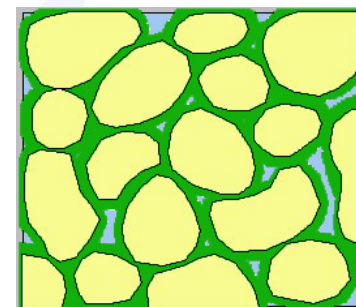
2000 mD



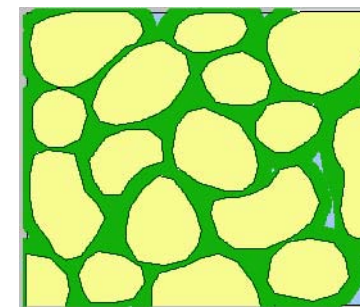
215 mD



51 mD



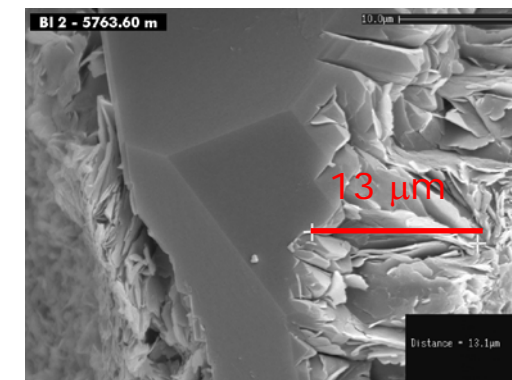
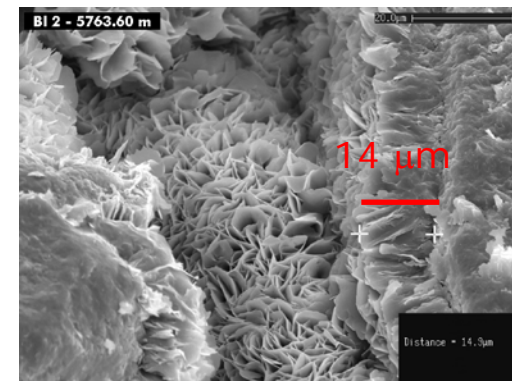
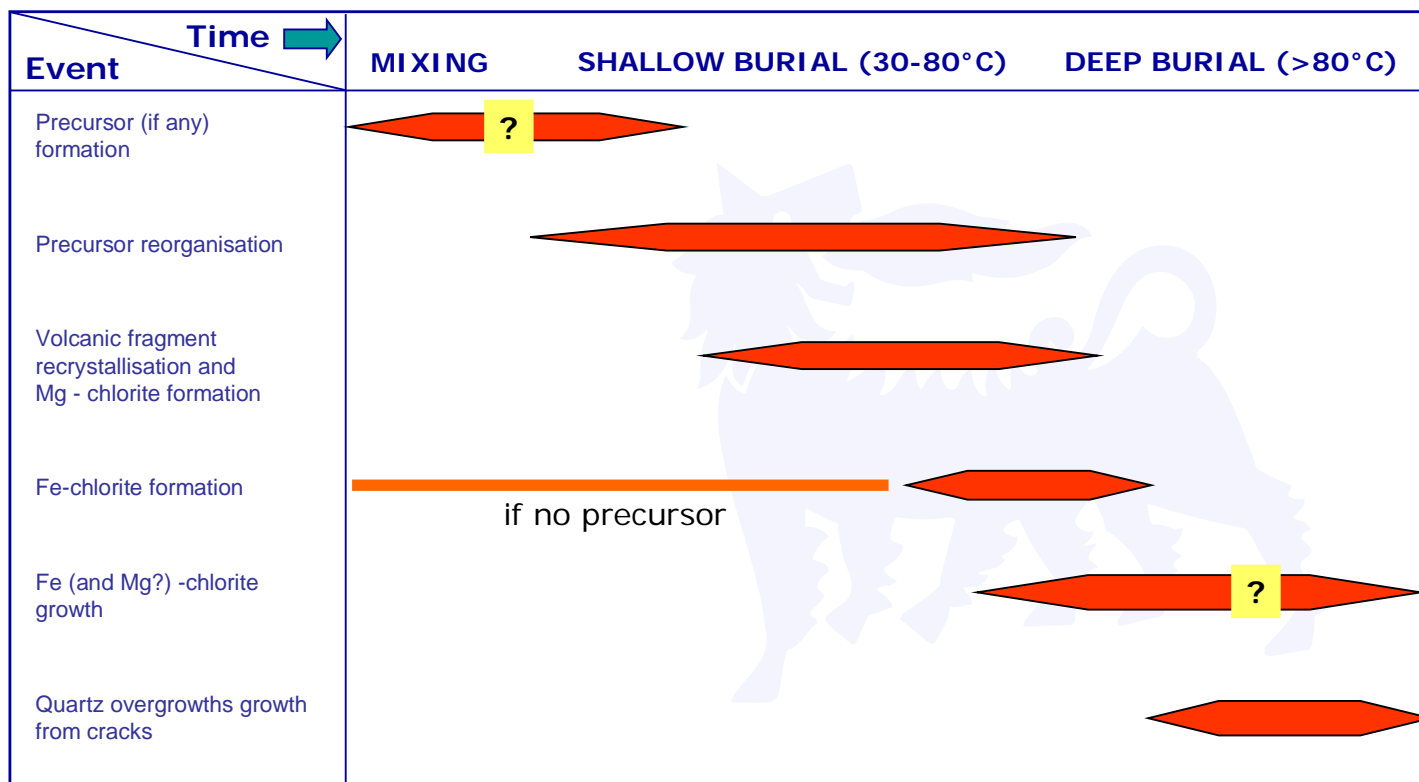
0.26 mD



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# The Chlorite-bearing Reservoirs

