Enhanced Reservoir Characterization Using Continuous Mineral Composition Logs*

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Search and Discovery Article #80502 (2015)**
Posted December 28, 2015

*Adapted from oral presentation given at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015

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Abstract

Reservoir characterization is critical for the exploration and evaluation of oil and gas resources, but also in the context of geological carbon storage. Interbedded baffles play a key role in controlling the CO_2 plume dynamics and geometry and, as a consequence, residual CO_2 trapping capacity can be greatly enhanced due to the presence of baffles. Mineral trapping capacity is also enhanced where CO_2-rich fluids are in contact and react with baffles containing Ca-, Mg-, and Fe-rich silicate minerals leading to the precipitation of carbonates. Importantly, interbedded baffles of a few centimeters are sufficient to affect CO_2 injection and storage conditions as described. In this study, we explore the merit of Hylogger™ data as a complementary approach to traditional reservoir characterisation. The recent development of the Hylogger™ −3 technology with the thermal infrared (TIR) sensor allows the rapid and continuous semiquantitative determination of common minerals in cores and chips from siliciclastic reservoirs at centimeter resolution. As a case study, data from sediment cores from a recent CO_2 storage exploration program in the Darling Basin (New South Wales, Australia) are presented. Hylogger™ data are used in two distinct ways. Firstly, the percentage of mineral groups (framework, carbonate, and clay minerals) is calculated based on Hylogger™ data and compared to XRD results on discrete samples. Secondly, the distribution of clay mineral rich intervals is compared to interpreted shales based on wireline log data. We generally found very good agreement between the relative abundance of framework, carbonate, and clay minerals when Hylogger™ TIR data were compared to traditional XRD data. The advantage of the Hylogger™ data is it provides a high (centimeter-scale) resolution record of litho-types, while the complementary XRD data can be used to validate the accuracy of the mineral determination by Hylogger™. The comparison of wireline log interpreted shale intervals with clay-mineral rich intervals based on Hylogger™ data mostly showed a good correlation. However, two wireline log shale intervals were found to be composed of almost entirely quartz based on Hylogger™ data. We suspect relatively high gamma ray emissions from very low concentrations of minerals such as K-containing muscovite or kaolinite may have led to the false wireline log interpretation. Spectral gamma ray analysis is currently planned to further explain the observed discrepancy.

References Cited

Haese, R.R., and M. Watson., 2014, Comparison of the Mineral Trapping Capacity in Three Reservoirs with Variable Mineral Compositions under CO_2 Saturated Conditions: Energy Procedia, v. 63, p. 5479-5482. doi:10.1016/j.egypro.2014.11.579

Higgs, K.E., R.H. Funnell, and A.G. Reyes, 2013, Changes in Reservoir Heterogeneity and Quality as a Response to High Partial Pressures of CO_2 in a Gas Reservoir, New Zealand: Marine and Petroleum Geology, v. 48/12, p. 293-322. doi:10.1016/j.marpetgeo.2013.08.005

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Presenting to
AAPG ICE, 15 September 2015

Questions to be addressed relating to CO_2 mineralisation:

