Role of Mass-Transport Deposit (MTD) Related Topography on Turbidite Deposition and Reservoir Architecture: A Comparative Study of the Tres Pasos Formation (Cretaceous), Southern Chile and Temburong Formation (Miocene), NW Borneo*

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Abstract

Submarine-slope topography has a fundamental control on turbidity current routing and the subsequent distribution and geometry of associated deposits. Although typically controlled by tectonics, an increasing number of field and subsurface-based studies have demonstrated that topography developed at the top of mass-transport deposits (MTDs) also influences turbidite depositional patterns. This has clear implications for the distribution and architecture of turbidite-sandstone reservoirs, although there is a paucity of outcrop analogues with which to understand these relationships in the subsurface. This study focuses on the slope to base-of-slope Tres Pasos Fm (TPF), Southern Chile and Temburong Fm (TF), NW Borneo; in these locations the effect of MTD-related topography on turbidite depositional patterns is highlighted.

The upper surfaces of the mud-rich MTDs are highly irregular at both field locations, commonly due to large intrabasinal clasts. Three hierarchical levels ('Tiers') of topographic relief are identified, which have a varying impact on the geometry of overlying turbidites; (i) Tier 1 – metre-scale topography caused by the cohesive nature of mud-rich MTDs; controls individual bed-scale onlap and pinchout within overlying turbidites; (ii) Tier 2 – metre- to decametre-scale topography related to either rafted clasts or possibly imbricate-thrust faulting within the debrites; controls onlap, pinchout patterns, and internal architectural styles within bed packages; and (iii) Tier 3 – topographic relief of up to several hundred metres related to either cohesion-related topography or large, out-sized clasts; controls the pinchout of entire turbidite packages (i.e., 'fans').

MTDs, depending on their composition and thickness, may cause stratigraphic compartmentalisation of turbidite reservoirs, resulting in the multiple fluid contacts and highly-variable pressure regimes. It is important, therefore, to understand the scale and potential impact of MTD-related topography on turbidite reservoirs through incorporation of outcrop data and, for example, forward-seismic models. Synthetic profiles of exposures in the TPF illustrate the uncertainties associated with identifying subtle stratigraphic relationships on standard industry seismic-reflection datasets and further emphasize the need to constrain reservoir models with detailed outcrop studies.

Selected References

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Role of mass-transport deposit (MTD) related topography on turbidite deposition and reservoir architecture: A comparative study of the Tres Pasos Formation (Cretaceous), Southern Chile and Temburong Formation (Miocene), NW Borneo

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Rationale

Deep-water depositional processes and the resultant architecture of associated (reservoir-prone) deposits are typically controlled by seabed bathymetry related to active syn-depositional structural development.

The role of basal erosion and relict topography associated with the emplacement of large-volume mass-transport deposits (MTDs) is less well understood.

Rationale

Deep-water depositional processes and the resultant architecture of associated (reservoir-prone) deposits are typically controlled by seabed bathymetry related to active syn-depositional structural development.

The role of basal erosion and relict topography associated with the emplacement of large-volume mass-transport deposits (MTDs) is less well understood.

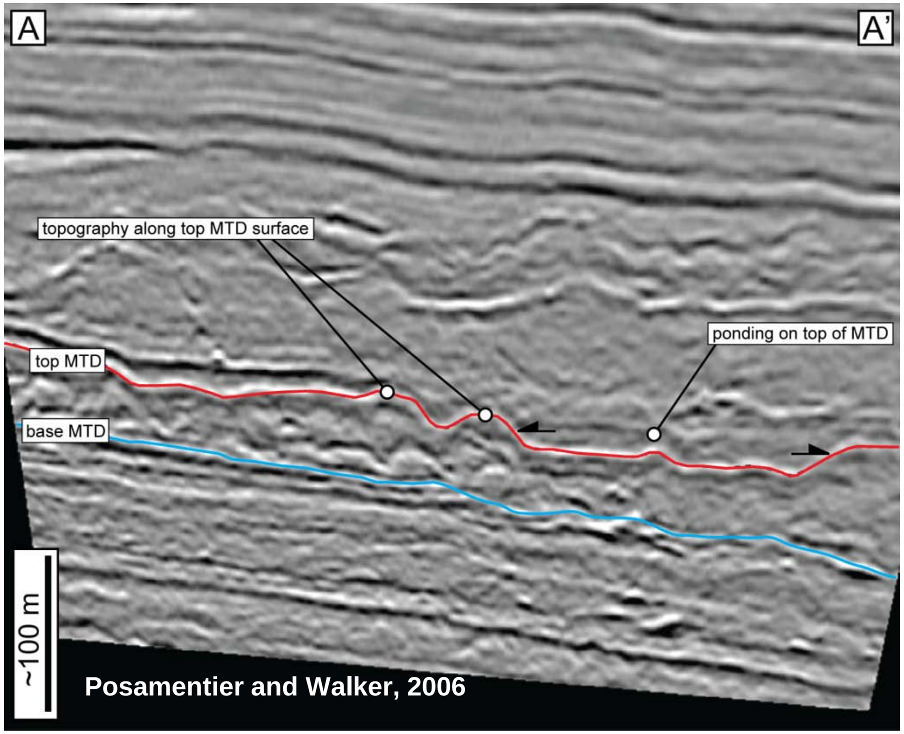
Talk Outline

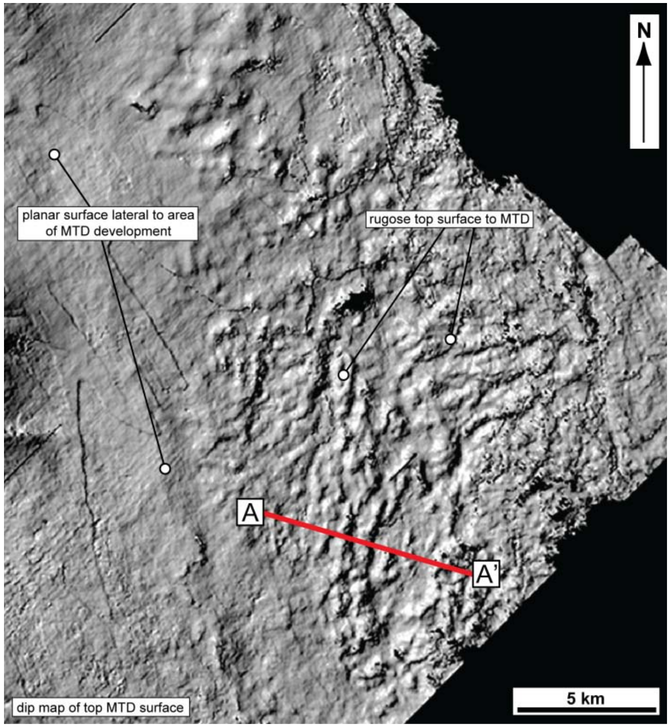
Provide seismic-reflection examples of basal erosion and relict topography related to MTDs.

Present two case studies which highlight the role of these processes and their impact on reservoir distribution and geometry.

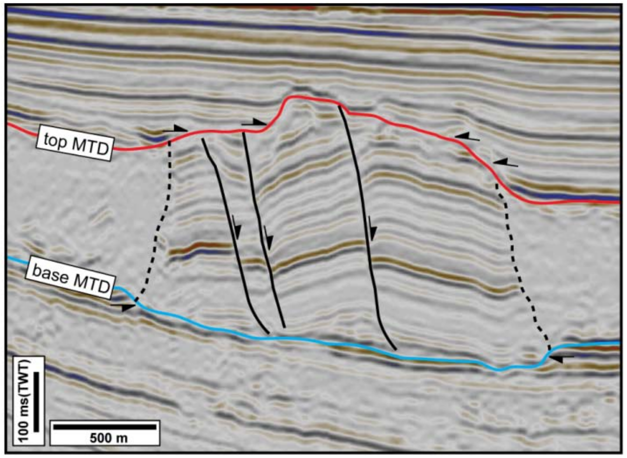
Highlight the limitations of high-quality 3D seismic-reflection data when trying to understand the influence of MTD erosion and topography on deep-water sandstone reservoirs.

