Architectural Elements and Implications for Deepwater Overbank Deposition of Fine-Grained Lithofacies in the Cerro Toro Formation (Cretaceous), Silla Syncline, Chile*

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Abstract

Fine-grained lithofacies in the Cerro Toro Formation exhibit two architectural patterns: (1) Broad (>200 m) undulating or wavy-bedded elements that laterally terminate by onlap, truncation (toplap) and downlap patterns, and (2) laterally persistent (> 400 m), horizontal, thin-bedded mudstone and sandstone. These facies exhibit a stratigraphic transition from horizontal to wavy and curved beds concurrent with pronounced aggradation of laterally equivalent, and possibly coeval, channel facies. Sandstone and mudstone beds within the wavy-bedded facies exhibit turbidite lithofacies that include current-ripple lamination (Tc), planar lamination (Tb) massive, graded intervals (Ta), and laminated to structureless silt- and clay-rich beds (Tde). Typically, these beds are a few centimeters thick, but locally, sandstone beds form bedsets over 1 m thick. These thick sandstone bedsets display inclined bedding associated with mudstone rip-up clasts and are confined to swales within large-scale, wavy-bedded units. Erosion surfaces within this thin-bedded fine-grained lithofacies are spaced vertically at 10-15 m, commonly associated with the crest of curved bedding and display at least 5 m of relief. The fine-grained lithofacies located adjacent to and eroded into by a channel facies are interpreted as a coeval levee facies. Planar, tabular bedsets located at the base of this fine-grained lithofacies are interpreted as the initial overbank deposition associated with development of a channel complex, whereas curved, wavy-beds are interpreted as sediment waves developed on the backside of a levee. The curved bedding, lenticular, medium-grained sandstone bedsets, scattered erosional surfaces, and onlap-downlap stratal geometries in the Cerro Toro bear resemblance to sediment waves associated with Quaternary coarse-grained, channel-levee systems. Turbidity currents spilling onto a levee surface are the main processes invoked for deposition of these
sediment waves. Significantly, the volume of sand and silt in the system may be adequate for hydrocarbon reservoirs, particularly gas, but the processes that shaped these rocks were not conducive to bed continuity and did not enhance reservoir potential.

**References**


Wilson, T.J., 1991, Transition from back-arc to foreland basin development in the southernmost Andes; stratigraphic record from the Ultima Esperanza District, Chile: GSA Bulletin, v. 103/1, p. 98-111.
Architectural Elements and Implications for Deep-Water Overbank Deposition of Fine-Grained Lithofacies in the Cerro Toro Formation (Cretaceous), Silla Syncline, Chile

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Outline

• A few questions regarding mud-rich systems
• Architecture of Quaternary systems
  – Benin Major Channel – Channel stacking, sediment waves and levee growth
  – Var Sedimentary Ridge – details of levee architecture and lithofacies distribution
• Cerro Toro stratigraphy
  – Architectural elements and lithofacies associations
• Summary
Questions regarding mud-rich systems in general and overbank systems in particular:

- Where does the mud accumulate? Slope? Basin floor?
- Is there a link to channels?
- How important are turbidity currents in mud accumulation?
- What architectural elements exist?
- How persistent or continuous are the beds?
- Is sandstone associated with the overbank system? Where?
Benin Channel, Nigeria

Lifted from Deptuck et al, 2007

Sediment Waves

Slumps

0  2500  5000  Meters
Levee Development

- Levee confinement works at multiple scales – outside the large container and intrachannel.
- Contacts between channel fill and levee are erosional, not a transitional pattern.
- Aggradation of channels and levee system work together – Is this possible in the Cerro Toro without levee aggradation?

Deptuk et al, 2007
**Var System**

**Vital Stats**

- Located in the western Mediterranean
- Steep gradient (slope >11)
- 2000 – 2600 m water depth
- Asymmetric levee system up to 400m (range 400 – 30 m) relief
- Middle fan valley gradient (<1)
- Levee gradient ~ 2
- Cobble- to clay-sized detritus transported in the system
- Active system – notable event associated with the collapse of a portion of tarmac from the Nice airport in 1979 and cable break offshore.
1979 CABLE BREAK
Sediment waves are distinctive architectural features of the levee.

Sediment waves are more prominent with aggradation of channel/levee system.

Variable lithology.