1. What do we know & what we not know about fluid - rock reactions?

2. What have we learned from natural analogues?

3. How can continuous mineral composition logs support realistic predictions of CO_2 mineralisation?

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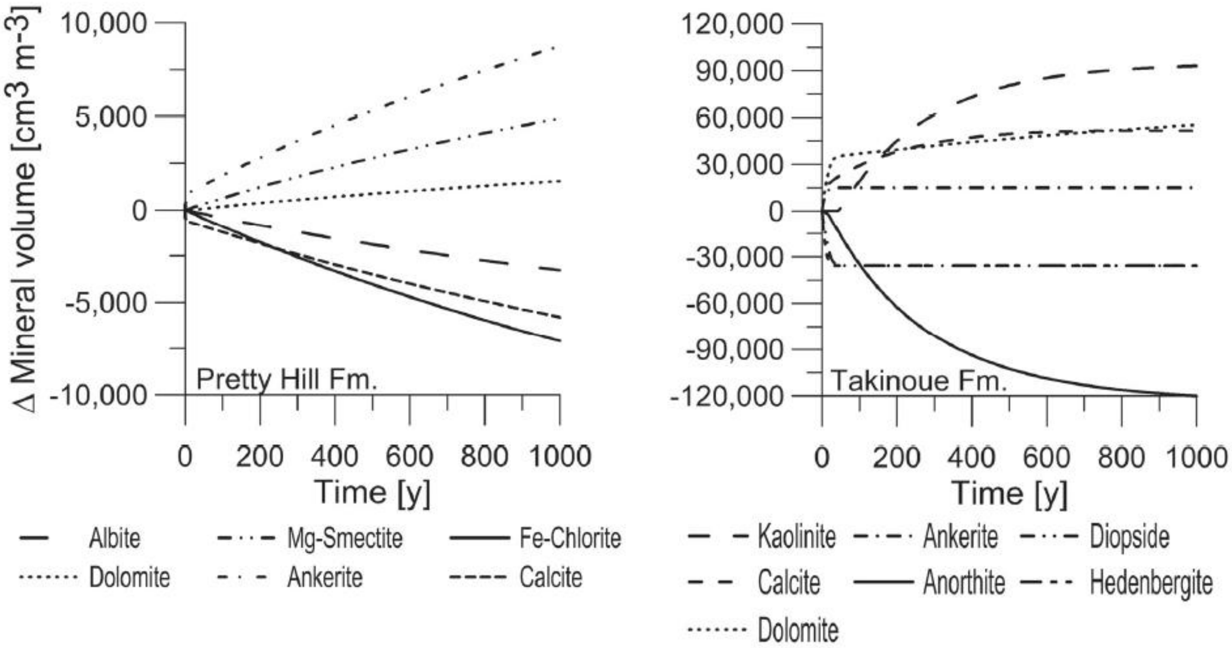
Differences in mineral reactivity in reservoir rocks

Primary mineral composition

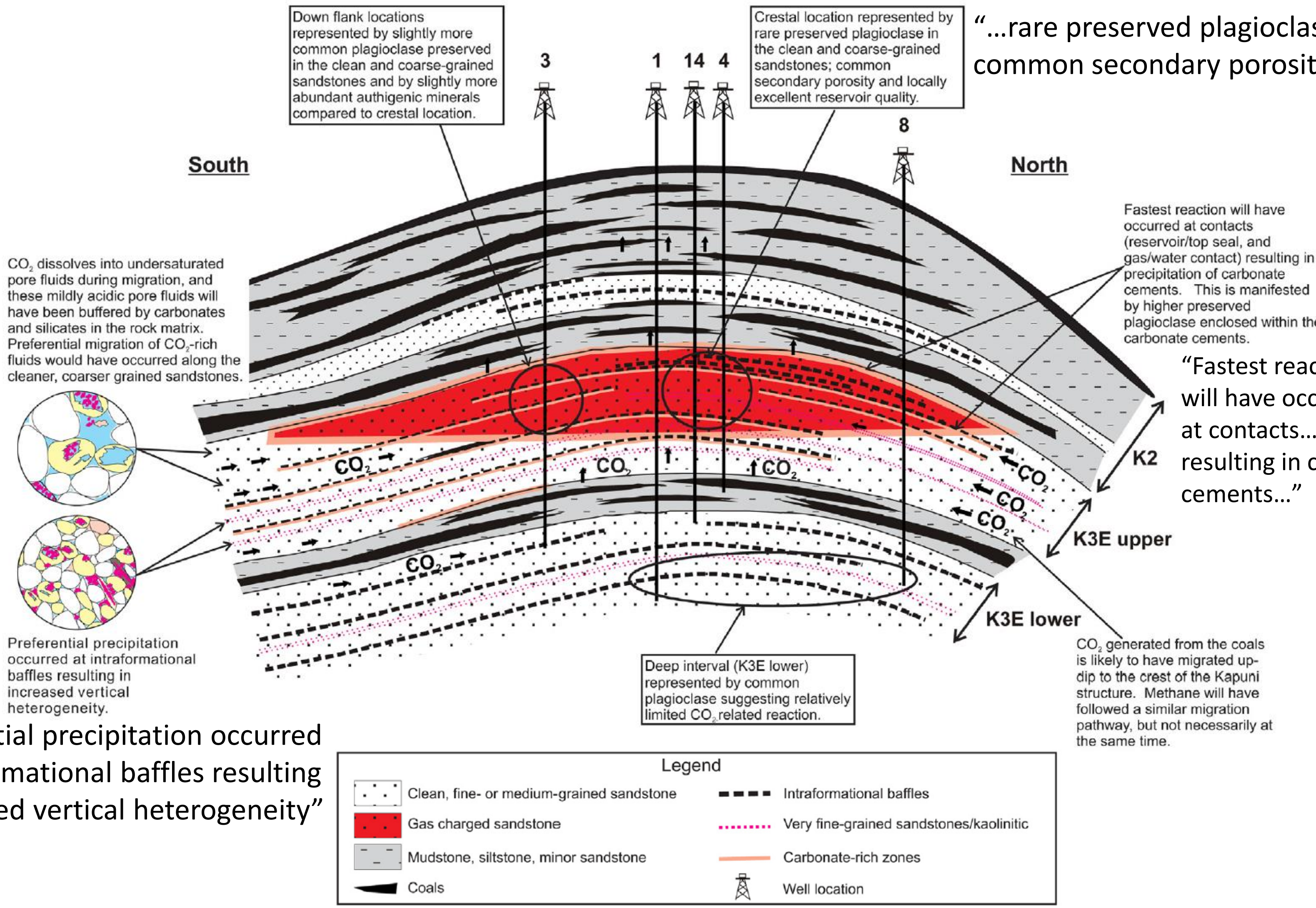
	Pretty Hill Fm.	Takinoue Fm.
Quartz	60	6
Ca-Na-plagioclase		38
K-feldspar	2	
Albite	19	
Mg-Fe-pyroxene		23
Fe-Chlorite	10	12
Calcite	5	1
Kaolinite	1	22
Illite	1	