## 2 - What we know about chlorite



# The Chlorite-bearing Reservoirs

## 2 – What we know about chlorite



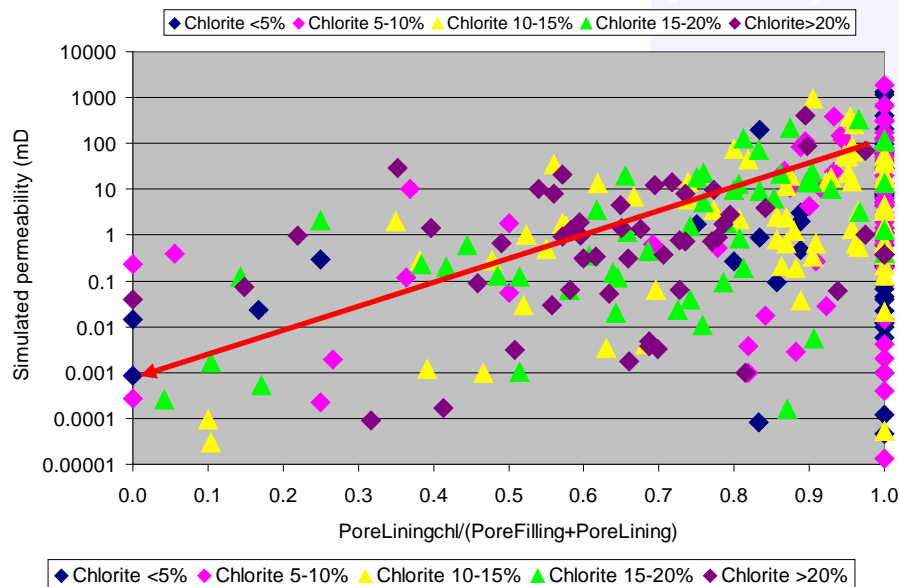
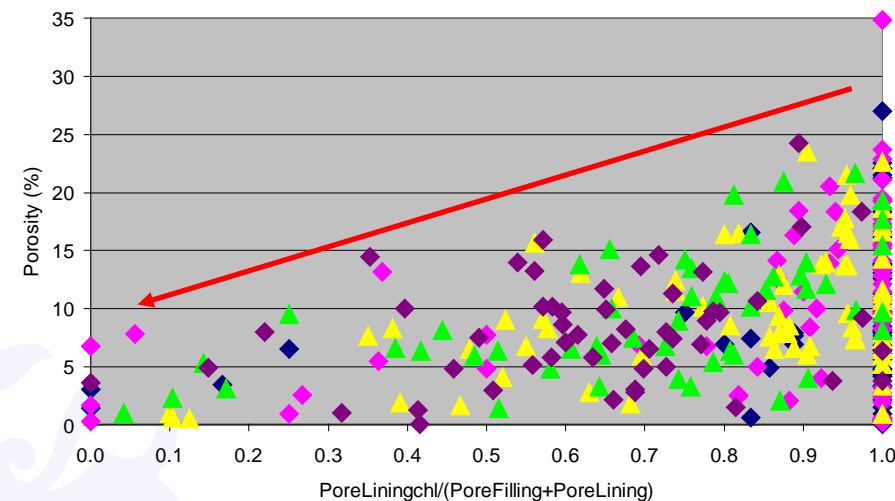
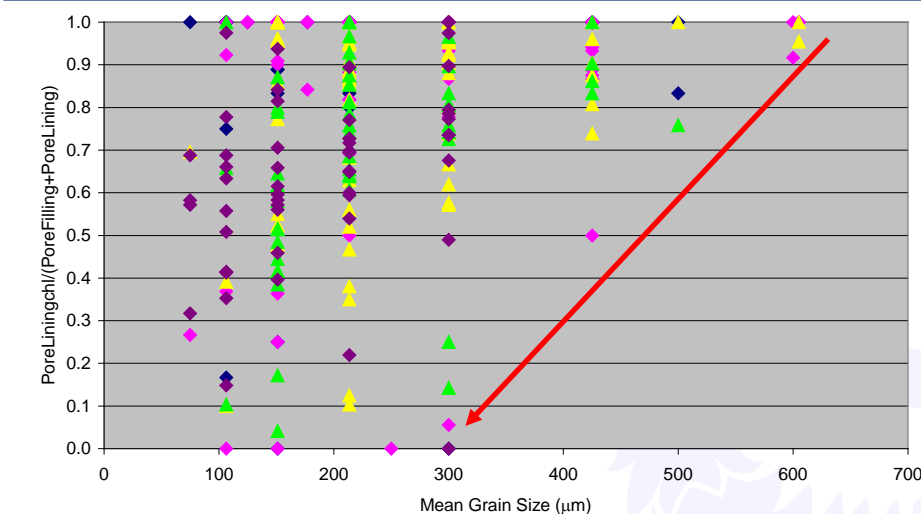
1. Analogues	Presence, position in the sequence.....
2. Paleogeography	Paleolatitude, basin morphology, drainage system
3. Depositional environment	Depositional system, facies association, energy...
4. Petrography	<b>Composition, grain dimension, sorting, chlorite texture.....</b>
5. Reservoir geometry	Continuity/discontinuity vertical and horizontal
6. Temperature	Burial and thermal history

Back in 2002, we prepared a basic chart for the occurrence of chlorite-bearing reservoirs. It is quite general and in this talk, we will focus on some of the main petrographic variables that have proved to be important in determining the reservoir quality.



# The Chlorite-bearing Reservoirs

## 3 - Chlorite and reservoir quality



As it is often the case in geological data-sets, there are no statistically meaningful correlations, but just *trends or tendencies*. The maximum porosity lowers with increasing proportions of pore-filling chlorite, whilst permeability decreases; above lower medium-grained sandstones, chlorite is rare and is mostly pore-lining.

