PSData Integration from Side Wall Cores to Image Log to Seismic Architecture of Deepwater Cretaceous Section: An Example from Sierra Leone*

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Abstract

Exploration of Cretaceous deepwater sediments in West Africa provided information on reservoir potential that can be assessed at different scales. The understanding of depositional processes and architecture of the reservoirs relied on integration of the entire dataset including upscaling with iterations between steps. An example of data integration from an exploration well is provided here.

As full conventional cores in wildcat is uncommon, several runs of side wall cores provide key information on the texture of the sediments, shale content, pore network, reservoir properties, and depositional facies. Close inspection of the SWC provided information on deepwater sedimentation as each facies was identified and interpreted in an updated facies classification based upon Mutti (1992 and 1999).

Discreet information provided by SWC was used for a close calibration of the image logs and to a lesser degree the set of conventional wireline logs in order to produce a continuous sedimentological log of the entire Cretaceous section.

Stacking pattern was analyzed and compared with a detailed biostratigraphical study. Stratigraphical breakdowns and taxon events were used to validate the sequence analysis performed at different orders. A three-fold stratigraphic hierarchy was performed at 3rd order system, 4th order complex and 5th order storey, the later being the flow unit. Stacking pattern and facies succession led to a prediction of the architecture near the well bore.

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The hierarchy of the stratigraphy and stacking pattern were used to calibrate various 3D seismic cubes (PSDM: Full stack, angle stacks) in order to get a better understanding of the different flow units in both map view and 3D as numerous incisions between channel storeys supply communicating points within lower order channel complexes.

Finally, an attempt to tie the stacking pattern, architecture and biostratigraphical breakdowns with eustatic sea level curve was done and checked against results from other exploration wells using random seismic lines tying these wells.

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Location map



Workflow

RESERVOIR DESCRIPTION:

- 1- Description and facies typing of four runs of Side Wall Cores (SWC) - Based upon turbidite facies classification adapted from Mutti et al. (1999)
 - CT scan images of the SWC

 - Information from the mud loa
- 2- Depth match of the SWC against OBMI and wireline logs
- 3- Drawing of a 1:100 scale sedimentological log calibrated by
 - SWC facies interpretation
- Oil-Based Mud Image log (OBMI)
- 4- Comparison of Facies, Phi-K, XRD-SEM for each stratigraphic interval to evaluate the reservoir
 - Provenance
 - Diagenesis, Burial effect

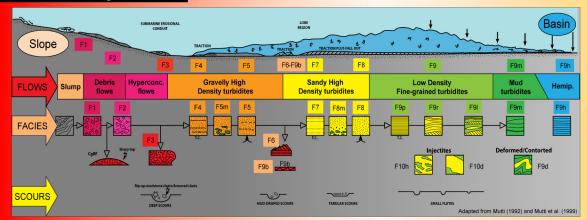
SEQUENCE STRATIGRAPHY, STRATIGRAPHIC HIERARCHY and SEISMIC STRATIGRAPHY:

- 1- Sequence analysis (1D) of well data:
 - Posting of biostratigraphic data on the sedimentological log Stacking pattern analysis

 - Preliminary architectural element interpretation
- 2- Seismic stratigraphy analysis in the neighborhood of the wellbore in order to validate the architectural element interpretation:
 - Key surfaces,
- A.E. interpretation: channels, lobes, sheets, hemipelagite drapes...
- 3- Summary of the reservoir potential of the Cretaceous section in Sierra Leone area for each stratigraphic interval correlating with other wells (Not shown in the poster).

1- Facies interpretation

Facies classification of deepwater systems



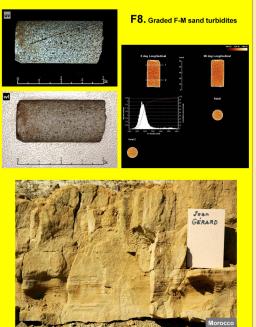
F9d-F10d Deformed F10h Injectites F9h Hemipelagites F9m Mud turbidites F9I Thin-bedded turbidites F9r Rinnled VF sand turbidites F9p Laminated VF sand turbidites F8 Graded F-M sand turbidites F5m-F8m Sand with mud clasts F7 Laminated F-M sand F6 Cross-bedded C-M sand F5 Graded C-vC sand turbidites F4 Laminated C-vC sand F3 Conglomerate F2 Grain-supported flow F1 Matrix-supported debrites

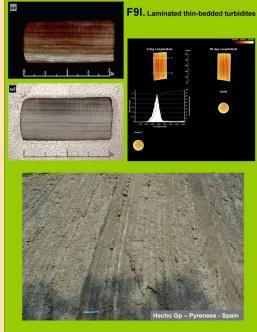
Low density fine-grained sediments were added to the original facies classification -mostly derived from field work- in order to describe cores and interpret image logs in thin-bedded sections which are commonly reservoir for light oil and gasbegring sections in opposition mud turbidite and hemipelagite that are baffles and barriers or seals.