Source: Haese and Watson., 2014, Energy Procedia

Lessons learned from a natural analogue, The Kapuni Field, New Zealand

"…rare preserved plagioclase… common secondary porosity…"

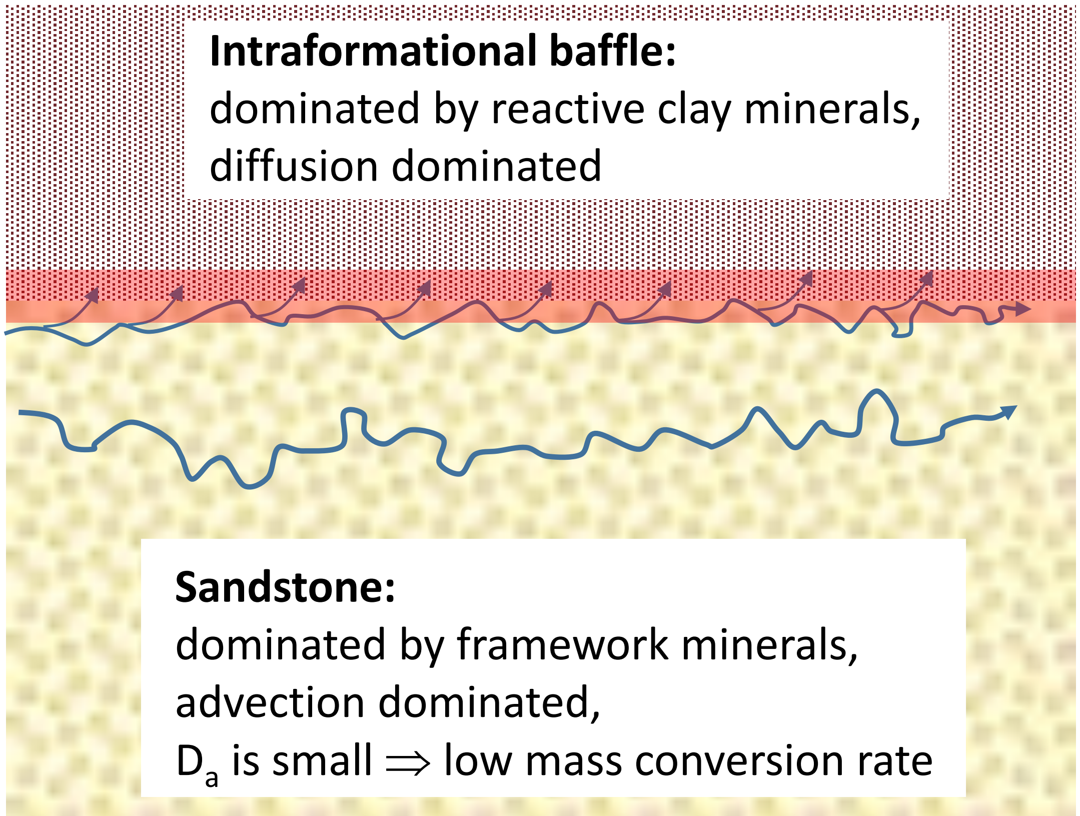


"Fastest reaction will have occurred at contacts… resulting in carbonate cements…"

"Preferential precipitation occurred at intraformational baffles resulting in increased vertical heterogeneity"