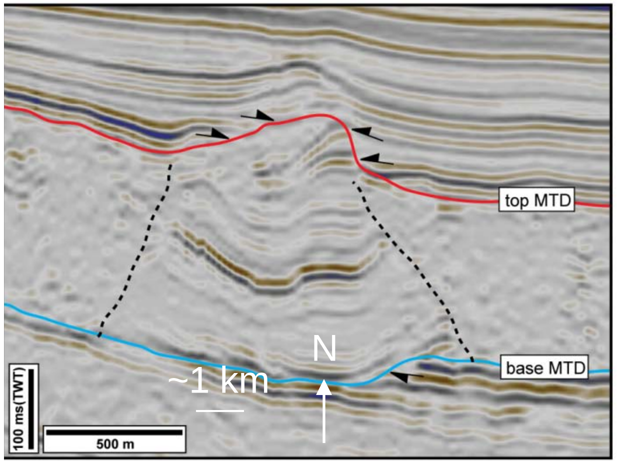
Examples of mass-transport deposit topography in seismic-reflection data:





Posamentier and Walker, 2006

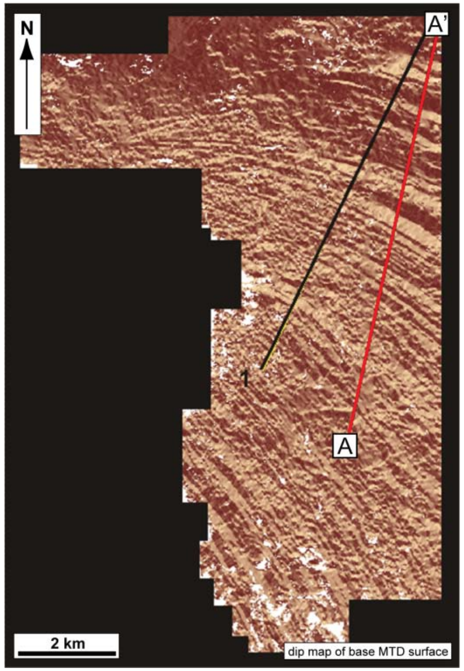


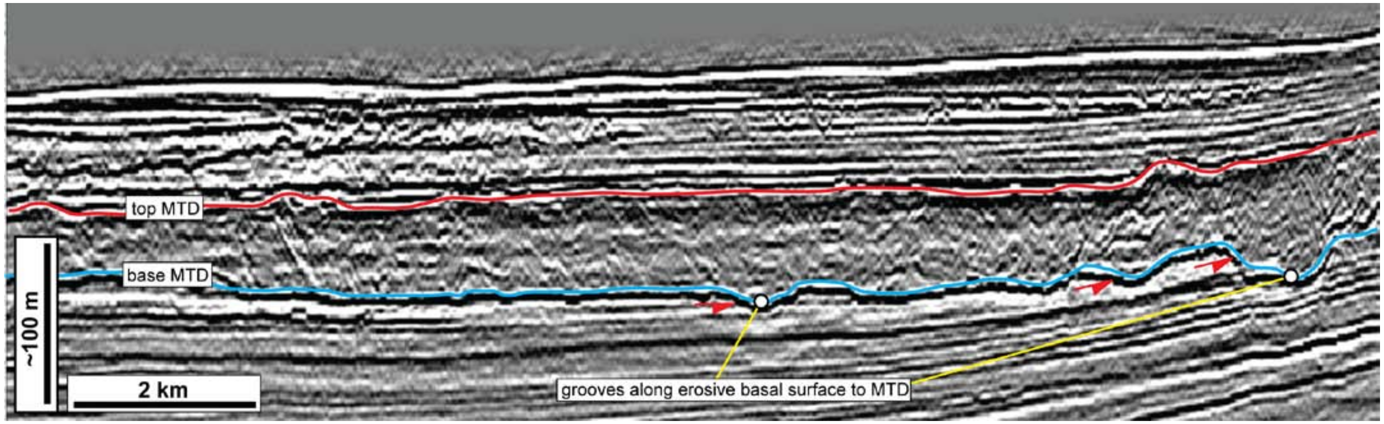


Chris Jackson, *in prep*

- Seismic-reflection data image decametre-scale topography at top of MTDs.
- Topography is highly irregular.
- Related to inherent cohesiveness of the debris flow or rafted blocks.

Seismic-reflection expression of MTD basal erosion:





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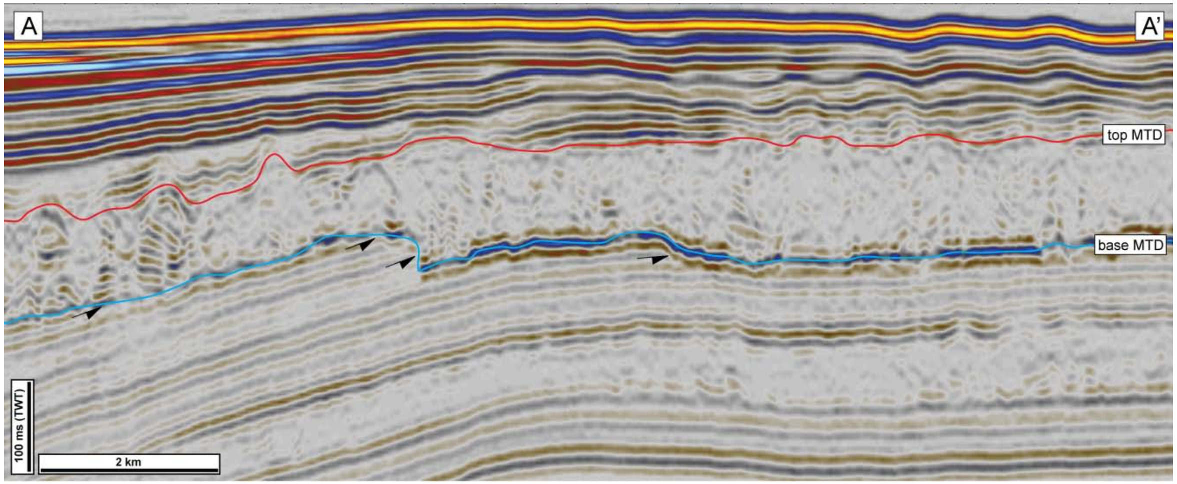

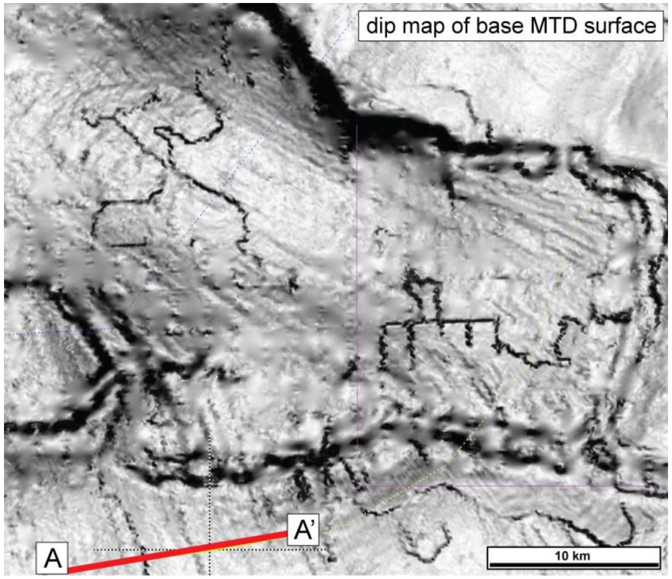

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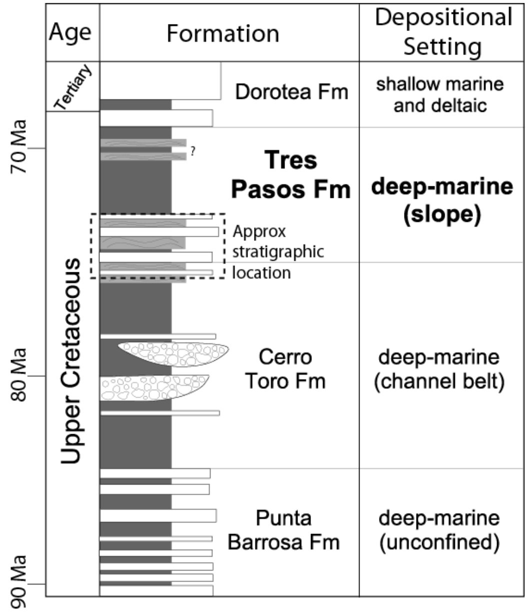
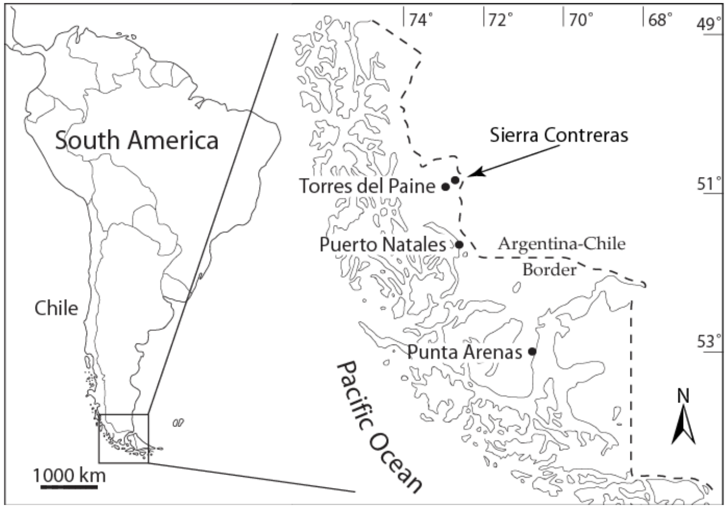
Case Study 1 - Tres Pasos Formation (Cretaceous), Southern Chile

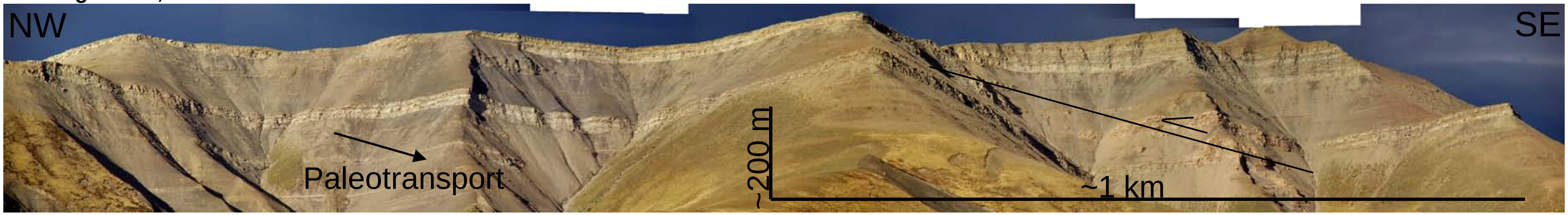
- MTD-dominated submarine slope environment
- Locally developed turbidite sandstone