Examples of facies identification of SWC



F2. Grain-supported





Depositional facies and reservoir characteristics

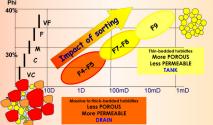


- CT-scan images

 The whole core
 - •Three sections of CT-scans
 •A spectrum of CT scan response
- · Whole rock RXD analysis for a few samples as shown on the right

A grain size comparator magnified to the scale of the photos was used to evaluate the grain Sorting was appreciated with a close inspection of the photos and the CT-spectrum.

A catalog of facies from outcrop photos was used to back up the facies identification. Sorting and grain size distribution are the main controlling factors of the pore system prior to diagenesis. The diagrams on the right highlight the close relationship between depositional facies, flow processes and reservoir properties (before cementation took place).

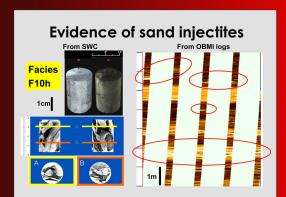


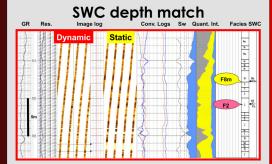


2- Image log interpretation

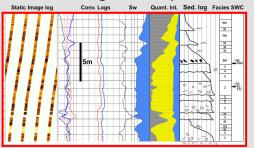
• Image logs are quite essential to compensate for the lack of continuous coring program in exploration wells but runs of side wall cores must be taken to calibrate

•Texture, continuity, contrast... in image logs give information of the stratigraphy in the well and more importantly give access to facies interpretation and facies succession once interpreted. Stacking pattern analysis constrains prediction of deepwater architecture which can be checked against 3D seismic data at a later stage

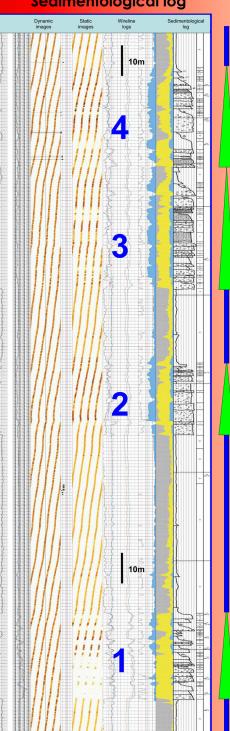




Sedimentological interpretation

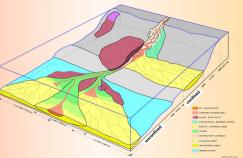


Sedimentological log



3- Stratigraphic hierarchy and stacking pattern

Deepwater depositional model

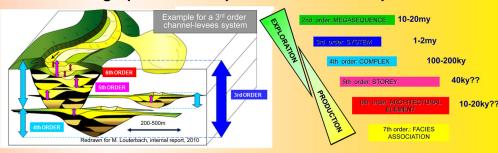


•The shape of deepwater basin has direct impact on the architecture of deepwater systems. Unconfined basins are opposed to confined systems at the broad scale and this difference is generally related to the nature of the substrate, i.e. mobile vs rigid. Basin with mobile substrates include shale and salt tectonics, by contrast with basin sitting on a rigid substrate as faulted blocks in both extensional and transfersional regimes and fold belts in compressional

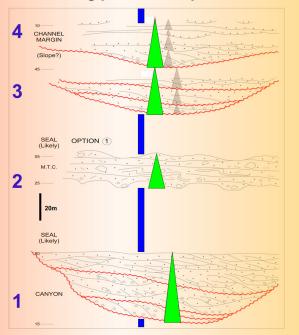
•Flow confinement favors extensive geobodies with large geometrical ratios (width:thickness) showing a fair to high degree of lateral migration with erosional processes kept to a minimum. Conversely, confined basins have geobodies which tend to show more aggradational patterns generally more

•This confinement concept defined at basin scale can be scaled down to flow processes. Genetic deepwater flow models and related facies classifications which separate high density flows from low density flows can translate into strongly erosional lows and depositional flows respectively. Therefore careful facies analysis once grouped into recurring facies stacking pattern provide an understanding of the evolution of the flow through time and a key to prediction of the architecture of the various architectural elements and their relationship inside larger scale cycles.

Stratigraphic hierarchy of channel-levees systems

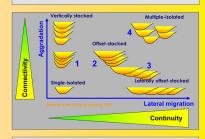


Stacking pattern and prediction



 Deepwater depositional systems various levels of hierarchy equivalent to coastal depositional systems. Deepwater sediment stratigraphy is first ordered by allocyclicity and secondly by autocyclic controls as a result of shifting of depocentres through time in response to the efficiency of turbidite depositional systems.