Source: Higgs et al., 2013, Marine and Petroleum Geology

Processes at the interface of intraformational baffles and sandstone



Interface:
D_a is large
$\Rightarrow$ high mass conversion rate

$$\text{Damköhler Number, Da} = \frac{Reaction\ Rate}{Mass\ Transport\ Rate}$$

Continuous semiquantitative mineral analysis using the Hylogger™ at Mena Murtee-1 (Darling Basin, NSW)

Data acquisition:
SWIR/VNIR & TIR sensors
at NSW Geological Survey

Data processing and interpretation:
The University of Melbourne,
TIR data analysis using
software: TSG HotCore

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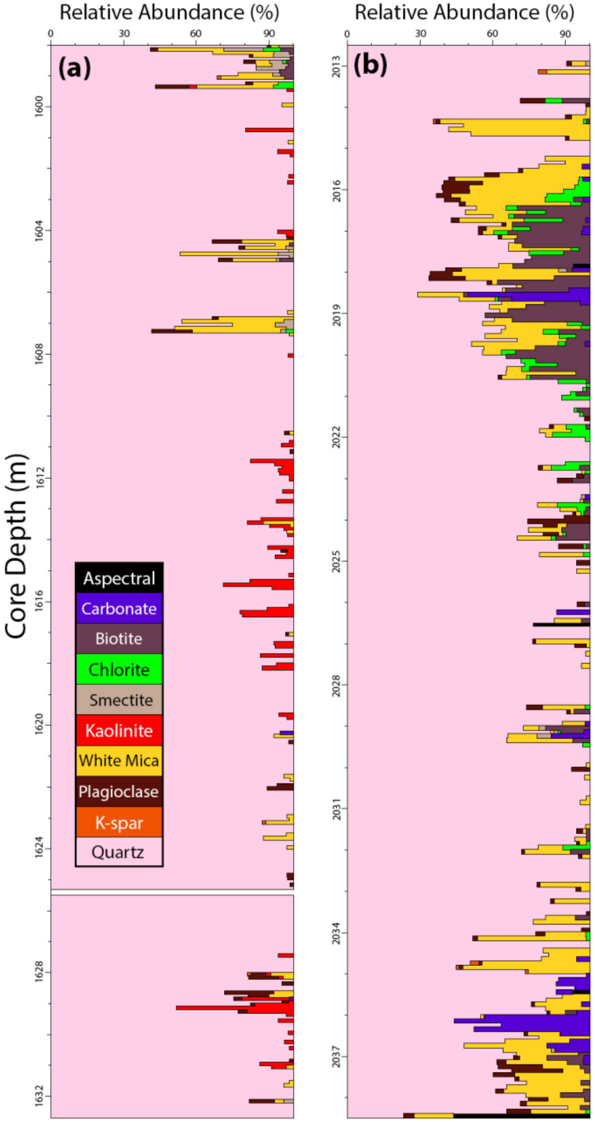
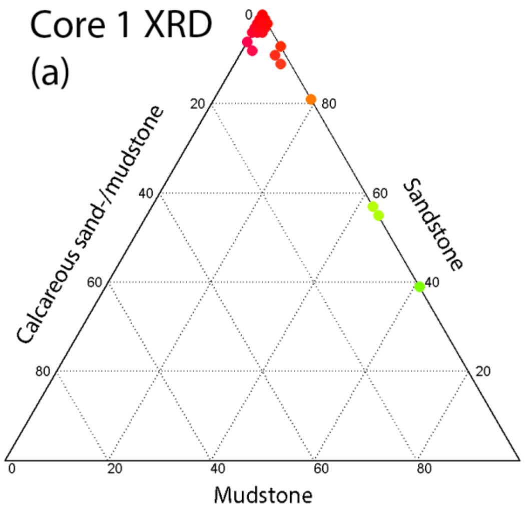
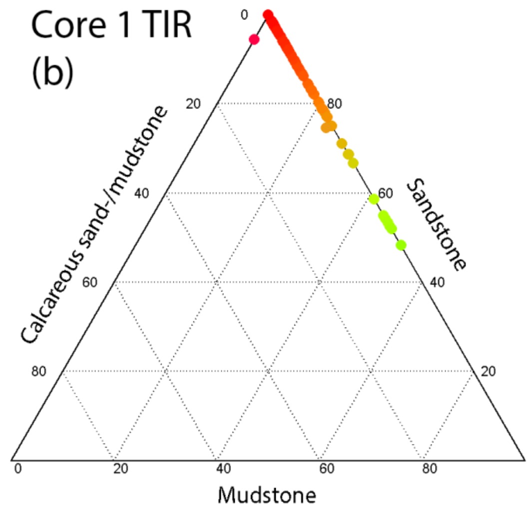
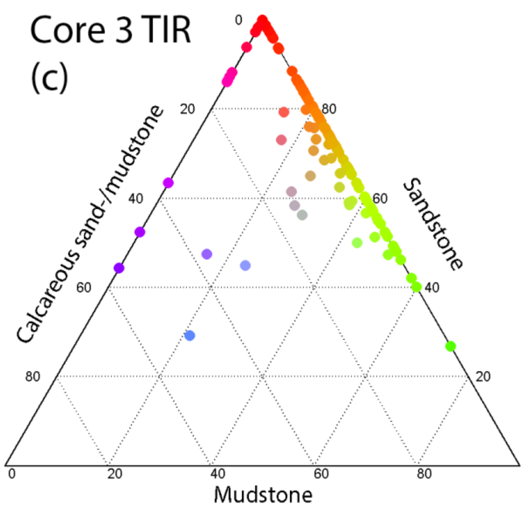
Definition and distribution of lithotypes based on mineral composition









