

PS Data 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 up-scaling 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.

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.

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 up-scaling with iterations between steps. An example of data integration from an exploration well is provided here.

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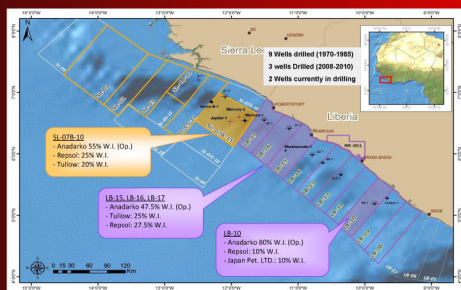
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Location map



Workflow

RESERVOIR DESCRIPTION:

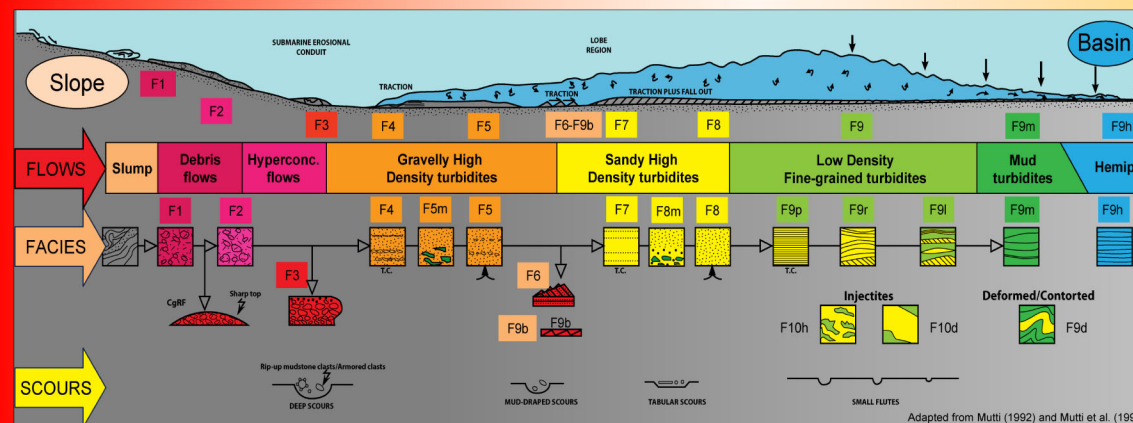
- 1- Description and facies typing of four runs of Side Wall Cores (SWC)
 - Based upon turbidite facies classification adapted from Mutti et al. (1999)
 - CT scan images of the SWC
 - Information from the mud log
 - Maximum Grain Size
 - Sorting
- 2- Depth match of the SWC against OBMI and wireline logs
- 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 potential
 - Provenance,
 - Diagenesis,
 - Burial effect,
 - HC charging...