•Therefore, access to turbidite aeometry in subsurface relies on vertical and horizontal resolution of the techniques and tools made available to the projects. Production projects dealing with reservoir issues need higher resolution techniques that exploration projects

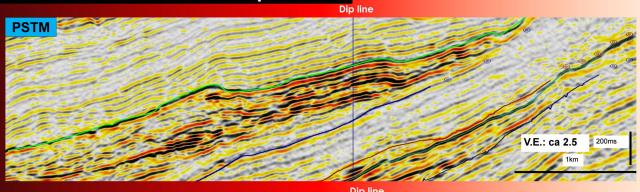


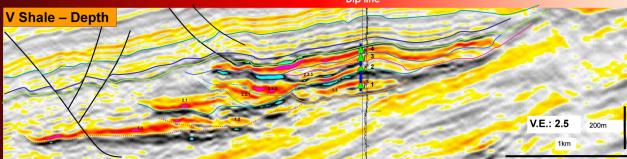
• Prediction of 2D architecture from facies succession interpreted from image log is always a challenge. Nevertheless the following observations can be made:

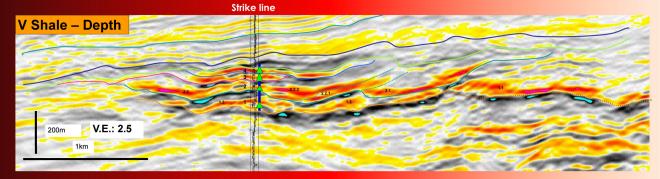
- •Fine-upward and thinning-upward cycles point to stacked channels storeys as clearly evidenced on seismic data. These sediments were deposited at base of slope up-dip of the basin
- •There is a gradual change between Cycle 1 and Cycle 4 suggested by facies association successions.
- •Cycle 1 shows likely much pass-by •Cycle 3 and 4 shows more aggradation and lateral



4- Seismic calibration and interpretation





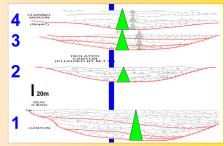


Data

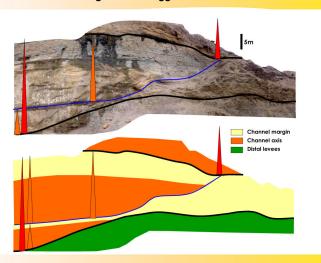
- •3D PSTM and PSDM seismic cubes
- •3D V-shale cube was processed by the operator Anadarko
- Hot colors represent sand-prone sections.
- Dark colors represent shale-prone sections.
- · Gamma-Ray log is displayed for calibration.
- •The four 5th order cycles interpreted from image logs are depth
- *Each 5^{th} order cycle has been split into a set of channels (6 th Architectural elements).

- •V Shale cube shows clearly the channel complex (gross thickness >200m) made of four 5th order storeys (thickness 25 to 40m each) whilst the reflectivity cube (PSTM) did not show the architecture so accurately and particularly the storeys.
- Each channel storey is capped by a muddy section recording the abandonment phase associated to high stand of the 5th order cycles
- Storey 1 has a very erosive base
- Each storey can be split as follows:
- •The oldest channel storey set 1 subdivided into storeys 1.1, 1.2 and 1.3
- The second channel storey set 2 is split into storeys 2.1 and 2.2
- •Channel storey 2.2 is split into 6th order channel architectural elements 2.2.1, 2.2.2 and 2.2.3.
- Dimension of storeys gets smaller with time (from 1 to 4).
- •Each storey shows laterally migrating architectural elements (A.E.) with a rather low vertical aggradation component.
- ·Likely storey 1 was drilled in an axial setting while storeys 2 to 4 penetrated off-axis sub A.E.
- Channel A-E, dimensions fall in the 200-500m width range.
- Duration of the complex might be 5MY

Predicted architecture from image log interpretation



Channel outcrop showing an example of migration and aggradation in the field



Conclusion

- Runs of SWC compensates -partly- the lack of conventional core in exploratory wells.
- Both depositional facies and reservoir characteristics can be appreciated rather than using cuttings
- SWC provide calibration to image log interpretation and stacking pattern analysis.
- Seismic calibration take advantage of the upscaling approach from SWC to image log to seismic:
- Architectural element interpretation (6th order)
 Connectivity between 5th order storeys within 4th order channel complexes
- Well correlation at the basin scale
- At field scale, these surfaces and cycles can be interpreted carefully
- inela scule, mass solitices and cycles can be minipreted calefully

 On various seismic cubes simultaneously

 With support of seismic attributes computed between stratigraphic surfaces

 To build a first reservoir model.

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