1. Abstract

Whereas many well-known outcrops of deep-water channels are dominated by conglomerates and sandstone deposited by turbidity currents, channel-fill units of the Upper Puckirkamen Formation in the Puckirkamen gas field, Austria, consist mainly of thick debris-flow deposits with less abundant interbedded reservoir sandstones. During the deposition of the Puckirkamen Formation, sedimentation in the Midost Basin was dominated by a large deep-water, axial channel belt that served as a conduit for debris flows and turbidity currents. This low-energy, channel belt was 3.5 km wide and more than 100 km long. Architecture of the reservoir interval within the channel area controlled mainly by the deposition of mass transport complexes. Thick-beded sandstones representing gas reservoirs are concentrated in the tailings of the channel belt where they locally reach more than 30 m in thickness. To date, no reservoir-scale channels and associated reservoirs have been recognized within the larger channel. In fact, mass transport dominance of the channel system may have prevented the development of a complex internal channel belt architecture with differentiated architectural elements such as channels and levees. Controls on sandstone deposition could have included local topography on the tops of the debris-flow deposits, local cut and fill by the turbidity currents, or geographic barriers within the channel associated with mass transport deposits. We believe that a debris-flow-dominated channel system, as present within the study area, allows for unconventional stratigraphic traps.

2. Geological Background

Figure 1. Cross section of the Upper Austro-Mesozoic Basin (from de Ruig and Hubbard, 2006). The Mesozoic Basin is part of the Northern Alpine foreland basin. Formation and structural evolution of the basin were closely linked to the convergence of the Northern European craton and the Alpine orogenic system. It is a classically asymmetric (traversed basin bounded by a steep, tectonically active southern slope formed by the overthrust front of the Alps and a gently sloping northern margin).

Figure 2. Paleogeographic reconstruction of the Midost Basin (de Ruig and Hubbard, 2006) showing the deep-water channel flowing eastward, parallel to the Alpine thrust front.

Figure 3. A) Overview map of the Upper Austro-Mesozoic Basin modified from Hubbard, 2006, indicating red is the Puckirkamen gas field. B) The enlarged area shows the wells that cover the field, indicated in red are the wells in which the Puckirkamen Formation has been cored.

Figure 4. RMS-amplitude map of the Puckirkamen channel belt at the reservoir interval imaging 25 m of stratigraphy at 5 m below the unconformity of the Tarak Formation (see also Figure 5, horizon interpretation courtesy of Mercier de Groot). Note the west-to-east trending, high-amplitude channel. The location of the Puckirkamen gas field is highlighted in red. Reservoir facies is located within the tailing of the channel.

Figure 5. Seismic cross section through the Puckirkamen gas field (see Figure 3 for location). A) Cross section through the channel belt of the Upper Puckirkamen Formation. The dashed line shows the approximate location of the channel margin. Note the string pattern of high-amplitude channel deposits formed by lateral migration and vertical aggradation. The bright red reflector at the top marks the unconformity at the base of the overlying Hall Formation. The bright blue reflector below indicates the location of the Puckirkamen reservoir. The gas is trapped in a four-way closure formed during compaction. B) Enlarged is the upper portion of the channel belt. The dashed line marks the horizon on which the following p-impedance, facies and variance maps are based on.

3. Study Area

The Puckirkamen Field

This study focuses in particular on the core, well log, and seismic data of one gas field, the Puckirkamen field (Fig. 1). The Puckirkamen reservoir is located within the main channel belt (Fig. 7) and the reservoir facies are restricted to the channel belt. Top and base of the reservoir is not resolved at two separate seismic events. The reservoir location is indicated by a bright blue reflector (Fig. 7). The top of the reservoir is an unconformity, which marks the base of the overlying Hall Formation, the only seismic horizon that can be traced over the study area. The gas is stratigraphically trapped in a dome-like composition structure (Fig. 7). The field is depleting and is now used for gas storage.

4. Data

Wells and Core

Thirty wells have been drilled in the Puckirkamen field. All of them provide SP logs, some of them have additional GR logs. Twelve wells have been cored and provide 256 m of core.