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

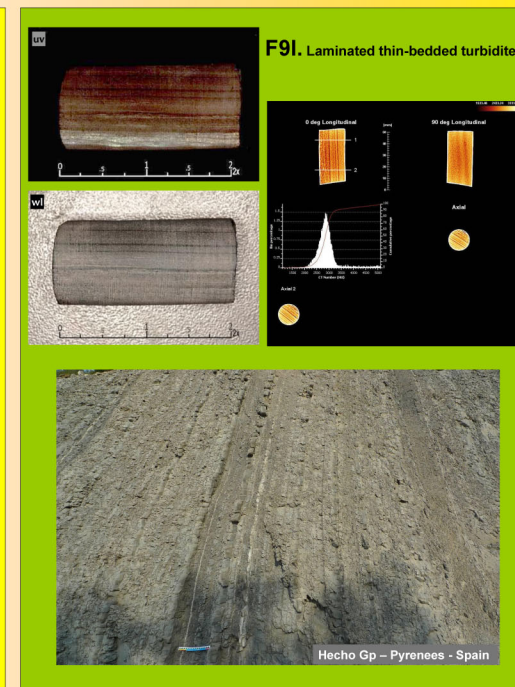
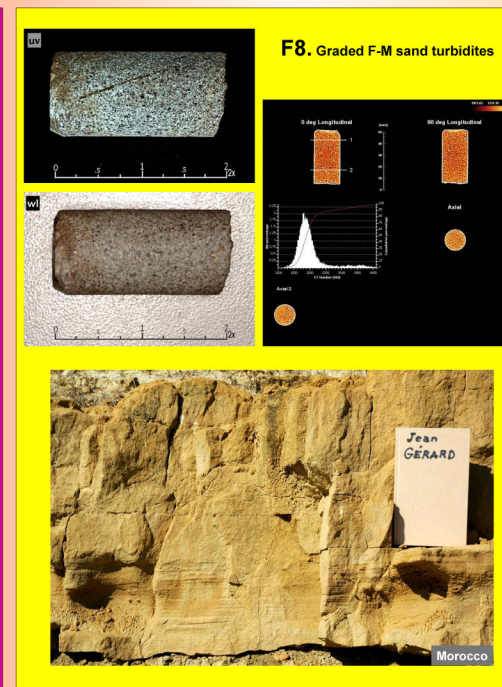
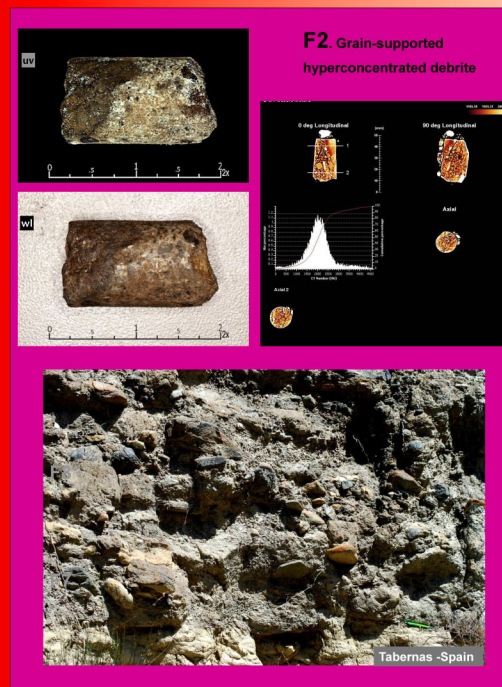
Facies classification of deepwater systems



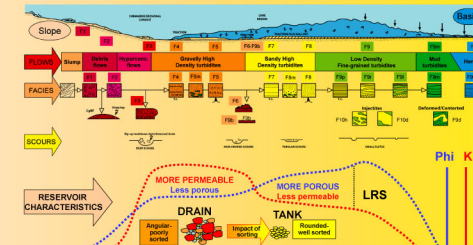
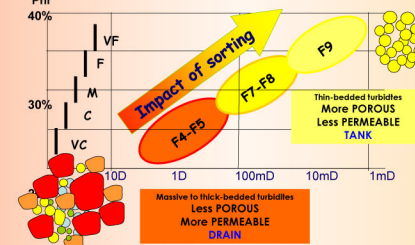
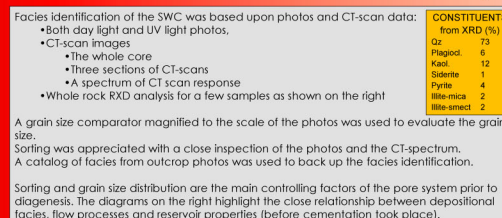
- F9d-F10d Deformed
- F10h Injectites
- F9h Hemipelagites
- F9m Mud turbidites
- F9i Thin-bedded turbidites
- F9r Rippled VF sand turbidites
- F9p Laminated VF sand turbidites
- F8 Graded F-M sand turbidites
- F5m-F8m Sand with mud clasts
- F7 Laminated F-M sand
- F6 Cross-bedded C-M sand
- F5 Graded C-V sand turbidites
- F4 Laminated C-V sand
- F3 Conglomerate
- F2 Grain-supported flow
- F1 Matrix-supported debris