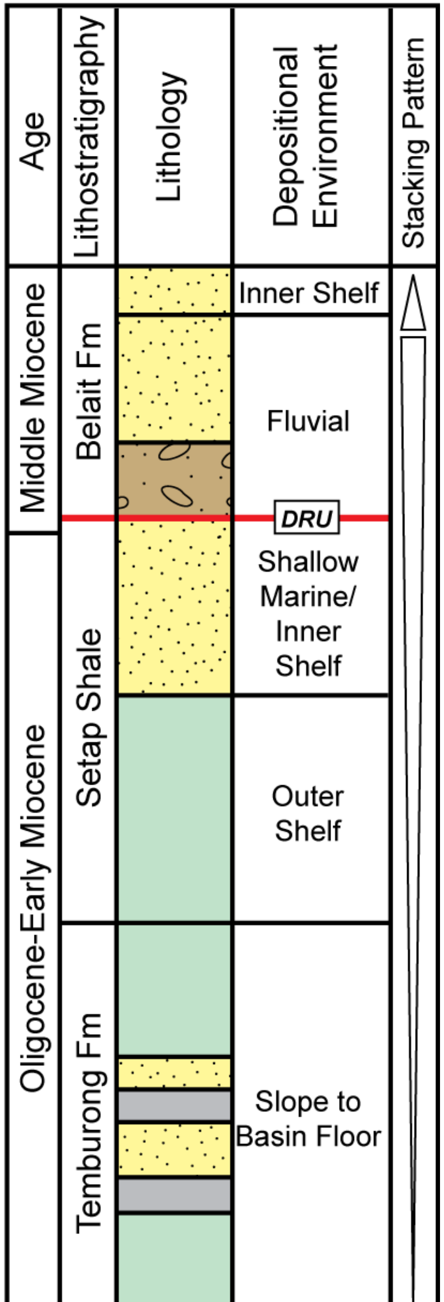




Modified from Fildani and Hessler, 2005

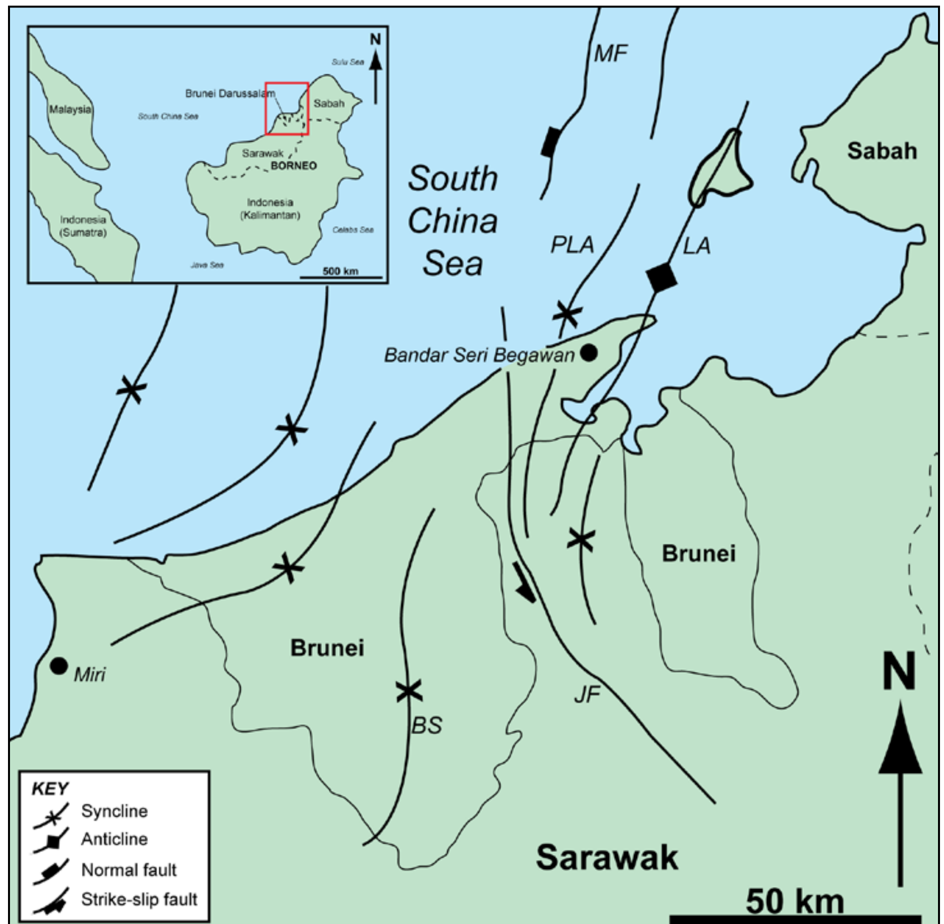
Armitage et al., 2009





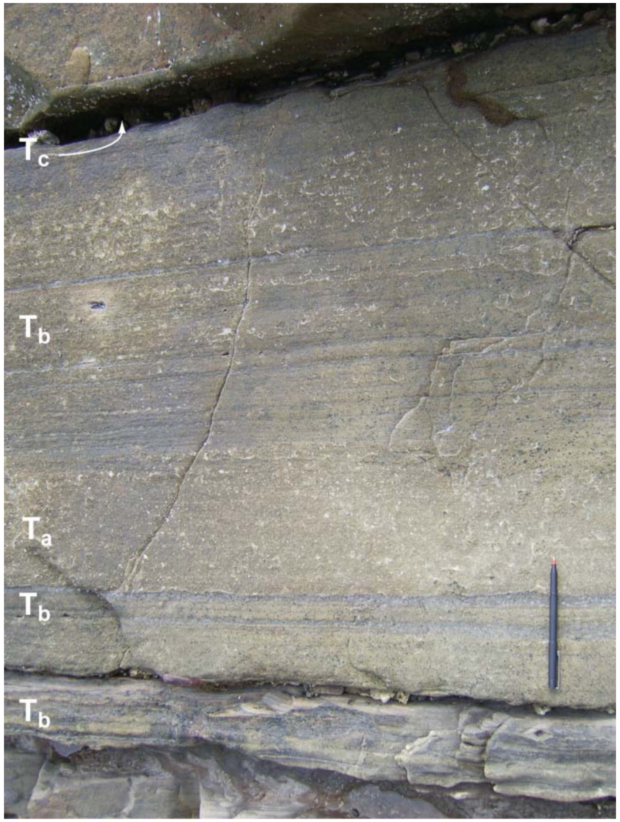
Case Study 2 - Temburong Formation (Miocene), Labuan, NW Borneo

- MTD-dominated submarine slope environment
- Locally developed turbidite sandstone



Jackson and Johnson, 2009

Outcrop sedimentology - coarse-grained facies:

<table>
<tr><th>Tres Pasos Fm</th><th>Temburong Fm</th></tr>
<tr><td>
• Fine- to medium-grained, normally graded turbidites with evidence for traction.</td><td>
• Fine- to medium-grained, poorly sorted, ungraded to normally graded turbidites.</td></tr>
</table>

Armitage et al., 2009

Jackson and Johnson, 2009

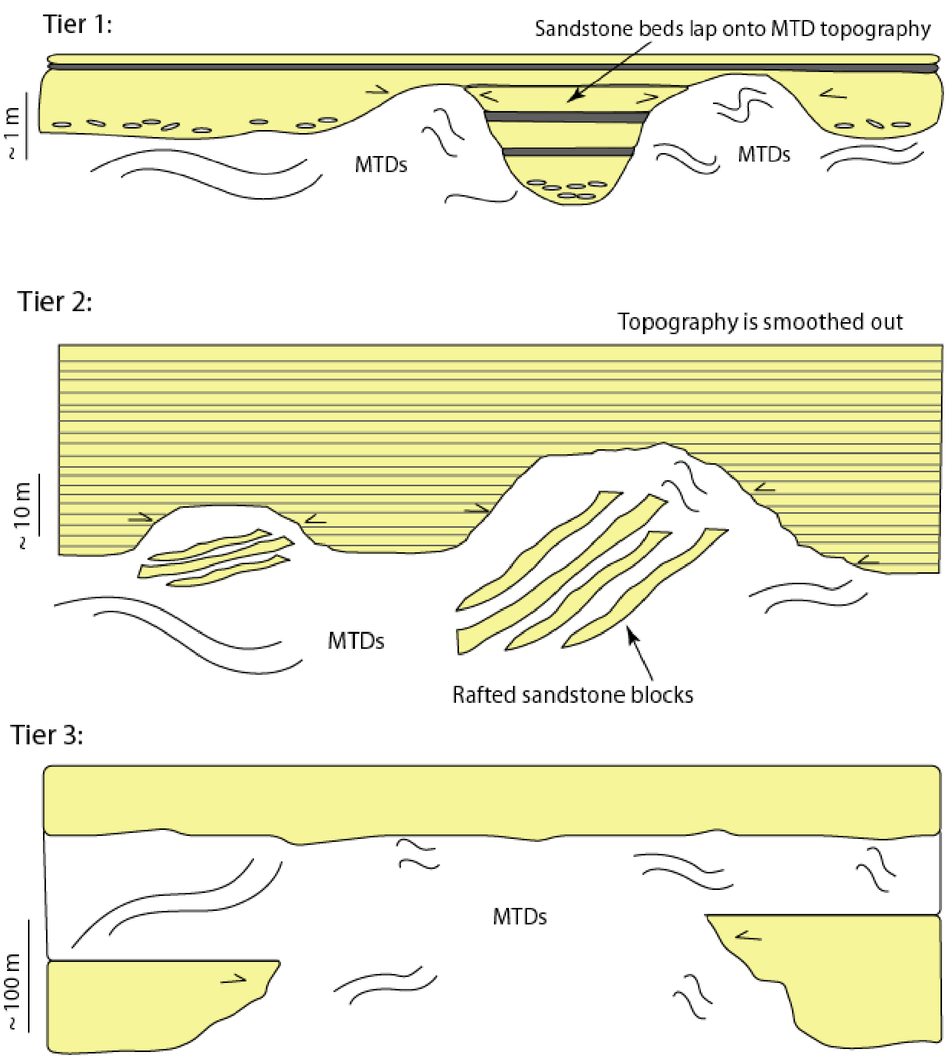
Outcrop sedimentology - fine-grained facies:

