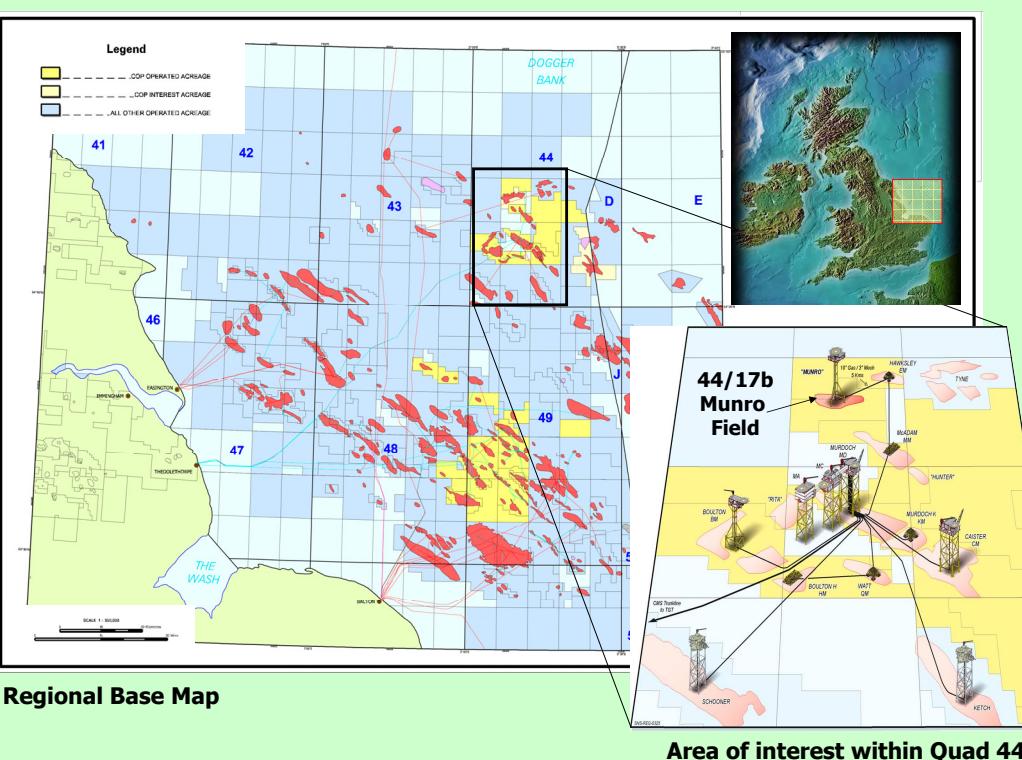


Using Chemostratigraphy to identify reservoirs with optimal deliverability to increase gas production from the Carboniferous (Pennsylvanian) of the UK Southern North Sea

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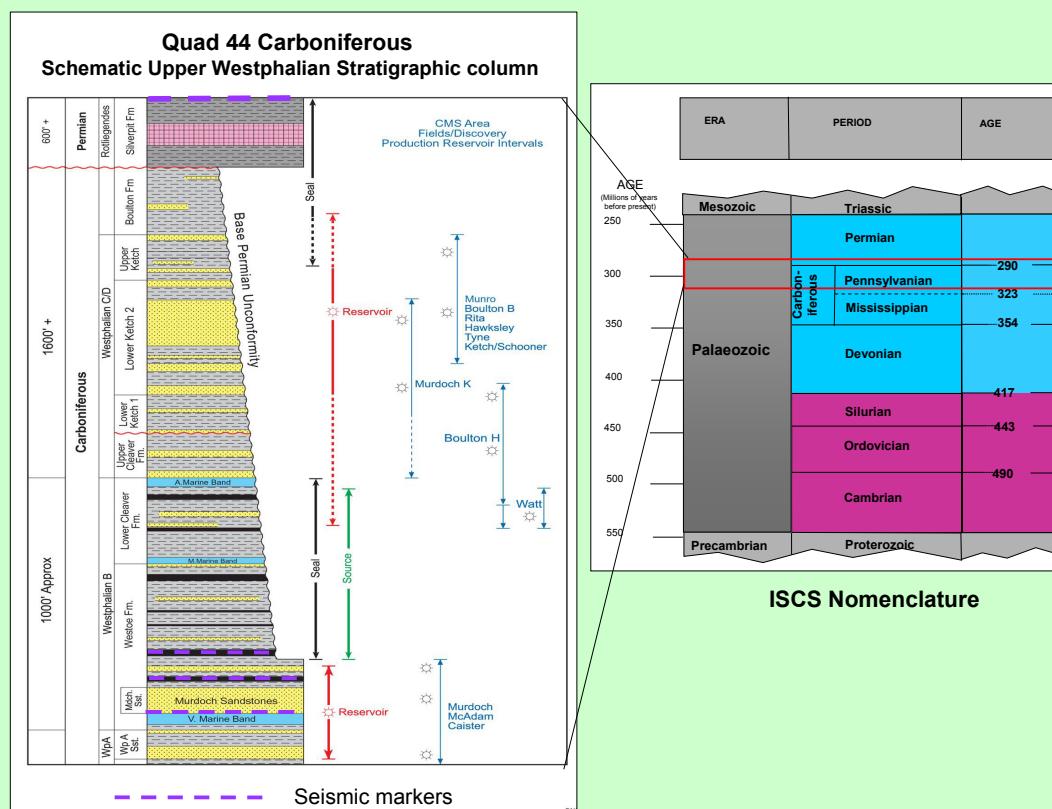
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1. Introduction to the Carboniferous of UK Quad 44, Southern North Sea