# The Chlorite-bearing Reservoirs

## 4 - Case studies - Temperature



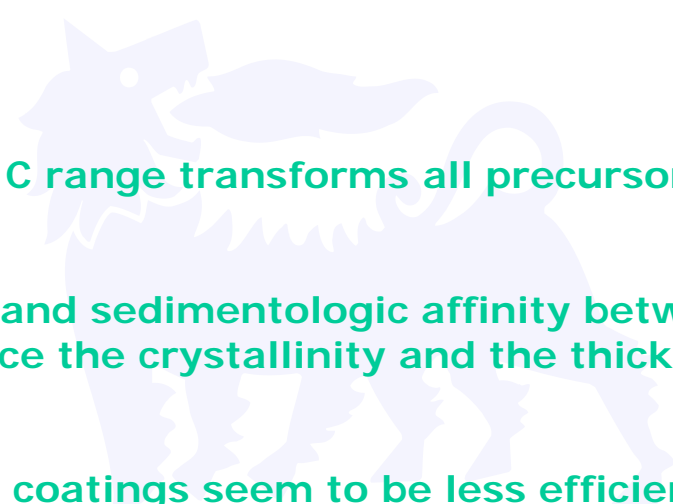
*Presented as poster at the 58th EAGE in Vienna : "Fe-Chlorite Coating evolution in Sandstones during Late Diagenesis – Is Temperature a Key parameter?"*  
*A. ORTENZI (ENI E&P Division) and E. PREVIDE MASSARA (Enitecnologie S.p.A.)*

### CONCLUSIONS

Temperature in the 100-160° C range transforms all precursor (if any) clay minerals in Fe-chlorite.

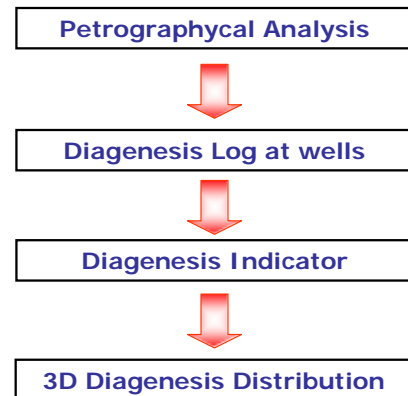
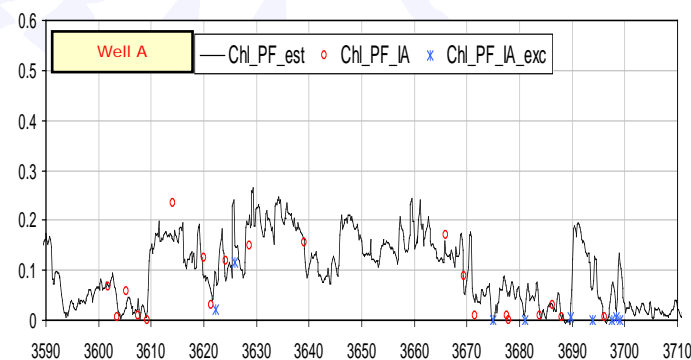
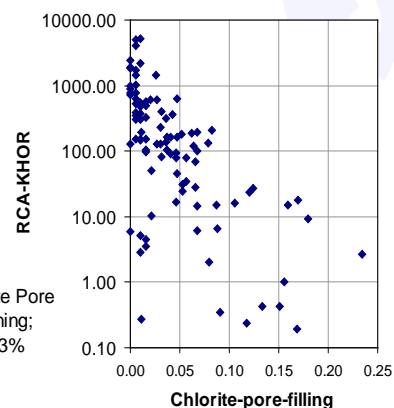
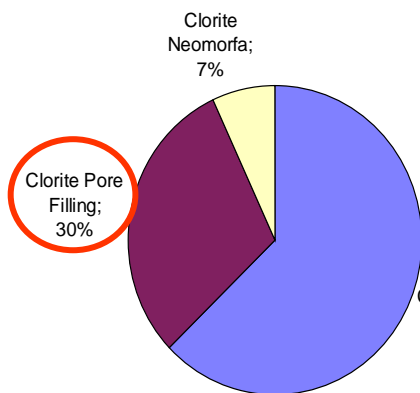
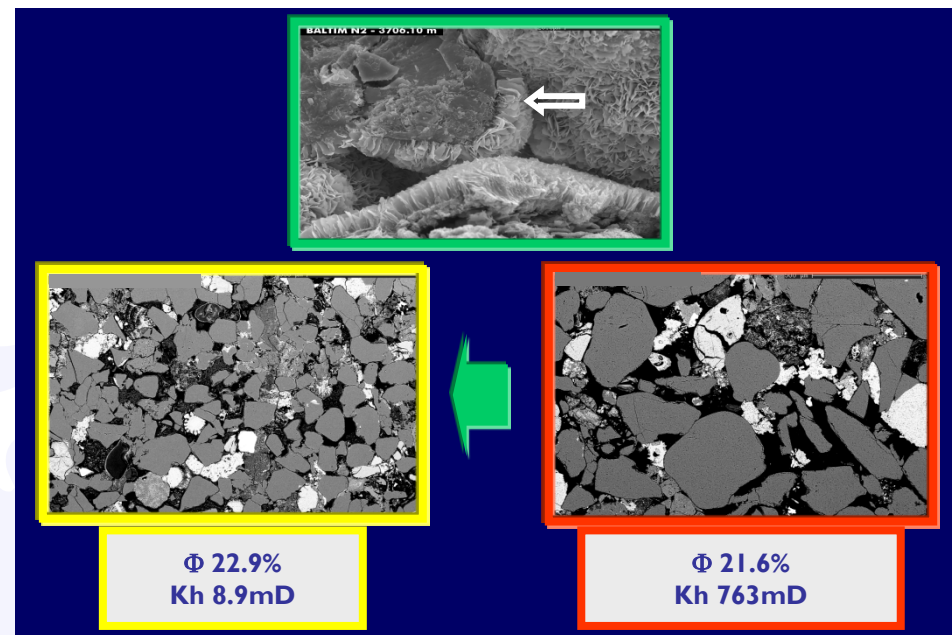
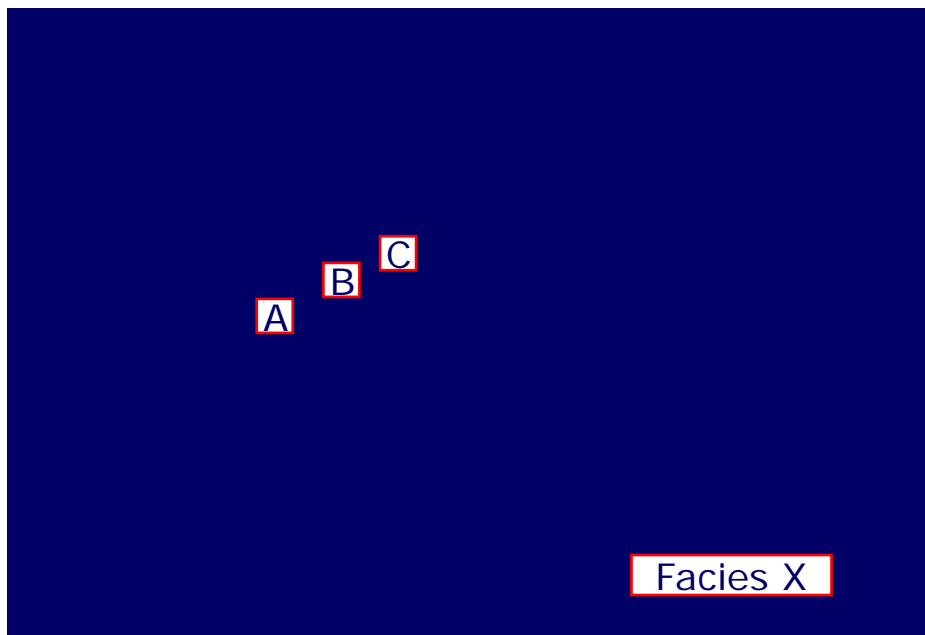
Considering the petrographic and sedimentologic affinity between the two cases, temperature seems to influence the crystallinity and the thickness of the perpendicular Fe-chlorite coatings.