Tres Pasos Fm	Temburong Fm
	
• Clast-rich, matrix-supported debrites in units up to 160 m thick. • Poorly sorted silty-shale matrix. • Clasts of deformed, medium-grained sandstone up to several tens of meters in diameter.	• Clast-rich, matrix-supported debrites in units up to 65 m thick. • Poorly sorted silty-shale matrix. • Sharp erosive bases. • Clasts of deformed siltstone and sandstone.

Armitage et al., 2009

Jackson and Johnson, 2009

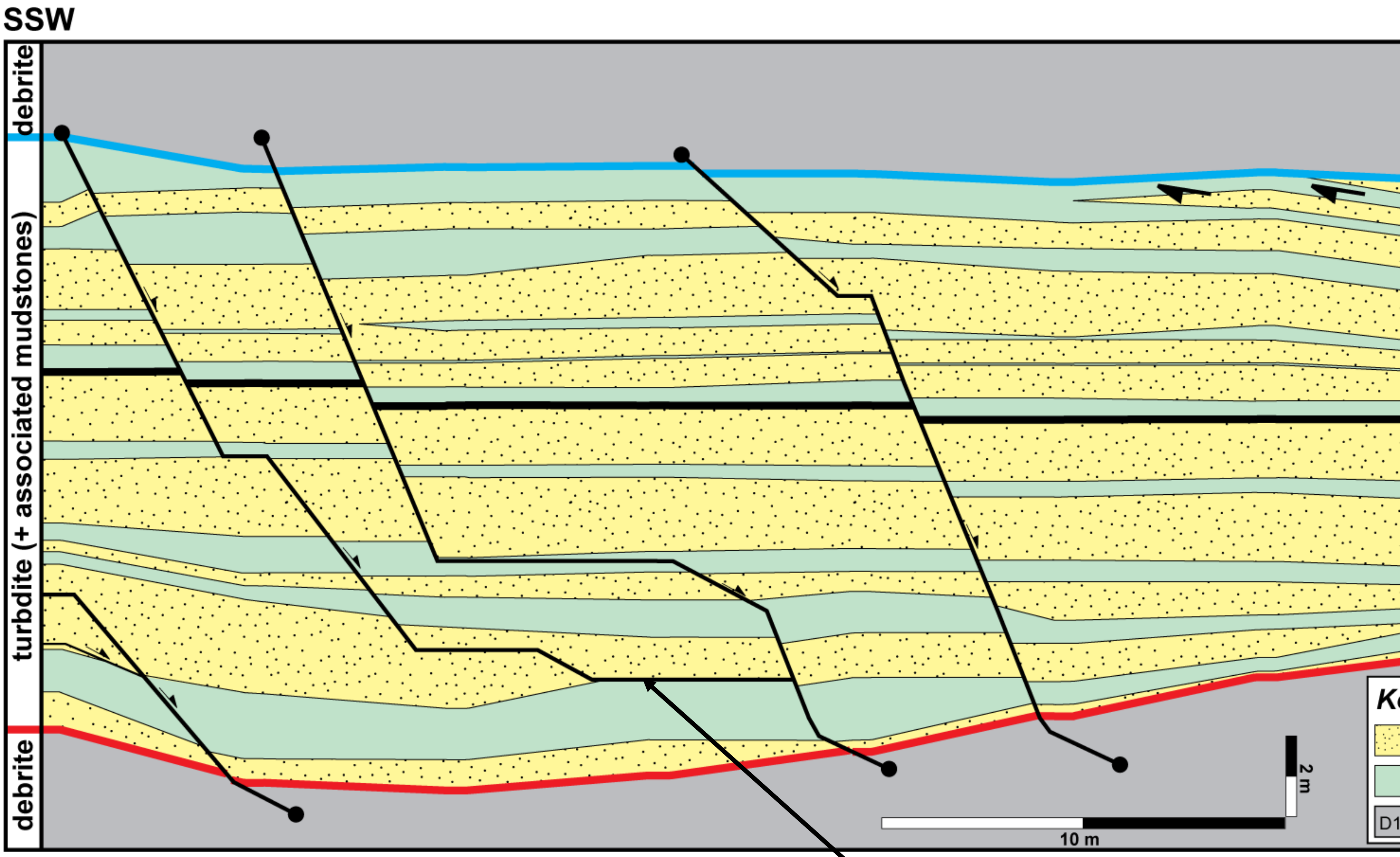
Scales of MTD-related surface topography



Armitage et al., 2009

Control on topographic development	Effect on flow-behaviour and sandstone architecture	Scale (H/V) in metres
Tier 1 - Cohesive freezing of mud-dominated debris flow, possibly augmented by loading of overlying deposits	Local routing of individual turbidity currents leading to ponding of turbidite sandstone **beds** and **bedsets**	1-10/1-10
Tier 2 - Rafted blocks	Local routing of a succession of turbidity currents leading to lateral partitioning of individual **lobes** or **channels**	10-100/1-10
Tier 3 - Individual MTD or outsized blocks within an MTD	Long-term control on routing of turbidity currents leading to spatial localisation of entire **turbidite system**	>100/10-100