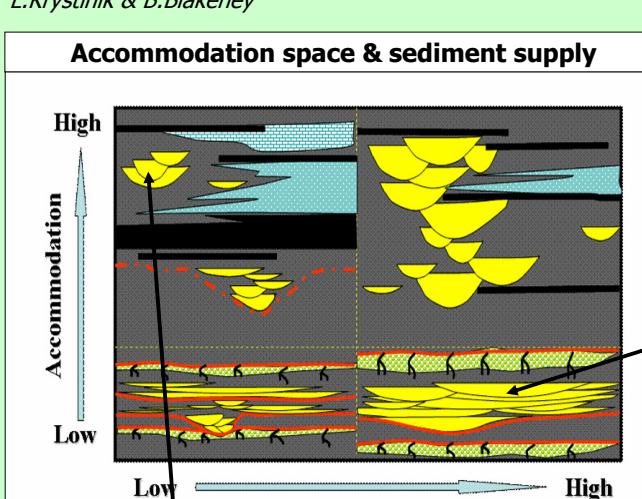
Regional Base Map
Area of interest within Quad 44

The Upper Westphalian section of the Carboniferous corresponds approximately to the Pennsylvanian Period, 300 Million Years ago. This Upper Westphalian, Carboniferous play in Quad 44 consists of several reservoirs at different levels, sourced from Westphalian B coals and Namurian marine shales, and sealed by several different units. The diagram below is a schematic of the Upper Westphalian stratigraphy, showing the different reservoirs, source and seals.



The diagram below shows the different types of systems that occur throughout the Westphalian, and explains why the Lower Kett 2 is a better reservoir in terms of connectivity than a Westphalian B system. This has led exploration efforts to concentrate on prospects with Lower Kett 2 reservoir (like the **Munro** exploration success).

Diagram adapted from Reservoir Sedimentology of Continental Clastic Systems field course, L.Krystnik & B.Blaeney

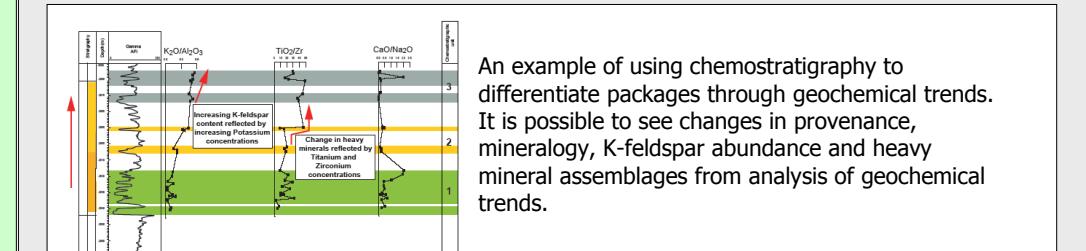


Westphalian B: Deposited during a period of higher accommodation space due to subsidence, and low sediment supply. Narrower, high sinuosity, meandering streams flow from W-E. Channels have low width:thickness ratios, and due to more accommodation space are less likely to be connected. In addition the presence of coals and marine bands means vertical barriers are more likely.