Composition	RGB Triplet	Color
100% sandstone	[1, 0, 0]	
100% mudstone	[0, 1, 0]	
100% carbonate	[0, 0, 1]	
80% sandstone, 20% calcareous sandstone	[1, 0, 1]	
80% sandstone, 20% mudstone	[1, 0.5, 0]	
60% sandstone, 40% mudstone	[0.75, 1, 0]	
65% sandstone, 27% mudstone, 8% calcareous sand-/mudstone	[0.81, 0.68, 0.4]	
60% sandstone, 25% mudstone, 15% calcareous sand-/mudstone	[0.75, 0.63, 0.75]	

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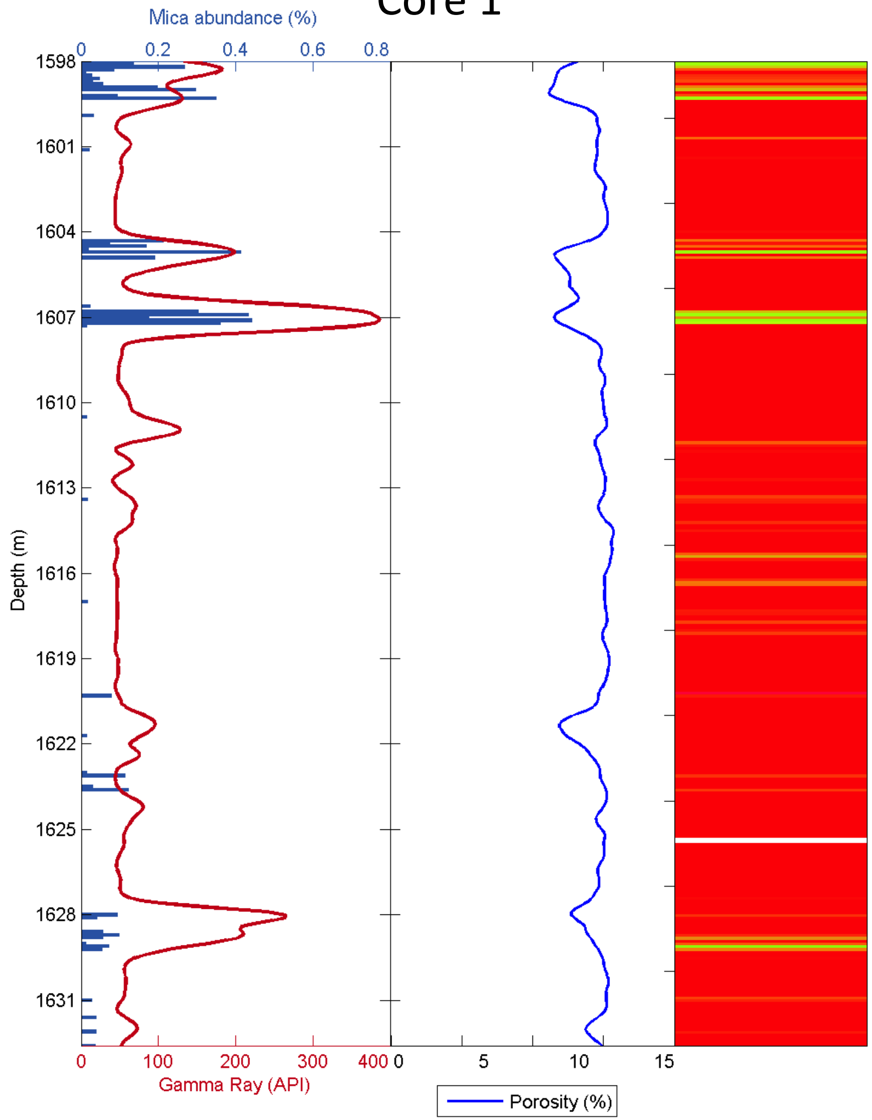
Correlating wireline log with hyperspectral core logging data