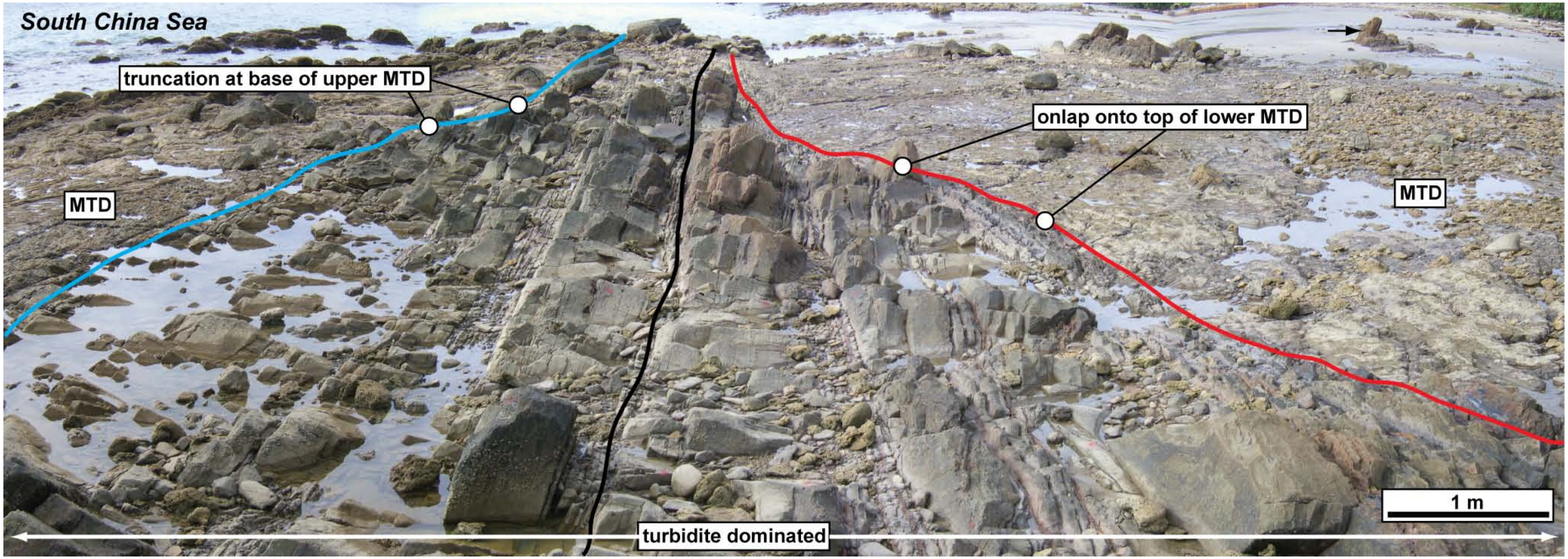
Stratal architecture: Temburong Fm



Jackson and Johnson, 2009

MTD-related surface topography

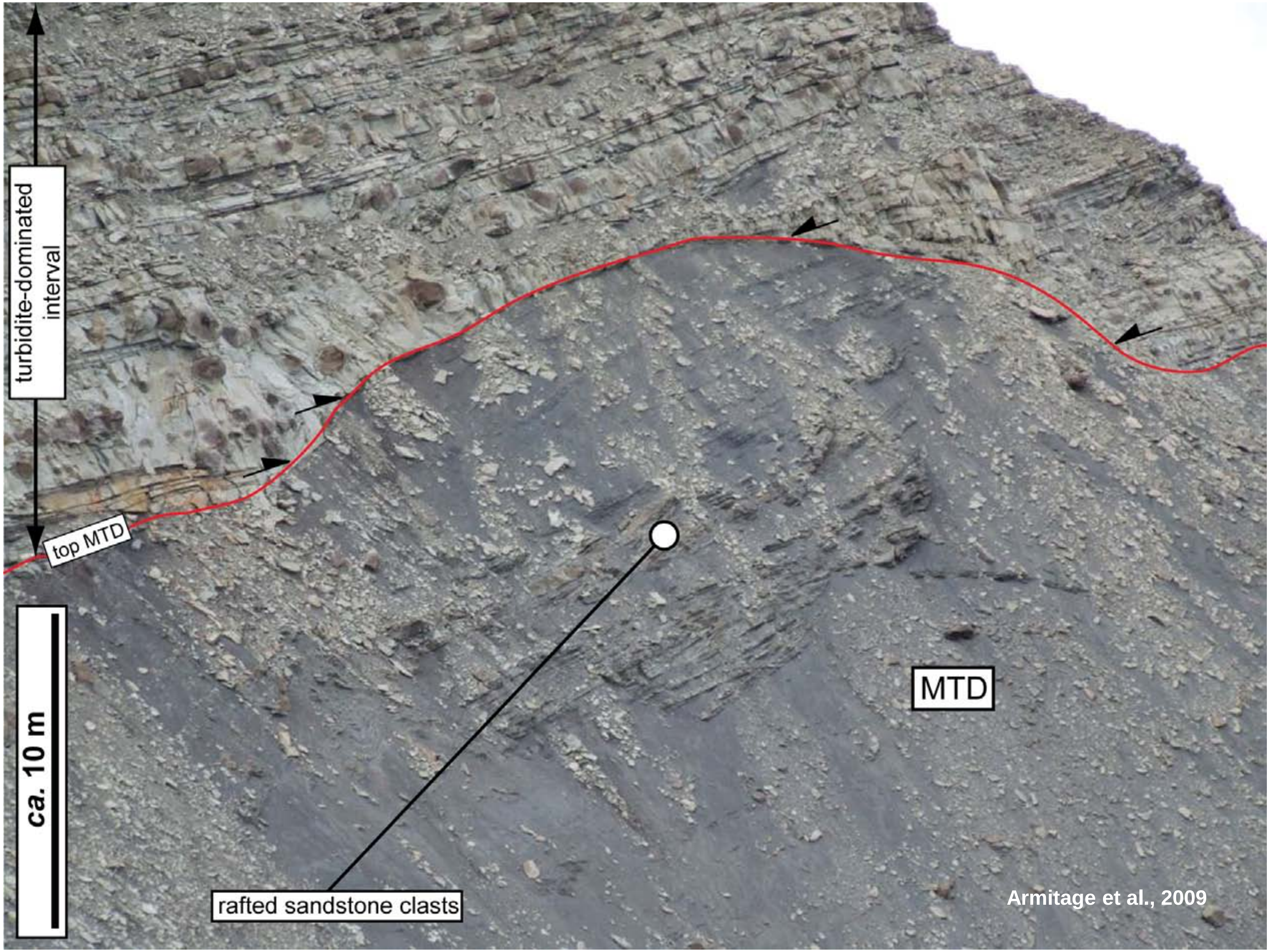
Tier 2 MTD-surface topography: Temburong Fm



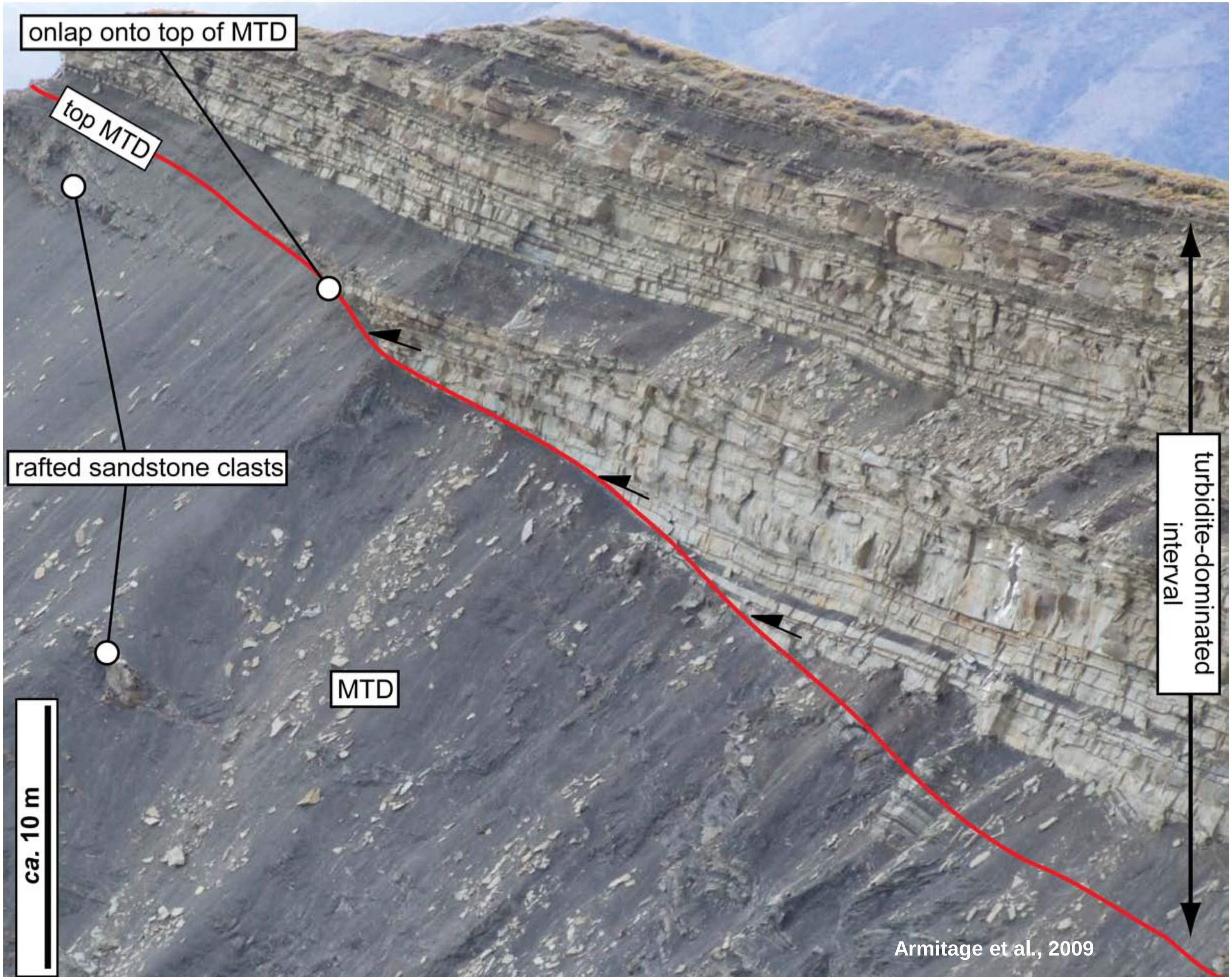
Jackson and Johnson, 2009

- Turbidites filling in local MTD-related accommodation.
- Seafloor topography was created by cohesive freezing of muddy debris flow, not by subsequent erosion of turbidity currents.