AAPG Houston 9-12th April 2006: Non-bio chrono- and Chemostratigraphy

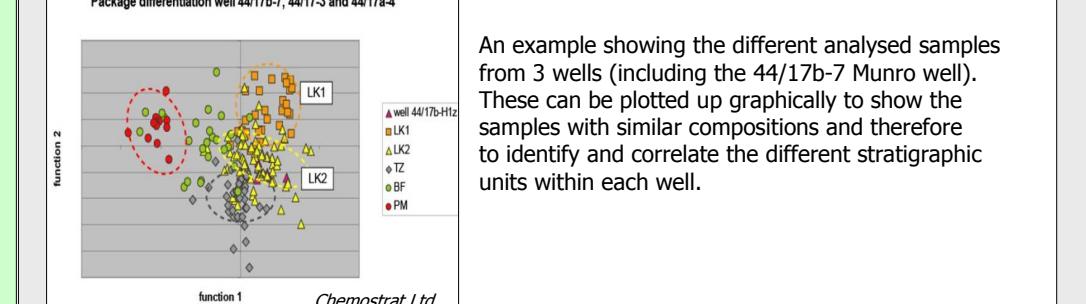
2. Why use Chemostratigraphy?

Chemostratigraphy is the identification and correlation of sedimentary units using inorganic geochemical (elemental) data. The inorganic geochemistry of sediments is highly variable and sensitive to subtle changes in mineralogy which may reflect changes in: sediment provenance; facies; weathering or diagenesis; palaeoenvironment and climate. Chemostratigraphy has significant advantages over other methods of correlation such as palynology, as it can be applied to any lithology in most geological settings, core and cuttings can be used and only a very small amount of sample is required, 0.25g per sample.



An example of using chemostratigraphy to differentiate packages through geochemical trends. It is possible to see changes in provenance, mineralogy, K-feldspar abundance and heavy mineral assemblages from analysis of geochemical trends.

Package differentiation well 44/17b-7, 44/17-3 and 44/17-4



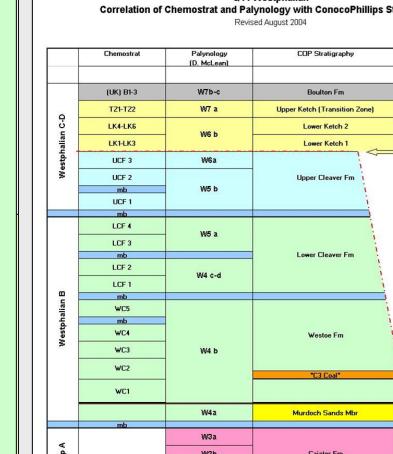
An example showing the different analysed samples from 3 wells (including the 44/17b-7 Munro well). These can be plotted up graphically to show the samples with similar compositions and therefore to identify and correlate the different stratigraphic units within each well.

Now we understand which reservoirs we want to target, we need to know how to differentiate them from other sand packages. This is where Chemostratigraphy is important. Lithological correlation is difficult due to the similar nature of some of the sand units. It is possible to differentiate the Westphalian C/D from the B, due to the presence of coals in the older Westphalian B, that show a change in climate and depositional environments.

Palynology is helpful in the older Westphalian B interval, in identifying individual coals and marine bands for correlation purposes. However, by Westphalian C/D times, the climate was arid and few palynological indicators remain. This stratigraphic section has been called the 'Barren Red Measures'.

