Abstract

Petroleum in the Weald Basin has been produced since the late 19th century from conventional sandstone and carbonate reservoirs sourced from Jurassic marine source rocks. These source rocks include the Kimmeridge Clay, the Lower Oxford Clay, and the Liassic Shale intervals. To date 13 small oil fields have been discovered and all of them are located on the basin margins, while only gas shows and seeps have been recorded in the basin centre. The exploration success and production have undergone a major downturn in the last 30 years as existing production has declined and exploration has ceased. Our view of the Weald Basin hydrocarbon potential changed radically in 2014 following the Horse Hill 1 oil discovery. This well successfully tested two previously unknown naturally fractured Kimmeridge Limestone horizons. Dry-oil flowing at rate of around 400 and 900 bopd were recorded from the Lower and the Upper Kimmeridge Limestone horizons respectively.

In this study a regional 3D basin and petroleum systems model has been built using 70 available boreholes data and composite 2D seismic lines. The research is focused on gaining a better understanding of how the Weald Basin petroleum system has developed through time, taking into account its complex tectonic evolution and erosion/uplift history. Furthermore, some of the outcomes of the model are used to address some key questions, such as: why are the conventional oil fields limited to the basin margins? Why do we find only gas shows in the basin centre? Is there a basin centre petroleum system preserved in tight rocks?

Selected References

Unconventional hydrocarbon potential of the Weald Basin, Southern England, UK

Francesco Palci¹, Alastair Fraser¹, Martin Carles¹, Martin Neumaier¹
Stephen Sanderson², Rob Wallace², Jamie Burford²

¹Imperial College London
²UKOG
• Aims and objectives

• Geological setting and exploration history

• Interpretation and petroleum systems modelling

• Conclusions and learning
Aims and objectives

• Assess the unconventional potential of the Weald Basin

  • Reconstruct the burial history of the basin

  • Assess the thermal maturity of the Jurassic source rock intervals

  • Understand the distribution of the present day conventional oil and gas fields and shows
Geological setting

BGS surface geology

Present day oil and gas fields and HC shows

Andrews, 2014
Section A: Geological cross section of the Weald by John Farey (1807)
Section B: Geological cross section of the Weald by William Smith (1819)
Early Jurassic (200 Ma)

NA: North America
SA: South America
A: Africa

Hawkes et al, 1998

Early Jurassic (200 Ma)
Tectonic evolution

Hawkes et al, 1998

Late Jurassic (145 Ma)

NA: North America
SA: South America
A: Africa

(Blakey R. 2011)
Jurassic Shales (Wessex Basin outcrops)

- Oxford Clay (Middle Jurassic)
- Weymouth (Oxford Clay)
- Lyme Regis (Lias)
- Kimmeridge Bay (Kimmeridge Clay)
- Lias (Lower Jurassic)
- Kimmeridge Clay (Upper Jurassic)

Kimmeridge Clay – fractures and joints
Exploration history

- **Phase 1**: exploration focused on big anticlines, carbonate reservoirs & big hopes
  - Portsdown, Kimmeridge Bay (1934)

- **Phase 2**: Seismic and the hidden fault blocks
  - Wytch Farm (1977) - Wessex Basin
  - Humbley Grove, Hornedean, Stockbridge, Storrington, Singleton - Weald Basin

- **Phase 3**: shale oil in tight fractured carbonate (return to the big anticline?)
  - Horse Hill-1 (2014): oil flowed from two micritic limestone intervals within the Kimmeridge Clay
Seismic interpretation

- TWT ms
- Lias
- Kimmeridge Clay
- Oxford Clay
- Chalk
- Upper Greensand
- Wealden
- Parback Anhydrite
- Kimmeridge Clay
- Top Micrite
- Base Micrite
- Corallian
- Oxford Clay
- Great Oolite
- Lower Lias
- Lower Penarth
Seismic interpretation
Seismic interpretation

TWT ms

Km

Chalk
Upper Greensand
Wealden
Purbeck Anhydrite
Kimmeridge Clay
Top Micrite
Base Micrite
Corallian
Oxford Clay
Great Oolite
Lower Lias
Penarth

Kimmeridge Clay
Oxford Clay
Lias

C

C

N

S

N
Basin and Petroleum systems modelling

- **Lias (Lower Jurassic)**
- **Oxford Clay (Middle Jurassic)**
- **Kimmeridge Clay (Upper Jurassic)**

Diagram showing layers of geological formations including Chalk, Greensand, and Wealden Group. The map and sections are color-coded to represent different depths and geological units.
Facies distribution

KL1
KL2
KL3
KL4

Kimmeridge Clay (TOC ≈ 6%)
Oxford Clay (TOC ≈ 4%)
Lias (TOC < 2%)

3D model

Wealden
Purbeck Anhydrite
Portland Sst
Kimmeridge Clay
KL4
KL3
KL2
KL1
Litoral Sst
Corallian
Oxford Clay
Great Oolite
Inferior Oolite
Upper Lias
Middle Lias
Lower Lias
Penarth

\{\text{Lias}\}
Burial restoration (metres)

Cumulative erosion map

55 Ma (maximum burial)

VR Calibration

Storrington X1

Holtye 1

Godley Bridge 1

Mixed_Corallian
Oxford Clay
Great Oolite
Inferior Colite
Upper Lias
Middle Lias Limestone
Middle Lias
Lower Lias
Ponarsth
Carboniferous
Devonian

Tertiary
Chalk
Greensand
Wealden
Purbeck Anhydrite
Portland Sandstone
Kimmeridge Clay
Mixed_KL4_Facies
Mixed_KL3_Facies
Mixed_KL2_Facies
Mixed_KL1_Facies

Depth m
Thermal maturity

Transformation Ratio 3D model present day

Transformation Ratio

Oil Generation
HC migration and accumulations

45 Ma
Accumulations within the anticline
HC migration and accumulations

0 Ma
Present day erosion
HC migration and accumulations

0 Ma
Great Oolite
Present day oil and gas fields
Conclusions and learning

• Restoration against the VR suggests circa 1500 m erosion towards the eastern part of the Weald Basin

• Only the Lias and the Oxford Clay have generated gas, the Kimmeridge Clay entered the oil window during the maximum burial in certain parts of the basin

• Main accumulations in the Weald anticline have been breached during the uplift, however oil generated within the Kimmeridge Clay may be still preserved within tight fractured limestone layers

• The model can explain the current distribution of the oil and gas fields and shows in the basin