Tier 2 MTD-surface topography: Tres Pasos Fm

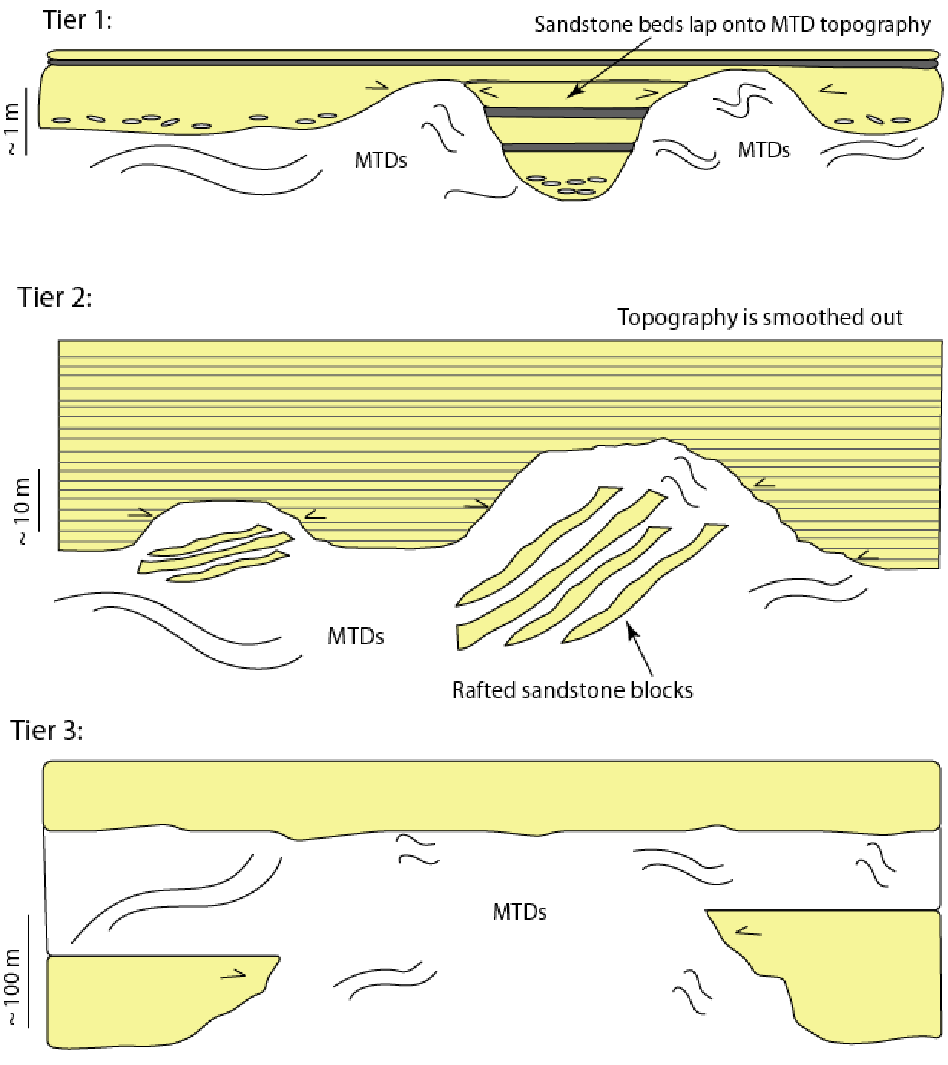


Tier 2 MTD-surface topography: Tres Pasos Fm



Comparison between Tres Pasos and Temburong Fm topography

- **Tier 1** - directly related to inherent cohesiveness of MTDs, present in both examples – related to the mud-rich nature of the source area.



Armitage et al., 2009

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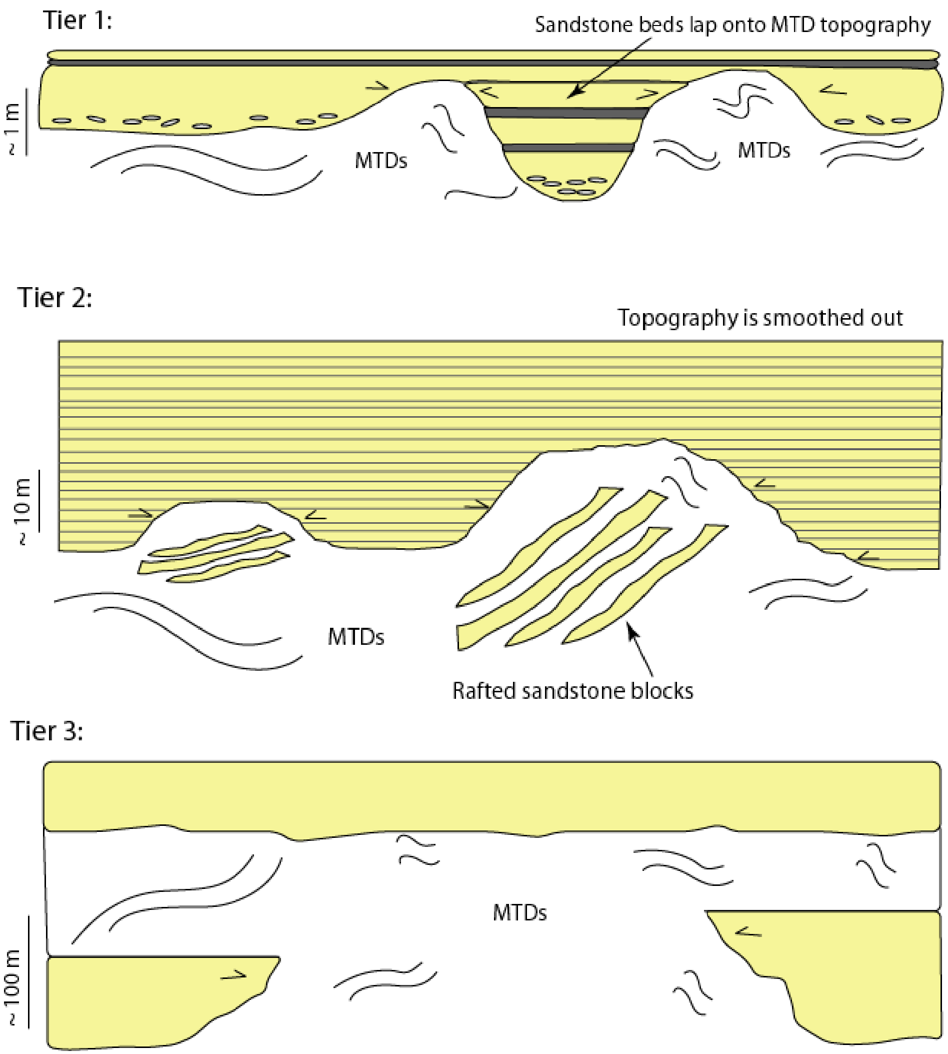

Armitage et al., 2009

• **Tier 1** - directly related to inherent cohesiveness of MTDs, present in both examples – related to the mud-rich nature of the source area.

• **Tier 2** - in the Tres Pasos Fm slope system this is created by rafted blocks (N.B. rafted blocks become larger up section suggesting blocks are larger on upper slope than lower slope); MTD-related topography in the Temburong Fm not created by rafted blocks:

- This suggests size and distribution of rafted blocks can be used to locate position on a generalized slope profile (exceptions include 'outrunner' blocks)

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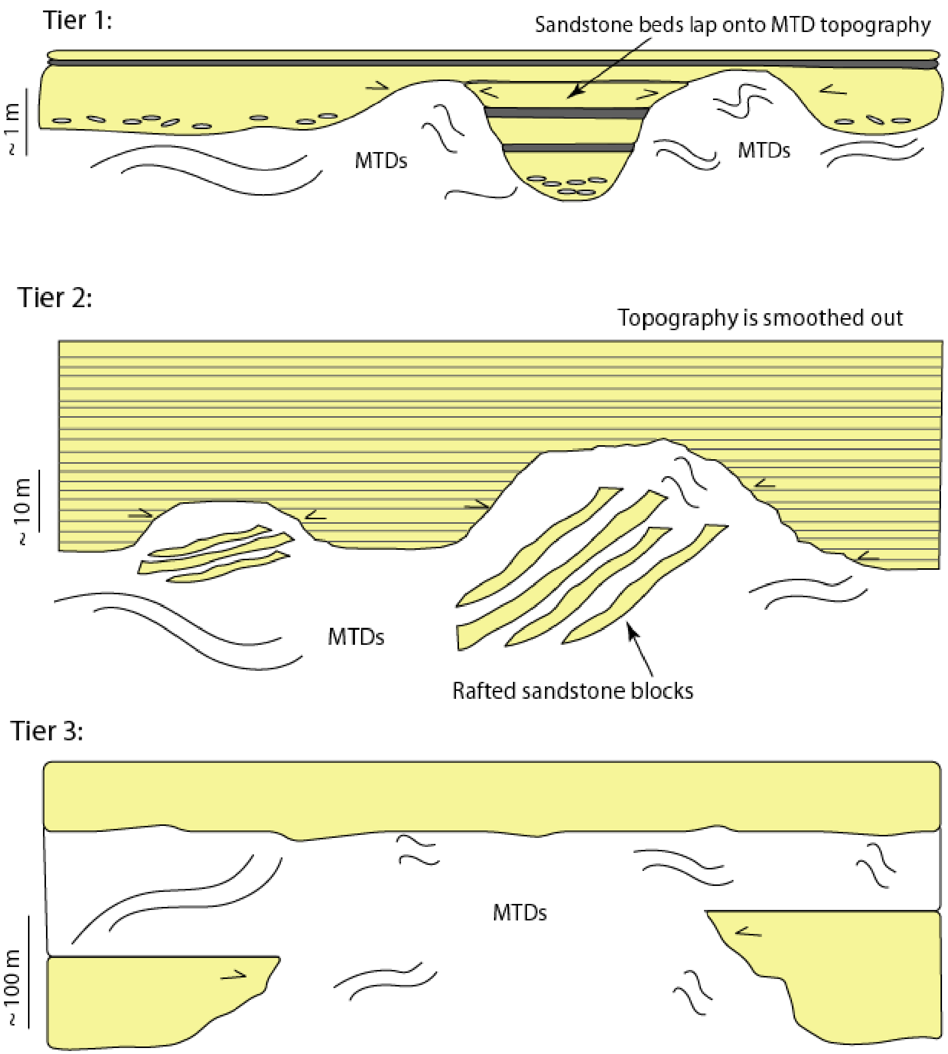