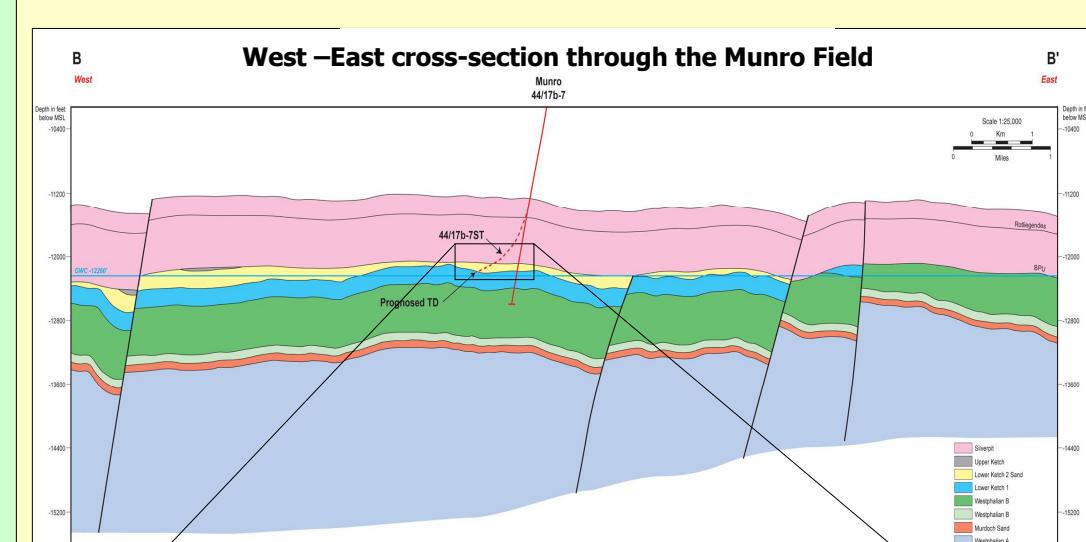
Palynology can provide a broad stratigraphic framework. But since chemostratigraphy can be applied in any depositional environment, it is here in the 'Barren' Westphalian C/D that it proves invaluable. Through Chemostratigraphy we have been able to sub-divide the Westphalian C/D into many more units and therefore identify exactly which sand packages are our highest productivity reservoirs.

Q44 Westphalian Correlation of Chemostrat and Palynology with ConocoPhillips Stratigraphy Revised August 2006

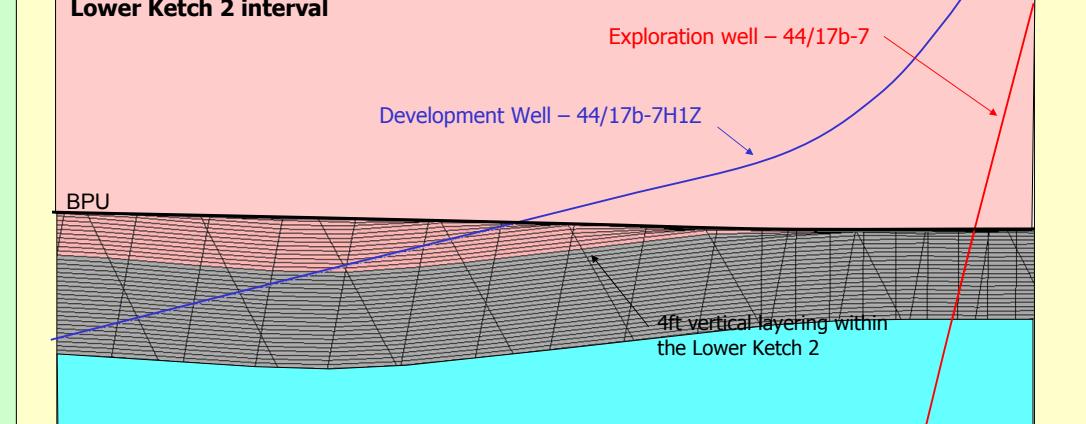


Revised ConocoPhillips Stratigraphic nomenclature derived over the past year using chemostratigraphic and palynological indicators.

4. Munro - the Development phase



Section as above but zoomed in to show the detailed modelling of the Lower Kett 2 interval



