Revised reservoir model for the Paleocene mounds of the Utsira High, North Sea, Norway

John Wild (1) & Nowell Briedis (2)

(1) Mobil North Sea LLC
(2) Esso Exploration & Production Norway A/S
(ExxonMobil Subsidiary Companies)
DEVEX 12-13 May 2009
Summary

• Up until 2005, ExxonMobil’s geological model for the mounded Paleogene oil fields of the northern Utsira High consisted of sandy debrite and turbidite fan reservoirs of three distinct ages, linked by post-depositional sand injections.

• However, it was well recognised that some of the data did not fit this model.

• Recently improved seismic imaging does not show the expected geometries for the stratigraphic relationships. Stratigraphically-climbing injected sills are now recognised to be of much greater significance.

• In all the simple mounds, disruptions are imaged in the underlying Chalk that are interpreted to be large fluid escape features. Stratigraphically anomalous sands have been encountered by wells drilled through these features.

• We now re-interpret the Balder mounds to be extensive fluidised injection complexes. The mound morphology may be entirely secondary in origin, caused by fluid escape from the pre-Chalk section underlying the Utsira High.

• A new simulation model based on these ideas is more closely matching production history at Balder than previous models.
Location and early Tertiary setting
Previous geological model: Compensational stacking of reservoirs

- Five major Paleocene-Early Eocene sands were identified
- Heimdal and Hermod sand mounds were interpreted to be sandy debrites (shed from the East Shetland platform)
- Younger Balder sands were thought to be mostly turbidites
- All reservoirs were thought to be compensationally stacked, in a relatively unconfined deep-water setting.
- Much of the mounded relief was thought to be due to post-depositional sand re-mobilisation

Sand Re-mobilisation

Conceptual Line of Section
Unusual characteristics of the sand

- Sands are not found at consistent stratigraphic levels
- The sands are clean, fine to medium grained and consistently high porosity (~33%)
- Massive sands in the Heimdal, Hermod and Balder are visually indistinguishable and mineralogically identical
- Angular shale intraclasts are seen in core
- No distal or off-axis facies encountered (in over 150 wells)
Unusual characteristics of the shale

- Erosion of shale is minimal or absent
- For 25 years the uniform shale (thickness) model has been used to predict net sand prior to drilling
- *Local variation in Paleocene isopach is due to variable sand thickness*
Beneath the mounds: intriguing anomalies in the Chalk

- Detached rafts of chalk are associated with all simple mounds
- Allochthonous glide blocks derived from the east?
- But - matching underlying depressions in the Chalk surface
Balder “raft” penetration

- The raft is elevated about 10m
- Matching depression in the underlying Chalk
- High quality massive sand beneath raft
**Ringhorne raft, Ty and Heimdal sand relationship**

- Sand beneath the raft is in seismic continuity with Heimdal sands drilled 250m away.
- Well 25/8-C3 shows 20m repeat shale section over chalk.

- The raft is elevated by ~35m.
- Size: ~1,100 x 600 x 15m.
- Mass: ~16 Million tonnes.
Cretaceous Chalk clasts in Paleocene sands

- Chalk clasts have been penetrated in core
- Larger 25+ cm clast is in massive well-sorted fine-medium grained sand
- Smaller 5 cm clast is contained within angular intraclastic breccia, typical of thinner injection sands in area
- Many more wells show probable chalk clasts on wireline logs
Chalk “rips”

- Progression seen from:
  - Short deflections in chalk (>100m) with dipping reflector above, to a
  - Rip – a normal to reverse fault rarely exceeding 200m in length, sometimes with a small partly-detached raft
Relationship of Heimdal, Hermod and Balder sands

- Rip in Chalk under mound
- Reflectors cross-cut Base Balder, joining M3 to M4
Relationship between Heimdal, Hermod and Balder sands

- Reflectors cross-cut biostratigraphy on mound margins
- Higher continuity of sand is consistent with well performance
Distribution of Balder Fm. (Eocene) sand

- Massive (~40m, 100% N/G) high quality (Ø~33%) Balder sand is unusual for a distal turbidite
- No source or feeder channels have ever been found
- No contemporaneous sands have been drilled in main basin to west
- East Shetland Platform undergoing transgression during Balder period - unlikely sediment source
- We now interpret the majority of the Eocene Balder sand to be intrudites and extrudites
Summary of Seismic-Stratigraphic relationships

- Most or all of the Hermod and Balder sands are interpreted to be sourced directly from the Heimdal mounds, rather than deposited compensationally around them.

- All the mounds are underlain by disruptions in the Chalk.

- We interpret there to be a genetic relationship between the two.
Possible control on location of the Paleocene mounds

- The mounds overlie the flank of the Utsira High, a prominent tectonic high lying between the Viking Graben and Stord Basin.
- The chalk rafts are generally confined to an area underlain by a subcrop of thick Paleozoic clastics below a Lower Triassic angular unconformity.
Summary of the new model

- Our observations are consistent with most of the sand in the Paleocene mounds and the overlying adjacent Eocene being continuous bodies injected across stratigraphy
  - This model can explain the:
    + Minimal erosion of shale
    + Lack of stratigraphic consistency
    + Absence of transitional facies
    + Lack of vertical variations in porosity
    + Common, field-wide OWC and GOC
    + Excellent reservoir communication on a production time-scale

- The mounds are related to Chalk rips and rafts, which are thought to be fluid escape structures
- The location of mounds appears to be controlled by deeper structure
- The original distribution and geometry of depositional Paleocene sand is obscured by the extensive remobilisation
- The volume of injected pre-Paleocene sand remains uncertain
Potential importance for field production

- Modified mound geometries in a new field simulation is improving history match to production
- Our model helps to explain:
  - The high degree of communication between reservoirs of differing ‘ages’
  - Observed common oil and gas contacts over large areas
  - The shared aquifer over entire region
- ...And we hope will lead to the optimal placement of future wells