How to Interpret Turbidites: The Role of Relative Confinement in Understanding Reservoir Architectures

Turbidite interpretation for non-specialists

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A deceptively simple question...

Strike section through a medial to distal lobe with an advancing and off-set stacked channel/lobe transition above.

Yes, but **how** did you reach that interpretation?

Objective: How to organise these parameters in a manner the non-specialist can understand....?

**All these (and more) parameters can be viewed through the context of relative flow confinement**
Outline

• Confinement and *relative* confinement
• Relative confinement index
• Why we care!
• Interpretation parameters
• Vertical expressions of lateral bed continuity
• Integrating expressions
• Inverting the process

*Zumaya Flysh, SE Spain – unconfined*
What is Confinement?

- Turbidity currents expand radially – i.e. they are unconfined
- Barriers along flow (e.g. channels) prevent lateral expansion & promote downdip flow
- Down-dip barriers to flow (e.g. salt ridge) prevents down-dip expansion and promotes flow along strike
- Confinement operates at all scales from mm to basin-scale
- Confinement may be static or dynamic (i.e. structural or depositional)
Relative Confinement

• Same architectural expression
  • Large flow in large container
  • Small flow in small container
  • Same degree of relative confinement

• Varying degrees of relative confinement
  • different flow sizes in same container
  • same flow size in different containers

• Different expressions with different degrees of relative confinement
Relative Confinement and Lateral Continuity

- Degree of *relative confinement* is a function of the size of the flow and the size of the container it flows through.
- Changes in flow and topography causes variations in *relative confinement*.
- Lateral continuity of turbidite bed is result of interaction of turbidity current and topography over *and through* which it flowed.

- Low *relative confinement* = thin laterally continuous sands.
- High *relative confinement* = thick laterally discontinuous sands.
Why we should care.

Basin size
Flow size
Confinement
Architecture
Kv/Kh
Outcome

Confinement
Low
High

Architecture
Large
Small

Kv/Kh
Low
High

Outcome
Amalgamated
Non-amalgamated

Why we should care.
Vertical Expression of Lateral Continuity

• High relative confinement:
  • Lower lateral continuity & greater depositional thickness
  • Greater net erosion & amalgamation

• Low relative confinement:
  • Greater lateral continuity & thinner depositional units
  • Lower net deposition & amalgamation

• Ultimately results in / from different architectural expressions...
  • High relative confinement: e.g. channel forms, axial lobe
  • Low relative confinement: e.g. distal lobe sheets, levees
Relative Confinement Index

- Dimensionless container \( v \) dimensionless flow size
- Derives trend in relative confinement
- Illustrates idea of common expression if relative confinement is same
Interpretable Parameters

- Many parameters viewable through the relative confinement lens
- Linear and non-linear relationships to degree of confinement
- NB: Simplified for ease of understanding

- Some worked examples...
Amalgamation Ratio

• All bedding contacts versus amalgamated contacts (i.e. erosive) expressed as %

\[
\frac{\text{Amalgamated}}{\text{Preserved}} = X \% \text{ Amalgamation}
\]

• Greater amalgamation ratio =
  • Greater erosion
  • Greater confinement

*Source data: Core and image log*
Amalgamation Ratio

- Individual turbidity current deposits vary in thicknesses
- Individual deposits rarely exceed 2-3m thickness with ‘maximum’ of 5m
  - ‘5m rule of thumb’
- Unit greater than 5m thick must represent amalgamated events
- Apply to log curves empirically, taking into account ‘stability’

- Greater than 5m stable low GR interval =
  - Greater amalgamation ratio
  - Greater erosion
  - Greater confinement

Infer from: petrophysical logs
Net:Gross

- Net = Sand
- Net sand related to amalgamation ratio
- Erosion removes shale caps (Te’) increase net
- Increased Net =
  - Increased erosion
  - Increased confinement
  - Lower lateral continuity

*Source data from: Core, Image log, petrophysics. Infer from: Seismic facies*
Grain Size