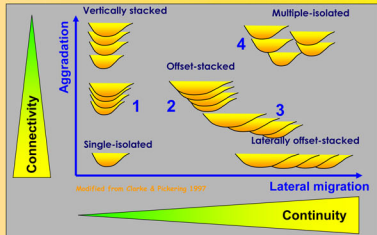
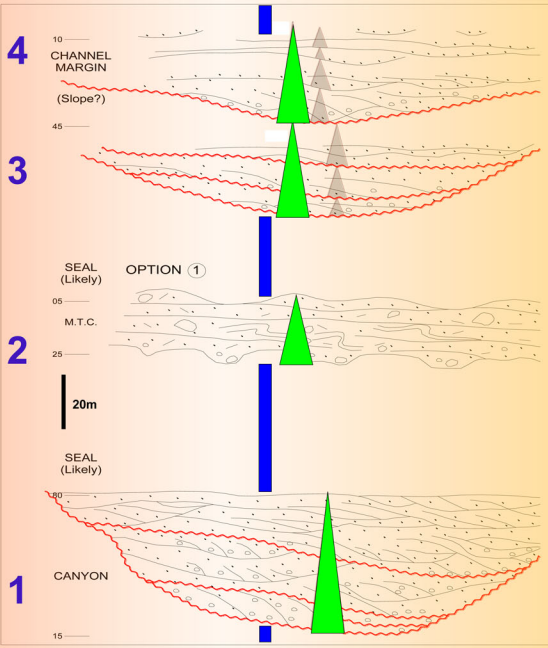
Low density fine-grained sediments were added to the original facies classification - mostly derived from field work - in order to describe cores and interpret image logs in thin-bedded sections which are commonly reservoir for light oil and gas-bearing sections in opposition mud turbidite and hemipelagite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

Examples of facies identification of SWC



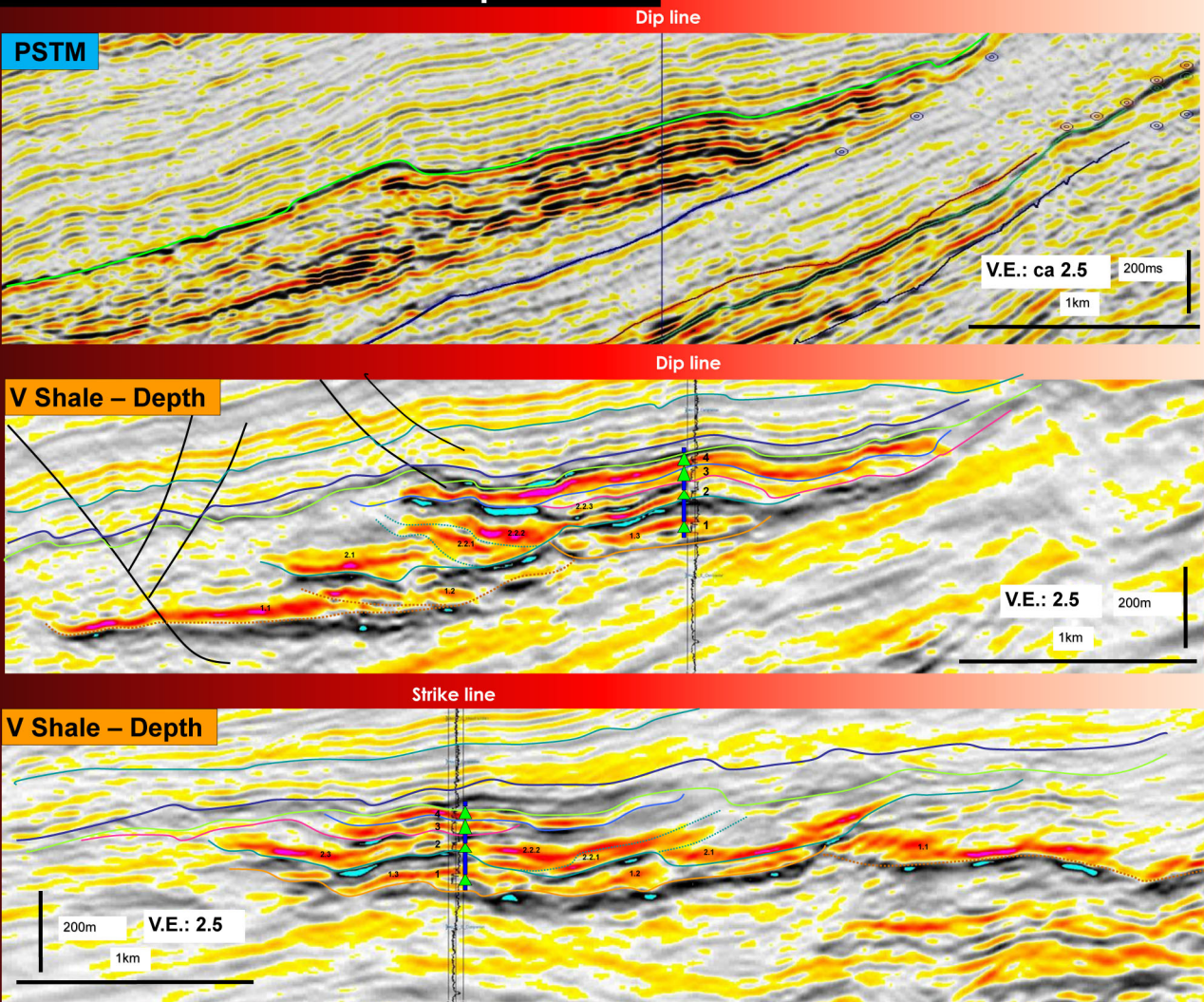
Depositional facies and reservoir characteristics