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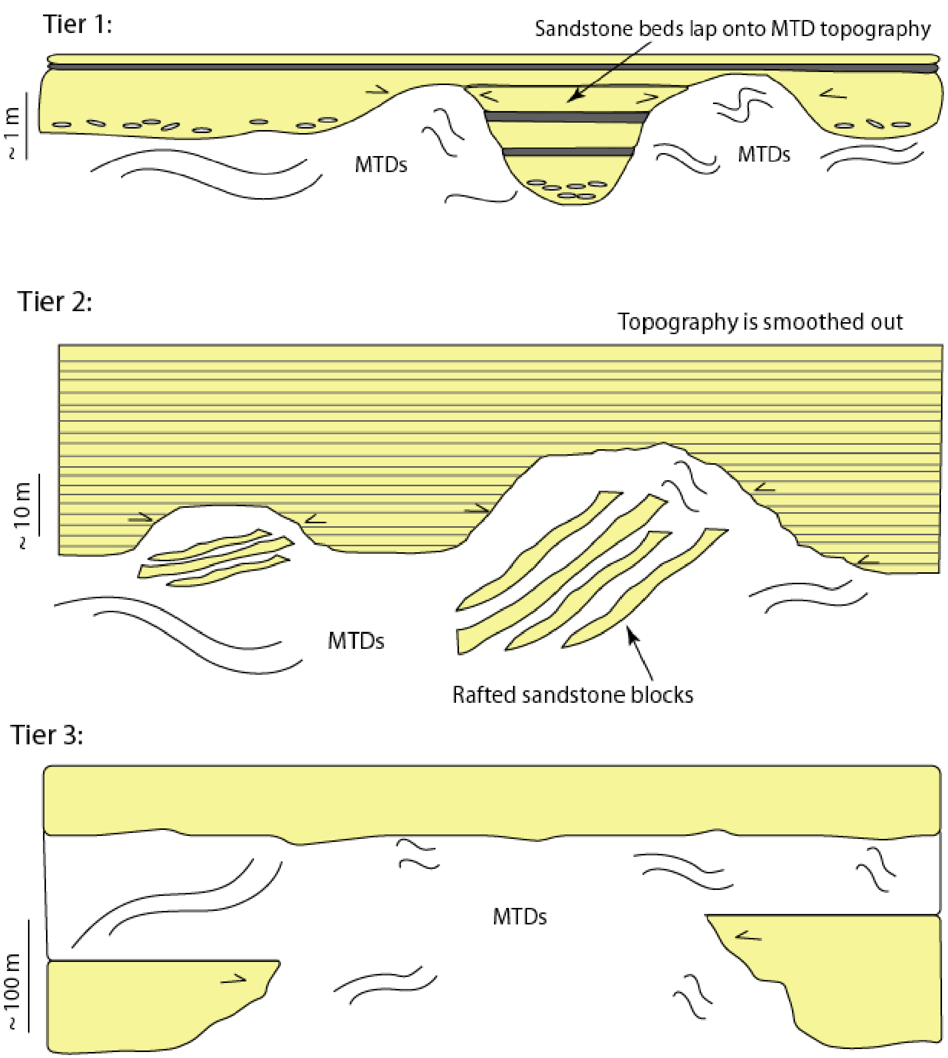

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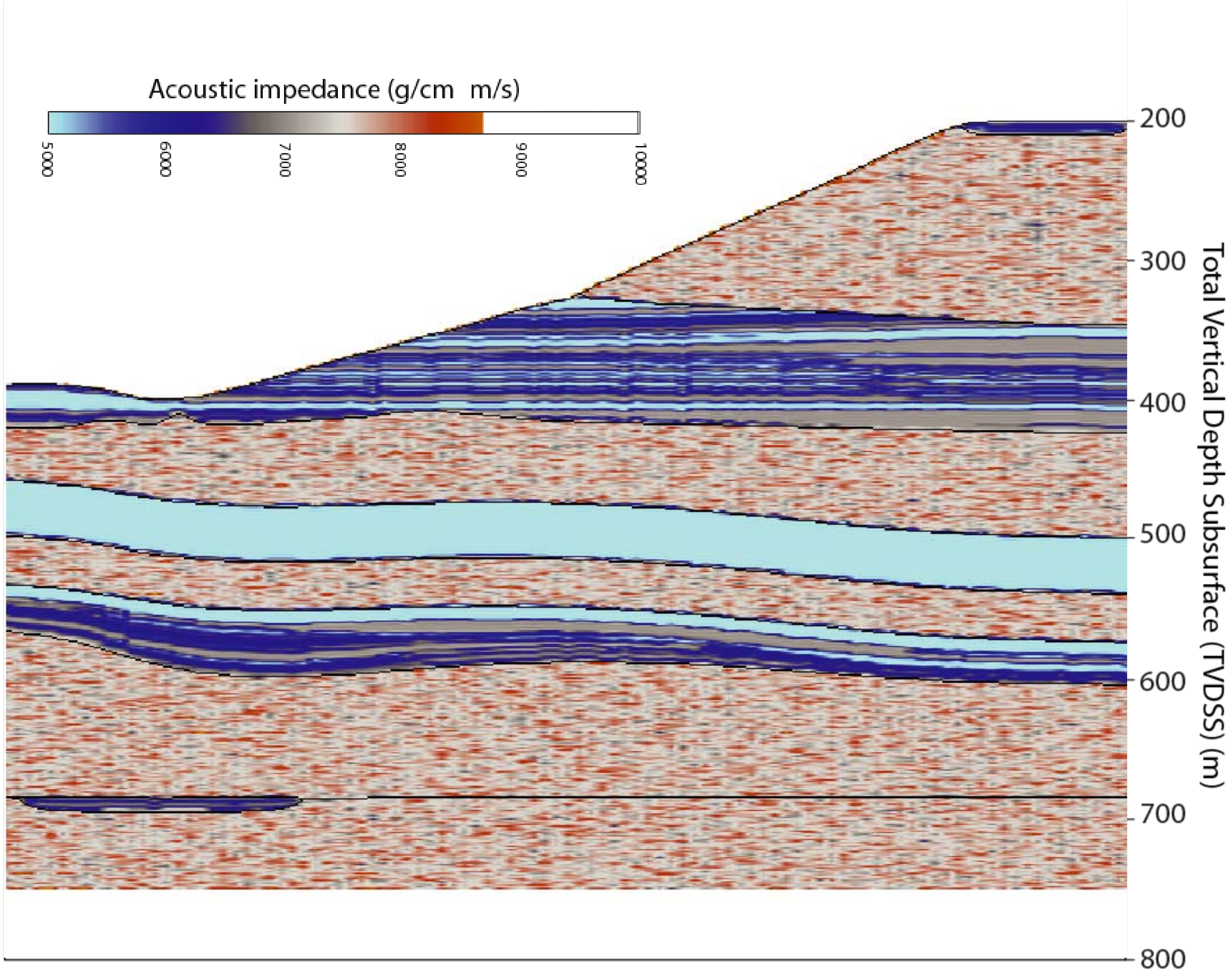
- ***This has an important control on turbidite sandstone deposition, but what seismic imaging issues are related to this in the subsurface, and how can we better understand this?***