Seismic Data

The 3D seismic dataset (35 Hz) covers almost 2000 km², which represents a large area of the Upper Austro-Mesozoic Basin. Simultaneous elastic inversion has been performed on a 2.5 km 3D seismic cube centered at the reservoir resulting in volumes of p-impedance, s-impedance and density.
"Facies Architecture In A Mass Transport Dominated Axial Channel Belt, Miocene To Oligocene Puchkirchen Formation, Upper Austrian Molasse Basin"

Anne Bernhardt, Lisa Stright and Donald R. Lowe
Department of Geological and Environmental Sciences Stanford University

Lithofacies

<table>
<thead>
<tr>
<th>Lithofacies</th>
<th>Lithology</th>
<th>Thickness</th>
<th>Grading</th>
<th>Physical Structures</th>
<th>Turbidite Divisions</th>
<th>Depositional Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Medium to thick-bedded sandstone</td>
<td>0.5 m</td>
<td>Normally graded from lower medium to upper fine to lower fine sand</td>
<td>A1 unit: very massive</td>
<td>T2c, T3b</td>
<td>High: low-density turbidity currents mainly re-suspension sedimentation</td>
</tr>
<tr>
<td>L2</td>
<td>Diamictal Disturbed units</td>
<td>0.2 m</td>
<td>Often normal grading in diamicite sequence, increasing abundance of mud clasts towards the top of the unit; clay, silt, fine sand and silt; intraformational breccia, clast-supported sandstone, mudstone and sandstone, mudstone, siltstone, sandstone and conglomerate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3</td>
<td>Thinly- laminated, undrained mudstone</td>
<td>Max 12 m</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Sediment input from hemipelagic suspension</td>
</tr>
</tbody>
</table>

Table 1.

Description of lithofacies as observed in core. The Puchkirchen gas reservoir is cored only within the channel. Therefore, out-of-channel lithofacies are not considered in this classification.

Figure 6. Abundances of the individual lithofacies in core showing that sedimentation within the channel belt at this location is dominated by mass transport processes. Turbidity current deposits are not very abundant. This suggests that the internal architecture of the channel belt may not be primarily constructed by turbulent flows and consequently differs from conventional models that include smaller scale channels, inner convexity, etc.

Figure 7. Lithofacies 1 of the Puchkirchen field: Medium to thick-bedded sandstone. A: Thick-bedded sandstone. B: Thin-bedded sandstone. C: Graded (well P18: 711.67 m - 717.5 m, core boxes are 1 m long, base of core at bottom right). Individual sedimentation units are dominated by sandstone that indicate sudden collapse of the high-density turbidity current (ponding).


Figure 9. Channel fills lithofacies association within the gas reservoir at A1. Gr and Sp logs showing A1 channel fills association. Thick-bedded sandstone packages show a consistent blocky log signature in Gr and Sp logs. Mass transport deposits show a U-shaped log signature. B: Core log of the channel-fill lithofacies association in well P18. Thick-bedded, structureless sandstone is dominated by S3 divisions and "sandwiches" between mass transport deposits.
"Facies Architecture In A Mass Transport Dominated Axial Channel Belt,"
Rock Physics and Seismic

**Rock Physics**

Rock physical properties within a single lithofacies described from core can vary widely.

For rock physics modeling purposes the rock type division has been modified from the original lithofacies scheme. Rock physics cross plots show that conglomerate, sandstone, and mudstone are not well differentiated. However, it is likely that the conglomerate fraction on the rock physics facies maps (Fig. 11) represents the matrix-supported conglomerate with high peddle abundance at the base of debris flow deposits (Fig. 6).

**Seismic Data**

- **A** Reservoir Horizon
- **B** Reservoir 0 to +20m
- **C** Reservoir +20m

**Potential analogues**

Figure 12. Slope map of the Alka 2 sandstone offshore Messina Lido (Romano and Cristallino, 1986). Steeper slopes are darker. Hold the straight geometries of the debris flow "levees" and the extensive distal toes.

**Conclusions**

The Puchkrinchen gas field is dominated by massive sandstone sandwiched between mass transport deposits. Mass transport dominated sections within a large channel belt may develop a complicated channel architecture with smaller scale "ribbon" channels and inner levees. P-impedance and rock physics facies maps show rather straight features that are aligned close to the channel margin. We suggest that these depositional geometries of coarse-grained features are related to the conglomeratic of debris flows. Furthermore, lobe-like bodies also seem to be deposited from mass transport processes. These could act as barriers for turbidity currents causing the flows to collapse and trigger rapid suspension sedimentation as seen in the Puchkrinchen reservoir sand. We believe that mass transport dominated channel systems yield the potential for unconventional, probably often overlooked stratigraphic traps.