The thicker Lower Cretaceous coatings seem to be less efficient in preventing quartz cementation, probably as a side-effect of the more favourable conditions for quartz precipitation.



# The Chlorite-bearing Reservoirs

## 4 - Case study 1 – The paleovalley



### CASE STUDY 1 – LESSON LEARNED

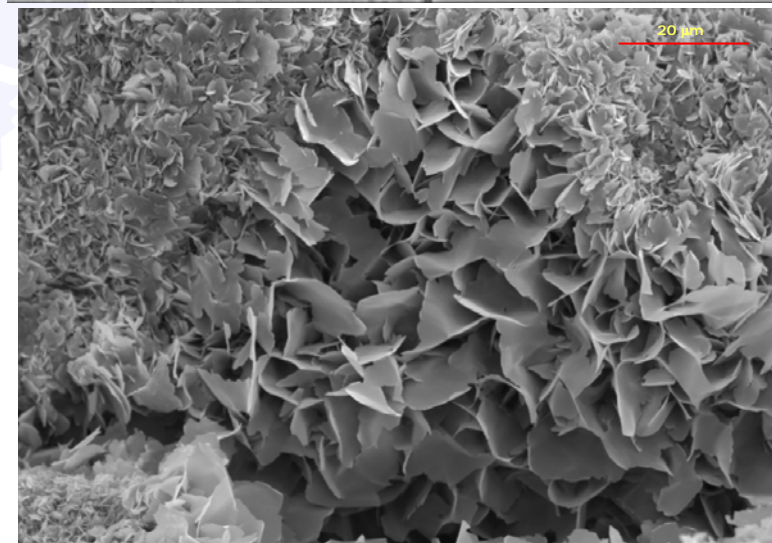
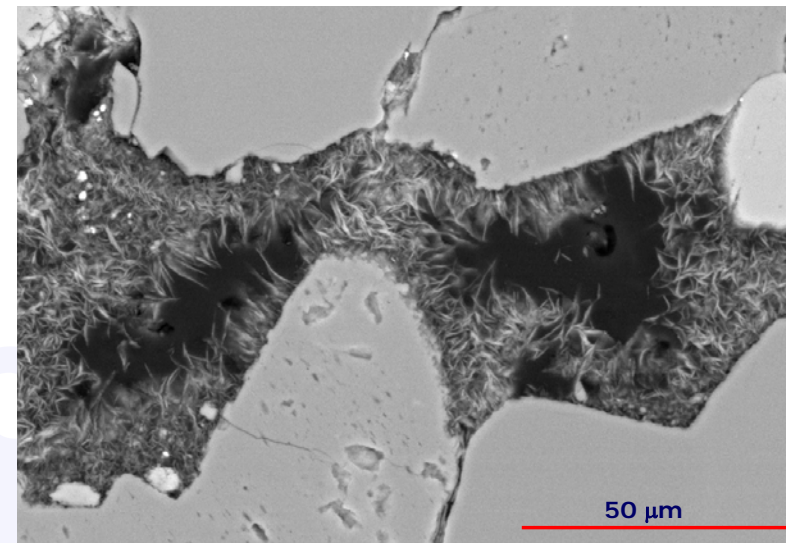
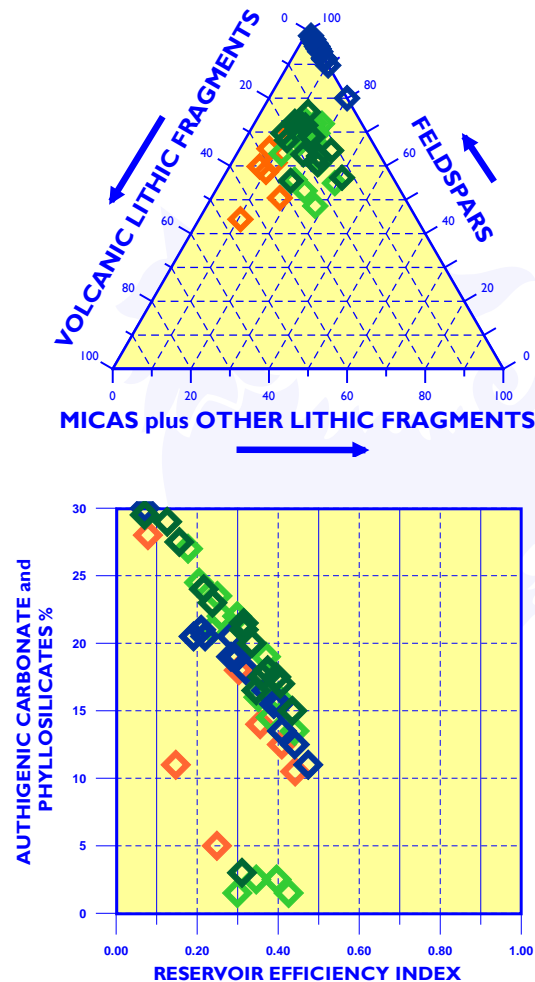
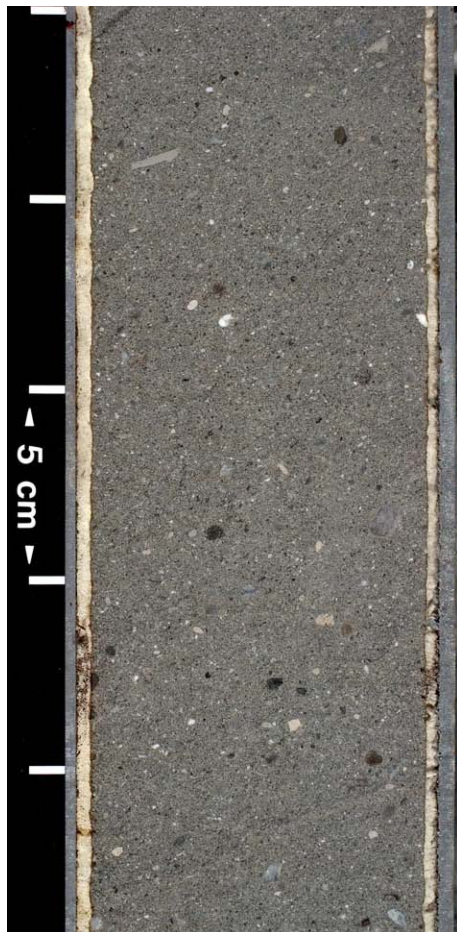
*For a given facies, the amount and distribution of Fe-chlorite varies on the base of the environment of deposition, more or less influenced by marine waters (mixing)*

