Abstract

Predictive model for coal-bearing fluvio-deltaic successions in the subsurface are required to drive the effective and cost efficient hydrocarbon development of both unconventional coal-bed methane and conventional reservoir projects. The Eastern Kentucky and West Virginia road network provide world-class exposures of Upper Carboniferous coal bearing successions where the interplay between sand and shale intervals and intervening coals can be studied in detail. In this paper we present a summary of ongoing research recently carried out on the Pennsylvanian Hyden and Pikeville Formations where architecture and lateral facies variability can be observed and followed for several kilometers thanks to exceptional outcrop quality and dense borehole data from coal mining operations. Coals, usually genetically associated with transgressive system tract, lies often on top of channel-fill sandstone and under shale dominated intervals the latter recording the transition from a flooded coastal plain to shallow to deep marine environment. However coals are found as well draping irregular topographic surfaces where wide and relatively deep (10–20 m) incisions can be recognized. In this situation coals are typically overlain by channel fill sandstone forming the stratigraphical unit above. In this case, the coals are interpreted as forming during a low stand phase and thus possibly the true indicators of development of incised valleys. Five to ten meters-high inclined beds made of mixed heterolithic successions of sandstones and shales are associated with both fluvial-dominated mouth bars and point-bars develop in large meandering river systems often developed within estuarine environment. This study highlights the typical 3D features of these deposits allowing the definition of sedimentological and stratigraphical criteria to distinguish these two systems in the subsurface. The Carboniferous succession of Eastern Kentucky is compared with the coeval succession in the North Sea (The...
Netherlands) to highlight the importance of outcrop based analogues studies to help understanding the overall distribution of subsurface geology by providing practical criteria for a) carrying out a well-to-well correlation and b) reconstruct the overall 3D reservoir architecture.

Selected References


Architecture and Connectivity of Coal-Bearing Reservoirs: New Insights From Outcrop Analogues

A. Moscariello ¹, D. Ventra ¹, A. Le Cotonnec ¹, E. Braccini ²

¹ Earth and environmental sciences, University of Geneva, CH-1205 Geneva, Switzerland
² Total SA, Pau, France
Geological age distribution of principal World’s black coal and lignite deposits (modified form Walker, 2000 and Thomas, 2002)
Geological age distribution of principal World’s black coal and lignite deposits (modified form Walker, 2000 and Thomas, 2002)

COAL WILL REMAIN AN IMPORTANT GEO-ENERGY RESOURCE IN THE NEAR FUTURE
Producing from Carboniferous the Dutch/UK SNS: Where are we now?

- Effective production of deep Carboniferous gas reservoirs is largely driven by understanding reservoir properties distribution and sand connectivity in a relatively low net:gross environment.

- Develop a predictive model assisting the location and characterization of reservoir quality and connected net-volumes is challenging:
  - complex facies heterogeneity
  - internal reservoir architecture
  - diagenetic history.

Carboniferous Reservoirs
DISTRIBUTION OF CARBONIFEROUS FIELDS IN THE SNS

Legend

Age of reservoir unit
- Westphalian C/D - Secondary reservoir
- Westphalian C/D
- Westphalian B/C
- Westphalian A/B
- Westphalian
- Upper Namurian / Lower Westphalian A
- Silesian
- Namurian
- Visean
- Dinantian

Subcrop at base Permian
- Stephanian
- Westphalian D
- Westphalian C
- Westphalian B
- Westphalian A
- Namurian
- Namurian/Westphalian
- Dinantian
- Devonian
- Pre-Devonian
- Igneous

Stratigraphy at TD
- Upper Carboniferous
- Lower Carboniferous
Upper Carboniferous (Westphalian B / Mid Pennsylvanian)
NW Europe Coal-bearing reservoirs
NW Europe Coal-bearing reservoirs

NW-SE CORRELATION

Coal reach unit Maurits Fm. (WB)
NW Europe Coal-bearing reservoirs

High N/G Klaverbank Fm.
Laterally accreting Klaverbank sst system

NW Europe Coal-bearing reservoirs
OUTCROP ANALOGUES:
1 VARIABLE NET/GROSS
2 TYPICAL ALTERNATION OF FLUVIAL SANDS AND DELTAIC SHALES/COALS

NW Europe Coal-bearing reservoirs
Western Kentucky

Westphalian B / Middle Pennsylvanian
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**KGS GEOLOGICAL DATA BASE**
1) Can we describe and quantify the stratigraphic and sedimentologic changes along the paleoflow direction (east to west)?
2) Paleo-drainage dominated by westwards paleoflow? Any influence from local highs?
3) What’s the impact on reservoir continuity and modelling?
1) Can we describe and quantify the stratigraphic and sedimentologic changes along the paleoflow direction (east to west)?
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Study Approach

- Regional and Reservoir-scale approach
  - 30 x 30 km area
  - 0.5 x 0.5 km area (sector models)
- Closely spaced detailed stratigraphic logs (1:20 scale) of outcrop sections and cores.
- Large photo-panel correlations
- Detailed petrographic study using conventional petrography and QEMSCAN (UNIGE)
  - Provenance, texture, diagenesis (ca. 300 samples)
- Reservoir Property analysis
- Data integration in Geo-cellular models
TWO-SCALE APPROACH

1) Basin/Regional scale
2) Reservoir /Field scale
John's Creek outcrop

- Fluvial deposits
- Floodplain
- Upper delta deposits
- Delta-front deposits
heterolithics prodelta sst to marine siltstones
Pikeville Fm: Qz, K-Feld, Plag

Local High (Can. Shield?)

Elkorn coals

Local Structural Highs?
Sector model approach

Pikeville Formation - Harold Sst
Unraveling internal reservoir architecture
lateral expansion

coal

cut & fill

bank collapse
Complex erosively based networks NOT simple channel-forms.
Bodies 10’s km wide

Networks in which the different “branches” develop more simple channel form geometries.
Bodies km’s wide

Aggradational networks.
True distributary channel-levee systems.
Bodies 100’s m to 2 km wide

Williams and Davis in Moscariello et al., 2013
Fluvial and tidally influenced channel fills have similar Phi-K distribution with higher variability for the latter. Mouth-bar deposits have the highest heterogeneity, while channel-base facies contain high-permeability streaks.

Analyses performed by G. Hunger, A. Le Cotonnec, E. Rusillon
Conclusions

• Composition, architecture and properties of coal-bearing strata bear a complexity which can be unraveled by detailed outcrop studies and integration with subsurface data.

• Two-scale approach is key to predict both large- and small-scale architectural complexity.
  – Integration between sedimentology and petrography to develop conceptual geological model.
  – Detailed architecture of genetic elements in different sequential system tract (incision and aggradational)

• Eastern Kentucky outcrop data are used to build predictive subsurface geological models (UK, Russia).
Conclusions...

Thank You