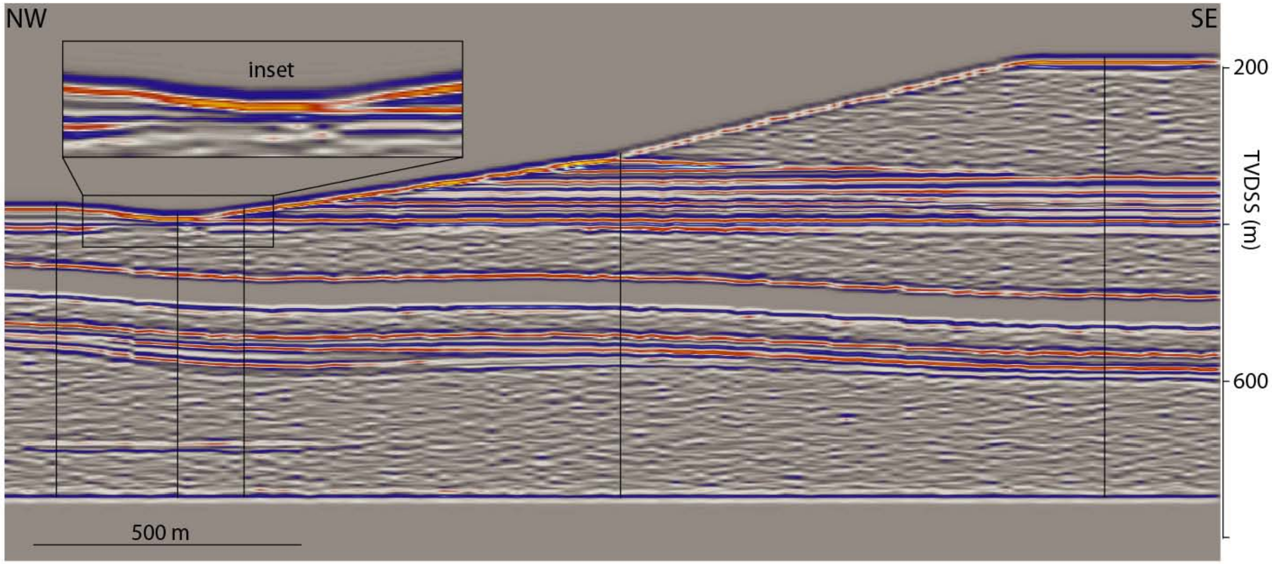
Outcrop seismic forward-modeling



Lithological model and impedance model – based on measured sections

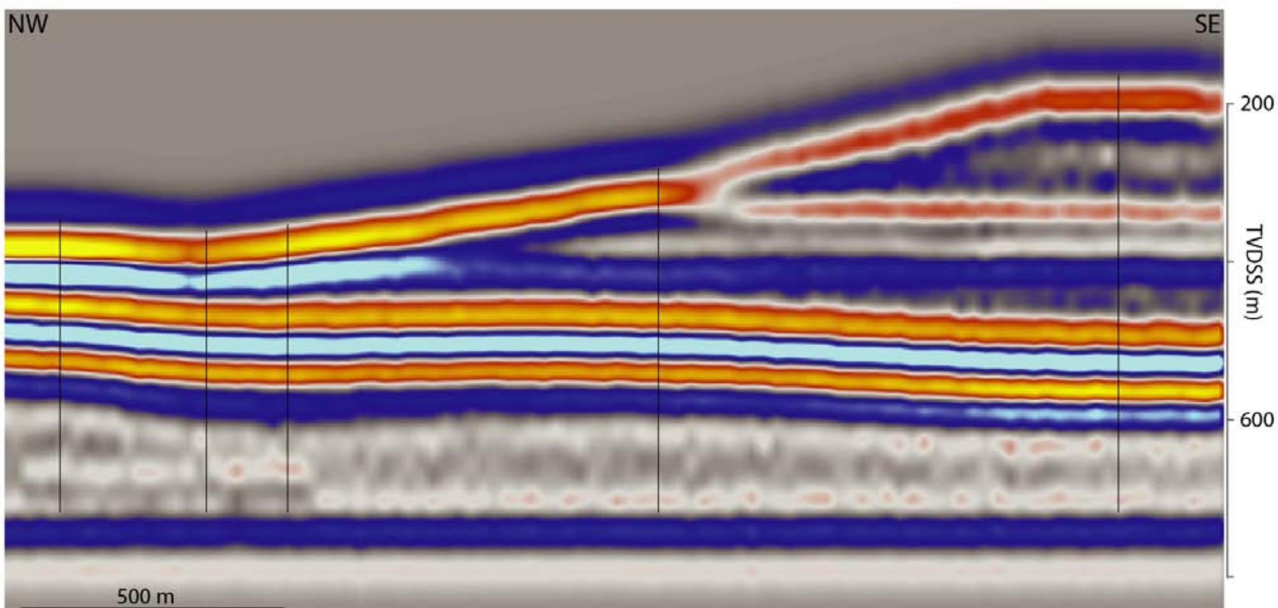
Armitage & Stright 2010

Synthetic seismic-reflection profiles



120 Hz:

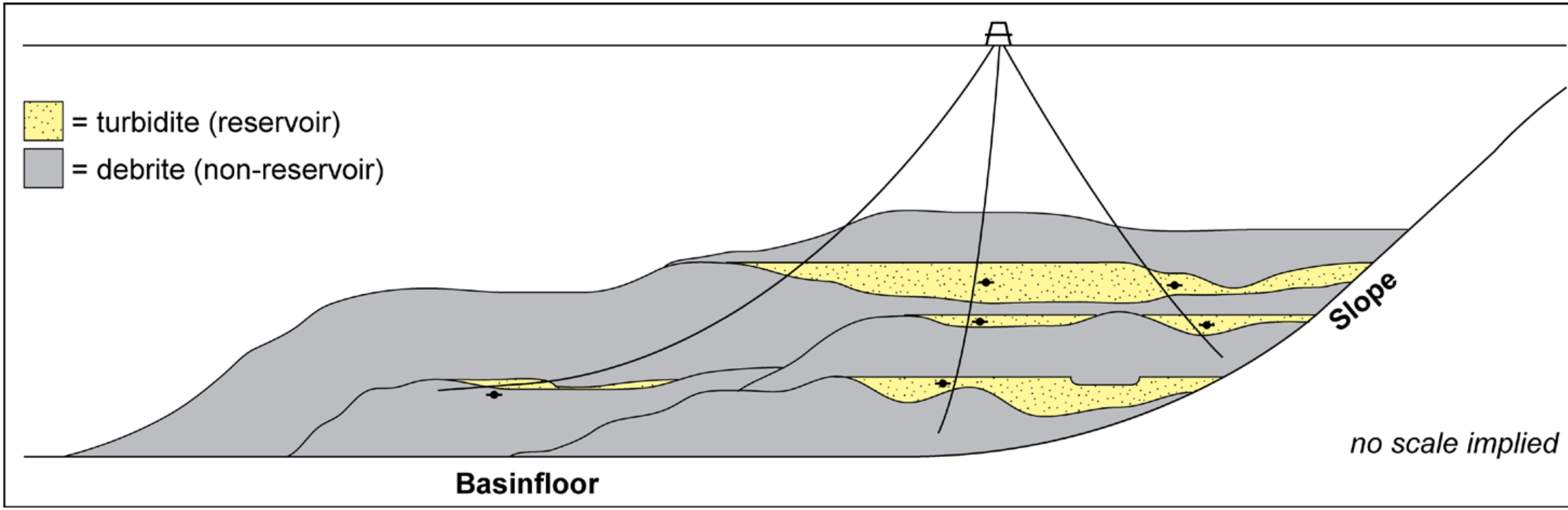
- Tier 2 topography resolved.
- Detailed facies changes.
- Bed pinchout could be interpreted as erosion.

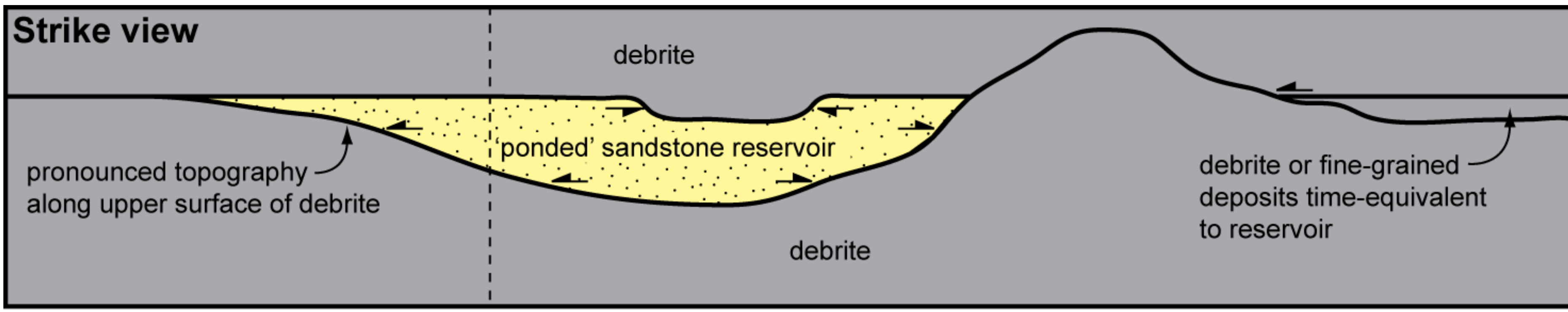


15 Hz:

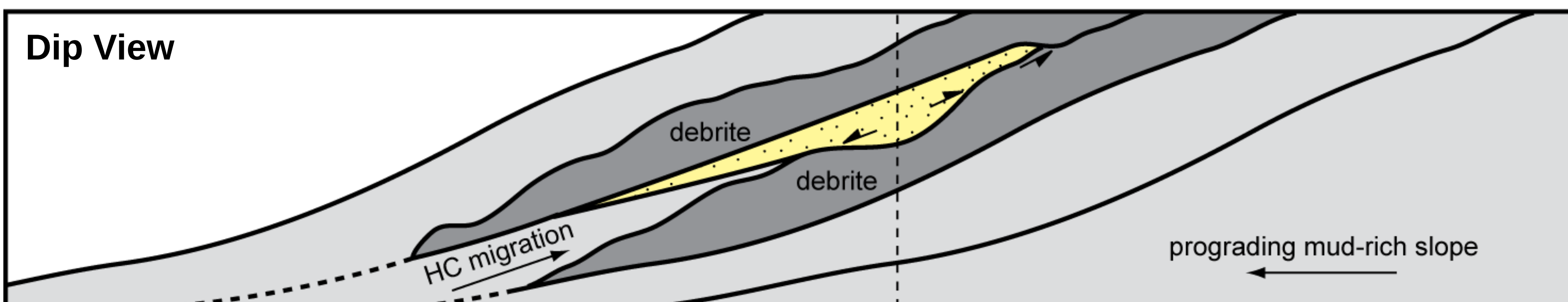
- Sandstone/MTD package boundaries are ambiguous.
- Subtle response to Tier 2 topography.

Armitage & Stright 2010





Jackson and Johnson, 2009



Applied relevance of integrated studies:

- Topography developed along the upper surface of MTDs can control the distribution and internal architecture of turbidite sandstone reservoirs.

- Understanding the scales of MTD-related surface topography will help in predicting the distribution and internal architecture of such reservoirs.

- Compartmentalization of MTD-ponded reservoir may require an unconventional production strategy.

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- This study emphasizes the need for high-resolution analogues (e.g. outcrop, near-seabed 3D seismic-reflection data) for low-resolution subsurface data (e.g. widely-spaced wells, seismic data at economic depths).

- Erosion at base of MTDs can cause truncation of underlying turbidite reservoir sandstones.

- Depending on lithological composition and spatial extent, MTDs may act as local or regional seals.

Acknowledgements

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- Azli Abu Bakar (Petronas)
- CGGVeritas