*The best facies in term of reservoir quality are the coarser-grained ones, where chlorite forms a thin pore-lining layer that does not hinder significantly the permeability and preserves porosity*

*The compositions helps in understanding the increase of marine influence, with the presence of chlorite ooids*

# The Chlorite-bearing Reservoirs

## 5 - Case study 2 – The turbidites



### **CASE STUDY 2 – LESSON LEARNED**

*The presence of volcanic lithic fragments causes the growth of thick Fe-(Mg)- chlorite coatings that fill the pore throats and lower the permeability*

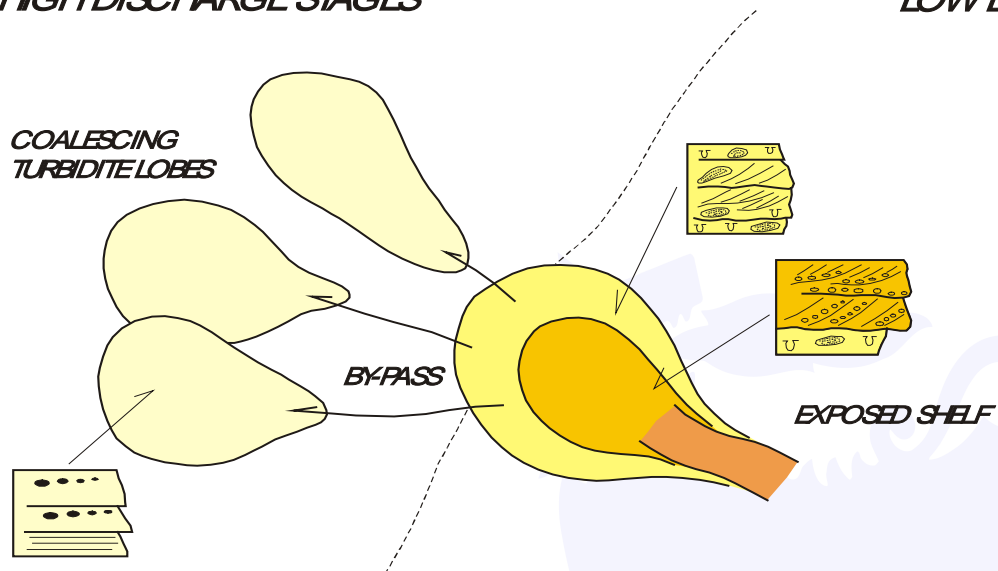
*The turbiditic facies may inherit some of the coatings from shallower settings; however, the texture of the chlorite is different and the thickness reached is more important*

*The onset of significant chlorite growth seems to be in the shallow to intermediate burial settings*