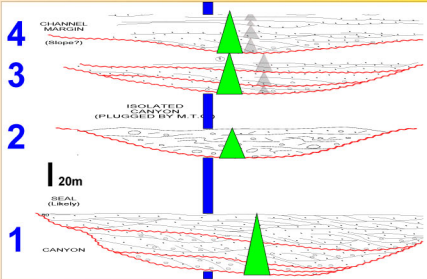


- Prediction of 2D architecture from facies succession interpreted from image log is always a challenge. Nevertheless the following observations can be made:
 - Fine-upward and thinning-upward cycles point to stacked channels storeys as clearly evidenced on seismic data. These sediments were deposited at base of slope up-dip of the basin plain.
 - 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 migration

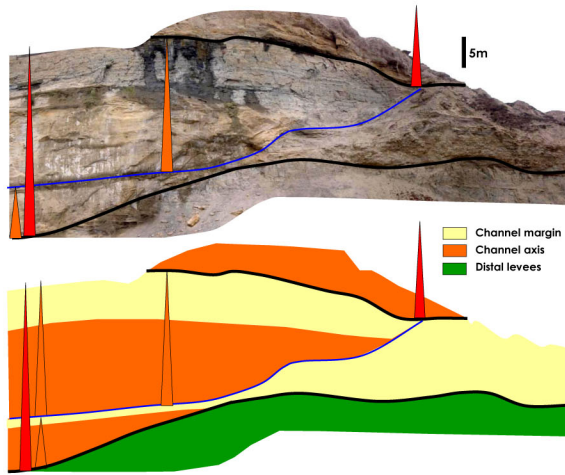
4- Seismic calibration and interpretation



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 solely.
- 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
 - On various seismic cubes simultaneously
 - With support of seismic attributes computed between stratigraphic surfaces
 - To build a first reservoir model.

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Data

- 3D PSTM and PSDM seismic cubes
- 3D V-shale cube was processed by the operator Anadarko Petroleum Company.
 - 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 match to seismic cubes.
- Each 5th order cycle has been split into a set of channels (6th 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.