- Transport of different size grains / clasts dependant on flow velocity
- Higher velocities = Movement of larger clasts
- Highest velocities occur where flows are confined
- Increased grainsize =
  - Increased flow velocity
  - Greater relative confinement

Source data from: Core, Mud-logs. Infer from: Image log, petrophysics (density)
Bed Continuity

- High relative confinement
  - lower lateral continuity
  - higher vertical continuity
  - high Kv/Kh

- Low relative confinement
  - higher lateral continuity
  - lower vertical continuity
  - low Kv/Kh
Architecture

- **High relative confinement**
  - lower lateral continuity
  - higher vertical continuity
  - high $K_v/K_h$
  - e.g. channels

- **Low relative confinement**
  - higher lateral continuity
  - lower vertical continuity
  - low $K_v/K_h$
  - e.g. sheets
 Decreasing Parameters

- Amalgamation ratio
- Net:Gross
- Grain Size
  - If range is present
- Sedimentary structures
  - Flow regime (Harms et al 1982)
  - T-division (Bouma, 1962)
  - S-Division (Lowe, 1982)
Increasing Parameters

- Bioturbation Index
  - Degree of reworking (Taylor & Goldring, 1993)
- Hemipelagic
  - Non deposition in confined
  - Non erosion in unconfined
- Bed continuity
Non-Linear Parameters

- Bed thickness distribution
- Bioturbation diversity
  - E.g. Bromley 1990
- Facies variability
  - Including seismic facies
Integration

• Vertical expression used to determine degree of relative confinement
• Relative confinement central linking theme
• Can be used as direct or indirect expression of each other

HEALTH WARNING: SIMPLIFICATIONS!
Integration

- Vertical expression used to determine degree of relative confinement
- Relative confinement central linking theme
- Can be used as direct or indirect expression of each other
  - Consider different parameters to suit purpose or data available
  - Exploration, development, outcrop studies
Process Inversion

• No wells data, no vertical expression...only seismic
• External controls
  • Basin sizes
  • Other morphologies (channels)
  • Hinterland proximity, sediment source type
• Relative confinement can infer probable architectural, facies and other characteristics
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Tools of investigation</th>
<th>Trend (proximal to distal)</th>
<th>Key References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral bed continuity</td>
<td>Bed continuity at point of deposition</td>
<td>Outcrop, Seismic</td>
<td>Linear Increasing</td>
<td>Kneller (1995)</td>
</tr>
<tr>
<td>Net:gross</td>
<td>Net sands present as a percentage of the gross rock interval</td>
<td>Outcrop, core Image-log, petrophysics, Seismic</td>
<td>Linear Decreasing</td>
<td>Thomas &amp; Stieber (1977), Passey et al (2006) - for thin-bed petrophysics</td>
</tr>
<tr>
<td>Sedimentary structures</td>
<td>Sedimentary structures relating to combination of flow velocity and grainsize</td>
<td>Outcrop, Core</td>
<td>Linear Decreasing</td>
<td>Hjulström (1935), Lowe (1982), Bouma (1962)</td>
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<td>Grain size and grain size variability</td>
<td>Grain size and range of grain size related to different velocity of transport and source material</td>
<td>Outcrop, Core, Cuttings Log</td>
<td>Non-linear</td>
<td>Hjulström (1935), Lowe (1982), Bouma (1962)</td>
</tr>
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<td>Mineralogical content and variability / textural maturity</td>
<td>Expression of transport duration for sediment in single or multiple transport &amp; deposition episodes</td>
<td>Outcrop, Core, Cuttings Log</td>
<td>Non-linear</td>
<td>Hjulström (1935)</td>
</tr>
</tbody>
</table>

• These, and other, parameters explained in Extended Abstract
• Full references therein
Summary

- It is possible to view all turbidite expressions through the idea of relative confinement
- Relative confinement index allows all parameters to be compared against each other
- Relative confinement can be used to predict reservoir expression from seismic or vice versa
Thanks for listening.

Thanks to the participants of Nautilus Course M33