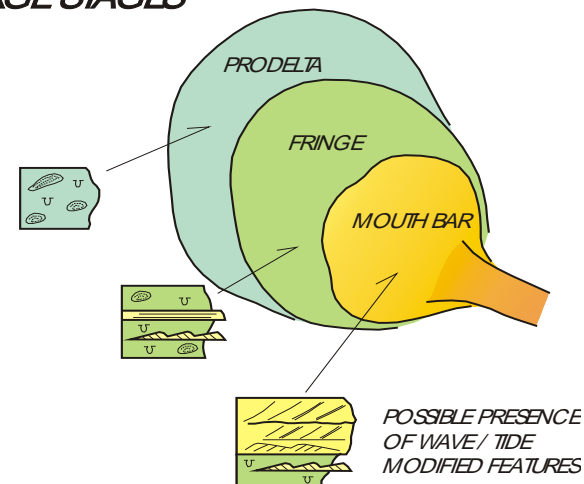
# The Chlorite-bearing Reservoirs

## 6 - Case study 3 – The delta

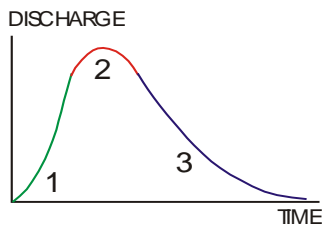
### HIGH DISCHARGE STAGES



### LOW DISCHARGE STAGES

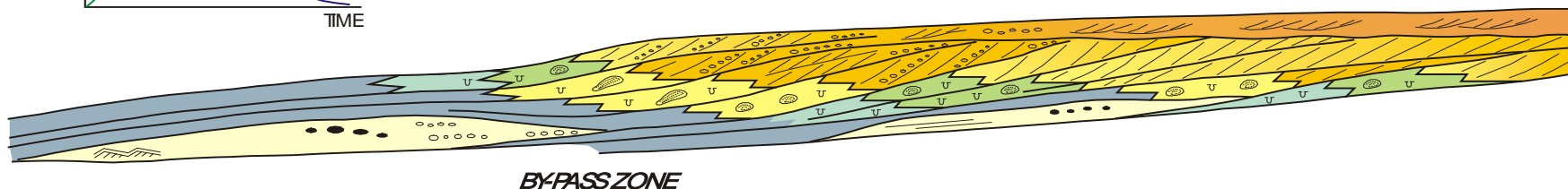


### FLOOD HYDROGRAM



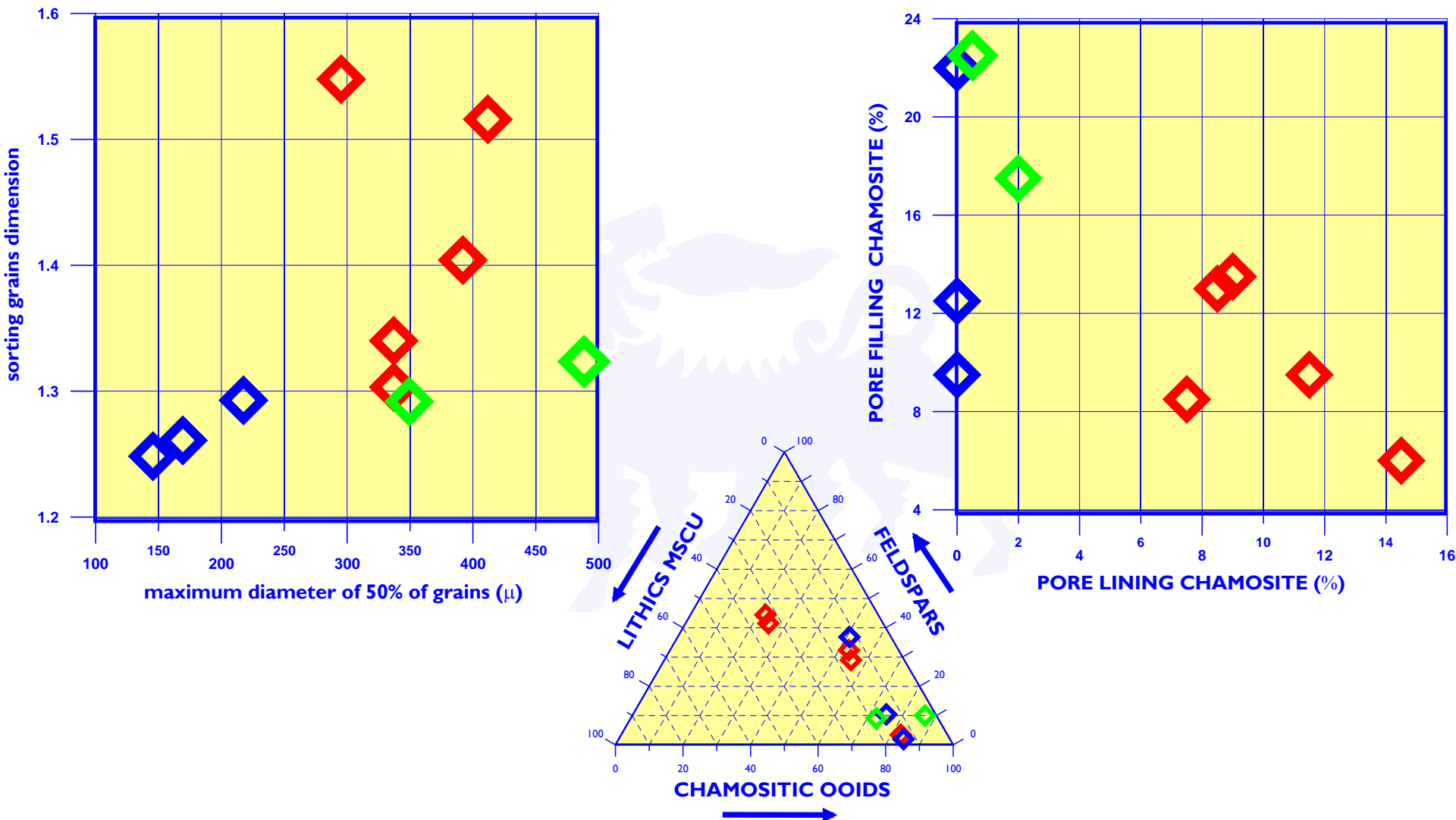
OVERALL "FORCED REGRESSION" GEOMETRY DUE TO SYN-SEDIMENTARY TECTONICS (MARGIN UPLIFT AND INCREASE OF SEDIMENT SUPPLY)