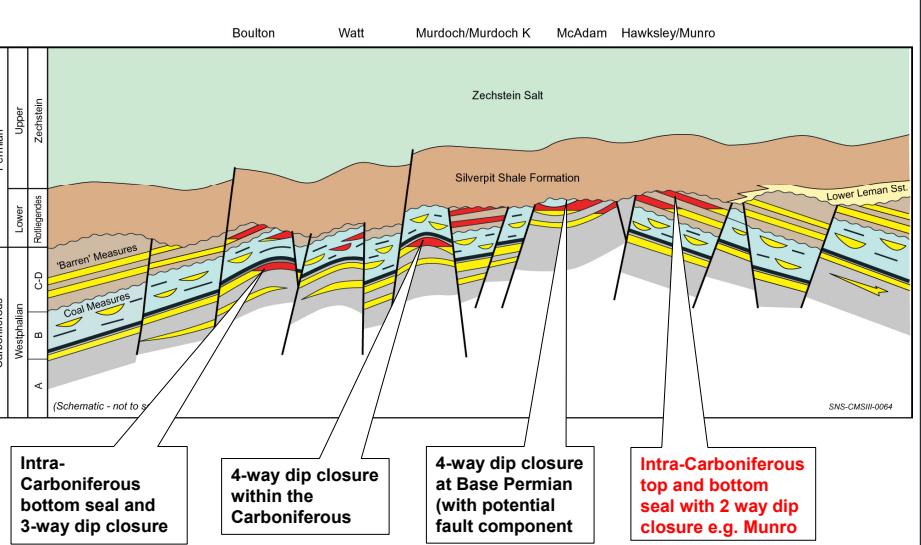
Lower Kett 2:
 Deposited during a period of relatively low accommodation space, but fairly high sediment supply coming from the uplifted North. Wide, low sinuosity, braided rivers flow from N-S. Channels in this system have high width:thickness ratios, and tend to spread out and amalgamate, creating a well connected system of stacked channels.

Lower Kett 2:
 Chemostrat units encountered in exploration well
 Chemostrat units thought to be present up-dip & targeted by the development well

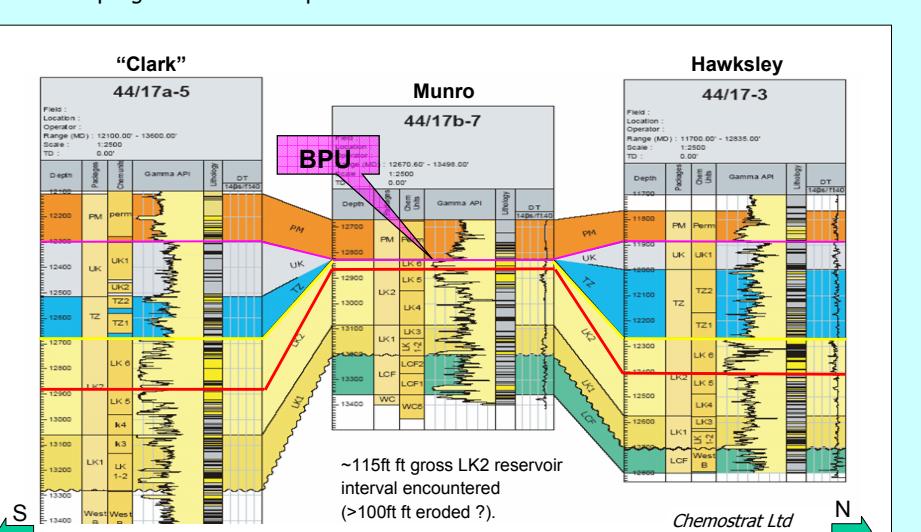
3. Munro - the Exploration phase

Munro was the first exploration well to be drilled following our improved understanding on reservoir connectivity and deliverability. It targeted the Lower Kett 2 sands, now thought to be the highest deliverability reservoir in this area. It was also the first well to successfully test a new complex trap type, relating to the Base Permian (Saalian) Unconformity (BPU) and relying on intra-Carboniferous seals.