Core 1



Qz: 42, Ab: 9, K-spar: 6, Illite: 28, Chl: 15%

Av. of sandstone:
Qz: 88.5, Ab: 7.5, K-spar: 1, Calcite: 1.5, Illite + Chl: 1.5%

Qz: 33, Ab: 11, K-spar: 6, Illite: 32, Chl: 18%

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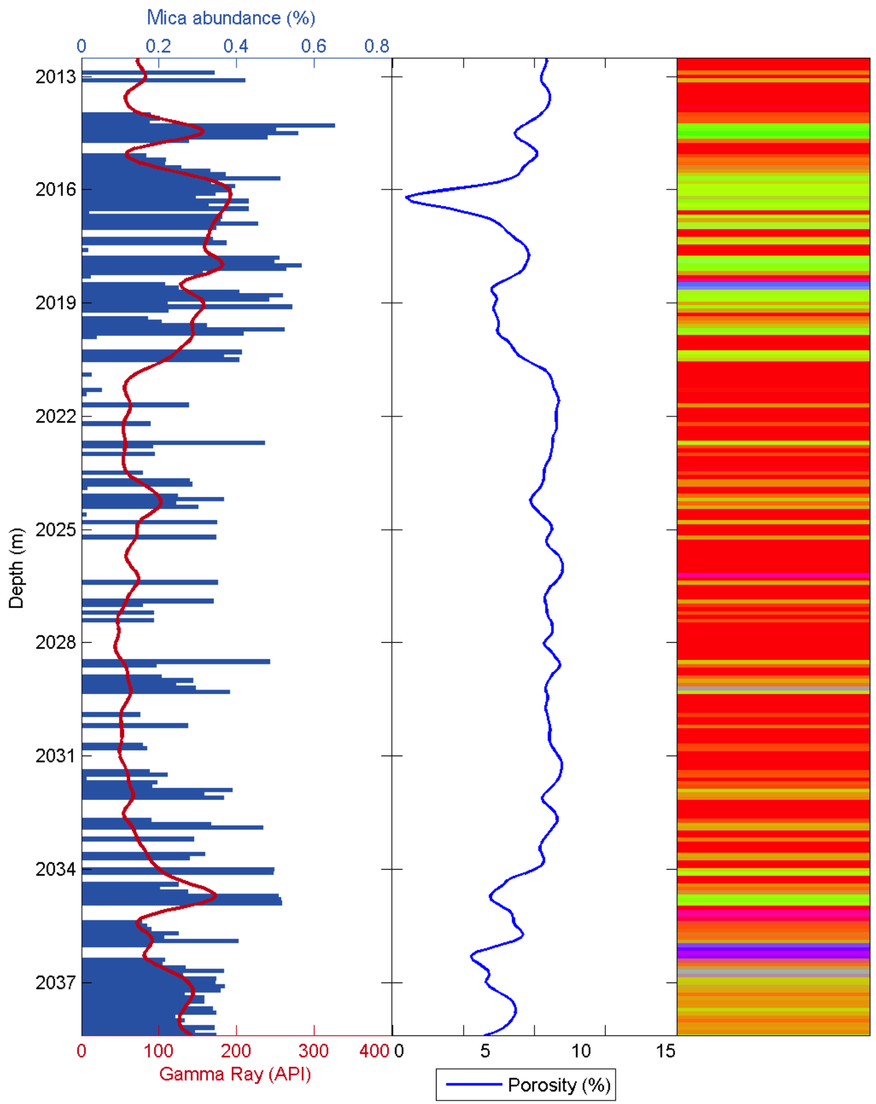
Correlating wireline log with hyperspectral core logging data

Core 3



Conclusions

Reservoir scale CO_2 mineralisation estimates require reactive – transport modelling.

The interfaces between sandstone and intraformational baffles are primary zones of mineralisation.

Continuous mineral logs provide important data for the required modelling.

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