DETACHED TURBIDITES BEDS GENERATED ONCE THE PROGRADATION HAS REACHED THE SLOPE BREAK OF UNDERLYING SEQUENCE IN THE INITIAL PHASE OF PROGRADATION, PEAK DISCHARGE EVENTS ARE RECORDED BY "ATTACHED" GRAVITY FLOW BEDS (BASE OF SAWAN-9 AND SAWAN-2)



# The Chlorite-bearing Reservoirs

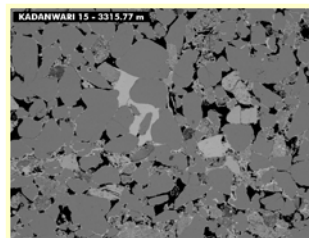
## 6 - Case study 3 – The delta



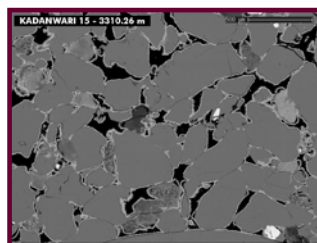
# The Chlorite-bearing Reservoirs

## 6 - Case study 3 – The delta

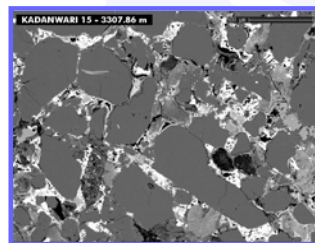
20.9%



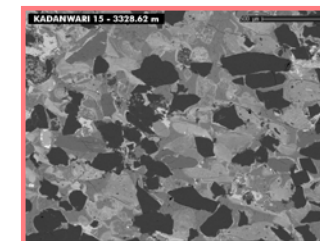
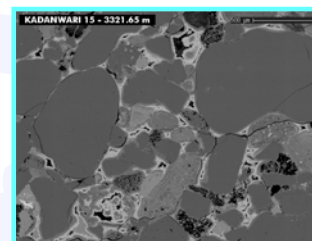
20.6%



18.1%

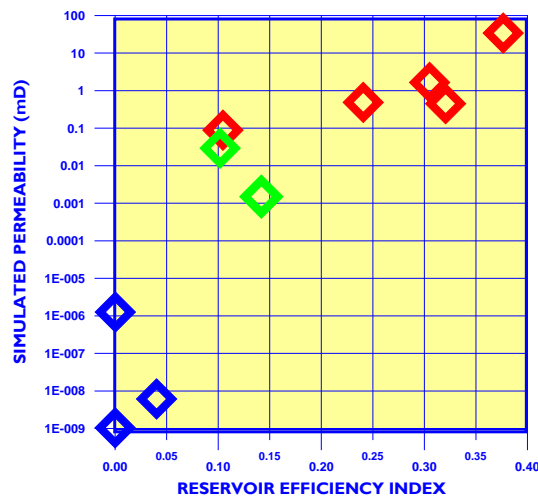
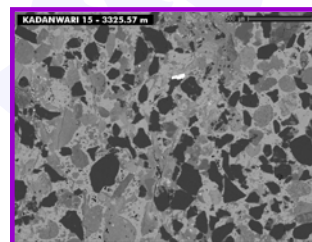


16.1%



8.5%

9.1%



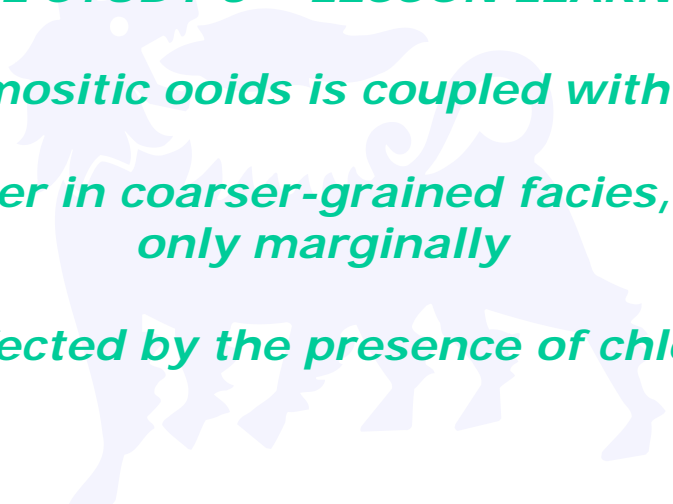
- Chamositic Delta Topset (CDT)
- Proximal Delta Front Foreset (PDFF)
- Proximal Burrowed Delta Front (PBDF)
- Chamositic Topset (CT)
- Chamositic Proximal Foreset (CPF)
- Distal Delta Front Foreset (DDFF)