From Migeon et al, 2001
Core Lithofacies

Sediment Wave Lithofacies

- Symmetrical waves are mud-prone
- Beds are relatively thin <10 cm
- Coarsest material is fine-grained (.012 mm)

From Migeon et al, 2001
**Var Seismic Characteristics**

**Sediment Waves**

- **Two-Way Travel Time (secs)**
  - 2400
  - 2600
  - 2200

- **Depth (meters)**

- **Regional Flow**
  - VE ~10:1

**Profile Nic 34**

- **Sand Prone**

From Migeon et al, 2001

- **NW**
  - KN127
  - KN126
  - KN124

- **SE**

- **Var Seismic Characteristics**

- **Sediment Waves**

  - Sand is localized on upstream side of sediment wave and diminishes down slope
  - Sand is coarsest near “swale”
Core Lithofacies

Sediment Wave Lithofacies

- Sand prone on the upstream flank
- Thickest beds are about 40 cm
- Coarsest material is medium-grained (.02 mm)

From Migeon et al, 2001
Setting:

- Basin is located in a backarc setting
- Basin fill is primarily upper Cretaceous in age
- Sediment derived from the rising arc to the west and a large axial component derived from the north
- Paleo flow is NW to SE
Silla Syncline, Chile

**Setting:**

- Basin is located in a backarc setting
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### Magallanes Basin

#### Stratigraphy

<table>
<thead>
<tr>
<th>Ma</th>
<th>Period</th>
<th>Stage</th>
<th>Generalized Lithology</th>
<th>Magallanes Basin Nomenclature</th>
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<tbody>
<tr>
<td></td>
<td>Tertiary</td>
<td>Danian</td>
<td></td>
<td>Dorotea Formation</td>
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<td></td>
<td></td>
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<td>Tres Pasos Formation</td>
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<tr>
<td>80</td>
<td>Late Cretaceous</td>
<td>Maastrichtian</td>
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<td>Cerro Toro Formation</td>
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<td>90</td>
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<td>Campanian</td>
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<td>Punta Barrosa Formation</td>
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<td>Coniacian</td>
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<td></td>
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<td>Turonian</td>
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(Jurassic - Earliest Late Cretaceous Backarc Basin Deposits)

(adapted from Natland et al., 1974; Wilson, 1991; and Fildani et al., 2003)
Beaubouef (2004)
Focused Study Area

Lago Sarmiento Chico

Base CC3U

Top CC1

Base CC2

Base CC3L

1 km

Stratigraphy

Modified from Crane and Lowe (2008)
Cerro Toro

- Stacked channel pinch out along the north/south shore of Lago Sarmiento Chico
- Channels stacking is aggradational
- Channel margins are localized
- Channel aggradation associated with aggradation of adjacent mudstone facies
Cerro Toro

Channel Complex 3 (Upper)

- Pinch out along the north/south shore of Lago Sarmiento Chico
- Channels stacking is aggradational
- Channel margins are localized
- Channel aggradation associated with aggradation of adjacent mudstone facies
**Cerro Toro**

**Overbank/Levee Facies**

- Classic turbidite facies
- Common onlap, downlap, truncation stratal patterns
- Decreasing sandstone content with distance from channel margins
- Slump facies common near channel margins
Base CC3L

Base CC3U (Stacking Pattern Change)

Interchannel Facies

Levee(?)

Base CC3L
Thin-bedded siltstone (Tde)

Lenticular Sandstone
- Medium grained
- Abundant rip up clasts
- Inclined lamination
Base CC3L
Interchannel Facies
Levee (?)

Overbank 1
Curved, Lenticular Beds

Overbank 2
Planar, Persistent Beds

Interchannel Facies
Levee (?)
Onlap and truncation patterns pervasive in overbank facies.
Var Ridge

Levee Architecture

23:15

125 ms

23:30

Savoye et al, 1993
• **Conventional seismic data unlikely to resolve sand lithofacies**
• **Thick sands may not be the most continuous**
• **Reservoir?**
Conclusions

• Deceleration of turbidity currents deposited and shaped the sediments in the fine-grained Cerro Toro

• Most of the mudstone in the system is deposited in an overbank setting – some collapse into channels

• Thin, persistent beds associated with initial overbank development and laterally amalgamated channel complex (CC3L)

• Thin, persistent beds associated with initial overbank development and laterally amalgamated channel complex (CC3L)

• Possible sediment waves in the Cerro Toro correlate with areas of high sediment supply (assumed from the aggradational pattern displayed in CC3U)