Upper Westphalian Trap styles



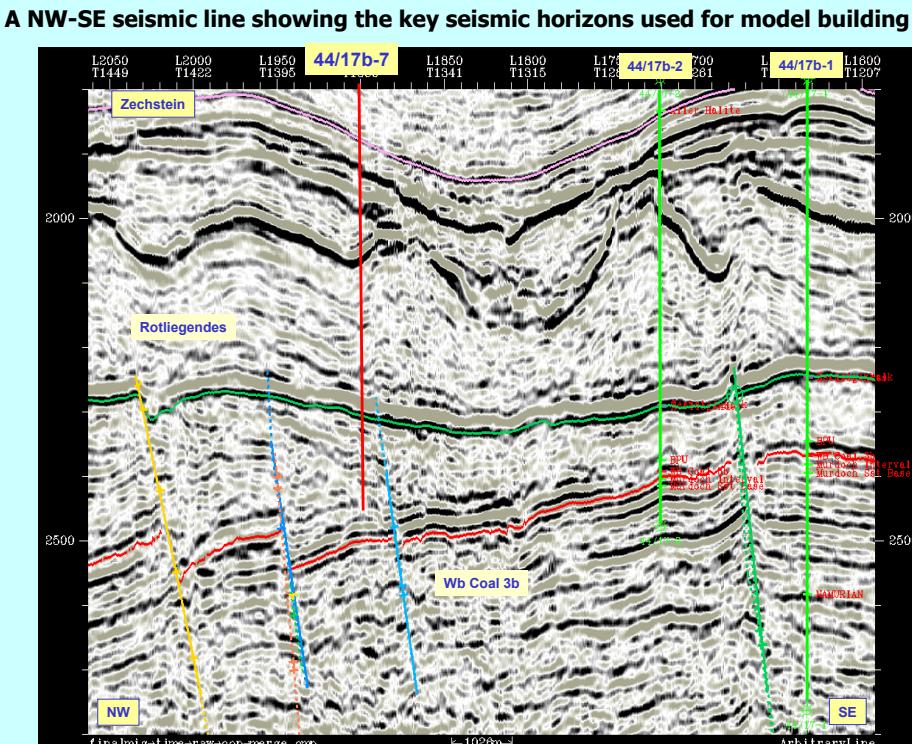
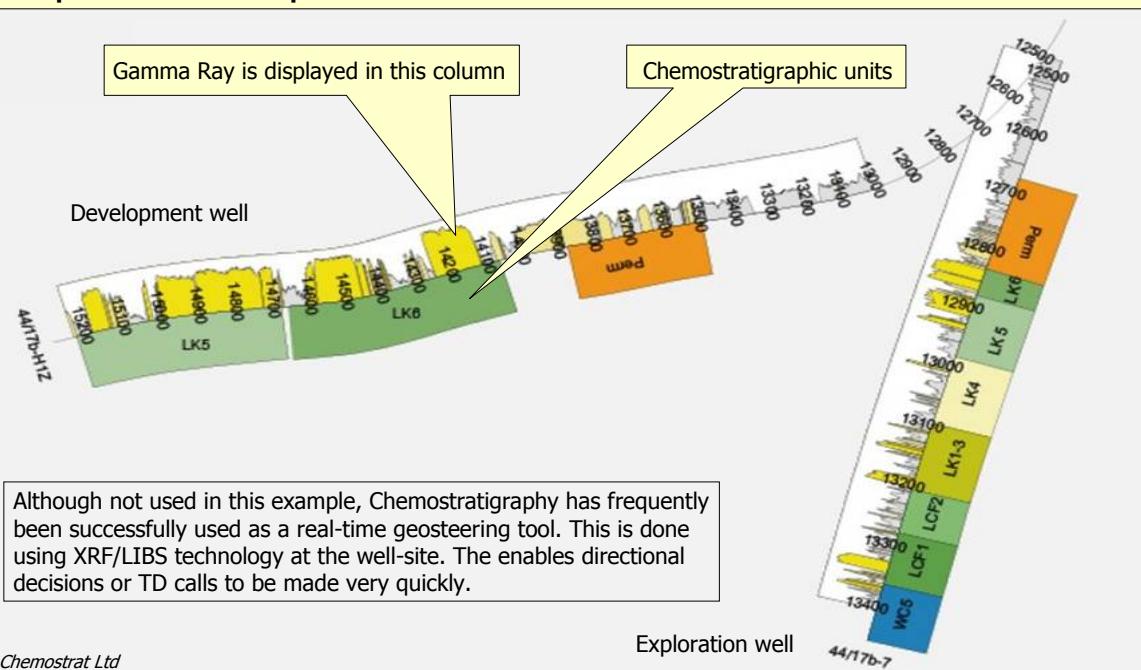
The well was drilled and encountered an eroded section of Lower Kett 2 reservoir, which suggested the top section of the reservoir at this location had been eroded by the BPU. This was confirmed by post-well chemostratigraphy showing the upper most unit of the Lower Kett 2, the LK6, was missing. There was however, still sufficient reservoir quality sand and gas to decide to progress with development of Munro.