### ***CASE STUDY 3 – LESSON LEARNED***

*The presence of chamositic ooids is coupled with pore-filling chlorite*

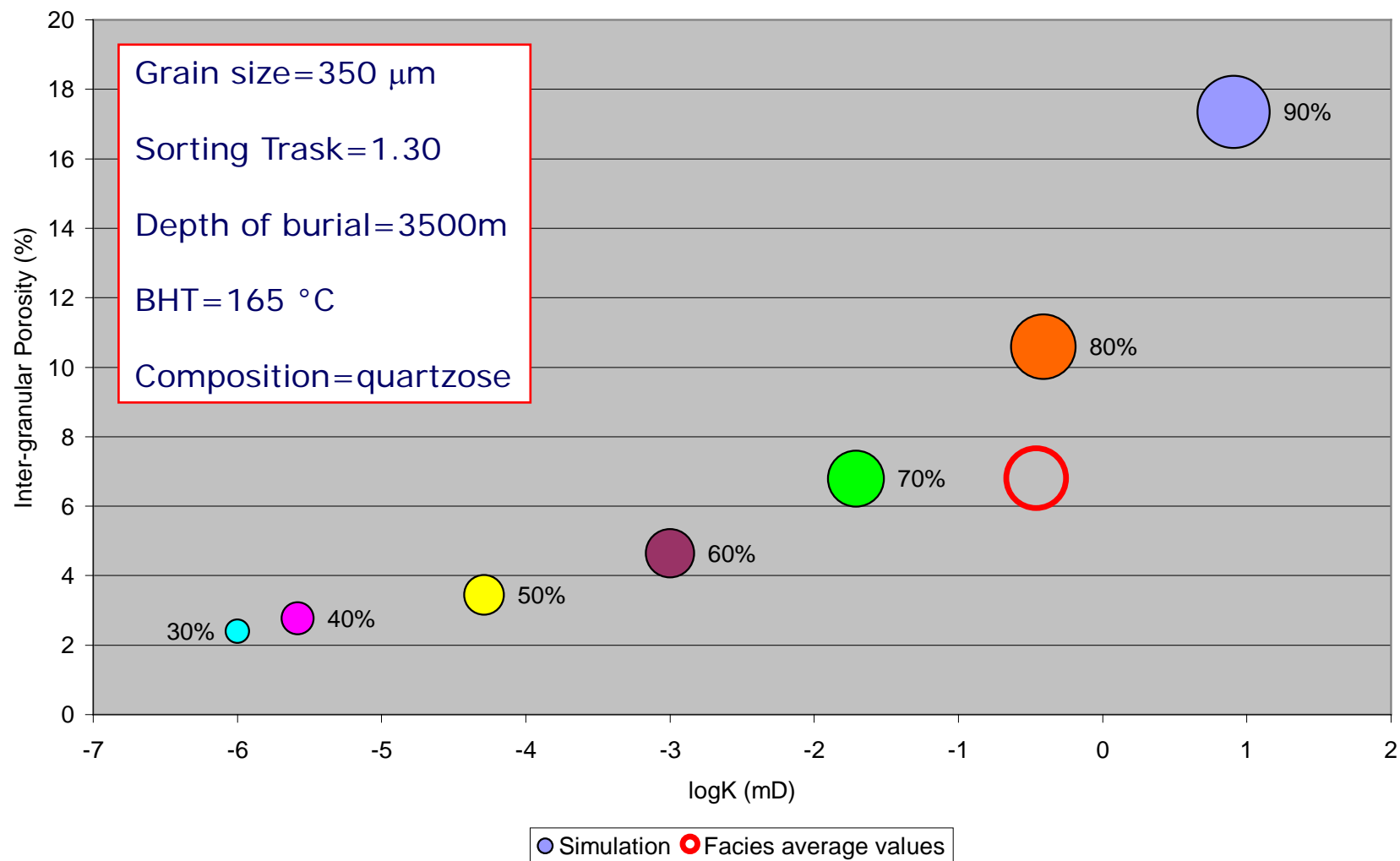
*Reservoir quality is better in coarser-grained facies, whilst the sorting acts only marginally*

*Porosity is much less affected by the presence of chlorite than permeability*



# The Chlorite-bearing Reservoirs

## 7 - A Touch of Modelling



AAPG International Exhibition and Conference "African Energy – Global Impact" – Cape Town – 26-29 October 2008

# The Chlorite-bearing Reservoirs

## 8 - Conclusions and way forward



1. Analogues	Presence, position in the sequence.....
2. Paleogeography	Paleolatitude, basin morphology, drainage system
3. Depositional environment	Depositional system, facies association, energy...
4. Petrography	<b>Composition, grain dimension, sorting</b>
5. Reservoir geometry	Continuity/discontinuity vertical and horizontal
6. Temperature	Burial and thermal history

Probability of Chlorite coatings	<input type="text"/> <div>low high</div>
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Possible coating thickness	<input type="text"/> <div>1-2 <math>\mu</math> 20 <math>\mu</math></div>
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# The Chlorite-bearing Reservoirs

## 8 - Conclusions and way forward



### CONCLUSIONS

*The best chlorite-bearing reservoirs are found in fluvial-dominated coarse-grained sediments of deltaic and estuarine settings laterally and vertically in contact with more marine facies*

*Reservoir quality is determined by the ratio between pore-filling and pore-lining chlorite; this ratio depends on grain-size and also on composition*

*The sorting does not exert a strong control on chlorite abundance*

*The presence of volcano-clastic grains either enhances the growth of coatings (if already present) or induces, during the shallow to intermediate burial, the growth of more Mg-rich thick coatings; these coatings have, however, a lower potential for reservoir quality preservation*

### WAY FORWARD

*As we do not know exactly why coatings form, it is mandatory, for a proper forward modelling and for prediction to ascertain the mechanism of formation (chemical, biologic...) of the Fe-chlorite*

# The Chlorite-bearing Reservoirs Acknowledgements



*"It has long been an axiom of mine that little things are infinitively the most important"*  
*Sherlock Holmes – A Case of Identity*

*We acknowledge ENI E&P Division for the permission to present. We also thank deeply  
all our colleagues that participated to the different studies and, above all, Michela  
Idiomi, Enrico Giomo and Onorino Zacchetti.*

*We also want to thank this beautiful country for its unparalleled hospitality*

## Reference

Ortenzi, A. and E.P. Massara, 2006, Fe-Chlorite coating evolution in sandstones during late diagenesis – Is temperature a key parameter?: EAGE 68<sup>th</sup> Conference, Vienna, Austria, Web accessed 9 April 2009, <http://www.earthdoc.org/detail.php?pubid=7>