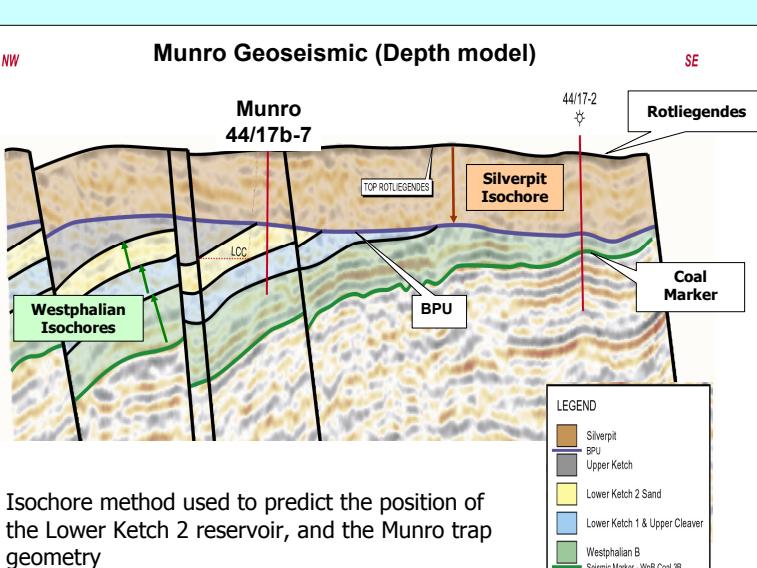
The development strategy depended on maximising reservoir penetration and proving-up additional sand units in the Lower Kett 2. Understanding the chemostratigraphy as well as the dip & azimuth of the beds was critical for designing an optimal development well and placing it where it would penetrate as much section of the Lower Kett 2 as possible while staying above the GWC.

A detailed geological model was built for the Lower Kett 2 interval encompassing all data from the exploration well - 4ft layering was used to ensure the heterogeneity was captured. The Lower Kett 2 section was divided into two units - those Chemostrat units seen in the exploration well and those expected to be present up-dip. This enabled the design of the best possible development well.

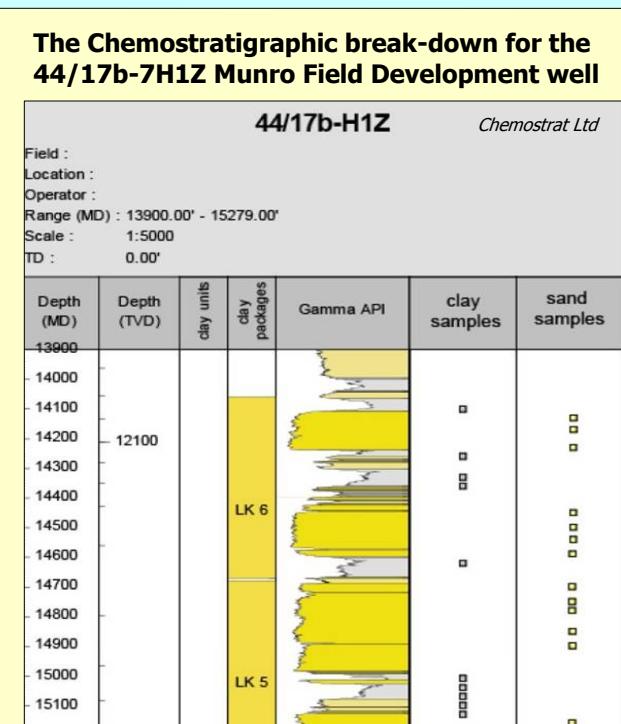
Schematic diagram showing the approximate well trajectories and chemostratigraphic units in both the exploration and development wells for the Munro Field.



From seismic data it is not possible to identify the reservoir, so the trap model is built taking marker horizons which are seismically imaged, and using regional well based isopachs to predict the position of the reservoir within the prospect. There is a high degree of uncertainty when drilling an exploration well as to whether it will encounter reservoir and if so how much.



Isochore method used to predict the position of the Lower Kett 2 reservoir, and the Munro trap geometry



To Conclude:

The 44/17b-7H1Z development well was brought on stream ahead of schedule in August 2005. A small 'Harvester' type platform was used for this Field and it was tied back into ConocoPhillips' CMS system with a pipeline to the nearby Hawksley Field.

Determining the likelihood of additional sands and designing a development well to target these could not have been done without the use of Chemostratigraphy. Better understanding of the varied depositional environments in the Westphalian C/D has enabled us to concentrate our exploration and development efforts on those reservoirs likely to have higher deliverability. Chemostratigraphy is key to differentiating these reservoirs from others within the Westphalian C/D.

ConocoPhillips would like to acknowledge and thank their partners on the Munro Field, Gaz de France Britain Ltd and Tullow Oil UK Ltd.